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DETERMINATION OF LITHOLOGY AND GROUNDWATER QUALITY IN AWE, OYO STATE, NIGERIA, USING RESISTIVITY METHOD

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ABSTRACT: Vertical electrical soundings (VES) method using the Schlumberger array was used in the study area. 20 VES were probed and the data interpretation was carried out with aid of computer softwares IPI2Win and surfer 8. The results revealed three subsurface geoelectric layers (top soil, weathered layer and fresh layer) at VES 4, 5, 6, 7, 8, 9and 10, and the rest VES stations have four subsurface geoelectric layers (top soil, lateritic clay, weathered layer and fracture/fresh layer). The top layer resistivity values range from 112-829 ohm-m, and thicknesses from 0.5-8.85m. VES 1, 2, 3, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 with four layers, the second layer constitute the Lateritic clay and its resistivity values range from 34.9-406Ωm, and thicknesses from1.37-5.78m respectively. The second layer of VES 4, 5, 6, 7, 8, 9 and 10, and the third layer of VES 1, 2, 3, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 which constitute the Weathered zone has resistivity values that range from 8.99-339Ωm and thicknesses between 3.01-41.6m. The fourth layer of VES 11, 12, 17, 18 and 19 constitute the Fractured basement with resistivity values that range from 182-547Ωm. The third layer of VES 4, 5, 6, 7, 8, 9 and 10, and the fourth layer of VES 1, 2, 3, 13, 14, 15, 16 and 20 constitute the Fresh basement with resistivity values that range from 2090-19465Ωm. It was also observed that the Total Dissolved Salt values range from 12.797-778.643mg/l. VES has shown that it's very reliable for the determination of lithology and groundwater quality in the study area.

KEYWORDS: Vertical Electrical Sounding, Schlumberger array, Lithology, Groundwater quality, Total Dissolved Salt.

1 INTRODUCTION

Groundwater is one essential but necessary substitute to surface water in every community. It's no doubt a hidden replenishable resource whose occurrence and distribution greatly varies according to local as well as regional hydrogeologic settings and to an extent the nature of human activities on the surface. Groundwater in a basement terrain is hosted within zones of weathering and fracturing which often are not continuous in vertical or lateral extent [7]. The monitoring of the groundwater level exhibits a decreasing trend of water level. The main reason for this decline in the groundwater table is that wells pumping from groundwater resource have exceeded natural recharge in the recent years. It is important to get an overview of the ground conditions in early stages of planning and design of water related projects. Often the investigations are carried out using conventional geotechnical methods only, which is costly and only provide information in discrete points. The use of resistivity meter makes the groundwater exploration survey to estimate quantity and quality of groundwater. It can be said to be an alternative of a trial boring to some extent. The available groundwater resources can be estimated after preparing lithological logs and utilized usefully to supplement the canal water supplies for municipal and agricultural productions in order to remove the shortage of water [8].

In geophysical investigations for water exploration, depth to bedrock determinations, sand and gravel exploration etc., the Electrical Resistivity Meter (ERM) method can be used to obtain, quickly and economically, details about the location, depth and resistivity of subsurfaceformations. Emenike tested the groundwater potential and a correlation of the curves with the lithological log from a nearby borehole and suggested that the major lithological units penetrated by the sounding curves were laterite clay sandstone and clay [3].

ERM uses an artificial source of energy, rather than the natural fields of force, such as are used in gravity surveying and so the source detector separation can be altered to achieve the optimum separation, which effectively controls the depth of measurement. The water exploration survey with the help of ERM is low cost, easy for operation, speedy and accurate. Liu used ERM method for imaging changes of moisture content in the vadose zone [5]. The ability of the integrative approach was tested by directly estimating moisture distributions in three-dimensional, heterogeneous vadose zones.

The ERM solves the problems of groundwater in the alluvium formation aquifer as an inexpensive and useful method. Some uses of this method in groundwater are: determination of depth, thickness and boundary of an aquifer, determination of interface saline water and freshwater porosity of aquifer, hydraulic conductivity of aquifer, transmissivity of aquifer, specific yield of aquifer, and contamination of groundwater [2]. Contamination usually reduces the electrical resistivity of pure water due to increase of the ion concentration [4]. However, when resistivity methods are used, limitation can be expected if ground inhomogeneties and anisotropy are presented [6]. However, the use of geophysics for both groundwater resource mapping and for water quality evaluations has increased dramatically over the last few years in large part due to the rapid advances in microprocessors and associated numerical modeling solutions.

The purpose of this paper is to use the resistivity data to study the aquifer conditions, such as depth, thickness, boundaries and location of the aquifer and groundwater quality by calculating the total dissolved salt (TDS) in order to determine the level of salinity. This study can be used to prove groundwater supplies as a unique source of water for this area.

