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Application of 2D and 3D Geoelectrical Imaging for Site Investigation at a Proposed Hotel Building Site in Benin

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Abstract

At the planned location of a four-star hotel project in Benin City, Edo State, geophysical investigations using 2D and 3D electrical resistivity imaging techniques were conducted to study the nature of the subsurface structure and assess its Suitability for the superstructure building. Finding the depth of the bedrock and any potential faults, fractures, voids, or clay that can endanger the structures that were supposed to be built are the primary goals. Using the Wenner arrangement, ten (10) high-resolution 2D electrical resistivity pictures were obtained, with minimum electrode separation of 5m and profile separations of 10m. The 200m constant profile length for each line was covered using the roll-along technique. The collated resistivity data was processed and inverted using the RES2DINV software. The 3D Imaging was gotten by combining and inverting the 2D resistivity data. A profile length of 200m was achieved from each profile and a depth of 39.6m was probed. The surveyed are showed suspected accumulation of laterite, clayey soil at the top soil with resistivity ranging from 120ohmm to 250ohmm, and a highly compacted middle layer which extends to the base of the surveyed site suspected to be compacted laterite, sandstones and ferruginized soils. The study area was confirmed to be suitable for the proposed hotel as no fractures, voids and accumulation of clay materials were found.

1. Introduction

It is common knowledge that subsurface studies utilizing geophysical methods are crucial for determining if a site is suitable for the development of structures such as bridges, dams, and buildings. Over the past three decades, Nigeria has seen a large increase in the construction of high rise buildings. Reports of collapsing structures have also been made throughout the nation. It is well known that the majority of these structures were built without first undergoing geophysical studies to ascertain the type of subsurface that exist at the area.

A building's ability to be constructed depends critically on the site's geology. Majority of buildings are built on land with insufficient bearing capacity. to sustain the structure's weight. Additionally, expansive clays that shrink or enlarge in response to changes in moisture content may be present in the near-surface soils. Inconsistencies in the wetting and drying of the clay might cause movement in the foundation. Building structures, particularly their foundations, are hindered by subsurface geological characteristics such voids, cracks, and the proximity of the water table to the surface or the depth to bedrock.

As a helpful tool for comprehending the subsurface structure, the geoelectrical approach is gaining popularity. It is particularly beneficial for identifying anomalies and defining the complexity of the subsurface geology [1-3]. Recently, there has been a lot of interest in the electrical resistivity tomography (ERT) approach [4-7]. According to [3], it is affordable and provides a high spatial resolution with a comparatively short field data gathering time. Subsurface geology in environmental and engineering studies is often finely heterogeneous and multidimensional, so lateral and vertical variations in subsurface properties can be very rapid and irregular [8].

Areas with fairly complicated geology have been studied using 2D geoelectrical resistivity imaging, where it is believed that the surface varies laterally and vertically down the profile but remains constant across [4], [9]). [10,11]. Subsurface characteristics, however, are effectively three-dimensional, and the two-dimensional assumption is typically broken for such a heterogeneous surface. In 2D inversion models, this violation frequently leads to out-of-plane resistivity, which can be deceptive for interpreting subsurface features [12,13]. Therefore, more accurate and trustworthy surface resistivity models should be produced using a 3D geoelectric resistivity image that permits fluctuation in all directions, particularly in very heterogeneous circumstances.

2. Methodology

2.1 Geology of the Area

The study area is located in Nigeria's Niger Delta Basin. The area is between 5^{o}35'48.55’’ to 5^{o}35'49.48" in the East and 6^{o}27'21.73’’ to (6^{o}27'25.48’’) in the North. Benin City, which is underlain by sedimentary formation of the South Sedimentary Basin. The geology is generally marked by top reddish earth, composed of ferruginized or literalized clay sand. It is the youngest of the Niger delta basin assigned to the Oligocene-Pleistocene period in the continent of Africa and to the Oligocene-Pleistocene recent at the sub-oceanic [14] [15] . The formation is characterized by top reddish to reddish brown lateritic massive fairly indurate clay and sand. This is often marked with reticulate muderacks. This caps the underlying more friable pinkish-yellowish white often gravelly-pebble sands clayey soils, sands and clay [16] .

