HYDROLOGICAL MODELLING OF UNIVERSITI TEKNOLOGI MALAYSIA SUB CATCHMENT USING HECHMS

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ABSTRACT

Various medium has been used in computer programming to simulate the rainfall-runoff within a catchment. Using computer program are handy for hydrologist and hydraulic researchers. This research objective is to determine the catchment and hydrological parameters of UTM sub-catchment using HEC-HMS model. By identifying the catchment properties and hydrological parameters, flood impact simulation may be conducted within UTM catchment. Simulation results and calibration includes estimating the peak discharge using Rational Method. Digital elevation (DEM) data was used to obtain the catchment area and slope. River network of the catchment was identified using topographic map, while the rainfall data were collected from rain gauge installed in UTM. Time of concentration, Tc for river was obtained by using the hyetographs and hydrographs from the rainfall and automatic water level recorder installed inside the sub-catchment. The Tc observed from storm events were compared with calculation using MSMA2 and Hydrological Procedure No.27. The Tc of the sub catchment is estimated between 0.25 to 0.67 hour depending on the storm events. The rainfall-runoff event was simulated. Effectiveness of the storm water management conducted by UTM such as the existence of lakes and detention pond were assessed.

Keywords: *HEC-HMS, catchments, rainfall-runoff simulation, Universiti Teknologi Malaysia*

1.0 INTRODUCTION

The total land area of Peninsular Malaysia is approximately 13.2 million ha, of which 5.97 million ha or 45.3% is forested. Growing population cause scarcity of forested land and widespread changes in land use [1]. To ensure that future generations can enjoy the benefits of forest resources, more efficient management of these resources is needed. The term flood is referred to an occasion when excess water in the basin overflow beyond its normal surface level. It is one of the most lethal natural disasters that has cause casualties and property loss on every inhabited continent [2]. Flood has severely affected human in the Asia continent, particularly Malaysia. The average annual physical damage cause by flood in Malaysia were estimated to be RM915 million, affecting almost 29,800 km² area and 4.82 million people [3].

In line with the era of globalization, various new technologies have been introduced. Various models have been created to simplify everyday work, especially in the field of hydrology. The use of computerized models may be used for storm water management. Peak runoff estimations may be simulated by adopting computer models such as HEC-HMS. The objective of this study is to identify the catchment properties within Universiti Teknologi Malaysia (UTM), Skudai campus. Then, to

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estimate the runoff volume generated in a sub-catchment in UTM Skudai using HEC-HMS. Otherwise, to assess the catchment storage and storm water management conducted by UTM.

This study will benefit the residents in UTM by being a future reference source for further hydrological and hydraulic simulation. The UTM catchment area was produced using Arc-GIS by processing raw DEM data from Alaska Satellite Facility. The DEM data was on year 2011 with accuracy 12.5m. HEC-HMS 4.3 hydrological model software was used to get the peak flow rate for a particular sub-catchment area within UTM. Evaluation of the accuracy of the simulation was performed by comparison between the flow rate from Rational Method against the simulated hydrograph.

Study Area and Data

The total area for UTM catchment area is only 2.35 km². The characteristic of the catchment was tabulated in **Table 1**. The river flow from upstream and enter the lake as shown in **Figure 1**. The catchment elevation ranges between 92m to averagely 40m from the mean sea level. Due to complexity and limitation of the lake's and detention ponds' hydraulic parameters, rainfall-runoff simulation conducted excluded the existence of the lakes and detention ponds. The functions of the lakes and ponds are to be discussed.

