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# Assessment of Drainage System in Bangetayu Kulon Village, Genuk District, Semarang City

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***Abstract* - The drainage system is infrastructure related to urban spatial planning and must be considered. This planning was carried out in Bangetayu Kulon Village, Genuk District, Semarang City, which consists of residential, commercial and other areas. Bangetayu Kulon sub-district has inundation problems at several points due to a lack of channel capacity caused by high sedimentation at the bottom of the channel, vegetation, rubbish and changes in land use. In evaluating the drainage system, a 5 year return period hydrological analysis will be carried out using EPA SWMM 5.1 software. Apart from that, a hydraulic analysis will also be carried out which begins with an analysis of existing conditions, then applies SUDS and continues with evaluation through channel normalization in the form of sediment burrowing and changes in channel dimensions. The concept of implementing SUDS in the Bangetayu Kulon Village drainage system is the application of Permeable Pavement on road areas that do not yet have paving pavement of 30,877 m$^2$ and a Retention Pool with a storage capacity of 10,560 m3. This plan succeeded in reducing flooding by 52.06% from initially 147.82 x 106 L to 70.84 x 106 L.**

***Keywords:*** drainage, sustainable, system, hydraulic, sedimentation.

## I. INTRODUCTION

Drainage is a term used for handling excess water. The water in question is surface water/ground water that is unwanted and must be disposed of immediately from a certain location. Drainage is also one of the basic facilities designed as a system to meet community needs and is an important component in city planning, especially in infrastructure planning. Drainage infrastructure in urban areas plays a crucial role as part of city infrastructure, which has a close relationship with spatial management. Flood events that frequently hit various regions and cities in Indonesia are often caused by poorly structured spatial management (Suripin, 2004).

Semarang City is the capital of Central Java Province which is located between 6°50' - 7°10' South Latitude and 109°35 - 110°50' East Longitude. Administratively, Semarang City is divided into 16 sub-districts and 177 sub-districts with an area of 373.78 Km$^2$ (BPS Semarang City, 2023). Geographically, Semarang City is located on the north coast of Central Java with low topographic conditions in the south with a slope of 0 – 2% and height from 0 – 3.5 m. The city of Semarang often experiences flooding during the rainy season due to high rainfall, blockage of drainage by rubbish, robs, and excessive groundwater consumption in the Lower Semarang area, resulting in land subsidence and reduced water catchment areas (Soedarsono, 2012).

Quoting from CNN Indonesia, at the beginning of 2023, 7 sub-districts in Semarang City experienced flooding, one of which was Genuk Sub-district. According to data from BPS Semarang City in Figures 2023, Genuk District has a population density of 7.75% and in the last 10 years the population has increased by an average percentage -an average of 40.6% with the population in 2012 being 91,527 people and in 2022 being 128,698 people. Population increase occurred every year except in 2014 which experienced 2%. The increase in population in Genuk District has resulted in changes in land use to residential areas. This change in land use results in the land's function as a water catchment being reduced and there being a discharge of water runoff in the drainage channels.

This change in land use results in the land's function as a water catchment being reduced and there being a discharge of water runoff in the drainage channels. The problem of flooding and inundation still occurs frequently at several points in Genuk District, such as in Bangetayu Kulon Village. This is also supported by data from the Semarang City Public Works drainage website which explains that areas experienced flooding/inundation for up to 48 hours at the end of 2023. Based on direct observation, there are several points in Bangetayu Kulon Village that do not have drainage channels. In several locations that already have drainage systems, not all of them are able to accommodate high levels of rainfall. Apart from that, there is also channel sedimentation, accumulation of

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rubbish or vegetation which reduces the capacity of drainage channels, as well as closed channel type drainage channels resulting in difficulties for maintenance and upkeep personnel and resulting in channels becoming clogged andcausing puddles and even flooding during the rainy season. These problems must be addressed immediately by restructuring and improving the function of the drainage system in Bangetayu Kulon Village so that it can function effectively. Planning for evaluation and improvement of the drainage system is carried out based on the Sustainable Urban Drainage System (SUDS) concept which is expected to minimize the occurrence of inundation because the SUDS concept is directly related to water resource conservation efforts known as the TRAP principle (Accept, Absorb, Flow and maintain). The purpose of the TRAP principle is to control rainwater so that it can seep into the soil so that the amount of runoff in the study area can be reduced (Maryono, 2022). Therefore, the author is encouraged to conducting studies on System Evaluation Drainage of Bangetayu Kulon Village, Genuk District, Semarang City with the Implementation of a Sustainable Urban Drainage System (SUDS).

