Geophysical Investigation along East coast of Chennai, Tamilnadu, India-A Base line Approach

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**GEOPHYSICS**

# 1.1. INTRODUCTION

Geophysics is the study of the science and disturbance by the nature of the earth and its environment as such that seeks to apply the knowledge and techniques of physics, mathematics and chemistry to understand the structure and dynamic behavior of the earth and its environment. Geophysics is widely classified into many fields such as seismology, the study of earthquakes; hydrology, the study of the movement and distribution of water; and meteorology, the study of atmospheric weather. There are many methods which are followed to understand the physical properties of the earth materials such as density, elasticity, magnetization, and electrical conductivity, all allow conclusion about those materials to be made from measurements of the equivalent physical fields such as gravity, seismic waves, magnetic fields, and electrical fields. There are two types of Geophysics, conservatively labeled as Exploration Geophysics, and Global Geophysics. Exploration Geophysics, applies physical principles to determine and evaluate resources, such as oil, gas, minerals, water and building stone.

In Global Geophysics, we study earthquakes, the main magnetic field, physical oceanography, study of the Earth's thermal state and meteorology. Exploration geophysicists also work in the management of resources and the associated environmental issues. The geophysical surveys were very useful to calculate the thickness of the saturated zone, area feasible for groundwater development, deepening of shallow bore wells and the gradient of the aquifer zone to assess the subsurface groundwater flow. Geophysical surveys were conducted specifically to identify the feasible locations of groundwater storage. Electrical resistivity methods are used extensively in the search for suitable groundwater and to monitor types of groundwater pollution (Zohdy, 1974, Stollar and Roux, 1975 and Urish, 1983).Electrical methods have extensive application to mineral and Geoenvironmental problems that may be used to identify sulfide minerals, are directly applicable to hydrologic investigations, and can be used to identify structures and lithology.Resistivity method is mainly used to determine the thickness of aquifer and other parameters by direct current resistivity methods mainly used in the field of geophysical exploration (Kosinky and Kelly, 1981; Sri Niwas and Singhal, 1981; Mazac*et al*., 1985; Yadav and Abolfazli, 1998). One of the new developments in recent years is the use of 2-D and 3-D electrical imaging surveys to map areas with moderately complex geology (Griffiths and Barker 1993), and another popular method, the Direct Current (DC) resistivity sounding, has been extensively applied for solving hydrological (Verma*et al*., 1980), geothermal (Kumar *et al.,* 2011), environmental (Song *et al.,* 2007), and engineering problems (Chambers *et al.,* 2006).

Many of the people have been working with an electrical resistivity survey to delineate the sea water intrusion of groundwater along the coastal settings in the world (Frohlich*et al*., 1994; Nowroozi*et al*., 1999; Gnanasundar and Elango, 1999; Choudhury *et al*., 2001; Nouri *et al*., 2008; Martinez *et al*., 2009; Calvache, *et al*., 2011;Sathish, *et al*., 2011; Srinivas, *et al*., 2012; and SaumenMaiti, *et al*., 2012).Aquifer susceptibility to contaminants near solid waste landfill sites in a coastal environment was assessed using resistivity tomography by Ehirim and Ofor, (2010). Among the available geophysical methods, electrical and electromagnetic methods have been found remarkably suitable for environmental studies due to the conductive nature of most contaminants (Ulrych*et al*., 1994; Lanz*et al*., 1994 and Sauck, 2000). Some of the previous studies carried out along coastal areas are in Kancheepuram district (Gnanasundar and Elango, 1999 and Sathish, *et al*., 2011).

# 1.2 BASIC PRINCIPLES OF RESISTIVITY

Plenty of electrical prospecting methods are available for determining the conductivity of materials form which resistivity method is the most commonly used method pertaining to ground water. The electrical resistivity or specific resistance of a medium is the resistance offered by a unit cube of it when a unit current passes normal to the surface of the cross-sectional area ‘A’.

 = RA

L

Where,  = resistivity and R = resistance offered by the medium of length ‘L’ and cross-sectional area ’A’.

