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Interpretation of Resistivity Subsurface Models in Isele-Mkpiteme

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***Abstract*: Electrical resistivity (ER) surveys are a valuable tool for identifying freshwater aquifers. This study demonstrates the application of ER data for depth and permeability interpretation in Isele-Mkpiteme, Delta State, Nigeria. The investigation aimed to locate suitable zones for drilling boreholes to access clean drinking water. High-resolution ER measurements were conducted using an ADMT series instrument with mobile app integration for efficient data acquisition and processing. The analysis of resistivity contour maps and 3D models revealed zones with high resistivity values, indicative of freshwater-bearing formations. These zones were further interpreted to estimate aquifer depths ranging from 50 to 120 meters. The correlation between resistivity values and soil types was established, with high resistivity corresponding to medium to coarse sand – characteristics typically associated with good permeability and potential for significant freshwater flow. This approach allowed for the identification of not only the depth of potential freshwater aquifers but also their suitability for sustained water extraction. The findings of this study highlight the effectiveness of ER surveys in conjunction with resistivity-permeability relationships for freshwater exploration. This non-destructive technique provides valuable data for targeted borehole drilling, optimizing the success rate of accessing clean drinking water resources in Isele-Mkpiteme.**

***Keywords*: Electrical Resistivity (ER), Freshwater aquifers, Depth interpretation, Permeability interpretation, High resistivity data, Isele-Mkpiteme, Nigeria, Mobile app integration, Resistivity contour maps, 3D resistivity models, Borehole drilling.**

1. Introduction

Access to clean and sustainable freshwater resources is a critical challenge facing communities worldwide. Population growth, particularly in coastal regions, puts a strain on existing freshwater supplies. Saltwater intrusion, a phenomenon where saltwater mixes with freshwater due to over-extraction or changes in sea level, further exacerbates this issue (Obunadike et al., 2024). In Isele-Mkpiteme, Nigeria, this growing demand for freshwater necessitates effective strategies for exploration and management of this vital resource.

Traditional methods for locating freshwater aquifers often rely on drilling boreholes. While these methods can be successful, they can be expensive, time-consuming, and have a disruptive impact on the environment (Telford et al., 1990). Geophysical techniques offer a promising alternative for freshwater exploration. These non-destructive methods allow for the assessment of subsurface properties without physically altering the environment.

Among various geophysical techniques, electrical resistivity (ER) surveys have emerged as a valuable tool for identifying freshwater aquifers (Loke & Barker, 1996; Ozioma et al., 2022). ER surveys measure the electrical resistance of subsurface materials. Different materials exhibit varying resistivity values, with freshwater typically having higher resistivity compared to saltwater or clay formations (Loke & Barker, 1996). This characteristic allows geophysicists to use ER data to map potential locations for freshwater resources (Thiagarajan et al., 2018).

The advantages of ER surveys extend beyond their non-destructive nature. Compared to drilling, ER surveys offer a more cost-effective and efficient method for exploring large areas (Telford et al., 1990). Additionally, modern ER instruments equipped with mobile app integration allow for real-time data collection and processing in the field (future publication citation). This facilitates immediate analysis and visualization of results, significantly enhancing the efficiency of ER surveys.

This study investigates the effectiveness of ER surveys in identifying and characterizing freshwater aquifers in Isele-Mkpiteme, Nigeria. The primary objectives are twofold:

1) *Depth Interpretation:* To determine the depth of potential freshwater aquifers by analyzing ER data. This involves interpreting 2D resistivity contour maps and creating 3D resistivity models.
2) *Permeability Interpretation:* To assess the permeability, or the ease with which water can flow through the aquifer material. Permeability is a crucial factor for determining the long-term viability of a freshwater source (Niwas & Singhal, 1981). By correlating resistivity values with soil properties (e.g., high resistivity indicating medium to coarse sand), the study aims to assess the potential water flow within the identified aquifers.

Understanding potential freshwater zones' depth and

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permeability is essential for successful and sustainable water well drilling. This research contributes valuable insights into applying ER surveys for freshwater exploration in Isele-Mkpiteme.

The findings have the potential to not only reveal the location and depth of freshwater resources but also provide crucial information regarding their long-term sustainability. Ultimately, this non-destructive technique can play a vital role in ensuring access to clean drinking water for the growing population of Isele-Mkpiteme. Furthermore, the success of ER surveys in diverse geological settings, including hard rock terrains (Sk et al., 2018), highlights its versatility as a powerful tool for freshwater exploration across various landscapes.

