

Geophysical Investigation from Thiruporur to Mahaballipuram Using Resistivity Method

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Abstract:

The work entitled geophysical investigation from thiruporur to mahaballipuram using resistivity method was investigated using various techniques such as vertical electrode sounding (VE S), auxillary chart array, Werner and schlumberger configuration, out of which vertical electrode method showed good output values with the aid of resist 87. The spatial distribution shows the thickness and resistivity of different layers further it showed that the resistivity decreases because of the intrusion of sea water. The chosen geological study area proved that the weathered, fractured and altered areas of rock acts as a storage of ground water potential.

Introduction:

Geophysics deals with the physics of the earth and its surrounding atmosphere, further it deals with all aspects of the physics of the earth, its atmosphere and space. The science of geophysics applies the principles of physics to the study of the earth. The term geophysics sometimes refers to the geophysical applications: earth shape; its gravitational and magnetic fields; its internal structure and composition; its dynamics and their surface expression in plate tectonics; the generation of magmas, volcanism and rock formation. However modern geophysics organizations use broader definition that includes water cycle including snow and ice; fluid dynamics of the ocean and the atmosphere; electricity and magnetism and solar terrestrial relations and analogous problems associated with the moon and other planets.

The medium of earth is made up of solid, liquid and gas. The solid is the main material to form the structure of the earth, so it is very significant to study the solid matter of the earth. Rock is a solid medium which is studied commonly by geophysicist. The physical properties of all sorts of elements are mainly controlled by the atomic structure of the elements. The characteristics of the comprehensive physical properties of minerals are also controlled by cumulative density of atoms and atomic structures. The presence of minerals and their various properties such as magnetic property, electrical property, resistivity and seismic method and many other properties have paved the way for scientific researches regarding the property of rocks. Geophysics is the study of earth (rock surface) and planets by quantitative physical method including the physical properties and modeling of the physical behavior of natural materials.

Although geophysics was only recognized as a separate discipline in the 19th century its origin date back to ancient times. The first magnetic compasses were made from loadstones, while more magnetic compasses played an important role in the history of navigation. The first seismic instrument was built in 132 AD. Issac Newton applied his theory of mechanics to the tides and precision of equinox and instruments were developed to measure the earth shape and density and gravity field as well as the components of water cycle.

In the 20th century, geophysical methods were developed from the remote exploration of the solid earth and the ocean, and geophysics played an essential role in the development of the theory of the plate tectonics. Geophysics is applied to social needs such as mineral resources, mitigation of natural hazards and environmental protection. Geophysical techniques have been used in mineral prospecting for the past 300 years, beginning in Sweden around 1640 with the use of magnetic compasses.

Several near surface geophysical exploration methods like magnetic survey, resistivity investigations, shallow seismic survey etc can be adopted in integration with geological mapping (or) lithology analysis to better understand subsurface geological settings. The Thickness of weathered zone, presence of intrusive bodies, dipping beds etc are some of the geological inferences expected from geophysical investigations. Geophysical investigation results are generally represented in terms of resistivity contrast, density contrast, susceptibility contrast etc for the subsurface lithology (geological setting). Geophysical techniques are routinely used in an exploration program to help the project geologist delineate areas favourable for the type of target being pursued. Geophysical techniques (method) can look beneath the alluvial cover. They can be used directly to detect some minerals, indirect detection and to map geological and structural features in exploration programs.

Direct detection includes using induced polarization to find disseminated sulphides, magnetics to delineate magnetic hosting rocks, gravity and electrical techniques for massive sulphides.

Different geophysical prospecting methods:

Gravity method

Resistivity method

Seismic method

Magnetic method

Gravity method:

Galileo Galilei in 1589, dropped light and heavy weights from leaning tower of Pisa is an attempt to determine how weight affects speed at which a given object falls. John Kepler worked out on laws of planetary motion and this enabled Sir Isaac Newton to discover the law of gravitation. The French Academy of Sciences to Laplace and Peru in (1735 – 45) can be said to have given Pierre Bouguer an opportunity to establish many of the basic gravitational relationships which include variation of gravity with elevation and latitude, the horizontal attraction due to mountains and the density of earth. Captain Henry Kater in (1817) introduced compound pendulum, with interchangeable centers of oscillation and suspension which became the major tool for gravity investigation for a century. Because the variation in gravitational attraction are so small, F. A. Venning Meinesz in 1923, measured gravity with pendulum on board a Dutch submarine and demonstrated gravity variations over various areas of the oceans, especially the large gravity effects near the Indonesia trench.

Principles of gravity:

NEWTONS LAW OF GRAVITATION:

The force of attraction is expressed by Newton's law. The force between two particles m_1 and m_2 is directly proportional to the product of the masses and inversely proportional to the square of the distance between the centre of masses

$$F = \gamma(M_1 \cdot M_2)/r^2$$

ACCELERATION OF GRAVITY:

The acceleration of m_2 due to the presence of m_1 can be found by

$$g = (\gamma m_1 / r^2)$$

GRAVITATIONAL POTENTIAL – NEWTONIAN (Or) THREE DIMENSIONAL POTENTIAL: gravitational fields are conservative that is the work done in moving a mass in a gravitational field is independent of the path traversed and depends only on the end points. If the mass is eventually displaced the net energy expenditure is zero, regardless of the path followed. The gravitational force is a vector, whose direction is along the line joining the centre of the masses. The force giving rise to conservative field may be derived from the scalar potential function $U(X, Y, \text{ and } Z)$ called Newtonian or three dimensional potential.

GRAVITY OF EARTH:

(a) **General:** gravity prospecting evolved from the study of earth's gravitational field a subject of interest to geodist for determining the shape of the earth , because the shape of the earth is not a perfect homogenous sphere, gravitational acceleration is not a constant over earth's surface.

The magnitude of earths depends on five factors:

1. Latitude
2. Elevation
3. Topography of the surrounding terrain
4. Earth tides
5. Density variations

The gravity exploration is concerned with anomalies due to last factor and these anomalies generally are much smaller than the changes due to latitude and elevation.

(b) THE REFERENCE SPHEROID:

The shape of the earth, determined by geodetic measurements and satellite tracking is nearly spheroidal, bulging at the equator and flattened at the poles. The flattening is given by $(R_{eq}-R_p)/R_{eq}$; R_p is the reference point at the poles and R_{eq} is the reference point at the equatorial region.

(c) THE GEOID:

Mean continental elevations are about 500 m and maximum land elevation and ocean depressions are of the order 9000 m referred to the sea level. Sea level is influenced by variations and other lateral density changes. We define mean sea level (the equipotential for earth's gravity plus the centrifugal force).

