Hydrodynamic Modelling of Flood Inundation on Welang River, Indonesia

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Keywords: A 1D-2D Coupled Hydrodynamic Model, Flood Inundation, Welang River, MIKE FLOOD.

Abstract: A flood inundation in a river can be caused by an increase in river water level due to the addition of water discharge from both the rainfall and the tides from the sea. Flood inundation simulation can be done by using a numerical flood model flood model. In the Welang basin, floods occur every year and cause many problems. Floods that occurred on April 29, 2019, caused the closure of national and regional roads and many houses that were flooded. In the present study, flood model was carried out by using MIKE FLOOD software. Semare Village and Tambakrejo Village are critical points where floods occur. The depth of the water from the simulation model occurs 0.3 m - 2.2 m compared to the flood map report by the Indonesian National Disaster Management Agency which estimates it at 0.1 m - 1.5 m.

1 INTRODUCTION

The Welang Basin is threatened with flooding every year. It happened during the rainy season from December to June. The higher the surface of the river water from the increasing intensity of rainfall and rising sea level due to the tide cycle, this results in a higher risk of flooding. The Welang River has many tributaries (about 21) with a total watershed area of 509.5 km^2 and a length of about 53 km, so that the river's water level becomes high when the intensity of rainfall increases.

(Wahyudi et al., 2018) investigated a method to apply eco-drainage to control flooding that often occurs in the Welang river, however, the flood can't be predicted how far it can spread of eventhough the flood affects Pasuruan districts so that flood control using the method of harvesting rainwater, by using infiltration ponds requires a large number of wells to be applied. (Wahyudi and Sumirman, 2019), showed how the flood management in the Welang basin can be done by injecting flood water into ground water using Artificial Storage Recharge (ASR). However, there have been no studies on two-dimensional flood inundation models in the Welang River Basin.

MIKE FLOOD 1D-2D coupled model is a powerful software for integrated hydraulic (1D) – hydrodynamic (2D) modelling purpose. A lot of research has been done using MIKE FLOOD 1D-2D coupled model (e.g., Dat, et al., 2019, CTCN, 2017, Timbadiya et al., 2014, Kadam and Sen, 2012, Patro et al., 2008). In the present paper, the existing condition of flood in the Welang river is simulated by using the MIKE FLOOD 1D-2D coupled model. The expected final result is a flooding map.

2 STUDY AREA

The modelling area is located at the downstream of Welang River. The desired model area is located at Kraton sub-district, Pohjentrek sub-district (Pasuruan district), and Gadingrejo sub-district (Pasuruan City) from Dhompo village to river mouth on the north, where river levels data is measured at Dhompo village in the coordinate system (-7.665908 latitude, 112.856342 longitude). The model area showed in Figure 1 within the red area.

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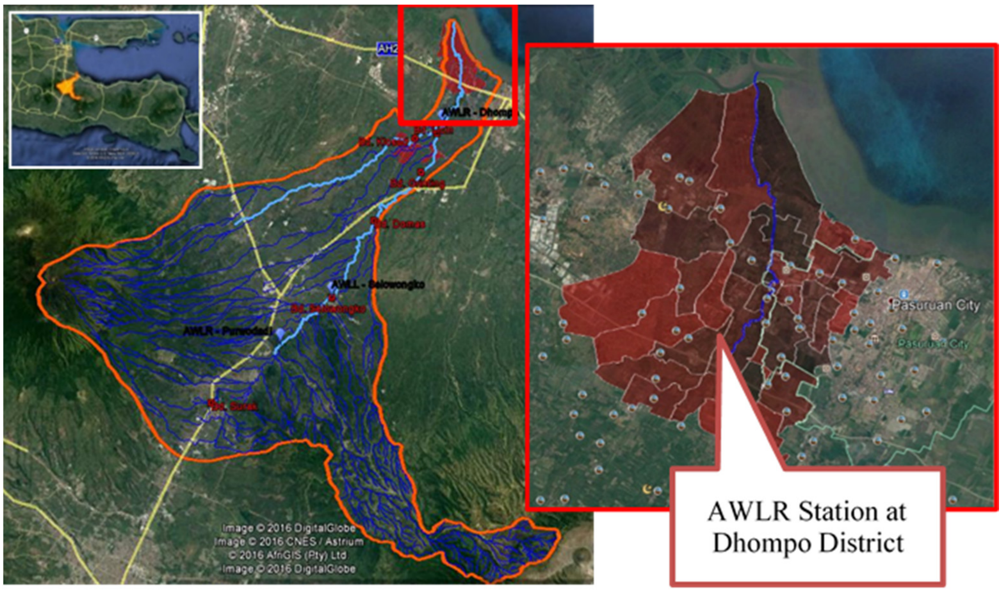

Figure 1: Modelling area of Welang River (Google Earth Pro).

