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Evaluation of Soil permeability and Aquifer parameters of Alanthurai watershed located at Coimbatore district in TamilNadu

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Abstract: The present study was carried out to extract the soil permeability of the collected surface soil samples and estimated the aquifer parameters of the Alanthurai watershed region located at Coimbatore district. Twenty one numbers of undisturbed surface soil samples were collected throughout the watershed area using standard mould and it was tested in the soil mechanics laboratory. The permeability values of the collected soil samples ranged from 1.39 x 10^{-3} cm/sec to 8.3 x 10^{-3} cm/sec. From the results of the soil study, it was observed that the watershed consists of moderate degree of permeability. Pump out test was conducted in the field and the values of drawdown in the observation well were measured and tabulated. The values of co-efficient of transmissibility and storage co-efficient were obtained by Cooper Jacob's and Chow's methods.

Keywords: Permeability, Watershed, Transmissibility, Storage Co-efficient, Pump out test

I. INTRODUCTION

Permeability is an important Engineering property, which governs the rate of settlement of saturated compressible soil layers and the rate of flow of an aquifer. Permeability is taken into account for pumping groundwater, spacing well points for dewatering foundations sites for excavation, retention of water in reservoirs, design of dams, classification of soils to be used for various zones of embankments of earthen dams and reservoirs. In this project work an attempt was made to estimate the permeability values of the soil samples collected at Alanthurai watershed was estimated for the further hydrological investigations and the aquifer parameters such as transmissibility and storage co-efficient were estimated from the pump test for the purpose of augmenting of ground water storage in the watershed region. Skibitzke, (1958) has developed an equation for calculating transmissibility value by means of the recovery of the water level in a well that was repeated bailed. It was found that the technique is limited to wells in confined aquifer with sufficiently shallow water level and to permit short time intervals between bailing cycles. Dhruvanarayana (1973) has discussed the procedure for determining the transmissibility and storage co-efficient values of an unconfined aquifer by analyzing the water table fluctuations, which are unaffected either by pumping or recharge during the period selected for the analysis. Carlsson and Carlstedt (1976) have estimated the storage co-efficient for an aquifer in lower Cambrian sand stone, partly from pumping tests and partly from correlations of water level fluctuations with changes in atmospheric pressure. Cooper (1976) derived an equation for the rise or fall of the water level in a completely penetrated well in confined aquifer after sudden lowering or rising respectively. Their equation was based on non-steady flow to a pumped and completely penetrating well. Sumita Sarkar et al (2001) evaluated the aquifer characteristics through pump test analysis and they also carried out vertical electrical soundings using schlumberger electrode at Edilpur, Kathagolaghat, Burdwan district, West Bengal. The storativity and transmissibility of the aquifer is estimated from the pumping test data using Cooper-Jacobs method. In this project work the two methods were used to find the aquifer parameters.

II. METHODOLOGY

The area selected for the study is Alanthurai watershed region. The Alanthurai watershed is lies in between 10°50' and 11° 5' North latitude and 76° 39' and 76° 50' East longitude and covers an area of 161.275 km^2 from the Western Ghats in the west to Alanthurai village in the east. Most of the catchments are surrounded by hilly region and higher vegetation. Intensive cultivation was carried out in the watershed where groundwater is the main source of irrigation. The geographical location and landuse pattern of the watershed is shown in figure 1. Coefficient of Permeability could be computed from laboratory method by using an apparatus called permeameter. Specimen used in a permeameter is small, time taken is less, and results obtained are accurate. There are two types of permeability tests namely constant head permeability test and falling head permeability test. In this project work variable head permeability test was used.

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The permeameter mould is consists of a cylinder of internal diameter of 10 cm and 10 cm effective height. The diameter of the standpipe is 1.1 cm. The collected undisturbed soil samples were placed inside the permeameter apparatus.

