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Geophysical assessment of groundwater potential in Divine Estate, Sango Ota, Southwestern Nigeria

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Abstract

This study evaluates the groundwater potential of Divine Estate, Sango Ota, southwestern Nigeria, through geophysical investigation using the Vertical Electrical Sounding (VES) method. Sixteen VES points were surveyed with the Schlumberger electrode configuration (AB/2 = 100 m) to delineate subsurface conditions affecting groundwater occurrence. The area, situated within the Dahomey Basin, experiences persistent water scarcity and frequent borehole failures. Geoelectric interpretation revealed a three-layer structure comprising topsoil, weathered/fractured basement, and fresh basement rock. The dominant curve type is H (68.75%), with minor occurrences of K, KH, A, HQ, and HA types (each 6.25%), indicating varying subsurface conditions with H-type curves suggesting favorable groundwater zones. Overburden thickness ranges from 0.8 to 25.7 m (mean: 1.9 m), which is significantly below the 20–30 m threshold for reliable groundwater development. Transverse resistance varies between 71 and 9,591.4 Ωm^2, implying spatially variable aquifer transmissivity. Longitudinal conductance (0.001–0.625 Ω^{-1}) indicates poor aquifer protective capacity, raising concerns about contamination vulnerability. Integrated analysis of aquifer resistivity, overburden thickness, and Dar-Zarrouk parameters identified high groundwater potential zones at VES stations 2, 7, and 8, where moderate resistivity weathered layers (51–209 Ωm) occur at drillable depths (10–13 m). The findings highlight limited groundwater potential across much of the estate due to shallow overburden and resistive basement conditions. The study recommends strategic borehole placement, adoption of integrated water supply solutions, and rigorous aquifer protection to address the estate's water supply challenges sustainably.

Keywords: Overburden Thickness; Dar-Zarrouk parameters; Groundwater potential; Transverse resistance

1. Introduction

Groundwater constitutes one of the most precious natural resources, fundamentally determining the health and well-being of communities worldwide [1]. Representing approximately 98% of the world's freshwater resources, groundwater serves as the primary source for nearly 90% of global freshwater needs [2]. The occurrence and distribution of groundwater are controlled by complex interactions between climatic conditions, geological formations, subsurface structural features, geomorphological characteristics, and hydrological processes [3][4]. Geophysical methods have emerged as cost-effective tools for subsurface hydrogeological characterization [5]. Electrical resistivity methods have gained widespread acceptance due to their operational simplicity and effectiveness in areas with contrasting resistivity between weathered overburden and bedrock [6]. Vertical Electrical Sounding (VES) has proven particularly valuable in groundwater studies, effectively investigating subsurface structures and delineating potential aquifer zones [7]. The Dominion Estate area faces significant water supply challenges that necessitate scientific intervention. Over time, the area has experienced difficulty in developing reliable water supplies, leading to portable water scarcity for the populace. Unscientific approaches to groundwater exploration have resulted in numerous dry boreholes, while existing hand-dug wells yield substantial water during rainy seasons but run dry during dry periods.

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Notably, no thorough hydro-geological research has been conducted for groundwater characterization in this environment. Surface geophysical techniques for groundwater exploration offer considerable hope for future groundwater development in the area by delineating favorable zones for borehole drilling. This study aims to use geophysical methods to delineate the hydro-geologic framework of Divine Estate, Ota, for assessing groundwater prospects. The research objectives include identifying potential aquifer units within the subsurface, characterizing different subsurface lithologies and their hydrogeological properties, and locating optimal sites for borehole construction. The findings will provide essential data for sustainable groundwater development, contributing to improved water security and supporting regional socio-economic development.

2. Location and Geology of the study Area

The study area is located in Ota, a major industrial and administrative center within the Ado-Odo/Ota Local Government Area of Ogun State, southwestern Nigeria. It lies between longitudes 2°53′E and 3°14′E, and latitudes 6°30′N and 6°39′N, covering an area of approximately 878 km^2 at an elevation of about 53 meters above sea level. Ota's rapid population growth is fueled by urban migration from Lagos State, owing to available land, commercial activity, and industrial employment. The terrain is gently undulating, with elevations ranging between 6 and 7 meters, and is susceptible to seasonal flooding. Drainage is influenced by major water bodies such as the Ogun and Yewa Rivers, and adjacent features like Ologe Lagoon and Badagry Creek. The climate is tropical rainforest, characterized by a wet season (April–October) and a dry season (November–March), with annual rainfall ranging from 316 mm to 600 mm and average temperatures above 18°C. Geologically, Divine Estate (Fig 1) in Ota lies within the eastern margin of the Dahomey Basin (also referred to as the Benin Embayment), a coastal sedimentary basin situated along the West African continental margin (Fig 2).

