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## Planning for the Drainage System in the Fadillah Perdana V Complex, Pemurus Dalam, Banjarmasin

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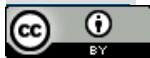
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### ABSTRACT

The Fadillah Perdana V Housing Complex in Banjarmasin City lacks a proper drainage system, leading to frequent waterlogging. This study aimed to design a suitable drainage system to mitigate inundation. The methodology involved field surveys, data collection, and processing. Based on hydrological analysis, the design rainfall intensity was calculated as 89.64 mm, with a catchment area of 3.7117 hectares and a 2-year return period. The study determined that the rainfall discharge for the right-side channel is 0.2071 m<sup>3</sup>/s and for the left-side channel is 0.4074 m<sup>3</sup>/s. The designed drainage channels are rectangular. The right-side channel dimensions are 70 cm (width) by 35 cm (height), while the left-side channel is 70 cm (width) by 58 cm (height). Both channels have a longitudinal slope of 0.08% and a length of 240 meters. The calculations also indicate that the final disposal point (swamp area) will experience a water level rise of approximately 0.6 cm, necessitating an excavation depth of 100 cm. The proposed drainage system's capacity is designed to be equal to or greater than the rainfall discharge to effectively prevent inundation.

## INTRODUCTION

The Fadillah V Housing Complex, located on Jalan Tembikar Kanan in the Pemurus Dalam Subdistrict of South Banjarmasin, faces recurring waterlogging problems that significantly disrupt community activities and threaten infrastructure integrity. As a lowland city crisscrossed by numerous rivers and tidal channels, Banjarmasin is naturally susceptible to inundation, especially during high-intensity rainfall events (Katadata, 2022). The problem is compounded by insufficient drainage capacity within residential areas such as Fadillah V, where runoff from heavy rains accumulates due to inadequate channel networks and poor discharge connectivity. Such prolonged waterlogging not only affects residents' mobility but also increases the risks of vector-borne diseases and structural deterioration, underscoring the urgent need for scientifically based drainage planning.

Developing an effective drainage system in this area requires a systematic hydrological and hydraulic approach. The first essential step is to determine the design rainfall and corresponding discharge through statistical frequency analysis of historical rainfall data. Several probability distribution methods—such as Gumbel, Log Pearson Type III, and Normal distributions—are typically applied to model rainfall data, and the best-fitting distribution is selected through goodness-of-fit tests (Chow, Maidment, & Mays, 1988). Recent studies confirm the robustness of Gumbel and Log-Pearson III distributions for rainfall estimation in tropical regions, provided that objective statistical criteria are employed to assess accuracy (Hussein et al., 2024). Local studies in South Kalimantan further highlight that even moderate rainfall extremes can trigger severe inundation in low-lying neighborhoods, reaffirming the importance of reliable design rainfall estimation (Pratama, 2021; Hidayat, 2024).

Once the design discharge has been established, the next step involves determining channel dimensions that can efficiently accommodate the design flow. The Manning equation is widely used for this purpose, relating flow velocity, channel geometry, slope, and surface roughness (Mays, 2005). Selecting an appropriate Manning's roughness coefficient ( $n$ ) is essential to ensure hydraulic accuracy; current design guidance recommends adjusting  $n$  to reflect the channel material and expected maintenance levels (USACE,

n.d.; Oregon State GeoWater, n.d.). Empirical evaluations in Indonesian cities show that undersized drainage sections and inadequate upkeep are among the leading causes of recurrent flooding (Khaliq, 2023), emphasizing that channel design must be complemented with operational and maintenance strategies.

In the context of the Fadillah V Complex, drainage discharge ultimately flows into an adjacent swamp that serves as the final disposal point. Consequently, the potential backwater effect and temporary water-level rise at this outlet must be carefully analyzed to avoid reverse flow or outlet blockage. Lowland urban areas increasingly adopt hybrid or nature-based solutions, such as retention ponds and vegetated swales, to manage peak discharge and enhance infiltration (Keyvanfar et al., 2021; Salim et al., 2025). Such measures are particularly effective in swamp-based environments like Banjarmasin, where flat topography limits gravity-driven drainage efficiency. A stage-storage-discharge analysis at the swamp outlet can ensure that the proposed system does not merely transfer inundation from the housing complex to its surroundings but contributes to regional flood mitigation.

