ANALYSIS OF DRAINAGE CHANNEL CAPACITY AT SINDANG STREET IN SINDANG HOUSE PUMP AREA

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ABSTRACT

Sindang street, which is located in North Rawabadak Sub-district, Koja District, is one of the areas in North Jakarta Administrative City which is an area that is prone to flooding. Even though a working pump house is available, there are still puddles in several places. One of the problems that occur is the channel that drains water into the storage pool narrowing due to sedimentation in the channel. By analyzing the channel using the Log Pearson III distribution method using data obtained from the STA Tanjung Priok Rainfall Station, the rainfall intensity that occurs in a 5 year cycle is 170.748 mm, the Mononobe equation is used to find the intensity of rain per hour that occurs. Then it can be searched for the planned rain discharge using a Rational Method so that it is known that there are 2 channels, namely (P and Q) unable to accommodate the rainfall that occurs.

Key word: puddle; channel; drainage; pump area; rainfall.

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INTRODUCTION

Sindang Pump House is one of the pump houses located at 6 ° 6'56.70 "south latitude and 106 ° 53'45.57" east longitude. To the west of the Sindang Pump House is the Rawa Badak Market, to the south there is a residential area and an industrial area, while to the east there is the Sunter River which empties into Jakarta Bay. The north side of the Sindang Pump House is a busy shopping center. Although there is a Sindang Pump House that is prepared to deal with flooding, puddles still occur when there is rain with high rainfall intensity. However, this condition does not last long, if the rain stops, the puddles will disappear over time. Another problem is natural factors in the form of sedimentation and dry leaves in the channel along Jl. Sindang which blocks the flow of water to the Sindang Pump House. The channel around Rawa Badak Utara Park has a closed channel which makes it difficult to clean up sedimentation and trash in the channel. Where the channel also has deep sedimentation, the channel also has a pungent odor that is not good because the water does not flow into the reservoir of the Sindang Pump House. In the western part of the Sindang Pump House there is also a shopping center and Rawa Badak Market, the problem that occurs in this area is that the drainage channel in front of the market is misused by local traders for selling places. From the above conditions, the writer wants to analyze the problems of the channel around the Sindang Pump House area which can be an evaluation of citizens and the government in order to handle carefully the problems surrounding frequent flooding.

The rain that comes every day will cause the volume of water to increase on the surface, this volume of water will affect the water reservoir to overflow. This water overflow will cause flooding so that the performance of the pump house always works optimally (Iban S, 2017); (Siti NF et al, 2016); (Muslim PA, Muhamad L, 2016).

Research purposes

The aim of this research is:

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a. Knowing the rain discharge that enters the channel.

b. Knowing the channel's ability to accommodate rain discharge.

Frequency and Probability Analysis

In statistics, there are several parameters related to data analysis which include the average value ($\bar{X}$), standard deviation (s), coefficient of variation (Cv), coefficient of skewness (Cs), and coefficient of kurtosis (Ck).

$$\bar{X} = \sum_{i=1}^{n} Xi/n \tag{1}$$

$$S = \sqrt{\frac{\sum_{i=1}^{n}(Xi-\bar{X})^2}{n-1}} \tag{2}$$

$$Cv = \frac{S}{\bar{X}} \tag{3}$$

$$Cs = \frac{n \times \sum_{i=1}^{n}(Xi-\bar{X})^3}{(n-1) \times (n-2) \times S^3} \tag{4}$$

$$Ck = \frac{n^2 \times \sum_{i=1}^{n}(Xi-\bar{X})^4}{(n-1) \times (n-2) \times (n-3) \times S^4} \tag{5}$$

Explanation:
$\bar{X}$ = Average value
Xi = Value of variant
n = Amount of data
S = Standard deviation
Cv = Coefficient of variation
Cs = Coefficient of skewness
Ck = Coefficient of kurtosis

Normal Distribution

Normal distribution is also called the Gauss distribution, the normal distribution equation:

$$X_t = X + K_t . S_x \tag{6}$$

Explanation:

X_t = Rainfall plan return period T year (mm)

X = Rainfall average value (mm)

K_t = Frequency factor (Gauss variable value)

S_x = Standard deviation

Gumbel distribution

The following is the formula for the Gumbel Method:

$$X = \bar{X} + \frac{(Y_t - Y_n)}{S_n} . S_x \tag{7}$$

Explanation:

X_t = Rainfall plan return period T year (mm)

$\bar{X}$ = Rainfall average value (mm)

