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Identification of potential and aquifer vulnerability in basement terrain of southern Nigeria, using geophysical approach

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ABSTRACT

This research study used a vertical electrical sounding approach to investigate the transmissibility size of the hydrogeologic units under inquiry. This was brought on by failed water scheme initiatives and rapid population growth. Aquifer resistivity and thickness values were utilized to generate the hydraulic parameters that were used to describe the transmissibility magnitude.The Schlumberger design was used to conduct 16 VES surveys for the investigation, with a maximum electrode spacing of 200 m. The Dar-Zarrouk parameters longitudinal conductance (S), transverse resistance (T), longitudinal resistance (L), average transverse resistance (t), coefficient of anisotropy (λa), transmissivity (T), and hydraulic conductivity (H) were used to evaluate the aquifer's protective capability. Results from VES data indicated that the layer model ranges from three to six layers, and it was found that curve A was the most common type of curve. Results from the study revealed that S, Tr, ρL, ρt, λa, T, and H ranges from 0.02 to 0.18 Ω^{-1} , 761.7 to 31336.1 Ω /m^2, 287.8 to 12314.4, 101.7 to 767.7, 0.15 to 0.69, 0.000003 at VES/12 to 0.0538 m/day, and 0.05 to 65.56 m^2/day respectively. Deduction from the study revealed that northwest, and northeast parts of the study area tends to be more aquiferous when compared to other parts of the study area.

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***Keywords*:** Resistivity, Aquifer, thickness, depth, Nigeria

1. INTRODUCTION

The 21st Century presents humanity with a significant issue in the form of water quality contamination (Eyankware and Akakuru, 2022). Groundwater has been a major source of portable water for mankind and therefore, the need to undertake geophysical exploration to ascertain the integrity of the overburden on the aquifer. The idea that mankind should continue to enjoy a diversity of water-related products and services is supported by the task of improving water resource management and ensuring access to water supply and sanitation services (Eyankware, et al., 2022b; WWAP 2019). One of the most crucial natural resources for biological diversity, long-term growth, and human health is groundwater (Obasi, et al., 2022).

Due to a number of its intrinsic properties, it has emerged as a significant and dependable source of water supplies in all climatic regions, including urban and rural areas of established and developing nations (e.g., widespread and continuous availability, excellent natural quality, limited vulnerability, low development cost, and drought reliability). Ground water has been successfully found in basement terrains using a number of geophysical techniques. Examples include electrical, magnetic, and electromagnetic techniques. Of all of these techniques, the electrical resistivity method has been the most commonly applied for groundwater exploration (Alile et al., 2008; Umayah and Eyankware, 2022). The VES (Vertical Electrical Sounding) method is frequently used for depth sounding due to its simplicity and durability (Asfahani, 2013).

Because the electrical resistivity of most rocks is influenced by the quantity, distribution, and salinity of the water in the pore spaces within the rocks, it is used to measure the vertical variation of electrical resistivity beneath the earth's surface. The study region is supported by Precambrian Basement Complex rocks that have limited porosity and permeability. Where substantial overburden overlies broken zones in such terrains, where these zones are usually characterized by relatively low resistivity values, the largest groundwater yield is found (Olorunfemi et al., 1999). Locating wells for portable, pollutant-free groundwater production in such zones is advantageous (Ebong, et al., 2016; Gupta, et al., 2015). The majority of water sources used by the residents of this village are streams and hand-dug wells, both of which are vulnerable to contamination and water-borne diseases (Eyankware., 2014).When determining the protective capacity of the overburden units in earlier studies on aquifer vulnerability, longitudinal conductance, a second-order geoelectric characteristic, was used (Aweto, 2011; Eyankware et al. 2020; Akintorinwa and Olowolafe 2013). In order to establish the depth to the water table, aquifer shape, aquifer vulnerability, and groundwater feature by evaluating observed apparent resistivity field data, the VES method has been extensively employed in groundwater investigations (Eyankware 2014; Eyankware and Aleke 2021; Aziz et al. 2018).

Oli et al. (2020); Nwosu et al. (2014.) found that the Dar Zarrouk characteristics generated from surface geoelectric soundings were crucial for understanding the spatial distribution of aquifer geometry and protective capacity parameters.The vulnerability of the aquifer in Nigeria's sedimentary and hard rock terrain has also been determined using the VES method. Warmate (2016) used data from the VES method to estimate the Dar Zarrouk parameters, which were then used to determine hydrological properties (Christian, et al., 2021)

Values from the study showed that the aquifer was considered to be highly productive with resistivity values > 1000 m, and that the aquifer was considered to be vulnerable to contamination with high groundwater potentials. Dar Zarrouk parameters were used to delineate an aquifer in some areas of Akwa Ibom, Niger Delta. The results showed that the area is susceptible to contamination because of the high aquiferous layer permeability and high yield of the aquifer (Laouini et al. 2017). According to Ankidawa et al. (2018), the estimated aquifer transmissivity of the northern portion of Nigeria ranged from low to high, and the estimated transverse resistance value from their study showed that the aquifer potential is high in the study area's northwestern and southwestern regions. Numerous geoscientists have investigated the aquifer's susceptibility in southern Nigeria's Benue Trough. Although geophysical methods have been used to assess the protective capacity of aquifers in other regions of southern Nigeria, little to no research has been done to ascertain the protective capacity, transmissivity, and hydraulic conductivity of aquifers in the study area and its surrounding areas. Therefore, in order to determine how well the aquifer is protected and how water-bearing units are transmissivity within the study region, a complete investigation is absolutely necessary.

Location and Climate

The study area is situated in the Odigbo Local Government Area of Ondo State near the Ondo-Ore junction, Ore. Latitude 6º29ˈN - 6º59ˈN and longitude 4º20ˈE - 5º15ˈEare the coordinates for ore. It serves as the local government area's administrative center. The research area is reachable via the town's surrounding network of highways, including the Ondo-Ore, Benin-Ore, and Okitipupa-Ore expressways. Ore, the study area, serves as the administrative center for Ondo State's Odigbo Local Government Area. The region is located in the tropical rain forest belt, with temperatures ranging from 23 to 27 ºC and mean annual rainfall of over 1500 millimeters. Omosuyi et al. (2013). The month with the most precipitation, on average, is July, with 279mm. the hottest month of the year The coldest month of the year, March, averages 28.5 °C. The lowest annual average temperature is 24.8 ºC in August. The wettest month and the driest month differ in precipitation by 268mm.

Geology

The Precambrian basement complex rocks of south-western Nigeria are the rocks that underlie the northern portion of the research region. These rocks are distinguished by older granites, charnockites, quartzite, migmatite-gneiss complex, and minor intrusive lithologies (Rahaman 1981; Jones et al 1964). Charnockite, fine-grained biotite granite, and gneiss are the main types of local rock. Field observation reveals the presence of huge, mostly coarse-grained biotite granites in the region, according to Jones et al. (1964). Akinbo, Ewekoro, and Abeokuta formations, as well as coastal plain sands of the Benin formation, are present beneath the study area's southernmost portions.

Sand dominates the Abeokuta Formation in surface outcrops, with interbeds of sandstone, siltstone, silt, clay, mudstone, and shale.

Typically, it comprises a basal conglomerate that can be up to 1 m thick and is composed primarily of irregularly shaped quartz pebbles in a silicified and ferruginous sandstone matrix or a soft, gritty white clay matrix. The basal bed in outcrops devoid of conglomerate is made up of course, poorly sorted pebbly sandstone and a lot of white clay. The sands on top are coarse-grained, clayey, micaceous, and poorly sorted, indicating that they were transported over short distances or weathered quickly and may have originated from the granitic rocks to the north. In the eastern Dahomey basin, the Ewekoro Formation sits on top of the Araromi Formation. It is a sizable limestone mass that may be followed for roughly 320 km, from Ghana in the west to the eastern edge of the Dahomey basin in Nigeria. The Formation dates from the Palaeocene to the Eocene. Rivers and streams that run in the same direction as the rock strike provide good drainage for the area. These streams originate at a relatively high height of 200 m above mean sea level and flow through valleys by striking downhill.

