



# GEOELECTRICAL RESISTIVITY IMAGING OF SUBSURFACE GROUNDWATER CONTAMINATION AT A WASTE DISPOSAL SITE IN CHOBA EXTENSION, RIVERS STATE

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## ABSTRACT

Groundwater quality in Rivers State is increasingly threatened by human activities, particularly in Choba Extension where aquifers are vulnerable to leachate infiltration. Conventional assessment methods, such as water sampling and borehole logging, are limited by their point-based nature and often fail to capture the spatial extent of contamination. This study evaluates groundwater pollution at Muffa Street, Choba Extension, using geoelectric imaging techniques. The Electrical Resistivity Method was employed with AIDU and Guilin Technology terrameters to map subsurface resistivity variations and delineate contaminant plumes. Results revealed low resistivity zones ranging from 1 to 100  $\Omega \cdot m$ , with values below 10–20  $\Omega \cdot m$  indicating highly conductive and contaminated regions. These anomalies were detected at depths corresponding to the water table, suggesting pollution from surface sources such as improper waste disposal infiltrating sandy aquifer layers of the Benin Formation. The findings confirm significant groundwater contamination in the study area, posing serious public health risks. This study highlights the effectiveness of geophysical methods in mapping subsurface pollution and recommends immediate remediation, continuous monitoring, and improved waste management practices to ensure environmental sustainability.

**KEYWORDS:** pollution, aquifer, tetrameter, electrical resistivity, groundwater

## INTRODUCTION

Groundwater is commonly understood to mean water occupying all the voids within a geologic stratum. It is one of the nation's most valuable natural resources; which serves as source for approximately 40 percent of the water used for all purposes, It is commonly utilized in hydropower systems and electric power plant cooling. Groundwater occurs everywhere but sometimes its availability in economic quantity depends solely on the distribution of the subsurface geomaterials that are referred to as the aquifers Delineating Aquifer is necessary because it helps in identifying and mapping the boundaries of an aquifer, which is a geological formation that can store and transmit groundwater.

Several studies have reported its efficiency and effectiveness in prospecting for groundwater, fresh water/ saline water boundary predication and contaminant plumb predication (Emenike, 2001; Amaresh et al., 2006). This process is crucial for groundwater management, water resource planning, and environmental protection. There are various methods used to delineate aquifers, including geophysical survey; which involves the use of techniques such as electrical resistivity, seismic reflection, and ground-penetrating radar to image the subsurface and identify the boundaries of the aquifer (Zohdy et al., 1989). Hydrogeological modeling is another important method that uses computer simulations to analyze the behavior of groundwater flow within the aquifer.

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This method can help in predicting the movement of groundwater and identifying potential recharge areas or sources of contamination (Singh and Singhal, 2011). And drilling which allows for direct sampling and measurement of groundwater levels and quality. (Freeze and Cherry, 1979). One of the modern tools used in aquifer delineation is the digital tetrameter, which measures electrical resistivity. Aquifers are underground layers of water-bearing rock or sediment that hold groundwater. They are classified into unconfined and confined aquifers based on their geological surroundings. Accurate delineation helps in determining the quantity and quality of groundwater resources. It aids in identifying recharge areas, protecting water supplies, and managing contamination. The study was aimed at using a digital terrameter to delineate potable groundwater at Community Secondary School, Nkpolu, Obio/Akpor LGA, Rivers State. It is based on the principle that groundwater investigations are more reliable when relationships between aquifer properties and geoelectrical parameters are established. Previous studies such as Freeze and Cherry (1979) have shown that over-abstraction due to population growth can lead to saline intrusion, while also confirming that groundwater may be suitable for various uses when properly assessed. Similarly, Kulke (1995) and other researchers have demonstrated correlations between aquifer characteristics, transmissivity, and geoelectrical parameters, assuming relatively uniform subsurface conditions. The study is also situated within the Niger Delta, a complex sedimentary basin characterized by depobelts and significant groundwater and petroleum systems. The region is known for both freshwater availability and risks of saline intrusion and contamination, especially within formations like Benin and Agbada. Therefore, scientific geophysical methods are necessary to accurately delineate aquifers and identify freshwater zones. This research is justified by the need to move away from unreliable methods such as water divining and toward geophysical imaging that ensures accurate borehole placement. It also addresses issues of groundwater sustainability in high-demand institutional settings, where parameters like transmissivity and specific capacity are essential for long-term water supply planning. Ultimately, the study provides a scientific basis for identifying safe, high-yield aquifers to support reliable and potable water supply for the school community. The study area, Community Secondary School Nkpolu, is located in Obio/Akpor Local Government Area of Rivers State, in the southern part of Nigeria. It lies within the coastal Niger Delta region. On the map of Nigeria, Rivers State is situated in the south-south geopolitical zone, and Nkpolu falls within its capital region, Port Harcourt metropolis. An inset map of Rivers State would typically highlight Obio/Akpor LGA, showing Nkpolu within the urban and peri-urban settlements

