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# EVELUATION OF DRAINAGE SYSTEM IN SUKUN VILLAGE RW7 TO MITIGATE INUNDATION RISKS USING EPA-SWMM 5.1

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***ABSTRACT***

*Sukun District frequently experiences flooding during the rainy season, particularly when rainfall exceeds two hours, due to blockages in drainage channels, population growth and a limited number of inlets. This study aims to evaluation flood discharge, determine the necessary dimensions for drainage channels and inlets, as well as estimate the cost of redesigning. The required data for this study included daily rainfall data from 2013-2022 obtained from Sukun, Ciliwung, and Dau stations, existing channel dimensions, a topographic map, and the 2022-unit price of work in Malang city. The data were processed using the Log-Pearson III distribution to determine the flood design for a 10-year return period. The intensity of rain was calculated using the Mononobe formula. The Storm Water Management Model (EPA-SWMM 5.1) was employed to simulate the quality of surface runoff, as well as the flow rate. The results of the Log-Pearson III distribution indicated that the maximum recorded rainfall was 93.827 mm/day, which was deemed acceptable based on the Chi-Square and Smirnov-Kolmogorov test results. The simulation revealed that the existing drainage channels have a capacity of 1.648 m3/sec, which is insufficient to handle the design discharge of 1.685 m3/sec. As a result, overflow occurs during peak flow conditions, indicating that four channels (RT4C, RT4F, RT4H and RT4I) are not effective to convey the 10 years return period of discharge. However, the simulation also demonstrated that the proposed redesign of the drainage channels, which involves increasing the channel height depending on the amount of discharge each channel should accommodate while keeping the width constant due to space limitations, significantly improves their capacity. The redesigned channels have a capacity of 2.278 m3/sec, exceeding the design discharge of 1.685 m3/sec. The new design ensures that the channels can accommodate the expected volume of water without experiencing overflow, even during peak flow conditions. The estimated cost of this redesign is IDR* 280,450,000.

***Keywords*** *:* ***drainage evaluation, EPA- SWMM 5.1, Log Person III rainfall distribution.***

## 1. INTRODUCTION

The dumping of trash in drainage channels and the overgrowth of weeds and clogging in some areas of Rukun warga seven of Sukun district, particularly in JL Raya Walet and some portions of JL Rajawali, have decreased the efficacy of the current drainage channels. The waterway's supporting structures in the shape of inlets are still not in the best condition when measured by the number. As a result, throughout every rainy season, inundation can occur in various regions if it rains for longer than 1-2 hours.

The purpose of this study is to evaluate the drainage channel discharge that presently exists in Rukun warga seven of the Sukun district, determine the necessary dimensions for drainage channels and inlets to effectively manage stormwater during rainy seasons, and estimate the cost of redesigning these systems.

***Table 1 Data collection techque***

| No | Data | Specification | Source |
|---|---|---|---|
| 1 | rainfall Rain | Daily, 10 years 2013-2022, 3 STA (Dau, Sukun, Ciliwung) | BMKG |
| 2 | Topography Map | watershed Kelurahan Sukun. | Dinas Malang City |

| | | | |
|---|---|---|---|
| 3 | HSP Kota Malang | Year 2022 | Dinas Malang City |
| 4 | Existing Dimensions | Field measurement | Surveys |
| 5 | Existing supportin g structures | inlet | Surveys |
| 6 | Existing road condition. | Visual, documentation | Surveys |

**Source: Personal survey**

## 2. METODE

The study was conducted in Sukun district particularly. RW7 strating from Jalan Raya Walet (RT 01) to Jalan Empirt mas (RT 04) with 5.1 hacters. It has a longitude coordinates of 122°37'52", latitude coordinates of -7°59'28" and an altitude above sea level of about 440 meters.

The research's data was gathered in two ways: through conducting literature reviews, field surveys, and other secondary data collection sources. The necessary secondary data and primary data are displayed below based on the findings of data collecting from relevant departments and government agencies.

