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Flood Model of Downstream Kali Lahar Using HECRAS

(Pemodelan Banjir Hilir Kali Lahar Dengan HEC-RAS)

Ayisya Cindy Harifa[1]*, Fadjar Purnomo[2], Sutikno[3]

[1,2,3] Jurusan Teknik Sipil, Politeknik Negeri Malang - Jl. Soekarno Hatta No.9, Malang, Jawa Timur

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***e-mail corresponding author :**
ayisya_civil@polinema.ac.id

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ABSTRACT

Flooding that occurs in the area around Kali Lahar is a problem that always occurs when the rainy season. This research aims to find the causes of flooding in Kali Lahar, located on Jalan Letjen Sutoyo, Malang City, by considering the hydrological conditions in the Kali Lahar subwatershed. The data used in the analysis is rain data from the Sukun, Ciliwung, and Petungsewu stations, with the same data range between 2008 and 2020. There is also spatial data such as DEMNAS and river networks. The analysis is carried out by modeling floods with synthetic unit hydrographs, which are then modeled with HEC-RAS 1D and 2D software to determine whether the river can accommodate flood discharge with a return period of 10 years. The discharge produced by Unit Hydrograph Nakayasu was 134.25 m^3/s. This discharge is modeled using HECRAS and produces water levels up to 1.5 m above the banks. Increasing the depth of the channel is an alternative solution for flooding in this area. The simulation results of the new dimension show no flooding in the area around the channel. The results of this research can contribute to the planning and arrangement of existing canals in Malang City so that they can prevent or reduce flooding that occurs.

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1. INTRODUCTION

A watershed (DAS) is where rainwater falling in the area will go to the same point, called an outlet. The outlet can be a river, lake, sea, or other body of water. When rain falls on houses, it flows into rivers, so human activities in houses in the region contribute to flooding. Solving flood problems cannot be seen only from one flood point; what must be seen are the watershed activities that occur because each activity contributes greatly to the magnitude of the flood. Activities that affect changes in land function will cause flooding, so proper flood handling is to look at the activities of a watershed system.

Problems in a watershed system must first be understood through physical modeling and mathematical models[1]. Suppose the problem faced in a watershed is drought. In that case, the solution of planting trees will not be effective because the trees will consume more water, and the leaf headers will intercept rainwater and evaporate back into the air[2].

Floods in the city of Malang are not uncommon. Even when every rainy season arrives, there are floods in several locations. As in a study conducted in 2020, which discussed surface runoff in Jalan Veteran Malang City, the influence of land use is one of the factors influencing flooding [3]. Inundation is also a significant problem in Purwantoro Village; changes in land use and the ineffectiveness of drainage channels are factors causing flooding in this area [4]. Likewise, Jalan Letjen Sutoyo is an area affected by the overflow of water from the Lava River [5]. Water overflow from Kali Lahar always occurs during rainy conditions with a fairly high intensity and a long duration. This study was conducted to determine whether the water flowing along Jalan Letjen Sutoyo could accommodate floods with a 10-year return period discharge. Also, to see the flood pattern that occurs in Kali Lahar, taking into account the area Catchment area, which is formed from the boundaries of the ridge. The catchment area is much larger than previous research on the evaluation of drainage channels in the Channel along Jalan Letjen Sutoyo [5].

2. METHOD

This research was conducted on the Kali Lahar Sub-watershed in Malang District and Regency, East Java Province. Based on the delineation process of the catchment area, the basin area was obtained at 940.3 Ha.

The tools used in the analysis process include ArcMap 10.4 software for spatial analysis and HEC-RAS for flood modeling. Rain data for analysis was obtained from three stations: Sukun Station, Ciliwung Station, and Petungsewu Station, with a range from 2008 until 2020. Spatial data such as river networks and the Digital Elevation Model (DEM) shown in Figure 2, which is used to create catchment area boundaries, were obtained from the Geospatial Agency. Land use data from BING satellite images in 2020, as shown in Figure 1, was also used.

