 P-ISSN : 2598-1277
E-ISSN : 2621-3966

JOURNAL OF GREEN SCIENCE AND TECHNOLOGY

EVALUATION OF THE EFFECTIVENESS OF MODULAR INFILTRATION BOXES IN REDUCING SURFACE RUNOFF IN URBAN AREAS: A CASE STUDY IN CIREBON CITY, INDONESIA

Awliya Tribhuwana[1], Slamet Imam Wahyudi[2*], Moh. Faiqun Ni'am[2]

[1]) Civil Engineering Departemen, Universitas Swadaya Gunung Jati, Cirebon*
[2]) Civil Engineering Department, Universitas Islam Sultan Agung, Semarang.*
Corresponding Author's Email: wahyudi@unissula.ac.id
No.HP Corresponding Author : 08122920826

ABSTRACT

The urban area of Cirebon City, Indonesia, with its tropical climate, in the Sunyaragi sub-district, is increasingly affected by surface runoff and flooding due to limited drainage capacity and extensive impervious surfaces. This study evaluates the effectiveness of a modular infiltration box system in reducing urban stormwater runoff. Hydrological data from Harjamukti, Kamun, and Kertajati stations from 2014 to 2023 were analyzed using a Log Pearson Type III distribution to determine rainfall intensity for return periods of 2, 5, and 10 years. Field Experiment and Laboratory Analysis Methods: Soil infiltration characteristics were tested using a double ring infiltrometer and modeled with the Horton infiltration equation. Infiltration boxes measuring 1.00×0.50×0.45m were installed on the road median in two configurations, single layer (22 units) and double layer (44 units). The results showed that the single-layer system reduced runoff by 43.06% for a 5-year return period (15-minute duration), while the double-layer system achieved a reduction of up to 86.60% for a 2-year return period (20-minute duration). Further improvements were observed when combined with infiltration wells, achieving runoff reductions of over 95%. These findings demonstrate that modular infiltration boxes are an effective and scalable alternative solution for decentralized urban stormwater management, contributing to flood mitigation and sustainable drainage planning.

Keyword: *Extreme Rainfall, Infiltration Box, Soil Infiltration, Surface Runoff, Urban Drainage.*

1. INTRODUCTION

Cirebon City is one of the urban areas with rapid growth in terms of both infrastructure and population density [1]. The city's population growth rate has been approximately 2.9% per year from 2018 to 2023 [2], contributing to a substantial rise in built-up land, which now constitutes about 55% of the area [3] . Development has a significant impact on the increase in watertight areas [4], which will reduce the soil's absorption capacity for rainwater during the rainy season, this area will experience inundation to flooding which will disrupt the activities of road users. This problem is exacerbated by a less than optimal drainage system and the lack of adequate water absorption space in urban areas. The need for a more efficient and environmentally friendly rainwater management system is becoming increasingly urgent in the context of climate change which increases the frequency and intensity of extreme rainfall [5], [6], [7], [8], [9]. This problem is exacerbated by suboptimal drainage systems and the lack of adequate water catchment spaces in urban areas. The need for a more efficient and environmentally friendly rainwater management system is becoming increasingly urgent in the context of climate change that increases the frequency and intensity of extreme rainfall [10].

P-ISSN : 2598-1277
E-ISSN : 2621-3966

Along with the development of the concept of sustainable development, nature-based solutions have been widely used in urban stormwater management [11], [12]. Various studies have shown the effectiveness of green infrastructure such as bioretention, infiltration wells, and infiltration boxes in reducing surface runoff and increasing the capacity of water infiltration into the soil. [13], [14] showed that the use of a modular infiltration system can reduce peak runoff discharge by more than 70% in dense urban areas. In Indonesia, the application of infiltration technology is still limited to the individual scale, while research at the regional scale and empirical data-based testing have not been widely carried out, especially in areas with high rainfall such as Cirebon.

The main problem faced during the rainy season is the high volume of runoff that cannot be accommodated by the existing drainage system [6] in the Cirebon City area, causing puddles at various main road points [15], especially during periods of extreme rainfall. The general solution offered is to implement an artificial infiltration system that can and is able to accommodate and infiltrate rainwater quickly into the soil, thereby reducing the burden of surface flow and improving the performance of the drainage system.

One of the specific solutions studied in this study is the use of modular infiltration boxes installed in the median area of the road. This system is a combination of temporary storage and infiltration functions to manage surface flow locally (on-site stormwater management) [16]. Based on literature analysis and field testing, this system has proven effective in absorbing runoff during high-intensity rainfall in a short time. namely by using and applying the Horton formula, infiltration parameters will be obtained at public facilities and residential locations which show that the final infiltration rate ranges from 4.63–4.75 cm/hour, so it is sufficient to absorb runoff from rain lasting 15–20 minutes.

