

The Implications of Subsurface Resistivity Variations at Alvan Ikoku Federal University of Education, Owerri, Southeastern Nigeria

² B. C. Ejiogu, ² V.N. Nwugha, ⁵ B.O. Eke, ¹C.U. Nwachukwu, ¹ M.O. Ngumah,

³ G.J. Okore, ⁴ M.N. Fidelis

¹ Biology, ² Physics, ³ Chemistry, ⁴ Integrated Science, ⁵ Health Science Departments,
Federal University of Education Owerri Imo State, Nigeria.

doi: <https://doi.org/10.37745/ijeer.13/vol14n15061>

Published October 04, 2026

Citation: Ejiogu B.C., Nwugha V.N. Eke, B.O. Nwachukwu, C.U., Ngumah, M.O., Okore, G.J., Fidelis, M.N. (2026) The Implications of Subsurface Resistivity Variations at Alvan Ikoku Federal University of Education, Owerri, Southeastern Nigeria, *International Journal of Energy and Environmental Research*, 14 (1), 50-61

Abstract: This study investigates the implications of subsurface resistivity variations at Alvan Ikoku Federal University of Education, Owerri, Southeastern Nigeria, utilizing vertical electrical sounding (VES) techniques. The research aims to characterize the subsurface geology and assess groundwater potential within the Benin Formation, which is of late Cretaceous to Paleocene age. Eleven VES stations employing the Schlumberger array were conducted, and data were modeled using IPI2Win software to delineate geoelectric layers. Results revealed topsoil resistivities ranging from 203 $\Omega\cdot m$ to 250,000 $\Omega\cdot m$ at an average thickness of 1.31 m, indicating variability in surface materials. Middle layer resistivities varied from 16.5 $\Omega\cdot m$ to 260,000 $\Omega\cdot m$, corresponding to sandy-clay, clayey-sand, sand/gravel, and sandstone at greater depths, indicative of a predominantly sandy subsurface. The aquifer resistivities ranged from 1,795 $\Omega\cdot m$ at CKC to 134,777 $\Omega\cdot m$ at the Nursery School, suggesting zones of high permeability. The average electrical conductivity was found to be (7.4496×10^{-6}) S/m, implying low dissolved ion content in groundwater. Aquifer thickness varied from 36 m to beyond 142 m, with transverse resistances from (1.168174×10^5) $\Omega\cdot m^2$ to (1.53511003×10^8) $\Omega\cdot m^2$, indicating high lateral resistance and prolific groundwater flow. The aquifer is semi-confined beneath a sandy-clay overburden that offers natural protection from contamination. These findings have significant implications for sustainable groundwater development and management within the university campus.

Keywords: investigation, implication of subsurface, aquifer, vertical electrical sounding, Benin formation, resistivity variations

INTRODUCTION

Groundwater remains a vital component of the Earth's freshwater resources, providing essential water for domestic, agricultural, industrial, and ecological needs (Foster et al., 2016). In Nigeria, especially in urban centres and educational institutions, groundwater often serves as the primary water source due to limited access to surface water and the increasing demand for

sustainable water supply (Nwugha, 2016). Effective management and sustainable utilization of groundwater resources hinge upon a comprehensive understanding of the subsurface hydrogeological conditions, including aquifer extent, lithology, permeability, and potential contamination pathways.

Over the years, geophysical methods have become indispensable tools in hydrogeological investigations owing to their non-invasive nature, cost-effectiveness, and ability to cover extensive areas rapidly (Aizebeaya et al., 2018). Among these, Vertical Electrical Sounding (VES), based on the electrical resistivity method, has been extensively employed for delineating subsurface stratigraphy and identifying aquifer zones (Olayinka & Olorunfemi, 2009). Resistivity surveys provide critical insights into the lateral and vertical heterogeneity of subsurface materials, which directly influence groundwater occurrence, movement, and storage (Olorunfemi & Olayinka, 2014).

The resistivity of subsurface formations is determined by lithology, porosity, saturation levels, and mineralization, making it an effective parameter for hydrogeological assessments (Telford et al., 1990). For instance, saturated sand and gravel layers typically exhibit low resistivity, indicating high permeability and potential groundwater yield, whereas clay-rich formations tend to have high resistivity but act as aquitards (Aizebeaya et al., 2018). Therefore, interpreting resistivity variations at different depths can reveal the presence of aquifers, their lateral extent, thickness, and quality.

In Nigeria, numerous studies have utilized geophysical techniques to evaluate groundwater potential in various geological settings. For example, Nwugha et al. (2016) employed electrical resistivity imaging to delineate aquifer zones within the Benin Formation in Owerri, emphasizing the importance of understanding resistivity heterogeneity for effective groundwater management. Similarly, Obiefuna and Chukwu (2019) highlighted the role of geophysical methods in assessing aquifer vulnerability and contamination risks in urban environments.

The Benin Formation, which underlies the study area, comprises late Cretaceous to Paleocene sediments predominantly made up of sands, clays, and gravel, which form the principal aquifer system in southeastern Nigeria (Nwugha et al., 2012; Olamijan et al., 2020). The heterogeneity within this formation affects groundwater flow, recharge, and storage capacity, making resistivity surveys valuable for detailed characterization. Understanding the spatial and vertical resistivity variations within this formation can aid in optimal borehole siting, groundwater abstraction, and pollution mitigation.

Furthermore, urban and institutional settings like Alvan Ikoku Federal University of Education face unique challenges related to surface contamination, waste disposal, and infrastructural development (Obiefuna & Chukwu, 2019). Geophysical investigations, especially resistivity surveys, serve as vital tools for identifying sustainable groundwater sources, delineating confining layers, and assessing natural protection mechanisms against contamination.

