Redesign Drainage Channel in Jetis District Mojokerto Regency

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Abstract. There are up to 50-centimeter-high puddles on the road due to the Jetis Road Drainage Channel in Mojokerto Regency's incapacity to handle the flood discharge from the drainage catchment area. The Jetis Road drainage channel's size and channel bed slope will be affected by the meeting point of the 1000 m long secondary channel and the Jetis Road drainage outlet. The objective of this research is to evaluate the efficiency of drainage channel design considering the implications of the drainage existing condition due to inconsistent dimension and sedimentation. The drainage channel is designed to handle a total discharge of 4.6 m^3/sec during 10 years return of period. Under these circumstances, a trapezoidal channel with a width of one meter and a depth of two meters is needed. The Jetis Road drainage channel's enlarged dimensions result in a flood water level of 1.8. The Jetis Road drainage channel has a freeboard of 0.2 meters since the flood water level that occurs in the channel with its new dimensions is 1.8 meters. The flow rate in the intended channel serves as the control in this study to determine channel size. The channel's maximum flow velocity of 1.44 m/sec satisfies the 1.5 m/sec maximum flow velocity allowed in concrete channels.
Keywords: drainage, open channel flow, hydraulic, channel dimensions

1. Introduction

Infrastructure development and land use changes can have an impact on runoff discharge in each area. Thus, a drainage system which can accommodate runoff discharge is required. Drainage is a water structure that function to collect water runoff in a catchment area, allowing both the area and the infrastructure in the drainage catchment area to function properly [1]. The catchment area is determined by the specific type of coverage provided by the drainage system. The catchment area for roadways is the width of the roadway's structure as well as the surrounding region [2], [3]. Policymakers and city dwellers alike are facing an increasing amount of difficulty when it comes to urban innovation. As a result, flood assessment is becoming more and more significant globally. Many indicators in urban catchments are included in this thorough assessment, but correct evaluation is greatly hampered by the high-dimensional and non-linear relationship between the indices and the risk [4].

Mojokerto is one of the cities that has experienced substantial changes in land use as infrastructure development has occurred. Jetis District is one of an area in Mojokerto that is experiencing development. There are numerous industrial and residential developments in this sub-district. The current land already has a drainage channel that functions to accommodate runoff discharge in the area. However, the drainage channel can no longer handle the flood discharge that occurs. Thus, causing flooding in roadway. Problems like sewer overflows and rising urban flooding that causes a spike in the amount of pollutants entering recipient water bodies are quickly spreading as these systems become less effective [5]. Redesigning the dimensions of the existing drainage channel is one of a solution to this problem because the limitation of the land which can be utilized for minimizing flooding. The existing drainage channel capacity is 2.1 m^3/sec, while the run off discharge according to 10-year period return is 4.5 m^3/sec. Thus, it is required to redesigning the channel's width existing from 2 m and depth 1,5 m to its requirement. Effective stormwater discharge is made possible by well-designed drainage systems, which lowers property losses and recovery costs [6].

Several studies have been carried out to redesign drainage channels. Inundation problems within Surabaya's densely populated residential neighbourhoods have been solved by redesigning the drainage dimensions [7], [8], [9], [10], [11]. The improperly designed slope of some canals is another factor contributing to this kind of flooding. Certain roads flood because there are no street inlets, which prevents water from flowing to the side channels [10]. The dimensions of the drainage channel that will be studied in this study is in Jetis Road, Jetis District, Mojokerto Regency. The catchment area and the tertiary channel that relies into this channel are used to determine the dimensions of the drainage channel. Thus, the flooding problem on Jetis road can be resolved. The objective of this research is to determine the efficiency of drainage channel design to accommodate the maximum discharge for 10 years return of period according to the regulations.

2. Materials and Methods

2.1 Methods

Drainage functions accommodate water surplus to be discharged rapidly to prevent negative effects. Rain and area runoff can also contribute to surplus water. The rational method using the following formulation can be used to analyse a flood discharge plan for a catchment area less than 500 ha [12]

$Q = 0.00278\ CIA$ (1)

$I = (R_{24}/24)\ (24/t)^{2/3}$ (2)

Where:

Q = discharge (m^3/det)

C = coefficient runoff

I = rainfall intensity (mm/jam)

A = catchment area (hectare)

Flow velocity is the control for channel dimensioning. The following formula can be used to redesign the dimensions of the drainage channel [13]

$Q = V.\ A$ (3)

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$V = (1/n).\ R^{2/3}.\ S^{1/2}$ (4)

Where:

Q = discharge (m^3/det)
A = wetted area (m^2)
R = hydraulic radius (m)
S = channel slope

2.2 Materials

This study carried out the primary and secondary data. The primary data is a survey result for existing drainage channel dimension. The secondary data is for the rainfall data which collected from Mojokerto Regency government. According to Figure 1, the rain gauge that close to the study location is Wates. Thus, the rainfall data that will used in this study is from Wates rain gauge during 10 years, as shown in Table 1. This study's channel is 1100 m long and flows into a secondary channel that flows into the river, as shown in Figure 2.

