THE EFFECTIVENESS OF RIVER MORPHOLOGYCAL MODIFICATION TO SOLVE SEDIMENTATION PROBLEM AT SAMPORA WATER TREATMENT PLANT FREE INTAKE

EFEKTIFITAS MODIFIKASI MORFOLOGI SUNGAI UNTUK MEMECAHKAN PERMASALAHAN SEDIMENTASI DI INTAKE BEBAS WTP SAMPORA

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ABSTRACT

Sampora Water Treatment Plant (WTP) free intake has been suffering from problems due to sediment and trash deposition at the intake pond that disrupt the water collection process through the intake pump. In this study, several technical approaches were carried out to overcome the related problems such as riverbank cutting, intake length addition, and combination of both approaches. A Physical Hydraulic Model Tests was conducted in order to assess the effectiveness of each approach before it is applied in the field. The Physical Hydraulic Model Tests was performed into four series examinations, there is the existing condition, riverbank cutting at the upstream and downstream of intake, intake length addition, and combination between riverbank cutting and intake length addition. The results showed that riverbank cutting has been directing the river main flow from right to the left side of river with an average flow velocity at in front of intake above 0.70 m/s. The main flow shifting causes the suspended load sediment deposition in front of intake reduced significantly. This condition also causes bed load sediments in front of intake area almost completely scoured. Riverbank cutting chosen as the best approach because the flow pattern is smoother and more streamlines than the other series.

Key words: *Sedimentation, river morphology, Sampora WTP free intake, physical hydraulic model test, flow velocity distribution.*

ABSTRAK

Intake WTP Sampora saat ini mengalami permasalahan sedimentasi dan masuknya sampah ke dalam kolam intake yang mengganggu proses pengambilan air melalui pompa pengambilan. Dalam penelitian ini, beberapa pendekatan teknis dilakukan untuk mengatasi permasalahan tersebut, antara lain: pemotongan tebing sungai, penambahan panjang mulut intake, serta kombinasi kedua pendekatan tersebut. Uji Model Hidraulik (UMH) Fisik dilakukan untuk menilai efektivitas setiap pendekatan tersebut sebelum diterapkan di lapangan. UMH Fisik dalam penelitian ini dilakukan dalam empat seri yang meliputi model sesuai kondisi eksisting, pemotongan tebing sungai di hulu dan hilir intake, penambahan panjang mulut intake, dan kombinasi antara pemotongan tebing sungai dan pendekatan penambahan panjang mulut intake. Hasil penelitian menunjukkan bahwa pemotongan tebing sungai telah mengarahkan aliran utama sungai dari sisi kanan ke sisi kiri sungai dengan kecepatan aliran rata-rata di depan intake lebih dari 0.70 m/s. Bergesernya aliran utama menyebabkan endapan sedimen tersuspensi di depan intake berkurang secara signifikan. Kondisi ini juga menyebabkan sedimen dasar di depan area intake hampir sepenuhnya tergerus. Pemotongan tebing sungai terpilih sebagai pendekatan terbaik karena pola alirannya lebih halus dan lebih steramline dibandingkan dengan seri lainnya.

Kata Kunci: *Sedimentasi, perubahan morfologi, Intake WTP Sampora, uji model hidraulik fisik, distribusi kecepatan aliran*

INTRODUCTION

Sampora WTP was built to provide clean water, especially for residents at Bumi Serpong Damai (BSD), Tangerang, Banten which inhabited by around 20.525 households, or about 100,000 people. Sampora WTP service area is quite extensive covering approximately 6.200 hectares which consists of residential, commercial, educational, and business areas.

Raw water source for Sampora WTP is taken from Cisadane River by free intake which is located in Sampora Village. Sampora WTP Free Intake suffered problems due to sediment and trash deposition in intake pond. Sedimentation around the intake culvert caused flow disruption into intake pond, and even can made culvert closedd. Due to this reason, it is important to restore Sampora WTP Intake function as optimum as the original design.

The objective of this study is to determine the effectiveness of river morphologycal modification to solve sedimentation problem at *S*ampora WTP free intake. The study location area of this research is located at *S*ampora WTP free intake, Sampora Village, Bumi Serpong Damai. The physical hydraulic model test was performed at the Experimental Station of River Laboratory in the Research Center for Water Resources Development in Surakarta.

