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Original Research Article

Integrated Geoelectric Characterization and Groundwater Potential Mapping in a Metamorphic Basement Terrain: A Case Study of the Agbaje-Ijokodo Community, Southwestern Nigeria

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Abstract

In the crystalline basement terrains of Southwestern Nigeria, groundwater exploration remains a significant challenge due to the extreme lateral and vertical heterogeneity of the subsurface. This study investigates the Agbaje–Ijokodo area in Ibadan, a region historically plagued by high borehole failure rates, using an integrated geophysical approach. By combining 1D Vertical Electrical Sounding (VES) at 28 locations with 2D Electrical Resistivity Tomography (ERT) across 14 profiles, we mapped the complex architecture of the local aquifer system. The results reveal a predominant three-layer geoelectric sequence: a clayey topsoil, a weathered saprolite layer (averaging 10.8 m in thickness), and a basal fractured-to-fresh basement. Interpretation of geoelectric curves, primarily H-type (57%) and Dar-Zarrouk parameters indicates that while the weathered regolith provides storage, its productivity is often hampered by high clay content. Critical secondary porosity was identified in deep-seated fracture zones and basement depressions, particularly in the Agbaje sector, where reflection coefficients below 0.75 and longitudinal conductance values (0.2 - 0.69 mhos) suggest both high groundwater potential and moderate protective capacity. In contrast, the Ijokodo area is characterized by shallow bedrock ridges and thin overburden, explaining its poor-to-fair yield history. These findings suggest that sustainable groundwater development in the area must shift from targeting shallow saprolite to deeper, localized fracture networks. This research demonstrates that an integrated resistivity framework is indispensable for reducing the risks associated with borehole siting in complex metamorphic terrains.

Keywords: Groundwater exploration; Electrical Resistivity Tomography (ERT); Vertical Electrical Sounding (VES); Crystalline Basement; Ibadan; Dar-Zarrouk parameters.

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INTRODUCTION

Access to clean water remains a fundamental pillar of human development, yet for many rapidly urbanizing regions, surface water is simply too vulnerable to pollution to be a reliable source. Groundwater often serves as the only viable alternative, acting as a natural, protected reservoir. However, in the crystalline basement terrains of Southwestern Nigeria, finding water is rarely a straightforward task. These metamorphic rocks lack the natural pore spaces found in sedimentary basins; instead, water is "trapped" within a complex network of weathered soil (regolith) and bedrock fractures (Pavelic, 2012; Ariyo *et al.,* 2021). Relying on a single geophysical method often provides an incomplete picture, leading to the high failure rates seen in local drilling projects. Modern hydrogeophysical research now emphasizes a more integrated approach, moving beyond simple point-data to a more holistic view of the earth (Oladunjoye *et al.,* 2021). By combining 1D Vertical Electrical Sounding (VES) with the continuous cross-sectional imagery of 2D Electrical Resistivity Tomography (ERT), the structural hidden layers, such as basement depressions and fracture zones, that actually dictate where water stores can be detected (Saores *et al.,* 2022; Aweda *et al.,* 2023).

The Agbaje–Ijokodo community in Ibadan represents a particularly challenging hydrogeological

environment, marked by a high frequency of failed or dry boreholes, which underscores the need for precise, data-driven exploration strategies. To address these local water shortages, this research employs the electrical resistivity method, a cost-effective and non-destructive geophysical tool, to delineate subsurface targets. By identifying high-conductivity anomalies associated with deep weathering and fracture connectivity, the study seeks to characterize the geoelectric properties and spatial extent of the area's aquifer units. The primary objectives are to define geoelectric layer thicknesses, ascertain depth to the saturated zones, and precisely target borehole locations within zones of maximum regolith thickness and intense fracturing. This integrated approach aims to transition groundwater development in the Agbaje–Ijokodo area from an uncertain endeavor into a sustainable, scientifically informed practice.

Location and Geological Setting

The study area is located in Ibadan, Southwestern Nigeria, situated between latitudes 7º 25′ 30″ N and 7º 25′ 50″ N and longitudes 3º 52′ 10″ E and 3º 52′ 40″ E (Fig. 1). It is bounded by the Eleyele River to the north and the Eleyele Dam to the south. Accessibility is provided by a network of lateritic and unpaved roads branching from the Sango–Eleyele axis, facilitating field operations despite the region's undulating terrain.

Geologically, the area is part of the Precambrian crystalline basement complex, dominated by migmatite gneiss with subordinate quartzite and quartz schist. The migmatite gneiss is medium-to-coarse-grained and predominantly melanocratic, often featuring quartz veins and pegmatitic intrusions that fill shear zones and joints. These pegmatites are particularly significant as they weather into clayey-sand particles, which act as primary water-bearing horizons within the regolith (Palacky *et al.,* 1981). Recent studies in the Southwestern Nigerian Basement Complex (Oyeyemi & Gomo, 2025; Ariyo *et al.,* 2021) confirm that this weathering process creates a gritty saprolite with enhanced effective porosity, which is essential for sustainable groundwater storage in metamorphic terrains. The hydrogeological framework is structurally controlled by faults, joints, and micro-folding, which dictate the localized accumulation and movement of groundwater within the crystalline rocks.

