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Observation of Short Duration Rainfall in Yogyakarta

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Abstract*: *On the observation of hourly rainfall data in Java Island, for the modelling watershed purpose, it can be seen that short duration rainfall events are the most dominant. The percentage of short duration rainfall event is almost 70% of the observation data. By using the high resolution of hourly rainfall data with 5 minutes' intervals, it can be easily to describe the rainfall distribution patterns that occur. This research observed high resolution of hourly rainfall data in hilly and mountainous at Mount Merapi area in Yogyakarta. It purposed to mitigation effort due to the rainfall events that often falls with short duration and high intensity.

Keywords* : *intensity, rainfall event, rainfall distribution pattern, short duration rainfall

I. INTRODUCTION

A simplified mathematical modelling of part of hydrological cycle process is very important [1][2]. However, hydrological modelling is a tool that is usually used to predict the hydrological response of the basin due to the rainfall [3]. However, rainfall is one of the God's graces which gives many benefits but it also has the potency of disaster if the quantity and the distribution are uncontrolled.

On the modeling of watershed, using a unit hydrograph, the main input is effective rainfall, base flow, runoff hydrograph and rainfall distribution patterns (RDP) [4]. The RDP is easy to build if there is hourly rainfall data record availability in the design area. If there isn't, then empirical equations can be used. We observed that rainfall events in Java Island mostly occurs short duration events with almost 70% of observation data. Short duration rainfall events can be described as a rainfall event below 24 hours. Short duration rain is needed in urban drainage system planning to show the response characteristics of the design area / watershed [5]. In disaster mitigation efforts, a RDP with short intervals is needed to define peak time of heavy rainfall.

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To define the RDP under 2 hours high resolution rainfall data is needed from automatic rainfall gauge. The high resolution rainfall data is reflecting the level of risk to be protected, given the level of disaster due to water behavior occupying the top place in Indonesia [6].. This research is adopting high resolution rainfall data of 5 minutes interval in hilly and mountainous region at Merapi Mount, Yogyakarta to define RDP. By using this RDP which has 2 hour duration in watershed modelling, is expected to minimize the level of error carried in discharge design for the area which less of Automatic Rainfall Gauge.

II. MATERIALS AND METHODS

A. Heavy Rainfall

In order to recognize the characteristics of rainfall events in some area, we have to know the rainfall depth, rainfall duration, rainfall intensity and maximum intensity occurs inside the rainfall event [7]. Heavy rainfall in Indonesia is defined in literature as rainfall events which have intensity between 10-20 mm/h or 50-100 mm/24h [8]. The characteristics of heavy rainfall events in the southern region of Portugal are define as rainfall events with intensity exceed the value of 40 mm in 24 hours [9]. The characteristics of heavy rainfall events in the South African region is define as rainfall events with intensity exceeds the value of 15 mm and define as a very heavy rainfall with intensity exceeds the value of 25 mm [10]. The characteristics of heavy rainfall events in the Peninsular Malaysia region is classify as a heavy rainfall if the rainfall events intensity reach value between of 8 <I <12 mm / hour [11]. Khalig [12] provides a threshold for heavy rainfall with intensity value between 10mm/h or 0.5mm/min. The research of the characteristics of heavy rainfalls in the Merapi Yogyakarta region is defined by the rainfall events with a rainfall depth of 50 mm /rainfall event [13].

B. Minimum Inter-Event Time (MIT)

Rainfall events are part of a hydrological cycle which has various possibilities and always changes during times [14][15]. In an observation of hourly rainfall data, a simple rainfall event is defined by time of start and time of ended. In some case, we can notice that there is rainfall events occurs separated by a lag time in between those events. The lag time between those rainfall events is known as the minimum inter-event time (MIT) which is then used as a characteristic of rain events in an area. Shamsudin *et.al.* [16] conducted a study on the rainfall events at the Larkin observation station in Johor Malaysia. Research using the MIT method was carried out on rainfall events duration 2, 4, 6, 9, 12.18 and 24 hours to show their effects on statistical parameters.

