THE DEVELOPMENT OF INTENSITY-DURATION-FREQUENCY CURVES FOR PAHANG

NUR ASMA' BINTI SUHAIMEE

Report submitted in partial fulfilment of requirements
for the award of the degree of
B. Eng. (Hons) Civil Engineering

Faculty of Civil Engineering & Earth Resources
UNIVERSITI MALAYSIA PAHANG

JUNE 2015

ABSTRACT

In past few years, Pahang was experienced flooding in certain area and it getting worse by year with heavy rainfall especially at low level area cause of clog drain, design failing, wrong estimation and other natural causes. IDF curve use to design rainfall data by estimate peak discharge from IDF curve for engineering design such drainage, flood elevation, and other hydraulic design. This study purpose to develop intensity-duration-frequency (IDF) curve for all 12 district in Pahang based on this past year data and compare it with Log-Person Type III method than Gumbel method that use in Urban Storm Water Management (MSMA) to compare the differences value of IDF curve using both method. IDF curve requires rainfall data from the Department of Irrigation and Drainage (DID) for period of 5 minutes to 72 hour starting on year 1990 to year 2014. To designing IDF curve, process involved are find the missing data from nearest station, mean, standard deviation, frequency factor, and intensity value for 2, 5, 10 ,20, 50 and 100 years return period for both methods Gumbel and Log-Pearson Type III. Both methods, Gumbel and Log-Pearson Type III is compared to see the different value given by both methods. To test the accuracy of both methods, Komogorov Smirnov (KS) was constructed for fitting distribution. Based on the result, Gumbel method give clear trend than Log-Pearson Type III with 26.92% test accepted from 78 tests while Log-Pearson Type III almost all test was rejected.

ABSTRAK

Dalam tahun-tahun kebelakangan ini, Pahang telah mengalami banjir di kawasan tertentu dan ia semakin teruk setiap tahun dengan hujan lebat terutama di kawasan rendah menyebabkan tahap longkang tersumbat, reka bentuk gagal, anggaran yang salah dan lain-lain sebab-sebab semula jadi. IDF menggunakan keluk untuk mereka bentuk data hujan dengan anggaran pelepasan puncak dari lengkung IDF untuk reka bentuk kejuruteraan saliran, ketinggian banjir, dan reka bentuk hidraulik lain. Tujuan kajian ini adalah membangunkan keamatan-tempoh-frekuensi (IDF) lengkung untuk semua 12 daerah di Pahang ini berdasarkan data tahun-tahun lepas dan membandingkannya dengan kaedah Log-Pearson Jenis III dengan kaedah Gumbel yang digunakan oleh Pengurusan Air Ribut Bandar (MSMA) dengan membandingkan nilai perbezaan lengkung IDF menggunakan kedua-dua kaedah tersebut. Lengkung IDF memerlukan data hujan daripada Jabatan Pengairan dan Saliran (JPS) untuk tempoh 5 minit hingga 72 jam bermula pada tahun 1990 hingga tahun 2014. Untuk mereka bentuk lengkung IDF, proses yang terlibat adalah mencari data yang hilang dari stesen terdekat, min, standard penyimpangan, faktor kekerapan dan nilai keamatan untuk 2, 5, 10, 20, 50 dan 100 tahun kembali tempoh untuk kedua-dua kaedah Gumbel dan Log Pearson Jenis III. Kedua-dua kaedah, Gumbel dan Log-Pearson Type III dibandingkan dengan melihat nilai yang berbeza yang diberikan oleh kedua-dua kaedah. Untuk menguji ketepatan kedua-dua kaedah, Komogorov Smirnov (KS) telah dibina untuk diagihkan sesuai. Berdasarkan keputusan, kaedah Gumbel memberikan trend jelas daripada Log-Pearson Type III dengan ujian 26,92% diterima daripada 78 ujian manakala Log-Pearson jenis III hampir semua ujian telah ditolak.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOL

P_i	The rainfall at neighbor stations
N_x	Annual rainfall at missing data station
N_i	Annual rainfall at neighbor station
n	The number neighbor station whose data are used
P_x	The missing precipitation
P_n	The precipitation value at n station
σ	Standard Deviation
μ	Mean
X_i	The variate i.e record used in the computation
N	The total number of record
$\bar{x}_i$	Mean of the sample
α_z	The scale
λ_z	Shape parameters of the gamma distribution
P_T	The frequency precipitation
K	Gumbel frequency
S	Standard deviation of P value
P_{ave}	The average of the maximum precipitation in a specific duration
T_d	Duration in hours
$P*_T$	The frequency precipitation
$S*$	Standard deviation of $P*$ value
K_T	The Pearson frequency factor which depends on return period (T) and skewness coefficient (Cs).
v	Degree of freedom

s	Number of parameter using fitting distribution
A^2	Anderson-Darling statistic
$F_n(x_{(i)})$	Empirical Distribution (PDF)
$x_{(i)}$	The ordered data
T	Return period (years)

