Analysis of flood vulnerability in urban area; a case study in deli watershed

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Abstract. Based on the National Disaster Management Agency of Indonesia, the distribution of disasters and victims died until the year 2016 is the largest flood disaster. Deli River is a river that has the greatest flood potential through Medan City. In Deli Watershed, flow discharge affected by the discharge from its tributaries, the high rainfall intensity and human activity. We should anticipate reducing and preventing the occurrence of losses due to flood damage. One of the ways to anticipate flood disaster is to predict which part of urban area is would flood. The objective of this study is to analyze the flood inundation areas due to overflow of Deli River through Medan city. Two-dimensional modeling by HEC-RAS 5.0.3 is a widely used hydraulic software tool developed by the U.S Army Corps of Engineers, which combined with the HEC-HMS for hydrological modeling. The result shows flood vulnerability in Medan by a map to present the spot that vulnerable about flood. The flooded area due to the overflowing of Deli River consists of seven sub districts, namely Medan Johor, Medan Selayang, Medan Kota, Medan Petisah, Medan Maimun, Medan Perjuangan and Medan Barat.

1. Introduction
Flood disaster is one of natural hazard that affected human safety and economic growth in the world. This disaster has a big risk in the future, it supported to climate change, high rainfall intensity, and flood frequency in many area of the world [1]. The system of urban development, land cover and land use change along watershed caused the loss of ecosystem services in urban area and an increase in urban flooding vulnerability. This problem combines the interaction among exposure, sensitivity, and adaptive capacity for studying flood vulnerability. There is construction for flood vulnerable concepts and developing flood emergency that investigated the spatiality of urban flooding vulnerability in a watershed by using geographic information system [2]. The study with high developing urbanization is potent about flood. In addition, the urban area that has bigger potential effect is not always has the bigger flood vulnerable in extreme climate condition. The system can effectively shows urban flooding vulnerability [3].

One of the factors is economic and social development that derived land cover and land use changes. It is potential to effect on water flow in a watershed. Land cover and land use change influence several parameters, they are infiltration, the evapotranspiration; surface runoff and groundwater recharge [4]. The effects in urbanization and population growth are catchment area responses especially to the hydraulic parameters. This condition will influence land cover change that related to landscape modifications. This problem is potential to increase catchments hydrologic
response. Meanwhile, based on the observation data, this urbanization is not always tends to rose of flood vulnerability [5]. Some efforts to control the flood that happened in urban area, especially about flood infrastructure, but in modern cities over the world are still vulnerable to flood hazards. Even though, management of water resources focused on non-structural effort to face the flood hazard, the investigation will stay in a statement to control the flood. This case will consider as a disaster and make damage in urban area [6].

Those reviewed studies show that the study of flood vulnerability has to pay attention in urban area. The objective of this study is to analyze the flood inundation areas due to overflow of Deli River through the city of Medan. Flood inundation area will show flood vulnerability area in Medan by using a map. Results suggest this modeling is a feature of urban responses to Deli River overflow across different part regions in Medan. This flood map vulnerability will describe which part of Medan that vulnerable about flood. Limitations of the data obtained and the accuracy of selection of flood modeling methods will reduce the accuracy of the modeling results in predicting flooding. Therefore, the suitability of methods in predicting floods influences the flood control analysis to perform the best result.

2. Study Area and Materials

2.1. Study Area
The study area is located in Medan, North Sumatera of Indonesia. It is located in the Deli Watershed that flows from Karo Regency, Deli Serdang Regency and passes Medan city then empties into Melaka Strait. Deli watershed administratively passes several cities and districts; it defines, as one area that has total area is 472 kilometers square and long river main is 55 kilometers. This study focused on Deli River that through Medan city.

The upper forest in Deli watershed is not able to absorb water with maximum, the rainfall that is not absorbed by tree roots in the forest, making the river water flow exceeds the normal limit. If the water seep into the soil so that water reserves continue to be available, if the rainy season is not flooded and the dry season is not short of water, but what happens is flooding in the main river and the river watersheds. Based on the study of JICA (Japan International Cooperation Agency), in 2015 there will be a water crisis in Medan. Then, some areas of Deli Serdang are if the Deli River condition cannot recover.

2.2. Data Sources
In this study, the rainfall data used is the record data from 2006 to 2015. The data of rainfall sourced from the data of Major River Basin Organization of Sumatera, Ministry of Public Works. The data of debit recording in this research obtained from Research Centre and Development of Water Resources, Ministry of Public Works. The data of the discharge serves as the calibration and verification reference of the modeling created. Deli watershed utilizes remote sensing technology to provide information on land coverage by interpretation of objects in the image. The information obtained to show areas that have the most critical and most sensitive land capability. Digital Elevation Model data is used for two-dimensional modeling. This data interprets of topographic data that implemented flood inundation area.

