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IMPLEMENTATION OF LOW IMPACT DEVELOPMENT (LID) FOR URBAN DRAINAGE OPTIMIZATION AND FLOOD MITIGATION

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Abstract

The frequent problems of flooding and waterlogging in Serang City are triggered by unpredictable rainfall patterns and the limited capacity of the drainage system. The increasing land-use changes and rapid development put additional pressure on the existing drainage channels, leading to excessive runoff and exacerbating the flood risks in several urban areas. This study aims to evaluate the implementation of Low Impact Development (LID) approaches to improve the performance of urban drainage systems in Serang City to reduce water runoff and enhance the capacity of the drainage system to handle the frequent flooding risks. Unpredictable rainfall patterns, combined with the limited capacity of drainage channels, have caused waterlogging and flooding in some areas of the city. Simulations using the Storm Water Management Model (SWMM) software indicate that the implementation of LID techniques, such as bioretention and permeable pavement, is effective in reducing runoff volume flowing into the drainage system and improving water flow efficiency. The simulation results show a reduction in the continuity error value of surface runoff from -0.62% to -0.38%, which is still within an acceptable limit. However, one channel still experiences waterlogging due to limited channel capacity and suboptimal slope. These findings suggest that LID implementation can be a long-term solution to address drainage and flooding issues in urban areas. This study also contributes significantly to designing more environmentally friendly drainage systems, taking into account the impacts of climate change and rapid urbanization.

Keywords:
LID; drainage system; flood control

Abstrak

Masalah genangan dan banjir yang sering terjadi di Kota Serang, dengan dipicunya perubahan pola curah hujan yang tidak menentu dan kapasitas sistem drainase yang terbatas. Meningkatnya perubahan tata guna lahan dan pembangunan yang pesat menambah tekanan pada saluran drainase yang ada, sehingga menyebabkan terjadinya limpasan air yang berlebihan dan memperburuk risiko banjid ri beberapa kawasan kota. Penelitian ini bertujuan untuk mengevaluasi penerapan pendekatan *Low Impact Development* (LID) dalam meningkatkan kinerja sistem drainase perkotaan di Kota Serang guna mengurangi limpasan air dan meningkatkan daya tampung sistem drainase terhadap potensi banjir yang sering terjadi. Perubahan pola curah hujan yang tak terduga, ditambah dengan kapasitas saluran drainase yang terbatas, menyebabkan terjadinya genangan dan banjir di beberapa area kota. Simulasi menggunakan perangkat lunak *Storm Water Management Model* (SWMM) menunjukkan bahwa penerapan LID, seperti bioretensi dan perkerasan berpori, efektif mengurangi volume limpasan yang mengalir ke dalam sistem drainase dan meningkatkan efisiensi aliran air. Hasil simulasi menunjukkan penurunan nilai *continuity error* pada *surface runoff* dari -0,62% menjadi -0,38%, yang masih berada di bawah batas yang dapat diterima. Meskipun demikian, terdapat satu saluran yang masih mengalami genangan karena kapasitas saluran terbatas dan kemiringan yang tidak optimal. Temuan ini mengindikasikan bahwa penerapan LID dapat menjadi solusi jangka panjang untuk mengatasi masalah drainase dan banjir di perkotaan. Penelitian ini juga memberikan kontribusi penting dalam merancang sistem drainase yang lebih ramah lingkungan, dengan mempertimbangkan dampak perubahan iklim dan urbanisasi yang cepat.

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Kata Kunci:
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1. INTRODUCTION

Flooding in urban areas remains a major challenge for large cities worldwide, including Indonesia. In particular, flooding in central urban areas has become a critical issue due to its potential for substantial damage, including the destruction of residential areas, disruption of daily activities, economic losses, environmental degradation, and even loss of life (Yuono et al., 2024). A primary contributor to this issue is the high intensity of rainfall, which places excessive pressure on existing urban drainage systems. Therefore, effective interventions are needed—not only to provide short-term solutions but also to comprehensively and sustainably address drainage issues (Raharjo, 2024), especially during rainy seasons with extreme precipitation.

The rapid expansion of infrastructure development in many major cities, including Serang City in Banten Province, has significantly affected land use. Areas that once functioned as natural water infiltration zones have been converted into built-up spaces for residential, industrial, and infrastructure purposes. This shift has reduced green spaces and influenced changes in water flow, rainfall patterns, and land management practices (Fadhil et al., 2021). Unfortunately, these developments have not been matched by adequate planning for stormwater management systems, resulting in a drastic decline in water infiltration capacity and increased pressure on existing drainage infrastructure.

Urban drainage systems are typically designed using historical data that assumes hydrological variables are stable. However, climate change has disrupted these assumptions by making rainfall patterns and intensity increasingly unpredictable. This affects new constructions, such as residential buildings, office complexes, and infrastructure, which must be designed to minimize surface runoff and incorporate adequate drainage systems (Deliana & Utomo, 2017).

Climate change broadly impacts environmental systems, particularly hydrology. Key indicators—such as rainfall and surface temperature—can significantly disrupt the balance of the hydrological cycle. These disruptions result in altered precipitation patterns, rising temperatures, sea-level rise, and increased frequency and intensity of extreme weather events, all consequences of global climate change (Nuraisah et al., 2019). These conditions directly impact urban drainage systems, which were originally designed under the assumption of climatic stability. Additional factors contributing to flood frequency and intensity include variable topography, land-use changes, weather conditions, and the impacts of climate change (Aprianto et al., 2024).