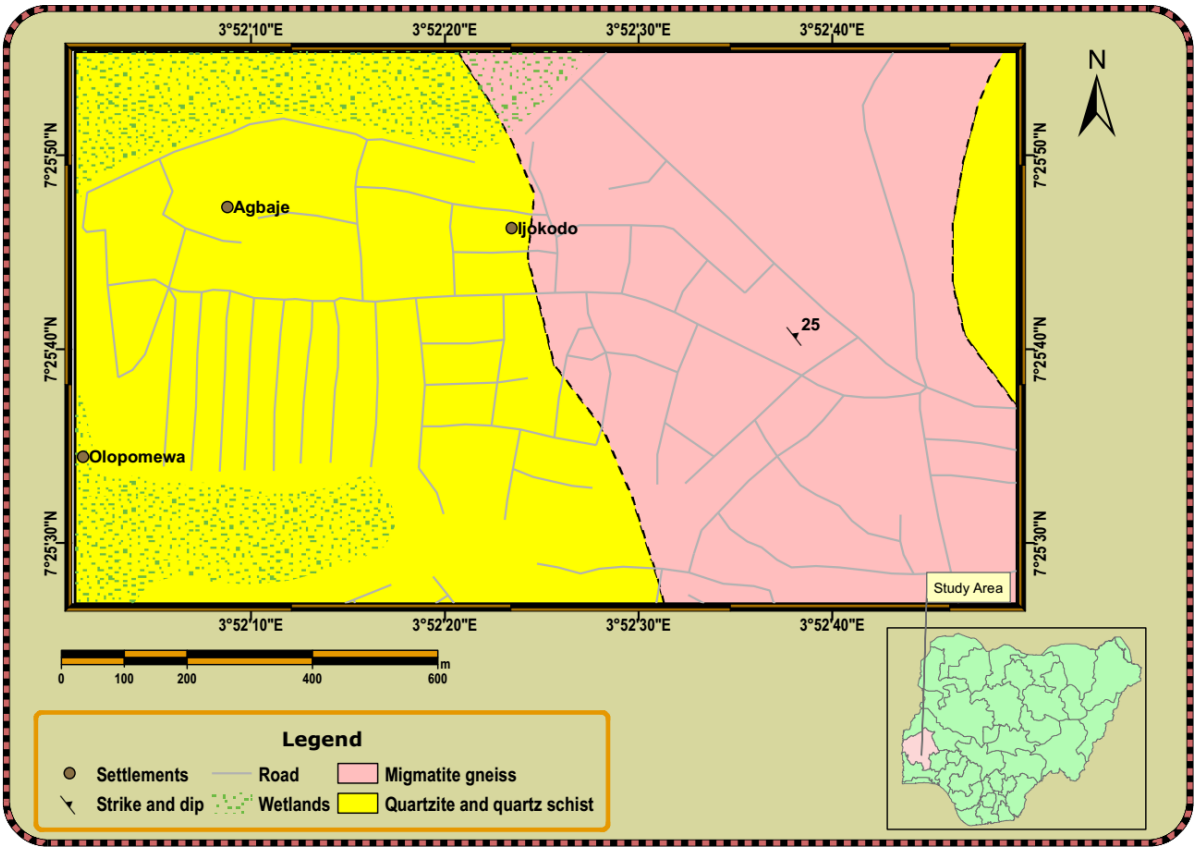


Figure 1: Geological Map of the Study Area

MATERIALS AND METHODS

A reconnaissance survey was conducted to assess site accessibility and establish GPS coordinates for key outcrops and features. Recognizing the limitations of point-source data in the highly heterogeneous metamorphic rocks of Agbaje - Ijokodo, this study adopts the integrated geophysical framework advocated by recent researchers (Ahaneku *et al.,* 2025; Falade *et al.,* 2025; Solomon *et al.,* 2022). By marrying the vertical precision of 1D Schlumberger soundings with the lateral 'vision' of 2D Wenner imaging, we bridged the gap between depth-to-basement estimates

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and the actual structural geometry of the fractured aquifer system in the Agbaje - Ijokodo community, Ibadan, Oyo State by employed Electrical Resistivity Imaging (ERI) and Vertical Electrical Sounding (VES) as two primary electrical resistivity techniques. Fourteen ERI profiles were conducted along accessible routes using the Wenner array. These profiles served to delineate buried subsurface structures and guide the placement of sounding points. Vertical Electrical Sounding (VES): Twenty-eight VES stations were established using the Schlumberger array, with several points collocated on ERI profile lines to ensure data integration. Resistivity measurements were obtained by injecting current into the ground and recording the resulting potential differences. For the VES surveys, a fixed central point was maintained while electrode spacing was progressively expanded to increase the depth of investigation. The Campus Ohmega resistivity meter, AEMC model 6472 was employed for resistance measurement. Data acquisition map for the study area is presented in figure 2.

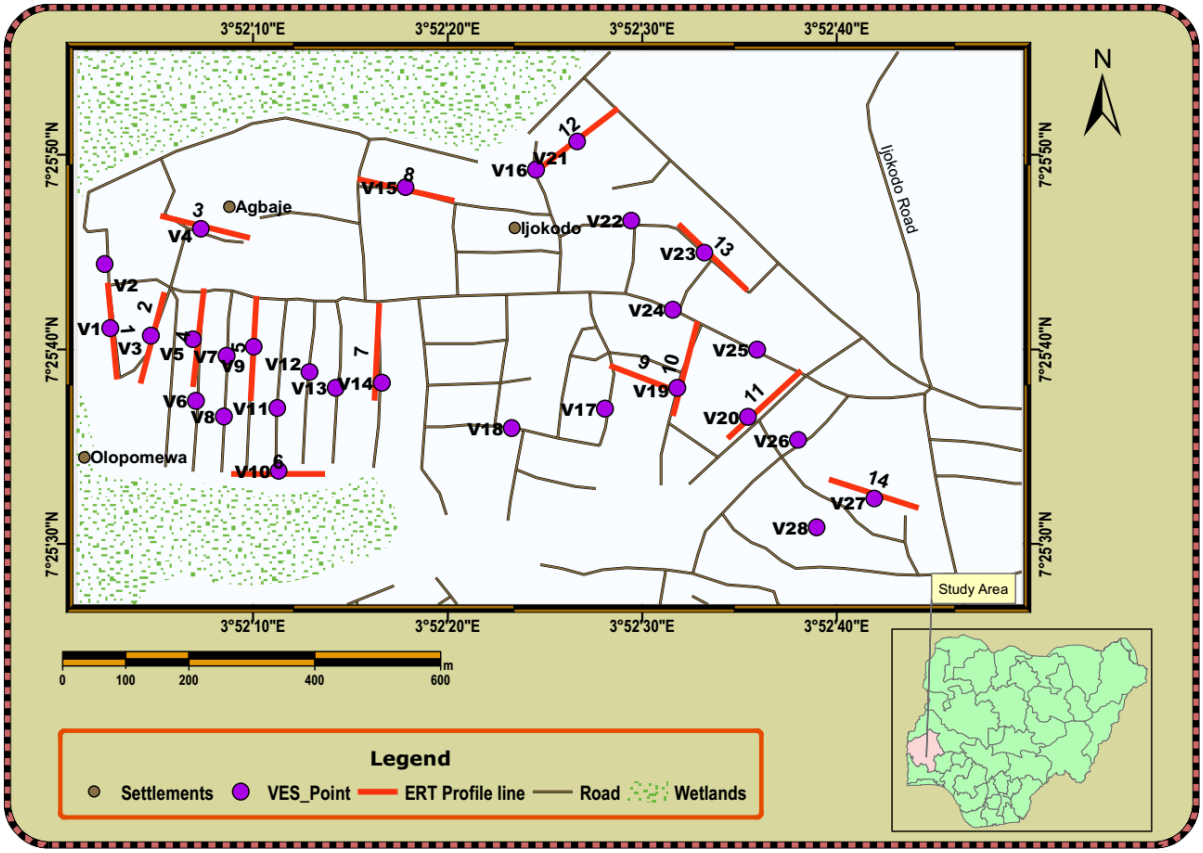


Figure 2: Data acquisition map of Agbaje - Ijokodo community, Ibadan

RESULTS AND DISCUSSION

Two dimensional (2D-) Electrical Resistivity Imaging

The 2D electrical resistivity imaging (ERI) results for the 14 profiles reveal a complex subsurface architecture characterized by high geological inhomogeneity. The study area generally follows a three-layer geoelectric model: topsoil, weathered basement, and fractured/fresh basement, though the thickness and continuity of these layers vary significantly due to differential chemical weathering and structural anomalies typical of tropical crystalline terrains (Oyeyemi *et al.,* 2021).

Profiles 1 through 6 are characterized by a well-developed, thick weathering profile. Profiles 1 and 2 establish a sequence of clayey topsoil (20 - 120 Ωm) approximately 10 m thick, underlain by a weathered basement (150 - 350 Ωm) and a basal fractured/fresh basement (400 Ωm), deep overburden model (Figure 3). In contrast, Profiles 3, 5, and 6 exhibit an extensive weathered overburden reaching depths of 13 m, where the clayey materials (20 - 70 Ωm) are so thick that the fresh basement remains undetected within the imaging depth (Figure 4). While these thick weathered zones provide high storage capacity, the seasonal failure of nearby shallow wells suggests that the high clay content may limit permeability during the dry season (Ariyo *et al.,* 2021).

Profiles 7 through 10 demonstrate significant structural variation, with prominent basement intrusions and outcropping. Profile 7 and 8 show high-resistivity intrusions (>300 Ωm) within the weathered layer, while Profile 10 features a fresh basement outcrop (>600 Ωm) at the surface between 70 - 80 m. The uneven topography across these sections results from uneven in-situ chemical weathering, creating localized depressions.

Profile 9 specifically highlights a fractured zone (120 - 250 Ωm) which, according to established geophysical criteria, represents a promising target for water saturation (The "Sweet Spot", Figure 5) despite a relatively thin overburden (Oladunjoye *et al.,* 2021).

