The Effect of Detention Pond's Outlet Design to the Peak Discharge of a Watershed

By

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as certified in the reference and acknowledgements, and the original work contained herein have not been taken or done by unspecified sources or persons.

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ABSTRACT

Flood occurs when the water discharge of a watershed exceed the drain capacity. One of the solutions to avoid flood when this occurs is by having a detention pond to control the amount of water discharge below the discharge capacity of the drain. This research project is to explore further on the effect of detention pond built in terms of its outlet design base on simple outlet structures frequently used by JPS

PROJECT BACKGROUND

Background study

The urbanization in Kota Bharu, Kelantan has caused the need to enhance the management of hydrology and water resources. The main focus of this study is to avoid the flood from occurring by managing the peak discharge of a watershed to be under the discharge capacity. This can be done in many ways such as increasing the drain capacity by doing modification on the drain, introducing a dam, water gate, detention pond etc. This study will focus on how the variation of characteristic of the detention pond outlet design and how will it reduces the peak discharge of a watershed.

A detention pond is a low lying area that is designed to temporarily hold a set amount of water while slowly draining to another location. They are more or less around for flood control when large amounts of rain could cause flash flooding if not dealt with properly. For example, in housing flat, it has a detention pond that collects all of the drainage from streets. Normally it is a grassy field with a couple of concrete culverts running towards a drainage pipe. With all the rain, all of water in the street (considered as watershed) was directed into the pond area. The water level will reduce slowly due to the planned drainage and evaporation. Thus, reducing the discharge water of the watershed.

Inability to reduce a discharge of a watershed could cause a flood at the outlet area due to high peak discharge which could not be handled by small drain. The continuity in heavy rain could cause major flood as happened in last December 2012 which stroked on Kelantan, Terengganu and Pahang and of course, the previous year when the flood problem is not attained. Figure 1 shows an example of detention pond

Figure 1: Detention pond

Problem statement

Due to vast urbanization in Malaysia, hydrology and water resources area have been gaining attention. Flood is the main concern in hydrology and water resource problems. Flood in in the past has caused more than billions of ringgit loss to property. Flood occurs when the peak discharge of a watershed due to rainfall exceeds the discharge capacity of the drain of a watershed. This cause water to overflow out of the drain. To avoid this, the peak discharge of a watershed needed to be reduced below the drain capacity. Figure 2 shows a conceptualview of how urban flood occurs. Further study in flood mitigation is very crucial in Malaysia in order to engineer a better place to live in.

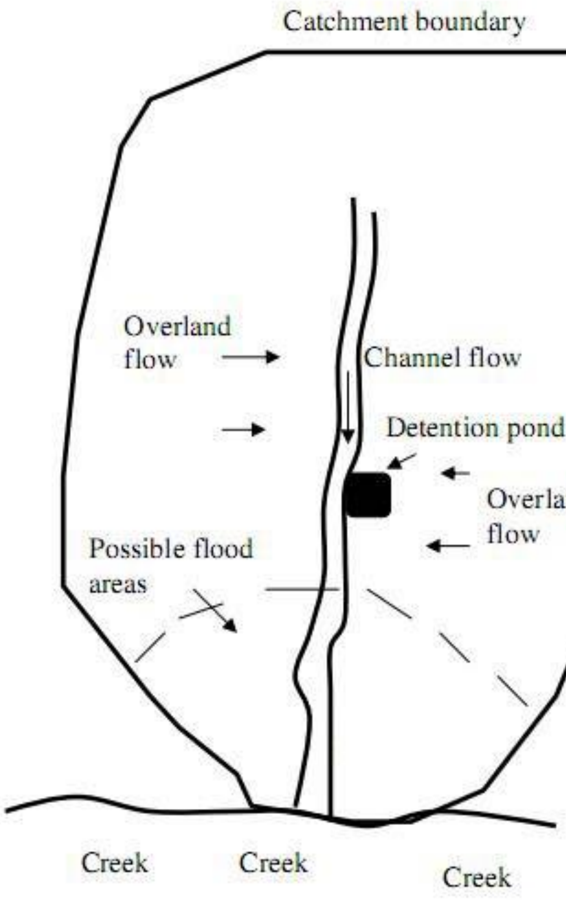


Figure 2 : Conceptualized view of coastal urban flooding

In this context, several common outlet of the detention pond is being studied and how it helps in reducing the peak discharge of a watershed by collecting the water runoff and releasing the flow slowly. Thus, manage flood and water resources' problem. This include the study in the current peak water discharge of a watershed in Kota Bharu, Kelantan after detention pond was built with certain characteristics, which affect the study area and formulate comprehensive analysis to satisfy the study objectives.

Circled area in Figure3 shows an area in Kota Bharu which is prone to flood due to ineffectiveness of the drain and the absence of the required detention pond. Since water from the south cannot flow efficiently to the blue labeled river, the circled area gets flooded during the rainfall.

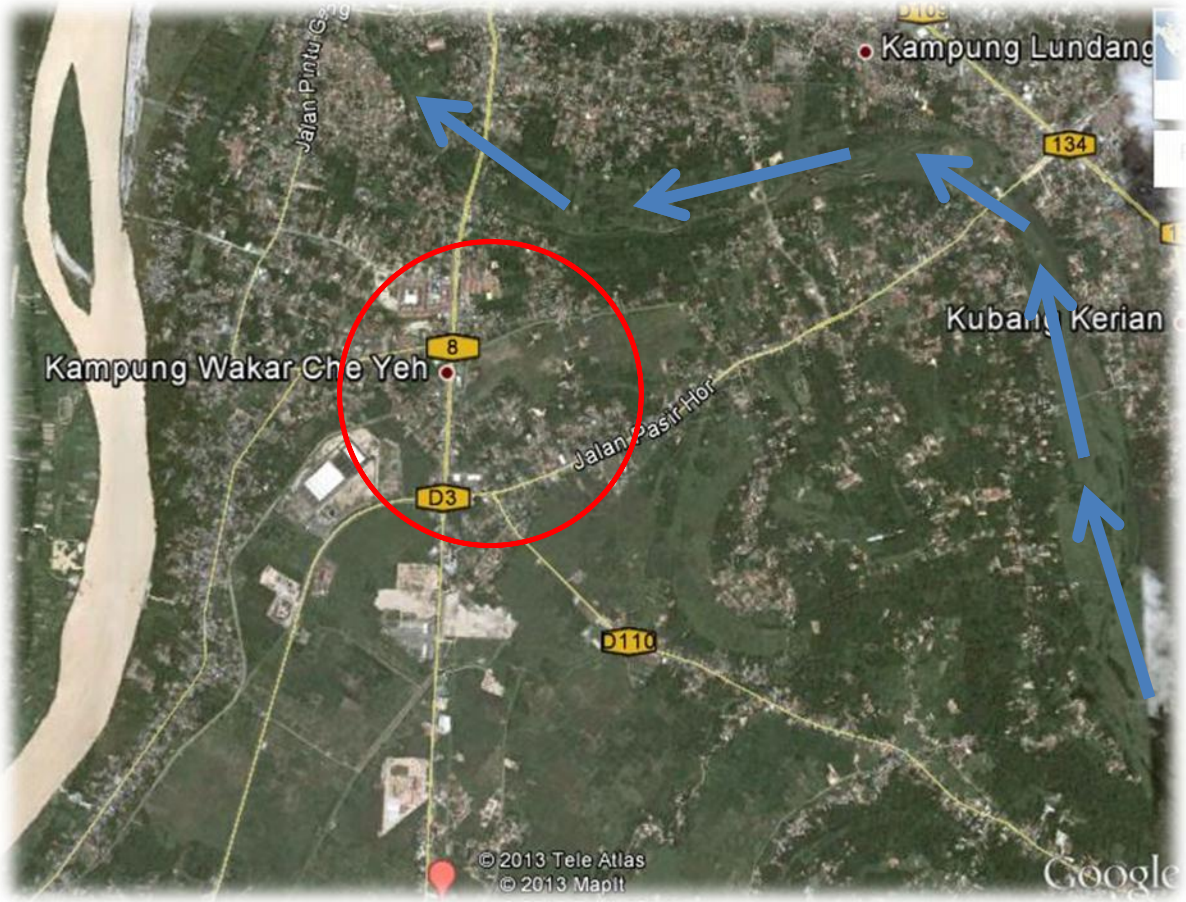


Figure 3 : Kota Bharu

Study Objectives

The principal objective of this study is to formulate a comprehensive analysis of rainfall pattern that causes flood and detention pond’s outlet designs, and how it will affect the discharge of peak water flow of a watershed. The main part of the study will:

- Analyze the several heavy rainfalls that could occur
- Analyze the peak discharge of the heavy rainfall
- Recommend an optimum detention pond’s outlet design

Scope of Work

This study shall assess and examine the current rainfall data, watershed characteristic in the area of study and calculate the water discharge of the watershed.

- Scope of area is within Kota Bharu, Kelantan
- Software Simulation are based on SCS method (Soil Conservation Service) using HEC-HMS
- Using rainfall data from JPS

LITERATURE REVIEW

Storm-water studies often require estimates of the volumes of detention storage needed to reduce flood discharges to desired levels. Such estimates are useful in identifying and evaluating potential sites for detention reservoirs. Once a detention site has been selected and a preliminary design has been developed, the engineer can use the standard reservoir-routing procedure to refine the design. Several approximate relationships for the sizing of detention reservoirs with uncontrolled outlets are available. Several of these relationships express the required flood storage, S_f, as a fraction of the flood volume, V_f, and the peak outflow, Q_p, as a fraction of the peak inflow, I_p. The ratios S_f/V_f and Q_p/I_p are termed the flood-storage and peak-discharge ratios. Baker (1979) and Abt and Grigg (1978) derived formulas of this type through the use of simple geometric approximations for the inflow and outflow hydrographs. Baker showed that, if the inflow and outflow hydrographs are both triangular, the flood-storage and peak-discharge ratios are related by the formula

$$\frac{S_f}{V_f} = 1 - \frac{Q_p}{I_p} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (1)$$

Abt and Grigg (1978) derived a formula that is based on a triangular inflow hydrograph and a trapezoidal outflow hydrograph, with the rising limbs of the two hydrographs coincident up to the maximum release rate. Abt and Grigg's relationship is

$$\frac{S_f}{V_f} = \left(1 - \frac{Q_p}{I_p}\right)^2 \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (2)$$

Wycoff and Singh (1976) fitted a regression equation to the results of 50 numerical simulations in which 10 hydrographs with different characteristics were routed through five hypothetical reservoirs with outlets of different sizes. They did not investigate the effect of the type of outlet on the storage requirement. Their empirical formula is

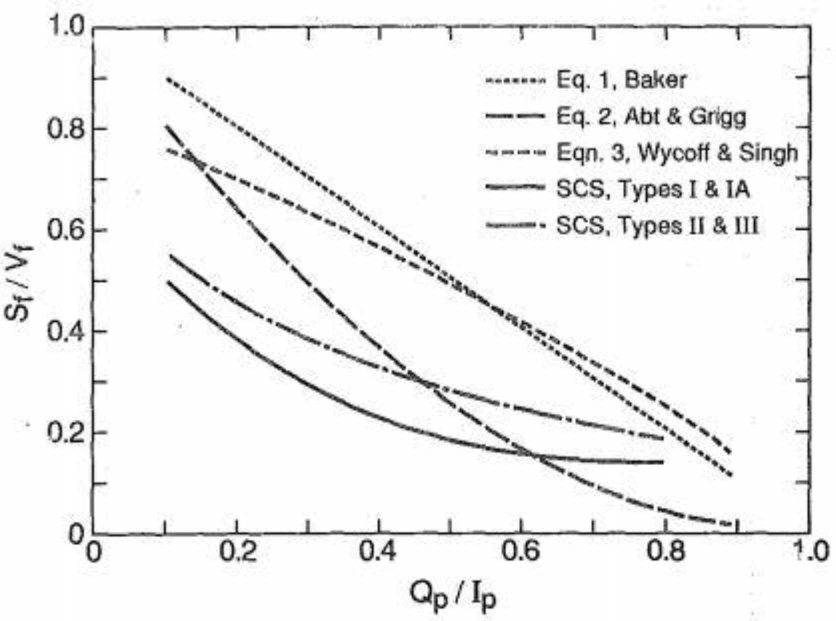
$$\frac{S_f}{V_f} = \frac{1.291\left(1 - \frac{Q_p}{I_p}\right)^{0.753}}{\left(\frac{t_b}{T}\right)^{0.411}} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (3)$$

in which tb and T = the time base and time to peak on the inflow hydrograph. They define the time base as the time on the falling limb for which I/Ip = 0.05.

The most widely used relationships for the sizing of detention reservoirs are those from technical release 55, Urban Hydrology for Small Watersheds, of the U.S. Soil Conservation Service ("Storage" 1986). This report presents two curves that relate the flood-storage and peak-discharge ratios for different geographic regions. These curves were fitted to the results of flood-routing simulations with inflow hydrographs generated for hypothetical storms by means of the TR-20 flood-hydrograph model of the Soil Conservation Service (SCS).

Akan (1990) presents a graphical procedure that is useful for the preliminary analysis of a particular reservoir site. Akan's procedure yields an approximate size for the outlet. Inputs to the procedure are the peak inflow, the time to peak on the inflow hydrograph, the peak outflow, the stage-storage relationship expressed as a simple power function, and the type of outlet (orifice or rectangular weir). Once the outlet has been sized, the required flood storage can be determined from the peak outflow and the stage-discharge and stage-storage functions. Akan's graphical relationships were developed for inflow hydrographs with a single shape, that of the SCS dimensionless unit hydrograph.

The relationships of Baker, Abt and Grigg, Wycoff and Singh, and the SCS are compared in Fig. 4. (The SCS recommends the curve labeled "Types II, III" for the continential U.S. except for the Pacific coastal region, and the curve labeled "Type I, I A" for the Pacific coastal region, Alaska, and Hawaii.) These relationships yield widely differing estimates of detention-storage requirements. In this paper, a generalized flood-routing analysis is used to assess the validity of the relationships in Fig.



1.

