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DELINEATION OF GROUND WATER POTENTIAL USING ELECTRICAL RESISTIVITY METHOD IN OROGUN, DELTA STATE – NIGERIA

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ABSTRACT

Vertical Electrical Sounding was utilized to delineate the aquifer pattern of three communities in Orogun. Six locations were used studied with current electrode spacing of AB/2 with maximum of 100m and electrode Spacing of 0.5m to 10m. The equipment used iswas the ABEM Tarrameter with inbuilt booster which was used to acquire the data. The result shows four geophysical layers in all locations. The Shallowest aquifer was found at VES 4 of 6.8m and the highest VES 1 of 16.7m. the aquifer depth fall within the ranges of 6.8m to 16.7m. The resistivity values for all the layers in the study area are moderate, the highest is at VES 4 (866.1Ωm) and the lowest at VES 1 (63.6 Ωm). To ascertain the aquifer potential, the formation parameters were also evaluated, and it reveals that the longitudinal conductance values < 0.2 except VES 1 and 2. This showed aquifer protective capacity at Ves1 & 2 are moderate but VES3-6 have weak protective capacity. The parameters also reveal high-resistivity formations, with the reflection coefficient values range from 0.535 to 0.952 for all the VES locations. The value of Resistivity contrast for VES 1–6 (2.52 to 40.41) revealed polluted especially from hydrocarbon sources and other manmade pollutants. The physicochemical parameters show that pH fall within 6.50–6.90 (mean 6.6) moderate, conductivity 9.80–22.40 μS/cm (mean 19.1 μS/cm) low, temperature 28.42–28.47°C (mean 28.3°C) moderate but Turbidity 9.50– 15.00 NTU (mean 12.17 mgl^{-1}) is very high as compared to Standard Organization of Nigeria (SON) permitted limit of 5NTU. The major ions Cl^-, SO_3^-, NO_3, PO_4^-, No_2^-, Pb, Cd, Fe, Ni and Zn respectively, revealed that all cations studied were not above the world health organization standard and Standard Organization Of Nigeria(SON) permitted limit except Cd^{2+} and Pb^{2+} which is slightly above the permitted limit of 0.003 and 0.01 mg/l. hence the water is conducive for drinking.

Keywords: Vertical Electrical Sounding, Delineation, Groundwater, Aquifer

INTRODUCTION

The abundance of water on earth makes the earth habitable for plant, animals and human activities. Water is undeniably one of the most crucial liquids on Earth, essential for sustaining life. While it's often perceived as pure, it's important to recognize that water is never completely devoid of impurities. As noted by Ibitoye (2012), water invariably contains traces of various substances, including organic compounds, particles, gases, minerals, and ions, all of which contribute to its physical, chemical, and bacteriological properties. It's essential to acknowledge that groundwater can become contaminated when the level of these impurities exceeds certain thresholds, leading to what is commonly referred to as groundwater pollution.

Groundwater pollution occurs when pollutants are introduced into the subsurface either through human activities or natural processes, eventually reaching the aquifer. The health of aquifers, rivers, lakes, and wetlands is closely linked to the land cover and land use practices in their respective watersheds. But since the level of demand of water quality becomes higher as land uses intensify through the spectrum of agriculture, timber harvesting, housing, industralization and roads. Land conversion of farms and forests from 2000 to 2022 reveals an increase of many acres of land been developed for building sites (Bolduc, et al., 2022). More than 31%, or acres, came from agricultural land, whereas 32%, or more acres, came from forest land. Forest is the dominant land cover, it protects water quality by slowing runoff, stabilizing soils and filtering pollutants. When forest land is converted to other uses interrupts these natural processes and increases the potential for water quality impairment. Water remains a major source of life to all, it comes in either small or large quantity. It is essential to consider the quality of water for both domestic and industrial purposes. Despite the abundance of water on Earth, with over two-thirds of the planet's surface covered by water, whether in the form of surface water or underground reservoirs, it's crucial to note that groundwater accounts for only about 1% of the Earth's total water.

Groundwater is found beneath the unsaturated zone where all the open spaces between sedimentary materials or in fractured rocks is filled with water and the water has a pressure greater than atmospheric pressure. . To comprehend the occurrence of groundwater, it's necessary to consider the properties of groundwater-bearing formations, such as porosity and permeability. An aquifer is defined as a geological formation that is porous enough to store water and permeable enough to allow water to flow through it in significant quantities that can be economically utilized.

An economical method for prospecting groundwater, applicable on both small and large scales, is the electrical resistivity method of geophysical prospecting. This approach is characterized by its speed, repeatability, cost-effectiveness, and non-intrusive nature, making it a viable alternative to traditional methods (Skinner and Heinson, 2004). The electrical resistivity of rocks is influenced by various factors, including the presence of conductive minerals such as base metal sulphides or oxides, as well as graphites within the rock.Most rocks without these minerals are usually poor conductors and their resistivity is determined primarily by their porosity, degree of fracturing and the degree of saturation of the pore spaces (Cook et al., 2001). Electrical method uses direct current or low frequency alternating current for subsurface investigation (Brooke and Kearey, 1984).

STATEMENT OF PROBLEM

The rate at which industrialization, socioeconomic land use and urbanization of the rural communities within Ughelli town call for urgent attention, because it has increase the demand of quality water. The stresses of providing quality water for various human activities remain a threat to quality of underground water, because human activities have affected the distribution, quantity, and chemical quality of water resources. The range of this human activities that has affect the interaction of ground water and surface water is broad and majority of such activities takes place in Ughelli and environs. The research work will not provide an exhaustive survey of all human effects, but emphasizes those that are relatively widespread and can easily affect the aquifer in the area.

Progressive population growth and human developmental activities which is already a threat, that has gear up this researcher to want to investigates the depths of the aquifers of those areas were these severe human activities are much, that may have probably act as threat to the aquifer and quality of potable water of the area. Activities such as the widespread use of combustion engines, disposal of food and domestic waste, industrial operations, oil exploration activities, dredging, and others have presented significant challenges to both citizens and government authorities. To gauge the magnitude of humaninduced impacts on water resources across virtually all landscapes in the study area, the researcher considers it essential to delineate subsurface water and assess the effects of these activities on the aquifer of the Ughelli North local government area. This endeavor is deemed necessary to understand and address potential threats to the aquifer system. Various structures and features associated with human activities are overlaid on different parts of the conceptual landscape. The impacts of these activities on the quantity and quality of water resources span across diverse spatial and temporal scales, requiring immediate attention. This research aims to delineate the subsurface water and assess the aquifer properties and capacity in Orogun town, Delta State. This endeavor is crucial for understanding and managing the water resources in the area effectively.