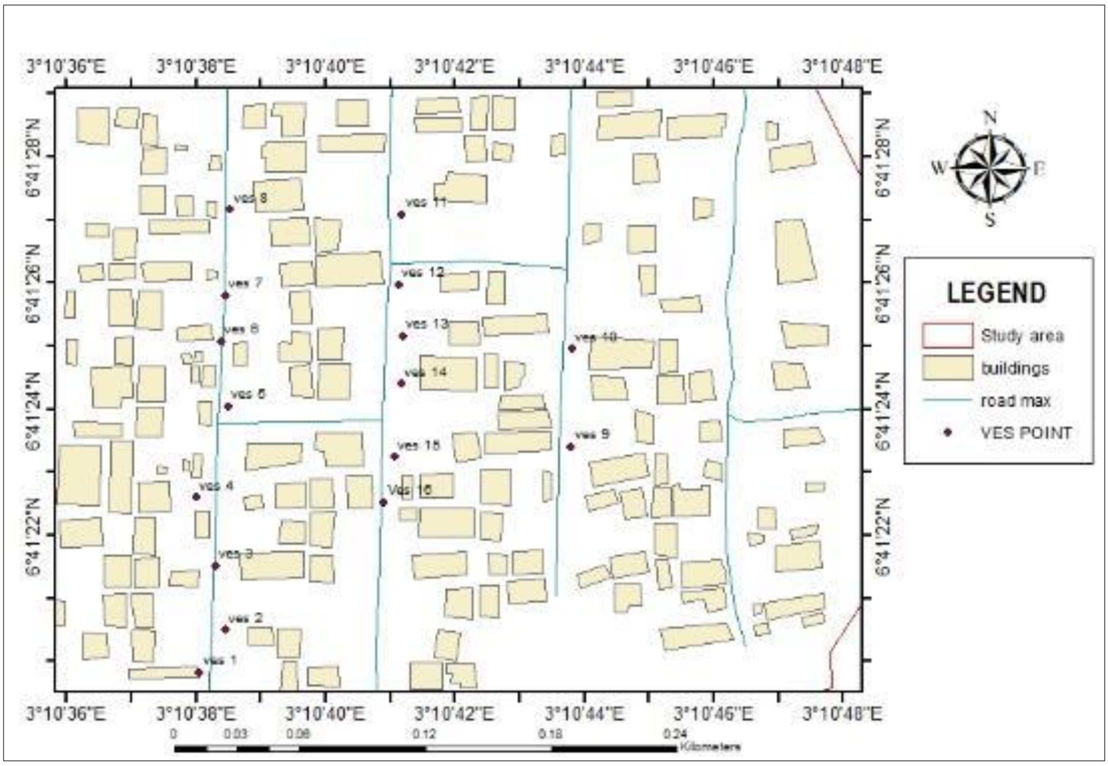

Figure 1 Location map showing the VES points at the study Area

This basin stretches from southeastern Ghana through southern Togo and the Republic of Benin into the southwestern part of Nigeria, where it terminates at the Benin Hinge Line a major structural boundary that delineates the western limit of the Niger Delta Basin [8]. The subsurface lithology of the Dahomey Basin comprises a sequence of Cretaceous to Recent sedimentary units. These include marine and non-marine deposits ranging from shales, sandstones, claystones, and limestones to unconsolidated alluvial materials. In the Nigerian sector of the basin, the sedimentary sequence is underlain by Precambrian Basement Complex rocks composed of migmatites, banded and granite gneisses, which are intruded by granitic and charnockitic bodies of Pan-African age [9]. Tectonically, the Dahomey Basin originated during the Late Jurassic to Early Cretaceous rifting events associated with the opening of the South Atlantic Ocean. Its evolution was controlled by extensional faulting and subsidence, resulting in variable sediment thickness across the basin. The thickest sediment accumulations are observed near the Nigeria–Benin border, slightly west of the study area [10].

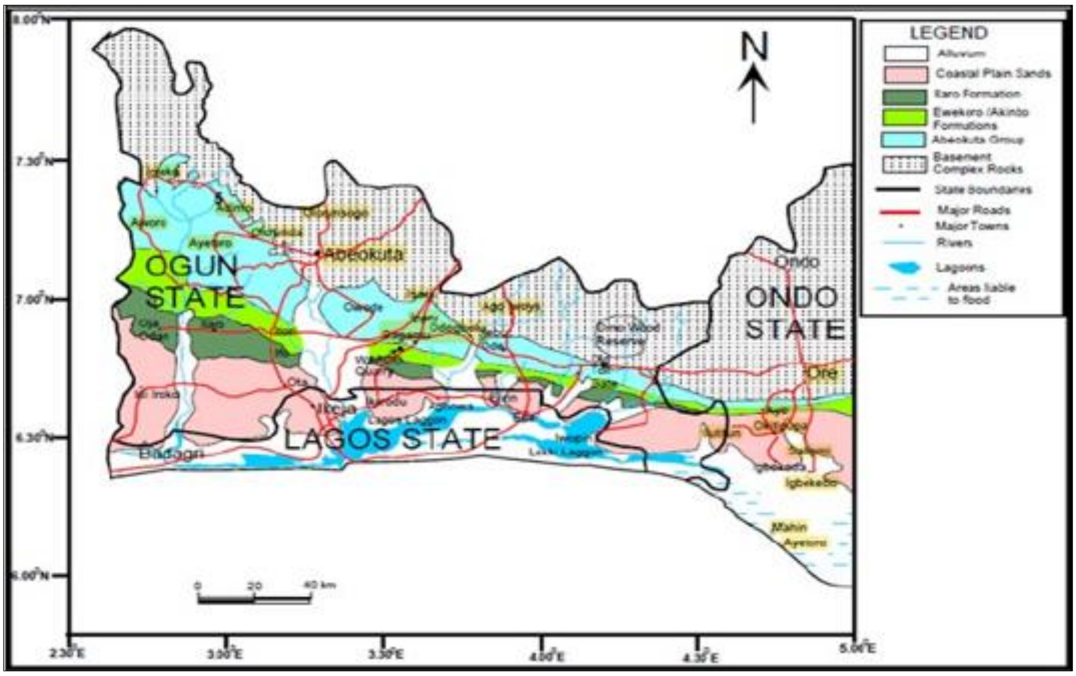

Figure 2 Geologic map of Dahomey Basin in the Nigerian sector showing the states located on the basin [11]

3. Material and methods

A preliminary reconnaissance survey was conducted to evaluate the terrain, identify lithological outcrops, and select appropriate locations for geophysical measurements. This exercise enabled effective planning of the field layout and ensured representative coverage of the study area. The geophysical investigation employed the electrical resistivity method, which is widely used for groundwater exploration due to its sensitivity to changes in subsurface lithology and moisture content. The Vertical Electrical Sounding (VES) technique was adopted using the Schlumberger array configuration, known for its depth penetration efficiency and suitability for hydrogeological studies. Field measurements were conducted using an Erde P-150 resistivity meter, a digital instrument designed for accurate acquisition of resistivity data. The Schlumberger array involves injecting electrical current through two outer electrodes (A and B) and measuring the resulting potential difference between two inner electrodes (M and N). The depth of investigation increases with wider electrode spacing. A maximum current electrode separation (AB/2) of 100 meters was used to ensure sufficient depth coverage. A total of sixteen (16) VES points were surveyed across the study area. The electrode spacing at each point was systematically increased to probe deeper geological layers, and data were recorded on standard Schlumberger resistivity data sheets. Apparent resistivity values were calculated using the field data and the appropriate geometric factor. Data interpretation was carried out using partial curve matching techniques followed by computer-assisted forward modeling. This helped define subsurface geoelectric layers, estimate their resistivity and thickness, and identify potential aquifer zones. This method provided a reliable understanding of the subsurface geology and the distribution of groundwater-bearing formations within the study area.

