GROUNDWATER EXPLORATION IN PART OF MAIKUNKELE, MINNA, NORTH–CENTRAL NIGERIA USING VERTICAL ELECTRICAL SOUNDING

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Abstract
Maikunkele, a suburb of Minna, Niger State (Nigeria) usually experiences shortage of potable water supply especially in dry seasons. This results from decrease in productivity of existing boreholes and hand-dug wells during the season. It could also be attributed to increase in demand due to population increase the area is witnessing as a result of several government establishments located in the area and the fact that the area provide a cheaper accommodation for people (including those that work at the Minna city centre). It is in view of the above that groundwater exploration was carried out to determine the groundwater potential of the area. A total of 48 Vertical Electrical Soundings (VES) using Schlumberger Array was adopted for the study. VES results were interpreted with the aid of IX1D Software. The result obtained show some area have three geoelectric layers while others have Four geoelectric layers Over 80 percent of VES results indicated good potential for groundwater development. The results show that the southern part of Maikunkele has higher groundwater potential compared with the northern portion. The aquifer system of the southern portion consists of thick overburden, weathered basement and fractured basement. Recommended drilling depth should be at least 60m. Although the overburden in the Northern part is thinner when compared with the southern part, it also has good potential for groundwater development as the results of VES in the area show that the aquifer system comprises of weathered basement and fractures in some places. The drilling depth for the northern portion should not be less than 80 meters except for VES 14 where 30 – 40m is recommended.

Keywords: Groundwater, Exploration, Maikunkele, Aquifer, Basement

1.0 Introduction

Maikunkele is a suburb of Minna the capital city of Niger State, Nigeria. It is also the headquarters of Bosso Local Government Area. It is home to many important Federal Government facilities such as the Nigeria Air Force Base and offices of Nigerian Meteorological Agency, Federal Airport Authority of Nigeria, Nigerian Airspace Management Agency and Nigerian Civil Aviation Authority. The area provides essential services that include food production and others services to the city centre. The area is currently witnessing increase in population not just because of the presence of facilities mentioned above but also the low cost of living which is suitable for middle and low income earners. Pipe borne water supply is almost none existing in the area. Therefore, groundwater from boreholes and to lesser extent from hand-dug wells provide good alternative sources of potable water supply for the people living in the area. This is because the cost of groundwater development and maintenance is cheaper compared to surface water development for various uses (i.e. domestic, irrigation, industrial). The quality of groundwater is often better than other sources of water except water from rainfall that is not from polluted environment. The area usually experience water scarcity especially during dry seasons due to reduction in productivity of many existing boreholes and wells. This could result from improperly sited boreholes and wells and could also be due to lack of adequate professional maintenance. With increasing population, the water scarcity will only get worse because of resulting increase in water demand. Properly sited boreholes can enhance productivity of wells which has implication for water scarcity reduction currently being witnessed by the inhabitant of Maikunkele.

2.0 Review of Literature

Several workers have carried out researches in Minna and its environs. Among them are the work of Akande *et al.* (2016) which evaluated the groundwater potential of Chanchaga area, Minna using the electrical resistivity method and concluded that the study area has poor to marginal groundwater potential. And also suggested the effective depth of drilling should be between 40 to 50 meters for optimum yield. Amadi *et al.* (2015) evaluated the Groundwater Quality in Shallow Aquifers in Minna using Pollution Load Index and reported that Fe, Mn, NO_3, colour and total coliform are higher than the permissible limit for drinking water by World Health Organisation and the Nigeria standard for drinking water quality. Idris-Nda *et al.* (2013) in their appraisal of the chemical composition of the groundwater in Minna metropolis, noted that there is a gradual enrichment of manganese, arsenic and lead in groundwater within Minna metropolis. Amadi *et al.* (2009) studied the Hydrogeology and Chemical Quality of Groundwater in south-western part of Minna and concluded that the groundwater from this area is of good quality and that it occurs in the regolith and fractured bedrock. The work of Muhammed *et al.* (2007) carried out research on the regional geoelectric iInvestigation for groundwater exploration in Minna area showed that the average aquifer thickness of regoliths is 24m. Existing literature showed that south and central part of Minna have attracted the attention of most groundwater researches in Minna. The groundwater potential of the northern part especially Maikunkele has not been reported. The aim of the present study is to explore the groundwater potential of parts of Maikunkele, Minna, North-central Nigeria using vertical electrical sounding technique.

The study area which is located on latitude 9° 40' 00"N to 9° 43' 00"N and longitude 6° 27' 00"E to 6° 30' 00"E is part of south east portion of Zungeru Sheet 163, north – central Nigeria (Fig. 1). The study covers a total area of approximately 30.80 km^2. The area comprises of Maikunkele village and Federal Housing Estate. The area is accessible via Minna – Zungeru road with secondary roads and paths. The area has guinea savannah type of vegetation. It is drained by first order streams mostly and these streams take their source from the surrounding highlands. These streams would eventually empty their content into larger streams or rivers that are tributaries of River Chanchaga that drains Minna and its environs. It is characterised by two major climatic conditions (wet and dry seasons). The wet season starts from May and ends in October while the dry season starts from November and ends in April every year. The north-east trade wind popularly known as harmattan in Nigeria that blows across the savannah forms part of the dry season. This (harmattan) usually occurs between the months of November and March. Data from Nigerian Meteorological Agency shows that the highest temperature (average of about 39°C) is recorded in the month of March while the lowest (average of about 28°C) is recorded in the month of August. The major occupation of the inhabitants of the study area is agriculture (both crop and animal production). The topographic map (Figure.1) shows that the relief of the area ranges from 260 – 410m above sea level. The eastern part of the studied area is relatively flat while the western half has a higher relief especially the north-western part.

