

# EFFECTIVENESS OF SAND TRAP COMPARTMENT IN SUPPORTING IRRIGATION SERVICE OPERATION

Susi Hidayah<sup>1</sup>, Indri S. Setianingwulan<sup>1</sup>, Slamet Lestari<sup>2</sup>

## ABSTRACT

*One problem often faced in operation and maintenance of irrigation systems is the sedimentation in the canal which may change the flow pattern and dimension of canal and consequently affecting water flows to irrigated land. Sand trap as a controller of the sediment entering the canal must be designed in such a way in order to have optimal performance. This paper is to highlight the effect of compartment design on trapping and flushing. The parameters studied include distribution of flow velocity, sediment transport and trapping. The effect on flushing is examined visually in the field. The comparisons are made with one, two and four compartment design of sand trap. Observations in each configuration of compartment include flow velocity distribution, distribution of the sediment layer addition, sediment transport, the trapping and flushing. Comparative value of L / B for Pamarayan's sandtrap is the smallest. with (L / B = 9), L / B = 11,58 in Serayu and L / B = 26 in Sokawati. The highest average flow velocity is 0.27 to 0.64 m / s in Sokawati, Serayu 0.08 to 0.28 m / s and Pamarayan 0.06 - 0.44 m / s. The results indicate that the smaller the ratio of L / B the smaller the settling velocity. The highest effectiveness of trapping is in Serayu Weir (> 95%) with two compartment and then followed by Pamarayan Weir (87.19%) and Sokawati (<40%). Ratio between length and width of the building (L / B), flow velocity, number of compartment and volume of storage building of sand trap are the factors influencing the effectiveness of sand trap. Trapping is necessary to control the flow of sediment into irrigation canal, while flushing is needed to flush sediment in sand trap with appropriate pattern of flushing operation as it is not to interfere with service to the irrigation system.*

**Key words:** sand trap, compartment, trapping and flushing effectiveness.

## I INTRODUCTION

### 1.1 Background

One problem often faced in operation and maintenance of irrigation systems is the sedimentation in the canal which may change the flow pattern and dimension of canal and consequently affecting water flows to irrigated land. Therefore suspended sediment loads which are carried by irrigation water must be prevented from entering the irrigation network and land because of its adverse effects on the sedimentation of the canal and on rising land elevation.

Sand trap as a controller of the sediment entering the canal must be designed in such a way in order to have optimal performance. Sand trap performance is influenced by several parameters, including flow velocity, dimensions of compartment, the trapping rate, the concentration and the diameter of the grain which can be deposited (Manual Hydraulic Engineering Planning, Operation, and Maintenance of Sand Trap Pusair Type, Ministry of Settlement and Infrastructure Region, 2004). In this context, it needs assessment on sediment controller buildings in the main irrigation networks as one of the important criteria to measure irrigation performance.

Most of the sand trap structural designs currently available are still not considering the number of compartment. In irrigation service operation. The number of sand trap of more than one is considered effective. especially if it took long enough time for flushing, the operation of irrigation will be disrupted.

### 1.2 Site and Time of Research

Primary data collection activities was conducted at several locations as follows:

- Sand trap of west Pamarayan Weir, Ciujung River, Serang, Banten
- Sand trap of Serayu Barrage, Serayu River, Central Java
- Sand trap of Sokawati Weir, Kali Comal, Central Java
- Sample analysis activities was done at the land laboratory in Bekasi.

Sediment sampling is conducted during the rainy season in which the concentrations of sediment entering the building are considered high.

<sup>1</sup>Experimental Station for Irrigation, Research and Development Center for Water Resources, Ministry of Public Works Indonesia 1 Jl. Cut Meutia PO BOX 147, Bekasi 17113 E-mail: susi\_qut@yahoo.com; indri.swatini@gmail.com

<sup>2</sup>Experimental Station for Hydraulic and Geotechnical Inundated, Research and Development Center for Water Resources, Ministry of Public Works Indonesia Jl. Ir. H. Juanda No. 193, Bandung mame\_ind@yahoo.com

### 1.3 Scope of Study, Objective and Goal

This study is focused on the influence of design namely the amount of compartment in the sand trap on the effectiveness of trapping and flushing. Parameters studied include the distribution of flow velocity, sediment transport and the effectiveness of trapping. While studies on the effectiveness of flushing are examined visually in the field.

The objective of this research is to understand the relationship between sand trap design and the performance of irrigation service. While the targets is to determine the optimum performance of sand trap and to improve the structural performance, particularly the sand trap and network service quality in general.

## II LITERATURE REVIEW

### 2.1 Settling Velocity, w

For the shape factor  $SF < 1.0$ , settling velocity of the sediment in quiet and clear water can be calculated using the formula following (Manual of Hydraulic Engineering Planning, Operation, and Maintenance of Sand Trap Pusair Type, Ministry of Settlement and Infrastructure Region, 2004) :

$$w_s = \frac{\Delta g D^2}{18\nu} \text{ for } 1\mu < D \leq 100\mu\text{m} \quad \dots\dots\dots 2.1$$

$w_s$  = settling velocity of sediment in quiet and clear water ( m/s )

$$= \frac{10D}{\Delta} \left[ \left( \frac{1 + 0,01 \Delta g D^3}{\nu^2} \right)^{0,5} - 1 \right] \text{ for } 100\mu < D \leq 1000\mu\text{m} \quad \dots\dots\dots 2.2$$

$$\Delta = \frac{\rho_s - \rho_a}{\rho_a} \quad \dots\dots\dots 2.3$$

$\rho_s$  = sediment density ( kg/m<sup>3</sup> )

$\rho_a$  = water density ( kg/m<sup>3</sup> )

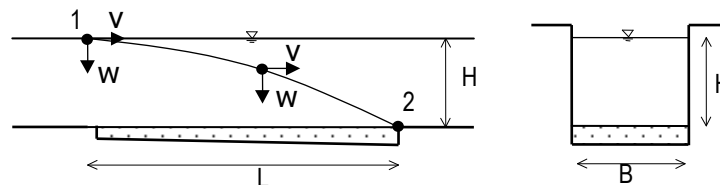
$g$  = gravity velocity ( m/s<sup>2</sup> )

$\nu$  = kinematic viscosity coefficient ( m<sup>2</sup>/s )

The value of water density  $\rho_a$  and kinematic viscosity  $\nu$  is strongly influenced by temperature with the range of values that can be seen in Table 1.

