Research Article

Flood Water Level Modeling In Bukit Tiara Residential

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Abstract: Flood is a natural phenomenon that can threaten the existence of human life, especially during the rainy season. Bukit Tiara Residential, which has a land area of ± 282 hectares in Kecamatan Cikupa, Kabupaten Tangerang, plans to develop its area. To get a building elevation that is safe against flooding, a flood water level modeling study was carried out in Bukit Tiara Residential. In this study, the analysis carried out is the calculation of planned rainfall, choosing the type of rain distribution, calculating the time of concentration, determining the amount of rain intensity, calculating flood discharge and modeling the water level using the HEC-RAS program. From the results of the analysis and calculations, it is known that there is a need for land exaltation in several areas so that the planned land elevation is safe from the threat of flooding.

Keywords : Flood Water Level Modeling, HEC-RAS, land elevation

1. Introduction

Bukit Tiara Residential, which has a land area of ± 282 hectares in Kecamatan Cikupa, Kabupaten Tangerang, plans to develop its area. To get a building elevation that is safe against flooding, a flood water level modeling study was carried out in Bukit Tiara Residential. The study will be used as a reference in planning the elevation of land and buildings in such a way as to minimize the potential for flooding in the land area.

2. Literature review

The location of this study is from the Cilongok River and Cirarab River segments as well as the channel through the Bukit Tiara Residential which is in the vicinity of the Kecamatan Cikupa, Kabupaten Tangerang, which has the possibility to have an impact on the surrounding area, especially Bukit Tiara Residential.

The condition of the area plan, land topography and river flow are the most basic things in planning. Topographical data of the study location is obtained through secondary data, namely the results of terrestrial topographic measurements carried out/owned by the developer.

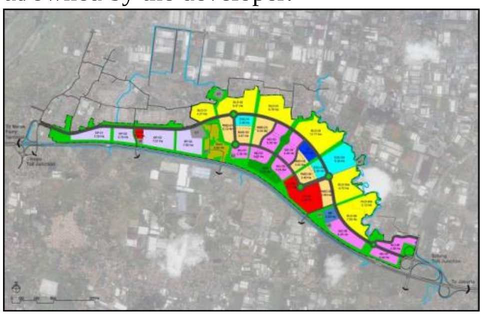

Figure 1. General Map of the Study Location

Channel at Bukit Tiara Cilongok River Cirarab River

Figure 2. River that passes through Bukit Tiara Residential

The hydrological study at the study location will use rainfall data from the nearest BMKG Station, namely Station No. 26a Cengkareng. The maximum daily rainfall data available at the rain station is from 1969-2014.

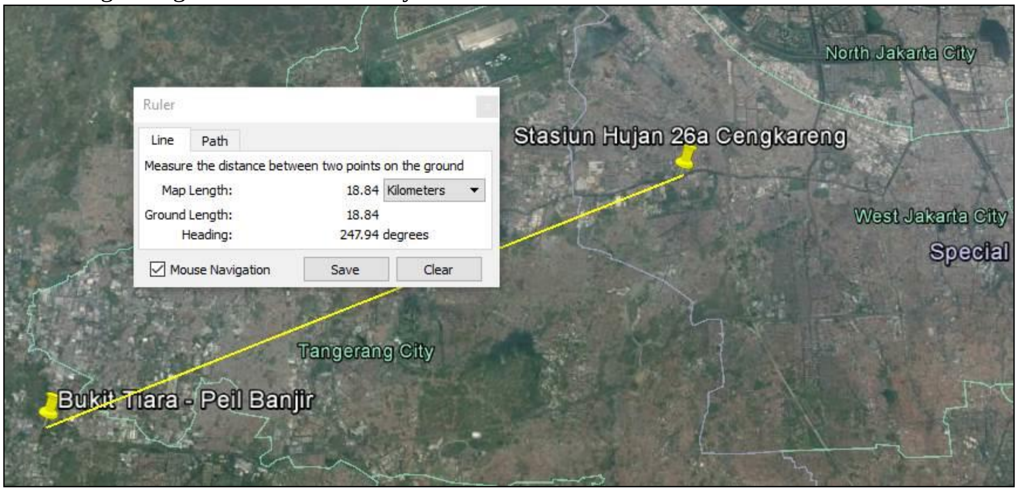

Figure 3. Orientation of BMKG Station Locations

3. Methodology

The process of completing this research can be explained as follows:

1. Preparatory work

Preparatory work includes the preparation of a work planner and work approach methods. In this preparation stage, the collection and evaluation of existing secondary data is also carried out.

