iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VIII **Month of publication:** August 2026

DOI: https://doi.org/10.22214/ijraset.2026.84689

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VIII Aug 2026- Available at www.ijraset.com

Integrated ERT and PQWT Investigation for Sustainable and Climate-Resilient Groundwater Development in the Basement Complex Terrain of Oban Farmland, Southeastern Nigeria

Mfoniso U. Aka[1], Okechukwu E. Agbasi[2]
Department of Physics, Federal University of Technology Ikot Abasi, Nigeria

Abstract: Groundwater is essential for agricultural development, particularly where surface-water resources are limited. However, groundwater occurrence in crystalline basement terrains is difficult to predict because lithology and geological structures vary considerably over short distances. This study evaluated the groundwater potential of Oban Farmland, Akamkpa Local Government Area, Cross River State, Nigeria, using integrated Electrical Resistivity Tomography (ERT) and Portable Quantum Water Detector (PQWT) surveys. ERT delineated vertical and lateral variations in subsurface resistivity, while PQWT provided reconnaissance information for identifying favourable groundwater zones. Two ERT profiles were acquired, processed, and inverted using RES2D software. Resistivity values ranged from 50.70 to 11,830.00 Ωm along ERT-01 and from 20.50 to 1,140.00 Ωm along ERT-02, indicating substantial subsurface heterogeneity. Low-resistivity zones were interpreted as weathered, potentially water-bearing materials, whereas very high-resistivity zones represented relatively dry lateritic deposits and fresh crystalline basement. The subsurface comprises lateritic topsoil, weathered materials, fractured basement, and fresh basement rock. Weathered-zone thickness ranged from approximately 24 to 78 m. Weathered and fractured basement units constitute the principal aquifers because they provide groundwater storage and flow pathways. Fractured zones with resistivity values of approximately 852–1,165 Ωm were identified as promising drilling targets. Integrated interpretation indicated suitable borehole depths of approximately 70–135 m, especially where thick weathered materials coincide with fractured basement structures. The results demonstrate that combining ERT and PQWT significantly improves borehole siting and reduces groundwater-exploration uncertainty in complex basement environments. Borehole logging, pumping tests, and water-quality analyses are recommended to validate aquifer conditions and support sustainable agricultural groundwater development.
Keywords: Hydrogeophysical integration; Weathered–fractured basement aquifer; Borehole-site selection; Agricultural groundwater development.

I. INTRODUCTION

Groundwater constitutes a vital source of freshwater, particularly in regions where rivers, streams, and other surface-water resources are seasonal or insufficient. Across many parts of sub-Saharan Africa, groundwater supports drinking-water supply, domestic activities, agriculture, and other livelihood needs, especially in communities underlain by crystalline basement rocks (Nasara et al., 2025; Agyemang, 2025; Obuobie et al., 2025). However, groundwater exploration in crystalline basement terrains is inherently challenging because fresh basement rocks generally possess very low primary porosity and permeability. Groundwater occurrence is therefore controlled mainly by secondary features, including weathered layers, fractures, joints, and fault zones. The thickness, continuity, and interconnection of these features may vary considerably over short distances, making groundwater exploration and borehole siting difficult (Aizebeokhai & Oyeyemi, 2017; Adebisi et al., 2026).

The demand for reliable groundwater is particularly important in agricultural areas, where a dependable water supply is required to sustain irrigation during dry periods and seasons of inadequate rainfall. Access to groundwater enables farmers to maintain crop production, improve food security, and reduce the effects of seasonal rainfall variability and changing climatic conditions (Fartassi et al., 2025; Teweldebrihan & Dinka, 2025). Nevertheless, drilling boreholes without adequate knowledge of subsurface conditions can result in unsuccessful or low-yielding wells. Such outcomes represent substantial financial losses and the inefficient use of time and resources, particularly in large-scale agricultural projects (Akaolisa et al., 2022; Adeoti et al., 2024). Consequently, detailed subsurface investigation is essential before borehole drilling.

Geophysical methods provide a relatively rapid and non-invasive means of investigating subsurface conditions without extensive excavation. Electrical resistivity techniques are among the most widely applied methods in groundwater exploration because geological materials exhibit contrasting electrical properties. These properties are influenced by lithology, mineral composition, porosity, moisture content, degree of weathering, fracture intensity, water saturation, and pore-water conductivity (Oyeyemi et al., 2023). Variations in subsurface resistivity can therefore be used to differentiate lateritic materials, weathered zones, fractured basement rocks, and relatively fresh crystalline basement. However, resistivity values must be interpreted carefully because low resistivity may indicate either water-saturated materials or clay-rich formations.

Electrical Resistivity Tomography (ERT) is particularly useful because it produces a two-dimensional representation of the lateral and vertical distribution of subsurface resistivity. This capability facilitates the identification of weathered zones, fractured bedrock, buried basement depressions, and lithological boundaries that may influence groundwater storage and movement (Imani et al., 2020; Akingboye & Osazuwa, 2021). Previous investigations have demonstrated the effectiveness of ERT in delineating potential groundwater-bearing zones within crystalline basement environments (Lee et al., 2021; Akpa et al., 2025).

The Portable Quantum Water Detector (PQWT) has also been applied as a reconnaissance tool in groundwater investigations. However, because its scientific basis and reliability remain subjects of continuing evaluation, PQWT results should not be interpreted independently or used as the sole basis for selecting borehole locations. Instead, the method may provide supplementary reconnaissance information when its responses are carefully compared with results obtained from established geophysical techniques (Isah et al., 2022; Shuaibu, 2024).

Accordingly, this study integrates ERT and PQWT surveys to investigate groundwater potential at Oban Farmland. The specific focus is to delineate the principal subsurface geological units, identify potentially water-bearing weathered and fractured basement zones, recommend suitable borehole locations and drilling depths, and reduce the risk of unsuccessful groundwater development. Integrating the two methods is expected to strengthen subsurface interpretation and support sustainable groundwater development for agricultural activities in tropical crystalline basement environments.

II. STUDY AREA AND GEOLOGICAL DESCRIPTION

Oban Farmland is located in Oban Community, Akamkpa Local Government Area of Cross River State, southeastern Nigeria. The study area lies between latitudes 5°28′00″ N and 5°32′00″ N and longitudes 8°40′00″ E and 8°50′00″ E. It covers approximately 881,620 m², equivalent to about 0.882 km². The farmland is accessible through the Calabar–Ekang road corridor and is situated approximately 57.2 km from Calabar metropolis and 7.65 km from Oban settlement, as shown in Figure 1.