Advancements in geophysical data acquisition and interpretation, including the deployment of computer modeling software such as IPI2Win, have improved the resolution and reliability of subsurface resistivity profiles (Olayinka & Olorunfemi, 2009). These tools facilitate detailed layered earth models, thereby enabling more accurate assessment of aquifer characteristics relevant to sustainable development.

This study aims to investigate the subsurface resistivity variations within Alvan Ikoku Federal University of Education, Owerri, using VES techniques. The specific objectives include delineating aquifer geometry, assessing lateral and vertical heterogeneity, and understanding the implications of resistivity variations for groundwater development, pollution control, and sustainable management. The findings are expected to contribute valuable insights into the geoelectric properties of the Benin Formation within the study area, offering guidance for effective groundwater exploration and management in southeastern Nigeria.

Location and Accessibility of The Study Area

Alvan Ikoku Federal University of Education lies on the plains beside Nworie River in the heart of Owerri in the present-day Imo State in the South-Eastern Nigeria. It is easily accessible through a popular Orlu Road from Orlu from the northern part, Okigwe and Aba from the East through Okigwe Road and Douglas Road respectively and Port Harcourt from Port Harcourt road, Figure 1a.

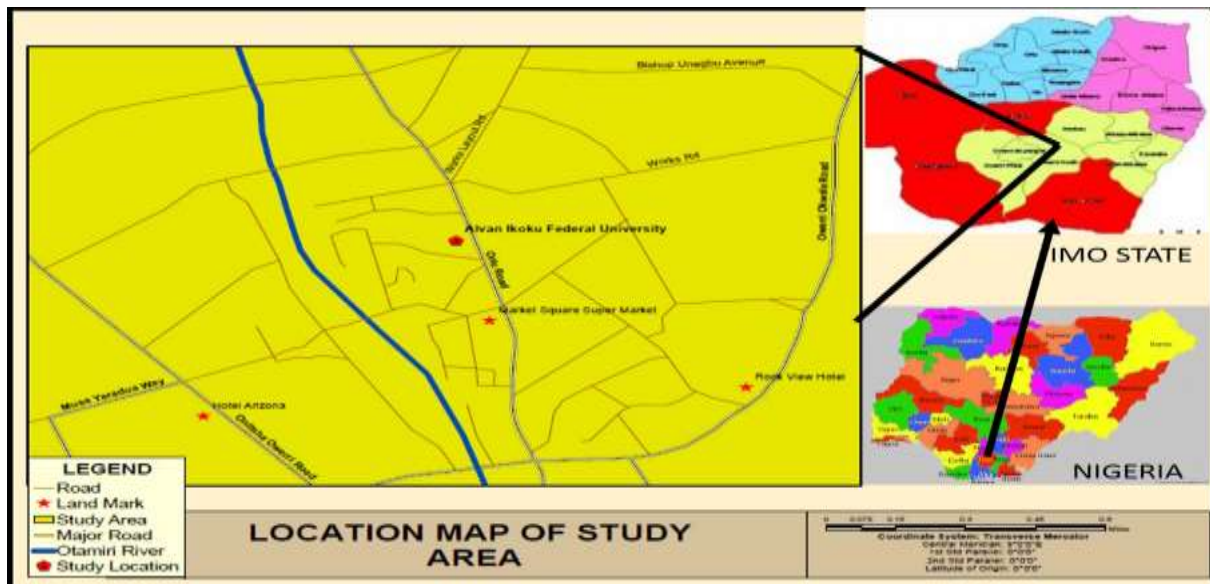


Figure 1a: Location and Accessibility of the Study Area

Geology of the Area

Owerri is situated within the southeastern Nigeria region, predominantly underlain by the Benin Formation, which is part of the West African Cretaceous to Paleocene sedimentary sequences (Ofoegbu, 1985). This formation is characterized by late Cretaceous to Paleocene

deposits, consisting mainly of sands, clays, and sandstones, which have significant implications for groundwater occurrence and movement (Egboka et al., 1990).

The sediments of the Benin Formation in Owerri are generally heterogeneous, with alternating layers of permeable sands and less permeable clay lenses. This stratigraphy influences the groundwater flow patterns and storage capacity within the aquifer system. The sands are typically porous and serve as primary aquifers, capable of storing substantial amounts of groundwater, whereas the clay layers act as confining units, limiting vertical flow and acting as barriers to recharge (Opara et al., 2012).

Hydrogeologically, the aquifer system in Owerri is primarily unconfined, with recharge occurring through infiltration of rainfall and lateral flow from surrounding areas. The high permeability of the sandy units facilitates the movement of groundwater, which is often tapped through boreholes and hand-dug wells. However, the presence of clay lenses can compartmentalize the aquifers, leading to variations in water quality and yield (Igwebuike G. et al., 2014).

Furthermore, the resistivity variations within the Benin Formation, as revealed through geophysical investigations such as electrical resistivity imaging, can be instrumental in delineating aquifer boundaries, identifying zones of high porosity, and optimal borehole siting (Nwugha et al., 2016). Understanding these subsurface characteristics is crucial for sustainable groundwater development, especially in urban centres like Owerri where groundwater is a major source of domestic and industrial water supply.

