Effect of change of channel width in the downstream of the check dam on controlling sedimentation in Mrica Reservoir

by Dyah Ari Wulandari

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Effect of change of channel width in the downstream of the check dam on controlling sedimentation in Mrica Reservoir

D Ulfiana[1,*], D A Wulandari[1], P N Parmantoro[1], Susilowati[1]

[1]Civil Engineering Department, Engineering Faculty, Diponegoro University, Semarang, Indonesia

[*]Corresponding author e-mail: desyta@live.undip.ac.id

Abstract. The increasing sedimentation of Mrica reservoir shows that the sedimentation control has not been effective. The sedimentation control has been made include the disposal of sediments that settle in the reservoir by dredging or flushing. However, the results are not optimal. This is caused by the large volume of sediment entering the reservoir each year. The controlling volume of sediment that goes into the reservoir has also been carried out by conducting a watershed conservation program and building a check dam in the upstream Mrica reservoir. However, the existing check dam is still less effective in controlling sediments, especially suspended load sediments, that are transported in the river. Therefore this study was carried out by adopting the sediment trap concept to deposit sediments that escaped from the check dam. This study simulated changes in the width of the downstream channel of the check dam by three variations using HEC-RAS. There was a width of 20%, 40%, and 60% wider than the initial width. The results showed the effect of changing the channel width on volume sediment deposited. Based on the results of the study, the change in width to wider than the initial width could increase the volume of sediment deposits.

1. Introduction

Mrica Reservoir or Panglima Besar Soedirman Reservoir is one of the strategic reservoirs located in Bawang District, Banjarnegara Regency, Central Java Province. It began operating in 1988 and has the main function as a hydropower plant with an installed capacity of 180.93 MW. Besides, this reservoir is also used as a provider of irrigation water in Banjarcayana, covering an area of 6550 hectares and Penaruban covering an area of 900 hectares. Mrica reservoir has a watershed area of 957 km^2. This reservoir has an area of 8.26 million m^2, with a capacity of 148.287 million m^3. It is planned to have a service life of 60 years with a sedimentation rate of 2.4 million m^3 / year.

The problem that occurs in the management of Mrica Reservoirs is siltation caused by sedimentation. Sediment deposited above the dead reservoir will reduce the effective volume of the reservoir, thereby reducing the economic service life of the reservoir [1]. According to reports from PT Indonesia Power [2] as the manager of the Mrica Reservoir in 2016, the effective volume of this reservoir decreased by 48.7%. The total sediment volume of the Mrica Reservoir up to October 2016 was 114.254 million m^3, meaning 22.40% of the reservoir volume has been filled with sediment.

Based on PT Indonesia Power's research from year to year, the sediment deposition in Mrica Reservoir has increased [2]. Mrica Reservoir sedimentation, which continues to grow, shows that sedimentation control is less effective. There have been some studies on sedimentation control of the Mrica Reservoir. A study conducted by Alfianto and Soewarno [3] developed a micro sabo dam on agricultural land in the upstream watershed of the Mrica Reservoir. Suroso and Widiyanto [4] also researched controlling sedimentation using a combination of flushing and fluidisation.

Several sedimentation control has been done, including the removal of sediments that deposited in reservoirs by dredging and flushing [5]. However, sediment dredging requires a very high cost. While sediment flushing has been done regularly, but the results are less than optimal. It is caused by the large volume of sediment entering the reservoir each year. Efforts to reduce the rate of sedimentation entering reservoirs have also been carried out by watershed conservation programs and building sediment control structures (check dam) in the upper reaches of the Mrica Reservoir. However, the existing check dam is still less effective in depositing sediments, especially suspended sediments.

Based on the problems above, a study was carried out by adopting a sediment trap concept to deposit suspended sediments that escaped from the check dam. Some research on the sediment trap has also been carried out. One of them is a study conducted by Guillaume and Alain [6] that combines sediment traps with an open check dam. In this study, the sediment trap was designed at the upstream of the check dam. Schwindt et al. [7] also conducted a study on modifying the design of a sediment trap with an open check dam by adding a guiding channel. A modification of a sediment trap was also carried out by Thaxton and Mclaughlin [8] by adding baffle technology.

The design approach of sediment trap structures used in this study is irrigation sediment traps. In irrigation channel, flow discharge passing through sediment trap is the amount of water used for irrigating plants, so that the passing water is planned and tends to be stable. While on the river, flow discharges are more fluctuating. Therefore, research is needed to determine the effectiveness of the sediment trap concept in the river channel, mainly to deposit sediment suspension. The adaptation of the sediment trap concept is made by varying the width of the river.