Location of the study Area

The study area, Orogun town, is situated within the Ughelli North Local Government area, a significant urban center in Delta State. It is positioned between latitude 5°28'N and latitude 5°32'N of the equator and longitude 5°58'E and longitude 6°03'E of the Greenwich meridian. The region is characterized by low-lying terrain, with elevations ranging from 0 to 100 meters above sea level. Hydromorphic and organic soils predominate in the area, with brown to sandy loam soils being prevalent. Both types of soil typically exhibit a surface accumulation of peaty materials. The area's drainage is primarily facilitated by River Ase, also known as River Ocumeci, which is a distributary of the River Niger.. Also the area is riddled with an intricate system of natural water channels and valleys, culminating in poorly drained landscape. The area is mainly occupied by small farming activities and residual dweller of Urhobo people very few industrialization has taken place as seen in the presence of major oil and construction companies such as SHELL etc.

Fig 1

METHODOLOGY

Data from resistivity surveys are customarily presented and interpreted in the form of values of apparent resistivity ρ_a. Apparent resistivity refers to the resistivity of a half-space that is electrically uniform and isotropic. This resistivity value would produce the observed relationship between the applied current and the resulting potential difference, given a specific electrode configuration and spacing. The equation describing apparent resistivity in terms of applied current, potential distribution, and electrode arrangement can be derived by examining the potential distribution resulting from a single current electrode. The impact of multiple electrodes, including electrode pairs or other combinations, can be assessed through superposition. This involves considering the effect of each electrode separately and then combining their effects. To illustrate, one may begin by considering a theoretical scenario involving a single point electrode situated on the boundary of a semi-infinite, electrically uniform medium, which serves as a simplified representation of the earth. If an electrode carries a current I, measured in amperes (A), the potential at any point within the medium or at its boundary can be expressed as follows:

$$U = \rho \frac{I}{2\pi r}, \qquad (1)$$

where U = potential, in V, ρ = resistivity of the medium, r = distance from the electrode. The mathematical proof for deriving this equation can be found in geophysics textbooks, such as Keller and Frischknecht (1966).

For an electrode pair comprising electrode A with current I and electrode B with current -I (as depicted in Figure 1), the potential at a given point is determined by the algebraic sum of their individual contributions:

$$U = \frac{\rho I}{2\pi r_A} - \frac{\rho I}{2\pi r_B} = \frac{\rho I}{2\pi}\left[\frac{1}{r_A} - \frac{1}{r_B}\right], \qquad (2)$$

where rA and rB denote the distances from the point to electrodes A and B, respectively. Plate 1 provides a visual representation of the electric field surrounding the two electrodes, depicted in terms of equipotential and current lines.

The equipotentials depict imaginary shells or bowls enveloping the current electrodes, where the electrical potential remains constant at every point. Meanwhile, the current lines illustrate a selection of numerous paths taken by the current, paths determined by the requirement that they are perpendicular to the equipotential surfaces at all points.

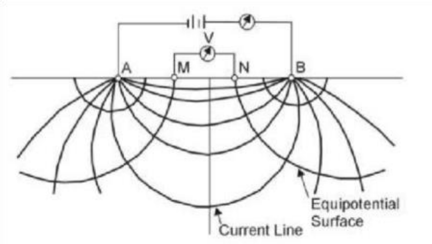

Plate 2 showcases the equipotentials and current lines for a pair of current electrodes A and B situated on a homogeneous half-space.

In addition to the current electrodes A and B, Figure 1 illustrates a pair of electrodes M and N, which do not carry any current but between which the potential difference V can be measured. Using the equation mentioned earlier, the potential difference V can be expressed as follows

$$V = U_M - U_N = \frac{\rho I}{2\pi}\left[\frac{1}{AM} - \frac{1}{BM} + \frac{1}{BN} - \frac{1}{AN}\right], \quad (3)$$

where UM and UN represent the potentials at M and N, respectively, and AM denotes the distance between electrodes A and M, and so forth. It's important to note that these distances are always the actual distances between the respective electrodes, regardless of whether they are aligned on a straight line. The expression within the brackets is solely dependent on the various electrode spacings,The quantity denoted as 1/K enables us to rewrite the equation as follows:

$$V = \frac{\rho I}{2\pi}\frac{1}{K}, \quad (4)$$

where K represents the array geometric factor. Solving Equation 4 for ρ yields:

:

$$\rho = 2\pi K \frac{V}{I}, \quad (5)$$

) The resistivity of the medium can be determined using measured values of V, I, and K, the geometric factor. K is solely determined by the geometry of the electrode arrangement.

Materials used for the study

Terameter: ABEM terameter with inbuilt booster was utilized. This instrument was employed to introduce electric current into the earth through two current electrodes. Subsequently, the potential difference was measured across two potential electrodes, enabling the determination of the resistivity value.

Crocodile clips: These are commonly employed for creating temporary electrical connections. Electrodes: These are conductors utilized to establish contact with nonmetallic substances.

Measuring tape: Used for measuring distance or dimensions. Cabled wires: These wires are employed for power transmission to convey electricity.

Procedure

: For this study, the symmetrical Schlumberger array, specifically the Vertical Electrical Sounding (VES), was conducted along four lines spaced approximately 150/160 meters apart. The VES surveys were conducted with a maximum current electrode spacing (AB/2) of 100/120 meters. Electrical current was injected into the ground using two outer electrodes, while the resulting potential difference was measured by the second pair of potential electrodes positioned at the center of the potential electrode array..

The current electrode spacing selected for those surveys was AB/2 (in meter) 1m, 2m, 3m, 4m, 6m, 6m, 8m, 12m, 15m, 15m, 20m, 25m, 32m, 40m, 40m, 50m, 65m, 80m, 100m, 100m, 120m, 150m, and the spacing electrodes was MN/2 (in meter) 0.5m, 0.5m, 0.5m, 0.5m,1.0m,1.0m,1.0m,1.0m, 2.0m, 2.0m, 2.0m, 2.0m, 5.0m, 5.0m, 5.0m, 5.0m, 5.0m, 5.0m, 10.0m.

The repeated calibrations are taken at 15m, 40m, 100m, in order to remove the ambiguity of compile a d diurnal variation curve for later correction. Our results were positive, if there was a negative result, our readings are wrong, so our connections and our electrodes must be properly checked in case there is any breakage of connectivity.

