

# Juana River Flood Mapping

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**Abstract**— Juana River is a river in Indonesia having high vulnerability degree toward flood occurrence. The major factors causing flood in Juana River are river slope having value of 0,00001 and narrowing river channel. Therefore, the river experiences discharge capacity reduction. Juana River flood mapping is necessary to analyze extent of inundated area, especially regarding disaster risk reduction activity. This study used GIS software to process Alos Palsar image as Juana Valley topography, HEC-RAS 4.1 application for modeling the unsteady river flow, and HEC-GeoRAS 10.2 application to bridge HEC-RAS 4.1 results into GIS software. As hydraulic modeling boundary condition, this research used 52 Juana sub basin discharge having return period of 50 years and tides level at Juana Estuary. Research results showed that the extent of flood due to Juana River discharge was 37,406 hectares in both Kudus and Pati.

**Keywords**—*Juana River, Inundation Map, HEC-GeoRAS, HEC-RAS*

## I. INTRODUCTION

Flood occurrence can be caused by high intensity of rainfall, basin topography, small river discharge capacity, and land use conversion. Rainfall intensity and basin topography can be classified as natural factor thus river discharge capacity has major role in conveying river discharge. Juana River in Central Java has small discharge capacity, on the other hand, Juana Basin intensity rainfall is high, and its estuary is located at northern of Java Island. Juana river hydraulic characteristic is also influenced by a tide elevation where tide can flow into Juana River upstream reach. The illustration of Juana River is illustrated in Fig. 1.

In the past, Juana Valley was a swamp area and had purpose as retention for Serang River flood. Colonial administration had policy to convert Juana Valley became agriculture area by diverting Serang River discharge into Juana Valley. Sediment contained by Serang River discharge would be settled in Juana River. After many years, the swamp area could be converted as agriculture area [1]. Juana Basin topographic slope condition consists of area with high slope, moderate slope, and small slope. High topographic slope can be found in Muria Mount hillside and Kapur Utara Mount, while middle area of Juana Basin has moderate slope. Moreover, most of small topographic slope are located on area around Juana River.

Recently, Juana River also has a purpose as Serang River bifurcation. Serang River discharge is diverted to Juana River through Wilalung Flood Gates. Total discharge that must be conveyed by Juana River is 1,540 m<sup>3</sup>/s, whilst Juana River only has small topographic slope which is approximately 0,00001 and narrow distance between river bank. Small river topographic slope causes small water velocity; thus, velocity

will reduce river discharge capacity. Therefore, there are many inundated areas around Juana River. Lately, area that was planned as agricultural area in the past had been converted as settlement area. The condition gets worse when small water velocity caused sedimentation, hence, the sedimentation will reduce river discharge capacity. Thus, flood inundation map is needed to be produced for disaster risk reduction activity.

## II. LITERATURE REVIEW

There are many researches regarding flood inundation mapping especially in utilization of HEC-GeoRAS. Romali et al. [2] compared inundated area size of Segamat River in Malaysia for several different flood return period. The research showed that 100 years return period of flood inundated area size was 5 times larger than the size area of 10 years return period flood. Martin et al. [3] generated flood prone area of Sirinko river in Uganda. The research found that middle reach of Sironko river has high flood vulnerability. Several villages were safe from 10 years return period flood, while the villages suffered flood for higher return period. Khattak et al. [4] identified flood vulnerable area of Kabul River by employed HEC-RAS, HEC-GeoRAS, and GIS Tools. The finding stated that flood discharge inundation area was 400% greater than normal river discharge. Agriculture area was the most vulnerable flood area. Cook [5] analyzed the influence of topographic data quality with respect to inundated size area of Strouds Creek in North Carolina and Brazos River in Texas. The finding revealed that inundated size area increased as the resolution of topographic data decreased.

## III. METHODOLOGY

### A. Data

This research needed several types of data for hydraulic model boundary condition. All utilized data was secondary data obtained from Balai Besar Wilayah Sungai (BBWS) Pemali Juana. Discharge hydrographs were utilized as upstream boundary condition and lateral discharge. Fig. 2 shows flood discharge hydrograph of 52 Juana sub-basins with 50 years return period [6]. Meanwhile, as downstream boundary condition, this research applied tides elevation data. Furthermore, ALOS PALSAR digital elevation model (DEM) was employed as topographic data source.