Profiles 11 through 14 are defined by a shallow basement architecture, where fresh bedrock (>500 Ωm) is typically encountered beneath a thin (3 - 5 m) clayey topsoil. While the weathered layer (150 - 400 Ωm) in these sections is generally too thin to support productive shallow wells, Profiles 12, 13, and 14 reveal critical structural depressions and fractured zones at their terminal ends. These fractures provide essential secondary porosity for groundwater accumulation in an otherwise competent rock mass (Troeger and Chambel, 2021; Olatinsu and Salawudeen, 2021.). Overall, the integration of these 14 profiles suggests that sustainable groundwater development in the Agabaje - Ijokodo community should target these deep-seated fractured zones and basement depressions (Figure 6), rather than the seasonal, clay-rich shallow overburden.

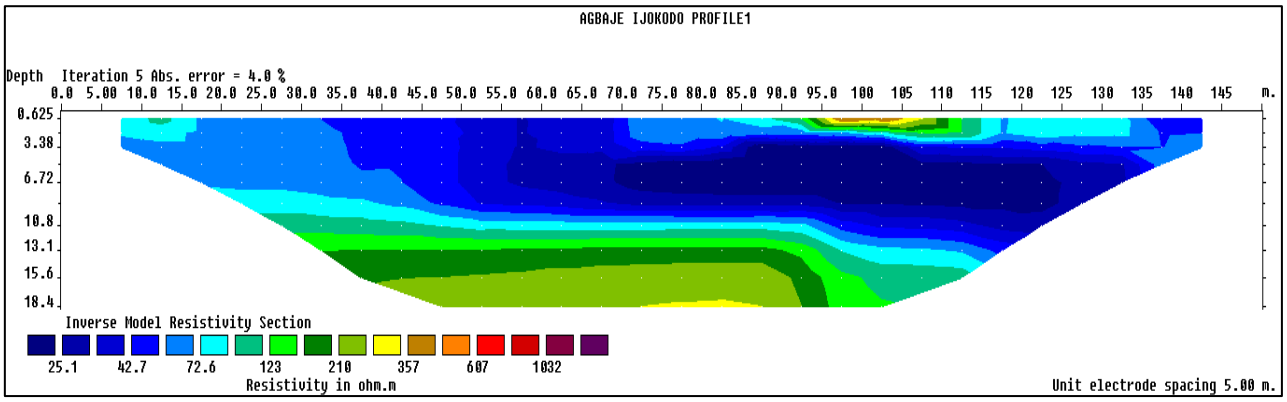


Figure 3: Inverted model section of profile line 1

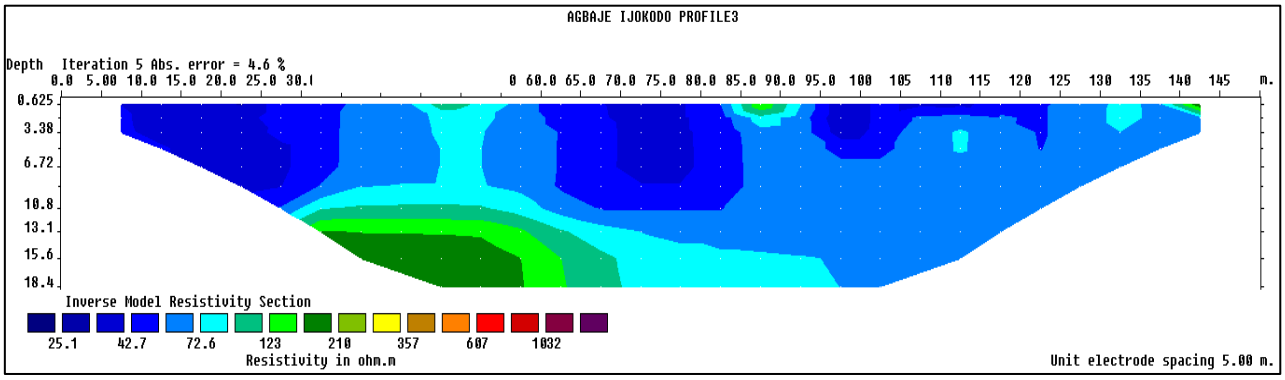


Figure 4: Inverted model section of profile line 3

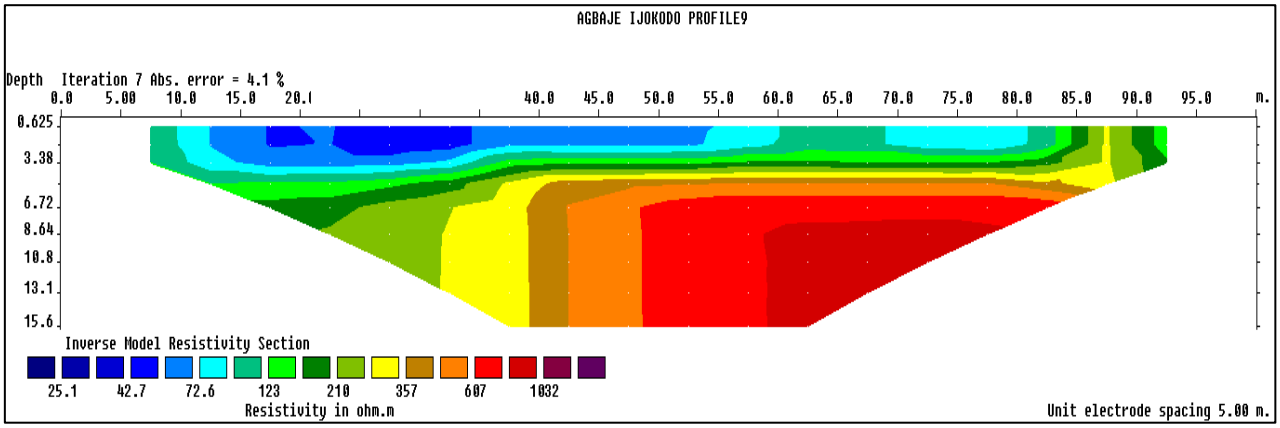


Figure 5: Inverted model section of profile line 9

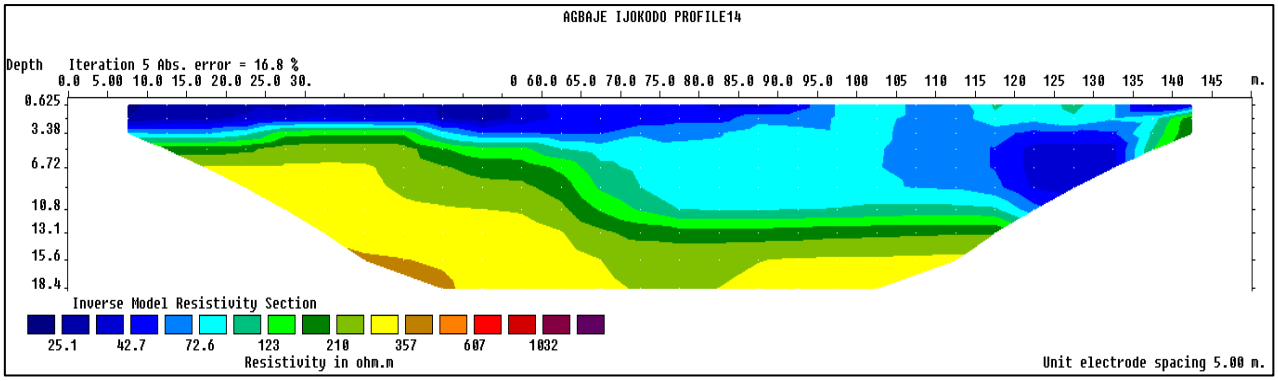


Figure 6: Inverted model section of profile line 14

4.2 *Geoelectric Investigation (VES)*

Vertical Electrical Sounding (VES) using the Schlumberger array was conducted at 28 locations to characterize the subsurface lithology and hydrogeological potential. The resulting sounding curves revealed a geoelectric sequence ranging from two to five layers, characterized by four distinct curve types: H (57%), A (28%), KH (8%), and HKH (4%). The predominant H-type curve (Figure 7) confirms the presence of the classic three-layer model typical of the Nigerian Basement Complex: a topsoil layer, a low-resistivity saprolite (weathered basement), and the underlying fractured or fresh bedrock (Ariyo *et al.,* 2021). This intermediate weathered layer typically exhibits high porosity but low permeability, serving as a significant though complex water-bearing unit. However, its high clay content often presents a hydraulic challenge, as high porosity does not always translate to high permeability in these tropical crystalline aquifers (Jean-Christophe *et al.,* 2018; Lachassagne *et al.,* 2021). In contrast, the A-type curves represent a simplified two-layer model of topsoil directly overlying the basement, while the KH and HKH types (Figure 8) indicate more complex multi-layering involving lateritic clay and deeper weathered horizons. By integrating these vertical data points, the study generated thematic maps for bedrock topography and overburden thickness, providing a scientific basis for identifying high-yield zones where basement depressions align with significant regolith thickness (Oladunjoye, Korode *et al.,* 2019; Raji and Abdulkadir, 2020)

