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Application of Dipole-Dipole Electrical Resistivity for Subsurface Probing Within Golf Club Centre of University of Benin Teaching Hospital, Benin City

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ABSTRACT

Imaging Electrical Resistivity in two Dimensions to determine and ascertain the degree of erosion threat at the profound University of Benin Learning/Teaching Hospital (UBTH) Golf Club in Ovia North-East Local (district) Government Area, Benin City, Edo State, Nigeria, survey profiles ranging in length from 150 to 170 meters were conducted for subsurface and sub-structural investigations. An electrode spacing (separation) of 10 m was employed. Utilizing the Abem SAS 1000 Terrameter (Resistivity Meter), a dipole-dipole array was utilized to acquire and collect field data. To established the 2-D real resistivity of the subsurface and substructure selected for display, the field data were subjected and processed deploying Dipro software. According to the findings, topsoil, lateritic sand, particle sand, and sandstone beneath the subsurface were visualized. Within the con depth range of 0 to 5 m, the 2D results unveil topsoil with described resistivity obtainable values ranging from 349 to 4555 Ωm. The second obtainable layer is assured of lateritic, sandy sand with mathematical resistivity values between 650 and 3365 Ωm down to 10.0 m. The resistivity values of the third stratum/layer, with displayed range from 568 to 8662 Ωm at a depth of 20 meters, indicate lateritic sand, sand, and sandstone. Lateritic sand, sandstone, and sandstone are found down to 35 meters in the fourth stratum. Sand and sandstone are represented by resistivity values in the fifth horizon, which range from 956 to 22573 Ωm. 50.0 m was the furthest depth that could be imaged. The 2-D resistivity picturing (imagery) indicates the presence of an aquiferous domain (zone) and the non existence of clay division (formation), given that the range of 1-150 ohm-meters distinctively associated and linked up with clay in the study area explained the best and most appropriate area for the construction of buildings. The inverted 2-D resistivity shape (structure) depicts intermediate resistivity observed distribution near-surface >340 Ωm, which are indications (evidences) of vulnerabilities to wearing and erosion in the study area.

Keywords:
Resistivity,
Lithology,
Dipole-Dipole Method,
Substructure.

INTRODUCTION

Assessing an area's appropriateness for building constructions, durable bridges, lasting dams, and other vital structures requires and carefully need subsurface research using geophysical techniques. Over the last 20 years precisely, a number of vital structures in Nigeria have collapsed while being built or soon after. It is well known that the failure to conduct suitable geophysical investigations to ascertain and describe the nature of the underlying structures is one of the pertinent reasons these expensive buildings collapse (Akpoyibo et al., 2023). The majority of these structures were constructed on soils that were not strong and robust enough to sustain their weight. An area's geology plays a crucial and essential role in determining whether it is suitable for the kind of construction that will be constructed there.

The expansive and shrikage clay found in near-surface soil may expand or contract in response to variations in moisture content (Sands, 2002; Akpoyibo et al., 2022; Eigbike and Eigbike, 2023). If the clay does not hydrate and dry evenly, the foundation may move and crack up. Common limitations to building projects, particularly and uniquely to their foundations, include subsurface geological features with voids, cracks, shallow bedrock depth, and the depth of the studied water table close to the surface. The geotechnical data needed and essential for the engineering design to improve (upgrade) the stability and strength of buildings or structures is provided and made available by the geophysical research. Electrical resistivity shaping (imaging) is gaining popularity as a tool for solving a wide range of hydrological, oil and gas, environmental, and geotechnical issues. Using electrical resistivity readings (measurements) taken at the surface or by electrodes in one or more drilled boreholes, the electrical resistivity method is a geophysical technique for visualizing subsurface structures. A two-dimensional (2-D) model in which the resistivity fluctuates both horizontally and vertically along the survey line is a more accurate (correct) representation of the subsurface. Under these circumstances, it is assumed that resistivity does not vary perpendicular or at right angle to the survey line. This is a reasonable and reliable assumption in many situations, especially for surveys conducted across and transversely extended geological bodies (Loke, 2001). However, 2-D surveys are now the best viable economic compromise method between maintaining cheap survey costs and obtaining extremely perfect and also complete results (Dahlin and Loke, 1997).

It is assumed that the resistivity of the 2D model is fixed and unmovable in the direction perpendicular to the survey line but varies laterally (horizontally) and vertically along the survey line. A reasonably realistic representation of the subsurface resistivity distribution is provided by the pseudo-section contouring, which is frequently used to depict and display the measured apparent numerical resistivity values (Figure 2-9). The distribution of the genuine near-surface resistivity and the configuration type employed and utilized in the study both affect the contours' shape. In order to identify inherent geological structures and hydro-geological changes, dipole-dipole (2D) models of subsurface electrical characteristics (features) distributions are created (Kuras et al., 2008; Okolie and Akpoyibo, 2012; Babaiwa and Airen, 2021; Esi et al., 2023). The technique has been shown to be a very useful tool for discovering, identifying anomalies and specifying the complexity of all the subsurface geology (Griffiths and Barker, 1993; Babaiwa and Airen, 2021; Esi and Akpoyibo, 2023). These days, 2D electrical resistivity figuring (shaping) is used to detect anomalies, fractures and cavities in the subsurface, as well as for geotechnical investigations for buildings, roads, bridges, and durable dams. It can also define archeological properties (features), locate surface utilities, and monitor pollution (plums) seepage through the earth's subsurface.

With the appropriate software for processing and analyzing the collected field data, the electrical resistivity method can be fully used to do 2D electrical resistivity imaging. A useful guide for a thorough and precise quantitative interpretation is the pseudo-section plot. The pseudo-section display makes it simple to unveil and identify observations with poor apparent resistivity. The Frechet derivative or sensitivity values for a homogeneous half-space serve as the foundation for the pseudo-depth values (Aizebeokhai, 2010; Babaiwa and Airen, 2021). According to Loke (2001), the main drawback of 2D geoelectrical resistivity representation is that data made with a wide electrode separation are frequently impacted by both structures farther horizontally from the line of survey and deeper near and sub-surface sections.

