ASTONJADRO: CEAESJ

pISSN 2302-4240
eISSN 2655-2086

Volume 11, Issue 2, June 2022, pp.241-252
DOI: http://dx.doi.org/10.32832/astonjadro.v11i2

EVALUATION OF DRAINAGE NETWORK ON GAYA MOTOR ROAD OF SUNGAI BAMBU SUB-DISTRICT TANJUNG PRIOK

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ABSTRACT

Drainage is a way to dispose of excess water that is not in an area. In other words, this drainage also works in controlling checked areas, puddles, and also flooding. Flooding is an event when excessive water flows overland. North Jakarta is an example of the city area in Indonesia that often experiences such flooding events with a repeated frequency every year. With low topographic conditions and also located in the northern coastal area of Java Island, resulting in a large flow of water through North Jakarta. One of the areas that always experiences flooding is Jalan Gaya Motor, Sungai Bambu Village Tanjung Priok sub-district. Flooding in this area caused major losses in economic mobility in North Jakarta because the road is the main access to an s considerable automotive factory area in the Jakarta area. Drainage systems in the area need to be designed to accommodate water discharge especially when it is raining. Drainage capacity needs to be accounted for to accommodate existing water discharge. From the results of the analysis obtained the amount of channel capacity value of 0.46 m^3/s, then bulk discharge flood plan in the period of-2 Years 22.95 m^3/s, for 5 Years 34.26 m^3/s, for 10 Years 41.75 m^3/s. With the flooded value of the plan, it was concluded that the capacity of the existing channel could not accommodate rain at the peak discharge of the plan, so the area always experienced flood events. Also, drainage channels in the area were affected by the high rise in water levels due to the influence of tides with an average increase of 0.6 m with an average elevation of water level of 0.607.

Keyword: drainage; flood; flood discharge; tidal; capacity.

Received:	Revised:	Accepted:	Available online:
2020-07-20	2020-11-09	2020-11-13	2022-05-06

INTRODUCTION

Drainage is a system for channelling rainwater. This system has a very important role in creating a healthy environment, especially in densely populated areas. Drainage is a way to dispose of excess water that is not in an area. In other words, this drainage also works in controlling checked areas, puddles, and also flooding. The growing number of settlements and urban areas makes this drainage system more needed, especially lately the knowledge of the community in the management of drainage system is still lacking as a result of many areas that are often inundated until flooding in the rainy season arrives.

Flooding is an event when excessive water flows overland. Flooding is a popular event in Indonesia considering the number of regions that have experienced this event. This event is almost every year repetitive, especially when the rainy season even the frequency of events increases. Flooding in urban areas has different characteristics with natural land (plantations, rice fields, etc.). In general, rainwater that falls will flow into artificial channels that will be flowed into the river. However, there are times when the capacity of the channel is insufficient to accommodate the rainwater that falls and results in flooding.

North Jakarta is an example of the city area in Indonesia that often experiences such flooding events with a repeated frequency every year. With low topographic conditions and also located in the northern coastal area of Java Island, resulting in a large flow of water through North Jakarta. With these conditions, the flow of water that can flow in North Jakarta depends on the level of sea level. One of the areas that always experiences flooding is Gaya Motor Road, Sungai Bambu Village Tanjung Priok sub-district. Flooding in this area caused major losses in economic mobility in North Jakarta because the road is the main access to as considerable automotive factory area in the Jakarta area.

Drainage systems in the area need to be designed to accommodate water discharge especially when it is raining. Drainage capacity needs to be accounted for to accommodate the water discharge in the area so that the area can be free from flood events.

In calculating the tide and the condition of the flow of water, determine the location and location of the water source. Water will flow according to the laws of nature, from the highest to the lowest. The estuary is the place where the flow of water ends up to the wide sea. This condition is very influential with the rainfall in the mountains as a natural source of water (Iban S 2017; Alam MP, Lutfi M 2016; Imamuddin MI, Larasati L, 2021; Imamuddin MI, Cahyanto D, 2020).

RESEARCH METHODS

This research was conducted at Gaya Motor Road Sungai Bambu Subdistrict Tanjung Priok City Administration North Jakarta Implementing this Research in from March to May 2020.

