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by Titi Purwantini

Modeling and Flood Control Mapping (Case Study : Surakarta City Indonesia)

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***Abstract*—Flood is a natural disaster that can occur in a region within a country. Some things can cause flooding, for example: high rainfall, blockage of drainage, improper environmental damage, insufficient water pump capacity in flood prone areas, and so on. Flood disaster will result in the loss of an area both material and immaterial losses. Therefore, several things can be done to minimize the incidence of flooding. Surakarta region is located in the lowlands at 105m above sea level and in the city center 95m above sea level, with an area of 44.1 square km (0.14 percent of Central Java area). The highest rainfall is 560mm, while the average rainfall during the rainy day is 22 mm on that day. Land elevation in downtown is lower than suburban Surakarta, therefore it is necessary to model water drainage to know water movement in Surakarta area. Of course this system must be accompanied by accurate information, appropriate early flood handling, and good water management engineering to minimize flooding. The method used to create water channel mapping model using MASIM method approach (Material Simulation). This research modeled and observed the process through simulation. The objectives of this research are: 1) to know the result of the flooded flood model based on the assessment of the main parameters covering rainfall, water flow discharge, and regional drainage capacity, 2) identifying the distribution of potential flood inundation, 3) evaluating the existing drainage management. The discovery of this study is a new model in controlling water flow.**

***Index Terms*—drainage Surakarta, flood management, water drainage mapping model.**

I. Introduction

Indonesia is an archipelago country, where its surroundings have vast territorial waters. While water is one important element in the needs of everyday life both for individuals and for industrial purposes. Indonesia is a tropical country that has a high rainfall, therefore high rainfall is one factor that causes the region has the potential for flooding. To overcome the potential for flooding is required river flow management, handling of water channel obstruction, water absorption media, and environmental destruction due to spatial abuse. In line with the development of urban areas, now open areas in the city of Surakarta tend to switch functions into a wake area. Meanwhile, it is known that the transfer of open area function will affect the area of the catchment area as one of the flood control media (flood control).

Surakarta or the community call it Solo city, has a Bengawan Solo river which is the main water channel in Solo city. The Bengawan Solo river becomes important because the Bengawan Solo river is the estuary of all the waterways in Solo city, when the Bengawan Solo river overflows then the surrounding Solo area will experience major flood disaster. To overcome this problem, water distribution modeling system is needed to know the movement of water in Solo city. Making this simulation model using MASIM (Material Simulation) method, according to Blikstein and Wilensky MASIM is a simulation that was built using simulation tool for modeling the atom structure that make up an object or material. MASIM allows one to model and observe the process through simulation, the results of the simulation can improve understanding of the concepts that want to be learned [1]. The simulation tool used for this study uses anylogic program [2], developed by XJ technologies [3].

The hydrologic cycle is an ongoing process whereby water moves from the earth into the atmosphere and then back to earth again. Water balance in one year against rain falling on the mainland 100 percent as relative value. Groundwater and sea water evaporate into the atmosphere. The water vapor rises into the atmosphere, which then undergoes cooling (condensation) and turns into a cloud-shaped water particle. Furthermore, the cloud clumps fall as a water point which is rain to the surface of the sea and land. Rainfall that falls to the mainland, partly retained by plants and the rest fall to the ground. The rainfall that reaches the surface of the soil will seep into the soil (infiltration) and some rainwater flows over the soil surface fills the lake, the soil basin, the river and finally flows into the sea [4]. The water that seeps into the ground partially flows in the soil fills the groundwater which then goes out into a spring or flows into the river. Eventually the flow of water in the river will reach the sea. The process takes place continuously called the hydrologic cycle, according to V.T Chow in Bambang Triatmodjo [5].

II. Mapping Scheme Of Flood Handling

This section discusses the previously preceded map modelling scheme. The flood handling map modelling will be divided into Fig. 1, Fig. 2, and Fig. 3.

Fig. 1 shows that flood impact mapping uses a new river flow path connected to a Bengawan Solo river in a blue area [6]. If the flow of water that flows from the river to the

Bengawan Solo very heavy, then the burst of water from the river will flood the area along the river flow, the blue area is a distribution of puddles of water that overflows. Although this research has mapped the impact of flooding based on major river flows in Solo towns, this research has not yet explained if the southern region of Solo is hit by floods. In addition there are still rivers that pass through the city Solo as pepe waterways downstream, jenes waterways, tanggul waterways, wulung pelem waterways that have not been described in this Solo city drainage research. Similar research on the use of the Hec-Ras tool in flood mapping on the Ogunpa river in nigeria [7].