Electrical techniques using VES have been meticulously utilized to probe the subsurface for the aim and purpose of sitting wasteland fill (Alile et al., 2008; Eigbike and Eigbike, 2023) and to create subsurface geological maps in Edo state (Ezomo et al., 2009; Alile et al., 2008; Babaiwa and Airen, 2021; Esi and Akpoyibo, 2024; Vwavware et al., 2024; Akpoyibo et al., 2025). The subsurface geologic parameters and characteristics of the survey aquifer layers at Uhunmwode, Edo State, Nigeria, were examined by Aigbogun and Egbai (2012). They found that the earth layers in their study area range in thickness from 13.8 to 182.4 m, depth from 39 to 199 m, and resistivity from 114.5 to 18120 Ωm. Aigbogun et al. (2020) examined Auchi's subsurface lithology using electrical resistivity tomography. The values of subsurface resistivity varied and changes between 207 and 8357 Ωm. The subsurface lithology was categorized (grouped) as topsoil, clayey grained sand, sandy clay, and sand based on the survey's findings and 50 meters was the deepest that could be penetrated. In order to check out and examine the shallow subsurface electrical properties, Oladele et al. (2015) used 2-D with Wenner configuration on various five (5) profiles, each measuring 180 m. The purpose of their survey was to search and identify the potential cause or causes of the structural instability that caused some of the buildings in the study region to sink, crack, crumble and collapse. Their findings demonstrated that the damages were caused by the unusually low resistivity seen in the clayey components of the stratigraphic make-up. In order to find out and discover the depth of a potential aquiferous zone and to furnish geophysical and also geological data regarding the subsurface outlined structures of the study area, the basic goal of this research is to examine the subsurface precise structures of a sectional area of the prestigious Benin University, Teaching Hospital (Golf route Area).

MATERIALS AND METHODS

Survey Area Location and Geology: The UBTH Hospital Golf Club course's coordinates were latitude 06.390°N to 6.392°N and longitude 5.615°E to 5.622°E, where the geophysical survey took place (Figure 1). The Global Positioning System (GPS) was appropriately employed (used) to acquire these coordinates. Its highest point is 459 feet, and its lowest point is 383 feet. The region is located in the central regional part and section of Edo State, which has a sedimentary landscape with paleocene to modern sedimentary rocks beneath it. About 90% of the sedimentary rock is composed of intercalations of sandstone and shale (Eigbike & Eigbike, 2023). Because of her proximity to the oil reserves in the Niger-Delta region, it is a significant sedimentary basin in Nigeria. The coastal plain sands, often known as Benin sands, make up the geological setting.

According to Eigbike & Eigbike (2023), the Benin sands are partially lagoon, partially deltaic, and partially marine, all of which are signs of a shallow and shoal water environment for deposition. The formational division is composed of sandstone with describable local thin clays and also with shale interbeds that are thought to have originated from braided streams, and top reddish discoverable clayey sand that caps extremely porous fresh and uncontaminated water bearing loose pebbly granular sands. Nearly all of the formation is water-bearing, with investigated water levels ranging from roughly 20 to 52 meters. It is coated with loose brownish colour sand (quaternary drift), which varies in thickness with estimated roughly 799 meters thick (Kogbe, 1989). Prior to the Bende Ameki compositional Formation and the Imo clay-shale categorization, the study area's coastal plain sand was surrounded by mangrove swamps and alluvium (Eigbike & Eigbike, 2023). The rainy and dry seasons are the only two main climatic phases in Benin City's Ugbowo neighborhood. From April to October, there occur, a lot of rain, which is a typical sign of the wet season. This region receives more than 2000 mm of rain on average each year (Eigbike and Eigbike, 2023). During the rainy season, the temperature ranges comparatively from 19 to 28 degrees Celsius. Dry winds and bright sunshine are hallmarks of the dry season. The temperature may drop to 19°C in the morning and rise to 30°C in the afternoon.

Along the creeks and depressions in the area, there are a variety of shrub species and high forest plants that formed and make up the Guinea savannah's vegetation. Asseez (1989), Ofomola et al. (2017), Vwavware et al. (2024), Molua et al. (2024), and flora along the area's streams and depressions have all provided in-depth descriptions of the geology of Niger-Delta. Asseez (1989), Ofomola et al. (2017), Chukwunwike et al. (2024), Akpoyibo and Vwavware (2024), Molua et al. (2024), Ikegu et al. (2024) and Omajene et al. (2024) have all provided substantial and important descriptions of the geology of the oil bloom Niger-Delta.

