8.1 Introduction

The geophysical survey refer to the scientific measurements of physical properties of the earth crust with the intention of the detecting differences in the same which may be interpreted in terms of geological structure, rock type and porosity water content and quality. This method is most applicable in hard rock areas that can give direct confirmation of the presence of drinkable water. But these are only additional bits and pieces of information which when interpreted together with the geological observation in the integrated manner will lead to recommendations for drilling a well at such a location where chances of good potable water in adequate quantities.

There are various geophysical methods of which are generally used for ground water prospecting. The simple economic method, which is suitable for the condition of this area, is electrical resistivity method and magnetic method.
8.2 Electrical resistivity method

The electrical resistivity of a rock formation limits the amount of current passing through the formation when an electrical potential is applied. It may be defined as the resistance in ohms between opposite faces of a unit cube of the material. If a material of resistance ‘R’ has across sectional area ‘A’ having the length ‘L’ then its Resistivity can be expressed as

\[ \rho = \frac{RA}{L} \]

Units of Resistivity is ohm/metre

Resistivity of rock formation vary over a wide range depending upon the material, density, porosity, size, shape, Water content, Water quality and temperature. There is no fixed limits for resistivities of various rocks but there are certain magnitude of resistivities for different materials.

In relatively porous formations, the resistivity is controlled more by the content and quality of water within the formation then by the resistivity of the (dry) formation itself. In an aquifer composed of unconsolidated materials such as residual soil covered areas, electrical measurements can therefore directly indicate the presence and quality of water which is not possible when dealing with true hard rock ground water deposits. In those areas the value of these method lies in its capacity to measure the depth to bed rock. Presence of fractures in hard rock without any moisture can show low
conductivity whereas presence of moisture or water can give high conducting power.

In the field work the electrodes are arranged along a straight line, the potential electrodes placed inside the current electrode and symmetrically disposed with respect to the center of the configuration. The configuration of the symmetric type that mostly used are those introduced by Wenner and Schlumberger. There layouts are shown in fig.

\[
\begin{align*}
&\text{A} - \text{M} - \text{N} - \text{B} \\
&\downarrow \quad \downarrow \quad \downarrow \\
&a \quad a \quad a
\end{align*}
\]

\begin{align*}
&\begin{array}{c}
A & M & N & B \\
\downarrow & \downarrow & \downarrow & \downarrow \\
& a & a & a \\
& b & & \downarrow & \downarrow & \downarrow
\end{array} \\
&\text{AB} = l \quad \text{MN} = b
\end{align*}

\text{Wenner configuration} \quad \text{Schlumberger configuration}

By inserting the symbols used in the figure the following formula are obtained for the computation of resistivity from measured potential difference.

For Wenner configuration

\[
\rho_a = 2\pi aR = KR
\]

where \( K \) = constant.

\( R \) = resistance in ohms
For Schlumberger configuration

\[ \rho_a = \Pi \left( \frac{(l/2)^2 - (b/2)^2}{b} \right) \times R = KR \]

The factor K is called geometric factor and depends only on the electrode intervals. R corresponds obviously to the resistance of the volume of ground between the potential surface passing through the potential electrodes. If the distances is in meters then the resistivity obtained is in ohm-metres. This corresponds to the true resistivity if the ground is homogeneous and isotropic when obtained from measurements on heterogeneous ground it is an apparent resistivity and is denoted by \( \rho_a \).

There are two different techniques of carrying out resistivity investigations. One is horizontal profiling and other is the vertical electrical sounding (VES) or vertical profiling.

**8.2.1 Horizontal Profiling**

This method is used to determine the variation in the apparent resistivity in a horizontal direction within the preselected depth range. The length of the electrode configuration must be carefully chosen since it is the dominating factor for depth penetration. The traverses are normally oriented perpendicular to the geological striking direction. Parallel three or more traverses facilitates the identification and correlation of anomalies from line to line. The distance between the traverse depends upon the problem and
investigation. The horizontal profile is of immense one in deciphering horizontal structural variation like fault zone, shear zone, jointed areas which shows very low resistivity due to the presence of large number of fractures filled with ground water.

8.2.2 Vertical Profiling (VES)

Contrary to the horizontal profiling in which the apparent resistivity is studied directly and qualitative conclusion are drawn about the geological subsurface conditions, the method of electrical sounding or vertical profiling furnished the detailed information on the vertical succession of different conducting zones and their individual thickness and true resistivities. For this reason the method is particularly valuable for investigation on horizontally or near horizontally stratified ground.