In electrical resistivity methods, a known electric current (I) is sent into the ground through a pair of current electrodes ‘A’ and ‘B’ and the potential difference

(∆V) created in the medium between another pair of potential electrodes ‘M’ and ‘N’ is measured and the resistivity of the formation is given by,

 = K. ∆V

I

K is termed the geometric factor of the electrode arrangement, and is computed as

K= 2

(1/AM- 1/BM- 1/AN+1/BN)

Where, AM, BM, AN and BN are the distance between the designated electrodes.

‘’ represents the true resistivity of the formation if the formation is homogeneous and isotropic nature, but only the apparent resistivity ‘a’ if the formation is anisotropic, consisting of two or more layers of different resistivities (Karanath, 1987). Depending on the electrode configuration and geology, the apparent resistivity may be an approximate weighted average of the true resistivities which may be even negative (Zohdy*et al*., 1974). The current, ‘I’ depends on various factors such as shape, density and porosity of aquifer material, quantity and quality of water contained in the aquifer and the temperature of subsurface environment (Keller and Frischnecht, 1966). The resistivity of igneous or metamorphic rocks is normally found to be in the range of 102 to 108 Ohm-m, whereas in unconsolidated sedimentary formations, it may range from 101 to 104 Ohm-m (Todd, 1980). Dry rocks are practically non-conductors and their resistivity decreases with increasing amounts of pore water (Karanth, 1987).

The advantages of resistivity survey are: 1) noninvasive technique and no requirement of water sampling; 2) relatively inexpensive, can be used for rapid and economical monitoring of large areas; 3) assist in the optimization of the required number of monitoring wells; and 4) electrical conductivity/ resistivity are intrinsic properties of groundwater chemistry that are readily interpreted in terms of the degree of groundwater contamination.

Wenner and Schlumberger are most common methods of the resistivity surveys. Many scientists have used Schlumberger method along the coastal area (Sathish, *et al*., 2011; Srinivas *et al*., 2012 and SaumenMaiti, *et al.,* 2012). In Schlumberger arrangement, all four electrodes are placed in line, and the distance between the current electrodes (L) is maintained more than three to five times the distance between the potential electrodes (b). The electrode configuration of Schlumberger arrangement is given in the **Fig.4.1.** Schlumberger method has been employed in the field for the study of physical properties beneath the earth's surface of the study area.

A M N B a

b

# Fig 4.1 Schlumberger Configuration

K = AM \* AN

MN

where, b = MN- potential electrode separation

and a = AB- current electrode

# 1.3 VERTICAL ELECTRICAL SOUNDING (VES)

Vertical Electrical Sounding (VES) data, can be interpreted using curve matching technique, is very useful for estimating the subsurface geology (Flathe, 1955; Mooney *et al.,* 1966 and Ghosh, 1971). The potential electrodes (M and N) remain fixed, and the current electrodes (A and B) are expanded symmetrically from the center of the spread. A known amount of electric current is passed in the earth through the current electrodes AB. The difference in potential is then measured between the potential electrodes MN. The current electrodes move to different settings and for the each setting, potential difference obtained are recorded.Maximum half current electrode (AB/2) separation used in these surveys. Usually, the depth of penetration is proportional to the separation between the electrodes and varying the electrode separation provides information about the stratification of the ground (Telford *et al*., 2010).

Apparent Resistivity ρ = K. (∆ V/ I)

2∏

K = 1/AM - 1/AN - 1/BM + 1/BN

ρ = apparent resistivity; K = Geometric Constant

The apparent resistivity values computed for the different values of half current electrode separations (AB/2) are plotted on a tracing sheet placed on a double logarithmic graph paper with apparent resistivity on ‘Y’ axis and AB/2 on X axis. The smooth double logarithmic curve is used for further interpretation.

