GEOELECTRIC EVALUATION OF GROUNDWATER POTENTIALS OF FACULTY OF SCIENCE AND ITS ENVIRONS, FEDERAL UNIVERSITY OYE –EKITI PHASE TWO, SOUTH WESTERN NIGERIA.

BY

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MATRIC NO: GPY/11/0292

A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF GEOPHYSICS, FACULTY OF SCIENCE FEDERAL UNIVERSITY OYE EKITI, EKITI, STATE NIGERIA.

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE DEGREE IN GEOPHYSICS

(B.Sc. Hons)

OCTOBER 2015.

CERTIFICATION

This is to certify that this project work carried out by me DARAMOLA OLUWAYOMI DAMILOLA,

Matric NO: GPY/11/0292 is valid, and that any falsification will render it invalid.

.... 30/11/2015 ....

DARAMOLA O.DAMILOLA **DATE**

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This is to certify that this project work was carried out by Daramola Oluwayomi Damilola with matriculation number GPY/11/0292, in the department of Geophysics, Faculty of science, Federal University Oye-Ekiti, Ekiti State, under my Supervision.

.... 15-12-2015 ....

PROF. A.O ADELUSI **DATE**

SUPERVISOR

DEDICATION

This project is dedicated to the one who is responsible for my existence, my father, my Lord my King and my All in All, The Almighty God. He established my feet in this great school, and against my very wish in order for me to fulfill my destiny on earth. I also dedicate this to my mother and father who are great supports to me, and to my dear pastor Alonge Julius, whom God use to bring me to Federal University Oye-Ekiti.

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Ajimoko, Eustace Valentino, Hannah Iortyom, Adeyemo Adedoyin, my loving and caring daughter, Chidinma Vincent and all my sons and daughters in the Lord. Iam so glad I met you all. Words are too short to express my gratitude to all that I have met in life and that has always being a source of help to me.

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ABSTRACT

A Geophysical integrated research work involving the use of Electrical Resistivity (ER) and the Very Low Frequency Electromagnetic methods (VLF-EM) were carried out for groundwater potential on the Precambrian basement complex terrain of Federal University Oye-Ekiti Phase two (2), Ekiti-State Southwestern Nigeria. Five traverses running from East to West were established in the study area. The length ranges from 110m to 160m. Five VLF-EM measurements were acquired, while a total of twenty Vertical electrical sounding (VES) stations were occupied within the study area. The VLF- EM responses were interpreted using the Karous Hjelt (KH) package and inverted into its 2D Pseudosection. On the basis of these VLF-EM responses, series of conductors were identified (C1 – C6). The six (6) major conductive zones are suspected to be fractures. The VES data were quantitatively interpreted using the partial curve matching technique and 1-D forward modeling with WinResist 1.0 version software. The VES result also delineated four major Geo-electric layers within the study area. The topsoil, weathered basement, partly weathered/ fractured basement and fresh basement. The top soil (resistivity varies from 28 to 175 ohm-m and thickness ranges from 0.3 to 3.7 m); weathered basement (resistivity varies from 22 to 498 ohm-m and thickness ranges from 1.3 to 38.7 m), Partly weathered/fractured basement (resistivity varies from 381 ohm-m to 775 ohm-m and thickness ranges from 8.5m to infinity) and bedrock with resistivity 809 to 6693 ohm-m and depth to bedrock 1.5 to 43 m). The interpreted data revealed A-curve type as the dominant curve type in the study area. It has 55% dominance. Other curve types include the KH (10%), HKH (5%), AA (5%), H (5%), K (5%), AKH (10%) and HA (5%).

Therefore, VES 3, 5, 10 and 15, are thereby classified as good potential zones for groundwater development because of their bedrock relief and depression, thickness and resistivity values. VES 6, 7, 8 and 9 have low groundwater potentials, while VES 1, 2, 12, 13, 14, and 20 have poor groundwater potentials. Other VES points were not chosen on conductive zone parameters. VES 4, 11, 16, 17, 18 and 19 are partly weathered/ fractured basement and would have been good points for groundwater prospects if their thicknesses (at the third geoelectric layers for VES 4, 11 and 16, and second geoelectric layers for VES 17, 18 and 19) were known.

The interpretation of the results classifies the area from poor to medium groundwater potential zones.

CHAPTER ONE

INTRODUCTION

1.1 GENERAL STATEMENT/ PROBLEM DEFINITION

Water remains the world's most widely distributed resource that exist as either surface or subsurface water. Its role in human activities cannot be over emphasized because it is essential directly or indirectly. It has found its way into the agricultural, industrial and manufacturing sector of every nation's economy. Its availability and quality have always played an important part in determining not only where people can live but also their quality of lives. Even though there have always been plenty of fresh water on earth, water has not been readily available when and where it is needed, nor is it always of suitable quality for all usage. Water is a necessary resource and a major factor. It plays an important role in the existence and sustenance of life (Egbeyemi, 2013).

Water occurs on our planet in three forms as very large, medium and small standing water such as oceans, seas and numerous lakes, as bodies of flowing water in form of major rivers, streams, rivulets and springs; and as subsurface water, in films around grains, droplets in pore spaces and cavities in rocks filling them completely over variable areas and creating underground reservoirs (Parbin 2009).

Subsurface water is further distinguished into two main types, namely: Vadose water and groundwater.

Vadose water occurs from surface downwards up to a variable depth and is in rate of downward movement under the influence of gravity. It's movement is commonly described as INFILTERATION. The thickness of soil and rock through which vadose water infilterates is called ''zone of aeration''. Obviously, in the zone of aeration, the soils and rocks remain unsaturated with water.

Groundwater includes all the subsurface water reaching a depth below which the pore spaces, openings and other cavities of the soil and rocks are completely filled with water. The thickness, length and width of the saturated strata, the aquifer, constitute the groundwater reservoir in a given area. In this zone of saturation, movement of water is principally under the influence of hydrostatic head. Water table is the name given to the upper surface of the zone of saturation and is of vital importance in the study of groundwater reservoirs (Parbin 2009).

Groundwater resides within the zone of saturation in the subsurface, and it remains a valuable natural resource that is of immense importance to life. Its availability and characteristics are greatly determined by the properties of the immediate geological formations and other environmental factors.

Groundwater is said to be better than surface water in terms of pollution (Todd, 1980) because it is pathogen free, it has high storage capacity, its temperature is uniform, turbidity and color are absent.

There is presence of primary porosity in the sedimentary rock at the time of their formation, but the basement complex however lacks primary porosity and can only serve as an aquifer in trapping groundwater, but if there are some degrees of fracturing, faulting, jointing or thick overburden, then secondary openings can be created. It is therefore important that the geological formation of any study area be known to ascertain its formation and aquifer characteristics for the purpose of determining the aquifer characteristics and siting viable wells or boreholes. As water occurs on the surface and subsurface, there is need to delineate where water of durable yield can be obtained. Hand dug wells and modern boreholes are constructed for potable water supply to meet this growing demand of water by the people all over the world for their day to day activities (Egbeyemi, 2013).

The unquenchable need for water in various areas of human lives has led many Geologists and Geophysicists in times past to develop various techniques that could be used in the exploration and exploitation of Groundwater. The most common geophysical techniques employed in ground water exploration include: Electrical Resistivity, Seismic Refraction and the Electromagnetic method (EM). The VLF-EM and the Electrical Resistivity method has been used over the years as an integrated geophysical methods to locate fracture zones, faults, shear zones or aquiferous zones that aid groundwater development. Geophysical methods generally can provide information on the depth to bedrock in subsurface layering and lithology, extent of saturation, porosity of regolith and location of steeply dipping structures such as dykes and faults (Egbeyemi, 2013).

The quest for potable water for both the faculty of science block, and possibly, the entire University campus was the reason this survey was carried out. Also, with the increasing population in the University over the past years, there is need to delineate potential zones that will aid groundwater development to meet water requirement of the school.

1.2 DEFINITION OF TERMS

Zone of Aeration or Unsaturated Zone - where most of the pore spaces are filled with air.

Saturated Zone – This is where rain that falls on the surface seeps down through the soil into the pore space in the rock.

The Water Table-The surface below which all openings in the rock are filled with water (the top of the saturated zone). The water table may be very near the ground surface or it may be hundreds of feet below.

Aquifer – A rock mass, layer or geologic formation which is saturated with groundwater and by its virtue of its properties is fast enough to hold and transmit groundwater. I.e. an area that holds a lot of water, which can be pumped up with a well. It is a storage reservoir and a transmission conduit at the same time. Limestones and sandstones generally form good aquifers.

Confined aquifer- overlain by a confined layer, a geologic unit having little or no intrinsic permeability which separates it from the influence of atmospheric pressure. Naturally, water held in this type of aquifer is not under atmospheric pressure but under a great pressure due to the confining medium. The recharge to the confined aquifer can occur either in a recharge area where the aquifer crops out or by slow downward leakage through a leaky confining layer.

Unconfined aquifer – it is otherwise known as water table aquifer. It is very close to the ground surface with continuous layers of materials of high intrinsic permeability extending from the land or ground surface to the base of the aquifer. The upper surface of the water table is under atmospheric pressure. The recharge to this aquifer can be a downward seapage through precipitation into the aquifer. Water occurring in this type of aquifer is called Free Groundwater.

Aquiclude – rock body or formation which may be porous enough to hold enough quantity of water and by virtue of its other properties does not allow an easy and quick flow through it, is termed an Aquiclude. It is to be treated as a practically impermeable rock mass. Compacted clay formations are the best examples.

Aquifuge – an absolutely impermeable rock formation through which there is no possibility of movement of water. Such a formation is almost free from pores and other interstices. Examples are compact interlocking granites and quartzites.

Aquitard- a layer of low permeability that can store groundwater and also transmit it slowly from one aquifer to another. E.g. clayey sand.

Hydrogeological cycle – This is the vertical and horizontal movement underground as infiltration or subsurface and continuous movement of all forms of water.

Overburden – The loose materials e.g. soil, sand, silt or clay that overlies crystalline bedrock.

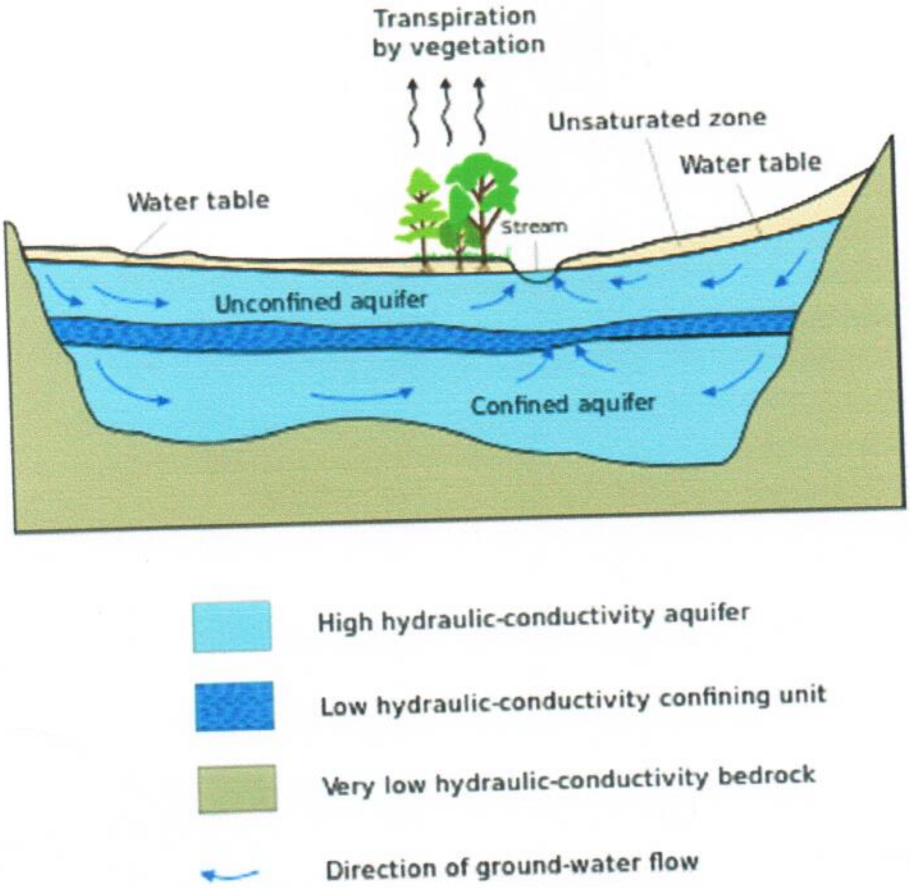


Fig.1.1 Typical diagram of an aquifer showing the water table and the unsaturated zone.

1.3 JUSTIFICATION OF THE STUDY

The increasing need of water in the University, especially the Faculty of Science located at phase two (2), as a result of increasing population of the school as the years go by has led to the reason this study was carried out.

1.4 AIM OF THE STUDY

The main aim of this project work is to evaluate the subsurface geology and groundwater potential of the study area.

1.4.1 OBJECTIVES OF THE STUDY

The objectives of the study are to:

i. locate geological structures such as fracture zones, joints, fault zones, shear zones and weathered zones that are favorable for groundwater development.
ii. generate the geo-electric parameters of the subsurface under the study area and determine the subsurface layering, thickness and resistivity.
iii. determine aquifer zones for groundwater development and
iv. characterize the hydrogeological setting of the area with the view to delineating potential zones for groundwater exploration.

1.5 SCOPE OF THE STUDY

The scope of this study involves the consultation of previous works of different geoscientists on related topics in scientific and geological journals, texts and googling online researches on Precambrian basement complex, aquifer units, groundwater resources, potentials and exploration.

Preliminary study of the area for reconnaissance survey, geological and geophysical mapping of the study area were carried out. The geophysical mapping involves cutting of parallel traverses from East to West of the study area and locating station positions (10m interval), as well as acquiring data through the VLF-EM and Electrical Resistivity methods (the Schlumberger array) using the Abem Wadi VLF equipment and the Ohmega campus resistivity meter respectively. Data processing and interpretation through drawing of profiles and generation of sounding curves were also carried out. The sounding data were interpreted in terms of layer parameters underneath the sounding positions, and were used to generate resistivity structures, geoelectric sections and maps of the study area. Reasonable conclusions about the geology of the study area were made from the profiles, sounding curves, geoelectric sections and maps generated.

1.6 PHYSIOGRAPHIC SETTINGS OF THE STUDY AREA

1.6.1 DESCRIPTION OF THE STUDY AREA

Federal University Oye-Ekiti is located at the Southern axis of Oye-Ekiti. The study area lies between latitudes $7^0 46.52'$N and 7^0 $46.74'$N (860072 and 860494) N, and longitudes$5^0 18.71'$E and $5^0 19.05'$E (755598 and 755977) E in the Universal Transverse Mercator (UTM) scale. (Figure 1.2)

FUOYE campus is generally accessible and motorable with the availability of both tarred road from Ilupeju axis and untarred roads from Iworoko, Afao and Ayegbaju axis as well as footpaths. These provide good accessibility to the area (Figure 1.3).

The study area is moderately undulating with the elevation ranging from 520 m to 536 m above the datum (Figure 1.4).

The area is drained by few seasonal streams with dendritic drainage pattern flowing from Northwest to South east.

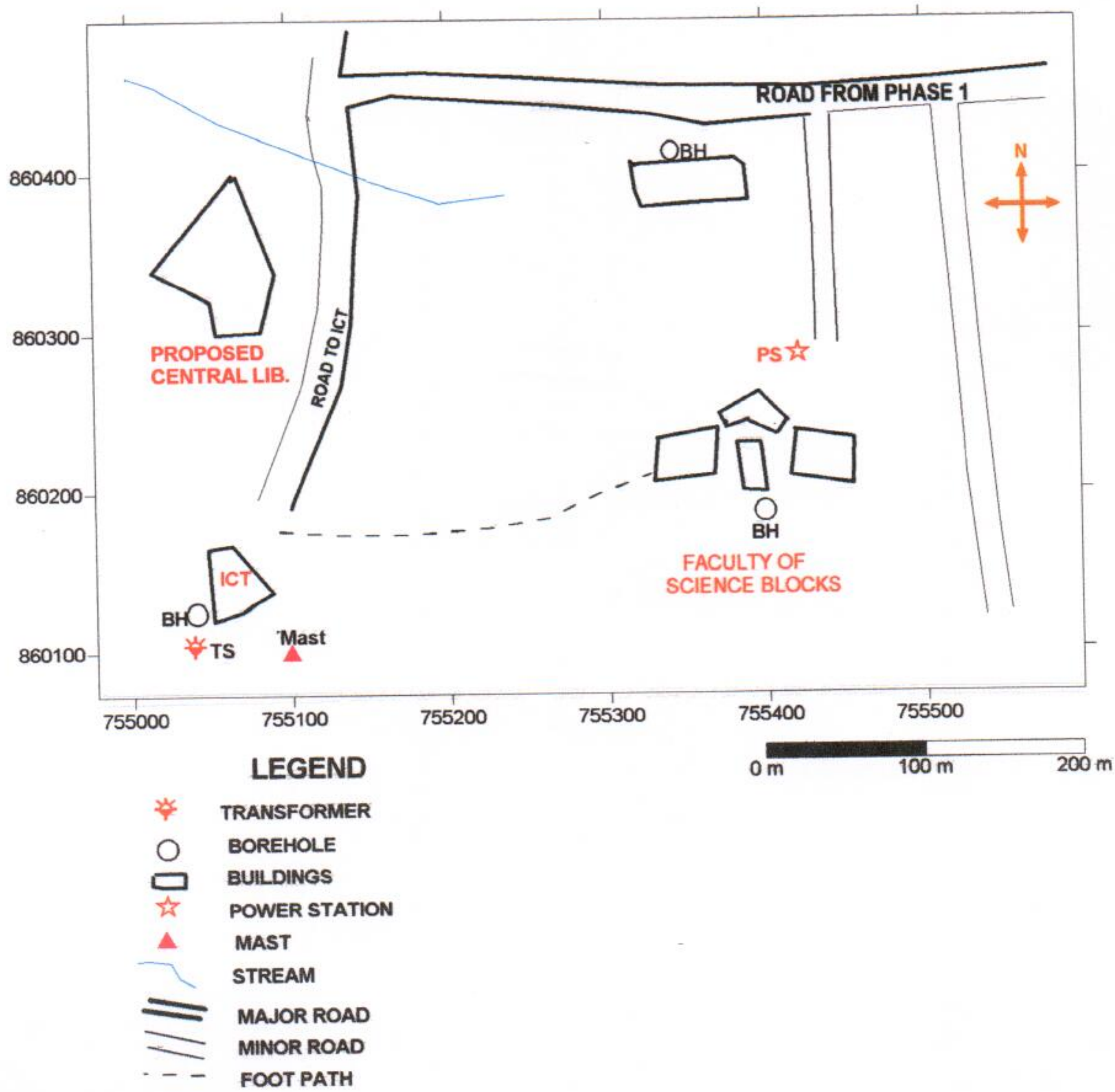


Fig. 1.2 – Base Map of Federal University Oye-Ekiti phase 2 (generated by Daramola, O.D, 2015).

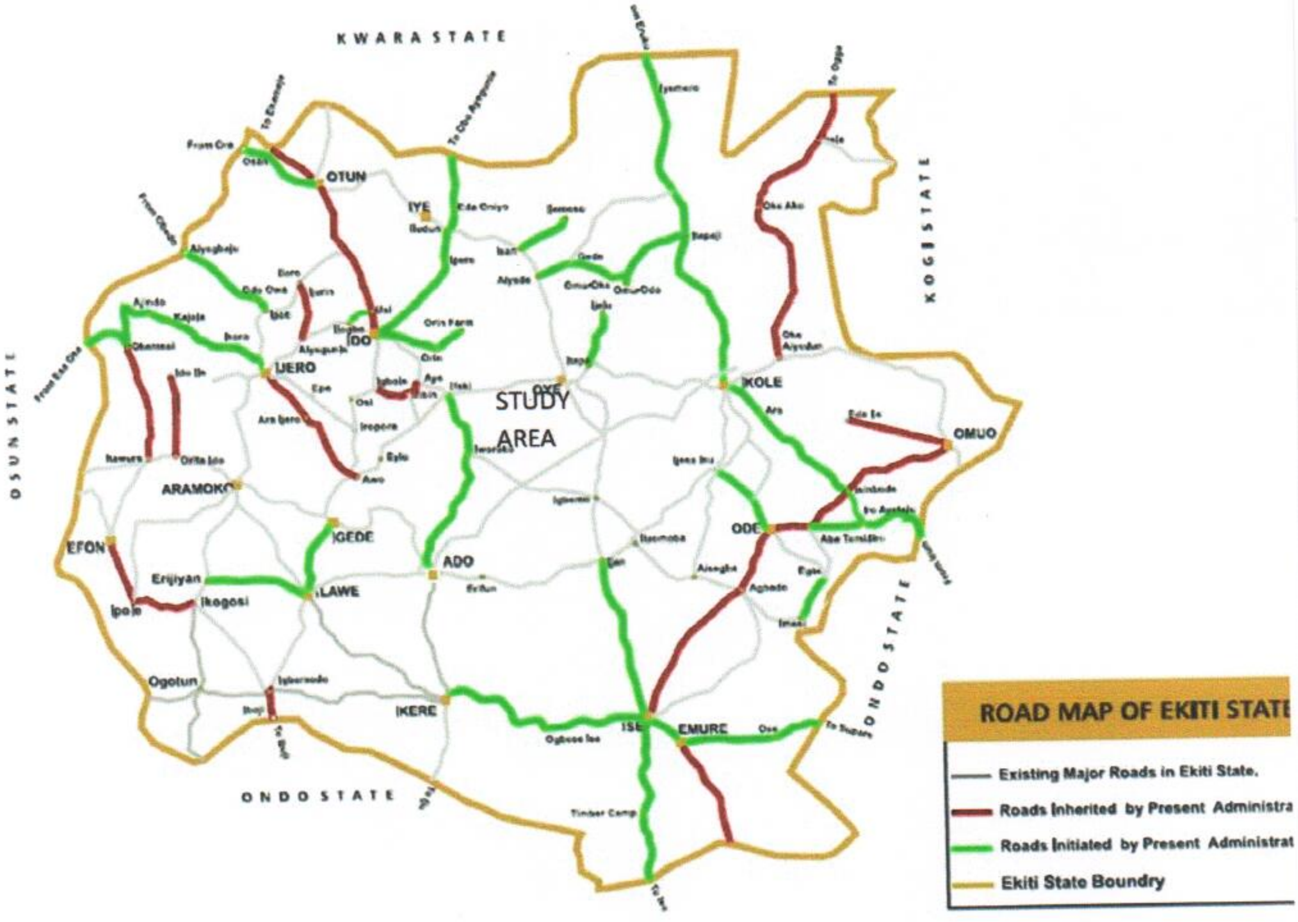


Fig 1.3 Roadmap of Ekiti state showing the study area.

