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**FULL LENGTH RESERCH ARTICLE**

# HYDROGEOPHYSICAL INVESTIGATION FOR GROUNDWATER POTENTIAL IN CENTRAL MINNA, NIGERIA.

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## ABSTRACT

This hydro geophysical investigation is aimed at delineating the aquiferous units in the central part of Minna by determining their depths, thicknesses, resistivities and the potential borehole depth at various locations within the area employing the technique the Vertical Electric Sounding (VES) using the Schlumberger array. A grid of 7 profiles with a total of 49 sounding stations was occupied. The area was found to be underlain by 4 geological formations. The second and third formations underlying parent bedrock form the aquiferous unit. This unit was found to have an average resistivity value range of 120 – 900 Ωm and an average thickness of 25 m. It is deeply seated in some areas with an average depth of 25 – 30 m.

***Keywords*:** Vertical Electrical Sounding (VES), Resistivity, Aquifer, Borehole.

## INTRODUCTION

The development of the city in terms of size and population has been very rapid ever since increasing populace becomes inadequate. In addressing this situation, the government has developed two dams; the Bosso dam to the north and the Tagwai dam to the south of the city. The Rural Water Supply and Sanitation (Ruwatsan) Agency focuses only in addressing the water needs of the suburb. It is in line with this challenging demand that this hydro geophysical survey project was undertaken with the aim to delineate the aquiferous units by determining their depths, thicknesses, resistivities and the possible potential borehole depths for various locations within the area.

## MATERIALS AND METHODS

The study area consists mainly of the central part of Minna, an area of about 324 km$^2$. It is bounded by latitudes 9°32'N and 9°42'N and longitude 6°30'E and 6°40'E in the topographic map of Minna, sheet SW 164 (Fig 1).

**Geology and hydrogeology:** The Minna area falls within the larger northwestern Nigerian Basement Complex. The rocks of the area are mostly crystalline rocks consisting of Gneisses and Migmatites, and Meta-Sedimentary Schist (Adeleye, 1976). The area is thus underlayed by two lithological units of Granites and Gneisses with Pegmatite's and quartz veins as minor intrusive. The Granites, which cover about 80% of the area, are mostly exposed on the western part of the town. They mostly form high batholiths, which are extensive in size. The Granitic outcrops are highly jointed, fractured, foliated and in some places appear as boulders (Adeniyi, 1985). The second lithological unit, the Gneiss, covers about 20% of the area and occurs to the east of city. They are fine grained with gneissose banding defined by the alternating lighter colored minerals (quartz and feldspars) and the dark coloured ones (biotite micas). They are intruded by the granitic rocks and in most cases are highly fractured and weathered. Some of the Gneisses contain augen structures, banding and boundinages. Apart from these two major rock types, there are other rock types in form of minor intrusives such as pegmatites and quartz veins. They are closely associated with the granitic rocks and the gneisses. These cut across one another and are generally characterized by coarse textures. Geometrically, they occur as Dykes, Sill lenses and Phenocrysts. The width of Pegmatite on the average ranges from 15 to 35cm and several meters long. Minerologically, they mostly contain quartz, feldspars and some minerals of precious quality e.g. tourmaline, emerald, aquamarine, epidotite, etc (Wright *et al.,* 1985). The quartz veins are generally less in dimension and in most cases barren while some may be mineralized. Hydrogeophysically, Minna area is made up of only the crystalline hydrogeogeological province, as there is a complete absence of Sedimentary rocks in the study area. This Crystalline hydrogeological province is made up of two interconnected aquifers, namely:-

i the aquifer within the overburden/weak zone and
ii the partial Weathered/Fractured Basement aquifer.

The depth to the water table lies on the average between 3 – 15 m below the surface in the Crystalline Basement Complex (Offodile, 2002). The average yield of borehole in this aquifer is between 0.75 – 1.80 litres per second with an average depth of about 37.3 m (Davis & De West, 1970). However, this aquifer yield decreases with depth.

