

Study of Drainage Channel Capacity in Tebalo, Gresik District

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Abstract

The growth of Gresik City is shown by the development of various infrastructures such as settlements, highways, and others. Along with the growth of Gresik City area, an increase in flood inundation due to increasingly dense settlements, decrease of vacant land as an infiltration area in Tebalo Village. Flooding is caused due to lack of development of drainage systems in the area of Tebalo Village. To normalize Tebalo drainage channel, good planning must be prepared for Tebalo drainage channel system including planning the layout of the channel system, calculating the designed flood discharge for each channel, hydraulics analysis for flood flow conditions and also along high sea water tide conditions, and finally designing the dimensions of the channel. After the channel is normalized, it is expected that the flow would be much smoother so that no flooding occurs.

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Keywords: Type your keywords here, between 3 and 6, separated by semicolons.

1. Introduction

Based on field observations, it is known that the flood inundation is caused by Jl. K. H. Syafi'i in Tebalo Village which is unable to accommodate flood discharge, accumulated by sedimentation in several sections of the channel due to lack of maintenance, and some narrowed channel sections that need some improvements. The contour pattern of the land in the area is relatively flat; which results in inevitably slow flowing water. High flood inundations an average of 20 cm to 25 cm were found, the puddle causes the road and part of the residents' houses around the channel area to be submerged.

Therefore, in order to deal with the puddle, a good and integrated drainage system planning is needed so that it can reduce flood discharge in the drainage channel in Jl. K. H. Syafi'i in Tebalo Village. The result would be to create the flood-free, clean, orderly, and healthy environmental areas.

The water flowing through Tebalo drainage system is coming from the northern area of Jl. Dr. Wahidin Sudirohusodo, going north along the K. H. Syafi'i, and then flows west; joining the Tebalo primary channel plan and finally empties

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into Manyar river. To minimize the flood discharge flowing from upstream, the drainage system planning concept of Tebalo channel which is located on the northern side of Jl. Dr. Wahidin Sudirohusodo will have to be united with Banjaranyar channel located on the southern side of Jl. Dr. Wahidin Sudirohusodo. The dimensions of Tebalo channel are designed based on the flood discharge calculated by its catchment areas. Later, these catchment areas would be likely built with higher elevation building; so that both channels will receive runoff from the road surface and residential areas beside the road.

Map of drainage channels on Jl. K. H. Syafi'i in Tebalo Village at coordinates: Latitude $7^{\circ} 23'48''$ S Longitude $112^{\circ} 39'08.67''$ T with the length of channel is 479 m.

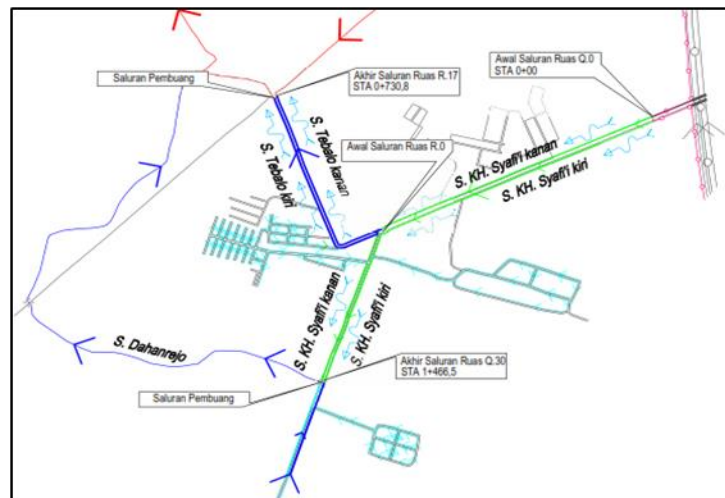


Fig.1 Tebalo Channel Scheme

1.1 Problems

Regarding the flood inundation that occurs around the drainage channel on Jl. K. H. Syafi'i in Tebalo Village, there are several important issues as follow:

1. What are the designed flood discharges values for Q₂, Q₅, and Q₁₀ in the drainage channel on Jl. K. H. Syafi'i in Tebalo Village?
2. What are the dimensions requirements of the drainage channel on Jl. K. H. Syafi'i in Tebalo Village in the return period of 2, 5, and 10 years?

