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Evaluation of Existing Drainage Capacity for Flood Mitigation Measures at Segamat, Malaysia

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Abstract: The drainage system is used for controlling, management, or convey the storm water into certain areas. The system is used to prevent the entry of water into the soil structure and reduce the strength and durability of the ground. The present study aimed to evaluate the existing drainage capacity and propose a conceptual flood mitigation measures. The study area was located at Kampung Paya Lang, Segamat with two types of drainage system included concrete and earth drainage. Determintion of the rainfall hydrograph was investigated in the site area, survey of existing drainage (cross-section), drainage profile and flow measurement in each existing drainage. The data of rainfall was analyzed in XP SWMM software to know the storm water movement when the existing drainage is not properly well. The rainfall data were obtained from Department of Irrigation and Drainage (DID) in the form of hours and minutes for nearby rain station for a period of 10 years from 2006 to latest. Therefore, the inventory for each drainage should fulfill the requirement of MSMA. The results revealed that the existing drainage was less effective in the process to convey the flow of storm water runoff due to the continuous rain occur that would cause overflow of drainage and flooding. The existing concrete drainage and earth drain was less effective to prevent the occurrence of flooding situation in every catchment area at the study area location.

Keywords: Drainage system, runoff mode (RNF), hydraulics mode (HDR), XP-SWMM software analysis, Segamat

1. Introduction

A flood is defined as any high water flow that dominates the natural or artificial banks in any part of the river system. Therefore, when a river bank is overtopped, the water extends over the flood plain and generally becomes hazard to the society (Ching et al., 2013). There are no formal categorizations of floods in Malaysia but is often broadly categorised as monsoonal, flash or tidal floods (DID, 2014). Floods are described based on its location, characteristics, the cause (NFRA, 2011). In Malaysia the type of flood is classified under the category of river flooding, where the whole area of East Coast including the state of Pahang, Terengganu and Kelantan are under the effect of Northeast monsoon season with high precipitation combine with high tide.

A river flood occurs when water levels rise over the top of river banks due to excessive rain from tropical systems making landfall and persistent thunderstorms combined rainfall over the same area for extended periods of time (Boren, 2010). This is the major cause of flooding extensive areas as a result of heavy rains in the catchment areas as well as local areas thereby increasing the river levels that can cause major rivers to overflow their banks. Therefore, the present study aimed to evaluate the existing drainage capacity at Kampung Paya Lang, Segamat as well as to propose a conceptual flood mitigation measure.

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2. Materials and Methods

2.1 Study Area

The study area of the current work was located at Kampung Paya Lang, Segamat which has two types of the existing drainage iunclude concrete drainage and earth drainage. The existing drainage system at this location contribute effectively in causing flood.

2.2 Data Collection

The information collected in the present study included, Length of existing drainage, Cross-section of drainage, Depth, d (m) and width, b (m) of existing drainage, Profile of existing drainage and Velocity, v (m/s) dry season. These data were analysed to get the parameter of the existing drainage such as Discharge of each existing drainage, Q (m^3/s), Hydraulic Radius, R (m), and Manning's, n value.

The rainfall data was obtained from Department of Irrigation and Drainage (DID) in the form of hours and minutes for nearby rain station for a period of 10 years from 2006 to latest. The land survey was conducted at the study area to know the information of existing drainage. The information's of existing drainage included Condition of each existing drainage, Flow of water in existing drainage, Size of concrete drainage and earth drainage (cross-section).

2.3 Drainage Inventory

Tachymetry survey was carried out to determine the existing drainage parameter and area. All of the details for existing drainage was observed using Total Station. Seventeen stations have been established to observe the required details area around the existing drainage at site location. The observation data from the details included ground northing, ground easting and elevation for every point of the details.

2.4 Assessment of Drainage Capacity

The flow measurement was conducted in existing drainage at Kampung Paya Lang to achieve the flow data from each existing drainage. They included; Uniform flow (Manning's equation); Flow velocity (*v*) and Hydraulic radius, *R*. The uniform flow was computed from the Manning's Equation:

$$Q = AV \tag{1}$$

$$Q = \left(\frac{1}{n}\right) A R^{\frac{2}{3}} \sqrt{S} \tag{2}$$

where Q is Discharge of flow water (m^3/s), A is Cross-sectional area of flow (m^2), V is Channel velocities (m^2/s), n is Manning's roughness coefficient, R is Hydraulic radius = A/P, P is Wetted perimeter, and S is Channel slope (m).

