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Aquifer Characteristics of Ogwashi Formation using Vertical Electrical Sounding.: A Case Study, of Living Christ Mission, Umugarra Nkwerre Southeastern Nigeria.

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Abstract-- Aquifer characteristics of living Christ mission umugara nkwerre Imo State, South-eastern Nigeria and their environs was done using vertical electrical sounding The area is located within the latitude of 5°45'N to 5°46'N and longitude of 7°06' 255E to 7°06'46E.It falls within Ogwashi Asaba formation which contains sands, silt and lignite. From the results it is observed that Height ranges from 572FT to 481FT which is relatively low in topography aquifer depth varies from 15m to 130m with thickness of 10m to50m.The higher thickness of the aquifer the more the volume of water it can store (Storactivity). The depths show shallow to deep aquifer systems. The dominant rock unit of being shales, clay, silt with traces of sands and lignite deposits. This shows that groundwater exploitation in this zone will be little difficult excepts the area with sands.

Keywords--Aquifer, livingchrist, umugara, Nkwerre,

I. INTRODUCTION

Water is vital to all life on Earth. No human, animal or plant can live without it. It is essential and there is no substitute. Water consumption has doubled at least twice this century, and some estimated it could double again within the next 20 years.water constitutes the most essential resource need to man (Brown, 1984). He can survive longer without food than water. An aquifer is an underground layer of permeable rock or sediment that contains water or a rock layer that stores and allows the flow of ground water; while ground water can be defined as water that is collected and is stored underground. Some aquifers lie deep under layers of impermeable rock. Other aquifers lie just beneath the topsoil. An aquifer might be a bed of sand or gravel few meters thick. Or it might be an enormous layer of sandstone, several hundred meters thick, holding water in countless pore spaces.

II. THE LOCATION AND PHYSIOGRAPHY OF THE STUDY AREA

The study area is Living Christ mission Umugara Nkwerre, Imo State, South-eastern Nigeria. The area is located within the latitude of 5°45'N to 5°46'N and longitude of 7°06' 255E to 7°06'468 E Temperature, Relative humidity and the visibility/hazy condition: Within the Anambra River Basin, the climate is hot and humid, with mean annual rainfall of 152.4mm to 203.2mm. The dry season is relatively short from November to March; while rainfall usually last in the study are from April to October with a break usually referred to as "August break". Maximum temperature is 34°C, while towards the end of the rains; it is 18°C - 21°C. The study area has a temperature that ranges from 27°C to 34°C

Vegetation: The vegetation is tropical rain forest with shrubs and elephant grasses, stunted trees. This shows that the area falls within the tropical rainforest of the south-eastern Nigeria, where different abundant and different classes of plants such as grasses, shrubs, trees, exist. The area is dense and made up of many types of broad-leaved trees that are mostly evergreen i.e. the trees drop their leaves gradually throughout the year and new leaves grow continuously to replace them. The trees form three layers. The tree tops form a thick canopy that prevents sunlight from reaching the forest floor. As a result, the vegetation on the forest floor is sparse. Epiphytic plants and woody climbers known as lianas are common features of these forests.

As stated above that the vegetation in the study area is a tropical rainforest type, it will be pertinent to note here that the study area has been altered by the constant clearing and fallowing systems from time to time.

But on over much of the area, the retention of useful trees and the clearance of other trees have transformed the rainforest into a “palm-bush” where oil-palm trees are the predominant trees as well as a predominant factor.

Relative Humidity: Relative humidity is the amount of water in the atmosphere at any given time; moreover, it is a term that refers to dampness, especially that of the air. Relative humidity is a function of rainfall and temperature.

The study area normally experiences a high amount of relative humidity during rainy season which is around April to October and harmattan season which starts from November through January; while it experiences a low relative humidity during a hot season which occurs from January to April.

Climate: The two main climatic conditions in the area are: Rainy season and Dry season. The dry season is between November and April while the rainy seasons are mostly between May and October. Average rainfall is between 1000mm and 1500mm with temperatures as high as 36.7° (Udo, 1970).

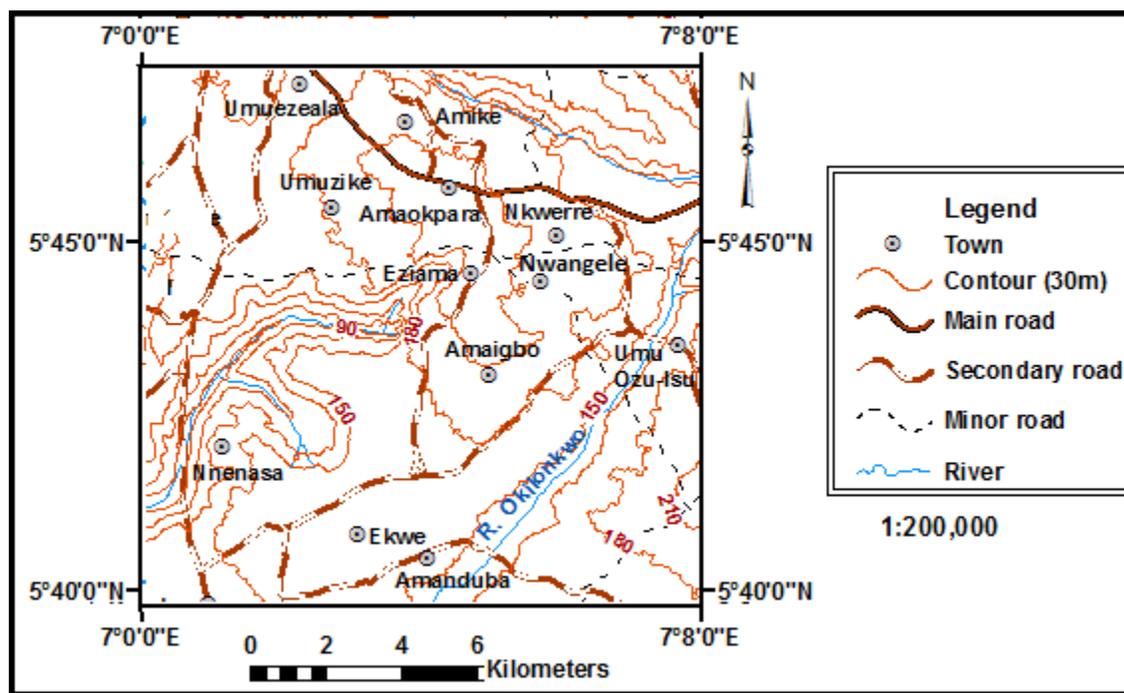


Fig 1: Topographic Map of Study area

III. GEOLOGY OF THE STUDY AREA

The geology of the study area is within the Ogwashi-Asaba Formation. The Formation (Oligocene-Miocene vertically succeeds the Ameki Formation. The Formation is generally made up of clays, sands, grits and seams of lignite alternating with gritty clay (Dessauvagie, 1974).

The dominance of thick sandy units in the Ogwashi/Asaba Formation (as revealed by the strata and geophysical logs of boreholes penetrating its outcrop area) appear to contrast the known lithostratigraphy of the formation (Uma 1989). A characteristic feature of the formation within the Imo river Basin is the up dip and down dip pinch outs.