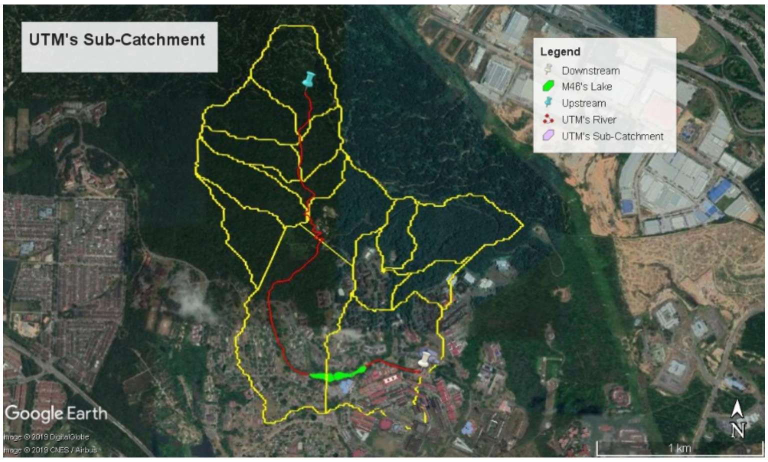

Figure 1: UTM sub-catchment area.

Table 1: Characteristic of study area.

Catchment	Area (km²)	River length include lake (km)	Channel Slope %
UTM sub-catchment	2.34	2.96	2.22

The land use information was obtained from Office of Asset and Development UTM, and from satellite images using Google Earth Pro. At present, the upper catchment of UTM area is covered by forests and bushes. The types of land use are then translated into percentage of pervious and impervious surface as summarized in **Table 2**.

Table 2: Percentage of pervious and impervious present land use type.

Catchment	Area (km²)	Pervious (%)	Impervious (%)
UTM	2.34	10	90

Methodology

Identifying the catchment boundaries using ArcGIS 10

Watersheds, also known as basins or catchments, are physically delineated by the area upstream from a specified outlet point. Watersheds can be delineated manually using paper maps, or digitally in a GIS environment. [4]. UTM sub-catchment area was obtained using ArcMap10. Data Elevation Model (DEM alos palsar) from Alaska Satellite Facility 2011 with accuracy 12.5 m was used to get the

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catchment properties such as catchment area, river length, area of the lake and the elevation of the upstream and downstream of the catchment using ArcGIS.

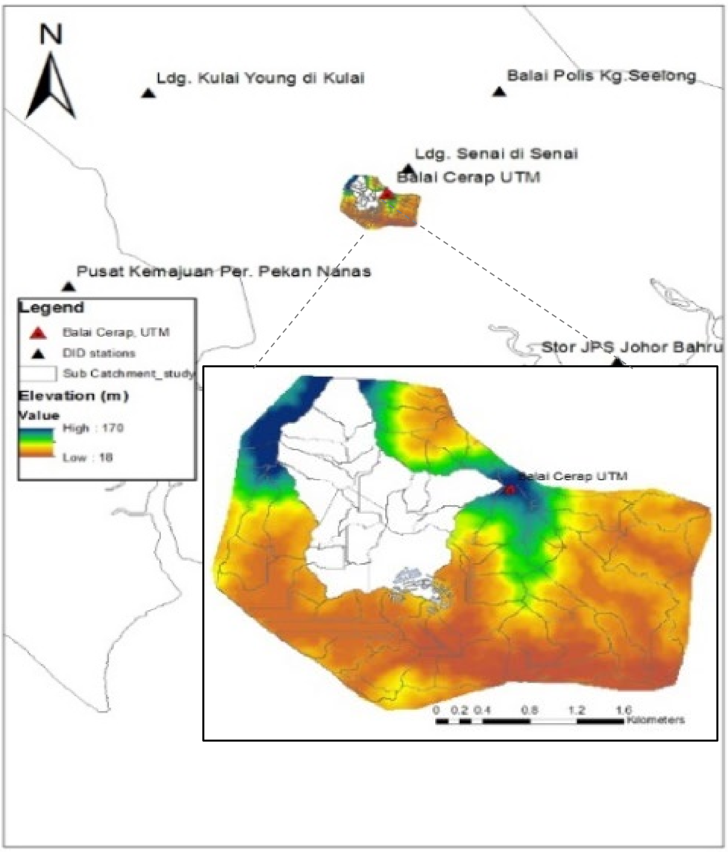

Figure 3: UTM sub-catchment area.

