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Geophysical investigation of groundwater potential in Kwang Village, Jos South Local Government Area of Plateau State. using Electrical Resistivity.

[1*] Abdulmalik Aliyu, [1]Jack Zuhumnan kevin [2] Dakon Retji Josiah [2]Godfrey Boniface Tonga [3]Samuel Mathew

[1]Department of science laboratory Technology, Federal University of Technology Ilaro, Ogun, Nigeria.
[2]Department of physics, Faculty of science, University of Abuja Nigeria.
[2]Department of physics, Faculty of science, Federal college of Education (Technical) Yauri, Kebbi State, Nigeria.
[3]Department of Science Laboratory Technology, Faculty of science, Federal college of Forestry Jos, Plateau State Nigeria.

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ABSTRACT

Electrical resistivity survey method involving the Vertical Electrical Sounding (VES) technique was carried out to investigate the groundwater potential of Kwang village, Jos-South, Plateau state, Nigeria. The survey was carried out with a view to identify and delineate groundwater potential zones through integration of various subsurface layers and geoelectric characteristics that are favourable for groundwater accumulation. The Schlumberger array was employed which comprises of 41 VES points explored along the study area using the SAS300B terameter, with maximum current electrode spacing (AB/2) of 165m.The results obtained from the interpretation of the VES data within the study area showed earth models with geoelectric layers ranging from three (3) to five (5). Thirty-two (32%) and twenty-four (24%), respectively, percent of all sounds curves in the research region are HA and HK types, while the remainder 17% are H types, 12% are KH types, AHA and Q types are 5% each, and 2% are A and AH curve types. The geoelectric layers obtained were grouped into Group 1 and Group 2 with group the first group consisting of typical curves inferring shallow or non-aquifer. These constitute about 56% of the study area; the second group which covers about 44% of the study area consist of geologic layers where curve types are typical curves for aquiferous zones. Overall, the study area is comprising of the topsoil/laterite, weathered granite, partly weathered/fresh granite, fractured granite and the fresh basement.

I. INTRODUCTION

A vital portion of Plateau State's Jos metropolis, which has recently seen a rise in infrastructural development and population expansion, is the Jos South Local Government Area (Adzandeh *et al.*, 2015). Kwang Village, a suburb around Rayfield Area of the local government, is one of the locations that has witnessed most of this development. This is perhaps because of its proximity to the Jos University Teaching Hospital (Juth) and the Centre for Remote Sensing in Jos. Today, demand for water has increased for most residents, for whom well and borehole water are the main sources of water in this village.

Groundwater plays a crucial role in natural water resources. Groundwater is defined as subsurface water that fills soil pore spaces and fractures in rock formations (Muchingami, 2012). It is recognized as the supplementary source of water that sustains all living organisms. The occurrence of groundwater resources in an area is defined by various geological factors that include structure, geological sequences, and stratigraphic distributions of hydrological units (Diat *et al.*, 2013). Well drilling is one of the conventional methods applied in exploring subsurface groundwater systems in Kwang; however, the cost is very expensive, and the dug wells may dry up as the recharge rate of the well may be slow if the geometry and properties of the aquifer in the location are not investigated. These can be observed from women seen waiting close to well sides for hours to have the wells recharged. Another common problem in these fields was subsurface failure and underground contamination of these shallowly dug wells.

Groundwater is an important but hidden replenishable resource whose occurrence and distribution greatly vary according to local as well as regional geology and hydrogeology. Communities situated on terrain with complex basement rocks often face challenges in accessing safe drinking water from groundwater sources because the crystalline rocks underneath lack primary porosity. The ability of groundwater storage in such areas relies on the degree of weathering and fracturing of the underlying rocks. To function as good aquifers, the basement complex rocks need to be deeply weathered and/or fractured. The thickness of the weathered overburden and fracture zone plays a crucial role in determining the type and intensity of hydrodynamic activities within the distinct aquifer bodies in the terrain. As the basement aquifer systems are fragmented, conducting thorough geophysical, geological, and hydrogeological investigations is crucial (Amidu and Olayinka, 2006).

Drinking water sources are under increasing threat from contamination (Miner *et al.*, 2016) as a result of sewage seeping from nearby soak-always and refuge dumps around abandoned mining ponds to the ground through fractures in the subsurface. In areas where there is no dependable public water supply, the majority of households rely on hand-dug wells that extract water from the shallow water table located within the weathered overburden. Again, the increasing economic activities and rapid construction work, along with the occurrence of building and structure collapses in the country, has necessitate the use of geophysical methods for obtaining geological information in various fields, including data on groundwater pollution, leachate, and underground water sources.

Location of the Study Area

The study area (Kwang) is in Jos South Local Government Area of Plateau State (Fig 1). It is located within longitude 09050’31.8" N and latitude 008054’46.6" E. The topography of the study area is characterized by impressive ridges and isolated rocky hills separated by extensive plains, with hills interspersed among the highlands. The elevation above sea level ranges from 3,800ft near the west and northern margins to nearly 6000ft in the Shere Hills. Most of the area lies within a height range of 4,100 – 4,500 ft. The area experiences two distinct seasons: the dry season (November – March) and the rainy season (April – October). The vegetation of the area consists of a desert of bread-leaved savannah with some scattered trees.

Geology of the Study Area

In General, (Fig 2) falls within the Jos-Bukuru Complex, and the site is predominantly underlain by the biotite granite series (Dilimi, N'gell, and Jos biotite granites), as exhaustively studied by Falconer (1911), Falconer (1921), and MacLeod (1971). The regional geology of the Jos Plateau, however, is made up of the Precambrian Basement migmatite-gneiss-quartzite complex, which underlies about half of the entire state and, in some places, has been intruded by the Precambrian to the late Paleozoic Pan-African granite (Older Granite), diorite, charnockite, etc. The Jurassic anorogenic alkali Younger Granites are intrusive into the basement complex rocks and are accompanied by volcanic rocks like basalts and rhyolites, which either overlie or intersect this formation as well as the basement rocks. These volcanic rocks were supposedly formed during the early Cenozoic era, including the Tertiary "Older Basalts" and the Quaternary "Newer Basalts" (Macleod, 1971). According to Macleod's account, minerals with significant economic value such as tin and columbite are present in the area and were extensively mined from 1902 to 1978.

