USE OF PROPOSED RESERVOIRS TO REDUCE FLOOD IN SEMARANG CITY

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ABSTRACT: Hydrological and hydraulic flood simulations are performed by using existing conditions and reservoirs for flood reduction. The hydrology model (HEC-HMS 3.2) was used to simulate the design flood and reservoir reduction, while hydraulic model (SOBEK 2D) to simulate the high and flooded area in Garang Basin. Results show that 64 percent of flood reduction is at Pajangan observation station (from 1869.2 m^3/sec to 669.5 m^3/sec), and flooded area approximately reduced with 51.6 ha (from 111.6 ha to 60.1 ha). The simulations used the 25 years flood return period

KEYWORDS: flood, reservoirs, modelling, flooded area, flood reduction

1. INTRODUCTION

1.1 BACKGROUND

Semarang City as the capital of Central Java has a strategic location as center of administration, industry, commerce and economic development, but the flood problem in Semarang has hampered the city's development. Environment of Semarang has also degraded because of the from year to year increase of flooded area. These floods are caused by a combination of high tide (local name, *ROB*), local rainfall, and flood from upstream area. The report shows that the flooded area caused by *ROB* is ± 3100 ha and by rainfall upstream ± 450-600 ha. (*Master plan Document of Semarang Drainage*, 2007).

In order to solve the flood problem due to high rainfall in upstream location, the Government of Semarang plans to develop 51 reservoirs or small ponds throughout the Semarang area (*Master plan Document of Semarang Drainage, 2007*). This study has selected 5 (five) reservoirs attached to Garang River Basin out of the 51 (fifty-one) proposed reservoirs or ponds, namely Jatibarang, Mundingan, Gribik, Jatisari and Garang Reservoirs. Simulation was performed using these 5(five) reservoirs with aim to obtain the flood reduction if the 5 reservoirs are developed.

1.2 AIM AND OBJECTIVE

Aim of study is to obtain the reduction rate and extent of flooded area if the 5 reservoirs are built in the upstream of Garang Basin. The objective of study is to get an illustration of effectiveness of reservoirs reducing flood at Garang Basin.

1.3 LOCATION OF STUDY

The location of study selected Garang Basin in Semarang area, Central Java.

2. METHODOLOGY

This study consist of two methods comprising rainfall-runoff method using HEC-HMS 3.2 software package, and flood routing using SOBEK 1D-2D software package. The hydrology model with HEC-HMS is used to simulate the design flood with various return periods and simulate the reduction of floods using reservoirs as flood controlling structure. Moreover, SOBEK model is used to simulate the extent of flooded area at Garang Basin.

The hydrology model at Garang Basin uses the SCS Curve Number and Snyder Unit Hydrograph method, while Kinematics Wave method is used in the river. SCS Curve Number method chooses base on data availability and basin characteristics. Reservoirs data used in this study are storage elevation curve, and spillway data. Hydraulic modeling in the rivers was done by using 1D and 2D models. Cross-section data used in the model are very limited, only some cross-sections in the downstream, and a few cross-sections in the upstream. DEM was developed with Arch GIS 9.0 software using contour and elevation data from *Bakosurtanal* , *2000*. The DEM data is 8 years old; this condition makes it difficult to verify the flooded area in the downstream considering the relatively high land subsidence in Semarang.

Hydrographs data for hydrologic model calibration were collected from AWLR (automatic water level recorder) stations. These data must have the same events with rainfall events. Not all data have the same events between flood and rainfall, only three collected events, i.e. 1997, 2004 and 2006. From three events, 2004 had no rainfall data at all from ARR (automatic rainfall recorder) in the Garang Basin, except data collected from several rainfall stations. This condition makes calibration for that year very difficult. For better results, hydraulic model verification was done at Garang-Pajangan and downstream area. Interviews with the people living close to the river were done for verification. Their main question was on the extent of flood occurring every year in the Garang River, which is then to be compared with the flood elevation from model in 2 years return period. Downstream verification was done to obtain flood information because of *ROB*.

3. RESULT AND DISCUSSION

3.1 LOCATION OF STUDY

Garang River is the largest river in Semarang that flows from upstream area (Ungaran Mountain) to Semarang City. There are three major rivers flowing from the upstream to downstream combining into one river that is the Garang River. Those three major rivers from west to east are the rivers Kreo, Gribik, and Garang. The downstream of Garang River is developed into the West Flood Canal and the Semarang River itself, the existing river. Location of study is shown on Figure 1.