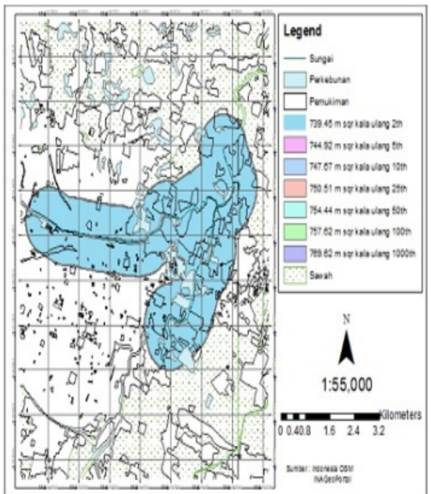

Fig. 1. Output Buffer Riverflow Using Hec-Ras

Fig. 2 provides a bigger picture than the research in Fig. 1. In Fig. 2, the yellow color of the picture shows the area affected by the flood. In this study, the calculation of the flood area using many variables, namely rainfall, rainfall, rainfall area, river bernouli, satellite image matrix, river map, altitude matrix. To figure out the process of spreading the flood using Cellular Automata method, Fig. 2 shows the result of cellular automata process [8]. Disadvantages of this study, the results of this study have not shown the overall map of the solo area. The study focused only on flooding around the river basin [9].

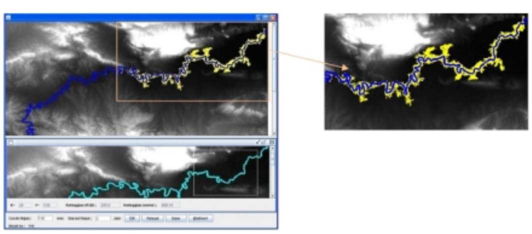

Fig. 2. Output of Flood Dissemination Visualization with Satellite Imagery

Fig. 3 provides a better modeling view of the flood-handling map by using anylogic simulation program [10]. The Solo city has 56 main waterways connected to 11 river channels that surround the Solo city, which is on the final channel to the end point of the Solo river. In this simulation, the drains are drawn with green boxes, while the rivers are depicted with rectangular shapes. This simulation has orange variables to monitor the depth of each water channel in 56 water channels, as well as variables to monitor the depth of 11 rivers in the city of Surakarta. The simulation also has a chart on the right that monitors the movement of water depth in 11 rivers in Surakarta city.

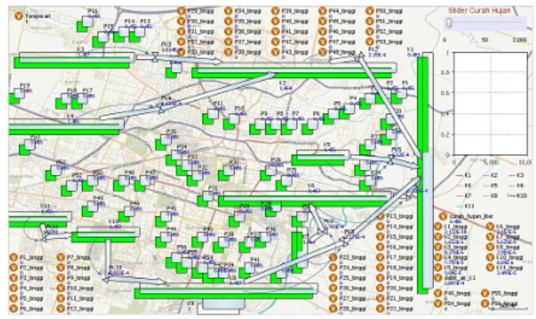

Fig. 3. Visualization of Flood Spread with Material Simulation

III. Defining Rules Used in Drainage Model

This section aims to describe the flood management model using the Material Simulation (MASIM) method. As explained above, that Material Simulation allows researchers to observe the processes that occur through simulation. Based on these methods, some advantages can be obtained from previous research, as example: it can directly observe water channels that are not able to accommodate the rainfall over the Solo area, it can see the process of rising water levels in all rivers in Solo city, it can Observing the ratio of water supply capacity to the volume of rainfall, and it can know the outline of the cause of the overflow in the area more clearly.

A. In Previous Research with Mathematical model

Research to observe processes with mathematical models has a weakness of flexibility in presenting reporting results. To generate an analysis result, requires a static variable that has been specified first before the analysis process begins. Then the results that have become a mathematical model is relatively more difficult to learn, because the conclusion of the analysis produces tables in the form of numbers from the first process until the final process. The development of research with mathematical models is relatively more difficult, because the mathematical model takes longer time to add new variables in the next research.

B. In The Study with Material Simulation

Research to observe the process with the simulation model has an advantage of flexibility in presenting the results report. To produce an analysis result, it allows the researcher to change the static variable in the simulation that has been specified during the analysis process is still in progress. The result of using Simulation model is relatively easy to learn, because the conclusion of the analysis resulted in realtime process from first to final process. The development of research with the simulation model is relatively easier, because the simulation model requires a shorter thinking time to know which variables need to be added in subsequent research.

IV. Research Simulation and Research Findings

Simulation requires several indicators for the research process in order to be analyzed. Indicator variables obtained through research in the field, in order to get accurate results so that the resulting analysis closer to reality. The following is a simulation design along with indicators and formulas used to analyze the simulation.

