APPLICATION OF ELECTRICAL RESISTIVITY SURVEY FOR LOCATING GROUNDWATER AQUIFER AT MAISANDARI WARD DAMATURU YOBE STATE.

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ABSTRACT

This study investigates ground water source using resistivity method at Maisandari ward in Damaturu, Yobe state of Nigeria. A terrameter WDDS-2 was used to acquire resistivity data on two profiles each having a Vertical Electric Sounding (VES) point utilizing Schlumberger configuration at maximum spread of AB/2 200m. The data acquired were processed and interpreted using IXID computer software to give information on the geo-electric layers, the thickness of the layers, the resistivity of the layers and information about the depth. The findings revealed seven-layer model on VES1 and six-layer model VES2.The values of resistivity for each layer was inferred from standard resistivity values for soils found within the geological area. The inference deduced shows the layers investigated consist of top soil, clay, sandy/clay sand and laterite/sand. Profile (VES1) shows a potential aquifer for groundwater at a depth 160 m with formation resistivity value is 359.28Ω-m, while the second profile (VES 2) indicates potential ground water body at a depth of 160 m with formation resistivity value at 130Ω-m. Conclusively, the use of geophysical resistivity method can be applied to locate groundwater that could be exploited to provide sustainable water needs of man.

Keywords: Schlumberger configuration, Groundwater Aquifer, Maisandari.

INTRODUCTION

Natural water sources are rivers, oceans, streams, lakes, rainwater, springs and ponds. In northern eastern Nigeria, hand dug well, springs, surface run-off and ponds provide water to settlements to sustain human activities. Some of these sources, however, are seasonally dependent and cannot provide sustainable water requirements where increase in population has placed high demands on water. Damaturu, an urban settlement in northeastern Nigeria alongside with its environs rely on tube wells and boreholes as sources of water. Despite the large number of tube wells, water is still not sufficient (Babagana et al., 2017). This perennial problem, requires planning for sustainable sources of water that will match the increasing demand due to high rise in population. Emeka and Weltime (2008) reported that source of water in Damaturu has shifted to groundwater source. This is apparently informed by the potency of groundwater in addressing sustainable water needs for population in both sedimentary and basement terrains (Hoque et al., 2009; Olorunfemi and Fasuyi 1993; Obiora,2005; Offodile, 2002; Alabi, 2010).

Groundwater is the water in porous rocks beneath the water table (Adanu, 1989; Saad et al., 2012). In other words, it is the water that is contained in aquifers. An aquifer is any geologically deposited material that can store and transmit significant quantity of water. Aquifers are found deep beneath the earth's surface, and due to their depth of storage and natural filtration through the different subsurface layers (soil horizons), groundwater is relatively pure and grossly protected from surface pollutants. It is a source of uncontaminated water, and it is the largest reserve of drinkable water in the regions where humans live. According to Alhassan et al., (2009) groundwater may appear at the surface in the dorm of springs, or it may be tapped by wells/borehole. Therefore, to have a sustainable groundwater development, exploration and exploitation of groundwater becomes pertinent.

In this work, dc resistivity survey was deployed for groundwater exploitation. It was chosen among various geophysical methods owing to its simplicity and accuracy which makes it a popular groundwater investigation technique. The method incorporates the Vertical Electrical Sounding (VES), which involves injecting current into the sub-surface of the earth and measuring its perturbation effects on surface. It provides depth and thickness of various subsurface layers and their relative water yielding capabilities (Telford, Geldart and Sheriff, 1990).

LOCATION OF THE STUDY AREA

The study area is Maisandari ward (Fig. 1) located at the eastern part of Damaturu Local Government area and lies between the latitude of 11° 4° N and 11° 5° N, and longitude of 11° 5° E and 11° 6° E. It has area of 15km^2 and a population of about 10,000 people according to (National Census, 2006). It has boundaries with Gambir ward at south and Kukareta and Damakasu wards by its North all in Damaturu, Yobe State. Maisandari is pluralistic in ethnic composition, with Kanuri and Fulani as the dominant ethnic groups, others are Karai-Karai and Hausa which are minority tribes of the ward (Maisandari L.G Dairy, 2003).