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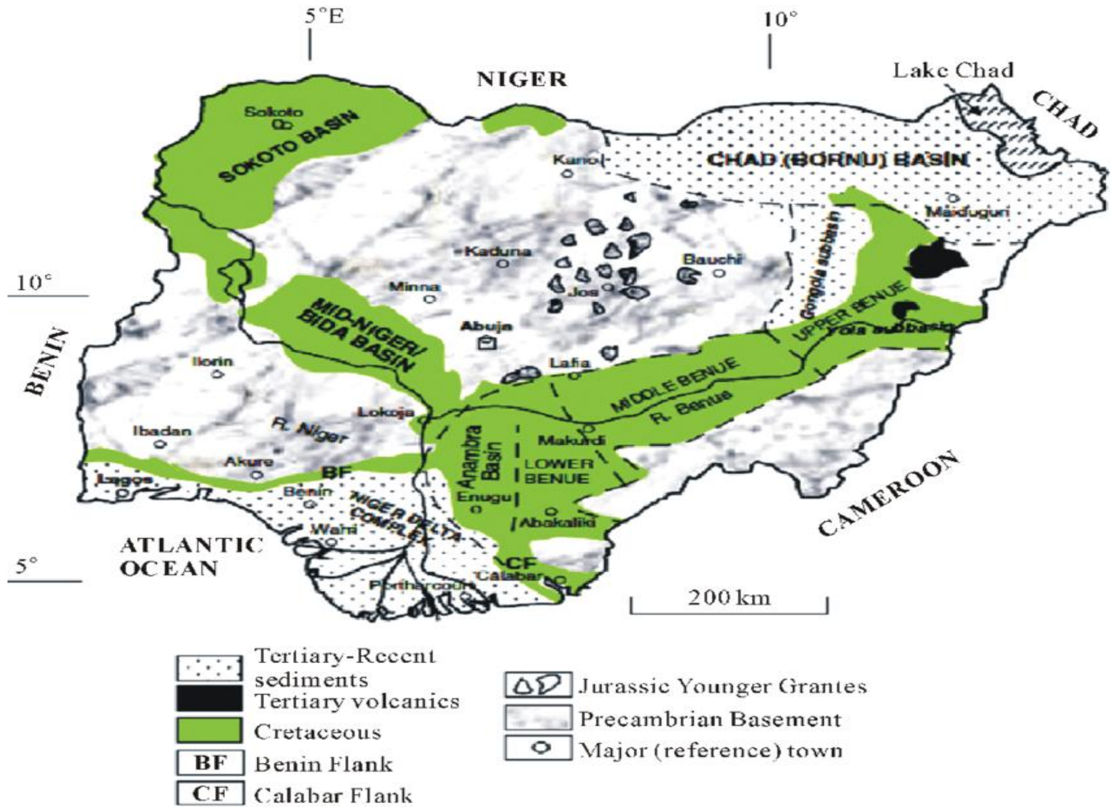

Geological map of Nigeria showing the study area (modified after Obaje, 2009).

II. MATERIALS

These data sets were obtained using the ABEM's terameter signal averaging system (SAS) model 300B series. It is part of the ABEM LUND imaging system. It is powered by a direct current (Dc) power supply of 12 volt (V). Other accessories for the Tarrameter include jumpers' cable, written pads, cable joint, connecting cable, steel electrode cable, four harmers, Salt, water, umbrella, measuring tapes, Global position system (Gps), reels electrode selectors, and the computer programs Surfer 8 Golden software, Win-resistivity iteration software for data interpretation.

III. METHOD

The Schlumberger electrode configuration was used in the data acquisition. A total of 41 geo-electric sounding (VES) numbered VES1 to VES41 were carried out in the survey locations covering about $3x10^6$ m^2 radius in Kwang village in order to infer the subsurface conditions along the village which will provide information on its ground water potential. The field procedure consists of expanding AB/2 (distance between current electrodes) with a maximum distance of 165 m, while the potential electrode spacing (MN) was varied between 0.5m to 14 m. This process yields a rapidly decreasing potential difference across MN, which eventually exceeds the measuring capacity of the instrument; therefore, a larger value for MN was taken to continue with the survey. The maximum value of MN during the survey was 14 m. At each sounding point, the reading is taken, the set-up is then expanded at increasing distance of AB/2 until a maximum spacing of 165 m is reached. The choice of the distance is to ensure sufficient depth of current penetration as probe of depth increases with increasing electrode spacing (Telfort *et al.*,1990).

No booster was used as the expected depth is within the range of penetration of the instrument. In this instrument consecutive readings are taken automatically and the results averaged continuously and displayed.

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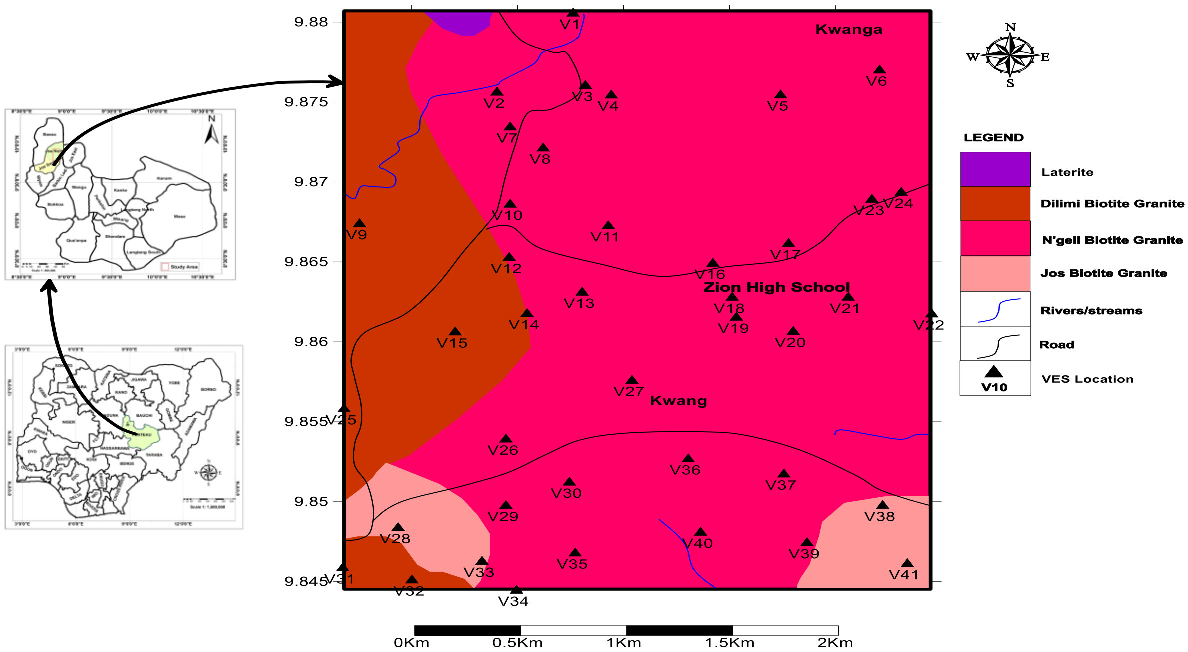