The actual discharge, Eq. (1) was calculated to get the value of Manning's, n with using Manning's Eq. (2). The Manning's n equation was used to calculate the velocity of flow in open channel and the basic equation used for computing the velocity by the Manning's, n method is:

$$V = \left(\frac{K}{n}\right) R^{\frac{2}{3}} \sqrt{S} \tag{3}$$

where, V is the cross-sectional average velocity (m^2/s), K is conversion constant equal to 1.486 for U.S customary or 1.0 for SI units, n is the Gauckler- Manning's coefficient (independent of units), R is the hydraulic radius, and S is the slope of the water surface

The hydraulic radius is a measure of channel flow efficiency. Flow speed along the channel depends on its cross-sectional shape, and the hydraulic radius is a characterization of the channel that intends to capture such efficiency and its define as the ratio of the channel cross-sectional area of the flow to its wetted perimeter.

$$R = \frac{A}{P} \tag{4}$$

where R is the hydraulic radius (m), A is the cross-sectional area of flow (m^2), and P is the wetted perimeter (m).

2.5 Modelling Using XP-SWMM Software

Two modes included runoff mode (RNF) and hydraulics mode (HDR) were used XP-SWMM software analysis. RNF is working by interpreting the provided rainfall data to provide the maximum runoff flow and the total rainfall occurred at study area. In contrst, HDR was used to analyze the runoff mode. Water from RNF mode was used as input for hydrological mode in which the movement of water from rainfall data drained via the connecting links representing as the surrounding drains at research site.

The characteristics of the catchments and drainage system components, which included the drainage of inlet and outlet, were modeled in the XP-SWMM using the link-node concept. The calibration of Storm Water Management Model (SWMM) is performed using rainfall storm event provided by DID based on rainfall data from 2006 until 2016. The rainfall data on the end of 2006 and early 2007 (02 November 2006 until 09 January 2007) is analyzed in runoff mode in order to determine flow (m^3/s) based on rainfall event at 4 catchments in Kampung Paya Lang.

2.5.1 Drainage Modelling

The Storm Water Management Model (XP-SWMM) was used to model the hydrologic catchment processes and to simulate the hydraulics of existing drainage system. The link-node model of XP-SWMM was used to represent the characteristic of the catchment and drainage system. A link represents a hydraulic element of flow in the system where the model offers many different types of conduits for simulation. The node represents a point junction to represent a point of change in channel or conduit geometry, or a boundary condition in the model. A node also represents the junction of hydraulic elements (links). The storm water runoff hydrograph is generated from catchment area enters the drainage system through the node.

3. Results and Discussion

3.1 Geometry profile of existing drainage

The process to produce the existing drainage geometry profile started with tachymetry and hydrographic survey. The survey data was conducted to obtain ground level at instrument station. The data of overall survey was processed in AutoCAD software to produce the detailing and profile of each existing drainage. The process to produce each existing drainage area is presented in Fig. 1, which show that the volume for each existing drainage in simulation model was 50.57 x 10^3 m^3.

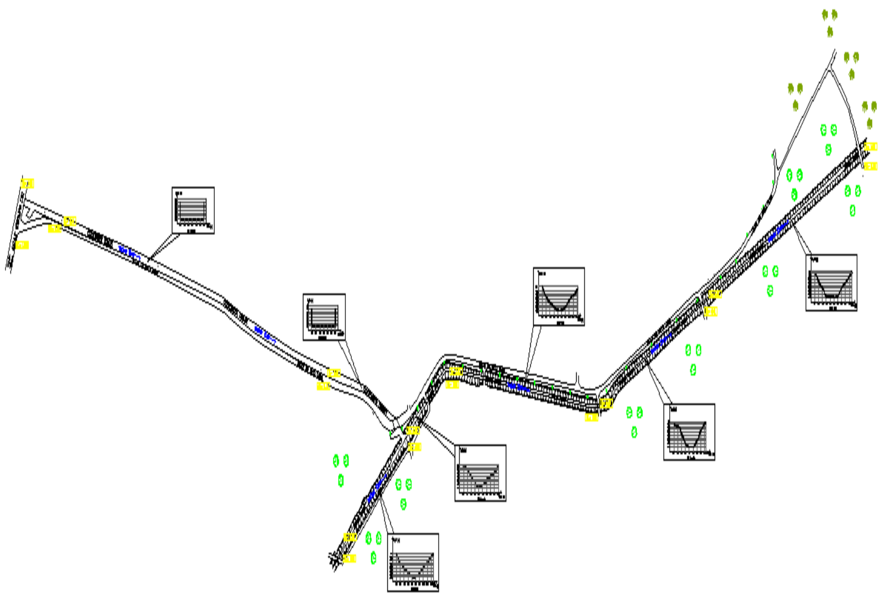


Fig. 1- Concrete and drainage plan at Kampung Paya Lang.