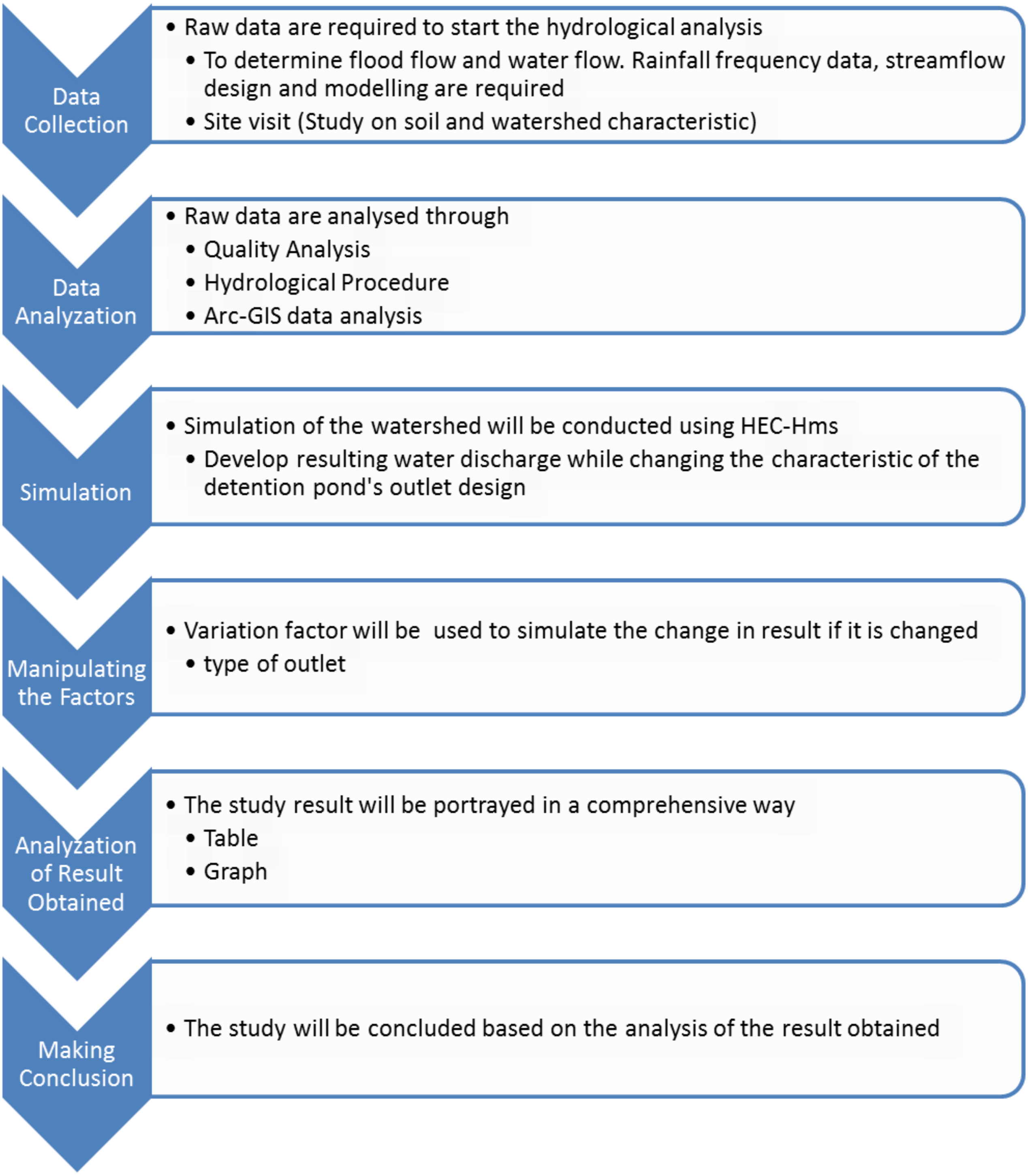
Figure 4 : Comparison of Existing Relationships for Sizing of Detention Reservoirs

The standard reservoir-routing assumptions, which are invoked here, are that the water surface is essentially horizontal and the outflow is unaffected by tailwater. Under these conditions, outflow can be expressed as a function of storage because both outflow and storage are functions of stage (water-surface elevation). Given an initial storage, an inflow hydrograph and an outflow-storage relationship can be integrated numerically to determine the peak storage and the corresponding peak outflow. In this analysis, the inflow hydrograph, the stage-outflow relationship and the stage-storage relationship are represented by generalized functions with appropriate forms. These three functions contain a total of eight empirical constants. The effects of the shapes of the inflow hydrograph and the stage-outflow and stage-storage curves on the relationship between the flood-storage and peak-discharge ratios are investigated by varying the values of these constants systematically.

The volume of detention storage needed to produce a specific reduction in peak discharge for a design flood depends primarily on the type of outlet structure on the reservoir. Simple uncontrolled outlets can be classified as submerged outlets and overflow outlets. Submerged outlets include orifices and pipes; overflow outlets include spillways, weirs, and perforated risers. A submerged outlet is more efficient than an overflow outlet in that considerably less storage is needed to achieve the same peak outflow.

METHODOLOGY

The methodology for conducting this research project is exploration and discovery. The project activities in this research are mainly software simulation work. After thorough literature review is done, the simulation can later be conducted to investigate how the variation factors affect the output of the result.



Data Collection

- Raw data are required to start the hydrological analysis
  - To determine flood flow and water flow. Rainfall frequency data, streamflow design and modelling are required
  - Site visit (Study on soil and watershed characteristic)

Data Analyzation

- Raw data are analysed through
  - Quality Analysis
  - Hydrological Procedure
  - Arc-GIS data analysis

Simulation

- Simulation of the watershed will be conducted using HEC-Hms
  - Develop resulting water discharge while changing the characteristic of the detention pond's outlet design

Manipulating the Factors

- Variation factor will be used to simulate the change in result if it is changed
  - type of outlet

Analyzation of Result Obtained

- The study result will be portrayed in a comprehensive way
  - Table
  - Graph

Making Conclusion

- The study will be concluded based on the analysis of the result obtained

DATA ANALYSIS

1. Quality Analysis

It is an analysis to decide whether the data obtained from a rainfall station is reliable based on the cumulative graph plotted. Several nearby rainfal stations are determinened and data was collected from JPS. A straight line cumulative graph proves that the data from the rainfall station do not have errors. The nearby rainfall stations are Lemal Pasir Mas, Jeti Kastam and Stor JPS Kota Bharu. Table 1 shows the cumulative data of Stor JPS Kota Bharu which is the most reliable data to consider.

Table 1 : Cumulative rainfall data from Stor JPS KotaBharu

Year Text	Annual RF (mm)	Cumulative RF (mm)	Remark
1970	1691.4	1691.40	starts on 5 july
1971	2615.6	4307.00	
1972	1584.6	5891.60	
1973	2989	8880.60	
1974	2321.6	11202.20	
1975	2537	13739.20	
1976	2753.5	16492.70	
1977	2571	19063.70	
1978	2175	21238.70	
1979	2397.5	23636.20	
1980	2512.9	26149.10	
1981	2455.5	28604.60	
1982	1862.1	30466.70	
1983	2704.9	33171.60	
1984	530.5	33702.10	jun-dec
1985-1988	-	33702.10	
1989	1601.3	35303.40	
1990	1548.7	36852.10	
1991	2300.5	39152.60	
1992	752	39904.60	sept-dec
1993 - 2002	-	39904.60	
2003	79	39983.60	jan-nov
2004	2416.2	42399.80	
2005	1882.9	44282.70	
2006	939.7	45222.40	
2007	1076.3	46298.70	
2008	2477.9	48776.60	july-sept
2009	3088.5	51865.10	
2010	2246.6	54111.70	
2011	2937.3	57049.00	
2012	1146.6	58195.60	ended at 10 july

Figure 5.1, Figure 5.2 and Figure 5.3 shows the cumulative graph of the rainfall stations are plotted

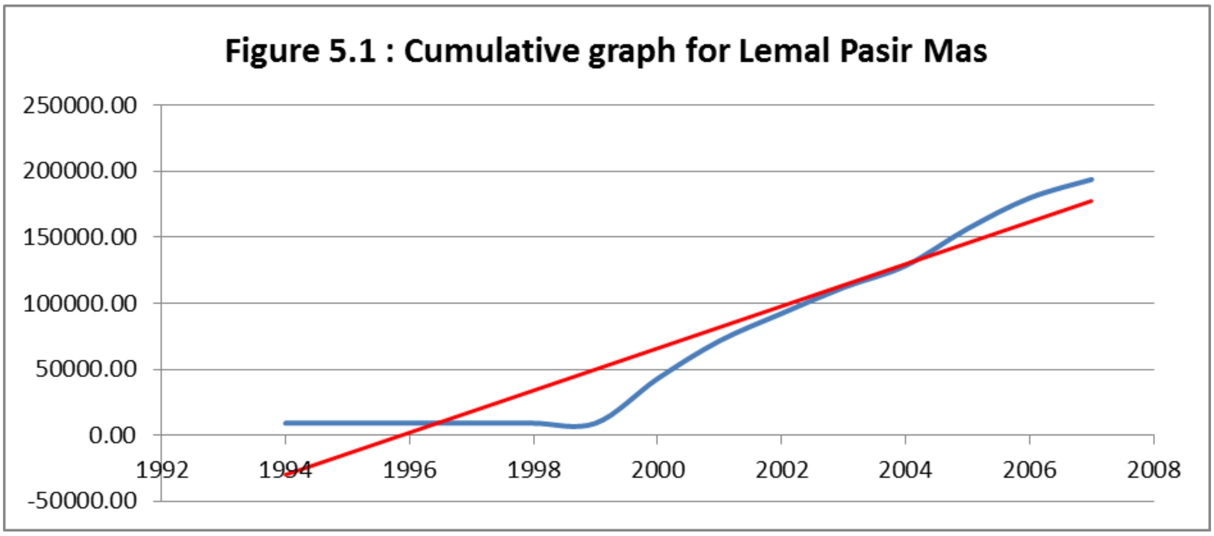


Figure 5.1 : Cumulative graph for Lemal Pasir Mas

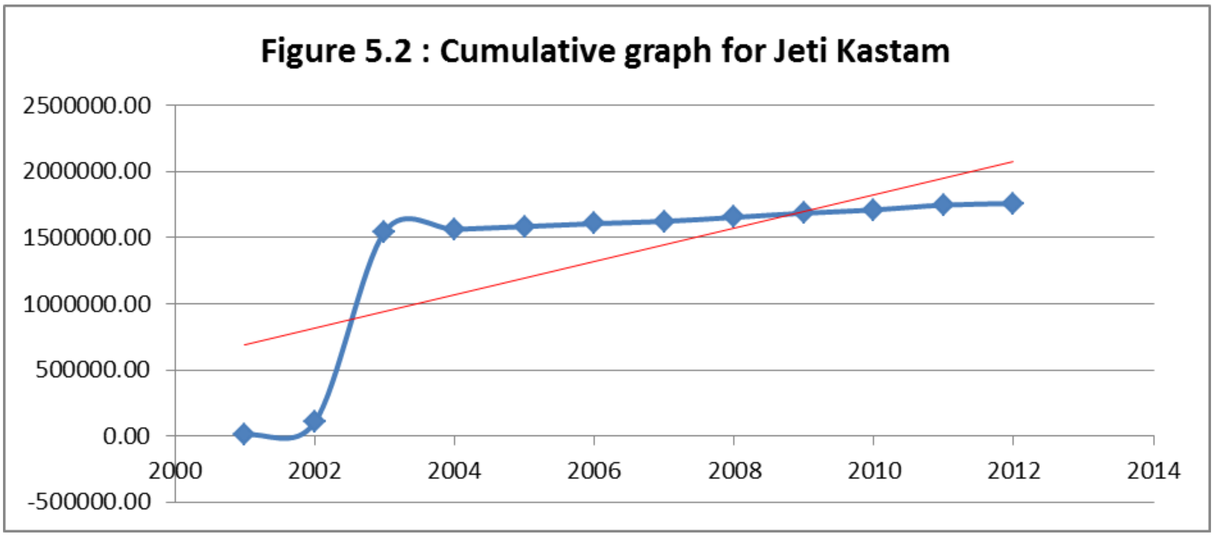


Figure 5.2 : Cumulative graph for Jeti Kastam

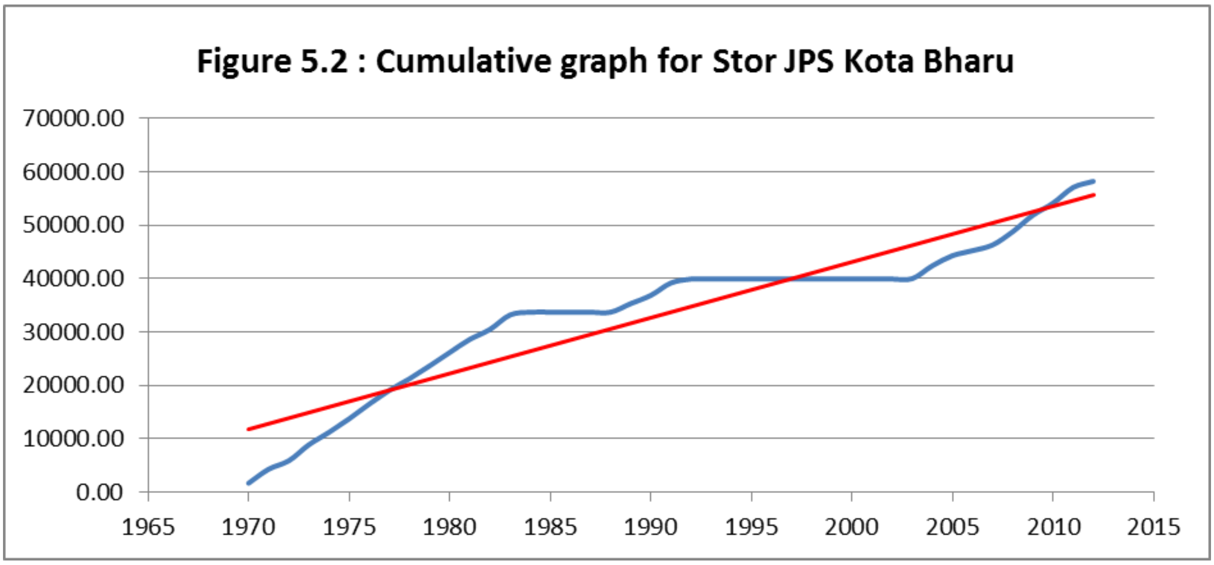


Figure 5.2 : Cumulative graph for Stor JPS Kota Bharu

Lemal Pasir Mas and Jeti Kastam rainfall station should not be chosen because the change in rainfall collected was too significant. Please refer Appendix 2.1 for the data. Stor JPS Kota Bharu however is more reliable with considerably slight changes in the cumulative rainfall collected. The horizontal lines refer to the rainfall station stopped its operation temporarily. If the blank years were removed, straighter line will be produced. Straight graph in the Figure 6 is the chosen rainfall station when the blank years were removed.