Location and Geological Map of the study area showing VES profile point

IV. RESULT

The VES curves were qualitatively and quantitatively interpreted. Qualitative interpretation involves analysing the shape and characteristics of the VES curve to determine the possible subsurface geology. This involves identifying the different layers or horizons and estimating their resistivity values based on the observed curve characteristics such as the shape, slope, and inflection points. Qualitative interpretation is useful in situations where there is limited prior knowledge of the subsurface geology, and it can provide a preliminary understanding of the subsurface without requiring a detailed mathematical analysis (Ramos, 2018).

The measurement of resistance and their corresponding apparent resistivity value for VES 1, VES 2, VES 4, and VES 6, at the control site are presented in figure 1, 2 ,3, and 4 respectively.

Interpretation of VES data point

The apparent resistivity values obtained from the field measurements were plotted against half current electron spacing on a log-log graph sheet. The resulting data were iterated to the lowest root mean square (RMS) percentage error with the aid of Win-Resist 2.0 version Software, which uses raw data sounding interpretation method.

An important step in the interpretation of resistive sounds survey data is to classify the apparent resistivity curve into types. In this research, fifty-six (56%) and seventeen (17%) percent of all the sounding curves in the study area are H and HK types respectively, Whereas the remaining 12% are KH types, 5% are HA and Q types while 2% are A and AH curve types respectively. this classification is made on the basis of curve which depends on the number layers in the subsurface and the thickness of the layer. The uses of Win-Resist 2.0 version Software which produce graphical representation of data grant the basis of making qualitative statement and observation of the study area. Figure: 1,2, 3, and 4 shows the graph of the of apparent resistive plot against half current electrode spacing for VES 1, VES 2, VES 4, and VES 6, (control) and the corresponding depth of each layer in the survey sits.

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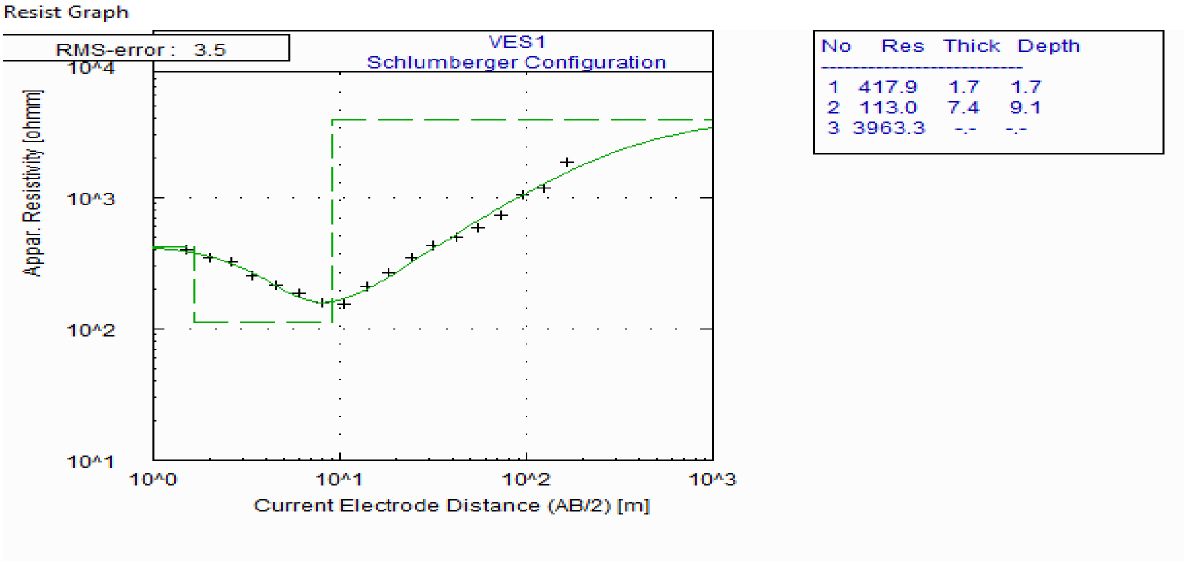

Fig 1: Geoelectric Section of VES 1 Point.

