

Drainage Planning for the Bojong Gede Underpass

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ABSTRACT

Underpasses are commonly used to reduce congestion caused by level crossings, but their position below ground elevation creates a significant risk of water accumulation, making drainage planning a critical component. This study presents the drainage system design for an underpass located approximately 675 meters from Bojong Gede Station toward Jakarta. The design flood discharge was calculated based on SNI 2415:2016, including the determination of design rainfall, rainfall intensity, composite runoff coefficient, and peak discharge estimation. With a catchment area of 30,000 m², a composite runoff coefficient, and a 2-year design rainfall of 126.3 mm, the resulting design flood discharge is 0.792 m³/s. The drainage system utilizes a sump pit and pumps. Analysis shows that the sump pit would reach full capacity in approximately two hours without pumping, requiring six pumps with a capacity of 135 L/s per unit to ensure the underpass remains operational without flooding. This design can serve as a reference for similar underpass drainage planning in urban areas with comparable flood risk.

Keywords: Bojong Gede, drainage, hydrology, rainfall, underpass, discharge.

INTRODUCTION

The increase in the number of vehicles and transportation activities in urban areas has driven the need for more efficient and integrated road infrastructure. One widely implemented solution to reduce traffic conflicts at level crossings between roads and railway lines is the construction of underpasses. However, due to their position being lower than the ground surface, underpass structures are highly vulnerable to flooding, especially during periods of intense rainfall [4][14]. This condition necessitates the implementation of a carefully engineered and optimally designed drainage system that can anticipate both surface runoff and stormwater accumulation [10][13].

Inadequate drainage in underpasses can lead to significant safety, economic, and operational consequences. Ahmad emphasized that an efficient drainage system is crucial in urban areas to prevent waterlogging that can disrupt daily community activities [1]. Furthermore, Sitorus highlighted that the application of appropriate technology in drainage systems can reduce the duration of flooding by up to 90%, underscoring the importance of data- and technology-driven approaches in drainage infrastructure planning [11]. Supporting this, Ardiansyah et al. and Waskita have demonstrated that integrating hydrological simulation models, such as SWMM, with pump and sump pit designs can significantly enhance drainage performance in underpass areas [2][15].

Such conditions are also evident along Jalan Raya Bojong Gede, Bojong Gede District, Bogor Regency, an area with multiple functions including transportation, commercial, and residential uses. This location frequently experiences flooding due to a suboptimal drainage system and insufficient runoff capacity. Moreover, the local government has planned the construction of an underpass at the level crossing on Jalan Raya Bojong Gede intersecting the railway line. This project aims to alleviate traffic congestion caused by the closing of railway crossing gates. However, without proper drainage planning, the underpass is at high risk of recurring flooding events during the rainy season [7][9].

Previous studies also highlight that the inclusion of underground infrastructure, such as underpasses, within urban flood modeling is crucial to assess the complete hydrodynamic behavior of urban stormwater [7]. Innovative systems such as Sustainable Urban Drainage Systems (SUDS) with infiltration capability have also been proposed to mitigate runoff volume and improve climate resilience [8].

Considering the hydrological characteristics, land use, and rainfall intensity in the study area, this research is crucial for formulating an appropriate drainage system plan. The planning is expected not only to address local issues but also to serve as a reference for similar infrastructure projects in other urban areas facing comparable challenges, such as those in Beaumont, Texas (Beaumont Enterprise), where flooding at underpasses has led to reevaluation of drainage designs by public agencies [3].

Based on the background above, there exists a gap between the need for safe and functional underpass infrastructure and the presence of a drainage system capable of anticipating potential flooding. This issue falls within the field of civil engineering, particularly hydrology and hydraulics, and must be analyzed using a scientific, data-informed approach to ensure that the proposed solutions are both applicable and sustainable.

This study aims to:

1. Analyze maximum rainfall and design flood discharge using appropriate statistical distribution methods at the study site.
2. Design a drainage system comprising channels, sump basins, and pumps capable of mitigating the flooding potential in the Bojong Gede underpass.

