J. Ind. Geophys. Union (July 2014)
v.18, no.3, pp:356-362

Delineation of groundwater potential zones along the coastal parts of Kanyakumari district, Tamilnadu

Y. Srinivas[1*], D. Hudson Oliver[1], A. Stanley Raj[2], N. Chandrasekar[1]
[1]Centre for GeoTechnology, Manonmaniam Sundaranar University, Tirunelveli, Tamilnadu
[2]Vel Tech Dr. RR & Dr. SR Technical University, Avadi, Chennai 600 062
Email: drysv@yahoo.co.in

ABSTRACT
Electrical resistivity method is widely used in groundwater exploration studies because it is a fast and less expensive geophysical tool. The vertical electrical soundings were carried out at 21 sites along the coast of Agastheeswaram taluk between Muttom and Vattakkotai, Kanyakumari district, Tamil Nadu using the Schlumberger configuration. The field data were interpreted using the IPI2win software and the resistivity versus depth models for each location was prepared. Groundwater in this region occurs mainly under semi confined to confined conditions. The study was aimed at improving the success rate of boreholes. The results obtained from the interpreted data indicate three to four geoelectric layers. The thickness of the first and second layers lies between 1 to 4.7m and 1.1 to 13.3m respectively. The sounding locations showing resistivities between 18-100 ohm m are expected to be potential zones with potable water as revealed by TDS value of groundwater from the nearby wells. The areas affected by over exploitation and saline water intrusion into groundwater are also delineated by very low resistivity zones (between 1and 9.6 ohm m) .The geoelectric sections prepared on the basis of VES results clearly delineated the fresh and saline water zones both laterally and vertically. The saline water intrusion can be reduced significantly by construction of barriers to prevent the intrusion of saline water from the nearby estuaries and salt pans. It is also necessary to construct structures to increase the groundwater level through artificial recharge. The saline water intrusion can also be reduced by adopting a suitable pumping pattern. Thus, these studies supported by available litholog data helped in suggesting suitable management techniques to prevent the groundwater degradation.

INTRODUCTION

One of the most serious environmental problems in many countries is the progressive increase of water consumption and the consequent over drafting, together with quality deterioration of groundwater. Most of the people residing in coastal region rely on groundwater as their main source of fresh water for domestic, industrial and agricultural purposes. Study of the nature of groundwater conditions and information on saline water intrusion will be vital for groundwater management. Saltwater intrusion is the induced flow of seawater into freshwater aquifers primarily caused by groundwater development near the coast. Wherever groundwater is being pumped from aquifers that are in hydraulic connection with the sea, induced gradients may cause the migration of salt water from the sea towards a well, making the freshwater well unusable as revealed by several studies worldwide (Batayneh, 2006, Sung Ho Song et al., 2007, Mondal et al., 2008, Pervaiz et al., 2010).

The present study is aimed at mainly understanding the lateral and vertical variations of groundwater quality through geoelectrical characteristics aided by litholog and well data of coastal areas from Muttom to Vattakottai, Agastheeswaram taluk of Kanyakumari district, Tamil Nadu, India.

GEOLOGY AND HYDROGEOLOGY

The study area is covered by charnockites, leptinites, leptinite gneiss, granite gneiss, laterites, sandstones, variegated clay, river alluvium, etc. The northwestern region of the Kanyakumari district is completely occupied by Western Ghat Mountain ranges with a maximum elevation of 1658m. The coastal region in the south is a thin strip of plain region with a width of 1- 2.5 km. The coast line has narrow stretches of beaches and sand dunes characterized by laterite capping.

Charnockite group consists mainly of charnockites, pyroxene granulites and their associated migmatities. Charnockites also are exposed within the gneisses as bands and lenses.

Fig1. shows the geology of the study area (GSI, 2005). The groundwater occurrence is limited to only weathered mantle of the hard rock with its depth varying between 10m to 35m below the ground level with respect to the weathered thickness range. Most of the regions of the district are covered by vegetated lands, beaches and water bodies. In alluvial formation, the groundwater occurs under water table conditions.

