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# Determination of Groundwater Level Based on Rainfall Distribution: Using Integrated Modeling Techniques in Terengganu, Malaysia

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## Abstract

Development and effective utilization of groundwater resources is essential especially in semi-arid region and even in a region with abundant rainfall such as the study area for activities such as water supply and irrigation. The present study aims to analyze statistically the groundwater level data and rainfall data of 13 years (2000-2012) collected from the Department of Minerals and Geosciences Terengganu and Department of Irrigation and Drainage Terengganu for the seven (7) stations: Besut, Dungun Jerengau, Kemaman, Bukit, PakaLuit, Cherul at Ho, and Berang Menerong of Terengganu Malaysia. The sum of least square method was adapted to analyses the relationship of groundwater level variability with the rainfall distribution. The analysis indicated that the rainfall distribution has an influence on groundwater level in the study area due to positive relationship indicated by regression analysis. Although in some of the stations the influence is not much significant, that is the groundwater levels depends on runoff and other factors rather than rainfall. Such stations are Site 4930401 SG. Berang at Menerang Terengganu shows 14.7%, Site 4232401 SG. Kemaman at Jam. Air Puteh, Terengganu shows 27.2%, and Site 4732461 SG. Paka at KG.Luit, Terengganu shows 35.2%. The station that shows great influence of rainfall in determining the groundwater level is Site 5229436 SG. Nerus at KG. Bukit, Terengganu which has 58.5%, while the remaining stations are moderate.

**Keywords:** Groundwater level; Rainfall; Time series regression analysis; Trend analysis; Correlation; Least square method

## Introduction

Groundwater is the most important water resource on earth. It comprises of the major and the preferred source of drinking water in rural as well as urban areas. Groundwater constitutes the largest available source of water supply and irrigation in the study area. Therefore the development of this vital resource is of great importance to meet these requirements. All the water resources are interrelated to the hydrologic cycle process and it's called water cycle, starting from precipitation, infiltration, evaporation, transpiration and condensation. The relationship of groundwater and rainfall is usually strong.

Groundwater is dynamic natural resources and can be recharge. The amount of recharge depends upon the rate and duration of rainfall, as rain is the most essential means for replenishment of moisture in the soil water system and recharge to groundwater. Groundwater is understood as the downward flow of water recharging the water table which forms an addition to the groundwater reservoir. Groundwater starts with rainfall and snow melt which seeps or infiltrates into the ground. The amount of water that infiltrates in to the ground differs widely from place to place due to different type of land surface present. In porous surface materials, such as sand and gravel water is readily infiltrates through the ground. About 40% to 50% of rain and snow melt may seeps in to the ground. While in less porous surface material the seepage may range from 5% to 20%. The remainder of the rain and snow melt runs off the land surface in to streams or return to atmosphere by evaporation. Seepage or infiltration is strongly influenced by the season of the year. During the warm months, evaporation is greater, including transpiration by plant leaves. In the cold months, the ground may be frozen, hindering water seepage and evaporation is less. Rain and snow melt that flow into the ground continues downward and under force of gravity it will reaches the saturated zone. The top of the saturated zone is known as water table. This water table rises and falls with the seasons and also the seasonal amount of rain and snow. Between the water table and the top soil or land surface, is another zone called unsaturated zone where the water are partially filled by the opening of soil and rocks. The plant roots can capture the moving water through this zone on its way to the water table.

In humid region, the amount of recharge is high during wet season because the region is receiving excessive amount of rainfall and the relative proportion of these components fluctuate according to the climatic conditions, geology and geomorphology of the area. In spite of the fact that, in Terengganu, the most important mechanism of groundwater recharge are considered to be indirect recharge by infiltration from floods through the beds of ephemeral streams.

A very useful tool for analyzing groundwater level fluctuation is the use of geostatistics [1]. Geostatistical methods are good tools for water resources management and can be effectively used to drive the long-term trends of the groundwater. Statistical methods for trend analysis vary from simple linear regression to more advanced parametric and non parametric method [2].

