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Sedimentation and Mitigation Strategies to Maintain Benanga Dam Capacity, North Samarinda

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ABSTRACT

Purpose: Benanga Dam, located in Lempake, North Samarinda, East Kalimantan, plays a crucial role in controlling water flow and storage. Initially designed with a capacity of 1.6 million cubic meters, the dam's capacity has significantly reduced to approximately 500,000 cubic meters due to sedimentation over time, exacerbated by human activities such as illegal mining and deforestation in the upstream areas. This sedimentation has not only decreased the dam's capacity but also increased flood risks in the Karang Mumus River Basin, as evidenced by severe flooding events in recent years.

Design/methodology/approach: To address this issue, a bathymetric survey using echosounder technology was conducted to assess the current state of the dam's capacity.

Findings: The survey results from 2018 and 2022 reveal an increase in reservoir volume by 111,941 cubic meters, attributed to dredging activities in 2021 by the Ministry of Public Works and Housing. However, ongoing sedimentation, estimated at 27,985 cubic meters per year, poses a significant threat to the dam's capacity. Without effective mitigation strategies, it is projected that the reservoir will reach its normal water level elevation of +7.2 meters within 7 to 8 years. This study underscores the urgent need for regular contour measurements and dredging efforts to maintain the dam's functionality and mitigate flood risks in the surrounding areas.

Paper type: Research Paper

Keyword: *Benanga Dam, Sedimentation, Capacity Reduction and Flood Risk*

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I. INTRODUCTION

Benanga Dam, located in Lempake, North Samarinda, East Kalimantan, is a vital infrastructure for controlling and storing water. Originally designed with a capacity of 1.6 million cubic meters, the dam has experienced a significant reduction in capacity to approximately 500,000 cubic meters (Liana, U.W.M, et al., 2023). This decline is primarily due to sedimentation over time (Santoso, 2015). Sedimentation is often driven by human activities such as illegal mining and deforestation in the surrounding areas. The forests upstream of the dam play a crucial role in filtering water before it reaches the dam, but deforestation has led to direct water flow from upstream into the reservoir. This reduction in the dam's storage capacity has become a critical issue, threatening the sustainability and optimal functioning of this infrastructure.

The situation is particularly concerning for residents living in the Karang Mumus River Basin. The high water levels in the dam, which overflow into the Karang Mumus River, have caused flooding in nearby residential areas. A notable flood in June 2019 inundated several neighborhoods across three districts, affecting 56,000 people and leading the Samarinda city government to declare a two-week emergency response. Similar incidents occurred in December 2019 when heavy rainfall caused the dam's water level to reach a critical point, resulting in prolonged flooding in several areas.

Benanga Dam covers a large area, originally spanning 200 hectares, but its effective area has now reduced to less than 100 hectares due to activities like land clearing for housing and mining upstream. These activities

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have contributed to the dam's siltation and reduced its water storage capacity. The dam now only reduces flood volume by about 10 percent.

To address these challenges, it is essential to regularly monitor the dam's contour and capacity. In 2022, the government responded to this need by initiating a program for water resource management, including bathymetric analysis and measurements at Benanga Dam. This study aims to analyze the impact of sedimentation on Benanga Dam's capacity and propose effective mitigation strategies to minimize the negative effects and ensure the dam's continued functionality

II. METHODS

A. Study Location

The research was conducted at Benanga Dam, located in Lempake, North Samarinda, East Kalimantan. This dam is critical for water management, particularly in controlling flood risks in the Karang Mumus River Basin.

Fig. 1. The research location.

B. Bathymetric Survey

A bathymetric survey was carried out to determine the depth and contour of the reservoir, providing insights into sediment accumulation. The survey employed an echosounder device, specifically the GARMIN GPSMAP 585Plus model. This device measures water depth by emitting ultrasonic waves from the surface to the bottom of the reservoir and receiving the reflected waves back to the transducer.

Fig. 2. Bathymetry Recording Process at Study Location

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C. Equipment and Data Collection

Echosounder: The echosounder works by emitting ultrasonic pulses vertically from the surface of the water to the reservoir bed. The time taken for the pulses to travel down and back is used to calculate depth using the following formula (Poerbandono, 2005):

$$d = v \cdot t$$

where:
d is the depth (in meters),
v is the speed of sound in water (in meters per second), and
t is the time for the ultrasonic pulse to travel to the bottom and back (in seconds).

