International Journal of GEOMATE, May 2019, Vol.16, Issue 57, pp.195 - 200
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2019.57.16095
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

ANALYSIS OF DRAINAGE CAPACITY TO RESOLVE INUNDATION PROBLEM ON JEND. H. AMIR MACHMUD STREET CIMAHI CITY WEST JAVA PROVINCE

In Karnisah[1], *Yackob Astor[2], Bambang Setio Budianto[3], Fitra Ramdhan Arrizal[4], and Reynaldy Putra Herlambang[5]

[1] Department of Civil Engineering, Polytechnic State of Bandung, Indonesia

*Corresponding Author, Received: 22 Oct. 2018, Revised: 2 Dec. 2018, Accepted: 30 Dec. 2018

ABSTRACT: Nowadays, water inundation often occurs in some areas in Cimahi. One of the highest inundation occurred on Jenderal H. Amir Machmud street with a depth of 100 cm with the receding time 1 – 2 hours. This condition causes a very high level of congestion, so it can cut access from Bandung to Cimahi. In addition, of course, this condition can cause damage to the road itself. Using a drainage cross-section data from Cimahi government and field measurement, rainfall data, topographic map, and land use data the existing drainage capacity can be calculated by manual and HEC-RAS. Based on the result of manual calculation, there is total debit in drainage channel on 2 year return period is 2.86 m^3/sec, 5 year return period is 3.59 m^3/sec, and a 10 year return period is 4.08 m^3/sec with the existing channel debit is 2.02 m^3/sec so that cause the water overflows from the channel. The Cilember River flows with a large discharge 2 years period is 59.64 m^3/sec, a 5 year return period is 93.74 m^3/sec, and 10 years 118.30 m^3/sec crossing Amir Machmud Street affecting high inundation at the site of the review. To solve the problem, some models of solution have been made in the form of new box culvert drainage channel planning with the smallest dimension is 2 × 2 m and biggest dimension is 3 × 3 m. Meanwhile, to handle the overflow of water from Cilember River planned 2 pieces of culverts with dimensions 2.5 × 2.5 m.

Keywords: Inundation, Drainage, Cilember river, HEC-RAS

1. INTRODUCTION

With rainfall intensity that can reach 700 mm/hour, Cimahi City is a prone area to flood and inundation problems. Among the three sub-districts in Cimahi City, the area of South Cimahi Sub-district is the most prone area to flood and inundation. South Cimahi Sub-district is located at an altitude of ± 700 meters above sea level (masl), almost the same as the altitude of Center Cimahi Sub-district but lower than the North Cimahi Sub-district [1]. Although North Cimahi Sub-district is ± 35m higher than two other sub-districts, flood and inundation problems with depths between 30-100 cm often occur in this area. One of the inundation points in this area is on Jend. H. Amir Machmud Street, more precisely in front of Cibabat gas station. As one of the main traffic access in Cimahi City, Jend. H. Amir Machmud Street became one of the crowded roads that were passed by vehicles from Bandung and Padalarang.

The occurrence of inundation on the road can be a serious problem for the Government of Cimahi City because it may cut the access to and from Cimahi City.

Based on the results of field observation, it can be seen that at the location of inundation the drainage conditions are filled with soil sediments and most of the inlet holes beside the road are blocked by garbage (Fig.1). This caused the water flowing from Cibabat Street to Cimindi Flyover to become stagnant in front of Cibabat gas station. In addition, there is Cilember River with 2 culverts crossing Jend. H. Amir Machmud Street (Fig.2).

Fig.1. Drainage Condition

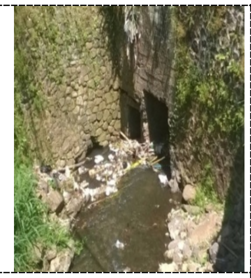

Fig.2. Water Tunnel Condition

The analysis of drainage capacity is essential in determining the cause of flood [2].

2. DEFINITION OF FLOOD AND INUNDATION

The definition of flood is an event when a certain amount of water overflows from a river and soaks the surface that is not supposed to be. Same as flood, inundation is also defined as an event where overflowing water soaks the surface that is not supposed to be but the source of the water is rainwater that cannot be streamed from the road body [3].

