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Flood Control Measures through the Integrated Application of Conservation Technologies based on an Analysis of the Performance of Existing Drainage Channels

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Abstract *– Urban flooding in the Buun River area, Pangkalan Bun, Central Kalimantan, Indonesia, is frequently associated with high rainfall, sediment accumulation, drainage constrictions, reduced infiltration, and insufficient capacity of the existing drainage system. This study evaluates drainage performance and proposes an integrated flood-mitigation strategy emphasizing water conservation through infiltration wells. Hydrological analysis was conducted using Gumbel, Normal, Log Normal, and Log Pearson Type III distributions, followed by Smirnov–Kolmogorov and Chi-square goodness-of-fit tests. Design discharge was estimated using the Rational Method, while existing channel capacity was evaluated using Manning's equation. The results show significant hydraulic deficiencies at several critical reaches. Existing capacities at Prima, the wooden bridge–Rocket Chicken reach, Rocket Chicken, and Ratu Mangku were 0.372, 1.723, 0.0733, and 0.618 m³/s, respectively, compared with design discharges of 0.490, 2.213, 0.569, and 1.178 m³/s. These deficiencies, combined with elevation discontinuities, channel bottlenecks, and sediment accumulation, contribute to recurring overflow and inundation. An integrated mitigation strategy is proposed by prioritizing 784 infiltration wells, each 1 m in diameter and 10 m deep, supported by drainage normalization, elevation correction, selective channel upgrading, and retention storage. The proposed approach integrates drainage improvement with decentralized water conservation to reduce surface runoff and improve the hydraulic resilience of flood-prone urban areas.*

Keywords— Urban flooding; infiltration wells; water conservation; hydraulic capacity; sustainable drainage.

I. INTRODUCTION

Urban flooding is a persistent challenge in developing areas where rapid land-use change increases impervious surfaces and reduces natural infiltration [1]. The resulting increase in surface runoff places greater pressure on drainage networks and may cause recurrent inundation when their conveyance capacity is exceeded [2]. Effective flood management therefore requires strategies that address both drainage performance and runoff generation [3].

The Buun River area in Pangkalan Bun, West Kotawaringin Regency, Central Kalimantan, Indonesia, frequently experiences flooding associated with seasonal rainfall, sediment accumulation, drainage constrictions, and declining infiltration capacity. Field observations identified insufficient channel capacity, sediment deposition, local bottlenecks, and elevation discontinuities that restrict gravity flow. These conditions indicate that flooding is influenced by both hydrological loading and limitations within the existing drainage network [4] .

Conventional measures such as channel enlargement and normalization can improve conveyance but do not directly reduce runoff entering the drainage system [5]. Water-conservation measures provide a complementary approach by retaining stormwater near its source and promoting infiltration. Among these measures, infiltration wells offer a practical solution for reducing surface runoff and temporarily storing stormwater before it enters the drainage network. Integrating infiltration wells with targeted drainage improvements may therefore provide a more sustainable flood-control strategy than relying solely on channel enlargement [6].

This study evaluates the hydraulic performance of the existing drainage network in the Buun River area and identifies critical factors contributing to inundation [7]. Hydrological and hydraulic analyses are used to assess design discharge and channel capacity, followed by the development of an integrated mitigation strategy that prioritizes infiltration wells and supports them with drainage normalization, elevation correction, selective channel upgrading, and retention storage [8]. The study provides a practical framework for combining source-based water conservation with drainage improvement to enhance flood resilience in urban areas.

II. THEORETICAL FRAMEWORK

A. *Urban flooding and drainage challenges*

Conventional flood mitigation commonly relies on drainage normalization and channel enlargement to increase conveyance capacity [9]. However, these measures primarily accelerate stormwater transfer downstream without directly reducing runoff generation. Their effectiveness may also decline when drainage systems are affected by sedimentation, constrictions, inadequate dimensions, or unfavorable channel elevations.

Evaluating existing drainage performance is therefore essential for identifying critical sections and determining

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appropriate interventions. In this study, hydrological analysis is used to estimate design discharge, while hydraulic analysis is applied to assess the capacity of the existing drainage network. The comparison between hydraulic capacity and design discharge provides the basis for identifying sections susceptible to overflow and prioritizing flood-control measures.

B. *Integrated drainage and water conservation approach*

A more sustainable flood-mitigation strategy should combine drainage improvement with source-control measures. Infiltration wells are considered a suitable conservation measure because they can temporarily store stormwater and promote infiltration before runoff enters the drainage network. This approach can reduce pressure on existing channels while supporting water conservation within the catchment [9].