Svoboda *et.al.* [7] used MIT for 6 hours in the Czech Republic, Central Europe to analyze the characteristics of rainfalls in mountainous regions with altitudes of 500 to 1200 msl. The MIT value of 6 hours was chosen by considering the erosive force of rainfall in the USLE equation, 1978.

Gaal *et.al.* [17] In determining heavy rainfall events, we need to investigate inside the rainfall events; if there is peak intensity occurs during 10 minutes' rainfall duration can be considered as heavy rainfall. In this The research was conducted in Switzerland, with MIT value of 2 hours.

Carbone *et.al.* [18] conducted research on the Liguori watershed, covering 414 Ha in southern Italy. This study is intended to find the optimum MIT value in urban areas, with characteristics of rainfall duration of less than 1 hour. The results of this study conclude that for urban drainage system planning, the optimum MIT value obtained is 5-15 minutes. The choice of MIT values also considers the characteristics of rainfall; depth rainfall and average rainfall.

C. Rainfall Distribution Patterns (RDP)

In observing the RDP on the Java island, the uniform RDP was almost not found. The RDP always occurs with characteristic of upward on first hour then downward at the seconds hour [19] [14] states, nowadays the current RDP in Indonesia uses a rainfall duration of 2 to 4 hours, in contrast to the previous RDP, which is has rainfall duration of 5-7 hours. An empirical approach to build RDP for ungauged area, this method can be used such as the Uniform RDP, Triangle RDP, Alternating Block Method, Tadashi Tanimoto and Mononobe [20].

D. Data Use

The research location is in Special Region of Yogyakarta in Indonesia with coordinates: 7°47′S and 110°22′E. The Special Region of Yogyakarta is located in southern part of Java with Indian Ocean at the south side and Merapi Mount at the north side. Merapi Mount is the most active volcano in Indonesia and has erupted regularly since 1548. The point rainfall data is provided from the Faculty of Civil Engineering, Gadjah Mada University Yogyakarta and Balai Besar Wilayah Sungai Serayu Opak Ministry of Public Work and Housing. Rainfall data form each rainfall station has been tested through data reliability. Some of the initial tests carried out include the Consistency Test, Trend Absence Test, Stationary Test, Persistence Test and Outliers Test. Table- I. present the rainfall stations and events.

Table- I. Rainfall stations and events

No	Rainfall station	Elevation m.s.l	Observation adta	Rainfall events
1	Sta CH Tepus	15	2010-2016	1386
2	Sta CH Pundong	27	2010-2016	1467
3	Sta CH Siluk	30	2010-2016	1949
4	sta CH Gembongan	50	2010-2016	1853
5	Sta CH Lembah UGM	130	2013-2018	1802
6	Sta CH Kalibawang	150	2010-2016	1733
7	Sta CH Beran	208	2010-2016	2053
8	Sta CH Angin-angin	320	2010-2016	2126
9	Sta CH Kemput	575	2010-2016	1708
10	Sta CH Prumpung	575	2010-2016	1628
11	Sta CH BE D4	590	2013-2018	3631
12	Sta CH Kaliadem	925	2015-2018	1331
13	Sta CH Ketep	985	2013-2018	1658

The location of point rainfall observations can be seen in the Fig. 1.

