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EVALUATION OF DRAINAGE CHANNELS ON RESIDENTIAL AREA

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Abstract

The incompatibility of construction of urban or residential drainage channels with design criteria is often found due to difficulties in designing drainage channels. designers often make design mistakes when designing drainage channels. This study aims to evaluate the drainage system and designs a drainage channel that can collect runoff discharge on Residential Area in Bekasi, Indonesia. The results of flood discharge obtained using the Gumbel method for the 10 and 25 year return periods are 298.78 mm and 370.38 mm. From the calculation of the channel capacity in the field and the discharge plan most of the existing channel capacity cannot accommodate the current planned discharge of 2.261 m^3s^{-1} for the primary channel and 1.824 m^3s^{-1} for the secondary channel. The current channel cannot accept runoff discharge during rain, so the channel rehabilitation plan is carried out by expanding and extracting the dimensions of the drainage channel.

Keywords: drainage system, floods, residential drainage system, run off

1 Introduction

The drainage channel is a channel that serves to collect the flow and flow of rainwater and domestic liquid waste. The drainage channel capacity will determine the volume of water that can be collected and distributed to the drainage or water collection (Dewi Sartika T, Prastowo, & Pandjaitan, 2016; D. Sartika, 2016; T. D. Sartika, Prastowo, Pandjaitan, & Sitorus, 2017). If there is high rainfall, there will be water overflow. According to Lubis (Lubis, 2012) water flooding that occurs in a specific area shows that the standard capacity of the drainage canal has reduced due to several factors.

Factors that can cause a decrease in the drainage capacity includes maximum rainfall intensity, catchment area, and runoff coefficient. According to Kodoatie and Sugiyanto (Kodoatie, 2002), water discharge has not been a problem if it does not interfere with activities and it causes harm to human life. But if it has created a loss, then this problem must be addressed immediately. Therefore, planning a drainage system, especially in a residential area, needs to be given necessary attention, one of which is to deal with the occurrence of rainwater inundation.

Acceleration of development in urban areas will cause the water catchment area to decrease which will increase runoff discharge. The runoff would be a disaster if it balanced with the construction of proper drainage channels. From this condition, it is necessary to evaluate the drainage system and design drainage lines that can accommodate runoff discharge.

2 Methodology

2.1 Data collection

The method of data collection consists of collecting data relating to the planning of drainage channels, namely: field observations, measurements, interviews, and data collection. The data needed is a maximum 10-year daily rainfall data from BMKG, hydraulic drainage design factor data, and drainage network data. Data for hydraulic drainage design factors are flow velocity, slope, roughness, flow depth, and size of the cross-section of the drainage channel. This data is obtained through primary data collection or in measurements and field observations. Data on drainage network obtained by plotting the data in the field, topography and land use.

2.2 Data Analysis

The initial stage of the research was carried out in the field of observation and tracking of channels in the pattern of drainage networks and measuring the dimensions of drainage channels (length, width, depth, slope, and embankment). From this data, network drainage networks based on measurements (length, depth, width and slope of the channel), topographic maps and planned housing locations are carried out using the Sketch Up 8 and ArcView programs.

Before analysis of runoff discharge, it is known first when the concentration of rain then analyzed the intensity of rainfall using 10-year daily rainfall data using the Mononobe method. The maximum runoff discharge is obtained using the Rational method. From (Suripin, 2004), this method ware used limited to a relatively small watershed, which is a maximum of 300 ha. The feasibility of drainage channels will be evaluated using standard channel design criteria.

3 Results and Discussion

3.1 Characteristics of Research

The residential area is locate in Kaliabang Tengah, North Bekasi Regency which is between 6˚10'21,96" to 6˚10'29,47" South Latitude and 107.1'18,54" to 107˚1'25,37" East longitude. The area of the residential area is 3.39 ha which consists of rainwater catchment areas, buildings, and roads. 499 housing units in this cluster will be built by local developers, where the completed house is 235 units. The research location is at 5-9 m above sea level and slopes 0-2%. From the search results with the help of a location plan map, the traces of the drainage channel and the direction of the flow shown in Figure 1.