Mostly, in hard-rock regions, the nature and thickness of weathered zone vary both laterally and with depth

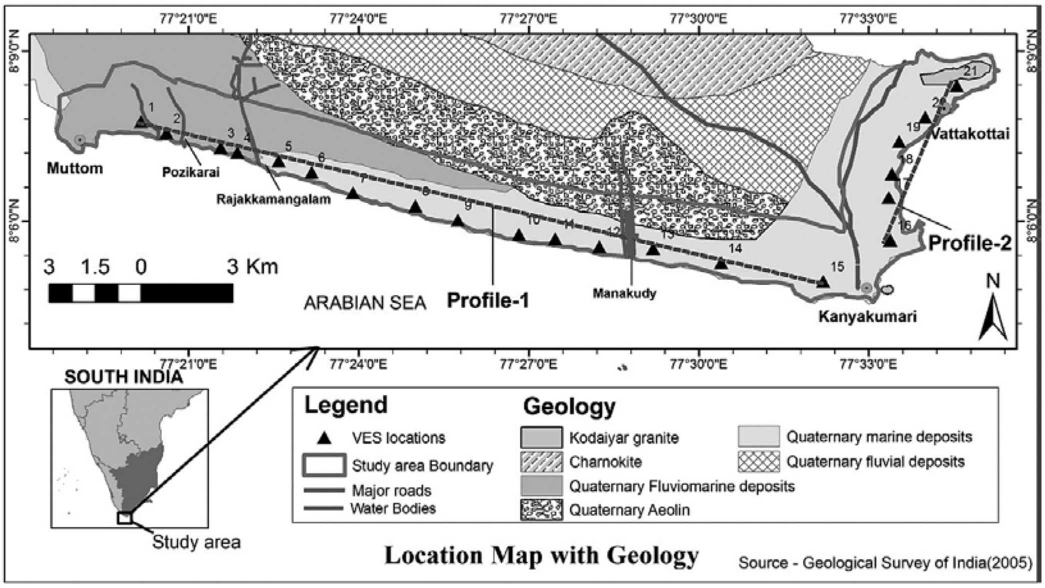


Figure 1. Geological map of the study area along with VES locations

influencing the groundwater recharge. Geomorphologically, the study area comprises several land forms like marine uplands, shales, saltpans, water bodies like rivers and estuaries (Chandrasekar et al., 2007). The overall water level fluctuation in general reveals the water level raise during October to December and decrease from February to September as per the well inventory data of PWD and CGWB. A slight rising trend is seen during July because of southwestern monsoon. However, general water level conditions during past 10 years show a decreasing trend (PWD, 2005).

METHODOLOGY

Twenty one vertical electrical soundings (VES) with Schlumberger electrode configuration with a maximum current electrode separation (AB/2) of 100 m were carried out to understand the resistivity distribution of the area (Fig.1). Electrical Resistivity Method is used in the present study because of its efficacy to detect the water-bearing layers as well as the quality of groundwater (Zohdy 1974, Kosinky and Kelly 1981, Sri Niwas and Singhal 1981, Mazac et al., 1985, Telford et al., 1990, Yadav and Abolfazli 1998).

The apparent resistivity (ρa) values calculated from the field data were plotted on a double log graph with AB/2 on X-axis and the corresponding apparent resistivity (ρ_a) on Y-axis. The sounding curve thus obtained is interpreted by matching with master curves of three and four-layer cases for various ratios of absolute resistivity given by Orellena and Mooney (1966) to obtain layer parameters. To refine the results obtained by curve matching technique, the 1-D inversion software IPI2win was employed. All the interpreted VES curves are shown in the Fig.2 and the geoelectric parameters are provided in the table.1.

RESULTS AND DISCUSSIONS

The results obtained from resistivity survey revealed different hydro-geological conditions varying between high saline areas and the freshwater locations. The studies also brought out other anthropogenic activities affecting the quality of the groundwater. From the results, it was observed that ten out of twenty one VES curves show three-layer model H type curves (VES 5, VES 6, VES 8, VES 13, VES 15 to VES 20) revealing a low resistivity intermediate layer(aquifer) sandwiched by high resistive layers. The curves obtained for VES 2, VES 3, VES 4, VES 7, VES 9 and VES 11 indicate three layer K- type curves with the second layer resistivity higher than the top and bottom layers. The other sounding curves are interpreted as four layer model. The interpreted results showed a good correlation with the available nearby lithlog data (Fig.3).