This study also shows that with the dimensions of the infiltration box of 1.00 × 0.50 × 0.45 m and an effective volume of 0.18 m^3, the system is able to reduce runoff by up to 87.4% at a return period of 2 years with a duration of 20 minutes. This shows that the right infiltration box design, combined with an understanding of local soil characteristics and rainfall intensity, can provide an efficient and applicable technical solution for urban conditions such as in Cirebon. Although various previous studies have evaluated the effectiveness of infiltration systems for rainwater management, most of them were conducted in the context of a temperate climate or urban area with sandy soil structure. On the other hand, areas such as Cirebon have a dominant soil structure of silt and clay with low permeability, as well as a very high seasonal rainfall pattern. These conditions have not been studied specifically in national and international literature, so validation of the performance of the infiltration system under these conditions is needed. In addition, some studies only emphasize theoretical aspects or computer simulations without direct laboratory and field testing.

This study fills the gap with an empirical approach based on historical rainfall data, local soil physical characteristics, and laboratory tests for infiltration parameters. This study also adds value by testing the system performance at two different rainfall durations and comparing the infiltration capacity to the actual runoff discharge, including comparing it with the existing channel capacity. Thus, this study provides a practical basis for adaptive and contextual infiltration-based drainage planning.

The purpose of this study was to evaluate the effectiveness of infiltration boxes in reducing rainwater runoff discharge in the Cirebon City area using an empirical approach based on soil infiltration tests and actual hydrological data. The novelty of this study lies in the testing of a modular infiltration system in an area with high rainfall intensity and dominant silt soil structure, which has not been widely studied so far. This study also applies a combination of laboratory tests and theoretical modeling based on the Horton equation to calculate the actual infiltration rate and infiltration volume. The scope of the study includes hydrological analysis, soil characteristic tests, infiltration box design, and evaluation of its effectiveness at 15 and 20 minute rainfall durations with return periods of 2, 5, and 10 years. This study is expected to be a reference in the development of infiltration-based drainage systems in tropical urban areas.

P-ISSN : 2598-1277
E-ISSN : 2621-3966

2. RESEARCH METHOD

This study uses an experimental quantitative approach that aims to design and evaluate the effectiveness of infiltration boxes as a micro-drainage solution in tropical urban areas. [17], [18], [19]. The research location was chosen in a densely populated residential area in a tropical area that has a high level of surface runoff due to the dominance of impermeable surfaces such as asphalt and concrete.

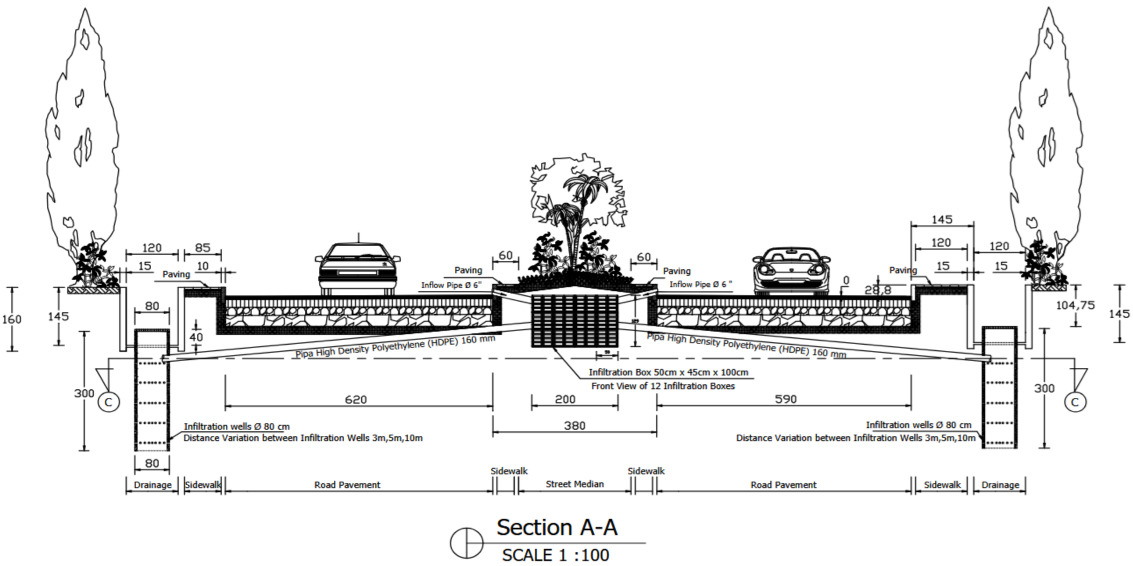
Source: Researcher, 2025

Figure 1 Overflow of Cirebon Youth Park Road

The infiltration box design process begins with the calculation of runoff volume based on maximum daily rainfall data in return periods of 2, 5, and 10 years. The catchment area and surface characteristics are calculated using a simple hydrological formula, namely

$$Q = C \ x \ I \ x \ A \qquad (1)$$

where Q is the runoff volume, C is the runoff coefficient, I is the rainfall intensity, and A is the catchment area.