It is important to note that while other geophysical methods, such as magnetic susceptibility surveys, can be used to complement ER surveys (Ofomola et al., 2016), this study focuses specifically on the application of ER due to its well-established effectiveness in identifying variations in water content within the subsurface. ER data, when analyzed and interpreted appropriately, can provide valuable insights into the presence, depth, and potential yield of freshwater aquifers.

2. Location of Study Area

Issele Mkpitime is one of the three communities of the. Isseles in Aniocha North Local Government Area of. Delta State, Nigeria.

Issele-Mkpitime lies in the Southern Nigerian Sedimentary Basin Complex and falls within the southern limits of the Anambra Basin (Figure 1).

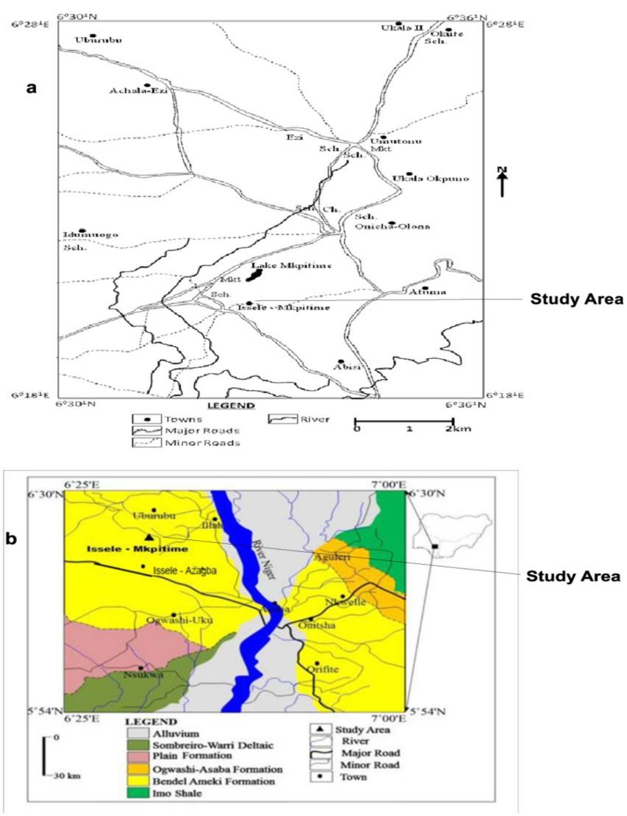

Fig. 1. Map of the study area (a) Location map (b) Geological map of the study area

In the Anambra Basin, the sedimentary fill is bounded at the base by the Santonian (folding and uplift of the Abakaliki region and a westward translation of the depocenter towards the Anambra platform and Afikpo region) and at the top by the Eocene unconformities which marked the beginning of the Niger Delta progradation. The resulting succession comprises the Nkporo Group which ages back to the deposition of marine sediments from the Late

Campanian-Early Maastrichtian and consist of Nkporo Shale, aranaceous facies of the Afikpo and Owelli Sandstone and Enugu Shale (Obi et al., 2001; Obi, 2006) Overlying the Nkporo Group is the Mamu Formation (Lower Coal Measure) and Ajali Sandstone deposited in early Maastrichtian during the overall regression of the Nkporo Group with associated postgradation (Kogbe,1989). It consists of coal measure, mudstone and silt. The Ajali Formation which marks the height of the regression at a time when the coastline was still concave has been identified as the most important aquiferous Formation in the Anambra Basin. The Mamu Formation is overlain by diachronous, fluvial-deltaic Nsukka Formation and Imo Shale deposited during the Paleocene era in the up-dip Niger Delta Basin. It marks the onset of another transgression in the Paleocene. Regional correlation (Avbovbo,1978) shows that the Palaeocene succession can be mapped southward into the Niger Delta where the Imo Formation is equivalent to the hydrocarbon-bearing Akata Formation. It consists of sand, clay, and some silt and is overlain by the regressive Ameki formation (also known as the Upper Coal measure) deposited during the Eocene regression which marked the beginning of the Niger Delta progradation (Obi et al., 2001). The Ameki Formation consisting of clay and sandstone and limestone is equivalent to the reservoir-containing Agbada Formation of the Niger Delta. The Oligocene-Miocene Ogwashi-Asaba Formation overlays the Ameki Formation and consists of coarse-grained sandstone, clay and carbonaceous shale and is capped by the continental Benin formation (Miocene-recent) made up of coarse to medium sand, silt, and clay lenses (Jan et al.,1978). Table 1 shows the geologic unit of the Anambra Basin.

