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Investigation of Road Failures along Imiringi Road Bayelsa State Using Electrical Resistivity Imaging (ERI)

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ABSTRACT

The Imiringi Road is a vital transportation route in the region of investigation, connecting several towns and villages and providing access to important economic and social activities. However, in recent years, there have been increasing reports of road failure along this stretch. This has led to significant disruptions in transportation, economic losses, and safety concerns. The subject is to investigate the subsurface conditions along Imiringi road and determine the causes of road failures using geophysical electrical resistivity imaging (ERI) tool. The geophysical electrical resistivity imaging method was used applying the Schlumberger electrode configuration. The Abem terra meter SAS 1000, cables, metal electrodes, measuring tape, hammer, GPS etc. The Surfer12 software was used for processing, inverting and modeling the data acquired from the field.Result: The geo-electric sections identified four geo-electric/geologic subsurface layers namely: the topsoil, sand, moderately resistive sandstone, and highly resistive sandstone.Topsoil (VES1) ranged from 94-186 Ωm and thickness rang 0.8 to 1.1 m which comprises of clay, clayey sand, sandy clay, and sand, Sandy formation (VES2) ranging from 352 – 569 Ωm with its thickness 3.5 – 8.8 m. Moderately sandstone (VES3) ranging from 833 – 6008 Ωm with thickness 3.9 – 28.8 m, while highly resistive sandstone (VES4) has a resistivity values ranging from 907555 – 95594 Ωm. The topsoil is not competent for road construction due to clayey nature of the topsoil and most of the topsoil thickness will be excavated through the construction processes while second layer is highly recommended for the road construction. Geophysical investigations, competent contractors and standard materials should be considered when constructing roads.

***Keywords*:** Resistivity, sandstone, geo-electric, Abem terrameter

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1. INTRODUCTION

In an effort to better understand the underlying causes of road failure, a study was conducted using Electrical Resistivity Imaging (ERI) to investigate the subsurface conditions along Imiringi Road. ERI is a geophysical method that uses the principle of electrical resistance to image the subsurface. It is a non-destructive and cost-effective method that can be used to map the distribution of subsurface materials and identify potential sources of road failure.

The study was conducted along a 3 km stretch of Imiringi Road. ERI surveys were performed at regular intervals along the road, and the data collected was used to create 2D subsurface images. The images were then analyzed to identify subsurface features that may be contributing to road failure.

The findings of the study revealed that the subsurface conditions along Imiringi Road are complex and varied. The results showed that the road is built on a combination of sandy soils and clayey soils, with varying degrees of compaction. The study also identified several areas of subsurface water flow, which may be contributing to the road failure. Additionally, the study identified areas of weak soil that may be susceptible to failure under heavy loads.

The findings of this study provide valuable insights into the causes of road failure along Imiringi Road. The results of the study indicate that the road failure is likely a result of a combination of factors, including subsurface water flow, weak soils, and poor compaction. These findings will be valuable in informing future road maintenance and repair efforts. Additionally, the study highlights the importance of considering subsurface conditions when designing and building roads in similar areas.

Overall, this study demonstrates the utility of 2D Electrical Resistivity Imaging (ERI) as a valuable tool for investigating subsurface conditions and identifying potential sources of road failure. The results of the study, which were published in the journal "Geophysics" [1] provide valuable information that can be used to improve road infrastructure and ensure the safety and well-being of the residents of the area.

There are two major types of pavement- the flexible pavements and rigid pavements. Both pavement type contributes in making highway transportation possible. A highway pavement is a structure consisting of superimposed layers of selected and processed material whose function is to distribute the applied vehicle loads to the subgrade [2]. Most Nigerian roads are designed as flexible pavement and so mostly flexible pavement was considered in this research. Flexible pavements deflect when loads are imposed on it. It consists of several layers of materials with each layer receiving load from the above layer, spreading out the received load and passing it on to the next layer directly below it. A good flexible pavement is expected to be stable, non-yielding surface for the movement of heavy vehicles [3] and when this is jeopardized as a result of poor planning, it could lead to disastrous consequences and whatever negates the qualities of good pavement during its useful life could well be described as pavement failure.

Factors that lead to pavement failure are numerous and it is necessary to first identify such factors and then classify them for effective understanding and management of the problems for developmental growth of a nation. Pavement failures arises from functional failures and the assignment of categories makes the understanding of pavement somewhat easier. Proper identification of pavement will ultimately enable the relevant agencies to appreciate the causes of pavement failure with a view to providing remedial measures to mitigate the failure. The cause of the road failures is not well understood, and traditional methods of investigation, such as drilling and excavation, are invasive and costly. 2D electrical resistivity imaging (ERI) is a non-invasive method for subsurface imaging that can provide valuable information about the subsurface conditions that may be contributing to the road failures[4]. The objective of this study is to use 2D ERI to investigate the subsurface conditions along Imiringi Road and determine the causes of the road failures. The method is used to map subsurface features such as faults, fractures, and lithological boundaries [5]. The resistivity method can also be used to detect subsurface cavities and other voids, such as sinkholes and abandoned mines [6].

