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Identification of Flow Behavior Base on Drainage Elevation Profiling

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Abstract Floods are a natural disaster that often occurs every year in this country. Floods occur due to the several factors, but the main factor is due to the failure of the drainage system to accommodate the excessive flow of water. This research is to study the effectiveness of drainage system in Bukit Bakri, Muar, Johor. This area is often flooded when continuous heavy rains. The objective of the study was to identify drainage inventory along study area and to analyze a drainage elevation profiling. This can increase the effectiveness of the drainage system in the area and reduce the risk of flash floods. Using the surveying data that collected at the study area it be assist in proposed a new drainage that more effective. From the result, the highest value of discharge is 3.884 (m^3/s) at chainage 1600 while the lowest discharge of flow is 0.169 (m^3/s) at chainage 2000. The highest value of discharge flow, the more effectiveness of the drainage to flow the water to avoid the flood. It can be concluded, that chainage 1600 more effective to flow the water than the chainage 2000. From the result, the highest value of time concentration is 37 minutes to proposed a new drainage system. With this study, it can reduce the flood at the study area and prevent the loss to flood victims.

Keywords: Floods, Drainage System, Surveying Data

1. Introduction

Malaysia is a country with a hot-humid climate all year round [1]. Malaysia's position at the equator which caused Malaysia to be spared from active volcanic disaster and earthquakes made Malaysia a country less affected by the disaster. However, Malaysia is prone to flood disasters due to Malaysia receiving high rainfall throughout the year. Periodic rainfall of around 2000-2500 mm per year received for the Malaysian tropical rainforest climate [2].

Flash floods often occur in urban areas due to its rapid development. However, flash floods can also occur in rural areas for a few reasons. Many factors that can cause flooding in an area but the main factor is due to the drainage system not working properly. Human activities such as uncontrolled

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littering causing clogged drains and waterways also infrastructure development near the river areas which caused flash floods [3]. The main purpose of drainage system is to flow the water by determining the optimum layout and the proper size of the conduit (pipe or open channel). It also to provide a smooth gradient that keeps the hydraulic integrity requirements within the limitation of the hydraulic design [4].

Drainage system plays a role in collecting rainwater coming from the urbanize surface to control flooding as in the area affected by phenomena of urban sprawl [5]. The importance of the drainage system is to collect the surface water runoff to enter the existing drainage systems [6]. A lot of data that needs to be collected to identify the effectiveness of the drainage system such as studying the flow behavior, area and width of the drainage system to flow water smoothly. By identifying the elevation profiling in the study area can help in planning the drainage system to ensure its effectiveness.

Low areas are more prone to flooding than high areas because the water will flow from high areas to low areas. However, high areas can be flooded if the drainage system does not function properly to flow water to lower areas. Floods are natural disasters that can destroy property and building structures in flooded areas. Floods can be avoided if have a careful strategy and planning in controlling floods and avoid large property losses if flooded occur. Using the survey data to collect data of cross section and long section of drainage, the profile of drainage can be useful to propose a new drainage system.

2. Materials and Methods

2.1 Survey of the study area

The survey has been conducted at the study area at Bukit Bakri, Muar. The survey is to know the information of the existing drainage at that location. There are information's of existing drainage such as:

a) The existing drainage inventory along study area
b) Condition of existing drainage
c) Size of cross-section drainage

2.2 Data of analysis

The data analysis can be done to calculate the information that be needed. The formula to determine the discharge of flow is used the Manning's Equation. It was introduced by the Irish Engineer Robert Manning in 1889 as an alternative to the Chezy Equation and it an empirical equation that applies to uniform flow in open channels and is a function of the channel velocity, flow area and channel slope [7]. In this case study, there are several of data that have been to analyze such as:

a) Discharge of each existing drainage, Q (m^3/s)
b) Manning's, n value
c) Hydraulic Radius, R (m)
d) Slope of the drainage

2.3 Drainage Inventory

To analyzed of this case study, the data from drainage inventory at Bukit Bakri, Muar should be taken to know the surrounding of existing drainage. There are including drainage inventory (concrete and earth drainage) such as:

a) Profile data

To analyze the efficiency of existing drainage, the profile data of drainage is important. There are two type of existing draining which is concrete drainage and earth drainage. The concrete drainage is more effective because the water cannot penetrate the concrete surface and the water will flow smoothly. Meanwhile, the earth drainage is built by natural that built by using soil at surrounding location.

b) Tacheometric survey

Tacheometric survey is carried out to determine the existing drainage parameter and area. All of the details for existing drainage are observed using Total Station. 9 stations have been established to observe the required details area around the existing.

