Drainage Channel Planning Between Gadobangkong Station to Padalarang Station

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Abstract. Drainage is a supporting construction that functions to drain water in an area to avoid flooding. However, if the drainage is damaged, then the damage can cause flooding which can result in disruption of the road structure. On the Gadobangkong- Padalarang route, there was an inundation in the drainage system which had not receded within 4 days of observation. The purpose of this research is to plan the construction of drainage channels around Padalarang Station to Gadobangkong Station in order to meet the technical requirements so as to support train operations and passenger comfort. This study observed the existence of stagnant water in natural drainage channels on the Padalarang-Gadobangkong route, especially in flood-prone areas such as Ngamprah and Padalarang. This study uses field observations with the help of software in the simulation of dimensional results. This research resulted in a 50-year return period planned flood discharge of 0.79 m3/second and 2 new types of drainage sections with dimensions that can accommodate a 50-year planned flood discharge. From the simulation results using the EPA SWMM 5.2 software, the planned drainage design is able to accommodate flood discharges with a return period of 50 years without runoff occurring. In addition, the simulation also produces more efficient drainage dimensions, namely open rectangular and open trapezoidal drainage with dimensions that are smaller than the design dimensions but still able to accommodate the planned flood discharge for a period of 50 years.

Keywords: Drainage, Flooding, EPA SWMM 5.2 Simulation

1 Introduction

A railroad track is a line consisting of a series of railroad plots which include track-owned space, track utility space, and track control space, including the superstructure and under-rail construction. The condition of railroad infrastructure and construction must be in a proper and proper condition to ensure the smooth, comfortable and safe operation of the train. The drainage channel is an important supporting construction in fulfilling the requirements of railroad infrastructure. The drainage channel functions to drain water from the railroad construction so that puddles do not occur. Stagnant water will cause delays in train travel because the track is impassable [1].

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Drainage is one of the technical measures to reduce excess water, both from rainwater, seepage, and excess irrigation water in a land/area so that the land/area can function optimally [2]. In planning a drainage channel system, it is necessary to consider the problems that can occur if the construction is not appropriate. One of the problems that occur is flooding. Floods can occur if there are stagnant water that does not recede quickly, coupled with high rain intensity.

On the Padalarang – Gadobangkong KM 142+000 – 143+100 route, there is inundation, especially in natural drainage channels. Based on the disaster risk assessment document for West Bandung Regency, this route is located around areas that have a high class of flood hazard, namely Ngamprah and Padalarang [3]. These puddles routinely occur during the rainy season, even when the intensity of rain is light. From 3 observations that the researchers made on 4 different days, the inundation had not receded. If the puddle does not drain properly immediately, with high rain intensity in Bandung, West Java, there will be flooding in the KM.

Floods that cover the railroad tracks will disrupt the operation of trains that will pass and affect the train schedule so that the departure time will be delayed from the proper schedule. In addition, flooding that inundates the road body will cause mud to form, so that the mud will rise and enter the ballast gap because it is carried by traffic pressure and the mud is mixed with ballast rock (dirty ballast)/mud pumping. Mud pumping causes ballast failure, weakens the consistency and strength of rail construction. Therefore, the purpose of this research is to obtain the planned flood discharge for a period of 50 years, the dimensions of the plan that are able to accommodate the planned flood discharge for a period of 50 years, and review the ability of the planned drainage to accommodate the planned flood discharge with the help of the EPA SWMM 5.2 software.

2 Methodology

This case study uses primary data in the form of drainage channel geometry data at KM 142+000 to 143+100 between Gadobangkong Station and Padalarang Station. The geometry data referred to are in the form of existing drainage conditions, drainage width, inundation depth, and drainage channel elevation data. In addition to primary data, this study also uses secondary data in the form of monthly rainfall data for Bandung Station, Cipatat Station, and Lembang Station for the last 10 years. The selection of the 3 stations was based on the location of the rain stations which were close to the study location.