**Table 1** Effect of Temperature on Kinematic Viscosity and Mass Density

Temperature (°C)	0	4	12	16	20	30	40
$\rho_a$ (kg/m <sup>3</sup> )	999,87	1000,0	999,5	999,0	998,3	995,7	922,3
$\nu$ (10 <sup>-6</sup> m <sup>2</sup> /s)	1,79	1,56	1,24	1,11	1,01	0,80	0,66



**Figure 1** Settling Process on Sand Trap

Settling velocity of sediment is strongly influenced by the concentration of sediment. Effect of sediment concentration against the grain of sand settling velocity can be calculated using the formula (Velikanov in Manual Hydraulic Engineering Planning, Operation, and Maintenance of Sand Trap Pusair Type, 2004) as following:

$$w = (1 - 2,15 c) (1 - 0,75 c^{0,33}) \times w_s \quad \dots\dots\dots 2.4$$

$w$  = settling velocity of sediment grains by considering the influence of the presence of grains other sediment ( m/s )

c = sediment concentrations which are calculated based on volume percentage ( % )

Concentration of sediment consist of bad loads and suspended one should be measured directly in the field at various different discharge conditions. If this is not feasible, the minimum data that must be obtained from the field is a gradation of the riverbed material.

In such circumstances only the riverbed material gradations are known, then the sediment concentration can be calculated by applying the method Engelund-Hansen, Meyer-Peter-Meuler, Van Rijn, Ackers-White, or other methods suitable for the condition of the river which was investigated.

## 2.2 Sand trap hydraulic design

Flow velocity is deigned low enough so that grain of sand that is on the surface of the initial section flow field can be deposited in the downstream end of the compartment. Flow velocity in the compartment should be distributed evenly, turbulence flow, which can against the force of sediment settling in order to low enough and vortex flow direction should be avoided so that the compartment can be exploited optimally. This can be obtained by :

- (i) Applying  $\frac{L}{B} \geq 8$  of the length and width of the comparative figures of compartment. If this value can not be attained, it should be divided into several chambers by installing divided walls, so the length and width ratio of the number of compartment for each booth is  $\frac{L}{b_i} \geq 8$
- (ii) Building an initial canal with a big radius of curvature which is large enough to influence the flow curve does not lead to convergence on the outside of the curve.
- (iii) Setting up the referring walls to muffle the directional flow on the outside of the arch, so that the flow conditions that are not profitable does not continue to carry over to the settling compartment.

## 2.3 Trapping effectiveness

To check the effectiveness of the settling basin, it can be used sediment removal graphs of the Camp, in the Directorate of Irrigation (2009). The graph in Figure 2 provides effectiveness as a function of two parameters. The parameter is  $w/w_0$  and  $w/v_0$

Where :

w = settling velocity of particles outside of the particle size was planned, m/dt

$w_0$  = settling velocity plan, m/dt

$v_0$  = average flow velocity in settling basin, m/dt

By using Camp graph, the effectiveness of the settling process for particles with different settling velocity from the plan one can be checked.

Effectiveness of trapping should be examined in two different condition, both of the empty basins and full one conditions. For an empty basins, the minimum velocity should not be too small to allow the growth of vegetation or clay particles settling.

According Vlugter (1963) on Ministry of Settlement and Infrastructure Region (2004) for  $v > \frac{w}{1.61} \dots\dots\dots 2.5$

Where :

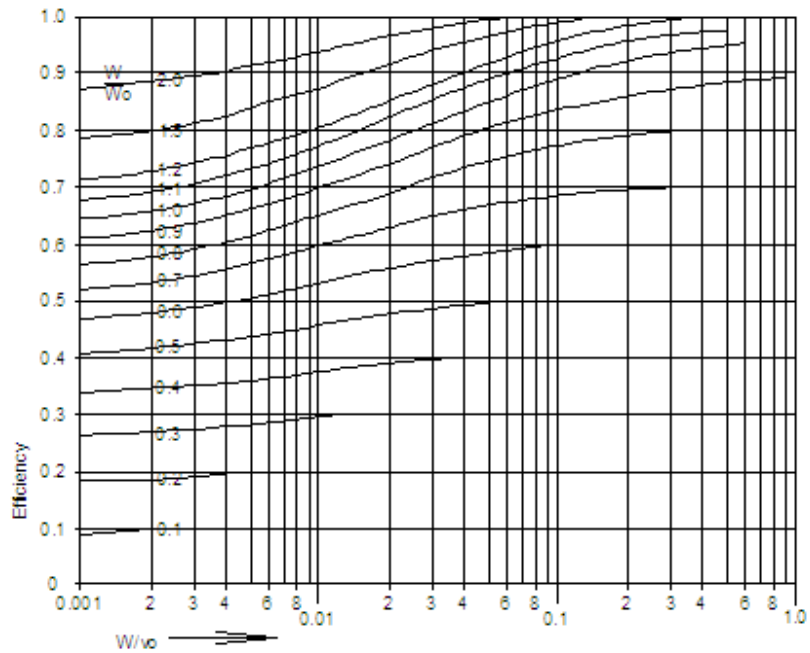
v = velocity average, ( m/dt )

w = sediment settling velocity, ( m/dt )

