The Effect of Urban Drainage on The Determination The Time of Storage In The City Development Area

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Abstract. Increasing development activities in various fields in Surabaya will impact the occurrence of flooding, where the growth of residential buildings changes the function of the drainage area into runoff land. Therefore, there is a need for regional drainage recommendations. This study aims to provide a reference for a safe number that follows the storage needs and the duration of the peak partial drainage required by the region, following the study of water resources science. The data needed are rainfall data, average area, land function, and land slope maps. This study uses a 5-year return period probability. Moreover, the Nakayasu Hydrograph method is also used. It has a grace period starting from the rain surface to the top of the hydrograph, the area of the watershed, and the length of the main river channel. The comparison of the length of time of concentration (Tc) of the area with the length of waiting for time (Tp) of the urban drainage hydrograph shows that the area's Tc value is greater than the Tp value of the urban drainage.

Keywords: drainage, flooding, runoff, urban

1. Introduction

Surabaya city is a business center with economic growth, especially in east java [1]. The increase in places of business or development activities for various fields in the city of Surabaya has logistical consequences with the emergence of changes to the flood disaster, where the growth of buildings or changes such as changing the area of water flow reservoirs into the land (flow)[2]. Therefore, the Surabaya City Government always tries to oversee applying for a building permit. This process by requires licensing requirements accompanied by regional drainage recommendations to avoid discharge generation or the possibility of high surface flow and change the existing drainage system in the termination area determined outside the area [3,4]. One of the efforts to prevent flooding early before an activity starts is to apply technical guidance recommendations for regional drainage system directions in the Surabaya area. This guidance follows the mandate of mayor regulation (Perwali) No.21 of 2019 concerning Licensing and/or Non-Building Permits in the City of Surabaya [5].

The city of Surabaya has a drainage network area or commonly referred to as an area, where five areas spread throughout the city [6]. The discussion of the study area in the current study is the drainage network in the Tandes area (western part of Surabaya) and Genteng area (northern part of Surabaya) [7]. The slope of the land's topography in the two areas is different from the slope value in the west Surabaya area is 2–20%, while for the central part of Surabaya to the east is an average of 2%.
This study begins by looking for the concentration value in the built-up area and the concentration value in the city drainage channel by paying attention to the catchment area to obtain recommendations regarding the relationship between changes in the development area and the need for storage volumes according to watershed conditions in each region. The length of time this concentration becomes the basis for determining the length of time used to calculate the built-up area's reservoir.

2. Material and Method

2.1 Literature Study
A literature study is an initial stage where several theoretical references to support activities related to the same field can be collected and reference the stages of conducting and completing this research activity [8]. For this reason, a literature study can be carried out as an initial form of starting this research.

2.2 Research study location
The locations selected in the scope of the first part of the study are shown in table 1.

| Rayon Name | Name of Built Area       | Channel Length (m) | Catchment Area (Km²) |
|------------|--------------------------|--------------------|-----------------------|
| 1          | Genteng                  | Praxis             | 598                   | 0.098                 |
| 2          | Genteng                  | Tunjungan Plaza    | North Side: 1355      | 0.41                  |
|            |                          |                    | South Side: 672       |                       |
| 3          | Gubeng                   | Grand City         | 1502                  | 0.15                  |
| 4          | Gubeng                   | Pakuwon City       | Kalidami: 6022        | Kalidami: 12          |
|            |                          |                    | Kalibokor: 9064       | Kalibokor: 8.83       |
| 5          | Jambangan                | Puri city          | 944                   | 0.55                  |
| 6          | Jambangan                | Trans Icon         | North Side: 235       | 0.094                 |
|            |                          |                    | South Side: 672       |                       |
| 7          | Jambangan                | Medokan Ayu        | 3740                  | 3.28                  |
| 8          | Wiyung                   | Ciputra World      | 681                   | 0.27                  |
| 9          | Wiyung                   | Royal Residence    | 331                   | 0.18                  |
| 10         | Tandes                   | Warehouse at Kalianak 55 street | 463 | 0.23 |
| 11         | Tandes                   | North West Park    | 1076                  | 2.1                   |

One of the research locations is as follows:

Figure 1. Survey Locations for Built-up Areas and Their Persilient Drainage Channels
2.3 Calculation of Discharge Hydrograph and Peak Time

The following are the steps for calculating Hydrology and Hydraulics on a partial drainage channel when looking for a discharge and peak time hydrograph.

