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ANALYSIS OF THE CARRYING CAPACITY OF URBAN DRAINAGE DIMENSIONS

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ABSTRACT

The rain that fell in the city of Cirebon, especially the drainage on Jalan Pemuda, could not accommodate and drain the water so that it could create puddles on the roads and surrounding areas. Hourly rain intensity, planned flow rate and channel cross-sectional dimensions are the first steps for flood prevention. Hydrological analysis is used to calculate the discharge capacity of the drainage plan. The results were then analyzed the dimensions of the channel, the drainage ability to accommodate the falling rainwater where $Qs \geq Qp$. the channel discharge has not been able to accommodate the Q plan in the channel so that there will be a runoff of 17.759%. So to anticipate runoff, it is necessary to have a channel improvement plan of 33.477%. In addition to channel improvement solutions, arrange and define the boundaries of water storage areas by measuring and mapping boundaries and issuing regulations that prohibit or limit the construction of buildings that can reduce the ability of areas to store and absorb rainwater by referring to the basic building coefficient (KDB) permitted as stated in the RT/RW.

Keyword: *channel dimensions, discharge, rain intensity.*

I. INTRODUCTION

1.1. Background

Drainage is defined as facilities and infrastructure built to drain rainwater and domestic waste from one place to another in an area. Excess water can be caused by high rain intensity or due to long duration of rain, as well as due to overflowing of rivers and drainage channels. The rain that fell for an hour in Cirebon City, especially on Jalan Pemuda and Terusan Pemuda, Cirebon City, could cause flooding, other flood-prone points besides the youth road were Cipto Mangun Kusumo, Perumnas and Sudarsono roads. One of the causes of inundation at a number of points when it rains is because the urban drainage system is clogged by the large amount of garbage in the culverts and between the youth road and the youth pass is separated by the Pantura road, causing puddles when heavy rains.

Evaluation of the dimensions of drainage channels and improvement of water infiltration is needed to minimize the occurrence of high amounts of inundation. Basically, before water empties into rivers, it enters through drainage flows and enters tertiary reservoirs, secondary reservoirs, primary reservoirs and into urban or river drainages, this will also be evaluated in flood management on Jalan Pemuda and Jalan Terusan Pemuda.

In addition to the problems above, several things were found, including the narrowing in Jalan Pemuda and the narrowing due to a number of utilities or various objects along the sewer. Starting from the stretch of cable to building materials that ultimately inhibit the passage of water to the drain.

1.2. Problems

Based on the description of the background of the problem above, the problems in this study can be formulated, namely: How to manage drainage network infrastructure in Cirebon City, how to solve flood management on Jalan Jemuda and Jalan Jerusan Jemuda.

1.3. Purpose

This research or study has the following objectives:
1. Identify the existing condition of the drainage system at Jalan Jemuda, Cirebon City.
2. To find out how to manage the drainage system and get solutions to problems related to the drainage system in several areas of Jalan Pemuda.

1.4. Study Limitation

This research is limited to the management of the existing drainage system which is located in Jalan Pemuda Kota Cirebon

II. LITERATURE REVIEW

2.1. Rain Intensity

The distribution of regional rainfall is the rainfall that is estimated to be evenly distributed in the affected areas, also known as evenly distributed rainfall, which is estimated using rainfall observation data from several stations in the region.

The intensity of rainfall for a short period of time (usually within 2 hours) is converted into the intensity of rainfall per hour and is called the intensity of rainfall. The calculated discharge volume is based on a rational formula using this rainfall intensity.

Frequency analysis is an analysis of the recurrence of an event, both the number of times per unit frequency and the return period.

To analyze the planned rainfall, existing hydrological data from an event, consists of several theories that suggest equations about the analysis. Theories that propose the equations for the distribution of planned rainfall in technical planning include: Gumbel Method, Haspers Method, Iwai Kodoya Method, Weduwen Method, and Log Pearson Type III Method.