# 1.4 INTERPRETATION OF RESISTIVITY CURVES

The field data obtained in the form of apparent resistivity is interpreted using curve matching technique to derive the true resistivity of the formations at different depths. The resistivity curves interpretation is usually made in two types such as qualitative and quantitative. The changes in values of apparent resistivity are observed from the shape of the curve to understand whether the resistivity with depth increases or decreases, is called as qualitative interpretation. In respect of quantitative interpretation, several methods are available. In recent years, analyses have been made easy with the aid of computer using information technique. In quantitative interpretation layers depth and thickness (parameters) are determined. The true resistivity and thickness of various layers are ultimate output from the quantitative interpretationBased on the interpretation of reference soundings, the true resistivity values were derived for different subsurface formations in the study area.

# 1.5 GEO-ELECTRIC SECTION

“Geo-electrical section” is the vertical distribution of resistivity value within a given volume of earth. Generally, the subsurface geology can be correlated to geoelectric section.



1



2

h1

h2

3

A typical geo-electric cross section is shown in the above sketch, where, ‘**h**’ refers to its thickness and ‘**ρ**’ refers to the resistivity of an individual layer. The last layer or ‘**n**th’ layer is considered to have infinite thickness. The geo-electric section is classified as 2 layers, 3 layers, 4 layers depending on the number of layers present. In addition, each category may be sub-divided according to the patterns of resistivity layers with respect to depth.

# 1.6. TYPES CURVE

A three layer section can be representative of any one of the geometries given below,

|  |  |  |
| --- | --- | --- |
| **ρ1 > ρ2 > ρ3** | **----** | **Q** type |
| **ρ1 < ρ2 > ρ3** | **----** | **K** type |
| **ρ1< ρ2< ρ3** | **----** | **A** type |
| **ρ1> ρ2< ρ3** | **----** | **H** type |

where, ρ1, ρ2, and ρ3are resistivity of first, second and third layers respectively.

In the case of multi-layer systems, other than 3 layers, they are designated by combinations, for example, AA type HK type etc. In general, an ‘nth’ layer section can be grouped into 2n-1 types and identified by n-2 letters from 3 layers classifications.

# 1.7. GEO-ELECTRICAL MASTER CURVES

Master curves are set of theoretically computed curves plotted on double logarithmic graph paper and such master curve sheet contain one or more families of curves such as type H, K, A and Q for three year earth and also the combinations HK, AA, A etc, for four layered earth.

# 1.8. METHODS OF INTERPRETATION

The Curve-matching method is the only widely used technique which is based on sound physical theory and clearly stated assumptions. The detailed procedures of interpretation are well explained by Deppermann*et al*. (1961),Kuntez (1996),Van Nostrand and Cook (1996) and also byKalendv (1957). The apparent resistivity and Current electrode separation plots the field data on double logarithmic graph with modulus 62.5 mm. The transparent curve is then superimposed on the respective master curves to approximation of the true thickness and true resistivity of individual layer. The auxiliary point method permits the use of three layers master curves for the interpretation of four layers and five layers field curves. Master curves are computed on the assumption that the sub-surface layers are horizontal that no lateral variations in resistivityare present.

# 1.9 FIELD GEOPHYSICAL SURVEY

The vertical electrical sounding survey (VES) has been carried out in the study area, at twenty one locations, from the coast to inland area, adopting the Schlumberger configuration. VES survey data were obtained from the survey conducted to study groundwater condition.

# 1.10 GEO-SURVEY EQUIPMENT

The geo-physical instrument was used for field work is DDR-2, which is the indigenous IGIS make from Hyderabad. The 21 Vertical Electrical depth Soundings (VES) were taken for critical analysis of the qualitative and quantitative interpretations. The 21 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. Then the interpreted data has been verified using the software and details are as follows:

# 1.11 ANALYSIS WITH “RESIST – 87”

Subsequently these vertical electrical soundings were analyzed critically with

Resist 87 software called “Resist version 1.0, ITC Mic Research Project by Vander

Velpen B. P. A. developed during 1988 by IBM”. Some prominent results of the

Resist 87 for the study area**.** In all the cases, the start model was assumed based on curve matching. In the study area 4 four layers, 16 three layers and 1 two layers were observed. With regards to curve type, the four layers they consist of 2 KH type and 2 QH type. Where in 3 layers consist of 9 ‘A’ types and 7 ‘H’ types. Where in 2 layers consist of one two layer type.