surrounding Port Harcourt. Geologically, the study area is part of the Niger Delta sedimentary basin, which is characterized by three major subsurface formations: the Benin Formation, Agbada Formation, and Akata Formation. The study area is mainly underlain by the Benin Formation, which consists of highly permeable continental sands and gravels with intercalations of clay lenses. This formation is the primary aquifer unit in the region and is responsible for the occurrence of relatively abundant groundwater. It is generally characterized by high porosity and permeability, making it suitable for borehole development. However, the area is also prone to groundwater quality challenges such as saline intrusion and contamination due to its proximity to coastal environments and increasing human activities.

### **Location and Geology of the Study Area.**

#### **Location of the Study Area**

The study was carried out at Community Secondary School, Nkpolu, located in Obio/Akpor Local Government Area of Rivers State, in the southern part of Nigeria. Obio/Akpor is one of the major urban local government areas within the Port Harcourt metropolis and lies within the Niger Delta region of southern Nigeria. The area is geographically located between latitudes 4°30'N and 4°55'N and longitudes 6°55'E and 7°00'E. It occupies a low-lying coastal plain characterized by relatively flat topography with elevations generally below 30 m above sea level. The area experiences a tropical monsoon climate with distinct wet and dry seasons, high annual rainfall, and high relative humidity throughout the year. Annual rainfall in the area ranges from approximately 2,000 mm inland to over 4,000 mm toward the coastal zones, creating favorable conditions for groundwater recharge (Nwankwoala et al., 2015). Nkpolu, where the study was conducted, is situated within the densely populated urban environment of Obio/Akpor, where groundwater constitutes a major source of domestic, institutional, and industrial water supply. The increasing population and rapid urbanization in the area have significantly increased dependence on groundwater resources, making hydrogeophysical investigations necessary for sustainable groundwater development.

#### **Geology of the Study Area**

The study area lies within the Niger Delta Basin, one of the world's largest regressive deltaic systems. The Niger Delta developed from the Eocene to the present through the accumulation of thick sedimentary sequences deposited by the Niger-Benue river system. The stratigraphy of the Niger Delta consists of three major lithostratigraphic units, namely the Akata Formation, Agbada Formation, and Benin Formation (Doust & Omatsola, 1990; Kulke, 1995). The Akata Formation forms the basal unit and consists predominantly of marine shales with minor sandstone interbeds.

Overlying the Akata Formation is the Agbada Formation, which comprises alternating sequences of sandstone and shale and serves as the principal hydrocarbon-bearing unit of the Niger Delta. The uppermost unit is the Benin Formation, which constitutes the major freshwater-bearing formation in the region. The Benin Formation is composed mainly of unconsolidated to poorly consolidated sands, gravels, and minor clay intercalations, exhibiting high porosity and permeability, which make it an excellent aquifer system (Nwankwoala et al., 2015). In Obio/Akpor, the near-surface geology is dominated by Quaternary deposits overlying the Benin Formation. These deposits consist of rapidly alternating sequences of sands, silts, and clay layers with