### B. Software

Overall, there were three main pieces of software used to produce inundation map of Juana River. Firstly, GIS tool was employed to process topographic data from ALOS PALSAR DEM in order topographic data could be applied by HEC-RAS. Moreover, at the final step, ArcGIS was also utilized to produce inundation map as a result of hydraulic simulation.

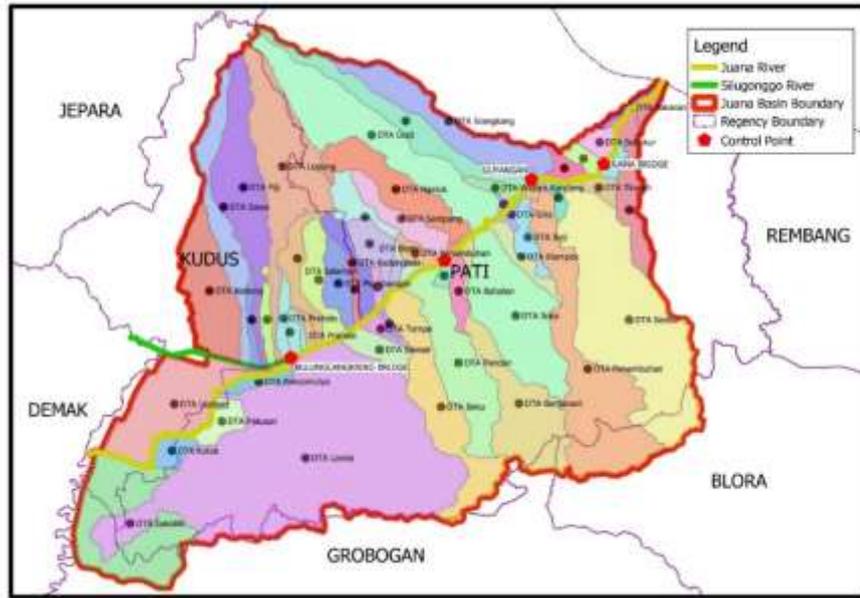


Fig. 1. Juana Basin Map [6]

Secondly, HEC-GeoRAS is ArcGIS extension developed by U.S. Army Corps of Engineers that become bridging program between ArcGIS and HEC-RAS. At pre-simulation process, one could define flow direction, cross section, channel bank, etc. At post simulation, HEC-GeoRAS was utilized to interpret HEC-RAS result into ArcGIS data structure.

Finally, HEC-RAS is software established by U.S. Army Corps of Engineers for one-dimensional hydraulic simulation where flow is assumed taking place in the middle of channel. HEC-RAS treats flow in the open channel as physical process adhering momentum conservation and law mass conservation law. The physical process can be written by (1) and (2) known as Saint Venant equation below [7].

Continuity equation

$$\frac{\partial A_t}{\partial t} + \frac{\partial Q}{\partial x} - q_t = 0 \quad (1)$$

Momentum equation

$$\frac{\partial Q}{\partial t} + \frac{\partial QV}{\partial x} + gA \left( \frac{\partial z}{\partial x} + S_f \right) = 0 \quad (2)$$

In which  $A$  is cross sectional area,  $Q$  is discharge,  $q_t$  is lateral discharge per unit length,  $V$  is average velocity,  $g$  is gravitational acceleration,  $x$  is lateral distance,  $z$  is water level elevation,  $t$  is time,  $S_f$  is energy grade line slope calculated by using Manning equation,  $n$  is Manning roughness, and  $R$  is hydraulic radius.

#### IV. RESULTS & ANALYSIS

##### A. Unsteady Hydraulic Simulation Result

Based on the Fig. 3 below, upstream cross section is located at station 62,152 (located at right side of Fig. 3).

Meanwhile, the downstream cross section is positioned at station 269 (located at left side of Fig. 3). Simulation result revealed that maximum water was 37.69 at station 62,152. Water surface elevation fell significantly at station 57,918, station 56,363, and station 50,945 where water surface elevations were 35.60 meter, 33.91 meter, and 32.81 meter respectively. Water level height was stable until station 8,164 where water level was 32.11 meter. The lowest water level was located at station 269 (the most downstream cross section) where water level was 31.56 meter.

Fig. 4 below shows a cross section example of Juana River at station 33,577 where cross section was located in the middle of Juana River channel. Water level in that cross section was 32.81 meter and flow discharge was 94.73 m<sup>3</sup>/s.