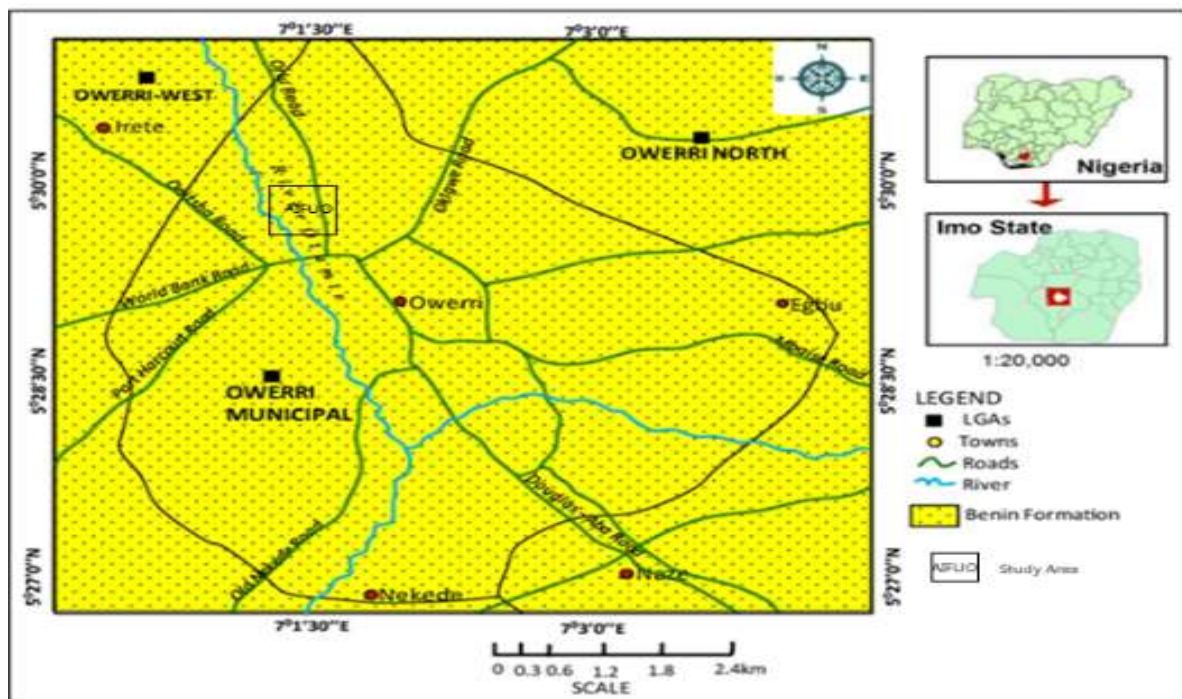


Figure 1b: Geology of Owerri and the Environments

METHODOLOGY

Eleven Vertical Electrical Sounding (VES) stations were systematically conducted across the university campus utilizing the Schlumberger array, a widely adopted configuration for delineating layered subsurface conditions due to its suitability for resistivity investigations at varying depths (Nwugha et al, 2016). The data acquisition involved the deployment of a terrameter, which measures electrical resistance within the subsurface, and was complemented by the use of IPI2Win software for data processing and modeling to interpret resistivity variations and layer thicknesses (Afolabi et al., 2018). The resistivity values obtained facilitated the identification of different subsurface materials and aquifer characteristics.

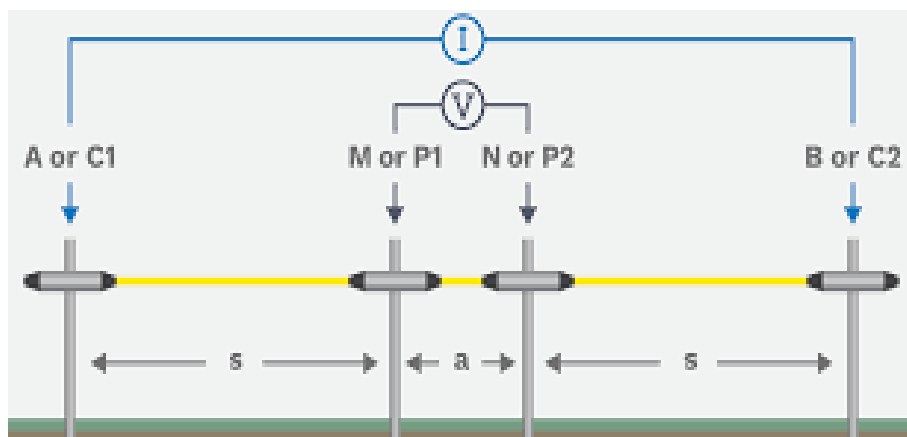


Figure 3: Electrical Resistivity Method Showing the Schlumberger Array

A schematic representation of the Schlumberger array is illustrated in Figure 3. The array comprises four collinear electrodes arranged symmetrically around a central point, a configuration optimal for Vertical Electrical Sounding (VES) aimed at assessing resistivity variations with depth (Dahlin & Zhou, 2004). The Terrameter, functioning as a resistivity meter, is positioned at the midpoint of the array, connecting to the electrodes via cables. In operation, the terrameter transmits a controlled current (I) through the outer electrodes (A and B) and measures the resulting voltage difference (ΔV) between the inner electrodes (M and N). These measurements are used to calculate the apparent resistance ($R = \Delta V / I$) and apparent resistivity (ρ_a), incorporating geometric factors based on electrode spacing (Telford et al., 1990). The measurement procedure involves sequentially increasing the current electrode spacing (AB), while maintaining a small and constant potential electrode spacing (MN). This approach allows for profiling resistivity at increasing depths. When voltage readings become too low for reliable measurement, the potential electrode spacing (MN) is increased, and the process continues to extend the depth of investigation. This systematic variation of electrode spacing facilitates the generation of sounding curves that reflect resistivity variations with depth (Dahlin & Zhou, 2004). Data processing entailed converting raw field measurements into

apparent resistivity values using appropriate geometric correction factors. The processed data were subsequently analyzed using IPI2Win software, which employs inversion algorithms to model the subsurface resistivity distribution in two dimensions. The results are presented as sounding curves, generated by plotting apparent resistivity against half-current electrode spacing on double logarithmic scales, enabling interpretation of the layered geological structures (Adebayo A. S.et al., 2024).