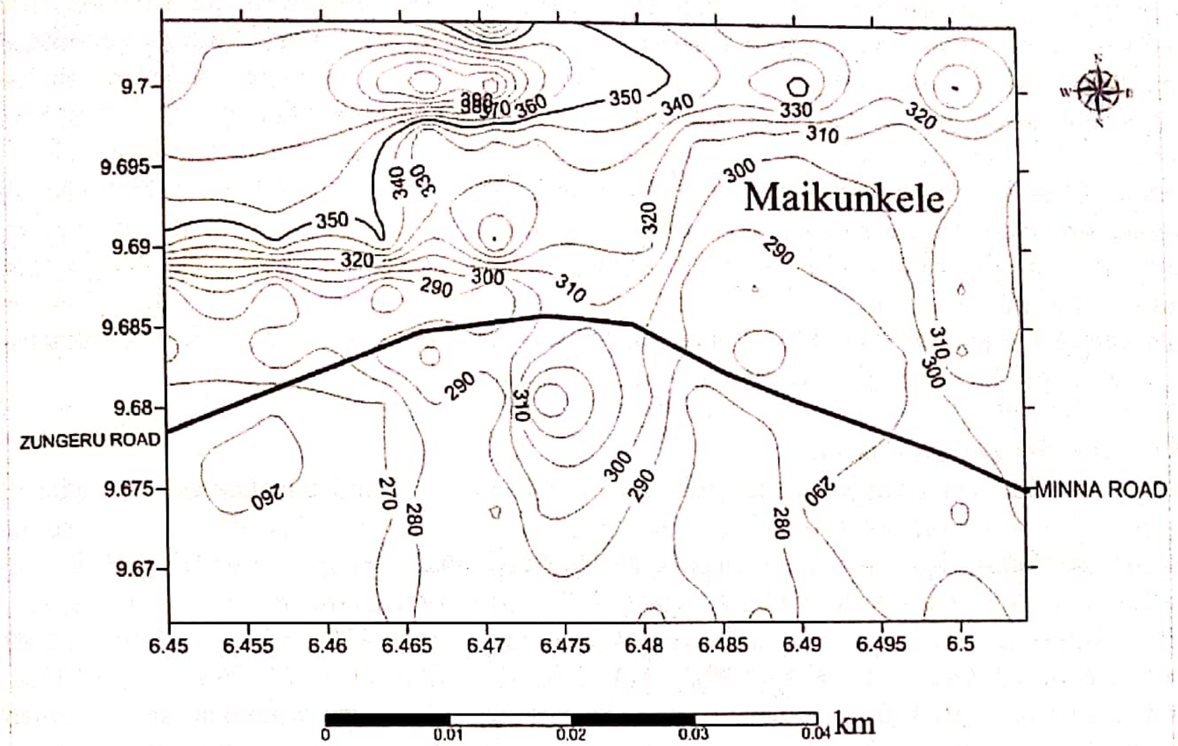

Fig. 1: Topographic map of part of Maikunkele, Minna, Nigeria

Minna and its environs are part of the North – Central Basement Complex as stated by Ajibade (1980). Maikunkele which is a suburb of Minna is underlain by basement rocks that includes granites, gneisses, migmatites and meta-sediment according to Adeleye (1976). The granitic rocks are highly jointed and foliated in some places (Adeniyi, 1985). Turner (1983) identified four formations for Kusheriki Schist group in areas around Minna. They are the Kusheriki Psammite Formation at the base of the succession followed by the Kushaka Schist Formation, then the Zungeru Granulite Formation and Birnin Gwari Schist Formation at the top. Kusheriki Schist group are usually intruded by granitic rocks and separated by both granitic and migmatite-gneiss rocks (Ajibade, 1987). Hydrogeologically, Minna and its environs belong to the North Central Basement Complex Terrain (Olugboye, 2008). Basement rocks are generally poor sources of groundwater but accumulation is aided by tectonic features such as fractures. Permeable sandy-clayey laterite and weathered rock materials overlying bedrocks also contribute to groundwater accumulation in basement complex. Idris-Nda *et al.* (2013), Muhammed *et al.* (2007) and Adeniyi (1985) established that the average superficial deposit (overburden) for Minna and its environs is 15m, 24m and 30m respectively. Muhammed *et al.* (2007) and Adeniyi (1985) obtained an average yield of 0.5 litre per second and 1.5 litres per second for groundwater within Minna and its environs respectively.

3.0 Materials and Methods

The electrical resistivity method of groundwater exploration was adopted for this study. Vertical Electrical Soundings (VES) using Schlumberger electrode configuration (one of the electrical resistivity method) was employed for this research. The maximum current electrode spacing (AB/2) was 100m while the maximum potential difference electrode spacing (MN/2) was 15m. Five traverses were defined for the research with a minimum of three VES and a maximum of eleven VES per traverse. The differences in the numbers of VES per traverse were caused by obstructions such as outcrops and buildings in some places. A total of 48 soundings were carried out in the studied area. The instrument utilized for carrying out VES was Resistivity Meter. An electric current was passed into the ground through two outer electrodes, and the resultant potential difference was measured across two inner electrodes that were arranged in a straight line, symmetrically about a centre point. The ratio of potential difference to current displayed by the Resistivity Meter was calculated as resistance. Geometric factors were calculated as a function of the electrode spacing. The resistance reading obtained by the Resistivity Meter was multiplied by geometric factor to give an apparent resistivity value. The electrodes spacing were progressively increased, keeping the centre point of the electrode array fixed. Interpretation was done with the aid of curve matching technique and computer iteration program with IX1D software. Surfer 13 software was used to produce topographic map, iso-pach and iso-resistivity maps.

