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# Geophysical and Physico-Chemical Investigations of Saline Water Intrusion in a Coastal Stretch between ULLAL and Thalapady, Mangalore, Karnataka, India.

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***Abstract: The coastal population largely depends on the fresh water resources which are in hydrodynamic equilibrium with the sea water. In coastal region, fresh water is becoming a rare commodity due to improper ground water management practices. In this work, an attempt is made to delineate salt water affected areas in a coastal stretch of Ullal and Thalapady of Mangalore using geophysical and physico-chemical methods. Geophysical surveys have delineated different subsurface geological formations such as dry sand, laterite, saturated layer, brackish zone and fractured gneiss on the basis of their characteristic resistivity values. Few locations that are vulnerable for saline water intrusion have been identified and these zones should be avoided for ground water developments. Some safer zones for effective ground water exploitation have been identified and delineated. These kind of integrated geophysical and physico-chemical methods are highly useful in the environmental studies for assessment of saline water intrusion in the coastal tracks.***
***Keywords: Saline water intrusion, resistivity, TDS, coastal stretch, brackish water.***

## I. INTRODUCTION

Groundwater is one of the most important natural resources. Groundwater exploration has gained attention due to its increasing demand. More than half of the world's population relies on the groundwater for their drinking and agricultural needs (Alabi et al. 2010). Hence the quality and quantity of groundwater is an important aspect. The physico-chemical properties of ground water depends on geological characteristics of the area, the quality of rainwater which is being infiltrated, the external pollutants fed into the groundwater system etc. (Todd 1980; Choudhury et al. 2001).In the coastal stretch, groundwater salinization is a major issue which is characterized by the inland movement of the saline water into the freshwater aquifers (Georgescuet al. 1993; Sathishet al. 2011). Groundwater salinization occurs due to various natural mechanisms like, saline water intrusion and presence of geogenetic contaminants etc. (Choudhury et al. 2001; Frohlich and Urish 2002). Other mechanisms include anthropogenic causes like, over exploitation of ground water which is in continuity with the sea (Urish and Frohlich 1990), percolation from a contaminant source etc. Areas adjacent to sea, where fresh water has a hydraulic connection with the seawater, the displacement is more pronounced (Todd 1980).

Many of the coastal aquifers of the world experience the saline water intrusion problem (Frohlich et al. 1994; Choudhury et al. 2001; Batayneh 2006). The coastal stretch of Karnataka also experiences similar threats. Like most other coastal areas of the world, Ullal - Thalapady coast of Mangalore which is one of the highly populated coastal stretch of Karnataka rely on the groundwater resources for their domestic and other needs. As the shallow coastal aquifers are deteriorated due to salt water ingress, an attempt is made to delineate such polluted ones along the coastal stretch of Ullal and Thalapady of Mangalore, Karnataka and to demarcate areas for groundwater development that are not susceptible to saline-water intrusion hazards.

In order to ascertain the subsurface aquifer characteristics, expensive methods like drilling and exploitation of bore holes are usually carried out. In this study, a less expensive geophysical vertical electrode sounding (VES) method which can respond to variation in conductivity of ground water bearing formation is integrated with physico-chemical methods. VES can generate continuous data of a given location and this helps in generating a spatial relationship between freshwater, brackish water and saline water which commonly coexist in the coastal area (Nowroozi et al. 1999; Lee and Song 2007). In a coastal stretch the differences in the resistivity of fresh and saline water would help in demarcating the regions contaminated by the saline water intrusion (Van Overmeeren 1989; Goldman et al. 1991;Nowroozi et al. 1999; Choudhury and Saha 2004; Himiet al. 2010).

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### A. *Study area*

Ullal - Thalapady coast is located between 12$^o$ 45’06’’ - 12$^o$50’025’’ N latitudes and 74$^o$ 49’058’’ - 74$^o$53’136’’E longitudes with its hydraulic boundaries as Arabian Sea in the west, Netravathi River in the north and Thalapady River in the south(Fig 1). The area receives on an average 3800mm of rainfall during the southwest monsoon season.