The rainfall data obtained is then processed with several calculation steps until it finally produces a planned flood discharge for a period of 50 years. From the planned flood discharge, the dimensions and design of the drainage plan are obtained. The dimensions of the planned drainage are simulated with the help of EPA SWMM 5.2 software to determine the ability of the planned drainage to accommodate the planned flood discharge for a period of 50 years. The choice of this software is because EPA SWMM can simultaneously simulate hydraulics and hydrology [4].

After the simulation results are processed, it will be known whether the planned drainage design can accommodate the planned flood discharge or not. If the simulation results show that the planned drainage can accommodate the planned flood discharge, then it can be said that the drainage design design is valid to be used as a construction design plan. However, if from the simulation it is found that the planned drainage cannot accommodate the planned flood discharge, a reassessment is necessary

3 Result And Discussion

Drainage planning starts from the calculation of the planned flood discharge. To obtain the planned flood discharge, it is necessary to calculate monthly rainfall data for the last 10 years from 3 rain stations around the study site. Rain stations taken from this research are Bandung rain station, Cipatat rain station, and Lembang rain station. The initial step to obtain the planned flood discharge is to test the validity of the rainfall data obtained. The data validity test method used by the author is a multiple mass curve.

3.1 Data Validity Test Method

Calculation of data validity uses the total amount of each monthly rainfall data from each rain station.To test the validity of this data, the author took Bandung Station as the review station, so the following results were obtained:

Table 1. Calculation of rainfall validity test

Period	St. Bandung	St. Lembang	St. Cipatat	Average St. Lembang and St. cipatat	Cumulative St. Bdg	Cumulative Average St. Lembang and St. Cipatat
2012	2510,7	2590	1771	2180,5	2510,7	2180,5
2013	2681,4	2003	2496	2249,5	5192,1	4430
2014	2385,3	1633	1806	1719,5	7577,4	6149,5
2015	2216,9	769	1452	1110,5	9794,3	7260
2016	2975,4	800	2834	1817	12769,7	9077
2017	2298,5	1379	1378	1378,5	15068,2	10455,5
2018	2188,7	1300	1599	1449,5	17256,9	11905
2019	2031,5	963	1254	1108,5	19288,4	13013,5
2020	2417,8	1205	2108	1656,5	21706,2	14670
2021	2170,7	1213	2068	1640,5	23876,9	16310,5
2022	2311,4	1893	2141	2017	26188,3	18327,5

After the calculation is complete, the cumulative results for Bandung Station and the average cumulative results for Lembang Station and Cipatat Station are depicted in x-y coordinates like the curve graph in the image below:

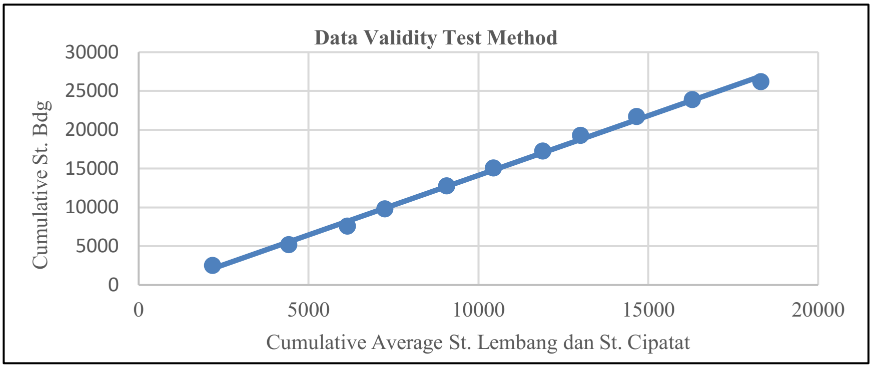

Fig. 1. multiple mass curve

The results of the multiple mass curve graph above show a straight line (no faults), according to Ministry of Public Works and Public Housing, 2018 regarding module 3 hydrological and sedimentation analysis[5], the results of the graph show that rainfall data from Bandung Station, Cipatat Station, and Lembang Station can be said to be valid and can be used for further calculations.