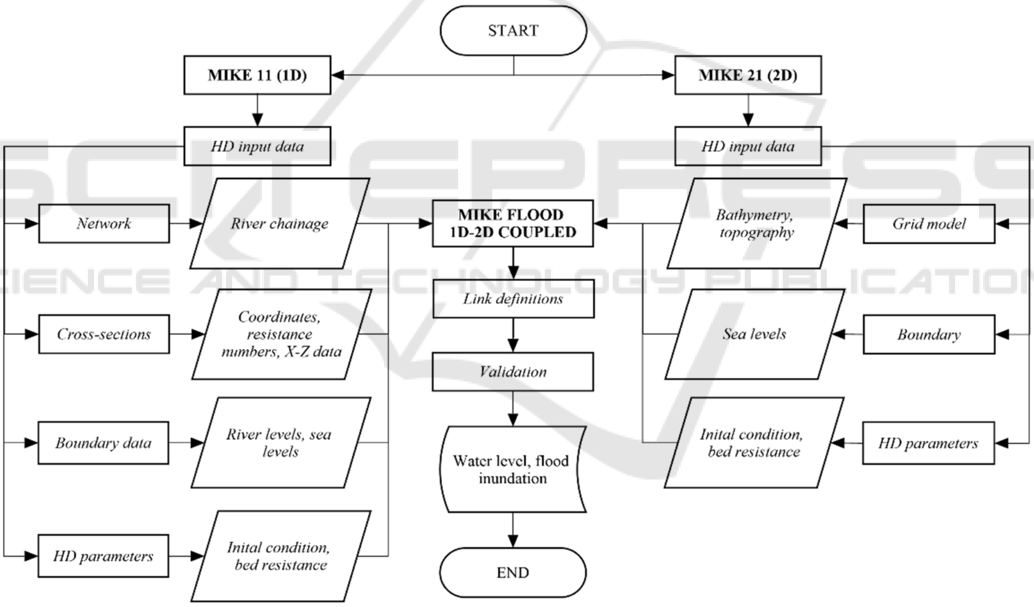

Figure 2: Flow chart of MIKE FLOOD 1D-2D coupled model.

3 METHOD

The methodology applied for solving this problem consists of the data collection, the model settings on MIKE 11 1D and MIKE 21 2D, the models added MIKE FLOOD 1D-2D, and the model validation can be seen in Figure 2. The MIKE FLOOD 1D-2D coupled model consists of upstream river surface and sea level at the river mouth (Figure 3). Hourly river level data collected for 1 year in 2019 and sea level forecast data were collected from measurements for 15 days in 2014 in Grati, Pasuruan.

Bathymetry and topography data were collected from the Indonesian Geospatial Information Agency. Surface height and cross-section data collected from the Water Resources Public Works Department of East Java Province. The model runs from 27 April 2019 11:00 PM and finishes on 29 April 2019 6:00 AM.

