



Evaluation of the Settling Basin of Keumala Weir, Krueng Baro River, Aceh, Indonesia

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Abstract – Krueng Baro Irrigation network is a strategic technical irrigation area in Pidie, Aceh, Indonesia. The primary water source is the Krueng Baro River flow using the infrastructure of Keumala Weir in which sedimentation is currently a significant problem in its operations. To prevent the sediment from entering the irrigation channel is to settle it in the settling basin. However, the primary irrigation channel with the stone masonry walls kept experiencing high sedimentation. Therefore, this study aimed to evaluate the performance of the Keumala Weir settling basin including its capacity and efficiency. This study used a survey method for data collection and an evaluation method following the current guidelines for data analysis. The sediment sampling was conducted in the settling basin and the primary channel. The flushing was currently carried out for seven days. However, the settling basin capacity of 2,436.75 m³ did not meet the flushing requirements. Thus, the flushing should be performed daily for a volume of 1,859.43 m³ to fulfill the condition, so that the capacity of the settling basin was controlled. The efficiency of sediment settling was 75%, and the effect of water turbulence was in a safe condition, that the sediment settled in a settling basin would not be eroded when it is empty or full. For the flushing efficiency, the shear stress was 15,538 N/m² that can rinse less than 16 mm particles. Based on this evaluation, it can be concluded that the sediments in the primary channel were from the settling basin. It is suggested to limit the speed in the regulating building to approximately 1.5 m/s to reduce the sediments entering the primary channel. It also requires accuracy in the operation of the primary channel intake.

Keywords: Performance evaluation, efficiency, settling basin, sediment, Krueng Baro Watershed.

Introduction

Water engineering comprises the facilities to collect, divert, drain, store or dispose of water in a controlled manner. However, sediments can hinder the performance of water facilities management and even have detrimental effects on the downstream water body (Janssen, 2003). Sediments are the rock and mineral fragments experiencing a weathering process from the earth surface because of the rain, wind gusts and running water (Munyanzeza *et al.*, 2015; Kamarudin *et al.*, 2017). Sedimentation problems, especially in irrigation networks, can decrease the channel capacity, the bottom of erosion and the sidewalls; potentially grew weeds; and raise the maintenance costs (Boushehri *et al.*, 2010; Omran and Jaber, 2017). The management of sediment particles from the river water is a critical issue in water diversion (Chapokpour and Daneshfaraz, 2013). Sediment particles in the river water disrupt the operation of irrigation intakes. Therefore, resolving the sediment issues related to the intake system will highly benefit the irrigation networks (Wahab *et al.*, 2016; Toriman *et al.*, 2014).

The use of longitudinal settling basin, commonly referred to a settling basin, is one of the prominent curative methods of an irrigation system (Raudkivi, 1990; Liu *et al.*, 2010). The cross-section of the settling

basin is usually rectangular or sometimes trapezoidal (Mahtabi *et al.*, 2015). The type of settling basin is adjusted to the type and condition of the sediment at the study location.

A settling basin may consist of one or often more several chambers that are far wider than the channel and intake gate. The inlet and outlet openings of the chambers are equipped with gates. The gate is elevated above the bottom of the settling basin to create the space to store sediments. The flushing chambers are connected with a guide that flows into the riverbed. When the mixed water-sediment enters the settling basin, the water rapidly loses its velocity, and thus there is adequate time to settle the suspended particles; the basic sediments accumulated before the outlet threshold is flushed periodically. Thus, the outlet opening is closed, and the flushing gate in each room is opened alternately (Zaloğlu, 2013). The settling basin comprises a large section of a channel, built in the downstream of the intake gate, and it is designed based on the increase of the channel area to decrease the flow velocity adequately low to enable many suspended particles deposited (Boushehri *et al.*, 2010). Next, the sediments can be removed by the mechanical means or manual flushing.

