HIDROLOGICAL SIMULATION OF THE RIVERS' FLOOD CONTROL IN SUBDISTRIC WONOKERTO IN PEKALONGAN REGENCY

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Abstract: Flooding problem still become serious problem in subdistrict Wonokerto of Pekalongan regency. There are six rivers that have the potential caused flooding in setelment area. In this research, the researcher wanted to do hydrological simulation at six rivers in Wonokerto. The hydrological simulation is done by calculating the inflow in the river in the form of flood discharge hydrograph design with nakayasu method, and evaluate the capacity of river catchment to flood discharge. Based the results research on six rivers, it is known that the river capacity is not able to accommodate the flood discharge when enters the river. The River water are also known unable to flow by gravity caused of rob dikes that isolated the river water to flow into the sea, therefore to prevent overflow in the river needs and to prevent overflow and to control the river water level a pumping in rivers.

Keywords: Hydrological Simulation, River Flood Control, Storage Evaluation, Pumping

1. Introduction

Flooding is a condition that water can not be accommodated in a river or water in the drainage channel is obstructed, so water overflows inundated the surrounding area. Flooding can be caused by overflow of water from rivers caused by a lack of river storage capacity. (Suripin,2004). Hydrological simulations can be defined as mathematical modeling which aims to synthesize the continuous recording of some hydrological data variables over a period of time in an attempt to estimate and characterize the characteristic properties of an object by modeling as closely as possible (Fortin et al, 2001).

2. Basic Theory

The main theoretical basis in hidrology simulation of rivers flood control in sub distric Wonokerto of Pekalongan regency are rainfall plan calculation, calculation of flooding hydrograf discharge by Nakayasu synthetic unit hydrograph method and pump routing calculation.

2.1 Rainfall Plan Calculation

Rainfall intensity calculate to determine the largest annual rainfall with a return period of 2, 5, 10, 25, 50 and 100 years using Gumbel (Suripin, 2004), the equations to calculate rainfall plan is:

$$\text{R design} = x + \frac{Yt - Yn}{Sn} \times Sx \quad (1)$$

Where are x = input data Rainfall intensity, G = Coefficient, S = standart deviation

2.2 Efecctive Rainfall Calculation

Flood discharge hydrograph represents the total number of analyzes of efecctive rainfall from period 1 hour to 6 hour, this unit data is approximately suitable for use in rainfall analysis. If the those unit is taken longer then the variation of rainfall intensity, flood hydrograph becomes irregular, the equations are:

$$rT = (T \times RT) - (T-1) \times R(T-1) \quad (2)$$

2.3 Nakayasu Synthetic Unit Hydrograph Method

To calculate the Hydrograph of Unit of Synthesis The Nakayashu method has the following equation:

$$Q_p = \frac{A.R_o}{3{,}6.(0{,}3T_p + T_{0,3})} \quad (3)$$

$T_p = T_g + 0{,}8T_r$, $t_g = 0{,}4 + 0{,}058L$ for L > 15 km, $T_g = 0{,}21L^{0,7}$ untuk L < 15 km, $T_{0,3} = \propto t_g$

Where are Qp = flood peak discharge, A = basin area (km^2), Re = effective rainfall (mm), Tp = the time from the beginning of the flood to peak flood hydrograph (h), T0,3 = 0,3 times the peak flood discharge flood peak (hours), tg = time of concentration, Tr = the time unit of rainfall (hours), $\propto$ = coefficient watershed characteristics, L = The main river length (km).

2.4 Pumps Routing calculation

In this research, river storage serve to accomadate flood discharge, The difference of flood discharge and the pump capacity in a river storage water volume (Wahyudi et al., 2016) can be seen in figure 1.