These VES data (Table 1) were spatially distributed to ensure comprehensive coverage, providing the basis for interpreting bedrock topography, overburden thickness, and groundwater potential. The derived parameters were subsequently used to generate thematic maps, including weathered layer resistivity and basement relief, to delineate the most favorable zones for groundwater abstraction

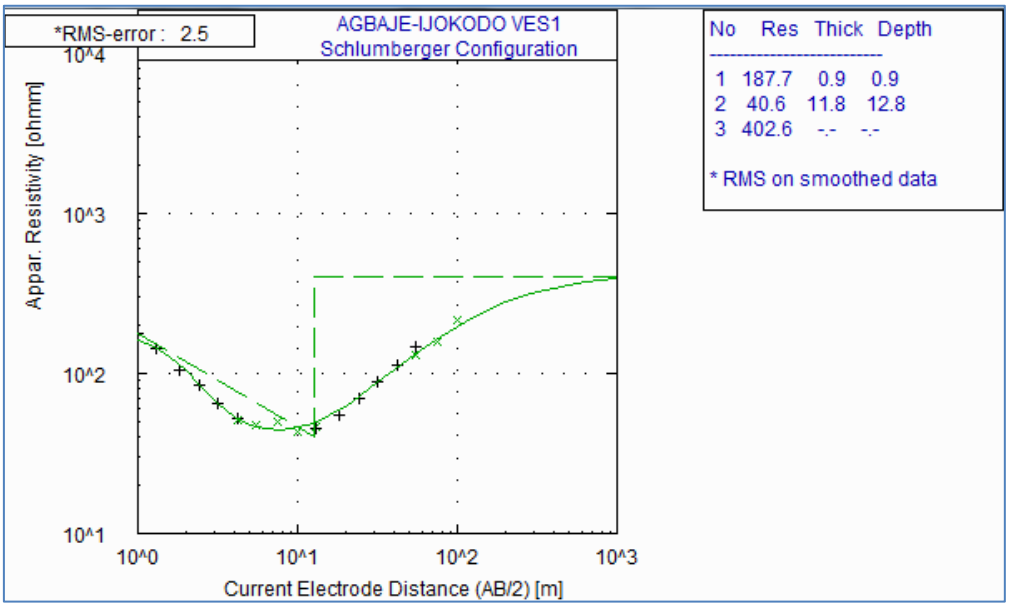


Figure 7: Representative layer model interpretation for H-curve type for Agbaje–Ijokodo VES

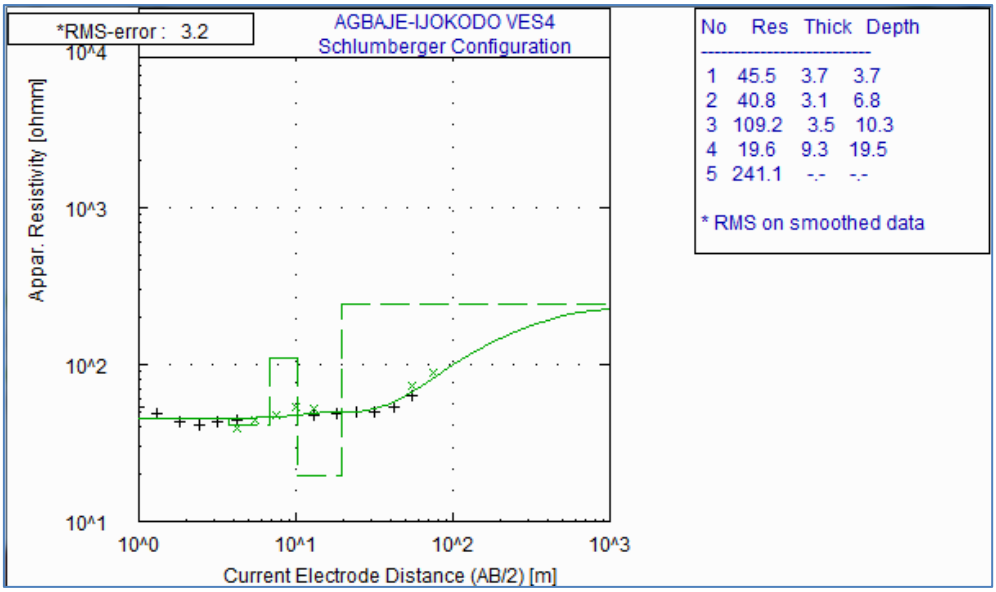


Figure 8: Representative layer model interpretation for HKH-curve type for Agbaje–Ijokodo VES

Table 1: Summary of Vertical Electrical Sounding (VES) Data and Interpretations

Curve Type	Frequency (%)	Geoelectric Layers	Typical Lithology	Hydrogeological Significance
H-type	57%	3 Layers	Topsoil → Weathered Basement → Fractured/Fresh Basement	Intermediate layer (clay/sandy clay) is often water-saturated; high porosity but low permeability.
A-type	28%	2 Layers	Topsoil → Fractured/Fresh Basement	Limited overburden; groundwater potential depends primarily on basement fracturing.
KH-type	8%	4 Layers	Topsoil → Lateritic Clay → Weathered Basement → Fractured/Fresh Basement	Complex sequence with multiple weathered horizons; potential for perched aquifers.
HKH-type	4%	5 Layers	Multi-layered sequence (as above with additional lithological variations)	Highly stratified subsurface; indicates deep and varied chemical weathering.

Overburden Thickness

The overburden thickness across the Agbaje-Ijokodo community, defined as the total depth of all materials overlying the fractured or fresh basement, ranges from 2.2 m to 22.1 m, with an average thickness of 11.5 m. The overburden in the study area is considered relatively shallow compared to the characteristic ranges established for similar basement terrains by Olorunfemi and Okhue (1992), Dan-Hassan and Olorunfemi (1999). Spatially, the eastern portion of the study area (Agbaje Community) exhibits a thicker overburden, with values exceeding 15 m. This significant thickness correlates with the presence of productive deep hand-dug wells in the locality. In contrast, the Ijokodo Community is characterized by much shallower overburden, indicating that groundwater abstraction in that sector may be less feasible unless specific fractured zones within the basement are targeted.

Weathered Basement Resistivity

The weathered basement across the Agbaje–Ijokodo community exhibits significant resistivity variation, ranging from 17 Ωm to 365 Ωm with a mean of 74 Ωm reflecting a highly heterogeneous subsurface. A clear spatial divide is evident: the Agbaje area displays lower resistivity values that fall within the high-yield range (50 Ωm - 150 Ωm established by Obaro *et al.,* (2025), while the Ijokodo community is characterized by higher resistivity. Despite these promising signatures in Agbaje, the weathered layer remains relatively thin throughout the study area, maintaining a mean thickness of only 10.8 Ωm which may limit the overall storage capacity of the primary aquifer.