This study evaluates the performance of the existing drainage system and develops an integrated flood-mitigation strategy for the Buun River area [10]. The proposed approach prioritizes infiltration wells and combines them with drainage normalization, correction of critical elevation differences, selective channel upgrading, and retention storage [11]. The main contribution of this study is the integration of hydraulic performance assessment with decentralized infiltration-based conservation to improve drainage resilience and support sustainable urban flood management [5].

III. Materials and Methods

This study combined field investigation, hydrological analysis, and hydraulic assessment to evaluate the performance of the existing drainage system and develop an integrated flood-mitigation strategy for the Buun River area, Pangkalan Bun, Central Kalimantan, Indonesia.

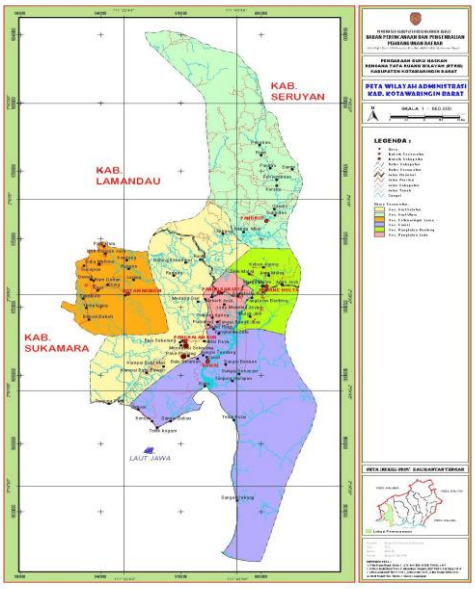


Figure 1. Map of the research location

Primary data were obtained through field surveys and observations of drainage conditions, while secondary data included rainfall, topography, land use, and supporting hydrological information. The analysis consisted of rainfall frequency analysis, design discharge estimation, evaluation of existing drainage capacity, identification of critical drainage sections, and development of conservation-based mitigation measures.

IV. Study Area And Data Collection

The study focused on the drainage network connected to the Buun River area, particularly the Prima, Rocket Chicken, and Ratu Mangku drainage reaches. Field investigations were conducted to evaluate channel geometry, elevations, sediment accumulation, constrictions, and existing flow conditions. Topographic data were used to examine channel elevations and flow continuity, while rainfall data were obtained from Iskandar Meteorological Station.

Annual maximum daily rainfall data for 2013–2022 were used for the hydrological analysis. During this period, recorded rainfall ranged from 73.8 to 137.8 mm, with a mean value of 99.38 mm. These data were used to estimate design rainfall for selected return periods ahli [12].

V. Hydrological Analysis

Design rainfall was estimated using four probability distributions: Gumbel, Normal, Log Normal, and Log Pearson Type III [10]. The suitability of the distributions was evaluated using the Chi-square and Smirnov–Kolmogorov goodness-of-fit tests [13]. The selected distribution was subsequently used to determine rainfall intensity and design discharge. Peak runoff was estimated using the Rational Method:

$$Q = 0{,}278.C.I.A$$

where (Q) is the peak runoff discharge (m^3/s), (C) is the runoff coefficient, (I) is the rainfall intensity (mm/h), and (A) is the catchment area (km^2). The calculated design discharge represents the hydraulic demand imposed on each drainage section and provides the basis for evaluating the adequacy of the existing drainage network.

VI. Conservation Based Flood Mitigation

Mitigation measures were formulated based on the identified hydraulic deficiencies. Rather than relying solely on channel enlargement, this study integrates drainage improvement with source-control and temporary-storage measures. The proposed interventions include drainage normalization, correction of critical elevation differences, selective channel upgrading, retention storage, and infiltration wells [14].

Infiltration wells were prioritized as the principal conservation measure for controlling runoff near its source [15]. Based on the design calculations, 784 wells with a diameter of 1 m and a depth of 10 m were proposed throughout suitable locations in the study area. Each well provides approximately 7.86 m^3 of geometric storage, corresponding to approximately 6,160 m^3 of distributed storage for the proposed system. The wells are intended to temporarily capture stormwater and promote infiltration before runoff enters the drainage network [16].

Two retention ponds were also proposed near the Rocket Chicken drainage reach, each measuring 30 m × 20 m × 6 m. These measures were integrated with targeted channel

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improvements to provide a combined source-control, storage, and conveyance strategy for reducing flood risk in the Buun River area.