PRESENTATION OF DATA AND ANALYSIS OF RESULT

The main objective of this research is to determine the effect of human activities on the aquifer of Orogun town. To achieve the objectives of this research, a field survey was carried out, three community were sited 6 VES location was taken, which are Obodetti-Orogun, Aragba-Orogun and Ugono-Orogun respectively. At list in each of these communities sited above, two VES location was taken as to determine the depth and properties of the aquifer with the help of Schlumberger Array method. The reading was taken at the different location of the town and villages as given in table 1. To further ascertain the effect of human activities on the water quality, water samples were collected randomly from the three different community close to the VES station and the samples was taken to the lab for further analysis.

TABLE 1 Field Data from 18 VES stations

AB/2	MN/2	VES1	VES2	VES3	VES4	VES5	VES6s
1	0.5	389.32	903.58	585.69	1083.8	1230.7	1844.0
2	0.5	357.72	853.172	455.63	1019.1	870.602	1253.8
	0.5	305.74	800.296	324.38	962.73	758.58	1112.4
4	0.5	291.211	756.085	301.82	922.73	804.76	1091.5
5	0.5	256.771	702.927	257.689	954.28	745.63	1054.52
6	0.5	204.51	654.361	220.86	1086.0	646.96	1011.0
6	1.0	182.44	602.286	180.00	1110.0	706.05	1022.8
8	1.0	165.182	568.767	162.975	1270.7	750.95	1207.4
12	1.0	156.351	405.302	140.284	1393.5	828.18	1366.0

15	1.0	142.34	408.611	150.3405	1392.6	437.73	1468.1
15	2.0	136.122	352.646	175.905	1497.1	786.54	1611.3
20	2.0	128.23	302.248	225.9754	1575.6	1005.9	1720.7
25	2.0	130.304	256.33	335.5835	1629.6	736.11	1887.1
32	2.0	156.155	262.35	425.0234	1788.4	1199.1	1989.9
40	2.0	186.219	285.358	574.3325	917.9	1460.5	2112.2
40	5.0	210.311	356.009	658.3955	1920.9	1565.4	2045.3
50	5.0	256.222	476.17	709.78	2003.5	1663.8	2190.0
65	5.0	304.23	550.80	758.04	2154.5	1764	2201.0
80	5.0	348.63	652.36	805.41	2234.0	1866	2276.4
100	5.0	369.35	700.19	778.63	1083.8	1876	1844.0
100	10.0						
120	10.0						

The field data were used to compute the apparent resistivity value (table 1) where plotted against half of the current electrode separation (AB / 2) on a log - log graph paper, were the apparent resistivity (ρa) and half current electrode spacing (AB/2) where plotted on the coordinate (Y-axis) and abscissa (X-axis) respectively. Below is the different values of resistivity and thickness obtained. The table 2 shows the summary of the results obtained from the curve matching interpretations.

Table 2: VES Station, Location, Layer, Resistivity, and Thickness

	Layers	App. Resistivity	Thickness h (m)	depth	Lithology
VES1	1	535.6	0.2	0.2	Top soil
	2	268.2	5.4	5.6	clay sand
	3	63.6	11.1	16.7	Sandy Clay
	4	943.3	……….	……..	Medium coarse Grain Sand
VES 2	1	716.2	0.2	0.2	Top soil
	2	745.0	7.5	7.7	clay sand
	3	86.9	8.8	16.4	Sandy Clay
	4	1773.2	……..	…….	Medium coarse Grain Sand
VES 3	1	395.9	0.4	0.4	Top soil
	2	590.9	1.5	1.9	clay sand
	3	**72.2**	4.9	6.9	Sandy Clay
	4	2917.8	…..	…….	Medium coarse Gran Sand
VES 4	1	1424.9	0.3	0.3	Top soil
	2	979.1	4.0	4.3	clay sand

	3	866.1	2.5	6.8	Fine grain Sand
	4	2180.3	………	……	Medium coarse Grain Sand
VES 5	1	1422.0	0.3	0.3	Top soil
	2	790.5	5.1	5.4	clay sand
	3	327.5	5.0	10.4	Fine grain Sand
	4	**2924.7**	……	…….	Medium coarse Grain Sand
VES 6					
	1	1071.4	0.3	0.3	Top soil
	2	1097.4	3.5	3.8	clay sand
	3	773.6	3.3	7.1	Fine grain Sand
	4	2553.5	…..	…..	Medium coarse Grain Sand