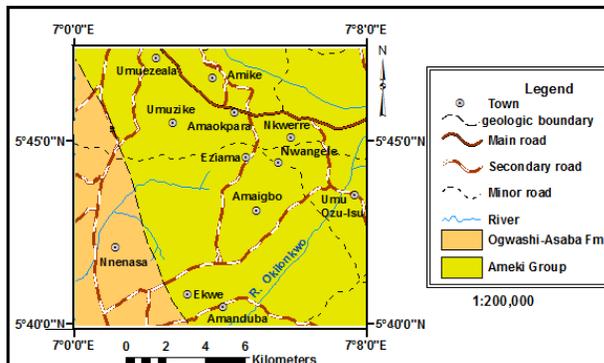


Fig 2: Geologic Map of Study area

IV. METHODOLOGY

The instruments employed for the data acquisition include: ABEM Terrameter SAS1000 resistivity metre, Etrex GPS, and Compass. Interpretation made use of resistivity computer modeling software by Henker (1985), IPIWIN and Sufer 12 software. The schlumberger array of the vertical electrical sounding technique was employed at maximum current electrode spacing of AB/2 of 400m for the four (4) locations, Mohammed I. N., et al (2008). The theories are well explained in standard texts such as Telford et al, (1976); Griffiths and King (1983), Dobrin M.S. and Savit (1988).

Electrode spacing was progressively increased to probe deeper subsurface layers. Apparent resistivity values obtained in the field were processed and interpreted to generate subsurface resistivity models. Interpreted lithologic layers from VES results were analyzed statistically to determine dominant units, vertical distribution patterns, and spatial variability. Lithology frequency analysis was conducted across all layers, while dominant lithology per VES point was determined using modal analysis. Geographic coordinates were used to generate VES location maps, and elevation data were analyzed to assess topographic influence on subsurface conditions.

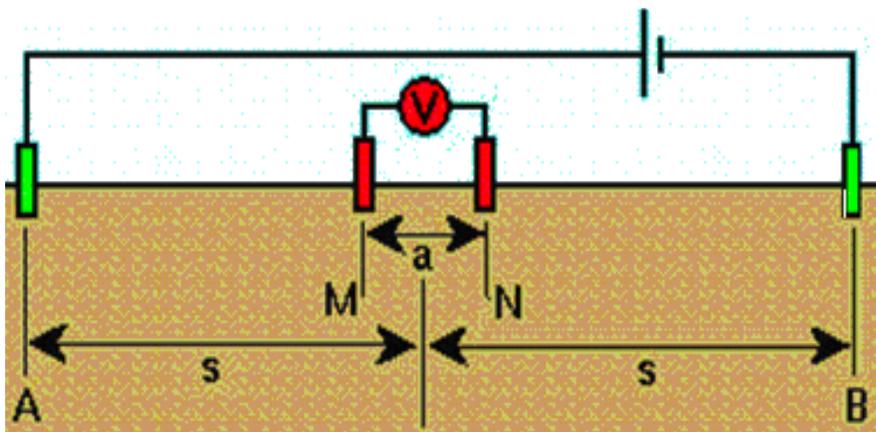
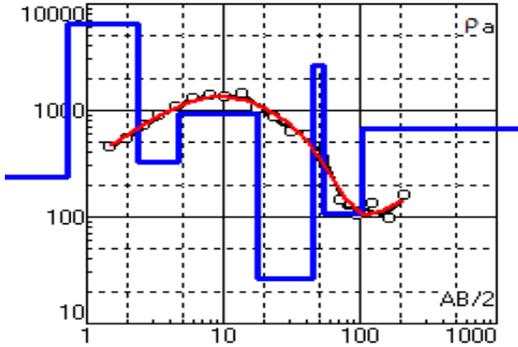
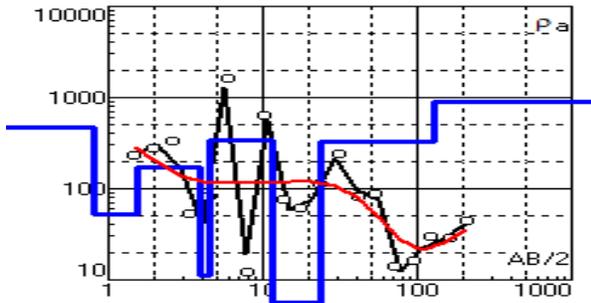


Figure 2: Typical Schlumberger Array. M and N; potential electrodes, A and B; current electrodes.

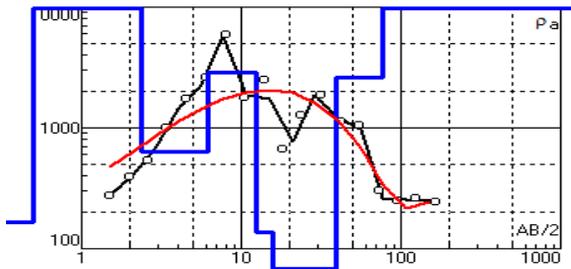
V. RESULTS AND DISCUSSION



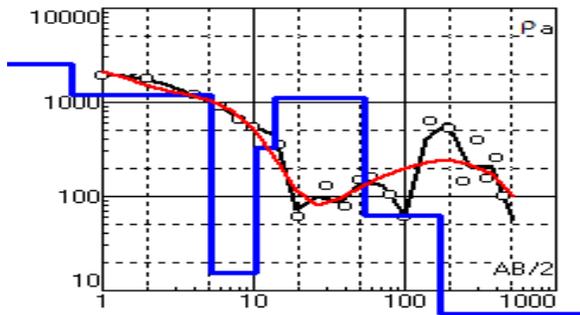
Ves1 Iyiukwa lat-5.2762 lon-7.380,520ft, K curve 8 layers			
Layer	$\ell(\Omega\text{m})$	D(m)	LITHOLOGY
1	239	0.7	TOP SOIL
2	6471	2.37	SANDS
3	330	4.64	SHALE
4	946	17.6	CLAY
5	26.4	44.6	LIGNITE
6	2605	54.0	SANDS
7	107	103	SHALE
8	672	>103	SHALE



