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An Investigation On Groundwater Potentials Using Electrical Sounding Techniques At Permanent Site Federal College Of Education Gidan Madi, Sokoto State Nigeria

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ABSTRACT

A geo electrical investigation was conducted on the groundwater potential at a fixed location, the Federal College of Education Gidan Madi, Tangaza, Sokoto State. This investigation utilized vertical electrical sounding (VES) with the primary objective of addressing the insufficient access to boreholes within the area. Four VES were deployed to identify zones with groundwater potential in the administrative block and clinic site of the college. Data acquisition was carried out using a modified half Schlumberger array across the four VES, employing half current electrodes (AB/2) with distances ranging from 1 to 100 m. The outcomes revealed the presence of five layers at each VES point. The initial layer consisted of topsoil containing sand, sandstones, and lateritic sandy clay. Furthermore, the resistivity values within this layer ranged from 1222Ωm to 6310Ωm, with thicknesses varying from 1.553 m to 4.112m. In the second layer, resistivity values were recorded between 913.1Ωm to 2976Ωm, and thicknesses ranged from 3.793m to 14.38m, characterized by ironstone with brown clay or clayed sand. Based on these findings, it is suggested that groundwater development could be achieved particularly along VES 3 and 4.

Keywords: Aquifers, thickness, ground water, vertical electrical sounding and resistivity

INTRODUCTION

Water is regarded as one of the fundamental resources indispensable for life to persist on Earth. The role of water in supporting the existence of flora and fauna is pivotal, hence giving rise to the well-known adage "water is life." Throughout the world, groundwater reservoirs are universally acknowledged as the optimal sources of water for both domestic and industrial purposes (Hoque et al., 2009). Particularly, groundwater stands out as the primary water reservoir essential for meeting the water demands of humanity, agriculture, and industrial operations in various regions (Rai et al., 2011; Kumar et al., 2011).

Groundwater signifies the water present below the Earth's surface within the interstices of soil and fractures within rock formations. In order to harness the water potential effectively, geophysical surveys are conducted to evaluate the groundwater availability in the specified region and pinpoint the most suitable locations for well drilling to extract groundwater resources (Helaly, 2012).

Furthermore, excessive exploitation has led to the depletion of groundwater levels, resulting in the lowering of the water table and impeding the natural flow of groundwater towards deeper and fractured zones. With water resources in Gidan madi becoming increasingly scarce, ensuring an adequate supply of high-quality water is progressively challenging due to the mounting pressures from population growth and

industrial expansion. Considering the unreliability of surface water quality year-round, alternative water sources must be explored to supplement surface water. Consequently, the escalating demand for water to cater to the needs of the rapidly expanding population, especially for household use, has triggered extensive and rigorous exploration of water sources in all communities within the study area. Groundwater levels are notably shallow and primarily influenced by geological structures and weathered surface layers. A majority of the rural settlements in the vicinity of the study area heavily rely on groundwater from wells to fulfill their water requirements, given the scarcity of surface water sources in the desert region. Hence, this study aims to analyze the geological anomalies and thickness of rocks to identify areas with significant groundwater potential that is not only abundant but also safe for consumption within the study area.

Geophysical Methods for Ground Water Mapping

The utilization of geophysical techniques for the purpose of mapping groundwater resources and assessing water quality has experienced a significant rise in recent decades owing to rapid advancements in electronic technology and the emergence of numerical modeling solutions (Olayinka, 1992; Metwaly et al., 2009; Ndlovu et al., 2010). Despite the availability of various hydro-geophysical methods, electrical resistivity stands out as a favored approach due to its uncomplicated operation, cost-effectiveness, and efficacy in regions exhibiting high resistivity contrasts, such as those between the weathered overburden and the bedrock (Sheriff et al., 2019). The process of geophysical exploration of the Earth's surface entails gathering measurements at or in proximity to the Earth's surface that are impacted by the internal distribution of physical properties. Geophysics is furthermore recognized for its role in the subsurface characterization of geology, geological structures, groundwater, pollution, and archaeological remains beneath the Earth's surface, achieved through the lateral and vertical delineation of variations in physical properties that are detected remotely utilizing non-invasive technologies (Afuwai, 2015).