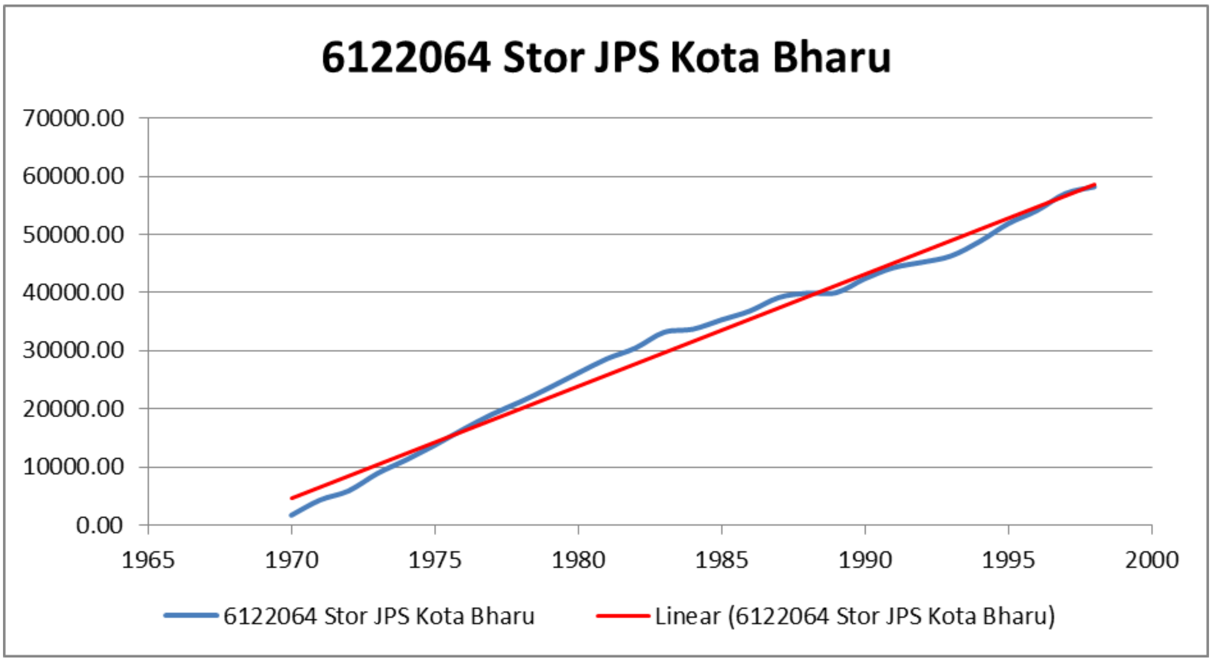


Figure 6 : Adjusted cumulative graph

Since the Lemal Pasir Mas and Jeti Kastam rainfall station collected for shorter period, data from Stor JPS Kota Bharu are chosen to be used as it was collecting the data since 1970’s.

2. Hydrological Procedure

The Hydrological Procedure has been widely used to determine the design rainstorm or rainfall intensity of water related project. The estimation of design rainfall intensity is based on Intensity Duration Frequency (IDF) relationship is used for many decades for the design of water resources and hydraulic structures. The IDF gave an idea about the frequency or return period of mean rainfall intensity within a period of storm duration.

HP is used to develop a hydrograph of the JPS rainfall station. This data is important in order to simulate the rainfall.

Intensity, $\iota = \frac{\lambda T^{\kappa}}{(d+\theta)^{\eta}}$

Table 2 : Derived IDF parameters of high ARI for Peninsular Malaysia

State	Station ID	Station Name	Derived Parameters			
			λ	κ	θ	η
Kelantan	6021001	Lemal Pasir Mas	**60.988**	**0.214**	**0.148**	**0.616**
	6122001	Jeti Kastam	**60.988**	**0.214**	**0.148**	**0.616**
	6122064	Stor JPS Kota Bharu	**60.988**	**0.214**	**0.148**	**0.616**

Table 3 : Rainfall Intensity

Rainfall Intensity (mm/hr)						
	Yearly Return Period (mm/hr)					
Duration(hr)	**2Yrs ARI**	**5Yrs ARI**	**10Yrs ARI**	**20Yrs ARI**	**50Yrs ARI**	**100Yrs ARI**
0.25	128.9	156.8	181.9	211.0	256.7	297.7
0.5	95.5	116.1	134.7	156.3	190.1	220.5
1	67.1	81.7	94.7	109.9	133.7	155.0
3	36.1	43.9	50.9	59.0	71.8	83.3
6	23.9	29.0	33.7	39.1	47.5	55.1
12	15.7	19.1	22.1	25.7	31.3	36.2
24	10.3	12.5	14.5	16.8	20.5	23.7
48	6.7	8.2	9.5	11.0	13.4	15.5
72	5.2	6.4	7.4	8.6	10.4	12.1

Rainfall depth was then calculated using the formula:

$$Rainfall\ Depth = i\ x\ Duration$$

Table 4 refers to the result from the formula calculated

Table 4 : Rainfall Depth

Rainfall Depth (mm)						
	Yearly Return Period mm					
Duration(hr)	**2Yrs ARI**	**5Yrs ARI**	**10Yrs ARI**	**20Yrs ARI**	**50Yrs ARI**	**100Yrs ARI**
0.25	32.22383	39.20454	45.47333	52.7445	64.17063	74.431496
0.5	47.73148	58.07164	67.35728	78.12768	95.05262	110.2515
1	67.1183	81.65825	94.71538	109.8603	133.6596	155.0317
3	108.1676	131.6001	152.6429	177.0504	215.4052	249.8484
6	143.2374	174.2671	202.1324	234.4533	285.2433	330.85363
12	188.3178	229.1135	265.7486	308.2417	375.0167	434.98173
24	246.673	300.1102	348.0977	403.7584	491.2253	569.77207
48	322.5063	392.3714	455.1114	527.8836	642.24	744.93392
72	377.0782	458.7654	532.1218	617.2079	750.9147	870.98574

An Intensity-Duration-Frequency curve (IDF Curve) is a graphical representation of the probability that a given average rainfall intensity will occur. Rainfall Intensity (mm/hr), Rainfall Duration (how many hours it rained at that intensity) and Rainfall Frequency (how often that rain storm repeats itself) are the parameters that make up the axes of the graph of IDF curve. An IDF curve is created with long term rainfall records collected at a rainfall monitoring station.

The nearly parallel lines on the IDF Curve represent the frequency of occurrence. So the 10-year line would represent rainfall events that have a probability of occurring once every 10 years. Note that the information presented in the graph is based on statistical analysis of past data, rather than a prediction of actual storms. Figure 7 shows the IDF graph that represent the curve for aast coast state in Malaysia

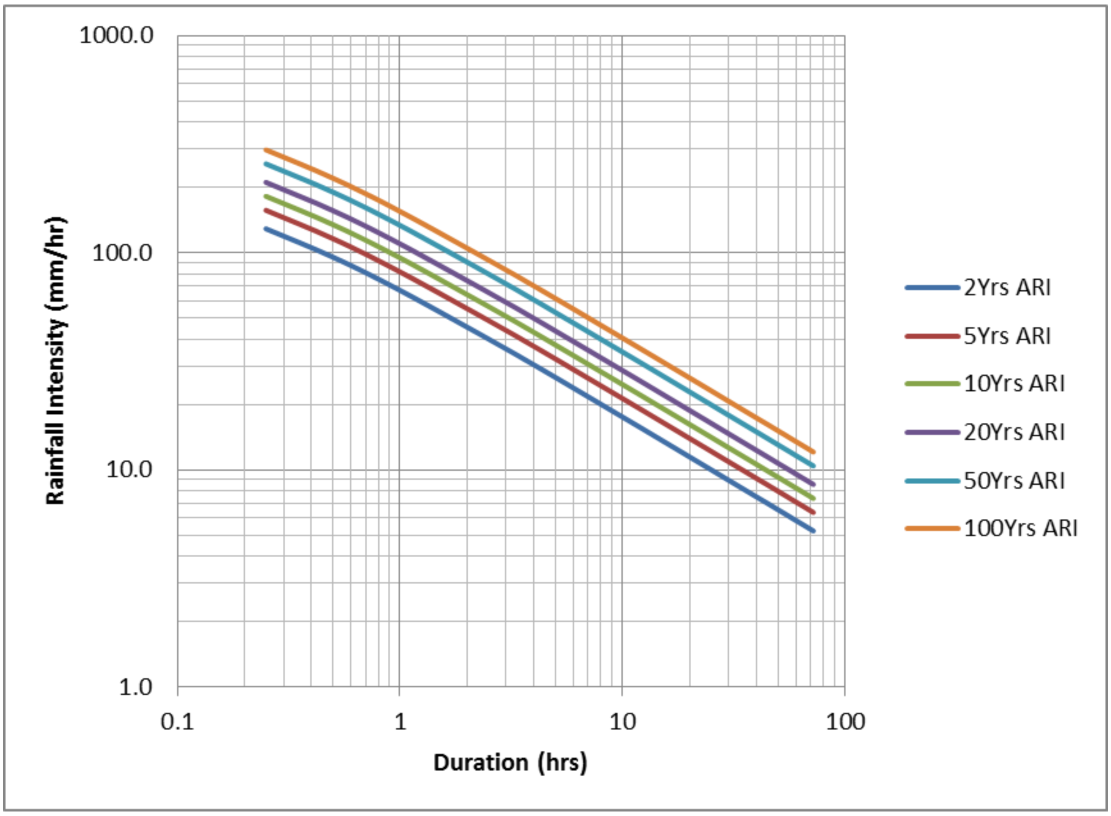


Figure 7 : IDF Graph

The uniform rainfall of the selected average recurrence interval requires a temporal pattern before input to a catchment model. Effect of rainfall spatial variability particularly for long-duration of rainfall and large catchments, can be corrected by applying US Area Reduction Factor (ARF). Since then, this spatial correction factor has been widely applied without notice of accuracy assurance. As for the effect of rainfall temporal variability, it has optimized local data from historical rainfall records by means of the standardized storm profiles technique. The temporal storm profiles were sub-divided into two regions, which were recognized as the West Coast Region and the East Coast Region of Peninsular Malaysia.

Table 5: Normalized Temporal Pattern of East Coast Region

No of Block	Duration								
	15min	30min	60min	180min	6hr	12hr	24hr	48hr	72hr
1	0.316	0.133	0.060	0.060	0.059	0.070	0.019	0.027	0.021
2	0.368	0.193	0.062	0.061	0.067	0.073	0.022	0.028	0.029
3	0.316	0.211	0.084	0.071	0.071	0.083	0.027	0.029	0.030
4		0.202	0.087	0.080	0.082	0.084	0.036	0.033	0.033
5		0.161	0.097	0.110	0.119	0.097	0.042	0.037	0.037
6		0.100	0.120	0.132	0.130	0.106	0.044	0.040	0.038
7			0.115	0.120	0.123	0.099	0.048	0.046	0.042
8			0.091	0.100	0.086	0.086	0.049	0.048	0.048
9			0.087	0.078	0.073	0.084	0.050	0.049	0.053
10			0.082	0.069	0.069	0.083	0.056	0.054	0.055
11			0.061	0.060	0.060	0.070	0.058	0.058	0.058
12			0.054	0.059	0.059	0.064	0.068	0.065	0.067
13							0.058	0.060	0.059
14							0.057	0.055	0.065
15							0.050	0.053	0.053
16							0.050	0.048	0.052
17							0.048	0.046	0.047
18							0.046	0.044	0.041
19							0.043	0.038	0.038
20							0.039	0.034	0.036
21							0.028	0.030	0.033
22							0.025	0.029	0.03
23							0.022	0.028	0.022
24							0.016	0.019	0.020

Refer Appendix 2-2 to see the plotted graph of normalize pattern

Rainfall temporal pattern was then calculated using formula:

$$\boldsymbol{Rainfall\ Temporal\ Pattern\ =\ Rainfall\ Depth\ x\ Temporal\ Pattern}$$

Refer Appendix 2-3 for the result obtained for rainfall temporal Pattern

Arial Reduction Factor (ARF) is a key parameter in the design for hydrologic extremes and it is a ratio between the area-average rainfall intensity over a duration D with return period T and the point rainfall intensity for the same D and T.

$$ARF = aA^b$$

The result was also repeated for different design year or Average Recurrence Interval which are 2, 5, 10, 20, 50 and 100 years ARI. The areal reduction factors are derived based on simulations with the stochastic spatial rainfall generator and after statistical analysis. The correction coefficients depend on the catchment area, the storm duration and the rainfall intensity. Two types of correction coefficients are derived: coefficients to correct the rainfall input volumes over a catchment obtained from historical point rainfall data (a) and coefficients to correct design storms (b). Refer table 6 below

Table 6 : ARF value

Storm Duration	**A (km2)**	**RETURN PERIOD, T (ARI)**						
	10.89211	**2**	**5**	**10**	**20**	**25**	**50**	**100**
1 hr	a	1.017	1.247	1.435	1.426	1.415	1.447	1.533
	b	-0.008	-0.047	-0.077	-0.083	-0.084	-0.094	-0.111
	ARF	**0.998**	**1.115**	**1.194**	**1.169**	**1.158**	**1.156**	**1.176**
3 hr	a	1.015	1.329	1.506	1.492	1.521	1.515	1.593
	b	-0.009	-0.059	-0.087	-0.092	-0.097	-0.103	-0.120
	ARF	**0.993**	**1.154**	**1.223**	**1.198**	**1.206**	**1.184**	**1.196**
6 hr	a	1.013	1.384	1.553	1.536	1.551	1.560	1.633
	b	-0.009	-0.067	-0.093	-0.098	-0.102	-0.110	-0.126
	ARF	**0.992**	**1.180**	**1.244**	**1.216**	**1.216**	**1.200**	**1.209**
12 hr	a	1.012	1.444	1.602	1.583	1.582	1.609	1.675
	b	-0.010	-0.074	-0.099	-0.104	-0.107	-0.116	-0.132
	ARF	**0.988**	**1.210**	**1.265**	**1.235**	**1.225**	**1.219**	**1.222**
24 hr	a	1.011	1.507	1.654	1.632	1.614	1.660	1.721
	b	-0.010	-0.082	-0.105	-0.110	-0.112	-0.123	-0.138
	ARF	**0.987**	**1.239**	**1.287**	**1.255**	**1.235**	**1.237**	**1.238**
48 hr	a	1.009	1.574	1.708	1.684	1.648	1.714	1.768
	b	-0.011	-0.090	-0.111	-0.117	-0.117	-0.129	-0.145
	ARF	**0.983**	**1.270**	**1.310**	**1.273**	**1.246**	**1.260**	**1.251**
72 hr	a	1.009	1.498	1.741	1.715	1.668	1.747	1.797
	b	-0.011	-0.085	-0.115	-0.120	-0.120	-0.133	-0.149
	ARF	**0.982**	**1.223**	**1.323**	**1.288**	**1.252**	**1.272**	**1.259**