Geoelectric parameters:

The resistivity of the top layer ranges between 6.5 to 499 Ωm, with isolated resistivity highs. The thickness varies from 1 – 4.7 m. Some areas were affected by high salinity due to the nearby estuaries and salt pans. The station VES 12 near to the Manakudy estuary and station VES 20 show low resistivity due to the saline nature of the top soils or saltpan abundance in these regions. The regions around the stations VES 6 and VES 8 show a high value of resistivity for top layer with a thickness above 3.5m, while it is less than 3m at other stations.

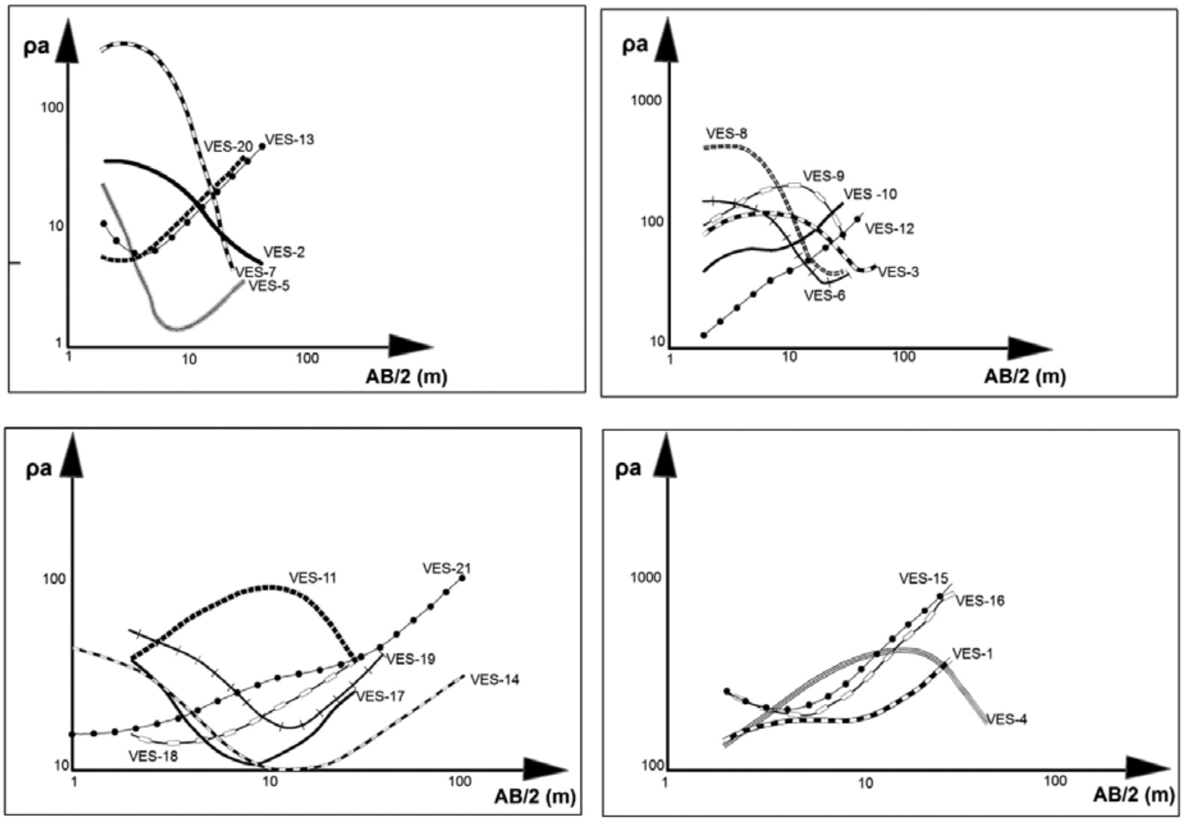


Figure 2. Interpreted VES curves.

Table.1: Interpreted results of the VES curves.