Community behavior plays a crucial role in maintaining water quality. The declining quality of urban water is largely due to domestic waste being discharged directly into drainage systems or rivers without prior treatment (Shaskia & Yunita, 2021). Low Impact Development (LID) strategies can also be used for water quality monitoring through Internet of Things (IoT)-based real-time observation systems (Setiawan & Handayani, 2021). This highlights the importance of public participation in flood mitigation and sustainable water management efforts.

Serang City, the capital of Banten Province, has experienced rapid development in recent decades. However, this growth has also led to increased urban flooding, particularly in densely populated residential areas where drainage systems cannot handle runoff from heavy rainfall. Mapping flood-prone areas can assist in designing improved drainage systems and building flood-resilient infrastructure (Fattah et al., 2023).

There is an urgent need to develop sustainable urban runoff management solutions. One increasingly adopted approach focuses on reducing the impact of surface water runoff through ecosystem-based strategies, particularly Low Impact Development (LID). This approach emphasizes green technologies and ecosystem-based water management. LID involves infrastructure design that slows runoff by increasing infiltration and/or evapotranspiration rates (S Hanastasia & Sudradjat, 2016). LID has proven effective in controlling peak water discharge, improving surface runoff quality, and minimizing the adverse impacts of urban development (Cristobal et al., 2024).

LID enhances water quality and promotes sustainable water resource management. For planning and optimizing drainage systems, the Storm Water Management Model (SWMM) developed by the U.S. Environmental Protection Agency (EPA) is essential. It simulates surface flow and stormwater management, including climate change scenario analyses, thereby improving drainage efficiency and flood risk mitigation in urban areas (Grace et al., 2022). SWMM can also model flow changes resulting from land cover alterations (Firmansyah et al., 2024).

This study evaluates the effectiveness of drainage system design by considering both existing drainage capacity and scenarios that implement LID schemes using SWMM. The findings aim to support decision-making processes for flood risk mitigation and improving drainage efficiency in urban environments. Consequently, drainage system designs can be better adapted to face the challenges posed by increasingly unpredictable rainfall patterns.

2. LITERATURE REVIEW

1.1. Low Impact Development (LID) in Urban Drainage

Low Impact Development (LID) is a planning approach designed to reduce the environmental impact of urban development by emulating natural hydrological patterns. LID focuses on managing stormwater runoff, minimizing surface flow, and enhancing infiltration to mitigate the adverse effects of urbanization on water quality and flood control. This approach has gained relevance amid climate change and rapid urbanization, particularly as traditional drainage systems often struggle to manage extreme rainfall events. Core principles of LID include managing runoff at its source, utilizing eco-friendly technologies, and incorporating green infrastructure. Techniques such as green roofs, permeable pavements, bioswales, and rain gardens are used to regulate runoff, improve water quality, and decrease the volume of water entering conventional drainage systems. These features make LID a sustainable solution for urban planning (Ahiablame et al., 2012; Miller & Hutchins, 2017; Pour et al., 2020).

1.2. Optimization Methods in Drainage Systems

Drainage systems are crucial for water management, especially in preventing urban floods. Various optimization methods have been developed to enhance their efficiency and effectiveness. One common approach is the analytical method, which uses linear programming to determine the optimal dimensions of drainage channels while considering cost and flow capacity. Several studies have also utilized optimization theories, such as genetic algorithms, to identify the ideal size and capacity of drainage systems. The findings indicate that these methods can simultaneously reduce construction costs and improve water flow efficiency (Malamataris et al., 2020).

1.3. Urban Drainage Modeling Using SWMM

The Storm Water Management Model (SWMM) is a dynamic simulation tool developed by the U.S. Environmental Protection Agency (EPA) for analyzing the relationship between rainfall and surface runoff. The model considers various hydrological processes, including precipitation, evaporation, water infiltration, and interactions with existing drainage infrastructure. SWMM enables a comprehensive analysis of urban runoff issues by identifying and quantifying critical points vulnerable to flooding and waterlogging, facilitating the design of more effective drainage systems tailored to urban environments (Belladona et al., 2023; Fransiska et al., 2020)

3. METHOD

This research was conducted in the Alun-Alun area of Serang City, Banten Province, with a focus on analyzing the urban drainage system and implementing Low Impact Development (LID) strategies. The study site was chosen due to its frequent flooding issues, primarily caused by increased stormwater runoff that exceeds the capacity of the existing drainage infrastructure. The research began with data collection, including field surveys, topographic maps, and rainfall data. These datasets were processed to determine catchment areas and conduct rainfall analysis using the Triangle and Weibull methods. The Storm Water Management Model (SWMM) software was then used to simulate the drainage system. LID approaches, such as bio-retention cells and permeable pavement, were implemented to reduce runoff and enhance infiltration. The effectiveness of LID implementation was evaluated to inform the design of a more efficient drainage system and mitigate flood risks in Serang City. The study area is shown in Figure 1.

