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Exploration of Subsurface Aquifer Zones in Kaiama Community, Kolokuma/Opokuma Local Government Area, Bayelsa State, Nigeria

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ABSTRACT: The subsurface aquifer zone is significant groundwater source, hence this paper investigates subsurface aquifer zones in Kaiama Community, Kolokuma/Opokuma local government area of Bayelsa State, Nigeria with the purpose of exploring groundwater using geoelectric sounding (GES) surveys. Five survey points were examined using Schlumberger electrode configuration and deploying SAS 1000 Terrameter set, with data processed with IPI2win software. Each survey station revealed distinct layers with varying resistivity, depth, and lithology, offering crucial insights into subsurface features and aquifer systems. For GES 1, indicates five layers showing their resistivity values with respect to depth as 400.7Ωm with a depth of 0.6m as top soil, 16.14Ωm-51.01Ωm with a depth of 3.219-7.4356m as clay and layer 6 expressed as 19527Ωm with a depth of 30.01m as coarse sand and aquiferous layer. GES 2 along Kaiama's East-West Road delineated four layers with resistivity value of 467.2Ωm with a dpth of 1.264m as top soil, 54.5Ωm with a depth of 18.8m as clay and 2738Ωm with a depth of 40.01m as coarse sand, which also indicates as a potential aquiferous layer. GES 3 at R.PM School 1 Field identified five layers, highlighting 121.1Ωm with a depth of 0.6m as top soil, 16.67Ωm-5795Ωm with depth of 40.2m as clay with a resistivity potential of 237.7Ωm with a depth of 60.01m as medium sand and subsurface aquiferous layer. GES 4 at Kaiama Grammar School field revealed six layers, with resistivity value of 327.9Ωm with adepth of 0.6m as top soil, 6.383-20.51Ωm with depth of 3.219-7.456m as clay and 800Ωm with depth of 17.27m as medium sand and resistivity of 91599Ωm with depth of 30.22m as coarse sand medium sand indicating potential aquifer zones. GES 5 at Isokiwari Compound Kaiama showcased five layers: resistivity of 43.7Ωm with depth of 0.6m as top soil, 300.5Ωm-417.8Ωm with depth of 1.39-7,521m as medium sand, 65.17Ωm-112.5Ωm with depth of 17.33-40.07m as clay. The findings provide valuable information for groundwater management and resource exploration in the region, emphasizing the significance of understanding subsurface geology for sustainable water access.

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Vertical Electrical Sounding method is one of the surface geoelectrical surveys used in prospecting for groundwater. Several Geophysicists and researchers including (Emenike 2001), (Onwuemesi *et al*. 2006), (Anakwuba *et a*l., 2014) and (Anizoba et al. 2015) have reported its efficiency and effectiveness in prospecting for groundwater, fresh water/ saline water boundary predication and contaminant plumb predication. However, this study is centered on the use of Vertical Electrical Sounding in prospecting for groundwater in Kaiama town. It is good to note that, Kaiama has been of high economic activity in Nigeria and its attendant high population coupled with subsequent cases of bore-hole failures have resulted in

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massive demand for potable and sustainable water supply for both municipal and domestic purposes. Hence, the need for proper groundwater development and management in the area becomes imperative, since it is readily available though in varying quantities.

The research is aimed at determining depths to potential aquifers in the area in order to establish a geophysical data that will serve as guide line for exploration and exploitation of groundwater in the area. This would be achieved by using the Vertical Electrical Sounding method in conjunction with available lithologic logs from the area. The method for the study was chosen because of its excellent vertical resolution and good depth sensitivity, simple instrumentation, easy field logistics and relatively economical, (Zhody *et al*, 2010). The electrical resistivity method is the most commonly applied geophysical tool for groundwater exploration as it can determine aquifer thickness and depth to bedrock, it is also capable of determining the quality of groundwater i.e. whether the water is saline brackish, fresh or contaminated (Idehai and Egai, 2014). The basic aim of resistivity survey is to delineate vertical and horizontal boundaries with respect to resistivity contrast. The Schlumberger array was used in this investigation due to its flexibility to delineate water bearing formations (aquifers), and also, because of its better depth interpretation and its usefulness in mapping subsurface aquifers and groundwater exploration this method find more superior compared to other methods (Egai,*et al*., 2013). This method involves the measurement of electrical resistivity variations in the subsurface, providing valuable insights into the lithological transitions and layer thicknesses. This study also seeks to understand the subsurface architecture of Kaiama, thereby enabling us to ascertain the extent and distribution of groundwater Groundwater is a vital resource for domestic, agricultural, and industrial purposes in many regions, including Kaiama in Kolokuma/Opokuma Local Government Area, Bayelsa State, Nigeria. However, the availability and sustainability of groundwater in this area are poorly understood,. Therefore, the objective of this paper is to investigate subsurface aquifer zones in Kaiama Community, Kolokuma/Opukuma Local Government Area of Bayelsa State, Nigeria with the purpose of exploring groundwater.

