



DEMARCATON OF GROUNDWATER RECHARGE ZONES IN PUDUCHERRY USING ELECTRICAL RESISTIVITY METHOD

K.Anil Kumar, G.Babu Rao

Assistant Professor,

Department Of Civil Engineering,

Narasraopeta Engineering College,

Kottapakonda Road, Yallamanda Post,

Narasaraopet-522 601

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Abstract

Groundwater identification using geophysical methods are quit common in now a days. To identify the groundwater recharge zones in puducherry, ten VES were conducted using Schlumberger electrode configuration. The results indicate the presence of three layers. The first layer resistivity varies from 2.18 Ωm to 475 Ωm , the second layer resistivity ranges from 0.879 Ωm to 271 Ωm and the resistivity of the bottom layer ranged from 0.226 Ωm to 1403 Ωm respectively. Based on thickness the study area is divided into two identifiable layers. The thickness of the first layer ranged from 3.75 m to 41.7 m. The thickness of second layer varies from 3.77 to 71.4 m. Transverse resistivity values indicate that the VES locations of 2, 5 and 7 are good groundwater potential zones. Based on Henriet classification of Longitudinal

conductance VES locations fall in weak (VES 7), moderate (VES 2, 5 and 8) and good aquifer (1,3,4 6,9 and 10) respectively. Anisotropy results indicate VES 2,4,5,7 and 9 locations are good groundwater potential zones.

1 Introduction

Groundwater is considered to be one of the valuable resources in many of the coastal areas of the world. Its extraction rate has increased nearly twice with the increase of population. Hence, it is important to understand, extract and assess the groundwater in a profitable manner as in recent times the groundwater utility is increasingly becoming a major constraint for sustainable development. In the last two decades the utility of groundwater consumption for food and energy production has increased so as to meet the demands of population growth and to enhance human wellbeing, a continuing global trend [1]. At present nearly one-fifth of all the water used in world are obtained from groundwater only [2]. The increasing demand of groundwater has stimulated investigations oriented towards quantification of resource, which is basic for planning exploitation, management and conservation. The present aims in identifying the subsurface layering and thickness and resistivity, depth of aquifers, the geological condition of the area with the help of Aquifer parameter characteristics by using the Geo electrical Resistivity method.

2 Study area

The study area is Puducherry, a union territory located on the Coromandel Coast as scattered isolated patches between 11°45' and 12°03' N latitudes and 79°37' and 79°53' E longitudes. It is surrounded by the Bay of Bengal on east, by Villupuram district on the north and west and by Cuddalore district on south directions (Fig.1). It falls in the Survey of India topographic sheets No.s 58M/9, 58M/13, 57P/12 and 57P/16. It is situated at a distance of 162 km to the Chennai in south direction and holds a population of 9,73,829. The major occupation of the people in the study area as it is located near the coastal region. The River

Godavari flows through the study area and makes it fertile to grow good quality agricultural crops. The majority of the people in this region depend on agriculture (i.e. cultivators and agricultural laborers). The normal annual rainfall in the study area is 1272.7 mm. Out of which 62% is received during northeast monsoon season and 26% during the southwest monsoon season. Groundwater is used for both drinking and irrigation purposes in the study area.

The study area is underlain by the semi-consolidated and unconsolidated sedimentary formations ranging in age from lower Cretaceous to Recent, lying on Archaean basement. The Archaean include signified by the rocks of Eastern Ghat complex including charnockites and gneisses. These formations are overlain by sandstones, limestones and claystones of Mesozoic. These formations are also conformably overlain by silt stone and limestone of Tertiary age. These are unconformably overlain by Quaternary deposits of Sands, Clays, silts, kankar and gravels which lie on the top of the formation (Fig.2). Geomorphologically the study area is divided into Coastal plains, alluvial plains and Uplands. The study area is a flat peneplain with an average elevation of 15 m above mean sea level. The terrain is undulating having altitude ranging from 30 to 100m above mean sea level towards northwest and northeastern parts of the region (Fig.3). The coastal plains in the study area extend as a narrow stretch for about 22 km and of 400 to 600 meters width on the eastern part of the region along the Bay of Bengal. The Alluvial plain is observed due to two major rivers namely Gingee and Ponnaiyar having a slope ranging between 1 and 3 percent. The high grounds are observed from the Red Hills of Puducherry having an altitude of 30 to 100m above mean sea level.