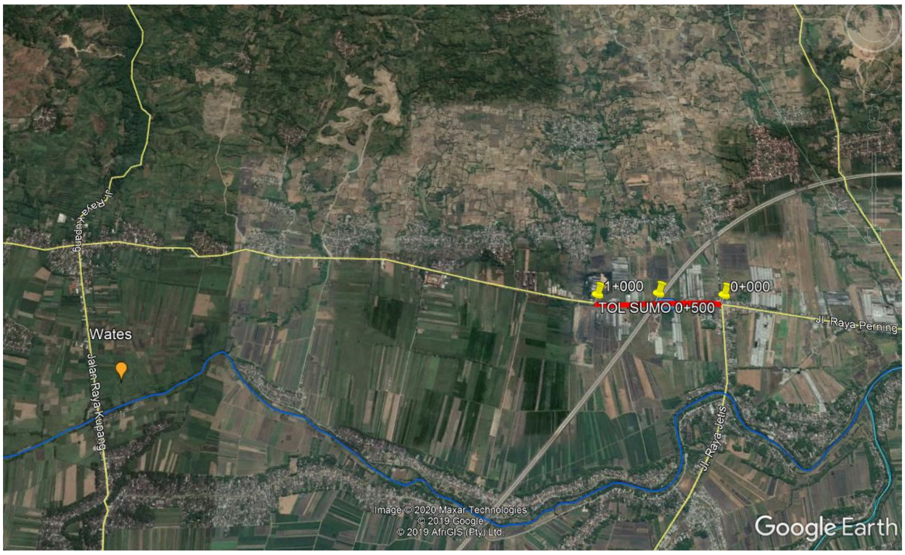

Figure 1. Project Location and Rain Gauge

Table 1. Annual Maximum Daily Rainfall in Wates Gauge

Year	**Annual Maximum Daily Rainfall (mm)**
2011	106.00
2012	106.00
2013	69.00
2014	45.00
2015	68.00
2016	78.00
2017	90.00
2018	90.00
2019	73.00

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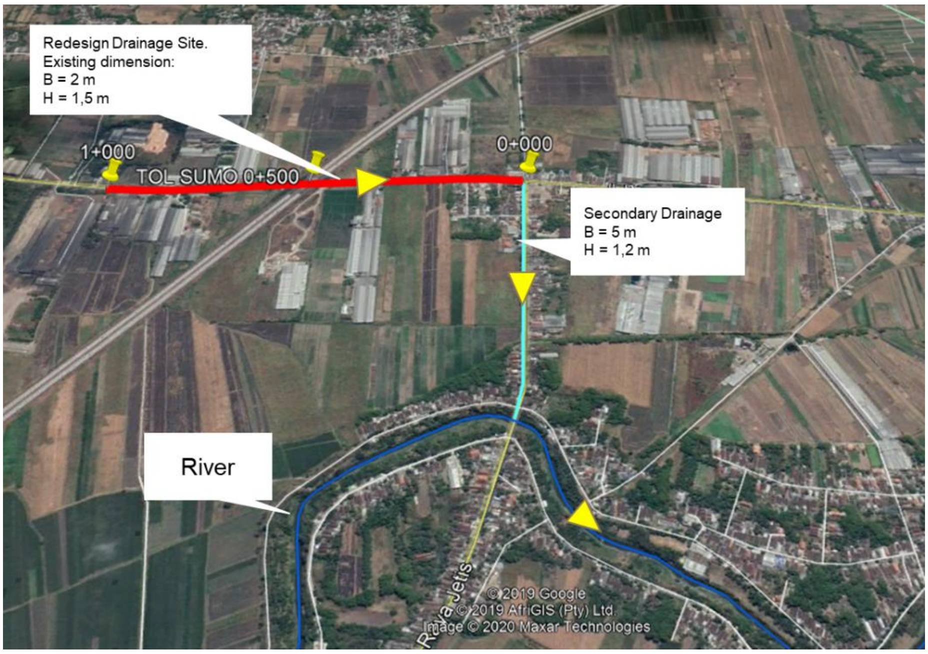

Figure 2. Drainage System Scheme

Figure 3. Drainage Channel's Existing Condition

According to Figure 2 and 3, the existing drainage channel's dimension measurement before the redesigning is 2 m for the width and 1,5 m for the depth. The existing channel has various rough and base channel slope due to sedimentation, thus this condition decreased the channel's capacity. The road width in this study is 8 m and the side width is 20 m, thus the total width is 28 m and the the road length is 1000 m. Thus the Catchmen Area for the drainage channel is 0.028 km^2.