Consequently, groundwater prospects transition from high in the western sectors to moderate or poor in the east, where the resistive nature of the materials suggests lower porosity and less intense weathering. This thinness of the weathered profile across the study area suggests that sustainable groundwater development cannot rely solely on the saprolite layer. Instead, the most viable abstraction strategies should prioritize the low-resistivity zones within the Agbaje community or target deeper, localized fractured zones where the overburden is insufficient to maintain long-term yields. These results are consistent with the hydrogeological models established by Olorunfemi and Okhue (1992) and Omosuyi *et al.,* (2003), which emphasize that in

crystalline terrains, the saprolite-fracture bedrock interface often acts as the primary zone of transmissivity. Recent studies in similar geological settings (Salami *et al.,* 2023) further confirm that while the weathered layer provides storage, the fracture network provides the necessary connectivity for high-yield boreholes.

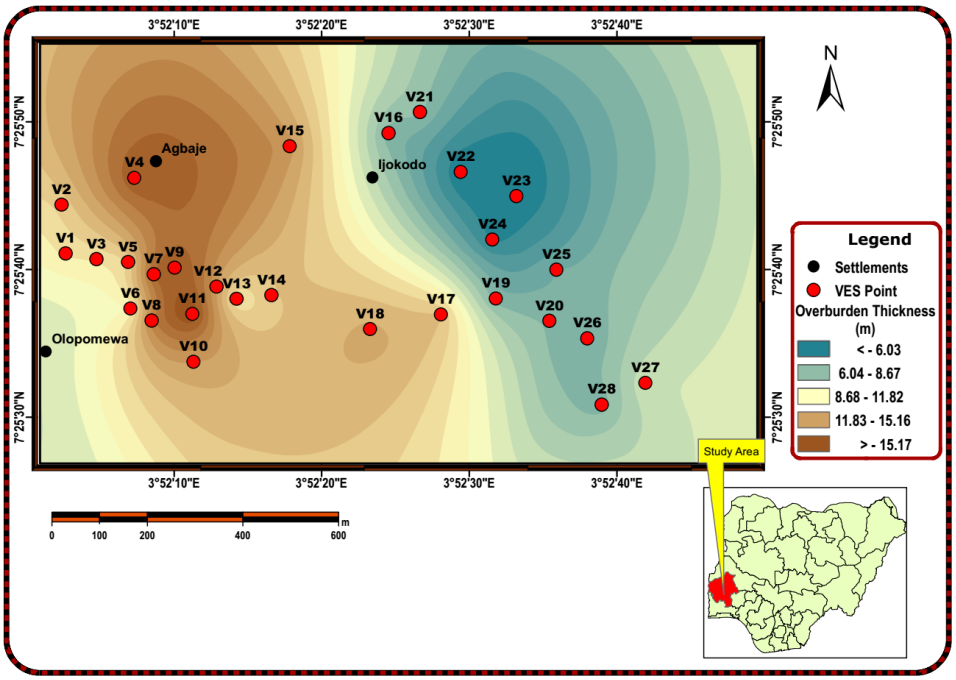


Figure 9: The overburden thickness map of Agbaje - Ijokodo community, Ibadan

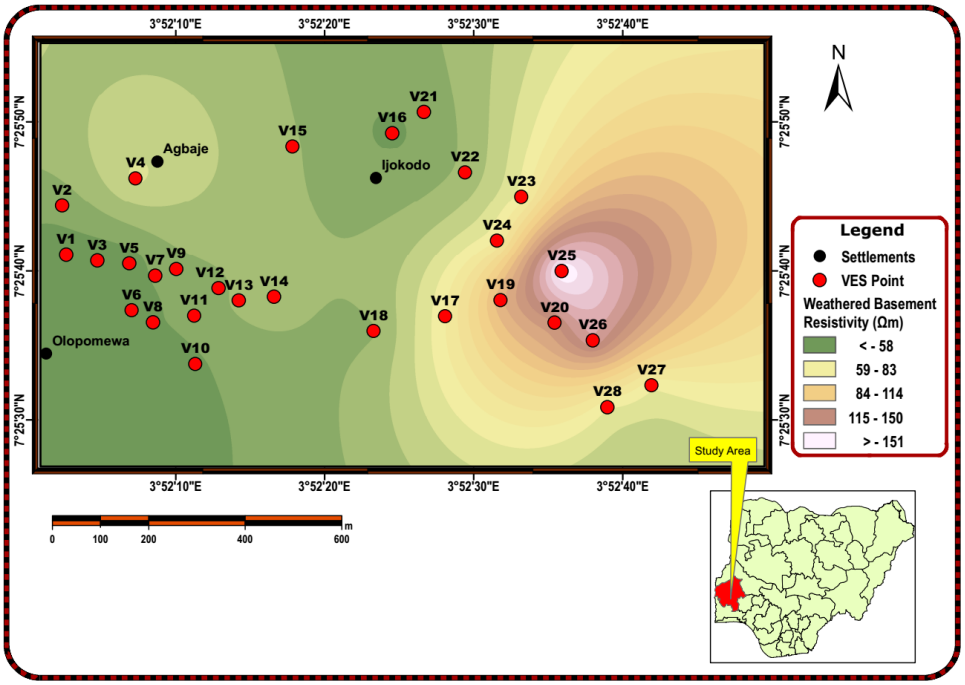


Figure 10: The weathered basement resistivity map of Agbaje - Ijokodo community, Ibadan

Bedrock Relief/Topography

The basement topography map (Figure 11) reveals an irregular subsurface relief shaped by differential weathering, resulting in a series of bedrock ridges and depressions. This structural architecture is hydrogeologically significant, as depressions typically coincide with intense weathering and thicker overburden, acting as natural reservoirs for groundwater accumulation (Doro *et al.,* 2023; Oyeyemi and Gomo, 2025; Bayewu *et al.,* 2017). Spatially, the Ijokodo community is dominated by bedrock ridges and shallow overburden, while the Agbaje community occupies broader basement depressions. This gradient suggests that groundwater migrates from the higher-elevation ridges in Ijokodo toward the low-lying collection centers in Agbaje. Specifically, a prominent depression

identified in the southeastern Olopomewa sector serves as a major regional sink, receiving subsurface flow from adjacent basement crests and representing the most favorable location for high-yield borehole development.

Basement Resistivity

The basement resistivity values of Agbaje – Ijokodo community in Ibadan range between 136 Ωm and 1921 Ωm; with a mean value of 524 Ωm. Olayinka and Olorunfemi (1992) demonstrated that any basement with resistivity values exceeding 1000 Ωm is fresh basement but where the resistivity values are less than 1000Ωm, the bedrock is fractured and saturated with freshwater. Fractures influence the groundwater yield more than weathered layer probably because of the relatively high permeability (Olorunfemi and Fasuyi, 1993; Ogundana and Talabi, 2014; Omosuyi, *et al.,* 2003) The basement resistivity map showed that fractured bedrock (<1000Ωm) is dominant within the study area with few occurrences of fresh bedrock (>1000Ωm) sparsely present in part of the area. The fresh basement could be observed to occur at the eastern part of the area which form part of Ijokodo community.

