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Effect of Minimum Inter Event Time on Water Quality Capture Volume

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ABSTRACT

In Malaysia, with lands and spaces becomes limited caused by urbanization, size of stormwater facilities should be effective to meet the needs of planning, designing and managing stormwater systems. Water quality captured volume (WQCV) has been practiced to give a balance between the storage size and water quality treatment effectiveness. WQCV is a concept to relate the urban runoff volume with the local rainfall pattern, and the focus of the WQCV is to capture the specified runoff volume of a storm event. 75th to 95th percentile runoff volume was used in WQCV estimation from historical rainfall series analysis. As a smaller event dominate long term rainfall records and this event did not produce runoff, it will affect the WQCV estimation. Independent rainfall event need to identify from rainfall series and separation of rainfall event depends on time chosen in minimum inter event time (MIT). MIT is a minimum dry period between two rainfall pulses and increasing of MIT will increase the rainfall depth of an event. This paper aims to study about the effects of different MIT in WQCV estimation. Historical rainfall data from a selected rainfall station in Malaysia was analyzed with different MIT at 2hr, 4hr, 6hr, 12hr, 18hr and 24hr. As it is more accurate to use shorter interval, 10 min interval of rainfall record was used to separate rainfall event. The relation between MIT and rainfall depth with different percentile was analyzed and their rainfall characteristic was assessed. This relation study has improved the accuracy of the design of stormwater quality control facilities especially in Malaysia.

Keywords: Rainfall events, long term rainfall analysis; water quality capture volume; minimum inter event time; rainfall characteristic.

1. INTRODUCTION

Urban development has negative impacts on the environment, especially in quantity and quality of stormwater. Urbanization changes the characteristics of the surface runoff hydrograph and also has a profound influence on the quality of stormwater runoff. In Malaysia, with lands and spaces becomes limited caused by urbanization, size of stormwater facilities should be effective to meet the needs of planning, designing and managing stormwater systems. To overcome this problem, water quality captured volume (WQCV) has been practiced to give a balance between the storage size and water quality treatment effectiveness. Malaysia has been introduced these concepts in the Second Edition of Urban Stormwater Management Manual for Malaysia (MSMA) (DID, 2011).

WQCV is a concept that relates the urban runoff volume with the local rainfall pattern. The focus of the WQCV is to capture the specified runoff volume of a storm event. This concept is suggested by Water Environment Federation (WEF) and American Society of Civil Engineering (ASCE) and has been used by many researchers for sizing Best management practices (BMPs) facilities. Guo and Urbonas (2002) used WQCV concept and local long term continuous rainfall record to produce a runoff capture curve. It was found that by knowing the runoff capture curve, the proper basin size can be identified. They also presented, the computer model to generate WQCV for stormwater BMPs design, which helped user to determine the long term runoff volume ratio and runoff event ratio and this volume can be used to size and design BMPs facilities. The challenge of WQCV estimation is to choose a suitable percentile of runoff volume from historical rainfall series. For stormwater quality improvement, design volume for BMPs facilities is more suitable to be designed by percentile and not based on maximizing volume. In current practice, 75th to 95th percentile runoff volume was used for WQCV estimation in many countries. USEPA (2009) recommended retaining the 95th percentile because it represents the volume that fully infiltrated in a natural condition. However UDCFM (2010) used 80th percentile of runoff event for design water quality facilities in Colorado.

Before WQCV can be computed, the continuous rainfall record must be separated into rainfall event. Typically, separation of rainfall event depends on time chosen in Minimum Inter Event Time (MIT) (Shamsudin et al., 2010) or Inter-Event Time Definition (IEDT) (Joo et al., 2013) - and also referred as the antecedent dry period (Tian, 2009). MIT defined as the minimum dry period between two rainfall pulses. The traditional method to determine MIT can be divided into three types ; using the autocorrelation coefficient of the rainfall pulses, coefficient of variation analysis and average annual number of event analysis. Based on several studies, MIT used for separation of rainfall event ranges from 4-hr to 8-hr. Dricollet et al. (1989) found that a 6-hours separation time produced most consistent statistical results when attempting to define individual rainfall events form continuous records. Park et al. (2011) also use 6-hr to separate rainfall event to study the effect of seasonal rainfall distribution on WQCV. There are also researchers who use MIT more than 8-hr in their research. Guo and Urbonas (2009) use three different MIT 6-hr, 12-hr and 24-hr to delimiting individual storm events from a continuous rainfall record. Shrestha (2013) recommended 6hr to 72hr of minimum inter event dry period for the separated storm event in the study of percentile analysis. Shamsudin et al. (2010) used rainfall data at Johor, Malaysia and confirmed that different MIT gives a varying number of rainfall events. She also claimed that shorter MIT have more varied duration and depth compare to rainfall separate by longer MIT. It has been shown that MIT plays an important role in the separation of rainfall event and increasing of MIT will increase the rainfall depth. As a smaller event dominates long term rainfall records and no runoff produced, it will affect the WQCV estimation. Under this circumstance, this paper studies about the effects of different MIT in WQCV estimation.