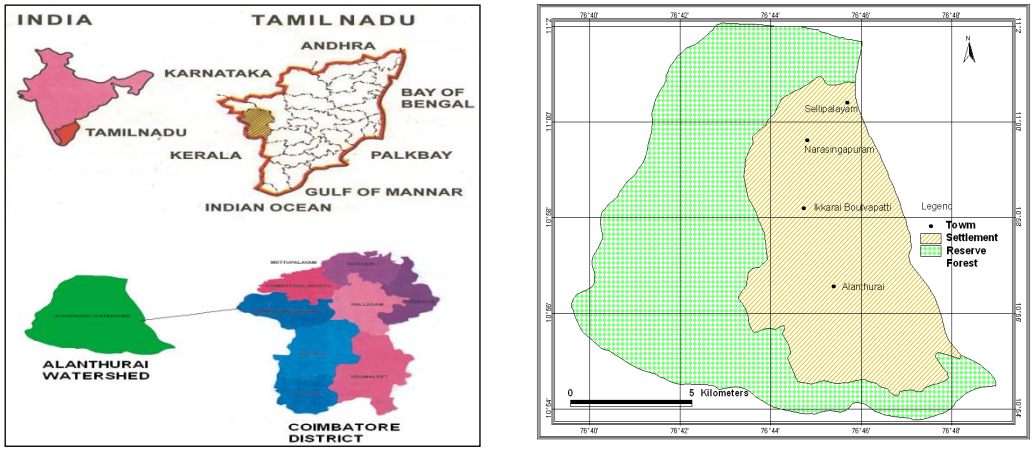

Fig. 1 Location and Landuse Map of the Alanthurai Watershed

The water is poured in to a vertical glass tube (stand pipe) through funnel and it is allowed for few minutes to fill the entrapped air gaps. The time taken (T) for the water level in the standpipe to fall from H1 to H2 was noted and repeated the above procedure. Based on the observation the co-efficient of permeability (K) was determined by the following formula.

$$K = \left(2.303 \frac{al}{AT}\right) \log (H1/H2) \text{ cm/sec}$$

Where 'a' is the area of the stand pipe in cm^2, 'l' is length of the sample in cm, A is cross sectional area of the sample in cm^2, T is the time taken for water level to fall from H1 to H2 in sec and H1, H2 are the initial and final head of meter in the stand pipe measured in cm. The range of co-efficient of permeability and approximate textural classification with degree of permeability was shown in table 1 and the tested soil samples values are shown in table 2.

Table 1: Standard values of Permeability of the soil with textural classification

Coefficient of Permeability K (cm/sec)	Degree of Permeability	Approximate Textural Soil Fraction
$> 10^{-1}$	High	Medium & Coarse Gravel
10^{-1} to 10^{-3}	Medium	Fine gravel, Coarse medium and fine sand, dune sand
10^{-3} to 10^{-5}	Low	Very fine sand, Silty Sand, loose silt, loess, rock flour
10^{-5} to 10^{-7}	Very Low	Dense Silt, Dense Loess, Clayey Silt, Clay
$< 10^{-7}$	Impervious	Homogeneous Clay

Storage Co-efficient (S) is the volume of water released from a vertical column of aquifer having unit cross sectional area per unit decline in head. Transmissivity (T) is simply the rate of flow through the entire thickness of an aquifer having unit cross sectional area under unit hydraulic gradient per unit time (C. S. De Silva and T. Mikunthan, 2010). The value of aquifer parameters S and T were founded by measuring drawdown in observation wells, when the well under study is pumped at a constant rate of discharge Q. Pump out test was conducted (G.Venkata Rao et al, 2015) in the field and the values obtained from the test were given in the table 3. Cooper Jacob's and Chow's methods were used for determining the values of S and T. The Equations of S and T suggested by Cooper Jacob's method are given below.

$$T = \frac{2.303\ Q}{4\pi\ \Delta s} \text{ and } \quad S = \frac{2.257\ T\ t_0}{r^2}$$

Where T is Transmissivity, S is Co-efficient of storage, Q is Constant withdrawal rate (in cum per day), Δs is Drawdown difference for one log cycle of time (in metre), r is Radial distance between the observation well and main well and t_0 is the time (since pumping started), at which the drawdown in observation well is still zero (in days).

In Chow's method a graph was plotted between time and drawdown first. On plotted graph, chosen an arbitrary point P and noted its co-ordinates. By drawing the tangent line for the curve at chosen point P the drawdown difference Δs per log cycle of time was determined. Computed the function F(u) by the following relation

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$$F(u) = \frac{s}{\Delta s} = \frac{w(u)}{2.303}$$

For F (u) < 2, the above Equation could be used. For F (u) > 2, u becomes large. Knowing F(u) and using standard chart, The value of u and W(u) was estimated. The values of S and T were computed from the following Equations.

$$T = \frac{Q\ W(u)}{4\pi\ s} \quad \text{and} \quad S = \frac{4\ u\ T\ t}{r^2}$$

III. Results and Discussions

Twenty-one members of undisturbed surface soil samples were collected throughout the watershed area by using the mould of size of 15 cm diameter with 20 cm height. The permeability values of the collected soil samples were analysed in the soil mechanics laboratory using variable head apparatus. The permeability values of the collected soil samples ranged from 1.39 x 10^{-3} cm/sec to 8.30 x 10^{-3} cm/sec which is tabulated in table 2. From the results of the soil study, it was observed that the watershed consists of moderate degree of permeability and the watershed was falls into the average catchment class according to the Strange's table.

