APPLICATION OF GEOELECTRICAL TECHNIQUE IN DELINEATING GEOLOGICAL STRUCTURES AROUND GANAWURI AREA, NORTH CENTRAL NIGERIA.

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ABSTRACT: *Geophysical investigation involving the use of geoelectrical technique has been carried out to delineate buried geological structures around the proposed Ganawuri Dam Site North Central Nigeria. The objective of this study is to establish the depth to fresh basement in the area using the VES technique with a view to delineating those near surface structures that could be deleterious to any construction work embarked upon within the area and to proffer a befitting recommendation that would necessitate the construction of a dam to impound the flowing stream and develop a reservoir which could be used for irrigation. The area is underlain by the Crystalline Basement rocks composed of granite gneiss, with late diorite, basalts and pegmatite intrusions. The older units have been intruded by the biotite granite of the Younger Granite province, occurring as a ridge bordering the north eastern margin of the area. ABEM Terrameter SAS 1000C model was used and the symmetrical Schlumberger configuration adopted. A total of twenty (20) Vertical Electrical Sounding (VES) stations were established and fully occupied along three (3) different profiles (AA/, BB/ and CC/) in the study area. Preliminary input data from the field were fed into Zohdy software to generate real resistivities and depths to geoelectric layers. Three (3) geoelectric layers were interpreted. The first geoelectric layer is a thin lateritic top surface with resistivity range of 270-4100 ohm-m with average thickness of 1.94m. The second geoelectric layer is interpreted as the weathered basement with resistivity range of 16-3510 ohm-m and the thickness ranges from 1.06-29.2m. This layer was observed to be very clayey at VES points 5, 6, 7, 10, 12, 16 and 17. The third interpreted geoelectric layer represents the fresh basement with infinite resistivity trend and thickness. The VES section delineated presence of fault/shear zones at 13m, 22m, 13-41m and 13-21m at VES 2, 3, 18 and 19 respectively along profile AA/. Along profile BB/, fault/shear zones were observed at 25-36m below 27m and 28m at VES 13, 14 and 15 respectively. Fault/shear zones were equally delineated between 11-17m at VES 10 along profile CC/. These shear zones are known for their structural weaknesses. Any construction work to be sited within the area should take into account these zones and geotechnical method such as grouting should be applied to seal off these shear zones.*

KEYWORDS: Basement, Ganawuri, Geoelectric Layer, Schlumberger array, Seepage, Shear zone.

INTRODUCTION

The need to improve the agricultural sector of Nigeria economy has been a major concern of successive governments. Consequently, the Federal Government has through the various River Basin Authorities planned a number of irrigation schemes in various parts of the country (Akanmu et al, 2007). The main focus being to construct small to medium sized dams in such area for water impoundment. One such scheme is the proposed dam site in Ganawuri, Riyom Area of North Central Nigeria. The construction of such structures normally requires adequate and thorough understanding of the subsurface geology and engineering properties of the materials along the proposed axis and adjoining areas. The geological investigation involved detailed geological and structural interpretations. This was followed by the geophysical studies using the Vertical Electrical Sounding (VES) technique to determine the thickness of the overburden (depth to fresh basement) in the area. Geophysical methods have been used extensively in dam site investigations (Ajakaiye, 1975; Ako, 1976; Artsybashev and Azeez, 1977; Kilty et al., 1986; Annor et al., 1989; Ojo and Olorunfemi, 1995; Olasehinde and Adelana, 1999). Geoelectric surveys, particularly resistivity measurements, still account for a large amount of work in using geophysical methods for surveys of shallow depths. The advantage is that they are not so demanding for instrumentation (Ibeneme et al, 2013).

THE STUDY AREA

The area of investigation is located within latitude $9^{o}37.473'$N and $9^{o}37.58'$N and longitude $8^{o}38.763'$E and $8^{o}39.072'$E. It is covered by the Federal surveys of Nigeria topographic map (Naraguta sheet 168SW) of scale 1:50,000. The area can be reached through a motorable road that branches at the Riyom town along the Jos – Kafanchan express way. It is located about 60km SW of Jos and 9km West of Hose Railway crossing. The Ganawuri area is sparsely populated and dominated by people of the Angas tribe. They live in thatched houses which are mainly based on topographic advantage as same are erected on the low land areas. Their major activity is farming. Their major cash crops are millet and Sorghum; these are favoured by the presence of flood plain vegetative cover in the area. There are also settled Fulani cattle men and some Berom-speaking people. The objective of this study is to establish the depth to fresh basement in the area using the VES technique with a view to delineating those near surface structures that could be deleterious to any construction work embarked upon within the area and to proffer a befitting recommendation that would necessitate the construction of a dam to impound the flowing stream and develop a reservoir which could be used for irrigation.

