Geo-Electric Investigation of Aquifer Characteristics and Ground Water Potential in Kafin Hausa, Jigawa State, Nigeria

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Abstract

In this paper, a geoelectrical study using Vertical Electrical Sounding (VES) technique of Schlumberger Array was carried out in Kafin Hausa, Jigawa State, Nigeria with a view to determining groundwater potentials and aquifer characteristics of the study area. During the study, the half current electrode separation (AB/2) ranged from 1.0 to 100mwhile the half potential electrode spread (MN/2) varied from 0.2 to 8.0 metres. A total of thirty-two (32) soundings were conducted using Alied Ohmega Terrameter. The data acquired has been processed and interpreted using IPI2winand Surfer software. The results of the study show three to five geoelectrical layers corresponding to clay, sandy clay, clayey sand, medium-coarse grained sand and coarse-grained sand, The result further reveal that VES 4, 5, 8, 14, 16, 19, 21, 23, 24 and 25 have thicknesses of 48.04m, 22.3m, 21.2m, 20.6m, 26.33m, 21.9m, 20.7m, 22.6m, 54.8m, and 19.1m and depths of 62.27m, 24.2m, 24.6m, 26.5m, 30.64m, 26.2m, 33.7m, 33.5m, 56.9m, and 22.4m, respectively. These VES locations constitute good aquifer zones and are therefore recommended for drilling of boreholes having moderate to high yields. VES 17 and 29, however, did not meet the hydro geophysical conditions for occurrence of groundwater within the vicinities of the VES point and are thus not recommended for drilling.

Keywords: Aquifer characteristics, geo-electrical layer, groundwater potential, Schlumberger configurations, vertical electrical sounding.

INTRODUCTION

Kafin Hausa lies in the north-eastern part of Jigawa state, in north-western Nigeria. It shares borders with Bauchi state to the south and east, as well as Auyo local government to the north. To the west, Kafin Hausa is bounded by Dutse emirate, Miga, Jahun and Kiyawa Local Governments. The area has a rapid population growth largely owing to establishment of a state-owned public university. The rising population has caused scarcity of water hence the need to explore new sources including ground water, In addition, unprotected shallow dug wells and boreholes are the dominant water sources. Groundwater is the water that lies below the ground surface, filling pore space between grains in bodies of sedimentary rock and filling cracks and crevices in basement rocks (Plummer, 1999).

Lawrence *et al.*,(2012) identified groundwater to be generally free from contamination, odour and colour. Many techniques have been used in investigations of groundwater by researchers (Emmanuel *et al*., 2017; Evans *et al*., 2017; Mohamaden *et al*., 2016; Emmanuel *et al*., 2011; Oseji *et al*., 2005). In the past decades, studies have shown that exploration of

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groundwater using electrical resistivity methods has been the commonly adopted technique due to its ease of implementation in the field and high accuracy (Asare and Menyeh, 2013;Dogara *et al*., 1998; Olorunfemi and Olorunniwo, 1985). Groundwater potential and aquifer characterization study has been conducted successfully in Southern Obubra, South eastern Nigeria using the resistivity method (Peter, 2013).

However, the electrical resistivity technique has improved the chance of drilling successes by identifying fractured and weathered zones in these areas (Akhter and Hasan, 2016; Faleye and Olorunfemi, 2015; Olorunfemi and Olorunniwo, 1985). The use of this technique for groundwater exploration has therefore earned an important place over decades despite some interpretive limitations. The main aim of this research is to identify good aquifer zones and evaluate groundwater potentials in Kafin Hausa.

STUDY AREA

Kafin- Hausa is among 27 Local Government that constitute Jigawa State with administrative headquarters in the town of Kafin Hausa and it falls under Hadejia emirate. It has an area of 1,380 km^2 and lies approximately between latitudes 11.0^0 N to 12.0 ^{0} N and longitude 9.0 ^{0} E to 10.0^0 E, (see figure 1) with a population of 271,058 at the 2006 census. It is served by Federal road; linking it to Katagum on the south and Jahun on the west. The topography of the area is a relatively flat surface.