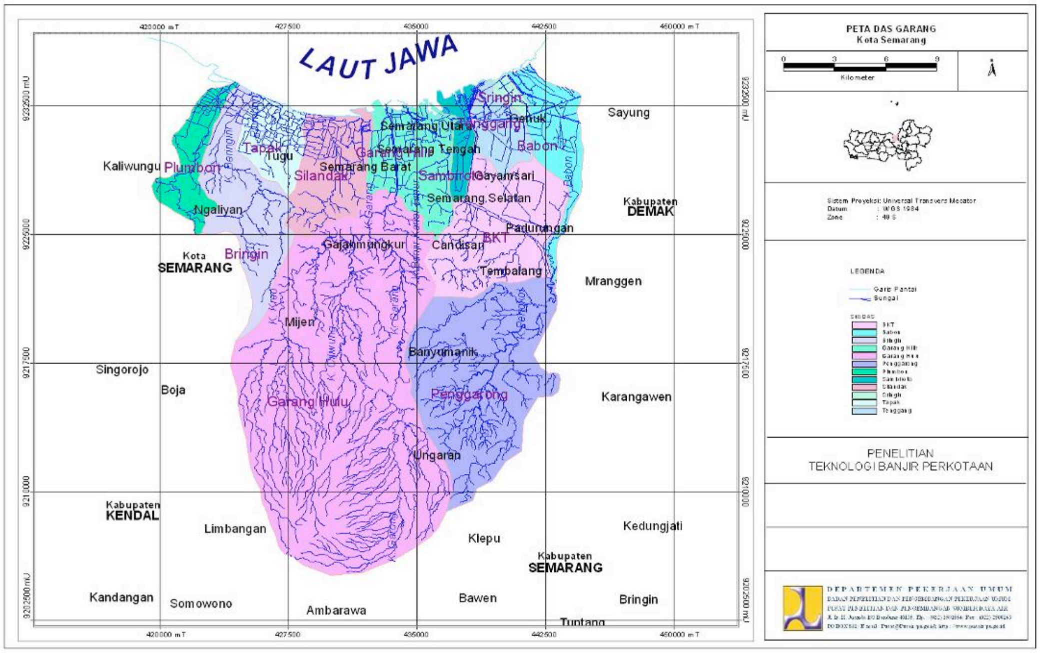

Figure 1. Location of Study

The Garang Basin, the most extensive catchment in Semarang with area 22,901.7 ha has a high flood potential. Major land-use at Garang catchment are paddy field, 523.5 ha, dry field, 437.3 ha and settlement area, 556.4 ha. Forest area left in the Garang Basin is only 189.9 ha. Soil at Garang Basin is classified as alluvial Hiromort, 144.9 ha, gray alluvial, 109.6 ha, brown Andosol 193.7 ha, brown Litosol, 540.5 ha, brown Meridian, 418.9 ha and brown Latosol, 718.8 ha. Land gradient at Garang Basin shows steep slopes in the upstream, flat, semi- steep and flat slopes in the downstream. Major land declivity is 0-2%, followed by 2-15%.

3.2 DESIGN FLOOD SIMULATION

3.2.1 Model Schematization

Hydrological modeling at Garang Basin was undertaken in the three major rivers namely: Kreo, Gribik and Garang. Due to limited data, calibration of these rivers was done at Garang-Pajangan station after the river confluence. Modeling divided each river catchment into two segments, upstream and downstream. Upstream segment includes the catchment area used as upstream boundary condition, whereas downstream segment for lateral inflow in the hydraulic model. Hydrology model schematization is shown on Figure 2.

