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Urban Flood Management Strategies in Kapanewon Depok, Sleman Regency
(A Simulation-Based Study Using EPA SWMM 5.2)

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Abstract

Kapanewon Depok has experienced frequent urban flooding in recent years, driven by rapid urbanization and the compounding effects of climate change. In response, the Sleman Regency Government, through the 2023-2043 RDTR for the Central Sleman Area, plans to implement various strategies, including the construction infiltration trenches as a flood mitigation strategy. This study aims to evaluate the strategic role and effectiveness of infiltration trenches in reducing urban flooding in Kapanewon Depok. The EPA SWMM 5.2 software was utilized to simulate urban flooding scenarios using rainfall data with a 5-year return period. The first scenario simulated the current urban drainage system, while the second scenario incorporated Low-Impact Development (LID) controls, specifically infiltration trenches. Results from the initial scenario revealed 30 junctions experiencing overflows. The use of infiltration trenches covering 0.5% of the sub-catchment area served by the overflowing channel, successfully reduced the number of overflow points to 18, with an average reduction of 62.5% and 62% total flood volume and hours flooded, respectively. This study highlights the importance of integrating infiltration trenches into broader flood management strategies, combining structural and non-structural approaches to enhance resilience in urban water management systems. The findings support regional planning by providing actionable recommendations for sustainable flood risk reduction strategies.

Keywords: infiltration trenches, SWMM, urban flood.

1. Introduction

Kapanewon Depok is rapidly becoming one of the fastest-growing areas in Sleman Regency. It has the largest population and the highest migration rate within the region (BPS Kabupaten Sleman, 2023). As the population continues to grow, there will be an increased demand for urban facilities and infrastructure (Irawan, 2017), resulting in the conversion of agricultural land--both paddy and non-paddy fields--as well as open space and farmland into built-up areas. Such land conversion can disrupt hydrological processes, resulting in reduced infiltration capacity and increased volume and rate of surface runoff (Christanto et al., 2018; Simpson et al., 2022). If this situation is not accompanied by an adequate drainage system, it has the potential to cause urban flooding.

Drainage systems are essential for managing stormwater and mitigating urban flooding. However, they are generally designed based on historical data (Lou et al., 2024), which often fails to account for the impacts of climate change and the dynamics of urbanization, potentially leading to system failures. When drainage capacity is inadequate, stormwater can overflow, causing flooding that disrupts accessibility and community activities. Urban hydrological processes are affected not only by changes in land use from

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natural landscapes to impervious built environments but also by variations in rainfall intensity (Bibi et al., 2023). Trend analyses of annual extreme rainfall in eastern Yogyakarta indicate that the number of rainy days has increased over the years (Abdila et al., 2022). In recent years, Kapanewon Depok has experienced urban flooding due to high rainfall intensity (BPBD Kabupaten Sleman, 2023; BPBD Provinsi DIY, 2024). On October 18, 2022, the Condongcatur-Gejayan intersection experienced significant flooding, resulting in a traffic jam that lasted for about an hour (SuaraJogja.id, 2022). Another instance of urban flooding occurred on October 25, 2024, affecting various locations, including Jalan Raya Candi Gebang, Condongcatur, and the area in front of the UPN Veteran Yogyakarta campus. This flooding has disrupted vehicular traffic in these areas (SuaraMerdeka.com, 2024).

Forecasts indicate that rain intensity may increase due to a weak La Niña phenomenon from October to December 2024, which is expected to last until March 2025 (Climate Prediction Center, 2024). The rainy season in Kapanewon Depok is expected to start in November 2024, with the peak of the rainy season in February 2025. Furthermore, the duration of this rainy season is projected to be two dasarians longer than usual (Badan Meteorologi Klimatologi dan Geofisika, 2024), indicating a higher probability of urban flooding in Kapanewon Depok.

Kapanewon Depok has a drainage system development plan outlined in the Central Sleman Detailed Spatial Plan (RDTR) for the years 2023-2043. The Sleman Regency Government plans to maintain the existing drainage network, develop ecologically based drainage solutions, expand public green open spaces, and construct infiltration trenches throughout the Central Sleman planning area. By utilizing existing drainage network data along with design rainfall data in EPA SWMM 5.2, this study simulates drainage system performance to identify potential urban flooding locations. Each identified site is then analyzed to determine the causes of flooding and recommend appropriate countermeasures, including Low Impact Development (LID) controls.

This research specifically evaluates the use of infiltration trenches in flood-prone areas, aligning with the infiltration trenches development plan outlined in the Central Sleman Region RDTR for 2023-2043. The focus is to assess the effectiveness of these infiltration trenches in mitigating flood events within the existing drainage system. By simulating different scenarios, the research highlights the potential of infiltration trenches to reduce surface runoff volume and peak flow rates. The findings are expected to provide actionable recommendations for sustainable urban water management strategies, which can be integrated into regional development plans.