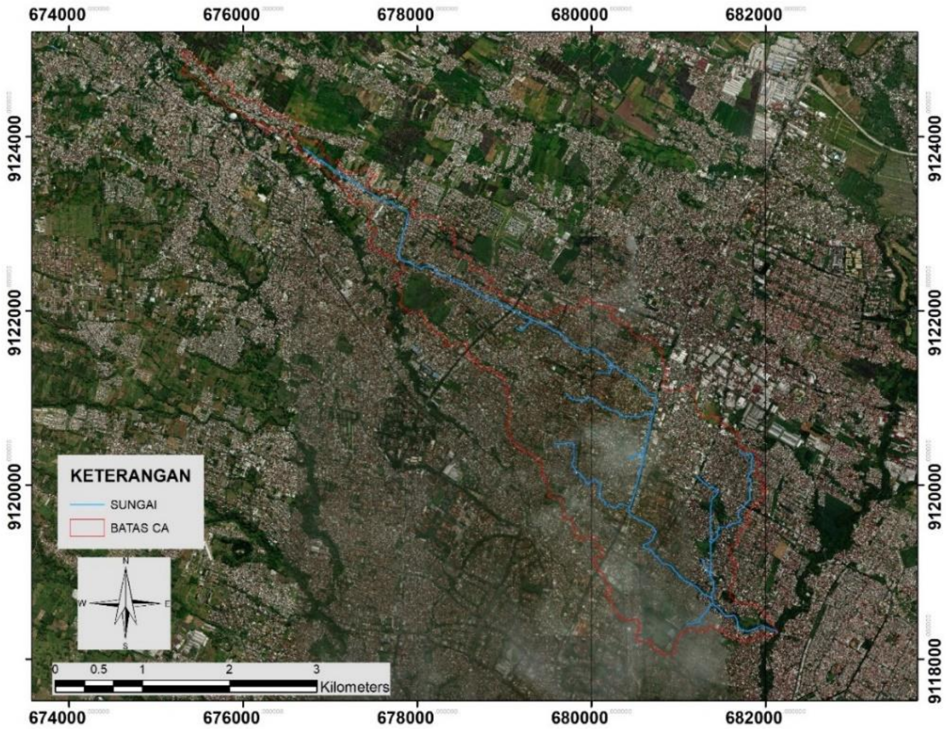

Figure 1. Catchment Area Boundary of Kali Lahar

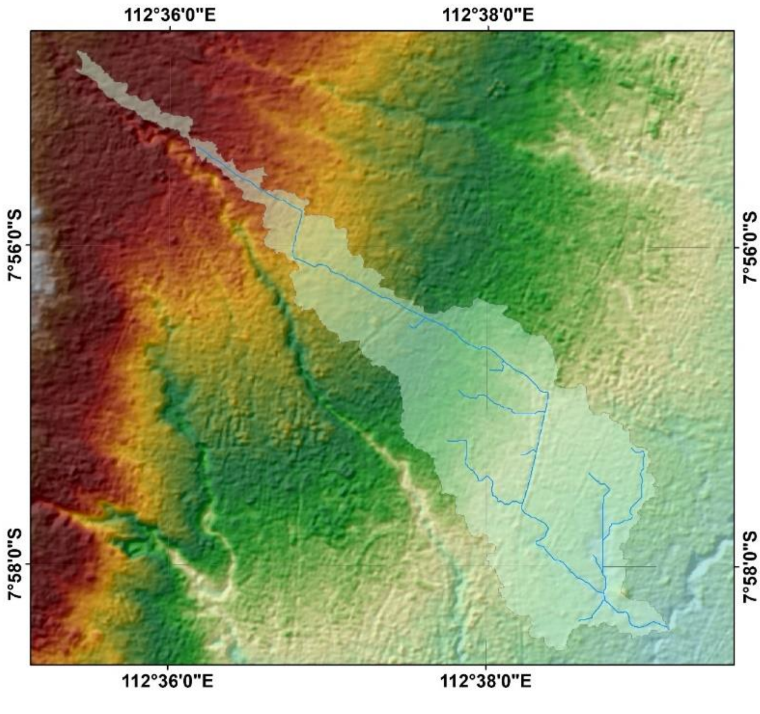

Figure 2. Digital Elevation Model and Stream Network

The stages of this research analysis are as follows:

1. Collecting Data

   The process of collecting secondary data, such as rain data, DEM, and spatial data, such as river networks projected first in the UTM 49S zone, is needed for model making.

2. Rainfall Data Analysis
   - Rain data is tested for data consistency using the Double Mass Curve method.
   - Furthermore, the calculation of rain distribution to find the distribution of rain using the PSA-007 method.
   - Then calculate the design rainfall using return period of 1.01, 2, 5, 10, 20, 25, 50, 100, 200 and 1000 years
   - Then calculate design flood using return period of 1.01, 2, 5, 10, 20, 25, 50, 100, 200 and 1000 years with the Nakayasu method

   The equation of discharge quantity by the Nakayasu method is obtained by the equation:

$$Qp = \frac{A.Ro}{3{,}6.(0{,}3T_p + T_{0,3})}$$

Keterangan:
Qp = Flood Peak flow rate (m^3/s)
A = Watershed Area (Km^2)
R_o = Unit Rain (mm)
Tp = Time Interval from the beginning of the rain until the flood's peak unit (mm)
$T_{0.3}$ = the time required by a decrease of peak discharge up to 30% of peak discharge up to 30% of peak discharge (hr)

In the graph (figure 3), the supporting parameters in a flooded hydrograph of the Nakayu Method are described.

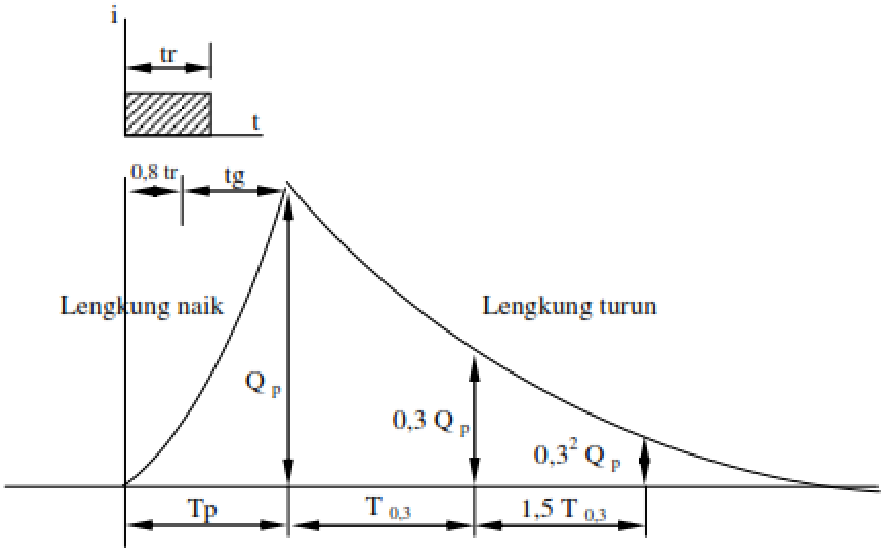

Figure 3. Graph of Nakayasu Hydrograph [6]

3. Using Ras-Mapper to make cross section
4. Input terrain data to the HECRAS model. The program is designed to calculate water table profiles for steady and unsteady flows in both natural and artificial channels [6].

The purpose of hydraulics analysis here is to determine the flow and profile of the river water level against flooding with a certain recurrence so that the maximum water level that occurs along the river under review can be known[7].

5. input the geometri data in HEC-RAS
6. *running* model
7. Flood mapping

3. RESULT AND DISCUSSION

A. HYDROLOGY ANALYSIS

Rainfall is the amount of water that falls on the ground surface over a certain period of time, which will further undergo processes of evaporation, runoff, and infiltration, measured in mm [8]. In this study, rain data was used from measurements of three adjacent stations, namely Ciliwung station, Sukun station, and Petungsewu station, with the data source being the related agency. The range of rain data from all three stations is the same, from 2008 to 2020. Table 1 shows a recapitulation of rain data from Ciliwung station, Sukun station, and Petungsewu station.