MATERIALS AND METHODS

Physiography and Geology of the Study Area: The area under investigation is located in Kaiama in Kolokuma/Opokuma Local Government, Bayelsa State between Latitude 5^0 00N and 5^0 17N and Longitude 6^0 00E and 7^0 00E. It is bounded to the south by Yenagoa L.G.A, to the North by Delta state, to the West by River Nun and Sagbama L.G.A, and to East by Ekeremor L.G.A. The study area is accessible through a network of riverine routes and road, along East – West road between Mbiama and Kaiama. The Geology of the area is within the Niger Delta Sedimentary belt of Nigeria has been geologically described by Rayment (2018). This basin evolved through several depositional cycles. The Late Createaceous (Maastrichtian) to Early Tertiary (Paleocene) Transgression terminated the southern advance of the upper Cretaceous proto-Niger Delta and heralded the Tertiary to Recent Niger Delta as it waned (Rayment, 2018). The Niger Delta is situated on the continental margin of the Gulf of Guinea in Equatorial West Africa between Latitude 3^o and 6o and Longitude 5^o and 8^oE. It covers all areas of about 75,000Km^2 (Short and Stauble, 1967). It extends from the Calabar flank and the Abakiliki trough in Eastern Nigeria to the Atlantic Ocean. Short and Stauble, 1967 recognized three subsurface stratigraphic units in the modern Niger Delta which are, Akata Agbada and Benin Formations in order of decreasing age

Materials Used: The materials and equipments used during the geophysical investigation include: Abem SAS 1000 Terameter (SAS = Signal Averaging System). This is the major equipment that was used in the cause of the survey. This equipment takes in four cycles of readings and takes the averaging reading of the four cycles which is the resistivity. The resistivity is measured in Ohm's (Ω) or milli Ohm's (MΩ).

Electrodes: Electrodes are of two types

i. Stainless steel electrodes
ii. Non-Polarizing electrodes

It was the stainless-steel electrodes that were used in the cause of the investigation
Eight pieces of electrodes were available in order to fasten the work, but only four (4) of the electrodes were used at a time to obtain reading. Two are current electrodes (C1C2) and two potential electrodes (P1P2).

Cable Reels: These were used for connecting the electrodes to the terameter. Usually four cables are used, two for current and the other two for potential. The cables were reeled around a wheel made of either steel or plastic.

Hammers: Two set of Hammers were used in the cause of the investigation. They were used to drive the potentials and current electrodes into the ground properly.

Recording Sheet: The recording sheet was used to record readings during the investigation.

Measuring Tape: Two sets of 100m tapes were used. This is used for measuring distance e.g. (inter-station and traverse spacing) during the course of the investigation.

GPS (Global Positioning System): It was used to acquire the geographical coordinates (latitudes and longitudes) of the study area.

Methodology: Five vertical electrical sounding (VES) data sets were generated using the Abem terameter SAS 1000. The vertical electrical sounding (VES) was used because of its reduced exploration cost, rapidness and effectiveness in operations. The Schlumberger array was used to obtain data of interest. The resistivity measurements were made by using the terameter which was placed on the earth surface at the point of interest and a set of hundred meters tapes are spread out on the ground, then two sets of cable are connected to the terameter at one end, and the cable are then connected to the stainless steel electrodes out of which two are current electrodes (C1C2) and the other two electrodes are potentials electrodes (P1P2). The current electrodes (C1C2) are the outer electrodes (AB/2) and (P1P2) are the inner electrodes (MN). All the four electrodes are introduced into the ground from a measured reference point on the tapes which are spread out on the ground. C1C2 increases in distance as measurement are made while P1P2 are relatively fixed as shown on the Schlumberger array form. The centre of the electrodes array remains fixed but the spacings of the electrodes was increased so as to obtain information about the stratification of the ground. The data are mostly taken in overlapping segments because at each step of AB spacing's, the signal of resistivity meter become weaker. Therefore, MN spacing was enlarge and two values of the same AB/2 were measured, one for the short and one of for the MN spacing. Measurement were made by introducing an artificially generated electric current into the ground from the terameter through the two current electrodes (C1C2), (AB) and the resulting voltage differences potentials drop (Pd) across the two potential electrode (MN/2) are noted. The resistance data collected are converted to apparent resistivity reading that can be modelled to provide information in the thickness of individual resistivity layer within a surface measurement are taken manually using a terameter. The apparatus (Abem SAS 1000 Terameter) is designed so that the ratio of the potential drop (voltage) to the measured current is read directly as resistance in ohms meter (ΩM) or mile ohms meter (MΩM) after a minimum average of two cycles or maximum averaging of four cycles. The value obtained is the resistance of the earth materials down to a depth which is proportional to the electrode spacing. The data obtained was later subjected to IP2WIN computer software programme, this programme was used to perform quantitative analysis and interpretation of the field curves.

Measurement Principle: Measurement of the resistivity of the ground was carried out by transmitting a controlled current (I) between two current electrodes pushed into the ground, while measuring the potentials (V) between two other potentials electrodes direct current (DC) used.

The resistance (R) is calculated using ohm's law.

$$R = V/I \qquad (1)$$

The material parameter resistivity (R), which is related to the resistance via a geometric factor (K). The resistivity of the ground can calculated using

$$P = K\ V/I \qquad (2)$$

Where geometric factor (K) is given as a geometry of the electrode arrangement,

$$P = \pi(a^2/2b - b/4) \qquad (3)$$

RESULTS AND DISCUSSION

The findings obtained from Geoelectric Sounding (GES) surveys carried out in different communities' offer valuable understanding into the subsurface features, especially concerning the existence and capacity of aquifer systems. Every survey identifies unique geological strata, providing details on resistivity levels, depths, widths, and rock compositions.