Source: Researcher, 2025

Figure 2 Infiltration Box Placement Scheme

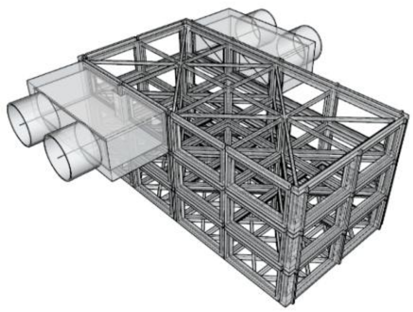
P-ISSN : 2598-1277
E-ISSN : 2621-3966

The infiltration box is designed using plastic material with a rectangular perforated grid to increase absorption capacity, the dimensions of the box are adjusted to the soil infiltration capacity and the volume of incoming runoff. Data collection is carried out through two methods. Primary data is obtained from direct measurements in the field, including soil infiltration tests using a double ring infiltrometer. In addition, secondary data is obtained from related technical agencies, such as historical rainfall data, soil types, and land use maps. After the box is installed, an evaluation is carried out by comparing the volume of water that has been successfully infiltrated with the total runoff that enters the box. Effectiveness is calculated using the formula:

$$Efektifitas\ (\%) = \left(\frac{V_{Infiltrasi}}{V_{Limpasan}}\right) x\ 100 \quad (2)$$

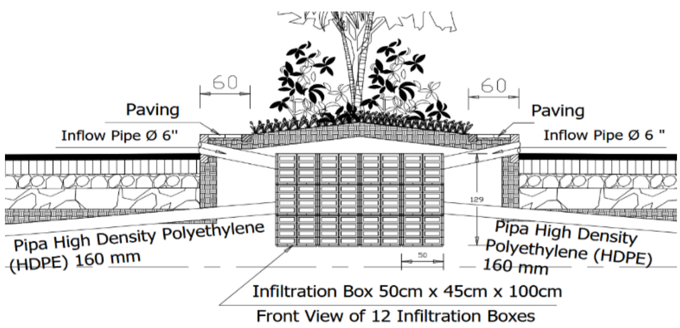
Performance simulations were also conducted with the help of hydrological software such as SWMM to test the system's response to rainfall with different intensities. Analysis of the results was done quantitatively, comparing the effectiveness of the design in reducing runoff volume and inundation duration.

The final result of this research is a prototype design of a micro-scale infiltration box that can be applied in tropical urban areas, accompanied by a quantitative evaluation of its performance. This research is also expected to produce technical recommendations regarding the design specifications and application of infiltration boxes for household scales and wider residential environments.



Source: Researcher, 2025

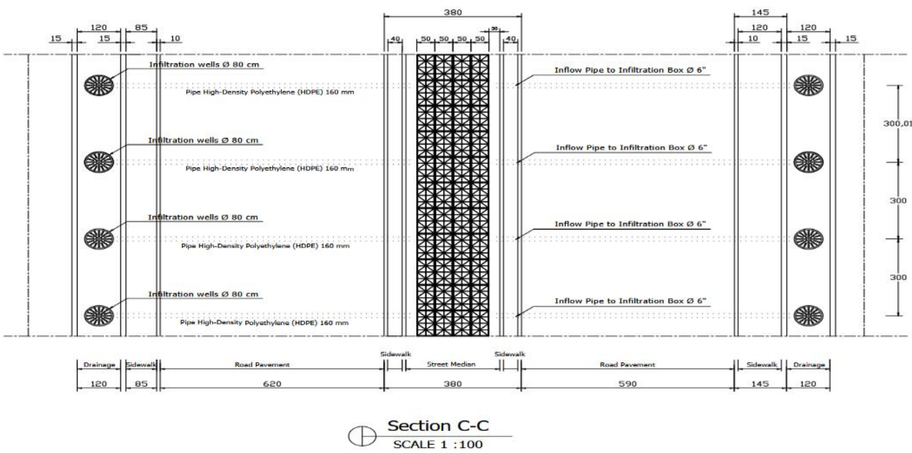
Figure 3 Infiltration box design



Source: Researcher, 2025

Figure 4 Location of Infiltration Box in the Median

The design of the infiltration box material is made of perforated plastic with dimensions of 1.00 m in length, 0.50 m in width, and 0.45 m in height. This box design has cavities that function to accelerate water infiltration into the soil. Each box unit has a volume of 0.18 m³ and a contact surface area of 1.85 m².



Source: Researcher, 2025

Figure 5 Appearance of the Location of the Infiltration Box Placement in the Road Median

In addition, other equipment used includes soil sampling tools (soil drill and hoe), double ring infiltrometer infiltration test tool, soil drying oven, mechanical sieve for gradation analysis, and water volume and discharge measuring tools. Climatology and hydrology data were obtained from BMKG Penggung Climatology Station and BBWS Cimanuk-Cisanggarung.

Soil samples were taken from two different locations, namely public facilities and residential areas. The sampling was carried out at a depth of 2 meters to obtain a representation of the soil layer of the infiltration cross-section. Soil samples were dried in an oven at a temperature of 110±5°C until the weight was stable to remove water content. Furthermore, the soil was milled to obtain a uniform particle size and analyzed using a combination of sieve and hydrometer methods to determine the grain size distribution. The prepared samples were then used in infiltration tests and other laboratory tests.