Table 1. Summary of Maximum Rainfall Data

Year	STA. SUKUN (mm)	STA. CILIWUNG (mm)	STA. PETUNGSEWU (mm)
2008	85	95	72
2009	79	73	84
2010	178	186	110
2011	101	113	85
2012	125	138	97
2013	101	93	85
2014	134	125	100
2015	170	98	65
2016	122	64	75
2017	132	104	105
2018	94	97	95
2019	135	82	93
2020	125	97	145

Reference: Result of Analysis

The rainfall data will then be used to calculate the area's average rainfall; Thiessen's polygon method, which provides a ratio of areas affected by rain to account for distance inconsistencies, is used. The zone of influence is formed by drawing an axis perpendicular to the line connecting the two nearest train stations [9]. Based on the location of the three stations, the extent of influence of each rain station on the study area is as follows (**Table 2**). Sukun Station has an area of influence of 3,965 Km^2, Ciliwung Station has an area of influence of 4,869 Km^2, and Petungsewu Station of 0,570 Km^2. The area is then compared with the area of the catchment area so that the Thiessen coefficient is obtained. Sukun Station has a Thiessen coefficient of 0.422, Ciliwung Station has 0.518, and Petungsewu Station has 0.061. Furthermore, this coefficient will later be used for the calculation of the average rain in the region.

Table 2. Area Of Influence By Rainfall Station At Kali Lahar Catchment Area

No.	Name	Area (km^2)	Thiessen Coef.
1.	Sta. Sukun	3.965	0.422
2.	Sta. Ciliwung	4.869	0.518
3.	Sta. Petungsewu	0.570	0.061
	Jumlah	9.403	1.000

Reference: Result of Analysis

The area in Table 2 is obtained based on the Polygon shown in Figure 4. The rain station is outside the catchment area, but the rain station still has an influence on the study area. Figure 3 below shows that the rain station that has a major influence is the Ciliwung station, with an area of influence of up to 4,868 km^2, because it has a location that is quite close to the catchment area. Meanwhile, the Petung Sewu rain station has an influence of only 0.57 km^2 in the downstream catchment area.

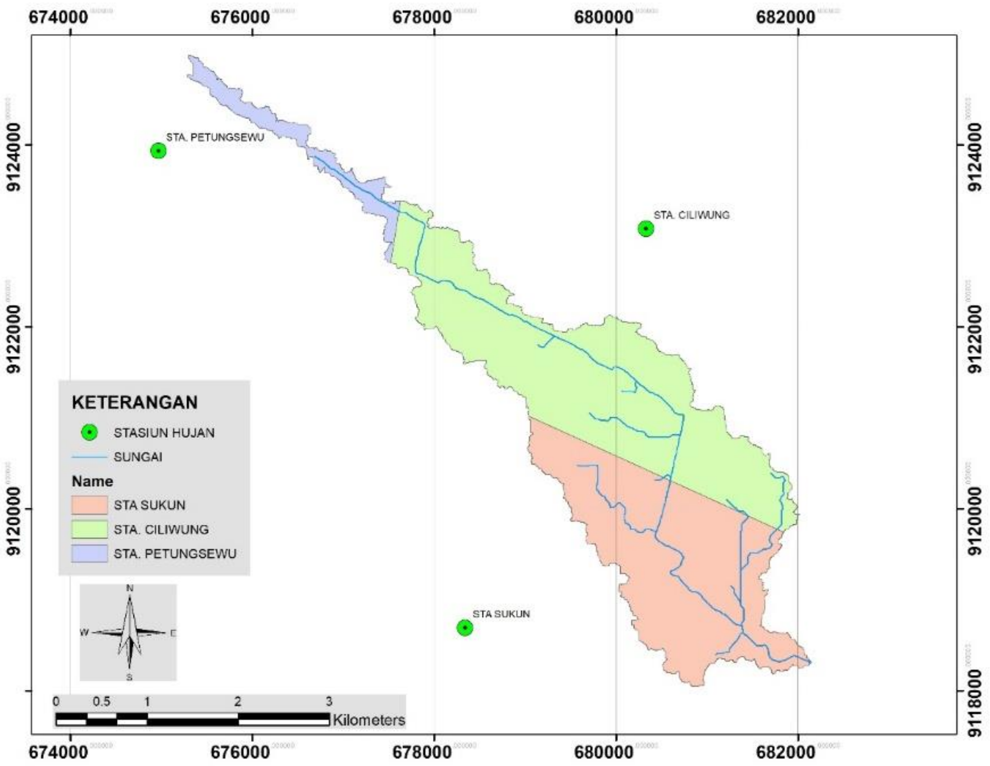

Figure 4. Thiessen Polygon For Mean Precipitation Calculation at Kali Lahar Catchment Area

Determination of mean area rainfall, using the maximum rainfall of each year and stations. In 2020, the Ciliwung station had a maximum rainfall of 122.42 mm, which occurred on March 31; then, on the same date, rain was also sought at two other stations. Thiessen's coefficient will be a multiplier in determining the average rainfall of the three stations. Regional rain represents the maximum rain from all three stations. Table 3 is a calculation of regional rainfall from the Suku Station, Ciliwung, and Petungsewu starting from 2008 to 2020.

