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Evaluation of Flood Control in Pakal District With The Construction of The Sumber Rejo Flood Pump in Surabaya City

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Abstract

Flood has always been expected in the rainy season at the Pakal District before 2019, where rainwater flows from Benowo channel to the Sumber Rejo channel and backwater flows from Lamong river to the Sumber Rejo channel. These water “attacks” from the two sides of the water bodies made Sumber Rejo flood every rainy season. In this analysis the maximum water flow rate in Sumber Rejo channel within the 20-year period (Q20) is 22,57 m3/second. To eleminate flood in Sumber Rejo channel, a flood pump station is needed to pump the waterflow from Benowo channel dan stop the backwater infiltrating from the Lamong river. Two flood pumps with a total flow rate of 6 m3/second are already installed and running at the moment, while the optimal capacity of this flood pump station should be 12 m3/second. A large water storage with capacity around 88.712 m3 is already built to keep the water elevation low enough to not overflow the Sumber Rejo channel.

Keywords
Flood, Lamong River, Pump, Sumber Rejo, Water Management.

1. Introduction

The Sumber Rejo Channel is a downstream from the Gunungsari Diversion Channel and the Benowo Channel, also a branch of the Lamong River. During the rainy season, flooding often occurs in the Sumber Rejo Channel due to backwater caused by the high discharge of Kali Lamong, so that water flows back into the Sumber Rejo primary channel (Jawa Pos 2020). The Lamong River with area of 720 KM2 and a total length of 103 KM has partially installed embankments with CCSP (Corrugated Concrete Sheet Pile) or concrete embankments so that water does not overflow into the city; however, to reduce flooding by 100%, a total CCSP management is needed along the Lamong River (Indrajayatama, Sholichin, and Dermawan 2020). The Sumber Rejo Channel also receives a large amount of water from the Gunungsari Diversion Channel. The Gunungsari Diversion Channel has a maximum design discharge of 21.2 m3/second (Harianto and Hidayat 2017).

To accelerate the flow of water from the Sumber Rejo Channel and to stop backwater that might occur during the rainy season, a pump house and a flood gate are needed at the downstream of the Sumber Rejo Channel. When the water level in Lamong River is higher than the water level in the Sumber Rejo Channel, the floodgate is closed and the pump is turned on to drain the water in the Sumber Rejo Channel. On the other hand, when the water level in Kali Lamong is low, the floodgates are opened so that the water flows by gravity. Sumber Rejo Pump has 2 pumps with a capacity of 3 M3/s so the total capacity is 6 M3/s. To the east of the Sumber Rejo Flood Pump Station, a rainwater reservoir is built to cope with the high water percipitation.

