GEOPHYSICAL INVESTIGATION OF GROUNDWATER POTENTIALS OF OKE-BADAN ESTATE, IBADAN, SOUTHWESTERN NIGERIA

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Abstract
Electrical resistivity survey using Schlumberger vertical electrical sounding (VES) field technique was carried out at Oke-Badan, Akobo area, Ibadan, Southwestern Nigeria. The dominant rocks comprise suites of quartzschist and pegmatite. The traverse length i.e AB/2 is 100m while the distance of separation between the VES station is 100m. A maximum of four geoelectric layers were delineated from the vertical electrical sounding. The geoeletrical sections for the study area were: the topsoil, the clayey sand, sandy clayey, shale/clay basement, and the fresh basement. Computer modeling using WinGLink program was used for the iteration to obtain the geoelectrical parameters. Interpretations of VES data were used to generate 2D basement relief / topography map, weathered layer resistivity map showing groundwater potential zones, overburden thickness map and aquifer unit(s) thickness map using computer software. The groundwater potential zones were identified in which poor, moderate and good zones are classified with respect to the prospects of finding groundwater in the study area. The study reveals that the weathered and fractured horizons that occur in the southeastern part, as a ridge at northeastern part and as an isolated patch at the western part of the area constitute the productive water – bearing zones referred to as good groundwater potential aquifers.

Introduction

Water is an essential commodity to mankind, our most precious resources that is the original elixir of life. It is found everywhere in the earth's ecosystem however, the only naturally occurring in organic liquid and is the only chemical compound that occurs in normal conditions as a solid, a liquid and a gas. However the water, which exists in such abundance on the earth, is unevenly distributed in both time and space and in circulation (Ajayi et al, 1988).

The search for groundwater has become quite intense in human history. This is due to the fact that government is unable to meet the ever-increasing water demand; inhabitants have had to look for alternative sources such as surface streams, shallow wells and boreholes.

Ibadan is one of the largest urban centres in West Africa (Olayinka et al, 1999) with several settlements around it (Fig.1.0), one of which is Akobo community where the research work was carried out. Groundwater exploration is gaining more and more importance in Ibadan owning to the ever increasing demand for water supply, especially in areas with inadequate pipe-borne and surface water supplies (Olayinka et al, 1999).

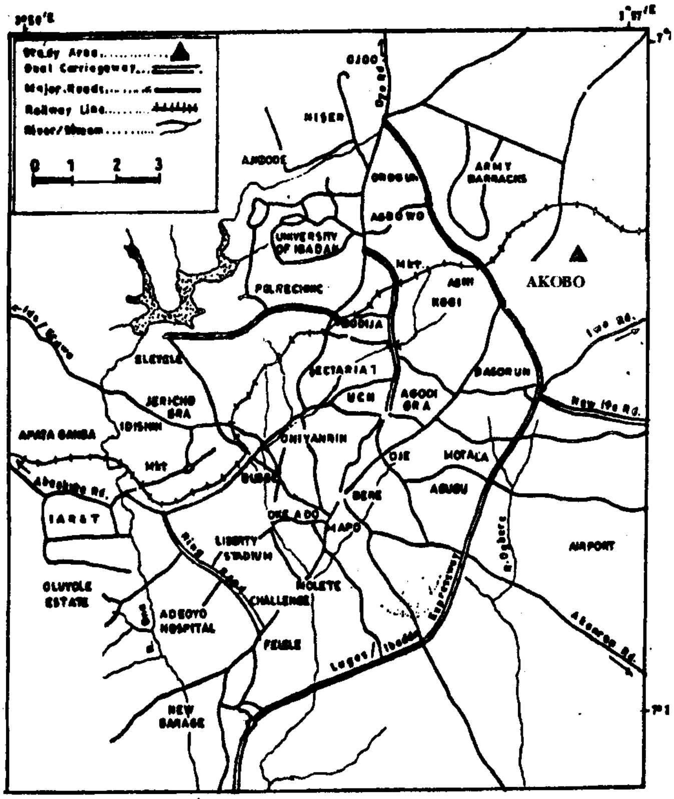

Fig.1.0:Map of Ibadan and Environs Showing Study Area

Many hand-dug wells that were sunk in the study area without an initial proper investigation failed and so were abandoned; a systematic and scientific approach to the problem is therefore essential for the study area in order to overcome these problems.

Regional Geology and Hydrogeology

The study area lies within the southwestern part of the Nigerian Precambrian basement complex The Nigerian Basements Complex, occupying approximately 50% of the surface area of the country is part of the Pan African crystalline shield (Figure 2.0).

The dominant rock types in the Ibadan area are quartzite, banded gneiss and granite gneiss. Associated rock suites found in all the major outcrops in the study area include pegmatites and quartz veins. Generally, wells from quartzite areas produce more water than wells from other rock types. This is because their transmissivites and permeability are higher due to the presence of fissures and quartz veins (Olorunfemi, 1992).