This study simulated changes in the width of the downstream channel of the check dam by three variations using HEC-RAS. There was a width of 20%, 40%, and 60% wider than the initial width. This research is expected to be able to reduce the volume of sediment effectively to maximize the management of sedimentation in Mrica Reservoir.

2. Methods

2.1. Analysis of study area

Based on research conducted by PT Indonesia Power, three main rivers become sediment entry media into Mrica Reservoir, namely Serayu, Merawu, and Lumajang rivers. In the Lumajang river channel, there is a check dam that serves to reduce sediment entering the reservoir. The check dam, which was built in 2007, is located in Linggasari Village, Wanadadi, Banjarnegara, or geographically located at coordinates 109^0 40' 34" E, 07^0 21' 40" S.

The existing check dam has a design capacity of 1009 m^3 of sediment storage with a flood discharge of 41.0 m^3/s. Based on PT Indonesia Power's data, the volume of suspended load sediment entering the Mrica Reservoir from November 2015 until October 2016 is 16544 m^3 while the bedload sediment is 9416 m^3. With a sediment storage capacity of 1009 m^3, the Lumajang River check dam in 2016 could only reduce sediment entering the reservoir by 3.88%. Besides, based on the research of Soewarno in 2007 until 2008, the volume of suspended load sediment entering the reservoir was 6821.33 m^3, and the bedload sediment was 5634.41 m^3. Then the effectiveness of the check dam in 2008 was 8.1%. It could be calculated from the data that there was an increase in sediment volume by 108.3% in 8 years. It could be said that the check dam performance is no longer effective in controlling sedimentation in Mrica Reservoir compared to when it was first built.

Another problem that exists is based on research conducted by Soewrno, showing that the check dam storage has been filled in only one rainy season. This is very ineffective, considering the high maintenance costs. Besides, most sediment that deposited in the check dam is bedload sediment, while suspended load sediment still escapes, even though around 63.73% of the sediment entering the Mrica Reservoir is suspended sediment. Therefore it is necessary to analyze the effectiveness of the sediment trap at the downstream of the check dam in overcoming the problem of suspended load sediment.

2.2. Data collection methods and analysis

Data used in this study are primary data, secondary data, and data from previous studies. Primary data used are sediment samples taken at the site. The sample is taken on upstream and downstream of the check dam to obtain concentration and gradation of bedload sediment. Secondary data used are river flow discharge, topographic maps, and design drawings of existing check dams. Other data needed are taken from previous studies that have been conducted by Soewarno and Sukatja [9] and PT Indonesia Power [2].

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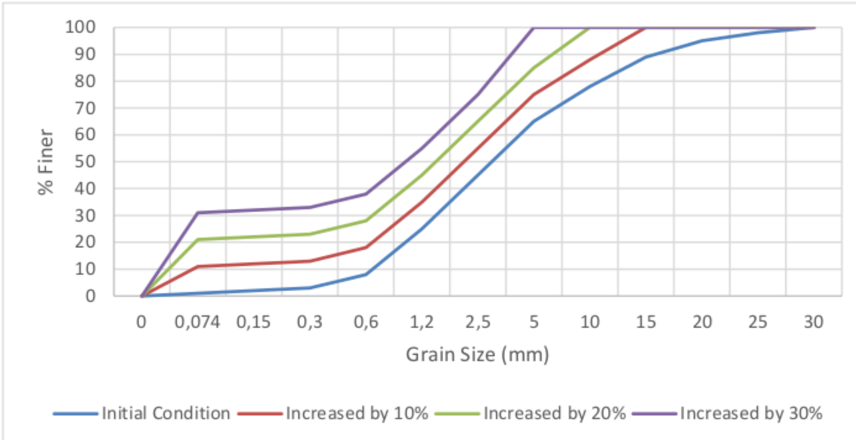

Figure 1. Variations of Sediment Gradations.

Suspended load sediment concentration and gradation data used are data from Soewarno's research. Considering that check dams are only effective for depositing sediment bedload sediment and the increasing of suspended load sediment volume from year to year, a variation of the percentage of suspended load sediment gradation is carried out to see the effectiveness of the sediment trap design. Three gradation variations are an increase in the percentage of suspended load sediment by 10%, 20%, and 30%, as seen in Figure 1.

2.3. *Preliminary design*

The next step is to make a preliminary design of a sediment trap as a basis for modelling in HEC-RAS software. This modelling is carried out to determine the effect of widening the channel cross-section on the volume of sediment deposited, especially on river flow conditions that have fluctuating discharge.

2.3.1. Sediment trap location. The location of the sediment trap is planned to adjust according to the downstream condition of the existing check dam. There is a bridge located on the downstream of the check dam. Therefore the sediment trap is planned to be made in the downstream of the bridge so that it does not disturb the bridge structure. Based on the topographic map, the length of the Lumajang River that could be used as a sediment trap is 145 m.

