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Hydraulic Analysis of the Cisangkuy River Weir Development Plan to Increase Flow at the PDAM (Regional Water Company) Inlet

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ABSTRACT

A hydraulic characteristic analysis was conducted to support the plan to construct the Cisangkuy River Weir in the Cikalong Hydroelectric Power Plant area, aiming to improve the fulfilment of raw water needs entering the inlet system of the South Bandung Regional Water Company. The main problem faced is the seasonal discharge fluctuations and watershed degradation, which cause the intake discharge during the dry season to only reach 0.09 m^3/s, far below the minimum requirement of 0.7 m^3/s. This study uses a research methodology that includes hydrological data collection, river cross-section surveys, and hydraulic modeling using HEC HMS and HEC-RAS 1D version 6.3.1 software. The simulation results show that the construction of a weir height of 1 m and a width of 1.5 m with a sluice gate system can significantly increase the intake flow rate. In dry conditions, the optimal flow rate reaches 0.62 m^3/s without downstream flow, if the hydroelectric power plant operates and the gate is opened 0.1 m, the flow inlet conditions will be 0.55 m^3/s with a downstream inflow of 4.69 m^3/s. In the rainy season, optimal conditions are achieved at a return period of 2-5 years by fully opening the two weir gates so that the water surface elevation does not exceed the peak of the hydroelectric power plant (+885.5 m) with an inflow discharge between 0.51 and 1.20 m^3/s. The integration of the weir with adaptive sluice gates has proven effective in ensuring the sustainability of raw water supply while mitigating flood risks.

Keywords: Cisangkuy river, HEC-RAS 1D, Hydraulics, Water supply discharge, Weir.

1. INTRODUCTION

Regional Water Company or PDAM according to **(Undang-Undang No 5 Tahun, 1962)** is a business unit owned by the regional government that provides services and public benefits in the field of drinking water. As a public clean water provider, PDAM faces challenges in maintaining supply sustainability, especially in areas that rely on surface water sources such as rivers. The Cisangkuy River, one of the Citarum River's tributaries, plays an important role

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in the raw water supply system in South Bandung **(Sampe et al., 2018)** . This river is one of the main sources for the Baleendah and surrounding areas' water company (PDAM). Study **(Resubun et al., 2018)** shows an imbalance between the potential water availability and the domestic and non-domestic water needs in the Cisangkuy watershed, leading to deficits during the dry season and the potential for high runoff during the rainy season.

A study by **(Ismail et al., 2024)** shows that changes in vegetation cover in the Cisangkuy watershed over the past three decades have significantly impacted runoff characteristics. Using Google Earth Engine, it was found that the runoff coefficient ranged from 60% to 63%, reflecting high surface runoff and limited infiltration due to urbanization and land degradation. **(Kusumawardani et al., 2018)** adds that this watershed is pressured from land use changes, leading to extreme fluctuations in river discharge between the rainy and dry seasons. This instability threatens the sustainability of the water supply for the regional water company (PDAM), especially when minimum discharge is insufficient to meet daily customer needs **(Maryati et al., 2021)**. Based on data from the Indonesian Agency for Meteorology, Climatology, and Geophysics, Katumiri and Pangalengan, it states that from June to November, rainfall is low, so that the raw water needed to enter the regional water company inlet system cannot be met, the water needs for the regional water company (PDAM Tirtawening) are 0.7 m^3/s.

One of the most efficient engineering approaches to storing water reserves and capturing potential energy to meet domestic and industrial needs is the construction of a weir **(Suad and Al-hadidi, 2025).** A weir is one of the water resources infrastructure structures that provides many benefits, such as irrigation, hydropower plants, and daily human needs **(Agustin et al., 2022).** The success of a weir in increasing water supply depends on proper hydraulic design.

The destructive power of the Cisangkuy River flow, triggered by high speed and sedimentation, demands a deep understanding of its hydraulic characteristics as a basis for flood mitigation. The identification of flow types is conducted thru the analysis of nondimensional parameters, namely the Reynolds number (Re) and the Froude number (Fr), which require flow velocity and discharge data **(Arifki and Erwanto, 2023).** The Reynolds number is used to distinguish between laminar flow regimes (Re < 500) and turbulent flow regimes (Re > 1000). Meanwhile, the Froude number (Fr) is used to determine the flow conditions against gravity, classified as subcritical (Fr < 1), critical (Fr = 1), and supercritical (Fr > 1). **(Setyandito et al., 2022)** demonstrated the importance of considering the Froude Number and the possibility of a hydraulic jump downstream of the weir as part of base erosion mitigation.

In this study, the HEC-HMS (Hydrologic Modeling System) and HEC-RAS version 6.3.1 (River Analysis System) programs were used to simulate 1D flow in the river. The Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) model **(U.S. Army Corps of Engineers, 2018)** developed by the US Army Corps of Engineers, has applications in various hydrological simulations, including urban flood analysis, flood frequency assessment, flood warning system planning, reservoir spillway capacity evaluation, and stream restoration planning.

In a study by **(Chalid et al., 2021**) HEC-RAS 1D was used to analyze the normalization of the Cisangkuy River. Simulation results indicate that changes in channel cross-section profile and slope can lower the water level by up to 3.3 m, which is significant for flood control and water intake efficiency. Hydraulic modeling using HEC-RAS 1D software is considered effective in providing solutions to existing flood problems along the river, analyzing water surface profiles, flow capacity, and the impact of weir design on upstream-downstream river conditions **(Syahputra, 2018).** Additionally, with the support of hydraulic and hydrological technology, such as river flow modeling, reliable discharge simulation, and intake capacity calculations, the construction of the weir on the Cisangkuy River can be carried out accurately and sustainably. This research aims to analyze the hydraulic characteristics in designing a weir to optimize the flow entering the Regional Water Company (PDAM) system and to evaluate the weir's performance against seasonal flow variations to maintain reliability.

2. MATERIALS AND METHODS

2.1 Research Location

The research location is on the Cisangkuy River section around the Cikalong Hydroelectric Power Plant area, Cimaung District, Bandung Regency **Fig. 1**. This location was chosen because it is part of the strategically important Citarum River system for The Regional Water Company (PDAM) water supply. There is an existing water intake structure and technical potential for building a new weir, The river at this location has a fairly stable geometric profile, and historical hydrological data is available from the hydropower plant.

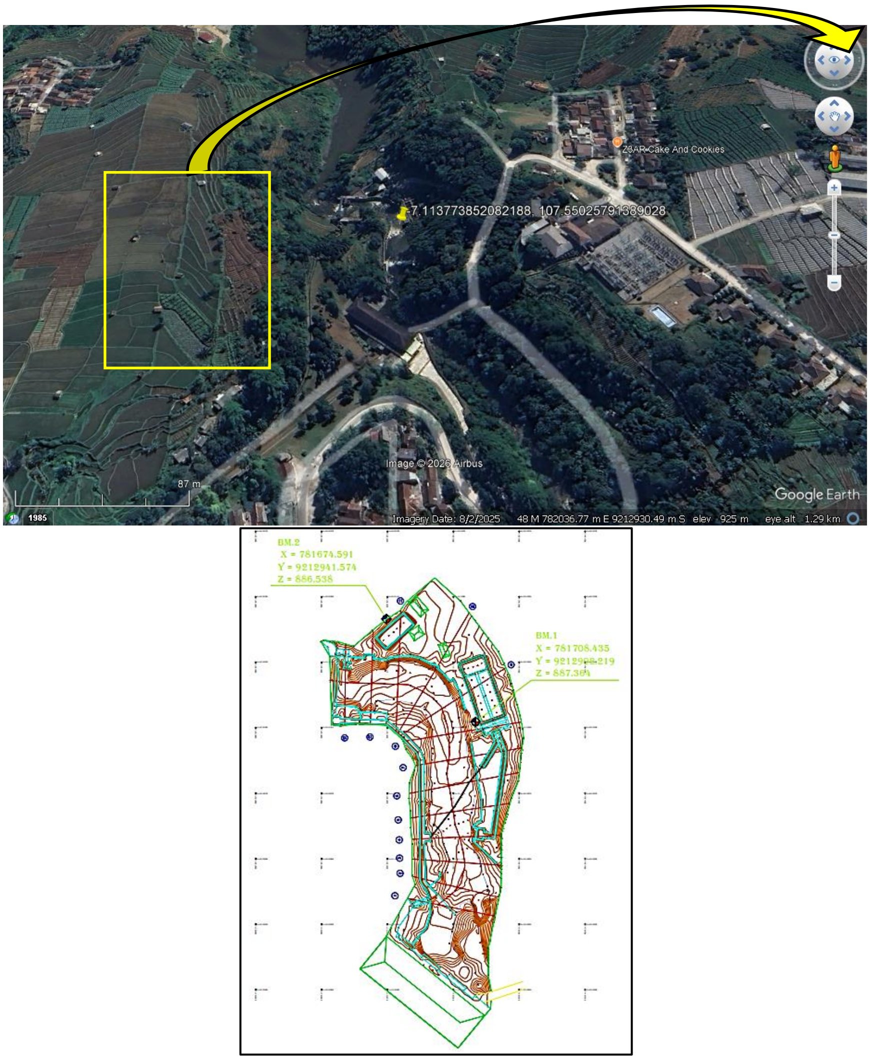


Figure 1. Study Location

2.2 Research Data

This research uses primary data consisting of river cross-section measurements, water surface elevation, and flow velocity. Secondary data includes the discharge data of the Cisangkuy River, maximum rainfall in 10 years (2013-2022), reference from the Indonesian Agency for Meteorology, Climatology, and Geophysics, Katumiri and Pangalengan, topographic maps/DEM, satellite imagery, and Manning's n values. The roughness coefficient (Manning's n) plays an important role in hydraulic analysis because it affects the estimation of river discharge capacity, with references for determining Manning's value based on Chow's research **(Chow, 1959).**

