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Performance Evaluation of the Drainage System at FMIPA University of Lampung under Extreme Rainfall Conditions

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Abstract: Urban drainage systems are facing increasing challenges due to the intensification of extreme rainfall caused by climate change and rapid urban development. This study aims to evaluate the performance of the drainage system at the Faculty of Mathematics and Natural Sciences (FMIPA), University of Lampung, in managing flood discharge during extreme rainfall events. Using 24 years of rainfall data, the design rainfall was calculated using the Log Pearson III distribution and converted into short-duration intensity using the Mononobe method. Peak discharge was estimated with the Rational method, and compared against the channel capacity calculated using Manning's equation. The results showed that the designed trapezoidal drainage channel (0.4 m × 1.2 m × 0.6 m) could safely convey runoff from a 25-year return period. However, previous study revealed that the installed channel at several points, particularly (0.35 m × 0.40 m), was undersized and could not accommodate the peak flow. This discrepancy highlights the need for upgrading existing drainage infrastructure on campus.

Keywords: Extreme rainfall; Urban drainage; Flood discharge; Drainage capacity, FMIPA University of Lampung

1. Introduction

Urban drainage systems are increasingly under pressure due to the intensification of extreme rainfall events associated with climate change and urban expansion. These systems, initially designed based on historical climate patterns, are often unable to manage current stormwater volumes, leading to urban flooding, deterioration, and disruptions to public activities [1,2]. In developing countries, this issue is compounded by poor maintenance, lack of system upgrades, and inadequate spatial planning [3].

The Faculty of Mathematics and Natural Sciences at the University of Lampung was selected due to its extensive coverage of impermeable surfaces such as rooftops, paved walkways, and parking lots. These impervious areas significantly increase surface runoff during heavy rains [4,5], making FMIPA a critical location for studying stormwater management. Moreover, as a busy academic hub with many students and staff, flooding in this area can disrupt activities and damage infrastructure. Therefore, evaluating the drainage performance at The Faculty of Mathematics and Natural Sciences is vital to develop effective flood control strategies that protect both the campus environment and its users. If the drainage network fails to efficiently convey the generated surface runoff, it may lead to localized flooding, especially during short-duration, high-intensity storms [6,7]. Evaluating the performance of drainage systems in such educational environments is essential for developing flood mitigation strategies and ensuring academic continuity and infrastructure safety [8,9].

Recent studies show that existing drainage channels in many urban areas are not adequately sized to accommodate rainfall intensities with 25 years return periods [10,11]. Hydraulic analysis, combined with runoff modeling methods such as the Rational Method, enables researchers to calculate expected discharge and compare it with channel capacity, identifying points of potential overflow [12,13].

Moreover, areas like The Faculty of Mathematics and Natural Sciences require periodic evaluation of the physical condition of their drainage infrastructure, including dimensions, slope, and obstructions, as these factors directly affect system performance during extreme rainfall events [14,15]. Climate projections also suggest an increase in both the frequency and magnitude of such events in Southeast Asia, highlighting the urgency for adaptive planning [16,17].

Therefore, this study aims to assess the capacity and performance of the Faculty of Mathematics and Natural Sciences drainage system under extreme rainfall conditions by analyzing flood runoff, channel geometry, and actual field conditions. The results are expected to serve as a reference for campus-based flood management and contribute to sustainable urban water infrastructure planning [18-20]. The purpose of this study is to determine the flood discharge generated during extreme rainfall events at the Faculty of Mathematics and Natural Sciences, University of Lampung, and to evaluate the capacity of the existing drainage system to manage that discharge. Specifically, the study aims to (1) calculate the discharge runoff based on rainfall intensity and land cover characteristics within the FMIPA area, and (2) assess whether the current drainage infrastructure is sufficient to prevent overflow under those conditions.

2. Methods

This study integrates hydrological and hydraulic analysis to evaluate the performance of the existing drainage system at the Faculty of Mathematics and Natural Sciences. University of Lampung under extreme rainfall conditions. The methodology consists of the following stages:

2.1. Field Survey and Data Collection

A direct field survey was conducted to collect primary data, including the geometry of drainage channels (width, height, length, slope), material type, and physical condition (e.g., sediment, blockages). Secondary data such as daily rainfall records (10–20 years), land use layout, and The Faculty of Mathematics and Natural Sciences drainage area maps were gathered from PERSIAN CCS and campus facilities.