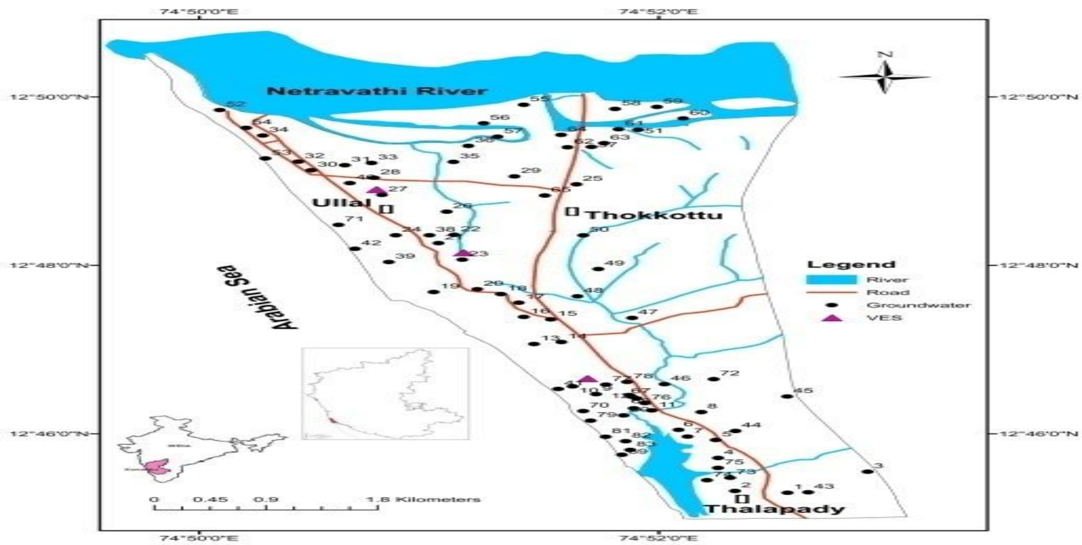


Fig. 1 Location map of the study area.

The area is characterized by charnockite and granitic gneiss of Pre-Cambrian age and laterite and coastal alluvium of Tertiary and Quaternary age. Sandy beaches, spits and rocky cliffs make the major geomorphic units (Radhakrishna and Vaidyanadhan 1997). Major part of the study area comprises sandy loam and lateritic soils (NBSS-LUP 1998).

## II. MATERIALS AND METHODS

83 well water samples were collected from various open wells in new 1 liter polyethlene bottle. Prior to sampling, these bottles were cleaned with pure water and rinsed with the water which is being sampled. Geographic coordinates of the sampling locations were obtained with the help of a Garmin GPS - eTrex-10. The physical parameters namely pH, EC, TDS and salinity were determined insitu with a HANNA – HI 98195 multi parameter water quality portable meter and the instrument was calibrated with HI9828-0 calibration solution prior to the measurement. Chemical parameters like calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$) and chloride ($Cl^-$) were determined by complex metric titration method recommended by APHA 2005. Sodium ($Na^{2+}$) and potassium ($K^+$) in the water samples we reanalyzed using Flame photometer - SYSTRONICS-130. All physico-chemical parameters were spatially plotted on an ArcGIS platform - ArcMap 10.3.

VES at three different locations were conducted with an AnvicCRM Auto-C Aquameter. A Schlumberger array was followed for the survey. The apparent resistivity and AB/2 values were plotted on double-log sheet in IP2Win inversion program (Moscow State University). The actual resistivity (□), thickness (h) and depth to layer interface (d) were obtained from the layered resistivity model and this was used for the further interpretation.

## III. RESULT

### A. *Ground water quality analysis*

Groundwater quality of certain locations adjacent to the Ullal and Thalapady river estuary suggest high levels of pH, EC, TDS, salinity, sodium and chloride (Fig 2, 3, 4). All these parameters show values above the maximum permissible limit prescribed by the WHO (2006) for the drinking water purpose. The hike in these values is attributed to saline water intrusion during the high tide along the Netravathi and Thalapady Rivers. Another cause of saline water intrusion might be the infiltration through the coastal fresh water aquifers which are in hydraulic continuity with the sea. High levels of these parameters might be the reason behind the brackish nature of groundwater. Among other physico-chemical parameters calcium, potassium and magnesiumare in normal concentration (Fig 5). Higher concentration of calcium in one of the sample reflects the influence of domestic input into the fresh water system.