2. Research Method

This study was conducted in Kapanewon Depok, Sleman Regency, covering a catchment area of 3,555 hectares. Administratively, Kapanewon Depok is located within Sleman Regency and forms part of the northern region of the Yogyakarta urban agglomeration. It consists of three sub-districts: Condongcatur, Caturtunggal, and Maguwoharjo. Kapanewon Depok is one of the southernmost districts in Sleman Regency, situated on the southern slopes of Mount Merapi, characterized by gently sloping topography (with a slope gradient of 0–3%). The dominant soil type in Kapanewon Depok is regosol, formed from volcanic materials (Pemerintah Kabupaten Sleman, 2012). A visual representation of the study area, showing the distribution of urbanized and non-urbanized zones as well as surface elevation inferred from hill shading, is presented in Figure 1.

The data required for this study include the existing drainage network and its geometry across Kapanewon Depok, obtained through field surveys; rainfall data from 2004 to 2023 collected from six rainfall stations provided by BBWS Serayu Opak; topography data derived from DEMNAS; and a map of existing inundation distribution, compiled by the Sleman Regency Development Planning Agency (Bappeda) in 2022, which serves as validation data. Additionally, urbanized area delineation was conducted using recent Google Earth imagery, supplemented by field validation to ensure accuracy.

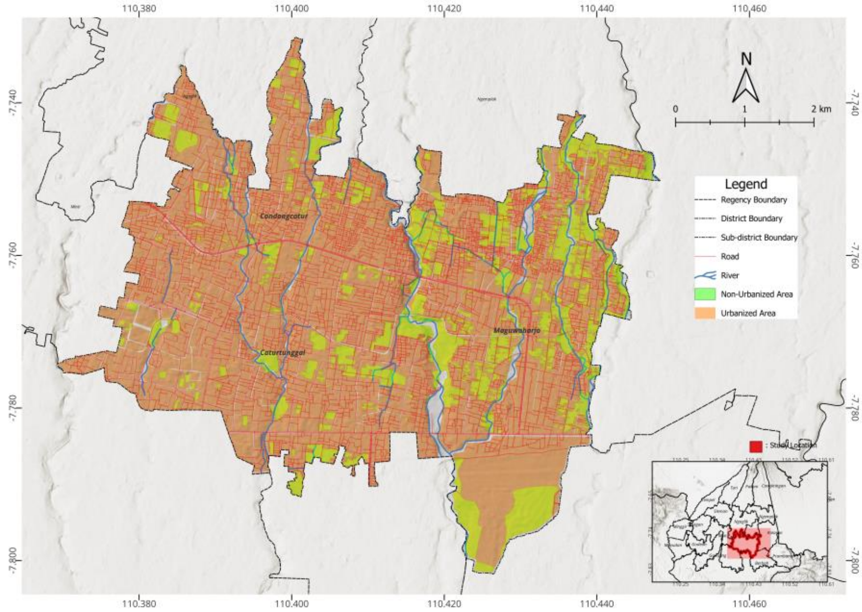

Figure 1. Map of urbanized area and topographic condition in Kapanewon Depok
Source: Author's analysis

2.1 Rainfall Analysis

The rainfall data used in this study consists of the annual maximum daily rainfall over a 20-year period (2014-2023) from six rainfall stations surrounding the study area. To ensure the reliability of the data, consistency testing was performed using the Rescaled Adjusted Partial Sums (RAPS) method, which is employed to detect any shifts or inconsistencies in the rainfall data. The RAPS method involves calculating the cumulative sum of rainfall data and comparing it with the expected statistical behavior. Following this, an F-test was conducted to evaluate the homogeneity of the variance among the data from different stations. A significant F value indicates heterogeneity in the datasets, suggesting that the data from different stations may not be pooled for further analysis.

After confirming the consistency and homogeneity of the data, the regional rainfall was computed using the Thiessen Polygon method. This method assigns each rainfall station a weight based on its proximity to the study area, allowing for a more accurate estimation of the average rainfall across the region. Finally, the design rainfall was calculated using the Mononobe equation, which estimates rainfall intensity based on a specific return period and duration. This Mononobe equation is crucial for estimating the rainfall intensity for a given return period, which is essential for flood design and drainage planning. In this study, the design rainfall data for a 5-year return period were used.

2.2 Sub-catchments Analysis

Delineating the study area into sub-catchments is an essential step in obtaining the sub-catchment input data for EPA SWMM 5.2 simulations. The delineation boundaries are based on the existing drainage network pattern and the natural topography that influences the direction of rainfall flow toward the concentration points. The delineation is performed using topography data and *Google Satellite* from *QuickMapService* tools in the QGIS software. Subsequently, within each sub-catchment, impervious areas (representing built-up land) and pervious areas (representing open land, vegetation, and rice fields) are delineated. The area of each land type is calculated, and Manning's roughness coefficient for each land type is determined. The slope for each area is also calculated from DEMNAS.