The groundwater is contained in weathered and fractured/jointed basement. Palacky et al (1981) state that localization of groundwater in fractured zone and weathered zone will make the yield of wells in crystalline bedrock terrain to be highly variable.

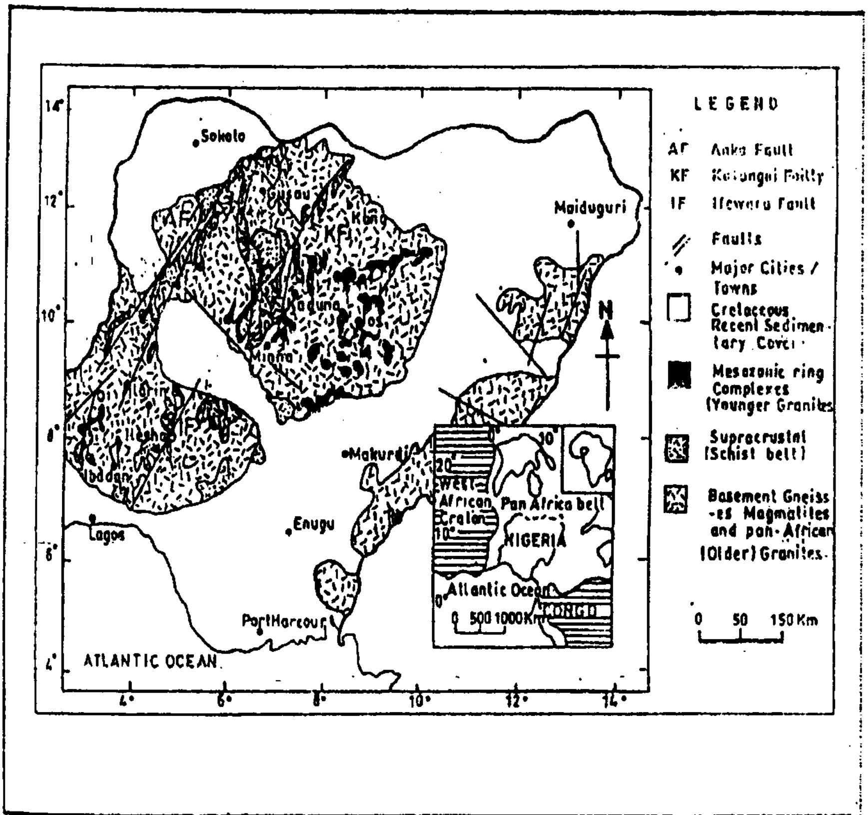

Fig.2.0: Regional Geology of the Pan-African Shied of Nigeria, Insert Geological Map of Africa (Modified after 1994 edition of the Geological Survey of Nigeria Map).