The speed of sound in water (v) typically ranges from 1,480 to 1,530 m/s depending on factors such as temperature, salinity, and pressure (Urick, 1983).

Table 1. Raw Data of Bathymetry Measurements of Study Locations

NO	*Y*	*X*	*Z*	*POINT_ID*
1	*521551.555*	*954806.928*	*9.613*	*"BM"*
2	*521551.555*	*955020.264*	*-6.6543*	*"Bathimetri 1"*
3	*521551.555*	*9954936.412*	*-6.7085*	*"Bathimetri 2"*
4	*521556.531*	*9954936.9*	*-6.5701*	*"Bathimetri 3"*
5	*521561.507*	*9954937.389*	*-6.2883*	*"Bathimetri 4"*
6	*521566.483*	*9954937.878*	*-6.3208*	*"Bathimetri 5"*
7	*521571.287*	*9954939.243*	*-6.2238*	*"Bathimetri 6"*
8	*521585.655*	*9954943.55*	*-6.4194*	*"Bathimetri 7"*
9	*521590.445*	*9954944.986*	*-6.3246*	*"Bathimetri 8"*
10	*521595.234*	*9954946.421*	*-6.2389*	*"Bathimetri 9"*

GPS (*Global Positioning System*): Integrated with the echosounder, the GPS records the precise coordinates (latitude and longitude) of each depth measurement, which is crucial for creating an accurate bathymetric map.

Survey Boat: A small boat was used to follow predetermined transects across the reservoir, ensuring that depth measurements were taken systematically.

D. Survey Procedure

Transect Planning: The reservoir was divided into several transects, which are planned paths across the water surface. The survey boat followed these transects, taking depth measurements at regular intervals.

Data Recording: As the boat traveled along each transect, the echosounder continuously recorded water depths, while the GPS logged the corresponding coordinates, resulting in a dataset containing X (longitude), Y (latitude), and Z (depth) values.

Data Processing: The collected data were processed to create a bathymetric map of the reservoir. This map showed the current contours of the reservoir bed, highlighting areas with significant sediment deposition.

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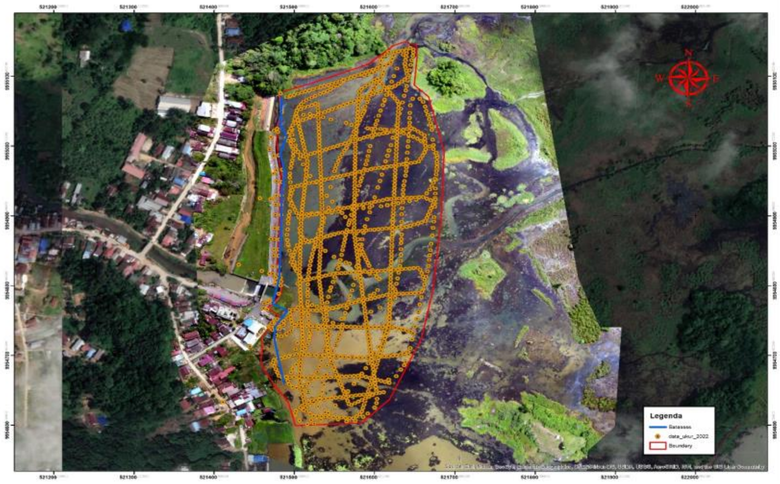

Fig. 3. Location Bathymetric Recording Flow Map

E. Sediment Accumulation Analysis

To analyze sediment accumulation, the bathymetric data from the 2022 survey was compared with data from a previous survey conducted in 2018. The volume of sediment deposited over the four years was calculated using the following method (Demers, 2002):

$$Sediment\ Volume = Initial\ Volume - Final\ Volume$$

The sedimentation rate was then determined using the formula:

$$Sedimentation\ Rate = \frac{Sediment\ Volume}{Time\ Period}$$

This rate was used to project future sedimentation impacts on the dam’s capacity and to estimate when critical levels of sedimentation might occur.

III. RESULTS AND DISCUSSION

A. Bathymetric Survey Findings

The bathymetric survey of Benanga Dam, conducted in 2022, revealed significant changes in the reservoir’s depth profile compared to the previous survey in 2018. The data indicated an increase in reservoir volume by 111,941 m³, largely due to sediment dredging efforts carried out in 2021 by the Ministry of Public Works and Public Housing. Despite this increase, the dam's capacity remains substantially lower than its original design capacity of 1.6 million m³, currently holding only about 500,000 m³.