Next, the survey data for each existing drainage was performed using Microsoft Excel software to produce cross-sectional drawing for each drainage. There are several parameters has been considered as the input for the software such as the coordinate of the point and the depth for each point. Based on input data, the depth distribution of existing drainage for each cross-section can be seen clearly. The example of existing concrete and earth drainage are as in Fig. 2.

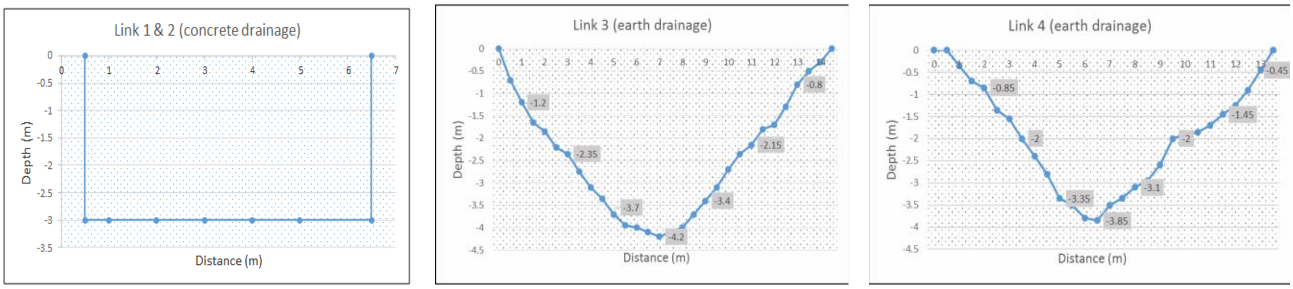
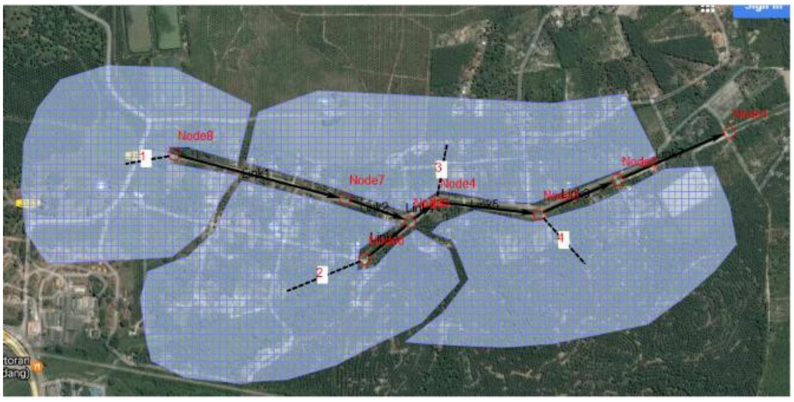


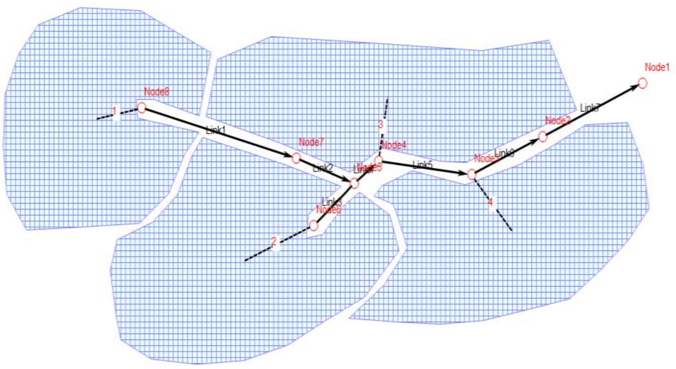
Fig- 2: Cross-section existing drainage for Link 4

3.2 XP-SWMM Data Analysis

Model for simulation using XP-SWMM software was created for the study area. This model was intended to obtain data about the effectiveness of the existing drainage in the event of rainfall. Fig. 3(a) shows the study area used in this software. Fig. 3(b) shows eight nodes have been made to produce simulations for the study area. Nodes 3, 4, 6 and 8 is the place where water flows in from the catchment area. In addition, Node 5 is a junction of concrete and earth drainage. Nodes represent the hydrological data that should be included in this model. By using this software, "link" is translated as drainage systems or closely related to the hydrology system which is size and profile drainage and also the cross section of the existing drainage.



