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THE PLANNING OF DRAINAGE SYSTEM OF TAWANG STATION TO TANJUNG MAS HARBOR

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ABSTRACT

Freight transportation by rail is considered to be more time-efficient than road transportation. In response, the government has activated the freight rail line between Tawang Station and Tanjung Emas Port.
Objectives: This study focuses on solving drainage system problems by designing a drainage channel.
Methodology: This study uses hydrological and hydraulic calculations that are needed to get drainage design.
Conclusion, Significance and Implication: The open space condition along the section of Stasiun Tawang – Pelabuhan Tanjung Emas from Km.0+275 to Km. 0+660 meets the standards ranging from 2.44 to 10.87 meters, while the standard used is 2.35 to 2.53 meters. Therefore, a drainage canal can be constructed. The results of the hydrological analysis show the planned flood discharge for 5-10 years. For 5 years, it is 0.906075 m^3/sec, and for 10 years, it is 1.029242 m^3/sec. The design for the new spillway includes trapezoidal and rectangular shapes. The trapezoidal design uses a cross-sectional width of 0.60 meters and a channel height of 0.70 meters, while the rectangular design uses a cross-sectional width of 0.80 meters and a channel height of 1.00 meters.

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1. INTRODUCTION

The need for rail freight transportation has been growing recently. Rail freight transportation is considered to be more time-efficient compared to road transportation [1][2]. In response, the government has activated the freight rail line between Tawang Railway Station and Tanjung Emas Port. The activation of this rail line has become a primary focus of the government to integrate

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freight transport modes between rail and sea transport. This line represents an economic corridor with the potential to connect sea freight to Jakarta and/or Surabaya.

By activating the rail line between Tawang Station and Tanjung Emas Port, freight transport can be spread across multiple modes, not just road transport by truck. This can have positive impact on traffic performance by reducing truck traffic, thereby increasing road capacity and performance [3]. The transit time for freight using rail transportation will be shorter [4]. Given this need, it is essential to study the supporting facilities for the reactivation of the rail line from Semarang Tawang Station to Tanjung Emas Port.

One of the supporting facilities for the railway line is the design of the drainage system [5] [6]. The existing conditions on the railway line to be reactivated are frequently subject to tidal flooding and heavy rainfall. Therefore, hydrological and hydraulic calculations are required [7] [8]. These calculations are necessary to design the drainage system for both the existing and new rail lines leading to Tanjung Emas Port. The drainage system for the rail line must be properly designed to prevent subsidence caused by the weight of the trains [9] [10], which can cause fine particles from the subgrade to mix with water and turn into silt under the ballast [11]. This condition can disrupt rail operations by affecting the stability of the subgrade[12]. Therefore, this study focuses on solving drainage system problems by designing a drainage channel.

2. RESEARCH METHODOLOGY

The types of data in this study consist of two categories: primary and secondary data. Primary data is collected through field surveys, while secondary data is collected through interview with relevant agencies. A hydrological method generally uses a watershed unit as a single integrated area[13]. In watershed response analysis, the watershed functions as a hydrological system where there is a close relationship between inputs in the form of rainfall, watershed hydrological processes, and outputs in the form of river discharge [14]. In this study, the watershed is analyzed using Quantum GIS (Geographic Information System) software and DEMNAS data with a resolution of 8.25 meters.

By considering the hydrological processes within a watershed, it can be concluded that rainfall distribution leads to direct runoff, which is influenced not only by the physical characteristics of the watershed surface, but also by the characteristics of the rainfall [15]. Given that rainfall in tropical humid climates exhibits significant spatial and temporal variability, it is essential to study the relationship between rainfall and runoff and its impact on watershed

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response. Due to the challenges of measuring hydrological phenomena [16], especially in areas without hydrological data collection, whether due to financial or human resource limitations, a correlation method between variables is necessary [17]. This method can reduce the need for direct measurement of hydrological phenomena.

2.1 Rainfall Data Analysis

Rainfall data analysis typically involves evaluating the catchment area, selecting rainfall stations, verifying the data, filling in any missing data, and verifying homogeneity using double mass curves [18]. For flood runoff analysis, the next step is to determine the maximum rainfall for the region. The analysis steps are catchment analysis, regional rainfall dataset, data screening, design rainfall, and goodness of fit [19].