Sediment particles will decrease the efficiency of the channel and other downstream facilities. So, the diameter of the eligible sediment particles entering the system must be established in designing the settling basin. In agricultural facilities, the approved sediment particle diameter should be less than or equal to 0.25 mm (Novak *et al.*, 1990). The settling basin operates to detach the sediments in the diverted water and plays a vital role in supplying water for the irrigation networks. The settling basin needs to be designed based on local circumstances (Mahtabi *et al.*, 2015). The initial phase of designing the hydraulic settling basin involves complete data collection concerning the characteristics and amount of sediments entering the system, the accumulation capacity of the settling basin and the percentage of sediment to be deposited (Ekama *et al.*, 1997).

The design and construction of the settling basin require an efficiency test (Bleything, 2012). Sediment samples, the upstream and downstream suspended sediments, are taken from the settling basin to examine the percentage of suspended sediments that can be flushed by the settling basin. Bleything (2012) argued that a settling basin could decrease the number of suspended sediments in the flow by 53%. Many other studies focus on the experimental and numerical studies to evaluate the performance and efficiency of settling basins. A series of laboratory experiments, field monitoring, and modeling studies can enhance the performance of the settling basin design (Swann, 2016).

Of the total area of Pidie Regency, 29,391 hectares are rice fields (BWSS-I, 2017) potential to be developed. The development effort of this area highly relies on local water resources. The water construction needs fixing and improving to realize the development effort. The regional government of Pidie seeks to prioritize the repair and improvement of the irrigation network systems to increase agriculture production. The irrigation network operates to stream water to all rice fields planned.

A surface irrigation is a widely used by agricultural system for crops production because it requires less skilled labor and less operational costs. This system accounts for around 90% of the world agricultural land irrigation that promotes furrow irrigation as the primary application method (Food and Agriculture Organization, 2013). However, poor design and management can result in inefficient irrigation (Damodhara, 2013).

The Krueng Baro irrigation scheme construction started to build in 1979 and completed in 1984. Serving for 34 years, the sediment deposition function of the irrigation system, that is the settling basin, may have declined. Concerns about the decrease of settling basin function were also caused by the land change in the upstream watershed. This condition can increase sedimentation. The Irrigation is currently experiencing sedimentation in the primary canal. Building a settling basin is one way to prevent sediments from entering the irrigation channel. The settling basin is a complementary building to settle the bed load and suspended load carried through the intake. It is usually placed right after the intake before the primary channel. Therefore, a study concerning the settling basin is necessary. This study was conducted on Keumala Weir, specifically in the settling basin of the Baro irrigation scheme. This study aimed to evaluate the settling basin of the Keumala Weir in the Pidie Regency. The scope of this study was analyzing the particle sizes, measuring the fall velocity of sediments, determining the settling basin capacity, and calculating the settling basin efficiency. This research provides information on the effectiveness of settling basin on the Keumala Weir which in turn is expected to increase the local agricultural production.

Materials and Methods

Study Area

The Baro Irrigation Area is a technical surface irrigation area located in Keumala district, Pidie Regency, Aceh. The irrigation services for rice field area of 11,950 hectares (Azmeri *et al.*, 2019). The primary water source originates from the Krueng Baro River flow through Keumala Weir at the coordinates of 5°13'10.2" S and 95° 51'38.8" E (Figure 1).