(a)



(b)

Fig. 3- (a) Model for simulation using XP-SWMM software in Kg Paya Lang, and (b) Location Link and Node in model in XP-SWMM software.

Based on the model, the surface runoff for catchment 1 area is routed to the Node 8, catchment 2 is routed to the Node 6, catchment 3 is routed to the Node 4 and catchment 4 area is routed to Node 3. The area for each catchment as shown in Table 1.

Table 1- Area for every catchment in model

No of Catchment	Area (hectare)
1	27.97
2	33.04
3	27.31
4	27.74

3.2.1 Hydrologic Data

Based on rainfall data from Department of Irrigation and Drainage (DID) for 10 years rainfall event (2006 until 2016), the rainfall data on the end of 2006 and early 2007 (02 November 2006 until 09 January 2007) is analyzed in runoff mode in order to determine flow (m^3/s) based on rainfall event at 4 catchment in Kampung Paya Lang.

3.2.2 Runoff (RNF) Mode Analysis

Runoff mode (RNF) was used to analysis rainfall data in order to determine flow rate value for every catchment in the designated model. The rainfall data (02 November 2006 until 09 January 2007) is inserted using constant time travel method and acts as intensity for every 5 minutes time interval. The Annual Rainfall Intensity (ARI) for 10 years and 100 years is inserted to know the comparison in XP-SWMM result. This method is chosen in order to design the worst condition of rainfall event for the whole model system. Fig.4 shown the graph for rainfall data using ARI 10 years and 100 years in design model.

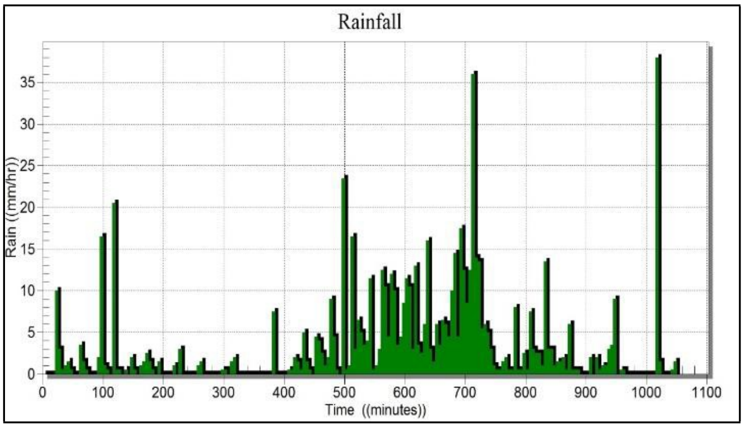


Fig. 4 - The graph rainfall (mm/hr) against Time (min) for rainfall data

From the analysis of rainfall data (between ARI 10 years and 100 years) in runoff mode (RNF), it is found that the flow rates value from every catchment to node. The difference flow rates value as shown in Table 3.

Table 1 - Flow rate data between 10 years and 100 years ARI

Location	Catchment area (ha)	Flow rates ARI 10 years (m^3/s)	Flow rates ARI 100 years (m^3/s)
Catchment 1 to Node 8	27.98	63.78	115.97
Catchment 2 to Node 6	33.04	77.61	140.69
Catchment 3 to Node 4	27.31	70.40	126.51
Catchment 4 to Node 3	27.74	60.47	110.53

Based on the Table 3, the highest flow rates is 77.61 m^3/s for ARI 10 years and for ARI 100 years is 140.69 m^3/s in Node 6 because the area of catchment 2 is most large with another catchment. From this data, it can be concluded that the area for every catchment is influenced with flow rates and the maximum flow rates occurred during the hydrology rates occur too often with high value. The graph for flow rates against time for every node can be refer in Fig. 5.