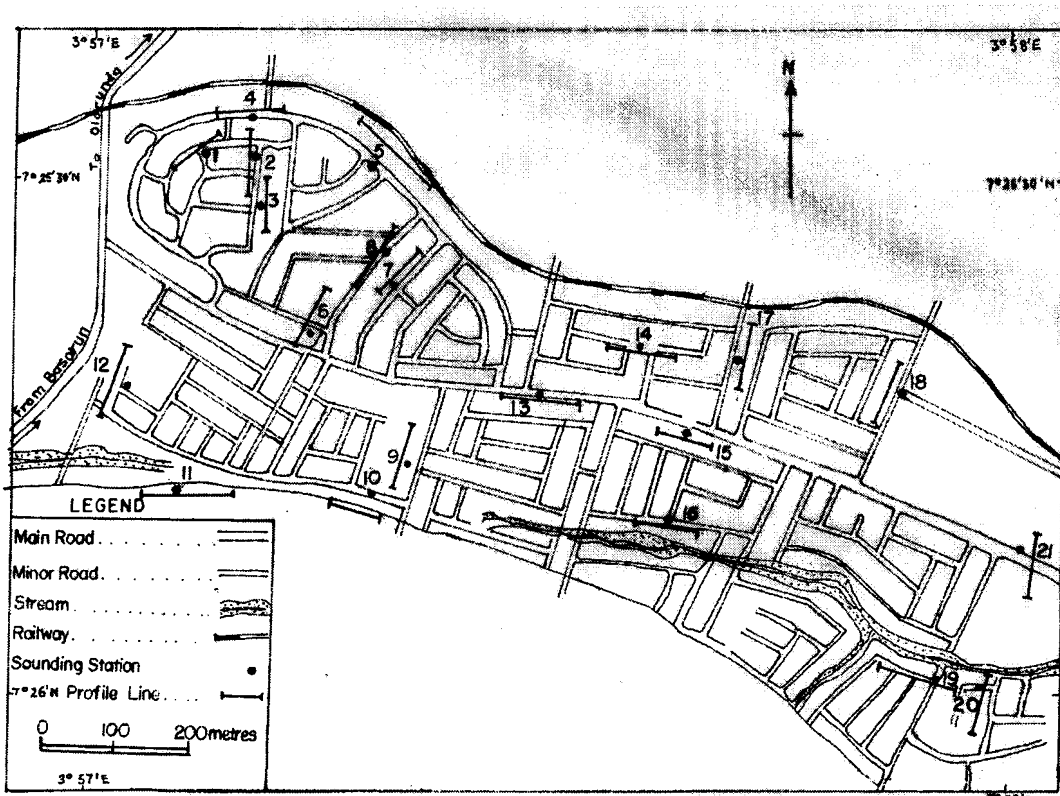

FIG. 3.0: LOCATION MAP OF OKE BADAN ESTATE SHOWING SOUNDING POINTS.

Field Method and Data Analysis

The electrical resistivity method, of all the surface geophysical methods, has been applied most widely in groundwater exploration studies (Todd 1980) because it can clarify the subsurface structure, delineate groundwater zone and is inexpensive (Mazae et al, 1985).

Figure 3.0 presents the data acquisition map of the study area showing sounding points. The electrical resistivity method can be best employed to estimate the thickness of overburden and also the thickness of weathered/fractured Zones with reasonable accuracy (Zohdy et al, 1974).

Schlumberger array, involving four electrodes spacing with two current electrodes widely spaced outside and two potential electrodes closely spaced within them along a line was used for this survey.

The maximum current electrode spacing (AB) was 200m. A terraemeter was used to measure and record the resistance of the subsurface. The resistance values obtained in the field was used to multiply with the geometric factor, which gives the required apparent resistivity results. Computer modeling using WinGLink program was used for the iteration to obtain the geoelectrical parameters.

Results and Discussion

The results and salient features of the subsurface parameters are presented in Table 1. The sounding curve H, is the only three – layer type of VES curves and a number of four – layered type of VES curves QH, HA and KH (Figs. 4a and b).

The types of curves obtained are H- type, HA – type, QH – type and KH- type (which is the least).In basement complex terrains, the intermediate layer of H-type is commonly water saturated and is often characterized by low resistivity, high porosity, low specific yield and low permeability (Jones, 1985)

The results of the VES interpretations were used to generate 2D Basement relief / Topography map, weathered layer resistivity map, overburden thickness map and aquifer unit(s) thickness map. Similarly, the interpreted result was also used to draw the geoelectric sections and they were correlated with the available borehole logs.

Table 1: Summary of Results

VES Station/Curve Type	Layer	Resistivity (Ohm-m)	Thickness (m)	Depth (m)	Lithology
1 QH	1	794.68	0.81	0.81	Topsoil
	2	438.34	6.11	6.92	Clayey sand
	3	224.53	8.35	15.27	Sandy clay
	4	1093.21	-	-	Fresh Basement
2 H	1	395.59	0.71	0.71	Topsoil
	2	25.34	5.09	5.8	Shale/Clay
	3	1337.58	-	-	Fresh Basement
3 QH	1	805.48	0.27	0.27	Topsoil
	2	183.45	6.41	6.68	Sandy clay
	3	24.73	6.41	13.09	Shale/Clay
	4	1319.92	-	-	Fresh Basement
4 H	1	2186.45	0.38	0.38	Topsoil
	2	42.87	5.98	6.36	Shale/Clay
	3	353.09	-	-	Clayey sand
5 QH	1	1697.76	0.33	0.33	Topsoil
	2	171.79	3.28	3.61	Sandy clay
	3	60.78	6.99	10.6	Shale/Clay
	4	5489.94	-	-	Fresh Basement
6 HA	1	2713.13	0.8	0.8	Topsoil
	2	239.32	7.86	8.66	Sandy clay
	3	407.33	5.89	14.55	Clayey sand
	4	1532.56	-	-	Fresh Basement
7 HA	1	1488.86	0.43	0.43	Topsoil
	2	388.05	3.27	3.7	Clayey sand
	3	770.68	8.42	12.12	Fractured Basement
	4	5236.94	-	-	Fresh Basement
8 HA	1	1015.82	0.31	0.31	Topsoil
	2	186.2	1.99	2.3	Sandy clay
	3	378.45	9.43	11.73	Clayey sand
	4	714.75	-	-	Fractured Basement
9 HA	1	1859.64	0.29	0.29	Topsoil
	2	232.35	2.84	3.13	Sandy clay