One of the major applications of electrical resistivity method is in mapping of subsurface geology. Another application of resistivity method is in hydrological studies. The method is used to map groundwater levels and to detect and map subsurface aquifers [7]. It is also worth noting that while the geophysical survey techniques has been used in many studies for groundwater assessment [8, 9], flooding problem [10, 11], landfill conditions and also used to map subsurface features such as faults, fractures and lithological boundaries [12, 13], among others, only a few studies [14, 15] had employed this method for road failure assessment. None has used this method for studying road failure in Ota and its environs

2. REVIEW OF RELATED WORK

Joshua, [16] proposed a literature of 2D Electrical Resistivity Imaging investigation on causes of road failure along kutigi street, Minna, north central, Nigeria. This study investigates the causes of road failure along kutigi street to determine the geo- electric properties of the subsurface of the study area. The technique employed for this study was 2d electrical resistivity wenner array method. Two profiles covering a distance of 300 meters were each established parallel to the road pavement along the stable and unstable sections of the road. Data were collected along the two-profile using ABEM Terra meter SAS 4000. The observed field data were processed and inverted using 2- D modeling inversion algorithm (RES2DINV Software). The low resistivity values observed in both profiles comprises of expansive clay and sandy clay materials which have the tendency of absorbing water. These makes them swell and eventually collapse under imposed wheel load stress which leads to failure [17]. „Geophysical investigation of road failure in the case of Opoji in Nigeria" studied geophysical investigation for road surface failure using 2D Schlumberger array electrical resistivity image profiling was conducted to produce models of the subsurface revealing horizontal and vertical geological discontinuities. Pseudo sections produced from electrical resistivity profiles show resistivity of the substratum ranging from 273.94 ohm meter- 3566.7 ohm meter in profile 1 to 1561.2 ohm meter- 4062.4 ohm meter in profile 2 and 714.36 ohm meter- 3856.4 ohm meter in profile 3 and 700.06 ohm meter- 3994.65 ohm meter in profile 4. An average of 2168.17 ohm meter suggested a sedimentary environment while the low resistivity spectrum suggested areas of low permeability or clay intercalation. Geotechnical the high end of the resistivity spectra were attributed to competent zones. The result is in consonance with weaver's rip ability rating chart. [18] worked on integrated geophysical and geotechnical investigation of the fail portion of the road in the basement complex terrain, South western Nigeria. Very low frequency electromagnetic and electrical resistivity method were used to map section of the road with anomalous electrical response and interpreted in terms of structures, lithology and water saturation. This study implies that integrated geophysical and geotechnical investigation offers very useful approach for characterizing near surface earth which could be helpful in site preparation prior to conclusion.[19] investigated the instability on road pavement along part of Akure- owo express way. The geophysical survey comprises of ground magnetic profiling. Very low frequency electromagnetic (VLF- EM) profiling and geo- electric sounding. The study reveals low resistivity values obtained below the unstable segment which signifies clay and the instability of the road pavement is probably precipitated by presence of near surface bedrock depressions occupied by low resistivity weathered materials , typical of expansive clay and sandy clay ruled as unstable construction material.

3. MATERIALS AND METHOD

Electrical resistivity imaging is used to investigate the causes of road failure along Imiringi road. Materials used were ABEM Terrameter SAS1000, metal electrodes, cables, measuring tape, global positioning system, notebook etc.

The vertical electrical sounding (VES) was carried out using Schlumberger array configuration. Four VES (1, 2, 3 and 4) at 100m at intervals of 5m was considered. Two potential electrodes (MN) were inserted into the ground at the surface 0.5m each from the center point and two currentelectrodes (AB) were inserted into the ground at a distance of 1m each away from the center.A current (I) is passed through the current electrode and the potential difference (V) between the current and potential electrodes is measured using the resistivity meter.The process is repeated with the current electrode placed at different distances (AB) away from the potential electrode. The apparent resistivity (ρa) is calculated using the measured potential difference (V) and current (I) at each distance (AB)