2.3 Methods

This research uses a quantitative approach with an analytical descriptive method **(Ghanad, 2023)**. The main focus of the research is to evaluate the hydraulic characteristics of the Cisangkuy River in the segment that crosses the Cikalong Hydropower Plant area to design a weir structure capable of optimally increasing water flow toward the PDAM (Regional Water Company) inlet. The research began with the collection of river geometric data, weir design drawings, observed flood discharge measurements, and daily rainfall data. The rainfall data was then processed into repeated flood discharge and verified with observed flood discharge using HEC-HMS. Meanwhile, the river geometric data and weir design drawings were input into HEC-RAS to create a river model **Fig. 2 (Yousif and Hamdan, 2026)**. Model calibration and validation were carried out to obtain simulation results that reflect actual conditions **(Halik et al., 2024)**. Here are the data analysis steps performed:

2.3.1 Hydrological Analysis

The planned rainfall analysis was conducted using normal, gumbel, log normal, and log pearson III distributions **(Upomo and Kusumawardani, 2016).** Based on the chi-square and smirnov-kolmogorov goodness-of-fit tests, the log-pearson III distribution was selected as the best method. as validation, a comparative calculation was performed using the Hydrognomon software. The Smirnov-Kolmogorov test results showed that all methods were within the acceptable range (ACCEPT). The log-pearson III method was used for hydrological analysis to determine the planned rainfall, because all distribution variables of this method met the minimum error statistics based on the Smirnov-Kolmogorov test.

2.3.2 Design Flood Discharge Analysis

-After obtaining the planned rainfall, the hourly rainfall intensity is calculated using the Mononobe formula. The use of the Mononobe formula in Indonesia is based on the limitation of short-duration rainfall data, as most of the available data is daily rainfall, necessitating an empirical method to convert it into rainfall intensity **(Nursaleh, 2010).**
-Determining the delineation of the watershed at the river location using DEMNAS data, after obtaining the calculation results of rainfall intensity and the size of the Cisangkuy River watershed, flood discharge modeling is then carried out using HEC HMS software. The use of HEC-HMS is considered more accurate for simulating design flood discharge with a recurrence interval of less than 100 years **(Nggarang et al., 2020).**

2.3.3 Hydraulics Analysis

The HEC-RAS (V.6.3.1) software was used to simulate water flow in open channels **(Daher and Ameen, 2025).** The model can perform different calculations for the flow regime subcritical, supercritical, and hydraulic jumps in the flow calculations model, including one-dimensional and two-dimensional flow for simulating the hydraulic characteristics (surface water elevations, water depth and velocities), with the use of the gathered data of scarce discharge. The connection between HEC-HMS and HEC-RAS lies in the flow of data from hydrological analysis to hydraulics **(Hashemyan et al., 2015)**. The discharge from hydrological simulations (HEC-HMS) is used as the main input in hydraulic modeling (HEC-RAS). **Fig. 2** shows that HEC-HMS plays a role in determining the magnitude of flood discharge, while HEC-RAS analyzes the impact of this discharge on river flow conditions, such as runoff potential and flow distribution at water structures (e.g., dams).

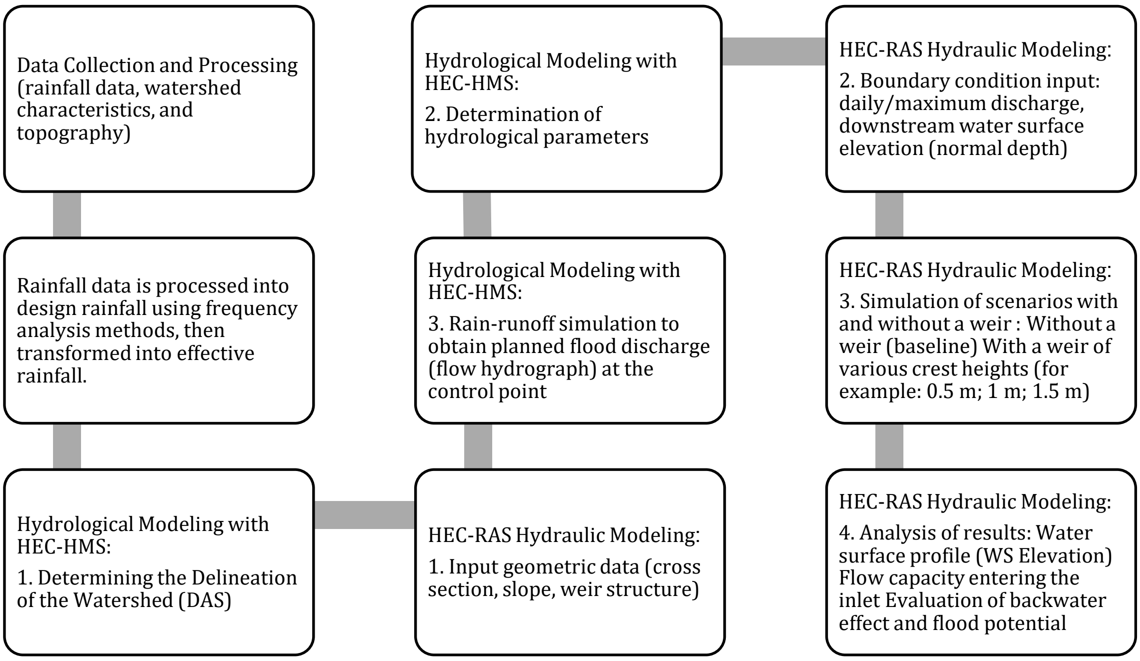


Figure 2. Research Methodology Diagram

3. RESULTS AND DISCUSSION

3.1 Hydrologic Analysis

3.1.1 Rain Data Analysis

Hydrologic analysis is conducted to obtain an overview of the design discharge under various flow conditions in the Cisangkuy River. Before being used in calculations, the annual rainfall data from Cileunca Station (2013–2022 period) were tested using consistency tests (trend, outlier, independence). The annual maximum daily rainfall value is determined by taking the highest daily rainfall value over 1 year, from January to December. Based on **Table 1**, a frequency analysis can be performed to obtain the design rainfall for a specific return period. The return period used in this study is 2–100 years.

Table 1. Maximum 10-Year Rainfall Data for Cileunca Station (in mm)

No	Event		Max rainfall
	Year	Month	
1	2013	December	95
2	2014	April	89
3	2015	February	100
4	2016	September	87.3
5	2017	December	83
6	2018	November	65
7	2019	March	74
8	2020	February	70
9	2021	June	79
10	2022	December	84

Several forms of continuous distribution functions are frequently used in frequency analysis, such as the normal, lognormal, Gumbel, and log-Pearson III distributions **(Syarifudin, 2017).** To determine the distribution to be used, a method that can be used to test whether the chosen type of distribution is suitable for the existing data is the Chi-Square and Smirnov-Kolmogorov tests **(Harto, 1993).** For comparison, calculations were performed using the Hydrognomon software. The Smirnov-Kolmogorov consistency test yielded acceptable results for all distributions. Based on these results, the frequency analysis results of the Log-Pearson III distribution were selected to be used as input for planned rainfall, as shown in **Table 2.**

Table 2. Planned Rainfall Data (mm)

P (x >= Xm)	T	LOG-PEARSON III	
Probability	Recurrence Interval	XT	KT
0.9	1.11	68.32	-1.05
0.5	2	83.17	-0.22
0.2	5	103.32	0.7
0.1	10	119.68	1.33
0.05	20	137.75	1.92
0.02	50	165.05	2.69
0.01	100	188.81	3.26
0.001	1000	293.56	5.13

After obtaining the planned rainfall, the rainfall intensity is then calculated. The design rainfall intensity is the height of rainfall that occurs over a specific period of time, where the water is concentrated **(Gunawan et al., 2023)**. Rainfall intensity can be calculated based on rainfall data using the Mononobe. After obtaining the results of the rainfall intensity calculation and the size of the Cisangkuy River watershed, as shown in **Table 3**. The flood discharge modeling was then carried out using HEC-HMS software **(U.S. Army Corps of Engineers, 2018)**

Table 3. Rainfall Intensity (mm/hour)

Time	Rain Plan					
Hours	2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
0	83. 174	103. 323	119. 677	137. 753	165. 049	188. 815
1	28.83	35.82	41.49	47.76	57.22	65.46
2	18.16	22.57	26.14	30.08	36.05	41.24
3	13.86	17.22	19.95	22.96	27.51	31.47
4	11.44	14.22	16.47	18.95	22.71	25.98
5	9.86	12.25	14.19	16.33	19.57	22.39

3.1.2 Watershed Delineation

A watershed is a catchment area with a river and tributaries that accommodate, store, and channel water from rainfall to lakes or the sea. The land boundary is known as topography, while the sea boundary consists of the water areas affected by land activities **(Alfansyuri and Farni, 2018).** Additionally, a watershed could be considered a hydrological unit because it converts rainfall (input) into runoff (output), sediment, and nutrients. The rainfall-runoff is a very complex scientific process influenced by several factors **(Bunganaen et al., 2021).** From the results of watershed delineation using Digital Elevation Model Nasional data, **Fig. 3** shows that the Cisangkuy watershed is part of the Pataruman watershed, with an area 124.84 km^2 for the Pataruman watershed, while the area of the Cisangkuy watershed is 111.55 km^2. However, according to information received from Water Resources Management Public Company (Jasa Tirta II Public Corporation), the area of the Cisangkuy watershed is not that large, only about 50% of the calculated watershed. Subsequently, all calculations used 50% of the calculated watershed area, in accordance with technical directions from the river basin management as the main stakeholder, **Fig. 3**.