The study area occurs within a humid tropical rainforest environment characterized by dense vegetation, high seasonal rainfall, and relatively limited infrastructure. Access to different parts of the farmland is primarily through narrow tractor routes and footpaths. These conditions can make geophysical field investigations difficult, particularly during periods of intense rainfall when the pathways become wet and less accessible. The terrain is generally low to gently undulating, with elevations ranging from approximately 142 to 173 m above mean sea level. Surface drainage exhibits predominantly parallel to trellis patterns, indicating that drainage development is partly controlled by the underlying geological structures, fracture systems, and differential weathering of the basement rocks (Ekwok et al., 2020).

Geologically, Oban Farmland is underlain predominantly by granite belonging to the Precambrian Nigerian Basement Complex. The broader basement terrain comprises crystalline rocks such as granite, gneiss, charnockite, and schist, together with occasional younger granitic intrusions (Uchenna et al., 2023). The granitic basement within the study area has undergone varying degrees of weathering, fracturing, and structural deformation, producing subsurface zones that may support groundwater accumulation and movement.

Fresh crystalline basement rocks generally have negligible primary porosity and low permeability. Consequently, groundwater storage and transmission depend mainly on the weathered overburden and secondary structural features, including fractures, joints, and faults within the basement rocks (Akiang et al., 2024). The groundwater potential of the area is therefore controlled by the thickness and composition of the weathered layer, the density and connectivity of fractures, fracture aperture, and the degree of hydraulic connection between the weathered overburden and fractured basement.

The thickness of the weathered layer and the spatial distribution of basement fractures may vary substantially across short distances. Locations where a thick weathered layer directly overlies and is hydraulically connected to fractured basement are generally considered the most favourable groundwater targets. At such locations, the weathered materials provide groundwater storage, while interconnected fractures within the basement facilitate groundwater movement and may enhance borehole yield.

Although streams occur within and around Oban Farmland, there are currently no known productive boreholes within the investigated area. Groundwater availability and aquifer productivity therefore remain uncertain. This uncertainty emphasizes the need for a detailed hydrogeophysical investigation to characterize the subsurface, identify potentially productive groundwater-bearing zones, and determine appropriate locations and depths for borehole drilling. A reliable understanding of the geological and hydrogeological conditions is essential for supporting sustainable groundwater development and meeting the irrigation requirements of the farmland.

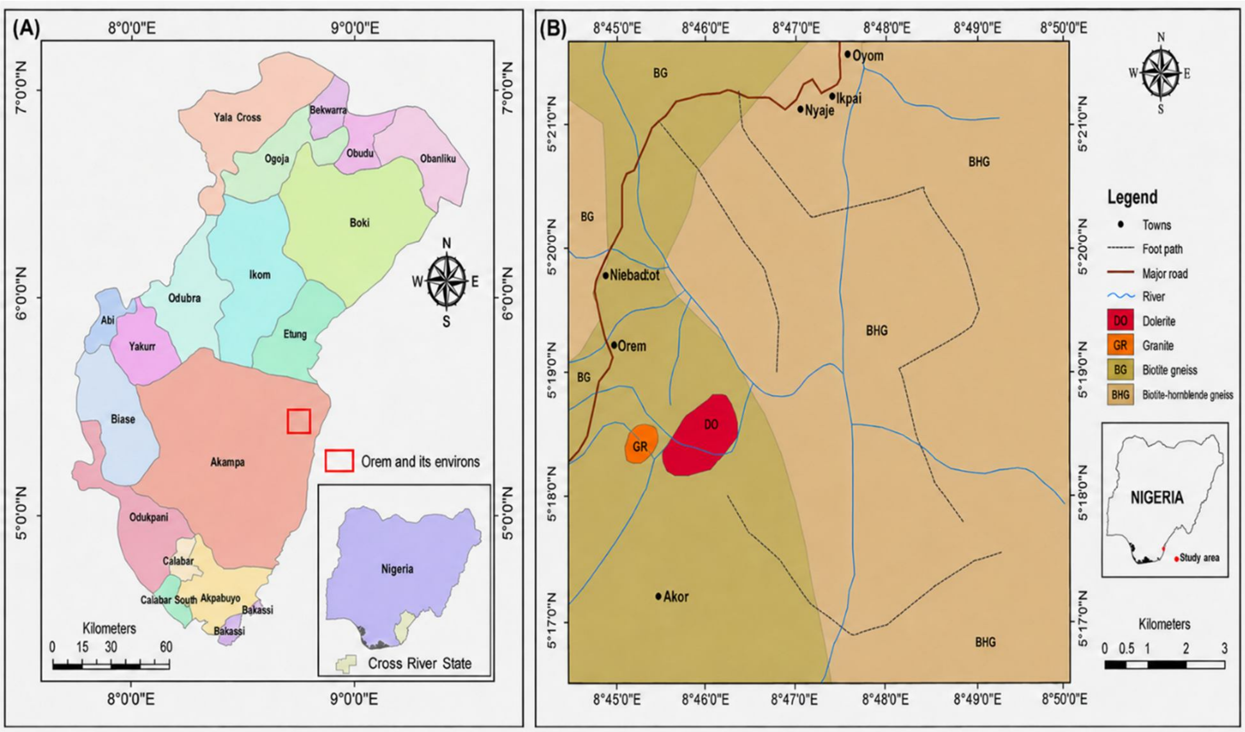


Figure 1: Location and geological setting of Oban Farmland: (A) location of the study area within Cross River State; (B) local geology, drainage network, access routes and settlements.

III. METHODOLOGY

A. *Electrical Resistivity Tomography Data Acquisition*

Two-dimensional Electrical Resistivity Tomography (ERT) surveys were conducted along two selected profiles, designated ERT-01 and ERT-02, to investigate lateral and vertical variations in subsurface resistivity across the study area. The Wenner electrode configuration was employed because of its high signal strength, sensitivity to vertical resistivity variations, and suitability for groundwater investigations in crystalline basement terrains (Ogunlana et al., 2019).

Field measurements were undertaken under relatively dry weather conditions to minimize short-term variations in near-surface moisture. Resistivity data were acquired using PASI 16GL and ABEM Terrameter SAS 1000 systems powered by a 12 V, 60 Ah external battery. Standard stainless-steel electrodes were used for current injection and potential measurements. The electrodes were firmly inserted into the ground, and their contact with the soil was checked to ensure stable current transmission and reliable potential measurements. A total of 61 electrode positions were established along each traverse at a minimum spacing of 5 m, producing an approximate profile length of 300 m. Successively wider electrode separations, extending to approximately 80 m, were used to obtain information from progressively greater investigation depths. Data acquisition was implemented using a roll-along procedure, which enabled successive electrode combinations to be activated along each traverse while maintaining consistent Wenner-array geometry and adequate spatial coverage. This approach produced a relatively dense dataset of apparent-resistivity measurements for each profile (Bienibuor et al., 2025).

