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Optimal Drainage System Strategy On Gringging Highway, Kediri To Address Water Logging During The Rainy Season

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ARTICLE INFO	ABSTRACT
Article History : Article entry : 17-07-2025 Article revised : 31-07-2025 Article received : 02-09-2025 **Keyword :** Drainage, Peak Flow, Hydrology, Water Pooling ***IEEE style for citing this article:*** *A. Wijaya, F. Rahmawaty, and E. Siswanto, "Optimal Drainage System Strategy On Gringging Highway, Kediri To Address Water Logging During The Rainy Season", CVL, vol. 10, no. 2, pp. 165–176.*	Rapid land use change in the Jalan Raya Gringging area necessitates a thorough analysis of the drainage system capacity to forecast increased flooding, especially during the rainy season. A mix of descriptive and quantitative methods was employed, including field surveys to measure the physical size and condition of the drainage channels, and hydrological and hydraulic analyses to assess system performance. Hydrological analysis used rainfall data from the past ten years to estimate peak discharge via rational method calculations. The hydraulic analysis evaluated the channel's ability to efficiently convey floodwaters. The results showed that the existing drainage capacity was able to accommodate the flow discharge according to the design discharge with various return periods. However, inundation conditions that occur during the rainy season are caused by elevation differences between the channel and the road surface, so as an effort to increase the efficiency of the drainage system and reduce the risk of inundation, it's recommended that the application of infiltration wells as a complementary strategy that serves to reduce the volume of surface inundation and can strengthen the effectiveness of the existing drainage system. This research expected to contribute to the development of SuDS-based adaptive drainage system planning.

1.   Introduction

The conversion of land from green open spaces and water absorption areas into residential zones and road infrastructure has changed the hydrological characteristics of the area [1]. This has caused an increase in surface runoff volume that exceeds the capacity of the existing drainage system, leading to flooding during the rainy season[2]. The drainage system's failure to handle this runoff is a main cause of flooding, especially in urban and suburban areas[3]. These impacts not only disrupt transportation and endanger road users but also speed up infrastructure degradation through erosion and physical damage to roads.

The concept of Sustainable Drainage System (SuDS) has been introduced as a sustainable approach to rainwater runoff management, to reduce flooding while maintaining environmental quality[4]. However, its application in various regions in Indonesia is still limited and has not been fully integrated into road infrastructure planning[5].

One of the areas experiencing drainage system problems is Jalan Raya Gringging, a local primary arterial road connecting Nganjuk Regency and Kediri City. This road plays a strategic role in supporting population mobility, goods distribution, and economic and social activities of the community. However, flooding often occurs during the rainy season, particularly at road sections where the drainage system has channel elevations higher than the road surface and inadequate channel slope for gravity flow[6]. This condition causes traffic congestion and poses a danger to road users.

