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Evaluation of Groundwater Condition Using Geo-electrical Soundings in Parts of Tiruchendur Taluk, Tamilnadu, India

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***Abstract*----** The present study is an approach to evaluate the groundwater condition near Tiruchendur, Tamil Nadu, Tuticorin District, India using Vertical Electrical Sounding method. Vertical Electrical Sounding is one of the most suitable geophysical method for groundwater prospecting and it provides the vertical variation of subsurface layer in terms of thickness and resistivity values. A total of 12 VES were carried out using the Schlumberger configuration in the area. DDR3 resistivity meter (IGIS Pvt. Ltd) was used for the data acquisition. The obtained field data was analyzed and interpreted with the help of IPI2WIN software which gives an automatic interpretation of the apparent resistivity. The results of quantitative interpretation of geo electrical data show that the study area comprises of three to five electrical layers. The layer resistivity obtained is ranging from 1.3Ωm to 1512Ωm respectively.Among the total 12 vertical electrical soundings, three VES are found to have good groundwater potentiality as well as quality and six VES are found to have good groundwater potentiality with poor quality.

Keywords: VES, Aquifer quality, Tiruchendur, Schlumberger, IPI2WIN

I. INTRODUCTION

Groundwater is the beneath water found under the subsurface of earth. Groundwater accounts for 98% of all available fresh water. It is more than 60 times abundant as freshwater available in the form of lake, river and stream. Groundwater is a most valuable renewable source. Hence protection and management of groundwater is crucial part of ecosystem. Generally, geophysical methods were applied to explore the hydrogeological targets in many places. The most common method for hydrogeological exploration is Vertical Electrical Sounding (VES). The use of Schlumberger array generally gives better resolution, greater depth of investigation and less time consumption during field data acquisition [1]. Groundwater is held in geological material such as soil, sand and rock beneath the surface such geologic layers is called an aquifer which can supply water continuously. Over exploitation of groundwater in coastal aquifer causes saline water intrusion [2]. In recent days several geophysical studies were carried out worldwide as well as southern region of India to assess the nature of the groundwater [3,4,5,6,7,8,9]. The present study is an approach to evaluate the groundwater condition near Tiruchendur, Tamil Nadu, Tuticorin District, India using Vertical Electrical Sounding method.

Rest of the paper is organized as follows, Section I contains the introduction of the study , Section II contain the study area description, Section III contain geological and hydrological settings, Section IV explain the methodology, Section V describes results and discussion and Section VI concludes research work with future directions.

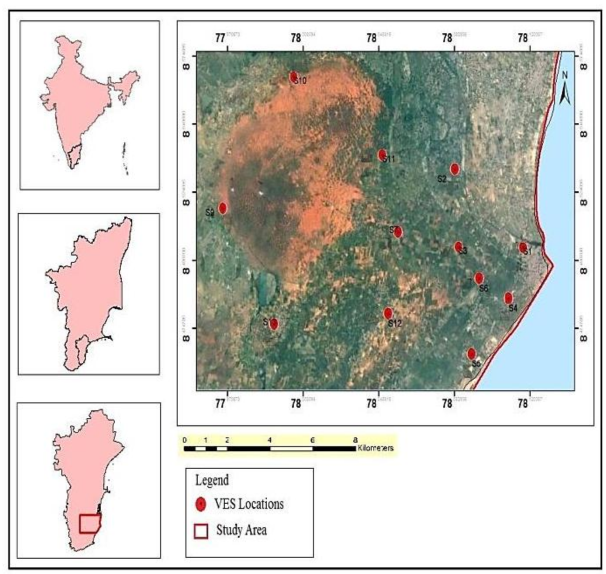


Figure 1. Study Area

II. STUDY AREA

Tiruchendur taluk is located in the south-east coast of India in Tuticorin district of Tamil Nadu. The geographical extent of the study area lies between $8^0$26'56.4" to $8^0$34'51.6" latitudes and $78^0$5'20.4" to 78^0 8'6" longitudes. Karamaniar river is the major drainage system, hence the study area is coming under Karamaniar river basin. The river originates from the upland of western Ghats and flows through semi-arid landforms towards southwest and confluences with Bay of Bengal. Most parts of the study area are generally plain terrain with a gentle slope towards south and east. There is a sand dune formation namely 'Teri sand' is seen in between Kayamozhi and Nazareth. The study area prevails sub-tropical climatic conditions with poor precipitation throughout the year. The optimum temperature extends up to 32 to 39 degree Celsius. The annual average rainfall is 280 mm and maximum rainfall receives during the NE monsoon (444mm) than the SW monsoon (117mm). Groundwater is the important source of water for drinking and irrigation purposes and influences the livelihood of the local people. Figure 1 shows the location map of the study area with VES points.

