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Analysis Of Drainage Channels in Bareng Village, Malang City Using SWMM (Storm Water Management Model) Application Simulation

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ABSTRACT

Malang City is the second city in East Java, facing an increased risk of flooding due to population growth, changes in land use, and reduced infiltration areas. Jalan Bareng Raya II is one of the affected locations, with flooding occurring on April 29, 2023 due to high rainfall intensity. This study aims to evaluate the condition of the existing drainage network in the area using quantitative descriptive methods, including data collection, analysis, and interpretation of results. The SWMM (Storm Water Management Model) application is used to simulate overflow channels. Primary data was obtained from direct observation, while secondary data came from the Malang City PUPR Service and BPS. The SWMM simulations show 11 channels overflowing, which can be reduced with a combination of infiltration wells and biopores.

INTRODUCTION

Malang is the city with the second largest population in East Java after Surabaya and continues to increase every year to reach 846,126 people in 2022 (Badan Pusat Statistik, 2023). A city with high population growth will certainly affect all aspects of life in the city. According to Martins (2017), increasing population growth that requires settlements as a place to live will certainly increase land use in an area. In addition, the effects of population growth are that land use becomes difficult to regulate and open areas (water catchment areas) are reduced. Drainage must be considered carefully to avoid overflow or flooding problems. The impact of reducing water catchment areas will result in a greater amount of water entering the drainage channels (Kencana, 2021).

Based on the news uploaded by Radar Malang on April 29, 2023, heavy rain that hit Malang City from the previous day until the evening caused severe flooding as high as an adult's waist. The flood occurred in various locations, one of which was on Jalan Bareng Raya II, Bareng Village, Malang City. The houses of residents living on Jalan Bareng Raya II were also affected by the flood. There are many causes that caused Jalan Bareng Raya II, Bareng Village to be submerged in water, one of which is that the capacity of the channels there cannot accommodate the discharge of rainwater so that it overflows onto the road. The problems that occur on this road really need to be considered because this road is one of the main roads and there are many residential areas (Wicaksana, 2023). Therefore, the author chose Jalan Bareng Raya II, Bareng Village as the research location.

Research related to this problem has been conducted by Jifa et al. (2019) with the title "Evaluation of Drainage Channels on Jalan Gajayana and Jalan Sumbersari, Malang City". The study showed that there was a problem with the existing channel that could not accommodate the maximum flood discharge, so the alternative provided by the author was to replace the channel dimensions so that they could accept excess flood discharge during rain for up to 25 years to come.

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The difference between this research and the research above is that it uses the help of the SWMM (Storm Water Management Model) application by providing alternatives in a sustainable structure and non-structure with the eco drainage concept based on the existing analysis that will be carried out.

This research utilizes SWMM (Storm Water Management Model) software as a tool to analyze the condition of the drainage channels on Jalan Bareng Raya II, Bareng Village, Malang City. SWMM (Storm Water Management Model) is software that can simulate water runoff due to rainfall, including evaluating the capacity of drainage channels. With the help of this software, researchers will conduct simulations to evaluate whether the drainage channels are able to handle rainwater discharge during high rainfall intensity, as well as analyze the potential for overflow that can cause flooding (Faizal et al., 2019). Based on the results of the simulation, this research will provide alternative solutions to overcome flooding problems in the area.

In addition to structure-based solutions, this research will also emphasize the importance of more sustainable non-structural solutions. One of the proposed approaches is the eco-drainage concept, which aims to create an environmentally friendly drainage system to increase the capacity of water catchment areas and reduce surface runoff. This eco-drainage approach includes the use of green open spaces, the construction of infiltration wells, biopore infiltration holes and increasing the soil's water absorption capacity (Wibisono et al., 2022).

Based on the descriptions above, it is necessary to conduct a drainage channel analysis to overcome the overflow that occurs in Bareng Village, Malang City. Therefore, the author is interested in conducting research entitled "Drainage Channel Analysis in Bareng Village, Malang City with SWMM (Storm Water Management Model) Application Simulation".