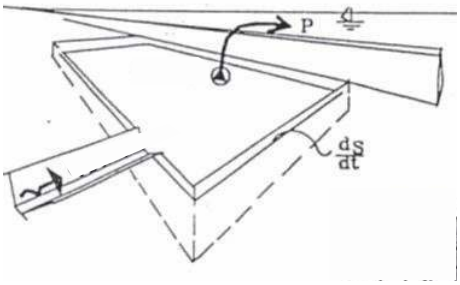

Fig. 1. Scheme of Capacity Retention Simulation

Whereby to simulate the continuity law are treated formula as follows:

$$S = V_{in} + V_{inf} - V_{out} \quad (4)$$

Where are S =Storage (reservoir volume), V_{in} = Inlet Volume, V_{inf} =Infiltration Volume, V_{out} = Volume exited by pump.

If the volume is created for a certain period of time equation becomes

$$\frac{dS}{dt} = Q_{in} + Q_{\text{inf}} - P \quad (5)$$

Because dike is protected by concrete sheet-pile, the simulation assumed Qinf = 0 (Harahap et al., 2014). So that the equation becomes

$$\frac{dS}{dt} = Q_{in} - P \quad (6)$$

Where are dS/dt = rate of change of reservoir volume, Q_{in} = Flood water discharge (m^3/dt), P = Pump discharge capacity (outlet) m^3/ dt. For the time interval t, the equation changes in the reservoir volume that can be written

$$0{,}5(Q_{in1} + Q_{in2})t + (S_1 - 0{,}5P_1t) = (S_2 + 0{,}5P_2t) \quad (7)$$

3. Existing Condition

Topography of the study in Subdistric Wonokertos plain areas with elevations between +0,00 m and +4,00 m above sea level. there are six rivers in the study area, it is Slempang river, Semut river, Tratebang river, Mrican river, Pekuncen river, and Pesanggrahan river. To

prevent the tidal flood in the study area will be built dikes with length 2868 meters and dike's elevation +2,00 above sea level . As a result of the development of the dike, water drainage of river can not flow by gravity. The following figure are the rivers and the rivers catchment area in the existing condition.

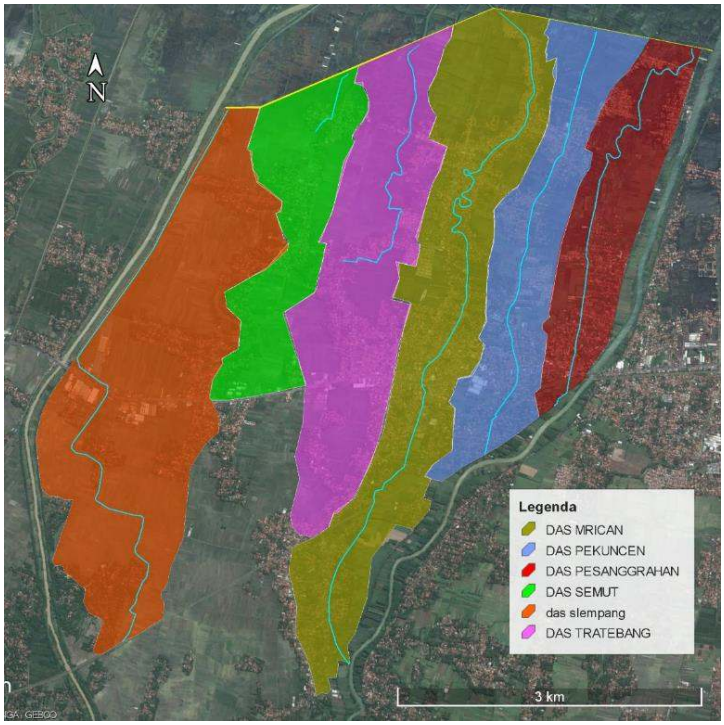

Fig. 2. Rivers and catchment area

Rivers' existing condition like length of river (L) and catchment area (A) is showing in the table 1:

Table 1. length and catchment area of rivers

No	River	L (m)	A (Km^2)
1	Sungai Slempang	6738	6,266
2	Sungai Semut	1751	2,145
3	Sungai Tratebang	3134	4,234
4	Sungai Mrican	8259	5,572
5	Sungai Pekuncen	4642.6	3,111
6	Sungai Pesanggrahan	2871	2,563

4. Research Methods

The research method are field orientation, data collection and processing as well as data analysis and rivers storage evaluation and simulation of pumping

4.1 Collection and processing of data

In this research, data collected including topographic maps and google maps, rainfall data Sta. No: 144 where located in Wiradesa subdistric and influence the study area, with 16 years duration of data from the 2001 s / d in 2016. The processed data is a topographical map and a map of Google which is processed into a map of the catchment area of rivers, rainfall data were processed by the method of Gumbel became rainfall plan with a return period of 2, 5, 10, 25, 50 and 100 years, river planning data are processed to get the storage capacity based on the water level.