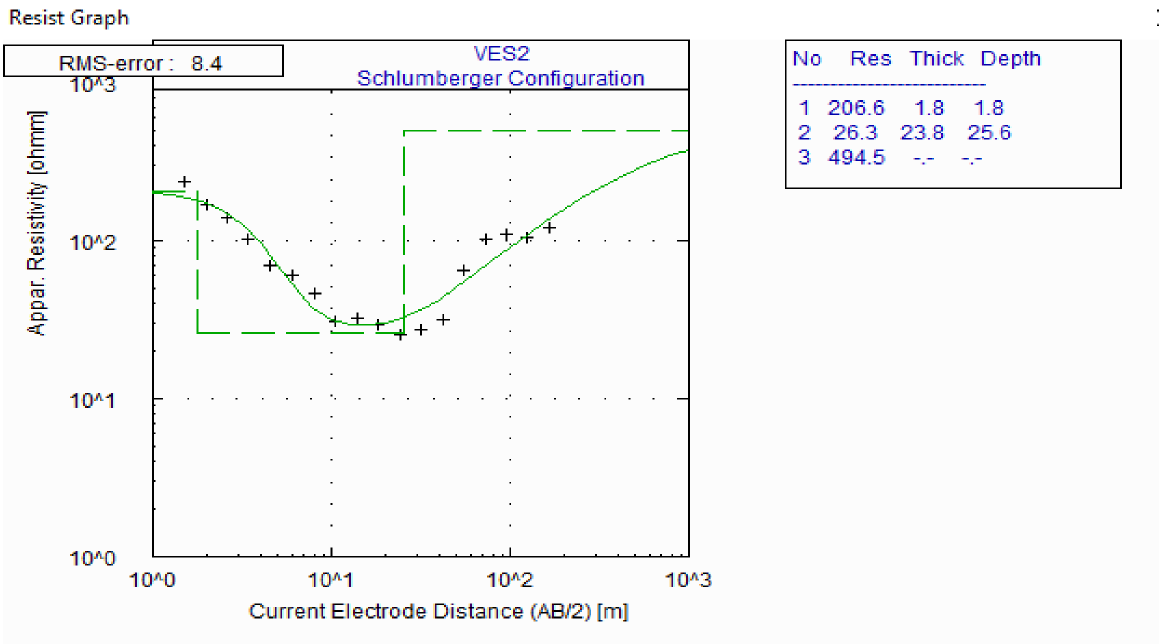

Fig 2: Geoelectric Section of VES 2 Point.

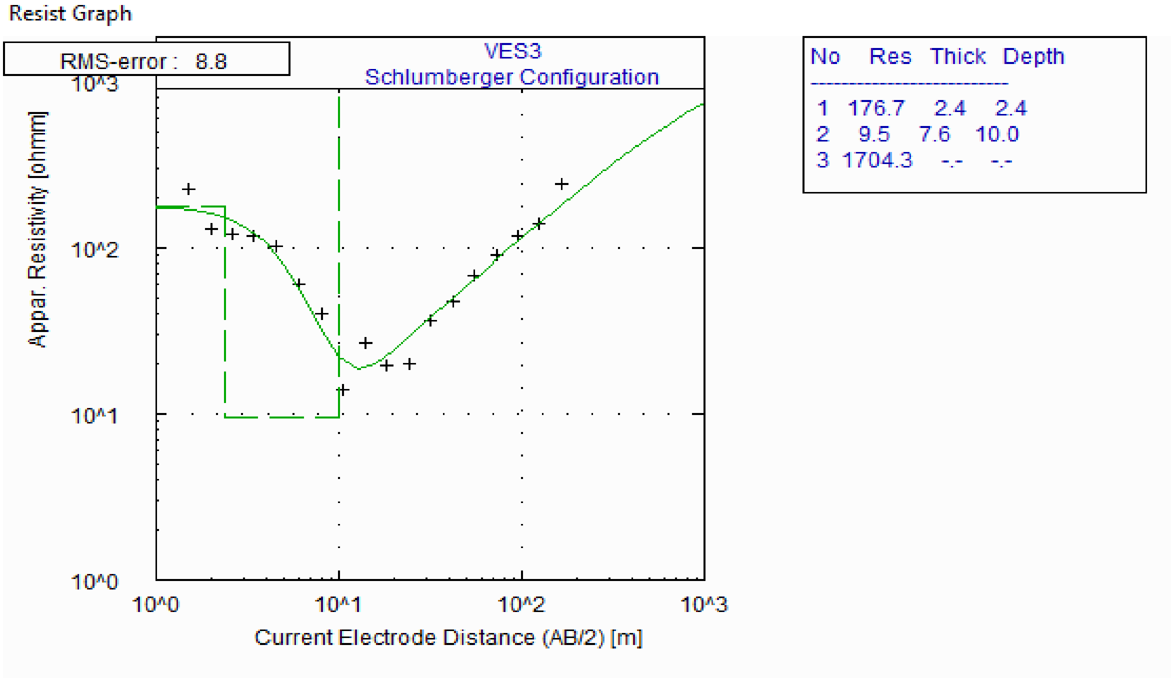

Fig 3: Geoelectric Section of VES 3 Point.

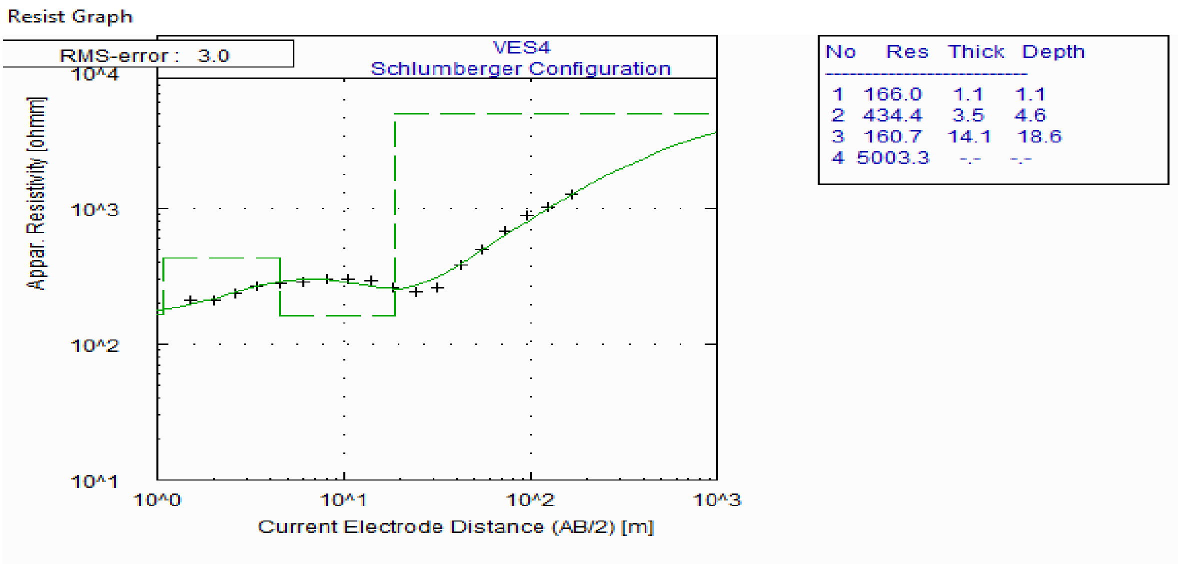

Fig 4: Geoelectric Section of VES 4 Point.

