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Control Studies Puddle with Planning Channel Cut (Shortcut) on the Channel Irrigation Sengkaling Kiri District Lowokwaru, Malang City

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Rainfall, Runoff surface, Design discharge, Channel Cut, Shortcut

ABSTRACT
The drainage system in Malang City currently relies on the *Sengkaling Kiri* irrigation network to discharge urban drainage water. However, the existing channel capacity is insufficient to accommodate the increasing water flow during rainfall events due to channel narrowing and sedimentation. This limitation has resulted in frequent waterlogging and localized flooding, particularly around *Jl. Soekarno Hatta*, *Jl. Ahmad Yani*, and *Jl. Lt. Gen. Sutoyo*. This research aims to evaluate the performance of the current drainage system, identify the primary causes of flooding, and propose effective solutions to reduce inundation in these critical areas. The study employs a descriptive and analytical approach, combining field surveys, hydrological data collection, and hydraulic modeling to assess the channel's capacity and identify critical points of overflow. The findings reveal that the current *Sengkaling Kiri* irrigation network has experienced significant sedimentation and reduced cross-sectional area, leading to a capacity deficit during peak discharge events. Proposed solutions include channel widening, sediment removal, and the construction of alternative drainage routes, such as diverting part of the flow directly from the *Sengkaling Kiri* network to the nearest *Sungai Brantas*. These interventions are expected to significantly reduce waterlogging and improve flood management in the affected areas. The implications of this study highlight the importance of regular maintenance, capacity upgrades, and the integration of urban drainage systems with natural waterways to ensure long-term flood resilience in rapidly developing urban areas.

INTRODUCTION

Flooding problems are generally closely related to urban development, which is typically accompanied by an increasing population, economic activities, and demand for land—whether for settlement or economic purposes (Yin et al., 2022; Latif et al., 2020). As a consequence of limited land availability in urban areas, activities often encroach on conservation lands and open green spaces, changing their function into developed land (Fekete et al., 2019; Herold et al., 2018). This reduces the area available for water absorption, leading to increased surface runoff, especially during heavy rainfall (Luo et al., 2021). This situation causes river shallowing, resulting in water overflow and triggering floods, especially in downstream areas (Huang et al., 2020). The infiltration and surface runoff processes are important components of the hydrological cycle. Infiltration determines the amount of rainwater that seeps into the ground and enters the soil directly, and consequently, the amount of runoff that occurs on the surface depends on the infiltration capacity (Beven, 2016; Zhang et al., 2023).

Due to changes in land use from rice fields to housing, combined with the absence of a comprehensive Drainage Masterplan in Malang City, the existing irrigation channels have been forced to function as drainage channels (Widodo & Suharyanto, 2020; Ramadhan et al., 2019). This has caused upstream drainage flows to increase, while downstream irrigation channels progressively shrink, resulting in water overflow downstream due to the irrigation channels being converted to drainage channels (Saputra et al., 2022; Prasetyo & Nurhasanah, 2021). Such land conversion practices significantly alter natural hydrological patterns, reducing water retention capacity and exacerbating flood risks in peri-urban and downstream zones (Putra et al., 2023).

Therefore, it is necessary to plan an integrated drainage system for Malang City that combines drainage channels and irrigation channels, using a draft Channel Cut (Shortcut) directing flow to the main river, supported by the development of regulators. Many irrigation channels still serve to drain rice fields downstream, albeit only in small remaining areas (Slaets et al., 2016).

The concept taken is to create synergy between drainage and irrigation channels by discharging water into the main river without compromising the primary function of irrigation channels to irrigate rice fields (Li et al., 2023; Zhang et al., 2025). This requires cooperation or the establishment of a Memorandum of Understanding (MOU) between stakeholders managing drainage and irrigation channels.

Relevant previous studies provide a foundation for this research. Hermawan and Mardyanto (2019) evaluated the drainage system in *Kecamatan Lowokwaru*, Malang City, and found that many channels were blocked by sedimentation and waste, causing recurring floods. Although their economic feasibility analysis showed potential, the study did not propose structural integration between irrigation and drainage channels. Meanwhile, Wibowo et al. (2023) developed an urban flood mitigation model in Bandung using the Zero Artificial Runoff (ZARo) approach, which successfully reduced surface runoff by nearly 40% through infiltration wells and retention basins. However, this model has yet to be practically applied to cities like Malang, where existing irrigation channels are used as drainage systems.

The objective of this research is to assess the technical feasibility and effectiveness of such strategies in reducing flooding along *Jl. Soekarno Hatta*, *Jl. Ahmad Yani*, and *Jl. Jenderal Sutoyo*. The study aims to provide a technical basis for integrated urban drainage planning and to support local governments in implementing sustainable flood mitigation measures. The results are expected to contribute to both practical urban drainage solutions and the academic discourse on the synergy between irrigation and drainage systems.