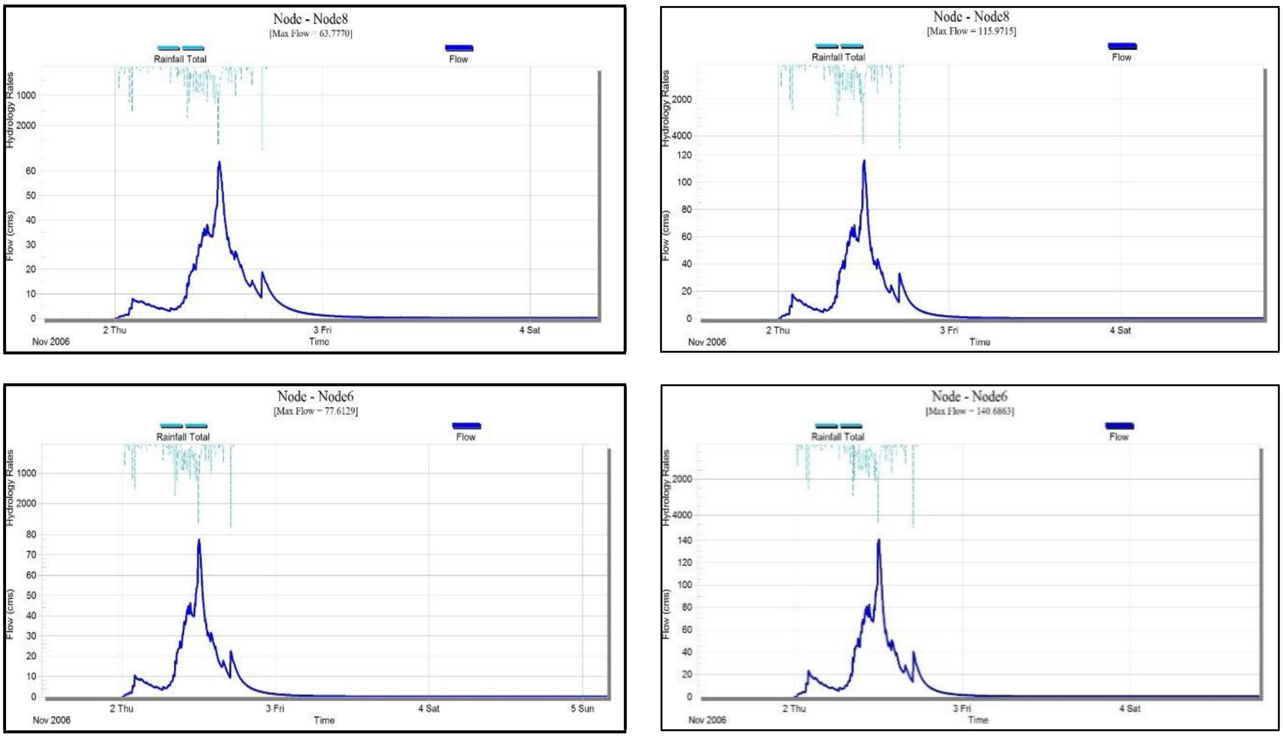


Fig. 5 - Runoff (RNF) mode result for Node 6 ARI 100 years

3.3 Hydraulics (HDR) Mode Analysis

Hydraulics mode (HDR) was used to simulate the storage and transport of water through a drainage or river network. The water flow characteristic in node and link can be determine by reviewing result in HDR mode. The result of maximum stage and maximum overflow for each node can be determined such as in Fig. 6a. Furthermore, the result for upstream elevation, downstream elevation, water flow and velocity for every links (existing drainage) is provided by software. The example result for link in HDR mode can be determined such as in Fig. 6b.

Maximum stage values in HDR mode for every node is referred to the maximum stage of water (in meter) for every node based on the setting time. Next, maximum overflow value in result is referred to the volume of water (m^3) flooding out from the node. This value from this result is important to determine the effectiveness of node to accommodate runoff storm water. The highest overflow value, the less effective of node to accommodate storm water.

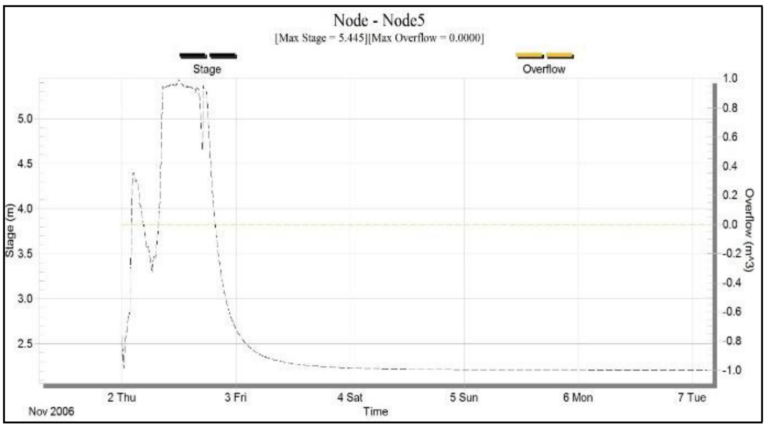


Fig. 6 - Hydraulics (HDR) mode result in Node 5 (IDF 10 years)

Based on Fig. 6, the overflow value result for Node 5 (drainage junction) is 0 m^3, hence, it means there is no water flooding away from junction of concrete and earth drainage. This because the ground level at this node is highest from maximum stage of water. The remaining HDR mode analysis results for every node can be referred to Table 4.