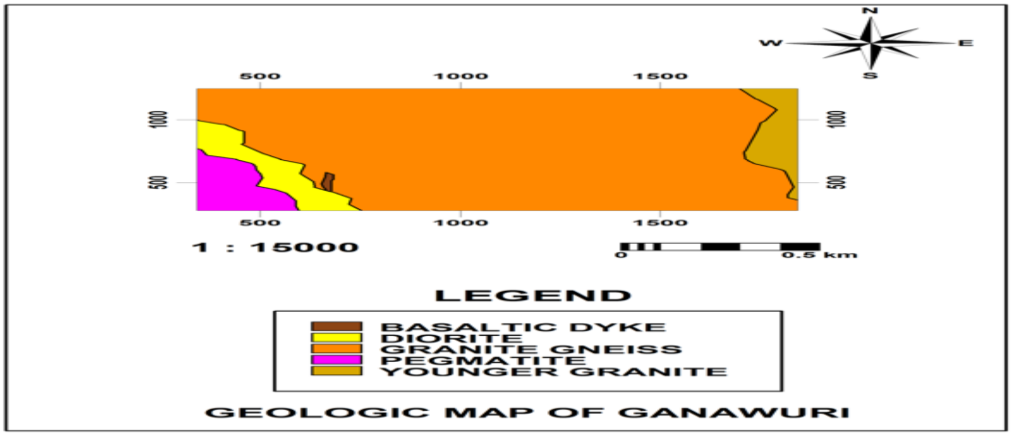

Figure 1. Geological Map of the study area.

METHODOLOGY

The vertical Electrical Sounding (VES) technique was employed in this study using the Schlumberger array. AB/2 values ranged from 1.5 meters to 75 meters, ensuring at least 50 meters of depth of investigation. An ABEM Terrameter SAS 1000C of accuracy of 0.001Ω was used. In addition to the dam axis which is about 1270 meters in length terminating at the base of the Younger Granite ridge (Figure 1). Two additional profiles were chosen parallel to the main axis. The aim of choosing additional profiles was to trace any structure(s) across the dam axis to areas adjoining it. The profiles were 100 meters apart, trending N60E across the main channel to be dammed. Distances between Vertical Electrical Sounding (VES) points ranged from 50 meters close to the channel and shear zones to 200 meters. In all, 20 VES locations were established, 12 of them were located along the main axis while 8 were located along the other two profiles (4 along each profile).

DATA REDUCTION, INTERPRETATION AND PRESENTATION

Data obtained in the form of resistance values, R from the ABEM equipment were reduced to apparent resistivity values using the relation:

$\rho_a = \pi(a^2/b - b/4)$ R …………………(1)

Where ρ_a = apparent resistivity in Ohm-m, a = AB/2, the Half Current Electrode Separation in meters, b= MN, Potential electrode separation in meters, R= Instrument reading in Ohms.
G is the Geometric Constant which is a function of the electrode configuration employed during the survey.

The use of this relation has been variously discussed (Telford et al, 1982; Azm et al, 1994; Lowrie, 1997; Akintorinwa and Adesoji 2009; Ibeneme et al, 2013). The data collected in the field were presented by plotting the apparent resistivity (ρ_a) values against the electrode spacing (AB/2) on bi-log graph. Quantitative interpretation of the VES curves involved partial curve matching and computer iteration technique using the Zohdy program (Zhody 1975) – designed for the Schlumberger array by ABEM organization. As a good fit, (up to 95% correlation) was obtained between field and model curves, interpretation was considered as right.

The interpretation showed between 2 to 4 geoelectric layers. Forty percent (40%) of the curves display the HA – type (Figure 2) but a few showed asymptotic nature typical of 2 layer cases. However, the presence of more than 3 layers in some sounding locations shows evidence of dykes, shear zones or highly resistive materials. These are adequately presented in Figure 3.