2.4 Assessment of Drainage Capacity

To identify the drainage capacity from the existing drainage is important to know the effectiveness of existing drainage when the heavy rain occur. It is to know the drainage can accommodate the capacity of water to prevent the flood. The flow measurement in Eq.1 is conducted in existing drainage to measure such as:

a) Uniform flow (Manning's equation)

$$Q = (1/n)\, AR^{2/3} \sqrt{S} \qquad \text{Eq. 1}$$

Where,

Q = Discharge of flow (m^3/s)

n = Manning's roughness coefficient

A = Area of drainage

R = Hydraulic Radius

S = Channel slope (m)

This equation is to calculate the discharge of flow (m^3/s) in the drainage to know the effectiveness the drainage system.

b) Hydraulic Radius, R

The hydraulic radius is a measure of channel flow efficiency. The water flow speed depends on the cross-sectional shape, and the hydraulic radius it defines as a ratio of the channel cross-sectional area of the flow to its wetted perimeter. The Eq. 2 was equation for calculated the hydraulic radius.

$$R = \frac{A}{P} \qquad \text{Eq. 2}$$

Where,

R = The hydraulic radius (m)

A = The cross-sectional area of flow (m^2)

P = The wetted perimeter (m)

c) Channel slope (m)

Channel slope will be calculated by different height of the drainage and divided with the distance of drainage. In applied hydraulic, the distance that recommended is 250 meters to 300 meter in calculated the channel slope. The Eq. 3 is to calculate the channel slope that can be used in calculate the discharge of flow.

$$S = \frac{Different\ height}{Distance} \qquad \text{Eq. 3}$$

2.5 Time of concentration (t_c)

In the design of stormwater drainage systems, t_c is the sum of the overland flow time (t_o) and the time of travel in small streams or channels (t_d). The Eq. 4 was to calculate the time concentration (t_c) to estimate the storm of duration.

Time of concentration $t_c = overland\ flow\ t_o + Drain\ flow\ t_d$ Eq. 4

The relevant equations necessary to calculate the t_c is given in Table 1 [8]. The overland time t_o can be estimated with proper judgement of the land surface condition due to the fact that the length of sheet flow is short for steep slopes and long for mild slopes. This equation shall be applied only for distances (L) recommended in Table 1.

Table 1: Equations to estimate time of Concentration [8]

Travel Path	Travel Time	Remark
Overland Flow	$t_o = \frac{107.n^*.L^{1/3}}{S^{1/5}}$	t_o = Overland sheet flow travel time (minutes) L = Overland sheet flow path length (m) *for Steep Slope (>10%), L ≤ 50 m* *for Moderate Slope (<5%), L ≤ 100 m* *for Mild Slope (<1%), L ≤ 200 m* n^* = Horton's roughness value for the surface (Table 2.2) S = Slope of overland surface (%)
Curb Gutter Flow	$t_g = \frac{L}{40\sqrt{S}}$	t_g = Curb gutter flow time (minutes) L = Length of curb gutter flow (m) S = Longitudinal slope of the curb gutter (%)
Drain Flow	$t_d = \frac{n.L}{60R^{2/3}S^{1/2}}$	n = Manning's roughness coefficient (Table 2.3) R = Hydraulic radius (m) S = Friction slope (m/m) L = Length of reach (m) t_d = Travel time in the drain (minutes)

Typical value of Horton's roughness n^*s for various land surfaces is given in Table 2 [8]. This value used while calculating overland flow t_o.

Table 2: Values of Horton's Roughness n^* [8]

Land Surface	Horton's Roughness n^*
Paved	0.015
Bare Soil	0.0275
Poorly Grassed	0.035
Average Grassed	0.045
Densely Grassed	0.060

3. Results and Discussion

3.1 Tacheometric Survey

The process to produce the existing drainage geometry profile started with the tacheometric survey. The survey data is to obtain ground level at instrument station and to produce the detailing and profile of each existing drainage. The data from tacheometric that have been inserted in SDR Mapping will be transferred into the AutoCAD and the geometry profile for earth drainage is produced by using AutoCAD software. Figure 1 shows the plan of existing drainage that have been completed. From the plan, the data of cross section and long section of drainage can be obtained. The length of drainage is around 2 Kilometer from Parit Keling to Parit Pateri.

