The impact of campus development on the flash flood potential: A case study at watershed USM Main Campus, Pulau Pinang, Malaysia

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ABSTRACT
Research about impacts of impervious areas in increasing the flash flood potential has been done intensively. Many previous studies found that the flash flood problems increased by the increase of the surface runoff rates due to impervious areas. The flash flood problem has become a main issue at USM Main Campus since its development to be a modern campus. This study presents the impacts of campus development on the flash flood potential due to the increase of the runoff rates at USM Main Campus area. It was done by investigating and comparing the runoff rates before and after campus development from 5 selected subareas using Win-TR55 hydrologic model. The results show that runoff rates from subarea 3 with 100% development area increase by 158.43% for 2 years ARI and 102.59% for 5 years ARI while the runoff rates from subarea 5 with 30% development area increase by 24.99% for 2 years ARI and 15.47% for 5 years ARI It demonstrates that subareas with higher percentages of development area can increase the runoff rates greatly compared with the subareas with lower percentages of development area and thus, can increase greatly the potential of the flash flood events in USM Main Campus area.

Keywords: Flash flood; impervious area; surface runoff; WinTR-55 model.

1 Introduction

Research about impacts of urbanization in increasing the flash flood discharges has been done intensively since 1960 in US and Eropa (Jacobson, 2011). Smith and Ward (1998), Akan and Houghtalen (2003), Camorani et al., (2005) and Suriya and Mudgal (2011, #2) mentioned that land degradations such as urbanization, industrialization, forest clearance and agriculture have increased the flood potential. These activities produced numerous changes in natural environment that caused changes in peak flow characteristics, changes in total runoff, changes in water quality, and changes in the hydrological amenity (Ali et al., 2011; Jacobson, 2011).

Flash flood problems have become a main issue at USM Main Campus area since its development (Friend of Tasik Harapan, 2010). Based on study carried out by Teh et al., (2006), it can be suspected that flash flood problems are triggered by the heavy local rainfall on monsoon season and the increased of surface runoff induced by expansion of USM main campus from an army barrack to a modern campus. This study tries to present the impact of campus development on flash flood potential by investigating and comparing the runoff rates before and after campus's development using Win-TR55 model.

Win-TR55 model is a common hydrological model used to analyze the hydrology for small watershed (Jacobson, 2011 #1). This model can generate the runoff hydrographs based on Soil Conservation Service (SCS, #7) (now is called the Natural Resources Conservation Service (NRCS)) method which depend on amount of rainfall intensity, synthetic 24-hr rainfall distribution type, curve number (CN) values and time of concentration (Tc) values (NRCS, 2009).

GIS tool is a computer-based technology that has the ability in collecting, managing, analyzing, modeling and presenting geographic data for a wide range of applications (Noman et al., 2001; Davis, 2001; Sinnakaudan et al., 2002).

2 Study area

This study was carried out at a selected area within USM Main Campus, Pulau Pinang, Malaysia which is susceptible to flash flood occurrences. The surface runoffs considered flowing into the study area were conveyed from several parts of inside campus and several part of outside campus through 5 major outlets as described in Figure 1. The total catchment area of the study is approximately 310.074 ha.

