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GEOPHYSICAL INVESTIGATION AND AQUIFER CHARACTERIZATION OF SOME SITED BOREHOLES IN SOME LOCAL GOVERNMENT AREAS IN KANO STATE, NIGERIA

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Abstract

Geophysical investigation were carried out on the study areas and pump out test were carried out on the sunk boreholes to determine the location, depth of potential aquifer, type of aquifers in the study areas and the yield of the aquifer. The geophysical investigation of the study area revealed the presence of four to five layers; topsoil, the second layer varies at different locations from clay to Laterite, third layer weathered rock, forth layer fracture rock, and fifth layer fresh basement rock. The study identifies the forth layer with resistivity value range of 43.00Ωm to 622.00Ωm and thickness of 16.30m to 49.10m to be a potential aquifer. The boreholes sunk were pump test and the yield, Transmissivity and hydraulic conductivity were calculated. The values range for yield or discharge, Transmissivity and hydraulic conductivity are 43.20m^3/day to 95.00m^3/day, 17.19m^2/day to 1502.10m^2/day and 1.43m/day to 64.19m/day respectively. The study revealed that the area has two types of aquifers; confined and semi - confined aquifer. Boreholes with Transmissivity value greater than 500m^2/day have high potential aquifer (Tasawar Dukawa, Gidan Darho and Sabaran Danmaidaki), those with value greater the 50m^2/day are of moderate potential (Gidan Jabir, Kabba and Galadimawa) and those with value less than 50m^2/day are of low potential (Danya). Wells with values indicating moderate to high potential aquifers can support hand pump and motorized pump while that with value indicating low potential can only support hand pump.

Keywords: Groundwater, Geophysical Survey, potential aquifer, Transmissivity, yield, hydraulic conductivity.

1.0 INTRODUCTION

The importance of groundwater as a valuable source of portable water cannot be over emphasized. Water is needed in any life support programs, such as domestic and industrial purposes. Most of the rural dwellers suffer from water scarcity with the study area not in exception. The source of water in the study areas is largely hand dug wells which are seasonal. With the increased in population and agricultural growth the demand of water increase beyond perception.

Government at various levels (Federal, State and Local government) and non government organisations such as UNICEF and WHO drilled boreholes (hand pump boreholes, Motorized boreholes and Solar powered borehole) to compliment the surface water. The effort by the government to provide sufficient and healthy water could not be achieved as most of the boreholes were poorly sited and mis-managed.The advent of geoscience and technology has made quest for water for all purpose in life to drift from ordinary search for surface water to prospecting for steady and reliable subsurfaceor groundwater from boreholes [1].

Geophysical survey and aquifer test were used to assess the groundwater potential ofthe study area. Geophysical survey to investigate the groundwater potential of some Loccal Govt. Areas in state. The study reveled the aquiferous layers of the region to have resistivity value of 178Ωm and thickness 14.33m at a depth of 16m [2]. The work by [3] revealed the presence of three to four layers in Kano metropolis. The topsoil, weathered fractured and fresh basement rock. The water bearing zone is is the weathered or fractured zones. The work by [4] carried out an investigation to locate borehole drilling sites along Gumsuri – Chibok route in NE Nigeria.

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An assessement of groundwater potential of parts of Ikono L.G.A (Akwa Ibom State) SE Nigeria was carried out by [5]. There work suggested moderate high value of transmissivity as an indicator of good potential aquifer. Though, further suggested that proper geophysical and hydrogeological study should be carried out on the area. Other works by [6, 7] were carried out in order to provide a solution to the problems with water scarcity areas. This study pays attention on investigating groundwater potential and occurrence as a tool to groundwater exploration.

2.0 OBJECTIVES OF THE STUDY

The specific objectives of the study are to;

a) Determine the groundwater potentials of the study area and depth of the potential aquifers to serve as a guide for drilling boreholes

b) Determine the types and properties of the aquifers in the study area

c) Determine the potential and yield of the boreholes in the study area.