thickness ranging from about 40 to 150 m. The Benin Formation in the area is highly porous and permeable, allowing easy infiltration of rainwater and significant groundwater storage. Groundwater in the area commonly occurs within shallow to moderately deep aquifer systems, usually within depths of 45–100 m, although deeper aquifers may occur at depths exceeding 300 m (Nwankwoala et al., 2015). The hydrogeological characteristics of the Benin Formation make it the principal source of potable groundwater in the study area. Its sandy lithology, high transmissivity, and favorable recharge conditions support sustainable groundwater abstraction. However, due to urbanization, industrial activities, and saline intrusion associated with the coastal environment of the Niger Delta, detailed geophysical investigations are necessary to delineate productive freshwater aquifers before borehole development.

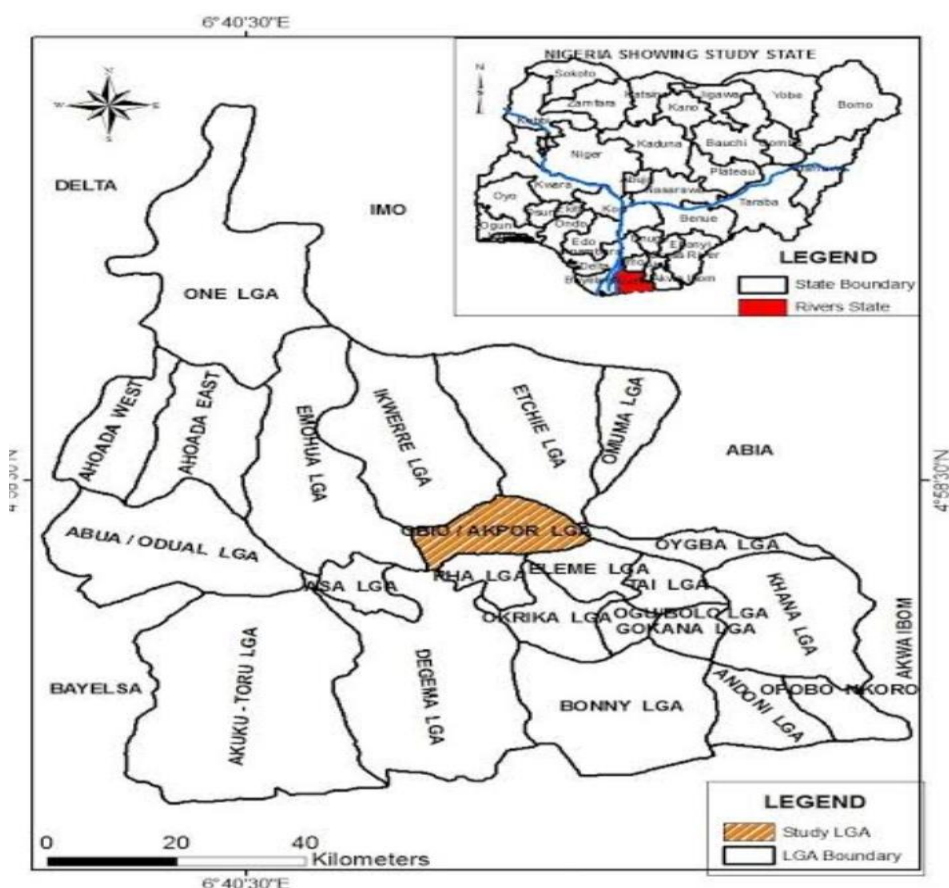


**Figure 1:** Study Area Location on the Nigeria map.

## MATERIALS AND METHOD

### Instrumentation and sources of data

The study utilized the ADMT (Advanced Dynamic Magnetotelluric) series intelligent geophysical prospecting system, a modern digital resistivity imaging instrument designed for rapid subsurface investigation. The system is used for both 2D and 3D groundwater mapping and operates through a mobile

application connected via Bluetooth. Its main components include wireless sensor probes, stainless steel electrodes, copper cables (for signal transmission where needed), and a GPS module for location tracking and spatial referencing. The system works on the principle of electrical resistivity methods, where variations in the ability of subsurface materials to conduct electrical current are measured.