Y_t = Reduced variate of Gumbel parameter for period T years

Y_n = Reduced mean is a function of the amount of data

S_n = Reduced standard deviation

S_x = Standard deviation

Log-normal distribution

The normal log distribution is the result of a transformation from another distribution, namely the normal distribution, where by changing the variate X into a logarithmatic value of the X value, the following is a mathematical model with a normal log distribution:

$$Y = \bar{Y} + K \, . \, S_d \tag{8}$$

Explanation:

Y = logarithmatic value of x or ln x value

$\bar{Y}$ = The calculated average value of the data

K = Characteristics of the log-normal probability distribution

S_d= Standard deviation

Pearson III Log Distribution

Karl Pearson developed several kinds of empirical equations from a distribution, one of which is the Pearson III log distribution, the following is the log Pearson type III probability distribution formula as follows:

$$\log X_T = Log\, X + G \, . \, S_x \tag{9}$$

Explanation:

$Log\ X_t$ = Rainfall plan return period T year (mm)

$Log\ X$ = Rainfall average value (mm)

G = Standard variable for X_t

S_x = Standard deviation

Rainfall Intensity

If the only available rainfall data is daily rainfall, dr. Mononobe formulates its rainfall intensity as follows:

$$I = \frac{R_{24}}{24}\left[\frac{24}{t}\right]^{2/3} \tag{10}$$

Explanation:

R_{24} = Maximum rainfall in 24 hours (mm)

t = Duration of rainfall (hour)

I = Rainfall intensity (mm/hour)

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Peak Runoff Rates

To calculate the Peak Runoff Rates at a drainage, the following Rational Method calculations are used:

$$Q = 0{,}278.C.I.A \quad (11)$$

Explanation:

Q = Surface runoff peak discharge (m^3/sec)
C = Run off coefficient
I = Rainfall intensity (mm/hour)
A = Area of drainage area (km^2)

Time of Rain Intensity Concentration (Tc)

To find the concentration time (Tc), it can be calculated using the Kirpich formula as follows:

$$T_c = \frac{0{,}0195 \times L^{0,77}}{S^{0,385}} \quad (12)$$

Explanation:

T_c = Concentration time (minutes)
L = The length of the water's path from the farthest point to the point under review (m)
S = Slope of the channel

Average Flow Speed (V)

To find the average flow velocity (V), use the following formula:

$$V = \frac{1}{n} . R^{2/3} . S^{1/2} \quad (13)$$

Explanation:

V = Average flow velocity (m/sec)
n = Manning's roughness coefficient
R = Hydraulic radius (m)
S = Channel slope

Calculating the Discharge of Existing Channels

The purpose of examining the existing channel is to find out the amount of water flow that can be accommodated by the channel with its current state. Analysis of the capacity of the drainage channel is carried out to determine the ability of the existing drainage channels to the calculated discharge plan.

Channel Discharge

The following is the channel discharge formula as follows:

$$Q = A . V \quad (14)$$

Explanation:

Q = Flow rate (m^3/sec)
A = Wet cross-sectional area (m)
V = Average flow velocity (m/sec)

Channel Slope

The slope of the channel is obtained from the slope of the contour map in Google Earth. Here is the formula for finding the slope of the channel:

$$S = \frac{\Delta H}{L} \tag{15}$$

Explanation:

S = The slope of the channel

ΔH = The difference between the height of the farthest point and the drainage area

L = Channel length (m)

Wet cross-sectional area

The following is the formula for finding the wet cross-sectional area of the channel:

$$A = b.h \tag{16}$$

Explanation:

A = Wet section of the channel (m^2)

b = Channel width (m)

h = Water height (m)

Hydraulic Radius

Here is the formula for finding the Hydraulic Radius on the channel:

$$R = \frac{A}{P} \tag{17}$$

Explanation:

R = Hydraulic Radius (m)

A = Wet cross-sectional area (m^2)

P = Wet circumference (m)

RESEARCH METHODOLOGY

Data collection

Data collection techniques in this study are primary data collection which is data obtained directly from direct observation in the field, namely in the form of dimensional data on drainage channels around the pump house area and secondary data collection which is data that already exists and obtained from other parties related to this research. Secondary data includes rainfall data and maps from google earth. Secondary data were obtained from STA Tanjung Priok and agencies related to research.

Figure 1. Research location

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Analysis of the frequency of rainfall data
The calculation of the frequency analysis of the rainfall data is carried out in order to obtain the value of the planned rainfall using several probability distribution analyzes including Gumbel, Normal, Normal Log and Person III Log. By using a 5-year rainfall cycle.