3. STUDY AREA

Based on the status and authority of the development, Jend. H. Amir Machmud Street belongs to the type of provincial road that connects Bandung and Cimahi City. This road is a passageway from Jend. Sudirman Street, South Cimahi until before Gadobangkong Main Street, West Bandung Regency. One of the inundation point that has the most major impact on the function of Jend. H. Amir Machmud Street itself is in front of Pertamina SPBU 34-40519 (Cibabat gas station) with the inundation point being reviewed is in the middle of the total length of Jend. H. Amir Machmud Street.

4. DATA AND METHODS

Before analyzing the drainage capability on Jend. H. Amir Machmud Street, it is necessary to process rainfall data from the selected rainfall stations. Based on its location, the closest station from the review site is the Dago Pakar Rainfall Station and Margahayu Rainfall Station I. The data used is data from 2006 to 2016 with the annual maximum rainfall recapitulation presented in Fig.3 and Fig.4.

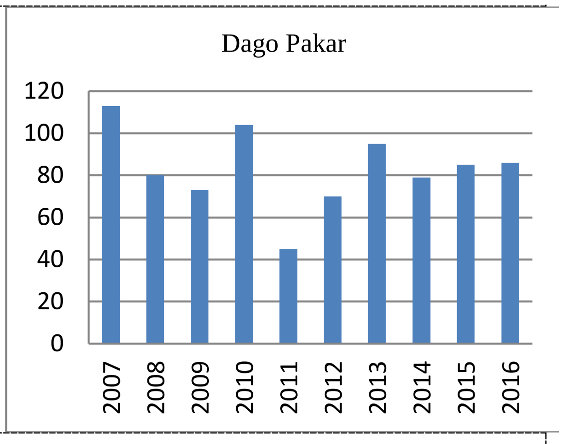

Fig.3.Recapitulation of Maximum Rainfall Data from Dago Pakar Rainfall Station.

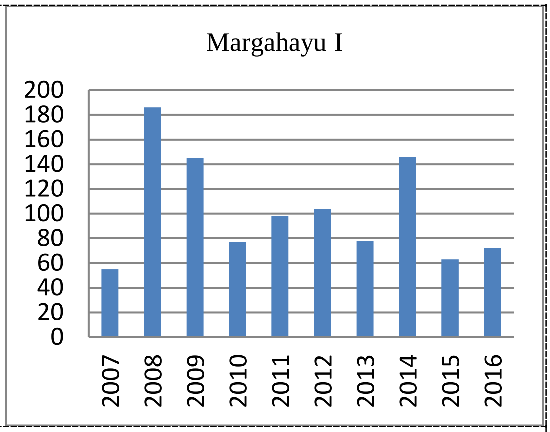

Fig.4. Recapitulation of Maximum Rainfall Data from Margahayu I Rainfall Station.

The first step in the hydrological analysis process is to calculate the average rainfall from the two posts. After that, the calculation of frequency distribution with the Gumbel Distribution method, Pearson Log Type III Distribution, Normal Log Distribution, and Normal Distribution was then tested for data distribution with 2 methods, namely Chi-Square and Smirnov-Kolmogorov. While the average rainfall calculation method used is the arithmetic mean method.

The distribution that meets the requirements after being tested with the Chi-Square and Smirnov-Kolmogorov method is used in the calculation of the flood discharge plan which is calculated by the Rational Method. The planned flood discharge is rainwater discharge plus wastewater discharge where the wastewater discharge is calculated based on total population, area, and population factor. To determine the size of the area, several Sub-watersheds have been produced from the direct observation and illustrated in Fig.5.

Fig.5. Distribution of Watershed and Flow Direction.

The calculation of planned flood discharge from Cilember River begins with calculating the effective rainfall. The definition of effective rain is part of the rain that becomes runoff directly into the river. Effective rain is the same as the total rain that falls on the surface of the land minus the loss of water in land use. The amount of effective rainfall in the area depends on rainfall intensity, land topography, tillage system,and plant growth rate [4]. After obtaining the effective rainfall then calculate the distribution of hourly rain with the Alternating Block Method (ABM) method. Alternating Block Method (ABM) is a simple way to make a hyetograph plan from the IDF curve [5], the hydrograph is made in the form of HSS Nakayasu.

The runoff simulation was carried out using the HEC-RAS software and combined with contour map data in the SRTM format for Java Island (Fig.6). The HEC-RAS have shown its effectiveness for analyzing both drainage capacity [6] and floodplain [7]. The drainage cross-section data obtained from the result of direct measurement while the river cross-section data is secondary data obtained from the Cimahi City Government.