For each measurement, the instrument injected an electrical current into the ground through a pair of current electrodes and measured the resulting potential difference using a second pair of electrodes. The apparent resistivity was calculated using the Wenner-array geometric factor:

$$\rho_a = 2\pi a R \quad (1)$$

Where ρ_a = apparent resistivity (Ω·m), a = electrode spacing (m), R = measured resistance (Ω).
The apparent-resistivity values obtained from the field measurements were subsequently processed and inverted to estimate the true subsurface resistivity distribution.

B. PQWT Data Acquisition

A supplementary groundwater reconnaissance survey was conducted using the ADMT-300SX Portable Quantum Water Detector (PQWT). The instrument records variations in the natural electric-field response at different frequencies and processes these variations to identify subsurface electrical anomalies that may be associated with changes in lithology, weathering, fracturing, and moisture conditions (Adagunodo et al., 2023). The PQWT survey was used only as a supporting reconnaissance method, while the ERT results provided the principal basis for subsurface characterization and groundwater-target delineation.

Weathered and fractured basement zones containing water commonly exhibit greater electrical conductivity than dry lateritic materials or compact fresh basement rocks. However, conductive responses may also be produced by clay-rich materials. Consequently, PQWT anomalies were interpreted cautiously and evaluated in relation to the geological setting and ERT-derived resistivity sections rather than being considered direct evidence of groundwater occurrence.

Eight PQWT measurements were conducted across the study area. Five measurements were obtained at locations where subsurface anomalies had previously been identified from the ERT sections, while the remaining three were acquired at independent locations selected from PQWT reconnaissance responses. At each station, the instrument recorded frequency-dependent natural electric-field variations and processed the measurements using its internal routines to generate subsurface anomaly models. These models were examined for responses potentially associated with weathered materials, fractured basement structures, and possible groundwater accumulation zones.

The PQWT results were subsequently compared with the ERT interpretations to determine whether the two methods identified corresponding subsurface features. Particular attention was given to locations where conductive PQWT anomalies coincided spatially with weathered or fractured zones delineated by ERT. Such coincident responses were regarded as stronger indications of favourable groundwater conditions than anomalies identified by either method alone. The integrated interpretation provided additional information about the thickness and continuity of the weathered layer, the possible distribution of basement fractures, and the selection of potential groundwater-development targets.

C. Data Processing, Inversion, and Interpretation

The ERT datasets were processed and inverted using EarthImager 2D software. The raw apparent-resistivity measurements were first subjected to quality-control procedures to identify noisy, erratic, or inconsistent readings. Measurements considered unreliable were removed before inversion to minimize their influence on the resulting resistivity models.

The quality-controlled datasets were inverted using a smoothness-constrained least-squares inversion algorithm to transform the measured apparent resistivity values into two-dimensional models of the subsurface resistivity distribution (Hojat, 2024). The inversion process was performed iteratively, with the model response progressively adjusted to reduce the difference between the measured and calculated apparent-resistivity values. Iteration was continued until the model became stable and an acceptable root-mean-square (RMS) error was obtained. The RMS error was considered alongside model stability, geological plausibility, and consistency with the field observations to avoid interpreting mathematical fit alone as evidence of geological accuracy.

The inverted resistivity sections were interpreted by relating the spatial resistivity variations to the known geology and expected electrical properties of subsurface materials in crystalline basement environments. Relatively low-resistivity zones were interpreted as possible clay-rich, weathered, fractured, or water-saturated materials, depending on their geometry, depth, and relationship with adjacent units. Moderate-resistivity zones associated with structural discontinuities were assessed as possible fractured or partially weathered basement rocks. Conversely, very high-resistivity zones were generally interpreted as dry lateritic materials or compact fresh basement rocks with limited weathering and groundwater-storage capacity.

Particular attention was given to zones where thick weathered materials were underlain by fractured basement structures because this combination can provide both groundwater storage and pathways for groundwater movement. The PQWT responses were superimposed conceptually on the ERT interpretations to identify spatially corresponding anomalies. Locations at which conductive PQWT responses coincided with ERT-delineated weathered or fractured zones were prioritized as potential groundwater targets. This integrated procedure reduced interpretational ambiguity and provided a more defensible basis for recommending borehole locations and drilling depths.

IV. RESULTS AND DISCUSSION

A. Electrical Resistivity Tomography Results

The inverted ERT sections presented in Figure 2 reveal substantial lateral and vertical variations in subsurface resistivity across Oban Farmland. Resistivity values along ERT-01 range from approximately 50.70 to 1,183.00 Ω·m, while values along ERT-02 range from approximately 20.50 to 1,140.00 Ω·m. These variations indicate pronounced subsurface heterogeneity and reflect contrasts among conductive weathered materials, fractured basement zones, lateritic deposits, and relatively resistive crystalline basement rocks (Thomas et al., 2020).

Such resistivity variations are characteristic of tropical crystalline basement environments, where prolonged chemical weathering commonly produces a heterogeneous regolith overlying fractured and comparatively fresh basement rocks (Ekwok et al., 2020b). The relatively low-resistivity zones are interpreted as weathered, clay-rich, fractured, or moisture-bearing materials. Their groundwater significance depends on their thickness, depth, geometry, and connection with underlying basement fractures because low resistivity alone does not uniquely indicate groundwater saturation.

The highest-resistivity zones are interpreted principally as dry lateritic materials or fresh to slightly weathered crystalline basement rocks. Fresh basement generally possesses negligible primary porosity and limited groundwater-storage capacity. Nevertheless, resistive basement units may retain groundwater potential where they contain open, interconnected fractures that provide secondary porosity and permeability. Consequently, the most promising groundwater targets are not determined solely by the lowest resistivity values but by the combined occurrence of a sufficiently thick weathered layer, structurally disturbed basement, and supporting PQWT anomalies.