Electrical Resistivity

The method known as electrical resistivity is a geophysical technique that has been effectively utilized by numerous researchers in the investigation of groundwater. As indicated by Seaton and Burbey (2016), Niwas and de Lima (2017), Ako and Osondu (2015), Adeoti and Ishola (2018), and Adiat et al. (2009), this method has been acknowledged. Various other geophysical methods, such as the gravity method, magnetic method, Remote Sensing, and Geographical Information Systems (GIS), have also been employed to identify potential groundwater zones, as highlighted by Adiat et al. (2015). Nonetheless, some of these methods lack the accuracy of an in-situ analysis. The electrical resistivity method, which is non-invasive, is often preferred due to the resistivity differences observed upon reaching the groundwater zone. Numerous studies, including those by Anudu, Onuba, and Ufondu (2014), Emenike (2015), Olorunfemi and Okhue (2017), as well as Oyedele, Adelusi, and Ayuk (2019), have demonstrated the successful use of this technique in delineating and mapping geo-materials in the subsurface to facilitate groundwater resource exploration. Remote sensing, with its spatial, spectral, and temporal data availability covering vast and remote regions, has emerged as a valuable tool for investigating, assessing, and managing crucial groundwater resources. The hydro-geological interpretation of satellite data has proven to be an essential survey instrument in regions where geological and cartographic information is scarce or inaccurate, as emphasized by Engman and Gurney (1991).

MATERIALS AND METHOD

Material

The resources utilized in this study comprised of the ABEM TERRAMETER SAS 300C, current and potential electrodes, a hammer for facilitating the insertion of the electrodes into the soil for effective electrical connection, a measuring tape, and a Global Positioning System (GPS) for recording the coordinates (longitude, latitude, and altitude).

Furthermore, the Vertical Electrical Sounding (VES) Schlumberger array configuration was utilized in the research project.

Method

The data were obtained using the ABEM SAS 300C Terrameter, which oversaw all measurements, including the use of a Global Positioning System (GPS) for precise VES point coordinates, as well as current and potential electrodes for penetration, a measuring tape for distances, labeled tags for station location, and a hammer for electrode insertion. The Schlumberger array was employed, with AB/2 electrode spacing ranging from 1 to 100 m on each profile. Four electrodes were symmetrically placed in a line, with current electrodes on the outer sides and potential electrodes on the inner sides. Adjustments to the depth range involved moving the current electrodes outward while the potential electrodes generally remained stationary, ensuring an appropriate ratio between the electrode distances. The positioning of current and potential electrodes was marked to maintain AB/2 >> MN/2, where AB/2 represents current electrode spacing and MN/2 represents potential electrode spacing.

The sounding data is depicted as curves showing apparent resistivity plotted against AB/2. The IPI2WIN software was utilized to generate n-layer models based on Schlumberger sounding curves, automatically interpreting the data. The resulting curves provide insights into the number of layers, thickness, depth, and average resistivity at various VES points.

Data processing involves positioning metal electrodes with two current electrodes at specific distances and two potential electrodes within them along a 100 m AB/2 survey profile. While MN potential electrodes can remain fixed, the A and B current electrodes are varied from the sources. An electric current is transmitted through the ground via two current electrodes, and the potential difference is measured across two potential electrodes, displayed by the ABEM SAS 300C Terrameter. After each five-meter measurement, the current electrodes are adjusted, followed by the potential electrodes. The potential electrodes are relocated only after the ABEM SAS 300C Terrameter completes four soundings and data collection. This methodology is consistent across VES 1, VES 2, VES 3, and VES 4.

Data processing

This involves spacing of metals electrodes with two current electrodes at a specific distances and two potential electrodes at a specific distance within them along (AB/2) of 100 m of the survey profile, in this array the potential electrodes MN can be fixed while the current electrodes A and B are changed from the current sources. An electric current is passed in to the ground through two current electrodes and the resulting potential difference is measured across two potential electrodes. The resulting potential difference to the current is displayed by the ABEM SAS 300C Terrameter. For each measurement the current electrodes are moved after taking the five-meter measurement, then the potential electrodes move at the same locations. The potential electrodes are moved only when the signal of the ABEM SAS 300C tetrameter complete four sounding and data to be measured. Similarly, the same methods used for the VES 1, VES2, VES3, and VES4.

RESULT AND DISCUSSION

Data Analysis

The following data were collected after imploying the vertical electrical sounding in the profiles of the study areas that is the Administration block (profile 1) and Clinic site (profile 2).

