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FLOODS ANALYSIS IN JEMBER URBAN DRAINAGE SYSTEM

E. Hidayah [1], Sriwahyuni [1] and W. Yunarni [1]

ABSTRACT: Recently flood innundation in the Jember urban area shows that an increase in the number of point locations, and the height of puddle. Therefore, traffic congestions, and community activities due to flood innundation in Jember urban area can be disrupted. The purpose of this study was to analyze the causes of flooding in Jember urban area using SWMM. The flood events in three city districts of Jember was evaluated by assessing the intensity of the rainfall, the slope of the land surface, drainage channels, land use, and channel capacity. Based on measurements of the topography (drainage area, slope, and flow direction) was made schematization of the network system consisting the location of raingauges, the sub catchments, junctions, conduits, and outlets. Each object properties required input parameters, such as: elevations, areas, manning roughness values on oveland flow and channels, and the dimensions of the channel. The reliability of the model parameters was determined by calibrating the model, which compares the water level in the channel of the observations with the results of the model output. Furthermore, the causes of the flooding were analyzed through simulation models. The analysis showed that there were 111 noodes flooding. The causes of flooding ie: the channel capacities were not able to accommodate desaign rainfall for 1, 2, 5 or 10 year return period, there were the contribution of water from irrigation drainage, there were the channel bottlenecks, inlet holes were not allow water to enter the drainage channels, and there were sedimentation on the channel.

Keywords: drainage system, urban floods, design precipitation, rainfall-runoff, SWMM.

INTRODUCTION

Lately, the expansion of the Jember urban area growing faster, it is characterized by the increasing number of housing by developers and private housing. The growing number of housing caused a land conversion of agricultural land into residential. This condition will trigger a flood due to the increased amount of surface runoff. In topography, the Jember urban area is possible to drain the precipitation into the Bedadung river and its tributaries, but in fact it is hard to avoid flooding. Rainfall event that only a few moments with a relatively high intensity will cause inundation in some locations.This leads so-called pluvial flooding which is saturation of drainage infrastructure and there are overland flow along streets (Maksimovic et al., 2009). This condition would disrupt community activities, triggering damage to roads, and smooth transportation that will ultimately have an impact on the increased costs of road maintenance and vehicle operating costs. The floodwaters for each area of the city have different causes. Therefore, before any treatment for flooding needs to know the factors that cause a flood in advance.

SWMM is hydrology-hydrolic model that is developed by the United States Environmental Protection Agency (EPA) (Meierdiercks, 2010). This model has been successfully applied such as: for urban flood forecasting in the city of Dongguan in southern China (Jiang, Chen and, Wang, 2014), to solve the problem of water and to reduce losses due to rain (Weilin, Changhong, Xiaowen, Zhaoli, 2014). In addition, it has been widely successful SWMM used to calibrate and to validate such as to Jinan, a typical piedmont city in China (Yu, Huang and Wu, 2014). In order to realize effective and scientific management of urban storm flood, the establishment of rainstorm and flood model has important significance for the city to find out the causes of develop urban waterlogging countermeasures (Chen, 2010), (Zhao, Tong, Wang, 2009). This paper used SWMM to simulate floods with a different design scenario in Jember urban area, to identify the flooding spots and find out a variety of possible reasons, so as to advance the corresponding measures on this basis and provide scientific basis for urban flood control and drainage construction.

SWMM

The swmm is hydrology and hydraulic model that is widely used in urban storm flood, combined sewers, drains and other drainage systems analysis and design since its initial development in the world (Jorge et.al, 2005), (Rosman, 2005). Swmm consists of many functional program blocks, besides a coordinating executive block. The blocks can be overlaid and run sequentially or can be run separately with the linking or interfacing data being transferred between the blocks (Eric et. al., 2006). In SWMM, the whole study area is divided into subcatchments, and precipitation is averaged on the subcatchment. The surface runoff is produced on subcatchments also, and three methods can be used to produce the surface runoff. The surface runoff in a subcatchment is regarded to fully enter the junction related to it to be

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transported in the storm sewer conduits to the area outlet, so there is only pipeline runoff flow and no surface runoff routing is considered.

