AN AQUIFER CHARACTERISTIC ANALYSIS FOR IDENTIFYING GROUNDWATER RESOURCE DEVELOPMENT ALTERNATIVES IN THE WET ZONE OF SRI LANKA

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Abstract: A proper management system for groundwater resources in the wet zone of Sri Lanka is crucially needed to avoid further exploitation of the resource leading to deterioration of groundwater quality. This research study mainly targets on the assessment of groundwater resources in the wet zone of Sri Lanka by means of collecting and analysing available groundwater pumping and aquifer characteristic data towards the identification of best management practices. The pumping test data are collected from well locations in Kalutara district and transmissivity values are estimated using both Theis and Cooper Jacob methods. The estimated transmissivity values are used to identify the spatial variation of transmissivity. It is recognized that there is no particular pattern identifiable in the spatial distribution of estimated transmissivity values, however, with the limited data set available. The observation is in line with the fact that there exists significant groundwater anisotropy and heterogeneity even within the same locality or within a single distinct aquifer system. The transmissivity values are further analysed using statistical testing and Krasny's classification system, transforming the data set into log distribution and assigning an index value to identify best management practices for selecting suitable locations for both local water supply schemes and landfills. The places with positive anomalies are very suitable for locating local water supply schemes, and the places with negative anomalies are best to have toxic waste disposal sites or landfills.

Keywords: Groundwater management, Wet zone, Sri Lanka, Transmissivity, Anomaly

1. Introduction

In the recent past the exponential increase in the tariff of pipe borne water has posed a huge economic burden to the users, especially to those large scale industries, hotels and apartments which are very dense in the wet zone of Sri Lanka, causing a significant change in the trend of using high amounts of surface and pipe borne water. As the groundwater is not well regulated, an increased number of individuals and industries have now started to shift to abstract vast volumes of groundwater in their own interest especially in the urban areas in the wet zone of Sri Lanka.

The presently existing regulations or legislation does not provide adequate measures to control over abstraction of groundwater and the lack of proper licensing and subsequent monitoring system has contributed to the worsening of the related issues. This has become a major issue in groundwater resourcemanagement in the recent past in Sri Lanka. This heavily threatens the sustainability of groundwater system and issues like sea water intrusion has been observed in the coastline due to over exploitation of groundwater.

Other than this, the global climate change effects such as extended drought periods and sea level rise have raised further issues over the availability and reliability of adequate surface water resources nowadays, highlighting the importance of developing groundwater usage as an alternative.

A proper management system for groundwater resources in the wet zone of Sri Lanka is thus crucially needed to avoid further exploitation and endangering of groundwater resources. To identify proper management practices, the groundwater data available for the wet zone of Sri Lanka should be collected and analysed properly using appropriate analysis methods.

Aquifer characteristics and other related data and information are vital to carry out a groundwater assessment study in an effective and efficient way. It ultimately aids to prepare a proper policy guideline addressing various possible alternatives or management options leading to the formulation of best management practices.

This research study mainly targets on the assessment of groundwater resources in the wet zone of Sri Lanka by means of collecting and analysing available groundwater data towards the identification of best management practices.

2. Methodology

2.1 General

The methodology includes the extensive literature survey, collaboration with agencies, data collection, field visits, identifying recharge characteristics, analysis and identifying best management practices to achieve final research objectives.

2.2 Data Collection

An effective collaboration with the National Water Supply & Drainage Board (NWSDB) was deemed extremely useful to collect and have access to existing groundwater pumping test data available in Sri Lanka, as NWSDB carries out pumping tests to check the availability of groundwater at some locations where a water supply scheme is required to be installed using groundwater as the main source. The pumping test data were collected for Kalutara district.

2.3 Calculation of Transmissivity Values

Transmissivity is the only aquifer parameter that can be readily calculated using pumping test data which do not have any observation well details. The transmissivity is first calculated using Theis method and crosschecked against values estimated based on Cooper Jacob method with adequate attention to the relevant assumptions made. The Figures 1 and 2 show procedures to estimate transmissivity values using Theis method and Cooper Jacob method respectively.

2.4 Comparative Study

To have further justification on the values obtained for transmissivity, a comparative study is also made between these two methods. The graphical comparison is provided in Figure 3.