2.1.1. Concentration Time (Tc)

Concentration time is the time required for the gathering of all rainwater flows that fall over a certain area which gives the maximum flow to the ditch at each point according to the area of the drainage area. The amount of concentration time is calculated by the formula:

$$tc = to + td \text{ (minutes)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where:
to = water flow time to the ground surface can be analyzed with pictures.

td = flow time on the channel, the amount can be analyzed by the formula:

td = L/V ………………………………..……[2]

where:

L = flow distance from the point of entry of water to the destination (m)

V = flow rate (m/s)

2.1.2. Coefficient of Flow (C)

When it rains, generally some of the rainwater will become runoff and some will experience infiltration and evaporation. The share of rain that flows above the ground surface and when thereafter constitutes runoff. The amount of the flow coefficient for the planning area is adjusted to the characteristics of the drainage area obtained by the land use contained in the drainage area.

2.1.3. Coefficient of Storage (Cs)

The coefficient of storage of the channel probability to the peak of the flood is directly proportional to the flow. The storage effect of the channel's chances of the flood peak is greater the larger the area of the drainage becomes. The effect of storage on maximum flooding is calculated using the coefficient of storage (Cs) with the following formula:

Cs = 2tc/(2tc +td) ….....……………………..… [3]

where :

Cs = coefficient of storage

tc = the length of time to concentrate

td = time taken for water to flow to the measured place (minutes)

2.2. Discharge Analysis

To plan a sewer channel, what needs to be considered is the highest flood discharge to be channeled or discharged through the channels to be planned. To calculate the maximum flood discharge in the channel planning, a modified rational formula will be used.

2.2.1. Discharge Channel

The discharge discharge for a drain is calculated using the general formula, namely:

Q = 0.278. C. Cs. I. A ……………………….… [4]

where:

Q = flood discharge (m3/dtk)

0,278 = constants used if the area unit uses Km2

C = flow coefficient ($0 \leq C \leq 1$)

Cs = storage coefficient

I = rainfall intensity (mm/jam)

A = the area where the water is discharged (Km2)

2.2.2. Channel Dimension

The channel shape used in the exhaust channel in Kuo is a trapezoidal section, where the channel capacity is determined by the area of the irrigated area. In general, the bottom width of the channel (b) is taken to be greater than or equal to that of the channel (h), with the intention of preventing silting of the channel when the water is channeled. In this plan, a trapezoidal type of open channel is used. Flow velocity (V) can be calculated using the Manning formula, namely:

V = 1/n . R 2/3 . S ½ …....……………..… [5]

where:

V = Flow velocity (m / s)

R = Finger - Hydraulic finger (m)

A = wet cross-sectional area (m2)

P = wet circumference (m)

n = Manning's roughness coefficient

S = slope of the channel base

b = Channel width (m)

m = slope of the talud (1 vertical : m horizontal)

h = water height (m)

2.2.2.1. Drain Capacity

Calculation of channel capacity can be estimated by the amount of runoff on a land or by planning discharge. The design speed of the flow can be seen from the type of material available on the land as shown in the table below.

2.2.2.2. Channel Slope (S)

The slope of the canal bed is generally determined by the soil topography or the high elevation and end of the channel desired. The slope of the channel base depends on the channel forming material. The formula used to calculate the slope of the channel is Robert Manning's formula, namely:

S = (Q / (AR)2/3)2 …………………………..… [6]

Continuity formula:

Q = A . V …………………………………...… [7]

where:
A = wet cross-sectional area (m2)
V = flow velocity in channel (m/s)
R = hydraulic radius of channel (m)
M = talud slope
N = Manning's roughness coefficient (see table 3.5)
H = water level in the channel (m)
S = slope of the channel base
Q = flow rate (m3 /s)

2.2.2.3. Guard Height

Guard height is the vertical distance from the top of the embankment to the water level under the planning conditions. The guard height at the discharge channel is planned to be able to avoid runoff, at the highest possible surface elevation of the water flow, plus the height of the waves and the possibility of floating objects present in the flow. The height of the guard varies according to the size and location of the canal, the type of soil, the amount of water entering due to rain and the rise in the water level due to the control structure. The formula used to obtain guard height is:

$$w = (c \cdot h)^{0.5} \quad \ldots\ldots [8]$$

for Q < 0,8 m3/s ; c = 0,14
0,8 m3/dtk ≤ Q ≤ 8 m3/s ; c = 0,14 – 0,23
Q ≥ 8 m3/s ; c = 0,23