LITERATURE REVIEW

A physical hydraulic model represents a real-world prototype and is used as a tool for finding technically and economically optimal solution of hydraulic problems (Novak, 1984 in Heller, 2011). Hydraulic physical model is a model reproduces dominant hydraulic forces in correct proportion to the real world. Modeling goal is to reproduce the real world in the model without losing something important. Its useful to seek qualitative insight about a physical process, obtain measurements to verify or disprove a theoretical result, and obtain measurements of phenomena that are beyond theoretical approach. Model has many advantages, such as: no simplifying of governing equations, allows complex boundary conditions, easy data collection compared to field work, control of forcing conditions, reproduces phenomena that cannot be mathematically described, and visual feedback contributes to physical insight. (Thornton, 2013)

One of the most important factor in conducting of physical hydraulic model is scaling factor. Considerable difference between models and prototypes scale parameter may occur because of the scale and/ or the effects of measurement (Heller, 2011).

To obtain accurate simulation results on a physical hydraulic model required certain dimensionless parameters that describe the properties of geometric and dynamic flow. This requirement usually is not fully achieved, because of natural limitations in fluid properties and the lower size of cohesionless sediment. Consequently, judicious compromises need to be made in order that the dominant processes are replicated in the model. (Muste & Ettema, 2000)

In determining the scale of the model, some basic similitude requirements for modeling free-surface flow references are used as follows:

1 Geometric Similitude

The model should be geometrically similar to the full-scale flow. If L represents some characteristic length, then

$$n_L = L_p/L_m \quad \text{1)}$$

in which n is the scaling factor for the quantity symbolized by its suffix; subscripts m and p refer to model and prototype (full scale) values, respectively

2 Dynamic Similitude

The basic requirement for dynamic similarity of fully turbulent, free-surface flow is satisfied if the model and full-scale flows have the same Froude number, Fr.

$$Fr_m = Fr_p \quad \text{2)}$$

The criterion $Fr_m = Fr_p$ is applied in open-channel hydraulics. Froude similarity is especially suited for models where friction effects are negligible (e.g. deep-water wave propagation) or for short, highly turbulent phenomena (e.g. hydraulic jump) since the energy dissipation of the latter depends mainly on the turbulent shear stress terms. These are statistically correctly scaled in a Froude model even though the turbulent fine structures and the average velocity distribution differ between the model and prototype flows (Le Me´haute´ 1976, Hughes 1993).

A moveable bed model is one which models loose boundary flow. Its have been used to model rivers, streams, coastal zones and estuaries (Ettema et al., 2000). The sediment material is scaled such that the material will move in the same manner for both the prototype and the model.

Three techniques are often used in modeling sediment to obtain model Shield parameters that equal or greater (which defines the sediments transport) is: use a lightweight sediment, vertical scale distortion, and increased model slope (Waldron, 2008).

Selander (2102) mentioned that the amount and size of sediment that a river can carry are determined by discharge and channel slope through the relationship:

$\tau_b = \rho_w gH*\sin(\alpha)$ …………………………………………… 3)

τ_b is the shear stress on the bed of the channel required for sediment motion (N/m^2), ρ_w is the density of water (kg/m^2), H is the height of the water column (m) (used as a proxy for discharge, an increase in discharge directly relates to an increase in H), and sin(α) is the local channel slope. In a broad sense, increasing discharge and flow velocity increase the amount of shear stress imposed on the channel bed and the amount of sediment that is transported via bed load or entrained.

Water discharge is the most important element of sediment transport process. Water discharge is responsible for picking up, moving and sediment deposition in waterways. Without flow, sediment might remain as suspended or settle out – but it will not move downstream. Flow is required to initiate the transport (Kemker, 2014). Relationship between velocity and grain size that influence on sediment transport phenomena can be seen in Sunborg graph or Figure 1.

METHODOLOGY

Three dimensional physical hydraulic model test was applied in order to analyze the sediment deposition at Sampora WTP Intake. The first step that must be done to make the model is to determine the model scale. Model scale is a comparison between prototype with the model parameter dimensions. Model scale is determined based several factors such as: objective of hydraulic model test; prototype size (width, depth, length); availability of laboratory field area; and water supply capacity.

Hydraulic physical model test of WTP Sampora Intake is made of approximately 500 m to upstream from intake, and approximately 200 m to downstream direction from intake. River model for hydraulic model test around intake is made of movable bed, and for other river model area made fix bed material. The Hydraulic physical model is created with three-dimensional models without distortion (undistorted model) using Eq. (3), with same vertical and horizontal scale, at 1: 25 (1 meter in prototype equal to 4 cm in model).