2.3.1 Calculation of Planned Rainfall (R24)

In planned rainfall analysis, several stages are needed to obtain the value of the planned rain in the area to be planned or evaluated. There are 11 rain stations in Surabaya, which are spread throughout the Catchment Area in Surabaya. Calculation of rainfall obtained maximum annual rainfall. The period used is the last 12 years [9].

2.3.2 Calculation of Probability Distribution of Planned Rainfall

The calculation of rainfall distribution is based on annual maximum rainfall data. The average rainfall data is calculated through log person III probability distribution. Furthermore, the frequency distribution test was carried out to calculate rainfall results from the Gumbel method and the log person type III method [10]. Results of the Gumbel method and the log person type III method were matched with the requirements of the frequency distribution test. From these data, the R24 rainfall limit value is obtained in the following calculation [11].

2.3.3 Calculation of Probability Distribution of Planned Rainfall

Guidance in assessing this coefficient value varies according to the land use around the area and the partial drainage channel (Table 2).

### Table 2. Run off Coefficient Values based on SNI 2415 – 2016

| Area Type          | Coefficient Runoff | Kondisi Permukaan     | Coefficient Runoff |
|--------------------|--------------------|-----------------------|--------------------|
| Shopping Area      |                    |                       |                    |
| Capital City       | 0.70 - 0.95        | Asphalt or Concrete   | 0.75 - 0.95        |
| Develop            | 0.50 - 0.70        | Brick or Concrete Brick | 0.70 - 0.85       |
| Residential Area   |                    | Sandy Grass Field     |                    |
| Cluster            | 0.40 - 0.60        | Flat slope < 2%       | 0.05 - 0.10        |
| Densely Populated  | 0.60 - 0.75        | Average slope 2 - 7%  | 0.10 - 0.15        |
| Apartment          | 0.50 - 0.70        | Precipitous slope > 7%| 0.15 - 0.20        |
| Industrial Area    |                    | Grass Field with Compacted Soil |          |
| Light              | 0.50 - 0.80        | Flat slope < 2%       | 0.13 - 0.17        |
| Heavy              | 0.60 - 0.90        | Average slope 2 - 7%  | 0.18 - 0.22        |
| Open Yard or Rail Road | 0.20 - 0.35       | Precipitous slope > 7%| 0.25 - 0.35       |

2.3.4 Calculation of Plan Debit Value

When finding the discharge value, various methods can be used based on the needs and location of the drainage channel's catchment area. In this case, the Nakayasu Synthetic Unit Hydrograph (HSS) was chosen because the river/channel in the Surabaya City area tends to have the same characteristics as the river in the Nakayasu variable, where the channel tends to be lengthy and its area divided into an elongated oval shape (like a plate shape). The following formula is used

\[
Q_p = \frac{(C \cdot A \cdot R_0)}{3.6 \cdot (0.3 \cdot T_p \cdot T_0.3)}
\]  

Where \(Q_p\) is peak discharge (m³/sec), \(C\) is land coefficient, \(A\) is catchment area (km²), \(R\) is return period rainfall (mm). Calculation of the return period discharge of the existing condition of the Kalimati channel with the function of pond land [12]. Calculation of the Hydrograph of the Nakayasu Unit of the
existing condition through the calculation of the concentration time, the calculation of the rain time unit, the calculation of the time from the beginning of the rain to the peak of the flood, the decrease in peak discharge, and the resulting $Q_p$ value, namely peak discharge. Furthermore, tables and graphs of the Nakayasu hydrograph were obtained for the existing condition of the 25-year return period [13].

2.3.5 Calculation of Channel Hydraulic Discharge Value
The dimensions of the drainage channel used are $b = 150$ cm and $h = 2 \times 75$ cm. In calculating the hydraulic discharge, the following formula is used

$$Q = A \cdot V$$  \hspace{1cm} (2)$$

Where $Q$ is the hydraulic discharge (m$^3$/s). $A$ is the cross-sectional area (m$^2$) and $v$ is the flow velocity (m/s). To calculate the flow velocity in the drainage channel using the following Manning formula as follows:

$$v = \frac{1}{n} \cdot R^{2/3} \cdot I^{1/2}$$  \hspace{1cm} (3)$$

Where $v$ is the flow velocity (m/s). $n$ Manning roughness coefficient. $R$ as the radius (m). $I$ as channel slope.