Or you can also use this formula:

$$w = 0{,}25\ h + 0{,}3 \quad \ldots\ldots [9]$$

where :
w = guard height (m)
h = water level in the channel (m)
c = the coefficient which depends on the discharge

2.2.2.4. Hydraulic Radius

The hydraulic radius is the ratio between the wet catchment area of the channel and the circumference of the channel. The formula used is:

$$R = A/P \quad \ldots\ldots [10]$$

where:
R = hydraulic radius (m)
A = wet cross-sectional area (m2)
P = wet roving channel (m)

III. METHODOLOGY

3.1. Data Collection

This stage is the stage of collecting data related to drainage in the area of Jalan Pemuda and Jalan Terusan Pemuda in Cirebon City. The data collection method used is in the form of data collection by:

1. Primary data collection The primary data collection method is the method used to obtain data directly from the source under study. Examples of primary data are: Measurement of dimensions of drainage channels and photo of drainage dimensions.
2. Secondary data measurement The secondary data collection method is a method used to obtain data from other sources related to the research material and is not a direct result of the researcher himself. Examples of secondary data are:
   a. Rainfall data (short term) for 10 years, starting from 2008 to 2018 Cirebon City.
   b. Cirebon City Administration Map.
   c. Topographic maps.

3.2. Data Processing and Analysis

After all the necessary data have been collected, analysis can be carried out. The rainfall obtained is analyzed using frequency analysis to get a suitable distribution, the frequency analysis used is the Normal Distribution method, Normal Log Distribution, Log Person III, Gumbel method. After obtaining a suitable distribution, the next step is to test the distribution compatibility, which in this study used the Smirnov-Kolmogorov test. The next step is to determine the intensity of rain, so the equations that can be used are the Talbot, Sherman, Ishiguro equations. The result of this equation shows the IDF curve. Then the next stage is to determine the flood discharge plan, the method used is the Rational method. In this method, runoff coefficient values, rainfall intensity, and rain catchment area are required. After the discharge data is obtained, the next step is to look for the dimensions of the drainage channel, to find the dimensions of the drainage channel, the discharge data, the Manning roughness coefficient, and the slope of the channel bed are needed. Calculating the discharge of existing drainage channels. Analyze whether the capacity of the drainage channel is sufficient to accommodate the planned discharge or not. If not, it is necessary to plan a new drainage channel.

IV. RESULT AND DISCUSSION

4.1. Drainage Channel Layout

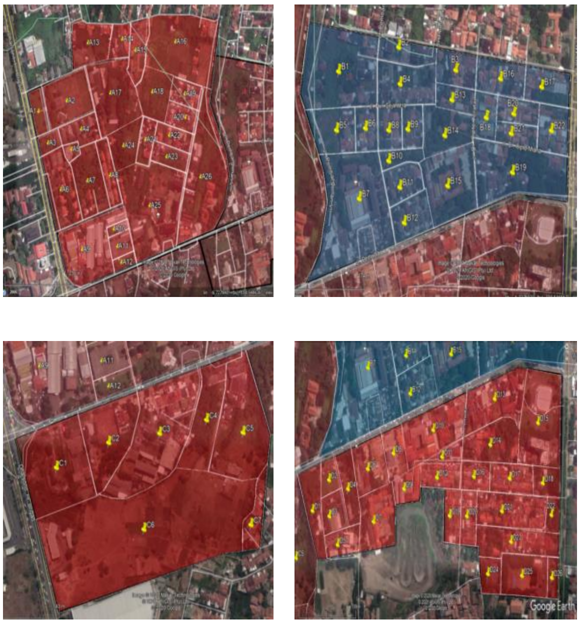

Figure 4.1 Zoning

4.2. Rainfall Calculation

Based on the results of the rainfall analysis carried out by the normal method and using data sourced from the Meteorological Station, the maximum daily rainfall is obtained in Cirebon City.