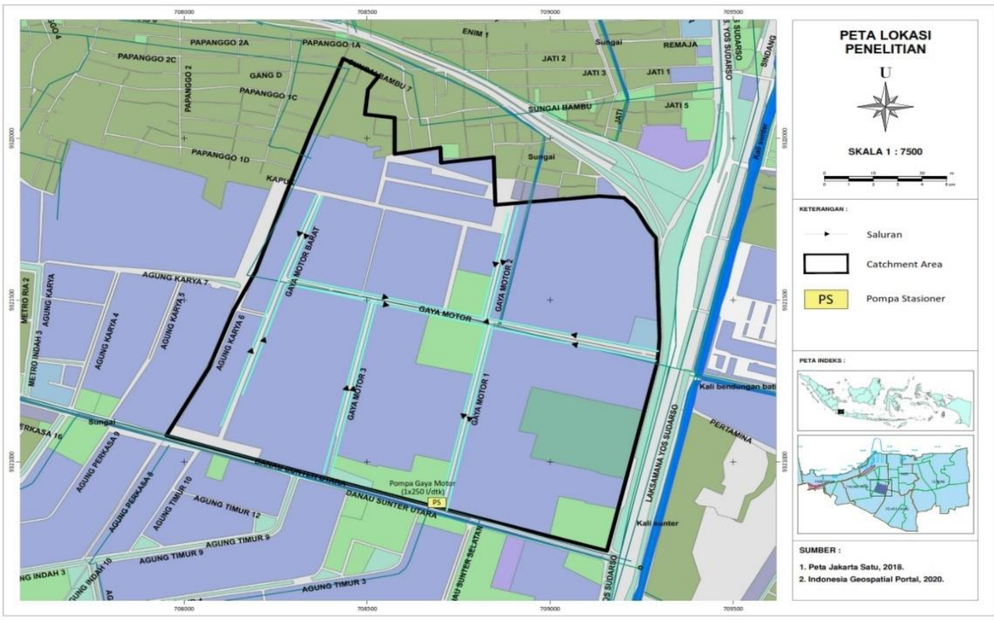

Figure 1. Research Site Map (Source: Analysis Results)

ASTONJADRO: CEAESJ
pISSN 2302-4240
eISSN 2655-2086
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DOI: http://dx.doi.org/10.32832/astonjadro.v11i2

The stages of this research are displayed in the form of flow charts such as the following:

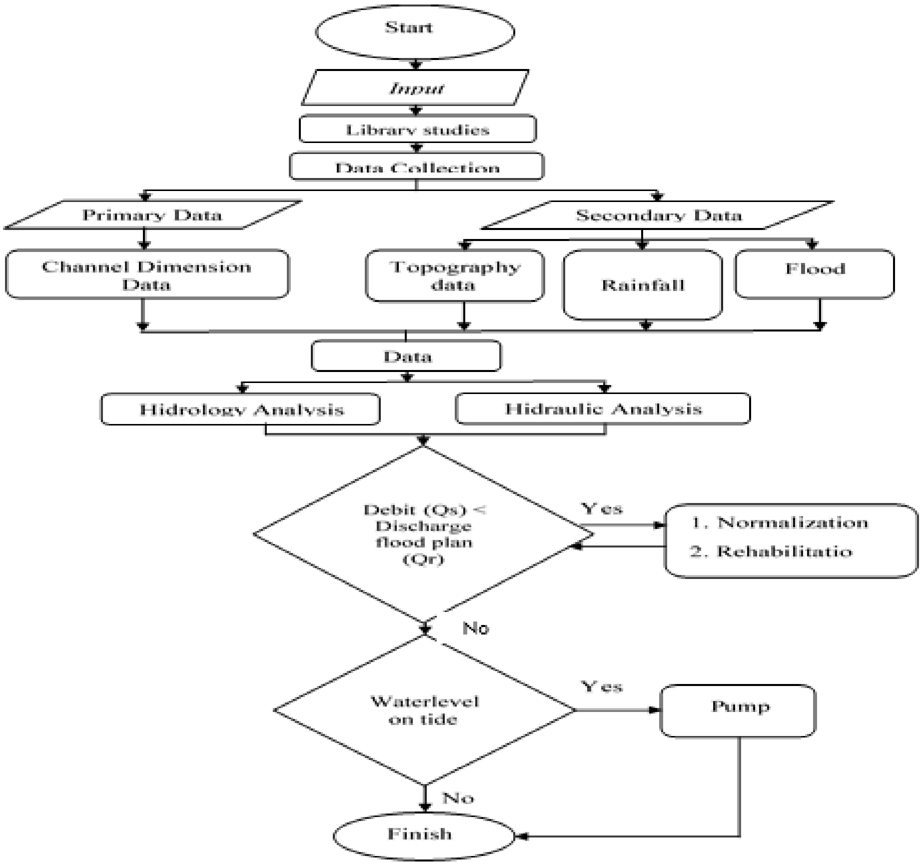


Figure 2. Flow Chart

RESULTS AND DISCUSSIONS

Drainage Network Condition

The state of drainage infrastructure in the research area is still relatively poor. This can be seen from some of the frequent flooding events in the area. On the Highway, there are drainage lines on both sides of the road which is the primary channel in the area. The channel serves to drain incoming water from secondary channels located on Gaya Motor Barat Road, Gaya Motor 2 Road, and Gaya Motor 3 Road.

Table 1. Drainage channels in the Gaya Motor area

No.	Channel	Dimensions (m)			Category	Channel Condition
		(h1)	(h2)*	(b)		
1	GM-BARAT-LEFT	1.00	0.25	0.95	Secondary	Open
2	GM-BARAT-RIGHT	0.70	0.30	1.00	Secondary	Open
3	GM-RAYA- LEFT	1.20	0.30	1.90	Primary	Open
4	GM-RAYA-RIGHT	1.00	0.30	1.50	Primary	Open
5	GM-1- LEFT	1.10	0.50	1.20	Primary	Open
6	GM-1-RIGHT	1.00	0.30	1.50	Primary	Open
7	GM-2- LEFT	1.10	0.43	1.40	Secondary	Open
8	GM-2-RIGHT	1.10	0.30	1.90	Secondary	Open
9	GM-3- LEFT	1.20	0.30	1.20	Secondary	Open
10	GM-3-RIGHT	1.20	0.30	1.00	Secondary	Open

(Source: Survey Results)

Rainfall Frequency Analysis

Frequency analysis required a series of rain data obtained from the rain pen post. This analysis is based on the statistical nature of past event data to get the probability of future rainfall. Assuming that the statistical nature of a rain event that will date is still the same as the statistical nature of past rain events. Daily maximum rain data obtained from 3 observation stations is as follows:

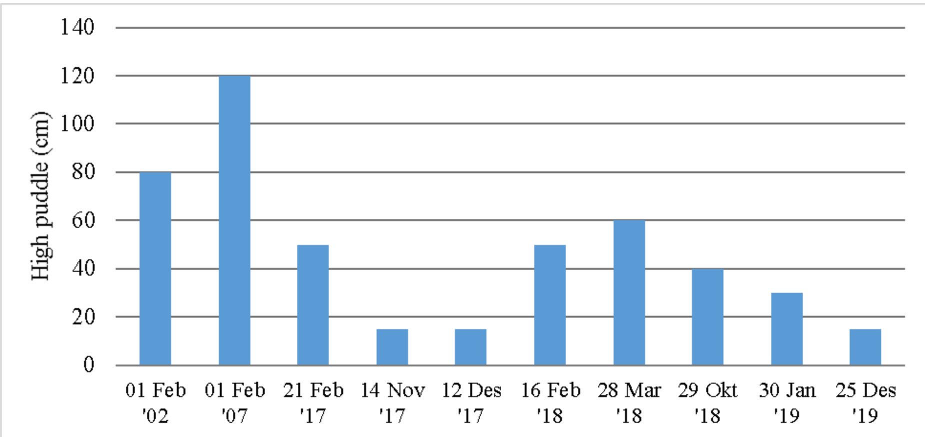
a. Halim Perdana Kusuma
b. Kemayoran Meteorological Station
c. Tanjung Priok Maritime Meteorological Station