3 Groundwater Levels

The depth to the water level in the alluvial aquifer ranges from 5 to 20 mts bgl. Whereas in Cuddalore sandstone formation, it is in between 15m and 25m bgl while in Cretaceous aquifer, the water level ranges from 20 to 45m bgl. From the previous observation wells data the trend is declining which shows there is a drop in

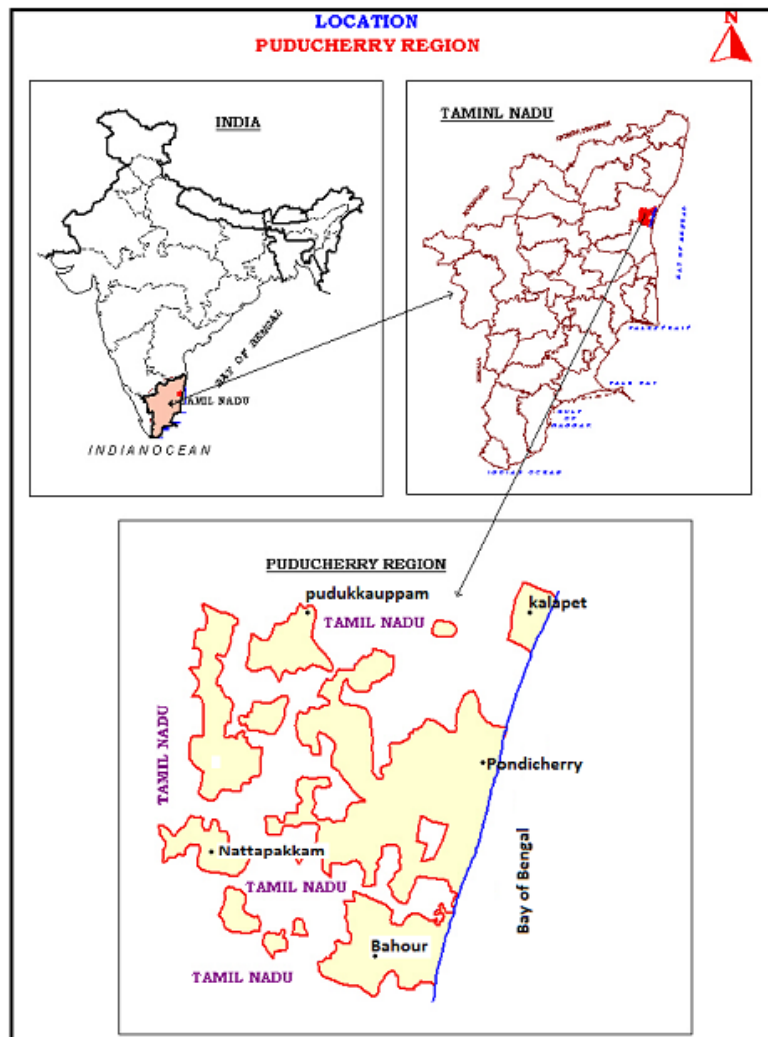


Figure 1: Location map of the study area

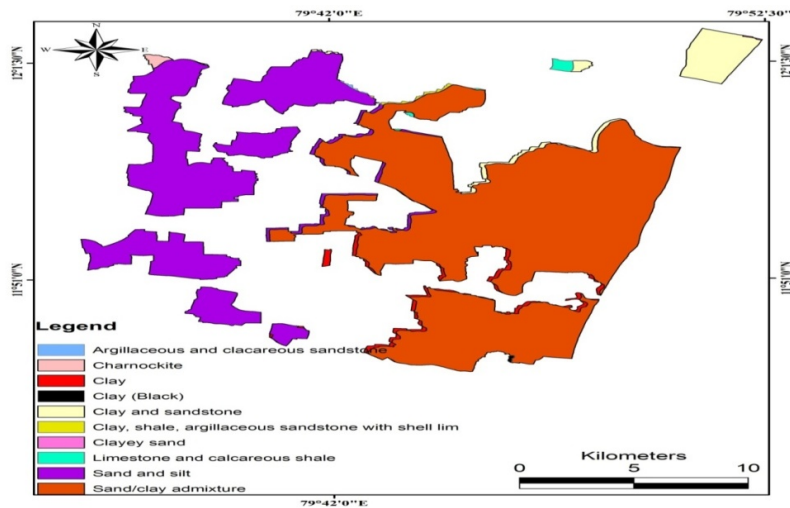


Figure 2: Geology map of the study area

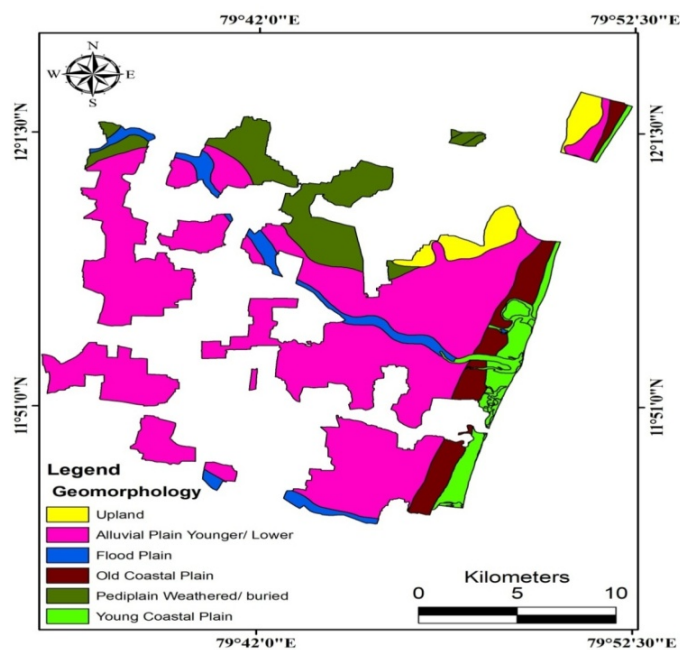


Figure 3: Geomorphology map of the study area

water level by 1 m to 1.5 m per year averagely. The causative factor is in sufficient rain and rainwater harvesting technologies are widely adopted. This is because of the reason that the people in the study area utilise groundwater for all purposes.

4 Methodology

The Schlumberger method being faster, easier, economical and easy availability of software for interpretation was adopted for this study [3, 4, 5, 6]. Vertical Electrical Sounding (VES), using Schlumberger electrode configuration, were carried out in ten locations in the study area (Table 1). These were conducted to delineate the sub-surface water potentiality, quality and resistivity of various sub-surface formations. The maximum distance of the spread of electrodes is 200mts. The resistivity value (ρ) for a fixed distance between the electrodes was noted by passing current between them. The groundwater potential zones were also identified by using secondary Aquifer Parameters. For measuring the resistivity Instrument WDD2 Resistivity meter was used. Each measurement was checked by repeating the process and by alternating current strength. The calculated apparent resistivity (ρ_a) value has been plotted against half current electrode separation ($AB/2$) on a transparent log-log sheet. The resultant curves were compared against the standard master curves to obtain values of different layers based on resistivity and thickness [7]. The final interpretation was done using the computer inversion program IPI2 win. The field curves were interpreted using the partial curve matching technique. True resistivity, thickness and depths of each layer were calculated. The hydro-resistivity map such as aquifer thickness, longitudinal conductance, and anisotropy were prepared. The computed value was compared with relevant field values (manual interpretation value). The error between computed and manual interpretation is found very meager and negligible. The field curves have been interpreted to prepare the geophysical logs and subsequently the lithological logs. Thematic maps were prepared by using ARC GIS-9.3 software package.