RESEARCH METHODS

This study employs a descriptive quantitative research design with a case study approach centered on the planned underpass location along Jalan Raya Bojong Gede, Bogor Regency. The case study method is chosen to allow an in-depth, site-specific investigation of hydrological and hydraulic conditions that influence the drainage system performance. This approach ensures that the analysis and design outputs are directly aligned with the actual characteristics and constraints of the project area, as suggested by Creswell [6].

The research utilizes two categories of data, obtained through systematic collection processes:

1. **Primary Data**
Primary data are gathered through direct field investigations conducted at the underpass development site. These activities include detailed observations of existing ground conditions, measurement of channel bed elevations, identification of the natural drainage pathways, and assessment of surrounding land use. As outlined by Suripin, tools such as handheld GPS devices, leveling equipment, and laser distance meters are employed to determine topographic variations, slope gradients, and spatial dimensions [12]. Additional observations related to sediment deposition, standing water, and the condition of adjacent infrastructure provide contextual insight that supports the drainage design process.
2. **Secondary Data**
Secondary data consist of historical hydrometeorological records and project-related technical documents. Daily maximum rainfall data spanning the last ten years are sourced from the West Java Climatology Station to support rainfall statistical analysis. Supplementary engineering drawings, topographic maps, and design specifications are obtained from WIKA–MCM KSO, the contractor responsible for the underpass construction. These documents supply essential information on planned roadway elevations, structural layouts, and construction constraints that influence the drainage system configuration.

The analytical framework of this study is organized into two major stages hydrological analysis and hydraulic analysis, each designed to systematically transform raw climatic and site-condition data into a complete, technically reliable drainage design for the planned underpass at Jalan Raya Bojong Gede. These two stages are applied sequentially but interpreted integratively to ensure that the resulting design not only meets theoretical requirements but is also feasible under actual field conditions.

1. **Hydrological Analysis**
The hydrological analysis constitutes the foundation of the entire drainage planning process, as it provides the design flood discharge that determines the required capacity of every downstream component. In this stage, rainfall data with a minimum record length of ten years are processed to capture temporal variability and extreme events. The analysis begins with

the derivation of areal rainfall using the Arithmetic Mean method, which is appropriate due to the spatial distribution of rainfall gauges and the moderate relief of the Bojong Gede area. To obtain the design rainfall, frequency analysis is conducted using several statistical probability distributions including Normal, Gumbel, and Log-Pearson Type III to identify the most representative model for extreme rainfall prediction. Each distribution is evaluated using Chi-Square and Smirnov–Kolmogorov goodness-of-fit tests to ensure statistical validity. The selected distribution is then used to compute rainfall intensity for various durations using the Mononobe method, which incorporates 24-hour maximum rainfall data and the time of concentration (t_c) calculated based on catchment length, slope, surface roughness, and flow regime.

The calculation of design discharge (Q) is performed using the Rational Method. The runoff coefficient (C) is determined as a composite value reflecting the heterogeneous land cover within the catchment, including paved road sections, residential areas, and semi-pervious surfaces. The catchment area (A) is delineated from field surveys and verified using topographic maps and existing drainage patterns. This hydrological stage ultimately yields the peak runoff discharge, which becomes the primary input for all hydraulic computations.

2. Hydraulic Analysis

The hydraulic analysis translates the hydrological outputs into the physical dimensions and operational requirements of the planned drainage infrastructure. This stage evaluates the flow capacity of channels, pipes, and storage components using hydraulic principles to ensure the system can safely convey peak discharges without causing backflow or surface flooding. The sizing of open channels and conduits is performed using the Manning equation, with roughness coefficients selected based on material type, expected flow conditions, and field verification of existing drainage textures.

For the underpass section, where gravity flow is insufficient due to the depressed roadway profile, a sump pit system is designed as a temporary stormwater containment structure. The sump volume is computed by comparing inflow hydrographs with the designed pumping rate, ensuring that water can be stored safely during intense rainfall. Pump capacity is selected based on required discharge, operational head, redundancy considerations, and energy efficiency, ensuring continuous drainage even under near-maximum inflow conditions.

