ELECTRICAL RESISTIVITY SURVEY FOR GROUND WATER POTENTIALS IN SHAKWATU, NIGER STATE, NIGERIA.

BY

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ABSTRACT

The Schlumberger configuration of the geophysical electrical resistivity method was employed to investigate the groundwater potential in Shakwatu, Niger State, part of the topographical Minna Sheet 164. Geologically the area is considered as part of the crystalline basement complex characterized with rocks such as migmatite-gneiss, granite, quartzite and schist. A total of 36 VES points were established along six profile lines employing the SAS 4000 Terameter. The interval between the profile lines and the intervals between the VES points was set at 100 m respectively. The maximum current electrode spacing (AB/2) was set at 100 m while the maximum potential electrode separation (MN/2) was set at 15m. The geoelectric data were plotted with the aid of the Win resist inversion software. Geoelectric parameter obtained from the iterated model geoelectric curves were interpreted through qualitative and quantitative methods such as geoelectric sections, iso-resistivity maps and iso-patch maps. Three curve types were noticed from the model geologic curve. These include the HA (ℓ1 > ℓ2 < ℓ3), A (ℓ1< ℓ2 < ℓ3) and AK curve types. All the geoelectric sections of the six profiles are composed of three geoelectric layers. The apparent resistivity of the first and second geoelectric layer ranges from 18 Ωm to 695 Ωm and 11 Ωm to 1782 Ωm respectively with a thickness range of 0.5 m to 1.6 m and 1.1 m to 16.4 m for the first and second layers. The depth to the first layer ranges from 0.5 m to 1.6 m and 1.9 m to 17.5 m for the second geoelectric layers. The third geoelectric layer shows a resistivity range of 493 Ωm to 5631 Ωm which extends to an infinite depth. The first layer iso-resistivity map indicates low to moderate resistivity with the lowest resistivity indicated within the southern, central and north-western portion of the mapped area. The iso-resistivity map of the second geoelectric layer indicates low resistivity values across the layer. The north-eastern, south-eastern and south-western portions of the area displayed the lowest resistive zones; the northern portion is the resistive portion of this layer. The iso-resistivity map of the third geoelectric layer indicates moderate to high resistivity values. The potential VES points for groundwater exploitation in the study area includes P_1V_3 which indicates low to moderate resistivity at greater depth. VES points P_6V_1 and P_2V_2 which indicate a fairly thick overburden material are also considered as potential points for groundwater exploitation.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The ever-increasing demand for water, made groundwater exploration more important in Nigeria. World Health Organization posited that ten percent of the world's population is affected by chronic water scarcity and is likely to rise to one-third by the year 2025 (Esimai, 2017). The water scarcity experienced by the people, led to the search for groundwater supply.

Water which occurs as stream, rivers and ocean are termed as surface water and are mostly subjected to pollution. Most Nigeria streams, rivers and ocean are highly polluted and the pollution are caused by the activities of Man via industrial or petroleum exploration. Ground water being very good source of drinking water and favourable all over the world, the Nigeria situation appears to be restricted by the fact that more than half of the country is underlain by sedimentary formations. These rocks comprise mainly sand stones, shales, clay and hard crystalline impervious rocks which are either igneous or limestone (Koeford, 1979).

Groundwater which is described as "water in the zone of saturation and from which wells, springs and underground run off are supplied" was the first alternative opened to man. This water is trapped by geological formation (Tefford *et al*., 1980). It underlie the surface of the earth almost everywhere, it is not accessible, or fresh enough for use without treatment, and it is sometimes difficult to locate or measure. This water may occur close to the land surface, as in marsh or may lodge many kilometres beneath the surface as in some arid areas. Groundwater is stored in and move slowly through moderately to high permeable rocks called aquifers. An aquifer may be a layer of gravel or sand, a layer of sandstone, a rubble top or base of a lava flows or even a large body of massive rocks such as granite that have sizable openings. Groundwater is believed to be the sub-surface water that fully saturates the pores or cracks in the soils and rocks. It is replenished in both quantity and quality depending on the local climate and geology of the area. When rainfalls, some water infiltrate into the pores or cracks in the rocks and soils. Between the land surface and the aquifer, lies an unsaturated zone where there is at least a little water mostly in smaller openings in the rocks. The larger openings contain air instead of water. The unsaturated zone is saturated after a sufficient rain has fallen and is almost dry after a long period of dry spell. Water is held in this zone by molecular forces so that it does not flow towards or enters a well (Esimai, 2017). Excess water infiltrates into the water table, below the water table, all the openings in the rocks are full with water that moves through the aquifer to streams, springs or wells.

The movement of groundwater is governed by pressure difference. The differences in pressure are influenced by gravity, hence groundwater moves from areas of higher elevation to areas of lower elevation. According to Parasnis (1987), exceptionally rapid movement may occur where water flows through open, interconnected fractures.

1.2 Statement of the research problem

The communities and individuals of Shakwatu mostly drink water from polluted streams, rivers and wells, which infects them with water related diseases like typhoid, rashes, dysentery and cholera. In response to this and because of the intimate relationship between water and life, there is need for research work of this nature to identify groundwater potential points for the community.

1.3 Scope of the study

The research location is at Shakwatu in Shiroro Local Government having an area of 0.25 km^2. Resistivity method with Schlumberger electrode array system was used for data collection. Win resist software was used in the analysis of the data collected.

1.4 Justification of the study

The need for water is important in every sphere of human life. Shakwatu is a settlement area. Thus, the need for clean water for the community is paramount for healthy living.

1.5 Aim and objectives of the study

The aim of this work is to apply electrical resistivity method to determine the groundwater potential of parts of Shakwatu of Niger State.

Objectives are to:

i determine the resistivity, depth and thickness of the subsurface layers

ii. produce isoresistivity, overburden thickness and geologic section maps of the study area

iii. delineate the aquifer potential of the study area

1.6 Geographical Location of the study area

The study area, which covers an area of 500 meters by 500 meters, is part of Shiroro local government area of Niger state, North-central Nigeria. It is located between latitude $9^0 40^/ 10.2^{//}$ to $9^0 40^/ 21.8^{//}$ and longitudes $6^0 42^/ 02.1^{//}$ to $6^0 42^/ 13.4^{//}$ (Figure 1.3).

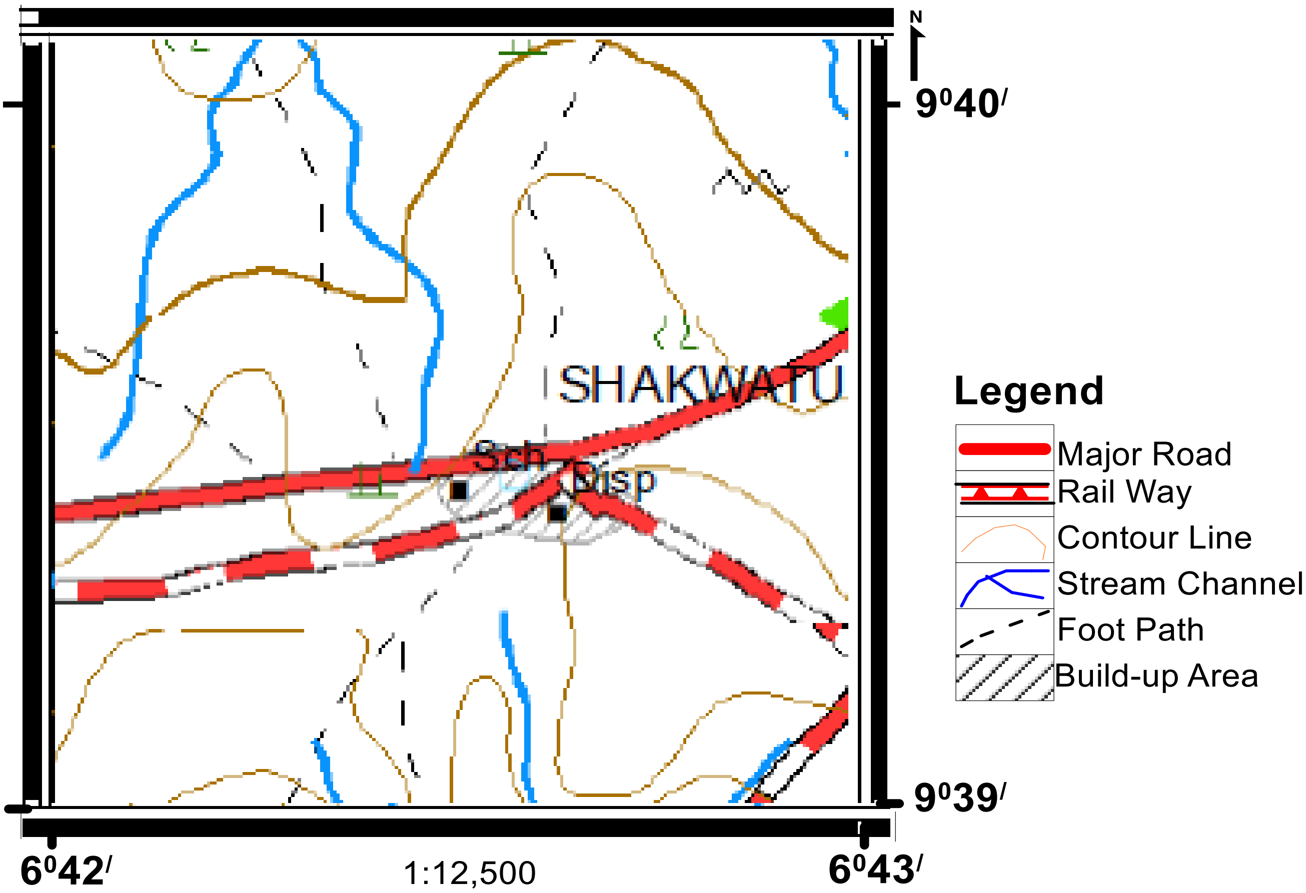

Figure 1.3: Geographical Map of the Area (Office of the Surveyor General of the Federation, 2018)

It is accessible and bounded to the South by Shakwatu-Gunu Road, to the west by Shakwatu-Gunudna road, to the North by Gunudna and to the east by Gunu-Sheroad.

1.7 Geology of the study area

Shakwatu is located 7 km East of Minna and is underlain by basement complex rocks consisting of medium-grained biotite granite inter banded with coarse-grained leucocratic granite and intruded in places by quatzo-feldspar pegmatite dykes. The dykes strike parallel to the strike of the foliation and they range from 0.5 km to 3.5 m in diameter. Outcrops are found along the river valleys as flat laying bodies. They range in sizes from 3 x 5 m to about 8 x 15 m. Pinkish feldspar (i.e. potassium feldspar) is the dominant mineral in the granite gneiss and the pegmatite. The rock types present in the area are part of the old granite suite which are mostly exposed along the stream channels (Udensi *et al.*, 1986). The major rock type is porphyritic, medium to fine grained granite (Adesoye, 1986; Adeniyi *et al.*, 1988). The rocks are found in East-West (E-W) trending quartz; this is in contrast to the porphyritic granite that are found in the North-South (N-S) trending quartz and aplitic veins ranging in length from 2 m to about 15 m. The medium to fine grained granite rocks are broken into boulders in some places and they show the effect of weathering in the form of colour change, and loose rock fragments (Adesoye, 1986).

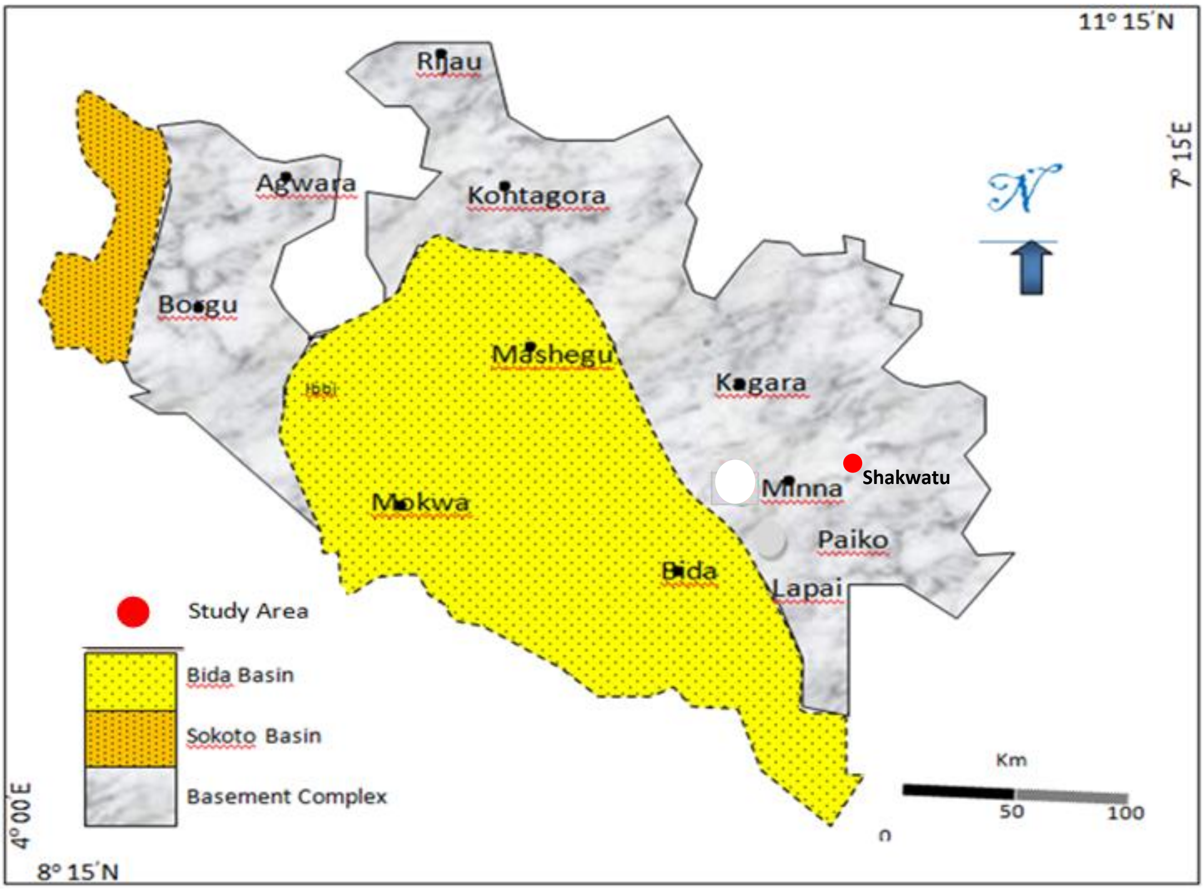

Figure 1.4: Geological Map of Niger State (Amadi *et al.*, 2012)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Geophysical literature

Several research works have been carried out on the use of resistivity methods in investigating groundwater potential within Minna metropolis, Niger State and Nigeria at large.

Ameh *et al*. (2020) carried out a hydrogeophysical investigation of groundwater systems in Otukpo, Benue state, North-Central Nigeria. The Schlumberger configuration of electrical resistivity method was used to establish the lithological variation and to establish the depth to groundwater formations in the area. Coherency was established between the predrilling geophysical investigation and post drilling activity which was verified through the drilling operations.

Ameh and Amadi (2020) carried out geoelectric prospecting for shallow aquifers in Otukpo town, North Central Nigeria to identify area suitable for shallow groundwater abstraction. It was established that the near surface resistivity in the area is high which is attributed to the occurrence of lateritic formation in the near subsurface. The middle layer of the profile was indicative of moderate resistivity readings. The investigation suggested that the depth of hand-dug wells should be limited to range of 18 m to 20 m due to the effect of shale which is a poor aquifer material that exist beyond this depth.

