IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Application of 2-D resistivity and seismic tomography in the control of environmental degradation

To cite this article: O. O. Adewoyin *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **993** 012018

Application of 2-D resistivity and seismic tomography in the control of environmental degradation

O. O. Adewoyin *, M. Omeje and T. A. Adagunodo

Department of Physics, College of Science and Technology, Covenant University, P.M.B 1023, Ota, Ogun State, Nigeria

(Adewoyin O. O.):olusegun.adewoyin@covenantuniversity.edu.ng;segadot@yahoo.com;orcid: 0000-0003-2868-4988
(Omeje M.): maxwell.omeje@covenantuniversity.edu.ng; orcid: 0000-0001-9124-1093
(Adagunodo T.A.): theophilus.adagunodo@covenantuniversity.edu.ng; orcid: 0000-0001-7810-3323

*Corresponding author's email address:olusegun.adewoyin@covenantuniversity.edu.ng

Abstract.One of the most serious dangers facing the world today is environmental degradation. The disruption of the earth is one of the factors that compose deterioration of the environment. The adverse effect of this cannot be downgraded. As important as site characterization is, if not properly managed can adversely affect our environment. As a result, alternative approaches may be considered to the traditional method of investigation, which is characterized by digging and invasion of the subsurface. Two methods of investigation were deployed in this study, they are electrical resistivity and seismic refraction tomography. The results obtained from these methods showed that the subsurface is non-homogeneous and vary in condition from place to place. The depth to competent layer for engineering construction purposes is between 7.5 and 16 meters, according to this survey, hence pile foundation is advised for building construction. This survey also discovered that the depth to competent layer for engineering construction purposes is between 7.5 m and 16 m, thus pile foundation is recommended for building construction. This research effort clearly revealed that engineering site characterization can be conducted without altering the original state of our environment.

Keywords: Electrical resistivity, Seismic refraction, Environmental degradation,Subsurface Characterization, Tomography

1. Introduction

It has been discovered that one of the factors responsible for environmental degradation is land damage [1]. The United Nations International Strategy for Disaster Reduction also characterizes environmental degradation as deterioration of the environment. This challenge may result from tools engaged in soil tests for subsurface characterization. Over the years, geotechnical techniques have been major tools for the investigation of the subsurface condition.Geotechnical methods have proved very good in that they can supply information on the soil structures, the composition of soil, the lithologic profile and the bearing capacity of the soil. However, these methods of investigation are not without their shortcomings in that they are cumbersome, very invasive and non-environmental friendly [2].

In recent times, geophysical techniques have been used to investigate the condition of a site for construction purposes. These methods have proven to be very reliable, non-destructive, environmentally friendly and less expensive. This approach can also give information on the horizontal changes in the geologic condition of the near surface with depth. The most relevant geophysical methods that are in this category are the electrical resistivity and seismic refraction methods, which are capable of presenting the condition of the subsurface in a photographic form [3][4] .

Laletsang et al. [5] showed that seismic refraction and magnetic methods are good combination in the study of geological structures. In terms of subsurface characterization, Khalil and Hanafy [6] acknowledged that the seismic refraction method would be very useful in engineering applications. Seismic refraction tomography proved to be highly effective in imaging the subsurface for the location of high permeability zones [7-9]. Furthermore, [10]unravelled the prevalent subsurface conditions of a study site where several buildings had undergone differential settlement of various degrees. Electrical resistvity method including both 1D and 2D resistivity measurements were conducted alongside cone penetration test.

This research work hopes to encourage methods of site characterization that would provide sufficient information on the state of the subsurface and will not alter the natural condition of our environment.

2. Geology of the Study Area

The study area is in Nigeria, Lagos state and in the Eti-Osa local government region to be precise. A detail geology and geomophorlogy of the area can be found in [3] as presented in Figure 1.