Figure 1. Map of the research location – Alun-Alun, Serang City, Banten Province

The data used in this study includes 15 years of historical rainfall records (2010–2024) from the Serang Meteorological Station, along with topographic data, existing drainage network information, and land use data from Serang City. Soil permeability data was also included to assess the soil's capacity to absorb rainwater, supporting the application of LID controls such as bioretention and permeable pavement.

The research used a simulation-based methodology using SWMM to evaluate various LID scenarios and their impacts on the drainage system. Analyzed variables included LID scenarios involving permeable pavement and bio-retention cells aimed at reducing stormwater runoff. SWMM calculated runoff volume, flow discharge, and flow depth within the drainage channels under both existing conditions and post-LID implementation scenarios.

In addition to running drainage system simulations using SWMM, this study also conducted a statistical analysis of rainfall data to estimate the potential for extreme rainfall events in the future. This step is crucial, as climate change and rapid urban growth can significantly increase flood risk. By understanding historical rainfall patterns, researchers can design more adaptive and resilient stormwater management strategis.

Accurate rainfall analysis plays a vital role in hydrological modeling, particularly in urban areas that are highly sensitive to flooding. By estimating the probability of extreme rainfall events, planners and engineers can better anticipate future risks and develop mitigation strategies accordingly. In this study, long-term rainfall data collected from the Serang Meteorological Station over a 15-year period (2010–2024) served as the basis for the statistical analysis. This approach allowed researchers to identify rainfall intensities with various return periods, which are critical for calibrating the design parameters used in the drainage system simulations.

To support the simulation process, rainfall frequency analysis was also conducted to provide more accurate input data for extreme rainfall scenarios. This analysis ensured that the simulated conditions reflect not only historical averages but also potential future extremes, which are essential for designing effective and resilient drainage infrastructure.

Data analysis was performed using Hydrognomon 4.0.3 software for rainfall frequency analysis with methods such as Gumbel, Log Pearson III, Normal Distribution, and Log-Normal Distribution to estimate future maximum rainfall events. The effectiveness of LID was evaluated by comparing drainage system performance before and after LID implementation, focusing on changes in runoff volume and drainage capacity. The overall research design is illustrated in the flowchart shown in Figure 2.