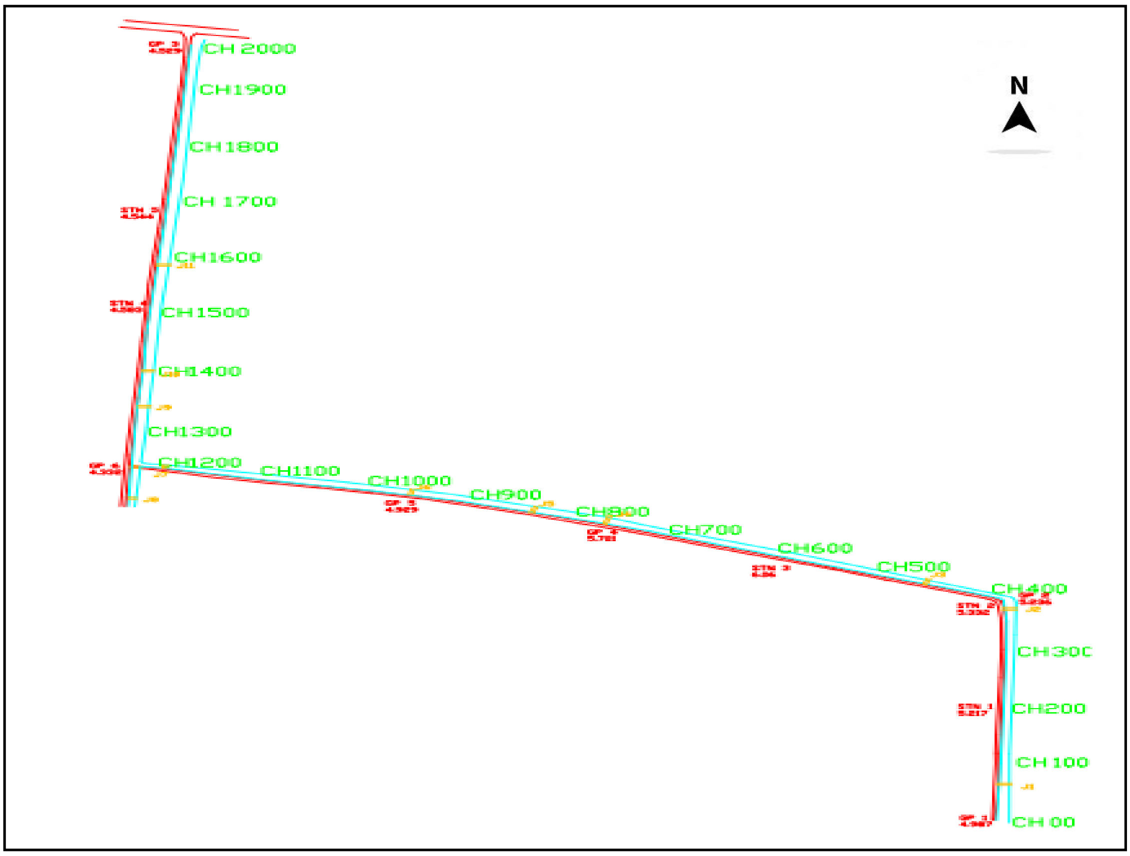

Figure 1: Plan of existing drainage at Parit Keling and Parit Pateri

3.2 Analysis data of cross-section for existing drainage

The analysis of data is to analysis of cross section of drainage to know the area and perimeter of each drainage. From the result of calculation of the area and wetted perimeter can be used to calculate the discharge of flow in each drainage. The Figure 2 was cross section of trapezium that can help in calculate the area Eq. 5 and wetted perimeter Eq. 6. The Table 3 was the calculation of the area, wetted perimeter and hydraulic radius Eq. 7 from chainage 0 until chainage 2000