Table 1
Geological unit of Anambra Basin

Age	Formation	Lithology	Basin
Miocene – Recent	Benin Formation	Coarse to medium sand, silt and clay lenses	NIGER DELTA BASIN
Oligocene – Miocene	Ogwashi Formation	Clay, carbonaceous shales and coarse grained sandstone	
Eocene	Ameki Formation (upper coal measure)	Sandstone, clay and limestone	
Paleocene	Imo Formation	Shale	ANAMBRA/AFIKPO BASIN
	Nsukka Formation	Sand, clay, silt or lignite, coals, limestone	
Maastrichtain	Ajali Formation	Sandstone and claystone/mudstone	
	Mamu Formation (lower coal measure)	Coal with clasttic sediments	
Campanian	Nkporo Formation	Shale, sandstone, clay limestone, siltstone	

Isele-Mkpiteme lies within the Niger Delta region of southern Nigeria. This region boasts a distinctive arcuate shape, formed by a wave and tide-driven prograding deltaic system. The geological history of Isele-Mkpiteme stretches back to the Eocene epoch, with sediments deposited from that period through the Quaternary period layering the area.

Underneath the surface, three main geological formations dominate the Benin, Agbada, and Akata Formations. The focus of the geophysical investigation mentioned earlier was the Benin Formation. This formation serves as a crucial aquifer, providing the area's groundwater needs.

The Benin Formation is characterized by poorly sorted coastal sands. These sands become increasingly loose and unconsolidated as you move closer to the surface. This characteristic, along with high porosity and permeability, makes the Benin Formation an efficient reservoir for storing groundwater.

While the surrounding water bodies and rainfall contribute some recharge to the aquifer, the report suggests this recharge is relatively minimal. This might be due to the presence of thick vegetation that reduces surface runoff, limiting the amount of rainwater that percolates down to replenish the aquifer. However, the existing geological properties of the Benin Formation appear to create a naturally favorable hydrological unit within the region.

In summary, Isele-Mkpiteme's location within the Niger Delta positions it amidst a geologically young and dynamic landscape. The Benin Formation, with its loose sands and high storage capacity, serves as a vital source of freshwater for the community. Understanding this geological context is crucial for effective water resource management strategies in Isele-Mkpiteme.

3. Methodology

The geophysical investigation in Isele-Mkpiteme employed a cutting-edge approach to pinpoint potential freshwater zones – the electrical resistivity (ER) survey. This methodology harnessed the power of modern technology to streamline data collection and analysis in the field.

At the heart of the system lies a mobile instrument, likely from the ADMT series (Figure 2). This innovative tool boasts Bluetooth connectivity to a dedicated mobile app. This eliminates the need for lengthy cables, allowing field personnel to seamlessly input, process, and visualize data in real-time. Gone are the days of cumbersome data management back in the lab – results are readily available on-site.

Data acquisition itself is revolutionized through the use of wireless sensor probes. Gone are the days of trailing long cables across the survey area. Instead, personnel can walk and stop at designated points to collect measurements, enhancing efficiency and significantly reducing the manpower required for the survey.

This methodology offers several key advantages. First, the mobile app facilitates the creation of 2D and 3D maps immediately after data collection. This allows researchers to visualize subsurface features and potential freshwater zones with minimal delay. Second, the operation is remarkably simple. Field personnel can efficiently complete the survey by simply walking and stopping at measurement points, eliminating the need for complex setup procedures. Third, the use of wireless technology contributes significantly to time and resource savings. A single person can conduct the entire survey, eliminating the need for a dedicated data management team. Finally, the equipment boasts strong anti-interference capabilities and incorporates field source correction and proprietary data processing techniques. This ensures the accuracy of the collected data, forming a reliable foundation for identifying freshwater resources.

Fig. 2. ADMT 2000 series resistivity equipment

In conclusion, the ER survey methodology employed in Isele-Mkpiteme showcases the power of modern technology in resource exploration. Mobile app integration, wireless data acquisition, and user-friendly operation combine to create a time-saving, efficient, and reliable approach to identifying freshwater zones, a crucial resource for the growing community of Isele-Mkpiteme.

4. Result and Interpretation

Resistivity contour maps: These maps (Figures 3 and 6) show areas with similar electrical resistivity values. Lower resistivity values typically indicate zones with more water saturation.

