The assessment of Urban Storm Inundation

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Abstract. A Sustainable and integrated plan in order to solve urban storm inundation problem, is an urgent issue in Indonesia. A reliable and complete datasets of urban storm inundation area in Indonesia should become its basis to give clear description of inundation area for formulating the best solution. In this study, Statistics Indonesia data in thirty three provinces were assessed during 2000 until 2012 providing data series of urban flood area, flood frequency and land cover changes. Drainage system condition in big cities should be well understood to ensure its infrastructure condition and performance. If inundation occurred, it can be concluded that there is drainage system problem. Inundation data is also important for drainage system design process in the future. The study result is provided estimation of urban storm inundation area based on calculation of Statistics Indonesia data. Moreover, this study is preceded by analyzing and reviewing the capacity of existing drainage channel, using case study of Mataram, West Nusa Tenggara. Rainfall data was obtained from three rainfall stations surround Mataram City. The storm water quantity was calculated using three different approaches as follows: 1) Rational Method; 2) Summation of existing inundation and surface run off discharge; 3) Discharge calculation from existing channel dimensions. After that, the result of these approaches was compared. The storm water quantity gap was concluded as quantity of inundation. The result shows that 36% of drainage channel in Brenyok Kanan River sub system could not accommodate the storm water runoff in this area, which causing inundation. The redesign of drainage channel using design discharge from Rational Method approach should be performed. Within area with the lowest level topography, a construction of detention or storage pond is essential to prevent inundation in this area. Furthermore, the benefits and drawbacks of the statistics database are discussed. Recommendations include utilizing more refined urban land use typologies that can better represent physical alteration of hydrological pathways

Keywords: Statistics data Indonesia, Inundation, Storm Water Quantity, Drainage Channel Capacity
1. Introduction

Drainage system’s problems in Indonesia are generally caused by land cover changes, deforestation, watershed area as settlements area, clogged drainage pipe/channel, low capacity of drainage pipes/channels. Also, overlapping of drainage system management among the governmental department or institution, climate change impact and insufficient regulation are worsened the drainage system performance in urban area of Indonesia [1]. As stated in one of inundation studies that inundation processes in urban areas are primarily affected by the artificial factors such as drainage facilities, local alterations of topography and land uses [2].

The development of drainage system has already conducted in many regions in Indonesia based on Drainage Master Plan that they have developed in the past. Urban drainage system was developed in order to overcome and anticipate inundation in urban area especially in big cities. There are government, economy, industry and tourism activities in these cities.

A Sustainable and integrated plan in order to solve urban storm inundation problem, is an urgent issue in Indonesia. A Drainage System Roadmap could provide clear future objective and strategies regarding inundation within a certain framework and time frame. Hence, in order to develop a road map for urban drainage system in Indonesia, a reliable and complete datasets of urban storm inundation area in Indonesia should become its basis.

*Badan Pusat Statistik* (BPS-Statistics Indonesia) is a non-departmental government institute of Indonesia who is responsible to conduct statistical surveys. Statistics Indonesia data in thirty three provinces were assessed during 2000 until 2012 providing data series of urban flood area, flood frequency and land cover changes. Therefore, drainage system condition in big cities should be well understood to ensure its infrastructure condition and performance. If inundation occurred, it can be concluded that there is drainage system problem. Inundation data is also important for drainage system design process in the future. The main objective of this research is to provide estimation of urban storm inundation area based on calculation of Statistics Indonesia data.

Drainage system’s problems in Mataram City, Indonesia are generally caused by land cover changes, watershed area as settlements area, clogged drainage pipe/channel, and insufficient capacity of drainage pipes/channels. According to report from Ministry of Public works in 2014, overlapping of drainage system management among the governmental department or institution, climate change impact and insufficient regulation are worsened the drainage system performance in urban area of Indonesia. As stated in one of inundation studies that, inundation processes in urban areas are primarily affected by the artificial factors such as drainage facilities, local alterations of topography and land uses [3]. The development of drainage system has already conducted in many regions in Indonesia based on Drainage Master Plan that they have developed in the past. Urban drainage system was developed in order to overcome and anticipate inundation in urban area especially in big cities. There are government, economy, industry and tourism activities in these cities. Urban storm inundation, which frequently has dramatic impacts on city safety and social life, is an emergent and difficult issue [4]. Floods can arise from a variety of causes. The best understood floods occur then, following intense or prolonged rainfall, water levels in rivers rise and the rivers overtop their banks (fluvial flooding). Also well-known are coastal floods caused by storm surges and wave action superimposed on high water levels generated during the diurnal cycle of tides [5]. Between 2007 and 2025, the world urban population is expected to increase by 1.3 billion people [6]. Thus, more houses will be built and as a result, it will reduce the open area of land cover and increase surface runoff off [7].