RESULTS AND DISCUSSION

The aquifer parameters such as aquifer resistivity, aquifer thickness, electrical conductance, Longitudinal conductance, Transverse Resistance and Transmissivity are presented in Table 1.

Table 1: Aquifer Parameters within the study area

VES Number	Longitude	Latitude	Location	Aquifer Resistivity	Aquifer Thickness	Electrical Conductivity	Longitudinal Conductance	Transverse Resistance	Transmissivity	Av. K-Value	Storativity
VES 1	7.0240095	5.4983901	Centre of Excellence	25143	119.5	3.9773E-05	0.00475281	3004588.5	0.01195	0.0001	0.0003585
VES 2	7.0225484	5.498618	Agric Department	13239	120.5	7.5534E-05	0.0091019	1595299.5	0.01205		0.0003615
VES 3	7.02198	5.49912	Hostel D	36385	126.9	2.7484E-05	0.0034877	4617256.5	0.01269		0.0003807
VES 4	7.02259	5.500498	Pavilion	10124	120.6	7.8775E-05	0.01191229	1220954.4	0.01206		0.0003618
VES 5	7.025388	5.499578	Alvan Gate	39950	130.7	2.5031E-05	0.00327159	5221465	0.01307		0.0003921
VES 6	7.026802	5.49816	CKC	1795	61.9	0.00055703	0.03448468	111110.5	0.00619		0.0001857
VES 7	7.0274	5.5012	HomeecDept	3415	127.3	0.00029283	0.03727672	434729.5	0.01273		0.0003819
VES 8	7.0274	5.5001	Alv Nur. Sch.	134777	113.9	7.4197E-06	0.0008451	15351100	0.01139		0.0003417
VES 9	7.02166	5.49776	NRiver/ Sand	66177	141.9	1.5111E-05	0.00214425	9390516.3	0.01419		0.0004257
VES 10	7.02455	5.4966798	Nathan E.	3227	36.2	0.00030989	0.01121785	116817.4	0.00362		0.0001086
VES 11	7.0263	5.500275	Centr For Ent	26534	125.6	3.7687E-05	0.00473355	3332670.4	0.01256		0.0003768

Aquifer resistivity values across the study area exhibited considerable variation, ranging from a minimum of 1,795 $\Omega \cdot m$ (VES 6) to a maximum of 134,777 $\Omega \cdot m$ (VES 8). This wide range indicates substantial heterogeneity in subsurface lithology and saturation levels, with low resistivity zones generally associated with higher saturation and permeability, thus representing more favorable conditions for groundwater extraction (Olorunfemi et al., 2010; Olatunji et al., 2018). Conversely, high resistivity areas may require further investigation to assess their potential as aquifers, Table 1, Figure 4.

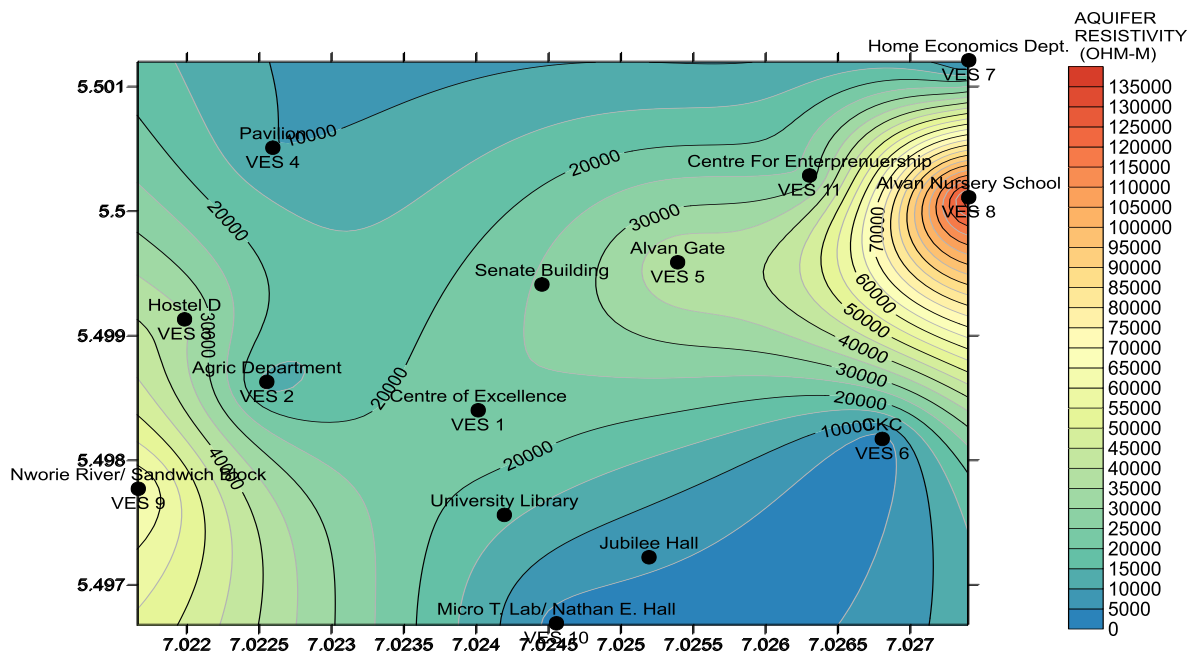


Figure 4: Spatial Aquifer Resistivity Image of the Aquifer Thickness

Aquifer thicknesses varied from 36.2 meters (VES 10) to 141.9 meters (VES 9), highlighting significant spatial heterogeneity in water-bearing formations. Regions such as VES 9, VES 3, and VES 7 with thicker aquifers are promising for reliable groundwater sources, whereas thinner zones may need additional exploration to determine their suitability for water supply or other uses (Adebayo A.S. et al, 2024). These variations underscore the importance of site-specific assessments for sustainable groundwater management Figure 5.

