Hydraulic analysis of Semarang River in supporting the drainage channel as water tourism

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Abstract. The Semarang River is a flushing channel located in the Semarang River Drainage Sub-System and has the potential to be used as a water tourism area with the concept of Historical River Front City Walk. The planned water tourism area is in the form of procuring boats in the Kota Lama area, which is a historic area in the city of Semarang. This analysis aims to hydrology and hydraulics model of the Semarang River using SWMM 5.1. The method is carried out by observing the existing conditions of the study area, determination of flood discharge plans, and hydraulic analysis. The analysis starts from the Simongan Weir Bridge upstream of the Semarang River to the Berok 2 Bridge, which is located in the Kota Lama area. The results showed the intensity of rainfall designed 25 years is 155.7 mm/hour with the capacity of the Semarang River in existing and planning conditions can still accommodate the flood discharge plan, and a weir with a height of 1 m is needed to maintain the water level in boundary condition so that boat tours can operate optimally.

1. Introduction

Population growth and industrial development have a considerable impact on the hydrological cycle, which impacts climate change. This phenomenon has an essential effect on the continuation of human life and other creatures on earth, including shifts in seasons, disruption of the watershed condition, and changes in rain patterns/distribution that trigger floods in the rainy season and drought in the dry season [1,2]. Small changes in rainfall patterns and variability can cause an increase in extreme rainfall that occurs more intensely and repeatedly [3]. Flood events and poor rainwater distribution systems can cause problems if left unchecked, which underlies an area's drainage planning.

Appendix VI Regional Regulation of the City of Semarang No. 7 of 2014 concerning the Semarang City Drainage System Master Plan 2011-2031 [4] states that the area of Semarang City, especially the lower part of Semarang, is experiencing land subsidence with an average land subsidence rate of 2.31 cm per year. Thus, special attention is needed in handling the drainage system in the Semarang River Sub-System. In 1980, normalization was carried out along the Semarang River by constructing a 7-meter wide inspection road on the riverbank. So, with the normalization, it can organize the Semarang River to be cleaner and more orderly. However, this did not last long because illegal buildings appeared on the banks of the Semarang River. In addition, there is also much garbage that can clog the Semarang River channel [5].

Based on the presentation from the Technical Design Section of the Semarang City Public Works Service on the Semarang City Government Youtube page, he stated that the Semarang City Government
has a structuring plan on the Semarang River with the Waterfront City concept which aims to make the rivers in Semarang City implicate the Historical River Front City Walk concept. Thus, the Semarang River not only functions to drain water but can also be used as a public space and can be used as a water tourism spot [6]. Therefore, it is necessary to review the design of the Semarang River sub-system by modeling the hydrology and hydraulics of the Semarang River using SWMM 5.1. The study area starts from the Simongan Weir Bridge upstream of the Semarang River to Berok 2 Bridge in the Kota Lama area.

2. Methodology

2.1. Purpose of study
This analysis aims to hydrology and hydraulics model of the Semarang River using SWMM 5.1.

2.2. Method of study
The method is carried out by field observations and literature studies. Field observations were made on the existing condition of the study area starting from the Simongan Weir Bridge to the Berok Bridge 2, then the data obtained from this observation can be used as a validation for hydraulic analysis of Semarang River in SWMM 5.1 software.

2.2.1. Observation existing condition of the study area. As a city flushing channel, the Semarang River receives a supplementary discharge from the Simongan Weir located in the Kanal Banjir Barat (KBK). In normal conditions, the amount of discharge that was flowed into the Semarang River is 240 liters/second and 500 liters/second under certain conditions, such as during the rainy season or if there is a request for additional discharge from the Semarang City Government. However, the supplementary discharge that enters the Semarang River is only about 30% of the total discharge from the Simongan Weir. It happens because the water level in the Semarang River is higher than the water level in the Bulu Channel. There are four weirs in the Kampung Pelangi area to temporarily store water. It is what causes the water level of the Semarang River in front of the Kampung Pelangi to be high, while the water level at the observation point of the Tugu bridge is low because the large channel of the river reduces the velocity of the flow.