2 Geological Setting Of The Study Area

The study area (Awe) is located in Afijio Local Government Area of Oyo State, southwestern Nigeria. It lies within latitudes $7^{o}49'0''$N to $7^{o}49'15''$N and longitudes $3^{o}56'57''$E to $3^{o}57'18''$E.

The Most of Southwestern part of Nigeria belongs to the schist belt. To be specific, Osun and Oyo (which is the parent case study) belong to crystalline basement region, Ogun State belongs to basement complex (undifferentiated) region. The major rocks in the southwestern Nigeria are igneous, sedimentary and metamorphic. The igneous rocks include the older granite, pegmatite, rhyolite and dolerite while the sedimentary rocks include the Shale, Coal measures, and Coastal plainsand Alluvium. The metamorphic rocks include the undifferentiated basement complex.

3 Field Procedure And Data Analysis

The vertical electrical soundings (VES) were conducted using Campus Ohmega Terrameter in twenty (20) locations.

Campus Ohmega Terrameter was used for data gathering at the field. It is made in such a way that it uses the potential difference as well as the current sent into the ground to automatically compute the resistance of the subsurface at any given point, for a particular set of electrode configurations. The instrument is programmed in such that it filters self-potentials and noise from incoming signals, so that the output is actually the true resistance of subsurface, which can be used, with appropriate formulae, in the calculation of the apparent resistivity of the subsurface in ohmmeter. Campus Ohmega Terrameter usually comes with self-rechargeable battery, four electrodes, cables, hammer, crocodile clips and measuring tapes.

Schlumberger configuration was employed in the data gathering process which is called VES (vertical electrical sounding). Twenty VES was acquired from the study area and with aid of computer software (IPI2Win), these graphs and others were obtained (fig 3.1 – 3.10).

The total dissolved salt (TDS) for each of geoelectric sounding (VES) station was computed (table 4.2), this is to determine the level of salinity of the groundwater at each VES station.