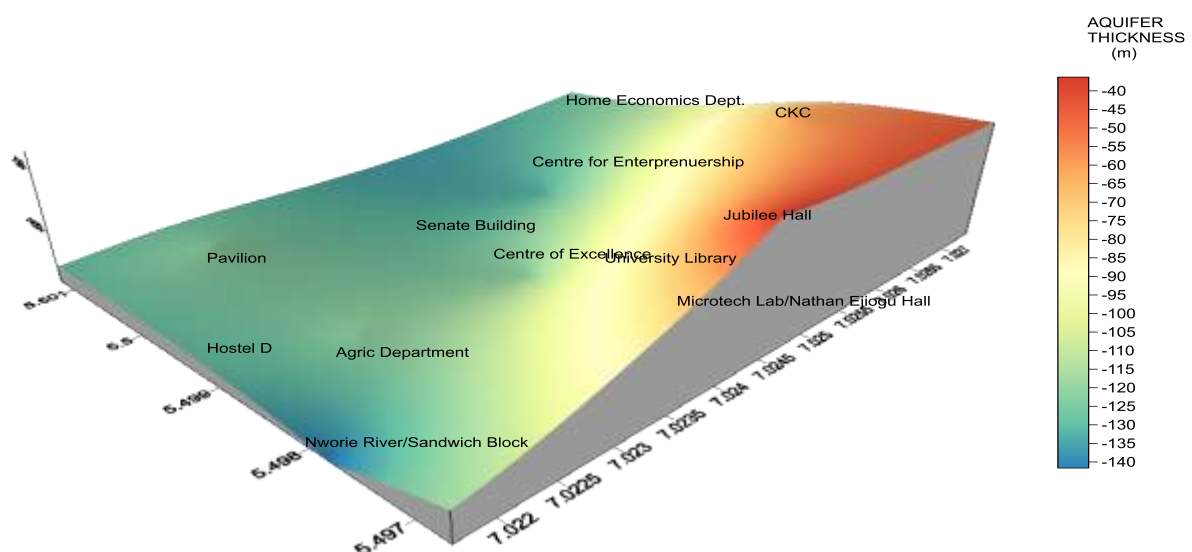


Figure 5: 3-D model of the Aquifer Thickness

Electrical conductivity (EC) values ranged from as low as 7.4197×10^{-6} S/m at Alvan Nursery School to 0.00055703 S/m at CKC, reflecting differences in subsurface mineralization and saturation. Zones with very low EC indicate relatively pure, fresh groundwater suitable for domestic and agricultural purposes, whereas higher EC zones may pose challenges for use without treatment, potentially indicating salinity or contamination risks (Agada L.E. et al., 2023). The heterogeneity in EC underscores the need for comprehensive water quality testing and continuous monitoring to ensure safe groundwater utilization, Figure 6.

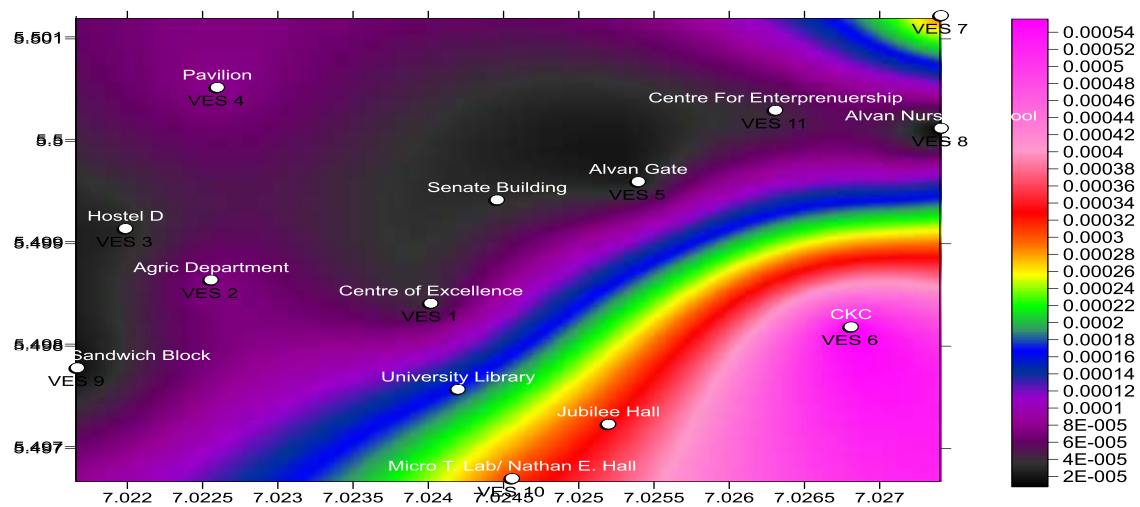


Figure 6: The Electrical Conductance (EC) image of the Aquifer

Longitudinal conductance values ranged from 0.0008451 (Alvan Nursery School) to 0.03727672 (Home Economics Department), implying varying degrees of conductive material presence, such as saturated clays or sediments that facilitate vertical flow (Agada L. and Yakubu M.S, 2023), Figure 7.