MAGNETIC METHOD:

Magnetic and gravity methods have much in common, but magnetic is generally is more complex and variations in the magnetic field are more erratic and localized. This is partially due to the difference between the dipolar magnetic field and monopolar gravity field, partly due to the variable direction of the magnetic field, whereas the gravity field is always in vertical direction and partly due to the time dependence of the magnetic field. Magnetic measurements are made more easily and cheaply than most of the other geophysical measurements and corrections are practically unnecessary. Magnetic field variations are often diagnostic of mineral structures as well as regional structures and the magnetic method is the most versatile of geophysical prospecting techniques.

HISTORY OF MAGNETIC METHOD:

The study of the earth's magnetism is the oldest branch of geophysics. It has been known for more than three centuries that the earth behave as a large irregular magnet. Sir William gilbert (1540 – 1603) made the first scientific investigation of terrestrial magnetism. Gilbert showed that the earth's magnetic field was roughly equivalent to that of a permanent

magnetic field lying in N-S direction near the earth's rotational axis. Karl fedrick gauss made extensive studies of the earth's magnetic field and he concluded from mathematical analysis that the magnetic field was entirely due to the source within rather than outside it. The publication in 1897, of the examination of the iron ore by magnetic measurements by thalen marked the first use of magnetic method. Until late 1940's, the magnetic field balance, which measured one component of the earth's field (usually vertical component)

PRINCIPLES AND ELEMENTARY THEORY:

CLASSICAL THEORY VERSUS ELECTROMAGNETIC CONCEPTS:

Modern and classical magnetic theory they differ in basic concepts, classical magnetic theory is similar to electrical and gravity theory. Magnetic poles are analogous to point electric charges and ppoint masses. Magnetic units in the centimeter – gram second and electromagnetic units. System international units are based on the fact that a magnetic field is electrical in origin. Its basic unit is the dipole which is created by a circular electrical current rather than fictitious isolated monopole of the cgs-emu system. Both emu and SI units are in current use. The CGS-EMU system begin with the concept of magnetic field given by coulombs law

$$F = (P1.P2/Ur^2)r1$$

Where F is the force on p2 in dyne .The pole strength P1 and P2 and r centimeters apart. U is the magnetic permeability (a property of a medium). r is the unit vector directed from P1 to P2

The magnetizing field (H) also called a magnetic pole strength is defined as a force on a unit pole.

$$H = F/ p2 = (p1/ur^2) r1$$

Molecules also have spin , which gives them magnetic moments. A magnetizable body placed in an external magnetic field becomes magnetized by induction , the magnetization is the re-orientation of atoms and molecules . so that their spins line up. The magnetization is measured by magentic polarization (dipole moment per unit volume). The line up of internal dipoles produces magnetic field (m) , which within the body is added to the magnetizing field (H). The S.I unit is (ampere/m)

For a low magnetic field (m) is propotional to H and is in the direction of H. The degree to which a body is magnetized is determined by its magnetic susceptibility (k)

$$M = KH$$

Susceptibility is the fundamental rock parameter in magnetic prospecting. The magnetic response of rocks and minerals is determining by the amount and susceptibility of magnetic materials in them.

SEISMIC METHOD:

The seismic method is by far the most important geophysical technique in terms of expenditure and number of geophysicists involved its predominance is due to the high accuracy, high resolution and great penetration. The wide spread use of seismic method is principally in exploring the petroleum, the location for exploratory wells are widely made

with seismic information. Seismic method are also important in groundwater searches and in civil engineering, especially to measure the depth of bedrock in connection with the construction of large buildings, dams and highways. Seismic technique have found little application in direct exploration for minerals, whereas interfaces between two different rock types are highly irregular. They are useful in locating features such as buried channels, in which heavy minerals may be accumulated. Exploration seismology is an offspring of earthquake seismology. When an earthquake occurs, the rock is fractured and the rocks on opposite sides move relative to one another. Seismologist use the data to deduce information about the nature of rocks through which the earthquake was travelled.

History:

Most of seismic theory was developed prior to the availability of instruments that were capable of sufficient sensitivity to permit significant measurements. Knott developed the theory of reflection and refraction at interfaces in a paper in 1899. Zeoppritz and wiechert published wave theory in 1907.

In 1919 mintrop applied for a patent on the refraction method and in 1922, mentropss seismos company furnished two crews to do refraction seismic prospecting. A distinctive refraction was the characteristic of the first reflection application. Hence the first reflection work utilized the correlation method whereby a map was constructed by recognized the same event on isolated individual records.

Seismic theory – theory of elasticity:

(a) general :

The seismic method utilizes the propagation of waves through the earth. Because this propagation depends on elastic properties of rocks. The size and shape of the solid body can be changed by applying forces to the external surface of the body. These external forces are opposed by internal forces.

(b) Stress:

Stress is defined as the force per unit area. When a force is applied to a body, the stress is defined as the ratio of force to the applied body (or ratio of force to the applied area). Normal stress (or) pressure can be defined as the force perpendicular to the area.

Consider a small element of volume, the stress is acting on each six faces of the cube. The force can be resolved into three basic components (X, Y and Z) . The perpendicular stress can also be explained as Normal stress .Further under seismic theory we can find out the magnitude of couple by using the formula

(Force x lever arm)

(c) Strain:

When an elastic body is subjected to stress, change in position occurs these changes we call it as strain

(d) Dilation:

If the dimension of the system is changed due to normal strain result in volume changes, the change in dimension per unit volume we call it as dilation.

(e) Elastic constants:

Although lame constants are convenient at times , other elastic constant are used in seismic method. Apart from the above mentioned terms and constants many other concepts and equations are used in seismic method , few of them are mentioned below.

- Wave equation
- Spherical wave solution

- Harmonic waves
- Amplitude

Further seismic method uses the wave format for better understanding of movement of platelets and rock surface.

RESISTIVITY METHOD

There are several variants in electrical methods. In fact, largest variety of methods is possible in electrical prospecting and it will be no surprise if new methods are developed in future. In electrical methods either the natural electrical field in an area is investigated or the ground is charged by an artificial electrical field and the distribution of the electric field at the surface of the earth is investigated.

ELECTRICAL PROSPECTING

Electrical resistivity techniques are based on the response of the earth to the flow of electric Current. With an electrical current passed into the ground and two potential electrodes to record the resultant potential difference between them, we can obtain a direct measure of electrical impedance of the subsurface material (Dobrin and Savit, 1988). The resistivity of the surface a material constant is then a function of the magnitude of the current, the recorded potential difference and the geometry of the electrode array. Depending on the survey geometry, the data are plotted as 1-D sounding or profiling curves or in 2-D cross- section in order to look for anomalous regions. In the shallow subsurface, the presence of water controls much of the conductivity variation. Measurement of resistivity is, in general, a measure of water saturation and pore space connectivity. Resistivity measurements are associated with varying depths relative to the distance between the current and potential electrodes in the survey, and can be interpreted qualitatively and quantitatively in terms of a lithologic and/or geohydrologic model of the subsurface.