3.0 LOCATION, GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

Eight locations were selected from four local government areas (Dam batta, Gwarzo, Makoda, and Kunchi). Gidan Jabrin, Gidan Darho and Kabba in Gwarzo L.G.A, Sabaran Danmaidaki and Dutsan Gima in Makoda L.G.A, Danya and Tasawar Dukawa in Dam batta L.G.A,and Galadimawa in Kunchi L.G.A, Kano state, Nigeria located on Latitude 11.917^{0}N, 12.422^{0}N, 12.446^{0}N, 12.503^{0}N and Longitude 7.935^{0}E, 8.430^{0}E, 8.606^{0}E, 8.273^{0}E respectively.The study areas lies within the basement complex of nigeria. Rocks in this basement complex includes gneisses, granite, migmatites, metasediments, dolomites and quartzite [2,13,14]. Post tectonic folding and fracturing are common [8]. These rocks are also weathered in places.Groundwater in basement complex rock formation occurs either in the weathered or in the fractured rock as comfirmed by [2].The availability of groundwater in any giving area depends on the rock type, the depth of the overburden, thickness of the weathered zone and extent of weathering [8]. There are two types of aquifer in the study area, the confined aquifer and semi-confined aquifer. These two types of aquifers are usually interconnected.

4.0 THEORETICAL BACKGROUND

The electrical resistivity method used in this studies depends on Ohm's law

$$R = \frac{V}{I} \quad (1)$$

For four electrodes inserted in to the ground as in Figure 1

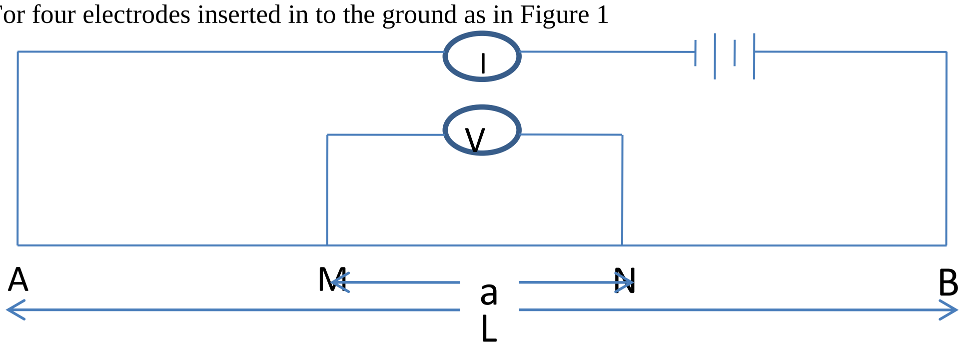

Figure 1: Schlumberger Configuration

For schlumberger configuration the potential V at M and N is given by

$$V_M = \frac{\rho I}{2\pi}\left(\frac{2}{L-a}\right) \quad (2)$$

$$V_N = \frac{\rho I}{2\pi}\left(\frac{2}{L+a}\right) \quad (3)$$

$$V_A = V_M - V_N \quad (4)$$

$$V_A = \frac{\rho I}{2\pi}\left(\frac{2}{L-a} - \frac{2}{L+a}\right) \quad (5)$$

$$V_B = V_N - V_M \quad (6)$$

$$V_B = \frac{\rho I}{2\pi}\left(\frac{2}{L+a} - \frac{2}{L-a}\right) \quad (7)$$

Thus, the potential between A and B is given by

$$V = V_A - V_B \quad (8)$$

$$V = \frac{4\rho I}{\pi}\left(\frac{a}{L^2 - a^2}\right) \quad (9)$$

$$\rho = \frac{V}{I}\frac{\pi(L^2 - a^2)}{4a} \quad (10)$$

$$\rho = KR \quad (11)$$

Where K is called geometric factor [15]

$$K = \frac{\pi(L^2 - a^2)}{4a} \quad (12)$$

The pumping test method used in this study is the pumping out test used in [9,10].