Ismail et al. [3] used regression analysis to determine the variability of groundwater depth based on rainfall distribution in Upper Swarnamukhi River Basin, as indicated by the result of eight (8) Stations. It is observed from the analysis that the groundwater table depth in any period is influences by rainfall. The study also reveals that the effect of antecedent groundwater table depth is more pronounced than that of rainfall and antecedent rainfall. The model proposed may

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be adopted for the estimation of groundwater table depths to effectively plan and efficiently manage groundwater resources of the basin.

Shamsudduha et al. [4], in their study used simple linear regression and a seasonal-trend decomposition procedure and applied to a groundwater level database in Bangladesh to resolved trends in a shallow groundwater level. They also used the data of the water level of 17 years (1988-2004) and assessed the water level fluctuation and trends was also predicted by the use of computer iteration software called MAKESENS.

Tirkey et al. used the sum of least square method to analyze the relationship between groundwater level and rainfall for the drought affected Palamu District of Jharkhand state of India. Their analysis revealed that the region, during the post-monsoon season exhibit shallow depth of water level (2-3 m) which declines up to 8-10 m during pre-monsoon in the month of May.

In the present study, the sum of least squares method using XLSTAT was used to determined the response of groundwater level with reference to rainfall distribution in the study area.

## Study Area

Terengganu is a state of Malaysia; it is situated in the coordinate 4°45′N latitude and 103°0′E longitude which is located in the north-eastern of Peninsula Malaysia. Terengganu is bordered in the northwest by Kelantan, the southwest by Pahang and the east by South China Sea. The state has a total area of 13,035 $km^2$ (5,033 sq mi) and the total population of 1,015,776 as for the 2010 census with a density of 78 $km^2$ (200/sq mi).

Like the other states of the country, Terengganu has tropical monsoon climate which is generally fairly hot and humid all year around. The temperature is relatively uniform within the range of 21°C to 32°C throughout the year. During the months of January to April, the weather is generally dry and warm. Humidity is consistently high which approximately 80% in day time and slightly cooler after sunset nevertheless, the sea breeze from south China Sea has somehow moderating the humidity in offshore areas while altitude and lush forest trees and plants has cooled the mountain and rural areas (Figure 1).

Terengganu has characterized by two main types of monsoon, the southwest monsoon season which is usually established in the latter half of May or early June and end in September. The northeast monsoon which is usually starts in November and end in March. Terengganu receives heavy rainfall of approximately between 2034 mm to 2504 mm per year which can easily break the bank of the rivers and cause overbank discharge. When the northeast monsoon blows between Novembers to January some areas suffer flooding at this time.

However in the whole of Peninsular Malaysia, the north-east monsoon is the major rainy season which develops in conjunction with cold air outbreaks from Siberia produce heavy rains which often cause severe floods along the east coast states of Terengganu, Kelantan, Pahang and east Johor in Peninsular Malaysia.

## Materials and Methods

The 13 years (2000- 2012) of the groundwater level (GWL) data recorded at seven (7) different hydrological stations that were obtained from the Department of Minerals and Geosciences Terengganu (JMG). The characteristics of the groundwater pattern, such as average depth, water level and variability trend in the study area were analyzed. The rainfall data of the same years (2000-2012) was obtained from the same location but was delivered from the Department of Irrigation and Drainage (DID). Rainfall analyses such as of monthly rainfall their frequencies as well as their total monthly rainfall are taken for consideration. The water level fluctuation pattern was analyzed for the monthly basis. However, curve fitting using regression equation y=ax+cwere done for the required places to fill in for the missing data.

The groundwater level and the rainfall datum collected on daily basis were converted into monthly basis and analyzed for their long-term pattern, and were interpreted graphically to understand the dynamics relationship between groundwater level and rainfall. The long-term Trend was signified using the average water level depths and average rainfall recorded for thirteen years as stated above. The least squares method under time series regression analysis was used to access the groundwater level and rainfall Trends within the groundwater response showed by rainfall distribution. The sum of least squares method under the time series regression analysis was adopted for estimating the trend of groundwater level, as well as the water level fluctuation and the trend of the rainfall data such as frequencies and total amount was calculated using XLSTAT 2014.