2. Field Survey

The main activity at this stage is to collect field data to meet the main needs for flood analysis purposes. The field survey includes:

- Survey of areas causing flooding and existing drainage
- Contour mapping

3. Hydrological Analysis

The scope of this activity includes analysis of flow rates in the area.

4. Hydraulics Analysis

At this stage, the recommended land elevation are modeled Using HEC-RAS.

5. Conclusions and Suggestions

This last activity was carried out in order to provide a picture that is easier to understand from the calculation data that has been done previously.

4. Analysis and discussion

4.1. General Condition of Research Location

This study was conducted in Bukit Tiara Residential, Kabupaten Tangerang, Banten Province with a total area of ± 282 hectares. Existing condition that there is a residential area that has been built and open land ready to build housing.

4.2. Rainfall Data

The rainfall data used for this analysis comes from one of the closest rainfall recording stations, with an observation period of 46 years (1969-2014; Lovrinic,2018). The selection and use of station data is based on the condition of the observation location of the Cirarab River catchment area.

Rainfall data uses the maximum annual rainfall data obtained from BMKG No. 26a Cengkareng 1969-2014 can be seen in the following table.

Table 1. Maximum Daily Rainfall Data for the study location

No.	Year	Maximum Rainfall (mm/day)	No.	Year	Maximum Rainfall (mm/day)
1	1969	53	27	1995	125
2	1970	56	28	1996	107
3	1971	41	29	1997	69
4	1972	40	30	1998	90
5	1973	152	31	1999	130
6	1974	130	32	2000	103
7	1975	88	33	2001	104
8	1976	151	34	2002	88.0
9	1977	142	35	2003	39.0
10	1978	60	36	2004	114.0
11	1979	123	37	2005	158.1
12	1980	86	38	2006	60.0
13	1981	70	39	2007	153.0
14	1982	60	40	2008	317.0
15	1983	112	41	2009	84.0
16	1984	93	42	2010	106.0
17	1985	88	43	2011	110.0
18	1986	139	44	2012	101.0
19	1987	71	45	2013	135.0
20	1988	74	46	2014	104.0
21	1989	100			
22	1990	110	Amount of data		46
23	1991	98	Maximum		317
24	1992	110	Minimum		39
25	1993	136	Average		103.59
26	1994	85	Standard Deviation		45.19

4.3. Catchment Area

In conducting a study of the water system at the activity location, the main thing that needs to be considered is the direction of surface runoff at the activity location and the surrounding catchment areas for the study location, in this case the Cilongok River, the Cirarab River and the channel that flows in Bukit Tiara.

The catchment area of the Cilongok River which has an outlet to the north of the study area is 5.65 km^2, while the catchment area of the Cirarab River which has an outlet to the north of the study area is 57.74 km^2. The catchment area of the channel that flows in Bukit Tiara which has an outlet to the north of the study area is 7.27 km^2.