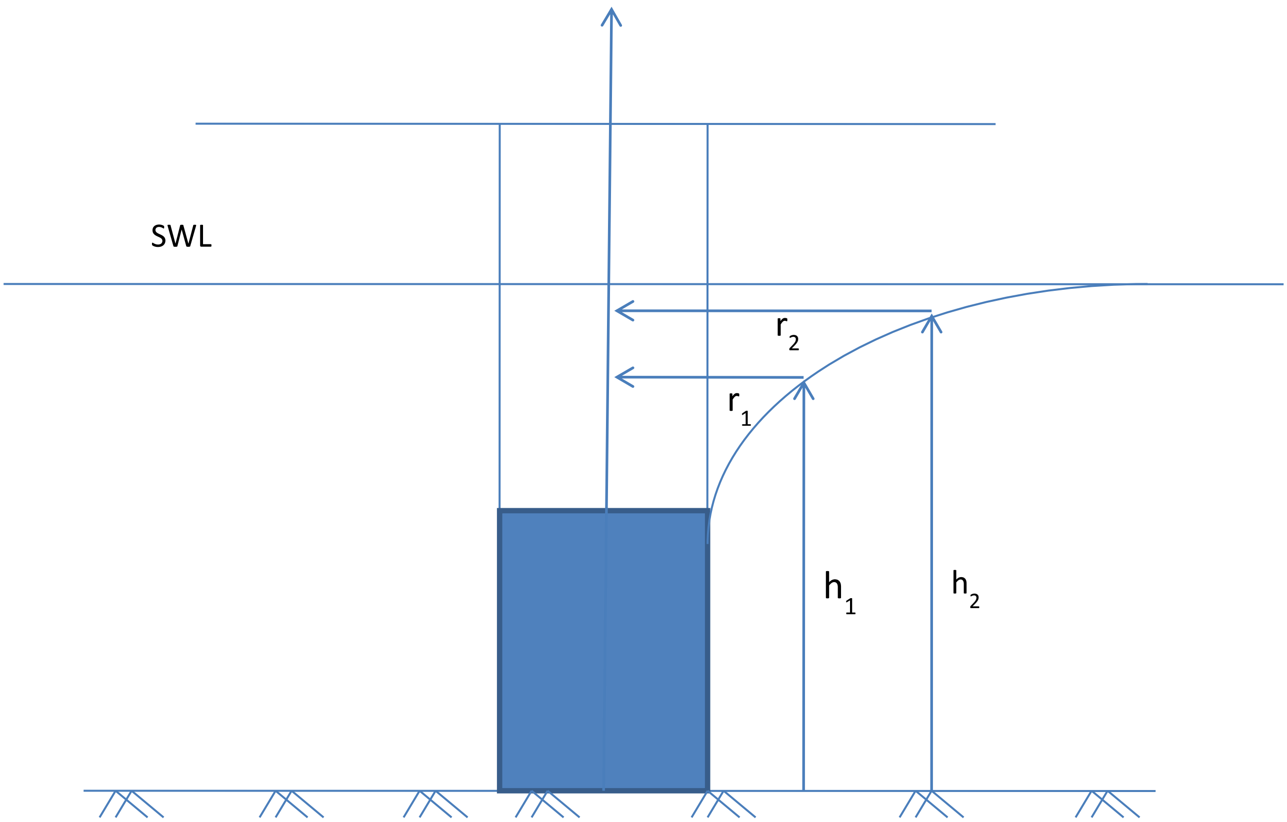

Figure 2: Sketch of Pumping Test

Darcy's law states that the rate of flow through a porous medium is proportional to the loss of head, and inversely proportional to the length of the flow path, or

$$v = k\frac{\Delta h}{\Delta l} \quad (13)$$

In differential form

$$v = k\frac{\partial h}{\partial l} \quad (14)$$

Where is v Darcy velocity or specific discharge, k is hydraulic conductivity and $\frac{\partial h}{\partial l}$ is the hydraulic gredient.

Groundwater velocity (v) and specific discharge (Q) is given by Darcy's law

The specific discharge is computed from Darcy's law

$$Q = vA \quad (15)$$

$$v = \frac{Q}{A} \quad (16)$$

Therefore

$$Q = k\frac{\partial h}{\partial l}A[10] \quad (17)$$

For the flow of water through a circular section of aquifer to well is describe as

$$Q = 2\pi rkb\frac{\partial h}{\partial r} \quad (18)$$

The transmissivity (T) is given by

$$T = kb \quad (19)$$

Where b is aquifer thickness

$$Q = 2\pi rT\frac{\partial h}{\partial r} \quad (20)$$

Rearranging equation (20)

$$\partial h = Q\frac{\partial r}{2\pi rT} \quad (21)$$

Integrating equation (21)

$$\int dh = \frac{Q}{2\pi rT}\int\frac{\partial r}{r} \quad (22)$$

$$h = \frac{Q}{2\pi rT}\ln r \quad (23)$$

$$T = \frac{Q}{2\pi rh}\ln r \quad (24)$$

Cooper Jacob's non equilibrium equation for transmissivity (T) is given as

$$T = \frac{2.3Q}{4\pi\nabla S} \quad (25)$$

Where $Q =$ discharge and $\nabla S =$draw down difference

5.0 MATERIALS AND METHODS

The studies was conducted in two stages. The first stage covered the geophysical survey and the second stage is the pumping out test of the well.