A. Rainfall

The calculation of rainfall according to international standards is millimeters. In this modeling, the amount of rainfall can be changed by the user, so the variable is dynamic.

$$Rainfall = Rainfall/1000 \quad (1)$$

B. Rainfall Time Period

Rainfall time period is the duration of rainfall, although the simulation model can be changed dynamically. In this simulation the duration of rain is 10,800 seconds (3 hours). .

$$Dur\_sec = dur\_hours * dur\_min * 60/1000 \quad (2)$$

C. Volume of Rainfall

The volume of rainfall is the amount of water that drops from the atmosphere to the soil surface. To calculate the volume of water by counting the number of litre of water falling to the soil surface. The volume of water dropped in the simulation depends on the rainfall in the rainfall regulation panel divided by the number of water channels in the Solo area.

$$Rainfall = Rainfall * 0.001 * total\_area \quad (3)$$

As for calculating the volume of rainwater in seconds is:

$$Rainfall = ((Rainfall*0.001*total\_area)/24)/3600 \quad (4)$$

D. Calculate The Depth of The River

As described in Fig. 3, each water channel has a water depth. Because the water channel is trapezoidal, so to calculate the water depth is :

$$D = Wtr\_Vol/(0.5*(Top\_w + Bottom\_w)*Canal\_leng) \quad (5)$$

E. Calculate The Flow of Water at a Certain Depth

The water channel spread in Solo city has different capacity diameter, therefore the flow of water flow of each channel must be calculated every iteration that runs.

$$WFD = 0.5*(Top\_w + Bottom\_w)*depth\_w*1)*c\_height \quad (6)$$

F. The Data of The Solo Rivers Capacity

Below Table I is 11 rivers data dimension in Solo city

TABLE I
THE CAPACITY OF SOLO CITY WATERWAYS

No	Name of The River	Length(m)	Dimension(m)		
			Top Width	Bottom Width	Depth
1	Bengawan Solo	7800	200	150	25
2	Kali Anyar	6808	100	80	20
3	Kali Pepe Hulu	2170	60	50	20
4	Kali Gajah Putih	2850	5	4	3.5
5	Kali Boro	2200	6	4	3
6	Kali Pepe Hilir	5760	6	5	3.5
7	Kali Jenes	3950	6	3	4
8	Kali Tanggul	6710	60	40	15
9	Kali Wingko	1842	50	35	15
10	Kali Pelem Wulung	2500	50	40	15
11	Kali Brojo	1143	30	20	10

Below Table II is 56 channel data dimension in Solo city

TABLE II
THE CAPACITY OF SOLO CITY WATERWAYS

No	Name of The River	Length	Dimension		
			Top Width	Bottom Width	Depth
1	Mipidan	1087	4	4	3
2	Kp Sabrang Kulon	529	3.5	3.5	3
3	Kedung Tungkul	1479	3	3	3
4	Sktr Perum Solo Elok	340	3	3	3
5	Untoroloyo	847	3	3	3
6	Debegan	420	3	3	3
7	Sktr Tentara Pelajar St.	500	1.5	1.5	1.5
8	Kedung Jumbleng	2030	5	5	3
9	Nayu	2253	6	5	2.5
10	Kp Nusukan (Around Nusukan pawnshop)	1034	4	3	3
11	Kp Minapadi	445	3	2	2
12	Singosari Timur St.	987	1.5	1.5	1.5
13	Ngipang-Mangunsarkoro	3050	2	1.5	1.75
14	Wonorejo-bayan	1893	6.5	5	3.5
15	Kp Banyuagung	630	1.5	1.5	1
16	Pleret-Belakang Pengadilan Agama	1267	1.3	1	1.2
17	Sumber	2014	3	2	1.5
18	Slamet Riyadi (M.Faroka) A. Yani St.	1943	2.5	2	1.75
19	Adisucipto St.	2551	1.5	1.5	1
20	Rear RSJ	1343	5	4	3
21	Kentingan Area	1417	1.7	1.4	1.5
22	South Makam Pahlawan	540	1.8	1	1.2
23	Kp Pucang Sawit	714	2.1	1.5	1.3
24	Kedung Kopi	1165	6	5	3
25	Kp Rear PMI river boro	720	3.5	2.5	2
26	Jebres Station Boro river	1900	4	2.5	1.5