THE STUDY AREA

Jember urban area is located at latitude 8°4'30"S to 8°13'0"S and longitude 113°38'30"E to 113°45'30"E which is cleaved by Bedadung river with tributaries: Rembangan, Antirogo and Jompo. Its total area is approximately 108,98 km^2, and consist of third district: Patrang 36,99 km^2, Sumbersari 37,05 km^2 dan Kaliwates 24,94 km^2 (**FIG. 1**). Population densities in the Patrang District, Sumbersari district, and Kaliwates district are 2553.96 persons / km2, 3408.34 personss/km2 and and 4485.20 persons/km2 respectively.

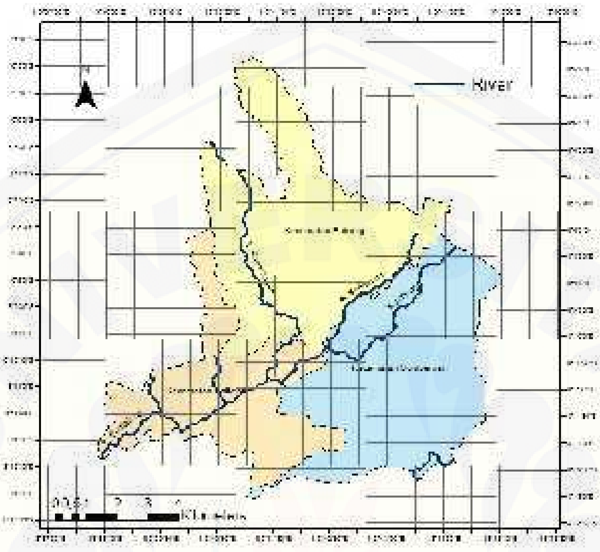

FIG. 1 Location of the study area.

THE THOPOGRAPHY

An average elevation in urban area is 80 m above sea-level. Based on DEM Aster GDEM 30, these area consist of two slope. The upstream portion has a steep slope that is almost entirely made up of natural terrain, with average slopes close to 7.43%, and these urban area are almost completely flat and their ground elevation is not so flat and their elevation ranges fluctuate between 5-10 ma.sl (above sea level) (Fig .2). According to the measurements results of surface topography of project, the steep slope is generally the case in the Patrang district to range between 0-10%, and the flat slope occurred in the Sumbersari and Kaliwates district with 0-3% and 0-2% respectively.