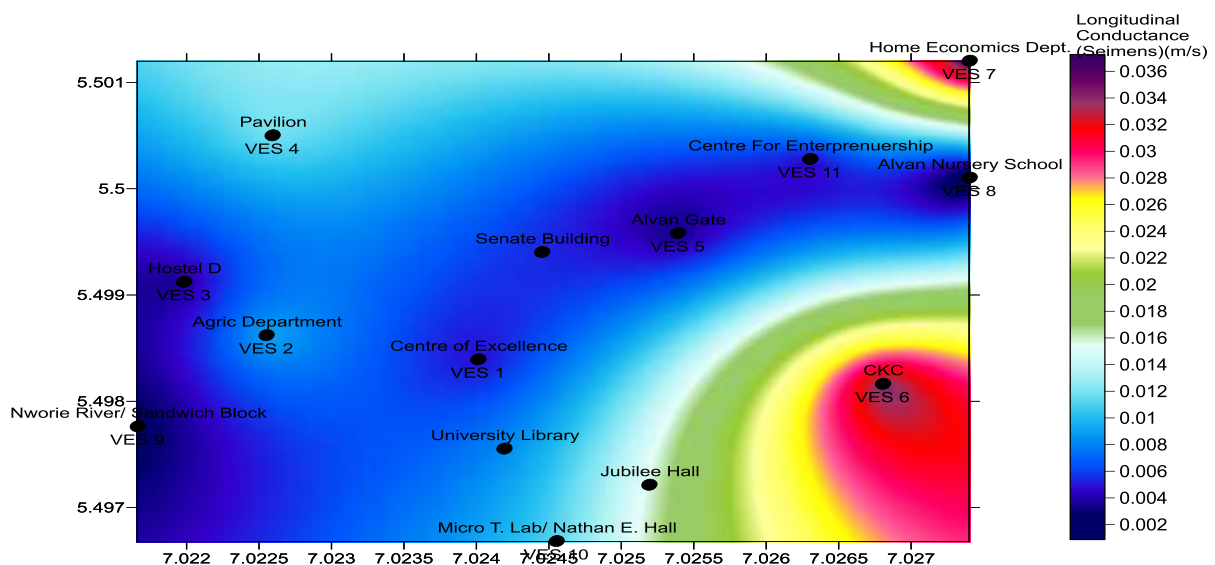


Figure 7: The Longitudinal Conductance (LC) image of the Aquifer

Similarly, transverse resistance values ranged from 111,110.5 $\Omega \cdot m$ (CKC) to 15,351,100 $\Omega \cdot m$ (Alvan Nursery School), indicating differences in lateral permeability and aquifer transmissivity. High transverse resistance suggests more resistive, potentially thicker aquifer zones with substantial storage capacity, whereas low resistance points to more permeable, transmissive layers, Figure 8.

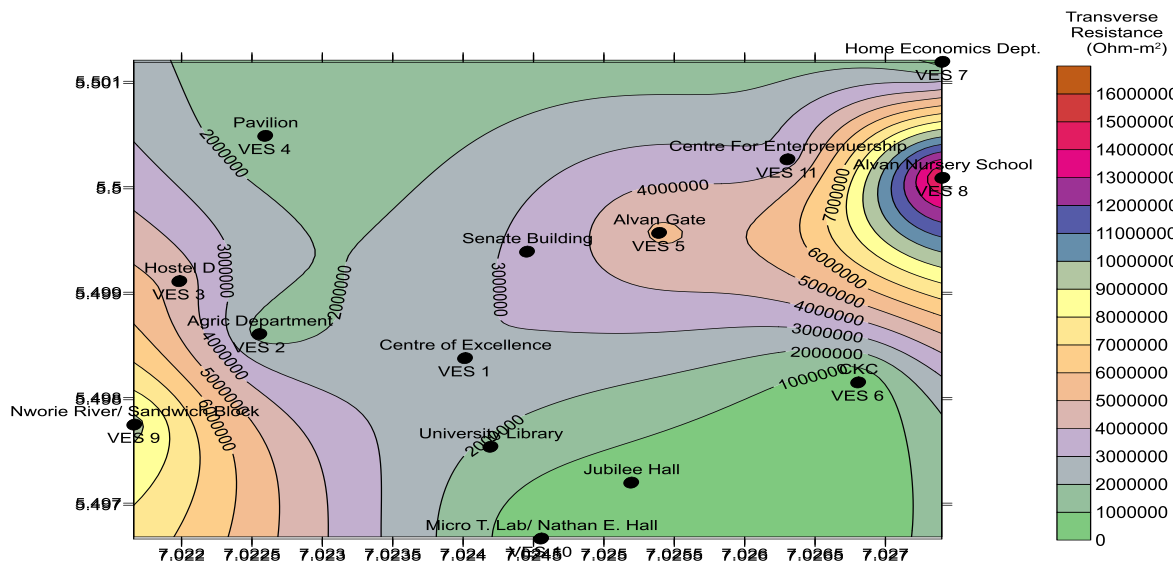


Figure 8: The Spatial Distribution of Transverse Resistance within the Study Area.

Three geophysical profiles (AA', BB', and CC') revealed subsurface lithology characterized by sand, silty-sand, clayey-sand, gravel, and sandstone formations. Notably, clay and sandy-clay layers between the centre of excellence and the university gate extend to depths of 20–50 meters, acting as confining units for the underlying aquifer. These profiles support the resistivity findings, confirming the presence of semi-confined aquifers protected by overlying clay-rich layers, Figure 9.