Computer iteration

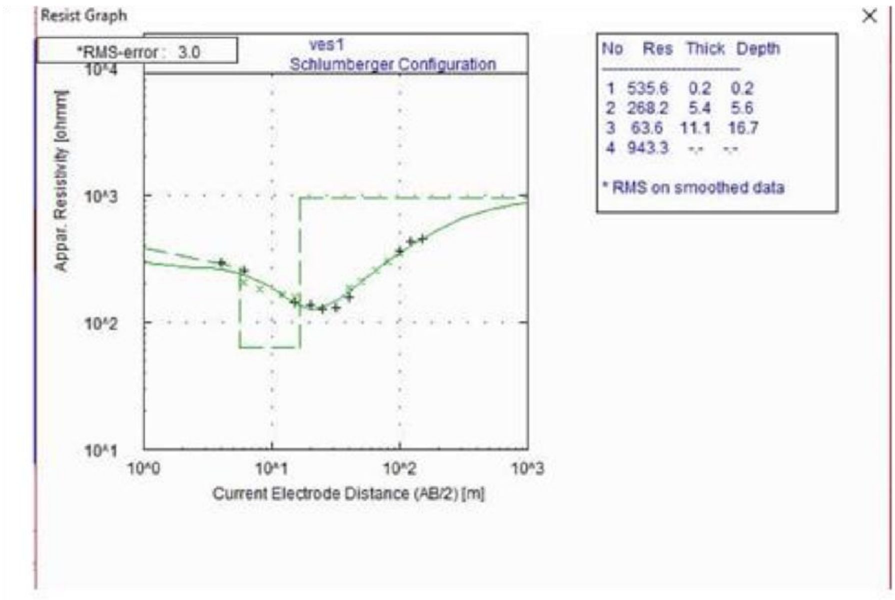

Figure 1: VES location 10 Aragba Orogun town

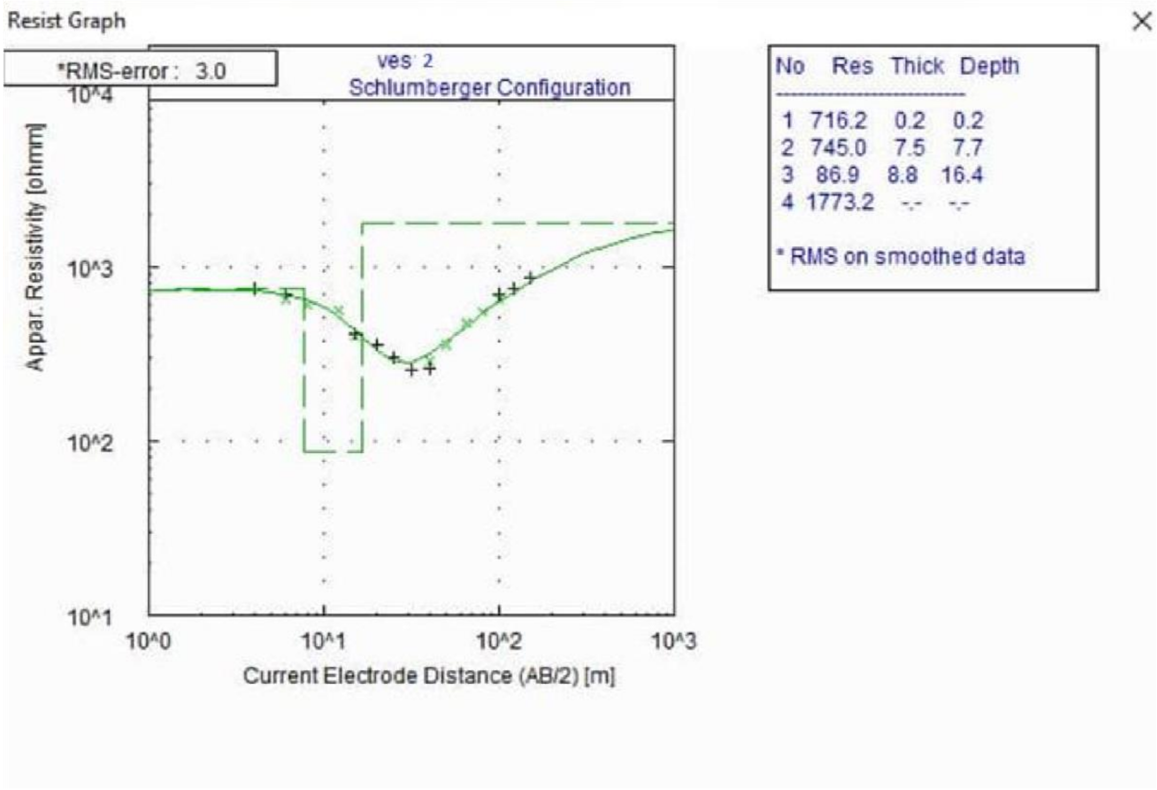

Figure 2: VES location 2 Obodetti Orogun town

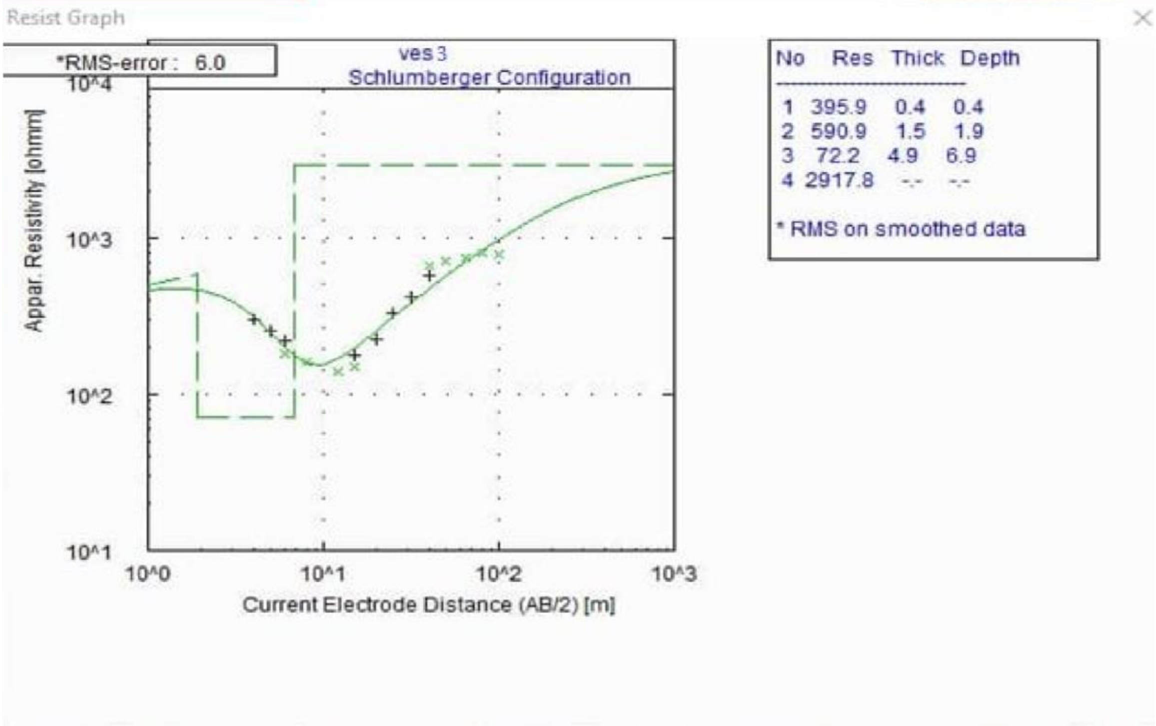

Figure 3: VES location 3 Ugono Orogun town

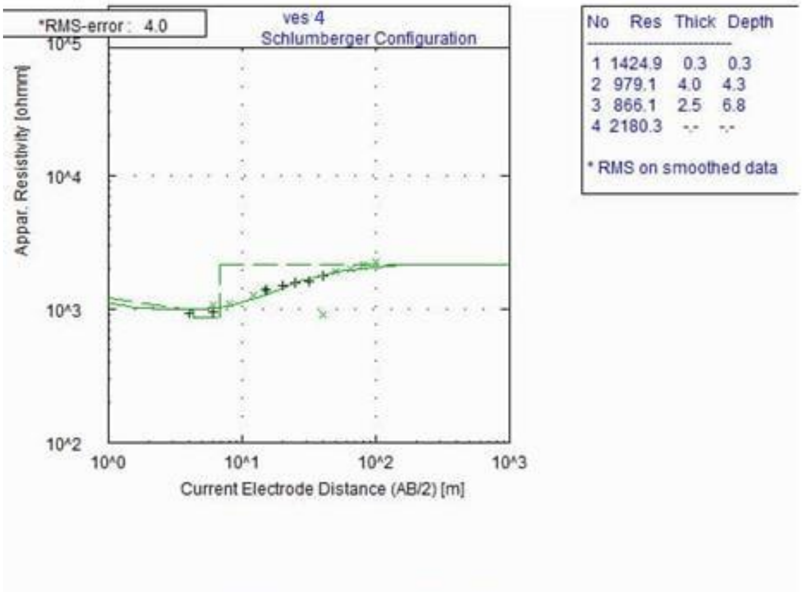

Figure 4: VES location 4 Aragba Orogun town

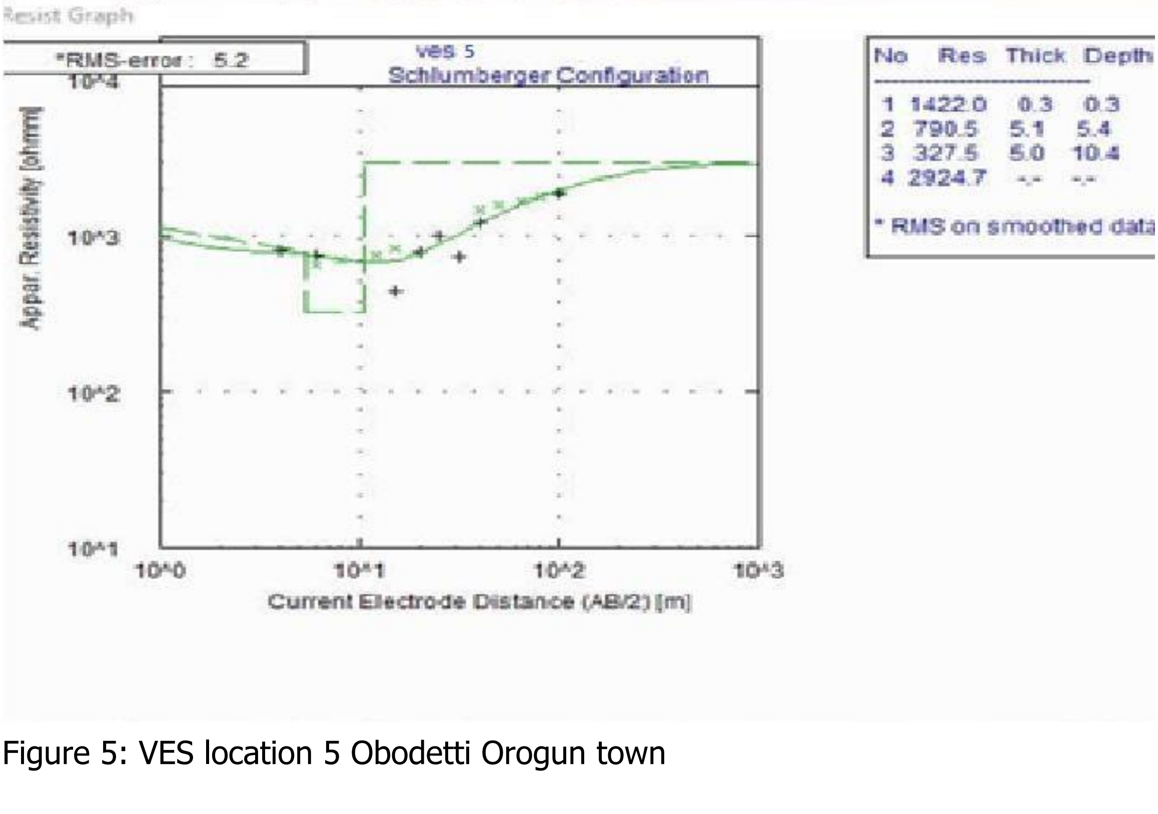