VES No	ρ1	h1	ρ2	h2	ρ3	h3	ρ4	Depth to Bedrock (m)	TDS (mg/l)
VES 1	72.4	1	593	1.1	69.6	3	5067	5.1	900
VES 2	34.4	1.9	21.1	4.9	4.2			_	1598
VES 3	61.7	1	157	4.6	34.4			_	_
VES 4	102	1.6	1249	5.2	77.8			_	167
VES 5	42.9	1	1.1	7.9	73.7			8.9	_
VES 6	160	4.7	8.7	6.2	1901			10.9	2420
VES 7	281	1	693	1.5	2.7			_	
VES 8	499	3.6	15.6	4.7	61.9			8.3	
VES 9	62.7	1.1	399	5.9	1.1			_	
VES 10	28.6	1	167	1.2	23.6	3.2	5200	5.4	539
VES 11	21.3	1	225	3.9	6.9			_	5387
VES 12	6.81	1	143	2.3	29.4	4.4	1440	7.7	689
VES 13	17.9	1	2.7	2.2	253			3.2	4057
VES 14	41.9	1.5	10.2	13.3	4.8	4.1	99.3	18.9	3590
VES 15	388	1.2	91.8	2.3	9304			3.5	
VES 16	260	1.8	95.8	2.4	5296			4.2	
VES 17	49.1	1.4	8.4	8.2	83			9.6	
VES 18	18	1.3	12.6	4.8	120			6.1	
VES 19	50.5	2.8	9.6	9.2	5077			12	
VES 20	6.5	1.1	2.6	1.7	1266			2.8	
VES 21	15.4	2.3	43.5	6.8	17.9	9.9	613	20	497

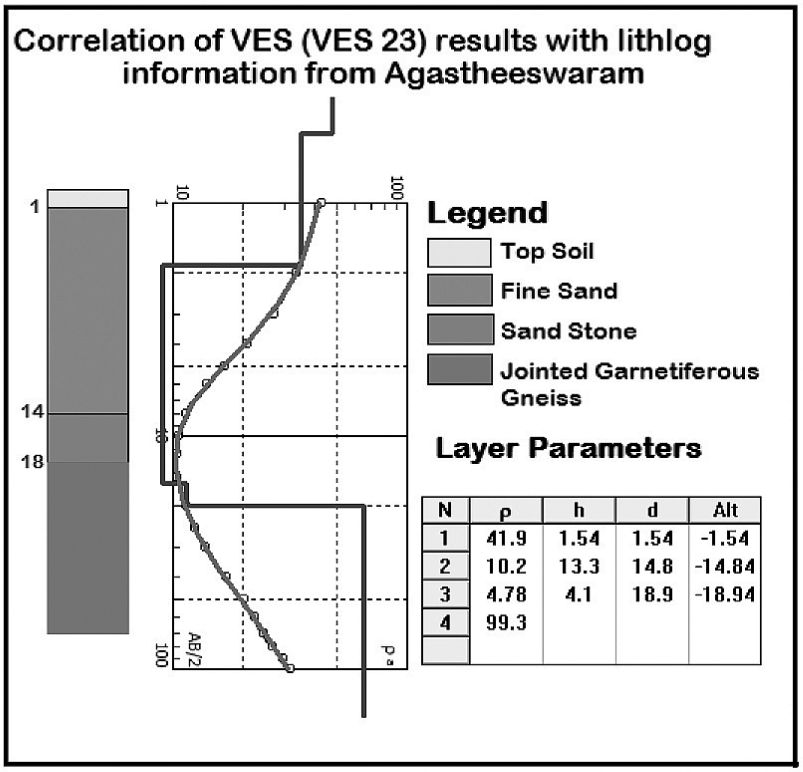


Figure 3. Comparison of interpreted results with available litholog.

In general, the second layer resistivities were low compared to the top layer in majority locations, ranging between 1.1 – 1249 Ωm. The thickness of the second layer varies from 1.1 – 13.3 m. Isolated patches of weathered gneiss/charnockite/leptinite and sandyclay/clay/ sand deposits with groundwater corresponding to this layer may be responsible for such variation of resistivity. Generally, the aquifer with thickness more than 2 m can be considered as potential in terrains as in the present study. In such terrains the aquifers with the resistivity ranging between 10 Ωm to 100 Ωm can be considered as good aquifers. At some of the locations VES 5, 6, 13, 17 and 19, the groundwater potential zones are revealed by reasonably thick weathered gneiss or sandy clay/clay/sand formations by VES and lithological information (PWD, 2005). However, the quality of water is poor as reported by local people and supported by the resistivity values of less than 10 Ωm. This may be because of the salt water intrusion and other anthropogenic activities. Because of the elevated ground near the stations VES 10, 12, 15 and 16 of the study area, the groundwater quality is good. This is confirmed near VES12 with relatively high resistivity value greater than 10 Ωm and low TDS value.