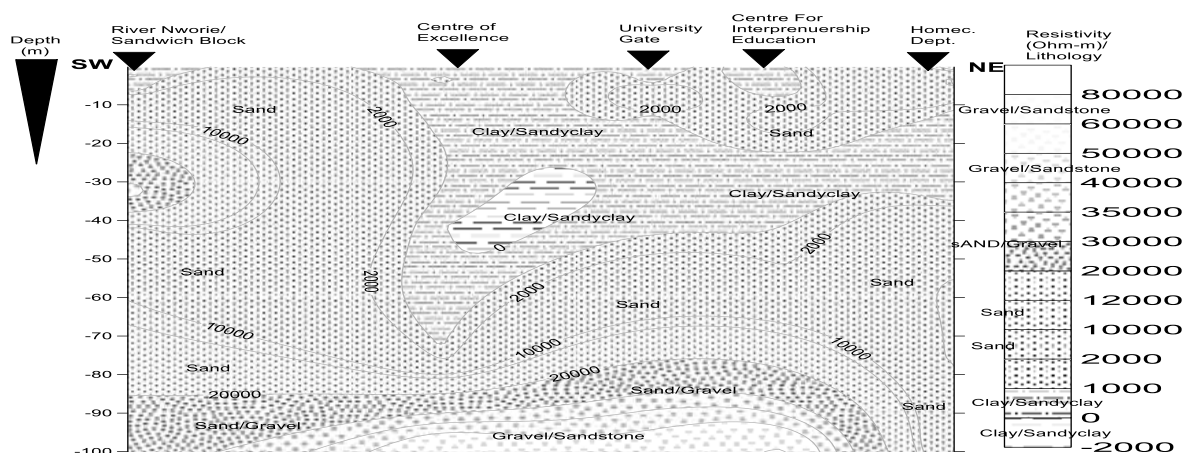


Figure 9: Showing Profile AA' From Nworie River to Homec Dept. in the SW-NE Direction

The topsoil resistivities ranged from $203 \Omega \cdot m$ to $250,000 \Omega \cdot m$, with an average thickness of approximately 1.31 meters, indicating variable moisture content and soil composition affecting surface water infiltration and contamination pathways (Nwugha, et al 2016).

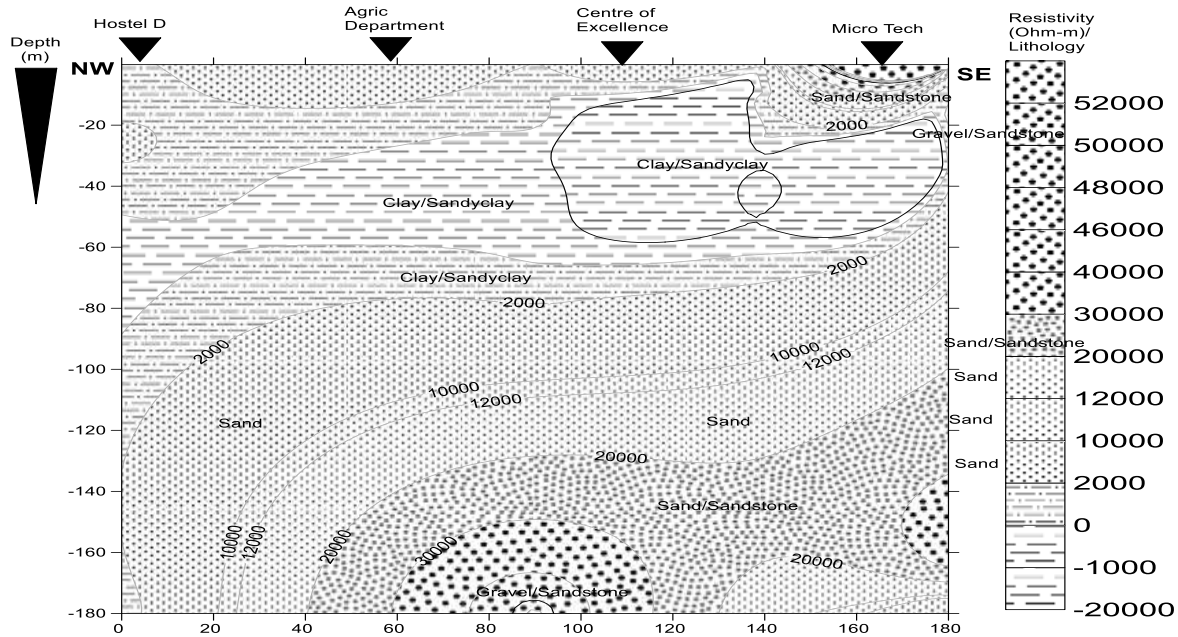


Figure 10: Showing Profile BB' from Microtech Block to Hostel D in the SE-NW Direction

The middle-layer resistivities, spanning from $16.5 \Omega \cdot m$ to $260,000 \Omega \cdot m$, correspond to sandy, clayey, and sandstone formations at greater depths, which constitute the main aquifer zones, Figure 11.