METHOD

The study employed a descriptive and analytical approach, combining field surveys, hydrological data collection, and hydraulic modeling to assess the channel's capacity and identify critical points of overflow. The general study area is the *Sengkaling Kiri* Irrigation Area, which spans the administrative boundaries of Malang Regency and Malang City. The main structure, *Bendungan Sengkaling* (Sengkaling Dam), is in *Tegalgondo Village*, *Karang Ploso District*, Malang Regency. The precise coordinates of the dam are 7°54'47.91"S latitude and 112°35'16.73"E longitude.

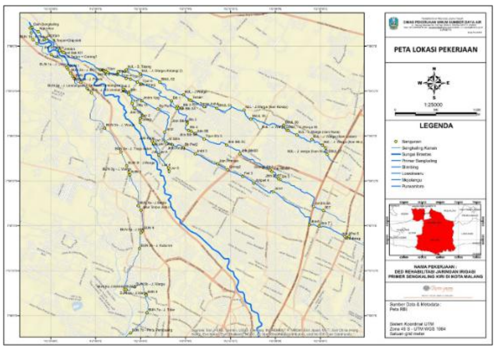

Figure 1. Map of research locations

The *Irrigation Area Sengkaling Kiri* is an irrigation area that spans across districts and cities, covering a total service area of approximately 455 hectares—16 hectares in Malang Regency and 439 hectares in Malang City. The water source originates from the *Brantas River*, with the main infrastructure being the *Sengkaling Dam*. Irrigation water from the *Sengkaling Dam* is conveyed to tertiary plots through several irrigation channels, including the *Sengkaling Kiri* primary channel, and secondary channels named *Mojolangu*, *Blimbing*, *Purwantoro*, and *Lowokwaru*. Excess irrigation water, rainwater, and drainage from surrounding residential settlements are discharged through drainage channels such as the *Mojolangu* exhaust duct, *Starfruit* waste channel, and the *Lowokwaru* waste channel.

The *Irrigation Area Sengkaling Kiri* consists of one primary channel, namely the *Sengkaling Kiri* primary channel, which has an approximate length of 1,745 meters, and five secondary channels: *Blimbing*, *Lowokwaru*, *Mojolangu*, *Purwantoro*, and *Tunggulwulug*.

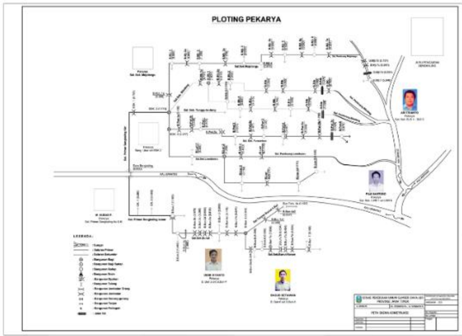

Figure 2. Irrigation Map

Research Data Collection

After assessing the study area's condition, data were collected from relevant agencies to support this study. The required data are as follows:

1. Rainfall Data: A 10-year dataset of final rainfall records from 2012 to 2022 was obtained. This rainfall data is essential for calculating the design discharge. Rainfall stations used for data collection in this study are Karangploso Station and Blimbing Station.
2. Area Data and Plans: Area data and plans are necessary to understand the waterlogging conditions in the study area as well as to analyze the impact of rooftop and road slope areas on surface runoff. This data was collected through direct field observations that reflect the current real conditions. Measurements of the area were conducted using contour maps with a scale of 1:25,000 for accurate spatial assessment.
3. Irrigation Data: The *Sengkaling Kiri* irrigation channel begins at the *Weir Sengkaling* in *Dau District*, Malang Regency. It consists of one primary channel and five secondary channels, with three secondary channels crossing *Jl. Soekarno Hatta*. Required irrigation data include longitudinal and transverse sectional data of the channels, irrigation infrastructure details, operating procedures (OP), and irrigation personnel information.
4. Topographic Data: Topographic measurements were conducted in accordance with the *Standard Planning Irrigation Mapping Section Technical Requirements PT-02*, published by the Directorate General of Water Resources, Ministry of Public Works.

These detailed measurements aim to collect field data and details that correspond to the function, usage, and needs of surveying and mapping activities.

5. Soil Investigation: Geological investigations were performed to understand the actual field conditions necessary for the preparation of detailed planning. This investigation was carried out at the planned building sites. Existing morphological and geological conditions will influence the type and dimensions of the planned structures.