Normalization of the Semarang River has not been carried out in its entirety. It is motivated by the scale of development priorities and the funds owned by the Semarang City government. Normalization has been carried out in the Kampung Pelangi area, the Tugu area, and the Pekunden area. So that from the Thamrin bridge to the Berok 2 bridge, normalization has not been carried out. It is indicated by the broken river stones with varying degrees of damage and the uneven, wet cross-sectional area; there is still much sediment due to the absence of dredging.

2.2.2. Determination of flood discharge plans. In planning a drainage system, calculations are needed to determine the design flood with hydrological analysis. Rainfall data comes from three rain stations, namely Candi Station, Tanjung Emas Station, and Tlogosari Station, and uses maximum annual rainfall data, which is used as input in SWMM 5.1 software. The rainfall intensity analysis is using the equation Dr. Mononobe as follows.

\[ I = \frac{R_{24}}{24} \times \left( \frac{24}{tc} \right)^{\frac{2}{3}} \]  

(1)

2.2.3. Hydraulic analysis. Manual hydraulic study was performed on the Semarang River's current circumstances to assess whether the river's capacity can meet the design flood discharge with return periods of 25 years. In addition, a hydraulic analysis of the Semarang River was conducted based on the findings of measurements taken of the current and planned conditions along the Semarang River. The planned scenarios of the Semarang river are used as boat tours to support the Semarang River as the Historical River Front City.
3. Results and discussion
Based on the explanation above, the following results were obtained.

3.1. Hydrological analysis
The results obtained from the calculation of rainfall intensity analysis using the equation Dr. Mononobe from three rain stations data, namely Candi Station, Tanjung Emas Station, and Tlogosari Station, show that the 25-year design rainfall intensity is 155.7 mm/hour.

3.2. Dependable discharge analysis
The availability of water for several purposes, especially for river tourism, is crucial. One of the strategies used is to provide supplementary discharge from the upstream river. In general, the water availability in this river uses a probability of 50%, which means the probability of a discharge occurring is more significant than planned [7]. The data used is monthly data from the Supplementary discharge by the Simongan Weir for the Semarang River for the last four years. The results of the dependable discharge analysis obtained are as follows.

![Figure 1. Dependable discharge graph.](image1)

3.3. SWMM 5.1 software simulation
The first stage in the simulation using SWMM 5.1 software is to determine the catchment area. The determination of the catchment area is based on the flow direction contained in the DED (Detailed Engineering Design) drainage system and observations of the flow direction when observing the field and paying attention to the contours that allow the water to be flow gravitationally. In this modeling, the study area consists of 14 villages, where each village is divided into several sub-catchments so that there are 62 sub-catchments.

![Figure 2. Drainage system modelling in Semarang River sub-system.](image2)
Next, the second stage in modeling is drawing the study area and inputting data into the SWMM 5.1 software. The data needed is on Subcatchment (% Impervious and Curve Number, N-Impervious and N-Pervious, and D-Store Impervious and D-Store Previous) and Conduit (value of n manning). Then in the third stage, it is necessary to input time series data in the SWMM software. The input data is 25-year design rain data. In the fourth stage, before doing simulation modeling on the SWMM software, it is necessary to set the simulation options. On the “simulation options” page, ensure that rainfall/runoff and flow routing are selected in the process model. The routing model uses a dynamic wave model, and the infiltration model uses a number curve [8].

