UNIVERSITI PUTRA MALAYSIA

FREQUENCY ANALYSIS AND EVALUATION OF SHORT DURATION STORMS FOR PENINSULAR MALAYSIA

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By

RATNA RAJAH SIVAPIRAGASAM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

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DEDICATION

To my beloved

mother

Madam Krishnamal Sivapiragasam

brother

Mr. Sivaneswaran Sivapiragasam

and grandmother

Madam Valli Trivinggadam

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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The Department of Irrigation and Drainage (DID) published the Stormwater Management Manual (SWMM) in year 2000. The Manual requires Intensity-Duration-Frequency (IDF) values of low average recurrence interval (ARI) ranging from 1 month to 12 months for the design of water quantity and quality control facilities. However, these IDF values are currently not available because past analysis using annual maximum series (AMS) of rainfall depths could only derive the IDF values for ARIs of 2 years and above.

The SWMM has recommended as an interim solution to use simple coefficients to convert 2 year ARI rainfall intensity to obtain the 1, 3, 6 and 12 months ARIs rainfall intensity for short durations. The coefficients were derived by fitting Gumbel distribution to the 1 hour duration rainfall depths obtained for the city of Ipoh and extrapolating the distribution to obtain the low ARIs . The coefficients need to be verified as they have been recommended for use in any location of Malaysia for any duration of rainfall.

Twenty six rainfall stations distributed throughout Peninsular Malaysia were chosen and monthly maximum series (MMS) rainfall depth for 15 minutes, 30 minutes, 1 hour, 3 hours, 6 hours and 12 hours durations were extracted from rainfall records obtained from DID Hydrological Databank. For every station, frequency analysis was performed using the Gumbel distribution and method of moments with Gringorten Plotting Position formula to obtain rainfall intensity for 2, 3, 6, 9, 12, 15 and 18 months ARI. Concurrently, the same frequency analysis was performed using the same durations and length of data but by using AMS to obtain 2 years ARI rainfall intensities.

The coefficients obtained from this analysis differed significantly from those recommended by the SWMM. As such, IDF curves were developed for the 26 rainfall stations, and are suggested for use in SWMM. Further analysis was performed on the MMS to determine the better method of estimate between the method of moment and the method of L-moment by computing the standard error of estimation based on Random Number Generation method. The findings were that the method of L-moment is a better method of estimation generally. Identification of appropriate families/parent distribution for various durations was determined from L-Moment Ratio Diagram. The study showed that Pearson Type 3 was best fit for 15 minutes, and 30 minutes durations, Generalised Normal curve for 1 hour duration and Generalised Extreme Value curve for 3 hours, 6 hours and 12 hours durations.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

ANALISIS FREKUENSI DAN PENILAIAN TEMPOH HUJAN YANG PENDEK SEMENANJUNG MALAYSIA

Oleh

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Jabatan Pengairan dan Saliran (JPS) Malaysia telah mengeluarkan Manual Saliran Mesra Alam 2000 (MSMA) yang memerlukan nilai Keamatan-Tempoh-Frequensi (KTF) bagi tempoh hujan yang pendek dengan Kala Kembali Purata (KKP) yang rendah iaitu antara 1 bulan hingga 12 bulan dalam merekabentuk struktur-struktur kawalan kuantiti dan kualiti air. Walaubagaimanapun, nilai KTF tersebut tidak dapat diperolehi buat masa ini kerana analisis sebelum ini yang menggunakan siri taburan hujan maksimum tahunan (STHMT) hanya dapat menghasilkan nilai KTF bagi KKP yang melebihi 2 tahun.

MSMA telah mengesyorkan sebagai suatu penyelesaian sementara dengan menggunakan pekali untuk menukarkan keamatan hujan KKP 2 tahun kepada keamatan hujan KKP rendah. Pekali yang disyorkan telah diperolehi dengan pemadanan taburan Gumbel dengan kedalaman hujan bagi tempoh1 jam untuk bandaraya Ipoh dan dengan memanjangkan taburan untuk mendapatkan keamatan hujan bagi KKP rendah. Pekali-pekali tersebut perlu disahkan memandangkan ia disyorkan untuk seluruh Malaysia bagi sebarang tempoh hujan.