The infiltration model used in this study is the SCS Curve Number (SCS-CN) method. The SCS-CN values for each sub-catchment are determined based on soil type and land use. The soil types are classified into four groups (A, B, C, D), with Type A having high permeability and high infiltration capacity, Type B having moderate permeability and high infiltration capacity, Type C having low permeability with limited infiltration capacity, and Type D having very low permeability with a small infiltration capacity. In addition to soil type, land use differences also affect the SCS-CN value. The SCS-CN values based on land use and soil type are presented in Table 1.

Table 1. SCS Curve Number

Land Use Description	**Hydrological Soil Group**			
	A	**B**	**C**	**D**
Cultivated Land				
- without conservation treatment	72	81	88	91
- with conservation treatment	62	71	78	81
Pasture or range land				
- Poor condition	68	79	86	89
- Good condition	39	61	74	90
Meadow				

Land Use Description	Hydrological Soil Group			
	A	B	C	D
- Good condition	30	58	71	78
Wood and forest land				
- Thin stand, poor cover, no mulch	45	66	77	83
- Good cover	25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.				
- Good condition: grass cover on ≥ 75% of the area	39	61	74	80
- Fair condition: grass cover on 50-75% of the area	49	69	79	84
Commercial and business area (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Residential				
Average lot size				
- I1/8 acre or less (65% impervious)	77	85	90	92
- 1/4 acre (38% impervious)	61	75	83	87
- 1/3 acre (30% impervious)	57	72	81	86
- 1/2 acre (25% impervious)	54	70	80	85
- 1 acre (20% impervious)	51	68	79	84
Paved parking lots, roofs, driveways, etc.	98	98	98	98
Streets and roads				
- Paved with curbs and storm sewers	98	98	98	98
- Gravel	76	85	89	91
- Dirt	72	82	87	89

Source: SCS Urban Hydrology for Small Watershed, 2nd Ed., (TR-55), June 1986.

2.3 EPA SWMM 5.2 Simulation

This study utilizes two types of simulations: one that uses the existing drainage network and another that incorporates Low Impact Development (LID) controls in the form of infiltration trenches. Sub-catchment delineation maps and property data from QGIS are exported to SWMM. Simultaneously, junctions, conduits, and outfalls are manually created in EPA SWMM 5.2. The hydrological and channel geometry data are entered into their respective properties to simulate the flow through the existing drainage network. SWMM produces outputs in the form of diagrams, graphs, tables, cross-sectional channel profiles, and statistical summaries (Rossman, 2022).

The dimensions of infiltration trenches are determined in accordance with the Indonesian National Standard (SNI) 03-2459-2002, which specifies guidelines for infiltration systems in residential areas. These trenches typically have a width ranging from 0.8 to 2 meters and a depth between 1.5 and 3 meters, depending on the soil conditions (Badan Standarisasi Nasional, 2002). To facilitate percolation into the ground, the bottom of the trench remains uncovered, and a layer of gravel or crushed stone, measuring 20 to 30 cm in thickness, is used for sediment filtration. In this study, infiltration trenches with a width of 1 meter and a depth of 1.5 meters are employed, without a drain, allowing the outflow from the trench to return to the sub-catchment as runoff. The number of infiltration trenches implemented is approximately 0.5% of the total sub-catchment area, based on an area requirement of 4 m² per trench. This strategy is informed by research conducted by Martin-Mikle et al. (2015), which demonstrated that well-placed Low Impact Development (LID) measures that occupy less than 1% of the sub-catchment area can effectively manage 25% of runoff and reduce sediment and nutrient loads by up to 15%. The allocation of 0.5% is deemed suitable for Kapanewon Depok, considering the constraints of available land and the rapid urbanization occurring in the region.

The results of these simulations are used to identify locations that are prone to urban flooding during a rainfall event with a 5-year return period. The identified flood-prone areas are then analyzed to determine which drainage channels need evaluation and improvement (Bibi et al., 2023). subsequent simulation includes the addition of infiltration trenches as LID controls in the sub-catchments surrounding these flood-prone areas, aiming to assess their impact on flow reduction and flood mitigation potential.

3. Result and Discussions

3.1 Rainfall Design

Rainfall data were collected from one rainfall station located within the study area, namely Santan Station, and from five stations closest to the study area: Beran, Gemawang, Nyemengan, Karang Ploso, and Tanjung Tirto Stations. The annual maximum daily rainfall data from each station are presented in Figure 2.

