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Susceptibilty Test for Road Construction: A Case Study of Shake Road, Irrua, Edo State

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Keywords: road, susceptibility test, dipole-dipole, geoelectric section, longitudinal conductance.

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SUSCEPTIBILTYTESTFORROADCONSTRUCTIONACASESTUDYOFSHAKEROADIRRUAEDOSTATE

Strictly as per the compliance and regulations of:

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Abstract- This research showed the significance of electrical resistivity method for road construction along Shake road, Irrua, Edo State, Nigeria. The aim of the study is to establish the near surface geological features that are predisposed to incessant case(s) of road failures few months or years after construction. The geophysical investigation involved three techniques; Vertical Electrical Sounding (VES), 2-D Electrical Resistivity Tomography (ERT) and Horizontal Profiling (HP) which covers a pilot test of 220 meters. Ten (10) VES were carried out using Schlumberger array with current electrode spacing varying from 1.00 to 100.00 m, with 2-D ERT using Dipole-Dipole electrode array with inter-station separation of 10 m and an expansion factor that varied from 1 to 5 and HP using Wenner array with an electrode spacing of 5 m interval. The VES interpretation results were used to determine the second order parameters for determination of integrity and susceptibility test of failure. The result obtained from the VES delineated three geoelectric units which Comprise of topsoil, clay layer, sand layer/shale horizon units. The 2 D imaging (Dipole-Dipole) gave information on the subsurface characteristic which indicates high, moderately high integrity and low integrity/a low competence material. The Wenner profile is characterised by low resistivity. The entire results correlate well with one another showing that all the techniques used was complemented. The result obtained from the pilot test of 220 m reveals that only 10% of the road survived susceptibility test, with a longitudinal conductance value of 1.099, and 30% of the class distribution were moderately susceptible to failure with longitudinal conductance values between 0.1000 to 0.999, while the rest of the study location with total longitudinal conductance values of 0.010 to 0.099, implying 60% susceptibility chance of failure.

Keywords: road, susceptibility test, dipole-dipole, geoelectric section, longitudinal conductance.

I. Introduction

Nigeria as a country has suffered many consequences of incessant road failure leading to loss of life through preventable accidents and financial resources coming from Budgeting of road construction which may not last a year before remedial and rehabilitation work is required. This is a source of major concern not only for safety and sustainability of life but as well as saving Billions of Naira that is been wasted for sustaining and maintaining of roads after construction. There is no doubt that one of the major challenges facing Nigeria as a nation, is the sustainability of infrastructural developments which includes the road. The rate of failure of our road shortly after construction is very bothersome and a sizeable percentage of our annual National Budget is usually allocated for it. Indeed no nation can experience social and economic breakthrough without proper and adequate planning and utilisation of its scarce resource to develop infrastructural facilities including roads, in such a way that will achieve durability and sustainability to give room to the development of other sectors. Our experience has shown that most road that have been constructed within the last twenty to thirty years have not survived sustainable five years continuous integrity test without post construction/rehabilitation efforts, involving surface dressing, road cutting, and reinforcement, and many times total rehabilitation and reconstruction, when most often fail few years after such exercise (Ajayi, 1987). According to Akintorinwa, (2009), the statistics of failures of structures such as roads, buildings, dams, and bridges throughout the nation has increased geometrically. Although, road failure is an inevitable consequence of man's activities and a natural phenomenon as well (Ozegin, *et al.,* 2016), the usefulness of geophysical investigation in engineering sector of our economy cannot be overemphasised. Hence the application of geophysical imaging methods has been increasing in site characterisation (Ilugbo *et al.,* 2018) and geotechnical investigations throughout state and Federal high way departments. Geophysical methods have been used to assist in highway design construction repair and maintenance phases. Detailed knowledge of unforeseen, highly variable subsurface ground conditions reduces project risk and costs associated with "change of conditions" claims and improve construction and safety. Falowo, (2012), Yahya, 1989, Oladapo, 1997, Orange, 1997. Olorunfemi and Mesida, 1987; Olorunfemi, *et al.,* 2000. Therefore, this research work is to justify the need to carry out detailed pre-construction studies before any road construction work is embarked upon for safety, sustainability and economic survival of the country within Shake road, Irrua Area of Edo State.

