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ANALYSIS OF INFILTRATION WELLS NEEDS IN FLOOD MANAGEMENT IN SUNYARAGI URBAN VILLAGE CIREBON CITY

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ABSTRACT
The development of a city results in increased urbanization. This development leads to changes in land use in urban areas, creating large areas covered by buildings and roads, which reduces infiltration and increases surface runoff. With high rainfall of 147.238 mm per month, Sunyaragi Village often experiences flooding during the rainy season, especially on St. Taman Pemuda. This study aims to determine the number of infiltration wells needed to reduce the risk of flooding in Sunyaragi Urban Village, Cirebon City. The research employs descriptive methods using Arc-GIS remote sensing and quantitative methods, including hydrological analysis to measure rainfall intensity, hydraulics analysis to assess drainage channel capacity, and infiltration well analysis to determine the required number of infiltration wells. Based on the analysis results, the maximum runoff discharge value in the 5-year return period on St. Taman Pemuda is 0.00562 m^3/sec, indicating that eight infiltration wells are needed. These wells are planned to be cylindrical, with a diameter of 1 m and a depth of 3 m, achieving an efficiency value of 85.04% in reducing runoff discharge.

Keywords: drainage; infiltration wells; rainfall intensity; runoff

INTRODUCTION

The extent of land covered by buildings and roads is the impact of the development of a city, and this causes the value of infiltration to decrease while surface runoff increases; one of the cities experiencing the effects of development is the city of Cirebon (Moser et al., 2024; Natsukawa et al., 2024; Taşkın & Manioğlu, 2024; Yadem Lamien & Farzaneh, 2025). Cirebon City is constantly faced with flooding problems, and this indicates an imbalance between the process of water flow on the surface and the environmental system (Bramanto et al., 2023; Farid et al., 2023; Nirwansyah et al., 2022; Nirwansyah & Braun, 2021). This imbalance occurs because the water discharge increases more than the drainage capacity (Syam, 2015). Sunyaragi is one of the urban villages in Cirebon City that was affected by flooding. It is located in the lowlands with a gentle slope. This condition makes the area vulnerable to inundation during high rainfall, especially on the St. Taman Pemuda. Several other flood-prone spots in Cirebon City include Perumnas, St. Cipto Mangunkusumo, and St. Sudarsono.

Heavy rainfall during the rainy season contributes significantly to flooding (Gao et al., 2024; Guo et al., 2022; Tong et al., 2025). Previous research states that rain that occurs for one hour can cause flooding or inundation of the St. Taman Pemuda segment (Tribhuwana et al., 2021). On February 15, 2023, flooding inundated the St. Taman Pemuda area with a height of 20 cm to 50 cm. This made cars and motorcycles unable to pass through the road segment; even vehicles parked in the campus 3 area of Swadaya Gunung Jati University were submerged.

The selection of solutions to overcome flooding is tailored to the area's conditions (Farid et al., 2023; Istomi et al., 2025; Wei et al., 2025). One method of government efforts to overcome flooding and adapt to the need in areas with limited land is utilizing rainwater according to Cirebon Mayor Regulation 38 of 2019 guidelines. Infiltration wells are one way that can be implemented based on the regulation to control the use of rainwater to reduce flood discharge. Another impact of infiltration wells is increased infiltration in the watershed (Januriyadi et al., 2019).

Sunyaragi urban village is prone to flooding due to the loss of water catchment areas caused by high housing density and inadequate drainage infrastructure. Thus, the author conducted research to offer solutions for handling flood disasters in Sunyaragi Village. This study aims to determine the number of infiltration wells needed to reduce the volume of rainwater runoff and determine the efficiency of implementing the infiltration wells.

The rapid urban development in Cirebon City has significantly altered land use, resulting in reduced infiltration and increased surface runoff. This study focuses on Sunyaragi Urban Village, which is particularly vulnerable to flooding due to its geographic and infrastructural conditions. This research comprehensively analyzes the required number of infiltration wells to mitigate flood risks in Sunyaragi. Unlike previous studies that primarily addressed flooding through conventional drainage methods, this research employs advanced hydrological and hydraulic analyses, integrating remote sensing technology and GIS mapping. This study offers an innovative solution that aligns with modern flood management strategies by assessing the infiltration well designs tailored to the local soil characteristics and rainfall patterns.