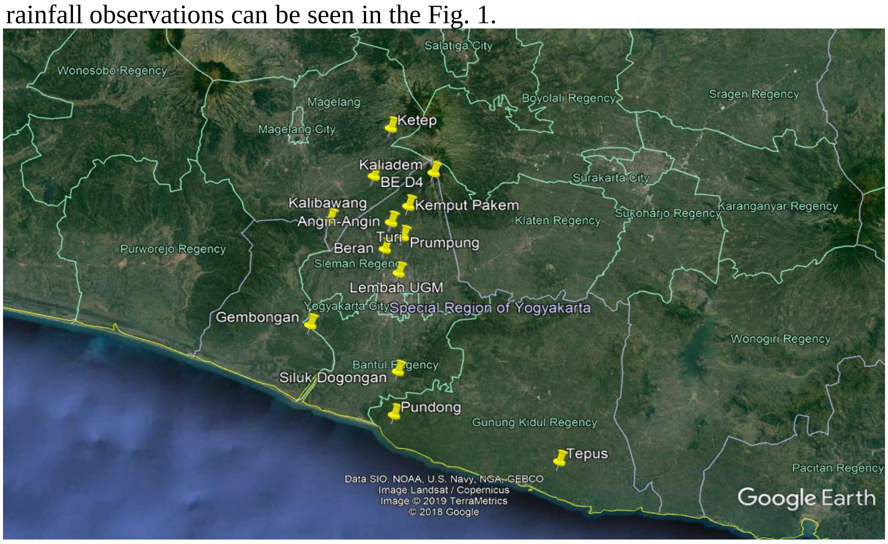

Fig.1. Location of point rainfall

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III. RESULTS AND DISCUSSION

Based on the observation of point rainfall at each rainfall station in Java, rainfall events duration of 1 and 2 hours are the dominant rainfall events. The percentage of rainfall events with duration of 1 and 2 hours is almost 70%, with the RDP upward in the first hour and subsequent hours climb down. It is proving the research of [14] which mentions the current average rainfall events duration in Indonesia.

The hourly rainfall data was recorded during 24 hours with observation time starting at 00 until 24 or at 07 am to 07 am on the next day. Several factors occurred in recording hourly rainfall data such as rainfall events are not recorded, the malfunctioning of the time piece is still ignored. Inconsistency of rainfall recording devices can still be found in some recording data. This deficiency factor is neglected by assuming that if there is no recording data, then it is assumed that there is no rain event. We noticed on hourly rainfall data, rainfall events with duration of 1 or 2 hours, are not always fully rainfall along its duration. Rainfall event may occur at the beginning of first observation hour then recorded in the range of its hours. If the rainfall event occurs at the end of the first hours, then continues to the second hour even though the rain duration is not fully 2 hours it will be recorded as a 2-hour rainfall event. This is made by the rainfall recording device which has accumulated in hourly duration. Furthermore, these rainfall event duration 1-2 hours sometimes is ignored on watershed modelling.

To find out the occurrence of Rainfall Distribution Patterns (RDP) in duration of less than 2 hours, a rainfall recorder with a recording interval of less than 1 hour is needed. Based on the observation of point rainfall in hilly and mountainous region of Merapi Mount, four number of automatic rainfall recorder data (Lembah, Ketep, Kaliadem and BE-D4) will proving the RDP below 2 hours duration. Those station are observing high resolution of rainfall data in 5 minutes' intervals. Based on Carbon *et.al.* [18] research, the optimum MIT value for the drainage system planning is 5-15 minutes, then all rainfall events from 4 stations are investigated. The rainfall events in the observation area, is inseparable from the time lag between the rainfalls. So if there is more than one rainfall event, with a MIT between 5-15 minutes, then the rainfalls event can be merged into one rainfall event. To determine that the rainfall event is categorize as a heavy rainfall event, khalig in Nuryanto *et.al.* [12] method is used. If the rainfall intensity is greater or equal to 0.5mm / minute or 10 mm / hour, then the rainfall event is categorized as a heavy rainfall event. Furthermore, the rainfall events are sorted and grouped according to the rainfall duration.

Based on simulation from 4 automatic rainfall recorder stations, it is observed the occurrence of heavy rain with the duration of 2 hours, obtained 15 minutes' pattern as in the Table- II.