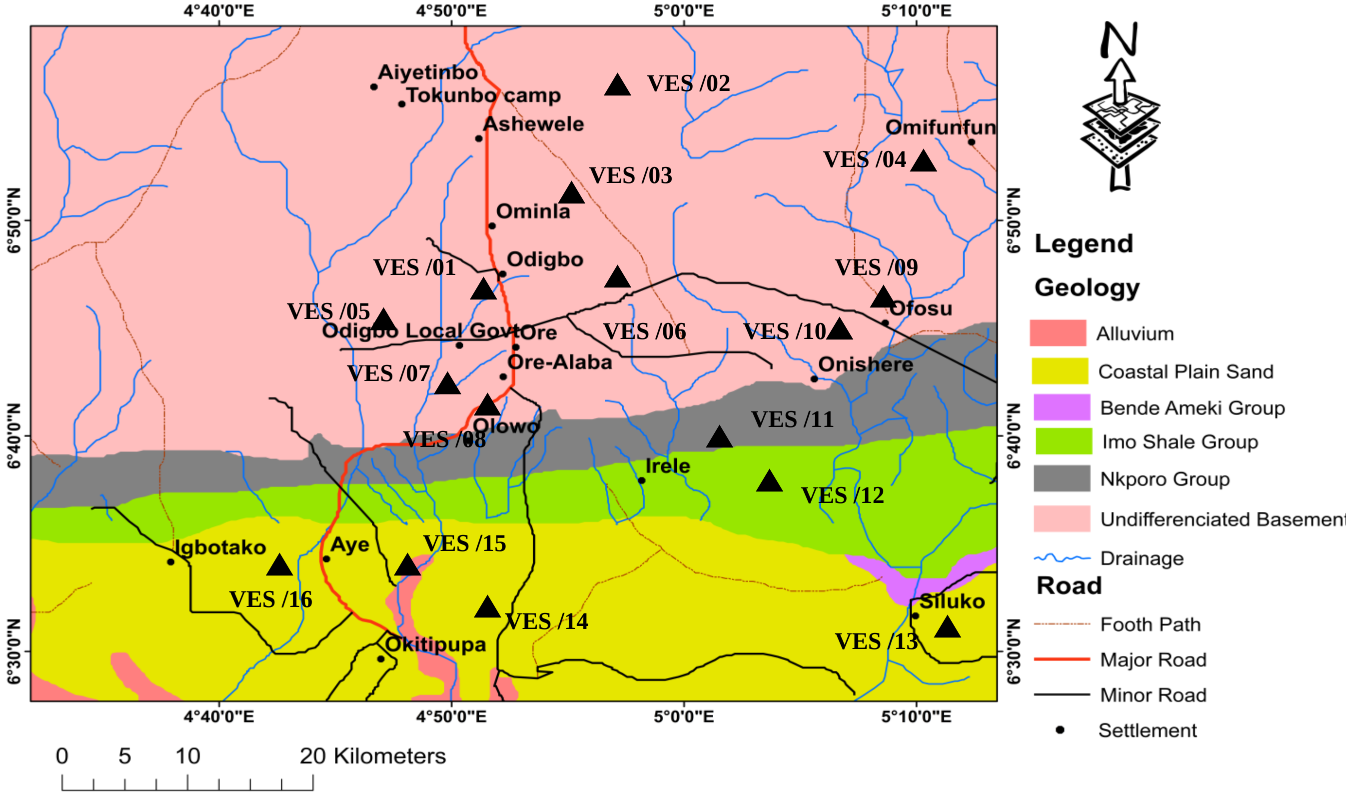

Fig. 1. Geology Map of the study area showing VES sampling points.

Hydrogeology of the study area

Thus, groundwater extracted from certain boreholes and hand-dug wells in the city is augmenting the meager pipe-borne water supply. Unlike other natural resources, groundwater is dynamic in nature, occurring to variable degrees and moving over space and time (Oladapo and Afuda, 2017). The flow, storage, and yielding capacity of groundwater are all reliant on the geological environment due to limited pipe-borne water supply. In the city, some boreholes and hand-dug wells extract groundwater to supplement the meager pipe-borne water supply. Unlike other natural resources, groundwater is dynamic in nature, with variations in its occurrence and movement with time and place (Eyankware, et al., 2021b). The geological environment affects the yielding capacity, accumulation, and circulation of groundwater, the assertions of Kazeem (2010). The most significant river in Ondo State is the Ero River, which starts from the Igbara Oke road and is located 16–18 kilometers from Akure town. Smaller rivers like the Owuruwu

River and the Osun River both contribute to water runoff in Akure. Minor rivers like the Otenre River and Omi Atamo serve as local runoff and converge with the Osun River at Osun Amon. Before joining the Ogbese River in Ondo State, the Osun River flows from the eastern to the western portions of the town.

2. METHODOLOGY

Geoelectric measurements

Resistivity methods involve measurements of apparent resistivity along the earth surface. An electrical current is injected into the ground by means of two current electrodes, and the potential difference is measured between two other electrodes. The arrangement of the four electrodes (two current and two potential) on the ground surface is referred to as electrode array or configuration. Various electrode arrays such as Wenner, Schlumberger, pole–pole, and dipole–dipole are used in resistivity surveys. Resistivity equipment include a resistivity meter, power source, two steel electrodes to inject current into the ground, two steel or non-polarisable electrode to measure potential, cables and reels for connection (Telford et. al. 1998).

With the aid of an OHMEGA Terrameter and its accessories, sixteen (16) VES were carried out inside the study region, as depicted in Fig. 1. A Schlumberger electrode array was utilized for each VES profile, with a maximum electrode separation of 100 m for half current (AB/2) and 5 m for half potential (MN/2). The spatial distribution of S, Tr, L, and pt was mapped using the Surfer program. The field data was observed, and apparent resistivity (a) values were calculated using equation (1) as follows:

$$\pi\left(\frac{\left(\frac{AB}{2}\right)-\left(\frac{MN}{2}\right)}{MN}\right)\Delta V/I \qquad (1)$$

The apparent resistivity values were plotted against the current electrode spacing (AB/2) to create the geoelectrical curves. The development of sound curves was made possible by the use of the winrest software, which aided in the data processing. The geoelectrical sections, which were created using the data from the sounding curves, were used to determine the aquifer's thickness. Using the charts provided by Loke (1999), lithologies that matched the geoelectric section were determined. Some elements related to the various combinations of the thickness and resistivity of the geoelectric layer are essential for the study and understanding of the geologic model (Zohdy et al. 1974; Maillet, 1947).

Dar Zarrouk's longitudinal (S) and transverse (T) parameters are derived via

$$S = \frac{h}{p} \qquad (2)$$

$$T = hp \qquad (3)$$

Using the formula below, we determined the total Longitudinal Unit Conductance (S). The total longitudinal conductance is equal to the number of layers (n).

$$S = \sum_{i=1}^{n} \frac{h_i}{\rho_i} = \frac{h_i}{\rho_i} + \frac{h_2}{\rho_2} + \cdots + \frac{h_n}{\rho_n} \qquad (4)$$

as proposed by Asfahani (2013); Oli et al. (2020)

For the equation below, the Transverse Unit Resistance (Tr) was determined.

The total resistance of the transverse unit is

$$Tr = \sum_{i=1}^{n} h_i\rho_i = h_i\rho_i + h_2\rho_2 + \cdots + h_n\rho_n \qquad (5)$$

as proposed by Oli et al. (2020); Nwachukwu et al. (2019)

Below is the average longitudinal resistance for a given VES points

$$\rho_L = \frac{H}{S} = \frac{\sum_{i=1}^{n} h_i}{\sum_{i=1}^{n} \frac{h_i}{\rho_i}} \qquad (6)$$

as proposed by Suneetha andGupta (2018).