Kolawole *et al.* (2019) used electrical resistivity technique to correlate the aeromagnetic anomaly in basement complex terrain around Ilorin, West Central Nigeria. A total of twenty vertical electrical sounding (VES) using Schlumberger array of the electrical resistivity method was carried out in the study area. The results were presented in the form of sounding curves, geoelectric sections and pseudo sections. A low resistivity of E-W trend of fractures were observed at depth greater than 35 m.

Alhassan *et al*. (2019) carried out a geoelectric survey in parts of three arms zone in Minna, north central Nigeria. The aim of the survey was to evaluate the aquifer potential of the area and its protective capacity. Fourty eight vertical electrical sounding stations were investigated across the area. Schlumberger electrode configuration with maximum current electrode spacing (AB/2) of 100 m was employed. The area was gridded into six profiles with profile separations of 100 m and VES spacing of 100 m apart. Two to four geologic layers were delineated from the interpreted results. The geoelectric layers of the subsurface shows topsoil with resistivity range from 2.1 to 434.4 Ωm, Weathered/fractured basement layer resistivity range from 20.4 to 4491.1 Ωm and fresh basement resistivity ranging between 1,021.4 and 19,418.4 Ωm. The weathered/fractured layer is considered as the major aquiferous zone. Iso-resistivity and longitudinal conductance maps were produced. Eight VES points were considered as the aquifer potential of the area having weathered/fractured resistivity varying between 108.5 Ωm and 647.1 Ωm with thickness range from 11.8 m to 30.7 m. The longitudinal conductance value ranged from 0.002642 Siemens to 2.340909 Siemens. The protective capacity evaluated shows that about 50% of VES points are poorly protected, 14.48% are weakly protected, 22.92% are moderately protected and 12.50% have good protective capacity.

Markus *et al*. (2018) combined the methods of electrical resistivity profiling (ERP) and vertical electrical sounding (VES) to investigate the groundwater potential of parts of Rafin-Yashi, Minna, North central Nigeria. Out of the 200 VES points probed, 15 were chosen as priority locations suitable for groundwater development. Also, it was established that the area was characterized by three to four discrete geoelectric layers, namely, the top layer, the weathered layer, the fractured/fresh layer, and the fresh basement layer.

Shehu *et al*. (2018) carried out vertical electrical sounding at Union Site, Gidan Kwano Campus, Federal University of Technology, Minna, Nigeria. Their objective was to delineate areas suitable for structural development and to determine the soil corrosivity of the study area. A total of sixty (60) vertical electrical sounding points were covered and their result revealed the existence of three (3) distinct geologic layers, the layers include topsoil, fractured basement and the fresh basement. The topsoil has resistivity and thickness values ranging from 11.41 – 1009 Ωm and 1 – 6 m respectively. The fractured basement has its own resistivity value and thickness ranging between 11 – 963 Ωm and 1 – 45 m respectively indicating high fracture and/or water saturation. The resistivity value of the fresh basement ranged from 12 – 2983 Ωm. A, H and Q curve types were observed and seventeen (17) vertical electrical sounding stations having depths to basement varying between 2 – 5 m were delineated for high rise building.

Alhassan *et al.* (2017) carried out vertical electrical sounding (VES) in northern part of Paiko, North Central Nigeria to determine the subsurface layer parameters (resistivities, depths and thickness) employed in delineating the groundwater potential of the area and established three to four distinct geoelectric layers, namely, the top layer, the weathered layer, the fractured/fresh layer, and the fresh basement layer. Eight VES stations were delineated as groundwater potentials of the area, with third and fourth layer resistivities ranging from 191 to 398 Ωm. Depths range from 13.60 to 36.60 m, and thickness varies from 9.23 to 30.51 m.

Akande *et al.* (2016) investigated the groundwater potential of Chanchaga area, Minna, North-central Nigeria with a view to delineating the suitable aquifer for groundwater development. The technique employed for the study was vertical electrical sounding (VES) of the electrical resistivity (ER) method. They concluded that the central and northern parts of the study area have meagre to marginal groundwater potential, and this is supported by the occurrences and concentration of fractures which can constitute weathered/fractured aquifers around these regions.

Gonzales *et al* (2016) studied the geometry of the aquifer structure in the Punata alluvial fan using geoelectrical techniques of electrical resistivity tomography and IP. The study proved the applicability and effectiveness in describing the subsurface layering and thicknesses of the diverse geological lithologies in the alluvial fan of Punata. It was concluded that the geoelectrical procedures of electrical resistivity methods are valuable and efficient methods for mapping the aquifer systems in the Punata alluvial fan, and in another geological terrains.

Ejepu and Olasehinde (2014) used the vertical electrical sounding (VES) to give information about the subsurface lithology and structures of the Gidan Kwano Campus, Federal University of Technology Minna, with the aim of evaluating its groundwater potential. Out of the 48 VES made, 8 VES stations have been selected as priority locations for the development of groundwater resources. The study area has been found to have a very high potential for groundwater development.

Vertical electrical sounding was used at Pompo village in the neighbourhood of Gidan Kwano campus of Federal University of Technology, Minna. The study showed underlying geo-electric section comprising top soil, weathered basement, fractured basement and fresh basement was established. The vertical electrical sounding curves revealed that the area is generally characterized by five geo-electric layers. The top soil layer is a highly resistive layer with thickness ranging from 0.3 m to 1.6 m. The second geo-electric layer is a resistive dry layer with thickness ranging from 0.9 m to 4.3 m. The weathered basement layer thickens varies from 0.9 m to 9.1 m. The fractured basement ranges from 2.1 m to 16.4 m in thickness, while the depth to basement varies between 4.9 m and 25.3 m. Out of the 12 VES carried out, 5 VES stations were chosen as the most viable locations for the development of groundwater resources. Two types of aquifers, which are the weathered basement and fractured basement aquifer, have been delineated in the study. The aquifer units were believed to have significant groundwater potential.

Waheed S.U *et al.* (2014) employed vertical electrical sounding (VES) in resident areas of Minna Metropolis, Niger state, Nigeria. The study revealed predominantly H-type curve typical of the basement complex system with three geoelectric layers: the top soil, weathered/fractured basement and fresh basement. The resistivity of the first layer ranged from 2.5 – 928 Ω m with a corresponding thickness of 0.5 m – 3.1 m, second layer has resistivity values of 8.3 – 41.3 Ω m with a corresponding thickness of 2.1 – 33.0 m and the third geoelectric layer has resistivity values ranging from 74– 4173.5 Ω m with an indefinite thickness. A careful examination and integration of the isopach map with the isoresistivity maps (at 30 and 40 metres depths) indicated that the central and northern parts of the area have very low to low apparent resistivity values and shallow overburden which is capable of constituting shallow aquifer units.

Adetona *et al.* (2013) employed (VES) and seismic refraction methods to determine the groundwater potentials of western part of Federal University of Technology, Gidan-Kwano Campus, Minna and locate those that could be useful for civil engineering purposes. The interpretation of the seismic data obtained shows two geologic sections within the study area. The first layer has an average seismic velocity of 1237.86 m/s and has an average depth of 4.74 m. He concluded that the result of the two methods shows that the study area is underlain with maximum of three geologic layers. The electrical method shows that the second layer is characterized by weathered and fracture basement, while the third layer is the fresh basement rock. Seismic (with two layers) was characterized with first layer velocity ranging from 716.33 m/s to 2024.29 while the second layer has velocity range from 1935.36 m/s to 7485.03 m/s. However, the refractor depth within the survey area ranges between 2.79 to 6.66 m with an average depth to refractor of 4.74 m and is mainly composed of granites. The results of the VES interpretations shows that the depth to basement rock in some areas were found to be in the range of 18 m to 32 m, while seismic refraction method only shows that the refractor depth was found to be in the range of 2.79 and 6.66 m

Mijinyawa *et al*. (2013) carried out a comprehensive geophysical and hydrogeological investigation aimed at locating optimal drilling points at Daura town. The Schlumberger configuration was utilized with, AB/2 electrodes separation set at 350 m. Quantitative and qualitative analysis of the data obtained was used to delineate distinct geoelectric layer. It was noted that qualitative interpretation of subsurface information provides control and confirms the inference drawn from geophysical investigation. Three optimal drilling points for groundwater development were identified based on the investigation.

Ismail and Yola (2012) carried out a vertical electrical sounding survey at Dawakin Tofa Local Government Area of Kano State. They indicated that dynamic water levels from open wells were collected and these were used as guides for the selection of the electrode spread distance. Further, they pointed out that the Schlumberger array with a maximum electrode spread of 100 m was employed at all points. The authors reported that the results from the sounding data of their investigation indicate that the area is generally underlain by five geoelectric or geologic section as follows: lateritic top soil or lateritic sand, silty sand or sandy clay, weathered basement or clayey sand, fractured basement, and fresh basement. Based on the results obtained, the authors concluded that the fractured and the weathered basement constitute the aquiferous zone within the area and that the resistivities of these zones varies from 7.3 to 772 Ωm with an average value 178 Ωm, while the thickness varies from a value of 1.66 to 28 m with an average value of 14.33 m. Depth to this zone varies from 5 to 31 m with an average value of 16 m.

Okolie and Akpoyibo (2012) investigated subsurface lithology and aquifer distribution using the vertical electrical sounding (VES) method at Edjekota, Ughelli North Local Government Council, Delta State, Nigeria. The authors remarked that this community is prone to annual flooding that result in massive deposition of materials over many years, thereby polluting sources of potable water. The authors acquired ten VES sounding points that were then plotted on bi-log graphs to obtain the associated sounding curves. The result obtained by the authors showed that Edjekota has homogeneous subsurface stratification with AAK, KHAA, AKHA and KQHQ curve types. The authors concluded that the generated geoelectric sections have five to six sub-layers to a depth of over 70 m with a lot of loose sand deposits. However, the aquifer zone is between 30 and 50 m depth.

Badmus and Olatinsu (2010) reported on a geophysical survey involving thirty four vertical electrical sounding (VES) that was carried out at Federal College of Education, Osiele, Abeokuta, southwestern Nigeria using Schlumberger electrode array. The authors pointed out that the locations were selected based on existing boreholes. According to their report, the results revealed a maximum of five geoelectric layers, viz: topsoil, sandy clay, clayey sand, shale/clay, sandstone, fractured basement and fresh basement. Furthermore, the authors recognized that three probable aquifer units and one aquitard were delineated with clayey sand occurring in 50%, sandy clay constitutes 24%, fractured basement 24% and shale/clay 2%. The authors concluded that VES 10, 26 and 30 with weathered layer (shale/clay) of thicknesses 14.7, 23.5 and 9.9 m respectively revealed very low yield (not productive). The authors recommended that borehole drilling in the area should be executed in the peak of the dry seasons during which groundwater level is expected to be low because recharge of the existing boreholes in the area is largely due to falling precipitation. They expatiated by pointing out that existing boreholes located within the area characterized by unconfined aquifer while some are confined under pressure between relatively impermeable materials, thus problems of recharging and drying up of borehole can be solved.

Mohammed *et al.* (2007) employed the vertical electrical sounding (VES) to delineate geological structures of Minna and its environ in Nigeria aimed at assessing the lithology underneath the area, delineate the aquiferous formations and its depths and thicknesses. The weathered/fractured layers along the transitional zones form the aquiferous formations in the area with a maximum thickness of about 45 m.

Udensi *et al.* (2005) employed vertical electrical sounding (VES) method to carry out hydro geological and geophysical surveys for groundwater at designated locations of the Gidan Kwano main campus of the Federal University of Technology, Minna and reported that the thickness of the weathered zone appears to be too thin to sustain a productive borehole by itself. They concluded that, the prospect of exclusively exploiting the aquifer of the weathered zone is not realistic and opined that there was no other alternative than to consider the fracture aquifer system.

2.1.1 Electrical resistivity

Electrical property of rocks commonly depends on their porosity, texture and permeability. Resistivities of formation vary widely, not only from one formation to another but even within a particular deposit, this being particularly true of near surface unconsolidated materials. A formation for instance can show wide variation in porosity and water saturation, which may cause its resistivity to change considerably over a short distance. There is therefore no precise correlation of lithology with resistivity (Esimai, 2017).

The basis of resistivity method is that when current is artificially introduced into the ground through current electrodes, the resulting potential differences are measured at the surface. According to Parasnis (1976), the departure from the pattern of the potential difference expected from homogenous ground provides information on the form and electrical properties of subsurface inhomogeneity.

If a direct current (dc) or a low frequency alternating current (ac) is introduced into the ground, any subsurface variation in conductivity alters the current flow within the earth. This also affects the distribution of the electric potential. The degree to which the potential at the subsurface is affected depends upon the size, location, shape and conductivity of the material within the ground (Kearey and Brooks, 2002). Hence, measurements of the electric potential at the surface yield information about the subsurface distribution of this material.

2.2 Aquifer and its type

2.2.1 Aquifer

An aquifer is defined as a geological formation that can store water and transmit water (saturated) in economic quantity to wells or springs. Earth materials are considered to be aquifers when they are porous and permeable. Good aquifers have interconnected pore space and are competent of producing sufficient quantity of water to wells. Depending on the geology of an area in which aquifers exist, it is categorized into four vital aquifer kinds which includes; confined, unconfined, semi-confined, and perched.

2.2.2 Confined aquifers

Confined aquifer occurs when groundwater is trapped by two impermeable geological layers or formations (Figure 1.1). The groundwater under a confined aquifer in constantly under pressure and the water in a well under the confined state will rise beyond the ground limit of the aquifer. Most wells that encounter confined aquifers are artesian well, where the water level increases above the land surface level. Confined aquifers recharge is mostly from zones where the restraining bed is penetrated, either by fracturing, erosional unconformity, or by absence of deposition.

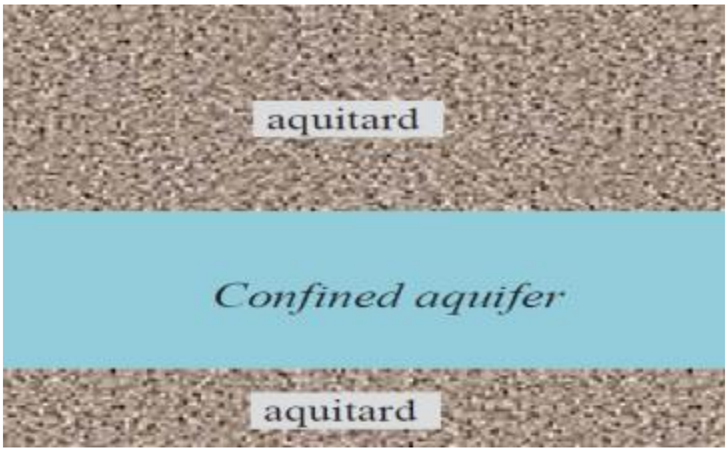

Figure 1.1: Confined aquifer (Dawei, 2010)

2.2.3 Unconfined aquifer

An unconfined aquifer occurs where a water table divides the unsaturated area above from the saturated water area below (Figure 1.2). Unconfined aquifers possess a water table as an upper level that rise and fall in reaction to groundwater discharge and recharge. Unconfined aquifers are commonly near to the land surface with endless seams of materials characterised by high fundamental permeability. It has a direct interaction with the atmosphere.

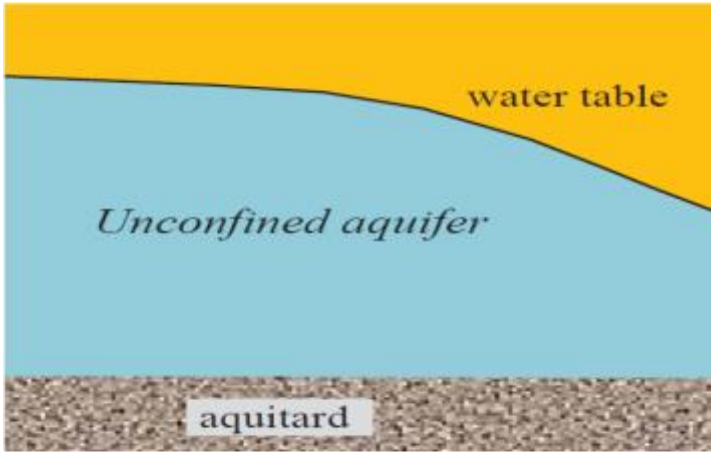

Figure 1.2: Unconfined aquifer (Dawei, 2010)

2.2.4 Semi-confined aquifers

Semi-confined aquifer also known as leaky aquifer arise once water-bearing formations are restricted, either above or below, by a semipermeable geologic layer. When water is driven from a leaky aquifer, water travels in both horizontal and vertical directions through the semi-permeable layer.