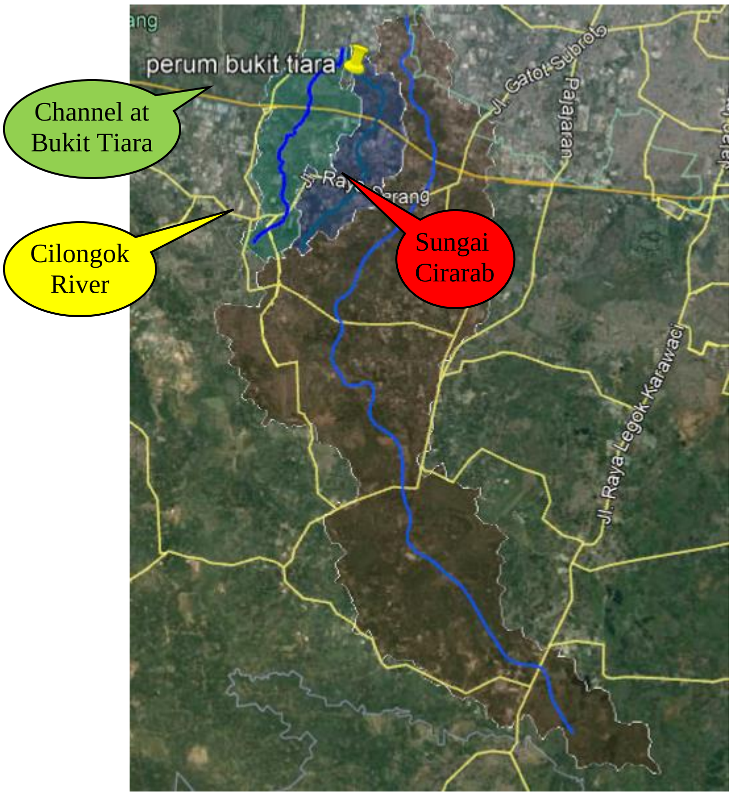

Figure 4. The catchment area of a river flowing through the Bukit Tiara

4.4. Rainfall Analysis

Based on the collected hydrological data, a planned rainfall analysis is then carried out, where the planned rainfall is taken for return periods of 2, 5, 10, 50, and 100 years. The maximum rainfall calculation is done by several methods, namely; Normal Method, Log Normal Method, Gumbel Method, and Log Pearson III Method.

Table 2. Rainfall Frequency Calculation Results

Return Period (Year)	t	Probability Distribution					
		Normal	Lognormal 2 Paramet.	Lognormal 3 Paramet.	Gumbel I	Pearson III	Log Pearson III
2	0.0000	98.8	94.0	98.6	93.8	99.1	97.5
5	0.8416	125.9	122.7	125.8	125.4	125.9	127.3
10	1.2816	140.0	141.1	140.1	146.3	139.8	143.0
20	1.6449	151.6	158.3	152.0	166.4	151.3	155.6
25	1.7507	155.0	163.7	155.5	172.8	154.6	159.2
50	2.0537	164.8	180.1	165.5	192.4	164.1	169.3
100	2.3263	173.5	196.4	174.5	211.8	172.6	177.9
500	2.8782	191.2	233.9	192.8	256.8	189.6	194.0
1000	3.0902	198.0	250.1	199.9	276.1	196.2	199.7

The results of the calculation of the planned rainfall value from each method have different values so that their suitability must be tested for the properties of each type of distribution. This is done by reviewing the statistical parameter boundary requirements of each distribution. Determination of the distribution type can be seen from the statistical parameters of field observation data, namely the values of Cs and Ck. Parameter testing is carried out by the Kolmogorov - Smirnov method. Resume calculation of rainfall station distribution test with each frequency distribution analysis method can be seen in the following table.

Table 3. Resume of Kolmogorov-Smirnov Frequency Analysis Results

Return Period (Year)	t	Probability Distribution					
		Normal	Lognormal 2 Paramet.	Lognormal 3 Paramet.	Gumbel I	Pearson III	Log Pearson III
2	0.0000	98.8	94.0	98.6	93.8	99.1	97.5
5	0.8416	125.9	122.7	125.8	125.4	125.9	127.3
10	1.2816	140.0	141.1	140.1	146.3	139.8	143.0
20	1.6449	151.6	158.3	152.0	166.4	151.3	155.6
25	1.7507	155.0	163.7	155.5	172.8	154.6	159.2
50	2.0537	164.8	180.1	165.5	192.4	164.1	169.3
100	2.3263	173.5	196.4	174.5	211.8	172.6	177.9
500	2.8782	191.2	233.9	192.8	256.8	189.6	194.0
1000	3.0902	198.0	250.1	199.9	276.1	196.2	199.7
Maximum Deviation		6.08	9.90	6.15	9.54	6.09	6.14
Critical Delta (Sig. Lvl 5 %)		21	21	21	21	21	21

From the calculation results, it is concluded that all probability distributions meet the calculation of the frequency test. However, the fit test provides a minimum difference for the Normal distribution. Therefore, for planning in the study location, the results of the frequency analysis for normal distribution are selected with the amount of rain plan as can be seen in the following table.

