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Investigation of electrical properties of soil in relation to gully development in Orlu, South-eastern Nigeria

Onwubuariri C.N[1], Mgbeojedo T.I[2]
[1]*(Department of Geosciences, Federal University of Technology, Owerri, Nigeria)*
[2]*(Al Gazal Business Solutions W.L.L, Doha, Qatar)*
Corresponding Author: Mgbeojedo T.I

Abstract: *The interpretation of 12 Schlumberger vertical electrical sounding (VES) data was carried out to investigate the electrical properties of soil and how it can contribute to gully formation. Terrameter Signal Averaging System (SAS) model 300 was used in the absence of any signal enhancer as the expected targeted depth to be investigated is within the range of penetration of the instrument. During this data acquisition, readings were taken using maximum electrode separation of 400m, with layer resistivity values at 65.168Ωm and 44800Ωm for both minimum and maximum values respectively. The depth and thickness values of layers under investigation were also taken and have the values of 0.9m and 177m for minimum and maximum values respectively. These acquired values were computed together and as well were interpreted. The results of the interpreted VES data showed that the saturated groundwater layer (aquifer) is non-saline, and there is no trace of any clayey or muddy material within the areas of investigation. Considering resistivity values obtained and the geology of the area under investigation, it is clearly seen that the area has a high tendency of gullying when under the influence of any erosion agent, most especially, running water.*
Keywords: *Gully formation, Layer resistivity, Orlu, Vertical electrical sounding*

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I. Introduction

Gully erosion is the major problem faced within Orlu and environs, South-eastern Nigeria. This menace has posed several challenges to the livelihood and economic survival of people within the area. As we all know, erosion is the process of removal of soil and rock particles from the Earth's surface via exogenic processes such as wind or water flow, and then transported and deposited in other locations. The removal of top soil has caused several environmental degradations, which in turns makes life difficult in terms of agricultural participation because of loss of soil nutrient from the top soil as well as reduction of the surface area for agricultural activities, transportation, housing and desertification. The fact that erosion is a natural occurrence is not in doubt, but human activities have aided the rate at which erosion occurs globally.

Water and wind are the two major causes of soil erosion and both combined are responsible for about 84% of erosion menace, thereby making erosion one of the most significant global environmental problems. Due to high rate of rainfall in South-eastern part of Nigeria, most erosion gullies seen within the area has been attributed to high rainfall intensity, with topography, poor engineering and agricultural practices contributing immensely to the rate of soil degradation. Irrespective of these human activities that tend to accelerate erosion processes, some geological influences and soil properties within the area make it prone to erosion. Some early researches have made useful discussions and inferences on the problem and solution of soil erosion in South-eastern Nigeria[1, 2, 3, 4, 5, 6, 7]. Two main types of gully on the scarp slopes of the Udi plateau and the Awka-Orlu upland have been recognized[4].

II. Materials and method

A reconnaissance survey of the area was undertaken. Observations were also made with respect to the geographical features of the study area, exposed sand units around the erosion sites, streams, valleys, erosional surfaces and as well as outcrops. These observed features were also noted. This survey involved multiple stops at the individual erosion locations, observations, visual analysis of outcrops and lateral measurements of gullies at intervals of 5m using measuring tape and levelling staff, for length, width and depths measurements.

Vertical electrical soundings (VES) were carried out at all the chosen sites of study. Using VES, a series of potential differences were acquired at successively greater electrode spacing while maintaining a fixed central reference point. The induced current was passed through progressive deeper layers at greater electrode spacing. From the VES carried out, apparent resistivity values for layers, thickness of layers and depth of layers were obtained. Practically, as the spacing between the current electrodes is increased about a centre, the total volume of earth included in the measurement also increases both vertically and horizontally. Below is a typical vertical electrical sounding design (Schlumberger array) used in this study.

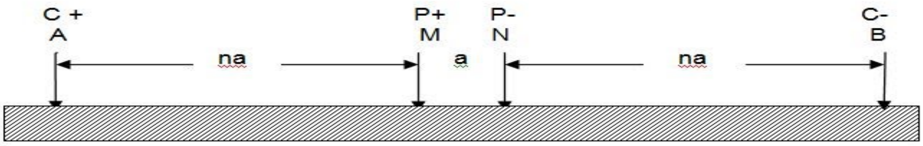

Fig no1: Schlumberger array

During the sounding survey, electrodes were distributed along a line, centred about a midpoint that is considered the location of the sounding. In this process, two current electrodes A and B and two potential electrodes M and N were fixed, placed in line with another and centred on a location, but the potential and current electrodes were not placed equidistant from one another. To acquire the resistivity data in the field, current was introduced into the ground through current electrodes and the potential electrodes were then used to quantitatively measure the voltage pattern on the surface resulting from current flow pattern of the first set of electrodes. The array was achieved by knowing the distance of the potential of MN as (a) and the distance of AB equals a (2n + 1). The distance between the different electrodes is shown in the figure above. The value ‘K’ which is called the Geometric factor is calculated from the appropriate distances between the electrodes and for certain electrode configuration. Voltage and current were converted in millivolts and milliamperes respectively with distances in metres to obtain the apparent resistivity measured in Ohm-metre.