5 Results and Discussion

The analysis of these curves shows that they perfectly coincide with the three-layered curves and fit best with two-layered curves. So, the three layered curve is used for the present study. The first layer resistivity (Fig. 4) varies from 2.18 Ωm (VES.No.5) to 475 Ωm (VES No.3). The higher resistivity values are observed in the west and central parts of the study area. The low resistivity (below 12 Ωm) is identified from the northern, eastern and south-western parts of the study area. The low resistivity might be due to occurrence of clay formations or by the impact of silt. The second layer resistivity (Fig.5) ranges from 0.879 Ωm (VES No.7) to 271 Ωm (VES No.1). Lower resistivity values (< 54) area observed from northern to western region covering the Eastern part. Rest of the area exhibits higher values in the study area. The resistivity of the bottom layer (Fig.6) ranged from 0.226 Ωm (VES No.2) to 1403 Ωm (VES No.9: Table 1). The higher resistivity values implies the presence of fresh water horizons and a very high resistivity values indicates the presence of shallow depth (< 4.5 m) below the ground level.

Table 1 VES Locations with different layer thickness, resistivity values and Curve types

VES No.	VES Location	Resistivity (Ωm)			Thickness (m)		Type of Curve
		ρ_1	ρ_2	ρ_3	h1	h2	
1	Lawspet	12.9	2.51	8.95	7.61	6.67	H
2	Karasur	475	178	0.226	6.38	54.1	Q
3	Pondicherry University	3.43	15	9.13	3.75	15.8	K
4	Moolakuppam	6.04	19.3	3.2	3.75	15.8	K
5	Thavalakuppam	200	271	505	3.75	71.4	A
6	Kanniyokolil	6.03	1.56	156	41.7	33.3	H
7	Vadanur	235	4.52	-	37.9	-	Q
8	Pudukuppam	12	38.5	10.4	3.78	10.8	K
9	Alankuppam	2.18	8.11	1403	3.75	53.4	A
10	Seelaimedu	73.7	0.879	14.8	10.6	3.77	Q

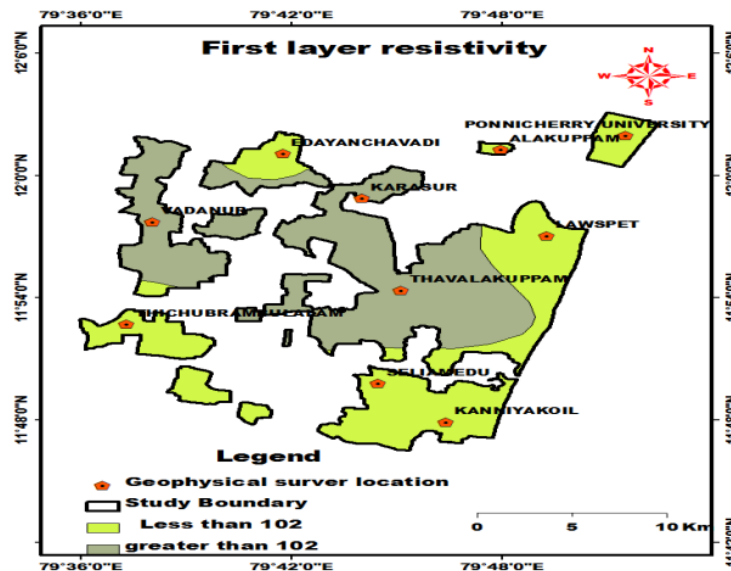


Figure 4: Map of first layer resistivity

Preparation of Depth to Basement Map: From the interpreted data layer wise maps were prepared for the study area using ARC GIS software. The thickness of the first layer (Fig.7) ranged from 3.75 m near Thavalakuppam (VES No. 8) to 41.7 m near Moolapakkam (VES No.4). The thickness of the second layer (Fig.8) ranged from 3.77 (VES no.10) m near Seelaimedu (VES No. 8) to 41.7 m near Thavalakuppam (VES No.5).