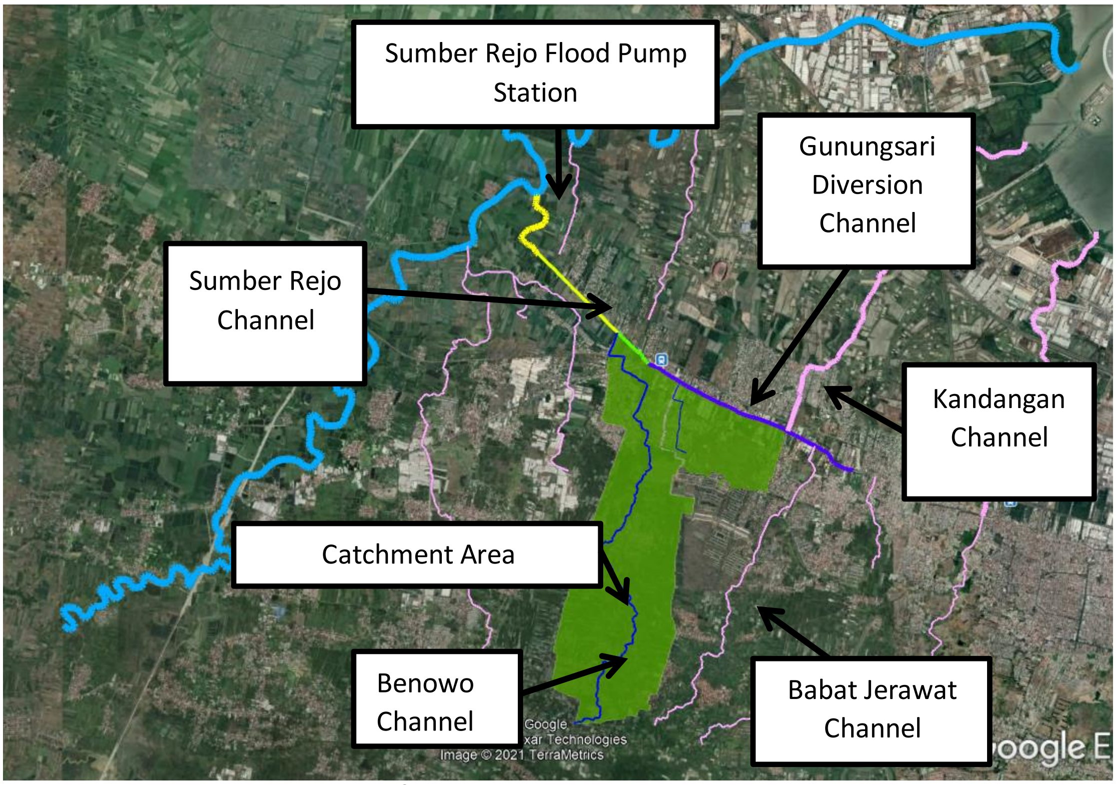


Figure 1. Map of Sumber Rejo channel and the catchment area

2. Literature Review

The city of Surabaya has a long history of dealing with floods. Based on data from the Department of Highways and Pematus Surabaya City, 2008, from 1999 to 2008, the inundation area decreased by 43.6% from 4382 ha to 2471.5 ha (Riman 2011). Several locations have also built boezem to temporarily accommodate rainwater runoff (Rahmananta 2017). Many new pump houses have also been built so that inundation in Surabaya has drastically reduced in recent years. To calculate hydrology, it is necessary to calculate the average rainfall using 2 (two) methods, namely the Arithmetic Average Method and the Thiessen Polygon Method (Kusnan 2012). The distribution calculation uses 3 methods to choose the most suitable, namely the Normal Distribution Method, the Gumber Distribution Method and the Pearson Type III Log Distribution Method (Retnowati, Lasminto, and Savitri 2015). The main calculation that will be used in this research is basically divided into 2 analyses, which are hydrologic analysis and hydraulic analysis.

3. Research Method

3.1. Hydrology Analysis

Hydrology calculation is a calculation of the water persipitation in an area, based on the measurement of the local rainfall stations. The rainfall data from the rainfall stations are then processed to find the arithmetic mean data, statistics, frequency analysis and distribution analysis. The final product of the hydrology calculation is the hydrology flow rate in m3 / second.

3.2. Hydraulic Analysis

The hydraulic calculation is a calculation of the physical river or channel to determine if the dimension is enough to cope the rain water. The final product of the hydraulic calculation is the hydraulic flow rate in m3 / second.