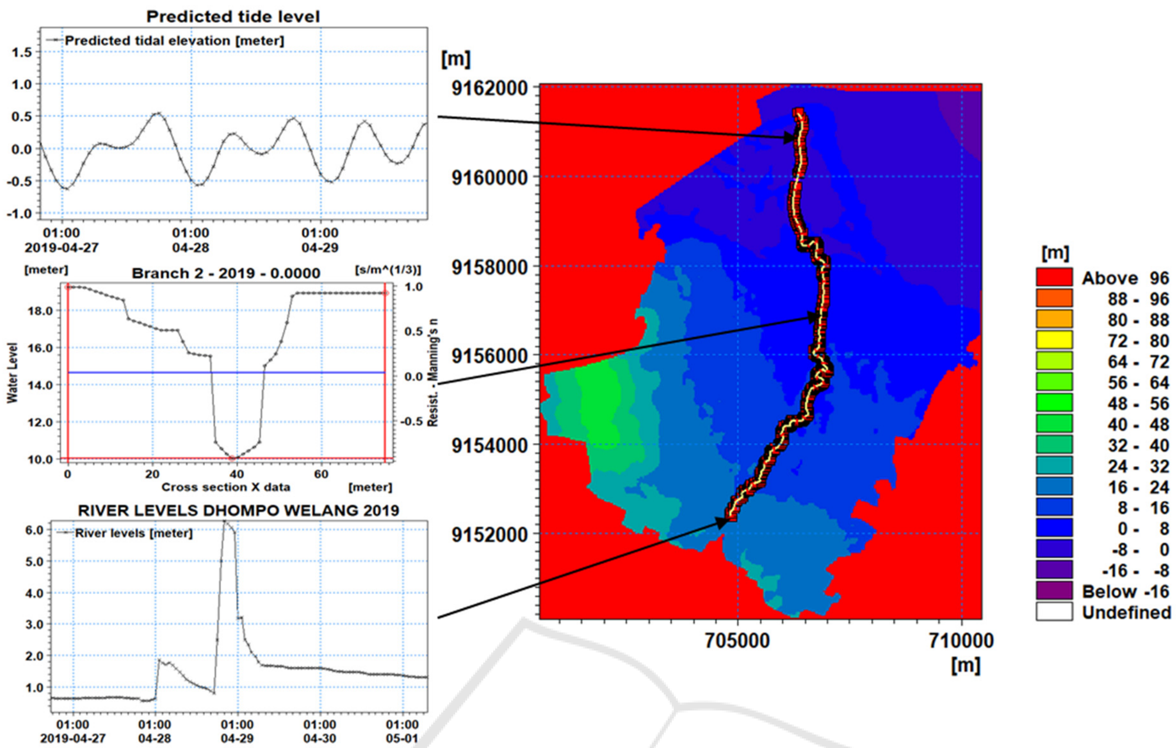

Figure 3: Modelling setup of MIKE FLOOD coupled model.

Manning coefficient is used for determining the bed roughness parameters. Applied bed roughness coefficients are divided into river, landuse and sea bed areas, which use a uniform distribution. The bed roughness coefficient values are estimated based on (Chow, 1959) and the MIKE 21 recommendation summarized in Table 1.

Table 1: Applied Manning number.

Natural stream	Manning's n
River upstream	0.040
River downstream	0.045
Landuse	**Manning's M**
Vegetation, natural areas	22
Sea	**Manning's M**
Seabed	32

Table 2: Average Bed Slope of Welang River.

Area	Stations (m)	Slope
Dhompo	0 – 1000	0.002408
Sungi Wetan	1000 – 3000	0.001601
Sukorejo	3000 – 5200	0.001890
Tambakrejo	5200 - 6000	0.002657
Semare	6000 – 11400	0.000870

According to the Manning equation, the slope of the river bed also contributes to the increase in river water flow and flow discharge. Areas that have a low slope are at risk of water deposition, causing flooding to occur. Semare village has a low slope shown in Table 2. Because the location of the Sumare village close to the river mouth causes a very high tidal effect as seen in Figure 4.

Model validation was performed using the flood map data from National Disaster Management Authority of Indonesia (BNPB, 2019) shown in Figure 5.

4 RESULTS AND DISCUSSION

Comparison of flood maps from flood models and flood map reports from BNPB is shown in Figure 6. Green polygons represent inundation in Tambakrejo Village and yellow polygons represent inundation in Sukorejo Village. At 01:00 28 April 2019, this model showed good results compared to the flood map report from BNPB, 2019. The validation process is carried out through water depth data where the results of this validation are shown in Table 3.

The time of the flood occurs when the highest tide is 0.47 m MSL at 20:00 28 April 2019. At 20:00, 28

