The Effect of The Length of Rainfall Data to IDF Curve

By Dwi Jokowinarno

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ABSTRACT

IDF Curve is significant for determining the rainfall intensity of design rainfall in calculating design flood which is crucial in designing hydrologic structures. The intensity of design rainfall is determined by rainfall data used. This study aims to analyse the effect of the length of rainfall data on IDF curve. This is done by comparing IDF curve developed from the entire rainfall data set to some part of rainfall data set. This study used rainfall data collected from automatic rainfall recorder from Station BMG Radin Inten II and from geophysics station Kotabumi. Rainfall data from Station BMG Radin Inten II is grouped into several data sets with data lengths of 4, 6, 8 and 10 years. While rainfall data from station Kotabumi is also grouped into several data sets with data lengths of 5, 7, 9, 11 and 13 years. All the data sets were analysed to determine the IDF curve for return periods of 2, 5, 10, 25, 50 and 100 years. This study shows that rainfall inensities of design rainfalls as expressed in IDF curves from station BMG Radin Inten II are higher compared to those from geophysics station of Kotabumi. In addition, IDF curve developed using longer rainfall data tends to be more stable dan reflects more possible rainfall events.

Keywords: rainfall intensity, IDF curve, length of data

1. INTRODUCTION

Sufficiently long time series of rainfall data is required for designing hydraulic structures. First rainfall data is analysed to define designed rainfall and then it is transformed into designed runoff which determine the dimension of hydraulic structures. Therefore rainfall data is significant for hydaulic structure design. Rainfall intensity designs for various rainfall durations and return periods are set in IDF (Intensity – Duration – Frequency) curve. IDF analysis is conducted to estimate peak discharge in small catchment area, such as for urban drainage system, curverts and bridges (Triatmodjo, 2008). IDF curve used as the design basis affects the reliability of hydraulic structures built. If the IDF curve does not represent the actual condition, then the resulted hydraulic structure becomes ineffective or inefficient.

The quality of the rainfall data largely determines the result of IDF curve analysis. The availability of time series rainfall data or data length plays an important role too. Different length of rainfall data impacts on different rainfall designs for the same return period. The shorter the data length the greater the deviation (Harto, 1993). According to Aslan (1997) time series of rainfall data required for urban drainage design is 10 years at minimal.

IDF analysis conducted in this research used rainfall data collected from automatic rainfall station in Lampung Province. There are four automatic rainfall stations in Lampung Province, i.e. BMG Maritim Panjang station, BMG Radin Inten station, Kotabumi geophysics station and Masgar climatology station. Of the four stations used in this study are rain data from BMG Radin Inten II station and Kotabumi geophysics station. BMG Radin Inten II station is located in Radin Inten II airport area in South Lampung, while BMG Kotabumi is located in North Lampung. The selection of the two rain stations due to their location is far apart and based on the results of the preliminary analysis shows the mean annual rainfall significantly.

Researches on IDF have been done widely which generally can be categorized into two major methods, using empirical equation to derive daily rainfall data into small rainfall duration and using small duration of rainfall data to determine rainfall intensity. Susilowati and Kusumastuti (2010) in their research for the calculation of rain intensity used van Breen method with Talbot equation as reference to form IDF curve. Some other researches which used empirical method for deriving small rainfall durations include Alfieri *et al*. (2008). Rashid et al. (2012), Russel and Hossain (2015), Fauziyah et al. (2013), Yulius (2014) and Handayani (2007). On the other hand, some researches which used small duration recorded rainfall data to develop IDF curve were done by Kusumastuti et al. (2016), Adam and Howard (2013) and Moncho et al. (2009). In those studies recorded rainfall data at small durations are directly converted to rainfall intensity. In the conversion from rainfall depth (P) to rainfall intensity (I) used the relation I = 60 P/t (Triatmodjo, 2008).

The intensity of extreme rainfall for various return period presented in the IDF curve, was calculated using frequency analysis. This analysis aims to determine the relationship between the magnitude of extreme events to the frequency of events by using the probability distribution. The rainfall data used for the frequency analysis is selected from the complete series of records for several years. Data selection can use either partial duration series or annual maximum series. Partial duration series is a series of rainfall data that is greater than a certain lower limit value, so that in one year it is possible to have more than one data used for analysis. On the other hand, the annual maximum series uses only one maximum rainfall data for each year.