The study area, which is assumed to be the catchment area in the rainfall analysis and design rainfall intensity analysis, is based on the Digital Elevation Model (DEM) analysis, which includes DEMNAS or National DEM data, as well as interpretation from Google Earth maps. The rainfall required for a water use plan and water structure design is the average rainfall over the entire relevant area, not the rainfall at a specific point.

$$Rave = \frac{R1 + R2 + R3 + \cdots \ldots \ldots . Rn}{n}$$

The Thiessen polygon method is a weighted average method. Each rain gauge has an area of influence, which is formed by drawing perpendicular bisectors to the lines connecting two rain gauge stations [13]. Hydrological data, which can be historical data, can be processed and presented either as a distribution or as a time series. It is presented as a distribution when the hydrological data is arranged based on the magnitude of the values, while a time series is presented chronologically as a function of time with consistent time intervals. In general, field data, after being processed and presented in a hydrological data publication, serves as basic data for hydrological analysis [20]. Before these data can be used for analysis, they must undergo a process often referred to as data screening. Rainfall data analysis typically includes data consistency analysis, probability analysis of the maximum rainfall (design rainfall) for flood runoff estimation, areal rainfall analysis, and the distribution fit testing. The calculations of the above distributions, will produce different results. Therefore, it is necessary to perform tests to determine the best result, i.e., the one with the least deviation. There are two commonly used goodness-of-fit test: the Chi-Square test (χ^2 test) and the Smirnov-Kolmogorov method. The results of these two methods are then compared, and the one with the least deviation is selected.

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2.2 Rainfall Intensity

Rainfall intensity is the amount of rainfall, expressed in terms of height or volume of rain per unit of time, that occurs during a period when the rainwater is concentrated. The amount of rainfall intensity varies depending on the duration and frequency of the rainfall. In general, high rainfall intensity lasts for a short time and affects a small area. Rainfall over a large area is rarely of high intensity, but may persist for a longer period of time.

Rainfall intensity analysis is used to determine the height or depth of rainfall per unit of time. The general property of rainfall is that the shorter the duration of the rainfall, the higher its intensity, and the longer the recurrence interval, the higher the intensity of the rainfall (Suripin, 2004). This analysis starts with daily maximum rainfall data, which is then converted to rainfall intensity. The data are processed using statistical methods commonly used in hydrological applications. It is preferable to use short duration rainfall data, such as 5-minute, 10-minute, 30-minute, 60-minute, and hourly data. If rainfall duration data are not available, an empirical approach based on a 60-minute duration and annual maximum daily rainfall should be used.

2.3 Planned Flood Discharge Analysis

A one commonly used method for estimating peak flows (flood flows or design flows) is the USSCS (1973) Rational Method. This method is used for drainage areas of less than 300 hectares (Goldman et al., 1986). The Rational Method is based on the assumption that rainfall has a uniform and evenly distributed intensity over the entire drainage area for a duration at least equal to the time of concentration (tc). The mathematical equation for the Rational Method is:

$$Q = 0{,}278.C.I.A$$

The time of concentration for a watershed is the time required for rainwater to flow from the point of precipitation to the watershed outlet (control point) after the soil is saturated and minor depressions are filled. It is assumed that if the rainfall duration equals the time of concentration, then each part of the watershed has contributed simultaneously to the flow at the control point. One method of estimating the time of concentration is the formula developed by Kirpich (1940), which can be written as follows:

$$t_c = \left[\frac{0{,}87\ x\ L^2}{1000\ x\ S}\right]$$

where t_c is the time of concentration in hours, L is the length of the main channel from upstream

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to downstream in kilometers, and S is the average channel slope in meters per meter. The time of concentration can also be calculated by dividing it down into two components: (1) the time it takes for the water to flow over the land surface to the nearest channel t_o, and (2) the travel time from when the water enters the channel until it reaches the outlet t_d, such that:

$$t_c = t_o + t_d$$

In this design, the drainage system consists of U-ditches, concrete channels, and pipes. The drainage is divided into several segments to ensure that the flow rate is not too high and that the channels are not too long or deep. The drainage is designed for a 10-year rainfall event. The method used is the modified rational method.