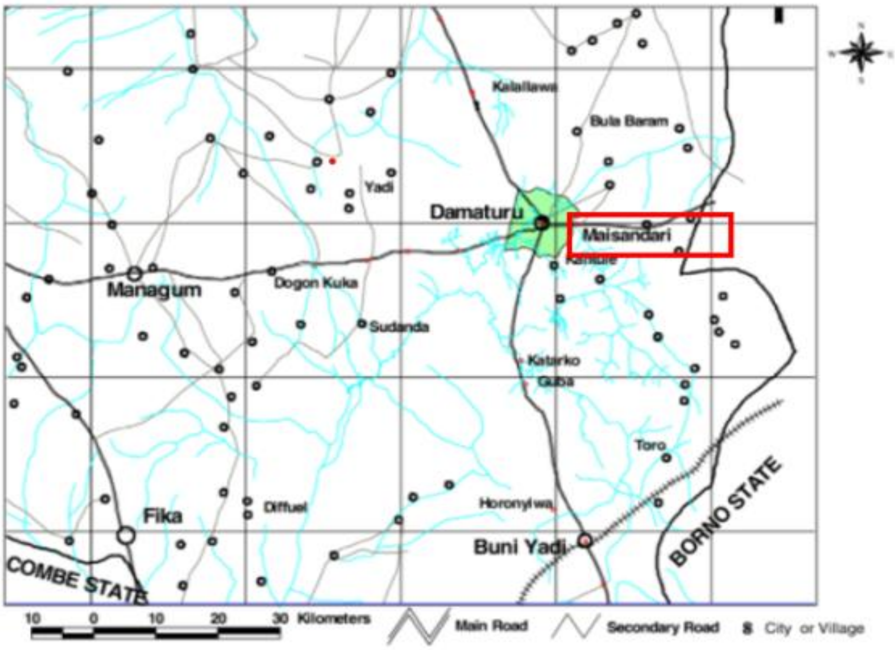


Fig. 1. Location of Maisandari Ward (Adopted from Dawoud & Raouf, 2009)

THEORY

The electrical resistivity method is an active and non-invasive geophysical method. It utilizes an artificial source which is injected into the ground through a pair of electrodes (Fig. 2). The procedure requires measurement of potential difference between other two electrodes in the proximity of current flow. Apparent resistivity, ρ_a is calculated by using the potential difference for the interpretation. The electrodes by which current is injected into the ground are called Current electrodes (C_1 and C_2) and electrodes between which the potential difference is measured are called Potential electrodes (P_1 and P_2).

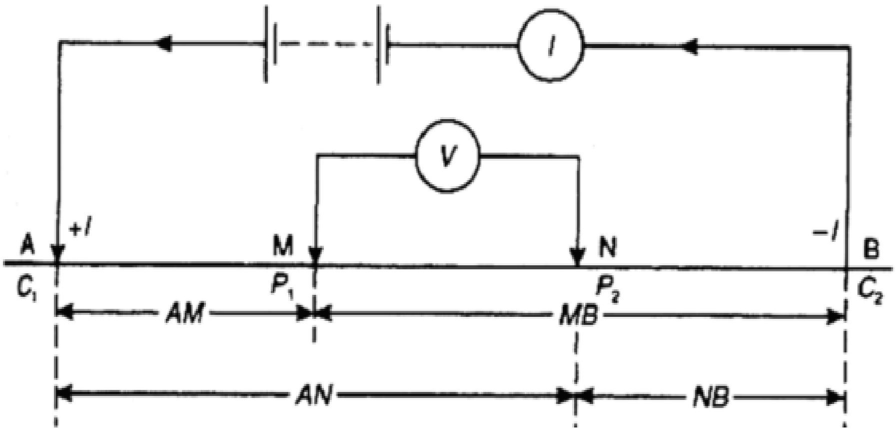


Fig. 2. Electrodes by which current is injected into the ground.