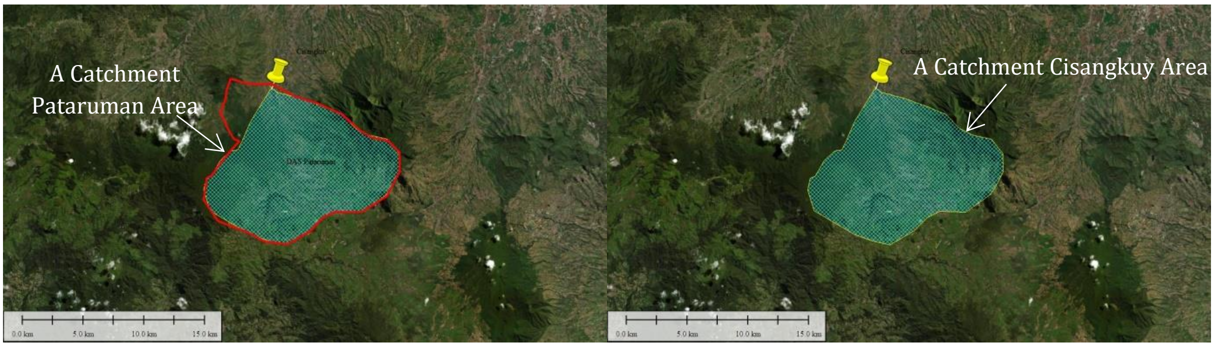


Figure 3. Watershed Delineation

3.1.3 Flood Discharge Modeling

After obtaining the results of the rainfall intensity calculations and the size of the Cisangkuy river basin, flood discharge modeling was then carried out using the HEC-HMS software **(Feldman, 2000).** The layout of the Cisangkuy river basin in the HEC-HMS interface can be seen in **Fig. 4.**

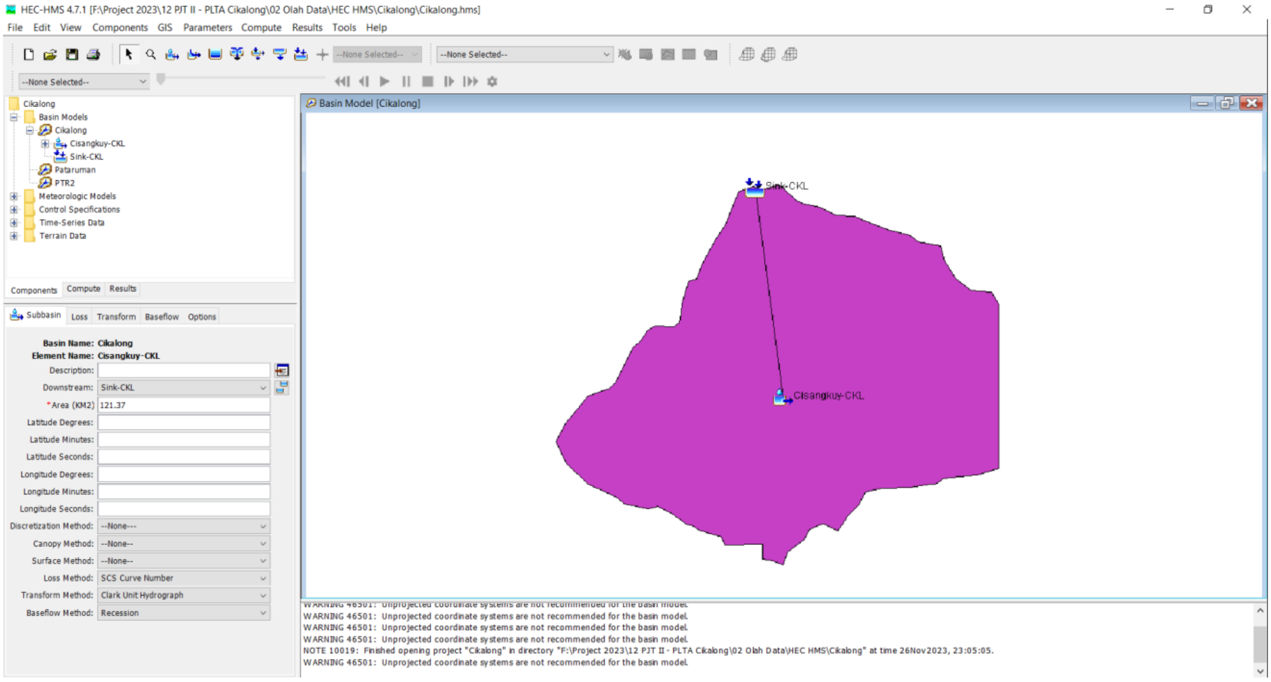


Figure 4. HEC-HMS Modeling

Flood discharge modeling was conducted in February, based on monthly maximum rainfall data over 10 years. The results of the modeling plotting using HEC-HMS were then replotted using Microsoft Excel, as the software can only display one discharge graph at a time. The modeling results yielded the following flood discharge values, **Fig. 5**.

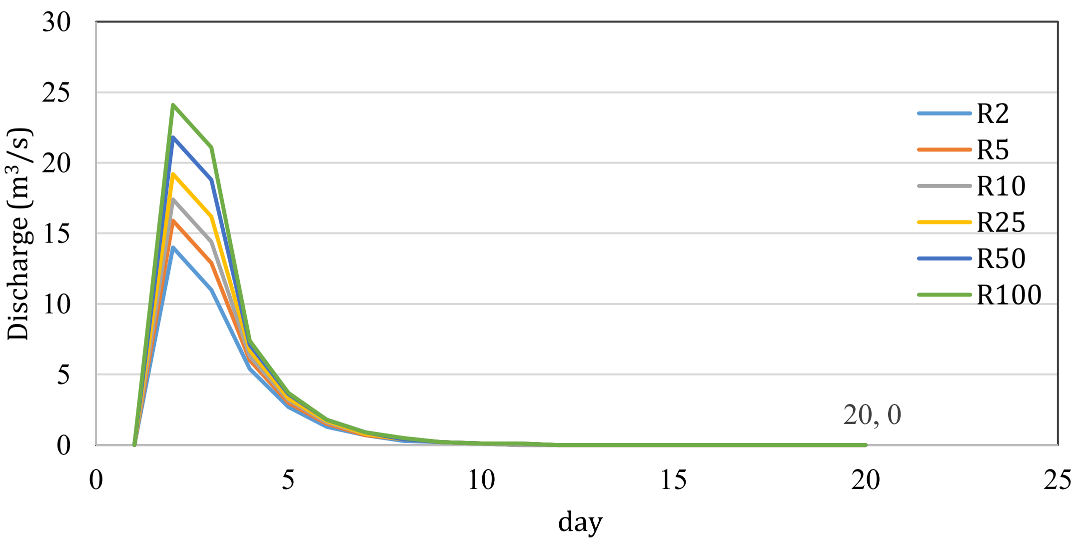
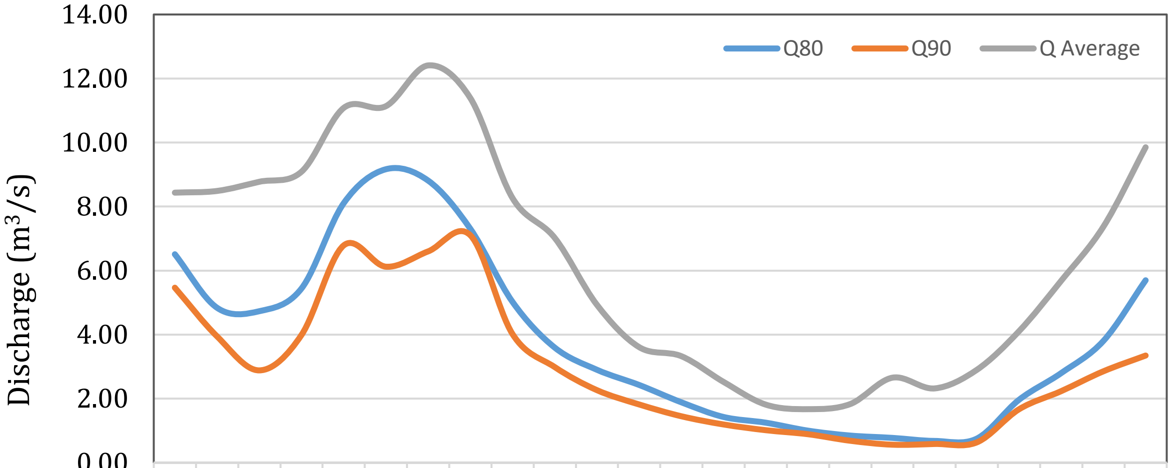


Figure 5. Daily Flood Discharge

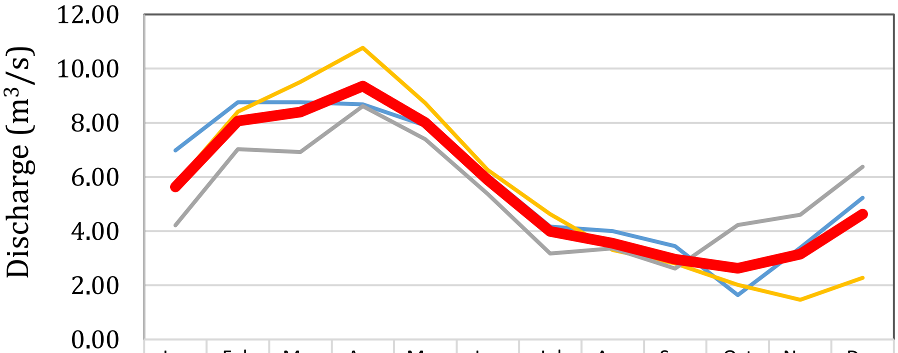
Meanwhile, for the calculation under dry month conditions using the discharge input of the Cisangkuy River, data obtained from Public Corporation for Water Management II is used as follows, **Fig. 6**.



	Jan I	Jan II	Feb I	Feb II	Mar I	Mar II	Apr I	Apr II	May I	May II	Jun I	Jun II	Jul I	Jul II	Aug I	Aug II	Sep I	Sep II	Oct I	Oct II	Nov I	Nov II	Dec I	Dec II
Q80	6.51	4.84	4.73	5.44	8.10	9.17	8.81	7.31	5.02	3.59	2.90	2.43	1.88	1.43	1.25	1.00	0.85	0.77	0.68	0.75	1.96	2.80	3.80	5.70
Q90	5.47	3.94	2.88	3.99	6.79	6.12	6.60	7.10	4.02	2.99	2.26	1.82	1.45	1.19	1.01	0.89	0.68	0.56	0.58	0.63	1.67	2.23	2.85	3.35
Q Average	8.43	8.49	8.77	9.09	11.0	11.1	12.4	11.3	8.26	7.02	4.93	3.61	3.33	2.52	1.81	1.67	1.83	2.65	2.32	2.90	4.11	5.68	7.37	9.85

Figure 6. Availability of water in the Cisangkuy River

Next is the Outflow Water data from the Cikalong Hydroelectric Power Plant, which can be seen in the following image, **Fig. 7**.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water Discharge 2018	6.97	8.76	8.76	8.68	7.90	6.05	4.17	4.00	3.45	1.64	3.38	5.23
Water Discharge 2019	5.72	8.41	9.51	10.77	8.73	6.25	4.62	3.30	2.81	2.02	1.47	2.28
Water Discharge 2020	4.21	7.03	6.92	8.62	7.39	5.37	3.17	3.36	2.62	4.23	4.61	6.38
Water Discharge Average	5.64	8.07	8.40	9.36	8.01	5.89	3.99	3.55	2.96	2.63	3.15	4.63

Figure 7. The Outflow Water data from the Cikalong Hydroelectric Power Plant

Frequency analysis using the Log Pearson III distribution shows that the design flood discharge with a recurrence interval of 2–100 years is in the range of 12–24 m^3/s **Fig. 5**. Meanwhile, according Public Corporation for Water Management the minimum discharge during the dry season (September) only reaches ±1.8 m^3/s that shown in **Fig. 6**. The outflow condition from the Cikalong Hydroelectric Power Plant shows that the highest outflow occurred in April with a discharge of 9.36 m^3/s, and the lowest outflow occurred in October with a discharge of 2.63 m^3/s **Fig. 7**. These results indicate significant hydrological fluctuations, with a relatively high runoff coefficient, making the Cisangkuy River vulnerable to drought during the dry season and peak runoff during the rainy season.

3.2 Hydraulic Analysis

Hydraulic modeling uses HEC-RAS software to control the flow of water in rivers, canals, and streams. Hydraulic structures need to be built. One of the economic structures used to regulate water levels is an inflatable weir **(Abdul et al., 2025).** River geometry data were obtained from topographic surveys, including cross-sections, channel length of approximately 1,000 m, and riverbed elevation. Flow conditions are modeled using two approaches steady flow and unsteady flow.

This modeling was conducted during the lowest flow of the Cisangkuy River in September and the flood flow in February. The steady flow simulation results show that during the dry/low flow season, the current tends to be supercritical (Fr > 1) **(Auel et al., 2014)** with an average speed of 3.5–4.2 m^3/s , causing most of the flow to pass thru the intake channel. In this condition, there is no additional Water Outflow from the hydropower plant to observe the extreme flow rate entering the intake channel when the flow rate is at its minimum point, resulting in an inflow rate to the water intake channel of 0.09 m^3/s **Fig. 9** and a river flow rate of 0.53 m^3/s **Figs. 8 and 10**. It can be said that the inflow rate to the water intake channel is still below the regional water company (PDAM Tirtawening) requirement of 0.7 m^3/s.

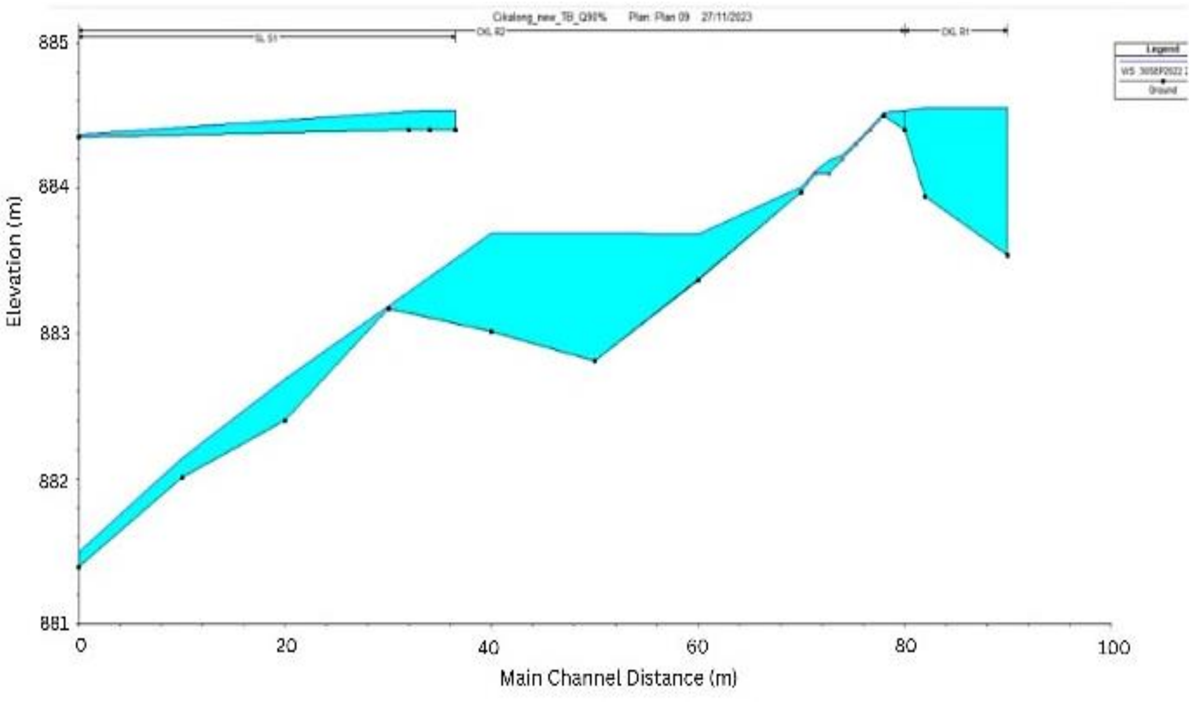


Figure 8. Flow Conditions in the River at Minimum Discharge (September)

Therefore, efforts are needed to increase the inflow to the water intake channel by constructing a weir. With a weir height of 1 m and a width of 1.5 m, the water surface upstream rises, and the flow profile changes to subcritical (Fr < 1) **(Kamiana et al., 2022)**, and the inflow increases significantly, with the inflow to the water intake channel reaching 0.62 m^3/s **(Fig. 12)**. In this condition, there is no downstream flow (0.00 m^3/s) **(Fig. 11)**. It can be said that the amount of inflow to the water intake channel is still below the needs of PDAM Tirtawening, with a flow deficit of 0.07 m^3/s. Therefore, in this condition, the focus is on ensuring that PDAM's water needs are met and the downstream flow rate remains stable.

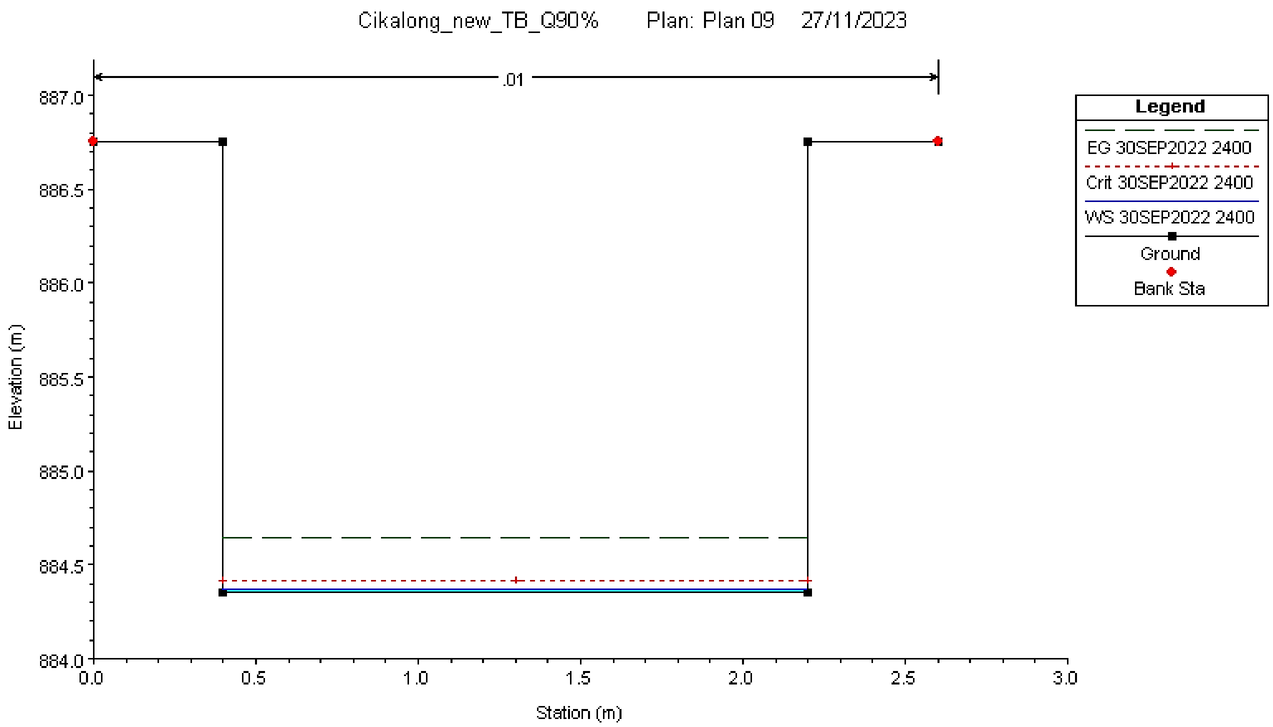


Figure 9. Flow Conditions at the Channel Intake during Minimum Discharge (September)

HEC-RAS Plan: Plan 09 Profile: 30SEP2022 2400

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
SL	S1	3	30SEP2022 2400	0.09	884.40	884.54		884.54	0.000044	0.17	0.54	4.00	0.15
SL	S1	2	30SEP2022 2400	0.09	884.40	884.54		884.54	0.000045	0.17	0.54	4.00	0.15
SL	S1	1	30SEP2022 2400	0.09	884.40	884.53		884.54	0.000277	0.39	0.23	1.80	0.35
SL	S1	0	30SEP2022 2400	0.09	884.35	884.37	884.41	884.65	0.090270	2.32	0.04	1.80	4.99
CKL	R1	1	30SEP2022 2400	0.00	883.54	884.56		884.56	0.000000	0.00	11.31	19.35	0.00
CKL	R1	0.1	30SEP2022 2400	0.00	883.94	884.56		884.56	0.000000	0.00	3.37	8.16	0.00
CKL	R1	0	30SEP2022 2400	0.62	884.40	884.54	884.54	884.57	0.002304	0.80	0.78	11.45	0.98
CKL	R2	8.1	30SEP2022 2400	0.53	884.40	884.54	884.57	884.66	0.011382	1.55	0.34	6.02	2.08
CKL	R2	8	30SEP2022 2400	0.53	884.50	884.52	884.61	892.79	6.654349	12.74	0.04	3.79	38.82
CKL	R2	7.83333*	30SEP2022 2400	0.53	884.40	884.42	884.51	904.11	15.848990	19.66	0.03	2.46	59.90
CKL	R2	7.66666*	30SEP2022 2400	0.53	884.30	884.32	884.42	929.41	36.296470	29.75	0.02	1.62	90.64
CKL	R2	7.5*	30SEP2022 2400	0.53	884.20	884.23	884.34	904.15	10.759480	19.77	0.03	1.81	51.87
CKL	R2	7.33333*	30SEP2022 2400	0.53	884.10	884.19	884.26	884.51	0.036749	2.49	0.21	4.54	3.67
CKL	R2	7.16666*	30SEP2022 2400	0.53	884.10	884.12	884.24	953.85	56.150000	36.99	0.01	1.31	112.71
CKL	R2	7	30SEP2022 2400	0.53	883.97	884.01	884.14	900.51	6.311759	18.00	0.03	1.54	41.46
CKL	R2	6	30SEP2022 2400	0.53	883.37	883.69		883.70	0.000326	0.53	1.01	6.38	0.42
CKL	R2	5	30SEP2022 2400	0.53	882.81	883.69		883.69	0.000003	0.11	5.05	11.37	0.05
CKL	R2	4	30SEP2022 2400	0.53	883.01	883.69		883.69	0.000002	0.09	5.78	12.79	0.04
CKL	R2	3	30SEP2022 2400	0.53	883.17	883.19	883.32	964.25	65.308440	39.89	0.01	1.21	121.54
CKL	R2	2	30SEP2022 2400	0.53	882.40	882.69		882.69	0.000093	0.30	1.79	10.25	0.23
CKL	R2	1	30SEP2022 2400	0.53	882.01	882.14	882.32	884.49	0.179830	6.79	0.08	1.19	8.46
CKL	R2	0	30SEP2022 2400	0.53	881.39	881.49	881.59	882.20	0.072082	3.72	0.14	2.75	5.22

Figure 10. Profile Output Table at Minimum Discharge (September)

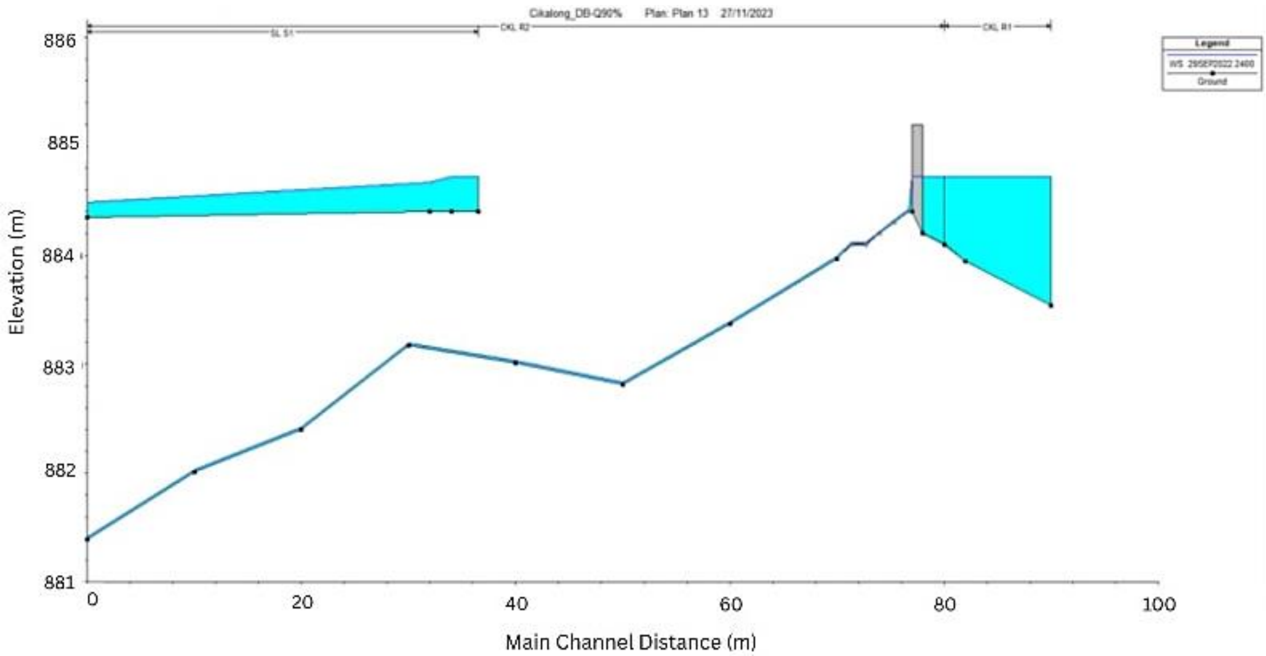


Figure 11. Flow Conditions in a River with a Weir at Minimum Discharge (September)

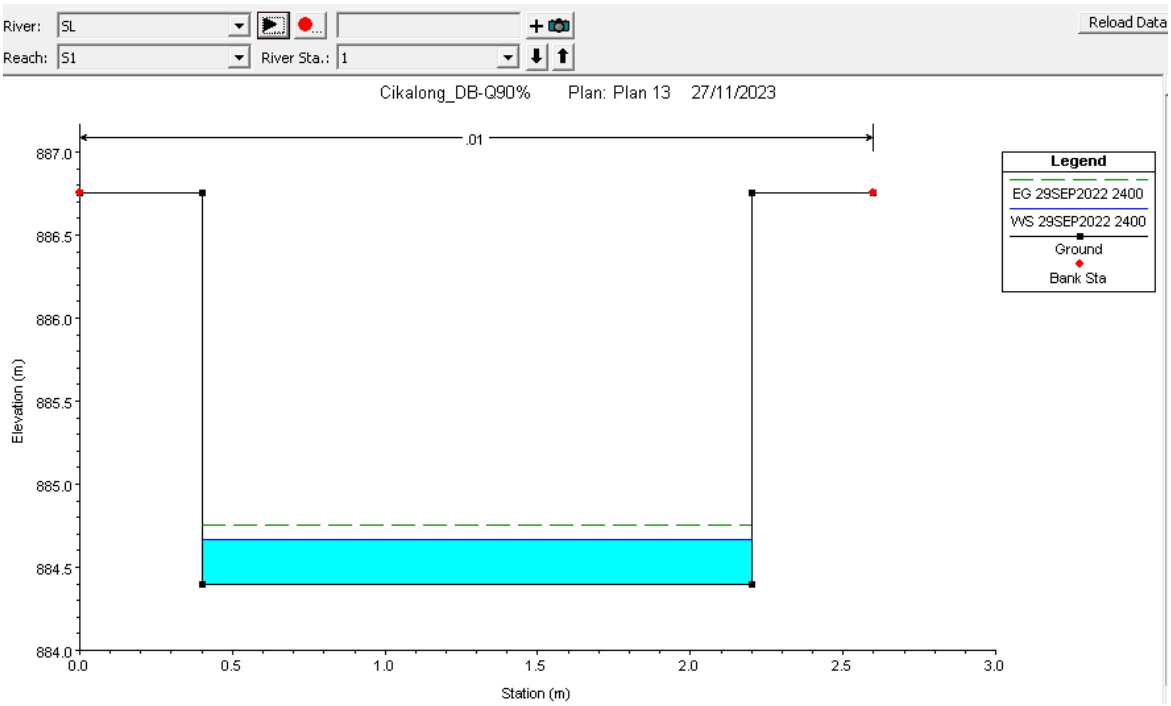


Figure 12. Flow Conditions at the Channel Intake during Minimum Discharge (September) with a Weir.

Meanwhile, during the rainy season, the unstable flow simulation for a 50–100 year flood discharge, with a weir height of 1 m and a width of 1.5 m shows that the water surface can exceed the elevation of the hydropower plant peak (+885.5 m). In this condition, the concern is that the flood water level (FWL) behind the planned weir should not exceed the elevation of the existing hydropower plant weir peak, which is +885.5 m. The blue lines in **Figs. 13**

and 14 represent the flow conditions according to their recurrence intervals, ranging from 100, 50, 20, 10, 5, and 2 years **(Slamet and Reviana, 2021).**

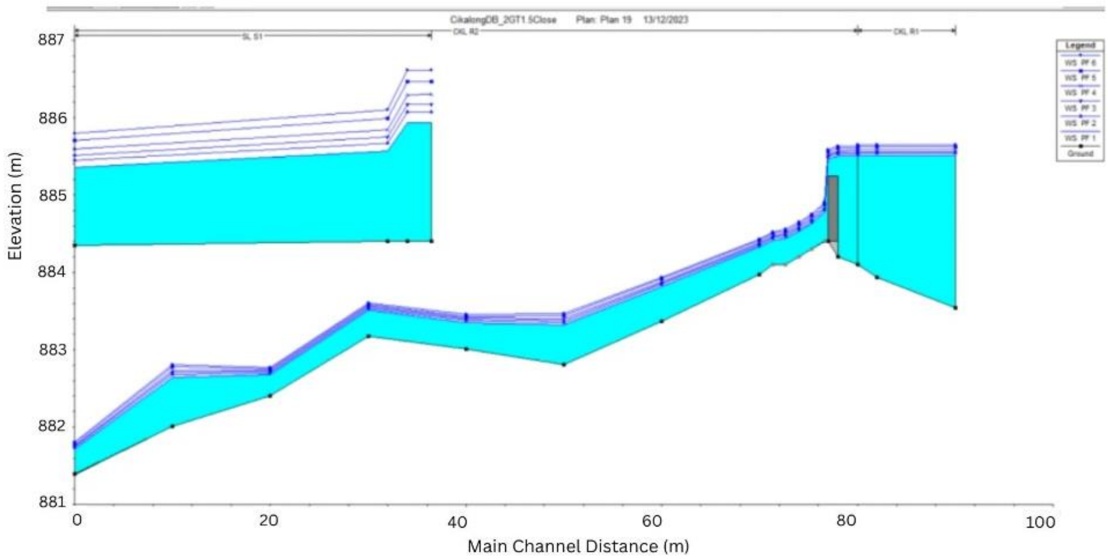


Figure 13. Flow Conditions in the Cisangkuy River with Weir and Intake Structures at 2, 5, 10, 20, 50, and 100-year Flood Discharges

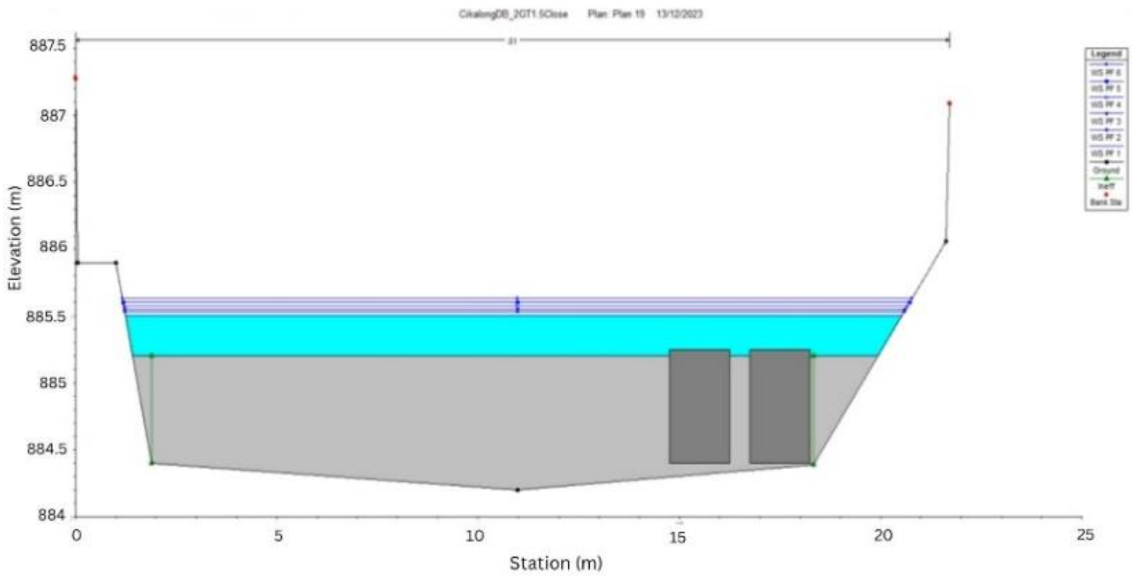


Figure 14. Flow Conditions in the weir Structure

3.4 Hydraulic Modeling Calibration

Calibration of the Cisangkuy River hydraulics model was performed to ensure that the HEC-RAS simulation results matched field conditions. This process compares water surface elevation and measured discharge data from the field with model results for existing discharge, adjusting parameters such as channel roughness coefficient (Manning's n), downstream boundary conditions, and flow expansion and contraction coefficients. The initial Manning's n value of 0.02 was set based on the physical condition of the river, but it resulted in a water surface deviation of 0.12 m. To fix this, Manning's n value in the vegetated downstream segment was raised to 0.025, which brought the deviation down to less than

0.05 m. Additionally, the contraction and expansion coefficients were adjusted to 0.3 and 0.8 in areas with geometric changes to make the flow velocity distribution more realistic.
Calibration was also performed for the minimum discharge scenario. Under existing conditions in September, the model results show an intake flow rate of 0.09 m^3/s. This value is close to the field measurement of 0.11 m^3/s, so the model is considered valid for use in evaluating other flow rate scenarios. For large discharges (Q50 flood), verification is done using peak flood data from hydrological analysis. The simulated water surface profile shows excellent agreement with the observed flood elevation within ±0.1 m, indicating that the model is suitable for use without further adjustments.
Overall, the calibration process resulted in a hydraulic model capable of accurately representing the conditions of the Cisangkuy River **(Rusmaldi and Hidayat, 2022).** The final Manning's n parameter ranged from 0.020 to 0.025, which is consistent with the physical condition of the river. The average error rate (mean absolute error) between the model results and field data is less than 5%, which is acceptable for technical analysis. With this calibration, discharge scenarios such as a weir with a 0.1 m open gate or two open gates during a Q50 flood can be evaluated with confidence that the simulation results are sufficiently representative of real-world conditions.

3.5 Evaluation of Hydraulic Modeling Scenarios

The results of the hydraulic modeling of the Cisangkuy River show variations in the performance of the weir under several flow scenarios, both in dry and flood conditions. Under existing dry season conditions, the flow that can enter the intake is only about 0.09 m^3/s, while the minimum needed by the water company is in the range of 0.7 m^3/s. The hydraulic characteristics of the flow at that time were dominated by supercritical conditions with a Froude number (Fr) > 1 and an average velocity above 3.5 m^3/s, causing most of the flow to pass through the intake without being utilized. The construction of a 1 m high weir with a crest width of 1.5 m has been proven to increase the inflow to the intake by up to 0.62 m^3/s, with more controlled flow velocity and an increase in upstream water surface elevation, causing the flow conditions to shift toward subcritical (Fr < 1). This conclusion indicates that the weir structure is effective in increasing water intake capacity during the dry season.
Next, the simulation during the dry season, when the weir is operated simultaneously with the release of water from the hydropower plant, the discharge to the intake surges to 5.23 m^3/s. However, the downstream flow decreased to 0.00 m^3/s, potentially causing ecological degradation and conflicts over water use. This condition is characterized by an excessively high water level upstream of the weir, resulting in a backwater effect. Backwater is the rate of flow being restrained due to obstructions, causing the water level upstream of the building to rise to a certain distance **(Daoed et al., 2023)** and an increase in specific energy that risks causing local scour around the structure. To address this, a scenario with a weir and a 0.1 m gate opening is proposed. Simulations show that the intake flow rate is in the range of 0.55 m^3/s, with the downstream flow rate remaining constant at 4.69 m^3/s. The flow characteristics under these conditions are stable, with a relatively uniform water surface profile and controlled flow velocity, making it the best compromise between meeting the water needs of the local water company and maintaining the sustainability of the river flow **Figs. 15 to 17.**

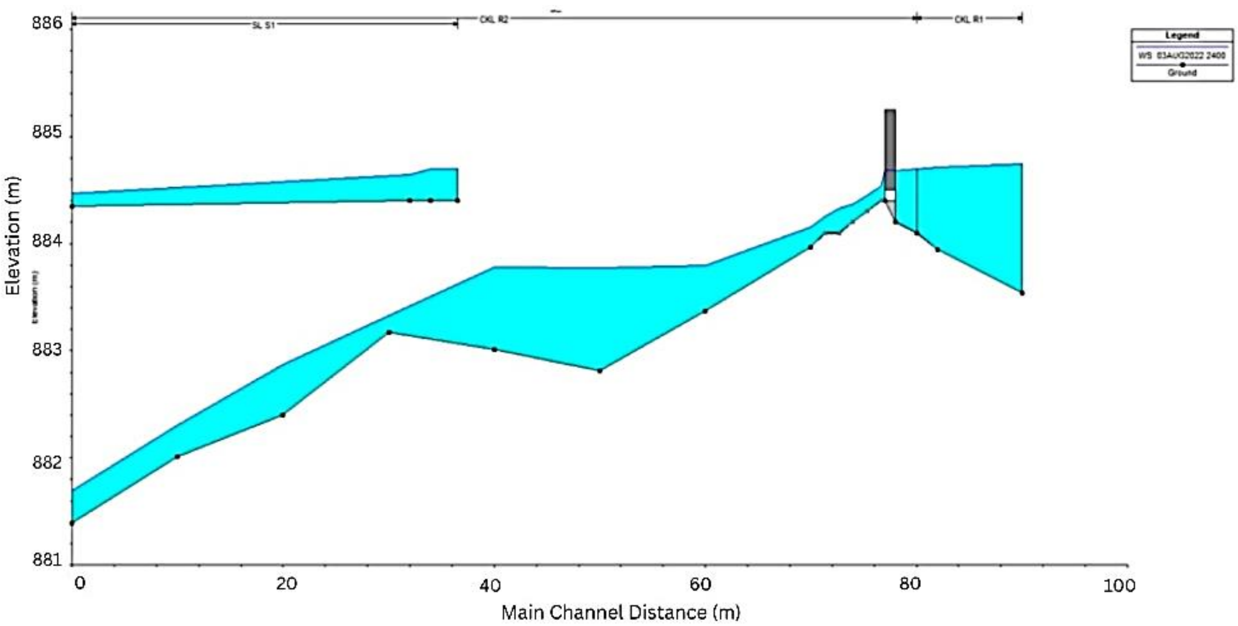


Figure 15. Flow conditions in a river with a weir and intake structure at minimum discharge (September) and the hydroelectric power plant operating with a gate opening of 0.1 m.

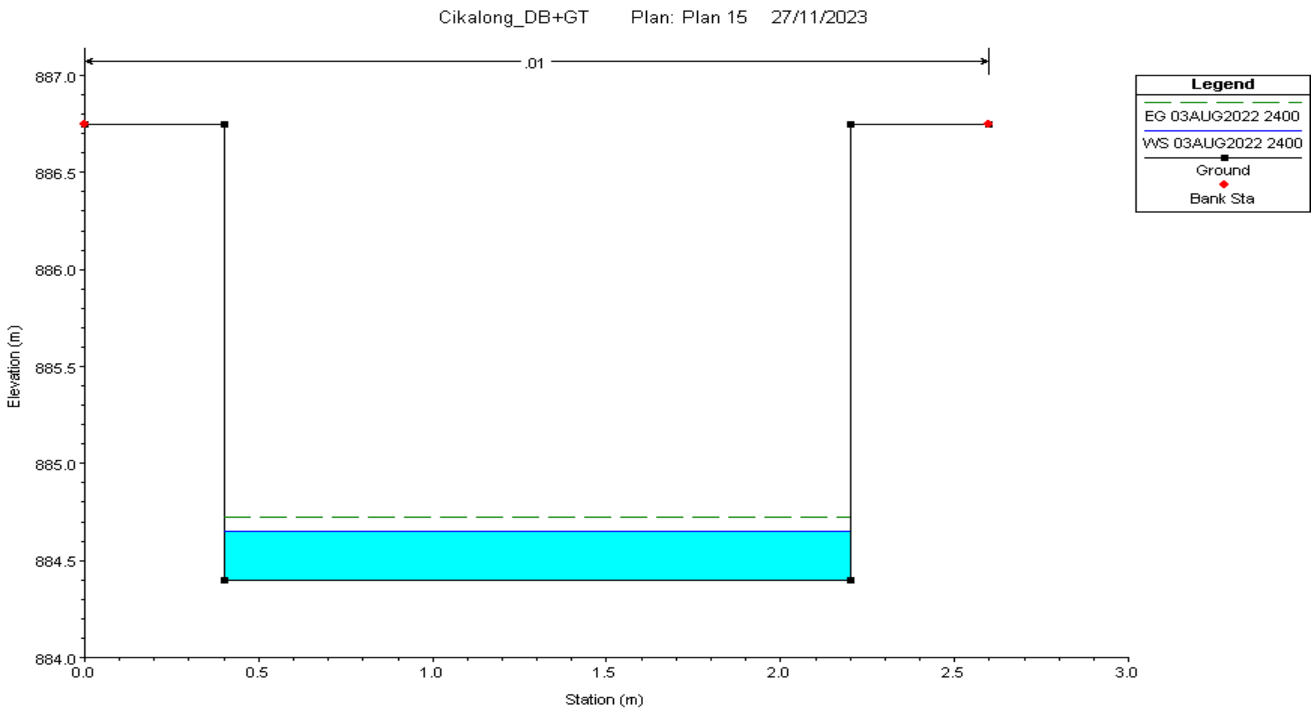


Figure 16. Flow Conditions at the channel intake during minimum discharge (September) with the addition of hydropower plant discharge when the weir gate is opened 0.1 m.

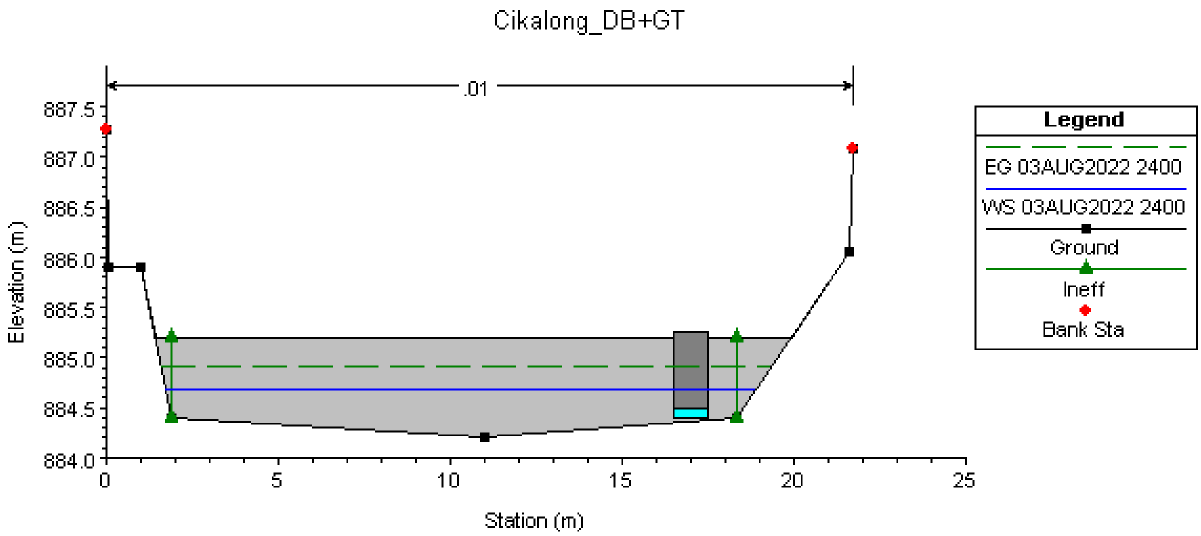


Figure 17. Flow Conditions at the weir during Minimum Discharge (September) with the addition of Hydropower Plant Discharge when the weir gates are opened 0.1 meters

Under flood discharge conditions with the gate closed, such as with a 50-year return period, the simulation results indicate that the flow entering the intake can reach 8.94 m3/s. The water level upstream rose above the peak of the hydropower plant (+885.5 m), potentially causing excessive lateral pressure and backwater phenomena **(Legowo and Fadhlillah, 2015)** . The flow in this condition tends to be subcritical with high specific energy, which, if not dampened, can result in a hydraulic jump downstream of the weir and increase the risk of riverbed erosion. However, when weir gates were opened, the water level was controlled, and the downstream discharge increased. The hydraulic conditions become more balanced, with flow energy dissipated through the stilling basin and the hydraulic jump concentrated in the area reinforced with energy dissipation structures.

Next, the simulation under flood discharge conditions, this boundary condition is given when the flood discharge in the Cisangkuy River starts from a 2-year flood discharge. In this condition, the focus is on the flood water surface elevation (MAB) behind the planned weir, which must not exceed the crest elevation of the existing PLTA weir at +885.5m. Below are the modeling results for the flood discharge condition without additional external PLTA discharge, with both closed and open gates **Figs. 18 and 19**.