Table no 1: Site locations with their Easting, Northing and Elevation

Locations	Name	Easting	Northing	Elevation
Location 1	Njaba River	7.193056	5.774767	115m
Location 2	Orlu/Ihiala Road	7.060278	5.878056	102m
Location 3	Okwelle/Urualla Road	7.312500	5.886667	152m
Location 4	AforUkwu-AforNta	7.360556	5.861944	155m
Location 5	Okwelle/Urualla Road 2	7.322222	5.810833	137m
Location 6	Owerri/Orlu Road	7.253889	5.761111	107m
Location 7	UmungumaIhioma	7.263889	5.927222	110m
Location 8	Ikpa/Ihioma	7.142778	5.960000	94m
Location 9	UmuazzalaOgberuru	7.028722	5.830389	195m
Location 10	Umueshi 1	7.110472	5.829000	260m
Location 11	Umueshi 2	7.109669	5.830806	273m
Location 12	Ogberuru 2	7.015389	5.832028	121m

III. Results

The iso-resistivity table is as shown below

Table no 2: Iso-Resistivity values for AB/2 from 5-65m

Station	Longitude	Latitude	5	10	15	20	25	30	35	40	45	50	55	60	65
Njaba River	7.193056	5.774767	550	1070	1330	1680	2070	2380	2500	2480	2450	2410	1900	2080	2310
Orlu/Ihiala Road	7.060278	5.878056	765	800	840	960	1140	1240	1240	1170	1153	1120	1200	1200	1200
Okwelle/Urualla Road	7.312500	5.886667	900	1180	1500	1660	1940	2260	2510	2740	2880	2940	3020	3340	3380
Afor Ukwu-Afor Nta	7.360556	5.861944	1050	850	850	1100	1350	1600	1900	2250	3550	2750	3020	2850	3000
Okwelle/Urualla Road 2	7.322222	5.810833	1200	1900	3000	3700	4350	4900	5300	5450	5550	5650	4750	4750	4800
Owerri/Orlu Road	7.253889	5.761111	10600	12200	13400	14200	14600	15800	16200	16180	16000	15800	14600	13800	12900
Umunguma Ihioma	7.263889	5.927222	2050	1525	1075	750	650	650	650	650	650	650	650	750	700
Ikpa/Ihioma	7.142778	5.960000	380	940	1360	1340	1100	880	580	580	490	410	360	570	460
Umuazzala Ogberuru	7.028722	5.830389	3300	4700	6300	6200	6100	4900	3700	2700	1900	1550	1400	1370	1320
Umueshi 1	7.110472	5.829000	135	440	760	1060	1400	1900	2420	2880	3210	3290	3100	2860	2600
Umueshi 2	7.109669	5.830806	440	560	950	1250	1550	1900	2300	2650	2820	2850	2680	2410	2200
Ogberuru 2	7.015389	5.832028	300	550	900	1380	1450	1680	1750	1900	2240	2550	2720	2920	3050

