Integrated systems of major drainage and minor drainage towards low impact development

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Abstract. Many studies have been conducting in providing urban floods solutions to reduce runoff water in various ways. In developing urban areas equipped with drainage systems, where the channel has full capacity and flooding in some urban areas. One of the problems that can be identified is the condition where drainage has a peak flow load at the same hour leading to the same meeting point, outlet, or discharge, resulting in an increase of peak flow. This paper give an approach to how to integrate the runoff capacity of flow from minor drainage to major drainage for anticipating a peak flow in a particular area. The most important result was when high rainfall intensity started in the first hour, it should be no obstacles until the flow from minor drainage flow through the outlet towards major drainage, in the four hours after rainfall, peak flow happens to flow through study area. In the analysis, it is known that the peak flood discharge period of 5-yr and 10-yr returns is one hour after the rainfall. Therefore this will not happen when the flow from the drainage outlet has a travel time of under one hour or after 3 hours after rainfall.

1. Introduction

Urban areas are equipped with a drainage system to flow runoff. The drainage system that has been designed is no longer able to accommodate the capacity of runoff because of high rainfall intensity, and sedimentation. This condition is where channel has the full capacity of and causes flooding in some urban areas causes damage on buildings and infrastructures [1]. Especially in developing urban areas equipped with drainage systems, to make urban flood simulations it is essential to describe the dynamic flow from rainfall to runoff to analyze the discharge to outlet [2]. It is important to pay attention to reducing runoff to flow through the drainage. Problems will arise, where we have to normalize the existing drainage channels, while the runoff water will be forwarded to the primary channel which is the river as a drainage flow, it will cause a new more significant problem, where the river will receive a flow load that exceeds its capacity. This means that we must plan to reduce and retain the runoff water so that it does not entirely enter the drainage channel and flow to the primary channel. Many studies have been conducted in providing urban flooding solutions to reduce runoff water in various ways including, making a garden (garden rain), green roof, green walls, Bioretention, land holes, and infiltration wells [3]. The latest technological development for the drainage system is the concept of Sustainable Urban Drainage Systems (SuDS), which applies the idea that rainwater that falls to the surface is not entirely runoff but partly is stored to increase groundwater reserves and create good water and air quality. Floods that often hit urban areas are caused by runoff, which is identified over the amount that is no longer able to be accommodated by drainage channels, causing flooding and inundation in specific locations.

One of the problems that can be identified is the condition where drainage has a peak flow load at the same hour leading to the same meeting, outlet or discharge, resulting in an increase in peak flow discharge load (Q peaks) [4]. Priority urban drainage sub-catchments are areas that need an intervention due to problems related to runoff management or the characteristics of the environment [5]. As a result, it is crucial to make simulations. A study analyzing rainfall-runoff to model the length of the flow trip from rainfall to runoff becomes a basis for estimating the course of flood flows [6]. This Study objective
is to integrate minor drainage with major drainage to avoid the impact of increased flow load when minor drainage discharges flow to major drainage. This study also analyzes the boundaries that can affect the significant flood impact includes factors: drainage elevation, Q drainage discharge, outlet dimensions, outlet elevation, watershed flow load (on major drainage), at the same time in specific flood and rain conditions (for simulations).

This research and previous research is an attempt towards the concept of Low Impact Development (LID). A theory is an alternative approach to managing stormwater runoff impacts [7]. As a result, this paper would give an approach to how to integrate the runoff from minor drainage to mayor drainage for anticipating a peak flow in a particular area. It is hoped that the concept can be implies towards a zero runoff concept to become a flood-free city.

The simulation and prediction modeling analyzed here can only be utilized in the absence of a broken channel, meaning that the damaged channel is blocking the flow. Besides, this modeling is limited to the condition that there is no sediment, so if you want to be simulated it must be in the condition that the sedimentation has been handled by the operation and maintenance (O&M) of the local government. If this model is to be applied to situations where sedimentation still exists, the alternative is to reduce the channel capacity or dimensions. This paper will be useful for modeling drainage systems in a city that still relies on drainage channels to drain all rain runoff water. Besides this modeling, it is helpful for a city that has problems with the allocation of rain flow to the outlet outlets to the primary channel.