Dua puluh enam stesen hujan telah dipilih di seluruh Semenanjung Malaysia dan siri taburan hujan maksimum bulanan (STHMB) bagi tempoh 15 minit, 30 minit, 1 jam, 3 jam, 6 jam dan 12 jam diekstrak daripada rekod hujan yang diperolehi daripada JPS. Analisis frequensi bagi setiap stesen telah dibuat dengan memilih taburan Gumbel dan kaedah momen dengan menggunakan *Grigorten Plotting Position* untuk mendapatkan keamatan hujan bagi KKP rendah 2, 3, 6, 9, 12, 15, dan 18 bulan. Pada waktu yang sama, analisis frequensi yang sama dibuat dengan menggunakan tempoh dan rekod data hujan yang sama tetapi dengan menggunakan STHMT untuk mendapatkan keamatan hujan untuk KKP 2 tahun.

Pemalar yang telah diperolehi daripada analisis tersebut didapati tidak sama dengan pemalar yang disyorkan dalam MSMA. Oleh itu, lengkung KTF telah dihasilkan untuk setiap satu daripada 26 stesen hujan tersebut dan akan dicadangkan untuk digunakan dalam MSMA. Analisis lanjutan dibuat dengan menggunakan STHMB untuk menentukan kaedah anggaran yang lebih sesuai di antara kaedah momen dan kaedah momen-L dengan menghitung anggaran ralat piawai berdasarkan kaedah *Random Number Generation*. Taburan keluarga yang sesuai juga ditentukan untuk tempoh-tempoh hujan daripada Rajah Nisbah Momen-L. Purata pencongan-L dan kurtosis-L adalah hampir kepada lengkung *Pearson Type 3* bagi tempoh hujan 15 minit dan 30 minit, lengkung *Generalised Normal* untuk tempoh hujan 1 jam dan lengkung *Generalised Extreme Value* untuk tempoh hujan 3, 6 dan 12 jam.

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LIST OF ABBREVIATIONS

AMS	Annual Maximum Series
ARI	Average Recurrence Interval
D	Duration
DID	Department of Irrigation and Drainage
EV1	Gumbel Extreme Type 1
F	non-exceedance probability
F_i	ith plotting position
GEV	Generalised Extreme Value
GLO	Generalised Logistic
GNO	Generalised Normal
GPA	Generalised Pareto
HP	Hydrological Procedure
IDF	Intensity-Duration-Frequency
IEA	Institution of Engineers in Australia
KTF	Keamatan-Tempoh-Frequensi
KKP	Kala Kembali Purata
L-CV	L-coefficient of variation
LMRD	L-moment Ratio Diagram
LMOM	Method of L-moments
LN3	3-Parameter Lognormal
LP3	Log Pearson Type 3
ML	Method of Likelihood

MMS	Monthly Maximum Series
MOM	Method of Moments
MSMA	Manual Saliran Mesra Alam Malaysia
NERC	Natural Environment Research Council, United Kingdom
P	rainfall depth
PDS	Partial Duration Series
PE3	Pearson Type 3
POT	Peak Over Threshold
PWMs	Probability Weighted Moments
SEE	Standard Error of Estimation
SWMM	Stormwater Management Manual
T	return period
USWRC	US Water Resources Council
a	constant (in plotting position formula)
F(x)	cumulative distribution function
f(x)	probability distribution function
G	sample skewness
i	rank, rainfall intensity
k	sample kurtosis
n	sample size
s	sample standard deviation
s^2	sample variance

