GEOELECTRICAL INVESTIGATION OF SUBSURFACE STRUCTURES AND SOIL CORROSIVITY AT UNIONS SITE, GIDAN KWANO CAMPUS, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA

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ABSTRACT

Vertical electrical sounding (VES) was carried out at Union Site Gidan Kwano Campus, Federal University of Technology, Minna, Nigeria. The objective is to delineate area suitable for structural development and soil corrosivity of the study area. Schlumberger electrode configuration was adopted with maximum current electrode spacing (AB/2) of 100 m. The profile separations was 100 m with inter grid pacing of 100 m. Total number of sixty (60) vertical electrical soundings (VES) stations were covered. The interpretation was done using IP2WIN software and it revealed three distinct geologic layers. These include topsoil with resistivity values range between 11.41 and 1009 ohm-m and thickness is relatively thin and ranges between 1 and 6 m. The weathered/fractured layer has resistivity values also ranges from 11 to 963 ohm-m with thickness ranges from 1 m to 45 m which indicate high degree of weathered/fracture and/or water saturation, The fresh basement has resistivity values that range between 12 and 2983 ohm-m. All the soundings were 3-layered and are characterised by A, H and Q curve types. Seventeen (17) VES station were delineated for high rise building having depths to fresh basement varying between 2 m to 5 m (where consolidated basement is shallow with high resistivity value). The corrosivity ratings of the study area shows that 13% is moderately corrosive, 8% is slightly corrosive and 79% suggest practically noncorrosive. The result reasonably provide information areas where high rise building can be sited and iron pipe can be laid in order to safeguard the hydrological setting of the area.

Keywords: Vertical electrical sounding, high rise, resistivity, depth, geologic layers, corrosivity.

Introduction

For the past two decades, geophysics has proved quite relevant in groundwater investigations and several of the engineering and geological problems have been successfully solved by geophysical methods (Nelson and Haigh, 1990 and Adiat *et al.*, 2009). The integrity of near surface geophysical investigation methods to complement geotechnical studies in some foundation engineering problems cannot be overemphasised (Osinowo *et al.*, 2011).

The non-recognition of this fact has led to loss of integrity of many Boreholes and other engineering structures across the country as observed by Olorunfemi *et al.* 2000a & 2000b) and Ozegin *et al.* (2011). This research therefore uses Electrical Resistivity surveying method to investigate the subsurface structures at Unions Site of Gidan Kwano Campus, Federal University of Technology Minna. It involve determination of the subsurface lithologies, types and enclosing resource, the Schlumberger electrodes configurations was adapted in data acquisition.

Geophysical investigation applies the principle of physics to the study of the earth. In other to achieve this, measurements are made at or near the earth surface to obtain data, the interpretation of these data obtained are capable of dictating and delineating local and regional features that could be of economic interest which are uncommon in nature such as anomalies, so the geophysical investigation provides rapidly collected information on the geological structure and prevailing lithology of a region without the large cost extensive drilling program, the results of the geophysical investigation determines the location of a borehole. Geophysical investigation involves taking measurements on or near the surface of the earth that are influenced by internal distribution of physical properties. Analysis of this measurement can reveal how the physical properties of the earth interior vary laterally or vertically (Udensi, 2012).

Alhassan *et al* (2015) used Electrical Resistivity to Investigate the Subsurface Formation for Its Suitability for High-Rise Buildings in Southern part of Paiko, Niger State, North Central Nigeria, three to four distinct layers were observed namely; Top layer, weathered layer, fractured layer and Fresh basement. Eight VES stations were delineated for Construction, having depths to bedrock varying between 0.63 m and 3.99 m.

Physiographic, Geological and Hydrological Sittings of the Study Area

The study area lies within the middle belt of Nigeria with a mean annual rainfall of about 1,334 mm. The highest mean monthly rainfall is in the month of September and the temperature is highest in March about 30^{0}C, and the lowest temperature is in the month of August about 25^{0}C. Minna lies in a transitional zone between extreme North and South (Town Planning Division, Ministry of Housing & Environment, Minna, 1984).

The vegetation of the area consist of broad leaved Savannah woodland with some of the trees reaching about 10 meter in height. Along the river courses, the vegetation is more wooded. The predominant vegetation consist of shrubs and grasses (Adesoye, 1986). Basically, the study area consist of low-lying terrain and gentle hills. The Northern and Southern parts of the site are typified by gentle hills and landscape underlain by biotite-hornblende granite as evidenced by petrographic analysis (Adesoye, 1986).