Figure 5: VES location 5 Obodetti Orogun town

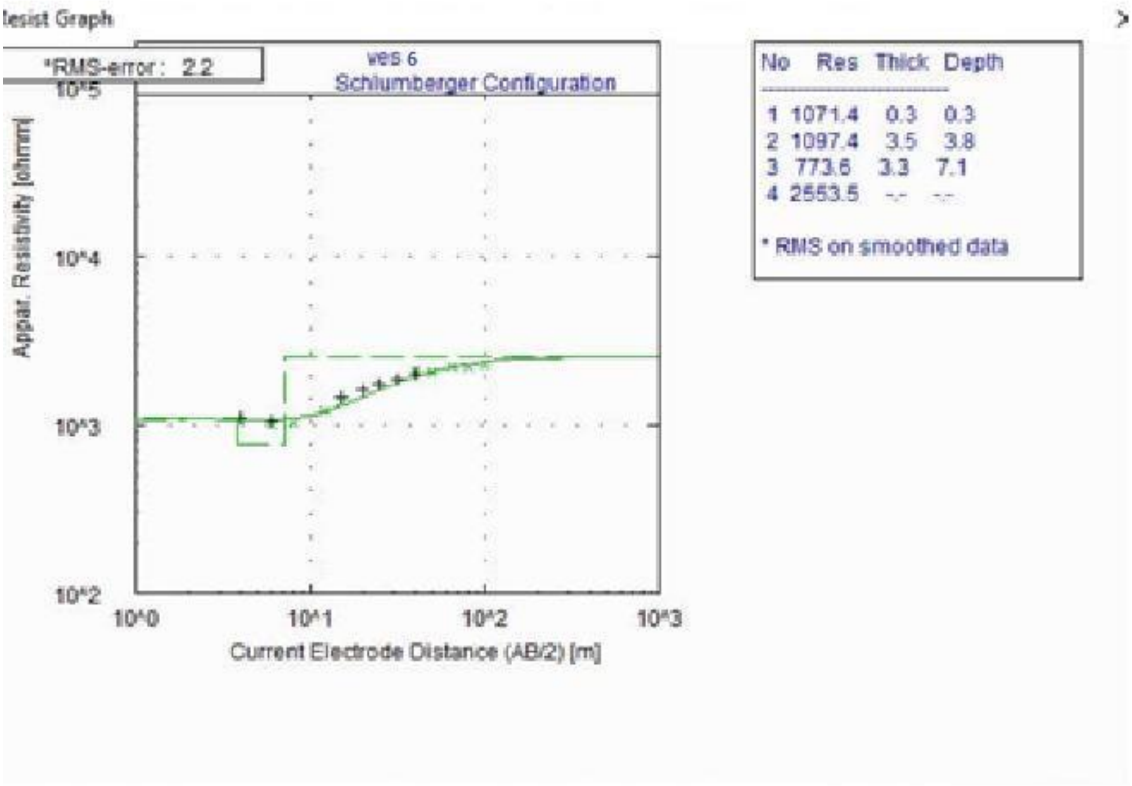

Figure 6: VES location 6 Ugono Orogun town

These process of interpretation is very essential because it compare the resistivity field curve with a standard or characteristic curves. These standard curve are determined from area layer earth mode. Field curves / standard curves in vertical Electrical sounding (VES) are classified into four types.