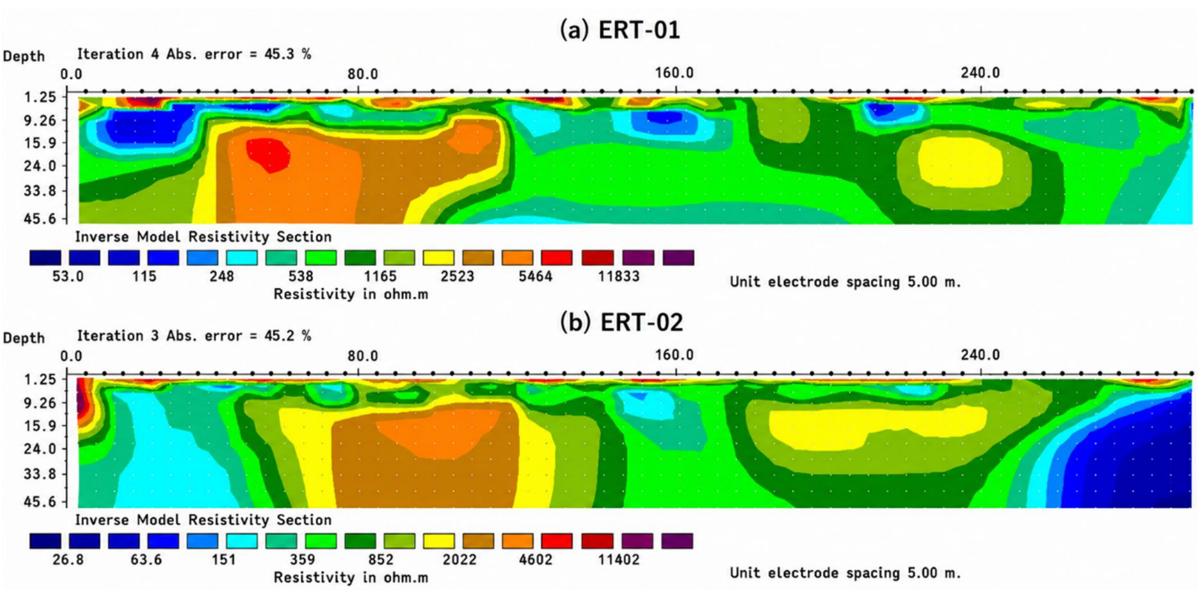


Figure 2: Inverse-model resistivity sections along (a) ERT-01 and (b) ERT-02 at Oban Farmland.

B. Electrical Resistivity Tomography Results

Figure 2 presents the two-dimensional inverted resistivity models obtained from profiles ERT-01 and ERT-02. The sections reveal pronounced lateral and vertical variations in subsurface resistivity, allowing the principal geoelectric units beneath the study area to be differentiated. The shallow portions of the profiles are dominated by conductive weathered regolith, while discontinuous zones of moderate-to-high resistivity at greater depths are interpreted as fractured or partly weathered basement. The deeper and more resistive zones represent relatively fresh and competent crystalline basement rocks. The weathered and fractured zones may support groundwater accumulation where they are sufficiently thick, saturated, and hydraulically interconnected (Fatoye et al., 2022).

Table 1 summarizes the representative resistivity values obtained from the two ERT profiles and their corresponding geological and hydrogeological interpretations. The resistivity distribution generally indicates a transition from the near-surface weathered regolith through fractured basement to deeper fresh basement. This succession is characteristic of crystalline basement terrains, where groundwater storage and transmission occur primarily within the weathered overburden and open, interconnected fractures in the underlying bedrock (Ifeanyichukwu et al., 2021).

Along ERT-01, the relatively low resistivity values of approximately 50.70–240.05 Ω·m are associated with the weathered regolith. These conductive materials may represent clay-rich, moist, or water-saturated weathered formations. Their groundwater potential depends on the thickness and continuity of the weathered layer, its clay content, and its hydraulic connection with underlying basement fractures. Thick weathered zones with limited clay content are generally more favourable for groundwater storage and transmission than thin or predominantly clay-rich layers (Olabode et al., 2020; Aizebeokhai et al., 2021; Doro et al., 2023).

ERT-02 is characterized by low resistivity values of approximately 20.50–145.40 Ω·m within the shallow subsurface. The value of 20.50 Ω·m indicates a highly conductive layer that may contain wet or clay-rich weathered materials. Because clay can produce a conductive response similar to that of groundwater saturation, this zone cannot be classified as an aquifer solely on the basis of its low resistivity. However, the weathered zone represented by values approaching 145.40 Ω·m may constitute a shallow regolith aquifer where it is sufficiently thick, continuous, and hydraulically connected to fractured basement structures (Zarif et al., 2022; Menegbo et al., 2024).

Zones with resistivity values of approximately 855.00–1,125.00 Ω·m are interpreted as fractured or partly weathered basement. Their groundwater significance is based not only on resistivity magnitude but also on their geometry, structural discontinuity, and relationship with the overlying weathered layer. Open and interconnected joints and fractures provide secondary porosity and permeability, allowing groundwater to infiltrate, accumulate, and move through otherwise compact crystalline rocks (Pradhan et al., 2022; Ohenhen et al., 2023). These zones are therefore considered priority groundwater targets, particularly where they coincide with PQWT anomalies.

The deeper, highly resistive zones, represented by approximately 1,183.50–2,500.20 Ω·m along ERT-01 and 1,140.00–2,030.50 Ω·m along ERT-02, are interpreted as relatively fresh, dry, and competent basement rocks. These materials possess negligible primary porosity and generally have limited groundwater potential. Nevertheless, localized groundwater may occur where the fresh basement is intersected by open fractures or fault-related structures.

Table 1. Interpreted ERT resistivity models and hydrogeological significance

Profile	Representative resistivity value/range (Ω·m)	Interpreted subsurface zone	Hydrogeological assessment
ERT-01	50.70	Highly conductive weathered regolith	Shallow weathered material that may be clay-rich or seasonally wet; groundwater potential remains uncertain without further verification.
ERT-01	240.05	Weathered or potentially saturated basement	Potential regolith aquifer where the weathered layer is sufficiently thick, continuous, and relatively free of clay.
ERT-01	1,125.00	Fractured or partly weathered basement	Priority groundwater target where fractures are open, interconnected, and hydraulically linked to the overlying weathered zone.
ERT-01	1,183.50–2,500.20	Fresh, relatively unsaturated basement	Compact crystalline basement with limited groundwater potential except where intersected by fractures.
ERT-02	20.50	Highly conductive shallow regolith	Possibly wet or clay-rich surface material; low resistivity alone does not confirm groundwater occurrence.
ERT-02	145.40	Weathered or potentially saturated basement	Possible shallow regolith aquifer where the weathered layer is sufficiently thick and laterally continuous.
ERT-02	855.00	Fractured or partly weathered basement	Potential fractured-basement aquifer and priority drilling target where supported by structural geometry and PQWT evidence.
ERT-02	1,140.00–2,030.50	Fresh, relatively unsaturated basement	Competent basement with low groundwater potential except along localized fractures or faults.