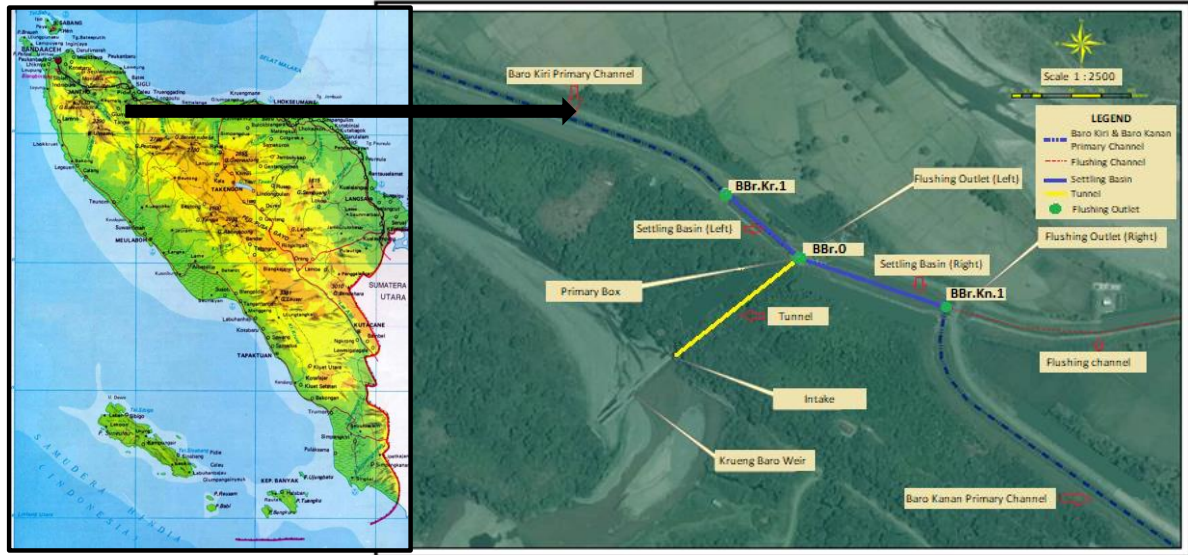


Figure 1 Location Study – Keumala Weir

Data Collection

The primary data required for this study included the site survey, the sediment sampling, and the measurements of the settling basin dimension (Moradinejad *et al.*, 2014; Motallebian and Hassanpour, 2013). The suspended load samples were obtained using PONOT-BSA. The sampling was conducted in three points, where was the left, right and center of the settling basin channel simultaneously. The sampling procedure for the suspended load complied with the guideline in the Decree of the Directorate General of Water Resources (2009). The sampling of bed load employed the Grab Sampler. The sampling procedure for the bed load also complied with the guideline in the Decree of the Directorate General of Water Resources (2009).

The specific gravity test aimed to determine the mass density or the specific gravity of the soil to be tested. The specific gravity is the ratio of the density of soil grain and the density of water at the same temperature and volume. This test was conducted at the Soil Mechanics Laboratory of the Civil Engineering Department, Faculty of Engineering, Syiah Kuala University. The properties of soil rely on its size, and thus the grain size is the basis for soil types classification. This test was also undertaken at the Soil Mechanics Laboratory in the Civil Engineering Department of the Faculty of Engineering, Syiah Kuala University. This test aimed to examine the fall velocity of sediment particles. The fall velocity of particles influences the dimension design of the settling basin (the length and width). The sediment concentration (Total Suspended Solid, TSS) in the settling basin flow was examined at the Instrumentation and Analysis Laboratory at the Chemical Engineering Department, Faculty of Engineering, Syiah Kuala University. Syiah Kuala.

The measurement of the settling basin dimension using a meter included measuring the length, width, depth and the slope of the settling basin as well as the height of deposited sediments. According to the Directorate General of Irrigation, the Department of Public Works (a) (2013), The design of adequate settling basin depends on the availability of sediment data including grain distribution, vertical distribution, suspended load, bed load and the volume of sediments. The settling basin is the enlargement of the channel cross-section to a certain length to reduce the flow velocity and allow the sediments that enter the intake to settle. It is one of the efforts to prevent vegetation growth and sediments coming into the primary channel. Thus, it is crucial to building a settling basin. The base of the construction for a settling basin is usually deepened or widened for holding sediments and being cleaned in a certain period. It is cleaned approximately every one or two weeks by flowing fast water resulting in the sediments transported back to the river flow. The control of the dimension and the efficiency of the settling basin must consider several issues, including

the volume, the length, the width and the slope of the settling basin as well as the efficiency control.

Data Processing

The Volume of the Settling Basin

The number of sediments passing through the intake cannot be determined because it depends on the intake construction itself (Shah-Fairbank and Julien, 2015). If the intake is equipped with an adequate barrier or a settling basin, the transported bed load entering the irrigation network can be ignored. The Directorate General of Irrigation, the Department of Public Works (a) (2013) argued that the volume of sediments depends on the amount of the bed load and the suspended load that will be settled until flushing period.