Geoelectric Sounding (GES) 1: The Geo-electric Sounding (GES) method plays a crucial role in groundwater exploration, offering insights into the subsurface characteristics that can indicate the presence and properties of groundwater-bearing formations. In the case of the GES conducted at Ikatibiri Compound Kaiama, the results presented in Table 1 provide valuable information about the resistivity values, depths, and thicknesses of interpretative geo-electric layers (Figures 1 and 2), which are essential for understanding the hydrogeological setting of the area.

Table 1: Resistivity, thickness and depth of VES 1 result in Ikatibiri Compound Kaiama

Layers	Resistivity (Ωm)	Thickness h (m)	Depth d (m)	Rms Error (%)	Curve Type	Lithology
1	400.7	0.6	0.6			Top soil
2	794	0.7897	1.39	0.881	KHAA	Medium sand
3	16.14	1.829	3.219			Clay
4	57.01	4.237	7.456			Clay
5	708	9.814	17.27			Medium sand
6	19827	12.74	30.01			Coarse sand

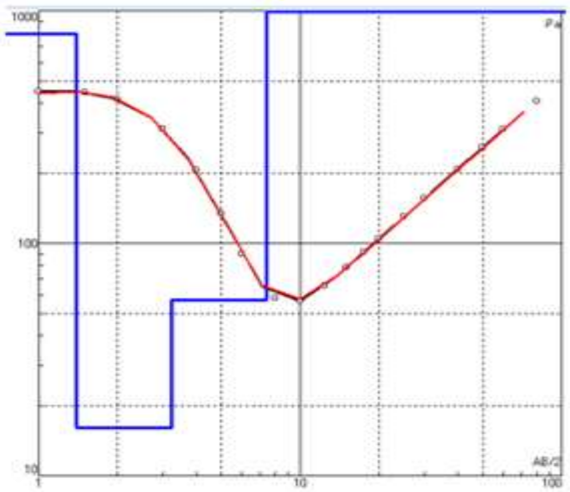

Fig 1: Computer Modelling for GES 1

Layer 1, representing the topsoil within the depth range of 0-0.6 meters, exhibits a resistivity of 400.7 Ωm, suggesting the presence of dry, loose material, likely organic-rich topsoil. The relatively thin thickness of 0.6 meters indicates minimal soil development in this layer. Moving down to Layer 2, which spans from 0.6 to 1.39 meters, the higher resistivity value of 794 Ωm compared to Layer 1 implies the presence of coarser, less conductive material, possibly medium sand. With a thickness of 0.79 meters, this layer indicates a moderately developed sand zone. Layer 3, extending from 1.39 to 3.219 meters, is characterized by a significantly lower resistivity of 16.14 Ωm, suggesting the presence of fine-grained, water-bearing material, likely clay. The substantial thickness of 1.83 meters in this layer indicates a significant clay layer, potentially serving as an aquitard, which could restrict groundwater flow. Continuing to Layer 4, which ranges from 3.219 to 7.456 meters, a similar resistivity value of 57.01 Ωm to Layer 3 reinforces the presence of clay, possibly with varying composition or water content. The thickness of 4.24 meters indicates a thick clay layer, further emphasizing its potential role in restricting groundwater movement. Layer 5, spanning from 7.456 to 17.27 meters, exhibits a higher resistivity of 708 Ωm relative to Layers 3 and 4, suggesting the presence of another sand zone, likely medium sand. With a substantial thickness of 9.81 meters, this layer indicates the presence of a significant sand aquifer with considerable potential for groundwater storage and transmission. Finally, Layer 6, extending from 17.27 – 30.01 meters onwards, demonstrates infinite resistivity, implying highly resistive material such as weathered/fractured bedrock or coarse, dry sand/gravel. This layer likely serves as the aquifer base.

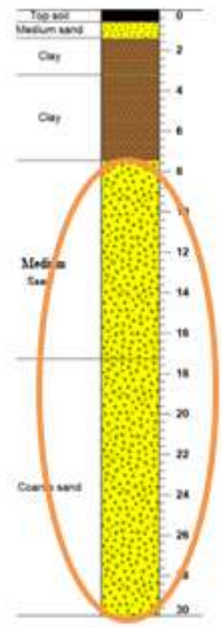

Fig 2: Geoelectric Log for GES 1

Aquifer Potential: Based on the geoelectric interpretation, the most promising aquifer zone lies within Layer 5 (medium sand, 7.456-17.27 meters). Its thickness of 9.81 meters and relatively high resistivity of 708 Ωm suggest good water-bearing potential. However, the presence of thick clay layers above (Layers 3 and 4) might limit recharge and necessitate careful well placement to ensure access to the deeper aquifer.

Geoelectric Sounding (GES) 2: The Geoelectric log (GES) 2, as delineated in Table .2 and illustrated in Figure .3, portrays a stratigraphic depiction consisting of four distinct soil layers characterized by varying resistivity values, depths, and thicknesses. Complementing this representation, Figure .4 further elucidates the Geoelectric log within each layer, showcasing their respective resistivity values alongside their depths, notably utilizing a curve HA type along Kaiama, East-West Road in Kolokuma/Opokuma LGA, Bayelsa State Nigeria.