**Resistivity of Rocks and Minerals:** The electrical resistivity of subsurface materials (rocks, minerals etc.) can be determined by the subsurface resistivity distribution to the ground. This can be related to the physical conditions of interest such as lithology, porosity, degree of water saturation and presence or absence of

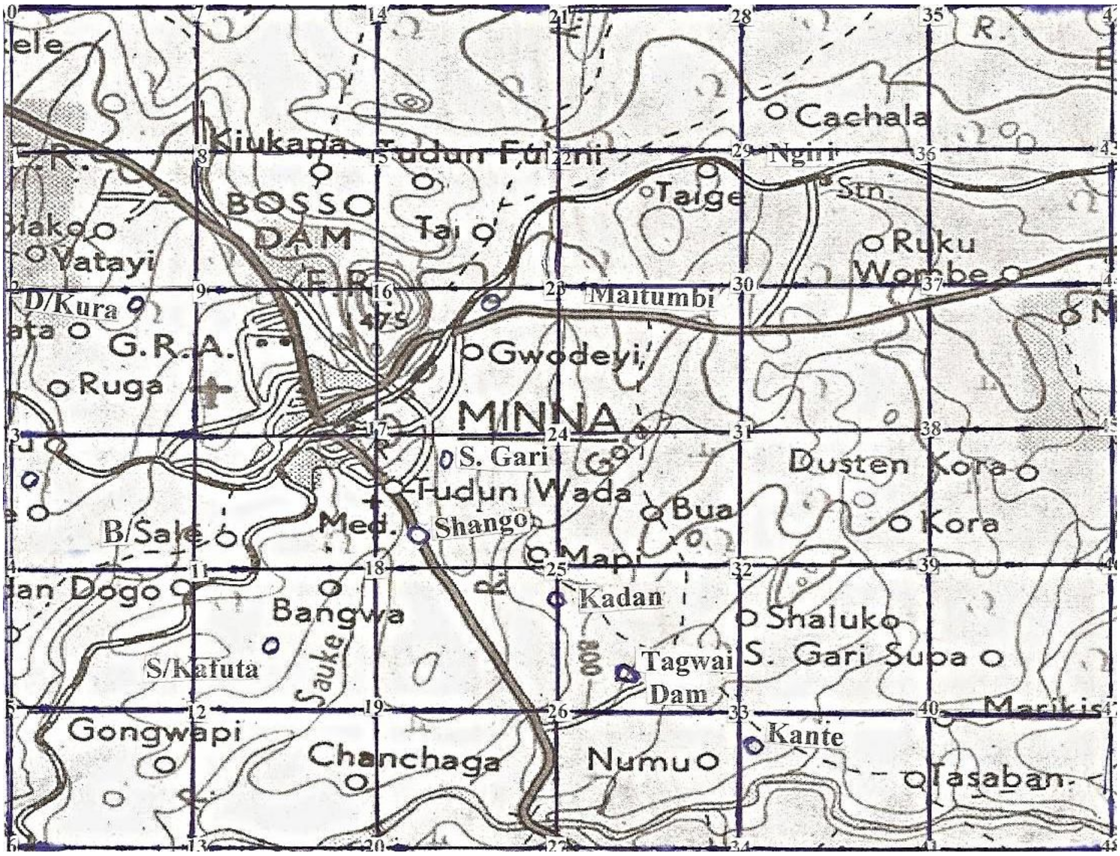


FIG. 1. TOPOGRAPHY OF MINNA SHEET SW 164 SHOWING VES STATIONS

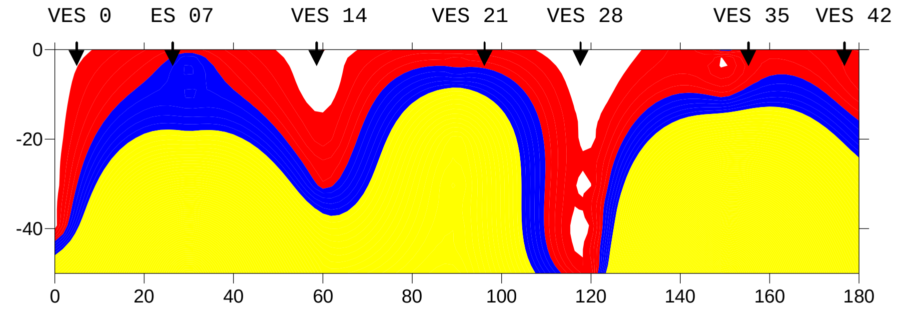
voids in the rocks (Ako, 2002). The resistivity of crystalline rock formations such as granite, granulite, diorite etc is largely dependent upon the water in the fissures and fractures (Sheriff *et al.,* 2002). Hard rocks are known to be of high resistivity of several thousands of Ohms-metre (Ωm). Zones of crushed and badly fractured rocks may sometimes have resistivities of as low as 1 – 2 Ωm. Water being one of the most important minerals may occur as subsurface groundwater, accumulating in reservoir rocks (sands, gravels, silt, limestone etc) in the sedimentary rocks, and in weathered overburden, joints, fractures and faults zones in crystalline basement rocks (Ako, 2002). Some clays as well as water logged soils may possess very low resistivities of the order of 1 – 20 Ωm.