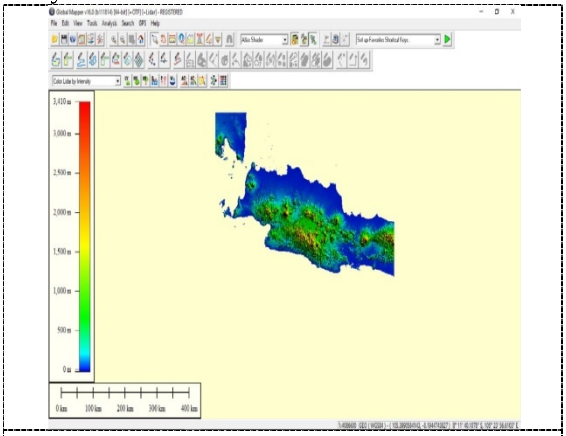

Fig.6. Contour Map in SRTM Format

5. RESULT AND DISCUSSIONS

After calculating the empty rainfall data using the normal ratio method, a maximum rainfall can be made from 2007 to 2016 by the two rain stations used (Table 1). Based on the result of the data suitability test using the Chi-Square and Smirnov-Kolmogorov methods, it can be seen that the Gumbel Distribution and Pearson Type III Log Distribution meet the requirements but the result that been used is Gumbel Distribution. The result of rainfall distribution calculations is shown in the resume (Table 2).

Table 1.Maximum Annual Rainfall

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Dago Pakar (mm)	113	80	73	104	45	70	95	79	85	86
Margahayu I (mm)	55	186	145	77	98	104	78	146	63	72

Table 2.Calculation of Rainfall PlanResume.

Return Period	Distribution Method			
	Normal	Log Person III	Gumbel	Log Normal
2	92.700	89.582	90.797	91.014
5	109.110	106.936	114.065	107.624
10	117.847	127.926	129.470	117.671

5.1 Rainwater Discharge

To find out the composite flow coefficient of the existing channel, it is necessary to separate the calculation of each channel. Table 3 shows the result of flow coefficient calculation of each channel.

Table 3. Calculation of Rainfall

Channel	Service Area	C
S 5 - 6	F	0.635382953
S 4 - III	F and G	0.642264347
S 9 - 2	C	0.629404897
S 7 - 8	D	0.65
S 1 - III	A, B, C, and D	0.638415728

Calculation of flow time in the highway drainage channel includes calculating the time of water flow on the land surface (to) and calculating the time of water flow along the channel (tc) until it obtains the time of water flow at the point being observed (tc) or commonly referred to as concentration time [8]. The result of flow time calculation is shown in Table 4 below:

Table 4Flow Time Calculation.

Channel	Service Area	Channel Type	To (minute)	Td (minute)	Tch (minute)	Tc (minute)
S 5 - 6	F	Open	1.8559	0.0668	-	1.9227
S 4 - III	F and G	Close	1.9227	0.0513	0.1052	2.0791
S 9 - 2	C	Close	1.7803	0.0837	0.1667	2.0306
S 7 - 8	D	Close	1.8292	0.0395	0.1667	2.0354
S 1 - III	A, B, C, and D	Close	2.0354	0.0686	0.1857	2.2897

Afterward, the tc value is used to calculate the value of rain intensity with the mononobe formula [9] so it can be calculated the rainwater discharge in the return period 2, 5, and 10 years as shown in the table below.

Table 5Calculation of Rainwater Discharge (Qah) in 2 Year Return Period

Channel	C	I (mm/hours)	A (m^2)	Qah (m^3/sec)
S 5 - 6	0.63538295	312.008	28652.1684	1.5778
S 4 - III	0.64226435	296.155	54140.2413	2.8606
S 9 - 2	0.6294049	300.855	26246.7993	1.3806
S 7 - 8	0.65	300.381	22099.5109	1.1986
S 1 - III	0.63841573	277.704	92196.4337	4.5404

Table 6.Calculation of Rainwater Discharge (Qah) in 5 Year Return Period

Channel	C	I (mm/hours)	A (m^2)	Qah (m^3/sec)
S 5 - 6	0.63538295	391.963	28652.1684	1.9821
S 4 - III	0.64226435	372.048	54140.2413	3.5936
S 9 - 2	0.6294049	377.952	26246.7993	1.7344
S 7 - 8	0.65	377.356	22099.5109	1.5057
S 1 - III	0.63841573	348.868	92196.4337	5.7040

Table 7.Calculation of Rainwater Discharge (Qah) in 10 Year Return Period.