2.2.5 Perched aquifer

A perched aquifer sometimes referred to as a hanging aquifer is an unconfined aquifer in which groundwater is parted above the water table by a level of geological material that is unsaturated. A perched aquifer arises when water descending across the unsaturated area is interrupted by an impermeable Lithologic layer. Wells that penetrate perched aquifers largely produce seasonal and slight amounts of groundwater.

2.2.6 Aquiclude

An aquiclude is affiliated to porous and non-permeable rocks a saturated impermeable or semi-impermeable lithological formation that may contain water but it cannot transmit appreciable quantity of the water under normal hydraulic gradient. Examples of aquiclude includes clay and shale.

2.2.7 Aquitard

An Aquitard is defined as any porous and poorly permeable lithological formation which is saturated but permits groundwater movement at very low rate. Negligible quantity of groundwater can be obtained from an aquitard. Examples of aquitard include silts, fluvial and sandy-clays, fractured crystalline rock and some crystalline sedimentary rocks with limited fractures.

2.2.8 Aquifuge

An Aquifuge is a non-porous and non-permeable lithological material that can neither store nor transmit water in any form e.g. fresh basement rock that is not fractured.

2.2.9 Zone of saturation

The zone of saturation is the subsurface lithological zone beneath the water table in which all the pore spaces are occupied with water.

2.2.10 Zone of aeration

The zone of aeration is the lithologic formation that is partially filled with water and air occurring just above the zone of saturation.

2.2.11 Water table

The water table is the unconfined surface of the zone of saturation. It is the surface at which atmospheric pressure is precisely equivalent to the water pressure. It is the boundary between the zone of saturation and the zone of aeration.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Materials

In this survey, a number of instrument and equipment were used for data acquisition. The major one was Abem Terrameter SAS 4000 which was used for collecting earth resistivity. Other accessories and equipment used were:

1. Four Non-Polarisable Electrodes
2. Reels of Insulated Wire
3. Metal Hammers
4. Survey Tape (100 m)
5. Magnetic Compass
6. Global Positioning System (GPS)
7. Pegs

3.2 Method

An extensive preliminary field survey was carried out to ascertain the total area coverage and also to clear off rugged terrains in the site. This is to ease the survey process.

The field procedure began by pegging at equal distance of 100 m along each profile and profile interval of 100 m; the pegs are spots for electrode. The Gridding ropes ensure that the profile is straight, the tape aided in the measurement of distances. After the pegging was done, an array of four non-polarisable electrodes consisting of two potential electrodes flanked on the extremes by two current electrodes traversed each profile measuring 100 m long.

The vertical electrical sounding (VES), furnishes detailed information on the vertical succession of different conducting zones and their individual thicknesses and true resistivity. For this reason, the method is particularly valuable for investigations of horizontal or nearly horizontal stratified ground (Adesoye, 1986).

Six VES points was investigated along each of the six profiles at an interval of 100 m giving a total of Thirty-Six (36) VES points in the survey. Figure 3.1 shows the profile layout.

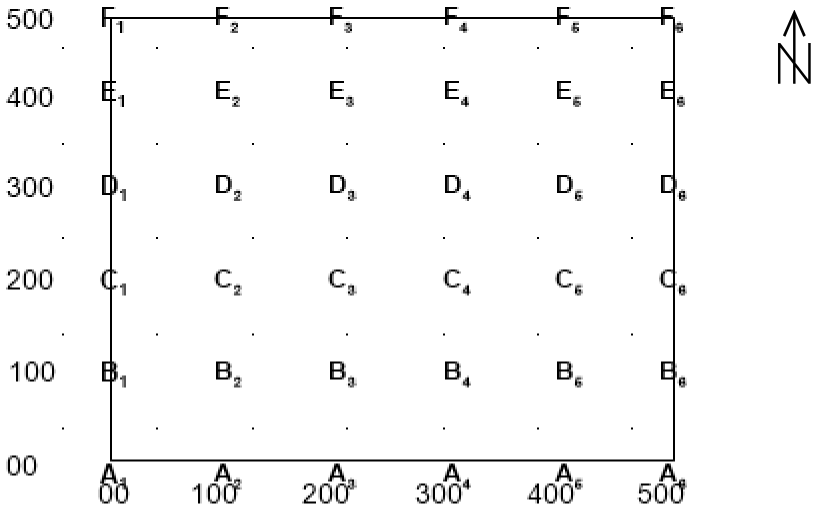

Figure 3.1: Profile layout.

There are a number of electrode configurations that could be used during electrical resistivity prospecting. These include the Schlumberger array, the Wernner array, the Dipole array and the three points- partition arrays. The choice of a configuration for prospecting is dependent on a number of factors, amongst which are the type of investigations required, the terrain of the area of investigation, structures etc. The Schlumberger array was employed for this work. This is because it is the most widely used geophysical method in groundwater investigation and also due to its relative simplicity, relative low operational costs and depth range commensurate with depth required in most groundwater problems. The method involves the use of two potential electrodes, M and N fixed about the centre O while current electrodes, A and B are moved in steps collinearly with M and N as shown in Figure 3.2.

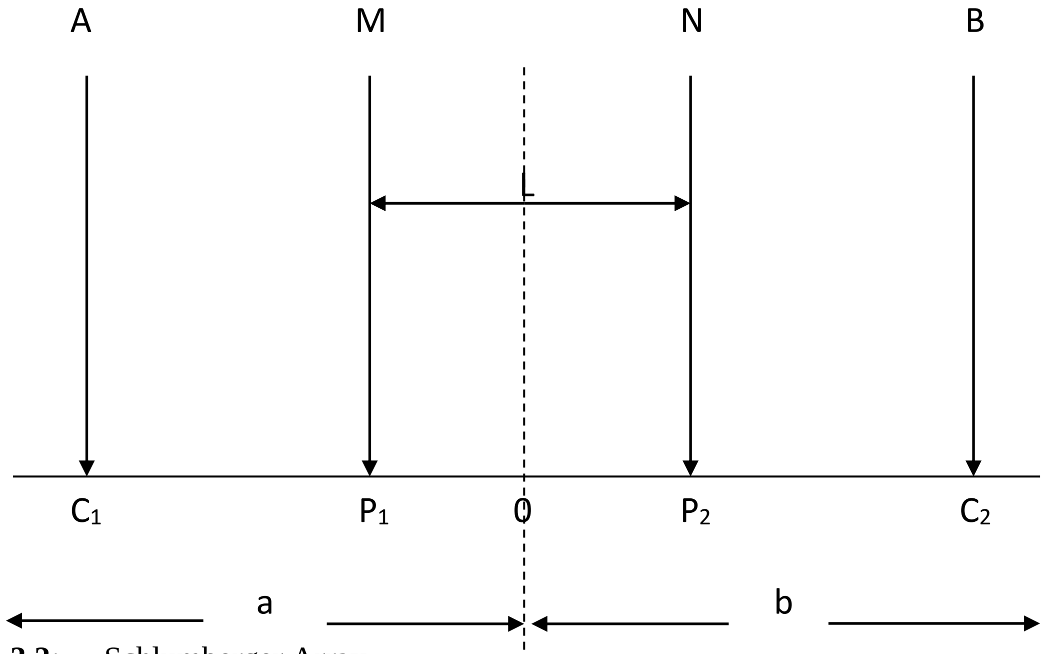

Figure 3.2: Schlumberger Array

The generally accepted configuration is that MN should be made as small as possible in comparison with the separation AB (i.e. AB >> MN).

As one keeps on expanding AB however, a stage is reached when MN falls below the reading accuracy of the voltmeter in which case distance MN is increased maintaining of course the condition AB >> MN. The values of and the corresponding values of were chosen to obtain overlapping readings whenever a changeover of MN from one value to another was made.

In vertical electrical sounding survey, the area of investigation is to be gridded to establish a coordinate system in which every observation is clearly and uniquely marked. Gridding enable us to identify the position of any observation so that follow up, like drilling can be directed to the proper places. Six profiles numbered A, B, C, D, E, F were established covering an area of 0.25 km^2. A station interval of 100 m was used to establish the various sounding points along each profile by wooden pegs. The current electrode spacing was made to range from 1-100 m with the potential electrode changing correspondingly from 0.5 – 15 m so as to maintain the usual requirement of the field measurement of much less than for Schlumberger array.

Reading were taken on a total of six (6) VES points on each profile and hence each profile is 0.5 km long. All earth resistance data were recorded on recording sheets at the field. In all cases, the obtained values from the terrameter was used to estimate the apparent resistivity values. A table of the apparent resistivity values with electrode separation was produced for each VES point.

3.2.1 Theory of electrical resistivity

Electrical Resistivity is a form of geophysical survey that aids in imaging the subsurface by utilizing the resistivity contrast of the subsurface materials and layers, It is based on the principle of Ohms law. When current (I) is introduced into the ground, a potential difference (V) is created and the earth’s resistance (R) is given by the ratio of the potential difference to the current.

$$R=V/I \qquad (3.1)$$

where V potential difference in Volts and

I is current in amperes

In-field practice, direct current is passed into the ground through two outer electrodes (current electrodes), and the resultant potential difference is measured across two inner electrodes (potential electrodes) that are arranged in a straight line, symmetrically about a centre point.

The ratio of the potential difference to the current is displayed by the Terrameter as earth resistance.

To increase the depth of investigation, the current electrode separation was increased while the potential separation remained constant. The sensitivity of the potential electrode measurement decreases as the current electrodes spacing increases, therefore, at some point, it was necessary to increase the potential electrode spacing.

A geometric factor ***K*** in metres is calculated as a function of the electrode configuration adopted, for schlumberger array,

$$K = \pi\left(\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN}\right) \quad (3.2)$$

Then the apparent resistivity (ρ_a) values were obtained by multiplying K with the resistance (R) values

$$\rho_a = KR \quad (3.3)$$

Also, the apparent resistivity values obtained ware plotted against the inter current electrode spacing (AB/2) using win Resist software and from the plots; the resistivity, depth and thickness of each of the subsurface layer were estimated.

3.2.2 Vertical electrical sounding

Vertical electrical sounding (VES) were made with a four electrode configuration commonly referred to as the Schlumberger array (Keller and Frischknecht, 1966). The method uses four in-line electrodes; the inner pair for recording electrical potential as a current is passed through the outer pair. Measurements are made in a series of readings involving successively larger current electrodes separations. The data are plotted on a logarithmic scale to produce a sounding curve representing apparent resistivity variations as a function of full current-electrode separation (AB/2). For Schlumberger sounding the greater the current, or outer electrode separation, the greater the depth of exploration. Each sounding curves has been inverted by use of a computer program to give a one-dimensional layered model (Zohdy, 1973). Interpretation of the sounding data assumes homogeneous, horizontal layering; therefore, where lateral heterogeneities in resistivity exist within the influence of the energizing current field, the sounding may exhibit distortions which, when present, the computer will model as horizontal layering. Data distortions resulting from lateral variations in rock resistivity are not always recognizable from shape of the field curve.

Table 3.1: Ranges of resistivity of various rocks component in basement complex (Esimai, 2017).

Rock Type	Range of Resistivity (Ω m)
Famada loam	30-90
Weathered laterite	150-900
Fresh laterite	900-3500
Granite	$300\text{-}10^5$
Alluvium and sand	10-800
Quartzite (various)	$10 – 2 \times 10^8$
Weathered basement	20-500
Fractured basement	500-1000
Fresh basement	> 1000

3.3 Field electrical resistivity data

Vertical Electrical Sounding (VES) data for profiles 1 to 6 with six VES points on each profile as collected from the field are shown on Table 3.2. The minimum AB/2 value was set at 1 m while the maximum AB/2 was 100 m. The minimum MN/2 spray was set at 0.5 m and the maximum MN/2 spray was set at 15 m.

Table 3.2 VES Geoelectric Data for Profile 1

			VES01	VES02	VES03	VES04	VES05	VES06
Latitude (N°) ⟶			7°16′11.6″					
Longitude (E°) ⟶			8°10′27.1″					
AB/2	**MN/2**	**K**	**ρ_a (Ωm)**	**ρ_a(Ωm)**	**ρ_a(Ωm)**	**ρ_a(Ωm)**	**ρ_a(Ωm)**	**ρ_a(Ωm)**
1	0.5	2.36	67.2	81.0	110.6	76.0	47.5	74.7
2	0.5	11.8	56.3	62.1	84.1	61.5	18.5	25.3
3	0.5	27.8	44.7	56.4	91.3	50.5	20.9	22.5
5	0.5	77.8	39.8	63.1	80.7	175.0	28.2	37.0
6	0.5	112	57.4	79.2	82.4	44.8	33.3	34.2
6	1	55	41.4	81.1	54.6	56.0	37.6	33.6
8	1	99	48.4	97.5	62.4	69.1	132.4	31.9
10	1	156	57.7	120.2	70.0	83.4	55.7	36.5
10	2.5	58.9	57.1	98.8	55.3	68.9	58.2	40.5
15	2.5	137	81.9	182.2	87.4	114.2	87.3	64.0
20	2.5	247	107.8	249.1	109.6	155.0	98.6	85.8
30	2.5	562	172.7	349.5	177.8	170.8	165.8	151.9
40	2.5	1001	218.6	501.2	214.9	663.3	236.9	133.5
40	7.5	323	166.7	485.2	171.3	107.6	170.1	101.9
50	7.5	512	195.9	520.4	227.6	312.2	313.8	154.0
60	7.5	742	357.7	500.2	288.8	-154.6	401.1	160.3
70	7.5	1014	396.6	590.6	435.0	423.8	482.9	182.2
80	7.5	1329	472.1	520.8	392.2	399.1	428.7	349.7
80	15	647	485.3	620.5	525.2	463.5	433.8	248.8
90	15	829	523.8	624.9	463.2	500.7	442.0	165.9
100	15	1024	581.8	662.5	512.0	585.1	496.5	355.1

AB=Current Electrode MN=Potential Electrode K=Geometric Constant ρ_a=Apparent Resistivity

3.4 Geoelectric curve types

There are basically two forms of curve in relation to VES data; Ascending and Descending curve types. The ascending curve types are recognized where the land has a structure of two-layer, mostly where the crystalline basement underlying topsoil, regolith or weathered layer. The descending curve types are recognized wherever a top layer is covering a dense clay or aquifer of saline water. Visual inspection from manual plots can tell how many layers are present in a VES curve. Each curvature change shows the presence of a new layer. They are four major kinds of resistivity curves. These curve types include A, K, H and Q types.

'A' curve types are obtained mostly in basement rock environment while some can be found in sedimentary environment with conductive topsoil. The resistivity of the layers increases upward continuously ($\rho_1 < \rho_2 < \rho_3$/Low-Low-High). With the 'K' sounding curve types the first layer resistivity is less than that of the second layer whereas the second layer resistivity is greater than the third layer ($\rho_1 < \rho_2 > \rho_3$/Low- High-Low). 'H'-type curves are sounding curves with central minimum ($\rho_1 > \rho_2 < \rho_3$/High-Low-High). The formations with the 'H' curves contains dehydrated top soil of great resistivity as the first layer, saturated water layer of least resistivity as second layer and third layer with elevated resistivity. 'Q' curve types are sounding curves with continuously downward decreasing resistivity values ($\rho_1 > \rho_2 > \rho_3$/High-Low-Low). The 'Q'-type curves are commonly obtained in sedimentary environment.

