Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/21245
DOI URL: http://dx.doi.org/10.21474/IJAR01/21245

ISSN NO. 2320-5407

RESEARCH ARTICLE

INTERPRETATION OF RESISTIVITY DATA IN IDENTIFYING POTENTIAL AQUIFER HORIZONS AT CHOBA FIELD, UNIVERSITY OF PORT-HARCOURT, RIVERS STATE, NIGERIA

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Manuscript Info

Manuscript History
Received: 18 April 2025
Final Accepted: 21 May 2025
Published: June 2025

Key words: -
Resistivity, Delineating, Subsurface, Vertical Electrical Sounding (VES), Aquifer

Abstract

Interpretation of Resistivity Data for Extracting Subsurface Geological Parameters at Choba Field, University of Port Harcourt, the accurate characterization of subsurface geological formations is essential for various environmental, hydrogeological, engineering, and geotechnical applications.This study applies electrical resistivity methods,specificall y Vertical Electrical Sounding (VES), to delineate lithological layers, identify potential aquifer horizons, and assess soil strata within Choba Field, University of Port Harcourt. The study area is underlain by the Benin Formation, a major aquifer system within the Niger Delta Basin, characterized by unconsolidated sands interspersed with clay lenses. Given the rapid urbanization in southern Nigeria, understanding groundwater distribution and geological stability is crucial for sustainable development. A Schlumberger electrode configuration was employed to collect resistivity data, which was processed using RES2D INV software to generate resistivity-depth curves and geoelectric sections. The interpretation reveals a five-layer stratigraphic sequence with alternating resistivity trends. Layer 2, with elevated resistivity, suggests compact formations influencing groundwater movement, while exhibits significantly high resistivity, indicating a potential aquifer zone at 47 meters depth. Conversely, Layer 5 presents the lowest resistivity, likely due to high moisture content or contamination. Visual analysis of the geoelectric section and VES curve confirms heterogeneous subsurface properties, highlighting distinct lithological boundaries. The resistivity variations provide valuable insights into lithological properties, fluid storage, and groundwater quality. The high-resistivity aquifer zone necessitates further validation through borehole testing to confirm its suitability for water extraction. Overall, this study contributes to subsurface geological mapping and underscores the importance of resistivity techniques in groundwater exploration and infrastructure planning, supporting sustainable resource management within the University of Port Harcourt and its surrounding communities.

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Introduction:-

The accurate understanding of the subsurface is a critical component in addressing various environmental, hydrogeological, engineering, and geotechnical challenges (Nnurum et al., 2025). In regions experiencing rapid urbanization and population growth, such as southern Nigeria, this understanding becomes vital for sustainable groundwater development, infrastructure planning, and environmental protection. Electrical resistivity methods—especially Vertical Electrical Sounding (VES)—have been widely applied for decades as reliable tools for delineating lithologic boundaries, identifying aquifer systems, and inferring geological structures based on differences in the subsurface resistivity distribution (Telford et al., 1990; Reynolds, 2011).

The method operates on the principle that different geological materials exhibit distinct electrical resistivity values depending on their mineralogy, fluid content, porosity, and saturation level. For instance, clay-rich formations typically have low resistivity due to their high conductivity and water content, whereas sandy or gravelly layers tend to have higher resistivity values due to their lower water retention and higher porosity (Zohdy et al., 1974; Loke, 1999; Nnurum et al., 2025; Udoh et al., 2023). As such, resistivity surveying provides a non-invasive, efficient, and relatively low-cost approach for imaging subsurface features in both sedimentary and crystalline terrains.

The Choba Field, situated within the University of Port Harcourt, is underlain by the Benin Formation, a key component of the stratigraphic sequence of the Niger Delta Basin. This formation, largely composed of unconsolidated sands with occasional clay interbeds, serves as a significant aquifer system in southern Nigeria (Reijers, 1996; Avbovbo, 1978). Given its high porosity and permeability (Nnurum et al., 2021), the Benin Formation supports widespread groundwater exploitation through shallow wells and boreholes. However, due to the heterogeneous nature of these sediments—resulting from complex fluvial depositional processes—accurate characterization of subsurface layers is essential to avoid problems such as borehole failure, inadequate water yield, and foundation instability (Ikechukwu et al., 2015).