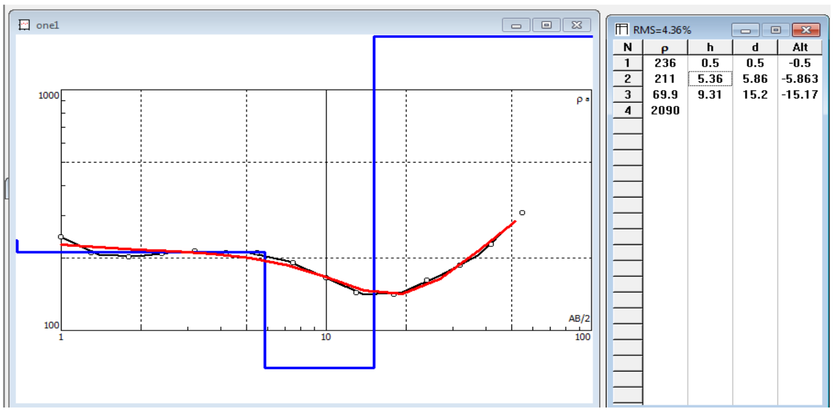

Fig. 3.1: VES 1

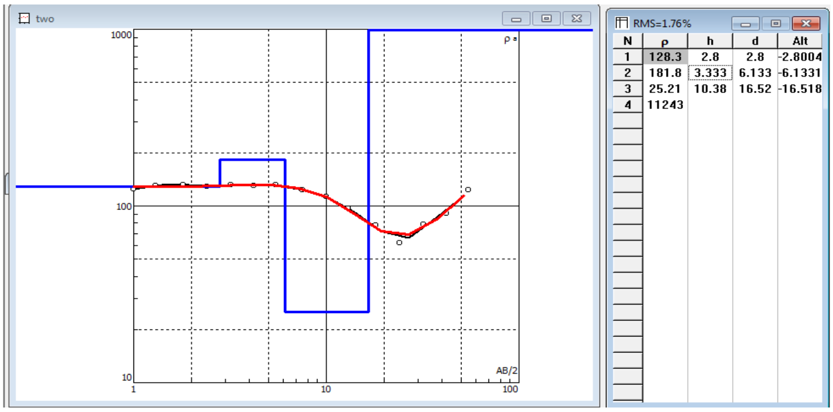

Fig. 3.2: VES 2

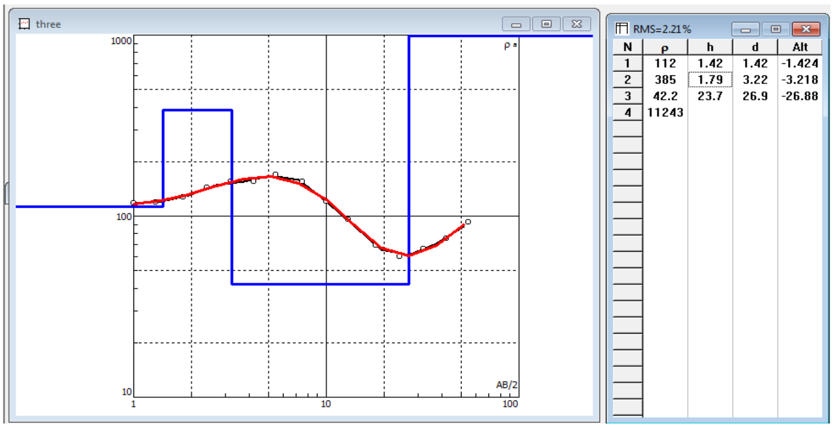

Fig. 3.3: VES 3

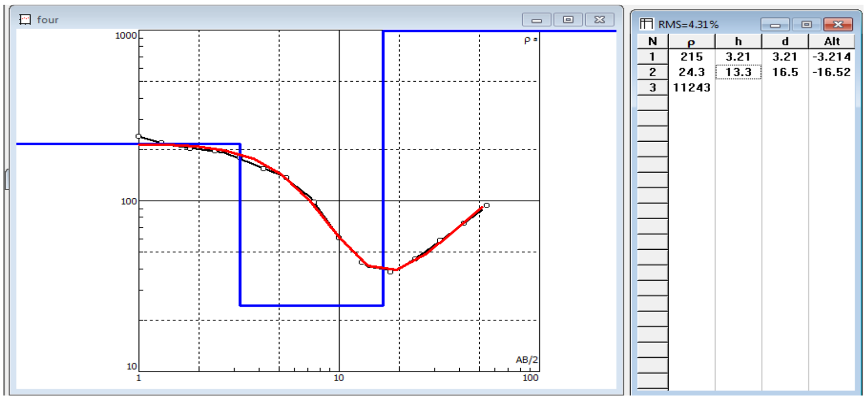

Fig. 3.4: VES 4

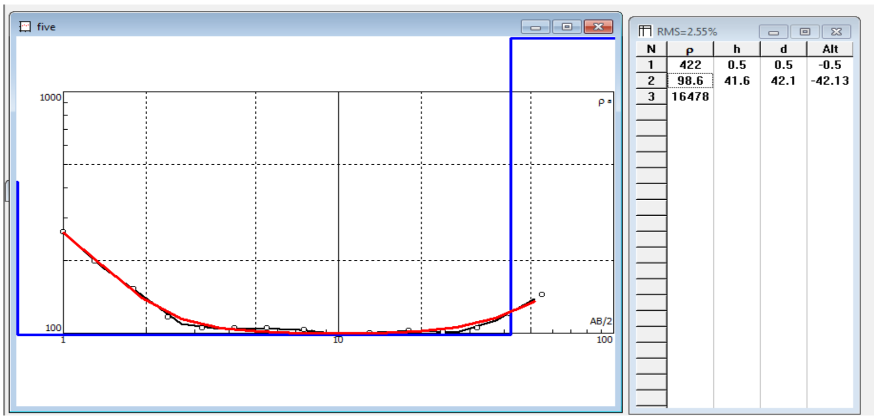

Fig. 3.5: VES 5

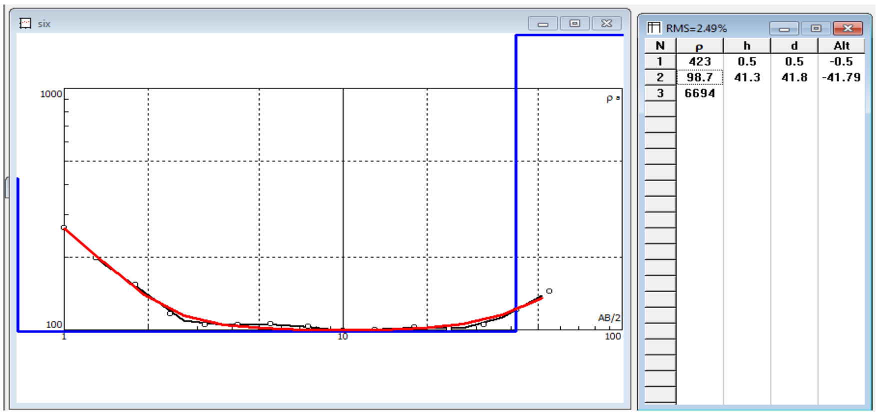

Fig. 3.6: VES 6

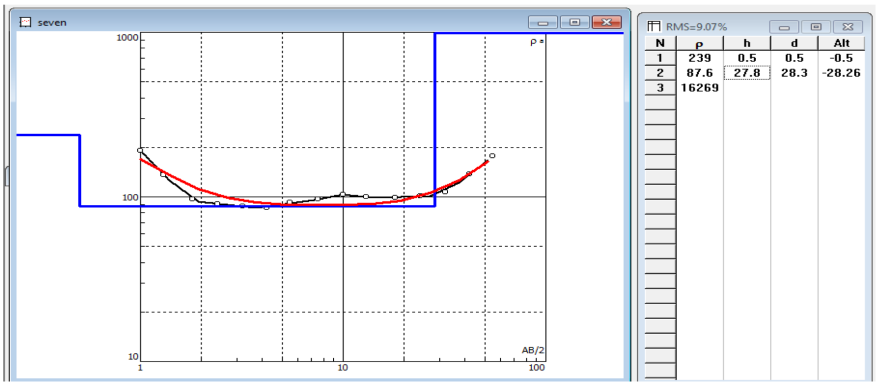

Fig. 3.7: VES 7

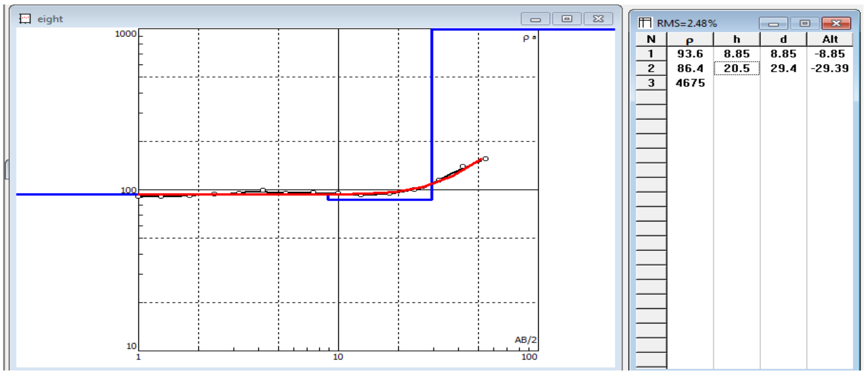

Fig. 3.8: VES 8

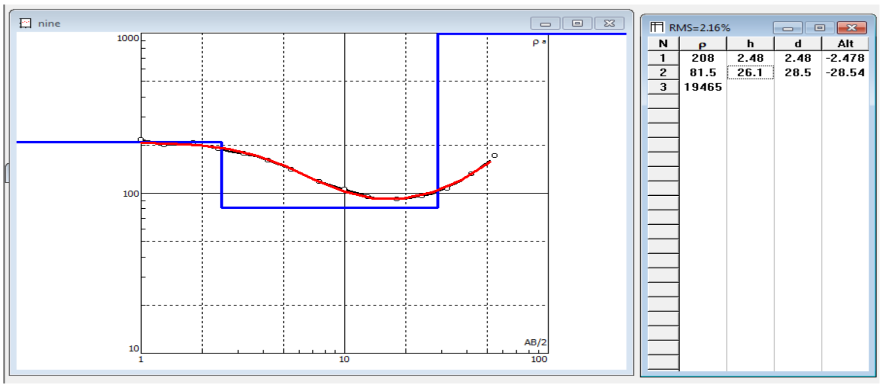

Fig. 3.9: VES 9

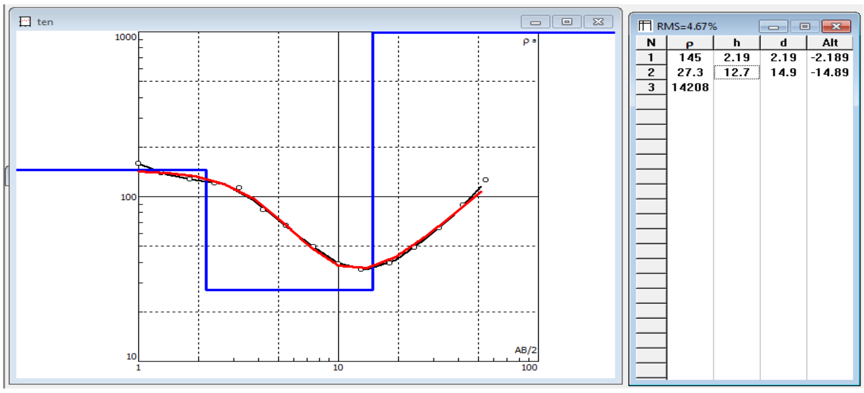

Fig. 3.10: VES 10

3.1 Conductivity and Salinity of Waters [1]

Conductivity (siemens) = 1/resistivity (ohm.m)

Usual unit of conductivity = microS/cm

Conductivity (microS/cm) = 10^4/resistivity (ohm.m)

Salinity (mineralization): Total Dissolved Salt (TDS)

TDS (mg/l) = 0.7 × Conductivity (microS/cm)

Usual rule for drinkable water is that salinity must be less than 700mg/l (salinity < 700mg/l) [1]

Table 3.1: Numerical values for various types of water [7]

Type of water	Resistivity(ohm.m)	Conductivity (microS/cm)	Salinity (mg/l)
Very fresh	200	50	35
Fresh	20	500	350
Salted	10	1000	700
Very salted (sea water)	0.3	30000	21000