C. Portable Quantum Water Detector Results

The PQWT survey identified several subsurface anomalies, which were presented as two- and three-dimensional subsurface-response models. These anomalies were evaluated in relation to the local geological setting and the ERT-derived resistivity sections. Areas characterized by relatively strong conductive responses were interpreted as possible weathered, fractured, clay-rich, or water-bearing formations within the crystalline basement terrain.

The most prominent PQWT anomalies occurred at locations where the ERT models also delineated conductive weathered materials or structurally disturbed basement zones. This spatial correspondence suggests that some of the detected anomalies may be associated with weathered and fractured basement systems. Such formations can provide secondary porosity for groundwater storage and interconnected pathways for groundwater movement. Nevertheless, conductive PQWT responses were not regarded as direct confirmation of groundwater because similar anomalies may be generated by clay-rich or highly weathered materials.

The PQWT results were therefore not used independently to define aquifer boundaries or determine drilling depths because of the method's limitations in quantitative resistivity inversion, lithological discrimination, and precise depth estimation (Ali et al., 2024). Greater interpretational weight was assigned to anomalies that coincided with ERT-delineated weathered or fractured zones and were consistent with the expected geological conditions. Locations where both methods identified corresponding subsurface features were classified as favourable hydrogeological zones and potential targets for groundwater development (Adeniji et al., 2024).

In the absence of borehole lithological logs, pumping-test results, and confirmed groundwater-interception depths, the PQWT responses were treated as complementary rather than confirmatory evidence. Integrating the PQWT anomalies with the ERT models improved the characterization of the weathered and fractured basement system, reduced ambiguity in the interpretation, and provided a stronger basis for prioritizing potential borehole locations. However, exploratory drilling, borehole logging, pumping tests, and water-quality analyses are required to confirm the lithology, aquifer thickness, groundwater yield, and suitability of the identified targets.

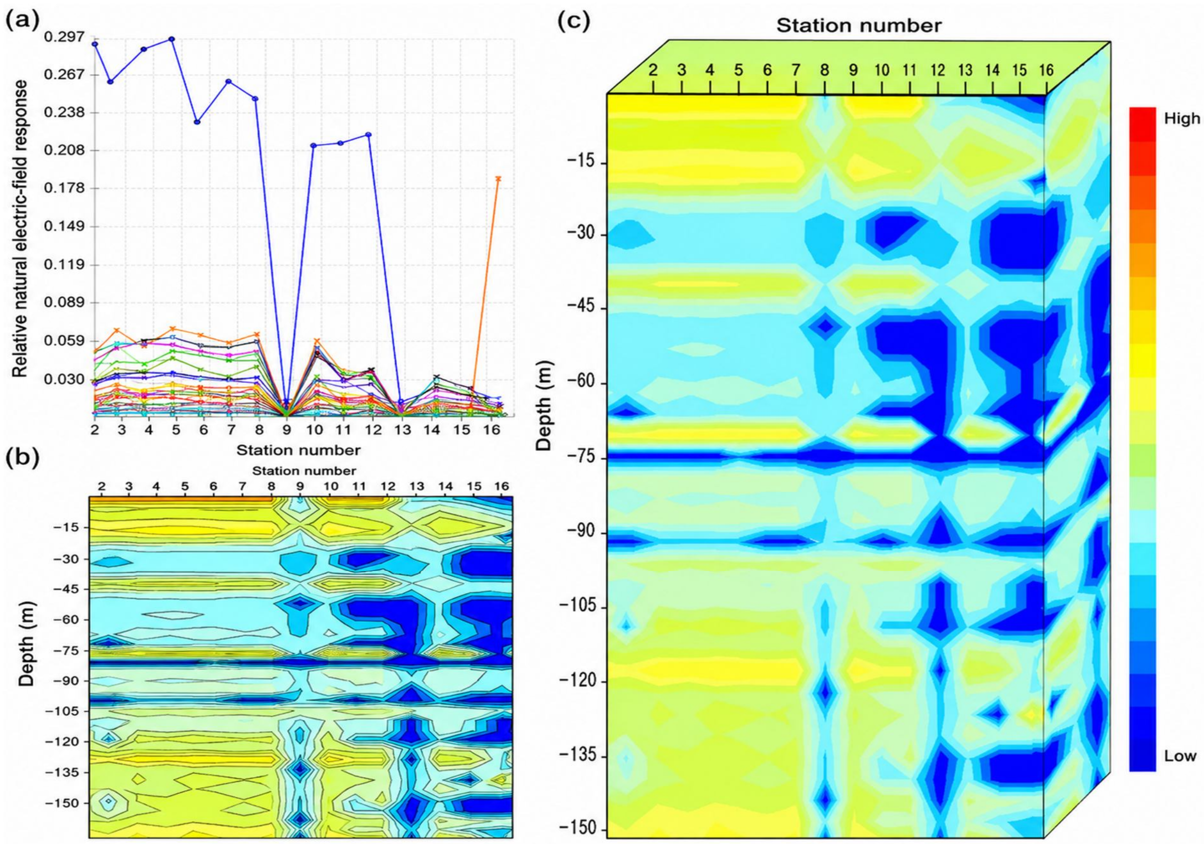


Figure 3: PQWT subsurface responses showing (a) Multi-frequency station-response curves, (b) Two-dimensional subsurface response section and (c) Three-dimensional subsurface response model.

D. *Integrated ERT and PQWT Analysis*

The integrated interpretation of the ERT and PQWT datasets clarified subsurface hydrogeological conditions at Oban Farmland. The ERT sections supplied quantitative information on lateral and vertical resistivity variations, enabling the weathered regolith, fractured or partly weathered basement, and relatively fresh crystalline basement to be differentiated. The PQWT survey provided supplementary reconnaissance information for determining whether conductive anomalies coincided with features identified by ERT.

The ERT models revealed conductive near-surface zones with resistivity values ranging from approximately 20.50 to 240.05 Ω·m. These zones were interpreted as weathered materials that may be clay-rich, moist, or water saturated. Their groundwater significance depends on their thickness, continuity, clay content, and hydraulic connection with deeper fractures. Low resistivity alone was therefore not regarded as definitive evidence of groundwater. Conductive zones connected to structurally disturbed basement were considered more favourable than isolated shallow anomalies.

Intermediate resistivity values of approximately 885.00–1,125.00 Ω·m were associated with fractured or partly weathered basement. These zones are important groundwater targets because joints, fractures, and faults create secondary porosity and permeability within crystalline rocks that otherwise possess negligible primary pore space. Where fractures are open, interconnected, and linked to the overlying regolith, they can facilitate groundwater recharge, movement, and storage (Van Riet et al., 2022; Ewumi et al., 2025). Their groundwater potential therefore depends more on fracture geometry and connectivity than on resistivity magnitude alone.