Table 3. Precipitation Mean for Kali Lahar Catchment Area

Year	Date	STA SUKUN (mm)	STA CILIWUNG (mm)	STA PETUNGSEWU (mm)	Average	Max. Mean Precip.
2020	31-Mar	122.42	0.00	13.34	52.42	68.413
	22-Mar	0.00	132.13	0.00	68.41	
	3-Mar	60.72	64.02	107.45	65.26	
2019	10-Feb	132.21	76.28	44.46	97.94	97.936
	11-Feb	0.00	111.70	3.71	58.06	
	13-Mar	49.95	0.00	68.92	25.24	
2018	24-Feb	92.06	0.00	0.00	38.82	95.425
	21-Jun	62.68	132.13	9.63	95.42	
	5-Feb	26.44	34.05	70.40	33.05	
2017	1-Apr	129.28	27.24	23.71	70.05	97.507
	4-Apr	54.84	141.67	17.04	97.51	
	26-Mar	98.92	54.49	77.81	74.63	
2016	29-Jun	119.48	61.30	25.94	83.69	83.687
	12-Apr	54.84	87.18	18.53	69.39	
	2-Feb	36.24	68.11	55.58	53.91	
2015	29-Mar	170.00	0.00	50.00	74.71	74.707
	3-May	12.00	98.00	10.00	56.41	
	1-Dec	31.00	61.00	65.00	48.59	
2014	26-Apr	134.00	56.00	15.00	86.40	86.402
	27-Apr	0.00	125.00	30.00	66.54	
	5-Jan	12.00	89.00	100.00	57.20	
2013	29-Mar	101.00	25.00	5.00	55.83	73.779
	8-Dec	50.00	93.00	75.00	73.78	
	26-Nov	33.00	15.00	85.00	26.83	
2012	3-Dec	125.00	40.00	34.00	75.47	90.979
	20-Nov	42.00	138.00	30.00	90.98	
	13-Mar	1.00	19.00	97.00	16.14	
2011	21-Dec	101.00	22.00	20.00	55.19	60.084
	26-Mar	0.00	113.00	26.00	60.08	
	13-Feb	0.00	2.00	85.00	6.19	
2010	8-Nov	178.00	186.00	102.00	177.54	177.536
	8-Nov	178.00	186.00	102.00	177.54	
	5-Mar	35.00	111.00	84.00	77.32	
2009	24-Jan	79.00	0.00	0.00	33.31	41.431
	21-Feb	1.00	73.00	53.00	41.43	
	12-Jun	0.00	0.00	72.00	4.36	
2008	14-Dec	85.00	5.00	16.00	39.40	55.336
	30-Mar	13.00	95.00	11.00	55.34	
	29 Feb	17.00	27.00	72.00	25.51	

Reference: Result of Analysis

After the average rainfall area is obtained, the next step is to calculate statistical values to obtain a method for calculating the draft rain. The selection of rain distribution methods is based on the selection of static parameters, namely average rain, standard deviation, density coefficient, kurtosis coefficient and variance coefficient[5] shown in Table 4. The data used to calculate these statistical parameters are used in a recapitulation of the average rain area obtained from table 3 which has been sorted from smallest to largest values. Based on this coefficient, it is found that the method that can be used is the Log Pearson Type III method.

Table 4. Statistic result Calculation from Precipitation Mean

No.	Year	Prec. Mean (mm)
1.	2009	41.431
2.	2008	55.336
3.	2011	60.084
4.	2020	68.413
5.	2013	73.779
6.	2015	74.707
7.	2016	83.687
8.	2014	86.402
9.	2012	90.979
10.	2018	95.425
11.	2017	97.507
12.	2019	97.936
13.	2010	177.536
Average		84.863
Sd		32.839
Cs		1.868
Ck		6.406
Cv		0.387

Reference: Result of Analysis

Based on statistical calculations, shown in Table 4, the average regional rain is 84,863 mm, with a standard deviation (Sd) of 32,839, an astonishment (Cs) of 1,868, a kurtosis coefficient (Ck) of 6,406, and a variance coefficient (Cv) of 0.387. Then, the statistical value is calculated, and a result of 1.903 is obtained for the average, with a standard deviation of 0.151. Then, look for the K value, based on the Log Person III table, and get the K value as in Table 5, according to the opportunity sought. Then, calculate the design rain with the log Person III equation, obtaining the results as in Table 5.

Table 5. Result of Design Rainfall Calculation

No	Tr	R Average	Stand. Deviation	Probability	K	Design Rainfall	
	(yr)	(Log)	(log)	(%)		Log	mm
1	1.01	1.903	0.151	99.000	-2.040	1.595	39.312
2	2	1.903	0.151	50.000	-1.528	1.672	46.981
3	5	1.903	0.151	20.000	-1.233	1.717	52.077
4	10	1.903	0.151	10.000	-0.855	1.774	59.416
5	20	1.903	0.151	5.000	-0.064	1.894	78.277
6	25	1.903	0.151	4.000	0.817	2.027	106.405
7	50	1.903	0.151	2.000	1.316	2.102	126.603
8	100	1.903	0.151	1.000	1.689	2.159	144.185
9	200	1.903	0.151	0.500	1.876	2.187	153.872
10	1000	1.903	0.151	0.100	2.102	2.222	166.537

Reference: Result of Analysis

The 1.01-year return period yielded 39,312 mm, while the largest draft rainfall was 166,537 mm for the 1000-year anniversary. The results of this design rain calculation will be used as input for the calculation of design discharge with a repeat time of 1.01, 2, 5, 10, 20, 25, 50, 100, 200, and 1000 years.

The next calculation is the calculation of rain distribution method PSA-007. The pattern of rain distribution is obtained if there are rain posts in the study area. Based on mutilation data, large rainfall events were selected, and an average pattern replaced the area. If there is no rain post, patterns are used from other regions whose conditions resemble the area studied[10]. The pattern of the reference study area cannot be directly used because the tempo pattern of each region is different.

Table 6 shows the relationship between CMB/PMP precipitation over 1 to 24 hours, and PSA-007 shows the distribution of rain over 1 to 12 hours and 1 to 24 hours. The high intensity of rain at the beginning of the rain then decreases as the rain progresses.

The following is a table calculating the distribution of rain hours using the PSA 007 method. Rain is distributed more and more in a small percentage because the duration of rain will be smaller and smaller. So, the longer the duration, the more the percentage of rain will be reduced.

Table 6. Calculation Result of Distribuition Rainfall Using PSA-007

Return Period	R_{24}	R_6		Rainfall Distribution (mm) Time					
(yr)	(mm)	(%)	(mm)	1	2	3	4	5	6
1.01	48.47	79.60	38.58	1.54	2.16	27.62	4.17	1.54	1.54
2	98.56	79.20	78.06	3.12	4.58	55.58	8.53	3.12	3.12
5	128.60	78.00	100.30	4.01	6.69	70.21	11.37	4.01	4.01

Return Period	R_{24}	R_6		Rainfall Distribution (mm)					
				Time					
(yr)	(mm)	(%)	(mm)	1	2	3	4	5	6
10	148.08	76.00	112.54	4.50	9.00	76.53	13.51	4.50	4.50
25	163.44	75.00	122.58	4.90	10.62	82.13	15.12	4.90	4.90
50	171.70	73.00	125.34	5.01	12.53	81.47	16.29	5.01	5.01
100	190.27	72.00	137.00	5.48	14.61	87.68	18.27	5.48	5.48
200	208.09	71.67	149.13	5.97	16.24	94.95	20.05	5.97	5.97
1000	268.25	69.00	185.09	7.40	23.44	112.91	26.53	7.40	7.40

