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Full Length Research Paper

Hydrogeophysical investigation of groundwater potential in Emu kingdom, Ndokwa land of Delta State, Nigeria

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A study of 10 vertical electrical soundings from different quarters of Emu kingdom using Schlumberger array were undertaken. This is an attempt to obtain useful information on the aquifer distribution within the area and hence delineate possible site boreholes could be drilled for potable and sustainable water supply. Based on the geoelectric section which is in agreement with the driller's log, the best environments for sustainable water supply were identified. This coincides with the third layer of the aquifer in Emu kingdom and consists of medium-grained sand formation. The average depth to this aquifer is 45 m whose thickness is not defined at Obiogo since it is the last layer, but in other parts of Emu-Kingdom, the thickness ranges from 45.00 m in Ikosa quarter to 95.00 m in Etevie quarter. The resistivities of these layers vary from 1000.00 - 3000.00 ohm-m. The aquifer system of Emu Kingdom has an overlying confining bed without an underlying confining layer, hence it is leaky or semi-confined. The thickness of this confining upper bed is greater at Ebendo and Obodoeti, hence in the event of pollution, groundwater at Obiogo, Ikosa and Etevie quarters in Emu-Uno are highly contaminated.

Key words: Vertical electrical sounding, groundwater potential, aquifer, Ebendo, Obodoeti Obiogo, Etevie and Ikosa quarters in Emu-Uno.

INTRODUCTION

Water is one of the prime necessities of life next to air in the order of importance for the survival of man and a host of other living things. This paper is to create awareness on the productive and prolific aquifer so as to guide both the government and individuals involved in groundwater development on the possible areas and depth that boreholes could be drilled for potable and sustainable water supply. This was achieved by obtaining information on the near surface aquifer distribution, formation and type, using vertical electrical sounding.

In this method, current is introduced artificially into the earth through a pair of electrode pinned to the ground (current electrode) and the resulting potential difference due to the current is measured through another pair of electrode (potential electrode) that is also pinned to the ground. Any subsurface variation in resistivity alters the current flow, which in turn affects the distribution of electric potential at the surface (Chukwurah, 1992; Dobrin, 1960; 1976 and Parasnis, 1966; 1972 and 1986).

Generally, materials that lack pore spaces will show high resistivity. Materials whose pore spaces lack water will show high resistivity such as dry sand or gravel. Materials whose water content is clean will show high resistivity such as clean gravel or sand even if water is saturated. Weathered rocks and clay will show medium to low resistivity. Frozen ground will show much higher resistivity than unfrozen ground.

In the sedimentary environment, high resistivity may broadly be associated with the presence of fresh groundwater in porous medium aquifer while low resistivity may be due to the presence of clay and/or brackish water (Emenike, 2000). The type of curve (Selemo et al., 1995), the modified water and sediments resistivity table by Oyedele (2001) and Zohdy and Martins (1993) as well as

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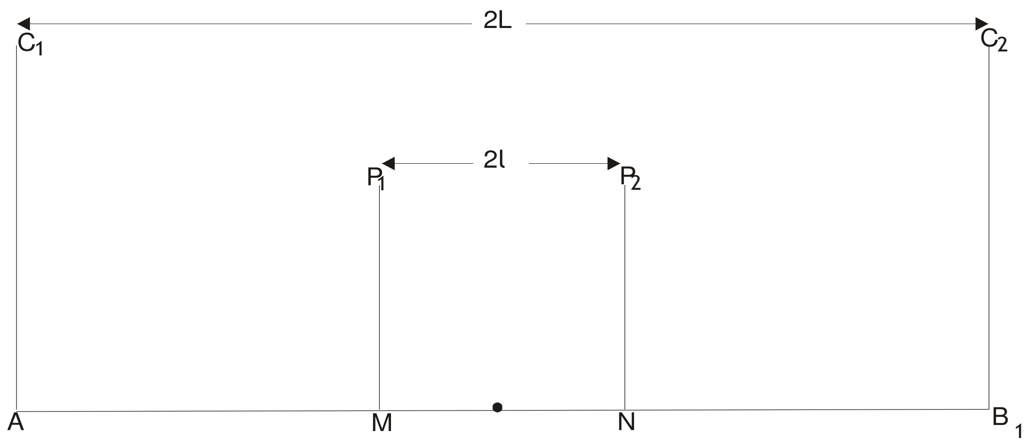

Figure 1. The Schlumberger array configuration (Whitely, 1973).

the knowledge of the local geology of Emu-Kingdom were used as guides in the interpretation of the ves data in terms of probable aquifer in this work.