Channel	C	I (mm/hours)	A (m^2)	Qah (m^3/sec)
S 5 - 6	0.63538295	444.900	28652.1684	2.2498
S 4 - III	0.64226435	422.295	54140.2413	4.0789
S 9 - 2	0.6294049	428.996	26246.7993	1.9686
S 7 - 8	0.65	428.321	22099.5109	1.7091
S 1 - III	0.63841573	395.985	92196.4337	6.4743

5.2 Wastewater Discharge

In Cimahi City, 80% of the drainage channels are mixed between wastewater channels (residential drainage) and rainwater channels (road drainage), so for this case, the calculation of rainwater discharge and wastewater discharge is calculated. The results of the calculation of wastewater discharge for return period 2, 5 and 10 years can be seen in Table 8 below:

Table 8. Calculation of Wastewater Discharge (Qal) in 2 Year Return Period

Channel	Service Ar	PE	Total Area (Km^2	Total Popula tion	Qal (m^2/sec)
S 5 - 6	F	1	0.025860101	406	0.000422977
S 4 - III	F and G	1	0.051348174	806	0.000839868
S 9 - 2	C	0.27	0.022643096	356	9.99967E-05
S 7 - 8	D	1	0.022099511	347	0.000361467
S 1 - III	A, B, C, ar D	1	0.105469043	1656	0.001725088

Table 9. Calculation of Wastewater Discharge (Qal) in 5 Year Return Period

Channel	Service Area	PE	Total Area (Km^2)	Total Popula tion	Qal (m^2/sec)
S 5 - 6	F	1	0.025860101	437	0.000455169
S 4 - III	F dan G	1	0.051348174	868	0.00090379
S 9 - 2	C	0.27	0.022643096	383	0.000107607
S 7 - 8	D	1	0.022099511	373	0.000388978
S 1 - III	A, B, C, dan D	1	0.105469043	1782	0.001856383

Table 10.Calculation of Wastewater Discharge (Qal) in 10 Year Return Period

Channel	Service Area	PE	Total Area (Km^2)	Total Popula tion	Qal (m^2/sec)
S 5 - 6	F	1	0.025860101	494	0.000514359
S 4 - III	F dan G	1	0.051348174	980	0.001021319
S 9 - 2	C	0.27	0.022643096	432	0.000121601
S 7 - 8	D	1	0.022099511	422	0.000439561
S 1 - III	A, B, C, dan D	1	0.105469043	2014	0.002097786

5.3 Existing Drainage Capacity

Data obtained from measurements of drainage dimensions directly in the field are used as input data when calculating existing drainage capacity. After the capacity is known or the channel discharge value is obtained, the value must meet Qsal> Qtotal condition where the total Q is the sum between Qah and Qal. Only secondary channels that are calculated because water from the tertiary channels flows directly into the secondary channel.

Table 11.Analysis of Existing Drainage Capacity in 2 Year Return Period.

Channel	Material	Vsal (m/sec)	Vmax (m/sec)	V sal ≤ Vmax	Q Sal (m^3/sec)	Q tot (m^3/sec)	Q sal ≥ Q tot
S 4 - III	Concrete	2.377	1.5	ineligible	2.021	2.861	Overflow
S 1 - III	Concrete	1.346	1.5	eligible	1.144	4.542	Overflow

Table 12. Analysis of Existing Drainage Capacity in 5 Year Return Period

Channel	Material	Vsal (m/sec)	Vmax (m/sec)	V sal ≤ Vmax	Q Sal (m^3/sec)	Q tot (m^3/sec)	Q sal ≥ Q tot
S 4 - III	Concrete	2.377	1.5	ineligible	2.021	3.594	Overflow
S 1 - III	Concrete	1.346	1.5	eligible	1.144	5.706	Overflow

Table 13. Analysis of Existing Drainage Capacity in 10 Year Return Period

Channel	Material	Vsal (m/sec)	Vmax (m/sec)	V sal ≤ Vmax	Q Sal (m^3/sec)	Q tot (m^3/sec)	Q sal ≥ Q tot
S 4 - III	Concrete	2.377	1.5	ineligible	2.021	4080	Overflow
S 1 - III	Concrete	1.346	1.5	eligible	1.144	6477	Overflow

5.3.1 Simulation of Existing Drainage Channel Water Runoff.

Based on the simulation results shown in Fig.7, it can be seen that the inundation height is caused by overflowing of water from drainage only 10 to 60 cm but according to various sources, the height of the inundation at that location can reach 100 cm. Therefore, it is necessary to analyze and calculate other factors that cause the occurrence of inundation problems on Jend. H. Amir Machmud Street, Cimahi City.