4. Results and Discussion

The occurrence of groundwater in any geological formation is primarily governed by two fundamental properties: porosity and permeability. In their unaltered state, Basement Complex rocks, which are predominantly igneous and metamorphic in origin, inherently lack both properties due to their crystalline structure [12]. Consequently, these rocks are generally regarded as poor aquifers, as they do not possess the primary porosity and permeability required for effective groundwater accumulation and transmission. However, groundwater potential in Basement Complex terrains is significantly enhanced by the development of secondary porosity and permeability, which arise from structural deformations such as fracturing, jointing, fissuring, and intense weathering [13]. These structural features facilitate the infiltration, movement, and storage of groundwater, thereby transforming otherwise impermeable rocks into viable aquifer systems. In the present study, vertical electrical sounding (VES) data acquired from sixteen (16) selected points were modeled and interpreted to generate geoelectric sections along multiple profiles across the study area. These geoelectric profiles provide insights into the lateral and vertical variation of subsurface resistivity, enabling the identification of zones likely to exhibit enhanced secondary porosity and permeability. The interpreted geoelectric layers serve as a valuable guide for delineating groundwater-bearing formations and for understanding the structural controls on groundwater occurrence within the environment.

Four representative sample of the curve types found within the study area are shown in Fig 3. The sounding curves obtained from this area ranges from 2 to 4 layers with H curve type dominating. Varying sounding curves were obtained from the study area which includes: H (68.75%), K (6.25%), KH (6.25%), A (6.25%), HQ (6.25%), HA (6.25%). [14] showed that field curves often mirror image geo-electrically the nature of the successive lithologic sequence in an area and hence can be used qualitatively to assess the groundwater prospect of an area. The H and HA curves which are often associated with groundwater possibilities [15] are pertinent to the study area. The interpretations of the VES curves were used to prepare geoelectric sections fig 4. The geo-electric parameters of the lithologic units were delineated from the interpreted sounding curves and shown on Table 1. The geoelectric sections show three subsurface geologic sequence which include the topsoil, the weathered/fractured layer and the fresh basement bedrock. The sections depict an area with an overburden thickness with range from 0.5 – 3.5 m. The summary of the VES interpretation is given in table 1. The geoelectric layers deduced from the resistivity data are topsoil, clay soil, lateritic clay, weathered layer, fractured unit and fresh basement. Estimated geoelectric parameters are overburden thickness, resistivity contrast, reflection coefficient and Dar-Zarrouk parameters.

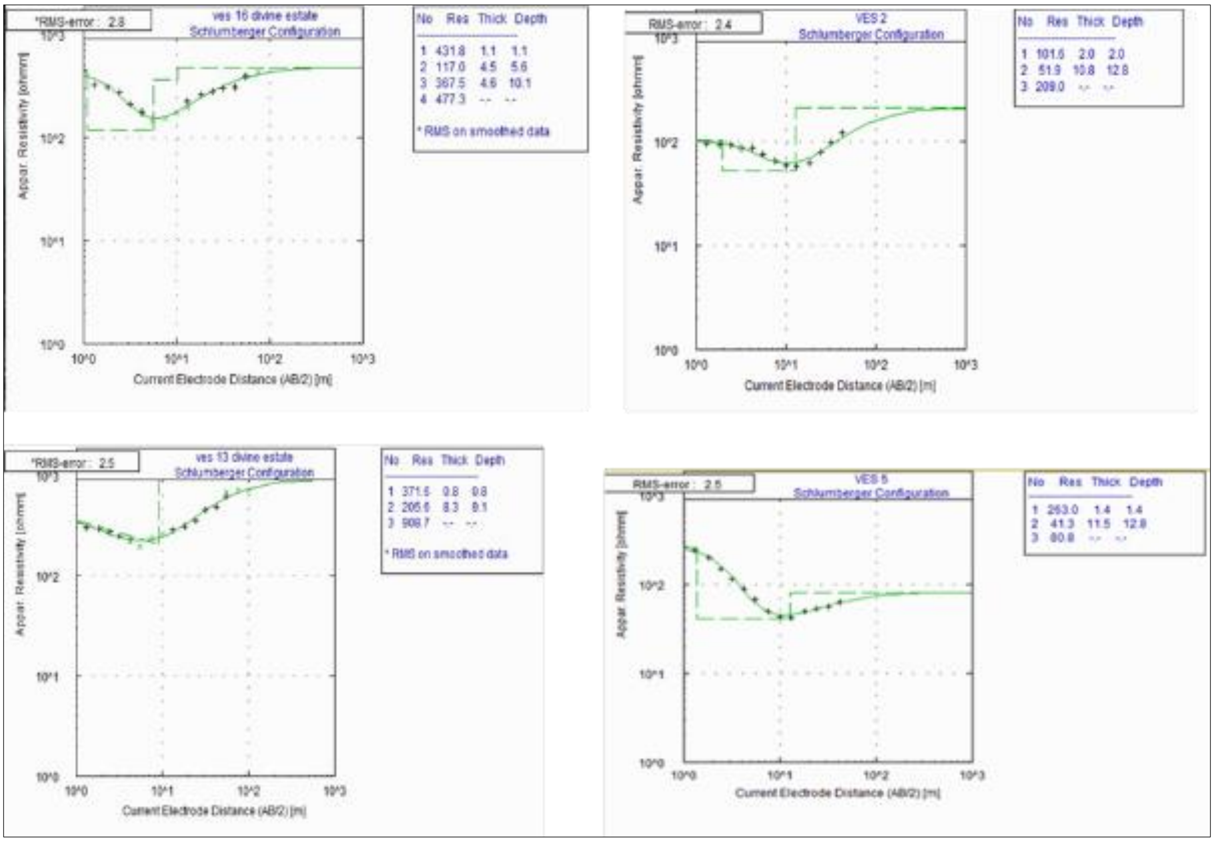

Figure 3 Typical VES curves obtained in the study area

Table 1 Summary of Geo-electrical parameter of the VES curves

VES points	Layers	resistivity (Ωm)	Thickness (m)	Lithology	Curve type
1	1	98.4	1.6	Topsoil	H
	2	5.1	9.5	Clay/weathered basement	
	3	239.4		Fresh basement	