Different geological materials (such as sand, clay, and saturated zones) exhibit different resistivity values. Low resistivity zones often indicate water-saturated or clay-rich formations, while high resistivity zones indicate dry or consolidated materials. This principle is widely applied in geophysical surveys (Dobrin, 1960).

#### **Description of equipment used**

The ADMT equipment consists of several integrated components that work together during data acquisition and processing. These include:

**Electromagnetic Sensors/Probes:** Highly sensitive wireless probes are used to detect variations in the earth's electric and magnetic fields. These sensors measure the electromagnetic response of subsurface materials as the operator moves along the survey line.

**Data Acquisition Unit:** This unit receives signals from the probes and converts the analog electromagnetic measurements into digital data. It ensures accurate signal recording while minimizing external interference.

**Wireless Communication Module:** The system is equipped with Bluetooth or other wireless communication technology, enabling real-time transmission of field data from the sensors to a mobile device without the need for extensive cable connections.

**Mobile Processing Application:** A dedicated mobile application serves as the control and processing platform. It receives field measurements, performs signal filtering, noise reduction, field-source correction, and inversion processing, and displays subsurface resistivity images in real time.

**Power Supply Unit:** Rechargeable batteries provide portable power to the sensors and communication units, allowing efficient field operation in remote locations.

**Positioning and Navigation System:**

Some ADMT systems incorporate Global Positioning System (GPS) functionality for accurate positioning of measurement points along the survey traverse.

#### **Working principle of ADMT(Advanced Dynamic Magnetotelluric) system.**

The ADMT (Advanced Dynamic Magnetotelluric) system improves this method by using a wireless "walk-and-stop" data acquisition technique, where measurements are taken as the operator moves along survey lines. Data collected are automatically transmitted to the mobile application, which processes and displays real-time subsurface images. The system also applies field source correction to reduce noise and improve data accuracy, making interpretation more reliable. ADMT (Advanced Dynamic Magnetotelluric) works by detecting natural or induced electromagnetic signals in the subsurface. These signals are influenced by variations in underground geological structures and water content. The instrument records changes in the

electromagnetic field and converts them into resistivity values, which are then processed into 2D or 3D images showing subsurface layering.

In operation, the ADMT(Advanced Dynamic Magnetotelluric) system functions through, signal detection using wireless probes placed or moved along the survey line, data transmission via Bluetooth to a mobile application, real-time processing where the app performs filtering, correction, and inversion of data and image generation, producing subsurface resistivity models that help identify aquifer zones.

#### **DATA ANALYSIS**

Data analysis was carried out immediately via the APP(Application) i.e Mobile Application Software, The APP(Application) functions as the central control and data processing unit of the system. It is connected to the ADMT(Advanced Dynamic Magnetotelluric) instrument via Bluetooth wireless communication, allowing seamless transfer of field measurements directly into the software during data acquisition.

During operation, the APP(Application) performs the following functions;

**Data acquisition and control:** It receives measurement signals from the wireless sensor probes and allows the operator to input or monitor survey parameters in real time.

**Data processing:** It automatically applies filtering and corrections (including field-source correction) to reduce noise and improve signal quality.

**Inversion and modeling:** The APP(Application) performs automatic inversion of resistivity data, converting raw measurements into interpretable subsurface models. These models are displayed as 2D and 3D profiles showing subsurface structures.

**Interpretation support:** The processed results are interpreted based on variations in electrical resistivity, which are influenced by factors such as pore fluid content, soil texture, and electrolyte concentration. This interpretation is guided by the inverse relationship between electrical resistivity and electrolyte volume (Dobrin, 1960).

**Visualization:** It presents results in graphical and map formats for easy identification of aquifer zones and geological boundaries. included automatic inversion for 2D/3D profiling, with interpretations based on pore fluid saturation, textural variations, and, the inverse relationship between electrolyte volume and electrical resistivity (Dobrin, 1960).