This study addresses the urgent issue of flooding in Sunyaragi Village, Cirebon City, by systematically analyzing the need for infiltration wells as a viable solution. The research contributes to flood management by comprehensively assessing the current drainage infrastructure and its limitations. This determines the specific number of infiltration wells required to mitigate flooding effectively. Additionally, detailed hydrological and hydraulic analysis offers insights into the efficiency of these wells in reducing runoff, thereby enhancing urban resilience to heavy rainfall. By proposing evidence-based recommendations, this research fills a critical gap in local flood management strategies and serves as a model for similar urban areas facing flooding challenges.

METHOD

This research employs a descriptive research type, focusing on analyzing infiltration wells in flood management. The research approach integrates both qualitative and quantitative methods. Qualitatively, it comprehensively reviews existing literature and regulations about flood management and infiltration systems. Quantitatively, the study utilizes hydrological and hydraulic analyses to assess rainfall intensity, drainage capacities, and the effectiveness of infiltration wells in mitigating flood risks.

The research is organized into four main stages: remote sensing, hydrological analysis, hydraulic analysis, and infiltration well analysis. Each stage is designed to gather and analyze data systematically, ensuring a thorough understanding of the flooding issues in Sunyaragi Urban Village. Data collection is critical and includes literature reviews, rainfall data from relevant agencies, soil permeability tests, and geographical mapping using GIS technology. This structured approach allows for a detailed evaluation of the flooding dynamics and the necessary interventions to reduce runoff and enhance water infiltration.

1. Data Collection

   Data collection is the most important thing when conducting research. The stages of data collection are:

   a. Literature data: previous studies, reference books on data analysis, and additional information on the internet.
   b. Rainfall data: data from the relevant agency, BBWS Cimanuk-Cisanggarung Cirebon City, for the last ten years.
   c. Soil data: used to determine the soil permeability coefficient.
   d. Research location data: includes the area to calculate the runoff plan.

2. Analysis Stage

   a. GIS-Based Mapping Analysis

      Mapping the area to calculate the planned discharge, mapping the research location, mapping the flood inundation area, and mapping the infiltration well points.

   b. Hydrological Analysis

      Analyzing rainfall plans using the Log Person III method, analyzing the intensity of rainfall plans with an annual return period, and analyzing the planned discharge in Sunyaragi Village, Cirebon City.

   c. Hydraulics Analysis

      Analyzing drainage discharge to determine the discharge that the drainage channel can receive.

   d. Infiltration Well Analysis

      Conduct permeability tests to determine the permeability coefficient value, analyze the dimensions of infiltration wells, the total number of infiltration wells needed, and analyze the infiltration efficiency value.

Geographic Information System (Sig)-Based Mapping Analysis

Mapping analysis described the study locations, land cover, and regional rainfall influence levels. This study's mapping analysis was assisted by ArcGIS software and was based on secondary data accessible on the geoportal (Tri Hayatining Pamungkas et al., 2023).

Hydrological Analysis

Hydrology is the science that examines the relationship between water systems and the earth's surface. The amount of rain that falls in an area can indicate factors that affect flooding (Hasanah Balqis et al., 2023). Before the application of infiltration wells, hydrological analysis is used to obtain the initial runoff value.

1. Rainfall Frequency Analysis

Soemarto states that in statistics, there are several parameters related to data analysis: average rainfall, Coefficient of variation, Coefficient of skewness, and Coefficient of punctuation, with the following equation:

$$\bar{x} = \frac{\sum_{i=1}^{n} xi}{n}$$

$$Cv = \frac{s}{x}$$

$$S = \sqrt{\frac{\sum_{i=1}^{n}(xi - \bar{x})^2}{(n-1)}}$$

$$Cs = \frac{n\sum_{i=1}^{n}(xi - \bar{x})^3}{(n-1)(n-2)s^3}$$

$$Ck = \frac{n^2\sum_{i=1}^{n}(xi - \bar{x})^4}{(n-1)(n-2)(n-3)s^4}$$

Description:
$\bar{X}$ = Average rainfall value per year (mm)
N = Number of data
Xi = Annual maximum rainfall (mm)
Cv = Coefficient of variation
Cs = Coefficient of asymmetry
Ck = Coefficient of kurtosis
S = Standard deviation