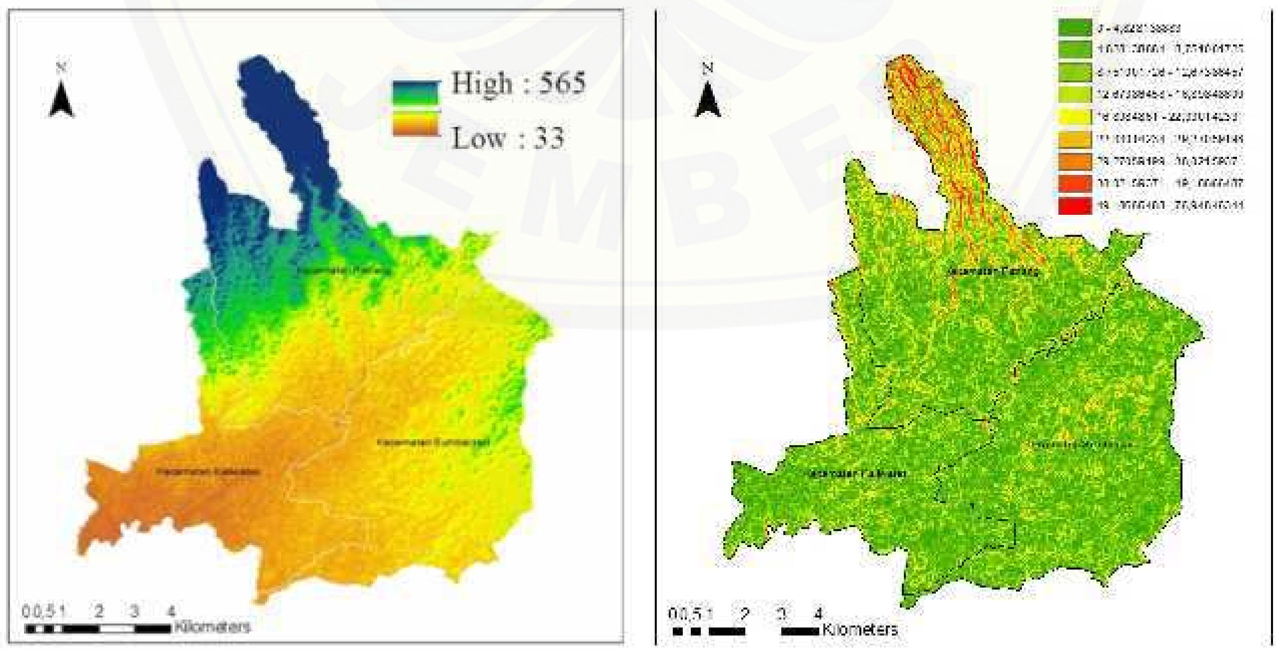

FIG. 2. Digital Elevation Model and Slope Map

LANDUSE INTERPRESTION AND CURVE NUMBER COEFICIENT CALCULATION

The main types of land use accoding to land cover that developed by google Earth (http://www.google.co.id/net/place/Jember,+Kab.Jember, 2015) include green space (evergreen broadleaf forest, cropland, and cropland natural vegetation mosaic) and urban and built up. The classified result is shown in FIG. 4. that the area proportions of different land cover classes. It is seen that the most of upper reaches of the study area is green space. In the low reaches, the land cover is dominated by urban and built up. Also, the curve numbers for each class are listed in Table 1. The curve number values of green space, and urban and built up were 55-91, and 68-98.

Table 1. Land cover and curve numbe values for each class

Class Number	Class description	Proportion %			Curve Number value
		Patrang	Sumbersari	Kaliwates	
1	green space	77.71	23.7	40.73	55-91
2	urban and built up	22.29	76.3	59.27	68-98

THE DRAINAGE NETWORK

Drainage network in the area is relatively complicated; the construction combines of sewage, irigation drainages and rainwater drainage canals on municipal roads. Drainage network system in all three districts can be grouped into 16 networks (FIG. 3). Five nerworks are located in Patrang District these are Jalan Srikoyo Drainage (JSRD), Rembangan River- Jalan Srikoyo Drainage (RR-JSRD), Kemuning-Rembangan River Drainage (KRRD), Polo Kemuning River Drainage (PKRD), and South Patrang–Polo River Drainage (SPPRD). Seven nerworks are located in Sumbersari district these are Kotok Irrigation–Ajung River Drainage (KIARD), Kotok Irrigation –Cakol River Drainage (KICRD), Jalan Mastrip Drainage (JMD), Jalan Kalimantan Drainage (JKD), Jalan Jawa Drainage (JJD), Jalan Sumatra Drainage (JSUD), Cakol River–Bedadung River (CRBRD), Four nerworks are located in Kaliwates District, these are Bedadung River–Jompo River Drainage (BRJRD), Jompo River–Argopuro River Drainage (JRARD), Argopuro River–Semanggir Irrigation Drainage (ARSID), and Bedadung South River Drainage (BSRD).