4.0 Results and Discussion

The results obtained from VES are presented in Tables 1 – 3 and attached as Appendix I. Figures 2- 6 show the interpretation of some of the VES curves. The data were used to generate isopach and iso-resistivity maps at the depth of 60m, 80m and 100m (Figs. 7, 8, 10). The results of VES curves show that A-type (37.5%) curves forms the majority of the curves. This is followed by QA (12.5%) and HA (12.5%) curves. HQ (10%) and AH (8.3%) curve types also occur. Others are KA (4.2%), AQ (4.2), H (2.1%), QAQ (2.1%), HAQ (2.1%), HAH (2.1%) and QAH (2.1%) curve types. The curve types generally have no special order of distribution except for the HQ that occurs only on the northern portion of the studied area. The results also show that the studied area is characterised by three to four geoelectric layers but three – layer system are dominant. These layers comprise of top soil, weathered basement and fresh/fractured basement. The top soil and weathered basement constitute the superficial deposit (regolith or overburden). The isopach map (Fig. 7) shows that the thickness of the superficial deposit ranges between 2 to 30m with an average of 10.875m. The southern portion (especially the south western part) has thicker superficial deposit compared with the northern portion. The geoelectric layers include top soil (16.5 – 517.8 Ωm), lateritic/sand (37.6 – 881.8 Ωm), weathered basement (14.4 -9020.8 Ωm), fractured basement (43.8 – 2557.9 Ωm) and fresh basement (296.9 – ∞ Ωm).