Table 2: Permeability values of the collected soil samples in the watershed

Sl.No.	Location	Values in 10^{-3} cm / sec
1	Ikkarai Boluvampatti	2.84
2	Vellingiri hills	1.49
3	Boluvampatti	1.39
4	Karunya Nagar	2.31
5	Alanthurai	5.92
6	Semmedu	3.74
7	Narasipuram	3.52
8	Thondamuthur	2.68
9	Perumalkovilpathy	4.13
10	Sadivayal	1.67
11	Irrutupallam	3.83
12	Mathvarayapuram	8.30
13	Kottaikkadu	6.20
14	Sethupallam	5.40
15	Nerunchikkadu	3.10
16	Mullankadu	5.67
17	Poondikoviladivaram	6.37
18	Vellimalaipattinam	4.20
19	Thompilipalayam	2.30
20	Zaheernayakan palayam	4.60
21	Thennamanallur	8.20

Size of observation well : 6.5 m x 5.5 m (Open well)
Size of pumping well : 10 cm Diameter (Bore well)
Rectangular notch size : 22 cm x 10 cm
Radial distance between the observation well and pumping well (r) = 15 m.

Theoretical discharge Q = $2/3\ Cd\ b\ \sqrt{2g}\ H^{3/2}$ = 1065 m^3/day.

Table 3: Drawdown Values for finding S and T measured from pumping test

Time since pumping started		Water level from G. L. in metre	Drawdown values (m)
t (minutes)	t (days)		
0	0	13.60	0.0
1	0.000694	13.85	0.25
2	0.00139	13.88	0.28
3	0.00208	13.90	0.30
4	0.00278	13.92	0.32

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5	0.00347	13.94	0.34
6	0.00417	13.96	0.365
7	0.00486	13.98	0.38
8	0.00556	13.99	0.39
9	0.00625	14.00	0.40
10	0.00694	14.10	0.50
15	0.0104	14.15	0.55
20	0.0139	14.20	0.60
25	0.0174	14.25	0.65
30	0.0208	14.28	0.68
35	0.0243	14.32	0.72
40	0.0278	14.35	0.75
45	0.0313	14.38	0.78
50	0.0347	14.47	0.87
60	0.0417	14.65	1.05
70	0.0486	14.78	1.18
80	0.0556	14.85	1.25
90	0.0625	14.94	1.34
100	0.0694	14.97	1.37
110	0.0764	15.00	1.40
120	0.0833	15.15	1.55
150	0.104	15.35	1.75
180	0.125	15.43	1.83
210	0.146	15.52	1.92
240	0.167	15.57	1.97
270	0.188	15.59	1.99
300	0.208	15.70	2.10
330	0.229	15.80	2.20
360	0.25	15.85	2.25

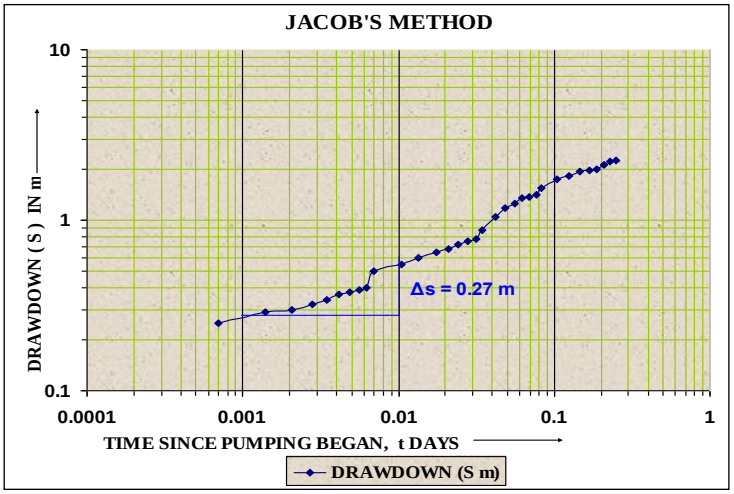

Fig. 2 Graph between Time and Drawdown for Jacob's Method

From Cooper's Jacob's graph as shown in figure 2 Δs and t_0 values were determined. Substituting the Δs and t_0 values in the formula Transmissivity value was calculated. Δs =0.27 metre, $t_0 = 2.0 \times 10^{-4}$ days.