2	1	101.6	2.0	Lateritic topsoil	H
	2	51.9	10.8	Weathered basement	
	3	209.0		Fresh basement rock	
3	1	647.4	1.4	Lateritic topsoil	H
	2	100.8	14.9	Weathered/fractured basement	
	3	2468.1		Fresh basement rock	
4	1	312.1	1.3	Lateritic topsoil	H
	2	47.2	7.7	Weathered saprolite	
	3	2526.8		Fresh basement rock	
5	1	263.0	1.4	Lateritic topsoil	H
	2	41.3	11.5	Weathered basement	
	3	80.8		Fractured basement	
6	1	185.8	1.5	Lateritic topsoil	H
	2	22.4	14.0	Clay rich Weathered zone	
	3	203.2		Fresh basement rock	
7	1	117.9	2.1	Lateritic topsoil	H
	2	12.9	5.5	Clay layer	
	3	433.8		Fresh basement rock	
8	1	173.2	1.5	Lateritic topsoil	H
	2	37.9	9.4	Weathered basement	
	3	382.4		Fresh basement rock	
9	1	93.1	2.0	Topsoil	H
	2	45.7	4.7	Weathered layer	
	3	95.9		Fractured basement	
10	1	3.8	0.8	Clay topsoil	K
	2	108.6	1.5	Lateritic layer	
	3	2.1		Clay basement	
11	1	849.5	0.8	Lateritic topsoil	H
	2	618.8	15.5	Weathered basement	
	3	8282.6		Fresh basement rock	
12	1	232.8	0.5	Topsoil	KH
	2	1654.2	1.3	Lateritic Layer	
	3	103.2	5.1	Weathered basement	
	4	1256.6		Fresh basement rock	
13	1	371.6	0.8	Lateritic topsoil	H
	2	205.6	8.3	Weathered basement	
	3	908.7		Fresh basement rock	
14	1	410.9	2.0	Lateritic topsoil	

	2	453.8	5.3	Weathered basement	A
	3	1085.8		Fresh basement rock	
15	1	529.5	3.2	Lateritic topsoil	HQ
	2	190.4	9.7	Weathered basement	
	3	305.9	12.8	Partially weathered basement	
	4	26.6		fracture zone	
16	1	431.8	1.1	Lateritic topsoil	HA
	2	117.0	4.5	Weathered layer	
	3	367.5	4.6	Partially weathered basement	
	4	477.3		Fresh basemen rock	

Electrical methods are primarily used to detect variations in subsurface resistivity, which reflect differences in lithological properties. These resistivity contrasts between geological units [16][17] are typically sufficient to distinguish between aquiferous and non-aquiferous zones [18]. In this study, two geoelectric sections (Figures 4a and 4b) were developed to provide a clearer understanding of the subsurface stratigraphy and structural configuration within the survey area. Interpretation of the Vertical Electrical Sounding (VES) data revealed three distinct geoelectric layers: a surface topsoil layer, an underlying weathered or fractured horizon, and a deeper, highly resistive unit interpreted as consolidated sediments. The intermediate weathered/fractured layer is considered the main groundwater-bearing formation due to its potential for enhanced porosity and permeability.

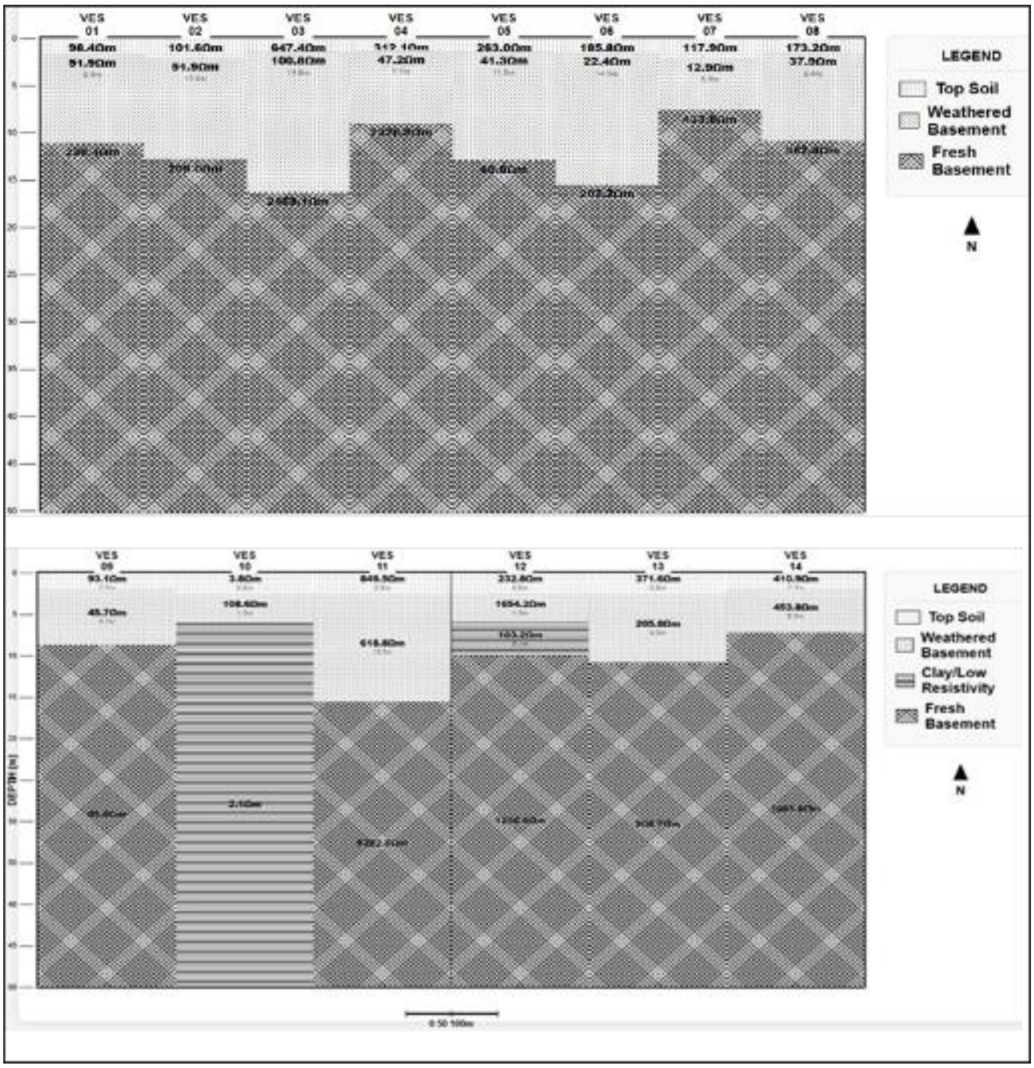

Figure 4 (a) N-S Geoelectric Section VES 1 - 8 (b) N-S Geoelectric Section VES 9 – 14