3. Hydraulic simulation results are used to refine channel dimensions, sump depth, and pump specifications. The integration of both hydrological and hydraulic outcomes allows the drainage system to be evaluated under multiple design rainfall scenarios, ensuring that the final layout and structural dimensions are robust, technically sound, and appropriate for the hydrological characteristics of the Bojong Gede underpass location.

Both stages are integrated to simulate drainage behavior under design rainfall events, with results informing the final drainage layout and dimensions appropriate for the planned underpass location.

Hydrological Analysis

The hydrological analysis was conducted to determine the design flood discharge for the underpass drainage system. Historical rainfall data spanning a minimum of 10 years were obtained from the West Java Climatology Station. Areal rainfall was determined using the Arithmetic Mean method, suitable for the study area's relatively flat topography and gauge distribution.

To estimate the design rainfall, frequency analysis was performed using Normal, Gumbel, and Log-Pearson Type III distributions. The goodness-of-fit for each distribution was evaluated using the Chi-Square and Smirnov–Kolmogorov tests. The selected distribution was then used to calculate rainfall intensity via the Mononobe method, utilizing 24-hour maximum rainfall data and the calculated time of concentration (t_c).

The peak design discharge (Q) was estimated using the Rational Method ($Q = 0.278 C I A$). The runoff coefficient (C) was derived as a composite value, accounting for varied land cover including road surfaces and surrounding settlements.

Hydraulic Design

The hydraulic design focused on sizing the drainage channels and the sump pit system to handle the calculated peak discharge. According to Chow, channel dimensions were determined using Manning's equation to ensure adequate flow capacity based on channel slope and roughness coefficients [15].

For stormwater management within the underpass, a sump pit was designed to function as a temporary storage basin. The sump volume was calculated to accommodate the inflow volume during peak events relative to the pumping rate. The pump capacity was then determined to ensure efficient dewatering and prevent overflow, adhering to safety standards for critical infrastructure.

Implementation Stages

1. Literature Review
This stage involves an extensive review of references related to hydrology, hydraulics, and urban drainage engineering. The review includes national standards such as SNI 8196:2015 and SNI 2415:2016, previous studies on underpass drainage systems, rainfall statistical analysis methods, and technical guidelines on pump and sump pit design. The purpose of this stage is to establish a strong theoretical foundation, understand commonly applied methodologies, and identify relevant parameters for designing an effective drainage system for the Bojong Gede underpass.
2. Field Survey
The field survey focuses on collecting primary data required for the analysis and design process. Activities include measuring topographic elevation differences, identifying channel slopes, assessing the land use conditions within the catchment area, and documenting the existing drainage infrastructure. Observations also include the potential flow paths during rainfall events, soil characteristics affecting infiltration, and available space for sump pit and pump installation. The field data serve as essential input to ensure that the system design reflects actual site conditions.
3. Analysis and Calculation
This stage comprises a series of technical analyses based on hydrological and hydraulic principles. Hydrological analysis includes determining design rainfall intensity using statistical distribution methods, calculating time of concentration, and estimating the design flood discharge using the Rational Method. Hydraulic analysis covers the sizing of drainage channels, evaluation of flow capacity, determination of sump pit storage volume, pump sizing and quantity requirements, and operational performance under peak rainfall scenarios. The calculations integrate field survey results and standard design criteria to ensure accurate and reliable outputs.
4. Design Planning
The final stage involves translating analytical results into detailed engineering plans. Technical drawings are prepared to illustrate the configuration of the drainage channels, sump pit geometry, pump layout, and overall site drainage system. This stage also includes specifying construction materials, defining maintenance access, and validating the design against safety and operational requirements. The design planning ensures that the proposed drainage system can be implemented effectively in the field and function optimally throughout the underpass's service life.

The construction of retaining walls in drainage channels requires careful consideration of hydraulic, geotechnical, and structural factors to ensure stability, durability, and effective water flow. First, soil conditions must be investigated to determine bearing capacity, soil pressure, groundwater levels, and the potential for settlement. Second, the wall must be designed to resist lateral earth pressure, hydrostatic pressure, surcharge loads, and possible impacts from flowing water or debris. Adequate drainage provisions, such as weep holes, filter layers, and drainage pipes, should be installed where appropriate to prevent excessive water pressure behind the wall [16]-[18].