Analysis of channel capacity
Calculation of channel drainage capacity analysis at the study location points using the equations contained in the literature review related to channel drainage capacity calculations.

RESULTS AND CONCLUSION

Rainfall Data Analysis

Maximum daily rainfall data is obtained from badan Meteorologi, Klimatologi, dan Geofisika (BMKG). The observation location of Tanjung Priok Maritime Meteorology Station for 15-years.

Table 1. Maximum rainfall data

Year	Maximum Rainfall
2005	109,9
2006	90,3
2007	182,2
2008	87,9
2009	148,9
2010	88,3
2011	78,5
2012	75,1
2013	117,8
2014	284
2015	247
2016	112,7
2017	148,6
2018	129,6
2019	130,3

Table 2. Distribution calculation for rainfall

No	Xi	$(Xi - \bar{X})$	$(Xi - \bar{X})^2$	$(Xi - \bar{X})^3$	$(Xi - \bar{X})^4$
1	109,90	-25,51	650,59	-16594,38	423267,41
2	90,30	-45,11	2034,61	-91774,54	4139643,46
3	182,20	46,79	2189,62	102459,43	4794418,42
4	87,90	-47,51	2256,88	-107217,01	5093522,58
5	148,90	13,49	182,07	2456,73	33149,50
6	88,30	-47,11	2219,04	-104531,49	4924129,84
7	78,50	-56,91	3238,37	-184284,77	10487031,91

8	75,10	-60,31	3636,89	-219328,96	13226998,29
9	117,80	-17,61	309,99	-5457,97	96096,72
10	284,00	148,59	22079,98	3280937,64	487525459,88
11	247,00	111,59	12453,07	1389679,82	155079003,34
12	112,70	-22,71	515,59	-11707,39	265835,84
13	148,60	13,19	174,06	2296,48	30298,29
14	129,60	-5,81	33,72	-195,79	1136,86
15	130,30	-5,11	26,08	-133,17	680,06
∑	2031,10		52000,57	4036604,65	686120672,42

From the table above we can find out the values which include the average value ($\bar{X}$), standard deviation (s), coefficient of variation (Cv), coefficient of skewness (Cs), and coefficient of kurtosis (Ck):

1. Average value ($\bar{X}$) = 135,40
2. Standard deviation (S_d) = 60,94
3. The coefficient of variation (C_v) = 0,45
4. The coefficient of skewness (C_s) = 1,46
5. The coefficient of kurtosis (C_k) = 5,12

Table 3. The results of the calculation of the distribution method and the terms of the distribution method

No	Distribution	Requirements	Result	Explanation
1	Gumbel	Cs < 1,14	Cs = 1,4696	not eligible
		Ck < 5,4	Ck = 5,1235	eligible
2	Normal	Cs = 0	Cs = 1,4696	not eligible
		Ck = 3	Ck = 5,1235	not eligible
3	Log Normal	Cs = 1,441	Cs = 1,4696	not eligible
		Ck = 6,908	Ck = 5,1235	not eligible
4	Log Pearson III	Don't have any requirement		eligible

Rainfall Plan Pearson Log Method III

After calculating the rainfall, the standard deviation, the slope coefficient, and the sharpness coefficient. Next, calculate the return period according to the method that meets the requirements, namely the Log-Pearson III method.

Table 4. Rainfall plan log Pearson III method

No	Tahun	Xi	Log Xi	$(\text{Log Xi} - \log \bar{X})^2$	$(\text{Log Xi} - \log \bar{X})^3$
1	2005	109,9	2,0410	0,0032	-0,0002
2	2006	90,3	1,9557	0,0200	-0,0028
3	2007	182,2	2,2605	0,0267	0,0044

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4	2008	87,9	1,9440	0,0235	-0,0036
5	2009	148,9	2,1729	0,0057	0,0004
6	2010	88,3	1,9460	0,0229	-0,0035
7	2011	78,5	1,8949	0,0410	-0,0083
8	2012	75,1	1,8756	0,0491	-0,0109
9	2013	117,8	2,0711	0,0007	0,0000
10	2014	284,0	2,4533	0,1268	0,0451
11	2015	247,0	2,3927	0,0873	0,0258
12	2016	112,7	2,0519	0,0021	-0,0001
13	2017	148,6	2,1720	0,0056	0,0004
14	2018	129,6	2,1126	0,0002	0,0000
15	2019	130,3	2,1149	0,0003	0,0000
	∑	2031,1	31,4592	0,4150	0,0467
	Log $\overline{X}$	135,40	2,09728		