The resistivity values of the third geoelectric layer vary between 1.1 to 9304 Ωm corresponding to the bedrock, laterite or clay/sand bearing fresh and saline water in patches. The third geoelectric layer resistivity drops for the stations VES 2, 7, 9, 11 and 14, when compared to the first and second layer mainly because of the water content in the weathered/fractured bedrock and saline water intrusion in the favourable geological formations. VES 6, 13, 15, 16, 19 and 20 show higher resistivity third geoelectric layer ,which may be attributed to the gneiss/ leptinitic/Charnockite bedrock. The basement was not revealed by some of the sounding curves (VES 2, 3, 4, 7, 9 & 11) of the study area probably as electrode separation was not sufficient to reach down to the bedrock. To assess the groundwater conditions of the region, the distribution of the geoelectric parameters such as true resistivity and thickness of individual layers were taken into account.

Geoelectric section:

Geoelectric sections prepared from VES data clearly reveal the lateral and vertical variations of ground water quality as well as aquifer thickness (Prabhakara Rao and Negi, 2003). Two such geoelectric sections were prepared along two profiles from the interpreted results considering the linear placement of VES stations (Fig.4 a&b). The profile-1(Fig.4a), from VES 1 to VES 14 in a line reveals that the areas around VES 2, VES 5, VES 6, VES 7, VES 9, VES 11, VES 13 and VES 14 are affected by salinity as shown by very low resistivities, probably due to saline water intrusion. However, a well penetrating up to 14 meters at VES 14 may

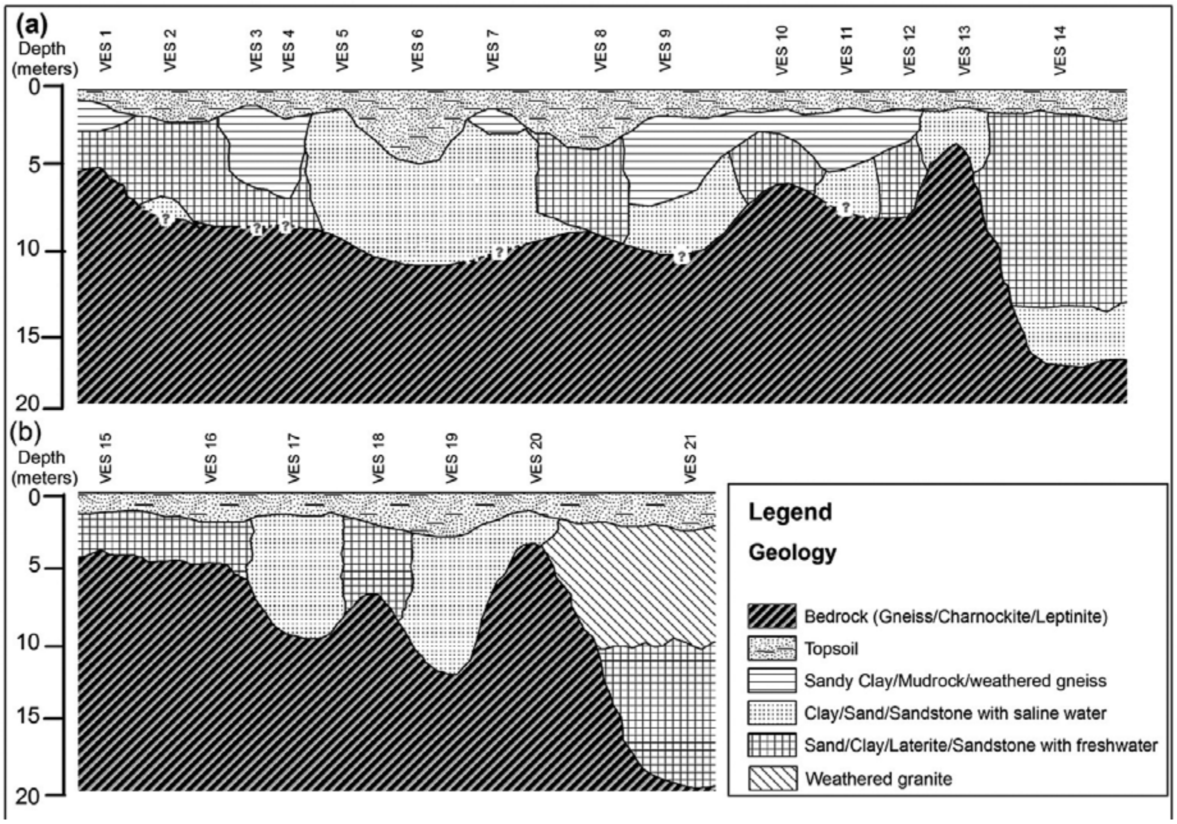


Figure 4. (a) – Geoelectric section along profile – 1. (b) – Geoelectric section along profile – 2.