4 Results And Discussion

Table 4.1: Summary of VES Interpretation

VES	LAYER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	Probable LITHOLOGY	CURVE TYPE	CORDINATES	ELEVATIONS (m)
	1	236	0.5	0.5	Topsoil		Latitude	
1	2	211	5.36	5.41	Lateritic clay	QH	7.8172°N	327
	3	69.9	9.31	15.2	Weathered basement		Longitude	
	4	2090	-	-	Fresh basement		3.9521°E	
	1	128.3	2.8	2.8	Topsoil		Latitude	
	2	181.8	3.333	6.133	Lateritic clay		7.8176°N	319
2	3	25.21	10.38	16.52	Weathered basement	KH	Longitude	
	4	11243	-	-	Fresh basement		3.9514°E	
	1	112	1.42	1.42	Topsoil		Latitude	

3	2	285	1.79	3.22	Lateritic clay	KH	7.8191°N	340
	3	42.2	23.7	26.9	Weathered basement			
	4	11243	-	-	Fresh basement		Longitude 3.9510°E	
4	1	215	3.21	3.21	Topsoil	H	Latitude	319
	2	24.3	13.3	16.5	Weathered basement		7.8191°N	
	3	11243	-		Fresh basement		Longitude 3.9496°E	
5	1	422	0.5	0.5	Topsoil	H	Latitude	351
	2	98.6	41.6	42.1	Weathered basement		7.8174°N	
	3	16478	-	-	Fresh basement		Longitude 3.9508°E	
6	1	423	0.5	0.5	Topsoil	H	Latitude	366
	2	98.7	41.3	41.8	Weathered basement		7.8168°N	
	3	6694	-	-	Fresh basement		Longitude 3.9510°E	
7	1	239	0.5	0.5	Topsoil	H	Latitude	365
	2	87.6	27.8	28.3	Weathered basement		7.8167°N	
	3	16269	-	-	Fresh basement		Longitude 3.9502°E	
8	1	93.6	8.85	8.85	Topsoil	H	Latitude	337
	2	86.4	20.5	29.4	Weathered basement		7.8174°N	
	3	4675	-	-	Fresh basement		Longitude 3.9500°E	
9	1	208	2.48	2.48	Topsoil	H	Latitude	366
	2	81.5	26.1	28.5	Weathered basement		7.8180°N	
	3	19465	-	-	Fresh basement		Longitude 3.9501°E	
10	1	145	2.19	2.19	Topsoil	H	Latitude	368
	2	27.3	12.7	14.9	Weathered basement		7.8179°N Longitude	
	3	14208	-	-	Fresh basement		3.9514°E	
11	1	829	1.59	1.59	Topsoil	HK	Latitude	330
	2	221	2.74	4.33	Lateritic clay		7.8185°N	
	3	339	8.75	13.1	Weathered basement		Longitude	
	4	256	-	-	Fractured basement		3.9524°E	
12	1	543	1.39	1.39	Topsoil	QH	Latitude	337
	2	34.9	5.78	7.16	Lateritic clay		7.8194°N	
	3	16.8	15.1	22.2	Weathered basement			
	4	299	-	-	Fractured basement		Longitude 3.9518°E	

13	1	122	0.589	0.589	Topsoil	QH	Latitude	343
	2	56.4	1.37	1.96	Lateritic clay		7.8204°N	
	3	17.1	19.2	21.2	Weathered basement			
	4	6008	-	-	Fresh basement		Longitude 3.9520°E	
14	1	133	0.955	0.955	Topsoil	QH	Latitude	350
	2	106	3.57	4.53	Lateritic clay		7.8195°N	
	3	8.99	10.1	14.6	Weathered basement			
	4	6008	-	-	Fresh basement		Longitude 3.9526°E	
15	1	280	1.27	1.27	Topsoil	QH	Latitude	360
	2	108	1.51	2.78	Lateritic clay		7.8199°N	
	3	38.8	36.7	39.5	Weathered basement		 Longitude	
	4	6008	-	-	Fresh basement		3.9530°E	
16	1	152	0.5	0.5	Topsoil	QH	Latitude	366
	2	63.9	5.3	5.8	Lateritic clay		7.8204°N	
	3	29.8	10.1	15.9	Weathered basement			
	4	6008	-	-	Fresh basement		Longitude 3.9527°E	
17	1	198	1.95	1.95	Topsoil	KH	Latitude	364
	2	263	1.95	3.9	Lateritic clay		7.8195°N	
	3	49.8	5.37	9.27	Weathered basement		 Longitude	
	4	182	-	-	Fractured basement		3.9545°E	
18	1	216	0.5	0.5	Topsoil	QH	Latitude	375
	2	111	1.78	2.28	Lateritic clay		7.8200°N	
	3	70.9	30.8	33.1	Weathered basement			
	4	547	-	-	Fractured basement		Longitude 3.9537°E	
19	1	146	1.54	1.54	Topsoil	KH	Latitude	369
	2	406	1.38	2.92	Lateritic clay		7.8187°N	
	3	33.8	3.01	5.92	Weathered basement		 Longitude	
	4	256	-	-	Fractured basement		3.9540°E	
20	1	278	1.58	1.58	Topsoil	QH	Latitude	370
	2	124	3.03	4.61	Lateritic clay		7.8183°N	
	3	21.9	7.93	12.5	Weathered basement		 Longitude	
	4	5718	-	-	Fresh basement		3.9534°E	