The broader Niger Delta Basin, where Choba is located, is one of the most studied sedimentary basins in Africa due to its significant hydrocarbon resources and dynamic depositional history. The basin evolved during the Late Cretaceous through extensional tectonics and has been shaped by continuous subsidence and massive sediment influx from the Niger-Benue River system (Doust & Omatsola, 1990; Short & Stauble, 1967). Its stratigraphy is typically divided into three main lithostratigraphic units:

1. Akata Formation – deep marine shales that act as the primary source rock,
2. Agbada Formation – alternating sands and shales representing delta front environments, and
3. Benin Formation – continental sands deposited in fluvial and alluvial settings.

The Benin Formation ranges from Oligocene to Recent in age and attains thicknesses exceeding 2,000 meters in some parts of the delta. In the Choba area, the formation is characterized by lateritic topsoil, loose sands, and scattered clay layers, which influence both the hydrogeological potential and geotechnical integrity of the subsurface (Amadi et al., 2012).

As Port Harcourt and its environs continue to experience urban expansion, the demand for reliable groundwater resources and stable construction grounds is rising (Nnurum et al., 2021). However, this growth also increases the risk of aquifer contamination, unregulated drilling, and geohazards such as subsidence or poor foundation stability (Nnurum et al., 2024). Therefore, accurate subsurface mapping using resistivity methods becomes indispensable. These geophysical approaches offer detailed insights into subsurface layering, depth to groundwater, and the distribution of conductive and resistive zones—all of which are crucial for borehole siting, foundation design, and land-use planning (Evwienure et al., 2025; Adepelumi et al., 2008).

Moreover, this study is particularly important given the climatic and hydrological conditions of the Niger Delta region. The area receives annual rainfall exceeding 2,500 mm, with pronounced wet and dry seasons, leading to significant recharge of shallow aquifers and seasonal variations in the water table. The resistivity method is sensitive to such moisture changes and can help assess aquifer dynamics, recharge zones, and even detect saline intrusion or contamination plumes in vulnerable areas (Okolie et al., 2015).

The objectives of this study are therefore to employ resistivity sounding techniques to Delineate subsurface lithological layers in the Choba Field, identify potential aquifer horizons and their depths, Assess the thickness of overburden and the nature of soil strata, and
Provide baseline data for future groundwater development and geotechnical evaluations within the university and surrounding communities.

By integrating geophysical data with regional geology, the study contributes to a broader understanding of the subsurface framework of the Choba area. It also aligns with ongoing efforts to ensure sustainable resource management and infrastructure development in Nigeria's southern sedimentary basins.

Geologic Settings
The Choba Field, located within the campus of the University of Port Harcourt in Rivers State, Nigeria as shown in the Location map in Figure 1 below, is geologically situated in the eastern segment of the Niger Delta Basin, a major hydrocarbon province and sedimentary system of global significance. The Niger Delta lies on the Gulf of Guinea along the Atlantic margin and covers an area exceeding 75,000 km². Its evolution is closely linked to the rifting and subsequent drifting of the African and South American plates during the Late Jurassic to Cretaceous, leading to the formation of passive continental margins (Doust & Omatsola, 1990).

The Niger Delta stratigraphy consists of a classic tripartite sequence formed through a progradational depositional regime. These units, in ascending order, are:
1. Akata Formation (Paleocene–Recent): A thick marine shale unit, rich in organic matter, serving as the principal petroleum source rock.
2. Agbada Formation (Eocene–Recent): An alternation of sands and shales deposited in a delta front to shallow marine environment. It serves as the primary petroleum reservoir in the basin.
3. Benin Formation (Oligocene–Recent): The topmost and most extensive unit, comprising thick, unconsolidated continental sands, gravels, and minor clay layers. This formation is of fluvial origin and is widespread across the Choba Field. The stratigraphy of the Niger Delta is shown in the table below in Table 1.