Hydrological Model Set-Up

In HEC-HMS, hydrologic elements are linked in a network to imitate watershed hydrologic structure, and the computation are performed in an upstream-to-downstream sequence. **Figure 3** shows the setup of HEC-HMS model for UTM sub-catchment. The execution of a simulation in HEC-HMS requires combination of four sets of data, which are Basin Model, Meteorological Model, Control Specification, and Time Series Data. The following steps are adopted to construct the rainfall-runoff model for UTM sub-catchment. Firstly, the sub-catchment network was established by inserting hydrological elements available such as sub-basin, reservoir, junction, and reach. The hydrological parameters such as sub-basin area, rate of losses, coefficient and baseflow were set. The next component was precipitation model using rainfall data as input. Finally, the control specifications for how many hours period rainfall were selected with 5-minute time interval.

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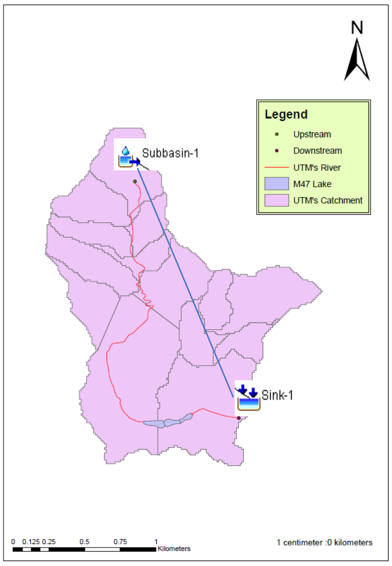

Figure 3: HEC-HMS model for UTM sub-catchment showing modelled sub-basin.

Clark Time Area method was used to determine how the runoff is distributed over time. There are two parameters used to develop this synthetic unit hydrograph, namely Tc and R. These two data can be obtained from observed hydrograph. UTM river was an ungauged area, meaning none observed hydrograph is available but. At the outlet however, the water level data was measured to estimate the flowrate using an automatic water level. Tc is estimated from Hydrological Procedure 27 – Estimation of Design Hydrograph using Clark Method for Rural Catchment in Peninsular Malaysia [5] and as below.

$$T_c = 2.32\, A^{-0.1188} L^{0.9573} S^{-0.5074} \quad (1.1)$$

$$R = 2.32\, A^{-0.1943} L^{0.9995} S^{-0.4588} \quad (1.2)$$

where is the time of concentration (minutes); R is catchment storage coefficient; A is catchment area in km²; L is main stream length in km; and S is weighted slope of main stream in m/km. Meanwhile, the baseflow for the area was assumed to be constant monthly. The results from HEC-HMS (in term of peak flow) will be compared with Rational Method [6]. The equation for Rational Method were listed below.

$$Q = \frac{CiA}{360} \quad (1.3)$$

where Q is peak flow in m³/s; C is runoff coefficient (from Table 2.5 MSMA 2nd Edition August 2012); i is average rainfall intensity in mm/hr; and A is drainage area in ha.

Results and Discussion

Table 3: Q peak comparison

Q peak Comparison (m³/s)		
Q peak	**Event 1**	**Event 2**
Q peak (simulated)	10.2	3.5
Q peak (Rational Method)	10.21	3.62
% Different	0.01	0.12

Table 4: Time of concentration Tc comparison

Time of Concentration Tc Comparison					
Method	**Tc (hr)**	**Rainfall Duration (minutes)**	**Rainfall Volume (Simulated) (m³)**	**Rainfall Volume (Observed) (m³)**	**Rainfall Volume (Pond & Sub-catchment) (m³)**

