Hydrology Analysis and Modelling for Klang River Basin
Flood Hazard Map

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Abstract. Flooding, a common environmental hazard worldwide has in recent times, increased as a result of climate change and urbanization with the effects felt more in developing countries. As a result, the explosive of flooding to Tenaga Nasional Berhad (TNB) substation is increased rapidly due to existing substations are located in flood prone area. By understanding the impact of flood to their substation, TNB has provided the non-structure mitigation with the integration of Flood Hazard Map with their substation. Hydrology analysis is the important part in providing runoff as the input for the hydraulic part.

1. Introduction

Globally, floods are frequent natural disaster that cause severe damage to both lives and property. It is estimated that of the total economic loss caused by all kinds of disasters, 40% are due to flooding [1]. In Malaysia, floods are the most important natural hazard in terms of population affected, frequency, areal extent, and socio-economic damage [2]. As the largest utility company in Malaysia, Tenaga Nasional Berhad (TNB) is facing a major threat due to the rising severity and frequency of flood poses to their supply performance, inflicting unexpected revenue loss and high repair and maintenance cost. During the flood event on December 2014, TNB’s losses are RM10million in the state of Kelantan. [3]. This has given lots of pressure to TNB for the early recovery from the flood impact. With the facts that the nature disaster such as flood cannot be stopped, the mitigation measure becomes the most critical part for TNB in protecting their assets.

Flood Hazard Map (FHM) is one of the non-structure approach practice by Department of Irrigation and Drainage (DID) under the flood mitigation scheme. Up to 2013, there are 28 FHMs for selected river basin available from the total of 189 [4] main river basin. These FHMs are develop by using combination of Hydrological and Hydraulics modelling. This map is developed by using different Average Recurrence Interval (ARI).The accuracy of the modelling is highly depending on the quality
and accessibility of the data. With the cooperation of FHM in TNB system, it will help in identifying the risk of flooding to all their existing substations and planning for their upcoming substation.

This study is focusing on development of FHM in Klang River Basin. With an estimated population of over 3.6 million, (about 21% of the national population) and with a growth rate of almost 5% per year, the basin has experienced the highest economic growth in the country [5, 6]. Klang River basin is bonded with 2 states which are Selangor and Wilayah Persekutuan Kuala Lumpur. Major cities such as Kuala Lumpur grew at the confluence of the Klang and Gombak rivers and is exposed to flood risk [4]. Situated in a flood plain, Kuala Lumpur has been experiencing a number of major flood hazards. The development of FHM map will give a huge impact to the TNB itself in improving the resilient their substation from flooding.

This paper is focusing on the hydrological analysis aspect of the development of Klang River Basin FHM. In this analysis involved three important parts; design storm, catchment characteristic and calibration. All calculation is adopted from Urban Stormwater Management Manual for Malaysia (MSMA) 2nd edition that has been publish by Department of Irrigation and Drainage. [7]

2. Objective

The main objective of hydrologic analysis is to generate runoff from all the tributaries/sub-catchment using rainfall runoff model. This runoff value will become the main input to the river and flood plain model which carries out the flood routing. This subsection discusses on the process for the development of rainfall runoff model. The rainfall runoff model is based on the Soil Conservation Service (SCS) unit hydrograph method. This method was chosen since it is capable to produce runoff hydrograph and suitable for unsteady flow simulation which requires river and flood plain analysis.

3. Methodology

The preparation of hydrologic data is the major part to produce an accrued flood hazard map that reflects the real situation. This analysis will involve the rainfall estimation and sub-catchment of Klang River basin. As a result, the data that been analysed will become the input for the Infoworks RS to develop the runoff hydrograph. The river catchment had been develop in the model include the river alignment by using all the nodes and river line. In the Infoworks RS, the parameter that need to be include for the hydrological modelling are rainfall intensity, types of soil concentration and river alignment. In this paper the SCS hydrograph method.

The design storm involves the rainfall data from DID rain-gauge stations, while the catchment characteristic involve the time of concentration (tc) for each of the sub catchment in Klang river basin. The calibration is used to compare the actual rainfall event with the simulation done based on the available data. In the simulation, there are few assumptions done to provide an accrued model that reflects the real situation.