Reflection Coefficient

To assess the degree of basement fracturing and distinguish competent rock from aquiferous zones, the reflection coefficient (k) was calculated for each VES point using the method established by Bhattacharya and Patra (1968) and Olayinka (1996):

$$r = \{\frac{\rho_n - \rho(n-1)}{\rho_n + \rho(n-1)}$$

In this equation, 'n' represents the resistivity of the basement and 'n-1'is the resistivity of the overlying weathered layer. As the reflection coefficient approaches a maximum value of 1.0, the bedrock is interpreted as increasingly fresh and competent. Conversely, coefficients below 0.75, combined with a relatively thick overburden, are indicative of high groundwater potential due to increased fracturing (Olayinka, 1996; Oladunjoye, Adefehinti *et al.,* 2019). The resulting reflection coefficient map shows that approximately 60% of the study area falls within the favorable threshold (k < 0.75). While the Ijokodo community and peripheral parts of Agbaje are characterized by higher coefficients, suggesting a fresher, less permeable basement, the central portion of the study area exhibits lower values. This central zone is interpreted to have a significantly fractured basement with average weathering, marking it as a primary target for groundwater development.

Longitudinal Conductance

Longitudinal conductance (S), a key Dar-Zarrouk parameter, was calculated to evaluate the clay content and protective capacity of the overburden (Anamika and Birendra, 2025) across the Agbaje - Ijokodo community. Values range from 0.0162 $\Omega^{-1}$to 0.6532 Ω^{-1} (mean: 0.2488 Ω^{-1}) where higher values signify a greater accumulation of clayey materials. While high clay content can reduce aquifer transmissivity (Lopane, 2024), it simultaneously enhances the natural filtration of surface contaminants. Following the classifications by Anamika and Birendra (2025) and Abiola *et al.,* (2009), the study area exhibits a distinct spatial gradient in aquifer protection. The eastern sector and Ijokodo community are characterized by poor protective capacity (S < 0.1 Ω^{-1}), while the central transition zone is rated as weak (0.1 - 0.19 Ω^{-1}). Conversely, the western portion (Agbaje community) demonstrates moderate protective capacity (0.2 - 0.69 Ω^{-1}) indicating that its thicker clayey overburden provides a more effective natural shield for the underlying groundwater units.

Transverse Resistance

Transverse resistance (T), another critical Dar-Zarrouk parameter, was evaluated to estimate the transmissivity of the aquiferous zones across the Agbaje - Ijokodo community. According to Reinhard and William, (1985); Tijani *et al.,* (2021); Ugbor and Ogbodo, (2023), transverse resistance maintains a direct relationship with transmissivity, where higher T values generally indicate superior hydraulic conductivity. In the study area, transverse resistance values range from 146 to 3,547 Ωm^2, with a mean value of 894 Ωm^2. Transverse resistance (T) ranges from 146 to 3547 Ωm^2 (mean: 894 Ωm^2) across the Agbaje - Ijokodo study area. While more than 70% of the site is characterized by weak to moderate transmissivity (400 to 2000 Ωm^2), spatial analysis identifies the eastern and southern Ijokodo community, along with central Agbaje, as having high-yield potential where T values exceed 1000 Ωm^2. In contrast, the northern Ijokodo and Olopomewa sectors exhibit poor transmissivity (< 400 Ωm^2), suggesting negligible groundwater prospects in those specific zones.

Electrical Anisotropy/Coefficient of Anisotropy

The coefficient of anisotropy (λ) map (Fig. 4.23) illustrates the directional variation of resistivity within the subsurface, reflecting the degree of rock fracturing and metamorphism. In the Agbaje - Ijokodo community, the electrical anisotropy (λ) values range from 1.00 to 1.57 with a mean of 1.13. This range aligns with the established average of 1.56 for metamorphic rocks in the Southwestern Nigeria Basement Complex (Olorunfemi *et al.,* 1991), corroborating the local geological map. Research by Olorunfemi and Olorunniwo (1985) and Olorunfemi and Okhue (1992) highlights a direct linear relationship between electrical anisotropy and groundwater yield, where higher anisotropy often indicates more intense fracturing and higher secondary porosity. Spatially, the eastern sector within the Ijokodo community displays the highest anisotropy values, suggesting that this area possesses a more fractured bedrock architecture and likely offers fair groundwater potential despite its relatively thin overburden.

Groundwater Potential Evaluation

The subsurface architecture of the Agbaje - Ijokodo community (Figure 12) reveals a classic, albeit inhomogeneous, three-layer sequence typical of the Southwestern Nigerian Basement Complex: clayey topsoil, a weathered saprolite layer, and a basal fractured-to-fresh basement. 2D Electrical Resistivity Tomography (ERT) and 1D Vertical Electrical Sounding (VES) data indicate a topsoil layer (20 - 120 Ωm) up to 10 m thick, underlain by a weathered basement (150 - 400 Ωm) averaging 10.8 m in depth. While this weathered zone serves as the primary unconfined aquifer due to its high porosity, its overall yield is often constrained by high clay content and limited thickness. This observation aligns with recent findings by Ariyo *et al.,* (2021), who noted that excessive clay in the saprolite can significantly impede hydraulic conductivity despite high storage volumes. However, the underlying fractured basement units, identified by reflection coefficients below 0.75, provide the necessary secondary porosity to enhance sustainable groundwater abstraction, particularly in the central and southern sectors where transmissivity is highest.