Hence, the changing of imperviousness of land cover also contributes to surface runoff occurrence [8]. The developments that change land cover in urban area can cause increasing of rainfall runoff [9]. Also, it has been studied that there is an effect of land cover changes on flooding in Asia with high intensity of rainfall [10]. In order to get effective solution for inundation, we are conducting an evaluation regarding the cause of this problem. It is important to understand whether the capacity of existing drainage system is sufficient for surface runoff discharge from Brenyok Kanan River watershed. Result of this study could be utilized as an alternative of inundation solution in Mataram City.
2. Methodology

2.1. Data Preparation Stages

Basic/raw data being used for calculation is from Village Potential Data (PODES) of Statistics Indonesia in year 2000, 2003, 2006, 2008, and 2011. It consists of natural and human resource data of every village in Indonesia which collected every 3 years by Indonesia National Statistical Bureau (BPS). These data will be utilized by the stakeholders as a basis data to further usage in managing and developing the village.

In this study, Statistics Data of village which located in urban area will be processed and analyzed. Study areas are all urban villages in Indonesia that have flood occurrence. Preliminary processing of Statistics Data should be performed during inundation data analysis. The data processing phases consist of: 1) Administrative Line Calibration, 2) Morphology data calculation; and 3) Inundation related data compilation. After that, inundation data is ready to be analyzed. Analysis phases are comprised Monte Carlo-statistics inundation data analysis, and master plan-statistics inundation data analysis. Inundation unit is stated in area (hectare).

In statistics Indonesia data, administrative area is differentiating by its code. If the administrative border line is changing (e.g. due to break up of one village into two or more villages) then, the code is also change. This analysis was conducted because there are an increasing number of cities and regencies in Indonesia from time to time (see Figure 1). Therefore, it is crucial to perform analysis of administrative data before compilation process is conducted, both morphological and inundation data. The analysis is conducted by performing a calibration.

![Figure 1. Increasing number of cities/regencies from 2000 until 2014.](image-url)

Source: Statistics Indonesia Data (Podes) 2000-2011; and Master File Village (MFD), 2014

This calibration process applied in village/regency level, by conducted a cross check data each year; to identify administrative changes occurred in each year. The result shows that there is an increasing in numbers of villages in year 2000, 2003, 2006, 2008, 2011, and 2014.

2.2. Inundation probabilistic Analysis based on Morphological features using Monte Carlo Simulation

The risk of inundation occurrence of these morphological data is calculated for each area using Monte Carlo analysis. It is an analysis tool that integrates the concept that every variable will have some impact on overall risk. Every individual and institution has different risk/return tolerances. The 4 (four) morphological features above are variables uses in the analysis. The Monte Carlo approach has found...
wide application in the analysis of stochastic problems and is based on repeated solutions of the deterministic equations using realizations of input values. There is no need to implement linear approximations and the method is very flexible. The probability distributions produced by a Monte Carlo model create a picture of risk. Hence, in this study, it shows the inundation probability of each area. The higher the percentage of probability, the higher the chances of inundation occurs in that area.

Morphological feature of an area is one of the factors that influence the surface runoff thus, later will impact the probability of inundation occurrence [11, 12]. Morphology data utilized in this study are: a) Topography characteristics; b) Water body (existence of a river); c) Geographical feature (located on coastal area or not) and; d. Land cover (open area, partly built-in, built-in). Topographical characteristics divided into three categories: hill area, slope area and valley/flat area. The hilly area has the lowest chances of inundation occurrence, while slope has higher chances and valley has the highest chances of inundation occurrence. Regarding water body category, river consider as output of surface runoff. Hence area with river has lower inundation probability compare to area without river. Area with geographical feature of coastal area consider as prone to inundation due to low land altitude and high tide. Finally, land cover with category ‘open area’, ‘partly built-in’ and ‘built-in’ is defined as an area with open area of more than 75%, open area between 25-75% and; open area less than 25%, respectively. This morphology data was taken within regency, so the Monte Carlo Probability analysis was conducted within regency. Table 1 shows a scoring (number in bracket) of each variable and percentage of Monte Carlo probability. There are 36 arrangement of topology, water body; geography and land cover combinations, with percentage of Monte Carlo probability ranging from 99% to 49%. The result of Monte Carlo probability analysis gives information about the probability of inundation occurrence.