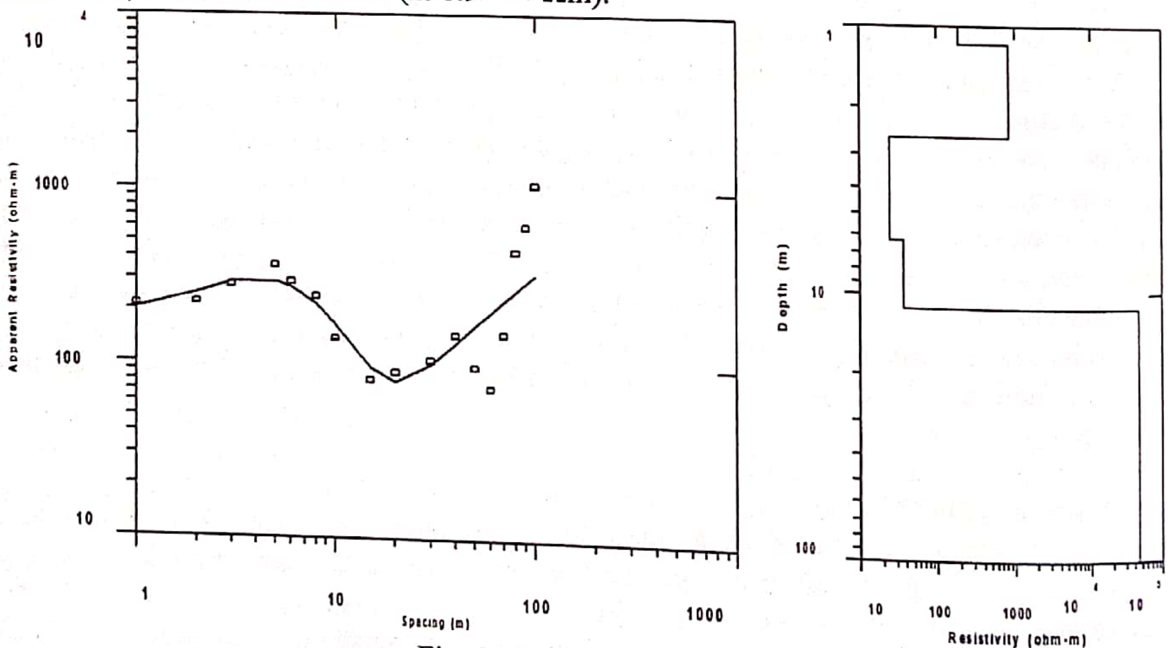

Fig. 2: A Curve of VES 2

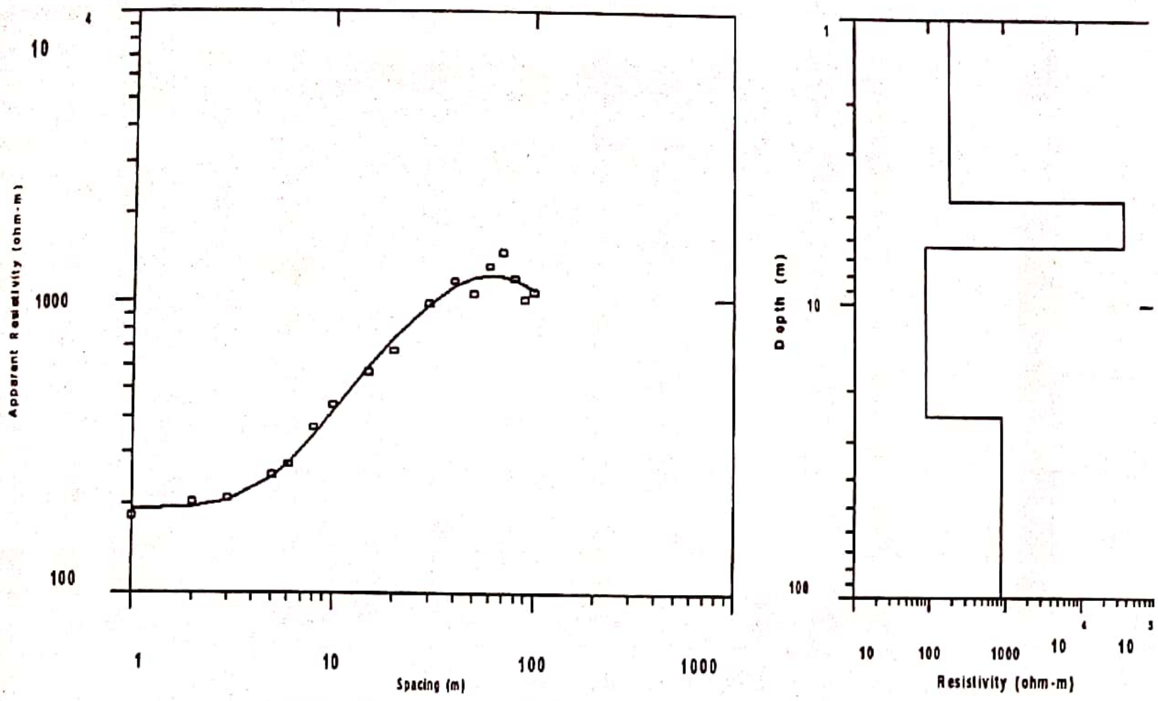

Figure 3: AH Curve of VES 22

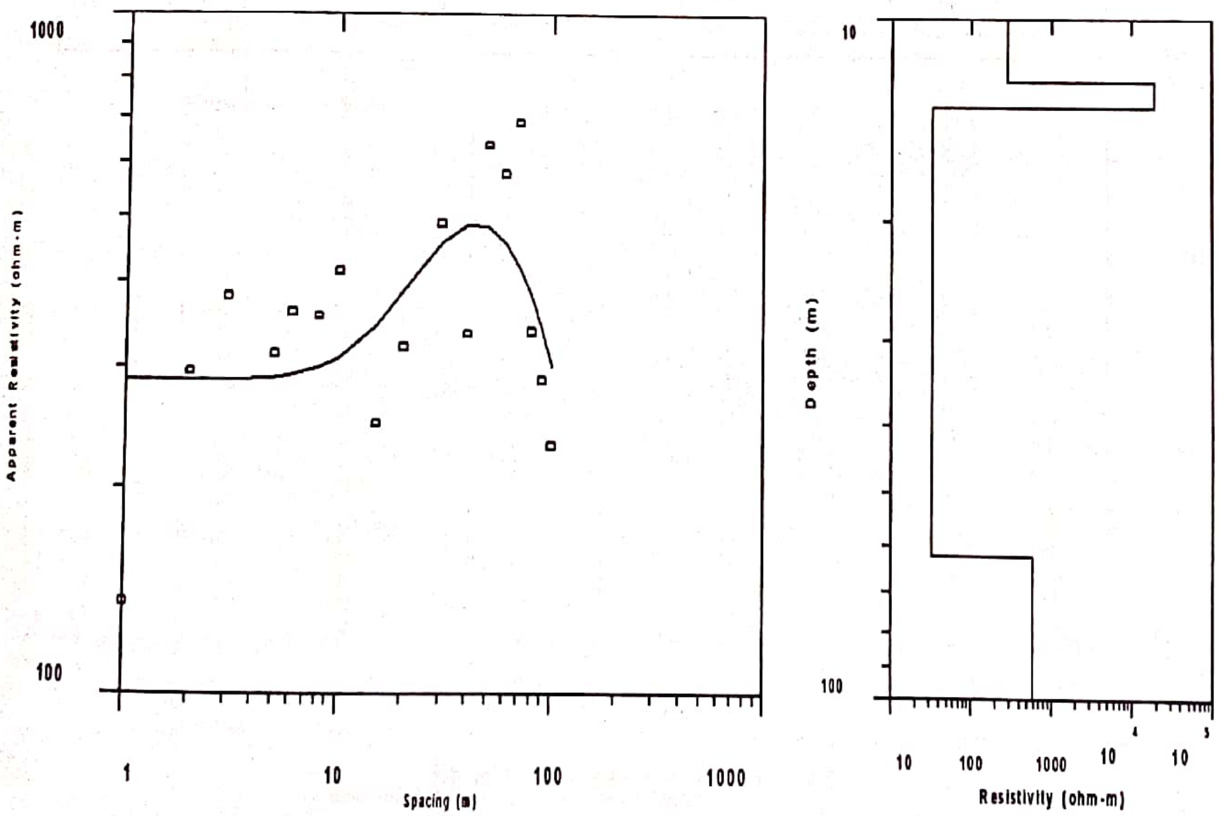

Fig. 4: AK curve of VES 23

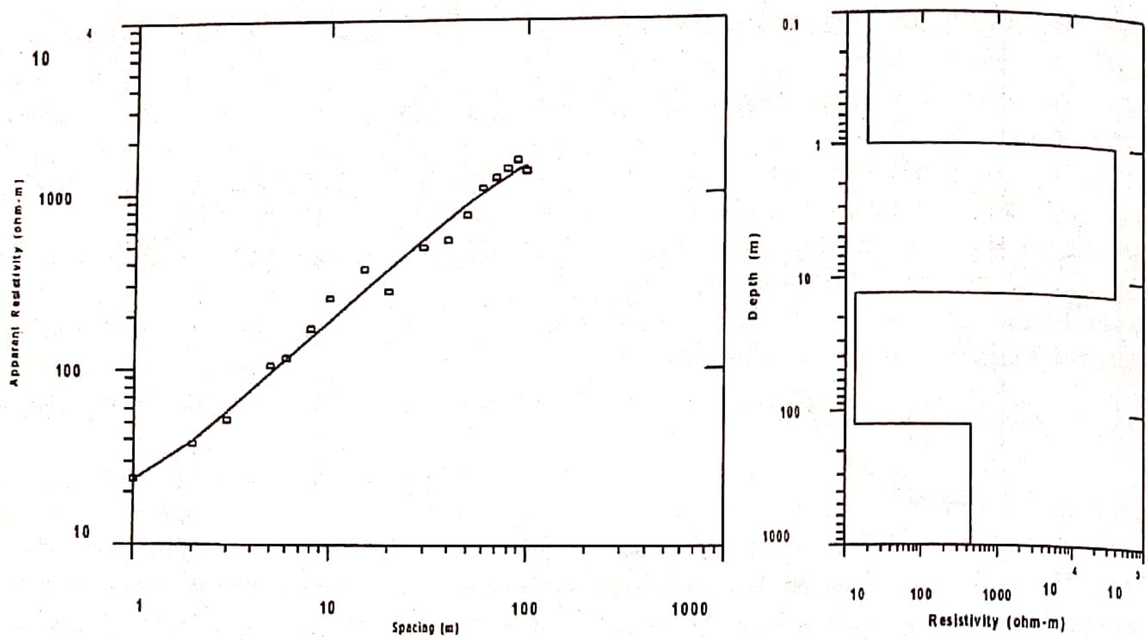