3D models: These models (Figures 4, 5, 7, 10 and 11) provide a visual representation of the subsurface, including the depth to freshwater and potential locations for drilling boreholes.

Depth of freshwater: The report identifies several potential freshwater zones at depths ranging from 50 meters to 120 meters (Table 2 and Figures 3, 6, 8 and 9).

Soil properties: The resistivity values also indicate the type of soil present. For example, lower resistivity values typically correspond to sand or clay layers, while higher resistivity values may indicate less porous materials like bedrock.

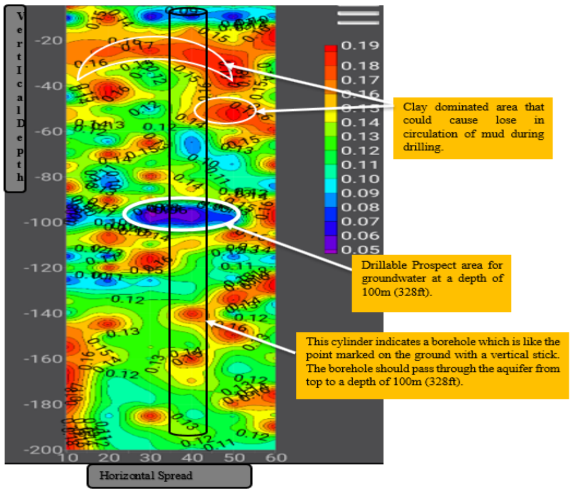

Fig. 3. Resistivity contour map of location one which shows the area or zone of portable drinking water that can be tapped by a borehole

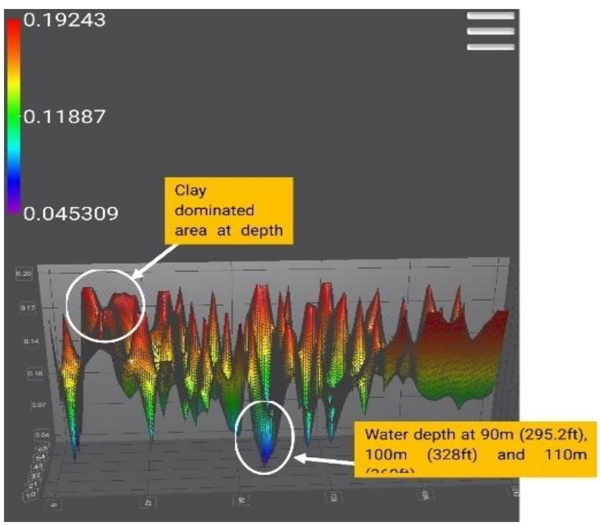

Fig. 4. A 3D model of location one which shows the depth to portable drinking water and the point to introduce screens on the PVC pipes

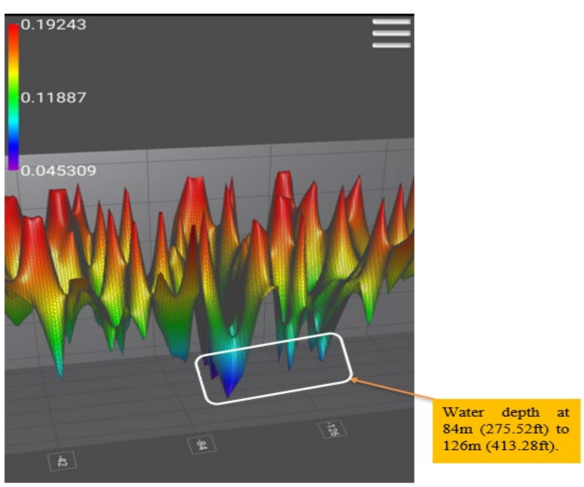

Fig. 5. A 3D model of location one confirming depth of portable drinking water

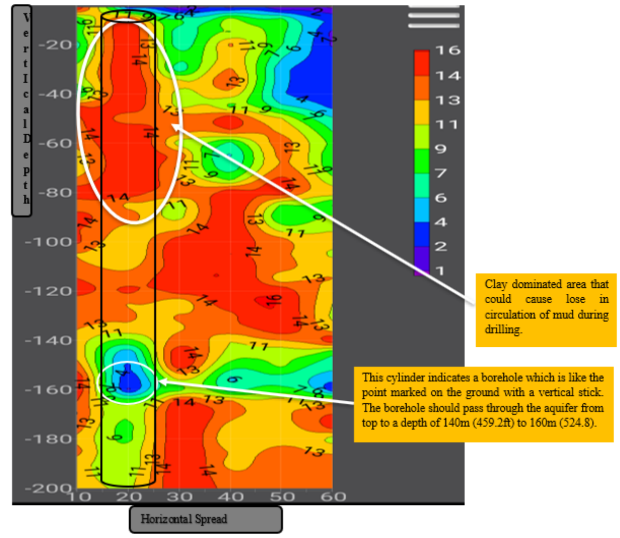

Fig. 6. A contour map of location two which indicates portable drinking water depth at 140m (459.2ft) to 160m (524.8)