## Results and Discussion

Analysis of rainfall data and groundwater level data from 7 stations in the Terengganu for the period 2000-2012 shows a trend and relationship between the two variables. The percentage relationship between the two variables was lower in some of the stations, which indicate that rainfall is not the only factor responsible for the formation of groundwater of that area, although all the stations showed a positive relationship between the two variables. The groundwater level in any month at any station in the study area is correlated with the rainfall of the month. The partial correlation coefficient which measure the extent of association of independent variable with dependent one indicate that, some stations have strong relationship more than the others. This may be due to other factors not observed in this analysis which has an influence in the formation of groundwater of the district/station. Some stations showed a significant changes in amount and distribution of rainfall as determine by the line graph, however some showed similarities between them. The results also show the similarities in the stations that were in the same coordinate and differ on the others with different locations. Stations that were located near the Sea (Dungun) have less percentage of rainfall influence for the groundwater


**Figure 1:** The Map of the Study Area: showing different District/Stations where data was collected.

formation. This indicates that other factors such as stream flow, flood have more influence on that area.

Some of the linear regression tables' results and scatter plots of dependent variables against independent one are shown below:

Table 1 explains the coefficient of determination ($R^2$) as the percentage variability of the dependent variable (Groundwater) which explained by explanatory variable (Rainfall). The closer to 1 the $R^2$ is, the better fit. As in the station 4 the $R^2$= 0.58.5, meaning the % variability of groundwater which is explained by rainfall is 58.5%. The remainder of the variability is due to some effects (other explanatory variables) that have not been included in this analysis.

The Table 2 explained whether or not the rainfall brings significant information (null hypothesis) to the model. Given the fact that in all the stations for this analysis the probability corresponding to the F value (Pr>F) is lower than 0.0001, we will be taking a lower than 0.01% risk in assuming that the null hypothesis (no effect of the rainfall data) is wrong. Therefore we concluded that the rainfall do bring a significant amount of contribution to groundwater level of the study area.

The Table 3 is helpful when we want compare the coefficient of the model for a given station with the result obtained from another station, or when prediction is needed. This also shows that 95% confidence range of rainfall parameter is very narrow compared for the intercept.

The Table 4 showed the equations for the all stations, which shows how increases of rainfall influence the groundwater level. As in the case of station 4, when the rainfall increases by one millimeter (1 mm), the groundwater will also increases by 0.003 m. This all applied to all other stations but depending on their increases rates.

This residuals (Figure 2) gives the assumptions of the linear regression model, should be normally distributed, meaning that 95% of the residuals should be in the interval [-1.96, 1.96] all values outside this interval are potential outlier, or considered that the normality assumption is wrong. This software XLSTAT's data flagger brought those values which are not in the interval out. As in the scatter plots represented in the Figure 3 for Station 4 (Site: 5229436 SG. Nerus at Bukit, Terengganu), out of 156 observations only 7 residuals were outside the [-1.96, 1.96] range, an analysis that does not lead us to reject the normality assumption.

| | |
|---|---|
| Observations | 156.000 |
| Sum of weights | 156.000 |
| DF | 154.000 |
| R² | 0.585 |
| Adjusted R² | 0.582 |
| MSE | 0.289 |
| RMSE | 0.537 |
| MAPE | 4.767 |
| DW | 1.607 |
| Cp | 2.000 |
| AIC | -191.771 |
| SBC | -185.671 |
| PC | 0.426 |

**Table 1:** Goodness of fit statistic table.

| Source | DF | Sum of squares | Mean squares | F | Pr>F |
|---|---|---|---|---|---|
| Model | 1 | 62.670 | 62.670 | 217.006 | <0.0001 |
| Error | 154 | 44.474 | 0.289 | | |
| Corrected Total | 155 | 107.145 | | | |