Fig. 5: A curve of VES 22

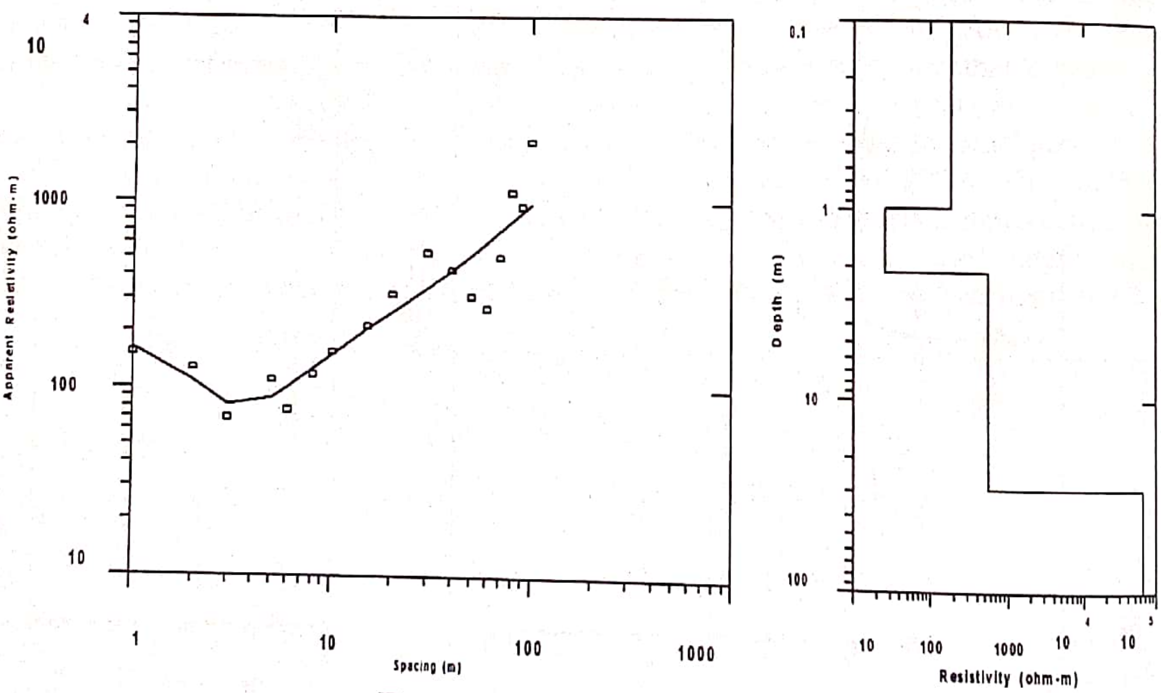

Fig. 6: HA Curve of VES 48

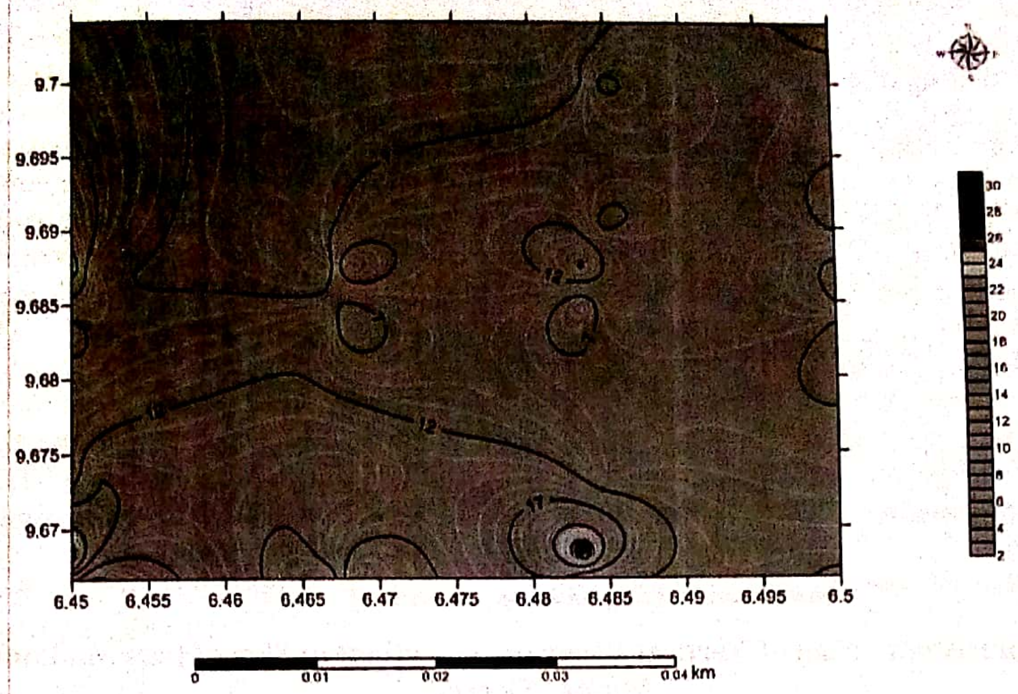

Fig. 7: Isopach Map of part of Maikunkele, Minna, Nigeria

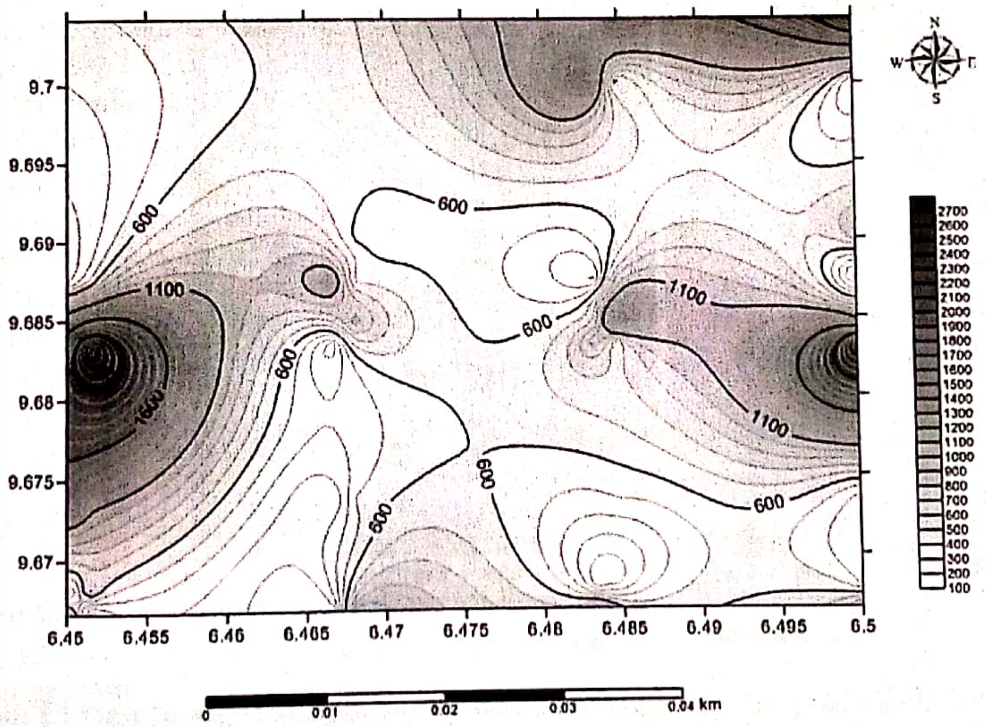