JRSD drainage network is divided to 115 the sub catchments, that is a contribution from residential area and drainage above and the outlets are the Baratan and Patrang rivers. RRJSRD network is divided to 120 the sub catchments that is a contribution from road drainage and irrigation, and outlet is the Patrang River. RRD network is divided to 124 the subcatchments that is a contribution from road drainages, the Branjangan canal and irrigation drainage, and outled is the Rembangan Rivers. PKRD network is divided to 61 the subcatchments that is a contribution from road drainage, residential area, and irrigation drainage, and the outlet are the Polo and Kemuning River. SPPRD network is divided to 142 the subcatchments that is a contribution from residential area, and irrigation drainage, and the outlet is the Jompo River. KIARD network is divided to 129 the subcatchments that is a contribution from Sriwijaya residential area, and Dam Konto overflow, and the outlet is the Ajung river. KICRD network is divided to 80 the subcatchments that is a contribution from residential area, and irrigation drainage, and the outlet is the Cakol River. JMD network is divided to 31 the subcatchments that is a contribution from residential area, and irrigation drainage, and the outlet is the Antirogo River. JKD network is divided to 68 the subcatchments that is a contribution from of road and campus drainage, and the outlet is the Bedadung River. JJD network is divided to 32 the subcatchments that is a contribution from drainage channels from urban areas, campuses and irrigation, and the outlet is the Antirogo River. JSUD network is divided to 39 the subcatchments that is a contribution from residential area which is outflowed to the Antirogo River. CRBRD network is a contribution from irrigation drainage and residential area of Jl. Karimata, and the outed is the Cakol river. BRJRD network is divided to 131 the subcatchments is a contribution from residential area and the outlet to the Jompo River and partly derived from Jln A Yani, and the outlet is the Bedadung River. JRARD network is divided to 117 the subcatchments that is a contribution from irrigation at the norhtern railway and a residential area, and the outlet is the Bedadung river. ARSID network is divided to 393 the subcatchments that is combination of residential area, and road drainage and the outlet is the Semangir canel. BSRD network is divided to 129 the subcatchments is a collection of residential area and the outlet is the Bedadung River.

The drainage network in Patrang district consists mostly of a network of natural ditches and drains, with the condition. The drainage network in Sumbersari district and Kaliwates district consists mostly of a network of artificial drains, including short stretches of closed conduits. Natural channels in pristine condition or overgrown shrubs or gravel, curved, and walled sand hollow, shallow, and irregularly shaped, with a range of manning rougness values between 0.028 to 0.125. Meanwhile, the condition of the artificial channel is protected by masonry with finishing or without finishing, or concrete with a range of manning rougness values between 0.016 to 0.033