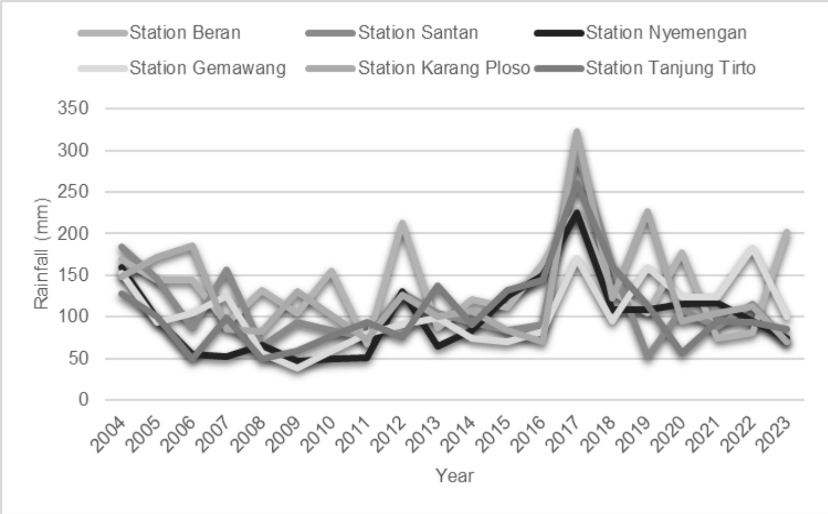

Figure 2. Annual Maximum Daily Rainfall 2004-2023 from 6 rainfall stations
Source: Author's analysis

The RAPS test calculations were performed using a 90% confidence level for each station, as shown in Table 2. The rainfall data from each station in this study were determined to be consistent.

Table 2. RAPS test results

Stations	Test Results		Confidence level (90%)		Remarks
	$Q/n^{0.5}$	$R/n^{0.5}$	$Q/n^{0.5}$	$R/n^{0.5}$	
Beran	0.444	0.766	1.1	1.34	Consistent
Santan	0.740	0.991			Consistent
Nyemengan	0.622	0.877			Consistent
Gemawang	0.451	0.833			Consistent
Karang Ploso	0.703	0.927			Consistent
Tanjung Tirto	0.719	0.976			Consistent

Source: Author's analysis

The rainfall data, which has been tested for consistency, is then tested for homogeneity using the F-test. Results of the F-test calculation that are smaller than the critical F value are considered to have a stable or homogeneous variance. Based on the calculations presented in Table 3, the rainfall data is declared to be homogeneous.

Table 3. F-test results

Stations	$F_{test\ results}$	$F_{critical\ value}$	Remarks
Beran	0.7264	3.18	Homogeneous
Santan	0.3150		Homogeneous
Nyemengan	0.8532		Homogeneous
Gemawang	0.6426		Homogeneous
Karang Ploso	0.2837		Homogeneous
Tanjung Tirto	0.2846		Homogeneous

Source: Author's analysis

The calculations are then continued to determine the regional rainfall using the validated data. This study employs the Thiessen Polygon method. The results of the regional rainfall calculations are presented in Figure 3. The data from these regional rainfall calculations serve as the basis for the design rainfall calculations.

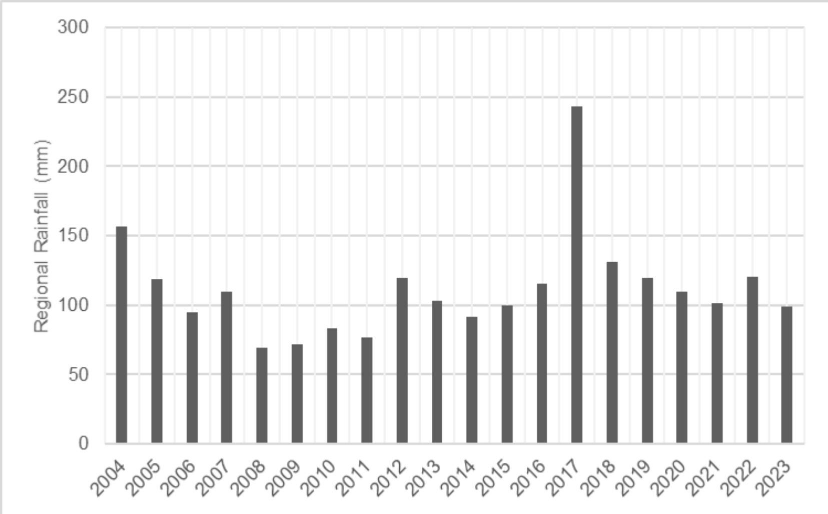

Figure 3. Regional Rainfall
Source: Author's analysis

In this study, we conducted frequency analysis to determine design rainfall values for various return periods using four methods: Gumbel, Log Pearson III, Normal, and Log Normal. For the 5-year return period, which will be used in the drainage flow simulation in EPA SWMM 5.2, the Gumbel method produces the highest rainfall value, whereas the Log Pearson III method yields the lowest. The design rainfall calculations for all four methods are presented in Table 4. Choosing the appropriate method is essential as it can significantly impact simulation outcomes and the drainage system's planning. The Gumbel method is generally more suitable for assessing extreme rainfall events, while the Log Pearson III method tends to be more conservative when estimating lower rainfall amounts (Ruhiat, 2022). Consequently, comparing the results from these four methods offers a more comprehensive understanding of potential rainfall for different return periods.

