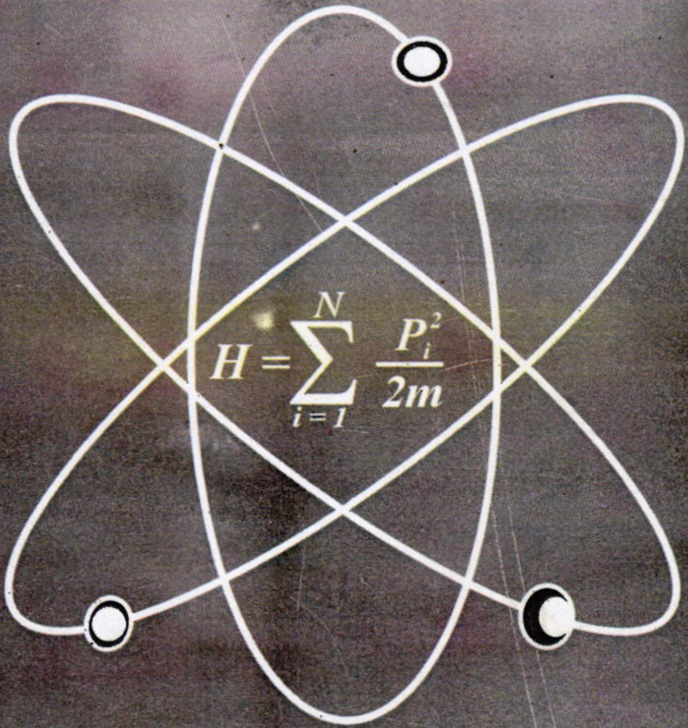
BAYERO JOURNAL OF PHYSICS AND MATHEMATICAL SCIENCES



VOLUME 3, No. 1
AUGUST, 2010.

Published by: THE DEPARTMENTS OF PHYSICS AND MATHEMATICAL SCIENCES, BAYERO UNIVERSITY, KANO.

HYDROGEOLOGICAL AND GEOPHYSICAL STUDY OF BOSSO AREA OF MINNA, NORTH-CENTRAL NIGERIA

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Abstract

The hydrogeological potential of Bosso area was carried out using a combination of geology, hydrogeological and geophysical methods. Detailed geological mapping of the area was carried out to determine the dominant rock type and fracture pattern in the area. The Static Water Level (SWL) in the in most hand-dug wells in the area was measured and the data obtained were used to generate groundwater flow direction in the area from where stations were picked for Vertical Electrical Soundings. The Field mapping reveals that granites are the major rock type in the area followed by schist and gneiss respectively. The analysis of the vertical electrical sounding showed that the area is characterized by three geo-electric layers. The rosette diagram and the radial geo-electrical sounding polygons show a fracture pattern of NE–SW and NW–SE direction. The vertical and lateral variation in the thickness of weathering of the rocks in the area favours groundwater exploration.

Keywords: Aquifer Characteristics, Weathering Thickness, Minna, Nigeria.

Introduction

Nigeria is considered to be abundantly blessed with water resources. However, there is temporal and spatial variation in water availability, the north with low precipitation of only about 500mm in the northeastern comer, and the south with precipitation of over 4,000mm in the southeast. According to the United Nations Development Programme, meaningful progress in water supply is fundamental for environmental sustainable development [1]. Adequate supply of water is central to life and civilization. Food production as well as other socio-economic activities depends on availability of water. Water has been a very important factor in settlement development in the country where it usually serves as human settlement boundaries. The study is aimed at illustrating the effectiveness of multiple approaches in groundwater exploration and exploitation as against a particular technique. Geophysical techniques together with geological, structural and hydrogeological mapping have shown a positive synergy. Understanding structures is the key to interpreting crustal movements that have shaped the present terrain [2]. Structures also indicate potential sites for locating water, oil and gas reserved by characterizing both the underlying subsurface geometry of rock units and the amount of crustal deformation experienced by the rock body [3].

Location, Drainage Pattern and Accessibility of the Area.

