

Development of Flood Forecasting Using Statistical Method in Four River Basins in Terengganu, Malaysia

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Abstract. One of the critical regions in Malaysia is Terengganu which is located at east coast of Peninsular Malaysia. In Terengganu, flood is experienced regularly because of attributed topography and climate including northeast monsoon. Moreover, rainfall is with high intensity during the November to February in Terengganu as forcing factor to produce of flood. In this study, main objectives are water stage forecasting and deriving the related equations based on least squared method. For this study, it is used two methods which called inclusion of residual (Method A) and non-inclusion residual (Method B) respectively. Result depicts that Method B outperformed to forecast the water stage at selected case studies (Besut, Dungun, Kemaman, Terengganu).

1. Introduction

Among all natural hazards, floods are the most frequent, destructive, and costly disasters in Malaysia. The east coast of Peninsular Malaysia have experienced floods regularly because of their geographical location that exposed to northeast monsoon that bring heavy rainfall and eventually contribute large volume of runoff to the relatively large catchment areas [1]. The need for accurate predictions of floods has been highlighted by the recent occurrences of floods Terengganu. The aim of flood forecasting analysis is to provide in-time useful information for making crucial decisions such as issuing alerts or activating required protection measures and mitigating a potential disaster [2]. The forecasting process during the non-flood period involving field data collection of past water level from the stations at upstream in respective basin is significance and can be used to assist the authorities to forecast the severity of upcoming flood event at downstream; hence reduce the overall impact of severe events. Main reason of flood is involved with the incrementing of water level at upstream areas which is dangerous for settlement near the rivers [2]. Using conventional methods as basic and primary analysis provide a valuable review on behaviour of water stage in vulnerable area [2]. The process of statistical method involves regression process between water level at upstream and



downstream. The objective of this study is presentation of forecasted water levels with two methods related with inclusion of residual (Method A) and non-inclusion residual (Method B). Also, related empirical equations are derived for this study based on multiple regression.

2. Methodology

The concept of least square method reduces the sum of the squared vertical distance between the observed and forecasted values. After coefficient is obtained, multiple linear regression analysis is used to generate the equation. It is used as a procedure for fitting an equation to a set of data that might be comprises two or more variables [3]. Next, extracting the water level data in upstream are used to forecast water level in downstream data (e.g. outlet station). The water level data at upstream, which are used for regression, should have same period and validity with water level data at downstream. The data are analysed by two methods; with inclusion of residual (Method A) and non-residual (Method B) based on Department of Irrigation and Drainage of Malaysia (DID) guidelines [4].

3. Research area

Figure 1 shows four river basins in Terengganu that discharge into South China Sea. In this study, multiple linear regression is used to model relationship of explanatory variables (water level at upstream) and the outcome of the response variable (water level at downstream).

Multiple Linear Equation Model, $Y = CX_1^a X_2^b X_3^c$ (1)