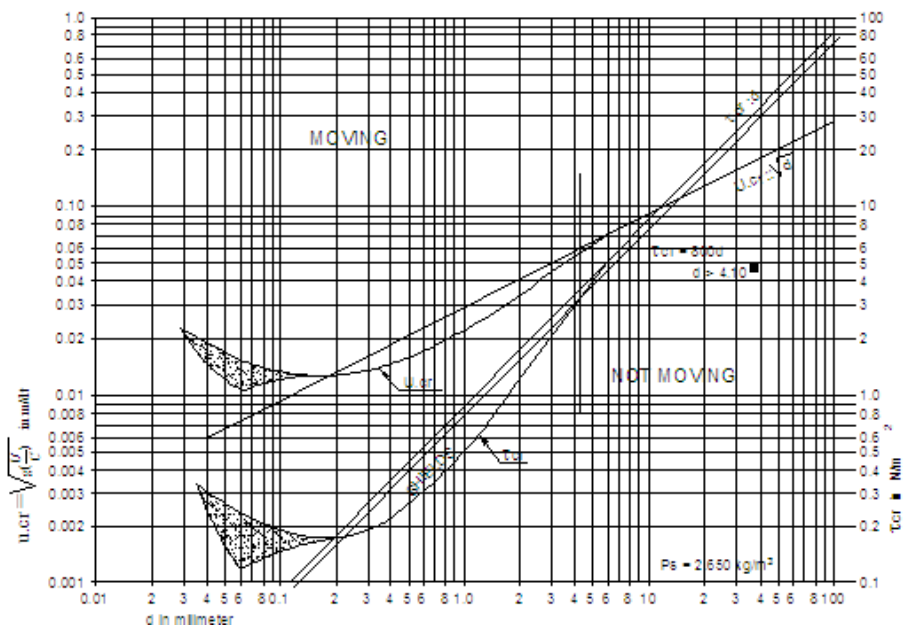
l = slope energy

All material with settling velocity w, will be in suspension at any concentration.

If the basin is full, it should be examined whether the trapping was still effective and whether the settled material was not going to burst anymore. The first one, can be checked by using Camp graphical (see Figure 2) and the second by Shields graphs (see Figure 3).



**Figure 2** Efficiency of Individual Particles Sedimentation for Turbulent Flow (Camp 1945 in Directorate of Irrigation 2009)



**Figure 3** Critical Shear Stress and Shear Velocity as a function of grain size for  $\rho_s = 2650 \text{ kg/m}^3$  (Sand)

### III METODOLOGY

#### 3.1 Research Method

Stage of data collection was done by collecting technical data, sediment sampling and laboratory analysis.

##### a) Technical Data Collection

Technical data includes physical technical data of the sand trap, design parameters, operational and technical data of sand traps.

##### b) Sediment Sampling

Sediment sampling conducted in the upper reaches of weir (river), sand trap, and irrigation canals. Sediment sampling carried out in some segments of the sand trap with the furthest distance of 50 meters. Boat used as a tool for sediment sampling based on the width of sand trap wide enough, more than 10 meters.

- c) Laboratory Analysis  
Include of aggregate grading testing, sediment concentration, and density. The analysis used numerical and graphic relationships between parameters.
- d) Trapping Effectiveness Analysis  
Relations between various parameters was searched by empirical to determine the effectiveness of sand trap.
- e) Flushing Effectiveness Analysis  
Performed directly on field observations and questionnaires to a technical unit of the sand trap.

### 3.2 Research Hypothesis

The number of compartment, the distribution of flow velocity, sediment transport, sediment concentration on sand trap influence the trapping effectiveness and the flushing effectiveness on the sand trap.

## IV RESULTS OF RESEARCH

### 4.1 Sand Trap Profile

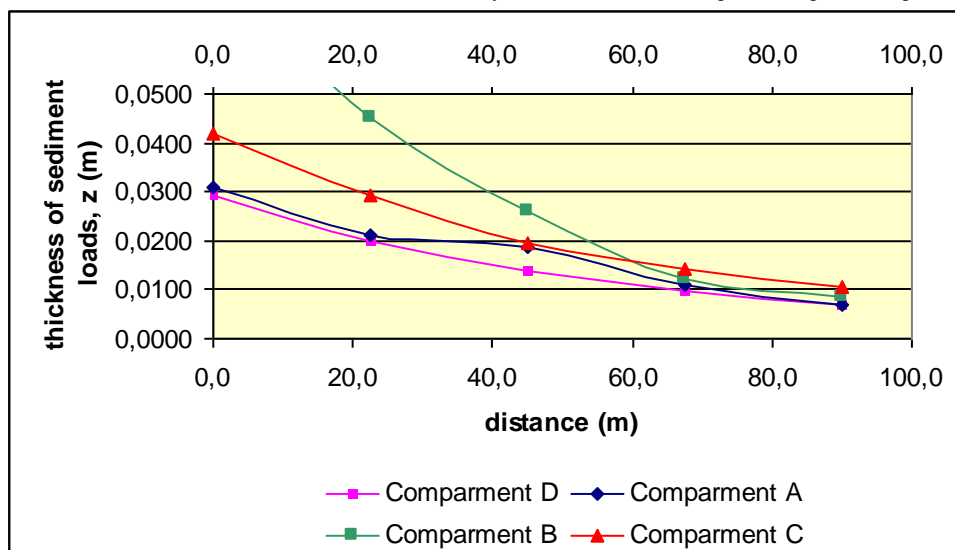
Hydraulic design of sand trap at each study site can be seen in Table 2.

**Table 2** Hydraulic Design of Sand Trap was reviewed

No	Desain hidraulik	Sand Trap		
		Pamarayan Weir	Serayu Barrage	Sokawati Weir
1	Length of sand trap (m)	90	272.242	390
2	Wide of sand trap (m)	4 x 10	2 x 23.5	1 x 15
3	Width of wasteway (m)	5	6 x 2.50	
4	Introduction canal width (m)	4 x 3.5	2 x 6	
5	Spillway Width (m)	5	5,53	
6	The slope of the sluices canals	1/14.52		
7	Bottom slope of the sand trap (i)	1/70	0.006	0.00224
8	Wasteway slope	1/60		
9	Number of compartment (units)	4	2	1