3.3.1. Flood simulation. The drainage system modeling in the planning area of the Semarang River Sub-System, which was carried out using SWMM 5.1 software, aims to determine the cross-sectional ability of the Semarang River to accommodate and drain water, so there is no flooding. In carrying out this flood simulation, there are two simulations, namely the existing condition and the planning condition of the Semarang River. Simulation of flooding in existing conditions using primary data is conducted by surveying per field conditions. At the same time, the planning conditions used secondary data DED (Detail Engineering Design) of the Semarang River, which was obtained from the Semarang City Public Works Service, which was the DED of the Semarang River normalization plan [6]. The simulation results obtained in both conditions are pretty good, or it can be said that there is no flood. The longitudinal profile in both conditions during peak hours can be seen in the image below.

![Figure 3. Longitudinal profile of the Semarang River in existing conditions.](image1)

![Figure 4. Longitudinal profile of the Semarang River in planning conditions.](image2)

Based on the profile picture above, it can be seen that the existing condition of the Semarang River at the peak of the rain at 11.00 a.m. still fulfills and does not exceed the channel capacity so that it can
be said that this condition is not flooding. However, it can also be seen in the longitudinal profile of the river in the existing conditions at the point of Agus Salim Bridge to Berok Bridge; there will be flooding if there is high-intensity rain. So to reduce this risk, it is necessary to normalize the Semarang River channel. Meanwhile, the longitudinal profile of the Semarang River in the planning conditions shows that there is no runoff of the Semarang River. It is indicated by the blue line, which is still below the river channel. Therefore, the Semarang River can accommodate flood discharge in the Semarang River Sub-System.

3.3.2. **Boat tour simulation.** Based on the Historical River Front City Walk planning concept, this simulation will examine the flow of tourism by observing the width and depth of the Semarang river, precisely at Agus Salim Bridge to Berok 1 Bridge using SWMM 5.1 software. The author assumes the type of tourist boat used in the simulation is a sampan with a draft depth of 0.5 meters based on data from Perhubungan Darat dalam Angka 2013 [9]. This sampan-type boat uses fiberglass measuring 4 m x 1.6 m x 0.6 m, with a maximum capacity of 4 people. So, based on Pedoman Konstuksi dan Bangunan (Pd T-07-2004-A) tentang Perbaikan Muara Sungai dengan Jeti, simulation of boat tourism in existing and planning conditions will use a standard water level of 0.65 m and a minimum width of a river with two lanes is 12.16 m for canoes [10]. The simulation was carried out with two scenarios, namely the existing conditions and the planning conditions of the Semarang River, precisely on link 13 (Agus Salim Bridge to Berok Bridge) during tourist operating hours, assumed to be 8 a.m. – 10 p.m., West Indonesian Time (UTC+7).

Scenario 1 is to simulate the dependable discharge of the Simongan Weir and Semarang Rivers with the existing river conditions. The river's width for link 13 in the existing condition is 16 m (Wn ≥ 12.16 m); this still fulfills the standard for calculating the width of the river used for the sampan as planned. Scenario 2 simulates the addition of the dependable discharge for the Simongan Weir and Semarang River in the planning conditions. The river's width for link 13 in the planning condition is 15.421 m (Wn ≥ 12.16 m); this still fulfills the standard for calculating the width of the river used for the sampan as planned.

The results of the water level depth obtained by simulating the existing and planning conditions for link 13 at 8 a.m. – 10 p.m., West Indonesian Time (UTC+7) are as follows.

