Conceptual Design for Flood Warning Study for Gunung Pulai Recreational Area at Gunung Pulai, Johor

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Abstract. In order for Gunung Pulai Recreation Area to be opened to public, a detail hydrological study needs to be carried out. The purpose of this study is to establish the preliminary baseline information on hydrological characteristics of the study area and to assess and analyze the existing hydrological parameter that can potentially cause flash flooding within the recreational area. Then, proposing a long term engineering solution towards prevention loss. A study area within the recreational area needs to be determined where the flash flood occurred. Next, hydrologic modeling is conducted to get a better understanding of the parameters in the study area. Field data collection by placing rain gauge and water level at certain level of the study area is needed to provide the hydrological parameters needed to estimate the relationship between the rainfall and water level. Data obtained from the rain gauge and water level will be plotted into graph. The relationship between rainfall and water level is imperative to show the time needed for the alarm to be triggered. In conclusion, the parameters that can potentially cause flash flood has been analyzed and can be altered to make them useful against future flash flood events. A long term solution has also been devised and ready to be deployed.

Introduction

On December 27th, 2001, tropical storm had caused massive flash flood to occur at Gunung Pulai. The tropical rainstorm occurred non-stop approximately from 2 p.m, December 26th to 2 a.m, December 27th the next day.The two-day cumulative rainfall prior to the date of debris flow was 15mm, and the total rain on December 27th was 90mm. The increased in the intensity of the rain has caused the water level of the river to increase steadily. Therefore, as a result of increased in water level of the river, flash flood has occurred. The unprecedented flash flood has caused some serious casualties. Nearby residence were unable to react as they did not know that a massive flood has occurred. Not to mention, the Rangers, Bomba dan Penyelamat cannot take further action at such predicament. They have to wait until the flood has subsided. Therefore, until a detail hydrological study is carried out at the Gunung Pulai Recreational Area, the area is not safe for public. Jabatan Perhutanan Malaysia has decided that a solution or mitigation measure must be created to overcome the potential danger due to flash flood and artificial dam burst problems within the study area.

The proposed project area (Gunung Pulai Recreational Area) is located within the Gunung Pulai, Pontian, Johor. The proposed recreational area is located within Level 1 and Level 2 of Gunung Pulai (Figure 1). The Gunung Pulai Recreational Area is located within the lower level area of Gunung Pulai and could be potentially exposed with frequent cases of flash flooding. (Figure 2) shows the flooded area within the catchment area during the 2001 flood. The 2001 flood causes not only losses of lives but also damages to properties and infrastructures, and causes the park to be closed to the public.