Distortion Number $= \frac{n_l}{n_h} = \frac{(1/25)}{(1/25)} = 1$ …………… 4)

Where: vertical scale (n_l) = 1 : 25
horizontal scale (n_h) = 1 : 25

Consider that the model to be created is an open channel model, where the inertial forces that affect the water movement is dominated by the earth's gravity acceleration, so conversion of the prototype scale into a model scale was conducted using Froude equation (5a) (5b) (5c).

Froud Number (Fr) = $\frac{v}{\sqrt{gh}}$ ……………………………. 5a)

$\frac{v}{\sqrt{gh}}$ model = $\frac{v}{\sqrt{gh}}$ prototype …………………… 5b)

$\frac{V_p}{V_m} = \frac{(\sqrt{gh})_p}{(\sqrt{gh})_m}$ or $n_v = n_g{}^{½} . n_h{}^{½}$ ………… 5c)

Gravity acceleration at prototype and at model are same, then ng = 1, so the velocity scale (nv) =nh^{½}. where v = flow velocity (m/s) h = depth of flow (m); g = gravity acceleration (m/s^2). Parameter model scale showed in Table 1:

Table 1 Scale Physical Hydraulic Model Test Parameters

Hydraulic parameter	Model		
	Notation	Pattern	Scale
Length, L	n_L	n_L	25
height, h	n_h	$n_h = n_L$	25
Area, A	n_A	$n_A = n_L^2$	625
Volume, V	n_V	$n_V = n_L^3$	15625
time,t	n_t	$n_t = n_L^{1/2}$	5
velocity, v	n_v	$n_v = n_L^{1/2}$	5
discharge, Q	n_Q	$n_Q = n_L^{5/2}$	3125
Manning coefficient, n	n_n	$n_n = n_L^{1/6}$	1,709976

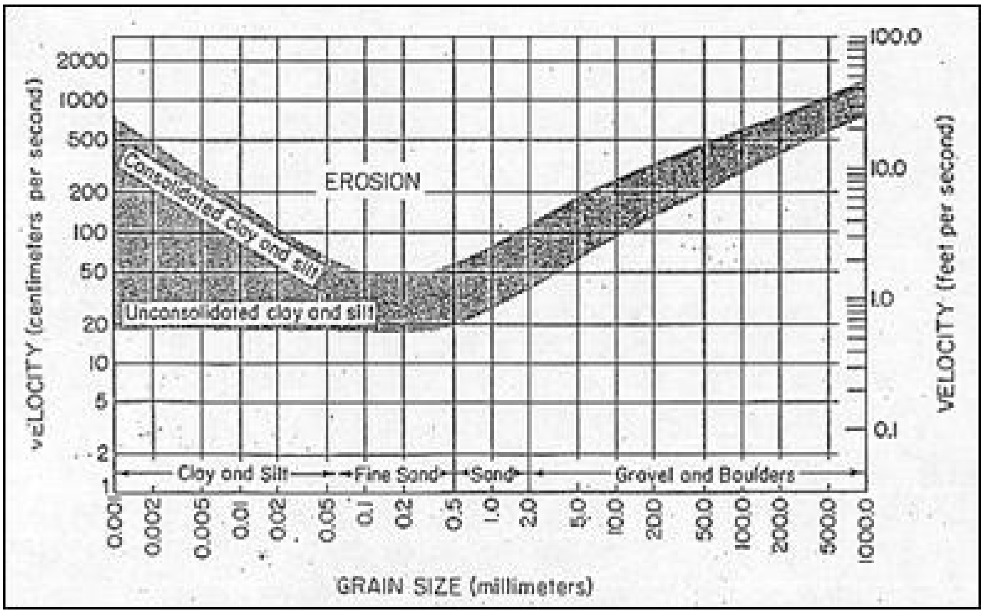


Figure 1 Relationship between velocity and grain size material (Sunborg Graph).

Sediment materials are difficult to scale. If the sand is made with the same ingredients in prototypes (weight of the same type), the model will consist of sediment grains are very fine. To fit this constraint, model sediment is made of coal powder material with specific gravity of 1.56 to obtain a sediment grain size model larger.

Due to the difficulty in modeling sediment that similar to the prototype condition, so the sediment material in model is made with lightweight aggregates from flyash with very fine diameter that produced by stone crusher.

Sampora WTP Intake culvert model shape and dimension are made based on exsiting condition. There are 5 culverts in which dimension of each culvert is 1.25 m x 2.00 m with bed elevation at + 10.00 m. Geometry and hydraulic data are obtained from PT Indokoei International.