B. Sedimentation Analysis

The comparison between the 2018 and 2022 bathymetric surveys indicated a consistent rate of sedimentation in the reservoir. The estimated sedimentation rate was calculated to be approximately 27,985 m³ per year. This rate is alarming, as it suggests that, without ongoing and effective dredging, the dam's storage capacity will continue to diminish rapidly.

The sedimentation is primarily caused by upstream human activities, including illegal mining and deforestation. These activities have increased the amount of sediment entering the dam, leading to a faster rate of siltation. The deforestation in the catchment area, in particular, has reduced the natural filtration capacity of the land, allowing more sediment to be washed into the reservoir during rainfall.

C. Impact on Dam Functionality

The reduction in the dam’s capacity has significant implications for its ability to manage water flow and prevent flooding. The diminished storage volume means that Benanga Dam can only reduce flood risks by about 10%, far less than its intended capacity.

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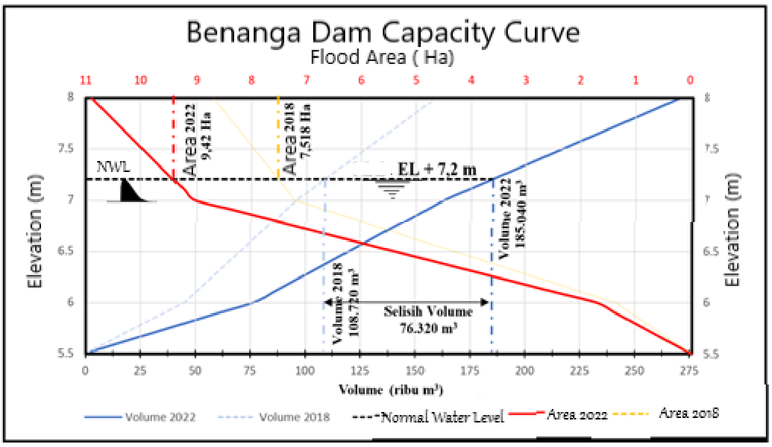

Fig. 4. Benanga Dam Capacity Curve, 2018 and 2022

This reduced functionality was evident during the severe floods of June 2019, when the dam's inability to hold back water contributed to widespread flooding in the Karang Mumus River Basin, affecting 56,000 residents and causing significant damage across three districts.

The analysis also suggests that if the current rate of sedimentation continues unchecked, the reservoir will reach critical levels of siltation within the next 7 to 8 years. At this point, the water level could rise to the normal water surface elevation of +7.2 meters, severely compromising the dam's flood mitigation capabilities.

D. Mitigation Strategies

To address these challenges, it is crucial to implement effective sediment management strategies. The key recommendation is to establish a regular dredging schedule that corresponds with the observed sedimentation rate of 27,985 m³ per year. By removing this volume of sediment annually, it may be possible to maintain the current capacity of the dam and prevent further reduction in its effectiveness.

In addition to dredging, upstream land management practices need to be improved. Reforestation efforts in the catchment area, combined with strict regulations against illegal mining and land clearing, could significantly reduce the amount of sediment entering the reservoir. These actions would not only protect the dam's capacity but also contribute to the overall health of the watershed.

E. Long-term Considerations

The results of this study underscore the importance of proactive management of the Benanga Dam and its catchment area. Regular monitoring of sediment levels and the implementation of sustainable land use practices are essential to ensure the long-term functionality of the dam. Without these measures, the dam's capacity will continue to decline, leading to increased flood risks and potential damage to the surrounding communities.

The study also highlights the need for ongoing research and adaptive management strategies to respond to changes in sedimentation rates and other environmental factors. As the region continues to develop, it is vital to balance economic activities with the preservation of critical infrastructure like Benanga Dam.

After undergoing the measurement data processing, the catchment area and runoff coefficient were successfully derived. The visualization of both the catchment area and runoff coefficient can be observed in Figure 2, while detailed results are elaborated in Tables 1 and 2.

IV. CONCLUSION

Benanga Dam plays a crucial role in water management and flood control in Samarinda, but sedimentation has significantly reduced its capacity over the years. Human activities, such as illegal mining and deforestation, have accelerated this sediment accumulation, leading to a drastic decline in the dam's effectiveness. As a result, the dam can now only mitigate about 10% of potential flood risks, far below its original design capacity. To prevent further deterioration, regular dredging and improved land management practices in the dam's catchment area are essential. Without these interventions, the dam's functionality will continue to decline, posing increased risks to the surrounding communities

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