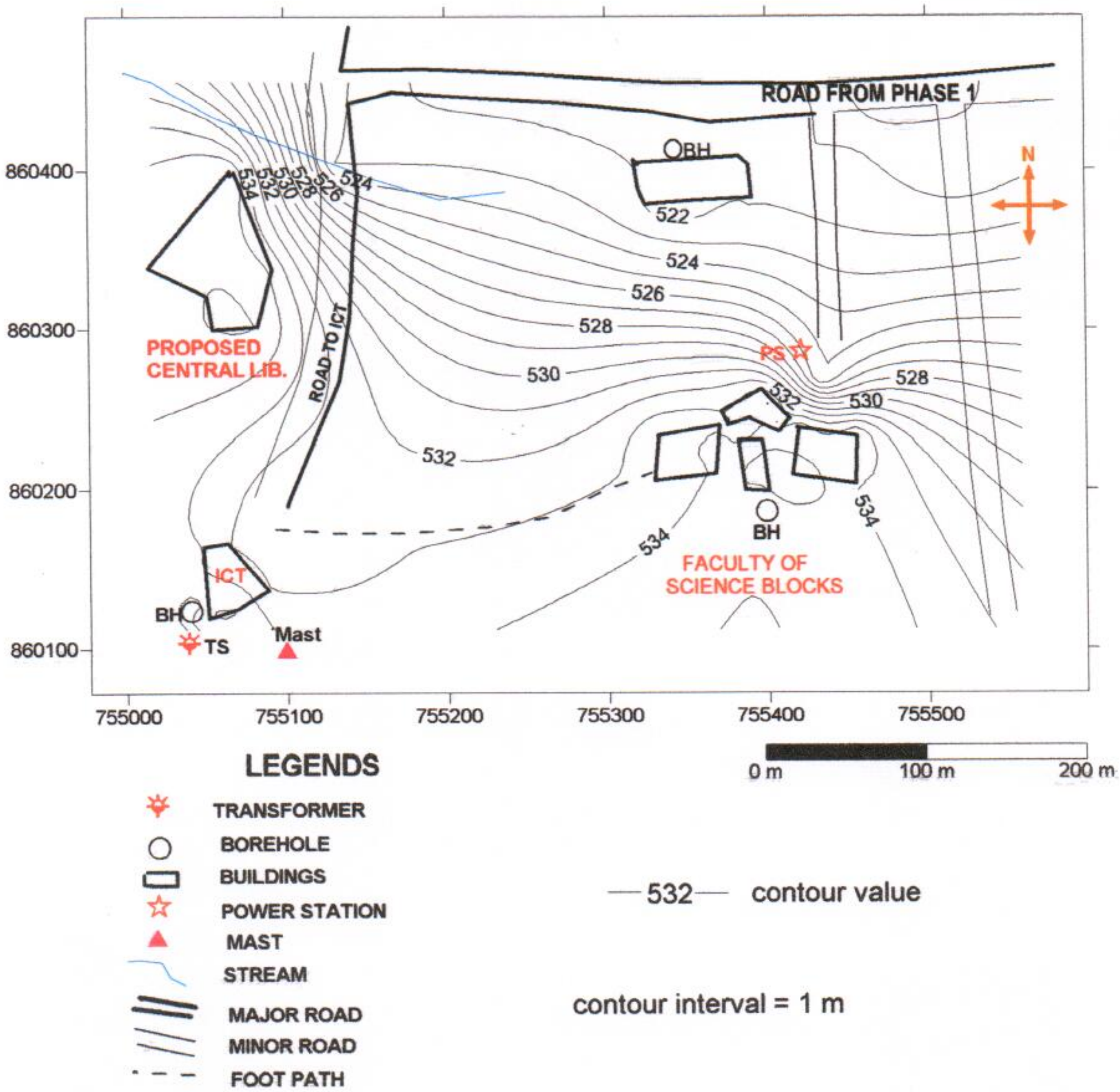


Fig. 1.4 Topographical map of the study area.

1.6.2 CLIMATE AND VEGETATION

The study area has essentially two seasons in a year: raining and dry seasons. The rainy season ushers in most Southwest monsoon wind from the Atlantic Ocean, while the dust winds from the Sahara marks the onsets of the dry season. The harmattan; which lies in the zone of transition between the humid and semi-humid climate is also present in the study area. Generally, the climate of the study area is characterized by high and low diurnal, monthly and annual temperature, high relative humidity and low atmospheric temperature (Olayinka 2000).

The study area is surrounded by abundant vegetations and good soils which encourage farming activities in the area. The vegetation is of tropical rain forest characterized by timbers and large trees used for lumbering activities. The vegetation also comprise of evergreen trees, palm trees, hard woods and green grasses. The natural vegetation is locally distributed by human activities especially farming.

1.7 REVIEW OF PREVIOUS WORK

Several people have worked on the exploration of groundwater in the Nigeria basement complex terrain using integrated geophysical methods. Amongst which are: Omosuyi *et al.*, 2008, Okafor and Mamah, 2012, Adelusi *et al.* 2013 as well as Ogundana and Talabi, 2014.

Omosuyi *et al.*, 2008 used the Electromagnetic and Geoelectric Sounding Data for Groundwater Resources around Obanla-Obakekere, near Akure, Southwestern Nigeria to map the hydrogeologic units and characterize the area into groundwater resources zones for the location of water wells. Conductive features, which are characteristic of appreciably positive VLF-EM amplitudes, were interpreted as probable geologic fissures, capable of holding significant quantity of water. Further evaluation with the vertical electrical sounding enabled the delineation of the aquifer units and determination of the spatial variation of their thicknesses. The composite thickness of the aquifer units varied from 1 m to 41.6 m across the area. This range of thickness enabled the characterization of the area into hydrogeologic zones. Areas with thick units were thought to have higher groundwater prospects while zones with thin aquifer units were believed to have low groundwater prospects. The former hydrogeologic zones are considered suitable for groundwater development. The study reveals that the groundwater prospect in the study area was generally low.

Okafor and Mamah, 2012 carried out "Integration of Geophysical Techniques for Groundwater Potential Investigation in Katsina-Ala, Benue State, Nigeria". Integrated geophysical techniques involving VLF-Electromagnetic and Electrical Resistivity sounding methods were used. The area was believed to be underlain by the crystalline basement complex of northeastern Nigeria with local geology predominantly granite. The qualitative interpretation of the VLF-EM results identified areas of hydro-geologic importance and formed the basis for Vertical Electrical Sounding (VES) investigation. The interpretation of the VES data assisted in the characterization of the subsurface into three to five geo-electric layers from which the aquifer units were delineated. The weathered and/or the fractured basement were the aquifer types delineated across the area. The thickness of the weathered aquifer unit varies from 5.3 m to 32.8 m in the area. On the basis of geo-electric parameters the study area was zoned into high, intermediate and low groundwater potential zones.

Adelusi *et al.* 2013, applied the VLF-EM and VES to groundwater exploration in a Precambrian basement terrain of SW Nigeria. The VLF-EM result mapped basement structures relevant in groundwater development. This was further studied using VES. Results of the investigation indicated that an HKH sounding curve was obtained with a maximum of five subsurface layers comprising: the topsoil, clay/sandy clay unit, the fresh basement, fractured basement and the basement bedrock. The fractured basement layer constitutes the main aquifer unit with thickness of 20-25 m. The geoelectric results compared favorably well with drilling information to above 90%. The yield of the well was 2 L/s with good recharge capability.

Ogundana and Talabi, 2014, carried out Geoelectric Characterization of Aquiferous Units and its Implication on Groundwater Potential of Owo, Southwestern Nigeria. Vertical electrical sounding method was employed and Schlumberger configuration was adopted. A total of 32 VES locations across 3 sections were spread over the study area. Six different subsurface lithologic units were established namely; lateritic topsoil, clay, sand, quartzite, weathered/fractured basement and fresh basement. The topsoil, clay, sand and weathered basement materials were characterized with relatively low resistivity values while the quartzite ridge materials were characterized with high resistivity values. Weathered/fractured basement was encountered across the three sections with average resistivity and thickness values of 86 Ωm and 12.0 m respectively. Basement was believed to be relatively deep in the study area and the average resistivity and depth values to the top of basement were 878 Ωm, and 24 m respectively. Overburden thickness was established across the area with an average value of 20 m. The overburden materials with the fractured basement constitute aquiferous units within the study area though the sand and weathered basement units were largely responsible for the groundwater potential. The groundwater potential of the area was classified to be generally moderate.

1.8 EXPECTED CONTRIBUTION TO KNOWLEDGE

The geoelectric evaluation of groundwater potentials of Federal University Oye- Ekiti phase two (2), south western Nigeria, using the VLF-EM and the Electrical resistivity method enabled the classification of the groundwater potential of the study area from poor to medium groundwater potential zones.

CHAPTER TWO

LITERATURE REVIEW

2.1 REGIONAL GEOLOGY OF NIGERIA

Generally, in Nigeria, about half of the total area is covered by igneous and metamorphic rocks. About 80% of these are Precambrian age and the remaining 20% are younger intrusive and volcanic lava. The crystalline rocks are collectively referred to as Basement Complex rocks. It is believed that the greater part of crystal growth took place during the Archean which is older than 2.65 billion years. Nigerian rocks can be grouped into the crystalline Basement and sedimentary rocks. Half of the crystalline Basement Complex in Nigeria is underlain by the cretaceous and younger sediments. The crystalline rocks are divided by Dada 1995 into the following:

- Basement Complex
- Younger Granite
- Tertiary to Recent Volcanic

The Precambrian of Africa consists of three major cratons which are:

- The West African craton
- Congo craton
- The Kalahari craton

The mobile belts which surround the craton were affected by late Proterozoic Pan Africa Orogeny about 600Ma or 0.6Ga (Clifford, 1970). Nigeria lies in the mobile belts that separate the West Africa and Congo cratons.

The essential features of the Nigerian Basement complex have been reviewed by Rahaman (1976). Basement outcrops are distributed in these areas:

- A triangular area in South Western Nigeria where the rocks continue westwards into the neighboring Benin-Republic.
- Roughly circular areas in North Central Nigeria
- A rectangular area are broken up into three zones by sedimentary rock on the eastern border with Cameroon findings from the numerous works revealed that the Basement Complex rocks of Nigeria are predominantly composed of migmatite and granitic

gneises, quartzite, slightly migmatised to unmigmatised metasedimentary schist and diorite rocks.

About 50% of the Nigeria Precambrian was believed to be the migmatite gneiss complex. The migmatite gneiss complex is composed of migmatite gneiss varying texture and origins, and meta-sedimentary and meta-volcanic rocks now represented by Quartzite, Marble, Calc-Sillicate rocks and Amphiboles, occurring as within the Gneisses and Migmatite are interlaid with them. The slightly migmatised to unmigmatised paraschist represent a sedimentary cover on the Gneiss Migmatite complex. The union of amphibolites (meta-igneous and volcanic rocks) and the effonpsammite formation, East of Ile-Ife, and the association of carbonates (marbles and Calc-Sillicates rocks) and argillaceous rocks (schist) in the Igarra area further to the East are thought to represent a Eugeosynclinal and Miogeosynclinal sequence of sediments respectively.

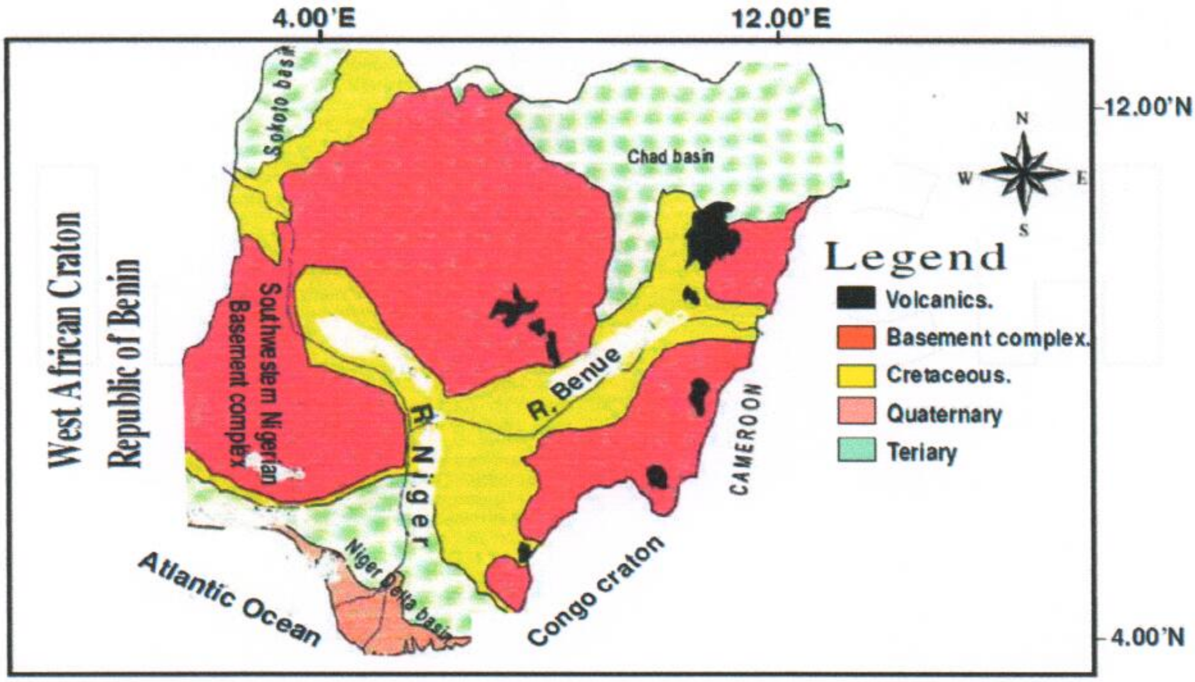


Fig.2.1 Geology of Nigeria (modified after Elueze, 1982)

2.2 GEOLOGY OF SOUTHWESTERN NIGERIA BASEMENT COMPLEX

The southwestern Nigeria basement lies to the west of the West Africa Craton in the region of the late Precambrian to early Paleozoic Orogenesis. The area covered by the southwestern Nigeria basement complex lies between latitudes 7°N and 10°N and longitudes 3°E and 6°E right in the equatorial rain forest region of Africa. The main lithologies include the amphibolites, migmatite gneisses, granites and pegmatites. Other important rock units are the schists, made up of biotite schist, quartzite Schist talk-tremolite schist, and the muscovite schists. The crystalline rocks intruded into these schistose rocks. (Akindele, 2013).

Five major rocks groups were recognized and described by Rahaman (1976) as:

- Migmatite Gnesis comprises of Biotite and Biotite Hornblende Gneisses quartzite and quartz schist and calc-sillicate rocks.
- Slightly Migmatised to unmigmatised paraschist and meta-igneous rocks, which consist of PelliticSchists, quartzite Amphibolites, Talcose rocks, meta conglomerates, marble and calc-sillicate rocks.
- Charnockitic rocks.
- Older granites, which comprises rocks varying in composition from granodiorite to true granites and potassicsyenite
- Unmetamorphorsed Dolerite dykes believed to be the youngest.

2.2.1 THE MIGMATITE-GNEISS COMPLEX

Three petrological units characterize the Migmatite-Gneiss-complex.

- A grey foliated Biotite acid or Biotite Hornblende Quartz Feldspartic Gneiss of Tonalitic to Granodioritic composition which is now known as the grey Gneiss or early Gneiss. It is present in most outcrops.
- Mafic to Ultramafic component which, where it is present, often outcrops with discontinuous bandaged lenses or concordant sheet Amphibolite with minor amount of Biotite-rich Ultramafic except it constitutes the Paleosome to the migmatite, it is present in grossly subordinate amount to the grey gneiss.
- Felsic component is a varied group of rocks consisting essentially to Pegmatite, Aplite, Quartz, Oligoclise veins, Fine grained Granite Gneiss, Prophyritic granites etc.

The three components may not be present together on a single outcrop. But the different types of Migmatite Gneiss e.g. Banded gneiss, Nebulites, and Agmatites etc. result from the varying different relationship between these components.

The simple banded structure observed in most outcrops is misleading and is as a result of strong deformation and migmatitic processes. The preservation of rocks definite sedimentary origin within the migmatite gneiss complex has led most authors to suggest that the early gneiss is derived from the sedimentary protolith. Rahaman (1988) carried out a field petrographic and geochemical study involving major, minor and REE (Rare Earth Element) of the three components of the migmatite in parts of southwestern Nigeria. These include:

- The progenitors of the early gneiss were magmatic rock of Granodioritic-Tonaritic composition rather than sedimentary greywacke or greywacke shale sequence.
- The Mafic components formerly thought to be metamorphosed marls or chloritic Calcareous sediments are metamorphosed basic dykes and sills.
- The Felsic components are either of magmatic or metamorphic origin and were generated during each of the Orogenic events that have affected the basement complex of Nigeria.

The conclusion from this brief review is that there is no consensus about the nature of Protolith and the most abundant rock type in the basement complex of Nigeria.

2.2.2 CHARNOCKITE

Charnockite occurs west of Ibadan dyke-like bodies scattered over a wide area. Jones and Hockey (1964) described two main areas of diorite occurrence, one West of Olokemeji and the other between Imala and Oyanriver in the S/W part of Nigeria. Charnockite outcrops in general are smooth, widely distributed rounded boulders which are composed of Quartz, Alkali Feldspar, Palgioclase and clinopyroxene, Hornblende, Biotite and accessory amount of opaque ore, Apatite, Zircon and Allanite.

The charcnockitic rocks are mainly of magmatic origin and not the result of high grade metamorphism in the granulites facies.

This belongs to two generations:

- The first preceding the emplacement of the older granites and;
- The second emplaced in the last stages of the older granite Orogeny.(A magmatic origin is suggested for most of the older granite bodies).

2.2.3 BAUCHITE

Bauchite is extremely coarse with about 2cm across, set in matrix Ferromagnesia, Plagioclase and Quartz. The color of the Feldspar is dark green and the Quartz brown or sometimes blue with resinous luster. In thin section, Bauchite is of xenomorphic granular texture and is composed of microcline (pertitic) plagioclase of Oligoclase –Andesine composition, Quartz-Fayallite, Eulite or Ortho-Ferrosilite and Hastingsite with accessory Appatite, Zircon.

2.2.4 OLDER GRANITES

This term was first introduced when the rocks were first distinguished from the younger or plateaus tin bearing Alkali-Granite by Falconer, (1911). They range in size from Plutons to Batholiths. The forms of the bodies appear to be related to the environment in which the granite is emplaced. Other granites include rocks of wide range of composition; Granite, Granodiorite, Adamellites, Quartz-Monzonite, Syenite, Pegmite, Granitic compositions are most common.

2.3 LOCAL GEOLOGY OF THE STUDY AREA

The study area falls within the basement complex of Southwestern Nigeria, and is dominated by Migmatite gneiss complex of Precambrian age. The migmatite gneiss is the most occurring outcrop in the area of study. It is found at the Eastern part of the University environment. Some of it is severely weathered where it outcrops.

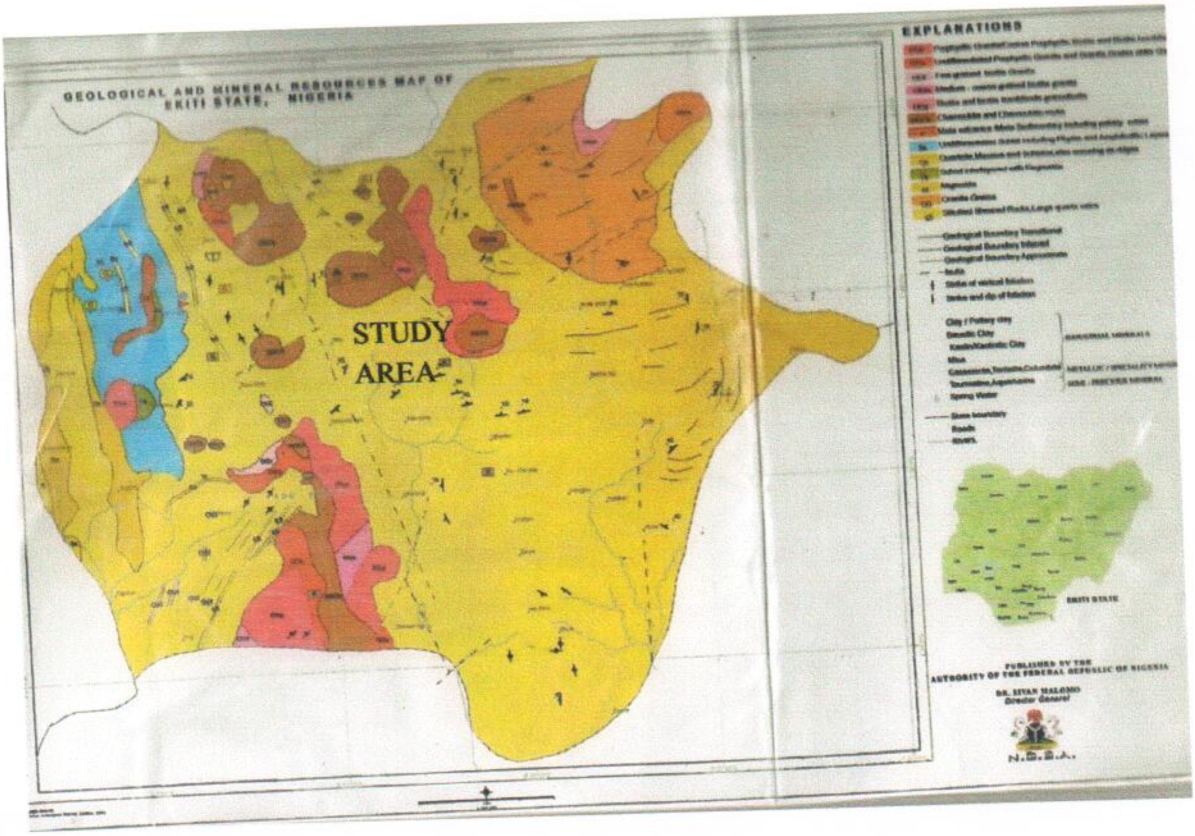


Fig. 2.2- Geological map of Ekiti State showing the study area (generated by the NGSA 2006)

2.4 HYDROGEOLOGY OF BASEMENT COMPLEX TERRAIN

Hydrogeology is the movement of water or fluids in rocks.