The equation is used to calculate the Transverse Resistance for a particular VES curve

$$\rho_t = \frac{T}{H} = \frac{\sum_{i=1}^{n} h_i\rho_i}{\sum_{i=1}^{n} h_I} \qquad (7)$$

as proposed by Suneetha andGupta (2018).

Equation 8 can be used to define the coefficient of anisotropy, a useful characteristic of an anisotropic media that shows the degree of fracturing.

$$\lambda = \sqrt{\frac{\rho_t}{\rho_L} = \frac{\sqrt{ST}}{H}} \qquad (8)$$

when interpreting sounding data, the parameters T and S—transverse resistance and longitudinal conductance, respectively—are crucial. The Dar-zarrouk parameters are those that are displayed in Equations 1 through 5.

$$K = 0.0538E^{0.0072p} \qquad (9)$$

where is the aquifer layer resistivity

Transmissivity (T) is the product of the hydraulic conductivity (k) and the aquifer layer thickness.

$$T = K \times h \qquad (10)$$

3. RESULTS

The summary of the interpreted VES survey is presented in Table 1. Findings from VES revealed geoelectric layers range from three to six layers with different intra-facies and inter-facies changes as shown in Table 1.

Table 1. Results of Vertical Electrical Sounding.

VES	Longitude	Latitude	Layer resistivity (Ohm-m)					Layer Depth (m)					Curve type	No of layer
			P1	P2	P3	P4	P5	DI	D2	D3	D4	D5		
VES 01	4°42'E	6°41'N	68.6	27	75.5	136.5	1183.1	0.6	1.9	4.0	7.7	∞	AAA	5
VES 02	4°54'E	6°49'N	25.7	148.5	2403.9			0.5	5.1	∞			A	3
VES 03	4°51'E	6°51'N	482.5	392.2	1991.9			0.6	9.9	∞			H	3
VES 04	4°42'E	6°41'N	293.2	279.8	285.3	4275.6		0.5	4.9	15.6	∞		HA	4
VES 05	4°40'E	5°46'N	153.6	196.4	1218.6			0.7	6.3	∞			A	3
VES 06	4°52'E	6°43'N	22.1	110.4	1357.6			0.5	6.8	∞			A	3
VES 07	4°45'E	6°57'N	18.4	44.2	378.6	225.3		0.3	2.4	7.5	∞		AK	4
VES 08	4°47'E	6°36'N	40.8	70.7	423.5	1640.7		0.5	3.4	7.4	∞		AA	4
VES 09	4°45'E	6°44'N	137.9	179.9	1053.2			1.7	12.2	∞			A	3
VES 10	5°04'E	6°42'N	141.1	305.3	6667.1			1.6	12.4	∞			A	3
VES 11	5°04'E	6°37'N	338.1	287.3	2520.6			1.2	10.6	∞			H	3
VES 12	5°06'E	6°37'N	171.5	205.1	1037.	4053.1		1.4	15.1	27	∞		AA	4
VES 13	5°09'E	6°31'N	247.9	490.4	1761.2			2.3	17.9	∞			A	3

VES 14	4°49'E	6°31'N	129.2	248	1341.3			1.4	14.3	∞			A	3
VES 15	4°45'E	6°35'N	124.3	296.9	414.8			2.1	24	∞			A	3
VES 16	4°41'E	6°32'N	169	80.1	928	779.2		0.8	2.8	15	∞		HK	4

Table 2. Results of calculated parameters.

VES Points	Longitudinal Unit Conductance (*S*)	Transverse Unit Resistance (*Tr*)	Average longitudinal resistance (ρ_L)	Transverse Resistivity (ρ_t)	Coefficient of anisotropy (λ)	Hydraulic Conductivity (m/day)	Transmissivity (m^2/day)
VES/1	0.188507	1445.51	1623.713	101.7965	0.250387	0.02013	23.82205
VES/2	0.053799	770.2	287.8743	137.5357	0.691204	0.01847	44.39673
VES/3	0.026486	4172.28	8443.775	397.36	0.216932	0.00319	6.363143
VES/4	0.073897	5968.3	12314.47	284.2048	0.151917	0.006897	29.48961
VES/5	0.036635	1344.84	1536.032	192.12	0.35366	0.0538	65.56068
VES/6	0.084219	761.77	322.7216	104.3521	0.568639	0.024298	32.98695
VES/7	0.070603	2951.1	625.6741	289.3235	0.680014	0.003523	0.793764
VES/8	0.060345	3394.68	922.1456	300.4142	0.570769	0.0025499	4.183702
VES/9	0.080143	2429.21	1127.603	174.7633	0.393683	0.01473158	15.5153
VES/10	0.051955	4011.48	1234.666	286.5343	0.481741	0.00597219	39.81718
VES/11	0.040444	3451.1	3324.687	292.4661	0.296594	0.00679858	17.1365
VES/12	0.081786	31336.11	5328.85	720.3703	0.367673	0.0000308	0.124725
VES/13	0.045779	9348.33	2177.245	462.7886	0.461039	0.0015752	2.774273
VES/14	0.068497	3727.28	1448.943	237.4064	0.404781	0.0090221	12.1013
VES/15	0.09773	7386.63	1544.952	283.0126	0.428002	0.0063445	2.631712
VES/16	0.03969	14279.48	3929.301	767.714	0.44202	0.0000674	0.052559

Min	0.026486	761.77	287.8743	101.7965	0.151917	0.0000674	0.052559
Max	0.188507	31336.11	12314.47	767.714	0.691204	0.0538	65.56068
Aver.	0.073084	7159.788	3266.389	327.8707	0.422343	0.012846	20.18686