Vertical Electrical Sounding (VES) Field Data
LOCATION: (ADMINISTRATIVE BLOCK) PERMANENT SITE FEDERAL COLLEGE OF EDUCATION GIDAN MADI
LGA: TANGAZA **DATE: 2**0/12/2023
STATE: SOKOTO **LATITUDE**: 13˚17′ 42˚N **LONGITUDE**: 4˚58′ 39˚E
INSTRUMENT: TERRAMETER SAS 300C SURVEY NO. VES 1
TABLE 1 DATA RESULTS

Electrode spacing (M)		Meter Readings in (ohm)	Apparent Resistivity in (ohm-m)	Geometric Factor
AB/2	MN/2			
1	0.5	690	1587	2.3
1.5	0.5	300	1800	6.0
2	0.5	142.5	1567.5	11.0
3	0.5	50.9	1425.2	28.0
5	0.5	16.0	1200	75
5	1	5.8	232	40
7	1	11.13	812.5	73
10	1	2.4	350.4	146
10	3	0.5	22.5	45
15	3	0.34	36.4	107
20	3	0.8	161.6	202
25	3	1.21	401.7	332
30	3	0.6	282.6	471
30	10	0.34	53.4	157

3.1.2 Vertical Electrical Sounding (VES) Field Data
LOCATION: (ADMINISTRATIVE BLOCK) PERMANENT SITE FEDERAL COLLEGE OF EDUCATION GIDAN MADI
LGA: TANGAZA **DATE:** 20/12/2023
STATE: SOKOTO **LATITUDE**: 13˚17′ 38˚N **LONGITUDE**: 4˚58′41˚E
INSTRUMENT: TERRAMETER SAS 300C SURVEY NO. VES 2
TABLE 2 DATA RESULTS

Electrode spacing (M)		Meter readings (ohm)	Apparent Resistivity in (ohm-m)	Geometric Factor
AB/2	MN/2			
1	0.5	620	1426	2.3
1.5	0.5	245	1470	6.0
2	0.5	134.5	1479.5	11.0
3	0.5	42.1	1178.8	28.0
5	0.5	7.0	525	75
5	1	1.4	56	40
7	1	3.3	240.9	73
10	1	1.66	242.4	146
10	3	40.0	1800	45
15	3	11.05	1182	107
20	3	0.20	40.4	202
25	3	0.07	23.3	332
30	3	0.31	146.0	471
30	10	9.15	1436.6	157

Vertical electrical sounding (VES) field data

Location: (Clinic site) permanent site federal college of education Gidan madi

LGA: Tangaza **date:** 20/12/2023

State: Sokoto **latitude**: 13˚17′ 22˚E **longitude**: 4˚58′ 10˚E

Instrument: Terrameter sas 300c survey no. VES 3

Table 3 Data results

Electrode spacing (M)		Meter Readings in (ohm)	Apparent Resistivity in (ohm-m)	Geometric Factor
AB/2	MN/2			
1	0.5	53	121.9	2.3
1.5	0.5	213	1278	6.0
2	0.5	6.9	75.9	11.0
3	0.5	26.1	730.9	28.0
5	0.5	5.3	397.5	75
5	1	1.9	76	40
7	1	4.0	292	73
10	1	2.0	292	146
10	3	0.5	22.5	45
15	3	0.4	42.8	107
20	3	0.2	40.4	202
25	3	0.2	66.4	332
30	3	0.6	282.6	471
30	10	0.2	25.8	129
35	10	0.3	53	177

3.1.4 Vertical electrical sounding (VES) fiel data

Location: (clinic site) permanent site federal college of education Gidan Madi

LGA: Tangaza **date:** 20/12/2023

State: Sokoto **latitude**: 13˚17′ 20˚N **longitude**: 4˚58′ 15˚E

Instrument: Terrameter sas 300c survey no. VES 4

Table 4 data results

Electrode spacing (M)		Meter Readings in (ohm)	Apparent Resistivity in (ohm-m)	Geometric Factor
AB/2	MN/2			
1	0.5	501	1152.3	2.3
1.5	0.5	234	1404	6.0
2	0.5	119.0	1309	11.0
3	0.5	50.7	1419.6	28.0
5	0.5	11	825	75
5	1	3.1	124	40
7	1	7.1	518.3	73
10	1	3.2	467.2	146
10	3	0.7	31.5	45
15	3	0.4	42.8	107
20	3	0.3	60.6	202
25	3	0.1	33.2	332
30	3	0.6	282.6	471
30	10	0.2	25.8	129
35	10	0.3	53	177

