



## **Use of Hec-Ras Software to Analyze Floods in Joyoakan Urban Village, Surakarta City, Central Java**

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**Abstract:** One of the natural phenomena that threaten the existence of human life in several regions in Indonesia every time the rainy season begins is flooding, one of which occurs in the Joyoakan sub-district in Surakarta City. Topographically, it is in a hollow area (under the main road), making it easier for water to enter the area. This is what makes the Premulung and Kaliwingko rivers unable to accommodate rainwater discharge and additional rainwater shipments from the Boyolali and Sukoharjo areas. The purpose of this study is to determine how much volume of inundation in the drainage canal can be reduced in the Joyoakan area and the appropriate efforts to deal with the inundation that occurs. The method used is descriptive research, to provide an overview of the variables studied and modeling using the HEC-RAS software. The result of the calculation is that the potential for inundation that can be reduced by the drainage channel is at the Q5 return period of 6,842.577 m<sup>3</sup>, the Q10 return period is 6,962.517 m<sup>3</sup>, and at the Q25 return period is 7,100.448 m<sup>3</sup>, while the results from the channel dimension modeling analysis, there are still puddles at several points, the right alternative in overcoming inundation is the need to revitalize the drainage channels by increasing the capacity of the drainage dimensions from the current size and improving the base slope of each channel and installing pumps as a means of control in accelerating water discharge.

**Keywords:** *inundation; flood tracing; drainage channels; HEC-RAS modelling*

### **1. Introduction**

Floods are one of the natural disasters that most damage infrastructure, hamper agriculture, animal husbandry, and industrial production, and greatly affect all aspects of human life. [1]. The very significant impact of floods on society in the last decade has caused more than 400 billion USD in damage affecting millions of people around the world [2]. Floods are theoretically caused by the volume of water in a body of water such as a river or lake overflowing and then overflowing from a dam so that water escapes from the river and inundates the land, factors such as the size and nature of the rivers in and around the river. The water level downstream also determines whether or not flooding occurs in that area [3] The risk of global flooding is expected to increase further due to climate change and urbanization, especially in Asia and Africa [4]. The impact of flooding can cause damage to community settlements if water overflows settlements. Joyoakan Urban village is one of the urban villages in Surakarta City which is topographically located in a basin area (under the main road) which makes it easier for water to enter the area. This is what

makes the water discharge in the Premulung and Kaliwingko rivers unable to accommodate rainwater and is added to rainwater shipments from the Boyolali and Sukoharjo areas, so that an evaluation step is needed for the drainage system that is already running so that the problem of flooding and inundation can be overcome. Flood analysis can be carried out using various approaches, from a general literature survey of 3-8% using other approaches, 12-16% using machines, 17-20% using graphical information systems and remote sensing, and more than 24% using modeling and simulation [5][6]. In this case, the approach used is modeling and simulation using HEC-RAS software. HEC-RAS is a computer program that models the hydraulics of natural water flow in rivers and other channels [7]. The purpose of this research is to determine how big the potential inundation is with the help of the HEC-RAS Software and from the results of the analysis and calculations it can provide a solution to the problem of flooding and inundation in the Joyoakan Urban village.