Table 4. Rainfall Plan

Return Period	Rainfall Plan
2	98.8
5	125.9
10	140.0
20	151.6
25	155.0
50	164.8
100	173.5
500	191.2
1000	198.0

4.5. Discharge Analysis

In the Bukit Tiara study area, no flow rate data were available. For this reason, the design flood calculation uses a runoff rainfall model.

In calculating the flood analysis, river data are needed, including:

• Watershed Area (A)
• River Length (L)
• Average River Slope (i)
• Flow Coefficient (C)

To determine the design flood discharge, flood discharge analysis was carried out using the Nakayasu Synthetic Unit Hydrograph method. The results of the discharge calculation from each channel / river can be seen as follows.

Flood discharge plan channel in Bukit Tiara

Table 5. Hydrological Data of the Channel in Bukit Tiara Watershed

No	Watershed	Area	Main River Length	Flow Coefficient	H_1	H_2	ΔH	Average River Slope
		(Km^2)	(Km)	(C)	(m)	(m)	(m)	(I)
1	S. Bukit Tiara	7.27	6.26	0.800	38.00	21.00	17.00	0.00302

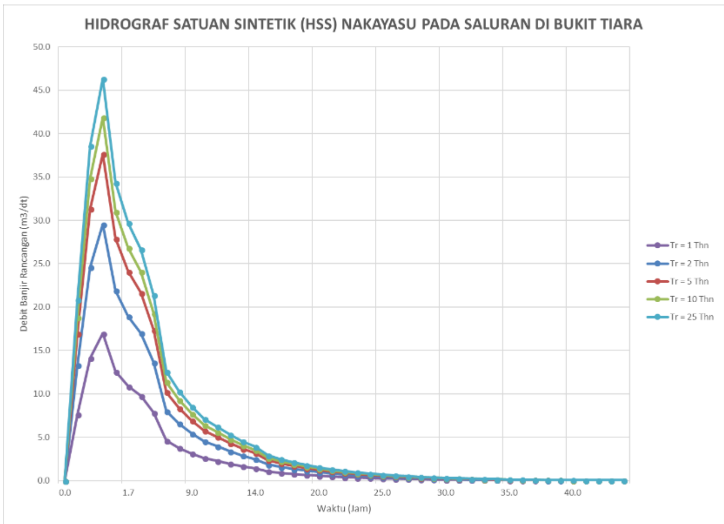

Figure 5. Flood Discharge Hydrograph of the Channel in Bukit Tiara Watershed

From the data mentioned above and based on calculations, the value of flood discharge using the Nakayasu synthetic unit hydrograph method for a 1-year return period is 16.96 m^3/s, for a 2-year return period is 29.55 m^3/s, while the flood discharge for the 10-year return period is 41.87 m^3/s.

Flood discharge plan Cilongok River

Table 6. Hydrological Data of the Cilongok Watershed

No	Watershed	Area	Main River Length	Flow Coefficient	H_1	H_2	ΔH	Average River Slope
		(Km^2)	(Km)	(C)	(m)	(m)	(m)	(I)
1	S. Cilongok	5.65	6.59	0.800	36.00	21.00	15.00	0.00253

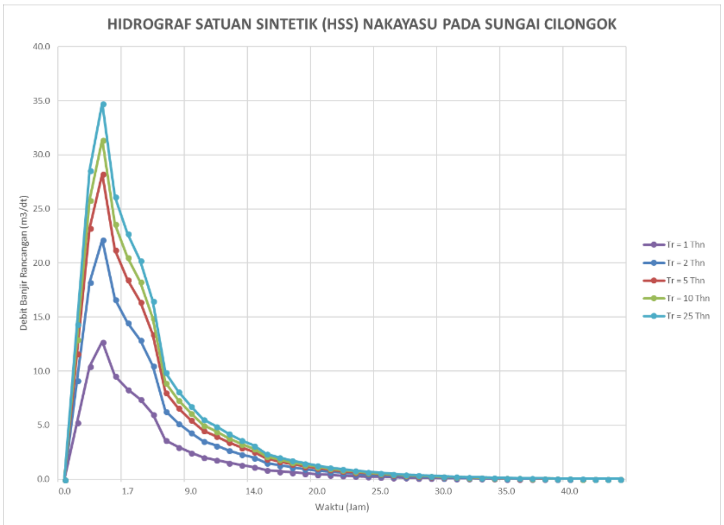

Figure 6. Flood Discharge Hydrograph of the Cilongok Watershed

From the data mentioned above and based on calculations, the value of flood discharge using the Nakayasu synthetic unit hydrograph method for a 1-year return period is 12,73 m^3/s, for a 2-year return period is 22,17 m^3/s, while the flood discharge for the 10-year return period is 31,42 m^3/s.