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

S

and

Clay

Sandy clay

Weathered Charnockite

In the study area, the resistivity for first layer ranges from 0.5 (location 4) to 4535.1 (location 15) ohm-m**.** The higher resistivity of the first layer has been observed in the central and eastern part (near coastal) of the study area. The resistivity for second layer ranges from 2.4 (location 8) to 2392.7 (location location 14) ohm-m. The higher resistivity of the second layer has been observed in the eastern part (near coastal) of the study area. The resistivity of the third layer ranges from 4.6 (location 7) to 8008.5 (location 2) ohm-m. The higher resistivity of the third layer has been observed in the southern part of the study area. The resistivity of the fourth layer resistivity ranges from 138 (location 9) to 4705.1 (location 14) ohm-m. Majority of the resistivity values have been observed near the coastal area (Kalpakkam) of the study area may be due seawater intrusion.

The thickness of the first layer ranges from 0.6 (location 12) to 3.2 (location

17) metres**.** The higher thickness has been observed in the eastern and central part of the study area. The thickness of the second layer ranges from 1.5 (location 8) to 25.2 (location metres. The higher thickness has been observed in central and eastern part of the study area. The thickness of the third layer ranges from 2.4 (location 9) to 9.8 (location 7) meters **.**

The detailed analysis in all the data show that the thickness of each layer varies in the study area. The maximum thickness of first and second layer are observed in the eastern (near coastal area) and southern part of the study area.

# 1.12 ISO-APPARENT RESISTIVITY CONTOUR MAPS

The Iso-apparent resistivity contours were prepared for various AB/2 separations of 10 m, 30 m and 60 m.

The iso-apparent resistivity contours of 10 meters half current electrode separation shows only one prominent local peaks corresponding to almost eastern and central part of the study area. The resistivity ranges from 3.2 to 1205.1 ohm-m and about 81 % of the area is covered by the resistivity less than 285.7 ohm-m.

In respect to iso-apparent resistivity contours of 30 m half current electrode separation, a similar trend as seen for the 10 m is noticed. The resistivity is fluctuating in wide range from 0 to 2699.4 ohm-m. Almost 90 % of the study area is below 362.8 ohm-m. The maximum levels are observed in southern part of the study area.

In respect to iso-apparent resistivity contours of 60 m half current electrode separation, a similar trend as seen in the 30 m is noticed. The resistivity is fluctuating in wide range from 0 to 8008 ohm-m. Almost 85 % of the study area is below 980.5 ohm-m. The maximum levels are observed in southern part of the study area. Though the peak resistivity value has been observed in the eastern and southern part of the study area, the general trend shows the resistivity value increase from the eastern and southern part of the study area may be due the seawater mixing in the groundwater. Further, the concentration of electrical conductivity, sodium, chloride and chloride/bicarbonate ratio and sodium/chloride ratio also increases in the eastern and central part of the study area.

# 1.13 SUMMARY

There are about 4 four layers, 16 three layers and 1 two layers were observed. With regards to curve type, the four layers is consist of 2 KH type and 2 QH type. Where in 3 layers consist of 9 A types and 7 H types. Where in 2 layers consist of one two layer type.

The resistivity for first layer ranges from 0.5 (location 4) to 4535.1 (location 15) ohm-m. The higher resistivity of the first layer has been observed in the central and eastern part (near coastal) of the study area.

The resistivity for second layer ranges from 2.4 (location 8) to 2392.7 (location location 14) ohm-m. The higher resistivity of the second layer has been observed in the eastern part (near coastal) of the study area.

The resistivity of the third layer ranges from 4.6 (location 7) to 8008.5 (location 2) ohm-m. The higher resistivity of the third layer has been observed in the southern part of the study area.

The resistivity of the fourth layer resistivity ranges from 138 (location 9) to 4705.1 (location 14) ohm-m. Majority of the resistivity values have been observed near the coastal area (Kalpakkam) of the study area may be due seawater intrusion.

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