HYDRAULIC SIMULATION OF TIDAL FLOOD HANDLING OF PABEAN DRAINAGE SYSTEM IN PEKALONGAN, INDONESIA

HENNY PRATIWI ADI
Assoc. Professor in Civil Engineering, Faculty of Engineering, Sultan Agung Islamic University, Semarang, Indonesia, henni@unissula.ac.id

WAHYUDI, S.I.
Professor in Civil Engineering, Faculty of Engineering, Sultan Agung Islamic University, Semarang, Indonesia, wahyudi@unissula.ac.id

JONATHAN LEKKERKERK
Lecturer in Water Management, Rotterdam University of Applied Science, Rotterdam, Netherlands, j.lekkerkerk@hr.nl

ABSTRACT

Tidal floods occur in Pekalongan, Indonesia. The length of tidal flood affected reaches more than 15 km coastal length, and upstream up to 4 km length. To handle tidal flood in Pekalongan, some efforts have been made by making a polder system, which is building of 9 km long beach embankment, making long storage and several pump houses. One area is in the center of Pekalongan called as the Pabean drainage system. In this system, the government has built 2.4 km sea dike. This study aims to calculate the flood discharge plan, flood hydrograph per hour, volume of retention basin and pump capacity required. Primary data was collected in the form of elevation and flooding. While secondary data included rainfall data, maps and existing drainage systems. The first analysis carried out was to determine the catchment area and water reservoir. Then the hydrology was analyzed with the Nakayatsu Hydrograph Formula, and hydraulics simulation with the EPA-SWMM application. The research results showed that maximum flood discharge plan was 23 m3/s. Retention basins are long storage (2,315 m length, 10 m wide and 2.5 m depth), existing ponds, rivers and drainage networks. The pump simulation is prepared with a capacity of 2 x 2 m3/s, the water flow reaches normal after 15 hours. In the future water reservoirs in the Pabean area must be preserved, in addition it is proposed to change the form of housing to a floating house, which does not cause a reduction in the volume of retention basin.

Keywords: Tidal Flood, Polder System, Pabean, Simulation, Hydraulics, storage, pump

1. INTRODUCTION

Flooding is a natural phenomenon that occurs as a result of several factors such as rain, river, upstream, cultivation areas and tides conditions [1]. The potential for the current threat of flood disaster is caused by the state of damaged river bodies, damage to water catchment areas, violations of spatial planning, violations of law increases, lack of integrated development planning, and low community discipline [2].

Pekalongan is a city located on Java Island, Indonesia. As a city located in a coastal area, tidal flooding is a routine problem in Pekalongan. The length of the beach affected by the tidal flood reached more than 15 km. This flood has a very wide impact on settlements, agriculture, industry, offices and social economic problems of the community. This tidal flood is caused by land subsidence, sea level rise, land changes, lack of waste management and others [3]. Handling efforts have been made by making a polder system with building of a 9 km long beach embankment, making long storage and several pump houses. One of the polder systems is located in the center of Pekalongan City called the Pabean drainage system. In this system, the government has built a 2.4 km sea dike and pump house (Figure 1). This study aims to calculate the planned flood discharge, hourly flood hydrograph, reservoir volume and pump capacity required.

Figure 1. Sea Walls and Pump Houses in Pabean Drainage Systems

2. LITERATUR REVIEW

2.1 Tidal Flood

A tidal flood is a flood caused by the tide, so that the tides flood the land [4]. Tidal floods often occur in areas whose surface is lower than sea level. Several factors that cause or support the occurrence of tidal floods are global warming, excessive use of ground water, clearing of mangrove forests, topographic conditions of an area, subsidence, narrowing of river banks, garbage disposal in rivers, and poorly maintained drainage systems [5]. Some ways that can be done to cope with flooding are as follows:

- Harvesting rainwater in the upper area, making pumps for the lower area, and damming the incoming sea water to land.
- Doing the concept of water front city, which makes water a part of daily life of the community. This concept can be applied in areas that have a high rate of land subsidence.
- Doing the concept of tidal gate, which is to put a water gate or tidal gate in an estuary area with the aim to prevent the sea water coming and entering the river from being too big.
- Doing the concept of polder, which is making a small pond that is used to accommodate rob. The polders must be arranged in such a way and carried out in an integrated manner, as well as being part of the city drainage.