Flood discharge plan Cirarab River

Table 7. Hydrological Data of the Cilongok Watershed

No	Watershed	Area	Main River Length	Flow Coefficient	H_1	H_2	ΔH	Average River Slope
		(Km^2)	(Km)	(C)	(m)	(m)	(m)	(I)
1	S. Cirarab	57.74	20.98	0.800	69.00	14.00	55.00	0.00291

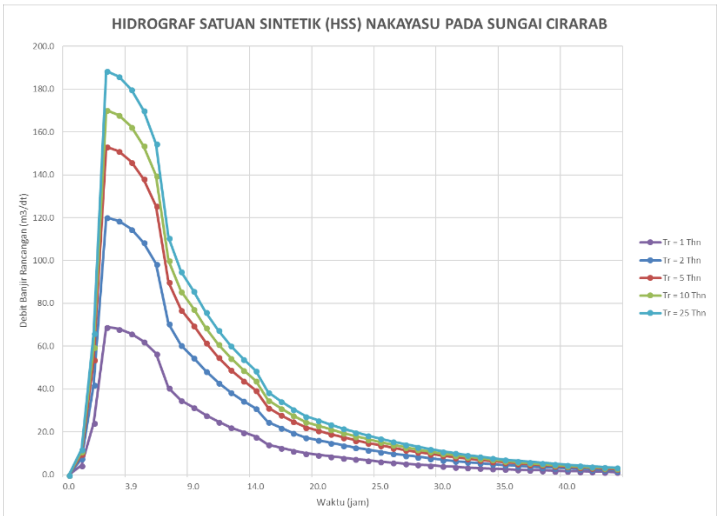

Figure 7. Flood Discharge Hydrograph of the Cirarab Watershed

From the data mentioned above and based on calculations, the value of flood discharge using the Nakayasu synthetic unit hydrograph method for a 1-year return period is 69,0 m^3/s, for a 2-year return period is 120,2 m^3/s, while the flood discharge for the 10-year return period is 170,32 m^3/s.

4.6. Hydraulic Analysis

To know the phenomenon of hydraulic flow behavior in the channel/river or the area that is the object of planning, a numerical simulation/analysis is needed that is able to describe the existing and planned conditions. The analysis was performed using the HEC-RAS 5.0.3 mathematical modeling program.

The purpose of this modeling is to determine the hydraulics of the flow that flows in the channel and the area that crosses the Bukit Tiara Residential Area, so that the elevation of the planned land can be found based on the modeling results. In this modeling will be carried out using 2 2-dimensional modeling scenarios.

1. Scenario 1

This scenario modeling contains channel geometry and land elevation using existing conditions as well as 1 year return period discharge. Schematic and modeling geometry data can be seen in the following figure.

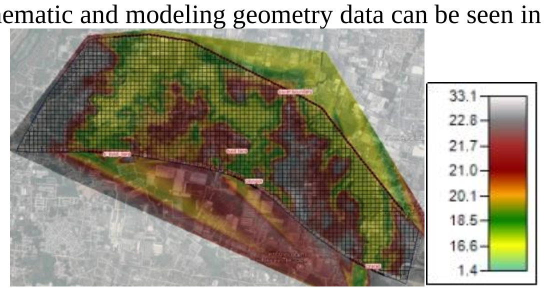

Figure 8. Geometry Data of the Bukit Tiara Residential

The amount of discharge to be served by the channel will act as a boundary condition in this mathematical modeling. The amount of discharge used as input is the flood discharge calculated in the previous sub-chapter, namely the return period of 1 year (Q1) to determine the capacity of each channel and inundation that occurs in the study area.