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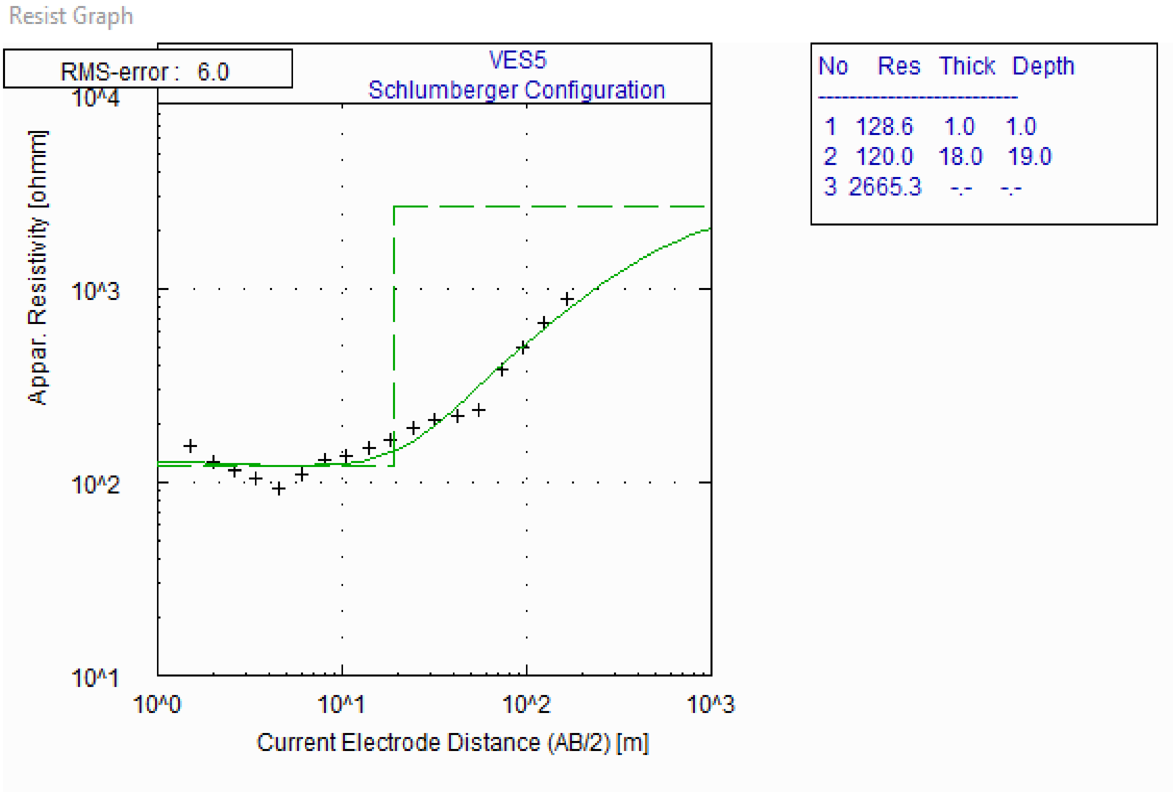

Fig 5: Geoelectric Section of VES 5 point.