3.3. Flood Pump Analysis

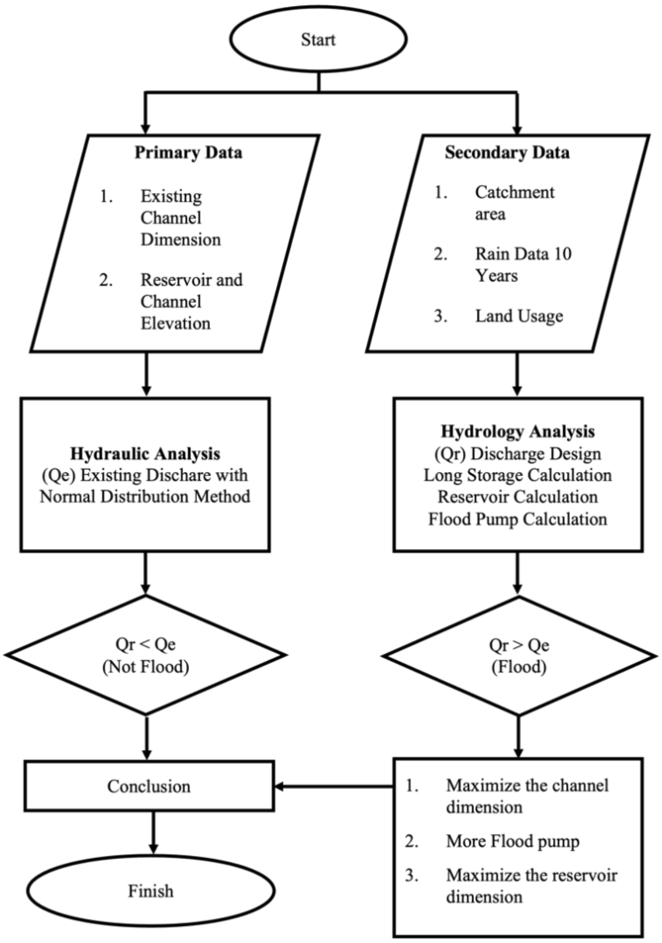
Since January 2020, 2 flood pumps in the Sumber Rejo flood pump station have been installed, at 3 m3 / second each pump, so the total capacity is 6 m3 / second. This pump house has a total of 4 pipe column holes, where 2 pipe column holes have been installed with pumps and the other 2 have not been installed with pumps.

3.4. Reservoir Analysis

Reservoir is built just east of the pump house, with a length of 200 meters, a width of 82 meters and a depth of 5 meters. The water capacity that can be accommodated by this reservoir is about 82,000 m3. This facility serves as a water reservoir or reservoir during heavy rains.

3.5. Sumber Rejo Channel Analysis

The Sumber Rejo channel has a higher elevation than the surrounding secondary and tertiary channels, in other words the Sumber Rejo channel has a "backward" characteristic. Therefore, the majority of the water flowing in Sumber Rejo is water from the Gunungsari diversion channel and the Benowo channel. In this final project, the water discharge from the residents, industry and commercials from the Sumber Rejo area is not calculated, because indeed there is no wastewater from the Sumber Rejo area that enters the Sumber Rejo channel.



Flowchart 1. Research flow diagram

4. Discussion

In order to calculate the water flow in the Sumber Rejo Channel, hyrdrology and hydraulic calculations need to be performed. Hydrology calculation is a calculation of the water persipitation in an area, based on the measurement of the local rainfall stations. The rainfall data from the rainfall stations are then processed to find the arithmetic mean data, statistics, frequency analysis and distribution analysis. The final product of the hydrology calculation is the hydrology flow rate. The hydraulic calculation is a calculation of the physical river or channel to determine if the dimension is enough to cope the rain water. The final product of the hydraulic calculation is the hydraulic flow rate. The hydraulic flow rate is then compared to the hydrology flow rate to find out if the channel / river floods or not. If the value of the hydraulic flow rate is more than the hydrologic flow rate, then the channel does not flood. On the contrary, if the value of the hydrology flow rate is more than the hydraulic flow rate, then the channel floods.

4.1. Hydrology Analysis

From the calculation of the hydrological perspective, this research uses 2 methods, Rational Method and Nakayasu Method. These 2 methods are both calculated to test if there are any major differences in the flood rate result. If there is only a slight difference in the result, then the calculation that will be used is the one with the bigger numbers. The return period this research uses is the 20 year return period, because Surabaya city is a metropolitan city. The 20 year return period means that this maximum discharge rate will only happen once in the next 20 years. This maximum discharge will not happen occur again in 20 years if it has already happened once in this 20-year period. The method this research uses is the rational methodology, because it produces higher flood rate design than the nakayasu methodology. The discharge rate design this research uses is the 20 year return period with flood rate design of 22,573 m3 / second.