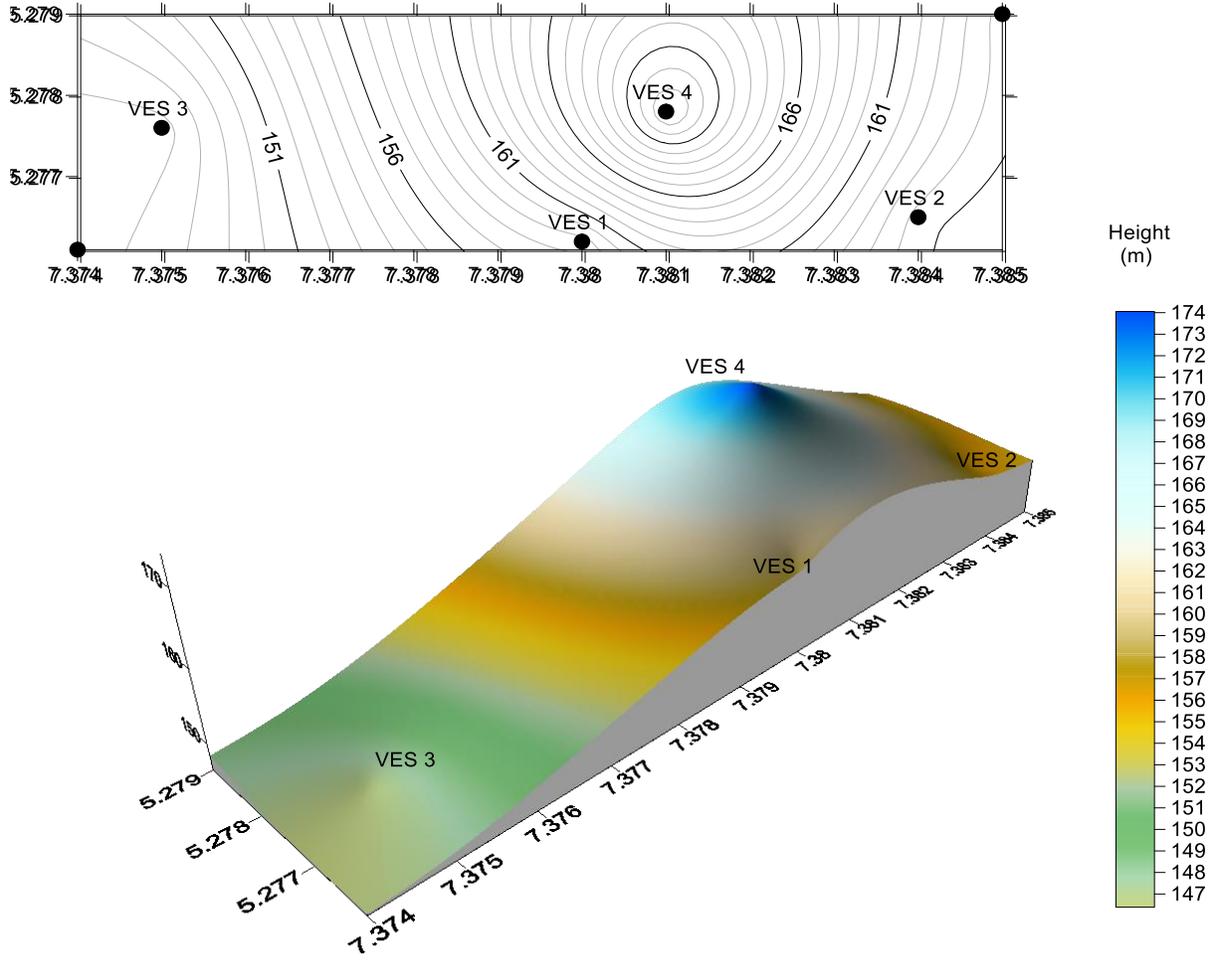
Ves2 Hezekiah house lat-5.2765 lon-7.384,513ft, Q curve 8 layers			
Layer	$\ell(\Omega\text{m})$	D(m)	LITHOLOGY
1	464	0.8	TOP SOIL
2	51.9	1.52	SHALE
3	169	3.95	SHALE
4	11.2	4.47	LIGNITE
5	345	11.7	SHALE/LIGNITE
6	2.16	23.5	LIGNITE
7	325	129	SHALE
8	884	>129	CLAY

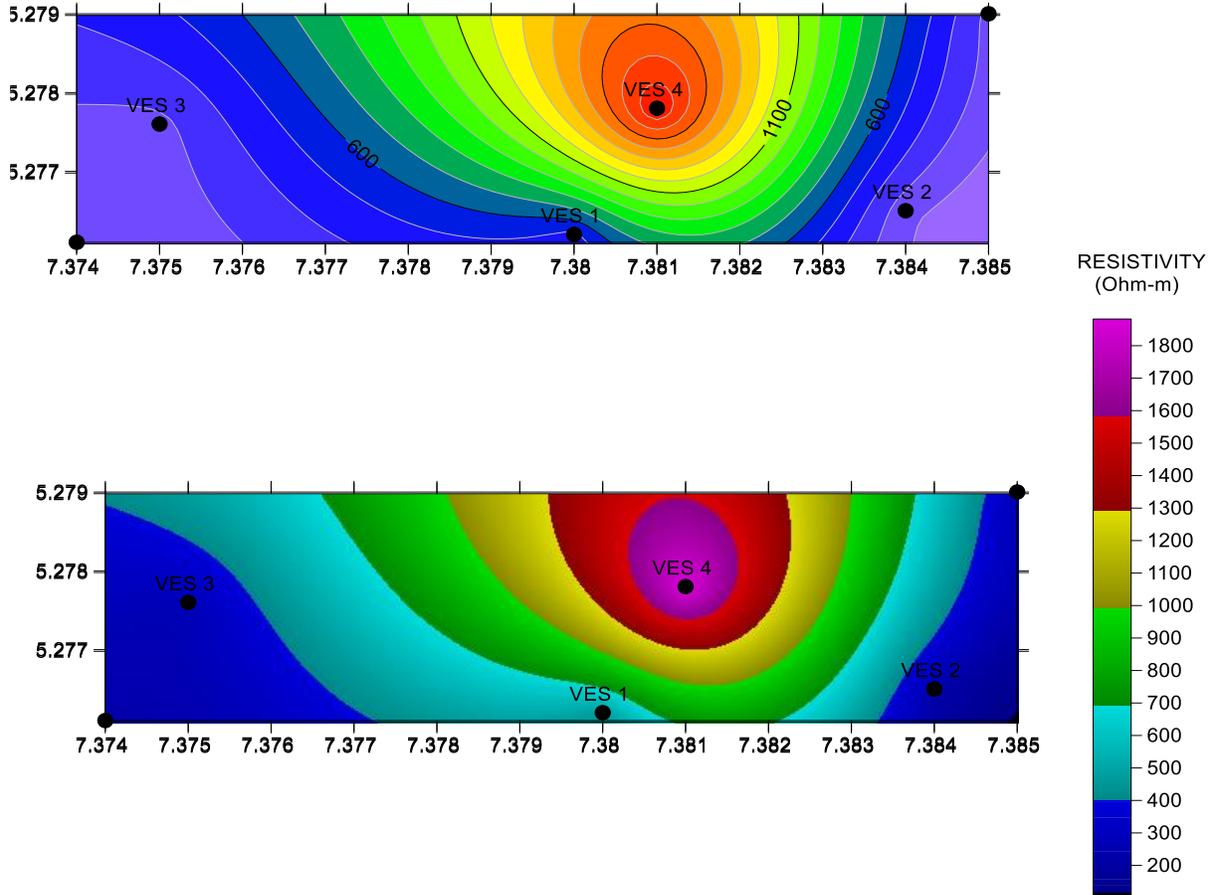


Ves3 school lat-5.2776 lon-7.375,481ft K curve 8 layers			
Layer	$\ell(\Omega\text{m})$	D(m)	LITHOLOGY
1	164	0.5	TOPSOIL
2	12561	2.38	SANDS
3	640	6.16	CLAY
4	2854	12.4	SANDS
5	138	15.6	SHALE
6	41.4	39.6	LIGNITE
7	2580	76.9	SANDS
8	19180	>76.9	SILT