Generally, locating drilling sites for areas underlined by basement complex rocks is a difficult task. The extreme variation in lithologies and structures coupled with highly localized water producing zones makes geological, hydro geological and hydro geophysical exploration for ground water difficult. (Bayode,1994). Among the factors which are considered for groundwater location in basement area is high topographical features, which it is related to high bed rock relief (e.g. ridges). It is an important factor for well location in some areas. Wells located on flat terrains and valleys tends to yield more than the wells located on hill tops and valley sides because bed rock ridges crest when present acts as radiating centre for groundwater, as water normally drain along steep slopes and hilltops of discharged in adjacent lowlands (Olorunfemi and Okhue, 1992).

The hydrogeology of an area is controlled by some factors such as geology, structures and climate of the area (Ademilua and Olorunfemi, 2000). This is because the geologic formations underlying the area and the structures determine the types of aquifer to be encountered and the means of recharging them, while the climate determines the amount and rate of recharge of the aquifer (Shemang, 1990).

In crystalline rocks, weathered, partially weathered, fractured zones form aquifers, the nature and extent of weathering varies and depends mostly on the presence of fractures at depths and favourable morphological features at the surface in the metamorphic terrains, faults breceias are useful guides for of well site. Ideal conditions for ground water aquifers exists when such as reef cut across a narrow part of a valley with good recharge area,, but hornblende gneiss and metabasic dykes acts as a barriers for groundwater flow (Verna, Rao and Rao, 1980). However, in weathered rocks, both intergranular and fracture porosities exists. The clay content in the weathered portion, reduce the permeability to some extent. In hard rock area, the weather and fracture aquifer are capable of yielding sufficient amount of water to meet the needs of small community or village (Verna, Rao and Rao, 1980). In areas underlain by crystalline rocks, groundwater is stored in the buried stream channels and the weather layer, joints and fracture. The groundwater is good unless it is polluted through human, industrial and agricultural activities. In the study area, groundwater is primarily recharged by rainfall and small amount from lateral ground water flow and river channel where possible.

2.4.1 GROUNDWATER

Groundwater begins with precipitation that seeps into the ground. The amount of water that seeps into the ground will vary widely from place to place, depending on the slope of the land, amount and intensity of rainfall, and type of land surface. Porous, or permeable land containing lots of sand or gravel will allow as much as 50 percent of precipitation to seep into the ground and become groundwater. In less permeable areas, as little as five percent may seep in. The rest becomes runoff or evaporates. Over half of the fresh water on Earth is stored as groundwater.

As water seeps through permeable ground, it continues downward until it reaches a depth where water has filled all the porous areas in the soil or rock. This is known as the saturated zone. The top of the saturated zone is called the water table. The water table can rise or fall according to the season of the year and the amount of precipitation that occurs. The water table is typically higher in early spring and lower in late summer. The porous area between the land surface and the water table is known as the unsaturated zone.

2.4.2 GROUNDWATER RECHARGE

Water that seeps into an aquifer is known as recharge. Recharge comes from a variety of sources, including seepage from rain and snow melt, streams, and groundwater flow from other areas. Recharge occurs where permeable soil allows water to seep into the ground. Areas in which this occurs are called recharge areas. They may be small or quite large. A small recharge area may supply all the water to a large aquifer. Streams that recharge groundwater are called losing streams because they lose water to the surrounding soil or rock.

2.4.3 GROUNDWATER DISCHARGE

Groundwater can leave the ground at discharge points. Discharge happens continuously as long as enough water is present above the discharge point. Discharge points include springs, stream and lake beds, wells, ocean shorelines, and wetlands. Streams that receive groundwater are called gaining streams because they gain water from the surrounding soil or rock. In times of drought, most of the surface water flow can come from groundwater. Plants can also contribute to groundwater discharge, because if the water table is close enough to the ground, groundwater can be discharged by plants through transpiration.

2.4.4 GROUNDWATER MOVEMENT

Groundwater usually moves slowly from recharge areas to discharge points. Flow rates within most aquifers can be measured in feet per day, though in karst bedrock the rate of flow can be measured in miles per hour. Flow rates are faster when cracks in rocks or very loose soil allow water to move freely. However, in dense soil, groundwater may move very slowly or not at all.

Groundwater typically moves in parallel paths, or layers. Since groundwater movement is slow, it doesn't create enough turbulence to cause mixing the way surface waters mix when a river or stream empties into another water body. That is, layers of groundwater remain relatively intact. This can be an important factor in locating and determining the movements of contaminants that might enter the groundwater supply. But eventually contaminants will disperse through part or all of an aquifer.

Wells affect groundwater flow by taking water out of an aquifer and lowering the nearby water table. Removed water is recharged from the water table, and the lowered water table caused by the well is called a cone of depression. The cone of depression from a well may extend to nearby lakes and streams, causing the stream to lose water to the aquifer. This is known as induced recharge. Streams and wetlands have been completely dried up by induced recharge from well pumping.

2.4.5 GROUNDWATER PROBLEMS

2.4.5.1 SOURCES OF GROUNDWATER CONTAMINATION

Groundwater contamination can come from a number of natural and human-made sources. These can include:

Leachate from landfills

If landfills are not properly constructed, liquid from decomposition of materials, or leachate, can leak out of the landfill into an aquifer. Leachate can contain high levels of bacteria, hazardous chemicals, metals, and ammonia. Runoff water from landfills after rains can also carry pollution to groundwater recharge areas and hence into groundwater.

New landfill construction methods are designed to prevent pollution of groundwater. Landfills are now built with liners to prevent leachate from seeping through soil into aquifers. Leachate collection systems store the liquid away from the water table. Clay caps prevent rainwater runoff from carrying pollutants from the landfill into the groundwater.

Saline Intrusion

In coastal areas, too much demand on potable groundwater can create induced recharge from ocean waters, resulting in saline intrusion into groundwater supplies. This can also happen in times of severe drought. (Induced recharge can not only contaminate groundwater, but enough induced recharge has been known to dry up wetland areas and destroy habitats for wildlife.)

Careful planning of coastal communities and water conservation are ways to avoid saline intrusion into groundwater supplies.

Fertilizers

Like pesticides, misuse of fertilizers can cause groundwater pollution. Overuse can allow nitrates from fertilizer to seep into the water table. In sensitive groundwater areas, rainfall seepage can cause fertilizer to migrate and contaminate an aquifer. Careful use can avoid or minimize these problems.

Pipeline breaks

Pipeline breaks can be sources of localized groundwater pollution. Breaks can be severe enough so that they are immediately detected, or they may be small and cause significant groundwater contamination before they are noticed. Pipeline breaks can cause pollution from sewage, petroleum products, or other chemicals. They can occur around roadways due to vibration from vehicles, or they can even be caused by plant roots, which slowly crack pipes and cause leaks. Careful inspection of pipelines and regular maintenance can reduce pollution problems from this source.

Radon contamination

Radon is a naturally occurring radioactive element that has been linked to cancer in humans. It occurs in certain geologic areas, and can be an air or water pollutant. Radon can collect as a gas in a basement, or it can contaminate well water. Test kits for radon detection are available for individual use. Once detected, radon can be removed from a home or water well.

2.5 RANGE OF RESISTIVITIES FOR COMMON ROCKS TYPES AND ITS APPLICATION

The range of resistivities for common rock types varies and so considerably overlap between different rock types. Consequently, identification of a rock type is not possible solely; on the basis of resistivity data (Kearey and Brooks, 1996).Table 2.1 shows the resistivities of different earth materials. Resistivity technique is widely used in engineering geological site investigation with relevance to depth to bed rock determination, structural mapping of bed rocks and detection of presence of unstable ground conditions, buried mine shaft and determination of superficial deposits and location of artifacts, etc. (Kearey and Brooks, 1996; Olorunfemi and Okhue 1992).

However, the most probable use of electrical resistivities survey is in hydro geological investigations in relation to aquifer delineation, lithologic boundaries and geological structures without the high cost of drilling to provide the sub surface information (Olorunniwo and Olorunfemi, 1987; Olayinka, 1992).

Table 2.1 RESISTIVITY OF SOME ROCKS AND MINERALS (after Parasinis, 1979)

ROCK TYPES	RESISTIVITY (OHM - M)	ORRES	RESISTIVITY (OHM -M)
Lime stone(marble)	$> 10^{12}$	Pyrrhotile	$10^{-5} - 10^{-3}$
Quartz	$> 10^{10}$	Chalcopyrite	$10^{-4} - 10^{-1}$
Quartzite	$50 - 10^{8}$	Graphite shale	$10^{-3} - 10^{1}$
Granite	$300 - 10^{8}$	Pyrite	$10^{-4} - 10^{1}$
Sandy soil	$500 - 800$	Magnetite	$10^{-2} - 10^{2}$
Sand storm	$35 - 4000$	Hematite	$10^{-1} - 10^{2}$
Alluvium sands	$10 - 800$	Galena	$100 - 300$
Top soil	$1 - 500$	Zinc blend	$> 10^{4}$
Clays	1-100		
Unconsolidated wet clay	$1 - 20$		

2.6 BASIC THEORY OF THE GEOPHYSICAL METHODS USED

2.6.1 ELECTROMAGNETIC METHOD

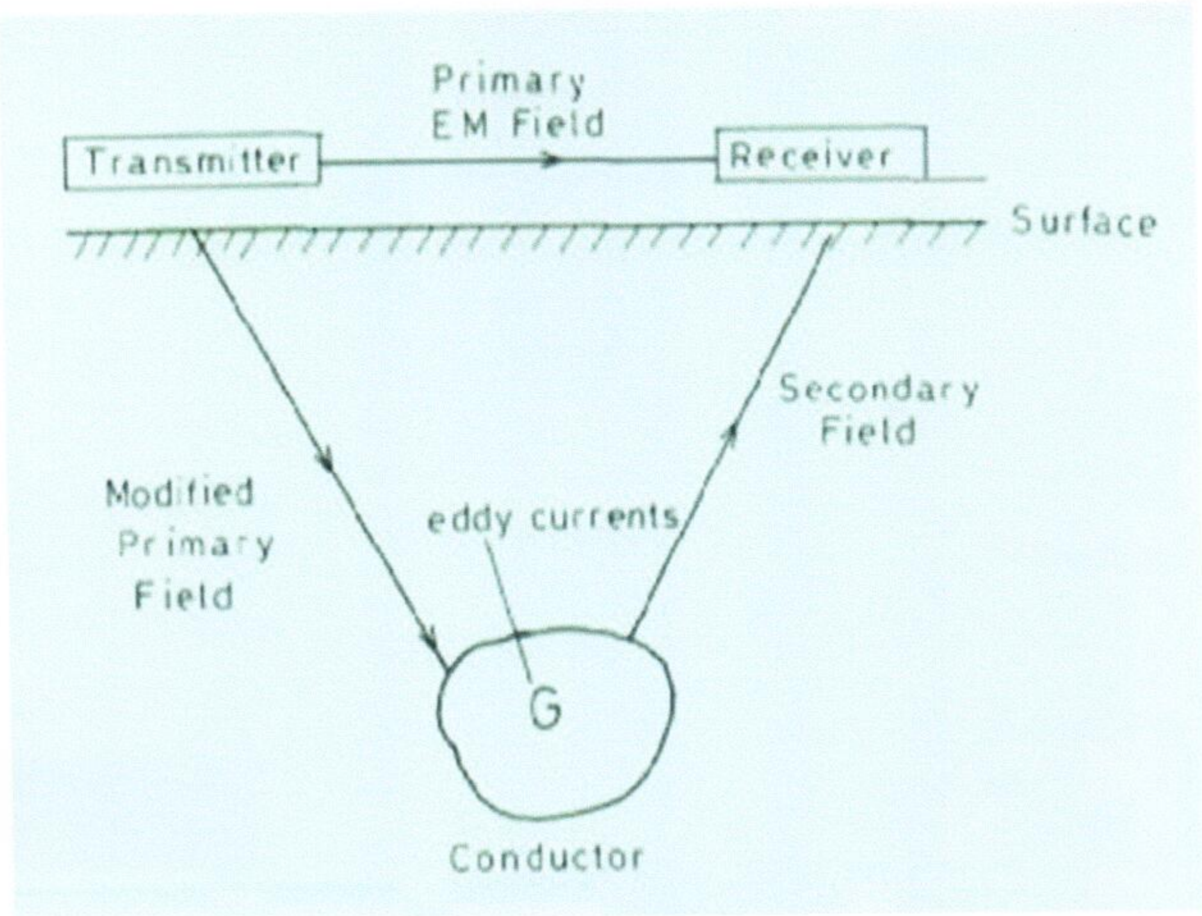


Fig.2.3- A Typical EM system

In Electromagnetic method, there is no contact between the ground and the instrument. This is an added advantage over the convectional resistivity survey where poor electrode ground contact limit current flow and increase ground noise level.

The Electromagnetic method utilizes the effect of the primary alternating magnetic field from the transmitter to interact with the subsurface conductor. This means that the ground is energized by sending a strong AC current through a coil. The primary magnetic field is induced thereby producing the secondary alternating magnetic field known as the Eddy current. Though this signal depends on the subsurface conductivity distribution. The secondary field induced is then received or measured as EM Signals by the receiver .E.g.

$I_P = I_P e^{jWt}$ or I_P sint 2.1

$I_P \rightarrow H_p$(primary magnetic field) 2.2

$H_P \rightarrow I_S =$ secondary current 2.3

$I_S = I_S e^{jWt}$ or I_S Sinwt 2.4

$I_S \rightarrow H_S$ (Secondary Alternating magnetic field). 2.5

Electromagnetic methods in geophysics are distinguished by:

1. Use of differing frequencies as a means of probing the Earth (and other planets), more so than source-receiver separation. Sometimes the techniques are carried out in the frequency domain using the spectrum of natural frequencies or, with a controlled source, several fixed frequencies (FDEM method ---"frequency domain electromagnetic").

The EM surveys can be conducted in frequency domain (FEM) as well as Time domain, also known as Transient (TEM). While FEM is a continuous excitation method, in TEM measurements are made at different times of the order of micro to milli seconds after the transmitter current is put off.

Applications of FEM and TEM methods in mineral exploration are quite common and popular. In applying EM methods for groundwater investigations, one of the differences observed is that the subsurface conductivity contrasts encountered are much smaller than that in mineral prospecting.

EM methods, and particularly FEM, are used for reconnaissance and for delineating saturated weathered and fracture zones having conductivities higher than the compact and dry surrounding, and also for selecting sites for water well drilling. FEM use either one or more frequencies. EM makes measurements as a function of time .Generally; EM methods are used in conjunction with electrical resistivity method.

In the pilot study of the aquifer mapping programme, Time-Domain Electromagnetic soundings are carried out at selected places in addition to the direct current resistivity soundings and imaging to confirm the results and jointly invert the data to reduce the ambiguities.

• EM does not require direct Contact with the ground. So, the speed with which EM can be made is much greater than the electrical methods.

• EM can be used from aircraft and ships as well as down boreholes.

Advantages
Lightweight& easily portable.

- EM can be either be:
a- Passive, utilizing natural ground signals (magnetotellurics)

b- Active, where an artificial transmitter is used either in the near-field (As in ground conductivity meters) or in the far-field (using remote high-Powered military transmitters as in the case of VLF Mapping 15-24 KHZ).

Factors Affecting EM Signal
The signal at the Receiver depends on:
1) The material
2) Shape
3) Depth of the Target
4) Design and positions of the transmitter and receiver coils

In electromagnetic method of geophysical prospecting, our interest is conductivity contrast. This is because the subsurface is not homogenous. It consists of variations. For example, the conductivity of granite is different from that of quartzite, clay, limestone or laterites.

Limitations of EM: Cultural Noise

2.7.1 ELECTRICAL RESISTIVITY PROSPECTING METHOD

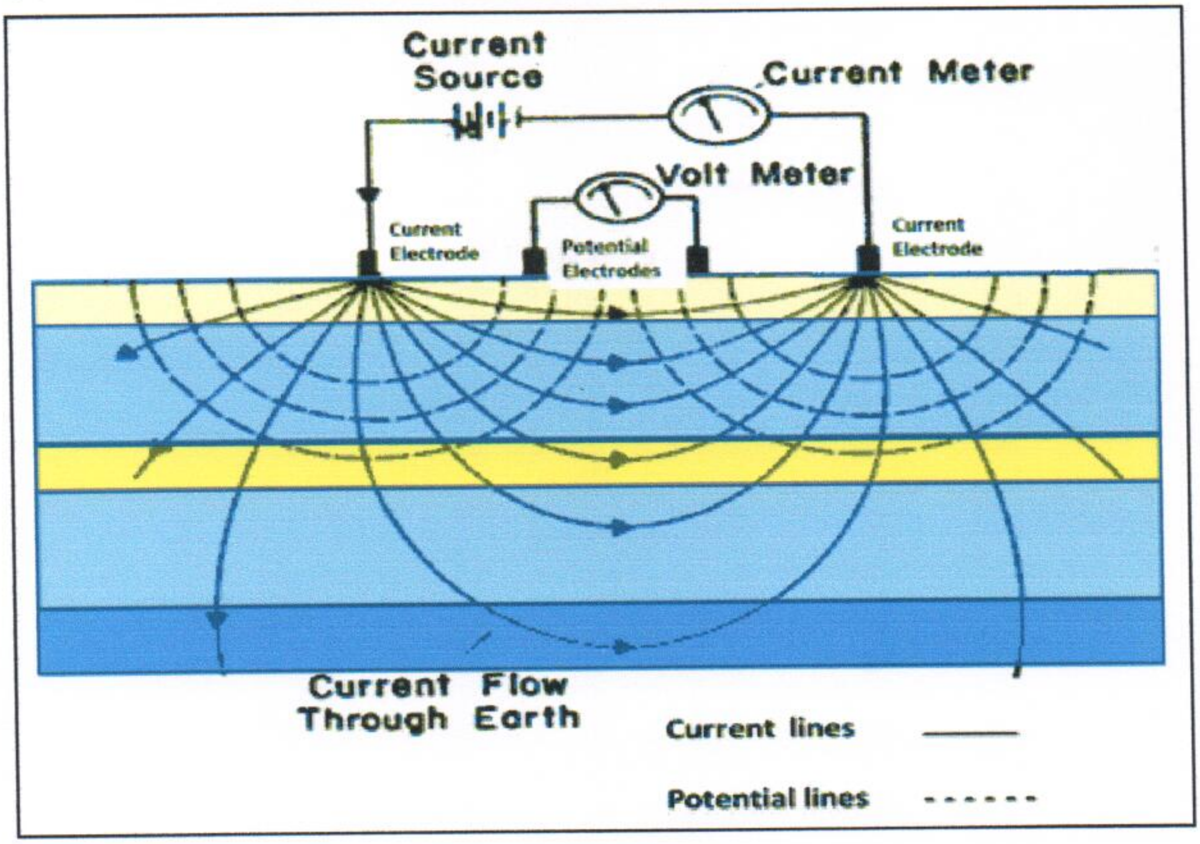


Fig.2.4- Diagram of four electrodes array for resistivity measurement on the surface with current flowing from a point source.

The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated.

The resistivity measurements are normally made by injecting current into the ground through two current electrodes (C_1 and C_2 in Figure 1), and measuring the resulting voltage difference at two potential electrodes (P_1 and P_2) based on the conductivity and resistivity of the sub-surface materials. From the current (I) and voltage (V) values, an apparent resistivity (pa) value is calculated.

$$Pa = k\,V / I \qquad 2.6$$

Where k is the geometric factor which depends on the arrangement of the four electrodes.

Resistivity meters normally give a resistance value, R = V/I, so in practice the apparent resistivity value is calculated by

$$Pa = k\,R \qquad 2.7$$

Where R = V/I

The calculated resistivity value is not the true resistivity of the subsurface, but an "apparent" value which is the resistivity of a homogeneous ground which will give the same resistance value for the same electrode arrangement. The relationship between the "apparent" resistivity and the "true" resistivity is a complex relationship. To determine the true subsurface resistivity, an inversion of the measured apparent resistivity values using a computer program must be carried out.

A single electrical measurement tells us very little. The most that can be extracted from it is the resistivity value of a completely homogeneous ground (a homogeneous half-space) that would produce the same result when investigated in exactly the same way. This quantity is known as the apparent resistivity. Variations in apparent resistivity or its reciprocal, apparent conductivity provide the raw material for interpretation in most electrical surveys.

Where electromagnetic methods are being used to detect very good conductors such as sulphide ores or steel drums, target location is more important than determination of precise electrical parameters. Since it is difficult to separate the effects of target size from target conductivity for small targets, results are sometimes presented in terms of the conductivity – thickness product

Electrical resistivity prospecting method involves the passage of electric current (usually direct current or low frequency alternating current) into the subsurface, through two electrodes (the current electrodes). The potential difference is measured between another pair of electrodes, which may not be within the current electrodes depending on the electrode array in use.

Actual resistivities of subsurface layer are determined from ground apparent resistivity, which are computed from the measurement of current and potential difference between the electrodes pair placed on the surface.

It adopts the use of three fundamental properties of rocks which are:

- The resistivity, or its inverse conductivity; governs the amount of current that pass through the rock when a specified potential difference is applied;
- The electrochemical activity with respect to electrolytes in the ground is the basis for the self-potential and induced-polarization methods;
- The dielectric constant; gives information on the capacity of a rock material to store electric charge and governs in apart the response of rock formation to high-frequency alternating currents introduced into the earth by conductive or inductive means (Dobrin, 1985).