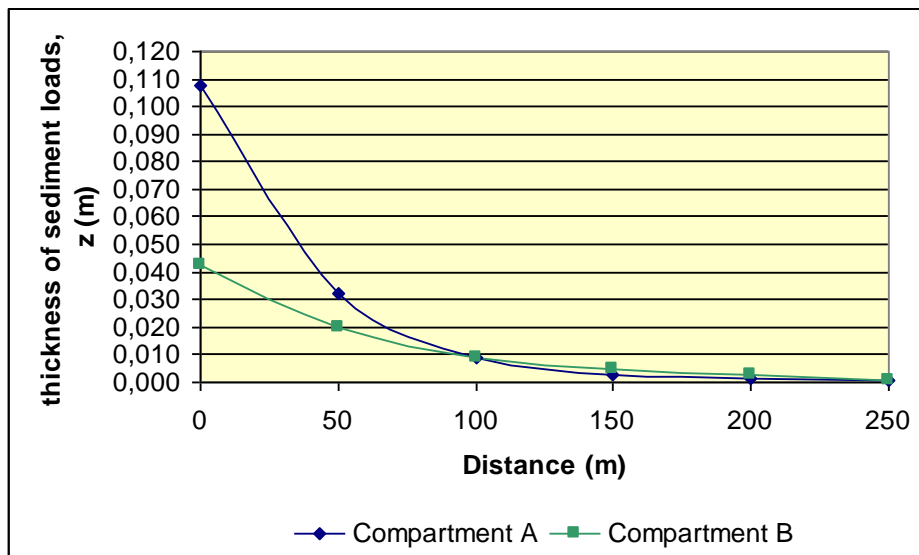
### 4.2 Bed Load Material Thickness

In sand trap of Pamarayan Weir, bed loads material settled on the sand trap are measured directly in the field of four segments of observations. Each segment there are three measurement points obtained at 60 days after flushing. Addition of sediment thickness measurements at each study site can be seen in Figure 4, Figure 5, Figure 6.



**Figure 4** Thickness of Sediment Loads Addition Throughout the Sand Trap of Pamarayan Weir

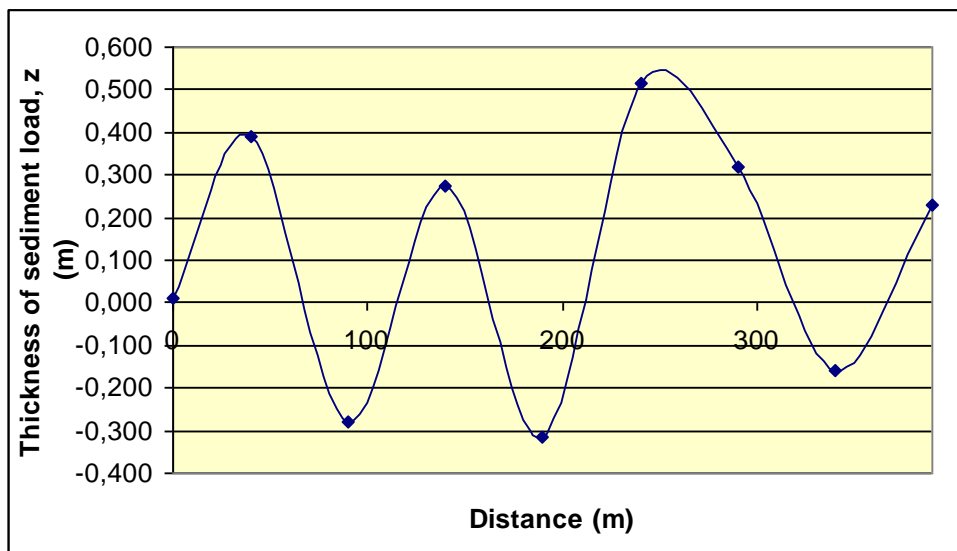
From Figure 4 can be seen that increasing the thickness of the sediments have a tendency to more additions in the early part of sand trap and progressively decreasing at the end of the sand trap, and the fourth chamber has a similar tendency.



**Figure 5** Thickness of Sediment Loads Addition Throughout Sand Trap in Serayu Barrage Weir

From Figure 5 it can be seen that increasing the thickness of the sediments have a tendency to accelerate in the early part of sand trap and progressively diminishing at the end of the sand trap. The results also indicate that both compartments have the same tendency. The tendency is also similar to that of Figure 4.

While the results of observation at Sokawati have a different inclination with two other locations. Additions to the thickness of sediment have a tendency to fluctuate throughout the building of sand catcher. At this location the actual sediment thickness measurements on three cross-sectional points, also showed that the data tend to fluctuate. This sand trap has only one compartment and it is not equipped with direction wall.



**Figure 6** Thickness of Sediment Loads Addition Throughout the Sand Trap of Sokawati Weir

#### 4.3 Flow velocity

The flow velocity was measured by using a current meter at two depths i.e. at 0.2D and 0.8D. While the performance analysis of data presented was using an average of the middle section. Flow velocity in the four compartments of the sand trap is between 0:06 until 0:44 m/s. Velocity distribution can be seen in Figure 7. Flow velocity is relatively evenly distributed in the field of sand catcher. Higher flow velocity at the outer edge of the field catcher. The form of sand trap shown in Figure 7 is a simplification of the actual form in the field.