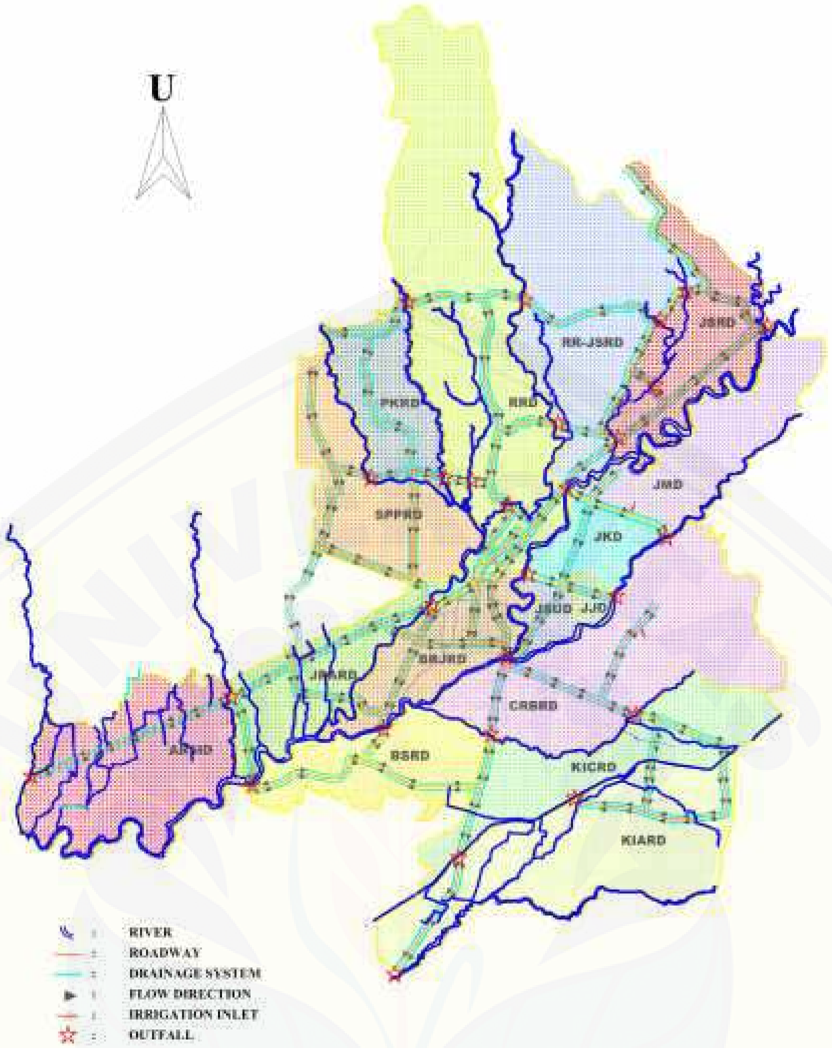

FIG. 3. Drainage network

RAINFALL INPUT AND FORCASTING

Rainfall Input

Rainfall data input is used in this study comes from the measurements of five raingauges (Semanggir, Jember, Wirolegi, Kasmaran, and Sembah) that is recorded from 2004 to 2014. Most of the rainfall is concentrated in the September to April. According to records of the fifth raingauges, a maximum rainfall depth of 135 mm occurred in 2006, while minimum rainfall depth of 54 mm occurred in 2012.

Rainfall Forcasting

Based on Smirnov-Kolmogorov goodness-of-fit test, rainfall distribution for Sumbersari districts and Patrang district were Log Pearson III distribution, while the Kaliwates District was Normal distribution. Design of rainfall for 1, 2, 5, and 10 year return period rainfall for Patrang district was 65.16 mm, 82.27 mm, 102.27 mm and 117.27 mm respectively; Sumbersari in consecutive sub-district is 74.19 mm, 91.32 mm, 100.29 mm and 104.13 mm; and District Kaliwates respectively is 71.87 mm, 100.60 mm, 119.46 mm and 129.32 mm. This indicates that, the sequence of the desaign rainfall depth from high to low in a sequence is Kaliwates districts, Patrang districts, and Sumbersari districts.

MODEL CALIBRATION

In order to ensure the reasonableness of the model, it is necessary to compare the calculated results with the actual flooding spots. The calibration was done by incrementally adjusting the manning parameter. This was determined at16 nodes based on event rainfall depth to compare with the actual flooding area. The results show that the error at Patrang, Sumbersari and Kaliwates district respectively between 3-8%, and 6-8%. It indicates that the flooding results simulated by the model and the actual situation are relatively consistent, so that the simulation results are basically reliable.

RESULTS AND DISCUSSION

Flood Simulation

The simulated surface runoff, infiltration and precipitation of three districts are shown that the increase of the return period, the total precipitation, the surface runoff, the runoff coefficient, and the infiltration, this is because the studied area has a high pervious area rate. The increase of the highest infiltration value in Patrang District, this is because the studied area has a high procentase of green space particularly in RRJSRD, but there is a drainage network that the decrease of infiltration in BSRD network at Kaliwates district, because this area has a high population density. Infiltration will increase for the green space areas, otherwise in residential areas will decrease.