Previous research highlights the importance of aligning channel dimensions with peak rainfall flow rates to reduce flooding risks. A study by Juliastuti, 2023 in Tangerang City revealed that mismatched channel capacity with runoff flow rates caused flooding up to 5–15 cm in residential areas[7]. Similar findings were reported by Erni S. Butar - Butar, 2015 in Samarinda, where land conversion of approximately 28% significantly increased peak flow rates, which existing channels could not accommodate[8].
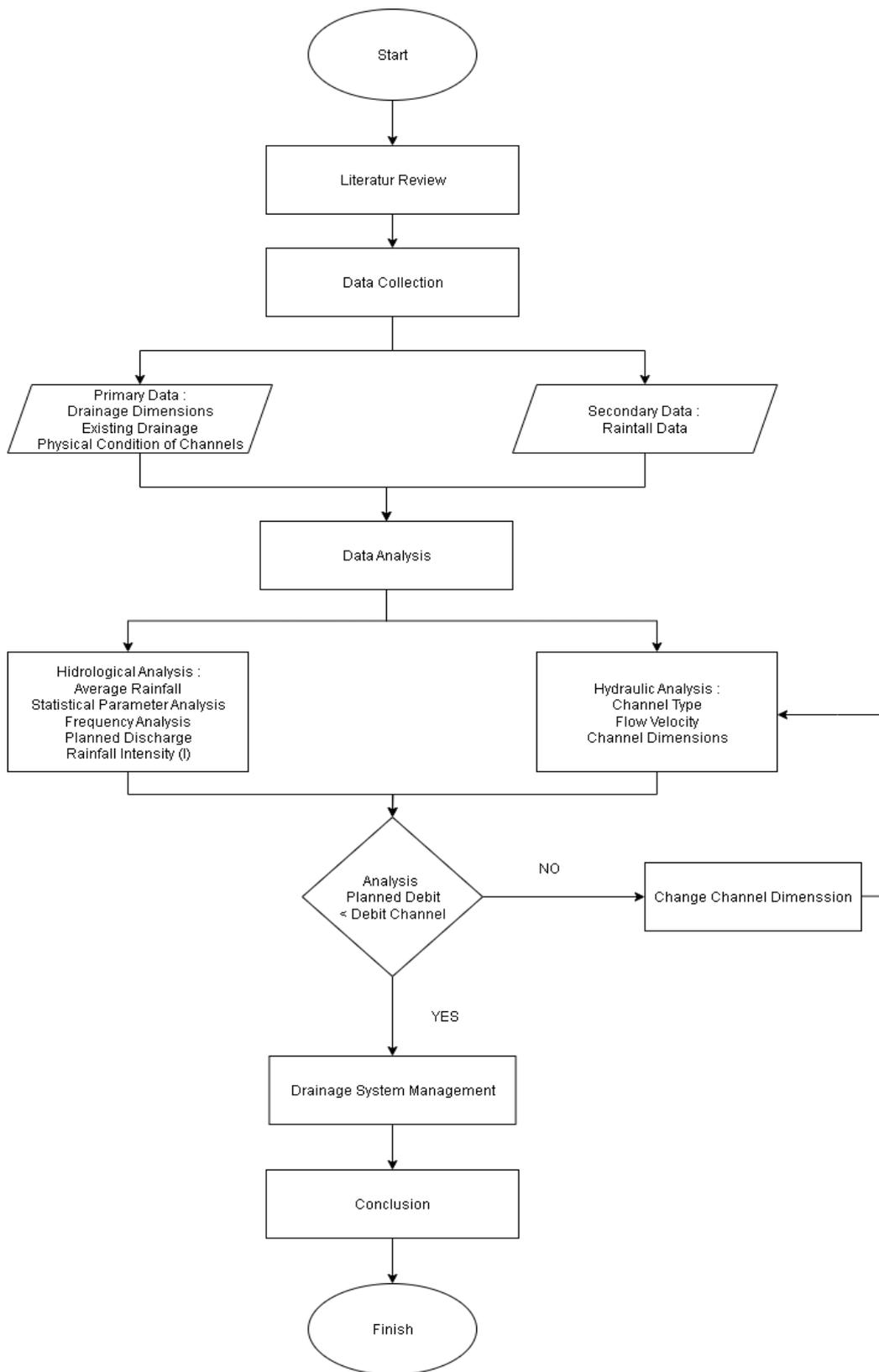
However, most of these studies focus on urban areas or main roads, while studies that focus on the technical conditions of local primary arterial roads such as Jalan Raya Gringging, with problems of elevation and slope that are not ideal, are still very limited. Therefore, a more in-depth study is needed to evaluate the capacity of existing channels and their suitability for peak flow based on the latest hydrological data[9].

This study aims to analyze the capacity of existing drainage channels on Gringging Highway and evaluate their suitability for peak flow calculated based on planned rainfall data. Additionally, this study seeks to formulate optimal technical strategies for drainage system planning to effectively and sustainably address flooding issues. This is done by collecting historical rainfall data, conducting field surveys to measure channel dimensions, performing hydrological analysis to estimate peak flow using the rational method, and conducting hydraulic analysis to evaluate the flow capacity of existing channels. The results of this study are expected to provide a tangible contribution to the development of an adaptive drainage system that can respond to environmental changes and serve as a reference for road infrastructure planning in similar areas.

2.   Research Methods

The research methods used in this study were descriptive and quantitative. The descriptive method was used to describe the existing drainage conditions, while the quantitative method was applied to calculate capacity and analyze the need for drainage optimization at the research site. There are several variables used in this research method, including independent variables, dependent variables, and control variables[10]. The following is a flowchart of the research method that illustrates the stages simply and systematically[11].

