Sediment Trap in the Downstream of Check Dam: The Effect of Changes in Channel Depth on Sediment Deposition

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Sediment Trap in the Downstream of Check Dam: The Effect of Changes in Channel Depth on Sediment Deposition

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Abstract. Reservoir sedimentation is a major problem experienced by reservoirs in Indonesia. Reservoir sedimentation can be overcome by reducing the amount of sediment that enters the reservoir, among others, by building a Check dam. Check dam deposits more sediment loads with coarse grains, while sediment loads with fine grains will escape and enter the reservoir. So it is necessary to have construction to hold and settle fine sediment loads downstream of the Check dam. Construction is planned like a sediment trap in an irrigation system with variations in the cross-sectional area. In this study, the cross-section was expanded by changing its depth. The purpose of this research is to determine the effect of changes in the channel depth with discharge and grain size distribution variation on sediment deposition that occurs. The calculation is done using the HEC-RAS software. Simulation results show the deeper the sediment trap, the smaller the amount of sediment deposit. The large discharge, the smaller of deposit percentage. The greater of fine sediment percentage, the less the deposit.

1. Introduction

A Reservoir is a pool of water formed by the construction of dams in rivers. In addition to storing water, the reservoir also holds sediment that is carried by the flow. Most of this sediment will then settle in the reservoir, and some will come out through the release building. The amount of sediment that settles is used to predict reservoir life. Changes in land use in the catchment area of the reservoir cause higher erosion rates so that the reservoir sedimentation rate is also higher. Many reservoirs in Indonesia experience this problem. What can be done to overcome this problem is to reduce the amount of sediment that enters the reservoir, such as by building a Check dam. However, not all sediments can settle at the check dam. Some sediments with coarse grains will settle, while sediment loads with fine grains will escape and enter the reservoir. According to Fauzi (2006), in [6], sediments with a diameter < 0.1 mm do not settle even though the water velocity is close to zero. Whereas sediments with a diameter > 0.1 mm will settle if the water velocity is zero or close to zero. Research on the size of sediment grains deposited in the Lumajang river check dam has been conducted by [6], from this study it was found that the gradation of sediment deposits deposited on check dams in the form of rocks, gravel, sand and a small portion of fine sand or silt. Small sediments only settle at the time of initial filling; this is because upstream of the check dam forms a puddle, which results in a decrease in flow velocity at the start of submergence. When 20 months after submergence, sediments measuring 0.10 - 1.0 mm only settle by 1% while sand, gravel until the rock rises to 99%. The efficiency of sediment capture itself depends on the size of the inflow and its storage capacity. The greater the capacity of the check dam, the greater the efficiency of sediment capture. Therefore it is necessary to have a building to hold and deposit sediment loads that still pass through a check dam. While research that has been done on average is research to improve the effectiveness of deposition at check dams ([5], [7]).

This research is part of the research on Sediment Trap in the Downstream of Check dam. The construction is planned as a mud bag system that is placed on a river body in the downstream part of the

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check dam. After determining the dimensions requirements, it is necessary to know the effect of changes in the depth of the sediment trap on sediment deposition to obtain an effective depth of sediment deposition. Because the discharge in the river always experiences fluctuations where the difference between the maximum discharge and the minimum discharge is very large, and the gradation of the suspended sediment grains will also fluctuate depending on the size of the sediment that settles at check dam. There are several studies have been conducted to determine the sedimentation behavior of sediments that occur in sediment traps in irrigation channels with some modifications and conditions ([1], [3], [4], [8]). This needs to be adjusted to the hydraulic conditions and sediment transport in the river.

2. Methods

The research location is in the downstream section of a check dam in Lumajang River, Linggasari, Banjarnegara. The purpose of this study was to determine the effect of changes in channel depth with variations in discharge and suspended sediment grain size distribution on sediment deposition. Changes in depth are done to get variations in the cross-sectional area because the sedimentation velocity of sediment particles is inversely proportional to the channel cross-sectional area. The wider the channel cross-section, the faster the sediment deposition. In this research, the modelling scenario is as follows:

a. The basic dimensions of the sediment trap are 145 m long, 10 m wide, 5.8 m deep, and the channel slope is 0.034.
b. The cross-section is expanded by changing the existing depth with three depth variations, namely depths of 6.4 m, 7.0 m, and 7.6 m.
c. The discharge used is an average discharge of 5 m^3/s, and the maximum flood discharge at 41 m^3/s
d. This sediment trap is planned to deposition the sediment load that escapes from the check dam. So that the fine sediment granules are varied to increase with a maximum grain size of 15 mm. Gradations of sediment grains are made in three scenarios, as in Table 1.
e. The relationship between water discharge and sediment is expressed by equation [1].