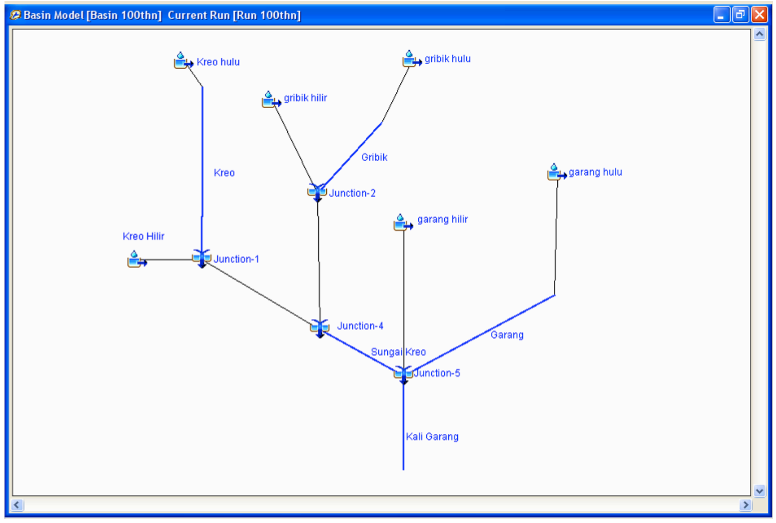

Figure 2. Schematization of Hydrological Model

3.2.2 Model Calibration

Calibration is required for every model simulation in order to obtain appropriate variables for the trial and error method. Known variables are obtained from data and the unknown variables from the trial and error method by changing the unknown variable until flood hydrograph results from the model fit the observed hydrograph. Flood hydrographs used in the calibration involve flood hydrographs from 1997, 2004 and 2006. The calibration model shows that the hydrograph between model and observation does not in shape each other in 2004, but results in 1997 and 2006 did. This condition occurred because rainfall data obtained from ARR were not sufficient. Model calibration is shown on Figure 3.

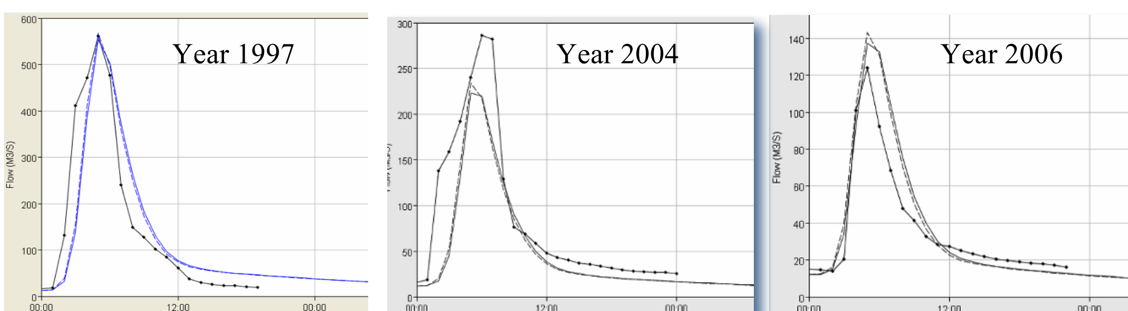

Figure 3. Calibration Results of HEC- HMS Model

3.2.3 Garang Basin Design Flood

Design flood is calculated based on the new parameters obtained from calibration. The rainfall data used in this simulation include design rainfall from isohyets. The result of Garang, Gribik and Kreo design floods with various return periods is shown in Table 1.

Table 1. Design Flood with Various Return Periods

Catchments	Return Period (m^3/s)					
	2 years	5 years	10 years	25 years	50 years	100 years
Garang-Pajangan	658.4	1092.3	1353.9	1869.2	2132.1	2445.0
Upstream Gribik	64.7	107.0	137.8	175.9	205.2	235.0
Upstream Garang	225.9	375.4	439.0	677.6	737.6	840.1
Upstream Kreo	208.7	344.1	437.1	556.8	643.7	729.4

3.3. FLOOD ROUTING SIMULATION

3.3.1 Model Schematization

Model schematization was developed to determine the location of cross-section and discharge inflow both from upstream and lateral inflow. Boundary conditions in the upstream comprise the design flood whereas boundary condition in the downstream is the HHWL (Higher High Water Level Tide) elevation. Cross-section data were obtained from the Experimental Station for River and tidal elevation from the Experimental Station for Coastal Areas. Most of these cross-sectional data are not appropriate for use, except a few data with exact coordinate. Benchmark used in this study is the TTG 447 from *Bakosurtanal*. Model schematization is illustrated on Figure 4.