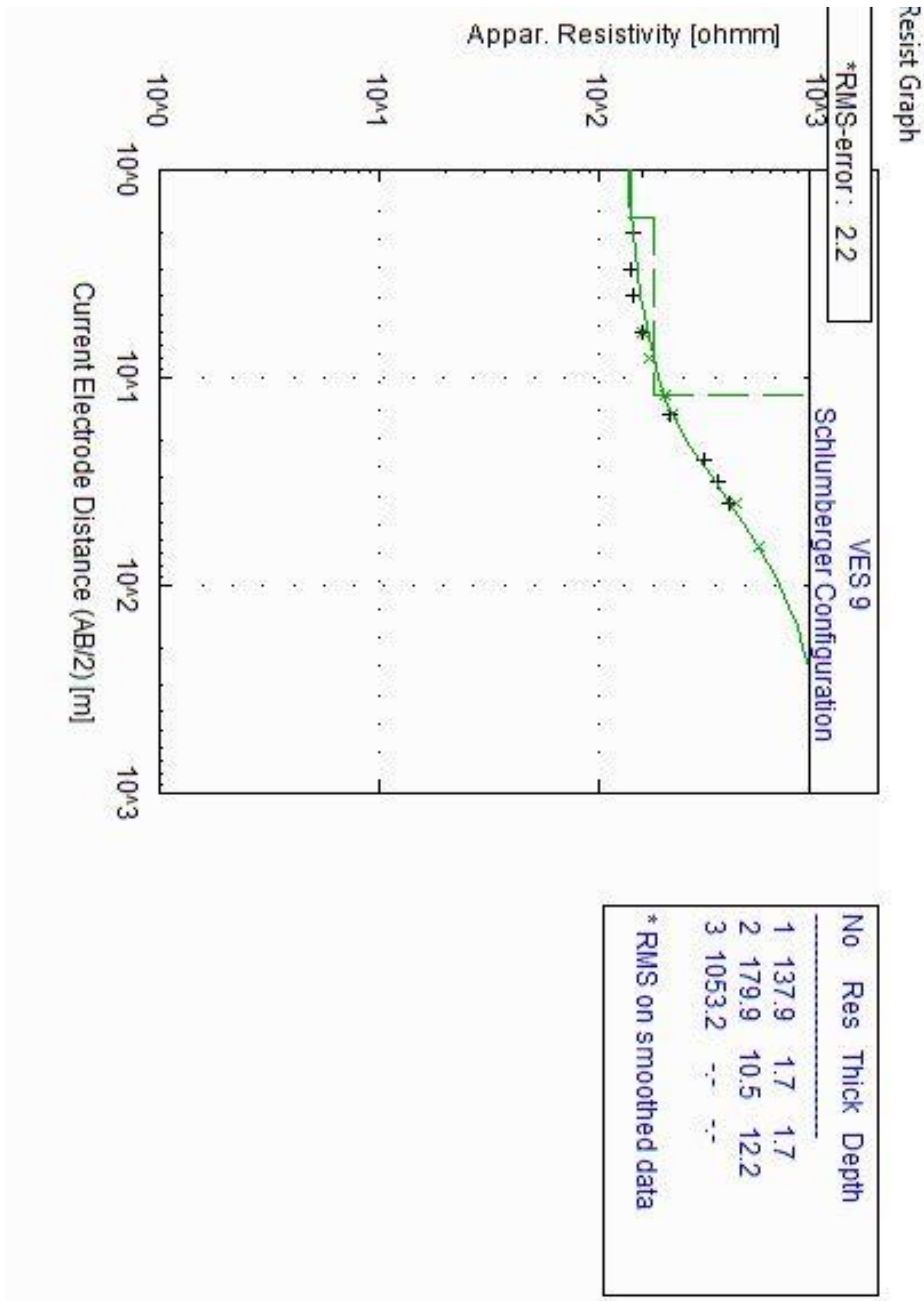

Fig. 2. Graphical interpretation of VES 9.

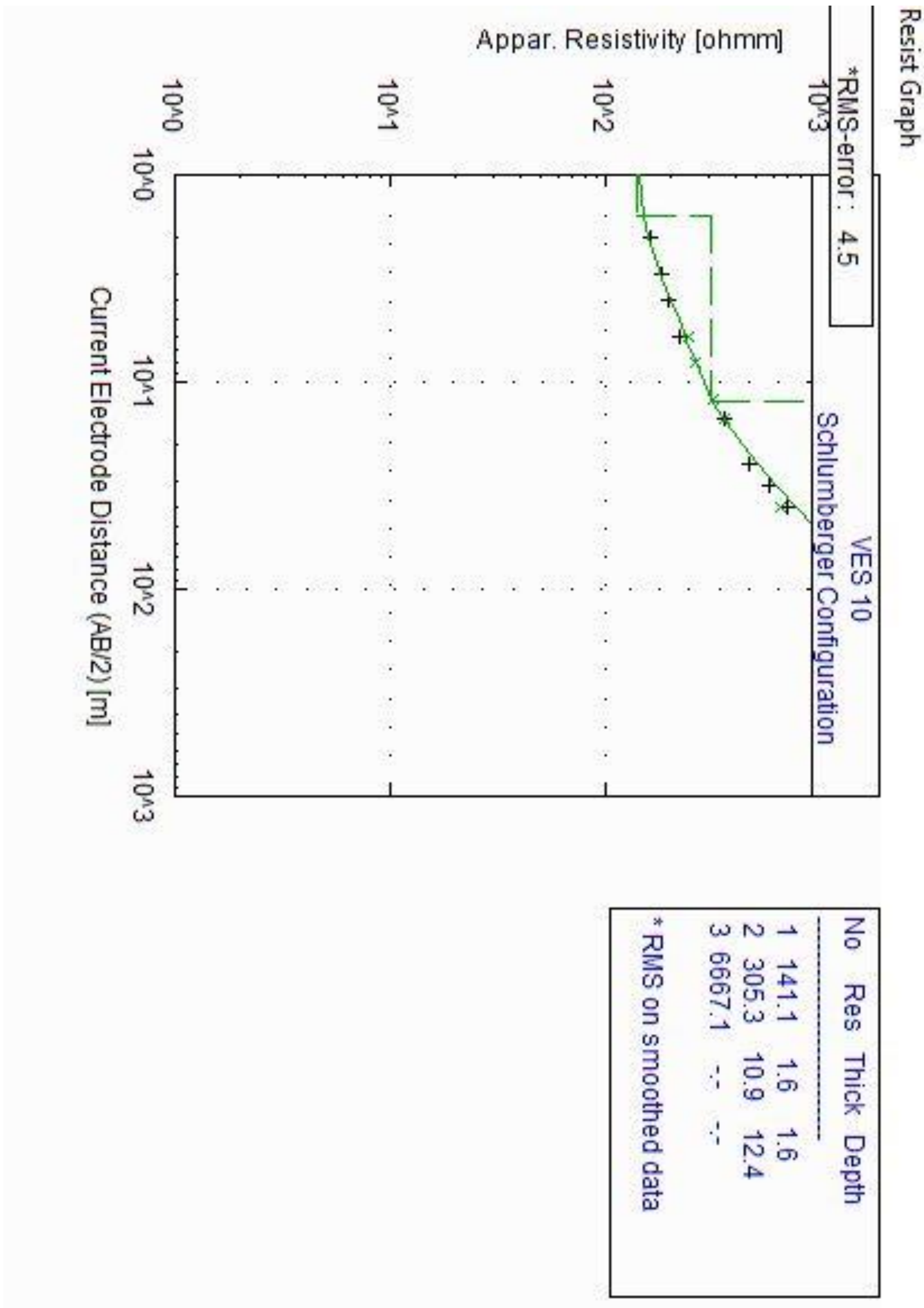

Fig. 3. Graphical interpretation of VES 10.