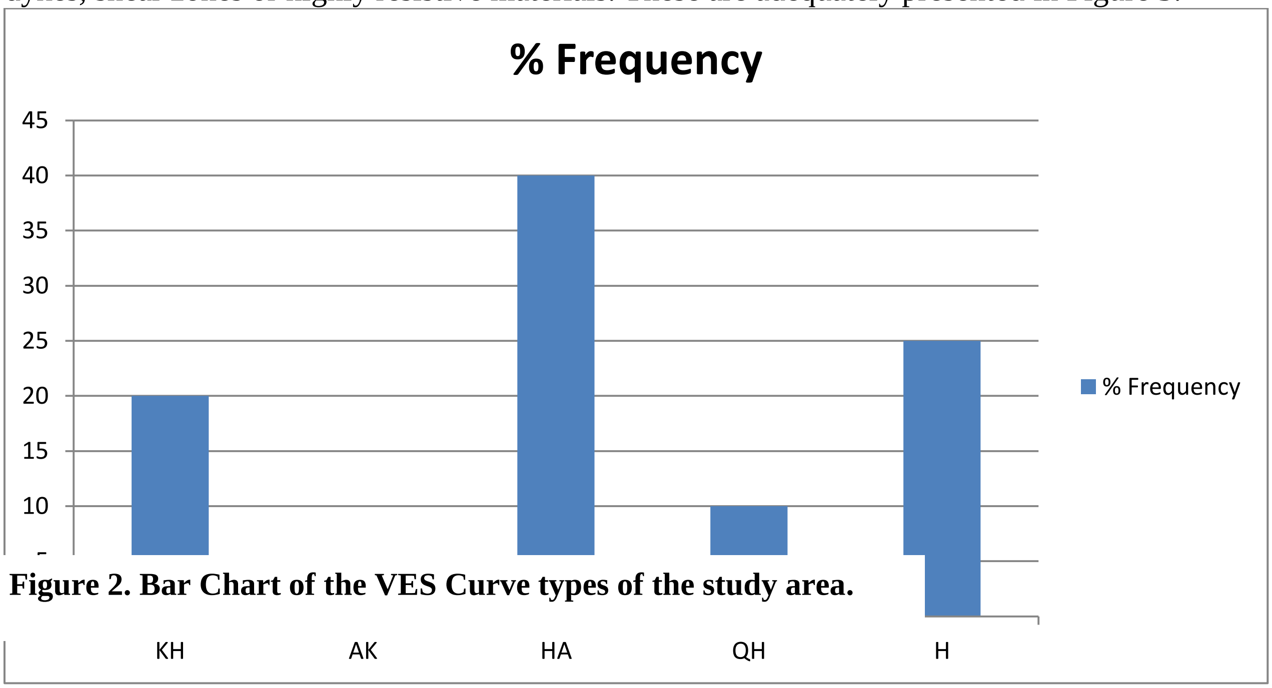

Figure 2. Bar Chart of the VES Curve types of the study area.

Tables 1a, 1b & 1c show the thicknesses of the three geoelectric sections and their respective range of resistivity values at different sounding points along the three profiles respectively.

Table 1a Along A-A^{1} Profile (DAM AXIS)

Sounding Stations	**Thickness of Lateritic Surface (m)**	**Resistivity of Lateritic Surface (ohm-m)**	**Thickness of weathered basement (m)**	**Resistivity of weathered basement (ohm-m)**	**Thickness Of fresh basement (m)**	**Resistivity of fresh basement (ohm-m)**	**Stations with fault/ shear zones**
VES1	0.01.4	1500-3657	2.06-4.43	458-2329	6.5-∞	588--∞	
VES 2	/	/	0.01.31	848-869	1.92-∞	971-∞	**F(13m)**
VES 3	/	/	0.01.56	54-125	2.28-∞	104-∞	**F(22m)**
VES 4	0.0-1.18	1481-1862	1.73-2.54	465-984	3.72-∞	529-∞	**F(∞)**
VES 5	/	/	0.0-1.06	22-27	1.56-∞	39-∞	
VES 6	0.0-1.92	2212-4081	2.82-8.92	92-3508	13.09-∞	131-∞	
VES 7	0.0-1.45	1247-1426	2.13-31.33	23-141	45.99-∞	54-∞	
VES 16	/	/	0.0-21.35	22-853	31.33-∞	49-∞	
VES 17	0.0-2.54	332-403	3.72-11.78	37-298	17.28-∞	52-∞	
VES 18	/	/	0.0-4.14	204-468	6.08-∞	366-∞	**F(13-41m)**
VES 19	/	/	0.0-2.82	341-473	4.14-∞	377-∞	
VES 20	0.0-4.14	270-676	6.08-13.09	170-497	19.21-∞	303-∞	**F(13-29m)**