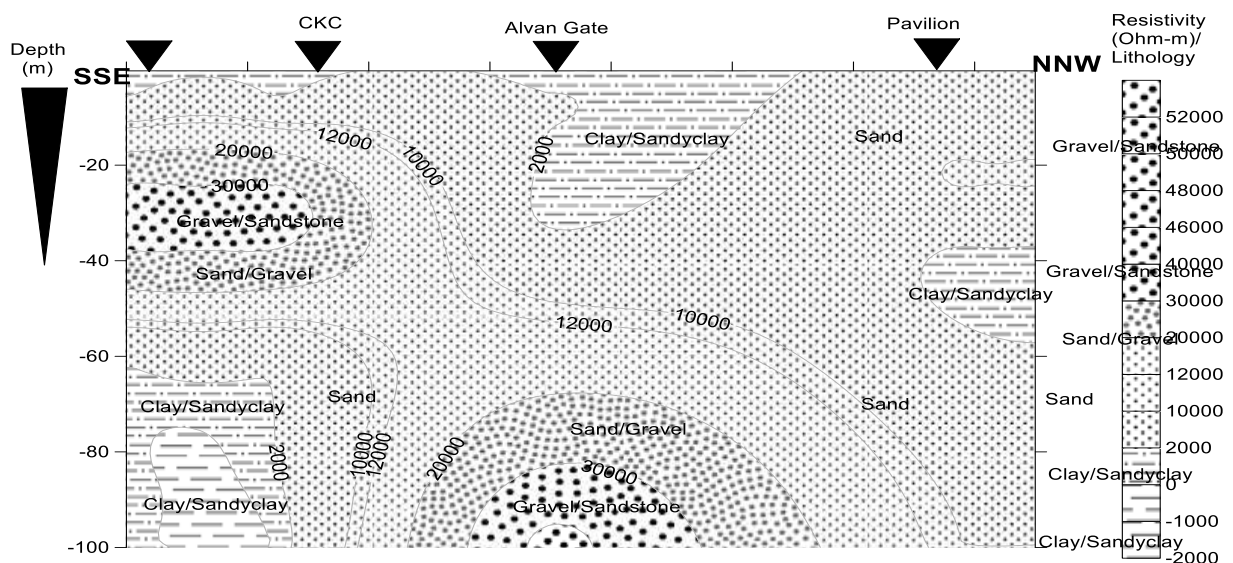


Figure 11: Showing Profile CC' from CKC to Pavilion in the (SSE-NNW) Direction

Implications for groundwater management suggest that the aquifer's semi-confined nature, with a sandy-clay overburden, offers resilience against surface contamination but necessitates careful regulation of extraction to prevent overexploitation. The high transverse resistance and resistivity variations imply a sustainable water resource if properly managed, with site-specific assessments guiding borehole placement and development strategies (Adebayo A.S. et al., 2024).

CONCLUSION

The geophysical investigation indicates that the subsurface aquifer at Alvan Ikoku Federal University of Education possesses significant potential for sustainable groundwater extraction. The heterogeneity in resistivity, thickness, and transmissivity emphasizes the importance of integrating geophysical data with hydrochemical analyses for comprehensive water resource evaluation and management.

REFERENCES

- A. S. Adebayo , O. A. Dasho , A. P. Olufemi , O. A. Babatunde and O. Oghenenyovwe (2024). Electrical Resistivity Survey for Groundwater Investigation in Parts of Osun State, Southwestern Nigeria. *Arid Zone Journal of Technology & Environment (AZOJETE)*, 20(3):625-632. ISSN 1596-2490; e-ISSN 2545-5818, www.azojete.com.ng
- Agada Livinus & Yakubu Minyi Samu (2023). Estimation of aquifer hydraulic parameters using electrical resistivity method: A case study for Damaturu, Northeast Nigeria. *Dutse Journal of Pure and Applied Sciences* 9(2a):191-202
DOI: 10.4314/dujopas.v9i2a.19
- Agada, L. E., Yakubu, M. S. and Lateef, R. A.(2023). Investigation of the Impact of Drought on Groundwater: A Case Study of Yobe State, Nigeria. *Nigerian Journal of Physics (NJP)* ISSN: 1595-0611 Volume 32(2), June 2023
- Dahlin, T., & Zhou, B. (2004). A numerical comparison of 2D resistivity imaging with different electrode arrays. *Journal of Applied Geophysics*, 55(4), 353-376.
- Dara, A., Olorunfemi, M. O., & Oladipo, O. (2012). Groundwater potential assessment using electrical resistivity method in southwestern Nigeria. *Environmental Monitoring and Assessment*, 184(5), 3383–3394.
- Egboka, B. C. E., Nwankwoala, H. O., & Okoye, C. O. (1990). Hydrogeological investigations of the Benin Formation aquifer in southeastern Nigeria. *Environmental Geology*, 16(4), 243-251. <https://doi.org/10.1007/BF01347280>
- Igwebuike G. Ndubuisi, Nwatarali N. Alex, Okonkwo C. Austin, Akinola A. Sunday(2014). Evaluation of Aquifer Hydraulics using Electrical Resistivity Method: A case of Nsugbe sandstone, Anambra State, Southeastern Nigeria *International Research Journal of Geology and Mining (IRJGM)* (2276-6618) Vol. 4(3) pp. 64-75, April, 2014 DOI: <http://dx.doi.org/10.14303/irjgm.2014.017>
- N. Nwugha Victor, I. Okeke Pamela, A. O. Selemono, C. Ibe Geogeline, P.C. Njoku, H. Oluwaseun (2016). Effects of Leaking Septic Tanks on Underground Water Quality in Owerri Municipal, Imo State, Nigeria. *British Journal of Applied Science and Technology*. 12(3): 1-10, 2016. Article No. BJASt. 20410. ISSN 2231-0843. NLM ID 101664541 DOI: 10.9734/BJAST/2016/20410.

- Nwagbara Johnbosco O., Nwugha Victor N. Ulor Miriam O. (2012). Electrical Resistivity Study for vulnerability of groundwater pollution: a case study of Landfill Dumpsites in Owerri, Imo Ste International Journal of Emerging trends in Engineering and Development ISSN 2249-6149 Issue 2, Vol 4 (May-2012) ISSN 2249-6149
- Ofoegbu, C. O. (1985). Hydrogeology of the Benin Formation in southeastern Nigeria. Geological Survey of Nigeria Bulletin, 11, 45-56.
- Opara, A.I., Onu, N.N. and Okereafor, D.U., 2012: Geophysical Sounding for the Determination of Aquifer Hydraulic Characteristics from Dar-Zurrock Parameters: A Case Study of Ngor Okpala, Imo River Basin, Southeastern Nigeria, Pacific Journal Science Tech. 13:590-603.
- Telford, W. M., Geldart, L. P., Sherif, R. E., & Spieth, M. (1990). Applied Geophysics. Cambridge University Press.
- V. N. Nwugha, A. C. Ezebunanwa, P. I. Okeke, A. I. Chinaka. (2012) Environmental Implications of Leachates of Sewage Dumpsites in Some Parts of Owerri, Southeastern Nigeria. *The Pacific Journal of Science and Technology*. 22 (1) 254-261. ISSN 1551-7624. <http://www.akamaiuniversity.us/PJST.htm>