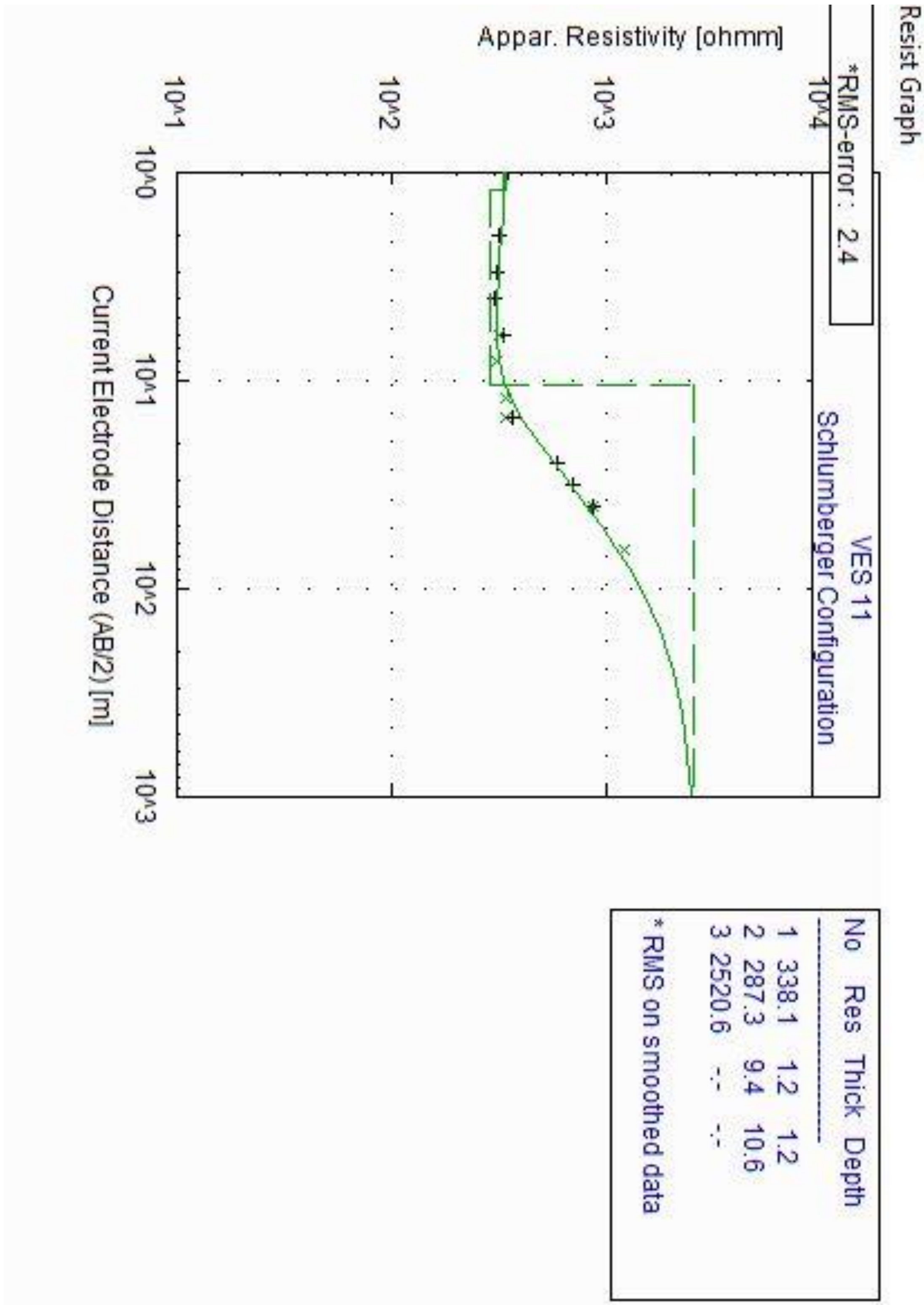

Fig. 4. Graphical interpretation of VES 11.

4. DISCUSSION

Aquifer vulnerability

Aquifer vulnerability describes the tendency or likelihood at which an aquifer system is prone to surface contamination. Aquifer vulnerability is not a quantity that can be measured rather it is a quantity that shows the tendency that contamination might occur or not. Therefore, it is dependent on some measurable quantities (Edwards-Jones and Gareth, 1996; Oli et al., 2020. In this study, the longitudinal conductance (S) and transverse unit resistance (Tr) values derived from the fundamental geoelectrical characters of the geoelectric layers were applied in assessing the groundwater vulnerability and aquifer potential respectively (Omeje et al. 2021).

Dar Zarrouk parameters of the study area

Equations 2 to 7 were used to calculate the study area's aquifer protection capacity, and the estimated results are reported in Table 2. Rating for aquifer protective capacity was shown in Table 3. One of the geoelectrical measures used to pinpoint the aquifer's protective capability in the study area is longitudinal conductance (S).

Longitudinal unit conductance (S)

A measure of an earth medium's protective capability is how well it can filter and delay percolating fume (Olorunfemi et al. 1999). The aquifer's susceptibility to pollution is indicated by this metric. The protective capability of a region increases with the height of the overburden unit of a geological formation, such as clay, shale, and compact sandstone (Henriet 1976; Oloruntola et al.2017). The value of S for this study ranges from 0.02 to 0.18 Ω^{-1} with an average value of 007Ω^{-1} as shown in Fig. 5 and Table 2. From Fig. 5, it was observed that the middle part of the study area (Odibgo Local Government area) tend to have high *S* values when compared to other parts of the study area. The aquifer's longitudinal conductance values show how protective it is; higher longitudinal conductance values signify more protective capability. Table 3 further revealed that the study area's aquifer protection capability fell into the weak to poor group; this is consistent with research done by Oladunjoye, et al (2021). They emphasized that topsoil with a high concentration of clay and worn rock has low permeability and does not easily release water after absorbing it. That suggests that the study area's aquifers are susceptible to surface contamination..

Table. 3. Based on Oladapo and Akintorinwo's (2007) longitudinal conductance scale, modified aquifer protective capacity rating of the investigated formation (Henriet 1976)

Longitudinal conductance (mhos)	Protective capacity Rating	VES Points
>10	Excellent	
5-10	Very Good	
0.7-4.9	Good	

0.2-0.69	Moderate	
0.1-0.19	Weak	VES/ 1
< 0.1	Poor	VES/2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16

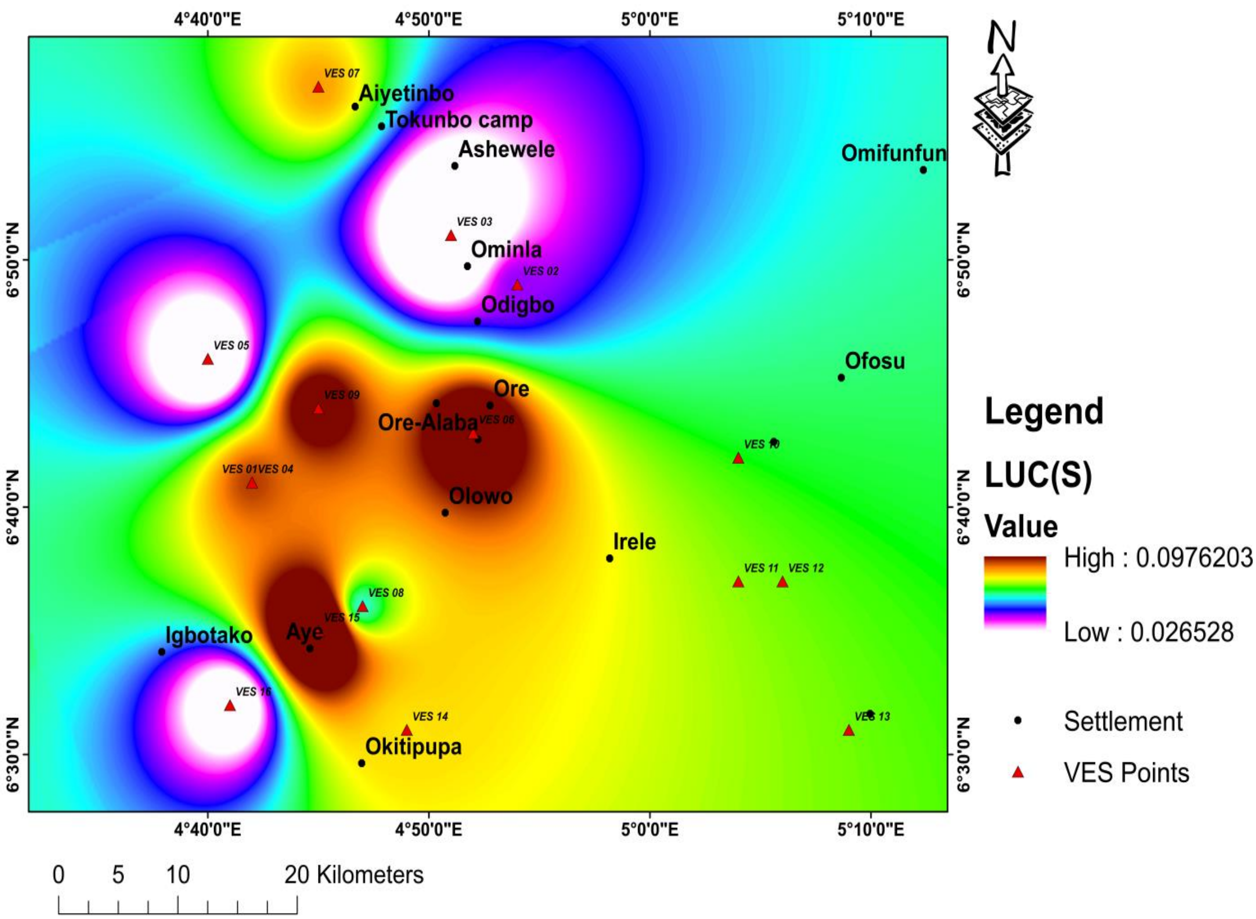

Fig. 5. Spatial distribution of *S* within the study area.