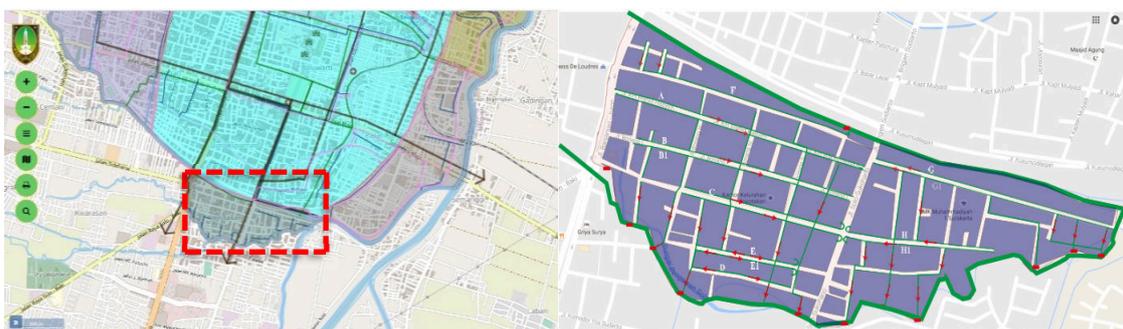
## **2. Research method**

### **2.1. Type of data and data collection techniques**

This research is a type of descriptive research, to provide an overview of the variables studied. Descriptive research is research that is not intended to test a particular hypothesis but only describes what is about a variable, symptom, or condition [8]. In terms of flood and inundation problems in the Joyoakan Subdistrict, the data collected is the capacity of the drainage system, the location and condition of the flood control devices, and the data on flood-resistant buildings, 20-year Rain Data at three (3) Rain Stations, namely: Pabelan Station, Baki Station and Mojolaban from (2001 to 2020) from the Surakarta City Council. Topographic map of the Surakarta City area with a scale of 1: 25,000 from the Geospatial Information Agency from the <https://tanahair.indonesia.go.id/> website, which also includes administrative maps, contour maps, and river maps.

### **2.2. Research sites**

This research was conducted in the Joyoakan Urban village, Surakarta City, Central Java. The location of this study includes drainage in the Joyoakan Urban village area which is in the Kaliwingko Watershed, Surakarta. As seen in the image below.



**Fig. 1.** Research sites

## **3. Results and discussions**

### **3.1. Hydraulics Analysis**

The hydraulic analysis is needed in planning the dimensions of the drainage channel which are expected to be able to accommodate water runoff in terms of hydrolysis or elevation in the field.

This hydrolysis review is carried out to evaluate the storage capacity of the drainage channel with a flood discharge for a certain period. Furthermore, the review in the context of field evaluation is intended so that direct observations in the field aim to see directly the condition of the existing canals. In analyzing the drainage channel, previously we obtained a network map document in the Joyoakan urban village that came from the Public Works and Public Housing Office of Surakarta City. Furthermore, the map will be plotted on the Geometry Data display in the Hec-RAS program, which in the process will later compare the capacity of the drainage channel with the amount of flood discharge planned for the return period to be studied, namely 5, 10 and 25 years in HEC -RAS so that it can be known the ability of the channel to receive flood plan floods.

Example of calculating the capacity of the drainage channel on Jalan KH. Wahid Hasyim:

$$\begin{aligned}
 \text{Channel height, } h &= 0,50 \text{ m} \\
 \text{Base width, } b &= 0,30 \text{ m} \\
 \text{Sediment height, } h_{\text{sed}} &= 0,10 \text{ m} \\
 \text{Maximum channel height, } h_{\text{maks}} &= 0,50 - 0,10 = 0,40 \text{ m} \\
 \text{The slope of the channel bottom, } S &= 0,0009 \\
 \text{Wet cross-sectional area, } A &= b \times h = 0,30 \times 0,40 = 0,1200 \text{ m}^2 \\
 \text{Wet circuit of the channel, } P &= b + 2h = 0,50 + (2 \times 0,40) = 1,300 \text{ m} \\
 \text{Hydraulic spokes, } R &= \frac{A}{P} = \frac{0,200}{1,300} = 0,1538 \text{ m} \\
 \text{Manning's coefficient, } n &= 0,013 \\
 \text{Flow speed, } V &= \frac{1}{n} R^{2/3} S^{1/2} \\
 &= \frac{1}{0,013} (0,1538)^{2/3} (0,0009)^{1/2} = 0,5161 \text{ m/s} \\
 \text{Channel capacity, } Q &= V \times A = 0,5161 \times 0,1200 = 0,0619 \text{ m}^3/\text{s}
 \end{aligned}$$

The results of the analysis of the capacity of the existing drainage channels can be seen in the table below