Table 2: Resistivity, thickness and depth of GES 2 result along East-West Road, Kaiam

Layers	Resistivity (Ωm)	Thickness h (m)	Depth d (m)	Curve Type	Lithology
1	467.2	1.264	1.264		Top soil
2	54.5	17.54	18.8	HA	Clay
3	141.7	7.989	26.79		Medium sand
4	2738	13.23	40.02		Coarse sand

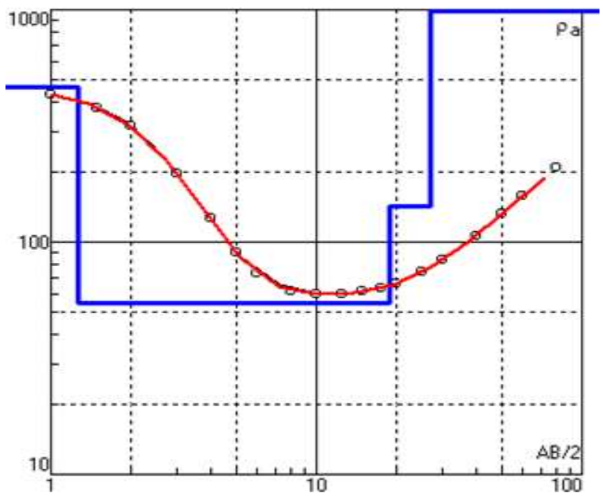

Fig 3: Computer Modelling for GES 2

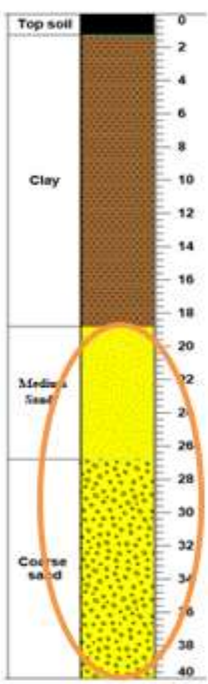

Fig 4: Geoelectric log for GES 2

Layer 1, boasting a resistivity of 467.2 Ωm and a thickness of 1.264 meters, signifies the topsoil stratum characterized by its relatively high resistivity. This attribute stems from its diminished moisture content and the prevalence of air-filled pores, indicative of surface conditions conducive to low water saturation. In contrast, Layer 2, characterized by a resistivity of 54.5 Ωm and a thickness of 17.54 meters, represents a clay stratum exhibiting markedly low resistivity levels. This phenomenon arises from the high-water content within the layer and the presence of conductive clay minerals. Its considerable thickness and conductive nature suggest its potential role as an aquitard, impeding downward water percolation and influencing groundwater flow dynamics within the geological system. Layer 3, possessing a resistivity of 141.7 Ωm and extending to a thickness of 7.989 meters, denotes a stratum comprised of medium sand exhibiting moderate resistivity. This layer likely denotes a transitional zone or finer-grained sand, with its water-bearing potential contingent upon factors such as porosity and hydraulic conductivity. Despite its promising characteristics, further investigation, including logging and pumping tests, is warranted to ascertain its viability as a shallow aquifer, including its yield potential and water quality considerations. Layer 4, distinguished by a resistivity of 2738 Ωm and 13.23 thicknesses extending to a depth of 26.79-40.02 meters, represents a stratum of coarse sand characterized by exceptionally high resistivity levels. This suggests arid conditions and the potential presence of fractured bedrock, which may influence groundwater flow patterns. Techniques such as logging data and geophysical methodologies like seismic analysis can provide valuable insights into its structural characteristics, including potential fractures that may enhance groundwater transmission.

Interpreting these geological findings unveils several significant implications for groundwater management and resource exploration:

Firstly, Layer 3's status as a medium sand layer presents an enticing prospect for shallow aquifer development. However, its moderate resistivity necessitates further scrutiny to evaluate its water-bearing potential accurately. Secondly, Layer 4's classification as coarse sand, despite exhibiting high resistivity, warrants closer examination due to its deep-seated occurrence. Elucidating its structural attributes and connectivity is imperative for assessing its groundwater contribution. Lastly, Layer 2's identification as a clay stratum highlights its potential role as an aquitard, imposing constraints on groundwater recharge to deeper aquifers. Understanding its lateral continuity and thickness is pivotal for effective groundwater management practices.

Geoelectric Sounding (GES) 3: The geo-electrical sounding (GES) depicted in Figure .5 provides valuable insights into the subsurface structure at R.PM

School 1 Field in Kaiama, specifically for groundwater exploration purposes. The information is detailed in Table 3, which outlines the resistivity values, depths, and thicknesses of the five distinct layers identified in the GES. Layer 1, identified as Topsoil (0-0.6 m), is characterized by a resistivity of 121.1 Ωm and a thickness of 0.6 m. The high resistivity value in this uppermost layer suggests a dry, sandy soil with minimal moisture content. This layer serves as the immediate surface cover, influencing the permeability and drainage characteristics of the area. Layer 2, denoted as Medium Sand (0.6-1.39 m), exhibits a resistivity of 383 Ωm and a thickness of 0.79 m.