III. GEOLOGICAL AND HYDROLOGICAL SETTINGS

The study area is geologically comprising of Hornblende-Biotite Gneiss, Garnet Sillimanite Gneiss, Garnet-Biotite Gneiss, Sandsatone with Clay, Aeolian, Fluvial, Fluvio marine and Marine. The detailed geological map of the study area is shown in Figure 2. The host rocks of coastal plains are mostly quaternary to recent age. Hornblende-Biotite Gneiss is a hard, foliated and easily weathered rock type which is distributed in the western part of the study area. Marine formations are distributed along the coastal stretch. Fluvial deposits are consisting of soft-unconsolidated sediment. A patch of sandstone with clay is seen in the south-west part of the study area.The important aquifer systems are comprised by semi-consolidated, unconsolidated formations with fractured crystalline rocks. In hard rock areas, the weathered zone exists up to 25 meters below ground level underlain by fractures up to 30 mbgl as per lithology of boreholes. In the sedimentary formations (Teri sands), the yield of bore wells range from 200 to 1950 lpm. Most of the wells are experiencing seasonal groundwater level fluctuations when they are not exploited or moderately used.

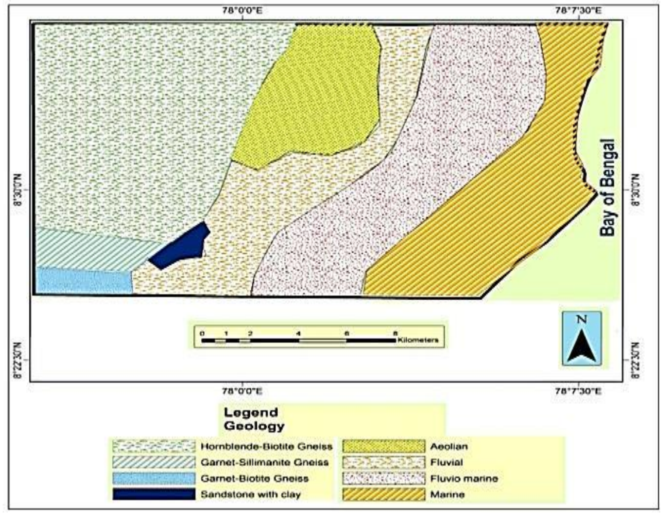


Figure 2. Geology of study area

IV. METHODOLOGY

The DDR3 resistivity meter is used in the study area for conducting the vertical electrical sounding. It is very compact, highly reliable and well designed. The instrument is able to store measuring data for more than 150,000 times, including measuring point, voltage, current, resistivity, SP, relative error, array constant and so on. The resistivity survey by vertical electrical sounding (VES) method was carried out at 12 locations in and around the Tiruchendur area. The vertical electrical soundings were carried out applying Schlumberger technique with maximum current electrode spacing (AB) up to 200 m (AB/2=100 m). Bhattacharya and Patra (1968) [10] and Bhimasankaran et al., (1967) [11] judged that the Schlumberger arrangement is more valuable in the groundwater related studies. The data analyzed by curve matching techniques using IPI2Win software.

V. RESULTS AND DISCUSSION

5.1 Data Processing

Vertical electrical sounding curves can be interpreted semi-quantitatively or quantitatively using computer modeling. VES field curves may have subtle inflections and cusps which require the interpreter to make decisions based on how real or significant such features are. The noise in the field curve is smoothed and a graph is easily modeled. As a general rule, depending on how sophisticated the field acquisition method is, layer thicknesses and resistivities are accurate to between 1% and 10%, with poorer accuracies arising from the cruder field techniques. Results from near subsurface layers provide more accuracy than those at higher depth, because field data from shorter electrode separations tend to be more reliable than those for very large separation, owing to higher signal-to-noise ratios.