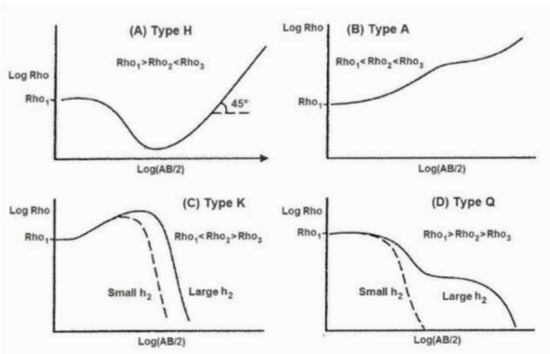

Figure 7: standard curves

The Q - type of curve exhibits the opposite effect it decrease continuously along with a progressive decrease of the resistivity with depth.However hybride or combination curve also exist, this is a multiple layered structure consisting of type K curve type H curve, Type HKH curve type AK curve type Q curve type A curve or more than three layers . These are HK, HA and HKH curves and a typical example of such curves are given in fig 4. 19

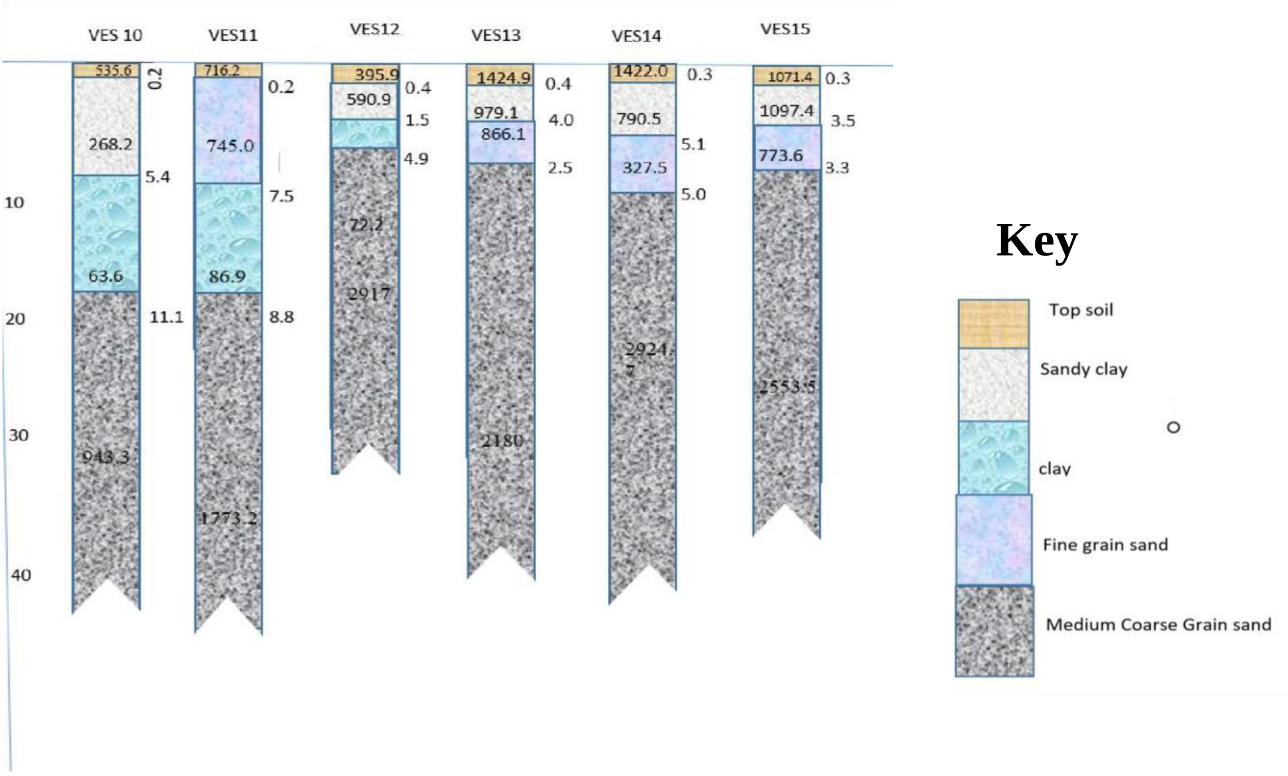

Figure 8: Geoelectric layers of VES 1-6

Aquifer protective capacity

The aquifer protective capacity of the study area was assessed using the parameters longitudinal conductance (S) and transverse resistance (T), as detailed in Table 2. The aquifer protective capacity ratings derived from this assessment are presented in Table 3.

	App. resistivity	Thickness h (m)	depth	Longitudinal Conductance(s)=h/p	Transverse Resistance(T)=h*p
VES1	535.6	0.2	0.2	3.73×10^{-4}	107.32
	268.2	5.4	5.6	2.01×10^{-2}	1448.28
	63.6	11.1	16.7	1.75×10^{-1}	705.96
	943.3				
		=16.7		Total=1.95×10^{-1}	Total =2261.56
VES2	716.2	0.2	0.2	2.79×10^{-4}	143.24
	745.0	7.5	7.7	1.01×10^{-2}	5587.50
	86.9	8.8	16.4	1.01×10^{-1}	764.72
	1773.2				
		=16.5		Total=1.11×10^{-1}	Total =6495.46
VES3	395.9	0.4	0.4	1.01×10^{-3}	158.36
	590.9	1.5	1.9	2.54×10^{-3}	886.35
	72.2	4.9	6.9	6.79×10^{-2}	353.78

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Table 3: Dar Zarouk parameters

	2917.8				
		=6.8		Total=9.43×10^{-2}	Total =1398.49
VES4	1424.9	0.3	0.3	2.11×10^{-4}	427.47
	979.1	4.0	4.3	4.09×10^{-3}	3916.4
	866.1	2.5	6.8	2.89×10^{-3}	2165.25
	2180.3				
		=6.8		Total=7.19×10^{-3}	Total =6509.12
VES5	1422.0	0.3	0.3	2.11×10^{-4}	426.60
	790.5	5.1	5.4	6.45×10^{-3}	4031.55
	327.5	5.0	10.4	1.53×10^{-2}	1637.5
	2924.7				
		=10.4		Total=2.20×10^{-2}	Total =6095.65
VES6					
	1071.4	0.3	0.3	2.80×10^{-4}	321.42
	1097.4	3.5	3.8	3.19×10^{-3}	3840.9
	773.6	3.3	7.1	4.27×10^{-3}	2552.88
	2553.5				
		=7.1		Total=7.74×10^{-3}	Total=6715.2

Table 4: The reflection coefficient (R_C) values of the study area are presented in Table 4 Areas of low reflection coefficient value have high water potentials. It is a measure of the degree of fractures of an area.