Table- II. The occurrence of heavy rain with the duration of 2 hours, obtained 15 minutes' patterns

Rainfall Station	Elevation msl	Minutes							
		15	30	45	60	75	90	105	120
lembah	150	14,48%	18,03%	16,67%	17,76%	12,84%	11,20%	6,28%	2,73%
Ketep	985	12,80%	17,47%	11,57%	32,56%	12,31%	8,61%	2,95%	1,72%
Kaliadem	925	13,23%	18,93%	27,03%	14,34%	8,64%	7,17%	7,17%	3,49%
BED4	590	17,72%	12,35%	15,44%	16,38%	16,78%	12,21%	6,44%	2,68%
Average		14,56%	16,70%	17,68%	20,26%	12,64%	9,80%	5,71%	2,66%

The average RDP for Yogyakarta is define as 14,56%; 16,70%; 17,68%; 20,26%; 12,64%; 9,80%; 5,71% and 2,66%. If we accumulated into hourly RDP will be 69,19 % and 30,81%. Fig. 2 presents the 2 hours rainfall distribution pattern

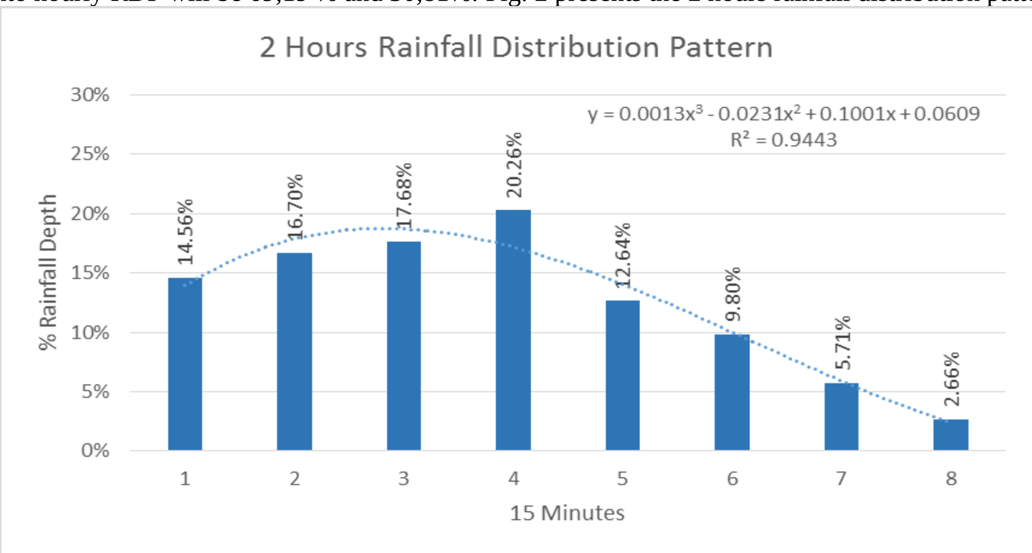

Fig. 2. Two hours distribution pattern

Then an RDP simulation is used in 9 hourly rainfall station surrounding Yogyakarta to prove its reliability. Data of rainfall events duration of 2 hours at all hourly rainfall observation stations in Yogyakarta and surrounding areas were carried out using a RDP of 69.19% and 30.81% compared to the RDP made from Modified Mononobe equation. The RDP made by Modified Mononobe equation was well performance rather others method [19]. Nash-Sutcliffe Efficiency (NSE) Test, Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) are used in this model accuracy testing. The results showed that RMSE and MAE values of RDP simulation are smaller than the RDP of Modified Mononobe equation. The NSE value of RDP simulation are closer to value of 1 rather than RDP of Modified Mononobe equation. The RDP simulation is proving good performance on the elevation in hilly and mountainous areas in the Special Region of Yogyakarta. The RDP for low land needs to be reviewed, because this RDP is built from the data of hilly and mountainous areas. The comparison value on model accuracy testing for RDP simulation and RDP of Modified Mononobe equations can be describe as in the Table- III. Fig. 3 presents the MAE of RDP simulation and RDP modified Mononobe.

