RAINFALL VARIABILITY AND DESIGN STORMS PREDICTION USING BLOCK PEAK METHOD

MASIMIN

UNIVERSITI TEKNOLOGI MALAYSIA

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

NOVEMBER 2008

To my beloved mother Hajjah Siti MASKINAH and
father Haji Sanmurja IBRAHIM

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my thesis supervisor, Associate Professor Dr. Sobri Harun, for encouragement, guidance, critics and friendship. Without his continued support and interest, this thesis would not have been the same as presented here.

I am also indebted to the TPSDP-Project and Syiah Kuala University for funding my Ph.D. study. Librarians at UTM and JPS Ampang Kuala Lumpur also deserve special thanks for their assistance in supplying the relevant literatures and data.

My fellow postgraduate students should also be recognized for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space.

I am grateful to my family members; my wife Zouhrawaty Abdullah Ariff, my daughters Aziza Sri Rezeki – Annisa Sri Sugiarti – Aisha Sri Masputri, and my son Mohammad Arif Sentana for their support and patience.

ABSTRACT

Design storm is essential for the water resources planning and management. It is derived using rainfall data that has great variability in nature. The structure of design storm basically shall contemplate the intensity-duration frequency (IDF) relation and the structure of temporal storm pattern. The primary research aim to explore and investigate the rainfall variability and the stucture of storm pattern. At first, inspection is conducted on the presentation issues of the data extraction, regionalization, spatial data generation and rainfall aggregation. The peak block method is used to improve and to confirm the structure of temporal pattern. The daily and 5-min increment rainfall data from Selangor including Federal Territory and Johor, Malaysia are utilized to perform the analysis. The spatial data for 13 duration patterns is derived by applying kriging method and used in frequency analysis. The *L*-moments parameter diagram is exercised to examine the best fit of data distribution and the probability weighted moments (PWM) is used in the method of analysis. The probable maximum precipitation (PMP) calculation for local used is improved and has remarkable stability to the presence of outliers. It has been identified that the short and long duration patterns are obviously a single storm and multiple storms respectivelly. For particular duration, the same storm paterns are indicated for different return frequencies and the IDF curve developed based on daily data is overvalue about 10% compared to those of increment data. The spatial data analysis is an alternative solution for the ungauged location within homogeneous region. It can also facilitate the IDF curve development in the location with lack of increment data by using daily data. The deviation of result values in storm intensity of the constructed IDF curve for West Coast of Peninsular Malaysia is caused of the differences in data presentation issues.

ABSTRAK

Ribut hujan rekabentuk memainkan peranan dalam perancangan dan pengurusan sumber air. Ianya dibina menggunakan data hujan yang secara semulajadinya memiliki tahap ketidakseragaman yang tinggi. Struktur ribut hujan rekabentuk pada asasnya mesti mengambil kira hubungan keamatan-tempoh-ulangan (IDF) dan struktur corak ribut hujan dengan masa. Kajian ini bertujuan untuk menerokai dan menyelidiki ketidakseragaman hujan dan pola struktur ribut hujan. Ianya meliputi kajian persembahan data yang melibatkan pilihguna data, pembahagian kawasan, penghasilan data ruang dan penjumlahan hujan. Kaedah blok puncak digunakan untuk tujuan membaiki dan mengesahkan struktur pola dengan masa. Kaedah yang dicadangkan untuk diselidiki ini menggunakan data hujan sela harian dan 5-minit untuk kawasan Selangor termasuk Wilayah Persekutuan dan Johor, di Malaysia. Data ruang untuk 13 pola tempoh diterbitkan dengan menggunakan kaedah kriging bagi digunakan dalam kaedah analisis frekuensi. Kaedah rajah parameter momen-*L* dipraktikan untuk mengkaji taburan yang sesuai dan kaedah kebarangkalian momen pemberat (PWM) digunakan dalam kaedah analisis. Kiraan kebarangkalian maksima hujan (PMP) yang dihasilkan untuk kegunaan tempatan bersifat stabil kepada kehadiran ketidakwajaran data. Pola tempoh pendek dan pola tempoh panjang didapati jelasnya menunjukkan masing-masing adalah dari ribut hujan tunggal dan ribut hujan berganda. Untuk suatu tempoh hujan, pola yang sama didapati daripada struktur ribut hujan dengan frekuensi berbeza, dan lengkung IDF yang dibina menggunakan data harian lebih besar nilainya sebanyak 10% daripada lengkung data sela pendek. Analisis data ruang menyediakan jawapan kepada lokasi tanpa tolok dalam kawasan segaya. Ianya memudahkan lengkung IDF menggunakan data harian untuk lokasi yang kurang data sela pendek. Terdapat kesamaan pola yang baik antara keputusan terutamanya lengkung IDF yang dibina untuk Pantai Barat Semenanjung Malaysia dengan wujudnya sedikit selisih dalam nilai keamatan akibat daripada perbezaan dalam persembahan data.

