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DELINEATION OF GROUNDWATER POTENTIAL ZONES USING VERTICAL ELECTRICAL SOUNDING (VES) IN ROCK FORMATION SETTINGS IN GOMBE

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ABSTRACT

Many people depend on groundwater for their water needs as its quality significantly impacts human health and agriculture. The electrical resistivity method using vertical electrical soundings (VES) was carried out in the study area, which had geographical coordinates between latitude 100 15' 02" and longitude 11005' 00". A bima formation of Northeastern Nigeria's upper Benue trough complex underlies the area. The aim is to delineate potential groundwater areas in the Gombe Local Government. Twenty (20) VES were carried out using Schlumberger electrode array configuration with AB/2 from 1 to 300 m. The VES data generated were processed and interpreted using computer iteration software (WinResist). The interpreted data revealed five geoelectric sections with varied thicknesses and resistivity. The lowest resistivity value ranges from 44 to 181 Ωm, with a thickness value between 0.4 and 4m at the top soil layer. In contrast, the highest value of resistivity, 424.0 Ωm and above, was recorded at the weathered basement with a thickness of ∞ m value. VES stations 2, 7, 9,16, and 18 showed good groundwater potential, as revealed by the thick overburden and weathered layer with low resistivity values. VES stations 1, 4, 5, 6, 8, 10, 12, 13, 14, 15, and 17 showed moderate groundwater potentials, while VES stations 3, 11, and 20 are non-aquiferous. The comprehensive analysis of these parameters suggested the excellent quality of groundwater for irrigation and drinking purposes. The results provide significant insights for policymakers and decision-makers to develop measures to preserve the groundwater quality of the study area.

Keywords: Groundwater, Electrical resistivity, Geoelectric sections, Topsoil layer

INTRODUCTION

Dependable water supplies are essential to the development and civilisation of every nation, and their failure has created difficulties (Olasehinde et al., 2015). Life on Earth depends on the availability of water. Water can appear in three ways: rain, surface flow, and subsurface flow (Alkali et al., 2019). Because Nigerian regulatory bodies are negligent in conserving water and purifying it for sustainability, rain, and surface water are easily contaminated. As a result, the main supply of water for homes and drinking is groundwater (Adagunodo et al., 2018). Groundwater is the most dependable and widely utilised natural resource (Joel et al., 2020). It is sufficient for man, inexpensive, safe, and consistent in amount and quality when thoroughly explored (Sunmonu et al., 2016). It is an essential and vital component of our daily system and is often utilized for irrigation and drinking (Gugulothu et al., 2022). Since groundwater is the primary potable water supply in the areas where people live, it is essential to civilisation (Alkali et al., 2019). At the depth of soil pore holes or cracks, it becomes fully saturated with rock voids, creating a water table (Abiola et al., 2009).

However, natural and human effects often cause the decline of groundwater quality in many nations. Declining groundwater quality has a significant impact on human health and agricultural productivity (Wang et al., 2022). Ineffective groundwater management, uncontrolled industrial growth and waste management, urbanisation, rise in population, waste from cities, and random waste disposal are some of the primary variables leading to groundwater quality deterioration (Ravindra et al., 2022). It is imperative to comprehend the groundwater stratigraphic structures before their terrain supply can be efficiently utilised through boreholes or wells (Olasehinde et al., 2015).

Worldwide, different techniques have been applied for groundwater research, from conventional approaches like the fracture trace method and borehole drilling to the application of geophysical techniques like magnetics, electrical resistivity, electromagnetics, radiometric, seismic, and many more (Rauff, 2020). Furthermore, geophysical techniques have long been able to map the depth of the groundwater table. Many researchers (Joel et al., 2020; Sunmonu et al., 2016; Umar et al., 2021) have also successfully used the resistivity approach to examine groundwater on sedimentary and foundation terrains.

Because of the increase in population in the study area (Gombe metropolis), the lack of public water and unequal water distribution has raised concerns about safe water sources. The total reliance of the settlements on surface water and the massive demand for water resources resulting from the continuous expansion have caused insufficient water supply. Thus, the community must look for groundwater resources as an alternative to meet the demand for water resources for residential usage and other related applications. Mapping the terrain of the community's groundwater potential system with the application of Vertical Electrical Sounding (VES) helps drill boreholes. Therefore, this present study uses VES to accurately investigate groundwater potential zones in some inter-bedded study areas of the Gombe metropolis in Gombe State to address the inadequate water supply experienced in the area. Due to the complex lithological, geological, topographical, and soil conditions in the Gombe, research on groundwater quality has been limited. The study aims to analyse groundwater around the study areas using the VES of the electrical resistivity method.