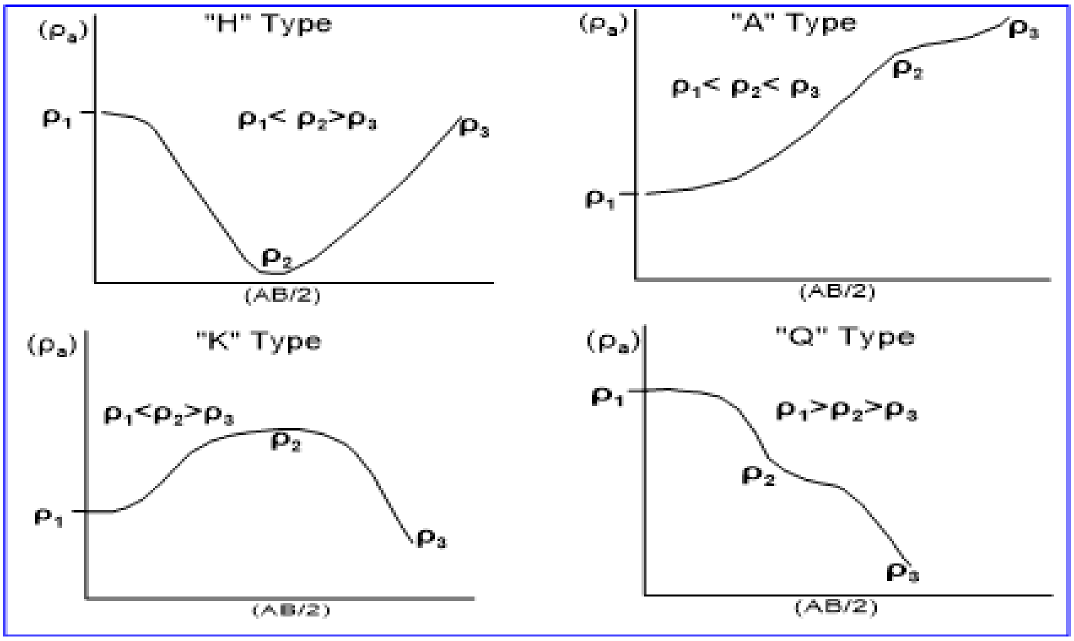

Figure 3.3: Types of Apparent Resistivity Curve (Orellana and Mooney, 1966)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The outcome of the geophysical investigation are presented and discussed in this chapter.

4.1 Synopsis of the geomorphology of the study area

The adjoining gently undulating land of Shakwatu falls within the basement complex of North-Central Nigeria, with an average elevation of 320 m above sea level (Figure 4.1). The highland covers the north-eastern and western part of the study area while the lowland is found around the north and north-eastern part of the area. Naturally the area is viewed to be sloping northward.

The area is characterized by surface outcrops and near surface underlying basement rocks. Migmatites, schist, and granites with intrusions of quartz and pegmatite veins are well exposed in the study area mostly along the perennial stream channels. The drainage pattern as express by the streams in the area is mostly dentritic.

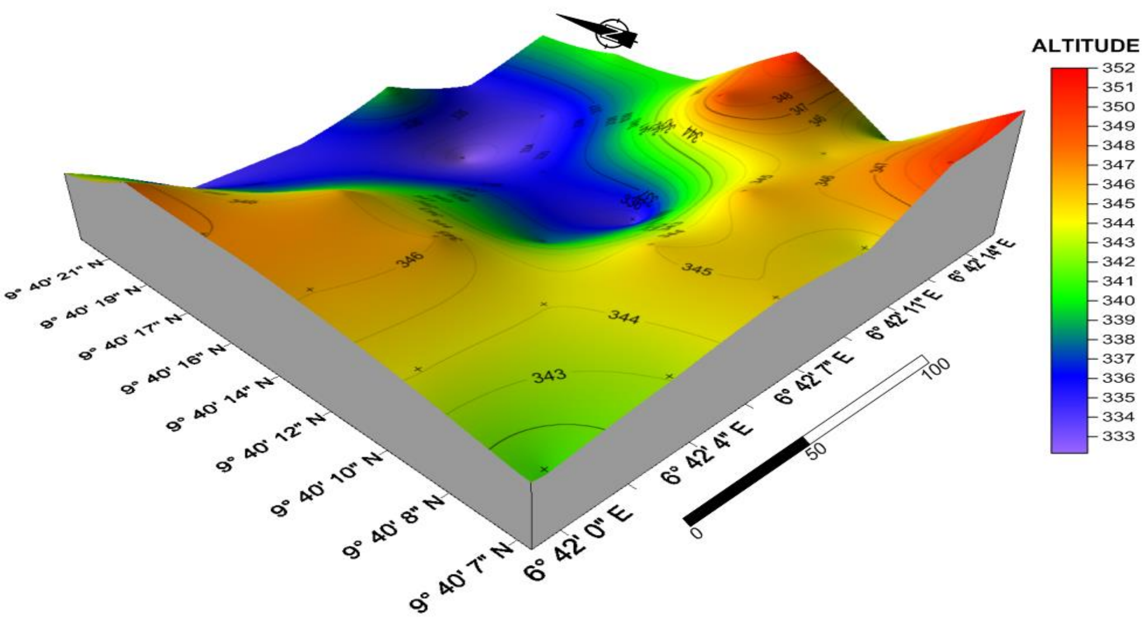

Figure. 4.1 Topography of the Study Area

4.2 Field layout

The field layout consists of the distribution of 36 VES points set at 100 m apart along 6 profile lines also of 100 m intervals established within an area coverage of 62, 500 m^2 (Figure 4.2). The maximum current electrode spacing (AB/2) is set at 100 m while the maximum potential electrode separation (MN/2) is set at 15 m.

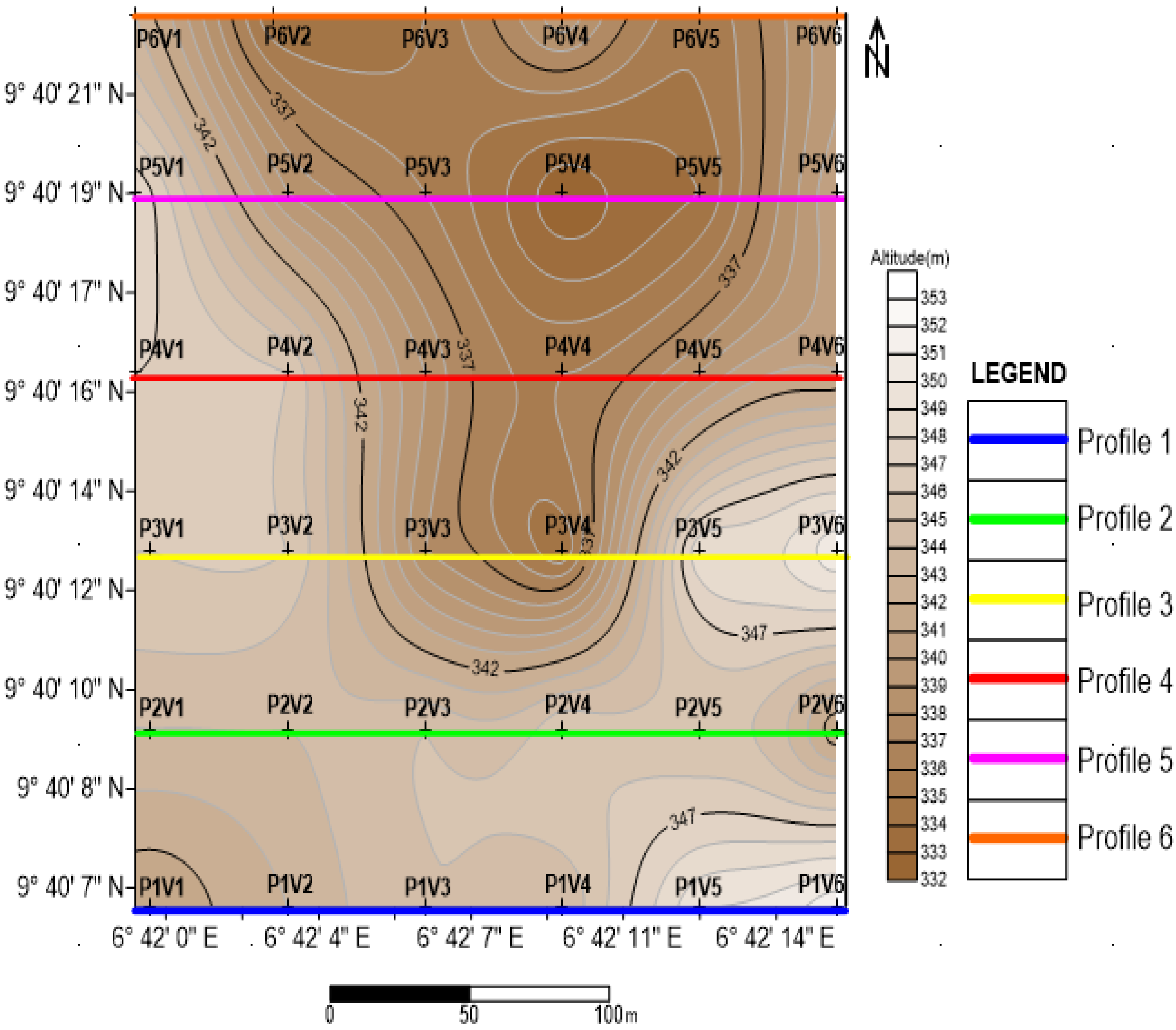

Figure 4.2: Distribution of 36 VES points along 6 profile layout

4.3 VES data curves and geo-electric parameters

The corresponding geo-electric layers with the respective curve type for each profile has been shown in Table 4.1.

The geometry of the geoelectric curves shows that the effect of anisotropy, equivalence and topography is evident in the results, as the resistivity values are changing with directional response to the subsurface anomalies.

The automatic plotting and interpretation of the VES data using the inversion software revealed that the generated curves are predominantly made up of three geoelectric layer HA-type curve with 58% ($\rho_1 > \rho_2 < \rho_3$) where ρ_1, ρ_2 and ρ_3 represent the resistivity of the first, second and third layers respectively. The 41% of the curves is made up of three geoelectric layers A-type curve ($\rho_1 < \rho_2 < \rho_3$).