Transverse Resistance (T): Generally, the conducting layers properties are well described in terms of the longitudinal conductance and resistive layer by transverse resistance [8, 9, 10]. A geological formation can be considered as good aquifer if its high transverse resistance values are high having high thickness layers. The Transverse resistance (T) of the aquifer media in this area ranges from 114.9 m^2 (VES No.1) to $20,099 \text{ m}^2$ (VES No.5; Fig.9; Table 2). The lower resistivity values are observed from the southwest, north and northeast parts of the study area. The higher resistivity is observed in the central part of the study part of the study area signified by substantial rock basement [11]. The

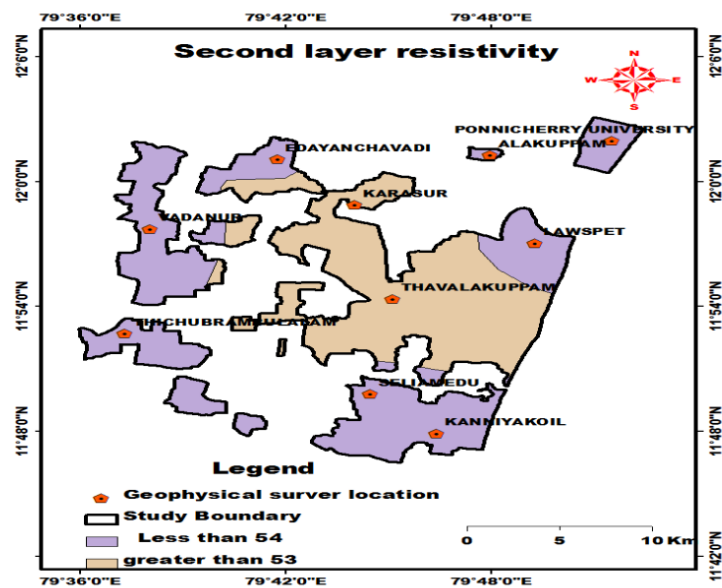


Figure 5: Map of second layer resistivity

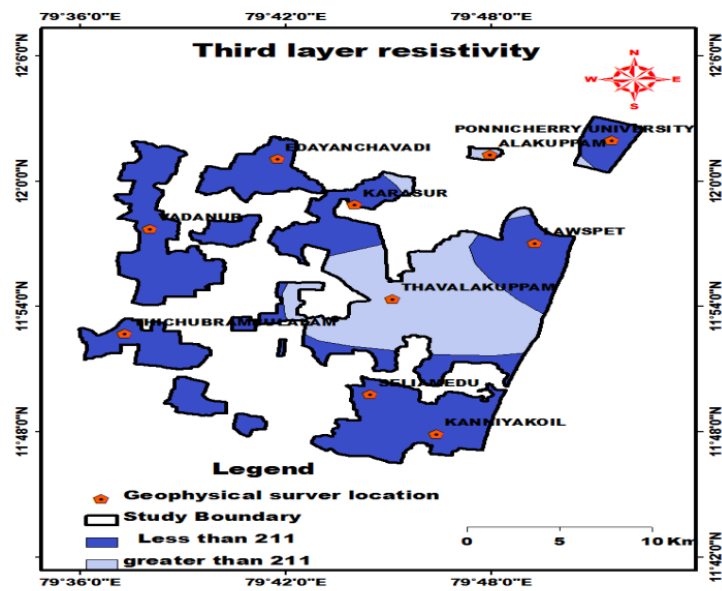


Figure 6: Map of Third layer resistivity

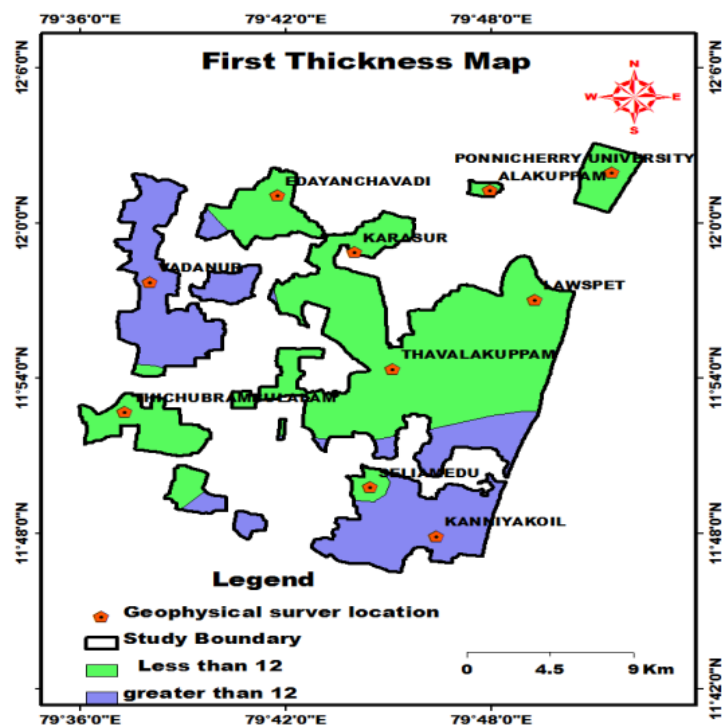


Figure 7: Thickness map of the first layer

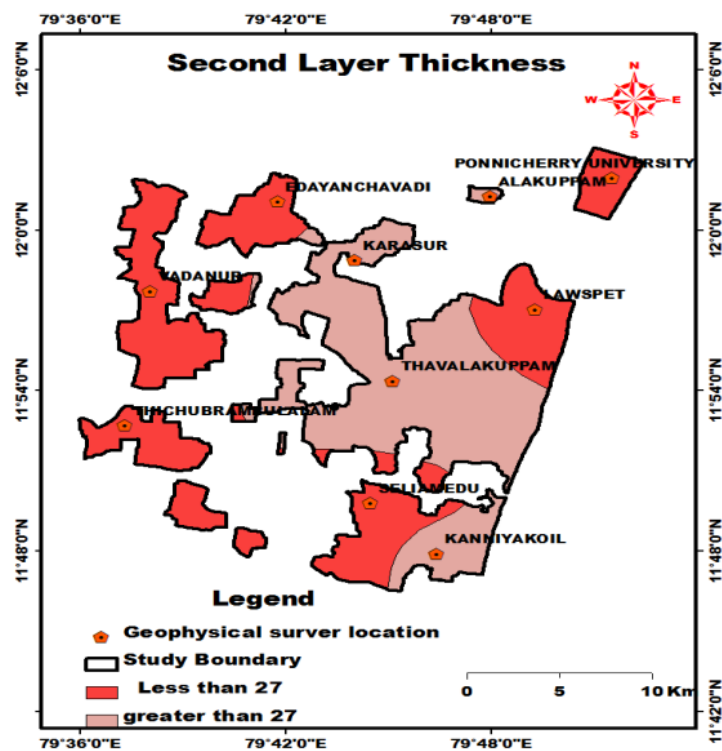


Figure 8: Thickness map of the Second layer

aquifer zones are noted in central part of the study and also along south west part of the study area. Higher transverse resistance values are observed in the VES locations of 2, 5 and 7 (Table 2), which indicate high transmissivity which in turn indicate a good groundwater potential zone.

