“Subsurface investigations in lower Palar river basin using vertical electrical resistivity surveys”

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Abstract:
Geophysical methods are widely employed all over the world due to its reliability and accuracy. Resistivity is one of the geophysical methods, which is indirect method in order to understand the formation characterization, so in this study also the same method has been followed. This study done on lower Palar basin, from where nineteen locations have been identified and VES has been conducted. The soundings are critically analysed using Auxiliary point chart method from which the resistance and thickness of each layer were found and it shows the formations are heterogeneity in nature

Key words: Geo-physics, Resistivity, VES, Aquifer, Groundwater, Palar.

1. Introduction
Geo-scientists are utilizing the advancement of Geo-physical tool to better understand the mother earth, which helps them to various fields such as Oil exploration, groundwater exploration, mineral exploration etc., numerous of methods are available in geo-physics they are electrical method, seismic method, gravity method, magnetic method, electromagnetic method etc., among which electrical method is used for groundwater exploration. Resistivity method is one of the widely using methods in order to understand the formation characterization. They are different type of methods in the resistivity survey, in which the conductive method involves the use of direct current, or alternating current with frequencies less than ten cycles per second, and the study of electric field (Battacharya and Patra 1969).

1.1 Study area
The study area is situated 75 km south of Chennai City, Tamil Nadu, India. It is semiarid region with temperatures ranging between 23°C and 42°C. The annual rainfall is about 1100 mm from the southwest monsoon (June to September), northeast monsoon (October to December). Figure 1.1 gives the resistivity sounding locations in the study area falling in the parts of Kancheepuram district, Tamil Nadu. Palar River that flows through this area is a non-perennial river active only during the months of October, November, and December. It, however, has not flowed since 1999, because of scanty rainfall in the catchment area. This region is intensively irrigated, and agriculture is the main source of livelihood. Paddy, sugarcane, and groundnut are the main crops.
2. Material and Methods

Geophysical method is widely using method, especially in the groundwater exploration techniques, in which Resistivity method is cost effective and reliable too. Many investigation has been carried out using resistivity method even for hard rock terrain (Balakrishna and Ramnijachary (1979), Balakrishnan et al. (1983), Verma et al (1980), Sharma (1982), Krishnaraju (1983), Sharma and Sastri (1986), Balasubramnain (1986) and Sakthimurugan (1995). The details of materials used and methods have been adopted is following below

2.1 Geo-survey equipment

The resistivity instrument namely DDR2 from the manufacture of electrical instruments, IGS, Hyderabad is used to carry out and collect all the nineteen Vertical Electrical Soundings from the study area.

2.2 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.

2.3 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 $\rho$ 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  
$\Delta 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 $L/A$ or we can write $R$ as:  
$R = \rho \frac{L}{A}$ or $\rho = R \frac{A}{L}$

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

$$ (\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN}) \times \frac{\Delta V}{I} $$

Where $AM, BM, AN, \text{ and } BN$ are the inter electrode distances. 

The factor, $2\pi / (1/AM-1/BM-1/AN+1/BN)$ is referred to as the geometric constant $K$, of the configuration used.

Hence,

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

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 earths subsurface generally is not so, the measured resistivity is not the true resistivity and is said to be the ‘apparent resistivity’ ($\rho_a$).

2.4 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 is the Wenner and Schlumberger arrangements. Bhattachary and Patra (1969) and also by Bhimasankaran et. al. (1967) discussed the merits of Wenner and Schlumberger arrays. They all orate that Schlumberger arrangement is best since less time consuming as the movement of potential electrodes are fewer.

2.4.1 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 $\rho_a$ for Wenner configuration is given by,

$$ \rho_a = \frac{2\pi a V}{I} $$

Where ‘a’ = distance between successive electrodes.
2.4.2 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,

\[ \rho_a = KV/I; \quad K = \pi \frac{AM \cdot AN}{MN} \]

\[ K = \text{Configuration constant} \]

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.

2.5 Field Procedure

Resistivity methods are employed for both lateral and vertical exploration

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

2.5.1 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 is generally associated with lateral variations, can be investigated by the profiling method.

2.5.2 Vertical Electrode Soundings (VES)

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 (VES) 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.

The nineteen vertical electrical depth soundings (VES) were taken for critical analysis of the qualitative and quantitative interpretations. The nineteen numbers of sounding were initially matched manually with the master curves prepared for vertical electrical sounding by the ERNESTO ORELLANA and HAROLD M. MOONEY, INTERCIEN Costanilla de Los Angeles, Madrid 1966.

2.6 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 VES data is both quantitative and
qualitative. The type of VES 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 study, all the resistivity data are interpreted with the help of Auxiliary Point Chart (APC) Method.