In electrical sounding the mid point of the electrode configuration is fixed at the observation station while the length of the configuration is gradually increased as the result thereof the current penetrates deeper and deeper: the apparent resistivity measured at successively increasing distances between the current electrodes becomes more and more affected by the resistivity condition at the layer depths. When using Schlumberger configuration the interval between the potential electrodes is increased only few times and in relatively small steps in order to obtain potential differences large enough to be measured. Normally the potential electrode distance will be maintained more than 1/5th of the current electrode distance.
8.2.3 Geo-electric parameters

The geo-electric parameters separated by the layers of different resistivities may or may not coincide with the boundaries separating layers of different geologic sections due to variation in mineral composition and fluid content. A geo-electric layer is described by the fundamental parameters; its resistivity 'p' and its thickness 'h' (Zohdy, 1969). The other geo-electric parameters derived from its resistivity and thickness are

- Longitudinal conductance: \[ S = \frac{h}{\rho} \]
- Transverse resistance: \[ T = h \times \rho \]
- Longitudinal resistivity: \[ \rho_L = H / S \]
- Transverse resistivity: \[ \rho_t = T / h \]
- Anisotropy: \[ \lambda = \sqrt{\frac{\rho_t}{\rho_L}} \]

These secondary geo-electric layers are important to describe the geo-electric section consisting of several layers. For \( n \) layers, the total longitudinal conductance is

\[ S = \left( \frac{h_1}{\rho_1} \right) + \left( \frac{h_2}{\rho_2} \right) + \ldots + \left( \frac{h_n}{\rho_n} \right), \text{ and} \]

the total transverse resistance is

\[ T = \left( \frac{h_1 \cdot \rho_1}{h_1} \right) + \left( \frac{h_2 \cdot \rho_2}{h_2} \right) + \ldots + \left( \frac{h_n \cdot \rho_n}{h_n} \right), \]

The unit of longitudinal conductance are

\[ \text{m/ohm-m} = \frac{1}{\text{ohm}} = \text{mho}. \]
The longitudinal conductance can be correlated with the hydrological parameter of an aquifer by

\[ S = \frac{h}{\rho} = \sigma \cdot h \] where \( \sigma \) is the conductivity (inverse of resistivity) which is analogous to Transmissivity \( T = k \cdot b \) where \( k \) is the aquifer hydraulic conductivity and \( b \) is the aquifer thickness.

The parameter \( T \) and \( S \) are named the "Dar Zarrouk" parameter by Maillet (1947).

The \( T \) and \( S \) values are determined by the interpretation of multilayer sounding curves. The study of the parameters \( S \), \( T \), \( \rho_L \), \( \rho_t \) and \( \lambda \) is an integral part of an analysis of electrical sounding data and also is the basis of important graphical procedures for the interpretation of the electrical sounding curves (Kalenov, 1957; Orellana and Mooney, 1966; Zohdy, 1965).

8.2.4 Vertical electrical sounding curves

In a horizontally stratified medium the form of curve obtained by sounding is a function of resistivity and thickness of the layers as well as electrode configuration. The hard rock terrain behaves like a three layer medium of soil/weathered zone, fracture/fissure zone and massive rock or multilayer medium depending on the degree of weathering and fracturing. In the three layer medium, the geo-electric section is described according to the relation between the value of \( \rho_1 \), \( \rho_2 \) and \( \rho_3 \) and there are four combinations. They are

\[ \rho_1 > \rho_2 < \rho_3 \text{ ....... H type} \]
\[ \rho_1 < \rho_2 < \rho_3 \quad \text{......... A type} \]
\[ \rho_1 < \rho_2 > \rho_3 \quad \text{......... K type} \]
\[ \rho_1 > \rho_2 > \rho_3 \quad \text{......... Q type} \]

In the multi layer medium, the geo-electric section is described by the combination of H, A, K, and Q types. The curves are mostly KH and HA type in hard rock area in which the terminal branch of sounding curve rises at an angle of 45°.

8.2.5 Analysis of vertical electrical sounding curves

There are two methods of qualitative and quantitative methods of interpretation. The qualitative interpretation involves the study of the type of the curve, preparation of apparent resistivity maps at a given electrode spacing and preparation of apparent resistivity sections and profiles. These maps, sections and profiles constitute the basis of the qualitative interpretation of the electrical sounding data.

Qualitative interpretation is made by several methods such as analytical methods, semi-empirical methods and empirical methods. The semi-empirical and empirical methods are not commonly used except in the preliminary examination of sounding curves. (Zohdy, 1965).