3.2 Calculation of Rainfall Data

The initial step in calculating rainfall data is to calculate the average rainfall for the region using the Al Jabar average.

Table 2. Average Rainfall Table

Years	*Average Rain*
2012	192,69
2013	194.21
2014	156.56
2015	112.69
2016	166.10
2017	134.39
2018	135.02
2019	110.54
2020	149.80
2021	143.79
2022	173.12

The calculation above is used to find the combined average annual rainfall from 3 stations and calculate other statistical parameters. In determining the method to be used in calculating planned rainfall, it is viewed from the statistical parameter values. Statistical parameters are the average annual rainfall from 3 stations, standard deviation of the average annual rainfall from 3 stations, variation coefficient, skewness coefficient, and kurtois coefficient. From the calculations, the following values are obtained:

Table 3. Statistical parameter values

Average	151,722
Standart Deviation	28,349
Variation Coefficient	0,187
Skewness Coefficient	0,1006

Kurtois Coefficient	0,2766

From the Skewness Coefficient and Kurtois Coefficient values, the distribution used is the Gumbel method. The formula for the Gumbel method's planned rainfall is as follows:

$$X_T = \bar{x} + K.S_d \tag{1}$$

$\bar{x}$ is the average, *K* is the frequency factor, and *Sd* is the standard deviation..

After determining the distribution method to be used, the planned rainfall value and rainfall intensity for a 50 year period for 2 hours are obtained. The formula for calculating rainfall intensity is as follows:

$$I = \frac{R_{24}}{24}\left(\frac{24}{Tc}\right)^{\frac{2}{3}} \tag{2}$$

R_{24} rainfall plan for a 50 year period and *Tc* is the duration of rainfall (hours)

Planned Flood Discharge. In calculating flood discharge, we only pay attention to the area around the planned drainage.

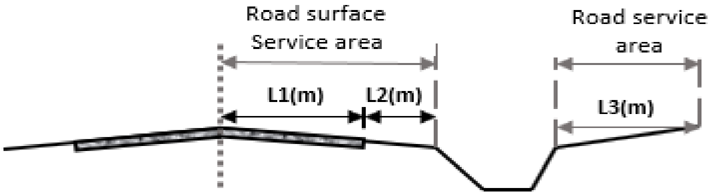

Fig. 2. Drainage Area

From field observations the following values were obtained:
L1 = 2.35 m (Road Class II) x 1100 m = 2585 m2
L2 = 0 m x 1100 m = 0 m2
L3 = 100 m x 1100 m = 110000 m2
A = 0.002585 + 0 + 0.11 = 0,112585 km2
The flood discharge calculation uses the following rational method:

$$Q = 0.278 \text{ x } C \text{ x } I \text{ x } A \tag{3}$$

Where C is the drainage coefficient of small plain rivers, I is the amount of rainfall intensity, and A is the area of the drainage area. Based on the calculation data from formula 2, 3 and formula 4, the values for planned rainfall, rainfall intensity and flood discharge for the 50 year period are obtained as follows.

Table 4. Recapitulation of calculated value results

Precipitation Plan	253,461 mm/day
Rainfall Intensity	55,815 mm/hour
Flood Discharge	0,79 mm^3/sec

3.3 Drainage Section Planning

The author decided to use 2 cross-sectional models to later be used as drainage planning models. Selection of cross-sectional models by comparing 4 types of drainage cross-sections and selecting the type of drainage that has a smaller cross-section. The cross-section calculation formula is based on PUPR Ministerial Regulation No. 12 of 2014[6].