Figure 4(a) shows a SW-NE geoelectric section (VES 1-8). The geoelectric section reveals three subsurface layers. The first layer constitutes the topsoil. It is composed of sandy /clayey sand with laterites in some places. Its resistivity value ranges from 98.4 – 647.4 ohm-m. The layer thickness varies from 1.3 – 2.1 m it is a well-drained surface with good porosity. Below this layer is a weathered layer which is composed of clayey /sandy clay and has resistivity value that range from 12.9 to 100.8 ohm-m with thickness from 5.5 to 14.9 m it is a water saturated zone with clay rich materials. The last layer is underlain by the fresh basement with resistivity of 80.8 -3468.1 ohm-m. The depth to fresh rock varies between 1.3 -16.3 m.

Figure 4(b) shows the geoelectric section joining (VES 9-14) trending in the N-S direction. three geoelectric layers have been identified across this section. The first layer constitutes the topsoil. It is composed of clay; its resistivity value ranges from 3.8 – 849.5 ohm-m. The layer thickness varies from 0.5 – 2.0 m. Below this layer is a weathered layer which is composed of clay rich weathered material and has resistivity value that range from 45.7 to 1654.2 ohm-m with thickness from 1.7 to 16.3 m. The last layer is underlain by the fresh basement with resistivity of 95.9 -8282.6 ohm-m. The depth to fresh rock varies between 6.8 -17.1 m.

Table 2 Summary of electrical properties at all stations

Ves points	Overburden Thickness(m)	Aquifer Thickness	Aquifer Resistivity	Longitudinal Conductance s(mho)	Electrical Anisotropy (λ)	Transverse Resistance (ωm²)	Reflection Coefficient	Resistivity Constrast
1	1.6	9.5	15.6	0.609	2.51	148.2	0.726	0.159
2	2.0	10.8	51.9	0.208	1.42	560.5	0.323	0.511
3	1.4	14.9	100.8	0.148	3.21	1501.9	0.730	0.156
4	1.3	7.7	47.2	0.163	3.18	363.4	0.735	0.151
5	1.4	11.5	41.3	0.278	2.53	474.9	0.729	0.157
6	1.5	14.0	22.4	0.625	4.13	313.6	0.784	0.121
7	2.1	5.5	12.9	0.426	4.60	71.0	0.803	0.109
8	1.5	9.4	37.9	0.248	2.07	356.3	0.641	0.219
9	2.0	4.7	45.7	0.103	1.45	214.8	0.342	0.491
10	0.8	1.5	108.6	0.014	0.59	162.9	0.483	2.868
11	0.8	16.5	618.8	0.025	1.17	9591.4	0.156	0.729
12	0.5	1.3	1654.2	0.001	0.38	2150.5	0.752	7.123
13	0.8	8.3	205.6	0.040	1.35	1706.5	0.288	0.553
14	2.0	5.3	453.8	0.012	0.97	2405.1	0.050	1.105
15	3.2	9.7	190.4	0.051	1.67	1847.9	0.470	0.360
16	1.1	4.6	117.0	0.038	1.92	526.5	0.573	0.271

5. Electrical Anisotropy

Electrical anisotropy reflects the directional variability in subsurface resistivity and is typically attributed to factors such as stratification, grain orientation, fracturing, metamorphism, or the presence of disseminated conductive minerals [19][20]. In sedimentary environments, such anisotropy is often influenced by sediment layering, structural deformation, and variations in lithology, all of which affect groundwater movement and storage. Vertical Electrical Sounding (VES) data from the study area reveal spatial differences in anisotropic behavior, as interpreted from curve symmetry. For example, VES 8 shows a smooth and symmetrical resistivity curve, indicating isotropic subsurface conditions. Whereas, VES 12 displays irregular, asymmetrical curves, suggestive of electrical anisotropy likely caused by subsurface structural complexity such as bedding or fracturing, which may enhance groundwater flow along preferred paths. The coefficient of anisotropy (λ), calculated to characterize these directional variations, ranges from 1.00 to 1.52 with an average of 1.13 (Figure 5). These values are lower than those typically reported for igneous and metamorphic rocks of the Nigerian Basement Complex 2.12 and 1.56 respectively [21]. This supports the sedimentary classification of the study area, as also corroborated by regional geologic mapping.

Furthermore, [22], and [23], established a linear correlation between the coefficient of anisotropy and groundwater yield, indicating that higher anisotropy values are often associated with increased aquifer productivity. Based on this relationship, the northeastern and parts of the southern zones of the study area which exhibit relatively higher anisotropy values may offer better groundwater potential. These observations underscore the importance of electrical anisotropy in hydrogeophysical evaluation and groundwater resource assessment.