Research Flow Chart

Source: Research Result Plan

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2.1 Data Collection Methods

Data collection is a systematic process of obtaining information needed for research, which is used to test hypotheses or answer research questions. Data collected directly by researchers in the field is called primary data. Meanwhile, data obtained from institutions or agencies in the form of ready-made data is called secondary data. The data used as material for analysis in this study are primary and secondary data.

1. Primary Data

Primary data is obtained through field surveys and direct observations at the research site, including physical measurements of existing drainage channel dimensions, such as width, depth, length, and channel bed slope. Physical Condition of the Channel involves observing the physical condition of the channel, including material condition, the presence or absence of debris or sediment causing blockages, and the extent of channel damage[12].

2. Secondary Data

The collection of secondary data involves gathering data from relevant agencies. Secondary data from agencies such as rainfall data is obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG) and the public works department.

2.2 Data Analysis Methods

1. Hydrological Analysis

Hydrological analysis in this study is an analysis used in research to calculate and model water flow. The method often used in hydrological analysis is the rational method, used to calculate peak water discharge[13].

Planned rainfall analysis involves obtaining the annual rainfall for the 10th year, which will be used to determine the planned flood discharge. Presentation of Table 1. The following is a table of monthly maximum rainfall data for the Kediri region.

Table 2.1. Monthly Maximum Rainfall Data for the Kediri Region

Year	Month												MAXIMUM MONTHLY RAINFALL (mm)
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
2014	266	222	141	215	90	58	6	2	-	-	220	290	290
2015	302	344	370	176	49	21	-	3	-	12	154	275	370
2016	446	786	400	238	186	319	40	125	102	200	362	252	786
2017	343	256	239	253	48	36	7	-	10	2	225	558	558
2018	290	429	347	135	13	2	7	-	6	-	67	113	429
2019	312	461	316	283	6	-	-	-	-	-	23	270	461
2020	391	261	385	198	379	57	42	12	9	60	220	344	391
2021	535	360	591	224	109	152	1	-	99	2	271	193	591
2022	291	302	291	316	118	133	21	103	18	307	584	218	584
2023	140	433	329	251	42	9	1	1	-	-	74	63	433

(Source: Meteorology, Climatology, and Geophysics Agency)

2. Hydraulic Analysis

The hydraulic analysis in this study is quantitative because the parameters that influence this study are quantitative. The methods used by the researcher to obtain data and then analyze it are as follows:

a. The researcher conducted direct observations of the research object to see the condition of the drainage channel

b. The researcher measured and recorded the dimensions of the drainage channels

c. The researcher directly documented matters related to the research object

d. The researcher analyzed the condition of the channels based on the data obtained

3.   Deskription dan Technical
3.1   Description and technical specifications
The research location is on Gringging Highway, Grogol Subdistrict, Kediri Regency. This research location is also a main traffic route connecting the Nganjuk and Kediri regions, which is approximately 5 km long and consists of several flood-prone areas.

3.2   Definition of variable operations
1. Planned Rainfall

Several factors that influence the calculation of planned rainfall include historical rainfall data, return periods, and rainfall analysis methods[14]. First, historical rainfall data plays an important role in determining planned rainfall. In this study, researchers used the last 10 years of planned rainfall data. Second, the selection of return periods (2, 5, and 10 years) greatly determines the intensity of the design rainfall used. These periods will influence the results of planned rainfall calculations that are more specific to the desired rainfall frequency[15]. Furthermore, rainfall analysis methods also influence the results. Some commonly used methods are the Gumbel method, Log Pearson Type III, Normal, and Log Normal.

2. Surface Flow Rate (Q)

Design Flow Rate is the estimated amount of water that will flow through a drainage channel or river channel during a specific period, based on design rainfall and the topography and land use conditions around the channel[16]. This flow rate is used in planning to design drainage systems or water flow infrastructure that can efficiently handle rainwater flow without causing flooding or inundation[17]. The steps in calculating surface flow discharge involve collecting rainfall data from the past 10 years, calculating the flow coefficient (C), then determining the rainfall intensity (I), and finally using the Rational Formula to calculate the planned flow discharge (Q)[18].

3. Existing Channel Capacity

The capacity of an existing channel refers to its ability to drain rainwater or surface runoff based on its current physical condition. This capacity is greatly influenced by various technical factors related to the channel, including its geometric dimensions, slope, elevation on the road, and the condition of the channel material[19].