Reference: Result of Analysis

The idea that the drainage area system affects the conversion of rain into flow due to translation and storage is the basis of synthetic unit hydrographs. Some of the parameters required to analyze the Nakayasu cystic unit hydrograph are as follows.[11]:

1. time to peak magnitude
2. time lag
3. time base of hydrograf
4. catchment area
5. Length of river
6. Convayance coefficient

The parameters used in the calculation of HSS Nakayasu include:

1. Watershed Area: 9.4 Km^2
2. Length of main stream: 1 km
3. Time lag : 0.21 hr
4. Time peak : 0.38 hr

Then, based on these parameters calculated, hydrograph units for each hour are illustrated through graphs of hydrograph units in Figure 5. The results of the calculation of the hydrograph unit showed that the fastest time for an increase in discharge is 1 hour, with a discharge of 1.07 m3/s.

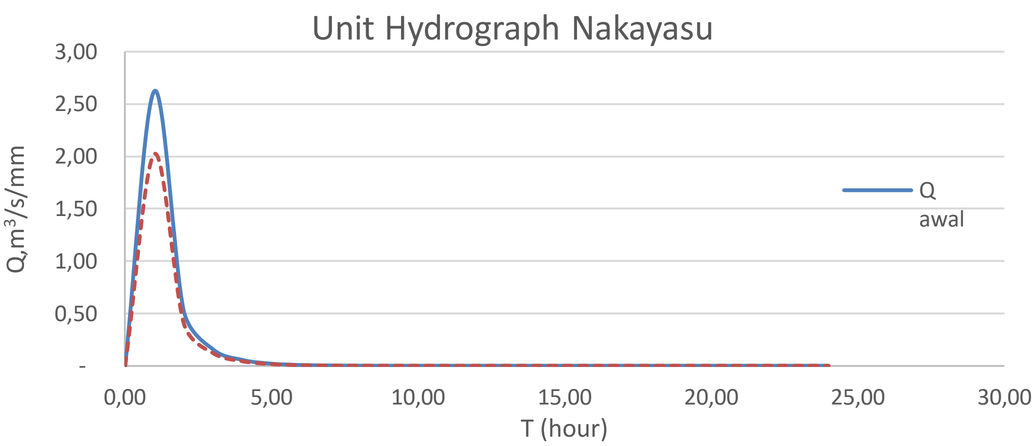

Figure 5. Unit Hidrograph Curve Using Nakayasu Method

Table 7. Unit Hydrograph Using Nakayasu Method

No.	t hour	$Q_{initial}$ (m^3/s/mm)
1	0.00	-
2	1.00	1.07
3	2.00	0.30
4	3.00	0.12
5	4.00	0.04
6	5.00	0.02
7	6.00	0.01
8	7.00	0.00
9	8.00	0.00
10	9.00	0.00
11	10.00	0.00
12	11.00	0.00
13	12.00	0.00
14	13.00	0.00
15	14.00	0.00
16	15.00	0.00
17	16.00	0.00
18	17.00	0.00
19	18.00	0.00
20	19.00	0.00
21	20.00	0.00
22	21.00	0.00
23	22.00	0.00
24	23.00	0.00

Reference: Result of Analysis

The results of the Q unit are used as the basis for making hydrographs of the Nakayasu method synthesis unit. In addition, rain parameters are also an input in making this synthesis unit hydrograph. The result obtained in the calculation for each repeat is that the largest discharge occurs at the 3rd hour. All recurrences show the same trend.

Table 8. Discharge Calculation Using NaKayasu

No	t	Q	Design Flood Discharge for Each Return Period (m^3/s)								
	hour	m^3/s/mm	1.01yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	200 yr	1000 yr
1	0.00	-	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
2	1.00	2.02	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
3	2.00	0.40	0.39	0.39	0.39	0.39	0.39	1.70	5.90	9.19	23.76
4	3.00	0.12	35.34	91.88	121.48	134.25	145.57	144.51	157.89	173.25	212.47
5	4.00	0.04	7.36	18.63	24.52	27.07	29.33	29.14	31.89	35.02	43.12
7	6.00	0.01	1.13	2.32	3.47	4.61	5.50	5.95	7.04	8.10	11.58
8	7.00	0.00	0.65	1.08	1.45	1.81	2.09	2.22	2.56	2.90	3.99
9	8.00	0.00	0.48	0.63	0.77	0.89	0.99	1.04	1.16	1.28	1.67
10	9.00	0.00	0.42	0.48	0.52	0.57	0.60	0.62	0.66	0.71	0.84
11	10.00	0.00	0.40	0.42	0.44	0.45	0.47	0.47	0.49	0.50	0.55
12	11.00	0.00	0.39	0.40	0.41	0.41	0.42	0.42	0.42	0.43	0.45
13	12.00	0.00	0.39	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.41
14	13.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.40

No	t	Q	Design Flood Discharge for Each Return Period (m^3/s)								
	hour	$m^3/s/mm$	**1.01yr**	**2 yr**	**5 yr**	**10 yr**	**25 yr**	**50 yr**	**100 yr**	**200 yr**	**1000 yr**
15	14.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
16	15.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
17	16.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
18	17.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
19	18.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
20	19.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
21	20.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
22	21.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
23	22.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
24	23.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
25	24.00	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Max. Discharge			**35.34**	**91.88**	**121.48**	**134.25**	**145.57**	**144.51**	**157.89**	**173.25**	**212.47**

B. FLOOD ANALYSIS USING HECRAS 2D

HEC-RAS is one of the software that can be downloaded without paying. This program is designed to benefit from water table image analysis for steady and unsteady flows in natural channels and channels. The main purpose of HEC-RAS is to calculate the elevation of the water table at the location of the transverse view studied along the river [12]. Cross-sectional analysis of the river using HEC-RAS, which was carried out in this study as in the simulation conducted on the Ciberang River; in the Ciberang River simulation with a 50-year birthday, the channel could not accommodate discharge, then river normalization was carried out by enlarging the dimensions of the river [13].