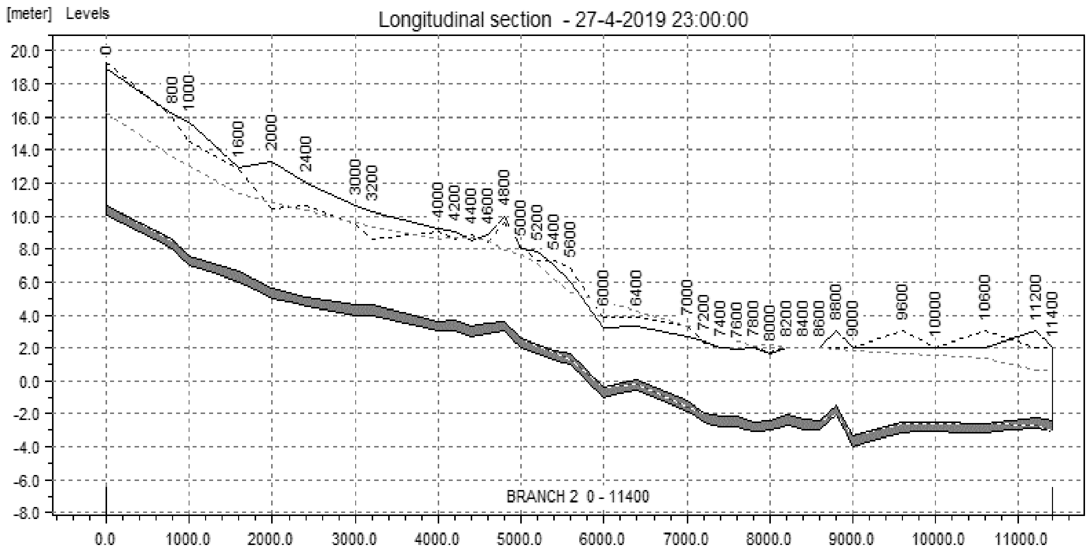

Figure 4: Modelling setup of MIKE FLOOD coupled model.

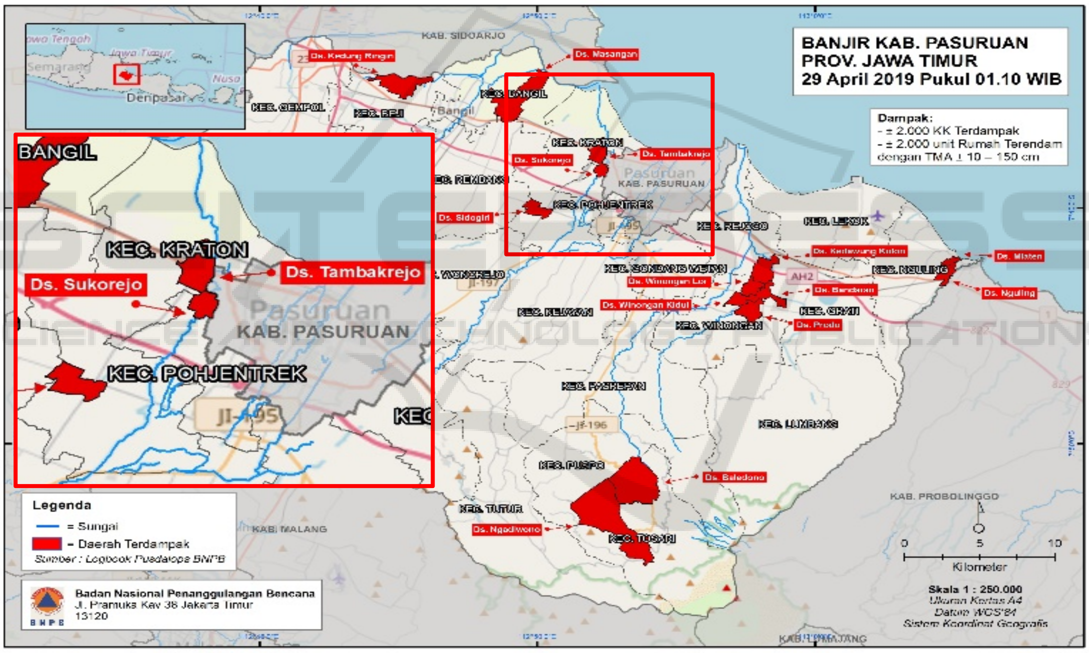

Figure 5: Flood map report from National Disaster Management Authority of Indonesia, (BNPB, 2019).

April 2019, the surface of the river shows 5 m as the initial flood time. At 21:00 April 28, 2019, the highest river water level reached 6.27 m which occurred at a tidal height of 0.39 m MSL until 0:00 April 29, 2019 with a river height of 5.91 m at tidal height -0 , 24 m MSL (Figure 7). At 3 am on April 29, 2019, the height of the river did not exceed the height of the riverbank so that the flood spill subsided. Figure 7 shows the relationship between river water level and tidal change when flooding occurs in the Welang river from the results of a modeling simulation. However, the temporal variation of flood map on Welang River has not been examined in detail, yet.

Table 3: Water depth validation 4/28/19 1:00 AM.