2.6.1 Auxiliary Point Chart Method

A much faster way of solving a VES curve makes use of two layer theoretical curves and the so called Auxiliary Point Charts (Bhattacharyya and Patra, 1969). Two Auxiliary charts are needed H-type for A and H-type VES 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 \( \rho_1 \) and \( h_1 \) (resistivity and thickness of the first layer). The theoretical curve also gives the ratio of \( \rho_2/\rho_1 \) from which \( \rho_2 \) 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 is layer (\( \rho_2 \)) is lower than top layer (\( \rho_1 \)) and bottom layer (\( \rho_3 \)), i.e. \( \rho_1 > \rho_2 > \rho_3 \). In A-type curve, the intermediate layer (\( \rho_2 \)) 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 \( \rho_1 \) 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 \( \rho_3/\rho_2 \). \( \rho_3 \) is read from the graph and \( \rho_2 \) 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 (\( h_1, \rho_1 \)) 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. The details of the procedure are given by Zohdy 1965.

All the field curves obtained from the study area were interpreted using this Auxiliary Point Chart method.

3. Results and discussions.

The Resistivity field data has been utilized to estimate the true resistivity. The result of Vertical electrical sounding is given in the table 3.1, which containing true resistivity of individual layers along with the thickness of the same.

3.1 VES locations

There are four layers were found in the VES1 location. The first layer resistivity and thickness is 4400 Ohm meter and 1.5 meter respectively. The second layer resistivity and thickness are 628 Ohms meters and 3.75 meters respectively. The third layer resistivity and thickness are 100 Ohms meters and 7.8 meters respectively. The fourth layer resistivity is 480 Ohm meters. VES 2 location has four layers. The first layer resistivity and thickness is 540 Ohm meter and 1.3 meter respectively. The second layer resistivity and thickness are 231 Ohms meters and 2.86 meters respectively. The third layer resistivity and thickness are 7.31 Ohms meters and 2.4 meters respectively. The fourth layer resistivity is 480 Ohm meters. VES 3 location has three layers. The first layer resistivity and thickness is 7600 Ohm meter and 1.7 meter respectively. The second layer resistivity and thickness are 76 Ohms meters and 3.2 meters respectively. The third layer resistivity is 770 Ohm meters. VES 4 location has three layers. The first layer resistivity and thickness is 3800 Ohm meter and 1.8 meter respectively. The second layer resistivity and thickness are 97 Ohms meters and 10.8 meters respectively. The third layer resistivity is 840 Ohm meters.
VES 5 location has three layers. The first layer resistivity and thickness is 6800 Ohm meter and 2.8 meter respectively. The second layer resistivity and thickness are 68.6 Ohms meters and 19.9 meters respectively. The third layer resistivity is 1700 Ohm meters. VES 6 location has three layers. The first layer resistivity and thickness is 4300 Ohm meter and 2.8 meter respectively. The second layer resistivity and thickness are 110 Ohms meters and 25.2 meters respectively. The third layer resistivity is 420 Ohm meters.

VES 7 location has three layers. The first layer resistivity and thickness is 2500 Ohm meter and 1.8 meter respectively. The second layer resistivity and thickness are 7000 Ohms meters and 7.2 meters respectively. The third layer resistivity is 138 Ohm meters. VES 8 location has three layers. The first layer resistivity and thickness is 11000 Ohm meter and 2 meter respectively. The second layer resistivity and thickness are 55 Ohms meters and 3.4 meters respectively. The third layer resistivity is 152 Ohm meters. VES 9 location has three layers. The first layer resistivity and thickness is 23 Ohm meter and 1.4 meter respectively. The second layer resistivity and thickness are 207 Ohms meters and 3.5 meters respectively. The third layer resistivity is 26 Ohm meters.

VES 10 location has three layers. The first layer resistivity and thickness is 32 Ohm meter and 1.7 meter respectively. The second layer resistivity and thickness are 128 Ohms meters and 3.4 meters respectively. The third layer resistivity is 264 Ohm meters. VES 11 location has three layers. The first layer resistivity and thickness is 23 Ohm meter and 1.8 meter respectively. The second layer resistivity and thickness are 19 Ohms meters and 4.8 meters respectively. The third layer resistivity is 1881 Ohm meters.

VES 12 location has two layers. The first layer resistivity and thickness is 47 Ohm meter and 1.9 meter respectively. The second layer resistivity is 20 Ohm meters. VES 13 location has three layers. The first layer resistivity and thickness is 70 Ohm meter and 1.4 meter respectively. The second layer resistivity and thickness are 7.7 Ohms meters and 2.5 meters respectively. The third layer resistivity is 507 Ohm meters.