2.2 Hydrology

Hydrological analysis is very necessary to determine the magnitude of the planned flood discharge, in which flood discharge plan will have a major effect on the magnitude of the maximum discharge and the stability of the construction to be built [6]. The steps in the hydrological analysis are as follows:

a. Determine the extent of the River Basin (DAS).
b. Determine the area of river rainfall stations and their extent.
c. Determine the maximum annual rainfall from available rainfall data.
d. Analyze rainfall plans using a T year return period.
e. Calculates plan flood discharge based on the amount of rainfall plan above at the T year return period.

2.3 Polder Drainage System

A polder system is a way to handle rob or flood by building a complete physical facility which includes, systems, retention ponds, drainage systems, round embankments, pumps and sluice gates, as an integral water management unit [7]. Polder is an area formed in such a way and bounded by embankments so that runoff water from outside areas cannot enter. Thus only surface runoff or excess water coming from the region itself that will be managed by a polder system [8]. Inside the polder there is no free surface flow as in the natural catchment area, but it is equipped with a control building at its disposal with a drain or pump that functions to control excess water. The water level in the polder system does not depend on the surface of the water in the surrounding area because the polder uses embankments in its operations so that water from outside the area cannot enter the polder system [9]. The polder system drainage component consists of :

1. The embankment serves to isolate the area from runoff / leakage from outside the system, such as floods and tides.
2. The flood gates function to hold flood water / tidal water from outside the system so that it does not enter the retention pond / channel and to channel flood discharge out of the system in the event of a pump failure and the water level outside the system which is lower than the water level in the system .
3. The water pump is used to channel the flood discharge to the outside of the system in the event of rain.
4. Retention ponds function to accommodate the flood discharge when it rains.
5. The drainage channel network functions to channel flood discharge from the entire system to the retention pond / pumping station.

2.4 SWMM Concept Model

Environmental Protection Agenda - Storm Water Management model (EPA-SWMM) is the Observation Hydrograph method (measured discharge) which is calibrated by the Nash method. Analysis of land changes used the 2005 land use map, the 2010 and 2014 Quick Bird Satellite Imagery is based on an information system (GIS). The use of quick bird high-resolution satellite imagery fulfills accuracy in determining impervious areas and catchment area morphometry as the main parameters in EPA-SWMM input. This model is used to plan, analyze and design a model related to rainwater runoff and drainage systems in urban areas. This model is also used to simulate the occurrence of single or sustained rainfall over a long period, both in the form of runoff volume and water quality, especially in an urban area [10]

The Process of EPA – SWMM is as follow :

a. Sub cathment division

   The initial step in the use of SWMM is the division of sub cathment in the study area. The division is in accordance with the catchment area (DTA) which is determined based on land elevation and runoff movement when it rains.

b. Network Model Making

   Network modeling is based on the existing drainage network system in the field. After the next network model, all parameter values are needed for all these properties.

c. Flow Response Simulation in Tien Series

   Flow Response Simulation on Tien Series is done to see the flow discharge response to time based on the amount of rainfall. The value entered is the value of rainfall distribution against time with the total value of all rainfall design results from hydrological analysis.

d. Simulation model

   This simulation is carried out after the drainage network model and all parameters successfully entered. The simulation can be said to be successful if the continuity error <10%. In a SWMM simulation, the amount of flood discharge is calculated by modeling a drainage system. SWMM output

   The outputs of this simulation include runoff quantity continuity, continuous routing flow, highest flow instability indexes, routing time steps, runoff subcatchment, node depth, inflow node, surcharge node, flooding node, outfall loading, link flow, and conduit surcharge presented in draft simulation statistics report. Visualization of the results displayed in the form of a drainage network output from the simulation results, flow profiles of several major channels and is known to be inundated, and flow graphs that occur in the channel

3. RESEARCH METHOD

Primary data in this study include elevation and inundation. Whereas secondary data includes rainfall data, study location maps and existing drainage systems. Data analysis included:

1. Calculation of Catchment Area and water catchment area using GIS and Auto-cad.
2. Calculation of hydrological analysis with the Nakayatsu Hydrograph Formula,
3. Hydraulics simulation with EPA's Storm Water Management Model (SWMM) application.

4. RESULT AND DISCUSSION

4.1 Catchment Area Calculation

For calculating the needs of the flood discharge plan, data on the catchment area for each river and drainage channel is needed. The data on the catchment area (DAS) of the Pabean channel is 738 Ha, as can be seen in Figure 2.