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LIST OF SYMBOLS

A	-	Area
C, c	-	coefficient, constant
D, d	-	distance, depth, constant
F	-	cumulatif probability
H	-	heterogeneity measure
I	-	intensity
K, k	-	frequency factor,
L, l	-	Likelihood
M, m	-	moment, slope, number of rank
N, n	-	number of sample
R, r	-	rainfall, correlation coefficient
s	-	standard deviation
T, t	-	time, duration
u	-	statistical test
x	-	sample
z	-	elevation
α	-	scale parameter
β	-	sample estimate
γ	-	spatial constant
ε	-	error
μ	-	mean
λ	-	weighting value, measure of location
Γ	-	gamma function
σ	-	variance
τ	-	measure of scale

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CHAPTER 1

INTRODUCTION

1.1 General

Design storm is to determine rainfall magnitude and threshold that can be analyzed through the method of frequency base storm (FBS), standard project storm (SPS), or probable maximum precipitation (PMP) (Viessman *et al.*, 1996). Rainfall depth is expressed for different duration pattern taken as long as or longer than its time of concentration, the time that rainfall produces flow from the most remote location to reach the observed site. The threshold refers to the interest of frequency for different probabilities that the choices of them are related to the project types and sizes. The FBS method uses statistical frequency analysis and SPS is based on the most severe rainfall that occurred in the region. The PMP method defines the maximum rainfall depth that would be probable in the region (Guthrie, 2001).

Design storm can be performed through an empirical method, hydrograph technique and system approach method (Sarma, 1973). The empirical method such as rational method can only define the peak of flow rate and hydrograph technique can produce not only the peak of flow rate but also the depth distribution. Watershed conceives as a complex system with rainfall as a main input also with some variability. Rainfall has significant variability in season, time, and space that need to be accommodated in design storm.

The study deals with statistical hydrology by considering rainfall variability and structure of temporal pattern within the design storm. It is developed through the FBS and PMP method. The analysis covers the topic of climate characteristic, data extraction, regionalization analysis, spatial data generation, statistical frequency analysis, PMP calculation and prediction of design storm.

Hydrologists in the daily working life deal with prediction of engineering scenarios solving the problems using standard methods as traditional tools. They become hydrologic engineers with a weak of understanding hydrology. This is because hydrology grows out of engineering and is mainly concerned with prediction. Due to the introduction of nonstationarity into hydrology, the traditional tools of prediction will not longer be valid, so the aid of understanding hydrology as a scientific problem in covering the prediction may be necessary in future hydrology (Dawdy, 2007).

Rainfall prediction for catchment is an engineering problem but in contrast to the study of hydrologic cycle, revealing the relationship between the various forms of water storage and water movement is a scientific problem (Dooge and O'Kane, 2003). Due to climate change that has a significant effect to the hydrologic component, such as the indication of trends for rainfall data, altering the prediction is to be guided by the understanding of world climate process in order to validate the analysis.

Rainfall has great variability in season, space and time. The seasonal variability is to see rainfall characteristics in the tropical monsoon while the data extraction deals with an annual maximum series that is used in hydrology extreme analysis. Rainfall analysis using point data is outdated and using spatial data of homogeneous region should be considered (Adamoswki *et al*., 1996). Statistical frequency analysis is to define parameter and quantile estimates based on statistical distribution and to finalize an intensity-duration frequency (IDF). PMP calculation is intended to get the greatest possible rainfall in the homogeneous region. Prediction of design storms is to perform temporal storm distribution for different duration pattern including for the PMP.

The hydrology analysis can only be conducted if the rainfall data is statistically available. It means that the number of stations and the duration length of record are significant. Daily and 5-minute incremental rainfall data available from Selangor including the Federal Territory and Johor are used in the research. The record length of data varies from 30 – 80 years for the daily data and 25 years for the incremental data. The data analysis uses an Excel Program that is available in the public domain. The choice of two locations is conducted with the consideration that

they are located in the West Coast of Peninsular Malaysia with differences in geographical condition. Selangor including the Federal Territory represents the northern part of the region that facing the Malacca Straits, while Johor as representation on southern region is facing the Malacca Straits and South China Sea.

The structure of temporal storm pattern applied in the prediction of design storm is a block peak method. It is intended to poll the higher values of storm depths or intensities to put in a block. The higher magnitudes of storm is significant in producing higher flow rate that to be treated specifically within design storms. The results of design storm to the Manual (DID, 2000) that using the averaging value based on short increment storm records in the development.

The aim of the study is to propose the design storm by accommodating climate condition through rainfall variability and the structure of temporal storm pattern by applying the block peak method. The results are expected to be used for revision of available standards and to be applied in real fields of engineering especially for civil works.

1.2 Background of Research

In water resources planning and management, it does not just about know the peak flow rate for designing hydraulic structures, but also the value of time to peak and temporal fluctuation of water volume that is needed for planning and managing the system. For those purposes, there are 4 (four) backgrounds of the research:

(1) responding the trends in design storms development to apply system hydrograph approach conducted by the availability of short time incremental data records;
(2) awakening the simplified design storm development with the consideration of rainfall variability as the main parameter input in analysis;
(3) trying to include the local hydrologic characteristics for available hydrologic standard or manually developed based on data out of the country, and
(4) improving the hydrologic analysis with latest development of statistical knowledge.