Type	Water depth (m)
Model	0.3 – 2.2
BNPB	0.1 – 1.5

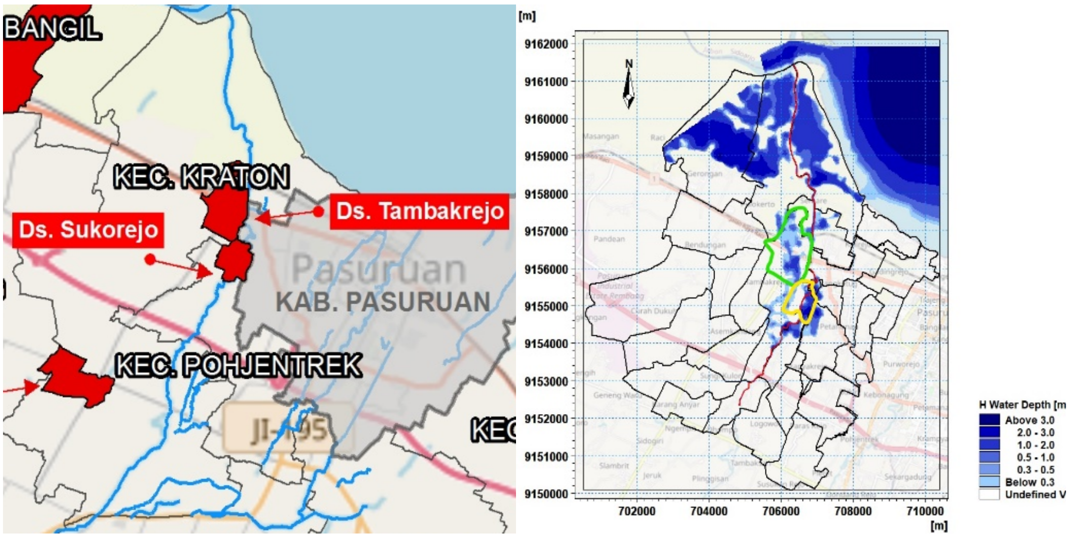

Figure 6: Flood model validation at 1:00 AM 28 April 2019.

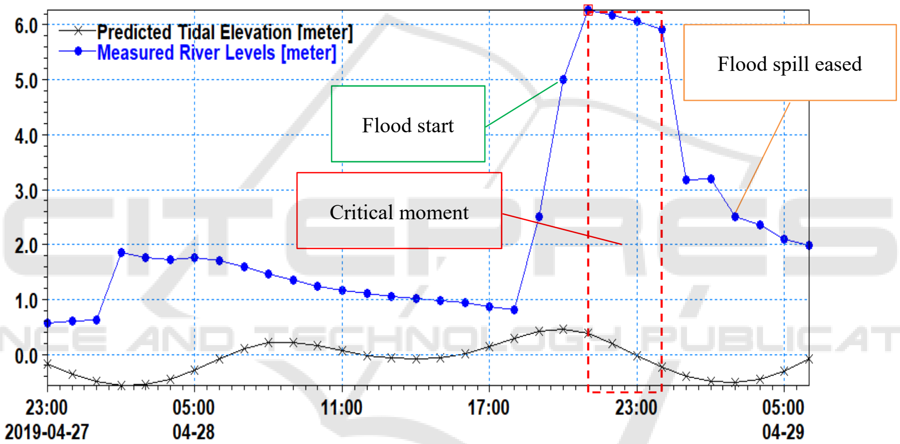

Figure 7: The relation of the river levels and tide levels when flood occured on Welang River.

5 CONCLUSION

Based on the modeling results and analysis in the paper, a few conclusions can be drawn as follows:

1. From the results of the hydrodynamic model it has been shown the critical point at which floods begin to overflow. Semare Village and Tambakrejo Village are critical areas where floods begin to overflow.
2. This Kali Welang flood modeling simulation is validated using water level data from the flood map report of the Indonesian National Disaster Management Agency (2019), which shows quite valid results, the simulation model results show 0.3 m - 2.2 m while the data used for this tie tie is 0.1 m - 1.5 m.
3. River water level 6.27 m occurs during tidal height 0.39 m MSL until 0:00 April 29, 2019 with river height 5.91 m at tidal height -0.24 m MSL. At 3 am on April 29, 2019, the height of the river did not exceed the height of the riverbank so that the flood spill subsided.

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