The Minna area falls within the larger northwestern Nigerian Basement Complex. The rocks of the area are mostly crystalline rocks consisting of Gneisses and Migmatites, and Meta-Sedimentary Schist (McCry 1976). The area is thus underlayed by two lithological units of Granites and Gneisses with Pegmatite and quartz veins as minor intrusive. The Granites, which cover about 80% of the area, are mostly exposed on the western part of the town. They mostly form high batholiths, which are extensive in size. The Granitic outcrops are highly jointed, fractured, foliated and in some places appear as boulders (Adeniyi, 1985). The second lithological unit, the Gneiss, covers about 20% of the area and occurs to the east of the city.

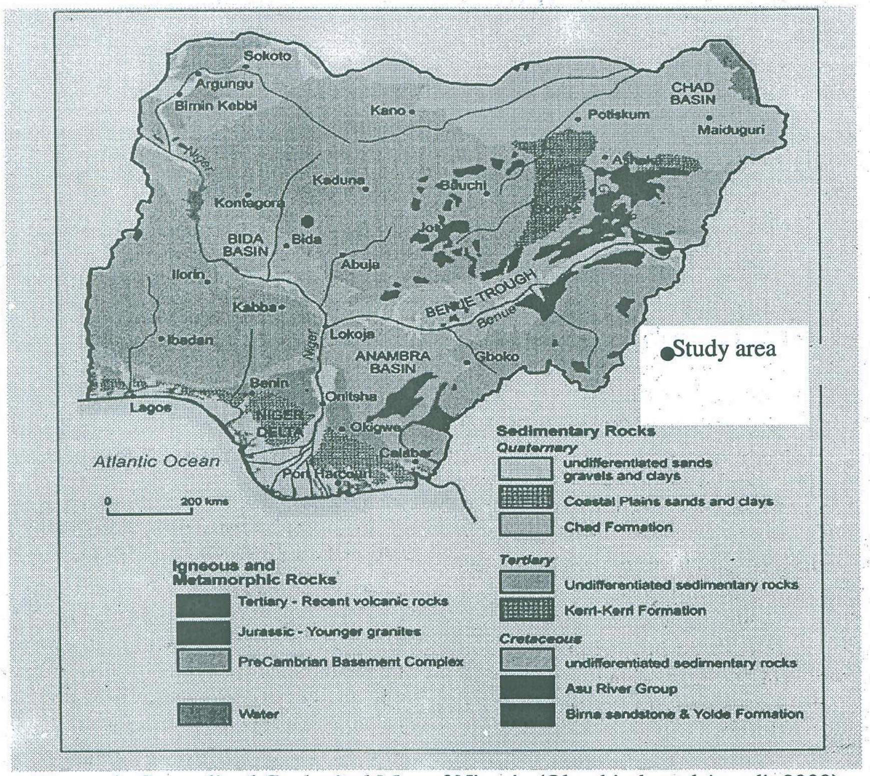

Figure 1: Generalized Geological Map of Nigeria (Olasehinde and Amadi, 2009)

Materials and Method of the study

The data was acquired with the Geosensor Terrameter (Model DDR1), Global Positioning System (GPS) for taking accurate coordinate of the VES point and elevations, Metal Electrodes, Measuring Tape, Labelled Tag (used in locating station position), Hammer (used in driving the electrodes into the ground), Connecting Cables. The Schlumberger array was adopted. The electrode spread of AB/2 was varied from 1 to a maximum of 100 m. Sounding data were presented as sounding curves, by plotting apparent resistivity against AB/2. The electrical resistances obtained were multiplied by the corresponding geometric factor (k) for each electrode separation to obtain the apparent resistivity.

$$R = \frac{V}{I} \quad (1)$$

where R is the resistance and above equation written as

$$\rho = kR \quad (2)$$

$$k = \pi \frac{\left[\left(\frac{AB}{2}\right)^2\right] - \left[\left(\frac{MN}{2}\right)^2\right]}{2\left(\frac{MN}{2}\right)} \quad (3)$$

The apparent resistivity obtained was used for computer iteration to obtain the true resisitivity and thickness of the layers. Computer-generated curves were compared with corresponding field curves by using a computer program "IP2WIN", surfer 11 was used to produce the contour maps.