Table 5: Resistivity and calculated Apparent Resistivity Values of the VES points across profile 1(Administrative block and clinic site)

AB/2	MN/2	K	VES 1		VES 2		VES 3		VES 4	
			RES	APP RES	RES	APP RES	RES	APP RES	RES	APP RES
1	0.5	2.3	690	1587	620	1426	53	121.9	501	1152.3
1.5	0.5	6.0	300	1800	245	1470	213	1278	232	1404
2	0.5	11.0	142.5	1567.5	134.5	1479.5	6.9	75.9	119.0	1309
3	0.5	28.0	50.9	1425.2	42.1	1178.8	26.1	730.9	50.7	1419.6
5	0.5	75	16.0	1200	7.0	525	5.3	397.5	11.0	825
5	1	40	5.8	232	1.4	56	1.9	76	3.1	124
7	1	73	11.13	812.5	3.3	240.9	4.0	292	7.1	518.3
10	1	146	2.4	350.4	1.66	242.4	2.0	292	3.2	467.2
10	3	45	0.5	22.5	40.0	1800	0.5	25.5	0.7	31.5
15	3	107	0.34	36.4	11.05	1182	0.4	42.8	0.4	42.8
20	3	202	0.8	161.6	0.20	40.4	0.2	40.4	0.3	60.6
25	3	332	1.21	401.7	0.07	23.3	0.2	66.4	0.1	33.2
30	3	471	0.6	282.6	0.31	146.0	0.6	282.6	0.6	282.8
30	10	157	0.34	53.4	9.15	1436.6	0.2	25.8	0.2	25.8

Data Interpretation

The data acquired from the VES was presented in resistance units (Ω), utilizing the Terrameter ABEM SAS 300C, which were subsequently multiplied by their respective geometric factors to derive an apparent resistivity in ohm-meter (Table 4.1 and 4.2) above. The data processing involved the utilization of a computer software known as IPI2WIN. The apparent resistivity values for each individual point were graphed against the half current electrode spacing (AB/2) on a log-log scale to generate sounding curves. These curves serve the purpose of identifying the underlying subsurface layers beneath each VES point, including their thicknesses and variations in resistivity. The outcomes were succinctly compiled in table 4.1.1, providing insight into the average resistivity and thickness of the geological/lithological layers present within the survey profiles. The aforementioned table illustrates the range of aquifer protective capacities, as adjusted by Figures (1 to 8), which depict iterative curves derived from the apparent resistivity data through the utilization of the IPI2WIN software (version 12.0).

DISCUSSION

Table 1 illustrates the outcomes derived from the Vertical Electrical Sounding (VES) data of profile 1. The findings suggested the presence of three distinct geological strata along the profile. The initial stratum comprises the surface soil layer, characterized by sand, sandstones, and lateritic sandy clay. It is further distinguished by resistivity values ranging between 312.2Ωm to 1752Ωm and thickness varying from 1.975 m to 14.37m. The subsequent stratum exhibits resistivity values within the range of 835Ωm to 2721Ωm, with thickness fluctuating from 4.062 m to 35.92m and is identified by ironstone accompanied by brown clay. The final stratum consists of unweathered bedrock formations. Groundwater potential within VES 2 of this profile could be explored for development purposes. Virtually all locations within zone A of this profile are deemed suitable for construction activities.