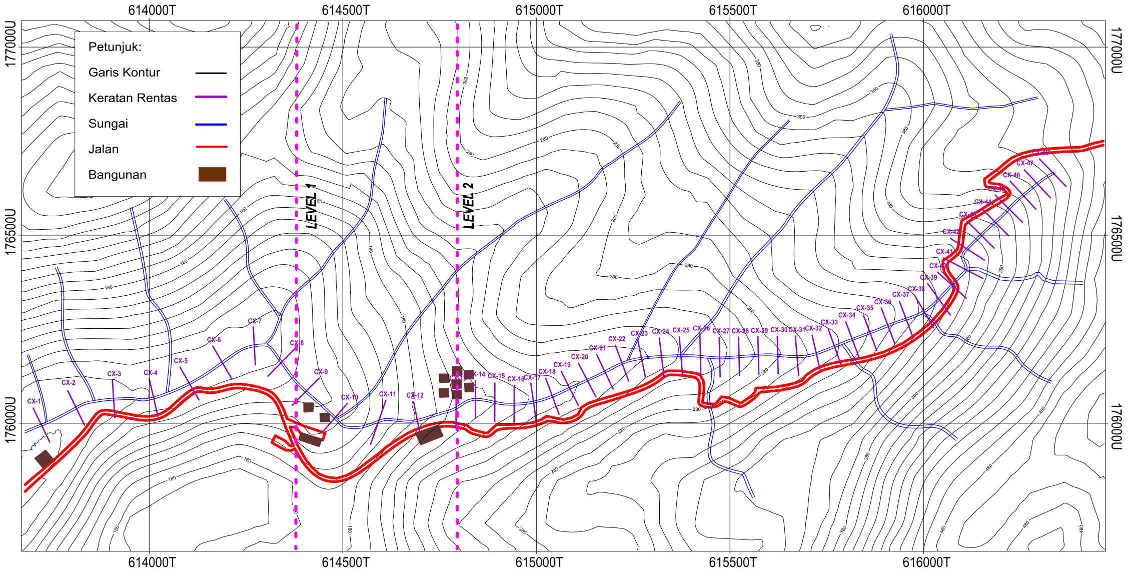


Figure 1: Location of the proposed recreational area

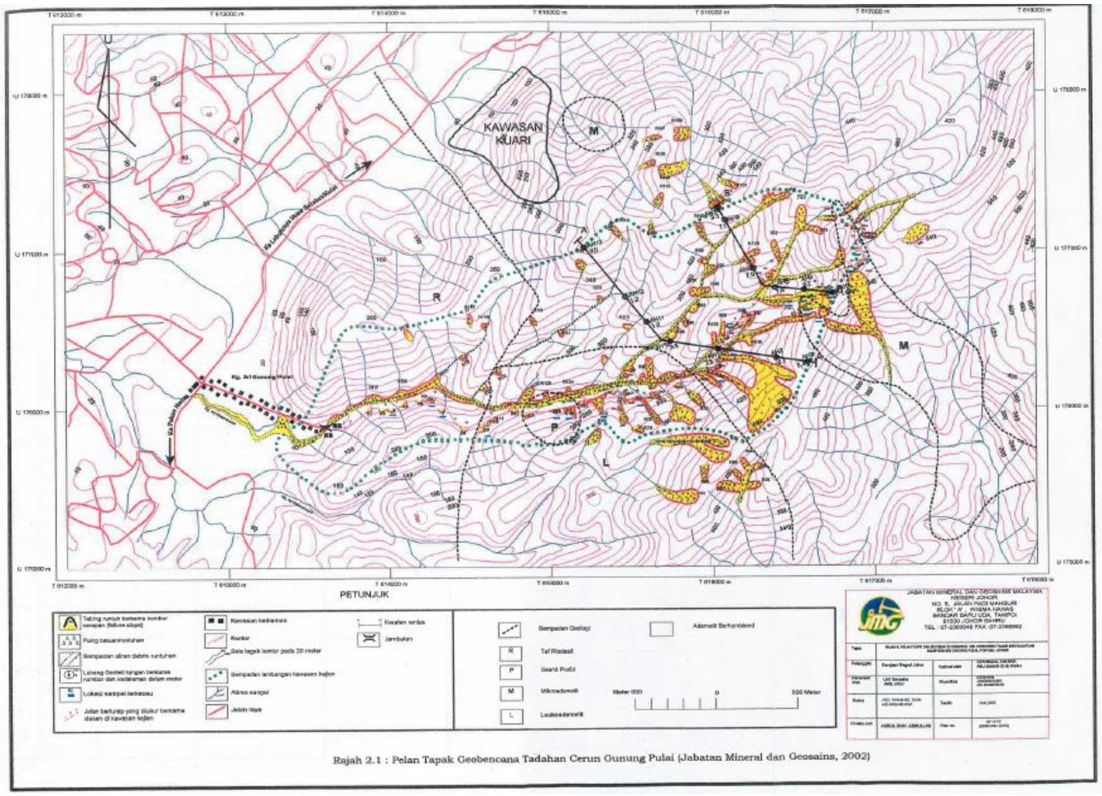


Figure 2: Affected area during the year 2001 flood

The proposed project area is located within Gunung Pulai Recreational Area as shown in Figure 3. Figure 4 shows the Sg. Air Hitam sub-catchment area, where the proposed recreational area lies within this catchment area. The project will also need to carry out the study on current rainfall pattern and possible erosion problem for the project catchment area.

Figure 3: Location of the study area

Objectives

The main objective of the study is to develop a detail understanding of the parameters available within the study area through field data collection and modelling process. The detail objectives are described as follows:

1. To establish the preliminary baseline information on hydrological characteristics of the study area.
2. To assess and analyse the existing hydrological parameter that can potentially cause flash flooding within the recreational area and proposed a long term engineering solution towards prevention loss.