5. Result and Discussion

5.1 Result of Rain Fall Plan Calculation

The result of rainfall intensity which calculate by Gumbel methods to determine the largest annual rainfall (R) with a return period (Tr) of 2, 5, 10, 25, 50 and 100 years is showing in the table 2 bellow.

Table 2. Result of Rain Fall Plan Calculation

No	Tr (Years)	R (mm)
1	2	109.956
2	5	156.032
3	10	186.538
4	25	225.082
5	50	253.676
6	100	282.06

5.2 Result Effective Rainfall Calculation

The Nakayasu Synthetic Unit Hydrograph is a method based on effective rainfall and rainfall distribution patterns at certain intervals. So it is necessary to know the intensity of rain hour-time first. The result of effective rainfall calculation show in the following table.

Table 3. Result of Effective Rainfall Calculation

Time Periods	Effective rainfall (mm)					
(ours)	2 th	5 th	10 th	25 th	50 th	100 th
1	22.42	35.78	46.24	59.93	70.36	80.9
2	5.83	9.3	12.02	15.58	18.29	21.03
3	4.09	6.52	8.43	10.93	12.83	14.75
4	3.25	5.19	6.71	8.7	10.21	11.74
5	2.75	4.39	5.67	7.35	8.62	9.92
6	2.4	3.83	4.95	6.42	7.54	8.67

5.3 Result of flood Hidrograph discharge calculation

Table 4. Result of flood Hidrograph discharge calculation

Period	**flood Hidrograph discharge** (m3/dtk)					
ours	Slempang	Semut	Tratebang	Mrican	Pekuncen	Pesanggrahan
1.00	37.73	32.96	41.65	28.95	24.18	19.75
2.00	35.92	17.25	24.20	30.54	18.69	15.41
3.00	29.46	8.82	24.20	26.14	10.90	8.99
4.00	19.69	4.29	11.35	21.89	9.25	7.64
5.00	17.39	3.90	8.29	15.95	7.77	6.43
6.00	15.25	3.36	7.52	14.28	5.23	4.32
7.00	10.89	2.63	6.06	10.54	3.94	3.11
8.00	7.08	1.28	3.86	7.97	2.83	2.31
9.00	5.47	0.79	2.77	5.43	2.07	1.70
10.00	4.28	0.41	1.95	4.35	1.55	1.27
11.00	3.38	0.22	1.32	3.51	1.16	0.95
12.00	2.70	0.11	0.85	2.86	0.83	0.68
13.00	2.12	0.06	0.58	2.35	0.60	0.51
14.00	1.65	0.03	0.41	1.91	0.43	0.37
15.00	1.28	0.02	0.27	1.54	0.31	0.27
16.00	1.00	0.01	0.18	1.23	0.23	0.19
17.00	0.78	0.00	0.12	0.99	0.16	0.14
18.00	0.60	0.00	0.08	0.80	0.12	0.10
19.00	0.47	0.00	0.05	0.64	0.09	0.07
20.00	0.37	0.00	0.03	0.52	0.06	0.05
21.00	0.28	0.00	0.02	0.42	0.04	0.04
22.00	0.22	0.00	0.02	0.33	0.03	0.03
23.00	0.17	0.00	0.01	0.27	0.02	0.02
24.00	0.08	0.00	0.01	0.22	0.02	0.01
25.00	0.09	0.00	0.00	0.17	0.01	0.01
26.00	0.07	0.00	0.00	0.14	0.01	0.01
27.00	0.00	0.00	0.00	0.11	0.00	0.00
28.00	0.00	0.00	0.00	0.09	0.00	0.00
29.00	0.00	0.00	0.00	0.07	0.00	0.00
30.00	0.00	0.00	0.00	0.06	0.00	0.00
31.00	0.00	0.00	0.00	0.05	0.00	0.00
32.00	0.00	0.00	0.00	0.04	0.00	0.00
33.00	0.00	0.00	0.00	0.03	0.00	0.00
34.00	0.00	0.00	0.00	0.02	0.00	0.00
35.00	0.00	0.00	0.00	0.02	0.00	0.00