MATERIALS AND METHODS

Geology of the Study Area

The Federal Military Government of Nigeria divided the erstwhile Bauchi State into Gombe State on October 1, 1996. Adamawa State borders Gombe State on the south, Yobe and

Taraba States on the north, Bauchi State on the west, and Borno State on the east, as presented in Figure 1. The terrain of Gombe State is primarily composed of flat, open plains in the west and mountains, hills, and undulations in the southeast. Additionally, Gombe State's hills feature stunning dome-shaped rock formations with captivating landscapes that make them perfect for hiking and climbing (Mayomi et al., 2016, 2018). The geographical coordinates of the study area lie between the latitude of 10^0 15′ N and 10^0 25′N and longitude of $11^0$10′ E and $11^0$16′E Figure 1.

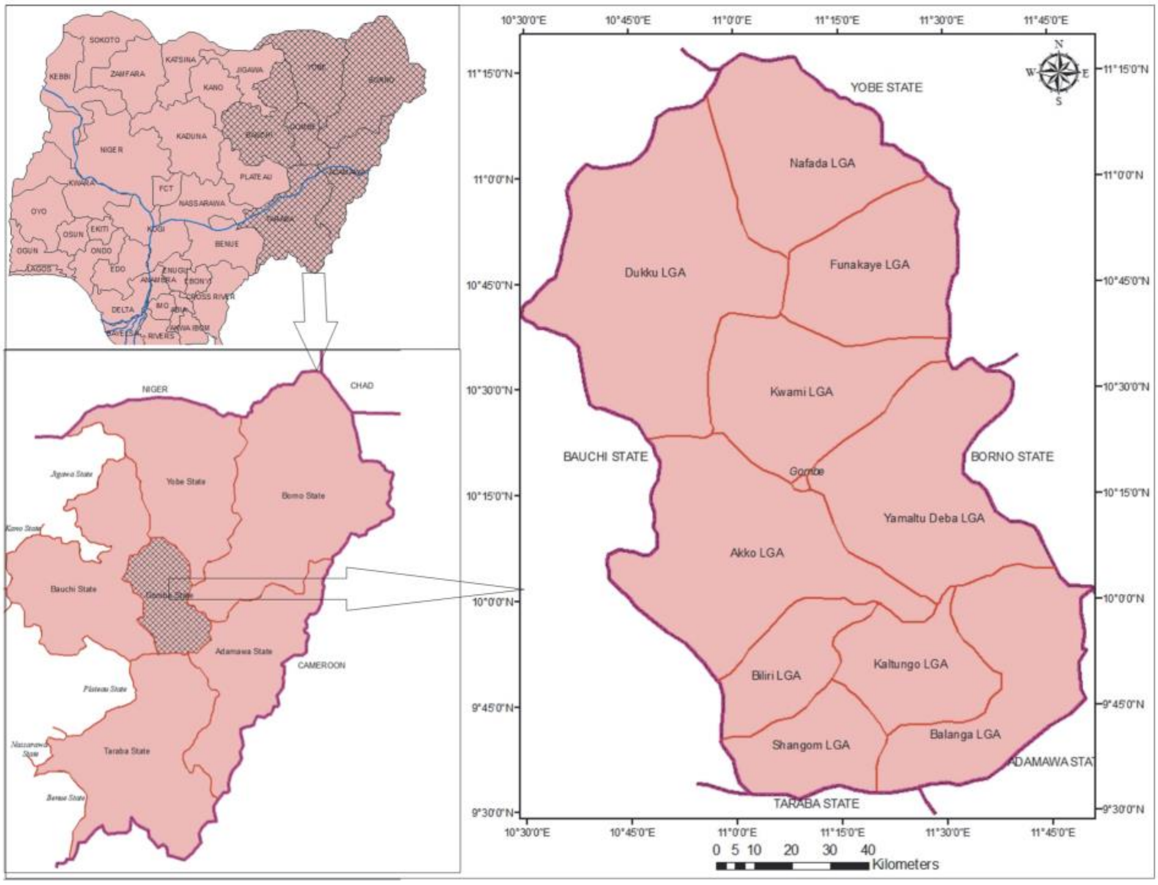

Figure 1: The geographical location of the study area

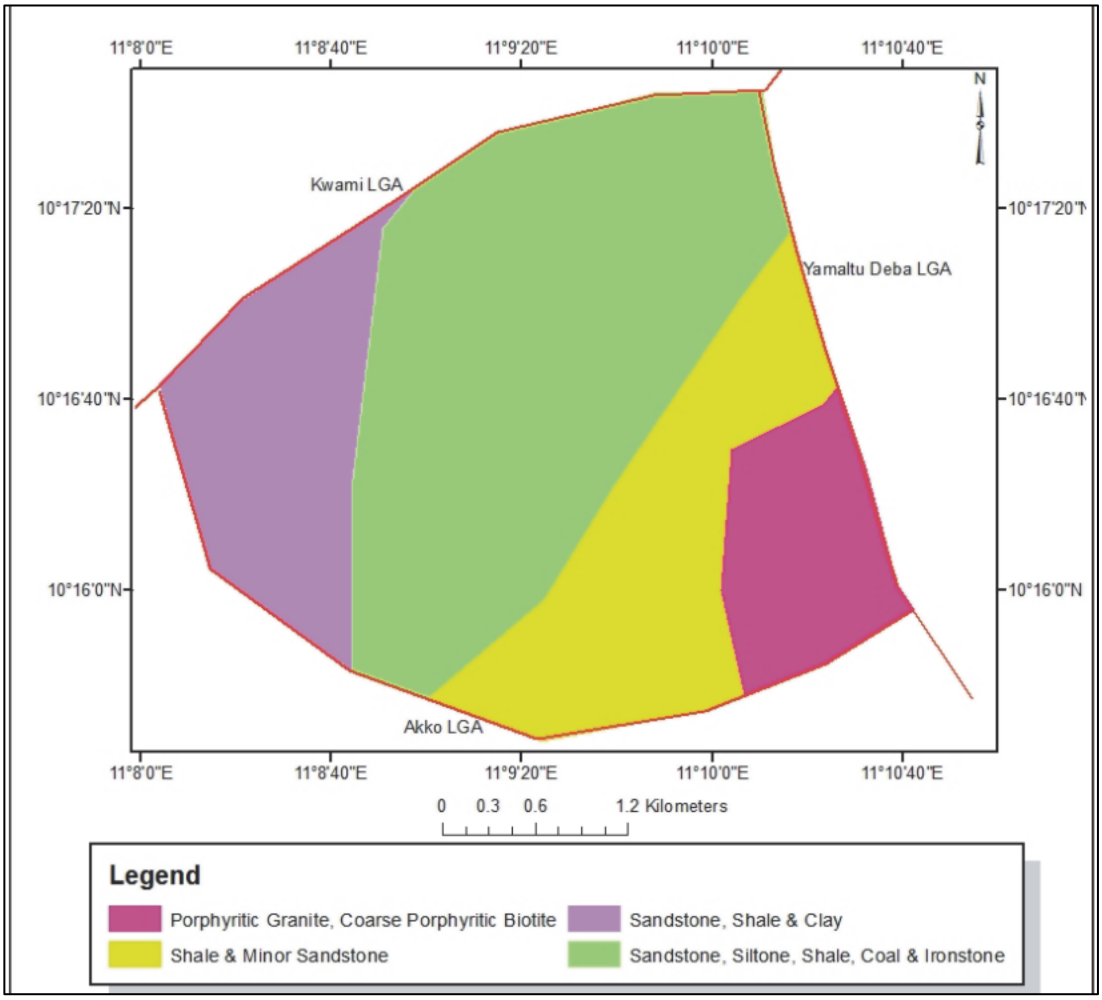

Figure 2: The geology's spatial distribution in Gombe town

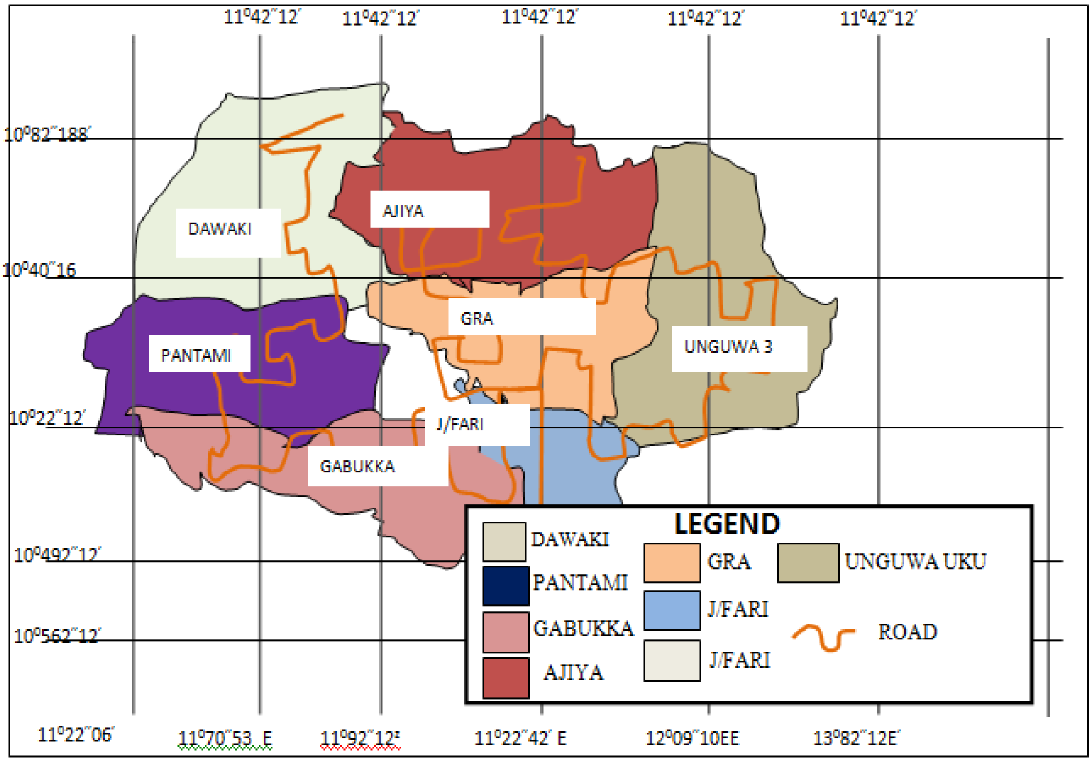

Figure 3: The survey locations

Methodology of Vertical Electrical Sounding (VES)

When investigating geologic environments with horizontal or almost horizontal layers, such as those found in unconsolidated sedimentary sequences, the vertical electrical sounding (VES) method is typically considered more appropriate. The finding and completion of water wells in bedrock regions with complex hydrogeology can be substantially aided by vertical electrical soundings in conjunction with other geophysical techniques, geologic mapping, and accessible sound data. As other authors have utilised (Rauff