The sedimentary sequences are poorly bedded with discontinuous clay horizons at various depths. It is estimated to be about 800m thick under Benin City and about 1,830m near the sea shore sections of the formation. They are exposed at various erosion sites, sand quarry sites, and road cuttings. The Benin formation covers 95% of the region. [14] described the thick continental sands that make up the Benin formation. It stretches southward past the current coastline and from the west across the entire Niger-Delta region.

Figure 1: Map of Edo State Showing the Location of Study

Figure 2: Location map of the study area with electrical resistivity imaging

2.2 Theory and Methods

The purpose of the resistivity survey was to evaluate the site's potential for the construction of large structures. The ABEM Terrameter SAS 4000 was utilized to measure the apparent resistivity (ρa). This instrument is equipped to conduct sounding, SP, IP, and resistivity profiling surveys. In order to detect the potential difference between the two potential electrodes and apply Ohm's law, the resistivity method makes use of two current electrodes that inject current into the ground.

$$V = IR \qquad (1)$$

Where V= Voltage, I = Current and R is the resistance

After calculating the resistance, the apparent resistivity was determined by multiplying the resistance by a geometric factor K that depends on the array. When comparing a Schlumberger array and a gradient array at the same place, the latter would display a different apparent resistivity model. Consequently, the following equation can be used to represent the apparent resistivity:

$$\rho a = 2\pi \, (\Delta V/I) * (1/G) \qquad 2$$

where G is the geometric factor, which varies from array to array and is defined as the spacing between the current and potential electrodes (m), ρa is the apparent resistivity measured in (Ω*m), and ΔV/I is the change in potential difference over current [17]. The electrode selector evaluates the apparent resistivity between two pairs of electrodes—two current and two potential—by automatically selecting them each time. Before the measurement begins, the electrode separation is continuously increased in accordance with the instrument's instructions. Using this technique, the device uses the identical a-spacing and n-factors for a Wenner array to produce a depth profile at the electrodes' midway. Two electrode cables, each 48 meters long and with an electrode taken every 5 meters, were used to set up the profile lines, totaling 40 meters in length. The primary display unit is connected to the electrode selector (Automated ES 46-10C) via the two electrode connections.

An external automobile battery (14V, 900Ah) powers the main device, enabling a wide range of measuring requirements. The profile lines were set up using stainless steel electrodes, which help to dampen noise around the electrodes. The electrodes were buried between two and three meters into the ground to provide a low possibility of noise caused by the electrodes. In order to guarantee correct contact between the electrodes and the ground, water the region adjacent to the electrodes. With crocodile clippers, the electrodes were attached to the cable takeout. The instrument's and the clippers' connectors were routinely cleaned of dirt and oxide to ensure long-term instrument functionality, as this could compromise the accuracy of the measurements. Since the inversion program would not recognize the DC resistivity values that were acquired in the field in the *.s4k format, a software called Erigraph was used to convert the data from the *.xyz format into the *.dat format.

The Data was then Loaded into the RES2DINV software a programme used to process and invert resistivity data into geologic model. the RES2DINV program was also used to merge the 2D pseudo-sections data files into a 3D data file, which was then inverted using the RES3DINV programme to view the model in 3D format. For the same reasons, the 3D inversion was also performed using the smoothness-constrained least-squares inversion. The Wenner array's 3D inversion sensitivity was taken into consideration when selecting the 5m spacing between profiles.

