PEAK FLOW ATTENUATION USING ECOLOGICAL SWALE AND DRY POND

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ABSTRACT

Data collection system to gauge the system effectiveness of BIOECODS is operating from June 2003. The data collection system focuses on the ecological swale, dry pond and ecological pond. The effectiveness of an ecological swale is considered from the aspect of quantity control in term of peak flow attenuation. The operational functional of a dry pond is calculated in terms of its capability to retain and drain storm water. Dry pond is an off-line storage with the function to reduce peak discharge at the downstream. The storm water in the dry pond recedes by infiltrating through the layer of topsoil and river sand to the storage module underneath and then flows downstream along the sub-surface module of the swale. Examples of recent data collected will be presented in this paper. The results on ecological swale show that there is a lag time between rainfall event and the resulting flow from the surface and subsurface ecological swale. The catchment response time to rainfall is about 40 min giving an indication that ecological swale has a capability to delay the flow to the downstream site. The hydrographs for the surface swale appear attenuated where the volume of the storm water is distributed over 3-hour period and a peak discharge at an upper reach of the swale is higher than the lower reach. The results show that ecological swale has the capability to attenuate the peak discharge. Water level that was measured using Ultrasonic Water Level sensor at the dry pond outlet confirms the retention behavior of the dry ponds. The storm water infiltrates and empties the dry pond outlets over the period of 20 hours. The emptying time depends on the capacity of the adjacent ecological swale.

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1. INTRODUCTION

Urban development in Malaysia with the construction of new towns may change the natural hydrology and infiltration characteristics of the previously rural catchments. This phenomenon has produced various problems regarding the stormwater runoff, such as increase in stormwater flow discharges into receiving waters, increase in flood peaks and degradation of the runoff water quality. Adverse impacts including flash flood at downstream, scouring of channel, sedimentation and transportation of pollutant load from upstream to downstream constantly occurs in major cities throughout Malaysia during rain event either on minor or major storm event. As the urban areas continue to develop, these problems become more severe and cost-effective options for treating such problems (Baber et. al. 2003).

The launching of New Urban Drainage Manual known as Urban Storm Water Management Manual for Malaysia (Manual Saliran Mesra Alam or MSMA) emphasizes the implementation of the concept of Best Management Practices (BMPs) e.g., wet ponds, grass swales, wetlands, sand filter dry pond, etc. (MSMA, 2000). Effective 1st January 2001 new development in Malaysia must comply with MSMA to control stormwater from the aspect of quantity and quality runoff to achieve zero development impact contribution to overcome the problems of inundation and increase of stormwater runoff pollution.

Effectiveness of a BMPs component is highly dependent on its design characteristics which influence the detention time and hence treatment efficiency (Yu et. al. 2001). Generally, there are many studies that have been completed that assess the ability of storm water treatment BMPs, to reduce pollutant concentrations and loadings in stormwater system discharges (Strecker et. al. 2001). It is essential to identify the effectiveness of the BMPs from the aspect of quantity as well. Consequently the hydraulic effectiveness from the aspect of quantity for ecological swale and dry pond is emphasized in this paper.

It is deemed that the ecological swale can provide control of certain peak runoff rates by retarding and impounding stormwater and conveying it downstream at velocities low enough to protect against channel and streambank erosion. Roesner et al. (2001) found that the higher frequency of the peak flow causes the stream to cut a deeper and wider channel. Meanwhile the dry pond is capable to retain and store the stormwater runoff in an average typical duration of 24 hour before draining into other stormwater systems. The objectives of the study are to identify percentage reduction of flow volume and peak flow, and lag time between the inflow and outflow for an ecological swale, and to determine the emptying time for a dry pond on typical rainfall events.