Open Square Cross Section

$$b = 2h \tag{4}$$

$$A = b \times h = 2h^2 \tag{5}$$

$$R = \frac{A}{P} = \frac{2h^2}{4h} \tag{6}$$

$$S = \frac{(t_2 - t_2)}{L} \tag{7}$$

Where b is the bottom cross-sectional width, A is the wet cross-sectional area, R is the hydraulic radius, S is the channel slope and h is the wetted cross-sectional height. The h value can be known from the following formula:

$$Q = \frac{A \times (R)^{\frac{2}{3}} \times S^{\frac{1}{2}}}{n} \tag{8}$$

n is the concrete wall Manning coefficient of 0.013. From the explanation of the formula above, an h value of 0.7 m is obtained. The total drainage height is obtained from the sum of h and w (maintenance height). The w formula is as follows:

$$w = \sqrt{0.5h} \tag{9}$$

It was found that the total drainage height was 1.3 meters and the cross-sectional width was 1.4 meters.

Open Trapezoidal Cross Section

$$A = h^2\sqrt{3} \tag{10}$$

$$P = 2h\sqrt{3} \tag{11}$$

By using formulas and calculation methods h and h total which is the same as the previous calculation, the value is obtained h of 0.65 meters and h total of 1.2 meters. Mark b below can be known from the following formula:

$$b = P - (2h\sqrt{m^2 + 1}) \tag{12}$$

By using values m equal to $\frac{1}{\sqrt{3}}$, then the value is obtained b bottom of 0.7 meters. For b top can be searched using the following formula:

$$b\ top = b\ bottom + 2mh \tag{13}$$

So we get the b top of 1.4 meters.

Open Triangular Cross Section

$$b = 2h \tag{14}$$

$$A = h^2 \tag{15}$$

By using formula 8, the value is obtained h of 0.865 meters and the total drainage height is 1.52 meters. Once h is obtained then the value can be obtained b of 1.73 meters.

Semicircular Drainage Section

$$b = 2h \quad (16)$$

$$A = \frac{\pi}{2h^2} \quad (17)$$

From formula 10 we can obtain h value of 1.23 meters and h total of 2.01 meters. From the h value, the b value is 2.46 meters.

From the calculations above, the author used a drainage plan with an open square and open trapezoid shape and then carried out a simulation using EPA SWMM 5.2 software to see whether the dimensions of the plan that had been obtained were able to accommodate the planned flood discharge for a 50 year period of 0.79 mm^3/sec.

EPA SWMM 5.2 Software Simulation

Simulations using EPA SWMM 5.2 software were carried out 4 times with each design carried out 2 times. The first simulation was carried out on the dimensions of the open square drainage design plan with a cross-sectional width of 1.4 meters and a total cross-sectional height of 1.3 meters. The second re-simulation is a trial-and-error simulation by reducing the dimensions of the planned drainage. This simulation aims to find the most effective design for existing land use. The author tries to reduce the dimensions by 1 meter for the cross-sectional width and 0.9 meters for the total height of the drainage. The third re-simulation is simulating the dimensional results of the trapezoidal drainage design plan. The fourth re-simulation is trial and error by changing the channel dimensions to find the most effective channel dimensions for land use. In this simulation the author tries to reduce the dimensions from 0.7 meters to 0.5 meters for the bottom cross-section width (b) and 1.2 meters to 1 meter for the total drainage height (h). The results of simulations are as follows:

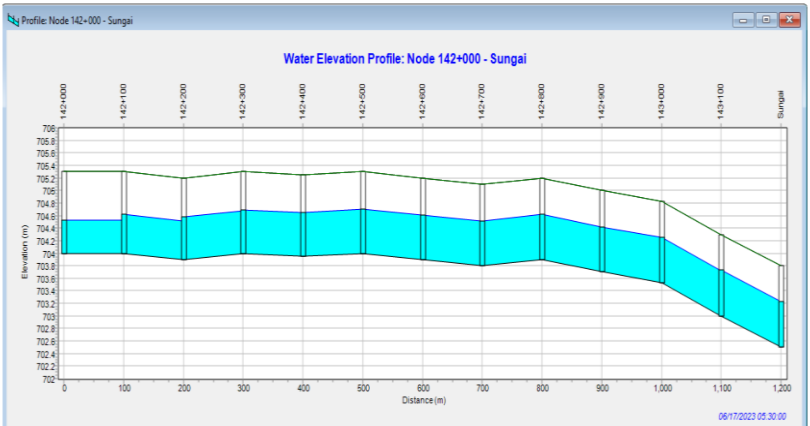

Fig. 3. First Simulation Results

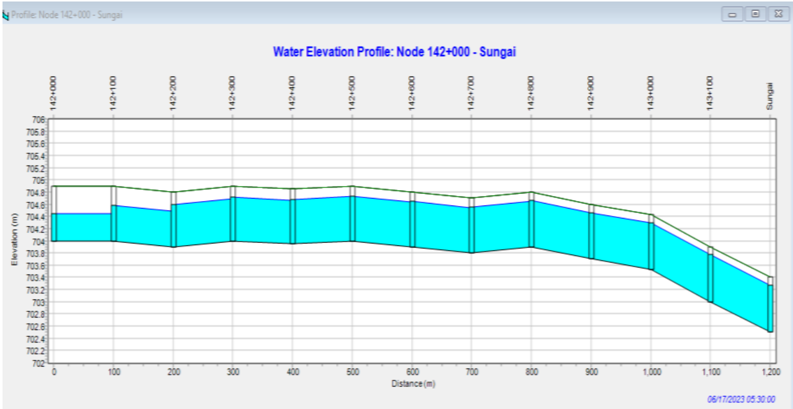

Fig. 4. Second Simulation Results

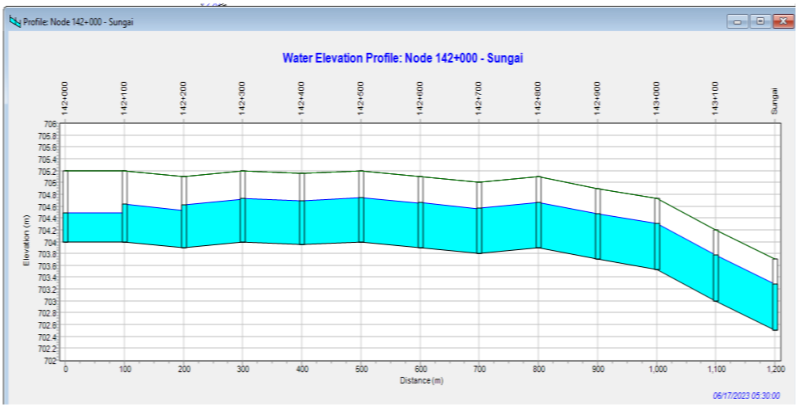

Fig. 5. Third Simulation Results

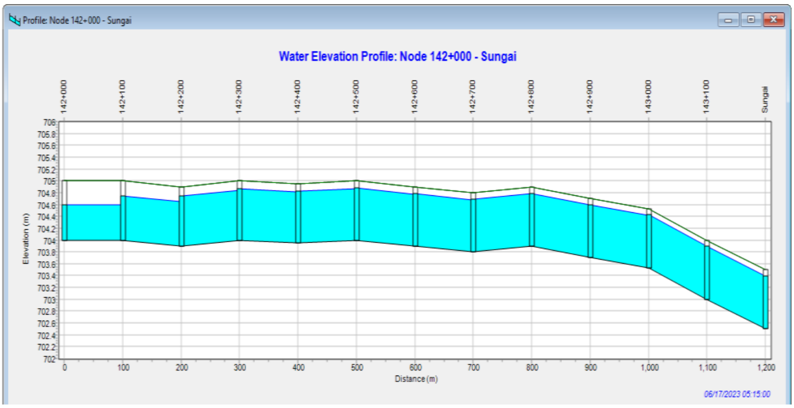

Fig. 6. Fourth Simulation Results

From the results of simulations 1, 2, 3, and 4, the rainfall for the 50 year period at KM 142+000 to the river, the highest flood discharge elevation is at an elevation of 704.85 meters. Meanwhile, the highest drainage dimension is at an elevation of 705 so it can be said that the drainage section is capable of accommodating rainfall runoff for a period of 50 years and there will be no flooding that exceeds the final drainage dimensions.