The discharge and water level data was used to make rating curve as the basis for model calibration. Rating curve data of cisadane river is shown at Figure 2. For the simulation series, discharges that applied in the model based on bankfull discharge as highest value. Then model simulation were used low flow, moderate flow and bankfull flow discharges as follows: 87 m^3/s, 150 m^3/s, 220 m^3/s, 300 m^3/s, 375 m^3/s. Several parameters were observed in order to get sedimentation characteristics, among others: longitudinal profile of water level, flow pattern, flow velocity, and sediment pattern. Situation of prototype that was modeled showed in Figure 3.

The measurement method used the reference as follows:

1 SNI 3411: 2008: procedure for water level measurement in the physical model
2 SNI 03-3408-1994: flow velocity measurement method on a physical model with flow measuring devices proppeler type
3 SNI 3410:2008: procedure for flow patterns measurement in the physical model
4 Work Instruction of Research Centre for River (IK-MU-07) and Research Centre for River Laboratory Report of Validation Method of Sedimentation Pattern Observation: sedimentation patterns observation

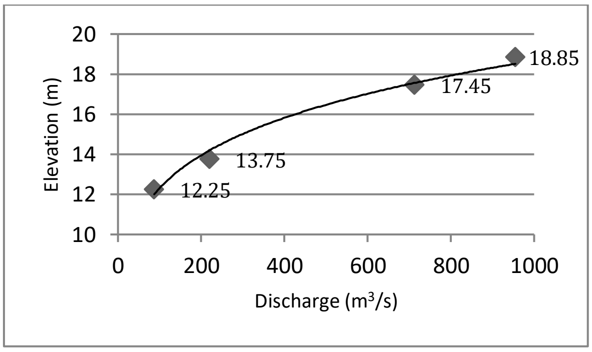


Figure 2 Rating curve of Cisadane River

1 Model calibration

In practice, the physical model difficult to fit between roughness at model with roughness at prototype (Webber, 1971). The roughness coefficients and water depth are generally over-predicted by the new dynamic roughness model, compared to the calibrated model, especially for low discharge (Paalberg et.al.).

Therefore, a physical hydraulic model must be calibrated to ensure the relationship between flow conditions and water level accordingly. In this way the satisfactory performance of model is verified (Webber, 1971).

Calibration is done by comparing the water level – discharge relation in the model with the observed data. To obtain similar value with the observed data, the channel bank roughness was adjusted by trial and error until the water level in model simulation similar to the observations water level on certain discharge.

2 Model test scenario

Hydraulic physical model test of Sampora WTP Intake was done with the following series: Series-0, in the form of existing conditions; Series-1 a test of existing conditions with cutting riverbank at upstream and downstream intake from +9.50 to +12.5 contour lines; Series-2, a test of existing conditions with the addition of 2.5 m length of the intake; Series-3, a modification of combined cutting riverbank at upstream and downstream intake at +9.50 to +12.5 contour lines addition of 2.5 m length of the intake (a combination of series-1 and series-2).