et al., 2022; Sunmonu et al., 2016), a maximum current electrode spacing of AB = 300 m was employed with the Schlumberger array electrode arrangement for adequate current penetration depth. In groundwater application, a contrast exists of resistivity between subsurface layers bearing water and dry non-water bearing layers. This makes it possible to detect these layers and estimate their depth. Since lithology mainly controls the obtained data, hydrogeological research frequently uses electrical resistivity. The Direct Current (DC) resistivity method is the most often utilised. The equipment from the ABEM 4000 series was employed to calculate and show the mean apparent resistivity for the selected electrode configurations. The concept is that current is sent into the ground via two electrodes, affecting the potential distribution around these two current electrodes.

In contrast, the potential drop is measured using another pair of electrodes. The ground resistance, a function of water content, is calculated using the current transmitted and the voltage measured. The technique used for this is called Vertical Electrical Sounding (VES), and it is based on the assumption that more profound layers of the Earth are where potentials are higher because more current flows through them as electrode spacing increases. This allows for the modification in resistivity depth—this way, a variation of resistivity depth can be obtained. The Schlumberger setup was used to conduct 20 VES points to examine the groundwater potential, aquifer protective capacity, and aquifer features of the subsurface layers within the study area. After the tetrameter readings were taken and analysed, the partial curve was modelled using WinResist2 software (1D inversion algorithm). This significantly reduced the interpretation errors in vertical electrical-sounding data (Adagunodo et al., 2018).

RESULTS AND DISCUSSION

Figures 1-6 present the results obtained from VES curve types in the study with their respective values of resistivity and thickness against the depth. Some of the modelled curves were generated by the application of WinResist software.

Geoelectric Parameters

Geoelectric parameters are interpreted from geophysical (electrical) resistivity survey data. Interpretations of vertical electrical sounding data using WIN-Resist2 software lead to the generation of geo-electrical layers. The information from these geoelectric layers enhances the identification and understanding of layer parameters, including the number of layers and their apparent resistivity, thicknesses and depth, and curve type.

Table 1 displays the summary of the interpreted electrical resistivity study. Based on the interpretation of the geoelectric data, the following geoelectric units have been established from the study area: high, reasonably high, medium, and low resistivity layers, which also correspond to their respective inferred lithologies. The top soil, lateritic layer, and highly worn and fractured layer of shale comprise most of the subsurface geology in the area under investigation. Some regions may have limited potential for aquifer formation or water storage, as evidenced by not all of the examined VES locations displaying ideal circumstances for groundwater development.