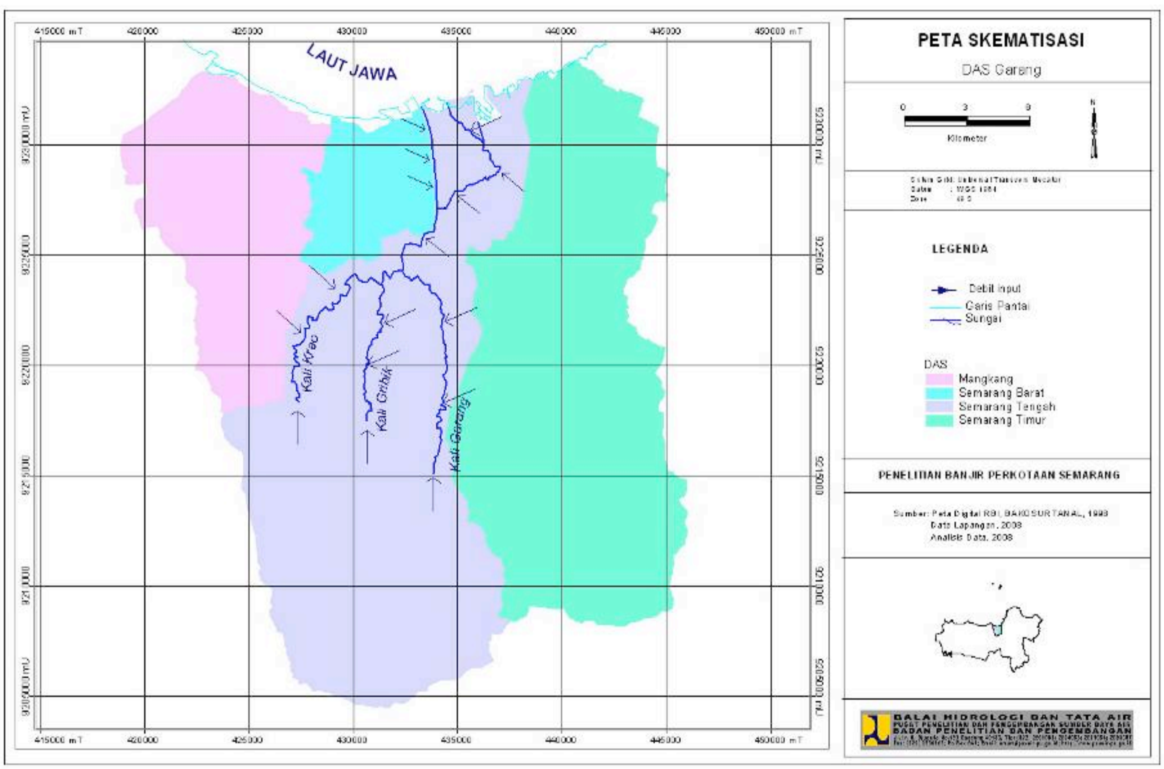

Figure 4. Model Schematization of Garang Basin

3.3.2 Flood Routing of Existing Condition

Flood Routing of existing condition was done by using the 25 years flood return period. The 1D-2D model simulation result shows that large flood occurs in downstream the Garang because of flood from upstream area and high tide. Floods were observed at three locations, i.e. middle reach of the Garang River after river confluence, West Flood Canal, and the Semarang River, with largest flood caused by the Semarang River. Total flooded area reached 111.6 ha. Flood routing with existing condition are seen on Figure 5.

