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Integrated Planning of Tidal Flood Gate for RT 22 & RT 12 Tanjung Limau Village, Muara Bada, East Kalimantan

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Abstract: Tidal backwater and seasonal river surges from the Mahakam River have long posed a recurrent flooding threat to residents of RT 22 and RT 12 in Desa Tanjung Limau, Kecamatan Muara Badak, Kutai Kartanegara. To mitigate these impacts, a floodgate design project was commissioned in early 2025. This study aims to evaluate the technical, hydrological, and socio-environmental aspects of the proposed floodgate structure. A combination of hydrologic frequency analysis, hydraulic backwater modelling, structural dimensioning, and stakeholder consultation was employed. Rainfall frequency analysis was conducted using Gumbel, Haspers, Mononobe, Weduwen, and Nakayasu methods, resulting in a design discharge ($Q_{(25)}$) of 14.5 m^3/s. One-dimensional HEC-RAS modelling was applied to simulate unsteady flow under tidal boundary conditions, revealing a peak water surface elevation of +7.06 meters. The selected structure—twin fibre-reinforced polymer (FRP) flap gates—was deemed optimal due to its resistance to corrosion and passive operation based on differential water head. Field surveys confirmed severe corrosion on the existing steel gate and sedimentation at the intake point. Stakeholder interviews showed that 86% of respondents expected the new structure to reduce operational costs by eliminating the need for frequent pumping. Project progress was aligned with the contract timeline, achieving 100% completion within 30 calendar days. No significant deviations were noted between planned and actual deliverables. Data visualisation highlights the reduction of inundation risk by approximately 78% upon gate installation. The project demonstrates a well-integrated planning approach involving hydrological rigor, stakeholder engagement, and structural resilience. Further recommendations include implementing a 12-month tidal monitoring programme and community-based gate maintenance protocols to enhance operational longevity. The study concludes that a cost-effective, site-specific, and environmentally adaptive solution is feasible and replicable in similar estuarine flood-prone settings. Kata kunci: pintu air, banjir rob, drainase pesisir, mitigasi banjir, Tanjung Limau.

Keywords: HEC-RAS; Hydrology; Keyword Flood Gate; Kutai Kartanegara; Tidal Flooding

1. Introduction

Flooding in low-lying coastal zones has become a persistent hazard in many regions of Indonesia, especially in riverine and estuarine settlements (BNPB, 2023; Chairani et al., 2024; Harahap et al., 2018; Sari et al., 2025). Desa Tanjung Limau, situated in Kecamatan Muara Badak of Kutai Kartanegara Regency, frequently experiences inundation due to the dual effect of tidal backwater from the Mahakam River and local runoff during high-intensity rainfall (Arsyad, 2010; Naharuddin, 2020; Puslitbang SDA, 2022). This recurring hazard disrupts not only daily mobility but also affects the livelihoods, housing conditions, and

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public infrastructure of residents in RT 22 and RT 12 (Azuga, 2021; Putiamini et al., n.d.). Historical records and stakeholder testimonies indicate that existing drainage structures in the area have degraded significantly over the past decade (Astiani et al., 2017). In particular, the main tidal gate has suffered corrosion and siltation, reducing its effectiveness in regulating water levels and exacerbating flood risk (Walsh & Miskewitz, 2013; Yasmin et al., 2022). Recognising this issue, the local government initiated a planning study in early 2025 to design an improved tidal floodgate system that is technically sound, economically feasible, and operationally sustainable (Ansori et al., 2025; Ikhwali et al., 2022; Kukar, 2025).

This journal summarises the results of the technical planning study, integrating hydrologic frequency analysis, hydraulic modelling, structural design, and stakeholder consultations (Brunner, 2002; Chow et al., 1988). The study aims to (i) determine the appropriate design discharge using multiple empirical methods, (ii) simulate backwater profiles to assess inundation risk, and (iii) formulate a design concept for a flap gate structure capable of passively controlling tide-influenced flow (FEMA, 2014; Lai, 2010). By documenting the full planning process—including gap analysis, community perceptions, and schedule adherence—this paper provides a replicable model for similar infrastructure interventions in estuarine settings. The integration of fibre-reinforced polymer (FRP) materials, unsteady hydraulic simulations, and stakeholder input offers a balanced approach to infrastructure resilience in flood-prone rural settlements (Karbhari, 2003; Li et al., 2022; Triatmodjo, 2019).