Table 1: Layers Resistivity, Thickness and Curve Types

VES Station	ρ_1	Layer ρ_2	Resistivity ρ_3	(Ohms) ρ_4	ρ_5	h_1	Layer h_2	Thickness h_3	(m) h_4	Curve type
1	54	139	43	225		1.0	2.90	3.8		KH
2	103.1	71.5	25.3	27.1		2.9	28.6	61.7		QH
3	89	174	20	1091		0.8	2.0	7.4		KH
4	30.0	7.1	335.5	69.6	90.7	3.3	7.2	45.8	25.4	HA
5	100	43	307			2.0	7.1			H
6	204.1	24.5	241.8	109.3	215.9	5.7	21.9	47.3	24.8	Hs
7	53	123	48	280		0.7	4.2	4.8		KH
8	59	122	48	565		0.8	2.5	6.7		KH
9	79.6	41.9	57.5	63.7	91.7	6.0	21.8	16.7	17.7	HA
10	69	50	148	269		1.3	4.5	2.5		HA
11	60	24	310	2945		0.8	2.2	1.4		HA
12	38.8	3.4	323.1	35.1	50.1	1.1	3.3	70.6	22.6	KHA
13	10.1	71.5	25.3	27.1		2.9	25.0	33.1		HK
14	63	174	50	1191		0.8	2.0	7.4		KH
15	45.0	5.1	37.5	69.6	90.7	3.3	7.2	45.8	25.4	KH
16	21.1	276.3	47.3	123.5	158.12	2.5	7.8	29.7	41.5	HKA
17	89	174	20	1091		0.8	2.0	7.4		KH
18	300.0	7.1	395.5	619.6	90.7	3.3	7.2	45.8	25.4	QA
19	432.8	89	31	800.87	280	1.5	15.1	9.0	5.89	KHA
20	204.1	24.5	241.8	109.3	215.9	2.7	25.9	47.1	24.8	KHA
Mean	**105.24**	**82.25**	**137.78**	**511.15**	**142.65**	**2.21**	**10.02**	**26.00**	**23.72**	

VES-Vertical Electrical Sounding ρ-Layer resistivity h-Layer thickness, m-meter

The 3-layer geoelectric section is characterised by H and QH curve types (Figures 1 and 2). It is generally comprised of topsoil, Lateritic layer, sandstone, and Highly weathered layer soil with variable thicknesses and resistivities as presented in Table 1.

