GIS-Based Flood Mitigation of Deli River

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Abstract. Structural actions to reduce floods such as the construction of reservoirs, dikes or dams are considered incapable of fully controlling the floods. Hence, information on flood risks through flood risk map is an obligatory to prevent and minimize losses caused by the floods. Regulation of Minister of Home Affairs no. 33 of 2006 on general guidelines for disaster mitigation states that one of the important things in disaster mitigation is the availability of information and map of disaster prone areas for each type of disaster [9].

1. Preliminary

Flood is a natural disaster that often occurred and caused many damage in the field of infrastructure, human life and the environment. Flood contributed about 39.26% of the worldwide natural disasters causing damage up to USD 397.39 billion between the years of 2000 to 2014 [3]. In Indonesia, there are 5,590 main rivers and 600 of them have the potential to cause flooding. Natural disaster risk management in Indonesia still tends to be low. Various natural disasters that followed showed the need for a more significant improvement. Regulation of Minister of Home Affairs no. 33 of 2006 on General Guidelines for Disaster Mitigation states that one of the important things in disaster mitigation is the availability of information and maps of disaster prone areas for each type of disaster [9].

Structural actions to reduce flooding are done by the maintenance of embankments, dams, or designing anti-flood buildings [10]. However, this method is considered insufficient in controlling [6]. Hazard and losses of flood can be prevented and minimized by providing accurate information to the public about the risk of flooding through flood risk maps [2]. Understanding of flood risks can help in making the decisions of land use and development plans, emergency response strategy, sewerage
selection, infrastructure development guidelines and maintenance of water infrastructure such as reservoirs, embankments, or drainage [8].

Meteorological variables are considered not sufficient to become as reference in flood control [1]. Several hydraulic models have been developed to estimate floods such as HEC-RAS [4]. HEC-RAS is usually used with GIS software to connect between the areas of inundation of the flood to the depth of flooding [5]. The previous study that integrates GIS and HEC-RAS has been carried out by Demir and Kisi (2016) that mapped flood prone areas using GIS and HEC-RAS with flood return period of 10, 25, 50, 100 and 1000 years in the Mert River, Turkey. Mardookhpoor and Jamasbi (2017) used SIG and HEC-RAS to determine the prone zone of flooding and water levels on the Sardaburd River, Manzandran-Iran [7].

2. Methodology
This research was conducted in Deli watershed area that flows from Karo district, Deli Serdang district and crosses the city of Medan later empties into the Straits of Malacca with the length about 55 km. The data used in this research are Digital Map of Deli River, Digital Elevation Model (DEM), elongated and transverse profile map, situation map, administration map of Medan City, Medan city road network map, Medan city buildings map, Landcover map of Deli River and data of the maximum daily rainfall of the last 10 years from six stations that can be seen in Table 1.

Table 1. List of Rainfall Monitoring Station

| No. | Station Name      | Latitude | Longitude  |
|-----|-------------------|----------|------------|
| 1.  | Staklim Sampali   | 3.62170  | 98.71460   |
| 2.  | Biru-biru         | 3.40000  | 98.68000   |
| 3.  | Stageof Tuntungan | 3.50000  | 98.56400   |
| 4.  | Stamar Belawan    | 3.78800  | 98.71500   |
| 5.  | Tongkoh           | 3.20200  | 98.54032   |
| 6.  | Helvetia          | 3.64200  | 98.63800   |

Source: BMKG, 2017

Subsequently, flood potential is analyzed by using HEC-RAS application which becomes the base in determining flooding area by using Geographic Information System (GIS) application. Furthermore, the estimated flood losses were carried out by digitizing the flood-affected houses and calculating the total cost of losses caused by floods according to the repeated periods based on the 2007 standards of the Ministry of National Development Planning. After that, the identification is conducted to determine the evacuation point and the evacuation route.

Data analysis started by calculating the area of rainfall. The rainfall used can be seen in Figure 1.

![Rainfall Data Graph](image)

**Figure 1.** Rainfall Data Graph

Periodic rainfall frequency analysis used four methods: normal distribution, normal log, pearson log III and gumbel. Then, the test of the suitability of distribution is used Smirnov-Kolmogorov method.
The method of Synthetic Unit Hydrograph (HSS) Nakayasu is used in analyzing the design flood discharge. The flood potential is analyzed by using HEC-RAS. And, Geographic Information System is used in predicting the flood inundation area.

Thereafter, the estimation of losses due to flood and the determination of points and evacuation routes and validation test are done. The flowchart of research can be seen in Figure 2.

**Figure 2. Flow Diagram of Research**
3. Discussion

Based on the rainfall data from six rainfall monitoring stations located upstream to downstream of Deli River, the calculation of rainfall area is conducted by using Polygon Thiessen Method. Then, Gumbel method is used in calculating the rainfall design. The test results of the distribution of statistical parameters of selected Gumbel Methods were tested by Smirnov Kolmogorov method. Smirnov-Kolmogorov test results obtained Dmax = 0.416 so it can be concluded that the data received.