If A, B are current electrodes and M, N are potential electrodes, then according to Telford et al (1990), the potential at M,

$$V_1 = \frac{\rho_a I}{2\pi}\left(\frac{1}{AM} - \frac{1}{MB}\right) \quad (1)$$

The potential at N,

$$V_2 = \frac{\rho_a I}{2\pi}\left(\frac{1}{AN} - \frac{1}{NB}\right) \quad (2)$$

The potential difference between M and N,

$$\Delta V = V_1 - V_2 = \frac{\rho_a I}{2\pi}\left\{\left(\frac{1}{AM} - \frac{1}{MB}\right) - \left(\frac{1}{AN} - \frac{1}{NB}\right)\right\} \quad (3)$$

$$\Delta V = V_1 - V_2 = \frac{\rho_a I}{2\pi} * K \quad (4)$$

Where K is the geometrical factor and I is the current injected into the subsurface.

DATA COLLECTION

The materials used in this study include WDDS-2 terrameter, four metallic electrodes, electrical cables, measuring tapes, portable Geographic Positioning System (GPS) device, hammer, battery, measuring tapes, a source of direct current (battery) and other accessories (Fig. 3).

Fig.3. Some equipment used for data acquisition

Two vertical electric sounding (VES) locations were sounded at two different locations on two profiles using Schlumberger configuration at Maisandari ward. The Schlumberger configuration refers to a particular configuration of the electrodes (Fig. 2). In this configuration, the current electrodes C_1 and C_2 were moved further apart and consequent to further separation, the current penetration probe deeper. The configuration provides a high resolution and less time is required for field procedures and sensitive to both horizontal and vertical resolutions. Schlumberger configuration with maximum current electrode separation (AB/2) of 100 m has the capacity to probe a depth of 0.125 AB and its apparent resistivity according to Sharma (1997).

$$\rho_a = \frac{\pi L^2}{I}\frac{\Delta V}{2\ell} \qquad (6)$$

Where L, l, I and ΔV represent current electrodes separation, potential electrodes separation, current injected into the ground and the potential difference across the potential electrodes respectively. The four electrodes during data acquisition were positioned in the Schlumberger configuration such that potential electrode spacing MN = AB/2. Current was injected into the ground through the current electrodes (C_1 and C_2) and potential across the potential electrodes (P_1 and P_2) was measured; the terrameter automatically calculates ΔV/I and displays the resistance R in mΩ (mili-ohm). After each reading was taken, the terrameter was switched off and the current electrode spacing increased and the next reading was taken continuously, until a maximum of AB/2 separation = 200m on each side was obtained for every vertical electrical sounding (VES) locations. The acquired field data was then plotted on the log-log paper or graph, with the apparent resistivity ρ_a values being on the vertical axis and the electrode spacing (AB/2) on the horizontal axis, to produce a field curves which were subsequently correlated with a standard curve using the curve matching method. The data generated were interpreted using IXID computer software to give information on the Geo-electric layers, the thickness of the layers, the resistivity of the layers and information about the depth.