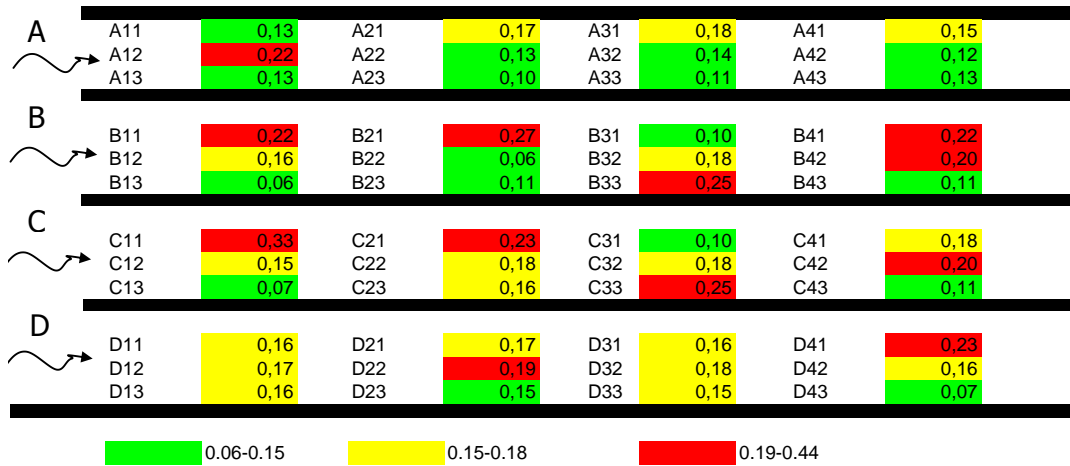


Figure 7 Flow Velocity Distribution Throughout the Sand Trap of Pamarayan Weir

Flow velocity in the sand trap in Serayu Barrage Weir can be seen in Figure 8. Flow velocity observed is 0:08 until 0:28 m / s. At B compartment, higher flow velocity occurs at the outer edge of the field of fishing, while a smaller place on the inside. In Figure 8 is a simple scheme of sand trap design from the actual condition in the field. On the actual condition of the sand trap has a curved configuration with a certain radius of curvature. Curvature on the outer side is the B compartment. At the beginning of the sand trap has a higher velocity and is getting smaller at the end (downstream).

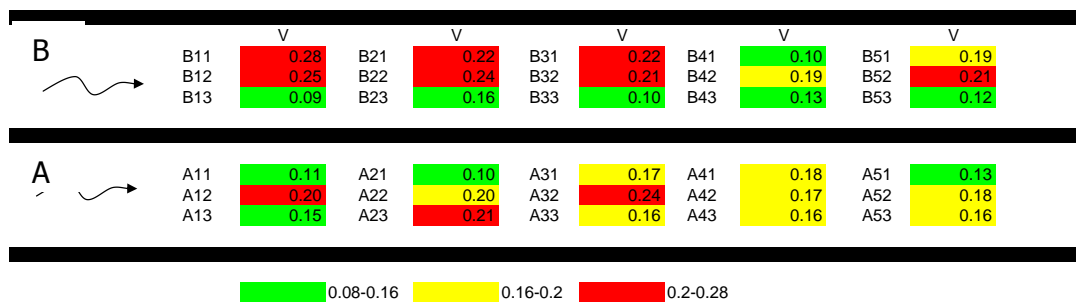


Figure 8 Flow Velocity Distribution Throughout the Sand Trap of Serayu Barrage Weir

In the sand trap of Sokawati Weir flows velocity is higher than that of the two other locations. Flow velocity that occurs is 0:27 until 0.64 m/s. Velocity distribution is quite fluctuative both on the outside and in the middle segment of the observed compartment. Sokawati Weir sand trap has a length of 390 meters, without a completed part of the transition as well as a direction the flow. Its configuration is curved and the left side of the direction of flow in the arc side part. Description of the velocity distribution measurements on the sand trap of Sokawati Weir can be seen in Figure 9.

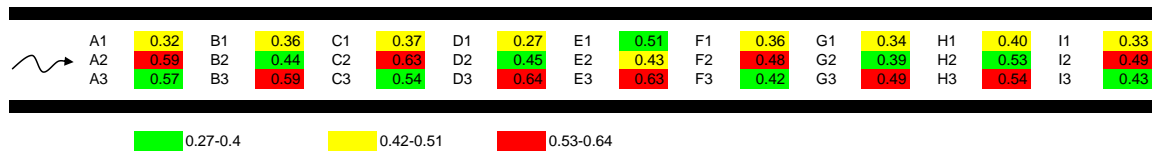
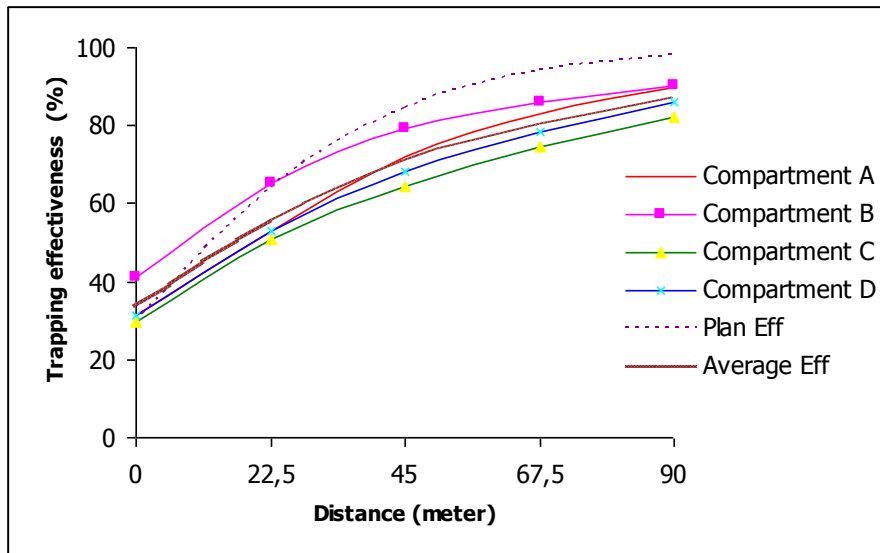