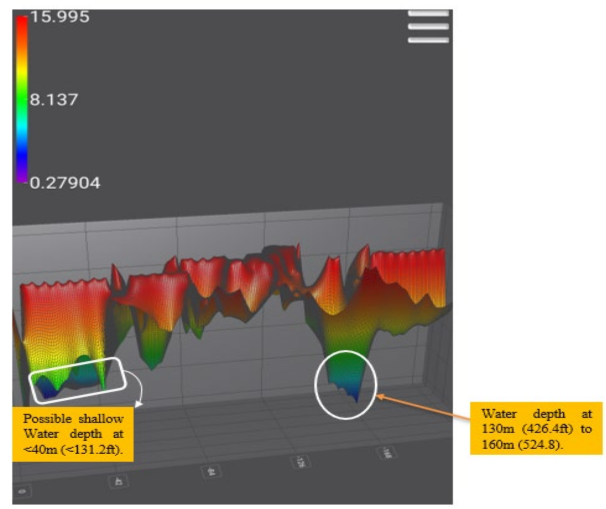

Fig. 7. A 3D model of location two which indicates portable drinking water depth at 130m (426.4ft) to 160m (524.8)

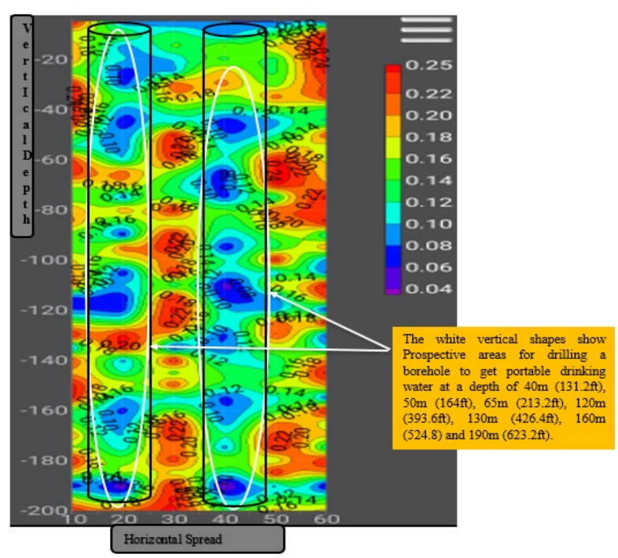

Fig. 8. A contour map of location three which indicates variable areas of portable water depths for introducing screen on the casing PVC pipe

Table 2
Depth of interest to freshwater formation

S.No.	Aquifer Depth	Resistivity Map/Line Number	Physical Property	Permeability Interval	Resistivity Nature of Soil
1	90m (295.2ft)	1	Porous and Permeable	82 – 93m	376.4 Ωm= Medium Sand
2	120m (393.6ft)	1	Excellent Porous and Permeable	120 – 138m	521.9 Ωm= Coarse Sand
3	90m (295.2ft)	2	Porous and Permeable	87 – 94m	304.1 Ωm= Medium Sand
4	50m (164ft)	3	Porous and Permeable	42 – 60m	298.6 Ωm= Sand
5	100m (328ft)	3	Good Porous and Permeable	85 – 120m	410.5 Ωm= Medium – Coarse Sand
6	120m (393.6ft)		Good Porous and Permeable	90 – 120m	621 Ωm= Coarse Sand

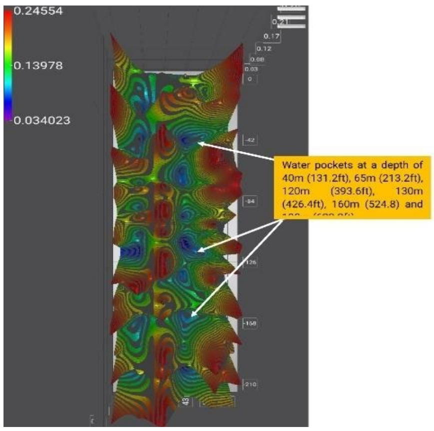

Fig. 9. A section of location three that shows areas of water pockets for inserting a borehole