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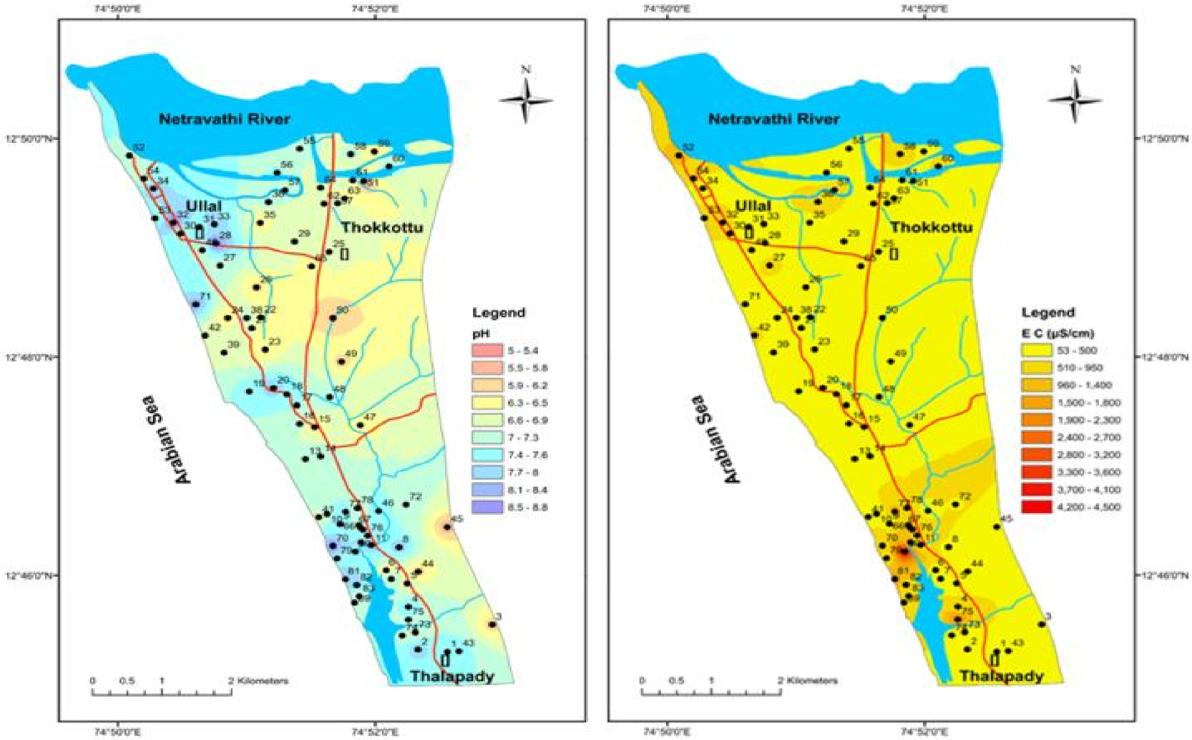


Fig.2Spatial distribution map showing pH and EC of groundwater samples.