Figure 9 Flow Velocity Distribution Throughout the Sand Trap of Sokawati Weir

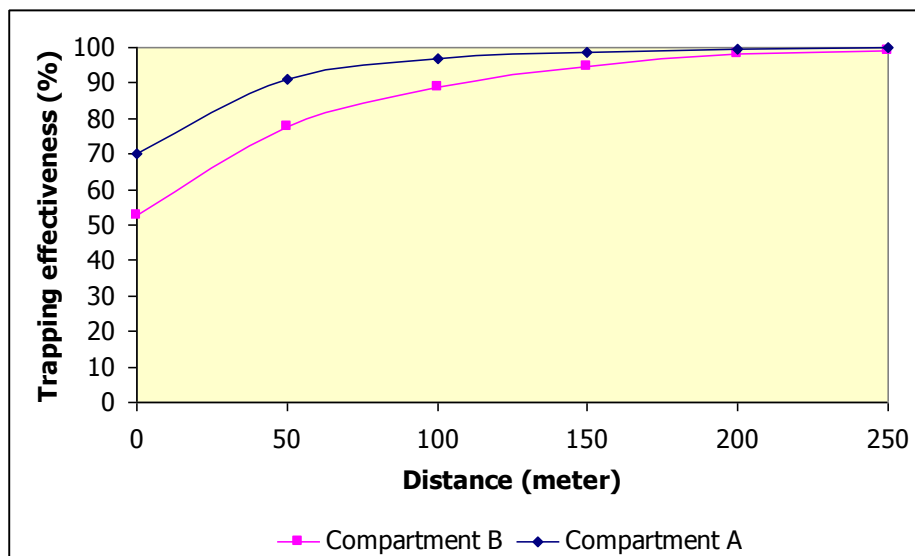
#### 4.4 Trapping Effectiveness

Pamarayan Weir sand trap has a high trapping effectiveness over 95%. Even up to the T60 (day after last flushing) the sand trap still has a high effectiveness of trapping. Although the length of the building catching only 90 meters and is divided into four compartment all with the same dimensions. Effectiveness of trapping generated is high enough at each compartment with building configuration as shown in Figure 10.



**Figure 10** Trapping effectiveness the Sand Trap of Pamarayan Weir

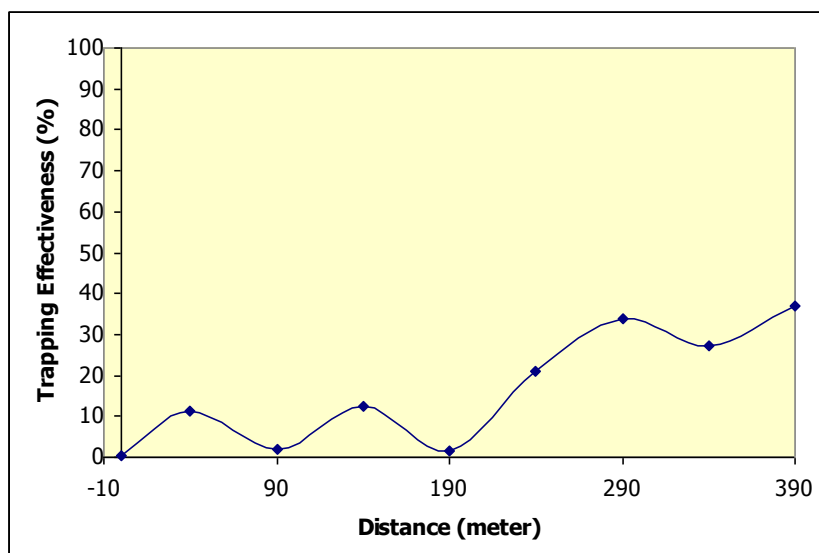
Sand trap of Serayu Barrage Weir also has a high effectiveness of more than 95%. Although the trapping effectiveness in the early part of the compartment A is higher than the compartment B but more to the downstream capture effectiveness is also achieved with relatively the same compartment of A, as shown in Figure 11.



**Figure 11** Trapping effectiveness of the Serayu Barrage Weir

Sokawati Weir sand trap has a low effectiveness of the trap that is less than 40% of the initial field by the end of the trap. The values are fluctuative along the distance from intake structure. Preview the effectiveness of the trap of building sand catcher Sokawati Weir can be seen in Figure 12.





**Figure 12** Trapping effectiveness of Sokawati Weir

#### 4.5 Flushing effectiveness

Flushing at each site research location of the sand trap is as follows:

##### a. Pamarayan Weir

Flushing period each quarter and was done together on four compartment of the sand trap for  $\pm$  1-2 days. Generally, the flushing was done mechanically and human power needed. Flushing can also be done by hydraulic (flushing with water), but it takes more than three days. In this building the sluice gate and the hallway sluice is not a straight line with the axis of sand trap because of the limited space availability. Although not a line the arch is large enough so the concentrated flow not occur.

In this building there are four hallways sluice, aimed to make deposits of sediment flushing operation can be performed alternately for each compartment. In this way the water supply to the irrigation network is undisturbed. Flushing in the sand trap visually is less effective because hydraulic flushing cannot be done in accordance with operating instructions.

##### b. Serayu Barrage Weir

Flushing conducted with seven daily periods alternately between one and another compartment. Operation of the doors can be made electrically. Discharge flushing is required in 24 m<sup>3</sup>/s. Flushing be done within one hour without the aid of human power.

##### c. Sokawati Weir

Sand trap flushing used to be done by weir operators with uncertain period. Flushing done is based on their visual observations. In the rainy season if it looks a lot of sediment, then the flushing could be done more often than the dry season. In the rainy season it is usually conducted once a month. Flushing sand traps is rarely done because the condition of the building with only one compartment. If carried out it would disrupt the flushing of irrigation water delivery at the end of system. In addition, the flush gate is operated manually and two of the four fruit door cannot be operated because the damage occurred on the trunk door lifter. The time used to carry out the flushing process is about 4 hours, but the results of flushing are not effective. There is still a lot of sediment that settles on the sand trap canal. The quantity of sediment thickness on the sand trap of Sokawati Weir before and after flushing based on the field measurement is presented in Table 3.

**Table 3** The thickness of sediment in the Sand Trap of Sokawati Weir Before and After Flushing

Segmen		A		B		C		D		E		F		G		H		I	
		t	t'	t	t'	t	t'	t	t'	t	t'	t	t'	t	t'	t	t'	t	t'
Thickness of sediment (cm)	Vert. 1	22	11	12	35	38	37	25	45	54	26	60	21	60	27	58	20	72	30
	Vert. 2	22	10	20	28	20	30	25	37	42	32	27	30	48	17	58	13	88	20
	Vert. 3	18	5	8	13	10	22	20	25	8	13	12	15	44	6	53	32	60	25

where t = before flushing, t' = after flushing

## V DISCUSSION

### 5.1 Influence of Sand Trap Profiles and Flow Velocity on Sediment Trapping Performance

Profiles of the three study sites of sand traps are very different, especially on the number of compartment that affect the trapping. Flow velocity should be low enough so that grain of sand on the surface flow can deposited. It can be obtained by comparing the length and width of the arrest  $\frac{L}{B} \geq 8$ . Comparisons can be seen in Table 4.