Based on MSMA, there are 135 numbers of rain-gauge stations that have developed IDF curves throughout Peninsular Malaysia at various return periods. Fifteen of the rainfall stations are within the Sungai Klang catchment and Table 1 lists the rainfall stations adopted in this study while Equation 1 is use to develop the rainfall intensity for various storm duration.

\[
i = \frac{\lambda r^k}{(d+\theta)^n} \quad (1)
\]
where:  
\[ i \] = Rainfall Intensity  
\[ T \] = Design return period  
\[ d \] = Duration of storm  
\[ \lambda, k, \theta, \eta \] = Derived Intensity Duration Frequency (IDF) parameters

**Table 1:** The list of rain gauge station used in hydrological modelling

| No. | Station No | Station Name          | Latitude       | Longitude       | \( \lambda \) | \( k \)  | \( \theta \) | \( \eta \) |
|-----|------------|-----------------------|----------------|----------------|--------------|--------|----------|--------|
| 1   | 3015001    | Puchong Drop, KL      | 03º 01’ 10.3” | 101º 35’ 50.7” | 69.65        | 0.151  | 0.223    | 0.88    |
| 2   | 3116003    | Ibu Pejabat JPS       | 03º 09’ 05”   | 101º 41’ 05”   | 61.976       | 0.145  | 0.122    | 0.818   |
| 3   | 3116004    | Ibu Pejabat JPS1      | 03º 08’ 50”   | 101º 41’ 15”   | 64.689       | 0.149  | 0.174    | 0.837   |
| 4   | 3116005    | SK Taman Maluri       | 03º 11’ 50”   | 101º 38’ 10”   | 62.765       | 0.132  | 0.147    | 0.82    |
| 5   | 3116006    | Ladang Edinburgh      | 03º 11’ 00”   | 101º 38’ 00”   | 63.483       | 0.146  | 0.21     | 0.83    |
| 6   | 3216001    | Kg.Sungai Tua         | 03º 16’ 20”   | 101º 41’ 10”   | 64.203       | 0.152  | 0.25     | 0.844   |
| 7   | 3216004    | SK Jenis Keb. Kepong  | 03º 14’ 04”   | 101º 39’ 38”   | 73.602       | 0.164  | 0.33     | 0.874   |
| 8   | 3217001    | ibu Bek.KM16,Gombak   | 03º 16’ 05”   | 101º 43’ 45”   | 66.328       | 0.144  | 0.23     | 0.859   |
| 9   | 3217002    | Emp.Genting Kelang    | 03º 14’ 10”   | 101º 45’ 10”   | 70.2         | 0.165  | 0.29     | 0.854   |
| 10  | 3217003    | ibu Bek.KM11,Gombak   | 03º 14’ 10”   | 101º 42’ 50”   | 62.609       | 0.152  | 0.221    | 0.804   |
| 11  | 3217004    | Kg. Kuala Seleh, H.Klg| 03º 15’ 30”   | 101º 46’ 05”   | 61.516       | 0.139  | 0.183    | 0.837   |
| 12  | 3217005    | Kg. Kerdas, Gombak   | 03º 14’ 45’   | 101º 42’ 55”   | 63.241       | 0.162  | 0.137    | 0.856   |
| 13  | 3317001    | Air Terjun Sg. Batu  | 03º 20’ 05”   | 101º 42’ 15”   | 72.992       | 0.162  | 0.171    | 0.871   |
| 14  | 3317004    | Genting Sempah        | 03º 22’ 05”   | 101º 46’ 15”   | 61.335       | 0.157  | 0.292    | 0.868   |
| 15  | 3117070    | JPS Ampang           | 03º 09’ 11”   | 101º 44’ 56”   | 65.809       | 0.148  | 0.156    | 0.837   |

### 4. Results and Discussion

The main objective for this paper is to provide the overall element in developing hydrological analysis for FHM Klang River. Table 2a and 2b are the results of Equation 1. This value will be an input together with the catchment characteristic of the sub-catchment for Klang river basin. The value of \( t_c \) for this study is gathered from Kirpich Method. The Kirpich equation is normally used for natural basins with well-defined channels. By using the Infoworks RS, the rainfall runoff hydrograph is produce. Figure 1 shows the calibration done for this model and the details location with the events is shown in Table 3.

The first calibration is at Sungai Damansara at TTDI Shah Alam 3 (Figure 1 (a)). It can be concluded that the results from the simulation is in agreement with the observation, the peak water level is lower than observed. The simulated peak is at 7.67m whereas the observed peak is 7.84m resulting in 0.17m variant. The overall shape of the simulated hydrograph is also a good fit, which gives confidence that the model is representing the complete runoff process. Based on the calibration Sungai Klang at Jalan AU3 (Figure 1(b)) it can be concluded that the results from the simulation is in agreement with the observation, albeit, the peak water level is slightly lower than observed. The simulated peak is at 46.813m whereas the observed peak is 46.830m resulting in 0.017m variant. The overall shape of the simulated hydrograph is also a good fit, which gives confidence that the model is representing the complete runoff process.