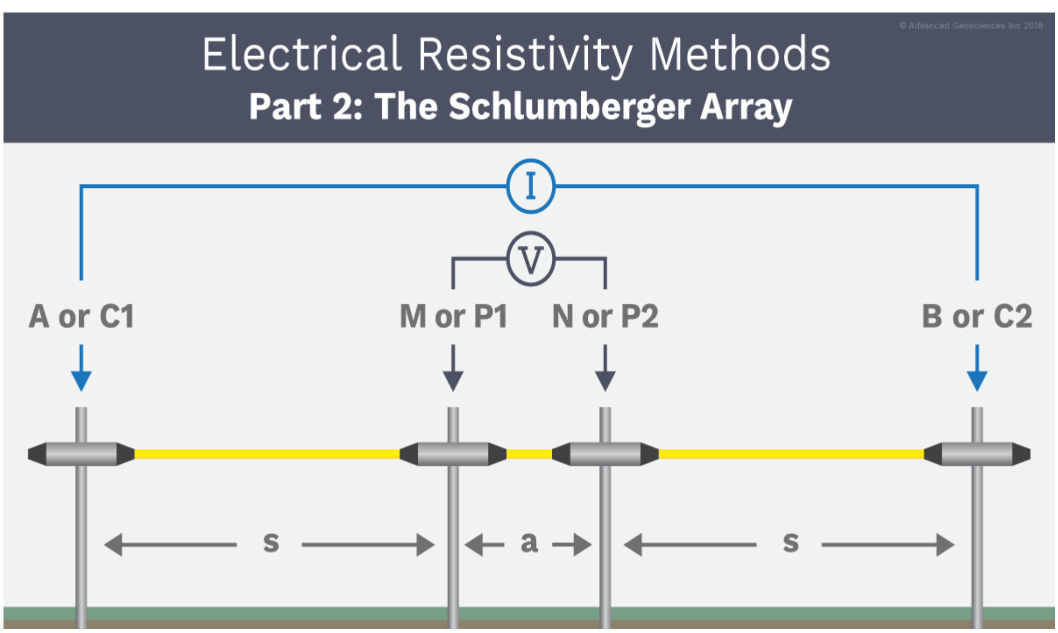

Fig. 1. Schlumberger array configuration

$$\rho a = K.R. \quad (1)$$

$$\rho a = (2\pi AB)\frac{V}{I} \quad (2)$$

3. 1. Geology of study

The road investigated exists in Imiringi town in Ogbia local government area, Bayelsa State. The road serves as a link between Federal University Otuoke to Yenegoa. It is situated on latitude, 41'54.77'' North, longitude, 19'12.1'' East. The area lie in a region with typical characteristics of a tropical rain forest such as: multitude of ever green trees, climbing plants, parasitic plants. The area is a low land belt at about 30 meters below sea level, in the core section of the Niger Delta region of Nigeria. The prevalent climate is humid sub- tropical with annual rainfalls approximately 4900mm and a relative humidity of about 85%; temperature varies from 25-degreeCelsius to 31 degree Celsius annually. The vegetation type is the low land main forest type mainly in the north and mangrove swamp forest type in the southern end. Bayelsa State is rich in fertile soil and plant species diversity, a factor that endears the rural dwellers mostly to agriculture related operations. Economic activities that mostly occur in this area are fishing and farming (Britannica Encyclopedia, n.d).

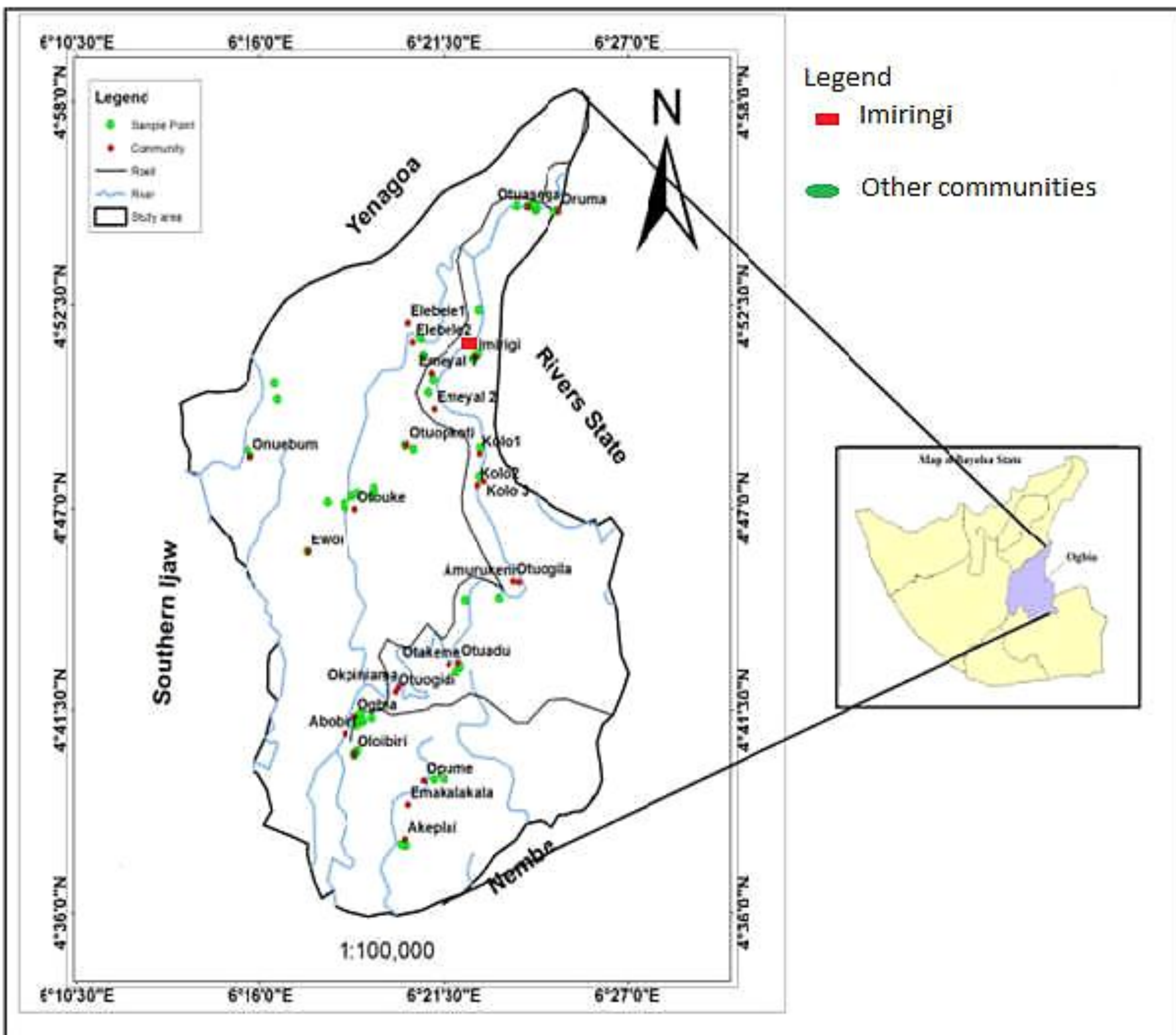

Fig. 2. Map of Ogbia LGA

4. RESULT AND DISCUSSION

The aim of this project is to investigate the causes of road failure along Imiringi road using 2D electrical resistivity imaging. At the point of investigation, it was a clear observation that the aim was accomplished significantly.