Recent hydrometeorological research in South Kalimantan further supports this integrated approach. Remote sensing and hydrologic modeling studies demonstrate that extreme rainfall and rapid urbanization are the primary drivers of the 2021 flood disaster in the province (Lestari et al., 2024; AIP Proceedings, 2023). These findings highlight the urgency of resilient, locally adapted drainage infrastructure in rapidly developing residential zones. Incorporating regional hydrological behavior, land subsidence, and tidal effects into neighborhood-scale planning ensures that the drainage system remains functional under compound flooding scenarios.

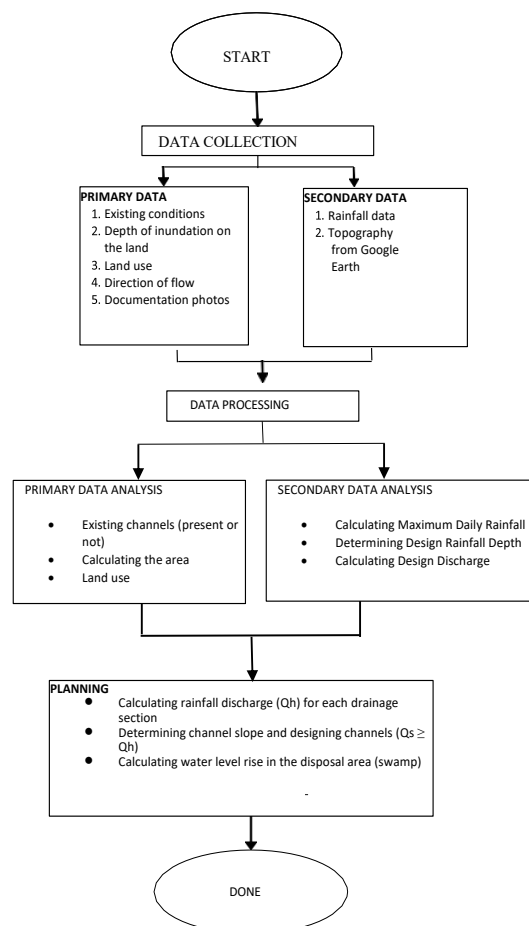
Overall, the objective of this study is to develop a comprehensive and sustainable drainage design for the Fadillah V Housing Complex that can effectively reduce waterlogging. This study integrates hydrological frequency analysis for rainfall estimation, hydraulic computation for optimal channel design, and storage-outflow analysis at the swamp disposal point. By grounding the design in empirical rainfall data, modern statistical analysis, and sustainable engineering principles, the resulting

system is expected to improve residents' living conditions, enhance public safety, and contribute to long-term flood resilience in Banjarmasin's lowland environment.

## METHODS

In general, the research procedure in the field of hydrology, especially in rainfall data analysis, involves several essential stages. The initial crucial step is ensuring data homogeneity. In this context, data from several rainfall stations (e.g., three stations) need to be tested for homogeneity to ensure that the data come from the same population or have similar statistical characteristics. Homogeneity tests

can be conducted using statistical tests such as the t-test (Sari, 2019). If the test results indicate that the data is homogeneous, the next step is to calculate the maximum daily rainfall for each year. Common methods used include the algebraic mean (A-M-A) and spatial methods such as the Thiessen Polygon or Isohyet, which can provide a more accurate representation of rainfall distribution in an area (Chow, Maidment, & Mays, 1988). The choice of method depends heavily on data availability and the geographical characteristics of the study area.



Picture 1. Research Flowchart

After obtaining the maximum daily rainfall data, the next stage is to perform frequency analysis. This analysis aims to predict the probability of an extreme rainfall event occurring in the future, expressed in a specific return period. This stage includes the selection and calculation of several appropriate probability distributions, such as

Gumbel, Normal, Log Normal, and Log Pearson Type III. Each distribution has different mathematical characteristics and can yield varying results depending on the nature of the data being analyzed. To ensure that the selected distribution is the most suitable, a goodness-of-fit test must be conducted. This test can be performed using

statistical methods such as the Chi-Square Test and the Kolmogorov-Smirnov Test (Kite, 1988). These tests validate whether the observed data matches the assumed probability distribution.