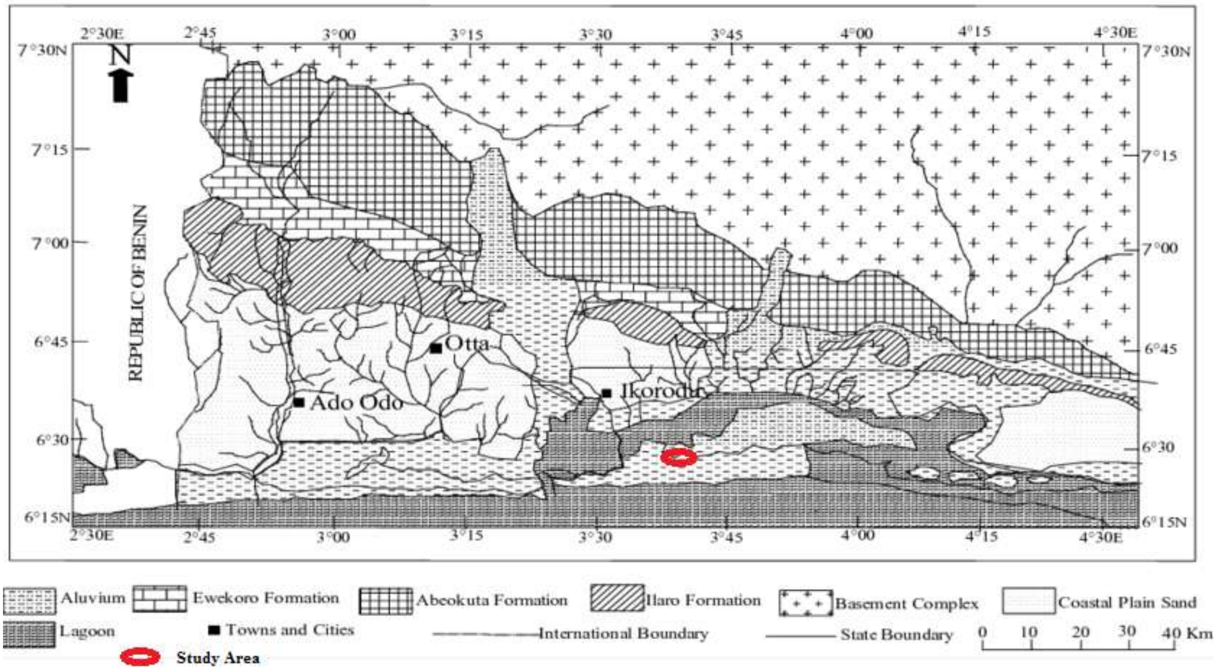

Fig. 1: Geologic map of the study area (modified after [11]).

3. Materials and Methods

The electrical resistivity survey was conducted with an ABEM Terrameter (SAS 1000/4000 model) [1]. 2-D resistivity imaging traverses were measured in this study (Figure 2). The Wenner array electrode configuration was used. The data was collected manually. The length of each 2D profile varied mostly between 85 and 250 m depending on the ease of access. The smallest electrode spacing was 5 m, and the largest spacing was 45 m. This gave a total data level ranging from 5 to 9 for the shortest and the longest traverses. The total data points ranges between 45 and 279. RES2DINV [13] was used to process and invert the obtained apparent resistivity data for the 2D profiles..

In addition, a 24-channel ABEM Terraloc Mark 6 Seismogram was used to conduct seismic refraction profiles in the research area [14].In this case, the length of each profile varied between 50 and 200 m based on the ease of access. The seismic refraction data acquired during the field exercise were initiallyseparated into folders based on the quantity of shot points. The data were later uploaded to a computer and processed using SeisImager/2D™ software [15].