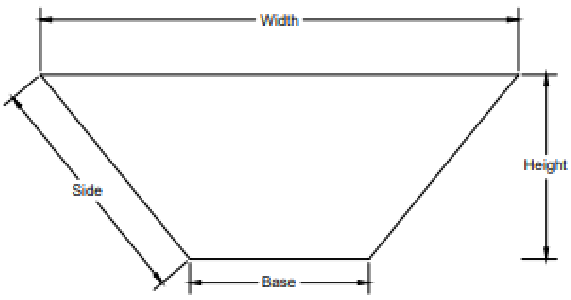

Figure 2: Cross section of trapezium

$$\text{Area} = \frac{1}{2} \times (Height) \times (Width + Base) \qquad \text{Eq. 5}$$

$$\text{Wetted Perimeter} = Side + Side + Base \qquad \text{Eq. 6}$$

$$\text{Hydraulic Radius} = \frac{Area}{Wetted\ perimeter} \qquad \text{Eq. 7}$$

Table 3: Area and perimeter of each drainage

CHAINAGE	Height (m)	Width (m)	Base (m)	Area (m^2)	Wetted Perimeter	Hydraulic Radius (R)
00	0.23	8.58	4	1.75	8.61	0.204
100	0.32	6.99	4	1.40	7.06	0.199
200	0.38	5.32	2	1.40	5.41	0.260
300	0.30	4.13	2	0.93	4.21	0.220
400	0.55	2.46	2	1.23	3.20	0.385
500	1.01	4.35	3	3.69	5.42	0.682
600	0.47	4.73	2	1.56	4.88	0.320
700	0.51	4.63	2	1.69	4.82	0.352
800	0.31	4.50	2	1.01	4.57	0.222
900	0.51	5.06	2	1.80	5.22	0.344
1000	0.62	4.60	2	2.05	4.88	0.420
1100	0.84	4.81	2.5	3.06	5.35	0.571
1200	0.24	2.24	2	0.50	2.53	0.199
1300	0.50	4.32	1.5	1.46	4.50	0.324
1400	0.93	5.78	3	4.10	6.35	0.646
1500	0.85	6.51	3	4.03	6.90	0.584
1600	0.89	5.71	3	3.89	6.25	0.622
1700	0.30	4.99	3	1.18	5.08	0.232
1800	0.20	5.36	4	0.94	5.41	0.173
1900	0.44	5.74	3	1.92	5.88	0.327
2000	0.15	4.95	3	0.60	4.97	0.122

3.2 Estimate of storm duration

Storm of duration is important in proposed the new design of drainage system. From this storm duration we can estimate the duration that be use to proposed the new drainage to avoid floods from occur. The data that be collected in this storm of duration is time of concentration t_c. The storm duration must be proposed bigger than time of concentration t_c.

(a) Slope in drainage

Slope can be calculated by using the long section of data that be collected by the survey. The center of chainage depth is used to calculate the slope in drainage. The Table 4 was the center of depth in chainage 0 until chainage 2000 while the Figure 3 and Figure 4 was the long section of the drainage from chainage 0 until chainage 2000. The data of slope is required in calculating the Manning's Equation and also for time concentration t_c. The Table 5 was the result calculation of the slope for chainage 0 until chainage 2000.

Table 4: The center of depth chainage 0 until chainage 2000

Chainage	Center (Depth)	Chainage	Center (Depth)
0	3.222	1100	1.989
100	3.222	1200	2.574
200	2.711	1300	2.413
300	2.978	1400	1.775
400	2.826	1500	1.998
500	2.251	1600	2.079

600	2.821	1700	2.442
700	2.674	1800	2.537
800	3.046	1900	2.593
900	2.315	2000	2.431
1000	2.778		