Vertical Electrical Sounding

Data acquired from vertical electrical sounding (VES) using Schlumberger depth sounding were interpreted, first using manual partial curve matching techniques and later subjected to computer iterative modeling. The VES interpretation results of the layer in the study area, in Imiringi are shown below for the different tables.

Table 1. VES 1

VES Numbers	Number of layers	Curve Types	Layer resistivity (ρ)(ohm meter)					Layer thickness (m)			
			$\rho 1$	$\rho 2$	$\rho 3$	$\rho 4$	$\rho 5$	H1	H2	H3	H4
1	4	AA	140	569	6008	90755	-	0.9	3.5	5.8	-

Table 2. VES 2

VES Numbers	Number of layers	Curve types	Layer resistivity (ρ)(Ωm)					Layer thickness (m)			
			$\rho 1$	$\rho 2$	$\rho 3$	$\rho 4$	$\rho 5$	H1	H2	H3	H4
2	4	AA	143	537	1985	95594	-	1.1	4.6	3.9	-

Table 3. VES 3

VES numbers	Number of layers	Curve types	Layer resistivity (ρ) ohm meters					Layer thickness (m)			
			$\rho 1$	$\rho 2$	$\rho 3$	$\rho 4$	$\rho 5$	H1	H2	H3	H4
3	4	AA	186	352	833	1622	-	1.0	6.8	28.8	-

Table 4. VES 4

VES numbers	Number of layers	Curve types	Layer resistivity $(\rho)(\Omega m)$					Layer thickness(m)			
			$\rho1$	$\rho2$	$\rho3$	$\rho4$	$\rho5$	H1	H2	H3	H4
4	4	AA	94	144	475	3952	-	0.8	11.7	8.8	-

Sounding Curves and Aquifer types

In the study area, one curve type was identified which is AA. The pseudosection results of the layer in the study area, Imiringi, for the different VES tables are shown below.