5.4 River Storage Capacity

Capacity volume of six river storage, Slempang River, Semut River, Tratebang River, Mrican River, Pekuncen River, and Pesanggrahan River which is calculated based on river dimension and water level elevation. The equations to calculate river storage capacity is:

Storage Volume = length of river x dimension area x river water level (8)

So the result of river storage calculated is show in table 5.

Table 5. River Storage Capacity

No	River Name	Storage Volume m^3
1	Sungai Slempang	± 508451
2	Sungai Semut	± 180325
3	Sungai Tratebang	± 247070
4	Sungai Mrican	± 429540
5	Sungai Pekuncen	± 175006
6	Sungai Pesanggrahan	± 107808

5.5 Evaluation Storage Capacity of Rivers

The evaluation of storage capacity determined by evaluating the capacity of the river storage against the inflow parameter on the river. Where as the inflow data on the river is used flood Hydrograph discharge plan of the 25 years return period. The river storage is categorized as overflowing if the water level elevation exceeds the elevation of the river channel +0.50 m. Calculate of evaluation storage capacity of rivers is showing in tabel 6 to tabel 8 below:

Table 6. Evaluation Storage Capacity of Slempang river

Routing Period (hour)	Q Floods (m^3/s)	Storage Volume (m^3)	EMA Rivers + (m)	Information
1	37.73	101070	-0.5	-
2	35.92	233634	-0.17	-
3	29.46	351306	0.12	-
4	19.69	439772	0.34	-
5	17.39	506511	0.5	-
6	15.25	565255	0.65	Overflow

Table 7. Evaluation Storage Capacity of Semut river

Routing Period (hour)	Q Floods (m^3/s)	Storage Volume (m^3)	EMA Rivers + (m)	Information
1	22.96	70040	-0.5	-
2	17.25	142417	0.12	-
3	8.82	189348	0.51	Overflow

Table 8. Evaluation Storage Capacity of Tratebang river

Routing Period (hour)	Q Floods (m^3/s)	Storage Volume (m^3)	HWL Rivers + (m)	Information
1	41.65	56412	-0.5	-
2	24.2	174942	-0.03	-
3	15	245498	0.43	-
4	11.35	292924	0.74	Overflow

Table 9. Evaluation Storage Capacity of Mrican river

Routing Period (hour)	Q Floods (m^3/s)	Storage Volume (m^3)	HWL Rivers + (m)	Information
1	28.95	82590	-0.5	-
2	30.54	189672	-0.19	-
3	26.14	291685	0.1	-
4	21.89	378132	0.35	-
5	15.95	446230	0.55	Overflow

Table 10. Evaluation Storage Capacity of Pekuncen river

Routing Period (our)	Q Floods (m^3/s)	Storage Volume (m^3)	HWL Rivers + (m)	Information
1	24.18	53627	-0.5	-
2	18.69	130804	0.17	-
3	10.9	184069	0.64	Overflow

Table 11. Evaluation Storage Capacity of Pesangrahan river

Routing Period (our)	Q Floods (m^3/s)	Storage Volume (m^3)	HWL Rivers + (m)	Information
1	19.75	21533	-0.5	-
2	15.41	84820	0.23	-
3	8.99	128733	0.74	Overflow

The results of Evaluate the capacity of storage with inflow in the form hydrograph nakayasu discharge at 25 years return period is known the six rivers capacity are not able to accommodate the incoming water discharge, so it is necessary to drain the volume of river water with pumping.