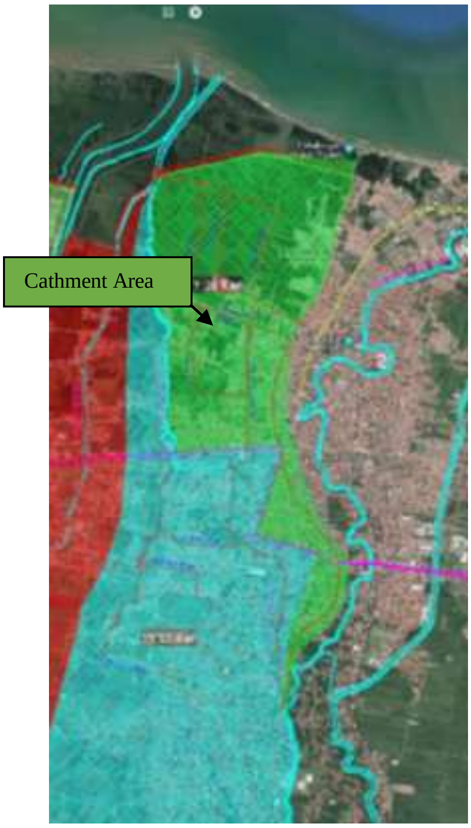

Figure 2. Catchment Area of Pabean

4.2 Hydrological Analysis

In hydrological calculations, a rain analysis plan is carried out for each of the watersheds reviewed. Analysis of rainfall frequency at the Pabean catchment area was based on maximum rainfall data at the Pabean catchment area with an area of 7.38 km2 with a river length of 8.204 km.

Frequency analysis of rainfall data used 6 methods, namely the Normal method, Normal Log (2 parameters), Normal Log (3 parameters), Pearson Type III, Pearson Type III Log and Gumbel Type I. The results of rainfall frequency analysis can be seen in Table 1.

Table 1. Results of Analysis of Maximum Daily Rainfall Frequency

Tr (Years)	τ	Probability distribution					
		Normal	Log Normal 2 Parameter	Log Normal 3 Parameter	Gumbel I	Pearson III	Log Pearson III
2	0.0000	111.8	103.9	106.7	105.3	106.5	102.9
5	0.8416	149.1	143.3	146.3	152.5	146.6	143.7
10	1.2816	168.6	169.6	170.3	183.8	170.8	172.2
20	1.6449	184.7	194.8	192.1	213.8	192.5	200.6
25	1.7507	189.4	202.8	198.8	223.3	199.2	209.8
50	2.0537	202.8	227.7	218.9	252.6	219.0	239.1
100	2.3263	214.9	252.7	238.3	281.7	237.9	269.4
200	2.5758	225.9	277.9	257.1	310.7	256.1	300.9
500	2.8782	239.3	312.0	281.5	349.0	279.3	344.7
1000	3.0902	248.7	338.3	299.6	377.9	296.3	379.7
10000	3.7190	276.5	430.1	5170.4	473.9	350.7	509.0
Maximum deviation		4.69	8.03	6.70	9.52	6.65	9.25
Delta critical (Sig. Level 5 %)		29.4	29.4	29.4	29.4	29.4	29.4

Based on the four methods above, we find the smallest deviation value. Based on these calculations, it can be concluded that the method used was the Normal method, because the maximum deviation is the smallest. The results of the rainfall analysis plan were used to calculate the flood hydrograph unit.

Hydrograph unit from the Pabean System catchment area can be seen in Figure 3 below:

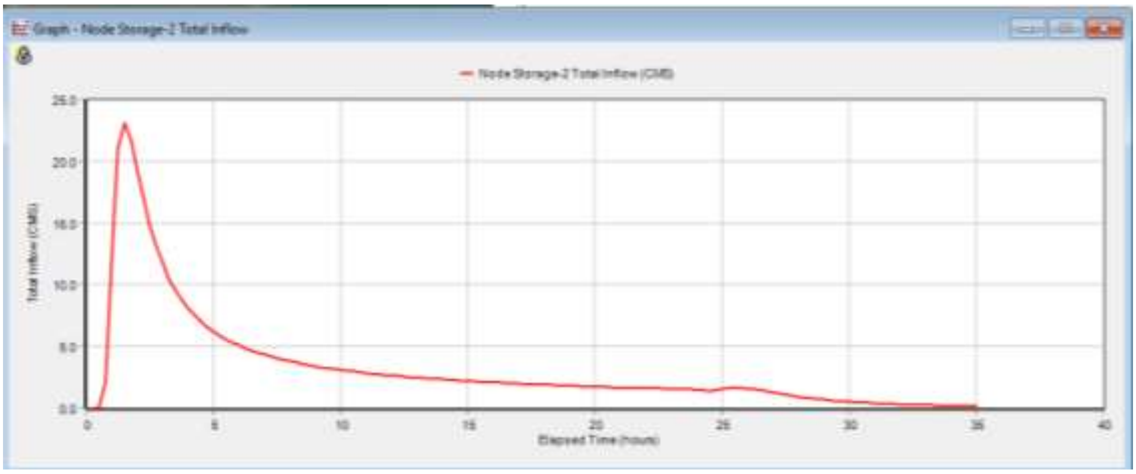

Figure 3. Hydrograph Unit of Pabean Flood Debit from the results of the SWMM analysis

4.3 Hydraulics Simulation with SWMM

The planned Technical Data for Retention Ponds includes the area of the reservoir which is the sum of the Longstorage area and is added by 5% of the catchment area in the upstream area of 39.30 Ha. The water depth is 2.50 m so that the maximum storage capacity is 982,500 m3. Based on local elevation references, the bottom of the pond is at -1.5 m elevations, while the maximum water elevation in the pool is +1.0 m, and the embankment elevation is at +3.00. At present, the maximum sea tide is at an elevation of +2.3 m. Retention ponds accommodate flood debit from upstream Pabean channels which were then pumped with a maximum capacity of 4 m3 / sec, where the difference between flood discharge and pump discharge was a change in the volume of retention ponds. The retention pond simulation scheme in long storage can be seen in Figure 4 below.

In this condition, the water level was with a depth of 2.5 meters in long-storage. The pump was activated from 1 m water depth which was identical to water elevation - 0.50 m.

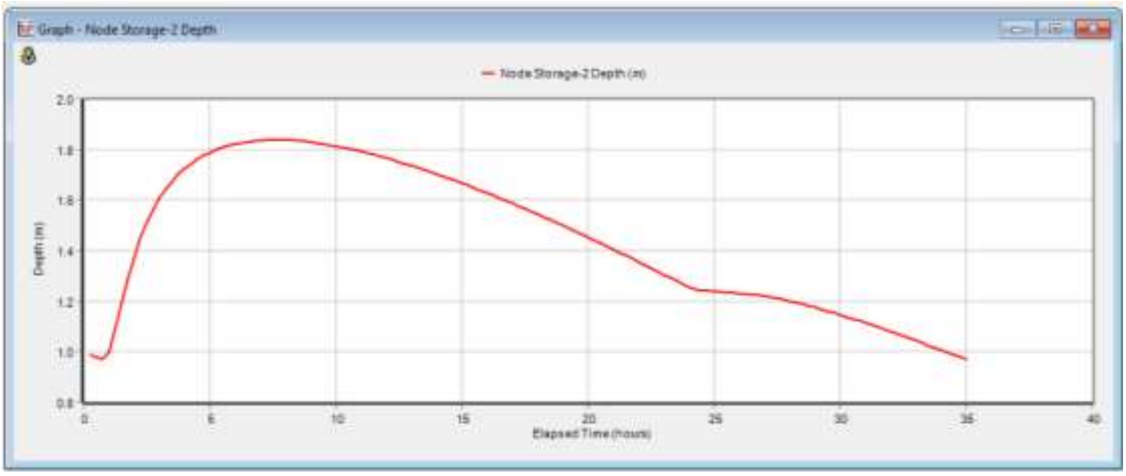

Figure 4. Depth of Water Level

The results of the water depth simulation would then be combined with the hydrograph and pump debit units. This hydrograph unit debit was an hourly discharge distribution, while pump discharge was a discharge that was activated during rainy conditions. Figure 5 shows the simulation results of the three variables.