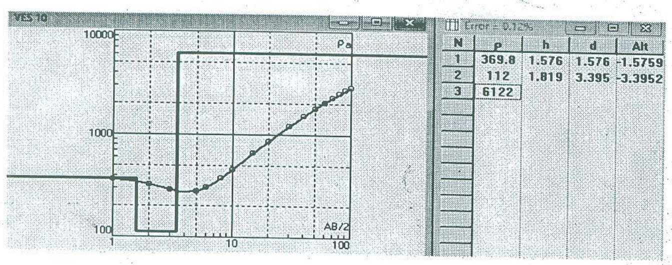

Figure 2a: Geoelectric section for VES A2

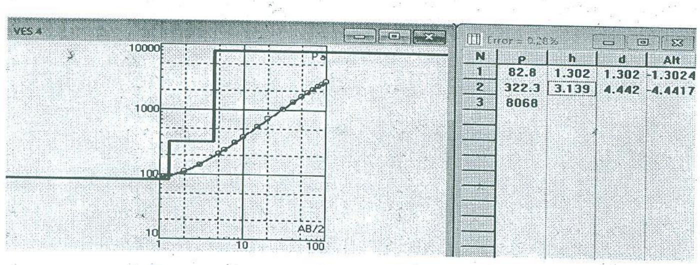

Figure 2b: Geoelectric section for VES A4

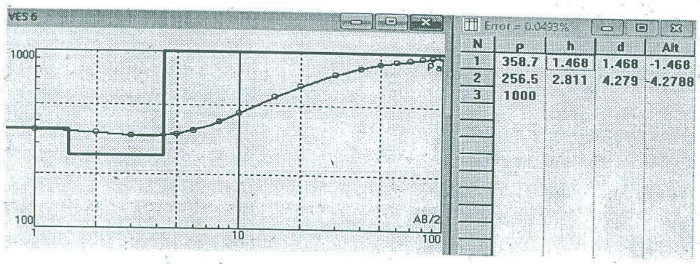

Figure 2c: Geoelectric section for VES B6

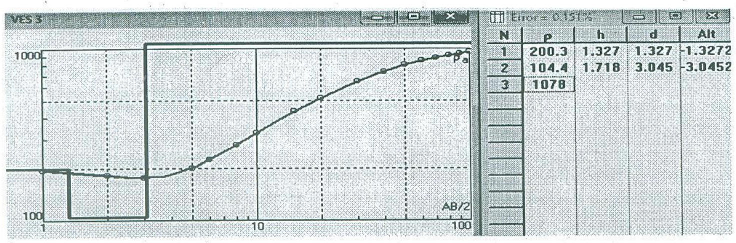

Figure 2d: Geoelectric section for VES C3

Table 2a: Summary of interpreted result of the study area

VES	Layer resistivity (Ohm-m)			Layer thickness (m)		Layer depth (m)			Curve
Station	ρ_1	ρ_2	ρ_3	h_1	h_2	d_1	d_2	Soil corrosivity	type
A1	138	347	1072	1.29	40.03	1.29	41.32	SC	A
A2	109.9	367.8	1136	1.573	33.36	1.573	34.93	SC	A
A3	51.66	404.2	1231	1.486	13.55	1.486	15.04	MC	A
A4	82.8	322.2	8068	1.302	3.139	1.302	4.442	SC	A
A5	49.74	208.8	40343	5.72	5.83	5.72	11.55	MC	A
A6	81.25	647.9	5654	3.11	31.2	3.11	34.31	SC	A
A7	57.85	557.1	1099	1.829	24.85	1.829	26.68	MC	A
A8	163	32.7	2383	1.64	2.719	1.64	4.359	SC	H
A9	23.83	233.8	1000	1.973	24.21	1.973	26.18	MC	A
A10	367.8	121.9	1012	1.254	1.128	1.254	2.383	PNC	H
B1	304.5	29.32	623.9	4.974	18.41	4.974	23.38	PNC	H
B2	589.5	411.9	2010	1.129	23.15	1.129	24.28	PNC	H
B3	662.5	103.8	1000	1.829	23.39	1.829	25.22	PNC	H
B4	523.4	106	965.7	1.231	2.378	1.231	3.609	PNC	H
B5	698.7	127.8	1163	2.474	27.98	2.474	30.45	PNC	H
B6	358.7	256.5	1000	1.468	2.811	1.468	4.279	PNC	H
B7	389.1	20.35	828	1.973	11.55	1.973	13.53	PNC	H
B8	45.26	176.2	1019	2.383	13.65	2.383	16.03	MC	A
B9	262.2	100	20469	1.332	27.15	1.332	28.48	PNC	H
B10	216.8	176.8	1136	1.9	32.85	1.9	34.75	PNC	H
C1	573	112.3	1000	1.486	11.54	1.486	13.02	PNC	H
C2	470.5	107.8	1177	1.573	34.89	1.573	36.46	PNC	H
C3	200.3	104.4	1078	1.327	1.718	1.327	3.045	PNC	H
C4	272.9	116.3	812.5	1.696	2.051	1.696	3.747	PNC	H
C5	418	250.6	341.1	1.556	1.498	1.556	3.054	PNC	H
C6	293.2	414.3	6717	2.483	30.52	2.483	33	PNC	A
C7	272.9	116.3	1000	1.696	25.49	1.696	27.19	PNC	H