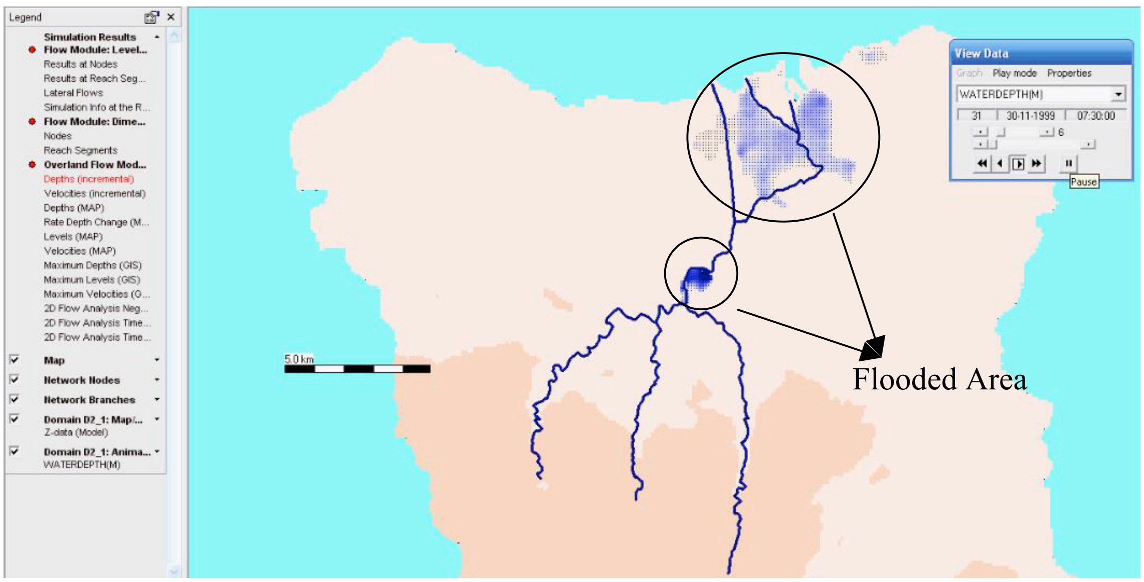

Figure 5. Flood Simulation with 25 years Return Period

3.3.3 Model Verification

Field survey for model verification was implemented at two locations, Garang-Pajangan Station and in downstream area. Interviews with the local community that lived near Garang-Pajangan River were also conducted. These people were among others asked on the every year flood occurrence and the highest flood ever experienced. According to their information, flood in the area happens almost every year with a height of 1 m below highest river dike. High floods in the Garang usually occur every December when the community is taking guard observing flood elevation when heavy rain is falling down. The yearly-observed flood elevation confirmed by the community should support the 2 years flood return period from model simulation. Flood simulation with 2 years return period is depicted on Figure 6.

Figure 6 shows flood elevation at Garang-Pajangan +10.2 meter with dike elevation +11.3 meter. The freeboard height of ±1 meter confirms the information from the local community on every year freeboard height of approximately 1 meter. Second model verification is on conditions in the downstream area, near the coastal area of north Semarang adjacent to the road overpass. *ROB* causes flood in the downstream area to occur almost every month especially during full moon whether it is raining or not. *ROB* in the downstream area is shown on Figure 7.

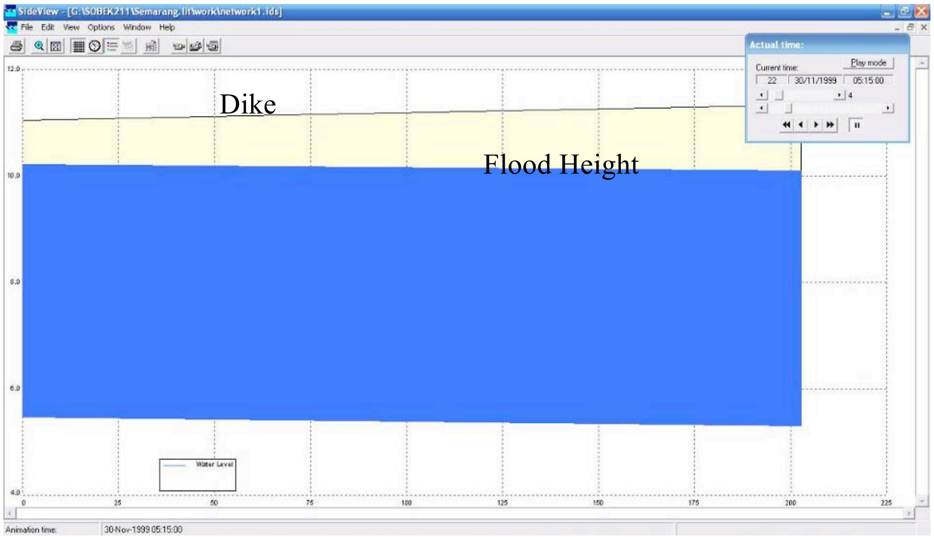

Figure 6. Flood Level with 2 years Return Period at Pajangan

Figure 7. *ROB* in North Semarang

3.5 RESERVOIR SIMULATION FOR FLOOD REDUCTION

3.5.1 Hydrology Simulation Using Reservoirs for Flood Reduction

The 5 (five) proposed reservoirs are located in three major rivers. Mundingan and Jatibarang Reservoirs are located in the Kreo River, Gribik Reservoir in Gribik River, Jatisari and Garang Reservoirs in the Garang River. If these 5 (five) reservoirs are constructed, flood can be reduced with 64% from 1869.2 m^3/s to 669.5 m^3/s at Pajangan Station with 25 years return period. These reservoirs are shown on Figure 8, and schematization model is shown on Figure 9. An example for inflow and outflow of the Jatibarang Reservoir is shown on Figure 10.