Table 4.1 Rainfall Recapitulation

NO	Return Period	RAINFALL (mm) METHOD				TAKEN MAX
		GUMBEL	HASPER	IWAI	LOG PERSON	
1	2	104.174	99.887	105.192	107.118	105.192
2	5	131.265	128.671	124.925	125.324	131.265
3	10	149.199	149.423	136.721	135.142	149.423
4	15	157.689	152.435	143.006	138.809	157.689

4.3. Rainfall Intencity Plan

Table 4.2 Rainfall Intensity

t	Rainfall Intensity (mm/h)			
(minute)	I_2	I_5	I_{10}	I_{15}
5	191.147	238.524	271.519	286.539
10	120.415	150.261	171.046	180.508
15	91.894	114.670	130.533	137.754
20	75.857	94.658	107.752	113.713
25	65.371	81.574	92.858	97.995
30	57.889	72.238	82.230	86.779
35	52.236	65.183	74.200	78.304
40	47.787	59.631	67.880	71.635
45	44.178	55.128	62.754	66.225
50	41.181	51.388	58.497	61.733
55	38.646	48.225	54.896	57.933
60	36.468	45.507	51.802	54.668
65	34.573	43.142	49.110	51.827
70	32.906	41.063	46.743	49.329
75	31.427	39.217	44.642	47.111
80	30.104	37.565	42.762	45.127
85	28.911	36.077	41.068	43.340
90	27.830	34.728	39.532	41.719

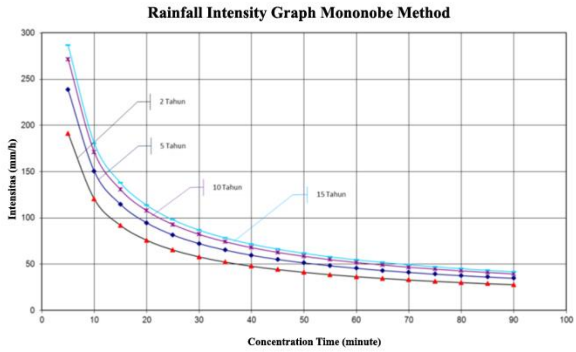

Figure 4.2 Rainfall Intensity Graph

4.2. Drainage Calculation and Planning

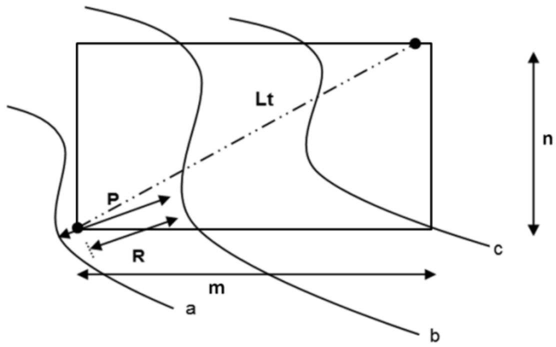

Figure 4.3. Determination of Eevation, Farthest Land Length, and land slope

Calculation of the initial and final elevations

R/P=X/r

P = distance of the area to the next line (m)
R = Distance between contours (m)
R = The interval between contours that delimits the point

4.2.1. Analysis of Q plans and Q channels

The results of the analysis on the drainage system of the study area showed that the problem of flooding and inundation still occurred around Jalan Pemuda. Changes in land use, growth in built-up areas, reduction of infiltration areas, changes in catchments and rivers and climate change are contributing to increased strength of floods and inundation.

4.2.2. Hydrological Analysis

In planning the drainage, a hydrological study is needed to determine the amount of flow that will be flowed by the drainage channel. The drainage discharge comes from rainfall which becomes surface runoff. The rainfall used to determine the amount of flowrate is the planned rainfall or maximum daily rainfall with a certain return period. Furthermore, the planned rainfall is used to calculate the rain intensity. From the calculated data, the results are shown in the hydrological analysis table and channel hydraulics.