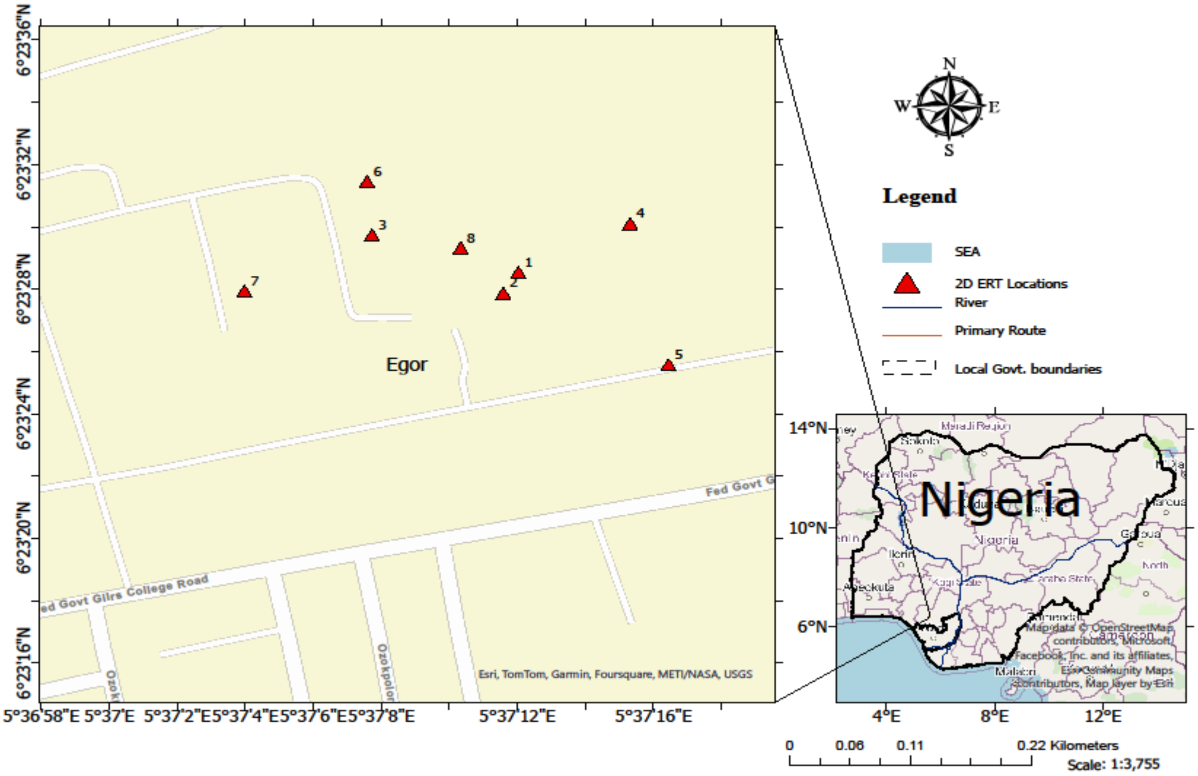

Figure 1: Base map of Golf study area displaying 2D locations

Method of Data Acquisition and Processing

By combining the methods of patterned electrical profiling and the unique vertical electrical sounding, two-dimensional (2D) electrical resistivity visualization utilizing a dipole-dipole (2-D) array was accomplished. It uses a variety of varied electrode spacing and midpoints to measure and calculate the apparent resistivity from electrodes arranged along a distant line. As many combination of current and pertinent potential electrode placements as specified by the survey absolute configuration are distinctly used to repeat and perform again the procedure. 2D resistivity imaging can be viewed as a mixture of sequential profiles with increasing (maximizing) electrode separation or as continuous vertical electrical sounding (CVES), where several VES performed in a grid are combined. Many electrodes coupled to multi-core cables are typically used to conduct two-dimensional (2D) resistivity studies. Many electrodes coupled to multi-core cables are distinctively and typically used to conduct two-dimensional (2D) resistivity studies. The roll-along technique can be utilized to extend the survey's coverage area along the survey line for a system with a restricted and given number/count of electrodes (Babaiwa and Airen, 2021). After finishing a series of measurements, this can be accomplished by moving forward or advancing the wires after one end of the line by numerous and several units of stretching electrode spacing. Terrameter, a resistivity meter powered by an external battery, is exploited in the 2D electrical resistivity study.

A Global Positioning System (GPS) is practically applied to determine the direction of the study region. As shown in Figure 1, a total of eight (8) 2D crosses were produced using the dipole-dipole exhibit arrangement in a square grid pattern. For each current infusion, multiple information focuses can be captured simultaneously since this cathode setup was suitable and adapted for stable division information collecting. To determine the horizontal (lateral) and depth differences in the ground's apparent resistivity, a 2-D imaging study using the 2-dipole pattern (array). Four electrodes; C_1, C_2, P_1, and P_2 were used to transmit (propagate) currents to the surface of the earth. Next, the possible variations in sensitivity between the possible electrodes were investigated. The range of investigated values for the expansion factor, n, was 1 to 4 and 1 to 5 and the preferred configuration was the dipole-dipole. The 2-Dipole arrangement was adequately chosen above the other configurations because to its greater horizontal data coverage and strong sensitivity to horizontal resistivity variations. The electrodes were set up with a consistent 10-meter gap. For the quantitative processing of the Double Dipole data, the apparent resistivity output (data) was 2-D inverted using the Dipro for Windows (2001) program. Using the Dipro for Windows (2001) program, the apparent resistivity data was 2-D inverted in order to perform a quantitative interpretation of the Dipole Dipole data. Eight (8) dipole dipole lateral lines encompassing that ranged in length from 150 to 170 meters made up the study regions. Double-dipole resistivity examined data were firstly obtained using the ABEM Terrameter SAS 1000 and to further invert the received apparent resistivity figures (values) and convert them into 2-D resistivity stable framework results, the Dipro software package has been used with Windows (2000).