The first stage of interpretation of apparent resistivity sounding curves is to note the curve shape. Based on the curve shape, soundings can be classify to one of four basic curve shapes. These basic shapes can combined to describe complex field curves for more than three layers. Note that the curve shape is dependent upon the relative thicknesses of the in-between layers. The maximum angle of slope that the rising portion of a resistivity graph may have on a log-log graph is 45°, given the same scales on both axes. If the field curve rises more steeply, then this suggests error in the data or geometric effect due to steeply inclined horizons are distorting the data. Figure 3 shows four types of apparent resistivity curve shapes for three layer formations.

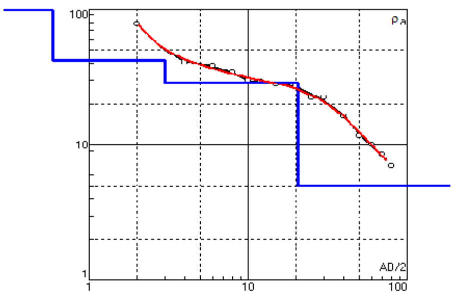
Apparent resistivity data processing and interpretation was carried out with the software package IPI2WIN. Apparent resistivity is plotted against AB/2 in double log sheet. Field curve was obtained (Black line). Model curve was generated in the software (Red line). Both curves were matched and resistivity model was obtained (Blue line). From the resistivity model, the layered resistivity parameters (ρ1, ρ2, ρ3 etc – Average apparent resistivity of layer1, layer2, layer3 etc.), (h1, h2, h3etc - thickness of the layer1, layer2, layer3 etc.), (d1, d2, d3 etc - depth to layer interface of layer1, layer2, layer3 etc.) were identified. The layered resistivity parameters were interpreted in terms of various lithological layers. The Schlumberger responses of interpreted VES curves obtained from 12 stations with layer parameters are shown in the figures 3 to 14.

5.1Data Interpretation

The obtained layer parameters like resistivity and thickness of all the 12 electrical sounding are shown in Table 1. The geoelectrical layers obtained from the vertical electrical sounding survey reveals various hydrogeological conditions in the subsurface of the study area varying between highly saline areas and freshwater regions. It was found that the aquifers with favorable low resistivity ie, may be in the range 10-100 Ωm and having considerable thickness can be considered as good groundwater potential aquifers. From the interpreted results, a total of 3 to 5 geoelectrical layers are found. VES2, VES7 and VES10 are the three stations showing three layered geoelectrical sections. The stations VES1, VES3, VES5, VES6, VES8, VES9, VES11 and VES12 are found to have four geoelectrical layers with differing resistivities. VES4 is the only station having five geoelectrical layers. Among the three layers cases VES2 and VES10 are of Q type curve and VES7 gives an H type curve. In the case of VES7, it can be foundthat, a low resistivity layer sandwiched between two high resistivity layers and here this low resistivity layer with considerable thickness may indicate the presence of aquifer.

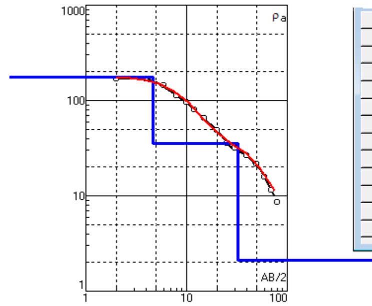
The four layered sections obtained from the curves belonging to the stations VES1,VES3 and VES11 are QQ type has the resistivity in the order $\rho1 > \rho2 > \rho3 > \rho4$. VES5 and VES6 are KQ type curve with resistivity in the order $\rho1 < \rho2 > \rho3 > \rho4$. VES8 is KH type curve with resistivity in the order $\rho1 < \rho2 > \rho3 < \rho4$, VES9 is HA type curve with resistivity in the order $\rho1 > \rho2 < \rho3 < \rho4$ and VES12 is QH type curve with resistivity in the order $\rho1 > \rho2 > \rho3 < \rho4$. The remaining curve of VES4 is five layered (KHK type) and has the resistivity in the order $\rho1 < \rho2 > \rho3 < \rho4 > \rho5$. Here the aquifer may present in the fourth layer.