8.2.6 Analytical method of interpretation

It is based on the calculation of theoretical sounding curves that match the observed curves. The interpretation of the multilayer curves is made by using the two layer type curves in conjunction with
auxiliary point diagrams. (Orellana and Mooney, 1966; Zohdy, 1965). With large electrode spacing of AB/2, four or more layer may be distinctly reflected on the curve in the hard rock area. The graphical interpretation of these multilayer-sounding curves is made by using three layer master curves and the auxiliary point diagrams (Bhatacharya and Patra, 1968; Kolenou, 1957; Orellana and Mooney, 1966). The accuracy of the interpretation depends on the effective relative thickness of layers and experiences of the interpreter over the terrain.

8.2.7 Depth of investigation

Divergent views are expressed by various authors regarding the depth of investigation in electrical methods. The term 'depth of investigation' was defined by Roy and Papa Ro (1971) and by schlumberger and schlumberger (1932) and Frohlich (1967). In the Schlumberger and Frohlich usage, depth of investigation is synonymous with the terms of 'depth of exploration', 'depth of penetration', 'depth of probing' etc. the limiting depth of exploration is equal to one half of AB. (Schlumberger and Schlumberger, 1932). The optimum electrode spread is nine times the depth explored (Evjen, 1938). Keller (1966) defined the effective probing depth for Schlumberger array as 'a', the half spacing between current electrode.

Frohlich (1967) of the opinion that one third to one fourth of the electrode separation in the schlumberger array equals to depth of investigation. Nabighian and Elliot (1975) are of the opinion that the
depth of penetration of the array or the search-depth depends on the
chosen array, electrode spacing, the resistivity and thickness of the
layers.

Roy and Elliot (1981) conducted a model experiment and found
that all views are correct with in a specified domain of resistivity, layer
thickness and electrode separation.

8.2.8 Geophysical investigation in the study area

Geophysical investigation using electrical resistivity method is
carried out in 20 locations in the watershed area. Schlumberger
configuration with electrode spacing of 200 m maximum is applied by
using D.C resistivity meter. Apparent resistivity for all VES is
calculated by multiplying the resistance obtained with geometric
factor.

The results of the 20 Schlumberger soundings are analyzed by
plotting the apparent resistivity values against the half-current
electrode separation (AB/2) on transparent double log graph paper
(62.5 mm) and a smooth curve is drawn for each of the soundings.
The field curves are interpreted by the method of curve matching
(Battacharya and Patra, 1968) using the two and three layer master
curves prepared by Rajkswatustaat, of the Netherlands (1975). Layer
thickness and corresponding layer resistivity are determined (Table
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Table: VIII.1 Layer resistivity and thickness p1 = Ohm-m and h1 = m

The layer resistivity and thickness are taken as model input and the field data are analysed by using the RESIST software developed for Wenner and Schlumberger configurations. The results of interpretation are shown in figure VIII.1-10. The qualitative and quantitative interpretation of the VES data shows multiple layer systems, which vary from minimum three layers, to maximum eight layers. The minimum and maximum resistivity obtained ranges from
Resistivity data analysis

Figure VIII.1

Resistivity data analysis

Weighted RMS: 4.1

Varagu Tank
Schlumberger Configuration

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* RMS on smoothed data

Resistivity data analysis

Weighted RMS: 2.2

Varagu Tank
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* RMS on smoothed data
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* RMS on smoothed data
Figure VIII.5

For the analysis, the following values were obtained:

- RMS error: 3.7
- RMS error: 3.0

* RMS on smoothed data.
Figure VIII.6

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* RMS on smoothed data
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<td>5</td>
<td>466.8</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

RMS on smoothed data
**Schlumberger Configuration**

**Kasturipatti-Pudur**

Table:

<table>
<thead>
<tr>
<th>No</th>
<th>Res</th>
<th>Thick</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
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<td>31.3</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
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<td>40.6</td>
<td>15.8</td>
<td>17.2</td>
</tr>
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<td>153.5</td>
</tr>
<tr>
<td>5</td>
<td>1178.5</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*RMS on smoothed data*

**Konangipatti West**

Table:

<table>
<thead>
<tr>
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<th>Thick</th>
<th>Depth</th>
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</thead>
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<td>1.6</td>
</tr>
<tr>
<td>2</td>
<td>128.4</td>
<td>34.4</td>
<td>35.3</td>
</tr>
<tr>
<td>3</td>
<td>2846.7</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*RMS on smoothed data*
Figure VIII.10

<table>
<thead>
<tr>
<th>No</th>
<th>Res</th>
<th>Thick</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2</td>
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</tr>
<tr>
<td>4</td>
<td>1265.7</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*MMS on smoothed data.*

**Muttancherry**

Schlumberger Configuration

**Singliankombal**

Schlumberger Configuration

Current Electrode Distance (R8/2) [m]
22 to 6277 ohm-m. Arithmetic mean of resistivity and the number of locations the layer observed in the watershed area are as below.