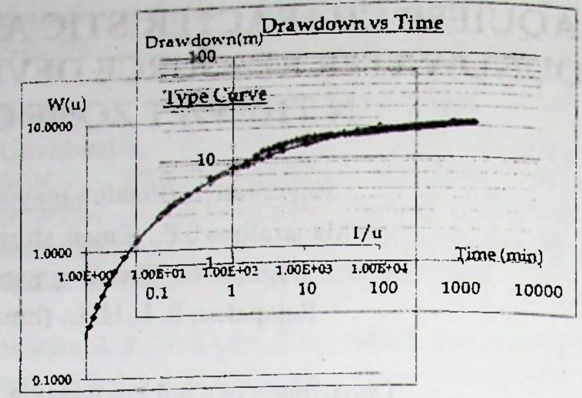

Figure 1-Procedure to estimate transmissivity using Theis Method

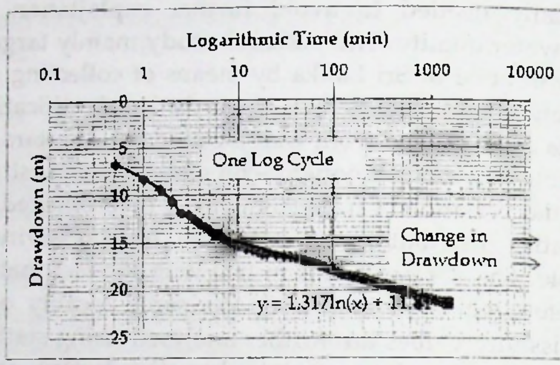

Figure 2- Procedure to estimate transmissivity using Cooper Jacob Method

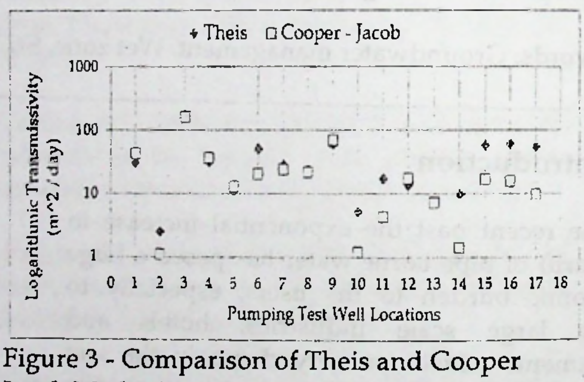

Figure 3 - Comparison of Theis and Cooper Jacob Methods

3. Results and Discussions

3.1 Spatial Variation of Transmissivity

The spatial variation of transmissivity is plotted to identify the trends in the spatial distribution of transmissivity. Figure 4 depicts the distribution of transmissivity values in Kalutara District.

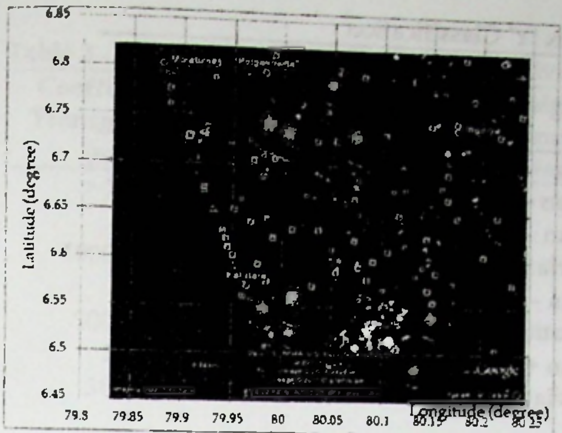

Figure 4 - Spatial Variation of Transmissivity values of pumping test wells inKalutara District

It is identified that there is no particular pattern identifiable in the spatial distribution of estimated transmissivity values, however, with the limited data set available. It is noted that it is possible to have a well with a very low transmissivity value much near to a well with a relatively higher transmissivity value. The observation is in line with the fact that there exist significant groundwater anisotropy and heterogeneity even within the same locality or within a single distinct aquifer system.

3.2 Transmissivity Analysis

The transmissivity analysis is carried out using two methods. One method is based on descriptive statistical testing by identifying background transmissivity and anomalies. And, the other method is based on a classification scheme introduced by Krasny in 1993.