| No | Topological condition | Existence of Water body | Geographical location | Land Cover characteristics | Inundation Probability |
|----|-----------------------|-------------------------|-----------------------|----------------------------|------------------------|
| 1  | Valley or Flat (3)    | River (2)               | Coastal area (2)      | Built-in area (3)          | 99%                    |
| 2  | Valley or Flat (3)    | River (2)               | Coastal area (2)      | Partly built-in area (2)   | 89%                    |
| 3  | Slope (2)             | River (2)               | Coastal area (2)      | Built-in area (3)          | 89%                    |
| 4  | Valley or Flat (3)    | River (2)               | No coastal area (1)   | Built-in area (3)          | 89%                    |
| 5  | Valley or Flat (3)    | No River (1)            | Coastal area (2)      | Built-in area (3)          | 89%                    |
| 6  | Valley or Flat (3)    | River (2)               | Coastal area (2)      | Open area (1)              | 79%                    |
| 7  | Slope (2)             | River (2)               | Coastal area (2)      | Partly built-in area (2)   | 79%                    |
| 8  | Valley or Flat (3)    | River (2)               | No coastal area (1)   | Partly built-in area (2)   | 79%                    |
| 9  | Valley or Flat (3)    | No River (1)            | Coastal area (2)      | Partly built-in area (2)   | 79%                    |
| 10 | Hilly (1)             | River (2)               | Coastal area (2)      | Built-in area (3)          | 79%                    |
| 11 | Slope (2)             | River (2)               | No coastal area (1)   | Built-in area (3)          | 79%                    |
| 12 | Slope (2)             | No River (1)            | Coastal area (2)      | Built-in area (3)          | 79%                    |
| 13 | Valley or Flat (3)    | No River (1)            | No coastal area (1)   | Built-in area (3)          | 79%                    |
| 14 | Slope (2)             | River (2)               | Coastal area (2)      | Open area (1)              | 69%                    |
| No | Topological condition | Existence of Water body | Geographical location | Land Cover characteristics | Inundation Probability | Code |
|----|-----------------------|------------------------|----------------------|---------------------------|-----------------------|------|
| 15 | Valley or Flat (3)    | River (2)              | No coastal area (1)  | Open area (1)             | 69%                   | P69  |
| 16 | Valley or Flat (3)    | No River (1)           | Coastal area (2)     | Open area (1)             | 69%                   | P69  |
| 17 | Hilly (1)             | River (2)              | Coastal area (2)     | Partly built-in area (2)  | 69%                   | P69  |
| 18 | Slope (2)             | River (2)              | No coastal area (1)  | Partly built-in area (2)  | 69%                   | P69  |
| 19 | Slope (2)             | No River (1)           | Coastal area (2)     | Partly built-in area (2)  | 69%                   | P69  |
| 20 | Valley or Flat (3)    | No River (1)           | No coastal area (1)  | Partly built-in area (2)  | 69%                   | P69  |
| 21 | Hilly (1)             | River (2)              | No coastal area (1)  | Built-in area (3)         | 69%                   | P69  |
| 22 | Hilly (1)             | No River (1)           | Coastal area (2)     | Built-in area (3)         | 69%                   | P69  |
| 23 | Slope (2)             | No River (1)           | No coastal area (1)  | Built-in area (3)         | 69%                   | P69  |
| 24 | Hilly (1)             | River (2)              | Coastal area (2)     | Open area (1)             | 59%                   | P59  |
| 25 | Slope (2)             | River (2)              | No coastal area (1)  | Open area (1)             | 59%                   | P59  |
| 26 | Slope (2)             | No River (1)           | Coastal area (2)     | Open area (1)             | 59%                   | P59  |
| 27 | Valley or Flat (3)    | No River (1)           | No coastal area (1)  | Open area (1)             | 59%                   | P59  |
| 28 | Hilly (1)             | River (2)              | No coastal area (1)  | Partly built-in area (2)  | 59%                   | P59  |
| 29 | Hilly (1)             | No River (1)           | Coastal area (2)     | Partly built-in area (2)  | 59%                   | P59  |
| 30 | Slope (2)             | No River (1)           | No coastal area (1)  | Partly built-in area (2)  | 59%                   | P59  |
| 31 | Hilly (1)             | No River (1)           | No coastal area (1)  | Built-in area (3)         | 59%                   | P59  |
| 32 | Hilly (1)             | River (2)              | No coastal area (1)  | Open area (1)             | 49%                   | P49  |
| 33 | Hilly (1)             | No River (1)           | Coastal area (2)     | Open area (1)             | 49%                   | P49  |
| 34 | Slope (2)             | No River (1)           | No coastal area (1)  | Open area (1)             | 49%                   | P49  |
| 35 | Hilly (1)             | No River (1)           | No coastal area (1)  | Partly built-in area (2)  | 49%                   | P49  |
| 36 | Hilly (1)             | No River (1)           | No coastal area (1)  | Open area (1)             | 49%                   | P39  |
2.3 Case Study Mataram Drainage system