VES	Reflection coefficient $R_c=\frac{p_n-p_{n-1}}{p_n+p_{n-1}}$	Resistivity contrast $F_c=\frac{p_n}{p_{n-1}}$	Longitudinal resistivity $p_l=\frac{h}{s}$(Ω/m)	Transverse resistivity $p_T=\frac{T}{h}$ (Ω/m)	Coefficient of anisotropy((λ) $=\sqrt{\frac{p_T}{p_l}}$	Resistivity of formation=$\sqrt{p_T p_l}$
1	0.874	14.832	85.64	135.422	1.257	107.692
2	0.907	20.41	148.65	393.66	1.627	241.904
3	0.952	40.41	72.110	205.66	1.689	121.779
4	0.431	2.52	945.76	957.22	1.006	951.47
5	0.799	8.93	472.73	586.12	1.183	526.38
6	0.535	3.301	917.31	945.80	1.015	931.446

Table 5: water analysis results

Parameters	**VES2**	**VES4**	**VES5**
Cl	98.43	131.40	127.43
SO_3	20.63	24.32	16.31
NO_3	10.98	13.63	9.86
PO_4	0.08	0.09	0.07

NO_2	0.91	0.073	0.42
Pb	0.01	0.04	0.03
Cd	0.03	0.04	
Fe	0.02	0.07	0.01
Ni	0.02	0.03	0.03
Zn	1.10	1.33	0.90

Table 6: physicochemical parameters

Parameters		**VES9**	**VES11**	**VES4**	**VES13**
Sn	Parameters	2	3	4	5
1	Turbidity NTU	12.00	15.00	8.70	9.50
2	Temperature	28.47°C	28.42°C	28.41°C	28.42°C
3	pH	6.90	6.50	7.20	6.60
4	Electrical conductivity µs/cm	16.50	22.40	20.00	18.40

DISCUSSION

Figure 8 is a geolectric section showing the different layers, thickness and depth of the various VES stations, the black hash layer is the fourth layer with and undefined thickness, the water colour layer is the aquifer layers, the sky blue layer is the fine grain sand layer is and the cream is the top soil.

The variations observed in longitudinal conductance result from transitions between different VES points, indicating the overall thickness of low-resistivity materials (Worthington 1977).

Longitudinal conductance (S) is a crucial geoelectrical parameter utilized in identifying areas with groundwater potential. Lower S values are typically associated with low-resistivity formations, such as clayed soil, and relatively shallow basement depths. Conversely, higher S values indicate high-resistivity formations and deeper occurrences of the basement. Extremely high transverse resistance values correspond to highly resistive formations in the subsurface. These values also facilitate the determination of groundwater flow direction within an aquiferous region. Total transverse resistance (T) is another geoelectric parameter used to characterize areas with significant groundwater potential. It exhibits a direct relationship with transmissivity, with higher T values suggesting higher transmissivity values for aquifers or aquifer zones, and vice versa.

Table 7: Table showing aquifer protective capacity rating (Olusegun et al. 2016)

Rating	Remarks
Greater than 10	Excellent
5–10	Very good
0.2–4.9	Moderate
0.1–0.19	Weak
Less than 0.1	Poor

The study area exhibits notably low values of longitudinal conductance, consistently registering values well below 0.2 across all surveyed regions (see Table 3). This indicates a very weak aquifer protective capacity within the surveyed area. Additionally, the area displays elevated values of transverse resistance, suggesting the presence of high-resistivity formations. The high resistivity observed in Orogun can be attributed to its status as an oilproducing region (Nwachukwu et al., 2019). Consequently, the aquifer in this area may be susceptible to contamination due to its short residence time in the coarse sand layers.

The thickness of the overlying layers in the aquifers is insufficient to shield them from percolating fluids. Typically, groundwater is shielded by geological barriers or layers with adequate thickness and low hydraulic conductivity, often referred to as protective layers. Silts and clays serve as effective protective layers, providing a barrier when found in thick layers above aquifers. Unfortunately, these conditions are not met in this study area (Olusegun et al., 2016).

These conditions are not the case for this study.

Dar Zarrouk parameters

Dar Zarrouk parameters were employed to evaluate the groundwater potentials of the area, based on several indices including sandy clay thickness, resistivity of overburden thickness, transverse resistance (T), coefficient of electrical anisotropy (λ), reflection coefficient (RC), formation resistivity (ρ_m), and resistivity contrast (FC). The water saturation zone consists of weathered or fractured layers which serve as aquifer units. Areas characterized by sandy clay thickness exceeding 25 meters and low clay content, as indicated by resistivity values (< 60 Ωm), are categorized as having high groundwater potentials (Kumar et al., 2001). Values of various formation parameters are presented in Table 4.

Reflection coefficient

The reflection coefficient indicates the presence of water-filled fractures in the bedrock interface, with a direct correlation with the anisotropy coefficient value being essential for these parameters to be considered. The reflection coefficient values for this study range from 0.43 to 0.96 across all VES locations, demonstrating a linear relationship with the anisotropy coefficient values in most locations

Resistivity contrast

The resistivity contrast provides valuable insights into the groundwater potential of an area. In this study, resistivity contrast values for VES 1-6 range from 2.52 to 35.139, with VES 1 and 6 showing the highest potential for groundwater exploration.

Coefficient of anisotropy

Coefficient of anisotropy (λ) can provide insight into the aquifer nature of the basement rock, and low λ values may be indicating high-density water-filled fractures. The reflection coefficient indicates the presence of water-filled fractures in the bedrock interface, with a direct correlation with the anisotropy coefficient value being essential for these parameters to be considered. The reflection coefficient values for this study range from 0.43 to 0.96

across all VES locations, demonstrating a linear relationship with the anisotropy coefficient values in most locations. These reflection coefficient λ values indicating a highwater potential according to Bawalla et al(2021), the electrical anisotropy is 1 and does not exceed 2 in most of the geological conditions (Zohdy 1974; Anudu et al. 2011), and compact rock at shallow depth increases the electrical anisotropy. Hence, these areas can be associated with low porosity and permeability.