RESULTS AND DISCUSSION

The Teaching Hospital's in the federal University of Benin (Golf track) electrical resistivity images of the beneath earth's surface (subsurface) are displayed as 2D resistivity structures in Figs. 2–9 and are provided in color-coded shapes. The image's vertical scale denotes depth, and its horizontal scale represents lateral distance and both are expressed in meters. Investigations were executed (conducted) with a maximum span of 170 m and a matching depth of 50 m. By decreasing the discrepancy between the estimated and observed pseudo sections of the obtainable apparent resistivity data sets, the Diprofwin optimization technique produced the resistivity models that are made visible. Sections with resistivity displayed values of ranged absolutely from 349 Ωm to 22573 Ωm are unveiled in the produced resistivity structure. A reliable sign of a dry sand landscape is a rising resistivity value with depth. Topsoil, acquired lateritic sand, dry sand, also medium sand, particle coarse sand, and sandstone are all indicated by the six resistivity structures that have been identified. Due to the high resistivity values in the study area, the high near-surface resistivity quantifiable values of the resistivity structures are indicative (revealing) of dry and unconsolidated geologic earth materials that are highly erodible (fret) and capable of withstanding engineering structures (durable roads, storey buildings) (Babaiwa and Airen, 2021). Because the sandstone is compacted and localized, erosion may not occur. The lateral and vertical (in depth) subsurface information with different resistivity arrangement values has been adequately and successfully revealed using 2D resistivity tomography. According to the 2D measurements, topsoil has resistivity describable values between 349 and 4555 Ωm with depth pattern ranging from 0 to 4.9 m. Since there is no evidence of clay formation even in the topsoil, the observed values at the topsoil are moderate, and this type of surface course is advised for building construction. With resistivity formation values patterns ranging from 650 to 3365 Ωm and depths varying from 5.0 to 10.1 m, the second layer on all 2D resistivity structures represents medium and coarse sand as well as sandy lateritic sand. The resistivity values of the third geoelectric layer, which correspond to the 2D results showing lateritic red sand, sand, and sandstone layer, range from 568.1 to 8662 Ωm within the depth range of 10.0 to 19.9 m. Because of the observable high resistivity values over the third strata within a depth of 20 m, the base course may therefore support deep building foundation without endangering the structure. Lateritic sand, huge sand, and sandstone ascertain with resistivity values between 888 and 15360 Ωm and a depth range of 20.0 to 34.8 m are shown by the fourth subsequent geoelectric layer. Sand and sandstone are represented by resistivity values in the fifth horizon, which range from 956 to 22573 Ωm. Since sandstones are found in cluster resistivity structures throughout the majority of the study region and given that sandstones are found almost everywhere in the examined area and that there is no clay deposits formed in any of the golf club course areas, as reflected by the 2D structures image revealed in fig. 2-9, it can be concluded that the study area cannot experience engineering structures failure without any concern (threat) in the future. Additionally, it was established and inferred that deeper depths were scanned with higher resistivity values.