Various distributions, including the Normal, Log Normal, Gumbel, and Log Person III, can be used to analyze rainfall frequency. The general formula is as follows.

$$X_{tr} = \bar{X} + K_T . S_x$$

Description:
X_{tr} = Year return period rainfall event
$\bar{X}$ = Mean value
K_T = Frequency factor
S_x = Standard deviation

The approach used to select the appropriate type of data distribution is to look at the results of statistical parameter calculations.

Table 1. Statistical Parameters to Determine Distribution Type

Frequency Distribution	Terms
Normal	Cs = 0, Ck = 3

Log-Normal	Cs = 3 Cv = 1.8, Cv = 0.6
Gumbel	Cs ≤ 1.1396, Ck ≤ 5.4002
Log Person Type III	Cs ≠ 0

Source: Applied Hydrology (Ahmadi et al., 2023)

The Chi-Square test determines whether the distribution that has been carried out matches the hypothesized distribution.

2. Rainfall Intensity Analysis

Rainfall intensity values are required to determine flood discharge. If hourly rainfall data is unavailable in the field, the Mononobe method can usually be used to calculate it (Poonia & Tiwari, 2020). The following is the formula for the Mononobe method.

$$I = \frac{R24}{24}(\frac{24}{t})^{2/3}$$

Description:
R24 = Maximum 24-hour rainfall (mm)
I = Rainfall intensity (mm/hour)
t = Rainfall duration (minutes or hours)

Hydraulics Analysis

Hydraulics are essential in engineering for designing and managing drainage systems, dams, and other water infrastructure. A hydraulics analysis calculates a drainage channel's capacity.

1. Rational Flood Discharge Analysis

The rational method is used to analyze the maximum flow discharge. Here is the flood discharge formula.

$$Q = 0{,}278 \, CIA$$

Description :
Q = Flood discharge (m^3/second)
C = Flow coefficient
I = Rain intensity (mm/hour)
A = Flow area (km^2)

2. Drainage Channel Discharge Analysis

Drainage channel discharge can be analyzed based on the following formula.

$$V = \frac{1}{n} \, x \, R^{2/3} \, x \, i^{1/2}$$

$$Q_{sal} = A \times V$$

Description :
V = Density (m^3/second)

R = Hydraulic radius (m)
n = Manning's Coefficient
i = Slope
Q = Drainage discharge (m^3/second)
A = Area (m^2)

Infiltration Well Analysis

Infiltration well planning is an important process in stormwater management and flood control, especially in areas where development and infiltration areas are decreasing.

1. Soil Permeability

   In applying the infiltration well method, it is necessary to know the soil type and permeability of the flooded area. The ability of soil to pass water is referred to as soil permeability. Each soil has a different permeability coefficient value. **Table 2.** shows some permeability coefficients.

Table 2. Classification of Soil Permeability

Permeability Classification	Soil Type	Permeability Value (cm/hour)
Medium	Silt	2,0 – 3,6
Somewhat fast	Fine sand	3,6 - 36
Fast	Coarse sand	>36

Source: SNI 8456:2017

2. Infiltration Well Implementation

   The infiltration well calculation method can be analyzed using the formula from Sunjoto (1988) as follows:

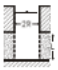
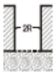
$$Q = F.\ K.\ H.$$

   As for calculating the depth of water in an infiltration well, Sunjoto provides the following:

$$H = \frac{Q}{FK}\left\{1 - exp\left(\frac{-FKTd}{\pi R^2}\right)\right\}$$

   Description:
   H = Water level at the infiltration well (m)
   Q = Runoff discharge (m^3/hour)
   F = Infiltration well geometry factor (m)
   K = Soil permeability coefficient (m/hour)
   Td = Rain duration (hour)
   R = Infiltration well radius