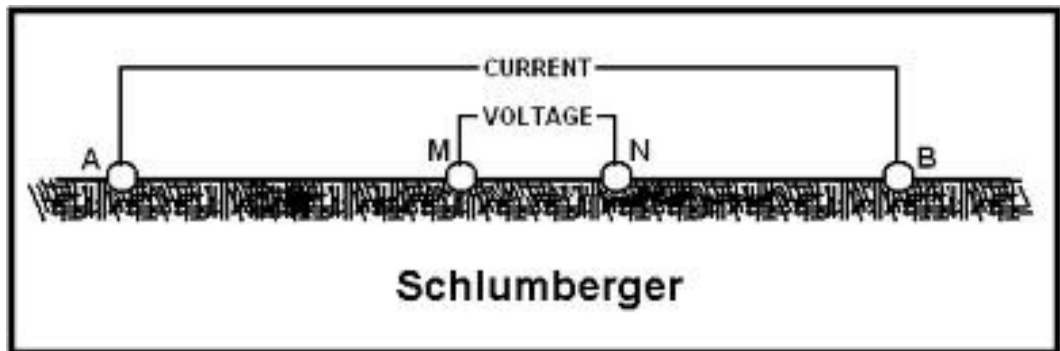


Figure 3.1. Position of the diodes

In electrical resistivity method, current is sent into the ground by means of two metallic electrodes (A & B) spiked into the earth shown as Fig (3.1), and the potential difference between two suitable points is measured by means of two more electrodes (M & N) as illustrated figure shown above. The apparent resistivity of the earth is then computed as the product of the ratio of the potential difference measured (ΔV) and current (I) sent and the configuration factor (K) which depends upon the mutual distance of the electrodes.

THE SCHLUMBERGER ARRAY

The Schlumberger array has been used throughout this study. An outline of its theory is given below. This is followed by a discussion of the limitations of the resistivity sounding methods. The field methods are then presented together with a description of the instruments used. Finally, presentation of results and methods of interpretation are explained.

Theory

In the Schlumberger array Fig (3.2), A and B are current electrodes, and M and N are potential electrodes. Let the current I enter the ground at A and return at B. Assuming the medium below the surface of the earth to be homogeneous and isotropic of resistivity ρ . Here the two current electrodes A & B are placed with a larger separation than the two inner potential electrodes (M, N) as in figure.

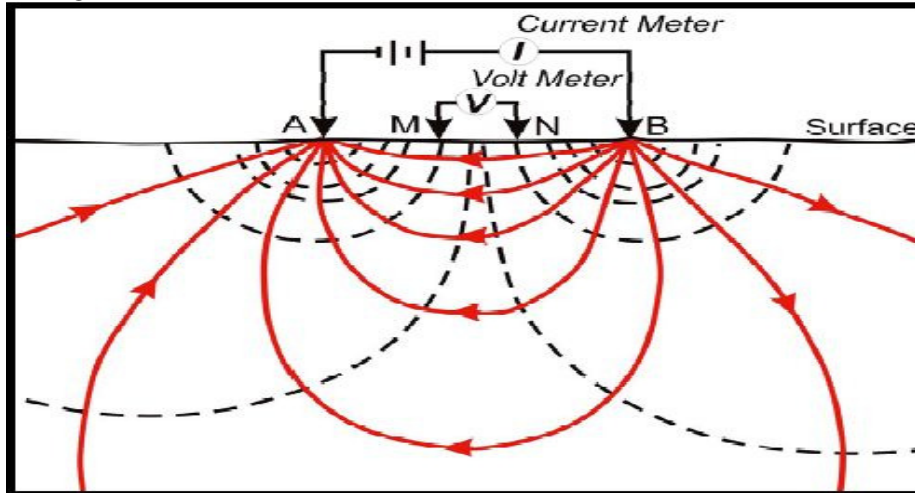


Figure 3.2. Schlumberger Arrays

Formula for schlumberger configuration

$$\begin{aligned} \rho_a &= KR \\ R &= \Delta V / I \\ K &= 2\pi / (1/AM - 1/AN - 1/BM + 1/BN) \\ K &= 2\pi / (2/MN - 2/AN) \\ K &= \pi / (AN - AM) / (AM - AN) \\ K &= \pi / (AN - AM) / (AM - AN) \\ K &= \pi / (AN - AM) / (AM - AN) \\ K &= (\pi \times AM \times AN) / (MN) \end{aligned}$$

Where

- ρ_a = Apparent resistivity
- R = Resistance
- K = Geometric factor / configuration constant
- A & B = Current electrodes
- M & N = Potential electrodes
- MN = Distance between the potential electrodes
- AB = Distance between the current electrodes

This arrangement has the advantage that in depth soundings, high voltage power carrying cables must be avoided

There are two types of exploration is made by employing the resistivity methods, one is lateral exploration and the other is vertical exploration.

LATERAL EXPLORATION OR PROFILING

A series of measurements of resistivity are made with constant electrode spacing, moving the whole electrode arrangements consequently to a number of points along a given line. Thus the lateral variations of resistivity of the ground can be measured. The resistivity so obtained plotted on the central points along a profile. This method of exploration is termed constant depth traversing or simply as resistivity traversing; a few also called it "electrical trenching".

VERTICAL EXPLORATION OR DEPTH SOUNDING

A series of measurements of resistivity are made by increasing the electrode spacing in successive steps about a fixed point. This method of exploration is known as expanding electrode method resistivity sounding or depth probing and few called as “vertical electrical sounding”(VES).

In the schlumberger arrangement the electrodes M and N kept fixed but the electrodes A and B are moved further away on either side in successive steps and obtaining the resistivity values for a series of such increase for one setting as MN. When the spacing of the latter is increased; the current electrodes are shifted for the next set of observation. The apparent resistivity values are plotted against $AB/2$.

For carrying out resistivity sounding, the following equipment are necessary.

1. One resistivity meter.
2. One D.C current source or an A.C. Generator with low frequency.

Insulated electrical cables al properties) which can give rise to the observed anomaly distribution. The geophysical interpretation techniques have basically two approaches. The first is based on the calculation of the anomaly curve for bodies or structure with simple assumed shapes and attitudes, and is sometime referred as DIRECT PROBABLY. The second approach aims at the inversion of the geophysical anomaly directly in to a possible geophysical model occurring at specified depths having specific physical properties.