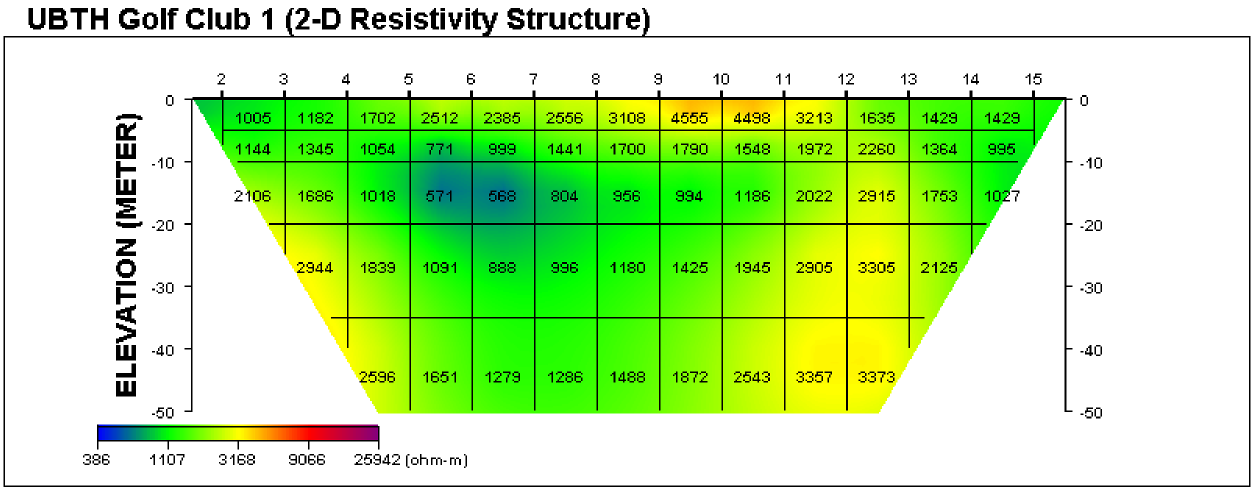

Figure 2: 2D electrical resistivity image along UBTH Golf Club 1

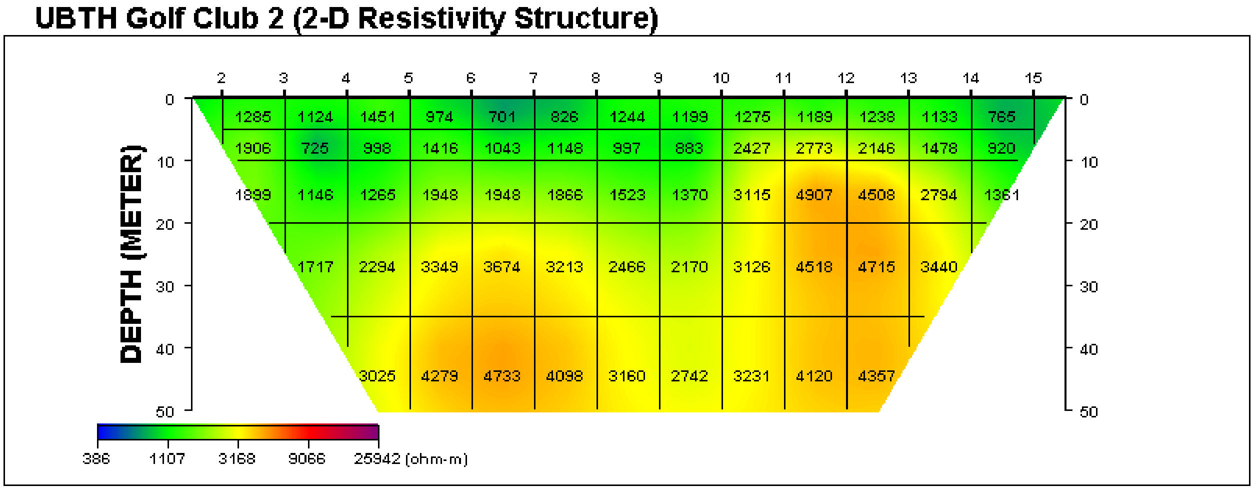

Figure 3: 2D electrical pictured resistivity shape along UBTH Golf Club 2

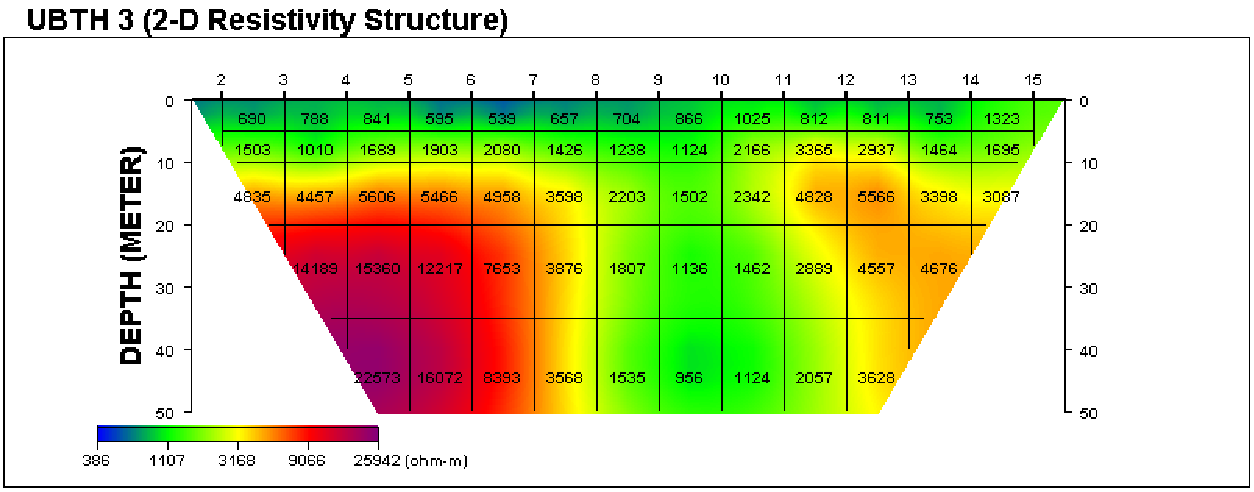

Figure 4: 2-D electrical resistivity observable pattern along UBTH Golf Club 3

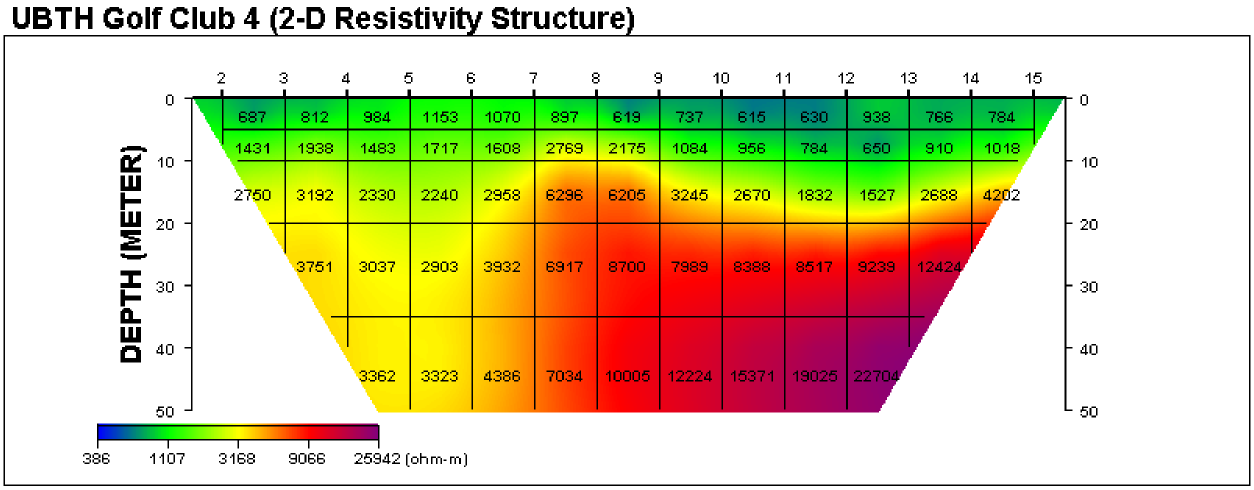

Figure 5: 2-D electrical inverted resistivity formative pattern along UBTH Golf Club 4