3. RESULTS AND DISCUSSION

In this study, the rainfall data is calculated from the year 2012 to 2021 as shown in Table 1. The rainfall data for the STA Karangroto location (mm/day) is used as the maximum rainfall data.

Table 1. Daily Rainfall Yearly Dataset

Tahun	Daily Rainfall Maksimum/Year
2012	182,00
2013	146,00
2014	154,00
2015	123,00
2016	82,00
2017	72,00
2018	158,00
2019	71,00
2020	100,00
2021	137,00

Source: BPSDA Bodri-Kunto

When a time series, after testing, shows:

- No evidence of a trend
- Stationarity, meaning the variance and mean are homogeneous/stable/same type
- Randomness, meaning independence or no persistence

Additional information is required for testing, such as changes in drainage areas or river channels due to natural disasters or human influences. It is important to understanding that:

1) Non-homogeneous data refers to deviations from statistical properties caused by natural factors and human influences.
2) Inconsistent data refers to deviations in the data.

Therefore, this screening stage requires field knowledge and information related to the data in the time series. This screening stage applies only to data from a single hydrological station and does not yet include comparison with similar data from other stations. A summary of the precipitation data screening calculations for all study sites is presented at Table 2.

Table 2. Summary of the Rainfall Data Screening Results

Regional Rainfall	Spearman Test			Varian			Average			Persistensi		
	Upper	Lower	Tt	Upper	Lower	Ft	Upper	Lower	t	Upper	Lower	t
STA Pegadingan	-2,306	2,306	1,594	0,104	9,605	0,925	-2,306	2,306	1,233	-0,727	0,541	0,100
	-2,306<Tt<2,306 (can be used)			0,104<Ft<9,605 (can be used)			-2,306<t<2,306 (can be used)			0,727<t<1,541 (can be used)		

Conclusion: Dataset can be used

The design rainfall is calculated using different methods and then compared based on the data fitting results. The design rainfall calculations using the various distribution methods mentioned above for the regional rainfall of the study area are presented in Table 2. Table 3 shows the distribution analysis result.

Table 3. Design Rainfall of Regional Study

Return Period	Design Rainfall of Regional Study (mm/day) with another method					
	Normal	Log Normal 2 Pearson	Log Normal 3 Pearson	Gumbel	Pearson III	Log Pearson III
2	122,5	115,6	121,9	117,2	123,1	119,2
5	155,6	151,8	155,4	164,1	155,7	156,4
10	172,9	174,2	173,2	195,1	172,5	177,9
20	187,2	195,2	188,2	224,9	186,1	196,7
25	191,3	201,8	192,5	234,4	190,0	202,4
50	203,2	221,9	205,2	263,5	201,3	218,8
100	213,9	241,6	216,6	292,4	211,3	234,0
200	223,7	261,2	227,2	321,2	220,2	248,2

Tabel 4. Results of Goodness-of-Fit Tests for Distributions using the Chi-Square Test and Smirnov-Kolmogorov Method

Station Distribution	Distribution Fit Test						Appropriate Distribution
	Chi Square			Smirnov-Kolmogorof			
	X_{kritis}^2	X^2_{hlt}	Kep	Δ max	Δ kritis	kep	
Normal	28,05	1,20	fit	12,13	40,90	fit	Log Pearson III
Log Normal 2 par	46,82	2,00	fit	15,09	40,90	fit	
Log Normal 3 par	28,05	1,20	fit	12,17	40,90	fit	
Gumbel	28,05	1,20	fit	10,55	40,90	fit	
Pearson III	9,29	0,40	fit	12,17	40,90	fit	
Log Pearson III	28,05	1,20	fit	11,97	40,90	fit	

If the probability (X_{critis}^2) > 5%, then the theoretical distribution equation used can be accepted. Numbers highlighted in orange indicate the highest distribution fit. Referring to the Guidelines for Design of Surface Road Drainage from 1990 issued by Dirjen Bina Marga Direktorat

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Pembinaan Jalan Kota, it is known that a 5-year recurrence interval is used for the design of road drainage (side channels). A summary of the comparison of results calculated using different methods is presented in Table 5.