RESEARCH METHODS

The research method used is a quantitative descriptive method in the form of data collection, data analysis and interpretation of the results of the analysis to obtain information so that it can contain conclusions. Direct observation was carried out by carrying out observations and measurements on the drainage channel on Jalan Bareng Raya II, Bareng Village, Malang City with an area of 74,295.04 m2. The stages carried out were carrying out preparatory work, data collection, and data analysis.

Preparatory work

In this section, it is done to plan research activities that run well and smoothly. After that, carry out observations at the location to be observed to find out the problems that exist on Jalan Bareng Raya II, Bareng Village, Malang City.

Data Collection

In the following section there are two types of data collected, namely primary data and secondary data. The collection of primary data is in the form of existing drainage channel data obtained using the observation method. This data includes channel dimensions, channel length and channel slope. Then, secondary data collection is obtained through related agencies. This data includes rainfall data, population data, and topographic data.

Data Analysis

The purpose of data analysis is to obtain conclusions from research used as analysis material on existing drainage channels. The data analysis process is carried out through the following steps:

Capacity Analysis

According to Saidah et al. (2021), Analysis of storage capacity is needed to determine the characteristics and profiles of the water level that is woven into the planned channel in the research area and flood or overflow areas due to rain. Determination of the size of the channel, both existing and to be built, is carried out based on the maximum discharge that will be flowed. Drainage planning, to find the channel discharge, the Manning formula is used which is formulated in the formula below.

$$Q = V \times A \quad (1)$$

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

$$A = b.h \quad (3)$$

With:

Q = Channel Capacity (m^3/s)
V = Average Flow Velocity (m/s)
n = Manning's Roughness Coefficient, Table 2.13
R = Hydraulic Radius of Channel, Table 2.14
S = Channel Slope
A = Wetted Cross-sectional Area (m^2)

Hydrological Analysis

At this stage, it is needed to determine the estimated runoff or the amount of surface flow that must be accommodated. In essence, hydrological discharge is a method related to rainfall measurements, data on the area of drainage areas, data on differences in slope or land height and land use, all of which have guidelines in determining average rainfall, concentration time, runoff coefficient, rainfall intensity and planned flood discharge (Suryaman, 2013).

One of the hydrological analysis techniques commonly used in flood planning is the Rational Method. This method is generally used in rivers with a wide flow coverage and in drainage planning for limited watersheds. In determining the Rational Method, you can use the formula, namely (Andawayanti et al., 2022).

$$Qh = 0{,}278.C.I.A \quad (4)$$

With:

Qh = Max flood discharge (m^3/s)
C = Flow coefficient depending on the type of land surface
I = Rain intensity (mm/hour)
A = Catchment area (ha)

Discharge Analysis

Waste discharge or also known as dirty water discharge is the volume of wastewater originating from public facilities or daily activities of urban residents, such as used water for washing, bathing and other activities. Waste discharge analysis is very important to carry out so that researchers can determine the maximum discharge received by the channel. In determining the waste discharge, it can be done using the following formula (Andawayanti et al., 2022):

$$Q_{ak} = \frac{Pn \times q}{A} \quad (5)$$

Dengan:

Q_{ak} = Wastewater/dirty water discharge (ltr/sec/km^2)
Pn = Total population (people)
q = Amount of waste/wastewater (ltr/sec/person)
A = An area (km^2)

SWMM Simulation

Simulation with SWMM is done when all the required data components have been collected. The data includes subcatchment, conduit, junction, divider, rain gage and outfall.

Overflow Handling Efforts

Overflow handling efforts are applied to drainage channels in locations whose capacity is unable to accommodate the design flood discharge based on the results of calculations and simulations using the SWMM (Storm Water Management Model) application on Jalan Bareng Raya II, Bareng Village. Therefore, each location requires a different handling approach according to the characteristics of the problems faced. These overflow control steps are based on references from books (Rizal, 2022).