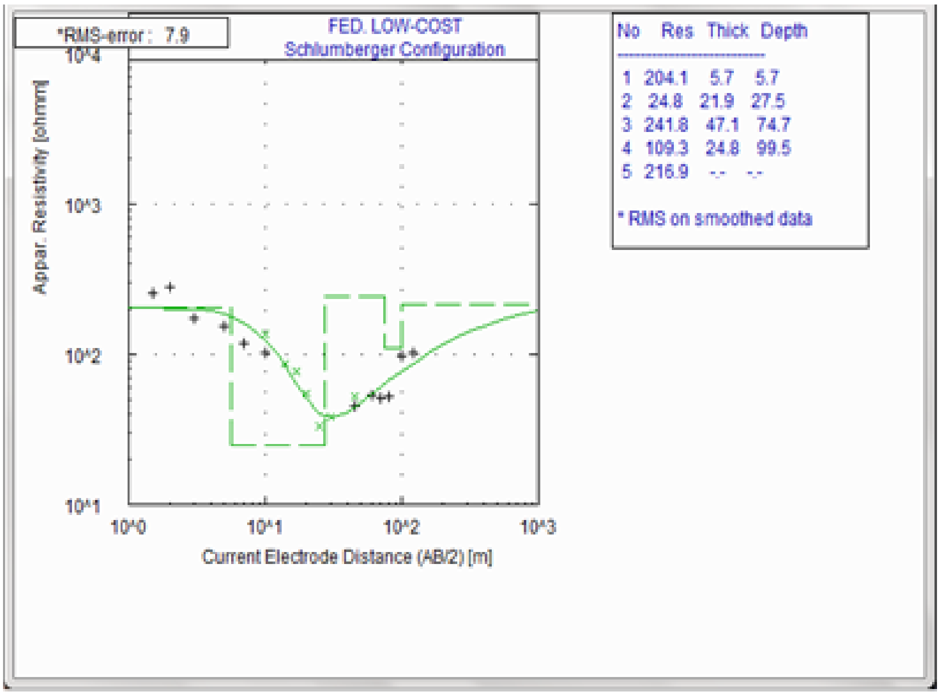

Figure 4: Typical H curve at Federal Low Cost, Gombe

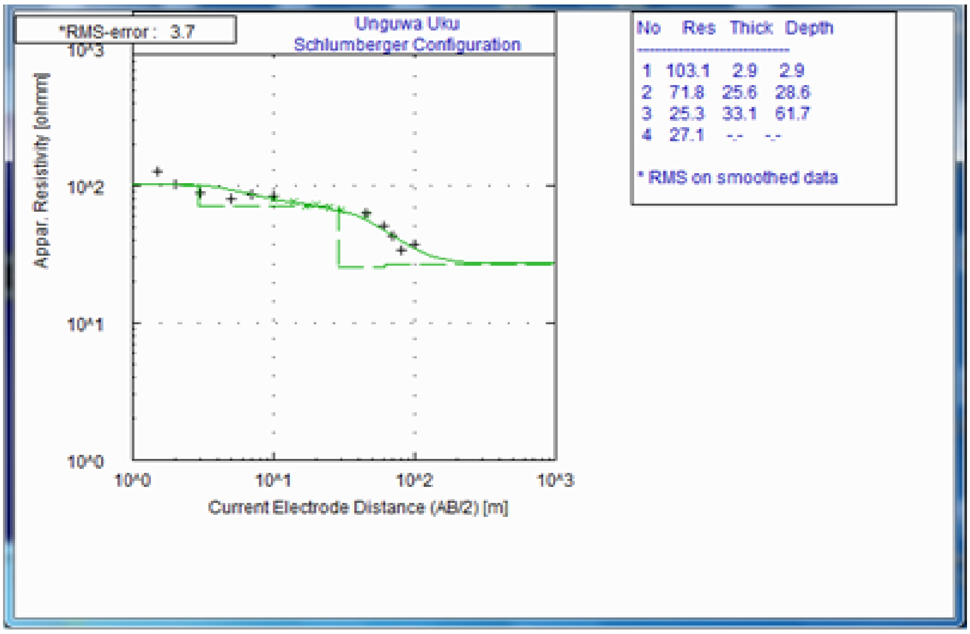

Figure 5: Typical QH curve type at Unguwa Uku, Gombe

Figures 5, 6, 7, 8, and 9 show that KHA and HA curve types describe the 4-layer geoelectric section. As also shown in Table 2, they are made up of Topsoil, Lateritic layer, sandstone, and fresh basement.