Simulation results are expressed below:

- Inflow at Mundingan Reservoir, 556.8m^3/s; outflow, 188.2m^3/s. Flood reduction reaching 66%.
- Inflow at Jatibarang Reservoir, 185.6m^3/s; outflow, 127.6m^3/s. Flood reduction reaching 31%.
- Inflow at Gribik Reservoir, 165.1 m^3/s; outflow, 34 m^3/s. Flood reduction reaching 79%.
- Inflow at Garang Reservoir, 677.6 m^3/s; outflow, 669.8 m^3/s. Flood reduction reaching 1 %.
- Inflow at Jatisari Reservoir, 662.1 m^3/s; outflow, 266 m^3/s. Flood reduction reaching 60 %.

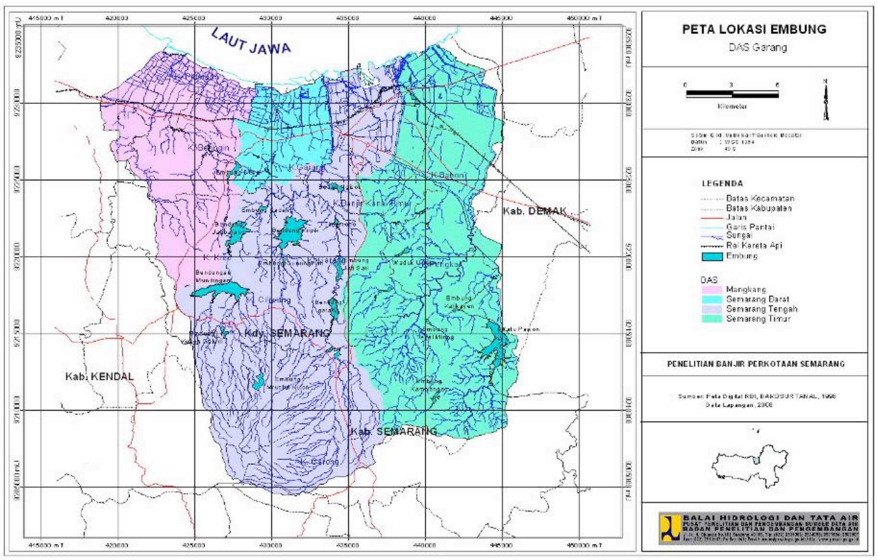

Figure 8. Location of Reservoirs in Garang Basin

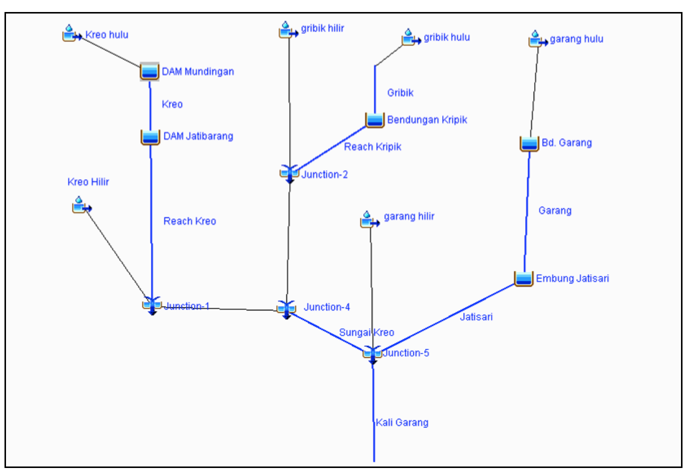

Figure 9. Model Schematization with Reservoirs

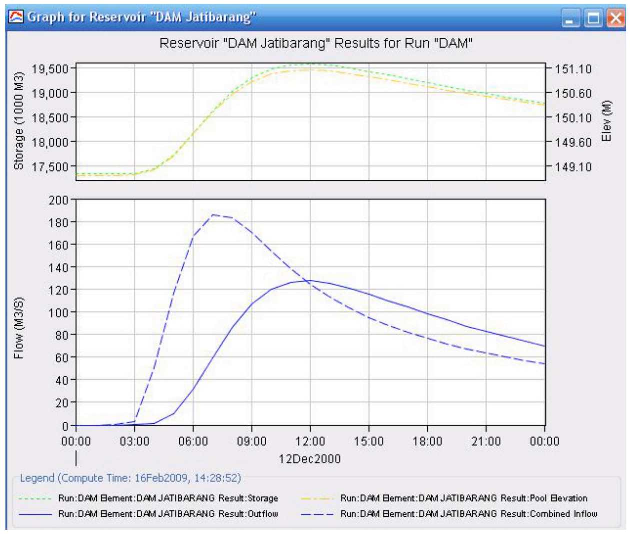

Figure 10. Inflow and Outflow in Jatibarang Reservoir

3.5.2 Hydraulic Simulation to Determine Flooded Area and Depth.

A hydraulic model using 5 (five) reservoirs for flood reduction was conducted to determine the flooded area and using SOBEK 1D-2D model to indicate depth. The simulation used a design flood with 25 years return period. The boundary conditions in the upstream changed to new discharge value while the boundary value in the downstream is still the same. These discharge values were modified using flood reduction values from HEC-HMS analysis. SOBEK results using reservoirs as flood reduction are shown on Figure 11.

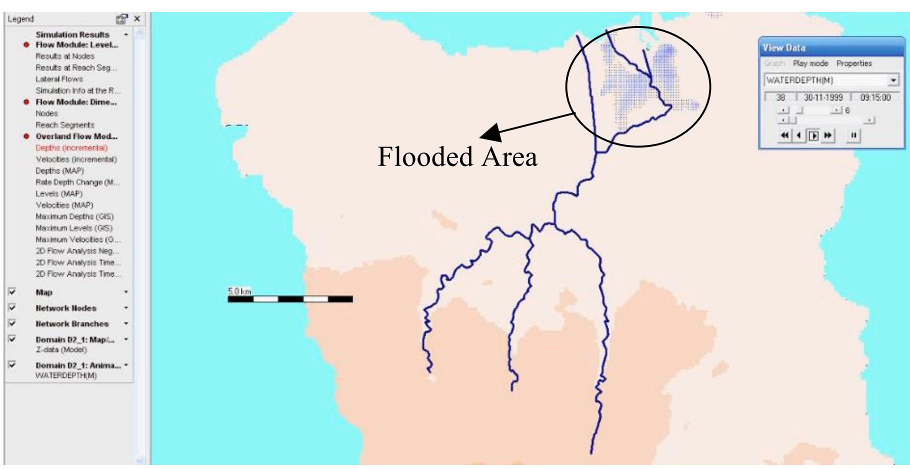

Figure 11. 2D Simulation Using Reservoirs as Flood Reduction

The simulation result using reservoirs as flood reduction showed that flood only occurred in downstream Garang namely from Semarang River, while the West Flood Canal and Garang River after confluence are not causing floods. Floods in the Semarang River are because of the small river dimension and low River dikes. Additionally, flow in the Semarang River is blocked by the high tide. This condition causes higher floods than normal. Flooded area also reduced from 111.6 ha to 60.1 ha. Meaning that 51.6 ha can be reduced from floods.