Table 4.3. Hydrological Analysis and Channel Hydraulics

No	Parameter	%
1	Q Plan Mean	53.047
2	Q Channel Mean	35.288
3	Q Plan and Q Channel Difference	17.759
4	Channel Repair Plan	33.477

The process of flooding or inundation is generally preceded by surface runoff after rain. Therefore, the main priority for flood and inundation control activities is aimed at managing surface runoff. From the results obtained, it can be concluded that the average Q plan with a weight of 53,047% has a weight greater than the average Q channel of 35,288%, this means that if the rain comes, the channel discharge cannot accommodate the Q plan in the channel so that runoff will occur. 17.759%. So to anticipate runoff, a channel improvement plan of 33.477% is needed

4.2.3. Land Use

In addition to considering hydrological aspects, the planning for infiltration/water storage will also consider land use. So that the location and form of water infiltration/storage area can be in line with the area planning plan. The design of infiltration/water storage areas will be made as part of the planning of parks, road shoulders, building yards or shops and other green open spaces. If the infiltration/water storage area is to be made part of the housing, the design does not have to reduce the aesthetic value and utilization of the area. Adding and managing green open spaces can be aligned with flood and inundation management plans. So that efforts to create a water infiltration/storage area can be carried out without encountering obstacles in providing the land.

Apart from needing to increase its area, the existing green open space needs to be maintained in function and area. Apart from maintaining its function and area, what is no less important is to ensure that no buildings are made in areas with the status of green open spaces or harden the soil surface (for example with concrete or asphalt) excessively. So that the function of green open space as a place for water absorption/storage can be maintained.

Based on table 4.9. above, besides repairing the drainage channel, there are also actions that need to be taken to prevent flooding and inundation, namely by:

1. Prevent closure of drainage channels and construction over drianage channels.
2. Prevent the act of throwing garbage into the drainage channel.
3. Enforce land use regulations in accordance with land use directions in the RT/RW.

Apart from these actions, flooding and inundation can also be managed by making efforts related to the process of flooding and inundation. Efforts to address the problem of flooding and inundation can be in the form of structural and non-structural.

Table 4.4. presents the forms of structural and non-structural measures to overcome flooding and inundation based on the process of flooding and inundation.

Table 4.4 Efforts to overcome flooding/inundation

Process	Purposes	Structural	Non-Structtural
Surface runoff	Slows down surface runoff into channels and rivers	- Rainwater collection - Infiltration/retention area	- Conservation of land land use regulation
Floods and puddles	Prevent flooding and inundation	- Increase channel capacity - Repair of river flow - Construction of flood evasion channels - Flood embankment	- Adaptation to flooding - Regional setting - Conservation of rivers, channels and their catchment areas
	Reducing the volume of flooding and inundation	- Increase channel capacity - Water pump	- Conservation of rivers, channels and catchments

4.2.4. Water Storage Area

On site storage is developed to store rainwater that falls in the area itself (local rain) which cannot be discharged directly into the channel because the channel is unable or because of the influence of return water. Storage facilities do not have to be buildings or special land, but can also take advantage of existing open spaces such as city parks, sports fields or parking lots. Municipal parks, sports fields and parking lots can also serve as infiltration facilities. The infiltration facility can also take advantage of the shoulder of the road, the yard of the building / building and the yard of the house.

Provision of water storage areas is carried out in the following manner:

1. Designating an area that will be used as water storage, for example a park or a riverbank area.
2. To organize and define the boundaries of water storage areas by measuring and mapping boundaries in the field.
3. Issue regulations that prohibit or limit the construction of buildings that can reduce the ability of areas to store and absorb rainwater by referring to the provisions regarding the permissible basic building coefficient (KDB) as contained in the RT/RW.

Meanwhile, additional efforts that can be made to remove inundation are:

1. Widen the channel. It is quite difficult to widen the channel because most of the land to the left and right of the channel in all zones is already filled with buildings.
2. Adding depth. Adding depth must be done carefully with high groundwater levels and low ground elevations.
3. Break up of the catchment zone to reduce drainage load. This can be done by making a secondary channel or an interceptor channel. Secondary channels and interceptors can also function as long storage to accommodate the drainage load at high tide, when the water in the primary channel cannot flow.

