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To cite this article: B Winarta *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **366** 012036

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# Dam Break Studies using Hydrologic and Hydraulics Model for Chereh Dam, Kuantan, Pahang, Malaysia

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**Abstract.** This current study is evaluating the risks of Chereh Dam failure. A dam break study basically consists of rainfall analyses; hydrologic modeling; dam breaching analysis and inundation mapping of the resultant flood. Precipitation analyses and development of Intensity Duration Frequency (IDF) curve has been prepared and published in Urban Storm water Management Manual by the Department of Irrigation and Drainage of Malaysia. In here, hydrologic modeling was performed with the HEC-HMS (Hydrologic Modeling System). The results of hydrological analysis revealed that the observed and simulated flow hydrographs in the calibration and confirmation exercises were reasonably close. Furthermore, dam breaching analysis and inundation mapping was executed with the HEC-RAS (River Analysis System). Dam break analysis result will be used to arrange policy of the state or city government in order to minimize the hazards of Chereh Dam failure.

**Keywords:** dam break, HEC-HMS, HEC-RAS

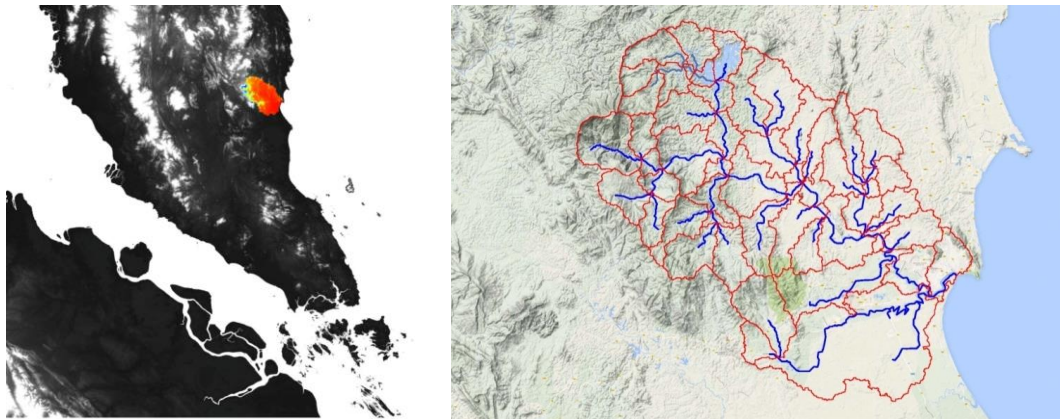
## 1. Introduction

Dams are built with a single and or multi-purposes such as for: water supply, flood and sedimentation control, hydropower and irrigation. Beside beneficial of constructing dam as mentioned before, we have to consider that dam may be fail during operation. When a dam breaks, a large amount of water will be stored and triggers a heavy flood through the breach into the downstream. In general, the peak flows created by dam breaching may be greater than floods caused by heavy rainfall. And the others main and important concern in here is the response time in dam failures to warn people living around and surround dam is much shorter than the travel time of flood wave to reach downstream area.

Predicting the potential hazards due to dam failure has been studied by some researcher [1, 2]. This paper discusses the use of HEC-HMS and HEC-RAS for performing the hydrology, hydraulics, and inundation mapping of flood due to dam break. The aim of the present study is to provide such emergency information in the downstream area of Chereh Dam, which are expected to help the public officials in making a proper Emergency Response Plan (ERP) for Kuantan City.

The ERP provides information how to alert people and evacuate them safely before the flood waves arrive. Chereh Dam is located about 40km north-west of Kuantan town and about 11km north of Lembing River (Figure 1). The main features of Chereh Dam are: an earth fill embankment dam of 48m high with a 50m width un-gated chute spillway.