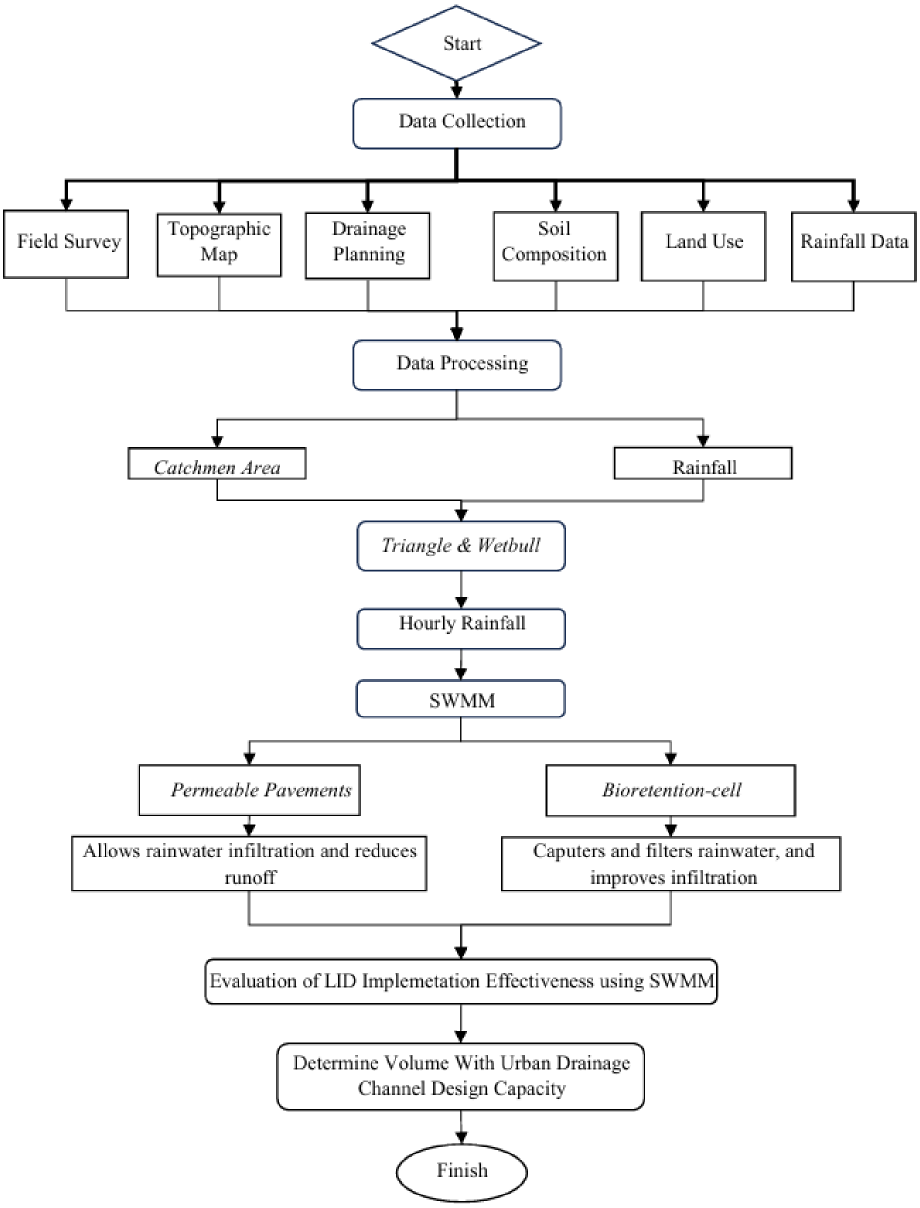


Figure 2. Reseach flow diagram

4. RESULTS

4.1. Design Discharge Analysis Using Hydrognomon 4.0.3 Application

The first step in flood discharge analysis involved collecting rainfall data from rain gauges near the study area. The main station used for this analysis was the Maritime Meteorological Rain Station in Serang. Rainfall data was obtained solely from this station, focusing on identifying the highest annual rainfall values. A summary of the rainfall data, sourced from BMKG for the period 2010 to 2024, is presented in Table 1.

Table 1. Summary of rainfall data from the Serang maritime meteorological station

No.	Year	Jan	Feb	Mrc	Apr	May	Jun	Jul	Agt	Spt	Oct	Nov	Dec
1	2010	52,00	50,00	30,00	27,00	59,00	59,00	70,00	46,00	52,00	44,10	44,00	33,00
2	2011	68,00	22,00	38,00	43,00	28,00	16,00	34,00	0,00	29,00	18,00	53,00	49,00

No.	Year	Jan	Feb	Mrc	Apr	May	Jun	Jul	Agt	Spt	Oct	Nov	Dec
3	2012	54,00	58,00	25,00	54,00	51,00	14,00	15,00	0,00	7,00	46,00	22,00	25,80
4	2013	64,00	34,80	101,00	35,60	85,00	14,00	64,00	46,00	9,00	0,00	6,00	130,00
5	2014	44,00	37,50	48,10	12,80	48,60	22,00	61,00	9,20	16,40	20,40	37,80	29,50
6	2015	60,80	37,10	35,20	32,00	26,00	36,10	4,20	7,50	0,20	28,50	26,50	40,90
7	2016	33,80	89,60	44,60	27,70	54,20	33,80	37,50	30,20	40,00	45,80	49,80	44,10
8	2017	51,10	54,80	38,00	24,60	46,00	40,00	41,20	15,10	19,20	37,40	39,80	78,50
9	2018	40,40	25,40	68,80	57,40	17,00	59,50	3,00	0,00	13,50	37,00	39,20	29,80
10	2019	64,90	55,60	41,00	26,20	44,20	3,60	6,00	1,00	0,00	11,20	22,60	31,60
11	2020	66,60	48,40	54,40	48,20	53,20	17,40	15,50	24,30	27,20	16,00	38,90	94,00
12	2021	34,50	59,10	25,50	77,80	8,20	61,60	38,00	12,20	105,80	52,60	77,40	52,50
13	2022	28,80	20,50	180,40	99,80	46,00	26,50	26,70	40,60	19,60	68,50	40,00	36,50
14	2023	55,80	81,90	68,50	61,70	48,30	84,20	51,90	0,00	0,00	0,00	63,60	18,90
15	2024	60,70	56,10	43,40	51,00	65,10	58,70	36,60	3,90	30,70	59,70	46,70	61,30

Source: BMKG Website

The maximum design rainfall for a specific return period was calculated using daily maximum rainfall data. This data was then used to compute the design discharge for various return periods under actual conditions. The annual maximum value method was employed, and the results are shown in Table 2.

Table 2. Maximum annual rainfall from 2010 to 2024

No.	Year	Maximum annual rainfall (mm)
1	2010	70,00
2	2011	68,00
3	2012	58,00
4	2013	130,00
5	2014	61,00
6	2015	60,80
7	2016	89,60
8	2017	78,50
9	2018	68,80
10	2019	64,90
11	2020	94,00
12	2021	105,80
13	2022	180,40
14	2023	84,20
15	2024	65,10

Source: Calculation

The return period modeling with Hydrognomon 4.0.3 aimed to identify acceptable and unacceptable probability distributions, guiding the selection of the distribution testing method for calculating the design discharge. The time series analysis results generated by Hydrognomon 4.0.3 are shown in Figure 3.