Computed against model Y=Mean(Y)

**Table 2:** Analysis of variance.

| Source | Value | Std.error | t | Pr>\|t\| | Lower bound (95%) | Upper bound (95%) |
|---|---|---|---|---|---|---|
| Intercept | 7.304 | 0.064 | 113.690 | <0.0001 | 7.177 | 7.431 |
| RAINFALL (mm) | 0.003 | 0.000 | 14.731 | <0.0001 | 0.003 | 0.003 |

**Table 3:** Model Parameter.

| | |
|---|---|
| Besut | Groundwater level (M) = 14.0948336481616+1.24460580239912E-03*Rainfall data (mm) |
| Dungun | Groundwater level (M) = 5.71539620806715+5.37986219758273E-04*Rainfall data (mm) |
| Kemaman | Groundwater level (M) = 8.78872824648013+9.71784894960001E-04*Rainfall data (mm) |
| Nerus | Groundwater level (M) = 7.30372586727423+2.90963416109421E-03*Rainfall data (mm) |
| Paka | Groundwater level (M) = 1.55707866643929+2.30421907511554E-03*Rainfall data (mm) |
| Cherul | Groundwater level (M) = 9.92062404289666+2.12755709963399E-03*Rainfall data (mm) |
| Menerong | Groundwater level (M) = 20.642225067975+5.90849337903912E-04*Rainfall data (mm) |

**Table 4:** Equations of the Models.

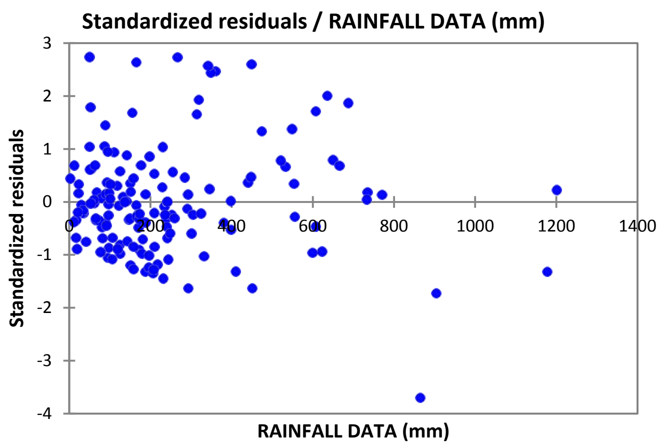


**Figure 2:** Residuals explanation.

The Figure 3 shows the confidence intervals on a single prediction for a given value of the rainfall, which shows a linear trend, but that there is high variability around the line. It also shows those observation that are outside the [-1.96, 1.96] interval are outside the second confidence interval as well. It explained the two confidence intervals and allow to visualized data, the regression line (the fitted model). Figure 4 explained the standardized residuals versus the rainfall. Figure 5 compared the predictions to the observed values. The confidence limits allow, as with the regression plot displayed in the Figure 3 to identify the outliers.

## Conclusion

The results of this linear regression analysis help us to explain the influence of the rainfall distribution on the groundwater level of the study area. These influences differ from one district/ station to another. Although some station showed almost the same response especially those in the same or nearest coordinate. Such that station 1 and 4 (Besut and Nerus), which showed high values of coefficient of determination of 54.2% and 58.5% respectively where in the nearest

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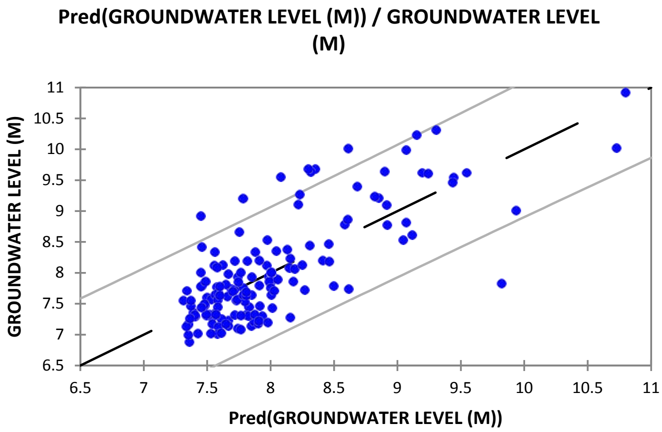