C8	179.5	118.5	29838	2.168	37.49	2.168	39.66	PNC	H
C9	256.1	111	782.4	1.431	2.316	1.431	3.747	PNC	H
C10	269.1	105.8	981.3	1.431	12.61	1.431	14.05	PNC	H

Note: Slightly corrosive (SC), Moderately corrosive (MC), Practically noncorrosive (PNC)

Table 2b: Summary of interpreted result of the study area

VES	Layer resistivity (Ohmm)			Layer thickness (m)		Layer depth (m)			Curve
Station	ρ_1	ρ_2	ρ_3	h_1	h_2	d_1	d_2	Soil corrosivity	Type
D1	444.2	567.7	876.3	1.254	28.63	1.254	29.88	PNC	H
D2	1009	228.4	17600	2363	16.4	2.363	18.76	PNC	H
D3	204.3	658.9	8675	1.367	37.77	1.367	39.13	PNC	A
D4	382.6	261	932.6	3.541	18.51	3.541	22.05	PNC	H
D5	709.3	329.7	4706	3.535	11.05	3.535	14.59	PNC	H
D6	804.5	19.79	1431	1.459	3.242	1.459	4.701	PNC	H
D7	513.8	109.9	893	2.389	31.08	2.389	33.47	PNC	A
D8	1407	197.8	5995	6.49	37.40	6.49	43.90	PNC	H
D9	11.41	282.4	1405	4.721	26.31	4.721	31.03	MC	H
D10	753.5	100	963	4.721	15.77	4.721	20.49	PNC	H
E1	427.7	113.6	6987	1.696	1.023	1.696	2.719	PNC	H
E2	299.4	19.08	725.6	1.548	2.729	1.548	4.277	PNC	H
E3	378.3	109.9	1060	4.042	26.85	4.042	30.89	PNC	H
E4	230.3	963	4974	2.757	25.48	2.757	28.24	PNC	A
E5	225.7	130.2	1110	1.292	27.63	1.292	28.92	PNC	H
E6	739.4	121.9	1000	1.936	39.39	1.936	41.33	PNC	H
E7	526.4	225.1	900.6	1.795	2.103	1.795	3.898	PNC	H
E8	393.2	114.1	1012	2.78	20.16	2.78	22.94	PNC	H
E9	369.4	13.21	7315	1.668	20.3	1.668	21.97	PNC	H
E10	56.77	11.93	93.26	1.544	1.272	1.544	2.816	MC	H
F1	503.5	116.3	1038	1.795	25.71	1.785	27.51	PNC	H
F2	283.1	14.31	1000	1.573	2.105	1.573	3.678	PNC	H
F3	283.1	151.5	927.3	1.573	30.05	1.573	31.62	PNC	H
F4	713.7	151.5	1024	4.588	16.35	4.588	20.94	PNC	H
F5	50.55	20.94	12.33	1.532	37.91	1.532	39.44	MC	Q
F6	347.5	44.89	1019	1.532	44.89	1.532	46.45	PNC	H
F7	230.7	112.3	965.7	1.327	1.496	1.327	2.823	PNC	H
F8	230.7	380.4	965.7	1.22	35.56	1.22	36.78	PNC	A
F9	303.6	140.1	820.6	4.012	11.37	4.012	15.3	PNC	H
F10	369.8	112	6122	1.576	1.819	1.576	3.395	PNC	H