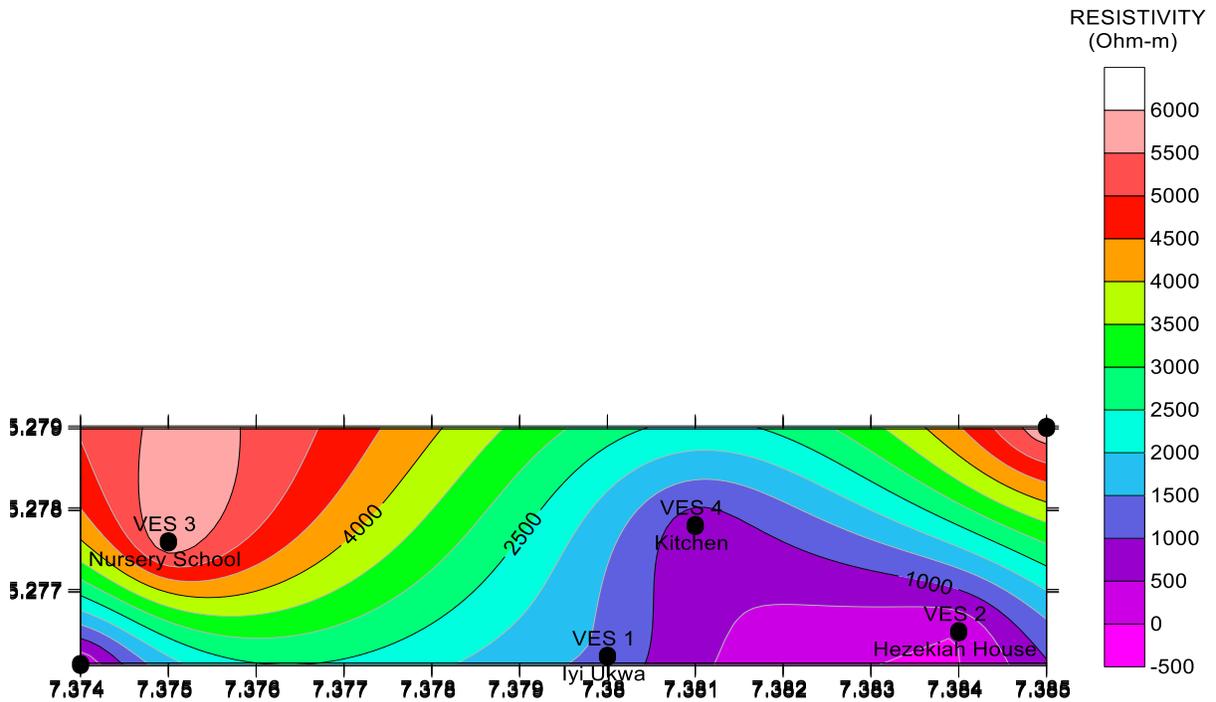
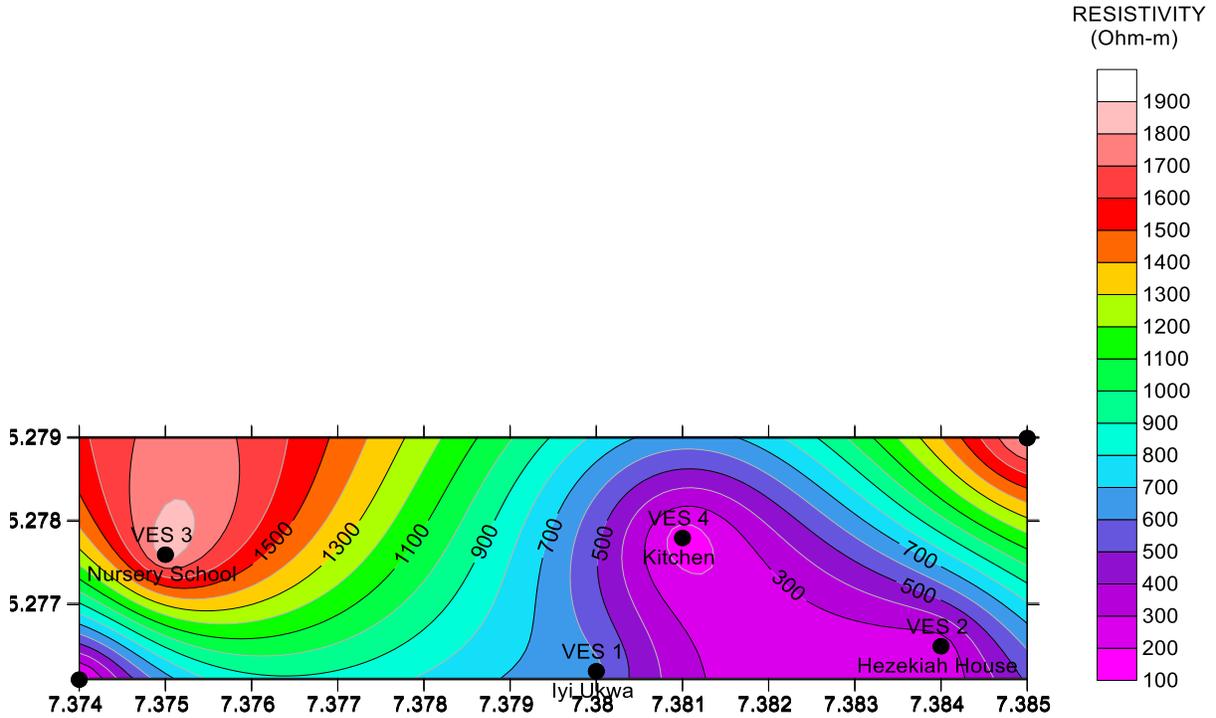


Ves4 kitchen lat-5.2778 lon-7.381572ft QK curve 7 layers			
Layer	$\ell(\Omega\text{m})$	D(m)	LITHOLOGY
1	2542	0.6	TOPSOIL
2	1158	5.15	SILT
3	15.4	10.3	LIGNITE
4	331	13.8	CLAY/SHALE
5	1133	54.6	SILT
6	61.8	172	SHALE
7	5.03	>172	LIGNITE