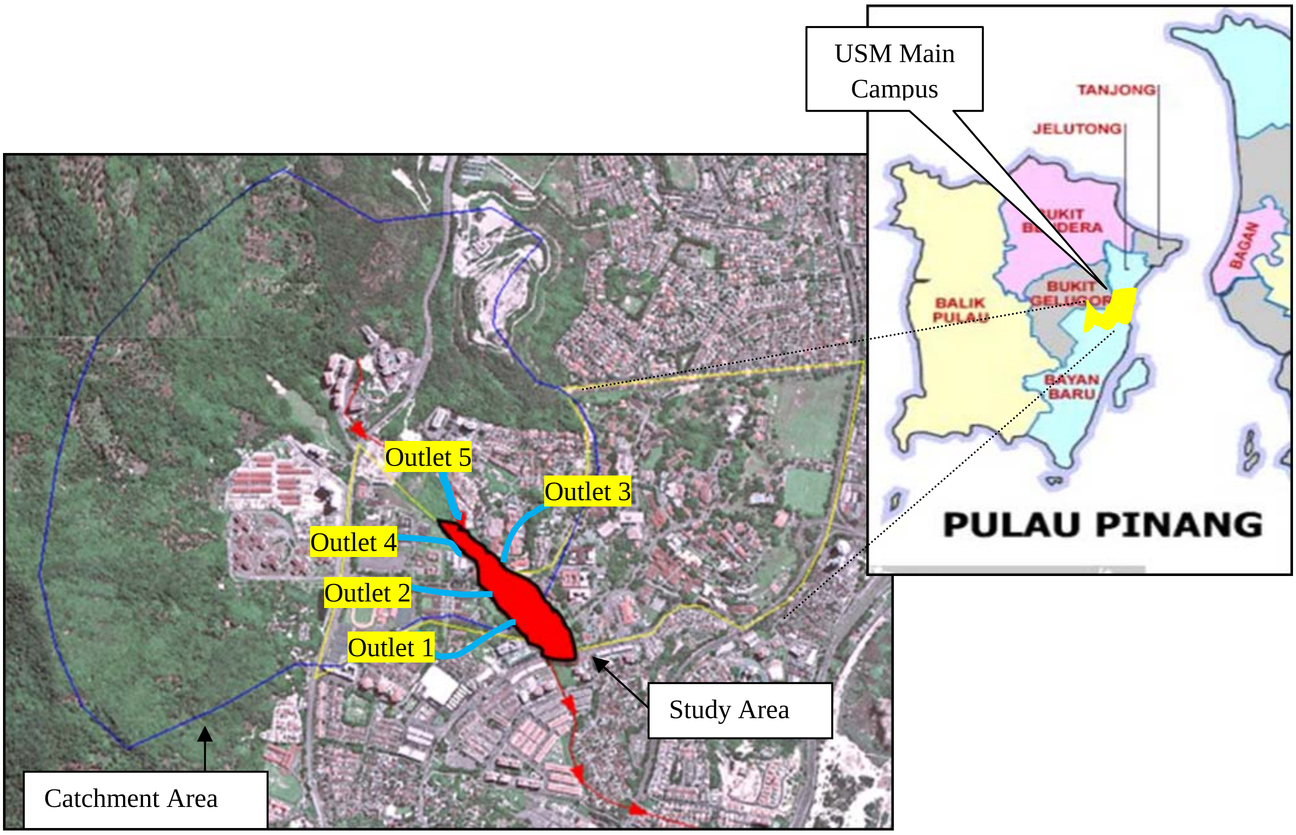

Figure 1 Study area description

3 Methodology

Required data in this study were topographic data for calculating slope, landuse data before and after campus development, Hydrologic Soil Group (HSG) type, rainfall intensity and hydraulic structure parameters. In general, some of the required data and their related sources are listed in Table 1 below.

Table 1 Sources of Required Data

Sources	Types of Data
Development Department of USM Main Campus	The topographic data in AutoCAD drawing format Landuse data before and after campus development in image format as shown in Figure 2
Google Earth	Landuse after campus development in image format
Department of Agriculture	Hydrologic Soil Group (HSG) type in shape file format

However, since no rain gage around the study area, the rainfall design method based on Urban Stormwater Management Manual for Malaysia (MSMA) (DID, 2000) have been applied in this study to determine amounts of the rainfall intensity. Observation and measurement in the field was carried out to obtain hydraulic structure parameters.