**Data collection**: The Vertical Electric Sounding (VES) method of electrical resistivity was employed using the Shlumberger electrode configuration. A maximum of current electrode spacing of AB/2 of 100 m was fixed in this work in view of the shallow nature of the basement rocks of the area.

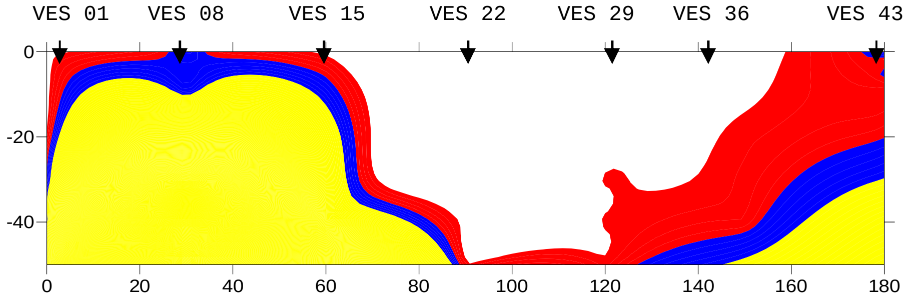
The study area was transformed into a grid of 7 profiles, with 49 sounding stations at intervals of 3 km (Fig. 1). The ABEM Terrameter SAS 300C was used in the data acquisition. The observed field data which is only a measure of resistance was converted to resistivity values in Ohm-meters. These computed apparent resistivity values as functions of electrode spacing were then converted to true resistivity values as functions depths of individual layers for a 2D profile by a program developed by Zohdy (Zohdy, 1989) to produce depth-sounding curves. The theories of both the electrical resistivity survey and the Shlumberger electrode configuration are well documented in the standard texts like Griffiths and King (1983), Keller & Frischnech (1966) and Telford *et al*., (1976).

## RESULTS

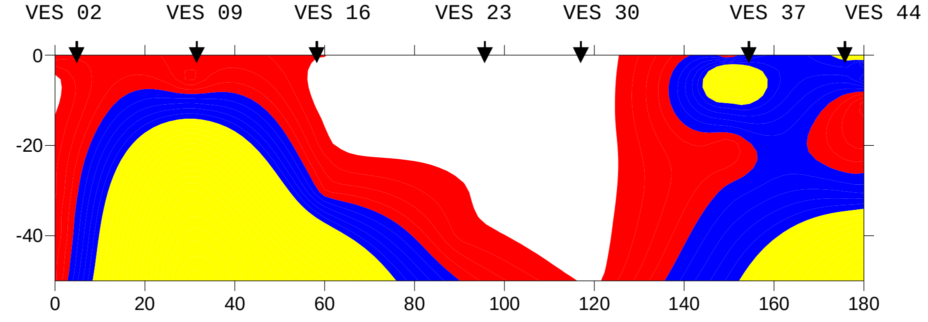
The depth-sounding curves so obtained were used to generate the depth-sounding contour maps and the geologic equivalent maps for the profiles through the VES points (Figs. 2a - g).