The experiment was conducted by testing the performance of the infiltration box against rainwater runoff using rain simulations with a duration of 15 and 20 minutes, based on the planned rainfall for a return period of 2, 5, and 10 years. The infiltration test was conducted using the double ring infiltrometer method on the soil of public facilities and settlements to obtain infiltration parameters. The Horton equation was used to model the infiltration rate as a function of time.

$$f(t) = fc + (fo - fc)e^{-kt} \quad (3)$$

$f(t)$ = infiltration rate at time t (cm/hr or mm/hr)
fo = initial infiltration rate (cm/hr)
fc = final infiltration rate (cm/hr), usually close to the soil permeability capacity
k = infiltration rate decrease constant (1/hour)
t = time (hour)

Additionally, the infiltration volume is calculated by integrating the Horton function:

$$V(t) = fc * t + \left(\frac{(fo-fc)}{k}\right)(1 - e^{-kt}) \quad (4)$$

The main parameters measured in this study include: High intensity rainfall based on historical data for return periods of 2, 5, and 10 years (mm/hour), Runoff discharge (Q) calculated using the Rational method based on the catchment area and rainfall intensity (m³/second), Initial infiltration rate (fo) and final infiltration rate (fc) (cm/hour) from the results of the double ring test, Infiltration constant (k) from the log(fo – fc) regression graph against time, Infiltration volume (Vt) from the integration of the Horton equation, Effectiveness of runoff reduction calculated by comparing the runoff discharge before and after the installation of the infiltration box

Data were analyzed quantitatively by comparing the actual runoff discharge and the infiltration capacity of the infiltration box. Statistical testing of rainfall distribution used the Log Pearson III method, with validation through the Chi-Square and Kolmogorov-Smirnov tests. Infiltration parameters were calculated based on the Horton method, which was then used to calculate the infiltration rate and the volume of water that could be absorbed by the soil. The effectiveness of the system was evaluated by calculating the percentage reduction in runoff discharge in each scenario of duration and return period of rainfall. The calculation results were then visualized in the form of tables, IDF graphs, and infiltration rate curves for the interpretation of the overall performance of the infiltration system.

3. RESULTS AND DISCUSSION

3.1. Results of Runoff Reduction Without Infiltration System

In existing conditions without an infiltration system, the analysis results show that most areas of Cirebon City experience inundation when there is high intensity rain.

P-ISSN : 2598-1277
E-ISSN : 2621-3966

Based on data from a 5-year return period and a duration of 15 minutes, the runoff discharge at various points exceeds the capacity of the existing channel. Jalan Pemuda 3 area, with a catchment area of 11.42 ha and rainfall of 137,361 mm/hour, the runoff discharge was recorded at 0.366 m³/second, while the channel capacity was only 0.122 m³/second. As a result, the excess runoff discharge reached 0.244 m³/second, which was not accommodated and caused significant inundation.

Table 1 Recapitulation of Runoff Discharge for 5-Year Return Period, 15 Minute Duration

No	Road	Area (Ha)	Q 5 year (m3/s)	Q channel (m3/s)	Q runoff (m3/s)	Information
1	sal. jl. Komp. Pd. Yudhasari	3,0858	0,0825	0,0252	0,0573	Flooding
2	Sal. Primer Tengah komp pdk	14,0460	0,2332	0,1434	0,0898	Flooding
3	Sal. Jl. Yudhasarii 2	1,8016	0,4816	0,1556	0,3260	Flooding
4	Sal. Jl. Yudhasarii 2	4,3093	0,5642	0,1609	0,4034	Flooding
5	Sal. Jl. Bima Stadion 1	3,2080	0,1290	0,0495	0,0795	Flooding
6	Sal. Jl. Brigjen Darsono	6,6412	0,4794	0,1844	0,2950	Flooding
7	Sal Jl.Taman pemuda 1	7,0010	0,4682	0,1910	0,2772	Flooding
8	Sal.Jl. Taman pemuda 3	11,4237	0,4876	0,1220	0,3656	Flooding
9	Sal Tengah Jl. Taman Pemuda	18,9333	0,2657	0,3397		Not flooded
10	Sal Jl. Taman pemuda 2	53,7914	0,3534	0,3219	0,0315	Flooding
11	Sal Jl. Bima Stadion 2	6,7225	0,8244	0,0898	0,7346	Flooding
12	Sal Jl. Bima Stadion 3	11,6424	0,3870	0,0807	0,3063	Flooding
13	Sal. Jl. Brigjen Darsono	76,4489	1,3677	0,0881	1,2796	Flooding
14	Sal Jl. Pemuda 1	17,6291	0,8408	0,1004	0,7403	Flooding
15	Sal. Jl Pemuda 2	11,0659	1,6666	0,7556	0,9110	Flooding
16	Sal Jl. Pemuda 3	12,9812	0,4984	0,1198	0,3786	Flooding
17	Sal Jl. Karjal 1	6,5305	0,3149	0,0881	0,2268	Flooding
18	Sal Jl. Karjal 2	9,5690	0,0862	0,0881		Not flooded
19	sal Jl. Karang sari 1	0,8358	0,1457	0,0898	0,0559	Flooding
20	Sal Jl. Pemuda 4	18,2265	0,2524	0,2986		Not flooded
21	Sal Jl. Sunyaragi	12,3852	0,1858	0,1087	0,0771	Flooding
Calculation results		308,2782	10,1145	3,6012	6,6353	

