Integrated multimodal disaster mitigation management for urban areas: a preliminary study for 2-d flood modeling

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Abstract. Flooding in urban areas is a common phenomenon in megacities due to the high population and settlement growth. Lack of knowledge from urban societies triggers them to intervene in the capacity of the river for housing. This impact affects various disasters, both quality and quantity of water. Kali Belik experiences flooding every year, although several solutions have been installed to mitigate, for example, Embung. Integrated multimodal disaster mitigation management is proposed to solve the problems and answer the research gaps. The preliminary research only focuses on flood analysis. The analysis uses 2-D modeling with HEC-RAS. The study concludes that the main factor of flooding in the research area is decreasing river capacity due to social behavior. Further research would be conducted to obtain a comprehensive understanding and solution by involving the government, academics, and society.

1. Introduction
Flood occurs most worldwide [1]. Most cities in South East Asia are situated in the flood-prone areas [2, 3], for example, Semarang, Jakarta, and Yogyakarta. Climate change triggers more variability of rainfall [2] and directly impacts the environment. The cities would experience more flood events, including Jakarta [2, 4]. The primary victims of the flood disaster is a low-income population with a lack of disaster preparedness system [5]. Management of water bodies, both rivers, reservoirs, and drainage, is needed to preserve the environment. The large number of natural disasters that occur today are primarily due to physical factors that have decreased their quality function in maintaining the natural balance. This problem is due to the rapid development of infrastructure along with the increasing number of people. In addition to settlements, the infrastructure built is intended to mitigate natural disasters [6, 7]. For example, normalizing rivers to overcome flooding [8].

However, today's infrastructure development that departs from the problem of natural disasters has not heeded the ecological factors of the environment. This case causes the survival of living things such as fish, macro-invertebrates, etc. are not stable. Declining quality of water bodies as a habitat for living things indicates that humans live in unhealthy environments. This problem will take root in the failure of the United Nation's objectives, as stated in the 17 Sustainable Development Goals (SDGs). One of the areas that were reviewed by this study was urban areas, precisely in the Klitren area,
which was passed by Kali Belik and emptied into Embung Langensari. Problems in the area have been flooded over the past decade that has not been overcome, poor sanitation, and poor quality of river and pond water. In general, the main study aims to carry out physical, chemical, biotic, and social analyzes in urban areas to conserve environments with various multidisciplinary research methods. Meanwhile, this paper only aims to identify the physical aspects of the inundated area. Further analysis would take place in future research.

2. Urban Flooding in Kali Belik: Research Gap

The flood in Belik River is nothing new because there are many studies on the analysis of floods in this region. Praja and Suyono [9] conducted an evaluation of the capacity of the Kali Belik channel in Yogyakarta and concluded that the Belik River channel at the UGM Valley and on Jalan Batikan was unable to accommodate the existing runoff. The same thing was done by Pratama and Sukono [10] who evaluated the Kali Belik flood by analyzing the application of the UGM detention pool and infiltration wells. This study concludes that the detention pond can reduce flooding by 0.6 m$^3$/s or 4.6 m$^3$/s. Flood reduction is also said to be done by building 87,113 infiltration wells for the 10-year discharge rainfall. Alternative solutions to flooding were also carried out by Fitri and Ulfa [11]. The solutions offered are the same as Pratama and Sukono [10] by making shallow infiltration wells.

Based on existing research [9 – 11], researchers only focused on physical problems. Solutions offered have not been through comprehensive analysis with Penta-helix stakeholder management. The Office of Public Works, Housing, and Settlement Areas of the Yogyakarta City Government is one of the policymakers in the arrangement of this area. Also, discussions or focus group discussions are needed for affected people. This study will conduct a study through the stakeholder management Penta-helix model. In addition to the physical aspects, environmental resilience also needs to pay attention to the chemical and biological aspects. Chemical characters can be assessed through the analysis of water quality. Iskandar, Sudjono, and Supraba [12] reviewed the quality of Kali Belik water and its effect on raw water sources at the Umbul Pace UGM Campus. However, it has not carried out further analysis of applied applications to improve water quality in Belik River. The last aspect is the ecology. Many infrastructure developments in handling floods do not heed the ecological issues so that many aquatic biotas that should be able to live could not adapt to an environment that is not supportive. In addition to water biota such as macroinvertebrates, the presence of fish has the potential to decrease due to the absence of a fish-way to swim upstream. This entire study will discuss the three aspects as a gap from the research that already exists in Belik River. Meanwhile, this preliminary research focuses on the scope of the physical.

3. Methodology

3.1. Flood analysis

In conducting flood analysis, many previous studies used conventional methods that have been widely developed, such as the Nakayasu Method [8], Gama I Method, SCS Method, and other methods. In addition to these methods, researchers began to develop flood analysis using 2-D and 3-D methods. Two-dimensional modeling uses software based on finite element methods such as HEC-RAS [8, 13 - 15] and HEC-HMS. While 3-D modeling also began to be developed to conduct flood analysis. Based on previous research in the analysis of floods in Belik River, the study used 2-D HEC-RAS modeling with channel view data as secondary data. This study will use primary data on the condition of the existing channel and modeled on a 3-D basis using photogrammetric methods with the help of Geographic Information System (GIS) software [14].