Table 4. Design rainfall from each method

Return Period [Tr]	Design Rainfall (mm)			
	Gumbel	Log Pearson III	Normal	Log Normal
5	145.97	132.12	143.03	135.59

Source: Author's analysis

The design rainfall calculations from each method were tested for their adherence to distribution fitting through the Smirnov-Kolmogorov and Chi-Square tests. The results indicated that all frequency analysis methods passed the distribution fitting criteria in the Smirnov-Kolmogorov test. However, in the Chi-Square test, both the Log Pearson III and Normal methods failed to meet the distribution fitting criteria at a 5% confidence level. The design rainfall data utilized in this study were based on the Gumbel method, which successfully passed all distribution fitting tests and produced higher rainfall values, making it suitable for predicting urban flood events. Subsequently, the Gumbel design rainfall was used to calculate the hourly rainfall distribution using the Mononobe model. The hourly rainfall data for the 5-year return period, as shown in Table 5, will be utilized as input for the rain gauge object in EPA SWMM 5.2. Using Gumbel design rainfall is anticipated to yield more conservative and realistic simulation results when assessing the flood potential in the existing drainage network.

Table 5. Hourly rainfall 5-year return period

t-th Hour	Percentage of the t-th Hour	Rainfall 5 year-return
1	55.03%	19.36
2	14.30%	5.03
3	10.03%	3.53
4	7.99%	2.81
5	6.75%	2.37
6	5.90%	2.07
	100.00%	
Effective	(mm/hari)	35.18

Source: Author's analysis

3.2 Sub-catchment Analysis

Kapanewon Depok is segmented into 530 sub-catchments, each differentiated into impervious and pervious zones. The categorization of these areas has been validated through field assessments. Results indicate that impervious areas—comprising residential, commercial, and road networks—predominate throughout Kapanewon Depok. Conversely, pervious areas, which include rice fields, shrubs, and open land, are primarily found in Maguwoharjo Village. However, the swift transformation of green open spaces into developed land poses a significant threat to the remaining pervious zones. Between 2010 and 2020, Kapanewon Depok witnessed a loss of 253.4 hectares of rice fields due to such conversions (Rahmawati & Arif, 2023). Consequently, it is essential to implement measures that protect the remaining pervious areas to mitigate increased surface runoff and reduce the risk of urban flooding.

The soil composition in Kapanewon Depok is categorized as *regosol*, which corresponds to soil type A for the determination of the SCS-CN (Soil Conservation Service Curve Number) values applicable to each sub-catchment, as outlined in Table 1. In this analysis, impervious surfaces are represented by paved roads, which include sidewalks and drainage systems, corresponding to a Curve Number (CN) value of 98. Conversely, pervious areas are characterized by open land, grass lawns, agricultural fields, and other similar terrains that exhibit a grass coverage of 50-75%, assigned a CN value of 49.

The overall CN value for each sub-catchment is computed by multiplying the CN value of each land use category by its respective area. Furthermore, designated depression storage values are allocated to each area type. For this study, a depression storage value of 2.54 mm is utilized for impervious areas, while a value of 7.62 mm is applied to pervious areas. All the data collected are subsequently integrated into the attribute table in accordance with the property standards mandated by the EPA SWMM 5.2.

3.3 EPA SWMM 5.2 Data Preparation

The existing drainage channels, derived from comprehensive field surveys and subsequent analyses, were systematically mapped onto the sub-catchments incorporated into the Storm Water Management Model (SWMM). Convergence points comprising two or more channels were designated as junctions, whilst the termini of the channels were classified as outfalls. The mapping results for Kapanewon Depok indicated the presence of 1,119 junctions, 1,115 conduits, and 89 outfalls (refer to Figure 4). An analysis of channel geometry was conducted based on a representative sample of 230 junction points, utilizing dimension measurements that accurately depict existing conditions. Sediment deposition observed at the channel bottom served as a reference for determining channel height. Subsequently, the channels were categorized according to their functional classifications, namely primary, secondary, and tertiary. For channels that fell within the same functional category but lacked specific geometric data, geometry values were assigned based on the mode derived from relevant sampling data.

In the subsequent phase, property data for each drainage entity (including conduits, junctions, and outfalls) were meticulously entered using Notepad++, adhering strictly to the input format mandated by SWMM. Following the data entry process for conduits, junctions, and outfalls into SWMM, the next critical step involved the verification and validation of the geometric and functional attributes of the drainage channels. During the data generalization stage, the potential for misrepresentation within the simulation model was identified. For instance, consider the scenario in which the channel sizes linking junctions J1 to J3, J2 to J3, and J3 to J4 are 0.5 m, 0.8 m, and 0.3 m, respectively. The pronounced variability in channel sizes among these junctions could introduce significant discrepancies in the SWMM outputs. Such differences may result in unrealistic flow distributions, emphasizing the necessity for a consistent and precise representation of channel conditions to ensure the integrity of simulation results. Ideally, junctions exhibiting substantial size discrepancies would be subjected to direct verification and validation through field inspections. However, to optimize efficiency in terms of both time and resource allocation, it is often more pragmatic to utilize comparable or closely matching channel geometries drawn from the nearest available datasets that possess valid geometric information.