	3	551.46	11.35	14.48	Fractured Basement
	4	1264.4	-	-	Fresh Basement
10 KH	1	185.09	1.74	1.74	Topsoil
	2	861.6	3.46	5.2	Clayey sand
	3	199.26	19.84	25.04	Sandy clay
	4	869.8	-	-	Fractured Basement
11 HA	1	634.71	3.18	3.18	Topsoil
	2	53.45	8.12	11.3	Shale/Clay
	3	295.16	2.29	13.59	Clayey sand
	4	552.95	-	-	Clayey sand
12 HA	1	261.01	0.92	0.92	Topsoil
	2	168.25	11.83	12.75	Sandy clay
	3	795.67	20.16	32.91	Fractured Basement
	4	1187.95	-	-	Fresh Basement
13 KH	1	184.84	1.77	1.77	Topsoil
	2	383.7	1.76	3.53	Clayey sand
	3	30.22	5.12	8.65	Shale/Clay
	4	3072.27	-	-	Fresh Basement
14 H	1	236.64	9.78	9.78	Topsoil
	2	85.53	17.06	26.84	Shale/Clay
	3	1084.08	-	-	Fresh Basement
15 KH	1	290.44	0.49	0.49	Topsoil
	2	468.26	5.18	5.67	Clayey sand
	3	241.47	22.06	27.73	Sandy clay
	4	491.59			Fractured Basement
16 QH	1	4209.29	0.15	0.15	Topsoil
	2	120.54	9.61	9.76	Sandy clay
	3	28.45	16.74	26.5	Shale/Clay
	4	1983.45	-	-	Fresh Basement
17 QH	1	355.75	0.82	0.82	Topsoil
	2	189.01	5.12	5.94	Sandy clay
	3	59.76	22.91	28.85	Shale/Clay
	4	210.31	-	-	Sandy clay
18 H	1	200.58	1.05	1.05	Topsoil
	2	80.36	16.52	17.57	Shale/Clay
	3	511.11	-	-	Clayey sand
19 QH	1	701.83	0.67	0.67	Topsoil
	2	165.81	5.56	6.23	Sandy clay
	3	32.55	21.91	28.14	Shale/Clay
	4	319.42	-	-	Clayey sand

20 H	1	224.55	0.89	0.89	Topsoil
	2	26.18	12.31	13.2	Shale/Clay
	3	1113.79	-	-	Sandstone
21 H	1	42.38	1.04	1.04	Topsoil
	2	24.61	13.11	14.15	Shale/Clay
	3	1249.4	-	-	Sandstone