This study used 2D simulations, such as those used in HEC-RAS modeling in the Welang watershed. Modeling using 2D is used to identify inundation patterns that occur in the area around Kali Lahar. The discharge used for the simulation is the result of calculations using the Nakayasu HSS method with a 10-year return period. Lava river modeling was carried out on rivers along 4.28 km on the main river and 1.11 km on branch rivers. Figure 7 shows the simulated flood distribution pattern with HEC-RAS for steady flow types.

The geometry is built on the model using RAS Mapper, with Digital Elevation Model data, from DEMNAS in Lowokwaru and Blimbing Districts of Malang City with UTM 49S projection zone. Cross-section intervals are made on the RAS Mapper so that the distance between stations is irregular; cross-sections are made of as many as 152 pieces along the main river and 106 along the branch river. In this simulation, modeling is considered using open channels, so it does not include river building variables such as culverts, bridges, and other river protection buildings.

The simulation of inundation patterns in the main river Kali Lava uses the type of unsteady flow, using a slope of 0.012 from the average slope of the river. The flood interval is used according to the hydrograph calculation, which is 1 hour, for branch rivers, which use unsteady flow as well, with a gentler slope of 0.013. The discharge interval also uses 1 hour. Simulated main river and branches within the same time of 48 hours.

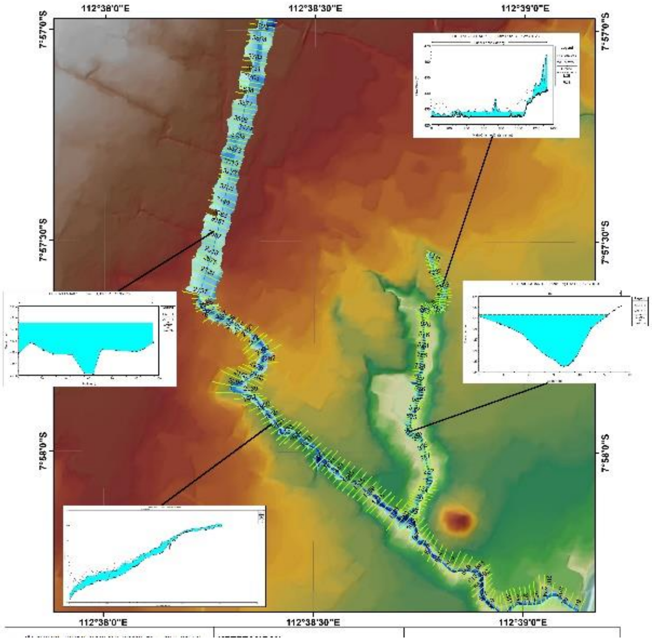

Figure 6. HEC-RAS Simulation Result Map

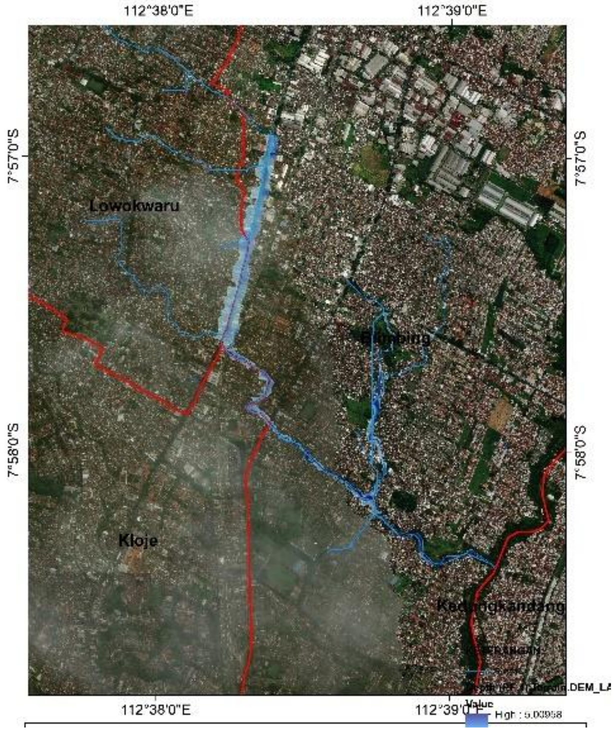

Figure 7. Flood Pattern of Q_{10}

The results of steady flow simulation with Q10 discharge of 134.25 m^3/s for the main river and 39.89 m^3/s for branch rivers obtained flood heights up to a height of 1.3 m from the left border boundary at sta. 3433 with a puddle area of 15 Ha at the starting point of the river channel along Jalan Letjen Pandjaitan to Jalan Letjen Sutoyo Lowokwaru and 3 Ha in Blimbing District through which the Kali Lahar branch passes, the flood height at the branch is up to 1.2 m from the highest river border. The area affected by the inundation is a settlement and shops along Jalan Letjen Pandjaitan and Jalan Letjen Sutoyo up to 50 m towards the settlement, as shown in Figure 8. The condition of the flow profile on the main river and branches, shown in Figures 8 and 9, shows that many flows exceed the boundary line, which is an indicator that there is an overflow of flow from the river, causing flooding around residential areas and shops.