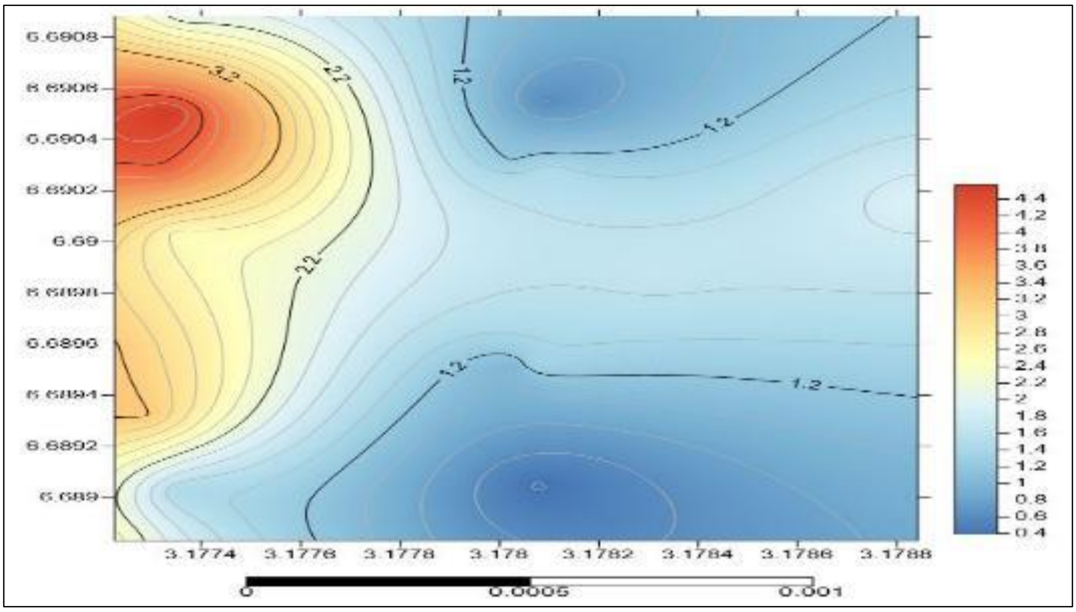

Figure 5 Electrical anisotropy map of Divine Estate Sango Ota

6. Transverse Resistance

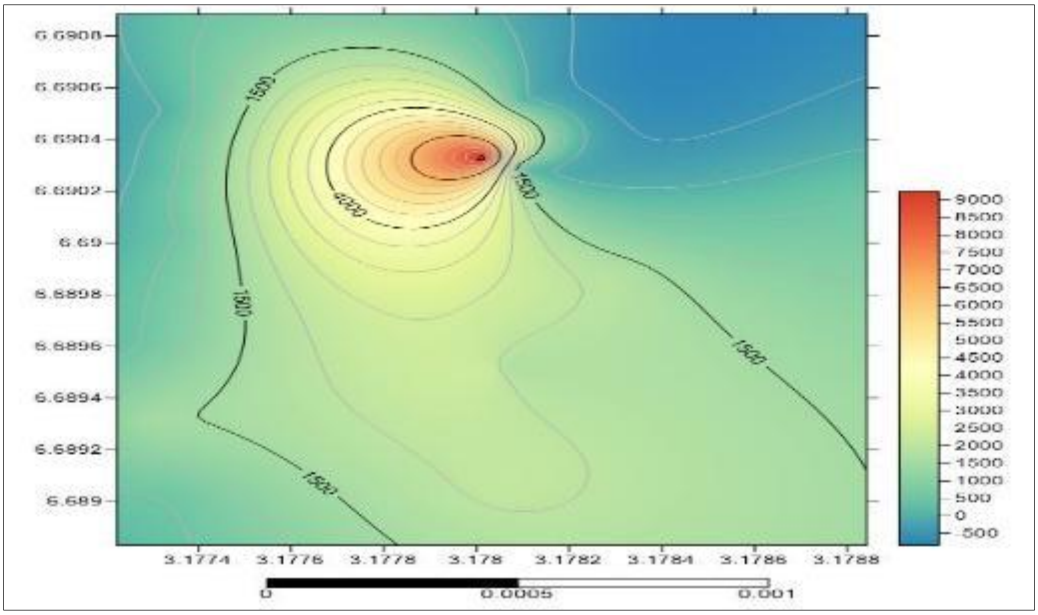

Figure 6 Transverse resistance map of Divine Estate Sango Ota

Transverse resistance is a critical Dar-Zarrouk parameter used to evaluate the hydraulic properties of subsurface formations, particularly their ability to transmit groundwater. It is computed as the product of layer thickness and resistivity and serves as a proxy for aquifer transmissivity [24][25]. In the present study, transverse resistance values derived from Vertical Electrical Sounding (VES) data range from 71 to 9,591.4 Ωm^2, reflecting significant lateral variability in subsurface conductivity and layer geometry. Based on established classification schemes, zones with transverse resistance below 400 Ωm^2 are considered to have poor transmissivity and limited groundwater potential. Values between 400 and 1,000 Ωm^2 are categorized as weak, those ranging from 1,000 to 2,000 Ωm^2 are regarded as moderate, while values exceeding 2,000 Ωm^2 indicate good aquifer transmissivity and are generally more favorable for groundwater development [25][24]. In this study, VES 3 and VES 11 stand out with notably high transverse resistance values, suggesting the presence of thick, moderately resistive layers likely representing well-developed weathered or sandy formations with enhanced capacity for groundwater flow. These zones are interpreted as having moderate to high transmissivity, making them potentially suitable targets for groundwater abstraction. This spatial variability in transverse resistance further emphasizes the need for site-specific investigations to optimize borehole placement and ensure sustainable groundwater development.

7. Longitudinal Conductance

Longitudinal conductance is a critical Dar-Zarrouk parameter employed in groundwater studies to assess the protective capacity of overburden materials and to delineate zones with varying susceptibility to contamination. It is calculated as the ratio of layer thickness to resistivity and is particularly useful in characterizing the ability of the overburden to shield underlying aquifers from surface-derived pollutants [26][27]. In the current study, longitudinal conductance values across the investigated area (as shown in Figure 7) range from 0.001 to 0.625 Ω^{-1}, with an average value of approximately 0.17 Ω^{-1}. These variations reflect the lateral and vertical heterogeneity in the composition and thickness of low-resistivity materials, typically clays, within the overburden. According to [28], higher longitudinal conductance values often suggest increased clay content, which, while beneficial for aquifer protection, generally corresponds to lower transmissivity due to reduced permeability. Based on the classification by [26] and [27] conductance values less than 0.1 Ω^{-1} are indicative of poor protective capacity, making the aquifer highly vulnerable to contamination. This category dominates the southwestern to central portions of the study area. Values ranging between 0.1 and 0.19 Ω^{-1} reflect weak protective capacity and are primarily observed in parts of the southwestern region. Meanwhile, conductance values between 0.2 and 0.69 Ω^{-1} represent moderate protective capacity, which is evident in most of the eastern section of the mapped area. These spatial patterns highlight the variability in aquifer protection potential across Divine Estate and underscore the need for wellhead protection and pollution control strategies, especially in poorly protected zones.