RESULTS AND DISCUSSION

Capacity Analysis

The storage capacity refers to the maximum amount of rain discharge or flow that can be managed by the drainage system without causing overflow. If the rain discharge exceeds the calculated capacity, the drainage channel needs to be re-evaluated. All calculations of the storage capacity on Jalan Bareng Raya II, Kelurahan Bareng are presented in Table 1.

Hydrological Analysis

This research uses rainfall data from two stations, namely Sukun and Lowokwaru, for the last ten years from 2013-2022. The data is analyzed using the Arithmetic Mean method. Frequency analysis is then carried out to determine the design rainfall, using the Log Normal distribution which is tested for validity with the Chi-Square and Smirnov-Kolmogorov tests. This distribution is proven valid for use in calculating the design rainfall, with results for a 10-year return period of 135.49 mm. Furthermore, rainfall intensity is calculated using the Mononobe formula, and flood discharge calculations are carried out using the Rational method. The results of the hydrological discharge calculations on Jalan Bareng Raya II, Bareng Village are presented in Table 1.

Discharge Analysis

In addition to rainwater runoff, the channel also receives dirty water discharge from surrounding houses. It is assumed that each building is occupied by 5 people, with a clean water requirement of 170 liters/person/day. The overall results of the wastewater estimation calculation are shown in Table 1.

Table 1. Recapitulation Results of Reservoir Capacity, Hydrological Discharge, and Waste Discharge

Channel Name	Q Storage Capacity (m^3/s)	Q hydrology (m^3/s)	Q Waste (m^3/s)
C1	0,280	0,141	0,000030
C2	0,788	0,128	0,000053
C3	0,853	0,129	0,000081
C4	1,098	0,366	0,000096
C5	0,193	0,055	0,000124
C6	1,013	0,005	0,000000
C7	0,263	0,086	0,000139
C8	0,788	0,086	0,000161
C9	0,855	0,117	0,000166

C10	0,685	0,966	0,000168
C11	6,311	0,003	0,000000
C12	1,717	0,088	0,001810
C13	0,439	0,090	0,000202
C14	0,372	0,086	0,000224
C15	0,172	0,091	0,000252
C16	1,226	0,003	0,000000
C17	0,105	0,086	0,000266
C18	0,222	0,137	0,000272
C19	0,445	0,146	0,000275
C20	0,365	0,362	0,000282
C21	0,388	0,372	0,000284
C22	0,581	0,797	0,000285
C23	0,232	0,104	0,000313
C24	0,409	0,104	0,000325
C25	0,792	0,009	0,000383
C26	0,360	0,202	0,000401
C27	0,525	0,160	0,000415
C28	0,448	0,086	0,000440

Existing Drainage Network Evaluation

Evaluation of the existing drainage network is done by comparing the capacity or dimensions of the channel with the volume of water flowing in it. The channel is considered safe if the maximum height of water passing through the channel does not exceed the height of the channel itself. If it is found that the channel dimensions do not meet the safe criteria and experience overflow or flooding, then the next step is to analyze efforts to control the overflow or flood. The following are the results of the evaluation of each channel presented in Table 2.

Table 2. Results of Existing Drainage Network Evaluation

Channel Name	Qs Storage Capacity (m^3/s)	Q Combined Hydrology and Waste (m^3/s)	ΔQ (Qs-Qgab) (m^3/s)	Channel Evaluation
C1	0,280	0,141	0,139	Fulfilling
C2	0,788	0,269	0,519	Fulfilling
C3	0,853	0,398	0,456	Fulfilling
C4	1,098	0,764	0,334	Fulfilling
C5	0,193	0,055	0,138	Fulfilling
C6	1,013	0,060	0,954	Fulfilling
C7	0,263	0,146	0,177	Fulfilling
C8	0,788	0,232	0,556	Fulfilling
C9	0,855	0,349	0,506	Fulfilling
C10	0,685	1,315	-0,630	Overflow
C11	6,311	3,487	2,825	Fulfilling
C12	1,717	4,239	-2,522	Overflow
C13	0,439	0,090	0,349	Fulfilling
C14	0,372	0,086	0,286	Fulfilling
C15	0,172	0,091	0,140	Fulfilling
C16	1,226	0,269	2,796	Fulfilling
C17	0,105	0,355	-0,250	Overflow