Fig. 8: Isoresistivity Map of Vertical Electrical Soundings at 60m of part Maikunkele, Minna, Nigeria

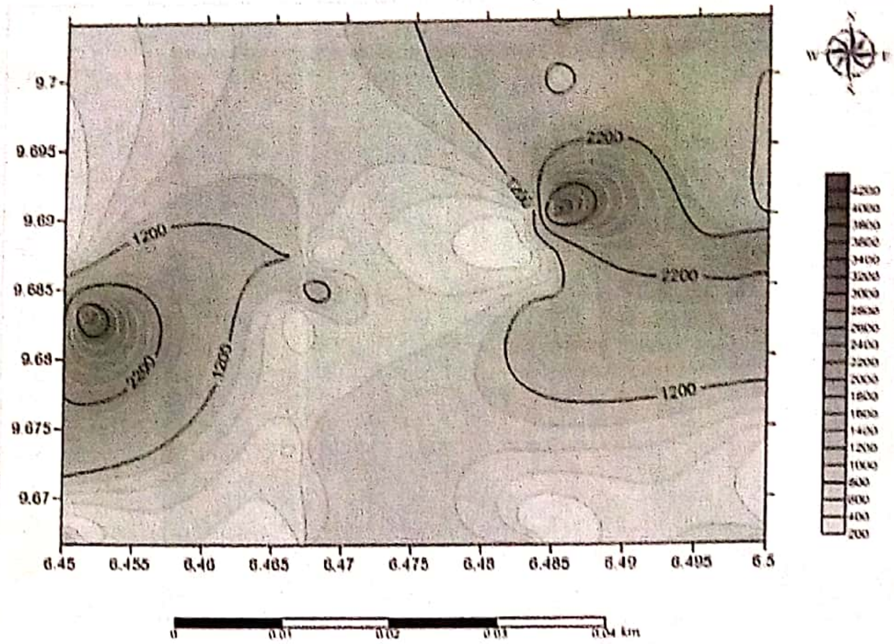

Fig. 9: Isoresistivity Map of Vertical Electrical Soundings at 80m of part Maikunkele, Minna, Nigeria