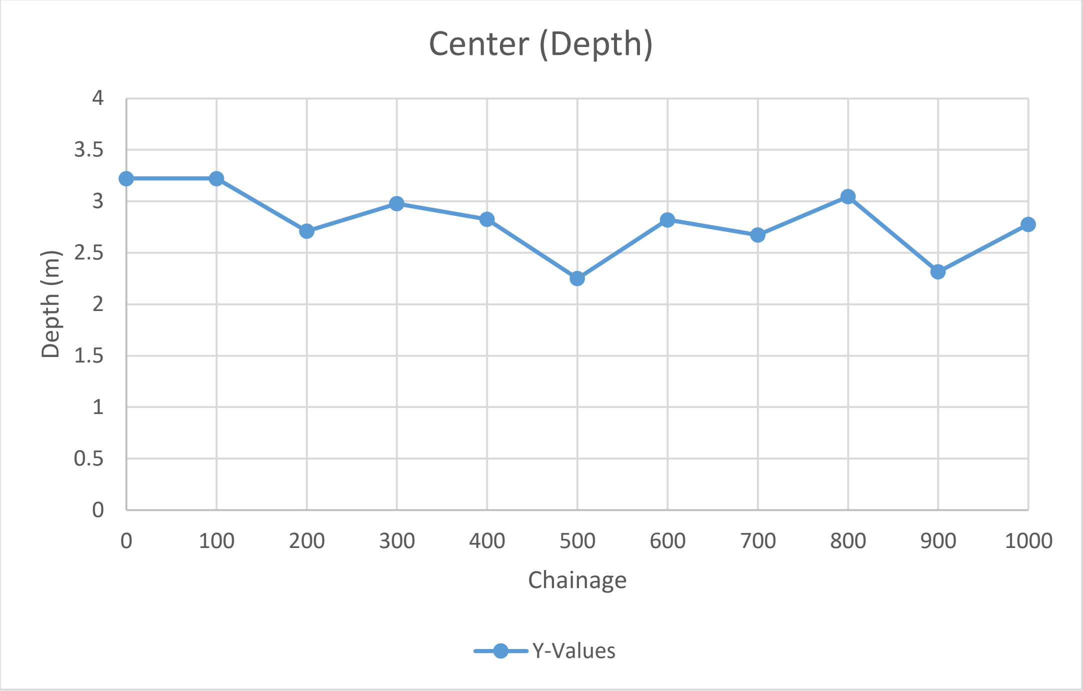

Figure 3: The long section of the drainage from chainage 0 until chainage 1000

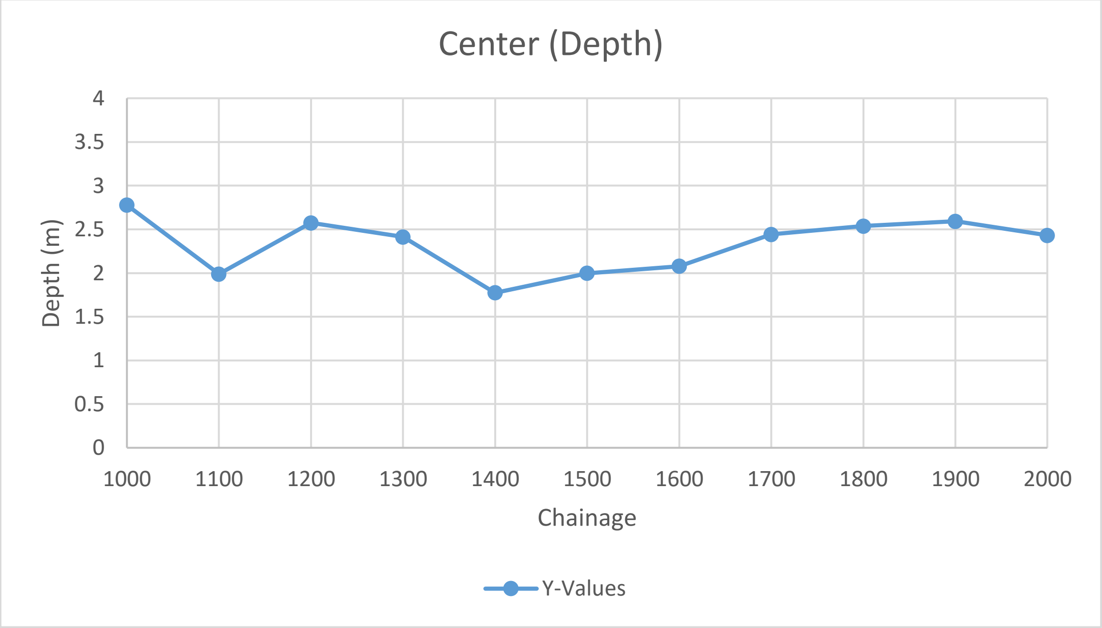

Figure 4: The long section of the drainage from chainage 1000 until chainage 2000

Table 5: The slope in drainage

CHAINAGE	SLOPE
0 - 300	$\frac{3.222-2.978}{300}=0.0008$
300 - 600	$\frac{2.978-2.821}{300}=0.0005$
600 - 900	$\frac{2.821-2.315}{300}=0.0017$
900 - 1200	$\frac{2.574-2.315}{300}=0.0019$
1200 - 1500	$\frac{2.574-1.998}{300}=0.0019$
1500 - 1800	$\frac{2.537-1.998}{300}=0.0018$
1800 - 2000	$\frac{2.537-2.431}{200}=0.0005$

(b) Time of concentration (t_c)

Time of concentration of runoff flows from the most hydraulically remote point upstream in the contributing catchment area to the point under consideration downstream. The Table 6 was the result of calculation of the overland flow (t_o) from the Eq 9 while drain flow (t_d) from Eq 10 and time of concentration (t_c) from Eq 8. All the data time of concentration (t_c) be calculated for each drainage.