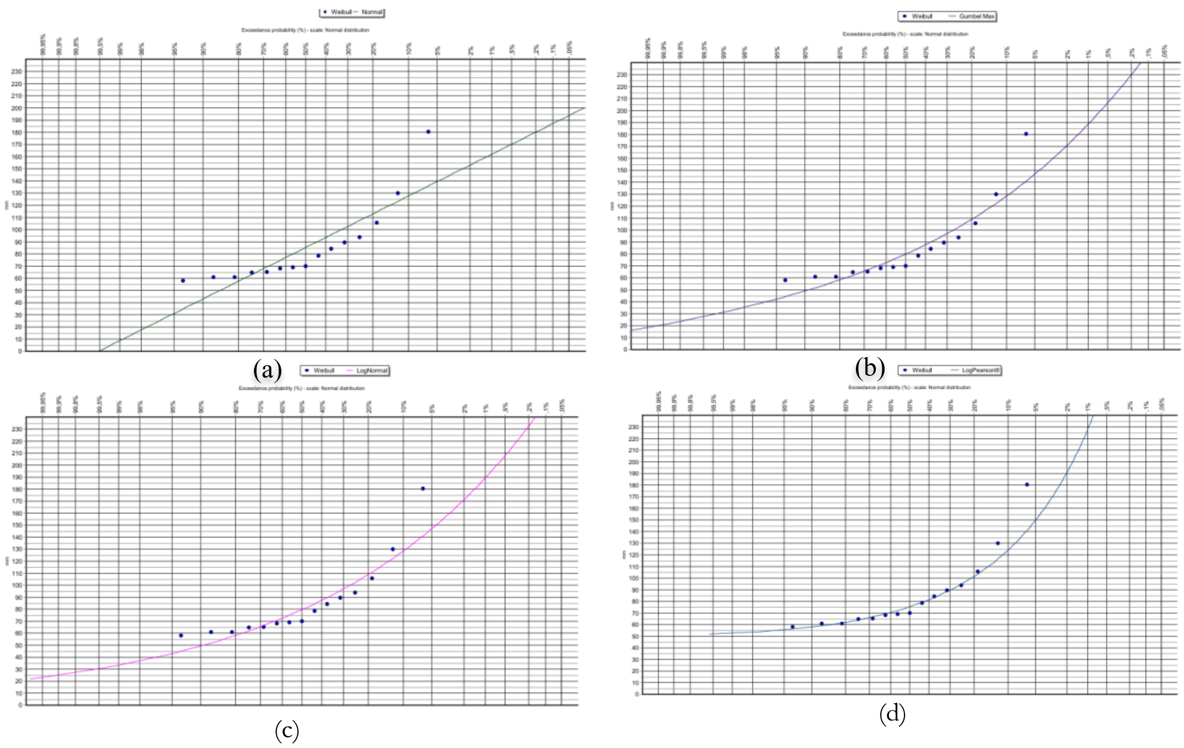


Figure 3. Probability distribution graphs: (a) Normal, (b) Gumbel, (c) Log-Normal, and (d) Log-Pearson Type III

Based on the calculations in Hydrognomon, the Gumbel distribution was chosen as the design rainfall distribution due to its lowest discharge values and its acceptance in both the Chi-Square and Smirnov-Kolmogorov tests. As shown in Figure 4, the observed data closely aligns with the Gumbel distribution, making it the most suitable model for calculating the design discharge, as presented in Tables 3 and 4.

Table 3. Results of probability distribution test with return period using Hydrognomon application

No	Return Period (years)	Probability Distribution			
		Normal	Gumbel	Log Normal	Log Pearson Tipe III
1	2	85,27	79,86	79,55	75,38
2	5	112,98	108,96	108,86	101,38
3	10	127,46	128,06	128,26	123,79
4	20	139,42	146,72	146,86	149,64
5	25	142,90	152,58	152,76	158,82
6	50	152,88	170,64	171,03	190,46
7	100	161,85	188,56	189,32	227,46

Table 4. Results of Chi-Square and Smirnov-Kolmogorov distribution tests accepted using Hydrognomon (5%)

No	Distribution	Chi-Kuadrat	Smirnov-Kolmogorov
1	Normal	REJECT	ACCEPT
2	Gumbel	ACCEPT	ACCEPT
3	Log Normal	ACCEPT	ACCEPT
4	Log Pearson Type III	-	ACCEPT

From the probability distribution tests, including the Chi-square and Smirnov-Kolmogorov tests at a 5% significance level, the highest value for the 5-year return period was obtained from the Gumbel distribution, with Reff = 108.96 mm.

4.2. Analysis of EPA SWMM under existing condition

The simulation of existing conditions used rainfall data from March 3, 2025, assuming it occurred hourly throughout the day, as shown in Table 5 and Figure 4. After determining the rainfall data, it was input into the time series section of the SWMM model. The hourly rainfall was considered uniform throughout the day, equal to the recorded daily total. The rainfall gauge was then set to match the time series, and parameters for the Subcatchment, Junction, and Conduit were adjusted based on site-specific data, as shown in Figure 4.

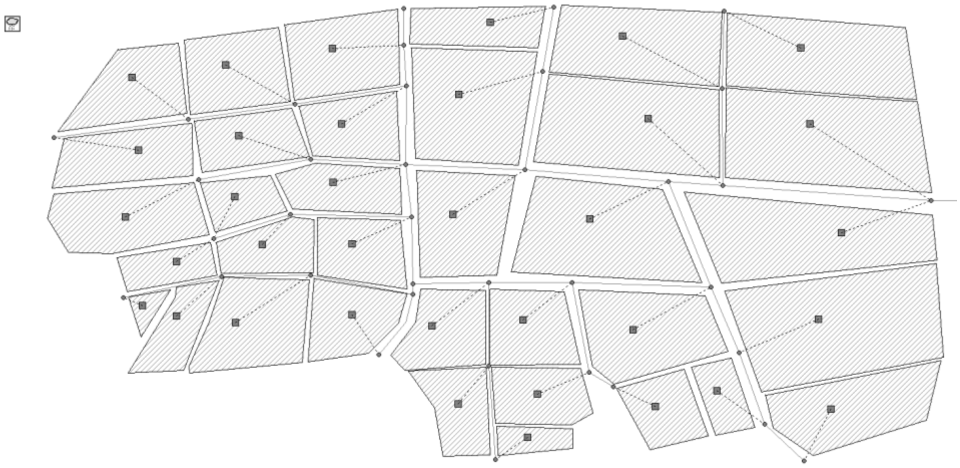


Figure 4. Digitization of parameters in SWMM

Table 5. Recap of the hourly rainfall time series calculation for a 5-year return period