3. Methods

3.1. Flood Modeling
The data processing of the land cover and its classification system uses the help the geographic information data. Based on the data obtained there is ten classifications of land cover that will be determined the area of each for year 2010. Then the data will compare into the form of bar charts [7]. The method defines the flood vulnerability by a quantitative magnitude called relative vulnerability score and results in the vulnerability zoning of the area under assessment. The method applied in
watershed and the obtained results showed that. The First, indexing method leads to a relative sense and an overall picture of the urban vulnerability toward floods. Secondly, the urban zones surrounded by two rivers, are in danger of a high level of the vulnerability, especially the first floors of the buildings. Then, it is necessary to review the location of the parking garage under construction, with regard to the flood vulnerability zoning [8]. A simple modeling framework provided based on accessible input data and a freely available and widely used hydrological model (HEC-RAS) to check the possible effect of land cover changes at a particular sub-catchment on the hydrograph at the basin outlet [9].

HEC-RAS is a widely used hydraulic software tool developed by the U.S Army Corps of Engineers, which combined with the HEC-HMS platform for hydrological simulations. HEC-RAS employs 1D flood routing in both steady and unsteady flow conditions by applying an implicit-forward finite difference scheme between sequential sections of flexible geometry. In all the above models, two boundary conditions required, which usually set at the upstream end of the channel through an imposed inflow as well as the assumption of uniform water depths at the upstream and downstream end (kinematic wave condition). Although an imposed depth would result in more stable solutions than the uniform flow, we choose the latter since, in practice, it is rare to know the temporal evolution of the water depth at a particular location. The models compute the appropriate time step based on the Courant number stability criteria [10].

This method applied the Hydrologic Engineering Center River Analysis System (HEC-RAS) model to estimate the potential catastrophes for different peak outflow scenarios with conclusions and recommendations [11]. Flooding damage appraisal can be obtained by interpolating real damage data caused by historical flooding events or accounting the effects of a flood in terms of the depreciation of assets. Most often, the expected damage evaluated by means of damage functions describing the relationship occurring between the damage and hydraulic characteristics of flood [12].

3.2. Flood Mapping Method

After incorporating resampling and vertical errors, all resampled raster datasets used to create a 1D HEC-RAS model. HEC-RAS is the most commonly used flood model tool in Indonesia. The HEC-RAS parameters kept unchanged for different DEMs because the goal is to investigate the sensitivity of inundation maps to topographic errors instead of trying to create newly calibrated model for each topographic dataset [13]. Two types of tools, hydrodynamic models and geographic information systems, commonly employed for these evaluations. For this assessment, a coastal digital elevation model developed using the same data on hydrometric and elevation. These models used to project the present and future impact of storm surges on flood extent at Pigeon Point [14].

After obtaining the result of flood potency analysis in the form of modeling showing high flood and flood plain with HEC-RAS software, it can show areas of flood inundation and flood area that occur along the river area, with geographic information system predicted using software. Geographic information systems will work with HEC - Geo RAS extensions in importing data from HEC-RAS into geographic information systems.

3.3. Calibration and 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 Nash-Sutcliffe model of efficiency coefficient (E). The Nash–Sutcliffe efficiency (NI) is the two criteria most widely used for calibration and evaluation of hydrological models with observed data [15]. Nash–Sutcliffe Index can range from \(-\infty\) to 1. The value of 1 (NI=1) corresponds to a perfect match of modeled discharge to the observed data. The value of 0 (NI = 0) indicates that the model predictions are as accurate as the mean of the observed data, whereas it is less than 0; it occurs when the observed is the better predictor than the model [16]. The verification process based on the observation flow verified parameter is the runoff.
4. Results and Discussions

4.1. Flood Model
In this paper, the model predictions of the flood are accurate and outperform the results of a simple rule based approach. Figure Two shows the elevation flood inundation while the water level at the time of the flood reached the banks. The area of flood inundation due to flood discharge with return period 25-years is about 3.69 Kilometers square.

![Figure 1. Deli River flood inundation when return period is 25 years](image1)

4.2. Flood Map Vulnerability
Based on the result of the flood modeling with the help of HEC-RAS and with DEMs obtained flood inundation with Deli watershed, analysis of flooded areas using topographic data shows potential flooding for some areas as shown in the following figure. Figure 3 shows the area that potentially about flood in Deli watershed. Based on this pictures the flooded area due to the overflowing of Deli River consists of seven sub districts, Medan Johor, Medan Selayang, Medan Kota, Medan Petisah, Medan Maimun, Medan Perjuangan and Medan Barat.

![Figure 3. Potential flood inundation areas of flood discharge with flood return period 25-year](image3)
4.3. Validation
The calibrated model applied for the discharge scenarios to assess the potential flood area impacts on the Nakayasu synthesized hydrographs obtained based on the parameters input into the Deli watershed, they analyzed for calibration and verification. The rain that occurs is the total daily rain that distributed evenly in the watershed. Calibration and verification of Deli Watershed carried out at each of the maximum floods in the study sites for three years, 2007, 2008 and 2010.

5. Conclusions
This study resulted in the deluge of the Deli River with a 10-year return period is 537 m³/s; 25 years is 575 m³/s; 50 years is 602 m³/s; and a 100-year return period is 627 m³/s. The inundation area is about 3.69 Kilometers square. The flooded area due to the overflowing of Deli River consists of 7 sub districts, Medan Johor, Medan Selayang, Medan Kota, Medan Petisah, Medan Maimun, Medan Perjuangan and Medan Barat.

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