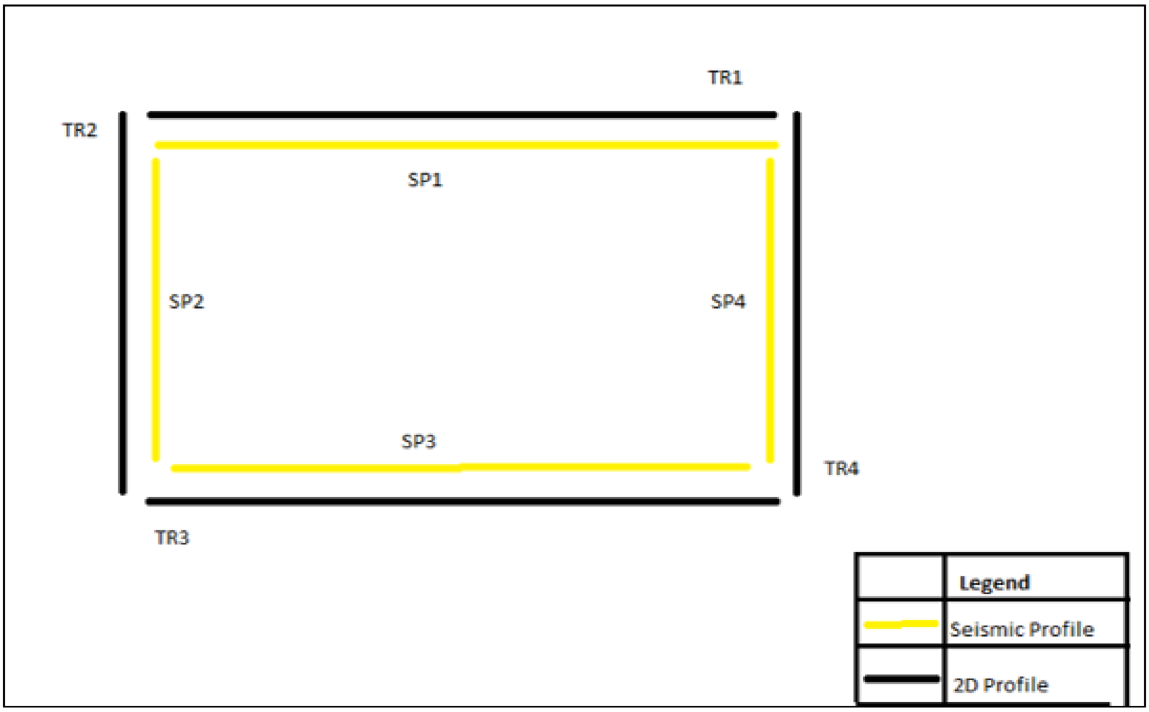

Fig. 2: Field survey layout of the area of study.

4. Results and Discussion

The resistivity value observed in the first layer ranges from 45 Ωm to more than 129 Ωm (Figure 3). The low resistivity observed for sand material in this area may largely due to high saturation with salt water, which is characteristics of coastal line zone. The sand deposit varied from 4 m in the north to 23.5 m about the middle, 8 m towards the south and 13.5 m at the extreme east of the profile in thickness. The second layer is made up of saline water saturated sandy clay. The second layer lies between 10 m and 23.5 m from the middle to the eastern part of the profile. This layer also varies in thickness to the between 4 m and 20 m towards the east of the profile. The resistivity of this layer varies between 12.7 Ωm and 40.4 Ωm. The reason for this very low resistivity for this layer when compared with the first traverse may be because of the direct flow of salinity of the sandy clay deposit. This may be because there is no material that is impermeable that could control the rate of flow of fluid in this area. As a result of the just stated reason, this region of the study area is always water logged despite all efforts to fill it up. The uncontrolled rate of water flow washes off the fill materials from its surface.

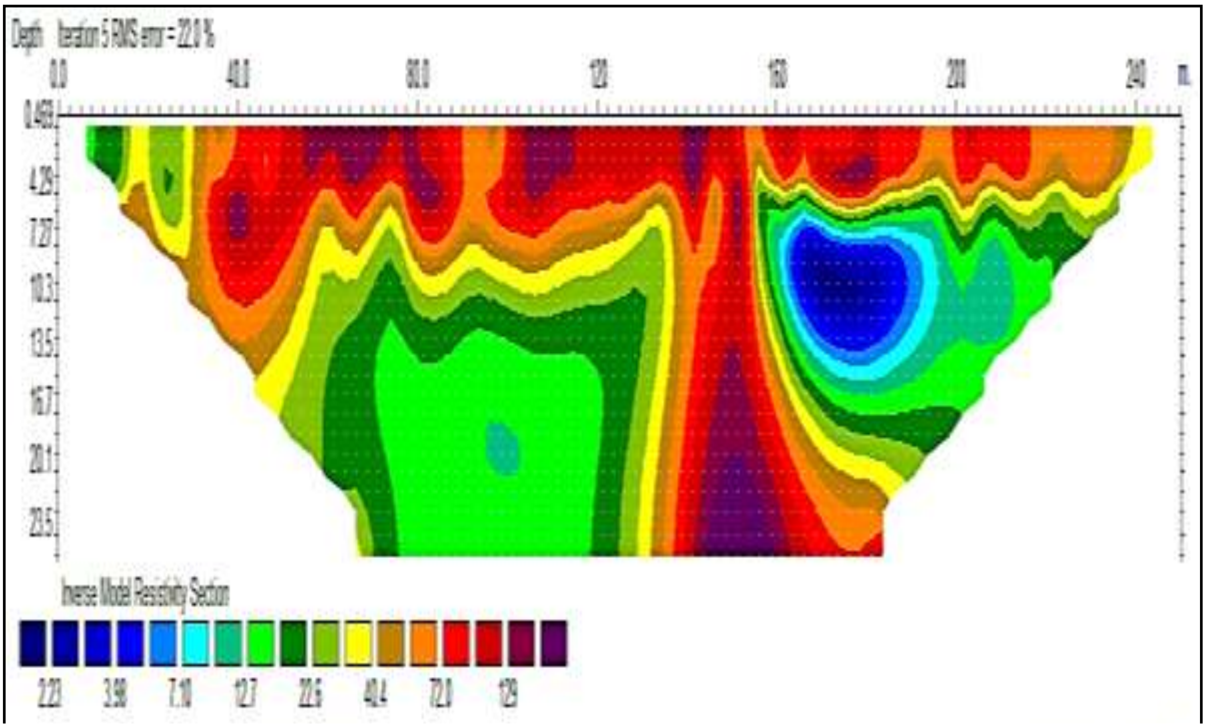

Fig. 3: 2D inverse resistivity model, measured pseudo-section, calculated pseudo-section