VES 14 location has three layers. The first layer resistivity and thickness is 17 Ohm meter and 9 meter respectively. The second layer resistivity and thickness are 51 Ohms meters and 25 meters respectively. The third layer resistivity is 297 Ohm meters. VES 15 location has three layers. The first layer resistivity and thickness is 30 Ohm meter and 9 meter respectively. The second layer resistivity and thickness are 3168 Ohms meters and 7.2 meters respectively. The third layer resistivity is 1482 Ohms meters.

VES 16 location has three layers. The first layer resistivity and thickness is 33 Ohm meter and 7.5 meter respectively. The second layer resistivity and thickness are 3267 Ohms meters and 11.2 meters respectively. The third layer resistivity is 26.4 Ohm meters. VES 17 location has three layers. The first layer resistivity and thickness is 90 Ohm meter and 1.4 meter respectively. The second layer resistivity and thickness are 10 Ohms meters and 5.6 meters respectively. The third layer resistivity is 546 Ohm meters.

VES 18 location has two layers. The first layer resistivity and thickness is 13 Ohm meter and 5 meter respectively. The second layer resistivity is 65 Ohm meters. VES 19 location has three layers. The first layer resistivity and thickness is 100 Ohm meter and 1.8 meter respectively. The second layer resistivity and thickness are 17.6 Ohms meters and 3.7 meters respectively. The third layer resistivity is 75 Ohm meters.

3.2 True Resistivity

The true resistivity of the study area reveals (table 3.1) that there are three layers of deposits were found and individual layers are discussed. Over all view of true resistivity of the first layer shows most of the coastal area composed of dry sand of various thicknesses ranging from 1.3 to 2.8 metres. The rest of the study area composed of wet top soil and thicknesses ranging from 1.4 to 9 metres. The resistivity of the second layer shows most of the study area composed of alluvial deposits containing groundwater; it may consider as shallow aquifer of the study area except few locations and the second layer varies from 2.5 to 25.2 metres. In some place the alluvial contains clay deposits as pockets, which may act as barrier for vertical flow of groundwater in the aquifer. The third layer resistivity shows some of the study area contains hard rocks, especially in the north western region. The rest of the area contains possibly highly composed of alluvial deposits, which is deposit and because of the overburden, the porosity of the formation get reduced which may devoid of conductance of groundwater through the rock and which form as a confined layer. The thicknesses of third were found in two locations 1 and 2, which are 7.8 and 2.4 respectively. The resistivity of the fourth layer found in location 1 and 2, which shows the compaction of alluvial deposit is high.

An attempt has been made to understand the thickness and resistivity of the formation in the study area through the spatial distribution of the thickness and resistivity map. The spatial distribution true resistivity of first, second, third layer is given figure 3.1, 3.2 and 3.3 respectively. The thicknesses of the first and second layers are given in the figure 3.4 and 3.5 respectively. The true resistivity of the first layer is comparatively higher in the eastern part of the study area and in second layer comparatively higher in small pocket in the eastern part of study area. The third layer the true resistivity is comparatively higher in all direction except in the middle of the
The thickness of the first layer is higher in the northern and western part of the study area, whereas in the second layer, the eastern part of the study area shows high thickness comparatively.

### Result of VES interpretation
(Apparent resistivities in Ohm m and thickness of layers in m)

<table>
<thead>
<tr>
<th>VES NO.</th>
<th>$\rho_1$</th>
<th>$\rho_2$</th>
<th>$\rho_3$</th>
<th>$\rho_4$</th>
<th>$h_1$</th>
<th>$h_2$</th>
<th>$h_3$</th>
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<td>100</td>
<td>480</td>
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<td>3.75</td>
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<td>540</td>
<td>231</td>
<td>7.3</td>
<td>138</td>
<td>1.3</td>
<td>2.86</td>
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<tr>
<td>3</td>
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<td>1.8</td>
<td>3.7</td>
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Fig. 3.1
Spatial distribution of True Resistivity for the First layer in the study area

Fig. 3.2
Spatial distribution of True Resistivity for the Second layer in the study area
4. Conclusions

Resistivity method has been adopted, in which Vertical electrical Sounding (VES) was conducted. Various Apparent resistivity values have been calculated and from which the true resistivity and thickness of various layers were estimated using Auxiliary Point Chart method. The thickness and resistivity of first layer is ranges from 1.3 to 2.8 meters and 13 to 11000 Ohms respectively. The thickness and resistivity of second layer is ranges from 2.5 to 25.2 meters and 10 to 7000 Ohms respectively. Likewise the thicknesses of third layer found in two places were 2.4 and 7.8 meters, whereas the true resistivity is ranges from 7.3 to 1881 Ohms. Over all the thickness of the first layer is higher in the northern part of study area and the second layer has high thickness in eastern part.

Acknowledgement

We would like to acknowledge the CWRDM-DST for the funding provided to carry out this work.

References