Table 3. Geometric Factor Value

Condition	Shape Factor (F)	Value of F when R=1; H=0; L=0 Except for F_1 => L=1
	$F = \frac{2\pi L}{ln\left\{\frac{2(L+2R}{R} + \sqrt{\left(\frac{L}{R}\right)+1}\right.}$	2.980
	$F_{2a} = 4\pi R$	12.566
	$F_{2b} = 18R$	18.000
	$F_{3a} = 2\pi R$	6.283
	$F_{3b} = 4R$	4.000

RESULT AND DISCUSSION

Hydrological Analysis

A statistical parameter analysis is carried out to determine regional rainfall distribution. Based on Table 3, the Log Person III distribution meets the criteria for analyzing rainfall data.

Table 4. Determination of Regional Rainfall Distribution

Distribution	Terms	Calculation Result	Description
Normal	Cs = 0	1,119	Does Not Meet
	Ck = 3	0,040	Does Not Meet
Log-Normal	$Cs = Cv^2 + 3Cv$	0,934	Does Not Meet
	$Ck = Cv^8 + 6Cv^6 + 15Cv^4+3$	3,101	Does Not Meet
Gumbel	CS = 1,14	1,119	Does Not Meet
	Ck = 5,4	0,040	Does Not Meet
Log Person III	Cs ≠ 0	1,119	Meet

Source: Analysis Result

The Chi-square distribution suitability test is carried out to determine the suitability of the frequency distribution of data samples with the probability distribution function (Asid et al., 2023). The chi-square test results are in Table 4. With a Chi-Count of 2 and Chi-Critical of 5.991 because Chi-Count < Chi-Critical, the Log Person III distribution type can be used to calculate rainfall intensity.

Table 5. Rainfall Plan Return Period

Frequency Distribution Analysis		
TR	KTR	Rainfall Plan (mm)
2	-0,054	116,078
5	0,822	147,238

10	1,311	168,139
25	1,857	194,987
50	2,223	215,397
Chi-Square Distribution Conformity Test		
Chi-Count	2	Retrieved
Chi-Critical	5,991	

Source: Analysis Result

For the rainfall intensity analysis, the Mononobe method used the Log Person III method with the highest rainfall amount during the annual high Saturn period. The results of the analysis are shown in Table 5.

Table 6. Rainfall Intensity

Time	**Return Periode**				
Minute	**2**	**5**	**10**	**25**	**50**
	116,078	147,238	168,139	194,987	215,397
5	210,927	267,550	305,528	354,314	391,403
10	132,876	168,546	192,471	223,204	246,568
20	83,707	106,177	121,249	140,610	155,328
40	52,732	66,887	76,382	88,579	97,851
60	40,242	51,045	58,290	67,598	74,674
61	39,801	50,485	57,652	66,857	73,856
90	30,710	38,954	44,484	51,587	56,987
120	25,351	32,156	36,721	42,584	47,042