Transverse unit resistance (Tr)

Table 2 shows that the study's average Tr value is 7159.7 Ω/m^2, with a range of 761.7 to 31336.1 Ω/m^2. Findings from from Fig. 6, revealed that the SW pars of the study area has high Tr values, this implies that such area might tend to have good groundwater potentials. Similarly, it has been found that a water bearing unit's transmissivity and transverse unit resistance are directly inversely related. As a result, high Tr values and high transmissivity values are related (Henriet 1976; Ward 1990; Harb et al, 2010). While low transmissivity is indicative of a significant amount of impervious clay that slows fluid movement within the aquifer, high transmissivity values indicate that the water bearing units of the formation are highly permeable, porous, and freely allow fluid movement within the aquifer, which could potentially enhance the migration and circulation of contaminants in the groundwater/aquifer system.

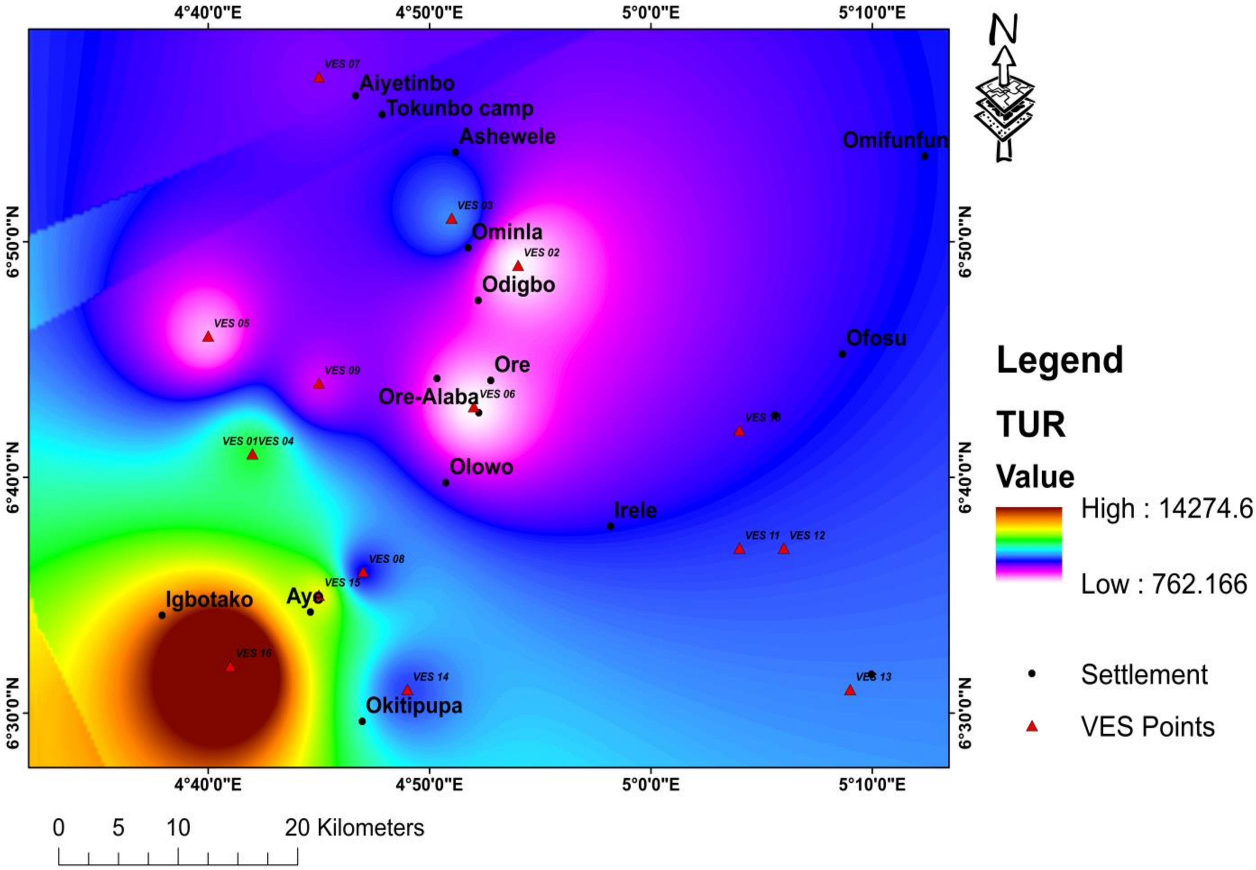

Fig. 6. Spatial distribution of *Tr* within the study area.

Average Transverse Resistance (ρt)

Table 2, showed that the value of average transverse resistance for this study ranges from VES 2 is 287.8 to VES 4 at 12314.4 with an average value of 3266.3. This suggests that genuine resistivity that is parallel to the plane of stratification, such as that found in shale, is less than true resistivity that is normal to the plane of stratification (Dewashish et al. 2014). Findings from Fig. 7, revealed that SW and NW tends to have high average transverse resistance.

Transverse resistivity (ρt)

The value of ρt for this study ranges from 101.7 to 767.7 with an average value of 327.8 as shown in Table 2. High ρt values was observed in SW part of the study area. It was also observed that the highest ρt of 767.7 was observed at VES/16 see Fig. 8, From Fig. 8, it was observed that SW (Igbotako, and Aye) part of the study tends to have high ρt values when compared to other parts of the study.

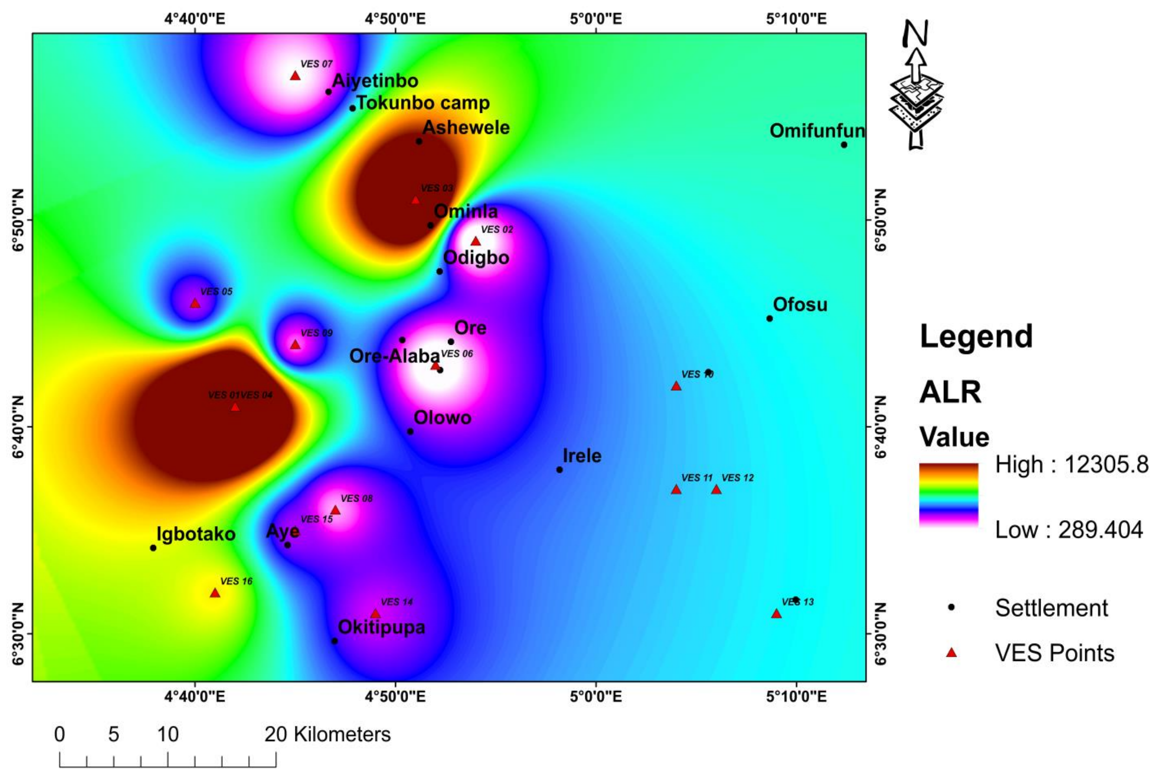

Fig. 7. Spatial distribution of ρt within the study area.