The Choba area, specifically, is underlain predominantly by the Benin Formation, which is composed of course to medium-grained sands, interspersed with lateritic and clayey lenses. These sediments were deposited in high-energy alluvial and deltaic environments, characterized by braided and meandering rivers (Reijers, 1996). The thickness of this formation in parts of the Niger Delta is estimated to exceed 2,000 meters (Avbovbo, 1978).

The structural setting of the Choba area is relatively stable, consistent with the overall tectonic quiescence of the Niger Delta. However, minor normal faulting and growth faults exist in deeper parts of the basin and may influence subsurface fluid migration patterns. The basin itself formed as a syn-sedimentary depocenter due to extensional tectonics, resulting in gravity-induced faulting and subsidence, which shaped sediment accumulation (Kulke, 1995).
Although such structural features are more prominent in offshore and central parts of the delta, their effects diminish toward the flanks—such as Choba—where tectonic influence is minimal, and stratigraphy is more horizontally bedded.

The sediments in Choba are mainly unconsolidated sands (Nnurum et al., 2025), with high porosity (25–40%) and permeability, making the area favorable for groundwater accumulation and movement. The presence of occasional clay layers serves as confining or semi-confining aquitards, which influence vertical water movement. The water table in the region is shallow (typically 3–10 meters), recharged seasonally by rainfall due to the tropical humid climate, which experiences annual precipitation exceeding 2,500 mm (Ikechukwu et al., 2015).

The Benin Formation thus hosts a prolific unconfined to semi-confined aquifer system, widely tapped through boreholes and hand-dug wells. The heterogeneity of the formation, especially the alternation between sandy and clayey units, is a key target in electrical resistivity surveys.

In geophysical terms, the resistivity contrasts in the subsurface at Choba are driven by the differences in moisture content, grain size, and clay content of the various sedimentary layers. Sandy layers, due to their lower moisture retention and higher grain connectivity, exhibit higher resistivity values, while clayey inter-beds, due to their high cation exchange capacity and water content, show lower resistivity.

This contrast makes the Choba Field an ideal environment for the application of Vertical Electrical Sounding (VES) using the Schlumberger or Wenner array configurations, to delineate:

1. Lithological boundaries (sand-clay interfaces)
2. Aquifer thickness and depth
3. Groundwater potential zones
4. Possible contamination pathways or lateritic overburden

These investigations are critical for groundwater exploration, environmental monitoring, and civil engineering foundation design within the University and its surrounding communities.

Table 1: -Shows the stratigraphy sequence of the Niger Delta (from Short and Stauble, 1967).

FORMATION	LITHOLOGICAL DESCRIPTION	AGE	THICKNESS(M)
BENIN	Loose continental sands, and gravels.	Miocene to Recent	0 – 2100
AGBADA	Paralic sequence of sand and shales	Eocene – Miocene	2100 – 4500
AKATA	Pro delta marine shales and clays with some turbidite sand bodies	Paleocene – Recent	4500 – 6000

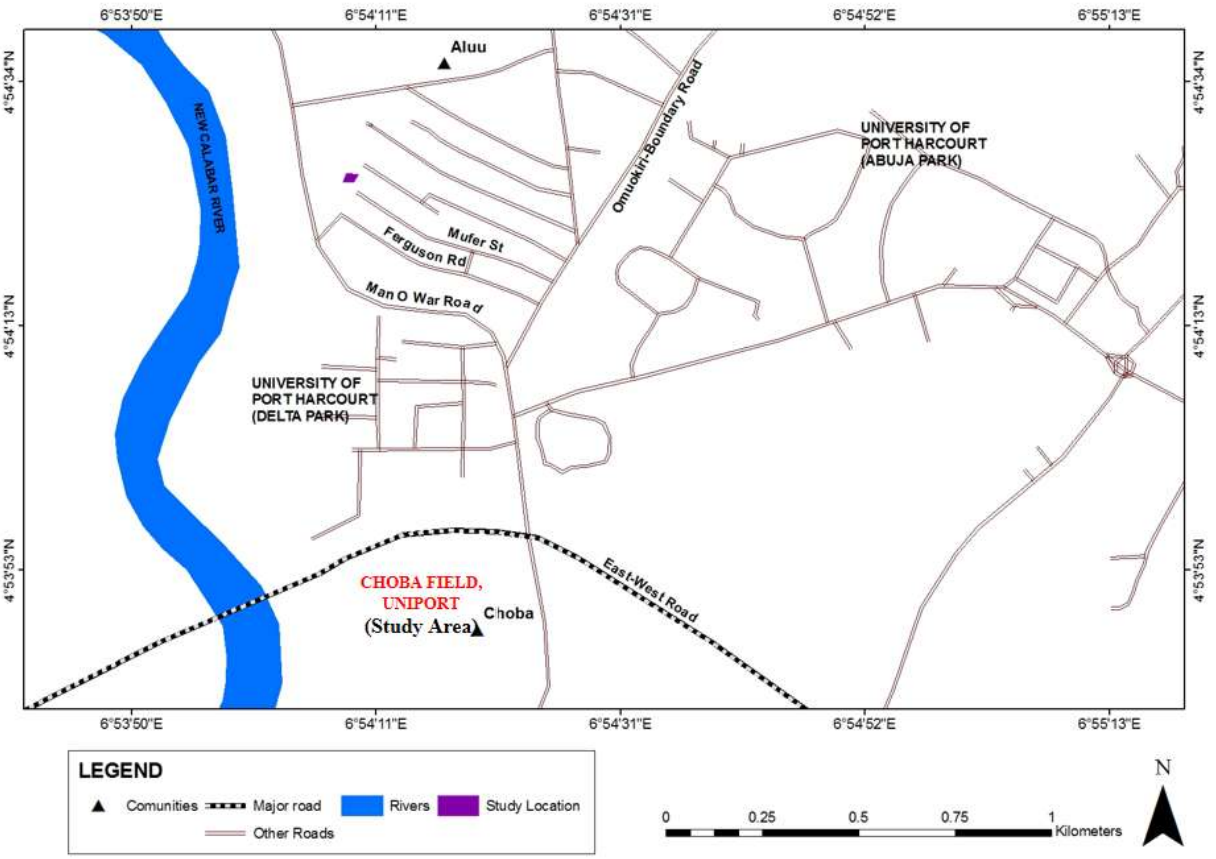

Figure 1: - Location Map of the study area.

Methodology: -

The study employed the electrical resistivity method, specifically vertical electrical sounding (VES) to investigate sub-surface geological formations in the Choba field, university of port-Harcourt. The methodology followed these key steps

Data Acquisition
A schlumberger electrode configuration was used to measure apparent resistivity at varying depths.
The current and potential electrodes were systematically expanded to capture subsurface resistivity variations
Geophysical equipments recorded resistivity values at multiple depths.

Data Processing
The raw resistivity measurements were processed using a specialize software (RES2DINV) to compute apparent resistivity values.
A resistivity-depth curve was generated to visualize subsurface electrical properties.

Geoelectric Development
Layer interpretation was conducted by analyzing the curve and corresponding tabulated resistivity values.

Interpretation and Validation
The resistivity curve type was identified by alternating resistivity variations

Results: -

The interpretation of resistivity curve in Figure 2 begins after the acquisition of data, which is done at long tennis court field, uniport. Then it is subjected to analysis or processing of the data and to the last known as the interpretation of the data. The Table 2 below shows the apparent resistivity, depth and thickness of the curve and the geoelectric representation was input for clearer interpretation as seen in Figure 3.

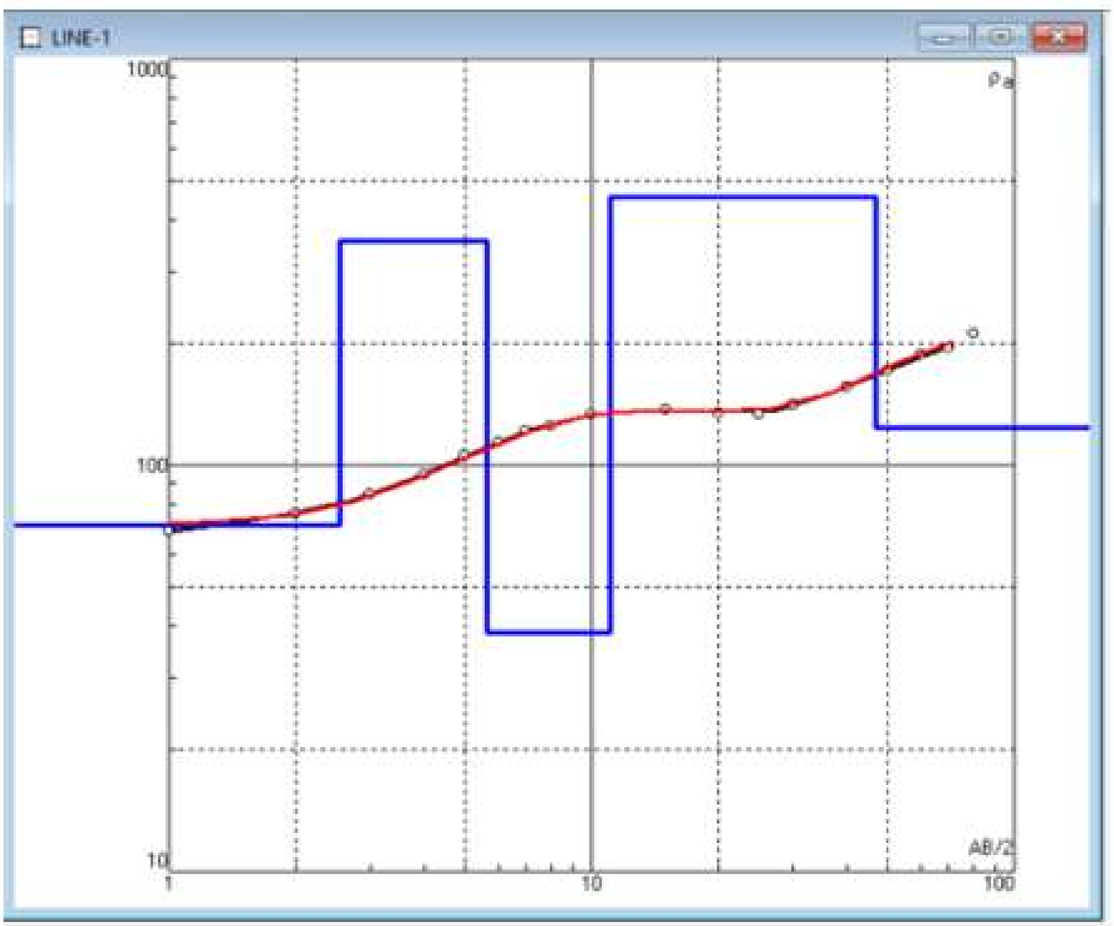

Figure 2: - A vertical electrical sounding-1 curve gotten from the Choba field.

Table 2: - Table showing the apparent resistivity, depth and thickness of the curve.

S/n	Resistivity (Ωm)	Depth (m)	Thickness (m)	Altitude
1	71.1	2.54	2.54	-2.535
2	356	5.65	3.11	-5.649
3	38.7	11.1	5.42	-11.07
4	457	47	35.9	-46.99
5	124			

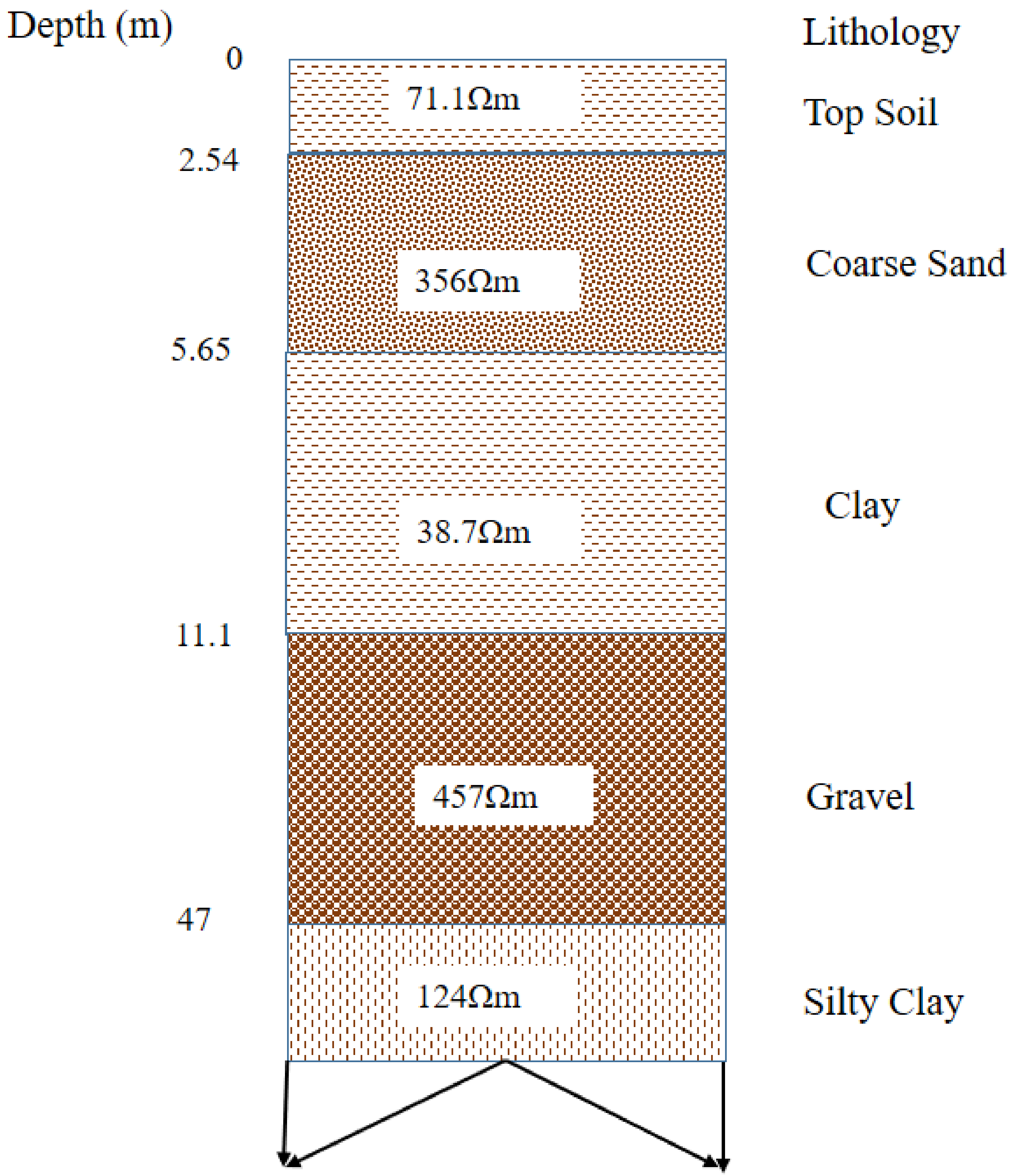

Figure 3: - Geoelectric section of the Curve.

Discussion: -

The electrical resistivity method is a fundamental approach for understanding the subsurface geophysical and geological information about the subsurface lithological characteristics. The concept gives clues to the nature of the soils at depth, the depth to potential aquifer beds, the depth to variations in lithology, etc. All of these properties are interpreted from the resistivity data for subsurface evaluation. However, the resistivity data was acquired from Choba field, University of Port-Harcourt using the resistivity method.

The data was processed to obtain the apparent resistivity components of the layers, so that, a plot of apparent resistivity values and half-current electrode spacing values can be done using a software. The software produced a 2D resistivity curve and table of values called geophysical parameters. These parameters are used to produce a geoelectric section for lithological characterization and evaluation.

The resistivity curve in figure 1 revealed a five (5) sub-surface stratigraphic earth model, four thickness of medium, depth to potential aquifer Formation, suggesting a complex lithological structure beneath the Choba field. This vertical electrical sounding (VES) technique provides insight into varying resistivity properties of different geological formations at increasing depth. The resistivity trend is in the form of $\ell_1<\ell_2>\ell_3<\ell_4>\ell_5$, which is characteristic of an H-type resistivity curve type as seen in Figure 2. In this pattern:

Layer 1 has a lower resistivity.
Layer 2 exhibits a higher resistivity (356Ωm) at depth 5.65m than both the overlying and underlying layers. Indicates the presence of a compact formation, possibly coarse-grain sediments or fractured rock with limited conductivity and may act as a semi-permeable zone, affecting groundwater movement.

Layer 3 returns to a lower resistivity.
Layer 4 has a high resistivity, significantly greater than layer 3 and the other layers (457Ωm) at 47m in depth, distinguishing it from the low-resistivity layer 3. It suggests the presence of a consolidated rock formation or a dense lithological unit capable of influencing fluid retention and it is a potential indicator of aquifer formation.

Layer 5 presents the lowest resistivity, potentially indicating the presence of highly conductive materials.
This geo-electric section visually represents the subsurface lithology and resistivity variations at different depths. It categorizes distinct layers, topsoil, coarse sand, clay, gravel, and silty clay along with their respective resistivity values. Topsoil (71.19Ωm, 0-2.54m depth): Characterized by moderate resistivity, likely due to surface moisture and organic content.

Coarse Sand (356Ωm, 2.54-5.65m depth): Exhibits high resistivity, indicating a permeable and well-drained layer.
Clay (38.72Ωm, 5.65-11.1m depth): Shows low resistivity, typical of water-retentive materials with poor permeability.
Gravel (457Ωm, 11.1-47m depth): Highly resistive, suggesting a consolidated, porous structure with potential groundwater retention.
Silty Clay (124Ωm, 47m depth): Moderately resistive, potentially representing a transitional layer with mixed lithological properties.
This resistivity profile is vital for hydrogeological analysis, particularly in identifying potential aquifer zones, contamination risks, and geotechnical stability for infrastructure projects. The gravel layer may serve as a significant groundwater reservoir, while the clay layer could act as an aquiclude, restricting fluid flow.

The least resistivity property is the fifth layer and this could be due to the presence of conductive materials because of a contaminant which led to the decrease in resistivity as depth increases. At a depth 47m, the resistivity property is high as 457Ωm for delineating potential portable water accumulation. Furthermore, the fluid type elaborates the fact that, that is the depth with the highest resistivity. Having a high resistivity explains a profound knowledge of having a chance in quality aquifer free from contamination, the lowest resistivity in layer 5 could be attributed to high moisture content, clay deposits or contamination, reducing its ability to sustain potable water accumulation. The alternating resistivity trends indicate varying lithological properties, affecting fluid flow and storage capacity in the subsurface layers.

Conclusions: -

The electrical resistivity survey conducted in Choba field provides key insights into the subsurface lithological characteristics. The identified H-type resistivity curve suggests a stratigraphy with alternating resistivity layers. While a high-resistivity zone at 47m depth indicates a possible aquifer.

Layer 4's high resistivity properties suggest a potential freshwater accumulation zone, which requires further validation through borehole investigation while layer 2 plays a critical role in defining groundwater movement pathways and should be examined for hydraulic conductivity characteristics.

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