Measured resistivities in earth materials are primarily controlled by movement of charged ions in pore fluids. Although, water itself is a poor conductor of electricity, groundwater generally contains dissolved compounds that greatly enhance its ability to conduct electricity. Hence, porosity and fluid saturation tend to dominate electrical resistivity measurements. In addition to pores, fractures within crystalline rocks can lead to low resistivity if they contain fluids. Other implications include:

- Increase in water decreases earth resistivity
- Increase in salinity decreases earth resistivity
- Increase in porosity of the earth materials decreases resistivity
- Increase in metallic content causes a decrease in the earth resistivity

Rock resistivity can be related to the properties of clay free (clean), saturated aquifer using Archie's law which states that:

$$\rho_r = a\rho_w\Phi^{-m} \qquad 2.8$$

Where ρ_r is the resistivity, a is the coefficient of saturation, ρ_w is the water resistivity, m is the cementation factor, Φ is the fractional porosity.

Ohm's law forms the foundation for electrical resistivity theory. The law governs the development of equation, which expressed the potential about a single point source of currents. For a conductor of length L and surface area A, allowing the passage of electric current, I;

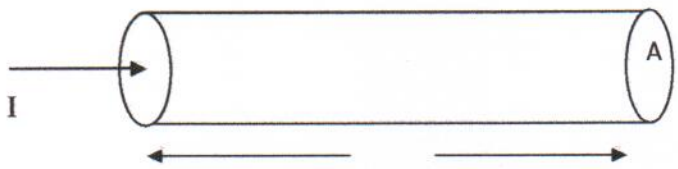


Fig. 2.5 - Current flow within a Cylindrical Model

For a conductor of length L and surface area A, allowing the passage of electric current, I;

From Ohm's law, V = IR 2.9

Where V is the voltage, and R the resistance.

But R = $\rho L/A$ 2.10

Equation (2) becomes V = I$\rho L/A$ 2.11

Recall j=I/A, such that equation (4) can be written as

$$V = j\rho L \quad 2.12$$

Where j = Current density measured in $Vm^{-1}Sm^{-1}$

σ = Conductivity; $1/\rho$

E = Electric field

The electric fields at a point electrode on the earth surface is then given as thus; since the earth is spherical, taking its half as though an hemispherical surface.

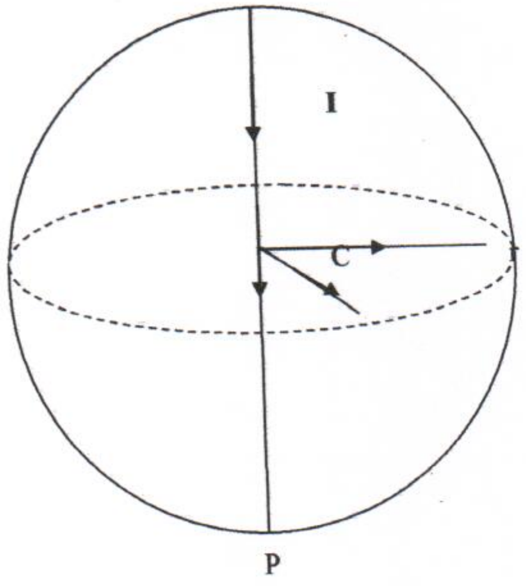


Fig.2.6 - Flow from a Point Source of a Current in a Homogenous (Spherical Surface)

Where I is current

r is the radius of the earth

c is the centre of the earth

p is the point to measure the potential

Area of sphere, $A = 4\pi r^2$ 2.13

Hemisphere, $A/2 = 2\pi r^2$ 2.14

Since, $j = \sigma E$ 2.15

Also, J = I/A 2.16

$$\sigma = \frac{1}{\rho}$$ 2.17

And $E = \frac{-dV}{dL} = -\nabla V$ 2.18

$$\frac{1}{2\pi r^2} = \frac{1}{\rho}(-\nabla V)$$ 2.19

$$I/\rho = (-\nabla V) * (2\pi r^2)$$ 2.20

But; $-\nabla V = \frac{-dV}{dr}$ 2.21

Where the r is the length, 1, of the radius.

Therefore; $\frac{dV}{dr} = \frac{Ip}{2\pi r^2}$ 2.22

$$dV = \frac{Ip}{2\pi r^2} * dr$$ 2.23

Integrating both sides; $\int dV = \int \frac{I\rho}{2\pi r^2} * dr$ 2.24

$$V = \frac{Ip}{2\pi r^2} * r$$ 2.25

$$V = \frac{Ip}{2\pi r^2}$$ 2.26

Where V is the potential difference of a point on earth surface due to source current. (Maillet, 1947).

2.7.2 AREAS OF APPLICATION

Vertical Electrical Sounding is widely used in

- Engineering site investigation
- Determination of depth to bedrock;
- Structural mapping
- Integrity of the bedrock
- Mineral exploration.

Horizontal Profiling is widely used in

- Determining the variation in the depth to bedrocks.
- Mapping of steeply dipping linear structure such as faults, cavities, shear zones, etc.

However, success in the application of electrical prospecting method lies on the fact that any variation in the subsurface conductor changes the mode of current flow within the earth and this affects the distribution of electrical potential in the earth's subsurface.

2.7.3 LIMITATIONS OF ELECTRICAL RESISTIVITY METHOD

The electrical resistivity method is mostly used in site investigation where the geology is simple and subsurface layers are horizontal.

The practical difficulty of dragging the electrodes and wire in the field is also a disadvantage of the method. Hence, this method is particularly not suitable for oil prospecting (Telford et. al 1976). Other limitation encountered in this method arises from field operational problems and ambiguities in interpretation procedures as stated below.

i. **Poor electrical contact** particularly at the current electrode positions. This could be due to a very dry ground surface. Creating saline water medium around the electrodes can solve this problem.

ii. **Lateral Inhomogeneity** in the upper layer of the earth can degrade the quality of resistivity sounding curves (Zohdy, 1980). This sensitivity to minor variations in near surface conduction can be described in electronic parlance as low signal to noise ratio or high noise ration or high noise level (Telford et al 1976).

iii. **Suppression**: A layer whose resistivity is intermediate between the resistivities of the enclosing layers may be suppressed. That is, it may not have any significant influence on the sounding curve unless it is of an appreciable thickness.

iv. **Equivalence**: This is a phenomenon whereby a multilayer resistivity curve can correspond to a great number of different geoelectric models. Ambiguity created by suppression or equivalence can be resolved if additional information in terms of borehole lithological logs is available (Van Overmeeran, 1981).

CHAPTER THREE

MATERIALS AND METHODS OF STUDY

3.1 INSTRUMENTATION

The instruments used in carrying out the integrated geophysical survey include:

- OHMEGA (Ω) resistivity meter
- Hammer
- Electrodes
- Measuring tape
- Meter rule
- Cables
- Calculator
- Recording sheets
- Crocodile clips
- Connecting twines and cables
- Cutlass
- GPS
- Compass Clinometer
- Abem Wadi VLF-EM equipment.

- OHMEGA (Ω) resistivity meter: The OHMEGA (Ω) resistivity meter is a high quality earth resistance meter capable of accurate measurement over a wide range of conditions. It has a maximum power output of 18 watts, manual selection of current in steps up to 200 mA, a choice of sample time/signal length averaged and three frequency settings. The receiver incorporates automatic gain steps, which provide a range of measurements from 0.001Ω to 360kΩ. The instrument is powered by a large capacity rechargeable battery providing several days of use without recharging in average terrain conditions. The OHMEGA Ω is housed in an impact-resistant steel case and a bag pack. See fig.3.1a

- Hammer: A hand tool consisting of a solid, heavy head metal which is used in driving electrodes into the ground. See fig.3.1c.

- Electrodes: These are metal rods which are about 0.5m long with a very sharp pointed end for easy penetration into the earth with the other end flat and blunt. It is used in passing direct current into the ground. The electrodes are placed strategically during geophysical survey, which also depend on electrode configuration used. They are four in number, two for current and the other two for potential. See fig.3.1f.

- Measuring tape: It is used for measuring distance e.g. (inter-electrode separation) in the field and also for the determination of the static water level of hand dug wells within the study area.
- Meter Rule: A round narrow band of woven/plastic fabric, which is used for linear measurement. Each meter rule is about 100m long. See fig.3.1e.
- Cables: These are used for connecting the electrodes to the resistivity meter. Usually four cables are used, two for current and the other two for potential. The cables are reeled around a wheel either made of steel or plastic. See fig.3.1b.
- Calculator: used to calculate and compute data on the field.
- Recoding sheets: This is the sheet on which data taken on the field are recorded and calculated in.
- Crocodile clips: These are metal instruments used in connecting the cables to the electrodes firmly.
- Connecting twines and cable: Cables fitted with crocodile dips at both ends were used to connect the current source to the electrodes.
- Cutlass: This is used to clear bushes and weeds that can hinder site surveys.
- Wooden pegs: This is used to mark the VES points sounded. See fig.3.1d.
- GPS: Also known as the global positioning system. It is used to get the latitudes, longitudes and elevations of the areas we are working on. The latitudes, longitudes and elevations will help us in creating other maps of the area like the contour maps etc. if the need arises, and it also helps us when we are trying to build our geo-electric sections.
- Compass Clinometer: This helps us to locate ourselves on maps, and it majorly helps us to take the Strikes and Dips of major outcrops in our study areas. See fig.3.1.g

- ABEM WADI VLF-EM: This is a device mainly used to detect water (up to100m). The ABEM WADI VLF-EM utilizes the magnetic component of the electromagnetic field generated by military radio transmitters that uses the VLF (Very Low Frequency) band (15 to 30 KHz) commonly used for low distance communication. The ABEM WADI VLF-EM measures this field strength and phase displacement around a fracture zone or any conductive body in the rocks (Telford et al., 1990). It detects the ratio (in percent) between the vertical and the horizontal field components. It has found wide application in geophysical survey. It is also used for subsurface explorations as well as geologic mapping. See fig.3.1h.

Fig. 3. 1a-Ohmega Resistivity Meter

Fig. 3. 1b-Cable reels

Fig. 3. 1c- Geological hammer

Fig. 3. 1d-Wooden peg

Fig. 3. 1e.-Meter Rule

Fig. 3. 1f -Electrodes

Conclusively, VES 10 has the highest groundwater potential beneath traverse three (3), followed by VES 9 and 8 in that order.

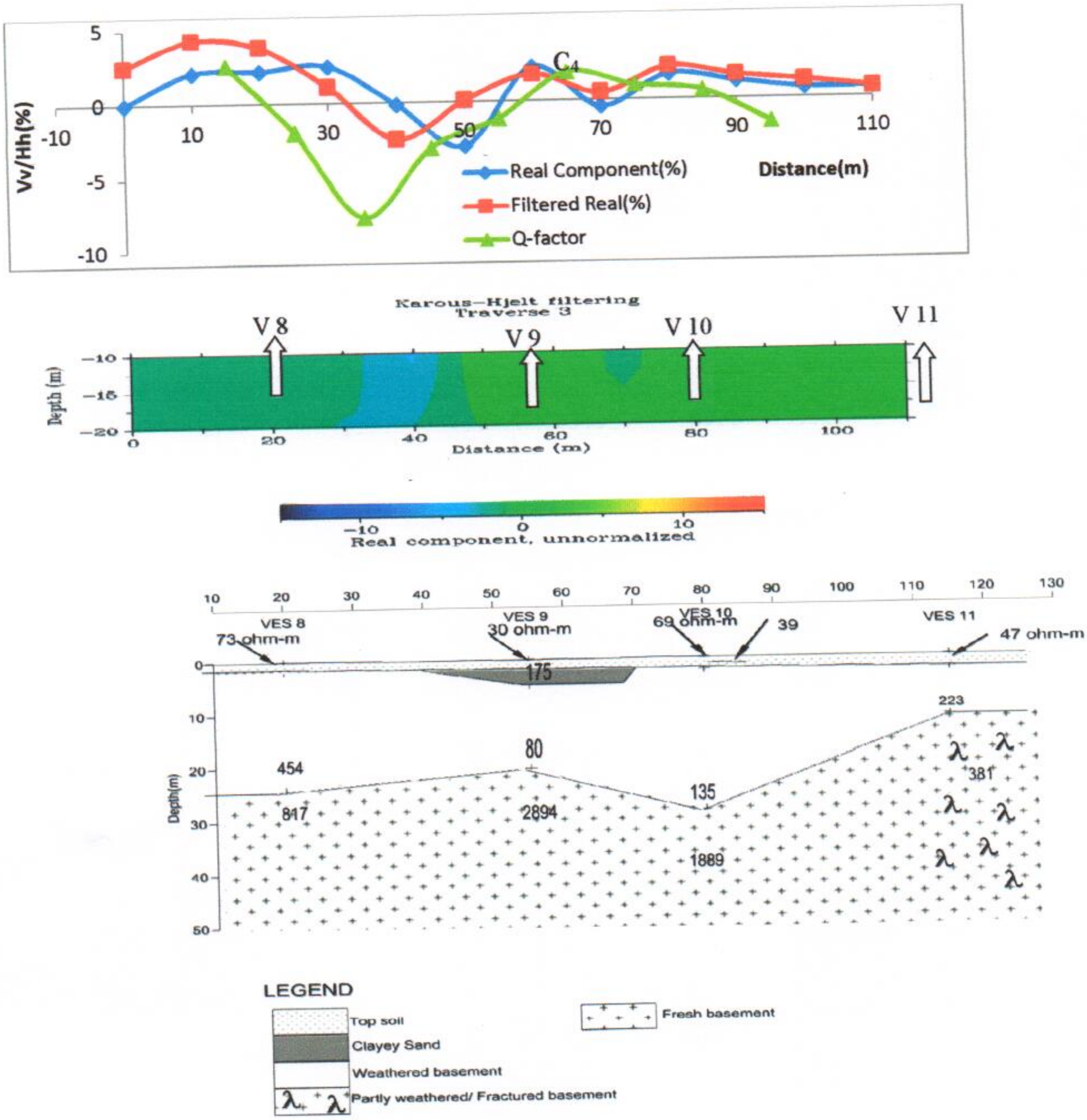


Fig.4.1c- - EM Profiles, 2D-EM model and the Geoelectric sections along the traverse 3

4.2.4 TRAVERSE FOUR (4)

Fig.4.1d shows VLF-EM profile and 2D-EM model with the corresponding geoelectric section beneath VES 12, 13, 14 and 15.

The EM response of the raw real, filtered real and the Q-factor ranges from - 30 to +18, -24 to + 12 and –37 to + 48 respectively.

From the VLF-EM profiles, the conductive zones fall between 70 and 80m. The profile also shows a moderately broad anomaly curve (between 15 m and 90 m) which is an indication of a shallow basement. It has positive peak amplitude of +48. Between 90 m and 140 m is a narrow anomaly curve (negative peak amplitude of-18) which indicates fairly thick overburden beneath it. The maximum negative peak of the filtered real and the real component on the profile also indicate a shallow overburden (I.e. shallow basement) Ariyo *et al.*, 2009.

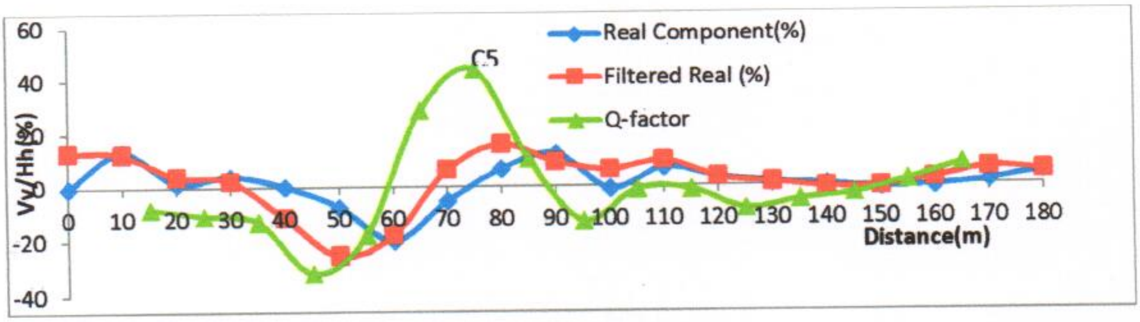
The KHFILT section or the 2D EM model shows a dipping, very conductive zone between 66 m and 95 m from a depth of 10m to 30 m, and fairly conductive zones between 120m and 143m at a depth of about 15 m to 30 m.

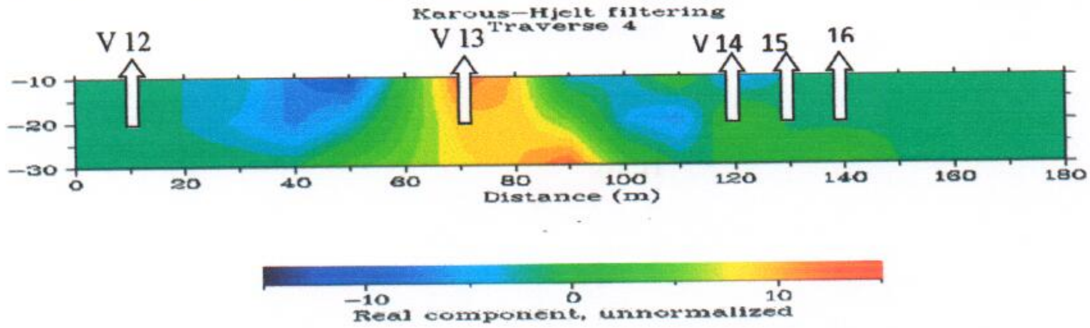
The Vertical Electrical Sounding (VES) technique allow the delineation of four (4) major geo-electric layers, namely: the Topsoil, weathered layer, partly weathered/fractured layer and the fresh bedrock. The curve types interpreted include the A, A, H, K and KH curves.

The top soil has resistivity values ranging from 67 to 125 ohm-m with thickness of 0.9 to 2m. The weathered layer has resistivities ranging from 207 to 767 ohm-m, with thickness ranging from 1.3 to infinity. The partly weathered/fractured layer has a resistivity of 560 ohm-m and an unknown thickness. The fresh bedrock has resistivities ranging from 809 to 1150 ohm-m. Other layers include Laterite (resistivity values of 622 to 656 ohm-m and thickness of 4.6 to 7.9m).

The geo-electric section beneath traverse four (4) shows the bedrock relief with a sign of depression. Beneath VES 13, the basement is very shallow and close to the surface because of its thin overburden. The overburden thickness increases towards the West (W). The dipping, very conductive zone on the 2D EM model may probably account for the depression and thick overburden between 90 m and 140 m, as seen on the geo electric section. See figure 4.1d. VES 16 is a partly weathered/fractured basement, and this could have been a good point for groundwater prospect had it been the thickness is known.

Therefore, VES 15 is the thickest weathered layer overlain with clay and Laterite, but with an unknown thickness. It could be said to have the highest groundwater potential beneath this traverse.





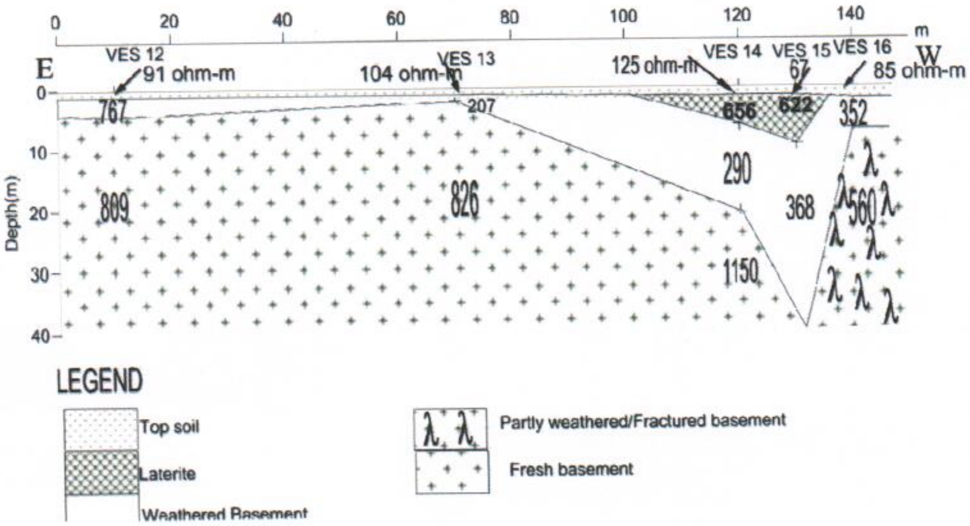


Fig.4.1d- EM Profiles, 2D-EM model and the Geoelectric sections along the traverse 4

4.2.5 TRAVERSE FIVE (5)

Fig.4.1e shows VLF-EM profile and 2D-EM model with the corresponding geoelectric section beneath VES 17, 18, 19 and 20.

The EM response of the raw real, filtered real and the Q-factor ranges from -36 to +12, -30 to+14 and -30 to + 37 respectively.

From the VLF-EM profiles, the conductive zone falls on 65 m. The profile also shows a moderately broad anomalous curve (between 25 m and 75 m) that indicates a shallow basement. It has positive peak amplitude of +37. The negative signals of the filtered real and the real component between 30 m and 60 m, 120 m and 145 m , and the very sharp rising positive peak amplitude of the Q-factor at 65 m is an indication of a very shallow overburden.

The KHFILT section or the 2D EM model shows slightly dipping, very conductive zones between 54m and 77m occurring close to the surface at 10m to a depth of 20 m, and fairly conductive zones between 120m and 150m also from a depth of 10m to 20 m.

The Vertical Electrical Sounding (VES) technique allow the delineation of four (4) major geo-electric layers, namely: the Topsoil, weathered layer, partly weathered/fractured layer and the fresh bedrock. The curve types interpreted include the A, A, A and A curves. This traverse is dominated majorly by two (2) layers.

The top soil and the weathered layer have resistivity values ranging from 40 to 423 ohm-m with thickness of 1.5 to 13.3m. The partly weathered/fractured layer have resistivity values between 471 to 673 ohm-m; their thickness unknown. The fresh bedrock has a resistivity of 952 ohm-m.

The geo-electric section shows that there are shallow overburdens beneath VES 17, 18 and VES 20, as well as fairly thick overburden beneath VES 19 with weathered layer thickness of 13.3m, and overlain by sandy clay which is 2.2m thick. The geo-electric section beneath the traverse also shows sign of depression towards VES 19.