RESULTS AND DISCUSSION

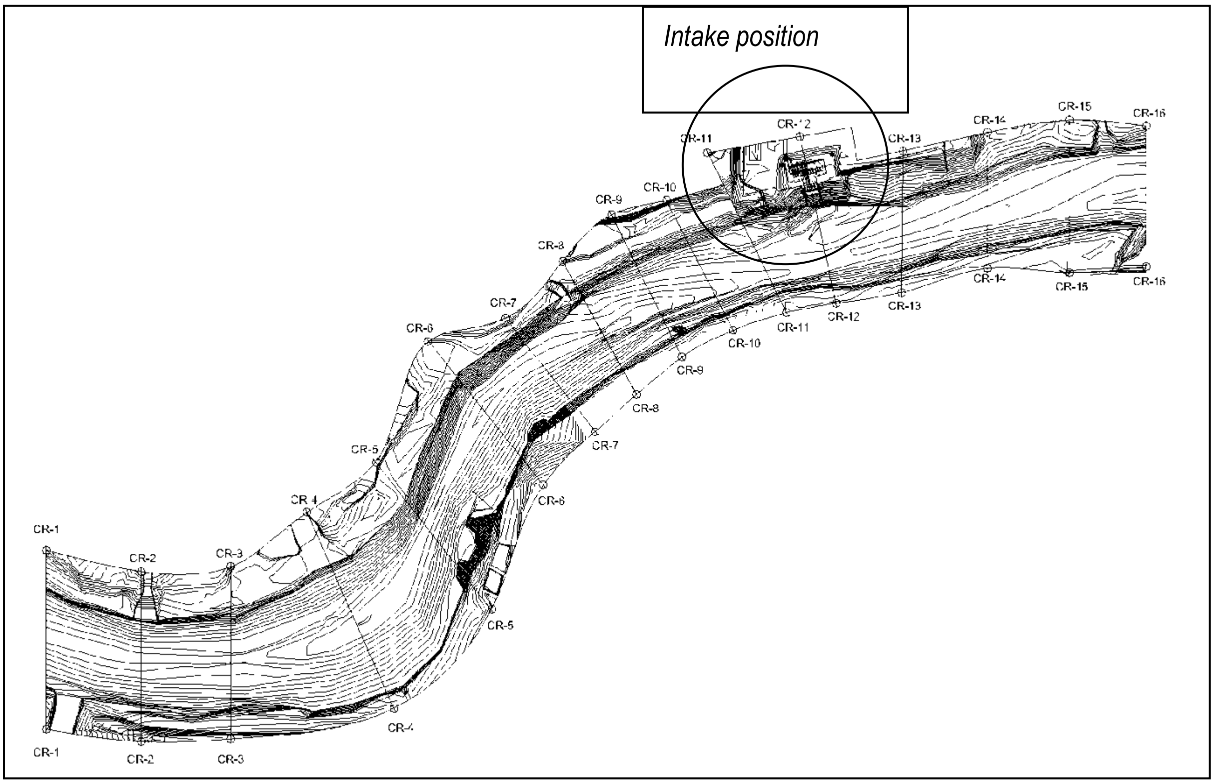
1 Results

a. Similarity Model Test

Similarity model test is shown in Table 2. It can be seen that in the first observation, the water level in the STA 2 to STA 12 have a water level difference to the observed data of more than -0.05 m, so it is necessary to increase roughness of model. From the second observation, the value of having different water level approximately ± 0,05 m, the physical model data can be considered similar to conditions on the field.

b. Series-0: Existing Condition

Conditions of physical models used for Series-0 is the existing condition in the field with the base line with the basic model fixed (fixed bed). Types of observations made are observation of water surface elevations, flow velocities, flow patterns and sediment movements at discharges of 87 m^3/s, 150 m^3/s, 220 m^3/s, 300 m^3/s, and 375 m^3/s. Water level is observed in the longitudinal direction of the river ranging from STA 2 to 15, at discharges of 87 m^3/s, 150 m^3/s, 220 m^3/s, 300 m^3/s, and 375 m^3/s. The observation of water levels series-0 can be seen in Table 3.



Source: Experimental station for river laboratory 2013

Figure 3 *Intake* WTP Sampora situation

Table 2 Water Level observation on Similaritas Test

STA	Water Level (Numerical Model)	Test 1 (physical model)		Test 2 (Physical Model)	
		Water level (m)	Height difference	Water level (m)	Height difference
	(Q = 375 m^3/s)		(m)		(m)
1	....	....	....	....	....
2	15.25	15.10	-0.15	15.22	-0.03
3	15.23	15.08	-0.15	15.2	-0.03
4	15.26	15.05	-0.21	15.23	-0.03
5	15.20	15.03	-0.17	15.17	-0.03
6	15.21	15.00	-0.21	15.18	-0.03
7	15.18	14.99	-0.19	15.15	-0.03
8	15.17	14.98	-0.19	15.14	-0.03
9	15.14	14.97	-0.17	15.11	-0.03
10	15.09	14.93	-0.16	15.06	-0.03
11	15.00	14.93	-0.07	15.05	0.05
12	15.04	14.92	-0.12	15.08	0.04
13	14.94	14.95	0.01	14.99	0.05
14	14.93	14.94	0.01	14.97	0.04
15	14.95	14.94	-0.01	14.95	0.00

Source: Experimental station for river laboratory 2013

Table 3 Water level observation on Series-0

Sta	Water Level Elevation				
	375 m^3/s	300 m^3/s	220 m^3/s	150 m^3/s	87 m^3/s
1	....	....	....	....	....
2	15.22	14.58	13.95	13.17	12.43
3	15.20	14.55	13.95	13.16	12.42
4	15.23	14.54	13.94	13.15	12.38
5	15.17	14.53	13.93	13.13	12.36
6	15.18	14.53	13.92	13.10	12.32
7	15.15	14.52	13.89	13.08	12.30
8	15.14	14.51	13.85	13.06	12.29
9	15.11	14.51	13.83	13.04	12.28
10	15.06	14.52	13.80	13.02	12.27
11	15.07	14.49	13.78	12.99	12.26
12	15.08	14.48	13.75	12.96	12.25
13	14.99	14.48	13.74	12.95	12.24
14	14.97	14.45	13.71	12.93	12.23
15	14.95	14.41	13.69	12.92	12.20