3.3   Data Analysis Techniques
1. Primary Data Processing

Primary data in the form of drainage channel dimension measurements and physical field conditions will be processed using Microsoft Excel software to compile tables, calculate averages, and visualize graphs. This data will be used to determine existing conditions and analyze drainage channel capacity.

2. Rainfall Data Analysis

Rainfall data obtained from BMKG over the past 10 years will be analyzed using statistical methods such as averaging, frequency distribution, and distribution fit tests to determine the planned rainfall value used in runoff discharge calculations.

4.   Results and Discussion
4.1   Analysis of Maximum Rainfall
After collecting monthly maximum rainfall data, a second analysis was conducted to obtain annual maximum rainfall data for frequency distribution analysis. Table 4.1 presents the annual maximum rainfall data for the Kediri region.

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Table 4.1 Data on Maximum Annual Rainfall in the Kediri Region

Year	Maximum Rainfall (mm)
2014	290
2015	370
2016	786
2017	558
2018	429
2019	461
2020	391
2021	591
2022	584
2023	433

(Source: Meteorology, Climatology, and Geophysics Agency)
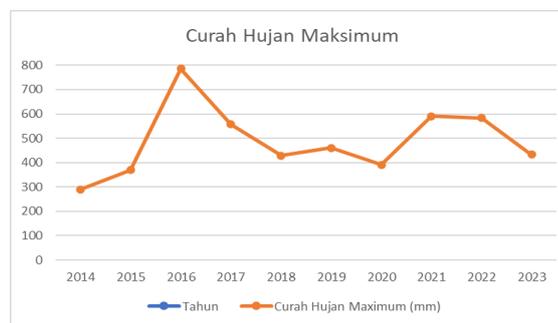
Source: Meteorology, Climatology, and Geophysics Agency

From Table 4.1, the maximum monthly rainfall in 2014 was 290 mm, and in 2015 it increased by 80 mm from 2014. The maximum rainfall over the past 10 years, specifically in 2016, saw a drastic increase, as evidenced by the rainfall level of 786 mm, which represents a 171% increase compared to 2014.

4.2   Statistical Parameter Analysis

From the data in Table 4.1, the maximum annual rainfall was obtained, and the distribution suitability test was calculated using frequency analysis calculations in the form of averages, standard deviations, variation coefficients, skewness coefficients, and kurtosis measurements[20].

a.   Analysis of Normal and Gumbel Distribution Frequencies

Presentation of Table 4.2. The following is a table of Distribution Conformity Statistical Parameters

Table 4.2 Distribution Conformity Statistical Parameters

Year	Xi	X	Xi-X	(xi-x)^2	(xi-x)^3	(xi-x)^4
2014	290	489,3	-199,3	39720,49	-7916293,657	1577717326
2015	370	489,3	-119,3	14232,49	-1697936,057	202563771,6
2016	391	489,3	-98,3	9662,89	-949862,087	93371443,15
2017	429	489,3	-60,3	3636,09	-219256,227	13221150,49
2018	433	489,3	-56,3	3169,69	-178453,547	10046934,7
2019	461	489,3	-28,3	800,89	-22665,187	641424,7921
2020	558	489,3	68,7	4719,69	324242,703	22275473,7
2021	584	489,3	94,7	8968,09	849278,123	80426638,25
2022	591	489,3	101,7	10342,89	1051871,913	106975373,6
2023	786	489,3	296,7	88030,89	26118765,06	7749437594
	4893	0		183284,1	17359691,04	9856677130

(Source: Data Analysis)

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From Table 4.2, calculations and statistical parameters are obtained to determine the type of distribution in the calculation, which can be seen in the following equation:

1. Average
$$\bar{X} = \frac{\sum Xi}{n} = \frac{4893}{10} = 489,3$$

2. Standard Deviation (Sd)
$$Sd = \sqrt{\frac{\sum(Log\ Xi - X)^2}{(n-1)}} = \sqrt{\frac{183284,1}{9}} = 142,71$$

3. Coefficient of Variation (Cv)
$$Cv = \frac{s}{X} = \frac{142,71}{489,3} = 0,29$$

4. Skewness Coefficient (Cs)
$$Cs = \frac{nx \sum(\log Xi - \log X)^3}{(n-1)(n-2)Sd^3} = \frac{10\ x17359691,04}{(9)(8)(142,71)^3} = 5,96$$