Mataram City is the capital city of West Nusa Tenggara, with an area of 61,30 km$^2$. Most of its topography has low and middle altitude, except at the southern part, that consists of mountain and hills. Mataram City is a relatively flat area. The land use includes settlement area (37.68%), agriculture (47.07%) and others (15.25%). Elevation of each district is vary, as at Cakranegara district is + 25 m, Mataram District is + 15 m and Ampenan District (coastal area) is + 5 m above the sea level (Profil Kota Mataram, 2009). There are 4 (four) inundated area within Brenyok Kanan River drainage system [14] as shown in Figure 2.

![Figure 2. Brenyok Kanan River drainage system (dashed line) and inundation areas.](image)

The description of each area are as follows: 1) Area 2; inundation area of 0.9 Ha, inundation height of 0.5 m, duration of inundation is between 2 – 4 hours with occurrence frequency of 2 – 3 times per year; 2) Area 16; inundation area of 2.75 Ha, inundation height of 0.5 m, duration of inundation is between 2 – 3 hours with occurrence frequency of 2 – 3 times per year; 3) Area 17; inundation area of 1 Ha; inundation height of 0.5 m, duration of inundation is between 2 – 3 hours with occurrence frequency of 2 – 4 times per year; and 4) Area 20; inundation area of 2.4 Ha; inundation height of 0.5 m, duration of inundation is between 2 – 4 hours with occurrence frequency of 2 – 4 times per year.

Primary data being used for calculation is a field measurement of existing channel dimension at Brenyok kanan Drainage system. The secondary data being used for the analysis of inundation are:

a) Maximum daily rainfall data from rainfall station surround Mataram City.

b) Inundation data of Mataram City

c) Topography Data Mataram City

d) Existing Drainage system of Brenyok kanan River

The maximum daily rainfall data was gained from Meteorology and Geophysics Biro at Kediri district (BMKG Kediri). Inundation and topography data was collected from Public work Department of
Mataram City. Existing data of drainage system of Brenyok Kanan River was gained from previous study by Arifuddin in 2012 [14] and a field measurement survey. There are 3 (three) rainfall stations in Mataram City, they are: Kediri, Cakranegara, and Selaparang station.

The data processing phases consist of: 1) Hydrology and hydraulic analysis of drainage system channels, 2) Surface runoff discharge and hydraulic characteristics of channel calculation; and 3) evaluation of drainage system. These phases are shown in figure 3.

![Flow diagram of evaluation of drainage system](image)

2.4. Hydrology Analysis

The discharge at weir capacity and for the run off analysis can be measured by using manual or conventional system [15]. In this study, maximum daily rainfall data from the rainfall stations in 12 years, from 2003 until 2014 was utilized in hydrology analysis. The rainfall data from each rainfall station is shown in Table 2. Distribution analysis was conducted to determine the method that represent rainfall data pattern. After that, maximum rainfall data was calculated using return period of 2, 5, 10 and 20, 50 and 100 years.

| Year | Maximum Daily Rainfall Height (mm) |
|------|-----------------------------------|
|      | Kediri Station | Cakranegara Station | Selaparang Station |
| 2003 | 81              | 61                  | 91                  |
| 2004 | 133             | 81                  | 114                 |
| 2005 | 86              | 93                  | 90                  |
| 2006 | 90              | 95                  | 77                  |
| 2007 | 98.1            | 60                  | 80                  |
| 2008 | 59.8            | 66.5                | 67                  |
| 2009 | 184.5           | 175                 | 91                  |
| 2010 | 156             | 161                 | 158                 |
| 2011 | 70              | 62                  | 74                  |
| 2012 | 82              | 79                  | 85                  |
| 2013 | 95              | 79                  | 137                 |
| 2014 | 96              | 79                  | 96                  |

(Source: Meteorology and Geophysics Biro at Kediri district)
2.5. Calculation of Surface Run Off ($Q_{limp}$) and Evaluation of Drainage System

Surface run off was calculated using Rational Method, as follows:

$$Q = 0.00278 \times C \times I \times A$$

Where $C$ is run off coefficient, $I$ is rainfall intensity and $A$ is drainage area.