2.3.6 Comparison of the results of the length of time of concentration ($T_c$) in the area with the length of waiting time from the hydrograph of the Persilial Drainage of the City Front of the Region
Calculation of concentration time for two conditions where the first is to calculate the concentration value ($T_c$) in the built area itself and the second calculates the time value of concentration in the partial drainage of city channels outside the area by calculating the area of the catchment area [14]. While the final result is to get the recommended value for the length of the built-up area that will be recommended.

3. Results and discussion

3.1 The results of the calculation of the distribution of rainfall using the Gumbel method and the log person type III method
Theoretical requirements for the Log Person III method are flexible Cs and Ck values [15]. The Cs value in the Gumbel method is -0.4996 and the Ck value in the Gumbel method is 2.7324. Meanwhile, the Cs value in the Log Person III method is -0.7 and the Ck value in the Log Person III method is 2.9483. Based on the theoretical requirements of the Gumbel method, the value of $Cs \leq 1.1396$ and the value of $Ck \leq 5.40002$. Meanwhile, based on the theoretical requirements of the Log Person type III method, the Cs and Ck values are flexible. So that the values of Cs and Ck in the Gumbel method and the Log Person type III method pass the statistical probability requirements. The following are the results of the calculation of the rain distribution using the Gumbel method and the log person type III method

| Table 3. Calculation of Rain Distribution with Log Pearson III |
|---------------------------------------------------------------|
| Return Period | Velocity (m$^3$/s) | Gumbel | Log Pearson III |
|----------------|-----------------|--------|-----------------|
| 2              | 88.513          |        | 91.55           |
| 5              | 109.502         |        | 107.37          |
| 10             | 123.397         |        | 115.10          |
| 25             | 136.727         |        | 122.75          |
| 50             | 140.955         |        | 127.21          |
| 100            | 166.909         |        | 130.90          |
From Table 3, the R5 value of the return period Log Person Type III is taken as the value of the R24 rainfall limit in the following calculation.

3.2 Result of Calculation of Planned Debit Value
The data is shown in the Genteng rayon and Praxis area. This location has a channel length of 0.598 km and a catchment area of 0.098 km$^2$. Calculation of the Nakayasu Unit Hydrograph is for the planned conditions through the calculation of the concentration time, the calculation of the rain time unit, the calculation of the time from the beginning of the rain to the peak of the flood, the decrease in the peak discharge, and the resulting $Q_p$ value, namely the peak discharge. Furthermore, tables and graphs of the Nakayasu hydrograph were obtained for the planned condition of the 25 year return period. Where $Q_p$ is the peak discharge ($m^3/sec$), $C$ is the land coefficient, $A$ is the catchment area ($km^2$), $R$ is the amount of return period rainfall (mm) \[16\]. Where the area of the watershed is 0.098 km$^2$, the length of the river is 0.598 km, the unit rain $(R_{2\text{ year}})$ is 91.55 mm, the unit rain $(R_{5\text{ year}})$ is 107.37 mm, the unit rain $(R_{10\text{ year}})$ is 115.10 mm, the unit rain $(R_{25\text{ year}})$ is 122.75 mm, the flow coefficient ($C$) is 0.7 (with the corrected control value 1 mm), and the alpha ($\alpha$) value is 1.5.

![Figure 2](image)

**Figure 2.** Hydrograph Chart of Nakayasu Flood Discharge Planned return period of 5 years.

From the results of the hydrograph calculation of the design conditions shown in Figure 2 above, the peak discharge at the $Q$ value is 2.366 m$^3$/second at 0.2 hours. This means that the hydrograph informs that the volume of water that occurs is $2.366 m^3 \times 0.2\ hours \times 3600\ s = 1.681.92\ m^3$.

3.3 Calculation Result of Channel Hydraulic Discharge Value
The results of the calculation of the hydraulic discharge value of the channel are shown in Table 4 below

| Channel Name | Channel Type | $b$ (m) | $h$ (m) | $z$ | $A$ ($m^2$) | $P$ ($m^2$) | $R$ | $R^{2/3}$ | $I$ | $I^{1.5}$ | $V$ ($m/s$) | $V$ ($m^3/s$) |
|--------------|--------------|---------|---------|-----|-------------|-------------|----|-----------|----|-----------|-------------|--------------|
| Sewer (A-1)  | Box culvert  | 1.5     | 1.5     | -0.018 | 2.25       | 4.5         | 0.5 | 0.629961  | 0.002 | 0.0447    | 1.565       | 3.522        |