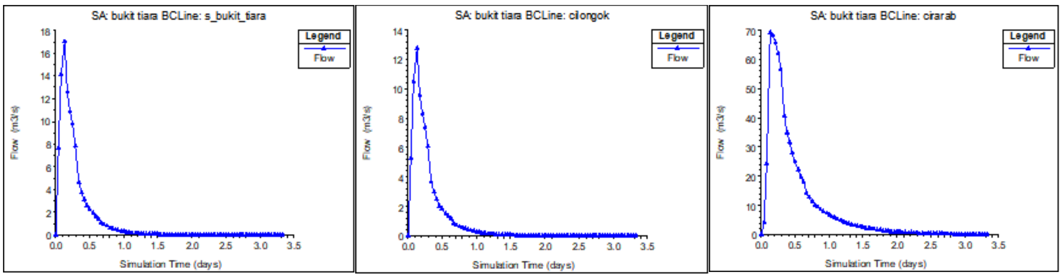

Figure 9. Input discharge of 1-year return period (Q1) for each river

Modeling Results

The modeling results are in the form of a water level profile in the study area at certain time intervals according to what has been determined when the program execution is run for each land height along the channel even in the study area, as well as the discharge and velocity and water level elevation. The modeling results can be seen in the following figure.

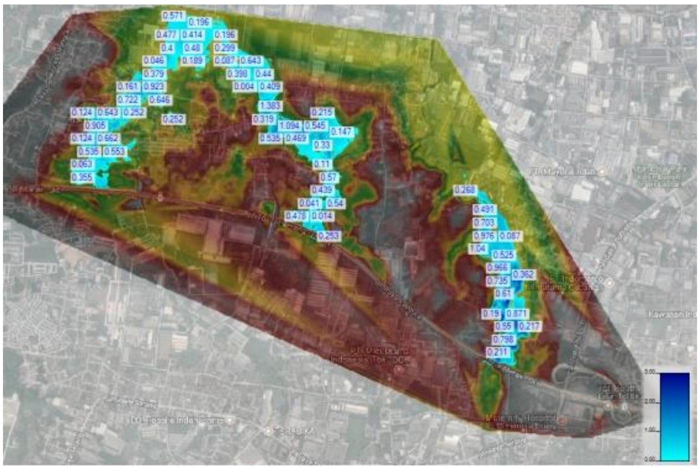

Figure 10. Modeling Results of Maximum Water Level Profiles (Q1)

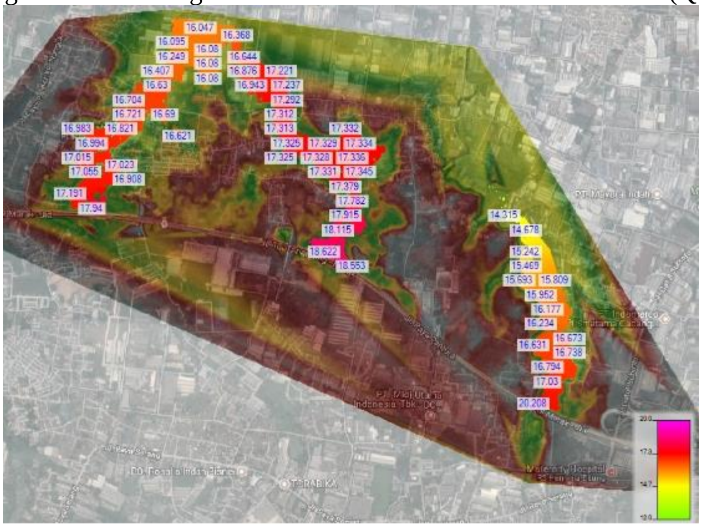

Figure 11. Modeling Results of Water Level Elevation (Q1)

From the results of the above modeling, it can be seen that the height of the inundation and water level in the Bukit Tiara area varies for each channel according to the existing land elevation. For the Bukit Tiara channel area, the maximum water level is 1.29 m with a maximum water level of +17.95 m. For the Cilongok river area, the maximum water level is 1.60 m with a maximum water level of +18.62 m. For the Cirarab river area the maximum water level is 3.0 m with a maximum water level of +20.21 m.