Table 1. Flood rate design with Rational Methodology

Return Period (Year)	Catchment Area (CA) (km2)	C (Flow Coeff.)	n (Land Rougness)	Land Slope	Concentration Time (Tc) (minute)	Rain Design (mm)	Rain Intensity (I) (mm/h)	Flood Rate Design (m3/s)
2	7,26	0,330	0,08	0,01	91,27	92,30	24,19	16,132
5	7,26	0,330	0,08	0,01	91,27	111,17	29,14	19,431
10	7,26	0,330	0,08	0,01	91,27	121,06	31,73	21,159
20	7,26	0,330	0,08	0,01	91,27	129,15	33,85	22,573
25	7,26	0,330	0,08	0,01	91,27	130,69	34,25	22,841
50	7,26	0,330	0,08	0,01	91,27	138,36	36,27	24,183
100	7,26	0,330	0,08	0,01	91,27	144,66	37,92	25,282

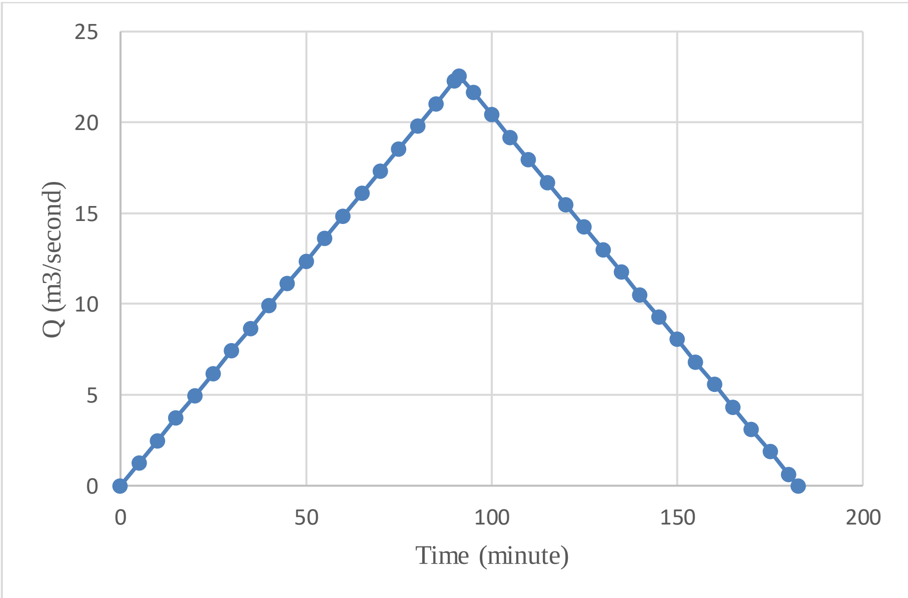


Figure 2. Flood hidrograph chart based on flood rate design

Table 2. Hydrology discharge in every check points

No	Check Points	Rain Design in 20 Years	Cathcment Area (A)	Channel Length	V	tf	tc	tb	I	Q hidrologi
		mm	km^2	m	m/sec	minute	minute	minute	mm/hour	m^3/second
1	STA 1 + 100	129	7,260	50	1,42	0,58	84,73	169,45	35,57	23,720
2	STA 1 + 050	129	7,260	50	1,43	0,58	84,73	169,45	35,57	23,720
3	STA 1 + 000	129	7,260	50	1,44	0,58	84,72	169,44	35,57	23,721
4	STA 0 + 950	129	7,260	50	1,42	0,59	84,73	169,46	35,57	23,719
5	STA 0 + 900	129	7,260	50	1,52	0,55	84,69	169,38	35,58	23,726
6	STA 0 + 850	129	7,260	50	1,48	0,56	84,71	169,41	35,58	23,724
7	STA 0 + 800	129	7,260	50	1,46	0,57	84,71	169,43	35,58	23,722
8	STA 0 + 750	129	7,260	50	1,63	0,51	84,65	169,31	35,59	23,733
9	STA 0 + 700	129	7,260	50	1,67	0,50	84,64	169,29	35,60	23,735
10	STA 0 + 650	129	7,260	50	1,57	0,53	84,67	169,35	35,59	23,729
11	STA 0 + 600	129	7,260	50	1,56	0,53	84,68	169,35	35,59	23,729
12	STA 0 + 550	129	7,260	50	1,61	0,52	84,66	169,32	35,59	23,732
13	STA 0 + 500	129	7,260	50	1,50	0,56	84,70	169,40	35,58	23,725
14	STA 0 + 450	129	7,260	50	1,47	0,57	84,71	169,42	35,58	23,723
15	STA 0 + 400	129	7,260	50	1,44	0,58	84,72	169,44	35,57	23,721
16	STA 0 + 350	129	7,260	50	1,35	0,62	84,76	169,52	35,56	23,714
17	STA 0 + 300	129	7,260	50	1,42	0,59	84,73	169,46	35,57	23,719
18	STA 0 + 250	129	7,260	50	1,36	0,61	84,76	169,51	35,56	23,714
19	STA 0 + 200	129	7,260	50	1,37	0,61	84,75	169,50	35,57	23,715
20	STA 0 + 150	129	7,260	50	1,54	0,54	84,68	169,37	35,58	23,728
21	STA 0 + 125	129	7,260	25	1,65	0,25	84,39	168,79	35,67	23,782
22	STA 0 + 100	129	7,260	25	1,78	0,23	84,38	168,75	35,67	23,785
23	STA 0 + 080	129	7,260	20	2,39	0,14	84,28	168,56	35,70	23,803
24	STA 0 + 050	129	7,260	30	2,39	0,21	84,35	168,70	35,68	23,790
25	STA 0 + 000	129	7,260	50	2,39	0,35	84,49	168,98	35,64	23,764