RESULTS AND DISCUSSION

Selecting Shortcut Locations

The selection of the channel cut location is based on the presence of puddles and drainage areas caused by the conversion of irrigation channels into drainage channels. The planned channel cut will connect the downstream end of the irrigation channel directly to the main river to improve water flow and reduce flooding. Several factors must be considered in selecting the channel cut site: first, the elevation difference between the upstream and downstream ends of the irrigation channel and its compatibility with the river's final elevation to ensure proper gravity flow; second, the status of the land to be traversed, prioritizing government-owned assets to facilitate land acquisition and minimize legal complexities; third, the licensing and potential costs associated with the demolition of assets such as billboards, electric poles, and other utilities; and fourth, careful avoidance of underground infrastructure including cables, water pipes, and other utilities belonging to business entities to prevent service disruptions and additional expenses. Cost considerations for constructing the channel cut will include expenses related to land acquisition, demolition, construction works, and potential relocations of existing utilities.

Mapping Situation

The topographic survey activity in irrigation planning aims to obtain a complete, clear, and comprehensive description of the land conditions, fulfilling the topographic requirements essential for irrigation design. This includes detailing the administrative boundaries, current land conditions, areas planned for development, as well as planned irrigation networks and infrastructure.

The survey process begins with determining the work boundary locations, commonly using GPS tools that assist in accurately marking and locating positions for measurements and construction. Field measurements follow established standards such as PT-02, Technical Requirements for Topographic Measurement, and Pd T-10-2004-A. For detailed depiction, the survey adheres to KP-07, Criteria Planning for Standard Mapping, which relates closely to the thematic and elemental features displayed on maps, ensuring that essential topographic elements—such as contours, elevations, natural features, and man-made structures—are properly captured and represented.

Measurement Longitudinal and Transverse

Measurement of the longitudinal and transverse traces is intended to obtain both longitudinal and cross-sectional profiles of the channel. The technical specifications for these measurements are as follows: Cross-sectional measurements must be taken in a direction transverse (perpendicular) to the channel, ensuring that the measurement line is upright and straight across the channel. The limits of measurement should capture the boundaries of the channel edges on both left and right sides, according to the official channel boundary lines or as needed for the study purpose. At each cross section, measurements must be taken at three marked points (reading three threads with upright posted signs) to ensure accuracy and repeatability. These cross-sectional profiles are to be carried out at intervals not exceeding 50 meters, or at designated points along secondary polygons oriented upright along the river direction. The measurement process should faithfully represent the field profile appearance, using the profile stake points as reference bases. Measurements must also include the positioning of the water surface elevation, base elevation of the river or channel bottom (including the centerline), the height of the left embankment, and the surrounding riverbank topography depending on land conditions. This comprehensive measurement approach ensures an accurate and detailed representation of the channel's geometry and topographic context.

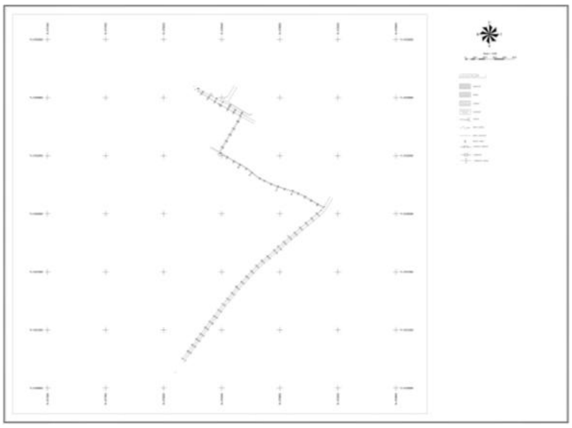

Figure 3. Long Cross Measurement Plan

Hydrological Analysis

Conditions of Water Catchment Areas (DTA)

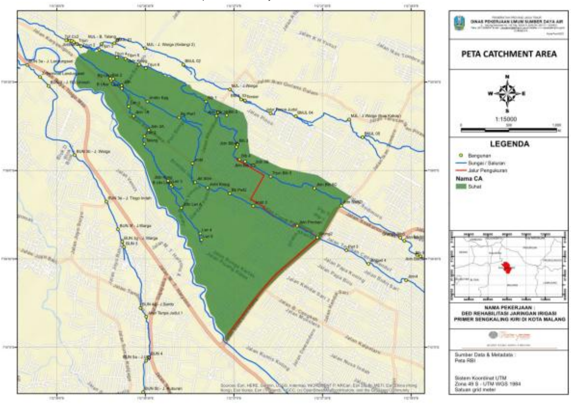

Figure 4. Regional Map Water Catchment

Area water catchment in each channel as following:

Table 1. Area table water catchment every channel

No.	Channel section	Outlet	direct distance (m)	B	H	Elevation Upstream	Elevation Downstream	Area DTA (Km2)	Area DTA (Ha)
1	Saluran Blimbing - B.LB.4 /PJ	Sal. Purwantoro	4285	2,00	1,50	589,503	539,045	0,950	95
2	PJ - KUA	Sal. Purwantoro	650	1,00	1,00	514,283	511,530	0,140	14
3	Sal. Sekunder	Sal. Purwantoro	2930	3,00	1,47	571,251	506,825	0,710	71

No.	Channel section	Outlet	direct distance (m)	B	H	Elevation Upstream	Elevation Downstream	Area DTA (Km2)	Area DTA (Ha)
	Purwantoro - Outlet KUA								
4	KUA - Sal. Sekunder Purwantoro	Sal. Purwantoro	770	3,00	5,00	506,825	504,049	0,230	23
5	Sal.Sekunder Purwantoro - RS UB	Brantas	310	1,00	0,80	500,797	498,849	0,050	5
6	Griya Shanta - RS UB	Brantas	1400	3,00	2,60	508,000	498,849	0,370	37
7	RS UB - Outlet Lowokwaru	Brantas	480	0,80	0,60	501,566	500,685	0,050	5
8	Lowokwaru - Soehat	Brantas	2700	1,00	1,00	504,000	500,767	0,630	63
9	Outlet Lowokwaru - Poltek	Brantas	370	1,00	1,20	500,685	495,904	0,180	18

Rain Data

In calculating the bulk rainfall for design discharge, daily rainfall data from at least 10 years are required, collected from rainfall stations located near or within the study area. When more than one rainfall station is available, the bulk rainfall value representing the catchment area can be obtained by averaging the rainfall data from these stations. This averaging helps to account for spatial variability in precipitation across the area.

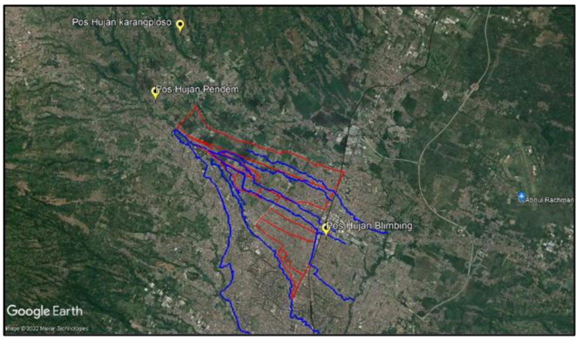

Figure 5. Point Rain Gauge

Rain Analysis Design

Calculation of Basic Statistical Parameters

Selection of rainfall design calculation methods based on basic statistical parameters typically involves statistical analysis of historical rainfall data to estimate design rainfall values corresponding to specific return periods. The calculation of basic statistical parameters provides a foundation for understanding rainfall distribution and variability, which is essential for selecting appropriate design storms in hydrological studies.

Average value: Standard Deviation:

$$\overline{X} = \frac{\sum_{i=n}^{n} X_i}{n} \qquad Sd = \sqrt{\frac{\sum_{i-n}^{n}\left(X_i - \overline{X}\right)^2}{n-1}}$$

Coefficient Skewness:

$$Cs = \frac{\frac{n}{(n-1)(n-2)} \sum_{i-n}^{n} (X_i - \overline{X})^3}{Sd^3}$$

Coefficient Kurtosis:

$$Ck = \frac{n^2 \sum_{i-n}^{n} \left(X_i - \overline{X}\right)^4}{(n-1)(n-2)(n-3)\,Sd^4}$$

coefficient variations:

$$Cv = \frac{Sd}{\overline{X}}$$

Where:

$\overline{X}$ = average value

SD = standard deviation

Cs = skewness coefficient

Ck = kurtosis coefficient

Xi = value of the ***i*** variant

N = amount of data

Cv = coefficient of variation

Table 2. Condition Election Distribution Frequency

Distribution Frequenci	CK	Cs
Gumbel	5,4002	1,1396
Normal	3.0	0
Log Person	Bebas	Bebas

Sources : Sri Harto,(1993)

Determination of Frequency Distribution for the Gumbel Method

Table 3. Gumbel Method

No	Year	X
1	2012	79,0
2	2013	111,0
3	2014	88,0
4	2015	59,0
5	2016	71,5
6	2017	74,5
7	2018	62,5
8	2019	72,5
9	2020	69,5
10	2021	88,5
Amount		776,00
n		10
Xrerata		77,6
SD		15,12
CS		1,16
CK		1,71