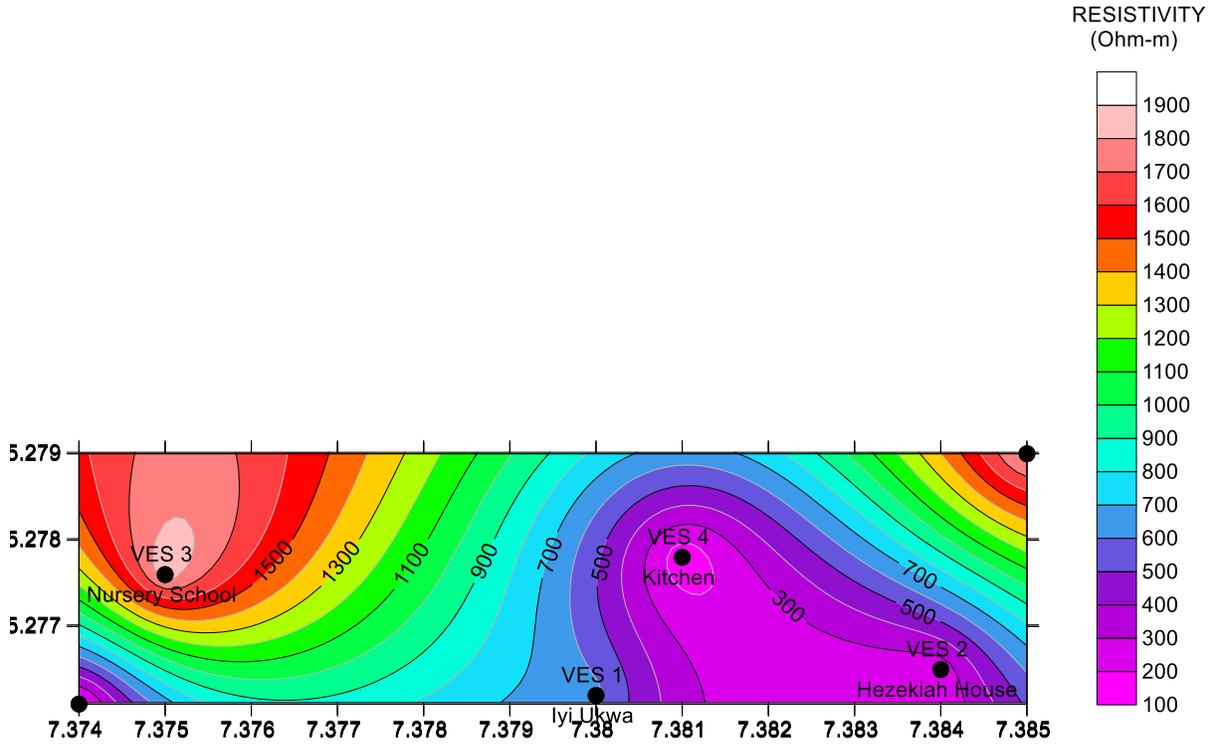




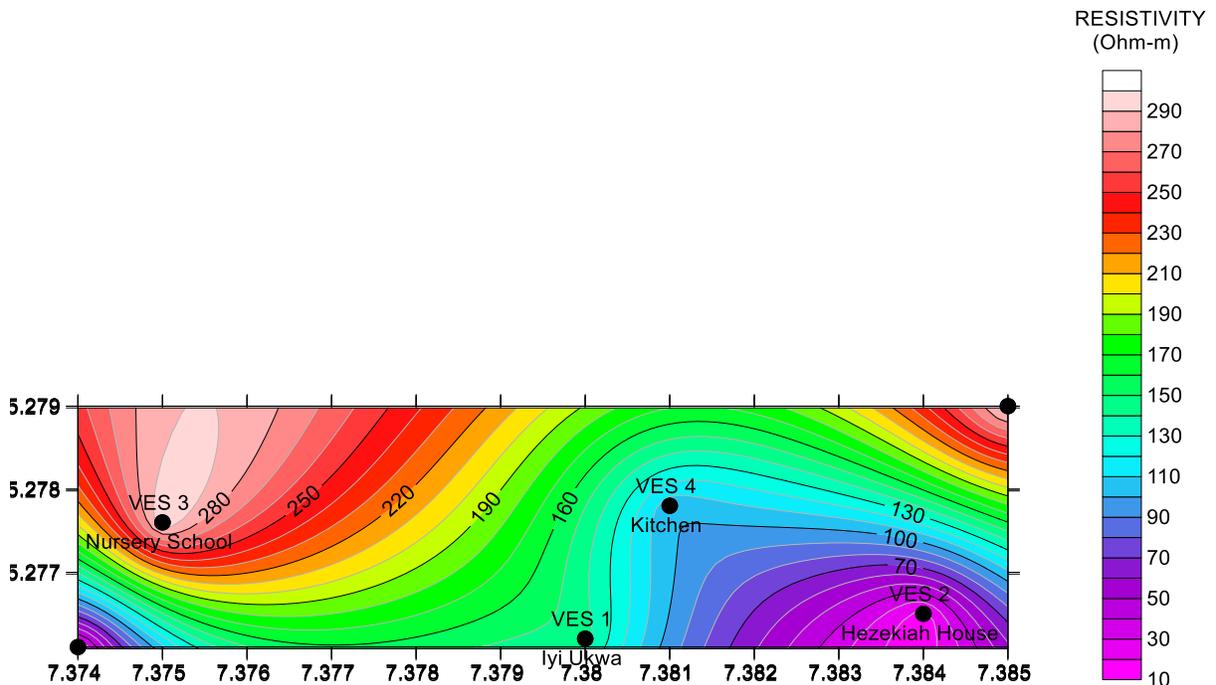
Ab/b=1.5m



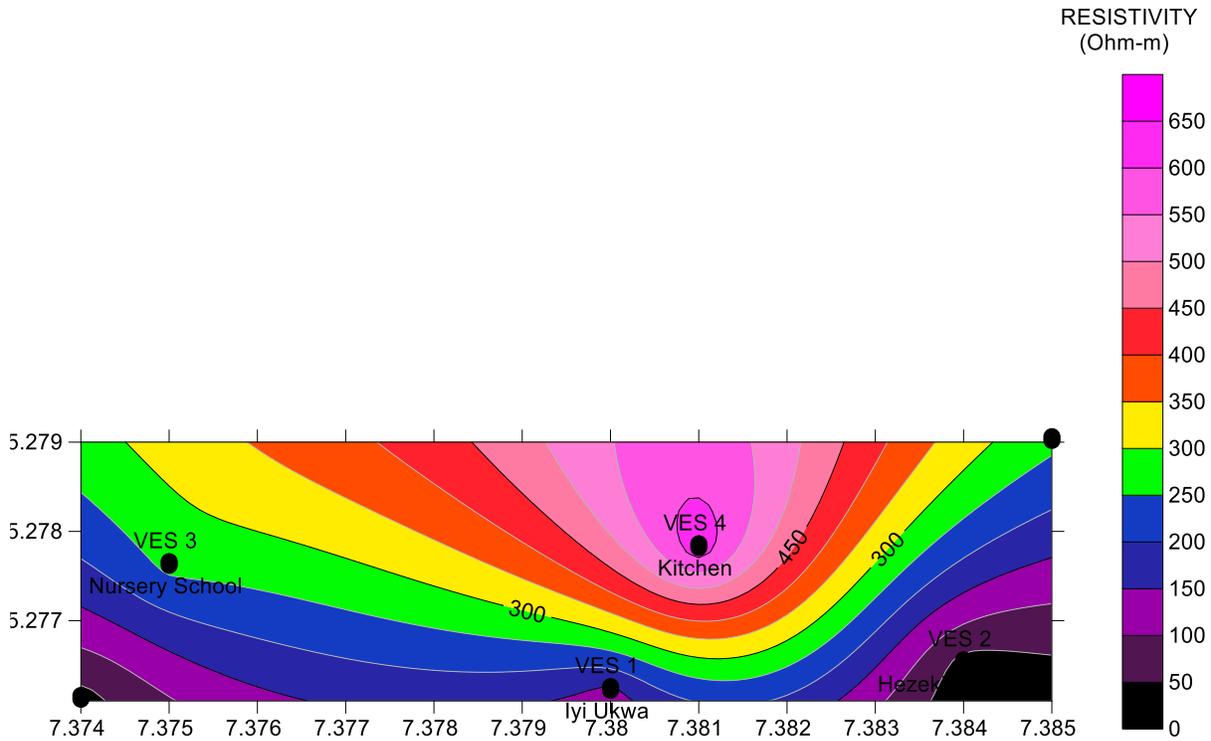
Ab/2=8m