2. BIOECODS, USM ENGINEERING CAMPUS

The site of the study is located in USM Engineering Campus Perai Selatan District, Pulau Pinang, Malaysia. The campus covers about 320 acres and is made up of mainly oil palm plantation land, which is fairly flat. The USM Engineering Campus project has taken a series of measures to reduce runoff rates, runoff volumes and pollutant loads by implementing a source control approach for stormwater management as suggested in MSMA. This include a series of components namely ecological swale, on-line underground storage, and dry ponds as part of the Bio-ecological drainage systems (BIOECODS) that contribute to the treatment of the stormwater before it leaves the campus.

Figure 1 Layout Plan for USM Engineering Campus.

3. DATA COLLECTION

3.1 Ecological Swale

Ecological swale is the main component of BIOECODS, which consists of a grass-earth channel as the surface channel and combined with a subsurface module enclosed within a permeable geotextile. The effectiveness of ecological swale is highlighted in this paper from the aspect of quantity control.

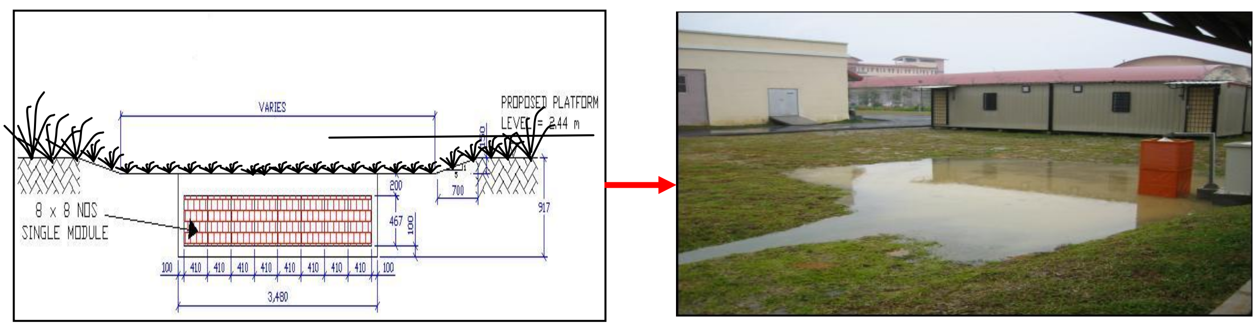
Flow data for inlet and outlet of an ecological swale are measured using the Area Velocity Module. The cross section of the ecological swale and monitoring station is shown in the Figure 2.

3.2 Dry Pond

The operational functional of a dry pond is evaluated in particular the capability of the dry pond to retain and drain storm water. Dry pond is an offline storage function to reduce peak discharge at the downstream. The storm water in the dry pond recedes by infiltrating through the layer of topsoil and river sand to the storage module underneath and then flows downstream along the sub- surface module of the swale. The cross section of a dry pond is illustrated in Figure 3. The flow from the dry pond drains into the adjacent ecological swales when the water in the surface swale is completely drained into the ecopond. Consequently, the water level data from dry pond can be used to access the performance and effectiveness of the pond outlet, which infiltrates the water through sand layer to the modular sub-surface storage. Water levels of five selected dry ponds have been measured using Ultrasonic Water Level sensors (Figure 4). The five selected dry ponds are labeled UWL 1 to UWL 5.

(a) (b)

Figure 2. Ecological Swale Type B (a) Cross Section and (b) Monitoring Station



(a) (b)

Figure 3 Typical Cross Section of A Dry Pond: (a) Cross Section and (b) Monitoring Station

4. RESULTS AND DISCUSSION

4.1 FLOW ATTENUATION OF ECOLOGICAL SWALE

The following presents the results of flow attenuation for an ecological swale. The effectiveness of the ecological swale is identified based on the percentage of reduction in volume or peak flow as summarized in the Table 1. The percentage reduction of volume or peak flow in Table 1 is calculated based on the differences between the inflow and outflow over inflow.