## II. METHODOLOGY

Method collection is data categorized based in nature of the data captured. Primary data is collected through surveys and documentation, while secondary data is obtained from literature reviews, field notes, or existing data repositories. Both primary and secondary data undergo processing and analysis. Data analysis is usually carried out in several stages as follows.

### 2.1 Analysis of Existing Conditions in the Study Area

This stage aims to determine the real conditions of the study area, such as a general description, existing drainage systems and inundation areas. Analysis of the existing conditions of the study area can be carried out using 2 (two)methods of location survey and condition analysis of Bangetayu Kulon Village, Genuk District, Semarang City, carried out by analyzing physical conditions including contours, RTRW maps, and system flow direction.

### 2.2 Planning/Scenario Stages Planning

#### 1. Check Existing Condition

Checking existing conditions is an activity to check the capacity of drainage channels in the study area in Bangetayu Kulon Village. In checking the existing condition, the existing debit will be calculated followed by analysis by comparing the existing debit with the planned debit. The analysis was continued by modeling in the EPA SWMM 5.1 software to determine the condition of the drainage channel's capacity to accommodate the maximum runoff discharge for the planned rainfall. If the channel does not experience runoff, the stage of checking existing conditions has been fulfilled in the Bangetayu Kulon Village System Evaluation.

#### 2. SUDS Implementation Scenario

At this stage, drainage channel calculations and planning are carried out using hydraulic analysis methods such as calculating channel dimensions using the Manning equation. Next, an analysis was carried out of the calculations that had been carried out using EPA SWMM 5.1 modelling software. Modelling using SWMM aims to check whether the capacity of the drainage network to accommodate the maximum runoff discharge for the planned rainfall is appropriate. Then, recommendations are given for implementing the Sustainable Urban Drainage System (SUDS) concept in accordance with the conditions of the study area and the needs for complementary buildings in the area. After that, make a detailed engineering design drawing of the drainage channel that has been planned and determine the technical specifications that will be used during the construction of the drainage channel later.

#### 3. Normalization Effort Scenario

Channel normalization efforts are to restore channel capacity to the original planning design. Calculations were carried out to compare the channel discharge after normalization efforts with the total planned discharge. The analysis was continued by modelling in the EPA SWMM 5.1 software to determine the condition of the drainage channel's capacity to accommodate the maximum runoff discharge for the planned rainfall. If the channel does not experience runoff, the stages of checking existing conditions and normalization efforts have been fulfilled in the Bangetayu Kulon Village System Evaluation.

#### 4. Redesign and Channel Addition Scenarios

Re-planning of the drainage channel was carried out after efforts to normalize the channel and compare the discharge after normalization with the total planned discharge but the result was that runoff still occurred. The redesign and addition of this channel was carried out by determining the dimensions of the new channel which was planned using U-ditch with the channel dimensions obtained using the hydraulics concept. Analysis followed by modelling in the EPA SWMM 5.1software to determine the condition of the drainage channel capacity to accommodate the maximum runoff discharge for the planned rainfall. If the channel does not experience runoff, the stage of checking existing conditions and efforts to normalize it has been fulfilled in the Bangetayu Kulon Village System Evaluation.

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## III. RESULTS AND DISCUSSIONS

### 3.1 Analysis of Existing Conditions

When a field survey was carried out, there were several secondary and tertiary channels that had high levels of sediment and were covered by a lot of vegetation. Based on the results of interviews with residents, puddles of water that occur in the Muktiharjo area when it rains are around 10-60 cm high with a queue duration of water flow that can reach more than 24 hours.