1.2 Purposes

The objectives of the drainage channel capacity assessment on Jl. K. H. Syafi'i in Tebalo Village are:

1. Analyze the designed flood discharge values for Q₂, Q₅, and Q₁₀ drainage channel on Jl. K. H. Syafi'i in Tebalo Village.
2. Evaluate the ability of existing channel capacity toward the designed drainage channel discharge on Jl. K. H. Syafi'i in Tebalo Village.
3. Calculate the Budget Plan (RAB) for the construction of Tebalo Channel.

2. Theoretical

2.1 Drainage System

According to Sidharta S. K., et al., 1997, in general, drainage is defined as science that studies the efforts to drain excess water in particular utilization contexts. Drainage is defined as the removal of surface or ground water from an area, either gravitationally or by using a water pump through a channel.

2.2 Hydrological Analysis

According to Soedibyo, 2003, the purpose of hydrological analysis is to calculate the water discharge for the need of channel design. Hydrological analysis is carried out in order to determine the validity of the data obtained, such as rainfall data, flood discharge data, and many others. These data will later be processed to determine the design discharge; and so, this simply shows the importance of hydrological analysis role.

2.3 Rainfall Data

Rainfall data is needed to calculate the amount of flood discharge for the plan. The rainfall data analyzed in this assessment is taken from the rainfall stations in Gresik City area (Cahyono, 2018).

2.4 Rainfall Station Data

Rainfall data that will be used in hydrological analysis is taken from several stations in Gresik City area. Selection of rainfall stations is chosen from several stations spreading in several areas of Tebalo channel, with the aim to better suit the conditions in the field. The location of the rainfall stations can be seen in Table 1.

Table 1. Location of Rainfall Stations Used

No	RF Station Name	District	Elevation (asl)	Geographic	
				Latitude	Longitude
1	St. Tambak Ombo	Manyar	+ 15 m	07° 4' 39" S	112° 34' 23,9" E
2	St. Bunder	Kebomas	+ 25 m	07° 10' 29,8" S	112° 34' 59,7" E
3	St. Cerme	Cerme	+ 26 m	07° 13' 8.3" S	112° 33' 20,9" E

Source: Water Resources Agency of East Java Province, 2018

2.5 Maximum Rainfall Data

There are several types of rainfall data, like daily rainfall data, monthly, or even annual rainfall data, and short period rainfall data. The rainfall data used in the calculation is daily rainfall data within the last 10 years of three rainfall stations recorder around Tebalo channel in Gresik. While the rainfall data analyzed is the maximum daily rainfall data to calculate the amount of the designed flood discharge. The maximum daily rainfall data is shown in Table 2.

Table 2. Maximum Rainfall Data

No	Year	St. Tambak Ombo (mm)	St. Bunder (mm)	St. Cerme (mm)
1	2009	100	103	111
2	2010	95	103	68
3	2011	71	72	102
4	2012	84	72	102
5	2013	100	68	68
6	2014	87	100	150
7	2015	91	103	109
8	2016	111	76	126
9	2017	64	57	85
10	2018	64	98	91

Source: Water Resources Agency of Gresik Regency, 2018

2.6 Designed Rainfall

Designed rainfall is the amount of rainfall expressed in height in millimeters measured as daily rainfall data. The designed rainfall is determined based on a certain return period; while a return period of 2, 5, and 10 years is determined for the purposes of flood analysis. This rainfall can be used to estimate the designed flood, although the rainfall known for specified frequencies rarely produces peak runoff for one rain (Sutanto, 2006). To get the amount

of rainfall, distribution methods are used, with the purpose of using those methods is to get the extreme values from the rainfall series. The methods used include:

1. Gumbel distribution method
2. Normal distribution method
3. Normal log distribution method
4. Pear log type III distribution method
5. Match Test

3. Research Method

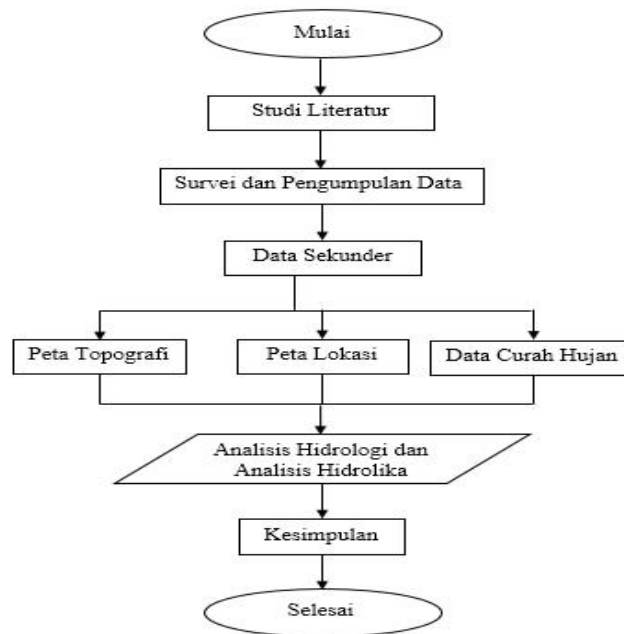


Fig. 2 Research flowchart (in Indonesia)