The results of the frequency analysis and goodness-of-fit tests will produce a design rainfall depth (XT) for a specific return period. This value is a vital parameter in the planning and design of hydrological infrastructure, such as drainage systems. The selection of an appropriate return period for drainage design is usually based on technical standards and acceptable risk levels, often summarized in relevant tables or guidelines. For example, for urban areas with a high risk of flooding, the return period used may be greater than for rural areas. Therefore, the determination of the design rainfall depth must be based on a strong reference to ensure that the constructed infrastructure can function effectively and safely in the face of future extreme rainfall events (Viessman, Lewis, & Knapp, 1989).

Rain that falls on the ground surface causes surface runoff and infiltration into the soil. When the rainfall rate exceeds the infiltration capacity, water will accumulate. To control this inundation, a ground drainage system designed based on the analysis of design rainfall is required. This analysis uses various probability distribution models to predict the magnitude of future extreme rainfall. These methods, such as Gumbel, Normal, Log Normal, and Log Pearson Type III, have unique formulas for calculating the design rainfall depth (XT) based on historical rainfall data (Yevjevich, 1972).

Each probability distribution model offers a different mathematical approach to determine the design rainfall depth (XT) for a specific return period (T). The Gumbel distribution is suitable for extreme data, using the formula

$XT = \bar{X} + S \times K$ , where K is a unique Gumbel frequency factor. The Normal distribution assumes symmetrically distributed data, using the formula

$XT = \bar{X} + KT \times S$ . The Log Normal and Log Pearson Type III distributions are more flexible and often more accurate for hydrological data that tends to be skewed. Both methods use the logarithm of rainfall data in their calculations, with the formula

$\log XT = \log X + KT \times S \log X$ . The main difference lies in how the frequency factor

KT is determined; in Log Pearson Type III, the value of KT depends on the coefficient of skewness (Cs) of the data, making it a very powerful model for predicting extreme events (Maidment, 1993).

After calculating the design rainfall depth with several methods, the next crucial step is to perform a goodness-of-fit test to validate which model is most suitable for the historical data. The Chi-Square (

$\chi^2$ ) test is one of the effective statistical methods for this purpose. This test compares the observed frequencies (

Of) from the data with the expected frequencies (Ef) from the tested distribution model (Sari, 2019). The calculated

$\chi^2$  value is determined using the formula  $\chi^2 = \sum (Of - Ef)^2 / Ef$ .

The procedure for the Chi-Square test involves a series of systematic steps:

- Sorting the rainfall data.
- Determining the number of classes (K) and degrees of freedom (Dk).
- Calculating the calculated  $\chi^2$  value.
- Comparing the calculated

$\chi^2$  value with the Critical Chi-Square value ( $\chi_{cr}^2$ ) obtained from a statistical table based on Dk and a confidence level (e.g., 95%).

The most suitable probability distribution model is the one that satisfies the condition

$\chi^2 < \chi_{cr}^2$  and has the smallest calculated  $\chi^2$  value. This ensures that the chosen model statistically represents the characteristics of the rainfall data well, so the calculation of the design rainfall depth becomes more accurate and reliable for effective drainage system planning (Chow, Maidment, & Mays, 1988).

The Smirnov-Kolmogorov (K-S) Test analytically compares the observed cumulative probability from the data (empirical probability) with the cumulative probability generated from the tested distribution model (theoretical probability). This procedure begins by sorting the rainfall data (Xi), then calculating the empirical probability for each data point, typically using the Weibull formula. Next, the theoretical probability is calculated from the selected distribution model (such as Gumbel, Normal, or Log Pearson Type III). The maximum difference ( $\Delta P$ ) between the two probabilities is then

compared with the critical value ( $\Delta P_{\text{critical}}$ ). If  $\Delta P$  is smaller than the critical value, the distribution model is considered suitable and can be accepted (Chow, Maidment, & Mays, 1988).