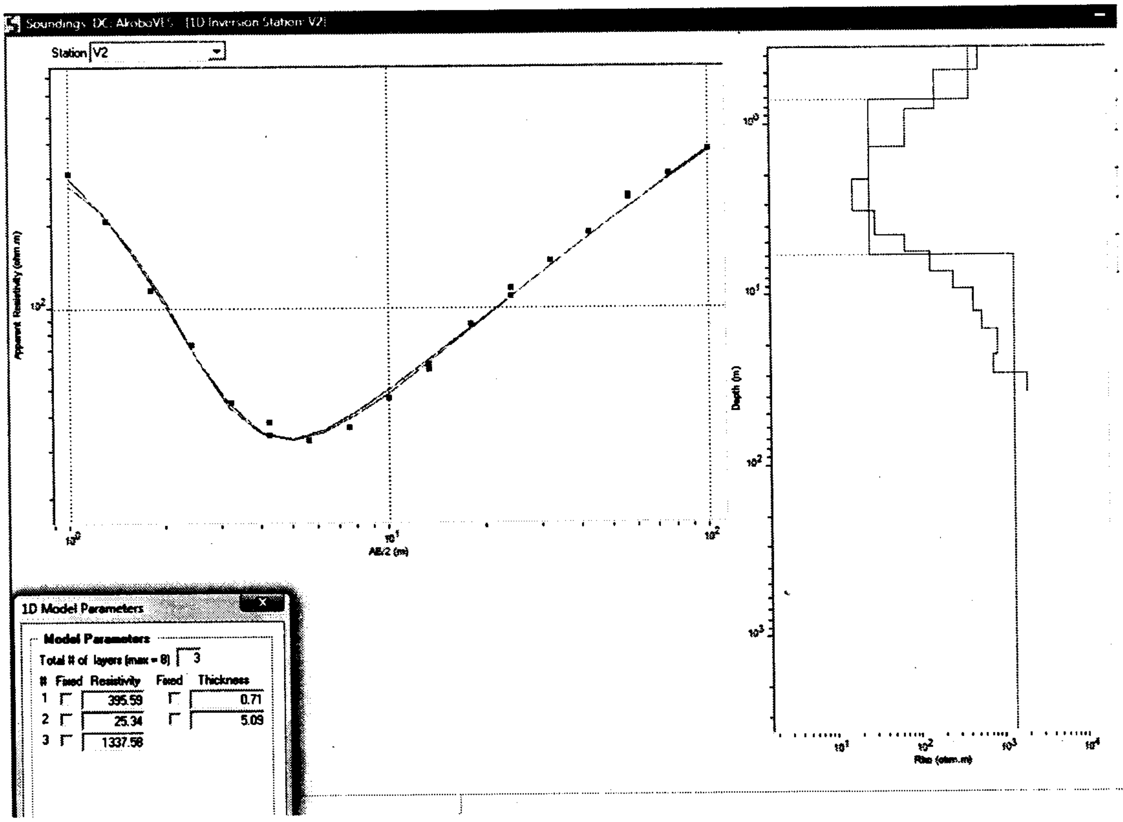

Fig.4(a):Typical three layered VES curves

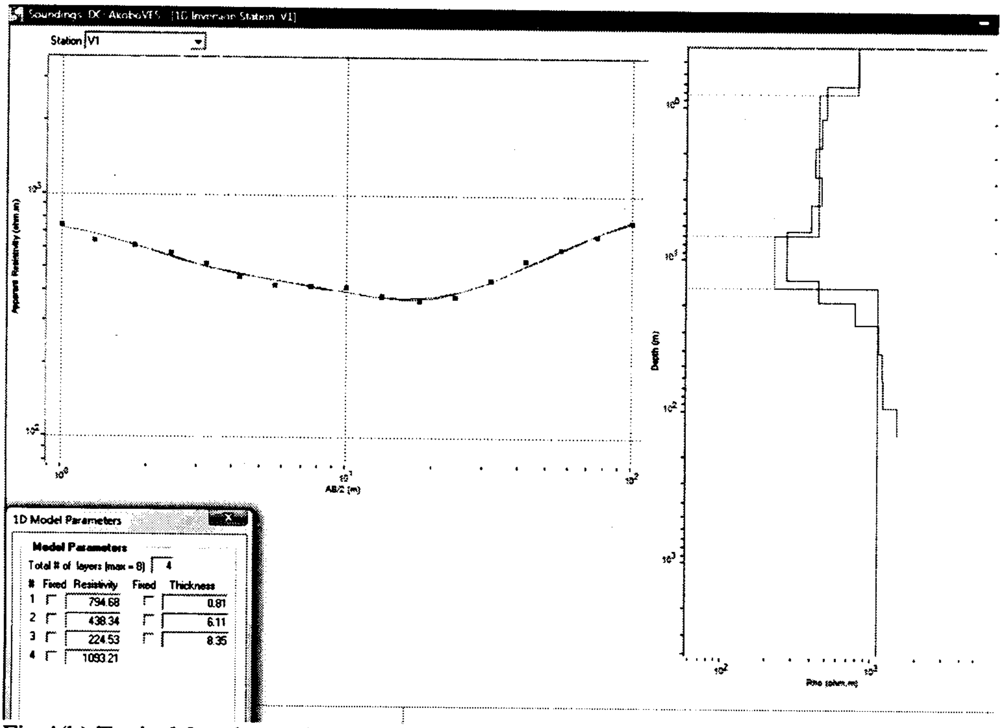

Fig.4(b):Typical four layered VES curves

2D Basement Relief / Topography map

The 2D basement relief map (figure 5) clearly show the morphology of the subsurface in the area investigated. The relief of the area indicated that the subsurface depth varies over 4m to greater than 28m. It has contour intervals of 6m.

The topography map considered shows the areas with geological formations such as trough (VES 9, 14, and 17) and ridges (VES 13 and 18) which predicts the depth at which we can get good groundwater potential because troughs and ridges are good groundwater collecting zones.

Weathered layer Resistivity map

The weathered layer resistivity map (figure 6) gives low range of resistivity value between 20 and 370 ohm-m. The map considered show the ranking level of groundwater potential zones at each of VES stations.

It can be seen on this map that VES stations that falls within the layer resistivity value between 20 and 90 ohm-m have higher potential groundwater values as well as the local geology.

Quartz schist was the outcrops found in the study area and if weathered into sand and gravel i.e. good aquifers, it will favour the area where to site the borehole. It should be noted that weathered layer resistivity alone cannot be used to infer groundwater potential zone, other factors needs to be considered.

Overburden Thickness Map

The overburden thickness map is showing in figure 7.Overburden is all formation/material overlaying the basement i.e. in basement zone. In most cases for some boreholes, the thickness of overburden should be less than the target i.e aquifer thickness.

The overburden thickness can be used to evaluate cost effectiveness of the area in terms of the amount and efficiency. It can be seen from the overburden thickness map that the area with VES stations whose value is less than 1.5m will cost less than other area with higher overburden thickness.

Aquifer Unit(s) Thickness Map

The aquifer unit(s) thickness map shown in figure 8 can be used in ranking geology formation because volume of water from each VES stations is a function of aquifer thickness. Thus prediction can be made based on thickness contrast and close resemblance with that of weathered resistivity layer map considered earlier.