Time of concentration $t_c = Overland\ flow\ t_o + Drain\ flow\ t_d$ Eq. 8

Overland flow $t_o = \frac{107\,n\,L^{1/3}}{S^{1/5}}$ Eq. 9

$$t_o = \frac{107\ (0.035)\ (100^{\frac{1}{3}})}{(0.08^{\frac{1}{5}})} = 29\ min$$

Drain flow $t_d = \frac{n.L}{60\ R^{2/3} S^{1/2}}$ Eq. 10

$$t_d = \frac{(0.035)(100)}{60\left(0.204^{\frac{2}{3}}\right)(0.0008^{\frac{1}{2}})} = 6\ min$$

Table 6: Time of concentration

CHAINAGE	Overland flow (t_o)	Drain flow (t_d)	Time of concentration (t_c)
00	29	6	35
100	29	6	35
200	29	5	34
300	29	6	34
400	32	5	37
500	32	3	35
600	32	6	37
700	32	5	37
800	21	3	24
900	21	2	23
1000	21	2	23

CHAINAGE	Overland flow (t_o)	Drain flow (t_d)	Time of concentration (t_c)
1100	21	1	23
1200	24	4	28
1300	24	3	27
1400	24	2	26
1500	24	2	26
1600	23	2	25
1700	23	3	27
1800	23	4	27
1900	25	3	28
2000	25	6	31

3.3 Discharge flow (m^3/s)

Discharge of flow is to know the effectiveness of each drainage and can be calculated by using the area of drainage and hydraulic radius that get from Table 3. The equation that be used is Manning's Equation. The Table 7 was the result of discharge flow for each chainage from 0 until chainage 2000 that have been calculated.

Manning's equation $Q = \frac{1}{n} AR^{2/3}\sqrt{S}$

$$Q = \frac{1}{0.035}(1.75)\left(0.204^{\frac{2}{3}}\right)\sqrt{0.0008} = 0.4904\ m^3/s$$

Table 7: Discharge of flow (m^3/s)

CHAINAGE	Discharge of flow (m^3/s)
00	0.490
100	0.483
200	0.461
300	0.274
400	0.417
500	1.828
600	0.468
700	0.539
800	0.627
900	1.490
1000	1.942

CHAINAGE	Discharge of flow (m^3/s)
1100	3.556
1200	0.214
1300	0.856
1400	3.815
1500	3.508
1600	3.884
1700	0.610
1800	0.398
1900	1.043
2000	0.169

4. Conclusion

Based on this study, the existing drainage at location of this study is less effective in the process to convey the flow of storm water runoff may be due to several factors such as the continuous rain occur that would cause overflow of drainage and flooding. By using the survey data on the site, the drainage inventory along the study case can be identify with collected the data of the cross section and long section of the drainage. The data that be collected can be analyzed to know the method that can be used to proposed a new drainage system. The data from the survey can be analyzed to calculate the area of drainage and wetted perimeter to get the hydraulic radius. The data of area, wetted perimeter and hydraulic radius can be referred in Table 3. All this data is important in calculate the discharge flow of each drainage to know the effectiveness of the drainage. From the result of the discharge flow in Table 7, the highest of the discharge flow is at the chainage 1600 with the value of discharge flow is 3.884 (m^3/s) while the lowest discharge flow at chainage 2000 with the value of discharge is 0.169 (m^3/s). The highest value of discharge flow, the more effectiveness of the drainage to flow the water to avoid the flood. It can be concluded, that chainage 1600 more effective to flow the water than the chainage 2000. For the storm duration, the time concentration t_c can be referred in Table 6. From the result, the highest value of time concentration is 37 minutes. So, to proposed the new drainage system the storm duration that can be used must exceed 37 minutes.

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