Scope of Study

In order to achieve the above objectives, the following scope of work is planned out for the study:

1. Assessment of the historical rainfall patterns including geographical distribution within and surrounding the project site.Assessment of the existing surface drainage patterns, flows, history of flooding which includes extent of flooding, flood levels and flood frequency.
2. Assessing present water uses and availability using historical rainfall data. The assessment on flooding within the project site and surrounding area would be based on hydrological modelling (HEC-HMS)

Literature Review

Malaysia is fortunate to be freed from natural disaster such as earthquakes, volcano and typhoon. The most severe natural disaster experiencing in Malaysia is flood [1]. Throughout Malaysia, including Sabahand Sarawak, there is total of 189 river basins with the main channels flowing directly to the south china sea and 85 of them are prone to recurrent flooding (89 of the river basins are in Peninsula Malaysia, 78 in Sabah and 22 in Sarawak). The estimated area vulnerable to flood disaster is approximately 29,800 km^2or 9% of the total Malaysia area, and is affecting almost 4.82 million people which is around 22% of the total population of the country [2]. Floods in Malaysia have been classified in two categories by the Malaysian Drainage and Irrigation Department, i.e. flash flood and monsoon floods. Based on the hydrological perspectives, the clear difference between these two disasters is the period taken by the river flow to recede to the normal level. Flash floods take only some hours to return to the normal water level, while monsoon flood can last for a month [3].

Flash flood can be triggered by natural causes such as local weather known as line-squalls and non-natural causes like inefficient urban drainage system and an increase in urban built-up areas. At Gunung Pulai however, debris flow occurred on December 28, 2001, which claimed the lives of 5 residents as a result of a tropical storm that passed through Johor Bharu from 14:00 pm on December 27 to 2:00 am. The two days of cumulative rain prior to the date of debris flow was 15mm, and the total rain on December 28 was 90 mm. It was suggested that strong wind caused trees to fall into the river and formed a natural dam, which breached, causing debris flow [4].

These intense rainfall events, sometimes called cloudbursts, can occur in remote areas as a result of topographic variations and are generally unreported because of inaccessibility and isolation. An intense rainfall event may occur in the high reaches of a mountain stream in an unpopulated area yet may produce a flash flood affecting downstream communities. Prolonged monsoon rainfall can also cause flash floods, as occurred in central Nepal in 1993 and in Niujuangou gully, China in May 2010. Monsoon depressions are another climatic factor that causes flash flood, particularly in Pakistan. In the western Himalayas, accumulated snow can melt rapidly during spring, leading to flash floods. Because of the young geology of the Himalayas and the instability of their slopes, the HKH region is prone to recurrent and often devastating landslides and debris flows. Such landslides and debris flows, released by torrential rain or seismic activity, may cause temporary dams across river courses impounding immense volumes of water. Subsequent overtopping or breaking through of the earth dam can result in a landslide dam outburst flood (LDOF), which, similar to a GLOF, is difficult to predict and may cause serious loss of life and damage to property [5].

Methodology

An assessment of the historical rainfall paterns including geographical distribution within the surroundingproject site. Assessment of the existing surface drainage patterns, flows, history of flooding which includes extent of flooding, flood levels and flood frequency. The study will also present water uses and availability using historical rainfall data.

Study Area

The study area (recreational area) is located within the catchment of Sg. Air Hitam. Sg. Air Hitam catchment lies within Sg. Pontian River Basin. Sg. Air Hitam eventually discharges toward Straits of Melaka. Sg. Air Hitam catchment area can be divided into three sub-catchment areas (Catch 1, 2, & 3) as shown in Figure 4 below.

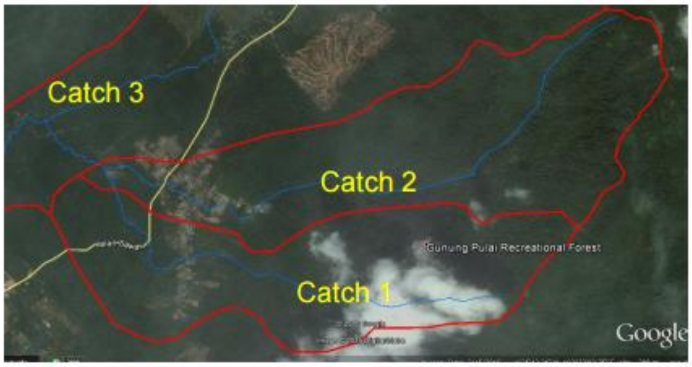


Figure 4: Location of the recreational area within catchment 2 (Google Map)

However, only sub-catchment 2 will be considered in this study because the recreational area lies withinthis catchment. Surface runoff from the catchment area drained toward streams and channels flows through the recreational area before discharging toward Sg. Air Hitam. The surface runoff discharges towards the upstream area of Sg. Air Hitam which is about 2.5 km from the project site.