The analysis showed that inundation occurred in all zones with different depths. Meanwhile, additional efforts that can be made to remove inundation are:

1. Widen the channel. It is quite difficult to widen the channel because most of the land to the left and right of the channel in all zones is already filled with buildings.
2. Increase the depth of the channel according to the elevation of each zone.
3. Break up of the catchment zone to reduce drainage load. This can be done by creating a secondary channel or an interceptor channel. Secondary channels and interceptors can also function as long storage to accommodate loads when water in the primary channel cannot flow.

Apart from the efforts that have been described, various other efforts also need to be made to overcome the problem of flooding and inundation by taking into account the physical, social and economic conditions of Pemangkat City. The proposed inundation and flood countermeasures are as follows:

1. Improve the ability of the drainage system to channel and store runoff from rain. For example, by maintaining existing drainage channels, caring for rivers and natural channels and building additional drainage channels.
2. Developing structural businesses other than canals, especially by building runoff retaining facilities in the form of water storage areas.
3. Infiltration wells and infiltration areas.
4. Issue local regulations to:
    a. prevent narrowing and closure of ditches or drainage channels
    b. river/ditch/canal boundaries
    c. size of ditches, bridges and water structures.
5. Developing non-structural business in the form of land use regulation, area use/development regulation, preservation of water catchment areas and preparing water storage areas.
6. Require the construction of housing, offices or shops to provide water storage and micro drainage systems in the area to be developed.
7. Improve urban waste management and hygiene campaigns to eliminate the habit of disposing of garbage in rivers and canals.
8. Separating rainwater drainage channels and sewage channels.

Apart from adding to the efforts described previously, the Pemangkat City drainage master plan also needs to integrate the inundation control concept proposed by the Cirebon City BAPPEDA in the RT/RW of Cirebon City, namely:

1. Demolishing the building above the channel.
2. Normalization of channels.
3. Dredging channels.
4. Control over the development of built-up areas, especially in areas that function as water catchment/storage areas.
5. Controlling building density.
6. Applying the basic building coefficient (KDB) rule to ensure the availability of water catchment areas. The KDB rules used are as follows:
    a. For a residential environment:
    - Environments with high density KDB 70 - 80%.
    - Environments with medium density KDB 50 - 70%.

- Environments with low density KDB 40 - 50%.
- Environments with very low density KDB <40%.

b. For areas other than residential:
- City center area, commercial area KDB 30%.
- 50% KDB health, arts, culture, recreation facilities.
- 60% KDB education, office and worship facilities.
- 50% KDB terminals, gas stations, power plants, industries and warehouses.
- Sports facilities KDB 40%.
- Green lane and KDB conservation 0 - 20% (only complementary buildings are allowed).

V. CONCLUSION

5.1. Hydrological Analysis

The process of flooding or inundation begins with surface runoff after rain. Therefore, the main priority for flood and inundation control activities is aimed at managing surface runoff. From the results obtained, it can be concluded that the average Q plan with a weight of 53,047% has a weight greater than the average Q channel of 35,288%, this means that if the rain comes, the channel discharge cannot accommodate the Q plan in the channel so that runoff will occur. 17.759%. So to anticipate runoff, a channel improvement plan of 33.477% is needed.

5.2. Land Use

Adding and managing green open spaces can be aligned with flood and inundation management plans. So that efforts to create a water infiltration/storage area can be carried out without encountering obstacles in providing the land.

5.3. Water Storage Area

The provision of water storage areas is carried out by means of a, determining an area to be used as water storage, for example a park or a riverbank area. b, arranging and determining the boundaries of water storage areas by measuring and mapping boundaries in the field. c, issuing regulations prohibiting or limiting the construction of buildings that can reduce the ability of areas to store and absorb rainwater by referring to the provisions regarding the Basic Building Coefficient which is permitted as contained in the RT/RW.

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