The foundation must be placed on stable soil with sufficient depth and bearing capacity to prevent sliding, overturning, and excessive settlement. Materials, including concrete, reinforcement steel, and masonry, must meet applicable technical standards. Proper excavation, formwork,

reinforcement placement, concrete mixing, compaction, and curing are essential for construction quality. Furthermore, channel dimensions, longitudinal slope, flow velocity, and sedimentation potential must be considered to maintain hydraulic capacity and minimize erosion and scour. Finally, regular inspection and maintenance are necessary to identify cracks, leakage, displacement, and blockages, ensuring long-term safety and functionality [19]-[21].

RESULTS AND DISCUSSION

Analysis Results of Pedestrian Facilities

Rainfall Data and Averages

To determine the design flood discharge accurately, reliable hydrological data is paramount. For this study, the primary dataset consists of daily maximum rainfall records acquired from the West Java Climatology Station, located in Bogor City. The data selection was based on the station's proximity to the Bojong Gede Underpass site, ensuring that the recorded precipitation patterns accurately reflect the actual meteorological conditions of the catchment area.

The dataset spans a continuous period of 33 years, ranging from 1992 to 2024. This duration significantly exceeds the minimum requirement of 10 years typically mandated by the Indonesian National Standard (SNI) for hydrological analysis (SNI 2415:2016). By utilizing a longer time series ($n = 33$), the potential for standard error in estimating return period values is minimized, providing a robust statistical foundation for the subsequent frequency analysis. This long-term data is critical for capturing the cyclical nature of extreme weather events in the region.

Preliminary statistical analysis of the dataset indicates an arithmetic mean ($\bar{X}$) of annual maximum rainfall of 126.32 mm. This high average value confirms that the study area is situated within a region characterized by high-intensity tropical rainfall. The fluctuation of rainfall values over these three decades highlights the variability of the local climate and the necessity of performing rigorous probability distribution tests to predict future extreme events. The complete chronological record of the annual maximum rainfall utilized in this analysis is presented in Table 1 below

Table 1. Daily Maximum Rainfall Data for 1992-2024

No	Year	CH (mm)
1	1992	112.20
2	1993	176.30
...	...	...
33	2024	146.60

Source: West Java Climatology Station Bogor City, 2025.

Distribution Analysis

To identify the most accurate probability model for predicting extreme rainfall events, a rigorous statistical analysis was conducted. While initial screening involved calculating statistical moments such as the Mean ($\bar{X}$), Standard Deviation (S), Coefficient of Variation (C_v), Skewness (C_s), and Kurtosis (C_k), the final selection relied on quantitative Goodness-of-Fit tests. Two primary distribution models were subjected to detailed verification: the Log-Pearson Type III and the Gumbel distribution.

The suitability of these distributions was evaluated using two standard non-parametric tests: the Chi-Square (χ^2) Test and the Smirnov-Kolmogorov Test. The Chi-Square test assesses the deviation between the observed frequency of rainfall data and the theoretical frequency expected under the distribution model. Meanwhile, the Smirnov-Kolmogorov test evaluates the maximum vertical deviation (D) between the empirical and theoretical cumulative distribution functions. The tests were conducted at a 5% significance level ($\alpha=0.05$), which corresponds to a critical Chi-Square value (χ^2_{cr}) of 9.488 and a critical Smirnov-Kolmogorov deviation (D_{cr}) of 0.214.

The comparative results of these tests are summarized in Table 2. The analysis reveals a distinct difference in performance between the two models:

1. Log-Pearson Type III: This distribution failed to meet the acceptance criteria. As shown in Table 2, the calculated Chi-Square value is 10.06, which exceeds the critical limit of 9.488

(10.06 > 9.488). This indicates a significant discrepancy between the model and the historical data, rendering it unsuitable for this specific catchment area.

2. Gumbel Distribution: Conversely, the Gumbel method demonstrated a superior fit. The calculated Chi-Square value is 3.27, which is well below the critical threshold (3.27 < 9.488). Although the Smirnov-Kolmogorov values for both distributions were high, the Gumbel distribution consistently showed lower deviation metrics compared to Log-Pearson Type III. Consequently, based on the "Remarks" conclusive assessment in Table 2, the Gumbel distribution is accepted as "Applicable" and is adopted as the basis for calculating the design rainfall intensity (I) and subsequent flood discharge in this study.

