Performance Analysis of Long Storage and Tidal Controlling Gate on the Flood of Kemuning River

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Abstract. Kemuning river flood is caused by watershed (DAS) quality factor, river capacity, and tidal influence. Effort of controlling that has been done is by making reservoir in upper stream, river normalization in the urban area, and pump installation in the mouth of river. Yet those efforts are not significantly decreasing the frequency of flood. In this paper, it proposed the installation of controlling gate in the downstream of the pump location as a means of controlling, so the current can only move one direction to the downstream of the river. The gate design is planned according to the topography of the local riverbed and utilized it as a long storage. To know the effectiveness of the plan, the performance analysis of long storage and the gate on flood of Kemuning river is conducted. The result of analysis shows that the peak of maximum hydrograph discharge Q2; Q5; Q10; Q25; Q50, is (m3/second): 121.608; 192.720; 220.258; 241.605; 263.558. The combination of long storage and one direction gate cannot control the discharge of flood for two years, therefore to control flood it needs additional water reservoir and or flood pump.

1. Introduction

The performance of the flood control system in the Kemuning river must continue to be improved, because the condition of the watershed (DAS) is increasingly damaged and sedimentation occurs at the river mouth. Kemuning river is crossing the urban area of Sampang and floods occur every year so that it becomes one of the centers of attention in flood control efforts in Indonesia [1]. The problem of flood and the causes that occur at Kemuning river are often found in some regions, with a larger scale. Thus, Kemuning river flood control is potential as a model in Indonesia, even in general it can also be applied anywhere.

The causes of flood in Kemuning river are: (1). Conditions of watersheds (DAS); (2). River flow conditions in urban areas, and (3). Influence of tidal water. The concept of flood control by improving watershed conditions has been exposed in previous papers, while in this paper it focuses on controlling the influence of tide [2-5]. Kemuning River watershed is shown in Figure 1.

At the time of maximum tide, the influence of sea level elevation spreads to the river in Sampang urban area. Therefore, efforts to control floods by increasing the capacity of water distribution at the mouth of the river must be done carefully, especially against the emergence of back water.

The use of long storage in flood control system is intended as an effort to increase the effect of water storage from riverbed [6]. This is considered to be quite profitable if the cost of making water reservoirs outside the riverbed is relatively expensive related to land acquisition. In hydraulic analysis, to determine the response of the storage capacity of the flood discharge hydrograph that enters the river system is by using the Muskingum concept. The use of this concept has been applied in various construction planning. Increasing accuracy has been carried out by adding storage parameters [4,3].

The efforts to improve the performance of temporary reservoirs [7] and water pumps in the control system of the tidal water influence, one-way water gates are used which in this case are called valve gate. The valve gate is one of the water gates that operate automatically, that is, the opening and closing doors use energy due to the changes in water level of upstream and downstream of the door. Valve gate applications have been carried out in the water management system plan in oil palm plantations [8,9] [10]. The use of the gate is described in Figure 1. In the applied test, it shows very good performance in terms of operation and accuracy of discharge capacity.

Maximizing the performance of the tidal influence control system is done by making: (1). temporary water reservoir, (2). water gate, and or (3). pump.

