Polder System to Handle Tidal Flood in Harbour Area (A Case Study in Tanjung Emas Harbour, Semarang, Indonesia)

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Abstract. Tanjung Emas harbour is one of the strategic harbours in Indonesia, which is located in Semarang City. Several problems arise nowadays; the drainage channel capacity decreases due to lack of treatment, rainwater storage reduced, land subsidence and the rise of tide sea level. The flood control used is polder system that classified into several clusters. The research location is focused on the Cluster IV, which the right side of harbour area. According to the data, catchment area is 29.3 hectares, the lowest elevation area is in +0.5 m, the dike elevation is +2 m LWS. Then retention pond area prepared is 900 m² (0.3% of CA), retention pond depth - 2m LWS. Based on simulation using 2x0.3 m³/sec pump and rainfall intensity return period of 25 years 303 mm, fluctuation in water retention pond can be maintained in +0.5 m water level. It is recommended to add 0.3 m³/sec alternative pump. A pump of 3x0.3 m³/sec needs to be prepared. Based on the simulation, by Polder system, the flood problem in harbour area can be solved.

Keywords: polder system, tidal flood, harbour

1. Introduction
The problem of flooding and inundation in the working area of Tanjung Emas harbour is caused by decreasing drainage channels capacity, increasing drainage loads due to lack of storage areas, land subsidence, and the rise of sea level. [1], Tanjung Emas harbour is one of the strategic harbours in Indonesia, which is located in the Capital City of Central Java Province, Semarang. [2].

Tanjung Emas harbour has a working area of 636 hectares and water area of about 17,800 hectares. The flood control used polder system which is classified into several clusters. The classification is based on hydrology, drainage system, and land use. Cluster I is located in Lamicitra area and Indonesia Power, Cluster II is located in Tanjung Emas Coaster area or Container Terminal area, Cluster III covers M. Pardi Road area, Inner Port Terminal, and east Kalibaru area, while Cluster IV covers office areas along west Kalibaru where is as the research location. The purpose of the research is to compile a Polder Cluster system design concept to protect port facilities against better and optimal integrated sea level rise and land subsidence.

2. Condition and Theoretical Review
The paragraphs explain to determine the rainfall plan in the catchment area and flood discharge, knowing the water reservoir in the drainage system and retention pond, and conducting Polder storage with pumping simulations.
2.1. Rainfall Plan Calculation
The method must be determined by look at the characteristics of rain distribution in the local area. The rainfall data covers 16 years with rainfall station in the area. The return period will be calculated on each method are 2, 5, 10, 25, 50 and 100 years period using Gumbel method. [3]. The equations to calculate rainfall plan are:

\[ R_{design} = X + \frac{Y_t - Y_n}{S_n} \times Sx \]  

(1)

Where \( x \) = input data Rainfall intensity, \( G \) = Coefficient, \( S \) = standard deviation

2.2. Pumping Simulation
Retention pond accommodates flood discharge through drain collector. Pump and water storage arrange water level in retention pond. The difference of flood discharge and pump discharge will change the water volume and level of the retention pond. Thus, it is needed to simulate the pump capacity. The scheme of retention pond and pump simulation can be seen in Figure 1. [4]

\[ \frac{dS}{dt} = Q_{in} + Q_{inf} - \frac{dS}{t} \]  

(3)

Since dike is protected by concrete sheet-pile, geomembrane, the simulation assumed \( Q_{inf} = 0 \). The equation becomes:

\[ \frac{dS}{dt} = Q_{in} - P \]  

(4)

Where \( \frac{dS}{dt} \) = rate of change of reservoir volume, \( Q_{in} \) = Flood water discharge (m³/sec), \( P \) = Pump discharge capacity (outlet) m³/sec. For the time interval \( t \), the equation changes in the reservoir volume which can be written. [5]

\[ 0.5(Q_{in1} + Q_{in2})t + (S_1 - 0.5P_1t) = (S_2 + 0.5P_2t) \]  

(5)

3. Research Method
The research methods are field survey, primary and secondary data collection, data processing, data analysis, and pumping simulation. [6]. The research methods include field survey to flood-affected
points. Primary data collection by measuring land elevation at location and canals. Secondary data collection in the form of climatology data and rainfall data for 16 years at the influential rainfall station.