Table 2. Distribution Test Results

Distribution	Log Pearson Type III	Gumbel
Chi-Square	10.06>9.488	3.27<9.488
Smirnov-Kolmogorov	1.061>0.214	0.953>0.214
Remarks	Not applicable	Applicable

Source: Calculation results

Design Rainfall Intensity Analysis

Following the statistical validation of the probability distributions, the Gumbel method was adopted to project the design rainfall depths (R_{24}) for various return periods. This step is critical in ensuring the infrastructure's resilience against extreme weather events that have a specific probability of occurrence.

Table 3 presents the calculated rainfall depths for return periods ranging from 2 to 100 years. The analysis indicates a consistent positive correlation between the return period and rainfall depth. For the purpose of the drainage channel design, the 2-year return period was selected as the design standard, yielding a rainfall depth of 123.00 mm. However, to ensure the safety of the pumping system under more severe conditions, the 5-year and 10-year return periods (146.00 mm and 162.00 mm, respectively) were also considered as stress-test scenarios. This multi-tier approach ensures that the underpass remains operational during standard storm events while maintaining structural integrity during rare, high-intensity storms.

Table 3. Planned Rainfall Based on Gumbel and Log Pearson III

Return Period (years)	Log Pearson Type III (mm)	Gumbel (mm)
2	124.00	123.00
5	145.00	146.00
10	158.00	162.00
25	172.00	182.00
50	182.00	197.00
100	191.00	211.00

Sumber: Calculation results.

Underpass Drainage System Concept

The geometric configuration of the planned underpass creates a topographic depression significantly lower than the adjacent road network. Consequently, the structure functions as a natural collection point (sink) for surface runoff, creating a high risk of water accumulation. To mitigate this, the drainage system is designed as a hybrid configuration combining gravity flow for surface collection and mechanical pumping for final evacuation. The system comprises closed rectangular channels (u-ditch) to convey water rapidly to the lowest point, a collection sump pit, and a submersible pump array to lift the water to the external drainage network.

Catchment Area and Flow Coefficient

The hydrological load entering the system is determined by the characteristics of the catchment area. The total contributing area (A) is identified as 30,000 m² (3.0 hectares). A detailed land-use analysis was conducted to determine the weighted Runoff Coefficient (C), which represents the percentage of rainfall that becomes surface runoff:

The catchment is classified into three distinct zones based on surface permeability:

1. Residential Zone: Covering 15,000 m², this area consists of building rooftops and paved yards. A coefficient of $C = 0.70$ was assigned, reflecting high impermeability.
2. Road Infrastructure: Covering 12,000 m², consisting of concrete and asphalt surfaces. This zone facilitates rapid flow with minimal infiltration, assigned a coefficient of $C = 0.70$.
3. Green Open Space: A minor portion of 3,000 m², acting as a semi-permeable buffer with a coefficient of $C = 0.20$.

This high degree of urbanization within the catchment results in a high composite runoff coefficient, necessitating a drainage system with substantial capacity.

Planned Discharge Analysis

The peak design discharge (Q_{design}) was calculated using the Rational Method ($Q = 0.278 \cdot C \cdot I \cdot A$), which is the standard approach for urban catchments under 500 hectares. The catchment was divided into two sub-areas (Area 1 and Area 2) to improve the accuracy of the flow estimation based on the slope direction towards the sump pit.

As detailed in Table 4, Area 1 represents the primary load, covering the residential and main road sections with a high rainfall intensity of 205.62 mm/hour. This high intensity is a result of the short Time of Concentration (t_c) inherent to the steep slopes of the underpass approach. Area 2 accounts for the secondary flow from the road and park areas. The summation of these discharges serves as the basis for sizing the hydraulic structures.