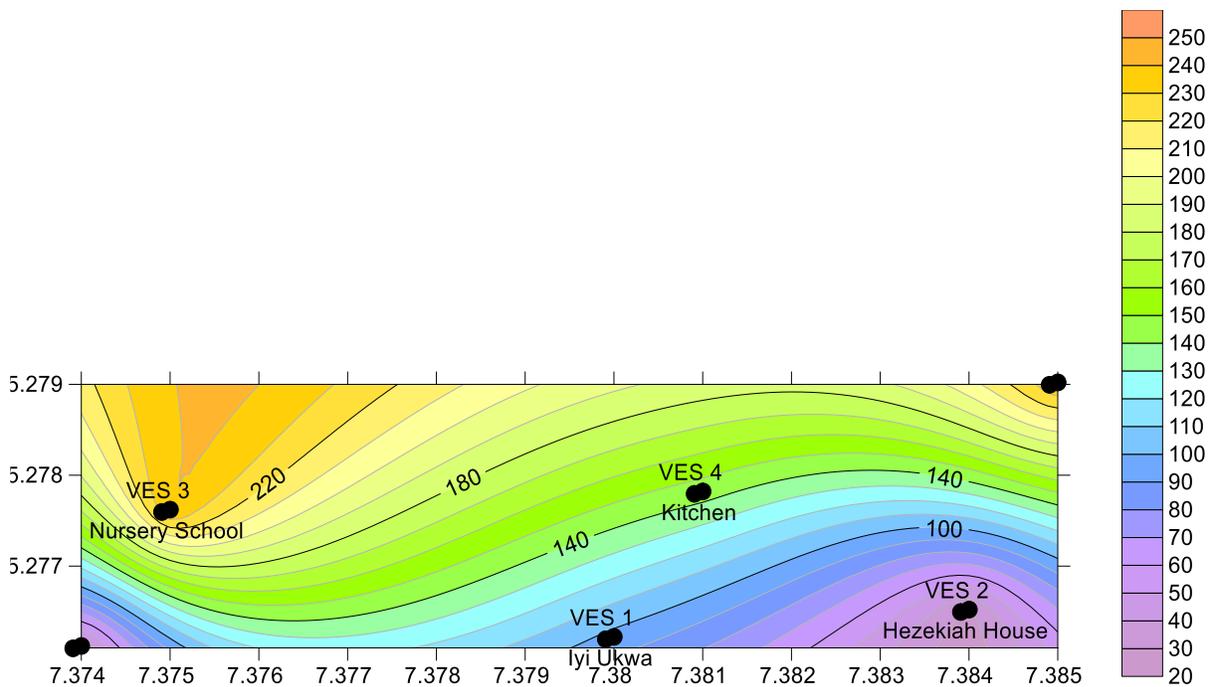
Ab/2=32m



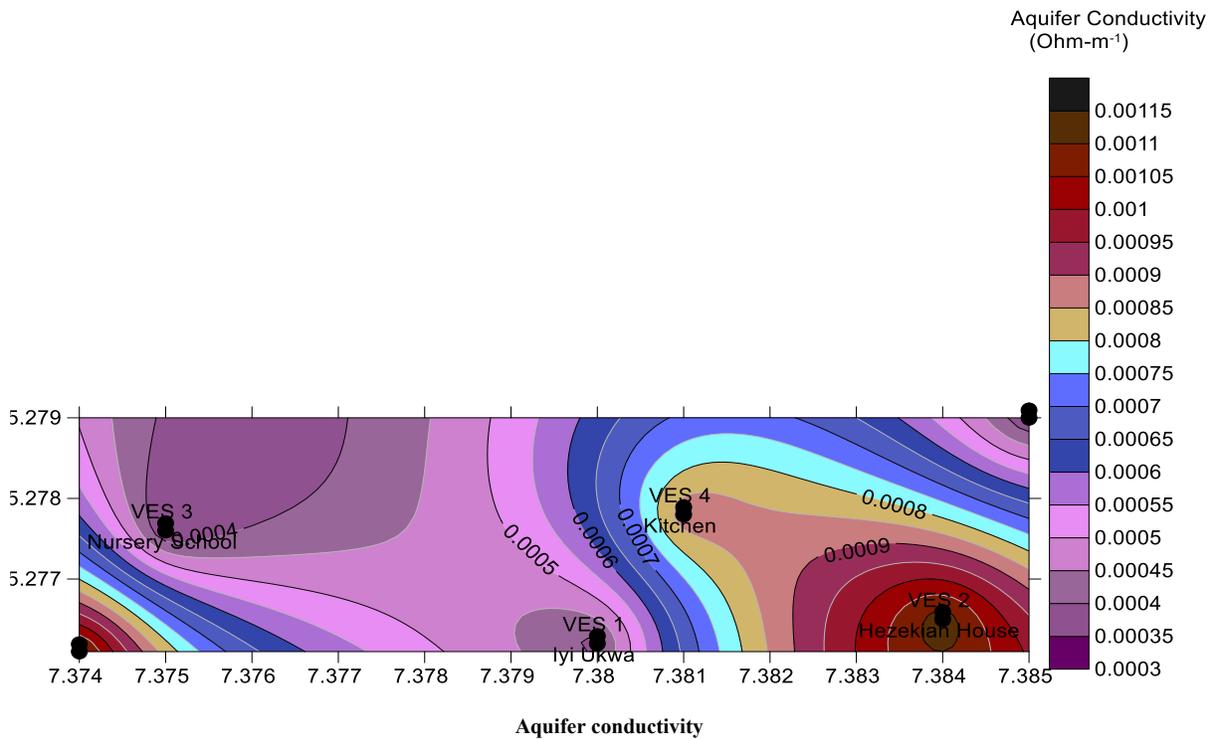
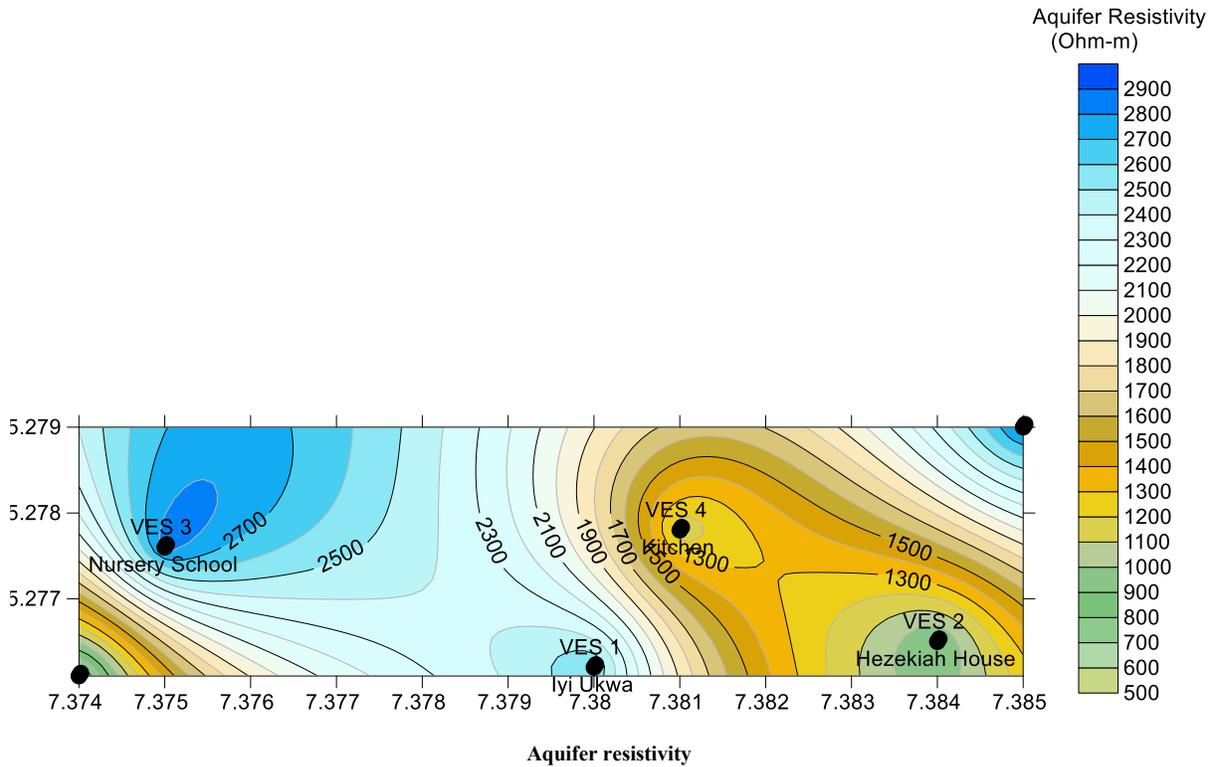
Ab/2=72m