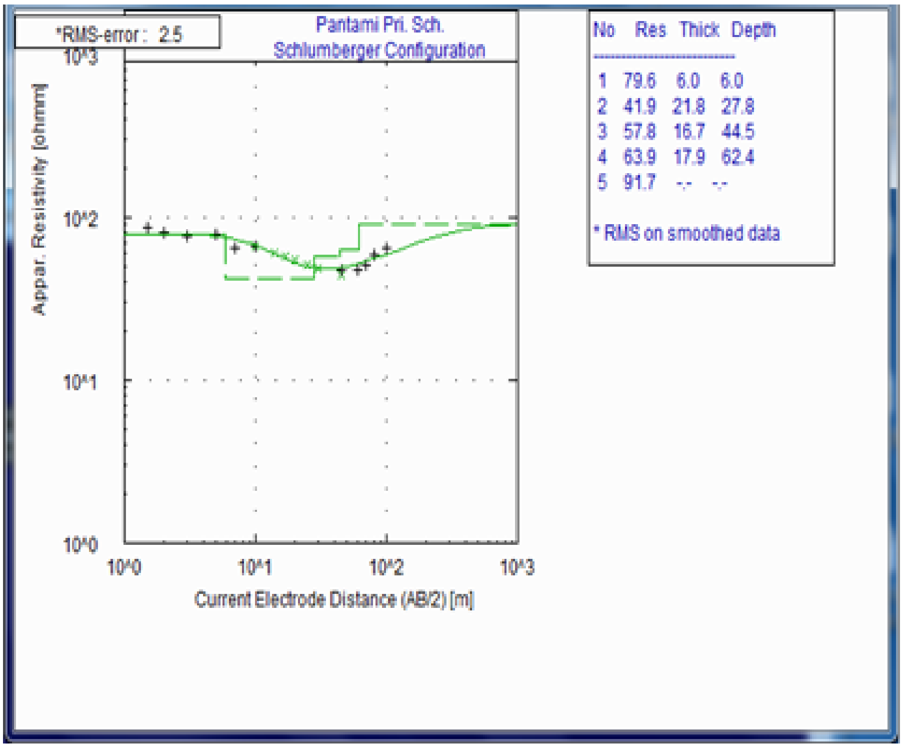

Figure 6: Typical HA curve at Pantami Primary School, Gombe

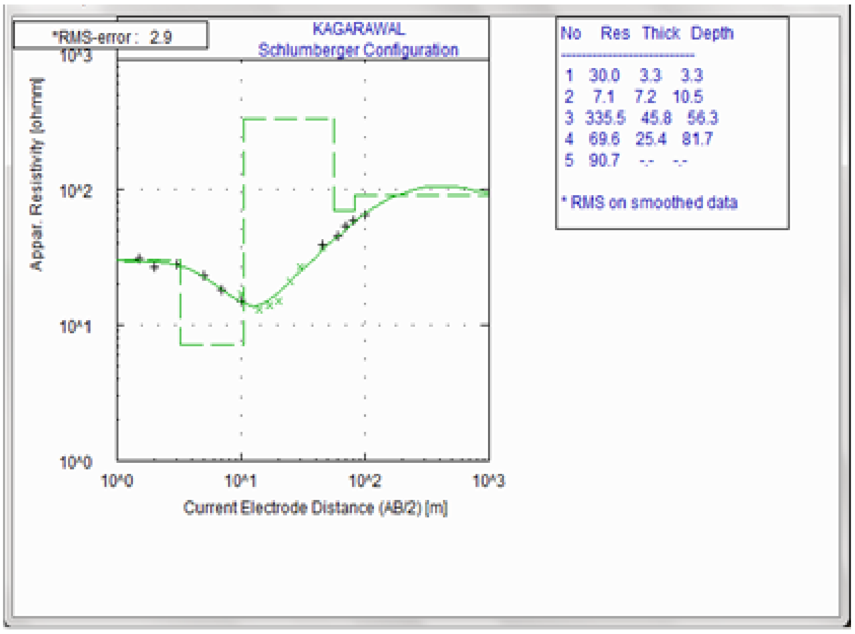

Figure 7: Typical HA curve at Kagarwal, Gombe

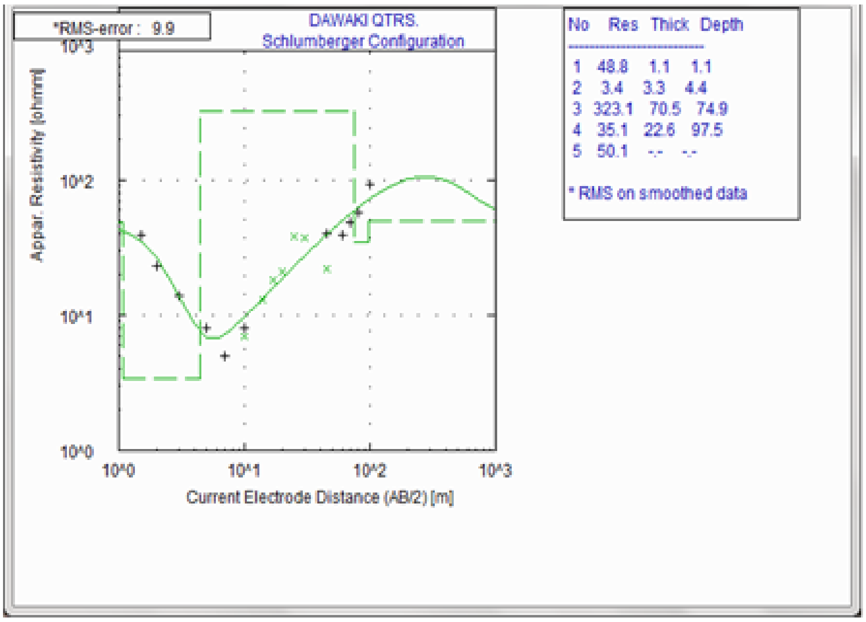

Figure 8: Typical KHA curve at Dawaki Quarters, Gombe

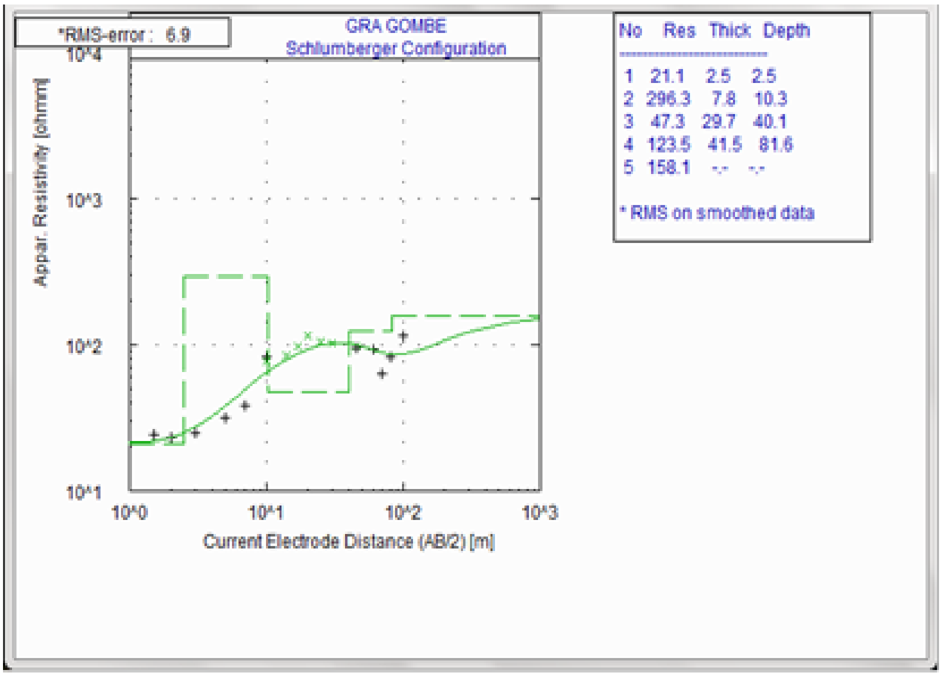

Figure 9: Typical KHA curve at Government Reserved Areas (GRA), Gombe

Near pre-existing boreholes, vertical electrical sounding (VES) stations were installed. The lithologic logs of the nearest boreholes were compared with the inferred lithologies and thicknesses of the different strata from the subsurface geoelectric sections of these VES stations. It was discovered that they have a strong correlation. The groundwater potentials in the research area were evaluated using the following indices: weathered layer thickness and resistivity, overburden thickness, transverse resistance, coefficient of anisotropy, reflection coefficient, and resistivity contrast. The topsoil layer comprises lateritic soil, loose sand, clay, and sandy clay. Its thickness ranged from 0.7 to 6.0 m, with a mean value of 2.21 m, and its resistivity ranged from 10.1 to 432.8 Ωm, with a mean value of 105.24 Ωm. The weathered layer beneath the topsoil layer has a 2.0 to 28.6 m thickness with an average of 10.02 m and a resistivity of 5.1 to 276.3 Ωm with an average of 82.25 Ωm. Beneath the weathered layer is a fractured layer with a thickness varying from 3.8 m to 70.6 m with a mean of 26.00 m and a resistivity ranging from 20 Ωm to 375.5 Ωm with a mean of 137.78 Ωm. The thickness of the final layer from the surface ranges from 17.7 m to 41.5 m, with a mean value of 23.72 m. The resistivity values also vary from 50.1 Ωm to 215.90 Ωm, with a mean value of 142.65 Ωm. The aquiferous units, which have noticeable thicknesses in the basement area, comprise this layer and the weathered layer. The weathered layer makes up the aquifereous units. Areas with weathered layer thickness ranging from 17.7 m to 41.5 m and resistivity values ranging from 50.1 Ωm to 215.90 Ωm are identified as having high groundwater potential. The trend of this research is similar to other reserchers output (Adeniji1 et a1., 2013).

CONCLUSION