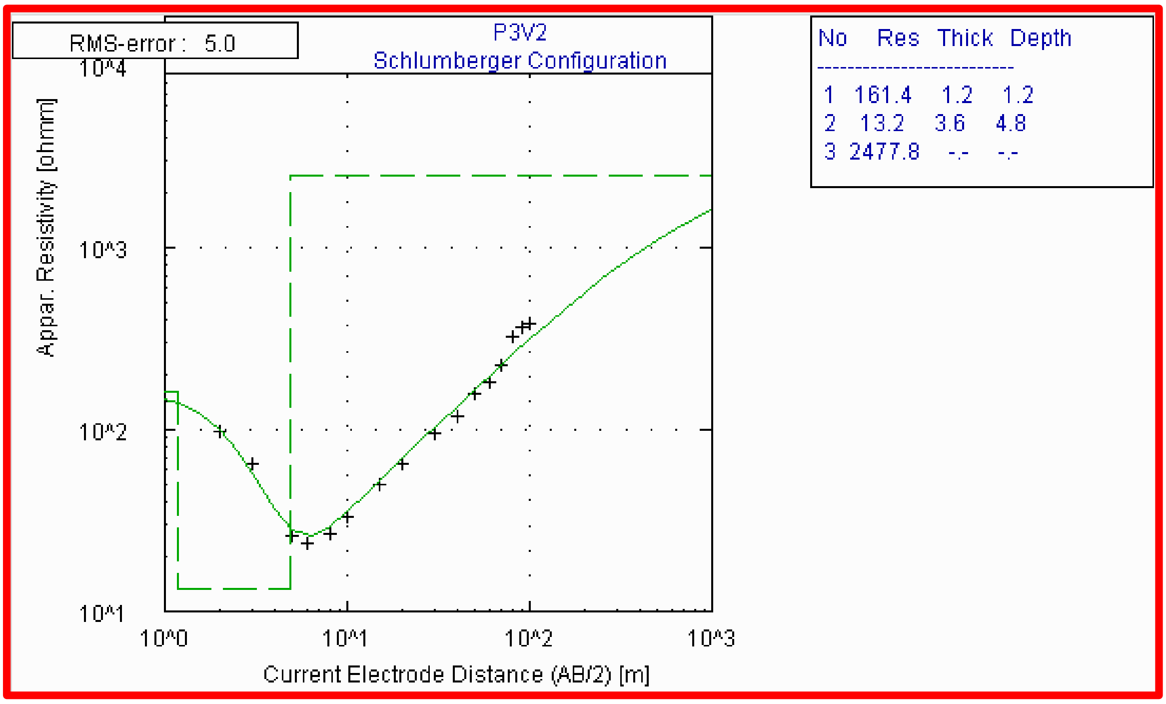

Figure 4.3 A Typical HA-curve type

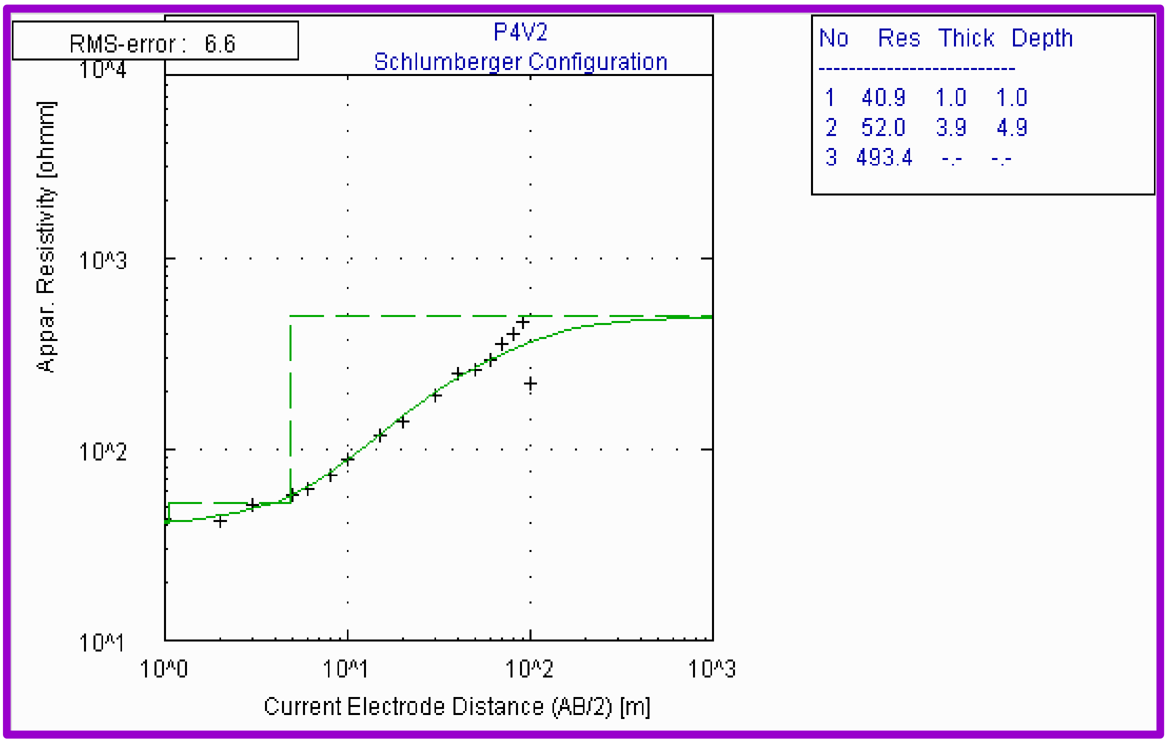

Figure 4.4 A Typical A-curve type

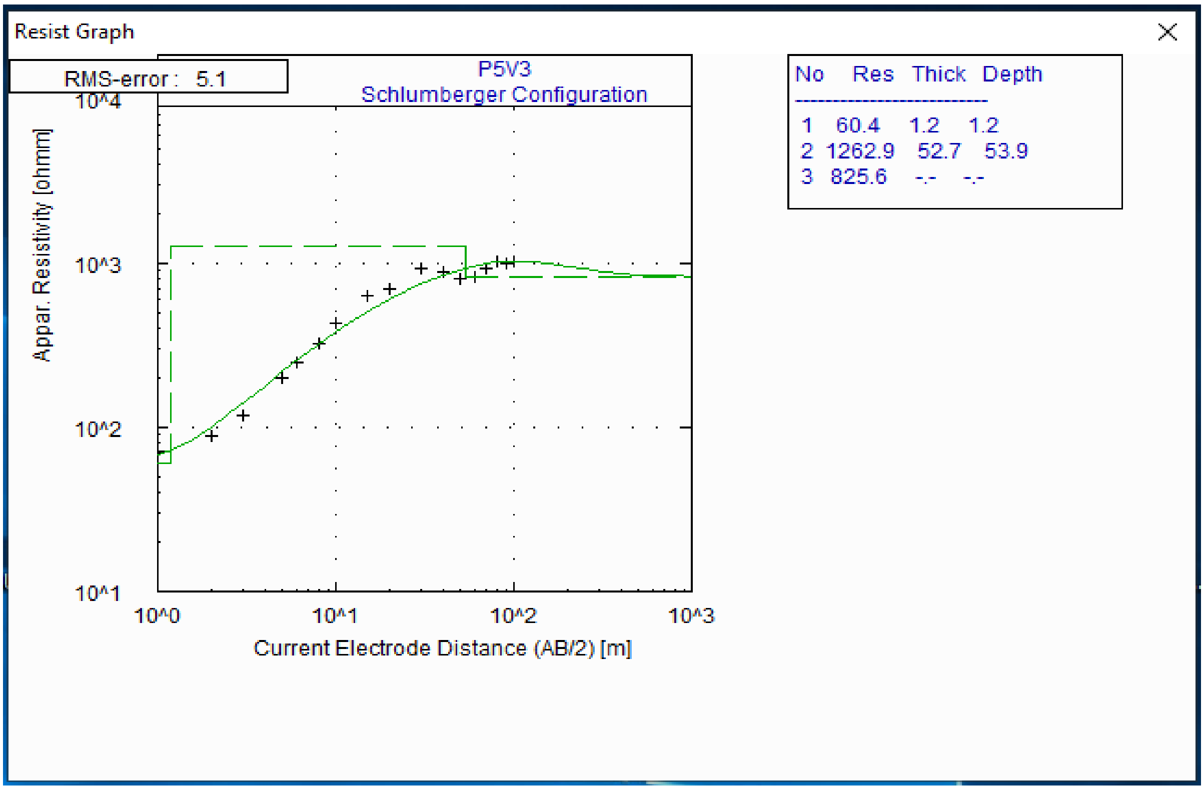

Figure 4.5 A typical AK-curve type

Table 4.1: Resistivity thickness, depth and curve types of the VES on the profiles

VES POINTS	APPARENT RESISTIVITY (Ωm)			THICKNESS (m)			DEPTH (m)			CURVE TYPE
	ρ_1	ρ_2	ρ_3	h_1	h_2	h_3	d_1	d_2	d_3	
1	40	31	892	0.9	2.5	∞	0.9	3.3	h_3	A
2	65	36	2451	0.8	2.1	∞	0.8	2.8	∞	A
3	109	61	1348	1.3	8.8	∞	1.3	10.1	∞	HA
4	80	40	1173	0.9	4.3	∞	0.9	5.2	∞	HA
5	67	14	2086	0.5	2.1	∞	0.5	2.6	∞	HA
6	119	23	656	0.5	5.1	∞	0.5	5.6	∞	HA
7	181	15	5631	0.6	2.7	∞	0.6	3.3	∞	HA
8	205	21	799	1.0	5.5	∞	1.0	6.5	∞	HA
9	44	11	1375	0.7	3.0	∞	0.7	3.7	∞	HA
10	48	25	1085	0.7	5.6	∞	0.7	6.3	∞	A
11	178	15	3234	0.6	3.3	∞	0.6	3.9	∞	HA
12	49	39	1517	1.0	5.0	∞	1.0	6.0	∞	A
13	278	36	2283	1.2	4.1	∞	1.2	5.3	∞	HA
14	161	13	2478	1.2	3.6	∞	1.2	4.8	∞	HA
15	39	15	888	0.7	3.9	∞	0.7	1.5	∞	HA
16	61	21	844	0.7	4.5	∞	0.7	5.2	∞	HA
17	695	1782	1104	0.8	13.0	∞	0.8	13.8	∞	K
18	56	25	715	1.2	7.4	∞	1.2	8.6	∞	HA
19	159	76	1951	0.9	6.8	∞	0.9	7.7	∞	HA
20	41	52	493	1.0	3.9	∞	1.0	4.9	∞	A
21	62	53	1514	1.0	4.5	∞	1.0	5.5	∞	A
22	141	49	1165	1.0	6.9	∞	1.0	7.8	∞	HA
23	18	13	893	1.2	4.3	∞	1.2	5.5	∞	A
24	181	30	1474	1.6	7.0	∞	1.6	8.6	∞	HA
25	93	59	2952	0.9	5.6	∞	0.9	6.5	∞	A
26	41	55	2644	1.1	6.7	∞	1.1	7.8	∞	A
27	60	1263	826	1.2	52.7	∞	1.2	53.9	∞	AK
28	127	37	1436	0.8	3.4	∞	0.8	4.3	∞	HA
29	117	21	1893	0.8	4.7	∞	0.8	5.5	∞	HA
30	323	23	1323	1.1	9.8	∞	1.1	10.9	∞	HA
31	226	112	1873	1.0	16.4	∞	1.0	17.5	∞	HA
32	133	118	3833	1.1	3.4	∞	1.1	3.4	∞	HA
33	55	69	1004	1.0	2.0	∞	1.0	3.0	∞	A
34	119	100	1389	1.0	4.6	∞	1.0	5.6	∞	A
35	137	34	1535	1.2	6.2	∞	1.2	7.4	∞	HA
36	74	28	2994	1.0	4.0	∞	1.0	5.1	∞	HA

4.4 Geologic section

The geologic sections of the six (6) profiles are made up of three geoelectric layers each.

4.4.1 Geologic section for profile one

The Geologic parameters of profile 1 (Figure 4.6) shows that from the surface there is a relatively low to moderate resistivity range of 40 to 109 Ωm with relatively shallow layers of top soil which correspond to the unsaturated zones. This is followed by a low resistive layer of variable thickness which corresponds to the weathered/fractured layer, the base of which depth ranges from 2.6 to 10.1 m. The lithological composition if this layer is composed of regolith materials and loess soil from one sounding point to another. The material shows low to moderate range of resistivity because of the disintegrated and highly weathered nature, although they are not saturated. The geoelectric layers terminate at the bedrock which is characterized by relative rise in the resistivity range from 892 to 2451 Ωm, its thickness extends to infinity.

4.4.2 Geologic Section for Profile Two

The Geologic section along profile two (Figure 4.7) revealed that the first layer is the top soil made of loose, loamy and clay/sandy materials. The resistivity of these layers ranges from 44 to 205 Ωm. The second layer has a resistivity range from 11 to 39 Ωm, layer thickness range from 2.7 to 5.5 m while the depth varies from and 3.3 m to 6.5 m. The third layer has a resistivity range of 799 to 5631 Ωm extending to an infinite thickness and depth.

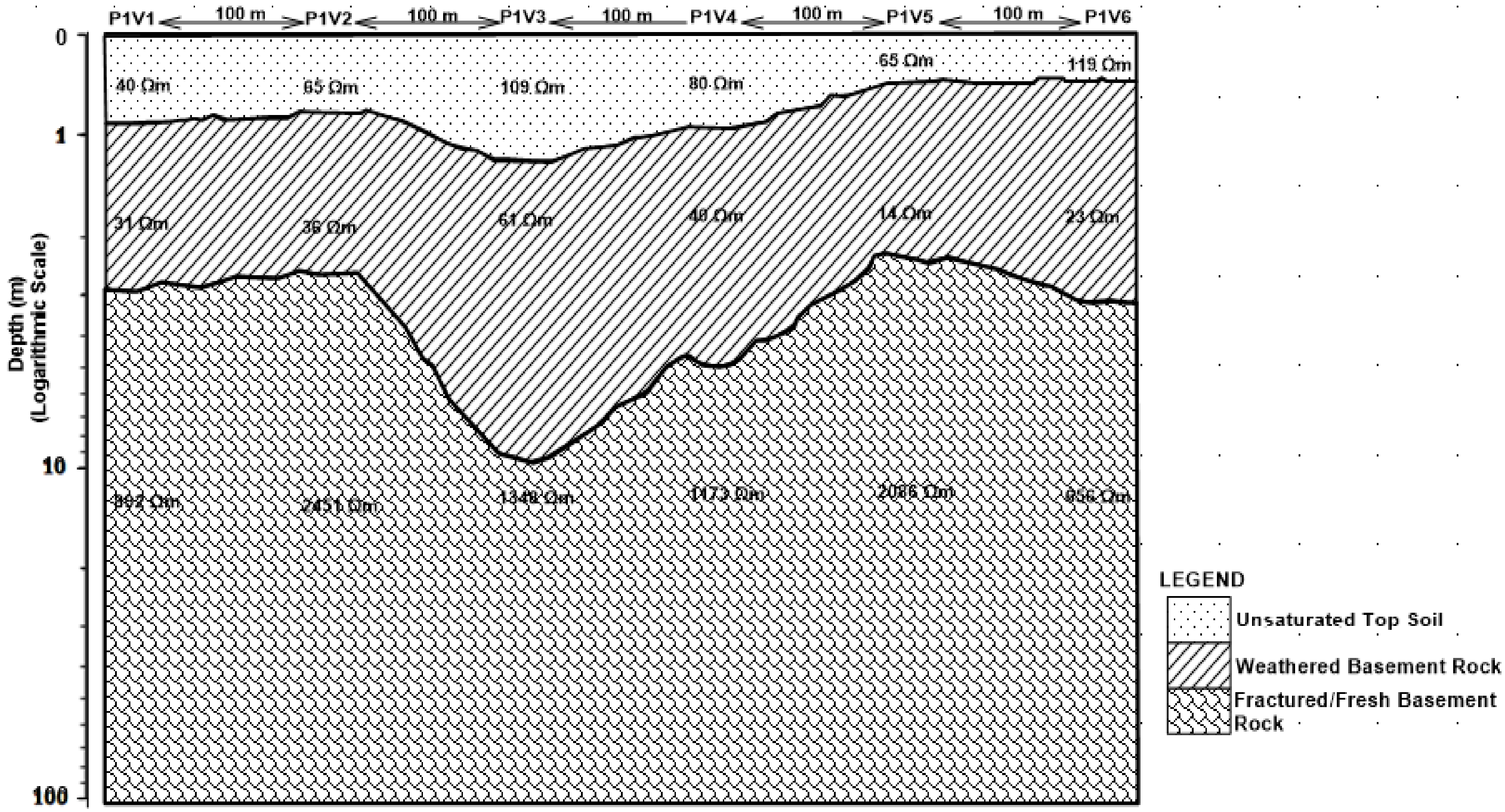

Figure 4.6 profile one geologic section

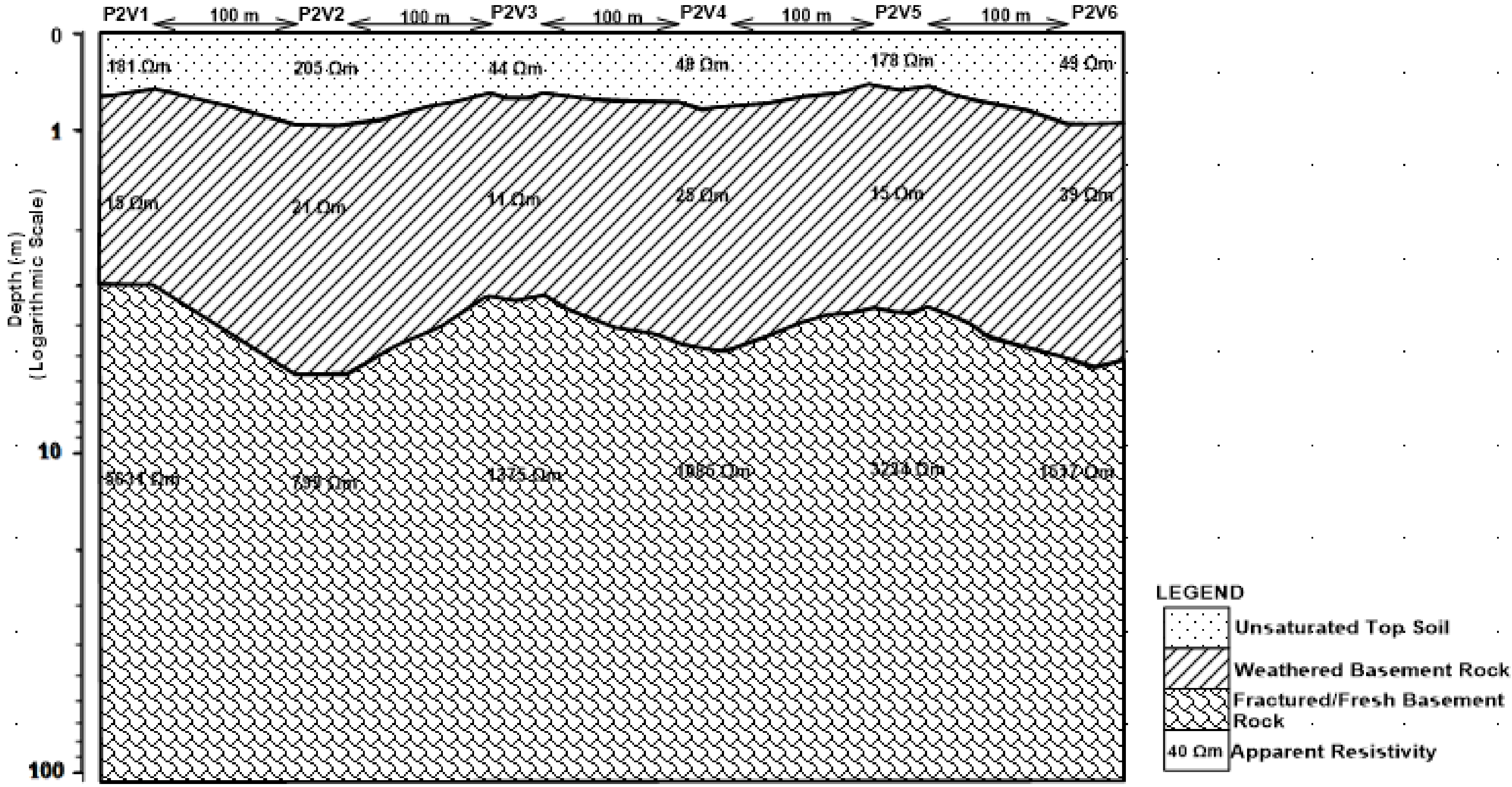

Figure 4.7 Profile two geologic section

4.4.3 Geologic section for profile three

The geologic section along profile three (Figure 4.8) indicates that the top layers of the sounded points on the profile shows variability of resistivity values, ranging from as low as 39 to 695 Ωm. The thickness and depth range of this profile ranges from as shallow as 0.7 to1.2 m. The second layer on the profile indicates a resistivity range of 13 Ω to 1782 Ωm and a thicknes and depth range of 3.6 to 13.0 m and 4.8 to 13.8 m respectively. The third layer shows an infinite extent of thickness and depth with a resistivity range of 715 to 2283 Ωm.