When considering VES1, the fourth layer may be the aquifer but the aquifer depth is not reached, where as in the case of VES2, third layer may be the aquifer. VES3 is very near to coast and the resistivity value indicates that the subsurface layers favor saltwater intrusion [12]. In the case of VES4, fifth layer may be the aquifer but the quality of water in this aquifer may be very poor. In VES5 and VES6, fourth layer may consider as the aquifer and here the basement is not reached. But in the case of VES7 second layer may be the aquifer with a layer thickness of 15.4 meter at a depth of 18.6 meter. When considering VES8, the third layer may be the aquifer and the resistivity value indicates that the water quality may be very poor. In the case of VES9, second layer may consider as the aquifer with layer thickness of 10.6 m. In VES10 third layer and in VES11 fourth layer may be the aquifer, but in both cases aquifer depth is not reached. When considering VES12 third layer may consider as the aquifer at 20.54 m depth with layer thickness of 14.84 m. VES7, VES8, VES9 and VES12 are found to be the aquifers with good productivity. Among these aquifers the quality of groundwater near VES8 may be poor and the reason of this poor quality may be local contaminations like domestic waste seepage, rock-water interaction and over exploitation and other anthropogenic activities. The remaining VES locations also found to have good potentiality but the aquifer depth was not reached. VES1, VES2, VES3, VES4, VES10 and VES11 have good groundwater potentiality but poor groundwater quality as the resistivity values are below 10Ωm and in these regions the poor groundwater quality may be because of the saline water intrusion from the nearby sea and other local contaminations. The aquifer near VES5and VES6 are vulnerable to get salinity contamination as the aquifer resistivities of the stations are in the range of 11 to 15Ωm.



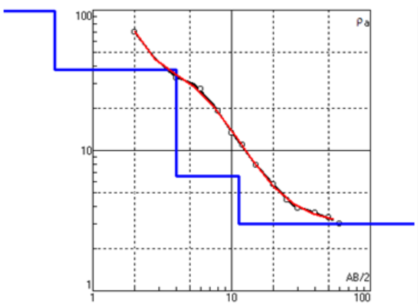
N	ρ	h	d	Alt
1	284	0.586	0.586	-0.586
2	41.9	2.41	3	-2.99
3	28.6	17.5	20.5	-20.4
4	5.02			

Figure 3.Apparent resistivity curve along with layer model VES1



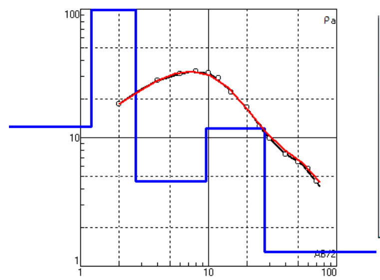
N	ρ	h	d	Alt
1	176	4.69	4.69	-4.69
2	35.6	27.5	32.2	-32.1
3	2.1			

Figure 4.Apparent resistivity curve along with layer model VES2



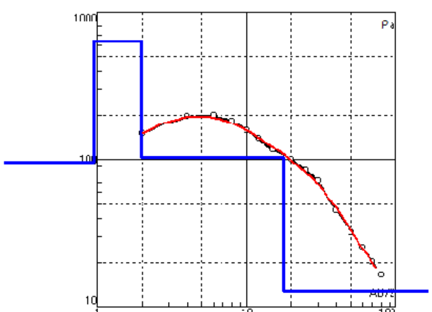
N	ρ	h	d	Alt
1	386	0.533	0.533	-0.533
2	37.4	3.47	4	-3.99
3	6.52	7.24	11.2	-11.2
4	3			

Figure 5.Apparent resistivity curve along with layer model VES3



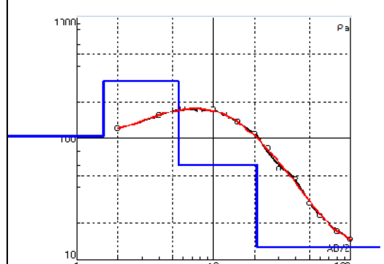
N	ρ	h	d	Alt
1	12.2	1.21	1.21	-1.20
2	159	1.5	2.71	-2.71
3	4.6	6.81	9.52	-9.52
4	11.8	17.8	27.3	-27.2
5	1.3			

Figure 6.Apparent resistivity curve along with layer model VES4



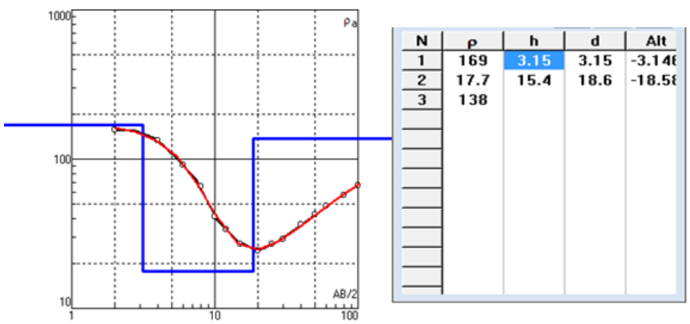
N	ρ	h	d	Alt
1	95.5	0.946	0.946	-0.945
2	633	1.02	1.96	-1.96
3	103	15.4	17.3	-17.3
4	12.7			