It has been observed that the percentage of volume reduction for surface channel is between 19.4% and 69.8% meanwhile the percentage of volume reduction for subsurface channel is between 23.7% and 89.2%. The reduction in peak flow ranges from 28.9% to 55.9% for surface swale while for subsurface channel from 0% to 59.5%. Besides, the catchments response time to rainfall is about 40 minutes giving an indication that ecological swale has a capability to delay the flow to the downstream site as shown on the inflow and outflow hydrograph in Figure 4.

Table 1 Flow Attenuation for Ecological Swale (June – November 2003)

Rain Event (2003)	Rainfall Intensity (mm/hr)	ARI	Location Channel	Peak flow (l/s)		Volume (m^3)		Percentage Reduction (%)	
				(Inlet)	(Outlet)	(Inlet)	(Outlet)	Peak Flow	Volume
24/6	11	3 month	Surface	128	91	418.5	246.6	28.9	41.1
			Subsurface	79	32	134.1	16.2	59.5	87.9
26/6	31.6	6 month	Surface	45	22	105.6	31.2	51.1	70.5
			Subsurface	53	53	53.1	31.2	0	41.2
30/8	14.5	3 month	Surface	59	26	388.8	123.6	55.9	66.6
			Subsurface	41	50	119.1	90.9	0	23.7
8/9	13.8	5 year	Surface	59	26	4043.1	3043.2	55.9	24.1
			Subsurface	70	51	160.2	83.1	27.1	48.1
4/10	6.18	2 year	Surface	201	167	2202.9	1560	16.9	29.2
10/10	33.6	2 year	Surface	226	168	1711.8	1380.3	25.7	19.4
3/11	44.2	1 year	Surface	172	120	1134.6	599.4	30.2	47.2
			Subsurface	41	23	108.9	11.7	43.9	89.2
8/11	9.3	6 month	Surface	115	75	607.8	357.9	34.8	41.1