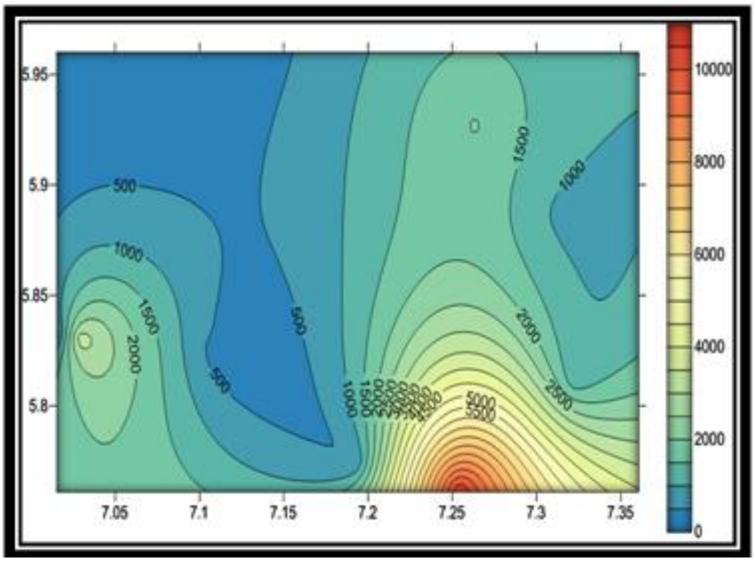

Fig.no 2: Iso-resistivity contour at the value AB/2 = 5

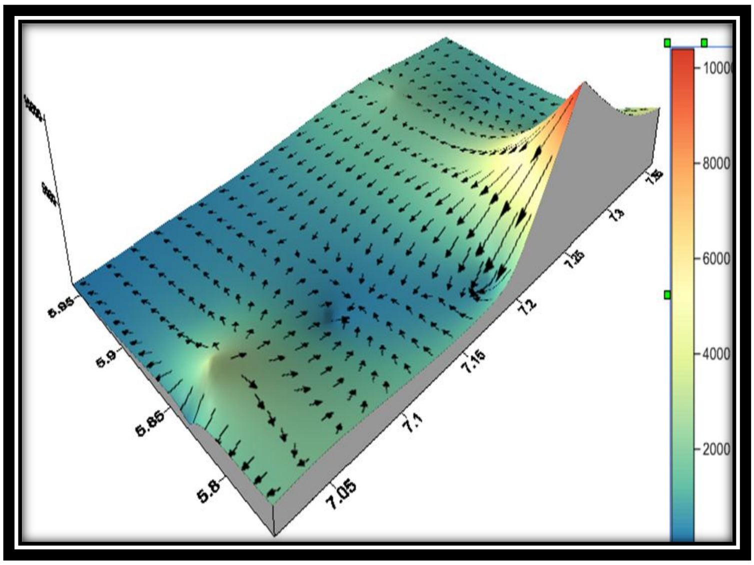

Fig. no 3:3D model with vector map of Iso-resistivity at the value AB/2 = 5

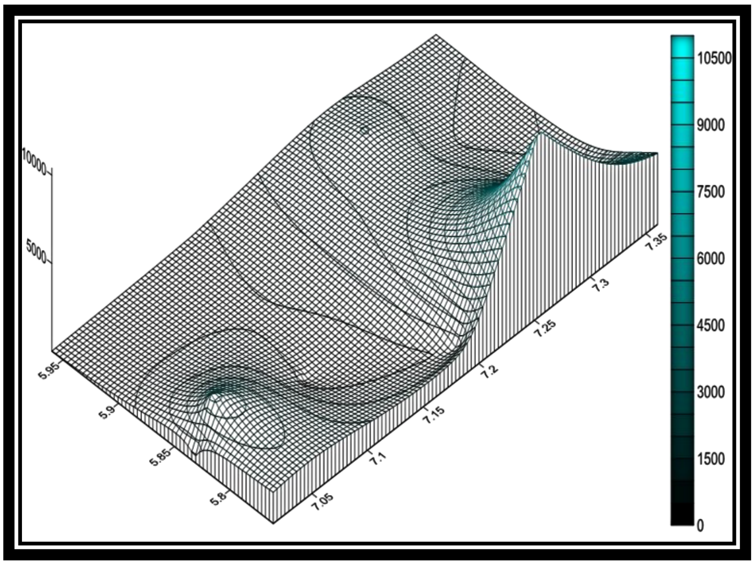

Fig. no 4: Wired 3D model Iso-resistivity at the value AB/2 = 5

Table no 3: Iso-Resistivity value for AB/2 from 70-135m

Station	Longitude	Latitude	70	75	80	85	90	95	100	105	110	115	120	125	130	135
Njaba River	7.193056	5.774767	2580	2750	2820	2890	2900	2950	3040	3110	3220	3310	3420	3530	3645	3790
Orlu/Ihiala Road	7.060278	5.878056	1184	1180	1170	1160	1150	1120	1045	970	900	840	760	720	680	640
Okwelle/Urualla Road	7.312500	5.886667	3400	3450	3410	3380	3340	3320	3320	3340	3360	3340	3260	3180	3020	2860
Afor Ukwu-Afor Nta	7.360556	5.861944	3200	3350	3500	3650	3750	3800	3800	3800	3750	3750	3700	3700	3750	3750
Okwelle/Urualla Road 2	7.322222	5.810833	4850	4900	5000	5050	5150	5190	5200	5280	5300	5300	5300	5280	5200	5100
Owerri/Orlu Road	7.253889	5.761111	12400	12400	14000	16800	18800	19000	18000	15400	13000	10400	8400	6900	6000	5400
Umunguma Ihioma	7.263889	5.927222	690	680	640	600	600	650	750	880	1025	1150	1250	1270	1250	1150
Ikpa/Ihioma	7.142778	5.960000	360	280	230	215	200	195	190	195	200	200	195	190	180	160
Umuazzala Ogberuru	7.028722	5.830389	1300	1290	1220	1120	1100	1100	1120	1205	1300	1500	1600	1750	1900	2000
Umueshi 1	7.110472	5.829000	2360	2190	2090	2030	1990	1960	1910	1860	1800	1750	1700	1640	1530	1550
Umueshi 2	7.109669	5.830806	1995	1860	1860	1950	2080	2125	2120	2080	2005	1940	1850	1770	1690	1600
Ogberuru 2	7.015389	5.832028	3150	3120	2880	2400	1950	1650	1605	1700	1880	2095	2350	2550	2820	3050