DIRECT MAPING

INTERPRETATION OF 2-LAYER VES CURVE

For interpreting a two layer field VES, the field (VES) is plotted on a double log transparent sheet having the same modulus as the master curves. The field curve is super imposed over the 2-layer master sheet and moved keeping both axes parallel to the corresponding axis of the master set, until the field curve fits with one of the master curves. The origin of the master curves is on the transparent sheet, the co-ordinates of the origin the giving the resistivity (ρ_1) and the thickness (h_1). The asymptotic value of the second layer read from the master curve is multiplied by ρ_1 to give ρ_2 .

INTERPRETATION OF A 3-LAYER MASTER CURVE

The procedure is the same except 3-layer master set is to be used in this case. A close fit of the field VES with one of the VES from family of 3-layer set yields the parameters. The origin of the master curve transferred over to the transparent sheet gives ρ_1 and h_1 . The 3-layer master set is drawn for a particular $\rho_1: \rho_2: \rho_3$ set from which ρ_2 and ρ_3 can be calculated. Since we already know ρ_1 and since h_2/h_1 value is also known for a particular closely fitting curve, h_2 can be calculated from h_1 . While the quantitative interpretation of a 3-layer field VES curve by curve matching technique can be carried out with the help of a 3-layer master set, it is not always possible to get perfect match between the field VES curve and the available theoretical curves, since the letter are limited. In order to overcome this limitation partial curve matching method of interpretation using auxiliary point technique has been proposed by Hommel (1932) and Ebert (1943), Orenella and Mooney (1966) for interpreting three are four layer field curves. In this method of interpretation, each of the branches of VES curves is approximated by two-layer VES curve. The co-ordinates of second or later two layer curve are considered to represent the thickness and resistivity of a fictitious layer that replaces the first and second layer or subsequent pairs of upper layers.

3. One pair of current electrodes in the form of iron stakes.
4. One pair of potential in the form of porous pots with copper sulphate solution and copper rods for picking up potentials from the ground.
5. Hammer to fix the electrodes in the ground.

INTERPRETATION OF FIELD VES CURVES

The final objective of conducting VES in field is to transform the field data in terms of subsurface geology. Mainly there are two approaches. Qualitative and quantitative one of which is used in interpreting the field VES.

QUALITATIVE METHODS OF INTERPRETING VES

Qualitative interpretation generally aims at locating areas where the geophysical field is distributed and forming some ideas about the extent, shape, attitude, depth etc. of the subsurface objects as judged from the shapes of anomalies either from visual observations or by using some empirical values.

The qualitative analysis of the sounding data involves the following.

1. Study of apparent resistivity maps.
2. Study of apparent resistivity sections.
3. Study of first derivative maps.
4. Study of residual apparent resistivity sections which are analogous to residual gravity by the removal of regional or background values.

QUANTITATIVE INTERPRETATION

This generally aims to determine a geophysical model (with a chosen shape and attitude, depth and physical structure)

These fictitious or equivalent layer parameters are represented in graphical form called the auxiliary charts which are available one of each type namely, H, Q, A and K.

REVIEW OF LITERATURE

Nepal *et al* (2010) followed efficacy of electrical resistivity and induced polarization method methods for revealing fluoride contaminated groundwater in granite terrain. Resistivity sounding results supplemented by IP sounding data are useful for delineating the fluoride contaminated aquifers in the granite terrain. The aquifers showing a correlation of low resistivity (7.42 – 8.00 ohm m) by low chargeability (1.5 -2.8 ms) are indicative of high fluoride concentration in ground Water study area.

Owen *et al* (2005) studied multi -electrode resistivity survey for groundwater exploration in the Harare greenstone Zimbabwe . The ability of multi – electrode resistivity profiling to provide a detailed continuous 2 D map of the subsurface , identifying the different lithologies , delineating contact zones and faults, and measuring the thickness of a weathered regolith , makes this technique a very useful tool for groundwater investigations, both for locating drilling sites and for obtaining an assessment of the general extent of the depth of weathering and the location of fractured zones, which are the principal groundwater reservoirs. John and Anthony (2010) studied 2 D electrical imaging and its application in ground water exploration in part of river basin – zaria , Nigeria . The electrical imaging method has in the past proved to be a powerful technique in the subsurface geology.

Abiola *et al* (2009) studied ground water potential and aquifer protective capacity of overburden units in ado- ekiti , southwestern Nigeria . In this study, the groundwater potential and protective capacity evaluation of rock units around ado- ekiti south western Nigeria was undertaken 51 schlumberger vertical electrical soundings (V E S) . The curve type varied from simple three layers A, K and H types to the complex HQ , KH , HA , KQ , HK , HKH , HAA , KQH , KHK , and QHK types . The computer assisted sounding interpretation revealed subsurface sequence composing topsoil with limited hydrologic significance, weathered layer, partially weathered / fractured basement and fresh basement. The high variability of the thickness of the top soil appeared responsible for observed overlapping resistivity across the study area. The weathered layer constituted the sole aquifer unit in the

area; the yield being dependent on degree of clay content. The higher the clay content, the lower the groundwater yield.

Lyndsay *et al* (2006) studied canal leakage potential using continuous resistivity profiling techniques, western Nebraska and eastern Wyoming. Resistivity techniques were successful in detecting changes in grain size along interstate and tristate canals. Both CC and DC resistivity techniques were capable of mapping coarse – grained sediments. Canal leakage can be more accurately simulated in ground water models. Improved understanding of hydrogeology. Areas of maximum ground water- recharge.

Sabet (1975) studied vertical electrical soundings to locate ground water resources: a feasibility study. This is because the resistivity of water – bearing sands depends mainly on the salinity of the water, the degree of saturation, and the presence of clay and slits. The resistivity of clean sands (not containing shale or silt) and gravel saturated with fresh water ranges between 20 and several hundred ohmmeter. On the other hand, the resistivity of the same and containing silt , clay or brackish water is much lower. It is thus established that fresh ground water is unlikely produced from horizons of resistivity less than 10 ohm meter.

Gnanasundar and elango (1999) assessed the groundwater quality using geoelectrical techniques .They have identified areas of sea intrusion , between 450m and 2200m , along the coastal aquifer as well as sea water intrusion.

Senthilkumar *et al* ; (2001) studied geophysical studies to determine hydraulic characteristics of alluvial aquifer .The hydraulic conductivity of the study area was found to be range from 21 to 74 m/day . The transmissivity was found to be range from 390 to 1100 m²/ day. This study shows the geoelectrical methods can be used not only for qualitative measurements , but also for quantitative estimates of aquifer properties.