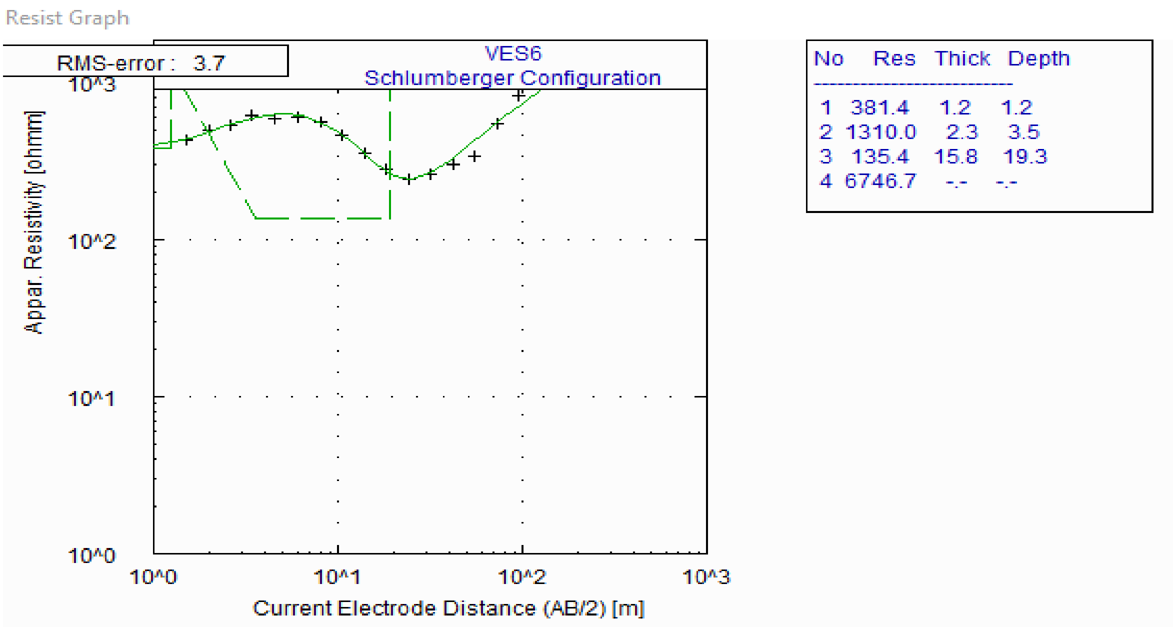

Fig 6: Geoelectric Section of VES 6 Point

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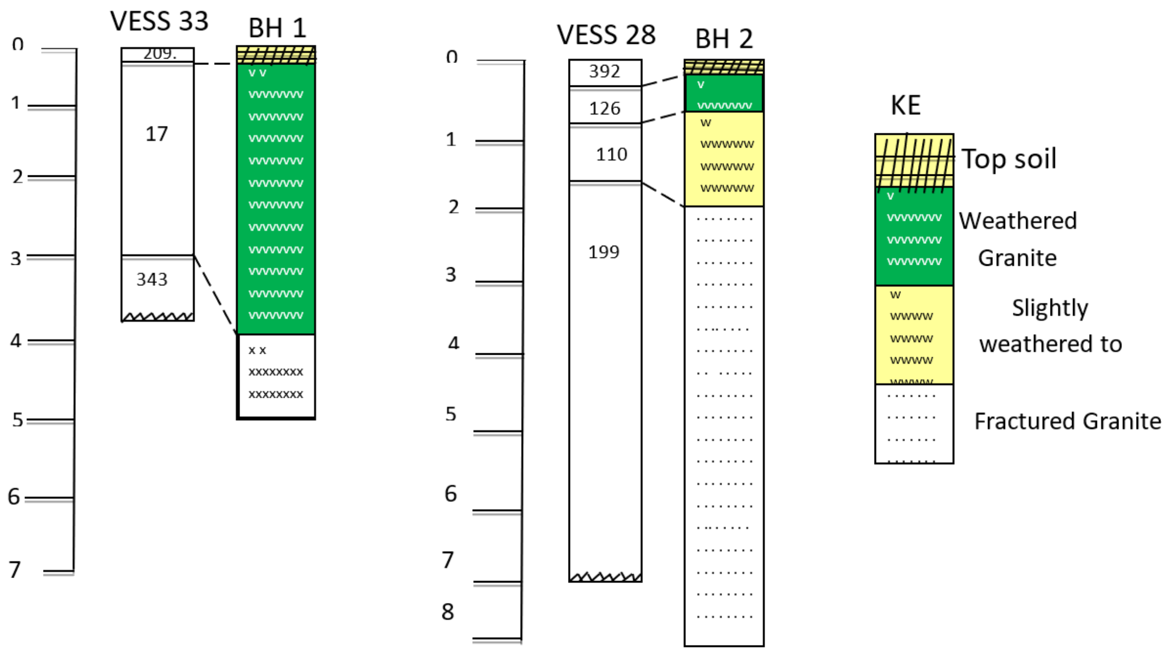

Fig. 4.7 Correlation of Geo-electric section and lithologic sections of boreholes (Adopted from Expert Drilling Company, 2020)

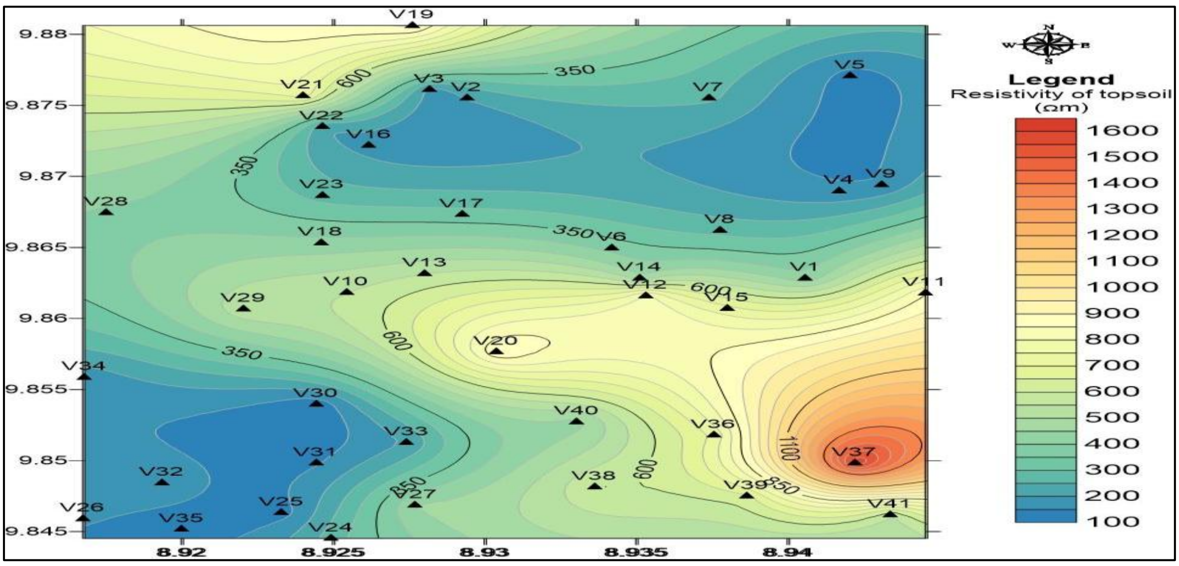

Fig 7: Iso Resistivity contour of topsoil

The Isopach resistivity and depth contour map generated (Figure 7). Low resistivity values between 100-400 ohm-m were inferred in the north eastern and south eastern part of the study area While higher resistivity of 500 - 1600 ohm-m was inferred in the south-eastern and north-western part of the study area. The high resistivity of the topsoil indicates that the layer is predominantly lateritic.