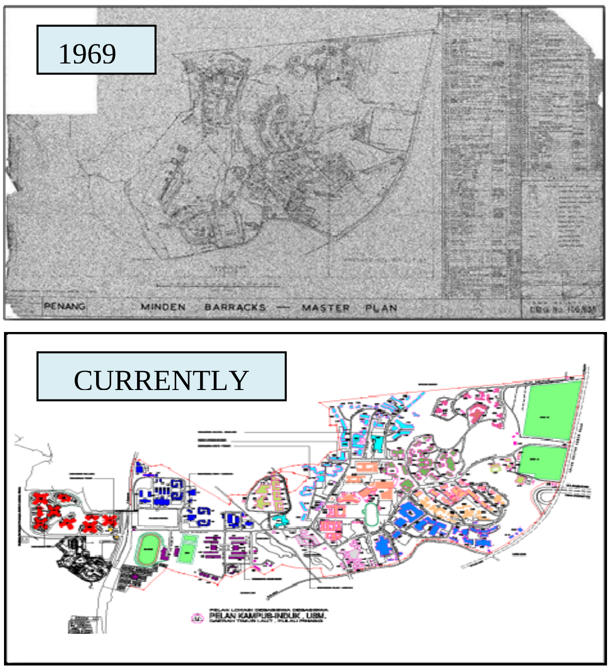

Figure 2 Landuse description (Development Department of USM Main Campus)

This study applied Win-TR55 model to generate the runoff hydrographs before and after campus development. Arcview-GIS was used to calculate areas of subareas inputted into the WinTR-55 software through X-Tool extension.

The runoff area distributions and runoff flow directions before campus development were assumed to be same with after its development. The runoff hydrographs from each outlet before campus development then were compared with runoff hydrographs after campus development and furthermore were analyzed.

3.1 *Win-TR55 modeling concepts*

This study used rainfall intensity for 2 years and 5 years Average Recurrence Interval (ARI). In the starting of the analysis, the total runoff areas were divided into 5 major subareas and 15 sub-subareas. A subarea can consist of single or several sub-subareas depend on runoff flow direction. Each subarea then was connected to 1 outlet at the end through several reaches for conveying the runoffs to the study area. The description of area distributions and runoff flow direction is shown in Figure 3.

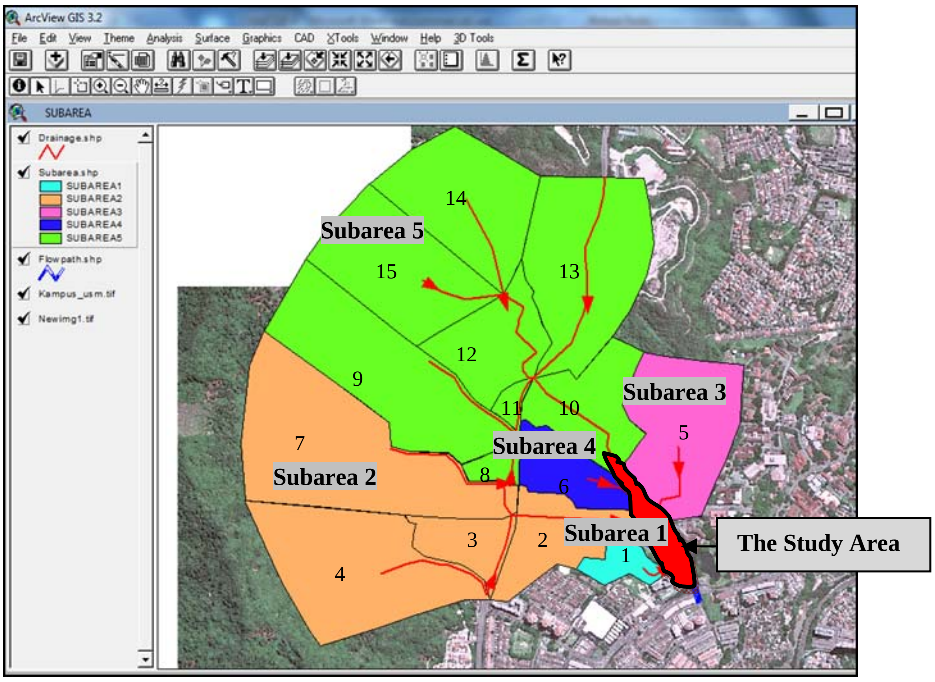

Figure 3 Description of area distributions and runoff flow direction

Win-TR55 model generate hydrographs for each outlet based on SCS method which depends on amount of rainfall intensity, synthetic 24-hr rainfall distribution type, curve number (CN) values and time of concentration (Tc) values.