2. Study Area and materials

2.1. Study area

The study area in this modeling is the study location as an example model to help how to analyze in integrating minor drainage and major drainage. The study location is located in the drainage system of the University of North Sumatra (USU) as the minor drainage, which has 3 (three) outlets leading to the Babura River (as major drainage). The drainage system at the Universitas Sumatera Utara is also equipped with several automatic floodgates. The campus environment, which has sufficient green open land will certainly minimize flooding [8]. However, if the flow conditions from the campus are unable to flow to the major drainage, it will undoubtedly be a problem. The definition of minor urban drainage is a network of drainage systems that serve such as residential areas, commercial areas, offices, and industrial estates, markets and tourist areas. The definition of major urban drainage is a network system drainage structurally composed of the primary channels that accommodate the flow of secondary channels. Secondary channels to provide the flow of the tertiary channels. Tertiary channels to accommodate the flow of Flow Regions respectively. Local drainage networks can directly stream flow channel to the primary, secondary and tertiary. Following is the location of the study to analyze the drainage system in minor drainage to major drainage.

The results of the watershed generation at this stage will be calculated by the size of the Babura watershed. Based on the calculation, the total Babura watershed is 89.28 km², where the basin includes the Kwala Bekala watershed because the flow also passes through the section point at USU.
2.2. Data sources
Rainfall data that can be used to analyze is rainfall data that is processed by the Mononobe Method to get rainfall intensity with 3 (three) observation stations, namely: Sta. Tuntung, Sta. Helvetia and Sta. Deli Serdang, Sampali. Medan spatial data is based on 2010-2030 Regional Spatial Planning data from Medan City Regional Development Planning Agency. Analysis of flood discharge using the EPA SWMM Method for floods return periods of five years and ten years.

The graph shows that the maximum rainfall increases almost every year. There is a significant rising of maximum areal rainfall more than 30 mm in ten years. An average of rainfall increasing 2 to 3 mm every year. It would be a specific problem for the urban drainage system, where the channel drainage capacity does not change following this condition.
3. Methods
Because of the lack of information, analyzing with a simulation approach is one practical way to identify flow encounters that get overloaded [9].

3.1. Data collecting
Data collection consists of primary data and secondary data: Primary data obtained from field surveys consist of data: direction of drainage flow, outlet/disposal position, base slope of drainage channel, coverage/land use, channel shape, channel wall roughness, width and type of road, cross-section of Babura River, flow velocity Babura River. Secondary data, namely: maximum daily rainfall data for data from at least the last 10 years (2009-2018 from January to December) obtained from Deli Serdang/Sampali BMKG offices for three rainfall measurement stations, Deli Serdang, Tuntungan, and Helvetia; in addition, daily rainfall data for the last 3 months for validation of discharge in the drainage channels and the Babura River; map of study locations (Universitas Sumatera Utara and Catchment area of Babura River).

3.2. Field survey
The field survey aims to obtain primary data completeness. The survey guidelines, among others, follow Indonesian National Standard number 2015 on "Procedures for Measurement of River Discharge and Open Channels." Field surveys include Flow direction survey: surveyors record the direction of flow from the right and left drainage canals in the existing condition of the study site. Channel bottom slope measurement (i) obtained from elevation difference measurement (ΔH) divided by distance (x). Survey the shape of the channel, whether trapezoidal, square, or circular on the sewers. Channel wall roughness survey for manning coefficient. Measurement of width and type of road to be added in calculating the catchment area, and to calculate the drainage coefficient C. Measurement of Babura River flowrate by measuring river cross-section (A) and velocity measurement (V) by using a current meter. Survey drainage channels when it rains (for some rainfall values) for validation purposes.

3.3. Modeling and simulations
This method would be helped by modeling with the help of EPA SWMM software version 5.1. Storm Water Management Model (SWMM) is a free software used to simulate rainfall-runoff models at certain events to get the quality and quantity of runoff (surface runoff) in urban areas. SWMM is produced by the Water Supply and Water Resources Division of the U.S. The Environmental Protection Agency's National Risk Management Research Laboratory. Models carried out include: describe the catchment area, drainage network analysis to integrate channel analysis with one another. Surface runoff analysis with the concepts where precipitation fall to be runoff and infiltration. Dynamic wave routing analysis: flow tracking analysis that can take account of storage in the channel and backwater effects. Modeling is done for the condition of flood discharge on the return period 5-yr and 10-yr. This research focuses on flood control in the return period 5-yr and 10-yr. Each region varies depending on the typology of the city. Flood discharge by the SWMM Method and modeling of the Babura River flood. Analysis of the Babura River flood discharge (the primary channel as a discharge from the case study area) is adjusted to the simulation on the 5-yr and 10-yr floods. The hydrological modeling with the Synthetic Unit Hydrograph, Nakayasu Method. Identify the condition of the case study area for the following factors: The meeting points of the nodes that experience peak loads (at the channel junctions and outlet discharge); channel capacity; travel time (includes time of concentration); the meeting points of the nodes that experience the backwater effect.