The higher resistivity compared to the topsoil indicates a slightly less porous formation with the potential for increased moisture content. This layer may influence the movement and retention of groundwater due to its intermediary position between the overlying topsoil and the underlying layers. Layer 3, identified as Clay (1.39-3.22 m), displays a significantly lower resistivity of 16.67 Ωm and a thickness of 1.83 m. The low resistivity is indicative of the conductive nature of clay minerals, which have the ability to retain water. This layer suggests a zone with higher moisture content, making it a potential candidate for groundwater accumulation.

Table 3: Resistivity, thickness and depth of GES 3 result in R.PM School 1 Field, Kaiama

Layers	Resistivity (Ωm)	Thickness h (m)	Depth d (m)	Curve Type	Lithology
1	121.1	0.6	0.6		Top soil
2	383	0.7897	1.39	KHA	Medium sand
3	16.67	1.829	3.219		Clay
4	57.95	36.98	40.2		Clay
5	237.7	19.81	60.01		Medium sand

However, the limited thickness of this upper clay layer may impact the overall volume and accessibility of groundwater. Layer 4, also identified as Clay (3.22-40.2 m), shares a similar resistivity of 57.95 Ωm with layer 3 but extends to a much greater thickness, surpassing 37 meters. This thick clay layer likely acts as an aquiclude, restricting the downward flow of groundwater. While the extensive depth suggests the potential for confining an aquifer, the higher resistivity compared to the upper clay layer may indicate less favorable water-bearing properties. Layer 5, classified as Medium Sand (40.2 m-60.01m), has an exceptionally high resistivity of 237.7 Ωm and a thickness of 19.81. This layer, positioned beyond the explored depth, signifies a highly resistive formation. It could potentially represent a deeper aquifer with limited connectivity to the shallower clay layers. Further investigation would be required to confirm the presence and accessibility of this deep aquifer.

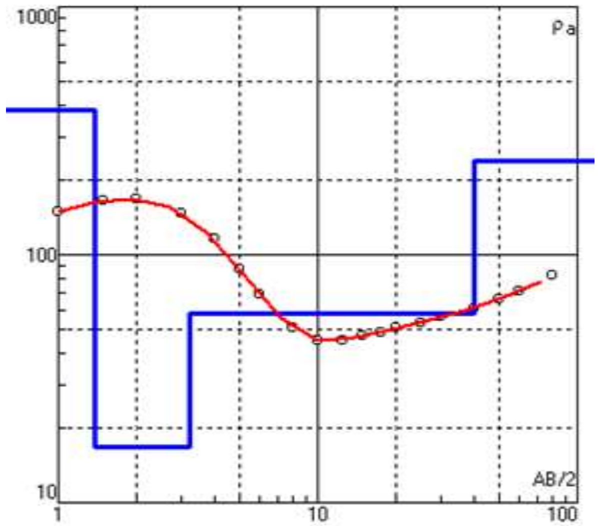

Fig 5: Computer Modelling for GES 3

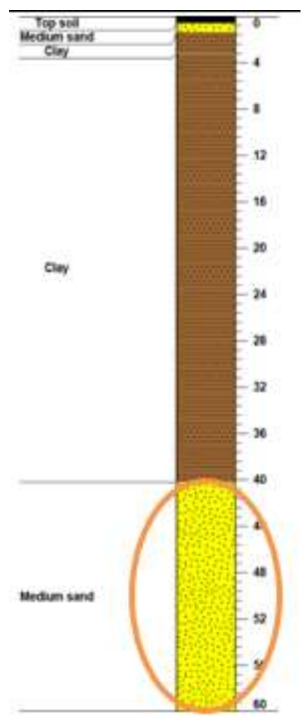

Fig 6: Geoelectric log for GES 3

Geoelectric Sounding (GES) 4: The Geoelectric Sounding (GES) 4, as illustrated in Figure .7, delineates six interpretative geo-electric layers, each characterized by distinct resistivity values, depths, and thicknesses as outlined in Table .4. Concurrently, the Geologic section depicted in Figure 8 correlates the soil type within each layer, identifying them with an KHAA curve type, along with their respective depths. Commencing with the topsoil layer (0-0.6 m), characterized by a resistivity of 327.9 Ωm and a thickness of 0.6 m, it presumably comprises dry, unconsolidated soil with minimal water content. Transitioning to the medium sand layer (0.6-1.39 m), possessing a resistivity of 592.1 Ωm and a thickness of 0.7897 m, it indicates a relatively porous and well-drained stratum, likely containing some air content.