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II. Site description and Geology of the Study Area

The study was carried out at Shaka Momodu Road in Irrua, Esan Central Local Government Area of Edo State, Nigeria. It is bordered approximately by Latitude 6° 44' 21.56" N and Longitude 6° 13'8.45" E (Figure 1). It is underlain by the sedimentary rocks of the Anambra Basin, and geologic Formations are largely Imo Shale and Ogwashi-Asaba Formations although, there are some places in that area also underlain by the Bende-Ameki Formation. The climatic condition of Irrua and its environs fall within the warm-horrid tropical climate region where the wet and dry seasons are noticed prominently in the area. The dry season is between November and March while the rainy seasons are mostly between April and October. The average rainfall is between 1000 mm and 1500 mm with temperature as high as 36.7°. The elevation of the study area ranges from 343.9 m to 416.6 m above sea level. The predominant vegetation is moist deciduous forest, which is very rich in timber resources. The canopy is more open in the north than in the rain forest region which lies to the South with the tropical hard wood, timber such as iroko, obeche. Industrial and food crops found in the area include palm oil, rubber, cassava, yams, rice plantains, and many local important fruits strive within the forest.

III. Methodology

The method that was used in this study is Electrical Resistivity using three techniques viz; Vertical Electrical Sounding (VES), 2-D Electrical Resistivity Tomography (ERT) and Horizontal Profiling (HP) with corresponding the configurations, Schlumberger, Dipole-Dipole and Wenner configurations respectively. Ten (10) sounding stations were occupied along the traverse, and the current electrode spacing (AB/2) was varied from 1 to 100 m. To process the electrical resistivity data, the apparent resistivity values were plotted against the electrode spread (AB/2). This was subsequently interpreted quantitatively using the partial curve matching method and computer-assisted 1-D forward modeling with WinResist 1.0 version software. The results from the VES interpretation was used to determined second order parameters such as the total transverse resistance (T) and the total longitudinal conductance (s). The dipole-dipole data were inverted using 2-D subsurface images using the DIPPRO™ 4.0 inversion software. The inter-electrode spacing of 5 m was adopted while inter-dipole expansion factor (n) was varied from 1 to 5. Resistivity values were obtained by taking readings using the Ohmega resistivity meter. The Wenner profiling was taken at 5 m interval and the data obtained was plotted on excel work sheet.

IV. Results and Discussion

The results of the study were presented as Sounding curves, geo-electric sections, pseudo sections and graphs.

a) Characteristic of the VES curves

Curves types identified ranges from K, A, H and KH varying between three to four geo-electric layers. The KH curve type is predominating. Typical curve types in the area are as shown in Figure 2(a-d)

b) Geoelectric and Lithological characteristic along the Traverse

The geoelectric sections were represented by the 2-D view of the geoelectric parameters (depth and resistivity) derived from the inversion of the electrical resistivity sounding data. The geoelectric section along the Traverse (Figure 3) attempted to correlate the geoelectric sequence across the study area. The geoelectric sections identified three to four lithology units, comprising of topsoil, underlain by sandy shale/shaly sand, following by sand, and sand stones with layer thickness ranged from 0.5 to 5.2 m, 2.5 to 11.8 m, 6.9 to 16.9 m and beyond respectively.

c) Dipole-dipole Pseudosection

The 2-D Pseudosection was produced from the dipole-dipole data taken along the traverse (Figure 4). The Dipole-Dipole traverse covered a distance of about 220 meter along East to West Orientation. It delineated three to four major subsurface material/layer components, identified with various colour for easy characterisation; The layer lithological materials varies from Top soil mainly of sandy/fairly competent material as indicated in green/red colour with layer resistivity variation of 102.0 to 312.0 Ωm. Following this layer is another characterised by low resistivity variation from 15.6 to 459.0 Ωm. With the dominant resistivity being between 15.6 Ωm and 112.6 Ωm. These are as characterised by lithologic units that can be classified plastic shales, sandy shales, and shaly sands, with layer thickness varying from 1.10 to 16.50 m they are indicated with green, light green, and green/blue colour. These zones are characteristically weak and made up of attributes of low foundation integrity. The few zones with materials of high/moderate integrity can be found around the pegging of the traverse, at 70 to 80 m, and 200 to 220 m most often they occur at a depth not feasible for road construction purpose.

d) Wenner Profiling

Wenner profiling was produced from the Wenner data obtained along the traverse (Figure 5). The result obtained further revealed that the zone is generally weak with apparent resistivity varying from 48.60 to 200.00 Ωm from the beginning of the profile to 170 m while within 180 to 220 m demonstrated fear competence with apparent resistivity value ranging from 220 to 290 Ωm.