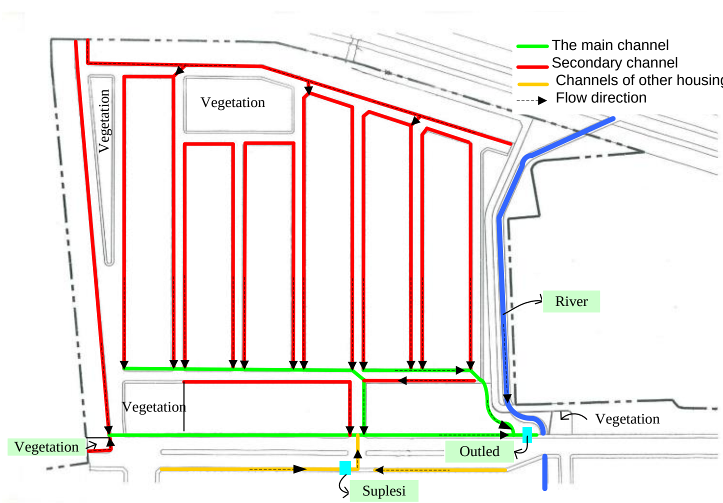

Figure 1. Drainage channel trace and flow direction

Based on observations in the field, the percentage of land is built more than vegetated land, so that rainwater is infiltrated to the soil a little and most of it becomes runoff. The rain which mostly falls to the ground without vegetation will be run down and flow towards the river so that the river flow increases rapidly. According to Yin, H, et al (Yin, Zhao, Wang, Xu, & Li, 2017). runoff coefficient is an important parameter for the decision support of urban stormwater management. Runoff coefficient is determined based on the land cover of water catchment area. According Verrina *et al.* (Verrina, Anugerah, & Haki, 2013), topography, land use and soil type will affect the amount of runoff that occured in the area. Land cover in the Sanur Cluster consists of multi-unit houses/buildings, parks, and roads. Land use type in the study location shown in Table 1.

Table 1. Land use type in study location

Land use	**Area**	
	m²	**%**
Building	11261.66	33.13
Undeveloped	11508.58	41.23
Vegetation	2508.21	
Road	8714.86	25.64
Total	33993.31	100.00

3.2 Surface Runoff

According to Froehlich (Froehlich, 2010), the runoff discharge value was determined by the rain intensity that occurred in the region during the time of concentration, runoff area, and runoff coefficients. Drainage channel's runoff discharge at the study location with 3.39 ha area, the C value of 0.65.

When it rains with high intensity in residence will experience flooding on the main channel, and the cross section of the main channel is trapezium. The Sanur Cluster drainage channel is made using concrete with a smooth surface with a Manning coefficient of 0.014. Based on the results of the main channel analysis, the concentration-time for the 175-meter channel with a slope of 0-17% is 13.3 minutes. The amount of concentration time will be relatively same if it occurs in relatively similar channel length and slope. Based on channel characteristics data, the channel discharge value on the main channel and on the secondary channels are 35.601 m^3/s and 1.905 m^3/s Characteristics of the channel and discharge channel are shown in Table 3.

Table 2. Land use classification and runoff coefficient for rational method

Land use	**Runoff coefficient (*C*)**
Multiunit, combined	0.60 – 0.75
Concrete/ asphalt paving	0.70 – 0.95
Pavement	0.50 – 0.70
Play parks	0.20 – 0.35
Garden or graveyard	0.10 – 0.25

Table 3. Characteristics of channel and discharge channel

Characteristic	**Channel**	
	Main	**Secondary**
Channel design	Trapezoid	Rectangular
Channel length, P (m)	175	1,686,000
Channel base width, B (m)	0.745	0.370
Channel top width, b (m)	0.945	0.370
Channel depth, H (m)	1.020	0.280
Freeboard, w (m)	0.200	0.100
Channel slope, S	3.600	2.000
Channel embankment, m_1	0.078	-
Channel embankment, m_2	0.118	-
Water depth, h (m)	0.820	0.270
Manning coefficient, n	0.017	0.017
Hydraulic radius, R (m)	0.312	0.110
Channel cross-sectional area, A (m^2)	0.693	0.100
Flow velocity, v (m /s)	51.379	19.073
Time of concentration, T (s)	0.2167	0.2167

Channel discharge, Q (m^3 / s)	2.0218	0.1067

Table 4. Analysis of planned rain probability (mm)

Repeat period (T year)	**Normal**	**Log Normal**	**Log Person III**	**Gumbel**
2	173.00	159.80	166.35	162.9
5	235.65	226.51	228.08	251.9
10	268.47	271.92	263.25	310.9
25	300.55	325.09	302.07	385.4
50	325.91	374.39	327.46	440.6

Table 5. The calculation results S, Cs, Ck, dan Cv

Factor	**Notation**	**Value**
Standard Deviation	S	74.5892
Slack coefficient	C_s	0.8064
Kurtosis coefficient	C_k	3.2111
Variation coefficient	C_v	0.4312
Factor	Notation	Value
Standard Deviation	S	74.5892
Slack coefficient	C_s	0.8064

Rainfall data is used to determine the planned rainfall in hydraulics planning. Determination of design channel discharge is calculated based on maximum annual rainfall data (maximum annual series) for 10 years (2004-2013). Rainfall data were obtained from the Meteorology, Climatology and Geophysics Agency Halim Perdanakusumah, Indonesia. From the maximum annual rainfall data, maximum monthly rainfall data will be collected which is then used to calculate the planned rainfall at the study site. Data were processed by distribution methods namely Normal, Log-Normal, Log-Person III, and Gumbel.

Based on the results of the analysis (Table 6) it can be concluded that the Gumbel distribution was used in the calculation.