Junction overflow will cause inundation around the junction area, and is an important index for urban flood forecasting. From the results it was found that with the increase of the return period, the overflow junction number, the overflow volume and overflow duration increase steadily. When the return period is 1 year, 2, 5,and 10 rainfall are overflow. The node flooding is shown in FIG .4 as the red circle, that are found 111noods flooding. The noods flooding with the most number is in Patrang district as many as 46 nodes with high floods ranging between 5-30cm. Futhermore, the second highest noods flooding is in the Kaliwates district as much as 37 nodes with high floods ranging between 10-30cm. The latter is in Sumbersari district as much as 28 points with a high range of flooding between 10-50cm.

The numbers of nodes flooding in Jember urban area, in the analysis of hydrology were caused by the contribution of discharge from irrigation drainage, or overflow dam to the urbanized drainage network, and high population density in urban area. While the analysis of hydraulics were caused by the channel capacity cannot accommodate the appropriate channel function, the slope of the line is too flat in FIG.5, the sedimentation or waste which reduces the capacity of the channel and a small part due to bottleneck. In general, the location of the noodes flooding in the Patrang district more than other districts, although a slope of this district is greater than other districts. This is due to the capacity of the natural channel in the Patrang district not be able to accommodate the desaign flood. Flooding in Kaliwates District was caused by many things, namely the existence of bottlenecks, curves, channel capacity does not accommodate etc. Flooding in the Sumbersari district higher than both other regions due to the channel capacity cannot accommodate, the slope of the line is too flat, there is the sedimentation of the channel, the addition there are a contribution of discharge from irrigation drainage. Based on the fact the field, this is caused by the land conversion of irrigated area into a residential area and a network system that has not been followed by changes in the drainage network system.

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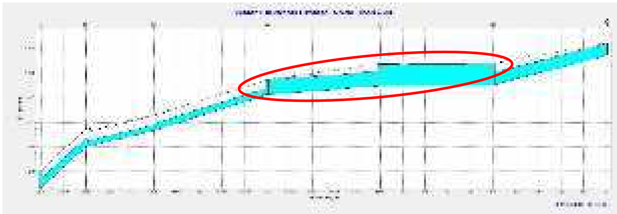
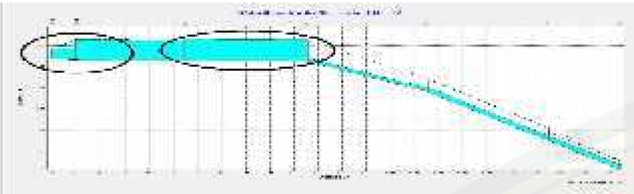
FIG. 4 Location of Nodes Flooding