VII. Results and Discussion

The annual maximum daily rainfall recorded at Iskandar Meteorological Station during 2013–2022 ranged from 73.8 to 137.8 mm, with an average of 99.38 mm. Frequency analysis was performed using Gumbel, Normal, Log Normal, and Log Pearson Type III distributions. The goodness-of-fit assessment showed that the Log Pearson Type III and Log Normal distributions satisfied both the Smirnov–Kolmogorov and Chi-square criteria. The Log Pearson Type III distribution produced a maximum Smirnov–Kolmogorov deviation of 0.09, below the critical value of 0.41, and was subsequently used in the design rainfall analysis.

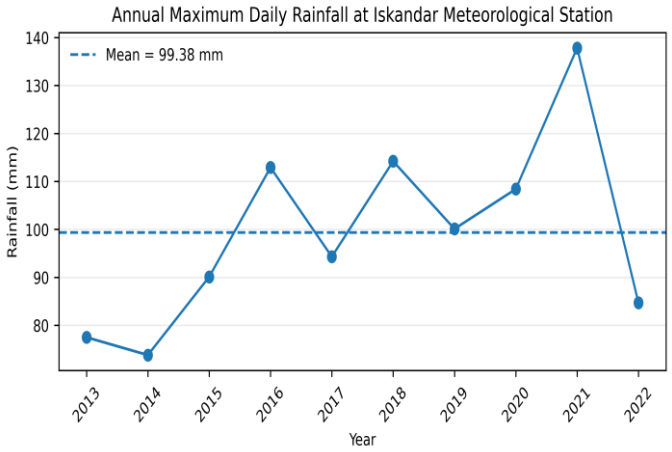
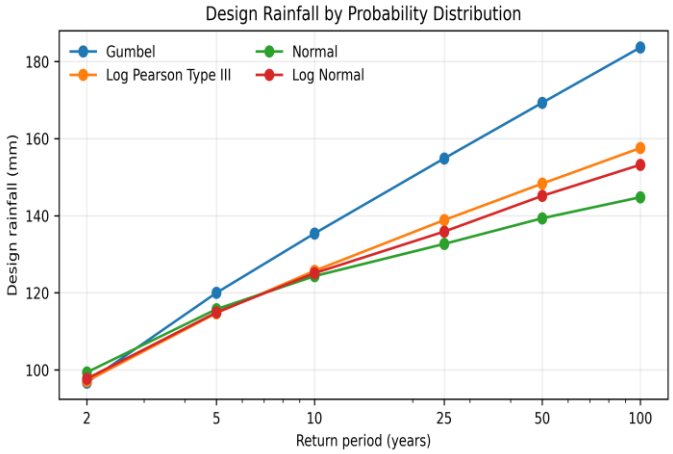


Figure 2. Annual maximum rainfall

The Log Pearson Type III analysis produced design rainfall depths of 97.10, 114.74, 125.72, 138.88, 148.34, and 157.57 mm for return periods of 2, 5, 10, 25, 50, and 100 years, respectively.



Figures 3. Design rainfall by probability distribution

These values show a consistent increase in rainfall magnitude with return period and were subsequently transformed into rainfall intensity using the Mononobe relationship. The resulting rainfall intensities were used to estimate design discharges for the individual drainage catchments.

TABLE 1. Design rainfall

Return Period (years)	Design Rainfall (mm)
2	97.10
5	114.74
10	125.72
25	138.88
50	148.34
100	157.57

The calculated discharges indicate that hydraulic demand varies considerably across the drainage network because of differences in contributing catchment area and flow accumulation. These design discharges provide the basis for evaluating whether the existing drainage sections can safely convey runoff generated during the selected design events.

Comparison between existing channel capacities and design discharges identified several hydraulically deficient sections. At Prima, the existing capacity is 0.372 m³/s compared with a design requirement of 0.490 m³/s. The wooden bridge–Rocket Chicken reach has a capacity of 1.723 m³/s against a required 2.213 m³/s. A more severe deficiency occurs at Rocket Chicken, where the existing capacity is only 0.0733 m³/s compared with a design discharge of 0.569 m³/s. At Ratu Mangku, the existing capacity of 0.618 m³/s is also below the design requirement of 1.178 m³/s.