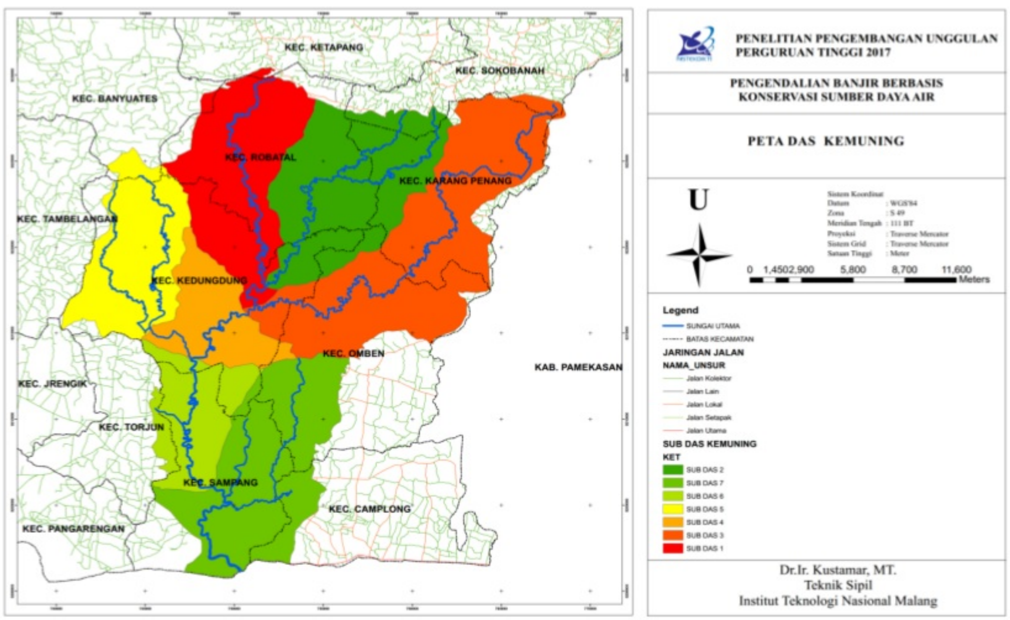

Figure 1. Kemuning river watershed.

Figure 2. The use of valve gate.

2. Method

The method used is by analyzing the influence of the use of auxiliary facilities (reservoirs, gate, and pumps) from the hydraulics review. Activities in the form of simulations with several pair scenarios, focusing on the analysis of the effectiveness of controlling the influence of tidal water with the use of river channels as long storage and equipped with water gates.

As input, flood discharge is used with various times, starting from 2 years. The river is dredged, with 2 assumptions: (1) the riverbed elevation is as low as tide surface and (2) the elevation of the riverbed below the level of low tide, with consequence it is necessary to always have a water pump. The flood water level due to back water is limited to 50 cm below the surrounding ground level.

3. Data analysis

The flood water level in up stream's water gate that is installed at the river mouth is carried out by searching the flood. In this activity, water storage capacity is calculated without additional water reservoirs outside the riverbed. The search is carried out using the Muskingum method, with the means of output in the form of box culvert. Output capacity is calculated in two conditions, namely free flow and compressive flow.

3.1. Artificial rain

The flood hydrograph was analyzed by the method of variance in rain to flood discharge. In Kemuning watershed area there are 2 influenced rain stations (STA) into Kemuning river flood discharge, namely Kedundung STA and Torjun STA. The maximum annual rainfall data for the last 10 years is presented in table 1. The average height of regional rainfall is calculated by 2 methods, namely Thiessen Algebra and polygon averages. The highest daily rainfall from the analysis results is generated from the Thiessen polygon method. This happens because the distribution of station locations is uneven. Thus, for the next calculation, the results of the rainfall analysis of the Thiessen polygon method (table 2) are used.

Table 1. Maximum annual daily rainfall data.

No	Year	Maximum Rainfall	
		Kedundung STA	Torjun STA
1	2008	75	67
2	2009	30	110
3	2010	65	210
4	2011	69	64
5	2012	33	70
6	2013	82	73
7	2014	80	78
8	2015	75	65
9	2016	64	88
10	2017	64	25

Table 2. Maximum annual average rainfall.

No	Year	Maximum Rainfall		d (mm)
		Sta. Kedundung	Sta. Torjun	
		0.68	0.32	
1	2008	75	67	72.42
2	2009	30	110	55.82
3	2010	65	210	111.81
4	2011	69	64	67.39
5	2012	33	70	44.94
6	2013	82	73	79.09
7	2014	80	78	79.35
8	2015	75	65	71.77
9	2016	64	88	71.75
10	2017	64	25	51.41

Artificial rain was calculated by the Gumbel method and Log Pearson Type III. The suitability test of the two methods was carried out with the smirnov-kolmogov test. The smallest deviation is used as a determinant of the selected frequency distribution. The results of the analysis show the Log Pearson Type III distribution. The artificial rain analysis results are shown in Table 3. Thus, even though the calculation results show that the artificial rain of the Gumbel EJ method is larger, but because the test results show that the more suitable distribution is Log Pearson Type III then the results of Log Pearson type III analysis are used (Table 3).

Table 3. Artificial rain.

Year	E J Gumbel	Log Person
5	100.876	89.823
10	120.229	105.804
20	139.038	128.346
50	163.347	146.903
100	181.647	167.045
1000	241.763	248.724
Average	946.898	886.645

3.2. Flood hydrograph

The flood hydrograph that was used as input in the flood trace analysis was carried out using the Nakayasu Synthetic Unit (HSS) hydrograph model. The use of Nakayasu HSS is done with the consideration that this model is very suitable [3]. The results of the flood discharge hydrograph analysis with various times are shown in Table 4.