**Table 1.** Depth of water level for simulation of boats in existing and planning conditions.

| Hours   | Existing Condition (m) | Planning Condition (m) |
|---------|------------------------|------------------------|
| 8 a.m.  | 1.35                   | 1.45                   |
| 9 a.m.  | 1.36                   | 1.45                   |
| 10 a.m. | 1.36                   | 1.46                   |
| 11 a.m. | 1.36                   | 1.46                   |
| 12 p.m. | 1.03                   | 1.12                   |
| 1 p.m.  | 0.85                   | 0.9                    |
| 2 p.m.  | 0.76                   | 0.81                   |
| 3 p.m.  | 0.72                   | 0.76                   |
| 4 p.m.  | 0.97                   | 1.03                   |
| 5 p.m.  | 1.13                   | 1.2                    |
| 6 p.m.  | 1.15                   | 1.22                   |
| 7 p.m.  | 1.15                   | 1.23                   |
| 8 p.m.  | 1.15                   | 1.23                   |
| 9 p.m.  | 1.15                   | 1.23                   |
| 10 p.m. | 0.96                   | 1.02                   |
Based on the water table depth, with the addition of the mainstay discharge for the Semarang River in existing conditions and this planning condition, it is possible to have boat tours during operating hours from 8 a.m. – 10 p.m., West Indonesian Time (UTC+7). Based on the longitudinal profile of the Semarang River in the existing conditions, there can be critical conditions that have a risk of the boat running aground, or the boat will hit the bottom of the channel if it exceeds the load. Meanwhile, in the planning conditions at link 13, the boat tour plan still fulfills the channel capacity. From the results of boat simulations in existing and planning conditions, the authors suggest that boat tourism plans can be carried out by adding a weir to keep the water level average during the dry or rainy season.

### Table 2. Depth of the water level by paying attention to the safety factor of sedimentation in existing conditions.

| Hours | Link 3 | Link 4 | Link 5 | Link 6 | Link 7 | Link 8 | Link 9 | Link 10 | Link 11 | Link 12 | Link 13 | Link 14 |
|-------|--------|--------|--------|--------|--------|--------|--------|---------|---------|---------|---------|---------|
| 8 a.m.| 0.75   | 1.12   | 1.37   | 1.35   | 1.26   | 1.27   | 1.25   | 1.21    | 1.07    | 1.5     | 1.18    | 0.68    |
| 9 a.m.| 0.76   | 1.14   | 1.38   | 1.37   | 1.27   | 1.24   | 1.22   | 1.22    | 1.09    | 1.52    | 1.18    | 0.69    |
2. The Semarang River has decreased the capacity of the river channel. Inlet channel to the Berok 1 Channel (0.65 m) as well as the longitudinal profile of the Semarang River, which can be seen in the Gang Selan tourism plan at certain hours. The results of the water level depth still do not fulfill the requirements (> 0.65 m) as well as the longitudinal profile of the Semarang River, which can be seen in the Gang Selan Inlet channel to the Berok 1 Channel (link 12 – link 13) experiencing water runoff because the capacity of the Semarang River has decreased the capacity of the river channel.

2. Simulation in planning condition

Table 3. Depth of the water level by paying attention to the safety factor of sedimentation in planning conditions.

| Hours   | Link 3 | Link 4 | Link 5 | Link 6 | Link 7 | Link 8 | Link 9 | Link 10 | Link 11 | Link 12 | Link 13 | Link 14 |
|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 8 a.m.  | 0.81   | 1.15   | 1.52   | 1.54   | 1.39   | 1.43   | 1.39   | 1.33   | 1.15   | 1.52   | 1.45   | 0.79   |
| 9 a.m.  | 0.82   | 1.16   | 1.53   | 1.55   | 1.4    | 1.43   | 1.39   | 1.34   | 1.16   | 1.54   | 1.46   | 0.8    |
| 10 a.m. | 0.83   | 1.16   | 1.54   | 1.55   | 1.41   | 1.45   | 1.4    | 1.34   | 1.17   | 1.54   | 1.47   | 0.8    |

Figure 7. Longitudinal water level profile by paying attention the safety factor of sedimentation at peak discharge in existing conditions.

Based on the water table depth above, the results show that some channels cannot fulfill the water tourism plan at certain hours. The results of the water level depth still do not fulfill the requirements (> 0.65 m) as well as the longitudinal profile of the Semarang River, which can be seen in the Gang Selan Inlet channel to the Berok 1 Channel (link 12 – link 13) experiencing water runoff because the capacity of the Semarang River has decreased the capacity of the river channel.
In this manual calculation analysis, it will be studied about the capacity of the Semarang River to accommodate flood loads using the current intensity of rain without regard to the amount of deep discharge entering the Semarang River from the Simongan Weir and the discharge from domestic activities of the community in the Semarang River Drainage Sub-System. Then, the design discharge will be calculated in the river channel by considering the value of C (runoff coefficient) and time concentration.