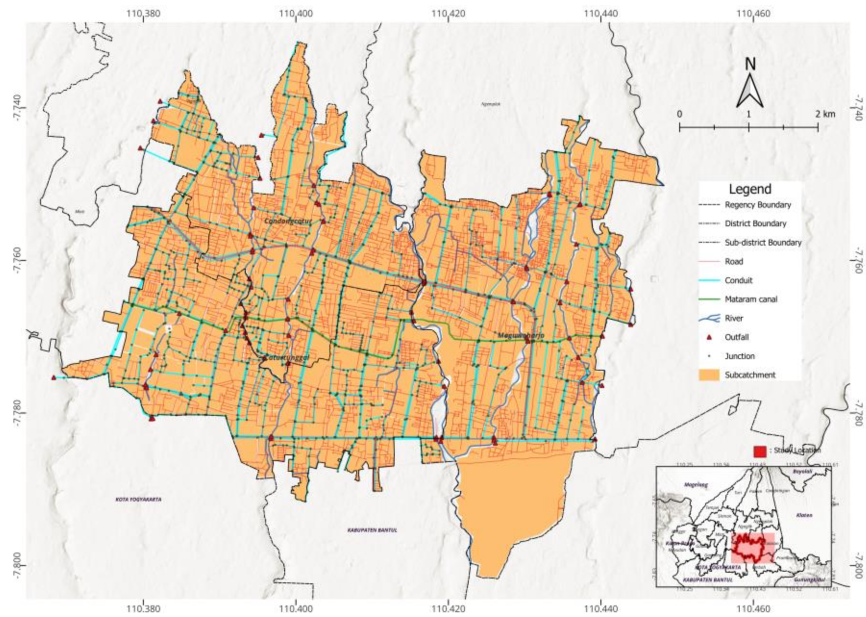

Figure 4. Urban drainage system in Kapanewon Depok for data input to EPA SWMM 5.2
Source: Author's analysis

3.4 EPA SWMM 5.2 Simulation

The drainage system has been rigorously modeled using the EPA SWMM 5.2, and subsequently subjected to a comprehensive simulation. The analysis revealed continuity errors, specifically for surface runoff and flow routing, that were maintained at less than 5%, indicating a commendable and acceptable state of model performance. Initial simulations of the existing drainage conditions revealed overflow occurrences at multiple channel points, with 229 out of 1,119 junctions identified as experiencing over-capacity conditions. However, it is essential to note that this figure does not fully encapsulate the actual field conditions, thereby necessitating further validation to enhance the accuracy of the findings.

Field validation efforts were concentrated on channel points situated outside of the flood-prone areas, utilizing the 2022 flood distribution map provided by Bappeda Sleman Regency as a reference. For those channels where no overflow was detected, geometric remeasurement was conducted to ensure that the model accurately reflects the prevailing conditions. Following this validation process, subsequent simulation results indicated a significant reduction in the number of overflowing channels, with only 30 out of 1,119 junctions exhibiting overflow conditions attributable to insufficient channel capacity. Moreover, it was observed that certain field points, which had not been identified as overflowing during the simulation, did experience ponding during the rainy season. These specific junctions include J779, J400, J679, and J756. This discrepancy underscores the importance of integrating field observations with simulation results for a holistic understanding of drainage performance.

The EPA SWMM 5.2 model incorporates uncertainties that can result in considerable variations between the initial simulation results and the validation outcomes. A primary factor contributing to this uncertainty is the model generalization process (Ma et al., 2022). Kapanewon Depok, which covers an area of 3,555 ha, necessitates the simplification of drainage geometry to enhance modeling efficiency. Furthermore, the identification of impervious and pervious areas within each sub-catchment is generalized based on the prevailing surface types that influence the level of impermeability in the region. Although this approach to generalization is practical, it has the potential to create significant discrepancies between the simulation results and actual field conditions. Inaccuracies in representing both the geometry and surface characteristics are believed to be the primary reasons for the differences observed between the initial simulation results and the validation outcomes. In addition, other flood locations identified in the analysis, which are not situated near the inundation distribution of 2022 but have been validated through field interviews, are also included in this study. Consequently, the findings from the urban flood analysis and validation in Kapanewon Depok encompass 16 points in Condongcatur, 5 points in Caturtunggal, and 13 points in Maguwoharjo (Figure 5).