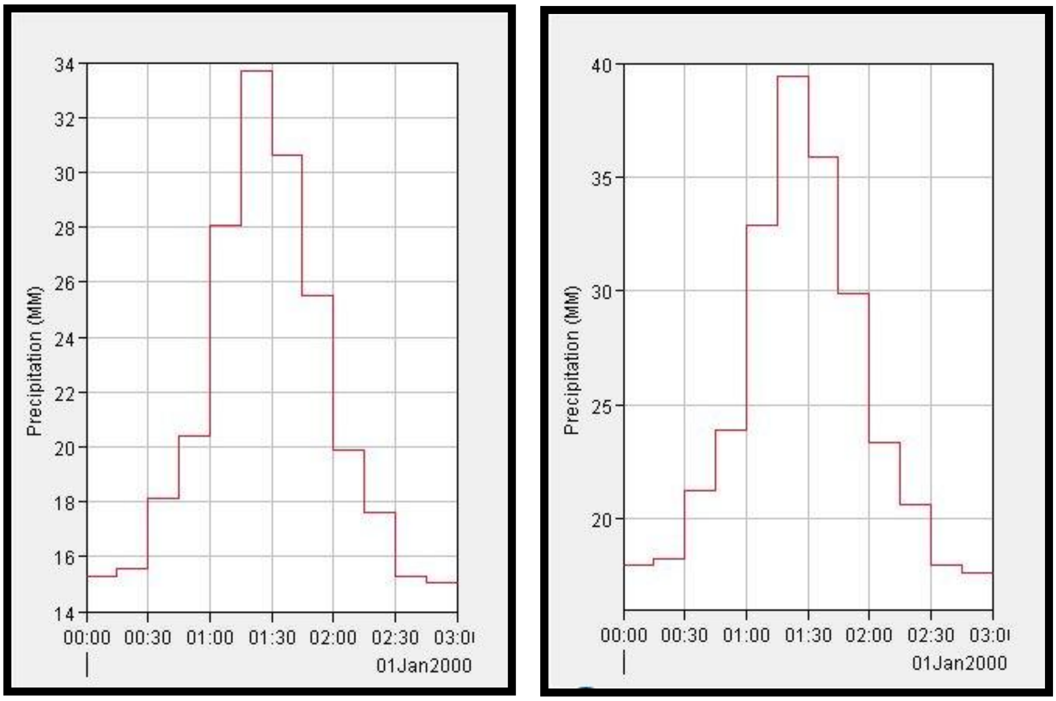
The temporal rainfall data will be corrected by multiplying it with ARF. Appendix 2-4 refer to the rainfall temporal pattern with ARF. The result will then be used to get the precipitation data to be used in HEC-HMS to simulate the rainfall storm in Kota Bharu, Kelantan.

The Precipitation Data

The resulting data from multiplication of ARF and Temporal pattern was used to plot hydrograph in HEC-HMS as shown in Figure 8. In this step, data from 50yrsARI and 100yrsARI are chosen because its value depict the heavy rainfall. This is actually chosen with advice of experienced engineer.

Table 7 : Precipitation data in mm

3-hr	**2yrsARI**	**5yrsARI**	**10yrsARI**	**20yrsARI**	**50yrsARI**	**100yrsARI**
ARF	**0.993**	**1.154**	**1.223**	**1.198**	**1.184**	**1.196**
	6.444795	9.112651	11.20383	12.72254	15.30674	17.92816
	6.552208	9.264529	11.39056	12.93458	15.56186	18.22696
	7.626341	10.7833	13.25786	15.055	18.11298	21.21499
	8.59306	12.1502	14.93844	16.96338	20.40899	23.90421
	11.81546	16.70653	20.54035	23.32465	28.06236	32.86829
	14.17855	20.04783	24.64842	27.98958	33.67484	39.44195
	12.88959	18.2253	22.40765	25.44507	30.61349	35.85631
	10.74132	15.18775	18.67304	21.20423	25.51124	29.88026
	8.378233	11.84645	14.56497	16.5393	19.89877	23.3066
	7.411514	10.47955	12.8844	14.63092	17.60276	20.61738
	6.444795	9.112651	11.20383	12.72254	15.30674	17.92816
	6.337382	8.960774	11.0171	12.51049	15.05163	17.62935
Total	107.41	151.88	186.73	212.04	255.11	298.80



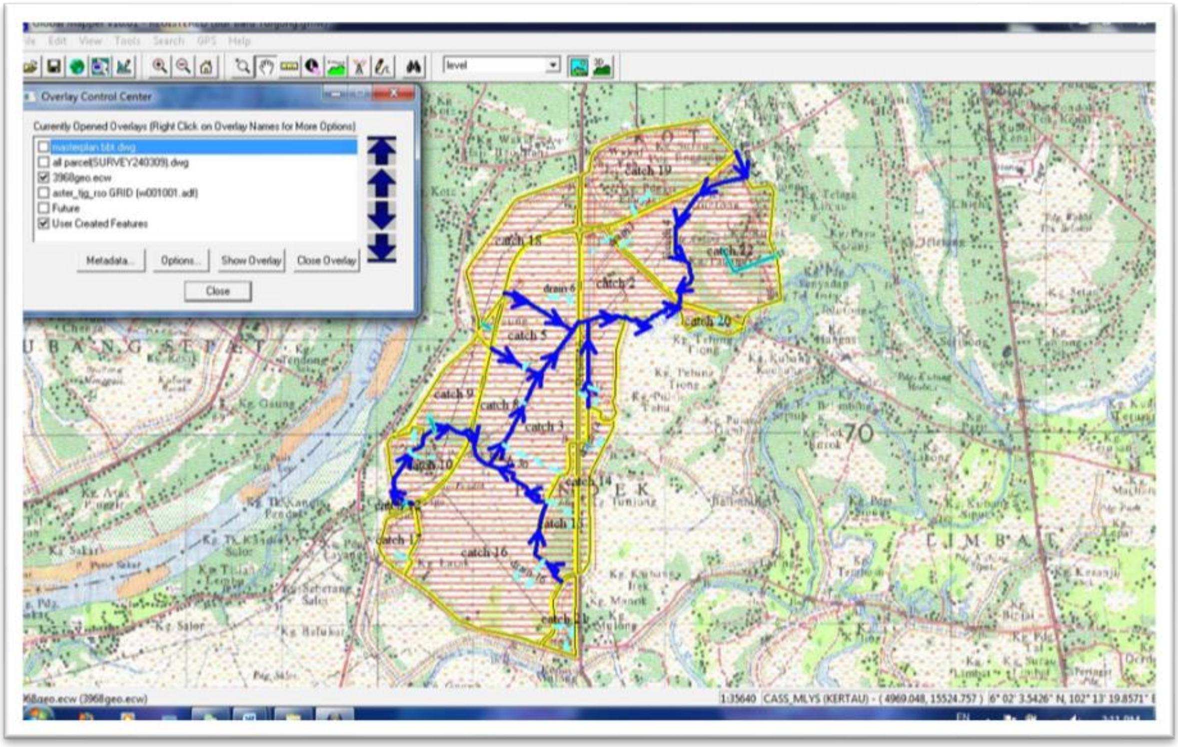
3 hours 50 years ARI **3hours 100 years ARI**

Figure 8 : Hydrograph Data Generated

3. Catchment Analysis

Another group of data required to do the simulation is the catchment data within the area of study. This part is mostly related to GIS. The studies have to divide the main catchment into several sub-catchments for a more accurate analysis. This will result in acquiring the SCS input parameter such as average slope of the area of sub-catchment, Lag time, average loss/gain etc.

The catchment for Bandar Baru Tunjong was divided into 22 sub-catchments for existing condition as shown in Figure 9 below. The division was made in Global Mapper software. The division was made base on ground level, roads and large drain because theoretically, this is how water will go during downpour, which is to lower ground.



Overlay Control Center

Currently Opened Overlays (Right Click on Overlay Names for More Options)

☐ masterplan bbt.dwg
☐ all parcel(SURVEY240309).dwg
☑ 3968geo.ecw
☐ aster_tjg_rso GRID (w001001.adf)
☐ Future
☑ User Created Features

Figure 9 : Existing Condition Catchment

➡ Drain

⇨ Longest small drain in sub-catchment

Please refer appendix 1for more information on the SCS data input parameter.

The divided sub-catchment was then opened in Arc-GIS to merge with the GIS data to obtain data regarding the soil level, sub-catchment slope, drain slope, river slope etc. Slope of each sub-catchment and river slope can be obtained from zonal analysis tool in ArcGIS software. The file global mapper workspace was converted into shapefile to be used in ArcGIS. Slope data was the aligned with the catchment for the analysis to be carried out. Figure 10 shows the work done in Arc-GIS software.

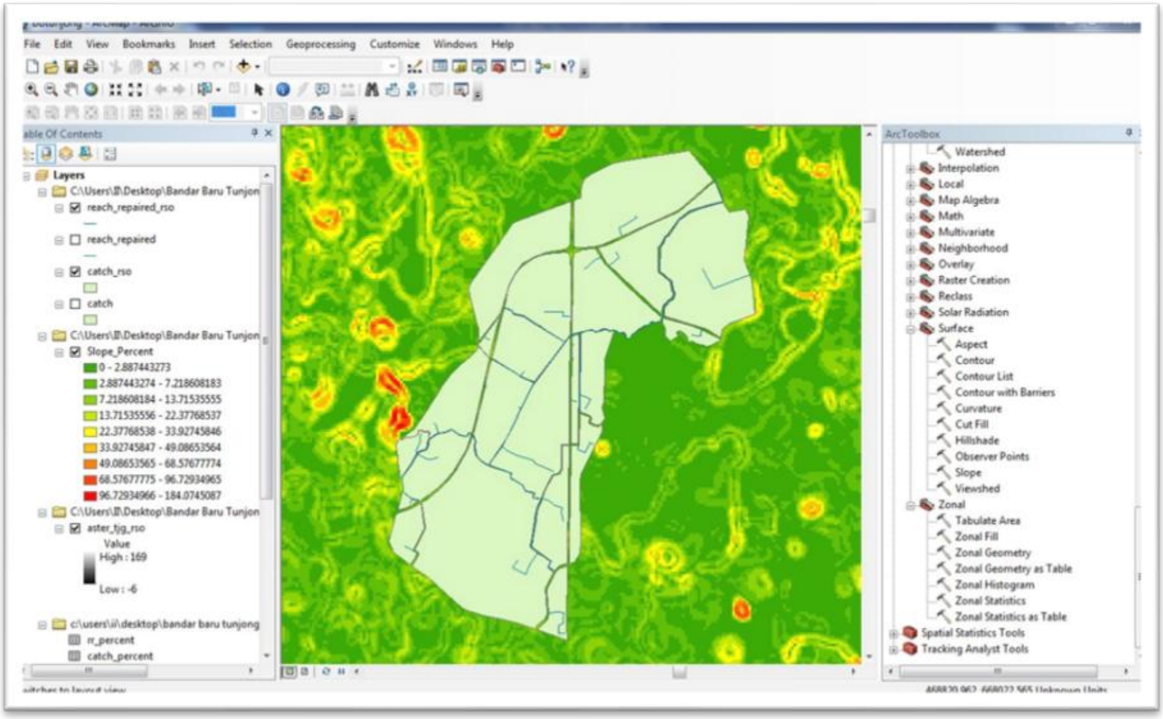


Figure 10 : The Arc-GIS software

Catchment ID	Area (ha)	Longest Hydraulic Length (m)	Slope (%)	CN Value	Lag Time (hr)	% Channel Improved	Hydraulic Length Factor	Impervious Area (%)	Impervious Area Factor	Adjusted Lag Time (hr)	Adjusted Lag Time (min)
1	54	224.9	1.44	85	0.18	0	1.00	10	0.95	0.17	10.0319
2	62	253.1	1.74	85	0.18	0	1.00	10	0.95	0.17	10.0308
3	83	672	1.36	85	0.43	0	1.00	10	0.95	0.41	24.7800
4	10	66.1	1.39	85	0.07	0	1.00	10	0.95	0.06	3.8338
5	40	66.4	3.15	85	0.04	0	1.00	10	0.95	0.04	2.5560
6	54	350.9	2.43	85	0.19	0	1.00	10	0.95	0.18	11.0235
7	4	82.5	7.02	85	0.04	0	1.00	10	0.95	0.03	2.0369
8	44	34.12	6.21	85	0.02	0	1.00	10	0.95	0.02	1.0687
9	45	146.5	3.27	85	0.08	0	1.00	20	0.90	0.07	4.4760
10	34	256.5	3.94	85	0.12	0	1.00	20	0.90	0.11	6.3829
11	10	235.1	8.67	85	0.07	0	1.00	10	0.95	0.07	4.2361
12	2	58.9	6.67	85	0.03	0	1.00	10	0.95	0.03	1.5959
13	36	414.8	3.55	95	0.12	0	1.00	15	0.97	0.12	7.0239
14	25	317	3.82	85	0.14	0	1.00	60	0.95	0.14	8.1118
15	30	273.8	0.74	85	0.29	0	1.00	10	0.95	0.27	16.3797
16	211	575	3.00	85	0.26	0	1.00	10	0.95	0.25	14.7282
17	18	116.1	4.24	85	0.06	0	1.00	10	0.95	0.06	3.4447
18	68	446.4	3.54	85	0.19	0	1.00	10	0.95	0.18	11.0727
19	109	372.9	3.44	95	0.11	0	1.00	50	0.95	0.11	6.4175
20	10	182.5	2.74	85	0.11	0	1.00	10	0.95	0.10	6.1533
21	17	531	3.54	85	0.22	0	1.00	10	0.95	0.21	12.7218
22	122	719	3.65	95	0.18	0	1.00	40	0.95	0.18	10.5344
Total	1089										

Table 8 : The SCS input parameter obtained from the analysis

SIMULATION

1. Data Input

After all the analyzed data obtained, the data was used to model the catchment into HEC-HMS. Figure 11 below show the modeled catchment of the project.