LIST OF ABBREVIATION

MSMA	Manual Saliran Mesra Alam
CDF	Cumulative Density Function
PDF	Probability Density Function
KS	Kolmogorov-Smirnov Test
LP3	Log-Pearson Type III
LN	Log-Normal
IDF	Intensity-Duration-Frequency

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Malaysia is one of the countries located at Southeast Asia, near the equator which is humid and hot all the year. The location of Malaysia at equator zone gives Malaysia experience tropical climate with two type of monsoon season which are the northeast and southwest through the year. Northeast occur during November to May bring moisture and more rainfall. Where southwest give wind blowing monsoon within May to September. These results give average rainfall in Malaysia in 2500mm with average temperature 27^{o}C a year.

Seasonal variation give effect on rainfall pattern depend on geography of Malaysia that surrounded by mountain. This condition give two different climate which is depend on highland and lowland region. As a result, both condition cause temperature raging between 23^{o}C to 32^{o}C through the year with humidity between 75% and 80% and annually receive rainfall between 2000mm to 4000mm with 150 to 200 rainy days.

From this rainfall pattern, the data will be used to construct temporal pattern using rainfall intensity-duration-frequency (IDF) curves. Rainfall intensity –duration-frequency (IDF) should be up to date in line with the changes of rainfall pattern due to global warming effect and temperature changes. Rainfall intensity-duration-frequency (IDF) is one of the most important tools in hydrology and hydraulic design use by engineer in planning, designing, and operate rainwater infrastructure like drainage structure and flood elevation in urban and rural area (Le Minh Nhat,etc,2007). Failing in implant the IDF estimation in design can cause public safety or fund at risk.

Those data from rainfall data was use in frequency analysis method to develop intensity-duration-frequency (IDF) curve. To use this method, local history data was needed to get maximum annual rainfall depth corresponding to various duration. Latest duration data will be taken within period of 5 minutes to 120 hours with different return periods 2, 5, 10, 20, 50 and 100 years. The IDF curve will show the infinite number of rainfall event with different average intensity and duration with same return period. For a specific return period, the average intensity will decrease as the duration increase. As the result, for same duration, the average intensity is higher for longer return periods than the shorter one (Akan et al., 2003).

1.2 PROBLEM STATEMENT

All rainwater design in Malaysia must refer to the Urban Storm Water Management Manual 2nd edition (MSMA 2) to follow standard. Based on observation in MSMA 2, the data of IDF curve for Pahang was updated until 2009. The climate change in Malaysia in storm rainfall intensity may affect the data by change of latest addition data (MSMA, 2012).

To get more accurate analysis, it necessary to estimate reliable rainfall intensity by comparing the IDF curve by using different theoretical distribution function in developing rainfall intensity and return period from rainfall data. Method being use for IDF graph in MSMA only Gumbel distribution using data until 2009 and never be compared before. Gumbel may suitable for condition in Malaysia but not been approved until it compared with other method. Beside data given in MSMA is updated to 2009, while until 2014 lot of change happen during that period of time.

New MSMA 2 has covered limited location which provided the parameter for intensity calculation. Average location provided in MSMA is 2 locations for each district while rainfall station for each district average in 10 stations each district. Department Irrigation and Drainage (DID) should provide more location area for value of intensity. For district not covered in MSMA need to use nearest district intensity parameter to calculate intensity for design drainage. That way may affect the value of intensity should be use for that location area and design drainage for that location.

1.3 OBJECTIVES

The objectives of this study are;

i. To calculate missing data for each station.
ii. To develop IDF curve for every district in Pahang.
iii. To compare differences values of IDF curves using Gumbel distribution and Log-Pearson Type III distribution.

1.4 SCOPE OF STUDY

This study was conducted in Pahang area using rainfall data from 1990-2014 to develop IDF curves. The duration of IDF curve from 5, 15, 60, 180, 360, 720, 1440 minutes until 72 hours and the return period including 2, 5, 10, 20, 50 and 100 years. The data collections are from Department of Irrigation and Drainage (DID).

In this study, arithmetic formula was used to find the missing data for each station. The best station was selected based on number of missing data which the lesser missing data, the best station was selected. Few stations were selected to represent each district. To calculate missing data, station within area 100 km radiuses was considered to use in formula arithmetic. To ensure data fit, the Komolgorov Smirnov (KS) was done.