<table>
<thead>
<tr>
<th>Number of Layers</th>
<th>Locations</th>
<th>Resistivity ohm-m</th>
<th>Thickness m</th>
<th>Depth m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>69</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>191</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>573</td>
<td>30</td>
<td>43</td>
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<td>4</td>
<td>19</td>
<td>1120</td>
<td>26</td>
<td>69</td>
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<tr>
<td>5</td>
<td>14</td>
<td>1921</td>
<td>21</td>
<td>75</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>1031</td>
<td>27</td>
<td>96</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>1532</td>
<td>20</td>
<td>119</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>4734</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The mean resistivity values indicate that there is a steady increase in the resistivity of the layers, where as in the sixth layer which is having mean thickness of 21 metres, there is a fall in resistivity due to the development of fracture/fissures, sandwiched between the highly resistive strata.

8.2.9 Hydrogeological concept and principle of equivalence

One of the first step in planning a geophysical survey is collect the available topographical geological and structural information about the area concerned to find out what is the nature of the rocks which are likely to occur with it and find out how they are likely to be interrelated. (Paranis, 1966).
Flathe (1974, 1976), Homilius (1961), Mundry and Dennert (1980) emphasize the great importance of the geological concept for the interpretation of geo-electric sounding curves. There are two main situations for which geological concept must be developed.

The first is the external information already exists for the area such as well descriptions, logs, maps or any other data which cannot be derived from geo-electric sounding curves. The other is the model based only on the sounding curve themselves when the external information is not available.

Slicher (1933) has demonstrated that there are three main influences that cause a random distribution of every measured value of geoelectric sounding curve. The first is geological influence i.e., deviation from the horizontal of the strata and alternate thin layers with different resistivity value shown the effect of macro-anisotropy. The physical influences are anisotropy, water pipes, wires etc. Experimental influences are deviation of Schlumberger array from ideal. Koefoed (1969, 1979) has shown that the principle of equivalence is only a result of natural circumstances and not one of theory. So it is obvious that external information or a model derived for the sounding curve itself is necessary.

Hydrogeologically the hard rock can be divided into four different types

Type A posses intergranular porosity with clay content. The weathered rock which contain clay content/highly
decomposed zone fall under this category. When saturated with fresh water they have low resistivity value.

**Type B** posses intergranular porosity with out clay content and when saturated with fresh water they have intermediate resistivity values. Disintegrated zone falls in this category.

**Type C** posses fracture porosity. They are fracture/fissured but unweathered and have no clay content. Saturated with fresh water shows relatively moderate to high resistivity values.

**Type D** posses hard massive formation devoid of joints / fissures acts as an impervious layer. It bears high to very high resistivity depending on the mineral assemblage.

The resistivity of different layers are correlated with the external information of the study area and broadly grouped into five groups as below.

<table>
<thead>
<tr>
<th>Resistivity range ohm-m</th>
<th>Lithological correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100</td>
<td>Soil / highly weathered zone</td>
</tr>
<tr>
<td>100 – 300</td>
<td>Weathered / fractured zone</td>
</tr>
<tr>
<td>300 – 600</td>
<td>Fractured zone</td>
</tr>
<tr>
<td>600 – 2000</td>
<td>Fracture zone (Moderate)</td>
</tr>
<tr>
<td>&gt; 2000</td>
<td>Massive rock</td>
</tr>
</tbody>
</table>

The grouping may overlap one another due to the geological influences (Slitcher 1933) such as thin layers of near equal resistivity,
saturation with water, quality of water, clay/fine material content, degree of weathering/fracturing, mineral assemblage etc.

8.2.10 Geo-electric sections

The geo-electric sections may reveal the lateral and subsurface configurations of an area. The general trend of the formation in the watershed area is in the NE-SW and NW-SE directions and the major set of lineaments also fall on the above directions. Two sets of cross section alignment one along the major structural directions in the NE-SW direction and across the structure in the E-W directions.