5.1 GEOPHYSICAL SURVEY

The survey was carried out using Syscal Irish Jr 300 mode resistivity meter at various locations with vertical electrical sounding (VES) using Schlumberger configuration. The resistivity meter, battery and the electrodes were arranged as in figure 1. The electrodes (AB) were shifted from minimum electrode spacing (AB/2) of 1.5m to maximum of 60m covering a total spacing of 120m with MN/2 as the center of investigation.The data collected at the VES point for all the locations were inform of resistivity. The field resistivity data were recorded as in Table 1. The apparent resistivity were then entered into IpI2win inversion software. The iterative sounding curves for each station or VES point was drawn for easy interpretation (See Appendix 1).

Table 1: Data collected from the VES points

LOCATION		Dam Batta		Makoda		Gwarzo			Kunchi
		Danya	Tasawar Dukawa	Sabarundan Maidaki	Dutsan Gima	Gidan jibrin	GidanDarho	Kabba	Galadimawa
S/N	Spacing (AB/2) (m)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)
1	1.5	181.20	310.81	281.02	201.28	273.20	280.30	248.19	210.09
2	2	153.01	289.12	260.42	173.01	159.80	160.24	176.30	195.20
3	3	145.09	258.01	245.11	145.31	97.86	93.96	106.34	167.04
4	4.5	130.11	230.24	229.30	121.10	60.27	58.68	78.24	139.08
5	7	119.30	201.89	218.01	106.34	52.40	56.75	60.34	120.11
6	10	100.12	185.03	198.20	82.04	60.34	70.36	54.76	117.20
7	10	91.18	150.13	187.04	81.49	64.12	68.94	55.15	116.04
8	15	76.11	125.29	160.30	62.35	98.86	107.90	69.79	100.83
9	20	60.11	101.10	130.01	60.11	136.40	147.30	116.96	84.11
10	25	85.01	85.94	118.49	81.30	169.40	184.62	158.62	60.81
11	30	101.06	60.24	102.14	102.12	214.36	220.34	197.11	59.02
12	35	118.30	62.58	80.03	121.90	246.96	238.96	231.63	66.06
13	40	125.04	80.12	59.20	132.40	268.96	270.38	246.38	80.12
14	45	138.08	80.20	62.13	140.02	268.34	291.42	252.40	101.05
15	45	139.40	112.30	63.09	141.09	274.14	292.30	253.51	102.30
16	60	149.02		100.08	152.30	294.11	300.11	260.11	135.30

After the points with potential aquifers were isolated using the geophysacal survey data, the boreholes were drilled and logged.

5.2 PUMPING OUT TEST

Pumping out test was carried out on the eightdrilled boreholes using flow meter, water level indicator and stop watch. The eight drilled boreholes were pump test for a period of 120minutes each. The results of the pumping out test in Table 2 were analyzed using method in [9,10,11] to determine the properties of the aquifer.

Table 2: Data collected for the pump test

Location	Total Depth (m)	Water columb (m)	Static Water Level (m)	Dynamic Water Level (m)	Drawdown (m)	Yield(Q) (m3/day)
1. Danbatta						
i. Danya	48.00	27.80	20.20	36.00	15.80	43.20
ii. TasawarDukawa	50.60	41.20	9.40	14.20	4.84	82.10
2. Gwarzo						
i. Gidan Jibrin	48.00	34.00	14.00	26.41	12.41	74.30
ii. GidanDarho	43.00	20.00	23.00	24.98	1.98	71.70
iii. Kaba	49.00	39.00	10.00	31.41	21.41	46.70
3. Makoda						
i. SabarundanMaidaki	60.00	52.40	7.60	11.60	3.98	95.90
ii. DutsanGime	60.00	40.90	19.10	25.20	6.10	78.60
4. Kunchi						
i. Galadimawa	55.00	47.30	7.70	17.20	9.50	71.70

6.0 RESULT AND DISCUSSION

6.1 GEOPHYSICS AND HYDROGEOLOGY

The results from the inversion of the field data (sounding curves) were presented in Figures 4, 5, 6, 7, 8, 9 and10 in appendix 1.The geoelectric layers and their thicknesses are given in Table 3.