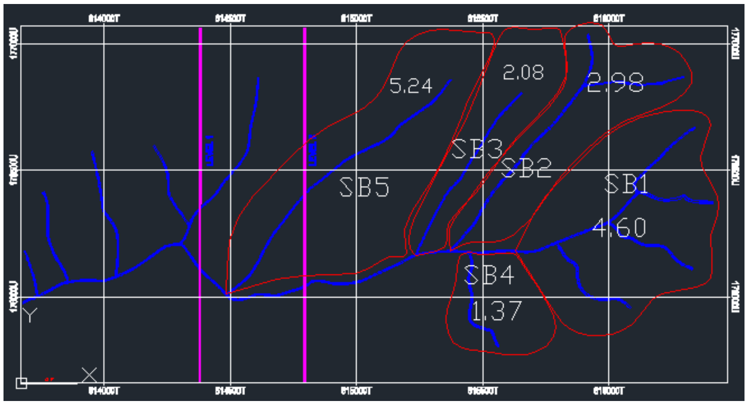


Figure 5: Drainage system within catchment 2

Figure 5 shows the existing drainage system within the study area. High water level in Sg. Air Hitam would result in flash flood within the recreational area at Level 1 and Level 2. The labeled sub-basin in figure 5 will be used in hydrologic modelling.

Hydrologic Modelling

The purpose of hydrologic modeling is to estimate flow hydrograph from tributary catchment for various ARI's. The estimated flow hydrograph serve as an input to the hydraulic modeling of the study area. The hydrologic model in HEC-HMS is available and can be downloaded from the US Army Corps website. There are plenty of options available in this module for calculating catchment losses, transformation of excess rainfall and base flow estimation. Loss methods used for HEC-HMS modelling are Initial and Constant Loss method. The parameters require to complete this modelling are Initial Loss, Constant Rate and Impervious Percentage Value. For the purpose of modeling, the catchment was divided into several sub-catchments. These sub-catchments are represented as basins in HEC-HMS. The selections of the basins are based on the consideration of certain aspects of the catchment characteristics and locations where determination of flow is required. The schematic representation of the study area for the hydrologic modeling in HEC-HMS showing all sub-catchment tributaries, junctions, and reaches are shown in Figure 6.

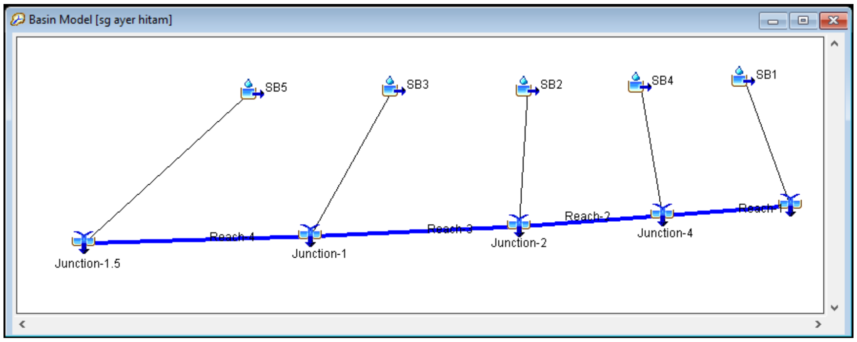


Figure 6: Study area in HEC-HMS modelling. (All the basins, junctions and reaches)

Hydrologic Simulation

Hydrologic modelling of flows for the catchment area was carried out using HEC-HMS model. The design storm selected for this study depends on the time of concentration of the study area (t_c). The tc was estimated by using the Barnsby-William formulae (Equation 1). The estimated $t_c$at the outlet and subcatchment is listed in Table 1.