2.2. Design Rainfall Analysis

To determine the magnitude of extreme rainfall events, two statistical methods were used:

- Log Pearson Type III Distribution was applied to estimate rainfall depth for 2, 5,10 and 25 years return periods using historical annual maximum rainfall data.
- Mononobe Formula was used to convert daily rainfall into short-duration rainfall intensity for use in peak discharge estimation. The formula used is:

$$I = R \cdot \left(\frac{24}{t}\right)^{n} \tag{1}$$

I = the rainfall intensity (mm/hour),
R = daily rainfall (mm), t is rainfall duration (hours),
n = an empirical constant (typically 0.2–0.4 for Indonesia).

2.3. Runoff Estimation using Rational Method

Runoff was estimated using the Rational Formula:

$$Q = C \cdot I \cdot A \quad (2)$$

Q = peak discharge (m^3/s),
C = runoff coefficient based on surface type,
I = rainfall intensity (mm/hours)

2.4. Drainage Channel Capacity Analysis

Channel capacity was calculated using Manning's Equation for open or closed channel flow:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2} \quad (3)$$

Q = channel capacity (m^3/s),
A = cross-sectional area, (m^2)
R = hydraulic radius (m)
S = is slope
n = Manning's roughness coefficient.

2.5. Performance Evaluation

The comparison between runoff and channel capacity was analyzed for each segment to identify sections that are under capacity or prone to overflow. Documentation includes sketches, tables, and flow diagrams to support the evaluation. Areas at risk were noted based on visual field indicators such as pooling, debris marks, or erosion.

2.6. Conclusion and Recommendations

Based on the analysis, conclusions were drawn regarding the system's adequacy. Recommendations were formulated for improvement, which may include resizing certain channel sections, remove blockages, and propose the integration of infiltration features in future development.

3. Results

This chapter presents the results of the hydrological and hydraulic analysis performed to evaluate the existing drainage system at The Faculty of Mathematics and Natural Sciences University of Lampung. The analysis includes rainfall data processing, runoff estimation using the Rational Method, and capacity analysis of the proposed drainage channels using Manning's Equation. A comparison between flood discharge and channel capacity is then discussed to assess the system's performance under extreme rainfall conditions.

1.1. Rainfall Data

In this study, rainfall data were obtained from the PERSIANN-CCS CHRS Data Portal, covering the period from 2003 to 2024. The data consists of annual maximum daily rainfall (R24) recorded for each year. This dataset was used as the primary input for the frequency analysis to determine design rainfall for several return periods.

Table 1. Daily Maximum on Rainfall data

Years	RMax
2003	69,00
2004	92,00
2005	89,00
2006	133,00
2007	140,00
2008	212,00
2009	167,00
2010	183,00
2011	94,00
2012	142,00
2013	238,00
2014	114,00
2015	109,00
2016	119,00
2017	216,00
2018	154,00
2019	198,00
2020	186,00
2021	213,00
2022	181,00
2023	138,00
2024	147,00
Summary	3334,00
Average	151,55

3.2. Rainfall Distribution Analysis

To estimate the design rainfall required for drainage planning, an analysis of rainfall frequency distribution was carried out using 24 years of daily rainfall data (2000–2024) from the CHRS PERSIANN-CCS dataset. The analysis focused on the annual maximum daily rainfall series, which represents the highest rainfall values recorded each year.

3.2.1. Selection of Distribution Method

To determine the suitability of the Log Pearson III distribution for modeling extreme rainfall events, a Chi-Square goodness-of-fit test was performed using the annual maximum daily rainfall data. The calculated Chi-Square value was 6.908, while the critical Chi-Square value for a 95% confidence level and 3 degrees of freedom was 7.815. Since the calculated value is lower than the critical value (6.908 < 7.815), the Log Pearson III distribution was accepted as a statistically valid model for the rainfall data, indicating a good fit for further hydrologic analysis.