TABLE 2. Hydraulic performance of the existing drainage system

Drainage Section	Existing Capacity (m³/s)	Design Discharge (m³/s)	Capacity Deficit (%)	Condition
Prima	0.372	0.490	24.1	Inadequate
Wooden Bridge–Rocket Chicken	1.723	2.213	22.1	Inadequate
Rocket Chicken	0.0733	0.569	87.1	Critical
Ratu Mangku	0.618	1.178	47.5	Inadequate

The Rocket Chicken reach represents the most critical hydraulic section, with an estimated capacity deficit of approximately 87.1%. This substantial mismatch indicates that the existing section can convey only a small fraction of the required design flow, making the area highly susceptible to overflow.

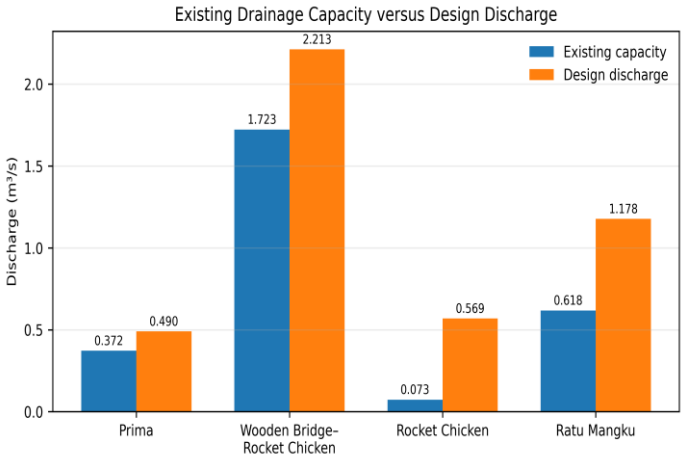
Topographic assessment identified a critical elevation difference at Box Prima. The Box Prima level was recorded at +1.65 m, whereas the existing drainage channel was at approximately +0.62 m. This configuration restricts gravity-driven drainage and contributes to local water accumulation. The problem therefore cannot be resolved solely by increasing channel dimensions; hydraulic continuity between interconnected drainage sections must also be restored.

Based on the hydraulic assessment, new rectangular drainage sections were designed for the critical reaches. The proposed Prima channel has a width of approximately 1.71 m and a total depth of 1.29 m. The wooden bridge–Rocket Chicken reach requires a larger section of approximately 3.64 m × 2.73 m, while the Gang Prima cross-connection toward Rocket Chicken requires approximately 0.83 m × 0.62 m. The

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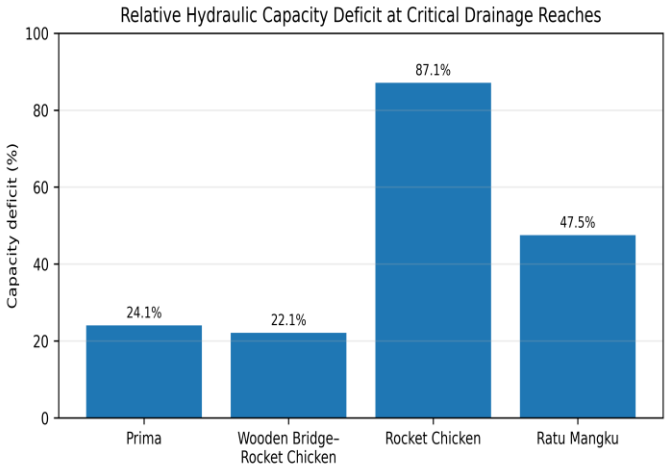
proposed channel along Rocket Chicken is approximately 1.85 m wide and 1.39 m deep, whereas the Ratu Mangku drainage section is approximately 3.24 m wide and 2.43 m deep.



Figures 4. Existing drainage capacity with design discharge

The hydraulic assessment indicates that increasing drainage conveyance alone may not provide a sustainable solution to recurrent inundation in the Buun River area. Several drainage sections have insufficient capacity, while increasing urban development has also reduced the available area for natural infiltration. Therefore, the proposed flood-mitigation strategy incorporates infiltration wells as a decentralized source-control measure to complement conventional drainage improvements.

These improvements are intended to restore sufficient conveyance at hydraulically deficient sections. However, increasing channel dimensions alone would maintain a conveyance-oriented approach in which stormwater is transferred downstream. For this reason, structural improvements were combined with distributed conservation measures designed to control runoff closer to its source.