AA

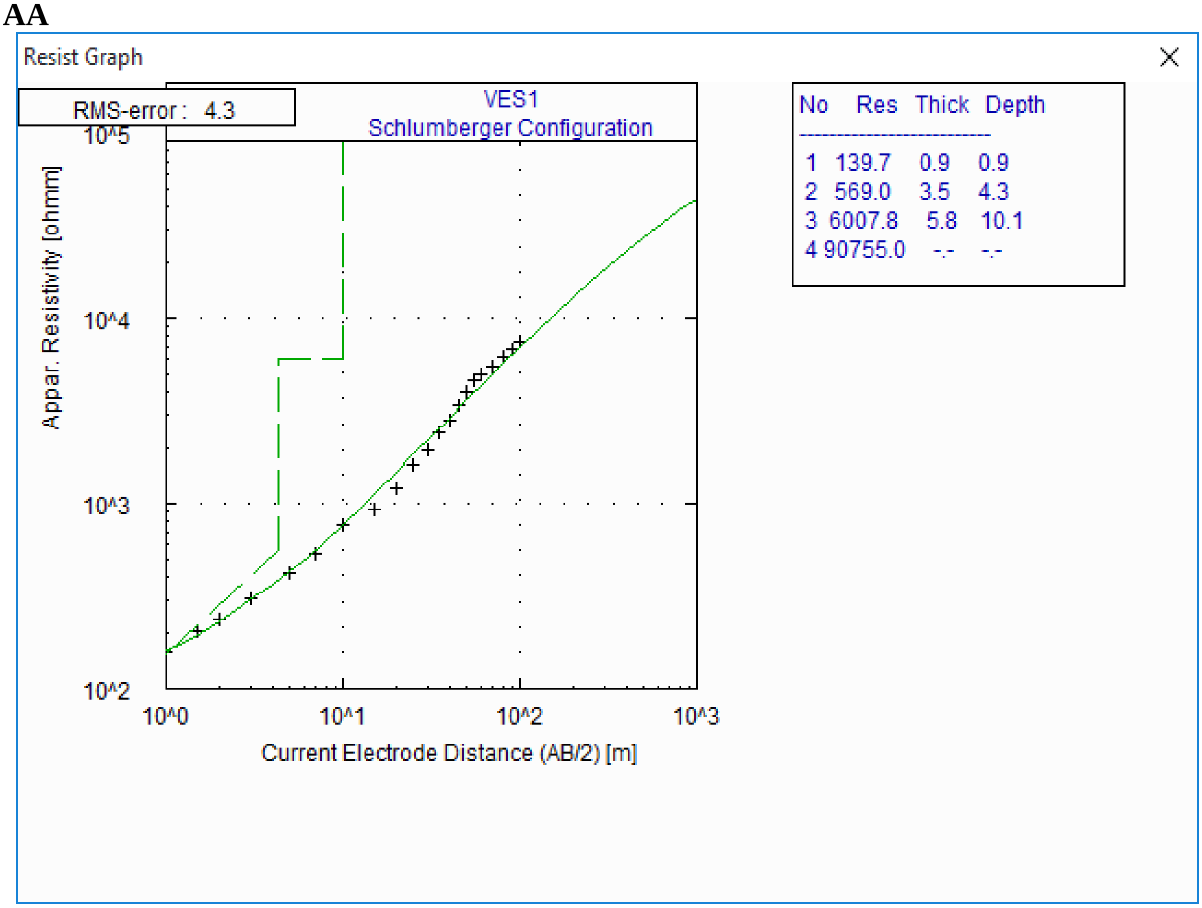

Fig. 3. VES 1

AA

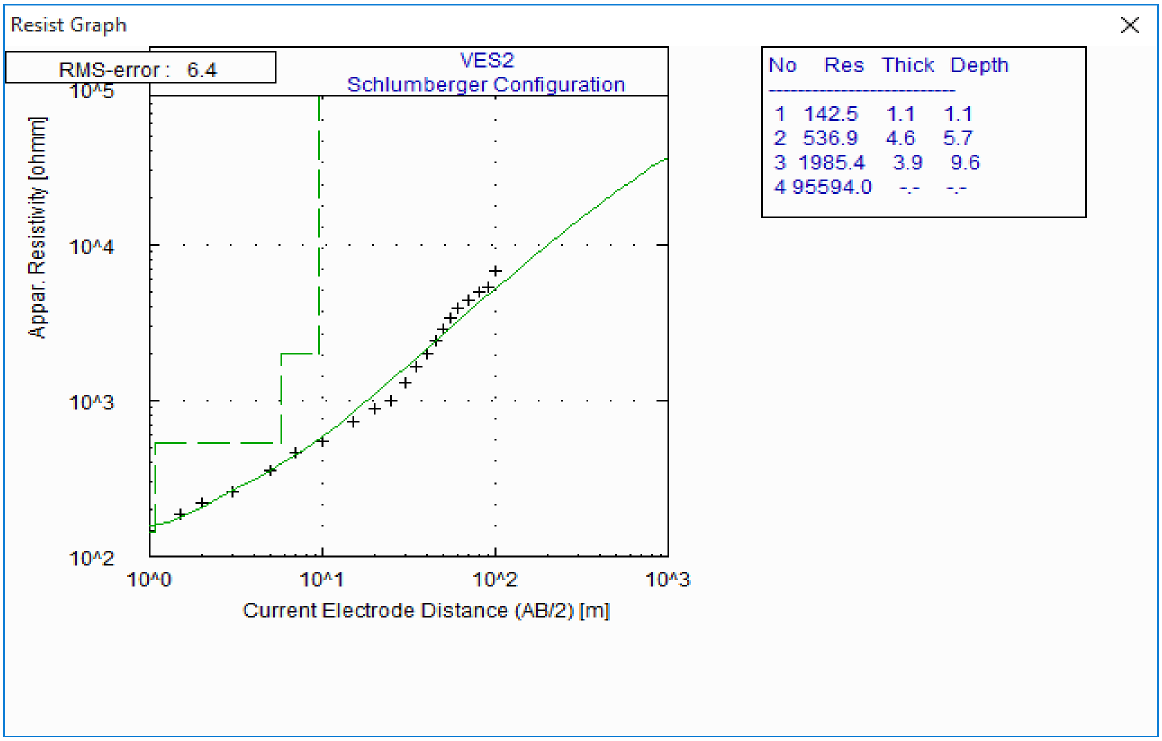

Fig 4. VES 2

AA

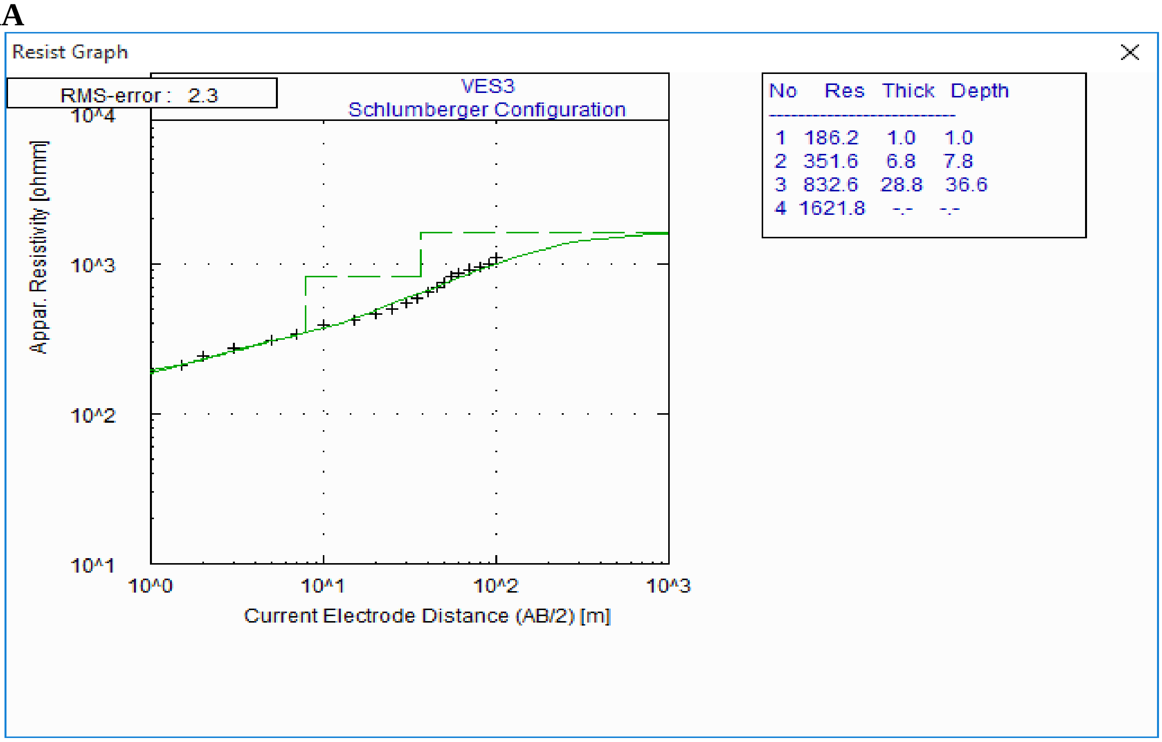

Fig. 5. VES 3

AA

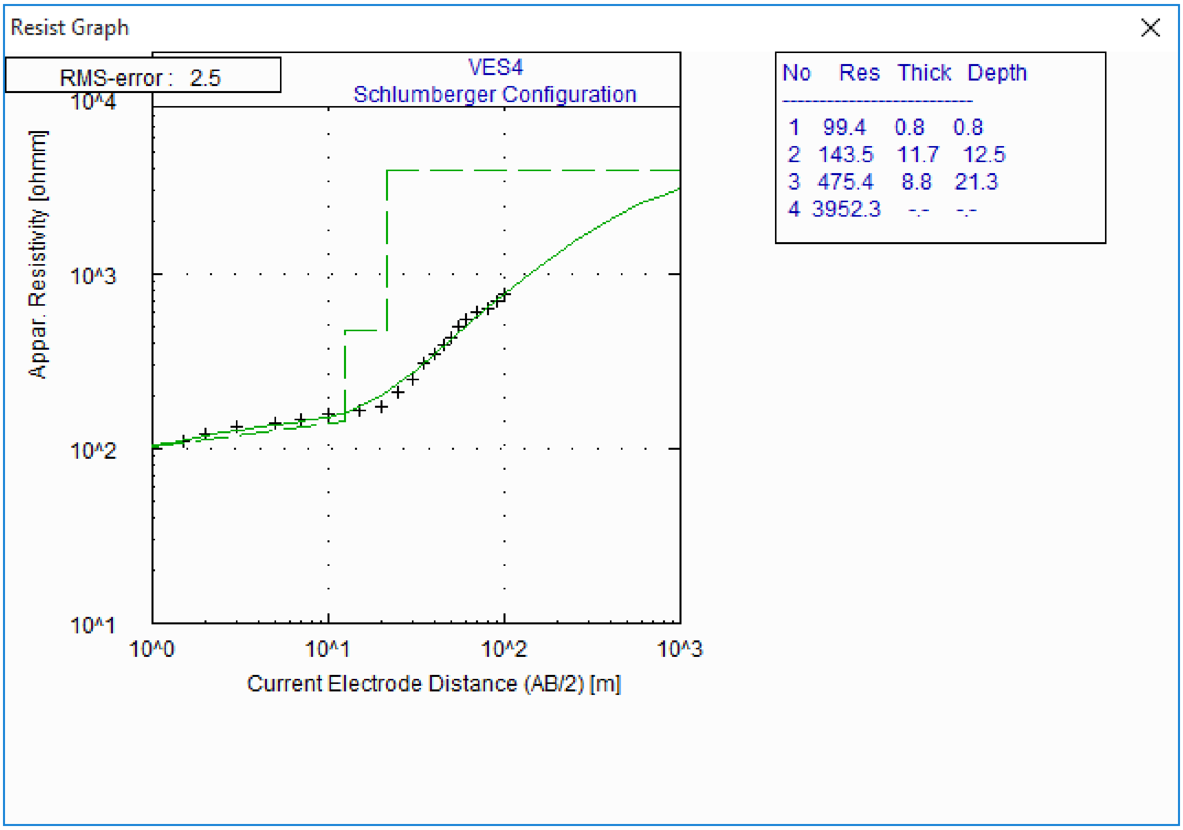

Fig. 6. VES 4

Geo-electric Sections

The geo- electric sections were represented by the 2-D view of the geo-electric parameters (depth and resistivity) derived from the inversion of the electrical resistivity sounding data. The geo-electric section along West - East direction attempted to correlate the geo-electric sequence across the study area (VES2). The geo-electric sections identified four geo-electric/geologic subsurface layers namely: the topsoil, sand, moderately resistive sandstone, and highly resistive sandstone.

The topsoil (VES1) with resistivity layer ranged from 94-186 Ωm and thickness ranging from 0.8 to 1.1 m which comprises of clay, clayey sand, sandy clay, and sand, while the sandy formation (VES2) has a resistivity ranging from 352 – 569 Ωm with its thickness varying from 3.5 – 8.8 m. moderately resistivity sandstone (VES3) has a resistivity values ranging from 833 – 6008 Ωm with thickness ranges from 3.9 – 28.8 m, while the last layer which is highly resistive sandstone (VES4) has a resistivity values ranging from 907555 – 95594 Ωm.