The highest resistivity responses, approaching approximately 1,183.50 Ω·m along ERT-01 and 1,140.00 Ω·m along ERT-02, were interpreted as relatively fresh and competent crystalline basement. These rocks generally have low primary porosity and limited groundwater potential unless intersected by open fractures or fault-related structures (Aizebeokhai et al., 2018; Wali et al., 2019; Shuaibu, 2024).

The PQWT results provided support where conductive anomalies coincided with weathered or fractured zones delineated by ERT. Locations where both methods indicated comparable features were assigned greater hydrogeological significance and prioritized as potential drilling targets. This correspondence increased confidence in the interpretation and reduced ambiguity associated with using one method. Nevertheless, PQWT responses were treated as complementary rather than confirmatory because conductive anomalies may also result from clay-rich materials, and the method lacks the quantitative inversion control of ERT. The integrated analysis therefore provided a practical framework for distinguishing favourable weathered and fractured zones from compact basement and prioritizing locations for borehole investigation.

V. CONCLUSION

This study assessed the groundwater potential of Oban Farmland, Akamkpa Local Government Area, Cross River State, using an integrated ERT and PQWT approach. The ERT models revealed variations in subsurface resistivity, ranging from approximately 50.70 to 1,183.50 Ω·m along ERT-01 and from 20.50 to 1,140.00 Ω·m along ERT-02. These variations enabled the subsurface to be characterized into conductive weathered regolith, fractured or partly weathered basement, and relatively fresh crystalline basement.

The most favourable groundwater conditions were associated with thick weathered materials that appeared hydraulically connected to fractured basement structures. These formations can provide groundwater storage within the regolith and secondary pathways for movement through interconnected fractures. The PQWT survey identified anomalies corresponding with several conductive and structurally disturbed zones delineated by ERT. Agreement between both datasets strengthened the selection of potential groundwater targets, although it did not independently confirm aquifer occurrence or productivity.

Overall, integrating ERT with PQWT improved subsurface characterization and provided a defensible basis for prioritizing prospective borehole locations in the crystalline basement terrain. However, the interpreted targets should be validated through exploratory drilling, lithological and geophysical borehole logging, pumping tests, and hydrochemical analyses. These investigations are required to confirm aquifer depth, thickness, yield, hydraulic properties, and water quality and to support sustainable groundwater development for agricultural activities within Oban Farmland.

A. Competing Interests

The authors confirm that there are no conflicts of interest

B. Funding

The authors gratefully acknowledge TETFund for the 2025/2026 intervention funding that supported this research work.

REFERENCES

[1] Adagunodo, T. A., Ojoawo, A. I., Anie, N. O., & Edukugho, P. O. (2023). Application of frequency selection and geoelectrical sounding methods for mapping of leachate's pathways in an active dumpsite. SN Applied Sciences, 5(12). https://doi.org/10.1007/s42452-023-05557-8

[2] Adebisi, W. A., Afolabi, F., & Babalola, K. K. (2026). Integrated magnetic and electrical sounding investigation of groundwater potential zones in Federal University of Health Sciences, Ila-Orangun permanent site. Discover Geoscience, 4(1). https://doi.org/10.1007/s44288-026-00390-z

[3] Adeniji, A., Ajani, O., Adagunodo, T., & Kolawole, T. (2024). Investigation of leachate infiltration on groundwater using georesistivity and natural electric field method around Ojoou-Olayanju's dumpsite, Ada, southwestern Nigeria. Nigerian Journal of Technology, 43(1), 159–171. https://doi.org/10.4314/njt.v43i1.18

[4] Adeoti, O. S., Kandasamy, J., & Vigneswaran, S. (2024). Water infrastructure sustainability challenge in Nigeria: A detailed examination of infrastructure failures and potential solutions. Water Science & Technology Water Supply, 24(6), 2066–2076. https://doi.org/10.2166/ws.2024.127

[5] Agyemang, V. O. (2025). Groundwater resources development for a sustainable water supply in developing countries: A case study of Ghana. Cleaner Water, 4, 100104. https://doi.org/10.1016/j.clwat.2025.100104

[6] Aizebeokhai, A. P., & Oyeyemi, K. D. (2017). Geoelectrical characterisation of basement aquifers: the case of Iberekodo, southwestern Nigeria. Hydrogeology Journal, 26(2), 651–664. https://doi.org/10.1007/s10040-017-1679-9

[7] Aizebeokhai, A. P., Ogungbade, O., & Oyeyemi, K. D. (2021). Application of geoelectrical resistivity for delineating crystalline basement aquifers in Basiri, Ado-Ekiti, Southwestern Nigeria. Arabian Journal of Geosciences, 14(1). https://doi.org/10.1007/s12517-020-06440-1

[8] Aizebeokhai, A. P., Oni, A. A., Oyeyemi, K. D., & Ogungbade, O. (2018). Electrical resistivity imaging (ERI) data for characterising crystalline basement structures in Abeokuta, southwestern Nigeria. Data in Brief, 19, 2393–2397. https://doi.org/10.1016/j.dib.2018.07.034

[9] Akaolisa, C. C., Agbasi, O., Okeke, O. C., & Okechukwu, S. (2022). An assessment of the groundwater potentials of the farm with preliminary geophysical method and grain size analysis prior to the drilling of boreholes. HydroResearch, 5, 85–98. https://doi.org/10.1016/j.hydres.2022.09.001

[10] Akiang, F. B., Amah, E. T., George, A. M., Okoli, E. A., Agbasi, O. E., & Iwuoha, P. O. (2024). Hydrogeological assessment and groundwater potential study in Calabar South Local Government Area: a vertical electrical sounding (VES) approach. International Journal of Energy and Water Resources, 9(2), 811–823. https://doi.org/10.1007/s42108-024-00279-y

[11] Akingboye, A. S., & Osazuwa, I. B. (2021). Subsurface geological, hydrogeophysical and engineering characterisation of Etioro-Akoko, southwestern Nigeria, using electrical resistivity tomography. NRIAG Journal of Astronomy and Geophysics, 10(1), 43–57. https://doi.org/10.1080/20909977.2020.1868659

[12] Akpa, C., Ugbor, C. C., Onuoha, K. M., Ani, C. C., & Obasi, I. A. (2025). An integrated geophysical approach for the precise delineation of sulphide ore within fractured zones of the southern Benue trough, southeastern Nigeria. Geological Journal. https://doi.org/10.1002/gj.70115