Table 4. Planned Discharge Calculation Results

Analysis	Area 1 – Residential & Road	Area 2 – Road & Park
Area (km ²)	0.0179	0.0132
Flow coef. (C)	0.70	0.70/0.20
Intensity (mm/h)	205.62	190.98
Charge (m ³ /s)	0.716	0.076

Source: Calculation results

Channel Dimension Analysis

To accommodate the calculated discharge, the drainage channels were sized using the Manning's Equation for open channel flow. The design prioritizes a rectangular cross-section to maximize the flow area within the limited right-of-way available in the underpass structure.

Table 5 summarizes the planned dimensions. For Area 1, a channel width of 0.50 m was determined to be sufficient to convey the design discharge. The analysis includes a "freeboard" safety margin the difference between the channel depth and the maximum water level to prevent overflow caused by waves or minor blockages. The calculation confirms that the Maximum Channel Capacity (Q_{max}) of 0.826 m³/s exceeds the Planned Discharge (Q_{plan}) of 0.716 m³/s, indicating that the design is safe and capable of handling the predicted peak flow.

Table 5. Planned Channel Dimensions

Analysis	Area 1	Area 2
Width (m)	0.50	0.30
Effective Height (m)	0.476	0.313
Planned Q (m ³ /sec)	0.716	0.076
Max. Channel Q (m ³ /sec)	0.826	0.140

Source: Calculation results

Sump Pit Volume Analysis

The sump pit serves as a temporary retention basin to manage the inflow before it is mechanically evacuated. To determine the required storage capacity, a critical scenario was simulated assuming a peak rainfall duration of 20 minutes where the pumps are initially inactive (worst-case accumulation scenario). The required volume calculation is detailed as follows:

1. Area 1 Inflow: With a discharge rate of $0.716 \text{ m}^3/\text{sec}$ (or 716 L/s), the accumulated volume over 1,200 seconds is 859.18 m^3
2. Area 2 Inflow: With a discharge rate of 0.076 m^3 (or 76 L/sec) the accumulated volume is 91.55 m^3
3. Total Required Storage: Summing these values yields a total required volume of 950.73 m^3

However, the geometric constraints of the underpass structure allow for a designed sump pit effective volume of only 388 m^3 . This comparison reveals a significant storage deficit; the available capacity covers less than 41% of the required 20 minutes runoff volume. Consequently, the system cannot rely on passive storage and requires an immediate and high-capacity mechanical pumping response to prevent overflow.

Pump Analysis

To bridge the gap between the high inflow rate and the limited storage capacity, the pumping system design was optimized. The selected pump unit provides a discharge capacity of 135 L/sec . The quantitative requirement for the pumps was calculated based on the peak discharge (Q_{peak}) for each sub-area:

1. Area 1 Requirement: To handle the inflow of 716 L/sec , the system requires $716/135 \approx 5.3$ units. This is rounded to 5 operational pumps.
2. Area 2 Requirement: To handle the inflow of 76 L/sec , the system requires $76/135 \approx 0.56$ units. This is rounded to 1 operational pump.

Therefore, a total configuration of 6 active pumps is mandated. This configuration provides a combined theoretical discharge capacity of 810 L/s , which slightly exceeds the total peak inflow (792 L/s), providing a necessary safety factor for the drainage operations

Pump Operation Simulation

To validate the proposed design, a hydraulic simulation was conducted over a 200-minute storm event. The simulation compares the water volume accumulation in the sump pit under two scenarios: without pumping and with the planned pumping system. The results are visualized in Figure 1.