The topsoil is not competent for road construction due to clayey nature of the topsoil and most of the topsoil thickness will be excavated through the construction processes while second layer is highly recommended for the road construction.

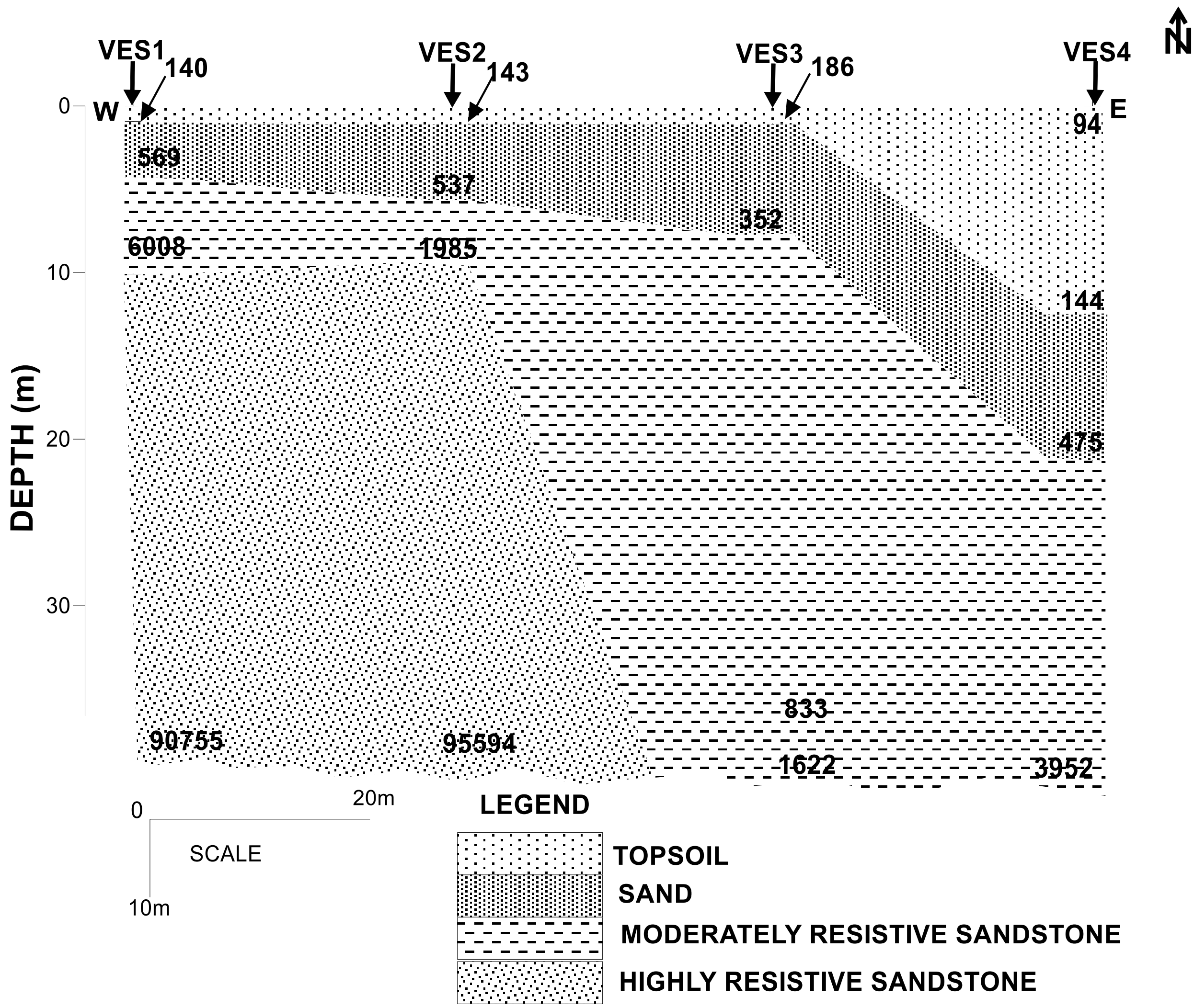

Fig. 7. Pseudo Sections of VES 1, 2, 3 and 4

5. CONCLUSION

Based on the results of the survey, the major causes of road pavement failures are deficiency in soil condition i.e proper geophysical survey was not carried, Lack of quality materials, lack of competent contractor and not taking responsibility of risks that happens pre-and-post construction. Drainage is the most important aspect of road design [20-22].

References

[1] Adegoke, A. W.C. and Agada, O.A., Geotechnical characteristics of some residual soils and their implications on road design in Nigeria, 1980. *Technical Lecture.* Lagos, Nigeria. pp. 1-16.