**Profile (a)**



**Profile (b)**



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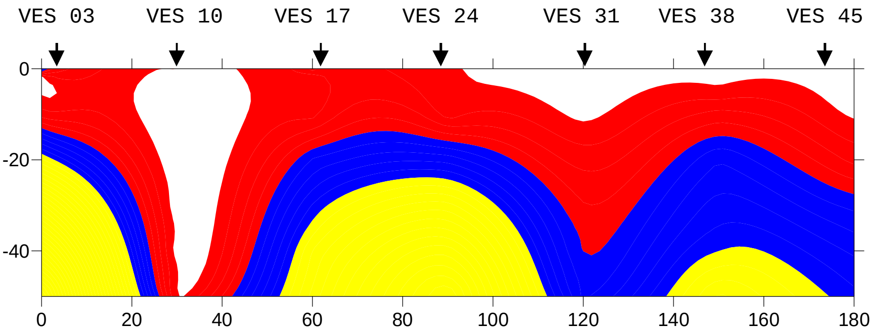

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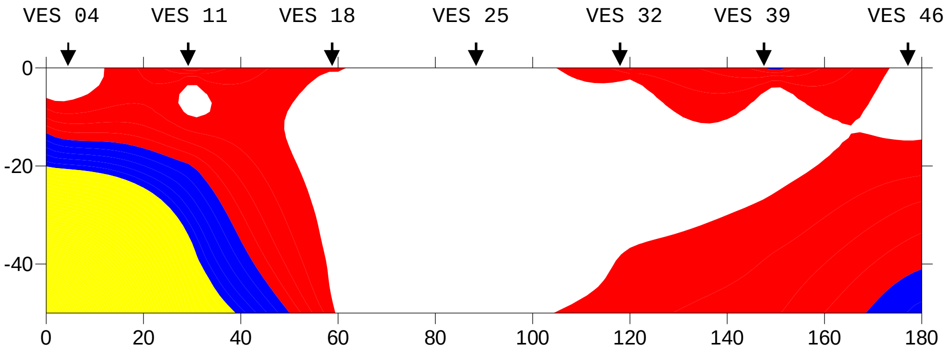
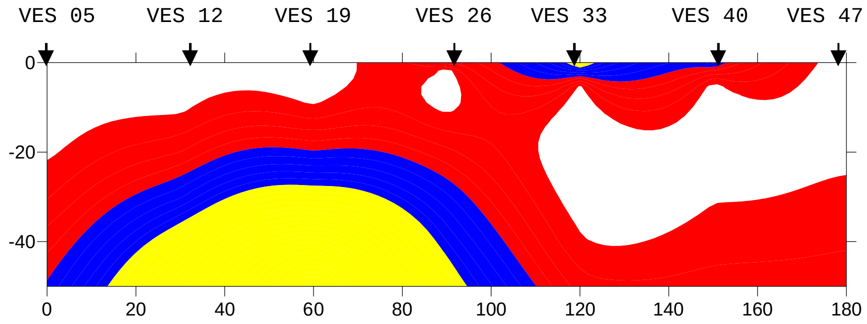
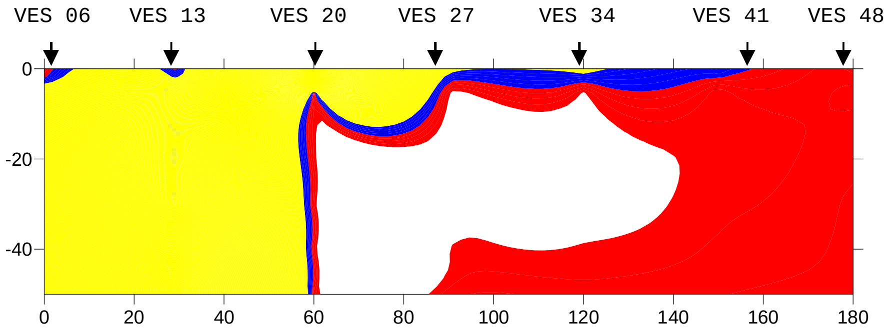


Profile (e)



Profile(f)



Profile (g)