**Table 4** Comparison of Dimensions, number of compartment, flow velocity and trapping effectiveness

Weir	Comparison of Length and Width (L/B)	Number of Compartment	Flow Velocity (m/dtk)	Trapping Effectiveness (%)
Pamarayan	9	4	0.06 – 0.44	87,19
Serayu Barrage	11,58	2	0.08 – 0.28	95
Sokawati	26	1	0.27 - 0.64	40

Data from Figure 4, 5 and 6, and Table 4 described the relationship between length and width ratio of the sand trap with the thickness addition of the sediment load along the sand trap. Pamarayan Weir has the smallest value compared with a high effectiveness of trapping. Its effectiveness, however, is lower than that of Serayu which has a value of L / B 11:58. Sokawati with L / B of 26 has the lowest value of effectiveness.

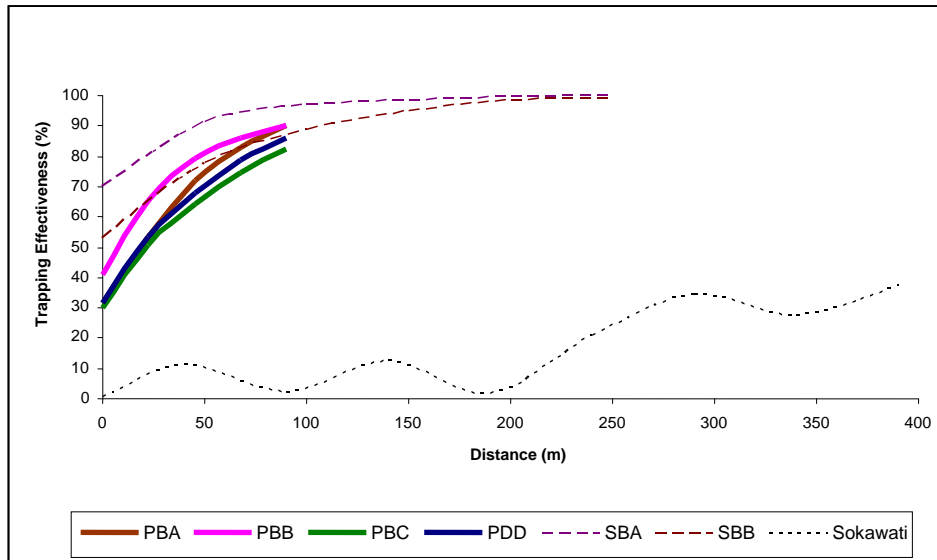
The highest average flow rate is in the Sokawati Weir sand trap, i.e. 0.27 - 0.64 m/s. With existing hydraulic design Sokawati has the lowest trapping effectiveness as it is compared with two other weirs. Its flow velocity is not suitable to precipitate the target grain. Meanwhile, two other weirs are Pamarayan and Serayu with respective flow velocity range between 0.06 to 0.44 m/s and 0.08 to 0.28 m/s, has a high trapping effectiveness value of each above 85% and 95%.

### 5.2 Trapping Effectiveness

The review in three sites indicates that the sand trap of Serayu Barrage Weir which has two chambers showed the most high trapping effectiveness. This can be seen from Figure 13, where the PBA ( Pamarayan A compartment) PBB ( Pamarayan B compartment) PBC( Pamarayan C compartment) PDD (Pamarayan D compartment) SBA ( Serayu A compartment) SBB ( Serayu B compartmen, and Sokawati with only one compartment.

SBA and SBB showed higher effectiveness than the PBA, PBB, PBC and PDD. At the SBA and SBB sampling conducted on H8 while at PBA and others it was done on H60. H60 at sampling is of course a thickness of sediment is already quite high. In conditions of compartment that has a high deposition it has fewer sediment, Serayu which is only designed with two compartments has a better performance than Pamarayan which is designed with four compartments. It can be concluded that the trapping effectiveness is more influenced by the volume of sediment that has settled on sand trap.

Sokawati has the lowest performance of the three sand traps . Although it is designed with the longer dimensions, it's trapping effectiveness is lower than short ones, even the trapping effectiveness is very poor. This is due to the configuration of building a sand catcher long enough without a booth or building equipped with the steering flow.



**Figure 13** Trapping Effectiveness of the Sand Trap Combined between Pamarayan Weir, Serayu Barrage Weir and Sokawati Weir

### 5.3 Flushing Effectiveness and Irrigation Services

With the design of sand trap consists of four compartments and is equipped with four hallway sluices, should be the flush operating of the sediment deposits of Pamarayan sand trap can be done effectively. At the time of flushing did not disrupt the water supply to the irrigation network because flushing can be done alternately for each compartment. Because of the tools damage, supporting means flushing in the sand trap is less effective. Hydraulic flushing cannot be done in accordance with operating instructions.

While in Serayu, flushing can be done effectively. Flushing conducted alternately between the chambers to each other in a hydraulic compartment. Time required for purging is also not more than two hours. Irrigation service also does not interfere with the operation pattern.

Flushing of the sand trap in Sokawati Weir is carried out with an uncertain period. Flushing of sand trap building is rarely done because the condition of the building with only one compartment. So when flushing is carried out, the irrigation system will disrupt underneath. Despite the flushing time of more than four hours, is still ineffective, a lot of sediment is still found. Results of analysis of the effectiveness of flushing in three study cases can be seen in Table 5.

**Table 5** The number of chambers, period of flushing, flushing effectiveness and irrigation service

Site	Number of Compartment	Flushing Period (day)	Flushing Effectiveness	Irrigation Services
Pamarayan Weir	4	90	Less good	Undisturb
Serayu Barrage Weir	2	7	Good	Undisturb
Sokawati Weir	1	Depending on the situation	Less good	Disturb

## VI CONCLUSION AND SUGGESTION

### 6.1 Conclusion

- Comparative value of  $L / B > 8$  on sand trap of Pamarayan Weir is the smallest as it is compared with the others ( $L / B = 9$ ). While Serayu Weir  $L / B = 11.58$  and Sokawati Weir  $L / B = 26$ .
- The average flow velocity is the highest at the weir of Sokawat namely 0.27 to 0.64 m/s, Serayu Weir from 0.08 to 0.28 m/s, and Pamarayan Weir 0,06 - 0 , 44 m / s. From these results and the L/B comparative value at point a, it can be said that smaller the ratio  $L / B$ , the smaller the settling velocity.
- Sand trap in Serayu Weir (> 95%) with two compartments showed the trapping effectiveness of the highest than that Pamarayan Weir (87.19%) and Sokawati (<40%).