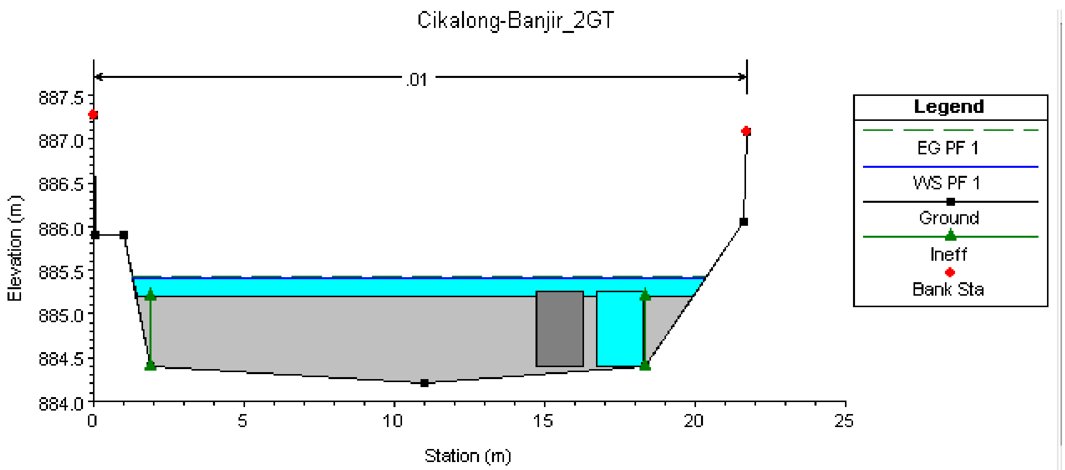


Figure 18. Flow Conditions in the weir Structure with a Single Gate Opening

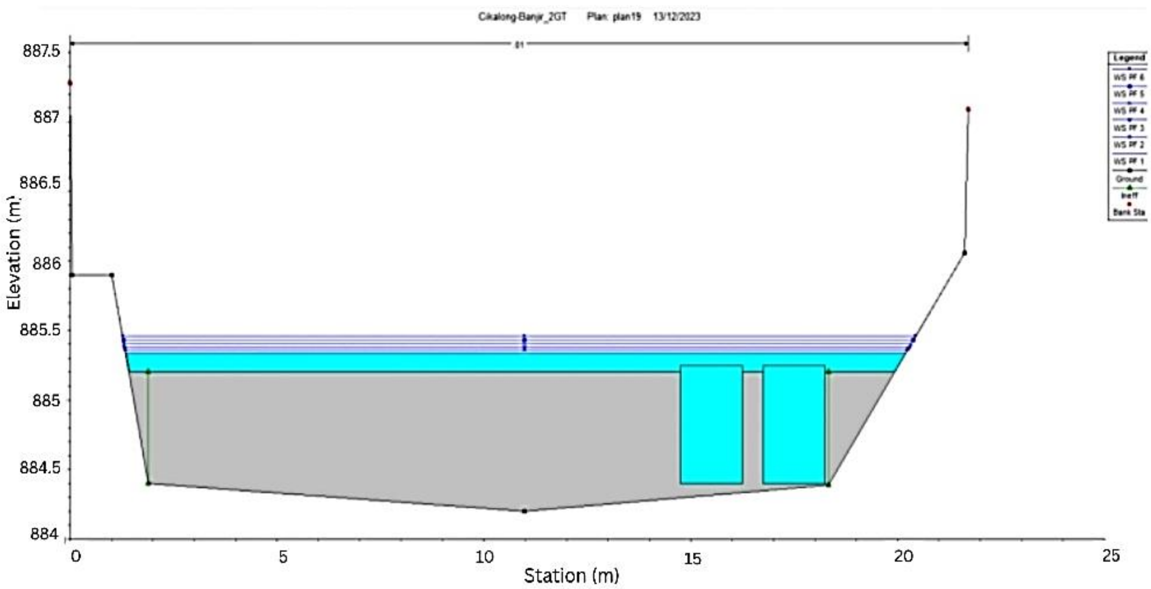


Figure 19. Flow Conditions in the weir Structure with 2 Gates Open

Table 4. Recapitulation of Water Level and Discharge at the Weir Location

Location of Return Period weir	Without weir gate		Full opening of 1 weir gate		Opening of 2 weir gates 0.5 m		Full opening of 2 weir gates	
	TMA (m)	Q (m^3/s)	TMA (m)	Q (m^3/s)	TMA (m)	Q (m^3/s)	TMA (m)	Q (m^3/s)
2	885.51	8.26	885.41	8.26	885.39	8.26	885.34	8.26
5	885.53	9.38	885.44	9.38	885.42	9.38	885.36	9.38
10	885.55	10.27	885.46	10.27	885.45	10.27	885.38	10.27
20	885.57	11.33	885.48	11.33	885.47	11.33	885.4	11.33
50	885.6	12.86	885.52	12.86	885.5	12.86	885.43	12.86
100	885.63	14.22	885.55	14.22	885.53	14.22	885.46	14.22

Table 5. Recapitulation of Water Level and Discharge at the Intake Location

Intake Location	Without weir gate		Full opening of 1 weir gate		Opening of 2 weir gates 0.5 m		Full opening of 2 weir gates	
Return Period	TMA (m)	Q (m^3/s)	TMA (m)	Q (m^3/s)	TMA (m)	Q (m^3/s)	TMA (m)	Q (m^3/s)
2	885.57	5.74	885.21	2.93	885.12	2.24	884.9	0.51
5	885.67	6.52	885.34	3.96	885.26	3.27	884.99	1.2
10	885.75	7.13	885.43	4.65	885.39	4.31	885.08	1.89
20	885.84	7.87	885.52	5.34	885.48	5	885.17	2.58
50	885.99	8.94	885.7	6.72	885.61	6.03	885.3	3.62
100	886.1	9.88	885.83	7.76	885.75	7.07	885.43	4.65

Recapitulation of Water Level and Discharge at the Intake Location. Overall, the evaluation of discharge scenarios shows that the weir with an adaptive gate system has the most stable hydraulic performance in the face of fluctuations in the Cisangkuy River discharge **(Sadan et al., 2025)**. During the dry season, the weir increases the intake discharge without disrupting downstream flow, while during the rainy season, the weir gates play a vital role in maintaining the water surface elevation below the critical threshold while reducing the risk of structural damage due to excessive flow energy. This confirms that regulating the weir's gate opening is a key factor in maintaining water supply continuity, hydraulic safety, and the sustainability of water resource management in the Cisangkuy Sub-watershed.

4. CONCLUSIONS

The hydraulic characteristics of the Cisangkuy River show high flow fluctuations, with minimum conditions during the dry season around 0.62 m^3/s and extreme flows of up to >24 m^3/s for a 100-year return period. Flow conditions are often supercritical, so weir design must consider flow stability and energy dissipation aspects. The optimal discharge to meet PDAM's needs can only be achieved through intervention in the weir structure. Under existing conditions, the intake discharge is very low (0.09 m^3/s), while PDAM's minimum requirement is 0.7 m^3/s. Simulations show that with a weir height of 1 m and a width of 1.5 m, the optimal condition during the dry season is an inflow rate of 0.62 m^3/s and no outflow. When the hydropower plant operates with a gate opening of 0.1 m, the inflow rate becomes 0.55 m^3/s, with an outflow of 4.69 m^3/s. The optimal wet season condition is achieved with a 2-5 year return period by opening 2 gates (each 1.5 m wide), which lowers the upstream water level below the weir crest elevation, with an inflow rate ranging from 0.51 to 1.20 m^3/s. Thus, the adaptive gate system at the weir is effective in maintaining the continuity of water supply and the safety of the structure under extreme conditions.

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Credit Authorship Contribution Statement

Raden Herdian Bayu Ash-Shiddiq: Supervision, Software, and Methodology. Nia Nuraeni Suryaman: Validation, Review, Editing, and Proofreading. Atry Maudyna: Writing the original draft

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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التحليل الهيدروليكي لخطة تطوير سد نهر سيسانغكوي لزيادة التدفق عند مدخل شركة المياه الإقليمية (PDAM)

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خلاصة

تم إجراء تحليل الخصائص الهيدروليكية لدعم خطة بناء سد نهر سيسانغكوي في منطقة محطة الطاقة الكهرومائية في سيكالونغ لتحسين تلبية احتياجات المياه الخام التي تدخل نظام المدخل لشركة المياه الإقليمية في جنوب باندونغ. المشكلة الرئيسية التي تواجهها هي تقلبات التدفق الموسمية وتدهور حوض النهر، مما يؤدي إلى أن يصل تدفق المدخل خلال موسم الجفاف إلى 0.09 م³/ثانية فقط، وهو أقل بكثير من الحد الأدنى المطلوب البالغ 0.7 م³/ثانية. تستخدم هذه الدراسة منهجية بحث تشمل جمع البيانات الهيدرولوجية، ومسح مقاطع النهر، والنمذجة الهيدروليكية باستخدام برنامج HEC HMS وHEC-RAS 1D الإصدار 6.3.1. تُظهر نتائج المحاكاة أن بناء سَد بارتفاع 1 متر وعرض 1.5 متر مع نظام بوابة سُدّ يمكن أن يزيد بشكل كبير من معدل تدفق المدخل. في الظروف الجافة، يصل معدل التدفق الأمثل إلى 0.62 م³/ثانية دون تدفق في الاتجاه السفلي، وإذا عملت محطة الطاقة الكهرومائية وتم فتح البوابة بمقدار 0.1 متر، ستكون ظروف تدفق المدخل 0.55 م³/ثانية مع تدفق في الاتجاه السفلي بمقدار 4.69 م³/ثانية . في موسم الأمطار، تتحقق الظروف المثلى بفترة عودة تتراوح بين 2-5 سنوات من خلال فتح بوابتين السد بالكامل بحيث لا يتجاوز ارتفاع سطح المياه ذروة محطة الطاقة الكهرومائية (+885.5 م) بتدفق داخلي يتراوح بين 0.51 و1.20 م³/ثانية . لقد أثبت دمج السد مع بوابات الصرف التكيفية فعاليته في ضمان استدامة إمدادات المياه الخام مع التخفيف من مخاطر الفيضانات.

الكلمات المفتاحية: نهر سيسانغكوي، HEC-RAS 1D، الهيدروليكيات، تصريف مياه الشرب، السد.