Source: Analysis and Calculation Results

Determination of Frequency Distribution for the Log Normal Method

Table 4. Log Normal Method

No	X	P(%)	Log Xi
1	59,0	9,1	1,77
2	62,5	18,2	1,80
3	69,5	27,3	1,84
4	71,5	36,4	1,85
5	72,5	45,5	1,86
6	74,5	54,5	1,87
7	79,0	63,6	1,90
8	88,0	72,7	1,94
9	88,5	81,8	1,95
10	111,0	90,9	2,05
Amount	776,0		18,8
Xrerata	77,6	CV	0,04
Sd	15,1	CS	0,13
LogXr	1,88	CK	3,03
Sdlog	0,08		

Source: Analysis and Calculation Results

Determination of Frequency Distribution for Metode Log Pearson III

Log Pearson Type III Method

Design Rain Calculation Metode Log Pearson Type III

Table 5. Log Pearson Type II

No	Return Period (Year)	CS	Log X	R(mm)
1	2	-0,116	1,9	74,8
2	5	0,790	1,9	88,4
3	10	1,333	2,0	97,7
4	25	1,968	2,0	109,8
5	50	2,408	2,1	119,1
6	100	2,826	2,1	128,6
7	200	3,225	2,1	138,5

Source: Analysis and Calculation Results

Rain Designs of Various Times Log Pearson Type III Method

Table 6. Log Pearson Type II

No	Return Period (Year)	R (mm)
1	2	74,8
2	5	88,4
3	10	97,7
4	25	109,8
5	50	119,1
6	100	128,6

No	X	P(%)	Log Xi
1	59,0	9,1	1,77
2	62,5	18,2	1,80
3	69,5	27,3	1,84
4	71,5	36,4	1,85
5	72,5	45,5	1,86
6	74,5	54,5	1,87

No	X	P(%)	Log Xi
7	79,0	63,6	1,90
8	88,0	72,7	1,94
9	88,5	81,8	1,95
10	111,0	90,9	2,05
Amount	776,0		18,83
Average	77,6	Sdlog	0,08
Sd	15,1	Cs	0,70
LogXr	1,88		

Source: Analysis and Calculation Results

Table 7. Chi Square Chi Square Method

Group	Value Range			Oi	Ei	Oi-Ei	(Oi-Ei)²/Ei
1	0	R ≤	65,2	2	2,00	0,00	0,000
2	65,2	< R ≤	71,4	1	2,00	-1,00	0,500
3	71,4	< R ≤	79,0	4	2,00	2,00	2,000
4	79,0	< R ≤	88,4	1	2,00	-1,00	0,500
5	88,4	< R ≤	-	2	2,00	0,00	0,000
				10	10		3,000
			Degrees Independence Dk				5,991
						Condition	Ok

Source: Analysis and Calculation Results

Table 8. Smirnov Kolmogorof Conformity Test Distribution Smirnov Kolmogorov method

No	Log X	Log xr	Sdlog	G	Pr	Px	Sn	Δ
1	1,77	1,88	0,08	-1,400	94,54	0,05	0,0909	0,0363
2	1,80	1,88	0,08	-1,088	89,34	0,11	0,1818	0,0752
3	1,84	1,88	0,08	-0,512	66,02	0,34	0,2727	0,0670
4	1,85	1,88	0,08	-0,358	59,79	0,40	0,3636	0,0385
5	1,86	1,88	0,08	-0,283	56,74	0,43	0,4545	0,0219
6	1,87	1,88	0,08	-0,135	50,62	0,49	0,5455	0,0517
7	1,90	1,88	0,08	0,183	40,10	0,60	0,6364	0,0373
8	1,94	1,88	0,08	0,768	20,73	0,79	0,7273	0,0654
9	1,95	1,88	0,08	0,798	19,71	0,80	0,8182	0,0153
10	2,05	1,88	0,08	2,027	3,73	0,96	0,9091	0,0536
					Max			0,075
					Δ critical			0,409
					Condition			Ok

Source: Analysis and Calculation Results

Runoff Discharge Surface

Plan debit calculated with rational method or rational method that has been modified or hydrograph unit for urban area.

1) Coefficient runoff is determined based on usage of land area catch.
2) Concentration time calculated with formula Kirpich .
3) Calculation intensity Rain reviewed with use method Mononobe

Plan debit calculated with method rational or method rational which has modified or hydrograph unit for urban area. Rational Method the equation is as follows:

Q = 0.00278 .CIA

Q = debit peak flood (m3/s).
I = intensity Rain during time concentration (mm)
A = area area water catchment (km^2)
C = coefficient rainwater runoff _

Concentration time (tc) is the equation according to Kirpich (1940) as following:

$$t_c = 0,0195L^{0,77} \cdot S^{-0,385}$$

Where:
Tc = time concentration in minute
L = length channel from furthest point _ until with point under consideration (m).
S = slope base channel
to = time water flowing above _ _ surface land going to channel (inlet time) in minute.
td = time flowing water inside _ _ channel until the point under consideration (conduit time) in minutes, or
V = speed of water inside channel in meters per minute.