3.1 Stages of Study

a. Study of Literature

Literature study is done by reading reference books from various sources to form the basis of thesis composing, so that the formulas or methods used do not deviate from the determined rules. Literatures are obtained through borrowing from library and related agencies.

b. Survey and Data Collection

These surveys and data collection are intended to obtain accurate data that later be used to evaluate the study. These data are divided into two categories, namely:

1. Primary Data

Primary Data is original data obtained or collected directly by researchers according to the field, such as:

➤ Topographic Map

2. Secondary Data

Data which is obtained indirectly, the data is obtained from several sources or related agencies. Thus, the data meant are as follows:

➤ Location Map.

- Rainfall Data.
- Cross and Long Profile Channel Measurement.

3. Hydrological Analysis

Hydrological Analysis is an analysis that processes rainfall data to become designed rainfall and designed flood discharge using several methods in the literature that have been collected.

4. Hydraulics Analysis

Hydraulics analysis is data processing to calculate the flood discharge tracing, and also its flow characteristic.

3.2 Conclusions and Recommendations

Conclusions and recommendations from the discussion above is that flood prevention in the Tebalo drainage system in Manyar District, Gresik Regency uses the drainage system as a long reservoir for flood and channel dimensions are planned according to the designed discharge.

4. Analysis and Discussion

4.1 Analysis and Discussion

Aiming to get the amount of rainfall, several distribution methods are used, while the purpose of using these methods is to get the extreme values from the rainfall series. The methods used include:

1. Gumbel distribution method.
2. Normal distribution method.
3. Normal log distribution method.
4. Pear log type III distribution method.
5. Match Test.

With the description as follows;

1. Distribution Analysis of Gumbel Distribution Method

Table 3. Calculation of the Gumbel Distribution Method

No.	Year	X	Xbar	(X - Xbar)	(X - Xbar) ²	(X - Xbar) ³	(X - Xbar) ⁴
1	2009	105	91,03	13,63	185,87	2534,00	34.546,83
2	2010	89	91,03	-2,37	5,60	-13,26	31,37
3	2011	82	91,03	-9,37	87,73	-821,78	7.697,33
4	2012	86	91,03	-5,03	25,33	-127,52	641,83
5	2013	79	91,03	-12,37	152,93	-1891,29	23.388,94
6	2014	112	91,03	21,30	453,69	9663,60	205.834,62
7	2015	101	91,03	9,97	99,33	990,03	9.867,33
8	2016	104	91,03	13,30	176,89	2352,64	31.290,07
9	2017	69	91,03	-22,37	500,27	-11189,32	250.267,85
10	2018	84	91,03	-6,70	44,89	-300,76	2.015,11
n = 10		910,33			1.732,54	1.196,34	565.581,30

Source: Calculation data

2. Distribution Analysis of Normal Distribution Method

Table 4. Calculation of Normal Distribution Method

No.	Year	X	Xbar	(X - Xbar)	(X - Xbar) ²	(X - Xbar) ³	(X - Xbar) ⁴
1	2009	105	91,03	13,63	185,87	2534,00	34.546,83
2	2010	89	91,03	-2,37	5,60	-13,26	31,37
3	2011	82	91,03	-9,37	87,73	-821,78	7.697,33
4	2012	86	91,03	-5,03	25,33	-127,52	641,83

No.	Year	X	Xbar	(X - Xbar)	(X - Xbar) ²	(X - Xbar) ³	(X - Xbar) ⁴
5	2013	79	91,03	-12,37	152,93	-1891,29	23.388,94
6	2014	112	91,03	21,30	453,69	9663,60	205.834,62
7	2015	101	91,03	9,97	99,33	990,03	9.867,33
8	2016	104	91,03	13,30	176,89	2352,64	31.290,07
9	2017	69	91,03	-22,37	500,27	-11189,32	250.267,85
10	2018	84	91,03	-6,70	44,89	-300,76	2.015,11
n =	10	910,33			1.732,54	1.196,34	565.581,30