Table 1. Grain Size distribution Scenario

Scenario	Diameter of sediment grains (mm)	Percentage of Grains (%)
1	≤ 0.074	11
	0.075 – 15	89
2	≤ 0.074	21
	0.075 – 10	79
3	≤ 0.074	31
	0.075 – 5	69

The calculation is done using the HEC-RAS software. There are 24 models combination of scenarios, as mentioned above.

3. Results and Discussion

Based on the results of calculations with HEC-RAS, in each scenario, a cross-section and a long section will be obtained, as in Figure 1 and Figure 2 respectively. So that in each scenario the elevation of the river bed can be determined. If the elevation of the initial riverbed is greater than the end condition of the river bed, it means that the section has been scoured. Meanwhile, if the elevation of the initial river bed is lower than the end condition of the river bed, it means that the deposition occurred in the section (Figure 3). Based on the results of changes in river bed elevation, the volume of sediments that settles and the percentage of sediments that settles is calculated, as in Table 2 and Table 3 respectively.

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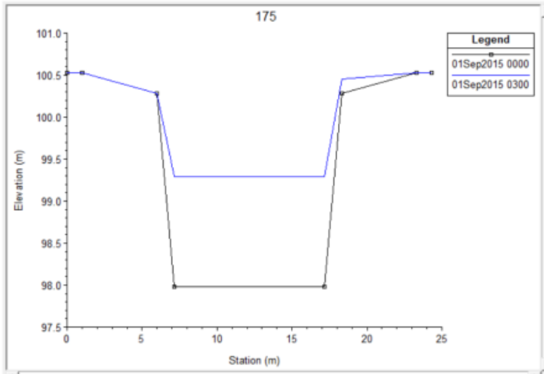
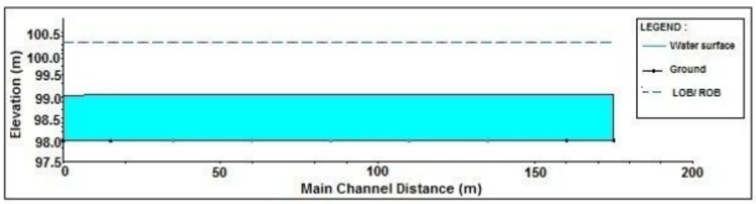
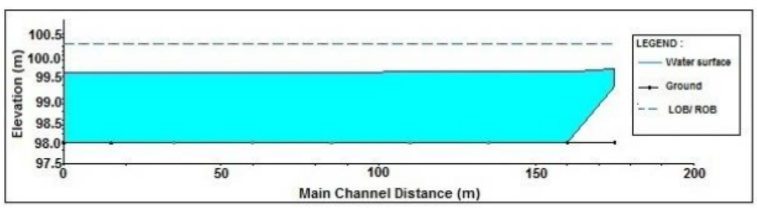


Figure 1. STA 175 cross section in scenarios with 16 m width, 5.8 m depth, 41 m^3/s discharge and grain size distribution 2.



a. Initial condition



b. Running result

Figure 2. Long section STA 175 in scenarios with 16 m width, 5.8 m depth, 41 m^3/s discharge and grain size distribution 2.

	01Sep2015 0000	Before	01Sep2015 0300	After
	Station	Elevation	Station	Elevation
1	0.00	100.5301	0.00	100.5301
2	1.00	100.5301	1.00	100.5301
3	6.00	100.2801	6.00	100.2801
4	7.15	97.9801	7.15	99.2939
5	17.15	97.9801	17.15	99.2939
6	18.30	100.2801	18.30	100.4547
7	23.30	100.5301	23.30	100.5301
8	24.30	100.5301	24.30	100.5301

Figure 3. Bed Elevation STA 175 in scenarios with 16 m width, 5.8 m depth, 41 m^3/s discharge and grain size distribution 2.

Based on Table 2 and Table 3, it can be seen that the discharge of 5 m^3/s and 7.0 m depth that settles sediment is the least, while the flow of 41 m^3/s is deeper than the sediment trap depth then the sediment that settles is also getting smaller. According to the [2], [3] and [4] the particles entering the pool at A, with the particle deposition velocity w and the velocity of water v must reach the bottom at C (Figure 4). Particles take time for H/w to reach the bottom and will move horizontally along the L distance in L/v time. If the depth of the sediment trap gets deeper than before, the cross-sectional area will be greater, and the flow velocity will be smaller. So that the horizontal sediment transfer time slows.

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However, the deeper the sediment trap is, the distance traveled by the sediment grains to reach the bottom is also getting farther and takes longer. In this case, it means slowing down the horizontal displacement time due to decreased flow velocity is still faster than the time required for sediment to reach the bottom, so the deeper the sediment trap, the smaller the amount of sediment that settles. In this case, the length of the sediment trap needs to be longer. Reducing the flow velocity by increasing the cross-sectional area by increasing the depth of the sediment trap proved ineffective. Consideration should be given to enlarging the cross-sectional area by increasing the width of the sediment trap.