e) Dar Zarrouk Parameters

Result obtained from the VES interpretations were used to determine the second order parameters (Table 1). The estimation shows that the total longitudinal conductance varies from 0.010 –2.500 Ω^{-1} in the area with high total longitudinal conductance between distance of 140 to 170 m and low total longitudinal conductance at distance between 5 to 130 m (Figure 6). The qualitative use of this parameter is to demarcate changes in total thickness of low resistivity materials. The total transverse resistance ranges from 572 to 13614Ωm, which gives information both about the thickness and resistivity of the area. The result reveals that the lower the longitudinal conductance, the greater is the probability of the road to failure and vis-a-vis

V. Synthesis of Results

Figure 7 displays the correlation of result obtained from the geophysical techniques. The Wenner profiling observed at a distance 170 to 220 m demonstrated fear competence with apparent resistivity value ranging from 220 to 290 Ωm which coincides with where the total longitudinal conductance is high at distance from 150 to 200 m. This also agrees with the high resistivity zone observed on the dipole-dipole pseudo-section at a distance 160 m and geo-electric section at a distance 180 to 200 m which indicate high integrity and low susceptibility to failure. The Wenner profiling zone is generally weak with apparent resistivity varying from 48.6 to 200.0 Ωm at a distance of 60 to 170 m correlate with where the total longitudinal conductance is low at distance between 5 to 140 m. These also agrees with the low resistivity zone observed on the dipole-dipole pseudo-section at distance between 80 to 120 m and the geoelectric section at distance 90 to 130 m which indicate low to moderate integrity and low to moderate susceptibility to failure. These results reveal that the techniques used for this study are complementary.

VI. Determination of the Probability Integrity Test

The results obtained from total longitudinal conductance were used to determine the probability integrity test and susceptibility of failure (Table 2 and 3). Figure 8 reveals that only 10% of the road survived susceptibility test, with a longitudinal conductance value of 1.099, about 30% of the class distribution of the total longitudinal conductance test/susceptibility to failure, had a total longitudinal conductance value of between 0.1000 to 0.999 respectively 30% susceptibility to failure, while, the rest of the study location had a total longitudinal conductance value of 0.010 to 0.099, implying a 60% susceptibility chance of failure. Therefore using this as a basis for failure and predicting of index factor of ten Year. The probability that the road will fail within Ten Year when constructed is 90% and last Ten Years before any failure is 10%. The result shows that clay/shale is more predominant within the study location which is the major factor and a challenge responsible for 90% problem of road failures in Nigeria. The investigation illustrates that in recent times, the road cannot survive Ten years at stretch durability and stability, without one form of intervention program unless a proper precaution took place. So the need to construct our road with a minimum number of years as a guarantee before any failure can occur has never been of priority to our road builders. However, before construction of any road, there must be adequate studies of this nature

VII. Conclusion

The study has revealled the significance of geophysical site study for highway construction design consideration. Geophysics, consequently, remains a very fundamental tool which can be applied in civil engineering work. The result obtained from VES delineated two to three geoelectric units which comprises of topsoil, clay layer, sand layer/weathered layer/shale horizon units. These results were used to determine the second order parameter which was used to delineate the integrity and susceptibility test of failure. All the results correlate well with one another showing that all the techniques used are complemented. No road can be constructed successfully in this area and most other part of the country with similar formation where clay or shale is a major factor without a thorough geophysical studies and information that will assist the construction Engineers; at using the right materials as well as excavating to a specific depth with a view to replacing the shale/clayey material, with necessary competent materials, complement with reinforcement and proper drainage. In addition to other geotechnical studies, no road can be constructed successfully without a good knowledge of the geology of that environment. Hence the inescapability of studies of nature before any construction work can be embarked on. The Government should insist on a guarantee of at least ten years, as part of contractual agreement with any road contractor and failure of which should be met with an appropriate sanction.