The volume of sediments to be deposited is around 0.5‰ of the flow volume in the settling basin. This value is a rough estimate, and the accuracy requires investigating. It is recommended that most sand particles (60-70%) above 0.06-0.07 mm can settle. The volume of the settling basin (V) depends on the flushing interval; the formula is as follows:

$$V = 0.0005 \times Q \times \Delta T \quad 1)$$

where: V = the volume of settling basin required (m³); Q = The discharge amount of designed channel (m³/s); and ΔT = Flushing interval (s).

The Length and Width of the Settling Basin

Based on the requirement of Directorate General of Irrigation, the Department of Public Works (a) (2013), the dimensions of the settling basin should comply with the requirement of L/B > 8 to prevent the flow meandering in the settling basin. If the topography does not enable the condition, the settling basin must be divided in a longitudinal direction to divider walls to accomplish the L and B ratio.

$$\frac{H}{w} = \frac{L}{v} \quad \text{with} \quad v = \frac{Q}{H \times B} \quad 2)$$

$$L \times B = \frac{Q}{w} \quad 3)$$

where: H = the depth flow of the settling basin (m); w = the settling velocity of sediment particles (m/s); L = the length of the settling basin (m); v = water flow velocity (m/s); and B = the width of the settling basin (m).

The measurement of flow velocity was conducted using a current meter with the propeller diameter of 80 mm and the pitch of 125 mm. The measurement was carried out in the center of the settling basin, and the results were used to evaluate its efficiency. The results of the measurement of the settling basin dimension enabled the calculation of the settling basin capacity to evaluate its storage capacity. Based on the testing results of the sediment samples, the efficiency of the settling basin can be evaluated, both the settling and flushing efficiency.

The Energy Slope of the Settling Basin during Normal exploitation and When the Settling Basin Is Empty

The energy slope is reviewed based on two circumstances, namely: during normal exploitation and when the settling basin is empty. The energy slope of the settling basin during normal exploitation (I_n) is as follows:

$$I_n = \left(\frac{v_n}{K_s \times R_n^{2/3}} \right)^2 \quad 4)$$

The energy slope of the settling basin when it is empty (I_b):

$$I_b = \left(\frac{v_b}{K_s \times R_b^{2/3}} \right)^2 \quad 5)$$

where: K_s = strickler roughness coefficient; R_n = hydraulic ratio during a normal exploitation (m); R_b = hydraulic ratio when the settling basin is empty (m); v_n = the settling basin flow velocity during a normal exploitation (m/s); and v_b = the settling basin flow velocity when the settling basin is empty (m/s).

If the velocity is increasing, the flow velocity must be maintained for the flow to remain in subcritical

conditions or $Fr > 1$ employing the following calculation (Hameed and Ali, 2012):

$$Fr = \frac{v}{\sqrt{gh}} \quad 6)$$

where: g = gravitational acceleration, $g = 9,81 \text{ m/s}^2$ and h = the height of flow (m).

The settling velocity of sediment particles

The settling velocity of sediment particles (w) relates to the temperature conditions. As for Indonesia, the average temperature is 20°C . In this study, the settling velocity of sediment is determined using the Shield graph for the settling velocity of discrete particles in calm water, that is the graph illustrating the relationship between the filter diameter and the settling velocity (Figure 2). The sediments coming into the settling basin must settle before reaching the flushing gate.