Table 2 - HDR mode analysis result for every nodes using ARI 10 years and 100 years

Node	Catchme	Max Stage (ARI 10yr)	Max Stage (ARI 100yr)	Max Overflow (ARI 10yr)	Max Overflow (ARI 100yr)
Node 1	1,2,3,4	4.	4.	172.63	178.
Node 2	1,2,3,4	5.	5.	1.	2.
Node 3	1,2,3,4	5.	5.	2.	7.
Node 4	1,2,3	5.	5.	11.	23.
Node 5 (junction	1	5.	5.	0	0
Node 6	2	5.	6.	0	0.
Node 7	1	5.	5.	3.	11.
Node 8	1	6.49	6.88	0	0.92

According Table 4, the result in HDR mode is difference between ARI 10 years and 100 years. The value maximum overflow for Node 1 is highest than another node because the invert level is lower between another node. Besides that, the rainfall value data for ARI 10 years and 100 years is influenced with value overflow for every node. It can be concluded that the increase of IDF in rainfall data, the value of overflow will be increase.

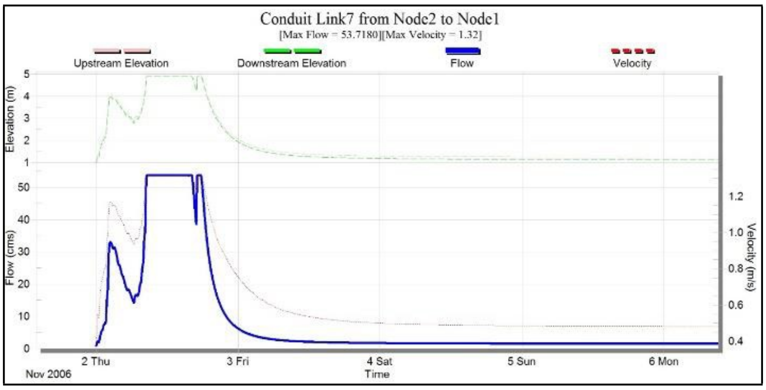


Fig. 7 - Hydraulics (HDR) mode result in Link 7 (Node 2 to Node 1) in ARI 10 years

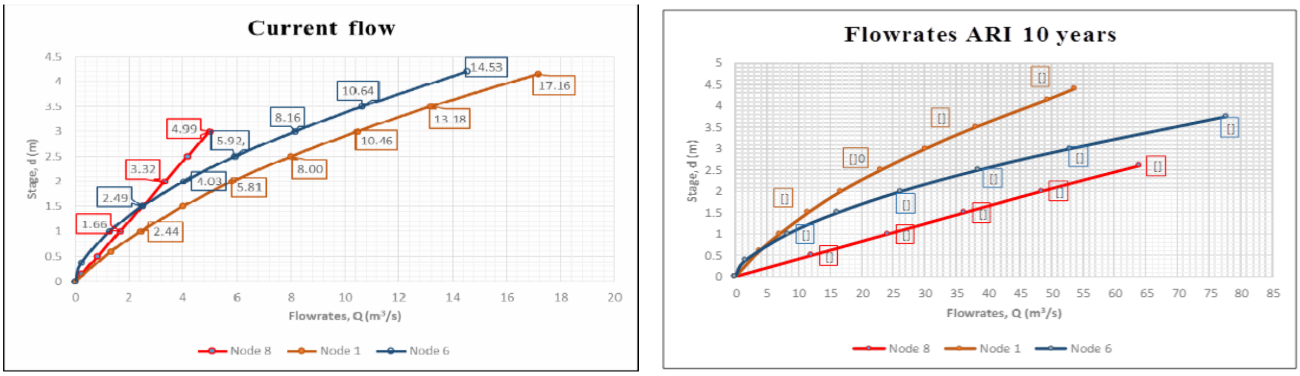
Based on Fig. 7, the blue line shown the value of maximum flow and red line shown the maximum velocity in HDR mode in Link 7 which is 53.72 m^3/s and 1.32 m/s. The remaining result for link (ARI 10 years and 100 years) in HDR mode shown in Table 5.