The study area lies between longitudes 6°30^{1}E and 6°38^{1}E of the Greenwich meridian and latitudes 9°31^{1}N to 9°42^{1}N of the equator (Figure 1). It covers a total area of about 294.7km^2. The area is accessible through the following express-ways: Lambata, Bida, Zungeru and Kuta. The area has a fairly flat-lying terrain with few gentle hills and drained by river Chanchaga and its tributaries.

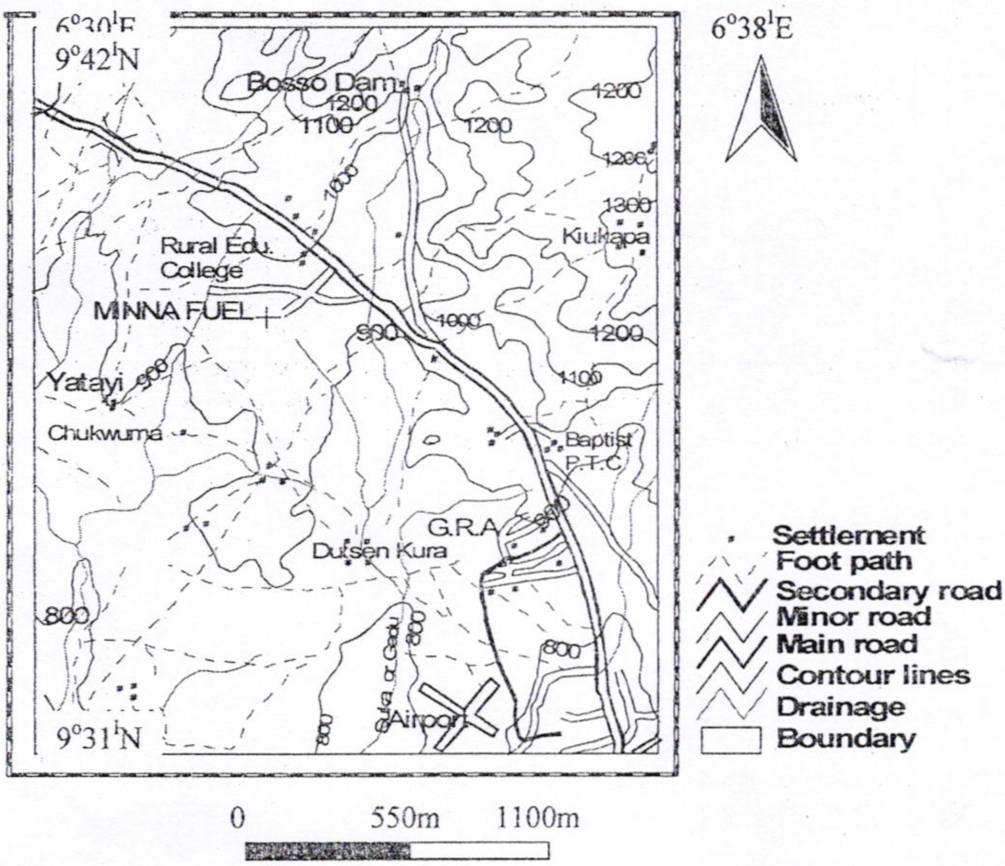

Fig. 1: Map of the study area showing the major road and drainage pattern.

Climate and Physiography of the Area

The study area lies within the North-central climatic system which is a transitional zone between the rainforest of Southern Nigeria and the Guinea Savannah of the Northern Nigeria. This area is characterized by tall grasses, Shrubs and trees. The annual rainfall distribution pattern shows a maximum of 1300mm rainfall and minimum of 1000mm. The daylight temperature ranges from about 24^{0}C at the climax of rainy season to about 35^{0}C at the peak of dry season [4]. Along the river channels, the vegetation becomes more forest-like.