METHODOLOGY

A total of 10 locations spaced 2.00 km apart were established and surveyed for 80 vertical electrical soundings using a method whereby readings were taken automatically and the results were averaged continuously with an ABEM SAS 300 terameter and a maximum current electrode spacing of 316 m. In this method, a fixed point called the VES station was marked and noted, 2 current electrodes (C_1C_2) of equal distance on the opposite sides of the VES station were measured and driven into the ground with the aid of a sledged hammer for proper contact to be made with the ground.

Similarly, two other electrodes called the potential electrodes (P_1P_2) of equal distance and between the current electrodes were measured and driven into the ground with the aid of the sledged hammer for proper contact to be made also with the ground. The arrangements of the current and potential electrodes were in such a way as to maintain a straight line. These electrodes were connected to the terrameter through points "AB" and "MN". As shown below in Figure 1.

The terrameter was switched "ON" and current was introduced artificially into the earth through the pair of electrode (C_1C_2) and the resulting potential difference due to the current were measured through the other pair of electrode (P_1P_2). Any subsurface variation in resistivity/conductivity alters the current flow, which in turn affects the distribution of electric potential at the surface; thereafter the terrameter was switched "OFF". The current electrodes were moved equally away on the opposite sides of the fixed point according to the designed acquisition parameter $C_1C_2 \geq 5P_1P_2$ and the readings were recorded at every new position. (Chukwurah, 1992; Dobrin, 1960, 1976; Parasnis, 1966 and 1972, 1986; Jakosky, 1950; Shichter, 1933; Bhattacharya and Patra, 1968).

The field procedure consists of expanding current electrodes (C_1C_2) while holding potential electrode's distance (P_1P_2) fixed. This process yields a rapidly decreasing potential difference across P_1P_2, which ultimately exceeds the measuring capabilities of the instrument. At this point, a new value for potential distance was established, typically five times greater than the proceeding value and the survey was continued (Keller and Frischknecht, 1966; Osemeikhian and Asokhia, 1994). The systematic movement of the current and potential electrodes continued until the survey was completed (Mooney, 1980).

DATA ANALYSIS AND INTERPRETATION

The vertical electrical sounding field curves were interpreted using partial curve matching (Zohdy et al., 1974). In this method, the log-log graph sheet was placed on the table and the apparent resistivity values were plotted against half current electrode spacing in a transparent paper on the log-log graph sheet with the same modulus as that of the 2-layer master curves. The field curves obtained were then superimposed on the master curve until a reasonable good fit were obtained between the field curves and one of the model curves. The interpretation of the field curves starts from the left portion of the graph to the right portion and the choice of the master and Auxiliary curves depends on the shape of the field curve.

A cross mark was introduced at the origin of the master curve on the field curve and this serves as the origin of co-ordinate which represents the parameters of the first layer. The constant on the master curves that corresponds to the segment of the field curve is also noted. The graph was then superimposed again on the log-log graph, while the resistivity and thickness values were traced to the intersecting points on the vertical and horizontal axis.

The field curves were then transferred to the appropriate auxiliary curves and the corresponding constant of the master curves were traced downward while taken into consideration the parallel nature of co-ordinate on both curves, this gives the (D_I) values.

The process was repeated until the segments of the field curves are significantly covered. Thus, the other values obtained from the graph are resistivity and thickness replacements. The true resistivity and corresponding thickness of the second and subsequent layers were obtained using parameters for which the relations below hold (Reinhard, 1974)

$$\rho_2 = \rho_1 \cdot k_1 \text{ and } \rho_3 = \rho_2 r \cdot k_2$$

Where; k_1 and k_2 are the resistivity constants called the reflection coefficient

Similarly $h_2 = (h_1 . D_1 1) + h_1$ and $h_3 = (h_2 r. D_1 2) + h_2$

Where; h_1 is the true thickness of the first layer, h_2r is the replacement thickness of the second layer, while $D_1 1$ and $D_1 2$ are the depth index of the first and second layers respectively. The interpretation of the sounding curves in order to produce the geoelectric section was obtained from the values of the geoelectric parameters that were derived from the partial curve matching. The resistivity and thickness obtained from the Partial curve matching were improved upon by employing an automatic iterative computer program