**Table 1.** Calculation of existing drainage capacity

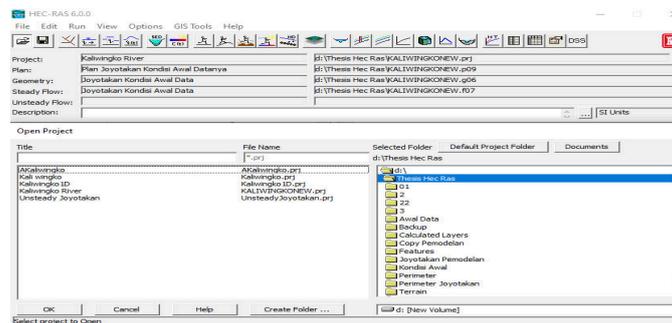
No	Channel	L (m)	n	S	B m	hsal m	hsed m	hmaks m	A m <sup>2</sup>	P m	R m	V m/s	Qsal m <sup>3</sup> /s
1	Saluran (A) Jl KH.Wahid Hasyim	0.04 27	0.013	0.000 9	0.30	0.50	0.10	0.40	0.120 0	1.10	0.109 1	0.51 61	0.061 9
2	Saluran (B) Jl Bonang1	0.04 03	0.013	0.003 6	0.50	0.50	0.10	0.40	0.200 0	1.30	0.153 8	1.32 00	0.264 0
3	Saluran (C) Jl Rebab	0.03 55	0.013	0.002 3	0.30	0.50	0.10	0.40	0.120 0	1.10	0.109 1	0.84 76	0.101 7
4	Saluran (D) Jalan Kenong	0.01 53	0.013	0.003 5	0.30	0.50	0.10	0.40	0.120 0	1.10	0.109 1	1.03 96	0.124 7
5	Saluran (E) Jalan Bedug	0.01 57	0.013	0.012 2	0.30	0.50	0.10	0.40	0.120 0	1.10	0.109 1	1.94 34	0.233 2
6	Saluran (F) Jl Kendang	0.01 93	0.013	0.000 4	0.80	0.80	0.30	0.50	0.400 0	1.80	0.222 2	0.54 46	0.217 9
7	Saluran (G) Jl Kahayan1	0.02 02	0.013	0.006 7	0.30	0.50	0.10	0.40	0.120 0	1.10	0.109 1	1.44 08	0.172 9
8	Saluran (H) Jl Karandan	0.01 62	0.013	0.004 7	0.30	0.50	0.10	0.40	0.120 0	1.10	0.109 1	1.20 56	0.144 7

### 3.2. Flood analysis with HEC-RAS

The analysis uses the HEC-RAS software to map the floods and inundations that occur in the Joyoakan sub-district on the Kaliwingko River, this model is used to analyze the volume of inundation that occurs from the runoff of the drainage canal in the Joyoakan Sub-district due to rain discharge that occurs in return periods of 5 years, 10 years, and 25 years. The results of the overlay on HEC-RAS are intended to obtain the profile of the water level in the drainage channel and also flood characteristics such as depth, velocity, inundation area, and others. The modeling steps are

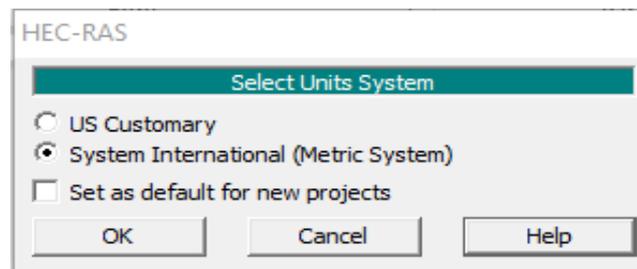
#### 3.2.1. Create a new project on HEC-RAS

Creating a New Project begins by selecting File then New Project. Then a dialog will appear as shown in Fig 2 below.



**Fig. 1.** New project on HEC-RAS

After the dialog box appears as above, then fill in the title of the new project, then OK to save the project. The system unit used in the International System (Metric System) method is, to click Options then select Unit System (US Customary / System International (Metric System)) so that a dialog box appears as below.



**Fig. 2.** Display Unit System Settings

#### 3.2.2. Geometry Data

In creating geometric data, is created by clicking Edit on the Menu Bar and then selecting Geometric Data or you can also directly click the View / Edit Geometric Data button.  then click File, New Geometry Data, and type the title Geometry Data in the Title column then OK.