Data analysis includes of rainfall distribution analysis and flood discharge analysis. Pump simulation is performed to control the water level at the location based on data and analysis. Figure 2 present the catchment area where in the paper focusing in Cluster IV of Harbors area.

![Figure 2. Catchment area of polder system in Semarang harbor.](image)

The rainfall data used are three rainfall stations in Pucang Gading, Maritime and Karangroto during 16 years observation since 2000 to 2015. The rainfall data is analyzed by Gumbel method become rainfall plan with the return period 2, 5, 10, 25, and 100 years.

Flood Discharge analyzed by Nakayatsu method for 25 years return period based on the characteristic of the canals. Pumping simulation shows pump capacity illustration and duration of heavy rain. [7]. The simulation result will be used for operation procedure.

4. Result and Discussion

4.1. Result of Rain Fall Plan Calculation

The result of rainfall intensity which calculates by Gumbel methods to determine the largest annual rainfall (R) with a return period (Tr) of 2, 5, 10, 25, 50 and 100 years that is shown in Table 1. [8]. The hydrograph flood discharge of 25 years return period by Nakayatsu method is shown in Figure 3.

| Number | Tr (Years) | R (mm) |
|--------|------------|--------|
| 1      | 2          | 165.19 |
| 2      | 5          | 220.38 |
| 3      | 10         | 256.91 |
| 4      | 25         | 303.08 |
| 5      | 50         | 337.33 |
| 6      | 100        | 371.33 |
Flood discharge in the channel of 1.35 m$^3$/sec will flow into the retention pond and then pumped into a Kalibaru River. The flood discharge analysis is important to calculate pump capacity required.

4.2. Pumping Simulation Result

The technical data of polder system simulation are 29.3 hectares catchment area, 1070 m canal length, 1.2 m canal depth, 1800 m$^3$ water storage volume. Bottom elevation of storage is -2.00 m LWS (Low Water Sea) and dike elevation is +2.00 m LWS.

The total pump capacity used in this simulation are 0.60 m$^3$/sec. Distribution analysis uses Gumbel method with return period 25 years which is 303.08 mm/day rainfall intensity. Discharge analysis uses Nakayatsu method getting flood discharge 1.35 m$^3$/sec [9]. The simulation results with 0.60 m$^3$/sec pump capacity give the highest water level elevation + 0.403 m and the pump is active for 24 hours.

The figure above is Cluster IV map in Tanjung Emas harbour. East boundary of the area is Kalibaru wharf, West boundary is housing and industry area, north side is sea, and south side is National route. Figure 5 shows simulation results of rainfall discharge, storage volume and pump capacity. According to the result, pump capacity can be used in 0.6 m$^3$/sec. And the researchers recommend to use 2 pump with 0.3 m$^3$/sec a pump capacity. [10]. Comparing to the previous paper in Plan of Mulyorejo Polder System that use optimum pump capacity 1 m$^3$/s for about 107 Ha catchment area.[11]
5. Conclusion
To Handle Tidal Flood in Tanjung Mas Harbour (Cluster IV) is used Polder system drainage. According to the simulation for 29.3 Ha catchment area, 1800 m$^3$ water storage volume, rainfall intensity returns period of 25 years 303 mm and 1.35 m$^3$/sec flood discharge, using 0.6 m$^3$/sec pump. The fluctuation in water retention pond can be maintained in +0.5 m water level. It is recommended using 2x0.3 m$^3$/sec pump capacity and add 0.3 m$^3$/sec for redundant pump. Therefore, pump capacity of 3x0.3 m$^3$/sec needs to be prepared. Based on the simulation, by the polder system, the flood problem in harbour area can be solved.

6. References
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