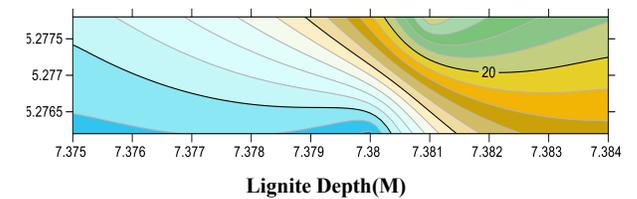
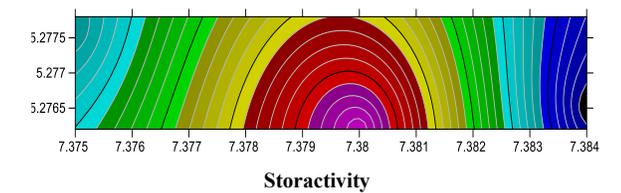
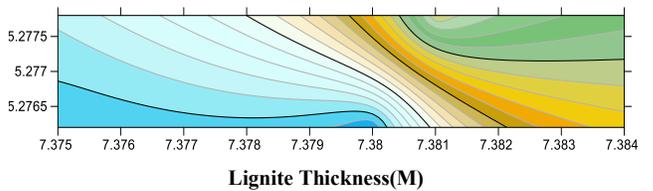
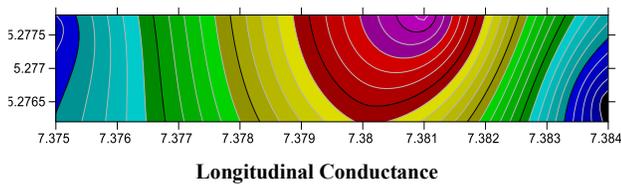
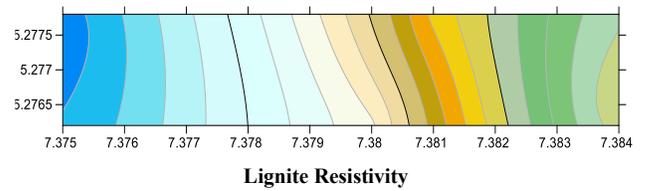
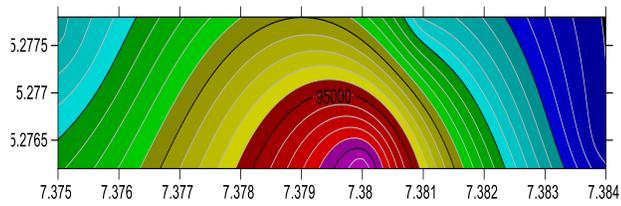
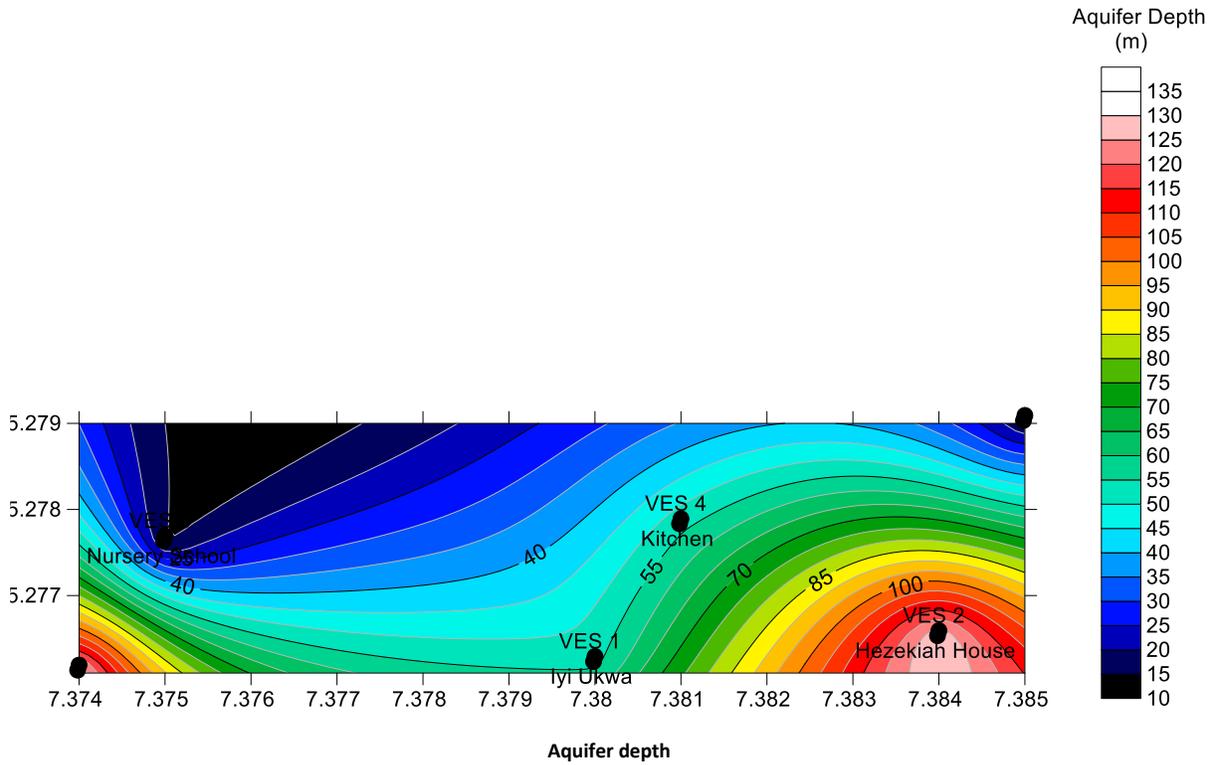


Ab/2=125m



Ab/2=165m





VI. DISCUSSION/ INTERPRETATION OF RESULTS

This study employed the Vertical Electrical Sounding (VES) technique at four locations within the Living Christ Mission area to delineate the subsurface lithology and characterize the aquifer properties of the Ogwashi Formation. The interpretation of the acquired geoelectrical data has yielded significant insights into the depth, thickness, resistivity, and hydraulic characteristics of the water-bearing layers. Four vertical electrical soundings (VES) were interpreted from apparent-resistivity curves (ρ_a vs. AB/2). Each plot shows: field data (black with open circles), a smoothed trend (red), and a step-like best-fit 1-D resistivity model (blue). Electrode spacings extend to a few hundred meters, giving depth of investigation on the order of $\sim 1/3$ – $1/2$ of AB/2, sufficient to resolve the shallow cover, a regionally continuous aquifer, and a deeper conductive horizon. Across all soundings, the curves display one or two pronounced drops in ρ_a with AB/2 followed by partial recovery—diagnostic of layered sedimentary successions in which resistive unsaturated cover overlies a more conductive, saturated unit and, at greater depth, an even more conductive bed (clay/carbonaceous shale/lignite).