No	Name of The River	Length	Dimension		
			Top Width	Bottom Width	Depth
27	Kp Sewu	437	2.5	1.5	1.75
28	Sorogenen Gandekan	1048	2	1.5	1
29	Simpon BI	430	2.5	2	1.75
30	Near Kospin	405	3	2	1.5
31	Toklo	1550	6	4	3
32	Rear Sahid Raya Hotel	731	3	2.5	2
33	Kawong	1288	5	4	2
34	Depok-Sambeng	506	3	2	1.5
35	UTP Brayat Minulya Hospital	450	3	2.5	2
36	Tegalkonas	764	3	2	1.75
37	Untung Suropati St.	1446	1.75	1.5	1.5
38	Kapten Mulyadi St.	612	3	2	2
39	Kp Gajahan - Baturono	1805	2	1.5	1.5
40	Kalilarangan	2301	1.75	1.5	1.5
41	Buntung	546	2.5	1.5	1.75
42	Brigjen Sudiarto St.	922	1	1	1
43	Kp Semanggi Kyai Mojo St.	1579	2.5	2.5	2
44	Honggowongso St.	1874	3	2	3.5
45	Gajah Mada St.	1164	3	3	3
46	Bayangkara St.	1580	2	1.5	2
47	Dr. Supomo St.	1209	2.5	2.5	1.5
48	Dr. Cipto Mangunkusumo	1312	3	2	1.5
49	Dr. Wahidin	950	5	3	3
50	Dr. Muwardi	686	4	2.2	2.5
51	Pintu Kleco Samanhudi St.	3351	2.5	2	1.75
52	Agus Salim St.	948	2.5	1.75	2
53	ATMI College area	1031	2	1.5	2
54	Yos Sudarso St.	406	1.75	1.5	1.5
55	Sraten	388	1.75	1.5	1.5
56	Kratonan	344	2	1.5	1.5

G. The Process of Rain Enter The River

Here is the process of rain into the river, causing the rise of river water level. Rain entering the water canal - flowing into the river - flowed to the final destination of the Bengawan Solo.

First, the amount of rainwater volume that has been calculated (per second) goes into the water channel. Second, the water channel will drain the water to the nearest river (in seconds) Third, the river will accommodate and flow into the main river Bengawan Solo. Fourth, the above path will be repeated continuously until the limit of simulation duration condition is reached.

$$Rain\_in\_canal > (canal\_capacity - outflow) \quad (7)$$

This means that if the volume of rain falling is greater than the capacity of the canal capacity and canal ability to drain the water, then the system decides that there is a flood. It is marked with a red box indicator. If the water depth reaches half of canal capacity, the box will be yellow.

H. Simulation Results with 22mm Rainfall

Fig. 4 shows the output of simulated test results with a duration of 10 800 seconds (3 hours) and 22mm rainfall indicates that neither flood nor water volume is still less than half the canal capacity. All water canal are still green.

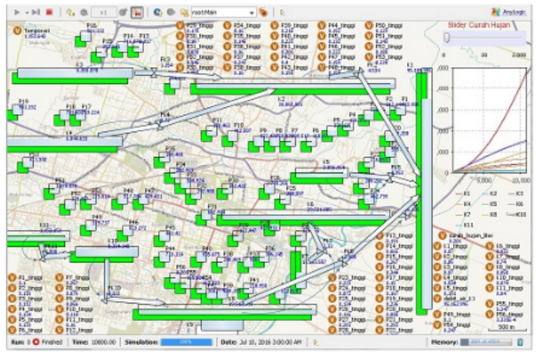

Fig. 4. Simulation result with 22mm rainfall

I. Simulation Results with 85mm Rainfall

Fig. 5 shows the output of simulated test results P(Pintu as Canal) and K (Kali as River)with a duration of 10,800 seconds (3 hours) and 85mm rainfall, the simulation results show that the waterways P15, P16, P42, K6 overflow. While the waterways P7, P11, P19, P21, P22, P23, P28, P37, P39, P40, P54, P55, K4, K7 the water level reached more than half the capacity of the waterways.

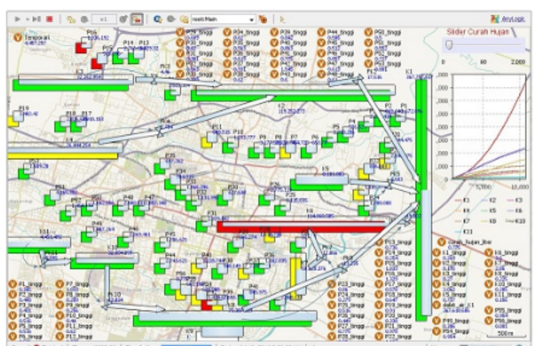

Fig. 5. Simulation result with 85mm rainfall

V. Conclusion

This paper presents another method, point of view of making simulations and modelling in a more specific section with material simulation method. Existing studies generally display a variety of tables of numbers that are quite difficult to understand by the layman, some research results also use the matrix numbers that show the map of the spread of flood, whereas government policy makers generally want the presentation of reports easier to understand and easy In the understand. The final simulation results show the water level in each river or water channel, the amount of water that is still present in each channel, and the overflowing area. However, this research can still be developed further, some things that can help this research more perfect are: the level of garbage blockage in the water channel, sedimentation in the water channel, the sending of rain water from the upper river Boyolali region because the ground surface is higher, the slope of the ground channel one Which is connected to other channels, it is necessary to add a flooded suction pump at the lower surface of the soil.

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