Note: Moderately Corrosive (MC), Practically Noncorrosive (PNC)

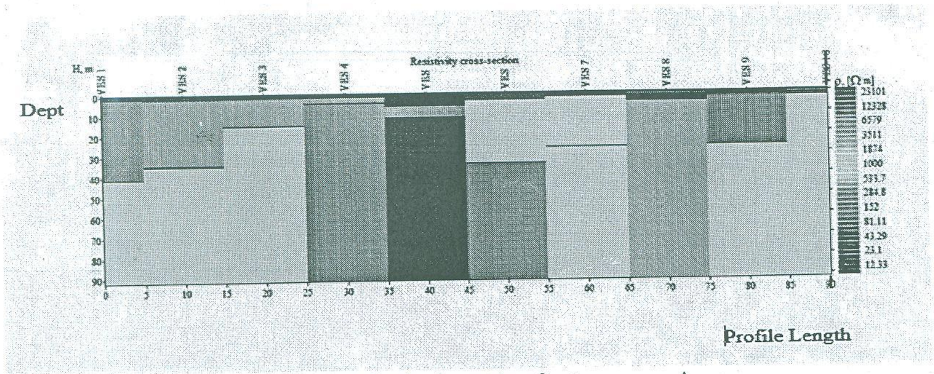

Figure 3a: Geologic section for transverse A

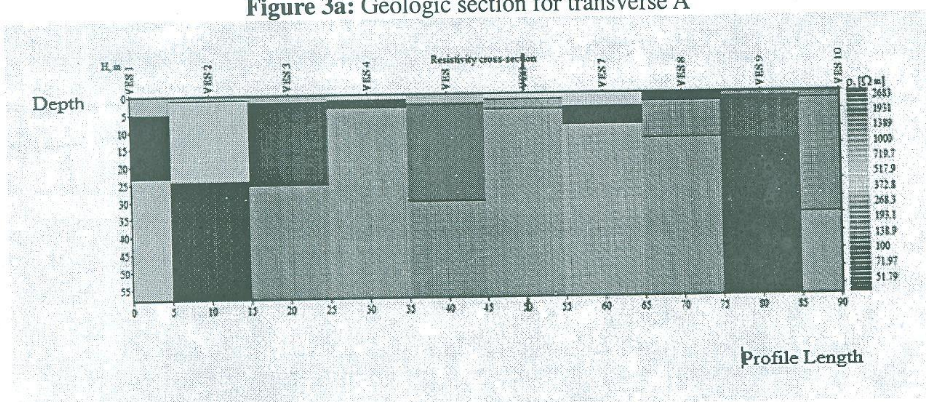

Figure 3b: Geologic section for transverse B

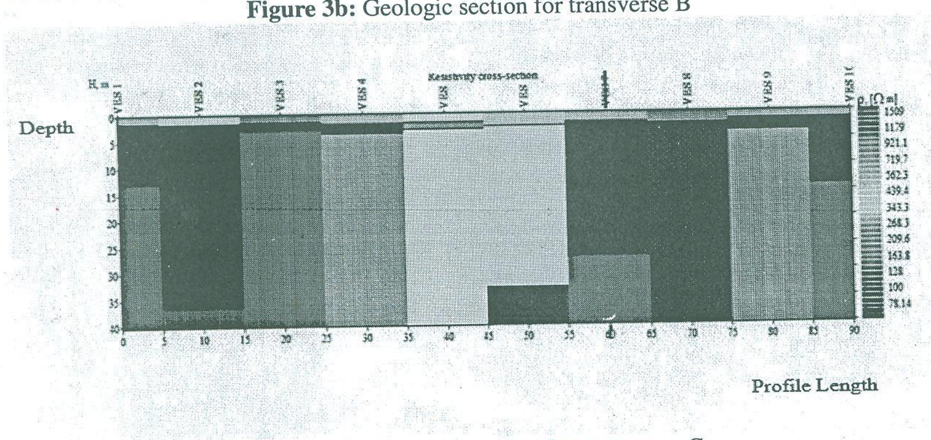

Figure 3C: Geologic section for transverse C

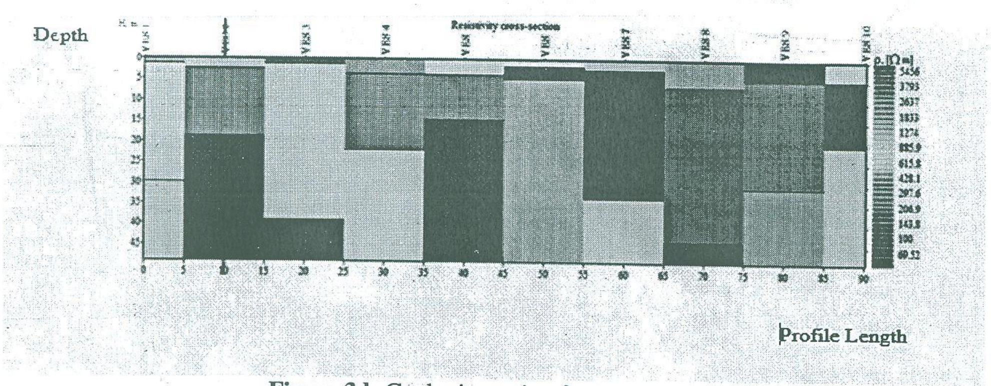