The study revealed four to five layers around the study areas. The topsoil which varies in composition from sandy, silty sand, sandy clay with resistivity value range of 140.00Ωm to 440.00Ωm and thickness ranging from 0.75m to 3.00m. The second layer composed of clay in GidanJibrin, GidanDarho and Kabba in Gwarzo L.G.A. with resistivity value ranging from 30.00Ωm to 86.00Ωm and thickness ranging from 2.30m to 9.00m. The second layer in Danya and TasawarDukawa in Danbatta L.G.A., Sabarundan Maidaki and DutsanGime in Makoda L.G.A., and Galadimawa in Kunchi L.G.A., is composed of Lateritic sand with resistivity value ranging from 121.00Ωm to 263.00Ωm with varying thickness ranging from 3.00m to 10.00m. The layer beneath the second layer in Danya, Tasawar Dukawa, Kabba, Sabarundanmaidaki, DutsanGime, Galadimawa and in Danbatta, Gwarzo, Makoda, and Kunchi L.G.As., respectively, is composed of weathered rock with resistivity value ranging from 24.00Ωm to 172.00Ωm and thickness ranging from 3.00m to 49.00m and Laterite in GidanJibrin and GidanDarho in Gwarzo L.G.A with resistivity value ranging from 810.00Ωm to 854.00Ωm and thickness ranging from 7.30m to 20.00m. The fourth layer in all the locations composed of the fractured rock with resistivity value ranging from 292.00Ωm to 622.00Ωm and thickness ranging from 16.00m to 49.00m. The last layer in all the locations is composed of fresh basement rock with resistivity value greater than or equals to 900.00Ωm.

The weathered and fractured basement zones constitute the major component of the aquifer of the study areas due to their thick overburden and low resistivity values which in conformity to the borehole log of the study area given in appendix 2.

Table 3; Geoelectric and Thickness Value of Layers for Danya

LOCATION		Danbatta		Makoda		Gwarzo			Kunchi
		Danya	Tasawar Dukawa	SabarundanMaidaki	Dutsen Gima	Gidan jibrin	GidanDarho	Kabba	Galadimawa
S/N	Thickness	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)	Resistivity (Ωm)
1	0.75-2.68	147.00	395.00	297.00	179.00	439.00	438.00	411.00	251.00
2	2.33-8.81	135.00	241.00	297.00	41.50	53.10	30.30	85.90	121.00
3	3.45-29.70	48.90	30.30	209.00	172.00	854.00	810.00	24.00	24.50
4	16.30-49.10	522.00	430.00	43.80	292.00	601.00	478.00	570.00	522.00
5		900	932.00	1018.00	983.00	932.00	1303.00	932.00	1000.00

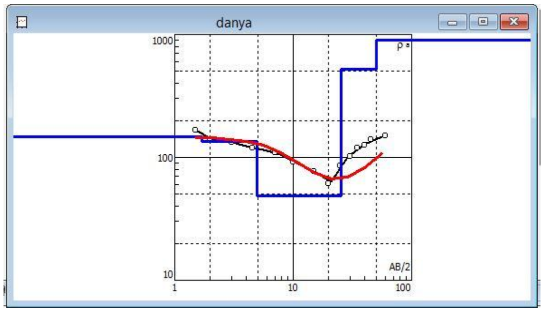

Figure 3: Iterative Sounding Curve for Danya

6.2 AQUIFER CHARACTERISTIC

The study revealed that two types of aquifers are present in the study areas; confined and semi confined aquifers. The confined aquifers are located at Danya in Danbatta, Gidan Jibrin and Kabba in Gwarzo, Sabarundan Maidaki and Dutsen Gima in Makoda. The semi confined aquifers are located in areas TasawarDukawa in Danbatta, GidanDarho in Gwarzo and Galadimawa in Kunchi.