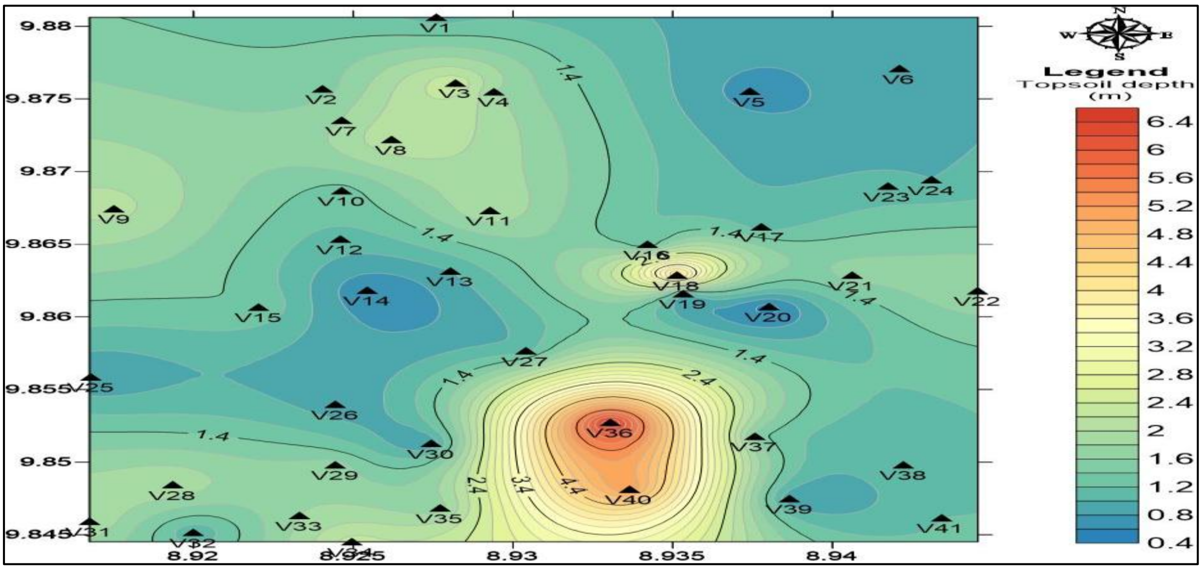

Fig 9: Isopach (depth) map of the Topsoil

The thickness of the topsoil ranges between 0 - 6.4m with the highest depth of 3.6 - 6.4m at the southern part of the study area (see Fig.9). The layer is generally thin in areas where the bedrock is near outcropping at the surface.

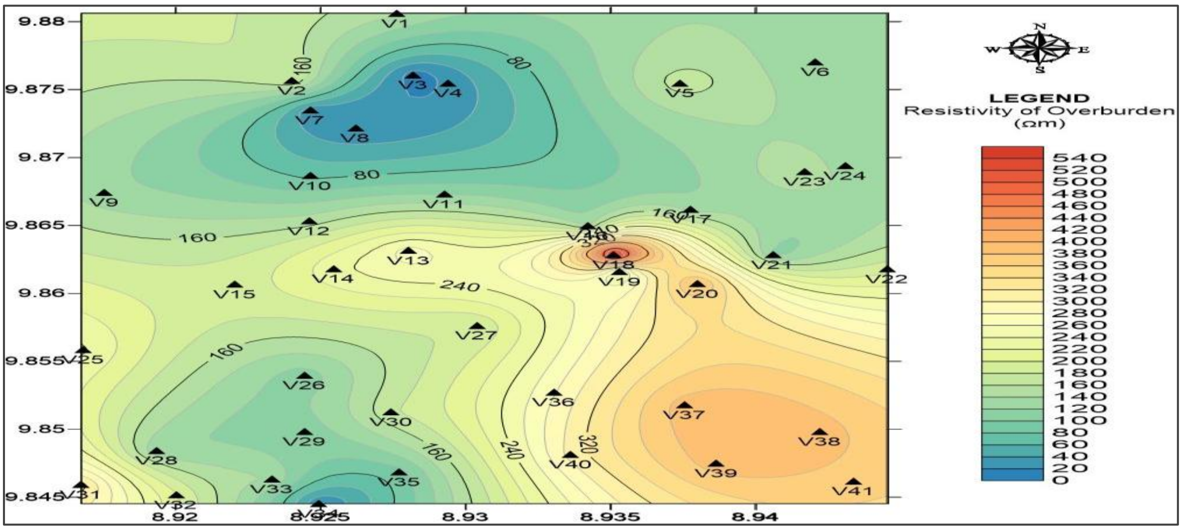

Fig10: Iso Resistivity contour of Overburden

This layer has resistivity range of 0 - 500 ohm-m along the north-western to south-western part of the study area (fig 10). The low resistivity characteristics in this type of layers are most-likely, controlled by its water saturation (Omosuyi and Enikaselum, 2003). A resistivity range of 0 - 150 ohm-m running through the North-Western to South-Eastern part of the study area with the lowest resistivity range of 0 - 40 ohm-m. However, this indication shows that the weathered layer is predominantly consisting of clays and sands. High resistivity values between 200 - 540 ohm-m were inferred around the South-Western running through the central parts of the study area with highest resistivity range of 500 - 540 ohm-m. The high resistivity value is an indication that the weathered layer consists predominantly of coarse-grained sands with little clays.

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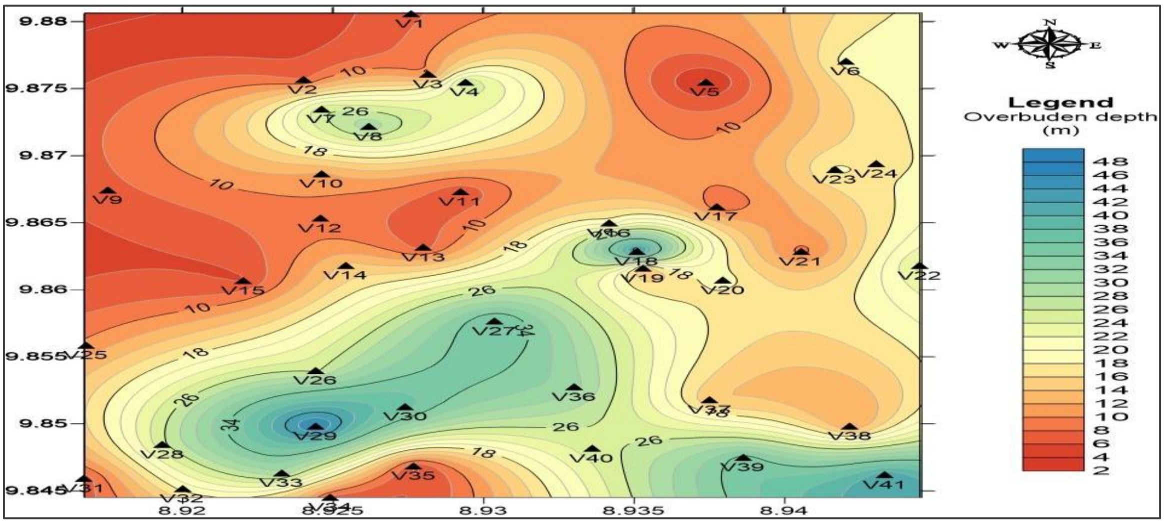

Fig11: Iso Isopach (depth) contour map of overburden

Fig 11: Generally, the inferred overburden thickness in the study area is moderate to high with a thickness varying between 0 - 48m. The isopach map shows areas with medium to thick overburden (>10 to 48 m) are predominantly located at the south-western, south-eastern, north-western to central part of the study area with highest depth of 34 - 48m on VES 18, 27, 30, 39 and 41 (Fig 11). Zones of thick overburden in basement terrain have been identified as areas of high ground water potential (Okhue and Olorunfermi, 1991). Therefore, these areas with thick overburden in the study area are preferential areas for the development of groundwater.