yield potable water as revealed by 10.2 ohm m resistivity underlain by saline layer. The geoelectric section also shows very low value of resistivity around VES13 due to the salt water intrusion from the nearby Manakudy estuary. The geoelectric section for profile-2 (Fig.4b) between VES 15 to VES 21 shows low resistivity in the areas surrounding VES 17 and 19 and this may be attributed to saline water intrusion from a large number of salt pans nearby. At the station VES 18, the resistivity of the aquifer is just above 10 Ωm (12.6 Ωm).

The depth to the aquifer is in general less than 5 m, which is normally observed in the study area. The stations VES 14 and 21 show comparatively higher depth to bed rock ,which may be due to the elevated topography. Depth to basement values varies widely in the study area ranging between 2.8 – 20 m, with an average depth to the basement of around 10 m coinciding with the bottom of the aquifers in many locations from the well inventory data (PWD, 2005).

SUMMARY AND CONCLUSIONS

The present study highlights the usefulness of electrical resistivity study in identifying the subsurface geological formations to locate the potential groundwater aquifers of different yields in this region. It can be concluded that the incursion of saline water from tidal creeks, estuaries, saltpans along the coast is affecting the quality of groundwater. TDS values of water samples collected from 10 stations in close proximity to the VES stations and the resistivity values of aquifer reveal a good correlation. The interpreted results of VES 1, VES 8, VES 10, VES 12, VES 15, VES 16 and VES 21 reveal potential aquifer zones with good quality of groundwater. Because of shallow water table depth and limited thickness of aquifer, most of these locations are suitable for dug wells except VES 21 ,which is suitable for dug cum bore well or bore well depending on feasibility. Even though VES 5, 6, 14 and 19 reveal a good thickness of aquifer, the water could be saline in nature. The stations VES 9 and VES 11 also indicated saline water while the basement rock is not revealed, probably due to less electrode separation/salinity. Near the stations VES 13, 19 and 20, the saline water intrusion is seen in the shallow subsurface. But, the layer with 9.6 ohm m resistivity at VES 19 may turn out to be potable or less saline water bearing zone, which could be tried after conforming to TDS values of water from nearby wells. The geo electric sections prepared from the results of VES show the saline water bearing zones around the stations VES 2, VES 5 and VES 13 coinciding with Pozhikarai, Rajakkamangalam and Manakudy estuaries, respectively. The region around station VES 17 and 19 shows low resistivity of aquifer, because of the intrusion of saline water from the nearby salt pans. Marine terraces and uplands along the coast act as natural barrier and prevent the saline incursion, which results in the availability of freshwater in the upstream side of these structures.

RECOMMENDATIONS

The saline water intrusion from the nearby estuaries and salt pans can be prevented by constructing barriers near the stations VES 2, VES 5, VES 13, VES 17 and VES 19. As all the stations are near to the sea, it is necessary to control the saline water intrusion by adapting a suitable pumping pattern and also by making necessary structures to increase the groundwater level through artificial recharge. Water samples from locations showing resistivity values around 10 ohm m should be monitored for their salinity with different pumping rates to fix the optimum pumping rate.

ACKNOWLEDGEMENT

The authors thank Central Ground Water Board (CGWB), Chennai for providing available litholog data. The authors also thank the reviewer and Dr. P.R. Reddy, Editor for critical review and useful suggestions.

REFERENCE

Batayneh, A.T., 2006. Use of electrical resistivity methods for detecting subsurface fresh and saline water and delineating their interfacial configuration: a case study of the eastern Dead Sea coastal aquifers, Jordan. Hydrogeology Journal, v.14, pp:1277–1283.

Chandrasekar, N., Loveson, V.J., Dajkumar Sahayam, J., Rajamanickam, M., and Saravanan.,& S., 2006. Appraisal of tsunami inundation and run up along the coast of Kanyakumari District, India. GIS analysis. Oceanologia, v.49, no.3,pp:397–412.