$$t_c = \frac{F_c . L}{A^{1/10} S^{1/5}} \quad \text{...Equation 1.}$$

where,
t_c = the time of concentration (minute).
F_c = a conversion factor (58.5 for area A in km^2, or 92.5 for A in ha.)
L = length of flow path from catchment divide to outlet (km).
A = catchment area (km^2 or ha).
S = slope of stream flow path (m/km)

Table 1: Estimated tc values

Catchment	C. Area (km^2)	L (km)	S (m/km)	Tc (min)	Tc (hr)
Level 1	7.5	2.5	130	45	0.8
Level 2	7	2	140	36	0.6

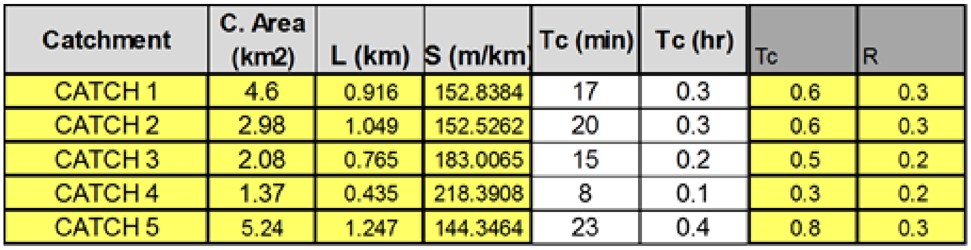
Therefore, the design storm used in this study for the Recreational Area area is 1 hour. The closest IDFcurve available for this study area is that for Pekan Nenas. Therefore, in this study, the IDF derived for Pekan Nenas will be used for the simulation. The proposed detention pond is designed for the return period of 20 years and checked with 50 years ARI. The hydrologic losses for the area will be based on initial and continuing loss method for forested area. The initial loss is assumed to be 15 mm and the continuing loss is assumed to be 25 mm/hr. It is also assumed that the existing land cover consists of about 5 % impervious area for the catchment area. The transformation of effective design storm to the outlet area will be based on Clark time-area method. The selection of design storm was described earlier. The two parameters used for the development of this synthetic unit hydrograph are TC and R. These two parameters can be obtained from observed hydrograph. In the absence of the observed hydrograph, the parameters can be estimatedfrom regression equations derived areas with gaged data. The regression equation used in this study isderived from a study in small rural watersheds in Illinois, USA. The regression equations are as listed below.

$$T_c = 1.54\, L^{0.875}\, S^{-0.181}$$

$$R = 1.64\, L^{0.342}\, S^{-0.790}$$

The Tc and R value within the sub catchment are listed below in Table 2. L is the stream length measure along the main channel from the outlet to the watershed. S is the slope of stream flow path.

Table 2: Estimated T_c and R values



Catchment	C. Area (km2)	L (km)	S (m/km)	Tc (min)	Tc (hr)	Tc	R
CATCH 1	4.6	0.916	152.8384	17	0.3	0.6	0.3
CATCH 2	2.98	1.049	152.5262	20	0.3	0.6	0.3
CATCH 3	2.08	0.765	183.0065	15	0.2	0.5	0.2
CATCH 4	1.37	0.435	218.3908	8	0.1	0.3	0.2
CATCH 5	5.24	1.247	144.3464	23	0.4	0.8	0.3

Field Data Collection

The approach of the current field data collection for the recreational area is to obtain lead time for flood warning purposes. Existing flood warning infrastructures within the recreational area is non-existence or almost negligible. There are two equipments being installed within the recreational area for the purposed of providing some early indication of incoming headwater. A rainfall station was installed at the highest elevation of the catchment boundary, while a water level was installed at Level 1. Figure 6 shows the location of the equipments installed within the study area.