3. Results and Discussions

PROFILE 1

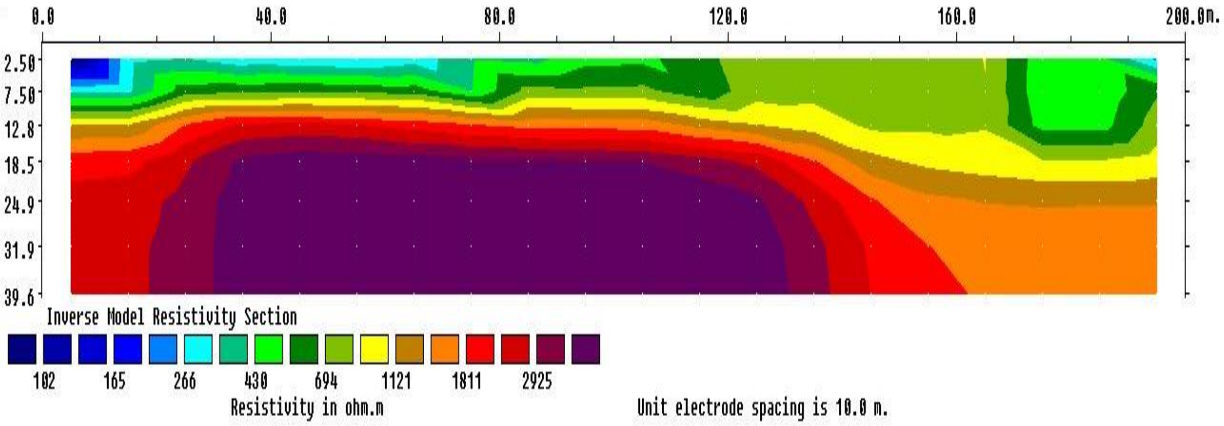

Figure 3: Inverse 2D Model Resistivity section along Profile 1

PROFILE 2

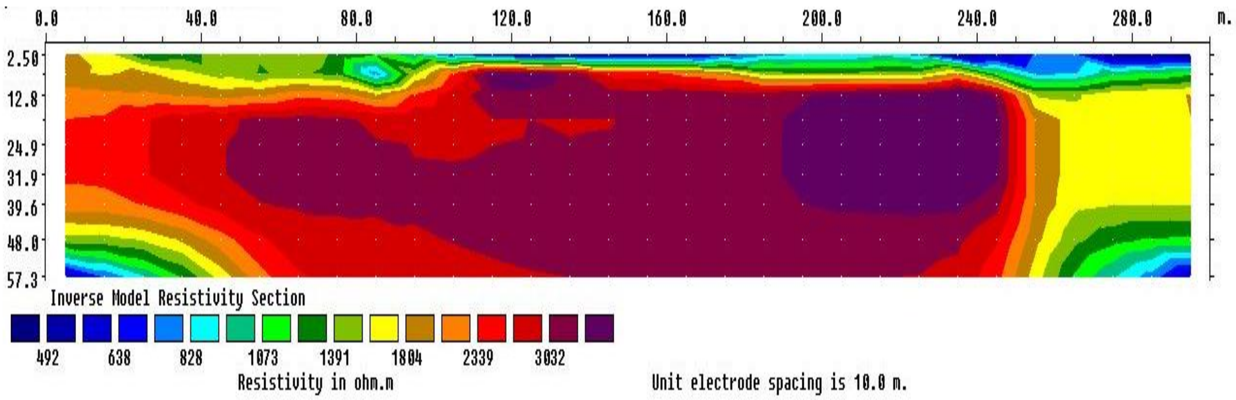

Figure 4: Inverse 2D Model Resistivity section along Profile 2

PROFILE 3

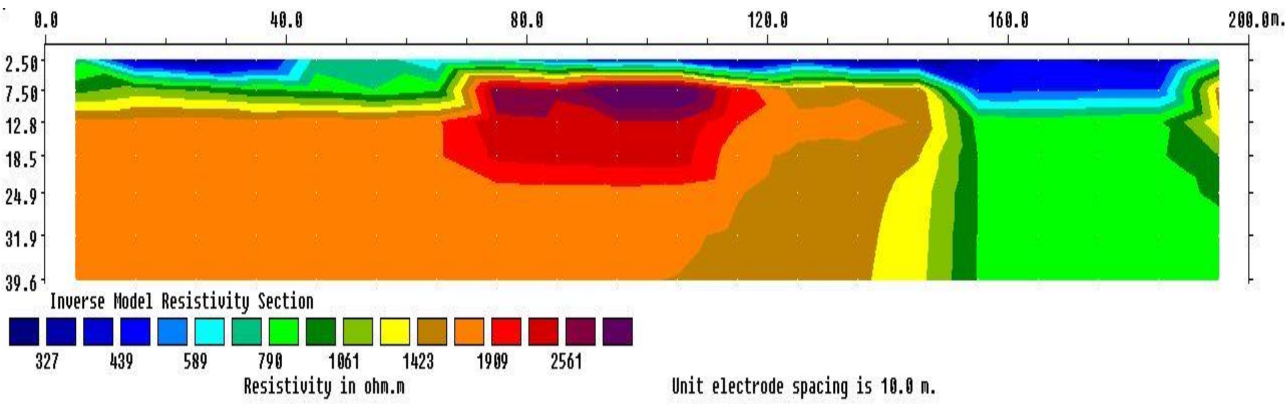

Figure 5: Inverse 2D Model Resistivity section along Profile 3

PROFILE 4

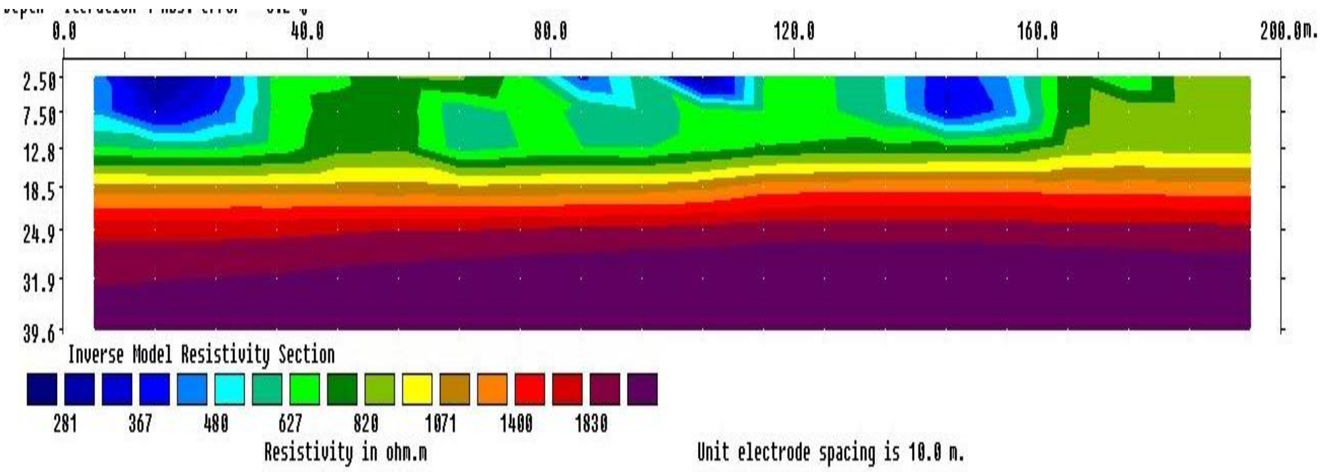

Figure 6: Inverse 2D Model Resistivity section along Profile 4

PROFILE 5

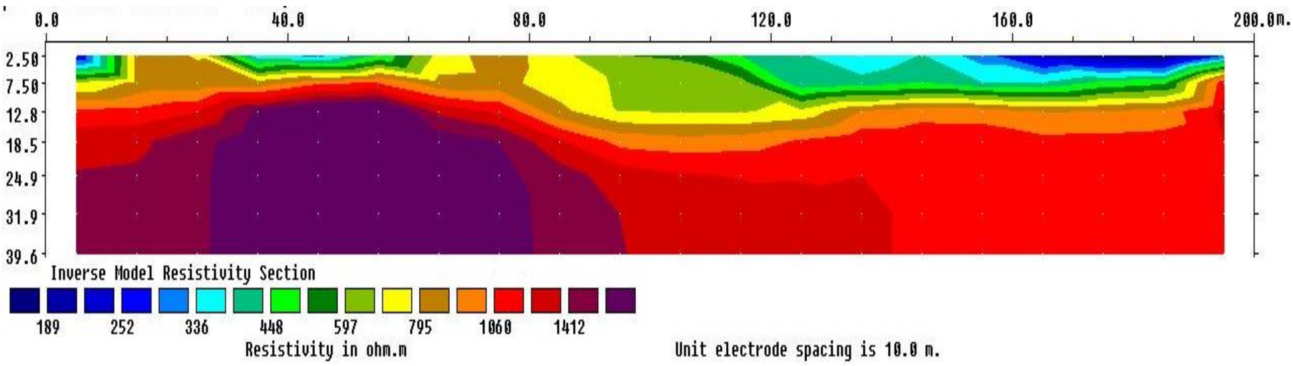

Figure 7: Inverse 2D Model Resistivity section along Profile 5

PROFILE 6

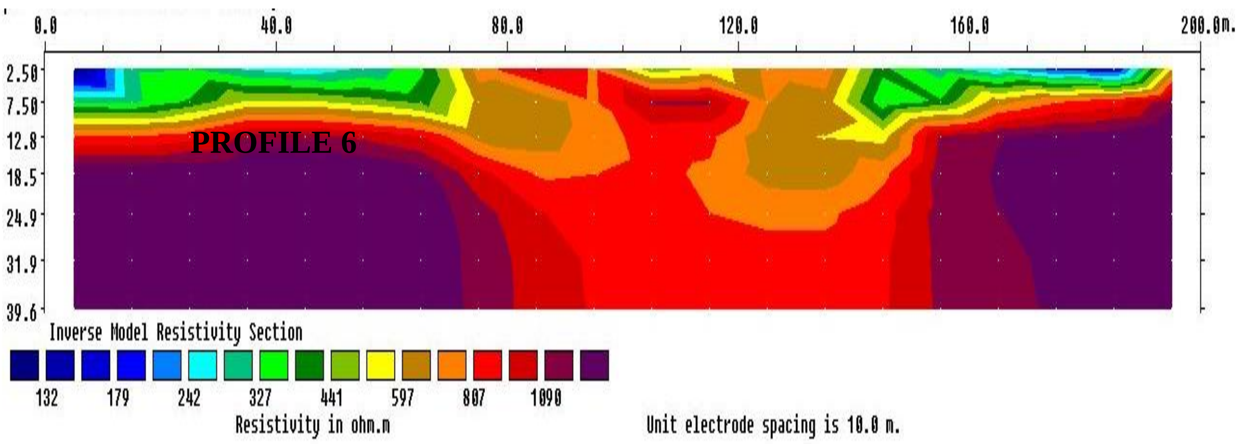