Weathering depth range of 0 – 10 m were inferred within the study area at north-eastern, north-western, eastern, western and some parts of the south-east, with lowest depth of 0-6m on VES 5, 15, 17, and 21. These areas are zones of low groundwater potential.

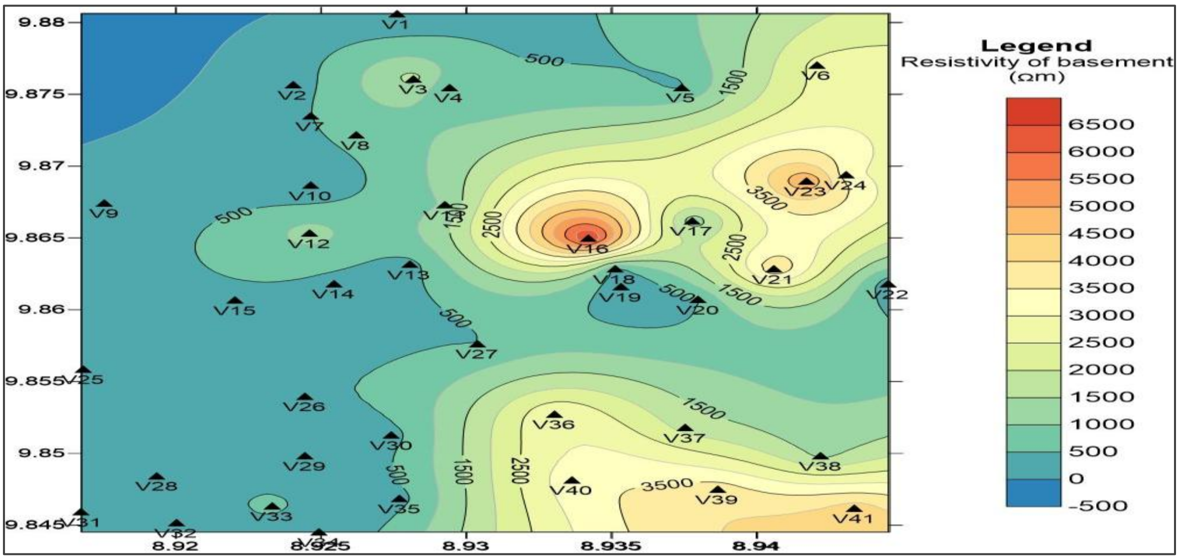

Fig 12: Iso Resistivity contour of basement

The bedrock is characterized by high resistivity values from 500 - 6500 ohm-m (Fig 12). Where there are bedrock outcrops within the study area, there is absent or thin overburden cover of 0.4 – 2 m as inferred in VES 5, 6, 12, 13, 14, 19, 20, 30 and 39. There is also indication of fractures in the basement as shown on VES 13, 19 and 31, this was further revealed in exploratory borehole BH2 (Fig 4.7).

II. Conclusion

Looking back on the entire research work, a draws conclusion from the findings was observed. On the basis of the conclusion drawn, recommendations for future groundwater investigation and development in the study area are proffered. The primary objective of this research is to assess the groundwater potential of Kwang community in Jos-South, Plateau state, Nigeria, utilizing the Electrical Resistivity Method (ERM). This investigation seeks to accomplish specific goals, including the determination of the subsurface lithology by analyzing geoelectric units or layers, inferring their depths and thickness through the electrical resistivity method. Furthermore,

Vertical Electrical Sounding (VES) technique was explored across the study area, employing the Schlumberger array and the SAS300B terrameter. The maximum current electrode spacing (AB/2) used for this survey was 165 meters. The data interpretation process revealed a diverse range of earth models with geoelectric layers varying from three to five. These layers were associated with characteristic curve types, including H, KH, HA, HK, Q, AH, and A types. Among these curve types, H and HK accounted for 56% and 17% of the sounding curves, respectively, while KH types constituted 12%, and HA and Q types each represented 5%. Additionally, 2% of the curves were categorized as A and AH types. The study area's subsurface was found to encompass distinct geological layers, such as topsoil/laterite, weathered granite, partly weathered/fresh granite, fractured granite, and the fresh basement. However, investigations revealed the generalized subsurface geo-electric layers/lithologic units to consists of Topsoil between a depth of 0 to 6.4 m and the resistivity range of between 100 – 1600 ohm-m, weathered layer with depth between 2 to 48 m and resistivity values ranging between 20 – 540 ohm-m, and the fresh/fractured bedrock at depths between 0.8 to ≥ 65 m and with resistivity values between 500 - 6500 ohm-m. The weathered and partially weathered/fractured zones and fractured bedrock constituting the aquifer units, these are combined in various ways to result in the weathered layer, partially weathered/fractured,and fractured (aquifers as the common aquifer types found in this study. The two-borehole lithologic log (BH1 and BH2) correlated well with the geo-electric parameters derived from the geo-electric sounding interpretations. It is recommender to alleviate the suffering of the inhabitants living in low groundwater potential areas, water from areas with high groundwater potentials could be harnessed, stored and supplied through pipe to neighbouring localities with little/low groundwater potentials. Therefore, drilling companies operating in the area should be encouraged to carry out standard water pumping test as part of their water development efforts and document the lithorologs. This will make vital hydrogeological data available for future hydrogeological studies on this area.

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