In order to see the effect of greater inundation, scenario 2 modeling was carried out by using the 10-year return period discharge input.

1. Scenario 2

What distinguishes this modeling is the amount of discharge input. The amount of discharge used as input is the return period of 10-years (Q10).

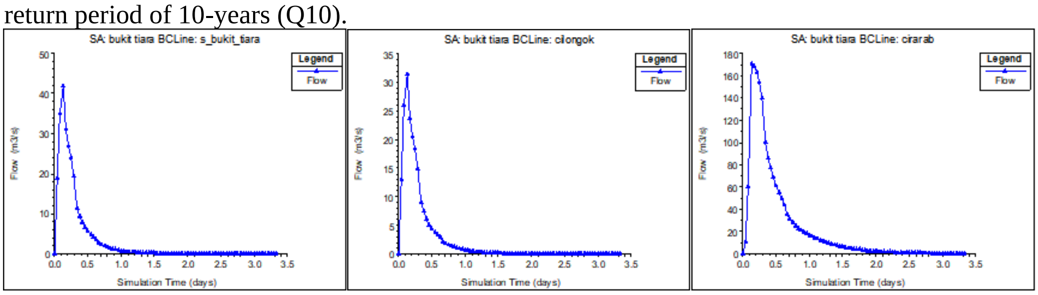

Figure 12. Input discharge of 10-year return period (Q10) for each river

Modeling Results

Modeling results with a 10-year return period discharge input can be seen in the following figure.

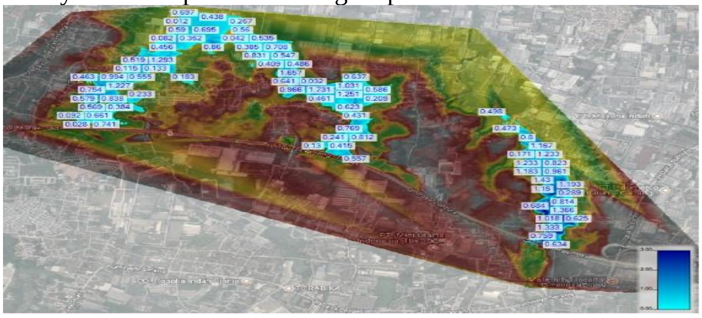

Figure 13. Modeling Results of Maximum Water Level Profiles (Q10)

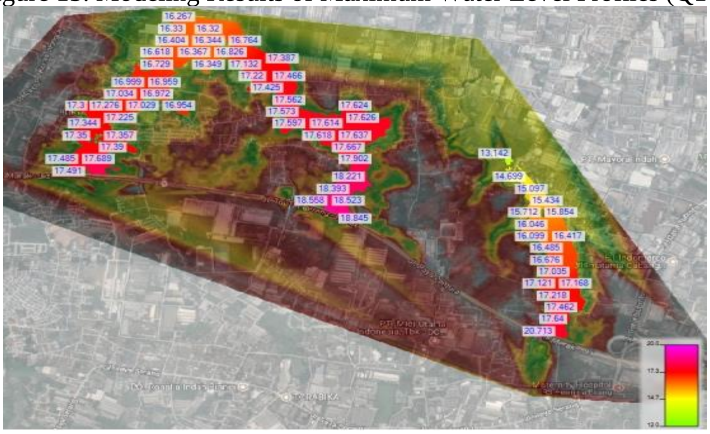

Figure 14. Modeling Results of Water Level Elevation (Q10)

From the results of the above modeling, it can be seen that the height of the inundation and water level in the Bukit Tiara area varies for each channel according to the existing land elevation. For the Bukit Tiara channel area, the maximum water level is 1.6 m with a maximum water level of +18.25 m. For the Cilongok river area the maximum water level is 2.03 m with a maximum water level of +19.10 m. For the Cirarab river area the maximum water level is 3.2 m with a maximum water level of +21.04 m.

The concept of the Bukit Tiara Masterplan and elevation plan can be seen in the following figure.