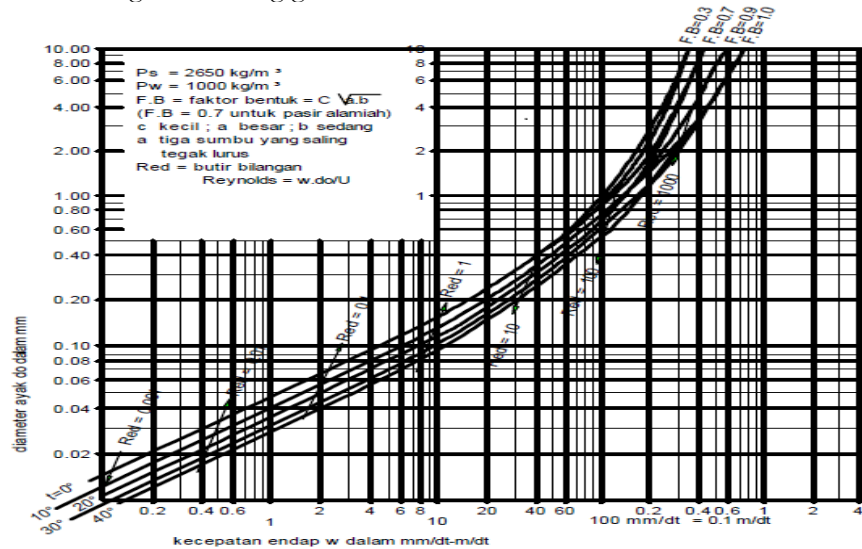


Figure 2 The test result of the filter diameter and the settling velocity

Source: Directorate General of Irrigation, the Departement of Public works (a) (2013)

The Performance Evaluation of the Settling Basin

The evaluation of the settling basin should also include the control of the deposition and flushing efficiency. Deposition Efficiency, the deposition efficiency is controlled in two conditions, namely:

- The settling velocity varies from the designed settling velocity, and the formula is given as follows:

$$\frac{h_n}{w} = \frac{L}{v_n} \quad 7)$$

where: h_n = the depth of water design (m).

- The control of water turbulence

The water velocity at a certain flow point causes turbulence, while the degree of turbulence is a velocity fluctuation to average speed. The degree of turbulence strongly influences the condition of suspension materials in the settling basin and is evaluated using the Camp graph (Figure 3). Shinohara Tsubaki has studied and provided criteria that the materials will remain in full suspension, only if:

$$\frac{v^*}{w} > \frac{5}{3} \quad 8)$$

$$v^* = \sqrt{ghI_b} \quad 9)$$

where: v^* = sliding velocity (m/s).

The Flushing Efficiency

Flushing is one of the crucial factors to consider in designing a settling basin. The flushing process aims to clean and remove the deposited sediments from the settling basin (Ji *et al.*, 2011). The flushing time interval depends on the circumstances of the irrigation channel exploitation, the number of deposited sediments, the size of the reservoir, and the availability of water discharge for flushing. In this design, the flushing interval is every one or two weeks.

The flushing evaluation depends on two factors, namely:
Adequate shear stress is formed on the surface of the deposited sediments. This circumstance can be evaluated using Shield graphics. The material moves when $\tau_0 > \tau_{cr}$.

$$\tau_0 = \rho_w \times g \times R_b \times I_b \quad 10)$$

where: τ_0 = initial shear stress (N/m²); τ_{cr} = critical shear stress (N/m²); ρ_w = water mass density (kg/m³).

The velocity is adequate to retain the materials in suspension after flushing. This condition can be examined on the criteria of Shinohara Tsubaki (equation 8).

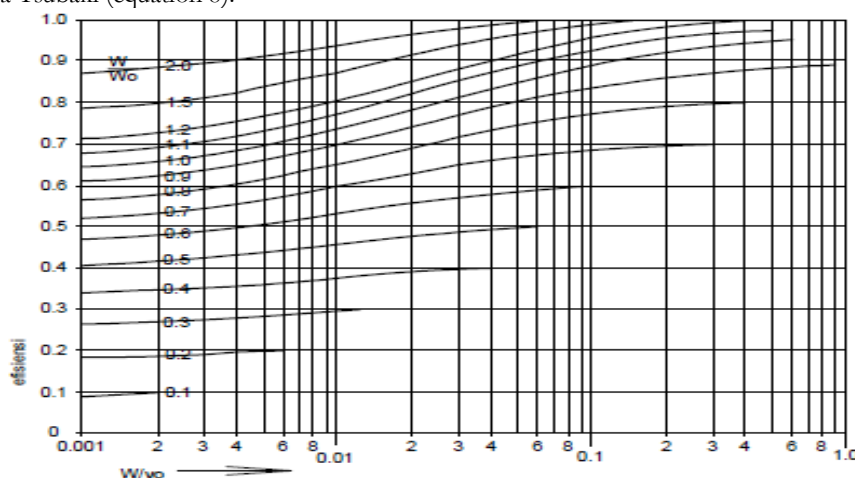


Figure 3 The Sediment Flushing Graph for Turbulence Flow

Source: Directorate General of Irrigation, the Department of Public works (a) (2013)