Evaluation of drainage system consists of comparison between calculated existing channel discharge and design flood discharge. Existing channel discharge was obtained using equation:

$$Q = A \times v$$

With $A$ is an area of channel ($m^2$) and $v$ is flow velocity of channel ($m/s$). Velocity is calculated using manning equation

$$v = \frac{1}{n} R^{2/3} I^{1/2}$$

Where, $R$ is Area of cross section channel ($m^2$) divided by wet perimeter of cross section channel ($m$);

$I$ is the channel slope ($m/m$) and $n$ is manning coefficient ($m^{1/3}/s$)

If channel discharge is bigger than design flood discharge, it means that the channel capacity is sufficient for the surface runoff in that area. Thus inundation will not occur. To the contrary, if design flood discharge is higher than channel discharge, it means that surface run off that goes to the channel will not be accommodate with the channel. As a result, inundation due to over flow from the channel will occur in that area.

3. Result and Discussion

3.1. Inundation Area Calculation

The Statistics Indonesia data related to calculation of inundation are as follows:

1. Inundation area
2. Numbers of inundation location
3. Frequency of inundation occurrence (maximum, minimum, average)

Area of inundation is calculated by using an approach as follows: an area of village with flooded status divided by total area of villages in one district (Kecamatan). If the result shows that percentage of inundation is less than 25%, that area in that district is directly categorized as inundation area. If it is bigger than 25%, then, the magnitude of the area will be multiplied by 1.3% and categorized as inundation area. The coefficient 1.3% was concluded from analyzing inundation area in each city compare to its city area. There are 24 cities calculated, they are: Surabaya, Pangkal Pinang, Bandar Lampung, Tangerang, Semarang, Mataram, Yogyakarta, Tangerang Selatan, Jayapura, Surakarta, Bandung, Medan, Binjai, Makasar, Padang, Palembang, Pekanbaru, Batam City, Cimahi City, Depok City, Cirebon City, Bekasi City, Manado City and Denpasar. The result shows that percentage of inundation area to city area are ranging between 0.04 % to 5.9%. Hence, the mean value of the percentage is 1.3%.

The inundated village data were compiled based on district, regency/city, and Province. Based on this approach, inundation data compilation of 32 cities in year 2000, 2003, 2006, 2008, dan 2011 were calculated. The results are as follows:
3.2. Channel Capacity Evaluation

If the result of channel discharge ($Q_{\text{channel}}$) substracted by surface runoff discharge ($Q_{\text{5yr}}$) is bigger than zero, it was concluded that the channel is sufficient. However, if the result is less than zero, the channel is not sufficient. It means that there will be an inundation during rainfall occurrence. The result of channel capacity evaluation shows that for area 20, there are 11 sufficient channels and 7 inundated channel; for area 16, there are 4 sufficient channel and 4 inundated channel; for area 17, there are 25 sufficient channel and 9 inundated channel; for area 20 there are 12 sufficient channel and 1 inundated channel. In total of 4 inundated area, there are 53 sufficient channel and 21 inundated channel.

An assumption was generated that inundation is occur due to insufficient channel capacity to accommodate the surface runoff. Hence, in order to overcome the inundation, the quantity of inundation should equal to quantity of channel capacity. Therefore, to calculate channel capacity that could accommodate the quantity of inundation, the unit of inundation will convert from height to discharge by dividing inundation volume with inundation time. Table 3 shows the result of conversion from inundation height to discharge. After that, calculation of channel width and height will be performed. Result of calculation of channel based on inundation discharge (Table 4) shows that there are still 12 channels that could not accommodate the surface runoff discharge. Although it could reduce the number of insufficient channels from 21 channels to 12 channels or about 60% reduction, it was not yet overcome the inundation problem in Mataram City.

| Location | Inundation Area (Ha) | Inundation height (m) | Duration of inundation (hour) | Inundation discharge (m³/sec) |
|----------|----------------------|-----------------------|-----------------------------|-----------------------------|
| Area 20  | 0.9                  | 0.5                   | 2.5                         | 0.500                       |
| Area 16  | 2.75                 | 0.5                   | 3                           | 1.273                       |
| Area 17  | 1                    | 0.5                   | 2.5                         | 0.556                       |
| Area 2   | 2.4                  | 0.5                   | 3                           | 1.111                       |

