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Drainage Channel Planning to Reduce Road Surface Runoff

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ABSTRACT

The road in Tapinalu - Ulatu hamlet is a road located in Luhu village. This road section connects the hamlets of Huamual behind. There are several points that already have drainage channels, while most points do not have drainage channels. This becomes a problem, over time there is a puddle of water on the road during high rainfall, it will be a factor that affects the road structure. The efforts made are by planning drainage channels. The research method used is the data collection and analysis method. The types of data in this study are primary and secondary data, then analyzed using the Log Person III method based on hydrological analysis and hydraulic analysis and planning based on the amount of existing channel discharge. Based on the calculation results for a 10-year return period, the planned rainfall is 326.587 mm, with a population growth percentage of 0.04% per year so that the population of Ulatu Hamlet in 2029 is 1,629 people. From the analysis results, the amount of runoff discharge (Qr) entering the drainage channel of the Tapinalu – Ulatu Hamlet Road Section is 0.089 $m^{3/}$second, and the drainage channel discharge (Qs) is 1.486 m^3/second. From the results of the channel dimension planning, the upper width is 58 cm, the base width of the channel is 40 cm, and the height of the channel is 74 cm.

1. INTRODUCTION

The road in Tapinalu - Ulatu hamlet is a road located in Luhu village, Huamual Belakang District, West Seram Regency, which is the location of a road construction project with a length of STA 03 + 100 Km, with a road width of 4.64 m. For the construction of new roads we need to see complementary road buildings, one of which is the drainage channel attached to attachment 5, there are several points that already have drainage channels, trapezoidal segments at STA 00 + 000 - 00 + 350 and at STA 01 + 850 with dimensions of channel cross-section width of 58 cm, channel base width of 40 cm, and channel height of 74 cm. While most points do not yet have a drainage channel system attached to attachment 1, attachment 2, attachment 3, and attachment 4. Changes in land use also cause a reduction in rainwater catchment areas. This triggers an increase in surface runoff discharge. This becomes a problem, because over time there is puddles of water on the road during high rainfall, which will become one of the factors that affect the road, such as damage to the road structure due to holding back excessive water runoff.

Efforts that can be made to overcome road surface runoff during high rainfall are by planning drainage channels in STA that do not yet have a drainage channel system. By using rainfall frequency analysis with the Normal Method, Log Normal, Log Person Type III Method, and Gumbel. To calculate the planned water channel discharge so that optimal dimensions can be obtained for drainage channel planning.

Figure 1. Does not have drainage channels yet

2. LITERATURE REVIEW

2.1 Definition of Drainage

According to Suripin (2004), drainage comes from English, namely drainage, which means flowing, draining, disposing of, or diverting water. In general, drainage can be defined as a technical action to reduce excess water, whether from rainwater, seepage, or excess irrigation water from an area or land, so that the function of the area or land is not disturbed.

Surface runoff is the ratio between surface flow and the volume of rainfall that falls. Factors that affect surface runoff are meteorological elements such as type of precipitation, rainfall intensity, and duration of rainfall (Nganrol Sudirman, 2019).

2.2 Purpose and Function of Drainage

Basically the purpose of drainage is to create a healthy and comfortable environment by controlling excess water in an area. With the existence of this drainage channel, among other things, to reduce excess water in an area or land, so that the land can function optimally, as a water / flood controller. (Suripin, 2004).

2.3 Types of Drainage

Drainage can generally be divided into several types;

2.3.1 Natural drainage is drainage that is formed naturally without any supporting buildings in it. This channel is formed from water erosion over time to form a permanent water channel like a river.

2.3.2 Open drainage is drainage used to channel rainwater in a wide area. Another function is as a medium to drain water that is not harmful to environmental sustainability.

2.3.3 Closed drainage is drainage that is made closed because it drains water containing hazardous waste, if not closed it will endanger public health and the surrounding environment. This drainage also functions as a channel in the city.

2.4 Hydrological Analysis

Hydrological analysis is the most influential factor in planning the size of the reservoir and drainage facilities. This is necessary to be able to overcome the surface flow that occurs so as not to cause puddles. The hydrological cycle is a continuous process in which water moves from the earth to the atmosphere and then back to the earth again. (Source: Bambang Triatmodjo, 2008)

2.5 Frequency Analysis

The purpose of hydrological data frequency analysis is related to the magnitude of extreme events related to their frequency of occurrence through the application of probability distributions. Frequency analysis of planned rainfall calculations can be calculated using various distributions such as the normal method, log normal, gumbel and log person type III.