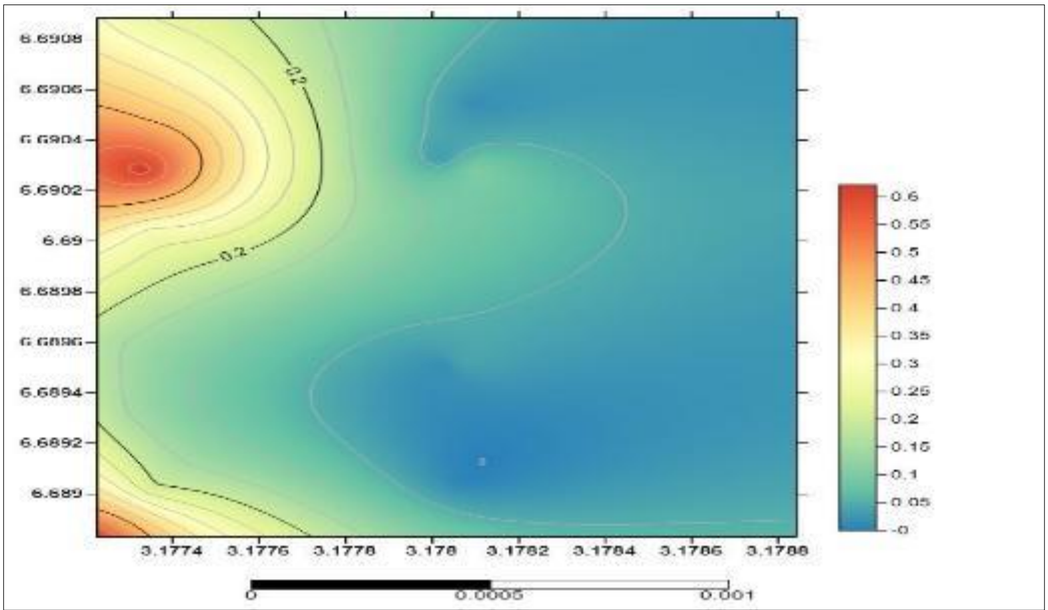

Figure 7 Longitudinal conductance map of Divine Estate Sango Ota

8. Overburden Thickness

The overburden thickness in the study area, encompassing topsoil, lateritic deposits, and weathered geological material, exhibits considerable spatial variability. It ranges from as shallow as 0.8 meters to a maximum of 25.7 meters, with a calculated average thickness of approximately 1.9 meters. This depth distribution is significantly lower than the threshold values recommended in hydrogeological literature for productive aquifer development.

According to [29], overburden thickness in the range of 20–30 meters is considered optimal for the accumulation and sustainable abstraction of groundwater, especially in crystalline and semi-consolidated terrains. Similarly, [23] and [26] suggest that a minimum of 25 meters of weathered overburden is necessary to ensure sufficient aquifer saturation and yield stability. When overburden is too thin, its water retention and transmission capacities become severely limited, thus reducing the effectiveness of boreholes and increasing the risk of failure. In the present study, only one Vertical Electrical Sounding (VES 15) meets the minimum overburden requirement, while the rest of the surveyed points fall substantially below this threshold. This indicates that over 90% of the study area lacks the stratigraphic thickness necessary to support significant groundwater storage, a factor that correlates with the documented prevalence of low-yielding or dry boreholes in the area. These findings point to a generally poor groundwater development potential across Divine Estate. The limited thickness of the unsaturated zone not only restricts the volume of water that can be stored but also increases the vulnerability of any existing aquifer to seasonal fluctuations and contamination. Therefore, groundwater abstraction efforts in this region must be guided by detailed geophysical assessments and targeted drilling in isolated zones of thicker overburden.