#### **RESULTS**

The reddish zone is the highly conductive zone while the blue zone is the highly resistive zone. Close to the highly conductive zone is the less conductive zone. Pollutants are conductive because they contain different constituents with different chemical composition.

The fresh water zone is the less conductive zone.

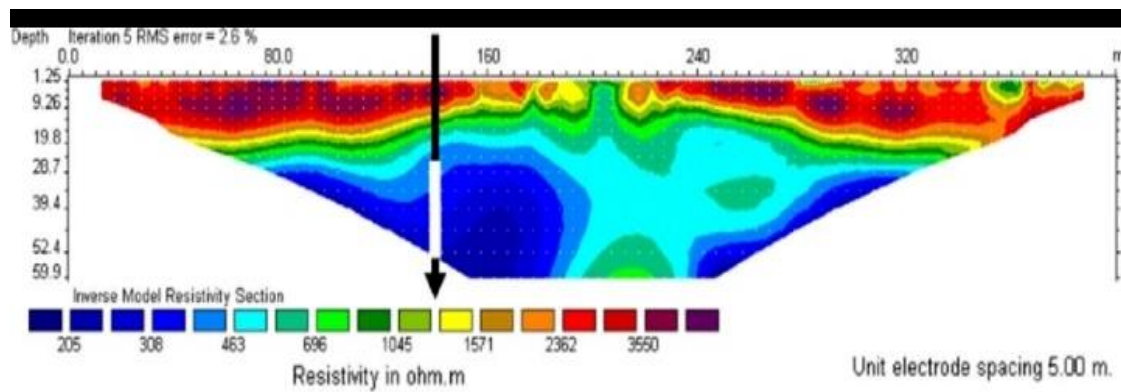


Figure 2: Resistivity Pseudo-section of the contaminated zone

## 2 Contaminant of flow (leachate plumes)

Based on the 2D resistivity/conductivity pseudo-section provided, the interpretation focuses on the subsurface migration of contaminants from the identified source. The top portion of the profile (Depth: 0-20m) shows high-intensity red and orange zones (0.15-0.20 units), which correspond to the dump site location. These high-conductivity (low-resistivity)

values indicate a high concentration of dissolved inorganic compounds and ions leaching from the waste into the soil. The interpretation labels clearly delineate pathways of fluid migration. The plume does not move uniformly; instead, it follows preferred paths indicated by the green and yellow contours (0.09-0.13 units).