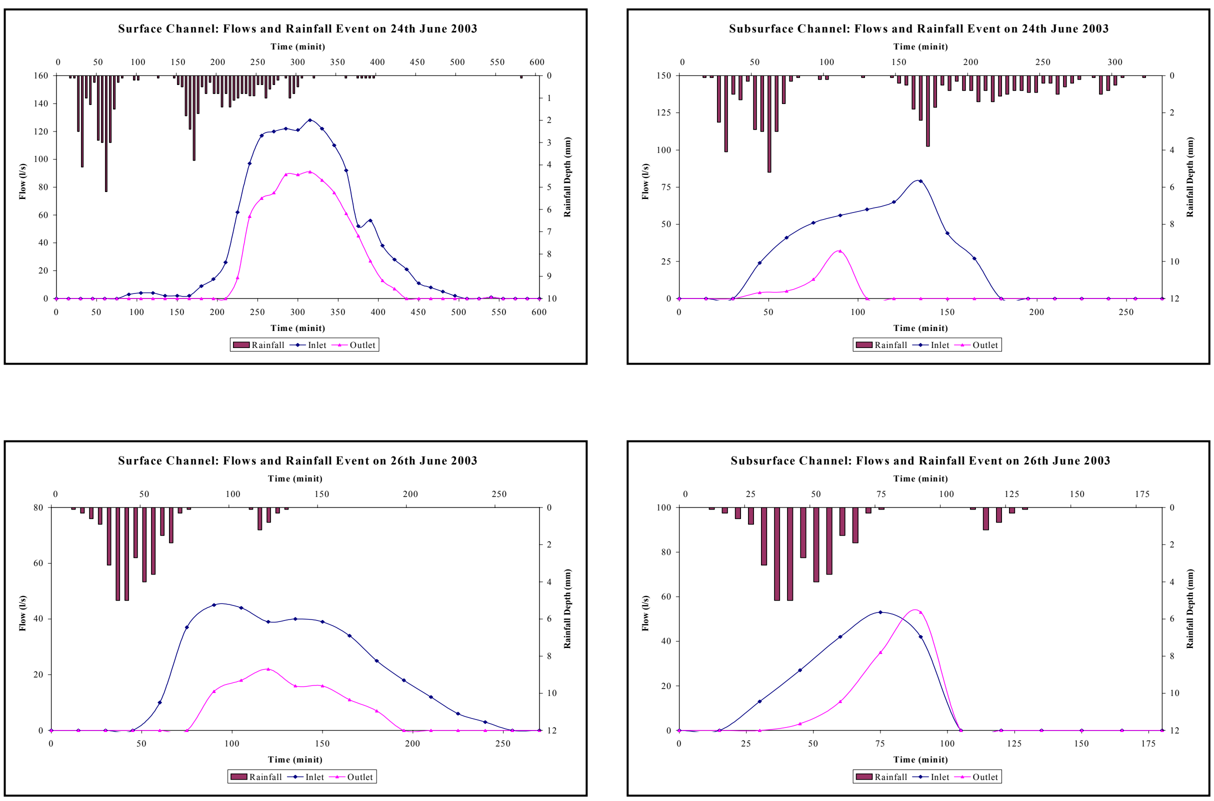


Figure 4 Inflow and Outflow Hydrograph for typical rainfall events

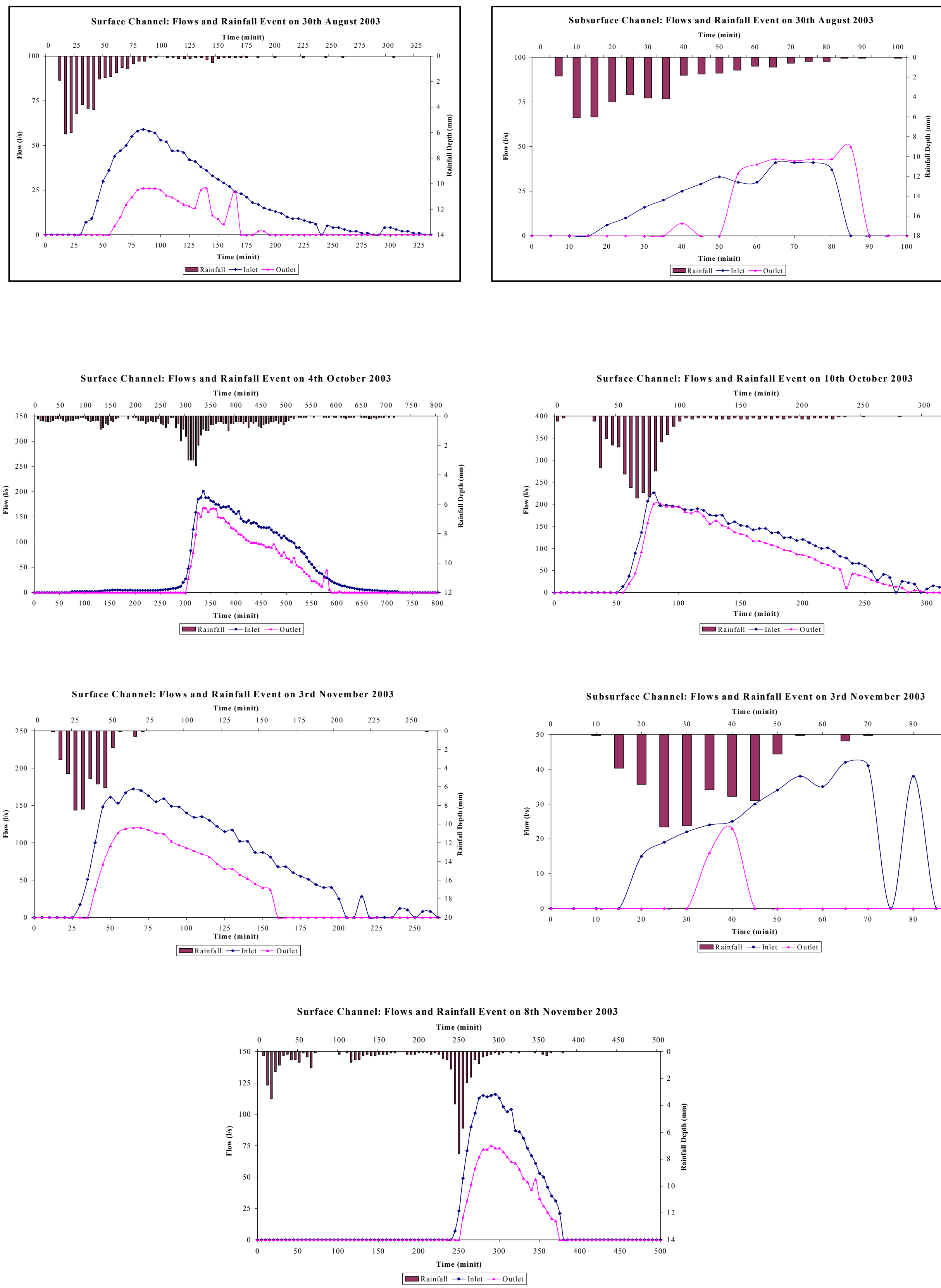


Figure 4 Inflow and Outflow Hydrograph for typical rainfall events (Continued)

4.2 RETENTION BEHAVIOR OF DRY POND

The water levels of five selected dry ponds, which are labeled as UWL 1 to UWL 5, on six typical rainfall events, are presented in the Figure 5. The water levels were measured using Ultrasonic Water Level sensors located at each dry pond outlet, to represent the retention behavior of BIOECODS' dry pond. The water level data are summarized and tabulated in Table 2.

Table 2 shows the emptying time of a dry pond depending on the Average Recurrence Interval (ARI). The higher ARI of a rainfall event, the longer time is needed for emptying the dry pond. For example, emptying time for dry pond UWL1 for the rainfall event on 8th of September 2003 with 5 year ARI is 48 hours, whilst 26 hours is needed to empty the dry pond for rainfall event with 3 month ARI, which fell on 30th of August 2003.