3. Result and Discussion

3.1 Runoff Analysis

Rainfall contributes for the runoff discharge that the channel is designed to accommodate. In this study, the distribution for the rainfall use Gumbel distribution method and Log Pearson Type III. According to Table 2, the highest rainfall distribution result is for Gumbel distribution, 117 mm. As the annual maximum daily rainfall in Table 1, the highest value is 106 mm. Thus, the result of the rainfall distribution in Table 2 is align with historical rain data that has occurred.

Table 2. Rainfall Distribution

Return Period (Year)	Rainfall Distribution (mm)	
	Gumbel	Log Pearson III
2	78.64	81.43
5	102.10	98.20
10	117.64	106.52

According to rainfall distribution result, the runoff analysis using the Equation 1 and 2 is shown in Table 3.

Table 3. Runoff Discharge

CA (km²)	L (km)	S	Tc (hour)	I (mm/hour)			C	Q (m³/sec)		
				2 Years	5 Years	10 Years		2 Years	5 Years	10 Years
0.02800	1	0.0061	0.5	44.9	58.3	67.2	0.95	0.33	0.43	0.50

Table 4. Drainage Channel Existing Capacity

B channel	H channel	A	P	R	S	n	V	Q
(m)	(m)	(m²)	(m)	(m)			(m/det)	(m³/det)
2.0	1.5	3.0	5.5	0.55	0.0013	0.035	0.70	2.41

According to the regulation [2] the Catchment Area in Table 3 is determined based on the road width and the length. The maximum flood discharge that occurs in the drainage service area of 0.028 km² for 10 year return period is 0,50 m³/det. Based on applicable regulations [14], with the condition of Jetis Road being in a big city, determining the dimensions of the new channel will use flood discharge with a return period of 10 years. The drainage channel is designed to have capacity to accommodate the discharge from both Catchment Area and existing channel as shown in Table 4. The total discharge that is planned to be accommodated in the planned channel, apart from rain, also comes from tertiary channels around the planned channel of 2.1 m³/sec and puddle discharge of 2 m³/sec, so the total discharge that will be accommodated is 4.5 m³/sec.

3.2 Dimension and Hydraulic Profile Anaylisis

The existing drainage condition of Jetis Road does not have various channel shapes and is formed from soil channels. The planned drainage is made of concrete and has a trapezoidal shape. Based on Table 5, the planned width of the channel base is 1 m and the depth of the channel is 2 m, while the slope of the channel base is planned to be 0.0046. The Manning coefficient value for concrete channels is 0.011 – 0.035 [15]. Thus, by using Equation 3, it is known that the planned channel can accommodate a discharge of up to 5.41 m³/sec.

Table 5. Re-design Dimension

B channel	H channel	z	A	P	R	S	n	V	Q
(m)	(m)	(m)	(m²)	(m)	(m)			(m/det)	(m³/det)
1.0	2.0	0.4	3.6	5.308	0.68	0.0046	0.035	1.50	5.41

The control for planning the dimensions of this drainage channel is the flow speed. The allowable flow velocity for concrete channels is 1.5 m/sec [2], Based on the results of the flow velocity analysis in Table 4, with the planned dimensions it is known that if the channel experiences fullbank, then using Equation 4 the flow velocity that occurs still meets the permit requirements. Meanwhile, if a Q_{10} of 4.6 m³/sec occurs, then in the channel there will be a water depth of 1.81 m with a flow speed of 1.44 m/sec as in Table 5.

Table 4. Water Depth and Velocity with Q_{10}

B channel	H water	z	A	P	R	S	n	V	Q_{10}	W
W(m)	(m)	(m)	(m²)	(m)	(m)			(m/det)	(m³/det)	(m)
1.0	1.81	0.4	3.1	4.901	0.64	0.0046	0.035	1.44	4.50	0.20

This study takes the freeboard (w) into account in addition to the flow velocity value as a control in channel size planning. This freeboard prevents overtopping of the canal by acting as a safety measure. According to channel planning standards [16], For channels with concrete embankments, the freeboard is between 0.1 and 0.2 meters. The freeboard in the plan dimensions is known to be 0.2 meters based on Table 4 and Figure 4, in order for these circumstances to comply with the relevant criteria.