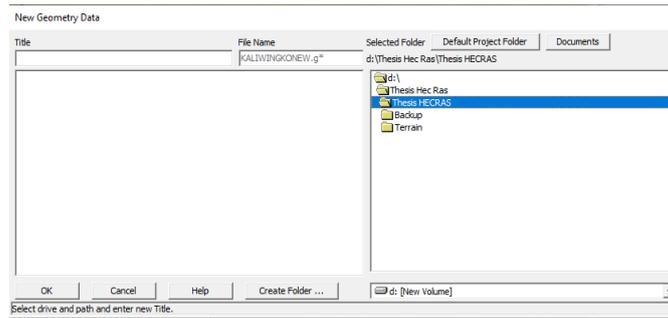


Fig. 3. Geometry data editor screen display

The next step is to make a canal schematic as well as a cross-section or cross-section of each canal. The data needed in the manufacture include channel length, channel elevation, channel dimensions, Manning coefficient, and others. The results of making a canal scheme for both primary and secondary are presented in Fig 4, and a cross-section view of one of the canals is shown in Fig 5 below.

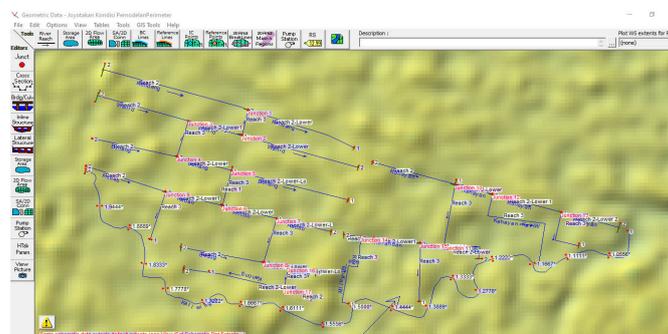
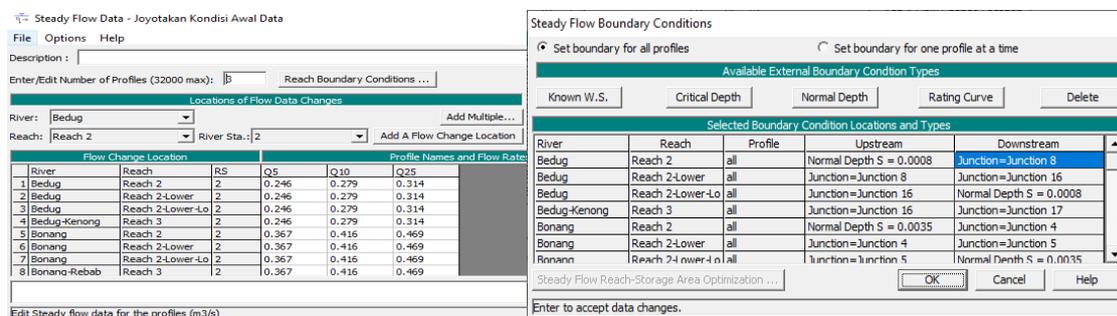


Fig. 4. Schematic View of Primary and Secondary Channels

### 3.2.3. Steady Flow data input

The next stage is after finishing creating the geometry data, then clicking Edit then clicking Steady Flow Data, or clicking on the box menu like this , a dialog will appear as shown in the image below. After that, enter the flood discharge data for the planned return period for each channel obtained from the rational method analysis calculations in the Profile Name and Flow Rates column. Then click on Reach Boundary Conditions to enter the downstream water level under normal conditions as shown in Fig 6.