5.6 Pumping Simulation

The river pumping simulation is determined by calculating the capacity of river basin against the inflows and the outflow stream. Where as the inflow data on the river is used the flood hydrograph discharge of 25 years return period and the outflow is the pumping capacity. After that is done simulation of pumping with large variation of pump discharge as outflow. In the simulation of pumping is attempted so that the river face elevation does not exceed the maximum height of river banks so that there is no overflow of river water that can inundate the settlements.

Pumping simulation is done with variation of pump discharge as outflow. During the pumping simulation, the river level elevation should not exceed the maximum height of the river channel so there will be no river flood or overflow that can inundate the settlement.

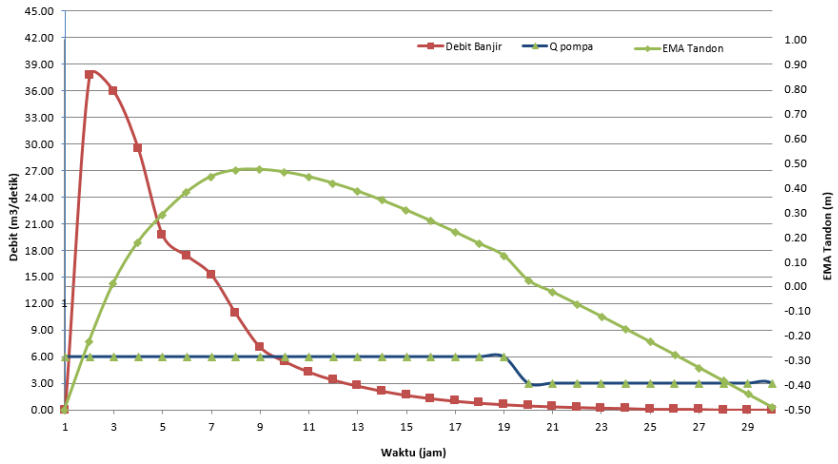

Fig. 3. Pumping Simulation graph of Slempang River

To prevent ourflow in Slempang River it is necessary to pumped with a capacity of 6 m^3/dt pumping for 19 hours from 1 to 19 hours and after 19 hours pumping capacity can be reduced to 3 m^3/s for 11 hours pumping up to hour periode to 30, where the river water level will decrease in the initial elevation - 0.5 m.

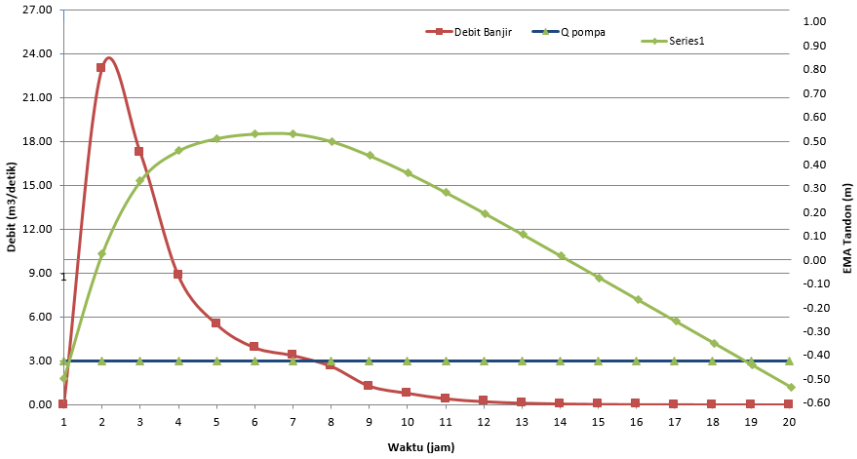

Fig. 4. Pumping Simulation graph of Semut River

To prevent outflow in the Semut river it is necessary to pumped with a 3 m^3 /s for 20 hours in the 1st to 20th hour period until the river water level will decrease at the initial elevation of -0.50.