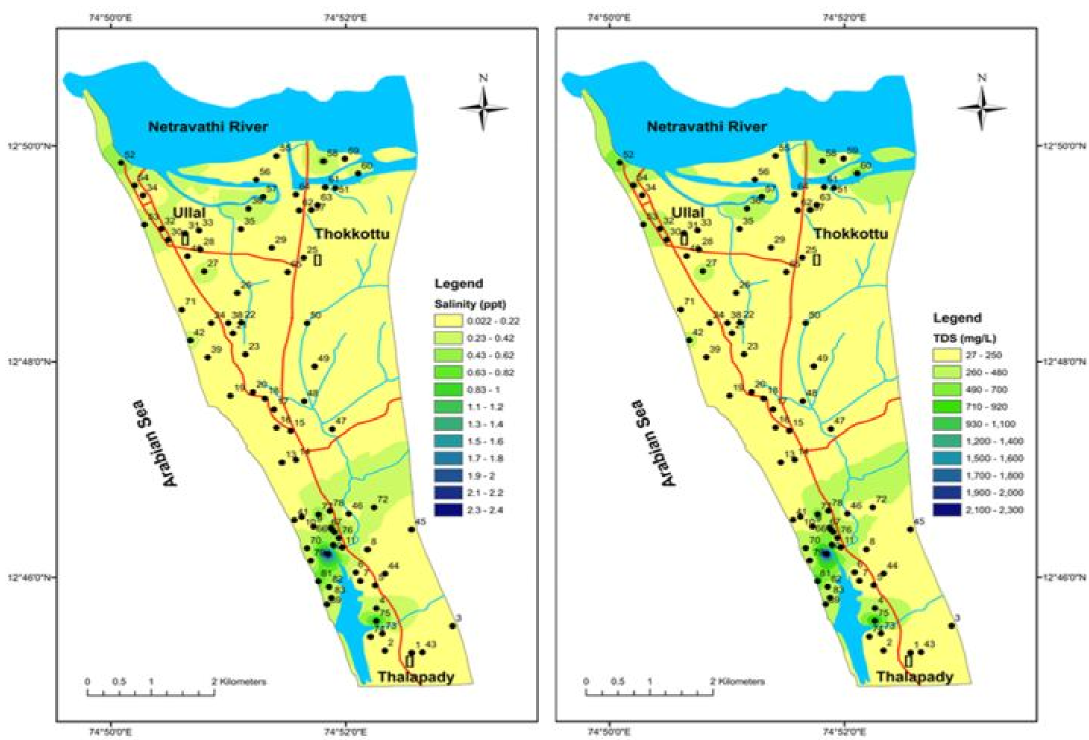


Fig.3Spatial distribution map showing salinity and TDS of groundwater samples.

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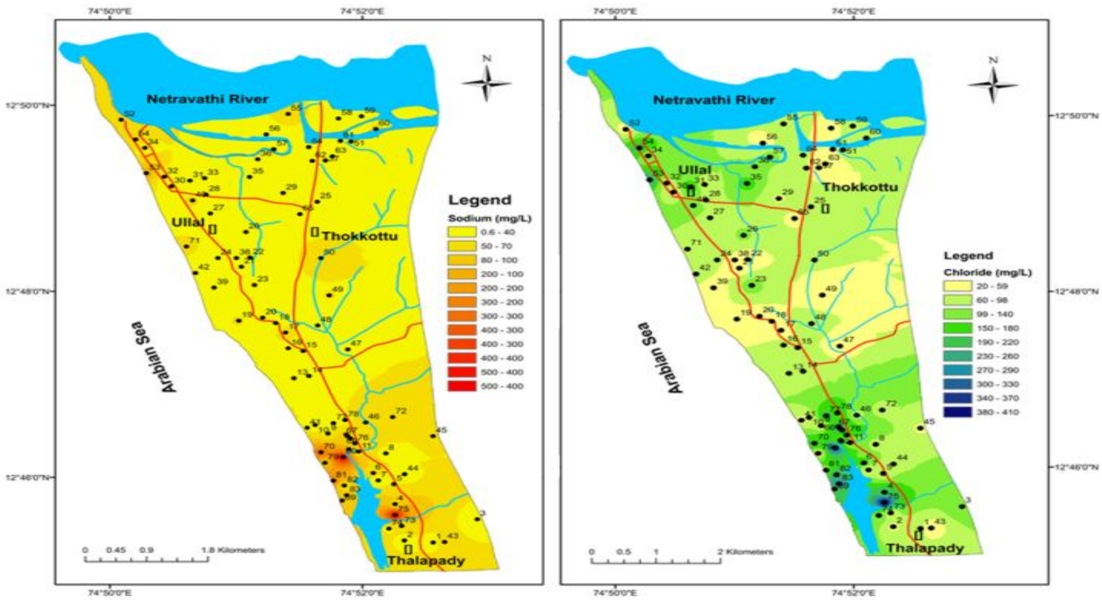


Fig. 4 Spatial distribution map showing sodium and chloride of groundwater samples.