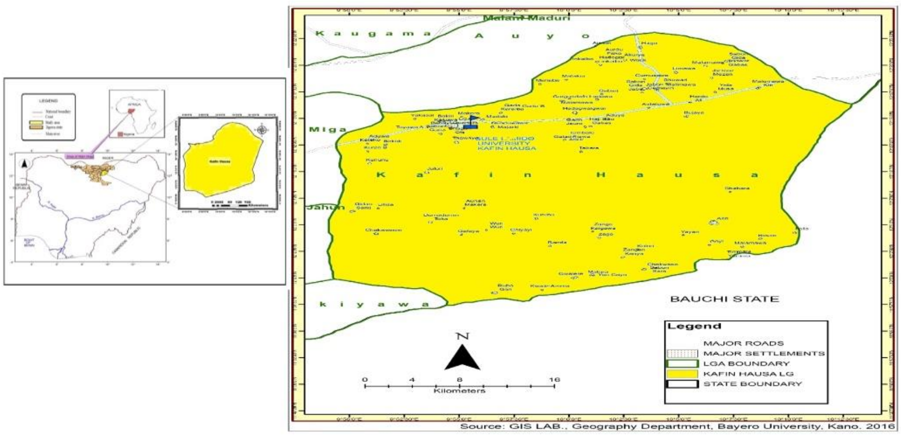

Figure 1: Location Map of Kafin Hausa

GEOLOGY

Kafin Hausa geological surface is covered by quaternary chad formation deposits of clay, clayey and sandy clay. These shows upland areas are dominated by clay soil while loamy-sands are found in the depressions. Groundwater availability is related to the climate change, which is determined by the amount of rainfall in each year.

MATERIALS AND METHODS

A total of thirty two soundings using Schlumberger Array were carried out in the study area. The instrument used was Alied Ohmega Terrameter. Some of the features of Alied Ohmega Terrameter include a digital display of data such as Self Potential (SP), Resistance(R). It is chargeable, portable and it has the ability to automatically compensate for polarization at the electrodes. Other devices and materials used are connecting wires on wheels, potential and current electrodes, hammers, measuring tapes and geographical positioning system (GPS). Figure 2 shows the VES survey setup. The field work was done on 11th and 12th January, 2017.

Figure 2:VES Survey Set Up

In this study, the geometric factor used is expressed as:

$$K = \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{\left(\frac{MN}{2}\right)} \right] \pi, \quad (1)$$

where AB and MN are current and potential electrodes separation, respectively.

The apparent resistivity ρ_a is calculated using Ohm's law equation given by:

$$\rho_a = RK, \quad (2)$$

R is the resistance and K, the geometric factor.

The Survey data was interpreted using IPI2Win inversion software. The VES sounding curves were obtained by plotting apparent resistivity values against current electrodes spacing (AB/2). Curve matching method was used to give qualitative and quantitative interpretation of plotted sounding curves. Thirty two soundings were conducted at the following sites: Ashura Quaters VES 01, Female Hostel SLU VES 03, Secretariat KHS VES 09, Unguwan Dawasa VES 11, Kangiwa VES 13, Gambawa VES 15, Kangiwa 2 VES 16, Turawa VES 19, Kasuwa VES 21, Kasuwa2 VES 25, Tamburawa VES 28, Tamburawa Opp Hosp. KHS VES 30 and KHS Hospital Main Gate VES 31.

RESULTS AND DISCUSSION

Table 1 shows geoelectrical soundings obtained within the thirty two locations in the study area. Figure 3, 4 and 5 shows calculated apparent resistivity plots against half current electrodes separation (AB/2) for VES 13, 28 and 3 locations, respectively. The result revealed three to five curve types namely; A, H, HK, K, KH, and Q, respectively. K-types represent 28%, 25% shows KH-types and 22% belong to H-types curve while 25% curves types represent A, Q, and HK-types within the study area.

ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 4 No. 2 December 2018*

Table 1: VES NO. 13 at Unguwan Kiginawa, Opposite Dan Bartso dump site

Instrument:	**Alied Ohmega Terrameter**	**VES NO:**	**13**
Northern(N)latitude:	12°14′32.1″	**Elevation:**	360m
Eastern(E) Longitude:	009°54′52.0″	**Azimuth:**	N/S
L.G.A:	Kafin Hausa	**State:**	Jigawa
Location:	Unguwan Kiginawa, Opposite Dan Bartso dump site	**Date:**	11/03/2017