Source: Calculation data

3. Distribution Analysis of Log Normal Distribution Method

Table 5. Calculation of Log Normal Distribution Method

No.	Year	X	Log X	Log Xbar	(Log X - Log Xbar)	(Log X - Log Xbar) ²	(Log X - Log Xbar) ³
1	2009	105	2,020	1,9546	0,0652	0,0043	0,0003
2	2010	89	1,948	1,9546	-0,0068	0,0000	0,0000
3	2011	82	1,912	1,9546	-0,0425	0,0018	-0,0001
4	2012	86	1,934	1,9546	-0,0201	0,0004	0,0000
5	2013	79	1,896	1,9546	-0,0588	0,0035	-0,0002
6	2014	112	2,051	1,9546	0,0959	0,0092	0,0009
7	2015	101	2,004	1,9546	0,0497	0,0025	0,0001
8	2016	104	2,018	1,9546	0,0638	0,0041	0,0003
9	2017	69	1,837	1,9546	-0,1178	0,0139	-0,0016
10	2018	84	1,926	1,9546	-0,0286	0,0008	0,0000
n =	10	910,33				0,04	0,00041
Log Xbar	1,9545901						

Source: Calculation data

4. Distribution Analysis of Log Pearson III Distribution Method

Table 6. Calculation of Log Pearson III Distribution Method

No.	Year	X	Log X	Xbar	Log Xbar	(Log X - Log Xbar)	(Log X - Log Xbar) ²	(Log X - Log Xbar) ³
1	2009	105	2,020	91,03	1,9546	0,0652	0,0043	0,00028
2	2010	89	1,948	91,03	1,9546	-0,0068	0,0000	-0,00000
3	2011	82	1,912	91,03	1,9546	-0,0425	0,0018	-0,00008
4	2012	86	1,934	91,03	1,9546	-0,0201	0,0004	-0,00001
5	2013	79	1,896	91,03	1,9546	-0,0588	0,0035	-0,00020
6	2014	112	2,051	91,03	1,9546	0,0959	0,0092	0,00088
7	2015	101	2,004	91,03	1,9546	0,0497	0,0025	0,00012
8	2016	104	2,018	91,03	1,9546	0,0638	0,0041	0,0003
9	2017	69	1,837	91,03	1,9546	-0,1178	0,0139	-0,0016
10	2018	84	1,926	91,03	1,9546	-0,0286	0,0008	-0,0000
n =	10	910,33					0,04	0,00041
Log Xbar	1,9545901							
Xbar	14							

Source: Calculation data

4.2 Calculation of Rainfall Intensity

Rainfall intensity is the amount of rain expressed in height or volume of rainfall per unit time. The magnitude of this intensity is highly dependent on the length of rainfall and the frequency of its occurrence. According to the Van Breen method, rainfall intensity is based on the assumption that, the duration of rain in Java is on average concentrated for 6 hours, with effective rainfall as much as 90% of rainfall for 24 hours (Melinda, 2007).

Distribution of hourly rainfall with the Mononobe formula:
$$Rn = \frac{R_{24}}{T} \left(\frac{t}{T} \right)^{2,3}$$

Where R_n = Ratio of rainfall distribution.
 R_{24} = Maximum rainfall (in 24 hours)
 T = Return time period of T years (mm / day)
 t = The duration of rain

Table 7. Hourly Rainfall Ratio

T (Hours)	RT mm
1	0,550
2	0,347
3	0,265
4	0,218
5	0,188
6	0,167
Total	1,73484

Source: Calculation data

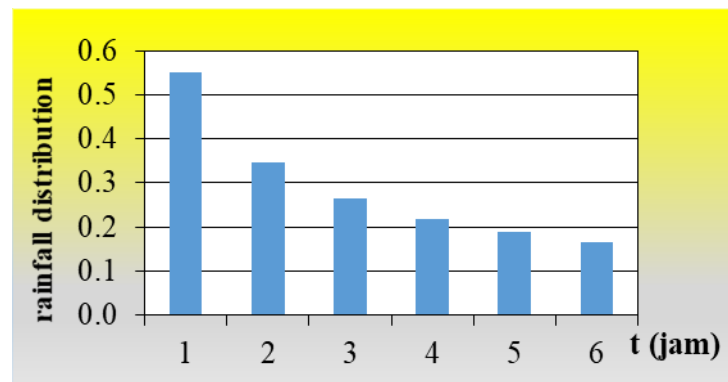


Fig 1. Rainfall distribution ratio

4.3 Grey Water Discharge Analysis

The amount of flood discharge can be obtained by summing rain water and household waste water. Furthermore, the capacity of the existing channel storage is analyzed; to measure its ability to withstand the rate of peak flow from both rain water and household waste water. If the channel is not able to withstand the current amount of flood discharge, it would be necessary to re-design the existing channel.