General Geology of the Area

The area investigated is part of the north-central Basement Complex of Nigeria which is composed of three lithological units- migmatite-gneiss complex, low grade schist belts and the older granite [5, 6]. Geological mapping revealed that the study area is underlain by granites, schist and gneiss with granites occupying greater portion of the area. The structural mapping carried out in the area shows two principal joint directions along NE-SW and NW-SE. The river Chanchaga at the southern part of the study area (Figure 2) which flows eastwards is structurally controlled [7]. The values of the joint directions taken were used to plot the rosset-diagram in Figures 3a and 3b. The determination of the major joint directions in the area serves as a guide to groundwater occurrence and movement.

Hydrogeological Mapping of the Area

The Static Water Levels (SWL) of the perched aquifer in hand-dug wells was determined with the aid of a measuring tape. The longitude, latitude and elevation of each location were obtained using the Global Positioning System (GPS). The value of the Static Water Levels (SWL) below the ground level was subtracted from their corresponding elevation heights to obtain the Static Water Level (SWL) above sea level.

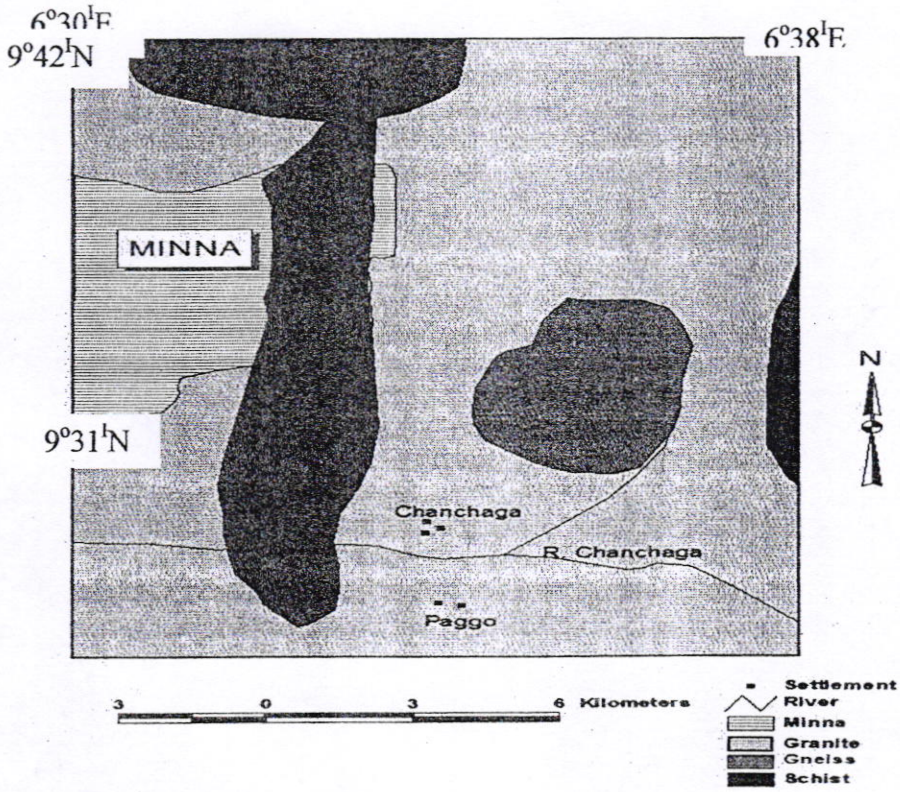

Fig. 2: Geological map of parts of Minna (Modified from [8].

Topography.

The GPS readings were used to generate the Digital Terrain Model (DTM) of the area using Surfer 8.0 software as shown in figure 3. The highland is at the north while the area slopes southward. The highlands are occupied by granite while the lowlands are occupied by granite, gneiss and schist. River Chanchaga flows from east to west through the granite and schist while Bosso Dam to the north is underlain by granite. The intervening ground is occupied by granite-gneiss. The southeast region is highly weathered and covered by vegetation.