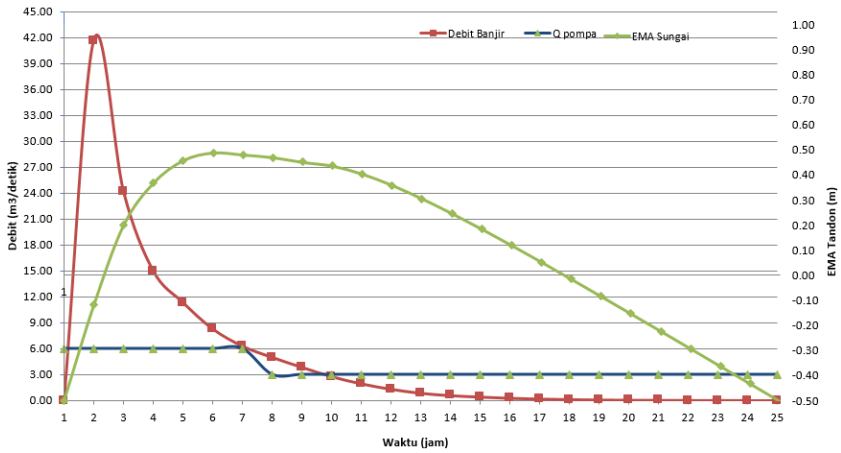

Fig. 5. Pumping Simulation graph of Tratebang River

In the Tratebang river it is necessary to pumped with a capacity of 6 m^3/sec for 7 hours at 1 to 7 hours, then after 7 hours of pumping, the pumping capacity can be reduced to 3 m^3/sec for 18 hours, where the river water level will decrease in the elevatawal -0.05.

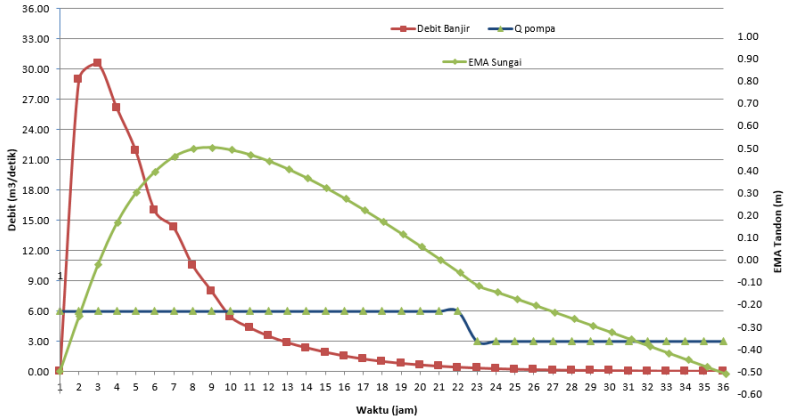

Fig. 6. Pumping Simulation graph of Mrican River

On the Mrican River it is necessary to pumped with a pumping capacity of 6 m^3 /sec for 22 hours from 1 to 22 hours, then pump with 3 m^3/sec capacity for 14 hours until water level will decrease at the initial elevation of -0.50.

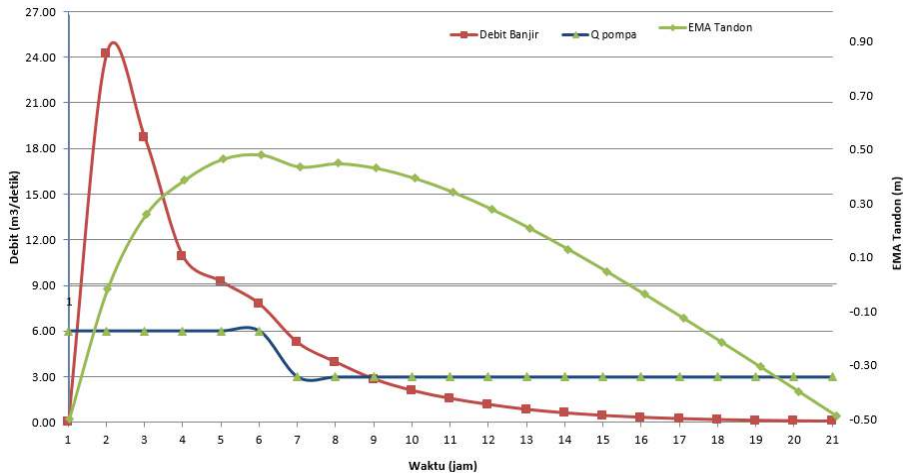

Fig. 7. Pumping Simulation graph of Pekuncen River

In Pekuncen River it is necessary to pumped with a 6 m^3 / sec for 6 hours in the 1st to 6th hour period. Then pumping capacity of 3 m^3/sec for 15 hours in the 7 th to 21th hour period until elevation the river water level will drop at the beginning of -0.50.