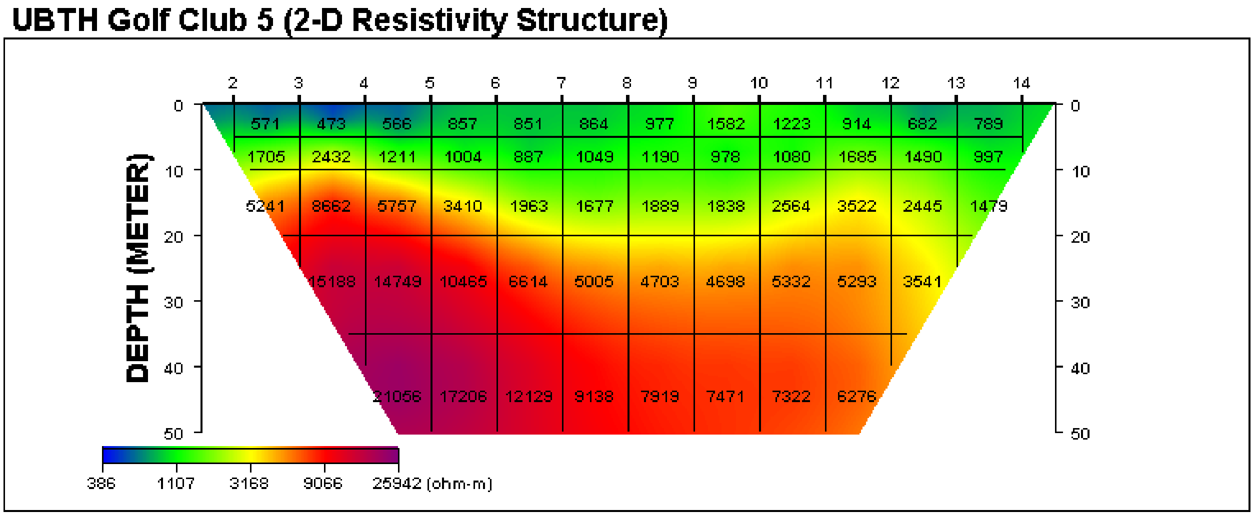

Figure 6: 2D electrical actual resistivity array along UBTH Golf Club 5

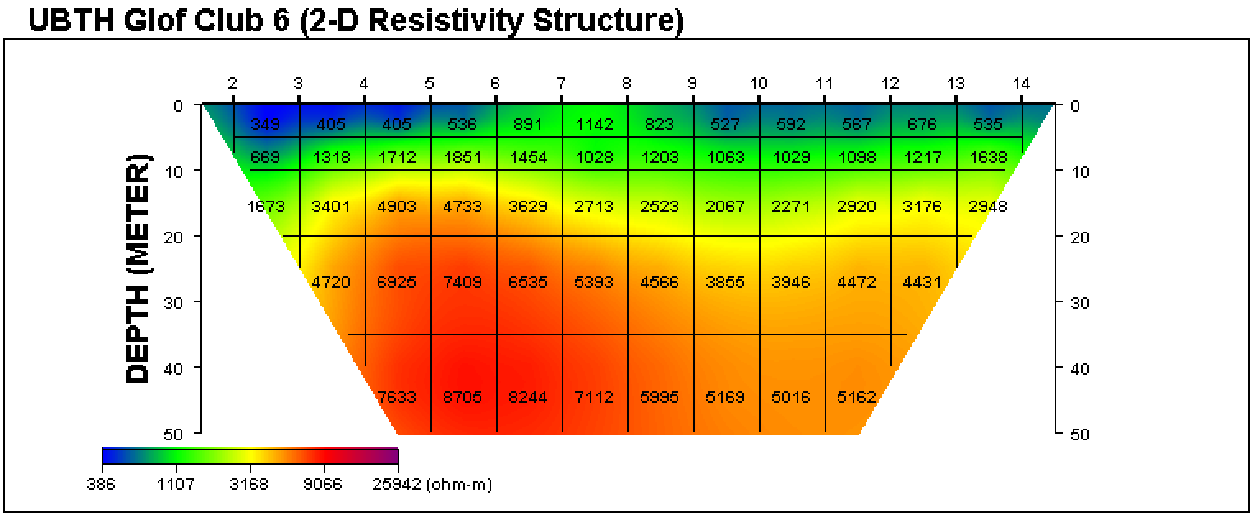
UBTH Glof Club 6 (2-D Resistivity Structure)

Figure 7: UBTH Golf Club 6's 2D electrical resistivity section

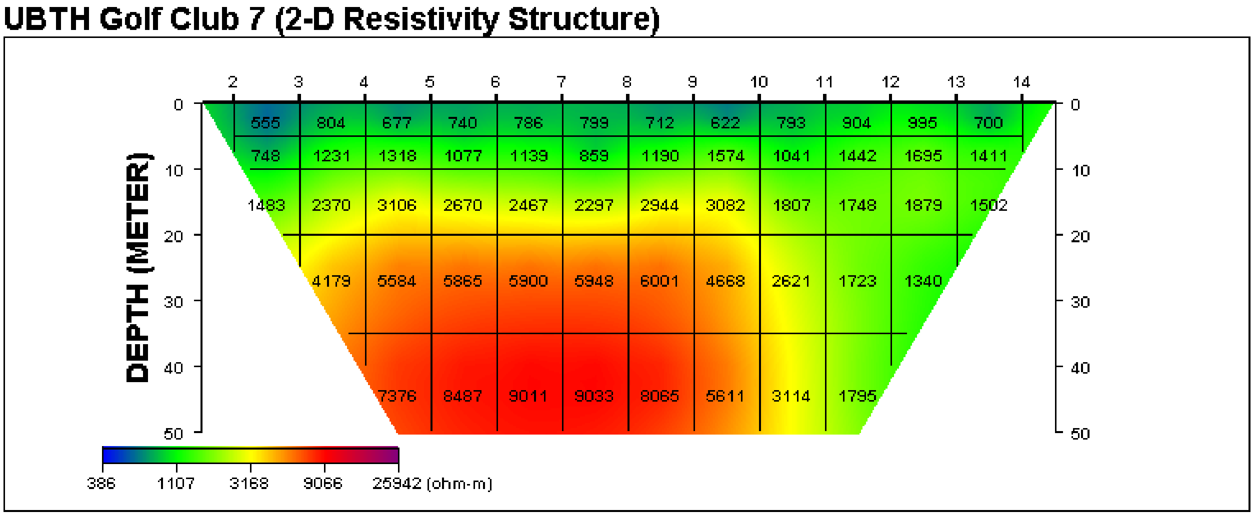
UBTH Golf Club 7 (2-D Resistivity Structure)