The weathered/ partly fractured basement seen on the geoelectric section beneath could be indicative of the conductive zones shown by the VLF-EM profile and the KHFILT section. The slightly dipping, very conductive zone shown by the 2D EM model may also account for the depression beneath VES 19. There is also an existing functional borehole at about 65 m as shown by the 2D EM model beneath this traverse.

Fractured basement is known and believed to have a high prospect for groundwater development. Therefore, VES 17, 18 and 20 could have been good points for groundwater prospects beneath this traverse, but their thicknesses are unknown.

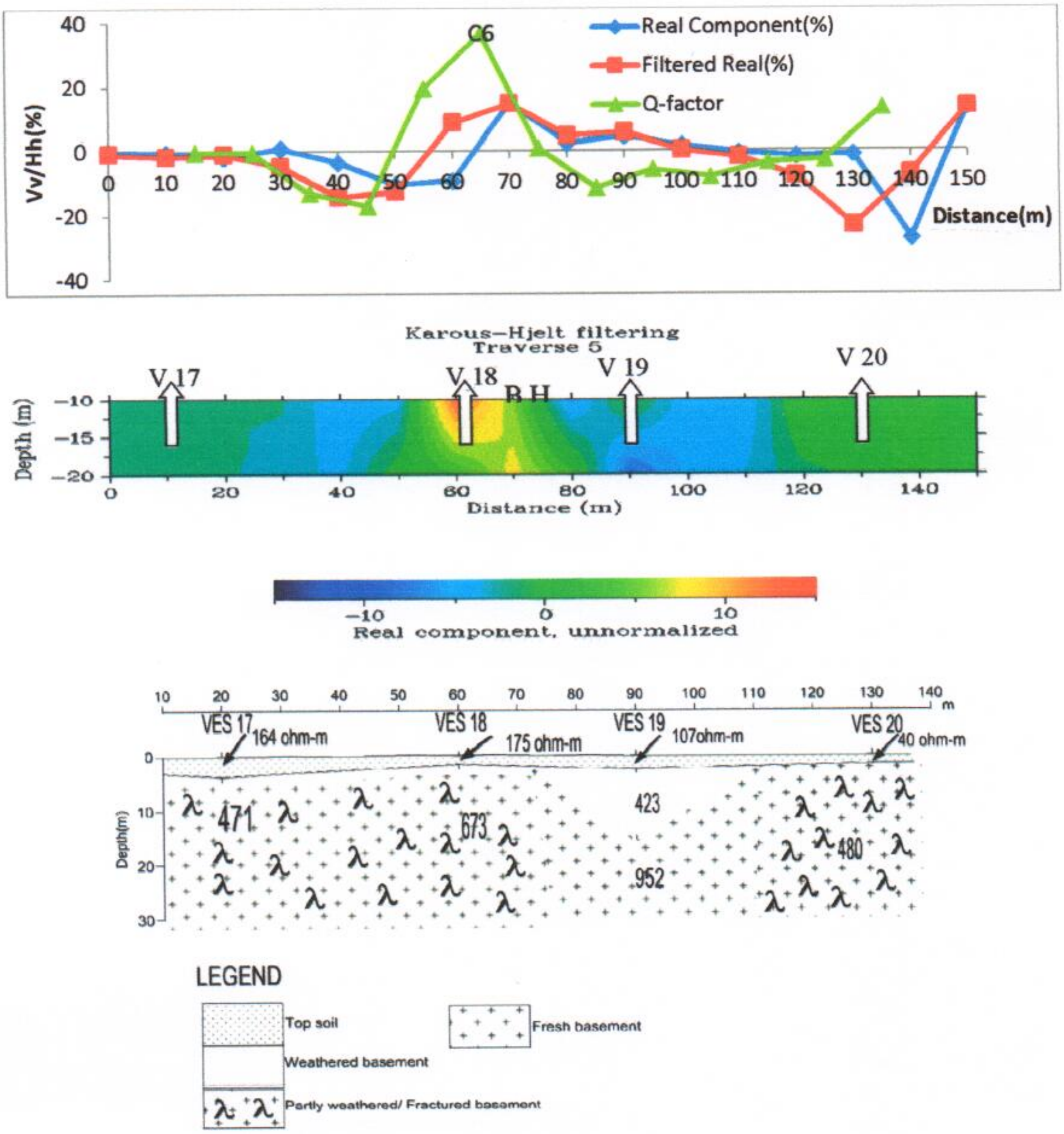


Fig.4.1e- - EM Profiles, 2D-EM model and the Geoelectric sections along the traverse 5

Table 4.1 Summary of Geo-electric Parameters

	No of Layers	Thickness(m) $h1/h2/h_3..../h_n$	Resistivity (ohm-m)	Lithological layers	Curve Types
1	3	1.9/2.2	113/498/856	Top soil/weathered basement/ Fresh basement	A
2	3	2.1/8.5	73/1901 /438	Top soil/weathered basement /partly weathered/fractured basement	A
3	5	1.3/0.8/3.7/ 27.3	28/111/386/106/ 5432	Top soil/Clayey sand/Laterite/Weathered/Fractured basement/ fresh basement	AKH
4	3	1.7/4.4	96/329/775	Top soil/ weathered basement/ partly weathered/fractured basement	A
5	4	2/2.3/38.7	64/155/237/2010	Top soil/Sandy Clay/weathered basement/ fresh basement	AA
6	5	0.7/1.1/2.5/6.8	52/30/379/22/2752	Top soil/ Clay/Laterite/Weathered basement/ fresh basement	HKH
7	5	1.3/1.3/3.4/11	46/124/336/88/669 2	Top soil/Clayey Sand/Laterite/weathered basement/ fresh basement	AKH
8	3	1.6/24.1	73/454/817	Top soil/ weathered basement/ fresh basement	A
9	4	1.8/2.9/15.8	30/175/80/2894	Top soil/ sand/ weathered basement/ fresh basement	KH
10	4	0.3/1.9/26.4	69/39/135/1889	Top soil/ Clay/Weathered basement fresh basement	HA
11	3	2.3/9.1	47/223/381	Top soil/Weathered basement/ Partly weathered/ fractured basement	A
12	3	1.2/3.5	91/72/809	Top soil/weathered basement/ Fresh basement	H
13	3	0.9/1.3	104/207/826	Top soil/weathered basement/ Fresh basement	A
14	4	1.8/4.6/14.4	125/656/290/1150	Top soil/Laterite/Weathered basement/ Fresh basement	KH
15	3	1.7/7.9	67/622/368	Top soil/ Laterite/Weathered basement	K
16	3	2/5.1	85/352/560	Top soil/ Weathered basement/ partly weathered/Fractured basement	A
17	2	3.7	164/471	Top soil/ Weathered /partly fractured basement	A
18	2	1.5	175/673	Top soil/ Weathered/ partly	A

				Fractured basement	
19	3	2.2/13.3	107/423/952	Top soil/ Weathered basement/Fresh basement	A
20	2	1.7	40/480	Top soil/ Weathered/ Partly Fractured basement	A

4.3 TYPICAL SOUNDING CURVES IN THE STUDY AREA

The result of the vertical electrical sounding technique applied allowed the generation of twenty (20) sounding curves beneath the study area. The VES result also delineated four major Geo-electric layers within the study area. See pages 50, 51, 53, 55, 57 and 59. The interpreted data revealed A-curve type as the dominant curve type in the study area. It has 55% dominance. Other curve types include the KH (10%), HKH (5%), AA (5%), H (5%), K (5%), AKH (10%) and HA (5%).

The implication of having A curve as the dominant curve type in the study area suggests that the basement is generally shallow in the study area. See figures 4.2a, 4.2g and the appendix.

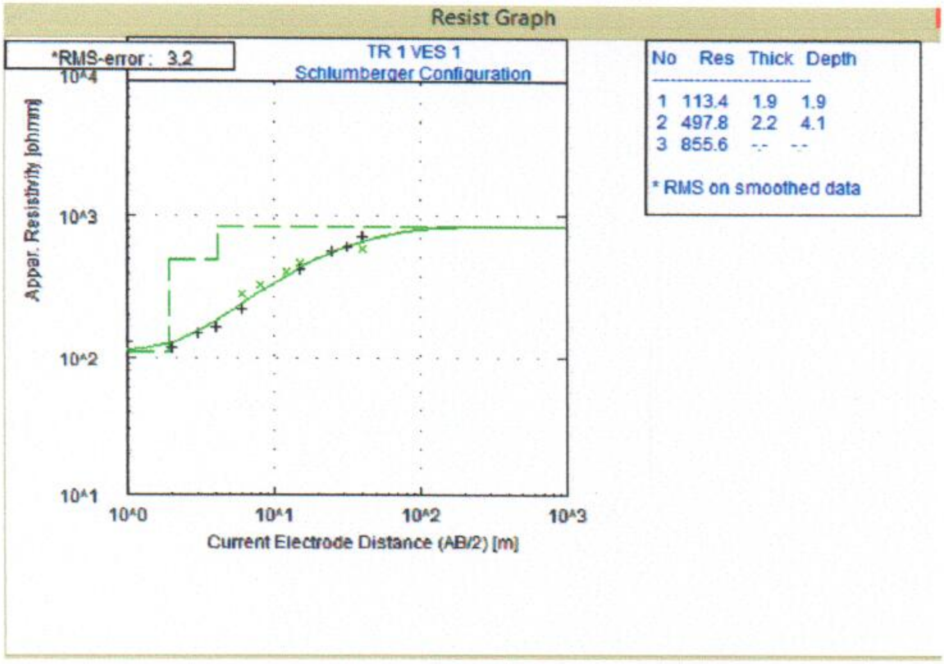


Fig. 4.2a –Typical sounding curve in the study area (A curve)

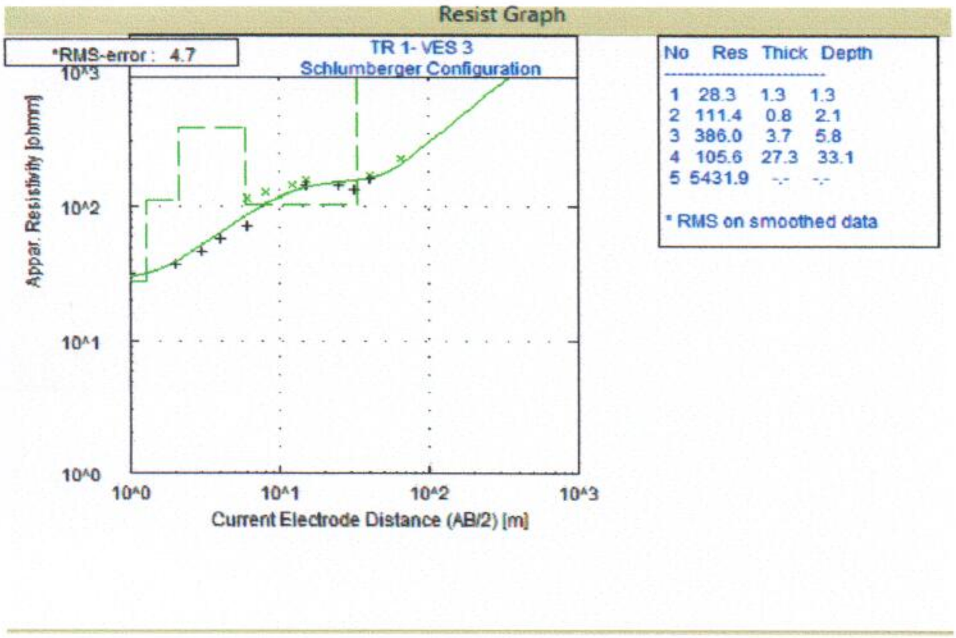


Fig. 4.2b- Typical sounding curve in the study area (AKH curve)

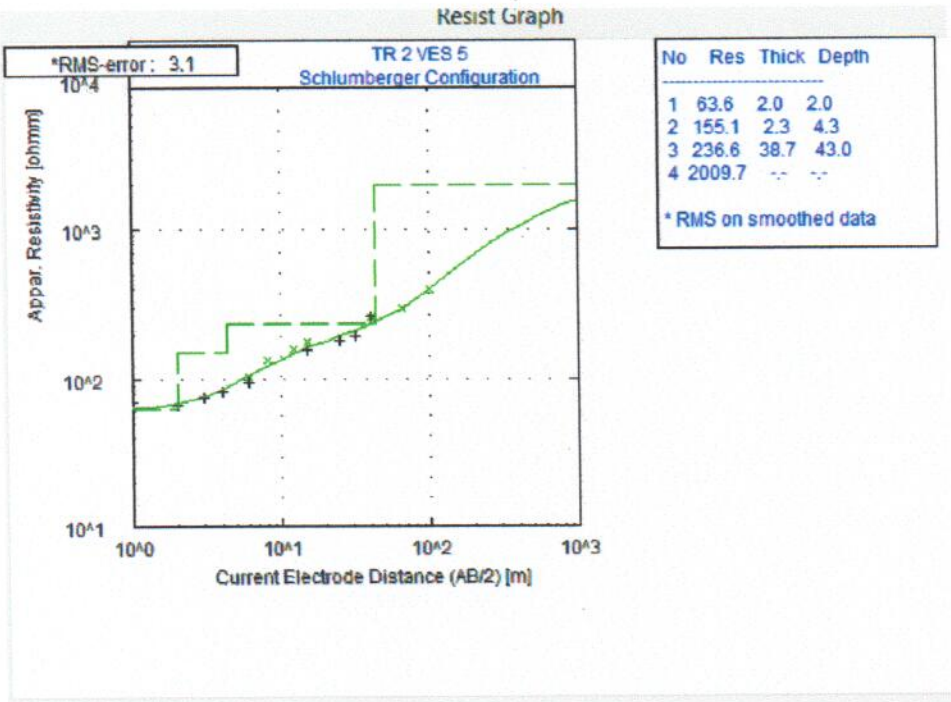


Fig.4.2c- Typical sounding curve in the study area (AA curve)

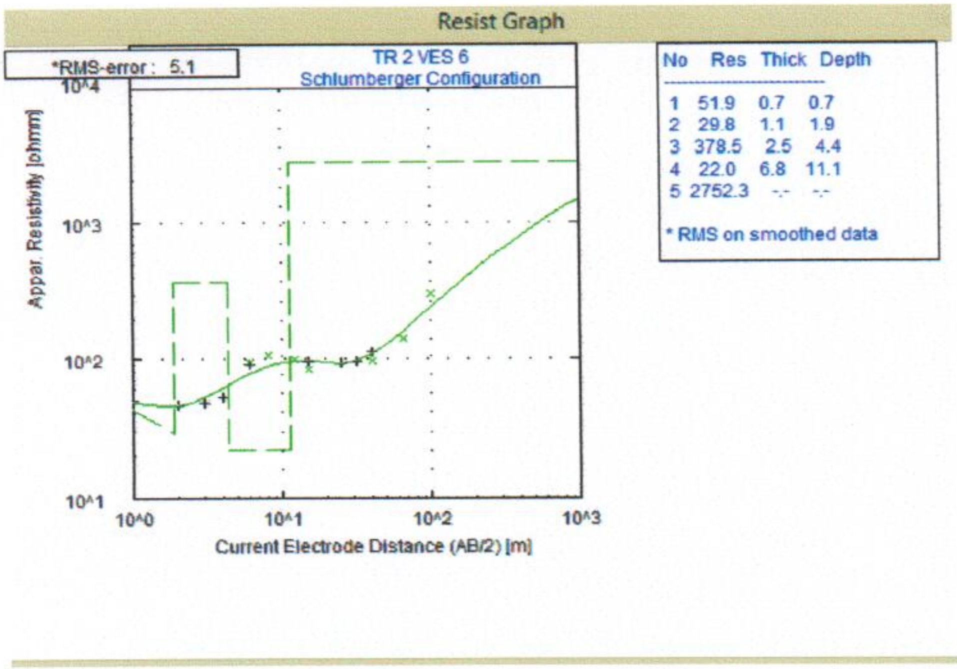


Fig.4.2d- Typical sounding curve in the study area (HKH curve)

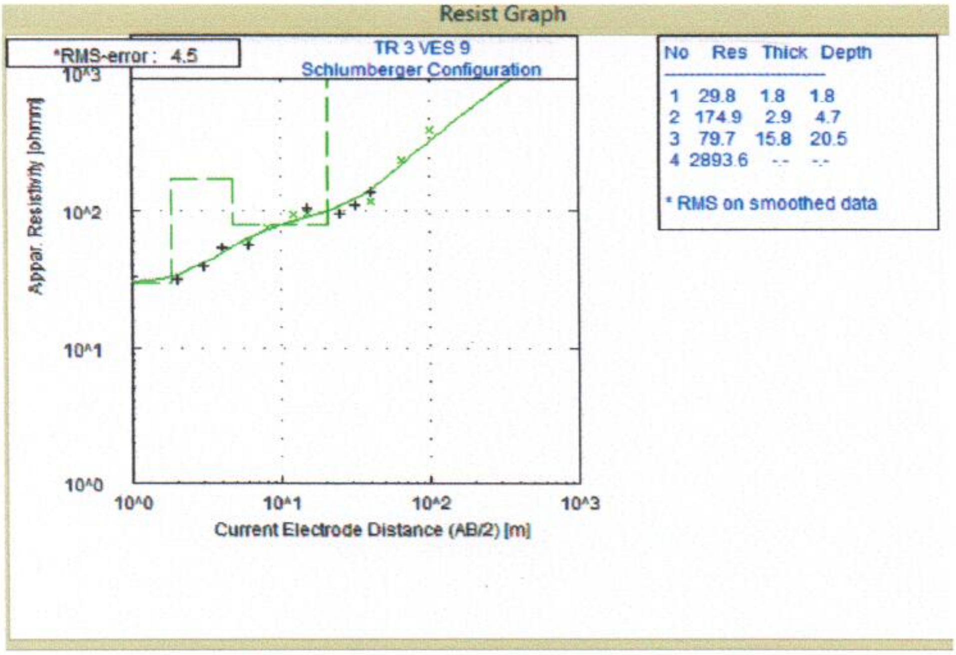


Fig.4.2e- Typical sounding curve in the study area (KH curve).

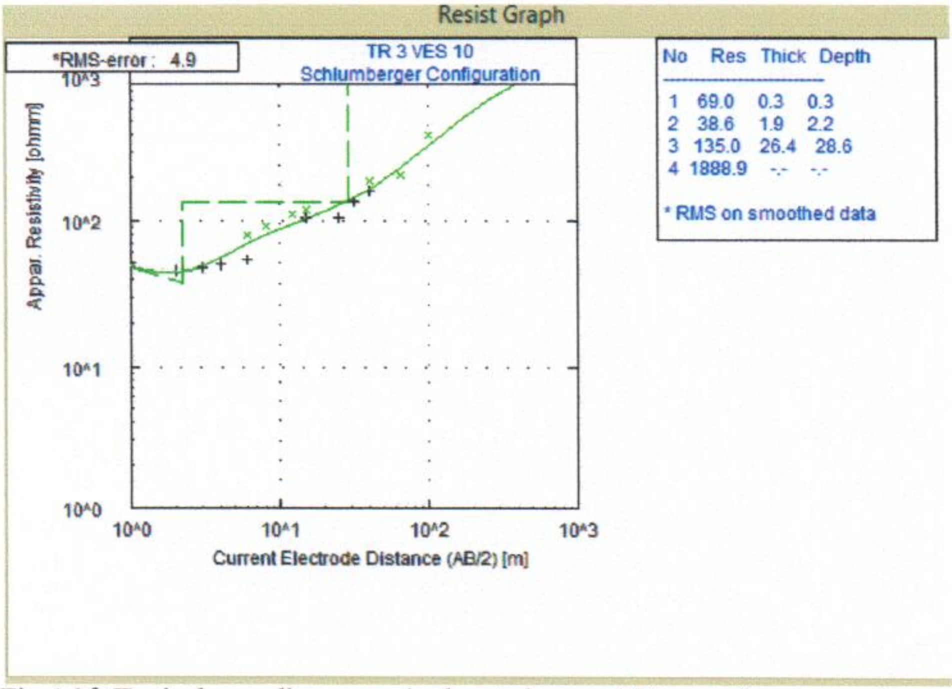


Fig.4.2f- Typical sounding curve in the study area (HA curve)

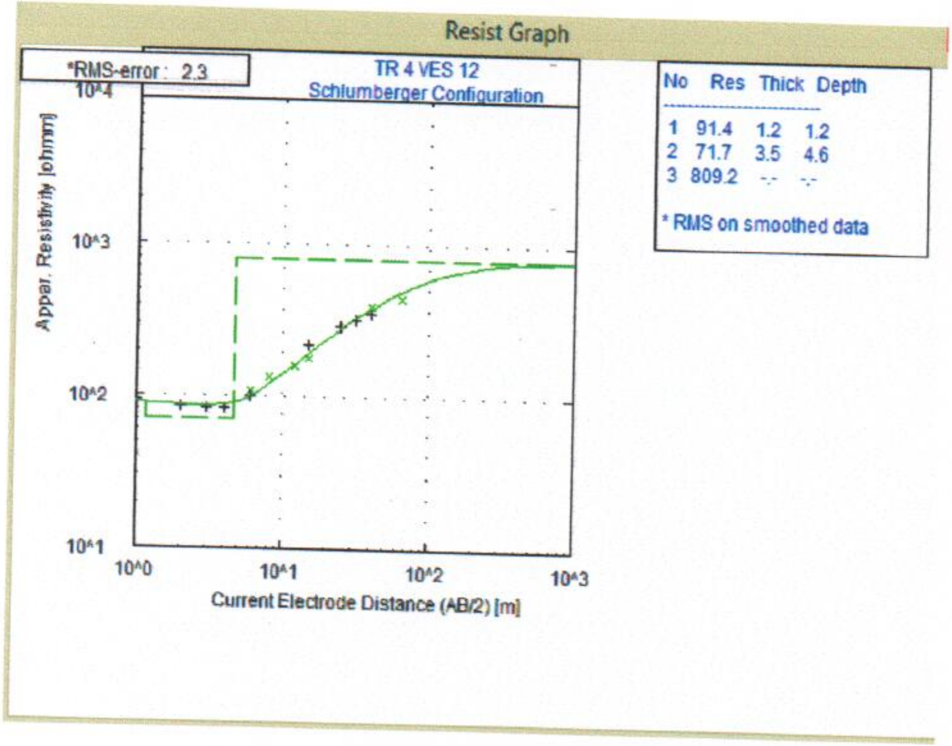


Fig.4.2g- Typical sounding curve in the study area (H curve)

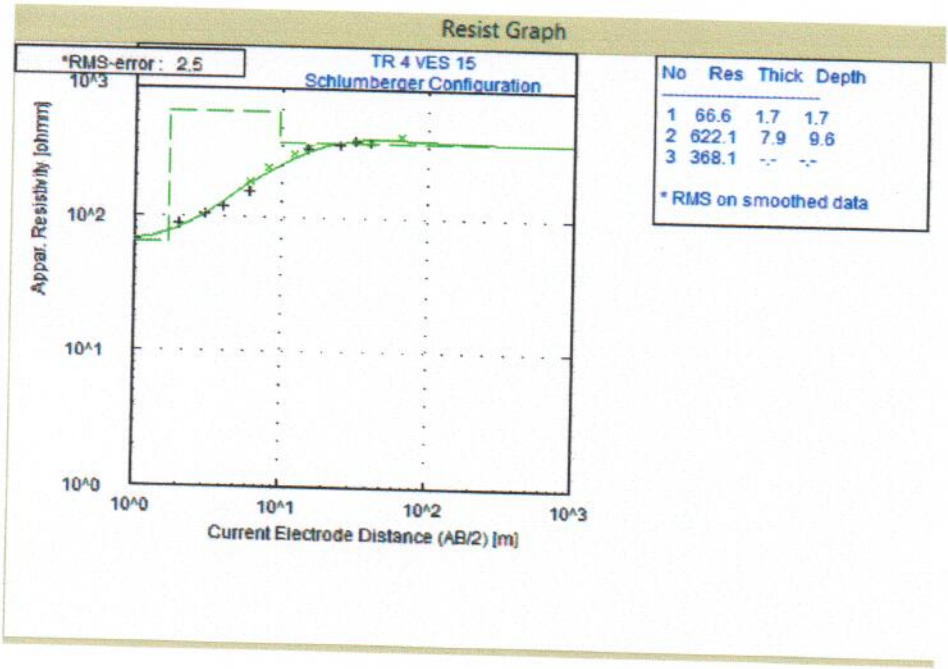


Fig.4.2h- Typical sounding curve in the study area (K curve).