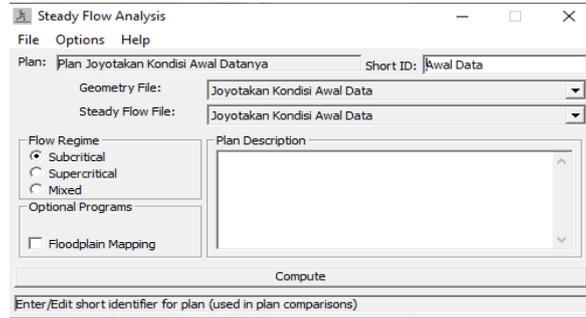
(a) Upstream boundary conditions

(b) Downstream boundary conditions

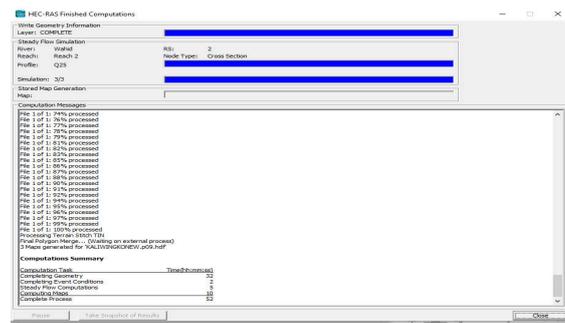
Fig. 5. Steady flow data display

### 3.2.4. Running compute project

After all the data is entered, the next step is to run the project that has been made. You do this by Run then selecting Steady Flow Analysis or clicking on the image. Then save the project by clicking File then New Plan, fill in the Plan according to the project plan and the Short ID then OK. Next, click Floodplain Mapping to get an inundation view, then Compute for the command to run the modeling in Fig 7. Furthermore, Fig 8 shows the Running Computation simulation process to get the simulation results.



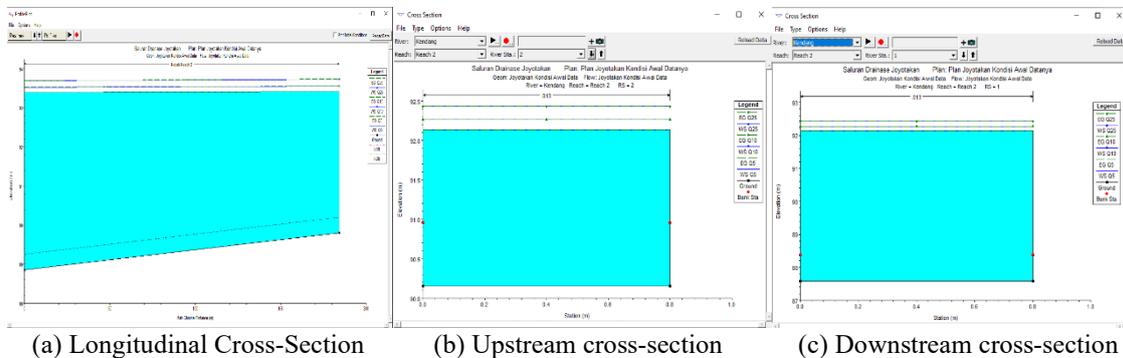
**Fig. 6.** Modeling count screen



**Fig. 7.** Proses of running computation

### 3.2.5. Results of running computation

The results of the analysis obtained from the HEC-RAS are in the form of profile images of the water surface in longitudinal and cross sections and in the form of tables containing flow data in the channel under review. An example of the results of the analysis of the water level profile on the longitudinal and longitudinal sections of the Jl. Kendang canal is as follows