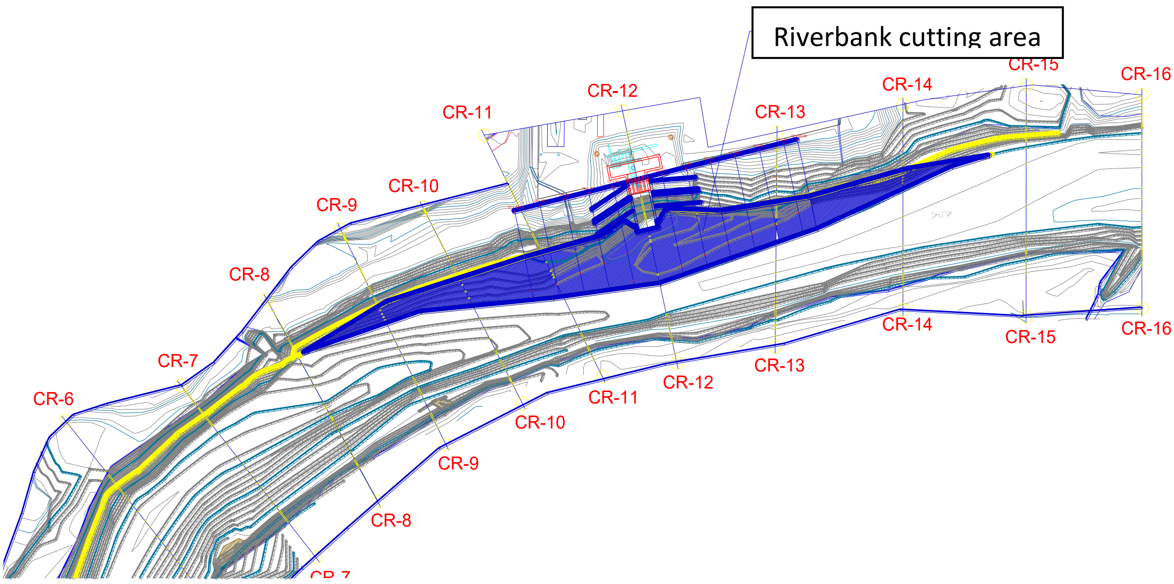
Source: Experimental station for river laboratory 2013

Model Series-0 simulation results indicates that the water surface slope in the discharge of 375 m3/s is equal to 0.00037. The average flow velocity around intake is greater than the average velocity in upstream intake. As can be seen in Table 4, the flow velocity at STA A (around intake) was 1.13 m/s, while the flow velocity at STA 4 and 7 that located in the upper intake are 0.62 m/s and 0.67 m/s. Flow velocity in the downstream intake is almost equal to the flow velocity around intake. Flow pattern observations results shows that in generally the main flow occurs in the middle of the river, but in front of intake area the main flow shifted toward the right side of the river (move away from intake). The main flow shifts are starting from STA 10 to 13. Sediment transport simulation result indicates that sedimentation occurred in front of intake (left side of river), while on the right side of river occurred scour. Sedimentation in front of intake occurs because the flow velocity in the left side are lower than the flow velocity in the right side of the river.

Table 4 Average flow velocity on series-0

STA	Flow Velocity (m/s)				
	375 m^3/s	300 m^3/s	220 m^3/s	150 m^3/s	87 m^3/s
4	0.62	0.47	0.40	0.33	0.26
7	0.67	0.64	0.58	0.47	0.43
11	1.07	0.90	0.98	0.85	0.77
A	1.13	0.86	0.84	0.74	0.62
12	0.91	0.85	0.73	0.61	0.55
B	0.87	0.85	0.82	0.58	0.53
14	0.95	1.02	0.82	0.70	0.54

Source: Experimental station for river laboratory 2013



Source: Experimental station for river laboratory 2013

Figure 4 Riverbank cutting situation

c. Series-1

Physical hydraulic model tests series-1 was performed by cutting riverbank elevation at +12.5 m to +9.50 m on the upstream and downstream intake (see Fig.4). Model series-1 result show that main flow pattern occurred in middle of river with uniform flow distribution from left side to right side. Velocity distribution occurs evenly in front of intake (STA12) with velocities range from 0.4 m/s to 0.9 m/s (see Table 5).