3.2.1 Statistical Testing

In this approach, all the transmissivity values collected are pooled in a particular region using Transmissivity index 'Y'.

The relationship between transmissivity (T) and logarithmic transmissivity index (Y);

$$T\ (m^2/day) = 10^{Y-8.96} \times 86400 \text{-------- (1)}$$

Found by Jetal and Krasny in 1968, is used calculate the logarithmic transmissivity index (Y) from transmissivity (T) values.

The above stated equation can be modified as below.

Logarithmic Transmissivity Index,

$$Y = \log\left(\frac{T}{86400}\right) + 8.96 \text{ ----------------- (2)}$$

Where T - Transmissivity in m^2 / day

The Figure 5 shows this work more clearly.

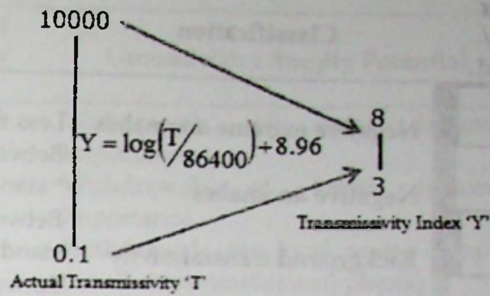

Figure 5 - Transformation from Actual Transmissivity 'T' to Transmissivity Index 'Y'

The interval between (mean - standard deviation) and (mean + standard deviation) of the logarithmic transmissivity index values represents the background transmissivity. The values outside this interval are considered as positive or negative anomalies. The positive anomalies represent prospective zones for groundwater exploration relatively compared to the areas of background transmissivity and the negative anomalies represent less favourable zones. Extreme anomalies can be found outside the intervals [mean ± (2 * standard deviation)]. The areas with extreme negative anomalies are suitable for toxic waste disposals and landfill locations due to their very lowtransmissivity values. The areas with extreme positive anomalies are highly suitable for local water supply points due to the indication of that the movement and availability groundwater are very high at those areas. This classification is tabulated in Table 1, in combination with a colour code system for clarity.

The logarithmic transmissivity index (Y) values are calculated using the modified equation and the calculations are tabulated in Table 2. The mean value of Transmissivity Index is obtained as 5.31 and the standard deviation of Transmissivity Index is as 0.41.

By using these two values, the classification is found as given Table 2.

3.2.2 Krasny's Classification

Jiri Krasny (1993) proposed a transmissivity classification system based on transmissivity magnitude and variation based on transmissivity and Transmissivity index values. The methods of classifications for transmissivity magnitude and variation are tabulated in Table 3 and 4, respectively.

Table 1 -Transmissivity Analysis based on Transmissivity Index 'Y' Classification

Colour Code / Legend	Classification	Description
	Negative extreme anomalies	Less than [mean – (2 * standard deviation)]
	Negative anomalies	Between (mean – standard deviation) and [mean – (2 * standard deviation)]
+	Background transmissivity	Between (mean – standard deviation) and (mean + standard deviation)
	Positive anomalies	Between (mean + standard deviation) and [mean + (2 * standard deviation)]
	Positive extreme anomalies	Greater than [mean + (2 * standard deviation)]

Table 2 - Transmissivity Classification for data Collected in Kalutara District

Names of the places	Transmissivity (m2/day)	Transmissivity index 'Y'	Classification
Alubogahawatta	2.55		negative extreme anomalies
Millagaswatta	5.35	4.75	negative anomalies
Paraduwa-temple premises	7.64	4.91	background transmissivity
Payagala estate 2	9.82	5.02	background transmissivity
Ihalawela-Rakshanagama	11.16	5.07	background transmissivity
Munhena	13.75	5.16	background transmissivity
Monokogama	17.44	5.27	background transmissivity
Kokkumbara	23.74	5.4	background transmissivity
Kimanthudawa	28.65	5.48	background transmissivity
Agalawatta	30.76	5.51	background transmissivity
Gorakagahadoowawatta	31.98	5.53	background transmissivity
Ihalanaragalakobowala	50.93	5.73	positive anomalies
Wetikala-coconut land	54.57	5.76	positive anomalies
Payagalaestate 1	57.3	5.78	positive anomalies
Walgama-Katugahahena	62.07	5.82	positive anomalies

The above results are spatially plotted in Google map and produced in Figure 6.