Table 4. Hydrograph of Kemuning river flood [4].

Times	Flood Discharge (m^3/s)					
(hour)	Q-5	Q-10	Q-20	Q-50	Q-100	Q-1000
0	0.000	0.000	0.000	0.000	0.000	0.000
1	19.393	22.843	27.710	31.716	36.065	53.699
2	89.463	105.380	127.831	146.313	166.375	247.726
3	79.540	93.692	113.652	130.085	147.921	220.250
4	66.878	78.777	95.560	109.377	124.374	185.188
5	57.059	67.211	81.530	93.318	106.113	157.999
6	48.147	56.714	68.796	78.743	89.540	133.322
7	33.513	39.475	47.885	54.809	62.324	92.798
8	23.906	28.160	34.159	39.098	44.459	66.198
9	17.693	20.841	25.282	28.937	32.905	48.994
10	13.619	16.041	19.459	22.273	25.327	37.710
11	10.601	12.488	15.148	17.338	19.716	29.356
12	8.340	9.824	11.917	13.640	15.510	23.094
13	6.630	7.810	9.474	10.843	12.330	18.359
14	5.306	6.250	7.581	8.677	9.867	14.691
15	4.246	5.001	6.067	6.944	7.896	11.757
16	3.398	4.002	4.855	5.577	6.318	9.408
17	2.719	3.203	3.885	4.447	5.056	7.528
18	2.176	2.563	3.109	3.558	4.046	6.025
19	1.741	2.051	2.488	2.847	3.238	4.821
20	1.393	1.641	1.991	2.279	2.591	3.858
21	1.115	1.313	1.593	1.823	2.073	3.087
22	0.892	1.051	1.275	1.459	1.659	2.470
23	0.714	0.841	1.020	1.168	1.328	1.977
24	0.311	0.366	0.444	0.208	0578	0.860

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3.3. Long storage capacity

The capacity of long storage is calculated based on topographic data at the location of the prospective box culvert building. The results of the analysis of the storage capacity of each water level are shown in Figure 3.

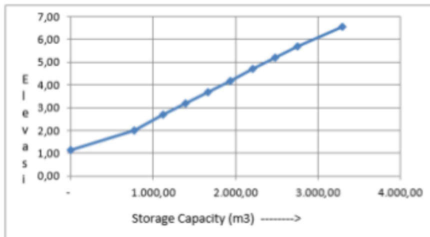

Figure 3. Long storage capacity.

3.4. Box culvert output capacity

The box culvert capacity is calculated in 2 conditions, when the water level in the reservoir is 0.0 m to 1.2 m x the box culvert height with the free flow equation, whereas if the water level is more than 1.5 x the box culvert height it uses the press flow approach. Whereas when the water level between (1,2 to 1,5) is considered the transition part. In an effort to get the number and dimensions of the box culvert, simulations were carried out. In this paper, 3 (three) choices are displayed as follows:

- Number of boxes culvert 1, with a size of 1m x 1m;
- Number of box culvert 1, with a size of 2 m x 2 m;
- Number of box culvert 3, with a size of 1.5 m x 1.5 m. The box culvert size selected is already on the market, so if it is implemented it will be easy to get in the field. The results of the analysis are stated in table 5.

Table 5. Box culvert capacity (m^3/second).

ELEV	NUMBER OF BOX CULVERT (DIMENSION)		
	1 (1 m x 1 m)	1 (2m x 2 m)	3 (1,5 m x 1,5 m)
3.69	0	0	0
3.93	3.507005	1.189487	9.250218
4.17	9.232588	3.131459	24.35225
4.41	15.68146	5.318751	41.36204
4.65	22.47099	7.62159	59.2704
5.69	47.62822	5.371493	33.88935
5.73	48.04972	5.442642	34.11453
5.77	48.46755	5.512873	34.33823
5.81	48.88181	5.58222	34.56049
5.85	49.29259	5.650716	34.78132
5.89	49.69997	5.718391	35.00077
5.93	50.10404	5.785275	35.21884
5.97	50.50488	5.851395	35.43558
6.01	50.90256	5.916776	35.65099
6.05	51.29716	5.981442	35.86511
6.09	51.68875	6.045416	36.07796
6.13	52.07739	6.108721	36.28957
6.17	52.46316	6.171376	36.49994
6.21	52.8461	6.233401	36.70911
6.25	53.2263	6.294816	36.9171
6.27	53.41538	6.325299	37.02065
6.29	53.60379	6.355637	37.12392
6.31	53.79155	6.38583	37.2269
6.33	53.97865	6.415881	37.32959
6.35	54.1651	6.445792	37.43201

Source: calculation results

3.5. Flood search

The response of long storage to inflow debit and output capacity was analyzed by tracing the flood, which in this case uses the Muskingum method. Flood tracing was carried out on 3 output capacities. The results of the analysis were presented in the form of a discharge hydrograph, in Figure 3, while the water level in the reservoir (long storage) in the simulation I was presented in Figure 3.