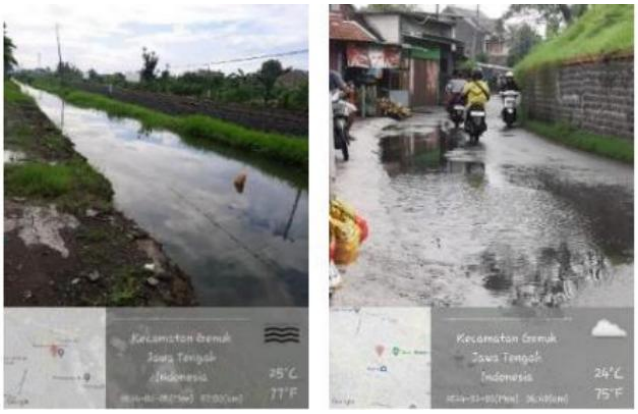

**Figure 1: Flooding on Muktiharjo Road and Bangetayu Raya Road**

### 3.2 Hydrological Analysis

Hydrological analysis in drainage system planning is needed to determine the amount of discharge and calculations in planning channel dimensions. Analysis Hydrology has an influence in controlling surface flow so that it does not cause flooding. The hydrological data that is the basis for planning drainage channels is the design discharge which is calculated from the planned rainfall in the return period certain.

### 3.2.1 Regional Rainfall Analysis

Rain in the area is calculated based on the expansion of the Watershed (DAS) in the spatial plan and rainfall data for 10 years from 2013 to 2022 obtained from three nearby weather stations. For determining the extent of influence of each weather station on the watershed, we applied the Thiessen Method. The results show that the watershed in the spatial plan is significantly influenced by Karangroto Station. Karangroto Station rainfall data can be seen in Table 1.

**Table 1: Karangroto Station Rainfall Data**

| Year | Karangroto Station | |
|---|---|---|
| | Date | Rainfall (mm) |
| 2013 | February 23 | 135 |
| 2014 | January 23 | 135 |
| 2015 | February 13 | 130 |
| 2016 | December 27 | 110 |
| 2017 | January 20 | 110 |
| 2018 | March 9 | 85 |
| 2019 | April 4 | 116 |
| 2020 | February 20 | 93 |
| 2021 | February 24 | 137 |
| 2022 | December 31 | 182 |

### 3.2.2 Frequency Analysis

In calculating planned rainfall, frequency analysis is needed, and it has an influence on determining the amount of discharge for a certain return period. Frequency analysis relates to repeated events by applying probabilities based on the magnitude of extreme events in the future (Soewarno, 1995).

**Table 2: Frequency Analysis Results**

| No | Distribution Method | Requirement | Result |
|---|---|---|---|
| 1 | Gumbel | Cs≤ 1,1396 | 0,81 |
| | | Ck ≤ 5,402 | 5,3 |
| 2 | Log- Pearson III | Cs ≠ 0 | 0,16 |
| | | Cv ≈ 0,3 | 0,22 |
| 3 | Normal | Cs ≈ 0 | 0,81 |
| | | Ck ≈ 3 | 5,3 |
| 4 | Log Pearson III | Cs ≈ 1,137 | 0,16 |
| | | Ck ≈ 5,383 | 0,22 |

Calculation of the planned amount of rainfall using the Gumbel Method is calculated using the following equation:

$$X_t = \bar{X} + \left(\frac{Y_T - Y_n}{S_n}\right) S$$

$X_t$ = return period rainfall (mm/day)
$X_{\bar{y}}$= average maximum rainfall (mm/day)
$Y_T$ = coefficient for the Gumbel distribution
$Y_n$ = coefficient for the nth Gumbel distribution
$S_n$ = nth standard deviation
S = standard deviation

### 3.2.3 Calculation of Rainfall Intensity

According to Minister of Public Works Regulation Number 12 of 2014 concerning Return Period based on City Area and Typology, for the rain catchment area of the planning area in Bangetayu Kulon Sub district which has an area of 200 Ha, a 5-year return period will be used.