Reff (mm)	R' at -n hour				
	0-1	1-2	2-3	3-4	4-5
	0,58 Reff	0,15 Reff	0,11 Reff	0,08 Reff	0,07 Reff
108,96	63,72 mm	16,60 mm	11,62 mm	9,25 mm	7,81 mm

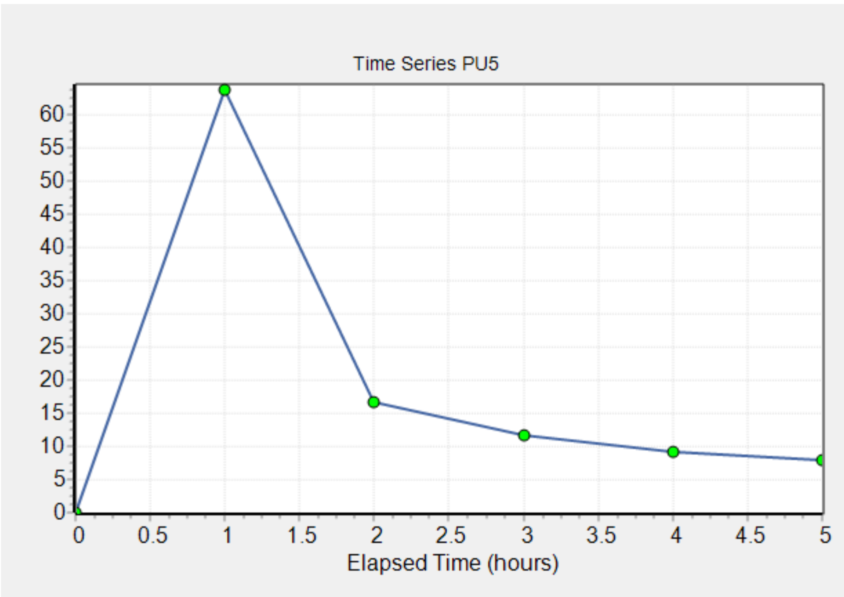


Figure 4. Proses input *time series* periode ulang 5 tahunan

4.3. Simulation results under existing condition

The simulation under current conditions yielded a surface runoff continuity error of -0.62% and a flow routing error of 0.00%, as shown in Figure 5.

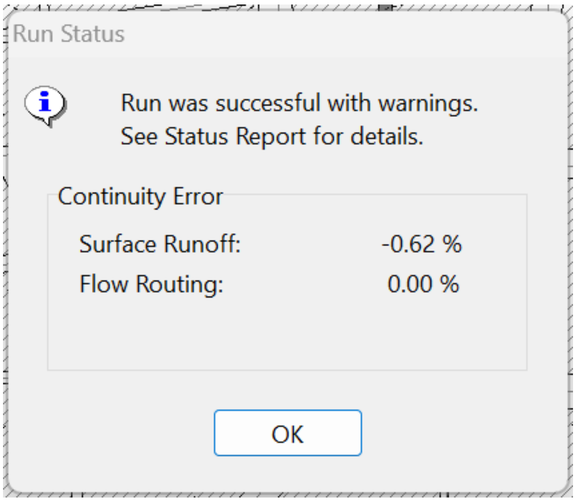


Figure 5. Value of the running results under the existing SWMM conditions

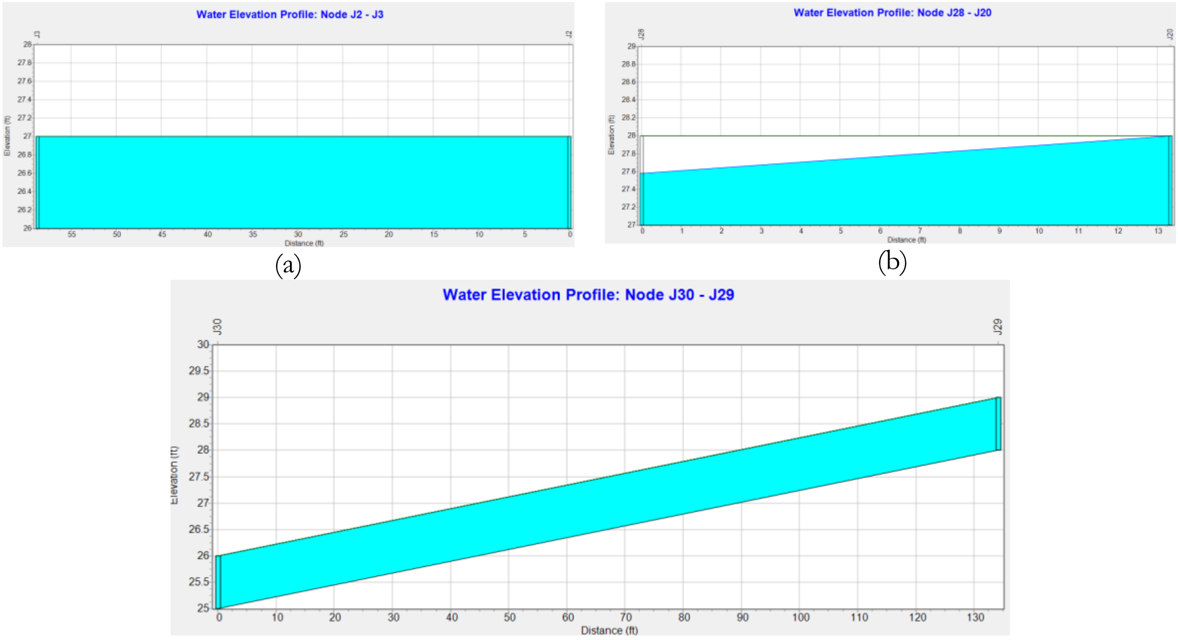
Table 6 shows that the junctions and conduits could not handle the incoming flow, resulting in overflow. The maximum recorded values indicate that channel capacity was exceeded.