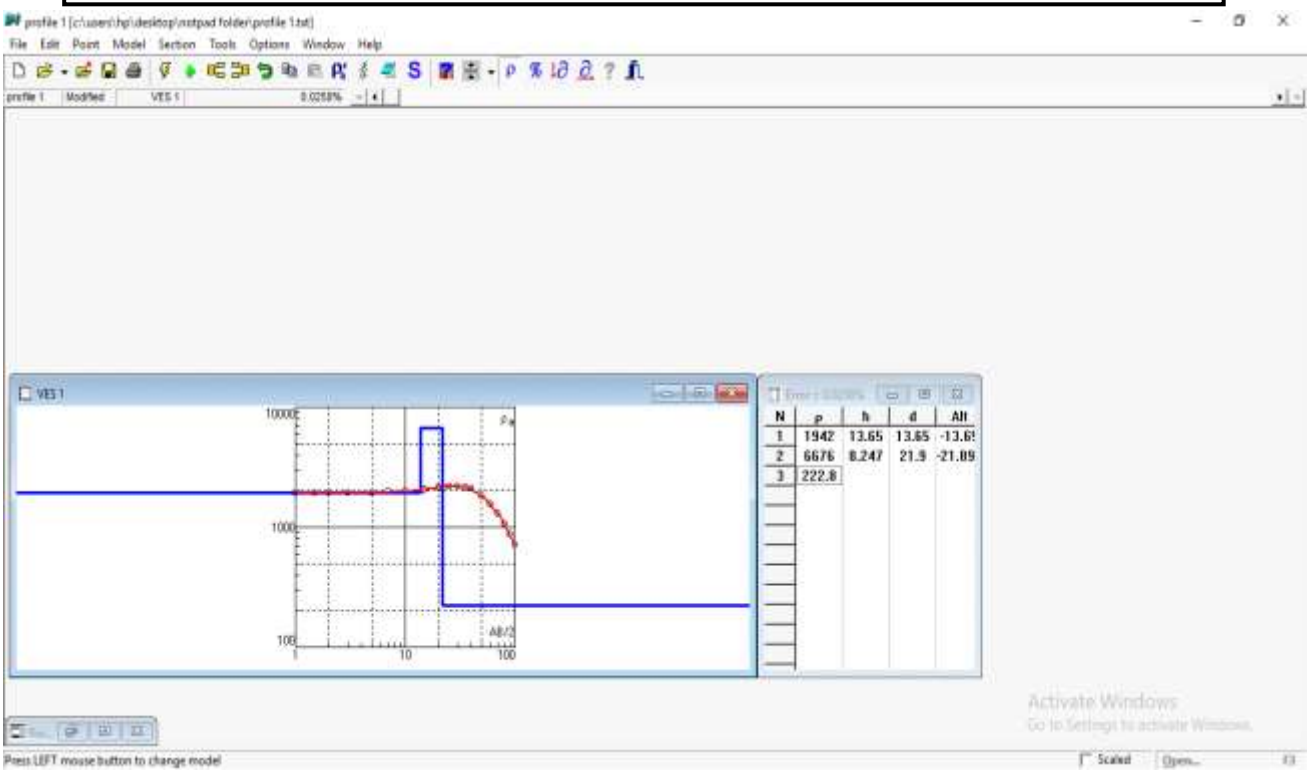

Figure 1 Resistivity curve along profile 1, VES 1.