Table 2. Maximum rainfall

No.	Year	Observation Station		
		Halim Perdana Kusuma	Kemayoran Meteorological Station	Tanjung Priok Maritime Meteorological Station
1	1999	42.0	147.2	106.0
2	2000	54.3	94.8	65.2
3	2001	92.8	82.2	210.0
4	2002	107.6	168.5	147.1
5	2003	71.7	199.7	126.7
6	2004	39.8	129.3	121.4
7	2005	96.6	124.1	109.9
8	2006	88.5	72.0	90.3
9	2007	217.6	234.7	182.2
10	2008	136.1	192.7	87.9
11	2009	140.4	122.5	148.9
12	2010	96.8	93.0	88.3
13	2011	305.0	119.2	78.5
14	2012	94.4	105.2	75.1
15	2013	161.0	193.4	117.8
16	2014	120.8	147.9	284.0
17	2015	124.6	277.5	247.0
18	2016	111.6	124.5	112.7
19	2017	136.3	179.7	148.6
20	2018	101.2	104.6	129.6

(Source: *dataonline.bmkg.go.id*)

From the daily rain data mentioned can be seen the number of extreme rain events during 20 Years in Figure 3. As follows:



ASTONJADRO: CEAESJ
pISSN 2302-4240
eISSN 2655-2086
Volume 11, Issue 2, June 2022, pp.241-252
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Figure 3. Frequency of extreme rain events (Source: Results of daily rain analysis of Tanjung Priok Maritime Meteorological Station 1999-2018)

The methods used in this rainfall calculation plan are as follows:

a. Gumbel Method

Table 3. Gumbel method frequency analysis

No	Years	X_i	$X_i - \bar{X}$	$(X_i - \bar{X})^2$	$(X_i - \bar{X})^3$
1	106.0	-27.86	776.18	-21624.36	602454.77
2	65.2	-68.66	4714.20	-323676.67	22223640.16
3	210.0	76.14	5797.30	441406.39	33608682.65
4	147.1	13.24	175.30	2320.94	30729.25
5	126.7	-7.16	51.27	-367.06	2628.16
6	121.4	-12.46	155.25	-1934.43	24103.06
7	109.9	-23.96	574.08	-13755.00	329569.68
8	90.3	-43.56	1897.47	-82653.95	3600406.06
9	182.2	48.34	2336.76	112958.77	5460426.73
10	87.9	-45.96	2112.32	-97082.30	4461902.54
11	148.9	15.04	226.20	3402.07	51167.16
12	88.3	-45.56	2075.71	-94569.51	4308586.95
13	78.5	-55.36	3064.73	-169663.43	9392567.52
14	75.1	-58.76	3452.74	-202882.86	11921396.93
15	117.8	-16.06	257.92	-4142.25	66524.58
16	284.0	150.14	22542.02	3384458.82	508142647.65
17	247.0	113.14	12800.66	1448266.63	163856886.20
18	112.7	-21.16	447.75	-9474.30	200476.12
19	148.6	14.74	217.27	3202.52	47205.21
20	129.6	-4.26	18.15	-77.31	329.34
Sum	2677.2		63693.27	4374112.71	768332330.73

(Source: Analysis Results)

Calculate average rainfall:

$$\bar{X} = \frac{\sum X_i}{N}$$

where: X_i = Maximum rainfall value (mm)
$\bar{X}$ = Average value
N = Number of years of observation

Calculate standard deviation:

$$S_x = \sqrt{\frac{\sum (X_i - \bar{X})^2}{N-1}}$$

where: S_x = Standard Deviation
X_i = Maximum rainfall value (mm)
$\bar{X}$ = Average value
N = Number of years of observation

Calculate probability factor value:

$$K = \frac{Y_{tr} - Y_n}{S_n}$$

where: K = Probability factor value
Y_{tr} = Reduce Variate
Y_n = Reduce Mean
S_n = Reduce Standar Deviation

The amount of rainfall data available is N = 20 years, so that the value of Y_n, and S_n are as follows:
Y_n = 0.5236
S_n = 1.0628
Calculate rainfall in return period (T):

Xtr = $\bar{X} - K\ S_x$

where: Xtr = rainfall in retutrn period
$\bar{X}$ = Average value
K = Probability Factor
S_x = Standard Deviation

Rainfall plan in year T presented in Table 4.