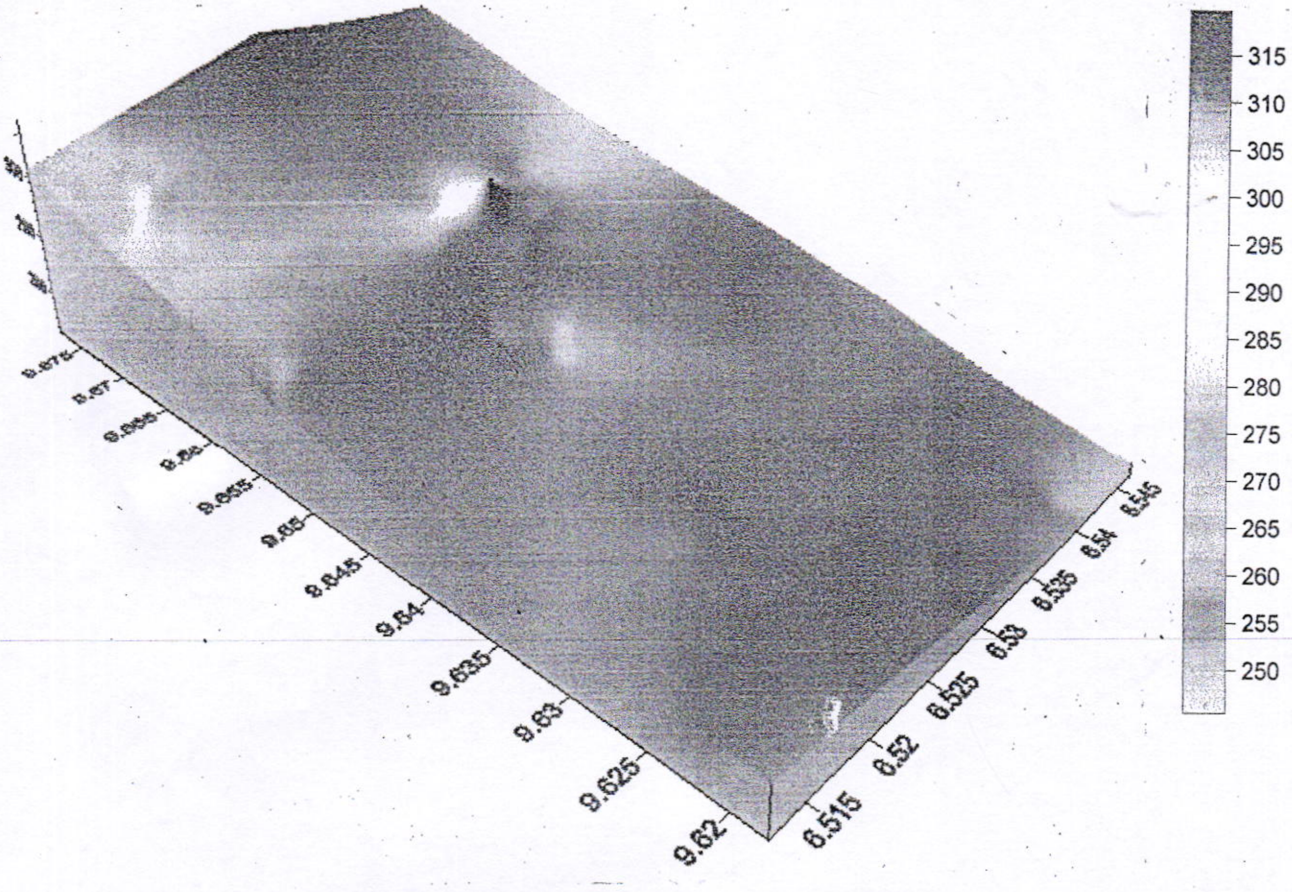

Fig. 3: Digital Terrain Model (DTM) of the Study Area

Groundwater Flownet

The groundwater flowline and flow direction were superimposed to generate the groundwater flownet. Groundwater flow in a NW-SE and NE-SW directions away from the high topographic area and converges towards the Central Southern part of the area (Figure 4). The convergence of the groundwater in the central portion is due to the presence of fractured (weathered) basement rock.