**Data Process (Rainfall data)**

**a. Missing data (Arithmetic Mean Method)**

$$d = \frac{dA+dB+dC}{n} \text{.......... (5)}$$

Where;

n = number of observation points (post)
d = regional rainfall (mm)

DA, dB and dC = Average rainfall at each observation point (mm)

**b. Consistency test**

Consistency test is carried out to determine the correctness of a rainfall data.

$$F_k = \frac{tg\beta}{tg\alpha} = \frac{TB}{TL} \text{........(2)}$$

Where;

α, β = slope angle of the rain data

$F_{k:}$ = correction factor

R = original rainfall

$R_k$ = rainfall after correction

**c. Areal Rainfall**

To estimate the areal rainfall in Sukun district, an arithmetic mean method was used.

$$d = \frac{dA+dB+dC}{n}$$

**d. Design rainfall (Log Pearson III distribution)**

X = Log X……. (3)

$$\text{LogXdesigned} = \bar{X} + G \times Sd$$

$$\text{Xdesigned} = 10^{logXdesigend}$$

**e. rainfall Intensity (Mononobe Method)**

$$I = \frac{R}{24} \left(\frac{24}{t_c}\right)^{2/3} mm/hour$$

Where: (4)

I = Rainfall intensity (mm/hour)

t = Length of rainfall (minutes)

R = Maximum design rainfall in mm

**f. Discharge**

According (Soemarto, 1995), If the catchment area is smaller than 0.80 $km^2$ (40-80 Ha), the channel capacity can be calculated by the formula;

**Q = C × I × A......(6)**

Information:

Q = discharge ($m^3$/second)

C = Flow coefficient

A = catchment area (ha)

I = Rainfall intensity (mm/hour)

**Data Process (Hydraulic)**

According to (Suripin, 2004) The existent channel discharge (Qe) must be the same or greater than design discharge (Qp).

Q = VA…… (6)

Where :
Q = channel discharge (m $^{3}$ / sec)
V = flow velocity in the channel (m/s)
A = wet Area in m $^{2}$

$V = \frac{1}{N} \cdot R^{2/3} . S^{1/2}$……. (7)
R = A/p
Where :
V =average flow velocity in the channel (m/s)
N = manning roughness coefficient
R =hydraulic radius of the channel (m)
S =bottom slope of the channel
A =the cross -sectional area of the channel perpendicular to the direction of flow (m)
P = wetted perimeter of the channel (m)

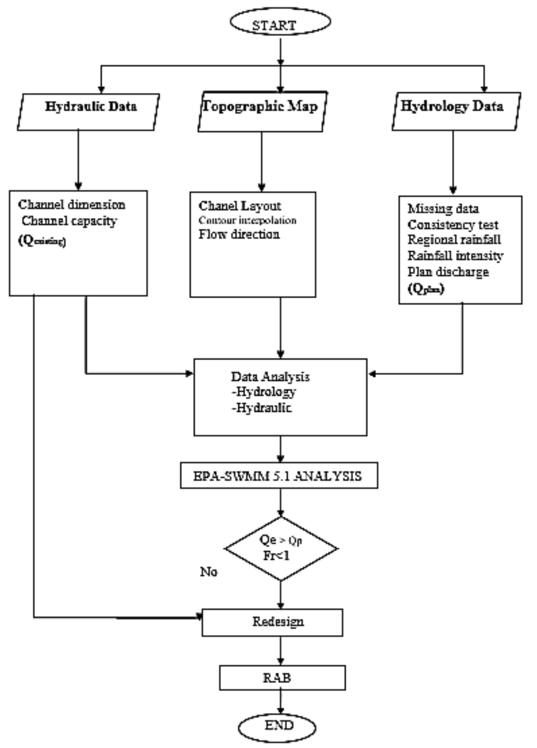



**Figure 1 Flow chart**

## 3. ANALYSIS AND DISCUSSION

The rainfall data that was used to calculate the amount of rainfall for the previous ten years (2013–2022) was obtained from (BMKG) Malang city in three Stations (Sukun, Ciliwung and Dau)

### a. Missing data

The arithmetic mean method was applied to estimate the rainfall data that was missing.

***Table 2 Missing data 2022 at station sukun***

| Year | Station Ciliwung | Station Sukun | Station Dau |
|---|---|---|---|
| 2022 | 3 | TTU | 5 |
| 2021 | 0 | 4 | 5 |
| 2020 | 0 | 11 | 3 |
| 2019 | 21 | 2 | 21 |
| 2018 | 42 | 42 | 15 |
| 2017 | 22 | 9 | 15 |
| 2016 | 27 | 14 | 30 |
| 2015 | 19 | 32 | 12 |
| 2014 | 0 | 0 | 0 |
| 2013 | 0 | 0 | 0 |
| AVERAGE | 13.4 | 13 | 10.6 |

**Source: BMKG Malang**

dB = $\left(\frac{dA}{Aa} + \frac{dC}{Ac}\right) x \frac{AB}{2}$……..(8)

dB = $\left(\frac{13.4}{3} + \frac{10.6}{5}\right) x \frac{13}{2}$

dB = 4.4 mm/day

### b. Annual rainfall analysis

The annual rainfall is calculated by summing up all rainfall that fall for each year.