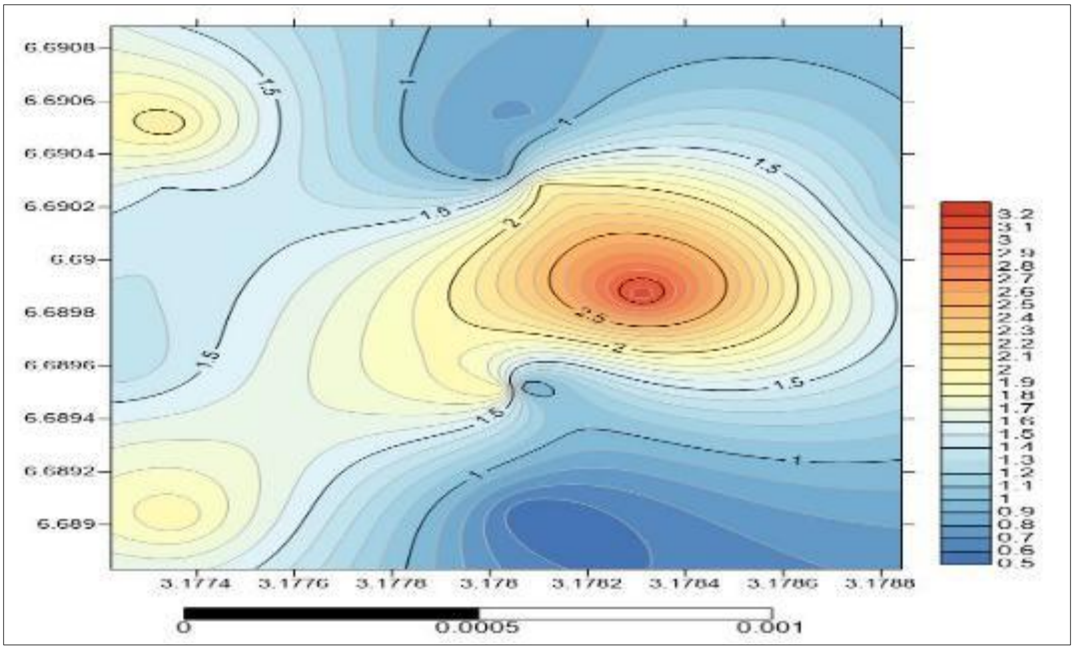

Figure 8 Overburden thickness map of Divine Estate Sango Ota

9. Groundwater Potential

The groundwater potential of Divine Estate, Ota, was assessed through the integration of geoelectric parameters and Dar-Zarrouk variables derived from Vertical Electrical Sounding (VES) data. Key diagnostic criteria for groundwater potential zones were adopted based on established thresholds: overburden thickness greater than 10 m, aquifer resistivity values between 50–300 Ωm, fractured basement resistivity ≤800 Ωm, reflection coefficient <0.75, transverse resistance >1000 Ωm^2, low longitudinal conductance (<0.2 Ω^{-1}), and a coefficient of electrical anisotropy >1.2—suggesting favorable secondary porosity and transmissivity [30][31]. A composite groundwater potential map (Figure 9) was generated by synthesizing these parameters. The study area was classified into three categories: poor, low, and good groundwater potential zones. High potential zones were identified around VES stations 2, 7, and 8, where the geoelectric conditions met the optimal criteria for groundwater occurrence, including moderate resistivity weathered layers at accessible depths. Conversely, VES stations 10, 11, 13, and 14 falls within low potential zones, characterized by highly resistive basement layers (>600 Ωm) and insufficient overburden, which significantly limits water storage capacity. Spatial analysis of the groundwater potential map shows that the northwestern to central and southwestern sections of the study area are dominated by poor to low aquifer potential. In contrast, the northeastern and southeastern regions exhibit good groundwater prospects, likely due to thicker overburden and enhanced secondary porosity. These findings provide critical guidance for targeted groundwater development and resource management across the estate.

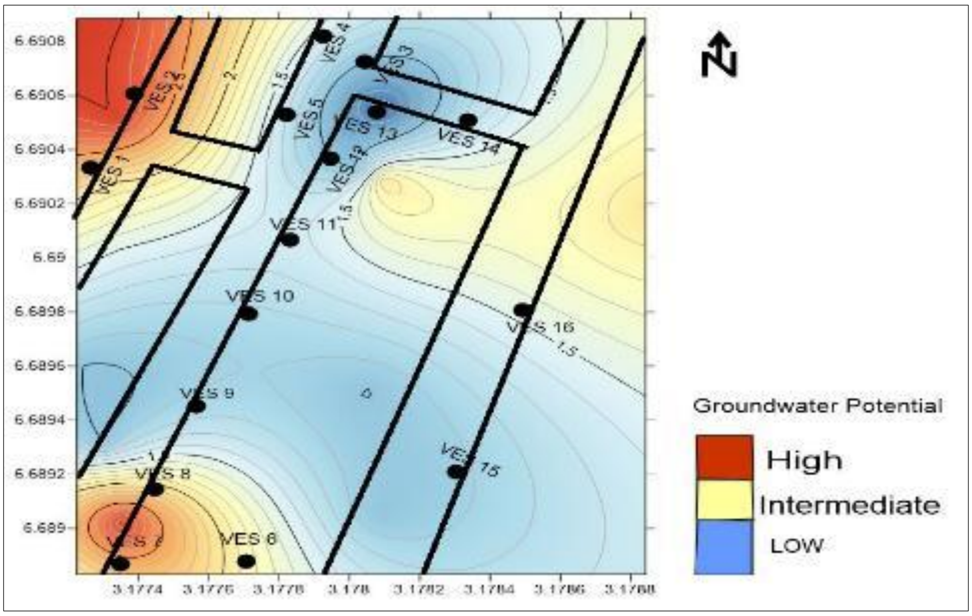

Figure 9 Groundwater Potential map of Divine Estate Sango Ota

10. Conclusion and Recommendation

The geophysical investigation at Divine Estate, Sango Ota, Southwestern Nigeria, using sixteen Vertical Electrical Soundings (VES) with the Schlumberger array, has effectively delineated the subsurface hydrogeology. The geoelectric interpretation reveals a predominantly three-layer structure comprising topsoil, weathered/fractured basement, and fresh basement rock. A majority of the soundings (68.75%) display H-type curves, indicative of zones potentially favorable for groundwater. However, quantitative analysis highlights major limitations for sustainable groundwater development. The overburden thickness across most of the area is significantly below the recommended 20–30 m, with only VES 15 exceeding this threshold. Transverse resistance values show considerable variability, with only VES 3 and VES 11 suggesting moderate transmissivity. Longitudinal conductance values (0.001–0.625 Ω^{-1}) indicate poor aquifer protective capacity, raising concerns about vulnerability to contamination. Groundwater potential zones were identified at VES 2, 7, and 8, where moderate resistivity weathered basement layers (51–209 Ωm) occur at shallow depths (10–13 m). Conversely, low-potential zones with resistivities >600 Ωm at VES 10, 11, 13, and 14 reflect fresh basement conditions with poor water storage capability. Overall, the findings explain the prevalent water scarcity and borehole failures in the area and emphasize the need for scientifically guided drilling and alternative water supply options.

Based on the geophysical findings, groundwater development at Dominion Estate should focus on VES stations 2, 7, and 8, which exhibit favorable geoelectric characteristics such as moderate resistivity and sufficient weathered sand thickness. Drilling depths of 15–20 m are recommended to efficiently access the aquifer zones. Stations with poor aquifer indicators (e.g., VES 10, 11, 13, and 14) should be avoided to minimize borehole failure. Given the limited overburden thickness and poor aquifer protective capacity, integrated water supply strategies are essential. These should include surface water abstraction from nearby rivers (Ogun and Yewa), rainwater harvesting systems, and limited, strategically placed boreholes. Centralized water treatment and distribution systems are recommended over isolated household solutions for efficiency and quality control. Further geophysical investigations across unstudied sections of the estate are advised to identify additional productive zones. Aquifer protection through wellhead safety measures and regular water quality monitoring should be prioritized due to the area's vulnerability to contamination.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors (Valentine Ezennubia, Rereloluwa Bello, Uwem-Umoh Samuel, Oladimeji T. Daniel) declare no conflict of interest.

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