Table 4. Calculation of rainfall gumbel method

Return Period	Yt	Yn	Sn	Kt	Xavrg.	Sx	Rainfall plan (Xtr)
2	0.3668	0.5236	1.0628	-0.148	133.9	57.90	125
5	1.5004	0.5236	1.0628	0.919	133.9	57.90	187
10	2.251	0.5236	1.0628	1.625	133.9	57.90	228

(Source: Analysis Results)

b. Log Pearson III Method

Table 5. Frequency analysis of Log Pearson III method

No	Years	X_i	$LogX$	$LogX - Log\bar{X}$	$(LogX - Log\bar{X})^2$	$(LogX - Log\bar{X})^3$
1	1999	106.0	2.03	-0.07	0.0046	-0.0003
2	2000	65.2	1.81	-0.28	0.0777	-0.0217
3	2001	210.0	2.32	0.23	0.0525	0.0120
4	2002	147.1	2.17	0.07	0.0056	0.0004
5	2003	126.7	2.10	0.01	0.0001	0.0000
6	2004	121.4	2.08	-0.01	0.0001	0.0000
7	2005	109.9	2.04	-0.05	0.0027	-0.0001
8	2006	90.3	1.96	-0.14	0.0189	-0.0026
9	2007	182.2	2.26	0.17	0.0281	0.0047
10	2008	87.9	1.94	-0.15	0.0222	-0.0033
11	2009	148.9	2.17	0.08	0.0064	0.0005
12	2010	88.3	1.95	-0.15	0.0216	-0.0032
13	2011	78.5	1.89	-0.20	0.0393	-0.0078
14	2012	75.1	1.88	-0.22	0.0473	-0.0103
15	2013	117.8	2.07	-0.02	0.0005	0.0000
16	2014	284.0	2.45	0.36	0.1298	0.0468
17	2015	247.0	2.39	0.30	0.0898	0.0269
18	2016	112.7	2.05	-0.04	0.0017	-0.0001
19	2017	148.6	2.17	0.08	0.0062	0.0005
20	2018	129.6	2.11	0.02	0.0004	0.0000
Sum		2677.2	41.86	39.77	0.5553	0.0425

(Source: Analysis Results)

Calculate average rainfall:

$$\bar{X} = \frac{\sum X_i}{N}$$

where: X_i = Maximum rainfall value (mm)
$\bar{X}$ = Average value
N = Number of years of observation

Calculate standard deviation:

ASTONJADRO: CEAESJ
pISSN 2302-4240
eISSN 2655-2086
Volume 11, Issue 2, June 2022, pp.241-252
DOI: http://dx.doi.org/10.32832/astonjadro.v11i2

$$S_x = \sqrt{\frac{\sum(LogX_i - Log\bar{X})^2}{N-1}}$$

where: S_x = Standard Deviation
$LogX_i$ = Maximum rainfall value (mm)
$Log\bar{X}$ = Average value
N = Number of years of observation

Calculate skewness coefficient (G):

$$Cs/G = \frac{N\sum_{i=1}^{n}(LogX_i - Log\bar{X})^3}{(N-1)(N-2)S^3}$$

$$= \frac{20\ x\ 0.0425}{(20-1)(20-2)\ 0.16^3}$$

= 0.50

Calculate rainfall in return period (T):

$$LogXt = Log\bar{X} + K\ S_x$$

where: LogXt = Rainfall antilog
K = Probability factor
S_x = Standard Deviation

with a value of G = 0.50 then the value of K for 2-years, 5-years and 10-years is as follows :
K_2 = 0.082
K_5 = 0.877
K_{10} = 1.320

Table 6. Comparison of rainfall plans

Return Period (T)	Gumbel	Log Pearson III
2 years	125	128
5 years	187	175
10 years	228	208

(Source: Analysis Results)

From the two calculations of rainfall, presented in Table 6 where the results of both calculations have a not far difference, therefore for the next calculation used gumbel method that has the largest value and also based on Volume I Procedure Manual Preparation of Urban Drainage System Master Plan 2012 by Directorate General of Cipta Karya, Ministry of PUPR and SNI 2415-2016 On How to Plan Floods.