[13] Ali, A. M., Sfada, A., & Lawan, A. Y. (2024). Validating the accuracy of natural electric field (NEF) water detectors for hydrogeophysical exploration. International Journal of Energy and Water Resources, 9(2), 973–985. https://doi.org/10.1007/s42108-024-00307-x

[14] Bienibuor, A. K., Preko, K., Aning, A. A., Menyeh, A., Wemegah, D. D., Appiah, M. K., & Gyilbag, A. (2025). Application of the electrical resistivity tomography (ERT) method in identifying high groundwater potential sites in the Atebubu municipality of Ghana. Discover Geoscience, 3(1). https://doi.org/10.1007/s44288-025-00120-x

[15] Doro, K. O., Adegboyega, C. O., Aizebeokhai, A. P., & Oladunjoye, M. A. (2023). The Ibadan Hydrogeophysics Research Site (IHRS)—An observatory for studying hydrological heterogeneities in a crystalline basement aquifer in southwestern Nigeria. Water, 15(3), 433. https://doi.org/10.3390/w15030433

[16] Ekwok, S. E., Akpan, A. E., Kudamnya, E. A., & Ebong, E. D. (2020). Assessment of groundwater potential using geophysical data: a case study in parts of Cross River State, south-eastern Nigeria. Applied Water Science, 10(6). https://doi.org/10.1007/s13201-020-01224-0

[17] Ewumi, T. O., Ogunlana, F. O., & Oyedele, A. A. (2025). Geotechnical challenges in crystalline basement terrain: mapping subsurface conditions with electrical resistivity tomography in Ado-Ekiti, Nigeria. Brazilian Journal of Science, 4(4), 29–39. https://doi.org/10.14295/bjs.v4i4.726

[18] Fartassi, I. E., Metcalfe, H., Alami, R. E., Diarra, A., Alonso-Chavez, V., Waine, T. W., Zawadzka, J., Milne, A. E., & Corstanje, R. (2025). Adaptations in agricultural water management in arid regions: Modelling farmer behaviour and cooperation on irrigation sustainability in Morocco. Agricultural Water Management, 319, 109789. https://doi.org/10.1016/j.agwat.2025.109789

[19] Fatoye, O. V., Olasehinde, D. A., Olatunji, J. A., Olasehinde, O. D., Abioye, O. M., & Olasehinde, P. I. (2022). Structural evaluation for groundwater within the crystalline basement of Ilorin, Nigeria, using multisensory data techniques. IOP Conference Series Earth and Environmental Science, 1054(1), 012009. https://doi.org/10.1088/1755-1315/1054/1/012009

[20] Hojat, A. (2024). An Iterative 3D Correction plus 2D Inversion Procedure to Remove 3D Effects from 2D ERT Data along Embankments. Sensors, 24(12), 3759. https://doi.org/10.3390/s24123759

[21] Ifeanyichukwu, K. A., Okeyeh, E., Agbasi, O. E., Moses, O. I., & Ben-Owope, O. (2021). Using geo-electric techniques for vulnerability and groundwater potential analysis of aquifers in Nnewi, south eastern Nigeria. Journal of Geology Geography and Geoecology, 30(1), 43–52. https://doi.org/10.15421/112105

[22] Imani, P., Tian, G., Hadiloo, S., & El-Raouf, A. A. (2020). Application of combined electrical resistivity tomography (ERT) and seismic refraction tomography (SRT) methods to investigate Xiaoshan District landslide site: Hangzhou, China. Journal of Applied Geophysics, 184, 104236. https://doi.org/10.1016/j.jappgeo.2020.104236

[23] Isah, A., Akinbiyi, O. A., Ugwoke, J. L., Ayajuru, N. C., & Oyelola, R. O. (2022). Detection of groundwater level and heavy metal contamination: A case study of Olubunku dumpsite and environs, Ede North, Southwestern Nigeria. Journal of African Earth Sciences, 197, 104740. https://doi.org/10.1016/j.jafrearsci.2022.104740

[24] Lee, S. C. H., Noh, K. a. M., & Zakariah, M. N. A. (2021). High-resolution electrical resistivity tomography and seismic refraction for groundwater exploration in fracture hard rocks: A case study in Kanthan, Perak, Malaysia. Journal of Asian Earth Sciences, 218, 104880. https://doi.org/10.1016/j.jseaes.2021.104880

[25] Menegbo, B. G., Davies, O. A., & Horsfall, O. I. (2024). Assessment of Aquifer Resistivity, Depth, and Thickness using Vertical Electrical Sounding (VES) in Parts of Bori Metropolis for Groundwater Exploration. World Journal of Advanced Research and Reviews, 24(2), 275–285. https://doi.org/10.30574/wjarr.2024.24.2.3293

[26] Nasara, M. A., Shahabi, H., & Shahid, S. (2025). Spatiotemporal assessment of groundwater sustainability across climatic zones of Nigeria. Physics and Chemistry of the Earth Parts a/B/C, 139, 103945. https://doi.org/10.1016/j.pce.2025.103945

[27] Obuobie, E., Akurugu, B. A., & Granaham, P. (2025). A review of the groundwater characteristics of the crystalline basement rocks in the Pra River Basin, Ghana. Environmental Earth Sciences, 84(15). https://doi.org/10.1007/s12665-025-12426-7

[28] Ogunlana, O. F., Alile, O. M., & Airen, O. J. (2019). Two-dimensional electrical resistivity tomography of bitumen occurrence in Agbabu, southwest Nigeria. Current Journal of Applied Science and Technology, 1–9. https://doi.org/10.9734/cjast/2019/v36i130216

[29] Ohenhen, L. O., Mayle, M., Kolawole, F., Ismail, A., & Atekwana, E. A. (2023). Exploring for groundwater in sub-Saharan Africa: Insights from integrated geophysical characterization of a weathered basement aquifer system, central Malawi. Journal of Hydrology Regional Studies, 47, 101433. https://doi.org/10.1016/j.ejrh.2023.101433

[30] Olabode, O. P., San, L. H., & Ramli, M. H. (2020). Analysis of Geotechnical-Assisted 2-D electrical resistivity tomography monitoring of slope instability in residual soil of weathered granitic basement. Frontiers in Earth Science, 8. https://doi.org/10.3389/feart.2020.580230

[31] Oyeyemi, K. D., Aizebeokhai, A. P., Olaojo, A. A., Okon, E. E., Kalu, D. V., & Metwaly, M. (2023). Hydrogeophysical investigation in parts of the eastern Dahomey Basin, southwestern Nigeria: Implications for sustainable groundwater resources development and management. Water, 15(16), 2862. https://doi.org/10.3390/w15162862