6.1 Subsurface Lithological Sequence

The interpreted VES data revealed a multi-layered subsurface structure across the four stations (VES 1–4),

VES	Cover thickness (m)	Aquifer top (m)	Aquifer resistivity ($\Omega \cdot m$)	Aquifer thickness (m)	Lignite top (m)	Deep conductor resistivity ($\Omega \cdot m$)
VES-1	20–30	25–35	50–90	50–80	100–120	10–25
VES-2	10–20	20–30	30–70	30–60	80–100	10–20
VES-3	20–40	30–45	40–80	40–70	90–130	12–25
VES-4	15–25	20–35	40–100	30–60	80–110	10–20

Aquifer Depth & Thickness: The depth to the primary aquifer varies significantly across the study area, from a relatively shallow 15m at VES 3 (Nursery/Primary School) to 130m at VES 2 (Hekezia House). Aquifer thickness also shows considerable variation, with the thickest unit (50m) found at VES 1 and the thinnest (10m) at VES 3. This heterogeneity is typical of the fluvial-deltaic depositional environment of the Ogwashi Formation. The higher thickness of the aquifer the more the volume of water it can store (Storage activity).

with layer counts ranging from 7 to 8 and height ranging from 572ft to 481ft which is relatively low in topography, aquifer depth varies from 15m to 130m with thickness of 10m to 50m. The sequences consistently show an overburden of topsoil and weathered layers underlain by intercalations of sands, clays, shales, and lignite seams—a lithology characteristic of the Ogwashi-Asaba Formation. Notably, lignite layers, a defining feature of this formation, were identified at varying depths across all VES points, serving as key stratigraphic markers. The geoelectric sections successfully identified potential aquifer units, primarily sand layers, distinguished by their relatively high resistivity values compared to the adjoining clay and shale layers. For instance, at VES 1, a prominent sand layer with a resistivity of 2605 Ωm was detected at a depth of 54m, with a considerable thickness of 50m. Similarly, VES 3 indicated a high-resistivity sand layer (2854 Ωm) at a shallower depth of 12.4m.

6.2 Aquifer Parameters and Hydraulic Characteristics

Quantitative analysis of the identified aquifers was conducted to evaluate their groundwater potential. The key derived parameters are summarized in the Aquifer Parameter Table and further elucidated below:

The depths shows shallow to deep aquifer systems with aquifer materials being silt, sands and shalysands. The resistivity of the aquifer is the function of its material poor materials gives low values to good ones.

Transverse Resistance & Longitudinal Conductance: These electrical parameters provide insights into the aquifer's bulk electrical behavior. VES 1 exhibits the highest transverse resistance (130,250 Ωm^2), indicating a thick, resistive aquifer, which correlates with its identified sand layer.

Conversely, VES 4 shows the highest longitudinal conductance (0.0265 Siemens), suggesting a greater cumulative conductivity, potentially influenced by finer-grained materials within the aquifer matrix at this location. These two factors are called dar zurrouk which measures the degree of how protected the aquifer is. From our study the aquifer shows good protection from ves one and decreases towards two and three

Hydraulic Implications: The resistivity values of the aquifer materials (ranging from 884 Ωm at VES 2 to 2854 Ωm at VES 3) suggest the presence of relatively coarse-grained, sandy materials with good pore space for water storage and transmission. Lower resistivity layers interbedded with or adjacent to these sands (e.g., clay and shale) act as confining layers or aquitards. The calculated storativity values, which are notably high (on the order of 10^7 to 10^8), further indicate that the aquifers possess significant storage capacity, a positive indicator for groundwater resource development. In this work the resistivity is low with exception of ves3 which has high value. Likewise conductivity which is opposite of resistivity high resistivity low conductivity and vice versa. Conductivity is relatively low because of relatively high resistivity of the area.

Spatial Distribution: The iso-resistivity maps and parameter distribution maps (e.g., Aquifer Depth, Thickness) reveal the spatial variability of the hydrogeological framework. This variability underscores the influence of local geological structures, such as the pinch-outs characteristic of the formation within the Imo River Basin, on aquifer geometry and continuity. From the iso resistivity values we contoured of AB/2 1.5m to 165m. The study area is characterized by low iso resistivity values which ranges from 12 Ωm to 5940 Ωm . The dominant rock unit of being shales, clay, silt with traces of sands and lignite deposits. This shows that groundwater exploitation in this zone will be little difficult except the area with sands.

5.3 Interpretation of Groundwater Potential

The integration of all parameters allows for a qualitative assessment of groundwater potential across the study sites, VES 1 (Iyi Ukwa) and VES 3 (Nursery/Pry School) exhibit the most favorable conditions. They possess aquifers with high resistivity (indicating clean, porous sands), significant thickness, and high calculated storativity. These locations are recommended as priority sites for productive water wells. VES 4 (Kitchen) shows a moderately promising aquifer (silt with a resistivity of 1133 Ωm) at a workable depth, though the yield may be less than that of the sand-dominated aquifers.

VES 2 (Hekezia House) presents a more complex scenario. While a deep layer is identified, its interpretation as clay and the associated electrical parameters suggest lower permeability. This site may represent a less productive zone or require targeting a different, shallower horizon not resolved as the primary aquifer in this survey. The ubiquitous presence of lignite layers, while diagnostically important, also plays a crucial hydrological role. These layers typically have very low resistivity (e.g., 5.03 to 41.4 Ωm , as recorded) and act as regional aquitards, often creating localized semi-confined conditions for the sand aquifers above or below them.

Groundwater implication

1. *Groundwater potential:* The low-resistivity unit at intermediate depth is continuous across all VES, indicating a regionally connected aquifer.
2. *Protection and vulnerability:* Cover thickness of 10–40 m provides modest natural protection.
3. *Water quality expectations:* Conductive deep beds below the aquifer could host mineralized formation water.

Lignite

The very low resistivity (<20–30 $\Omega\cdot\text{m}$) and lateral persistence at depth are consistent with lignite/carbonaceous shales. Top of lignite package occurs at ~80–120 m. The conductive package likely comprises multiple thin lignite seams interbedded with clays.

VII. CONCLUSION

The Vertical Electrical Sounding survey has effectively delineated the aquifer system within the Ogwashi Formation at the Living Christ Mission site. The subsurface is characterized by a heterogeneous sequence of sands, clays, shales, and lignite. The study successfully identified viable aquifer units, predominantly sandy layers, at varying depths between 15m and 130m. Key hydraulic parameters such as aquifer thickness, transverse resistance, and storativity were derived, providing a quantitative basis for evaluating groundwater potential. The results indicate variable groundwater prospects across the study area, with the most promising conditions identified at the Iyi Ukwa and Nursery School locations. Lithologies varies. Aquifers are low in productivity due to low porosity and permeability with most aquifers being silts and some sands. Presence of lignite is observed in all ves points. Aquifers have moderate vulnerability because of shales and clay. In general, the study area is good for groundwater potentials.

The research demonstrates the efficacy of the geoelectrical method in supporting sustainable groundwater exploration and development planning in the complex geological terrain of southeastern Nigeria.

VIII. RECOMMENDATIONS

We recommend as follows

Detailed geophysical investigation should be carried out in order to determine the aquifer characteristics.

There is presence of lignite so a regional geoelectric survey should be done to evaluate the lateral extent of the lignite at the study area and in southeastern Nigeria for possible reserve estimation

The lignite should be beneficiated so that it can be used to power trains, produce briquettes, cements, iron and steel

Coring of the rock units could be done to ascertain the actual thickness of the rocks.

Other dating techniques should be used to ascertain the age of the lignite

Future work integrating drilling and pumping test data would be valuable for calibrating the geophysical models and obtaining direct measurements of hydraulic conductivity and transmissivity.

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