Rainfall Intensity

The maximum rainfall unit is converted into a unit of rainfall within a certain time usually used unit mm/hour. By using formulas **Mononobe** as follows:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3}$$

where: I = Rainfall intensity (mm/hour)
R_{24} = Maximum rainfall in 24 hours (mm)
t = Duration of rainfall (hour)

Table 7. Rainfall intensity

Duration of rainfall (minutes)	Rainfull return period (mm)		
	2 Years	**5 Years**	**10 Years**
	125	187	228
1	665.85	993.98	1211.24
2	419.46	626.17	763.04
3	320.11	477.85	582.31
4	264.24	394.46	480.68
5	227.72	339.94	414.24

10	143.45	214.15	260.95
20	90.37	134.90	164.39
25	77.88	116.26	141.67
50	49.06	73.24	89.25
60	43.45	64.85	79.03
120	27.37	40.86	49.79
180	20.89	31.18	37.99
240	17.24	25.74	31.36

(Source: Analysis Results)

Then after the calculation of rainfall intensity in the return period 2, 5, 10 years is shown in Figure 4.

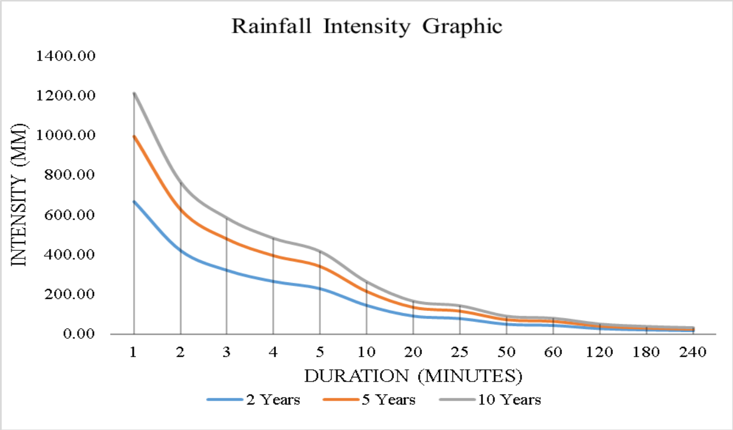

Figure 4. Rainfall intensity graph (Source: Analysis Results)

Flood Discharge Analysis Plan

The method for estimating flood discharge plans that are commonly used is the Rational Method. The formula used in this calculation is:

$$Q = 0{,}00278 \cdot C \cdot I \cdot A$$

where: Q = Discharge (m^3/s)
C = Runoff koefisien
I = Rainfall intensity
A = Flows area (Ha)

Gaya motor industrial area, thus having a runoff coefficient value (C) = 0.91. Thus obtained the discharge value of the flood plan as shown in Table 8 as follows:

Table 8. Flood discharge plan

No	Period	R24 (mm)	C	I (mm/hour)	A (km2)	Qr (m3/dtk)
1	2 Tahun	125	0.91	67.77	133.21	22.95
2	5 Tahun	187	0.91	101.16	133.21	34.26
3	10 Tahun	228	0.91	123.27	133.21	41.75

(Source: Analysis Results)

pISSN 2302-4240
eISSN 2655-2086

Volume 11, Issue 2, June 2022, pp.241-252
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Channel Capacity Calculation

Debit analysis on the channel is carried out to determine the capacity that can be flowed on the channel. The calculation of channel capacity can be seen in Table 9.