4.2. Hydraulic Analysis

The flow in the Sumber Rejo channel is a channel with an open flow. Analysis of river flood flow conditions in existing conditions is intended to find out how much is the ability of the Sumber Rejo Channel to be able to flow discharge, in other words how big the capacity / cross-sectional capacity of the river. This is often referred to as full bank capacity analysis, which is a river condition which is said to be a river boundary condition in flowing a certain amount of discharge. Thus, if there is a discharge that flows into the river greater than the boundary conditions, then there is one or several sections of the river cross section on certain sections that are abundant on the embankment (over topping). Contrary to the hydrology equation, the data needed to calculate the hydraulic equation are the downstream and upstream elevations of each check points, channel area, channel circumference and discharge speed.

Table 3. Hydraulic dishcarge in each check points

No	Check Points	Elevation Upstream	Elevation Downstream	b m	h m	A m^2	P m	R m	V m/second	Q Hydraulic m^3/second
1	STA 1 + 100	1,402	1,285	8,57	2,18	18,68	12,93	1,44	1,425	26,616
2	STA 1 + 050	1,285	1,255	8,00	2,28	18,24	12,56	1,45	1,429	26,073
3	STA 1 + 000	1,255	1,142	8,49	2,24	19,02	12,97	1,47	1,439	27,360
4	STA 0 + 950	1,142	0,981	7,86	2,27	17,84	12,40	1,44	1,421	25,348
5	STA 0 + 900	0,981	1,155	7,96	2,64	21,00	13,24	1,59	1,516	31,847
6	STA 0 + 850	1,155	1,042	8,51	2,39	20,33	13,29	1,53	1,480	30,086
7	STA 0 + 800	1,042	0,687	8,71	2,29	19,93	13,29	1,50	1,461	29,124
8	STA 0 + 750	0,687	0,561	9,08	2,90	26,32	14,88	1,77	1,631	42,91
9	STA 0 + 700	0,561	0,483	9,53	2,96	28,21	15,45	1,83	1,665	46,972
10	STA 0 + 650	0,483	0,403	8,32	2,78	23,13	13,88	1,67	1,567	36,239
11	STA 0 + 600	0,403	0,346	7,87	2,85	22,42	13,57	1,65	1,558	34,923
12	STA 0 + 550	0,346	0,262	7,86	3,09	24,27	14,04	1,73	1,606	38,981
13	STA 0 + 500	0,262	0,239	6,13	3,18	19,48	12,49	1,56	1,499	29,204
14	STA 0 + 450	0,239	0,611	7,89	2,46	19,41	12,81	1,52	1,470	28,541
15	STA 0 + 400	0,611	0,448	8,70	2,23	19,39	13,16	1,47	1,444	27,993
16	STA 0 + 350	0,448	0,588	8,42	1,96	16,49	12,34	1,34	1,353	22,314
17	STA 0 + 300	0,588	0,584	8,27	2,19	18,11	12,65	1,43	1,416	25,644
18	STA 0 + 250	0,584	0,320	8,00	2,03	16,24	12,06	1,35	1,359	22,075
19	STA 0 + 200	0,320	0,382	11,85	1,77	20,98	15,39	1,36	1,370	28,749
20	STA 0 + 150	0,382	0,431	10,34	2,37	24,51	15,08	1,63	1,541	37,757
21	STA 0 + 125	0,431	0,400	11,80	2,60	30,68	17,00	1,80	1,652	50,692
22	STA 0 + 100	0,400	0,400	13,80	2,84	39,19	19,48	2,01	1,776	69,623
23	STA 0 + 080	0,400	0,220	13,80	5,75	79,35	25,30	3,14	2,388	189,517
24	STA 0 + 050	0,220	0,220	13,80	5,75	79,35	25,30	3,14	2,388	189,517
25	STA 0 + 000	0,220	0,116	13,80	5,75	79,35	25,30	3,14	2,388	189,517