Table 1b Along B-B[1] Profile

Sounding Stations	Thickness of Lateritic Surface (m)	Resistivity of Lateritic Surface (ohm-m)	Thickness of weathered basement (m)	Resistivity of weathered basement (ohm-m)	Thickness Of fresh basement (m)	Resistivity of fresh basement (ohm-m)	Stations with fault/ shear zones
VES 12	/	/	0.0-14.52	16-547	21.35-∞	36-∞	
VES 13	/	/	0.01.18	175-196	1.73-∞	216-∞	**F(25-36m)**
VES 14	/	/	0.01.56	98-198	2.28-∞	143-∞	**F(27-∞)**
VES 15	/	/	1.0-6.08	837-2557	8.92-∞	1097-∞	**F(28m)**

Table 1c Along C-C[1] Profile

Sounding Stations	Thickness of Lateritic Surface (m)	Resistivity of Lateritic Surface (ohm-m)	Thickness of weathered basement (m)	Resistivity of weathered basement (ohm-m)	Thickness Of fresh basement (m)	Resistivity of fresh basement (ohm-m)	Stations with fault/ shear zones
VES 8	/	/	0.0-2.54	329-1052	3.72-∞	425-∞	
VES 9	/	/	0.0-1.18	567-625	1.73-∞	593-∞	**F(∞)**
VES 10	/	/	0.02.54	94-456	3.72-∞	276-∞	**F(11-17m)**
VES 11	0.0-0.95	121-188	1.4-2.06	129-158	3.02-∞	156-∞	

INTERPRETATION ALONG DAM AXIS (A – A[1] PROFILE)

A maximum of (3) geoelectric layers were interpreted along the dam axis as follows:
The first geoelectric layer is a thin lateritic top surface with resistivity range of 270 – 4100 Ohm-m. This layer was not encountered at VES 2, VES 3, VES 5, VES 16, VES 18 and VES 19 points (Table 1a). The base is at about 1.4m at VES 1. At VES 4, it is 1.18; at VES 6 it is 1.92m; at VES 7, it is 2m; VES 17, it is 2.54m; while the base is at 4.14m at VES 20 (Figure 3). At location VES 2, there is a shear zone marked by a dyke of seemingly dioritic materials of resistivity between the range of 1200 – 1900 ohm-m as shown in Plate 1. This shear zone was seen at about 13 – 28m at location VES 2 and grades to a deeper level of about 22m to infinite depth at location VES 3. It did not manifest at VES 1, 4, 5, 6 and 7 points. The second geoelectric layer is interpreted as the weathered basement. This layer has a resistivity range of between 22 – 3000 ohm-m. It outcrops at VES 2, 3, 5, 16, 18 and 19 points. It is thicker in VES 1, 6, 7, 16, 17, 18 and 20 points where the base is 4.43m, 8.92m, 31.33m, 21.35m, 11.78m, 4.14m and 13.09m respectively. In VES points 5 to 7, the weathered basement is very clayey, displaying very reddish tint as observed from pit materials at VES point 6. The last interpreted geoelectric layer is the fresh basement with infinite resistivity trend and thickness. However, fracturing/Shearing occurs between 20 and 40m at VES 3.

INTERPRETATION ALONG B-B[1] PROFILE

As noted along A-A[1] profile, 3 geoelectric layers characterize the B-B[1] profile. The weathered basement outcrops at all the sounding points – VES 12, 13, 14 and 15 (Table 1b). The fracturing that was observed at VES points 2, 3 and 4 were also recorded at VES points 13, 14 and 15 along B-B^1 profile (Figure 3). As in profile A-A^1, the shearing tends to wedge out or may be recorded at greater depths than 45m.