Figure 8: Section of 2D electrical resistivity along UBTH Golf Club 7

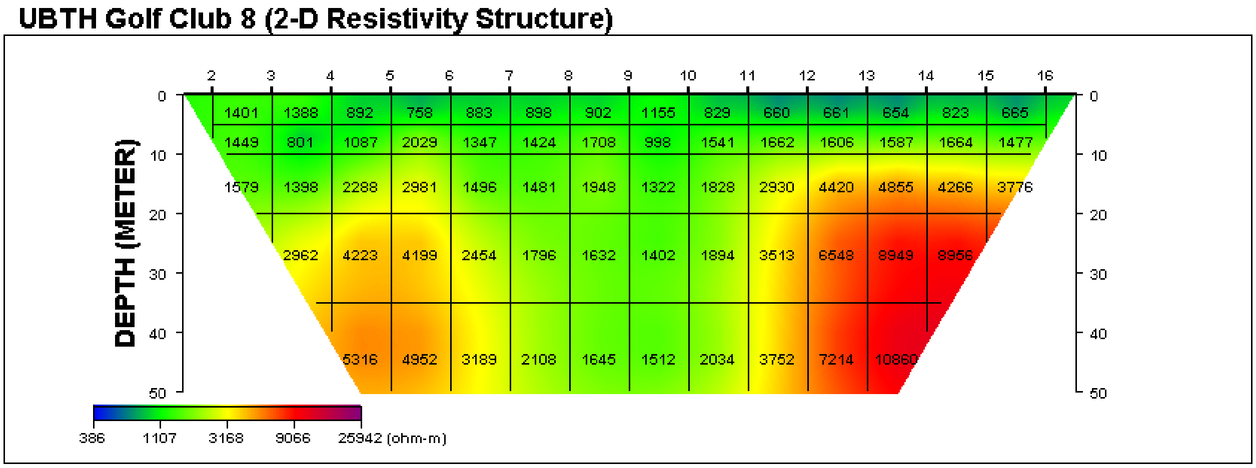
UBTH Golf Club 8 (2-D Resistivity Structure)

Figure 9: 2D electrical resistivity composition along UBTH Golf Club 8

CONCLUSION

The substructures at the UBTH golf course have been successfully examined applying 2D electrical probing technique in order to identify and distinguished any geological behavior that could potentially pose a scourge (threat) to the Golf buildings' lives and property. The area's surface and subsurface lithology are principally composed of viewable top soil, lateritic sand, sand (dry and silty sand), and sandstone, according to the results of the interpretation of the 2-D structures of the area. The 2-D images (Fig. 2-9) did not indicate the presence (possession) of clay divisions of any range of 1-150 ohm meter that are commonly associated and connected with clay. With a resistivity imaged range of 385.5 to 25942.6 ohm-meters throughout the examined region, the land is equal to supporting engineered huge projects like roads and buildings, and would not present any significant dangers. Thus, 2-Dimensional Survey ought to be done as a reconnaissance, exploration and probing tool for oil and gas, hydro-geological, engineering site (sand quantification), and environmental studies in regional geophysical surveys. The investigation demonstrated that the high growing resistivity values viewable at the near and subsurface are probably to generate erosion with strong scouring. In order for those in charge to use the vital information to take immediate and swift action to stop or nip this threat in the bud, a good civil engineering drainage system should be built, managed to stop erosion from developing in the study area. This study has established that the dipole-dipole method can be adequately (sufficiently) used to identify subsurface formations and area that are prone (vulnerable) to erosion.

REFERENCES

Aigbogun, C. O. and Egbai, J. C. (2012): Geophysical investigation of the aquiferous layers, in Uhunmwode local government area, Edo State, Nigeria. Advance in Applied Science Research, 3 (2):625-633.

Aigbogun, C.O; Babaiwa, D.A and Mujakperuo, B.J.O (2020): Application of 2-Dimensional Tomography to Investigate Subsurface Lithology in Auchi Polytechnic, Auchi, Edo State. Nig. J. Tech., 39(3):925–931.

Aizebeokhai, AP (2010). 2D and 3D Geological Resistivity Imaging: Theory and Field Design. Sci. Res. and Essays, 5 (23): 3592 – 3605.

Akpoyibo O., Abriku, E. O., Ugbe, F. C., Anomohanran O. (2025): Geophysical and geotechnical assessment of Obiaruku-Agbor road failure in Western Niger-Delta, Nigeria, Journal of the Nigerian Society of Physical Sciences, 7 (1) 2328:1-9. https://doi.org/10.46481/jnsps.2025.2328

Akpoyibo, O. , Anomohanran, O. and Ossai, C. (2022): Application of 2-D Imaging Survey for Ascertaining The Cause(s) of Road Failures Along Sapele/Agbor Road In Delta State, Nigeria, Scientia Africana, 21(3): 215-232. DOI: https://dx.doi.org/10.4314/sa.v21i3.17

Akpoyibo, O. and Vwavware, O. J. (2024): Assessing the Impact of Gas Flaring Activities in Ebedei, Southern Nigeria. Nigerian Journal of Physics (NJP), 33(2):137-145. https://doi.org/10.62292/njp.v33i2.2024.247

Akpoyibo, O., Abriku, O.E., Ugbe, F. C. and Anomohanran, O. (2023): Engineering assessment of Lateritic soils of Obiaruku highway sections in South-southern, Nigeria. Nigerian Journal of Theoretical and Environmental Physics (NJTEP), 1(1): 72-79. https://doi.org/10.62292/njtep.v1i1.2023.16

Alile, O; Amadasun, CVO and Evbuomwan, AI (2008): Application of vertical electrical sounding method to decipher the existing subsurface stratification and groundwater occurrence status in a location in Edo North of Nigeria. Inter. J. Phys. Sci., 3(10): 245-249.

Asseez, O.L (1989) Review of the stratigraphy, sedimentation and structure of the Niger Delta. In: Kogbe (ed) Geology of Nigeria, Rock View (Nig.) Ltd., Jos, Pp 311–324.