Source Calculation Results

Conventional drainage systems in Cirebon City have proven unable to accommodate peak discharge during high intensity rain. Analysis shows that channels with an average capacity of 0.1–0.3 m³/second are inadequate for runoff discharge that can reach 0.5 m³/second. The application of an infiltration box system provides an alternative to reducing the load directly at the runoff point, reducing dependence on conventional centralized systems and increasing the resilience of drainage infrastructure to extreme weather.

3.2. Effectiveness of Single Layer Infiltration Box System

The application of a single-layer infiltration box system with a configuration of 22 units on the road median showed an increase in absorption capacity for rainwater runoff. The infiltration reservoir volume of 0.1575 m³ for a duration of 15 minutes was able to reduce runoff discharge by up to 43.06% for a 5-year return period.

P-ISSN : 2598-1277
E-ISSN : 2621-3966

However, the capacity of the single-layer box began to be insufficient at a 10-year return period, with a reduction percentage of only 36.21%. This shows the limitations of the single-layer system in dealing with high rainfall intensity, although it remains effective at moderate rainfall.

Table 2 Runoff Reduction for Return Periods 2, 5 and 10 with a Duration of 15 minutes (22 Units)

No	Return Period (years)	Area (ha)	Q Plan (m3/s)	Q channel (m3/s)	Q Runoff (m3/s)	Q Reservoir and Infiltration (m3/s)	Q Runoff Reduction (%)
1	2	11.42	0.3844	0.122	0.2626	0.1575	59.98
2	5	11.42	0.4876	0.122	0.3658	0.1575	43.06
3	10	11.42	0.5568	0.122	0.4350	0.1575	36.21

Source Calculation Results

3.3. Effectiveness of the Two-Layer Infiltration Box System

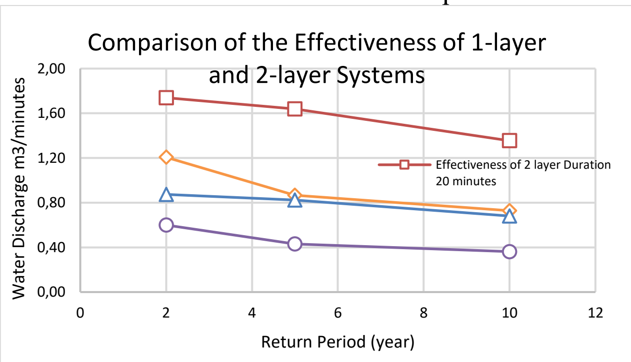
Capacity enhancement was done by adding a second layer of infiltration boxes, forming a two-layer system totaling 44 units. The analysis results showed a significant increase in runoff discharge reduction. At a 5-year return period with a duration of 15 minutes, this system was able to reduce up to 86.60% of runoff. Even for a 2-year return period, the effectiveness reached 120.63%. The addition of a layer of boxes increased the storage volume and extended the retention time, allowing for optimal infiltration before runoff occurs.

Table 3 Runoff Reduction for return periods 2, 5 and 10 with a Duration of 15 Minutes (44 Units)

No	Return Period (years)	Area (ha)	Q Plan (m3/s)	Q channel (m3/s)	Q Runoff (m3/s)	Q Reservoir and Infiltration (m3/s)	Q Runoff Reduction (%)
1	2	11.42	0.3844	0.122	0.2626	0.3168	120.63
2	5	11.42	0.4876	0.122	0.3658	0.3168	86.60
3	10	11.42	0.5568	0.122	0.4350	0.3168	72.82

Source Calculation Results

Efficiency Analysis Between Two Scenarios were compared based on reduction volume and system efficiency: without infiltration system, with single-layer infiltration box, and two-layer infiltration box. The effectiveness increased gradually from 0% (without system), to 36.21–59.98% (single-layer), 72.82–120.63% (two-layer). The two-layer scenario is the optimum point of spatial efficiency, while the combination scenario provides maximum effectiveness but requires additional cost and space.



Source: Processed by Researcher, 2025

Figure 6 Comparison of the Effectiveness of One-Layer and Two-Layer Systems

P-ISSN : 2598-1277
E-ISSN : 2621-3966

3.4. Combination of Infiltration Box System and Absorption Well

The achievement of rainwater runoff reduction efficiency of more than 95% in the combination system of infiltration boxes and infiltration wells is based on the results of quantitative analysis of the planned discharge, channel capacity, and the capacity of the infiltration system. In the rain scenario with a return period of 10 years and a duration of 20 minutes, the planned discharge was recorded at 0.4303 m³/second as listed in Table 4. Meanwhile, the capacity of the existing drainage channels at the research location was only able to drain 0.122 m³/second. The difference between the two resulted in a runoff discharge of 0.3086 m³/second which needed to be managed so as not to cause puddles.