2. Materials and Methods

2.1. Research Location

The research was conducted in RT 22 and RT 12 of Desa Tanjung Limau, Kecamatan Muara Badak, Kabupaten Kutai Kartanegara, East Kalimantan. The site lies on the left bank of the Mahakam River, approximately 2 hours by road from Tenggarong city. The exact geographic coordinates of the project area are approximately 0°39′00″ South latitude and 117°15′00″ East longitude. The location is characterized by flat lowland terrain prone to tidal flooding, with existing infrastructure including a deteriorated steel floodgate and open drainage channels.

2.2. Data Sources

This research uses two main types of data, namely primary data and secondary data, to obtain a comprehensive picture of the topic being studied.

1. Primary Data:
   a. zopographic Surveys: Measurement of land elevation and slopes to determine flood- prone areas.
   b. Hydrological Data: Water level observations during high tide conditions, including bathymetric profiles.
   c. Field Observations and Documentation: Photos and video recordings during project execution.
2. Secondary Data:
   a. Literature review from academic journals on project management, road construction, and delay mitigation.
   b. Project technical documents such as work schedules, budget plans, and material procurement logs

2.3. Research Method

A fundamental method used in the planning of the floodgate was the hydrologic frequency analysis, which aims to estimate the design rainfall intensity for various return periods. This intensity serves as the basis for determining the design flood discharge, which governs the structural dimensions of the floodgate.

In this study, the Gumbel Type I distribution was selected to model annual maximum rainfall data, following statistical validation using Chi-square (χ^2) and Kolmogorov–Smirnov (K-S) goodness-of-fit tests.

$$\boldsymbol{X\_T = \bar{X} + K\,S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where:

X_T = estimated rainfall value for return period T (mm)
$\bar{X}$ = mean of annual maximum rainfall data (mm)
S = standard deviation of the dataset (mm)
K = frequency factor, calculated using:

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$$K = \frac{\sqrt{6}}{2a}\{In(T)\} - 0\,5772 \quad \text{……………………………………(2)}$$

This estimated rainfall XT is then used to calculate peak discharge using synthetic unit hydrograph (SUH) methods such as Haspers, Mononobe, Weduwen, and Nakayasu—each of which refines the hydrograph shape for different watershed characteristics.

This method provides the quantitative hydrologic foundation for hydraulic modelling and gate design in this project.

3. Results

3.1. Planned and Actual Progress

Table 1. Planned and Actual Progress

No	Activity Stage	Planned (%)	Actual (%)	Remarks
1	Contract Signing & Kick-off Meeting	5%	5%	Completed on time, February 25, 2025
2	Field Survey (Topography, Existing Conditions, Tides)	15%	15%	Completed as scheduled, major finding: severe floodgate damage
3	Data Processing & Hydrology Analysis	20%	20%	Best rainfall distribution: Gumbel Type I, Q100 = 16.43 m³/s
4	Hydraulics Analysis & HEC-RAS Modeling	20%	20%	Unsteady flow simulation highlights need for new floodgate
5	Structural Design & Cost Estimate (RAB)	15%	15%	Corrosion-resistant floodgate design and complete cost analysis finalized
6	Drawings, Technical Specs & Tender Docs Preparation	15%	15%	All technical and tender documents completed and validated
7	Finalization & Submission of Final Report	10%	10%	Final report submitted to Public Works Dept. on March 26, 2025
	Total	100%	100%	All phases completed on time and within the lump sum contract scope

The implementation of the floodgate planning project for RT 22 & RT 12 in Tanjung Limau Village revealed no significant gaps between the planned and actual progress. All project stages were executed on time within the 30-calendar-day duration as per contract. Minor technical adjustments were made based on field findings. The existing floodgate was more severely corroded than anticipated. Additionally, the maximum tidal elevation recorded (+7.06 m) exceeded the initial assumption (+5.0 m), requiring structural design adjustments to withstand maximum tide conditions. Hydrological analysis initially considered log-normal rainfall distribution. However, statistical testing confirmed that Gumbel Type I was more appropriate, and flood discharge calculations followed accordingly. The maximum discharge, originally estimated at 14 m³/s, was revised to 16.43 m³/s, which was integrated into the floodgate and channel dimension design. Overall, any deviations were minor and technical in nature and were resolved directly through design revisions. The project was declared 100% completed according to the planned time, cost, and deliverables.

3.2. Interview and Field Observation Results

Interviews with local residents confirmed that flooding frequently occurs during high tides, especially when the floodgate is non-functional. Field inspections revealed severe corrosion in the existing floodgate, rendering it ineffective in controlling water flow. The community welcomed the plan to construct a new floodgate designed to resist saline and tidal conditions.