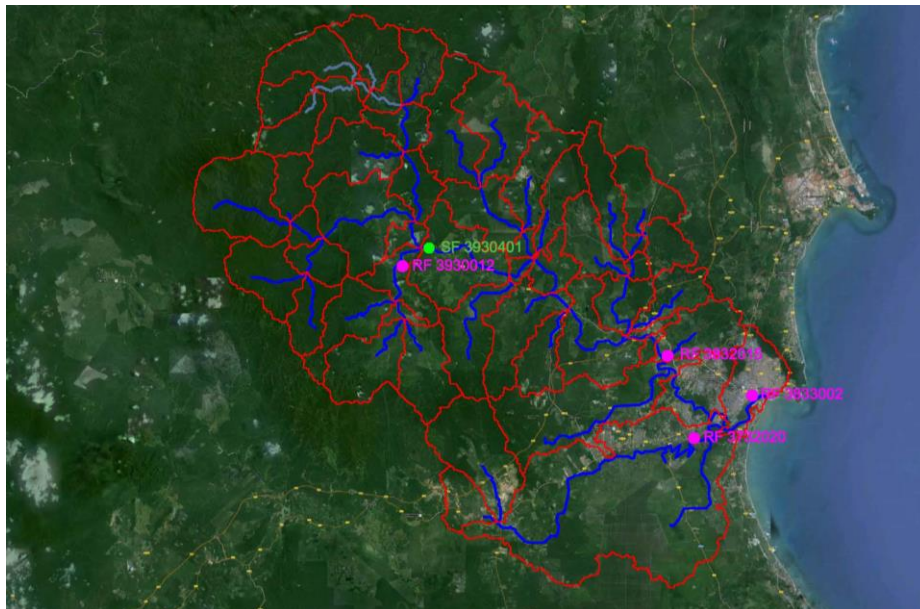




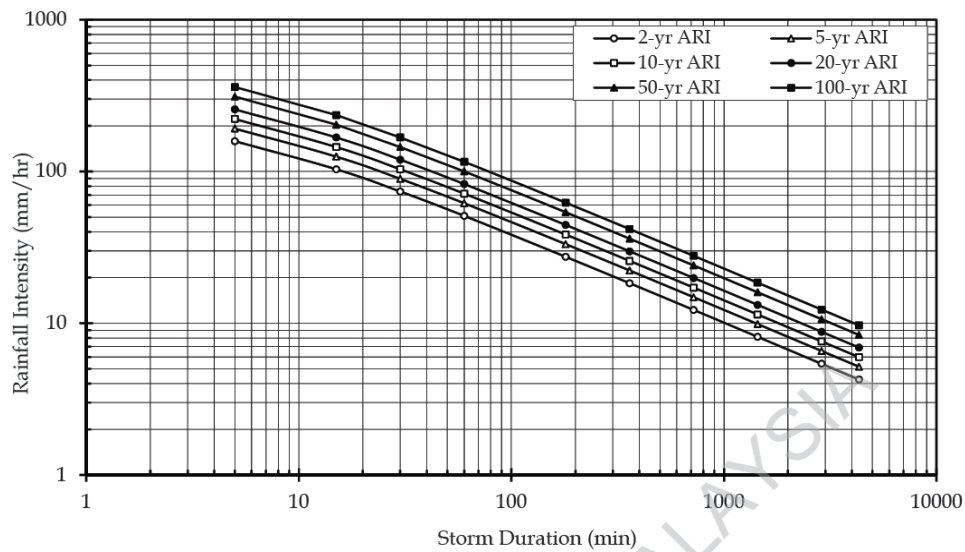
**Figure 1.** The location of study: Chereh Dam, Kuantan, Pahang - Malaysia

## 2. Precipitation Analyses

Precipitation analysis using certain period of historical events is needed to develop the rainfall boundary condition. The recorded streamflow and rainfall data is a key to construct proper and applicable rainfall runoff model. Kuantan River basin has 4 (four) rainfall stations (RF) and 1 (one) stream flow station (SF) at Lembing River. Both types of data are collected by Department of Irrigation and Drainage of Malaysia. Then, Intensity Duration Frequency (IDF) curves of some river basins in Malaysia have been developed also [3]. This figure was extracted as an input data of calibrated and confirmed HEC-HMS model to simulate flood hydrograph for 50 years and 100 years Annual Recurrence Interval (ARI).