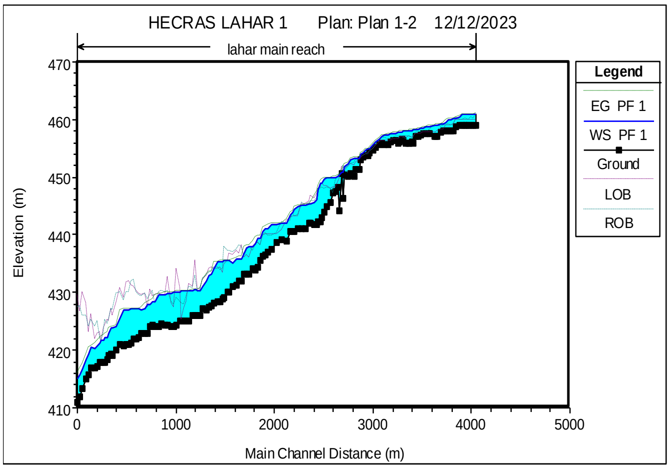

Figure 8. Long Section of Main River, Steady Flow Simulation

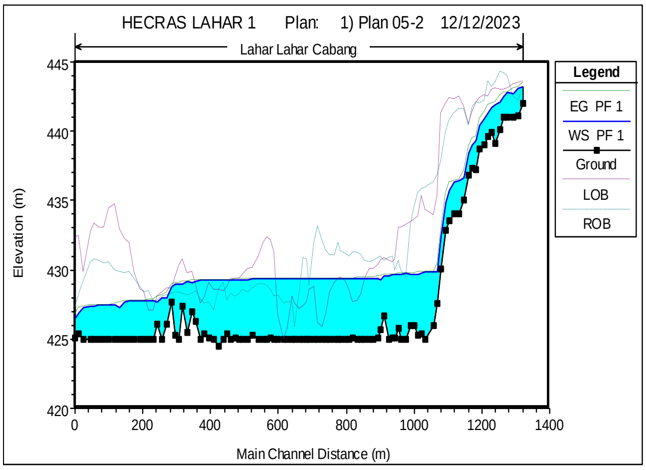

Figure 9. Long Section of Branch, Steady Flow Simulation

C. FLOOD CONTROLLING

The recommended alternative flood management is river normalization, either by dredging or increasing the depth of the existing channel so that the channel capacity is sufficient to drain the planned discharge. River normalization planning with channel bottom slope adjustment, upstream slope is planned at 0.00987 for STA. 4069 to STA.2666. Downstream uses a slope of 0.01051 for STA. 2636 to STA. 19, as in Figure 10. on STA 4069 to STA. 2666 uses a base width of 5 m, a channel height of 3 m, and a side slope of 0.3 using a manning of 0.025, as shown in Figure 11. While STA. 2636 to STA. 19 uses a base width of 5 m, a channel height of 1.8 m, a side slope of 0.3, and a manning of 0.025, as Figure 12.

The plan of adding channel depth and setting the base slope of the channel was simulated using HECRAS as well. So that the geometry/cross channel is adjusted following the results of changes in channel dimensions on the main river. The addition of channel depth is quite effective in overcoming flooding in the river (Figure 13); the simulation results of the new dimensions of the channel do not show any flooding along the river located on Jalan Letjen Padjaitan and Letjen Sutoyo. Widening the dimensions of the channel cannot be done considering the urban conditions are quite dense; costs will swell if widening is implemented.