[32] Pradhan, R. M., Singh, A., Ojha, A. K., & Biswal, T. K. (2022). Structural controls on bedrock weathering in crystalline basement terranes and its implications on groundwater resources. Scientific Reports, 12(1), 11815. https://doi.org/10.1038/s41598-022-15889-x

[33] Shuaibu, A. M. (2024). Application of Combined Geoelectrical Techniques for Groundwater Exploration at Federal University Gusau, Zamfara and its Environ, Northwest Nigeria. UMYU Scientifica, 3(4), 244–159. https://doi.org/10.56919/usci.2434.019

[34] Teweldebrihan, M. D., & Dinka, M. O. (2025). Sustainable water management practices in agriculture: The case of East Africa. Encyclopedia, 5(1), 7. https://doi.org/10.3390/encyclopedia5010007

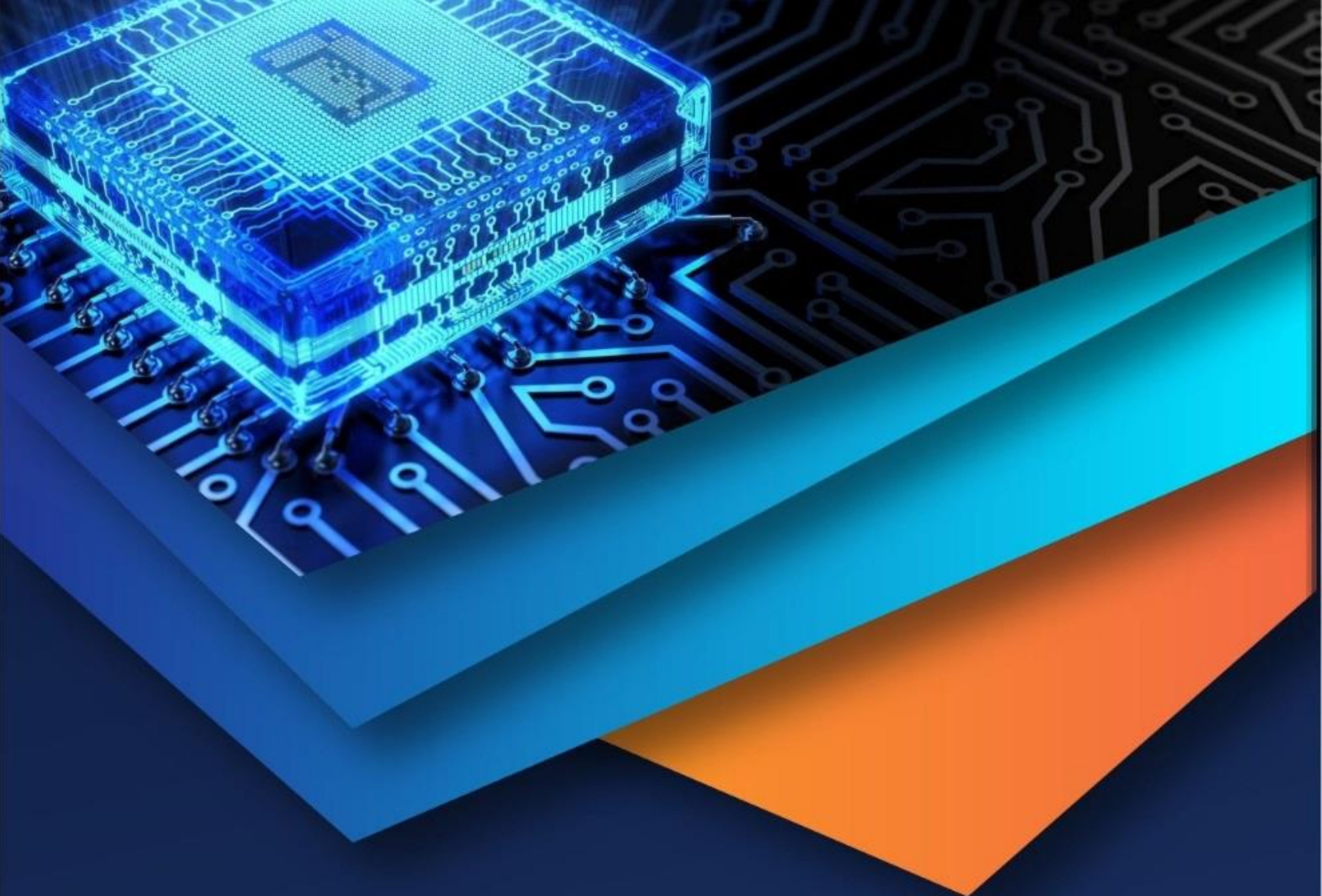
[35] Thomas, J. E., George, N. J., Ekanem, A. M., & Nsikak, E. E. (2020). Electrostratigraphy and hydrogeochemistry of hyporheic zone and water-bearing caches in the littoral shorefront of Akwa Ibom State University, Southern Nigeria. Environmental Monitoring and Assessment, 192(8), 505. https://doi.org/10.1007/s10661-020-08436-6

[36] Uchenna, U. P., Lancia, M., Viaroli, S., Ugbaja, A. N., Galluzzi, M., & Zheng, C. (2023). Groundwater sustainability in African Metropolises: Case study from Calabar, Nigeria. Journal of Hydrology Regional Studies, 45, 101314. https://doi.org/10.1016/j.ejrh.2023.101314

[37] Van Riet, B., Six, S., Walraevens, K., Vandenbohede, A., & Hermans, T. (2022). Assessing the impact of fractured zones imaged by ERT on groundwater model prediction: a case study in a chalk aquifer in Voort (Belgium). Frontiers in Water, 3. https://doi.org/10.3389/frwa.2021.783983

[38] Wali, S. U., Umar, K. J., Abubakar, S. D., Ifabiyi, I. P., Dankani, I. M., Shera, I. M., & Yauri, S. G. (2019). Hydrochemical characterization of shallow and deep groundwater in Basement Complex areas of southern Kebbi State, Sokoto Basin, Nigeria. Applied Water Science, 9(8). https://doi.org/10.1007/s13201-019-1042-5

[39] Zarif, F. M., Elshenawy, A. M., Barseem, M. S. M., Al-Abaseiry, A. A., & Sayed, A. N. E. (2022). Evidence of geoelectrical resistivity values on groundwater conditions in Wadi El Natrun and its vicinities, West Delta, Egypt (cases studies). Scientific Reports, 12(1), 10745. https://doi.org/10.1038/s41598-022-12644-0



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY