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# Flood Operation Pattern on Gated and Free-Flow Spillways of *Tiu Suntuk Dam*, West Sumbawa Regency

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**Abstract**
This study aims to assess the storage capacity and determine the effectiveness of gate operation in flood routing at *Tiu Suntuk Dam*. The analysis was conducted using the HEC-HMS hydrological model with a reservoir routing approach to simulate the relationship between inflow, outflow, and changes in reservoir water level (RWL) under various gate operation scenarios. The results from the supervision consultant indicate that the total storage capacity of the dam is 60.86 million m³, with an effective volume of 57.34 million m³ and a flood control storage of 13.51 million m³. Four gate operation scenarios were tested, combining fully open and closed conditions at initial water levels of +89.00 m (spillway gate sill) and +93.50 m (crest of the free-flow spillway). Additionally, an Early Warning System (EWS) with three alert levels (green, yellow, and red) has been established to anticipate emergency conditions. The best scenario was obtained under the closed-gate condition at RWL +89.00 m, achieving a 100% reduction in flood discharge for Q25 and maintaining dam safety against Q1000 (with a freeboard of 5.30 m). In contrast, the open-gate condition at RWL +93.50 m would result in downstream flooding, as the outflow discharge exceeds the bank full capacity; therefore, this scenario is not recommended for spillway gate operation. Overall, the study concludes that a well-planned gate operation system and an effective EWS can ensure dam safety and optimize its function as a flood control structure in the *Tiu Suntuk* watershed.
**Keywords:** *Tiu Suntuk Dam*, Flood Routing, Spillway Gate Operation, Early Warning System.

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## INTRODUCTION

Flood events in eastern Indonesia, including in *Taliwang* District, West Sumbawa Regency, West Nusa Tenggara Province, occur regularly with varying magnitudes almost every year. *Taliwang* serves as the capital city of West Sumbawa Regency and is traversed by the *Rea* River (*Rea* watershed), with a total river length of 65 km and a catchment area of 800 km². Historical flood records indicate that on December 3, 2000, flooding reached a depth of 3 meters in the city area and 2 meters near the river mouth. Similarly, on December 26–28, 2007, a major flood event inundated *Taliwang* City with water levels of up to 2 meters. Flooding in this region is attributed not only to forest degradation, but also to the confluence of two major rivers, *Brang Rea* and *Brang Ene*, in *Menala* Subdistrict; moreover, the topographic condition of *Taliwang* City, which lies between hills, further exacerbates flood risk (BWS Nusa Tenggara 1, 2021).

The Directorate General of Water Resources, Ministry of Public Works and Housing, through the *Nusa Tenggara* I River Basin Agency (BWS NT I), has constructed *Tiu Suntuk Dam*, located in *Mujahidin* Village, *Brang Ene* District, West Sumbawa Regency (Asdak, 2023). *Tiu Suntuk Dam*, with a total storage capacity of 59.06 million m³, was inaugurated by the President of the Republic of Indonesia, Mr. Joko Widodo, in 2024. *Tiu Suntuk Dam* is classified as a multipurpose dam, developed to provide a raw water supply of 68 liters/second, support irrigation for an area of 1,900 hectares, and control floods by reducing the Q25 peak discharge from 466 m³/second to 189 m³/second a reduction of 277 m³/second, or approximately 59% of the watershed inflow to the dam. The dam also has the potential to generate 0.81 MW of hydropower (*PLTM*) and serves as a facility for conservation, tourism, and inland fisheries (BWS Nusa Tenggara 1, 2023).

Flood control operation through dam construction is an effective method to reduce flood runoff and mitigate flood-related damages (Qin et al., 2010). The level of flood protection provided by a dam depends on several interrelated factors, including flood peak characteristics, reservoir storage capacity, and spillway operation. In many gated spillway cases, specific operational control is required to lower the reservoir water level (RWL) prior to a flood event, thereby providing additional storage capacity for flood detention. Accurate flood forecasting is therefore essential to optimize the utilization of flood control storage, whether below or above the normal reservoir water level (Darsono, 2015).

In general, flood operation of dams is still carried out using relatively simple methods, and coordination among dam operators remains limited (Pan et al., 2020). Reservoir management for flood control should also consider the urban areas downstream of the catchment that are potentially affected (Chen et al., 2020). Most reservoir operation planning and studies are based on simulation modelling, requiring well-defined specification of operating rules (Lund and Guzman, 1999). Practical real-time operation typically requires specific decision rules that govern water release and storage actions during simulation periods, supported by dam management personnel (Bower et al., 1962; Huschmidt and Fiering, 1966).

Previous research on dam operation for flood control has emphasized the importance of spillway gate operation strategies in determining flood routing outcomes. Studies by Darsono (2015) and Qin et al. (2010) highlight that gated spillways require specific operational rules to lower the RWL prior to flood events, thereby providing additional storage capacity for flood detention. However, most existing studies focus on theoretical or generalized operation models, with limited application to specific dam cases that incorporate both gated and free-flow spillways. Furthermore, while many dams in Indonesia have been constructed with flood control functions, detailed evaluations of gate operation scenarios under varying initial RWL conditions and their downstream impacts remain scarce. In the case of *Tiu Suntuk Dam*, preliminary design reports indicate that the spillway structure includes both free-flow and gated sections; however, no comprehensive analysis has been conducted to determine the most effective gate operation pattern for optimizing flood control while ensuring dam safety and minimizing downstream flood risk.

This study aims to address this research gap by evaluating the storage capacity and determining the most effective gate operation pattern for flood routing at *Tiu Suntuk Dam*. The novelty of this research lies in its integrated simulation approach using the HEC-HMS hydrological model to analyze multiple gate operation scenarios under varying initial RWL conditions, combined with an assessment of downstream channel capacity and the implementation of an Early Warning System (EWS). Unlike previous studies that often assume fixed operation rules, this research explicitly compares four distinct operation scenarios — varying gate status (open vs. closed) and initial water levels (+89.00 m and +93.50 m) — to identify the optimal strategy for flood control. Additionally, this study incorporates real-time operational considerations by linking flood routing results to the dam's EWS alert levels, providing practical recommendations for dam operators and relevant policymakers.

Considering the importance of flood operation rules on dam spillways particularly for gated dams this study presents a case analysis titled "Flood Operation Pattern on Gated and Free-Flow Spillways of *Tiu Suntuk Dam*." The objective of this study is to assess the storage capacity and determine the most effective gate operation pattern for flood routing at *Tiu Suntuk Dam*, in order to optimize its function as a flood control structure. The findings of this study are expected to serve as a reference for relevant agencies, particularly BWS *Nusa Tenggara* I, in managing the operation of *Tiu Suntuk Dam* for flood mitigation purposes.

## METHOD

Data collection for this study consists of several stages, including field surveys, literature reviews from various sources, and data analysis. The field survey serves as a preliminary investigation in the research process, conducted to obtain a comprehensive understanding of the study area and its physical conditions. The literature review aims to examine the theoretical foundations relevant to and supporting the implementation of this research. During this stage, an in-depth study of the research topic particularly regarding reservoir flood operation patterns was conducted to ensure that the final objectives of the research could be achieved. Secondary data were also collected from various institutional sources, as presented in Table 1.

**Table 1.** Secondary Data Sources

| No | Type of Data | Source |
|---|---|---|
| 1 | ARR Uthan Rea (2010–2020), ARR Seteluk (2010-2020), ARR Taliwang (2010-2020), and ARR Jereweh (2010-2020) data | BMKG & BWS NT-1 1 (2024) |
| 2 | Satellite rainfall data (GPM, 2001–2022) | https://giovanni. gsfc.nasa.gov/ giovanni/ |
| 3 | ARR and AWLR data from Bintang Bano & Tiu Suntuk (2023–2024) | BWS NT 1 (2024) |
| 4 | Data ARR dan AWLR Bintang Bano & Tiu Suntuk (2023-2024) | BWS NT 1 (2024) |
| 5 | Watershed (DAS) map of Rea and its characteristics | BWS NT I (2024) |
| 6 | Distribution map of hydro-climatological stations | BWS NT I (2024) |
| 7 | Land use map | Geospatial Information Agency (BIG, 2024) |
| 8 | Soil type map | http://www.fao.org/soils-portal/soil-survey/soil-maps anddatabases/ harmonized-world-soil-database-v12 |

**Study Area Location**

Administratively, *Tiu Suntuk Dam* is located in *Hijrah* Hamlet, *Mujahidin* Village, *Brang Ene* District, West Sumbawa Regency, West Nusa Tenggara Province. Geographically, the dam site is situated at 116.927° E longitude and 8.794° S latitude, approximately 30 km south of *Poto Tano* Port and about 12 km east of *Taliwang* City toward *Mujahidin* Village. The site is accessible by both two-wheeled and four-wheeled vehicles. Travel from *Poto Tano* Port to *Taliwang* City takes approximately 45 minutes, while the journey from *Taliwang* City to the dam site takes approximately 30 minutes.

The structural layout of *Tiu Suntuk Dam* is illustrated in Figure 1, which shows the locations of the main dam, the dam operation building, public facilities, and other associated structures.

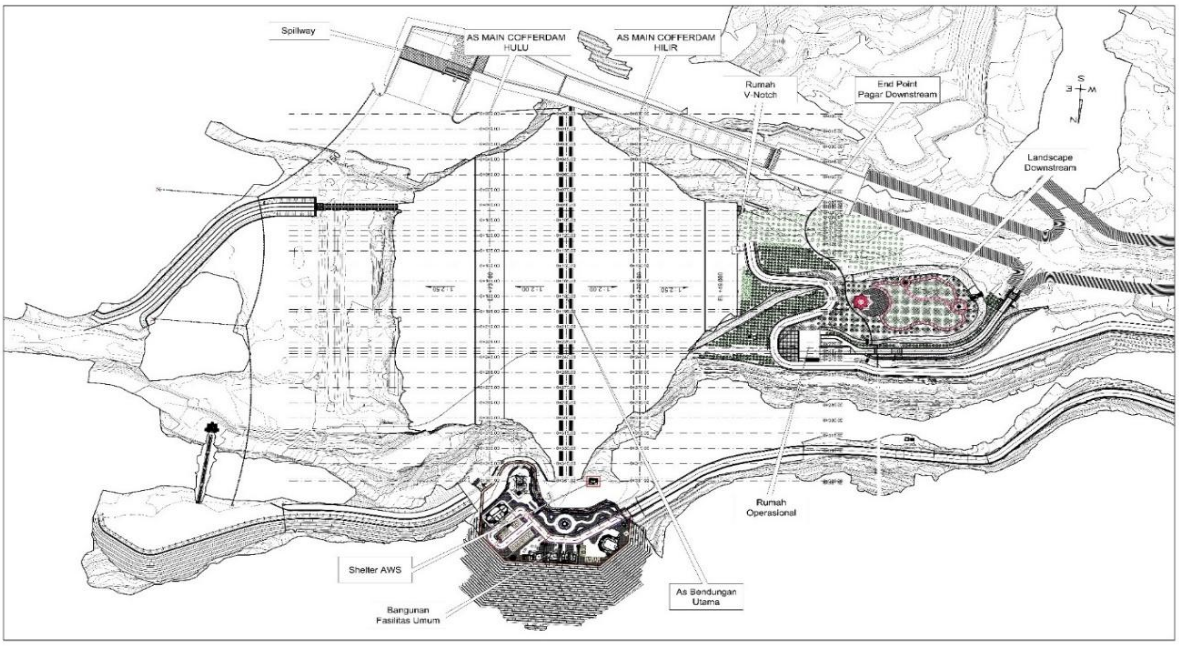


**Figure 1.** Layout of *Tiu Suntuk Dam*
Source: BWS NT1, 2023

**Data Analysis Method**

This research consists of five main stages: data identification and processing, rainfall–runoff modeling, reservoir flood routing, spillway gate operation simulation, and calibration and validation. The details of the method can be seen as follows:

1. Data Identification and Processing

The data used in this study include the following:

a) Hydrological data: Daily rainfall data from four manual stations and hourly rainfall data from Taliwang Station, as well as climatological data such as relative humidity, temperature, wind speed, and sunshine duration. These data sets were obtained from the Nusa Tenggara I River Basin Agency (BWS NT I).
b) Physiographic data of the watershed (DAS): Contour maps, soil types, and land use data were processed using ArcGIS 10.5 to produce sub-watershed boundary maps, Digital

Elevation Models (DEM), slope maps, and river length data. These datasets were sourced from the Geospatial Information Agency (BIG).

2. Flood Routing Analysis

Flood routing was conducted using the HEC-HMS model with the reservoir routing method to predict flood discharge and reservoir storage behavior. The model inputs included watershed characteristics (Curve Number, Initial Abstraction, Muskingum parameters), design rainfall, and physical dam characteristics. This stage aims to evaluate the reservoir's performance in reducing flood peaks and determining the water surface elevation corresponding to various design flood events.

3. Spillway Gate Operation Simulation

The gate operation simulation was carried out under several gate opening scenarios using the linear reservoir concept. The relationship between inflow, outflow, and storage volume in the reservoir is expressed as:

$$\frac{ds}{dt} = I\ (t) - O\ (t, S)$$

The outflow discharge is determined based on the type of spillway structure:

a) For ogee spillway:

$$Q = B.Cd.H_2^3$$

b) For sluice gate (vertical gate):

$$Q = Cd.w.B\ \sqrt{2}gh$$

where:

$Q$ : outflow discharge ($m^3/s$)
B : spillway width (m)
Cd : discharge coefficient
H : headwater energy height (m)
$w$ : gate opening height (m)
g : gravitational acceleration ($m/s^2$)

Each simulation scenario was tested for various return periods by considering the minimum required freeboard, spillway capacity, and the potential impacts of climate variability on gate operation patterns.

## RESULTS AND DISCUSSION

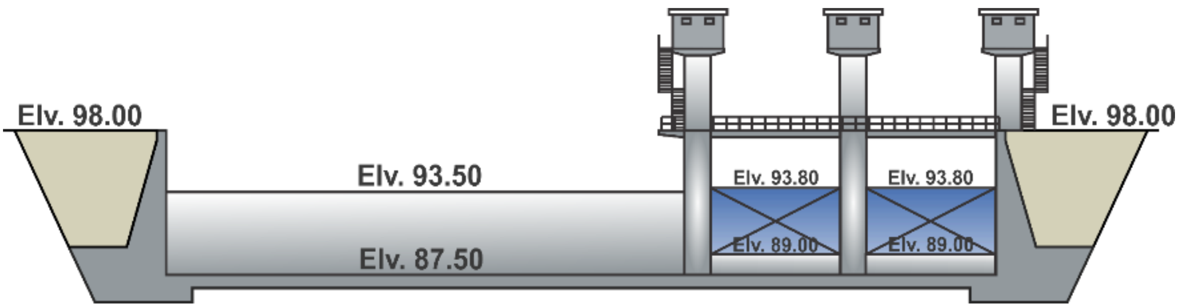


**Figure 2.** Sketch of the Spillway Structure of *Tiu Suntuk Dam*
(Source: BWS NT 1,2023)

In terms of flood control, the *Tiu Suntuk Dam* is designed to manage floods with a return period of 25 years (Q25). The spillway structure of *Tiu Suntuk Dam* has the following Figure 2. specifications:

a. Type : Side spillway with both free overflow and gated spillway sections
b. Free overflow width : 40.00 m
c. Free overflow crest elevation : +93.50 m
d. Type of gated spillway : Sluice gate
e. Gate dimensions : 2 units × 10.00 m (width) × 4.80 m (height)
f. Gate sill elevation : +89.00 m

Maximum gate opening height: 4.80 m

The main reservoir storage characteristics are as follows:

a. Crest elevation : +98.00 m
b. Spillway crest elevation : +93.50 m
c. Gate sill elevation : +89.00 m
d. Intake elevation : +62.00 m
e. Normal storage volume : 60.86 million m³
f. Dead storage volume : 3.52 million m³
g. Effective storage volume : 57.34 million m³
h. Flood control storage : 13.51 million m³ (between normal water level and gate sill elevation)

**Design Flood Discharge**

The design flood discharge based on the following calculation result as shown in Figure 3 and the following Table 2:

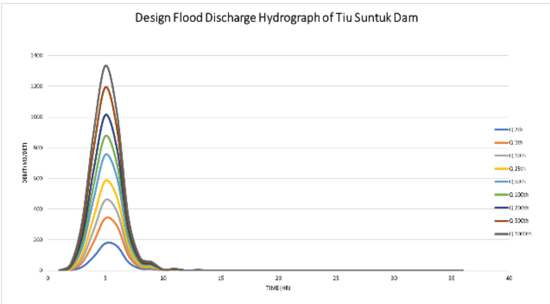


**Figure 3.** Design Flood Discharge Hydrograph of *Tiu Suntuk Dam*
Source: Data analysis results (2023)

**Table 2.** Design Flood Discharge Calculation of *Tiu Suntuk Dam*

| No | Hours | Return Period | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $Q_{2th}$ | $Q_{5th}$ | $Q_{10th}$ | $Q_{25th}$ | $Q_{50th}$ | $Q_{100th}$ | $Q_{200th}$ | $Q_{500th}$ | $Q_{1000th}$ |
| 1 | 00:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 01:00 | 2.40 | 5.70 | 9.00 | 12.90 | 19.00 | 23.80 | 29.40 | 37.30 | 43.80 |
| 3 | 02:00 | 23.10 | 52.20 | 77.70 | 107.50 | 151.50 | 185.60 | 224.90 | 279.40 | 323.20 |
| 4 | 03:00 | 90.00 | 188.60 | 265.80 | 350.70 | 471.00 | 561.00 | 662.20 | 799.70 | 908.10 |
| 5 | 04:00 | **175.80** | **340.30** | **458.90** | **583.80** | **753.70** | **877.00** | **1012.90** | **1193.30** | **1333.00** |
| 6 | 05:00 | 158.40 | 290.90 | 383.20 | 478.40 | 605.60 | 696.60 | 796.00 | 926.50 | 1026.70 |
| 7 | 06:00 | 53.30 | 97.10 | 127.70 | 159.40 | 202.00 | 232.60 | 266.00 | 310.10 | 344.00 |
| 8 | 07:00 | 12.00 | 23.00 | 30.70 | 38.70 | 49.40 | 57.00 | 65.30 | 76.30 | 84.70 |
| 9 | 08:00 | 9.10 | 16.10 | 21.00 | 26.00 | 32.80 | 37.70 | 43.10 | 50.20 | 55.70 |
| 10 | 09:00 | 0.90 | 1.80 | 2.40 | 3.10 | 4.00 | 4.60 | 5.30 | 6.20 | 6.90 |
| 11 | 10:00 | 1.90 | 3.20 | 4.10 | 5.00 | 6.30 | 7.20 | 8.20 | 9.50 | 10.60 |
| 12 | 11:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13 | 12:00 | 0.50 | 0.80 | 1.00 | 1.30 | 1.60 | 1.80 | 2.10 | 2.40 | 2.70 |
| 14 | 13:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 14:00 | 0.20 | 0.30 | 0.40 | 0.50 | 0.70 | 0.80 | 0.90 | 1.00 | 1.10 |
| 16 | 15:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 17 | 16:00 | 0.10 | 0.10 | 0.20 | 0.20 | 0.30 | 0.30 | 0.40 | 0.40 | 0.50 |
| 18 | 17:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 19 | 18:00 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.20 | 0.20 | 0.20 |
| 20 | 19:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21 | 20:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| 22 | 21:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 | 22:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24 | 23:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 25 | 00:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 26 | 01:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 27 | 02:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 28 | 03:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 29 | 04:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 30 | 05:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 31 | 06:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 32 | 07:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 33 | 08:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 34 | 09:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 35 | 10:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 36 | 11:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 37 | 12:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 38 | 13:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 39 | 14:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 40 | 15:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 41 | 16:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 42 | 17:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 43 | 18:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 44 | 19:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 45 | 20:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 46 | 21:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 47 | 22:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 48 | 23:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **Max** | **175.80** | **340.30** | **458.90** | **583.80** | **753.70** | **877.00** | **1012.90** | **1193.30** | **1333.00** |

Source: Data analysis results (2023)

The calculation results indicate an increase in peak discharge corresponding to the increase in rainfall return period, with the highest discharge occurring under the Q1000 period condition, reaching 1,333.00 $m^3/s$.

### *Tiu Suntuk Dam* Capacity

1. Reservoir Capacity

The relationship between elevation, inundation area, and storage volume shows that the total storage capacity of *Tiu Suntuk Dam* is 60.85 million $m^3$, with an effective storage of 57.33 million $m^3$ and a flood control capacity of 13.51 million $m^3$. As shown in Figure 4, this capacity from *Tiu Suntuk Dam* is considered sufficient to accommodate runoff from design floods up to the Q1000 event.

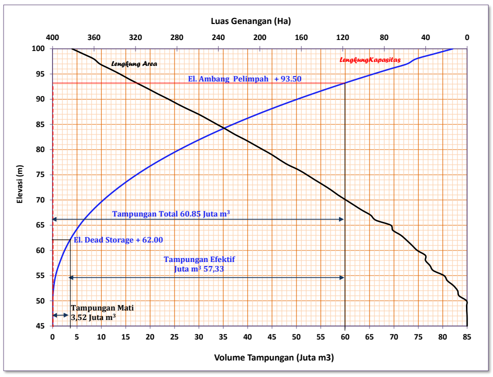


**Figure 4.** Storage Capacity Curve of *Tiu Suntuk Dam*
(Source: BWS NT 1, 2023)

2. Free Overflow Spillway Capacity

The free overflow spillway has a crest width of 40 meters at an elevation of +93.50 m. Based on the routing curve analysis as shown in Figure 5, the maximum capacity of this spillway is sufficient to safely pass design floods up to the Q100 return period. However, under Probable Maximum Flood (PMF) conditions, its capacity is insufficient without additional discharge from the gated spillway operation.

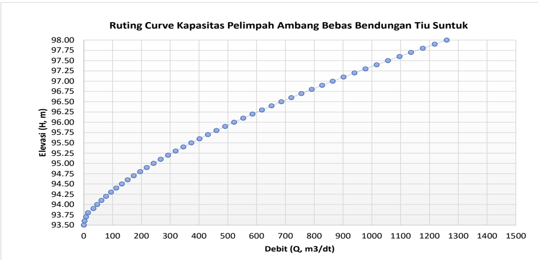


**Figure 5.** Routing Curve of the Free Overflow Spillway of *Tiu Suntuk Dam*
(Source: BWS NT 1, 2023)

3. Gated Spillway Capacity

The gated spillway (sluice gate) consists of two units, each measuring 10 × 4.8 meters. The routing curve analysis as shown in Figure 6, indicates that with optimal gate operation, the gated spillway can effectively lower the reservoir water level and discharge large flood inflows without causing overtopping.

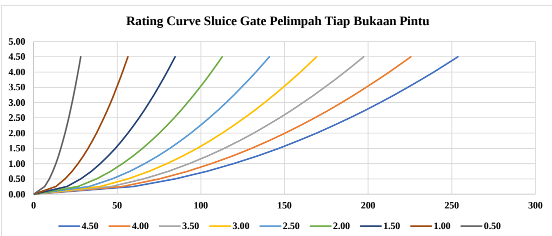


**Figure 6.** Routing Curve of the Free Overflow Spillway of *Tiu Suntuk Dam*
(source: BWS NT 1, 2023)

**Spillway Gate Operation Scenarios**

The dam operation pattern was analyzed through four simulation scenarios by varying the initial reservoir water level (RWL) and spillway gate conditions.

1. Scenario 1 – Fully Open-Gate (Initial RWL +89,00 m)

Flood routing results (Fully Open-Gate, RWL +89.00 m /gate sill elevation):

a) Flood reduction for Q25: 94,88%
b) For Q1000, Reservoir Water Level (RWL): +92.40 m, freeboard: 5.60 m (safe)

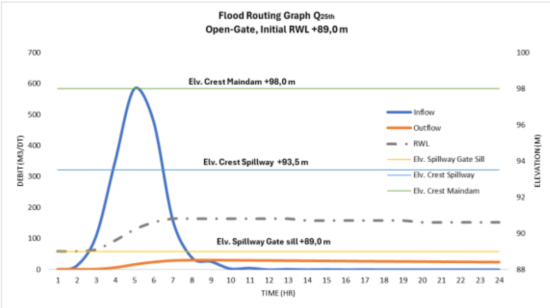


**Figure 7.** Flood Routing Graph Q25 Fully Open-Gate (Initial RWL +89.00 – Gate Sill)
Source: Data analysis results (2023)

At Q25 graph in Figure 7, the inflow discharge is 583.80 m³/s, outflow 29.90 m³/s, and flood reduction 533.90 m³/s (94.88%), with RWL elevation +94.00 m.

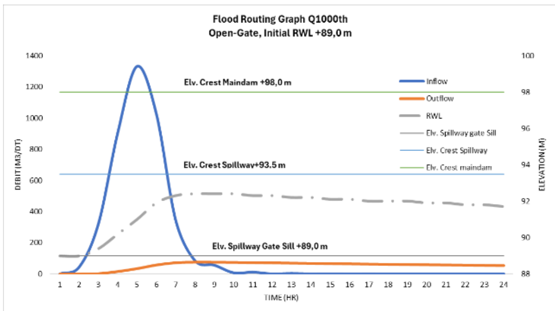


**Figure 8.** Flood Routing Graph Q1000 Fully Open-Gate (Initial MAW +89.00 – Gate Sill)
Source: Data analysis results (2023)

At Q1000 in Figure 8, the inflow discharge is 1,333.00 m³/s, outflow 75.70 m³/s, and flood reduction 1,257.30 m³/s (94.32%), with RWL elevation +92.40 m. This scenario is considered safe.

2. Scenario 2 – Closed Gate (Initial RWL +89,00 m)

- Flood reduction for Q25: 100% (no outflow)
- For Q1000, RWL: +92.70 m (safe),

freeboard: 5.30 m (safe)

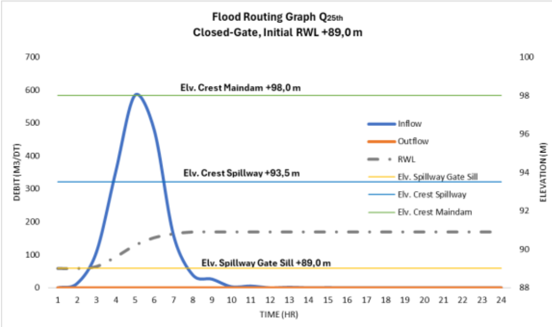


**Figure 9.** Flood Routing Graph Q25 Closed-Gate (Initial RWL +89.00 – Gate Sill)
Source: Data analysis results (2023)

At Q25 in Figure 9, the inflow discharge is 583.80 m³/s, outflow 0.00 m³/s, and flood reduction 583.80 m³/s (100%), with RWL elevation +90.90 m.

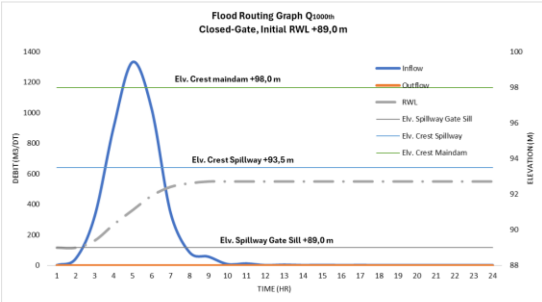


**Figure 10.** Flood Routing Graph Q1000 Closed-Gate (Initial RWL +89.00 – Gate Sill)
Source: Data analysis results (2023)

At Q1000 in Figure 10, the inflow discharge is 1,333.00 m³/s, outflow 0.00 m³/s, and flood reduction 1,333.00 m³/s (100%), with RWL elevation +92.70 m and freeboard 5.30 m, exceeding the minimum requirement of 0.75 m for an ungated spillway. This scenario is the most effective in reducing high flood discharges while maintaining dam safety.

4. Scenario 3 – Fully Open Gate (Initial RWL +93,50 m)
   - Flood reduction for Q25: 36.28%
   - For Q1000, RWL: +92.40 m (safe),
   freeboard: 5.60 m (safe)

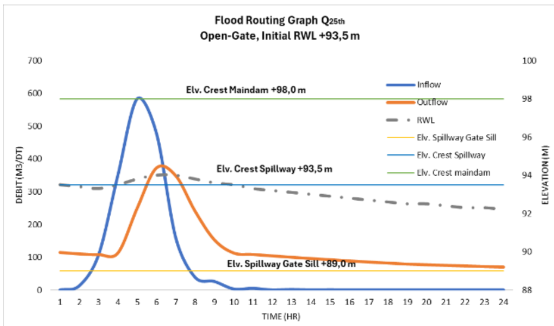


**Figure 11.** Flood Routing Graph Q25 Fully Open-Gate (RWL +93.50 – Crest Spillway)

Source: Data analysis results (2023)

At Q25 in Figure 11, the inflow discharge is 583.80 m³/s, outflow 372.00 m³/s, and flood reduction 211.80 m³/s (36.28%), with RWL elevation +90.80 m.

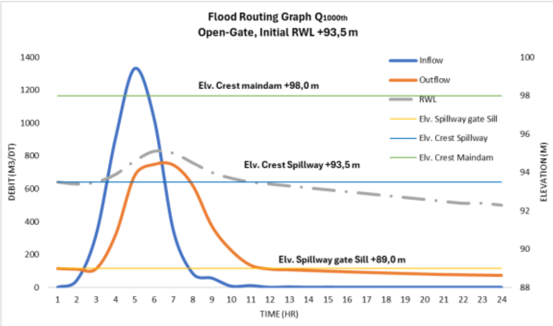


**Figure 12.** Flood Routing Graph Q1000
Fully Open-Gate (RWL +93.50 – Crest Spillway)
Source: Data analysis results (2023)

From the graph in Figure 12, at Q1000, the inflow discharge is 1,333.00 m³/s, while the outflow discharge reaches 749.70 m³/s, resulting in a flood reduction of 583.30 m³/s (43.76% of the watershed inflow area). The reservoir water level (RWL) reaches +92.40 m, leaving a freeboard of 5.60 m, which is greater than the minimum requirement of 1.25 m for gated spillways.

This scenario will be flooding downstream of the dam due to the outflow discharge greater than bank full capacity so this scenario is not recommended for use in spillway gate operation.