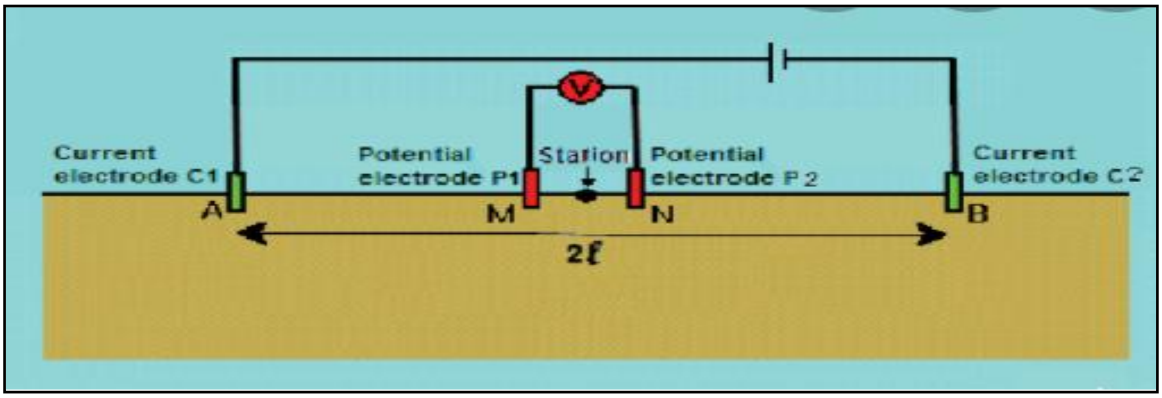


Fig. 4. Some equipment used for data acquisition (Adopted from Lemacha, 2017)

RESULT AND DISCUSSION

The result of the data collected and processed for the two VES stations are shown in tables 1 and 2 respectively.

INTERPRETED OF RESISTIVITY CURVE

The interpreted resistivity curves are shown in figures 5 and 6. Table 3 shows typical resistivity values of some common rocks which was used to correlate with the geology of the area to provide information for inference. Tables 4 and 5 show the resistivity values and the inferred geologic formation.