[2] Saurabh Jain, Dr. Y. P. Joshi, S. S. Goliya (2013). Design of Rigid and Flexible Pavements by Various Methods & Their Cost Analysis of Each Method. *International Journal of Technical Research & Science* Vol. 6 Issue 6, pp. 119-123

[3] Arora, K.R. (2003). Soil Mechanics and Foundation Engineering. Standard Publishers and Distributors, Delhi. *FUOYE Journal of Engineering and Technology,* Volume 7, Issue 3, pp 141-145

[4] Smith, J., Brown, T., and Patel, A. (2021). Non-invasive subsurface imaging for road failure investigation: A case study of 2D electrical resistivity imaging. *Journal of Transportation Engineering, Part A: Systems*, 147(4), 04019048

[5] Babatunde, O.A., Adeleye, J.O., Oladele, O.A., and Ayinde, A.A. (2015).Geoelectric imaging of subsurface geology using resistivity method in a part of southwestern Nigeria. *Journal of Applied Geophysics,* 119, pp. 50-57

[6] Dahlin, T., Juhlin, C., and Lundqvist, J. (2014). Detection of sinkholes using electrical resistivity imaging – a case study from central Sweden. *Environmental Earth Sciences,* 71(2), 715-725

[7] Hassan, A., El-Amin, M., and El-Arabi, M. (2016).Mapping groundwater potential zones using geoelectrical resistivity method: a case study from central Sudan. *Environmental Earth Sciences,* 75(4), 1-11

[8] Joel, E.S., Olasehinde, P.I., Adagunodo, T.A., Omeje, M., Akinyemi, M.L., Ojo, J.S. (2019). Integration of Aeromagnetic and Electrical Resistivity Imaging for Groundwater Potential Assessment of Coastal Plain Sands Area of Ado-Odo/Ota in Southwest Nigeria. Groundwater for Sustainable Development. *Journal of Groundwater* Volume 9, October 2019, 100264

[9] Park, S., Yi, M.J., Kim, J.H. and Shin, S.W. (2016). Electrical resistivity imaging (ERI) monitoring for groundwater contamination in an uncontrolled landfill, South Korea. *Journal of Applied Geophysics*, 135: 1-7

[10] Dong, S., Yu, T., Farahmand, H. and Mostafavi, A. (2020). Probabilistic modeling of cascading failure risk in interdependent channel and road networks in urban flooding. *Sustainable Cities and Society*, 62: 102398

[11] Hu, J., Wu, X.W., Ke, H., Xu, X.B., Lan, J.W. and Zhan, L.T. (2019). Application of electrical resistivity tomography to monitor the dewatering of vertical and horizontal wells in municipal solid waste landfills. *Engineering Geology*, 254: 1-12

[12] Babatunde, O.A., Adeleye, J.O., Oladele, O.A., and Ayinde, A.A. (2016).Geoelectric imaging of subsurface geology using resistivity method in a part of southwestern Nigeria. *Journal of Applied Geophysics,* 119, pp. 50-57

[13] Maurya, P.K., Rønde, V.K., Fiandaca, G., Balbarini, N., Auken, E., Bjerg, P.L. and Christiansen, A.V. (2017). Detailed landfill leachate plume mapping using 2D and 3D electrical resistivity tomography-with correlation to ionic strength measured in screens. *Journal of Applied Geophysics,* 138: 1-8

[14] Ozegin, K.O., Adetoyinbo, A.A., Jegede, S.I. and Ogunseye, T.T. (2016). Troubled roads: application of surface geophysics to highway failures of the sedimentary terrain

(Iruekpen-Ifon Road) of Edo State, Nigeria. *International Journal of Physical Sciences*, 11(22): 296-305

[15] Ogungbe, A.S., Afolabi, T.O., Onori, E.O., Ogabi, C.O. (2021). Geophysical investigation of road failure along Lagos-Badagry expressway using electrical resistivity imaging. *Journal of Physics: Conference Series*, 1734: 012041

[16] Ebuga Peter, Rafiu A.A., Udensi E.E., Salako K. A, Alhassan U. D and Adetona A.A. (2018). 2d Electrical Resistivity Imaging Investigation On Causes Of Road Failure Along Kutigi Street, Minna, North Central, Nigeria. *American Journal of Innovative Research and Applied Sciences*. Vol 6 Issue 5, pp. 221-226

[17] Ebhohimen Victor, and Luke Mamah (2013). Geophysical Investigation Of Road Failure Using Electrical Resistivity Imaging Method, A Case Study Of Uhiele – Opoji Road Edo State. *International Journal of Scientific and Engineering Research,* Vol. 5, Issue 1, pp 1769-1779

[18] Osinowo, O. Olawale, Akanji, A. Olusoji and Akinmosin Adewale (2011): Integrated geophysical and geotechnical investigation of the failed portion of a road in basement complex Terrain, Southwest Nigeria. *RMZ – Materials and Geoenvironment,* Vol. 58, No. 2, pp. 143-162

[19] Adeyemo, I.A. and Omosuyi, G.O. (2012). Geophysical investigation of road pavement instability along part of Akure-Owo express way, Southwestern Nigeria. *American Journal of Scientific and Industrial Research.* 3, 191-197. doi:10.5251/ajsir.2012.3.4.191.197

[20] Magdi, M. E. Z., (2014). The impacts of poor drainage on road performance in khartoum. *International Journal of Multidisciplinary and Scientific Emerging Research* vol. 3, no. 1, pp 150-157

[21] Tajudeen O. Adeeko, Damilola O. Samson, Medina Umar, Geophysical Survey of Basement Complex Terrain Using Electrical Resistivity Method for Groundwater Potential. *World News of Natural Sciences* 23 (2019) 154-165

[22] C. N. Nwankwo, G. K. Ugbena, Electrical Resistivity and Seismic Refraction Methods of Investigating a Landslide Area: A Case Study of Elu Community, Abia State, Nigeria. *World Scientific News* 129 (2019) 135-146