Results

The results of specific gravity test showed that the type of sediment found in the middle of the settling basin was gravels with a density of 2.676 gr/cm³. Fine sands with a density of 2.589 gr/cm³ and gravels with a density of 2.663 gr/cm³ were found at the end and the primary channel of the settling basin respectively. The grain size testing resulted in a graph of the grain distribution illustrating the percentage of the grain passing and settling. The test started from filter #4 (4.76 mm) to #200 (0.074 mm). The results showed that the sediments in the middle, the end and the primary channel of the settling basin contained sediments with the largest particle size of 4.76 mm, 0.42 mm and 4.76 mm respectively. For the fall velocity testing, the particle fall velocity was examined using three samples of 20 gr held by filter #140 with a diameter of 0.105 mm. The test was conducted at 30 cm of water. Table 1 illustrates the results of the fall velocity of particles.

Table 1. The Fall Velocity of Particles

Test	H (m)	t (s)	w (m/s)
I	0.3	35.24	0.00851
II		34.94	0.00859
III		35.00	0.00857
Average			0.00856

Therefore, the results will be used as a value of w in evaluating the settling basin efficiency. The results

of the settling efficiency are strongly associated with the maintenance and operation of the settling basin.

The Flow velocity of the Settling Basin

The measurement of the flow velocity of the settling basin was conducted at three vertical points (0.2H, 0.6H, and 0.8H). The results showed that the average fall velocity was 0.325 m/s, later being used to calculate the efficiency. Table 2 illustrates the sample testing of the settling basin generated.

Table 2. The sample testing of the settling basin

Parameters	Value
Sediment diameter (d_{90})	7.1 mm
Sediment diameter (d_{50})	3 mm
The suspended load mass (γ_{sl})	2.589 kg/m ³
The bed load mass (γ_{sd})	2,676 kg/m ³
Water mass (γ)	1000 kg/m ³
Suspended load concentration (c)	804 mg/L
The slope of the bottom of the channel (Ss)	0.002
The width of the bottom of the channel (B)	19.2 m
Discharge flow (Q)	13.43 m ³ /s
Hydraulic radius (R)	1.77 m
Energy slope (S)	0.0000243

Based on the sediment data from the test result, it is indicated that the transported suspended load (Q_s) was 932.92 tons/day or 360.34 m³/day, while the amount of transported bed load obtained using the Meyer-Peter-Mueller Method was 4,011.55 tons/day or 1,499.08 m³/day. The total transported sediments in the settling basin of Keumala Weir was 1,859.42 m³/day.

The length and width of the settling basin

The length and width of the settling basin influence the particle settling velocity and discharge. Based on a direct testing, it was identified that the settling velocity of the particles with a diameter of 1.05 mm was 0.00856 m/sec. The Shield graph indicated the relationship between the filter diameters and settling velocity, w was 0.008 m/sec. The direct observation reported that the width of the middle part of the settling basin was 5 m, the width of the left and right parts was 7 m (Figure 4), and the length of the settling basin (L) was 75 m. In this settling basin, each segment was separated by a divider wall (15 cm thick and 1.5 m high) to reach the ratio of L and B ($L/B > 8$). To satisfy the requirements of the $L/B > 8$, dimension suitability was examined and it was revealed that the length and width of the settling basin of Keumala Weir fulfilled the requirement of $L/B > 8$.