S/N	MN/2 (m)	AB/2(m)	SP (mV)	K(m)	R(Ω)	P_a (Ωm)
1.	0.5	1.50	79.53	6.28	2.040	12.81
2.	0.5	2.50	78.72	18.80	0.540	10.15
3.	0.5	4.00	78.52	49.50	0.201	9.95
4.	0.5	6.00	78.52	112.00	0.097	10.86
5.	0.5	8.00	78.52	200.00	0.041	8.20
6.	0.5	10.00	78.72	313.00	0.026	8.14
7.	0.5	15.00	78.92	706.00	0.008	5.65
8.	2.5	15.00	98.81	137.00	0.068	9.32
9.	2.5	20.00	86.84	247.00	0.037	9.14
10.	2.5	25.00	79.33	389.00	0.029	11.28
11.	2.5	32.00	74.26	639.00	0.025	15.98
12.	2.5	40.00	69.95	1001.00	0.025	25.03
13.	8.0	60.00	189.2	694.00	0.048	33.31
14.	8.0	80.00	89.47	1244.00	0.056	69.66
15.	8.0	100.0	89.97	1951.00	0.069	134.62

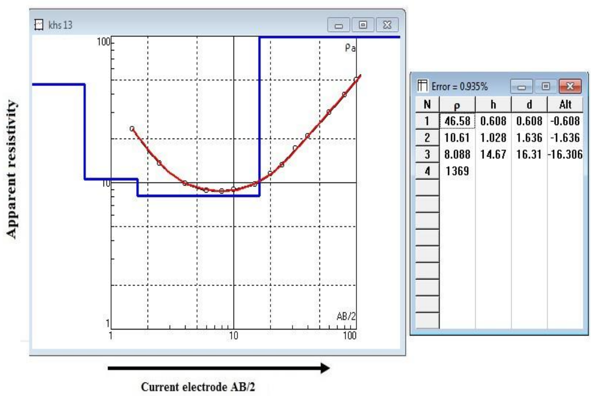

Figure3: VES13 sounding curve.

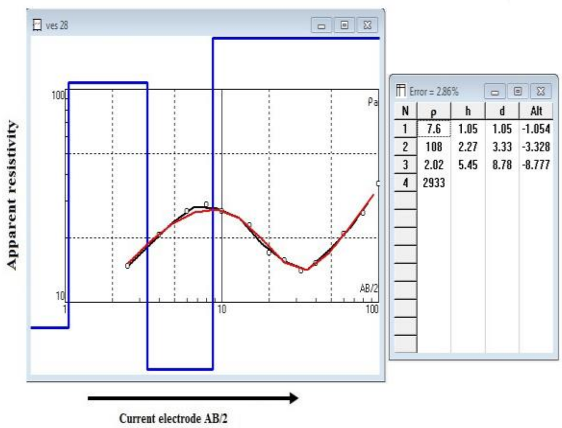

Figure4: VES28 sounding curve.

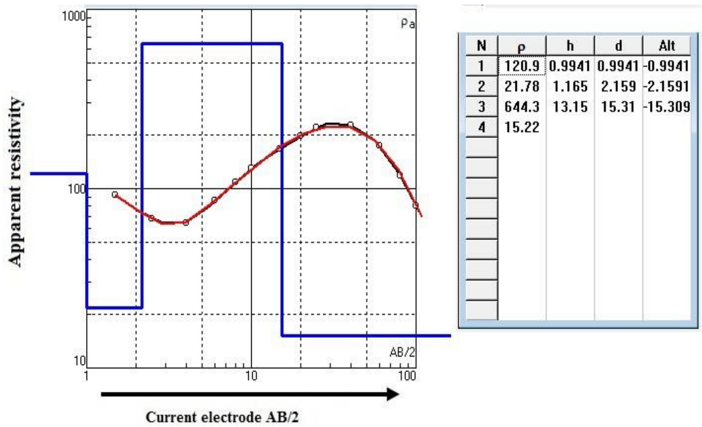

Figure5: VES3 sounding curve.