In the field of hydrology There are several probability distribution functions used in frequency analysis, such as normal distribution, log normal, Gumbel and Log Pearson III (Triatmodjo, 2008). Normal distribution is symmetrical to the vertical axis and bell-shaped. A normal log distribution is used if the value of the random variable does not match the normal distribution, but the logarithm value corresponds to the normal distribution. Gumbel distribution or often called probability distribution of the extreems suitable for maximum data analysis. The Log Pearson III distribution is used if the statistical parameters Cs and Ck have values other than the statistical parameters for other distributions (normal, normal logs and Gumbel distributions).

2. METHOD

The data required in this research are rainfall data used in this study is taken from the Hellman type automatic rain gauge at the following two stations (a) Kotabumi Geophysical Station from 1998 to 2011, with a data length of 13 years because the data in 2006 did not exist; and (b) BMG Radin Inten II Station from 2001 to 2014, with a data length of 14 years. Rainfall data used is short-term rainfall data with duration of 5, 10, 15, 30, 45, 60, 120 minutes, 3 hours, 6 hours, and 12 hours.

The procedure of this study includes :

1. Grouping rainfall data from BMG Radin Inten into 6 sets of data length, i.e. 4 years (2001-2004), 6 years (2001-2006), 8 years (2001-2008), 10 years (2001-2010), 12 years (2001-2012) and 14 years (2001-2014), and rainfall data from Kotabumi Geophysical Station into 5 sets of data length ie 5 years (1998-2002), 7 years (1998-2004), 9 years (1998-2006) , 11 years (1998-2009) and 13 years (1998-2011).
2. Conducting a frequency analysis to determine rainfall depth for each duration with return period of 2 years, 5 years, 10 years, 25 years, 50 years and 100 years.
3. Determining the rain intensity value for each duration and return period.
4. Drawing intensity duration frequency curve (IDF) for 2, 5, 10, 25, 50 and 100 years of return periods for each data set according to the length of the rainfall data
5. Comparing IDF curves generated from each set of data lengths with the longest data length in the same station to determine the effect of data length on IDF curve.

3. RESULT AND DISCUSSION

The maximum rainfall depth per year with various durations for BMG Radin Inten and Kotabumi Geophysics stations are presented in Table 1 and Table 2.

Table 1. The maximum rainfall depth for each duration on BMG Radin Inten II 2001-2014

Years	Rainfall Depth for Each Duration (in millimeters)									
	5 min	10 min	15 min	30 min	45 min	60 min	120 min	3 hr	6 hr	12 hr
2014	10.0	20.0	26.0	36.0	40.0	50.0	80.0	80.0	80.0	101.0
2013	10.0	18.0	26.0	45.0	50.0	56.0	87.0	90.0	115.0	160.0
2012	10.0	26.0	30.0	52.0	66.0	76.0	120.0	90.0	115.0	160.0
2011	11.6	26.8	40.7	59.4	64.5	73.0	90.6	94.6	98.5	99.1
2010	19.0	30.0	42.0	63.0	85.0	90.0	116.0	119.0	119.1	119.1
2009	15.0	25.0	35.0	40.0	48.0	72.0	74.0	74.8	74.8	81.0
2008	10.0	20.0	42.2	52.5	54.2	64.0	70.6	70.6	72.6	72.6
2007	15.0	27.0	30.0	44.0	58.5	83.0	103.0	107.0	113.0	113.0
2006	48.4	68.4	72.4	84.2	90.6	100.4	101.6	101.6	101.6	101.6
2005	12.0	22.0	29.0	37.7	40.0	40.0	51.3	60.0	76.0	76.0
2004	16.0	30.0	38.0	53.5	58.8	67.3	77.1	79.8	84.8	85.0
2003	15.0	27.0	37.0	50.5	57.4	58.6	68.0	68.0	68.0	68.0
2002	50.0	55.0	60.0	60.0	85.0	90.0	109.7	109.7	109.7	109.7
2001	30.0	30.0	36.4	42.3	49.8	57.0	66.4	69.4	71.4	71.6

Table 2. Maximum rainfall depth for each duration at Kotabumi Geophysics Station 1998-2011