Resistivity of formation

The resistivity of formation is a parameter that assesses the impact of pore structure on sample resistance. When a formation contains hydrocarbons, its resistivity tends to be very high (Okhue and Olorunfemi, 1991). In this study, the resistivity of formation values is moderate.

Physicochemical Analysis of Ground Water in the Study Area

The Physiochemical Analysis of Ground Water in the Study Area involved the examination of water sample from three wells of various of various physiochemical parameters pH, electrical conductivity, temperature, Turbidity, NH^{4+}, Al^{3+}, Zn^{2+}, Ni^{2+}, Fe^{2+}, Pb^{2+}, and Cd^{2+}.These result were compared with guideline outlined by Standard Organization Of Nigeria for portable water.in assessing the quality of any water resources for its suitability and intendeduse , it becomes evident that understanding its physical,and chemical characteristics is crucial , a detrermination that is influenced byb both geological composition of the area and the impact of human activities (Nwajei et al ,2014).Laboratory result and measurement of pH,conductivity ,temperature ,and total dissolved solids(TDS), along with major ions as Cl^-, SO_3^-, NO_3, PO_4^-, No_2^-, Pb, Cd, Fe, Ni and Zn are presented in table 5. This constituent exhibit the following ranges in the water: Ph 6.50 -7.20 (mean

6.8), conductivity 15.60-22.40 µS/cm (mean 18.58 µS/cm), Temperature 28.40–28.47°C (mean 28.44°C), Turbidity 8.70– 15.00 NTU (mean 11.24 mg/l). The Ph of 6.50 -7.20 suggest that the ground water in the area tends towards acidity. The Standard Organization of Nigeria (SON) specifies the acceptable pH range for drinking water as 6.5-8.50. With respect to this standard, groundwater samples in BH1–BH3 need no treatment in terms of the pH level. The slight acidity observed in groundwater within the area may be attributed to several factors, including the oxidation of dissolved ferrous iron, the presence of organic matter in the soil, or possibly industrial activities in the vicinity. Acidic water conditions can foster the growth of iron bacteria, leading to pipe encrustation (Oseiji et al., 2018). Results from the study indicate that electrical conductivity (EC) values range from 15.60 to 22.40 µS/cm, with a mean value of 18.58 µS/cm. These values fall below the standard set by the Standards Organization of Nigeria (SON) in 2007, which specifies a maximum allowable EC of 1400 µS/cm for drinking water. With EC levels up to 2000 µS/cm deemed permissible for irrigation purposes, the water in the area would not pose harm to crops As indicated by Egbai (2015), EC serves as a crucial indicator of salinity significantly Impacting the taste and , consequentely,the acceptability of the water for drinking purposes. Temperature values range from 28.40 to 28.47°C, with an average of 28.44°C. Turbidity readings range from 8.70– 15.00 mg/l, averaging at 11.24 NTU.This turbidity values exceed the acceptable limit of 5NTU,rendering he water in this area unstable for domestic use. The chloride ions exhibit values ranging from 98.48-131.40 mg/l with a mean value of 116.798 mg/l. Ni^{2+} ions ranges of 0.01 – 0.03 mg/l with a mean value of 0.02 mg/l;SO_3^-ions present values ranging from16.30–24.32 mg/l with a mean value of 21.144 mg/l with a mean value of 21.144 mg/l; Zn^{2+} ions show values in the range of 0.9–0.133 mg/l with a mean value of

1.148 mg/l; Ni^{2+} ions show values in the range of 0.01 – 0.03 mg/l with a mean value of 0.02 mg/l; Fe^{2+} ions show values in the range of 0.01–0.07 mg/l with a mean value of 0.034 mg/l; Pb^{2+} ions show values in the range of 0.01 – 0.04 mg/l with a mean value of 0.028 mg/l; and Cd^{2+} ions show values in the range of 0.02–0.04 mg/l with a mean value of 0.03 mg/l. All cations studied (Cl^-, SO_3^-, NO_3, PO_4^-, No_2^-) were slightly higher and show harmful level in the water sample apart from Cl^-.

CONCLUSION

In summary,the vertical Electrical Sounding carried out across three communities in Orogun town using the Schlumberger array unveiled the presence of four distinct geoelectric layers within the study area but qualitative and Quantitative analyses indicated variation in aquifer debt across different VES point(1-6), With the shallowest aquifer depth detected at VES3 in aragba -orogun , measuring 4.9m and the deepest recorded in aragba at 16.7m.Aquifer depth within the area range from 6.8-16.7m. The resistivity values across all layers were all moderate with the higest registered at VES 1(2924.7Ωm) and the lowest at VES3 (63.6Ωm),consistent with expectation for a sedimentary basin akin to that in the study area. Various formation parameters were evaluated, including longitudinal conductance, transverse resistance, reflection coefficient, resistivity contrast, longitudinal resistivity, transverse resistivity, coefficient of anisotropy, and resistivity of formation. The area is characterized by very low values of longitudinal conductance, indicating a weak aquifer protective capacity. High values of transverse resistance suggest the presence of highresistivity formations. Reflection coefficient values ranged from 0.431 to 0.874 across all VES locations. The resistivity contrast values for VES 1-6 (ranging from 2.52 to 40.41) suggest the area has significant potential for groundwater exploration. Coefficient of anisotropy values indicate low porosity and permeability in these areas, while resistivity of formation values are moderate.

Overall, the evaluated parameters indicate good groundwater potential in the area , although it may be affected by iinfestation , especially from hydrocarbon sources and other man made pollutant. but might have been infested especially from hydrocarbon sources and other manmade pollutants.

Physicochemical parameters such as pH (ranging from 6.50 to 6.60, with a mean of 6.60), conductivity (ranging from 15.60 to 22.40 μS/cm, with a mean of 19.1 μS/cm), temperature (ranging from 28.42 to 28.47°C, with a mean of 28.43°C), and turbidity (ranging from 9.50 to 15.00 NTU, with a mean of 12.17 mg/l) also provide insights into the water quality of the area. The major ions Cl^-, SO_3^-, NO_3, PO_4^-, No_2^-, Pb, Cd, Fe, Ni and Zn respectively, revealed that all cations studied were not above the world health organization standard and Standard organization of Nigeria except $Cd^{2+\wedge Pb2+}$

Which is slightly above the permissible limit of 0.003 and 0.01 mg/l respectively

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