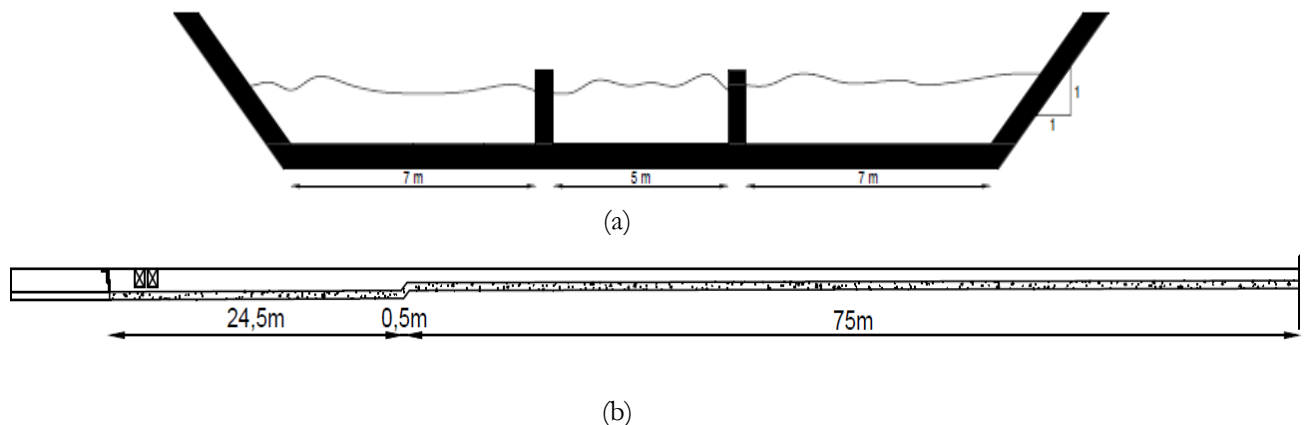


Figure 4 (a) Horizontal cross section and (b) Longitudinal Cross section of the Keumala Weir settling basin

Source: The Measurement Result

The energy slope of the settling basin

The energy slope of the settling basin was reviewed from two conditions, namely in normal exploitation and in the empty settling basin. The following are some conditions of the energy slope.

The energy slope of the settling basin during normal exploitation (I_n): The flow velocity of the settling basin during normal exploitation, v_n , was 0.325 m/s, so that the energy slope of the settling basin about 0.0000243. The energy slope of the empty settling basin (I_b): The flow velocity of the settling basin during the flushing was 1.5 m/s. so that the energy slope of the empty settling basin about 0.00266.

The examination of the flushing velocity condition was necessary using the Froude number (F_r), and the Froude number is about 0.665. Froude number was less than 1, indicating that the flow is in a subcritical condition. The flow velocity during the flushing should be designed for the deposited particles to move. However, the flow should remain in a subcritical condition as the supercritical speeds can decrease the flushing effectiveness.

The Evaluation of the Settling Basin Capacity

The volume of the settling basin is determined by the withdrawal discharge and the flushing period of the settling basin. The withdrawal discharge in the Baro Kanan irrigation network was 13.43 m³/sec. Based on the current circumstances, the flushing period of the settling basin was carried out once a week. It was assumed that the water in the intake consisting of 0.5 ‰ sediments to be settled in the settling basin, thus the number of deposited sediments for a week (V) was 4,061.23 m³. While the analysis of transported sediment employing the Meyer-Peter-Mueller method reported that a week volume of deposited sediments (V) was 13,015.98 m³. The maximum transported sediment occurred by the Meyer-Peter-Mueller calculations using sediment sampling data. The settling basin capacity based on its dimension ($b = 19.2$ m, divider wall (hd) = 1.5 m, $L = 75$ m, $I = 0.0015$ and $m = 1$) as illustrated in Figure 6, made up a total volume of = 2328.75 m³ + 108 m³ = 2,436.75 m³.

The Settling Basin Efficiency

The evaluation of the settling basin also involved controlling the settling and flushing efficiencies. The calculations concerning the settling and flushing efficiencies are as follows. The settling efficiency suggested that most sand particles (60-70%) with the diameter of 0.06-0.07 mm can settle. This condition can be controlled by Camp graph.

The settling velocity varying from the designed settling velocity. The designed settling velocity (w_0) was 0.00636 m/s and the appropriate grain diameter (d_0) to be deposited in the settling basin was 0.03 mm. The grain diameter that can settle was smaller than the diameter tested from the field survey, 0.105 mm. Thus, the materials settled will not scatter anymore. Next, the information on the Camp graph presented the settling efficiency of 75%. The efficiency value higher than 70% indicated that the settling efficiency was adequately satisfied.