***Table 3 Annual rainfall***

| **Year** | **Station Sukun** | **Station Ciliwung** | **Station Dau** |
|---|---|---|---|
| 2022 | 2800.15 | 2695.02 | 2823.00 |
| 2021 | 3080.00 | 2112.00 | 2869.70 |
| 2020 | 2674.00 | 2277.00 | 3215.00 |
| 2019 | 1727.00 | 2096.00 | 2058.00 |
| 2018 | 1977.00 | 1872.00 | 1808.00 |
| 2017 | 2323.00 | 2272.00 | 2391.00 |
| 2016 | 3304.00 | 3304.00 | 2347.00 |
| 2015 | 1861.00 | 1505.00 | 1243.00 |
| 2014 | 2110.00 | 2513.00 | 2480.00 |
| 2013 | 2799.00 | 2433.00 | 2947.00 |
| AVERAGE | 2465.51 | 2307.90 | 2418.17 |

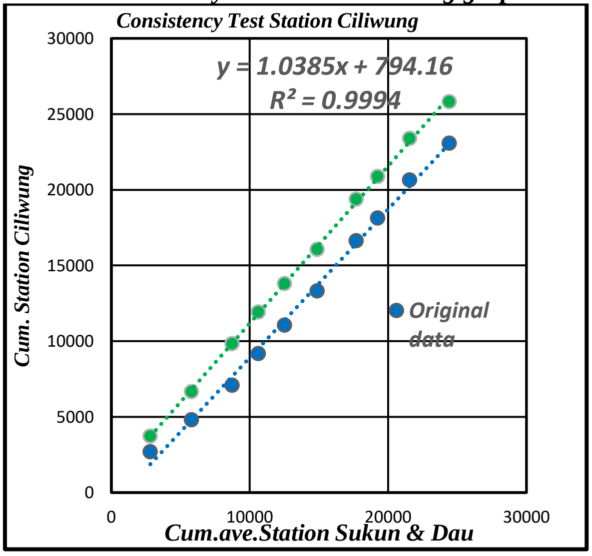
**Source: BMKG Malang**

### c. Consistency Test Analysis

The analysis results revealed that the analyzed rainfall data from station Ciliwung exhibited breaks in its slope, indicating inconsistencies. Therefore, a correction was necessary. This correction involved dividing M1 by M2.

F = M1/M2……. (9)
F = Correction factor
M1 = slope of consistency data = 1.02
M2 = slope of inconsistency data = 0.74
F = 1.02/0.74
F = 1.387

***Table 4 Consistency test station Ciliwung graph***




**Source: Calculation**

**d. Areal Rainfall**

To estimate the areal rainfall in Sukun district, an arithmetic mean method was used.

$d = \frac{dA+dB+dC}{3}$……. (10)

$d = \frac{82+40.24+59.74}{3} = 60.66$

***2022-11-28:*** $d = \frac{63+159.59+92.75}{3} = 104.95$

***2022-11-28:*** $d = \frac{63+159.59+92.75}{3} = 104.95$

The maximum average value is chosen among the three data sets and used for the design rainfall. (***Areal rainfall 2022 = 104.95***

**e. Design rainfall Distribution Analysis**

Log Pearson III distribution is typical probability distributions that was used in frequency analysis with 10 years return period 2013-2022.

***Table 5 Design rainfall Log Pearson III distribution***

| Year | Xi | Log Xi |
|---|---|---|
| 2022 | 104.95 | 2.021 |
| 2021 | 84.870 | 1.929 |
| 2020 | 83.667 | 1.923 |
| 2019 | 82.000 | 1.914 |
| 2018 | 73.333 | 1.865 |
| 2017 | 72.667 | 1.861 |
| 2016 | 68.333 | 1.835 |
| 2015 | 67.333 | 1.828 |
| 2014 | 65.606 | 1.817 |
| 2013 | 58.000 | 1.763 |
| Aver | 76.075 | 1.876 |

***Source: Calculation***

Based on the calculations that have been done, it is obtained that the value of standard deviation = 1.876, Cs = 0.57 and the value of Ck = 0.6 and the design rainfall (Xdesigned)= **93.827 mm/day.**

**f. Smirnov Kolmogorof Alignment Test**

With a value of N = 10 and ÿ = 5%, the value of Df = 41% obtained from the table. from the calculation results is 28.318% < Df, the distribution of the Log Pearson III method is acceptable.