Table 4.2 classification of VES curves

CURVE TYPES	FREQUENCY	PERCENTAGES (%)
A	11	55
H	1	5
K	1	5
AA	1	5
HA	1	5
KH	2	10
AKH	2	10
HKH	1	5

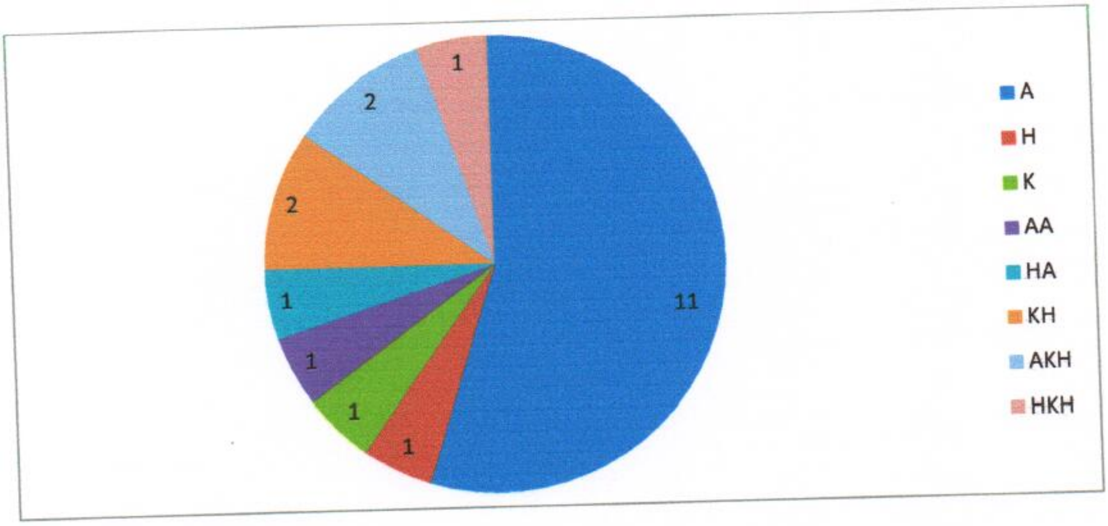


Fig. 4.3 Pie chart of VES curve types in the study area

4.4 GEO-ELECTRIC MAPS

4.4.1 ISORESISTIVITY MAP OF THE WEATHERED LAYER OF THE STUDY AREA

Figure 4.4a shows the Isoresistivity map of the weathered layer. The weathered layer resistivity values range from 22 to 498 ohm-m with thickness values ranging from 1.3 to 38.7m. From these range of resistivities, clay/sandy clay/clayey sand/sand/Lateritic formation were deduced as the possible lithological units making up the weathered layers. The highest resistivity values were identified towards part of the North and North-Eastern flank of the study area (380 to 500 ohm-m). The implication of this is that, the area may probably have medium groundwater potential. Some part of West, North and Southern flanks have moderate resistivities (150 to 340 ohm-m) which are good for groundwater development because of its probable clayey sand/sandy clay/sandy nature. The lowest resistivity values were identified at the North western, south western and southeastern region (20 to 150 ohm -m). It has a low suitability for groundwater development because of its clayey nature. See figure 4.4a

4.4.2 ISOPACH MAP OF THE WEATHERED LAYER OF THE STUDY AREA

Figure 4.4b shows the Isopach map of the weathered layer. The map shows the largest thickness at the Northern flank of the study area with thickness of about 38 m. Parts of North and north western flank has thicker weathered layer (up to 26m thick).The lowest thickness values were identified towards the north eastern, south western and south eastern flank of the study area from 2 to 6m.

The composite thickness of the aquifer units varies from 0m to 38 m across the study area. This range of thickness enabled the characterization of the area into hydrogeologic zones. Areas with thick units (2-12 m) are thought to have low groundwater prospects, while zones with thicker aquifer units (12-24 m) are believed to have medium groundwater prospects and areas with the thickest aquifer units (24-38 m) are believed to have a high groundwater prospects. See figure 4.4b. The aquifer units with the thickest hydrogeologic zones are considered suitable for groundwater development. Omosuyi *et al*., 2008.

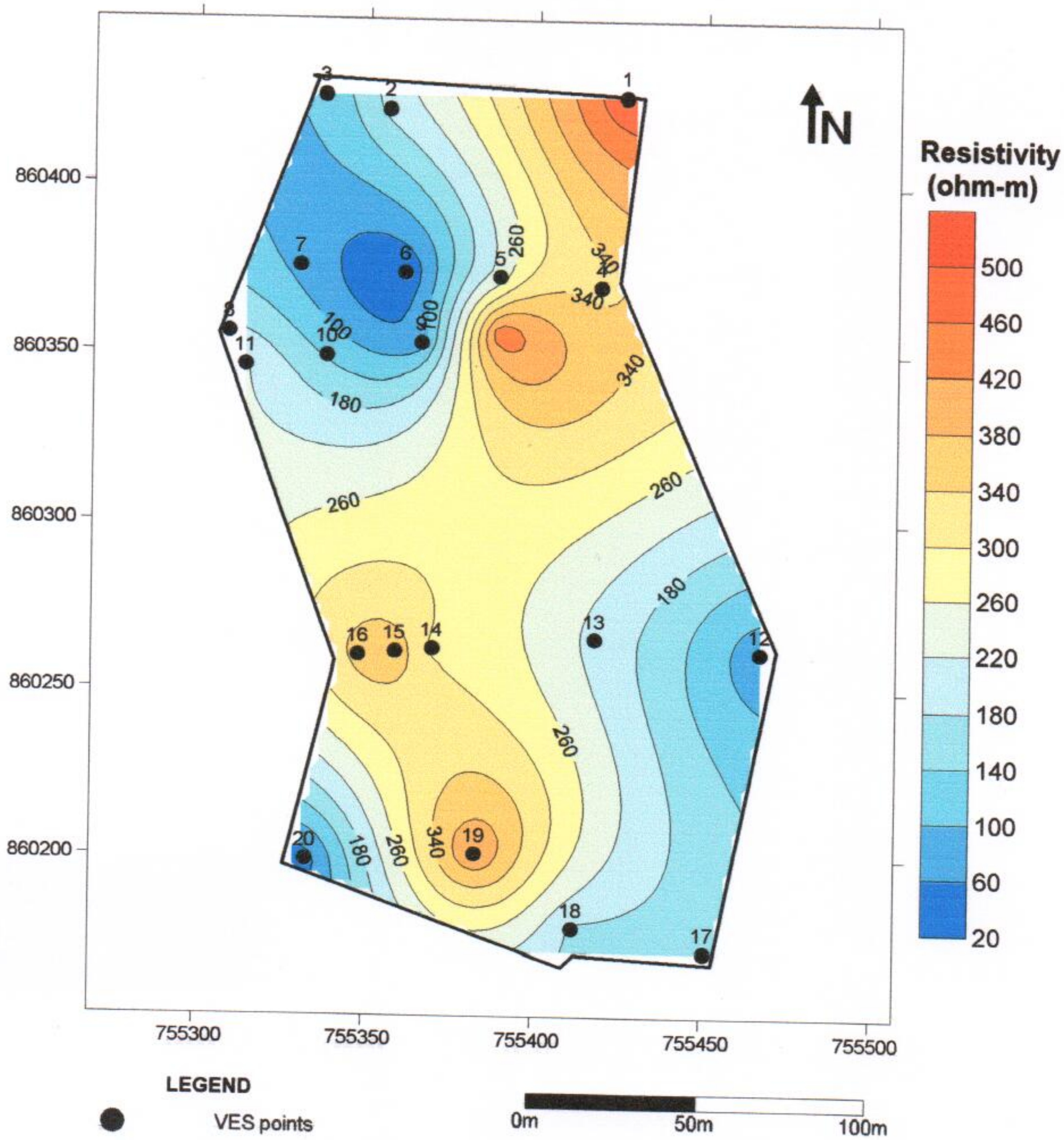


Fig. 4.4.a- Isoresistivity Map of the weathered layer.

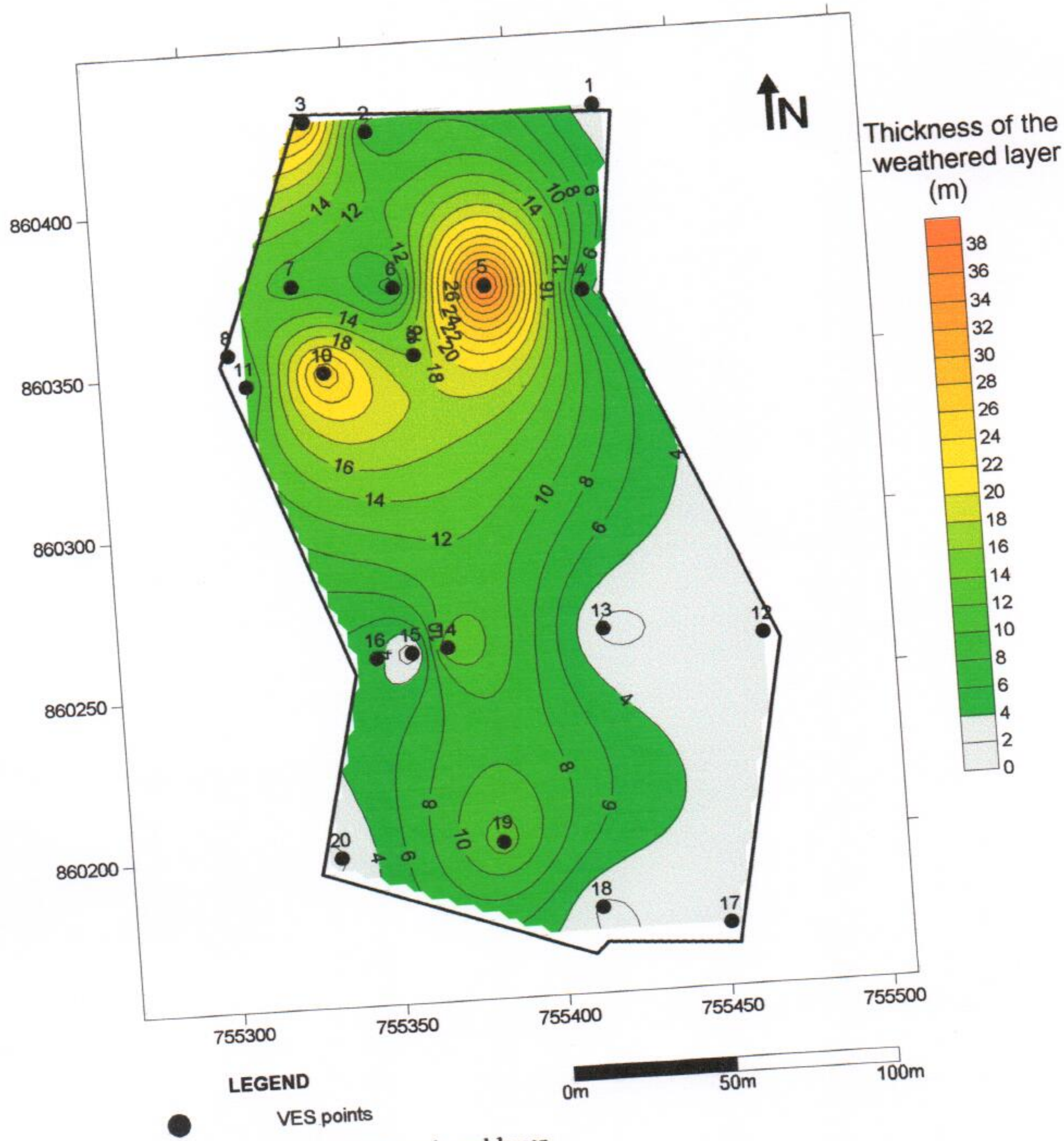


Fig. 4.4b- Isopach Map of the weathered layer

4.4.3 ISOPACH MAP OF THE OVERBURDEN IN THE STUDY AREA

Figure 4.4c shows the overburden thickness map of the study area. The overburden consists of two formations, the topsoil and the weathered layer. The Northern and the North western parts of the study area have the highest overburden thickness value of about 42 m. The lowest thickness values were identified towards the eastern, northeastern, south western and southern flank of the study area.

The overburden thickness varies from 2 m to 42 m across the study area. This range of thickness enabled the characterization of the area into hydrogeologic zones. Areas with thin overburden (2-14 m) are thought to have low groundwater prospects, while zones with moderately thick overburden (14-26 m) are believed to have medium groundwater prospects and areas with thick overburden (26-42 m) denoted as T on the Isopach map of the overburden are believed to have high groundwater prospects. The overburdens with the thickest hydrogeologic zones are considered suitable for groundwater development.

4.4.4 BEDROCK RELIEF MAP OF THE STUDY AREA

Figure 4.4d shows the bedrock relief map of the study area. The relief at the northwestern, northern and part of the southern flank is very low (480-496 m) compared to the part of the southern and northern flanks that have moderately high relief (496-510 m). The eastern, southern part, southwestern and part of the northern flank has a high relief ranging from 510-522 m.

The implication of this difference in relief is that, areas with a low relief has depression and could serve as a high prospect for groundwater development because of its depression (See figure 4.4d). While areas with moderately high relief have a low prospect for groundwater development compared to those areas with high reliefs that are very poor in aiding groundwater development because of its ridge nature.

The areas of thick overburden thickness (denoted as T) on the Isopach map of the overburden in the study area (Figure 4.4c) also show great sign of depression on the bedrock relief map denoted as D (Figure 4.4d), as it is considered one of the features that act as a trap for groundwater accumulation.

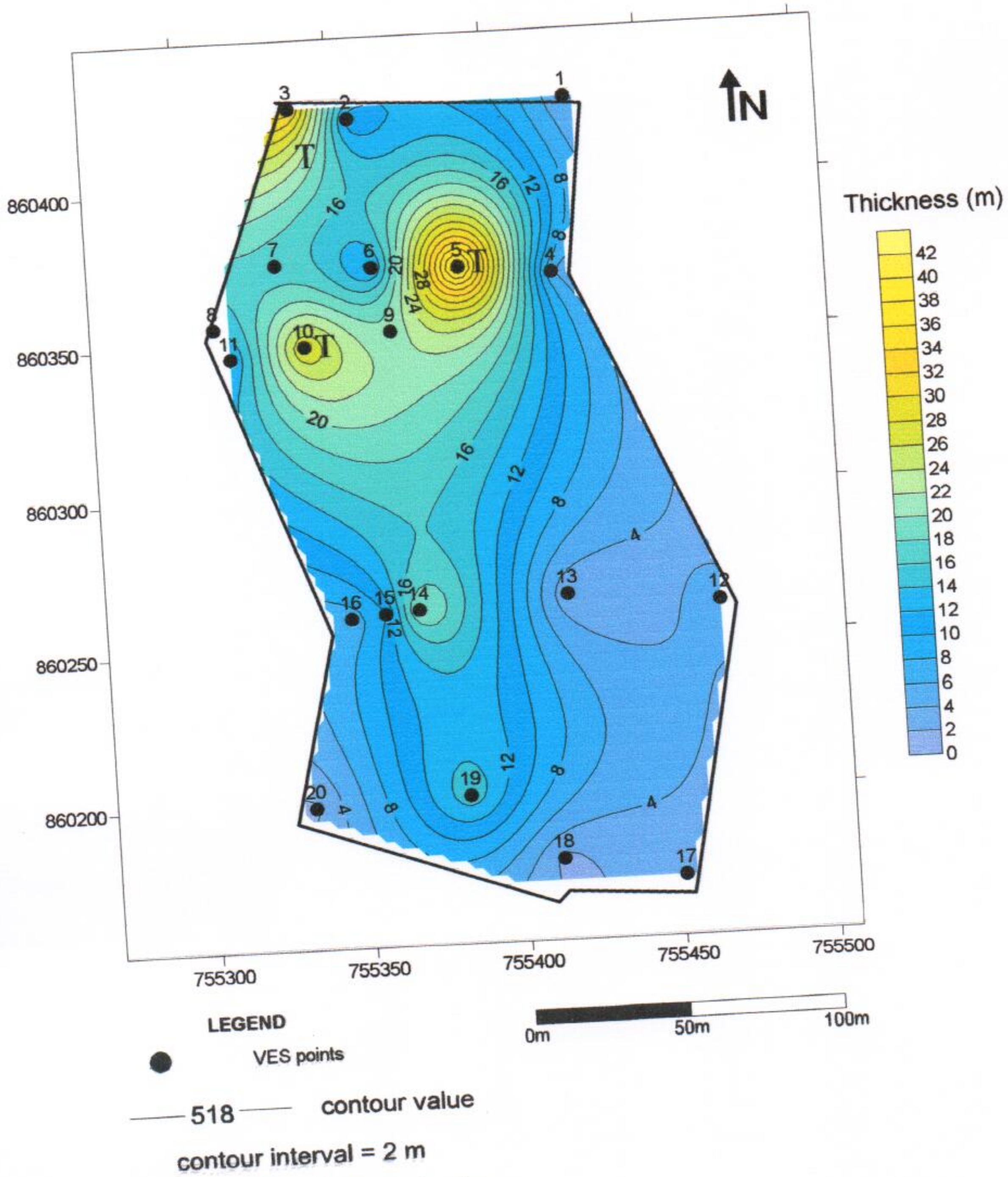


Fig. 4.4c- Isopach Map of the overburden

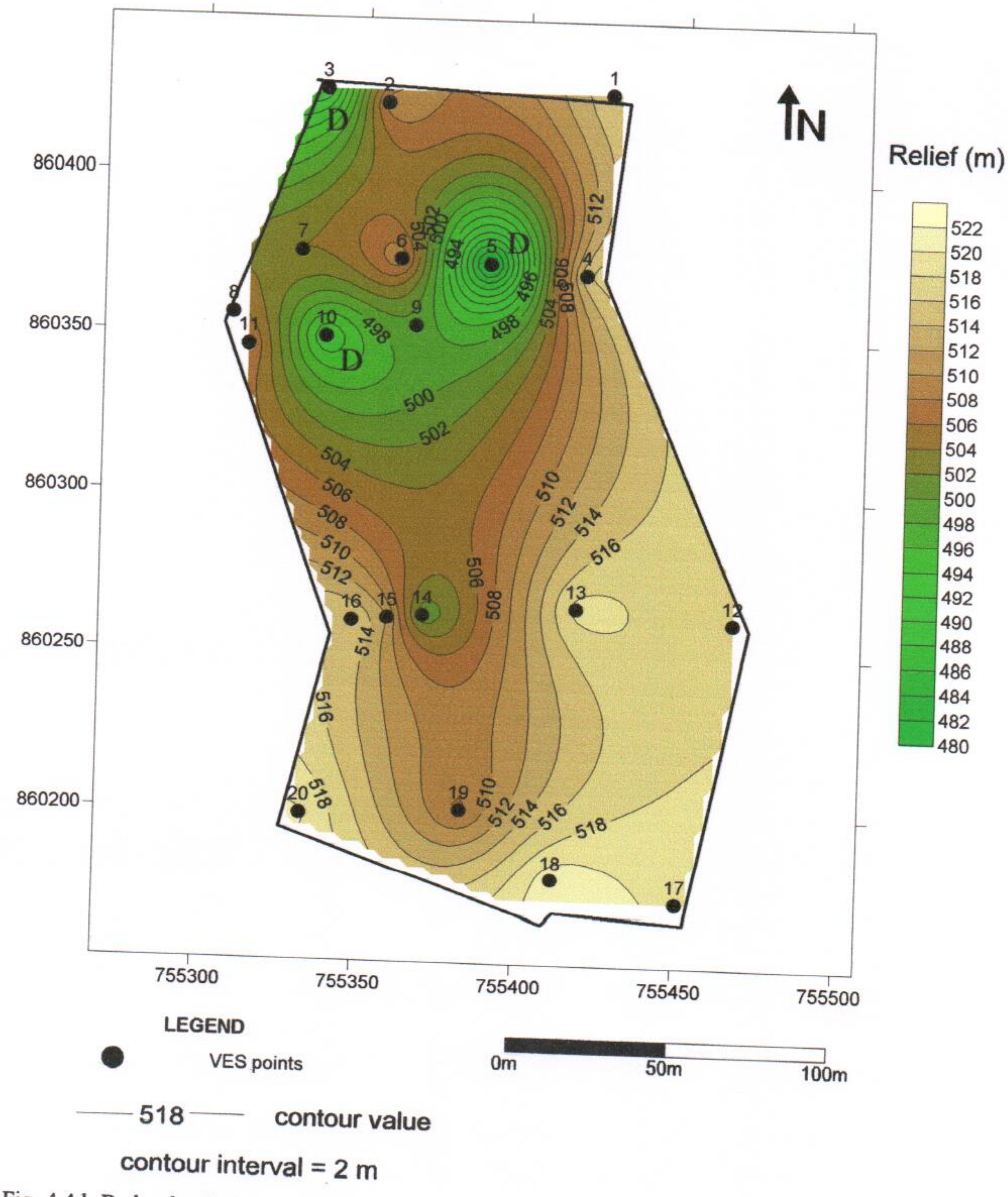


Fig. 4.4d- Bedrock relief Map of the study area.