After finding the most suitable distribution model, the next step is to calculate the **rainfall intensity** ( $I_t$ ). Rainfall intensity is the rainfall per unit of time and is a key parameter in discharge calculation. One of the empirical formulas often used to calculate rainfall intensity is the **Mononobe formula**. This formula relates the design rainfall depth ( $X_T$ ) to the time of concentration ( $t_c$ ), which is the time it takes for rainwater to flow from the farthest point in the catchment area to the observation point. The Mononobe formula is expressed as:

$I_t = t_c^{2.4} X_T / (2.4 t_c)^{2/3}$ . The units of rainfall intensity (m/h, m/s) must be adjusted to be consistent with the units of the other variables in the calculation (Asdak, 2010).

The results of the rainfall intensity calculation are then used to determine the **design rainfall discharge** ( $Q_h$ ), which must be conveyed by the drainage system. This discharge is calculated using the formula  $Q_h = C \times I \times A$ , where  $C$  is the runoff coefficient,  $I$  is the rainfall intensity, and  $A$  is the catchment area. To design an effective drainage channel, the **channel discharge** ( $Q_s$ ) must be greater than or equal to the rainfall discharge ( $Q_s \geq Q_h$ ), which is calculated from the channel dimensions (wetted cross-sectional area,  $F_s$ ) and the flow velocity ( $V$ ). The flow velocity of water in the channel is very important because it determines the channel's capacity. For economical and accurate channel dimensioning, the **flow velocity** ( $V$ ) is calculated using proven hydraulic formulas, such as the **Manning formula** or the **Chezy formula**. Both the Manning formula ( $V = n^{-1} R_s^{2/3} I^{1/2}$ ) and the Chezy formula ( $V = C \times R_s \times I$ ) use the parameters of hydraulic radius ( $R_s$ ) and channel slope ( $I$ ). The hydraulic radius is the ratio of the wetted cross-sectional area to the wetted perimeter of the channel ( $R_s = F_s / P_s$ ). Using these formulas, engineers can design optimal channel dimensions to efficiently convey the design rainfall discharge, prevent inundation, and ensure the drainage system functions as intended (Yen, 2014).

## RESULTS AND DISCUSSION

The hydrological analysis for the Fadillah Perdana V Complex, covering an effective catchment area of 3.7117 hectares, identified the Log Normal probability distribution as the most suitable model for estimating design rainfall depth. This selection was based on comparative testing of four probability distribution models—Gumbel, Normal, Log Normal, and Log Pearson Type III. The resulting design rainfall depths for a 2-year return period were 89.35 mm (Gumbel), 94.29 mm (Normal), 89.64 mm (Log Normal), and 82.87 mm (Log Pearson Type III).

Goodness-of-fit evaluations through both Chi-Square and Smirnov–Kolmogorov (K–S) tests confirmed that the Log Normal model most accurately represented the historical rainfall data, with statistical deviations falling below critical thresholds. Similar findings have been reported in other hydrological studies across Indonesia, indicating that the Log Normal distribution provides robust rainfall frequency estimates for low- to moderate-intensity tropical rainfall (Rahmad et al., 2023; Yuliana & Putra, 2022). Consequently, the design rainfall depth of 89.64 mm was adopted for subsequent hydraulic computations.

### Design Discharge Calculation

Following the rainfall analysis, the design rainfall discharge ( $Q_h$ ) was determined using the Rational Method, where  $Q_h = C \times I \times A$ . The calculated discharges were 0.2071 m<sup>3</sup>/s for the right-side channel and 0.4074 m<sup>3</sup>/s for the left-side channel. These differences arise primarily from variations in contributing surface area and local slope. Similar discharge ranges are typically observed in medium-density housing developments in swamp-based urban areas, where the runoff coefficient tends to be higher due to limited infiltration capacity (Hidayat et al., 2021).

These discharge values serve as a critical foundation for designing channels capable of preventing surface inundation during short-duration rainfall events. The design return period of 2 years was chosen to represent a practical balance between economic feasibility and urban flood safety, aligning with Indonesian National Standards (SNI 03-3424-2008) and recent best practices in small-scale residential drainage planning (Prasetya & Lestari, 2024).