4.3. Hydrology and Hydraulic Comparison

After calculating the Design Discharge (Q Hydrology) and Existing Discharge (Q Hydraulic), the two will be compared to determine the location of the channel that is safe or overflowing. This analysis is divided into every 25 to 50 meters so that it is able to accurately detect if it is safe or overflow in every location points. If there is no water overflow, then there is no need to normalize the channel. On the other hand, if the water overflows, normalization must be carried out at that point. Normalization can be done by widening the channel or deepening the channel.

There are 2 (two) overflow points which are STA 0+350 and STA 0+250. There are 12 (twelve) points on the Sumber Rejo channel which is almost overflowing because the channel width (b) is below 8 meters or the channel height (h) is below 3 meters. Therefore, it is necessary to normalize the channel at 2 points that overflow and 12 points that almost overflow, so that it can accommodate maximum rainfall. Each channel that overflows or almost overflows is normalized with a standard channel base (b) of 8 meters and a channel height (h) of 3 meters. Meanwhile, if the channel base (b) is greater than 8 meters, but the channel height (h) is less than 3 meters, then the channel height is normalized only. If the channel base (b) is less than 8 meters and the channel height (h) is greater than 3 meters, then only the channel base / width is normalized. By normalizing the channel, there will be no more overflow points on the Sumber Rejo channel.

Table 4. Hydrology and hydraulic comparison before being normalized

No	Check Points	Q Hidrology m^3/sec	Q Hidraulic m^3/sec	Δ Q m^3/sec	Result
1	STA 1 + 100	23,720	26,616	-2,897	Safe
2	STA 1 + 050	23,720	26,073	-2,353	Safe
3	STA 1 + 000	23,721	27,360	-3,639	Safe
4	STA 0 + 950	23,719	25,348	-1,629	Safe
5	STA 0 + 900	23,726	31,847	-8,121	Safe
6	STA 0 + 850	23,724	30,086	-6,362	Safe
7	STA 0 + 800	23,722	29,124	-5,402	Safe
8	STA 0 + 750	23,733	42,913	-19,179	Safe
9	STA 0 + 700	23,735	46,972	-23,237	Safe
10	STA 0 + 650	23,729	36,239	-12,509	Safe
11	STA 0 + 600	23,729	34,923	-11,194	Safe
12	STA 0 + 550	23,732	38,981	-15,249	Safe
13	STA 0 + 500	23,725	29,204	-5,479	Safe
14	STA 0 + 450	23,723	28,541	-4,818	Safe
15	STA 0 + 400	23,721	27,993	-4,272	Safe
16	STA 0 + 350	23,714	22,314	1,400	Overflow
17	STA 0 + 300	23,719	25,644	-1,926	Safe
18	STA 0 + 250	23,714	22,075	1,640	Overflow
19	STA 0 + 200	23,715	28,749	-5,033	Safe
20	STA 0 + 150	23,728	37,757	-14,029	Safe
21	STA 0 + 125	23,782	50,692	-26,911	Safe
22	STA 0 + 100	23,785	69,623	-45,838	Safe
23	STA 0 + 080	23,803	189,517	-165,714	Safe
24	STA 0 + 050	23,790	189,517	-165,727	Safe
25	STA 0 + 000	23,764	189,517	-165,753	Safe