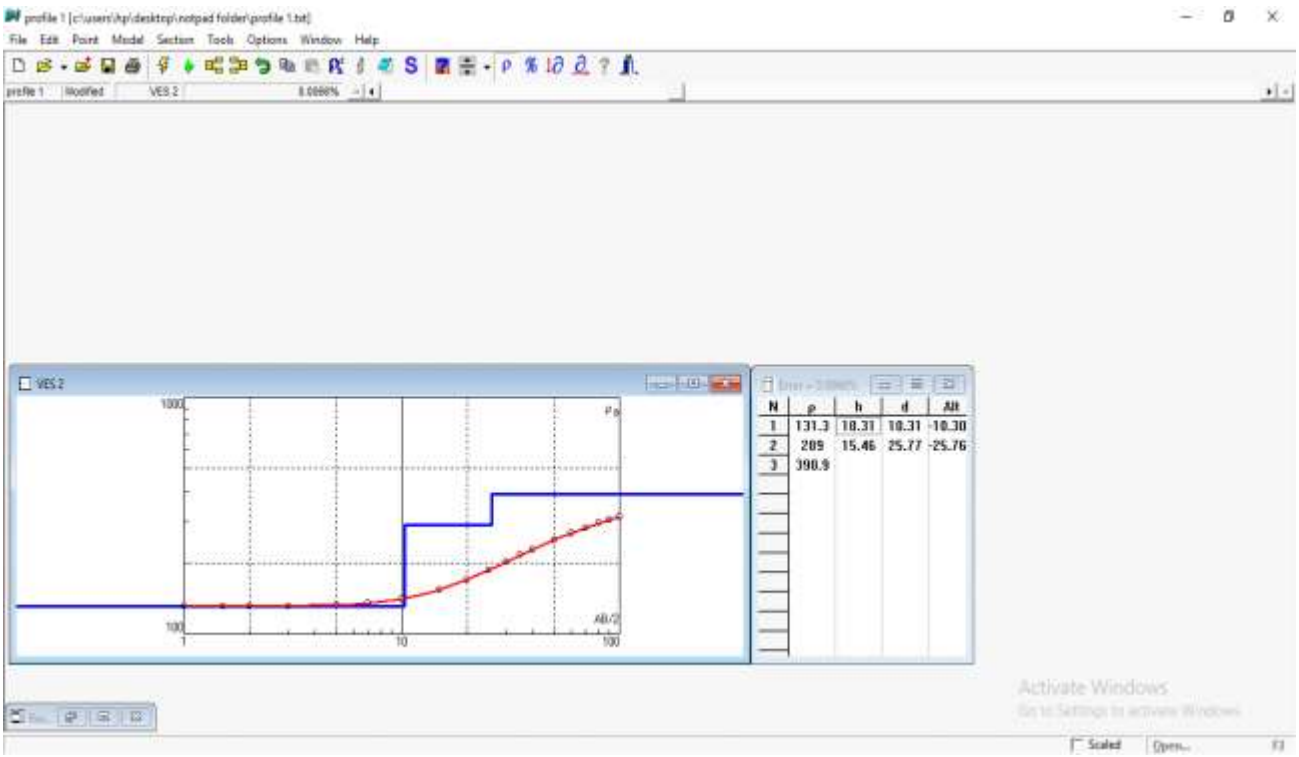

Figure 2 Resistivity curve along profile 1, VES 2.