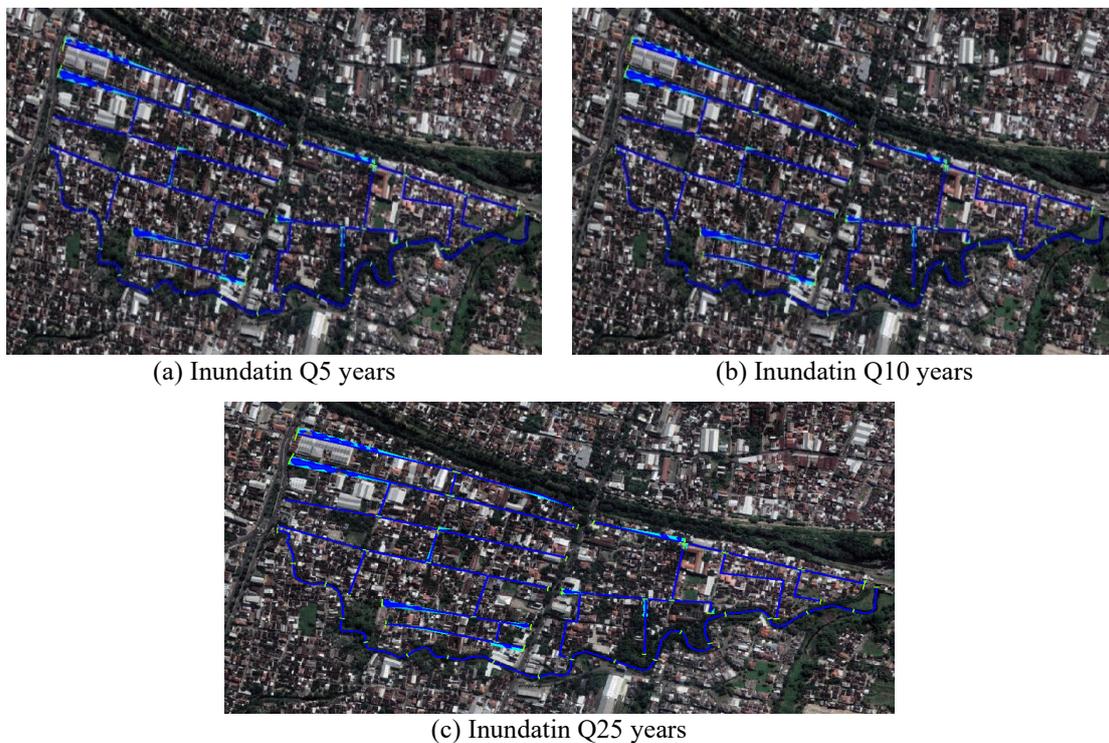


**Fig. 8.** The cross-profile of the water level in the Jl. Kendang channel

In the existing cross-section of the Jalan Kendang canal, it is unable to accommodate the return period flood discharge that occurs upstream and downstream of the channel which in the description of part of the Fig. 9(a) shows the water level in the return periods Q5 years, Q10 years, and Q25 years has exceeded the height of the right side channel (ROB) and the height of the left side of the channel (LOB) so that runoff occurs from the right and left sides of the channel. The Jalan Kendang canal has a width dimension of 0.3 m, and a cross-sectional height of 0.5 m, which receives a water input of 0.0664 m<sup>3</sup>/second and experiences inundation/flooding above the cross-section of 1.39 m as shown in Fig. 9(b). As for the downstream part, it can be seen in the description of Fig. 9(c), with the same cross-sectional size of the channel, there was a flood inundation with a height of 0.53 m.

### 3.3. Flood inundation mapping

In the HEC-RAS menu, the potential for inundation can be displayed from the input data in Geometry Data. From these results, data for potential inundation can be done in GIS Tools by selecting Ras Mapper. From the Ras Mapper, it can be seen that the map of the inundated areas produced as a result of the planned flood discharge for the Q5, Q10, and Q25 return periods of the year



**Fig. 9.** Inundation mapping results

Description of the Fig. 10(a) shows the area of the inundated area due to rain with a 5-year return period of 3,045.751 m<sup>2</sup>, while Fig. 10(b) shows the area of the inundated area due to rain with a 10-year return period of 3,045.782 m<sup>2</sup> and in Fig. 10(c) the area that is inundated due to rain with a return period of 25 years is the same as the 10 year period, which is 3,045.782 m<sup>2</sup>.