Figures 5. Hydraulic capacity deficit at critical drainage reaches

Infiltration wells constitute the principal conservation measure proposed in this study. A total of 784 wells, each 1 m in diameter and 10 m deep, were identified in the design analysis. Based on cylindrical geometry, each well provides approximately 7.86 m³ of temporary storage, corresponding to a total distributed geometric storage of approximately 6,160 m³.

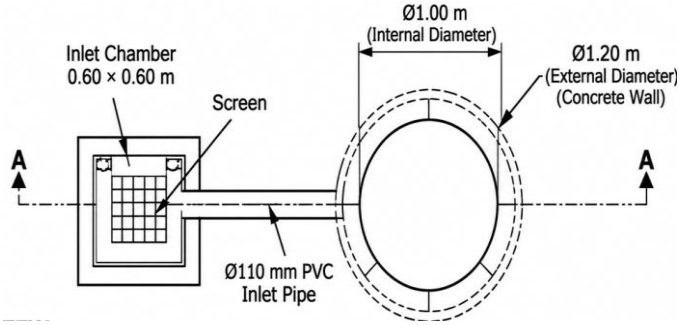
$$V = \frac{\pi D^2}{4} H$$

Based on the design analysis, a total of 784 infiltration wells are proposed at suitable locations within the study area. Each well has a diameter of 1 m and a depth of 10 m, corresponding to a geometric storage volume of approximately 7.86 m³ per well. The total distributed geometric storage provided by the proposed system is therefore approximately 6,160 m³.

The function of these wells differs fundamentally from conventional drainage enlargement. Instead of immediately conveying all stormwater downstream, the wells provide decentralized temporary storage and create opportunities for infiltration before runoff enters the drainage network. This source-control approach can therefore complement the existing conveyance system and reduce pressure on critical downstream sections.

The effective infiltration performance of the proposed wells, however, depends on local soil permeability and groundwater conditions. Therefore, the calculated storage volume should be interpreted as geometric storage capacity rather than verified infiltration capacity. Field permeability tests and groundwater-level observations are recommended before detailed implementation.

The results demonstrate that flooding in the Buun River area cannot be attributed to a single hydraulic deficiency. Insufficient channel capacity, unfavorable elevation differences, local bottlenecks, sediment accumulation, and limited infiltration collectively contribute to recurrent inundation. An integrated mitigation strategy is therefore more appropriate than isolated channel enlargement.

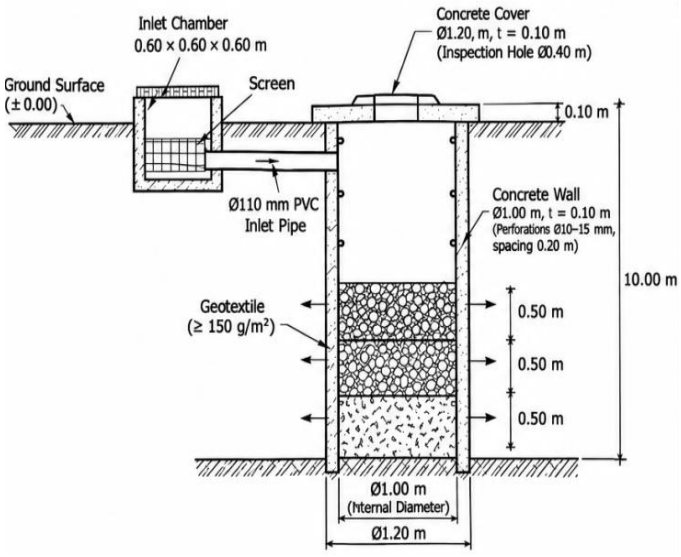


Figures 6. Plan view

The proposed system combines three complementary functions: source control through 784 infiltration wells, temporary storage through two retention ponds near Rocket Chicken, and improved conveyance through normalization and selective channel upgrading. Each retention pond is proposed with dimensions of 30 m × 20 m × 6 m. Critical elevation differences, particularly at Box Prima, should also be corrected to restore gravity-driven flow continuity.

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Figures 7. Details of the infiltration well cross-section

This integrated configuration shifts the drainage strategy from rapid runoff disposal toward a combined retention, infiltration, conveyance approach. Infiltration wells intercept runoff near its source, retention ponds provide additional temporary storage during high-flow conditions, and upgraded channels safely convey the remaining discharge. The approach therefore addresses both runoff generation and hydraulic limitations within the existing drainage network and provides a practical basis for more sustainable flood management in the Buun River area.