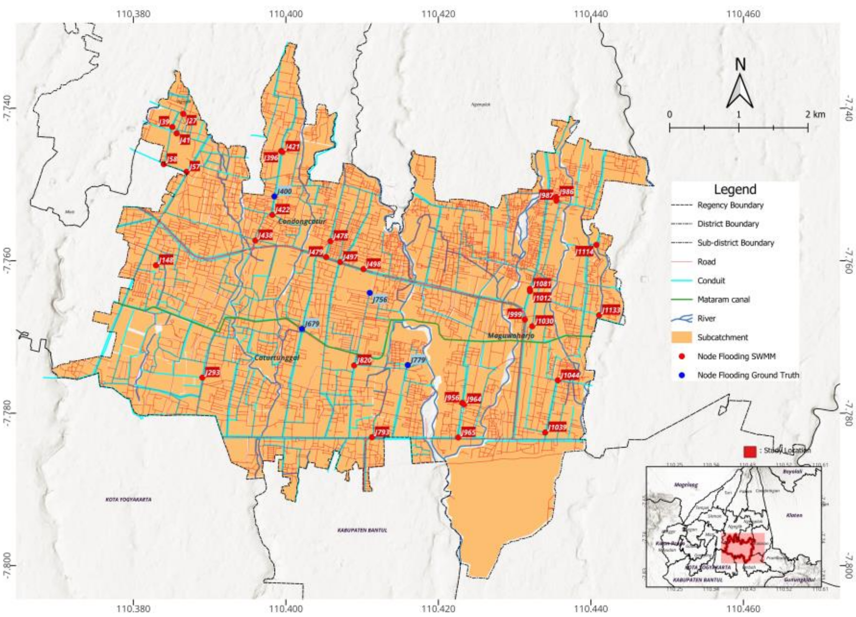

Figure 5. Flooding nodes identified from EPA SWMM 5.2 simulation results and additional flooding nodes discovered through field observations
Source: Author's analysis

The sub-districts of Condongcatur and Caturtunggal exhibit a higher prevalence of impervious surfaces compared to the sub-district of Maguwoharjo. The significant number of flood-prone areas in Condongcatur can be attributed to the limited capacity for water infiltration, leading to local runoff that surpasses the existing drainage system's capabilities. Field validation has also identified external inflows from the northern region, which further burden the drainage network in Condongcatur. This additional runoff intensifies the capacity constraints of the current channels, ultimately contributing to flooding. In a similar vein, Caturtunggal, having undergone a comparable rate of urban expansion and land-use transformation to that of Condongcatur, is located in a relatively low-lying area where water from the upper regions (to the north) naturally flows toward it. However, due to the region's topographical characteristics, the water primarily drains southward (toward outflow), resulting in a lower incidence of flood-prone areas compared to Condongcatur. Urban flooding results not only from insufficient drainage capacity caused by dimensions that are inadequate or by sediment and other obstructions but also from the transformation of irrigation channels into drainage channels due to the conversion of rice fields into residential areas. This issue is particularly evident in the Maguwoharjo sub-district. The Maguwoharjo sub-district has developed more recently than the other two sub-districts, which have been supporting the city for a longer period. As a result, some channels in this area, originally designed for rice field irrigation, have not been properly adjusted in terms of their dimensions and slope to effectively serve a drainage function. In certain locations, these irrigation canals continue to exist despite the risk of overflow, as some sub catchments still rely on them for irrigating rice fields.

In the second simulation, which incorporated the addition of infiltration trenches, the results revealed a reduction of 12 flooding points, alongside an average decrease of 62% in hours flooded (see Figure 6). This reduction is deemed effective compared to the conditions that existed before the implementation of the infiltration wells. However, the effectiveness of these wells is highly contingent on the specific characteristics of the location. The ability of an infiltration well to temporarily retain water before it percolates into the soil may not be optimal in certain areas. This can stem from factors such as the limited capacity of surrounding drainage systems or excessive surface runoff. Furthermore, to enhance the performance of infiltration wells, it is advisable to improve the dimensions of the drainage system and consider integrating them with rainwater harvesting systems, retention ponds, or other Low Impact Development (LID) controls. This study does not explicitly designate specific locations for the installation of infiltration trenches; however, it offers guidance on which sub catchments should be prioritized for their development. The suggested sub catchments areas for the establishment of infiltration wells are illustrated in Figure 7.