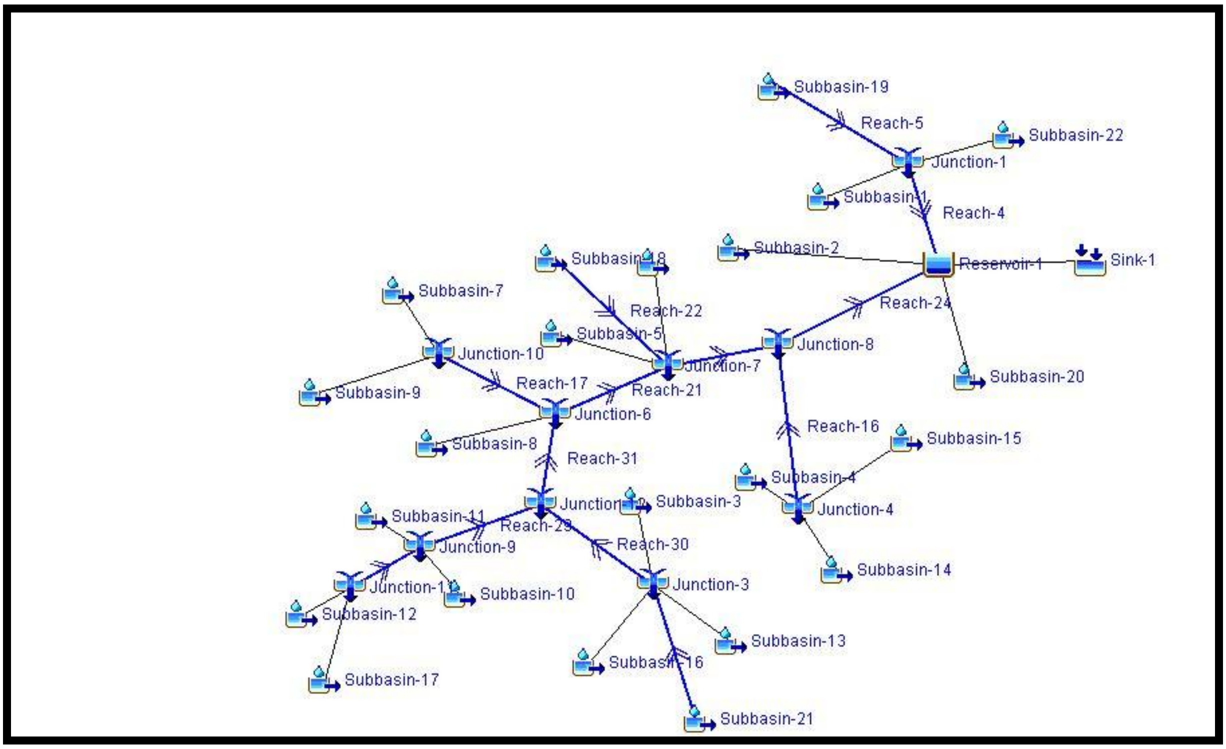


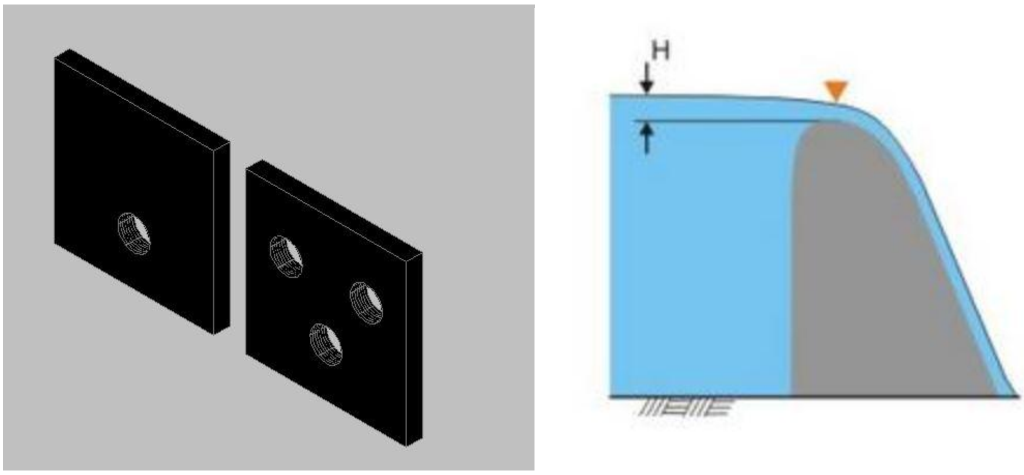
Figure 11 : Catchment Model in HEC-HMS

The Outlet Design and the Analysis

The analysis of the result will measure the effectiveness of detention pond's outlet design. For the manipulated variable, the outlet designs were changed to see how it will change the peak discharge. The designs are based on IOWA Stormwater Management standard design. These are the outlet type and their cross section is shown in Figure 12:

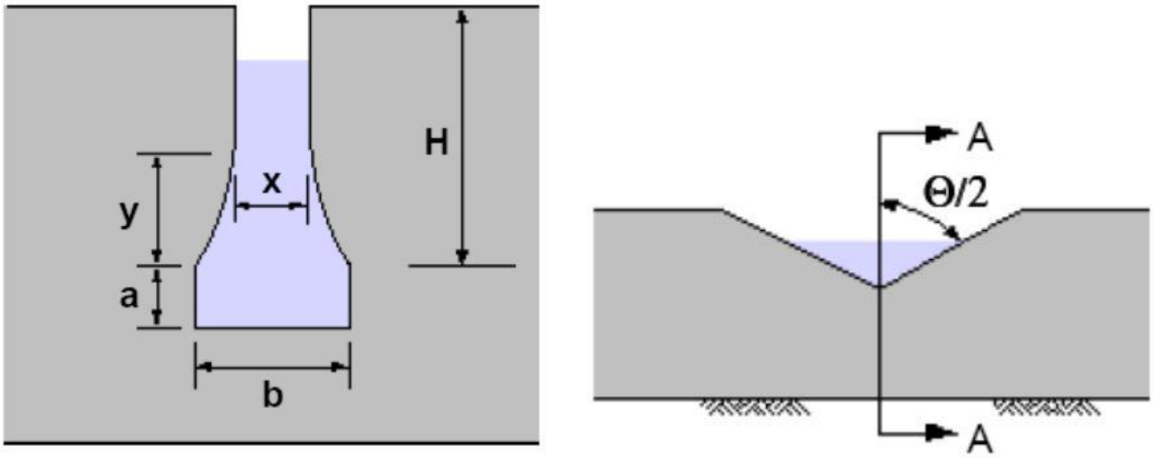
- Orifice
- Crested weir
- V-notch weir
- Proportional weir
- Rectangular weir
- Trapezoidal weir

The outlet are designed to make sure the water flow at all time, thus it is located at 51.21 m from the sea level which is around 4 m from the base of the detention pond. The area of outlet is fixed with different design and spillway is 4 m above the outlet.



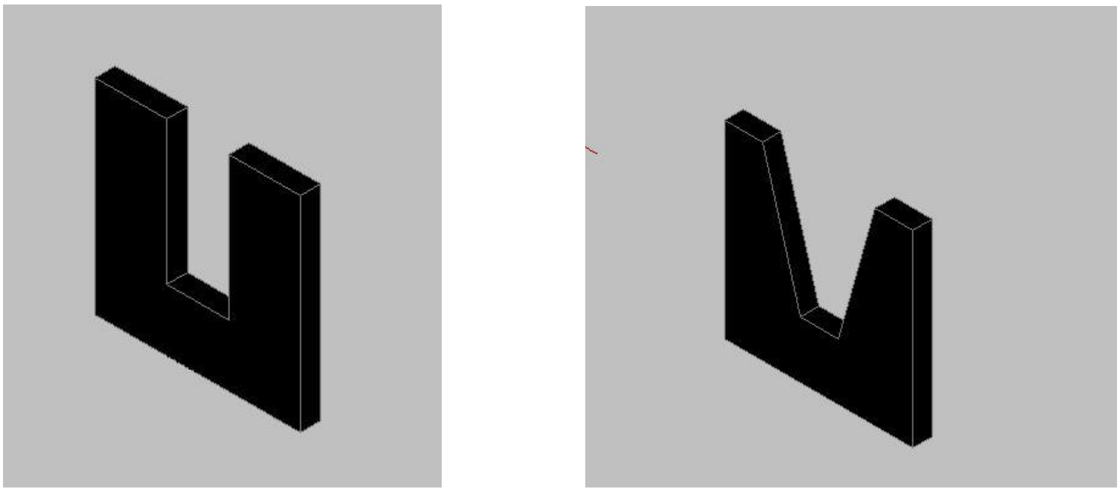
Orifice Type

Broad Crested Weir



Proportional Weir

V-Notch Weir



Rectangular weir

Trapezoidal weir

Figure 12 : Type of Outlet Design

Hence, the simulation was made. The result of Sink Unit refers to the peak discharge of the whole catchment. The results are transferred as in the table below. All units are in m^3/s.

Table 9 : Result Obtained from HEC-HMS simulation in m^3/s

ARI	Existing	Outlet Design						
		Orifice		Weir				
		single	triple	Crested	V-Notch	Rectangular	Proportional	trapezoidal
50	89.51	89.51	55.21	66.04	42.70	33.78	27.34	39.24
100	103.60	103.60	66.52	103.60	50.14	44.30	35.57	45.42

Percentage of reduction, % = $\frac{Peak\ Discharge - Reduced\ Peak\ Discharge}{Peak\ Discharge}\ x\ 100$

Percentage of peak discharge reduction is as shown in Figure 13:

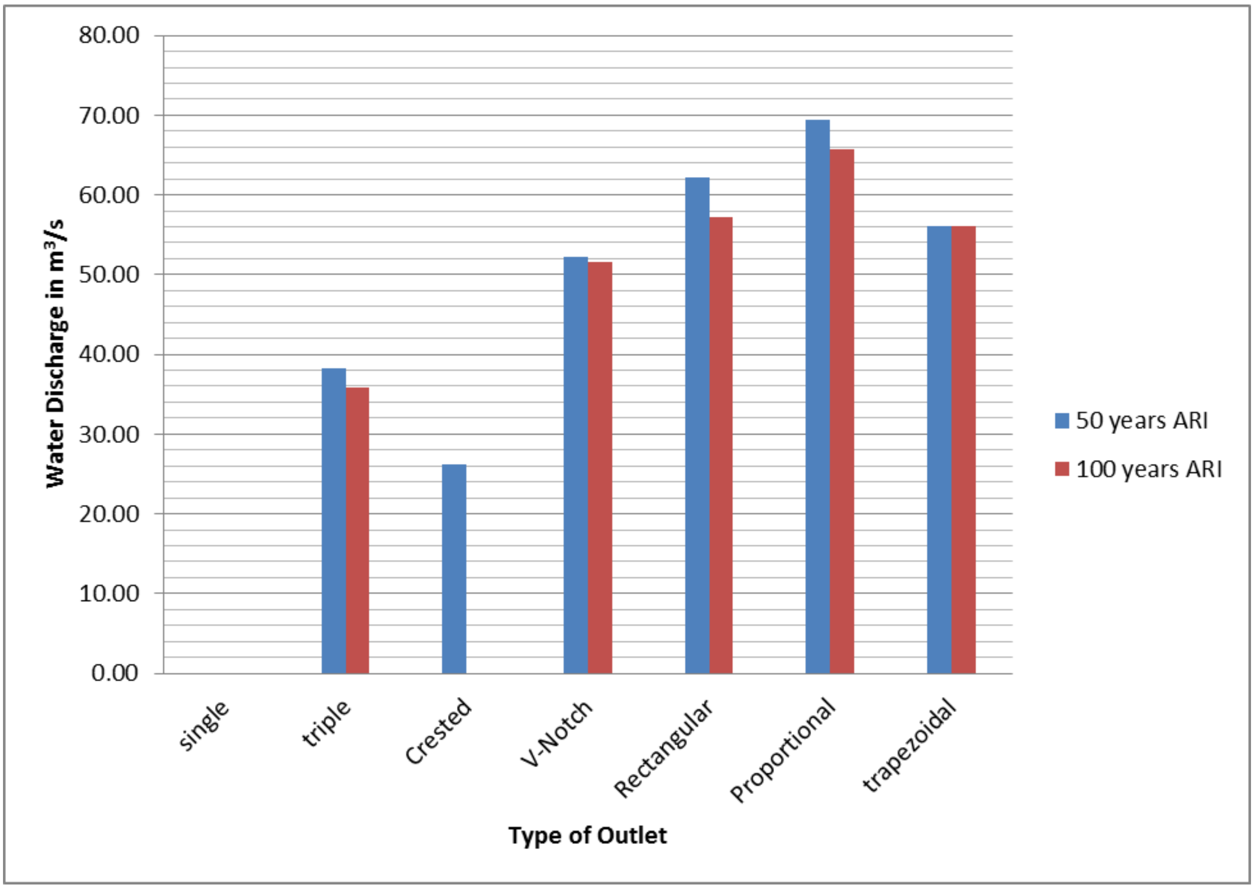


Figure 13 : Percentage of Water Discharge Reduction

DISCUSSION

1. Result Interpretation

Based on the result, the single orifice type of the outlet does not even reduce the peak discharge. This is due to the inability of outlet to let out the water at reasonable discharge causing it to accumulate too much in the detention pond and overflow the detention pond. When it overflows, the peak discharge of the detention pond is equal to the peak discharge of the whole catchment which is recorded in the sink unit. When this happen, 2 more of the same design of orifice was introduce slightly above the first orifice to support the water flow so that, overflow won’t happen again in the next simulation. Thus, riple orifice is able because of the extra outlet in place. However not good enough reduce the peak discharge. Same thing happen to the crested weir when 100 years ARI happen. As for the proportional weir, it is the most reliable unit to use in this catchment as it able to reduce the peak discharge below the river capacity which is around 35m^3/s. this is due to the upright rectangular cross-section that controls the water draining out of the detention pond at reasonable rate. For v-notch weir, rectangular weir and trapezoidal weir, the design was able to reduce about half of the detention pond peak discharge for rainstorm of 50 years ARI and 100 years ARI. This shows that this kind of outlet design were able to cater rainstorm of lower occurrence for examples are the rainstorm of once in every 20 years or 30 years.