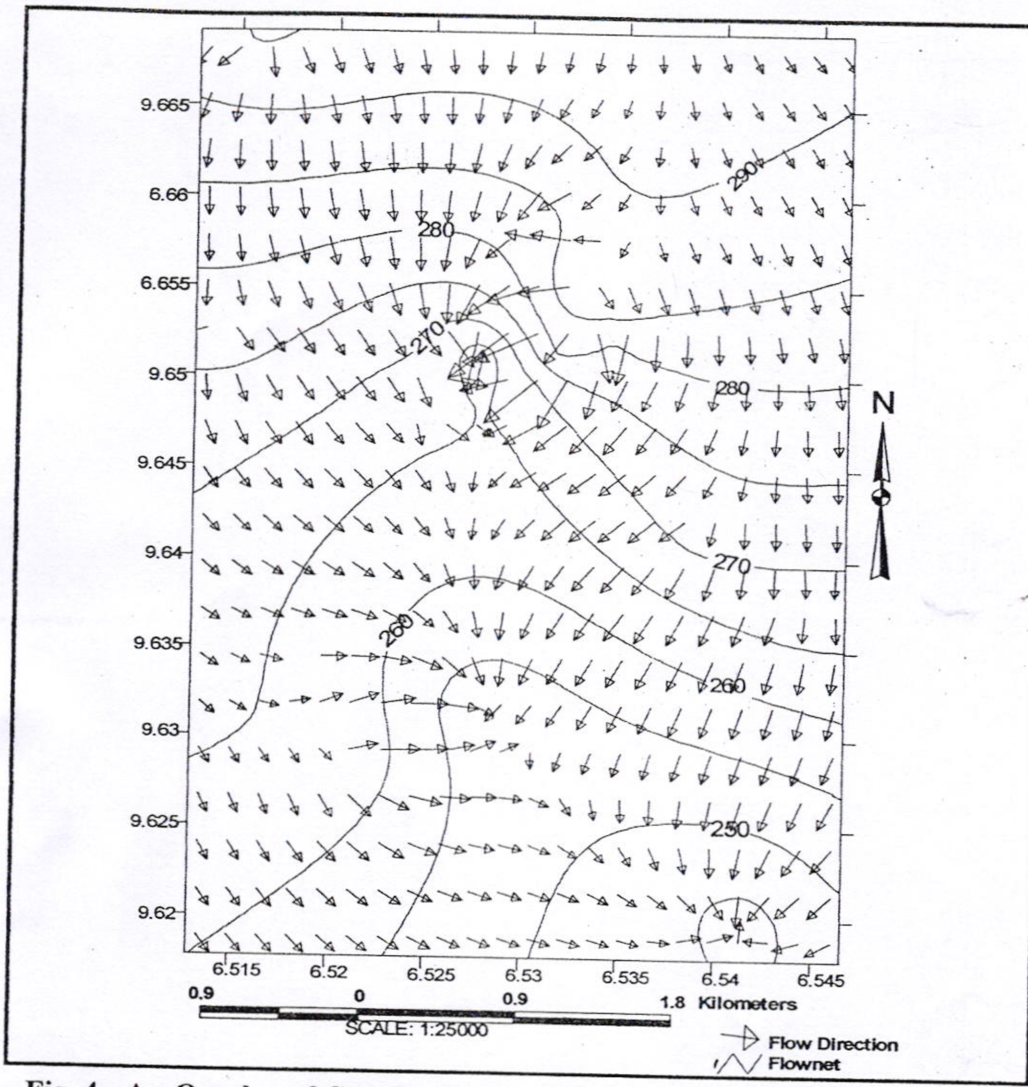

Fig. 4: An Overlay of Groundwater flownet in the study area

Radial geo-electric sounding

Radial geo-electric sounding is the act of conducting Vertical Electrical Sounding (VES) in three directions: 0°, 60° and 120°. The results of the radial geo-electric sounding carried out in some locations in the study area were used in determining the fracture patterns. The concept of the radial geo-electric sounding is that, lowest resistivity values are obtained along directions where fractures and weathering have taken place.