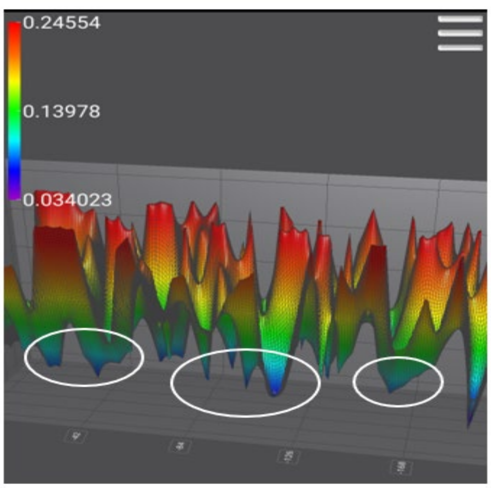

Fig. 10. A 3D view of location three showing different sections of water depths when a borehole is drilled through the soil layers

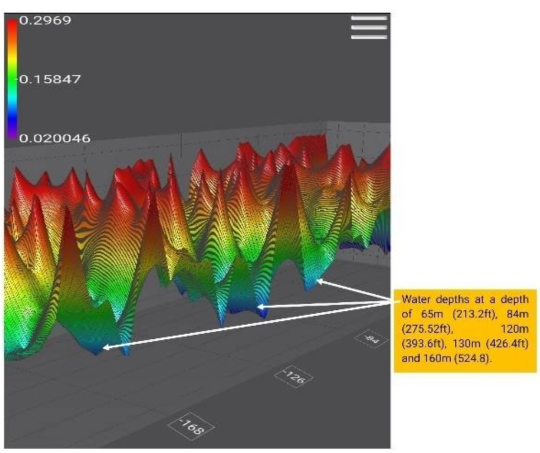

Fig. 11. A 3D model displaying various depths of fresh water for drinking can be tapped by a borehole

Figure 12 acts like a roadmap of the underground, revealing the different types of soil and rock formations. This information is essential for interpreting the other figures and ultimately choosing the most suitable locations and depths for drilling boreholes to access freshwater.

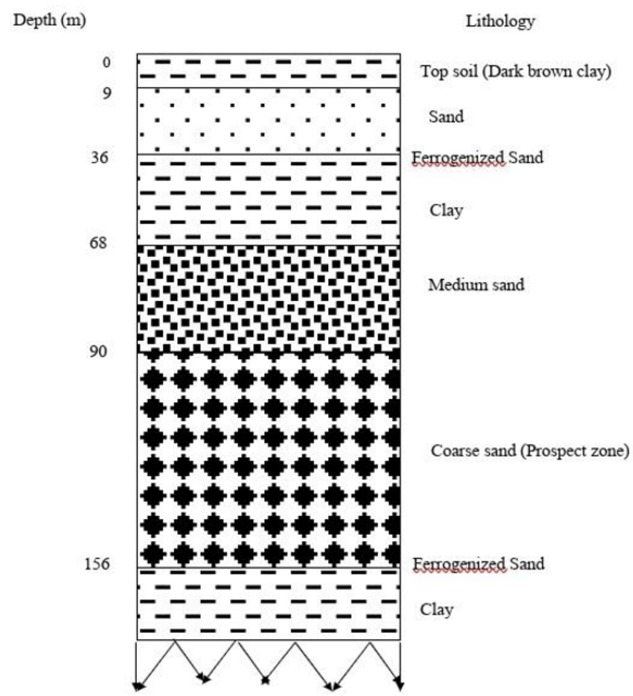

Fig. 12. A Geoelectric section of the subsurface layers showing the different soil types

5. Conclusion

In conclusion, the introduction of geophysical (resistivity) investigation to obtain a quick look at the subsurface layers in Isele-Mkpiteme, Aniosha North L.G.A., Delta State produced interesting depths where freshwater (portable drinking water) contained in porous and permeable bed units can be drilled by inserting a well for both human consumption and domestic activities.

However, five aquifer depths have been established as 50m (i.e., 164ft), 90m (295.2ft), 100m (328ft) and 120m (393.6ft) respectively as shown in the different 2D contour maps and 3D resistivity models. The aquifers have shown high resistivity properties which indicate the presence of freshwater in the soil layers.

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