2. Recommendation

From the result of this project, future water management can improves further with the outlet design of detention pond. What is seemed to be the common design used for detention pond by JPS are the triple orifice, v-notch weir, rectangular weir and trapezoidal weir. These designs as described before could only able to attain the small rainstorm such as 20 or 30 years ARI. Further improvement can be made from the result of this project which is to use proportional weir type as in this project proves it efficiency to reduce and maintain water discharge of a high peak water discharge. This improvement can help to reduce flood occurrence throughout the entire region in Malaysia. Further study on this outlet design should be done to improvise flood management in Malaysia especially in state which is prone to flood such as Kelantan and Terengganu.

CONCLUSION

From the final result of the project, heaviest rainfall simulated could happen in between 255.11mm and 298.80mm with peak discharge of 89.51m^3/s and 103.60m^3/s. after the simulation was done, it is proved that proportional type detention pond’s outlet serve the best design above other design in order to reduce the high peak discharge of heavy rain that could cause flood in Kota Bharu. Further study in proportional outlet design should be done to improve storm water management in the future.

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Appendix 1

Hydrologic Soil Group

The Soil Conservation Service (SCS) has classified about 4,000 major soils found in the United States into four basic hydrologic groups as follows:

Group A (Low runoff potential) - Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well-drained sands or gravels. These soils have a high rate of water transmission.

Group B - Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C - Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

Group D (High runoff potential) - Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

The SCS has performed modern soil surveys for many counties in Missouri, classifying the soils by a soil series name. The hydrologic soil group is given in the SCS soil survey for these soils. If a modern soil survey map is not available for the county in question, the hydrologic soil group should be determined by the designer. This may be done by evaluating information available from the soil survey performed by the Materials Division and/or from a site visit and choosing the appropriate hydrologic soil group from the descriptions given above. The district soils and geology technologist may provide assistance in determining the hydrologic soil group.

Runoff Curve Numbers - Urban Areas[1]					
Cover Description	**Curve Numbers for Hydrologic Soil Groups**				
Cover Type and Hydrologic Condition	**Average Percent Impervious Area[2]**	**A**	**B**	**C**	**D**
Fully Developed Urban Areas (Vegetation Established)					
Open Space (lawns, parks, golf courses, cemetaries, etc.)[3]					
Poor Condition (grass cover<50%)		68	79	86	89
Fair Condition (grass cover 50% to 75%)		49	69	79	84
Good Condition (grass cover>75%)		39	61	74	80
Impervious Areas:					
Paved Parking Lots, Roofs, Driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and Roads:					
Paved; Curbs and Storm Drains (excluding right-of-way)		98	98	98	98
Paved; Open Ditches (including right-of-		83	89	92	93

way)					
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western Desert Urban Areas:					
Natural Desert Landscaping (pervious areas only)		63	77	85	88
Artificial Desert Landscaping (impervious weed					
barrier desert shrub with 25- to 50 mm sand					
or gravel mulch and basin borders)		96	96	96	96
Urban Districts:					
Commercial and Business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential Districts by Average Lot Size:					
1/8 Acre or Less (town houses)	65	77	85	90	92
1/4 Acre	38	61	75	83	87
1/3 Acre	30	57	72	81	86
1/2 Acre	25	54	70	80	85
1 Acre	20	51	68	79	84
2 Acres	12	46	65	77	82
Developing Urban Areas					
Newly Graded Areas (pervious areas only, no vegetation		77	86	91	94
Idle Lands (CNs are determined using cover types similar to those in Runoff Curve Numbers - Urban Areas					
[1] Average runoff condition, and I_a=0.2S (see equation 7)					
[2] The average percent impervious area shown was used to develp the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. If the impervious area is not connected, the SCS method has an adjustment to reduce the effect.					
[3] CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space cover type.					

Runoff Curve Numbers - Other Agricultural Lands[1]					
Cover Description		**Curve Numbers for Hydrologic Soil Groups**			
Cover Type	**Hydrologic Condition**[3]	**A**	**B**	**C**	**D**
Pasture, Grassland, or Range — Continuous Forage for Grazing	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow - Continuous Grass, Protected from Grazing and Generally Mowed for Hay		30	58	71	78
Brush - Brush-Weed-Grass Mixture with Brush the Major Element	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[4]30	48	65	73
Woods - Grass Combination (Orchard or Tree Farm)[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6]	Good	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77
Farmsteads - Buildings, Lanes, Driveways and Surrounding Lots		59	74	82	86

[1] Average runoff condition, and I_a=0.2S (see equation 7)

[2] Poor: <50% ground cover or heavily grazed with no mulch
Fair: 50 to 74% ground cover
Good: >75% ground cover and lightly or only occasionally grazed

[3] Poor: <50% gound cover
Fair: 50 to 75% ground cover
Good: >75% ground cover

[4] Actual curve number is less than 30; use CN=30 for runoff computations.

[5] CNs shown were computed for areas with 50% grass (pasture) cover. Other combinations of conditions may be computed from CNs for woods and pasture.

[6] Poor: Forest litter, small trees and brush are destroyed by heavy grazing or regular burning.
Fair: Woods grazed but not burned, and some forest litter covers the soil.
Good: Woods protected from grazing, litter and brush adequately cover soil.

SCS Dimensionless Unit Hydrograph

The SCS unit hydrograph was developed based on analysis of a large number of natural unit hydrographs from a wide range of drainage basin sizes and geographic locations. The SCS unit hydrograph is given in a dimensionless form and provides a standard unit hydrograph shape. Table 9-02.9 gives the ordinates of the SCS dimensionless unit hydrograph.

SCS Dimensionless Unit Hydrograph

Time Ratio	**Discharge Ratio**	**Time Ratio**	**Discharge Ratio**	**Time Ratio**	**Discharge Ratio**	**Time Ratio**	**Discharge Ratio**
t/t_p	**Q/Q_p**	**t/t_p**	**Q/Q_p**	**t/t_p**	**Q/Q_p**	**t/t_p**	**Q/Q_p**
0.0	0.000	0.9	0.990	1.8	0.390	3.4	0.029
0.1	0.030	1.0	1.000	1.9	0.330	3.6	0.021
0.2	0.100	1.1	0.990	2.0	0.280	3.8	0.021
0.3	0.190	1.2	0.930	2.2	0.207	4.0	0.011
0.4	0.310	1.3	0.860	2.4	0.147	4.5	0.005
0.5	0.470	1.4	0.780	2.6	0.107	5.0	0.000
0.6	0.660	1.5	0.680	2.8	0.077		
0.7	0.820	1.6	0.560	3.0	0.055		
0.8	0.930	1.7	0.460	3.2	0.040		

Source: McCuen (1996)

Use of the SCS unit hydrograph requires calculation of the unit hydrograph peak discharge and the time to peak. The unit hydrograph peak discharge is given by:

$$Q_p = \frac{K_q A}{t_p} \quad \text{(Equation 10)}$$

where:

Q_p = unit hydrograph peak discharge, cfs
K_q = constant, 484
A = drainage area, mi^2
t_p = time to peak, hrs

The time to peak is assumed to be equal to the basin lag time plus one-half the duration of rainfall. Basin lag time is estimated as 0.6 times the time of concentration, leading to the following equation for time to peak:

$$t_p = \frac{t_r}{2} + 0.6t_c \quad \text{(Equation 11)}$$

where:

t_p = time to peak, hrs
t_r = duration of rainfall (unit hydrograph duration) = 0.133 t_c, hrs
t_c = time of concentration, hrs

Application of SCS Methodology

Unit hydrograph theory depends on the principles of linearity and superposition. Given a unit hydrograph, the runoff hydrograph for a runoff depth other than unity can be obtained by multiplying the unit hydrograph ordinates by the runoff depth using the principle of linearity. The flood hydrograph for a particular storm event can be obtained by dividing the storm event into incremental periods of runoff, then applying the unit hydrograph to each incremental runoff and summing the resulting hydrographs together using the principle of superposition to obtain the total runoff hydrograph.

The unit hydrograph duration (and the corresponding duration of the period of incremental runoff used in applying the unit hydrograph method) is estimated as $0.133t_c$. Since the SCS Type II rainfall distribution has a 24-hour time base, application of the SCS unit hydrograph methodology to typical watersheds by hand requires calculation of runoff hydrographs for a large number of increments. This can be cumbersome and time-consuming and a computer-based implementation is recommended.

Drainage Area

Drainage area (A) in mi^2, can be obtained by determining the area contributing surface flows to the site as outlined along the drainage divide on the best available topographic maps.

Limitations of Equations

The USGS Rural Regression Equations may be used to estimate magnitude and frequency of floods on most Missouri streams providing the drainage area and slope are within the limits shown in the table earlier.

However, the equations are not applicable for:

- basins where manmade changes have appreciably changed the flow regimen
- the main stems of the Mississippi and Missouri Rivers
- areas near the mouth of streams draining into larger rivers where backwater effect is experienced

Detention Storage

The traditional purpose of storm drainage systems has been to collect and convey storm runoff as rapidly as possible to a suitable location where it can be discharged. As areas urbanize this type of design may result in major drainage and flooding problems downstream. Under favorable conditions, the temporary storage of some of the storm runoff can decrease downstream flows and often the cost of the downstream conveyance system. Detention storage facilities can range from small facilities contained in parking lots or other on-site facilities to large lakes and reservoirs. This article provides general procedures for detention storage analysis.

An easement must be purchased for any land, outside of the right of way, that will be flooded by water from a detention storage structure.

Data Needs

The following data will be needed to complete storage calculations.

- Inflow hydrograph for all selected design storms. The inflow hydrograph for the detention basin can be determined using the methods in Flood Hydrographs.
- Stage-storage curve for storage facility.
- Stage-discharge curve for the facility.

Using these data, the inflow hydrograph is routed through the storage facility to develop the outflow hydrograph.

Stage-Storage Curve

A stage-storage curve defines the relationship between the depth of water and storage volume in a reservoir. The data for this type of curve are usually developed using a topographic map and the conic formula for irregular shaped basins, or the prismoidal formula for trapezoidal basins. The conic formula is expressed as:

$$V_{1,2} = \frac{1}{3}d\left(A_1 + A_2 + \sqrt{A_1 A_2}\right)$$ (Equation 14)

where:

$V_{1,2}$ = storage volume, ft^3 (m^3), between elevations 1 and 2
A_1 = surface area at elevation 1, ft^2
A^2 = surface area at elevation 2, ft^2
d = change in elevation between points 1 and 2, ft

The prismoidal formula for trapezoidal basins is expressed as:

$$V = LWD + (L + W)ZD^2\frac{4}{3}Z^2D^3$$ (Equation 15)

where:

V = volume of trapezoidal basin, ft^3
L = length of basin at base, ft
W = width of basin at base, ft
D = depth of basin, ft
Z = side slope factor, ratio of horizontal to vertical

Stage-Discharge Curve

A stage-discharge curve defines the relationship between the depth of water and the discharge or outflow from a storage facility. If the detention facility has both principal and emergency spillways the stage-discharge curve should take both into account. The following equations can be used to help develop the stage-discharge curve.

Sharp-crested weir flow equations for no end contractions, two end contractions, and submerged discharge conditions are presented below, followed by equations for broad-crested weirs, v-notch weirs and orifices, or combinations of these facilities.

Routing Calculations

The following procedure is used to perform routing through a reservoir or storage facility (Storage Indication or Puhls Method of storage routing).

Routing a flood through a reservoir results in an attenuation of the peak of the inflow hydrograph and an associated change in timing of the peak. Storage of flood waters within the reservoir causes the peak outflow from the reservoir to be lower than the peak inflow, and causes the peak outflow to occur at a later time than the peak inflow. The continuity equation relates the change of storage within the detention storage basin to the inflow and outflow for the basin:

$$I - O = \frac{\Delta S}{\Delta T}$$ (Equation 22)

where:

I = inflow, ft^3/s
O = outflow, ft^3/s
DS = change in storage, ft^3
DT = change in time, seconds

The Storage Indication method of reservoir routing uses a simple finite-difference form of the continuity equation. For any two points in time, the continuity equation can be written as:

$$\left(\frac{2S_{n+1}}{\Delta T} + O_{n+1}\right) = (I_n + I_{n+1}) + \left(\frac{2S_n}{\Delta T} - O_n\right)$$(Equation 23)

where:
S = storage

If the values at time step n are known, the only unknowns in equation 20 are on the left-hand side.

Substituting

$$U_{n+1} = \frac{2S_{n+1}}{\Delta T} + O_{n+1}$$(Equation 24)

$$W_n = \frac{2S_n}{\Delta T} - O_n$$(Equation 25)

U is known as the Storage Indication Number. With these substitutions, equation 20 becomes:

$$U_{n+1} = (I_n + I_{n+1}) + W_n$$(Equation 26)

For the first time step, W_n is calculated using the initial values of S and O, and equation 22. For subsequent time steps the following equation can be used as a shortcut.

$$W_{n+1} = U_{n+1} - 2O_{n+1}$$(Equation 27)

The procedure for using the storage-indication method of reservoir routing is as follows:

- Develop an inflow hydrograph, stage-discharge curve, and stage-storage curve for the proposed storage facility.
- Select a routing time period, t, to provide at least five points on the rising limb of the inflow hydrograph.
- Use the stage-storage and stage-outflow data from Step 1 to develop a plot of U versus outflow.
- Calculate W_1 using equation 22 and the initial values of S and O
- Calculate U_{n+1} using equation 23.
- Using U_{n+1} calculated in step 5 pick O_{n+1} from the plot of U vs. outflow.
- Using U_{n+1} and O_{n+1} calculate W_{n+1} using equation 24
- Start over at step 5 with n = n+1. Continue repeating until inflow ceases or the outflow peak discharge has been determined.
- From the stage discharge curve, determine the stage for the peak outflow.