Babaiwa, D.A and Airen, O.J. (2021): Electrical Resistivity Tomography (ERT) for the Investigation of Erosion site in Oredide Village, Auchi in Etsako West LGA of Edo State, Southern Nigeria. Journal of Applied Science and Environmental Management, 25 (5) 887-891.

Barker, R.D. (1997): Electrical imaging and its application in engineering investigations. Pp. 37-44, in McCann, D.M., Eddleston, M., Fenning, P.J., and Reeves, G.M., (Editors), Modern Geophysics in Engineering Geology. The Geological Society, London.

Chukwunwike O., Akpoyibo O., Vwavware O. J. and Ogholaja R.E (2024): Soil Exploration and groundwater prospect in Etua, Delta State Nigeria. Standard Scientific Research and Essays, 12(7):196-202. DOI:1015413/ssre.2024.0179. ISSN: 2310-7502

Dahlin T;Loke, MH (1997): Quasi-3D resistivity imaging-mapping of three-Dimensional structures using two-dimensional DC resistivity techniques. Proceedings of the 3rd Meeting of the Environ. Eng. Geophy. Soc., pp. 143-146. DOI: https://dx.doi.org/10.4314/jasem.v25i5.31

Eigbike, R.T. and Eigbike, O.C. (2023): Application of 2-Dimensional Electrical Resistivity Tomography for Substructural Investigations within the University of Benin Teaching Hospital, Benin City. International Journal of Science Academic Research, 4(7): 5861-586. https://www.researchgate.net/publication/377890263

Esi, E. O. and Akpoyibo, O. (2023): Estimation of aquifer transmissivity for typical oil producing communities of western Niger Delta using electrical resistivity survey. COAST, Journal of the School of Science, 5 (2): 893 – 908. https://doi.org/10.61281/coastjss.v5i2.2

Esi, E.O., Akpoyibo, O., Nwankwo, R. C. and Vwavware, J.O. (2023): Estimation of the variability of sand deposits in chosen communities in parts of Niger delta, Southern-Nigeria using geophysical techniques. Solid Earth Sciences, 8:267–282. DOI: https://doi.org/10.1016/j.sesci.2023.10.001

Esi, O.E. and Akpoyibo, O. (2024): Geophysical Survey and Radiometric Assessment of Aquifer Strata and Vulnerable Groundwater Quality of Ukwuani Communities in Delta State. Scientia Africana, 23(2):88-103. DOI: https://dx.doi.org/10.4314/sa.v23i2.9

Ezomo, F.O (2009): Master of Science degree Exploration Geophysics Lectures Note on Electrical and Electromagnetic Methods. Physics Department, University of Benin, Benin City, Nigeria.

Griffiths, D.H. and Barker, R.D. (1993): Two-dimensional resistivity imaging and modeling in areas of complex geology. Journal of Applied Geophysics, 29: 11-226.

Ikegu, O., Esi, E.O.., Olomukoro, J.O and Akpoyibo, O. (2024): Assessment of Physicochemical Parameters and Heavy Metals in Okpare Creek Drinking Waters, Delta State, Nigeria Academy Journal of Science and Engineering (AJSE), 18(1): 60-78. https://ajse.academyjsekad.edu.ng/index.php/new-ajse/article/view/349

Loke, M. H. (2001). Electrical Imaging Surveys for Environmental and Engineering Studies A Practical Guide to 2D and 3D Surveys. www.geoelectrical.com p. 62.

Molua, O.C., Ogholaja, E.R., Akpoyibo, O. (2024): Identification of Groundwater-Dependent Wetlands Physical and Hydrological Characteristics and Ecosystem Relationship in Nun River, Niger Delta Region, Nigeria J. Appl. Sci. Environ. Manage., 28 (8): 2333-2340. https://dx.doi.org/10.4314/jasem.v28i8.9

Ofomola, M.O, Umayah, O.S. and Akpoyibo, O. (2017): Contamination Assessment of Dumpsites in Ughelli, Nigeria using the Leachate Pollution Index method. Journal of Applied Science and Environmental Management, 21(1): 77-84. http://dx.doi.org/10.4314/jasem.v21i1.8

Okolie, E.C. and Akpoyibo, O. (2012): Investigation of subsurface lithology and prolific aquifer using VES in Edjekota, Delta State, Nigeria. International Journal of Research and Reviews in Applied Sciences, 12(3): 468 – 476. https://www.researchgate.net/publication/266165735

Oladele, S., Oyedele, K.F and Dinyo, M.O. (2015): Pre-construction geoelectrical and geotechnical assessment of an engineering site at Alapere/Agboyi, Lagos, Nigeria. Ife J. Sci., 17(3):543-552.

Omajene, A., Egbai, J.C. and Okolie, E.C. (2024): Investigation of Saltwater Intrusion into Freshwater Aquifers in Some Estuary Environment in Niger Delta. Journal of Water Resources and Ocean Science, 13(4):94-104. http://dx.doi.org/10.11648/j.wros.20241304.11

Sands TB (2002). Building stability and tree growth in swelling London clay – implication for pile foundation design. www.agu.org.

Vwavware, O. J.; Ojobeagu, O. A.; Akpoyibo, O. and Omoyibo, S. E. (2024): Climate Change and Crop Adaptation: Geophysical Data on Soil Moisture Changes and Agricultural Strategies. International Journal of Agriculture and Animal Production, 4(2):1-13. https://doi.org/10.55529/ijaap.42.1.13

Vwavware, O.J, Akpoyibo, O., Ojobeagu, O.A. and Omoyibo, S.E (2024): Assessment of Groundwater Resource Potential and Long-Term Sustainability in Abavo Agricultural Farmland through Geophysical Techniques. International Journal of Agriculture and Animal Production, 4(5):40-50. https://doi.org/10.55529/ijaap.45.40.50