Figure 3d: Geologic section for transverse D

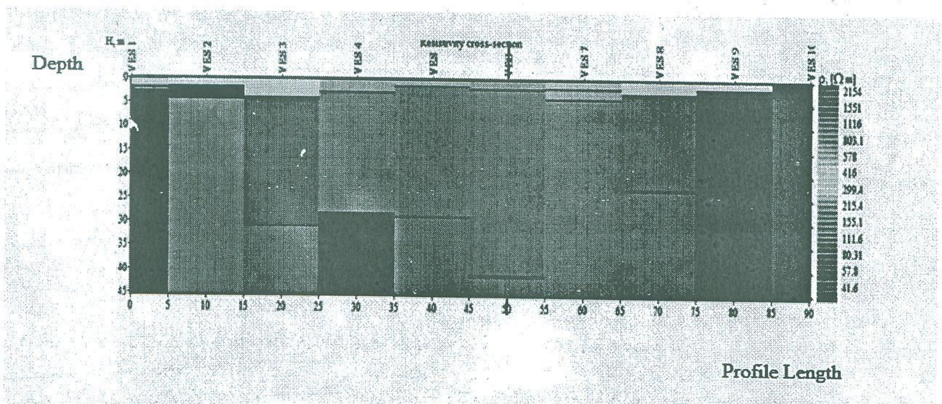

Figure 3e: Geologic section for transverse E

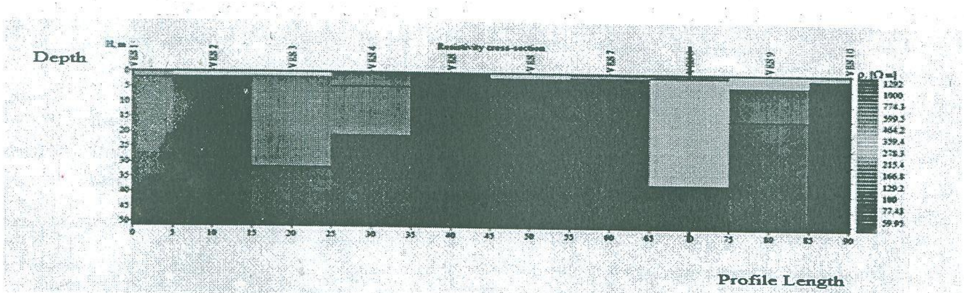

Figure 3f: Geologic section for transverse F

The geologic sections (Figure 3) shows three distinct layers (resistivity, thickness and depth) revealed the vertical sequence of the earth through each profile.

