Long-Term Rainfall Analysis for Estimating Water Quality Volume for Major Towns in Malaysia

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ABSTRACT
Urbanization increases the variety and amount of pollution carried into downstream waterways. Best management practices (BMPs) or stormwater facilities has been identified as an approach to solve the problems. The effectiveness of BMPs depends on the volume of storm runoff that can be captured and treated by them, which is referred to as water quality volume (WQV). To obtain optimal design of BMP facilities, simple and reliable procedures of estimating WQV are needed in Malaysia. Realizing these necessities, the objective of this paper is to carry out a detailed study on long-term rainfall analysis to determine water quality depth (WQD) in estimating WQV. From the analysis, rainfall distribution for all regions is identical to exponential distribution. The rainfall pattern also varies in every region. Every station consists of a large number of small events and a number of event decay as the magnitude of rainfall depth increases. Rainfall depth ranges of 2.5–5 mm and 5–10 mm give the highest percentage for all stations. The 75th, 80th, 85th, 90th and 95th percentile rainfall event depths for eight rainfall stations were calculated and compared with the values that are being used in Malaysia.

KEYWORDS
Long-term rainfall analysis, water quality volume, water quality depth, MSMA

INTRODUCTION
Urbanization increase the variety and amount of pollution carried out to downstream waterways . Best Management Practices (BMPs) or storm water facilities has been identified as an approach to solve the problems. Runoff and volume capacity is a key factor when designing BMPs or stormwater quality control facilities. The amount of runoff to be captured and treat by them is referred as Water Quality Volume (WQV) and this volume is very important in sizing stormwater quality control facilities . Moreover, WQV not only essential in water quality sizing criteria, it also can give reasonable cost for stormwater treatment practise. Because of its effectiveness in sizing stormwater quality control facilities with reasonable cost, many researchers have studied the effective methods to determine WQV.

Design method for estimation WQV was first studied and suggested by Water Environment Federation (WEF) and American Sociaty of Civil Engineering (ASCE). In determining of rainfall depth for Water Quality Capture Volume (WQCV), WEF and ASCE (1998) have suggested to use an approximate 85th percentile runoff volume from storm event. Furthermore, Guo and Urbonas (1996,2002) have develop WQCV estimation by using one parameter exponential distribution. They recommended that the required WQCV should be on average capture 75^{th} to 85^{th} percentile of runoff volume. On other hand, Song *et all*., (2013) was investigate an effect of other rainfall characteristics for estimation of WQCV and suggested that seasonal distribution of rainfall events have an effect in WQCV curve. Up to the present time, WQCV estimation approach has been applied in many area in developing country.

In Malaysia, stormwater quality design has been practiced in Stormwater Management Manual for Malaysia (MSMA) introduce by Department Of Irrigation and Drainage in year 2000. This manual recommended the use of 3 month Average Recurrence Interval (ARI) design storm for sizing a detention pond and treatment components of water quality structure. With rapid development in urban areas, authorities give more concern about stormwater quality to protect the environment. Therefore, In Second Edition of Urban Stormwater Management Manual for Malaysia (MSMA) (DID,2012), WQV concept was introduced and 40 mm of rainfall depth was selected for water quality design storm in WQV estimation. For the purposes to obtain optimal design of BMPs facilities, simple and reliable procedures of estimating WQV is needed in Malaysia. Realizing of this necessities , objective of this paper is to carried out a detail study on long term rainfall analysis to determine water quality depth (WQD) in estimating WQV. This preliminary study was done in the major towns because these areas are undergoing rapid development.

STUDY BACKGROUND AND METHODS

The long term continuous rainfall data were obtained from Malaysian Drainage and Irrigation Department for the period ranging from 15 to 43 years. All the stations are located in major cities and scattered over Peninsular Malaysia. The details are shown in Table 1 and Table 2.

Table 1. Location and period of data for rainfall stations.

Region	Town	Rainfall Station		Period of data
		Number	Name	
Southern	Johor Bahru	1437116	Stor JPS Johor Bharu	1970 - 2013
	Bandar Hilir	2222001	Bkt. Sebukur,Melaka	1979 - 1995
Central	Seremban	2719001	Setor JPS. Sikamat,Seremban	1970 - 2013
	K.Lumpur	3116003	Ibu Pejabat JPS, W.Persekutuan	1975 - 2013
Northern	Ipoh	4511111	Politeknik Ungku Omar	1982 - 2012
	Alor Setar	6206035	Kuala Nerang	1982 - 2012
East Coast	Kuantan	3930012	Sg. Lembing PCCL Mill, Pahang	1970 - 2013
	K. Terengganu	5331048	Setor JPS. K/Terengganu	1970 - 2013

Table 2. Geography coordinates for eight rainfall stations at Peninsular Malaysia.