Table 4 Runoff Reduction Return Periods 2, 5 and 10 with a Duration of 15 Minutes (22 Units)

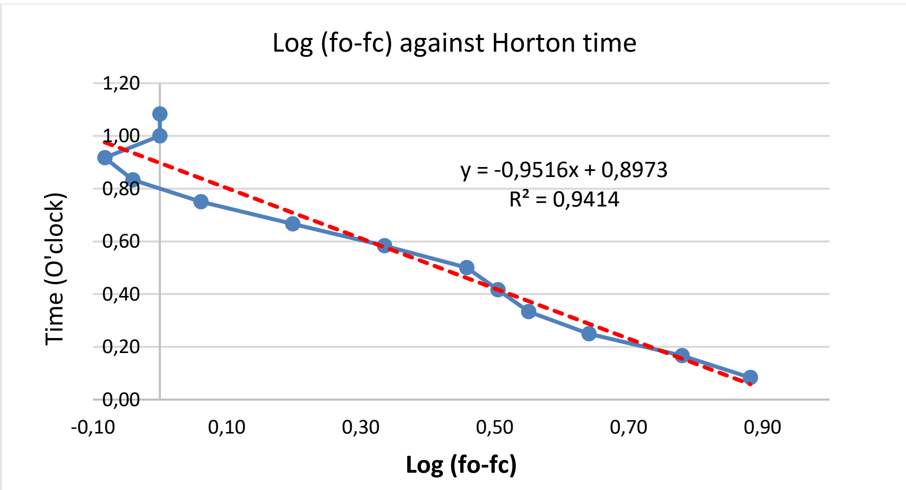
No	Return Period (years)	Area (ha)	Q Plan (m3/s)	Q channel (m3/s)	Q Runoff (m3/s)	Q Reservoir and Infiltration (m3/s)	Q Runoff Reduction (%)
1	2	11.42	0.3621	0.122	0.2403	0.2100	87.40
2	5	11.42	0.3769	0.122	0.2551	0.2100	82.32
3	10	11.42	0.4304	0.122	0.3086	0.2100	68.05

Source Calculation Results

The single-layer infiltration box system, with a total of 22 units, has an infiltration capacity of 0.210 m³/second in a duration of 20 minutes. Thus, the infiltration box is able to reduce around 68.05% of the runoff discharge. However, there is still a remaining runoff of 0.098 m³/second that has not been handled by the infiltration box. Therefore, the system is equipped with an infiltration well designed to absorb the excess volume. If converted into a volume for 20 minutes (1,200 seconds), the infiltration well needs to absorb a total of 117.6 m³ of water.

The addition of this infiltration well is specifically designed to accommodate the remaining runoff discharge in full. The combination of the capacity of the infiltration box and the infiltration well produces a total infiltration capacity of 0.308 m³/second, which is equivalent to the total runoff discharge. Thus, all runoff in the scenario was successfully handled by the combined system, resulting in a reduction effectiveness of 100%. This shows that this combined system not only meets, but exceeds the target of runoff reduction efficiency of more than 95%, and significantly strengthens the resilience of urban drainage to extreme rainfall.

3.5. Model Validation with Theoretical Data



Source: Researcher, 2025

Figure 7 Log (fo – fc) Against Time Horton Method Public Facilities

P-ISSN : 2598-1277
E-ISSN : 2621-3966

The infiltration model based on the Horton equation was validated against empirical data from field tests. The infiltration rate curve showed a high agreement with R^2 values > 0.94 for both public facilities and settlements. The values of the parameters fo, fc, and k calculated by logarithmic regression were close to the results of direct measurements. The calculation of the infiltration volume from the model was also in line with the actual absorption volume of the tested infiltration system, proving that the theoretical model can reliably represent the infiltration phenomenon in an urban context.

3.6. Impact of Soil Conditions on System Performance

The dominant soil type of silt in Cirebon City affects the infiltration rate and system performance. The test results showed that the final infiltration rate only reached 4.63–4.75 cm/hour, which is relatively low compared to sandy soil. This limits the absorption rate and requires adjustments to the box volume design. The system remains effective because the calculation has been adjusted to the local fc value, but under high saturation conditions or consecutive rains, performance can decrease significantly.