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| Table 2. Deli River Flood Peak Debit |
|-------------------------------------|
| Period | Flood Debit (Q) |
| 100    | 859,2          |
| 50     | 806,2          |
| 25     | 735,4          |
| 10     | 680,7          |

Source: Calculation, 2017

The Hydrograph Flood Calculation curve of the Nakayasu Method Design can be seen in Figure 2.

![Figure 3. Deli River HSS Nakayasu](image)

In order to know the phenomenon of hydraulic behavior of flow in Deli River required a numerical simulation that able to describe condition of existing channel. The analysis was performed using HEC-RAS 5.0 so that top flood surface can be obtained in each period of 10, 25, 50 and 100 years that can be seen in Table 3.

| Table 3. Elevation Based on Period |
|-----------------------------------|
| No. | Flood Period | Flood Height (m) |
| 1.   | Q10          | 0,58             |
| 2.   | Q25          | 1,18             |
| 3.   | Q50          | 2,18             |
| 4.   | Q100         | 2,78             |

Source: Calculations, 2017
The simulation of flood height is exemplified by Figures 3 and 4.

Determination of flooding inundation is done by using Geographic Information System (GIS) software 10.2. The analysis obtained four districts, Medan Labuhan, Medan Marelan, Medan Deli and Medan Belawan, that included as the flood-prone areas. 14 sub-districts of four districts are potentially affected by floods, namely Kota Bangun, Titi Papan, Tanah Enam Ratus, Rengas Pulau, Paya Pasir, Labuhan Deli, Besar, Martubung, Sei Mati, Pekan Labuhan, Nelayan Indah, Belawan Pulau Sicanang, Belawan Bahagia, and Belawan Bahari. They can be seen in Figure 5.

Then, the calculation of losses due to floods based on the standards of the Ministry of National Development Planning in 2007 can be seen in Table 4.
Table 4. Total Losses of Flooding

| No | Period | Total Losses Rp (Millions) |
|----|--------|---------------------------|
| 1  | 10     | 54.385                    |
| 2  | 25     | 92.310                    |
| 3  | 50     | 90.910                    |
| 4  | 100    | 93.530                    |

Source: Calculation, 2017

Furthermore, the determination of the evacuation point requires several considerations, such as at least 750-1500 meters distance from the river drainage (Santoso and Taufik, 2009). In determining the location of the evacuation point spatial analysis is done using ArcGIS with buffer tools. The result of spatial analysis with buffer is shown in Figure 6.

![Evacuation Point Map](image)

**Figure 6.** Evacuation Point Map  
Source: The Analysis using GIS, 2017

Evacuation route can be determined using the ArcGIS Network Analyst tools. Then, to validate the flow of traffic, no path against the tide, will require the help of Google Maps. Thus, the evacuation route shown in Figure 7 is obtained.

![Evacuation Route](image)

**Figure 7.** Evacuation Route  
Source: The Analysis using GIS, 2017
Based on Figure 5 can be determined the eligible evacuation route shown in Table 5.

Table 5. Evacuation Route

| No. | Route Name         | Route                                                                 |
|-----|--------------------|----------------------------------------------------------------------|
| 1.  | Kota Bangun        | JL. Yos Sudarso – JL. Rumah Potong Hewan                             |
|     |                    | JL. Platina IV – JL. Platina I – JL. Pulau Irian – JL. Pulau Jawa – JL. |
| 2.  | Titi Papan         | Yos Sudarso – JL. Rumah Potong Hewan                                 |
| 3.  | Tanah Enam Ratus   | JL. Pasar I Marel – JL. A. Sani Mutalib                              |
| 4.  | Rengas Pulau       | JL. Pasar I Marel – JL. Marel I – JL. A. Sani Mutali                 |
| 5.  | Paya Pasir         | JL. P. Danau Siombak – JL. PS Nippon – JL. Titi Pahlawan – JL.      |
| 6.  | Labuhan Deli       | Kapt. Rahmad Budin – JL. A. Sani Mutalib                             |
| 7.  | Besar              | JL. Titi Pahlawan – JL. Kapt. Rahmad Budin – JL. A. Sani Mutalib     |
| 8.  | Martubung          | JL. Bakti Abri – JL. Rawe – JL. Tol Balmer                           |
| 9.  | Pekan Labuhan Deli | JL. Yos Sudarso – JL. Tol Balmer                                    |
| 10. | Nelayan Indah      | JL. Chaidir – JL. Yos Sudarso – JL. Tol Balmer                       |
| 11. | Belawan Bahagia    | JL. Kakap – JL. Temenung – JL. Yos Sudarso – JL. ST – JL. Serma      |
| 12. | Belawan Bahari     | Hanfiah                                                              |
| 13. | Belawan Sicanang   | JL. Yos Sudarso – JL. ST – JL. Serma Hanafiah                        |

4. Conclusion

In this research, flood modeling in Deli River is done by using HEC-RAS integrated with GIS. The calculation is performed by dividing into four periods: 10, 25, 50 and 100 years. Maximum height flood occurs in 100 years period. The study was conducted as an early warning to diminish the risk of flooding in the Deli River area.

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