The results of the seismic refraction sections obtained at the Site are presented in Figure 4. 2D technique of seismic refraction in this location identified two (2) layers.The first layer's velocity is moderate, whereas the second layer's velocity is very high. The transition of the seismic energy between the first and the second layers was noticed to be sharp. This may be due to some pockets of geologic features in the second layer that gave rise to high velocity regimes. The first layer of p wave velocity varied between 373 and 554 m/s. The first layer of the secondary wave velocity varies between 219.41 and 325.88 m/s.The first layer from the top soil is between 7.0 and 7.6 meters deep.The principal wave velocity of the second layer, on the other hand, fluctuates between 588 and 2012 m/s.In addition, the first layer's secondary wave velocity varies between 345.88 and 1183.53 m/s.

The depth of the second layer was found to varybetween 10.3 m and 15.7 m. The low velocity observed in the first layer is interpretedas unsaturated and unconsolidated layer. The material beneath the first layer is thought to be a semi-consolidated to fully-consolidated layer. Other geotechnical parameters were estimated using the equations in [16]. The Poisson's ratio, σ was determined. For the first layer, the Poisson's ratio was in the range of $0.24 \pm 1.2 \times 10^{-5}$. The Poisson's ratio in the followed layer is within the range of $0.24 \pm 0.7 \times 10^{-5}$. The Poisson's ratio for the second layer is relatively lower than the first layer. As a result, the second layer is considered to be more competent than the first.This submission is consistent with [8] and [4], which showed that the second layer is more capable than the first. E, the Young's modulus, was also measured, and it was found to be larger in the second layer than in the first. The first layer's Young's modulus fell between 0.202 to 0.455 GPa. The second layer has a Young's modulus, which ranges between 0.514and 7.018GPa. The low value reported in the first layer could be due to the material's unconsolidated nature. A sharp increase was noted in the value of 'E' in the second layer when compared to the first layer. This may be that there is a layer that is similar in composition to the first layer, which could not be delineated by the software as a separate layer.

Also, the bulk modulus of the study area was determined. The bulk modulus of the topmost layer varied between 0.129 and 0.291GPa. Also, the bulk modulus for the second layer ranges between 0.330 and 4.499GPa. The second layer as relatively higher bulk modulus than the first layer. Thus, the second layer is more suitable than the first. The shear modulus μ, which also measures the level of strength/stiffness of the subsurface layers also showed an increment in values with depth. The μ for the first layer ranged from 0.081 to 0.147GPa. The μ of the second layer lied within 0.207 and 2.830GPa. The second layer is characterized by higher rigidity modulus than the first layer. Thus, the geologic formation of the first layer is less capable than the first.

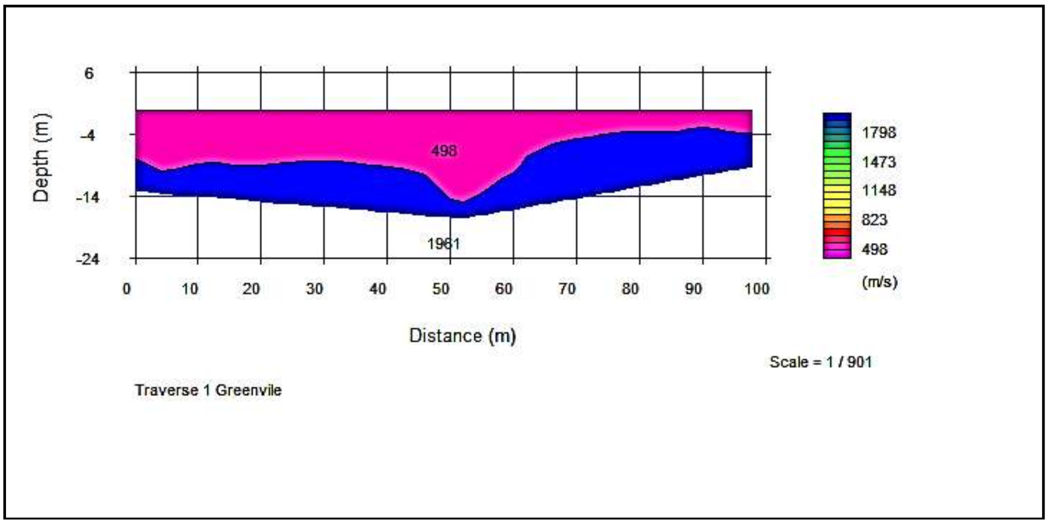

Fig. 4: 2D refraction sections, indicating the depth of investigation, their velocities and number of layers.