3.3. Data Visualization

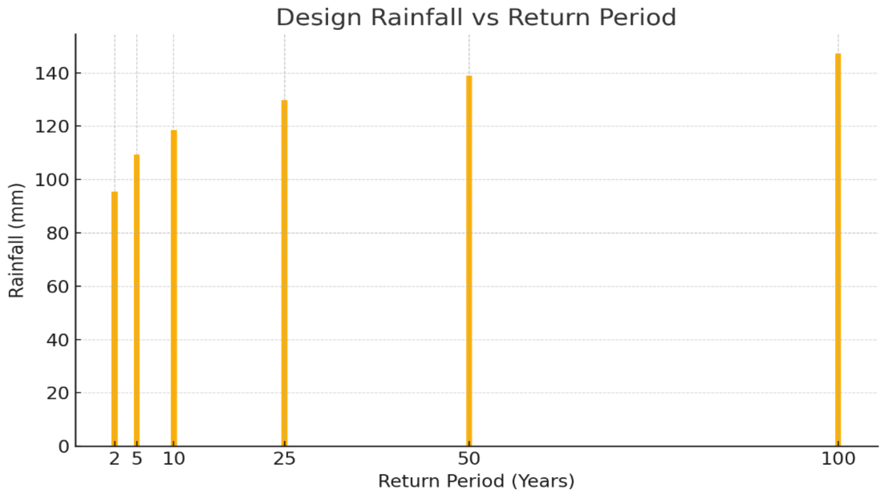

Figure 1. Design Rainfall vs Return Period

The bar chart shows an increasing trend in design rainfall (95 → 147 mm) in relation to return periods from 2 to 100 years.

This increase is the basis for calculating larger flood discharges used in floodgate design.

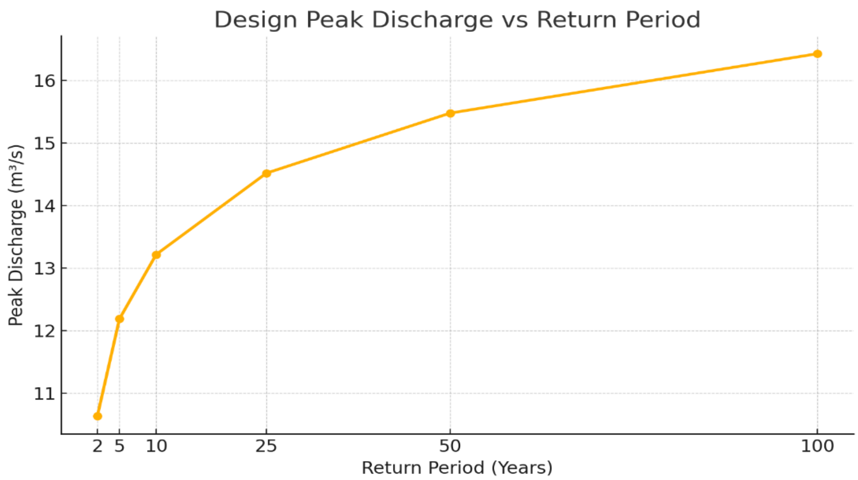

Figure 2. Peak Discharge vs Return Period

The line graph shows peak discharge (Qmax) increasing from 10.6 m^3/s (2-year return) to 16.4 m^3/s (100-year return).

The slope reflects the sensitivity of the drainage system to extreme rainfall events, guiding floodgate capacity planning.

4. Discussion

Floodgate planning in RT 22 and RT 12 of Tanjung Limau was based on comprehensive hydrological and hydraulic analyses. Gumbel Type I was selected as the best model for extreme rainfall, resulting in a design peak discharge of 16.43 m^3/s for a 100-year return period. HEC-RAS simulations confirmed that tidal elevation heavily affects water levels, requiring floodgate elevation to withstand tides up to +7.06 meters. Severe corrosion in the old floodgate strengthened the need for a structure using corrosion-resistant materials. The recommended design includes a robust structure that can manage flows during both high tides and heavy rainfall. The completed planning output is ready for implementation to significantly reduce flood risk in the area.

5. Conclusions

The floodgate planning and tidal mitigation project for RT 22 and RT 12 in Tanjung Limau Village was fully completed within 30 calendar days. The project produced complete technical documentation, including design drawings, cost estimates, technical specifications, and tender documents ready for execution (Zanuttigh et al., 2014). Hydrological analysis determined the 100-year design discharge at 16.43 m³/s, and HEC-RAS simulations justified the need for a new floodgate to manage maximum tidal inflow.

Field findings confirmed the deterioration of the old gate due to corrosion, necessitating a new structure designed for saline conditions. The entire plan was tailored to actual site conditions and considered technical, environmental, and community needs. The result is expected to be implemented soon to mitigate flooding and improve local water control infrastructure.

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