CN values of each subarea were obtained by inputting HSG type and landuse distribution in each sub-subarea and Tc values were obtained by inputting hydraulic structure parameters. In order to calculate the Tc values for before campus development, data of hydraulic structure parameters for after campus development were assumed to be same with before campus development and however they were differed by the slope and manning values. The slope values used for it were assumed between 2.0-2.5. The CN values and Tc values obtained from the modeling for all sub-subarea in this study then were summarized in Table 2.

Basically, CN values are used to determine the approximate amount of direct runoff from a rainfall event in a particular area based on Equation 1-4 (USDA, 1985). The direct runoff is then transformed into a runoff hydrograph based on travel time (NRCS, 1986). The total travel time is obtained by summing travel time from sheet flow, shallow concentrated and channel flow.

$$q = \frac{(p - I_a)^2}{(p - I_a) + s} \qquad (1, \#2)$$

$$Ia = 0.2S \qquad (2, \#2)$$

$$S = \frac{1000}{CN} - 10 \qquad (3)$$

By changed Ia parameter in Equation 1 to become S parameter based on Equation 2, the new equation become:

$$q = \frac{(p - 0.2S)^2}{p + 0.8S} \quad (4)$$

Where:
A = drainage area (m^2)
q = runoff (mm)
p = rainfall (mm)
Ia = initial abstraction, all losses before runoff begins (mm)
S = maximum potential retention (mm)
CN = curve Number, have a range from 0 to 100 (NRCS, 1986).

Table 2 CN Values and Tc Values for all sub-subareas

No Sub-subarea	CN Values		Tc Values (hours)	
	Before Development (BD)	After Development (AD)	Before Development (BD)	After Development (AD)
1	58	71	0.100	0.198
2	58	78	0.100	0.149
3	58	69	0.100	0.112
4	58	58	0.100	0.102
5	58	82	0.122	0.143
6	58	86	0.100	0.193
7	58	78	0.100	0.130
8	58	88	0.100	0.100
9	58	67	0.100	0.269
10	58	77	0.120	0.188
11	58	72	0.100	0.137
12	58	71	0.100	0.120
13	58	64	0.114	0.139
14	58	58	0.100	0.109
15	58	58	0.100	0.100

3.2 Landuse description for subareas 1 to 5

Based on obtained landuse data, subareas 1 to 5 for before campus development were identified as undulating land with grass and wood combination while after campus development were found 25% development area within subarea 1, 55% development area within subarea 2, 100% development area within subarea 3 and 4 and 30% development area within subarea 5.

3.3 Runoff hydrographs

Runoff hydrographs before and after campus development obtained from the modeling for 2 years and 5 years ARI were compared as shown in Figures 4 and 5. The peak flow rates from each outlet for 2 years and 5 years ARI (before and after campus development) together with percentages of its increment then were summarized in Table 3.

Table 3 The Summary of the Peak Flow Rates from Each Outlet (before and after Campus Development)

No Outlet	Runoff Peak Flows for BD (m^3/s)		Runoff Peak Flows for AD (m^3/s)		% increase at 2 years ARI	% increase at 5 years ARI
	2 years ARI	5 years ARI	2 years ARI	5 years ARI		
1	0.51	0.87	0.72	1.07	41.18	22.99
2	11.20	19.23	19.40	28.58	73.21	48.62
3	2.67	4.64	6.90	9.40	158.43	102.59
4	1.08	1.88	2.56	3.40	137.04	80.85
5	17.49	29.55	21.86	34.12	24.99	15.47