C18	0,222	0,492	-0,269	Overflow
C19	0,445	0,638	-0,192	Overflow
C20	0,365	1,000	-0,636	Overflow
C21	0,388	1,372	-0,984	Overflow
C22	0,581	2,170	-1,588	Overflow
C23	0,232	0,104	0,128	Fulfilling
C24	0,409	0,208	0,201	Fulfilling
C25	0,792	0,217	0,574	Fulfilling
C26	0,360	0,419	-0,059	Overflow
C27	0,525	0,579	-0,054	Overflow
C28	0,448	0,665	-0,217	Overflow

SWMM Simulation

Based on the network evaluation, it was found that channel C17 experienced overflow as presented in Figure 1. In this channel, overflow occurred due to grass and sedimentation in the form of soil around the drainage area. This is in line with the research conducted by Kamila (2016), with the research title "Environmentally Aware Drainage System Planning (Eco Drainage) in Jatisari Village, Mijen District, Semarang City". In his research, it was found that the cause of flooding was the large amount of grass or plants, sedimentation and scattered garbage.

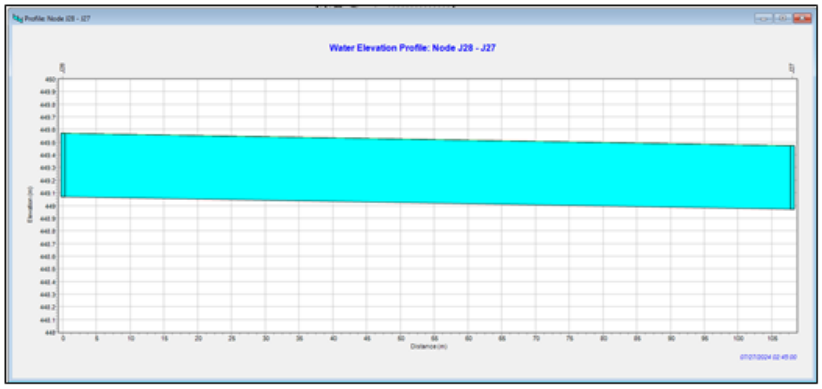

Figure 1. Longitudinal Section of Channel C17

Based on the simulation results that have been carried out, the simulation quality results are obtained as seen in Figure 2. These results are considered adequate because the continuity error in tracing and overflow shows values of -0.62% and -0.07%. The simulation quality is said to be poor if the continuity error exceeds 10.0%.

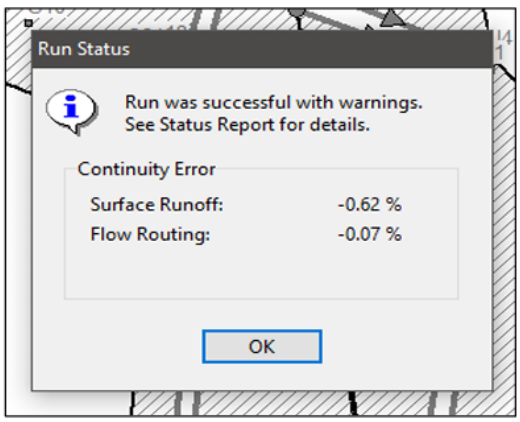

Figure 2. Continuity Error Value After Running

The results of observations of existing conditions in the field show that there are 28 channels that function optimally and suboptimally. According to Dwijaya (2014), optimal channels are characterized by a capacity that is greater than the flow rate (Qs>Qh), while suboptimal channels have the characteristic of a capacity that is smaller than the flow rate (Qs<Qh) (Pratama et al., 2023). This is in line with the results of observations made at the existing location. Where there are 17 channels that function optimally, and 11 channels that are suboptimal. The suboptimal channels include channels C10, C12, C17, C18, C19, C20, C21, C22, C26, C27 and C28. This is because the capacity in these channels is smaller than the design discharge (Qs<Qgab). This is in line with research by Pratama et al (2023) and Dwijaya (2014), which states that a channel is declared non-optimal if its hydrological discharge is greater than its hydraulic discharge (Qh>Qs).