The entire study area can be classified as good, moderate and poor groundwater potential zones. The study reveals that the productive water-bearing zone categorized as good potential zone occurs at southeastern part (VES 16 and 19) as a ridge, (VES 17) at northeastern part and as an isolated patch (VES 12) at the western part of the study area with a thickness value greater than 25m.

A range of value of an aquifer thickness 15m to 25m is suspected to give a moderate groundwater potential zone in which VES 10, 14, 15, 18. and 20 fall within the area. The remaining parts of the area were also suspected to be associated with low saturated zone with an aquifer thickness less than 15m, classified as a poor potential water zone.

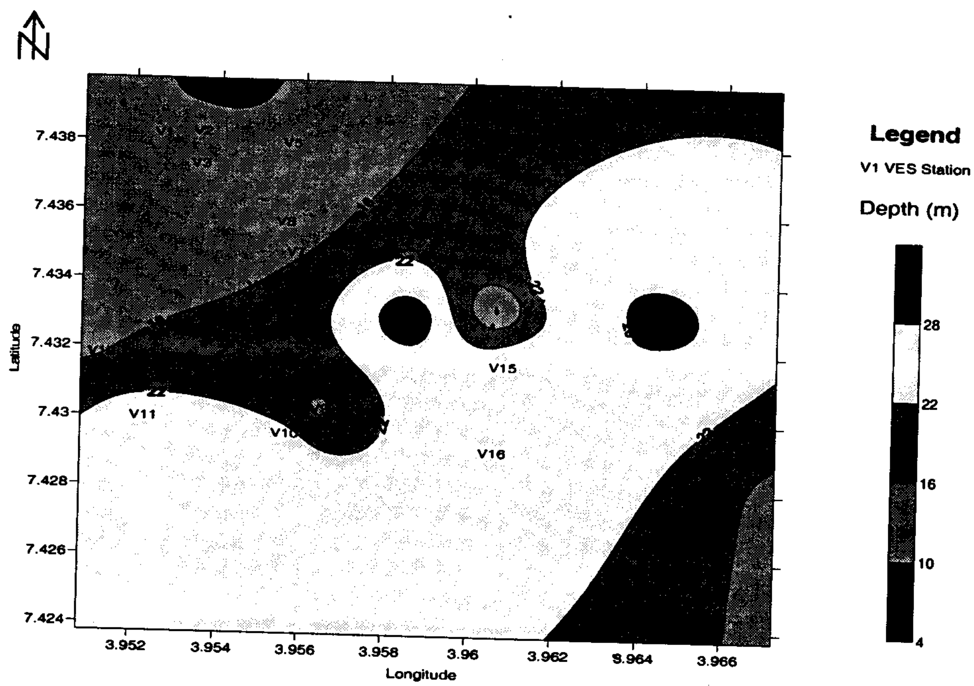

Figure 5: 2D Basement Relief/Topography Map

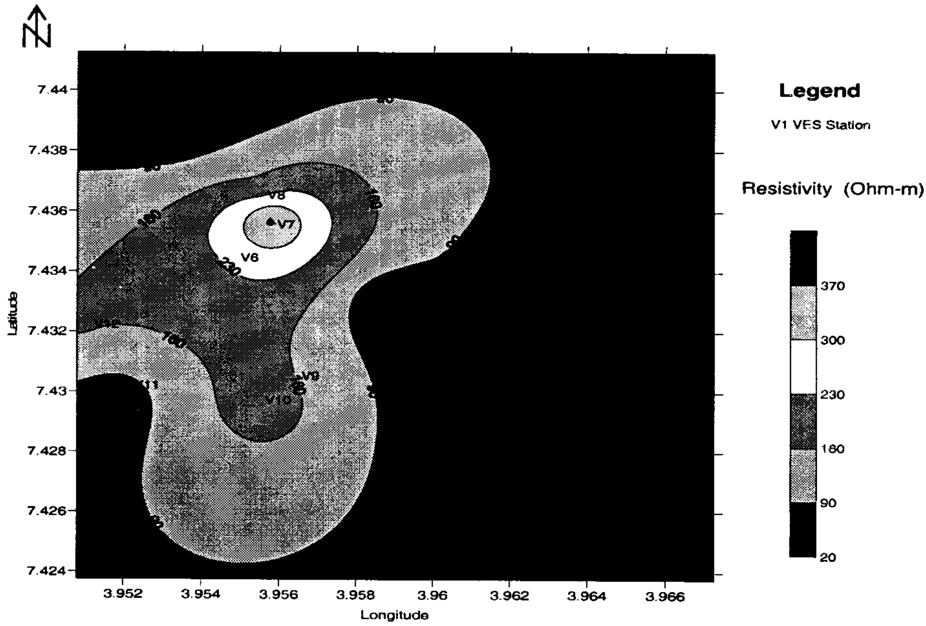

Figure 6: Weathered Layer Resistivity Map showing Groundwater Potential Zones

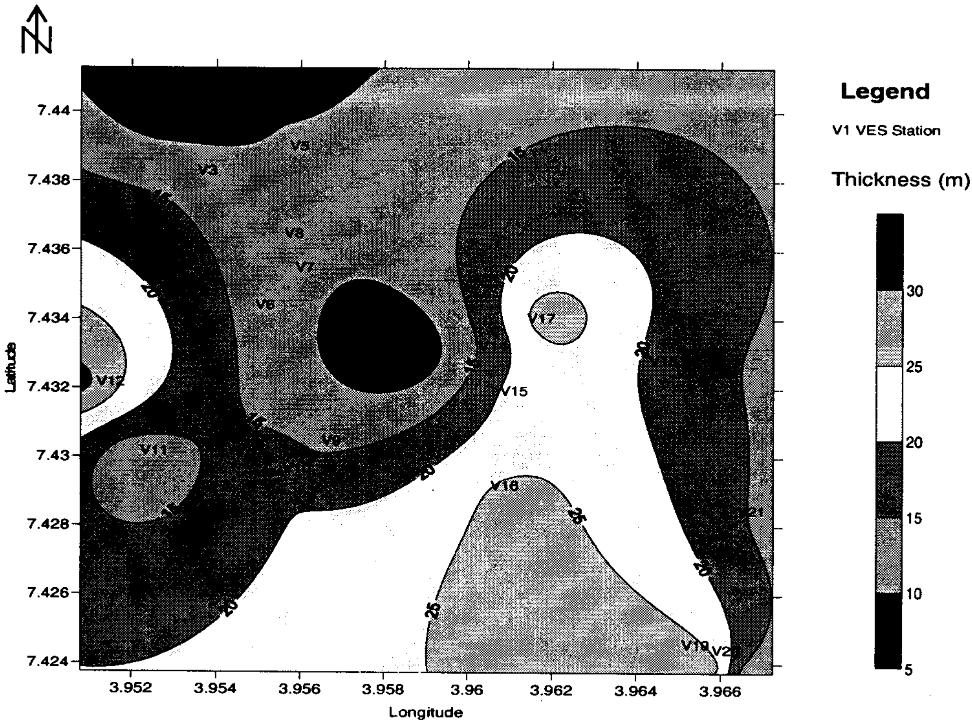

Figure 7: Overburden Thickness Map

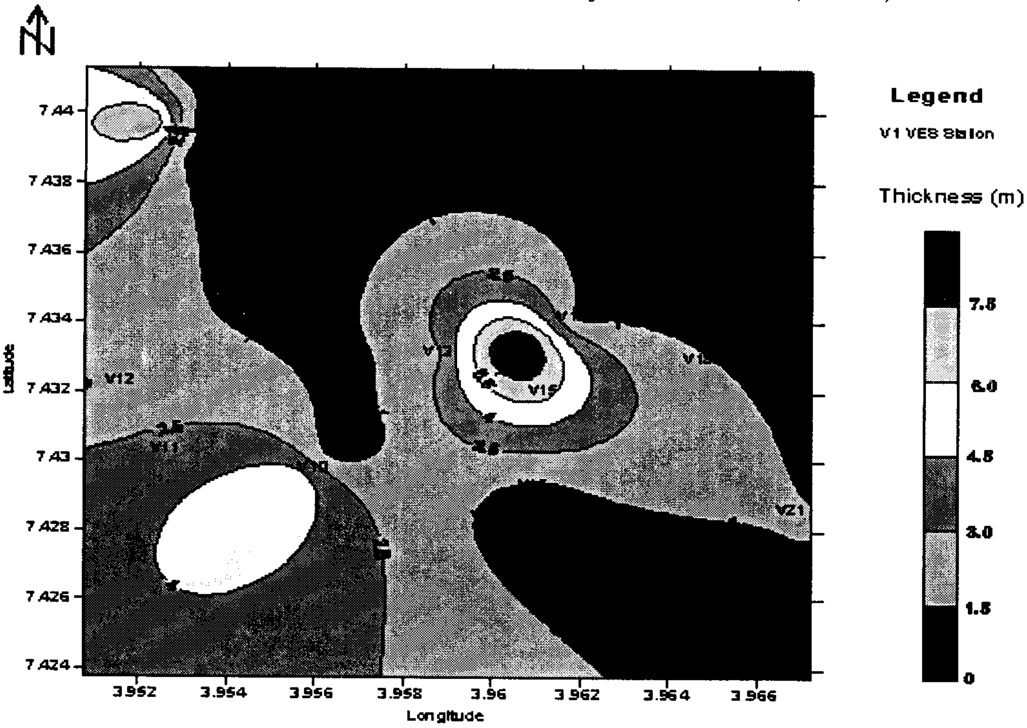

Figure 8: Aquifer Unit(s) Thickness Map

Correlation of VES Results with Lithology

To asses the accuracy of the VES interpretations, sounding was carried out in close proximity of an existing well. The results of the VES soundings were then correlated with the existing borehole lithology.