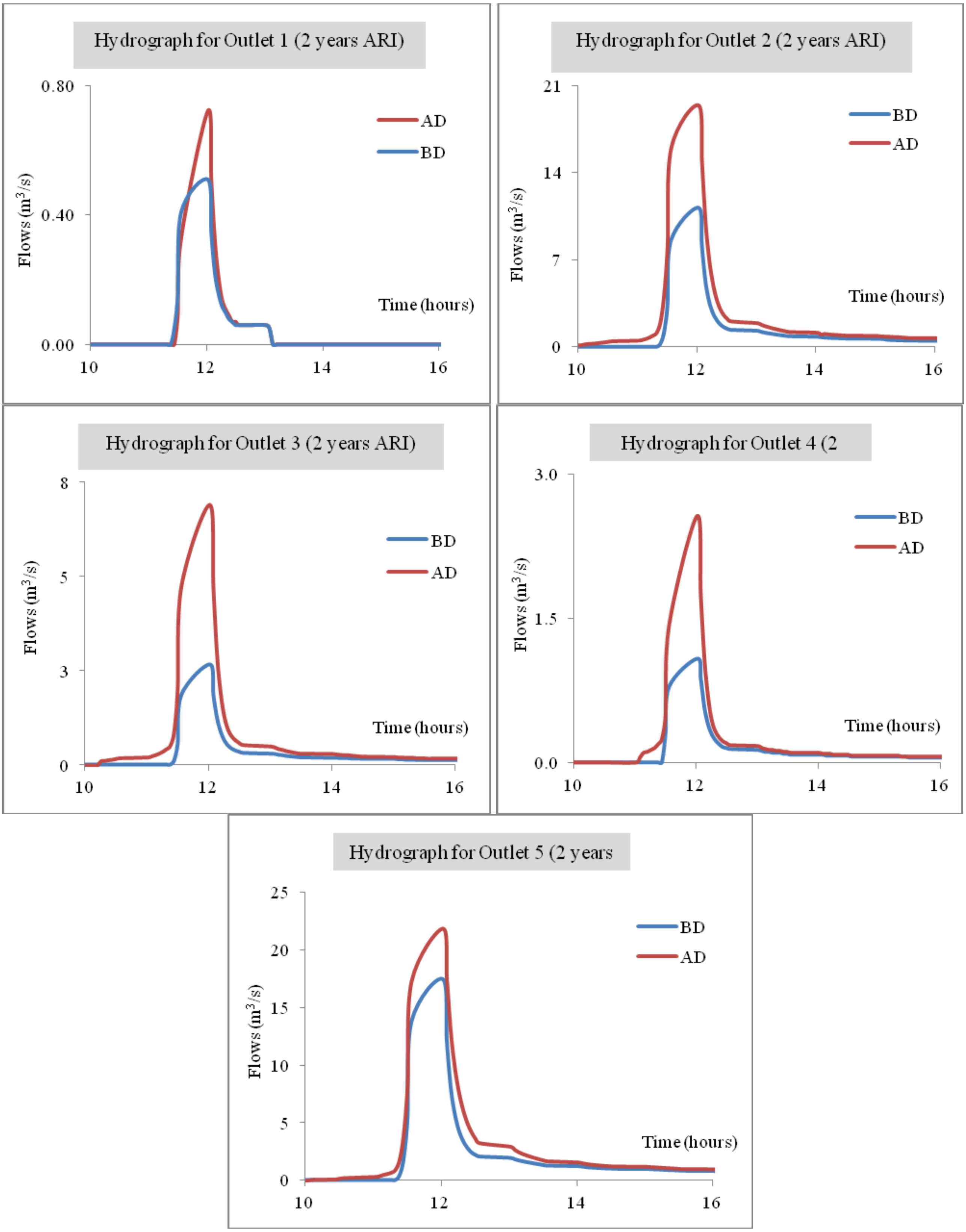

Figure 4 Runoff hydrographs for 2 years ARI

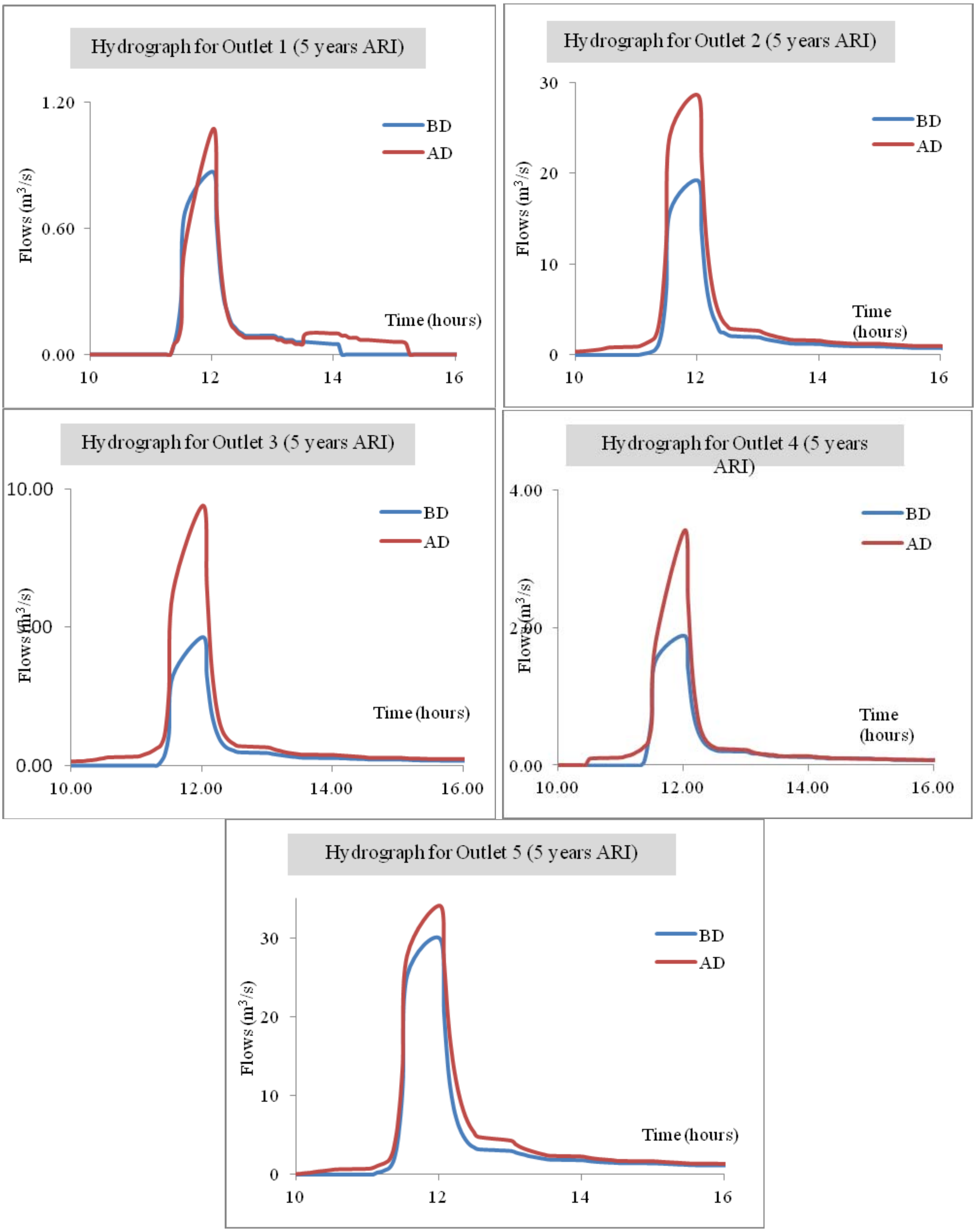

Figure 5 Runoff hydrographs for 5 years ARI

4 Results and discussions

Figures 4 and 5 show that runoff rates after campus development for subarea 1 and 5 with 25% and 30% development area produce the runoff increment smaller than runoff rates for subarea 3 and 4 with 100% development area if it is compared with the runoff rates before campus development. The result also show that runoff rates from subarea 3 increase by 158.43% for 2 years ARI and 102.59% for 5 years ARI while the runoff rates from subarea 5 increase by 24.99% for 2 years ARI and 15.47% for 5 years ARI based on Table 3. It demonstrates that subareas with higher percentages of development area can increase the runoff rates greatly compared with the subareas with lower percentages of development area.

5 Conclusions

Campus development has increased the construction of paved areas. Based on results obtained, it can be concluded that development area within USM Main Campus increase the runoff rates greatly and thus can increase the potential of the flash flood events.

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