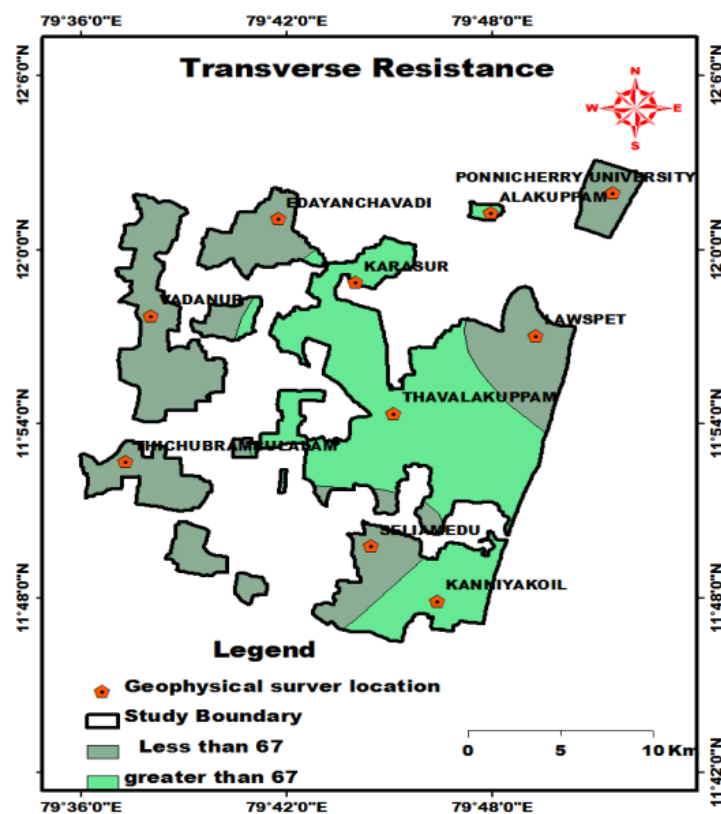


Figure 9: Transverse Resistance (T) of the study area

Longitudinal Conductance (S): The ratio of different layers to their respective resistivities can be described as longitudinal conductance (S). The increases in conductance values will reduce the resistivity of the aquifer indicating the groundwater potential zone [12,13]. In the present study area the

longitudinal conductance (S) of the aquifer media of this region range from 0.1612 mhos (VES No.7) to 28.26 mhos (VES No.6)(Fig.10; Table 2). The difference in S was used to recognize changes in the total thickness of high resistivity substantial. In the study area conductance high value might be noted in particular pockets in a small number of zone parts, which specify the existence of high transmissivity zone. Based on the Henriet classification of longitudinal conductance values in the study area, the VES locations fall in weak (VES 7), moderate (VES 2,5 and 8) and good aquifer (1,3,4 6,9 and 10) respectively[14]. Areas that are moderate are less susceptible, while areas with good soil cover are not susceptible to contamination from leachate infiltration. The average longitudinal conductance value indicates that the study area has good protective capacity. The weak protective capacity zone is related with clay material content compared to the areas with moderate and good protective capacity which the underlain aquifers are protected by the overlying clay minerals.

Aquifer Anisotropy (λ) The aquifer anisotropy (λ) in the present study area ranged from 1.7 (λ) to 7.27 (λ) (Table 2). The value of anisotropy ranged from 3(λ) and 7(λ) exists in the north zone of selaimedu (VES Nos. 7 and 10) and in the south zone of the study area near kanniyakovil (VES No.6). The zone with the value of above 4(λ) anisotropy exists in the area near Selaimedu (VES No.10). The area with 1.00(λ) and 2.00 (λ) anisotropy are considered as groundwater potential zones with high porosity and permeability. About 50% of the surveyed VES locations fall in groundwater potential zone in the present study area (VES 2,4,5,7 and 9). Rest of the VES locations exhibit higher anisotropy values ($> 2.00 (\lambda)$) suggests that these are due to the near surface heterogeneity and also due to structural features variation (faults, joints and fractures) which are useful for the groundwater development in the area [15].

6 Conclusion

Areas with <2.86 anisotropy are considered as potential aquifer for groundwater exploration. The aquifer thickness 15mts to 30mts is considered as medium potential zones with respect to top