4.5 GROUNDWATER POTENTIAL EVALUATION

To evaluate the groundwater potential of a place, the following parameters are considered.

- Overburden thickness
- Resistivity values (preferably low to moderately high layer resistivity values)
- Weathered layer thickness
- Bedrock relief and depression.

Therefore, VES 3, 5, 10 and 15, are thereby classified as good potential zones for groundwater development because of their bedrock relief and depression, thickness and resistivity values. VES 6, 7, 8 and 9 have low groundwater potentials, while VES 1, 2, 12, 13, 14, and 20 have poor groundwater potentials, though some of the VES points were not chosen on conductive zone parameters. VES 4, 11, 16, 17, 18 and 19 are partly weathered/ fractured basement and would have been good points for groundwater prospects if their thicknesses were known.

Generally, the study area can be classified from poor to medium groundwater potential zones.

Some parts of the Northern and the Northwest flanks of Federal University Oye-Ekiti, Phase two (2) have moderate (medium) groundwater potential, while the North south, parts of the West and North have low groundwater potential. But the Eastern, Southeastern and the Southwestern flanks have poor groundwater potentials, as well as little part of the Northern axis. See fig. 4.5 below.

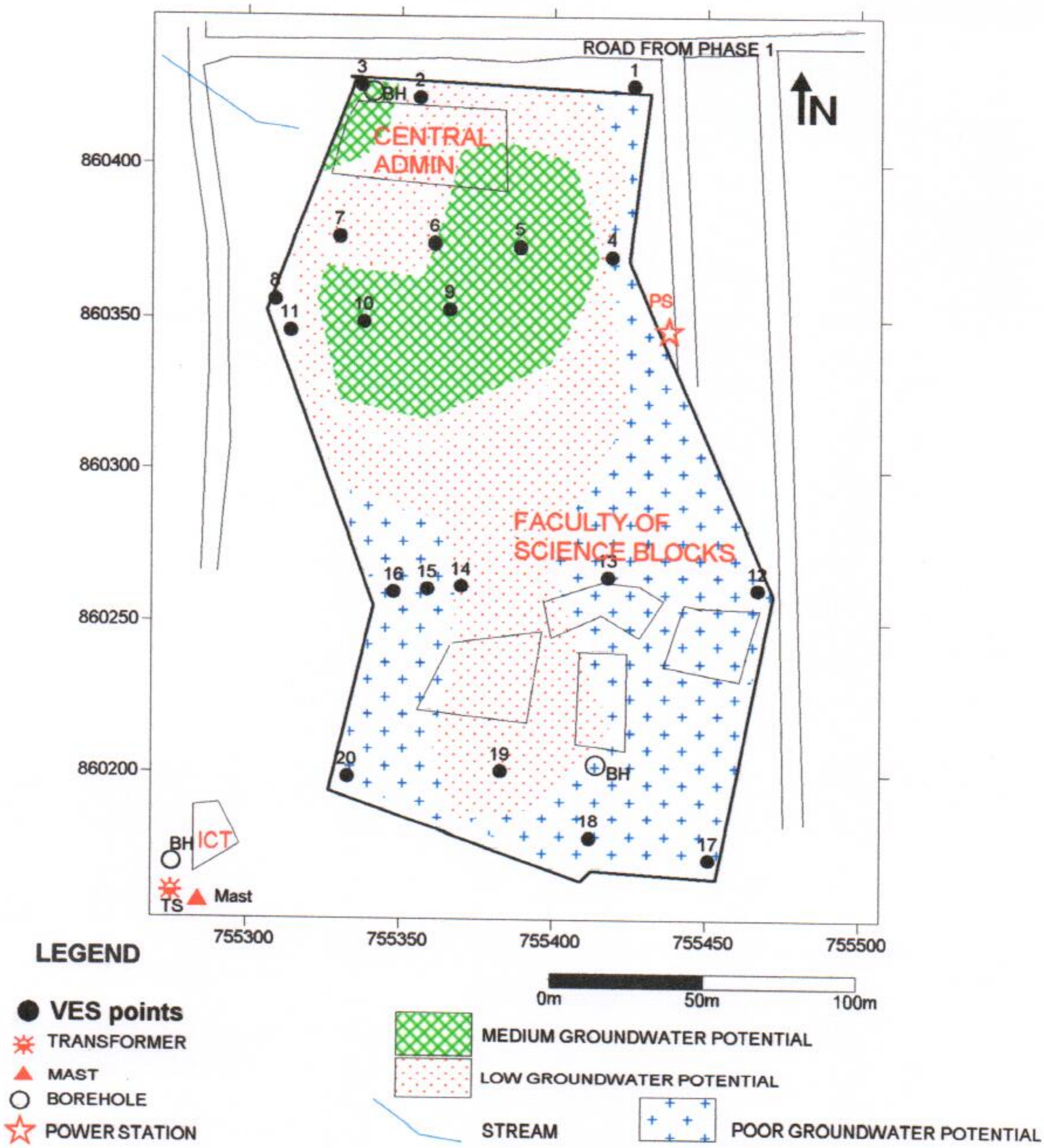


Fig. 4.5- Groundwater potential Map of the study area.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

A Geophysical integrated research work involving the use of Electrical Resistivity (ER) and the Very Low Frequency Electromagnetic methods (VLF-EM) were successfully carried out for groundwater potential on the Precambrian basement complex terrain of Federal University Oye-Ekiti Phase two (2), Ekiti-State Southwestern Nigeria. The interpretations of VLF–EM and VES in the study area have allowed the delineation of weathered and fractured zones in the study area. Six (6) zones believed to be a major fractured zone (as identified by the VLF-EM responses) underlies the study area with the 2D image of the subsurface identifying near surface conductive zones.

Twenty (20) VES points using the Schlumberger electrode array were occupied within the study area. The VES curves allows the delineation of four (4) major geo-electric layers which are the top soil, the weathered layer, the partly weathered/fractured layer and the fresh bedrock.

The top soil (resistivity varies from 28 to 175ohm-m and thickness ranges from 0.3 to 3.7 m); weathered basement (resistivity varies from 22 to 498ohm-m and thickness ranges from 1.3 to 38.7 m), Partly weathered/fractured basement (resistivity varies from 381ohm-m to 775 ohm-m and thickness ranges from 8.5m to infinity) and bedrock with resistivity 809 to 6693 ohm-m and depth to bedrock 1.5 to 43 m).

The interpreted data revealed A-curve as the dominant curve type in the study area. It has 55% dominance. Other curve types include the KH (10%), HKH (5%), AA (5%), H (5%), K (5%), AKH (10%) and HA (5%).

Therefore, VES 3, 5, 10 and 15, are thereby classified as good potential zones for groundwater development because of their bedrock relief and depression, thickness and resistivity values. VES 6, 7, 8 and 9 have low groundwater potentials, while VES 1, 2, 12, 13, 14, and 20 have poor groundwater potentials. Other VES points were not chosen on conductive zone parameters. VES 4, 11, 16, 17, 18 and 19 are partly weathered/ fractured basement and would have been good points for groundwater prospects if their thicknesses (at the third geoelectric layers for VES 4, 11 and 16, and second geoelectric layers for VES 17, 18 and 19) were known.

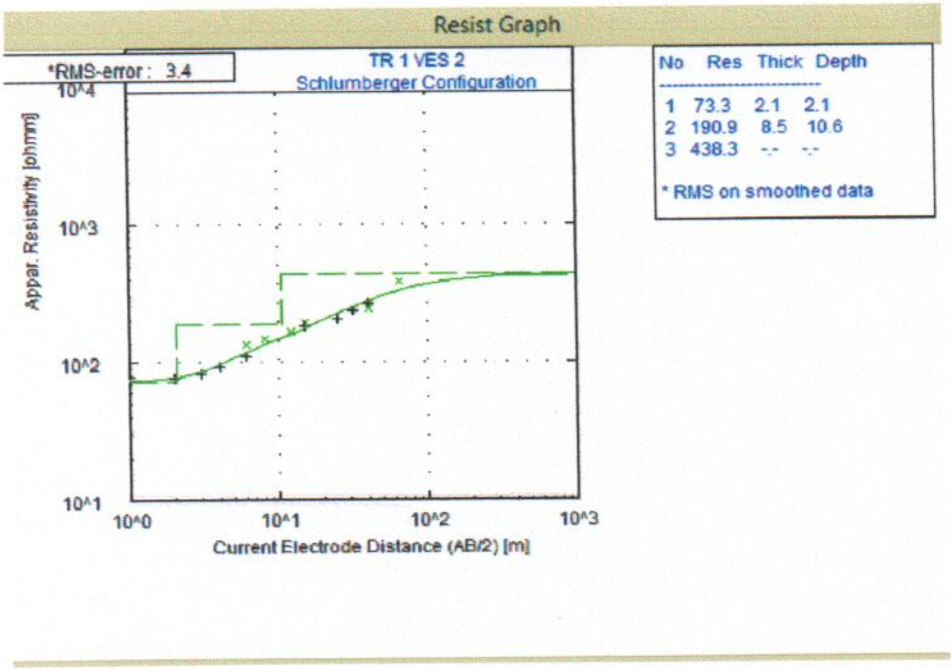
The interpretation of the results classifies the area from poor to medium groundwater potential zones.

Therefore, this project work has proven the relevance of the VLF-EM method as a reconnaissance tool in delineating fractured zones that aid groundwater development and has further proven the effectiveness of the Electrical Resistivity method in evaluating groundwater potentials of an area, as well as characterizing the subsurface geology.

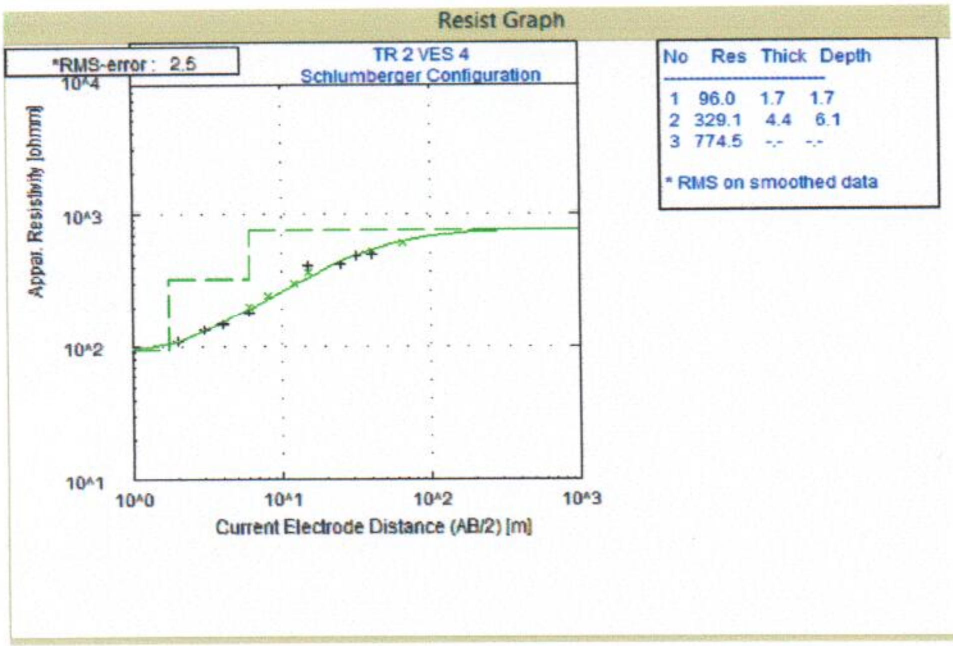
5.2 RECOMMENDATION

For groundwater development or siting of boreholes in Federal University Oye-Ekiti Phase two (2) around the study area, it is therefore recommended that VES 3, 5and 10 be considered because of their resistivities, thickness, lithological compositions and bedrock relief on the traverses on which they exist. The VES point chosen should be drilled to reach the fractured basement where appreciable volume of water can be exploited.

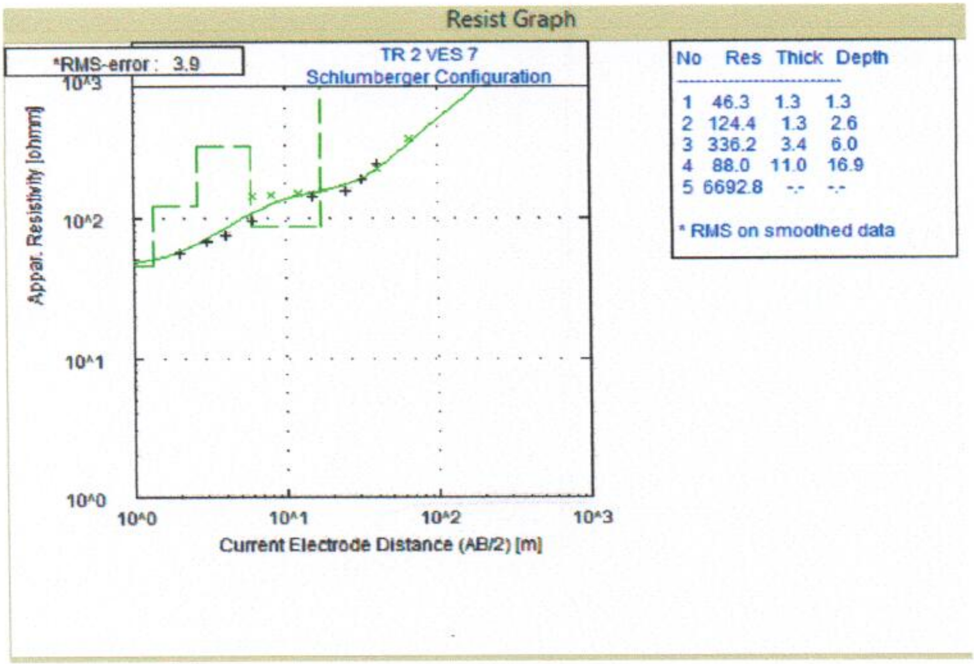
APPENDIX



Typical sounding curve in the study area (A-Curve type)



Typical sounding curve in the study area (A-Curve type)



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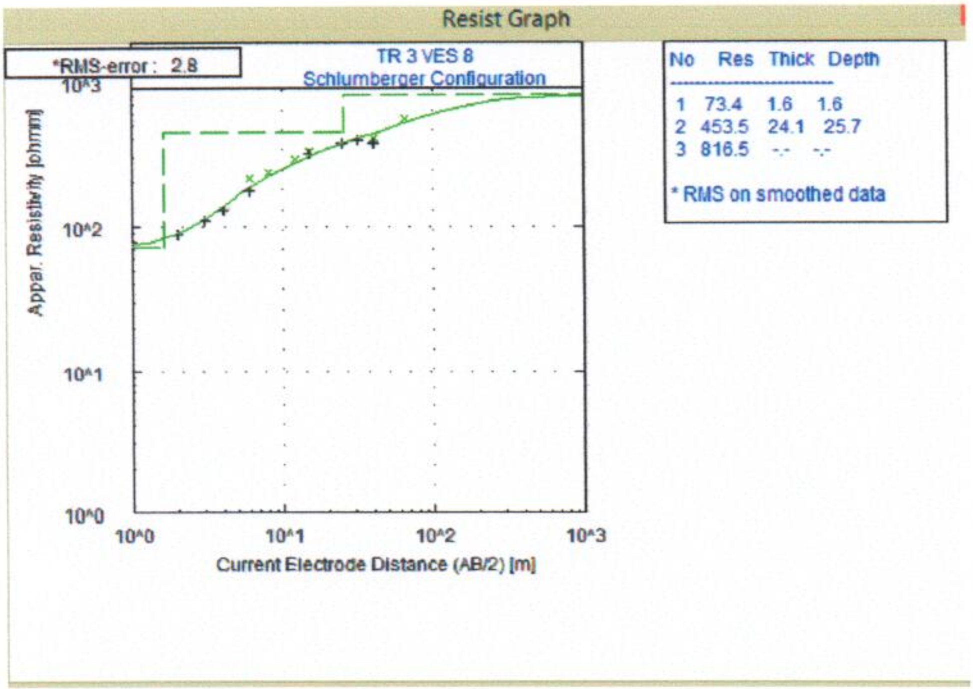

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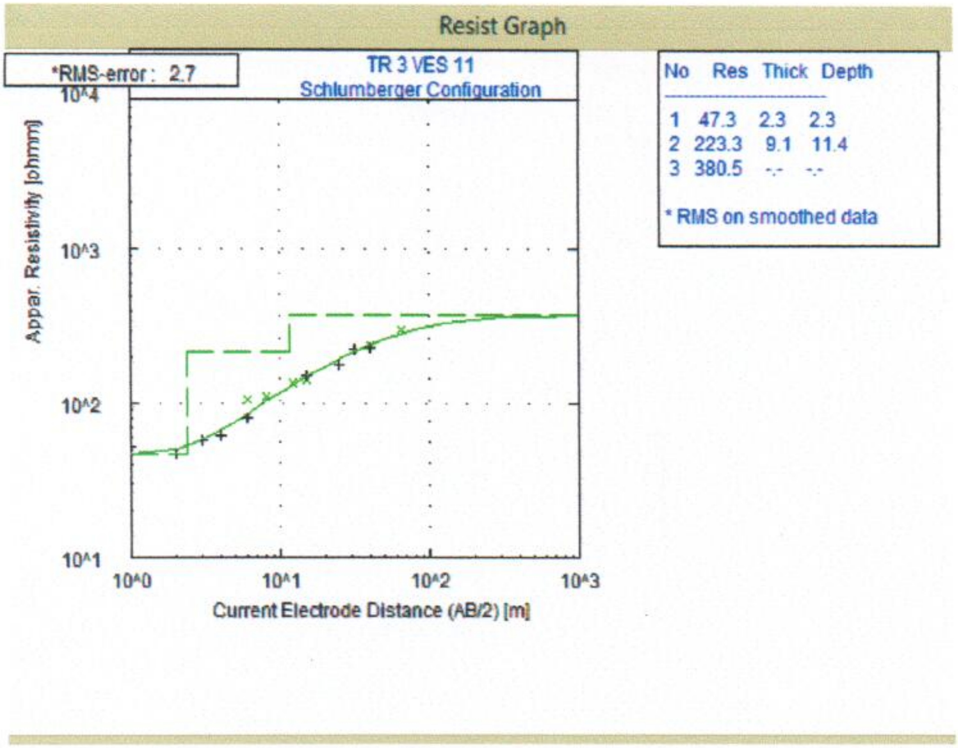

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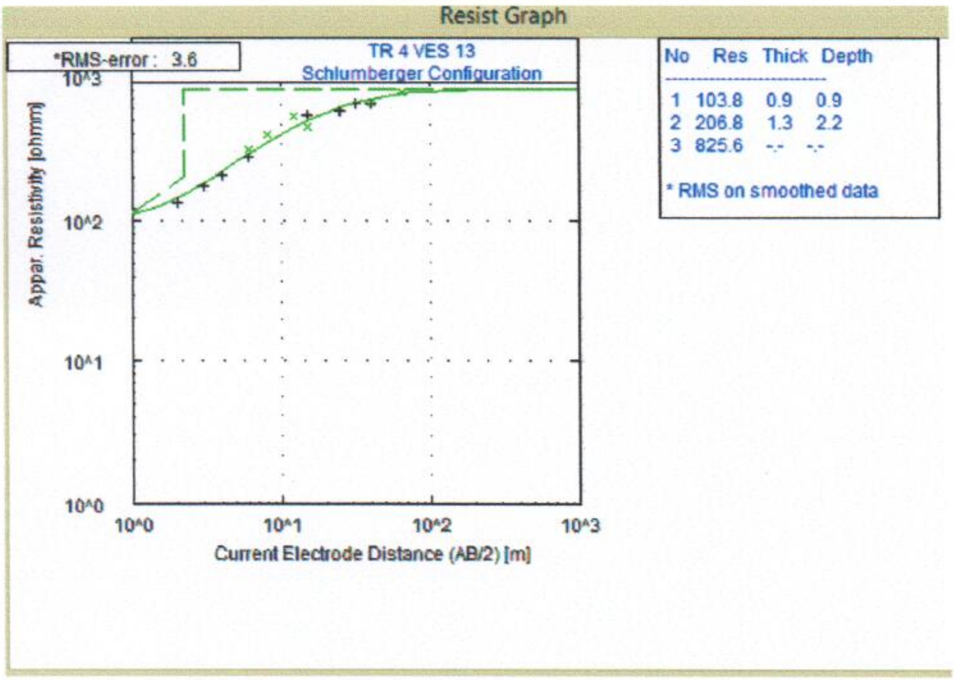
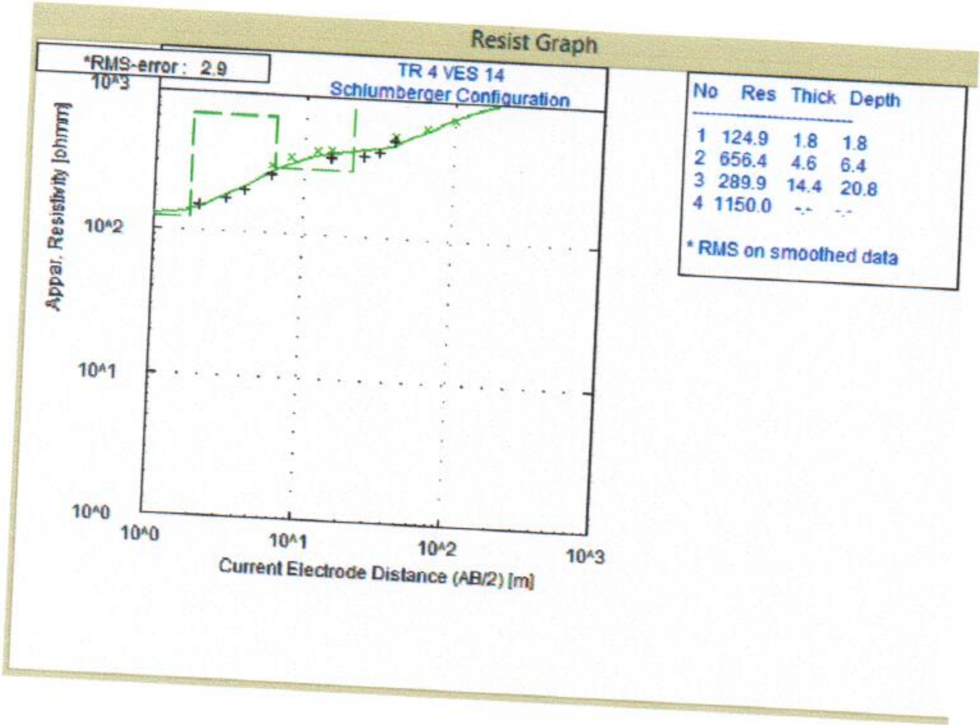