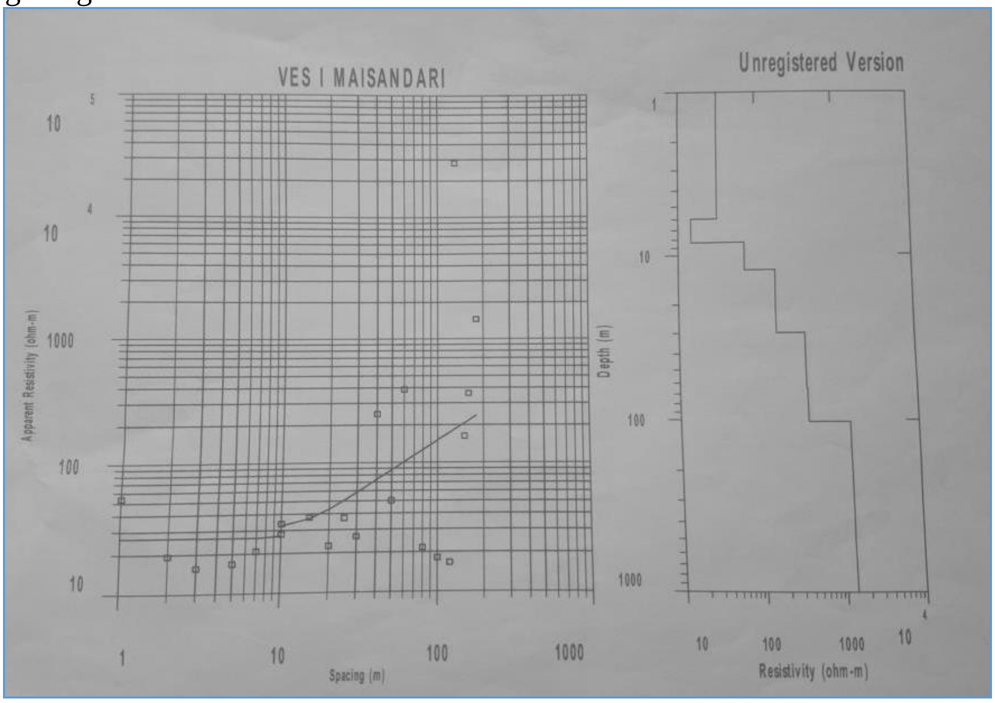


Fig 5. Apparent Resistivity versus Electrode Spacing Curve for VES 1

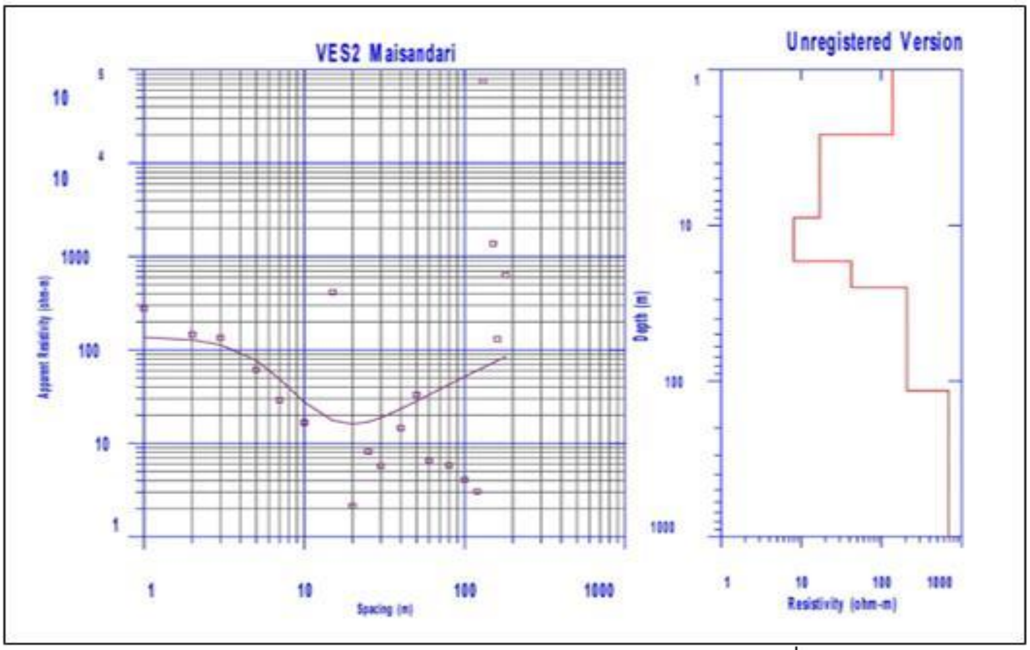
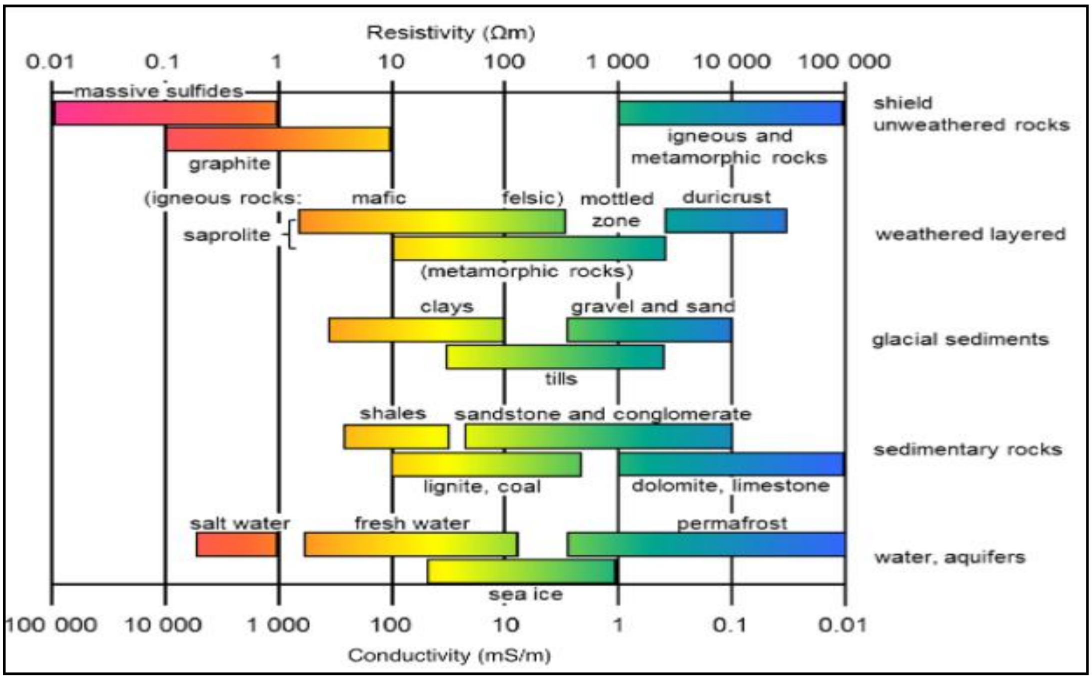