Calculation of rain intensity using the mononobe method is formulated as follows:

$$I = \frac{R}{24}\left(\frac{24}{t}\right)^{2/3}$$

 

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I = rainfall intensity (mm/hour)
R24 = maximum daily rainfall (for 24 hours) (mm)
t = duration of rain (hours)

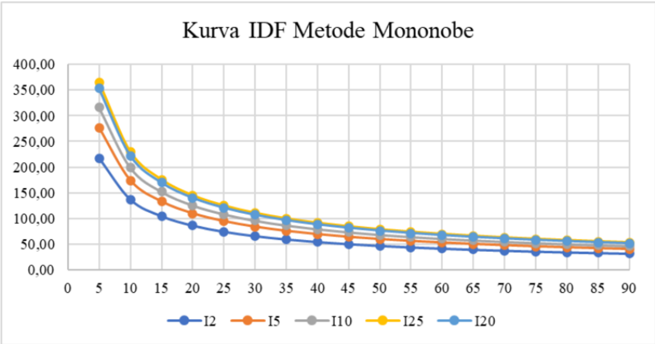


**Figure 2: IDF Curve for rain intensity using Mononobe formula**

### 3.3 Simulation of Existing Conditions

The use of EPA SWMM 5.1 (Environmental Protection Agency-Storm Water Management Model) software in drainage analysis aims to plan, analyze and design models related to storm water flow in urban environments.

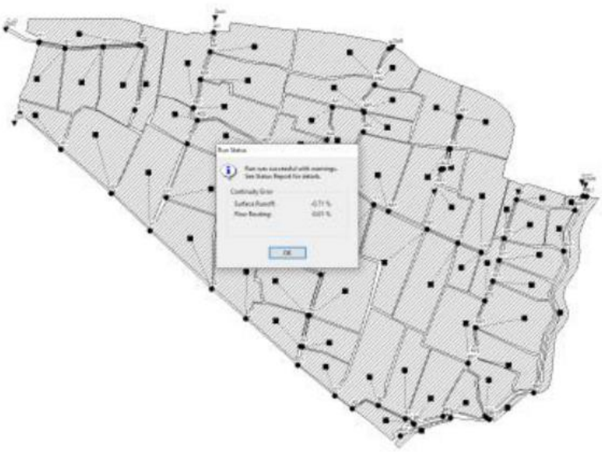

**Figure 3: Existing Channel Condition Modelling using EPA SWMM 5.1**

The result of this simulation has continuity error of -0.72% on surface runoff and -0.01% flow routing. Result of the simulation of the planning area in Bangetayu Kulon Village can be concluded as successful because the continuity error shows result below 5%. There were 39 nodes experiencing runoff with a total flooding volume of 147.82 x 106 L.

### 3.4 SUDS Implementation Simulation

The application of the Sustainable Urban Drainage System (SUDS) or Low Impact Development (LID) concept in EPA SWMM 5.1 aims to implement an environmentally sound drainage system. The Sustainable Urban Drainage System (SUDS) concept will be planned in the Bangetayu Kulon Village aimed at managing surface runoff effectively on a smaller scale. In this planning, SUDS will be used in the form of Permeable Pavement and Retention Ponds.

#### 3.4.1 Permeable Pavement

In this plan, the permeable pavement applied is composed of a paving layer that can absorb water with a thickness of 8 cm, a sub-base layer made of backfill sand with a thickness of 22 cm which functions to filter rainwater and distribute the load evenly, which is then followed by a sub grade layer in the form of soil original which functions as a basic support for permeable pavement.

The application of permeable pavement in this plan is carried out in areas that are affected by flooding or inundation and still have sufficient land. Permeable pavement is carried out on roads that do not have high traffic, damaged roads, home yards, and open areas that have been paved with either concrete or cement. Permeable pavement will be applied to 30,877 m2 of roads, the implementation plan of which can be seen in Figure 4.