3.4. Validation method
The method compares the observed discharge, and then analyzed the parameters that influence the modeling results. Optimum parameter values in calibration found by statistical measures. The result of comparison then determined the strength in predicting the modeling by the Nash-Sutcliffe model of
efficiency coefficient. The Nash–Sutcliffe efficiency (NSE) is the two criteria most widely used for calibration and evaluation of hydrological models with observed data [10].

4. Results and discussions

4.1. Flood modeling and simulations

The aim of this paper about how to integrate major drainage and minor drainage to lead to low impact development, namely the river as a major drainage or outlet drainage, and the urban drainage system as minor drainage. Measurements of river discharge and drainage discharge have been carried out, and the following is the Babura River flood hydrograph as USU’s major drainage. The following hydrograph is the flood discharge at coordinates 30 33 '17.528 "North Latitude and 980 39" 45.716 "East Longitude.

Figure 3. Flood hydrograph of Babura-Bekala watershed return period 5-yr and 10-yr.

The graph above shows that the maximum flow of Babura Bekala watershed in 5-yr return period is 123.5 m³/s, and 10-yr is around 166.6 m³/s. The figure also shows that the Babura Bekala watershed as a drainage outlet, based on the results of hydrological modeling using the SCS method, reaches a maximum discharge at the fourth hour after raining for 3 hours. Based on calculations from the Babura River cross-section survey data, it has a full discharge capacity, 170 m³/s. It is calculated based on the USU drainage outlet point. Due to limited access, measurements were made at 50 meters from the outlet point.

Figure 4. Major drainage and minor drainage system in EPA SWMM model.
4.2. Model validation

The modeling has been validated for two measurements on rainfall events on a specific date and made tuning of the synthetic unit hydrograph parameters. The following are the results of Babura-Bekala hydrograph validation.

Based on the analysis, Nash Index for the first validation is 0.88 and the second is 0.95. This index of Nash–Sutcliffe Index can range from $-\infty$ to 1. The value of 1 (NSE=1) corresponds to a perfect match of modeled discharge to the observed data. The value of 0 (NSE=0) indicates that the model predictions are as accurate as the average of the observed data, whereas it is less than 0; it means the observed is the better predictor than the model [11].

4.3. Integrated of the major and minor drainage

Based on the analysis, the Babura River has bank full capacity is about 170 m$^3$/s, where flood discharge of Babura-Bekala Watershed within return period of 5-yr and 10-yr are 123.5 m$^3$/s, and 166.6 m$^3$/s respectively. In the return period of 5-yr, the Babura river remains capacity is about 46.5 m$^3$/s, and it means there is no flooding condition where the rainfall return period of 5-yr. However, it is known that the channel as an outlet for the USU to Babura River has a maximum capacity of 74.7 m$^3$/s in full condition. The channel not only accommodates the drainage flow from USU drainage, which is a study area, but the channel receives flow from other drainages so that the channel is full, and the Babura River is unable to accommodate a total discharge of 198.2 m$^3$/s. Likewise, the flood conditions for 10-yr return period discharge with the total discharge of 241.3 m$^3$/s originating from the combined river flood discharge and drainage outlet. This condition is a prediction of the flow at maximum conditions (full capacity) at the same amount of rainfall and travel time. Based on the condition of total discharge and capacity, this will certainly cause the area around the study area to receive the impact of flooding caused by the overflowing of the Babura River. Some research on river overflows [12] and as an alternative measure is to make river embankments along the Babura River to increase the capacity of the river and prevent water overflows. For backwater conditions that are problems to enter the drainage system, there is certainly no need to worry when paying attention to the water level elevation and completing the drainage system with automatic water gates such as the existing condition of the study area's of drainage system. Another thing that must be considered is if there are limitations to normalize the river by making the river embankment, is to set the flow travel time so that it does not coincide at the same time. It is known that the peak flood discharge of return period of 5-yr and 10-yr is one hour after the rainfall occurs. Therefore this will not happen when the flow from the USU drainage outlet has a travel time of under one hour or after 3 hours after rainfall. Due to data limitations, this analysis does not yet involve time to flow from other drainages.
5. Conclusions
This study and have shown an approach to analyze integrated major drainage to minor drainage within a comparison between full capacity of major and minor drainage. The simulation shows how to explain peak time among the drainage channel. The most important result was when high rainfall intensity started in the first hour, it should be no obstacles until the flow from minor drainage flow through the outlet towards major drainage. The condition where in the four hours after rainfall, peak flow happens to flow through Universitas Sumatera Utara drainage. This approach can simulate another case study area. It is known that the peak floods of return period 5-yr and 10-yr is one hour after the rainfall. Therefore this will not happen when the flow from the USU drainage outlet has a travel time of under one hour or after 3 hours after rainfall. This analysis does not yet involve time to flow from other drainages.

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