Rainfall Station	Location	
	Latitude	Longitude
Stor JPS Johor Bharu	01^{o} 28$^{'}$ 15$^{'}$N	03^{o} 45$^{'}$ 10$^{'}$E
Bkt. Sebukur,Melaka	02^{o} 13$^{'}$ 55$^{'}$N	102^{o} 16$^{'}$ 05$^{'}$E
Setor JPS. Sikamat,Seremban	02^{o} 44$^{'}$ 15$^{'}$N	101^{o} 57$^{'}$ 20$^{'}$E
Ibu Pejabat JPS, W.Persekutuan	03^{o} 09$^{'}$ 05$^{'}$N	101^{o} 41$^{'}$ 05$^{'}$E
Politeknik Ungku Omar	04^{o} 35$^{'}$ 20$^{'}$N	101^{o} 07$^{'}$ 30$^{'}$E
Kuala Nerang	06^{o} 15$^{'}$ 1$^{'}$N	100^{0} 36$^{'}$ 4$^{'}$E
Sg. Lembing PCCL Mill, Pahang	03^{o} 55$^{'}$ 00$^{'}$N	03^{o} 02$^{'}$ 10$^{'}$E
Setor JPS. K/Terengganu	05^{o} 19$^{'}$ 05$^{'}$N	103^{o}08$^{'}$00$^{'}$E

In this study, a long continuous rainfall data series were divided into individual storm event. This is mainly because fraction of storm captured much more important in WQV estimation compare to fraction of total runoff volume captured. Range of the rainfall event – depth obtained by separating rainfall depth in every event into 16 intervals. Storm less than 0.1 inch @ 2.5 mm were excluded from data set because this value generally do not produce runoff due to rainfall losses (USEPA, 2009). Rainfall depth distribution for every station were analyzed by regions namely Central, Southern, East Coast and Northern.

RESULT AND DISCUSSION

Figure 1 present an example of rainfall event-depth graph for two major towns, Seremban and Kuala Lumpur respectively while Table 3 describe a distribution of rainfal event-depth in percentage for all rainfall stations.