In this hydraulic modeling, there were 4 locations determined as control point to analyze hydraulic characteristic, these locations were Bulucangkring Bridge, Tanjung Bridge, Guyangan, and Juana Bridge. In control point, one could analyze flood discharge behavior along simulation time (see Fig. 5).

In Bulucangkring Bridge, hydraulic simulation revealed that most of discharge had negative sign. The negative sign meant that the discharge flowed from downstream reach to upstream reach. The phenomena were caused by small slope of Juana river around Bulucangkring Bridge. Moreover, lateral discharge flowed into downstream reach of Bulucangkring bridge was higher than discharge conveyed by the upstream reach. The hydraulic condition at Tanjung Bridge seemed to be similar to the condition at Bulucangkring Bridge. The peak discharge flowing into upstream area occurred at 10<sup>th</sup> hours, moreover after 10<sup>th</sup> hours discharge flowing into upstream area was shrank significantly. However, the hydraulic characteristic saw discharge flow into upstream area just in the first 20 hours. After 20 hours, discharge gained positive value meaning that discharge flowed into downstream reach. Furthermore, it went up gradually after 40 hours.

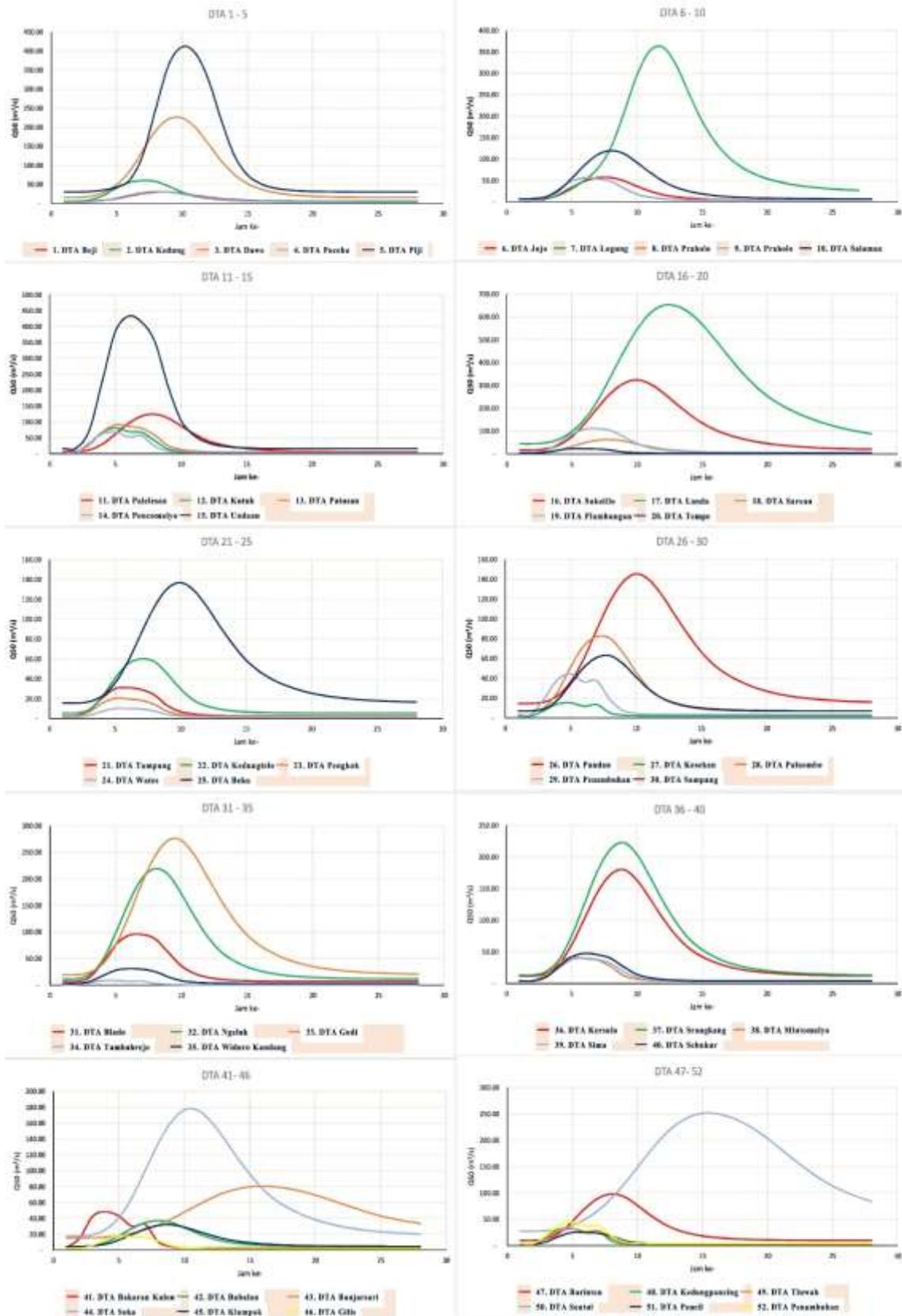


Fig. 2. Flood Discharge Hydrograph of 52 Juana Sub Basins with 50 Years Return Period [6]

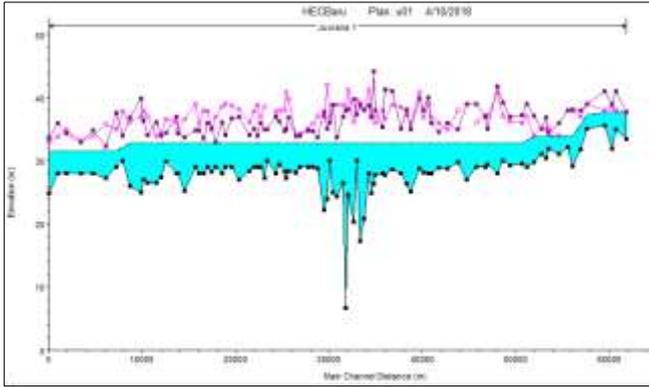


Fig. 3. Long Section Flood Water Elevation

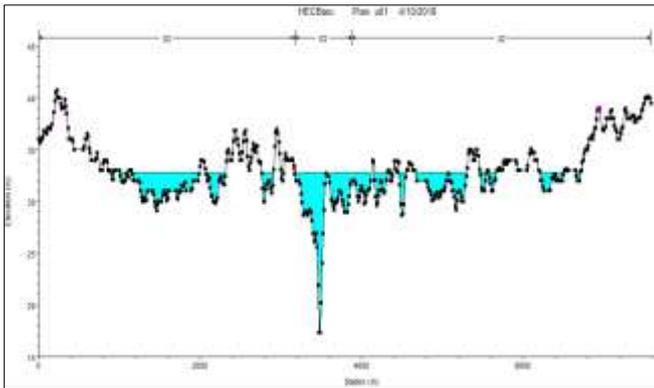


Fig. 4. Example of Juana River Cross Section at Sta 33,577