2. METHODOLOGY

Rainfall data from 8 stations were obtained from Malaysian Drainage and Irrigation Department (DID) for the period ranging from 36 to 42 years. Stations were selected to represent the four regions in Malaysia, namely Northern, Central, Southern and East Coast region. Location of all stations scattered over Peninsular Malaysia and details for area and geographic location is listed in Table 1. 10 min interval of rainfall record was used to obtain rainfall event from continuous rainfall data. Consistencies of rainfall data were checked by double mass curved method before used.

Visual Basic command was created in Excel Macro mode to convert the continuous rainfall record into individual storm events. Each continuous rainfall record was divided into individual storm events by assigning a storm separation time defined as MIT. MIT at 2-hr, 4-hr, 6-hr, 12-hr,18-hr and 24-hr were used to separate rainfall events. The range of the rainfall events – depth obtained by separating rainfall depth in every event into 16 intervals. Storm less than 0.1 inch @ 2.5 mm were excluded from the data set because this value generally do not produce runoff due to rainfall losses (USEPA, 2009).

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

Region	Rainfall station		Location		Period of data (years)	
	Number	Name	Latitude	Longitude		
Northern	6603002	Padang Besar	06^{0} 39' 25'N	100^{0} 18' 35' N	1975-2013	38
	4511111	Politeknik Ungku Omar	04^{0} 35' 20'N	101^{0} 07' 30' N	1973-2013	40
Central	3116003	I/Pejabat JPS Malaysia	03^{0} 09' 05'N	101^{0} 41' 05' N	1976-2013	37
	3217001	Ibu Bekalan km. 16	03^{0} 16' 05'N	101^{0} 43' 45' N	1973-2013	40
Southern	1437116	Stor JPS. Johor Bharu	01^{0} 28' 15'N	103^{0} 45' 10' N	1971-2013	42
	2033001	Stor Baru JPS Kluang	02^{0} 01' 10'N	103^{0} 19' 30' N	1977-2000	36
East Coast	5522047	JPS Kuala Krai	05^{0} 31' 55'N	102^{0} 12' 10' N	1971-2013	42
	5331048	Setor JPS. Kuala Terengganu	05^{0} 19' 05'N	103^{0} 08' 00' N	1971-2013	42

3. RESULT AND DISCUSSION

Table 2 listed a rainfall characteristic and rainfall depth with different percentile in various MIT at every station.

3.1 Mean annual rainfall depth

All stations showed an increase in mean rainfall depth as the MIT value increases from 2-hr to 24-hr. Station located at East Coast Region recorded the highest value of mean rainfall depth as the value of MIT altered from 2-hr to 24-hr. Rainfall station ID 5331048 at Setor JPS. Kuala Terengganu recorded 12.99 mm of rainfall depth at 2-hr of MIT and 34.55 mm at 24-hr of MIT due to the impact of North East Monsoon on the rainfall pattern in the eastern area of Peninsular Malaysia. During North East Monsoon, eastern part of Peninsular Malaysia received more rainfall compared to the western part (Suhaila et al, 2010). The lower mean rainfall depth was recorded at station ID 6603002 at Padang Besar. There is a clear tendency for smaller storm depths to occur in the northern region. At 2-hr MIT, the value of mean rainfall depth is 8.60 mm and increased to 22.78 mm at 24 hr MIT.