4.4. Reservoir and Long Storage Analysis

In this flood pump station there is a reservoir which is built on the east of the flood pump station, with 200 meters length, 82 meters width and 5 m depth. The water capacity that can be accommodated by this water reservoir is approximately 82,000 m3. In this reservoir, there is a 200x200 cm box culvert that connects the reservoir to the Sumber Rejo channel on STA 0+225. For the existing condition, there are 2 pumps with a capacity of 3 m3/second for each pump so that the total maximum capacity of the pump is 6 m3/second. Meanwhile, for this analysis, using a trial and error method, the number of pumps is increased so that it reaches a capacity of 12 m3/second and 16 m3/second; where a capacity of 12 m3/second uses 4 pump units of 3 m3/second and a capacity of 16 m3/second uses 2 pumps of 3 m3/second and 2 pumps of 5 m3/second. Some of these scenarios:

1. Flood gate closed and 6 m3/second pump activated
2. Flood gate closed and 12 m3/second pump activated
3. Flood gate closed and 18 m3/second pump activated

The current reservoir design only has 1 (one) inlet which also functions as an outlet from the Sumber Rejo channel. The position of the reservoir inlet/outlet is located far from the Sumber Rejo pump house, where the Sumber Rejo pump house inlet/outlet is STA 0+80 and the Boezem inlet/outlet is STA 0+225. In this calculation, the design flood discharge Q20 and concentration time (Tc) are used which have been calculated in the hydrological analysis.

Boezem Sumber Rejo is on the right side of the Sumber Rejo Channel. Inlet and Outlet as the entrance and exit of Boezem water are located at one point and are in the form of a box culvert measuring 2 x 2 m. For the calculation of the capacity, it is not only calculated from the boezem, but also the Rejo Source Channel which starts from the inlet/outlet point to the pump. After calculating the area and volume of the long storage and boezem Sumber Rejo, the next calculation is to combine the data with the inflow and outflow debits to calculate routing. The first step to calculate the routing is to find the volume of water leaving and entering the boezem. The second stage is to combine the data with flood and elevation pumps to find out how long it takes to pump water with flood pumps with capacities of 6 m3/second, 12 m3/second and 16 m3/second.

Table 5. Routing result

No	Description	Flood Pump Scenario		
		6 m3 / sec	12 m3 / sec	16 m3 / sec
1	Reservoir Capacity Requirement (M3)	74.837	42.222	24.965
2	Maximum Water Elevation (AMSL)	4,03	2,44	1,60
3	Flood Pump Operation Time (Hour)	6,08	3,50	3,00

With the 6 m3/second flood pumps installed, the reservoir capacity needed is 74.837 m3 which is still safe considering the maximum capacity of the reservoir is 88.712 6 m3. However the maximum water elevation is 4,03 meters above sea level, which means water will overflow from the Sumber Rejo channel. So with 6 m3/second flood pumps, the reservoir is capable to store the water, but the long storage of the Sumber Rejo channel will overflow.

The 12 m3/second flood pumps on the other hand, needed a reservoir capacity of 42.222 m3 which is safe considering the maximum capacity of the reservoir is 88.712 6 m3. The maximum water elevation is 2,44 meters above sea level, which means water will not overflow from the Sumber Rejo channel. So with 12 m3/second flood pumps, the reservoir and long storage is capable to keep the area from flooding.

The 16 m3/second flood pumps on the other hand, needed a reservoir capacity of 24.965 m3 which is safe considering the maximum capacity of the reservoir is 88.712 6 m3. The maximum water elevation is 1,6 meters above sea level, which means water will not overflow from the Sumber Rejo channel. However, there is a substantial diminishing return between the 12 m3 / second and 16 m3/ second flood pumps that made the latter inefficient in terms of value.