**g. Drainage layout map**

Drainage layout relies on occurate contour interpolation which can help to determine the elevation, slopes and flow direction in the drainage channel

***Figure 2 drainage layout map***

**h. Chi-square Alignment Test**

The value of X²table is obtained based on the value of Df and the degree of confidence (ÿ) a = 5%; X²table value = 14.067. Because the X²caculation < X²table (-22.1<14.067) the distribution of the Log Pearson III method is acceptable

| No | Rain Data | Log data | Rain (theo) | $X^2$ |
|---|---|---|---|---|
| 1 | 104.9 | 2.0 | 100.0 | -10.1 |
| 2 | 65.6 | 1.8 | 83.7 | 0.0 |
| 3 | 84.9 | 1.9 | 80.5 | -3.0 |
| 4 | 83.7 | 1.9 | 71.5 | -2.4 |
| 5 | 58.0 | 1.8 | 72.5 | -1.7 |
| 6 | 82.0 | 1.9 | 71.0 | -3.4 |
| 7 | 67.3 | 1.8 | 68.5 | 0.3 |
| 8 | 73.3 | 1.9 | 67.0 | -0.7 |
| 9 | 68.3 | 1.8 | 65.0 | -1.2 |
| 10 | 72.7 | 1.9 | 58.0 | 0.0 |
| | | | | **-22.1** |

**i. Waste Water**

The daily quantity of dirty water per person = 300L (Residential areas with single houses).

b. population/house = $\frac{416}{251}$ =1.66 people/house.

Houses per channel = observation from the topographic map = 38(RT4C)
d. Population Per capital = 1.66 (people/house) × 38 (houses/channel) = 63
e. Qwaste = (68×300)/1000/ (24×60×60) = **0.000219** m$^3$/day

**j. Rainfall Intensity Analysis**

- R24: = 93.827 mm/day from (Log Pearson III calculation)
- t = 0.065 hours

$$I = \frac{R}{24}\left(\frac{24}{t_c}\right)^{2/3} mm/hour$$

$$I = \left(\frac{93.827}{24}\right) \times \frac{\left(\frac{24}{0.039}\right)^{2/3} mm}{hour}$$

I = 0.0000792 m/s

**k. Design discharge (Qp)**

- Area: 6941.429 m$^2$ (house) & 825.9565 m$^2$
- C: Runoff coefficient = 0.7 (road) and 0.4 (house)
- I = 0.0000792 m/s

- **Qrain (house)**
  Qrain = C x A x I
  Qrain = (0.4× 6941.429 × 0.0000792) (house)
  Qrain = 0.156 m$^3$/d

- **Qrain (road/See intensity calculation in table 37 below)**
  Qrain = C x A x I
  Qrain = (0.7× 825.9565 × 0.0000658)
  Qrain = 0.038 m$^3$/d
- After the calculation, the maximum design flood is 1.685 m$^3$/sec

**l. Existing Channel Dimensions**

To meet the required permitted speed of flow in the channel, it must fall within the range of 0.2 m/s to 3 m/s. The flow control in the channel also requires the Froude number (Fr) to be less than 1 (Fr<1). The existing discharge (Qe) must be greater than the design discharge (Qp).

The dimensions of channel RT4C, RT4F, RT4H, and RT4J cannot accommodate the planned discharge. Therefore, it is essential to re-design the channel dimensions to ensure it can handle the required flow capacity.

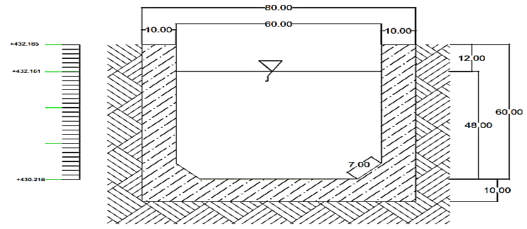



***Figure 3 Existing channel cross section***

**m. Redesign Channel Dimensions (example from RT4C)**

To meet the required permitted speed of flow in the channel, it must fall within the range of 0.2 m/s to 3 m/s. The flow control in the channel also requires the Froude number (Fr) to be less than 1 (Fr<1). The existing discharge (Qe) must be greater than the design discharge (Qp).