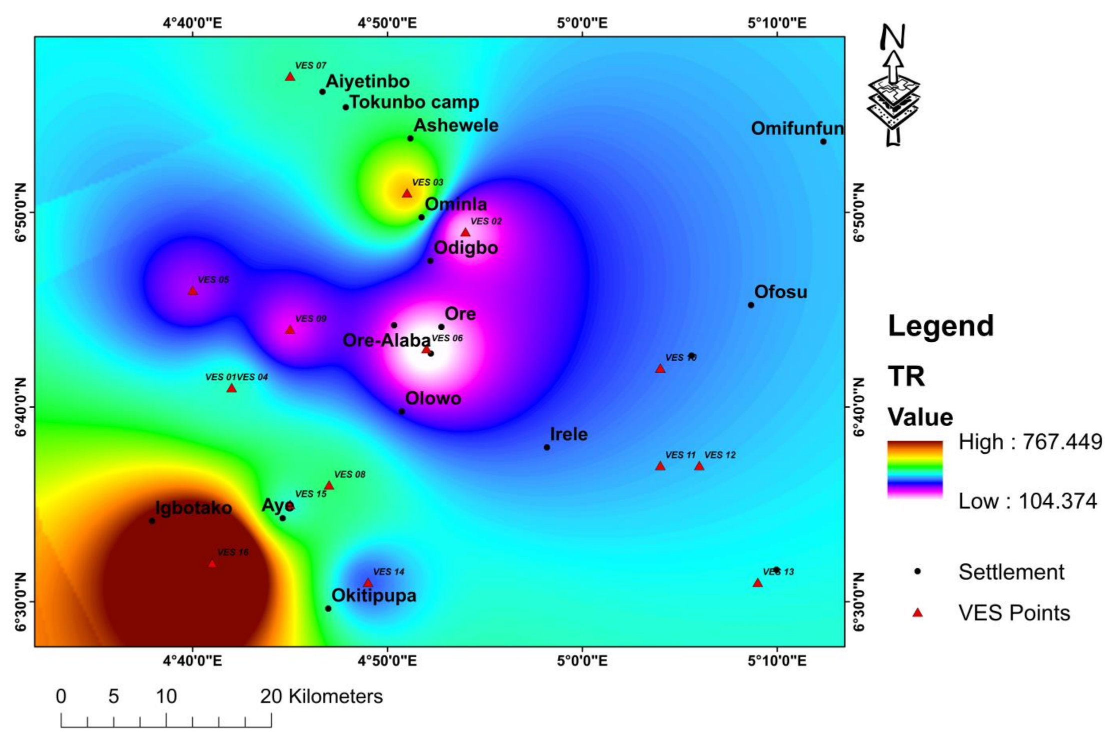

Fig. 8. Spatial distribution of ρt within the study area.

Coefficient of Anisotropy (λa)

According to Youssef (2020); Eyankware and Aleke (2021), is a root mean square resistivity and has no dimensions. Fig. 6 shows the areal distribution of coefficients of anisotropy within the study area. In this work, the estimated values of the coefficient of anisotropy range from 0.15 to 0.69, with an average value of 0.42; see Table 2. Deductions from Fig. 9, revealed that the NW, NE, and selected parts of SW has high value of coefficient of anisotropy. Fig. 9, also revealed that coefficient of anisotropy increases toward NE and NW axis of the study area. According to Eyankware, et al., (2022) one of the major feature that supports the higher values of anisotropy in the NW part of the study area is the occurrence of rivers and streams.

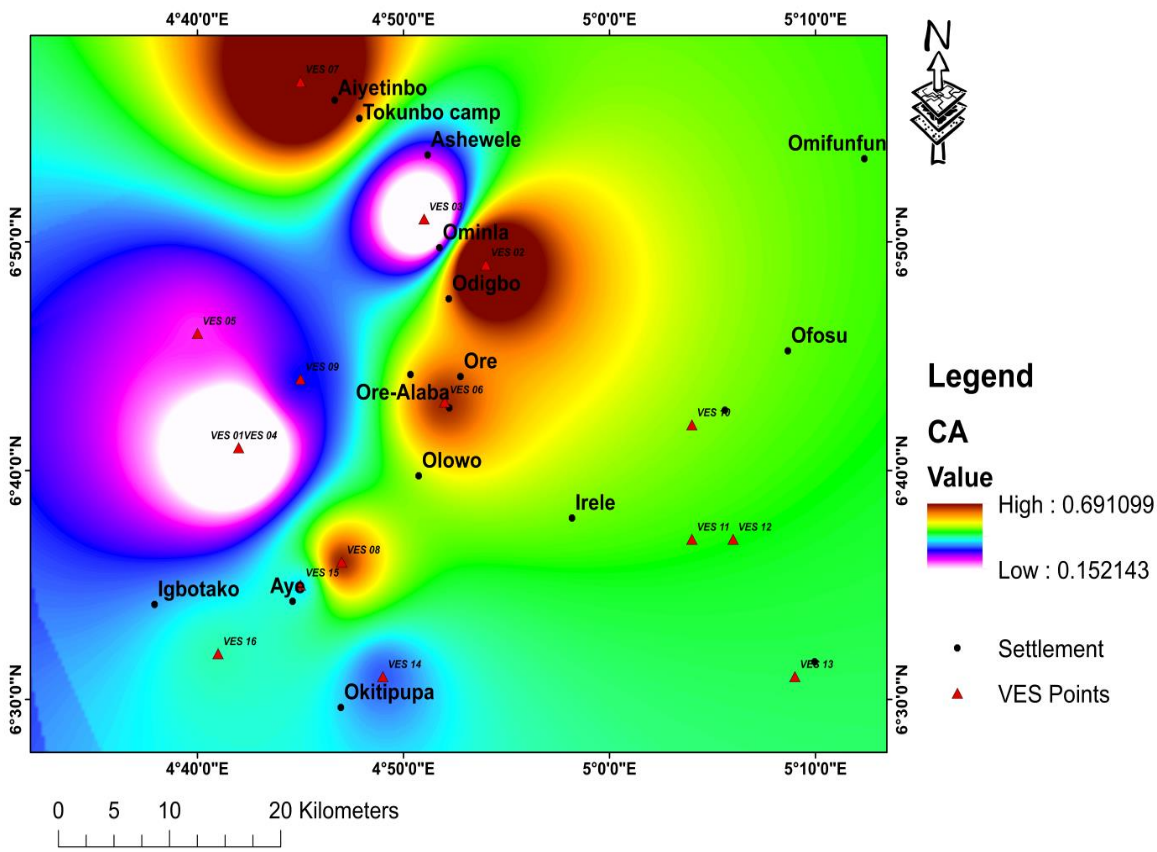

Fig. 9. Spatial distribution of λa within the study area.

Aquifer Hydraulic conductivity and transmissivity

Hydraulic conductivity (H)

H is the measure of how easily a fluid moves through a medium (Eyankware, 2014). For this study, the value of H ranges from 0.000003 m/day at VES/12 to 0.0538 m/day at VES/5 with an average value of 0.012 as shown in Table 2. Results from Fig. 10 revealed that the value of H increases towards to NW, and NE axis of the study area.

Hydraulic conductivity, in theory, is a measurement of the ease with which water may permeate rock or soil: high values denote materials that are permeable, through which water can move readily, while low values denote materials that are less permeable (Eyankware and Aleke, 2021). From Fig. 10, it was observed that high values was seen around VES/5, this implies that such area are permeable (allow free flow of liquid), while area around VES/12 with low value could be said to be less permeable.