Table 9. Channel capacity calculation

No.	Channel	h1 (m)	h2 (m)	b (m)	p (m)	A	R	S	N	V	Q
1	GM-BARAT-LEFT	1.00	0.25	0.95	2.95	0.95	0.322	0.00027	0.03	0.26	0.24
2	GM-BARAT-RIGHT	0.70	0.30	1.00	2.40	0.70	0.292	0.00093	0.03	0.45	0.31
3	GM-RAYA-LEFT	1.20	0.30	1.90	4.30	2.28	0.530	0.00034	0.03	0.40	0.92
4	GM-RAYA-RIGHT	1.00	0.30	1.50	3.50	1.50	0.429	0.00034	0.03	0.35	0.53
5	GM-1- LEFT	1.10	0.50	1.20	3.40	1.32	0.388	0.00039	0.03	0.35	0.46
6	GM-1-RIGHT	1.00	0.30	1.50	3.50	1.50	0.429	0.00067	0.03	0.49	0.73
7	GM-2- LEFT	1.10	0.43	1.40	3.60	1.54	0.428	0.00033	0.03	0.34	0.53
8	GM-2-RIGHT	1.10	0.30	1.90	4.10	2.09	0.510	0.00059	0.03	0.52	1.08
9	GM-3- LEFT	1.20	0.30	1.20	3.60	1.44	0.400	0.00037	0.03	0.35	0.50
10	GM-3-RIGHT	1.20	0.30	1.00	3.40	1.20	0.353	0.00051	0.03	0.38	0.45

(Source: Analysis Results)

Channel calculation sample of Gaya Motor Barat road left side:

- Area (A)

$A = b \times h$
A = 0.95 x 1.00
A = 0.95 m^2

- Circumference (P)

$P = b + 2h$
P = 0.95 + 2.(1.00)
P = 3.45 m

- Hydraulic radius (R)

$R = A / P$
R = 0.95 / 2.95
R = 0.344 m

- Channel speed (V)

$$V = \frac{1}{n} \cdot R^{\frac{2}{3}} \cdot S^{\frac{1}{2}}$$

$$V = \frac{1}{0.03} \cdot 0.322^{\frac{2}{3}} \cdot 0.00027^{\frac{1}{2}}$$

V = 0.26 m/s

- Channel debit (Q_s)

$Q_s = A \times V$
Q_s = 0.95 x 0.26
Q_s = 0.24 m^3/s

Water Level

The results obtained from field surveys on normal conditions of the average water level are at an elevation level of +0.607 or 30 cm from the bottom of the channel. This condition is the position where the water level of the channel outlet located in Sunter C river is in normal condition with an average level of +0.280. From Figure 4 it is seen that the highest increase in the water level of the channel is in November. In addition, the highest flood conditions that have occurred in the motor force area are at an elevation level of +2,367 or are at an average height of 60 cm from the surface. In these conditions flooded almost the entire Gaya Motor area and caused considerable losses.

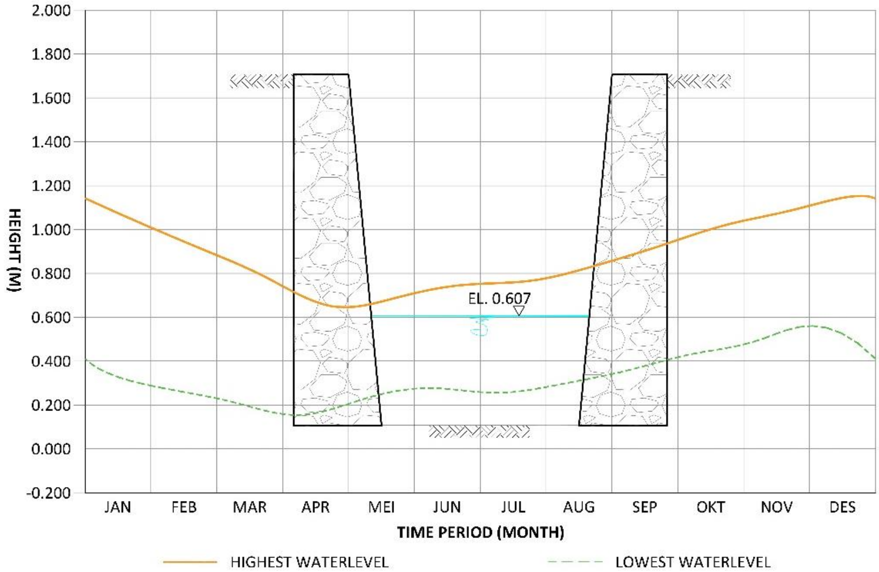

Figure 5. Water level graphic (Source: Analysis Results)

Tidal

In this study presented tidal data for 20 years from 2000 to 2019 presented in Figure 6.