The Department of Irrigation and Drainage (DID), Malaysia has already published the manual entitled '*Urban Stormwater Management Manual for Malaysia*' in the year of 2000. The standards were typical of latest practice in urban areas in developed countries. Because of differences of seasons and other factors, it would be appropriate to review the standards for application under the Malaysian condition from time to time. The frequency and intensity of rainfall in Malaysia is much higher than in most countries, especially those with temperate zones. Rainfall design methods, which have been developed in other countries, may not always be suitable for Malaysia. The manual based on Hydrologic Procedure HP1-1982 data was limited in time of observation and with few data points and also the interval records were greater than 5 min. After an elapse of more than 20 years since 1982, to have an additional data with shorter interval data record, it is suitable to evaluate the rainfall data input for design storm.

The knowledge of statistical hydrology plays an important role in engineering practice for water resources design and management. The determination of design storm is an unrest research topic in statistical hydrology that is needed in a broad spectrum of civil works. Following its role in the real world, the knowledge of statistical hydrology has steadily improved and developed its analysis methods. Regionalization rather than point data analysis, probability weighted moments (PWM) rather than conventional method of moments (MOM) are the examples.

1.3 Problem Statements

In water resource planning and management, design storm is needed to input rainfall-runoff modelling that engineering design for hydraulic structures and also operational and management of the system can be accomplished. Rainfall as the input has significant variability to the season, space, and time. It is defined the storm pattern to be used as input parameter that fulfills its variability as the representation of the real historical storms. Storm analysis is only relevant to be conducted for homogeneous region that partitions the region into homogeneous sub-regions is to be conducted. The spatial data generation is conducted and the results are used in statistical frequency analysis to get the quantiles magnitude.

There are two types of rainfall classified based on time scale, short and long rainfall duration that both of them are physically different in their characteristics. Short rainfall duration is considered as a single storm while long rainfall duration is a multiple storms that have implication in constructing the structure of storm shape. The transition between short and long duration storm is the duration of 24 hours called as the standard duration.

Design storms can be performed when the intensity-duration frequency (IDF) relationship and the structure of temporal storm pattern are confirmed. The IDF curve represents the relationship between intensity (mm/hr) and duration (min) for some rainfall frequencies. In hydrologic analysis, the frequencies are commonly set for 2-, 5-, 10-, 20-, 50- and 100-year return period. The rainfall study consists of data collection and analysis, statistical frequency analysis, and construction of IDF curves family. There are at least three types of temporal rainfall pattern that can be used in constructing design storms; triangle shape (Hromadka *et al.*, (1987), compound method (Vaes *et al.*, 2001), and block peak approach (Peyron *et al.*, 2004).

1.4 Objectives of Research

The primary aim of the research is to explore and investigate the rainfall variability and to apply the block peak method within the prediction of design storms. Design storm development need to accomplish the climate characteristics and procedure of data presentation. The shape pattern is not really the same as real storms but it is intended to produce the hydrograph that consistent to the hydrograph produced by real storms (DID, 2000). The analysis uses the local available data from Selangor including the Federal Territory and Johor and the result is to be verified to the available design storms of the cities/towns located in the West Coast of Peninsular Malaysia. The objectives of the research are as follows.

(1) To conduct the regionalization and spatial data generation based on climate characteristic and geographical conditions,
(2) To improve the statistical method of PMP calculation based on local data to accommodate the presence of outliers,

(3) To apply the block peak method to the structure of temporal storm pattern within design storm based on local IDF curve and rainfall aggregation, and

(4) To develop the IDF curve based on daily data for the region with the absence of incremental data.

1.5 Scopes of Research

The scopes of this research consist of data collection, data extraction, preliminary statistical tests, regionalization, statistical frequency analysis, PMP calculation, IDF curve development, structure of rainfall pattern and prediction for design storms. The type of rainfall data used in analysis is daily and 5-min incremental rainfall data available for Selangor including the Federal Territory and Johor. For Selangor, there are about 34 sets of daily data with the length of record varies from 30 to 80 years, while for 5-min increment, data is available for 5 sets with 25 years length of records. For Johor, there are 5 data sets with 25 years length of records for both daily and 5-min incremental data.

The 34 daily data sets available for Selangor including the Federal Territory are intended to be used in spatial data correlation within homogeneous region and the PMP calculation for envelope method of Hershfields approach for both analyses need large numbers of data sets. The 5-min increment data for Selangor including the Federal Territory and Johor is used for spatial data generation within homogeneous region. The storm area of 242 km^2 as the boundary of spatial data generation is covered by the location of 5 stations which produced the 5-min increment data.

The data sets are available from the Jabatan Pengaliran dan Saliran (JPS) Ampang Branch, Kuala Lumpur and they are extracted to fulfill the hydrologic extreme event analysis. This kind of analysis needs an annual maximum rainfall data that is only one data comes out from the defined year of observation. To fulfill the data prerequisite, the ‘water year time stick’ is used in data extraction rather than the Julian date method. The method is also to accommodate the climate characteristics of the region. The study area, the Peninsular Malaysia, is in tropical zone where tropical monsoons are dominantly affecting the region that is to be considered in storm transport analysis.