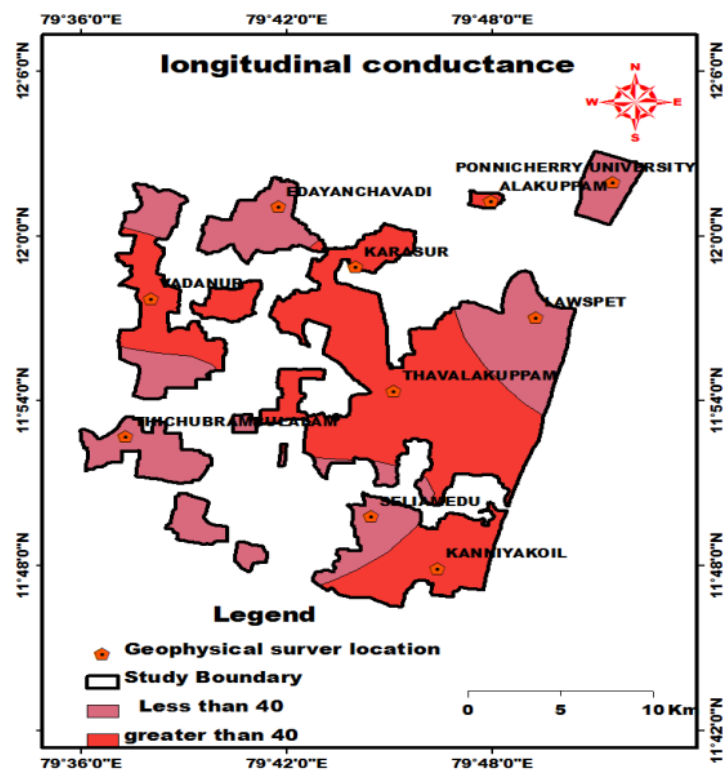


Figure 10: Longitudinal Conductance (S) of the study area

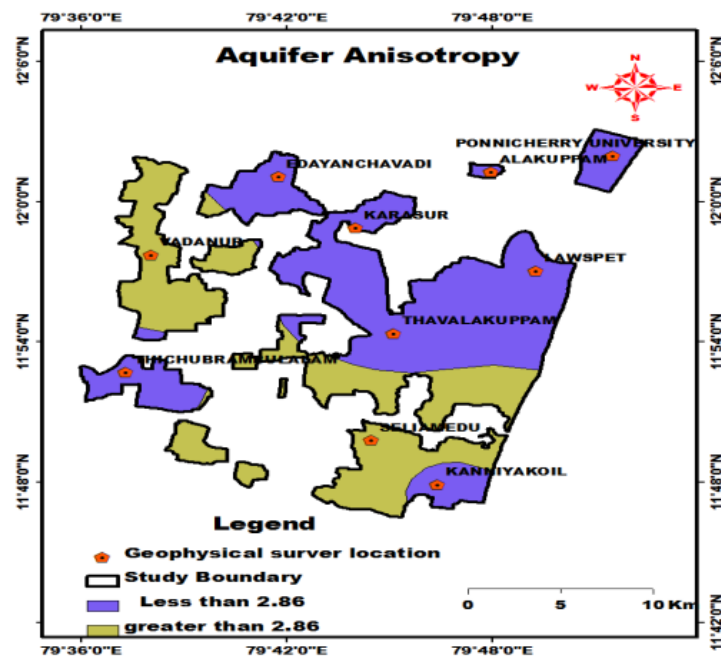


Figure 11: Aquifer anisotropy map of the study area

Table 2 Longitudinal conductance, Transverse Resistivity and Aquifer anisotropy of the study area

VES locations	longitudinal conductance (S) in mho	Transverse Resistance (T) m ²	Aquifer Anisotropy (λ)
1	3.247292999	114.9107	2.397661
2	0.317364163	12660.3	1.857651
3	2.146627794	249.8625	2.099699
4	1.439513777	327.59	1.968799
5	0.282218635	20099.4	1.776357
6	28.26157673	303.399	2.188361
7	0.161276596	8906.5	1.772454
8	0.595519481	461.16	2.014611
9	8.304647111	441.249	1.877419
10	4.432791056	784.53383	7.273821

soil and weathered zones. Aquifer thickness ranging 30mts to 60 mts is identified as good potential zones of groundwater in case of fractured layers. The potential zones are demarcated as good ($50\Omega\text{m}$ to $150\Omega\text{m}$) and medium ($150\Omega\text{m}$ to $250\Omega\text{m}$) potential zone based on the aquifer thickness. The aquifer zones with an aquifer thickness of 40 mts is considered as good and 30 mts as medium and 20 mts as poor with conformity to top soil layers. The locations like Ellakiampatti, Kondaharhalli (Loc.Nos.4,6,) comes under this category which is oriented along North-South direction falling in conformity with the lineaments indicating groundwater potential zones are noted in areas of lineaments and lineaments intersections. This is also confirmed by higher TDS values along this North-South trend indicating subsequent missing of groundwater along lineaments and lineaments intersections.

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