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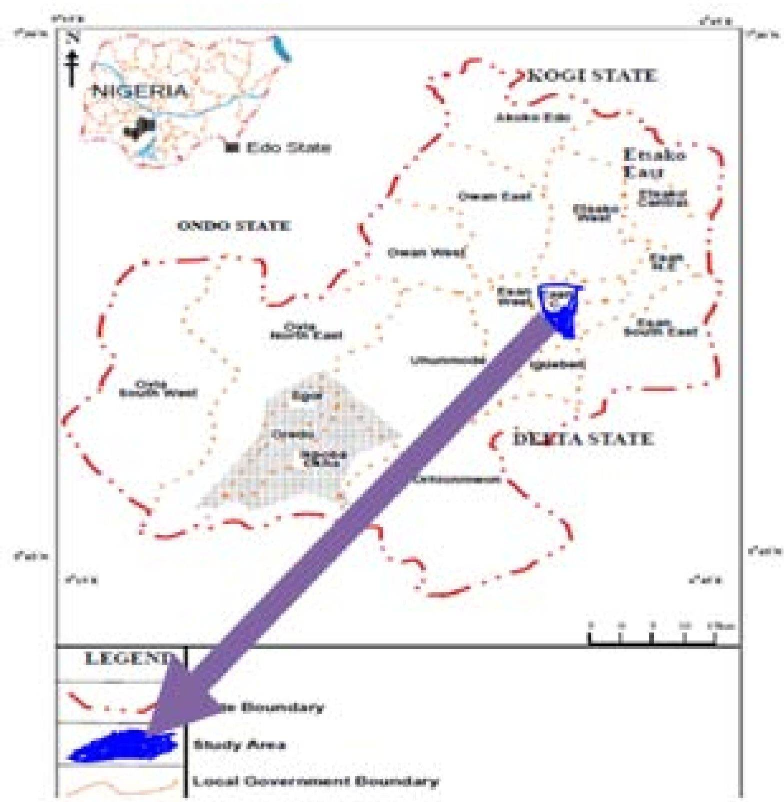


Figure 1: Map of Edo State Showing the Study Area (Ministry of Land and Survey, 2005.)

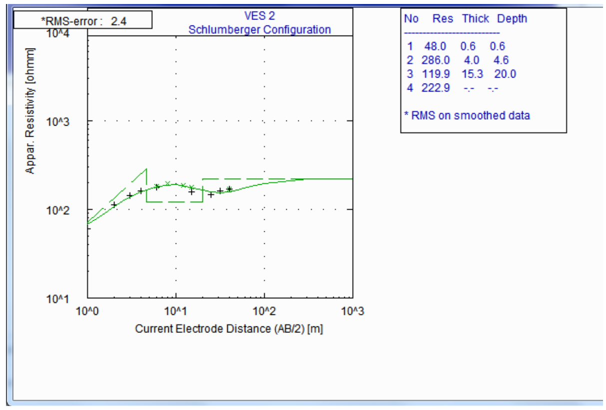


Figure 2 a: Typical Curve KH Type of the Study Area

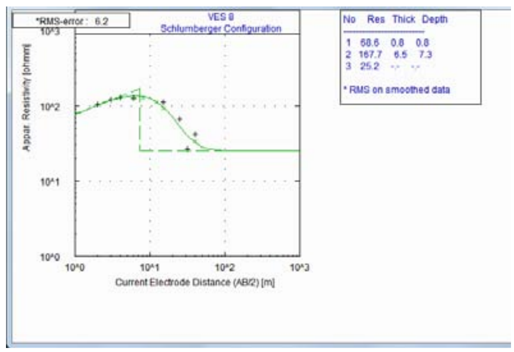


Figure 2b; Typical Curve K Type of the Study Area

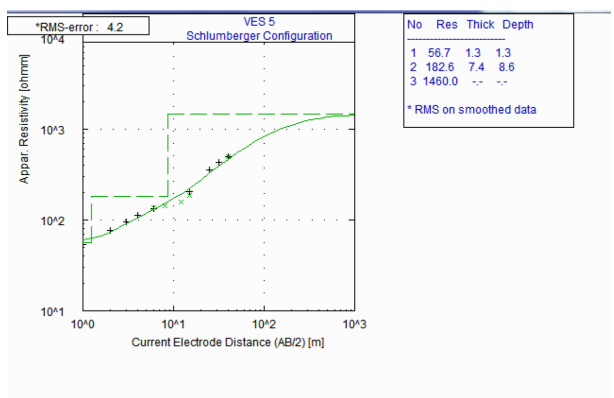
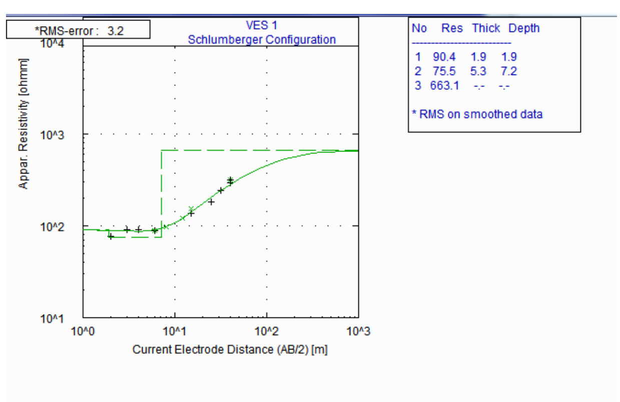