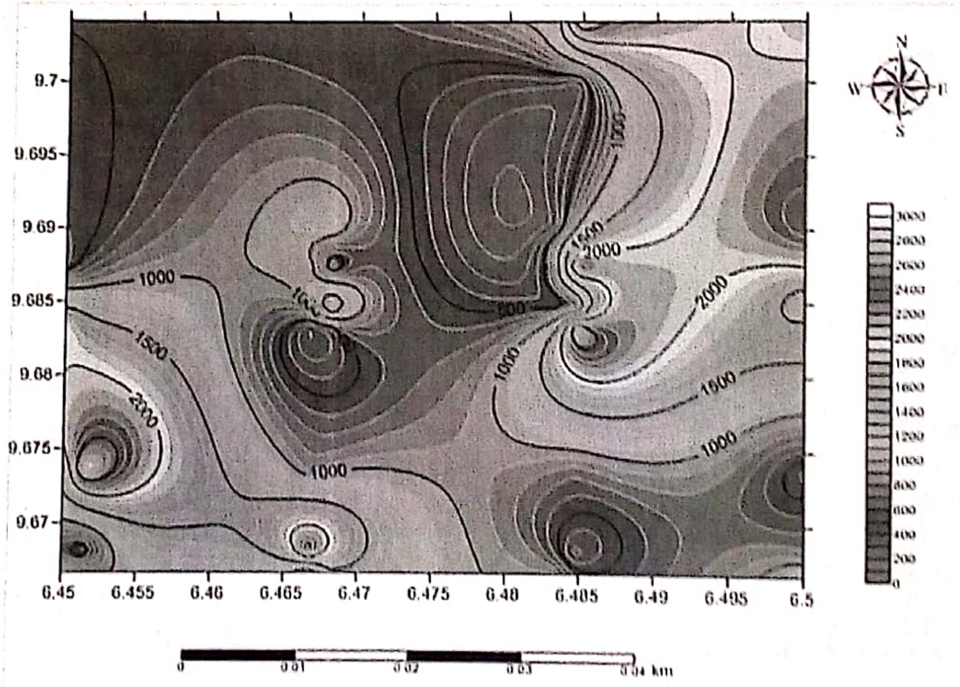

Fig. 10: Isoresistivity Map of Vertical Electrical Soundings at 100m of part Maikunkele, Minna, Nigeria

Isoresistivity maps at the depth of 60m (Fig. 7) shows that the highest resistivity values of up to 2500 Ωm exist in the north-western and eastern part of the area while the southern (200 Ωm) portion recorded the lowest resistivity values. Similarly, the resistivity at 80m (Fig. 8) depth indicated that the highest resistivity values greater than 3000 Ωm exist in the north-western and eastern part of the area while the south-eastern (400 Ωm) portion recorded lowest resistivity values. However, the highest resistivity values (>3000 Ωm) recorded at 100m (Fig. 9) exist in parts of the north-western, eastern and south-western regions of the studied area while the lowest were recorded in the central and south-eastern portion. Generally, low resistivities were observed in the central part of the studied area compared to other portions. Multiple fractures were recorded in 75% of the curves while single fractures were recorded for others. There is no particular pattern for the fracture system as both multiple and single fractures cut across all the quadrants. The southern portion recorded higher multiple fractures when compared with the northern half. The depths of occurrences of fractures in areas with single fracture are between 70 – 100m. Seven out of twelve single fractures recorded occur between 70 – 100m while only four and one of single fractures occur at between 40 – 60m and 15 -40m depth respectively. Integrating isopach with iso-resistivity maps, it can be deduced that the thicker superficial deposit as well as multiple fracture system suggests better groundwater potential than the northern half. The expected depth of drilling varies across the area since the fracture systems of the area occur at various depths. However, drilling depth of between 80 – 100m is recommended except for some parts whose fractures exist at shallower depth. Drilling depth of 60m is recommended for VES 3, 10, 16 and 37 whose fractures exist between 40 – 60m while drilling depth of 30m is recommended for VES 14 whose fracture exists between 15 – 30m. VES 14 may only be able to support hand pump while submersible pumps of various capacity could be used for others depending on the outcome of pumping test.

5.0 Conclusions

Geo-electric characteristics of the curves of VES obtained from the Mekunkele area of Minna show that the A–curve type dominated with 37.5%. QA (12.5%), HA (12.5%), HQ (10%) and AH (8.3%) curve types also occur in significant amount. The curves have no particular pattern of distribution across the studied area except for HQ that is restricted to the northern portion of the studied area. This study indicated that there are three to four geo-electric layers but three geo-electric layers dominate. The three layers comprise of top soil, weathered basement and fractures/fresh basement. The thickness of the superficial deposit ranges from 2 to 30 meters. The superficial deposit is thickest in the south-western portion followed by the south eastern portion followed by the north-eastern portion and lastly, the north-western portion of the studied area. The studied area is characterised by multiple and single fracture system. The frequency of multiple fractures recorded was more than that of the single fractures. Majority of these fractures occur at depth (between 70 to 100m). The southern portion of the studied area with greater numbers of multiple fractures and thicker superficial deposit is expected to have greater groundwater potential than the northern portion. The recommended depth of drilling is between 80 to 100m except for some such as VES 14 whose fracture occurs at shallow depth and may only support hand pump. The recommended depth of drilling for VES 14 is 30m. VES 3, 10, 16 and 37 have their fractures occurring at medium depth. The recommended drilling for them is 60m.