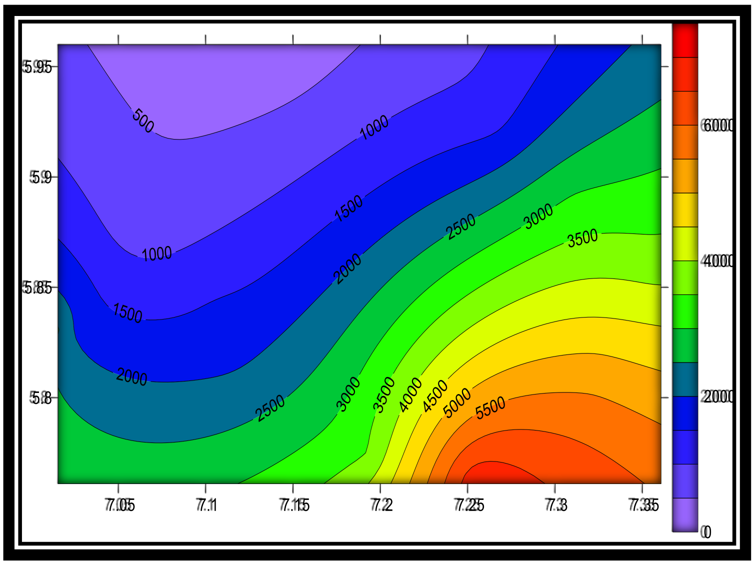

Fig.no 5: Iso-resistivity contour at the value AB/2 = 125

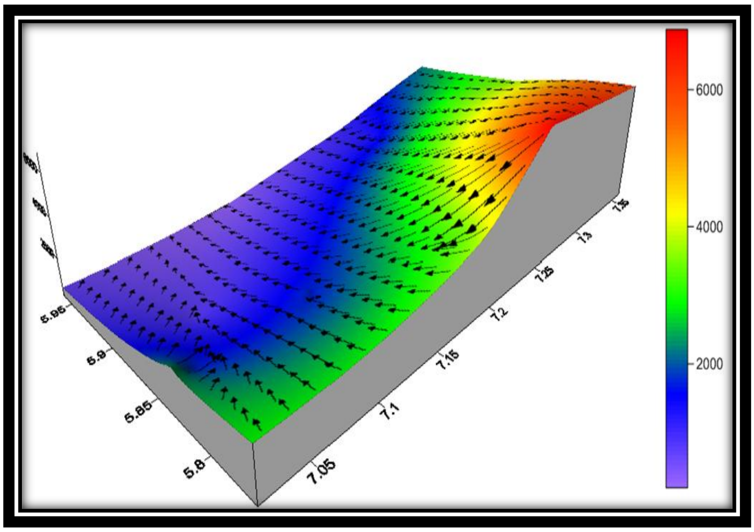

Fig.no 6:3D model with vector map of Iso-resistivity at the value AB/2 = 125

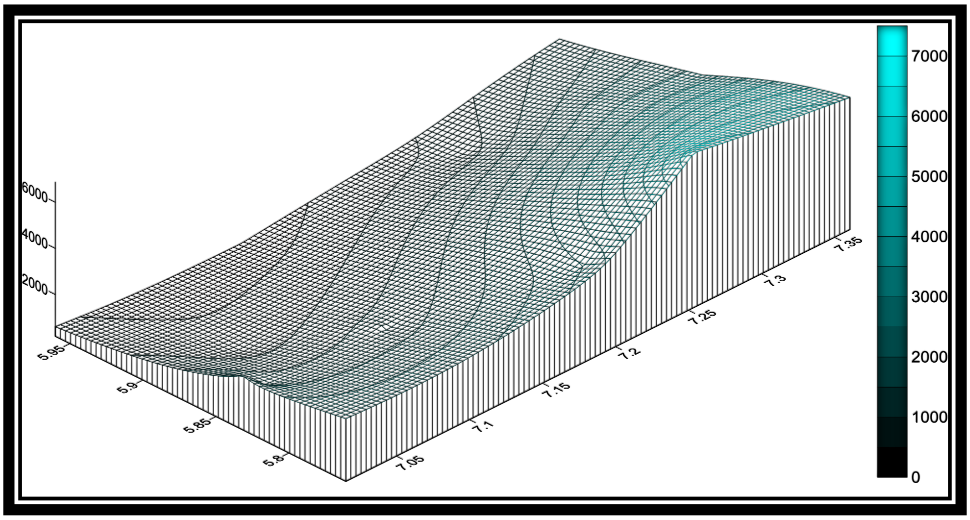

Fig.no 7: Wired 3D model Iso-resistivity at the value AB/2 = 125

Table no 4: Iso-Resistivity value for AB/2 from 135–195m

Station	Longitude	Latitude	135	140	145	150	155	160	165	170	175	180	185	190	195
Njaba River	7.193056	5.774767	3790	3905	4225	4180	4290	4350	4400	4420	4430	4480	4500	4545	4590
Orlu/Ihiala Road	7.060278	5.878056	640	635	605	595	580	560	520	460	400	325	280	240	240
Okwelle/Urualla Road	7.312500	5.886667	2860	2700	2540	2380	2220	2060	1930	1780	1620	1500	1340	1220	1220
AforUkwu-AforNta	7.360556	5.861944	3750	3800	3850	3900	3950	4100	4200	4300	4500	4600	4800	5000	5200
Okwelle/Urualla Road 2	7.322222	5.810833	5100	4850	4800	4650	4500	4400	4300	4200	4100	4000	3900	3800	3700
Owerri/Orlu Road	7.253889	5.761111	5400	5100	5000	4955	4900	4800	4700	4600	4600	4600	4600	4600	4650
Umunguma Ihioma	7.263889	5.927222	1150	1000	900	770	670	600	575	550	550	550	560	575	600
Ikpa/Ihioma	7.142778	5.960000	160	135	110	90	80	70	80	85	100	120	130	150	170
Umuazzala Ogberuru	7.028722	5.830389	2000	2150	2250	2350	2405	2500	2550	2595	2605	2630	2650	2670	2695
Umueshi 1	7.110472	5.829000	1550	1510	1480	1460	1450	1450	1460	1480	1500	1520	1550	1570	1590
Umueshi 2	7.109669	5.830806	1600	1520	1460	1400	1360	1320	1290	1260	1240	1220	1200	1180	1160
Ogberuru 2	7.015389	5.832028	3050	3250	3430	3550	3610	3620	3615	3580	3520	3450	3390	3320	3250

Table no 5: Iso-Resistivity value for AB/2 from 200–250m

Station	Longitude	Latitude	200	205	210	215	220	225	230	235	240	245	250
Njaba River	7.193056	5.774767	4685	5795	5810	5830	5865	5890	5905	5925	5985	6010	6100
Orlu/Ihiala Road	7.060278	5.878056	300	1960	1760	1560	1280	1145	840	620	420	250	150
Okwelle/Urualla Road	7.312500	5.886667	1940	2160	2020	2020	2020	2020	2000	1985	1980	1980	1950
AforUkwu-AforNta	7.360556	5.861944	5550	7550	7500	7400	7350	7250	7200	7100	7050	7000	7000
Okwelle/Urualla Road 2	7.322222	5.810833	3700	4850	5000	5100	5150	5250	5300	5400	5500	5600	5700
Owerri/Orlu Road	7.253889	5.761111	4700	4400	4100	3800	3600	3200	3000	2700	2400	2200	2000
Umunguma Ihioma	7.263889	5.927222	650	1450	1550	1600	1650	1700	1750	1775	1825	1875	1925
Ikpa/Ihioma	7.142778	5.960000	180	180	180	180	185	187	190	200	200	210	220
Umuazzala Ogberuru	7.028722	5.830389	2700	2705	2710	2720	2740	2750	2770	2780	2790	2795	2800
Umueshi 1	7.110472	5.829000	1600	1620	1630	1650	1660	1680	1690	1705	1720	1740	1750