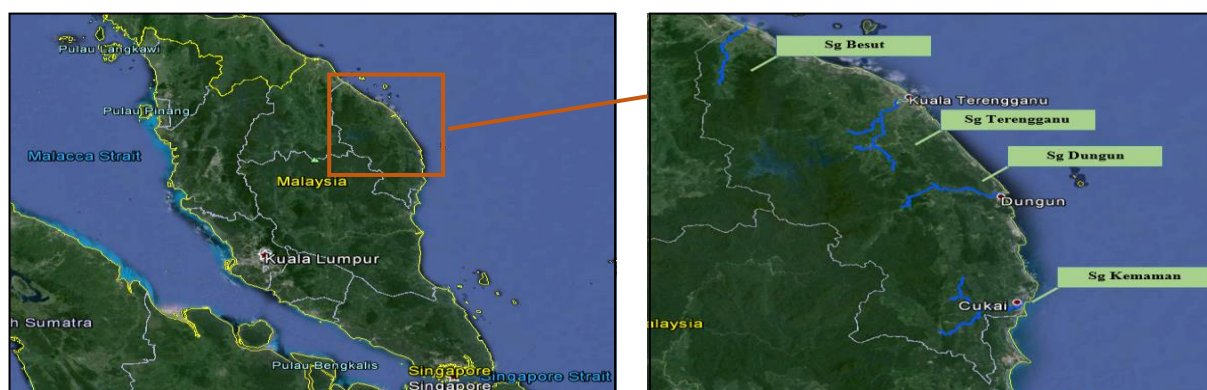


Figure 1: Location of four rivers basin in Terengganu

Data are correspond with maximum water level observed at gauge in upstream area of the river. Table 1, 2, 3, and 4 show the descriptions of the the water level stations in each river. Next, the information regarding operation service of available stations in this study as follows; Besut River (1997-2015), Dungun River (1993-2015), Kemaman River (1997-2015) and Terengganu River (2004-2015). In addition, each river has different number of upstream station available whereby three stations exist at upstream of Kemaman River, two stations for Dungun River, and finally only one station for both Besut and Terengganu River.

Table 1. Descriptions of water level stations in Besut River

Station Name	Station No	Data Transmission
Kg La	5524401	Logger
Jambatan Jertih	5724411	Logger

Table 2. Descriptions of water level stations in Dungun River

Station Name	Station No	Data Transmission
Rumah Pam	4529401	Logger
Paya Kempian		
Kg Surau	4730401	Logger
Jambatan Jerangau	4832441	Logger

Table 3. Descriptions of water level stations in Kemaman River

Station Name	Station No	Data Transmission
Sg Cherul at Ban Ho	4131453	Logger
Jambatan Air Puteh	4232401	Logger
Rantau	4232452	Logger
Jambatan Tebak	4332401	Logger

Table 4. Descriptions of water level stations in Terengganu River

Station Name	Station No	Data Transmission
Kuala Ping	5129438	Logger
Kg Bukit	5229436	Logger

4. Results and Discussions

In this section, results on forecasting water level are discussed briefly. Method B selected as chosen method because it has provide overestimation on the forecasted water levels at downstream at majority events in comparison with Method A; therefore suitable for safety precautions and warning system. Figure 1 and 2 illustrates the observed and forecasted water levels for all four rivers based on Method A and B. It indicates Method B obtained better results for forecasting water levels compare to Method A. The longer period of data collection increase the data reliability to forecast the flood.

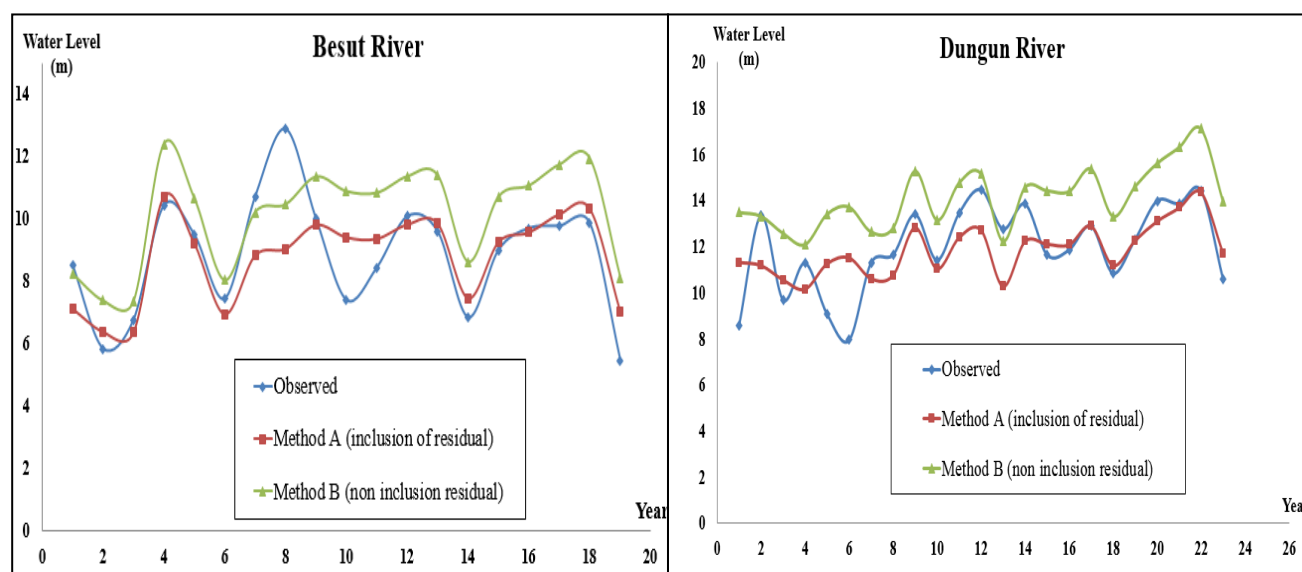


Figure 2. Comparison between Method A, Method B and observed water level for Besut River (left) and Dungun River (right).