3.2.2. *Calculated Rainfall Depths*

Using the Log Pearson III distribution formula, design rainfall values were calculated for return periods of 2, 5, 10, and 25 years. The calculation used the average and standard deviation of the annual maximum daily rainfall, along with the Log Pearson III frequency factor for each return period. The results are shown in the table below:

Table 2. Calculated Rainfall Depths Using Log Pearson III

No.	RP	X Average	YT	Yn	Sn	YT-Yn	YT-Yn/Sn	S	YT-Yn/Sn*S	XT
1.	2	151,55	0,3665	0,5268	1,0754	-0,16030	-0,14906	46,29	-6,90003	144,65
2.	5	151,55	1,5004	0,5268	1,0754	0,97360	0,90534	46,29	41,90808	193,46
3.	10	151,55	2,2510	0,5268	1,0754	1,72420	1,60331	46,29	74,21724	225,77
4.	25	151,55	3,1993	0,5268	1,0754	2,67250	2,48512	46,29	115,03629	266,59

3.3. *Rainfall Intensity*

To determine the rainfall intensity required for runoff calculation, the Mononobe method was applied to convert the estimated 24-hour rainfall (R24) into short-duration rainfall intensities. This empirical method is widely used in Indonesia for stormwater design when hourly data is unavailable.

Table 3. Rainfall Intensity using Momonobe

Return Period (years)	R24 (mm)	Duration (t)	n	Rainfall Intensity (I) [mm/hr]
2	144,65	1	0,4	50,15
5	193,46	1	0,4	67,07
10	225,77	1	0,4	78,27
25	266,59	1	0,4	92,42

These intensity values reflect the estimated maximum 1-hour rainfall for each return period, and are used as input for subsequent runoff analysis. The peak 1-hour intensity of 159.63 mm/hour (25-year return period) indicates a high potential for rapid surface runoff, requiring a properly sized drainage system to prevent flooding. These results are critical for ensuring that the drainage infrastructure can accommodate short-duration, high-intensity storm events typical in tropical climates.

3.4. *Flood Discharge Estimation*

The results show a clear relationship between return period and peak discharge: higher return periods generate significantly greater runoff due to increased rainfall intensity. The highest estimated discharge occurred during the 25-year return period scenario, which produced a peak discharge of 0.23408 m^3/ s

This discharge was calculated for a contributing drainage area of 0.0182 hectares, primarily consisting of paved surfaces and rooftops. The runoff coefficient used reflects the relatively impervious nature of the site, which limits infiltration and increases surface flow during storm events.

Table 4. Flood Discharge using Rational Method

Return Period	Rainfall Intensity (mm/hour)	Peak Discharge (m^3/s)
2 years	86.67	0.12717
5 years	115.91	0.17012
10 years	135.26	0.19846
25 years	159.63	0.23408

3.5. Drainage Channel Design Analysis

The drainage channel planned for The Faculty of Mathematics and Natural Sciences University of Lampung is designed in a trapezoidal shape. Based on field conditions and runoff estimates, the selected dimensions include a bottom width of 0.4 m, a top width of 1.2 m, and a height of 0.6 m. These dimensions were chosen to ensure the system can safely accommodate runoff during heavy rainfall events.