- Dirty Water Discharge.
- Clean water for the planning area is 150 liters / person. Estimated amount of waste water entering sewerage collection channel 90% = 135 Liters / person. So, Q dirty water = 1.5625 m³ / sec / person

c. Dirty Water Discharge: $Q_{ak} = \frac{(P_n \cdot q)}{A}$ with $P_n = P_o \cdot (1 + r)^n$

Where: Q_{ak} = Dirty water discharge (m³).
 P_n = Number of residents (people).
 q = Number of needs for dirty water (m³ / sec / person).
 A = Area of Settlement (ha)

4.4 Channel Capacity Analysis

Manning coefficient will be used for the calculation of channel planning. Tebalo channel with precast concrete surface have the coefficient of $n = 0.014$. The geometrical section used in Tebalo channel is rectangular. The amount of drainage channel capacity is determined based on the following (Chow, 1997):

$$Q_{kap} = A.v \quad \text{with} \quad v = \frac{1}{n} .R^{2/3} .S^{1/2}$$

Where: Q_{kap} = Channel Capacity (m³ / sec).
 A = Channel Sectional Area (m²).
 V = Flow Speed (m / sec).
 R = Hydraulic radius (m).
 S = Slope of the Channel.
 n = Manning coefficient..

Table 8. Evaluation of Channel Capacity Calculation

Channel Name	b m	h m	w m	S	n	R m
Q0-Q7	1,20	1,000	0,30	0,0036	0,014	0,375
Q7-Q11	1,40	1,200	0,30	0,0057	0,014	0,442
R0-R6	1,40	1,200	0,30	0,0044	0,014	0,442

Channel Name	v m/det	A m ²	Q _{kap} m ³ /det
Q0-Q7	2,220	1,20	2,66
Q7-Q11	3,123	1,68	5,25
R0-R6	2,750	1,68	4,62

Source: Calculation data

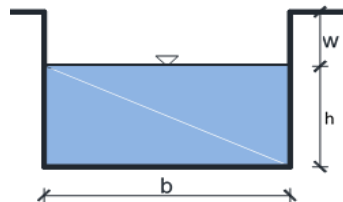


Fig2 . Channel crossing

Where:

b = Base width of channel (m)
 h = Depth of flow (m)
 w = Free space above water (m)

5. Conclusion

1. The evaluation results of Tebalo channel with Q_{kap} drainage channel Q0-Q7 is 2.66 m³ / sec, Q_{kap} drainage channel Q7-Q11 is 5.25 m³ / sec and Q_{kap} drainage channel R0-Q6 is 4.62 m³ / sec
2. The dimensions of the channel cross-sectional requirements for drainage channels Q0-Q7 are $B = 1\text{m}$, $H = 1.2\text{m}$ and $W = 0.3\text{m}$, drainage channels Q7-Q11 are $B = 1.4\text{m}$, $H = 1.2\text{m}$ and $W = 0,3\text{m}$ and drainage channel R0-Q6 are $B = 1.4\text{m}$, $H = 1.2\text{m}$ and $W = 0.3\text{m}$.

3. The estimated construction cost of Tebalo channel is Rp. 10,506,984,929.24 (Ten Billion Five Hundred Six Million Nine Hundred Eighty Four Thousands Nine Hundred Twenty Nine Rupiah Twenty Nine Cents). Details of the Budget Plan (RAB) are in the appendix.
4. To overcome the flood inundation and flood control in Tebalo channel, it is necessary to expand the channel dimension in order to be able to flow the flood discharge towards the Tebalo disposal.
5. In order to extend the channel dimensions, it is highly recommended to use precast concrete (U-Gutter) for practical in carrying out the work, the accuracy of dimensions, and the resistance against rain or heat.
6. This final project can be used by Public Works Office of Gresik Regency as a reference for the drainage channel development planning activities in Tebalo to reduce flooding within this area.

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