- d. Flushing of sand at sand trap can be done routinely when a building has more than one booth, so it will not interfere with the irrigation system. Serayu Weir has two compartments of the arrest so that flushing can be done routinely with less than 2 hours.
- e. Trapping effectiveness necessary to arrest high sediment which entering into irrigation system is needed for effective flushing of sediment in sand trap, and it also needs an appropriate pattern of flushing operation so as not to interfere with service to the irrigation system.
- f. Comparative dimensions of the building catcher (Length/Width), flow velocity, the number of compartments and conditions of storage in sand trap (full/no) are the factors influence the trapping effectiveness of sand trap.

## 6.2 Suggestion

From the analysis and discussion, this research can be developed by reviewing the analysis that has not been done, i.e.:

- a. Performance of sand trap may be retained if the operation and maintenance conducted in accordance with the guidelines of operation and management.
- b. Flushing period building at the sand trap of Pamarayan Weir, Ciujung River, Banten should be less than one month, because it would lead to deposition of thick sediment and ineffective flushing.
- c. Sand trap in Sokawati should be redesign in terms of dimensions and the number of compartment. At least it should has two compartments so that the flushing will not interrupt the flow of irrigation water.

## VII REFERENCES

- Bambang Agus Kironoto. 2007. Kajian Lokasi Pengambilan Sampel Sedimen Suspensi Arah Transversal Terhadap Nilai Konsentrasi Sedimen Suspensi Rata-rata Tampang. *Dinamika Teknik Sipil*, Volume 7, Nomor 2.
- Departemen Permukiman dan Prasarana Wilayah, 2003. Percobaan Pengendalian Sedimen di Saluran Irigasi melalui Pengaturan Pola Operasi Jaringan Irigasi. Departemen Permukiman dan Prasarana Wilayah, Jakarta.
- Departemen Permukiman dan Prasarana Wilayah, 2004. Pedoman Perencanaan Hidraulik, Operasi dan Pemeliharaan Bangunan Penangkap Pasir tipe PUSAIR. Departemen Permukiman dan Prasarana Wilayah, Jakarta.
- Dewan Standarisasi Nasional. 1996. Metode Pengambilan Contoh Muatan Sedimen Melayang di Sungai dengan Cara Integrasi Kedalaman Berdasarkan Pembagian Debit. SNI 03-3414-1994. Yayasan Badan Penerbit Pekerjaan Umum, Jakarta.
- Dewan Standarisasi Nasional. 1996. Metode Pengukuran Debit Sungai dan Saluran Terbuka dengan Alat Ukur Arus Tipe Baling-baling. SNI 03-2819-1992. Yayasan Badan Penerbit Pekerjaan Umum, Jakarta.
- Direktorat Irigasi. 2009. Kriteria Perencanaan KP-01 tentang Bangunan Utama. Direktorat Irigasi, Departemen Umum, Jakarta.
- Hossain Monowar, M. and Lutfur Rahman, M. 1998. Sediment Transport Function and their Evaluation using Data from Large Alluvial Rivers of Bangladesh.
- Van Rijn, L.C. 1985. Sediment Transport Part I. Delf Hydraulics Laboratory.
- Van Rijn, L.C. 1985. Sediment Transport Part II. Delf Hydraulics Laboratory.
- Whipple, K. 2004. Surface Processes and Landscape Evolution.
- Engelund, F. And Hansen, E., (1967). *A Monograph on Sediment Transport in Alluvial Streams*. Teknisk Forlag, Copenhagen, Denmark.
- Meyer-Peter, E. And Mueller, R., (1948). *Formulas for Bed-Load Transport*. Sec. Int. Symp. IAHR Congress, Stockholm, Sweden.
- Van Rijn, L.C., (1984)a. *Sediment Transport, Part I : Bed Load Transport*. *Journal of Hydraulic Engineering*, ASCE, Vol. 110, No.10.
- Van Rijn, L.C., (1984)b. *Sediment Transport, Part II : Suspended Load Transport*. *Journal of Hydraulic Engineering*, ASCE, Vol. 110, No. 12.
- Moerwanto, A.S., 1990, *On Optimisation of Sediment Exclusion Measures at Intakes*.
- Pusat Litbang Sumber Daya Air, (1990). *Laporan Uji Model Hidraulik Bendung Serayu*, Jawa Tengah, No. P.1496.
- Susi Hidayah, Indri S. Setianingwulan, Slamet Lestari

- Pusat Litbang Sumber Daya Air, (1991). *Laporan Uji Model Hidraulik Sedimen Trap Bendung Tami*, Irian Jaya, No. P.1561.
- Pusat Litbang Sumber Daya Air, (1985). *Laporan Penyelidikan Hidrolis dengan Model Operasi / Pengaturan Pintu-Pintu Bendung dan Sedimen Trap Bendung Aji Baru*, Lampung, No. P.1228.
- Pusat Litbang Sumber Daya Air, (1986). *Laporan Hasil Penyelidikan Hidrolis dengan Model Rencana Kantong Penangkap Pasir (Sedimen Trap) Bendung Krueng Tiro*, Daerah Istimewa Aceh, No. P.1150.
- Pusat Litbang Sumber Daya Air, (1971). *Perhitungan Hidrolis Kantong Lumpur / Pasir Saluran Induk Sindopradja Rentang*, Jawa Barat, No. P.221.
- Standar Perencanaan Irigasi Kriteria Perencanaan Bagian Bangunan Utama KP-02*, 1986, Departemen Pekerjaan Umum Direktorat Jenderal Pengairan.