Suspended sediment didn't settle in front of the intake, and the river bed around intake was scoured. This conditions can be seen from bed level observation which show that the river bed elevation lower than initial elevation.

d. Series-2

Hydraulic physical model test series-2 was performed by addition of 2.5 m length of culvert box towards the middle of the river. Addition of long box culvert can be seen in Figure 5. The observations carried in this series are water level, flow velocity, flow patterns and sediment movement observation in the discharge of 87 m^3/s, 150 m^3/s, 220 m^3/s, 300 m^3/s, and 375 m^3/s.

Table 5 Average flow velocity on series-1

STA	Flow Velocity (m/s)				
	375 m^3/s	300 m^3/s	220 m^3/s	150 m^3/s	87 m^3/s
11	0.80	0.71	0.64	0.57	0.41
A	0.76	0.75	0.63	0.53	0.42
12	0.73	0.72	0.67	0.53	0.42
B	0.76	0.71	0.63	0.49	0.41

Source: Experimental station for river laboratory 2013

Series-2 simulation results indicate that the main flow occurs in the middle of river at both low, medium, or high discharge conditions. At locations around intake occurs eddys flow which result a flow velocity nearly equal to 0 m^3/s.

Source: Experimental station for river laboratory 2013

Figure 5 Additional *Box Culvert Length*

Flow velocity distribution accurs after the addition of the intake length 2.50 m, can be seen in Table 6. Flow velocity at intake mouth (STA 12) ranged from 0.8 m/s to 1.1 m/s and evenly distributed at discharge 375 m^3/s. Flow velocity at upstream intake (STA 11) ranged from 0.2 m/s to 1.0 m/s. At STA A, flow velocity ranged from 0.7 m/s to 0.9 m/s and evenly distributed. While at downstream intake (STA B) flow velocity distribution ranged from 0.3 m/s to 1.0 m/s. Sediment pattern observation resulted in Series-2 shows that the area around the intake mouth occurs a little sediment depositions. While the riverbed observations result in front of intake indicate the occurrence of scour.

Table 6 Average flow velocities on series-2

STA	Flow Velocity (m/s)			
	375 m^3/s	300 m^3/s	220 m^3/s	87 m^3/s
11	1.00	0.93	0.80	0.59
A	0.86	0.79	0.61	0.50
12	0.95	0.87	0.64	0.46
B	0.86	0.75	0.60	0.47

Source: Experimental station for river laboratory 2013

e. Series-3

Hydraulic physical model test series-3 is performed by combined cutting riverbank at upstream and downstream intake at +9.50 to +12.5 contour lines addition of 2.5 m length of the intake (Figure 6).

Source: Experimental station for river laboratory 2013

Figure 6 Combined cutting riverbank at upstream and downstream intake at +9.50 to +12.5 contour lines with addition of 2.5 m length of the intake situation

The Series-3 simulation results show that main flow occurs on the left side of river near the intake mouth both in low, medium, or high discharge. Eddy flow occurs around the intake structure at upstream, downstream and above the structure. The observation result of flow distribution showed that at discharge of 375 m^3/s the average flow velocity at the intake mouth is 0.75 m/s, at upstream intake (STA 11) is 0.86 m/s and and at downstream intake (STA B) is 0.74 m/s (see Table 7). The sedimentation pattern obtained in the series-3 simulation shows that a little amount of suspended load material was settled down at in front of intake mouth. While scouring occurred at around of the intake area.

Table 7 Average flow velocity on series-3

STA	Flow Velocity (m/s)				
	375 m^3/s	300 m^3/s	220 m^3/s	150 m^3/s	87 m^3/s
11	0.86	0.86	0.63	0.49	0.43
A	0.81	0.82	0.63	0.48	0.46
12	0.75	0.73	0.75	0.62	0.53
B	0.74	0.58	0.65	0.45	0.42

Source: Experimental station for river laboratory 2013

2 DISCUSSION

From the data that has been obtained from the test show changes characteristic of flow and sediment in each series. Comparison of characteristics can be seen as follows:

a. Average flow velocity in each series

The observation of flow velocity that occurs in the discharge of 375 m^3/s on each model series are shown in Table 8. The highest average flow velocity in front of intake (STA 12 left) occur in Series-3. From Table 8 it can also be seen that the average flow velocity in front of intake on Series 1 (0.72 m/s) is almost equal to the highest average flow velocity in front of intake on Series-3.