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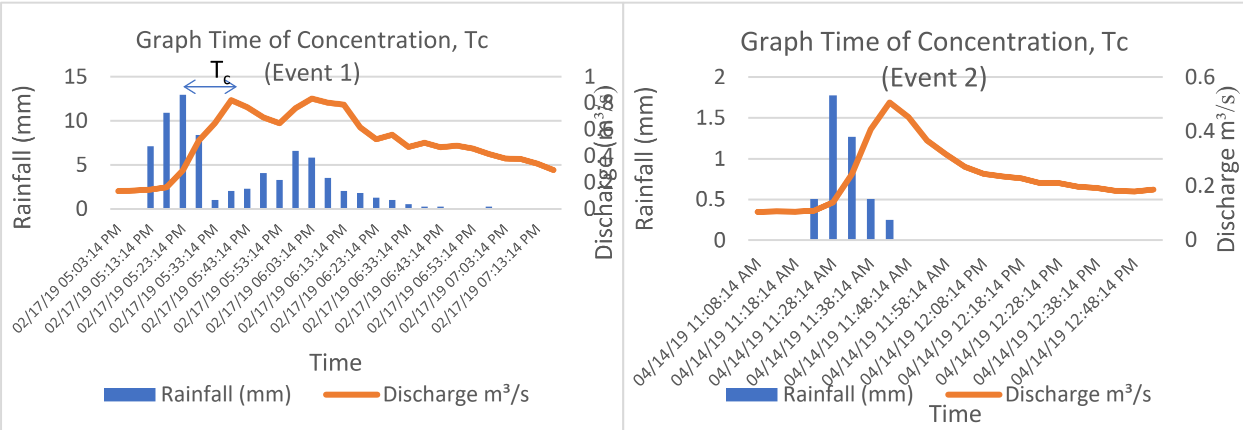
Hydrological Procedure 27 (HP27)	1.57	NA	NA	NA	NA
MSMA 2nd Edition	1.06	NA	NA	NA	NA
Event 1	0.67	110	71910	3335	68575
Event 4	0.35	85	15240	1050	14190

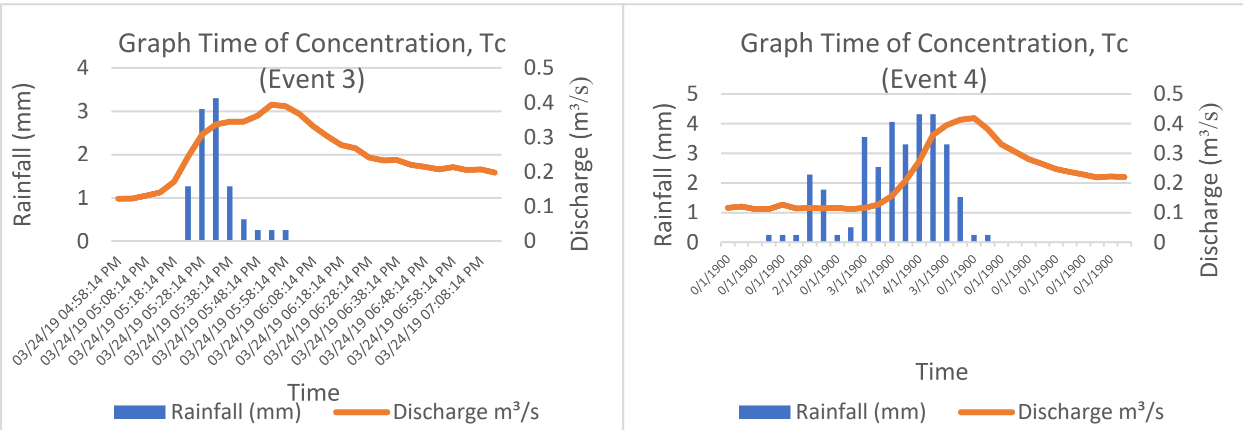
As we can see in **Table 3** and there are two rainfall events. The percentage difference for Q_{peak} in event 1 is 0.01% while on event 2 is 0.12%. The Q_{peak} was determined based on the assumption of no reservoir present in the catchment and was compared with Q_{peak} estimated using the Rational Method. For the time of concentration, T_c was estimated using the Hydrological Procedure 27, MSMA2 and hyetograph-hydrograph (observation data) assessment. Percentage difference between HP27 and MSMA was only 0.51% while for the rainfall event 1 and 2 was 0.5%.