5. Conclusion

The result of the 2D profiles showed that the near surface consist of formation that is low in resistivity, which may imply the presence of saturation fluid. The second layer contained sandy clay, which occurred within 7 m and 16 m depth in the subsurface. It is obvious from the present study that it may not be advisable to site a foundation in this kind of geologic formation without any form of soil improvement measures, therefore pile foundation is recommended. This study further showed that a combination of non-invasive geophysical techniques could provide reliable results that could prevent the use of invasive approaches that harm the environment.

Acknowledgement
The authors would like to express their gratitude to Covenant University's administration for providing funding for this study.

References

[1] Ruckelshaus, W. D. (2016): United States Environmental Protection Agency, [accessed: 15/03/2016], www.epa.gov.

[2]Mohd, H. Z. A., Rosli, S., Fauziah, A., Devapriya, C.W. and Mohamed, F. T. B. (2012): Seismic refraction investigation in near surface landslides at the Kindasang area in Sabah, Malaysia. Sciverse Science Direct, Procedia Engineering, 50: 516-531.

[3] Adewoyin O.O., Joshua E.O., Akinyemi M.L., Omeje M., Adagunodo T.A. (2021). Evaluation of Geotechnical Parameters of Reclaimed Land from Near-surface Seismic Refraction Method. Heliyon, 7: e06765. https://doi.org/10.1016/j.heliyon.2021.e06765. U.K

[4] Adagunodo T.A. and Oladejo O.P. (2020). Geoelectrical Variations in Residential Area of Ojongbodu, Oyo, Southwestern Nigeria. Nature Environment and Pollution Technology, 19(4): 1771 – 1774.

[5] Laletsang, K., Modisi, M. P., Shenang, E. M., Moffat, L. and Moagi, O. R. (2007): Shallow seismic refraction and magnetic studies at lake Ngami, the Okavango Delta, northwest Botswana. Journal of African Earth Sciences 48: 95-99.

[6]Khalil, M. H. and Hanafy, S. M. (2008): Engineering applications of seismic refraction method; a field example at Wadi, Warden, Northeast Gulf Of Suez, Sinai, Egypt. Journal of Applied Geophysics, 65: 132-141.

[7] Osazuwa, I. B. and Chinedu, A. D. (2008): Seismic refraction tomography imaging of high permeability zones beneath an earthen dam, in Zaria area, Nigeria. Journal of Applied Geophysics, 66: 44-58.

[8] Muhammad, Y. K. (2013): Engineering geophysical study of unconsolidated topsoil using shallow seismic refraction and electrical resistivity techniques. Journal of Environment and Earth Science, 3(8): 120-128.

[9] Babacan, A. E., Gelisli, K., Ersoy, H. (2014): Seismic tomography and surface wave analysis based methodologies on evaluation of geotechnical properties of volcanic rocks: a case study. Journal of Earth Science, 25(2): 348-356.

[10] Oyedele, K. F. and Olorode, D. O. (2010): Site investigation of subsurface conditions using electrical resistivity method and cone penetration test at Medina estate, Gbagada, Lagos, Nigeria. World Applied Science Journal, **11**(9): 1097-1104.

[11] Olorode, D. O., Olatinsu, O. B., Ugwoke, U. U. (2012):Site investigation using a combination of electrical resistivity technique and CPT-a case study of a coastal area of Lagos, Nigeria.

[12] ABEM Instrument AB, (2006): Equipment Manual for ABEM Terammeter SAS 1000/4000.

[13] Loke, M. H. (2001): Electrical imaging surveys for environmental and engineering studies: a practical guide to 2D and 3D surveys. Available at http:// www.geoelectrical.com. [Accessed: 14/01/2013].

IOP Conf. Series: Earth and Environmental Science **993** (2022) 012018 doi:10.1088/1755-1315/993/1/012018

[14] ABEM Instrument AB, (1996): Equipment Manual for TERRALOC MK6 Software Version 2.21, Bromma, Sweden.

[15] SeisImager (2009): SeisImager/2D™ Manual version 3.3.

[16] Tezcan, S. S., Ozdemir, Z., Keceli, A. (2009): Seismic technique to determine the allowable bearing pressure for shallow foundations in soils and rocks. ActaGeophysica, 57(2): 400-412.