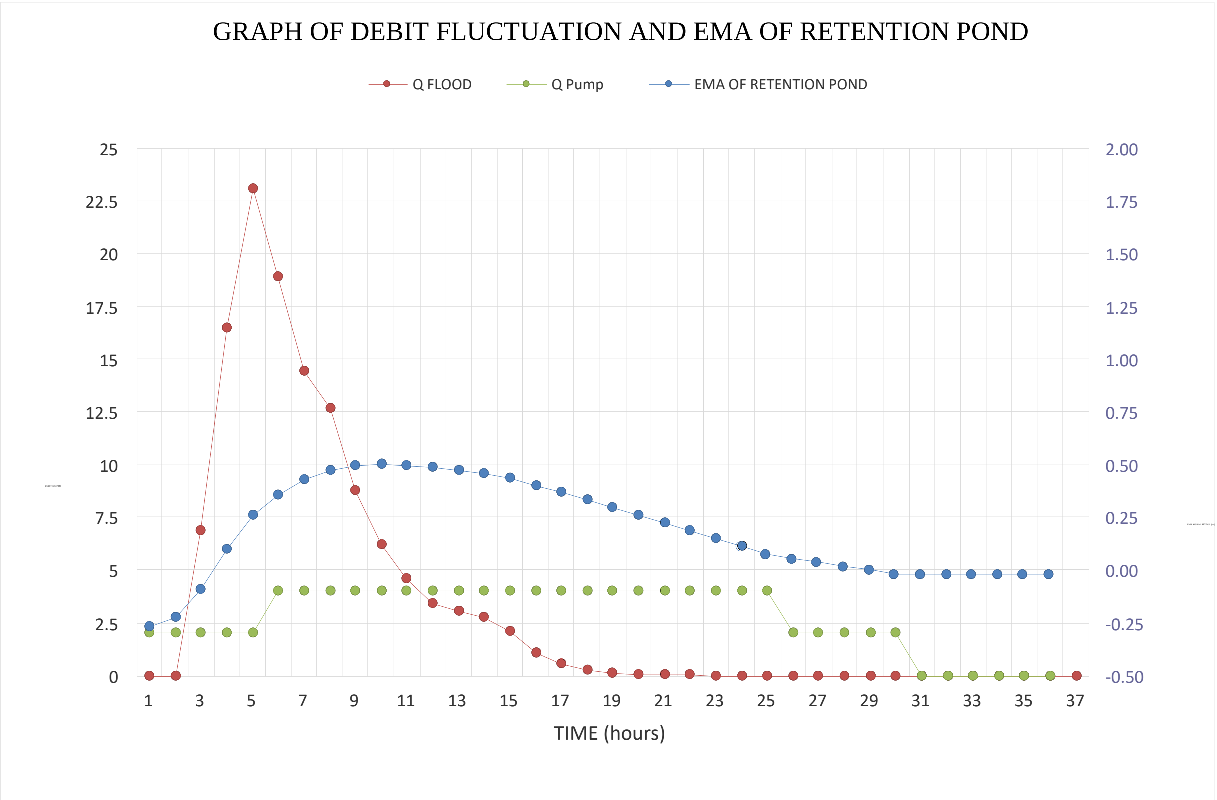

Figure 5. Result of Flood Discharge simulations, Pump capacity and water elevation of Pabean System Retention

The red line is the result of a flood discharge simulation. The green line is the capacity of a working pump, and the blue line is the result of water level elevation based on local references. The discharge parameter used the left-side ordinate, while the elevation parameter used the right-side ordinate. The results of this simulation would be used for pump operational guidelines. Based on the field survey, the water elevation began to occur in the Pabean area in the range of +1.8 m.

5. CONCLUSIONS

Based on the results of hydrological calculations and analysis, it can be concluded:

1. The calculation result of Pabean catchment area with an area of 7.38 km2 with a river length of 8,204 km. The maximum flood debit plan is 23 m3 / s.
2. The results of the long storage scheme, flood debit simulation, and pump capacity using the EPA-SWMM application are made to accommodate excessive water discharge in the Pekalongan Pabean area. The following are the results of the simulation.
   a. The Long storage scheme was planned to be 2,315 m long, 10 m wide, with a depth of 2.5 m. This storage was in the Bremi River channel, the calculation of debit used rainfall intensity data with a return period of 25 years, while the highest discharge was at storage 23.09 m3 / sec.
   b. Pumps in the Pabean area used the size of 2x2 m3 / sec or 4 m3 / sec. It was planned that the pump can operate for 35 hours. In the first 2 hours, it could throw 2 m3 / second of water. At the 3rd to 24th hours the pump could throw 4 m3 / second and at the 25th hour to the 35th hour the pump can throw 2 m3 / second. Water debit decreased significantly at the 2nd hour to the 15th hour. The water debit was normal again after the pump worked for 15 hours.

Based on the explanation above, it can be concluded that the pump shows enough performance based on the catchment area and existing storage condition. This simulation is recommended to be an operational guide for pumps in the Polder drainage system.

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