Figure 7.Apparent resistivity curve along with layer model VES5



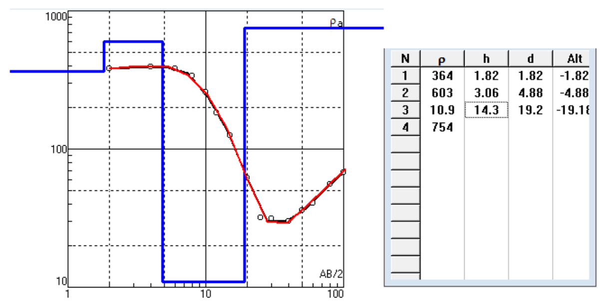
N	ρ	h	d	Alt
1	104	1.57	1.57	-1.57
2	301	3.97	5.54	-5.54
3	61.3	15.1	20.7	-20.6
4	12.7			

Figure 8.Apparent resistivity curve along with layer model VES6



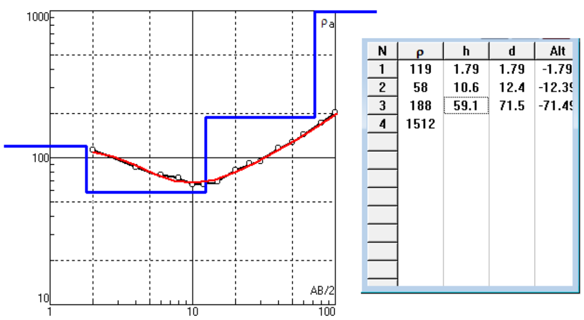
N	ρ	h	d	Alt
1	169	3.15	3.15	-3.14
2	17.7	15.4	18.6	-18.5
3	138			

Figure 9.Apparent resistivity curve along with layer model VES7



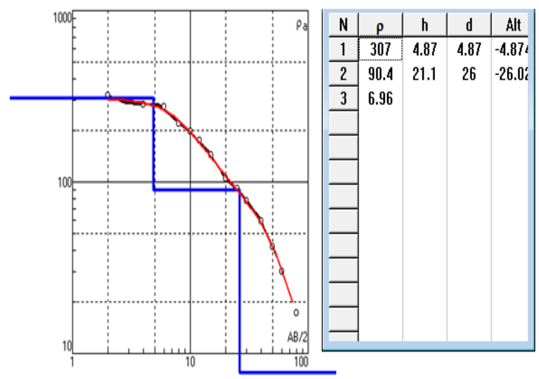
N	ρ	h	d	Alt
1	364	1.82	1.82	-1.82
2	603	3.06	4.88	-4.88
3	10.9	14.3	19.2	-19.1
4	754			

Figure 10.Apparent resistivity curve along with layer model VES8



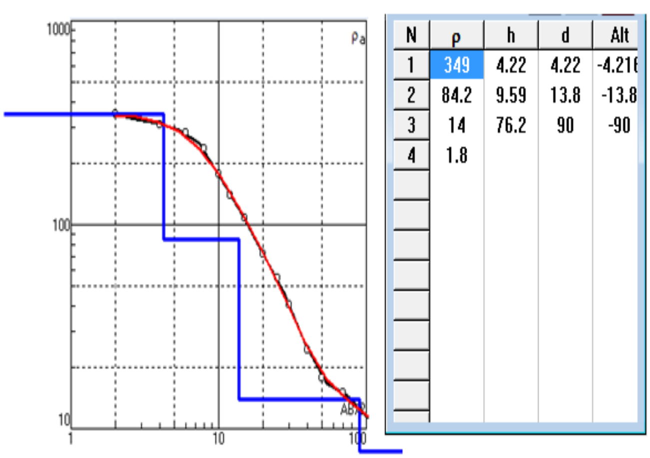
N	ρ	h	d	Alt
1	119	1.79	1.79	-1.79
2	58	10.6	12.4	-12.3
3	188	59.1	71.5	-71.4
4	1512			