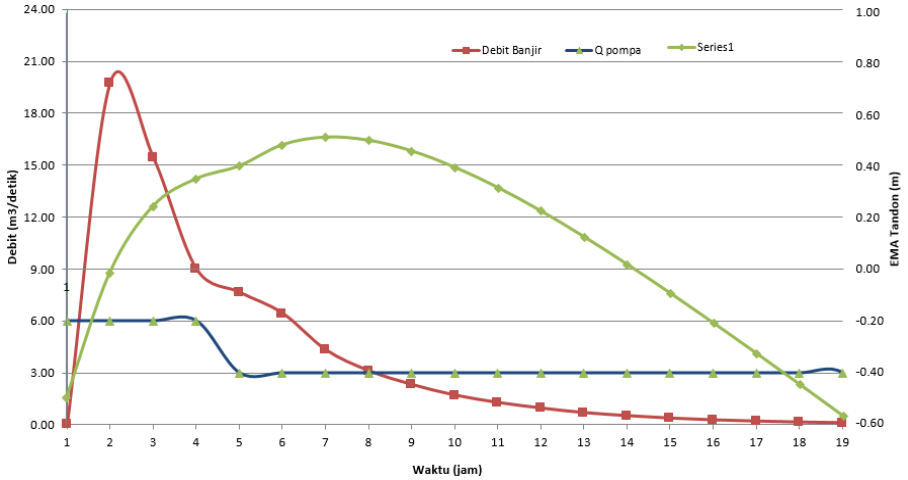

Fig. 8. Pumping Simulation graph of Pesanggrahan River

In Pesanggrahan River it is necessary to pumped with a pumping capacity of 6 m3/sec for 4 hours in the 1 to 4 hour period, then the pump capacity can be reduced to 3 m3 / s for 15 hours of pumping until the river water level will drop in elevation start -0.50 at the 19th hour.

6. Conclusion

The study results hidrological simulation of the rivers' flood control in Subdistric Wonokerto in pekalongan regency can be summarized as follows:

1. Based on the analysis of storage capacity, volume in Slempang River is 554451 m^3, Semut river is 131325 m^3, the Tratebang River is 329070 m^3, Mrican River is 495540 m^3, the Pekuncen River is 195006 m^3 and Pesanggrahan River is 177808 m^3. Based the results of evaluating rivers storage, the storage capacity of rivers are not able to accommodate the inflow water discharge, so it needs to be drainage out the water from the river with pumping.
2. Based of pumping simulation calculation, to prevent overflow in rivers, and to restore the river water level at initial conditions need pumping in river with pattern as follows:
   a. At Slempang river it is necessary to pump with capacity 6 m^3 /sec for 19 hours and continued with 3 m^3 /sec pump capacity for 11 hours.
   b. At Semut river it is necessary to pump with capacity 3 m^3/sec for 20 hours.
   c. At Tratebang river it is necessary to pump with capacity 6 m^3/sec for 7 hours and continued with 3 m^3 /sec pump capacity for 18 hours.
   d. At Mrican river it is necessary to pump with capacity 6 m^3/sec for 22 hours and continued with 3 m^3 /sec pump capacity for 14 hours.
   e. At Pekuncen river it is necessary to pump with capacity 6 m^3/sec for 6 hours and continued with 3 m^3/sec pump capacity for 15 hours.
   f. At Pesanggrahan river it is necessary to pump with capacity 6 m^3/sec for 4 hours and continued with 3 m^3 /sec pump capacity for 15 hours.

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