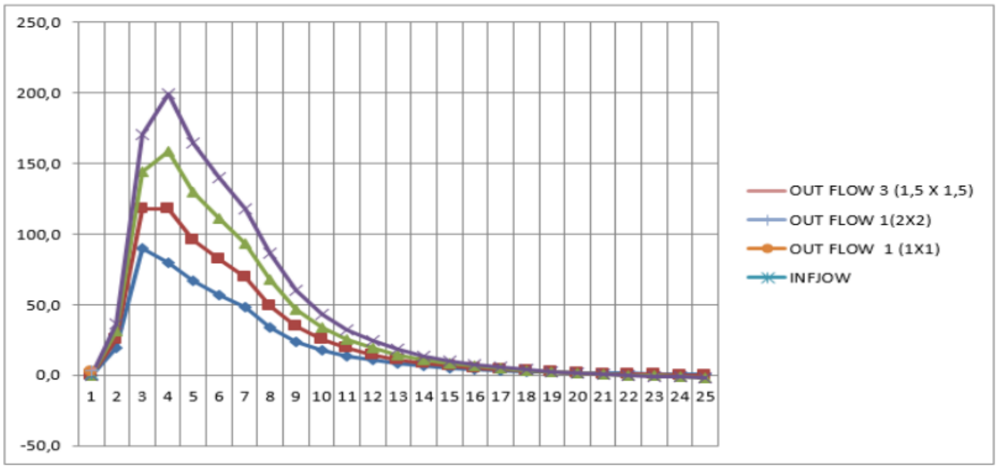

Figure 4. Water level elevation chart in reservoir (long storage).

The water level in the reservoir (long storage) of the three simulations obtained an illustration that alternative 3 is the best choice, considering the height of the right and left cliffs of the river is about 7 meters. The water level elevation graph in Alternative 1 is shown in Figure 5.

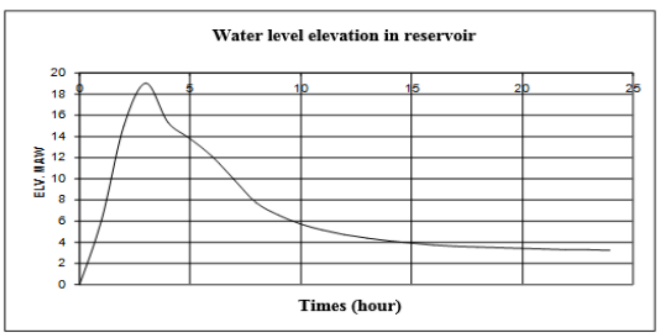

Figure 5. Fluctuation chart of water level elevation in reservoir.

4. Discussion

Regional average rainfall analysis, with the number of rain stations 2 (two) pieces, until now there are still incorrect assumptions, that is always use the algebraic mean method. This opinion is supported by the explanation that with only 3 points, polygons cannot be made to determine the area of influence. However, in this study, it proved that if the location of the rain station was not evenly distributed, the teissen polygon method was still more appropriate. This also agrees with CD Soemarto [6].

The results of flood trace analysis with several alternative means of output indicate that:

- By using 1 (one) box, the most profitable size culvert is 2 x 2 (m);
- By using 3 (three) boxes the most optimal size culvert is 1.5 x 1.5 (m).

Design selection is done with a large review of the maximum control, namely the maximum storage effect and flood water level not exceeding the limit.

Thus, the use of long storage by combining water gate and box culverts is not enough to control the influence of high tide water. It is recommended to add a pool of water outside the river trough or use a pump.

5. Conclusion

The use of Long storage is not effective for controlling the influence of tidal water in Kemuning River floods, so it needs to support Box culvert, water gates, and or water pumps. Box culvert 3 holes with 1.5 x 1.5 (m) designs most optimal with the aim of maximizing the reservoir effect with the maximum flood water elevation limit.

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