Table 4.2: TDS value for each station

VES Station	TDS (mg/l)
1	100.143
2	277.668
3	165.877
4	288.066
5	70.994
6	169.492
7	79.909
8	81.019
9	85.89
10	256.41
11	27.344
12	23.411
13	409.357
14	778.643
15	180.412
16	234.899
17	38.462
18	12.797
19	27.343
20	319.635

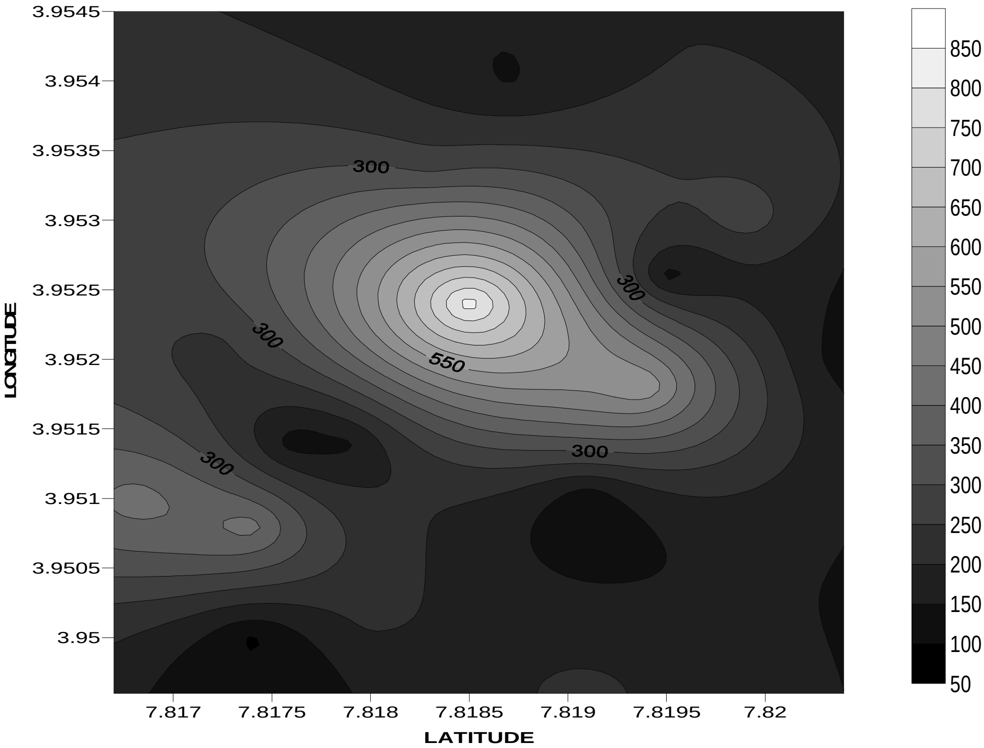

Fig. 4.1: Top Soil Iso-resistivity

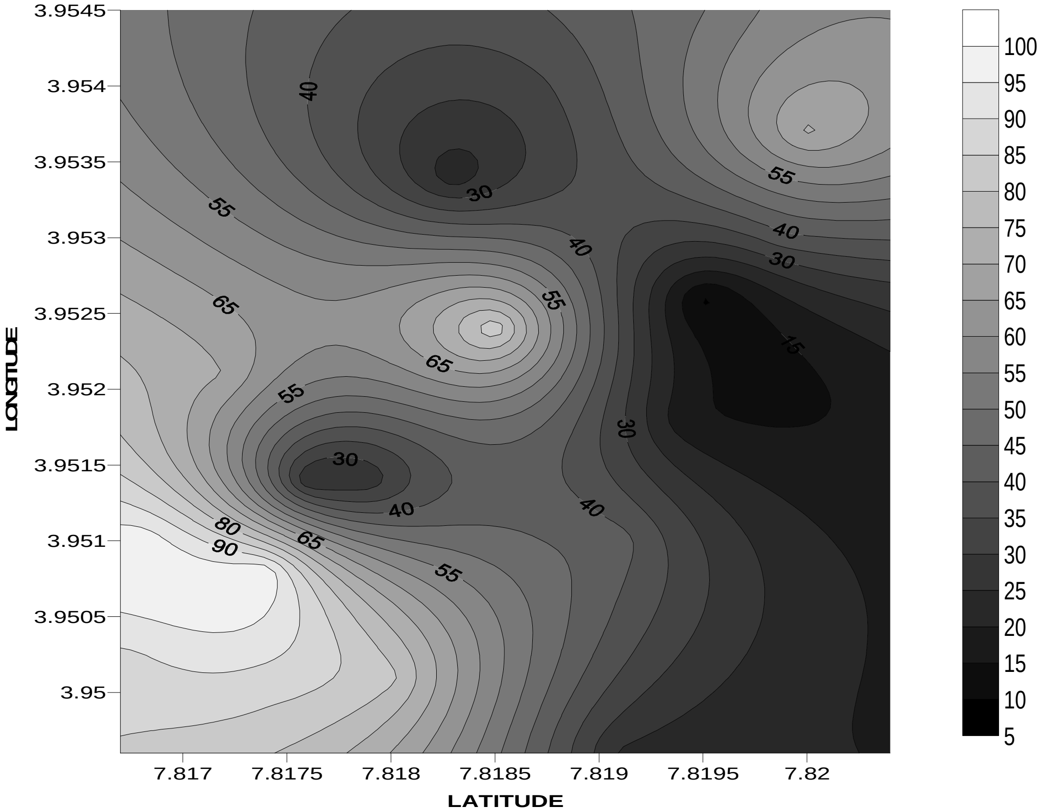

Fig. 4.2: Weather Layer Iso-resistivity

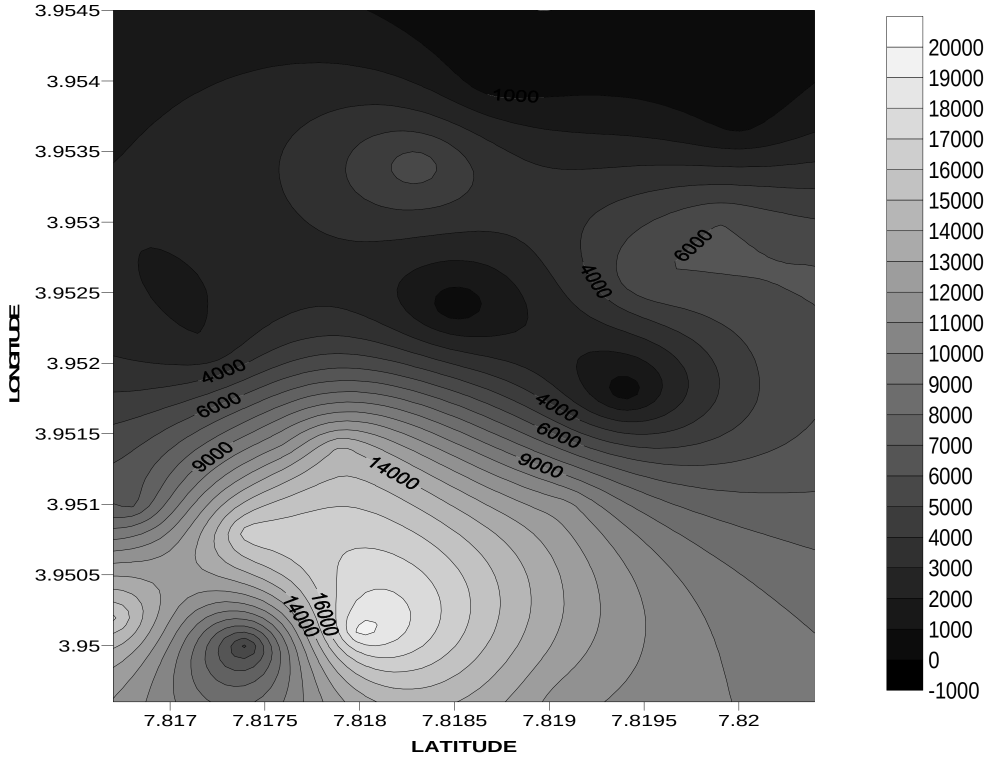

Fig. 4.3 iso-resistivity of basement layer

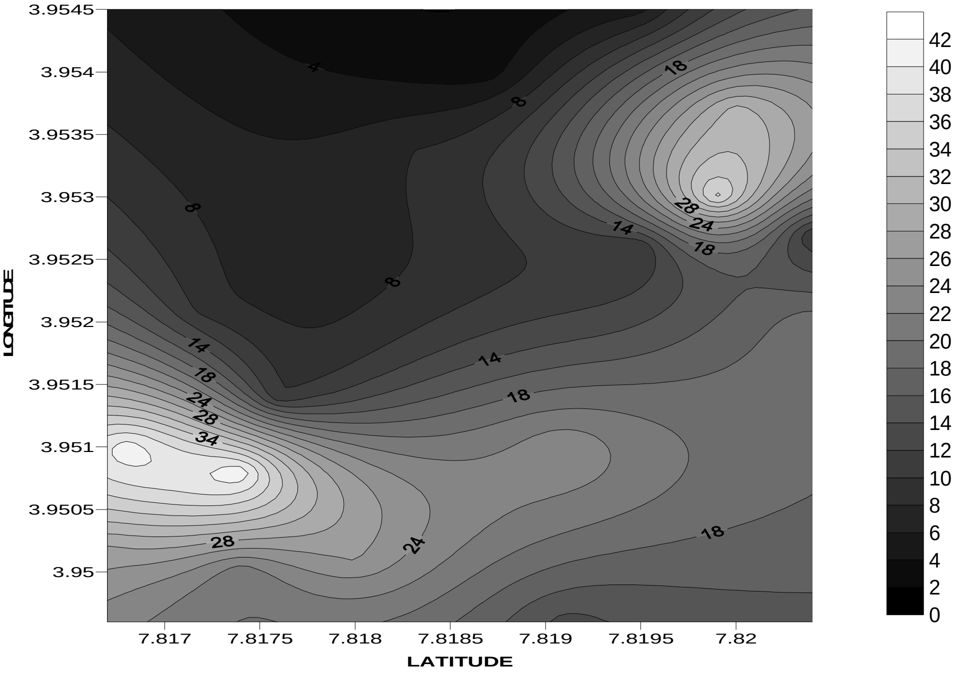

Fig.4.4: Weather Layer Thickness

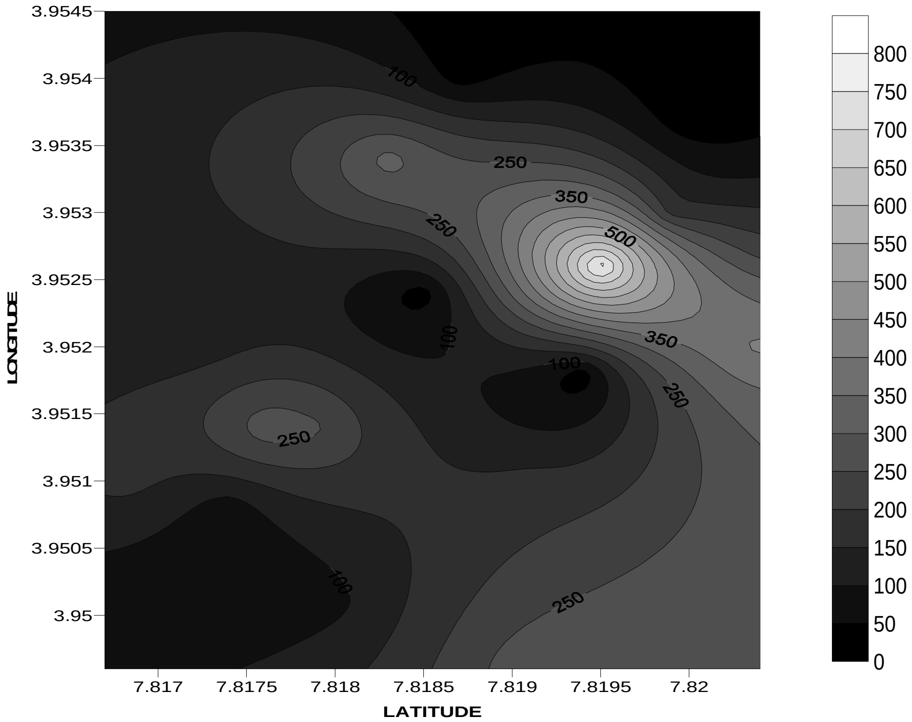

Fig. 4.5: TDS map

5 CONCLUSION

The results from geoelectric sounding to determine the lithology and groundwater quality in Awe, Oyo State, Southwestern Nigeria have been presented. The interpretation results obtained from the study area shows the sequence and relationships between the subsurface lithologies. VES test revealed three subsurface geoelectric layers(top soil, weathered layer and fresh layer) at VES stations 4, 5, 6, 7, 8, 9and 10, and four subsurface geoelectric layers(top soil, lateritic clay, weathered layer and fracture/fresh layer) at VES stations 1, 2, 3, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20. The iso – resistivity of topsoil, weathered layer, basement layer and thickness of the weathered layer is also presented showing variations in their values from one VES point to the other (as seen in fig. 4.1 – 4.4).

The interpretation results obtained from the study area also show the ground water salinity which help to determine the ground water quality. It is seen that all the VES stations have a Very Fresh groundwater quality except VES 19 and 20 that have a Fresh and a Salted groundwater quality respectively (as seen in fig. 4.5).

The research has shown that in basement environment, Vertical Electrical Sounding (VES) have proved to be very reliable for the determination of lithology and groundwater quality.

It is envisaged that the findings of this work will provide reliable background information for an elaborate groundwater development in in Awe, Oyo State, South western Nigeria.

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