3.2 Total storm event

Total of rainfall event in every stations decreased with changing MIT value from 2-hr to 24-hr. Shorter MIT gave a bigger number of rainfall event and longer MIT gave a smaller number of rainfall events. All stations located in Northern, Central and East Coast region showed significant changes in total numbers of event which declined by more than 60 percent when the value of MIT altered from 2 hr to 24 hr. Southern region recorded a 55 percent reduction of the total rainfall event from 2 hr MIT to 24 hr MIT. Station ID 3116003 - I/Pejabat JPS Malaysia gave a highest value of the total storm event. However, this highest value only occurs at MIT 2- hr to 12 - hr. For MIT 18 - hr and 24 - hr, rainfall station ID 1437116 located in Southern region recorded the highest value at 5167 and 3711 respectively. This has shown that, suitable MIT value for WQCV determination should take into consideration of the location of the station.

Number of event below than 2.5 mm were excluded from data set because this value generally does not produce runoff due to rainfall losses. Correspondingly, all stations recorded number of event below than 2.5 mm more than 40 percent from total of storm event at MIT-2 hr except for station ID 1437116-Stor JPS Johor Bharu. This percentage steadily declined to 20 percent as the value of MIT increase from 2-hr to 24-hr. Ultimately, shorter MIT provides a lot of rainfall event however the percentage of event below 2.5 mm is higher than the percentage of event below 2.5 mm for longer MIT.

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Table 2. Rainfall characteristic and rainfall depth with different percentile

Region	Station ID	MIT (hours)	Mean annual rainfall (mm)	Total storm event	Storm event less than 2.5 mm	Maximum rainfall depth (mm) in different percentile				
						75th	80th	85th	90th	95th
Northern	6603002	2	8.60	7235	3252	20	25	30	35	50
		4	10.08	6141	2647	20	25	30	40	50
		6	11.22	5489	2164	20	25	30	40	60
		12	14.03	4378	1478	25	30	35	50	70
		18	17.06	3610	1076	30	35	40	60	80
		24	22.78	2719	678	40	50	60	70	100
	4511111	2	10.23	8318	3745	25	30	35	40	50
		4	11.68	7259	2814	25	30	35	40	60
		6	12.60	6723	2340	25	30	35	40	60
		12	15.25	5553	1482	25	30	40	50	60
		18	18.95	4480	996	30	40	50	60	70
		24	25.34	3347	611	40	50	60	70	100
Central	3116003	2	10.68	9097	4020	25	30	35	40	50
		4	12.26	7914	3032	25	30	35	40	60
		6	13.23	7330	2556	25	30	35	40	60
		12	15.94	6069	1710	30	35	40	50	60
		18	19.66	4926	1208	35	40	50	60	80
		24	28.57	3408	706	50	60	70	80	100
	3217001	2	10.17	8984	4061	25	30	35	40	50
		4	11.69	7801	3024	25	30	35	40	60
		6	12.66	7190	2498	25	30	35	40	60
		12	15.49	5872	1571	30	30	40	50	60
		18	19.43	4691	1033	35	40	50	60	80
		24	26.29	3465	621	40	50	60	70	100
Southern	1437116	2	12.78	8193	3259	25	30	35	50	60
		4	14.14	7336	2553	25	30	35	50	60
		6	14.96	6906	2212	25	30	40	50	60
		12	17.01	6039	1656	30	35	40	50	70
		18	19.74	5167	1233	30	40	50	60	80
		24	27.47	3711	680	40	50	60	80	100
	2033001	2	11.28	7332	3228	25	30	35	40	60
		4	12.77	6434	2481	26	31	35	50	60
		6	13.58	6021	2142	27	32	35	50	60
		12	15.67	5187	1573	28	33	40	50	70
		18	18.32	4428	1178	30	35	40	60	80
		24	25.31	3217	688	40	50	60	80	100
East Coast	5522047	2	10.65	7813	3813	20	25	30	40	60
		4	12.89	6346	2642	20	25	35	40	60
		6	14.43	5620	2109	25	30	35	50	70
		12	17.49	4567	1429	25	30	35	50	80
		18	21.29	3752	1013	30	35	40	60	90
		24	28.76	2747	572	40	50	60	70	100
	5331048	2	12.99	7910	3530	25	30	35	50	80
		4	15.93	6396	2504	25	30	40	50	90
		6	18.01	5622	2011	30	35	40	60	100
		12	22.77	4435	1311	30	35	50	60	100
		18	27.95	3605	959	35	40	60	80	100
		24	34.55	2919	655	40	50	70	90	100

3.3 Maximum rainfall depth in different percentile

Value of rainfall depth in different percentile are listed in Table 2 and Figure 2 shows the relation between rainfall depth and MIT in different percentile for all stations. For 75th, 80th and 85th percentile, all stations provide a same value of rainfall depth from 2-hr MIT until 6-hr MIT except for rainfall station in East Coast Region. Rainfall depth for station-552047 JPS Kuala Krai and 5331048-Setor JPS Kuala Terengganu increased when MIT changes from 4hr to 6 hr at 75th and 80th percentile. The result indicate that short duration of MIT at 2-hr, 4-hr and 6-hr does not provide changes in rainfall depth for 75th, 80th and 85th. Only three station follows this assumption for 90th percentile and two stations for 95th percentile.