5. Measurement of Kurtosis (Ck)
$$Ck = \frac{n^2 \sum(\log Xi - \log X)^4}{(n-1)(n-2)(n-3)Sd^4} = \frac{10^2.\ 11165046063}{9.8.7\ (142,71)^4} = 5,34$$

From the above calculations, Cs = 5,96 and Ck = 5,34 are obtained, so the frequency distribution that meets the requirements is the Log Pearson III distribution. The Log Pearson III requirement is flexibility[21]. The above calculations yield a repeated period rainfall analysis, which is presented in Table 4.3 below:

Table 4.3 Analysis of Recurring Periods of Normal Distribution

PUH	Ytr	Yn	Sn	X	Sd	K	Xt
2	0,3668	0,541	0,9833	489,3	142,71	-0,1834	451,667
5	1,5004	0,541	0,9833	489,3	142,71	0,9502	622,479
10	2,251	0,541	0,9833	489,3	142,71	1,7008	735,581

(Source: Calculation Results)

a. **Frequency Distribution Analysis**

After obtaining the appropriate statistical analysis distribution according to the above calculations, frequency analysis was then performed using the Log Pearson III method, which can be seen in Table 4.4 below :

Table 4.4 Pearson III Log Frequency Analysis

Year	Xi	Log Xi	Log Xi- Log Xrt	(Log Xi-LogXrt)^2	(Log Xi-LogXrt)^3	(Log Xi-LogXrt)^4
2014	290	2,46240	-0,22718	0,051609	-0,01172	0,00266
2015	370	2,56820	-0,12137	0,014732	-0,00179	0,00022
2016	786	2,89542	0,20585	0,042373	0,00872	0,00180
2017	558	2,74663	0,05706	0,003256	0,00019	0,00001
2018	429	2,63246	-0,05712	0,003262	-0,00019	0,00001
2019	461	2,66370	-0,02587	0,000669	-0,00002	0,00000
2020	391	2,59218	-0,09740	0,009486	-0,00092	0,00009
2021	591	2,77159	0,08201	0,006726	0,00055	0,00005
2022	584	2,76641	0,07684	0,005904	0,00045	0,00003
2023	433	2,63649	-0,05309	0,002818	-0,00015	0,00001
N = 10	4893	26,73547967	-0,160272491	0,140836556	-0,004876335	0,004875763
		Log Xrt		2,689575216		

(Source: Calculation Results)

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Next, calculations are performed using statistical parameters to calculate a specific recurrence period, which can be seen in the following equation:

a. Average

$$X = \frac{\sum Xi}{n} = \frac{4893}{10} = 489,3 \text{ mm}$$

b. Log Xrt = Log X = 2,6895

c. Standard Deviation (Sd)

$$Sd = \sqrt{\frac{\sum(Log\ Xi-X)^2}{(n-1)}} = \sqrt{\frac{0,140836556}{9}} = 0,041$$

d. Slope Coefficient (Cs)

$$Cs = \frac{\sum(\log Xi - \log X)^3}{(n-1)(n-2)Sd^3} = \frac{10\ x-0,004876335}{(9)(8)0,041^3} = 3,14258$$

Using Log Pearson III parameter distribution analysis, the value obtained is Cs = 3.14258. The calculation of planned rainfall using the Log Pearson III method can be seen in Table 4.5 below:

Table 4.5 Planned Rainfall Using the Log Pearson III Method

Period (T)	Average Xi	Sd	Cs	Ktr	Rtr
2	489,3	0,04170	3,14258	0,0578524	526
5	489,3	0,04170	3,14258	0,85293112	588
10	489,3	0,04170	3,14258	1,23694096	707

(Source: Calculation Results)

Table 4.6 Annual Recurrence Period Combination (mm)

Recurrence Period (T)	Log Pearson III Distribution (mm)	Normal Distrubution (mm)
2	526	452
5	588	622
10	707	735

(Source: Calculation Results)

b. Planned Debit Analysis

Rainfall intensity is the amount of rainfall in a unit of time, such as mm/hour for short-term rainfall, and its intensity depends on the duration of the rainfall[22]. This can be seen in the following rainfall intensity calculation:

- Two-year period

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3}$$
$$I = \frac{526,73}{24}\left(\frac{24}{60}\right)^{2/3}$$
$$I = 277,69\ mm/hour$$

- Five-year period

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3}$$
$$I = \frac{588,31}{24}\left(\frac{24}{60}\right)^{2/3}$$
$$I = 310,15\ mm/hour$$

- Ten-year period

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3}$$
$$I = \frac{707,35}{24}\left(\frac{24}{60}\right)^{2/3}$$

$$I = 372,92 \ mm/hour$$

The drainage area of the Gringging Highway is 3.45 ha, with a runoff coefficient (C) = 0.25-0.40 (residential area). Therefore, the design flood discharge for a 2-year return period is:

Q = 0,00278 C.I.A

Q = 0,00278 x 0,04 x 277,69 x 3,45

Q = 0,10653 m³/second

The calculations for 5- and 10-year recurrence intervals can be seen in Table 4.7 below:

Table 4.7 Calculation of Q for the Gringging Highway Design

Period	C	tc (hour)	I (mm/hour)	A (Ha)	Q (m³/second)
2	0,4	1	277,69	3,45	0,10653
5	0,4	1	310,15	3,45	0,11898
10	0,4	1	372,92	3,45	0,14306

(Source: Calculation Results)

4.3 Hydraulic Analysis

Hydraulic analysis of the Gringging Highway drainage channel cross-section was conducted by comparing the planned flood discharge with the channel's capacity to accommodate it. If the planned flood discharge (Q) is greater than the channel's storage capacity (Q), the channel will not be able to accommodate a sufficiently large flood. The results of the field survey are shown in the data in Table 4.8 below.

Table. 4.8 Site Survey Results

Channel	Channel Size		Channel Length	Existing Channel Conditions
	B (meter)	H (meter)	(km)	
Drainage	1,40	0,85	0.98	Stone in cement

(Source: 2024 Survey Results)

- Surface Area (A)

    A = b x h

    A = 1,40 x 0,85

    A = 1,19 m²

- Wet Perimeter (P)

    P = (2 x h) + b

    P = (2x1,40) + 0,85

    P = 3,65 m

- Hydraulic Fingers (R)

    $$R = \frac{A}{P}$$

    $$R = \frac{1,19}{3,65}$$

    $$R = 0,326 \ m$$

- Speed *(Manning)*:

    Manning's flow coefficient for cemented stone channel conditions = 0,025

    $$V = \frac{1}{n} \ xR^{\frac{2}{3}}xS^{\frac{1}{2}}$$

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$$V = \frac{1}{0,025}\ x 0,326^{\frac{2}{3}} x 0,03^{\frac{1}{2}}$$
$$V = 3,28\ m/second$$

So the capacity of the channel cross-section is =

Q = V x A

Q = 3,28 x 1,19

Q = 3,903 m³/second

Table 4.9 Comparison of Hydraulic Q and Hydrological Q

Channel	Q Storage Tank	Q Flood Discharge Design			Description
		2 Year	5Year	10 Year	
Drainage	3,903	0,10653	0,11898	0,14306	Safe

(Source: Calculation Results)

The calculation results show that the existing channel capacity (Q = 3.903 m³/sec) is still capable of accommodating the planned flood discharge for a return period of 2 years, 5 years, and up to 10 years (maximum Q = 0.14306 m³/sec). However, regular maintenance is still required to ensure the channel remains functional without blockages caused by sedimentation, debris, or vegetation. Additionally, improvements to the water control system should be implemented, such as installing small check dams or inlet filters at the channel entrance to slow down the initial flow and capture sediment/waste.

The addition of infiltration wells at strategic points along the road can help reduce surface runoff load, although the current channel capacity is sufficient.

5 Conclusions and Recommendations

5.1 Conclusions

Based on the results of research on the optimization of the drainage system on Jalan Raya Gringging in Kediri Regency, it can be concluded that the existing drainage system at the research site has sufficient capacity to accommodate surface runoff from rainfall with various return periods. However, despite the channels having sufficient capacity, flooding still occurs at several points. This is due to the elevation difference between the channels and the road surface, where the channels are located at a higher elevation than the road. This condition hinders optimal water flow into the channels, leading to flooding. Therefore, to enhance the effectiveness of the drainage system, adjustments to the channel elevation or the implementation of additional technical strategies, such as the construction of infiltration wells, are necessary to reduce the volume of runoff directly into the channels. These measures are expected to create a more adaptive, environmentally friendly drainage system that supports the smooth operation of community activities in the area.