Figure 11.Apparent resistivity curve along with layer model VES9



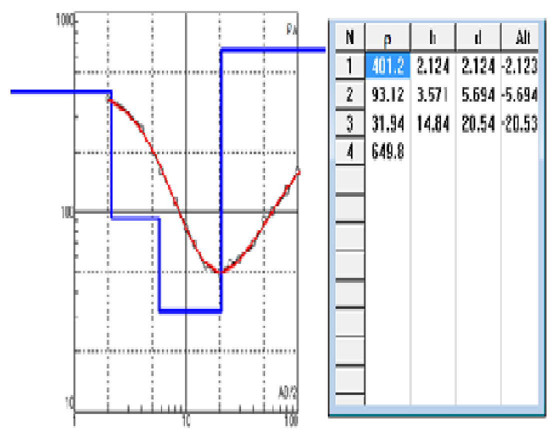
N	ρ	h	d	Alt
1	307	4.87	4.87	-4.87
2	90.4	21.1	26	-26.0
3	6.96			

Figure 12.Apparent resistivity curve along with layer model VES10



N	ρ	h	d	Alt
1	349	4.22	4.22	-4.21
2	84.2	9.59	13.8	-13.8
3	14	76.2	90	-90
4	1.8			

Figure 13.Apparent resistivity curve along with layer model VES11



N	ρ	h	d	Alt
1	401.2	2.124	2.124	-2.123
2	93.12	3.571	5.694	-5.694
3	31.94	14.84	20.54	-20.53
4	649.8			

Figure 14.Apparent resistivity curve along with layer model VES 12

Table1: Geoelectrical parameters obtained from the VES curves

Parameters	ρ1	h1	ρ2	h2	ρ3	h3	ρ4	h4	ρ5
VES1	284	0.586	41.9	2.41	28.6	17.5	5.02		
VES2	176	4.69	35.6	27.5	2.1				
VES3	386	0.533	37.4	3.47	6.52	7.24	3		
VES4	12.2	1.21	159	1.5	4.6	6.81	11.8	17.8	1.3
VES5	95.5	0.946	633	1.02	103	15.4	12.7		
VES6	104	1.57	301	3.97	61.3	15.1	12.7		
VES7	169	3.15	17.7	15.4	138				
VES8	364	1.82	603	3.06	10.9	14.3	754		
VES9	119	1.79	58	10.6	188	59.1	1512		
VES10	307	4.87	90.4	21.1	6.96				
VES11	349	4.22	84.2	9.59	14	76.2	1.8		
VES12	401.2	2.124	93.12	3.571	31.94	14.84	649.8		