Mahmoud *et al* (2009) studied geoelectrical survey for groundwater exploration at the asyuit governorate , nile valley , Egypt . A superficial geo electrical layer mainly covered the ground surface of the area under investigation with relatively high electrical resistivity values (105 – 40400 ohm –m) and varied depth (0.43 – 35 m) . This wide ranges of the electrical resistivity values are due to dry nature and percentage of gravel and sand.

Alabi *et al* (2010) studied determination of ground water potential in lagos state university , ojo; uses dielectric methods(vertical sounding and horizontal profiling) . It is observed that VES is not so different from the horizontal profiling , because both the methods gave depth , thickness and resistivity . So it cannot be said that one method is better than the other .

Amadi *et al* (2011) studied evaluation of ground water potential in pompo village , gidan kwano , menu using vertical electrical resistivity sounding . groundwater exploration in the basement is based on weathered basement aquifer and fractured basement aquifer . The contour plots revealed that then central portion of the study area has a potential for groundwater development . Despite all the limitations of the verse technique , it has been to be reliable for groundwater exploration in the basement complex terrain , particularly when using the schlumberger configuration and combining it with adequate geological mapping and using computer aided interpretation of the survey data.

Clark and Richard (2011) studied inexpensive geophysical instruments supporting ground water exploration in developing nations . With the cost so reasonable (less than 850 dollars) this equipment should become common among those desiring to provide water in developing countries . The instruments are small , light , robust , inexpensive and easy to construct . With the free software available the interpretation of data is not difficult , although care is still needed.

Joseph olakunle coker (2012) vertical electrical sounding (VES) methods delineate potential groundwater aquifers in akoo area , Ibadan , southernwestern Nigeria . Groundwater potential aquifers producing zones have been delineated through investigation

conducted by electrical resistivity survey . Weathered and fractured horizons have been identified in the study area underlying VES stations , and all of these constitutes the aquifer zones. Good prospects therefore exist for groundwater development in the study area where the depth to bedrock and high resistivity value have a lower potential aquifer .

Rosli saad *et al* (2012) groundwater deduction in alluvium using 2-D electrical resistivity tomography (ERT) . Groundwater will lower the resistivity value and silt also will bring down the resistivity value lower than the groundwater effect.

Mohamed metwaley *et al* (2012) groundwater exploration using geoelectrical resistivity technique at Al- quwy yia area central Saudi Arabia . Resistivity surveys were carried out in Al Quwy' yia area at the central part of Saudi Arabia to map the aquifer and groundwater potentiality in promising area close to Riyadh . The results of 1D and 2D resistivity data interpretation indicated the depth to basement at the southwestern part of the study area as well as the contact boundary between the basement complex and sedimentary rocks .

The static water table is found to be matching with the limestone rock as indicated from the comparison between the individual VES and the two wells in the study area . The thickness of the aquifer is increasing in the north eastern part where the possibility is of groundwater potentiality is increasing .The results of 1D data set were confirmed by 2D section interpretation . The difference between two data sets are observed only in the shallow parts as the 1D inversion is collected in dense manner and constrained with the available geological information . Collecting more data using deep VES and time domain electromagnetic are recommended for more analysis of the aquifer in the eastern part of the study area.

Yadav and shashi kant (2007) studied integrated resistivity surveys for delineation of fractures of groundwater exploration in hard rock areas. The efficacy of combined gradient profiling (GP) and geoelectrical sounding (G S) using schlumberger configuration is presented here to map the weathered and fractured zones in hard rock areas . The present study clearly indicates the exploration of ground water resources can be done with a proper planning especially in the hard rock areas.

Meena (2011) studied exploration of ground water using electrical resistivity method . The NIT Rourkela topography and its surroundings receive an average rainfall of around 130 cm and thus there is a great need of recharge of ground water . But due to this diversity in types of deposits or formations the quality of groundwater is not satisfactory . Also because of urbanization and growth of industry , there always a risk of water pollution inside the ground water basin . For this reason it becomes important to correctly investigate the quality of the groundwater before making them for use . In prospect of the discharge obtained from the surveyed point it is originate that the point is highly potential for utilization of ground water .If all points will be collectively taken into consideration for exploitation the water necessity of the campus and the halls together with academic areas can be meet adequately. Ground water can also be exploited through large diameter water table dug wells in the valley from the unconfined aquifers . On the other hand water from these wells has to be treatd before making them for domestic and other uses.

Srivatsava *et al* (2012) studied the study and mapping of ground water prospect using remote sensing . GIS and geoelectrical resistivity techniques – a case study of Dhanbad district , Jharkhand , India . Geologically it is observed that the ground water is mainly confined to secondary porosity i.e . fractured zone , fault , joint and weathered column . It is observed from the field survey and also from various wells located in region ,the hard granite gneisses and meta basic dykes sometimes act as barriers for the ground water flow in the region .

Selvam and Subramanian (2012) studied groundwater potential zones identification using geoelectrical survey : A case study from medak district , Andrapradesh district , India . The present work has shown that in the hard rock environment , vertical electrical sounding (VES) has proved to be very reliable for ground water studies and therefore this method can be excellently used for shallow and deep underground water geophysical resistivity investigation . The most part of the study area consist of good quality of ground water because the study area is dominated by the H type curve . The top layer is the black cotton soil and is followed by weathered zone, which is H by basement rock . The best layer which act as the good aquifer of medak districts is the second layer which consists of the fracture / weathered rock formations of the depth between 5m and 15m

Lateef (2012) studied geophysical investigation for groundwater using electrical resistivity method – A case of annunciation grammar school , Ikere Lga , Ekiti state , South – western Nigeria . Vertical electrical sounding technique of the electrical resistivity method has proven to be successful and highly effective in the identification and delineation of subsurface structures that are favourable for ground water accumulation in a crystalline basement complex area . The electrical resistivity survey method used in this project entails locating a favorable borehole at annunciation school , Ikere – Ekiti revealed five subsurface geo electrical layers. These consist of topsoil , weathered layer and the fractured basement . However the fractured basement is found in all the segments of the study area

Elasyed I.selim *et al* (2010) used two dimensional (2D) electrical resistivity imaging at the western shore of old Luxor city , Egypt . The geophysical survey methods offer the possibility of characterize and reconstruct the subsurface without destroying the minerals . The interpretation 2 – D resistivity imaging shows that there are two layer arranged from the top to bottom of the soil as solid layer consist of weathered clay. N. Kazakis *et al* (2016) used ERT to determine the geometrical characteristics of saline aquifer . An abnormal distribution of sea water intrusion was recorded by using the ERT (electrical resistivity technique) . The advantage of using ERT is that more data can be collected without a limited hydrochemical samples.