Table 3: Areas Delineated for Building Construction

VES STATION	Longitude (degree)	Latitude (degree)	Elevation (m)	Depth to Bedrock (m)	Resistivity of fresh basement (Ohm-m)
A4	9.32428	6.27429	238	4.442	8068
A8	9.3281	6.27	237	4.359	2383
A10	9.32407	6.2718	236	2.383	1012
B4	9.3235	6.27215	241	3.609	966
B6	9.32383	6.27213	239	4.279	1000
C3	9.32307	6.27212	243	3	1078
C4	9.32335	6.27196	241	3.747	813
C5	9.3237	6.27191	239	3.054	341
C9	9.32494	6.2156	240	3.747	782
D6	9.32398	6.27169	239	4.701	1431
E1	9.323	6.2711	240	2.719	6987
E2	9.3233	6.2711	239	4.277	726
E7	9.32435	6.27067	243	3.898	901
E10	9.32523	6.27085	243	2.816	93
F2	9.32264	6.27119	238	3.678	1000
F7	9.3236	6.276	238	2.823	966
F10	9.326	6.276	239	3.395	6122

In investigating the variation of overburden thickness, contour map using Golden surfer software was used to plot the depth to the fresh basement (Fgure 4). It shows the color range corresponding to the depth to the fresh basement. It reveals that sky blue represents a shallow depth between 2 m to 4 m, blue represent depth ranging from 7 m to 16 m, green corresponds to depth between 17 m to 30 m while yellow represent depth ranging between 31 m to 34 m and red represent depth between 35 m to 48 m.

The soil corrosivity in the study area was also determined, by comparing the first layer resistivity with Table 1. VES A_3, A_5, A_7, A_9, B_8, D_9, E_{10}, and F_5 suggest that the subsurface (soil) is moderately corrosive. VES A_1, A_2, A_4, A_6, and A_9 indicate slightly corrosive material. VES A_{10}, B_1, B_2. B_3, B_4, B_5, B_6, B_7, B_9, B_{10}, C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9, C_{10}, D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_9, D_{10}, E_1, E_2, E_3, E_4, E_5, E_6, E_7, E_8, E_9, F_1, F_2, F_3, F_4, F_6, F_7, F_8, F_9 and F_{10} suggest practically noncorrosive material.

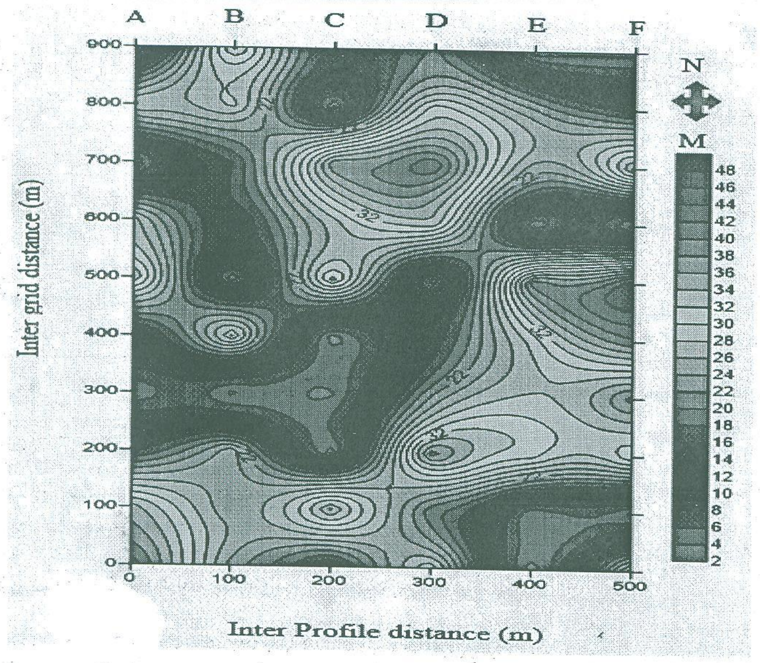

Figure 4: Contour map of depth to bedrock in the study area

Conclusion

Vertical Electrical Sounding method is an efficient technique for foundation design studies. It was used in the study to investigate the area for building construction and soil corrosivity of the area. Seventeen VES station were delineated for building construction, having depth to fresh basement varying between 2 m to 5 m. The corrosivity rating of the study area shows that 13% is moderately corrosive, 8% is slightly corrosive and 79% suggest practically noncorrosive. The unions are advice to make use of this research for site selection to reduce problem of building cracks and building collapse. The areas that are moderately and slightly corrosive are characterised with low resistivity and high moisture content of the soil, therefore iron pipe, underground tanks are not to be buried in those areas. Pipe could deteriorate, rupture or leak due to the reaction of corrosive materials with buried pipes, which can be hazardous to mankind and its environment. Plastic pipes are more preferable in the areas. Practically noncorrosive areas are very good for burying of iron pipes and underground tanks without deterioration.

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