Figure 2c; Typical Curve A Type of the Study Area



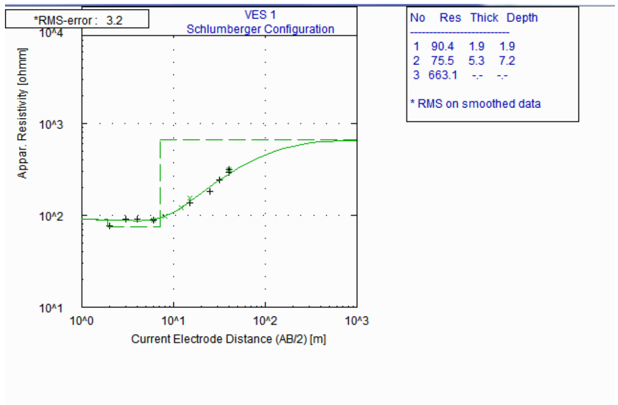


Figure 2d: Typical Curve H Type of the Study Area

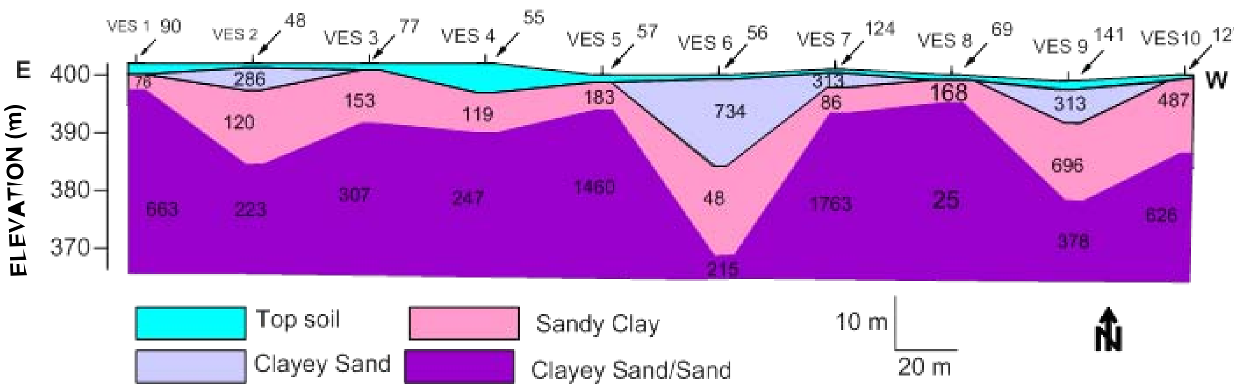
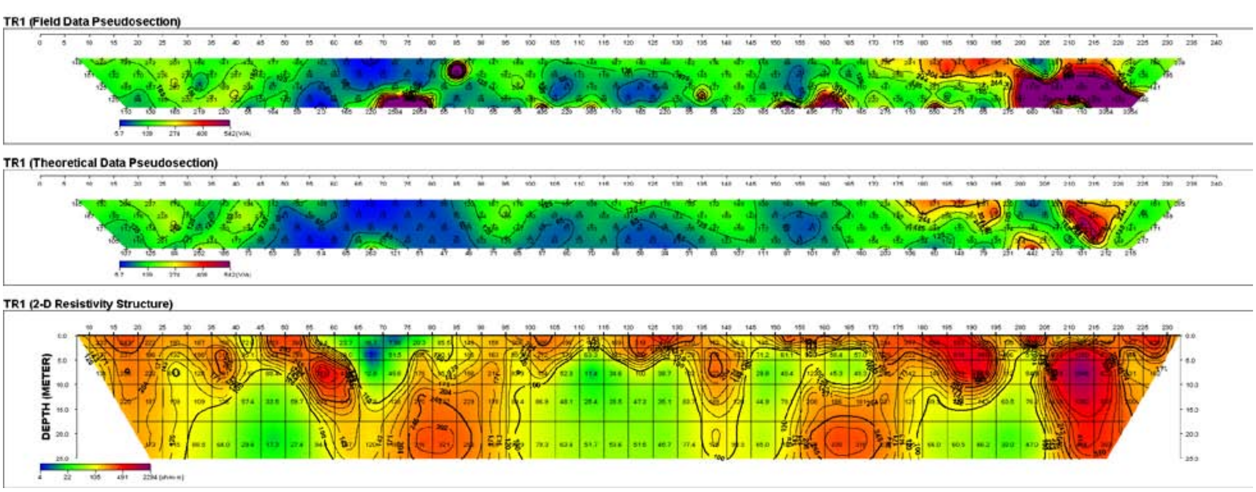