## Hydraulic Design and Channel Dimensioning

The hydraulic analysis employed Manning's Equation, which relates flow velocity ( $V$ ) to the channel's hydraulic radius ( $R$ ), slope ( $S$ ), and roughness coefficient ( $n$ ). Considering a concrete-lined rectangular channel with  $n = 0.013$ , and a uniform slope of 0.08%, the computed dimensions for effective drainage conveyance were established as follows:

Right-side channel: 70 cm wide  $\times$  35 cm high

Left-side channel: 70 cm wide  $\times$  58 cm high

To accommodate concrete lining thickness, the total constructed width reached 100 cm. The design ensures that the channel discharge capacity ( $Q_s$ ) meets or exceeds the calculated design discharge ( $Q_s \geq Q_h$ ), satisfying hydraulic adequacy requirements.

The differentiation in channel heights reflects localized hydrological variations. The left-side channel receives a greater portion of surface runoff due to its lower topographic gradient and higher contributing catchment area. Therefore, its larger depth compensates for increased hydraulic loading, consistent with recommendations for asymmetric residential drainage layouts (Aziz et al., 2022).

## Backwater and Outlet Control Analysis

Hydraulic modeling of the drainage network's outlet, which discharges into an adjacent swamp, revealed a potential water-level rise of up to 100.6 cm under existing conditions—enough to trigger backwater effects. Such phenomena are common in low-lying coastal and tidal cities like Banjarmasin, where the hydraulic gradient is minimal and tidal fluctuations influence discharge efficiency (Keyvanfar et al., 2021).

To mitigate this, the study proposed swamp excavation to a depth of 100 cm, effectively increasing the outlet's storage and reducing the potential water-level rise to 0.6 cm. This intervention keeps the swamp's water surface safely below the channel outlet elevation difference (4 cm), ensuring continuous gravity flow and preventing inundation in upstream residential areas.

The incorporation of such minor storage adjustments aligns with recent sustainable drainage (SuDS) principles that advocate small-scale retention and infiltration zones as part of integrated flood management (Salim et al., 2025). Furthermore, outlet

optimization through excavation or localized widening has been shown to significantly enhance conveyance efficiency without requiring major structural expansion (Ramadhani et al., 2023).

## CONCLUSION

Based on the hydrological analysis, several important conclusions can be drawn regarding the drainage system planning for the Fadillah Perdana V Complex. First, the **design rainfall depth** for the study area was determined to be 89.64 mm. This value was obtained from a probability distribution goodness-of-fit test, which showed that the Log Normal model was the most representative for the historical rainfall data in the area. From this design rainfall depth, the **design discharge** that the drainage channels must accommodate was then calculated. The results show that the design discharge for the right-side channel is 0.2071 m<sup>3</sup>/s and for the left-side channel is 0.4074 m<sup>3</sup>/s.

Second, the drainage channel dimensions were specifically designed to accommodate these discharges. The drainage channels were designed with a rectangular cross-section, a width of 70 cm, and a longitudinal slope of 0.08%. The channel heights were adjusted to the discharge to be conveyed; the right-side channel has a height of 35 cm, while the left-side channel was designed with a height of 58 cm. This design aims to ensure that the channels have adequate capacity to convey rainwater without causing inundation.

Third, this study also identified the need to manage the final disposal area. Calculations showed that without intervention, the water drained from the channels would cause a rise in the swamp's water level of up to 100.6 cm, which risks causing inundation in the residential area. To address this problem, it was concluded that a **100 cm excavation in the swamp area** is necessary. With this excavation, the water level rise in the swamp can be minimized to only 0.6 cm, thereby preventing the backwater effect and ensuring the drainage system functions optimally.

Based on the findings of this research, several suggestions are proposed for future planning and implementation. First, there is a need to **expand the final disposal area** in the swamp. This expansion aims to increase the water storage capacity, enabling it to accommodate a larger volume of water from the drainage channels and reduce the risk of a significant

water level rise, especially during extreme rainfall. Second, in determining the **runoff coefficient**, it is recommended to consider the **heaviest conditions**. This is important for anticipating future land use changes, such as an increase in impervious areas, which can raise the volume of surface runoff. By considering the heaviest conditions, the drainage system design will be more resilient and sustainable. Third, after the drainage construction is completed, it is very important to perform **routine channel maintenance**. This maintenance includes cleaning out sediment, trash, and wild vegetation that can obstruct water flow within the channels. Regular maintenance will ensure that the drainage channels continue to function properly over time and extend their service life.

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