Flood Vulnerability Study of Pangkalpinang City, Bangka Belitung Archipelago Province

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Abstract. Pangkalpinang city is one part of Bangka Belitung Archipelago Province which has an area of 118.41 km² with seven districts and consist of forty-two villages. Based on its location on the eastern part of bangka island make pangkalpinang closer to the coast and watersheds so that it can be said it have a relatively low average land elevation (topography) with a height of 20-50 meters above the sea with a slope of 0-25 %. The research was carried out quantitatively and qualitatively with the parameters of determining the administrative boundaries of each district, the selection of applicable rules regarding the applicable land use zoning or spatial planning (RT/RW), topography, surrounding watersheds, and population density of settlements in Pangkalpinang City. These parameters are then carried out using overlay, scoring and layout techniques to see the distribution of the flood vulnerability level pattern. The results showed that flood vulnerability (very vulnerable) with low topography (0-10 meters above sea level) was in the northwest area of Bukit Intan District and Taman Sari District. Flood vulnerability (vulnerable to less vulnerable) with moderate topographic values (10-19 meters above sea level) is in Gerunggang and Gabek Districts, while vulnerability is not vulnerable with high average topographic values (above 20 meters above sea level), in the northern part in the Districts of Gerunggang, Gabek, and Pangkalbalam. In the northwest part of Pangkalpinang City, if there is an increase in tides or high rainfall intensity, the area will be inundated (flooded).

1. Introduction

Flood events that cause natural damage due to climate change, unplanned rapid urbanization, changes in land use patterns, and poor watershed management [1]-[4]. Floods occur when the water flowing into the river exceeds the capacity of the river channel [5]-[13]. Flooding is a common problem that occurs in some parts of Indonesia, especially in densely populated areas such as urban areas. The losses incurred have a major impact both in terms of material and casualties that need serious attention and hurt direct to residential and non-residential buildings around [14].

Flood problems should be anticipated as early as possible, to minimize the losses that occur. Various parties must pay attention to the things that cause flooding [15]. The National Disaster Management Agency (BNPB) recorded 1,205 natural disasters that occurred from 1 January to 30 April 2021. Some of these natural disasters (41%) were hydrometeorological floods with 501 cases of the total disasters in Indonesia, followed by 339 tornadoes events and 233 landslides events [16].

The flooding that hit the Pangkalpinang area was caused by several factors other than inadequate river flow capacity, topographical conditions were also one of the factors driving the occurrence of flood
inundation. The topography of the Pangkalpinang area is in a relatively low average elevation condition with a height of 20-50 meters above the sea with a slope of 0-25%. This condition causes the potential for waterlogging to increase when there is high rainfall intensity [17]. Geogenic (nature) and anthropogenic (human) factors are the cause of flood disasters. Geogenic factors that cause flooding include the topographical height of Pangkalpinang City which is low or close to the mean sea level (MSL), the volume of river water is influenced by tides, high sedimentation, and factors of rainfall and high tides at certain times of the year. Vulnerability based on the International Strategy for Disaster Reduction (ISDR) are conditions determined by physical, social, economic, and environmental factors or processes that increase the vulnerability of a community to the impact of hazards. Flood vulnerability is to estimate the areas that may be the target of flooding. Flood-prone areas are usually located in flat areas close to rivers, basins, and tidal areas [18]. The level of vulnerability is aimed at identifying the physical impact of a flood disaster. So, there is a need for research of flood vulnerability studies in Pangkalpinang City, Bangka Belitung Archipelago Province.

2. Method
This study uses a descriptive method consisting of data collection, data processing and data analysis quantitatively and qualitatively with parameters determining the administrative boundaries of each district, selection of applicable rules regarding land use zoning or applicable spatial planning (RT/RW), topography, the surrounding watershed, and the population density of settlements in Pangkalpinang City.

These parameters are used to reveal a phenomenon of natural conditions that have the potential to cause flooding and then the level of flood hazard is seen by utilizing a Geographic Information System (GIS). GIS is used as a tool / analysis tool that is spatial (georeferenced). Determination of disaster vulnerability using scoring and weighting methods, all variables are scored and weighted. The making of a flood vulnerability map is done by overlaying several maps which are then presented in a flood vulnerability map that represents the condition of the Pangkalpinang City area.

3. Result and Discussion
Determination of flood vulnerability is carried out through several steps, based on previously obtained data. The data obtained is spatial data in the form of a jpeg file. The data used as parameters in determining the level of flood vulnerability in this study include slope, soil texture (in relation to soil infiltration), and topography (height). Each parameter is assessed by classifying it into classes according to the magnitude of its influence on the level of flood vulnerability in the study area. Parameters that have a large type of influence on the occurrence of flooding are given a large value, and vice versa, parameters with a small type of influence on the occurrence of flooding will be given a small value.

The results of the overlay analysis are then classified and the result is a map containing the class/level of flood vulnerability in Pangkalpinang City, the flood vulnerability classes are: class I (very vulnerable), class II (vulnerable), class III (less vulnerable) and class IV (not vulnerable), vulnerability classes are divided into classes based on topography values of each location and will explained at paragraphs below. Details on the extent and percentage of flood vulnerability levels in Pangkalpinang city are presented in the Pangkalpinang City Flood vulnerability map in Figure 1.
3.1 Pangkalpinang City Rivers Condition

Analysis of river conditions was carried out by overlaying river maps on aerial satellite images of Pangkalpinang City as a whole, both main rivers and tributaries (intermittent rivers) that flow through Pangkalpinang City. The watershed passes through the city of Pangkalpinang or becomes the administrative boundary of the city to the surrounding districts. In general, the main rivers, namely the Rangkui River and its tributaries, flow across Pangkalpinang City in a relatively southwest-northeast direction. The upstream is located on the south and west sides of Pangkalpinang City. The main river flow is influenced by the tides of the sea. When there is a high tide, the water level of the river will rise, and vice versa when the sea is receding every day.