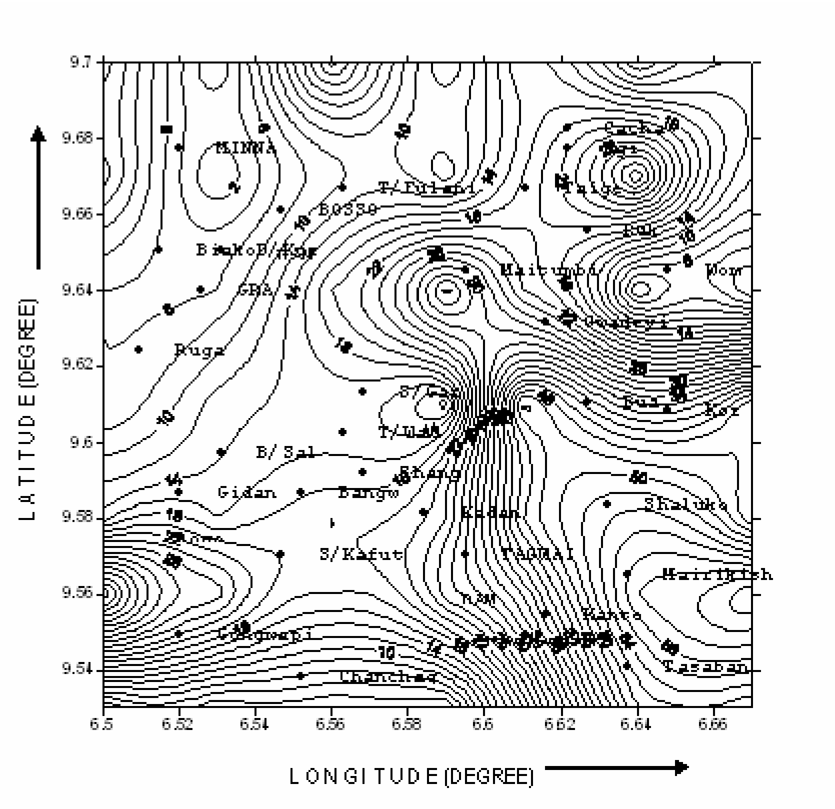


FIG. 3. CONTOUR MAP AQUIFER THICKNESS (CONTOUR INTERVAL 2 M)