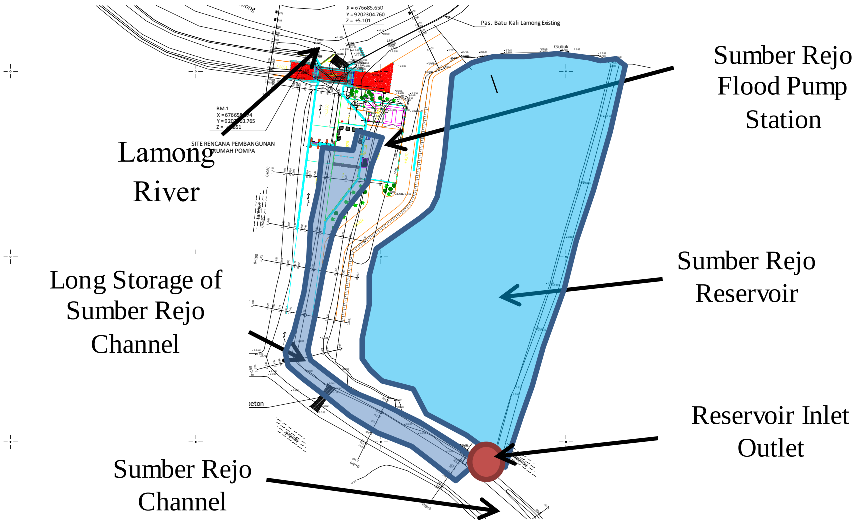


Figure 2. Detailed layout of the Sumber Rejo channel, reservoir and flood pump station

5. Conclussion and Suggestions

5.1. Conclusion

Based on the results of the analysis that has been carried out in this final project, it can be concluded that the main cause of flooding in the Sumber Rejo channel is tidal water from Lamong River, because in the calculation of the Hydraulics Analysis, it can be concluded that the water overflowing from the channel is only 2 points and easily normalized by means of the channel being deepened and widened. The flooding that occurred in the Sumber Rejo channel can be ascertained to have occurred because of the overflow of Lamong River, where the embankment in Lamong River was not high enough to stem the tide.

The maximum rainfall for the 20-year return period (Q20) is 22.5 m3/second, which means that in 20 years there will be one rainfall with a discharge of 22.5 m3/second. While the capacity of the existing pump installed is only 6 m3/second, which means that if there is no reservoir to accommodate it (boezem), the Sumber Rejo channel will still flood when it rains, because the sluice gate is closed and water can only flow through the flood pump. Therefore, on the east side of the Sumber Rejo pump house, a boezem has also been built with a maximum capacity of 88,712 m3 to prevent flooding. Therefore, routing calculations are needed to determine how much pump capacity is needed to keep the Sumber Rejo channel from flooding.

Boezem routing is calculated by trial and error system for capacities of 6 m3 / sec, 12 m3 / sec and 16 m3 / sec. With a pump capacity of 6 m3/second, it can be concluded that the reservoir is able to accommodate the maximum rainwater discharge, but the water will overflow from the long storage channel of the Sumber Rejo pump station. However, this maximum rainwater discharge only occurs once every 20 years so that the pump station and reservoir can work optimally with the current state of affairs. Meanwhile, if pumps with a capacity of 12 m3 / second are used, long storage and reservoir are safe without overflowing. The time it takes to pump the water with a 12 m3/sec pumps take only 3.5 hours to keep the elevation back at +0.89. As for the pump with a capacity of 16 m3/sec, it takes 3 hours to keep the channel elevation at +0.894. From the 3 routing scenarios, it can be concluded that the existing pumps and reservoir can overcome flooding at the sumber rejo channel with a note that the long storage embankment must be raised to avoid overflowing water. While a pump with a capacity of 16 m3 / sec is not needed, because the overall performance is not much different from a pump capacity of 12 m3 / sec and it is overall inefficient to install 16 m3 / sec pumps. An exception occurs if there is no water reservoir in the sumber rejo pump station, then the required pump capacity is 20 m3 / sec.

5.2. Suggestion

Based on the results of the analysis from this research, there are a few suggestions :

1. Normalize the channel so that it doesn't overflow at certain points
2. Increase the total pump capacity to a total of 12 M3/sec for optimal results

The embankment needs maintenance and elevation to keep the tide from overflowing from Lamong River

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