Assumption: If the earth is homogeneous and isotropic the values of resistivity should be equal irrespective of direction. However, the earth is anisotropic and non-homogenous. This implies that when VES are done in three different coordinates, the lowest resistivity values are obtained along the direction where fractures and weathering have taken place. This implies that the polygon drawn from the radial geo-electric soundings will have a long axis perpendicular to the fraction directions [9, 7]. A typical anisotropy polygon of the area is shown in figure 5.

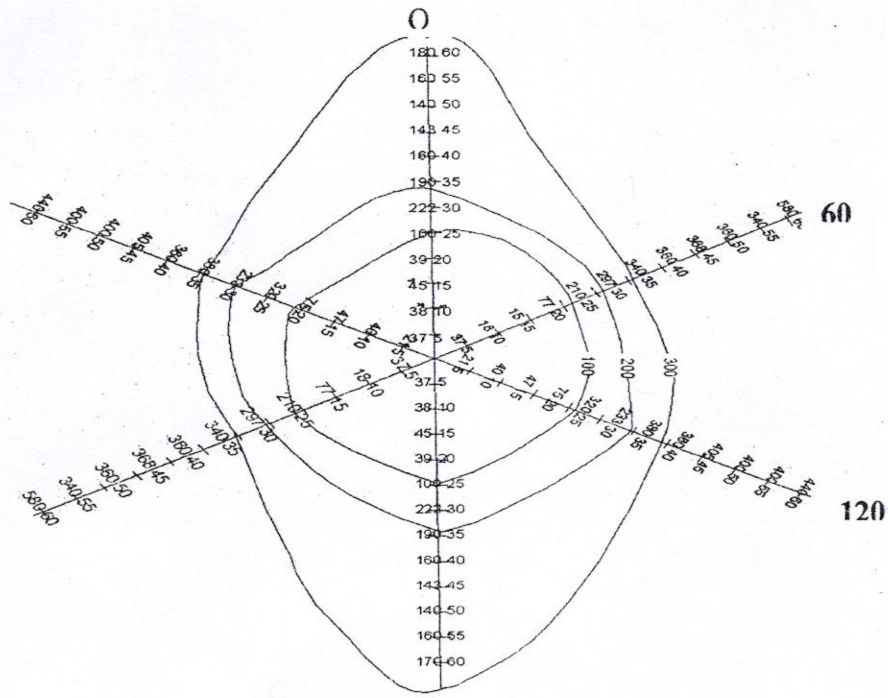

Fig. 5: Resistivity anisotropy polygon of part of the Minna

Geo-Electric Sections

The geo-electric section reveals three distinct layers: the top soil, weathered/fractured zone and the fresh bedrock. The thickness of each of the layers varies from place to place and an average value of 2.1m, 13.3m and 30m for top soil, weathered/fractured zone and the fresh bedrock respectively was obtained. The weathered/fractured zone is sandwiched between the top soil and fresh bedrock while the last layer is continuous and tends towards infinite. Resistivity method, using the Vertical Electrical Sounding (VES) Schlumberger array technique was used. The survey provides information about the nature of the subsurface geology (Figure 6) of the area. The lithostratigraphic information obtained through geophysical survey compliments geological and hydrogeological mapping carried out in the area.