Intensity bulk Rain
stated in Units are mm/ hour, that is calculated with equality from Mononobe as following:

$$i : \frac{R_{24}}{24}\left(\frac{24}{Tc}\right)^{2/3}$$

Where:
I = intensity bulk Rain in mm/hour.
R24 = bulk Rain daily maximum annual for birthdays.
Tc = time concentration in hours.
Rainfall _ design used _ is the correct Q5 reset time with the typology of Malang City classified as city big with area of DTA 101 - 500 Ha.
Calculation Rainfall Intensity

Table 9. Ranfall Intensity

No.	Channel Name	R24 (mm)	L (m)	s	Tc (jam)	I (mm/jam)
1	B.LB.4	88,358	4066	0,00040	15,92	4,840
2	PJ-KUA	88,358	296	0,00384	0,88	33,258
3	Purwantoro - KUA	88,358	2930	0,01132	3,41	13,523
4	Purwantoro -Suhat	88,358	770	0,00361	1,89	20,018
5	Suhat - RS UB	88,358	300	0,00649	0,73	37,771
6	Griya Shanta - RS UB	88,358	1400	0,00654	2,39	17,158
7	RS UB - Lowokwaru	88,358	600	0,00048	3,40	13,549
8	Lowokwaru	88,358	2700	0,00120	7,60	7,922
9	Jl. Soekarno – Hatta (RS UB-Brantas)	88,358	400	0,01209	0,72	38,222

Source: Analysis and Calculation Results

Calculation furthermore for rainwater runoff discharge for each other DTA can seen in the table following This .
Flood Discharge Plan Channel Drainage Jl. Sukarno – Hatta

Table 10. Runoff Discharge Surface

No.	Channel Name	A (Km^2)	I (mm/jam)	c	Qhjn (m^3/dt)
1	B.LB.4	0,950	4,840	0,800	1,022
2	PJ-KUA	0,140	33,258	0,800	1,035
3	Purwantoro - KUA	0,710	13,523	0,800	2,134
4	Purwantoro -Suhat	0,230	20,018	0,800	1,023
5	Suhat - RS UB	0,050	37,771	0,800	0,420
6	Griya Shanta - RS UB	0,370	17,158	0,800	1,411
7	RS UB - Lowokwaru	0,050	13,549	0,800	0,151

No.	Channel Name	A (Km^2)	I (mm/jam)	c	Qhjn (m^3/dt)
8	Lowokwaru	0,630	7,922	0,800	1,109
9	Jl. Soekarno - Hatta (RS UB-Brantas	0,180	38,222	0,800	1,529

Resources : Begeman, 1965

Soil Investigation

The geotechnical investigation is conducted to understand the actual field conditions essential for advancing the project planning phase. This investigation is carried out on-site at the planned building locations. The existing morphology and geological conditions will influence the choice of foundation types and the dimensions of the structures to be constructed. Two points have been selected for geotechnical investigation: Point 1 at the location of the water gate on *Jl. Candi Stage* and Point 2 in front of *RSUB* (Hospital). Soil data such as cone penetration resistance (qc) and skin friction (fs) will be obtained from the results of sondir (Dutch Cone Penetrometer) testing. These parameters are essential for classifying the soil type at the site.

The purpose of the investigation is to collect foundational soil data at critical building locations, which will be used to develop detailed design plans for the structures. The scope of work includes conducting sondir tests (using the Dutch Cone Penetrometer method) at two planned points, subject to the client's approval. It also involves collecting both undisturbed soil samples (original condition samples) and disturbed soil samples for laboratory testing. Laboratory tests will determine soil properties such as strength, compressibility, and other relevant geotechnical characteristics. The collected data will form the soil database essential for the final design of foundations and other structural elements.

Sondir (Dutch Cone Penetrometer)

The sondir investigation is intended to determine the bearing capacity of the soil to support the planned building foundation by measuring cone resistance (cone pressure) and the amount of skin friction (adhesive resistance). The sondir tool will be operated with a minimum weight of 2 tons and utilize a cone capable of applying a pressure of 200 kg/cm², or until reaching a depth of 15 meters. The penetration rate must be maintained at 1 cm per second, with testing intervals every 20 cm. The sondir results should clearly show the relationship between cone resistance, the amount of skin friction, and depth at each 20 cm interval.

Taking example land original (Undisturbed Sample)

Taking undisturbed soil samples (*example land original*) is intended for laboratory investigation of soil index properties and engineering properties based on the results of drilling. The undisturbed soil samples will be taken starting at a depth of 1.5 meters from the local ground surface. The implementation method for sampling refers to the ASTM D1587-67 standard.