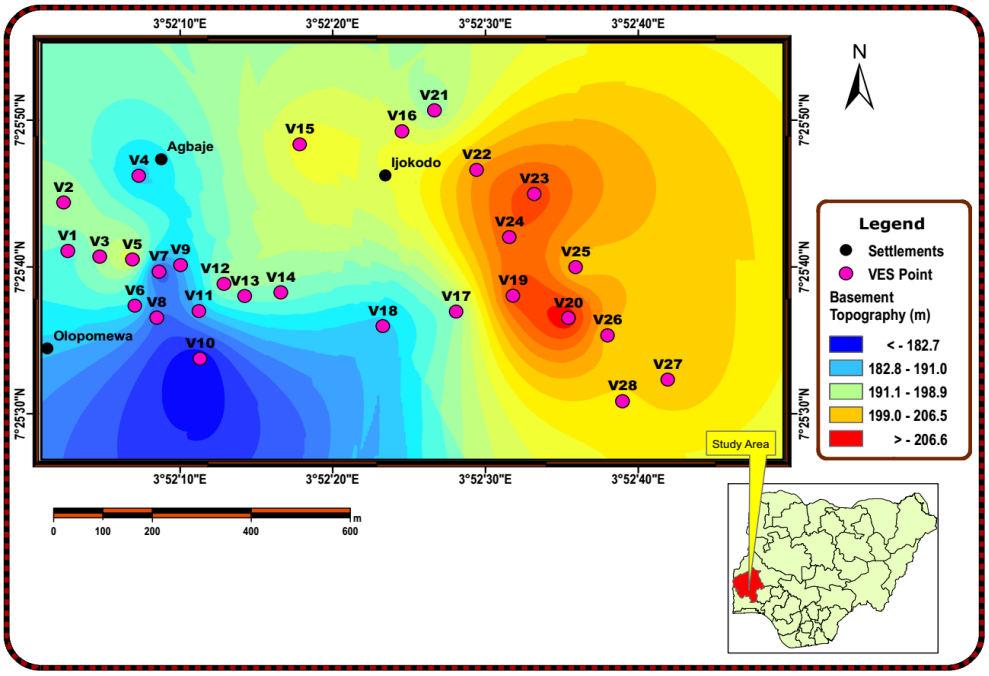


Figure 11: The basement topography map of Agbaje - Ijokodo community, Ibadan

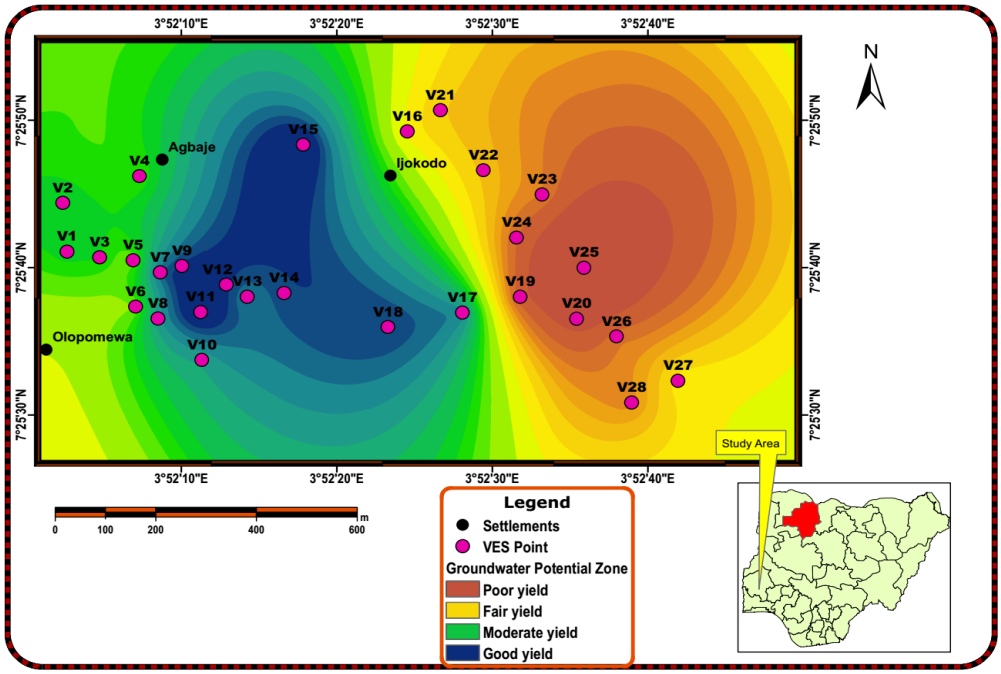


Figure 12: The groundwater potential map of Agbaje - Ijokodo community, Ibadan

CONCLUSIONS

This study utilized an integrated geophysical approach, combining 14 Wenner-array 2D profiles with 28 Schlumberger-array soundings (VES), to delineate the hydrogeological architecture of the Agbaje - Ijokodo community. By analyzing the subsurface lithology and local geology, the investigation revealed that shallow, near-surface aquifers within the regolith are largely insufficient. Instead, the most reliable groundwater sources are found within the deeper weathered and bedrock horizons. To pinpoint these zones, a comprehensive suite of geoelectric parameters, including overburden thickness, basement relief, anisotropy, and Dar-Zarrouk parameters, was mapped to evaluate both storage capacity and transmissivity. Integrating these geoelectric parameters with basement topography and Dar-Zarrouk parameters clarifies the spatial distribution of groundwater potential across the community. The Agbaje sector occupies broad basement depressions that act as natural collection centers with moderate protective capacity (0.2 - 0.69 Ωm) shielding the aquifer from surface contaminants. In contrast, the Ijokodo area is dominated by bedrock ridges and shallow overburden, resulting in poor to fair potential. Ultimately, the synthesis of these data highlights the central and Agbaje regions as the most viable targets for high-yield borehole development, as they satisfy the criteria of thick overburden (> 15 m) and intense basement fracturing. This confirms that an integrated resistivity approach is essential for navigating the complex hydrogeological variations inherent in metamorphic terrains.

By synthesizing these individual thematic maps into a single composite Groundwater Potential Map, the study area was categorized into zones of good, moderate, fair, and poor potential. The results indicate that the most sustainable prospects for groundwater development are localized in the central and Agbaje sectors, where geoelectric signatures align with thick overburden and favorable structural depressions. This integrated mapping provides a reliable, cost-effective framework for borehole siting, ensuring that future water development projects in this basement terrain target the most productive and protected aquiferous units.

REFERENCES

1. Abiola, Olubola & Enikanselu, Pius & Oladapo, Michael. (2009). Groundwater potential and aquifer protective capacity of overburden units in Ado-Ekiti, southwestern Nigeria. *International Journal of Physical Sciences*. 4. https://www.researchgate.net/publication/267948472
2. Ariyo, S. O., Bayewu, O. O., Ajibade, O. M., Odugbesan, O. O. and Adeyemi, G. O. (2023). Lithological and Structural Factors Affecting Groundwater Occurrence in Eruwa, South West Nigeria. Nigerian Journal of Physics (NJP) ISSN online: 3027-0936. Volume 32(4), December 2023. DOI: https://doi.org/10.62292/njp.v32i4.2023.164
3. Ogundana A.K, Talabi A. O. (2014). Groundwater Potential Evaluation of College of Engineering, Afe Babalola University, Ado-Ekiti, Southwestern Nigeria. *American Journal of Water Resources*. 2014; 2(1):25-30. doi: 10.12691/ajwr-2-1-4
4. P. K. Bhattacharya & H. P. Patra (1968). Direct Current Electric Sounding (Methods in Geochemistry and Geophysics, 9.) ix + 135 p., 47 figs., 16 tables. Elsevier Publishing Co., Amsterdam, London, New York. Geological Magazine. 106. 226. 10.1017/S001675680005216X.
5. Tijani, Moshood & Obini, Nnamdi & Inim, Iniemem. (2021). Estimation of aquifer hydraulic parameters and protective capacity in basement aquifer of south-western Nigeria using geophysical techniques. Environmental Earth Sciences. 80. 10.1007/s12665-021-09759-4.
6. Reinhard K. Frohlich, William E. Kelly (1985). The relation between hydraulic transmissivity and transverse resistance in a complicated aquifer of glacial outwash deposits. Journal of Hydrology,Volume 79, Issues 3–4, Pages 215-229, ISSN 0022-1694, https://doi.org/10.1016/0022-1694(85)90056-3.
7. Ugbor, C.C. and Ogbodo, U.K. (2023) Estimation of Aquifer Transmissivity Using Dar Zarrouk Parameters at Ogbozara-Ekwegbe-Agu and the Environ, Enugu State, Nigeria. *Open Journal of Geology*, **13**, 783-805. doi: 10.4236/ojg.2023.138035
8. 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
9. Lopane, N., Albéri, M., Barbagli, A., Chiarelli, E., Colonna, T., Gallorini, F., Guastaldi, E., Mantovani, F., Petrone, D., Pierini, S., Raptis, K. G. C., & Strati, V. (2024). Geoelectric Joint Inversion for 3D Imaging of Vineyard Ground. *Agronomy*, *14*(11), 2489. https://doi.org/10.3390/agronomy14112489
10. Anamika Pandey, Birendra Pratap (2025). Aquifer characterization and protective capacity evaluation using geoelectrical measurements in parts of Vindhyan Supergroup, Uttar Pradesh, India, Geosystems and Geoenvironment, Volume 4, Issue 4, 2025, 100412, ISSN 2772-8838, https://doi.org/10.1016/j.geogeo.2025.100412.
11. Oyeyemi, Kehinde & Gomo, Modreck. (2025). Hydrogeophysical Mapping of Basement Aquifers in Part of Southwestern Nigeria: Implications for Groundwater Resource Management. 10.5772/intechopen.115603.
12. Bayewu, O.O., Oloruntola, M.O., Mosuro, G.O. (2017). Geophysical evaluation of groundwater potential in part of southwestern Basement Complex terrain of Nigeria. *Appl Water*