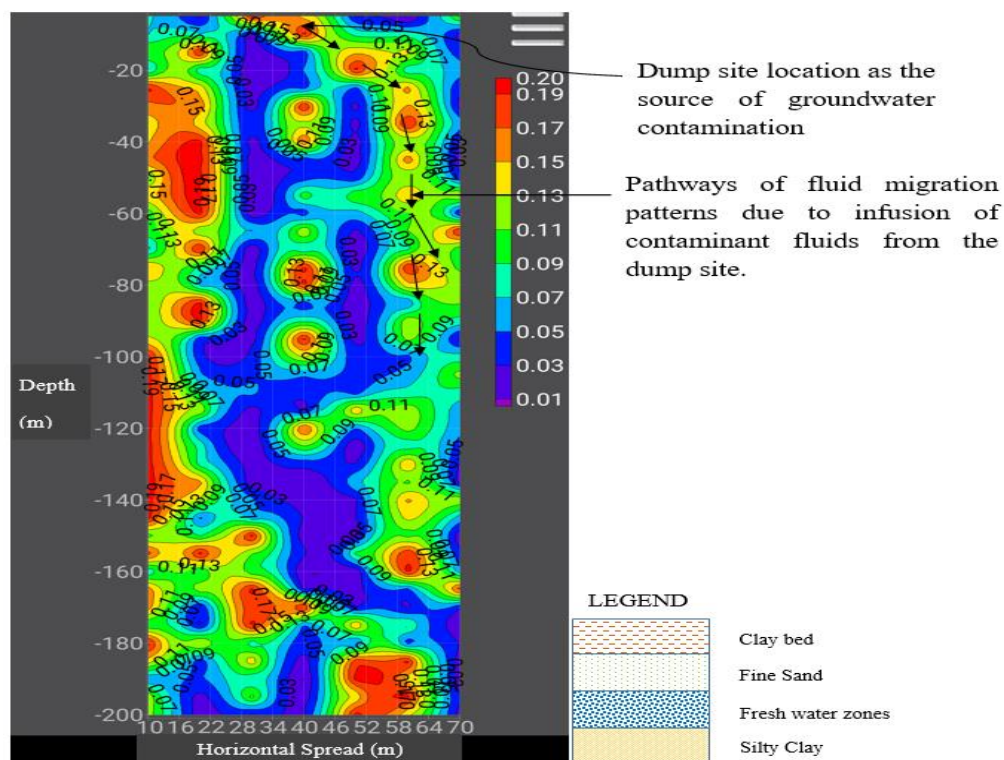


Figure 3: A 2D contour map the of contaminant zones in the area.

## 3 Interpretation of aquifer depth.

Based on the provided 2D pseudo-section and the associated Legend, here is the professional interpretation of the results. This discussion integrates the geoelectric parameters with relevant

hydrogeological research. The uppermost layer of the profile is characterized by green and yellow hues, with conductivity values ranging between 0.16 and 0.18. As indicated by the annotation, this represents a topsoil zone free from surface-derived contaminants.

A prominent horizontal blue band is visible at a depth of 40–80m (131.2–262.4ft).

**Geoelectric Signature:** This zone exhibits the lowest conductivity values on the scale (0.10–0.12), which translates to high resistivity.

**Hydrogeological Significance:** The high resistivity values observed at this depth suggest the presence of

a relatively fresh groundwater-bearing unit, as freshwater-filled formations generally exhibit higher resistivity compared to saline or contaminated zones due to lower ion concentration. The dominance of high-resistivity anomalies (shown as red and orange zones) particularly toward the left section of the profile indicates a more resistive subsurface layer, likely associated with coarse sand or gravel aquifer material with low clay content.

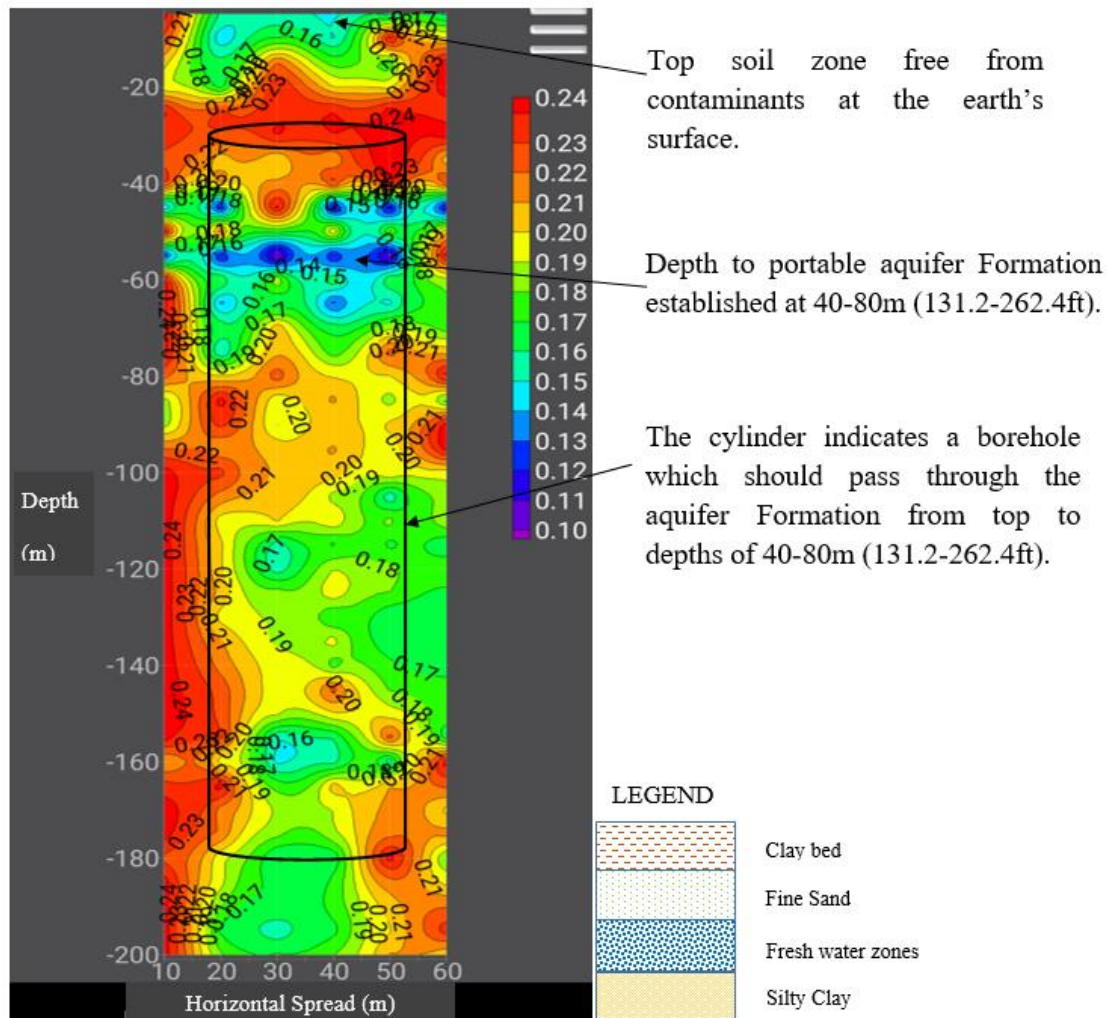


**Figure 4:** A 2D contour map from the control area.

## DISCUSSION

**Resistivity Pseudo-section of the contaminated zone**  
**Contaminant of flow (leachate plumes)**  
**Interpretation of aquifer depth.**

The 2D pseudo-section reveals noticeable spatial variation in subsurface geoelectric properties, particularly the presence of a low-resistivity zone. This zone is generally associated with higher electrical conductivity, which may indicate increased moisture content and possible influence of dissolved ionic substances such as leachate.

Such conditions often arise where surface-derived contaminants infiltrate permeable subsurface materials, reducing resistivity due to enhanced ion mobility. The observed pattern suggests a possible lateral variation in subsurface conditions, where resistivity increases toward the right side of the profile. This may reflect a gradual reduction in contaminant influence or a transition into cleaner, less saturated geological materials. The movement and distribution of any contaminant plume are likely controlled by the high-permeability sandy units typical of the local stratigraphy.

At deeper levels (approximately 40–50 m), a relatively high-resistivity zone is identified. This feature is interpreted as a potential freshwater-bearing aquifer, as such resistivity values are commonly associated with clean, water-saturated sandy formations. However, given the limited dataset, this interpretation should be considered preliminary and subject to confirmation through additional geophysical lines and hydrogeological validation.

Overall, the results suggest a heterogeneous subsurface structure with possible zones of both groundwater accumulation and localized influence of surface-related contamination, consistent with typical conditions in shallow aquifer systems of the Niger Delta region.

### CONCLUSION

In conclusion, this study presents a preliminary geoelectrical assessment of groundwater conditions in the study area using resistivity imaging.

The results reveal the presence of localized low-resistivity zones, which may indicate areas of increased moisture content and possible influence of contaminants, potentially linked to surface activities such as waste disposal and leachate infiltration. However, since the interpretation is based on a single traverse, the findings cannot be used to definitively confirm widespread groundwater contamination. Instead, the observed anomalies should be considered indicative, requiring further validation through additional traverses, borehole logging, and hydrochemical analysis to accurately determine the extent and nature of groundwater quality in the area. The study therefore provides a useful preliminary framework for understanding subsurface conditions and highlights the need for proper waste management and further detailed investigations to safeguard groundwater resources in the study area.

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