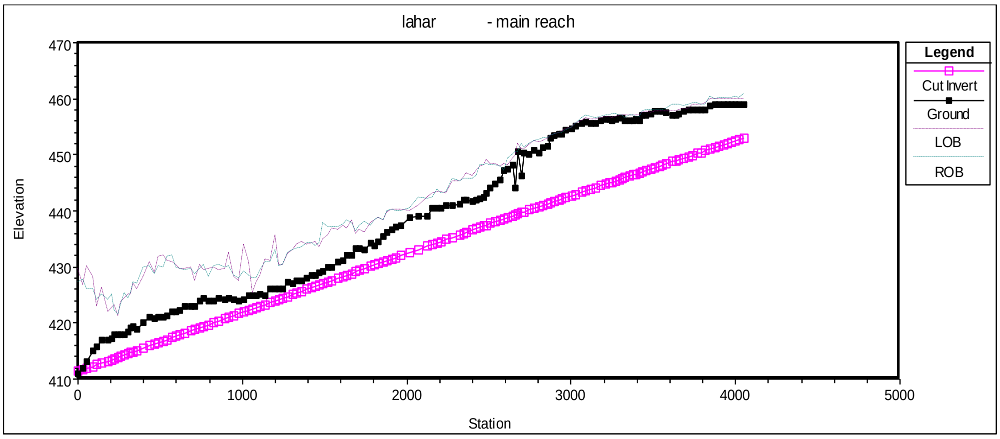

Figure 10. New Slope for Main River

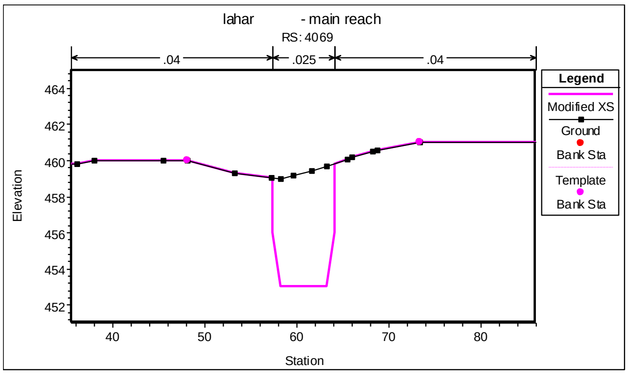

Figure 11. New Dimension for STA. 4069 Until STA.2666

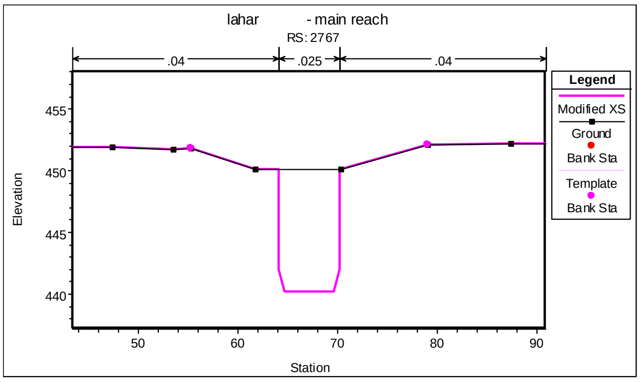

Figure 12. New Dimention For STA. 2636 Until STA.19

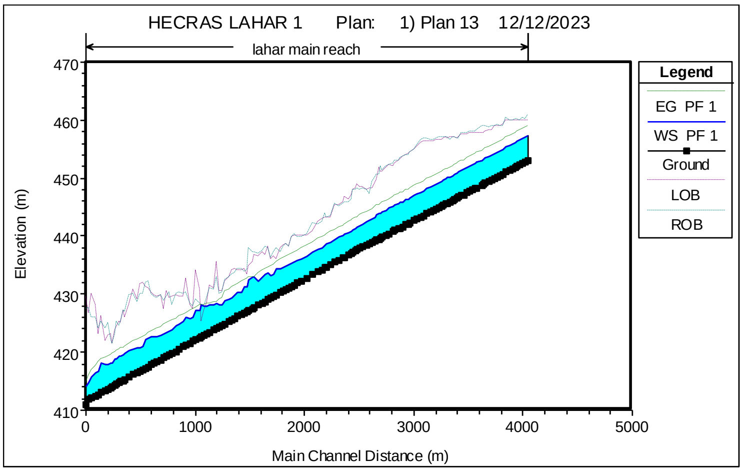

Figure 13. Long section from new design channel and slope

4. CONCLUSION

Based on the results of the HECRAS model analysis for existing conditions, it was found that the channel capacity could not accommodate flooding, which was the main factor in flooding problems that occurred along Jalan Letjen Sutoyo. Simulations of existing conditions show an overflow in the main river occurring in STAs. 4069 to STA. 2666 with maximum altitude occurs at STA. with a height of 1.3 m at STA.3433, while STA. 479 to 693 for Kali Lahar branches with a height of up to 1.2 m.

Flood management carried out by normalizing the river will produce dimensions and slopes that can reduce flooding. The proposed new dimensions are a base width of 5 m, a channel height of 3 m, and a side slope of 0.3 for STA. 4069 to STA.2666 with a slope of 0.00987, a base width of 5 m, a channel height of 1.8 m, and a side slope of 0.3 with a slope of 0.01051 for STA. 2636 to STA. 19.

5. REFERENCES

[1] R. N. Adawiyah, Y. Setiawan, and Y. B. Sulistioadi, “Pemodelan Hidrologi Pada Das Kendilo Di Kabupaten Paser, Provinsi Kalimantan Timur,” *J. Teknol. Lingkung.*, vol. 4, no. 2, pp. 18–23, 2021, doi: http://dx.doi.org/10.30872/jtlunmul.v4i2.5223.

[2] N. I. Rumagit, J. I. Kalangi, and F. B. Saroinsong, “Lolosan Tajuk, Aliran Batang Dan Intersepsi Pada Pohon Pakoba (Syzigium sp.) Nantu (Palaquium obtusifolium Burck) Dan Cempaka (Magnolia tsiampacca),” *EUGENIA*, vol. 25, no. 2, Nov. 2020, doi: 10.35791/eug.25.2.2019.31398.

[3] D. N. Khaerudin, P. Dinar, and A. Apriliyanti, “Pengaruh Pengembangan Penggunaan Lahan terhadap Pola Curah Hujan di Kota Malang,” *Media Tek. Sipil*, vol. 18, no. 1, pp. 9–15, 2020, doi: https://doi.org/10.22219/jmts.v18i1.11859.

[4] S. Kinanthi, M. Bisri, and J. S. Fidari, “Analisis Potensi Kerugian Genangan Menggunakan SWMM 5.2 di Kelurahan Purwantoro, Kota Malang,” *J. Teknol. dan Rekayasa…*, vol. 03, no. 02, pp. 451–461, 2023, doi:

https://doi.org/10.22219/jmts.v18i1.11859.

[5] M. Efendi, A. C. Harifa, and S. Sutikno, "Capacity and Perfomance Evaluation of Drainage Channel (Case Study on Letjen Sutoyo Street Malang City)," *Reka Buana J. Ilm. Tek. Sipil dan Tek. Kim.*, vol. 7, no. 1, pp. 41–62, 2022, doi: 10.33366/rekabuana.v7i1.2807.

[6] I. W. Sutapa, "Kajian Hidrograf Satuan Sintetik Nakayasu Untuk Perhitungan Debit Banjir Rancangan Di Daerah Aliran Sungai Kodina," *Maj. Ilm. Mektek*, vol. 7, pp. 35–40, 2005.

[7] I. Syahputra and C. Rahmawati, "Aplikasi Program HEC-RAS 5.0.3 Pada Studi Penanganan Banjir," *Elkawnie*, vol. 4, no. 2, 2018, doi: 10.22373/ekw.v4i2.3509.

[8] M. R. Wijayanto and N. Helda, "Aplikasi Program HEC-RAS 5.0.7 untuk Pemodelan Banjir di Sub-sub DAS Martapura Kabupaten Banjar," *J. Serambi Eng.*, vol. 7, no. 4, pp. 3868–3880, Oct. 2022, doi: 10.32672/jse.v7i4.4799.

[9] E. Q. Ajr and F. Dwirani, "Menentukan Stasiun Hujan Dan Curah Hujan Dengan Metode Polygon Thiessen Daerah Kabupaten Lebak," *Jurnalis*, vol. 2, no. 2, pp. 139–146, 2019.

[10] K. Christian, D. Yudianto, and S. R. Rusli, "Analisis Pola Distribusi Hujan Terhadap Perhitungan Debit Banjir Das Cikapundung Hulu," *J. Tek. Sumber Daya Air*, vol. 3, no. 3, pp. 153–160, 2017.

[11] D. S. Krisnayanti, E. Hunggurami, R. S. Heo, P. N. Tenggara, D. Banjir, and B. Raknamo, "Perbandingan Debit Banjir Rancangan Dengan Metode Hss Nakayasu, Gama I Dan Limantara Pada Das Raknamo," *J. Tek. Sipil*, vol. 9, no. 1, pp. 1–14, 2020.

[12] A. Aprizal and A. Meris, "Aplikasi Hec-Ras Dalam Pengendalian Banjir Sungai Way Kandis - Lampung Selatan," *J. Tek. Sipil ITP*, vol. 7, no. 1, pp. 1–9, 2020, doi: 10.21063/jts.2019.v701.01.

[13] R. Wigati and S. Soedarsono, "Analisis Banjir Menggunakan Software HEC-RAS 4.1.0 (Studi Kasus Sub DAS Ciberang HM 0+00 - HM 34+00)," *Fondasi J. Tek. Sipil*, vol. 5, no. 2, pp. 51–61, 2016, doi: 10.36055/jft.v5i2.1261.