Typical sounding curve in the study area (A-Curve type)



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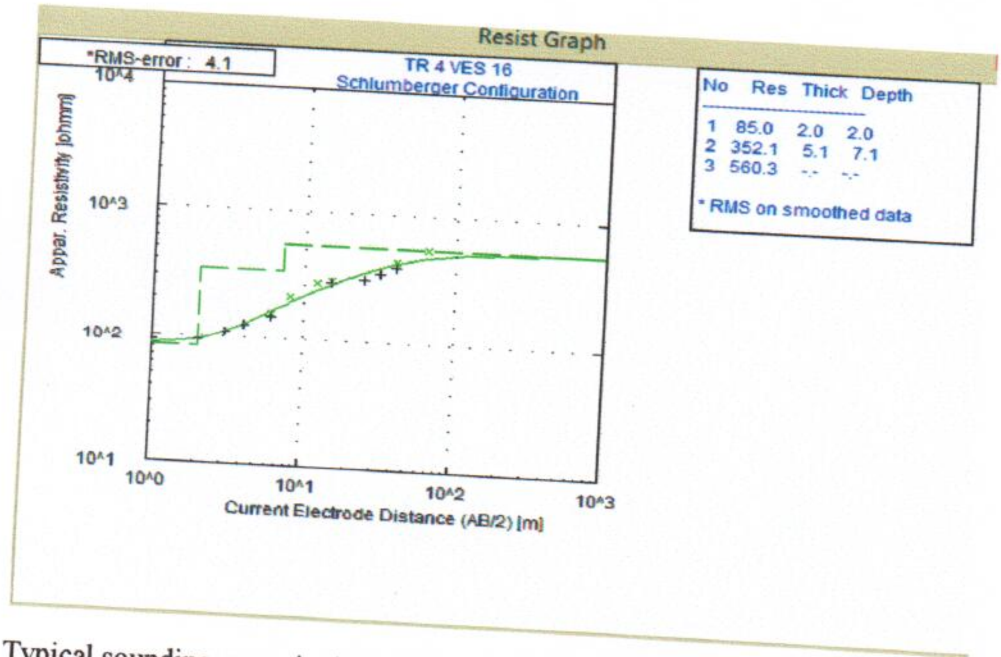
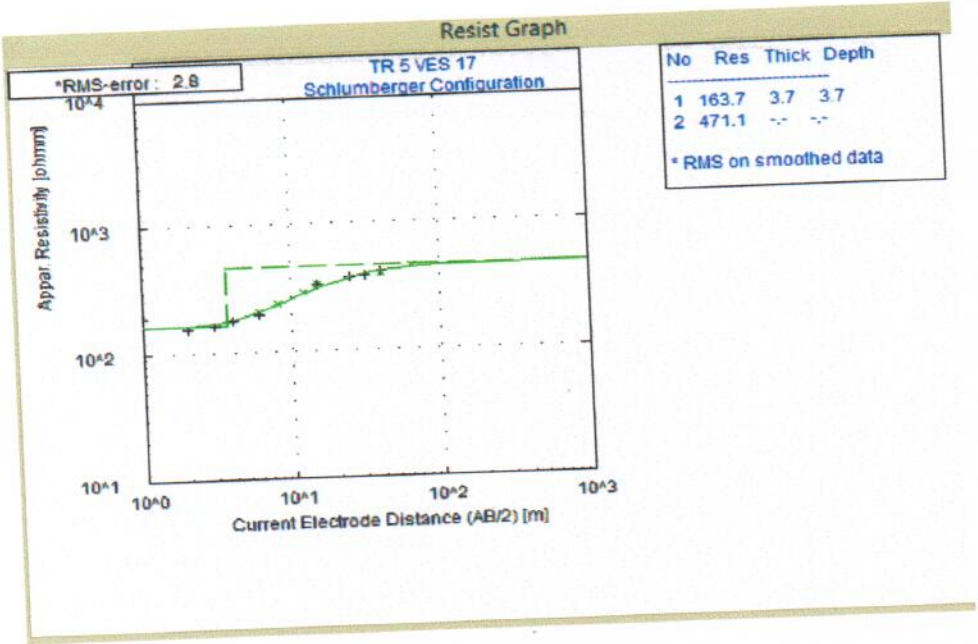
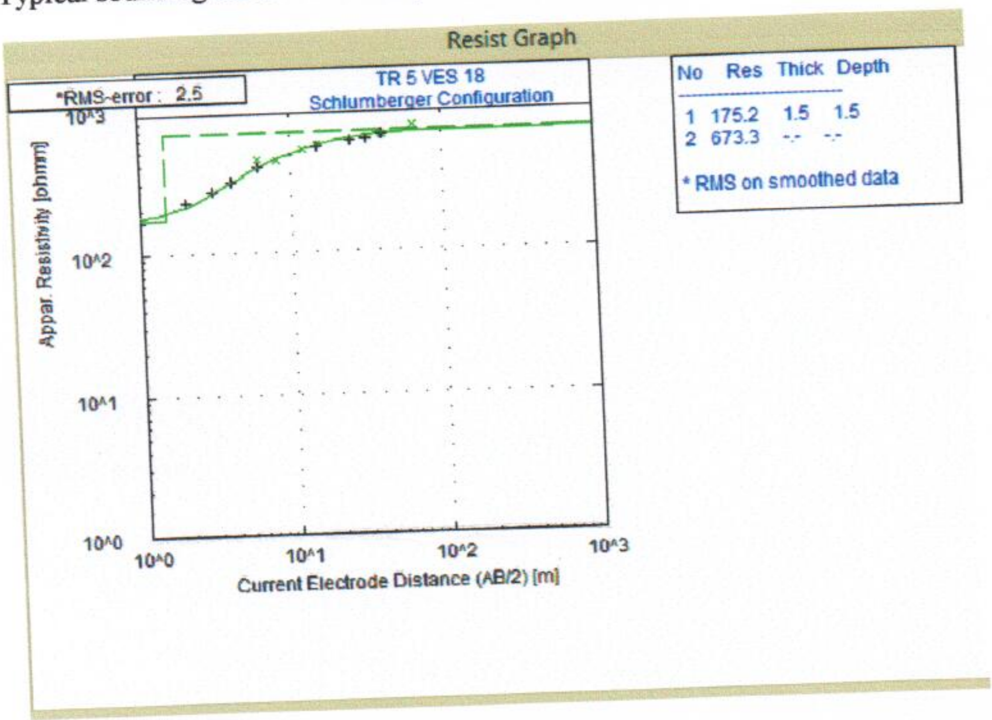


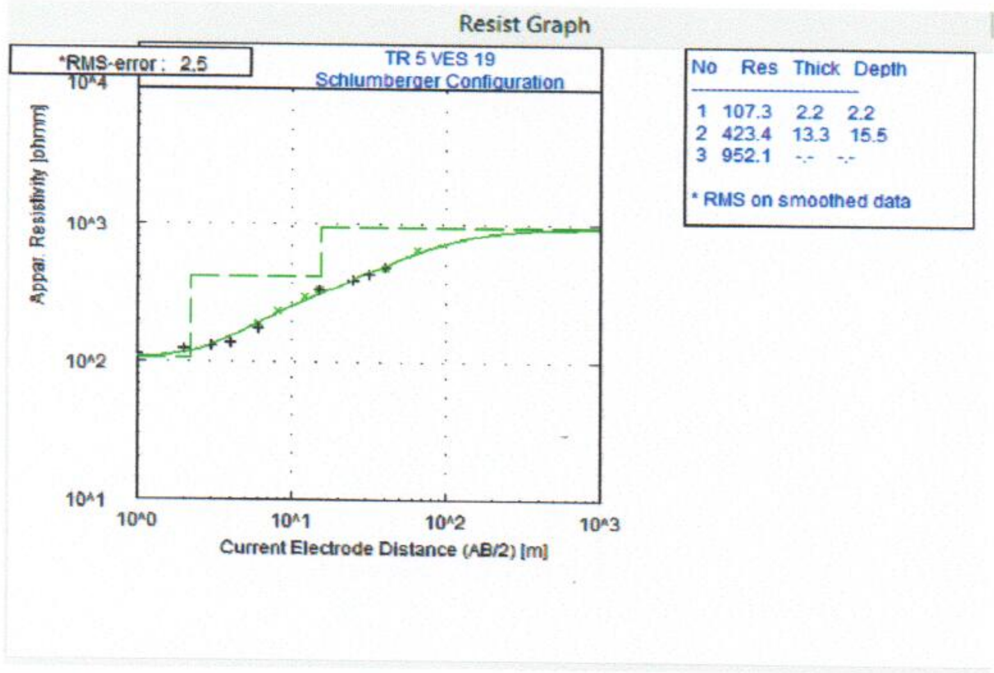
Typical sounding curve in the study area (A-Curve type)



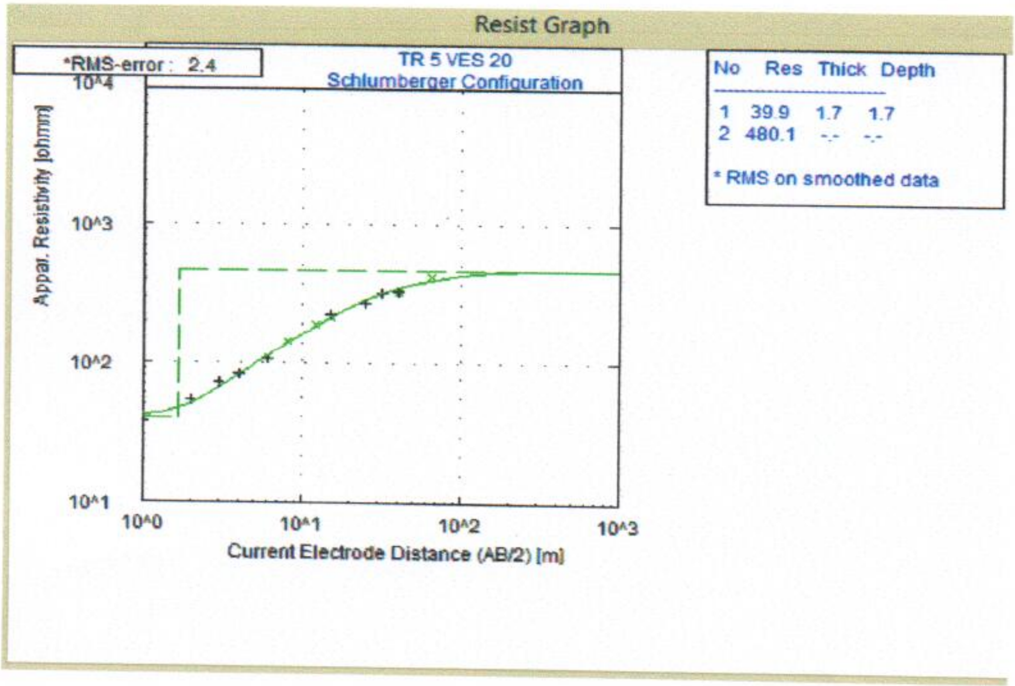
Typical sounding curve in the study area (A-Curve type)



Typical sounding curve in the study area (A-Curve type)



Typical sounding curve in the study area (A-Curve type)



Typical sounding curve in the study area (A-Curve type)

ELECTRICAL RESISTIVITY FIELD RECORD

Electrode Separation (m)	Geometric factor K	Apparent resistivity (ohm-m) VES 1@ 0m	Apparent resistivity (ohm-m) VES 2 @ 20m	Apparent resistivity (ohm-m) VES 3 @90m	Apparent resistivity (ohm-m) VES 4 @ 0m	Apparent resistivity (ohm-m) VES 5 @30m	Apparent resistivity (ohm-m) VES 6@ 60m	Apparent resistivity (ohm-m) VES 7 @90m	Apparent resistivity (ohm-m) VES 8 @ 20m
1	6.28	129	79	32	96	69	50	51	79
2	25.13	117	76	37	109	66	46	56	89
3	56.55	149	83	46	132	75	48	68	110
4	100.53	165	94	57	146	83	52	75	129
6	226.19	220	110	72	181	95	90	95	175
6	113.10	287	135	115	207	104	96	148	214
8	201.06	333	149	127	251	138	108	150	235
12	452.30	416	170	144	310	162	100	154	295
15	706.86	471	196	157	375	184	85	150	330
15	353.43	420	180	141	410	156	95	142	315
25	981.75	557	207	140	424	180	92	156	374
32	1608.50	599	235	130	490	195	95	193	389
40	2515.27	711	266	157	500	261	112	251	373
40	1005.31	590	251	168	540	264	98	231	411
65	2654.65		392	225	620	303	148	382	564
100	6283.19					402	310		

Electrode Separation (m)	Geometric factor K	Apparent resistivity (ohm-m) VES 9 @ 55m	Apparent resistivity (ohm-m) VES 10 @80m	Apparent resistivity (ohm-m) VES 11 @115m	Apparent resistivity (ohm-m) VES 12@10m	Apparent resistivity (ohm-m) VES 13@70m	Apparent resistivity(ohm-m) VES 14@120 m	Apparent resistivity (ohm-m) VES 15@ 130m	Apparentresistivity(ohm-m) VES16 @140 m
1	6.28	33	51	52	94	122	131	68	90
2	25.13	32	45	48	84	132	151	89	92
3	56.55	39	47	57	83	175	169	105	109
4	100.53	53	50	62	83	207	195	119	128
6	226.19	56	54	80	100	276	252	153	150
6	113.10	60	80	107	110	320	300	188	160
8	201.06	77	92	112	135	402	347	235	222
12	452.30	95	113	138	163	531	390	300	286
15	706.86	98	120	145	183	450	406	333	300
15	353.43	105	105	151	220	538	344	327	285
25	981.75	96	104	179	293	570	367	348	308
32	1608.50	110	137	224	326	650	395	372	345
40	2515.27	136	160	229	356	654	478	368	395
40	1005.31	118	193	240	398	664	529	376	444
65	2654.65	237	210	308	458	790	598	408	560
100	6283.19	388	400				699		

Electrode separation (m)	Geometric factor (K)	Apparent Resistivity (Ohm-m) VES 17 @ 20m	Apparent Resistivity (Ohm-m) VES 18@ 60m	Apparent Resistivity (Ohm-m) VES 19 @ 90m	Apparent Resistivity (Ohm-m) VES 20 @ 130m
1	6.28	193	166	114	37
2	25.13	153	228	124	54
3	56.55	160	270	130	72
4	100.53	178	308	135	83
6	226.19	197	386	175	108
6	113.10	210	439	193	114
8	201.06	240	437	235	150
12	452.30	296	510	300	195
15	706.86	336	548	340	221
15	353.43	335	528	331	228
25	981.75	375	570	389	276
32	1608.50	380	590	435	322
40	2515.27	410	629	485	334
40	1005.31	398	633	490	335
65	2654.65	460	736	665	428
100	6283.19				

ELECTROMAGNETIC (EM-VLF) FIELD RECORD

Instrument: ABEM WADI   Separation: 10m   Traverse Azimuth: EAST-WEST

Observer: Mr. Musa   Co-ordinate:

Traverse No: ONE (1)   Frequency: KHz

Site Description: FUOYE Phase 2   Signal Strength:

Station(M)	Real component(%)	Filtered real(%)	Imaginary Component (%)	Filtered Imaginary(%)	Distance (m)	Q-factor
0	0	-6.3	-0.8	0.8		
10	-2.4	-19.9	-0.7	4.5	15	-19.7
20	-18.1	-17.1	-12.4	6.5	25	17
30	-4	0.2	-23.7	-0.3	35	27.9
40	0.5	5.3	-11.7	-6.7	45	11.3
50	5.3	6.5	0.1	-4.9	55	-1.7
60	2.5	2.9	4.8	0.2	65	-7.5
70	1.6	0.8	-6.0	1.1	75	-1.9
80	-1.3	2.5	-2.6	-1.7	85	4.3
90	3.5	2.9	1.9	0.1	95	-0.7
100	1.1	-3.1	-3.6	-0.6	105	-7.5
110	-4	-1.8	3.1	-0.5		
120	1.1	1.1	-1.8	1.3		

TRAVERSE TWO (2)

Distance (m)	Real Component (%)	Imaginary Component (%)	Filtered Real (%)	Filtered Imaginary(%)	Distance (m)	Q-factor
0	0.0	-7.2	16.9	-4.4		
10	17.2	7.2	16.5	-3.1	15	-9.5
20	2.6	2.3	5.5	0.6	25	-13.6
30	5.1	2.0	6.1	0.6	35	-4.9
40	1.1	2.1	2.1	4.8	45	-4.7
50	1.7	-11.6	0.1	3.5	55	-7.6
60	-0.2	-14.2	-4.6	-3.3	65	-5.4
70	-4.6	2.3	-2.8	-3.8	75	-5.8
80	0.7	-1.0	0.7	-2.0	85	-6.1
90	0.3	3.8	-2.9	-3.9	95	-5.3
100	-2.5	9.2	-4.7	-1.2	105	-8.9
110	-1.8	9.0	-5.9	2.5		
120	-4.9	-0.8	-4.9	2.9		

TRAVERSE THREE

Station(M)	Real Component(%)	Filtered Real(%)	Imaginary Component (%)	Filtered Imaginary(%)	Distance (m)	Q-factor
0	0	2.5	-5.4	-3.6		
10	2.1	4.3	5.8	-3.2	15	2.6
20	2.2	3.8	5.1	12.2	25	-1.9
30	2.5	1.1	2.1	0.1	35	-7.7
40	-0.1	-2.4	3.4	-0.2	45	-3
50	-2.9	0.1	1.2	-1.8	55	-1.1
60	2.3	1.8	10.4	-1.4	65	1.9
70	-0.4	0.5	12.8	0.2	75	1
80	1.7	2.2	9.2	-0.8	85	0.6
90	1.2	1.6	5.7	-0.9	95	-1.5
100	0.7	1.2	10.7	-3.0		
110	0.7	0.7	15.8	-1.6		

TRAVERSE FOUR

Station(M)	Real Component(%)	Filtered Real (%)	Imaginary Component (%)	Filtered Imaginary(%)	Distance(m)	Q-factor
0	0	13.1	-8.1	-4.3		
10	13.4	12.5	5.9	-3.6	15	-8
20	1.6	3.9	2.0	-2.0	25	-10.7
30	4.1	2.3	5.5	-4.6	35	-13
40	0.2	-11.6	20.2	5.5	45	-31.7
50	-7.5	-25.6	-4.5	17.4	55	-17.9
60	-19.9	-17.8	-37.1	9.7	65	28.6
70	-5.3	6.4	-30.7	-7.0	75	44
80	6.5	15.7	-6.3	-11.7	85	10.2
90	12.3	9.1	2.1	-6.0	95	-12.9
100	-0.9	6	5.3	-3.5	105	-1.3
110	6.8	9.4	3.8	-3.1	115	-1.3
120	3.3	3.1	12.6	-3.5	125	-8.5
130	1.3	1.1	13.0	-2.1	135	-5.3
140	0.3	-0.7	18.5	0.1	145	-3.1
150	-1	-0.8	12.1	2.2	155	1.7
160	-0.5	2.3	7.8	-1.8	165	7.9
170	1.5	6.1	18.8	-2.0		
180	4.9	4.9	15.7	0.4		

TRAVERSE FIVE

Station(M)	Real Component(%)	Filtered Real(%)	Imaginary Component (%)	Filtered Imaginary(%)	Distance(m)	Q-factor
0	0	-0.7	4.5	-1.3		
10	-0.4	-1.6	8.3	-1.0	15	-0.2
20	-1.6	-1	8.2	1.4	25	-0.3
30	1	-4.6	4.3	3.8	35	-13
40	-3.3	-14.4	-2.0	5.8	45	-17.1
50	-10.3	-12.6	-11.9	3.8	55	19.5
60	-9.1	8.7	-16.7	-4.1	65	36.8
70	15	14.8	4.3	-6.1	75	1
80	2.4	4.5	2.8	-3.4	85	-11.5
90	4.5	5.6	11.1	-2.8	95	-5.8
100	1.6	0.2	9.8	2.3	105	-8.1
110	-0.5	-2	3.4	2.4	115	-3.6
120	-1.5	-7.8	-1.3	1.4	125	-2.6
130	-1	-23.1	9.7	8.1	135	13.5
140	-27	-7.2	-30.9	3.2		
150	13.7	13.7	-2.0	-7.0		

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