**Figure 8.** Longitudinal water level profile by paying attention to the safety factor of sedimentation at peak discharge in planning conditions.

Based on the water table depth above, the results show that some Semarang River channels cannot fulfill the water tourism plan at certain hours because the results of the water level depth obtained still do not fulfill the requirements > 0.65 m. The channel suitable for water tourism in the form of boats is on the Gang Selan Inlet channel to Berok channel 1 (link 12 - link 13). In the longitudinal profile of the Semarang River, it can be seen that the capacity of the Semarang River in the planning conditions after paying attention to the safety factor of sedimentation has decreased the capacity of the river channel. However, the river's capacity in the planning conditions can still accommodate water runoff, and this condition can support water tourism.
The above scheme shows that in the Semarang River Drainage Sub-System, 12 inlets originate from 12 sub-catchments along with segments I and II of the Semarang River. It shows that the further downstream, the amount of discharge contained in the river will be even more significant. In addition, the combined flow coefficient is very influential on the magnitude of the peak discharge. The greater the combined flow coefficient value, the greater the peak discharge produced. The greater the combined flow coefficient value, the greater the peak discharge produced. In addition, the combined time concentration (concentration-time) also affects the rain intensity, namely the greater the tc value, the smaller the rain intensity. So it can be concluded that Segments I and II of the Semarang River can withstand the design discharge load with a return period of 25 years. So, with a rain intensity of 155.7 mm/hour, the condition of Segments I and II of the Semarang River is still safe from inundation.

3.5. Weir design
The weir design is carried out at two locations, which are located after the Agus Salim Bridge and before the Berok 1 Bridge, where the function of the weir is to limit one pool to another. Weir maintains downstream water level elevation and as a conservation effort to accommodate water in the pond and does not flow continuously downstream of the river. Based on the survey results on the existing conditions, it was found that the flow in the Semarang River is a subcritical flow with Froude number < 1. So, it is necessary to design a weir with a sink type.

Table 4. Weir design results.

| Type of Weir          | Sink Type |
|----------------------|-----------|
| Amount of Weir       | 2         |
| Initial Elevation    | -2.89     |
| Weir Elevation       | -4        |
| Height of Weir       | 1 m       |
| Length of Weir (Ld)  | 1.2 m     |
| Hydraulic spokes (R) | 2 m       |
Figure 10. Longitudinal profile of weir location point.

The following is a map of the weir design points on the boundary conditions:

Figure 11. Weir location point map.

4. Conclusion
The SWMM 5.1 software simulation was conducted using a 25-year design rainfall intensity of 155.7 mm/hour. The capacity of the Semarang River in the existing and planning conditions can still accommodate a 25-year design rainfall as a water tourism plan located in the Kota Lama area (Agus Salim Bridge to Berok Bridge), the standard for water tourism routes includes a river width of 12.16 m and a water level of depth > 0.65 meters. In the existing condition, the river's width is still adequate, and the simulation results of the water level depth for water tourism have also been fulfilled but have the risk of the boat running aground. In planning conditions, the width and depth of the Semarang river have met so that water tours can be carried out with operating hours from 8 a.m. – 10 p.m., West Indonesian Time (UTC+7). The water tourism plan can be implemented by applying a height of 1 meter to maintain the water level in boundary conditions so the boat can operate optimally.

Acknowledgement
The author would like to express his deepest gratitude to the Faculty of Engineering, Diponegoro University for the opportunity for strategic research as well as the Semarang City Public Works Service
and other relevant agencies who have helped the author provide references in the form of secondary data that are indispensable in this research.

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