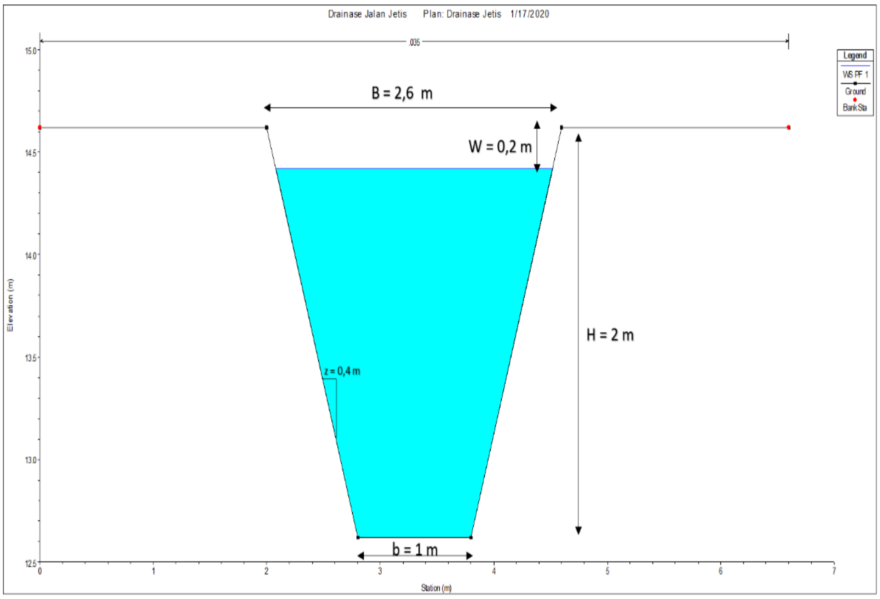

Figure 4. Re-design Drainage Channel Detail

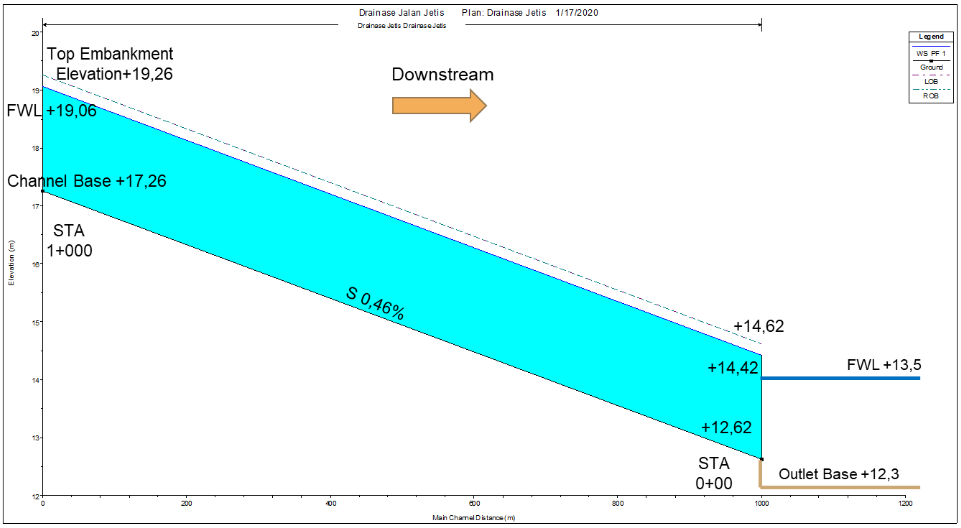

Figure 5. Hydraulic Profile in Drainage Channel

Since the Jetis Road drainage channel empties into a secondary channel, as shown in Figure 2, the flood water level and the channel base must be considered when calculating the size and slope of the channel base in Table 4. The planned channel can still flow by gravity if the secondary channel experiences a maximum flood water level at an elevation of +13.5 m, according to a simulation of the flow profile in the planned channel and the condition of the downstream secondary channel in Figure 5. In contrast, the maximum flood surface elevation is at the Jetis Road channel's outlet point, which is +14.42 m.

6. Conclusion

The conclusion for this study is Jetis drainage system has to be completely redesigned with a total flood discharge for 10 years return period is 4.6 m^3/sec. The channel satisfies the maximum velocity requirements for concrete channels since it is designed in a trapezoidal shape with a width of 1 m, a maximum depth of 2 m. The flood water level depth for new dimension is 1.8 m, thus the channel has the freeboard 0,2 m. The velocity in maximum run off is 1.44 m/sec, thus the value is less than 1.5 m/sec. According to the new channel dimension, the maximum channel capacity is 5.41 m^3/sec.

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