It has been demonstrated that the groundwater potentials of a basement terrain can be effectively classified by integrating several electrical resistivity metrics. Conjunctive use of surface water should be promoted to lessen total reliance on groundwater, and groundwater developments should be centred in areas with high groundwater potential. Typically, groundwater is found in basement complex areas in irregular aquifers. Due to the complex characteristics of the basement rocks, defining the aquifers' potential generally is exhausting. This project used the electrical resistivity sounding method using the Schlumberger array configuration to explore the study area. The work was carried out in Gombe state at Twenty locations, all within Gombe L.G.A. This work provided a general overview of the Geoelectric Resistivity Survey for the Groundwater potential of the study area. The promising wells from the resistivity survey were mapped based on the nature and properties that constitute the aquifer layer and the overburden material and thickness. For successful groundwater exploration, whether for domestic, agricultural, or industrial uses, pre-drilling information is necessary to determine the depth and yield of the groundwater location. A vertical electrical sounding method was applied, and the results delineated different geoelectric sections correlated with available borehole logs to determine their corresponding geological formations. Detailed knowledge of the aquifer layer and the lithology composition in any successful borehole drilling project is paramount and essential and cannot be ignored. Different geological formations have different groundwater yield potential; therefore, understanding these formations in groundwater exploration becomes imperative. This study adopts Vertical Electrical sounding in twenty locations group, of which all the stations are located in Gombe L.G.A of Gombe State using Schlumberger array and earth resistivity meter; with terra meter omega 1000, which displays apparent resistivity values digitally as computed from Ohm's law. The resistivity results were processed using WINRESIST software. Sounding curves were plotted as apparent resistivity against the electrode.

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