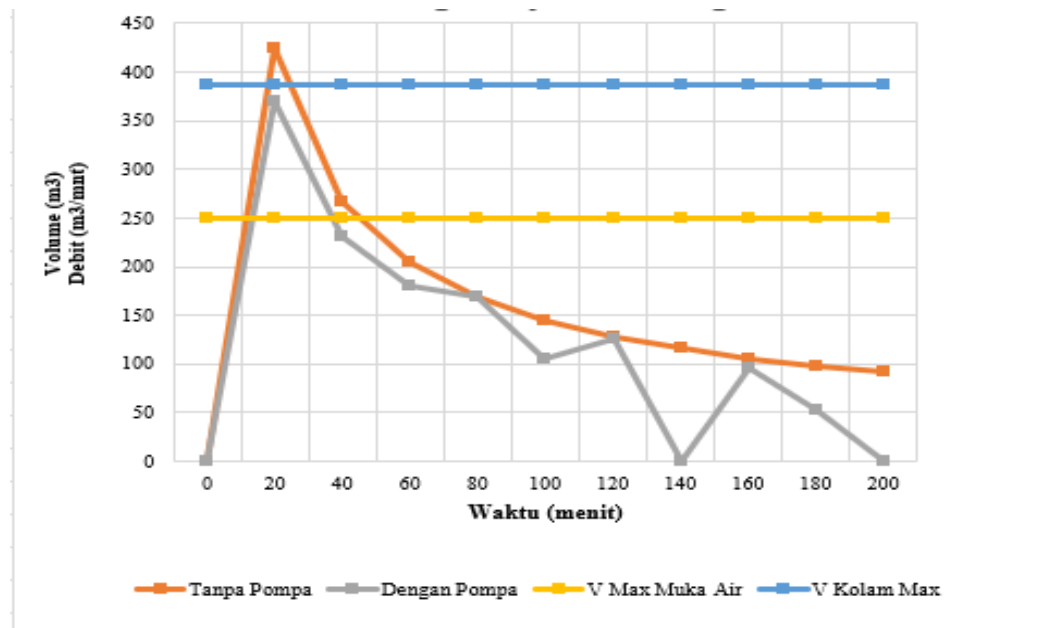


Figure 1. Pump Operation Simulation Source: Calculation results

The simulation results offer critical insights into the system's behavior:

1. **No-Pump Scenario (Orange Line):** Without mechanical intervention, the water volume accumulates rapidly, breaching the maximum sump capacity ($V_{\max}$) of 388 m³ within the first 20 minutes. This confirms that gravity drainage alone would lead to immediate flooding of the underpass.
2. **With-Pump Scenario (Grey Line):** With the activation of the 6 pump system, the water level is effectively managed. The graph demonstrates that while the volume fluctuates due to the dynamic interplay between inflow intensity and pump activation, it consistently remains below the maximum safety threshold (Blue Line). The sharp declines in the grey line indicate periods where the pumping rate exceeds the inflow, successfully draining the sump pit and resetting the buffer capacity for subsequent runoff.

CONCLUSION

Based on the analysis and design of the drainage system for the Bojong Gede underpass, several conclusions can be drawn as follows: 1) the design flood discharge calculated using the Rational Method indicates a peak runoff of 0.792 m³/s, derived from a total catchment area of 0.0311 km² with runoff coefficients of $C = 0.7$ for road/residential surfaces and $C = 0.2$ for green areas. The planned rainfall intensities used in the analysis were 205.628 mm/hour for Area 1 and 190.980 mm/hour for Area 2, with times of concentration of 8.57 hours and 9.575 hours, respectively, 2) the minimum dimensions of the drainage channel needed to convey this discharge are: a) area 1 Channel: width 0.50 m, water depth 0.452 m, and freeboard 0.476 m; b) area 2 Channel: width 0.30 m, water depth 0.195 m, freeboard 0.313 m, and channel slope 0.30%. 3) the sump pit was designed with a surface area of 155 m² and a water depth of 2.5 m, resulting in an effective storage volume of 388 m³. This capacity is insufficient compared to the total required runoff storage of 702.58 m³, indicating that mechanical pumping is essential for system reliability. 4) the planned sump volume of 388 m³ is not fully sufficient for the total runoff storage requirement of 406.46 m³. However, this capacity is supported by a mechanical pump system to ensure smooth water discharge. 5) the pumping system is designed using Tsurumi KRS1022 units, each providing a capacity of 135 L/s. Based on peak runoff calculations, the required number of pumps is approximately 5 units for Area 1 and 1 unit for Area 2. Therefore, a total of 6 pumps is deemed adequate for draining peak flows and ensuring continuous operational performance of the underpass drainage system. 6) overall, the combination of properly sized drainage channels, sump pit storage, and a high-capacity pumping system provides an effective and reliable design for mitigating water accumulation in the Bojong

Gede underpass. This configuration ensures functional safety, flood resilience, and supports long-term infrastructure performance under high rainfall conditions.

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