1.5 SIGNIFICANT OF STUDY

All the water rain design in Malaysia use MSMA as reference for engineer to design. Method use in MSMA to determine the intensity of rainfall is Gumbel distribution and never be compared with other method. To test the reliable of this curve to be used as reference, it needs to be compare with other method to see the reliability of the IDF curve in MSMA. By developing new IDF curve can plant awareness to

MSMA user about the changes in MSMA due to the climate change in Malaysia. With this development the risk for damaging hydrology design can be reduced while using MSMA for designing material.

By developing new IDF curve, new location for new IDF curve was developed and it can be used as designing material based on value of intensity for that location area. Limited location for IDF curve use in MSMA can be covered with new location. Thus nearest design location can refer to new IDF curve in new location to predict intensity value which more reliable than more nearest then provided in MSMA as now.

CHAPTER 2

LITERATURE RIVIEW

2.1 INTRODUCTION

Inadequate hydrologic data and the need for proper planning of water resources development have forced engineer to analyze available data more critically. This is particularly so in developing countries. The Intensity-Duration-Frequency (IDF) relationship is one of the most commonly use basis for water resources planning and development.

Break-point, short duration, rainfall data are not generally available in the historical records at the locations. Generalized accumulated rainfall patterns developed by Department of Irrigation and Drainage (DID) were matched with rainfall data for the locations of study, and the advanced pattern had the best fit with the observed characteristics was used to break down recorded daily totals into shorter duration rainfall data. The method of annual maxima series was used to select data sets for the rainfall analysis.

In the statistical method, the Type I extreme-value distribution (Gumbel) was applied to the annual maximum series for each of stations to estimate the relevant parameters of the IDF model. The non-parametric Kolmogorov-Smimov test and the test were used to confirm the appropriateness of the fitted distributions for the locations.

2.2 INTENSITY-DURATIOM FREQUENCY (IDF) CURVE

Extreme environmental events, such as floods, droughts, rainstorms, and high winds, have severe consequences for human society. Planning for weather-related emergencies, design of engineering structures, reservoir management, pollution control, and insurance risk calculations, all rely on knowledge of the frequency of these extreme events (Hosking and Wallis, 1997). The assessment of extreme precipitation is an important problem in hydrologic risk analysis and design. This is why the evaluation of rainfall extremes, as embodied in the intensity-duration frequency (IDF) relationship, has been a major focus of both theoretical and applied hydrology (Andreas and Veneziano, 2006). Dupont et al. (2000) defined rainfall IDF relationships as graphical representations of the amount of water that falls within a given period of time.

Intensity-Duration-Frequency is representing amount of water rainfall that fall in certain period of time in catchment area. This relationship was done since 1932 and still being constructed for other country but it may not accurately construct in many developing country.

Based on Koutyoyiannis , 2003, the IDF curves is a mathematical relationship between the duration, *d* the rainfall intensity and the return period. This is allow the estimation of return period in rainfall event corresponding to amount of rainfall at given period for different aggregation times. These graphs are used to determine when an area will be flooded, and when a certain rainfall rate or a specific volume of flow will reoccur in the future. Below in Figure 2.1 show example of IDF curve for station at Pulau Pinang.