### 3.4. Alternative flood management

Flood tracing using Hec Ras shows that many drainage channels are unable to accommodate the flood discharge planned for the return period of Q5 years, Q10 years, and Q25 years. This is

caused by the capacity of the channel which is no longer able to accommodate inundation, the dimensions of the channel that are too small which is also added by the presence of sediment in the channel, as well as physical damage to the channel and the slope of the bottom of the drainage channel which also plays a role in the ability and speed of the drainage channel to carry water. Besides that, there is also the influence of the installation of parapets that are installed to limit the area of the Joyoakan Sub-District which borders the Kaliwingko River on the right, causing water to be difficult to drain out when the rainy season arrives due to back water from the Kaliwingko River. The alternative in dealing with inundation that researchers are trying to do is to change the cross-section. Changes in the cross-section of the channel are made by repairing the slope of the channel base, then the dimensions of the channel cross-section are also changed according to the existing land. For channel changes, also consider that the area in Joyoakan Sub-District is the most densely populated, limited land is the main consideration in this case, so as a minimum, don't change the width of the canal too much, but change the depth of the canal. As a result, after making changes in this way, it is hoped that the channel capacity will be able to accommodate the planned flood discharge, while for the channel where the cross-sectional dimensions have changed, an analysis is carried out using HEC-RAS modeling. The results of an analysis of changes in channel dimensions with a planned return period flood discharge using the help of the Hec Ras software show a reduction in inundation points in the Joyoakan Urban village area, that almost all of the capacity of secondary drainage canals can accommodate the planned flood discharge up to a return period of 25 years, except for a few channels. including the Kahayan-Kerandan downstream canal, Jalan Kahayan 2 downstream canal, Jalan Kahayan 1 downstream canal, Bonang Rebab downstream canal, Jalan Bonang canal upstream and downstream, Jalan Bonang 1 downstream canal, Jalan Bedug 2 canal upstream and downstream, canal Jalan Bedug 1 upstream and downstream, Kh channel. Wahid Hasyim – Lower Bonang, channel Jl. KH. Wahid has 2 parts Upstream and Downstream, channels. Jl. KH Wahid hasyim 1 upstream and downstream, Rebab- Bedug canal upstream and downstream, Jl. Rebab 1, 2, and 3 downstream, Jl. Kerandan 1 and 2 downstream, Kendang 3 street downstream, and Jl. Kenong 2 Lower section.

In inundation modeling analysis, attempts have been made to change the dimensions of the canal to a size of 1.50 cm x 1.20 cm, but inundation still occurs, this indicates the need for a thorough canal revitalization, especially the slope of the canal bottom. However, if later revitalization of the canal is carried out, and with limited land availability, it may definitely come into contact with residents or communities in the Joyoakan sub-district area, where most of the existing land is privately owned land. So there is a need for socialization due to the impact that can occur if the canal revitalization plan will later disrupts and harms community activities. Another alternative is that apart from revitalizing the existing canals, it is also necessary to install pumps at every lowest point in the Joyoakan Urban village area, because during times of high rain intensity, if the drain gate in the parapet is closed, then the best alternative solution in dealing with inundation is with a pump that will be very effective in the process of discharging water into the Kaliwingko River.

#### **4. Conclusion**

Based on the results of the research that has been done, it can be concluded that the flood height of the Existing Condition at the Q5 return period is 2.76 m, Q10 is 2.90 m, and Q25 is 3.10 m, while in the Mitigation Plan Modeling during the Q5 return period, it is 1.25 m, Q10 is 1.27 m and Q25 is 1.3 m and the highest inundation time is in Existing Conditions Q5 return period is 21.7 hours, Q10 is 21.7 hours and Q25 is 21.9 hours, while at Modeling Handling on the Q5 return period was 5.09 hours, Q10 was 6 hours and Q25 was 6.15 hours. The potential for inundation that can be reduced by the drainage canal for the inundation that occurred in Joyoakan Subdistrict after the Handling Conditions was in the Q5 return period of 6,842.577 m<sup>3</sup>, the Q10 return period was 6,962.517 m<sup>3</sup>, and in the Q25 return period was 7,100.448 m<sup>3</sup>, while the results of the analysis of channel dimension modeling, there is still inundation at several points due to rain in

Joyoakan Sub-district, so the right alternative effort to overcome inundation is the need to revitalize the drainage channel by increasing the capacity of the drainage dimensions than the current size and improving the slope of the base on each -each channel and pump installation as a means of control in accelerating the disposal of water.

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