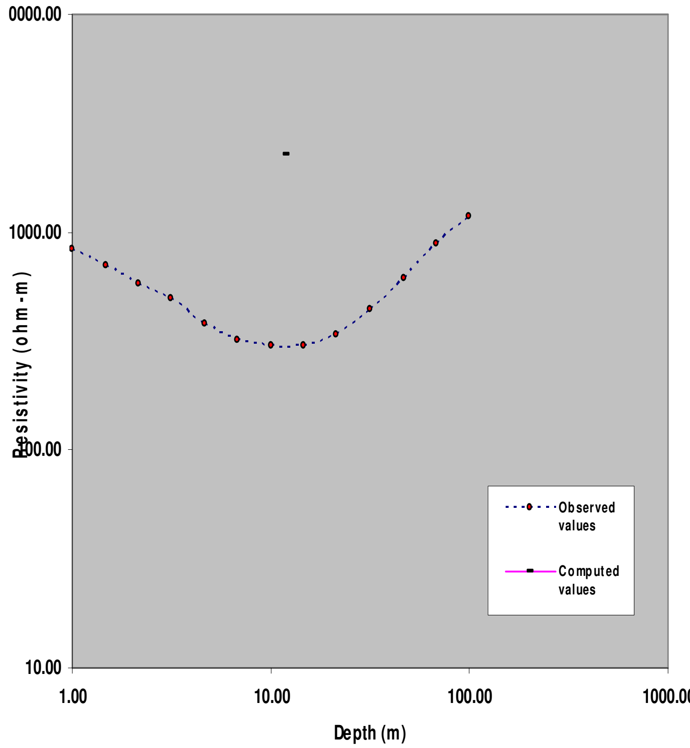

Figure 2. Resistivity sounding interpretation for VES 1Emu-Obiogo, Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted layer model

following the main ideas of Zohdy and martin (1993) to obtain the layers parameter (resistivity, thickness and depth). Here, the number of geoelectric layers and their corresponding specific resistivity were first taken to be equal to the number of measurable points and difference of adjacent current electrode spacing respectively. Layer parameters were consequently modified in iterative manner until subsequent iteration yields no improvement on the root mean square (rms) error values in percentage (Figures 2 - 6). The numbers of layers were modified based on the number of inflation points and it is modeled by showing the resistivity per layer versus depths in a step function (Figures 7 - 11). The low value of rms % is an evidence of the accuracy and reliability of the data acquired from the field.

RESULTS AND DISCUSSIONS

The numerous layers that were generated by the computer were grouped into relevant geologic depth intervals called geoelectric sections and the resulting layer parameters were then given geologic interpretation. The type of curves (Selemo et al 1995), the resistivity of the sediments (Oyedele, 2001) and the lithologic logs from nearby boreholes were used in conjunction with the knowledge of the local geology of the study as guides in the interpretation and analysis of the geologic section in terms of probable and sustainable water supply. Emu is within the Sombriero-Warri deltaic plain deposit invaded by mangrove. The interpreted sounding curves from the locations at Ebendo, Obodoeti, Obiogo as well as Etevie and Ikosa quarters in Emu-Uno shown in VES 1, 2, 3, 4,

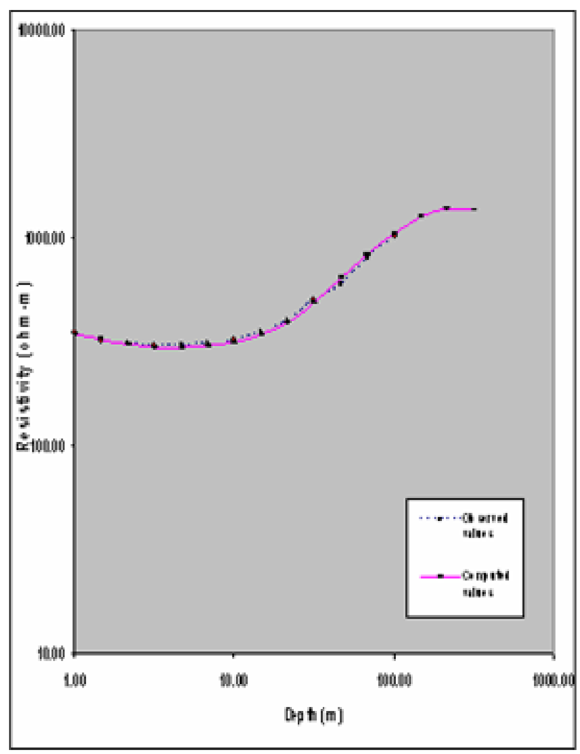

Figure 3. Resistivity Sounding Interpretation for VES 2 Layeralong Etevie Quarters) Emu-uno, Showing Observed (Field) and computed resistivity data and curves and interpreted layer model