2.5.1 Chi-square distribution test

Intended to determine whether the selected distribution equation represents the statistical distribution of the sample data being analyzed.

$$X^2 = \sum_{i=1}^{G} \frac{(O_i - E_i}{E_i} \quad (1)$$

2.6 Channel Dimension Calculation

2.6.1 Concentration Time (T)

The concentration time for open channels is calculated using the formula below:

$$Tc = t_1 + t_2 \quad (2)$$

$$t_1 = \left(\frac{2}{3} \; x \; 3{,}28 \; x \; L \; x \; \frac{nd}{\sqrt{s}}\right)^{0{,}167} \quad (3)$$

$$t_2 = \frac{L}{60 \; x \; V} \quad (4)$$

2.6.2 Maximum Rain Intensity

$$I = \frac{R_{24}}{24}\left(\frac{24}{T_c}\right)^{\frac{2}{3}} \quad (5)$$

2.6.3 Flow coefficient (C).

The flow coefficient (c) is influenced by the condition of the land surface (land use)

$$C = \frac{C1 \; x \; A1 + C2 \; x \; A2 + C3 \; x \; A3}{A1 + A2 + A3} \quad (6)$$

2.6.4 Channel roughness

To calculate the permissible slope of the channel base, use the formula:

$$\left[s = \frac{v.n}{R^{\frac{2}{3}}}\right]^2 \quad (7)$$

$$Q = A \; x \; V \quad (8)$$

2.6.5 In planning channel dimensions, efforts must be made to create economical channel dimensions.

$$Fd = \frac{Qr}{V} \quad (9)$$

$$A = d\,(b + md) \quad (10)$$

$$p = b + 2.d\sqrt{(m^2 + 1)} \quad (11)$$

$$R = \frac{A}{P} \quad (12)$$

2.7 Dirty Water Discharge Analysis

Dirty water discharge is discharge that comes from dirty water from households, buildings, installations, and so on. The need for clean water for the planning area is 135 liters/day/person. Household wastewater is calculated based on the provision of drinking water. It is estimated that the amount of wastewater entering the wastewater collection channel is 85% of the standard drinking water requirement.

2.7.1 Analyzing population growth rates

$$r = \frac{x_1 - x_0}{x_1} \quad (13)$$

2.7.2 Population Projection Using Geometric Methods

$$Pn = Po\,(1 + r)n \quad (14)$$

2.7.3 Dirty Water Discharge Analysis

$$q = 135 \; x \; 85\% = 114.75 \text{ lt/day/person} \quad (15)$$

$$Q = (Pn \,.\, q) / A \quad (16)$$

3. METHODOLOGY

3.1 Research Location

The research location is located on the Tapinalu - Ulatu hamlet road, Luhu Village, Huamual District, behind SBB Regency with a road length of STA 03+100

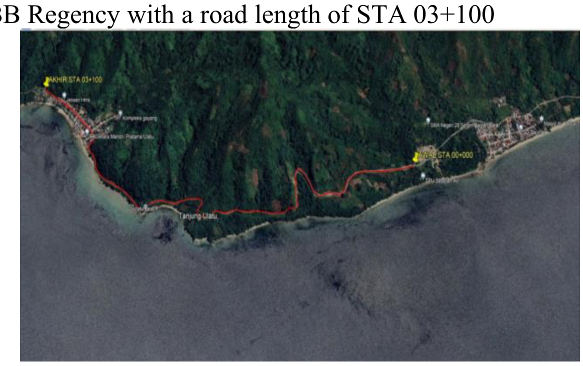

Figure 2. Research location

3.2 Data collection and analysis

Collection and processing of data obtained from field observations in the form of: (1) primary data: documentation, channel data, topographic maps and land use, (2) secondary data: 10 years of rainfall data and population data.

Data collection techniques are carried out using characteristic data collection techniques, namely through field observations at the research location, and library techniques, namely types of research with a series of activities related to library data collection methods. In this study, there is an analysis used to calculate water discharge, drainage channel planning, and population growth rates for household wastewater.

3.2.1 Dimensional channel planning using the method: Normal, log normal, log person type III, and gumbel.
3.2.2 Test the suitability of the selected distribution using: chi-square test distribution
3.2.3 Calculating the growth rate of the number of residents to household wastewater to drainage channel.