Years	Rainfall Depth for Each Duration (in millimeters)									
	5 min	10 min	15 min	30 min	45 min	60 min	120 min	3 hr	6 hr	12 hr
2011	8.0	10.0	15.0	54.3	55.6	72.0	72.0	72.0	144.7	145.9
2010	5.0	10.0	16.0	40.0	45.0	49.0	72.0	80.5	85.8	86.0
2009	4.0	10.0	14.0	23.0	50.0	63.7	69.2	69.2	78.5	78.5
2008	5.3	14.0	20.0	40.0	40.0	50.0	90.0	93.8	106.0	110.2
2007	8.5	10.0	20.0	36.0	45.0	65.0	71.8	74.6	80.0	81.2
2005	10.0	20.0	30.0	60.0	75.0	85.0	85.7	86.0	86.0	102.5
2004	5.5	10.0	15.0	40.0	47.4	53.0	68.2	68.2	97.7	98.5
2003	5.2	9.5	14.5	30.0	50.0	50.5	51.5	58.0	73.5	117.0
2002	8.6	16.5	25.0	46.5	62.0	64.0	74.5	78.5	78.6	104.8
2001	4.0	11.0	19.0	36.0	43.5	53.2	81.8	82.8	83.4	83.4
2000	3.0	10.0	20.4	32.0	42.2	49.0	59.8	59.8	59.8	59.8
1999	5.0	10.0	13.5	31.0	52.0	66.2	100.0	100.0	100.0	127.2
1998	5.0	13.0	18.0	38.6	56.0	62.0	103.9	109.4	112.8	114.1

The maximum rainfall depth for each year with various durations is converted into rainfall intensity. Table 3 and Table 4 presents the maximum rainfall intensity for each duration for BMG Radin Inten II and Kotabumi Geophysical Station respectively. Rainfall intensities for low durations in BMG Radin Inten II station are higher than rainfall intensities given the same durations recorded in Kotabumi geophysical station. The highest rainfall intensity for 5 minutes duration at BMG Radin Inten II station reaches 5 times of the highest rainfall intensity in the same duration at Kotabumi Geophysics Station. The different intensity of the rainfall decreases as rainfall duration increases.

Table 3. The maximum rainfall intensity of each duration on BMG Radin Inten II 2001-2014

Years	Rainfall Intensity for Each Duration (in millimeters)									
	5 min	10 min	15 min	30 min	45 min	60 min	120 min	3 hr	6 hr	12 hr
2014	120.0	120.0	104.0	72.0	53.3	50.0	40.0	26.7	13.3	8.4
2013	120.0	108.0	104.0	90.0	66.7	56.0	43.5	30.0	19.2	13.3
2012	120.0	156.0	120.0	104.0	88.0	76.0	60.0	30.0	19.2	13.3
2011	139.2	160.8	162.8	118.8	86.0	73.0	45.3	31.5	16.4	8.3
2010	228.0	180.0	168.0	126.0	113.3	90.0	58.0	39.7	19.9	9.9
2009	180.0	150.0	140.0	80.0	64.0	72.0	37.0	24.9	12.5	6.8
2008	120.0	120.0	168.8	105.0	72.3	64.0	35.3	23.5	12.1	6.1
2007	180.0	162.0	120.0	88.0	78.0	83.0	51.5	35.7	18.8	9.4
2006	580.8	410.4	289.6	168.4	120.8	100.4	50.8	33.9	16.9	8.5
2005	144.0	132.0	116.0	75.4	53.3	40.0	25.7	20.0	12.7	6.3
2004	192.0	180.0	152.0	107.0	78.4	67.3	38.6	26.6	14.1	7.1
2003	180.0	162.0	148.0	101.0	76.5	58.6	34.0	22.7	11.3	5.7
2002	600.0	330.0	240.0	120.0	113.3	90.0	54.9	36.6	18.3	9.1
2001	360.0	180.0	145.6	84.6	66.3	57.0	33.2	23.1	11.9	6.0

Table 4. The maximum rainfall intensity of each duration at Kotabumi Geophysical Station 1998-2011