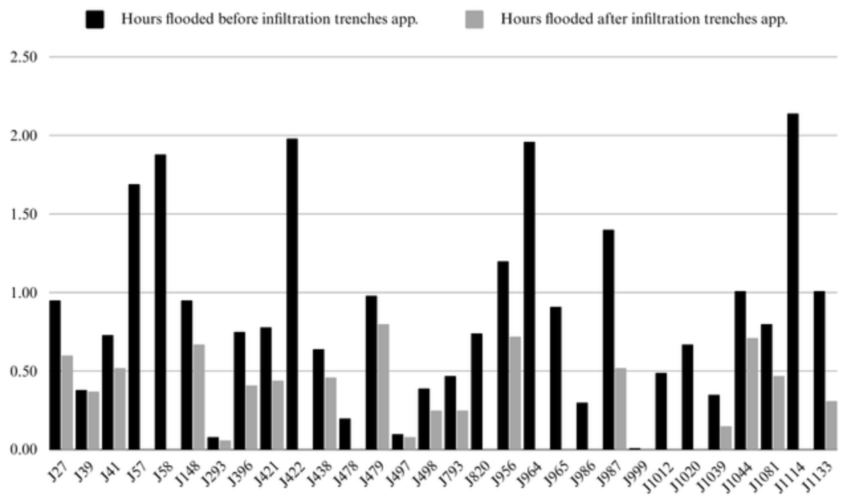

Figure 6. Comparison the flooded hours before and after implementing infiltration trenches
Source: Author's analysis

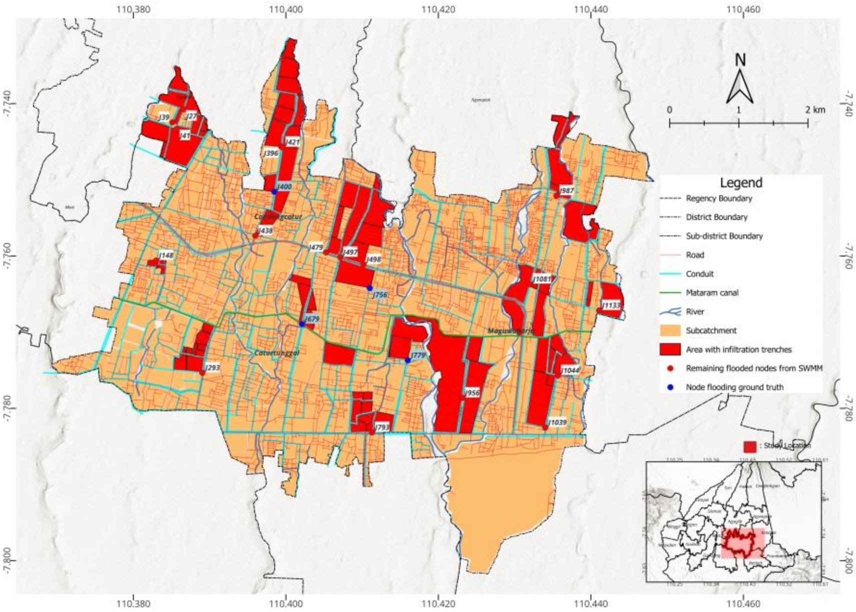

Figure 7. Map of recommended areas for infiltration trenches placement
Source: Author's analysis

4. Conclusion

Urban flooding in Kapanewon Depok is influenced by several key factors, including rainfall intensity, drainage capacity, and changes in land use. Simulations conducted on existing drainage flows during a 5-year return period rainfall event revealed 30 overflow points within the drainage system. This finding is corroborated by field validation through interviews with local residents living in flood-prone areas. Furthermore, during field observations, four additional drainage channels were identified as overflowing. The most significant longest flood duration was recorded in Maguwoharjo sub-district, where irrigation channels serve as drainage systems without proper dimensional modifications. The primary factors contributing to urban flooding in Kapanewon Depok includes: an increase in impervious surfaces due to the conversion of open land into built-up areas; a lack of drainage systems in areas previously used for rice cultivation; insufficient drainage dimensions to handle runoff volumes; and sedimentation and other blockages within the drainage channels.

The construction of infiltration trenches in sub-catchments that are prone to flooding can lead to a reduction in overflow volume by 62.5% and a decrease in flood duration by 62%. Based on the findings, strategic actions are recommended to enhance flood management in Kapanewon Depok, including:

1. Wider implementation of infiltration trenches: prioritize installation in high-risk sub-catchments as identified in this study.
2. Integration with other LID measures: combine infiltration trenches with rainwater harvesting systems, green roofs, and permeable pavements to maximize stormwater absorption and retention.
3. Drainage infrastructure improvement: upgrade the capacity and maintenance of drainage networks to support increased runoff volume.
4. Land-use regulation enforcement: strengthen zoning regulations to protect existing pervious areas and prevent further conversion of open spaces into built-up areas.
5. Community-based flood risk management: encourage community participation in maintaining infiltration systems and reporting drainage issues, ensuring sustainability and efficiency of implemented measures.

Incorporating these strategic actions into the RDTR for Central Sleman 2023-2043 will strengthen the region's resilience against urban flooding and support sustainable urban development in Sleman Regency.

Further investigation, with a specific focus on each individual village, is advised to yield more representative simulation results, especially given the expansive area of Kapanewon Depok. It is also essential to conduct simulations encompassing various land use change scenarios, due to the rapid development occurring in the study area. Additionally, exploring simulations that integrate LID controls or other flood control measures could lead to more effective mitigation recommendations.

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