Appendix 2.1: Cumulative Rainfall Data

Manual

6021001 Lemal Pasir Mas

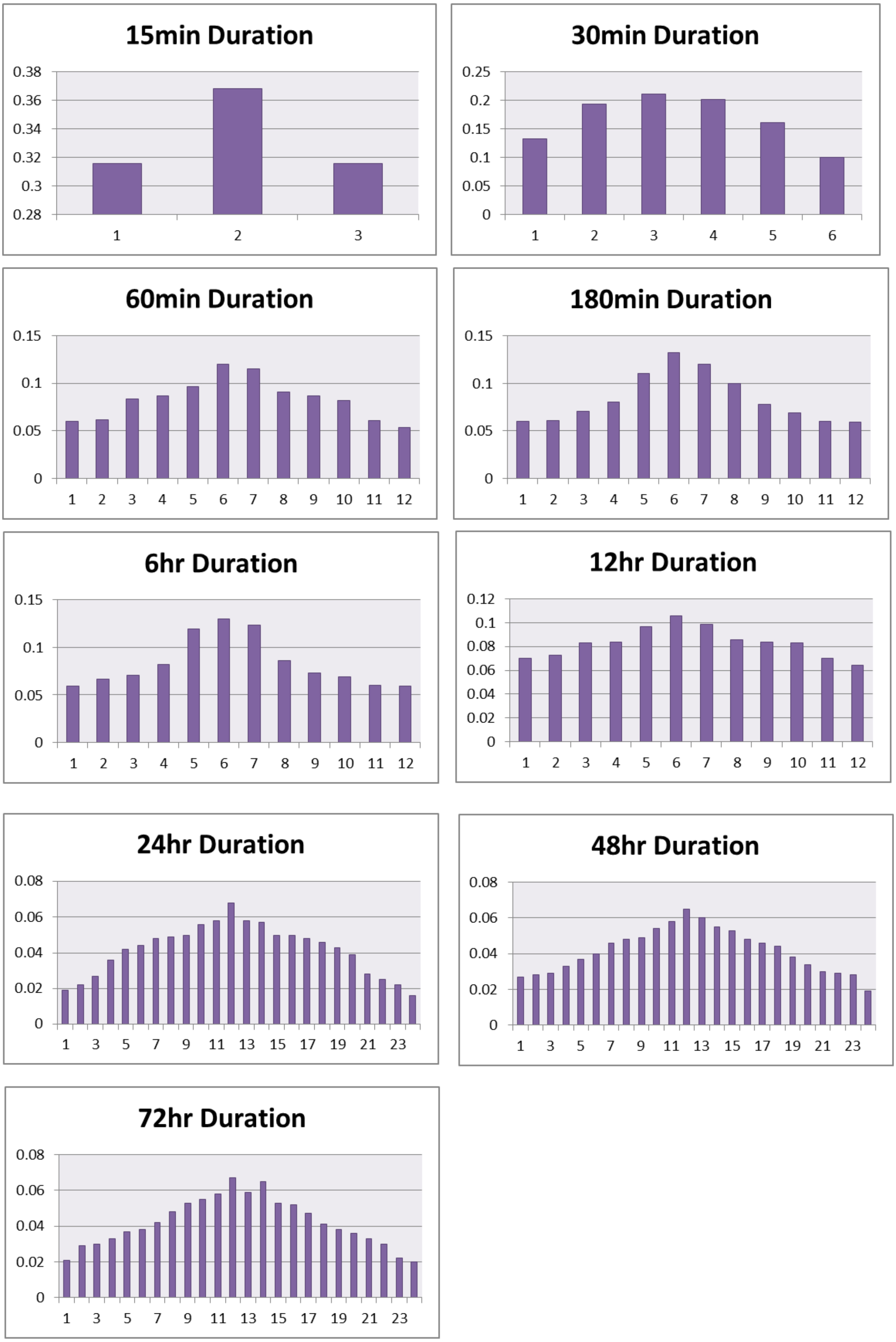
Year Text	Annual RF (mm)	Cumulative RF (mm)	Remark
1994	9112	9112.00	started on july. "0" on Oct - dec
1995 - 1999	-	9112.00	
2000	33728	42840.00	star on 31 jan
2001	28630	71470.00	
2002	20718	92188.00	feb-apr
2003	19736	111924.00	dec
2004	16448	128372.00	jan, mac-apr, nov
2005	28038	156410.00	jan, feb, july-sept
2006	23200	179610.00	jun, july, sept
2007	14049	193659.00	ended on 1 sept

Telemetry

6122001 Jeti Kastam

Year Text	Annual RF (mm)	Cumulative RF (mm)	Remark
2001	8681	8681.00	started on july
2002	96496	105177.00	
2003	1439732	1544909.00	
2004	16640	1561549.00	feb, apr
2005	21690	1583239.00	apr
2006	21981	1605220.00	
2007	17473	1622693.00	
2008	30187	1652880.00	
2009	31622	1684502.00	
2010	24529	1709031.00	
2011	36440	1745471.00	
2012	12493	1757964.00	ended on 15 aug

Appendix 2-2



Appendix 2-3: Temporal Pattern Without ARF

1-hr	2yrsARI	5yrsARI	10yrsARI	20yrsARI	50yrsARI	100yrsARI
	67.12	**81.66**	**94.72**	**109.86**	**133.66**	**155.03**
0.06	4.03	4.90	5.68	6.59	8.02	9.30
0.062	4.16	5.06	5.87	6.81	8.29	9.61
0.084	5.64	6.86	7.96	9.23	11.23	13.02
0.087	5.84	7.10	8.24	9.56	11.63	13.49
0.097	6.51	7.92	9.19	10.66	12.96	15.04
0.12	8.05	9.80	11.37	13.18	16.04	18.60
0.115	7.72	9.39	10.89	12.63	15.37	17.83
0.091	6.11	7.43	8.62	10.00	12.16	14.11
0.087	5.84	7.10	8.24	9.56	11.63	13.49
0.082	5.50	6.70	7.77	9.01	10.96	12.71
0.061	4.09	4.98	5.78	6.70	8.15	9.46
0.054	3.62	4.41	5.11	5.93	7.22	8.37

3-hr	2yrsARI	5yrsARI	10yrsARI	20yrsARI	50yrsARI	100yrsARI
	108.17	**131.60**	**152.64**	**177.05**	**215.41**	**249.85**
0.06	6.49	7.90	9.16	10.62	12.92	14.99
0.061	6.60	8.03	9.31	10.80	13.14	15.24
0.071	7.68	9.34	10.84	12.57	15.29	17.74
0.08	8.65	10.53	12.21	14.16	17.23	19.99
0.11	11.90	14.48	16.79	19.48	23.69	27.48
0.132	14.28	17.37	20.15	23.37	28.43	32.98
0.12	12.98	15.79	18.32	21.25	25.85	29.98
0.1	10.82	13.16	15.26	17.71	21.54	24.98
0.078	8.44	10.26	11.91	13.81	16.80	19.49
0.069	7.46	9.08	10.53	12.22	14.86	17.24
0.06	6.49	7.90	9.16	10.62	12.92	14.99
0.059	6.38	7.76	9.01	10.45	12.71	14.74

6-hr	2yrsARI	5yrsARI	10yrsARI	20yrsARI	50yrsARI	100yrsARI

	143.24	174.27	202.13	234.45	285.24	330.85
0.059	8.451005	10.28176	11.92581	13.83274	16.82936	19.52036
0.067	9.596904	11.6759	13.54287	15.70837	19.1113	22.16719
0.071	10.16985	12.37297	14.3514	16.64618	20.25228	23.49061
0.082	11.74546	14.2899	16.57486	19.22517	23.38995	27.13
0.119	17.04525	20.73779	24.05375	27.89994	33.94396	39.37158
0.13	18.62086	22.65473	26.27721	30.47893	37.08163	43.01097
0.123	17.6182	21.43486	24.86228	28.83775	35.08493	40.695
0.086	12.31841	14.98697	17.38339	20.16298	24.53093	28.45341
0.073	10.45633	12.7215	14.75566	17.11509	20.82276	24.15232
0.069	9.883378	12.02443	13.94713	16.17728	19.68179	22.8289
0.06	8.594242	10.45603	12.12794	14.0672	17.1146	19.85122
0.059	8.451005	10.28176	11.92581	13.83274	16.82936	19.52036

12-hr	2yrsARI	5yrsARI	10yrsARI	20yrsARI	50yrsARI	100yrsARI
	188.32	229.11	265.75	308.24	375.02	434.98
0.07	13.18225	16.03794	18.6024	21.57692	26.25117	30.44872
0.073	13.7472	16.72528	19.39965	22.50165	27.37622	31.75367
0.083	15.63038	19.01642	22.05714	25.58406	31.12639	36.10348
0.084	15.8187	19.24553	22.32288	25.89231	31.5014	36.53847
0.097	18.26683	22.22401	25.77762	29.89945	36.37662	42.19323
0.106	19.96169	24.28603	28.16935	32.67362	39.75177	46.10806
0.099	18.64346	22.68223	26.30911	30.51593	37.12665	43.06319
0.086	16.19533	19.70376	22.85438	26.50879	32.25144	37.40843
0.084	15.8187	19.24553	22.32288	25.89231	31.5014	36.53847
0.083	15.63038	19.01642	22.05714	25.58406	31.12639	36.10348
0.07	13.18225	16.03794	18.6024	21.57692	26.25117	30.44872
0.064	12.05234	14.66326	17.00791	19.72747	24.00107	27.83883

24-hr	2yrsARI	5yrsARI	10yrsARI	20yrsARI	50yrsARI	100yrsARI
	246.67	300.11	348.10	403.76	491.23	569.77
0.019	4.686787	5.702094	6.613856	7.67141	9.333281	10.82567
0.022	5.426805	6.602424	7.658149	8.882685	10.80696	12.53499
0.027	6.66017	8.102975	9.398638	10.90148	13.26308	15.38385
0.036	8.880227	10.80397	12.53152	14.5353	17.68411	20.51179
0.042	10.36027	12.60463	14.6201	16.95785	20.63146	23.93043
0.044	10.85361	13.20485	15.3163	17.76537	21.61391	25.06997
0.048	11.8403	14.40529	16.70869	19.3804	23.57881	27.34906
0.049	12.08698	14.7054	17.05679	19.78416	24.07004	27.91883
0.05	12.33365	15.00551	17.40489	20.18792	24.56127	28.4886
0.056	13.81369	16.80617	19.49347	22.61047	27.50862	31.90724
0.058	14.30703	17.40639	20.18967	23.41799	28.49107	33.04678

0.068	16.77376	20.40749	23.67064	27.45557	33.40332	38.7445
0.058	14.30703	17.40639	20.18967	23.41799	28.49107	33.04678
0.057	14.06036	17.10628	19.84157	23.01423	27.99984	32.47701
0.05	12.33365	15.00551	17.40489	20.18792	24.56127	28.4886
0.05	12.33365	15.00551	17.40489	20.18792	24.56127	28.4886
0.048	11.8403	14.40529	16.70869	19.3804	23.57881	27.34906
0.046	11.34696	13.80507	16.01249	18.57289	22.59636	26.20952
0.043	10.60694	12.90474	14.9682	17.36161	21.12269	24.5002
0.039	9.620246	11.7043	13.57581	15.74658	19.15779	22.22111
0.028	6.906843	8.403085	9.746736	11.30524	13.75431	15.95362
0.025	6.166824	7.502755	8.702443	10.09396	12.28063	14.2443
0.022	5.426805	6.602424	7.658149	8.882685	10.80696	12.53499
0.016	3.946768	4.801763	5.569563	6.460134	7.859605	9.116353

48-hr	**2yrsARI**	**5yrsARI**	**10yrsARI**	**20yrsARI**	**50yrsARI**	**100yrsARI**
	322.51	**392.37**	**455.11**	**527.88**	**642.24**	**744.93**
0.027	8.707669	10.59403	12.28801	14.25286	17.34048	20.11322
0.028	9.030176	10.9864	12.74312	14.78074	17.98272	20.85815
0.029	9.352682	11.37877	13.19823	15.30862	18.62496	21.60308
0.033	10.64271	12.94826	15.01868	17.42016	21.19392	24.58282
0.037	11.93273	14.51774	16.83912	19.53169	23.76288	27.56255
0.04	12.90025	15.69486	18.20446	21.11534	25.6896	29.79736
0.046	14.83529	18.04908	20.93513	24.28265	29.54304	34.26696
0.048	15.4803	18.83383	21.84535	25.33841	30.82752	35.75683
0.049	15.80281	19.2262	22.30046	25.8663	31.46976	36.50176
0.054	17.41534	21.18805	24.57602	28.50571	34.68096	40.22643
0.058	18.70536	22.75754	26.39646	30.61725	37.24992	43.20617
0.065	20.96291	25.50414	29.58224	34.31243	41.7456	48.4207
0.06	19.35038	23.54228	27.30669	31.67302	38.5344	44.69603
0.055	17.73785	21.58043	25.03113	29.0336	35.3232	40.97137
0.053	17.09283	20.79568	24.12091	27.97783	34.03872	39.4815
0.048	15.4803	18.83383	21.84535	25.33841	30.82752	35.75683
0.046	14.83529	18.04908	20.93513	24.28265	29.54304	34.26696
0.044	14.19028	17.26434	20.0249	23.22688	28.25856	32.77709
0.038	12.25524	14.91011	17.29423	20.05958	24.40512	28.30749
0.034	10.96521	13.34063	15.47379	17.94804	21.83616	25.32775
0.03	9.675188	11.77114	13.65334	15.83651	19.2672	22.34802
0.029	9.352682	11.37877	13.19823	15.30862	18.62496	21.60308
0.028	9.030176	10.9864	12.74312	14.78074	17.98272	20.85815
0.019	6.127619	7.455056	8.647117	10.02979	12.20256	14.15374

72-hr	**2yrsARI**	**5yrsARI**	**10yrsARI**	**20yrsARI**	**50yrsARI**	**100yrsARI**