6.3 TRANSMISSIVITY (T)

The Transmissivity(T) values were analyzed using Cooper-Jacob method (Non-equilibrium Equation) as presented in Table 4. The value of the Transmissivity range from 17.19m^2/day to 877.51m^2/day with an average of 307.76m^2/day for the confined aquifers located at Danya, Gidan Jibrin, Kabba, Sabarundan Maidaki and Dutsan Gima. The semi-confined aquifer has a Transmissivity value range of 145.81m^2/day to 1502.10m^2/day with an average value of 858.38m^2/day located at TasawarDukawa, GidanDarho and Galadimawa. The Transmissivity values mentioned above when compared with [12] standard indicates aquifers of high potential in Sabarandan Maidaki and moderate potential aquifers in Gidan Jibrin and Dutsen Gima and low potential aquifers Danya andKabba for the confined aquifers and highpotential in TasawarDukawa and GidanDarho and moderate potential in Galadimawafor the semi confined aquifers as shown in Table 4.

Table 4: Summary of the Pump Test Result

Location	TD (m)	WC (m)	SWL (m)	DWL (m)	DD (m)	b (m)	Aquifer Type	T(m^2/day)	Yield (m^3/day)	k (m/day)
1. Danbatta										
i. Danya	48.00	27.80	20.20	36.00	15.80	45.40	CA	17.19	43.20	1.43
ii. TasawarDukawa	50.60	41.20	9.40	14.20	4.84	42.20	SCA	1502.1	82.10	64.19
2. Gwarzo										
i. GidanJibrin	48.00	34.00	14.00	26.41	12.41	39.35	CA	79.98	74.30	3.81
ii. GidanDarho	43.00	20.00	23.00	24.98	1.98	39.60	SCA	656.16	71.70	50.47
iii. Kabba	49.00	39.00	10.00	31.41	21.41	46.53	CA	84.54	46.70	7.05
3. Makoda										
i. SabarundanMaidaki	60.00	52.40	7.60	11.60	3.98	59.26	CA	877.51	95.90	27.42
ii. DutsenGima	60.00	40.90	19.10	25.20	6.10	46.00	CA	479.59	78.60	20.85
4. Kunchi										
i. Galadimawa	55.00	47.30	7.70	17.20	9.50	44.75	SCA	145.81	71.70	60.75

Key; TD= Total Depth, WC= Water Column, SWL= Static Water Level, Dynamic Water Level, DD= DrawDown, b= Aquifer Thickness, T= Transmissivity, k= Hydraulic Conductivity, CA= confined aquifer, SCA= semi - confined aquifer

6.4 HYDRAULIC CONDUCTIVITY AND DISCHARGE

The hydraulic conductivity values for the semi confined aquifers vary from 50.47m/day to 64.19m/day and the confined aquifer has a value range of 1.43m/day to 27.42m/day. The hydraulic conductivity value for the different aquifers in the study areas indicates high to moderate performance in all the locations with exception of Danya in Gwarzo L.G.A which have a hydraulic conductivity of 1.43m/day (Table 4) this value in indicates low performance of the aquifer. Discharge values of the tested boreholes in the study area shows values range of 43.00m^3/day to 95.90m^3/day. These values indicates high to moderate yield in all the boreholes in the study area, yield values of less than 50m^3/day can support hand pump only.

7.0 CONCLUSION

The geophysical investigation of the study area revealed the presence of four to five layers; topsoil, the second layer varies from clay to Laterite about the study areas, the third layer weathered rock, the fourth layer fracture rock, and fifth layer fresh basement rock. The study identifies the fourth layer with resistivity value range of 43.00Ωm to 622.00Ωm and thickness of 16.30m to 49.10m to be a potential aquifer. The boreholes sunk were pump test and the yield, Transmissivity and hydraulic conductivity were calculated. The values range for yield or discharge, Transmissivity and hydraulic conductivity are 43.20m^3/day to 95.00m^3/day, 17.19m^2/day to 1502.10m^2/day and 1.43m/day to 64.19m/day respectively. The study revealed that the areas has two types of aquifers; confined and semiconfined aquifer. Boreholes with Transmissivity value greater than 500m^2/day have high potential aquifer (Tasawar Dukawa, Gidan Darho and Sabarundan Maidaki), those with value greater the 50m^2/day are of moderate potential (Gidan Jibrin, Kabba, Dutsen Gima and Galadimawa) and those with value less than 50m^2/day are of low potential (Danya). Wells with values indicating high to moderate potential aquifers can support hand pump and motorized pump while, that with value indicating low potential can only support hand pump.