Fig 6. Apparent Resistivity versus Electrode Spacing Curve for VES 2

Table 1. Typical resistivity ranges of some common rocks



Source: https://em.geosci.xyz/content/physical_properties/electrical_conductivity/electrical condctivity_values.html

Table 2 shows the interpreted resistivity curve for VES1 Maisandari Ward. The table, shows VES1 has a five-layer model. The first layer has the resistivity of 15.67 Ω-m at the depth of 3.0m which is inferred as a top layer clay. The second layer has the resistivity range of 20-50Ω-m at the depth of 7.0m and is inferred as sandy/clay layer. The third layer has the resistivity of 16.56 Ω-m at the depth of 120.0m which is made up of clay. The fourth layer has resistivity of 359.28 Ω-m at the depth of 160.0m which is made up of sand. The fifth layer has the resistivity of 1415.60 Ω-m is inferred to be laterite.

Table 2. INTERPRETED OF RESISTIVITY CURVE FOR VES 1

S/N	Resistivity (Ω-m)	Depth (m)	Inferred Formation
1	15.67	3.0	Top soil
2	20.85-50	50	Sandy/clay Sand
3	16.56	120	Clay
4	359.28	160	Sand
5	1451.60		Laterite

Table 3. INTERPRETED OF RESISTIVITY CURVE FOR VES 2

S/N	Resistivity (Ω-m)	Depth (m)	Inferred Formation
1	134.41	3.0	Topsoil
2	16.0	10	Clay formation
3	33.32-130	25	Sandy formation
4	635.7		Sand and laterite

Table 3 shows the interpreted resistivity curve for VES 2 Maisandari Ward, from the table it is observed that VES 2 has a four-layer model. The first layer has resistivity of 134.41 Ωm to a depth of 3.0m which is topsoil. The second layer has the resistivity of 16.0 Ωm at the depth of 10.0m which is inferred as clay formation. The third layer has resistivity range of 33-130 Ωm at the depth of 25.0m which is made up of sandy formation. The fourth layer has the resistivity of 635Ωm is inferred as sand/laterite.

DISCUSSION

The analysis and the interpretation of the surveyed data shows the presence of multi-layer models in the sedimentary formation, having a maximum of five and a minimum four layers models for VES 1 and VES2 respectively. The values of resistivity for each layer was inferred from standard resistivity values for soils found within the geological area. The inference deduced shows the layers investigated consist of top soil, clay, sandy/clay, sand and laterite/ sand. The resistivity values and ranges for each of the mentioned formations are given in the above tables. Profile (VES 1) shows a potential aquifer for sustainable groundwater at a depth 160 m with formation resistivity value is 359.28Ω-m, while the second profile (VES 2) indicates ground water body at a depth of 25 m with formation resistivity value at 130 Ω-m. This aquifer characteristic is in agreement with the study conducted by Dawoud & Raouf, (2009). Literature has also shown that unconsolidated sediments such as clay, sand, gravel and silt constitutes a good aquifer in the study area.

CONCLUSION

This study has helped to identify the nature and type of aquifer and depth of potential and sustainable aquifer present in the study area. The method of investigation adopted in this study has helped in the identification of the aquifer units and the depth required for locating points with high potentials for groundwater occurrence. The geophysical investigation survey has proven that sustainable groundwater supply can be achieved explored at the site of investigation through non-invasive method to locate groundwater source.

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