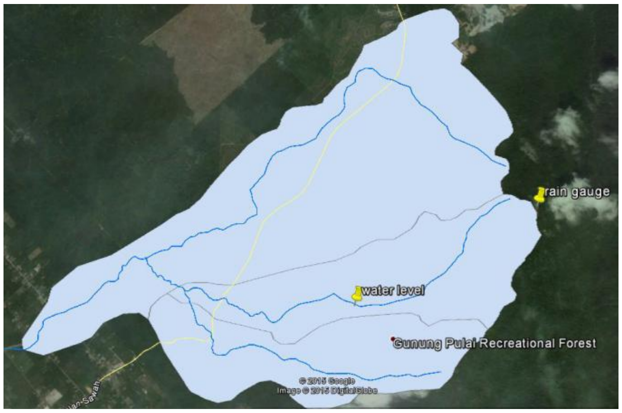


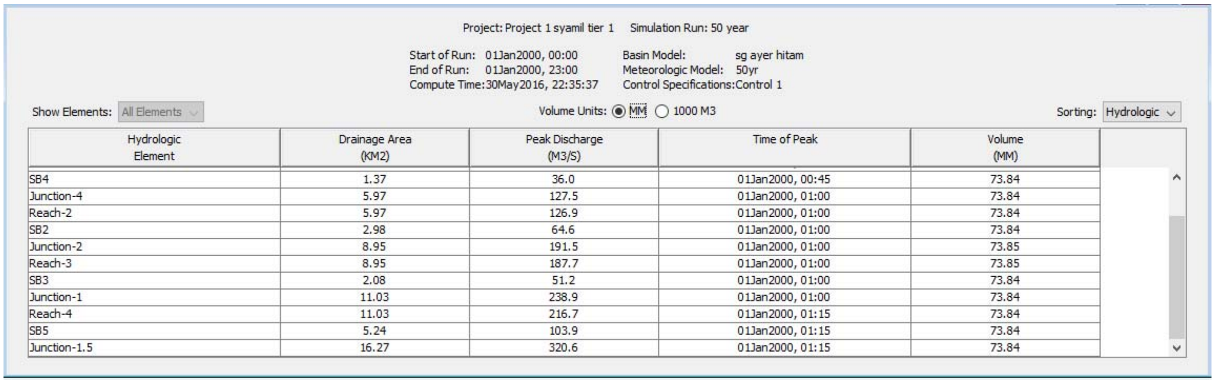
Figure 6: Location of equipment installed at project site

Results and Discussion

Data obtained from field work and modelling will be used to assess the hydrological characteristic of the study area.

Modelling

The modeling work in HEC-HMS contains 5 sub-basins, 4 reaches and 5 junctions as shown in Figure 6. The results of peak discharge for 50 years design storm is shown in Figure 10 below.



Project: Project 1 syamil tier 1   Simulation Run: 50 year

Start of Run: 01Jan2000, 00:00   Basin Model: sg ayer hitam
End of Run: 01Jan2000, 23:00   Meteorologic Model: 50yr
Compute Time: 30May2016, 22:35:37   Control Specifications: Control 1

Show Elements: All Elements   Volume Units: ● MM ○ 1000 M3   Sorting: Hydrologic

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
SB4	1.37	36.0	01Jan2000, 00:45	73.84
Junction-4	5.97	127.5	01Jan2000, 01:00	73.84
Reach-2	5.97	126.9	01Jan2000, 01:00	73.84
SB2	2.98	64.6	01Jan2000, 01:00	73.84
Junction-2	8.95	191.5	01Jan2000, 01:00	73.85
Reach-3	8.95	187.7	01Jan2000, 01:00	73.85
SB3	2.08	51.2	01Jan2000, 01:00	73.84
Junction-1	11.03	238.9	01Jan2000, 01:00	73.84
Reach-4	11.03	216.7	01Jan2000, 01:15	73.84
SB5	5.24	103.9	01Jan2000, 01:15	73.84
Junction-1.5	16.27	320.6	01Jan2000, 01:15	73.84

Figure 10: Peak discharge of 50 years ARI

From the figure above, we can clearly see that the highest peak discharge is 320.6 m^3/ s which is at level 1 of the study area. The time of peak is 0115. While at level 2, the peak discharge is 238.9 m^3/ s and the time of peak is 0100. This indicates that the time difference is 15 minutes for the water to flow from level 2 to level 1. Figure 11 shows the graph of flows against time for level 2 and level 1.