METHODOLOGY

There are several variants in electrical methods. In fact, largest variety of methods is possible in electrical prospecting and it will be no surprise if new methods are developed in future. In electrical methods either the natural electrical field in an area is investigated or the ground is charged by an artificial electrical field and the distribution of the electric field at the surface of the earth is investigated.

1.2 Electrical Resistivity Prospecting

Among the geophysical techniques, electrical resistivity methods enjoys the greatest popularity and are widely used for both regional and detailed groundwater surveys because of its better resolving power, less expenses as well as range of applicability.

The electrical resistivity methods has been used in this study in order to,

1. Delineate potential zones of ground water
2. Find out the thickness of saturated zones, depth to the basement topography
3. To determine the salt water-fresh water horizons with reference to space.

4.3. Apparent Resistivity

The ability to conduct current is an important physical property of rock forming minerals and this property is made use of in electrical prospecting .Electrical resistivity surveying is based on measuring of the resistivity ‘ ρ ’ of subsurface by passing a known electric current into the ground and measuring the potential difference between two points.

The technique is based on the validity of Ohm's law for linear conduction which is represented as,

$$R = \frac{\Delta V}{I}$$

Where,

R = Resistivity in Ohm's to the flow of current.

I = Current in Amperes

V = Potential difference in volts across the two end faces of a conductor

The resistance of the medium is directly proportional to its length 'L' and is inversely proportional to its sectional area 'A', so that

R proportional to L/A

i.e., $R = \rho L/A$

or

$\rho = R \cdot A/L$

While carrying out the survey in the field, either direct current or low frequency alternating current introduced into the ground, through two current electrodes (A, B) and the potential difference is measured between another pair of (potential) electrodes (M, N). By considering the values of current, potential difference and the geometry of electrode configuration it is possible to compute the resistivity of the material as

$$\rho = \frac{2\pi \times \Delta V}{(1/AM - 1/BM - 1/AN + 1/BN)} \times I$$

Where AM, BM, AN, and BN are the inter electrode distances.

The factor,
$$\frac{2\pi \times \Delta V}{(1/AM - 1/BM - 1/AN + 1/BN)}$$

is referred to as the geometric constant K, of the configuration used.

Hence,

$$\rho = \frac{K \cdot \Delta V}{I}$$

The resistivity measured by the above method is said to be the true resistivity of the medium only when the measurements are made over a homogeneous and isotropic medium. As the earth's subsurface generally is not so, the measured resistivity is not the true resistivity and is said to be the 'apparent resistivity' (ρ_a).

4.4. Electrode configuration

In actual field measurement, a variety of electrode arrangements or configurations are used, the difference being in the inter-electrode distance and geometry. The most commonly employed configuration are the Wenner and Schlumberger arrangements.

4.4. a. Wenner Configuration

In the Wenner electrode array, all the four electrodes, equidistant with respect to each other, are kept along a straight line, the outer two being the current electrodes. The inter electrode distance is commonly denoted by the letter 'a'. The relationship for apparent resistivity ρ_a , for Wenner configuration is given by,

$$\rho_a = 2\pi a R$$

Where 'a' = distance between successive electrodes.

4.4. b Schlumberger Configuration

The Schlumberger electrode configuration is also a symmetrical array like Wenner, but differs in placing the two current electrodes with a much larger interval than that between the potential (inner) electrodes. Only one set of electrodes either potential or current are

moved to expanded intervals at a time while conducting depth soundings unlike in Wenner array where there are four electrodes are moved simultaneously. The current electrodes are denoted by A and B, while the potential electrodes are denoted by M and N. The interval between M and N is denoted by 'b' while the interval AB is denoted by 'a'. The apparent resistivity is given by,

$$\rho_a = KR;$$
$$K = \pi \frac{AM \cdot AN}{MN};$$

K= Configuration constant

R = Obtained resistance

There are several other electrode configurations which are modifications of Wenner and Schlumberger arrangements, such as Lee partitioning, Carpenter tri-electrode arrangement, Single arrangement and Dipole system of electrode arrangement.

4.5. Field Procedure

Resistivity methods are employed for both lateral and vertical exploration

1. Resistivity profiling for lateral exploration,
2. Resistivity sounding for vertical exploration.

4.6. Resistivity Profiling

Horizontal profiling is done to examine lateral variations in the subsurface in the area of interest. A series of measurements of resistivity are carried out with constant electrode spacing, moving the whole of the electrode arrangements consecutively to a number of points along a given line. The apparent resistivities so obtained are plotted on the central points of the array along a profile. This method is also termed 'Constant depth traversing or Electrical trenching'. Structures like dyke, faults, shear zones (apart from changes in rock types) etc, which are generally associated with lateral variations, can be investigated by the profiling method.

4.7. Vertical Electrode Soundings (V.E.S)

In resistivity sounding, the measurements are made at one location (keeping the centre of the electrode system fixed) for various values of current electrode separations starting from an initially small value to several hundred meters, depending on the depth of interest. This is because, in general, larger the electrode separation, greater will be the depth of investigation. The variation of the apparent resistivity with current electrode separation thus obtained would give the variation in the electrical characteristics of the formation with depth. This method (V.E.S) is most commonly applied for groundwater investigations and will be discussed in detail in this project work.

Resistivity survey should be made paying due attention to possible disturbing elements such as pipe lines, wire fences, rail tracks, etc. These methods cannot be used in the vicinity of power plants, substations, high tension power lines and similar sources of extraneous earth currents which would adversely affect the accuracy of the field measurements.

4.8. Interpretation of Resistivity data

Interpretation of the electrical resistivity data in terms of the subsurface geology and hydrology forms two most important phase in the exploration of groundwater. The aim of interpretation of resistivity is to determine the thickness and resistivity of different horizons present. Interpretation of V.E.S data is both quantitative and qualitative. The type of V.E.S curve obtained indicates the qualitative nature of subsurface that may be expected in an area.

For example; a H type curve in a hard rock terrain may be interpreted as comprising of (1) a dry top soil cover followed by (2) moist weathered rock/regolith, underlain by (3) the bed rock. There are many ways to interpret the resistivity data starting from empirical method to sophisticated techniques using fast computers. In this project work all the resistivity data are interpreted with the help of Auxiliary Point Chart (APC) Method.

4.9. Auxiliary Point Chart Method

A much faster way of solving a V.E.S curve makes use of two layer theoretical curves and the so called Auxiliary Point Charts (Bhattacharyya and Patra, 1968). Two Auxiliary charts are needed H-type for A and H-type V.E.S curves and Q-type for Q and K type curves. This method can be used for solving three or more layered VES curves.