From the table above we can find out the values which include the Log average value ($\overline{X}$), standard deviation Log x (Sd) and skewness coefficient of Log x (Cs):

1. Log average value ($\overline{x}$) Log x = 2,0972
2. Standard deviation (S_d) log x = 0,1721
3. Skewness coefficient (Cs) log x = 0,7549

Table 5. Maximum return period rainfall

Year cycle (T)	(average value of Log X)	Nilai (G)	Sd log X	Log X tahun	Rain plain (mm)
2	2,0973	-0,125	0,17217	2,076	119,069
5	2,0973	0,785	0,17217	2,232	170,746
10	2,0973	1,335	0,17217	2,327	212,357
25	2,0973	1,981	0,17217	2,438	274,408
50	2,0973	2,432	0,17217	2,516	328,127
100	2,0973	2,861	0,17217	2,590	388,886
200	2,0973	3,272	0,17217	2,661	457,718

Calculate the Run off Coefficient

Based on the existing condition of the channel which has different dimensions and the location of the channel between the residential area and the main road, the catchment area is divided into 17 sections.

Table 6. Results of the calculation of the run off coefficient

Location	Area (Km)	Run off coefficient
A	0,009102	0,616710613
B	0,0000628	0,15
C	0,025433	0,579328038

D	0,039096	0,576074279
E	0,044537	0,578205762
F	0,046903	0,577645353
G	0,032986	0,838151337
H	0,165	0,814666667
I	0,023266	0,857040316
J	0,005255	0,899838249
K	0,1086	0,83035221
L	0,004487	0,95
M	0,009971	0,861854378
N	0,010916	0,858299743
O	0,004747	0,866305035
P	0,025905	0,856438911
Q	0,001401	0,871413276

Calculating Rainfall Intensity

Before looking for channel rainfall intensity, first calculate the time of rain intensity concentration that occurs using the Kirpich formula.

Table 7. Calculating Time of Channel Concentration (Tc)

Location	L	S	Tc	
			minute	hour
A	263	0,003802	12,1642	0,202737
B	6,33	0,020537	0,360402	0,006007
C	253	0,003953	11,63158	0,19386
D	245	0,004082	11,20783	0,186797
E	242	0,004132	11,04947	0,184158
F	218	0,004587	9,793814	0,16323
G	280	0,010714	8,566639	0,142777
H	797	0,003764	28,67658	0,477943
I	285	0,007018	10,22078	0,170346
J	175	0,005714	7,598775	0,126646
K	1220	0,001639	54,81301	0,91355
L	312	0,00641	11,34715	0,189119
M	73	0,013699	2,768041	0,046134
N	209	0,009569	7,143434	0,119057
O	124	0,008065	5,104305	0,085072
P	287	0,003484	13,45514	0,224252
Q	84,8	0,011792	3,29103	0,05485

Table 8. Rainfall Intensity

Location	Year cycle (T)	Rain plain	Rainfall intensity (I)

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		Tc (hour)	Log person III (mm)	Log person III (mm/hour)
A	5	0,2027	170,746	171,469
B	5	0,0060	170,746	1790,394
C	5	0,1939	170,746	176,664
D	5	0,1868	170,746	181,089
E	5	0,1842	170,746	182,815
F	5	0,1632	170,746	198,123
G	5	0,1428	170,746	216,617
H	5	0,4779	170,746	96,809
I	5	0,1703	170,746	192,567
J	5	0,1266	170,746	234,639
K	5	0,9136	170,746	62,858
L	5	0,1891	170,746	179,604
M	5	0,0461	170,746	459,993
N	5	0,1191	170,746	244,506
O	5	0,0851	170,746	305,909
P	5	0,2243	170,746	160,320
Q	5	0,0549	170,746	409,874

Plan Rain Discharge (Q_t)

The calculation of the planned rainfall discharge uses a rational method.