Figure 3: Geoelectric Section along the Traverse



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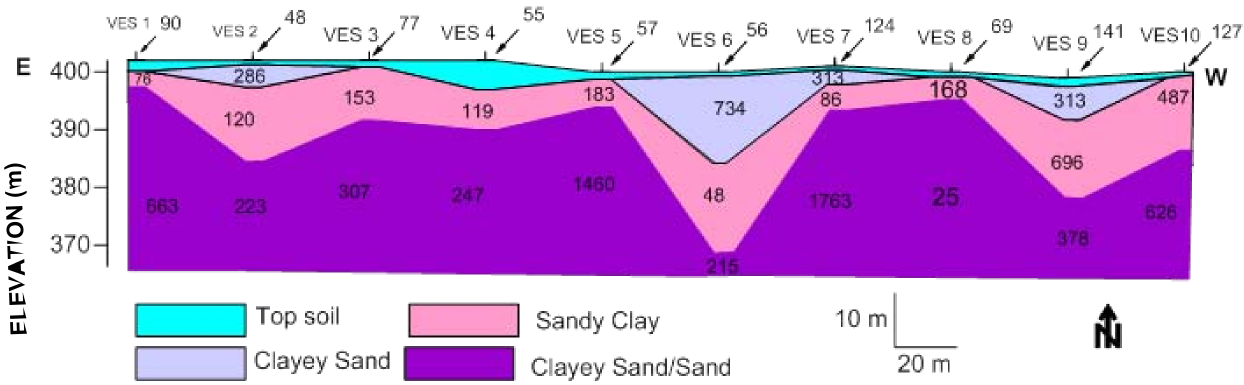

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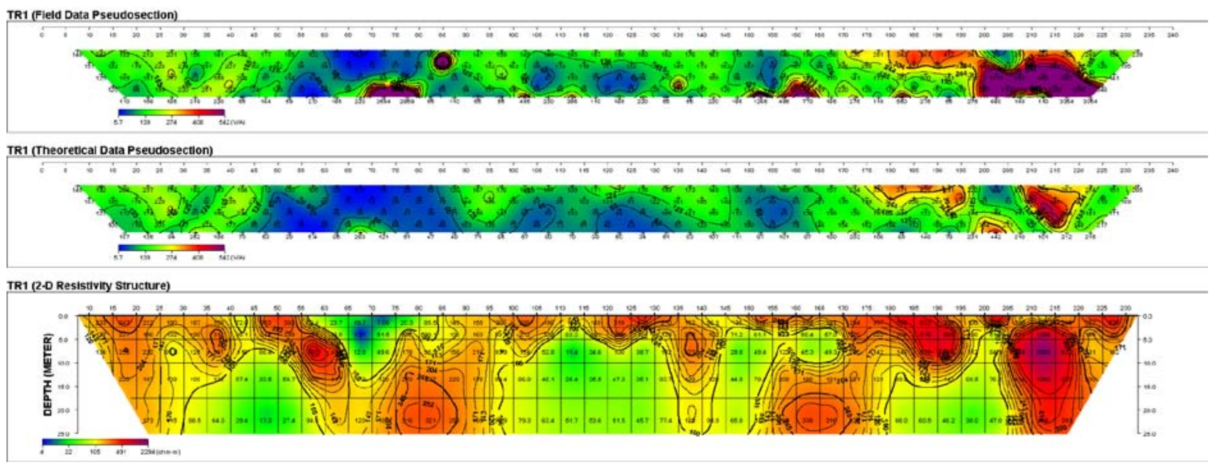