Table 2 Performance of Dry Pond on Typical Rainfall Event (June – November 2003)

Rainfall Event	Rainfall Intensity (mm/hr)	Average Recurrence Interval (ARI)	Location Dry Pond	Maximum Water Level at outlet (mm)	Emptying Time (hour)
17/6/2003	35.7	6 month	UWL 1	131	6
			UWL 2	560	16
			UWL 3	73	5
			UWL 4	429	19
			UWL 5	203	7
30/8/2003	14.5	3 month	UWL 1	210	26
			UWL 2	388	17
			UWL 3	144	20
			UWL 4	476	31
			UWL 5	268	15
8/9/2003	13.8	5 year	UWL 1	357	48
			UWL 2	669	36
			UWL 3	266	34
			UWL 4	511	44
			UWL 5	373	28
10/10/2003	33.6	2 year	UWL 1	321	45
			UWL 2	661	31
			UWL 3	242	24
			UWL 4	526	40
			UWL 5	356	21
3/11/2003	44.2	1 year	UWL 1	247	27
			UWL 2	505	25
			UWL 3	164	25
			UWL 4	503	36
			UWL 5	322	21
8/11/2003	8.3	6 month	UWL 1	240	33
			UWL 2	531	37
			UWL 3	169	30
			UWL 4	497	43
			UWL 5	300	22