4.4.4 Geologic section for profile four

Along profile four (Figure 4.9), the geologic section reveals a resistivity range of 18 Ωm to 181 Ωm with a relative shallow depth of 0.9 m to 1.6 m for the first geoelectric layer. The second geoelectric layers on the profile shows a low resistivity range of 13 to 76 Ωm, attributed to the depth range of 4.9 to 7.7 m. The thickness of the second layer on the forth profile ranges from 3.9 m to 6.8 m. The third layer on the profile indicates a resistivity range of 493 Ωm to 1951 Ωm with an infinite thickness and depth extend.

4.4.5 Geologic section for profile five

Profile five geologic section (Figure 4.10) indicates a thin thickness and depth of the first layers ranging from 0.8 m to 1.1 m with resistivity attributes of 41 Ωm to 232 Ωm. The second geoelectric layer on the profile shows a resistivity range of 21 Ωm to 165 Ωm with a thickness and depth range of 1.1 m to 9.8 m and 1.9 m to 10.9 m respectively. The third layer is attributed with a high resistivity range of 1323 Ωm to 2952 Ωm.

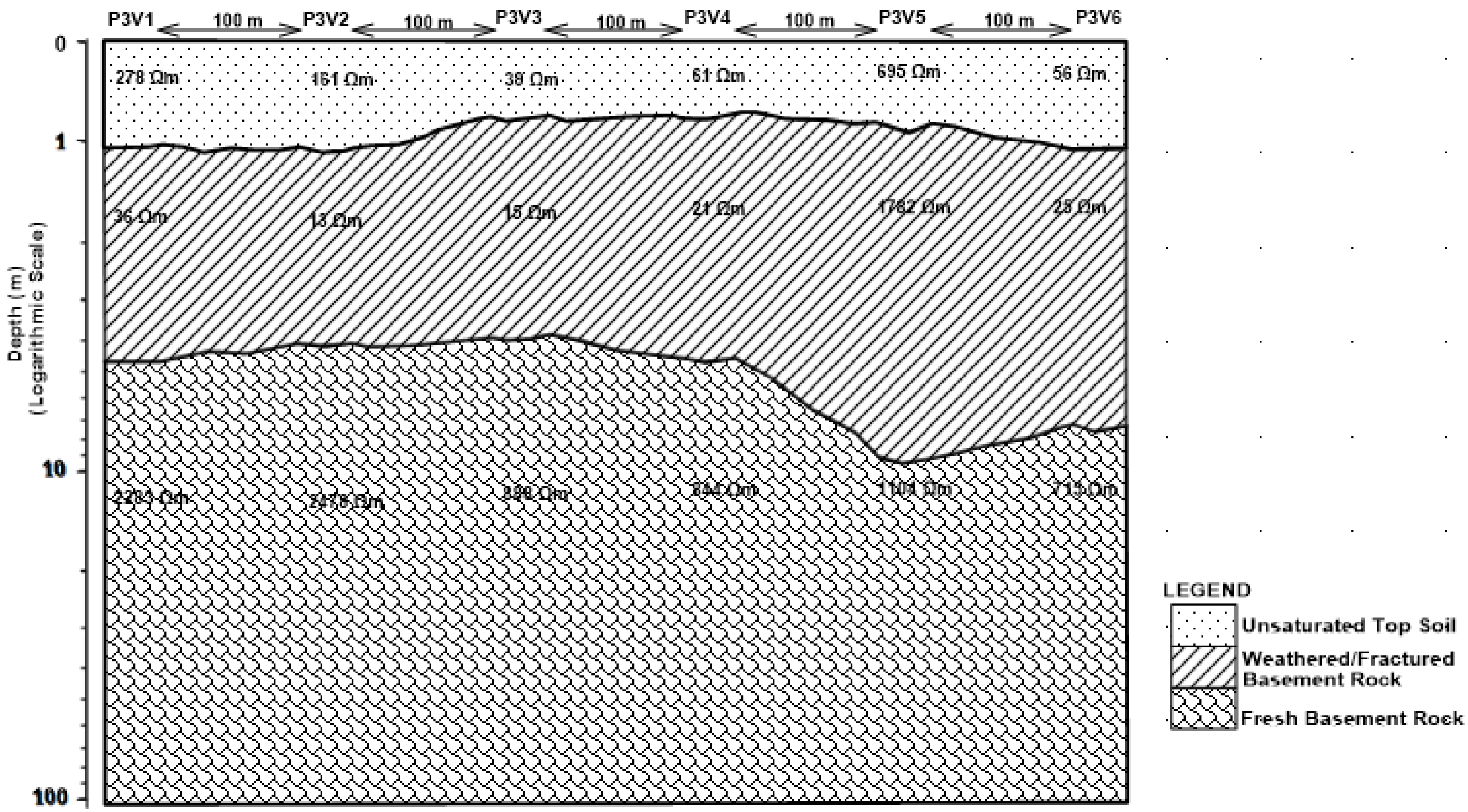

Figure 4.8 Profile three geologic section

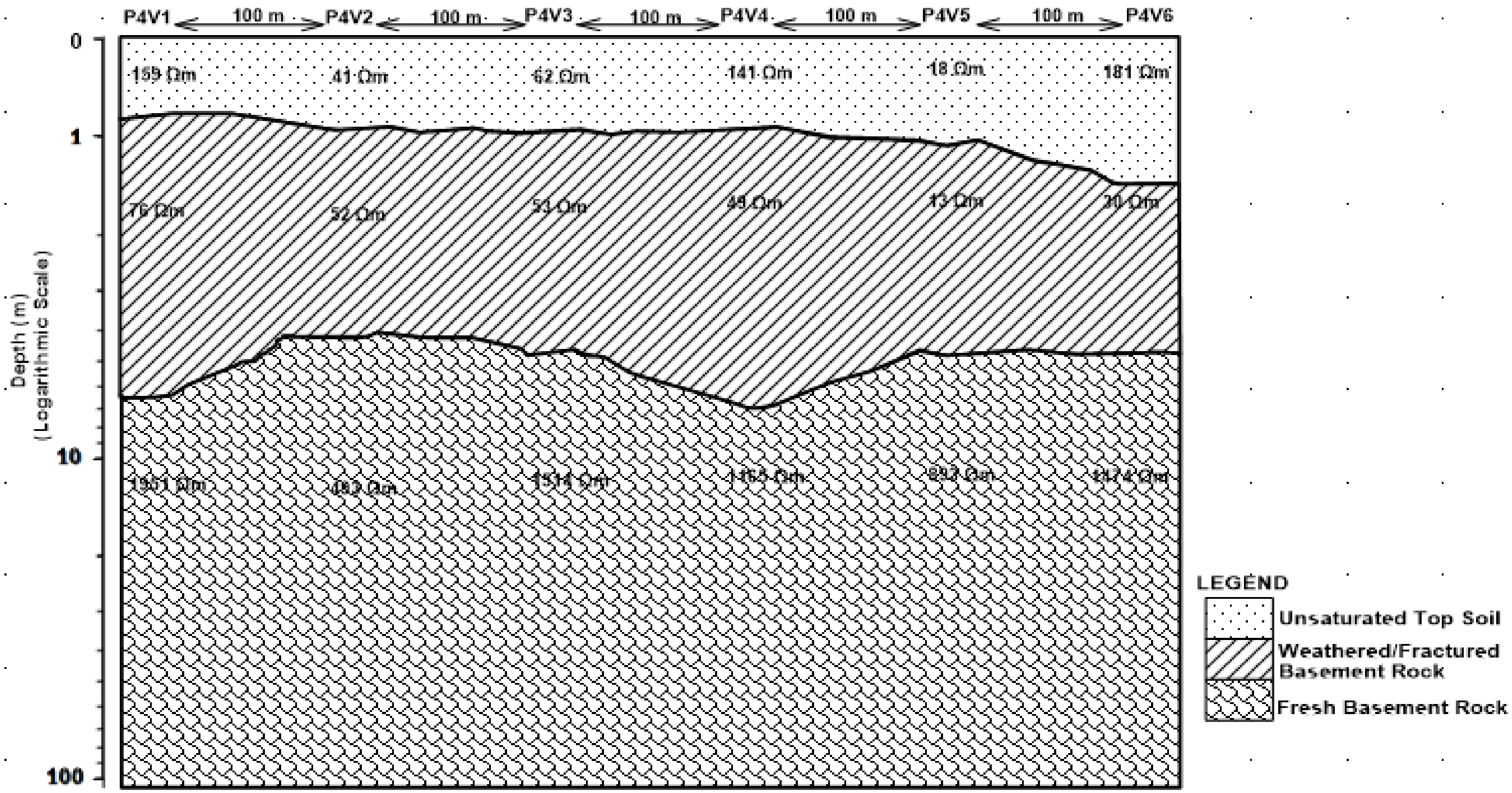

Figure 4.9 Profile four geologic section

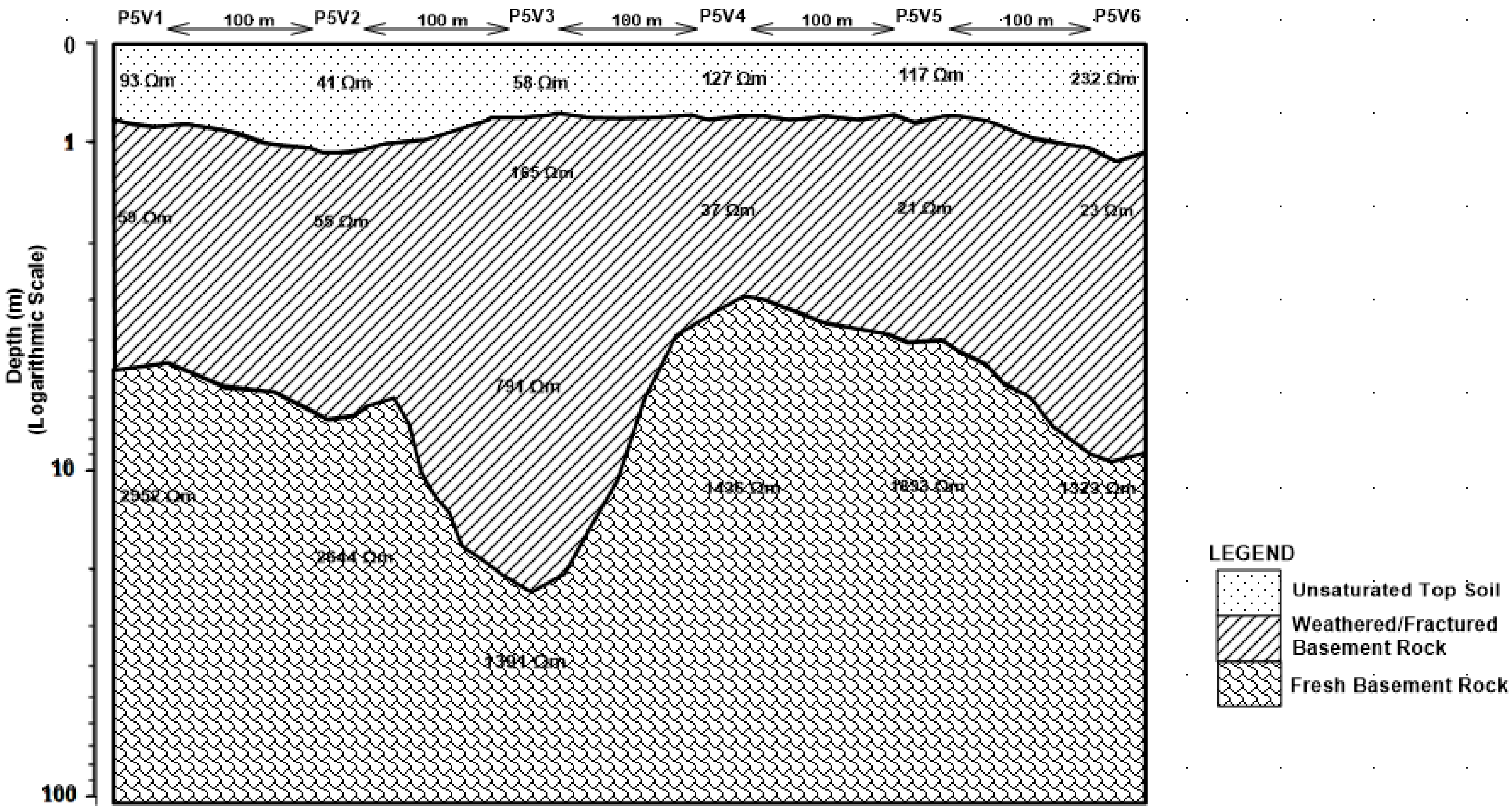

Figure 4.10 Profile five geologic section

4.4.6 Geologic section for profile six

The geologic section of the sixth and final profile (Figure 4.11) indicates a moderate resistivity range of 55 to 226 Ωm to a depth and thickness range of 1.0 m to 1.2 m for the first geoelectric layer. The second geoelectric layer is characterized with a thickness and depth ranges of 2.0 m to 16.4 m and 3.0 m to 17.5 m respectively with resistivity range of 18 Ωm to 112 Ωm. The third layers which extend to an infinite depth show a resistivity range of 1004 Ωm to 3833 Ωm.

4.5 Summary of the geologic sections

The first geoelectric layers are composed of dry unsaturated loose silt and compacted loamy soil with relatively low to moderate resistivity range of 18 Ωm to 615 Ωm with a thickness range of 0.5 m to 1.2 m. The difference in compaction of the clayey sand is responsible for the variation in the resistivity values. Though saturated to an extent, it might not be considered good aquifer material due to poor permeability effects. These curve types are indicative of probable groundwater occurrence in the study area. The potential for groundwater in this first layer is not visible.

The second geoelectric layer is composed of a mixture of unconsolidated geomaterial and weathered/fractured basement rock with varying degree of the weathered rock (partially weathered to highly weathered crystalline rocks) from one sounded point to another. The resistivity of these layers shows a great variation of resistivity values which might be attributed to the irregular weathering front. The resistivity values of this layer ranges from 11 Ωm to 1782 Ωm. The composition of the weathered materials determines the resultant resistivity. The layer is characterized with a thickness range of 1.1 m to 16.4 m and a depth range of 1.9 m to 17.5 m. Groundwater potential of this second layer is viable at VES locations where the depth and thickness of this layer extent to a moderate depth of about 15 m. The variability in the thickness of the layer depended on the extent and degree of weathering.

The high value of resistivity recorded may be due to the portions of the subsurface that the effect of rock weathering may not be pronounced.

4.6 Iso-resistivity contour maps

4.6.1 Iso-resistivity map of the first layer

The first layer (topmost layer) iso-resistivity map (Figure 4.12) shows a generally low to moderate resistivity within the study area. The lowest resistivity is pronounced within the southern, central and north-western portion of the area. The resistivity as indicated by the first layer may be related to moist nature of the earth materials that makes up the layer. Although the earth materials show low to moderate resistivity, it is not likely to be saturated.

4.6.2 Iso-resistivity map of the second layer

The iso-resistivity map of the second geoelectric layer (Figure 4.13) indicates low resistivity values across the entire layer. The north-eastern, south-eastern and south-western portions of the mapped area displayed the lowest resistive areas; the northern portion is the resistive portion of this layer. The low resistivity of the area might be attributed to the weathering nature of the geomaterials underlying the layer. The chemical and mechanical weathering of basement rock geomaterials may sometimes give rise to low resistivity reading, this may not imply that the layer is water saturated.