Figure 8: Inverse 2D Model Resistivity section along Profile 6

PROFILE 7

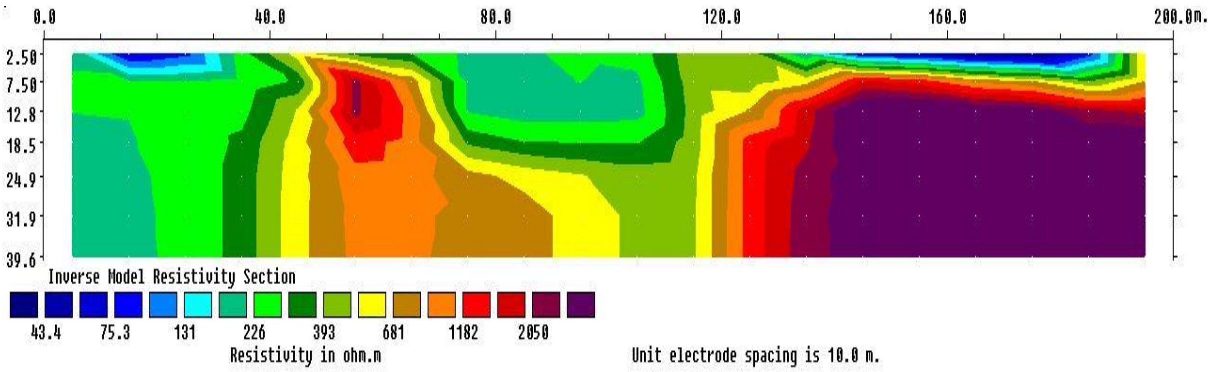

Figure 9: Inverse 2D Model Resistivity section along Profile 7

PROFILE 8

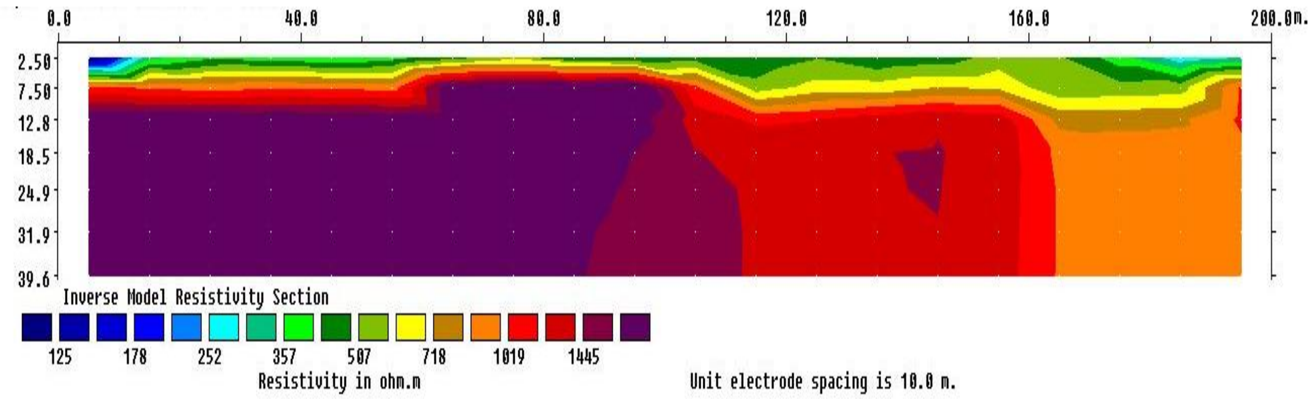

Figure 10: Inverse 2D Model Resistivity section along Profile 8

PROFILE 9

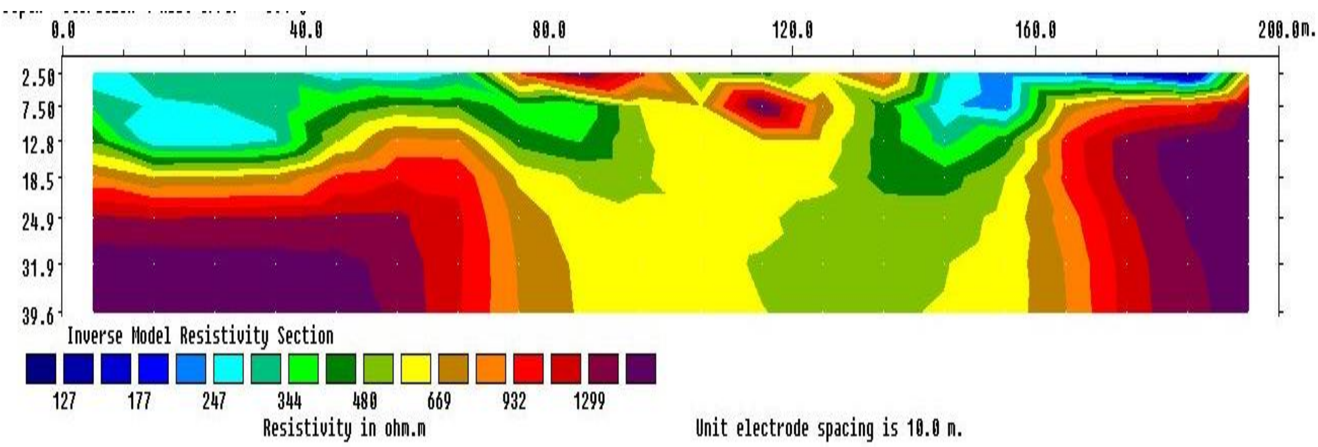

Figure 11: Inverse 2D Model Resistivity section along Profile 9

PROFILE 10

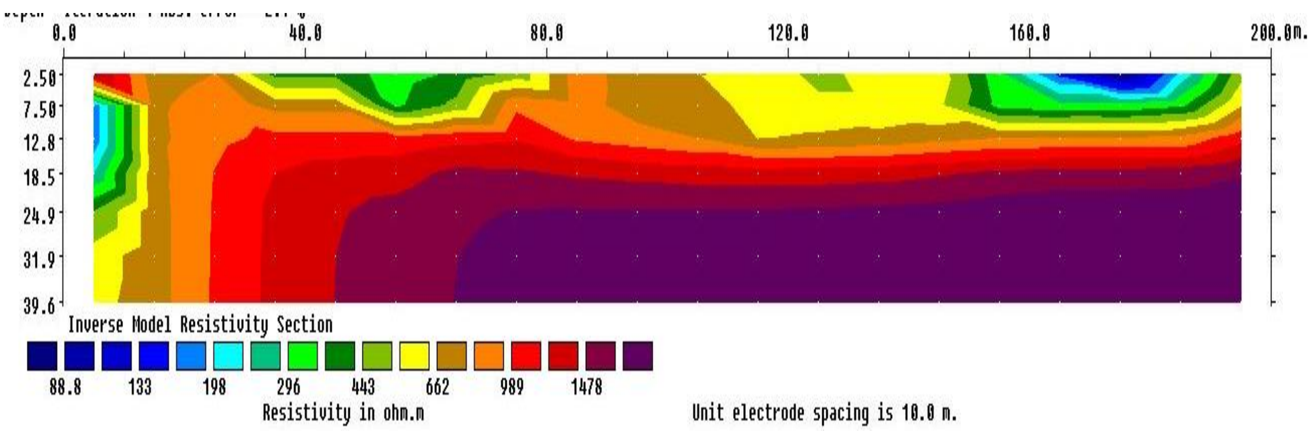

Figure 12: Inverse 2D Model Resistivity section along Profile 10

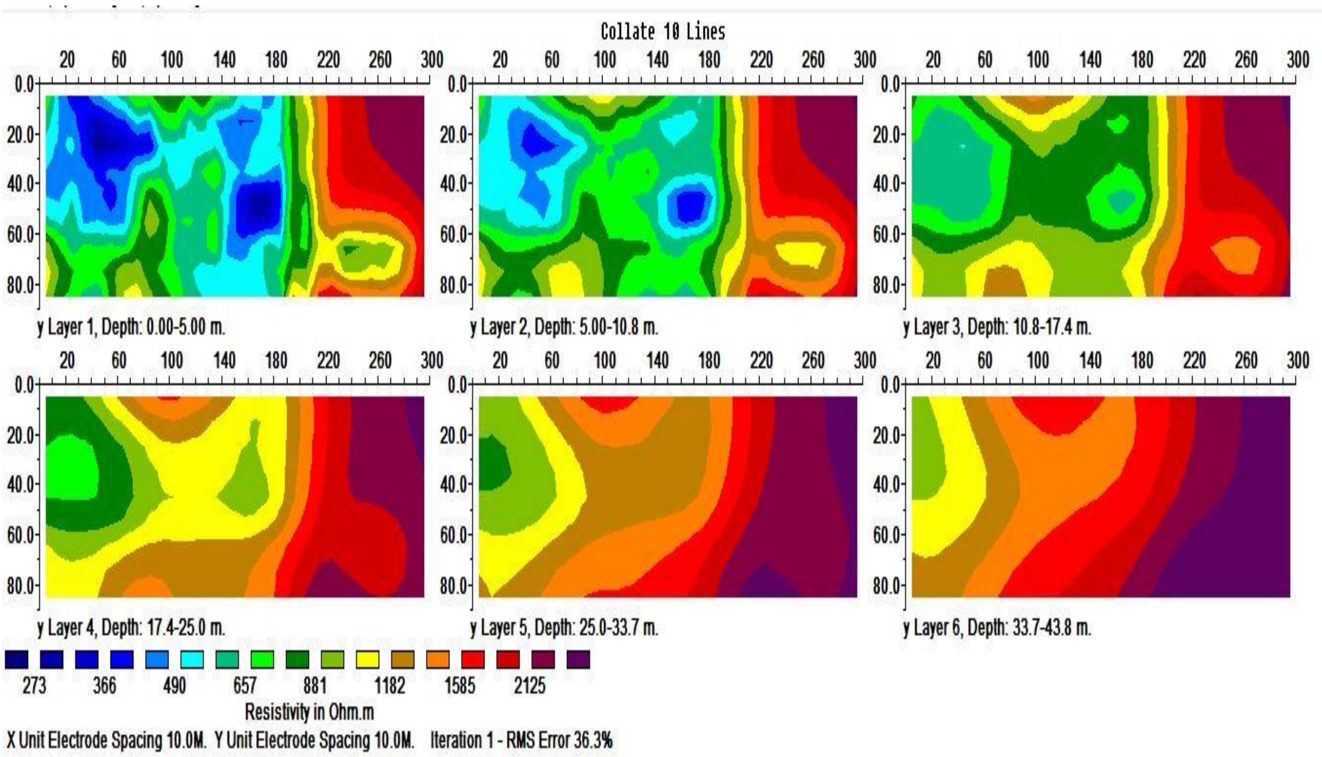

Figure 13: Combines 3D Resistivity Model of the surveyed area