In addition to using EPA SWMM 5.2 software, to further ensure the capacity of the new drainage, the authors compared the planned flood discharge value for the 50 year period from rainfall calculations and the flood discharge value from flow velocity and wet cross-sectional area of the new drainage. The new drainage flood discharge value is obtained from the following formula:

$$Q = \frac{1}{n}\,(R)^{\frac{2}{3}}\,(S)^{\frac{1}{2}}\,x\,A \tag{18}$$

Where R is the hydraulic radius of each design, and A is the wet cross-sectional area of each drainage. By using formula 24, the flood discharge for an open square drainage plan is obtained at 1.1 m^3/sec and 0.86 m^3/sec for open trapezoidal drainage. Both values are greater than the 50 year plan discharge of 0.79 m^3/sec, then both planned drainage designs can be said to be safe from flooding or inundation.

Drainage Channel Design

The drainage channel design was obtained based on the results of rainfall data calculations, planned drainage cross-sections, and EPA SWMM 5.2 software simulations. The author took the most efficient design, which was obtained from the EPA SWMM software simulation. The design was created with the help of Autocad 2018 software in millimeters. The following are the dimensions of the drainage channel across Gadobangkong-Padalarang KM 142+000 to 143+100.

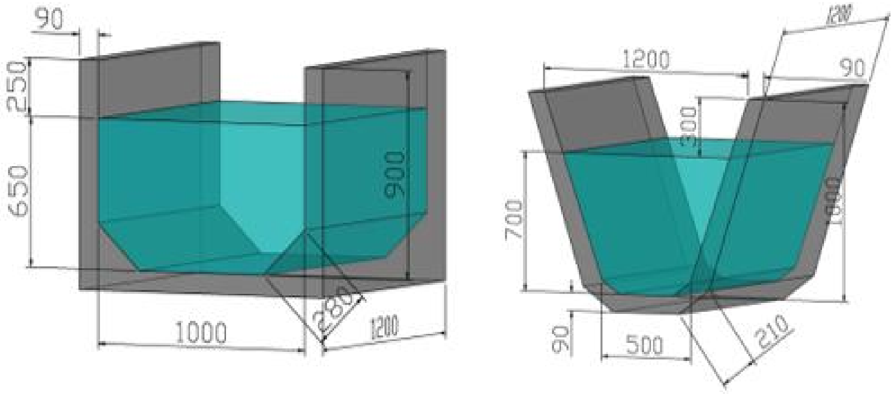

Fig. 7. Final Plan Drainage Design

4 Conclusion

From the calculation of flood discharge at the research location, it was found that the flood discharge based on a 50 year return period plan was 0.79 m3/second. From the flood discharge, 2 types of drainage were obtained with the drainage dimensions of cross-sectional width and cross-sectional height of open square drainage changing respectively by 1 meter and 0.9 meter, for open trapezoidal drainage the bottom width, top width and drainage height changed respectively to 0, 5 meters, 1.2 meters, and 1 meter. To find out whether the planned dimensions are capable of accommodating flood discharge or not, a simulation was carried out using EPA SWMM 5.2 software with the results on the planned drainage showing that there was no runoff of flood discharge at a 50 year return period that exceeded the dimensions of the two planned drainages. This means that the design of the two drainage plans is capable of accommodating flood discharges over a 50 year return period. The planned drainage has the capacity to accommodate flood discharge of 1.1 m^3/sec for square drainage and 0.86 m^3/sec for trapezoidal drainage. This means that the planned drainage can be guaranteed to be able to accommodate the planned flood discharge for a 50 year period.

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