2.3.2. Sediment trap dimension. The cross-section of the river in the downstream of the check dam has a width of 10 m and a depth of 5.8 m. The channel cross-section dimension is then used as an initial condition of the sediment trap. Variations are then made to the cross-section width of the river by widening the initial width by 20%, 40%, and 60%. Then, four designs of river cross-section are obtained, which is cross-section with widths (B) of 10 m; 12 m; 14 m; and 16 m.

2.3.3. Inflow. There were three types of discharge data inputted in modeling in the HEC-RAS software, that is check dam flood discharge, daily discharge of Lumajang River, and dependable flow discharge 50% of the river. Based on check dam technical data, the flood discharge is 41.0 m^3/s. The dependable flow discharge 50%v of the river is obtained from the flow duration curve, which is 5 m^3/s.

2.3.4. Sediment inflow. Sediment inflow discharge is calculated using equation (1).

$$Q_s = 17.94\ Q_w{}^{2.342} \tag{1}$$

Where Q_s is suspended sediment discharge and Q_w is flow discharge

2.3.5. Model scenario. Modelling the sediment trap is done by simulating four variations of sediment trap width with three types of discharge and four variations of the percentage of sediment gradations. Simulations are carried out to determine the volume of sediment that is deposited for each scenario.

3. Results and Discussion

The analysis of the modelling result is determined by measuring the total volume of sediment deposited in each variation of the sediment trap. The result of analysis for each variation of sediment traps include:

1. Modelling on Daily discharge of Lumajang River
   Based on the result of modelling by HEC-RAS software, the graph comparison between the width of the channel and the volume of sediment deposited was generate, as shown in Figure 2. The graph shows the percentage of suspended sediment gradation increased by 10% shows that the wider the channel, the greater the volume of sediment deposited. While the percentage increased by 20% and 30%, there is no sediment deposited.

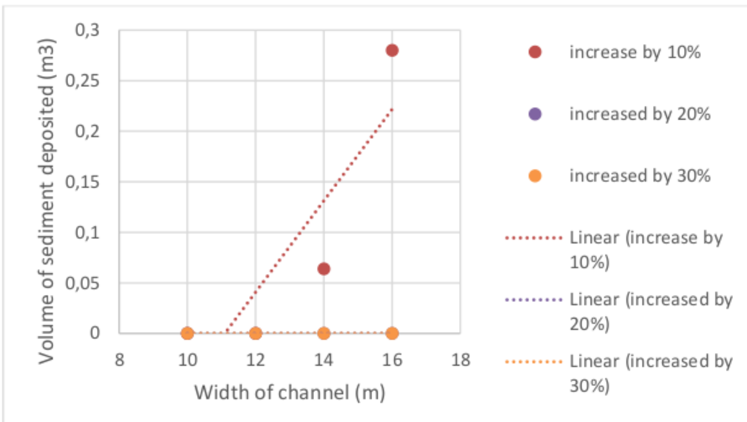

Figure 2. Width of Channel vs. Volume of Sediment Deposited Graph on Daily Discharge.

2. Modelling on Dependable Flow Discharge 50%
   The results of sediment trap modelling on dependable flow discharge, 50% are generated on the graph, as shown in Figure 3. The graph shows that the greater the width of the channel, the greater the volume of sediment that could be deposited. Based on the results of the analysis, the application of sediment traps with an increase in channel width of 20% could increase sediment volume deposited by 19.22%.
3. Modelling on Designed Flood Discharge
   The results of sediment traps modelling on designed flood discharge are generated on the graph, as shown in Figure 4. The graph shows that the greater the width of the channel, the greater the volume of sediment that could be deposited. Based on the results of the analysis, the application of sediment traps with an increase in channel width of 20% could increase sediment volume deposited by 19.40%.

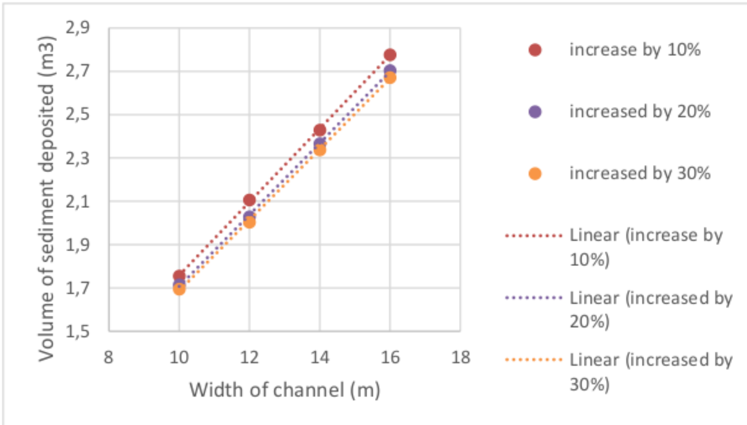

Figure 3. Width of Channel vs. Volume of Sediment Deposited Graph on Designed Flood Discharge.