Hydraulic characteristic at Guyangan showed almost similar behavior. However, flood discharge at beginning of simulation tended to flow into downstream reach. Meanwhile, the discharge direction returned to upstream region from 10<sup>th</sup> hour to 19<sup>th</sup> hour. After 19<sup>th</sup> hour, river discharge would flow into downstream area, and discharge amount tended to improve gradually. Different trend was shown by discharge characteristic at Juana Bridge. Flood discharge flowed into downstream reach along simulation time. The discharge rose significantly for first 20 hours and improved steadily for the remaining of simulation time.

**B. Analyzing Inundated Area**

HEC-RAS unsteady hydraulic simulation results showed water surface elevation for each cross section. To simulate inundated area, the simulation result needed to be exported into GIS tool by using HEC-GeoRAS as bridging software. In the utilization of digital elevation model as topographic data source, spot height phenomena must be given attention. Decision to specify the channel banks and channel levees would influence simulation. In this research, the hydraulic simulation was conducted twice. The first simulation was used to inspect the inundated area result. It was often found that the inundated area was restricted by the spot height, whereas, based on the visual inspection there were lower elevation around the spot height. Therefore, the channel banks and channel levees must be corrected to obtain rational inundated area. The levee position determination had significant role in water propagation along the cross section.

Fig. 6 (left) shows inundated area simulation by first run in which inundated area was restricted by spot height. Meanwhile, Fig. 6 (right) shows inundated area after the

correction of channel banks and channel levees position. Inundated area size caused by Juana River discharge with 50 years return period was 37,406 hectares. The Juana river inundated area map was shown by Fig. 6.