5. Scenario 4 – Closed Gate (Initial MAW +93,50 m)
   - Flood reduction for Q25: 92.75%
   - Q1000: (RWL) +96.40 m (safe),
   freeboard: 1.60 m (safe)

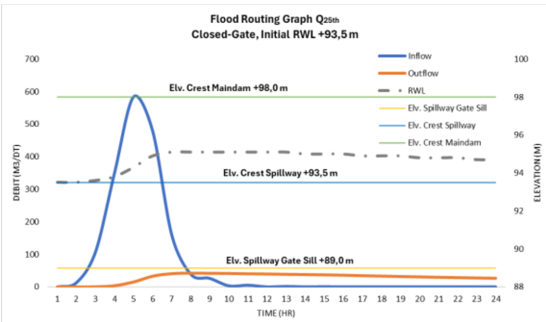


**Figure 13. Flood Routing Graph Q25**
**Closed Gate (RWL +93.50 – Spillway Crest)**
Source: Data analysis results (2023)

At Q25 in Figure 13, the inflow discharge is 583.80 m³/s, outflow discharge 42.30 m³/s, resulting in a flood reduction of 541.50 m³/s (92.75%), with the reservoir water level reaching +95.10 m.

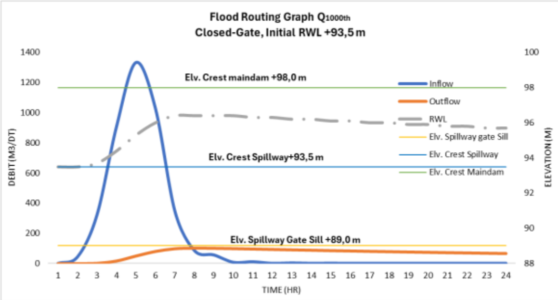


**Figure 14.** Flood Routing Graph Q1000
Closed Gate (RWL +93.50 – Spillway Crest)
Source: Data analysis results (2023)

At Q1000 in Figure 14, the inflow discharge is 1,333.00 m³/s, outflow 100.10 m³/s, resulting in a flood reduction of 1,232.90 m³/s (92.49%), and RWL elevation +96.40 m. This scenario is considered safe.

**Emergency Operation Pattern**

Under emergency conditions, *Tiu Suntuk Dam* implements an Early Warning System (EWS) to alert downstream communities.

The warning system applies three alert levels to ensure clear communication and coordinated response:

a. Green Alert: Normal condition, routine monitoring.
b. Yellow Alert: Moderate risk, warning issued to increase vigilance.
c. Red Alert: Critical condition, evacuation procedures activated.

Information dissemination is carried out via sirens, warning lights, radio announcements, mobile loudspeakers, and coordination with local authorities (district and village officials) as shown in Criteria for flood alert level and command procedures at Table 3.

**Table 3.** Criteria for Flood Alert Levels and Command Procedures

| The level of danger | Guard Height (freeboard) (m) | Time Interval for Monitoring Debit/TMA | Reporting Address | Reporting Duration |
|---|---|---|---|---|
| Red alert | < 0,80 | 15 minutes | Governor, Department of Water Resources, SATLAK PBP District/City, SATKORLAK Province | Every 30 minutes |
| Yellow alert | 0,80 - 1,20 | 2 hours | Department of Water Resources, SATLAK PBP District/City, SATKORLAK Province | Every 8 hours |
| Green alert | > 1,20 - 1,50 | 4 hours | Department of Water Resources, SATLAK PBP District/City, SATKORLAK Province | Every 1 hour |

| | | | | |
|---|---|---|---|---|
| Blue alert | > 1,50 | Normal | Normal | Normal |

source: BWS NT 1, 2023

Water level reduction can be performed via the spillway gates, from the crest elevation (+93.50 m) down to the gate sill elevation (+89.00 m). If further lowering is required, discharge can be conducted through the emergency hollow jet valves (DN500 and DN900) installed in the intake outlet system.

**Table 4.** Reservoir Water Level (RWL) Rise and Corresponding Conditions

| Reservoir Water Level (MAW) (m) | Water Height Above Overflow (H) (m) | Spillover Output Discharge (Qout) ($m^3$/dt) | Conditional Status | Descriptions |
|---|---|---|---|---|
| 93.50 | 0.00 | 0.00 | NORMAL | Operasi normal sesuai dengan Manual OP |
| 93.75 | 0.25 | 13.00 | | |
| 94.00 | 0.50 | 36.77 | | |
| 94.25 | 0.75 | 67.55 | | |
| 94.50 | 1.00 | 104.00 | | |
| 94.75 | 1.25 | 145.34 | | |
| 95.00 | 1.50 | 191.06 | | |
| 95.25 | 1.75 | 240.76 | | |
| 95.50 | 2.00 | 294.16 | WASPADA 1 | Kapasitas maksimum palung sungai di hilir terlampaui (Q > 300 $m^3$/dt) |
| 95.75 | 2.25 | 351.00 | | |
| 96.00 | 2.50 | 414.10 | | |
| 96.25 | 2.75 | 474.28 | | |
| 96.50 | 3.00 | 540.40 | WASPADA 2 | Diperkirakan terjadi banjir 1/2 PMF (Q > 500 $m^3$/dt) |
| 96.75 | 3.25 | 609.34 | | |
| 97.00 | 3.50 | 680.98 | | |
| 97.25 | 3.75 | 755.23 | SIAGA | Diperkirakan terjadi banjir Q1000 (Q > 700 $m^3$/dt) |
| 97.50 | 4.00 | 832.00 | | |
| 97.75 | 4.25 | 911.21 | AWAS | Diperkirakan telah terjadi banjir PMF (Fb < 0.75) (Q > 1000 $m^3$/dt) |
| 98.00 | 4.50 | 992.78 | | |