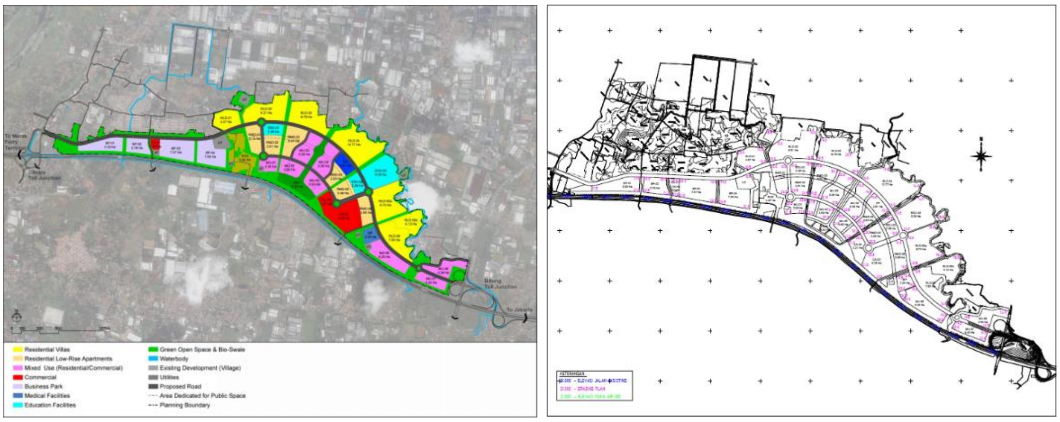

Figure 15. Bukit Tiara Masterplan And Elevation Plan

Based on the Bukit Tiara Masterplan data, the elevation plan of land is obtained as follows:

1. Elevation plan of land in Bukit Tiara channel
   a. Maximum elevation = + 21,5 m
   b. Minimum elevation = + 20,0 m
   c. Average elevation = + 20,5 m
2. Elevation plan of land in Cilongok River
   a. Maximum elevation = + 21,5 m

b. Minimum elevation = + 15,5 m
c. Average elevation = + 18,0 m

3. Elevation plan of land in Cirarab River
a. Maximum elevation = + 20,0 m
b. Minimum elevation = + 13,0 m
c. Average elevation = + 18,0 m

The overlay results between the existing land height, grading plan and water level can be seen as follows.

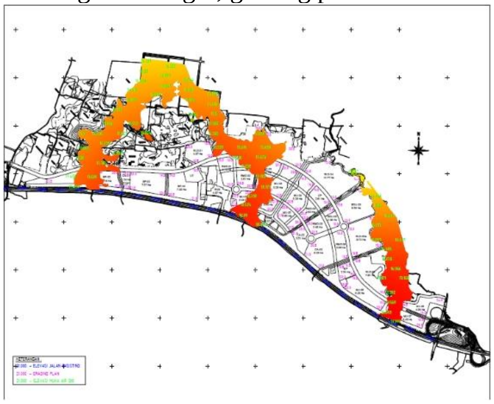

Figure 16. Overlay of the Bukit Tiara Flood Area

5. Conclusions and reccomendations

Based on the results of modeling and overlays that have been done, the following can be seen:

1. The elevation of the planned land for the Bukit Tiara channel area (+20.5 m) is above the flood water level (+18.25 m). So that the elevation of the planned land is safe from the threat of flooding.
2. The planned land elevation for the Cilongok river area (+21.5 m) is above the flood water level (+19.10 m). So that the elevation of the planned land is safe from the threat of flooding. However, in some parts (in an elevation area of +15.5 m) it is necessary to raise the land to be safe from the threat of flooding.
3. The planned land elevation for the Cirarab river area (+13.0 m to +20.0 m) is below the flood water level (+21.04 m). So that the elevation of the planned land is not safe from the threat of flooding. To overcome this, it is necessary to increase the land 1 to 3 m in the area.
4.

Table 8. Resume of Modeling Results and Overlays

No	River/channel	Elevation (m)				Information
		Plan		Flood water level		
		Min	Max	Min	Max	
1	Bukit Tiara	20	21.5	16.27	18.25	Safe
2	Cilongok	15.5	21.5	17.56	19.1	There needs to be an increase in the land in several area
3	Cirarab	18	20	13.14	21.04	

6. Acknowledge

The author would like to thank Mr. Hendra Darmawan, S.T., M.T. as a Senior Engineer and colleagues at Ganesha Reka Consult for the process of making this research so that it can be completed properly.

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