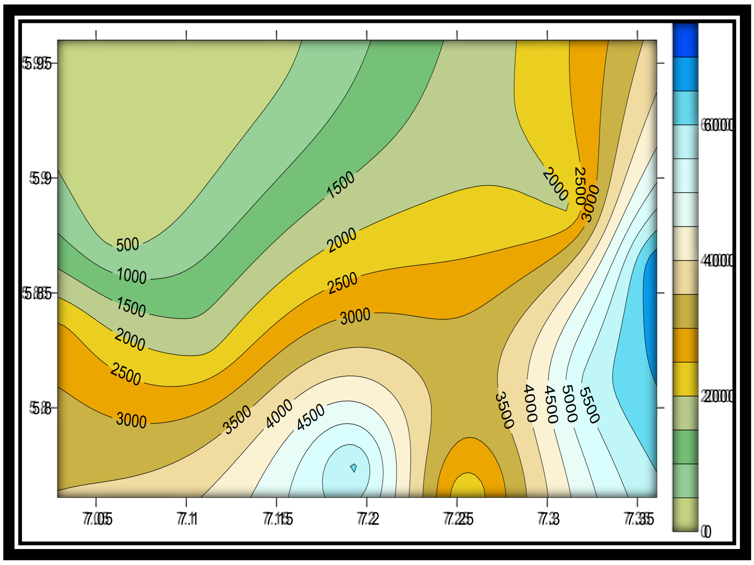

Fig.no 8: Iso-resistivity contour at the value AB/2 = 250

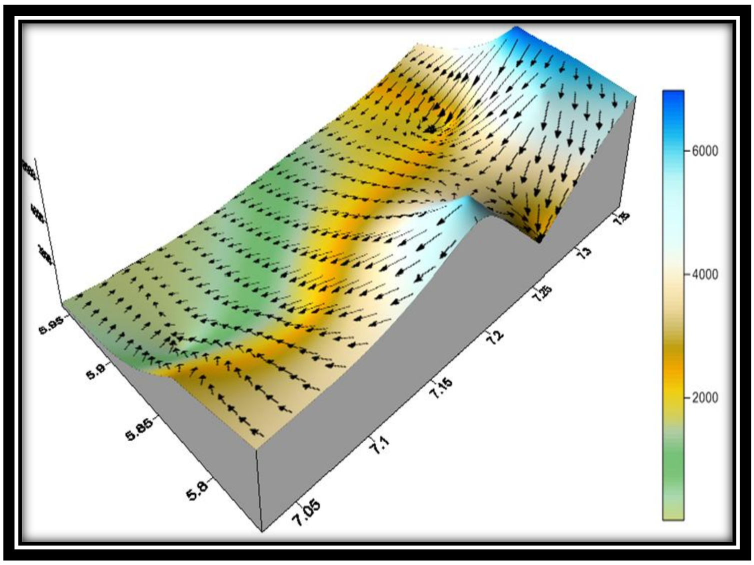

Fig.no 9: 3D model with vector map of Iso-resistivity at the value AB/2 = 250

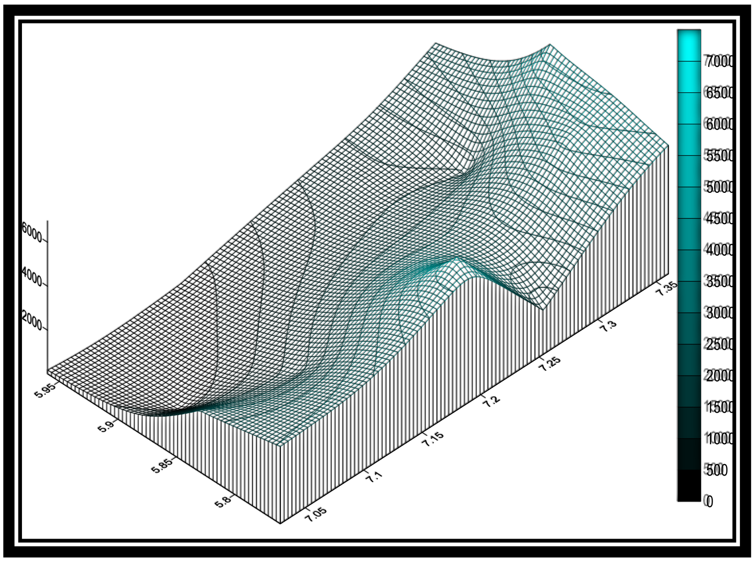

Fig.no10: Wired 3D model Iso-resistivity at the value AB/2 = 250

Table no 6: Table for layer resistivity, depth of layers and thickness of layers

Station	Longitude	Latitude	Layer Resistivity						Depth of Layers					Thickness of Layers					Elevation
			R1	R2	R3	R4	R5	R6	D1	D2	D3	D4	D5	T1	T2	T3	T4	T5	
Njaba River	7.193056	5.774767	186	10000	1090	9500	44800		1.6	8.7	33.6	65		1.6	7.1	24.9	31.4		115
Orlu/Thiala Road	7.060278	5.878056	383	940	1810	1190	528	38.9	1.1	14.6	33	67.5	104	1.1	13.5	18.4	34.5	36.5	102
Okwelle/ Urualla Road	7.312500	5.886667	650	5426	2870	910			4.8	34.5	61.8			4.8	29.7	27.3			152
AforUkwu-AforNta	7.360556	5.861944	970	521	11600	3710	7330	25500	4.7	10.6	36.	64.9	107	4.7	5.9	26.2	28.1	42.1	155
Okwelle/ Urualla Road 2	7.322222	5.810833	643	11200	2210	3700	11000		2.5	24.8	66.7	110		2.5	22.3	41.9	43.3		137
Owerri/ Orlu Road	7.253889	5.761111	5970	12800	24900	6520	1020		0.9	16.8	53.6	78.7		0.9	15.9	36.8	25.1		107
Umunguma Ihioma	7.263889	5.927222	1690	3100	560	748	621	7460	1.3	4.1	24.3	65.5	113	1.3	2.8	20.2	41.2	47.5	110
Ikpa/Thioma	7.142778	5.960000	213	3040	76.2	152	1060		1.6	9.9	64.2	106		1.6	8.3	54.3	41.8		94
Umuazzala Ogberuru	7.028722	5.830389	2708.7	6736	536.21	4843.4	320.54		3.0227	12.488	34.728	212.08		3.0227	9.4655	22.24	177.36		195
Umueshi 1	7.110472	5.829000	179.22	3498.7	897.07				3.4263	90.658				3.4263	87.232				260
Umueshi 2	7.109669	5.830806	65.168	471.34	1000.1	2999.2	2167	325.43	0.61059	1.5438	2.843	14.822	105.57	0.61059	0.93316	1.2993	11.979	90.745	273
Ogberuru 2	7.015389	5.832028	204.43	4430.9	1883	601.7			2.9033	119..34	181.91			2.9033	116.44	62.571			121

Below is the contour, 3D model and wired 3D models of elevation of Orlu and environs.