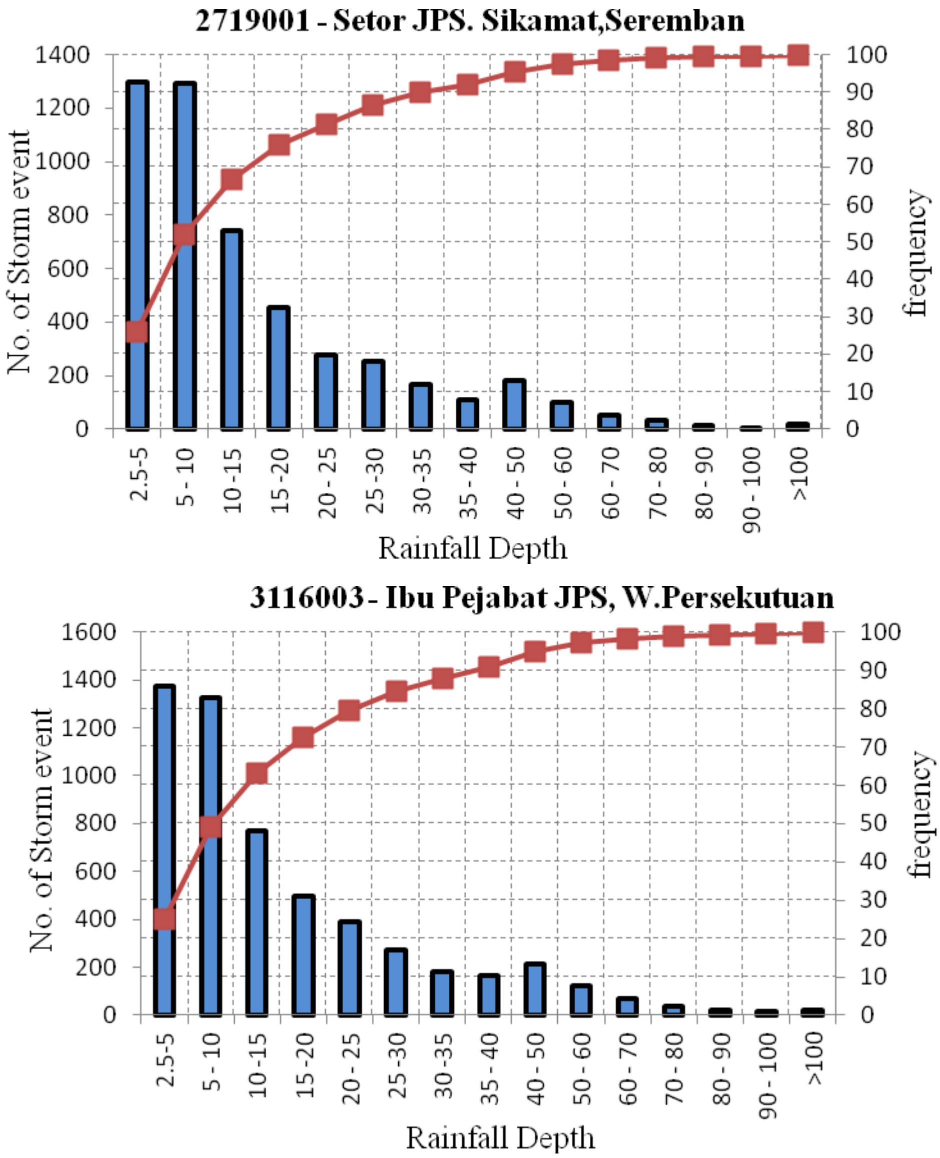

Figure 1. Rainfall event-depth graphs for central region.

Table 3. Distribution of rainfal event-depth in percentage for all rainfall stations.

Rainfall Station	Rainfall depth (%)

	2.5 - 5	5 -10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40	> 40
Stor JPS Johor Bharu	23.5	23.6	14.4	9.2	6.1	5.5	3.7	2.9	11.1
Bkt. Sebukur,Melaka	27.2	24.7	13.9	8.9	6.3	4.8	3.5	2.4	8.4
Setor JPS. Sikamat,Seremban	26.0	25.9	14.9	9.1	5.5	5.1	3.3	2.2	8.1
Ibu Pejabat JPS, W.Persekutuan	25.0	24.2	14.1	9.1	7.1	5.0	3.4	3.0	9.1
Politeknik Ungku Omar	26.2	24.3	13.6	9.0	7.1	4.7	3.5	3.1	8.5
Kuala Nerang	30.3	27.4	13.8	7.2	5.7	4.5	2.4	1.6	7.1
Sg. Lembing PCCL Mill, Pahang	27.6	26.6	13.5	9.1	5.8	4.4	2.8	2.2	8.0
Setor JPS. K/Terengganu	29.2	25.0	13.7	7.9	5.6	4.1	2.9	1.9	9.7

Rainfall distribution for all regions is identical to exponential distribution. Jamaludin and Abdul Aziz (2007) has explained in more detail about the concept of exponential distribution on fitting distribution of rainfall in Peninsular Malaysia for periods from 21 to 35 years. Overall, mixture of two Weibull distributions has been identified as the best fitting distribution for the majority of sites. This information will be useful for WQCV estimation. Rainfall pattern also varies in every regions because of its geographical, topographical and climatic changes. Every station consists of a large number of small events and number of event decay as the magnitude of rainfall depth increase. Rainfall depth range 2.5 to 5 mm and 5 to 10 mm gives the highest percentage for all stations.

The 75th, 80th, 85th and 90th together with 95th percentile event rainfall depth for eight rainfall stations were calculated and compared as shown in Table 4. This comparison give a general overview related to WQD that can be used in determining WQV. As mention before, value of 40 mm rainfall depth was selected for water quality design storm in MSMA, (DID,2012). From Table 4, 40 mm rainfall depth is in range of 95th percentile event rainfall depth at six stations. With this findings, it is possible to use 95th percentile event rainfall depth in WQV estimation in Malaysia. Furthermore, the USEPA(2009) were recommended retaining the 95th percentile rainfall event using long term daily rainfall record for onsite storm water management practice in its technical guidance. However, to ensure WQV estimation is appropriate for all regions, the long term rainfall data should be analyses for all rainfall stations in Malaysia.

Table 4. Percentile of event rainfall depth for all rainfall stations.

Rainfall Station	Percentile of event rainfall depth				
	75th	80th	85th	90th	95th
Stor JPS Johor Bharu	20-25	25-30	30-35	35-40	50-60
Bkt. Sebukur,Melaka	15-20	20-25	25-30	30-35	40-50
Setor JPS Sikamat Seremban	15-20	20-25	25-30	30-35	40-50
Ibu Pejabat JPS, W.Persekutuan	15-20	20-25	25-30	35-40	40-50
Politeknik Ungku Omar	15-20	20-25	25-30	35-40	40-50
Kuala Nerang	15-20	15-20	20-25	30-35	40-50
Sg. Lembing PCCL Mill, Pahang	15-20	20-25	25-30	30-35	40-50
Setor JPS. K/Terengganu	15-20	20-25	25-30	35-40	50-60

CONCLUSION

To preserve the quality of water in environment is protected with reasonable cost, simple and reliable procedures of estimating WQV is needed in Malaysia. As preliminary study, this paper gives initial finding in estimating WQV. Further details of required parameters should be considered so that the procedures is more practical to use in Malaysia.

ACKNOWLEDGEMENT

The author would like to acknowledge the financial assistance fully supported by from Ministry of Higher Education under Long Term Research Grant (LRGS) No. 203/PKT/672004 entitled Urban Water Cycle Processes, Management and Societal Interactions: Crossing from Crisis to Sustainability.

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