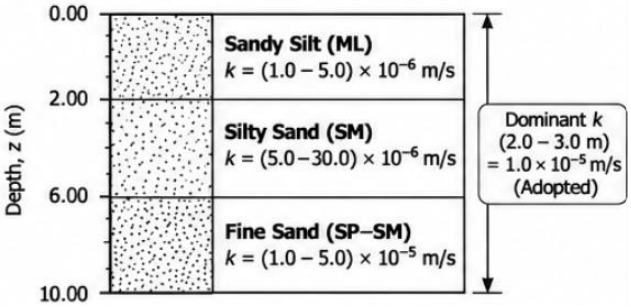
The proposed flood-mitigation strategy combines drainage optimization with decentralized water-conservation infrastructure to reduce the volume of surface runoff entering the existing drainage network. As illustrated in Fig. 5, infiltration wells are introduced as source-control facilities that intercept stormwater before it is conveyed downstream. The proposed system consists of an inlet chamber equipped with a screen, a 110 mm PVC inlet pipe, and a cylindrical infiltration well with an internal diameter of 1.0 m and a depth of 10.0 m. The screen provides preliminary removal of coarse debris before stormwater enters the well, thereby reducing the potential for clogging within the infiltration system.

Each infiltration well provides a geometric storage volume of approximately 7.86 m³. With 784 proposed wells distributed throughout technically suitable locations in the study area, the system provides approximately 6,160 m³ of total distributed geometric storage. This storage temporarily retains stormwater that would otherwise contribute directly to surface runoff and increase the hydraulic loading of the drainage network. The wells therefore function as decentralized runoff-control elements that complement, rather than replace, the existing drainage system.

Soil Hydraulic Considerations for the Proposed Infiltration Wells

The performance of the proposed infiltration wells is strongly controlled by the hydraulic properties of the surrounding soil. In the present design assessment, a hydraulic conductivity of ($1x10^{-5}$) m/s was adopted to examine the potential infiltration performance of the system. This value should be considered an assumed design parameter rather than a site-measured hydraulic conductivity, since the available soil investigation data do not provide a field permeability test from which the hydraulic conductivity can be directly derived.

For an infiltration well with an internal diameter of 1.0 m and a depth of 10.0 m, the theoretical infiltration area, considering the cylindrical wall and base, is approximately 32.20 m². Each well provides approximately 7.85 m³ of geometric storage, resulting in approximately 6,160 m³ of distributed storage throughout the study area. Under the assumed hydraulic conditions, a fully stored volume in an individual well would theoretically require approximately 6.8 h to infiltrate into the surrounding soil. This storage–infiltration mechanism is important because the wells are not intended to convey the entire stormwater inflow instantaneously. Instead, they temporarily retain runoff and gradually release the stored water into the surrounding soil.



Figures 8. Soil profile and hydraulic conductivity

The calculation demonstrates two complementary functions of the proposed infiltration wells. First, 784 wells provide approximately 6,160 m³ of distributed temporary stormwater storage. Second, using an assumed hydraulic conductivity of 1x10^-5 m/s, the system provides a theoretical infiltration discharge of approximately 0.252 m³/s.

The wells therefore should not be interpreted as structures that instantaneously infiltrate the entire incoming runoff. Instead, stormwater is temporarily stored within the wells and subsequently released into the surrounding soil through infiltration. This storage–infiltration mechanism can reduce the direct hydraulic loading imposed on the existing drainage network and complements drainage normalization, channel improvement, and retention infrastructure.

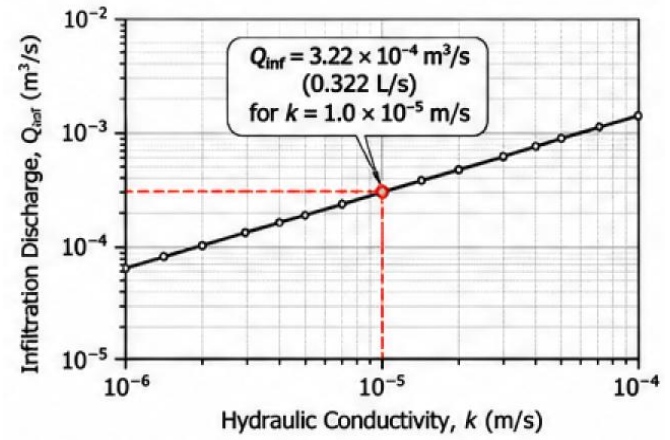
However, the adopted value of (k=1x10-5}) m/s and the conceptual soil profile should be regarded as preliminary design assumptions unless supported by site-specific permeability testing. Actual infiltration performance will depend on field hydraulic conductivity, soil stratigraphy, groundwater level, hydraulic gradient, antecedent moisture conditions, and long-term clogging. These parameters should therefore be verified before detailed design and construction.