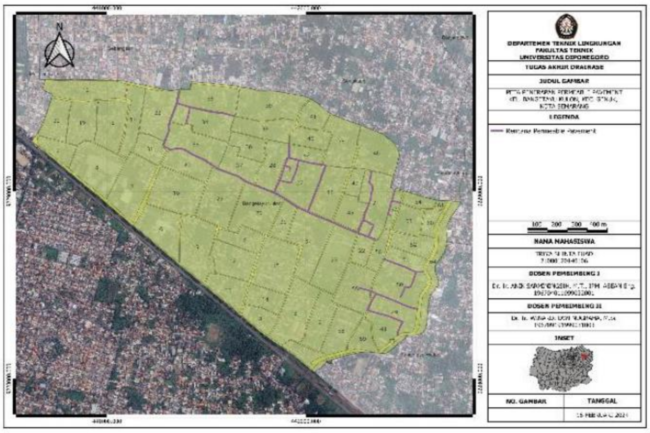

**Figure 4: Permeable Pavement Application Map**

#### 3.4.2 Retention Pool

The retention pond in this plan will be located on Street of Widuri III, Bangetayu Kulon Village, Genuk District, Semarang City. The retention pond is planned at coordinates X= 442125.881 m and Y= 9228928.582 m with a land area of ±6,000 $m^2$ and a storage area of 4,400 $m^2$. This location was chosen on land in the form of open land that is poorly maintained and is in accordance with the regional spatial plan of Semarang City.

Based on the calculation results, the retention pond will be designed with an area of 4,400 $m^2$ with requires a pump capacity of 200 L/second with a pump head of 1.02mand a pump power of 2.68 HP for 2 pumps, of which 1 pump is as a backup.

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The application of Permeable Pavement and Retention Ponds is then simulated in the EPA SWMM 5.1 application.

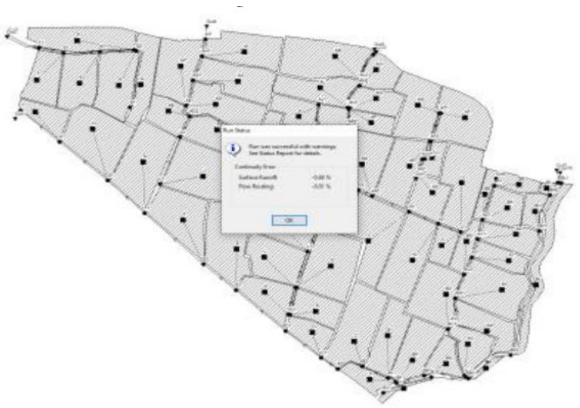

**Figure 5: SUDS Implementation Modeling**

Results from the simulation Figure 5 shows that there is a continuity error of -0.70% on surface runoff and -0.11% on flow routing. With the flow simulation continuity error value being below 5%, it can be concluded that this simulation is considered successful. Implementation of SUDS can reduce runoff discharge is 5% of existing conditions of 140.28 x 106L.

### 3.5 Chanel Normalization Simulation

Based on the result of condition simulations existing and implementing SUDS in SWMM 5.1 software, there is runoff in several channels in the planning area, in accordance with data in the field.

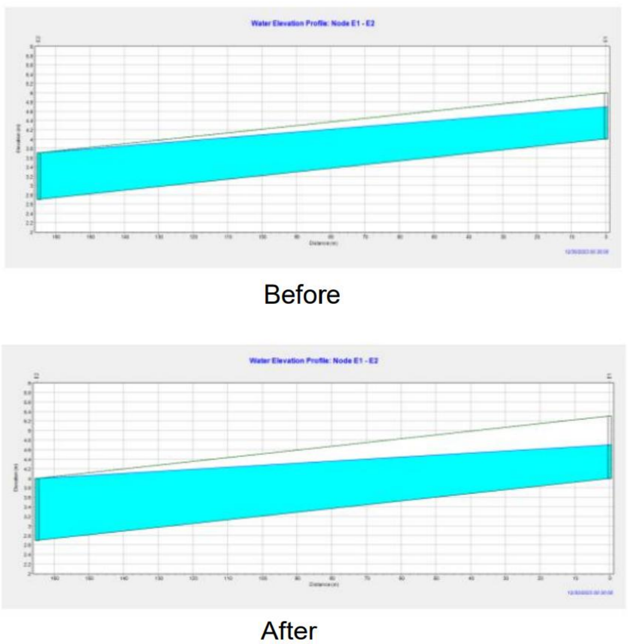


**Figure 6: Example of channel plot profile for Street of Bangetayu Raya before and after normalization**

Therefore, it is concluded that inundation and flooding are caused by sediment and rubbish contained in several channels and some other channels have inadequate capacity to handle runoff so that the performance of the Retention Pond is also not optimal. To overcome this condition, a normalization condition simulation was carried out and a redesign plan was carried out for drainage channels that experienced runoff to be able to accommodate the runoff discharge.