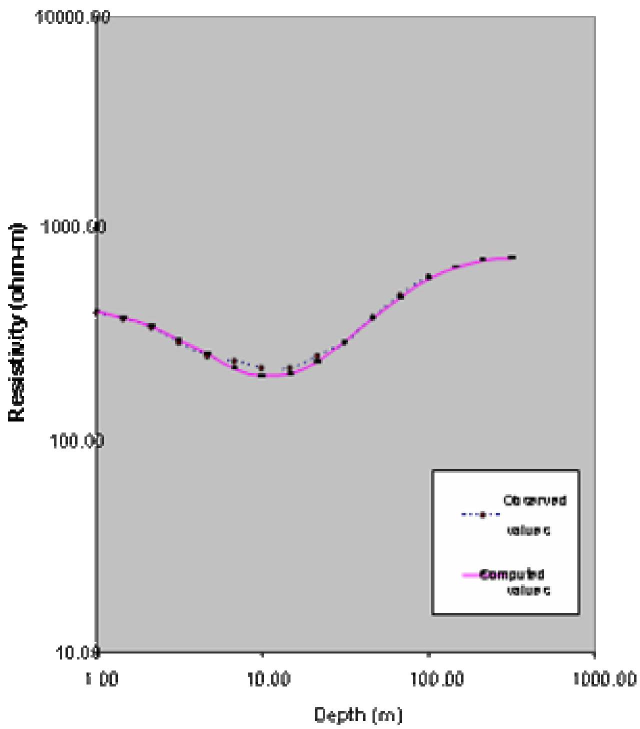

Figure 4. Resistivity Sounding Interpretation for VES 3 Along Ikosa Quarters) Emu-uno, Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted

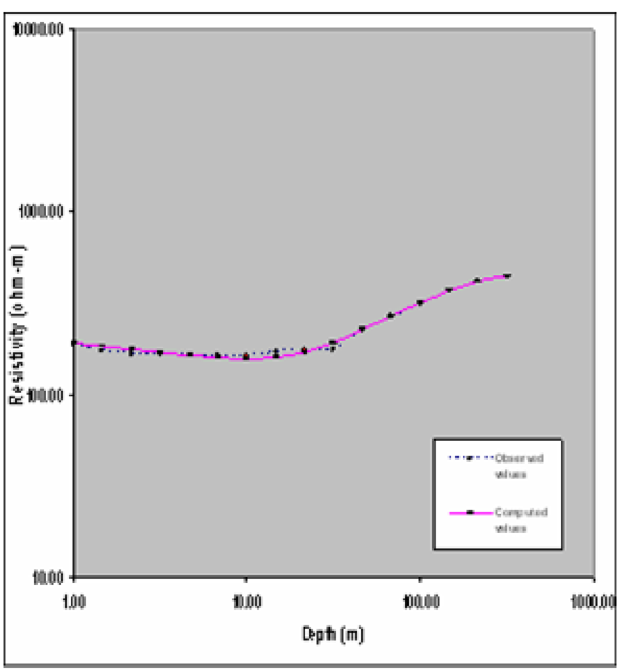

Figure 5. Resistivity Sounding Interpretation for VES 4 Enweshi Quarters Emu-Obodoeti, Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted layer model

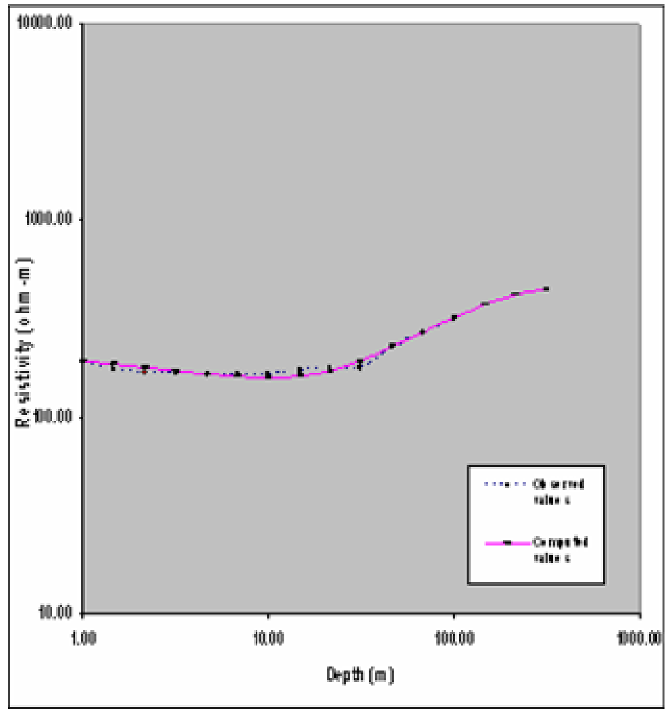

Figure 6. Resistivity Sounding Interpretation for VES 5 Emu-Ebendo, Showing Observed (Field) and computed resistivity data and curves and interpreted layer model.