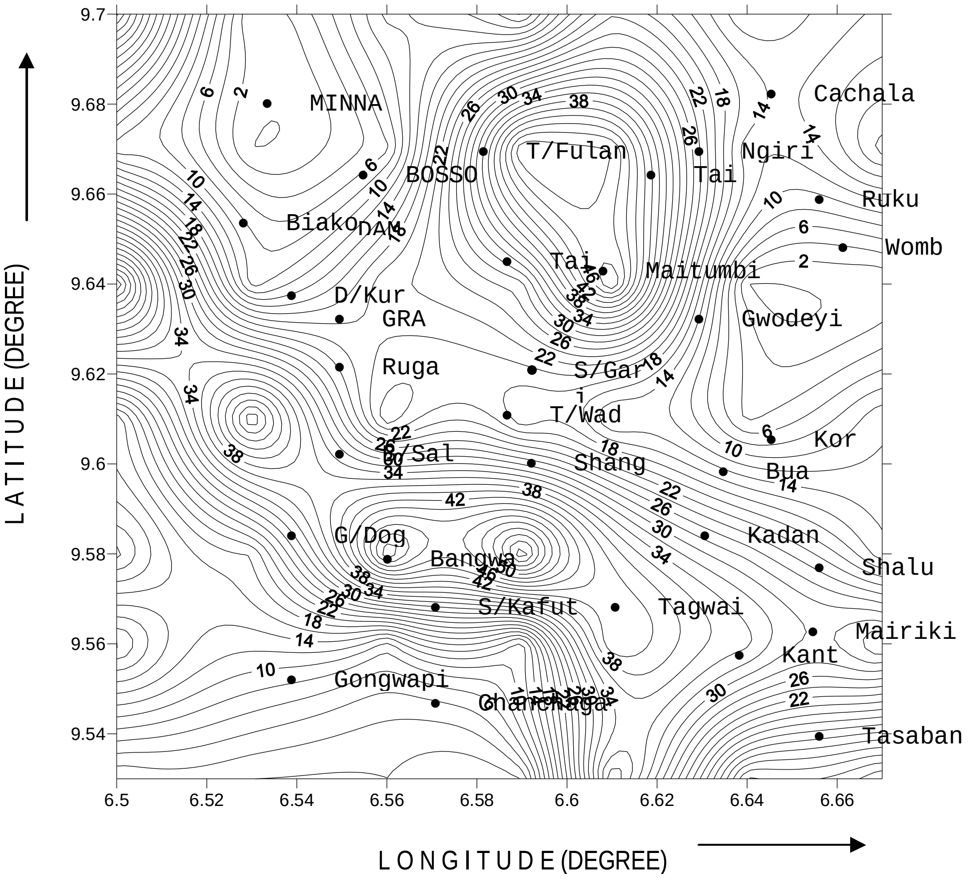


FIG.4. CONTOUR MAP DEPTH TO AQUIFER (CONTOUR INTERVAL 2 M)

A contour map of the depth to the aquifer, Fig. 4 reveals the variation of this depth within the study area. The sounding on the profiles revealed that the study area is underlain by 4 geological formations. This is shown in the aquifer thickness map shown in Fig. 3.

## DISCUSSION

The study area is underlain by materials which are largely Gneisses, Migmatites, and Meta-Sedimentary Schist. The surfacial materials, which form the first layer have average values of resistivity between 10 – 900 Ωm (Aboh & Osazuwa, 2000) and consist of sand, laterites, gravels and clayey soils in varying proportions. The low resistive areas are the weak zone. This formation has an average thickness of about 30 m. They are considered as part of the "secondary" aquifer system as a result of their poor transmitivity of groundwater. The aquifer here is generally regarded as unproductive due to low level of exploited groundwater (Adekeye & Ishaku, 2004). This soil types are found in areas like Barikin Sale, GRA, Minna Forestry Reserve, Tai, Maitumbi, Kora, Kadan, Marikishi, Chanchaga ,Gongwapi, Sauke Kafuta, Bangwa and Gidan Dogo.

The second layer with a resistivity value ranging between 102 – 600 Ωm is the weathered zone layers and consists of sand, gravels as well as high content of ferruginised particles derived from thick lateritic cappings of weathered lateritic materials with thickness ranging between 5 – 20 m. It is deeply seated in some areas like Kante and Tasaban. This layer is part of the "secondary" aquifer system.

The third layer is the transition zone with resistivity values ranging between 120 – 900Ωm. It is the weathered/fractured basement layer (Ako, 1996) with an average thickness of about 25m. Generally these rock types are usually liable to form aquitard and permeable zones to the crystalline basement complex bedrocks. They are thus characterized by the presence of fractures, fissures, veins, joints and such other structural deformations of the basement which controls the flow of groundwater and also influence the rate of recharge (Offodile, 1992). This formation is the main aquifer in the study area. The aquifer map (Fig. 4) gives a general view of the area's aquifer thickness and has been found to correlate with the borehole logs of selected wells dugs in similar geological formations (Aboh & Osazuwa, 2000). The area's aquifers are found to be deeply seated in places like Bua, Shaluko, Maitumbi and Mairikishi. The aquifers are located at an average depth of between 25-30m throughout the study area.

The fresh parent rock underlying this unit forms the fourth formation which is the bedrock. It is the fresh crystalline basement rocks with resistivity value ranging between 1000 – 20000 Ωm. These are hard rocks with extremely low to absent porosity. They are not water bearing due to their high cementation factor (Ako, 1996).

In conclusion, the weathered/fractured basement formations are the areas recommended which have good potential for successful borehole locations. Where these sites coincides with where the aquifer is deep they form the best sites for locations of the boreholes. Thus, the best sites for possible location of boreholes include areas like Sauke kafuta, Barikin Sale, GRA, Dutsen Kura, Tudun Fulani, Taige, Maitumbi, Tagwai Dam and Kante. Other sites which do not have as good promise for a productive yield of groundwater have similarly been found.

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