Source: Analysis Result

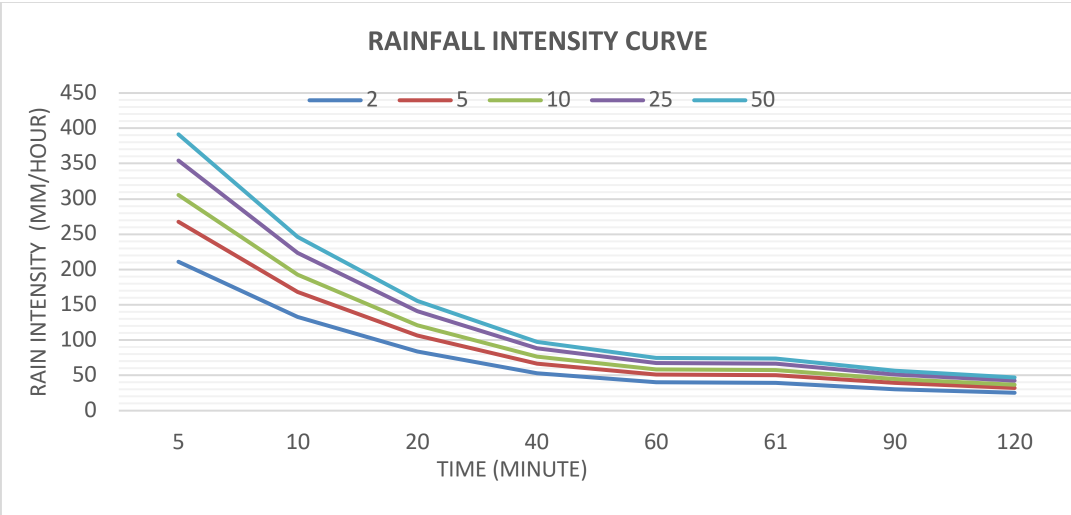


Figure 1. Rainfall Intensity Curve

Hydraulics Analysis

Flood discharge analysis is calculated using the rational method with a rainfall intensity duration of 61 minutes and a 5-year return period. Table 6. shows the results of the rational flood discharge analysis with a return period of 5 years.

Table 7. Rational Flood Discharge

A (km^2)	I	C	Qr 5
0,3309	50,4852	0,62	2,8986
0,5022		0,67	4,7418
0,0672		0,61	0,5779
0,1051		0,53	0,7924
0,0664		0,56	0,5286
0,6972		0,66	6,5338
0,0653		0,67	0,6180
0,0927		0,63	0,8216
0,1107		0,7	1,0872
0,1793		0,65	1,6446

Source: Analysis Result

Knowing the maximum discharge the existing drainage can accommodate is a prerequisite for designing infiltration wells (Munfarida & Rizal, 2022). If the maximum discharge of the current drainage is less than the desired discharge, infiltration well planning is required. Table 7 shows the results of calculating the maximum discharge of the existing drainage dimensions.

Table 8. Drainage Discharge

Segments	Drainage Dimension					I (%)	Manning (n)	V (m^3/s)	Qs (m^3/s)
	b	h	A	P	R				
Ch. St. Taman Pemuda 1	1,7	1,5	2,55	4,7	0,543	2%	0,017	5,5339	14,1113
Ch. St. Taman Pemuda 2	1,25	1	1,25	3,25	0,385	2%	0,020	3,7890	4,7362
Ch. St. Bima Stadion 1	0,5	0,5	0,25	1,5	0,167	3%	0,017	3,0856	0,7714
Ch. St. Bima Stadion 2	0,5	0,5	0,25	1,5	0,167	3%	0,017	3,1524	0,7881
Ch. St. Brigjen Darsono 1	1,15	1,5	1,725	4,15	0,416	3%	0,017	5,6746	9,7888
Ch. St. Brigjen Darsono 2	1,35	1	1,35	3,35	0,403	3%	0,020	4,8373	6,5304
Ch. St. Karang Jalak 1	0,5	0,5	0,25	1,5	0,167	3%	0,016	3,2785	0,8196
Ch. St. Karang Jalak 2	0,5	0,5	0,25	1,5	0,167	3%	0,016	3,2785	0,8196
Ch. St. Pemuda 1	1,5	0,8	1,2	3,1	0,387	3%	0,017	5,4116	6,4939
Ch. St. Pemuda 2	0,6	1,1	0,66	2,8	0,236	3%	0,017	3,8878	2,5659

Source: Analysis Result

Based on Table 8**.** 4 drainage channels cannot accommodate the planned rainfall discharge, causing the area around the drainage channel to inundate when there is high rainfall.