The NE-SW direction cross section consists of seven VES locations such as Varagur north, Varagur tank, Devarayapuram, Erumaipatti, Ponneri, Konangipatti and Varagur (Figure VIII.11). The interpreted geo-electric parameters are arranged and plotted with ref to the ground level elevation (GL). The cross section has the slope in the NE-SW direction and falls near parallel to the main stream with the elevation difference of 60 metres. The resistivity values which are close to the groupings are made into a single layer. The resistivity values in ohm-m and water level observed during Nov '97 and Jul '99 in the nearby wells is also incorporated in the section.

The sections in the VES locations 17, 1 and 6 shows similarity when compared to the other sections. Low resistivity layers of highly fractured zone with 100-300 ohm-m exists at the depth of 70-90 metres. In the location 17, the fracture zone is sandwiched between
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Fig VIII.11 GEO-ELECTRIC CROSS SECTION ALONG SW-NE DIRECTION

Soil zone
Weathered / fracture zone
Fracture zone
Moderate fracture zone
Massive rock

Water level Nov'97
Water level Jul '99
Resistivity in ohm-m
highly resistive layers (>3000 ohm-m). The fracture zones show a gentle dip towards SE direction.

The VES locations 18, 11, 16 and 19 fall in the SW of the watershed and the fracture zone with resistivity range of 300-600 ohm-m exists at the depth of 40-70 metres. Location 6 falls in the highly transmissive zone of NW-SE lineaments and the layer with 409 ohm-m extends even below 80-metre depth.

Five VES locations such as Pottireddipatti, Erumaipatti, Devarayapuram, Kasturipatti pudur and Varagur fall in the E-W direction. Slope of the section is very gentle from east to west and except the location at Varagur the other locations are in the same level. Water level observed in the nearby wells is also incorporated in the section. (Figure VIII.12). The soil and weathered zone is followed by the fracture zone with the resistivity of 242-586 ohm-m and vary in thickness from 10-60 metres. A 10-metre thickness fracture zone with resistivity of 377 ohm-m is sandwiched between the highly resistive layer in the VES 14. A highly fractured zone of 78 ohm-m of 49 metre thickness in the location 7 confirms the shear zone in the NE-SW direction.

8.2.11 Iso-resistivity map

The interpreted data of the geo-electric sounding is used for the preparation of the isoresistivity map of the watershed area. Resistivity contour maps display the lateral variation in the subsurface geology of the area. The area with low resistivity value indicates the occurrence
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Fig VIII.12 GEO-ELECTRIC CROSS SECTION ALONG W-E DIRECTION

Depth in m

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

VES No.

2 19 6 7 14

Soil zone
Weathered / fracture zone
Fracture zone
Moderate fracture zone
Massive rock

--- Water level Nov '97
----- Water level Jul '99
409 Resistivity in ohm-m
of relatively good conductors while those with high value indicate poor conductors (Anbalagan, 1993). The resistivity value of the layer at the depth of 5, 20, 40 and 80 metres depth are selected along with the X, Y coordinates of the locations and equi-resistivity contours are prepared by using SURFER software.

8.2.12 Iso-resistivity at 5 metre depth

In the figure VIII.13, the equiresistivity map of the 5 metre depth represents the top layer resistivity mostly soil zone. It suggests that the low resistivity of < 50 ohm-m in the eastern side of the watershed and the resistivity gradually increases towards west. The resistivity values coincides with the soil group classification of the watershed where the eastern side bears with D group soil and the western part is represented by B and C group. D group soil due to its clayey nature shows comparatively low resistivity. In general the resistivity is relatively high since it lies above the mean water level.

8.2.13 Iso-resistivity at 20 metre depth

Figure VIII.14 shows the equiresistivity if the layer at the depth of 20 metres. The resistivity ranges from 200-3600 ohm-m. The western side of the watershed shows low resistivity compared to the eastern side. There is a steep rise in the resistivity in the eastern boundary may be due to the existence of poor conductive layer. Near Varagur tank low resistivity of 400 ohm-m may be due to the existence of fractured formation of high conductive nature. Near Ponneri the resistivity is 800 ohm-m and diverges in all the directions
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ISORESISTIVITY - 5 METRE DEPTH

Figure VIII.13
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ISORESISTIVITY - 20 METRE DEPTH

HILL AREA
- <200 Ohm - M
- 200 - 400
- 400 - 600
- 600 - 800
- 800 - 1000
- 1000 - 2000
- 2000 - 3000
- >3000

0.9 Kilometers

Figure VIII.14
indicating the poor conductive isolated fractured formation. Another interesting feature is the low resistivity zone of less than 200 ohm-m form a linear zone in the NW-SE direction coinciding the major set of lineaments.