Taking example land No original (Disturbed Sample)

Taking disturbed soil samples (*example land no original*) will be conducted if the results from undisturbed soil samples (*example land original*) are found to be insufficient for soil identification in the laboratory. The collection of disturbed soil samples will take place after the drilling process. These disturbed samples are intended for visual observation of the soil and for conducting physical property tests, which include determining the natural moisture content.

Table 11. Cone Penetration Test Graph Point

Soil Consistency	Cone Pressureqc (kg/cm^2)	Undrained Cohesion (T/m^2)
Very Soft	< 2,50	< 1,25
Soft	2,50 – 5,0	1,25 – 2,50
Medium Stiff	5,0– 10,0	2,50 – 5,0
Stiff	10,0– 20,0	5,0 – 10,0
Very Stiff	20,0– 40,0	10,0 – 20,0
Hard	> 40,0	> 20,0

Source: Analysis and Calculation Results

Table 12. Consistency and Conus Pressure

Sondir Results		Classification
Qc	**fs**	
6,0	0,15 -	Humus, very soft clay
6,0 - 10,0	0,20	Loose silt sand, very loose sand
	0,20 -	Soft clay, soft silty clay
10,0 - 30,0	0,10	Loose gravel
	0,10 -	Loose sand
	0,40 -	Clay or silty clay
	0,80 -	The clay is a bit chewy
30 – 60	1,50	Silty sand, rather dense sand
	1,0 -	Clay or silt clay is chewy
60 - 150	1,0	Loose sandy gravel
	1,0 - 3,0	Dense sand, silty sand or dense clay and silty clay
	3,0	Pebble clay is chewy
150 - 300	1,0 - 2,0	Dense sand, gravelly sand, coarse sand, very dense silty sand

Source: Analysis and Calculation Results

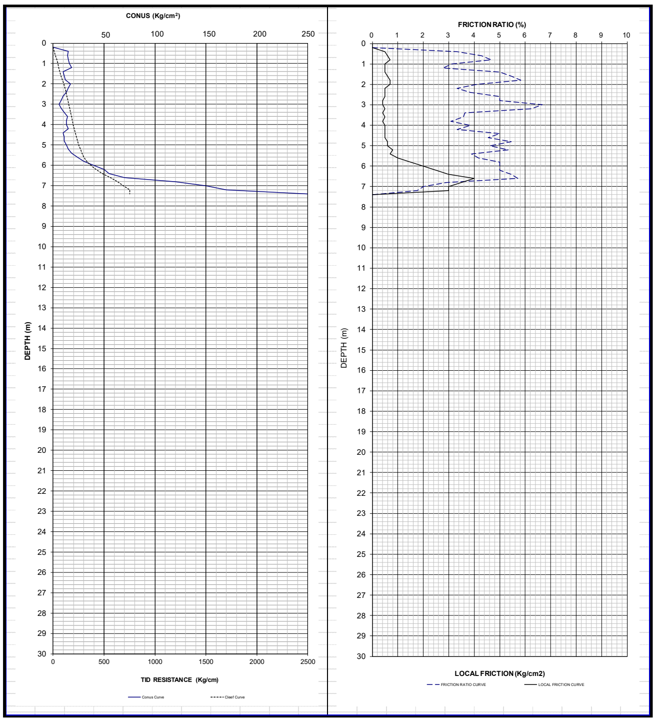

Figure 6. Cone Penetration Test Graph Point

Source: Analysis and Calculation Results

Investigation Laboratory

The soil samples obtained from drilling must be neatly arranged and stored in appropriate core boxes that allow for proper visual description of the soil. These core boxes, along with accompanying photographic documentation and investigation reports, must be submitted to the Project Owner at the conclusion of the geotechnical investigation.

Disturbed soil samples (*example land no original*) are to be tested in the laboratory for their index properties, which include:

1) Soil water content;
2) Specific gravity of the soil;
3) Sieve analysis, including the percentage of clay, sand, and gravel;
4) Soil classification and soil bulk density;
5) Porosity and pore size distribution.

Undisturbed soil samples (*example land original*) will be further investigated for physical characteristics, along with technical (engineering) properties, which include:

1) Permeability test;
2) Consolidation test;
3) Unconfined compression test;
4) Triaxial test;
5) Direct shear test.

Building Design

Drainage Channel Capacity

Based on the peak discharge calculation, the channel's capacity to convey flow can be analyzed and its dimensions determined whether the cross-section is trapezoidal or rectangular (square). According to Suripin (2004), the channel flow analysis is commonly performed using the **Manning equation**, which relates to the channel geometry, slope, roughness, and flow velocity.