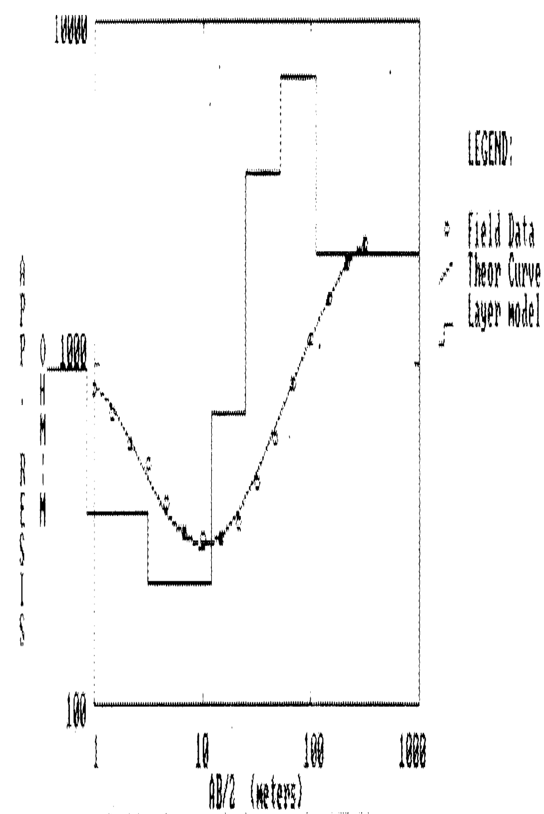

Figure 7. Field data, theoretical curve and the layer model of VES (Emu-Obiogo) in a Step Function.

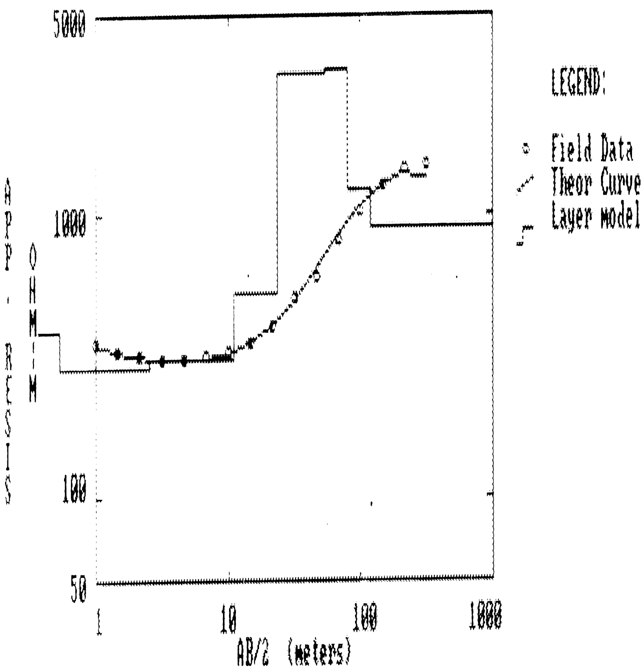

Figure 8. Field Data, Theoretical Curve and the Layer Model of VES 2 (Along Etevie Quarters) Emu-Uno, in a step function

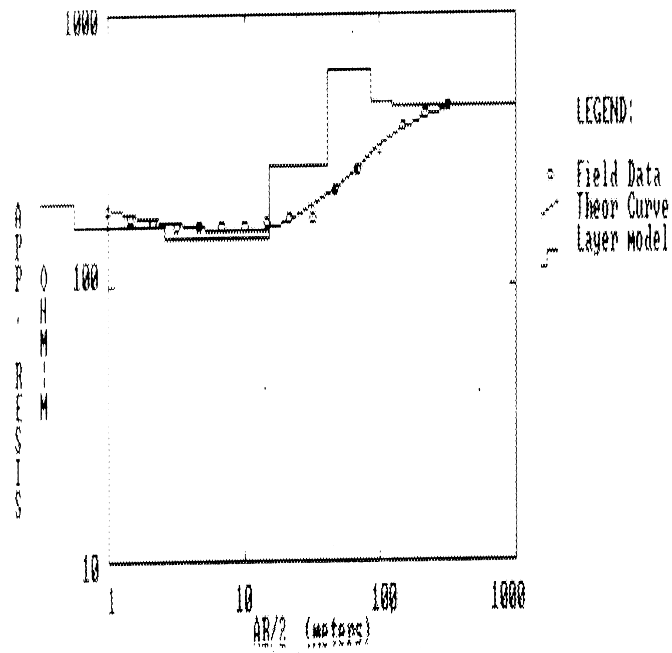

Figure 10. Field Data, Theoretical Curve and the Layer Model of VES 4 Enweshi Quarters Emu-Obodoeti In a step Function