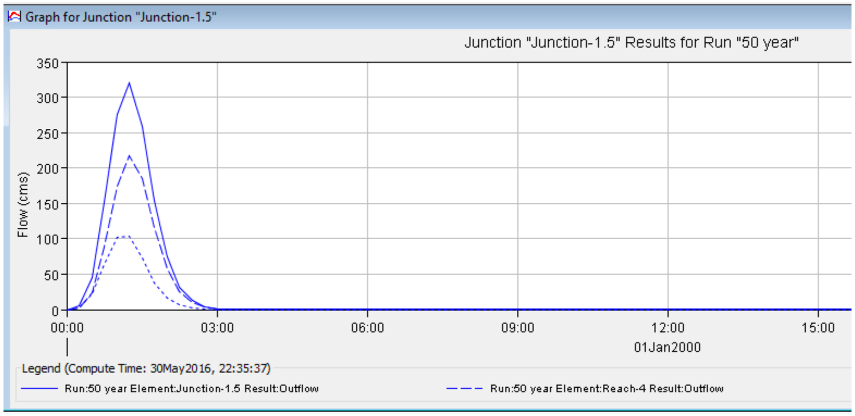


Figure 11: Graph showing the peak flow against time at Junction-1.5

Rainfall and Water Level

The rainfall and water level data collected from October to November is shown in Figure 12. There are a few rainfall events during that period that causes water level in the river to increase during that storm events. The highest water level recorded was during the 27th October storm event.

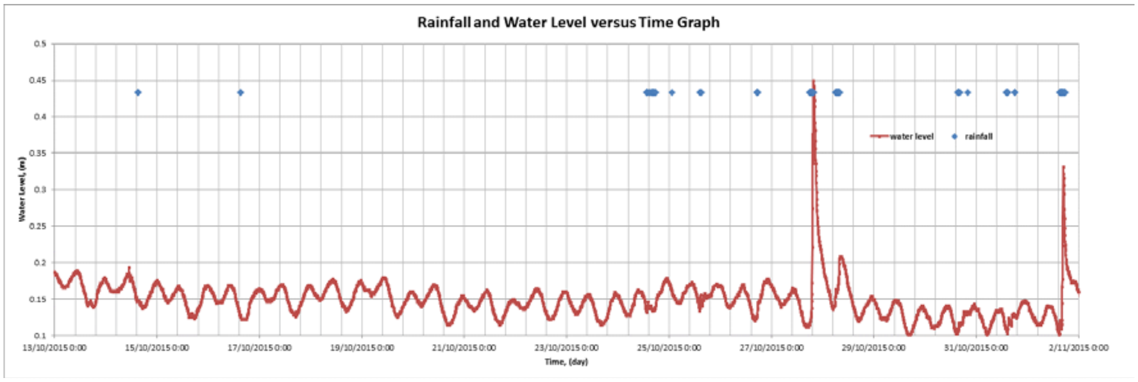


Figure 12: Rainfall Event and Water Level

The highest water level recorded was during the 27th October storm event. The two hour storm event (6.00-8.00pm) with total rainfall of 61mm (Table 3) has resulted in water level to rise to about 0.5 m (Figure 13). This amount of rainfall for this event is almost equivalent to 2 year ARI (70mm). The peak water level was recorded at 7.40 pm, which is about 40 minutes lag. This shows the response time is quite fast where the lead time or time available for warning is only about 1 hour. Therefore, the authorities should install telemetry water level recorder and rainfall station in order to prevent catastrophic event from happening.

Table 3: Rainfall on the 27th October 2015

Time	Ticking	Rainfall,/ Mm
11:00:00 AM - 12:00:00 PM	0	0
12:00:00 PM - 1:00:00 PM	0	0
1:00:00 PM - 2:00:00 PM	0	0
2:00:00 PM - 3:00:00 PM	0	0
3:00:00 PM - 4:00:00 PM	0	0
4:00:00 PM - 5:00:00 PM	0	0
5:00:00 PM - 6:00:00 PM	0	0
6:00:00 PM - 7:00:00 PM	167	33.4
7:00:00 PM - 8:00:00 PM	138	27.6
8:00:00 PM - 9:00:00 PM	0	0