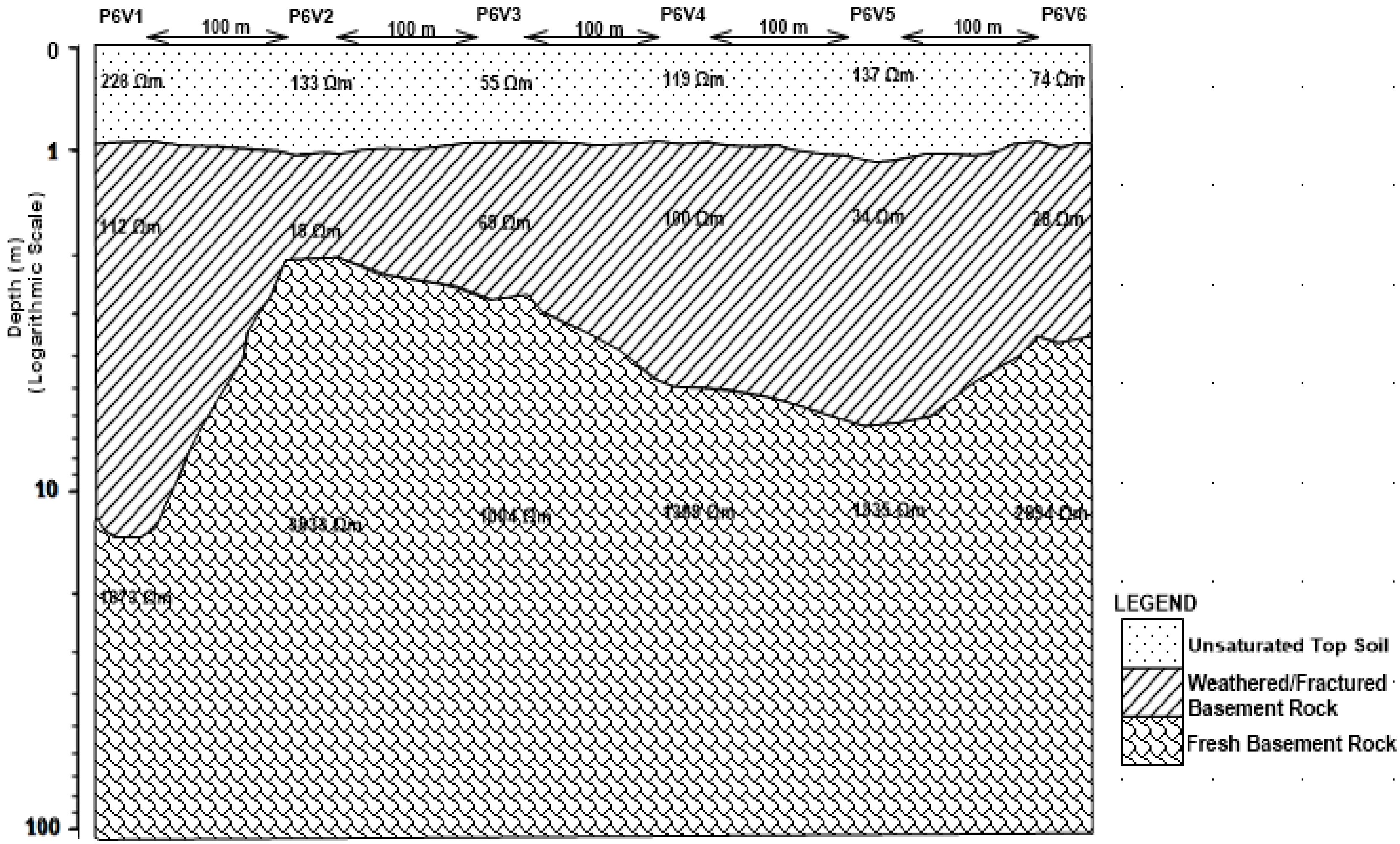

Figure 4.11 profile six geologic section

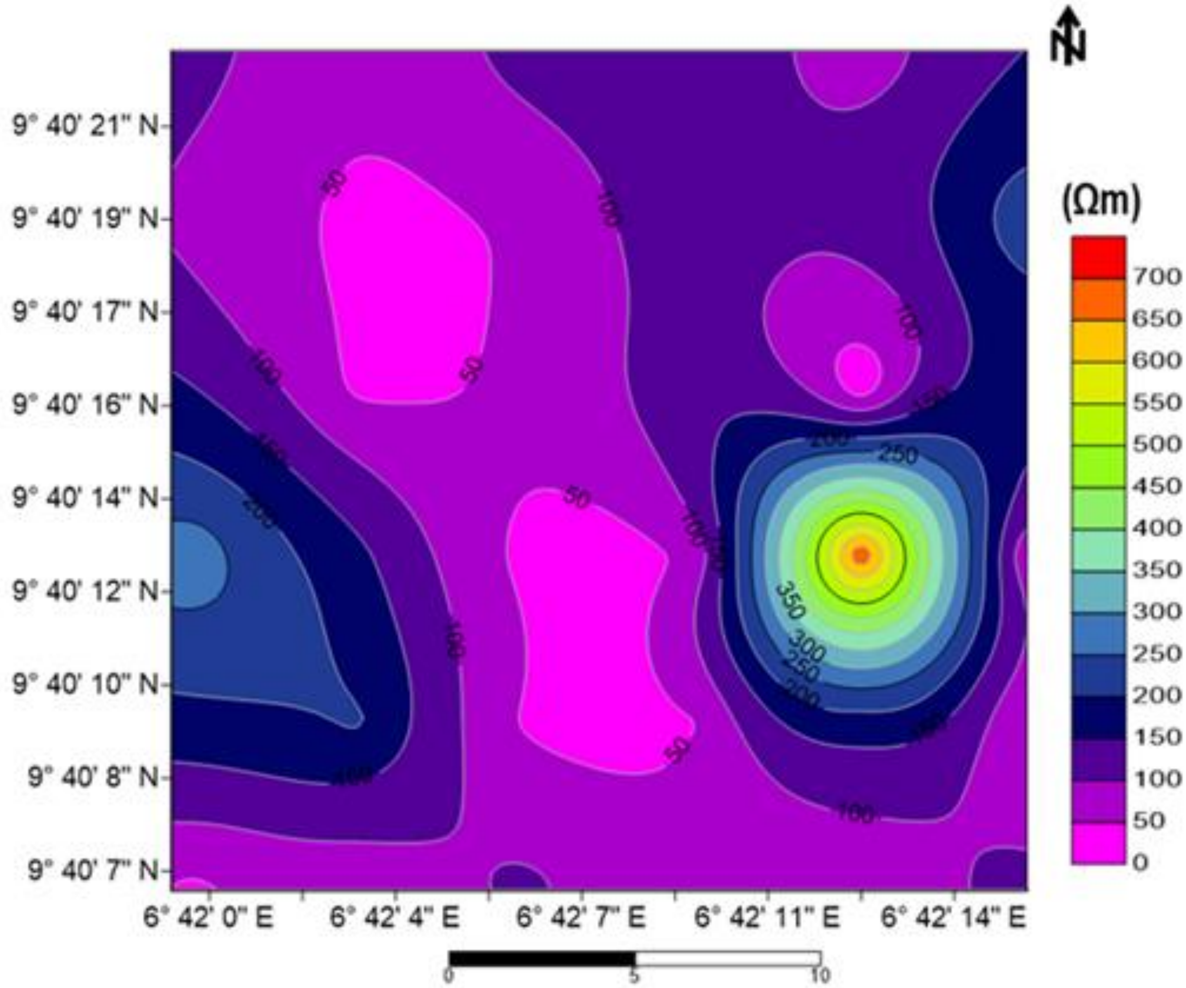

Figure 4.12: Iso-resistivity map of the first layer

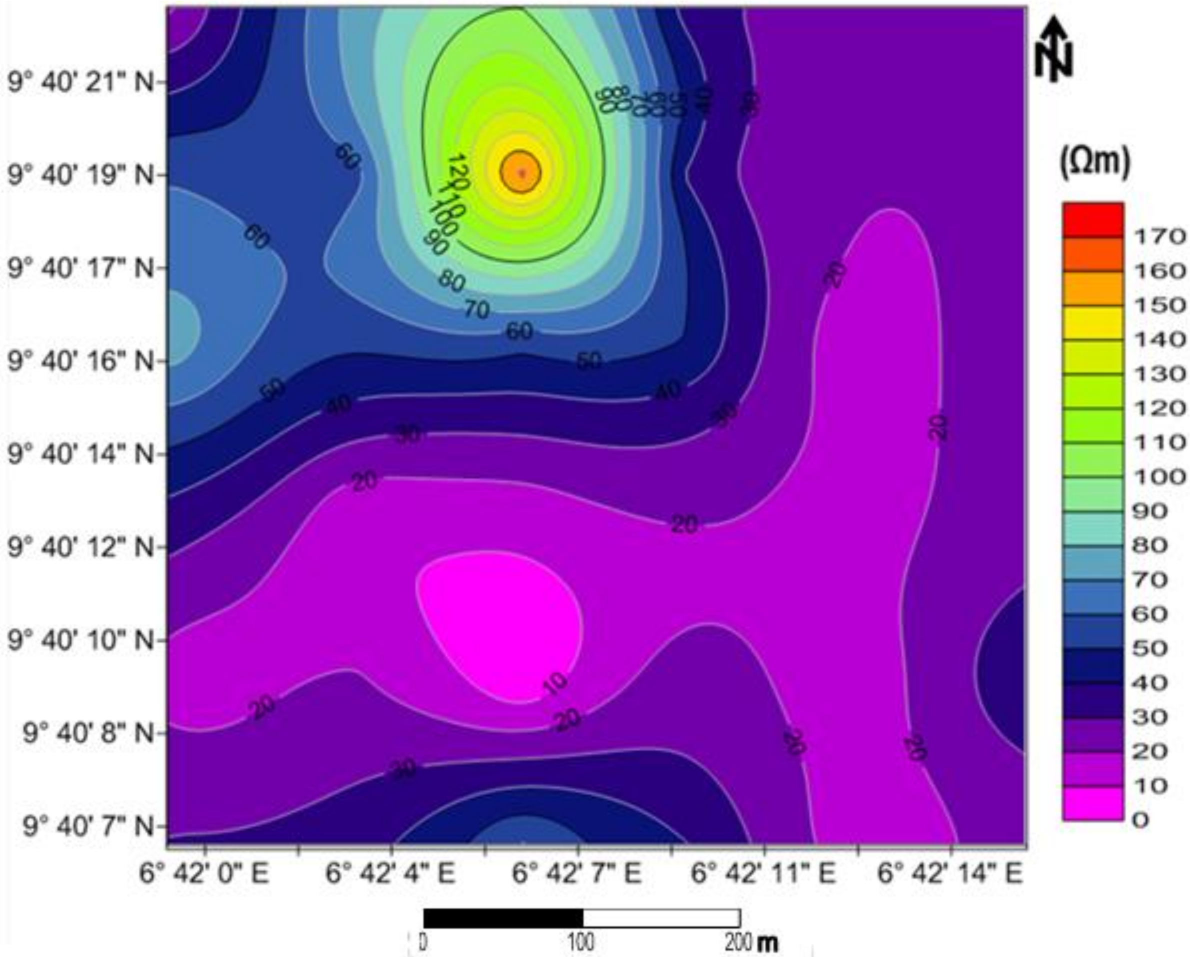

Figure 4.13: Iso-resistivity map of the second layer

4.6.3 Iso-resistivity map of the third geoelectric layer

The iso-resistivity map of the third geoelectric layer (Figure 4.14) display moderate to high resistivity values. The crystalline nature of the layer may be definitive of the high resistive values as shown on the iso-resistivity map of the layer. Areas with low to moderate resistivity values which cut across the eastern, southern and parts of the north-western portions might indicate fracturing of the basement rock.

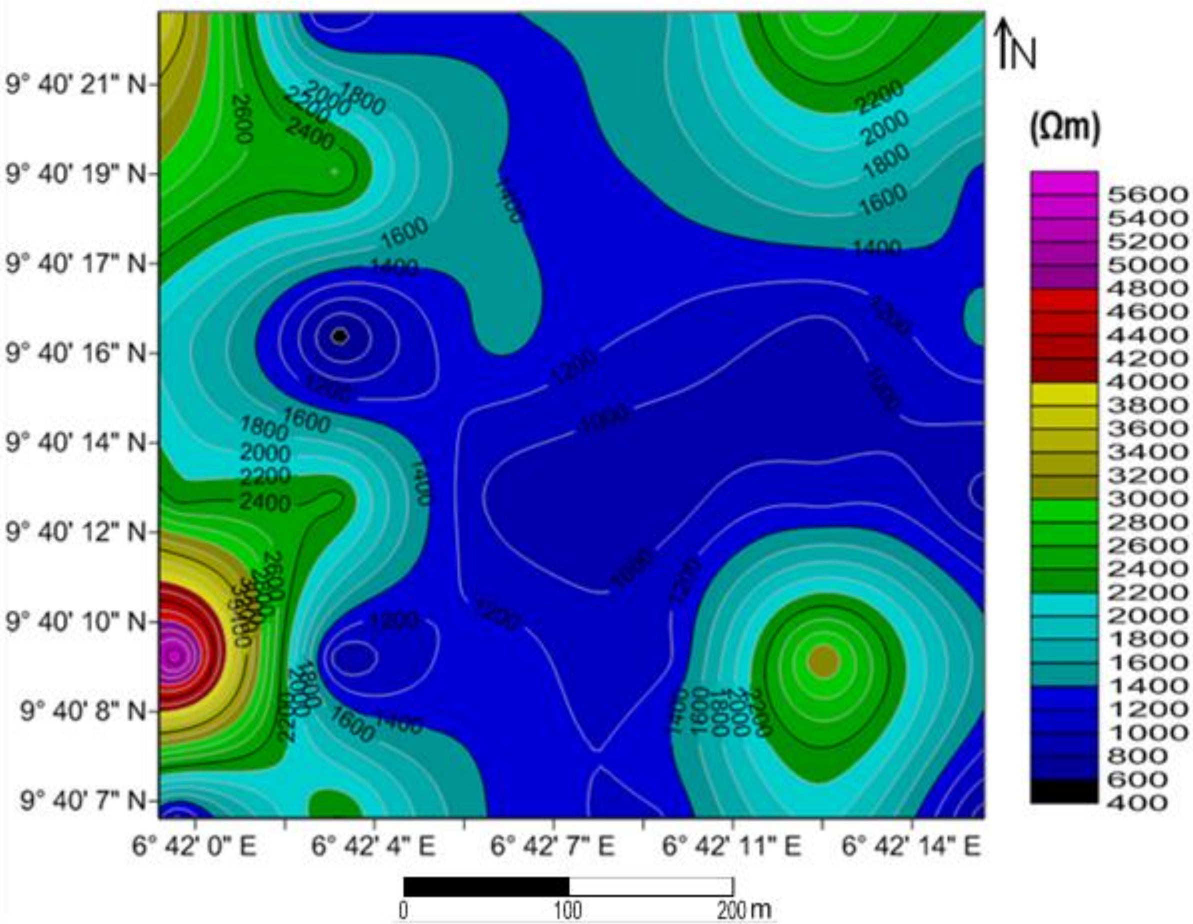

Figure 4.14: Iso-resistivity map of the third layer

4.7 Isopach maps of the geoelectric layers

The Isopach map represents the thickness of the geoelectric layer.

4.7.1 Isopach Maps of the First Layer

The depth and thickness of the first geoelectric layer are always the same in the interpretation of VES resistivity data. The isopach map of the first layer (Figure 4.15) indicates a thickness range of 0.45 m to 1.6 m. The portion with high thickness value is located at the eastern portion while the south-eastern portion of the area is characterised by low thickness value.