8.2.14 Iso-resistivity at 40 metre depth

Figure VIII.15 shows the equiresistivity at the depth of 40 metre. The resistivity ranges from less than 200 to 4145 ohm-m and the shape of the contours are similar to those at 20-metre depth. A high resistivity in the southern side of the watershed, south of Konangipatti may be a poor conductive formation. The resistivity diverges steeply towards north and at Konangipatti the resistivity is less than 200 ohm-m. The eastern boundary of the watershed shows high resistivity. The low resistivity linear zone in the NW-SE direction from Kolli hills to Muttanchetti and in the NE-SW direction from Varagur north to Konangipatti may be indicative of existence of highly fractured (Saturated). Near Pudukottai in the western side of the watershed shows high resistivity of 800 ohm-m.

8.2.15 Iso-resistivity at 80 metre depth

Figure VIII.16 shows the equiresistivity of the layer at the depth of 80 metres. The resistivity ranges from 500 to 6000 ohm-m. contrary to the resistivity at the depth of 20 and 40 metre depth the eastern side of the watershed shows comparatively low resistivity of less than 500 ohm-m indicating the fracture zone below the massive formation. The bazada zone in the foot of Kolli hills shows the low resistivity of
Figure VIII.15

ERUMAIPATTI WATERSHED
ISORESISTIVITY - 40 METRE DEPTH

HILL AREA
<200 Ohm-M
200 - 400
400 - 600
600 - 800
800 - 1000
1000 - 2000
2000 - 3000
>3000

0.9 0 0.9 Kilometers
ERUMAIPTTI WATERSHED

ISORESISTIVITY - 80 METRE DEPTH

0.9 0 0.9 Kilometers

HILL AREA
< 500 Ohm-m
500 -1000
1000 -1500
1500 - 2000
2000 - 2500
2500 - 3500
3500 - 4000
> 4000

Figure VIII.16
less than 500 ohm-m. A very steep fall in the resistivity from 6000 to less than 1000 ohm-m is noticed from Kavakaranpatti to Konangipatti and extends up to Erumaipatti.

8.2.16 Hydraulic transmissivity estimation

Flow of current during surface resistivity measurement and flow of water to a well during pumping, follow approximately the same path of least resistance (Yadav et al, 1994). The mode of conduction of electricity with in and around pores is ionic and thus the resistivity of the medium is controlled more by porosity and water than resistivity of rock matrix. Thus at the pore level the electrical path is similar to the hydraulic path and the resistivity should reflect hydraulic conductivity.


8.2.17 Analytical approach

Archie (1942) have experimentally established that resistivity of clean, water-bearing formation is proportional to the resistivity of the brine with which it is fully saturated. The constant of proportionality is called the Formation factor F. Thus if R is the resistivity of fully saturated formation brine resistivity of Rw then

\[ F = \frac{R}{R_w} \]
For a given porosity the ratio of $R/R_w$ remains constant. Though the porosity has no meaning for the 'fissured and fractured zone' of the hard rock an equivalent value of porosity can be obtained using the relation (Panchanathan, 1974)

$$\phi = \sqrt{1/F} = \sqrt{R/R_w}$$

Hydraulic conductivity $K$ is analogous to the hydraulic transmissivity $T$ used in ground water hydrology given by

$$T = Kb$$

where $b$ is the aquifer thickness. Niwas and Singhal (1981 & 1983) determined analytically the relationship between transmissivity and modified transverse resistance $Z'$ as

$$T = (K/R')Z'$$

Where $R' = R*R_w/R_w$, $R_w$: the average water resistivity which is the normalised aquifer resistivity and $Z' = Z* R_w/R_w$ which is the modified transverse resistance of the aquifer. From the same analogy it can also be analytically established that if the hydraulic conductivity of the aquifer material increases their longitudinal conductance $S$ decreases in the same order. Hence it can be rewritten as

$$T = (KS') R'$$

Where $S' = S * R_w/R_w$ is the normalised longitudinal conductance. It is clear from the above equation that transmissivity should be related to the normalised aquifer resistivity provided $KS'$ remain constant for an area.
8.2.18 Data interpretation

Out of the 20 VES locations interpreted, 8 locations fall near the existing borewells being pumped for water supply schemes. Pumping test to assess the aquifer characters is also conducted in the 8 borewells and water samples are collected and tested. The resistivity of the water is derived from the electrical conductivity (EC) values by

\[ R_w (\text{ohm-m}) = \frac{10000}{\text{EC (micro mhos/cm)}} \]

The layer parameter obtained with resistivity and layer thickness is shown in table VIII.1. The thickness of the fracture zone is assessed from the layer resistivity, which are correlated with yielding zones of the existing borewells. If two or more fracture zones occurs the cumulative thickness is taken as aquifer thickness. The calculated values of water resistivity, normalised aquifer resistivity, hydraulic transmissivity (calculated and observed) are presented in the Table VIII.2.