The first part of the curve (two layers) is matched with either the ascending or descending two-layer theoretical curves, as the case may be and the origin of the type curve is marked on the field curve sheet. The co-ordinates of the origin of the master curves as read on the field curve will give the value of ρ_1 and h_1 (resistivity and thickness of the first layer). The theoretical curve also gives the ratio of ρ_2/ρ_1 from which ρ_2 can be calculated.

There are four types of three layer curves. They are H-type, A-type, K-type and Q-type of curves. In the H-type the resistivity of the intermediate layer (layer ρ_2) is lower than top layer (ρ_1) and bottom layer (ρ_3), i.e. $\rho_1 > \rho_2 > \rho_3$. In A-type curve, the intermediate layer (ρ_2) is more resistive than first layer but less resistive than the third layer, i.e. $\rho_1 < \rho_2 < \rho_3$. In Q-type the resistivity of the intermediate layer is less than that of the top and bottom layer, i.e. $\rho_1 > \rho_2 > \rho_3$.

While interpreting a three layer field curve, the left hand part of the curve is superposed on the suitable set of two layer master curve and the values of ρ_1 and h_1 are obtained. The right hand part of the field curve is matched with the suitable two layer master curve and the origin of this match gives the ratio ρ_3/ρ_2 , ρ_2/ρ_1 is read from the graph and ρ_3 is calculated. Then the field curve is superposed on the proper set of Auxiliary Point Chart (i.e., A, K and Q) with the points (h_1, ρ_1) on the origin of the chart, and the ratio h_2/h_1 is read from the chart, and h_2 can be calculated.

Interpretation of four layer and multi layer curves involve the same procedure as described above, but in this case the field curves has to broken up in to more than two parts depending upon the number of layer encountered. All the field curves obtained from the study area were interpreted using this Auxiliary Point Chart method.

RESISTIVITY INVESTIGATIONS IN THE STUDY AREA

4.1. Resistivity field work

Vertical electrical soundings were carried out in the field by using schlumberger configuration. In all 11 soundings were carried out from Thiruporur to Mahabalipuram and analyzed. The minimum and maximum values of $AB/2$ chosen for the surveys are 1 meters to 60 meters. The field VES curves are discontinuous in nature, the discontinuity caused by the shifting of potential electrodes during the soundings. For analysis of VES curves, a continuous curve is required and this is obtained by smoothening of field curves. The smoothening was done by shifting the curve segments parallel to $AB/2$ axis till all the segments are joined together. The apparent resistivity data of VES locations have been plotted on log-log graph and matched with the master curves for obtaining the layer parameters (resistivity and thickness). Results of VES interpretation is given in the Table.4.1.

4.2. Data interpretation

4.2.1. Field Curve interpretation

Table. 4.1. Results of VES interpretation

VES	ρ_1	ρ_2	ρ_3	h1	h2	h3
1	16.5	9.2	--	1.9	3.2	--
2	45.2	285	650	2	3.8	5.2
3	65.2	310	1425	2.1	5.8	7.2
4	70.1	263	1665	2.9	6.5	--
5	3455	329	789	2.8	17.8	21.5
6	2.3	8.9	67.1	2.5	7.1	--
7	8.2	110.5	--	2.4	1.8	--
8	152	28.2	--	1.4	7.6	--
9	12.3	62.1	--	2.5	5.1	--
10	105	5.7	275	1.1	3.96	25
11	22.1	17.3	--	2.3	6.5	--

VES -1

Two layers were found in this location. The first layer resistivity and thickness are 16.5 Ohm meters and 1.9 meter respectively. The second layer resistivity and thickness are 9.2 Ohm meters and 3.2 meters respectively. The third layer resistivity and thickness are infinity respectively.

VES -2

In this location three layers were found. The first layer resistivity and thickness are 45.2 Ohm meters and 2 meters respectively. The second layer resistivity and thickness are 285 ohm meters and 3.8 meters respectively. The resistivity and thickness for third layer are 650 ohm meters and 5.2 meters respectively.

VES - 3

Three layers are found in this location. The first layer resistivity and thickness are 65.2 Ohm meters and 2.1 meters respectively. The second layer resistivity and thickness are 310 Ohm meters and 5.8 meters respectively. The resistivity and thickness for third layer are 1425 Ohm meters and 7.2 meters respectively.

VES - 4

Three layers are found in this location. The first layer resistivity and thickness are 70.1 Ohm meters and 2.9 meters respectively. The second layer resistivity and thickness are 263 Ohm meters and 6.5 meters respectively. The resistivity and thickness for third layer are 1665 Ohm meters respectively.

VES - 5

Three layers are found in this location. The first layer resistivity and thickness are 3455 Ohm meters and 2.8 meters respectively. The second layer resistivity and thickness are 329 Ohm meters and 17.8 meters respectively. The resistivity and thickness for third layer are 789 Ohm meters and 21.5 meters respectively.

VES - 6

Three layers are found in this location. The first layer resistivity and thickness are 2.3 Ohm meters and 2.5 meters respectively. The second layer resistivity and thickness are 8.9 Ohm meters and 7.1 meters respectively.

VES - 7

Two layers are found in this location. The first layer resistivity and thickness are 8.2 Ohm meters and 2.4 meters respectively. The second layer resistivity and thickness are 110.5 Ohm meters and 1.8 meters respectively.

VES – 8

Two layers are found in this location. The first layer resistivity and thickness are 152 Ohm meters and 1.4 meters respectively. The second layer resistivity and thickness are 28.2 Ohm meters and 7.6 meters respectively.

VES – 9

Two layers are found in this location. The first layer resistivity and thickness are 12.3 Ohm meters and 2.5 meters respectively. The second layer resistivity and thickness are 62.1 Ohm meters and 5.1 meters respectively.

VES – 10

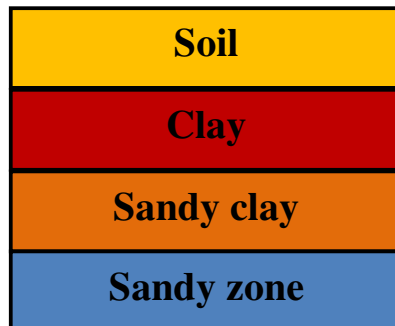
Three layers are found in this location. The first layer resistivity and thickness are 105 Ohm meters and 1.1 meters respectively. The second layer resistivity and thickness are 5.7 Ohm meters and 3.9 meters respectively. The resistivity and thickness for third layer are 275 Ohm meters and 25 meters respectively.

VES – 11

Two layers are found in this location. The first layer resistivity and thickness are 22.1 Ohm meters and 2.3 meters respectively. The second layer resistivity and thickness are 17.3 Ohm meters and 6.5 meters respectively.