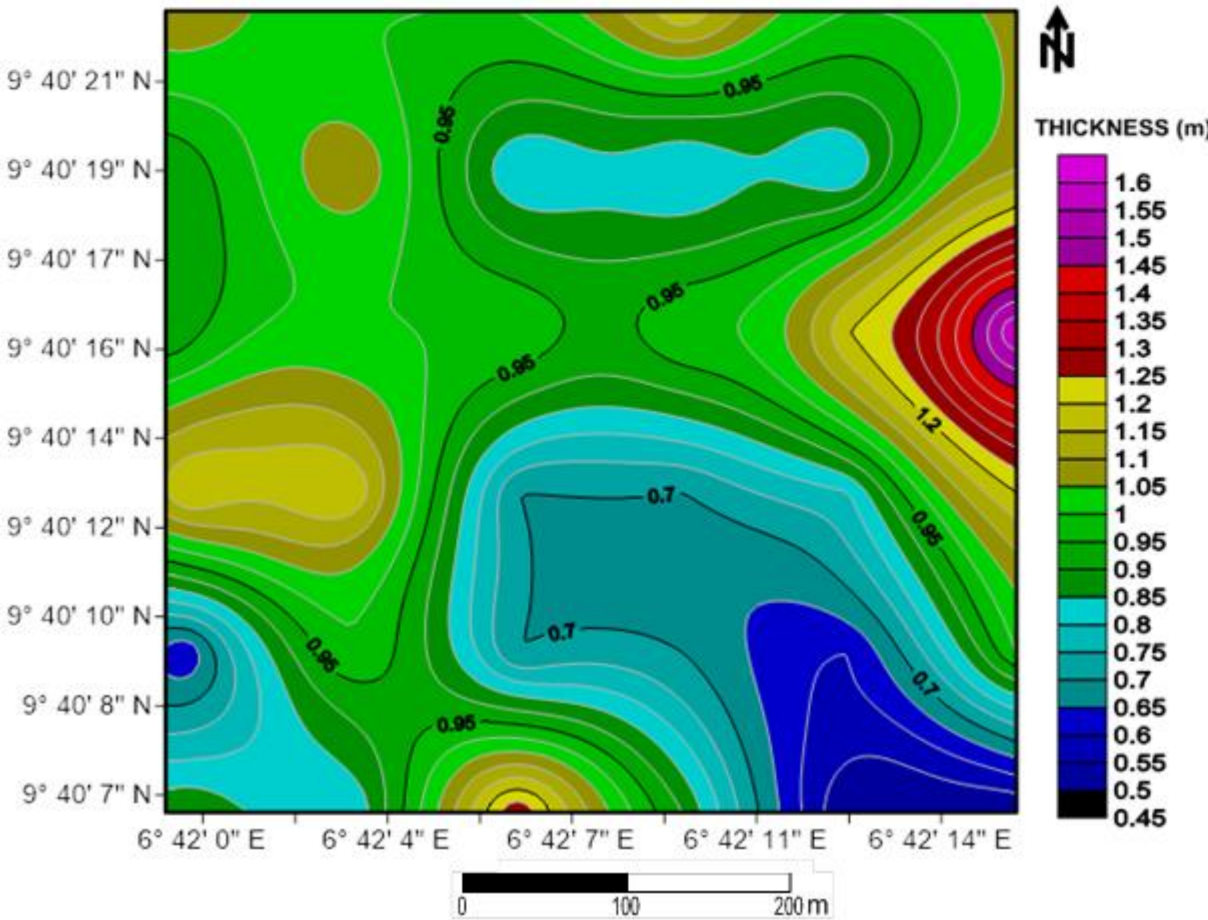

Figure 4.15: Isopach map of the first layer

4.7.2 Isopach maps of the second geoelectric layer

The northern portion of the layer indicates the shallower thickness to the basement rock, which implies that at that portion the basement rock is intruded to the earth’s surface. The thickness of this geoelectric layer ranges from one (1) to seventeen (17) meters across the mapped area. A slight portion of the north-west and the eastern portion of the area indicate moderate thickness of the layer. The thickness of this layer ranges from 1m to 18m (Figure 4.16 and Figure 4.17). The greater thickness is seen around the eastern and north-western portions of the area.

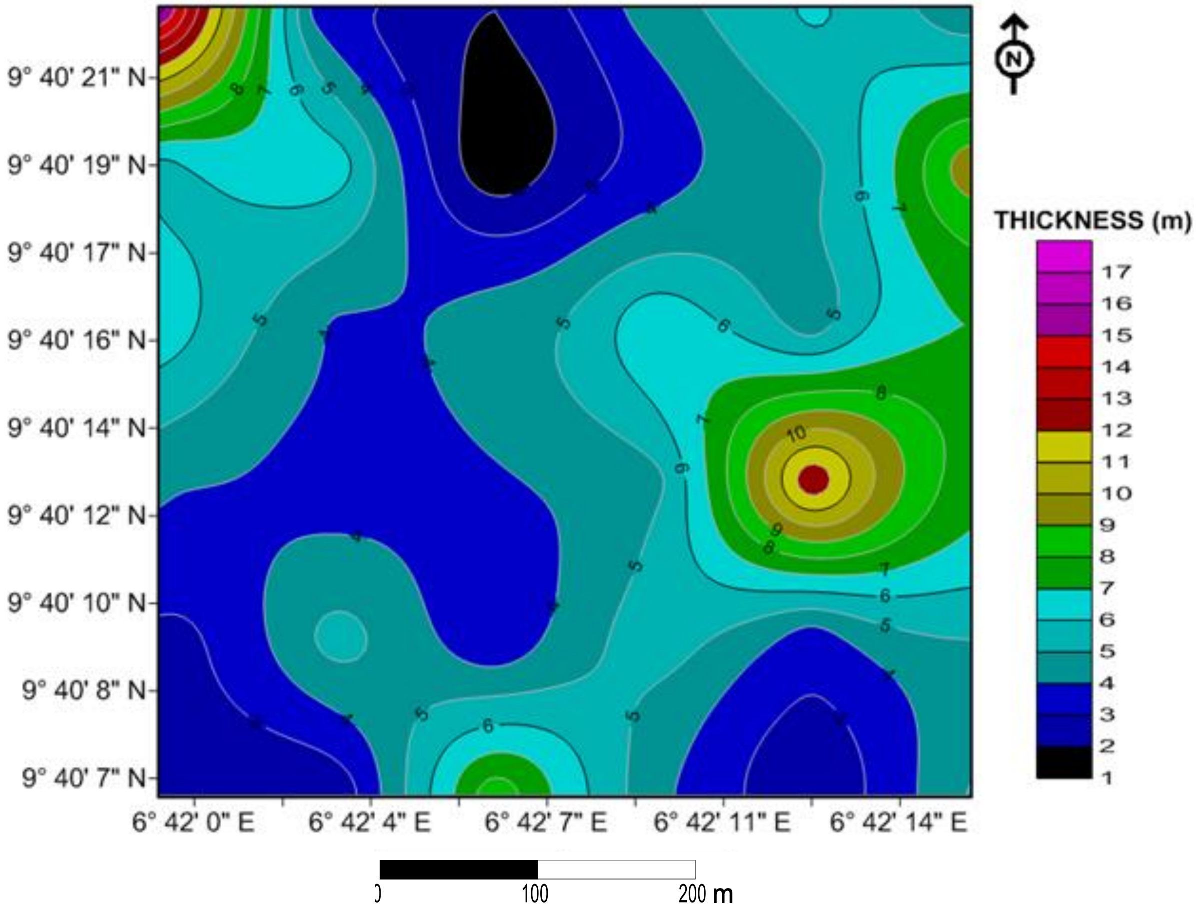

Figure 4.16: Iso-pach (thickness) of second layer

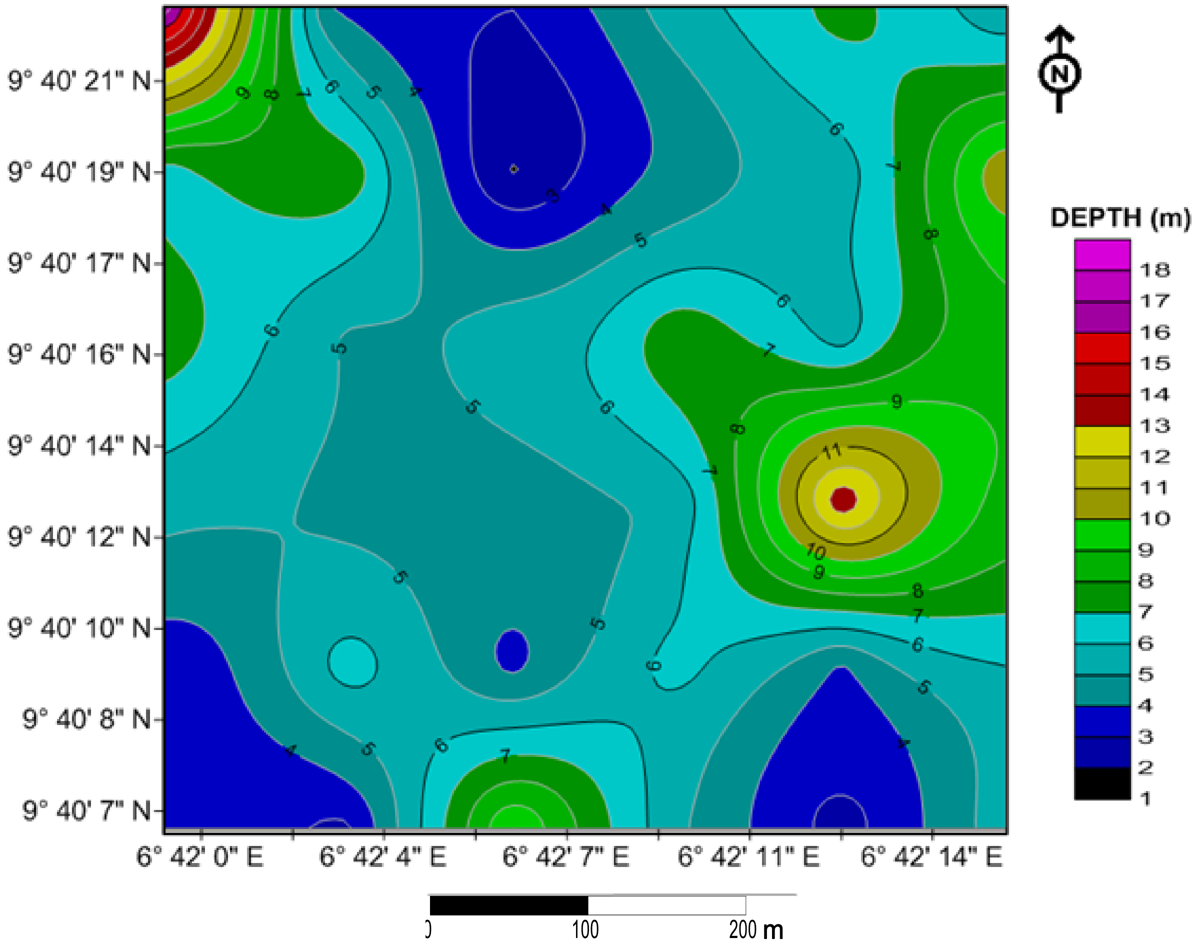

Figure 4.17: Depth of second geoelectric layer

4.7.3 Isopach maps of the third geoelectric layer

The thickness of the third geoelectric layer which serves as the ultimate layer in the interpretation of the geoelectric data extends to infinity as a function of the limit of the electrode spray (AB/2) at the surface.

Table 4.2: Delineated aquifer potentials of the study area

VES Stations	No. of Layers	Layer Resistivity ρ (Ωm)			Layer Depth (m)			Layer Thickness (m)			Curve Type
		ρ_1	ρ_2	ρ_3	d_1	d_2	d_3	h_1	h_2	h_3	
P_1V_3	3	109	61	1348	1.3	10.1	∞	1.3	8.8	∞	HA
P_2V_2	3	205	21	799	1.0	6.5	∞	1.0	5.5	∞	HA
P_6V_1	3	226	112	1873	1.0	17.5	∞	1.0	16.4	∞	HA

Table 4.2 contains the VES points delineated as aquifer potential of the study area, the range of resistivity, depth and thickness of these aquifers are 21 to 112 Ωm, 6.5 to 17.5 m and 5.5 to 16.4 m respectively.

CHAPTER FIVE

5.0 Conclusion and recommendations

5.1 Conclusion

Geophysical investigation for groundwater potential employing the electrical resistivity method was carried out in part of Shakwatu, Niger State, Nigeria. The study area falls under the basement complex of Nigeria which is characterized with lithologies such as granite, migmatite-gniess and schist. The field layout consists of the distribution of a total of thirty-six (36) VES carried out along six (6) established profiles. The distance between VES points and the distance between profile lines were set at 100 m. The maximum current electrode spacing (AB/2) was set at 100 m while the maximum potential electrode separation (MN/2) was set at 15 m.

A multidimensional approach which includes model geoelectric curves, pseudo-sections, geoelectric sections and iso-resistivity plots were adopted for data interpretation. The interpretation of the data sets employing various approach has made the study both very qualitative and quantitative which have necessitated a justifiable conclusion.

The geometry of the geoelectric model curves plotted with the aid of the Winresist inversion software shows that the effect of anisotropy, equivalence and topography is evident in the results, as the resistivity values are changing with directional response to the subsurface anomalies. The model geoelectric curves reveals three major curve types. The generated curves are predominantly made up of three geoelectric layer HA-type curve with 58%. The A-type curve occupies 41% of the curves in the area.

Generally, the geologic section of the six profiles are composed of three geoelectric layers.

The apparent resistivity of the first and second geoelectric layer ranges from 18 Ωm to 695 Ωm and 11 Ωm to 1782 Ωm respectively with a thickness range of 0.5 m to 1.6 m and 1.1 m to 16.4 m for the first and second layers. The depth to the first layer ranges from 0.5 m to 1.6 m and 1.9 m to 17.5 m for the second geoelectric layers. The third geoelectric layer shows a resistivity range of 493 Ωm to 5631 Ωm which extends to an infinite depth.

Attributing the apparent resistivity data to the subsurface lithology, the first geoelectric layers are composed of dry unsaturated loose silt, compacted loamy soil and lateritic soil. There exists a variation of lithological occurrence in this layer from one sounded location to another. The second geoelectric layer is composed of a mixture of unconsolidated geomaterial and weathered/fractured basement rock with varying degree of the weathered rock (partially weathered to highly weathered crystalline rocks) from one sounded point to another. The resistivity of these layers shows a great variation of resistivity values which might be attributed to the irregular weathering front. The combination of the first and second layers define the overburden materials of each of the sounded points. The third layer is composed of fresh basement rock to an infinite depth.

The first layer iso-resistivity map indicates low to moderate resistivity. The lowest resistivity is indicated within the southern, central and north-western portion of the mapped area. The peak of the resistivity of this geoelectric layer is indicated on the south-eastern portion of the mapped area. The iso-resistivity map of the second geoelectric layer indicates low resistivity values across the layer. The north-eastern, south-eastern and south-western portions of the mapped area displayed the lowest resistive areas; the northern portion is the resistive portion of this layer. The low resistivity of the area might be attributed to the weathering nature of the geomaterials underlying the layer. The iso-resistivity map of the third geoelectric layer indicates moderate to high resistivity values. The crystalline nature of the layer may be definitive of the high resistive values as shown on the iso-resistivity map of the layer.

The isopach map of the first layer indicates a thickness range of 0.45 m to 1.6 m. The thickest portion of the layer is located at the eastern portion while the shallowest depth and thickness located at the south-eastern portion of the mapped area. The northern portion of the area of the second geoelectric layer indicates that the basement rock is intruded to the surface. The thickness of this geoelectric layer ranges from 1 to 17 m. A slight portion of the north-west and the eastern portion of the mapped area indicate moderate thickness of the layer. The depth and thickness to basement of this layer ranges from one (1) meter to eighteen (18) meters as the greater depth is seen around the eastern and north-western portions of the mapped area. The thickness and depth of the third geoelectric layer which serves as the ultimate layer in the interpretation of the geoelectric data extends to an infinite depth.

5.2 Recommendations

1. Government or individuals who wish to site boreholes within the study area should consider VES stations P_1V_3, P_2V_2, and P_6V_1.
2. Protective capacity as well as corrosivity of the study area should be carried out.

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