8.2.19 Correlation of observed and calculated ‘T’

The calculated hydraulic transmissivity and the observed transmissivity during pumping test is correlated and shown in figure VIII.17. It indicates that the transmissivity calculated and observed are well correlated. The parameter of the regression line \( T(\text{observed}) = 0.712 \times T(\text{cal}) - 21.362 \).
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Figure VIII.17 Observed T Vs calculated T

y = 0.712x - 21.362
Table VIII.2 Aquifer thickness & resistivity, water resistivity, normalised resistivity, T calculated and observed.

8.2.20 Longitudinal conductance Vs Transmissivity observed and calculated.

The longitudinal conductance ‘S’ is calculated based on the layer thickness and resistivity interpreted. In the KH and HA type curves, which are common in the hard rock area the terminal branch of the sounding curve rises at an angle of 45° (S line). This usually indicates the layer of high resistivity. The intercepts of the extension of the S line with the horizontal line gives the S value on mho.

S value can also be calculated from the formula (Pathangay, 1971)

\[ S = \frac{(AB/2)}{p_a (Ab/2)} \]
In case of expected KH and HA type curves measurement of apparent resistivity by employing one or two large AB/2 separation is sufficient to determine $S$ at a place.

The $S$ value depends on the following factors (Natesan and Jayakumar, 1997)

The value will increase when

- Increase in thickness of weathered zone
- High conductivity of weathered zone
- Saline water in the weathered zone

The value will decrease when

- Decrease in thickness of weathered zone
- Presence of fracture zone
- Thin weathered zone followed by fracture zone
- Saturated with fresh water in the weathered and fractured zone

The longitudinal conductance is correlated with the Transmissivity $T$ calculated (Figure VIII.18) and Transmissivity observed during pumping test (Figure VIII.19). In both cases they are negatively correlated. The parameter of the regression line
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Figure VIII.19 Longitudinal conductance Vs 'T' calculated

\[ y = -1456.2x + 536.05 \]
Figure VIII.19 *Longitudinal conductance Vs 'T' observed*

\[ y = -1028x + 358.05 \]
The above regression line equation can be used for estimating the transmissivity with geo-electric sounding results while selecting a new site in the watershed area.

8.3 Magnetic method

Water is non-magnetic and ground water of any quality or quantity cannot produce any appreciable magnetic field parameter on the surface. Therefore in ground water prospecting magnetic method turns out to be an indirect approach, mostly employed in investigating geological structural configuration of the subsurface under favorable circumstances. Magnetic method can also be used to trace the zones of chemical weathering by ground water on ferruginous rock strata when water action turns ferric iron to ferrous, etc. in the places of reduction, heamatite transforms into magnetite causing changes in magnetic properties and therefore magnetic anomalies.

In principle, magnetic method of prospecting begins with measuring the total or vertical component of magnetic field in an area using sensitive magnetometers. Magnetic surveys are conducted on the ground at selected points along traverses or in grid. The magnetic field is corrected for the time and space variation of the earth's field and referred to a base so that magnetic anomaly contours or profiles
are constructed. These anomalies are then qualitatively to infer the nature of the subsurface and quantitatively to estimate the position, size, shape, extent and attitude of the anomaly objects. Surface and subsurface geological and geophysical information of the area and magnetic properties of the rocks will help in guiding the magnetic interpretation towards a reliable result.

8.3.1 Assessment of weathered zone thickness

Weathering in hard rock area causes redistribution of argillaceous and arenaceous material in the surface rock. Therefore, there will be a contrast in the magnetic response between the fresh and weathered rock. In the weathered rock area the anomaly varies smoothly where as in the fresh rock area there will be intensive fluctuations in the sign and magnitude of the anomalies. Usually the anomaly level decreases in the direction of increasing thickness of weathering. Also weathering will be more predominant along joints and fractures if situated at lower levels. Therefore, along with the assessment of weathering thickness, it is possible to trace the joint and fracture pattern through micro magnetic survey.