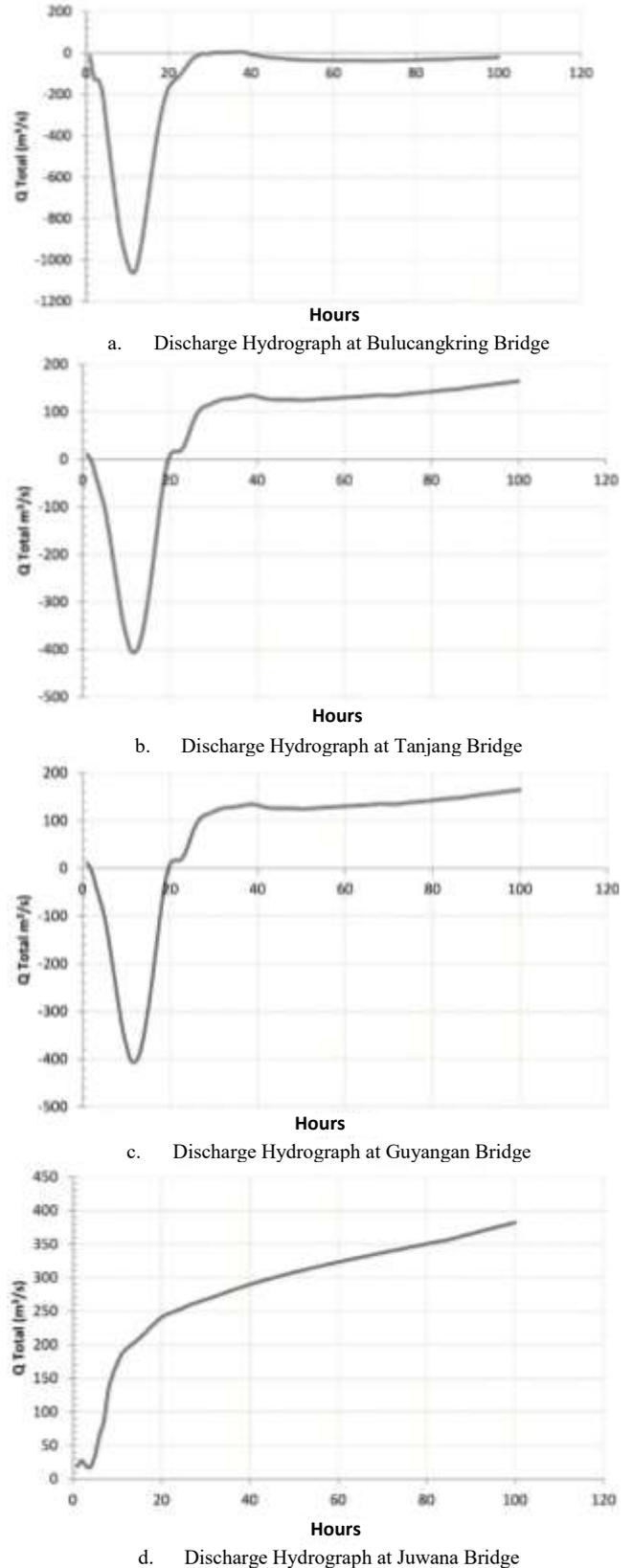


Fig. 5. Discharge Hydrograph at Bulucangkring bridge, Tanjung bridge, Guyangan bridge, and Juwana bridge