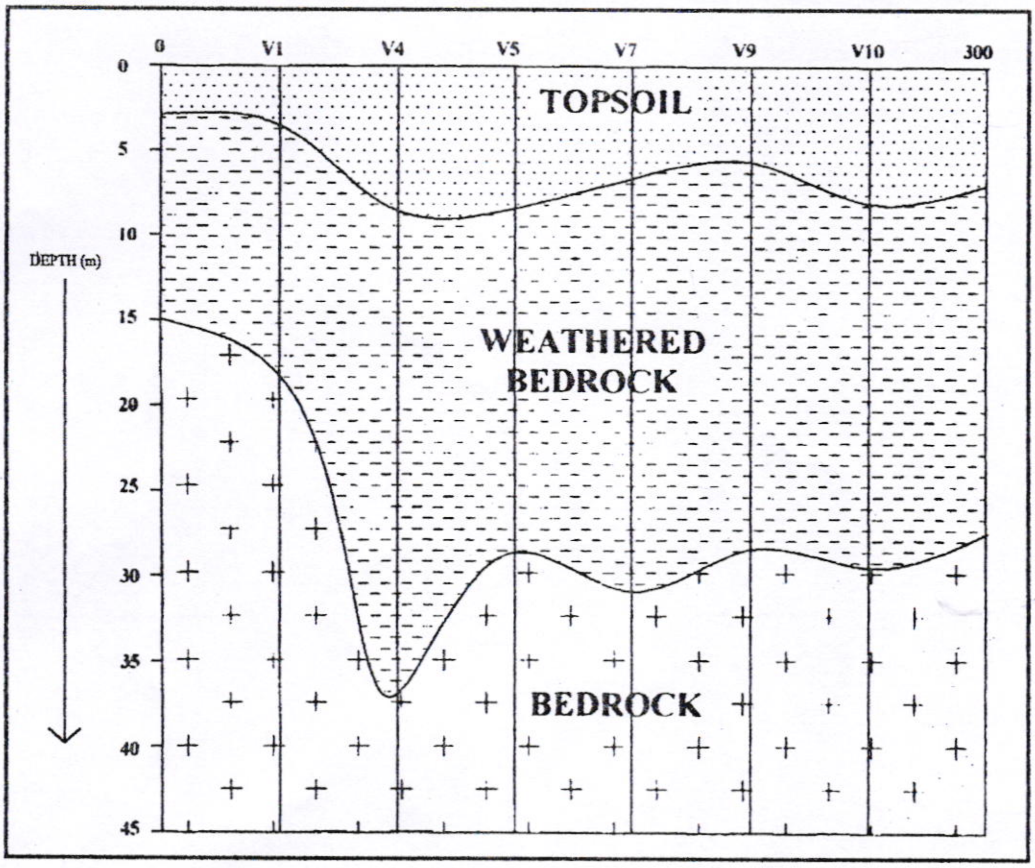

Fig. 6: A typical Geo-electric Section of the area

Summary of Findings

A total of 29 hand-dug wells were measured using a GPS and a measuring tape and the information obtained were used to construct Digital Terrain Model (DTM) using Surfer 8.0 software and groundwater flownet for the area. The groundwater flows in a NE-SW and NW-SE direction away from the high topographic area and converge towards the central and southern part of the area. The convergence of the groundwater in the central portion is judged to be structurally controlled. The high-grounds are occupied by granite while low lands in the south are occupied by schist. Radial geo-electric sounding involved vertical electrical sounding (VES) in three directions: 0°, 60° and 120° and at three stations while the data obtained are used in the construction of resistivity anisotropy polygons of the area which correspond to the NW-SE and NE-SW joint direction.

Recommendation

A combination of geology mapping, structural mapping, hydrogeological mapping and geophysical survey gives a synergy and enhances efficiency in groundwater exploration than any single method. Groundwater exploration should concentrate on the central portion of the area due to the presence of significant fractures.

Conclusion

The result of the geological mapping, hydrogeological investigation, radial geo-electrical sounding all confirm the existence of three major rock types (Granites, Schist and Gneiss) and two main joint directions (NE-SW) and (NW-SE) in the area. The flow of river chanchanga located at the southern part of the study area is fracture controlled. The geo-electric section shows the top soil, weathered/fractured zone and the fresh bedrock as three distinct layers. The topsoil layer has a thickness ranging from 0.8m to 3.2m; the weathered zone has an average value of 4.0m to 20.1m while the mean depth to fresh bedrock was calculated as 30m. The results of the VES data indicate a resistivity values range from 7ohm-m to 670ohm-m for the topsoil; 11ohm-m to 480ohm-m for the weathered zone and above 100,000ohm-m for the fresh bedrock.

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