Table 5 Results of Infiltration Calculation at Public Facility Locations

t (jam)	fo (cm/jam)	fc (cm/jam)	e	f(t) (cm/jam)
0,083	12,24	4,63	2,718	10,85
0,167	10,65	4,63	2,718	8,65
0,250	9,00	4,63	2,718	7,02
0,333	8,18	4,63	2,718	6,21
0,417	7,83	4,63	2,718	5,79
0,500	7,50	4,63	2,718	5,48
0,583	6,79	4,63	2,718	5,16
0,667	6,21	4,63	2,718	4,94
0,750	5,78	4,63	2,718	4,81
0,833	5,54	4,63	2,718	4,75
0,917	5,45	4,63	2,718	4,72
1,000	4,63	4,63	2,718	4,63
1,083	4,63	4,63	2,718	4,63

Source: Test Result

Table 6 Results of Infiltration Calculations at Residential Locations

t (jam)	fo (cm/jam)	fc (cm/jam)	e	f(t) (cm/jam)
0,083	13,14	4,75	2,718	11,54
0,167	11,25	4,75	2,718	9,01
0,250	10,59	4,75	2,718	7,85
0,333	9,94	4,75	2,718	6,99
0,417	9,00	4,75	2,718	6,23
0,500	7,66	4,75	2,718	5,57
0,583	7,26	4,75	2,718	5,32
0,667	7,02	4,75	2,718	5,17
0,750	6,10	4,75	2,718	4,95
0,833	5,71	4,75	2,718	4,87
0,917	4,75	4,75	2,718	4,75
1,000	4,75	4,75	2,718	4,75
1,083	4,75	4,75	2,718	4,75

Source: Test Result

3.7. Flow Distribution and Release Duration

The flow distribution in the infiltration system shows that most of the water is absorbed in the first 20 minutes, especially when the two-layer system is used. The duration of the runoff release lag is minimal because most of the flow is handled in the initial phase of rainfall. This system works optimally in short, high-intensity rain scenarios, but longer duration or consecutive rain events require a combination with a vertical release system such as an infiltration well.

3.8. Comparison with Other LID Technologies

Compared to other LID technologies such as bioretention and permeable pavement, infiltration boxes show advantages in volume-to-space efficiency. This system is easier to install in narrow spaces such as road medians, while other systems require large land areas. However, in terms of absorption capacity per time, infiltration wells have a larger vertical capacity. Infiltration boxes excel in modularity and scalability, making it easier to plan and replicate in urban areas.

 P-ISSN : 2598-1277
E-ISSN : 2621-3966

3.9. Implications for Groundwater Conservation and the Environment

By increasing infiltration into the soil, this system contributes directly to groundwater conservation. Significant infiltration volumes can increase groundwater reserves, which is especially important in urban areas with declining groundwater levels. In addition, reducing surface runoff reduces the risk of erosion, improves surface water quality, and reduces the pollution load on drainage systems and rivers. This system is in line with the principles of sustainable development and climate change mitigation.

3.10. Contribution to Urban Drainage Governance

This study provides empirical evidence that the implementation of local infiltration systems can be an integral part of urban drainage management. By adopting a decentralized flow approach, this system supports area-based rainwater management (micro-drainage systems). The research findings can be the basis for technical regulations and local government policies in designing adaptive drainage systems to extreme rainfall intensity, as well as supporting climate-resilient city programs.

4. CONCLUSION

The study results show that using modular infiltration boxes is an effective decentralized solution to reduce tropical urban surface runoff with high rainfall intensity and limited drainage capacity. Analysis of rainfall data from 2014 to 2023, field-based infiltration testing, and hydrological modeling indicate that a single-layer infiltration box can reduce runoff by up to 43.06% for a 5-year return period (15-minute duration), while a two-layer configuration increases the reduction to 86.60%. Because the infiltration box contains residual runoff, it is combined with an infiltration well, so that the combination of these systems can reduce runoff by more than 95%, successfully managing peak discharge even in extreme rainfall scenarios. This study also validates the reliability of the Horton infiltration model to predict infiltration performance in silt-dominated soils, with high agreement ($R^2 > 0.94$) between the model and field data. These findings support the integration of infiltration boxes into sustainable drainage strategies, providing a scalable, modular, and context-sensitive alternative to conventional drainage systems. Additionally, this approach contributes to urban flood mitigation, groundwater recharge, and climate-resilient infrastructure planning.

ACKNOWLEDGEMENT

The author would like to express his deepest gratitude to Sultan Agung Islamic University Semarang and Swadaya Gunung Jati University Cirebon for providing the laboratory facilities and technical support required to carry out this research

REFERENCES

[1] I. Fardani and M. R. Yosliansyah, “Kajian Penentuan Prioritas Ruang Terbuka Hijau Berdasarkan Fenomena Urban Heat Island Di Kota Cirebon,” *J. Sains Inf. Geogr.*, vol. 5, no. 2, p. 93, 2022, doi: 10.31314/jsig.v5i2.1708.

[2] M. Satar, M. R. Yosliansyah, and N. Yuniar, “Identification of Potential Land Locations for Green Open Space in Cirebon City Center (Case study: Pekalipan, Kesambi, and Kejaksan Districts),” *J. Tek. Sipil dan Perenc.*, vol. 25, no. 2, pp. 209–210, 2023, doi: 10.15294/jtsp.v25i2.47047.