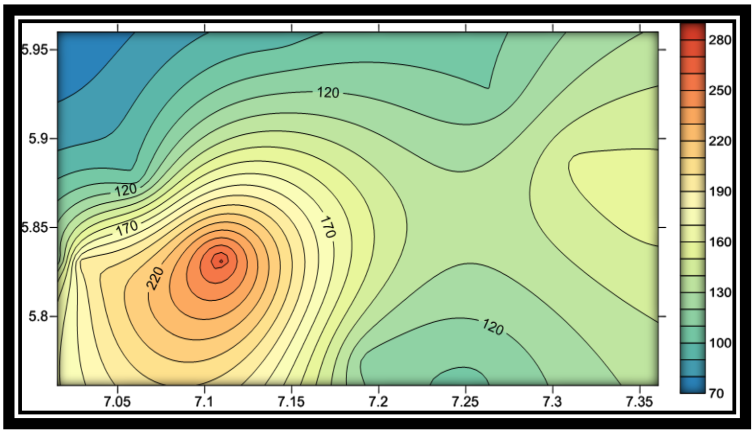

Fig.no 11: The elevation contour of the study area

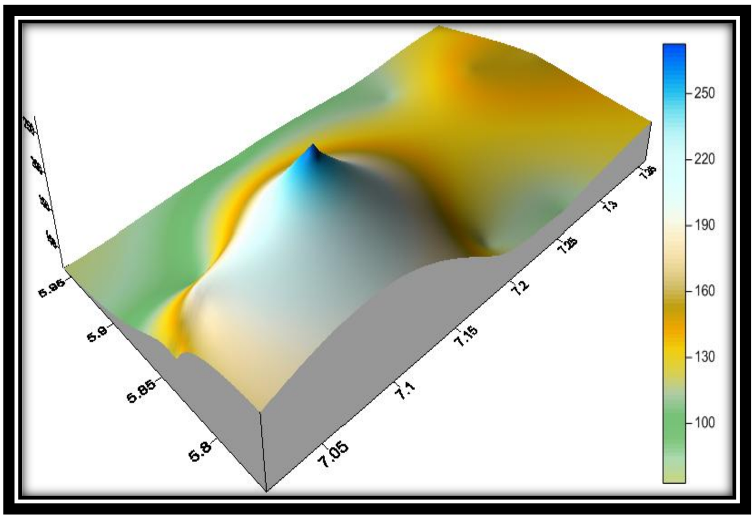

Fig.no 12:3D Model of the elevation of the study area

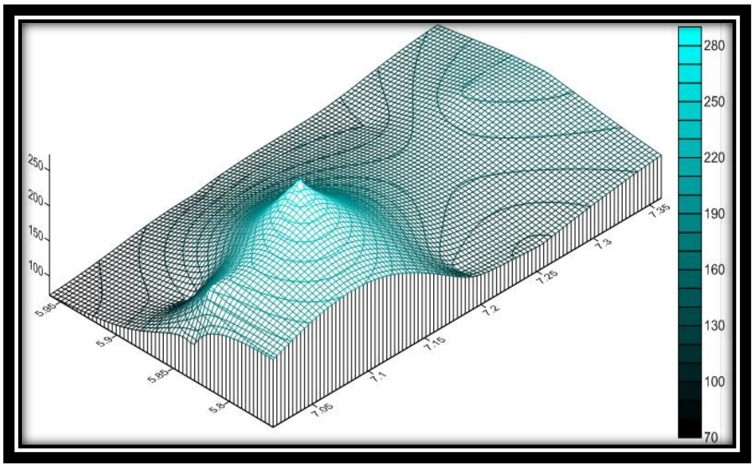

Fig.no 13: Wired 3D Model of the elevation of the study area

Below are the resistivity contours of layers within Orlu and environs.