4. ANALYSIS AND DISCUSSION

4.1 Hydrological Analysis

Analysis of maximum rainfall against rainfall data for the last 10 years can be seen in the table below.

Table 1. Maximum Daily Rainfall Data

Year	Ch Maximum (Xi)
2014	73.4
2015	159.1
2016	384.1
2017	200.5
2018	261.0
2019	265.0
2020	230.0
2021	160.5
2022	110.0
2023	105.5

4.2 Frequency Analysis

By using maximum rainfall, frequency analysis is carried out to determine the possibility of rainfall with a return period value. By finding the average value, standard deviation, coefficient of variation, skewness coefficient, and kurtosis coefficient, then with the specified conditions, the method for determining the return period value is the log person III method.

Table 2. Design rainfall using Log Person III distribution

When to repeat (Xr)	Average (x)	Standard Deviation (S)	The tilt	Mark	Planned rainfall	
Year	Log	S	CS	K	Log	Mm
2	2,243	0.216	-0.263	0.033	2,250	177,827
5	2,243	0.216	-0.263	0.850	2,426	266,685
10	2,243	0.216	-0.263	1,258	2,514	326,587
25	2,243	0.216	-0.263	1,680	2,605	402,717
50	2,243	0.216	-0.263	1,945	2,663	460,256
100	2,243	0.216	-0.263	2,178	2,713	516,416

4.3 Distribution suitability test

The distribution suitability test used is Chi-square. The chi-square test is intended to determine whether the selected distribution equation can represent the statistical distribution of the analyzed data sample.

Table 3. Recapitulation of X^2 and X^2cr values

Distribution	X^2	X^2 cr	Information
Pearson Log Type III	5	5,991	Accepted

4.4 Analyzing Channel Dimensions

4.4.1 Concentration Time (Tc) Calculation

Drainage planning area at STA point 01 + 550 – 01 + 750

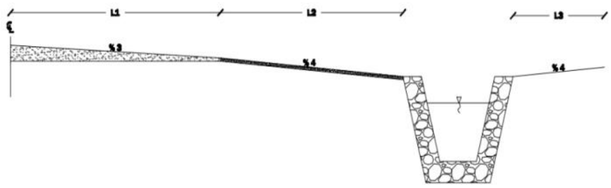

Figure 3. Watershed area Around the road and its boundaries

Concentration Time T_C

$$T_C = t_1 + t_2$$
$$= 3{,}740 + 2.2$$
$$= 5.94 \text{ minutes}$$
$$= 0.099 \text{ hours}$$

Maximum Rain Intensity

$$I = \frac{R_{24}}{24}\left(\frac{24}{T_C}\right)^{\frac{2}{3}}$$
$$= \frac{326{,}587}{24}\left(\frac{24}{0{,}099}\right)^{\frac{2}{3}}$$
$$= 529{,}060 \text{ mm/hr}$$

4.4.2 Channel Discharge Calculation

Area of drainage area (A)

A total = A1 + A2 + A3
= 460 + 400 + 400
= 1260 m^2 = 0.0012 km^2

Calculating the Flow Coefficient (C) Value

$$C = \frac{C1\ x\ A1 + C2\ x\ A2 + C3\ x\ A3}{A1 + A2 + A3}$$
$$C = \frac{(0{,}70\ x\ 460) + (0{,}10\ x\ 400) + (0{,}70\ x\ 400)}{460 + 400 + 400} = 0.509$$

Planned Debit Calculation

Qr = 0.2785 x C x I x A
= 0.2785 x 0.509 x 529.060 x 0.0012
= 0.089 m^3/second

4.4.3 Channel Dimensions

The planned channel is trapezoidal in shape with stone masonry.