Table 9. Planned Rainfall Discharge (Q_t)

Location	Year cycle	Run off coeffici ent (C)	Rainfall intensity (I)	Catchment Area (A)	Peak Runoff Rates (Q_t)
	(T)		mm/jam	(Km²)	(m³/det)
A	5	0,617	171,469	0,009	0,268
B	5	0,150	1790,394	0,000	0,272
C	5	0,579	176,664	0,025	0,996
D	5	0,576	181,089	0,039	2,130
E	5	0,578	182,815	0,045	3,438
F	5	0,578	198,123	0,047	4,931
G	5	0,838	216,617	0,033	1,665
H	5	0,815	96,809	0,165	3,618
I	5	0,857	192,567	0,023	4,685
J	5	0,900	234,639	0,005	11,589
K	5	0,830	62,858	0,109	1,576
L	5	0,950	179,604	0,004	1,789
M	5	0,862	459,993	0,010	2,888
N	5	0,858	244,506	0,011	3,524
O	5	0,866	305,909	0,005	3,874

P	5	0,856	160,320	0,026	0,989
Q	5	0,871	409,874	0,001	5,002

Table 10. Existing channel discharge

Lo cation	L (m)	S	b (m)	h (m)	A (m)	P (m)	R (m)	n	V m/sec	Qs m³/sec
LEFT (BOTTOM)										
A	263	0,004	1,0	0,676	0,676	2,352	0,287	0,013	2,066	1,396
B	6	0,021	1,0	0,747	0,747	2,494	0,300	0,013	4,935	3,686
C	253	0,004	1,8	1,317	2,371	4,434	0,535	0,013	3,186	7,552
D	245	0,004	1,8	1,110	1,998	4,020	0,497	0,013	3,084	6,161
E	242	0,004	1,6	1,364	2,182	4,328	0,504	0,013	3,133	6,837
F	218	0,005	1,7	1,276	2,169	4,252	0,510	0,013	3,326	7,215
G	280	0,011	0,6	1,052	0,631	2,704	0,233	0,013	3,019	1,905
H	797	0,004	1,9	1,128	2,143	4,156	0,516	0,013	3,035	6,504
I	285	0,007	1,5	1,000	1,500	3,500	0,429	0,013	3,663	5,494
J	175	0,006	2,4	1,275	3,060	4,950	0,618	0,013	4,220	12,912
RIGHT (UP)										
K	1220	0,002	1,9	1,347	2,559	4,594	0,557	0,013	2,109	5,397
L	312	0,006	2	1,370	2,740	4,740	0,578	0,013	4,274	11,710
M	73	0,014	1,3	0,980	1,274	3,260	0,391	0,013	4,812	6,131
N	209	0,010	1,5	1,207	1,811	3,914	0,463	0,013	4,501	8,149
O	124	0,008	1,252	0,976	1,222	3,204	0,381	0,013	3,633	4,439
P	287	0,003	0,4	0,375	0,150	1,150	0,130	0,013	1,168	0,175
Q	84,8	0,012	0,7	1,300	0,910	3,300	0,276	0,013	3,539	3,220

Based on the peak runoff rates and the existing channel capacity, it can be compared to determine whether the channel capacity is able or not to accommodate the rain discharge.

Table 11. Comparison of channel discharge capacity with rain discharge

Area	Discharge		Explanation	Discharge	Explanation
	Rainfall (Qt)	Existing Drainage (Qs)		New Drainage (Qi)	
A	0,268	1,396	Eligible	2,280	Eligible
B	0,272	3,686	Eligible	5,300	Eligible
C	0,996	7,552	Eligible	9,454	Eligible
D	2,130	6,161	Eligible	9,607	Eligible
E	3,438	6,837	Eligible	9,666	Eligible
F	4,931	7,215	Eligible	10,184	Eligible
G	1,665	1,905	Eligible	2,214	Eligible
H	3,618	6,504	Eligible	9,226	Eligible

Volume 9, No. 2, Desember 2020, Halaman 132-144
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I	4,685	5,494	Eligible	12,597	Eligible
J	11,589	12,912	Eligible	14,603	Eligible
K	1,576	5,397	Eligible	6,088	Eligible
L	1,789	11,710	Eligible	12,039	Eligible
M	2,888	6,131	Eligible	17,599	Eligible
N	3,524	8,149	Eligible	14,710	Eligible
O	3,874	4,439	Eligible	13,504	Eligible
P	0,989	0,175	Not Eligible	5,913	Eligible
Q	5,002	3,220	Not Eligible	16,329	Eligible

CONCLUSION

Analysis of the planned flood in the Sindang Pump House area with rainfall data using daily rainfall data for STA Tanjung Periok, it was obtained that the planned rainfall discharge with a 5-year return period with Log Pearson III analysis was 170.748 mm, then the P channel with the ability to accommodate rain discharge of 0.175 m^3/sec<0.989 m^3/sec and the Q channel with a discharge of 3,220 m^3/sec <4.093 m^3/sec cannot accommodate the rainfall that occurs, by making changes to the dimensions of the channel, the ideal channel discharge obtained for channels P and Q is 5,913 m^3/sec and 16.329 m^3/sec.

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