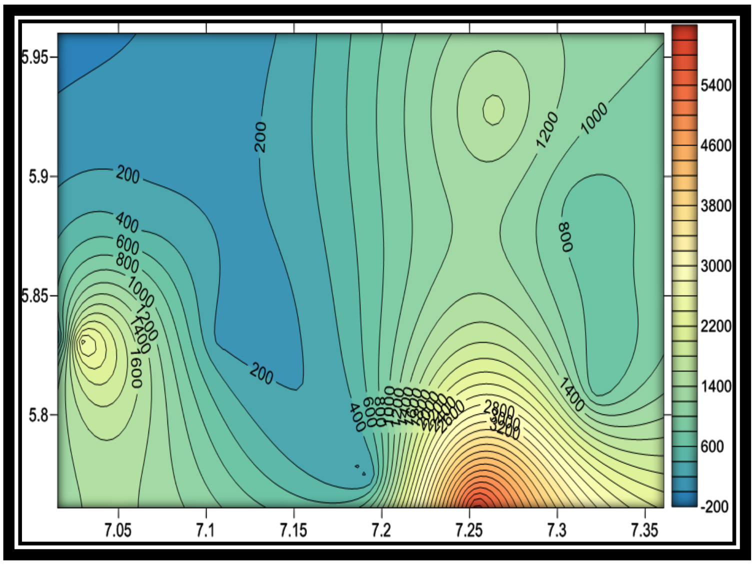

Fig.no 14: The resistivity contour of the entire first layers

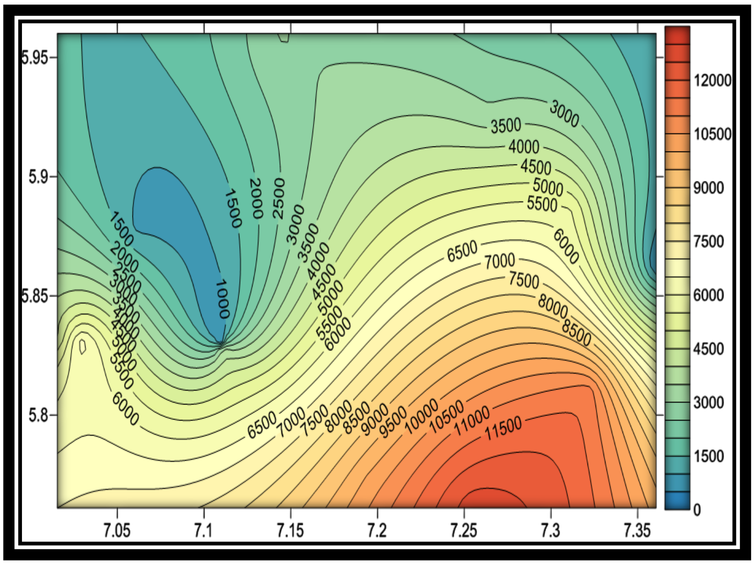

Fig.no 15: The resistivity contour of the entire second 2nd layers

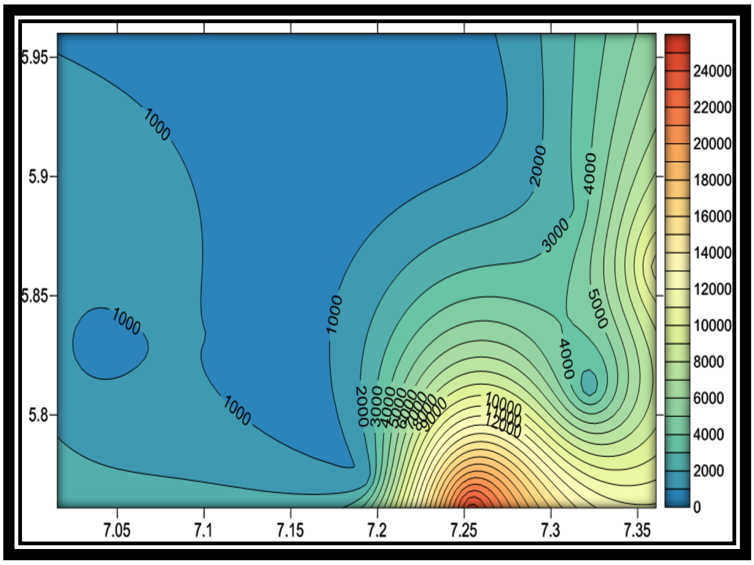

Fig.no 16: The resistivity contour of the entire third 3rd layers

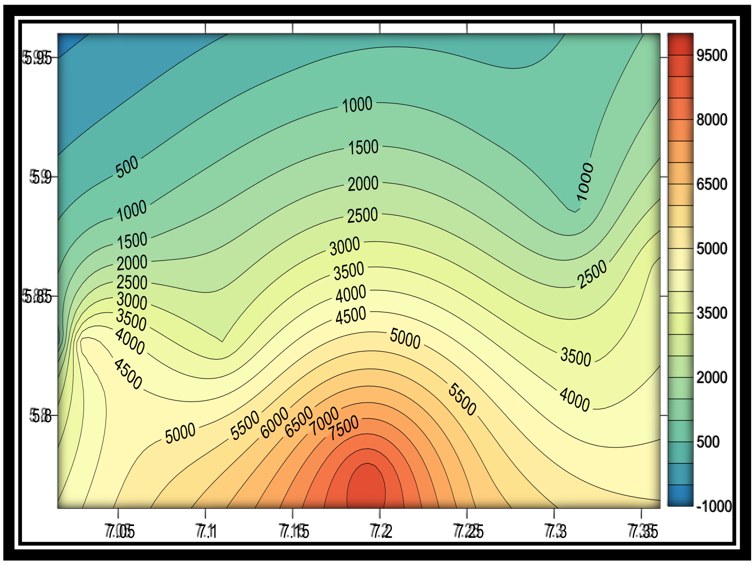

Fig.no 17: The resistivity contour of the entire 4th layers

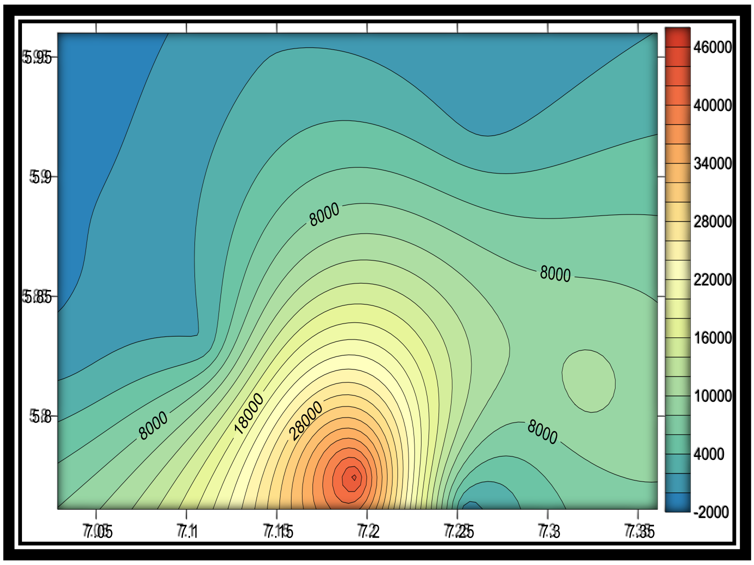

Fig.no 18: The resistivity contour of the entire 5th layers

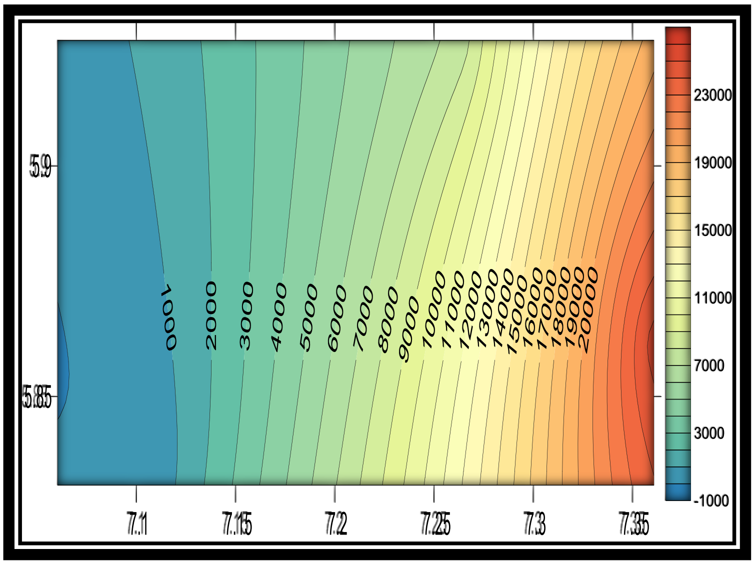

Fig.no 19: The resistivity contour of the entire 6th layers

IV. Discussion

The geo-electric sections and geo-electric profiling of the study locations given below helped in evaluating the properties of the earth materials in the study area.

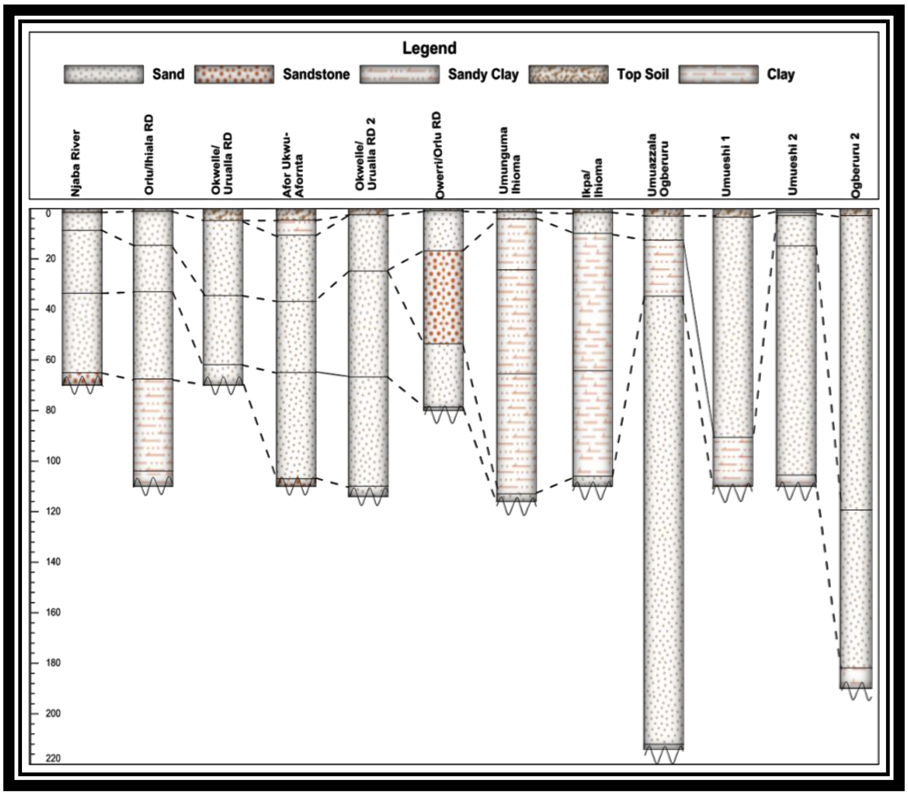

Fig.no 20: Geo-electric sections and profiling of the study locations

A combination of the interpreted sounding results together with information from lithological logs of existing boreholes in the study area were used to arrive at the conclusions that the top of the geo-electric sections (fig. 20) constitute the lateritic overburden. The upper segment of this overburden contains laterite while the immediate lower segment of this overburden is made up of coarse (reddish) sand. The lower layers of the geo-electric sections whose composition according to the lithological logs is mainly medium to coarse grained white and sands with relatively no clay were identified. The resistivity varies from place to place but lies within the range of 65–44800-Ωm. The resistivity would indicate clean non-saline groundwater.

Geo-electric sections of stratified layers which is deduced from electrical (resistivity) depth probing, where layers are identified by their apparent resistivities, in figures 20, shows variations in the apparent resistivity values of layers of different stations. The values of all the first layers of the entire stations did not coincide with each other as there are pronounced variations. This is also observed in the preceding layers of the entire stations, either in ascending or descending order to confirm the heterogeneity of the earth irrespective of being situated within the same geographical location. These differences in resistivities, shows areas with high pores to allow high rate of water penetrations and areas with minimal pores to permit water peculation or reduce the rate of penetrations. Areas with more retentive ability for fluids (water) are suggested to have less resistive ability as conducting minerals may dissolve in them to aid conductivity or reduce resistivity. These areas with high resistivity have much loose sand which is more often dry; and they are easily eroded in the presence of running water or any other erosion agent.

V. Conclusion

The identification of varying thicknesses of loose sand and unconsolidated sediments within the study area, combined with other exogenic and human factors render the area susceptible to erosional forces and gullying. Erosion control measures are suggested and human activities that interfere with soil stability should be discouraged.

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