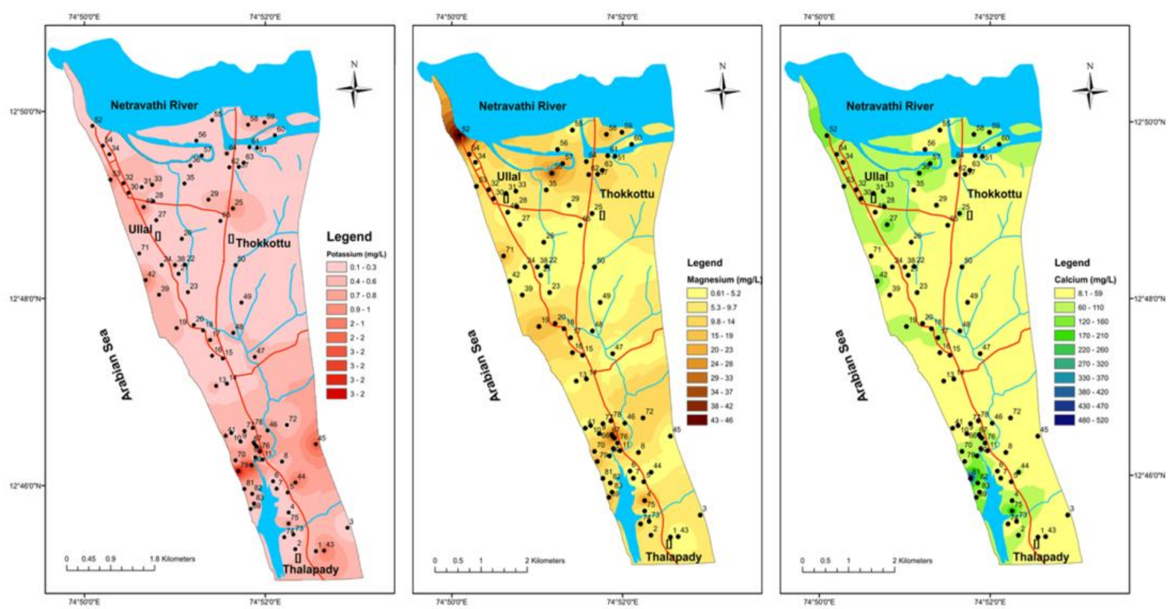


Fig.5Spatial distribution map showing potassium, magnesium and calcium of groundwater samples.

### *B. Geophysical investigation*

VES at various stations namely, VES1 - Uchila, VES 2 - Someshwara and VES 3 - Ullal respectively were conducted. Delineation of various subsurface layers was carried out with the IP2Win inversion program. The topmost layer of Uchila and Ullal are dry sand with a resistivity of 2999 Ωm and 1650Ωm and depth of 2.44m and 6.36m correspondingly (Fig 6, 8). In Someshwara a hard lateritic topmost layer with a resistivity of 10092Ωm and a thickness of 2.21m is observed (Fig 7). Figure 9 (a, b) illustrate the resistivity and thickness of topmost layers.

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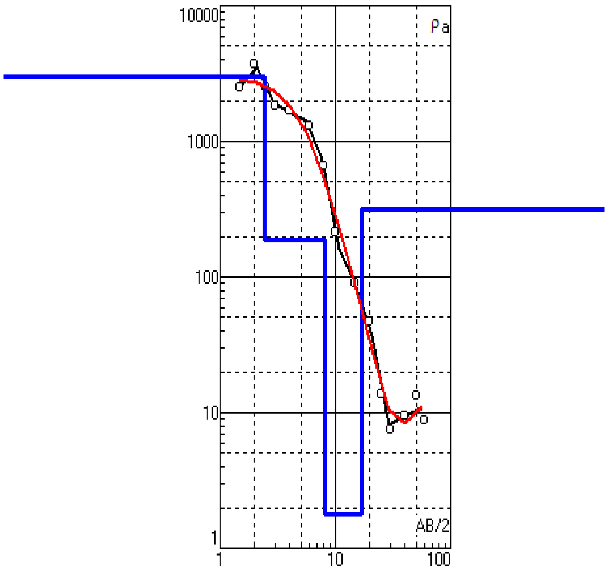
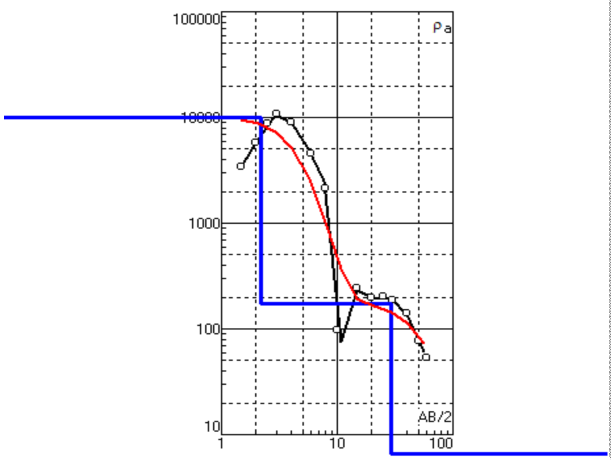