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

Where the values A and P are obtained from equality following

A = (B + mh) h (for channel cross-section trapezoid)

A = B xh (for channel cross-section rectangle)

P = B + 2h +$\sqrt{1 + m^2}$ (for trapezoidal cross-section channels)

P = B + 2h (for channel cross-section rectangle)

Where the value of m is obtained from :

$$m = \frac{B-b}{2\,x\,h}$$

Then calculated discharge capacity channel use equality following :

Q = V.A

Where the value of V is obtained from equality following :

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

$$S = \left(\frac{v x n}{R^{\frac{2}{3}}}\right)^2$$

Information:
Q = planned discharge (m3/ second)
V = Speed flow (m/ sec)
A = Cross- sectional area Wet (m3)
B = Base width channel (m)
b = Top width channel (m)
h = Water depth (m)
H = Depth channel (m)
W = Guard height (m)
R = Radius hydraulic (m)
P = Perimeter wet (m)
n = Coefficient Manning's rudeness
S = Slope channel

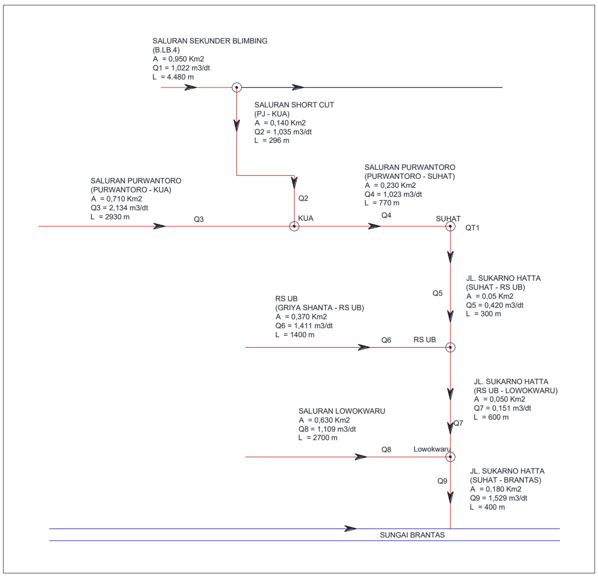

Figure 7. Schematic System Drainage Plant Sengkaling Left
IrigationChannel (Soekarno Hatta Road)

Plan Budget Cost

General

The intent of volume and budget cost calculations is to analyze the volume of work based on the planned construction activities. After determining the quantities of the work to be executed, the next step is to calculate the planned budget cost. This calculation relies on applying unit prices for labor wages, material prices, and heavy equipment rental rates applicable within Malang Regency and City.

To perform a thorough and accurate budget cost plan, sufficient and comprehensive data are required, including basic wage rates for workers, current material prices, rental rates for heavy equipment, unit price analyses for each type of work, detailed quantities (volumes) of work items, and a comprehensive price list.

The construction cost is calculated from the analysis of job unit prices, which are determined by summing the costs of labor wages, tools (equipment) used, and materials consumed for each construction activity. Unit prices for labor, materials, and equipment are based on the prevailing price levels as of 2022.

Unit Price Analysis of Work

Price analysis for unit work used in calculating the planned budget cost refers to the unit price list for Malang City works and is based on the Regulation of the Minister of Public Works and Public Housing Number 28/Prt/M/2016 concerning Unit Price Analysis for Public Works, Part 2: Unit Price Analysis for Water Resources Work. The unit price for each type of work is determined based on the base price for that work category. The primary types of work considered include: excavation work, heap work, masonry work, concrete work, sluice work, and other related jobs.

To obtain the total planned budget cost for the project, the first step is to calculate the volume of work involved through physical implementation. Quantity calculation for each work item is performed based on the project planning drawings, generally categorized by the types of work involved. From the analysis of work volume for the planned construction of buildings and channels, the total cost is estimated to be approximately Rp. 37,093,545,533.

CONCLUSION

Based on the results of site inspections, field measurements, and subsequent analyses, two shortcut channels have been planned to improve drainage efficiency: Shortcut I, an open channel with a control gate connecting the Blimbing channel to the Purwantoro channel, and Shortcut II, a box culvert with a control gate linking the Purwantoro channel directly to the Brantas River. These channels are designed considering channel slope, land availability, and construction costs, and are capable of handling a discharge of approximately 11,421 m^3/s. The implementation of this shortcut system is expected to effectively reduce flooding at critical locations such as Jl. A Yani and Jl. Letjet Sutoyo, known for frequent waterlogging. Furthermore, the cost estimation based on the design is Rp. 37,093,545,533, representing an economical solution for flood control along Jl. Soekarno Hatta. For future research, it is suggested to conduct detailed hydraulic modeling and long-term monitoring of the shortcut channels' performance during various storm events, as well as to explore the environmental impact and potential integration of green infrastructure to enhance urban flood resilience.

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