Table 2 and 3 shows resistivities, thicknesses, depths, curve types and probable lithology of selected VES locations. The locations of VES 8, 16, 17, 20, 24, 27, 30 and 32 are made of 3 layers with resistivities ranging between 0.0511Ωm to 25497Ωm with 0.967m to 54.8m thickness and 0.967m to 56.9 m depth while VES 4, 5, 7, 13, 15, 19, 23, 25, 28 and 29 are 4 layers ranging resistivities from 0.27 Ωm to 36367 Ωm, with 0.572m to 48.04m thickness and 0.572m to 62.27m depth. Figure 6 and 7 shows the aquifer thickness map contoured at 5cm interval and the overburden thickness map Contoured at 0.2cm interval of the study area. A comparison between aquifer thickness map and the overburden thickness map reveals that areas of low aquifer thickness corresponds to shallow basement depth and areas with large aquifer thickness corresponds to larger basement depth. Areas with large aquifer thicknesses are more likely to retain good quality of ground water.

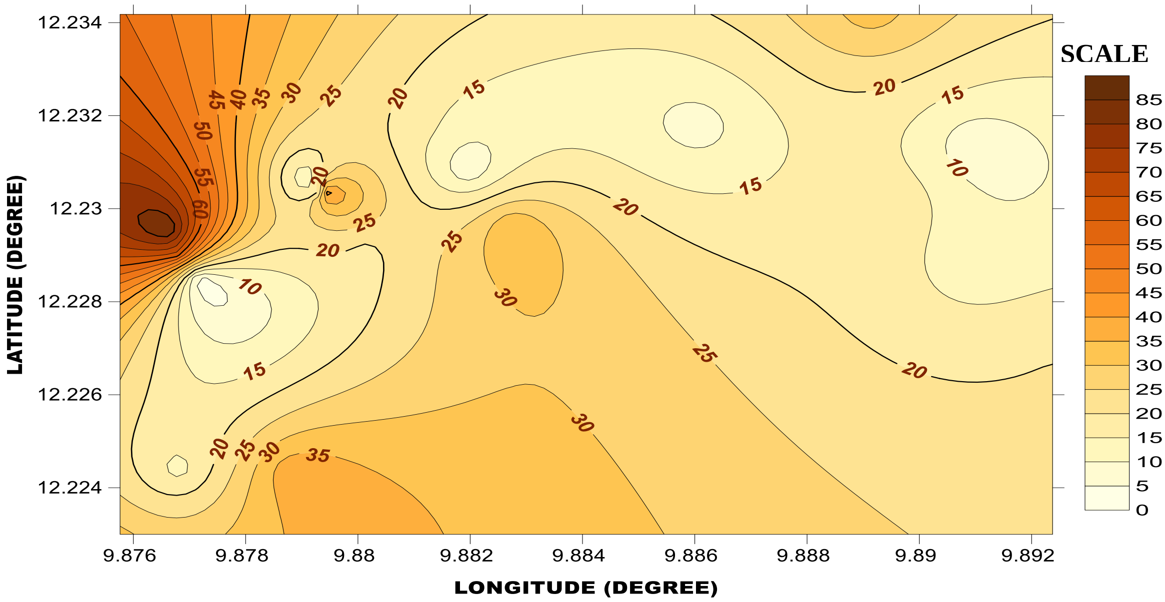

Figure 6: Aquifer thickness contour map of the study area.

ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 4 No. 2 December 2018*

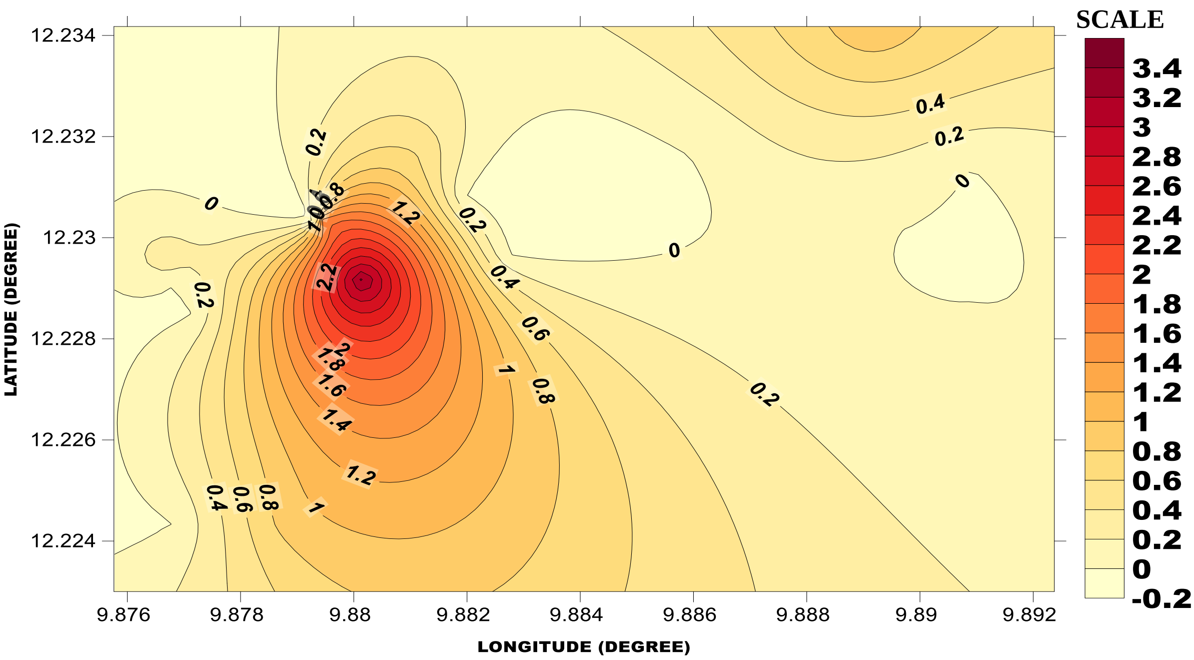

Figure 7: Overburden thickness contour map of the study area.

Table 2: Layer, Curve Types, Resistivities, Thickness and Depth of Selected VES locations

Location	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Curve type	Probable Lithology formation
VES4	4	139.6	0.6324	0.6324	Q	Clayey sand
		181.8	13.6	14.23		Clayey sand
		18.66	48.04	62.27		Clay
		0.27	-	-		Clay
VES5	4	75.7	0.572	0.572	K	Sandyclay
		3681	1.33	1.9		Coarse sand
		35.9	22.3	24.2		Clay
		14.9	-	-		Clay
VES7	4	118	1.5	1.5	KH	Sandy clay
		1231	2.104	3.604		Medium sand with coarse sand
		54.19	17.21	20.82		Sandy clay
		1771	-	-		Coarse sand
VES8	3	234	3.42	3.42	Q	Fine sand
		81	21.2	24.6		Sandy clay
		0.123	-	-		Clay
VES13	4	46.58	0.608	0.608	H	Clay
		10.61	1.028	1.636		Clay
		8.088	14.67	16.31		Clay
		1369	-	-		Medium sand with coarse sand
VES14	5	8.8	0.765	0.765	KH	Clay
		42	1.49	2.26		Clay
		1.57	3.64	5.9		Clay
		36.3	20.6	26.5		Clay
		0.275	-	-		Clay
VES15	4	27.09	0.9	0.9	KH	Clay
		456.5	1.11	2.01		Fine sand
		7.172	8.608	10.62		Clay
		674.3	-	-		Fine sand
VES16	3	30.08	4.314	4.314	H	Clay
		12.33	26.33	30.64		Clay
		1123	-	-		Basement
VES17	3	76.2	1.42	1.42	H	Sandy clay
		7.16	2.95	4.37		Clay
		25497	-	-		Basement

ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 4 No. 2 December 2018*

Table3: Layer, Curve types, Resistivities, Thickness and Depth of Selected locations

Location	Layer	Resistivity (Ω*m*)	Thickness (*m*)	Depth (*m*)	Curve type	Probable Lithology formation
VES19	4	79.4	1.44	1.44	HK	Sandy clay
		10.9	2.9	4.34		Clay
		113	21.9	26.2		Sandy clay
		61	-	-		Sandy clay
VES20	3	16.6	4.12	4.12	H	Clay
		2.95	11.9	15.9		Clay
		3700	-	-		Basement
VES21	5	16.3	2.12	2.12	HK	Clay
		1.48	2.64	4.76		Clay
		10.6	8.24	13.0		Clay
		0.953	20.7	33.7		Clay
		197	-	-		Clay sand
VES23	4	35.1	1.92	1.92	KH	Clay
		194	8.99	10.9		Clay sand
		13.2	22.6	33.5		Clay
		1910	-	-		Basement
VES24	3	6.84	2.13	2.13	H	Clay
		109	54.8	56.9		Clay sand
		2.99	-	-		Clay
VES25	4	6.82	0.814	0.814	A	Clay
		9.42	2.44	3.26		Clay
		218	19.1	22.4		Clay
		33.2	-	-		Clay
VES27	3	0.32	1.05	1.05	A	Clay
		5761	1.52	2.57		Basement
		18.4	-	-		Clay
VES28	4	7.53	1.04	1.04	KH	Clay
		108	2.26	3.3		Sandy sand
		2.01	5.42	8.72		Clay
		2876	-	-		Basement
VES29	4	217	1.08	1.08	KH	Fine sand
		2511	2.2	3.28		Coarse sand
		33.2	5.67	8.95		Sandstone intercalated with clay
		36367	-	-		Basement
VES30	3	13.2	0.967	0.967	K	Clay
		424	6.3	7.27		Clay
		0.0511	-	-		Clay
VES32	3	16.38	2.559	2.559	K	Clay
		23.72	10.63	13.19		Clay
		10.56	-	-		Clay