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Appendix I

DEPTH (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	11	215	146	210	26	48	48	27	30	136	27	112	109	106	18	134
2	404	222	69	158	65	44	78	35	57	719	32	99	109	104	21	111
3	273	279	28	156	72	38	55	71	76	218	35	89	121	105	54	141
5	170	360	43	231	42	39	68	85	89	161	39	82	149	106	17	141
6	160	290	25	282	45	48	85	115	101	177	59	93	148	109	33	134
8	162	240	23	224	44	50	125	148	162	153	82	123	131	110	36	144
10	184	140	26	357	72	70	135	208	205	132	111	245	181	117	37	146
15	422	81	31	517	128	131	234	329	161	150	86	438	210	107	58	169
20	412	90	72	1040	204	127	287	426	268	219	139	202	192	115	69	224
30	174	105	156	1514	190	121	497	623	686	245	196	345	230	137	99	316
40	431	147	95	868	404	215	760	807	893	166	277	489	420	164	188	331
50	690	97	113	939	746	307	713	1124	1198	136	695	364	415	112	314	240
60	1018	73	124	1079	897	630	964	1463	1157	192	515	513	369	166	542	337
70	1390	150	199	829	790	480	1170	1608	1983	304	1131	647	349	127	270	369
80	1373	443	248	843	1010	266	1149	1808	1688	235	1010	847	351	182	332	443
90	893	620	337	1481	843		1163	1650	2302	439	713	1169	387	316	317	619
100	997	1066	510	1406	939		1341	1478	3000	669	942	731	359	355	315	2515

Table 1: Vertical Electrical Soundings results

DEPTH (m)	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	18	134	150	116	107	123	242	183	136	86	162	89	159	119	452	227	124	48
2	21	111	147	131	132	154	182	203	295	49	190	76	158	594	354	137	138	50
3	54	141	135	142	147	151	172	209	380	48	138	72	144	470	233	125	152	49
5	17	141	141	118	124	124	152	251	313	44	111	53	177	241	127	275	106	47
6	33	134	112	116	155	119	149	273	361	43	71	76	213	153	120	259	117	94
8	36	144	96	116	145	149	117	365	356	40	116	136	259	159	121	259	172	88
10	37	146	106	115	139	116	180	436	415	32	164	170	212	316	120	181	225	129
15	58	169	106	130	163	138	121	566	248	30	304	258	487	297	174	147	379	98
20	69	224	82	132	189	145	160	671	321	68	406	343	250	314	231	129	280	142
30	99	316	75	152	249	213	245	970	488	88	606	614	463	690	415	293	500	131
40	188	331	214	162	269	229	313	1162	336	166	675	644	708	1029	668	321	446	208
50	314	240	116	187	330	232	358	1051	639	244	731	750	1164	2128	567	371	768	801
60	742	337	120	206	364	272	525	1306	578	265	928	106	1774	2626	412	791	1094	692
70	270	369	390	189	361	280	682	1458	690	200	1096	1178	2594	2173	583	825	1248	1601
80	332	443	221	228	337	332	650	1185	339	380	945	3220	1974	3836	433	745	1408	1805
90	317	619	353	309	322	363	590	998	287	235	1031	1767	2700	2825	386	694	1577	2708
100	315	2515		248	857	368	630	1059	230	803	2518	1998	2011	1632	274	410	1365	2880

Table 2: Vertical Electrical Soundings results

DEPTH (m)	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
1	48	320	119	177	154	161	89	227	119	452	177	24	48	132	96	471	154
2	50	205	118	217	128	190	76	187	594	354	157	38	50	205	83	331	128
3	49	210	122	217	119	137	71	175	478	233	135	52	47	210	124	217	69
5	47	270	129	246	111	110	53	275	241	127	250	106	94	270	191	246	111
6	94	291	130	131	106	71	76	225	202	120	200	117	88	291	109	145	77
8	88	375	136	138	219	115	135	259	114	121	234	172	129	375	264	138	119
10	129	521	152	124	232	164	171	176	316	121	181	257	98	516	607	120	157
15	98	927	115	184	316	304	258	307	340	314	232	379	142	927	715	234	216
20	142	1257	116	170	419	406	343	279	313	331	214	280	131	1257	718	220	319
30	131	1892	213	282	835	606	614	438	690	515	313	500	208	1892	813	382	535
40	208	1894	371	370	748	675	644	517	929	786	477	547	251	1911	980	489	433
50	801	2818	389	259	629	731	750	468	1127	967	543	768	692	2818	989	219	312
60	692	2683	581	444	598	927	1059	591	1624	1120	590	1094	1638	2683	1581	544	269
70	1601	1382	780	649	1070	1096	1178	625	1172	1861	724	1248	1601	1882	1780	849	507
80	1805	2139	919	525	4285	950	1578	716	888	1548	820	1409	2408	2139	1886	725	1129
90	2708	1718	1031	398		1031	1767	494	825	1170	673	1577	2208	1718	2031	498	954
100	2880	1776	1251	354		2518	1998	310	506	1048	407	1365	2880	1776	2251	252	2128

Table 3: Vertical Elect rical Soundings results