Table- III. RDP simulation and RDP pf modified Mononobe

No	Rainfall Station	Elevation msl	RDP Simulation						Modified Mononobe Equation					
			RMSE		MAE		NSE		RMSE		MAE		NSE	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	Tepus	15	1,42	1,42	6,79	6,79	0,35	0,67	1,63	1,63	7,28	7,28	0,14	0,56
2	Pundong	27	1,91	3,52	6,75	6,75	0,39	-0,05	2,31	4,04	7,21	7,21	0,11	-0,38
3	Siluk	30	1,27	1,27	6,45	6,45	-1,26	0,67	1,48	1,48	6,78	6,78	-2,10	0,54
4	Gembongan	50	1,16	1,16	5,34	5,34	0,49	0,28	1,27	1,27	5,28	5,28	0,40	0,15
5	Kalibawang	150	1,28	1,28	7,22	7,22	0,58	0,65	1,42	1,42	7,21	7,21	0,48	0,57
6	Beran	208	1,07	1,07	6,87	6,87	0,41	0,71	1,23	1,23	7,35	7,35	0,21	0,61
7	Angin Angin	320	1,16	1,16	6,36	6,36	0,45	0,63	1,25	1,25	6,00	6,00	0,36	0,57
8	Kemput	575	1,40	1,40	8,70	8,70	0,49	0,33	1,75	1,71	10,47	10,47	0,25	0,06
9	Prumpung	575	1,39	1,39	8,97	8,97	-0,14	0,68	1,65	1,65	10,20	10,20	-0,62	0,55

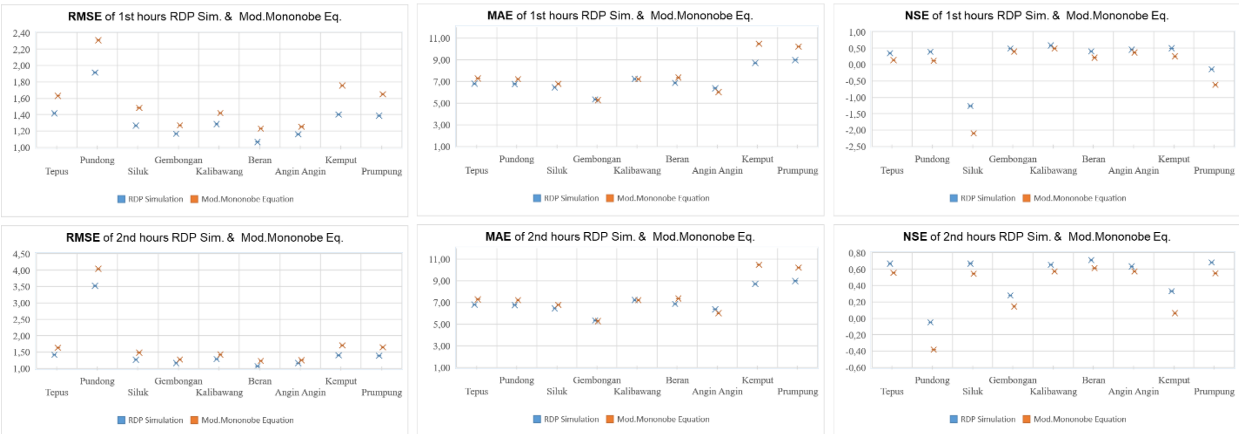

Fig. 3. MAE of RDP simulation and RDP modified Mononobe

IV. CONCLUSION

This rainfall observation data is a response to our curiosity for the rainfall distribution pattern with duration of 2 hours. The average RDP for Yogyakarta is define as 14,56%; 16,70%; 17,68%; 20,26%; 12,64%; 9,80%; 5,71% and 2,66%. Or at hourly RDP will be define as 69,19 % and 30,81%.

The rainfall distribution pattern in 15 minutes' interval is intended to mitigate disasters related to the destructive force of the water, to find out when the peak time of heavy rainfall occurs. The rainfall distribution patterns is vary greatly according to place and location, so high resolution automatic rainfall recorder need to be installed in places that need more protection.

Observation data of heavy rainfall generated by ARR for duration of occurrence of more than 3 hours has a minimal population of events. If there are observations of heavy rain events over 3 hours, it can answer the curiosity of the detailed patterns of rain events.

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