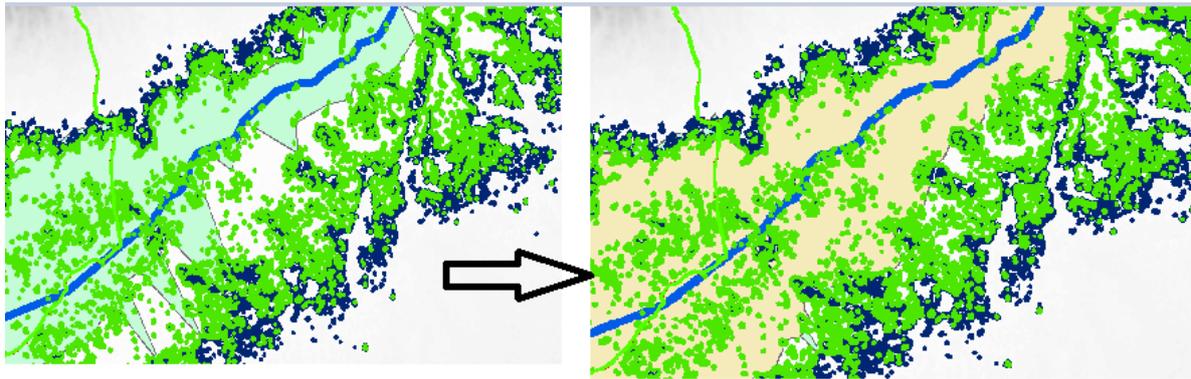


Fig. 6. Inundation Area Correction Caused by Spot Height

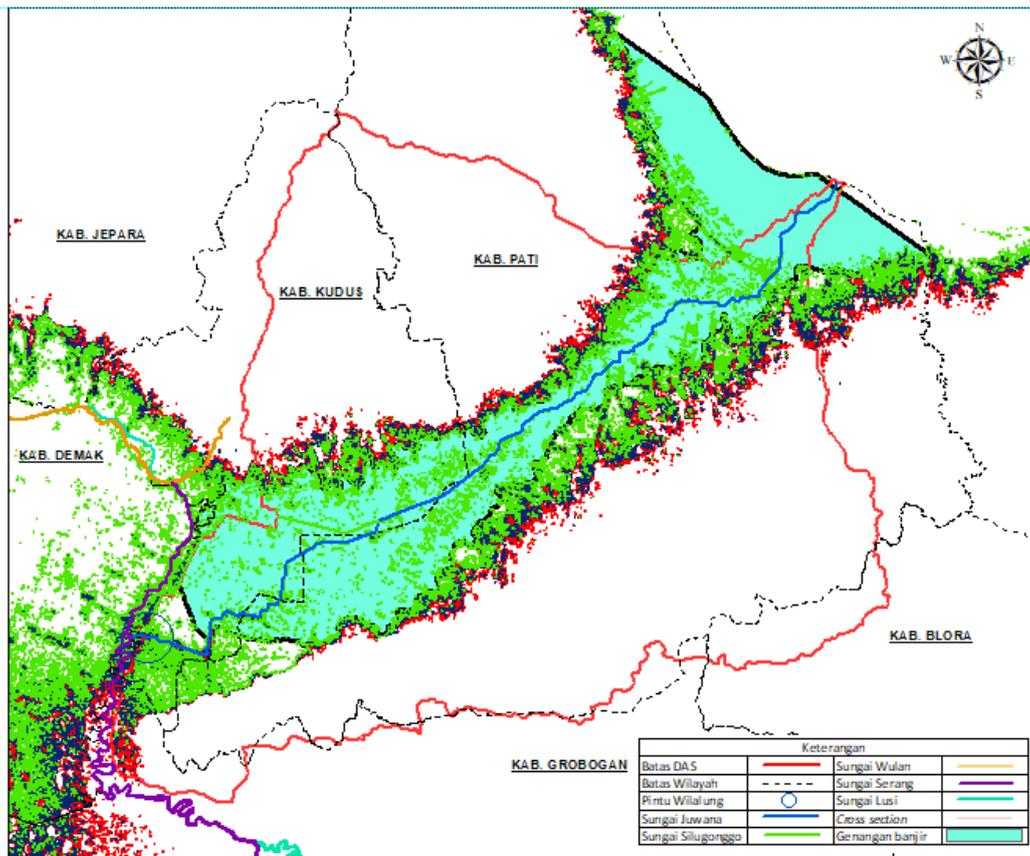


Fig. 7. Result of Inundation Area Correction

## V. CONCLUSION & RECOMMENDATION

### A. Conclusion

The presence of Alos Palsar digital elevation model (DEM) has given significant role in flood inundation area simulation especially inundation analyses for vast area. Utilization of DEM cannot be applied directly because of spot height presence. One must make correction in geometry model because the cross-section width can change significantly.

Hydraulic simulation result showed that water surface elevation plummeted significantly in upstream reach, while water surface elevation result slipped gradually in the middle reach and downstream reach. Small river slope had important

influence in hydraulic characteristic of Juana River. It could be seen in three control points such as Bulucangkring Bridge, Tanjung Bridge, and Guyangan where flood discharge flowed into upstream area. Inundation area size was caused by Juana River discharge with time return 50 years was 37,406 are.

### B. Recommendation

The research finding could be used as disaster reduction risk activity. The local agency could develop disaster contingency plan based on the inundation map. Moreover, the presence of automatic water level recorder would have overwhelming advantage. The AWLR could be applied as early warning system as well as for calibration and verification processes for hydraulic simulation.

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