However, VES 14 and 21 are 5 layers having 0.765m to 20.7m thickness and 0.967m to 56.9m depth with resistivities varying from 0.275 Ωm to 197 Ωm. VES 4, 5, 7, 13, 15, 19, 23 and 25 aquifer is located in the third layer with thickness 48.04m, 22.3m, 17.21m, 14.67m, 8.608m, 21.9m, 22.6m and 19.1m at a depth of 62.27m, 24.2m, 20.82m, 16.31m, 10.62m, 26.2m, 33.5m and 22.4m, respectively. The lithology for this locations composed of clayey sand, clay, sandy clay, coarse sand, medium sand with coarse sand and fine sand.

VES locations 8, 16, 20, 24 and 32 with depth 24.6m, 30.64m, 15.9m, 56.9m and 13.19m, respectively. Have aquifer located in the second layer with thickness 21.2m, 26.33m, 11.9m, 54.8m and 10.63m. VES is made of fine sand, sandy clay and clay, VES 16 consists of clay to medium sand with coarse sand lithology. VES 20 comprised of clay, clay, and coarse sand, while clay, clayey sand and clay forms VES 24 and only clay formed VES 32.

The aquifer for VES 14 and 21 have thickness 20.6m and 20.7m at a depth of 26.5m and 33.7m, respectively is located at the fourth layer. The lithology for this VES location is clay to clayey sand. The geophysical investigation could not determine the entire thickness of the aquiferious zones for VES 17, 27, 28, 29 and 30 locations. VES 17 has sandy clay, clay and fresh basement as lithologies and resistivity range between 76.2 Ωm to 25497 Ωm, VES 27 has resistivity ranging from 0.32 Ωm to 5761 Ωm with clay, fresh basement and clay formation. VES 28 is composed of clay, sandy clay, clay, and coarse sand with resistivity values ranging from 7.53 Ωm to 2876 Ωm. Locations 29 and 30 have 33.2 Ωm to 36367 Ωm and 0.0511 Ωm to 424 Ωm resistivity, respectively. VES 29 comprised of fine sand, coarse sand, clay and fresh basement while clay, fine sand and clay made up VES 30.

The results of the research show that groundwater can be sourced within the surroundings of VES 4, 5, 7,8 16, 14, 15, 16 19, 20, 21, 23, 24 and 25 which constitute good aquifer zones. These locations are recommended for siting of boreholes.

CONCLUSION

Geoelectric investigations of Kafin Hausa areas have been carried out by vertical electrical sounding using Schlumberger electrode configuration. The interpretation of results from the sounding curves obtained revealed three to five curve types namely; A, H, HK, K, KH, and Q, respectively. K-types represent 28%, 25% and 22% belong to KH-types and H-types curve within the study locations. These results showed that Kafin Hausa is underlined by clay, sandy clay, clayey sand, fine sand, mixed medium-coarse graineds and and coarse grained sand. The study found that groundwater can be sourced from VES 4, 5, 8, 14, 15, 16, 19, 20, 21, 23, 24 and 25 locations which have good aquifers and accordingly, the locations have been recommended for drilling. Resistivity values for VES 17 and 29 indicate dry conditions and are thus not recommended for drilling.

ACKNOWLEDGMENTS

We are indebted to Tertiary Education Trust Fund (TetFund) for funding this research work, Prof. Yusufu Abdullahi Ribadu, Prof. Lawan Sani Taura, Abdulmumin Aliyu and other members of Tetfund Implementation Committee (TIC) Sule Lamido University for their assistance.

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