Table 9. Runoff Discharge

Segments	Qr5 (m^3/s)	Q (m^3/s)	Description	Ql(m^3/s)
Ch. St. Taman Pemuda 1	2,8986	14,1113	Not Stagnate	-
Ch. St. Taman Pemuda 2	4,7418	4,7362	Stagnate	0,0056

Ch. St. Bima Stadion 1	0,5779	0,7881	Not Stagnate	-
Ch. St. Bima Stadion 2	0,7924	0,7881	Stagnate	0,0043
Ch. St. Brigjen Darsono 1	0,5286	9,7888	Not Stagnate	-
Ch. St. Brigjen Darsono 2	6,5338	6,5304	Stagnate	0,0034
Ch. St. Karang Jalak 1	0,6180	0,8196	Not Stagnate	-
Ch. St. Karang Jalak 2	0,8216	0,8196	Stagnate	0,0019
Ch. St. Pemuda 1	1,0872	6,4939	Not Stagnate	-
Ch. St. Pemuda 2	1,6446	2,5659	Not Stagnate	-

Source: Analysis Result

The Sunjoto equation is used with a cylindrical infiltration well shape to determine the dimensions and depth of infiltration wells. For example, the following describes the calculation of infiltration wells in the St. Taman Pemuda drainage channel.

$$H = \frac{Q}{FK}\left\{1 - exp\left(\frac{-FKTd}{\pi R^2}\right)\right\}$$

H = (20,2314/ (3,14 x 0,0402)) x (1 – exp (-3,14 x 0,0402 x 1/(3,14 x o,5^2)))
= 23,8094 m

Due to their high-water depth, the infiltration wells are made into a series system, each with a depth of 3 meters. The total number of infiltration wells required in the series system is n = 23.8094/3 = 8 units.

The infiltration well construction has two parts: the part that collects water and the part that serves as a filter media consisting of river stones and palm fiber. The infiltration well walls are planned to use perforated concrete blocks with a product type of 100 x 50 cm, which means that one infiltration well requires six concrete blocks. Above the well, a concrete block lid of the same size and with holes is given. Details can be seen in Figure 4.

The efficiency results of infiltration wells show significant positive impacts on stormwater management and surface runoff reduction. The analysis in Table 9. reveals that after the construction of infiltration wells, water infiltration increased by 85.04% compared to existing conditions, with total runoff that managed to infiltrate reaching 17.2057 m^3/hour.

Table 10. Infiltration Well Needs and Efficiency Analysis

Segments	Ql (m3/hour)	F (m)	K (m/hour)	Td (hour)	R	H	Numb. of Wells
Ch. St. Taman Pemuda 2	20.2314	3.14	0.0402	1	0.5	23.80943	8
Ch. St. Bima Stadion 2	15.4854	3.14	0.0402	1	0.5	18.22411	6

Ch. St. Brigjen Darsono 2	12.3786	3.14	0.0402	1	0.5	14.56781	5
Ch. St. Karang Jalak 2	6.9507	3.14	0.0402	1	0.5	8.179956	3

Source: Analysis Result

Table 11. Efficiency Analysis

F	K	H	Numb. of Wells	R	Q inf.	Ql (m3/hour)	Q reduction	Volume	T (hour)	Efficiency
3.14	0.04015	3	8	0.5	3.0257	20.2314	17.2057	18.84	1.0950	85.04%
	0.04015	3	6	0.5	2.2693	15.4854	13.2162	14.13	1.0691	85.35%
	0.04015	3	5	0.5	1.8911	12.3786	10.4875	11.78	1.1228	84.72%
	0.04015	3	3	0.5	1.1346	6.9507	5.8161	7.07	1.2147	83.68%