**Figure 2.** Meteorological stations; SF is stream flow and RF is rainfall stations

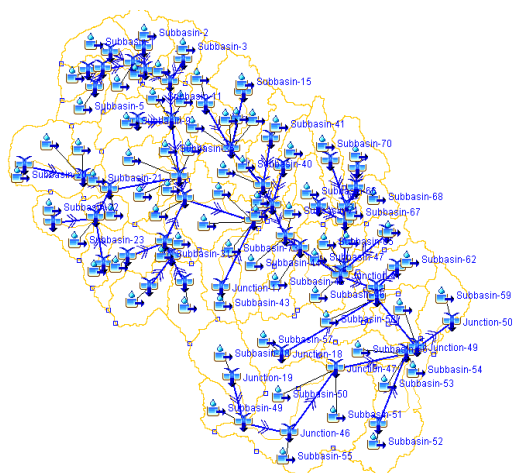


**Figure 3.** Intensity duration frequency (IDF) curve at lembing river PCC Mill [3]

### 3. Hydrological Modelling

HEC-HMS is designed to simulate the rainfall runoff processes in watershed systems. The output from HEC-HMS model can be used directly or by other software for some research and studies such as: water balance and availability, urban drainage, flow forecasting, future urbanization and climate change impact, flood control and damage reduction.

For Chereh dam break studies, HEC-HMS was used to model rainfall runoff relationship flowing into the reservoirs and also runoff from areas downstream of Chereh Dam. It was assumed that precipitation and storms would fall over the whole watershed. The model scheme is displayed in Figure 4. 68 sub-basins and 50 junctions have been built up to describe Kuantan River basin characteristics. Before modeling of flood hydrograph with 50 years and 100 years ARI an effort was made to calibrate the HEC-HMS models to insure that model parameters are more reasonable to simulate larger events. Due to, the number of stream-flow station in Kuantan River basin is only one at Lembing River (Figure 5), so the calibration of HEC-HMS model was done in Lembing River basin.



**Figure 4.** HEC-HMS model scheme for Kuantan River basin



**Figure 5.** HEC-HMS model calibration for Kuantan River basin

During model calibration process some parameters have been input in each sub-basin; such as: Time of concentration ( $T_c$ ); Storage Coefficient ( $R$ ), Base flow ( $Q_B$ ). In term of  $T_c$  and  $R$ , Department Drainage and Irrigation have published Hydrological Procedure No. 27 [4], in this guideline a multiple linear regression have been used to relate mathematically of  $T_c$  and  $R$  [5]. Equation for  $T_c$  and  $R$  are written below:

$$T_c = 2.32A^{-0.1188}L^{0.9573}S^{-0.5074} \quad (1)$$

$$R = 2.976A^{-0.1943}L^{0.9995}S^{-0.4588} \quad (2)$$

$$S = \left[ \frac{\sum I_i \sqrt{S_i}}{\sum I_i} \right]^2 \quad (3)$$

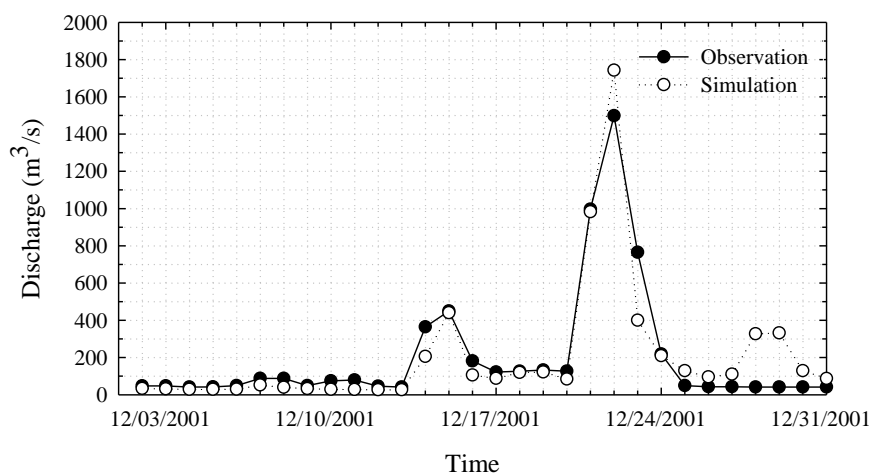
where  $A$  = catchment area in  $\text{km}^2$ ;  $L$  = main stream length in km;  $S$  = weighted slope of main stream in m/km;  $I_i$  is incremental stream length and  $S_i$  is incremental slope.