From the results above, the cross-section of the dimensions of the partial drainage channel in the Praxis area is sufficient to anticipate the 5-year return period discharge from the Nakayasu hydrograph calculation. Where the hydraulic discharge value obtained is 3.522 m$^3$/s greater than the calculated Nakayasu hydrograph discharge value, which is 2.366 m$^3$/s.
| No. | Name | First Data | Tck Value | Drainage Channel Name | L Channel (Km) | CA Area (Km²) | Q Hydraulics (m³/s) | Time Peak | TcK >=< Tp | Storage Time |
|-----|------|------------|-----------|----------------------|---------------|--------------|-------------------|----------|-----------|-------------|
| 1   | Jimerto Road No. 28 | 491.9 | S | 5.68 | 0.09 | Slamet road secondary channel | 0.031 | 0.0042 | 1 |
| 2   | Slamet Road No. 33 | 564.3 | S | 6.24 | 0.1 |  | 0.103 | 0.00122 | 1 |
| 3   | Kaca Piring Road No. 9 | 529 | S | 5.86 | 0.1 | | 0.182 | 0.0186 | 5.289 | 0.2 | P | 1 |
| 4   | Walikota Mustajab Road 67-68 | 988 | S | 6.23 | 0.1 | | 0.366 | 0.0669 |  |  |
| 5   | Praxis | 11,043.25 | S | 50.48 | 0.84 | Karimun Jawa Road | 0.598 | 0.098 | 2.336 | 0.2 | S | 1 |
| 6   | Tunjungan Plaza | 73,535.73 | MP | 123.71 | 2.06 | Kedundoro Embong Malang Road | 1.355 | 0.41 | 0.865 | 1.6 | S | 2.1 |
| 7   | Royal Residence | 10,068 | S | 51.9 | 0.87 | Pondok Manggala road | 0.33 | 0.18 | 1.589 | 0.4 | S | 1 |
| 8   | North West Park | 257,559.95 | S | 658 | 206 | Babat Jerawat Channel | 1.076 | 2.1 | 5.089 | 2.5 | S | 3.5 |
| 9   | Kalianak 55 | 19,505.77 | S | 64.62 | 1.08 | Kalianak Road | 0.463 | 0.23 | 0.244 | 1 | S | 1 |
| 10  | Grand City | 45,597 | MU | 90.6 | 41.77 | 0.7 | Slamet Road | 1.5 | 0.15 | 1.783 | 0.4 | S | 1 |
| 11  | Pakuwon City | - | MU | 898 | 298.3 | 4.97 | Bokor River | 9.064 | 8.83 | 24.73 | 3 | S | 5 |
| 12  | Puri City | 20,604.47 | MU | 216 | 82.53 | 1.38 | Anyar Mountain River | 0.94 | 0.55 | 5.429 | 0.6 | S | 1.5 |
| 13  | Trans Icon | 22,199.4 | MU | 199 | 65.46 | 1.09 | Gayungan Road | 0.235 | 0.094 | 0.92 | 0.3 | S | 1 |
| 14  | Medokan Ayu | 15,486.7 | S | 289 | 151.7 | 2.53 | Medokan ayu channel | 3.74 | 3.280 | 12.12 | 1 | S | 2.5 |

Siteplan (S); Mixed Plan (MP); Mixed Used (MU); Persil (P); Sector (S)

From table 5, the Tc value of the area is greater than the partial drainage Tp value, meaning that the old demand and storage volume using the results from the area calculation will be greater but as a form of safety factor it is advisable to use these results to avoid rapid flow in drainage, and has an impact on the inundation area around the location of the built area [17].

4. Conclusions
In this study, the following conclusions were obtained
- Catchment area calculation is based on SDMP 2018-2038 where a scalar calculation of the area from AutoCAD and the length of the channel is obtained by survey results with the average dimensions of measurements in the field
- The formulation of the hydrological calculation of the planned flood discharge using the Nakayasu HSS, with the Log Person Type III method where the R value of the 5-year planned rain period is smaller than the Gumbel method.
The calculation of the planned flood discharge uses a 5-year return period (Q5).

The planned flood discharge calculation results only accommodate the value of the rainfall that occurs, while the value for wastewater must be calculated (added) itself in accordance with the designation of the land function of the building that will be built later. The formula for QK = 150 liters/person/day x 70% x Total population x A.

The determination of storage time value for the area distribution is divided into the following:
- Area < 10,000 m², it is recommended to hold it for 1 hour
- An area of 10,000 m² to 75,000 m², it is recommended to hold it for 2 hours
- Area > 10,000 m², it is recommended to hold it for 3 hours.

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