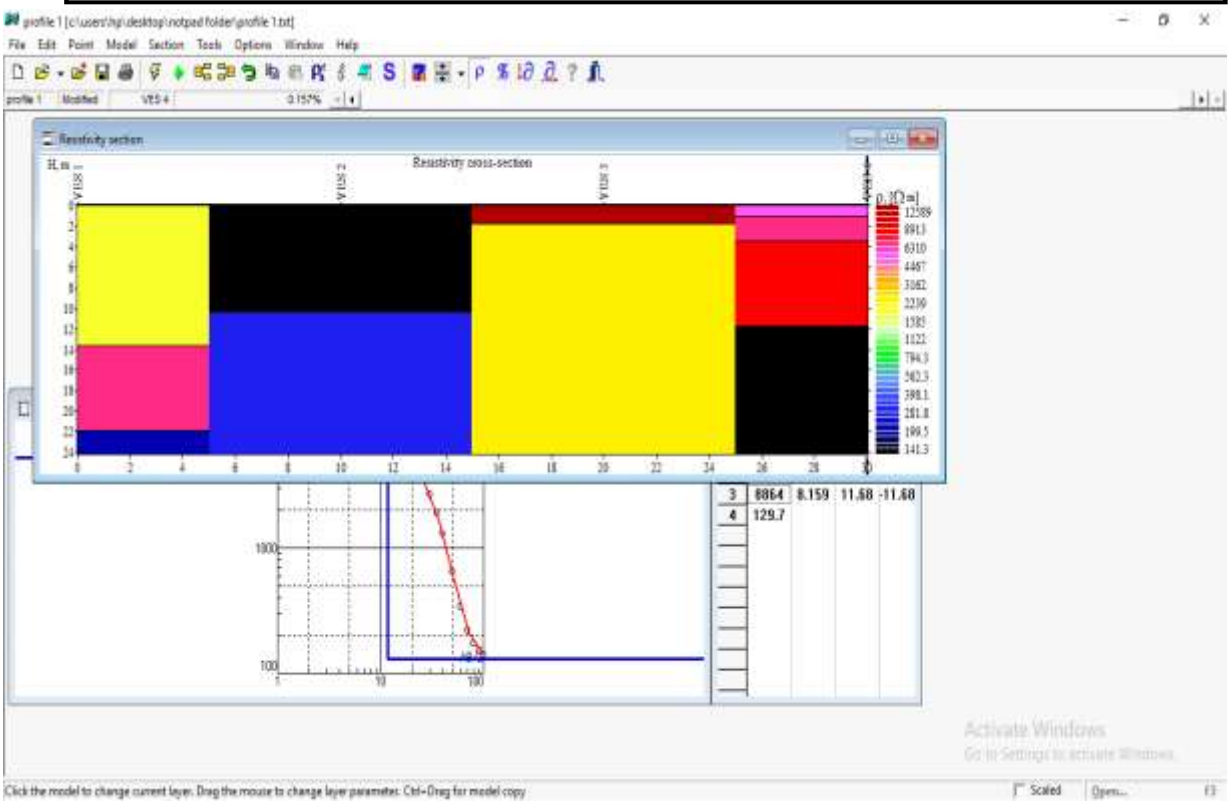

Figure 3 Geo-electric section across profile one

Table 2 and Figure 4-6 represents the results obtained from the VES soundings points across profile two. The results indicated that three geologic layers could be found along VES 3 while the remaining layer has five VES sounding points. The first layer is composed of the top soil, characterized with sand, sandstones and lateritic sandy clay. It is also characterized with the resistivity values ranges from 1222Ωm to 6310Ωm and thicknesses varied from 1.553 m to 4.112m. The second layer has resistivity values from 913.1Ωm to 2976Ωm and its thickness varies from 3.793m to 14.38m is characterized with this layer ironstone with brown clay/clayed sand and the last layer is the fresh bedrock rocks. Across this profile, the groundwater development can be achieves along VES 3.

Figure 4 Resistivity curve along profile 2, VES 3.

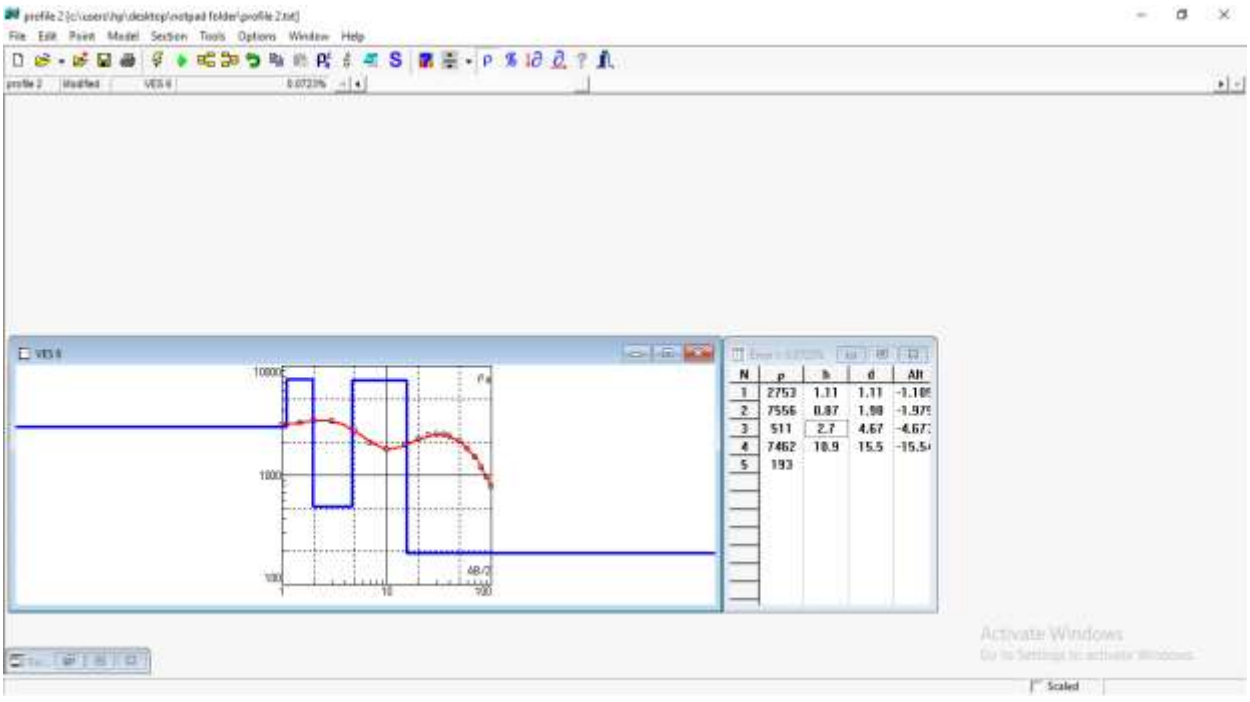

Figure 5 Resistivity curve along profile 1, VES 4.