Appendix 1

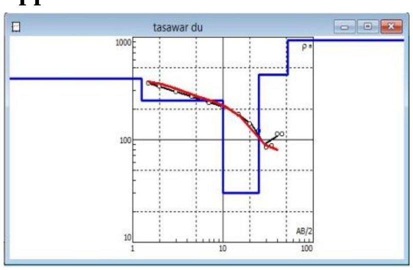

Figure 4: Iterative Sounding Curve for TasawarDukawa

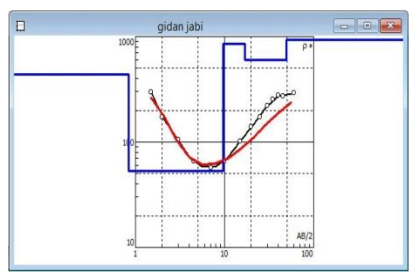

Figure 5: Iterative Sounding Curve for Gidan Jabir

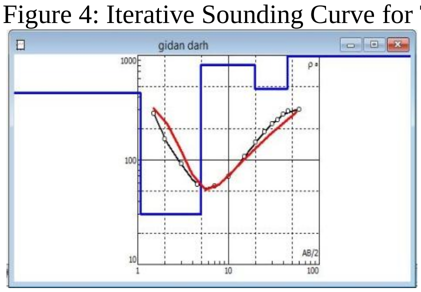

Figure 6: Iterative Sounding Curve for GidanDarho

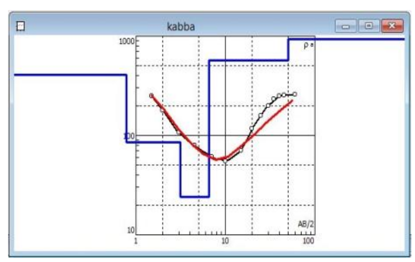

Figure 7: Iterative Sounding Curve for Kabba

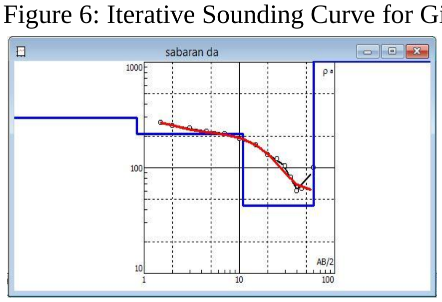

Figure 8: Iterative Sounding Curve for Sabaran Danmaidaki

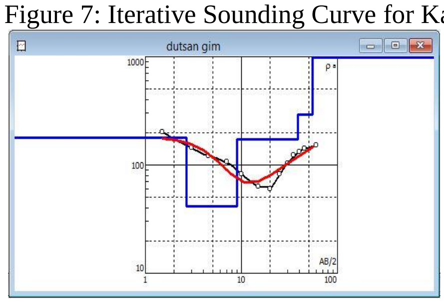

Figure 9: Iterative Sounding Curve for DutsanGime

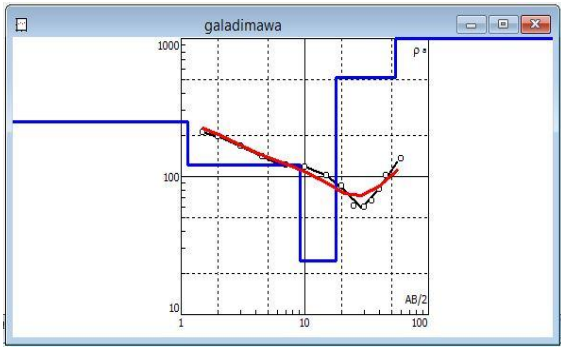

Figure 10: Iterative Sounding Curve for Galadimawa

Appendix 2: Borehole Log of the Study Area

S/N	Layer	Resistivity (Ωm)	Thickness (m)
1	Topsoil (sandy, silty sand, sandy clay	100 – 500	0 – 3
2	Laterite	200 – 700	3 – 9
3	Weathered Rock	10 – 200	9 – 30
4	Fractured Rock	500 – 900	30 – 50
5	Fresh Basement Rock	>900	>50

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