Source: Analysis Result

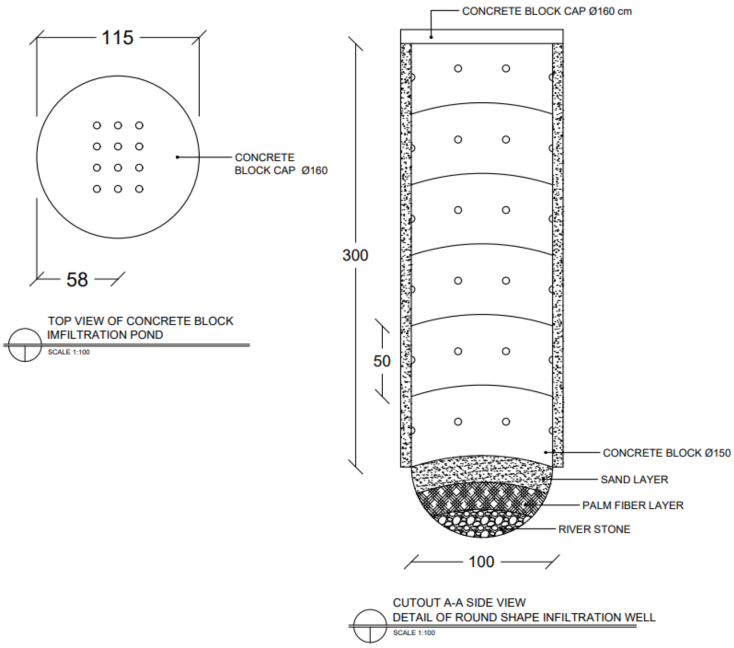


Figure 4. Infiltration Well Details

The following is a map of the flood inundation area and the placement of infiltration wells, the number of which follows the need for infiltration wells in each flooded area.

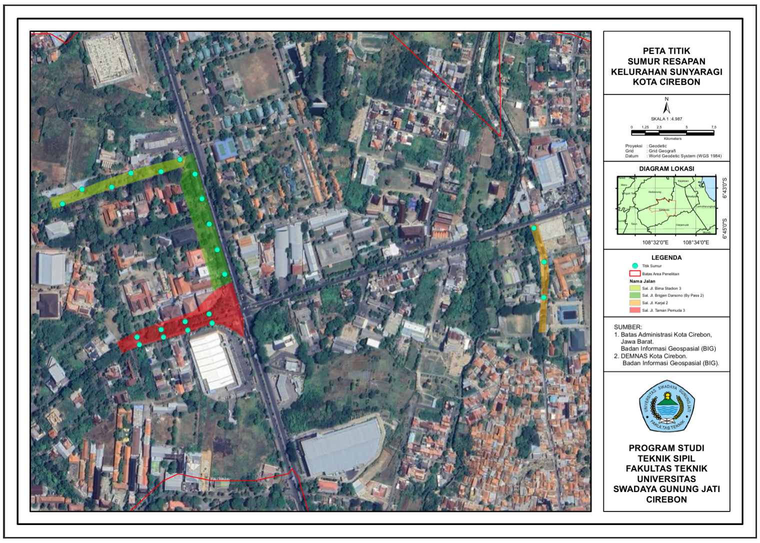


Figure 5. Flood Inundation Areas and Infiltration Well Points

CONCLUSION

The analysis reveals that inundation occurs in four areas of Sunyaragi Village during a 5-year return period. The runoff discharge per area is recorded as 0.00562 m^3/s at St. Taman Pemuda, 0.00430 m^3/s at St. Bima Stadium, 0.00343 m^3/s at St. Brigjen Darsono, and 0.00193 m^3/s at St. Karangjalak. To mitigate runoff discharge, 22 cylindrical infiltration wells with a diameter of 1 m and a depth of 3 m are proposed. These include eight wells at St. Taman Pemuda (total storage volume 18.84 m^3), 6 wells at St. Bima Stadium (14.13 m^3), five wells at St. Brigjen Darsono (11.78 m^3), and three wells at St. Karangjalak (7.07 m^3). The efficiency of these infiltration wells is estimated at 85.04% for St. Taman Pemuda, 85.35% for St. Bima Stadium, 84.72% for St. Brigjen Darsono, and 83.68% for St. Karangjalak. The study suggests that this research can serve as a guide for implementing infiltration wells to reduce flooding. Further research is recommended to enhance the accuracy of soil permeability tests and conduct infiltration well trials. Additionally, calculating a detailed cost budget is necessary to ensure the practical implementation of the study’s findings. Community awareness and involvement are crucial for maintaining drainage channels by removing sediment and debris to prevent blockages and subsequent flooding.

The findings of this study highlight several key areas for future research and practice. Practitioners must implement strategies grounded in the study's results, such as integrating targeted training programs for employees to enhance their skills. Additionally, organizations should consider developing a feedback loop that allows continuous improvement based on employee input. By focusing on these practical implications, organizations can better align their practices with the insights from this research, ultimately leading to improved outcomes and operational effectiveness.

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