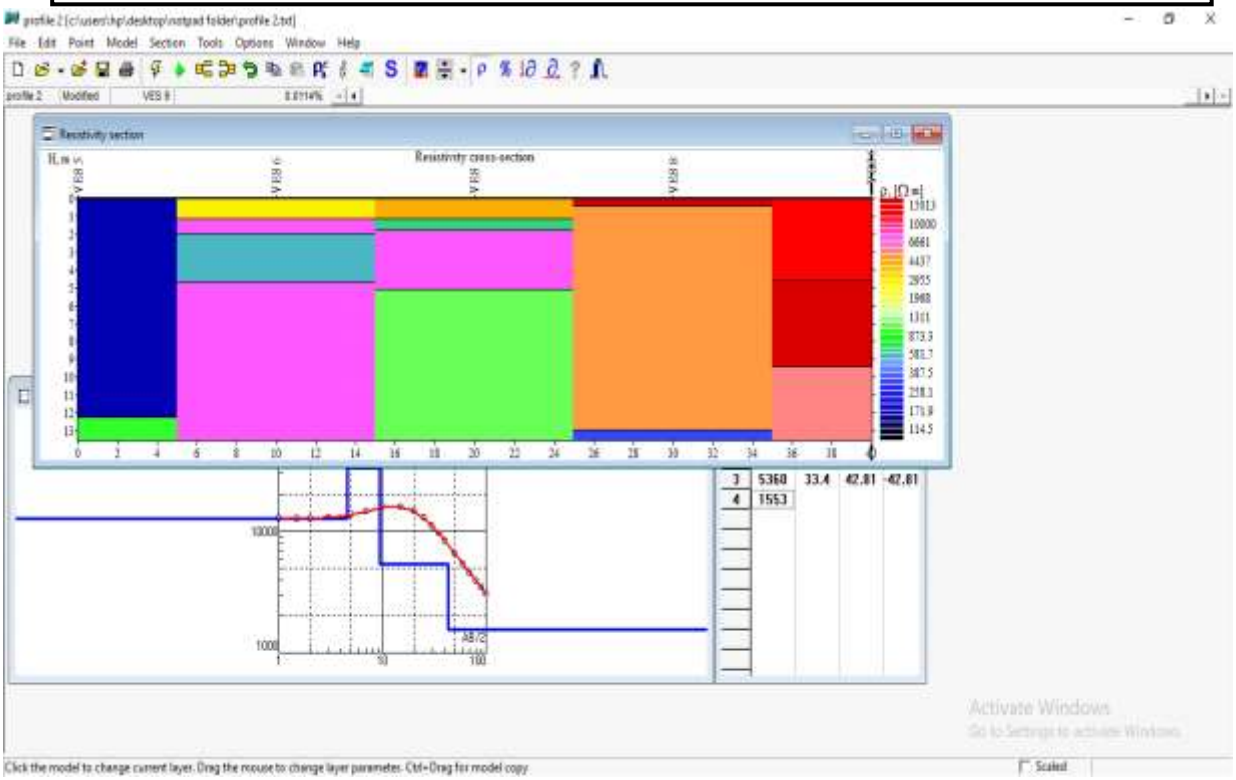

Figure 6 Geo-electric section across profile two

CONCLUSION

The delineated VES stations designated for assessing groundwater potentials are recommended for consideration in water resource development. The geological-electric sections corresponding to the profiles indicate a geological setting within the study area characterized by the presence of three to five layers with distinct lithological compositions. These layers include a surface cover composed of sandy, clay, silt, weathered laterite, fresh laterite, weathered basement, fractured basement, and fresh basement rock. Particularly noteworthy is the laterite present in the uppermost layer at select locations, as it plays a significant role in reducing surface run-off and facilitating infiltration into the underlying aquifer. Furthermore, the fractured basement underlying the weathered basement in the vicinity of VES 02 and 04 represents promising zones for groundwater extraction due to their potential for effective recharge through precipitation.

RECOMMENDATIONS

It is thus advisable that additional geophysical and geological surveys utilizing alternative techniques be conducted within the research site. This is due to the inadequacy of any individual method in offering comprehensive and sufficient data regarding the subsurface formations of the region. Furthermore, given the prevalent underdevelopment in a significant portion of the study area, a thorough geophysical examination is essential prior to commencing any construction of engineering structures**.**

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