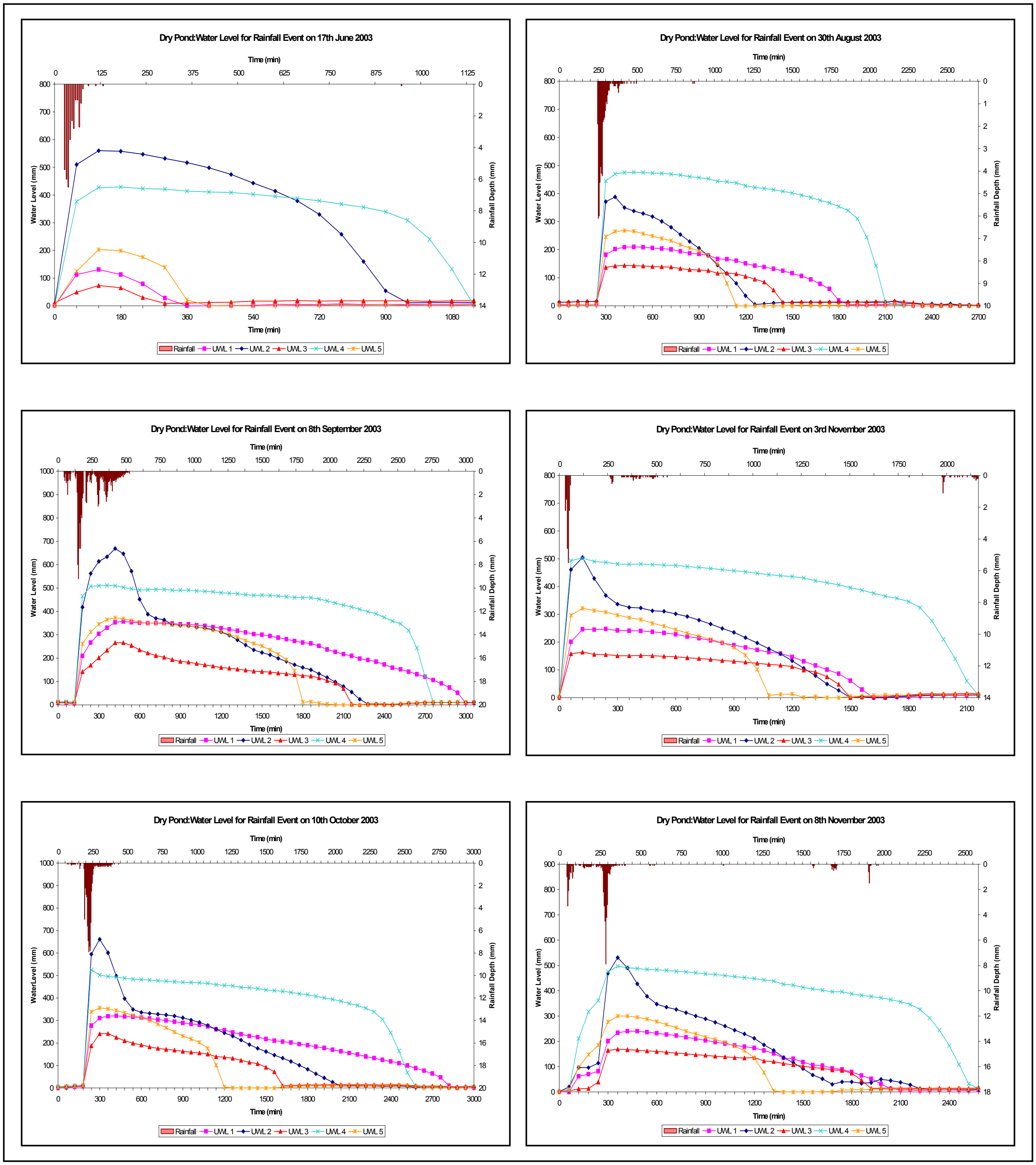


Figure 5 Water Level at outlets of UWL 1 to UWL5 on Typical Rainfall Events.

5. CONCLUSION

Nine different rainfall events were presented in this paper to show the ecological swale performance in attenuating flows. The results show that the volume reduction can be achieved at a minimum of 19.4% for surface channel and 23.7% for subsurface.

The retention behavior of the dry ponds has shown significant relationship between ARI and the emptying time. The higher ARI of a rainfall event, the longer time is needed for emptying the dry pond. It is shown that the five selected dry ponds perform very well in retention of the stormwater runoff for a typical duration before draining into the stormwater system, therefore avoiding the occurrence of inundation at the downstream end.

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