Figure 9 represents the correlated geoelectric sections beneath VES13, 14, 15 and VES 17 with available borehole logs BH1. The results from sounding no 17 located close to a successful borehole indicate four geoelectric layers with absolute resistivities of 355,189 and 60 ohm-m respectively, for the first three layers. The bottom-most layer has very low resistivity.

The top of the formation 355 ohm-m which extends down to a depth of 0.82m from the surface correlates to the clayey sand of the available borehole logs with an overburden thickness of 1.6m. The second geoelectric section is partly weathered with layer thickness of 5.12m which corresponds to the borehole of thickness 6.2m.

The third layer shows a decreasing trend in resistivity, indicating weathered layer exhibiting a low resistivity of 60 ohm-m up to a depth of 23m which correlate with gravelly clay of an existing borehole of depth 22.1m. The last layer has a very low resistivity value of 210 ohm-m thus, the layer is fractured. The results to a large extent show a degree of accuracy when compared with the lithological data of the existing bore-hole logs.

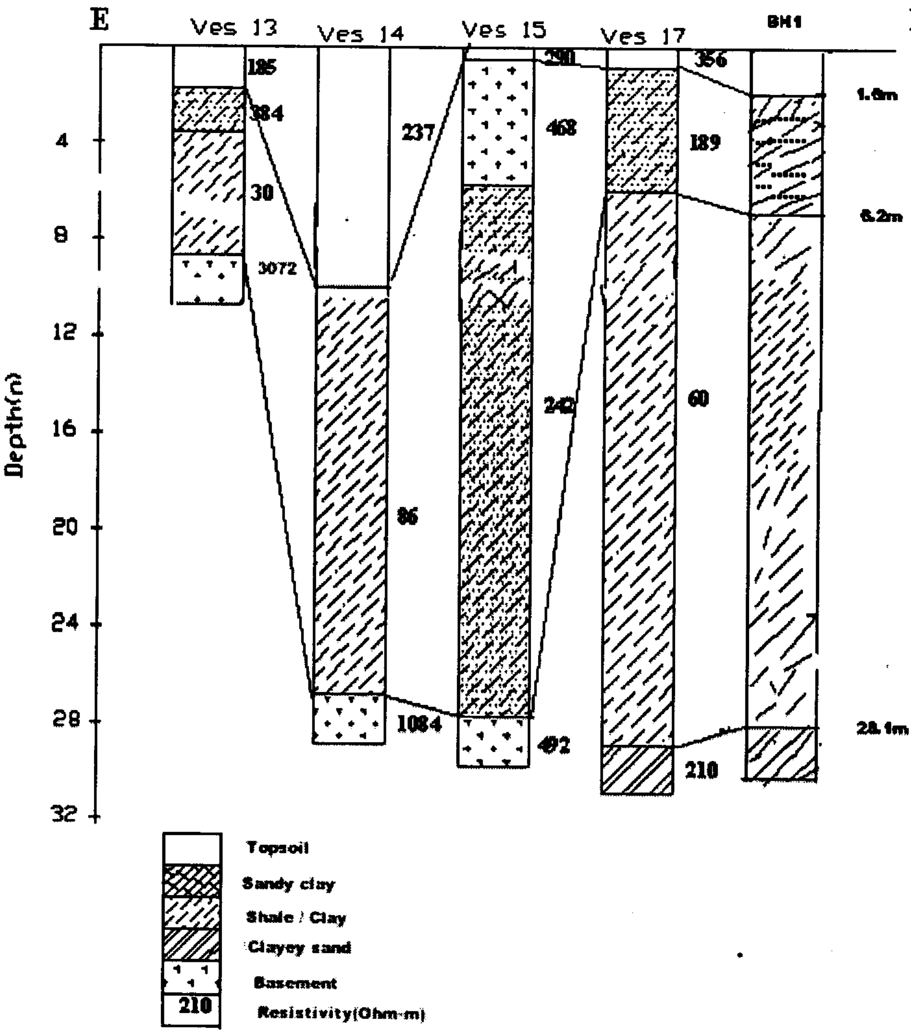

Figure 9.0: Correlation of field data with existing borehole lithological data

Conclusion

Based on the electrical resistivity survey conducted in the study area, groundwater potential producing zones have been delineated. The study reveals that about 50% of the study area has poor groundwater potential.

Weathered and fractured horizons have been identified in the study area underlying VES stations and all of these constitute the aquifer zones. Good prospects therefore exist for groundwater development in the stuay area where the depth to basement is relatively thick and has favourable low resistivity values.

The productive groundwater potential zones are identified at the southeastern part, as a ridge at northeastern part and as isolated patch at the western part of the study area.

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