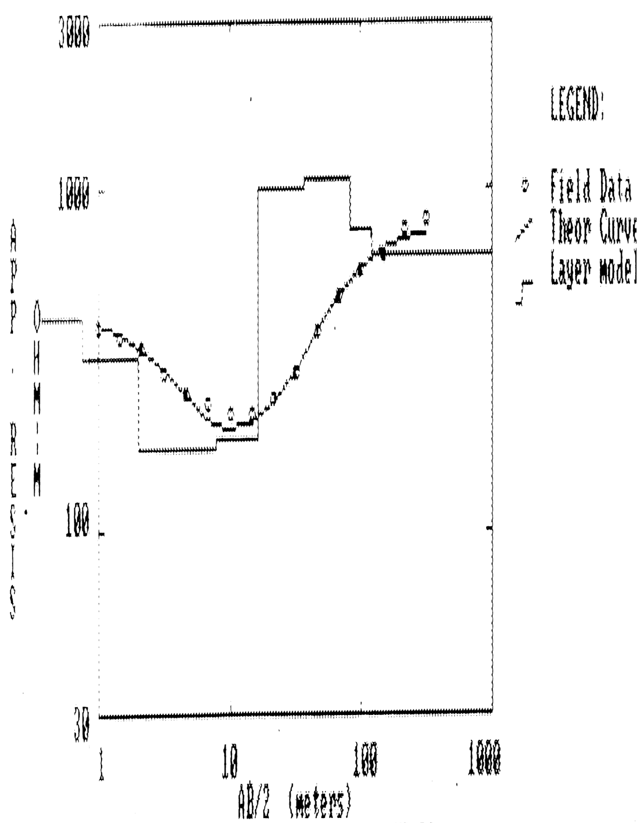

Figure 9. Field data, theoretical curve and the layer model of VES 3 (Along Ikosa Quarters) Emu-Uno, in a step function.

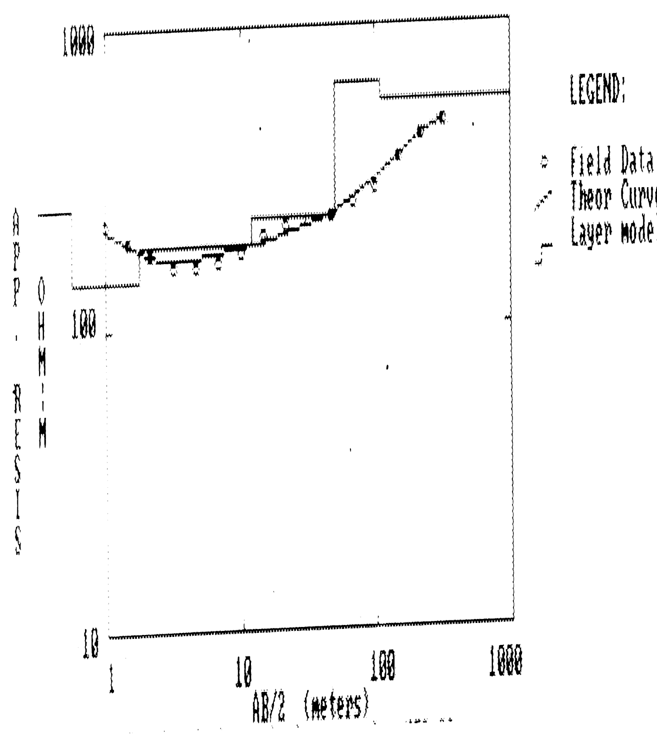

Figure 11. Field data, theoretical curve and the layer model of VES 5 (Ebendo) in a step.

and 5 revealed 4 - 6 relevant geoelectric layers. Qualitative analysis of the curve types revealed that Emu and environs basically have HA curve types. The lithologic formation from a producing borehole in conjunction with the knowledge of the local geology of Emu kingdom was used in constructing the earth model. The litholog indicates broadly that within the depth penetrated; the succession is sandy clay, clayey sand, and clay, fine-grained sand and medium-grained sand formations respectively.

The first geoelectric layer, which is the topsoil formation comprises of sandy clay soil with some silt. It has a very thin thickness of about 0.10 m. The resistivity of this layer is between 200.00 m – 4.00 m except at Obiogo where the resistivity is as high as 978.00 m due to the dried nature of the compacted smooth sandy clay soil formation.