Economical wet cross-sectional area

$$Fd = \frac{Qr}{V} = \frac{0{,}089}{1{,}50} = 0{,}059 \text{ m}^2$$

Wet cross-sectional area

A = d (b + m.d)
= 0.74 (0.40 + 0.20 x 0.74) = 0.405 m^2

Wet around

$P = b + 2.d\sqrt{(m^2+1)}$

$= 0.40 + 2 \,.\, 0.74\sqrt{(0{,}20^2+1)}$

$= 1{,}909\ m^2$

Hydraulic spokes

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

$= \frac{0{,}405}{1{,}909}$

$= 0.212\ m$

To calculate the permitted slope of the channel base, use

$S = \left[\frac{V \,.\, n}{R^{\frac{2}{3}}}\right]^2$; Value n = taken 0.020 stone pairs

$= \left[\frac{1{,}50 \times 0{,}020}{0{,}519^{\frac{2}{3}}}\right]^2 = 0.002\%$

Control :

$Q_S \geq Q_r$

It is known that the value of Q_r = 0.089 m^3/second

$Q_S = A \times V$

$= 0.405 \times 1.50$

$= 0.607\ m^3$/second

Q_S = 0.607 m^3/second Q_r = 0.089 m^3/second……… ok

The results of the planning of the dimensions of the drainage channels on the Tapinalu – Ulatu hamlet road section can be seen in the picture.

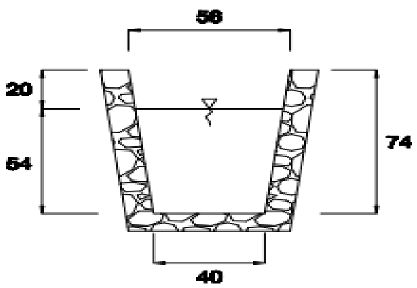

Figure 4. Dimensions of the Tapinalu – Ulatu hamlet road channel

4.5 Dirty Water Discharge Analysis

Table 4. Population data of Ulatu hamlet

Ulatu Hamlet	
Year	Population of Catfish
2020	1.288
2021	1.298
2022	1.315
2023	1,329
2024	1,339
Amount	6,569

Population Growth Rate (r) from 2020 – 2024

$r = \frac{x_1 - x_o}{x_1}$

$r = \frac{1.339 - 1.288}{1.339} = 0{,}04\%$ Per year

From the annual percentage, the population for the next 5 years can be calculated as:

$Pn = Po\,(1 + r)^n$

5 year population (0.04%) = $1{,}339\,(1+0.04)^5$

= 1,629 souls

Table 5. Population projection analysis calculation

Population Growth Rate	Total population	
	2024	2029
0.04%	1,339	1,629

The population projection of the Geometry method 5 years later is 1,629 people, the wastewater of the population is calculated based on the water needs of each person per day taken as 135 liters/hr/person. The amount of dirty water wasted is 85% of the clean water needs.

q = 135 x 0.85 = 114.75 lt/day/person

$q = \frac{114.75/1000}{24} = 0{,}004$ m^3/hour/person

Calculation of dirty water discharge in drainage channels:

Qab = (Pn . q) / A

$Qab = \frac{1.629 \,.\, 0{,}004}{2.334}$

$= \frac{6{,}516\ m^3/jam}{2.334} = 0.002$ m^3/hour/ha

5 Conclusion

Based on the calculation results and discussion of the drainage channel planning for the Tapinalu - Ulatu hamlet road section, it can be concluded as follows: The runoff water discharge is obtained at 0.089 m^3/second, with the results of the drainage channel planning analysis being a channel peak width of 58 cm, a channel base width of 40 cm, and a channel height of 74 cm, and the population growth rate for household wastewater into the drainage channel, namely for a population growth rate (r) of 0.04% of percent per year, then the population projection for the next 5 years is 1,629 people.

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NOMENCLATURE

X^2	Chi – Square Value
I	Maximum Rain Intensity (mm/hr)
R_{24}	Maximum daily rainfall occurring in 24 hours
Tc	Concentration Time (hours)
t_1	Time to reach the start of the channel from the furthest point (minutes)
t_2	Flow time in a channel of length L from the end of the channel (minutes)
A_{Total}	Area of drainage area (km^2)
C	Flow coefficient
Qr	Debit Plan (m^3/second)
Fd	Economical wet cross-sectional area (m$^{2)}$
A	Wet cross-sectional area (m^2)
P	Wet around (m^2)
R	Hydraulic spokes (m)
S	To calculate the permitted slope of the channel base (%)
V	Average water velocity in the drainage channel (m/s)
Qs	Channel Debit (m^3/second)
Q	Gross Water Discharge (m^3/sec/ha)
Pn	Population (people)
q	Amount of dirty water needed (m^3/sec/person)
A	Settlement Area (ha)
r	Population growth rate (%)
x_0	Population of the year before year n (people)
x_1	Population in year n (people)