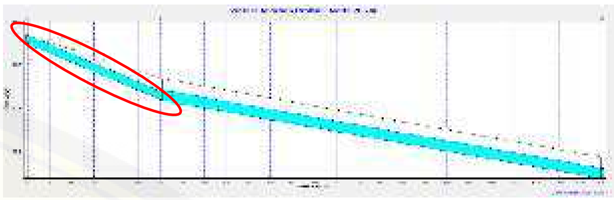
A.1 Flooding in



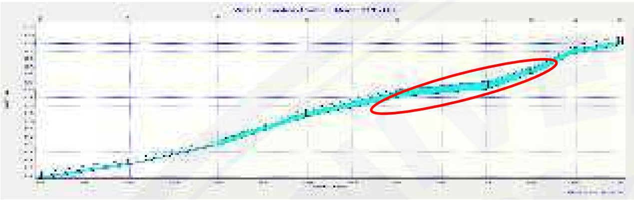
A.2 Flooding in RR-JSRD



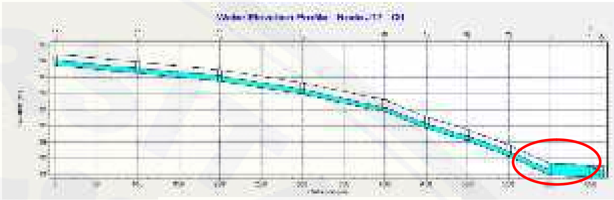
A.3 Flooding in RRD



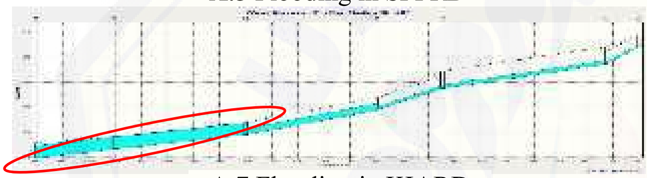
A.4 Flooding in PKRD



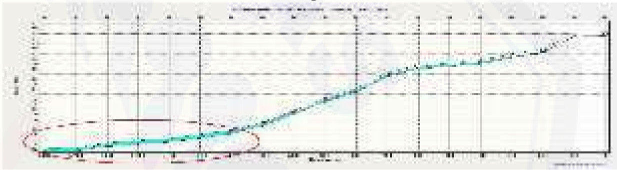
A.5 Flooding in SPPRD



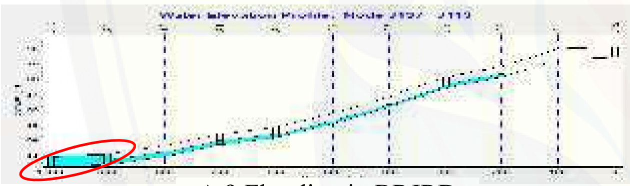
A.6 Flooding in KICRD



A.7 Flooding in KIARD



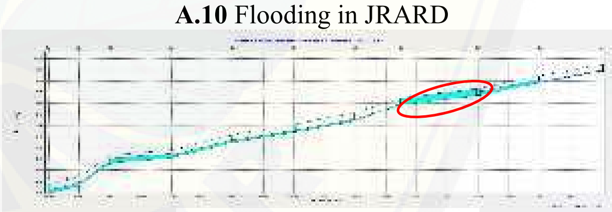
A.8 Flooding in CRBRD



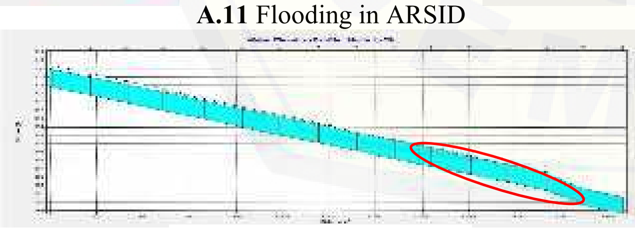
A.9 Flooding in BRJRD

A.10 Flooding in JRARD

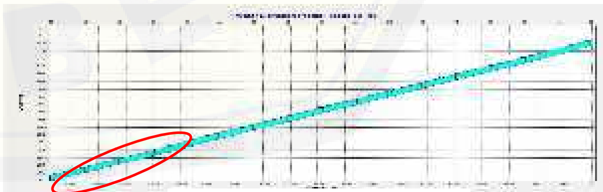
A.11 Flooding in ARSID



A.12 Flooding in BSRD



A.13 Flooding in JMD



A.14 Flooding in JKD

A.15 Flooding in JJD

A.16 Flooding in JSUD

FIG. 5. Result of running for 1 year time periode raifall

CONCLUSIONS

TheSWMM models have been used to demonstrate the simulation of flow and water surface depth at Jember urban drainage system. The SWMM model was set up based on the DEM, thopography measurement, digital map and underground cannel network, and parameters derived based on the properties of the subcatchments and the storm sewer conduits. The parameter calibration shows the parameter robustness.

The urban flood processes were simulated with different return period design precipitation, and the results show that with the 1, 2, 5, and 10 year return period rainfall, the studied area will be inundated at 111 noods flooding. The numbers of nodes flooding in Jember urban area, in the analysis of hydrology were caused by the contribution of discharge from irrigation drainage, or overflow dam to the urbanized drainage network, and high population density in urban area. While the analysis of hydraulics were caused by the channel capacity cannot accommodate the appropriate channel function, the slope of the line was too flat, the sedimentation or waste which reduced the capacity of the channel and a small part due to bottleneck.

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