The second and third geoelectric layer consists of clay to clayey sand formation. The clay soil is found in Ebendo and Obodoeti in the second layer while at Ikosa quarters in Emu Uno, the clay soil is found in the third layer. The thickness of this layer is between 10.00 m – 15.00 m with resistivity value of about 100.00 m. This may act as a confining bed to the aquifer. The clayey sand formation cut across Emu communities with thickness ranging from 2.00 m at Ikosa quarters in Emu-Uno to about 40.00 m in Ebendo. The resistivity value is between 200.00 - 300.00 m. This is not a good prospect for groundwater exploration since it contains clay and it derivatives. However, this is the first aquifer in Emu and environs and occurs at a depth of between 2.00 - 15.00 m. This aquifer is semi-confined at Ebendo and Obodoeti since it has an overlying high conductive layer on top but none below. At Obiogo and Emu-Uno, the aquifer is not confined because it is exposed to the atmosphere.

The fourth geoelectric layer is the second aquifer in Emu. It consists of fine-grained sand formation with resistivity values of between 400.00 - 700.00 m and thickness that ranged from 10.00 - 20.00 m at locations within Obiogo and Emu-Uno. In Ebendo and Obodoeti, this is the last layer, hence the thickness is not defined. In Ebendo and Obodoeti, this is the only region where water could be obtained at an appreciable quantity. However, this zone is not an encouraging prospect for groundwater development in Obiogo and Emu-Uno due to its small thickness.

The fifth geoelectric layer consists of medium-grained sand formation. This is the third aquifer in Emu. It is the best environment for sustainable water supply. The thickness is not defined at Obiogo since it is the last layer, but in Emu-Uno, the thickness ranges from 45.00m in Ikosa to 95.00m in Etevie quarter. The resistivity of this layer varies from 1000.00m – 3000.00m. The average depth to this aquifer is 45.00m.

The sixth geoelectric layer consists of fine-grained sand formation. It is the fourth aquifer at a depth of about 80.00 m with an undefined thickness since it is the last layer. This layer is not an encouraging trend for viable and sustainable groundwater development.

The aquifer system in Emu-Kingdom is leaky or semi-confined. This is because; it only has an overlying confining bed without an underlying confining layer. The thickness of this confining aquifer is greater at Ebendo and Obodoeti, in the event of pollution, groundwater at Obiogo, Ikosa and Etevie in Emu-Uno are highly contaminated.

Conclusion and Recommendations

The study revealed Emu-Kingdom as an extensive sandy unit. The interpretation indicates that the water bearing formation (medium grained sand) is prominent at Obiogo, Etevie and Ikosa quarters in Emu-Uno, while at Obodoeti and Ebendo fine-grained sand is the formation of the aquifer.

The third layer of the aquifer is the best environment for sustainable water supply. The thickness of this layer is not defined at Obiogo since it is the last layer, but in Emu-Uno, the thickness ranges from 45.00 m in Ikosa to 95.00 m in Etevie quarter. The resistivity of this layer varies from 1000.00-3000.00 m. It is therefore recommended that the average depth to the aquifer in Emu-Kingdom is 45.00 m.

The research did not only pave way for a clear picture of the hydrogeological knowledge of Emu-Kingdom in other to create awareness on the productive and prolific aquifer for sustainable groundwater supply but act as guides to both the government and individuals especially those involved in groundwater development on the areas and depths boreholes could be sited and drilled for sustainable water supply.

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Appendix

Field measurements and data interpretations by Oseji, Julius Otutu and Omi Ujuanbi.

AB/2 Values (m)	Observed Values (ohm-m)	Computed Values (ohm-m)	Geoelectric Layer	Resistivity (ohm-m)	Thickness (m)	Cumulative Thickness(m)
1.00	830.00	870.65	1	978.00	0.86	0.86
1.47	700.00	748.19	2	357.21	2.24	3.10
2.15	575.90	592.68	3	223.00	8.96	12.06
3.16	498.90	454.10	4	711.00	12.58	24.54
4.64	380.00	362.88	5	3619.00	27.09	51.70
6.81	320.00	310.64	6	6998.00	58.06	109.75
10.00	303.00	288.57	7	2140.00	infinity	infinity
14.70	303.20	302.17				
21.50	338.90	359.19	RMS Error	1.87%		
31.60	444.60	467.61				
46.64	609.00	634.76	Geoelectric	Resistivity	Thickness	Cumulative
68.10	879.80	870.23	Layer	(ohm-m)	(m)	Thickness(m)
100.00	1183.00	1179.29	1	978.00	0.86	0.86
147.00	1561.00	1651.45	2	357.21	2.24	3.10
215.00	1946.00	1936.46	3	223.00	8.96	12.06
316.00	2283.00	2272.19	4	711.00	12.58	24.54
	Observed	Computed	5	3619.00	27.09	51.70