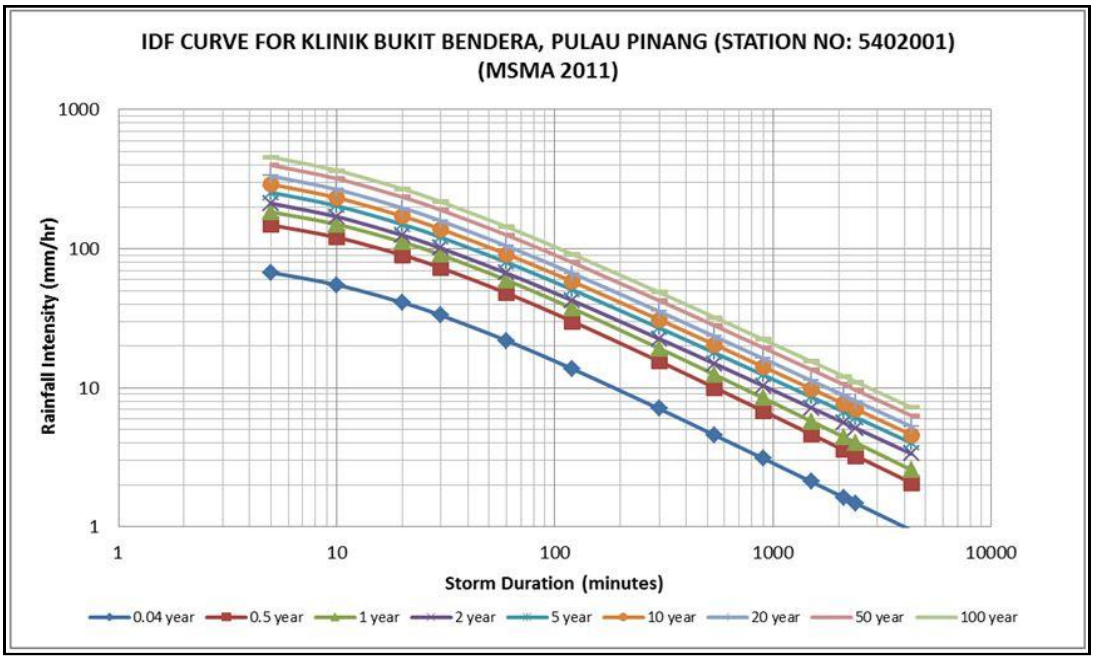

Figure 2.1: IDF curve

Source: MSMA, 2011

According to Brian (2006), rainfall frequency analyses are used extensively in the design of systems to handle storm runoff, including roads, culverts and drainage systems. Smith (1993) states that the "the precipitation frequency analysis problem is to compute the amount of precipitation *y* falling over a given area in a duration of *x* min with a given probability of occurrence in any given year." For engineering design applications, it is necessary to specify the temporal distribution of rainfall for a given frequency, or return interval. According to Stedinger (1993), IDF curves "allow calculation of the average design rainfall intensity [or depth] for a given exceedance probability over a range of durations" and is the result of the rainfall frequency analysis. IDF estimates are important statistical summaries of precipitation records used for hydrologic engineering design (Gerold and Watkins, 2005).

IDF curves received considerable attention in engineering hydrology over the past decades. Approaches based on statistical analysis of data were developed,. Bell (1969) and Chen (1983) derived the IDF formulae for the United States, Baghirathan and Shaw (1978), Gert (1987) and Niemczynowicz (1982) developed IDF formulas for ungauged sites, Sivapalan and Bloeschl (1998) proposed a method of constructing IDF curves based on the spatial correlation structure of rainfall, Koutsoyiannis (1998) proposed a new generalizing approach to the formulation of IDF curves using efficient parameterization.

The first attempts to construct regional IDF curves were made by Dub (1950). ‘Samaj and Valovi‘c (1973) presented a comprehensive IDF study based on 68 stations covering the area of Slovakia using data mostly from the period 11931-1960. Their results were re-evaluated by Urcik'an and Horv'ath (in Urcik'an and Imri‘ska, 1986); however, the analysis mostly concentrated on the different formal presentations of IDF curves. They also proposed a method for the spatial interpolation of IDF curves for sites with no direct observations. These procedures were data and time demanding, therefore it seemed advantageous to develop models which would describe rainfall characteristics through a number of timescales including interpolation or extrapolation at time resolutions that may not have been observed and start from there, IDF curve was widely use in drainage system design.

The IDF curve is commonly use in water resource engineering for designing and operating of water resources project. These methods usually use to estimate runoff during storm, Empirical method, Rational method, Unit-Hydrograph method and Flood frequency studies. To use those methods need to match with the purpose of study and depend to available data use based on importance of the project.

The use of IDF was widely use and being standard practice for many years in designing sewerage system and other hydraulics structure. IDF give idea about frequency and return period for mean and volume rainfall intensity that can be expected in certain period of storm duration. In this situation, storm duration is parameter can be compromise as part of rainfall event. Even now, IDF can provide a lot information for rainfall and can be used as base for determination of design storm (A.S.Wayal, 2014).

2.3 MASS CURVE

During high flows, water flowing in river has to be stored so that a uniform supply of water can be assured, for water resources utilization lake irrigation, water supply, power generation during period of low flow rivers.

A mass curve is graphical representation of cumulative inflow or outflow of water versus time which may be monthly or yearly. A mass curve shown in Fgure 2.2 is example of mass curve. The slope of the mass at any point is a measure of the inflow rate at that time. Mass curve or double mass curve is a commonly used data analysis approach for investigating the behavior of records made of rainfall data at a number of locations. It is used to determine whether there is a need for corrections to the data to account for changes in data collection procedures or other local conditions. Such changes may result from a variety of things including changes in instrumentation, changes in observation procedures, or changes in gauge location or surrounding conditions.

Mass analysis use for checking consistency of a rainfall record is considered to be an essential tool before taking it for analysis purpose. This method is based on the hypothesis that each item of the recorded data of a precipitation consistency (H. M. Raghunath, 2006).