The control of water turbulence was conducted in two conditions, that are when the settling basin was empty and when it is full. When the settling basin was empty, the value of sliding velocity $v^* = 0.119$ m/s. So that the ratio of sliding velocity and settling velocity of sediment particles about 13.9. This value indicates that the turbulence was under controlled. And when the settling basin was full, the value of sliding velocity $v^* = 0.0187$ m/s. So that the ratio of sliding velocity and settling velocity of sediment particles about 2.185. This value indicates that the turbulence was also under controlled.

The factors contributing to the flushing efficiency included water mass density, gravitational acceleration, hydraulic radius during the flushing and the energy slope during the flushing. Shear stress generated based on the existing conditions was 15,538 N/m². The examination of flushing efficiency using the Graph Shield reported the grain diameter d_m of 16 mm.

Discussion

The evaluation of the settling basin capacity was a ratio between the volume of sediments to be deposited during the flushing period (13,015.98 m³) and the settling basin capacity. The current volume of the settling basin concluded that the capacity of the settling basin was less than the sediment volume to be settled for seven days. Therefore, the flushing period was increased to every day to generate a volume of 1,859.43 m³. It was smaller than the volume of the settling basin capacity, and this condition was a controlled

condition for the settling basin capacity. This is in line with Faqih and Azizi (2018) arguing that fixed scheduling of the flushing period is required for the settling basin to effectively and efficiently function.

Based on the evaluation of the settling basin, it can be concluded that 75% of the sediments entering the intake settle in the settling basin. Following Nindito, *et al.* (2008) arguing that the settling efficiency of the settling basin depends on several parameters, including the control parameters of the sedimentation process and the number of deposited sediments. The amount of deposited sediments relies on the inflow characteristics of the sediments that is the magnitude of fall velocity, while the control parameters of the sedimentation process rely on the characteristics of the water flow in the settling basin that is the magnitude of flow velocity. These two parameters are controlled by the characteristics and the geometry of the reservoir. And based on controlling the influence of water turbulence, was conducted to investigate that the sediments deposited in the empty or full settling basin will not be eroded. This illustrates that the efficiency of the water turbulence in the settling basin of Keumala Weir was safe. However, the branch operator of Keumala should regulate and adequately comply with the schedule of the settling basin operation to avoid water turbulence. Based on the flushing efficiency, particles which smaller than 16 mm would be flushed. The diameter tested from the field survey was 0.105 mm. Therefore, the materials settled in the Keumala Weir settling basin can be flushed considering the existing hydraulic conditions. This is in line with Nindito *et al.* (2008) stating that the success of the settling basin design relies on the settling and flushing efficiencies.

The primary channel of the Baro Kanan Irrigation of Keumala Weir consisted of a stone masonry channel, but it had high sedimentation. The sediment samples testing at the Soil Mechanics Laboratory found that they contained gravels with a maximum diameter of 4.76 mm. It is indicated that the velocity in the regulating building was greater than 1.5 m/s and the sediments were carried from the flow of the settling basin. The sediments settled in the settling basin will continue to erode when it is full resulting in the sediment being carried in the flow. The Directorate General of Irrigation, the Department of Public Works (b) (2013) recommended limiting the velocity in the regulating building to approximately 1.5 m/s to reduce the sediments entering into the channel. This requires the accuracy in the operation of the primary channel intake.

Conclusion

The capacity of the settling basin Keumala Weir is 2,436.75 m³. Thus the volume of the settling basin in the flushing period must be smaller. The flushing interval is every day with the volume of 1,859.43 m³ to satisfy this requirement. The settling efficiency of Keumala Weir is 75%. It indicates that efficiency is adequately satisfied. This is due to the high height of flow (h), it takes longer to settle. The settling efficiency of the settling basin of Keumala Weir by considering the influence of water turbulence is in a safe condition. The deposited sediments in the empty or full settling basin will no longer be eroded. By controlling the flushing, the initial shear stress resulted is $\tau_0 = 13,346 \text{ N/m}^2$, it is capable of flushing particles for the diameters less than 16 millimeters. For the particle greater than 16 millimeter, manual flushing is required. Based on the performance evaluation of the settling basin, it is indicated that the deposited sediment in the settling basin will continue to erode when it is full, resulting in the sediments are carried along in the flow to the primary channel due to less meticulous operation in the primary channel intake.

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