Figure 4: Dipole – Dipole Horizontal Profiling along the traverse

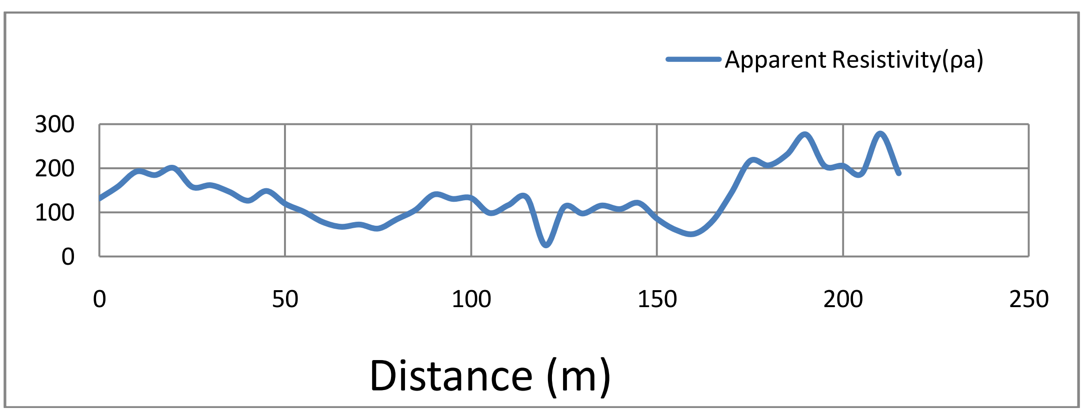

Figure 5: Wenner Profiling along the Traverse

Table 2: Dar Zarrouk Parameter of the Study Area

	VES 1	VES 2	VES 3	VES 4	VES 5	VES 6	VES 7	VES 8	VES 9	VES 10
Total traverse resistance (T)	572Ωm	1474 Ωm	1886 Ωm	1412 Ωm	1425 Ωm	2759 Ωm	461 Ωm	1442 Ωm	13614 Ωm	2518.5 Ωm
Total Longitudinal conductance (S)	0.091	0.155	0.092	0.174	0.064	0.273	0.095	1.099	0.051	0.075