Another factor that causes overflow is high rainfall intensity (Tri Sulistyowati et al., 2023). The rainfall intensity in channel C10 is 69.98 mm/hour, C12 is 199.52 mm/hour, C17 is 108.32 mm/hour, C18 is 82.26 mm/hour, C19 is 106.62 mm/hour, C20 is 107.69 mm/hour, C21 is 111.50 mm/hour, C22 is 116.69 mm/hour, C26 is 122.01 mm/hour, C27 is 158.44 mm/hour and C28 is 171.81 mm/hour. Of course, this is included in the heavy rain category because the rainfall intensity in these channels is more than 50.00 mm/hour (BMKG, 2024). This is in accordance with Fairizi's research (2015), which states that one of the causes of flooding in an area is high rainfall intensity.

Overflow handling efforts can be carried out through various methods such as structural and non-structural. Rizal (2022), in his book, states that the method that can be used to overcome overflows is by non-structural means such as cleaning drainage channels from garbage, plants and sedimentation and providing education or counseling to the local community. This is in line with the results of observations made at the existing location of Jalan Bareng Raya II which consists of channels C10 and C12, then Jalan Bareng Raya IIA which consists of channels C17, C18, C19, C20, C21, C22, C26, C27, and C28.

Steps that can be taken in handling overflows in existing conditions are by implementing infiltration well and biopore infiltration hole planning. In accordance with Bahunta's research (2019) which shows that infiltration wells and biopore infiltration holes are effective in controlling overflows. The planning of these two concepts includes a lot of calculations of the amount needed based on the large overflow discharge which is in line with the research (Hendriawan, 2013). The total planned infiltration well requirement is 11 units where Jalan Bareng Raya II was made 2 units and Jalan Bareng Raya IIA was made 9 infiltration well units. In addition, for the planned biopore infiltration holes as many as 262 units where on Jalan Bareng Raya II 111 units were made and Jalan Bareng Raya IIA 151 biopore infiltration hole units were made. The following are the overall results of the calculation of the need for infiltration wells and biopore infiltration holes for the area around the drainage that experienced overflows which are presented in Table 3.

Table 3. Recapitulation Results of Infiltration Wells and Biopore Infiltration Holes

Channel Name	ΔQ (m^3/s)	Number of Infiltration Wells	Number of Biopore Infiltration Holes
C10	0,63	1	22
C12	2,52	1	89
C17	0,25	1	9
C18	0,27	1	10
C19	0,19	1	7
C20	0,64	1	22
C21	0,98	1	35
C22	1,59	1	56
C26	0,06	1	2
C27	0,05	1	2
C28	0,22	1	8

CONCLUSION

Based on the results of analyzing the storage capacity and combined discharge analysis, it was found that several channels received a combined discharge greater than their storage capacity. This resulted in overflows in the channels. Based on existing conditions, there are 11 channels experiencing overflows, namely channels C10, C12, C17, C18, C19, C20, C21, C22, C26, C27 and C28. Efforts to handle the overflow that will be carried out on Jalan Bareng Raya II consisting of channels C10 and C12 are to clean the drainage channels from garbage, provide education in the form of rules to the community, create 2 infiltration wells and 111 biopore infiltration holes, while for Jalan Bareng Raya IIA consisting of channels C17, C18, C19, C20, C21, C22, C26, C27 and C28, overflows are overcome by cleaning the drainage channels from sedimentation in the form of moss and plants, implementing education and enforcing spatial planning at the location.

Based on the results of the analysis that has been carried out, the researcher provides several suggestions, namely that routine inspection and maintenance of drainage is needed to prevent more serious damage to drainage channels and related agencies need to conduct socialization regarding planning to support the function of drainage in water disposal.

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