5.2 Recommendations

To support the sustainability of the drainage system on Jalan Raya Gringging, it is recommended that the local government and related parties carry out routine maintenance of drainage channels to prevent blockages and physical damage. In addition, the application of environmentally friendly technologies such as infiltration wells should be considered as an additional solution to reduce surface runoff volume. The implementation of drainage planning based on regularly updated hydrological data is also necessary to ensure the system can adapt to climate change and increasing rainfall intensity. Education for the community on the

importance of maintaining the cleanliness of drainage channels is also expected to strengthen the effectiveness of the system that has been built.

Reference

[1]   A. N. Jifa, L. D. Susanaati, dan A. T. S. Haji, "Evaluation of Drainage Channels at Gajayana Street and Sumbersari Street Malang," *J. Sumberd. Alam dan Lingkung.*, vol. 6, no. 1, hal. 9–17, 2019.

[2]   E. Wardhani dan A. Rufina, "Evaluasi Saluran Drainase Di Kecamatan Bogor Selatan," *J. Reka Lingkung.*, vol. 10, no. 2, hal. 113–124, 2022, doi: 10.26760/rekalingkungan.v10i2.113-124.

[3]   A. Fitriyadi dan S. Permana, "Evaluasi Sistem Drainase terhadap Genangan Air pada Ruas Jalan Malangbong-Wado di Kabupaten Garut," *J. Tek. Sipil*, vol. 20, no. 2, hal. 302–317, 2024, doi: 10.28932/jts.v20i2.7367.

[4]   H. Pratikto, Rhomadon, H. Wahyudiono, R. Ajiono, dan T. W. Risni, "Modifikasi Sistem Drainase Ruas Jalan Gemaharjo – Prigi Kabupaten Trenggalek," *J. Civilla*, vol. 5, no. 1, hal. 318–329, 2020.

[5]   D. Febrianti dan C. S. Silvia, "Optimalisasi Pemeliharaan Drainase Berdasarkan Persepsi Masyarakat," *J. CIVILA*, vol. 4, no. 2, hal. 300–309, 2019, [Daring]. Tersedia pada: http://jurnalteknik.unisla.ac.id/index.php/CVL/article/view/380

[6]   E. Siswanto, S. Susanto, dan F. Rahmawati, "Evaluation of Rainfall Intensity and the Effectiveness of Green Infrastructure in Urban Water Management: A Case Study of the University of Kadiri," *Int. J. Eng. Contin.*, vol. 4, no. 1, hal. 118–139, 2025, doi: 10.58291/ijec.v4i1.364.

[7]   Juliastuti, T. K. Wihartono, O. Setyandito, Y. Wijayanti, L. Safitri, dan I. S. D. Sebayang, "The assessment of drainage performance in the residential area using SWMM," *Sinergi (Indonesia)*, vol. 27, no. 2, hal. 281–288, 2023, doi: 10.22441/sinergi.2023.2.016.

[8]   E. S. Butar Butar, A. Sabar, dan M. Handajani, "Sustainable Urban Drainage System to Land Use/ Land Cover Change in Samarinda, Indonesia," *Appl. Mech. Mater.*, vol. 747, no. July 2024, hal. 371–374, 2015, doi: 10.4028/www.scientific.net/amm.747.371.

[9]   A. Purbaningtyas, S. Suhartono, dan M. Zenurianto, "Perencanaan Ulang Sistem Saluran Drainase Di Jalan Xx – Jalan Xx Kecamatan Xx Kabupaten Xx," *J. JOS-MRK*, vol. 2, no. 1, hal. 179–183, 2021, doi: 10.55404/jos-mrk.2021.02.01.179-183.

[10]   R. Gibran, S. Syaiful, dan R. Rulhendri, "Perancangan Jalur Saluran Drainase Guna Menanggulangi Banjir Pada Perumahan Warga," *J. Pengabdi. Masy. UIKA Jaya Sink.*, vol. 2, no. 1, hal. 44, 2024, doi: 10.32832/jpmuj.v2i1.1948.