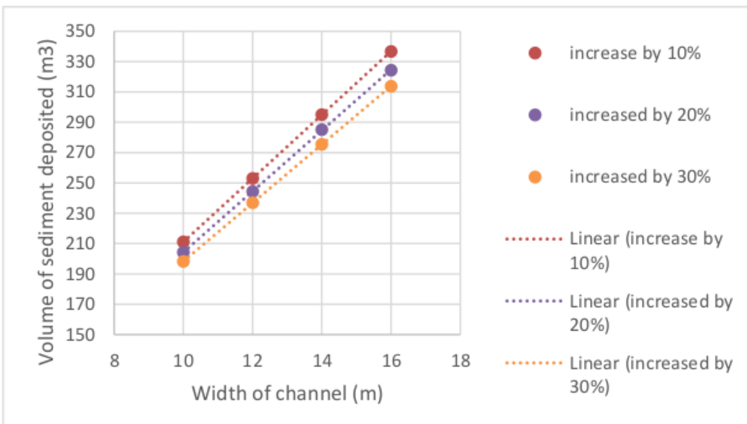

Figure 4. Width of Channel vs. Volume of Sediment Deposited Graph on Dependable Flow Discharge 50%.

Based on the results of the analysis on each discharge variations, it can be concluded that the wider the channel, there is an increase in sediment volume deposited. However, the ability of sediment traps to deposit suspended sediment is limited to this value. This is proven even though the percentage of suspended sediment gradation is increased, the volume of sediment that has settled tends to be constant.

4. Conclusion

Based on the analysis of the result, the application of the concept of sediment trap in a river channel by widening the cross-section gives effective results because it could increase the volume of sediment that deposited compared to the initial condition of the river cross-section. These results indicate that making sediment traps in the downstream of check dams could support the effectiveness of check dams in reducing the volume of sediment entering the Mrica Reservoir, especially in dealing with suspended sediment that cannot be deposited at check dams. However, the widening of the cross-section of the river has not been able to accommodate the condition of the sedimentation rate, which continues to increase from year to year because based on the results of the analysis of the increasing percentage of suspended sediment gradation that tends to remain constant.

Acknowledgements
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References

[1] D. A. Wulandari, "Penanganan sedimentasi waduk mrica," *Berk. Ilm. Tek. Keair.*, vol. 13, no. 4, pp. 264–271, 2007.
[2] PT Indonesia Power, "Laporan Pelaksanaan Penyelidikan Sedimentasi Waduk PLTA PB. Soedirman," 2016.
[3] A. Alfianto and Soewarno, "Techno Sabo for Overcoming Reservoir Watershed Sedimentation (Case Reservoir Mrica)," *J. Tek. Hidraul.*, vol. 5, no. 1, pp. 83–98, 2014.
[4] S. Suroso and W. Widiyanto, "Model Pengendalian Sedimentasi Waduk Mrica dengan Fluidisasi (Sedimentation Control Model Of Mrica Reservoir Using Fluidization)," *Din. Rekayasa*, vol. 5, Aug. 2009.
[5] P. Utomo, "Mrica Reservoir Sedimentation: Current Situation and Future Necessary Management," *J. Civ. Eng. Forum*, vol. 3, p. 365, Sep. 2017.
[6] P. Guillaume and R. Alain, "Design of Sediment Traps with Open Check Dams. I: Hydraulic and Deposition Processes," *J. Hydraul. Eng.*, vol. 142, no. 2, p. 4015045, Feb. 2016.
[7] S. Schwindt, M. J. Franca, A. Reffo, and A. J. Schleiss, "Sediment traps with guiding channel and hybrid check dams improve controlled sediment retention," *Nat. Hazards earth Syst. Sci.*, vol. 18, pp. 647–668, 2018.
[8] C. Thaxton and R. Mclaughlin, "Sediment capture effectiveness of various baffle types in a sediment retention pond," *Trans. ASAE*, vol. 48, Sep. 2005.
[9] Soewarno; and C. B. Sukatja, "Kinerja dam sabo k. lumajang untuk pengendalian sedimentasi waduk mrica," *J. Sumber Daya Air*, vol. 6, no. 1, pp. 17–32, 2010.

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