Table 3. The result for every link in HDR mode. (IDF 10 years and 100 years)

Li	Catchme	Velocity	Velocity	Flow Rates	Flow Rates
Link 1	1	4.	4.	63.	69.
Link 2	1	1.	1.	22.	-
Link 3 (earth)	2	2.	3.	77.	125.
Link 4 (earth)	1	2.	3.	78.	96.
Link 5 (earth)	1,2,3	1.	1.	48.	50.
Link 6 (earth)	1,2,3,4	2.	2.	61.	61.
Link 7(earth)	1,2,3,4	1.32	1.32	53.72	53.71

Based on Table 5, the maximum flow rates in this simulation at Link 3 using ARI 100 years. This can be concluded that the flow rates for every link in HDR mode influenced with Annual Rainfall Intensity (ARI). For value flow rate at Link 2 (concrete drainage) is -30.56 m^3/s using ARI 100 years and this mean the back flow occur in this link.

Fig. 8 shows the comparison of stage discharge curve between current flow and flow rates ARI 10 years in simulation model. The flow value in Fig. 8(a) is measured in dry season, so it can conclude that the maximum flow for dry season 17.16 m^3/s at Node 1 because the location at downstream for existing earth drainage and location upstream for this simulation model at Node 8 for existing concrete drainage. Fig. 9 also shown the maximum value for flow rates using ARI 10 years but this value is obtain from result hydraulic (HDR) mode data in simulation model.



(a) (b)

Fig.8 – (a) Stage discharge curve for current flow (b) Stage discharge curve for flow rates ARI 10 years

In hydraulic (HDR) mode, there is another graphical output for result analysis which is Dynamic Section View. This output allow the user to see a dynamic view of the flow and associated Hydraulic Grade Line (HGL) along with a cross-section view of the links and hydrograph. Fig. 9 shows the dynamic section view in HDR mode from Node 8 to Node 1 using ARI 10 years and 100 years.

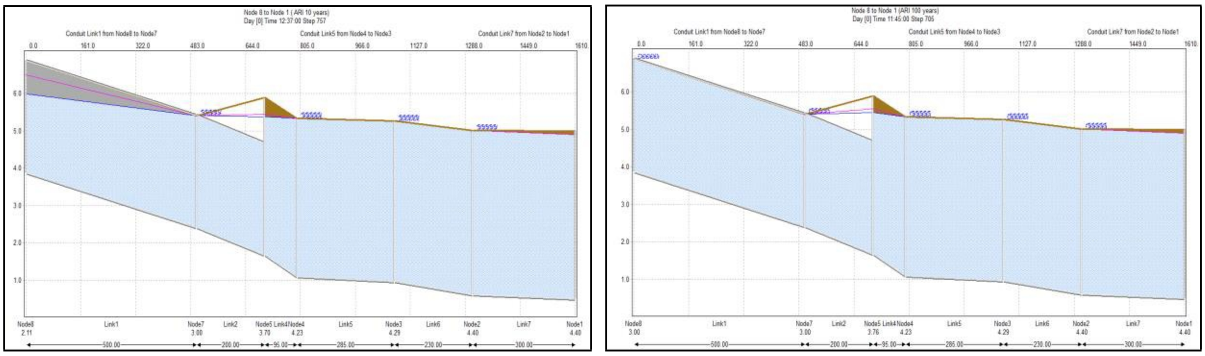


Fig. 9 -Dynamic section view result in HDR mode from Node 8 to Node 1 (ARI 100 years)

Based on Fig. 9, the magenta line shows the maximum hydraulic grade line (HGL) occurring during simulation process and the blue line shows the water grade line according to time step. The length value of link (drainage) is shows in x-axis and the y-axis shows the level elevation thus the ground level and water level for each section. In addition, the wave shape in dynamic section view means there is overflow occur on that section or flooding occur. From this result, it can be concluded that every section is overflow occur in this simulation. Dynamic section view for each link from Node 6 to Node 1 can be referred in Fig. 10.

In dynamic section view, the result display cross-section view of the downstream end of each link such as in Fig. 11. The figure shows hydraulics grade line from downstream view within selected link and the red dashed line indicated the maximum water elevation for selected link. If there is no red dashed, it is means the links (drainage) is full with water runoff and probability for overflow occur.