The equation to determine base flow has been published in Hydrological Procedure No. 27 [4].

$$Q_B = 0.11A^{0.85889} \quad (4)$$

where  $Q_B$  is base flow ( $\text{m}^3/\text{s}$ ) and  $A$  is catchment area ( $\text{km}^2$ ).

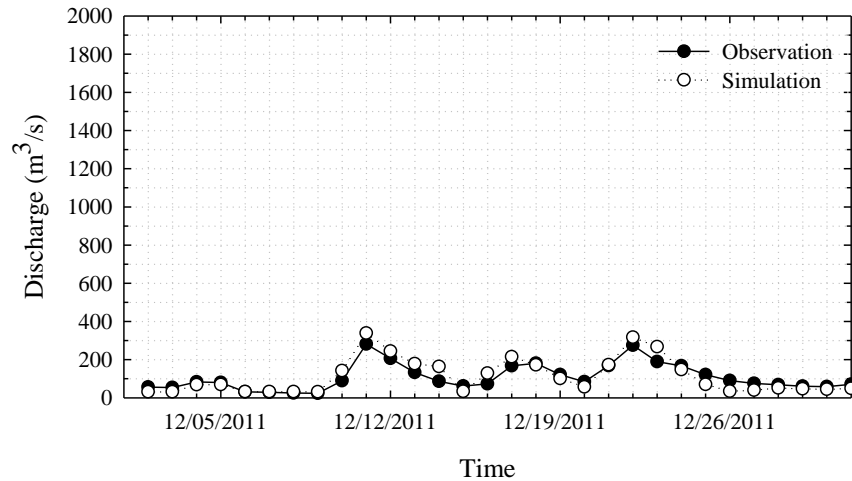
The result of HEC-HMS model calibration shows in Figure 6, the simulation result shows agree well with the values of Nash–Sutcliffe efficiency coefficient (NSE) and the coefficient of determination,  $R^2$  are 0.865 and 0.968. The value of Nash–Sutcliffe efficiency coefficient (NSE) ranges between 0.0 and 1.0 are generally viewed as acceptable levels of performance, then, the coefficient of determination,  $R^2$ , typically is considered acceptable when the value of  $R^2 > 0.5$  [6; 7]. It can be stated that HEC-HMS model can imitate flow hydrograph properly for Lembing River.



**Figure 6.** Observed and simulated flow hydrographs on December 2001

In order to validate the calibrated HEC HMS model, historical data on December 2011 was used. The result shows that a good agreement between observation and simulation can be achieved with the values of Nash–Sutcliffe efficiency coefficient (NSE) and the coefficient of determination,  $R^2$ , are 0.896

and 0.980 (Figure 7). Therefore, it can be concluded that HEC-HMS model can be applied for Kuantan River basin in order to generate flood hydrograph with 50 years and 100 years ARI.



**Figure 7.** Observed and simulated flow hydrographs on December 2011

#### 4. Hydraulics Modelling

The Hydrologic Engineering Centre's River Analysis System (HEC-RAS) software allows for two-dimensional steady-flow or unsteady-flow simulation through a full network of open channels. For the Chereh dam break studies, this software was used to model the impacts of Chereh Dam failure to downstream area which is happened during a design flood of 50 years and also 100 years ARI. The maximum inundation in 2 (two) scenarios as mentioned above is displayed in Figures 8 and 9 below.





**Figure 8.** The inundation mapping due to Chereh Dam failure during heavy rainfall with 50 years ARI



**Figure 9.** The inundation mapping due to Chereh Dam failure during heavy rainfall with 100 years ARI



## 5. Conclusions

Two scenarios have been simulated for Chereh Dam failure, a dam break occurs during heavy rainfall of 50-years and 100-years ARI respectively. Inundation maps were developed used HEC-RAS in order to show the level of Chereh Dam downstream floodwaters for all scenarios. U. S Bureau Reclamation [8] stated that city or state governments who responsible for public safety have to ensure that ERPs caused by dam failure have been developed and implemented well. They have to prepare informative and instructive map of the potential areas that would be flooded due to dam-break failures and also the safety areas. Then, some precautions should be taken by the city or state government to avoid or to minimize the hazards of dam failure.

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