Magnetic method is an effective tool to detect the fault zones and dykes. In a fault redistribution of ferromagnetic minerals takes place while dyke posses usually high Fe compared to the surroundings. Harichandran et.al (1984) conducted vertical
component of magnetic field along with resistivity survey over a dolomite dyke and estimated the dip, width and depth. Bhasker Rao and Murty (1967) conducted a study in the khondalitic crystalline by using magnetic methods.

8.3.2 Qualitative technique

The qualitative approach to magnetic interpretation, which is frequently used, is not confined to delineating trends. Changes in the separation of contours often provide useful criteria for indicating structure. The closer the contour i.e., the greater the gradients, the shallow in general is the source. Any sudden change in spacing over an appreciable distance suggests a discontinuity in depth possibly a fault. (Dobrin, 1960)

8.3.3 Quantitative technique

Quantitative analysis of the magnetic data is more difficult due to the variation in susceptibility and uncertainty in the direction of polarization since the magnetization is not always oriented along the earth's field.

Cook (1950) has applied the formula derived by Haalak and others to compute anomalies for large variety of dykes, size, shape etc. Peter (1949) has developed some analytical technique based on potential theory, which he developed for interpreting magnetic data. He also described two rule-of-thumb techniques for depth estimation, which are simple and applicable for large number of cases. The 'slope'
method developed by him makes it possible to determine the depth to the basement surface from the anomaly curve.

Breiner (1973) established the half width rule for determination of the depth. The half width is the horizontal distance between the principal maximum (or minimum) of the anomaly assumed to be over the center of the source. But this method may be suitable for the nearly vertical dykes. Depth = x.

\[
\text{Half width} \rightarrow x
\]

Slope technique is most commonly used set of methods estimating the depth. Based upon the empirical utility computed models these slopes are measured according to the horizontal extent of 'straight' portion of the slope. Each of these horizontal distance measurements when multiplied by an empirically determined factor 'k' equals the depth to the top of the anomaly source. Depth \( Z = k \times x \) (k=0.5 to 1.5)
The significant characteristics of magnetic anomaly is its variation with depth the magnetometer and source, the deeper the source broader the anomaly.

8.3.4 Magnetic survey in the study area

Magnetic survey is carried out in 85 selected locations on the ground, which is accessible in the watershed area, by using ABEM magnetometer. The instrument has the capability of measuring both vertical and horizontal component. Only vertical component of magnetic field is measured in gamma and it ranges from -1700 to +2500. Qualitative interpretation of the data are carried out and the data along with the corresponding X and Y coordinates are used for the preparation of the contour map by using SURFER software and profiles in the selected alignment are constructed.

The magnetic anomaly contour is presented in figure VIII.20. It indicates that the concentration of the positive anomaly is in the northeastern side and south and SW of the watershed area. An isolated positive anomaly is noticed in the north of Pottireddipatti. The negative anomaly concentration is mainly in the central part, western
ERUMAIPATTI WATERSHED
MAGNETIC INTENSITY

Figure VIII.20
part and north of Varagur. To certain extent, the negative anomaly correlates with the B and C group soils and deep weathering of the country rock while the positive anomaly correlates with the D group soil and shallow depth weathering. A linear zone of negative anomaly in the NW-SE direction and the elongated shape of the contours are mostly in the NW-SE direction indicative of major set of lineaments.

8.3.5 Magnetic profiles

Two magnetic profiles in the NE-SW direction and W-E direction are constructed and shown in fig VIII.21& 22.

The SW-NE profile, which extends from Valayapatti to Varagur North indicates two positive anomalies near Ponneri and North of Sellipalayam near Manickavelur. Both the anomalies are wider indicative of deep surface. It may be due to the moderate to deep weathering of the country rock and the basement rock devoid of any fractures/fissures. The three negative zones correspond to the deep weathered and fractured zone. The above magnetic profile correlates with the SW-NE resistivity cross section.
Figure VIII.21 Magnetic intensity profile in the SW-NE direction

Figure VIII.22 Magnetic profile in the W-E direction

The magnetic profile in the W-E direction is from Pudukottai pirivu to Varagur. The western part of the profile shows negative anomaly due to the deep weathered zone and fractured zone. Another negative anomaly near Devarayapuram confirms shear zone and deep weathering. Out of the three positive anomalies the first one in the
western side is very narrow indicating very shallow surface where as the other two are wider. The gentle slope in the western side and steep slope in the eastern side indicates that the deep surface is dipping towards west.

The total magnetic intensity profiles / maps are not an end themselves but will be useful when it is integrated with geology and structure.