Based on the simulation results display, before there are no significant differences in the normalized channels. However, if we look at the runoff discharge from each channel, there has been a reduction of 20.06%. With a total runoff discharge after normalization of $111.32 \times 10^6$ L.

### 3.6 Simulate Channel Re-design

After applying sediment and dredging sediment in the Bangetayu Kulon still has channels experiencing runoff. This runoff is caused by the channel capacity being insufficient to accommodate the cumulative discharge. It is necessary to re-plan the channel plan. Analysis of channel dimensions using depth (H) and width (B) of the planned channel then checking the cumulative discharge and channel velocity calculation data. Channel redesign planning will use U-ditch.

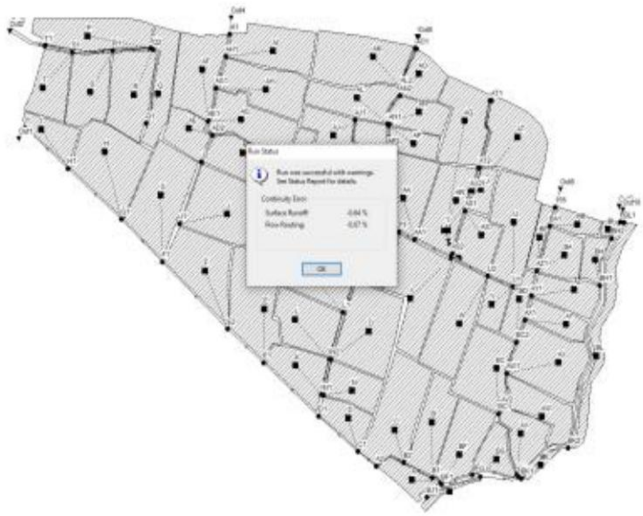

**Figure 7: Channel Redesign Modeling**

The results of the redesign and channel addition simulation can be said to be successful because the flow simulation continuity error value is below 5% with surface runoff of -0.64% and flow routing of -0.07%.

Based on the simulation results of the redesign and addition of this channel, the runoff discharge was obtained at $70.84 \times 10^6$ L which experienced a decrease of 36.4%. The results of this redesign have reduced 11 channels from normalization conditions.

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### 3.7 Drainage System Condition after Evaluation

The implementation of SUDS, channel normalization, and channel redesign, in Bangetayu Kulon Village succeeded in minimizing runoff by 52.08%, from initially $147.82 \times 10^6$ L to $70.842 \times 10^6$ L. In Table 3 below you can see the efficiency table for reducing conditions for normalization, redesign and implementation of SUDS.

**Table 3: Summary of Remaining Flooding Nodes for Each Scenario**

| Scenario | Total Flooding | Reduce | Decline |
|---|---|---|---|
| Existing Conditions | $147.827 \times 10^6$ L | 0 | 0% |
| Application Permeable Pavement | $143.82 \times 10^6$ L | 4.007 | 2,7% |
| Application Retention Pool | $140.28 \times 10^6$ L | 3.532 | 2,5% |
| Normalization Efforts | $111.32 \times 10^6$ L | 28.960 | 20,6% |
| Redesign Efforts | $70.842 \times 10^6$ L | 40.486 | 36,4% |

## IV. CONCLUSION

The drainage system in Bangetayu Kulon Village is experiencing a decline in function where there are road sections that experience runoff caused by inadequate channel dimensions, channel damage, high levels of sedimentation, vegetation and rubbish blocking the channels so that the capacity of the existing channels decreases. Dredging of sediment, vegetation and rubbish is carried out to normalize the channel to return the channel capacity to its original state. Drainage system planning from normalization, redesign, and SUDS succeeded in reducing 52.08%.

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