Table .4: Resistivity, thickness and depth of GES 4 result in Kaiama Grammar School field, Kaiama

Layers	Resistivity (Ωm)	Thickness h (m)	Depth d (m)	Curve Type	Lithology
1	327.9	0.6	0.6		Top soil
2	592.1	0.7897	1.39	KHAA	Medium sand
3	6.383	1.829	3.219		Clay
4	20.51	4.237	7.456		Clay
5	800	9.814	17.27		Medium sand
6	1599	12.75	30.02		Coarse sand

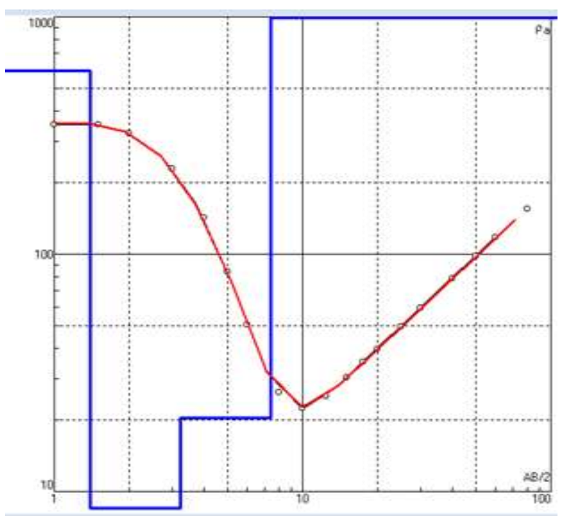

Fig 7: Computer Modelling for GES 4

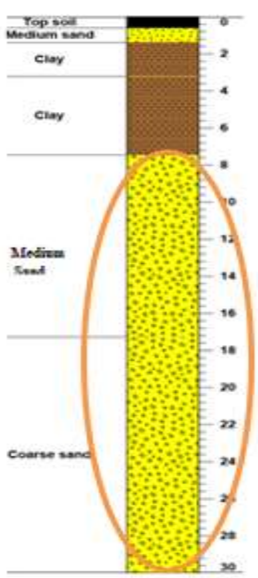

Fig 8: Geoelectric log for GES 4

The subsequent layer, identified as clay (1.39-3.219 m), exhibits a notably low resistivity of 6.383 Ωm, coupled with a thickness of 1.829 m, suggesting a fine-grained, water-saturated layer potentially prone to groundwater accumulation. Similarly, the following clay layer (3.219-7.456 m) maintains a low resistivity of 20.51 Ωm and extends to a thickness of 4.237 m, reinforcing the presence of significant groundwater within this zone. Transitioning to the subsequent medium sand layer (7.456-17.27 m), characterized by a higher resistivity of 800 Ωm and a thickness of 9.814 m, it likely represents a more consolidated and coarse-grained stratum with reduced water content relative to the underlying clay layers. Concluding with the coarse sand layer (17.27 – 30.02), exhibiting the highest resistivity of 1599 Ωm, it implies a highly permeable and water-resistant stratum, potentially comprising bedrock. Interpreting these findings, the delineation of two distinct clay layers (3 & 4) with low resistivity values between depths of 3.219 m and 7.456 m signifies potential zones conducive to groundwater accumulation. The intermediary medium sand layer (5) may serve as a semi-confining stratum, potentially influencing the movement and retention of groundwater within the underlying clay layers. Conversely, the presence of the impermeable coarse sand layer (6) beneath acts as a formidable barrier, potentially impeding further downward migration of groundwater.

Geoelectric Sounding (GES) 5: The geoelectric sounding (GES) survey conducted at Isokiwari Compound in Kaiama provides valuable insights into the subsurface characteristics, particularly relevant for groundwater exploration. This survey focuses on Vertical Electrical Sounding (VES) 5, as illustrated in Figure 9, presenting resistivity values, depths, and thicknesses of interpretive geo-electric strata. Additionally, Figure 10 offers a geologic section depicting soil types and depths for each layer. The first layer, comprising the topsoil, spans from 0 to 0.6 meters with a resistivity of 43.79 Ωm and a thickness of 0.6 meters.

Table 5: Resistivity, thickness and depth of GES 5 result in Isokiwari Compound Kaiama

Layers	Resistivity (Ωm)	Thickness h (m)	Depth d (m)	Curve Type	Lithology
1	43.79	0.6	0.6		Top soil
2	300.5	0.7897	1.39	AKHA	Medium sand
3	417.8	6.132	7.521		Medium sand
4	65.17	9.814	17.33		Clay
5	112.8	22.73	40.07		Clay
6	892	19.95	60.02		Medium sand