Years	Rainfall Intensity for Each Duration (in millimeters)									
	5 min	10 min	15 min	30 min	45 min	60 min	120 min	3 hr	6 hr	12 hr
2011	96.0	60.0	60.0	108.6	74.1	72.0	36.0	24.0	24.1	12.2
2010	60.0	60.0	64.0	80.0	60.0	49.0	36.0	26.8	14.3	7.2
2009	48.0	60.0	56.0	46.0	66.7	63.7	34.6	23.1	13.1	6.5
2008	63.6	84.0	80.0	80.0	53.3	50.0	45.0	31.3	17.7	9.2
2007	102.0	60.0	80.0	72.0	60.0	65.0	35.9	24.9	13.3	6.8
2005	120.0	120.0	120.0	120.0	100.0	85.0	42.9	28.7	14.3	8.5
2004	66.0	60.0	60.0	80.0	63.2	53.0	34.1	22.7	16.3	8.2
2003	62.4	57.0	58.0	60.0	66.7	50.5	25.8	19.3	12.3	9.8
2002	103.2	99.0	100.0	93.0	82.7	64.0	37.3	26.2	13.1	8.7
2001	48.0	66.0	76.0	72.0	58.0	53.2	40.9	27.6	13.9	7.0
2000	36.0	60.0	81.6	64.0	56.3	49.0	29.9	19.9	10.0	5.0
1999	60.0	60.0	54.0	62.0	69.3	66.2	50.0	33.3	16.7	10.6
1998	60.0	78.0	72.0	77.2	74.7	62.0	52.0	36.5	18.8	9.5

The maximum annual rainfall intensity data for various durations was analyzed using frequency analysis method. From the calculation it was found that data distribution was in accordance with Log Pearson Type III distribution. Based on the equation for Log Pearson Type III distribution, rainfall intensity for some return periods (2, 5, 10, 25, 50 and 100 years) were calculated and the curve which relates rainfall intensity and duration for various return periods were determined. Regression analysis was done to define the equation which represent data distribution for the IDF curve.

Rainfall intensity data at BMG Radin Inten station significantly higher than Kotabumi Geophysics Station (Table 3 and Table 4) has the consequence that the rain intensity from IDF curves for the same duration and return period is higher than that from BMG Radin Inten station.