4.2.2 Analysis with “Resist – 87”

The Resist-87 output shows good match with the concept of three-layers and few cases it matches perfectly. Based on the interpretations a typical geo-electric cross section arrived for the study area is as follows:



In the study area the first layer resistivity ranges from 2.3 to 3455 ohm-m (Fig.4.1a). The high resistivity of the first layer has been observed in the southern part (near coastal) of the study area. In the study area the second layers resistivity range from 5.7 to 329 ohm-m (Fig.4.1b). The high resistivity of the second layer has been observed in the central part, northern and southern of the study area. The high resistivity value has been observed near coastal area of the study area. Some of the locations recorded the resistivity value decreases may be due seawater intrusion. The thickness of the first layer ranges from 1.1 to 2.9 metres (Fig 4.2a) and the higher thickness has been observed in the southern and central part of the study area. The thickness of the second layer ranges from 1.8 to 17.8 metres (Fig 4.2b). The higher thickness has been observed in southern part of the study area. The final output of the results that the thickness of the third layer ranges from 5.2 to 25 meters.

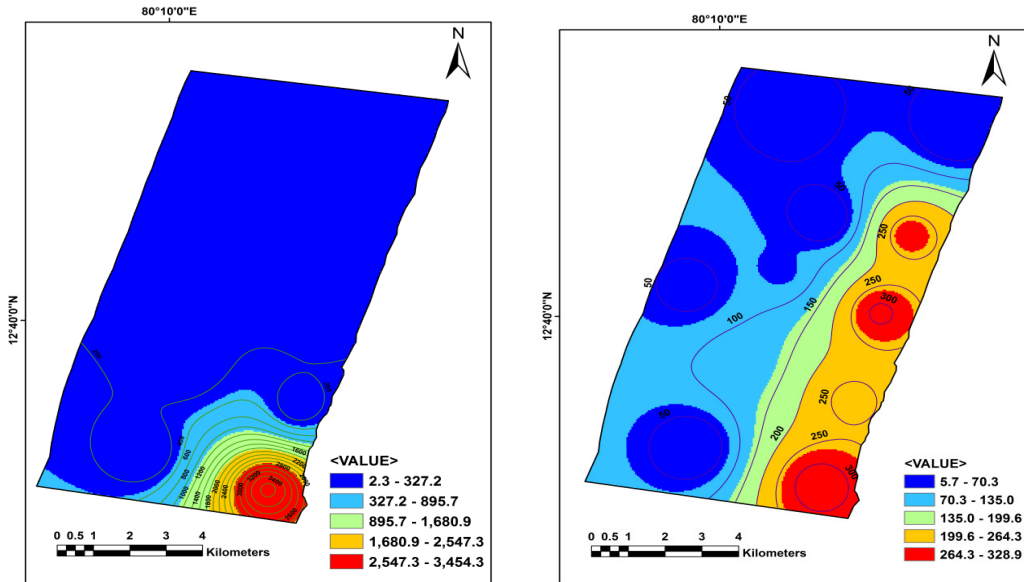


Fig.4.1. Spatial distribution of resistivity layers one ρ_1 and two ρ_2

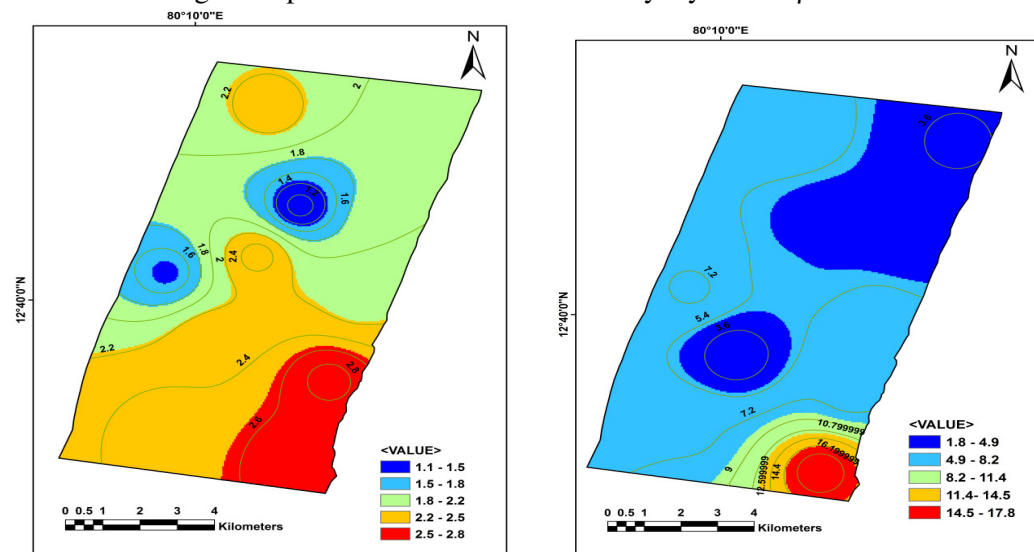


Fig.4.2. Spatial distribution of thickness of first layers (h1) and second (h2)

RESULTS AND CONCLUSION

Geologically the study area comprises of charnokite rocks of Precambrian complex and dolerites, which is classified as hard rocks as far as Hydrogeology is concerned. Out crops of these rocks are noticed in a few places. Joints and fractures are present in these rocks, these are very favorable for groundwater potential and recharge. Alluvium is found from the surface to a depth 5m in many places. This also increases the groundwater potential. The electrical resistivity investigations were carried out to understand the subsurface conditions prevailing in the area. Data is analyzed using curve matching techniques. Interpretation of resistivity data shows the presence of saline water in the east of the study area as indicated by the low resistivity values. Interpretation of resistivity data also reveals that the top soil cover

ranges from 1.2 meters to 2.2 meters followed by weathered zone and bedrock with very high resistivity.

The high resistivity of the first layer has been observed in the southern part (near coastal) of the study area. The high resistivity of the second layer has been observed in the central part, northern and southern of the study area. The high resistivity value has been observed near the coastal area of the study area. Some of the locations the resistivity values decrease may be due to seawater intrusion. The higher thickness of the first layer has been observed in the southern and central part of the study area. The higher thickness of the second layer has been observed in the southern part of the study area. In conclusion, it can be said that the electrical resistivity studies have helped in understanding the subsurface hydrology and the occurrence of saline and brackish water in the northern and center part of the study area indicating that it is contaminated by the landward migration of saline water from the backwater in the area. A detailed work in this area will help as in understanding the geology of the area and to determine the ground water potential zones to manage and enhance the ground water with the help of rain water harvesting structures in the fractured, weathered and altered rock layers.

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