Value of rainfall depth increase when MIT changed from 6-hr onwards. 24-hr MIT provides the highest value of rainfall depth in every percentile. Station 5331048-Setor JPS Kuala Terengganu recorded the highest value at 100 mm start from MIT 6-hr until 24-hr. This suggests that long duration of MIT at 12-hr to 24-hr increase the rainfall depth in every percentile.

Table 2 shows that differences in MIT value and percentile gave a different result for rainfall depth. As mentioned in MSMA, (DID, 2011) a value of 40 mm was selected for the water quality design storm. If MIT 6 - hr was used to separated independent storm events, rainfall depth equal and larger than 40 mm is at the 90th percentile for six stations and 85th percentile for two stations. However, if 95th percentile was considerate, a value of rainfall depth are 60 mm in all stations in Northern, Central and Southern region and 70 mm and 60 mm for the East Coast region. Although USEPA (2009) recommended 95th percentile in WQCV estimation, this percentile gave a value of rainfall depth larger than 40 mm for all stations. With reference to this, another factor such as catchment characteristic should be considered for selection of percentile in WQCV estimation especially in Malaysia.

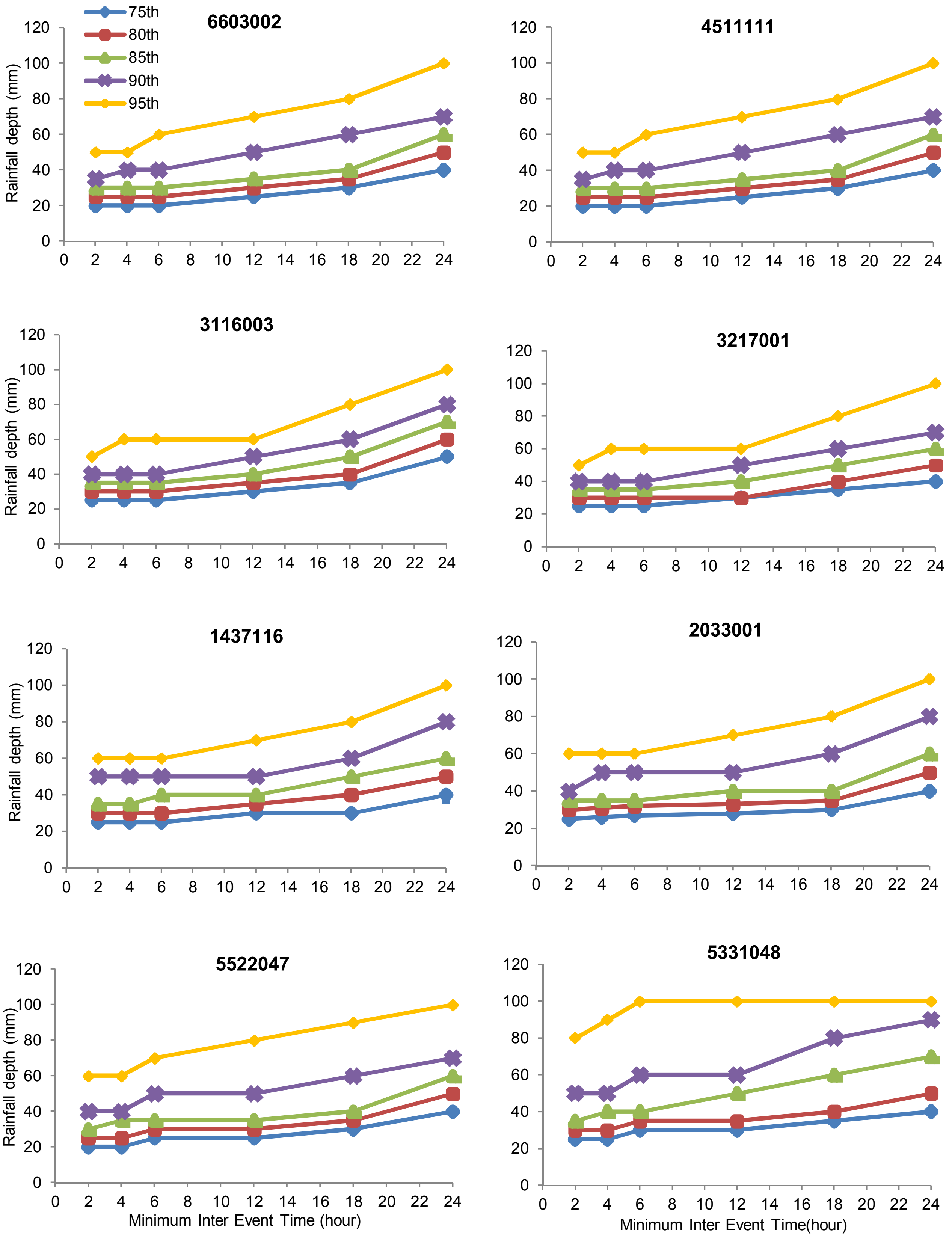

Figure 1. Relation between rainfall depth and MIT in different percentile.

4. CONCLUSIONS

MIT and percentile analysis play an important role for WQCV estimation and stormwater facilities design. This study has attempted to investigate the effects of different MIT in WQCV estimation for eight rainfall stations at different region in Peninsular Malaysia. The result shows that different MIT effects on WQCV estimation, especially in the rainfall depth of different percentile. A rainfall event characteristic also affected by any variation of MIT. Short duration of MIT does not change in rainfall depth for 75th, 80th and 85th percentile and long duration of MIT increased the rainfall depth in every percentile.

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REFERENCES

American Society of Civil Engineers or ASCE. (1996). *Hydrology Handbook*, New York.