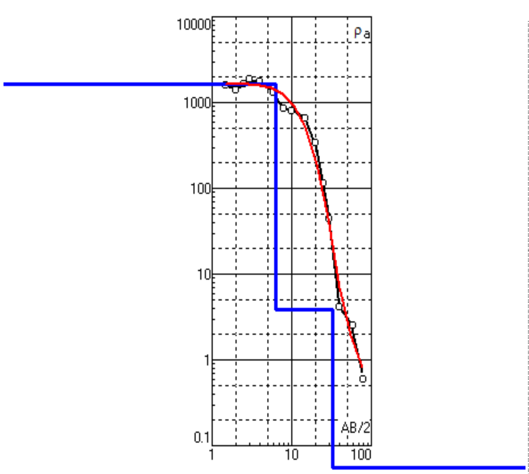

| N | ρ | h | d |
|---|---|---|---|
| 1 | 2999 | 2.44 | 2.44 |
| 2 | 190 | 5.66 | 8.11 |
| 3 | 1.79 | 8.68 | 16.8 |
| 4 | 315 | | |

Fig. 6 Resistivity curve and interpreted layered resistivity model of VES1 -Uchila.




| N | ρ | h | d |
|---|---|---|---|
| 1 | 10092 | 2.21 | 2.21 |
| 2 | 171 | 27.3 | 29.5 |
| 3 | 1.7 | | |

Fig.7 Resistivity curve and interpreted layered resistivity model of VES 2 - Someshwara.




| N | ρ | h | d |
|---|---|---|---|
| 1 | 1650 | 6.36 | 6.36 |
| 2 | 3.81 | 26.6 | 33 |
| 3 | 0.0452 | | |

Fig.8 Resistivity curve and interpreted layered resistivity model of VES 3 -Ullal.

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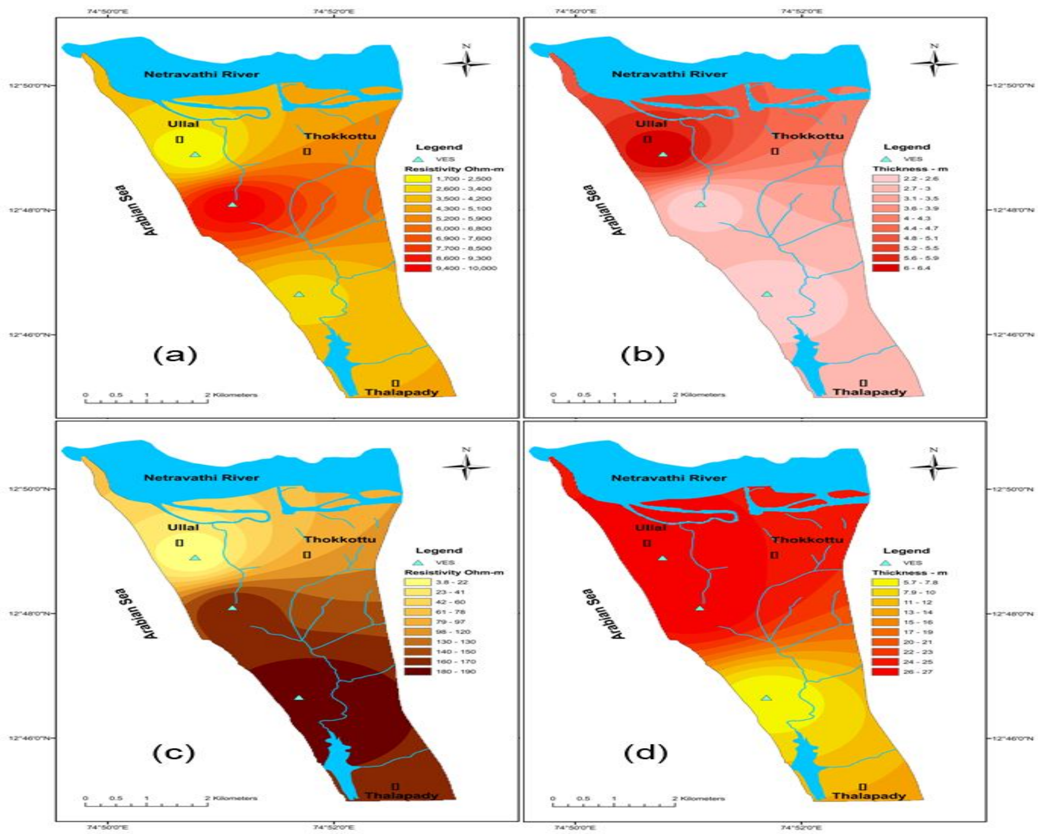