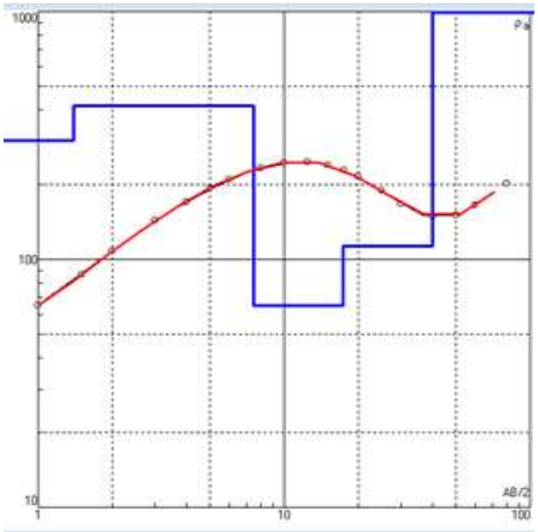

Fig 9: Computer Modelling for GES 5

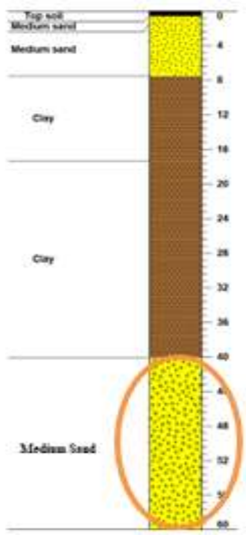

Fig 10: Geoelectric log for GES 5

The curve type, AKHA, indicates loose soil with organic matter, resulting in relatively low resistivity. This layer serves as a critical surface marker for subsequent interpretations. Moving deeper, the medium sand layer from 0.6 to 1.39 meters exhibits a resistivity of 300.5 Ωm and a thickness of 0.7897 meters. This layer suggests sandy material with higher resistivity, indicative of lower moisture content and potentially coarser grains. Continuing down, the subsequent layer, ranging from 1.39 to 7.521 meters, showcases a resistivity of 417.8 Ωm and a thickness of 6.132 meters. This further supports the presence of a zone of medium sand, potentially thicker and slightly more resistive than the previous layer. A significant shift in resistivity occurs in the clay layer, extending from 7.521 to 17.33 meters, with a resistivity of 65.17 Ωm and a thickness of 9.814 meters. The lower resistivity indicates higher moisture content, pointing to a potential water-saturated clay layer. The subsequent clay layer, spanning from 17.33 to 40.07 meters, exhibits a resistivity of 112.8 Ωm and a thickness of 22.73 meters. While still identified as clay, the slightly higher resistivity suggests variations in composition, density, or saturation levels within this layer. The final layer, starting from 40.07m – 60.02, displays a resistivity of 892 Ωm. The thickness is interpreted as exceeding the measurement range. This layer indicates a return to highly resistive material, likely another zone of medium sand.

Interpretation and Groundwater Potential: Based on the resistivity values and layer thicknesses, several key points emerge: The identified clay layers (layers 4 and 5) hold potential for groundwater exploration, given their tendency to possess higher water-holding capacity compared to sandy layers. The subtle difference in resistivity between the two clay layers may indicate variations in composition, density, or saturation levels. These nuances could significantly impact water storage and movement within these layers. The thick layer of highly resistive sand below the clay layers (layer 6) suggests a promising aquifer zone.

Conclusion: In conclusion, the Geo-electric Sounding (VES) surveys conducted at various locations in Kaiama have provided valuable insights into the subsurface characteristics, offering a comprehensive understanding of the hydrogeological setting of the area. The interpretation of resistivity values, depths, and thicknesses of interpretative geo-electric layers has enabled the identification of potential groundwater-bearing formations and their properties.. The aquifer's viability for groundwater extraction is contingent on careful consideration of these geological constraints. In essence, the findings from these Geoelectric Soundings underscore the importance of comprehensive subsurface characterization in groundwater exploration and management. By delineating aquifer zones, aquitards, and potential barriers, these surveys provide crucial information for sustainable groundwater resource utilization and development, paving the way for informed decision-making in water resource management practices.

REFERENCES

Abubakar, Y; Ismail A; Lawal Y. (2012). Geoelectric investigation of groundwater potential of DawakinTofa Local Government Area of Kano state Nigeria; *Am. Inter. J. Contem. Res.* 2(9): 1-10

Adesunloro, GM: Olumodeji, I; Itakorode, O. (2022); Geo-electrical investigation of ground water potential using vertical electrical sounding. *World Journal of Advanced Research and Reviews*. 15(02): 322–329.

Afuwai, GC; (2014). Geophysical investigation of groundwater potential of Kongo campus, A.B.U. Zaria-Nigeria *European journal of Education studies* 7(1): l 1-7.

Afuwai, GC; (2013). The variation in Depth of overburden at Different VES point within samara D.C. Resistivity Technique; *Acad. J. Interdisciplinary Stud.* 2(12): l-6.

Afuwai, GC; Lawal, KM; Sule, P; Ikpokonte, AE (2014) Geophysical Investigation of the Causes of Borehole Failure in the Crystaline Basement Complex: A Case Study of Kaura Area of Kaduna State, Nigeria. *J. Environ. Earth Sci.* 4(23) *Pp221-230*

Alabi, AA. Bello, .R; Ogungbe, AS; Oyerinde HO (2010). Determination of groundwater potential in Lagos State University, Ojo; using geoelectric methods (Vertical electrical sounding and horizontal profiling). *Report Opinion.* 24:68-75.

Alile, MO; Ujuanbi, O; Evbuomwan, IA. (2011). Geoelectric investigation of groundwater in Obaretin – Iyanomon locality, Edo State, Nigeria; *Journal of Geology and Mining Research.* 3(1). 13-20

Anakwuba, EK; Nwokeabia, CN; Chinwuko, AI; Onyekwelu, CU. (2014). Hydrogeophysical assessment of some parts of Anambra basin, Nigeria. *International Journal of Advanced Geosciences,* 2 (2), 72-81.

Anizoba, DC; Chukwuma, GO; Chukwuma, EC; Chinwuko, EC. (2015). Determination of Aquifer Characteristics from Geoelectrical Sounding data in parts of Anambra State, Nigeria. *International Journal of Innovation and Applied Studies,* 11 (4), 832-843.