Table 6. Comparison of distribution terms and calculation results

Distribution Type	**Terms**	**Results**	**Information**
Gumbel	$C_s \leq 1.1396$	$C_s = 0.1562$	conform
	$C_k \leq 5.4002$	$C_k = 3.2088$	
Log Normal	$C_s = 3\ Cv + C_{V2}$	$C_k = 3.2088$	inconform
	$C_s = 0.8325$		
Log-Person tipe III	$C_s \approx 0$	$C_s = 1.4670$	inconform
Normal	$C_s \approx 0$	$C_s = 0.1562$	inconform

Channel capacity is determined by the number of runoff peaks, which was used as disposal designs for channel planning. The amount of the design discharge is determined theoretically by a rational method that has been commonly used to determine the design debit for various estimates of design discharge in the form of drainage in urban areas. Calculation of design discharge is used as intensity of rainfall as a form of the amount of rain that occurs every hour which is influenced by the duration of precipitation or the frequency of rainfall.

The time of concentration is analyzed by considering the length of the main channel to drainage and the slope of the channel average. The concentration-time was obtained for 13 minutes. According to Manoj *et al.* (KC et al., 2013), the concentration time value must be calculated precisely if only predicted or determined based on local standards or engineering assessments. The value of time of concentration must be based on local standards or technical assessment. If the estimated concentration time is less actual, the estimated peak discharge will be more effective than the cost of building an expensive drainage channel.

According to Suripin (Suripin, 2004), an area of <10 can be used for a return period of 2 years and on land 10-100 can be used for a return period of 2-5 years (Table 7). The water catchment area at the research location is 3.39 ha. Based on this reference in the design of primary and secondary drainage channels is 10 years and 5 years. When it rains heavily, there will be a flood at the research site. Based on the Central Statistics Agency 2019, the population of the city of Bekasi is 2,733,240 people. According to Susilowati and Santita (Susilowati, 2006), in Table 8, the re-planning period with a population of> 2,000,000 for primary and secondary channels is 25 years and 10 years.

Susilowati and Santita (Susilowati, 2006) states that rural/ suburban/ city/ urban areas use tertiary drainage systems and in the planning of the channels used is a 2-year return period (Table 8). Based on the results of the recapitulation of rainfall data in certain return periods in Table 4, it was known that the design discharge is 162.9 mm.

Table 7. Criteria for hydrological design of urban drainage systems

Area of watershed (ha)	**Return period (year)**	**Return period (year)**
< 10	2	Rational
10-100	2-5	Rational
101-500	5-20	Rational
>500	10-25	Unit hydrograph

Table 8. Re-planning period

Channel type	**Regional classification**	**Population Density/PD (thousands of people)**	**Return period (year)**
Urban Primary Drainage System 1	Urban 1	PD<500	10
	Urban 2	500< PD <2000	15
	Urban 3	PD >2000	25
Urban Secondary Drainage System 1	Urban 1	PD <500	5
	Urban 2	500< PD <2000	5
	Urban 3	PD >2000	10
Tertiary Drainage	Rural / suburban / city / urban areas	-	2

System			

Table 9 shows the results of the design discharge analysis. In the plan for increasing drainage, the basic principle used is to maintain as many channels as possible. If not possible, changes will be made to the channel dimensions according to the planned flood discharge. According to Situmorang *et al.* (Situmorang & Nirmala, 2015), if the drainage channel capacity is higher than the planned flood discharge, the channel is still feasible, and there is no overflow of water. Handling flow discharge in a channel that has insufficient capacity is carried out by normalization (dredging of sediments), increasing channel height and making new channels.

Table 9. The relationship between the values of Q, h, and b / h for the drainage channel

Discharge, Q (m3 / s)	**h (m)**	**Ratio b/h**
< 0.5	< 0.50	1
0.5 – 1.1	0.5 – 0.75	2
1.1 – 3.5	0.75 – 1.00	2.5
> 3.5	> 1.00	3

Table 10. Results of analysis of hydraulic channel design criteria at the study site

Characteristic	**Channel**		
	Main		**Secondary**
Channel design	Trapesium (m=1)	Trapesium (m=0.5)	Square
Channel length, P (m)	175	175	1,686,000
Channel base width, B (m)	0.794	0.763	0.605
Channel top width, b (m)	-	-	0.605
Channel depth, H (m)	1.400	0.840	0.920
Freeboard, w (m)	0.300	0.200	0.200
Channel slope, S (%)	3.600	3.600	2.000
Channel slope, S (0)	3.240	3.240	1.800

Channel embankment, m1	1.000	0.500	
Channel embankment, m2	1.000	0.500	
Water depth, h (m)	1.100	0.64	0.720
Manning coefficient, n	0.020	0.02	0.020
Debit, (Q)	2.381	2.2896	1.815

4 Conclusion

This design was used for maximum discharge intensity. The planned flood discharge obtained using the Gumbel method for the 10 and 25 year return periods is 298.78 mm and 370.38 mm. Primary and secondary channel capacities are different. Channel capacity values are strongly influenced by primary and secondary channel discharge, which are 2.0218 m^3/s and 0.1067 m^3/s. From the calculation of the channel capacity in the field and the discharge plan respectively channels can be seen that most of the existing channel capacity is not can accommodate the currently planned discharge of 2,261 m^3/s for primary channels and 1,824 m^3/s for secondary channels. The current channel cannot receive runoff discharge during rain, then channel rehabilitation planning is carried out by widening and extracting the dimensions of the drainage canal.

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