Fig. 9Resistivity and thickness of layer I (a, b) and layer II (c,d) of VES locations.

Resistivity of the second layer in Uchilaand Someshwara are 190Ωm and 171Ωm with a thickness of 5.66 and 27.3m suggesting a saturated sand layer (Shenoy and Lokesh 2000a, b). In Ullal region a second layer with a resistivity of 3.81Ωm and a thickness of 26.6m suggest a brackish nature of the ground water. Resistivity and thickness of saturated layers of Uchila and Some shwara and brackish water layer of Ullal are shown in the figure 9 c, d.

In Uchila, brackish water zone is noticed in the third layer below a depth of 8.10m (resistivity of 1.79Ωm and thickness of 8.68m). Beyond 16.8m depth, fractured gneiss is observed here (Fig 6). But in case of Someshwara, this brackish water zone is encountered much deep, below 29.5m. Very low resistivity of 0.0452Ωm is noticed in Ullal, below a depth of 33m indicating the encroachment of saline water into the freshwater aquifer.

The depth of interface between fresh water and saline water in Uchila is around 8.1m and in Ullal it is 6.36m. Whereas in Someshwara area it is at a deeper depth of 29.5m.

## IV.DISCUSSION AND CONCLUSIONS

This integrated geophysical and physico-chemical investigation of ground water was successfully employed to delineate the areas susceptible to saline water intrusion in the shallow coastal aquifers of Ullal and Thalapady of Mangalore. The subsurface configuration of ground water system, the depth of interface between fresh water and salt water and area suitable for groundwater developments were identified. Physico-chemical parameters especially EC, TDS, salinity, sodium and chloride indicate the effect of seawater intrusion along certain stretch ofUllal and adjacent areas and Thalapady river and its adjoining areas. This is due to lateral movement of seawater through the river mouth during the high tide and due to hydraulic continuity of fresh water aquifer with the sea. The physico-chemical parameters of Someshwara area indicate the absence of any significant seawater intrusion in the shallow wells. The presence of large impervious gneissic pluton adjacent to the sea and their possible extension to deeper depths might be the reason behind this.

The differences in the resistivity of the subsurface formations are associated with the lithologic contrast, variations in the water saturation and the quality of water in the interstices. The presence of three or four distinct layers is identified by the resistivity values. The topmost layer is of unconsolidated dry sand in two of the locations and lateritic in one of the locations. Below this, fresh

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water saturated soil or/and a mixing (transition) zone of brackish groundwater is observed. In one of the locations, very low resistivity due to encroachment of seawater is also encountered. But in Someshwara area, salt water is encountered at much deeper depth of 29.5m. The shallow wells of this region can be used for the ground water developments.

Rapid urbanization in the Ullal and its vicinity has necessitated overdraft of ground water at many places, which in turn has intensified the saline water intrusion problem. If, over pumping and over-exploitation of ground water continues in this manner, the area is highly vulnerable for ground water degradation. Areas like Uchila and Ullal are identified as vulnerable zones where ground water withdrawal should be restricted. A regular monitoring of water quality parameters and groundwater levels are recommended for the management of the ground water in this region. Hence this study would help to limit the extraction of saline-water contaminated fresh water for consumption and general usage along the highly vulnerable coastal stretch of Karnataka.