Anomohanran, O. (2013). Geophysical investigation of groundwater potential in Ukelegbe, Nigeria. *J. Appl. Sci.* 13:119-125

Auken E; Pellerin L, Christensen NB,; Sorenson K (2017): A Survey of Current Trends in Near surface. *Electrical and Electromagnetic Methods Geophys,* 71(5): 249-260.

Egai, AO: Douglas,, RK 2015). Aspects of Geophysical Survey Using Vertical Electrical Sounding (VES) for Groundwater Exploration in Parts of *Ahoada West LGA of Rivers State, Southern Nigeria. Journal of Geoscience 5(1) 30-38*

Egai, AO, (2013). Environmental impacts of crude oil activities in Aguobiri, Southern Ijaw LGA, and Bayelsa State. *Unpublished M.Sc. thesis university of Benin, Nigeria.*

Emenike, EA. (2001). Geophysical Exploration for Groundwater in a Sedimentary
Envrionment: A case study from Nanka over Nanka Formation in Anambra Basin, Southeastern, Nigeria. *Global Jour. of Pure and Applied Sciences,* 7 (1), 56.

Emmanuel OJ, Olayinka OO: Oladotun OF (2011) Geoelectric investigation of the groundwater potential of Moniya Area, Ibadan. *Journal of Geology and Mining Research*. 3(3). 54-62

Griffiths DH; Barker RD. (2010) Two-Dimensional Resistivity Imaging and Modeling in Areas of Complex Geologys. 29:211-216.

Idehai, IM; Egai, AO. (2014) Aspects of Geophysical Exploration Using Vertical Electrical Sounding (VES) for Groundwater in Parts of University of Benin, Benin City. *J. Appl. Sci. Environ. Manage.* 18 (1): 21-28.

Loke, MH; Barker RD, (2011): Practical Techniques for 3D Resistivity surveys and data inversion. *Geophys. Prosp,* 44:499-524.

Karami, B; Dhumal, KN: Golabi, M (2014). Optimization the relationship between water quality index and physical and chemical poarameter of water in Bamdezh Wetland, Iran. *Journal of Applied science.* 9:3900-3905.

Kasidi, S; Victor, V. (2019) "Groundwater Exploration Using Vertical Electrical Sounding (Ves) Method In Musawa And Environs Of Katsina State, Nigeria." *IOSR Journal of Applied Geology and Geophysics* 7 (6): 73-83.

Majumdar, RK; Das, D (2011). Hydrological characterization and estimation of properties from electrical sounding data in sagar island region, south 24 parganas, west Bengal, India, Asia J. *Earth science*.4:60-74.

Molua, OC.;Emabetere,JU:((2015). Determination of water table using electrical sounding technique; A case study of afuze, Edo State, Nigeria. *J. Nig. Assoc. Mathematics and Physics.* 5; 457-464.

Musa, GA: Mohd, ET::Barzani, G: (2015). "The Application of Vertical Electrical Sounding (VES) for Groundwater Exploration in Tudun Wada Kano State, Nigeria. *J. Geology*. *Geophysics 3 (2) 331-339*

Nicholas U. Ugwu, R.; Ranganai1, T; Rapelang, E.; Simon, GO: (2016); Geoelectric Evaluation of Groundwater Potential and Vulnerability of Overburden Aquifers at Onibu-Eja Active Open Dumpsite, Osogbo, Southwestern Nigeria. *J. Water Resource and Protectio*n. 8, 311-329

Onwuemesi, AG; Egboka, BCE. (2006). 2-D polynomial curve fitting techniques on water table and hydraulic gradients estimations in parts of Anambra Basin, Southern Nigeria. *Natural. Appl. Sci. J.* 8 (1& 2), 6-13.

Otutu, OJ. ; Oviri, OM. (2010). Determination of groundwater flow direction in Utagba-Ogbe Kingdom, Nokwa land area of Delta State, Nigeria. *Online J. Earth Sci.* 4:32-34.

Osele, CE; Onwuemesi, AG; Anakwuba, EK; Chinwuko, AI (2016). Application of Vertical Electrical Sounding (VES) for Groundwater Exploration in Onitsha and Environs, Nigeria. *International Journal of Advanced Geosciences.* (10). 4419-4594 doi: 10.14419/ijag.v4i1.5594

Olusegun, OA, Adeolu, ;OO; Dolapo, F.; Akinpelul, A (2016). Geophysical Investigation for Groundwater Potential and Aquifer Protective Capacity around Osun State University (UNIOSUN) College of Health Sciences. *Am. J. Water Res.* 4 (6): 137-14.

Stummer. P; Maurer HR (2016). Real-time Experimental Design Applied to high Resolution Direct Current Resistivity Surveys. International symposium on optical science and Technology. *Expanded Abstracts,* 143-150.

Todd, DK., (2013). Groundwater Hydrology. 2nd Educational. John Wiley and Sons, New York. Federal Republic of Nigeria (2012). Federal Republic of Nigeria 2006 population and census priority table. Abuja: *National Population Commission*. 03 (1) 113-120

Zhody, AR.; Eaton, GI; Masay, DR., (2010). Appilcation of subsurface geophysics to groundwater investigation. Technical water resources investigation, *Washington Geological Survey. 3 (2) 112-121*