3.2. Environmental and macro-invertebrates analysis

One of the audit activities carried out is assessing the condition of the waters. To audit, the decline in water quality can be known physically, chemically, and biologically [16]. Physically it can be seen in plain views, such as changes in the color of the water. Chemically chemical parameters can be tested,
such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO). Biologically we can see from the diversity of biota in these waters.

In determining the biotic index there are several methods including Simpson's Diversity Index (D), Shannon-Wiener Diversity Index (H), Family Biotic Index (FBI, Metric 2- RBP), Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), and Taxa Richness (TR, Metric 1- RBP II).

3.3. Data acquisition with Unmanned Aerial Vehicle
Data acquisition with UAV consists of five main activities, namely determination of work area, flyway planning, GCP-ICP determination, GCP-ICP measurement, and aerial photo processing. The activity flow can be seen in Figure 1. The DEM extraction example from an aerial photo could be shown in Figure 2.

![Figure 1. Acquisition data with a serial photo](image)

![Figure 2. Extraction of DEM from Aerial Photography. A) Photo of Upright Aerial (Orthophoto) and B) DEM resulting from Aerial Photo Processing (These photos are taken by Angga Dwi Laksono (2018))](image)
4. Results and Discussion

4.1. Flood in Kali Belik
Flood in Kali Belik is a complicated phenomenon for an urban area. Figure 3 depicts the condition of Kali Belik surrounding area in the upper stream part. The population today reaches a critical point because green areas could not be found for rainfall infiltration. This situation triggers a flood disaster every year. People realize that developing settlements near the river is a wrong decision, and the government encourages them to move their settlement. Flood in Kali Belik occurs every year without any further solution. Figure 5 figures the research area.

![Figure 3. The upper stream part of Kali Belik catchment [17]. The blue line in the middle of the settlement is Kali Belik. The location of the nearest settlement from the river is approximately 0.5 meters. When a flood occurs, the houses are directly impacted. Water enters the settlements with another problem: bad odor, a water-borne disease, etc.](image)

4.2. Rainfall analysis
Rainfall data for flood analysis in the research area are driven from Gemawang rainfall station in Sleman, Yogyakarta, from the year 2004 – 2017. Figure 4 depicts the result of rainfall intensity for 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year rainfall.

This preliminary research only focused on flood analysis. Further analysis is still undertaken and does not get any full result yet. The study discusses the flood in the downstream part of Kali Belik. According to the preliminary study of discharge for 10-year period flooding, the discharge for seven segments of the downstream part of Kali Belik is 4.7; 2.2; 2.8; 6.1; 2.6; 3.2, and 4.7 m³/s, respectively, until the last segment in Embung Langensari. The chosen return period is the best representative of rainfall characteristics in the research area [9]. According to Figure 6, we could see the actual event in Figure 7. Figure 7 is the flood event in 2014.
Figure 4. The research area of Kali Belik [18]. According to the picture, there are several notable buildings: 1. Syantikara boarding house, 2. Stella Duce Senior High School, 3. Al-Ikhlas Samirono Mosque, 4. An-Nahr Mosque, 5. Al Husna Iromejan Mosque, 6. GKJ Gondokusuman, 7. Embung Langensari, 8. Al-Muthmainnah Mosque. The dashed picture of Figure 6 describes the flooded area.
Figure 6. Flooded Area

(a) Before flood event  
(b) After flood event

Figure 7. Flooding event in Kali Belik
Kali Belik in the downstream part is designed for 2-D flood modeling using HEC-RAS. Figure 8 depicts the HEC-RAS interface for Kali Belik. The initial survey for this research takes 3 location samples to analyze the flood disaster. According to the figure of the downstream part of Kali Belik, the investigation takes three samples in the upper, middle, and downstream. Figure 9 – 11 depict the condition of the river with 10-year flood analysis. The water overflows. The river capacity could not accommodate the discharge.

Figure 8. The user interface of 2-D modelling HEC-RAS of Kali Belik

Figure 9. Upper part condition of river  
Figure 10. Middle part condition of river
5. Conclusion and Suggestion
In conclusion, the capacity of Kali Belik could not accommodate the incoming rainfall. As a result, the inundated area along the river occurs and affects the lack of social life. This preliminary research results that the capacity of Kali Belik reaches critical conditions and needs comprehensive attention to mitigation. According to this initial result, the research suggests conducting a further comprehensive analysis, especially for flood analysis both in 2D and 3D modeling by using UAV. Further research would also conduct integrated multimodal disaster management in the research area. The research recommends involving the government as a policymaker to take parts in disaster mitigation.

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