(Source: Mataram City Public Work Biro, 2007)
### Table 4. Evaluation result of enlarging the channel capacity

| No | Title of Inundated Channels | Q<sub>channel</sub> before enlargement (m³/s) | Q<sub>channel</sub> after enlargement (m³/s) | Q<sub>5yrs</sub> - Q<sub>channel</sub> after enlargement | Evaluation |
|----|----------------------------|-------------------------------------------|-------------------------------------------|------------------------------------------------|------------|
| 1  | Perumnas Utara             | 0.23                                      | 1.26                                      | 0.57                                           | Sufficient |
| 2  | Kesra Raya Utara           | 0.16                                      | 0.75                                      | 0.17                                           | Sufficient |
| 3  | Kesra Raya Selatan         | 0.23                                      | 0.42                                      | -0.01                                          | Inundated  |
| 4  | Sal. Pamotan Kiri Meninting| 0.44                                      | 1.15                                      | -0.39                                          | Inundated  |
| 5  | Kekalik                    | 1.32                                      | 1.67                                      | 0.31                                           | Sufficient |
| 6  | Panji Tilar                | 0.55                                      | 0.60                                      | -0.10                                          | Inundated  |
| 7  | Pamotan Kiri Batu Dawe     | 2.26                                      | 4.25                                      | 0.11                                           | Sufficient |
| 8  | Panaraga Selatan 1         | 0.25                                      | 0.30                                      | -0.07                                          | Inundated  |
| 9  | Karang Bata 2              | 0.19                                      | 0.27                                      | -0.03                                          | Inundated  |
| 10 | Abian Tubuh Barat 1        | 0.21                                      | 0.26                                      | -0.01                                          | Inundated  |
| 11 | Abian Tubuh Barat 2        | 0.19                                      | 0.23                                      | -0.02                                          | Inundated  |
| 12 | Brawijaya Utara            | 2.98                                      | 3.99                                      | 0.69                                           | Sufficient |
| 13 | Pasar Cakra                | 0.31                                      | 0.54                                      | 0.05                                           | Sufficient |
| 14 | Kompleks MGM               | 1.03                                      | 1.34                                      | 0.04                                           | Sufficient |
| 15 | AA. Gde Ngurah 1           | 0.32                                      | 0.37                                      | -0.001                                         | Inundated  |
| 16 | Mayura 2                   | 10.26                                     | 10.93                                     | -1.30                                          | Inundated  |
| 17 | AA. Gde Ngurah Timur       | 15.29                                     | 20.04                                     | 4.53                                           | Sufficient |
| 18 | L. Mesir Selatan 2         | 0.11                                      | 0.21                                      | 0.07                                           | Sufficient |
| 19 | Abian Tubuh                | 1.92                                      | 3.36                                      | -0.29                                          | Inundated  |
| 20 | Abian Tubuh - Mayura       | 8.72                                      | 10.74                                     | -5.15                                          | Inundated  |
| 21 | Terminal Mandalika         | 0.94                                      | 1.29                                      | -0.54                                          | Inundated  |

### 4. Conclusion

Assessment of inundation could be performed by utilizing statistics data. Data calibration regarding administrative boundary line of each village is a very crucial phase at preliminary stage. It influenced the accuracy of inundation analysis. The morphological data from Indonesia Statistics data could be applied to calculate inundation risk. There are 10 Metropolitan cities in this study have an increasing inundation from 2000 to 2011. They are: Central Jakarta, South Jakarta, North Jakarta, Bekasi, Depok, Tangerang, Bandung, Medan, Palembang, and Semarang, out of 15 metropolitan cities in Indonesia.

Evaluation of Brenyok Kanan River drainage system shows that there are 21 insufficient channels out of 74 channels in the drainage system that causing inundation in 4 (four) areas, area 2, area 16, area 17 and area 20. Alternatives was generated in order to overcome this problem. First approach is to enlarge the channel dimension by cleaning the sedimentation inside the channels. The result shows that it reduce the number of inundated channel from 21 to 12 channels or about 60% reduction of insufficient channel. In order to eliminate inundation totally, second approach was employed. Open area was
introduced in the calculation of surface runoff discharge. Using return period of 5 years, the calculation result shows that drainage channel dimension is sufficient to accommodate surface runoff. Therefore, to prevent inundation occurrence in the future, the stakeholder of Mataram City development should consider land use more carefully in designing the drainage channel for the next 5 years.

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