Although the flood controlling method using reservoirs is significant to reduce floods, this method needs further consideration because normalization of the Semarang River and dike construction are still required. Funds to built reservoirs are also very large, but reservoirs can be an advantage if multifunction reservoirs are constructed for fisheries, hydro-power generator, water recreation, etc.

Flooded area from modeling only involves the Garang River and does not include the Semarang area. Tide prediction measurements were made in 2008, however in future, floods caused by *ROB* will be a more serious threat and cover wider areas due to global climate changes and land subsidence.

4. CONCLUSION

The conclusion from hydraulic and hydrology simulation can be summarized as below:

1) Mundingan Reservoir can reduce flood from 556.8 m^3/s to 188.2 m^3/s, Jatibarang Reservoir 185.6 m^3/s to 127.6 m^3/s, Gribik Reservoir 165.1 m^3/s to 34 m^3/s, Garang Reservoir 677.6 m^3/s to 669.8 m^3/s, and Jatisari Reservoir 662.1 m^3/s to 266 m^3/s. The analysis had made use of a 25 years return period. Overall total reduction of flood reached 64% at Pajangan.
2) Hydraulic flood routing results show that existing condition causes floods in the Garang-Pajangan, West Flood Canal and Semarang River. Flooding covers an area of 111.6 ha.
3) Hydraulic flood routing using reservoirs as flood reduction method shows that flood occurs only in the Semarang River with flooded area 60.1 ha, indicating a flooded area reduction of 51.5 ha.
4) Simulation used secondary or old data. In future, this simulation should be re-run using updated data of land subsidence and sea level rise due to global climate changes.

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