Sci **7**, 4615–4632 (2017). https://doi.org/10.1007/s13201-017-0623-4

13. Oladunjoye, M. A., Adefehinti A. & Akinrinola O. R. (2021). Integrated geophysical investigation for the characterization of valley bottom soil at Ilora, southwestern Nigeria. *NRIAG.* Journal of Astronomy and Geophysics, 10(1), 110-124. https://doi.org/10.1080/20909977.2020.1859668
14. M.A. Oladunjoye, A. Adefehinti, K.A.O. Ganiyu, (2019). Geophysical appraisal of groundwater potential in the crystalline rock of Kishi area, Southwestern Nigeria, Journal of African Earth Sciences, Volume 151, 2019, Pages 107-120, ISSN 1464-343X, https://doi.org/10.1016/j.jafrearsci.2018.11.017.
15. Olayinka, A.I., 1996. Non-uniqueness in the modelling of bedrock resistivity and its hydrogeological implications. *Journal of Water Resources*, *7, 49-55.*
16. Olayinka, A.I. and Olorunfemi, M.O. (1992) Determination of Geoelectric Characteristics in Okene Area and Implications for Borehole Siting. Journal of Mining and Geology, 28, 403-411. Link via AJOL
17. Olorunfemi, M. O., Dan-Hassan, M. A., & Olorunniwo, M. A. (1991). On the resolution and differentiation of the hydrogeologic units of the weathered layer overlying a copper-bearing metamorphic terrain. *Journal of Mining and Geology*, 27(1), 53-60. Link via AJOL
18. Olorunfemi, M. O., & Fasuyi, S. A. (1993). Aquifer types and the geoelectric/hydrogeologic characteristics of part of the central basement terrain of Nigeria (Niger State). *Journal of African Earth Sciences*, 16(3), 309-317. https://doi.org/10.1016/0899-5362(93)90051-Q
19. Olorunfemi, M. O. and Okhue, E. T. (1992) Hydro-geologic and geologic significance of a geoelectric sur-vey at Ile-Ife, Nigeria. Journal of Mining and Geology, 28(2), 221-229.Link via AJOL
20. MO Olorunfemi, MA Olorunniwo (1985). Geoelectric parameters and aquifer characteristics of some parts of southwestern Nigeria. Journal Geologia Applicata e Idrogeologia Volume 20 Issue 1 Pages 99-109. Link: Google Scholer, Worldcat Catalog.
21. Palacky, G. J., Ritsema, I. L., & De Jong, S. J. (1981). Electromagnetic prospecting for groundwater in Precambrian terrains in the Republic of Upper Volta. *Geophysical Prospecting*, 29(6), 932-955. https://doi.org/10.1111/j.1365-2478.1981.tb01036.x
22. Troeger, U., Chambel, A. (2021). Topical Collection: Progress in fractured-rock hydrogeology. *Hydrogeol J* **29**, 2557–2560 (2021). https://doi.org/10.1007/s10040-021-02414-z
23. Olawale Babatunde Olatinsu, Sikiru Yemi Salawudeen (2021). Integrated geophysical investigation of groundwater potential and bedrock structure in Precambrian basement rocks of Ife, southwest Nigeria, Groundwater for Sustainable Development, Volume 14, 100616, ISSN 2352-801X, https://doi.org/10.1016/j.gsd.2021.100616.
24. Ahaneku, C.V.; Obiamalu, C.C.; Aseh, P.; Elomba, U.F.; Muogbo, C. D. and Ogbuefi, C.E. (2025). Integration of Geophysical Methods for Comprehensive Site Characterization: Principles and Case Studies. International Journal of Science and Research Archive, 2025, 15(03), 1010-1025. Article DOI: https://doi.org/10.30574/ijsra.2025.15.3.1788
25. Falade, A.O., Oni, T.E., Bewaji, S. (2025). Integrated geophysical subsurface characterization for construction site suitability of the proposed central library at achievers university, Owo, Nigeria. *Discov Civ Eng* **2**, 56 (2025). https://doi.org/10.1007/s44290-025-00212-0
26. Solomon Nehemiah Yusuf, Mubarak Umar Faruk, Lucky Osaro Imagbe, Ovye Musah Yohanna, Ishaq Yusuf, Abraham Onoshagbegbe, Musa Kamal, Timbee Terunga Jacob (2022). Integrated geophysical investigation for lead and zinc mineralization in Wase, middle Benue Trough, Nigeria, Heliyon, Volume 8, Issue 12, 2022, e12541, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2022.e12541. (https://www.sciencedirect.com/science/article/pii/S2405844022038294)
27. Obaro, Reuben & Agbalajobi, Sunday & O, Adio. (2020). Hydrogeophysical Investigation Using Electrical Resistivity Method In Tanke Ilorin, Kwara State. Earth Sciences Pakistan. 4. 65-69. 10.26480/esp.02.2020.65.69.
28. Saores, Moises & Pereira, Anacleto & De, Filomena & Alves, Jesus & do Rosario, Juvencio & Silva, Domingos & Da, Leonisia & Carvalho, Silva & Celestino, Norberto & Amaral, Afonso & Valenca, Marcelo & Barros, Johanes. (2022). Electrical Resistivity Survey for Groundwater Investigation of River Basin Deposit at Laga Area, Baucau Timor Leste. Vol.5. 125-131. https://www.researchgate.net/publication/366524135
29. Aweda, A. K, Jatau, B. S, Goki, N. G, Bashir, I. Y, Obaje, N. G (2023). Application of VES and 2D Resistivity Methods for Groundwater Exploration in Kutigi-Enagi Region, Northern Bida Basin, Nigeria. Saudi J Eng Technol, 8(2): 29-40. DOI: 10.36348/sjet.2023.v08i02.001
30. Ariyo, S. O., Bayewu, O. O., Ajibade, O. M., Odugbesan, O. O. and Adeyemi, G. O. (2023). Lithological and Structural Factors Affecting Groundwater Occurrence in Eruwa, South West Nigeria. Nigerian Journal of Physics (NJP) ISSN online: 3027-0936. Volume 32(4), December 2023. DOI: https://doi.org/10.62292/njp.v32i4.2023.164
31. Pavelic, P.; Giordano, M.; Keraita, B.; Ramesh, V; Rao, T. (Eds.). (2012). Groundwater availability and use in Sub-Saharan Africa: A review of 15 countries. Colombo, Sri Lanka: International Water Management Institute (IWMI). 274 p. doi: 10.5337/2012.213

32. Kehinde D. Oyeyemi, Ahzegbobor P. Aizebeokhai, Mohamed Metwaly, Michael A. Oladunjoye, BabaMayowa A. Bayo-Solarin, Oluseun A. Sanuade, Cherish E. Thompson, Francis S. Ajayi, Osagie A. Ekhaguere, (2021). Evaluating the groundwater potential of coastal aquifer using geoelectrical resistivity survey and porosity estimation: A case in Ota, SW Nigeria. Groundwater for Sustainable Development, Volume 12, 2021, 100488, ISSN 2352-801X, https://doi.org/10.1016/j.gsd.2020.100488.
33. Jean-Christophe Maréchal, Adrien Selles, Benoit Dewandel, Alexandre Boisson, Jérôme Perrin, Shakeel Ahmed (2018). An Observatory of Groundwater in Crystalline Rock Aquifers Exposed to a Changing Environment: Hyderabad, India. Vadose Zone Journal, Volume17, Issue1Pages 1-14, https://doi.org/10.2136/vzj2018.04.0076
34. Lachassagne, P., Dewandel, B. & Wyns, R. (2021). Review: Hydrogeology of weathered crystalline/hard-rock aquifers—guidelines for the operational survey and management of their groundwater resources. *Hydrogeol J* 29, 2561–2594 (2021). https://doi.org/10.1007/s10040-021-02339-7
35. Raji, W.O., Abdulkadir, K.A. Evaluation of groundwater potential of bedrock aquifers in Geological Sheet 223 Ilorin, Nigeria, using geo-electric sounding. *Appl Water Sci* 10, 220 (2020). https://doi.org/10.1007/s13201-020-01303-2
36. Oladunjoye, M. & Korode, I. & Adefehinti, Afolabi. (2019). Geoelectrical exploration for groundwater in crystalline basement rocks of Gbongudu community, Ibadan, Southwestern Nigeria. Global Journal of Geological Sciences. 17. 25. 10.4314/gjgs.v17i1.3.