**Figure 3:** Pred (Groundwater Level (M))/ Groundwater Level (M).

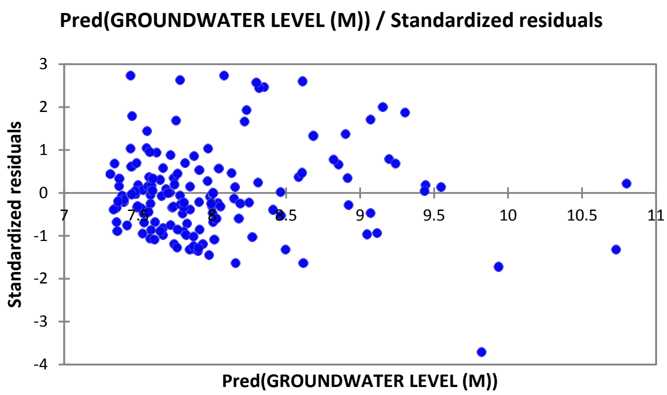


**Figure 4:** Pred (Groundwater Level (M))/ Standardized residuals.

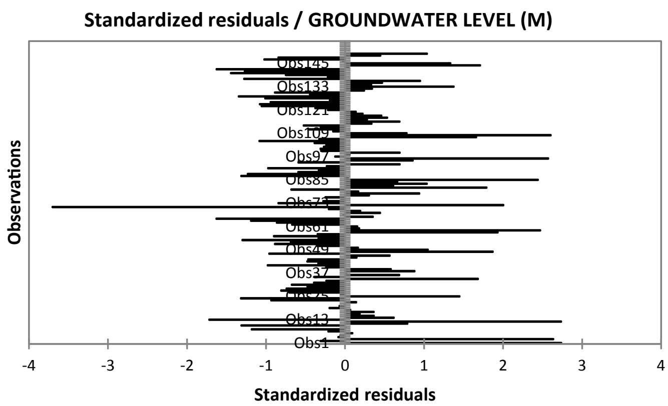


**Figure 5:** Standardized residuals/ Groundwater Level (M).

coordinate. Likewise station 5 and 6 (Paka and Cherul) where showed nearest values of the determinant of 35.7% and 47.7%. Others were station 2, 3 and 7 (Dungun, Kemaman and Menerong) which are also located in neighbors with determinant values of 4.6%, 27.2% and 14.7% respectively.

The results also indicated that there are other factors apart from rainfall that have a significant influence on groundwater level formation in the study area. These other factors will contribute to fill up the remainders of the percentage of the variability of the groundwater showed by the individual station. When these other factors are included a Multiple Linear Regression or Vector Error Correction Model are suggested to run.

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## References

1. Rouhani SH, Myers DE (1990) Problems in space-time Kriging of geohydrological data. Mathematical Geology 22: 611-623.
2. Helsel DR, Hirsch RM (2002) Statistical Methods in Water Resources. Book 4, Hydrologic Analysis and Interpretation US Geological Survey, Virginia 510.
3. Ismail J, Murali T, Mallikarjuna P (2010) Statistical Analysis of Groundwater table depths in Upper Swarnamukhi River Basin: Water Resources and Protection Journal 2: 577-584.
4. Shamsudduha M, Chandler RE, Taylor RG, Ahmad KM (2009) Recent Trends in Groundwater levels in a highly seasonal hydrological system: The Ganges-Brahmaputra Meghna Delta. Hydro-Earth Syst.Sci. Discuss 13: 2373-2385.