$$T = \frac{2.303 \times 1065}{4\pi \times 0.27}, \quad T = 723 \text{ m}^3/\text{day/m} \qquad S = \frac{2.257 \times 723 \times 2.0 \times 10^{-4}}{15^2}, \quad S = 0.0014$$

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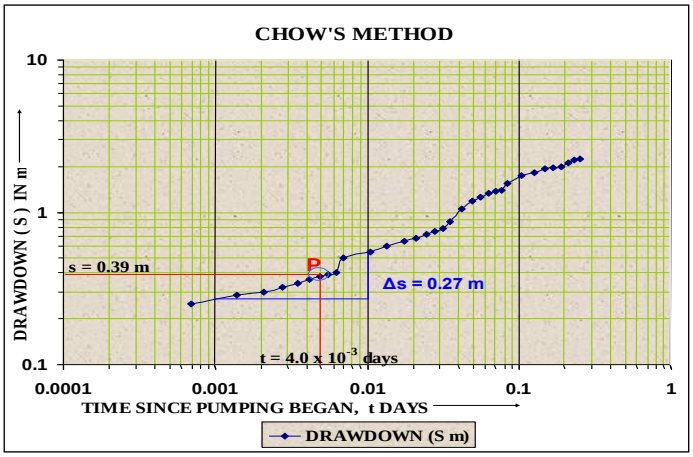

Fig. 3 Graph between Time and Drawdown for Chow's Method

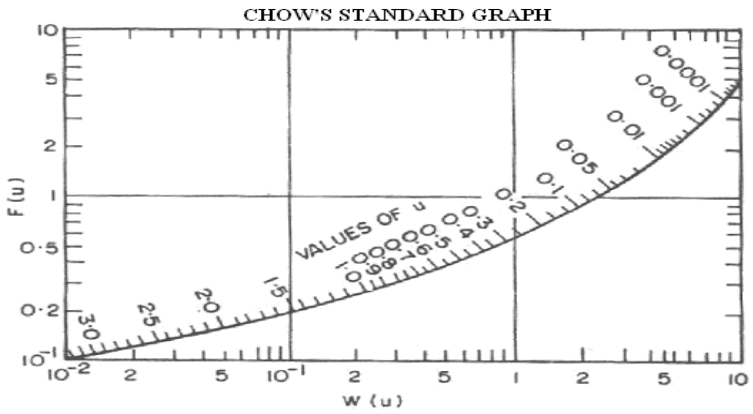

Fig. 4 Standard graph used in Chow's method

Using Chow's standard graph as shown in figure 3 and 4 the values of t, s and Δs were determined. Using this values $F(u)$ and w (u) are calculated from the formula. t = 4.0 x 10^{-3} days, s = 0.39 m, Δs = 0.27 m

$$F(u) = \frac{0.39}{0.27} = 1.44 \qquad F(u) = \frac{s}{\Delta s} = \frac{w(u)}{2.303}$$ Here F (u) < 2, so this equation could be used.

$$F(u) = \frac{w(u)}{2.303}; \qquad w(u) = 1.44 \times 2.303 = 3.326, \qquad T = \frac{1065 \times 3.326}{4\pi \times .39} = 723 \text{ m}^3/\text{day/m}$$

$$S = \frac{4 \times .02 \times 723 \times 4.0 \times 10^{-3}}{15^2} = 0.00103$$

IV. CONCLUSION

The average permeability value of the collected surface soil samples throughout the catchment area showed that moderately rapid permeability. From the field study it was concluded that the watershed is falls into the average catchment class according to Strange's table. It is used to calculate the annual percentage of surface run-off values for the watershed. From the ground water aquifer parameter studies two methods of analysis were used, the values of aquifer parameters S and T shows that the concurrence values in each method. This study would be helpful to assess the ground potential of the watershed and to delineate favourable zones in the study area for implementing suitable artificial recharge structures based on the soil conditions at the watershed region.

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