Source: Data analysis results (2023)

## CONCLUSION

Based on the results of the analysis of the flood capacity and flood routing of the *Tiu Suntuk Dam* in four overflow gate operation scenarios, it can be concluded that the initial condition of the reservoir water level (RWL) and the status of the gate have a great influence on the effectiveness of flood control and dam safety. Scenario 2 with closed door conditions at the initial RWL +89.00 m shows the best performance as it is able to reduce flooding by up to 100% both at Q25 discharge and remain safe against extreme Q1000 discharge, with the remaining 5.30 m freeboard still far above the required minimum limit. On the other hand, Scenario 3 with open door conditions at RWL +93.50 m results in an outflow that exceeds the capacity of the river channel (bank full capacity), so that it has the potential to cause flooding in the downstream area and is considered not suitable for overflow gate operations. Thus, the operation of overflow gates in closed conditions at low reservoir water levels is the most optimal alternative in flood control efforts and ensuring the safety of the *Tiu Suntuk.*

## REFERENCES

Asdak, C. (2023). *Hidrologi dan pengelolaan daerah aliran sungai*. Ugm Press.

Badan Standardisasi Nasional. (2016). SNI 2415:2016 - Tata Cara Perhitungan Debit Banjir Rencana. Jakarta.

Balai Wilayah Sungai Nusa Tenggara I. (2023). Laporan Akhir Pelaksanaan Konstruksi Bendungan Tiu Suntuk di Kabupaten Sumbawa Barat. Mataram.

Balai Wilayah Sungai Nusa Tenggara I. (2023). Laporan Penunjang Material Timbunan Pelaksanaan Konstruksi Bendungan Tiu Suntuk di Kabupaten Sumbawa Barat. Mataram.

Chen, J., Pan, Z., & Teng, X. (2020). A multi-objective risk management model for real-time flood control optimal operation of a parallel reservoir system. Journal of Hydrology, 590, 125264. https://doi.org/10.1016/j.jhydrol.2020.125264

Darsono, S. L. W. (2015). Waduk Pengendali Banjir (Flood Control Reservoir). Retrieved from https://bebasbanjir2025.wordpress.com/teknologi-pengendalian-banjir/waduk-pengendali-banjir/

Dinas Pekerjaan Umum Kabupaten Sumbawa Barat. (2018). Laporan Akhir Sertifikasi Desain Bendungan Tiu Suntuk di Kabupaten Sumbawa Barat. Taliwang.

Dinas Pekerjaan Umum Kabupaten Sumbawa Barat. (2018). Laporan Spesifikasi Teknik Sertifikasi Desain Bendungan Tiu Suntuk di Kabupaten Sumbawa Barat. Taliwang.

J. Li et al. (2019). Multi-objective optimization for flood control operation in multi-reservoir systems. *Water Resources Research*, 55(1), 1-16. https://doi.org/10.1029/2018WR023631

Kementerian Pekerjaan Umum dan Perumahan Rakyat. (2015). Peraturan Menteri PUPR No. 27/PRT/2015 tentang Bendungan. Jakarta.

Kementerian Pekerjaan Umum dan Perumahan Rakyat. (2017). Modul Operasi Waduk Pelatihan Alokasi Air. Pusat Pendidikan dan Pelatihan Sumber Daya Air dan Konstruksi.

L. Zhang et al. (2018). Optimization of flood control reservoir operation using multi-objective evolutionary algorithms. *Water Resources Management*, 32(10), 4459-4475. https://doi.org/10.1007/s11269-018-2032-3

Pan, Z., Chen, L., & Teng, X. (2020). Research on joint flood control operation rule of parallel reservoir group based on aggregation–decomposition method. Journal of Hydrology, 590, 125479. https://doi.org/10.1016/j.jhydrol.2020.125479

Peraturan Pemerintah Nomor 37 Tahun 2012. (2012). Pengelolaan Daerah Aliran Sungai. Jakarta.

Qin, H., Li, W., Liu, P., & Cheng, C. (2010). Multi-objective cultured differential evolution for generating optimal trade-offs in reservoir flood control operation. Water Resources Management, 24(11), 2611–2632. https://doi.org/10.1007/s11269-009-9570-7

R. Liu et al. (2020). Research on flood control strategy of cascade reservoirs based on system dynamics model. *Journal of Hydrology*, 590, 125441. https://doi.org/10.1016/j.jhydrol.2020.125441

Soemarto, C. D. (1995). Hidrologi Teknik. Jakarta: Erlangga.

Sosrodarsono, S., & Tekeda, K. (1981). Bendungan Tipe Urugan. Jakarta: Pradnya Paramita.

Sosrodarsono, S., & Kensaku, T. (2003). Hidrologi untuk Pengairan. Jakarta: Pradnya Paramita.

Triatmodjo, B. (2008). Hidrologi Terapan. Yogyakarta: Beta Offset.

X. Wang et al. (2021). Optimal flood control reservoir operation model for joint decision-making in a multi-reservoir system. *Environmental Modelling & Software*, 142, 105099. https://doi.org/10.1016/j.envsoft.2021.105099