AB/2 Values (m)	Observed Values (ohm-m)	Computed Values (ohm-m)	Geoelectric Layer	Resistivity (ohm-m)	Thickness (m)	Cumulative Thickness(m)
1.00	350.00	345.25	1	381.00	0.53	0.53
1.47	320.70	323.54	2	280.00	2.04	2.57
2.15	310.00	306.26	3	301.32	8.51	11.08
3.16	300.10	297.53	4	515.28	12.58	23.66
4.64	300.10	297.16	5	3125.74	29.90	53.56
6.81	310.30	302.84	6	3222.63	28.23	79.79
10.00	323.40	315.28	7	1191.96	37.96	117.74
14.70	349.60	341.28	8	903.00	infinity	infinity
21.50	399.40	393.56				
31.60	502.10	489.16	RMS Error	1.79%		
46.64	595.40	637.77	Geoelectric	Resistivity	Thickness	Cumulative
68.10	801.60	835.00	Layer	(ohm-m)	(m)	Thickness(m)
100.00	1005.70	1057.89	1	381.00	0.53	0.53
147.00	1248.20	1259.52	2	280.00	2.04	2.57
215.00	1452.80	1371.94	3	301.32	8.51	11.08
316.00	1506.00	1352.39	4	515.28	12.58	23.66
AB/2	Observed	Computed	5	3125.74	29.90	53.56

AB/2	Observed	Computed	Geoelectric	Resistivity	Thickness	Cumulative
Values (m)	Values (ohm-m)	Values (ohm-m)	Layer	(ohm-m)	(m)	Thickness(m)
1.00	400.00	405.93	1	429.00	0.75	0.75
1.47	370.00	380.96	2	323.32	1.27	2.02
2.15	340.00	345.06	3	174.30	5.83	7.85
3.16	289.10	299.72	4	184.68	8.53	16.38
4.64	250.10	258.32	5	972.84	20.37	36.75
6.81	234.60	218.03	6	1056.78	46.23	82.98
10.00	220.30	202.11	7	760.00	37.95	122.93
14.70	219.50	207.52	8	630.00	infinity	infinity
21.50	249.40	236.90				
31.60	287.70	294.80	RMS Error	2.22%		
46.64	378.90	378.00				
68.10	481.00	477.05				
100.00	585.70	578.76				
147.00	644.40	664.73				
215.00	755.00	714.31				
316.00	815.80	721.36				
AB/2	Observed	Computed	Geoelectric	Resistivity	Thickness	Cumulative

AB/2	Observed	Computed	Geoelectric	Resistivity	Thickness	Cumulative
Values (m)	Values (ohm-m)	Values (ohm-m)	Layer	(ohm-m)	(m)	Thickness(m)
1.00	190.00	193.72	1	206.00	0.56	0.56
1.47	175.00	185.25	2	167.73	2.04	2.60
2.15	169.60	177.20	3	148.05	12.61	16.21
3.16	167.00	170.59	4	278.00	26.01	41.22
4.64	165.00	165.14	5	615.30	44.03	85.25
6.81	165.90	160.71	6	481.85	37.96	123.20
10.00	165.10	158.52	7	460.00	infinity	infinity
14.70	169.70	161.26				
21.50	179.00	172.32	RMS Error	1.76%		
31.60	177.80	194.34				
46.64	223.30	227.25				
68.10	267.20	270.64				
100.00	314.30	322.13				
147.00	366.70	374.18				
215.00	435.80	416.03				
316.00	459.00	442.92				
AB/2	Observed	Computed	Geoelectric	Resistivity	Thickness	Cumulative

AB/2 Values (m)	**Observed Values (ohm-m)**	**Computed Values (ohm-m)**	**Geoelectric Layer**	**Resistivity (ohm-m)**	**Thickness (m)**	**Cumulative Thickness(m)**
1.00	227.30	219.34	1	259.00	0.56	0.56
1.47	199.60	194.44	2	144.90	1.21	1.77
2.15	176.40	176.12	3	187.82	10.24	12.01
3.16	162.80	169.92	4	235.00	38.17	50.18
4.64	160.00	173.12	5	638.40	58.06	108.24
6.81	167.50	179.35	6	570.00	infinity	Infinity
10.00	180.00	185.39				
14.70	200.30	192.05	RMS Error	1.96%		
21.50	215.50	201.41				
31.60	224.90	214.57				
46.64	236.80	238.74				
68.10	252.30	262.98				
100.00	252.90	307.68				
147.00	359.50	365.19				
215.00	435.80	424.25				
316.00	470.60	476.11				
AB/2	Observed	Computed	Geoelectric	Resistivity	Thickness	Cumulative