[3] M. N. Afandi, O. M. H. Fauzi, D. Oktaviani, and A. Tribhuwana, “Analysis of Infiltration Wells Needs in Flood Management in Sunyaragi Urban Village Cirebon City,” *J. World Sci.*, vol. 4, no. 1, pp. 1820–1833, 2025, doi: 10.58344/jws.v4i1.1274.

[4] C. Roberta Sugahara, D. Helena Lombardo Ferreira, and W. Pena Guedes, “Drainage system and urban planning in the city of Campinas/SP,” *Rev. Nac. Gerenciamento Cid.*, vol. 10, no. 75, pp. 87–96, 2022, doi: 10.17271/23188472107520223140.

P-ISSN : 2598-1277
E-ISSN : 2621-3966

[5] E. Feloni and P. T. Nastos, "Evaluating Rainwater Harvesting Systems for Water Scarcity Mitigation in Small Greek Islands under Climate Change," *Sustain.* , vol. 16, no. 6, 2024, doi: 10.3390/su16062592.
[6] Z. Zahmatkesh, "Low-impact development practices to mitigate climate change effects on urban stormwater runoff: Case study of New York City," *J. Irrig. Drain. Eng.*, vol. 141, no. 1, 2015, doi: 10.1061/(ASCE)IR.1943-4774.0000770.
[7] C. M. Monteiro, C. S. C. Calheiros, C. Pimentel-Rodrigues, A. Silva-Afonso, and P. M. L. Castro, "Contributions to the design of rainwater harvesting systems in buildings with green roofs in a Mediterranean climate," *Water Sci. Technol.*, vol. 73, no. 8, pp. 1842–1847, 2016, doi: 10.2166/wst.2016.034.
[8] D. Słyś and A. Stec, "Centralized or decentralized rainwater harvesting systems: A case study," *Resources*, vol. 9, no. 1, 2020, doi: 10.3390/resources9010005.
[9] J. L. Webber, T. Fletcher, R. Farmani, D. Butler, and P. Melville-Shreeve, "Moving to a future of smart stormwater management: A review and framework for terminology, research, and future perspectives," *Water Res.*, vol. 218, no. August, p. 118409, 2022, doi: 10.1016/j.watres.2022.118409.
[10] A. J. Shahi, M. Pokhrel, and S. Lamichhane, "Urban Roadside Flooding Analysis Using SWMM: A Case Study of a Road Section in Pokhara Metropolitan City, Nepal," *J. Eng. Sci.*, vol. 3, no. 1, pp. 36–44, 2024, doi: 10.3126/jes2.v3i1.66233.
[11] J. Su, M. Wang, M. A. M. Razi, N. M. Dom, N. Sulaiman, and L. W. Tan, "A Bibliometric Review of Nature-Based Solutions on Urban Stormwater Management," *Sustain.*, vol. 15, no. 9, 2023, doi: 10.3390/su15097281.
[12] C. Apollonio *et al.*, *The Use of Lamination Basins for Mitigation of the Urban Flooding Risk: The Case Study of Peschici*, vol. 146. 2021. doi: 10.1007/978-3-030-68824-0_53.
[13] S. T. Khan, F. Chapa, and J. Hack, "Highly resolved rainfall-runoff simulation of retrofitted green stormwater infrastructure at the micro-watershed scale," *Land*, vol. 9, no. 9, 2020, doi: 10.3390/LAND9090339.
[14] U. Vozelj, M. Šraj, and N. Bezak, "Analysis of the Impact of Green Infrastructure on Surface Runoff From an Urban Area," *Acta Hydrotechnica*, vol. 36, no. 65, pp. 111–121, 2023, doi: 10.15292/acta.hydro.2023.07.
[15] H. F. Abd-Elhamid, M. Zeleňáková, Z. Vranayová, and I. Fathy, "Evaluating the impact of urban growth on the design of storm water drainage systems," *Water (Switzerland)*, vol. 12, no. 6, pp. 1–22, 2020, doi: 10.3390/W12061572.
[16] O. Seyedashraf, A. Bottacin-Busolin, and J. J. Harou, "Many-Objective Optimization of Sustainable Drainage Systems in Urban Areas with Different Surface Slopes," *Water Resour. Manag.*, vol. 35, no. 8, pp. 2449–2464, 2021, doi: 10.1007/s11269-021-02840-4.
[17] C. L. Abbott and L. Comino-Mateos, "In-situ hydraulic performance of a permeable pavement sustainable urban drainage system," *Water Environ. J.*, vol. 17, no. 3, pp. 187–190, 2003, doi: 10.1111/j.1747-6593.2003.tb00460.x.
[18] E. Kuehler, J. Hathaway, and A. Tirpak, "Quantifying the benefits of urban forest systems as a component of the green infrastructure stormwater treatment network," *Ecohydrology*, vol. 10, no. 3, 2017, doi: 10.1002/eco.1813.
[19] H. M. Imran, S. Akib, and M. R. Karim, "Permeable pavement and stormwater management systems: A review," *Environ. Technol. (United Kingdom)*, vol. 34, no. 18, pp. 2649–2656, 2013, doi: 10.1080/09593330.2013.782573.