INTERPRETATION ALONG C-C^1 PROFILE

The geoelectric section along C-C^1 profile is shown in Figure 3. Lateritic top soil is only encountered at VES 11 point having its base at about 0.95m below the surface. This layer has resistivity range of 121-188 ohm-m. As in the profiles A-A^1 and B-B^1, the weathering depths increase in the NE and E directions with the highest depth of weathering located at VES 8. At this point, weathering is down to a depth of 2.54m. At a depth of between 10 and 20m at VES 10 point and at a depth of beyond 40m at VES 9 point, evidence of fracturing occurs (Table 1c). Thus the fracturing at VES 2, 3, 13 and 14 sounding points are consistent; hence the southwest end of the dam axis has more fracturing than the other locations.

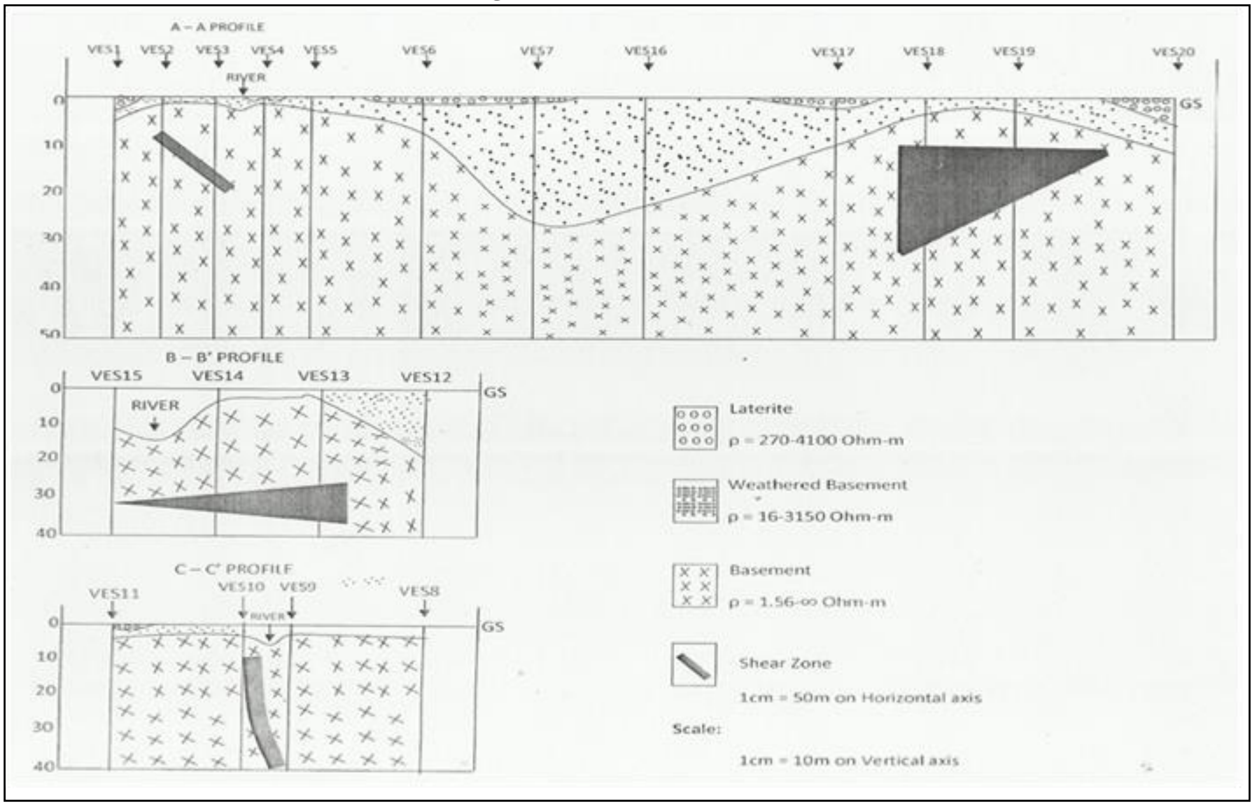

Figure 3. Geoelectric cross section along the three profiles A-A^1, B-B^1 and C-C^1.