In **Table 4** shows also two rainfall events. The time of concentration, T_c for event 1 is 0.67 hr (110 minutes rainfall) and for event 4 is 0.35hr (85 minutes rainfall) resulting 3335 m^3 of rainfall volume in event 1 and 1050 m^3 in event 4. The rainfall volume for simulation using HEC-HMS was 71910 m^3 for event 1 and 15240 m^3 for event 4. It can be concluded that runoff volume stored in the sub-catchment is 68575 m^3 for event 1 and 14190 m^3 for event 4.



(a) (b)

Figure 4: (a) Graph time of concentration, T_c for event 1 (b) Graph time of concentration, T_c for event 2



(a) (b)

Figure 5: (a) Graph time of concentration, T_c for event 3 (b) Graph time of concentration, T_c for event 4

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As per illustrate in all four graphs, conclusion is made per events. From event 1, shown in **Figure 4(a)**, the rainfall increases from 7.112 mm to 10.922 mm and highest rainfall is at 05:23 pm which is 12.954 mm. In 10 minutes time, the rainfall increases 45%. The average discharge during event 1 is 0.501 m^3/s which having 0.834 m^3/s as the highest reading at 06:03pm and 0.135 m^3/s at 05:03 pm with the changes difference of 83%. Time of concentration, T_c for event 1 is 0.67hr. For event 2, illustrate in **Figure 4(b)**, the highest rainfalls happen on 11:28 am with 1.778mm rainfall reading. The rainfalls only happen for 20 minutes which are from 11:23 am until 11:43 am. The percentage of difference is 86% which contribute for an average of 0.236 m^3/s of discharge. Time of concentration, T_c for event 2 is 0.25hr. The highest rainfall on event 3 recorded in **Figure 5(a),** a 3.302mm reading and with an average of 0.255 m^3/s of discharge. The percentage of difference in rainfall is 92%. Time of concentration, T_c for event 3 is 0.35hr. Event 4 shows from **Figure 5(b),** the highest readings of rainfall happen on 05:03 pm and 05:08 pm with 4.318 mm which last for 5 minutes. The average of discharge recorded is 0.219m^3/s and the percentage difference of the rainfall recorded is 94%. Time of concentration, T_c for event 4 is 0.35hr. To conclude, event 1 shows the highest number of T_c which is 0.67hr while event 2 is recorded for lowest T_c with 0.25hr and event 3 and event 4 shares the same Tc which is 0.35hr. For design purposes, the highest time of concentration was adopted which is estimated using equations as presented in MSMA and Hydrological procedures. From observation (hyetographs and hydrographs plotted), all the Tc values are lower than the values estimated from calculations.

Conclusion

As a conclusion the combination of Arc-GIS and HEC-HMS has been used as a tool to determine the UTM catchment properties and the discharge runoff for rainfall event in UTM. Two event rainfall was taken to observe the discharge at UTM sub-catchment area. The simulation results from HEC-HMS model was compared with peak flow obtained by Rational Method. For the time of concentration, Tc was compared by three data which is Hydrological Procedure 27, MSMA2 and rainfall event. Percentage difference between HP27 and MSMA was only 0.51% while for the rainfall event 1 and 2 was 0.5%. The catchment properties also successfully determined. At the end of the study, the catchment storage and water management conducted by UTM were able to be assessed, thus the objective is achieved.

This study only determines the peak flow of the UTM catchment without the reservoir. Therefore, further study is required in determining the parameter of the reservoir. This could help Office of Asset and Development UTM to maintain the level of river in UTM sub-catchment area to prevent flood in the future. Besides, current simulation only considers the present land use data.

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