Table 6. Summary of SWMM running results under existing runoff conditions

No Channel	Overflow Discharge (m3/s)	Overflow Duration (hour)	Condition	No Channel	Overflow Discharge (m3/s)	Overflow Duration (hour)	Condition
1	4,22	1,00	Overflow	20	6,16	1,00	Overflow
2	22,69	1,00	Overflow	21	2,85	1,00	Overflow
3	5,06	1,00	Overflow	22	8,66	1,00	Overflow
4	5,63	1,00	Overflow	23	1,16	1,00	Overflow
5	3,51	1,00	Overflow	24	0,61	1,00	Overflow
6	2,61	1,00	Overflow	25	5,70	1,00	Overflow
7	7,84	1,00	Overflow	26	6,23	1,00	Overflow
8	0,57	1,00	Overflow	27	3,31	1,00	Overflow
9	6,91	1,00	Overflow	28	9,64	1,00	Overflow
10	7,50	1,00	Overflow	29	9,07	1,00	Overflow
11	0,39	1,00	Overflow	30	7,27	0,82	Overflow
12	2,12	1,00	Overflow	31	10,92	0,82	Overflow
13	3,60	1,00	Overflow	32	4,24	0,82	Overflow
14	6,14	1,00	Overflow	33	6,27	1,00	Overflow
15	0,51	1,00	Overflow	34	5,71	1,00	Overflow
16	7,32	1,00	Overflow	35	6,13	1,00	Overflow
17	8,86	1,00	Overflow	36	2,95	1,00	Overflow
18	6,88	1,00	Overflow	37	4,44	0,89	Overflow
19	1,26	1,00	Overflow				

Source : Simulation results

The table and corresponding cross-sectional graphics show that the existing channels cannot handle the flow, as indicated by the overflow, with light blue water levels exceeding the conduit limits. All analyzed conduits experienced overflow. The top three conduits with the highest discharge were Conduit 2 (22.69 m^3/s), Conduit 31 (10.92 m^3/s), and Conduit 28 (9.64 m^3/s), as shown in Figure 6.



(a) (b) (c)

Figure 6. Simulation of water surface and flow discharge at (a) channel 2, (b) channel 31, and (c) channel 28

4.4. Modeling calibration

The simulation results under existing conditions indicated inundation reaching the Alun-Alun area of Serang City (see Table 6 and Figure 6). A report on the DPUPR Serang City website dated March 3, 2025, noted flooding at 18 points, including the Alun-Alun, confirming that the simulation accurately reflects field conditions. The rainfall data used in the model corresponds to that recorded on the same date. The simulation produced a surface runoff continuity error of -0.62% and a flow routing error of 0.00%. According to the SWMM User's Manual Version 5.1 (p.135), a continuity error below 10% indicates an acceptable model. Therefore, this model is considered valid.

4.5. Flood management using lid in two alternatives

After analyzing the modeled existing conditions, the next step was to implement Low Impact Development (LID) tools to assess the reduction in runoff from their application. This simulation focused on Subcatchment 7, Subcatchment 8, Subcatchment 24, Subcatchment 23, and Subcatchment 28, which drain through the three channels with the highest discharge for the application of LID controls.

4.6. Simulation results using the application of the LID control method

The simulation with LID implementation yielded a surface runoff continuity error of -0.38% and a flow routing error of 0.00%, both within acceptable thresholds (below 10%), validating the model. Figure 7 shows the simulation results after applying LID techniques and adjusting conduit designs. Despite improvements, inundation persisted in Conduit 2, which drains Subcatchment 8 and the surrounding area. This conduit has a flat slope and forms a basin-like depression, causing runoff to remain above the channel's water surface line.