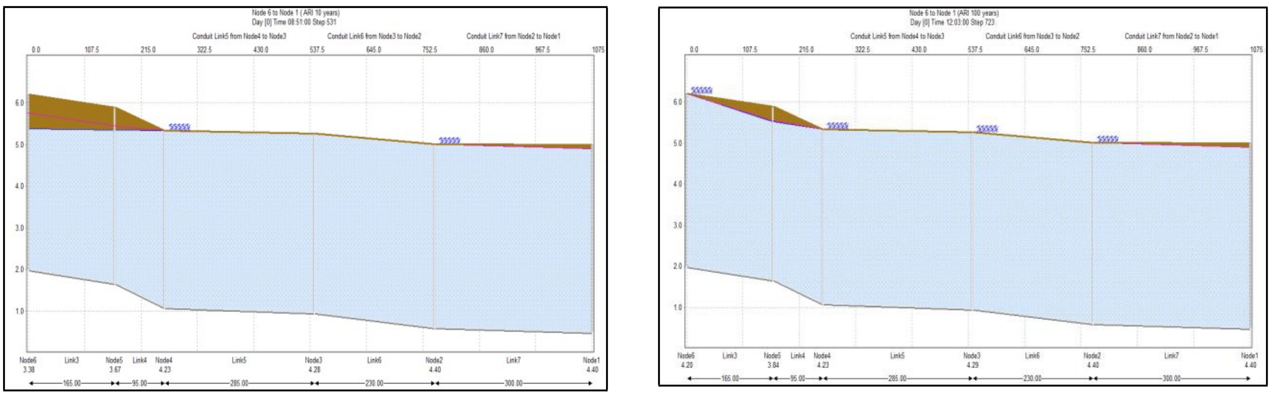


Fig.10- Dynamic section view result in HDR mode from Node 6 to Node 1 (ARI 100 years)

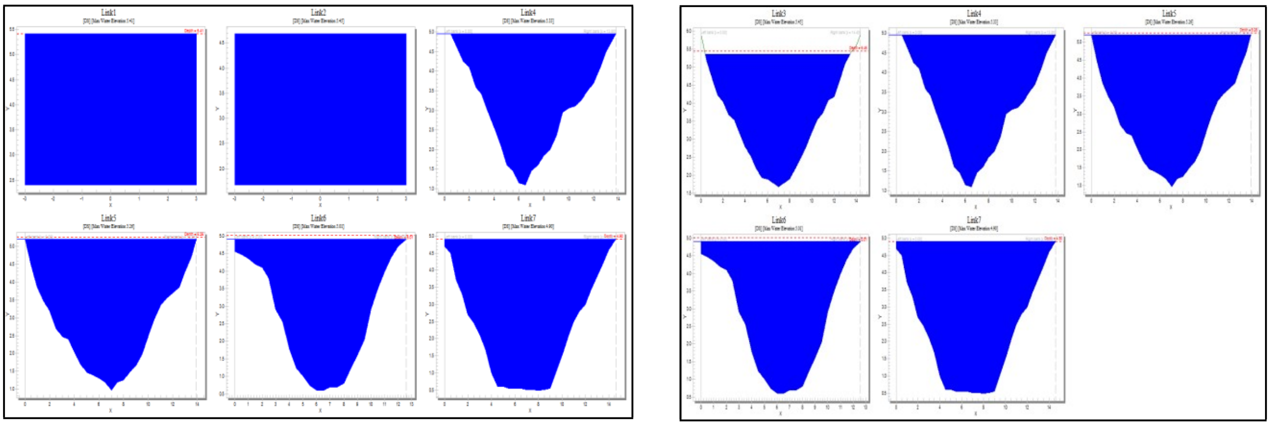


Fig.11-Links cross-section from Node 6 to Node 1 (ARI 10 years).

4. Conclusion

It can be concluded that the present volume of existing drainage is not sufficient to stored storm water runoff from every catchment area. Based on result in XP-SWMM software, the proposal of conceptual flood mitigation measures need to be conducted in the future work for example enlargement of existing drainage profile and build the storage or pond to store the storm water runoff from the catchment area when the continuous rainfall occur. Therefore, the design flood mitigation plan is viewed appropriate alternatives for accommodate the surface runoff in the study area. As the conclusion, the use of modern equipment in the survey works and use computer software to analyze the data is more practical because it can ease the work for future engineer. The process of obtaining the necessary data and time can also be minimized.

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