Based on Table 1 there are about 45,141 m of the total length of 254,850 m of the total river flow, (main rivers, tributaries, including intermittent rivers) that pass through residential areas that do not have ideal boundaries (local rivers protected areas) that can be seen at table 2 which explain how long areas at each rivers that do not have ideal boundaries. Especially for the Pasir Putih River and some of the Pedindang River have lost their natural condition, this can be seen from the lack of open space in the form of the remaining river boundaries because they are covered by residential areas along the river. Annual floods due to overflowing river water when it rains, often occur along the Pasir Putih River, which is densely populated.
Table 1. The condition of the main rivers that flows through Pangkalpinang City.

| No | River Name    | Length (m) | Description                                                                                                                                 |
|----|---------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Rangkui River | 7,347      | It is the largest (widest and deepest) main river in Pangkalpinang City which flows into the main river in the north, Batu Rusa River.          |
| 2  | Pedindang River | 3,628     | It is a tributary of the Rangkui River in the upstream part with the upstream being in Bukit Mangkol, some of the main flow has been normalized. |
| 3  | Pasir Putih River | 3,588    | It is a tributary of the Rangkui River that flows in densely populated areas, narrow river flows, have been normalized so that it is difficult to find natural flows. |
| 4  | Lantai River  | 3,609      | It is a tributary of the Rangkui River in the upper reaches which has a natural flow with the best conditions compared to other rivers, flowing in an area with low density of settlements. |

Table 2. Main rivers in Pangkalpinang City that do not have ideal boundaries.

| No | River Name       | Length at part that do not have ideal Boundaries(m) | Description                  |
|----|------------------|----------------------------------------------------|------------------------------|
| 1  | Rangkui River    | 2,279                                              | About third of the boundaries have lost |
| 2  | Pedindang River  | 3,016                                              | Majorities of the river       |
| 3  | Pasir Putih River | 3,495                                              | Majorities of the river       |
| 4  | Lantai River     | -                                                   | Boundaries condition is quite well. |

3.2 Spatial Analysis Versus Flood Disaster

The spatial pattern of Pangkalpinang City has been made to accommodate all human activities in it, including the fulfilment of residential areas, commercial needs, industry, and protected areas (green open space), et cetera.

Determination of local protected areas (river boundaries) accommodate the natural needs of the main river flow that flows through urban areas. The width of the river boundaries is 10-15 m in rivers with a flow width of more than 20 m, and the boundaries is 3 m wide for the main river with a narrower <20 m. On the outer side of the retention basin also has a local protected area (boundaries) of 15 m wide. The main river boundaries with a width of 10-15 m have a buffer zone by the presence of large green open spaces along the river flow.

The existing condition of the buffer zone is generally in the form of swamps. The condition still looks good from satellite imagery and is protected from destruction, although the river flow is threatened by siltation with high sedimentation. However, these conditions are not as good for the main river flow which has a narrower flow (<20 m) that divides or flows through Pangkalpinang City. The width of the boundaries is only 3 m wide, and there is no green open area as a buffer. The zone that has been designated as a river boundary has even turned into a residential area.
The occurrence of puddles and flooding in Pangkalpinang City during heavy rains often occurs in densely populated residential areas with river flows that have narrow river boundaries (3 m). River flows and narrow urban drainage systems are not able to compensate for the maximum capacity of surface runoff when it rains. The pressure of the urban population growth rate increases the demand for housing areas. The development of residential areas has occurred in low-lying areas (contour elevation 0 - <3 MASL), and swamps in Pangkalpinang City. Whereas lowland areas and swamps naturally for thousands of years have played their function as part of the balance of natural ecosystems, which at the same time act as flood run-off areas. Likewise, the existing distribution of residential areas with medium-high density levels is found along the main rivers of Pangkalpinang City. Residential areas with high density, drainage systems that are not ideal in terms of quantity, low soil absorption capacity of water due to houses built, simultaneously increase the runoff rate of surface water when it rains. Decreased groundwater infiltration is followed by an increase in surface water runoff. The implication of increasing the rate of runoff from surface water when it rains is that it increases the risk of flooding in low-lying areas.

The estimated area of the annual flood inundation that hit Pangkalpinang City is 2,379,094 m², with the residential area affected by the annual flood reaching 970,755 m². Residential areas with medium-high density are generally often hit by annual floods. The estimated area of major floods (30 annual floods) that hit Pangkalpinang City in 2016 is estimated at 10,060,818 m² or almost 5x greater than the annual flood incidence. At the time of a major flood, an area of 3,519,201 m² was submerged by water or 1/8 of the total residential area.

The cause of the flood disaster is the narrowing of urban river flows by the denser population, and the silting of rivers by sedimentation. The drainage system is not able to compensate for the runoff from surface water when it rains, the discharge increases as the green open space decreases. Tin mining in the upstream of the river resulted in a significant increase in river sedimentation, so that the river flow became shallow. The construction of settlements in low-lying areas and swamps increases the pressure on the threat of flooding.

4. Conclusion
The results showed that the level of flood vulnerability (vulnerable to less vulnerable) with moderate topographic values (10-19 MASL) is in Gerunggang and Gabek Districts, while vulnerability is not vulnerable with high average topographic values (above 20 meters above sea level) in the northern part in the Districts of Gerunggang, Gabek, and Pangkalbalam. The northwest part of Pangkalpinang City, if there is an increase in tides or high rainfall intensity, the area will be inundated (flooded).

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