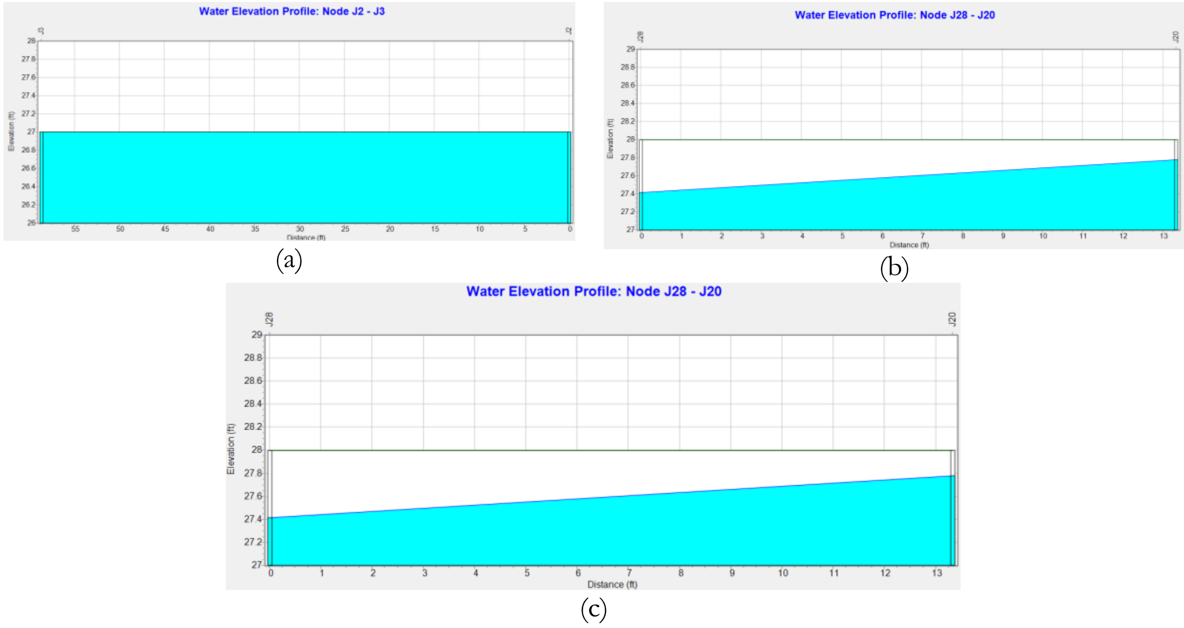


Figure 7. Simulation of water surface and flow discharge at channel (a) channel 2, (b) channel 31, and (c) channel 28

The selected subcatchments with applied LID strategies, including bioretention cells and permeable pavement, are illustrated in Figure 8.

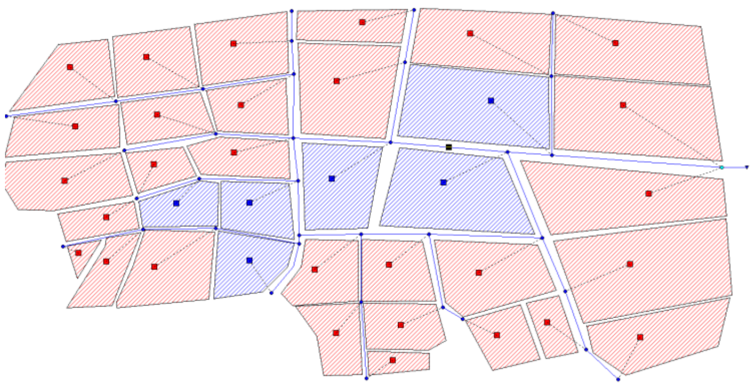


Figure 8. Subcatchment with applied LID

5. DISCUSSION

This study evaluates the application of the Low Impact Development (LID) approach to improve the performance of urban drainage systems in Serang City, which frequently floods due to the current system's inability to handle high rainfall intensity. Simulation results using the Storm Water Management Model (SWMM) show that several drainage channels, particularly Channel 2, cannot accommodate large flow rates, with runoff peaking at 22.69 m^3/s. The main factors contributing to this issue are limited channel capacity and flat topography, leading to water ponding.

However, after implementing LID techniques such as bioretention and permeable pavement, runoff volume significantly decreased. This improvement is evident in the reduction of the surface runoff continuity error from -0.62% to -0.38%, well below the recommended threshold. Despite the overall runoff reduction, Channel 2 still experiences ponding, likely due to suboptimal channel slope and insufficient capacity.

To address this issue, several solutions may be considered, including increasing channel dimensions or adding supplementary drainage channels. Improving the slope of the drainage system should also be considered to facilitate faster water flow. Additionally, incorporating drainage elements such as rain gardens or bioswales near Channel 2 could enhance water infiltration and further reduce runoff.

Overall, LID implementation has effectively reduced flood potential by enhancing infiltration and slowing surface runoff. A more sustainable and efficient drainage system can alleviate pressure on existing infrastructure and provide a long-term solution to urban flooding. These findings offer valuable insights for environmentally friendly urban drainage planning, capable of addressing the impacts of climate change and rapid urbanization.

5. CONCLUSION

This study successfully identified the effectiveness of LID implementation in optimizing the urban drainage system in Serang City, which has long faced flooding problems due to limited drainage capacity. Simulation results using the Storm Water Management Model (SWMM) show that LID measures, such as bioretention and permeable pavement, can reduce runoff volume and improve drainage performance, with surface runoff continuity error values remaining within acceptable limits. However, certain channels, like Channel 2, still experience ponding due to inadequate slope and limited capacity. To address this, further solutions are needed, such as increasing channel capacity and integrating additional drainage elements to achieve more effective and sustainable stormwater management. These findings provide guidance for developing environmentally friendly and climate-adaptive drainage systems and support ongoing research to enhance the understanding of urban stormwater management in the future.

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