Fig.7.Simulation of Existing Drainage Channel Water Runoff.

5.4 Influence of Cilember River

To determine the influence of Cilember River, it is necessary to calculate the flood discharge plan with the same return period as the drainage channel, 2, 5 and 10 years using the HSS Nakayasu method. The HSS Nakayasu calculation results in the form of the hydrograph graph are shown in Fig.8.

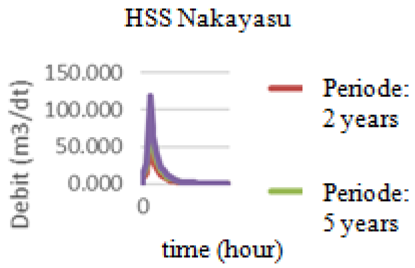

Fig.8.HSS Nakayasu Hydrograph.

5.4.1 Simulation of River water Runoff.

The simulation results of river water runoff using the HEC-RAS software show that the runoff from the Cilember River with the discharge size in Figure 8 affects the inundation height that occurs at Jend. H. Amir Machmud Street Cimahi City so the comprehensive handling is needed to resolve the problem of inundation at these locations. The main cause of the overflow water from the river is the dimension of the culvert which is too small and becomes worse by the sewage that clogged culverts. The simulation results can be seen in Fig.9.

Fig.9.Simulation of Water Runoff from Existing Drainage Channels.

6. CONCLUSION AND RECOMMENDATIONS

Based on the simulation result using HEC-RAS software, it can be seen that the inundation height at Jend. H. Amir Machmud Street was affected by the overflow of Cilember River. So there are 2 factors that cause inundation as high as 100 cm at that point. The first is the channel capacity that is unable to accommodate rainwater discharge and wastewater discharge from surrounding residential area and the second is the narrowing of Cilember River channel section when passing through the culvert. Changing the dimension of the secondary drainage section into a box culvert size of 2 x 2 m (for a return period of 2 years) and changing the dimension of the culvert to a size of 2.5 x 2.5 m (2 pieces) can be a solution to deal with inundation problems in these locations.

In addition to changing dimension, it is advisable to do an alternative combination of solutions between changing the cross-sectional dimension with making infiltration well in each yard of the residents' house and normalizing the Cilember River to reduce runoff discharge into the river.

REFERENCES

[1] Cimahi City BAPEDA 2015.

[2] Kusumastuti, K., Djajadi, R., Rumihin, A., 2015, Evaluation of drainage channels capacity in Ambon city: a case study on Wai Batu Merah watershed flooding, Procedia Engineering 125 (2015) 263 – 269.

[3] Gupta, R.S. 1989. *Hydrology and Hydraulic System.* Prentice Hall Inc. Ann Arbor. Michigan.

[4] Oldeman, Syarifuddin, 1977 An Agromatic Map of Sulawesi. Contr. Centr.Res.Inst.Agric. Bogor. No. 33.

[5] Chow, V.T., Open Channel of Hydraulics, Erlangga, Jakarta, 1989.

[6] Abdeveis, S., Houseini,F.Z., Zohrabi, N., James, M., Khedmati, H., 2013, Simulation Hydraulic Of Karoun River In Iran With Purpose Indicate Capacity Changes Of River Flow With HEC-RAS Model., International Research Journal of Applied and Basic Sciences Vol, 4 (1): 139-145.

[7] El-Naqa, A., and Jaber, M., 2018, Floodplain Analysis using ArcGIS, HEC-GeoRAS and HEC-RAS in Attarat Um Al-Ghudran Oil Shale Concession Area, Jordan., J Civil Environ Eng 8: 323.

[8] Pd-T-02-2006-B (Road Drainage System Planning).

[9] Triatmoodjo, Bambang. 2008. Applied Hydrology. Yogyakarta: Beta Offset.