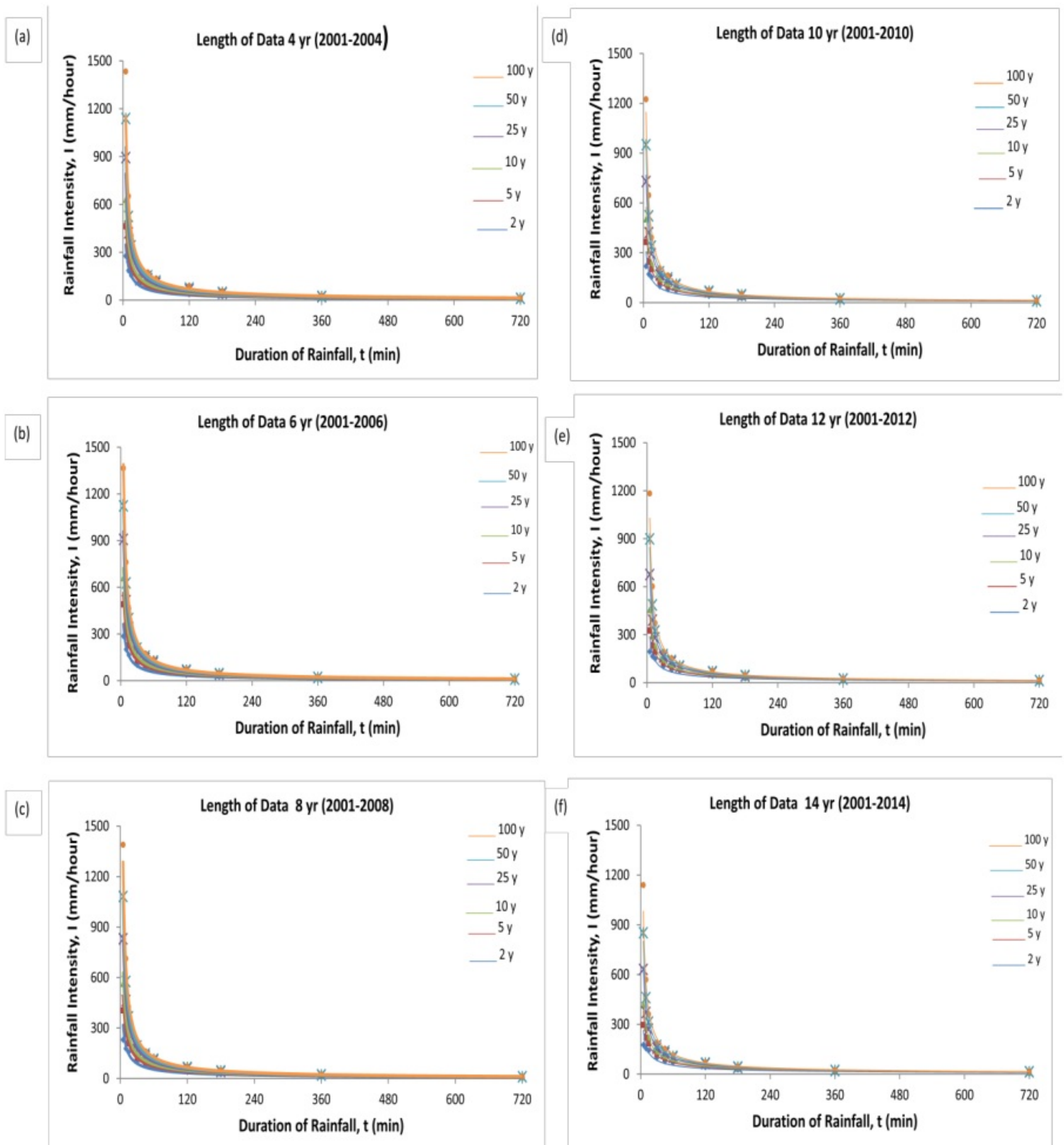

Figure 1. IDF curves for BMG Radin Inten II station using data length (a) 4 years (2001-2004), (b) 6 years (2001-2006), (c) 8 years (2001-2008), (d) 10 years (2001-2010), (e) 12 years (2001-2012) and (f) 14 years (2001-2014)