While for calibration no 3 (Figure 1(c)) shows the overall results show a good match between the simulated and observed water level. However, a close inspection shows that there can be some significant differences between the model and observed peak water levels.
Table 3. The list of rainfall and water level station for model calibration

| No | Location Of Calibration | Duration | List of Rainfall Station | Water Level Station |
|----|-------------------------|----------|--------------------------|---------------------|
| 1. | Sg Damansara @ TTDI Jaya | 13th & 15th October 2007 | 1) Air Itam Puchong (No. 2915117) 2) Rumah Pam Rantau Panjang (No. 3013001) 3) UTTM Shah Alam (No. 3014091) 4) Setia Alam (No. 3114085) 5) Ibu Peja JPS Wilayah Persekutuan (No. 3116003) 6) Ladang Edinburgh Site 2 (No. 3116006) | 1) Sg. Damansara TTDI Jaya (No. 3015490) |
| 2. | Sg Klang at AU3 | 3rd & 6th September 2008 | 1) IBMBS @ Kg. Kemensah 2) Sg Klang @ Jln AU3 3) Sg Klang @ Empangan Klang Gate 4) Kuala Seleh @ Empangan Klang Gate | 1) Sg. Klang @ Jln AU3 (No. 3015490) |
| 3. | Sg Gombak at Jalan Sultan Ismail – SMART hydrological stations | 1st May- 30th June 2011 | 1) Apartment UIA @ Jln Gombak 2) Sg Gombak @ Jln Changkat Tmn Greenwood 3) Pusat Pengajian Luar UM @ Jln Gombak 4) Sg Batu @ Jln Chendurah 5) Tmn Sri Sinar | 1) Sg. Gombak @ Jln Sultan Ismail 2) Sg. Gombak @ Jln Changkat |

Table 2a. Rainfall intensity (mm/hr) for various storm durations and ARIs at Station Puchong Drop, Kuala Lumpur

| Duration (hr) | Yearly Return Period, ARI (mm/hr) | 5 | 10 | 20 | 50 | 100 |
|---------------|----------------------------------|---|----|----|----|-----|
| 0.25          | 171.6                            | 190.6 | 211.6 | 243.0 | 269.8 |
| 0.5           | 118.1                            | 131.2 | 145.7 | 167.3 | 185.7 |
| 1             | 74.4                             | 82.6 | 91.7 | 105.3 | 116.9 |
| 3             | 44.0                             | 48.8 | 54.2 | 62.3 | 69.1 |
| 6             | 17.8                             | 19.7 | 21.9 | 25.2 | 27.9 |
| 12            | 9.8                             | 10.9 | 12.1 | 13.9 | 15.4 |
| 24            | 5.4                             | 6.0 | 6.6 | 7.6 | 8.4 |
| 48            | 2.9                             | 3.3 | 3.6 | 4.2 | 4.6 |
| 72            | 2.1                             | 2.3 | 2.5 | 2.9 | 3.2 |

Table 2b. Total rainfall (mm) for various storm durations and ARIs at Station Puchong Drop, Kuala Lumpur

| Duration (hr) | Yearly Return Period, ARI (mm/hr) | 5 | 10 | 20 | 50 | 100 |
|---------------|----------------------------------|---|----|----|----|-----|
| 0.25          | 42.9                             | 47.6 | 52.9 | 60.7 | 67.5 |
| 0.5           | 59.1                             | 65.6 | 72.8 | 83.6 | 92.9 |
| 1             | 74.4                             | 82.6 | 91.7 | 105.3 | 116.9 |
| 3             | 87.9                             | 97.6 | 108.4 | 124.5 | 138.2 |
| 6             | 106.6                            | 118.4 | 131.5 | 151.0 | 167.6 |
| 12            | 117.7                            | 130.7 | 145.2 | 166.7 | 185.1 |
| 24            | 129.0                            | 143.2 | 159.0 | 182.6 | 202.8 |
| 48            | 140.7                            | 156.3 | 173.5 | 199.3 | 221.3 |
| 72            | 148.0                            | 164.3 | 182.4 | 209.5 | 232.6 |
Figure 1. Result of calibration for water level output at: (a) Sg Damansara@TTDI Jaya (b) Sg Klang at AU3 (c) Sg Gombak at Jalan Sultan Ismail

5. Conclusion

As a conclusion, this hydrological analysis has shown a reliable result based on the calibration that has been done in the overall Klang River Basin. The production of rainfall runoff will be used in the hydraulic analysis to provide the complete FHM.

Acknowledgment

This paper was written as part of project Research of Floods on TNBD’s PMU/PPU/SSU/PE and The Proposed Mitigation Measures. This project is collaboration between Universiti Tenaga Nasional (UNITEN) under the Centre for Sustainable Technology and Environment (CSTEN) with Tenaga Nasional Berhad-Research (TNBR) for Tenaga Nasional Berhad – Distribution (TNBD). The authors would like to thank the Department of Irrigation and Drainage for all the data given and all the people that have contributed to this project.

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