The drainage channels' capacity is greatly increased by the suggested redesign, which entails increasing the channel height in accordance with the amount of discharge each channel should be able to accommodate while maintaining a constant width due to space constraints. Because of the modified design, the channels can accommodate the anticipated amount of water without experiencing overflow.

***Table 6 Existing channels dimensions***

| Name | Qp | B | H | V | Qe | Qe | Fr | Control | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **channel** | (m3/s) | (m) | (m) | (m/s) | (m3/s) | | | V | Q | Fr |
| **RT1B L** | 0.011 | 0.3 | 0.5 | 1.99 | 0.3 | | 0.9 | ok | ok | ok |
| **RT1AL** | 0.05 | 0.4 | 0.6 | 1.89 | 0.42 | | 0.81 | ok | ok | ok |
| **RT1C L** | 0.041 | 0.4 | 0.6 | 2.15 | 0.47 | | 0.92 | ok | ok | ok |
| **RT1D L** | 0.059 | 0.4 | 0.7 | 2.08 | 0.54 | | 0.82 | ok | ok | ok |
| **CUL. A** | 0.103 | 0.6 | 0.7 | 1.55 | 0.6 | | 0.61 | ok | ok | ok |
| **RT1A** | 0.032 | 0.5 | 0.6 | 1.7 | 0.47 | | 0.73 | ok | ok | ok |
| **RT1B** | 0.164 | 0.5 | 0.42 | 1.39 | 0.29 | | 0.68 | ok | ok | ok |
| **RT1C** | 0.121 | 0.5 | 0.7 | 2.05 | 0.74 | | 0.77 | ok | ok | ok |
| **RT1D** | 0.252 | 0.7 | 0.8 | 1.63 | 0.89 | | 0.98 | ok | ok | ok |
| **CUL. B** | 0.42 | 0.7 | 0.7 | 1.52 | 0.69 | | 0.95 | ok | ok | ok |
| **RT2A** | 0.025 | 0.5 | 0.6 | 1.6 | 0.44 | | 0.69 | ok | ok | ok |
| **RT2B** | 0.126 | 0.5 | 0.6 | 1.84 | 0.57 | | 0.75 | ok | ok | ok |
| **RT2C** | 0.1 | 0.5 | 0.6 | 1.85 | 0.51 | | 0.8 | ok | ok | ok |
| **RT2D** | 0.561 | 0.7 | 0.8 | 2.39 | 1.31 | | 0.86 | ok | ok | ok |
| **CUL. C** | 0.69 | 0.7 | 0.7 | 1.66 | 0.76 | | 0.66 | ok | ok | ok |
| **RT3A** | 0.041 | 0.5 | 0.55 | 1.34 | 0.37 | | 0.58 | ok | ok | ok |
| **RT3B** | 0.141 | 0.5 | 0.6 | 2.47 | 0.74 | | 0.98 | ok | ok | ok |
| **RT3C** | 0.1 | 0.5 | 0.65 | 1.87 | 0.61 | | 0.74 | ok | ok | ok |
| **RT3D** | 0.829 | 0.7 | 0.84 | 2.62 | 1.54 | | 0.91 | ok | ok | ok |
| **CULVERT D** | 0.981 | 0.7 | 0.65 | 2.45 | 1.12 | | 0.97 | ok | ok | ok |

**Source: Calculation**

**Table 7 Redesign channels dimensions**

| Name | Qp | B | H | V | Q | Q | Fr | Fr | V |
|---|---|---|---|---|---|---|---|---|---|
| channel | (m3/s) | (m) | (m) | (m/s) | (m3/s) | | Control | | |
| RT4C | 0.406 | 0.6 | 0.6 | 2.41 | 0.868 | 0.99 | ok | ok | ok |
| RT4F | 0.158 | 0.3 | 0.8 | 0.65 | 0.159 | 0.23 | ok | ok | ok |
| RT4H | 0.226 | 0.3 | 0.9 | 0.83 | 0.226 | 0.28 | ok | ok | ok |
| RT4J | 1.263 | 0.8 | 1 | 1.56 | 1.27 | 0.49 | ok | ok | ok |