GSI, 2005. Geology and mineral map of Kanyakumari district compiled by Sundaram, R., Renganathan, M., and Vasudevan, D., and published by Geological Survey of India.

Kosinky, W. K., and Kelly, W. E., 1981. Geoelectrical sounding for predicting aquifer properties, Groundwater, v.19, pp:163-171.

Mazac, O., Kelly, W. E., and Landa, I.,1985. A hydrophysical model for relation between electrical and hydraulic properties of aquifers, Journal of Hydrology, v.79, pp:1-19.

Mondal, N.C., Das, S.N., and Singh, V.S., 2008. Integrated approach for identification of potential groundwater zones in Seethanagaram Mandal of Vizianagaram District, Andhra Pradesh, India. Journal of Earth System Science, v.117(2), pp:133–144.

Orellena, E., and Mooney, H.M., 1966. Master tables and curves for vertical electrical sounding over layered structures. Interciencia, Madrid, Spain,v. , pp:150.

Pervaiz Sikandar., Allah Bakhsh., Muhammad Arshad., and Tariq Rana., 2010. The use of Vertical electrical sounding resistivity method for the location of low salinity groundwater for irrigation in Chaj and Rachna Doabs. Journal of Environmental Earth Science, v.60,pp:1113–1129.

Prabhakara Rao, M.R.K., and Negi, B.C., 2003. Geoelectrical investigations for locating potable aquifers in parts of Agra District, U.P., India. Journal of Indian Geophysical Union, v.7, no.4, pp: 219-226.

PWD, 2005. Groundwater perspectives: a profile of Kanyakumari district, Tamil Nadu. Tamil Nadu Public Works Department, India.

Sung-Ho Song., Jin-Yong Lee., and Namsik Park., 2007. Use of vertical electrical soundings to delineate seawater intrusion in a coastal area of Byunsan, Korea. Journal of Environmental Geology, v.52,pp:1207–1219.

Sri Niwas., and Singhal, D., 1981. Estimation of aquifer transmissivity from Dar-Zarrouk parameters in porous media. Hydrology Journal, v. 50,pp:393–399.

Telford, W.M., Geldart, L. P., and Sheriff, R. E., 1990. Applied Geophysics (second edition). Cambridge University Press, Cambridge.

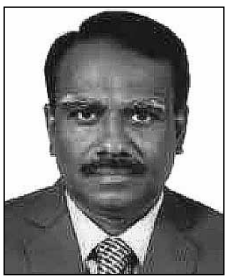
Yadav, G.S., and Abolfazli, H., 1998. Geoelectrical soundings and their relationships to hydraulic parameters in semi arid regions of Jalore, North West India, Journal of Applied Geophysics, v.39,pp:35-51.

Zohdy, A.A.R., 1974. Application of surface geophysics to groundwater investigations. US Dept. Interior, Geological Survey Book No. 2.

Dr.Y.Srinivas is presently working as Associate Professor at Centre for GeoTechnology, Manonmaniam Sundaranar University, Tirunelveli, Tamilnadu. He has completed his M.Sc.Tech and Ph.D in Geophysics from Osmania University, Hyderabad. He has worked in couple of sponsored research projects at NGRI, Hyderabad. He is having around 20 years of research and teaching experience in geophysics and published about 30 research papers in National and International journals.

Mr. D.Hudson Oliver is presently pursuing his Ph.D in Physics-Geophysics at Centre for GeoTechnology, Manonmaniam Sundaranar University, Tirunelveli. He obtained his graduation from Scott Christian College, Nagercoil and thereafter completed his M.Sc. Physics from Annamalai University, Chidambaram. He has published papers in national and international journals.

Dr. A. Stanley Raj is presently working as Assistant Professor at Vel Tech technical university, Chennai. He has completed his M.Sc. Physics in 2007 and Ph.D (Physics-Geophysics) in 2013 from Manonmaniam Sundaranar University, Tirunelveli. He has published research papers in the application of soft computing techniques in geophysics.



Prof. N. Chandrasekar is working as Professor and Head, Centre for GeoTechnology, Manonmaniam Sundaranar University, Tirunelveli. He has 34 years of teaching and research experience in the field of Marine geology, Coastal engineering, Remotesensing & GIS and Coastal hydrogeology. He has published more than 150 research papers in National and International journals. He has received several academic awards and Fellowship in National Environmental Science Academy.