The infiltration-well system therefore functions as a decentralized runoff control measure integrated with the existing drainage network. Surface runoff that would otherwise be conveyed directly into hydraulically deficient drainage sections can be temporarily intercepted and stored, while infiltration gradually restores available storage capacity. This mechanism complements drainage normalization,

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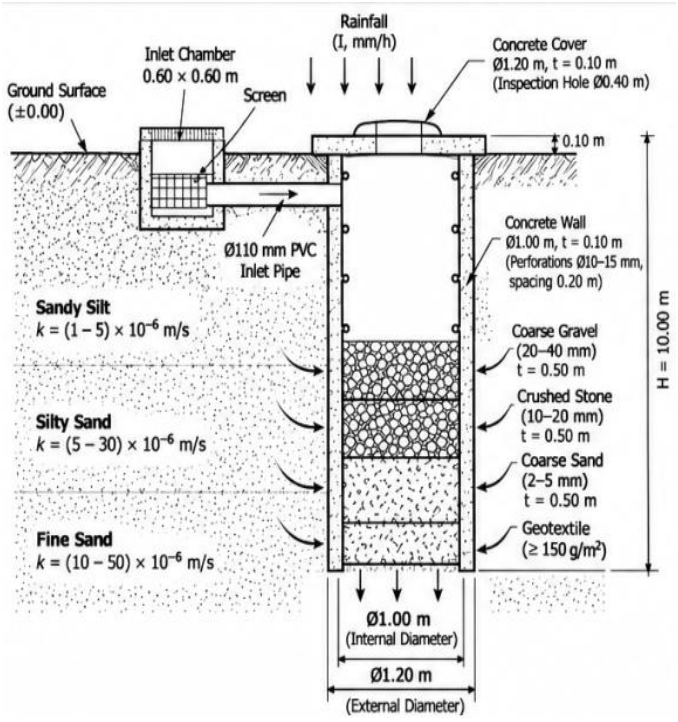
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channel upgrading, and retention storage by reducing the hydraulic load imposed on the downstream drainage system.



Figures 9. Infiltration discharge and hydraulic conductivity

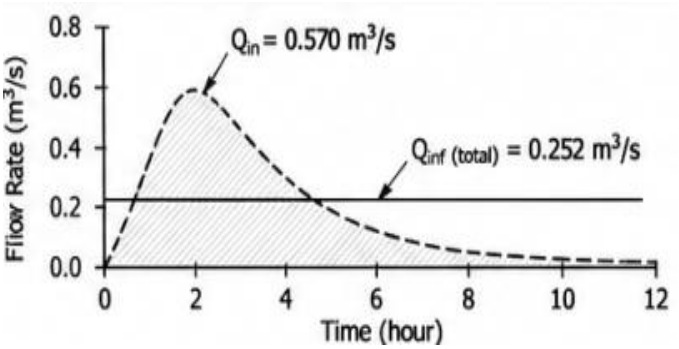
The relationship also demonstrates the sensitivity of infiltration-well performance to variations in soil permeability. Soils with lower hydraulic conductivity would result in a substantially lower infiltration discharge and a longer time required to restore the available storage volume. Conversely, more permeable soil conditions would increase the rate at which stored stormwater is released into the surrounding soil. Hydraulic conductivity is therefore a controlling parameter in determining the effectiveness of infiltration wells as water-conservation infrastructure.



Figures 10. Infiltration well interaction (cross section)

For the proposed 784 wells, application of the adopted hydraulic conductivity results in a theoretical combined infiltration discharge of approximately 0.252 m³/s (252 L/s), while the wells simultaneously provide approximately 6,160 m³ of distributed geometric storage. The system therefore does not depend solely on instantaneous infiltration. Instead, stormwater is temporarily retained within the wells and subsequently infiltrated into the surrounding soil, allowing the storage volume to act as a hydraulic buffer between surface runoff generation and the existing drainage network.

Hydraulically, the proposed system combines temporary storage and subsurface infiltration. For an internal diameter of 1.00 m and a depth of 10.00 m, the theoretical geometric volume of one well is approximately 7.86 m³. The cylindrical geometry also provides an effective theoretical infiltration area of approximately 32.20 m² when both the side wall and base are considered.