CORRELATION OF VES RESULTS WITH SURFACE GEOLOGICAL AND GEOMORPHOLOGICAL FEATURES

The topographic relief and structures observable in the Dam site have controlled the stream flow. All the observable surface structures like shear zones, pegmatite dykes and basic rock dykes appear to have NW-SE and NE-SW trends. There is correlation between the contour lines and structural trend. The VES 14, 15, 12, 10 and 11 have basic dykes with association quartz-mica-tourmaline pegmatite (Plate 2). The initial high resistivity values recorded at VES 1 point is confirmed by the pegmatite encountered at 1-1.5m depth and at 2m in Pit No1 located at SW of VES 1 point. The high resistivity values recorded at VES point 13 confirm the nearness of the fresh Basement to the surface. The schistose enclaves, (Plate 3), within the migmatitic gneiss near VES points 2 and 11 are also confirmed at Pit No 2 at TBM 8. The pit at location VES 6 did not have the Basement even at over 5m below. The low resistivity values of the weathered Basement at VES 6, 7, 12, 16 and 17 suggest high depth and prolonged accumulation of fine–grained matter from the feldspathic Basement over the geologic age.

Plate 1. Forceful injection of Dioritic matter into the pre-existing Granite Gneiss.

Plate 2. Quartz-Toumaline Pegmatite associated with the Granite Gneiss along the proposed

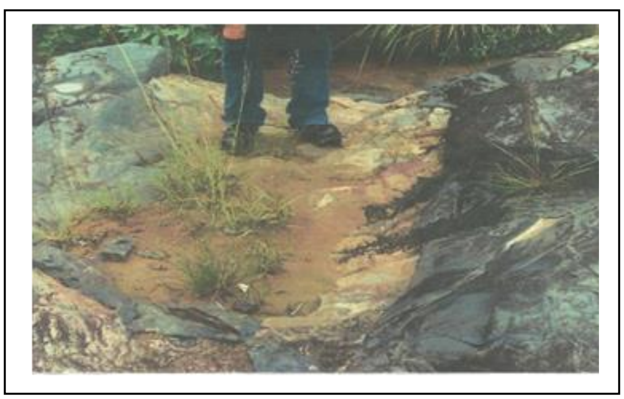

Plate 3. Schistose enclave of Older Granite Gneiss in the intruding basaltic matter.

The thickness of the weathered basement and depth to top of Fresh Basement range from 1.6-3.8m and 1.7-3.8m respectively (Figures 4 and 5).There is a low closure towards the east corresponding to the area occupied by the near surface exposed younger granite ridge. Resistivity of these two layers ranges from 200-1050 ohm-m and 160-500 ohm-m respectively increasing towards the east as well (Figures 6 and 7).