Table 8 Average Flow Velocity in Each Series

Series	STA	Position at cross section		
		Left	Middle	Right
0	A	0.35	0.96	1.01
	12	0.51	0.91	0.97
	B	0.48	0.98	0.93
1	A	0.54	0.90	0.80
	12	0.72	0.83	0.77
	B	0.75	0.92	0.85
2	A	0.35	0.94	0.90
	12	0.55	0.93	1.02
	B	0.35	0.88	0.98
3	A	0.65	0.87	0.96
	12	0.76	0.87	0.72
	B	0.65	0.82	0.80

Source: Experimental station for river laboratory 2013

b. Flow patterns in each series

Comparison of flow patterns is done by observing the beginning of flow. It was observed by measuring the current meter position since it starts to spin from the reference point on the left bank of the river. From Table 9, it can be seen that series-1 shows the current meter position began spinning closest to intake position. At series-1, the average flow velocity that occurred in front of intake mouth is 0.72 m/s which will prevent sedimentation in front of the intake mouth.

c. Sediment patterns in each series

Sediment patterns in Series-0 indicates that the sedimentation occurred in front of intake area. Sedimentation in front of intake occurred because of the flow velocity in the left side of river is slower than in the right side of the river. While on the right side of the river tends to occur riverbed scour. Sediment patterns in Series-1 shows that there wasn't suspended load deposition in front of intake. Suspended load was flushed away by the river flow due to riverbank cutting. Riverbank cutting caused main flow shifted to the left with velocity greater than 0.5 m/s. In Series-1, the riverbed scouring occurred in front of intake.

Sediment pattern in Series-2 show that a little suspended load settled at intake mouth and the riverbed scouring occurred in front of intake. While sediment pattern in Series-3 show that a little suspended load settled at intake mouth and the riverbed scouring occurred at area around intake.

Most of suspended load flow into pumps pond. Flow velocity at pumps pond. almost zero, so it will make suspended load materials become settle. In the long periods, the sedimentation will increase and interfere the pump performance. Therefore it's needs an effort to maintain pumps pond from sediment disturbance.

d. Best Series

Based on study results, it can be recommended that the Series-1 is the best series in terms of the average flow velocity in front of intake. Average flow velocity that occurred in front of intake mouth is 0.72 m/s which will prevent sedimentation in front of the intake mouth.

The riverbank cutting can shift the main flow to the left side closer to intake mouth compared to the existing condition. Moreover, flow patterns at Series-1 are more streamline than Series-2 and 3, where at Series-2 and 3 occurred Eddy flow. Eddy flow that occcurs can lower flow velocity in that area to almost zero, and potentially depositing the sediment material.

Sediment patterns in Seris-1 shows that suspended load deposition not occurs in front of intake. Suspended load flushed away by the river flow due to riverbank cutting that caused the main flow shifted to the left. In this series, the riverbed scouring occurs in front of intake.

Table 9 Distance of flow start to spin from reference point

SERIES	0		1		2		3	
No. Sta	Water's edge	Flow begin to spin	Water's edge	Flow begin to spin	Water's edge	Flow begin to spin	Water's edge	Flow begin to spin
	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
11	17.25	17.25	17.25	18.50	17.25	19.25	17.25	18.25
G	13.25	13.25	13.25	18.50	13.25	19.25	13.25	17.75
E	13.75	18.25	13.75	17.75	13.75	19.00	13.75	17.25
C	16.00	18.25	16.00	18.00	16.00	18.25	16.00	17.25
A	12.25	19.50	12.25	19.00	12.25	20.25	12.25	19.50
12	8.75	20.50	8.75	18.00	8.75	21.25	8.75	22.50
B	11.00	19.50	11.00	18.00	11.00	20.00	11.00	21.50
D	14.25	193.25	14.25	18.00	14.25	18.75	14.25	19.75

Source: Experimental station for river laboratory 2013

CONCLUSION

Riverbank cutting in the upstream and downstream of intake at elevation of +12.5 m to +9.5 m, causes main flow position shifted closer to intake mouth than the existing condition. This modification also increased flow velocity up to about 0.7 m/s and caused no suspended load deposition in front of intake. Riverbed scour still occures in front of intake. This modification needs to be done to shift main flow closer to intake mouth and increase flow velocity to avoid a greater sedimentation both suspended load also bed load depisition.

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