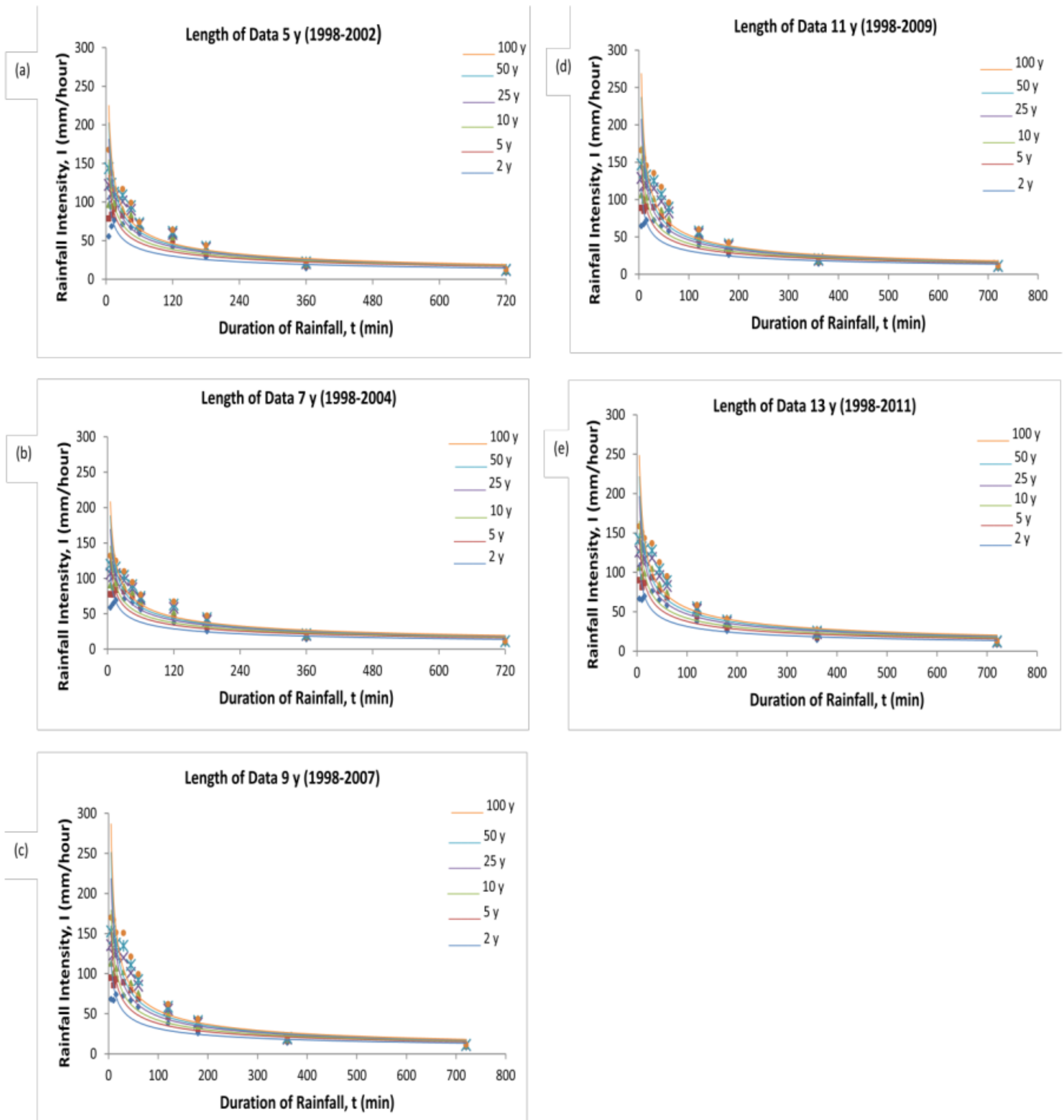

Figure 2. IDF curve for Kotabumi geophysical station using data length (a) 5 years (1998-2002), (b) 7 years (1998-2004), (c) 9 years (1998-2006), (d) 11 years (1998-2008) and (e) 13 years (1998-2001).

The effect of data length on the IDF curve is done by calculating the percentage of differences of rain intensity values resulted from regression analysis for the same duration and return period for a certain length of data data length compared to the longest data set on the station. For BMG Radin Inten II station the longest data set is 14 years of data, while other data sets have data length of 4, 6, 8, 10 and 12 years. The mean percentage of each data set compared to the longest data set for BMG Radin Inten II station is shown in Figure 3. It shows that for long data sets, i.e. 10 and 12 years, the differences of rainfall intensities from those data sets compared to those in the longest data set are small. Data set with 8 years data length indicates consistency of increasing values as return period increases, while data sets with data length less than 8 years do not show consistency of difference of rain intensity to return period.

The same trend is shown in the percentage of rainfall intensity difference of each data set compared to the longest data set on the Kotabumi geophysical station as shown in Figure 4. On the long data set, which is 9 and 11 years, shows the consistency of increasing difference of rainfall intensity values as return period increases. On data sets shorter than 9 years, there is no such consistency.

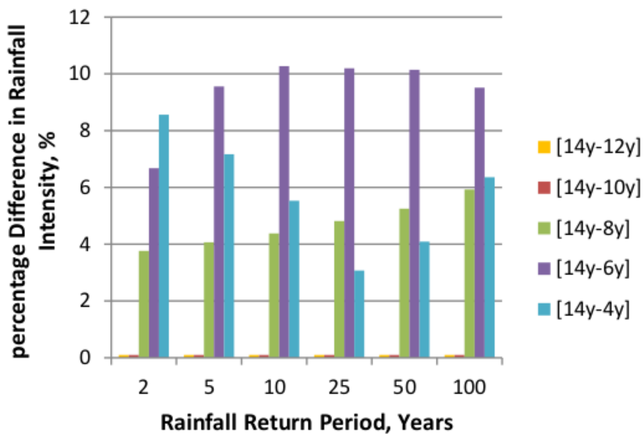

Figure 3. Percentage of mean difference of rainfall intensity and its return period for each data length BMG of Radin Inten II

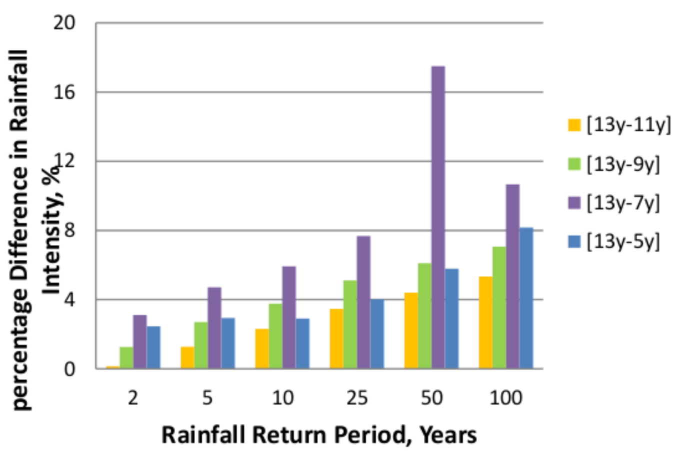

Figure 4. Percentage of mean difference of rain intensity and its return period for each length of Kotabumi Geophysics Station data

4. CONCLUSIONS

The IDF curves generated from analysing rainfall data from BMG Radin Inten II station and Kotabumi geophysical station show that the length of the data influences the IDF curve. The intensity of rainfall on IDF curves resulting from relatively long data tends to be more stable, as it reflects various possible rain events.

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