[11]   M. Oktavia dan R. Rulhendri, "1918-181-4538-1-10-20230810," *J. Pengabdi. Masy. UIKA JAYA Vol.*, vol. 1, no. 3, hal. 124–132, 2023.

[12]   A. A. R. R. WANGSA, I. B. SURYATMAJA, dan A. A. M. P. ANDINI, "Analisis Hidrologi Rancangan Menggunakan Metode Rasional Pada Saluran Drainase Di Kelurahan Sumerta Kelod Kota Denpasar," *Ganec Swara*, vol. 17, no. 2, hal. 607, 2023, doi: 10.35327/gara.v17i2.463.

[13]   E. Efrizal, Y. Adi Saputro, dan N. Hidayati, "Implementasi Software Hec-Ras 4.1.0 Dan Epa Storm Water Management Model (Swmm) 5.1.0 Pada Efektivitas Analisis Saluran Drainase (Studi Kasus Desa Kelet Kecamatan Keling Kabupaten Jepara)," *J. Civ. Eng. Study*, vol. 2, no. 01, hal. 7–16, 2022, doi: 10.34001/ces.02012022.2.

[14]   N. Faqih, S. Suharto, E. Eviani, dan M. Musthofa, "Rehabilitasi dan Perencanaan Saluran Drainase di Komplek Wisata Dieng Plateau," *J. Econ. Manag. Account. Technol.*, vol. 6, no. 2, hal. 307–315, 2023, doi: 10.32500/jematech.v6i2.5429.

[15]   J. J. Donovan, E. F. Perry, dan F. Wang, "Mine Flooding History of a Regional Below-Drainage Coalfield Dominated by Barrier Leakage (1970-2014)," *Geofluids*, vol. 2019,

2019, doi: 10.1155/2019/5703108.

[16]   F. Isnaini, "Evaluasi Kapasitas Daya Tampung Saluran Drainase Jalan Damanhuri Pada Kota Samarinda," *Angew. Chemie Int. Ed. 6(11), 951–952.*, vol. 1, hal. 5–24, 2018.

[17]   E. O. Z. H. F. S. Tiurma Elita Saragi, "Studi Evaluasi Kinerja Saluran Drainase Pada Jalan Perumnas Simalingkar Kota Medan Dalam Mengatasi Debit Puncak Air (Studi Kasus : Jalan Karet Raya Perumnas Simalingkar)," *J. Tek. Sipil*, vol. 2, no. 2, hal. 56–70, 2023.

[18]   D. Ariyani, A. T. Juniati, A. Sari, A. Untarti, dan A. Khaddafi, "Performance Evaluation for Surface Run off to Drainage System Normalization at Campus in Jakarta, Indonesia," *J. Pengelolaan Sumberd. Alam dan Lingkung.*, vol. 14, no. 2, hal. 364–375, 2024, doi: 10.29244/jpsl.14.2.364.

[19]   F. Agustina, N. I. Junaedi, dan I. Wijaya, "Analisa Debit Rancangan Dan Kapasitas Tampang Drainase Serta Mengevaluasi Sistem Saluran Drainase Di Jalan Kh Wahid Hasyim Sempaja Kota Samarinda," *Rang Tek. J.*, vol. 5, no. 1, hal. 94–103, 2022, doi: 10.31869/rtj.v5i1.2815.

[20]   S. A. Kartawijaya, A. Sutandi, dan V. Kurniawan, "Analisis Kapasitas Saluran Drainase Di Kecamatan Kelapa Gading," *JMTS J. Mitra Tek. Sipil*, vol. 4, no. 2, hal. 469, 2021, doi: 10.24912/jmts.v0i0.10517.

[21]   L. K. Mohanty, B. Panda, S. Samantaray, A. Dixit, dan S. Bhange, "Analyzing water level variability in Odisha: insights from multi-year data and spatial analysis," *Discov. Appl. Sci.*, vol. 6, no. 7, 2024, doi: 10.1007/s42452-024-05958-3.

[22]   Reni Andayani dan Ayu Marlina, "Analisis Saluran Drainase Sekunder Kecamatan Ilir Timur I Palembang," *J. Deform.*, vol. 5, no. 2, hal. 69–85, 2020.