Figures 11. Storage and infiltration performance

Fig. 11 shows the temporal relationship between runoff inflow (Qinf) and the total theoretical infiltration capacity of the proposed 784 infiltration wells. The runoff inflow reaches a peak of 0.570 m³/s, while the total theoretical infiltration capacity is approximately 0.252 m³/s. During the period when Qinf total, the excess runoff is temporarily accommodated by the available well storage. As Qin decreases below Qinf total, the stored water gradually infiltrates into the surrounding soil, restoring the available storage capacity. This interaction demonstrates that the infiltration wells function through a combined storage and infiltration mechanism, attenuating the immediate hydraulic load transferred to the existing drainage network. The infiltration capacity is theoretical and is based on hydraulic conductivity of ($1x10^{-5}$) m/s.

TABLE 3. Results and conclusion parameter

Parameter	Value
Number of wells, N	784 units
Well diameter, D	1.00 m
Well depth, H	10.00 m
Geometric storage per well, V	7.86 m³
Total geometric storage	6,160 m³
Effective infiltration area, A_{inf}	32.20 m²
Infiltration coefficient, k	1.0 × 10⁻⁵ m/s
Infiltration discharge per well	0.322 L/s
Total infiltration discharge	0.252 m³/s (252 L/s)
Theoretical emptying time	≈ 6.8 h

Table 3 summarizes the hydraulic design parameters of the proposed infiltration-well system. A total of 784 wells, each 1.0 m in diameter and 10.0 m deep, provide approximately 7.86 m³ of geometric storage per well, corresponding to a total

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distributed storage of approximately 6,160 m³. With an effective infiltration area of 32.20 m² and an assumed hydraulic conductivity of (1.0x10-5) m/s, the theoretical infiltration discharge is approximately 0.322 L/s per well, or 0.252 m³/s for the entire system. The corresponding theoretical emptying time is approximately 6.8 h. These results indicate that the proposed wells provide both temporary stormwater storage and gradual subsurface infiltration, thereby reducing the immediate runoff load transferred to the existing drainage network. The calculated infiltration performance represents a preliminary design condition and should be verified using site specific permeability and groundwater data.

VIII. Conclusion and Recommendations

The hydraulic assessment demonstrates that recurrent flooding in the Buun River area is caused by the combined effects of insufficient drainage capacity, sediment accumulation, local bottlenecks, elevation discontinuities, and limited infiltration. The existing capacities at Prima, the Wooden Bridge–Rocket Chicken, Rocket Chicken, and Ratu Mangku reaches were 0.372, 1.723, 0.0733, and 0.618 m³/s, respectively, compared with the corresponding design discharges of 0.490, 2.213, 0.569, and 1.178 m³/s. The Rocket Chicken reach was identified as the most critical section, with a capacity deficit of approximately 87.1%. In addition, the elevation discontinuity at Box Prima restricts gravity-driven flow, indicating that channel enlargement alone is insufficient to address the existing drainage problems.

An integrated storage, infiltration, conveyance strategy is therefore proposed. The system prioritizes 784 infiltration wells, each 1.0 m in diameter and 10.0 m deep, providing approximately 7.86 m³ of geometric storage per well and a total distributed storage of approximately 6,160 m³. Using an assumed hydraulic conductivity of (1.0 x 10^{-5}) m/s, the theoretical infiltration capacity is approximately 0.322 L/s per well and 0.252 m³/s for the entire system. The infiltration wells provide decentralized temporary storage and gradual subsurface infiltration, thereby reducing the immediate hydraulic load transferred to the drainage network.

The infiltration wells should be implemented together with drainage normalization, sediment removal, correction of critical elevation differences, selective upgrading of hydraulically deficient channels, and the proposed retention facilities. This integrated approach shifts flood management from conventional rapid runoff conveyance toward source control, temporary storage, infiltration, and controlled downstream conveyance.

For detailed design and implementation, site-specific permeability tests, groundwater level monitoring, and verification of soil stratigraphy are recommended to validate the assumed hydraulic conductivity and effective infiltration depth. Future studies should also apply event-based hydrological–hydraulic modeling to quantify changes in runoff volume, peak discharge, inundation depth, and flood duration before and after implementation. Long-term monitoring of infiltration performance and clogging is also required to evaluate system reliability and maintenance requirements.

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