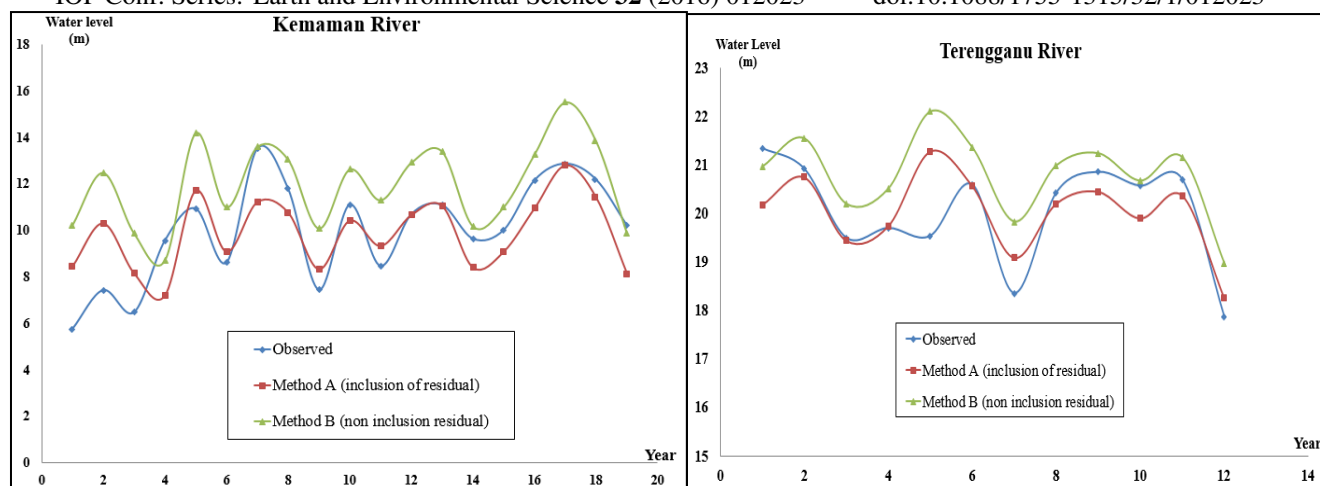


Figure 3. Comparison between Method A, Method B and observed water level for Kemaman River (left) and Terengganu River (right).

Table 5: Equation for both methods for each river basin.

River Basin	Method A (inclusion residual)	Method B (non-inclusion residual)
Besut	$Y_{T+t} = 0.003247X_1^{(1.491411985)}$	$Y_{T+t} = 0.003754X_1^{(1.491411985)}$
Dungun	$Y_{T+t} = (1.2047 \times 10^{-9}) \times X_1^{2.433032} \times X_2^{0.429334}$	$Y_{T+t} = (1.4355 \times 10^{-9}) \times X_1^{2.433032} \times X_2^{0.429334}$
Kemaman	$Y_{T+t} = (2.35846 \times 10^{-6}) \times X_1^{1.195391} \times X_2^{0.197861} \times X_3^{1.035824}$	$Y_{T+t} = (2.85983 \times 10^{-6}) \times X_1^{1.195391} \times X_2^{0.197861} \times X_3^{1.035824}$
Terengganu	$Y_{T+t} = 0.22551 \times X_1^{0.4709529}$	$Y_{T+t} = 0.234246 \times X_1^{0.4709529}$

Y = Forecasted Level at downstream station in time T + t

X_1, X_2, X_3 = Observed level at upstream stations

T = Lag time = 4 hours

5. Conclusion

Flood forecasting is a very challenging task due to high variability and noise in the data for both upstream and downstream stations. In this study, the observed and forecasted data presents non-inclusion of residual (Method B) outperformed the inclusion residual (Method A) for all four river basins. The equation for Method B is more applicable to forecast the water level at downstream area since it capable to provide overestimation of the water level at majority event compare to method A; hence provide sufficient time for safety precautions and relevant to become as early warning system for the citizens. In a nutshell, the Method B suited for flood forecasting process.

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