$x(F)$	quantile function
$\bar{x}$	sample mean
y	reduced variate
μ	theoretical mean
σ^2	theoretical variance
σ	theoretical standard deviation
γ	theoretical skewness
κ	theoretical kurtosis, shape parameter
β_r	rth probability weighted moment
λ_1	L-mean
λ_2	L-standard deviation
λ_r	rth L-moment
τ_2	L-coefficient of variation
τ_3	L-skewness
τ_4	L-kutosis
τ_r	rth L-moment ratio
${}^{0\ 083}I_D$	1 month ARI rainfall intensities for any duration
${}^{0\ 25}I_D$	3 month ARI rainfall intensities for any duration
${}^{0\ 5}I_D$	6 month ARI rainfall intensities for any duration
${}^{1}I_D$	12 month ARI rainfall intensities for any duration

$^{2}I_{D}$	2 year ARI rainfall intensities for any duration
ξ	location parameter
α	scale parameter

CHAPTER 1

INTRODUCTION

Urbanisation and the resultant increase in population and activities associated with urban life can dramatically change the quantity and quality of stormwater runoff within a catchment and its receiving waters. When a catchment is urbanised, large areas of natural vegetation are replaced by development containing a high percentage of impervious surfaces such as roads, roofs, car parks and surface paving. As such the majority of the runoff from an urban area occurs from impervious areas and these are normally caused by frequent storms events which have less than 2 year average recurrence interval (ARI).

Stormwater management in Malaysia has traditionally focused primarily on managing the impacts of flooding by adopting a conveyance-oriented approach. This approach provides for the collection of runoff, followed by the immediate and rapid conveyance of the stormwater from the collection area to the point of discharge in order to minimise damage and disruption within the collection area.

Stormwater management has developed to the point where there are now two fundamentally different approaches to controlling the quantity, and to some extent, the quality of storm runoff. In addition to the traditional conveyance-oriented approach, a potentially effective and preferable approach to stormwater management is the storage-oriented approach. In this approach, the temporary storage of stormwater runoff is provided at or near its point of origin with subsequent slow release to the downstream stormwater system or receiving water, termed detention, or infiltration into the surrounding soil, termed retention. This approach can minimise flood damage and disruption both within and downstream of the collection area. Runoff may also be stored for re-use as second class water supply for irrigation and domestic purposes.

The Department of Irrigation and Drainage Malaysia (DID) has developed a comprehensive manual known as Urban Storm Water Management Manual (DID, 2000), normally referred as SWMM for Malaysia adopting the use of storage-oriented approach for flood reduction to supercede or supplement the conventional method of conveyance-oriented approach. The storage-oriented approach requires rainfall intensities of less than the 2 year ARI for the planning and design of minor and major stormwater systems such as kerbs, gutters, inlets, open drains and pipes for open space, parks and agricultural land development in urban areas and for the design of water quality treatment facilities for all types of development are shown in Table 1.1.

The minor system is designed to convey runoff from a minor storm, which occurs relatively frequently, and would otherwise cause inconvenience and nuisance flooding. The major system is expected to protect the community from the consequences of large, reasonably rare events, which could cause severe flood damage, injury and even loss of life. Quantity control refers to design that deals with sizing of structures for collecting, conveying, controlling, and disposing of stormwater runoff.

Table 1.1: Design Storm ARIs for Urban Stormwater Systems (DID,2000)

Type of Development	Average Recurrence Interval (ARI) of Design Storm		
	Quantity		Quality
	Minor System	Major System	
Open Space, Parks and Agricultural Land in urban areas	**12 months**	Up to 100 years	**3 months**
Residential:			
• Low density	2 year	Up to 100 years	**3 months**
• Medium density	5 year	Up to 100 years	**3 months**
• High density	10 year	Up to 100 years	**3 months**
Commercial, Business and Industrial in Central Business District (CBD) areas of Large Cities	10 year	Up to 100 years	**3 months**
Commercial, Business and Industrial – Other than CBD	5 year	Up to 100 years	**3 months**

Quality control refers to design of water quality structures to control the transport of sediment from land development/construction sites and pollutants from urbanised areas, which will enhance the quality of discharges to receiving waters. It is stated in the SWMM (DID, 2000) that surface water collected from disturbed areas shall be routed through a sediment pond or sediment trap prior to release from the site. Sediment retention facilities shall be installed prior to the grading or disturbance of any contributing area. Sediment basins shall be sized to retain a minimum of 70% of coarse