Based on Table 3, it can be seen that in all depth variations, the percentage of sediment that settles at 41 m^3/s is smaller than the percentage of sediment that settles at 5 m^3/s. This is because a large discharge will increase the flow velocity, thereby reducing the sedimentation rate of sediment particles. In all variations of sediment trap depth, the difference in grain gradation also results in different sediment deposition. The greater the percentage of fine sediment, the less sediment settles. Fine sediment grains have slower deposition speeds so that the time needed to reach the bottom is longer, so the size of the sediment trap must be longer so that the fine sediment settles optimally.

Table 2. Sediment deposited

Length (m)	Wide (m)	Depth (m)	Sediment deposited (m^3)					
			Discharge (m^3/s)					
			5			41		
			Grain size Distribution			Grain size Distribution		
			1	2	3	1	2	3
145	10	5.8	1.755	1.715	1.695	211.090	204.190	198.200
		6.4	1.760	1.715	1.695	211.080	203.875	197.665
		7.0	1.710	1.690	1.645	211.050	203.765	197.510
		7.6	1.760	1.715	1.695	211.048	203.785	197.510

Table 3. Percentage of sediment that settles

Length (m)	Width (m)	Depth (m)	Percentage of sediment that settles (%)					
			Discharge(m^3/dt)					
			5			41		
			Grain size Distribution			Grain size Distribution		
			1	2	3	1	2	3
145	10	5.8	1.48	1.45	1.43	1.29	1.25	1.21
		6.4	1.49	1.45	1.43	1.29	1.25	1.21
		7.0	1.44	1.43	1.39	1.29	1.25	1.21
		7.6	1.49	1.45	1.43	1.29	1.25	1.21

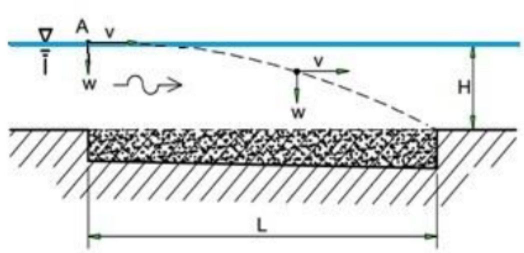

Figure 4. Schematic sediment deposition [2]

4. Conclusion

Based on the results of the analysis that has been done, it can be concluded that:

a. The deeper the sediment trap the smaller the amount of sediment that settles because the deeper, the longer time needed for the sediment grains to settle
b. In all depth variations, large discharges produce smaller sediment percentages than those generated in small discharges because large discharges increase the flow velocity, thereby reducing the rate of deposition of sediment particles.
c. In all depth variations, the greater the percentage of fine sediment the less the sediment settles because fine sediment has slower deposition velocity, so the time needed to reach the bottom is longer

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References

[1] J. Baade and R. Hesse, "An Overlooked Sediment Trap In Arid Environments: Ancient Irrigation Agriculture In The Coastal Desert Of Peru", *Sediment Dynamics In Changing Environments* (Proceedings Of A Symposium Held In Christchurch, New Zealand, December 2008), IAHS Publ. 325, 2008.
[2] Departemen Pekerjaan Umum, Standar Perencanaan Irigasi KP-02. 1986. Jakarta: Badan Penerbit Pekerjaan Umum
[3] Hanwar, Suhendrik and Revalin Herdianto, "Desain Bangunan Penangkap Sedimen dengan Teknologi Baffle", *Jurnal Teknik Sipil dan Perencanaan*, vol. 9, no. 2, pp. 145-154, 2007.
[4] R. Herdianto, and R. Hidayati, "Kombinasi Sekat Dan Tanaman Air Untuk Optimalisasi Bangunan Penangkap Sedimen", *Rekayasa Sipil,* vol. VI, no. 1, 2010.
[5] G. Piton and A. Recking, "Design of Sediment Traps with Open Check Dams. I: Hydraulic and Deposition Processes", *J. of Hydraulic Engineering*, 142(2): 4015045, 2016, https://doi.org/10.1061/(ASCE)HY.1943-7900.0001048
[6] 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.
[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] J.I.F. Slaets, P. Schmitter, T. Hilger, T.D. Vien, and G. Cadisch, "Sediment Trap Efficiency Of Paddy Fields AtThe Watershed Scale In A Mountainous Catchment In Northwest Vietnam", Biogeosciences Discuss., 12, pp. 20437–20473, 2015, Doi:10.5194/Bgd-12-20437-2015.

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