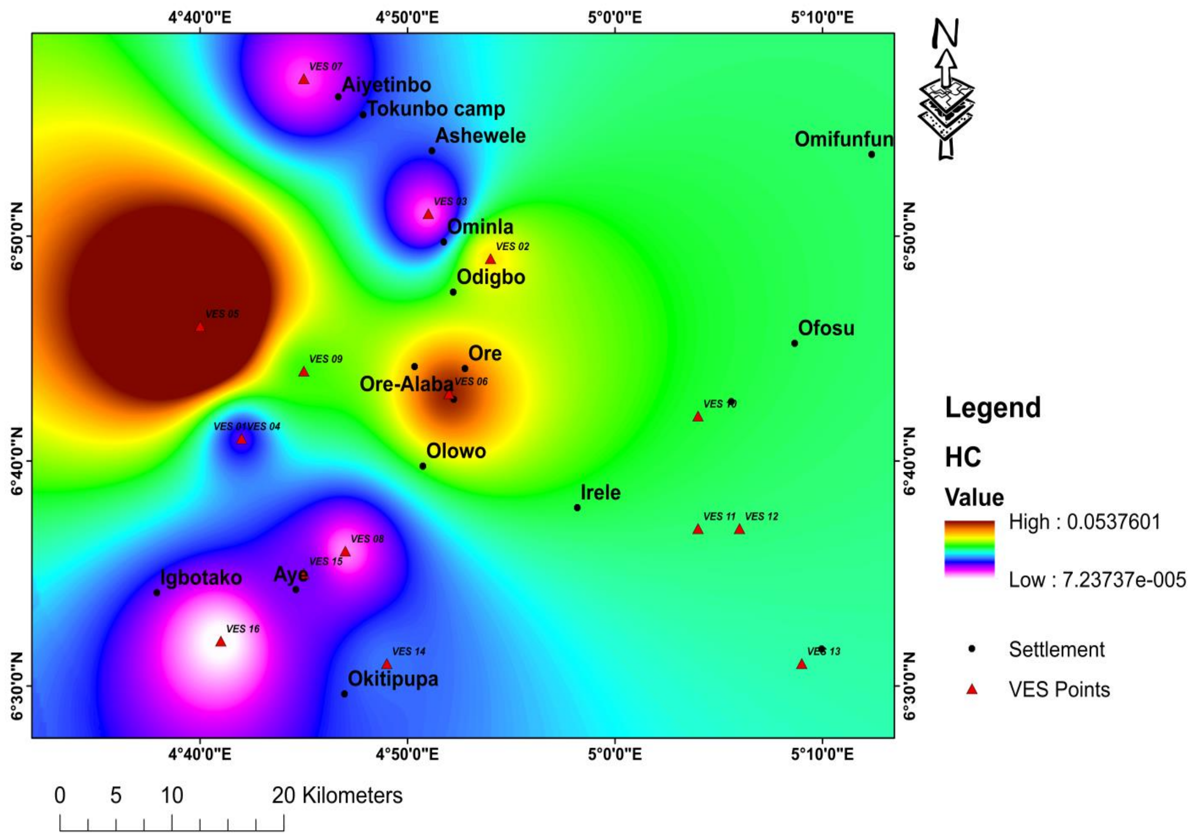

Fig. 10. Spatial distribution of *H* within the study area.

Transmissivity (T)

Transmissivity helps anticipate groundwater movement and determine the safe yield of an aquifer unit. Transmissivity, a hydraulic property that assesses an aquifer's capacity to transmit groundwater throughout its thickness, reveals that regions with these values are predominately characterized by moderate groundwater potential (Offodile 1983). An aquifer's potential is stated to be closely correlated with its transmissivity by the transmissivity criterion, much like the transverse resistance of the strata above it (Akintorinwa et al. 2020). T values range from 0.05 to 65.56 m^2/day and have an average of 20.18 m^2/day. The average transmissivity in the studied region is 20.18 m^2/day, which indicates that the groundwater potential is moderately high. Findings from transmissivity, hydraulic conductivity and coefficient of anisotropy in this study revealed that area of groundwater potentials are NE, and NW parts of the study area (Fig. 11).

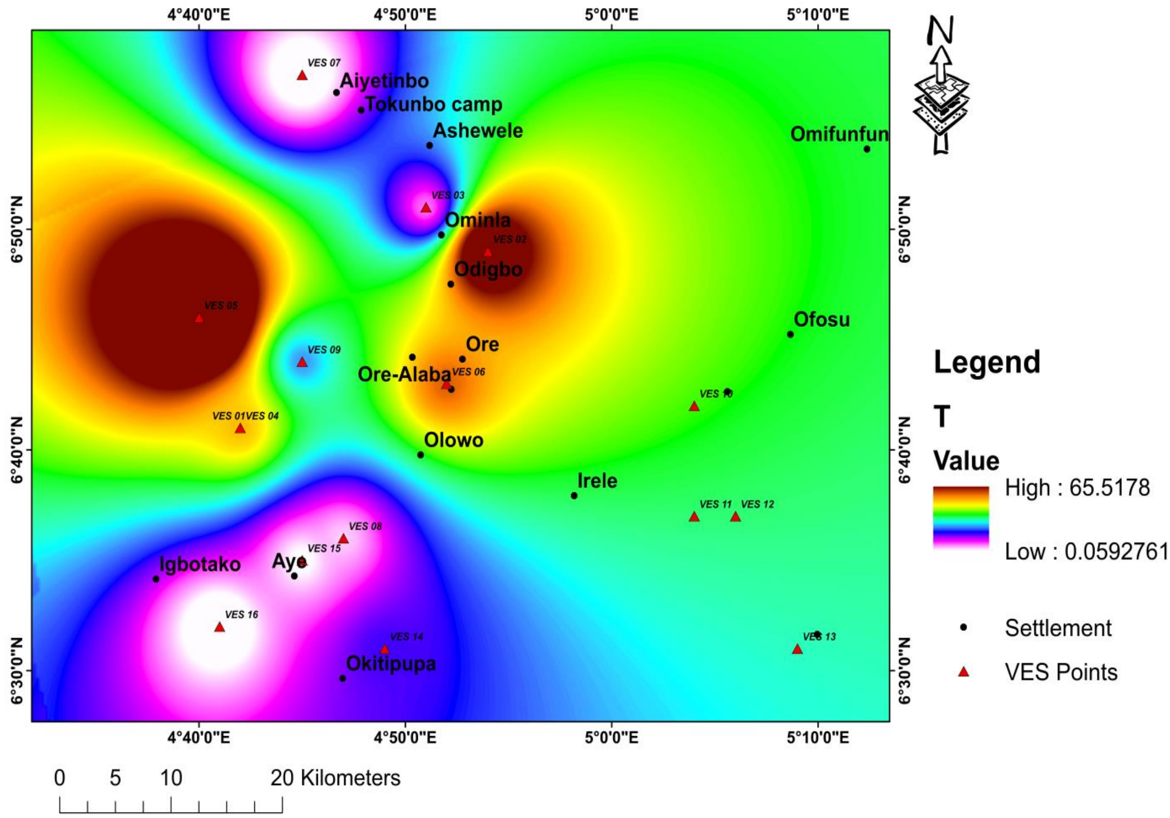

Fig. 11. Spatial distribution of T within the study area.

5. CONCLUSION

In order to identify fracture zones for aquifer potential, vertical electrical sounding was conducted in the study region. The results showed that the northeastern and northwest parts of the study area are more fractured than the other areas. This has a strong correlation with the high transverse resistance values found from local geoelectric parameter estimates and the weathered geology. When the aquifer protective capacity rating was compared to the longitudinal conductance values used to determine the area's aquifer vulnerability, it was found that 99.6% and 0.4% of the area's aquiferous zones had weak and poor permeable overburden, respectively, making them likely vulnerable to surface contamination. The spatial variation of the coefficient of anisotropy, hydraulic conductivity, and transmissivity revealed that the NW, and NE parts of the study area tends to be of good groundwater prospect when compared to other parts of the study area.

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