By using the classification given in Table 3, the groundwater supply potential is identified as given in Table 5.

And, the standard deviation value 0.41 observed in Transmissivity index 'Y' represents a moderate transmissivity variation and fairly heterogeneous hydro geological environment according to classification details provided in Table 4.

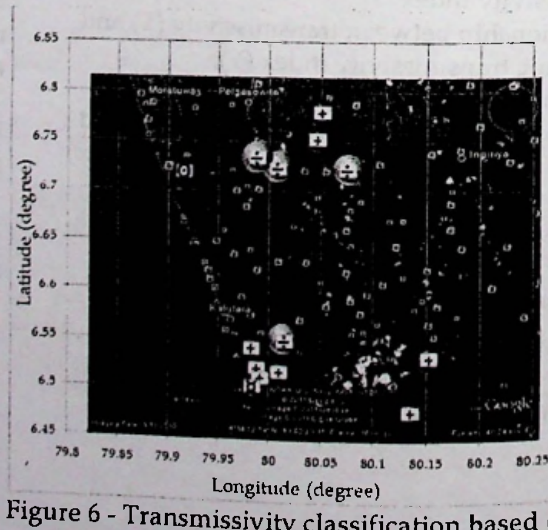

Figure 6 - Transmissivity classification based on Transmissivity Index 'Y' for Data collected in Kalutara District

Table 3 - Krasny's Classification of Transmissivity Magnitude

Coefficient of Transmissivity (m^2/d)	Class of Transmissivity Magnitude	Designation of Transmissivity Magnitude	Groundwater Supply Potential
> 1000	I.	Very High	Withdrawals of great regional importance
1000 - 100	II.	High	Withdrawals of lesser regional importance
100 - 10	III.	Intermediate	Withdrawals for local water supply (small communities and plants)
10 - 1	IV.	Low	Smaller withdrawals for local water supply (private consumption)
1 - 0.1	V.	Very Low	Withdrawals for local water supply with limited consumption
< 0.1	VI.	Imperceptible	Sources for local water supply are difficult

Table 4 - Krasny's Classification of Transmissivity Variation

Standard deviation of Transmissivity Index (Y)	Class of Transmissivity Variation	Designation of Transmissivity Variation	Hydro geological Environment
< 0.2	a	Insignificant	Homogeneous
0.2 - 0.4	b	Small	Slightly Heterogeneous
0.4 - 0.6	c	Moderate	Fairly Heterogeneous
0.6 - 0.8	d	Large	Considerably Heterogeneous
0.8 - 1.0	e	Very Large	Very Heterogeneous
> 1.0	f	Extremely Large	Extremely Heterogeneous

Table 5– Krasny'sTransmissivity Classification for data collected in Kalutara District

Names of the places	Transmissivity (m^2/day)	Designation of Transmissivity Magnitude	Groundwater Supply Potential
Alubogahawatta	2.55	Low	for smaller local water supply
Millagaswatta	5.35	Low	for smaller local water supply
Paraduwa-temple premises	7.64	Low	for smaller local water supply
Payagala estate 2	9.82	Low	for smaller local water supply
Ihalawela-Rakshanagama	11.16	Intermediate	for local water supply
Munhena	13.75	Intermediate	for local water supply
Monokogama	17.44	Intermediate	for local water supply
Kokkumbara	23.74	Intermediate	for local water supply
Kimanthudawa	28.65	Intermediate	for local water supply
Agalawatta	30.76	Intermediate	for local water supply
Gorakagahadoowawatta	31.98	Intermediate	for local water supply
Ihalanaragalakobowala	50.93	Intermediate	for local water supply
Wetikala-coconut land	54.57	Intermediate	for local water supply
Payagalaestate 1	57.3	Intermediate	for local water supply
Walgama-Katugahahena	62.07	Intermediate	for local water supply

4. Conclusive Remarks

The places like IhalaNaragalaKobowala, Wetikala-coconut land, Payagala estate1 and Walgama-Katugahahena with positive anomalies are very suitable places to have local water supply schemes while a place like Alubogahawatta with an extreme negative anomaly is best suited to locate toxic waste disposal sites or landfills. A place like Millagaswatta with negative anomaly can be considered for landfill site design.

5. Acknowledgement

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