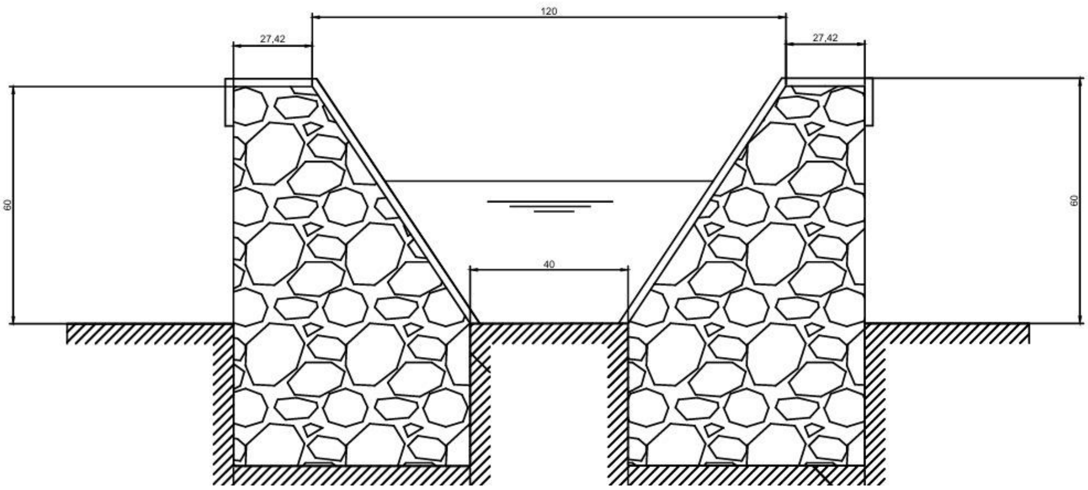

Figure 1. Drainage Design for FMIPA UNILA based on analysis [20]

The analysis shows that the designed channel has sufficient capacity to handle runoff generated from a 25-year return period rainfall. In addition to the channel's size, the slope and roughness of the material were also considered to ensure smooth water flow and prevent overflow. The channel layout connects several key buildings in the The Faculty of Mathematics and Natural Sciences area, including the mathematics, chemistry, and computer science departments. With proper construction and maintenance, this drainage system is expected to effectively reduce the risk of localized flooding across the campus.

4. Discussion

The hydraulic performance of the drainage system at The Faculty of Mathematics and Natural Sciences University of Lampung was analyzed by comparing the proposed channel design with the actual dimensions of the installed channel at several locations. The planned drainage channel was designed with a trapezoidal cross-section, having a bottom width of 0.4 meters, a top width of 1.2 meters, and a height of 0.6 meters. This geometry was selected based on runoff discharge calculations under extreme rainfall conditions with a 25-year return period [15].

In contrast, the existing drainage structure observed in the field, has a smaller rectangular section with a bottom width of 0.35 meters and a height of 0.40 meters. This difference in size is critical. While the designed trapezoidal channel is capable of conveying a discharge of approximately 0.6569 m^3/s, the smaller installed channel has a significantly lower flow capacity due to its reduced cross-sectional area and limited flow depth [16,17].

This discrepancy indicates that the installed drainage system does not meet the hydraulic requirements derived from design rainfall intensity. Under heavy storm events, the undersized channels are likely to become overwhelmed, leading to surface ponding or localized flooding especially at downstream which potentially receive cumulative runoff from upstream segments

These findings are consistent with a previous study by previous study [11,18], which identified as part of a natural drainage system with inadequate channel dimensions, and recommended new drainage designs to address recurrent overflow issues in the FMIPA zone. Their study also noted that channel experienced 9.5 meters of overflow during high rainfall, further reinforcing the importance of appropriate channel sizing in this area [19,20].

Therefore, it can be concluded that although the drainage network exists, the installed channel dimensions are insufficient to handle peak discharges expected during design storm events. A recommendation is made to resize the channels—particularly at and similar points—to match or closely approach the dimensions provided in the hydraulic design to ensure adequate drainage performance and reduce the risk of flooding on campus.

5. Conclusions

This study evaluated the ability of the existing drainage system at FMIPA University of Lampung to manage flood discharge generated during extreme rainfall events. Based on the analysis, the following conclusions can be drawn that the estimated flood discharge for a 25-year return period, derived from design rainfall intensity using the Momonobe method and Rational method, demonstrated that significant surface runoff is expected within the FMIPA area due to its mix of impervious surfaces and concentrated catchments. The designed drainage channel with a trapezoidal cross-section (0.4 m bottom width, 1.2 m top width, and 0.6 m height) was proven to be hydraulically sufficient to convey peak discharge under extreme rainfall conditions. Also, based on the analysis from a previous study, drainage channels with a rectangular section measuring 0.35 meters by 0.40 meters were found to be hydraulically insufficient to accommodate peak discharges during high-intensity rainfall events, making them vulnerable to overflow. When compared to the 0.35 m × 0.40 m rectangular channel, the trapezoidal design (0.4 m × 1.2 m × 0.6 m) demonstrated sufficient capacity to handle peak discharge. This comparison highlights that the installed drainage system is inadequate and does not meet the hydraulic performance of the proposed design.

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