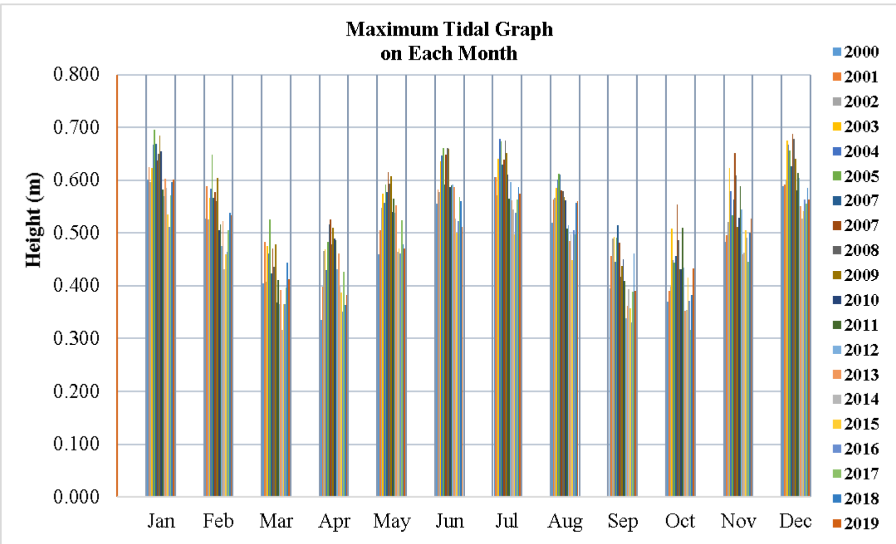

Figure 6. Tidal graphic (Source: Analysis Results)

Tidal effect on drainage system

Sea level tides have a considerable influence on drainage systems in urban areas located in coastal areas, especially for flat areas with low ground elevation. In this study, a comparison of flood events at the time with the high tide level of the sea level. Data is displayed in the following Table 10:

Table 10. Period of flooding

pISSN 2302-4240
eISSN 2655-2086
Volume 11, Issue 2, June 2022, pp.241-252
DOI: http://dx.doi.org/10.32832/astonjadro.v11i2

No	Date	High puddle (cm)	Duration (hour)	Rainfall (mm)	Tidal level (m)
1	01 February 2002	80	unknown	138.00	0.355
2	01 February 2007	120	unknown	235.00	0.577
3	21 February 2017	50	7.00	180.00	0.571
4	14 November 2017	15	4.00	60.70	0.210
5	12 December 2017	15	2.00	90.70	0.446
7	16 February 2018	50	2.00	105.00	0.373
8	28 March 2018	60	10.00	130.00	0.337
9	29 October 2018	40	3.00	94.50	0.382
10	30 January 2019	30	6.00	128.00	0.601
11	25 December 2019	15	4.00	103.00	0.547

(Sourcer: Water Resource Agency of North Jakarta)

CONCLUSION

From the results of hydrological analysis to discharge flood plans that occur in the return period of 2 Years can be a maximum rainfall value of 125 mm and discharge flood plan (Qr) 22.95 m3/s, in the period of 5 Years maximum rainfall of 187 mm and flood discharge plan (Qr) 34.26 m3/s, and also at the time of the 10-year periode the maximum rainfall is 228 mm with a flood discharge plan (Qr) of 41.75 m3/s. Based on the calculation of channel capacity located in Gaya Motor area is not able to accommodate rain discharge plan. With a capacity value of 0.46 m3/s on the channel outlet. The performance of this drainage network is affected by the level of water level that is at sunter river especially in December to February which is the highest average water level occurs. When the water level rises at the drainage outlet on Gaya Motor 1 road will reduce the discharge capacity that the channel is able to flow.

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