**Source: Calculation**

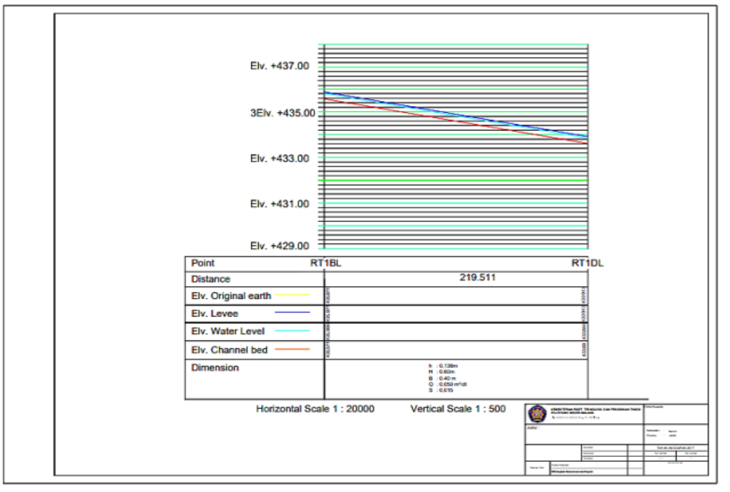



***Figure 4 Redesign channel long section***

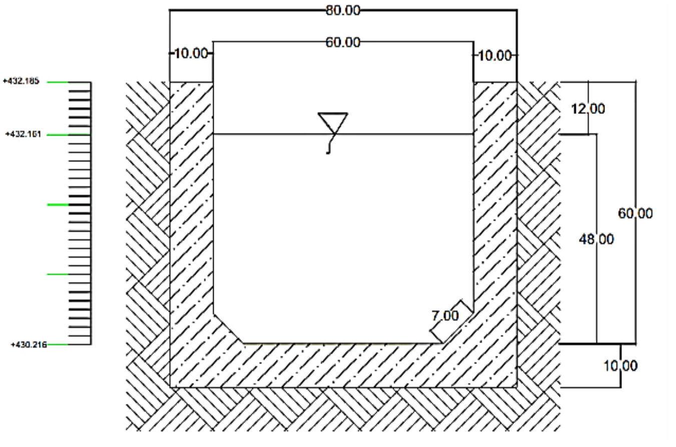



***Figure 5 Redesign channel cross section***

**n. Curb Inlet Dimension (example from RT4C - RT4J)**

- Width of inlet (B) = 0.4 m
- Half of road width = 5 m
- Qrain from road = 0.038 $m^3$/dt
- Height of inlet (L) = 0.2 m
- Road slop = 2% = 0.02
- Qi = 3.1 × B × L × h^0.5
  Qi = 3.1 × 0.4 × 0.2 × 0.1^0.5
  Qi = 0.0784 $m^3$/dt

- **Capacity control**
  Qroad = 0.038$m^3$/sec
  Q = Qi > Qroad
  Q = 0.0784 $m^3$/sec > 0.038 $m^3$/sec…**Ok!**

**o. Cost Budget Plan Analysis (RAB)**

The cost of redesigning the channel for Sukun's drainage system reconstruction has been calculated as follows:

- Cost of preparation work: 8,685,725.01 rupiah
- Cost of earthwork: 38,128,344.18 rupiah
- Cost of concrete work: 98,140,754.73 rupiah
- Cost of U-ditch and inlet: 135,494,938.00 rupiah

The total estimated cost for the reconstruction project is 280,450,000.00 rupiahs. This cost estimation takes into account various factors, such as materials, labor, equipment, and engineering services. It provides an approximate amount of money required for the successful completion of the drainage system reconstruction.

## 4. CONCLUSIONS AND SUGGESTIONs

### Conclusions

1. The maximum design discharge is 1.685 m3 / sec.
2. The existing channel capacity is 1.648 m3/sec, While the redesign channel capacity is 2.278 m3 /sec.
3. Rainfall Calculations and analysis is based on 10 years return period. PUH 10 = 93.827 mm/day.
4. The type of distribution used is the Log Pearson III distribution because it has the smallest (minimum) deviation and has fulfil both chi-square and Smirnova Kolmogorof test requirement.
5. The number of inlets needed for the redesign channels is 4 units.
6. The reconstruction of Sukun's drainage system is expected to cost 280,450,000.00 rupiahs.

### Suggestions

Some channels are joined to home walls. Even though they are not suffering flooding, this attachment has caused lower flow rates. This issue should be address by reconstructing the channels to separate them from the house walls and ensuring a uniform lining material.

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