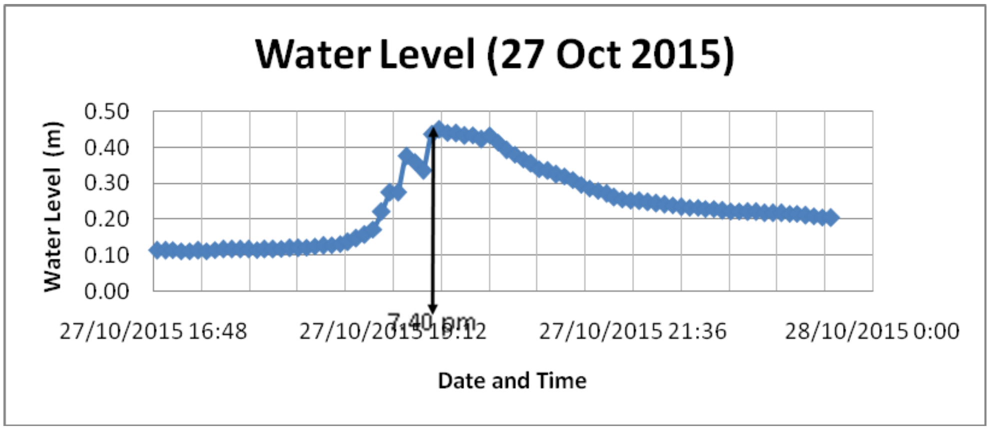


Figure 13: Water level recorded on October 27th, 2015

Conclusion

Based on the hydrologic modelling and field data study, the results can be used to assess and analyse the existing hydrological parameter. From the data, we can say that the modelling process helps in replicating the hydrological data and turn them into a simple flow against time graph which can help determining the response time needed for the alarm system. Not to mention, the data obtain from rain gauge and water level data set up at the study areas provide rainfall and water level data so that we know when the rain reaches certain level, the water level will rise accordingly.

The problem of opening the area to the public for recreational purposes especially for picnic and swimming could expose the visitors to possible danger of drowning or being washed away due to fast flowing flood as a result from heavy storm in the upstream area or artificial dam burst. The solution towards solving the impending danger to the tourist area (Level 1 and 2) due to these fast flowing flash flood phenomenon (steep slope or dam burst) could be based on various approaches which include structural and non- structural approach. The non-structural approach includes early warning system and flood zoning. The structural approach may include storage approach in the upstream area. While storage approach seems to be a more appropriate solution, but site conditions (steep slope and fast flowing flood) may not permit this approach. The hilly terrain with very steep slope limits the ability of using this approach. This approach could also disturb the natural beauty of the area.

Therefore, non-structural approach such as early warning system and limited time visit approach is moreappropriate for this recreational area. This early warning system approach would provide lead time (1 hour) to the authorities to warn pubic and visitors of the impending danger. The limited time visit approach is to limit the access to the recreational area to during the monsoon season (October – January). This approach is more economical and allows the authorities some time to do maintenance work when the park is closed. The non-structural measures include early warning system and flood zoning. The early warning system consists of telemetry rainfall and water level recorder at various locations in the upstream area of the recreational park. The authority should provide personnel to monitor the situation at the recreational area during visiting hours by monitoring the amount of rainfall and monitoring the water level that could trigger the alarm. The visitors to the park should be warned of the impending danger whenever the amount of rainfall or water level exceeds certain level. The telemetry rainfall station should be located at the existing location while the water level recorder should be located at the middle stretch between the catchment boundary and the park. Figure 13 shows the example of operating warning levels that could be adopted for this area. The upstream area of the recreational park should also be maintained regularly. Regular maintenance of the river in the upstream area by removing tree branches and tree trunks from blocking the water way. Tree branches and trunks can get trap among the rocks in the river. The blockage could create artificial dam. The artificial dam is not strong and could fail any time. The amount of flow accumulated could be released suddenly when the artificial dam fails. This could be very catastrophic to the visitors at the downstream area. Therefore, it is important to always avoid the formation of artificial dam by regularly inspecting the upstream area of the park and remove any logs or branches from the river.

Recommendations for Strengthening Flash Flood Risk Management

1. Promote effective early warning systems with the involvement of upstream and downstream communities to save lives and reduce the risk of flash floods in vulnerable areas.
2. Strengthen communication and coordination among relevant institutions and as part of national disaster risk management strategies.
3. Conduct flash flood modelling and hazard mapping to identify hazard prone areas and develop land use guidelines and building codes.
4. Develop a standard methodology and format for documenting flash flood events and for subsequentreflection on the causes, effects, and lessons that can be derived from such events.

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