## V. ACKNOWLEDGEMENT

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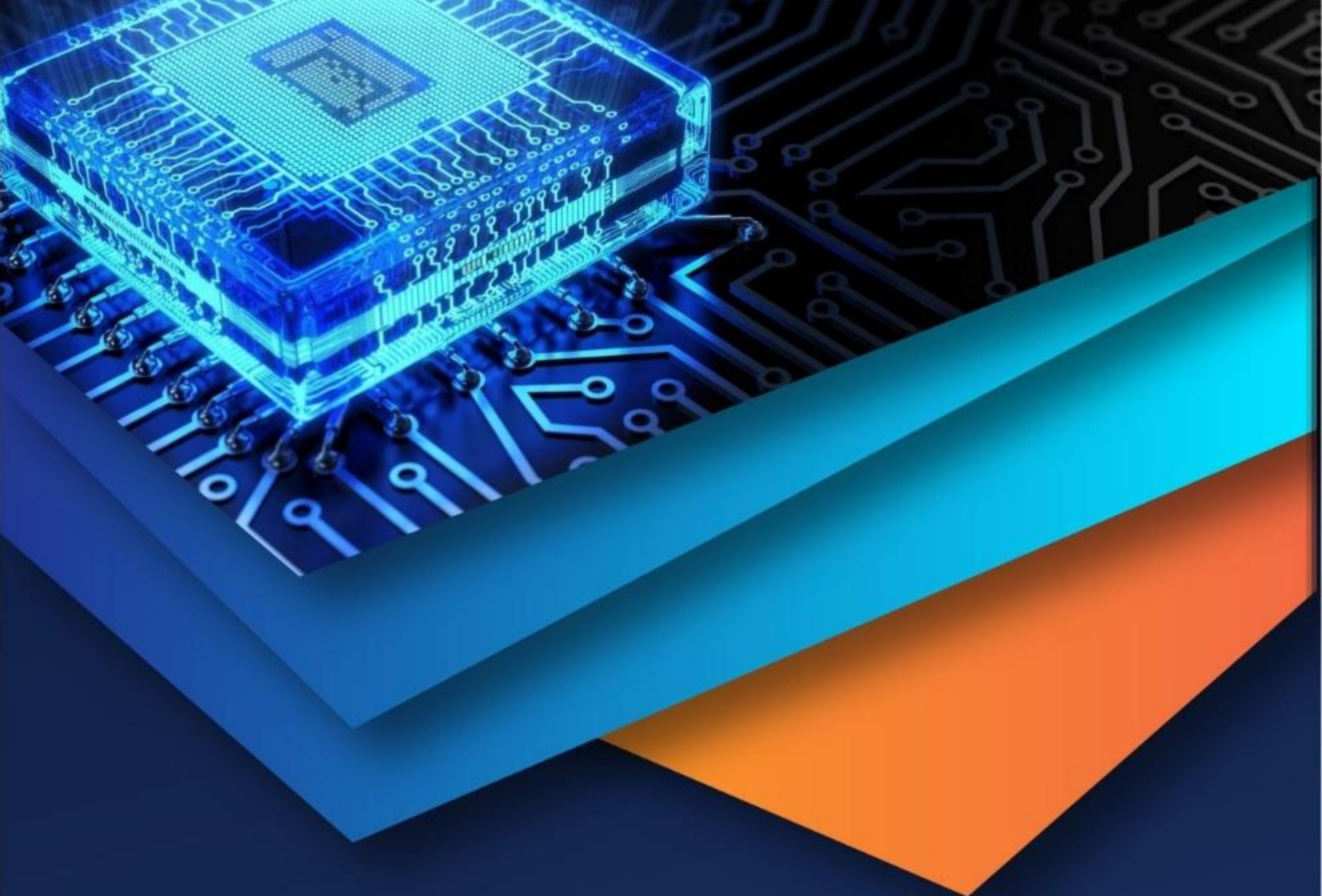


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