	377.08	**458.77**	**532.12**	**617.21**	**750.91**	**870.99**
0.021	7.918643	9.634073	11.17456	12.96137	15.76921	18.2907
0.029	10.93527	13.3042	15.43153	17.89903	21.77653	25.25859
0.03	11.31235	13.76296	15.96365	18.51624	22.52744	26.12957
0.033	12.44358	15.13926	17.56002	20.36786	24.78019	28.74253
0.037	13.95189	16.97432	19.68851	22.83669	27.78385	32.22647
0.038	14.32897	17.43308	20.22063	23.4539	28.53476	33.09746
0.042	15.83729	19.26815	22.34912	25.92273	31.53842	36.5814
0.048	18.09976	22.02074	25.54185	29.62598	36.04391	41.80732
0.053	19.98515	24.31456	28.20245	32.71202	39.79848	46.16224
0.055	20.7393	25.2321	29.2667	33.94643	41.30031	47.90422
0.058	21.87054	26.60839	30.86306	35.79806	43.55305	50.51717
0.067	25.26424	30.73728	35.65216	41.35293	50.31129	58.35604
0.059	22.24762	27.06716	31.39519	36.41526	44.30397	51.38816
0.065	24.51009	29.81975	34.58792	40.11851	48.80946	56.61407
0.053	19.98515	24.31456	28.20245	32.71202	39.79848	46.16224
0.052	19.60807	23.8558	27.67033	32.09481	39.04757	45.29126
0.047	17.72268	21.56197	25.00972	29.00877	35.29299	40.93633
0.041	15.46021	18.80938	21.81699	25.30552	30.7875	35.71042
0.038	14.32897	17.43308	20.22063	23.4539	28.53476	33.09746
0.036	13.57482	16.51555	19.15638	22.21948	27.03293	31.35549
0.033	12.44358	15.13926	17.56002	20.36786	24.78019	28.74253
0.03	11.31235	13.76296	15.96365	18.51624	22.52744	26.12957
0.022	8.295721	10.09284	11.70668	13.57857	16.52012	19.16169
0.02	7.541565	9.175307	10.64244	12.34416	15.01829	17.41971

Appendix 2-4: Temporal Pattern With ARF

1-hr	**2yrsARI**	**5yrsARI**	**10yrsARI**	**20yrsARI**	**50yrsARI**	**100yrsARI**
ARF	**0.998**	**1.115**	**1.194**	**1.169**	**1.156**	**1.176**
	4.017268	5.461017	6.787144	7.70743	9.270461	10.94085
	4.151177	5.643051	7.013382	7.964344	9.579476	11.30555
	5.624175	7.645424	9.502002	10.7904	12.97865	15.31719
	5.825039	7.918475	9.841359	11.17577	13.44217	15.86424
	6.494584	8.828644	10.97255	12.46034	14.98725	17.68771
	8.034536	10.92203	13.57429	15.41486	18.54092	21.8817
	7.699764	10.46695	13.00869	14.77257	17.76838	20.96997
	6.092857	8.282543	10.29384	11.6896	14.0602	16.59363
	5.825039	7.918475	9.841359	11.17577	13.44217	15.86424
	5.490266	7.46339	9.275764	10.53349	12.66963	14.9525
	4.084223	5.552034	6.900263	7.835887	9.424969	11.1232
	3.615541	4.914915	6.10843	6.936687	8.343415	9.846767
Total	66.95	91.02	113.12	128.46	154.51	182.35

3-hr	**2yrsARI**	**5yrsARI**	**10yrsARI**	**20yrsARI**	**50yrsARI**	**100yrsARI**
ARF	**0.993**	**1.154**	**1.223**	**1.198**	**1.184**	**1.196**
	6.444795	9.112651	11.20383	12.72254	15.30674	17.92816
	6.552208	9.264529	11.39056	12.93458	15.56186	18.22696
	7.626341	10.7833	13.25786	15.055	18.11298	21.21499
	8.59306	12.1502	14.93844	16.96338	20.40899	23.90421
	11.81546	16.70653	20.54035	23.32465	28.06236	32.86829
	14.17855	20.04783	24.64842	27.98958	33.67484	39.44195
	12.88959	18.2253	22.40765	25.44507	30.61349	35.85631
	10.74132	15.18775	18.67304	21.20423	25.51124	29.88026
	8.378233	11.84645	14.56497	16.5393	19.89877	23.3066
	7.411514	10.47955	12.8844	14.63092	17.60276	20.61738
	6.444795	9.112651	11.20383	12.72254	15.30674	17.92816
	6.337382	8.960774	11.0171	12.51049	15.05163	17.62935
Total	107.41	151.88	186.73	212.04	255.11	298.80

6-hr	2yrsARI	5yrsARI	10yrsARI	20yrsARI	50yrsARI	100yrsARI
ARF	**0.992**	**1.180**	**1.244**	**1.216**	**1.200**	**1.209**
	8.381319	12.12949	14.83037	16.81696	20.19265	23.59525
	9.517769	13.77417	16.84127	19.09722	22.93064	26.79461
	10.08599	14.59651	17.84672	20.23735	24.29963	28.39428
	11.64861	16.85794	20.6117	23.37272	28.06436	32.7934
	16.90469	24.46457	29.91211	33.91895	40.72755	47.59042
	18.46731	26.726	32.67709	37.05431	44.49228	51.98954
	17.47292	25.28691	30.91755	35.05908	42.09654	49.1901
	12.21684	17.68028	21.61715	24.51285	29.43335	34.39308
	10.37011	15.00768	18.34944	20.80742	24.98412	29.19412
	9.801882	14.18534	17.34399	19.66729	23.61513	27.59445
	8.523375	12.33508	15.08173	17.10199	20.5349	23.99517
	8.381319	12.12949	14.83037	16.81696	20.19265	23.59525
Total	141.77	205.17	250.86	284.46	341.56	399.12

12-hr	2yrsARI	5yrsARI	10yrsARI	20yrsARI	50yrsARI	100yrsARI
ARF	**0.988**	**1.210**	**1.265**	**1.235**	**1.219**	**1.222**
	13.02563	19.40212	23.52798	26.64469	32.01244	37.21218
	13.58388	20.23364	24.53632	27.78661	33.3844	38.80699
	15.44468	23.00537	27.89746	31.59299	37.9576	44.12301
	15.63076	23.28255	28.23357	31.97363	38.41492	44.65461
	18.04981	26.8858	32.60305	36.92193	44.36009	51.56545
	19.72453	29.38036	35.62808	40.34768	48.47597	56.34987
	18.42197	27.44014	33.27528	37.68321	45.27473	52.62865
	16.00292	23.83689	28.9058	32.73491	39.32956	45.71782
	15.63076	23.28255	28.23357	31.97363	38.41492	44.65461
	15.44468	23.00537	27.89746	31.59299	37.9576	44.12301
	13.02563	19.40212	23.52798	26.64469	32.01244	37.21218
	11.90915	17.73908	21.51129	24.36086	29.26851	34.02256
Total	185.89	276.90	335.78	380.26	456.86	531.07

24-hr	2yrsARI	5yrsARI	10yrsARI	20yrsARI	50yrsARI	100yrsARI
ARF	**0.987**	**1.239**	**1.287**	**1.255**	**1.237**	**1.238**
	4.624698	7.063467	8.512184	9.627489	11.54919	13.39717
	5.354913	8.178752	9.856213	11.14762	13.37275	15.51252
	6.571939	10.03756	12.09626	13.68117	16.41201	19.03809
	8.762585	13.38341	16.12835	18.24156	21.88267	25.38412
	10.22302	15.61398	18.81641	21.28182	25.52979	29.61481
	10.70983	16.3575	19.71243	22.29524	26.74549	31.02504
	11.68345	17.84455	21.50446	24.32208	29.1769	33.84549
	11.92685	18.21631	21.95247	24.82879	29.78475	34.55061
	12.17026	18.58807	22.40048	25.3355	30.3926	35.25572

	13.63069	20.81864	25.08854	28.37576	34.03972	39.48641
	14.1175	21.56216	25.98456	29.38918	35.25542	40.89664
	16.55155	25.27978	30.46466	34.45628	41.33394	47.94778
	14.1175	21.56216	25.98456	29.38918	35.25542	40.89664
	13.87409	21.1904	25.53655	28.88247	34.64757	40.19152
	12.17026	18.58807	22.40048	25.3355	30.3926	35.25572
	12.17026	18.58807	22.40048	25.3355	30.3926	35.25572
	11.68345	17.84455	21.50446	24.32208	29.1769	33.84549
	11.19664	17.10103	20.60844	23.30866	27.96119	32.43527
	10.46642	15.98574	19.26442	21.78853	26.13764	30.31992
	9.492801	14.4987	17.47238	19.76169	23.70623	27.49946
	6.815344	10.40932	12.54427	14.18788	17.01986	19.74321
	6.085129	9.294036	11.20024	12.66775	15.1963	17.62786
	5.354913	8.178752	9.856213	11.14762	13.37275	15.51252
	3.894482	5.948183	7.168155	8.107359	9.725633	11.28183
Total	243.65	372.13	448.46	507.22	608.46	705.82

48-hr	**2yrsARI**	**5yrsARI**	**10yrsARI**	**20yrsARI**	**50yrsARI**	**100yrsARI**
ARF	**0.983**	**1.270**	**1.310**	**1.273**	**1.260**	**1.251**
	8.560793	13.44925	16.10089	18.14675	21.84288	25.15543
	8.877859	13.94737	16.69722	18.81885	22.65187	26.08711
	9.194925	14.44549	17.29355	19.49095	23.46087	27.01879
	10.46319	16.43798	19.67887	22.17936	26.69685	30.74552
	11.73146	18.43046	22.06419	24.86776	29.93283	34.47225
	12.68266	19.92482	23.85317	26.88407	32.35982	37.2673
	14.58505	22.91354	27.43115	30.91668	37.21379	42.85739
	15.21919	23.90978	28.62381	32.26088	38.83178	44.72076
	15.53625	24.4079	29.22014	32.93298	39.64077	45.65244
	17.12159	26.89851	32.20179	36.29349	43.68575	50.31085
	18.38985	28.89099	34.5871	38.9819	46.92173	54.03758
	20.60932	32.37783	38.76141	43.68661	52.5847	60.55936
	19.02398	29.88723	35.77976	40.3261	48.53972	55.90095
	17.43865	27.39663	32.79811	36.96559	44.49475	51.24253
	16.80452	26.40038	31.60546	35.62139	42.87676	49.37917
	15.21919	23.90978	28.62381	32.26088	38.83178	44.72076
	14.58505	22.91354	27.43115	30.91668	37.21379	42.85739
	13.95092	21.9173	26.23849	29.57247	35.5958	40.99403
	12.04852	18.92858	22.66052	25.53986	30.74182	35.40393
	10.78026	16.9361	20.2752	22.85146	27.50584	31.6772
	9.511992	14.94361	17.88988	20.16305	24.26986	27.95047
	9.194925	14.44549	17.29355	19.49095	23.46087	27.01879
	8.877859	13.94737	16.69722	18.81885	22.65187	26.08711
	6.024261	9.464289	11.33026	12.76993	15.37091	17.70197
Total	316.43	497.12	595.14	670.76	807.38	929.82

72-hr	**2yrsARI**	**5yrsARI**	**10yrsARI**	**20yrsARI**	**50yrsARI**	**100yrsARI**
ARF	**0.982**	**1.223**	**1.323**	**1.288**	**1.272**	**1.259**
	7.778904	11.78374	14.78211	16.6902	20.05472	23.03145
	10.7423	16.27278	20.41338	23.04837	27.69462	31.80533
	11.11272	16.83391	21.11729	23.84314	28.6496	32.90207
	12.22399	18.51731	23.22902	26.22745	31.51456	36.19227
	13.70569	20.76183	26.04466	29.40654	35.33451	40.57922
	14.07611	21.32296	26.74857	30.20131	36.2895	41.67595
	15.55781	23.56748	29.56421	33.38039	40.10944	46.06289
	17.78035	26.93426	33.78767	38.14902	45.83937	52.64331
	19.63247	29.73992	37.30722	42.12288	50.6143	58.12699
	20.37332	30.86218	38.71504	43.71242	52.52427	60.32046
	21.48459	32.54557	40.82677	46.09673	55.38923	63.61066
	24.81841	37.59574	47.16195	53.24967	63.98411	73.48128
	21.85502	33.1067	41.53068	46.8915	56.34422	64.7074
	24.07756	36.47348	45.75414	51.66013	62.07414	71.28781
	19.63247	29.73992	37.30722	42.12288	50.6143	58.12699
	19.26205	29.17879	36.60331	41.32811	49.65931	57.03025
	17.40993	26.37313	33.08376	37.35425	44.88438	51.54657
	15.18738	23.00635	28.8603	32.58562	39.15446	44.96616
	14.07611	21.32296	26.74857	30.20131	36.2895	41.67595
	13.33526	20.2007	25.34075	28.61177	34.37952	39.48248
	12.22399	18.51731	23.22902	26.22745	31.51456	36.19227
	11.11272	16.83391	21.11729	23.84314	28.6496	32.90207
	8.149328	12.34487	15.48602	17.48497	21.00971	24.12818
	7.40848	11.22261	14.0782	15.89543	19.09974	21.93471
Total	373.02	565.06	708.84	800.33	961.67	1104.41

Gantt Chart

The gantt chart only represents the preliminary study of the selected topic with some milestone to be achieved to get the conclusion in term of result gained.

NO	DETAIL WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Title	🟦	🟦												
2	Preliminary Research Work and Literature Review		🟦	🟦	🟦	🟦									
3	Submission of Extended Proposal Defence						●								
4	Preparation for Oral Proposal Defence							🟦							
5	Oral Proposal Defence Presentation								🟦						
6	Detailed Literature Review								🟦	🟦	🟦	🟦	🟦		
7	Preparation of Interim Report			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		
8	Submission of Interim Draft Report													●	
9	Submission of Interim Final Report														●

NO	DETAIL WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
10	Data Collection using Time Dependant Data (TIDEDA)	🟦													
11	RF Data collected from JPS (Autologger and Manual)		●												
12	Quality Analysis on 5 rainfall stations in Tunjong			🟦	🟦										
13	Reliable RF data obtained					●									
14	Sub catchment analysis						🟦	🟦							
15	Catchment divided and analyzed							●							
16	HP temporal pattern calculation and analysis								🟦	🟦					
17	Flood Hydrograph obtained										●				
18	Simulation using HEC-HMS											🟦	🟦		
19	Outflow data obtained (result varies with design)												●		
20	Analyzation of the result											🟦	🟦	🟦	
21	Submission of final report														🟦