Guo, J.C.Y., and Urbonas, B. (2002). Runoff Capture and Delivery Curves for Storm-Water Quality Control Designs. *Journal of Water Resources Planning and Management*, 128(3), 208-215.

Department of Irrigation and Drainage or DID. (2011). *Urban Stormwater Management Manual for Malaysia* (MSMA 2nd Edition). DID, Kuala Lumpur.

Driscoll, E. D., Palhegyi, G. E., Strecker, E. W., and Shelley. P. E. (1989). *Analysis of Storm Events Characteristics for Selected Rainfall Gauges Throughout The United States*. Rep., U.S. Environmental Protection Agency (EPA), Washington, D.C., Nov.

Joo, J., Lee, J., Kim, J. H., Jun, H., & Jo, D. (2013). Inter-Event Time Definition Setting Procedure for Urban Drainage Systems. Water, 6(1), 45-58.

Park, D., Song, Y. I., & Roesner, L. A. (2011). Effect of the Seasonal Rainfall Distribution on Storm-Water Quality Capture Volume Estimation. *Journal of Water Resources Planning and Management*, 139(1), 45-52.

Shamsudin, S., Dan'azumi, S., & Aris, A. (2010). Effect of Storm Separation Time on Rainfall Characteristics - A Case Study of Johor, Malaysia. *European Journal of Scientific Research*, 45(2), 162-167.

Shrestha, S., Fang, X., & Zech, W. C. (2013). What Should Be the 95th Percentile Rainfall Event Depths?. *Journal of Irrigation and Drainage Engineering,* 140(1), 06013002.

Suhaila, J., Deni, S. M., Zin, W. Z. W., & Jemain, A. A. (2010). Trends in peninsular Malaysia rainfall data during the Southwest Monsoon and Northeast Monsoon Seasons: 1975–2004. *Sains Malaysiana*, 39(4), 533-542.

Tian, P., Li, Y., & Yang, Z. (2009). Effect of Rainfall and Antecedent Dry Periods on Heavy Metal Loading of Sediments on Urban Roads. *Frontiers of earth Science in China*, 3(3), 297-302.

United States Environmental Protection Agency or USEPA. (2009). *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects Under Section 438 of the Energy Independence and Security Act*, Washington, DC 20460.

Urban Drainage and Flood Control District or UDFCD. (2010). Urban Storm Drainage Criteria Manual - Volume 3: Best Management Practices, Denver, Colorado.