The Inverse resistivity of the surveyed area are presented as models in figures 3-13. The root mean square errors obtained in the inverted models were between a minimum of 2.1% to a maximum of 10.0%. There is a good correlation between the subsurface and resistivity distributions of the subsurface soils in the surveyed area. The profiles showed similar variations of resistivity at different depths characterized by low-resistivity materials at the Top soil in Profiles 2,3,4,5 which is interpreted as possible accumulations of Laterite, Clayey soil and compacted soils. Profile 6 and 9 however shows much lower resistivity at the top with resistivity values ranging from 40ohmm to 80ohmm. which is interpreted as possible accumulation of wet saturated soils, clay materials but in much less significant quantity. Profiles 7, 8 and 10 equally shows compacted soils with high resistivity values at the top layers which is interpreted as Laterite and Clayey soils.

The middle Layer from 7.5m in depth down to the base of the survey depth of about 39.6m shows that the surveyed area consists of possible accumulations of highly compacted soils of high resistivity with values ranging from 400ohmm to 2000ohmm the nature of the surveyed area is highly suitable for heavy building construction. The inverse 3D model in Figure 13 shows the horizontal sections of the model obtained after 5 iterations. The The first 2 Layers up to 10m in depth shows low resistive soil materials with resistivity values of 200 to 300m. This is interpreted as possible accumulations of saturated soil which could be Laterite. from 10m to 43m in depth, the 3D shows a very well compacted soil with high resistive values interpreted as possible accumulations of Laterite and sandstones. The base of all the surveyed site is suspected to be compacted coarse and ferruginous Soils. The surveyed site is suitable for heavy structure construction. Both the 2D and 3D images correlate and resistivity zones clearly seen in all the layers.

4. Conclusion

With the aid of the region's known geological data, the geophysical data were interpreted. The 2D and 3D picture models demonstrate the successful delineation of the numerous components that comprise the area's complicated geology. One quick and affordable way to conduct 3D geoelectrical resistivity surveys is to use parallel 2D profiles to generate 3D datasets. The research region did not contain any fractures, faults, or voids; nevertheless, a little amount of clay was identified at one location that posed no risk to the construction of heavy structures. The southern part of the research region was discovered to be more appropriate for the

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