Table 5. Summary of Average Deviation in the Selection of Rainfall Intensity Calculation

Return Period	Deviation Average Rainfall								
	Van Breen			Mononobe			Haspers Der Weduwen		
	Talbolt	Sherman	Ishigro	Talbolt	Sherman	Ishigro	Talbolt	Sherman	Ishigro
2	0,00	12,67	12,34	23,78	31,26	35,36	94,77	102,87	115,57
5	0,00	14,26	12,88	30,16	36,21	41,56	113,61	124,70	134,73
10	0,00	14,97	13,07	35,76	42,75	46,22	123,19	136,19	143,94
20	0,00	15,50	13,18	40,50	48,23	52,06	133,19	143,30	150,81
25	0,00	15,64	13,20	42,18	49,85	53,79	139,44	146,78	152,69
50	0,00	16,03	13,27	48,16	54,52	58,79	139,66	152,63	157,74
100	0,00	16,36	13,27	53,68	58,77	63,34	144,98	158,45	161,89
200	0,00	16,63	13,45	58,81	62,69	67,53	149,59	163,47	165,36
Deviation	0,00	15,26	13,10	41,63	48,05	52,22	128,79	140,80	147,84

Based on the results of Table 5 above, it is observed that the deviation between the measured data and the predicted data using the Talbot method with the Van Breen rainfall distribution equation provides the least deviation or is closest to the actual values of the measured rainfall intensity. In this design study, the drainage system consists of U-ditches, concrete channels, and pipes. The drainage is divided into several segments to ensure that the flow rate is not too high and the channels are not too long or deep. The drainage is designed for a 10-year rainfall event. The method used is the modified rational method shown in Table 6

Table 6. Summary Drainage Design Calculation

Area	No	STA	Dimension U-Dict	Service Area	t total (sec)	Rainfall intensity (mm/hour)	Q10th (m3/sec)	Qmaks (m3/sec)	Q10th < Qmaks
Kebonharjo	1a	Km.0+275 s.d Km. 0+323	60x70	Right	30,841	140,400	0,131	0,665	Ok
	1a	Km.0+275 s.d Km. 0+323	60x70	Left	30,841	140,400	0,131	0,436	Ok
	2a	Km.0+323 s.d Km. 0+495	60x70	Right	36,245	131,936	0,480	0,310	Not Ok
		(Rekomendasi)	80x100				0,480	0,966	Ok
	2b	Km.0+323 s.d Km. 0+495	60x70	Left	36,245	131,936	0,445	0,230	Not Ok
		(Rekomendasi)	80x100				0,445	0,718	Ok
	3a	Km. 0+495 s.d Km. 0+610	60x70	Right	37,208	130,532	0,427	0,469	Ok
	3b	Km. 0+495 s.d Km. 0+610	60x70	Left	37,208	130,532	0,395	0,398	Ok
	4a	Km. 0+610 s.d Km. 0+660	160x120	Right	36,564	131,467	0,088	2,122	Ok
	4b	Km. 0+610 s.d Km. 0+660	60x70	Left	36,564	131,467	0,082	0,556	Ok

4. CONCLUSION

Based on the analysis and discussion of the drainage channel redesign, the following conclusions can be drawn:

1) The open space condition along the section of Stasiun Tawang – Pelabuhan Tanjung Emas from Km.0+275 to Km. 0+660 meets the standards ranging from 2.44 to 10.87 meters, while the standard used is 2.35 to 2.53 meters. Therefore, a drainage canal can be constructed.
2) The results of the hydrological analysis show the planned flood discharge for 5-10 years. For 5 years, it is 0.906075 m^3/sec, and for 10 years, it is 1.029242 m^3/sec.
3) The design for the new spillway includes trapezoidal and rectangular shapes. The trapezoidal design uses a cross-sectional width of 0.60 meters and a channel height of 0.70 meters, while the rectangular design uses a cross-sectional width of 0.80 meters and a channel height of 1.00 meters.

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