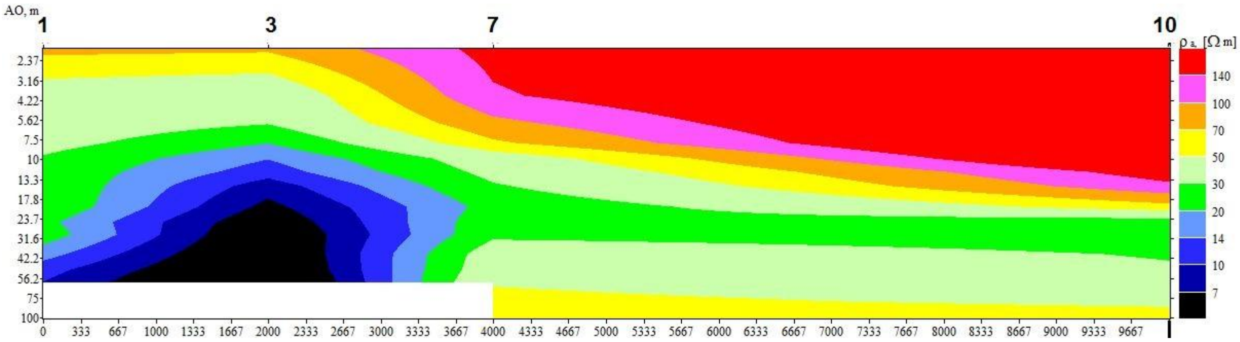


Figure 15.Pseudo section of profile-1

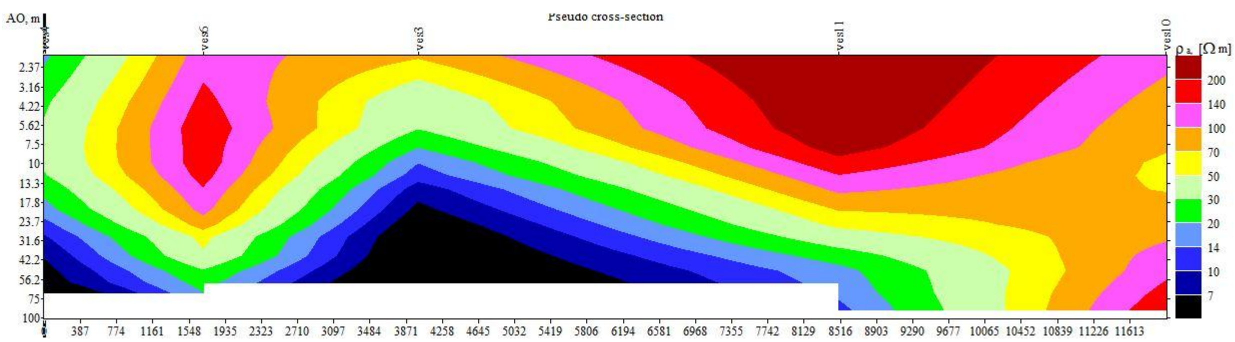


Figure 16. Pseudo section of profile-2

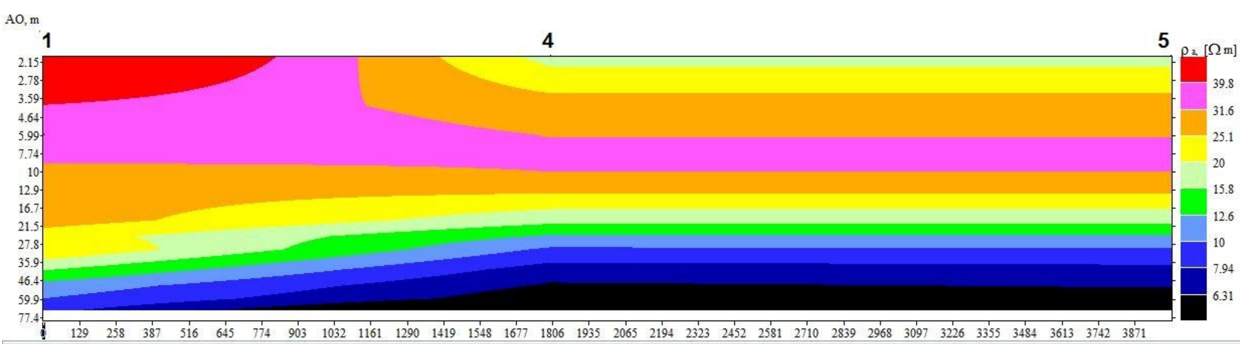


Figure 16. Pseudo section of profile-3

VI. *Pseudo Cross-section*

The profile-1 consists of the VES stations 1, 3, 7, and 9.The pseudo resistivity cross-sections along the profile 1 indicate low resistivity value 5Ωm at the depth of 17m [12,13,14].It revealed that saline water intrusion near the coastal area.

The profile-2 consists of the VES stations 4,6,3,11,10 was located near the coastal area. In this pseudo section black color clearly indicates saline water intrusion. It is occurred due to over extraction of groundwater [15]

The profile-3 consists of the VES stations 1,4,5 was located near the coastal area. Similar to the pseudosection of profile 1 shows that seawater intrusion in the coastal area mainly in Tiruchendur area.

VII. Conclusion

Electrical resistivity studies explore the subsurface characteristics based on the surface field results. This work helps to depict the groundwater conditions in parts of TiruchendurTaluk and it gains importance in the view of saving and warning the society from the threatened future. The inverted results of VES data after inversion from IPI2win software shows that the study area comprises of 3 to 5 geoelectric layers. The study area falls in the close proximity to Tiruchendur coast so the nature of groundwater in this area seriously affected by sea water intrusion. Of the 12 VES soundings, VES7,VES9 and VES12 are found to have good groundwater potentiality as well as quality. Seven VES soundings are found to have good groundwater potentiality but poor groundwater quality. Aquifer near two soundings is vulnerable to get salinity contamination as the aquifer resistivity ranges between 11 and 15 Ωm. The aquifer system in the study area is productive but is contaminated due to seawater intrusion and anthropogenic activities. This study has practical importance as it guides the local people for selecting suitable places for drilling wells thereby reducing their risk efforts

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