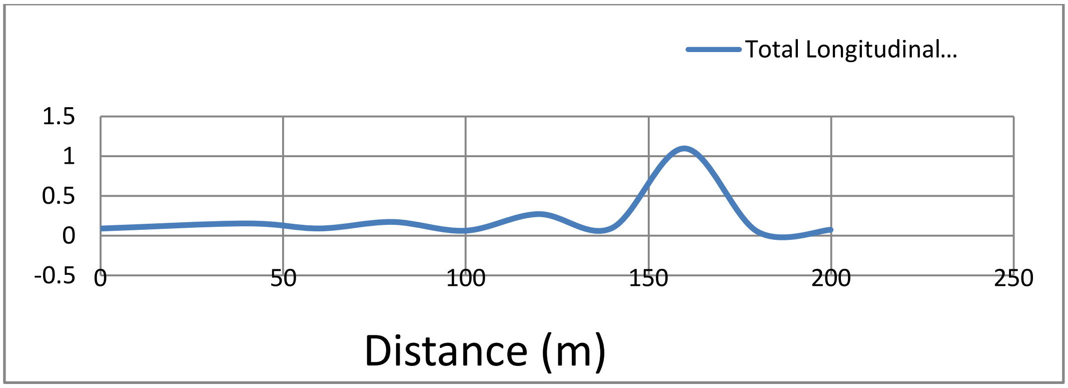

Figure 6: Total Longitudinal Conductance Profile of the Study Area

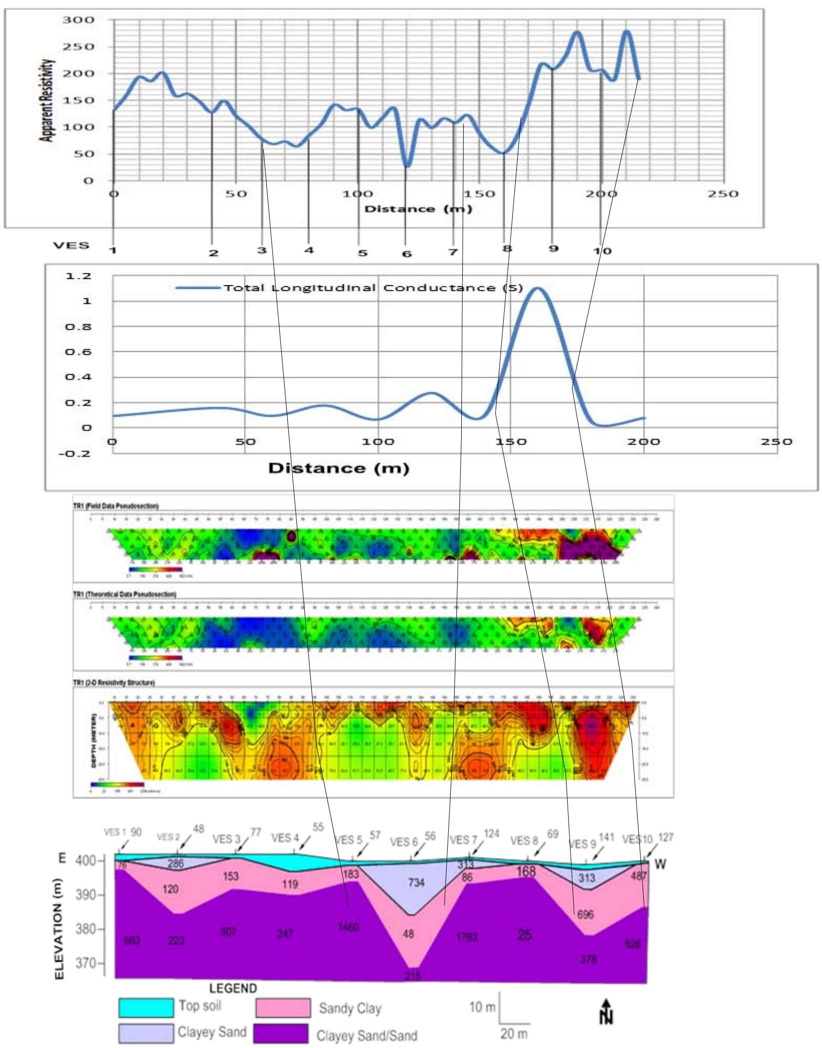

Figure 7: Showing the Correlation of Results

Table 2: Showing Longitudinal Range

Longitudinal Conductance Range	Integrity Test	Susceptibility to Failure
1.000 – 2.500	High	Low
0.100 – 0.999	Medium/Moderate	Moderate
0.010 – 0.099	Low	High

Table 3: Probability integrity test table / prediction of failure (in 10 years) before failure

VES No	Total longitudinal conductant (S)	Class	Rating	Rating in %	Probability of failure/No of year before failure
1	0.091	0.010 – 0.099	Low integrity / High susceptibility to failure	70%	Below 3 years
2	0.155	0.1000 – 0.999	Medium / Moderate integrity / Moderate susceptibility to failure	20%	8 Years and above
3	0.092	0.010 – 0.099	Low integrity/High susceptibility to failure	70%	Below 3 years
4	0.174	0.1000 – 0.999	Medium / Moderate integrity / susceptibility to failure	20%	8 year and above
5	0.064	0.010 – 0.099	Low integrity / High susceptibility to failure	70%	Below 3 years
6	0.0274	0.010 – 0.099	Low integrity / High susceptibility to failure	70%	Below 3 years
7	0.095	0.010 – 0.099	Low integrity / High susceptibility to failure	70%	Below 3 years
8	1.099	1.000 – 2.500	High integrity / Low susceptibility to failure	10%	9 years and above
9	0.051	0.010 – 0.099	Low integrity / High susceptibility to failure	70%	Below 3 years
10	0.075	0.010 – 0.099	Low integrity / High susceptibility to failure	70%	Below 3 years

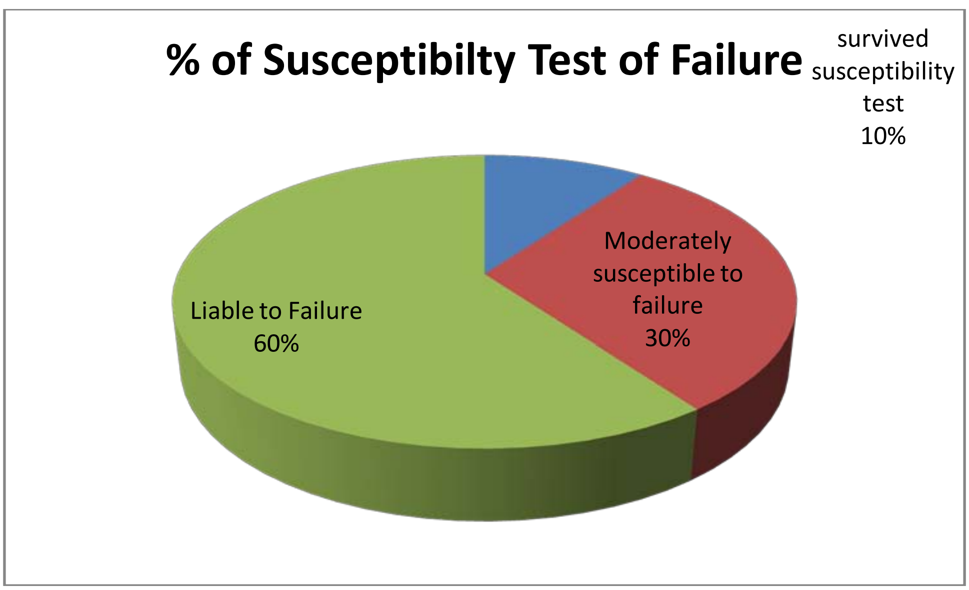

Figure 8: Show the Susceptibility Test of Failure

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