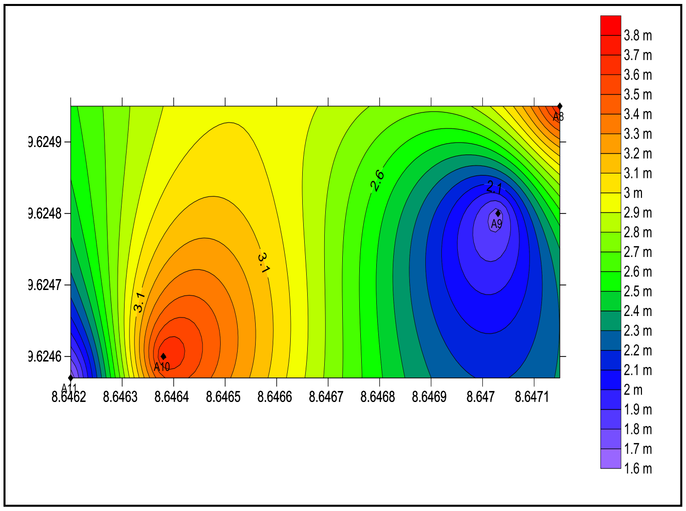

Figure 4. Thickness of weathered Basement

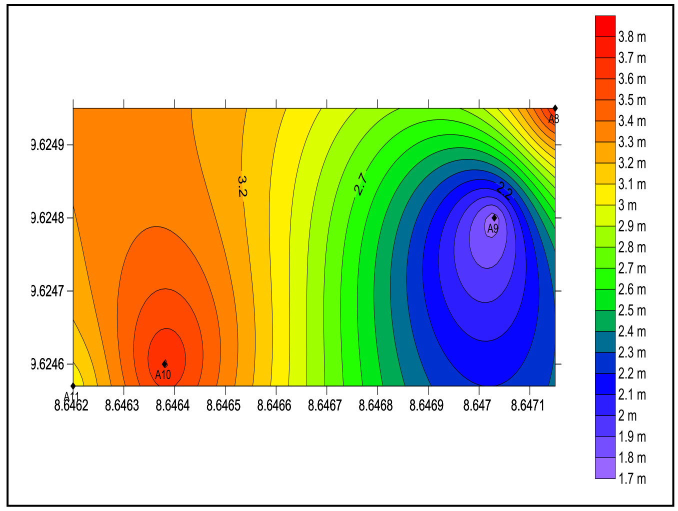

Figure 5. Depth to top of Fresh Basement.

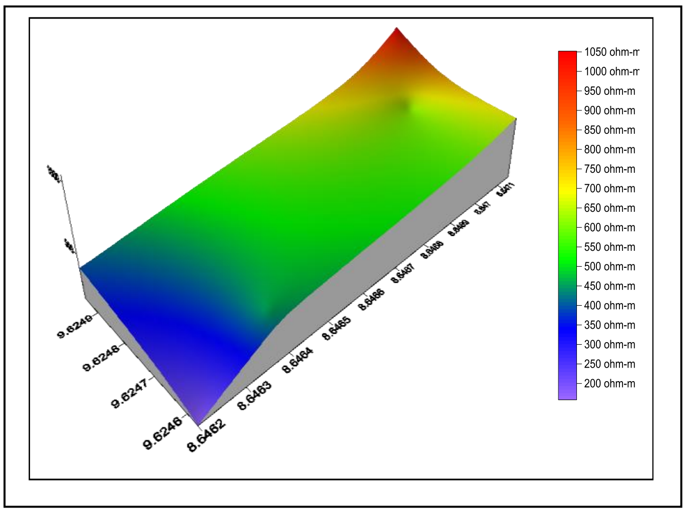

Figure 6. 3D Display of the Resistivity of weathered Basement.

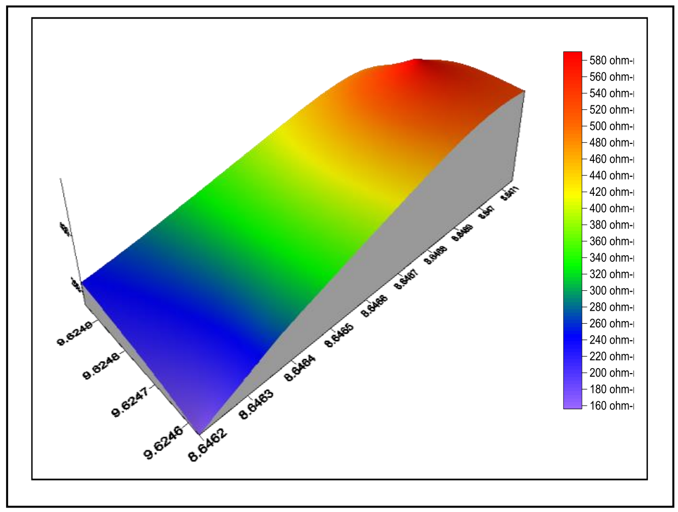

Figure 7. 3D Display of the Resistivity of Fresh Basement.

CONCLUSSION

VES 3, 5, 16, 18 and 19 are characterized by sandy weathered/sand alluvial matter. These are very porous and may increase infiltration rather than impounding the water. The presence of pebbly horizons at the bank of the river should be of interest to the designer or the expert and as such must be addressed. Most joints are sealed while others are open; such joints must be grouted. From the interpreted resistivity data and sections produced, the NE and E part of the dam site have relatively higher weathering depths. Furthermore, the lower resistivity values of 20–1000 ohm-m suggest that the weathering product is rich in clay matter. This is evident in pits 5 and 6 along the dam axis. With 10 to 40m depth of weathering at VES locations 6, 7 16 and 17 along the dam axis, the abundance of sand as the major weathering product may result in greater seepage. This must be checked.

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