Performance for Flow Attenuation Using Subsurface Tanks: Case Study in USM Perak Branch Campus

LAU TZE LIANG, *Research Associate, River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

AMINUDDIN AB. GHANI, *Deputy Director, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

CHANG CHUN KIAT, *Research Officer, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

NOR AZAZI ZAKARIA, *Director, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

ROZI ABDULLAH, *Research Associate, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

ABSTRACT

Urbanisation of a catchment will always increase the quantity of strormwater runoff. To maintain the post-development peak flow of runoff equal or less to the pre-development peak flow of runoff as idealised in 'zero peak flow contribution', "control-at-source" concept is the crucial solution to minimise the impact development on stormwater quantity. This paper presents a case study of subsurface storage and infiltration tanks performance in Universiti Sains Malaysia Perak Branch Campus. Three types of storage and infiltration tanks were designed and their performance were evaluated through a 15-month data collection. These systems were constructed and then modified later to increase the flow attenuation. The results of this study can be used as a reference or a guide for designing a subsurface storage or infiltration tank at any designated flow reduction level of a similar system.

Keywords: storage tank; infiltration tank; peak flow reduction; detetion; retention.

1 Introduction

Malaysia is undergoing rapid development since the last two decades. The existing drainage system which adopts the rapid disposal practice has failed to keep up with the country's rapid pace of urbanization and industrialization. As a result, Malaysia is experiencing frequent flash flood over the years. The allocation for flood mitigation project has exceeded RM6000 million for the 8th Malaysian Plan (RM8) (DID, 2001). Flash flood has caused physical damage and mental stress to the people who live in flood risk areas. Due to the shortcoming of the previous drainage design approach, the government of Malaysia via Department of Irrigation and Drainage (DID) has taken an aggressive and immediate step to transform the design practice through the introduction of a new stormwater management manual. This new stormwater management manual, namely "Urban Stormwater Management Manual for Malaysia", supersedes the earlier guideline entitled "*Urban Drainage Design Standards for Peninsular Malaysia*", Planning and Design Procedure No. 1 published by DID in 1975 and utilises the 'control at source' concept for stormwater management. It is a comprehensive manual that takes into consideration of the present problems encountered by the nation such as flash flood, river pollution, soil erosion, development in the highlands and lowlands and so on.

The impact of urbanisation on a watershed has been well studied in the literature. From Roesner et. al. (2001), the resulting effect on the hydrology of the receiving water is dramatic, and flow peak are increased by a factor of 2 to more than 10. Development has not only increased the stormwater quantity, the frequency of the predevelopment peak flows has also significantly increased. In term of water quality, the development has deteriorated the quality on the receiving waterbody and degraded the environmental ecology and recourses.

2 Project Background

The project was located in previous USM Engineering Campus in Tronoh, Perak Darul Ridzuan as depicted in Figure 1. The objective of the project is to study the peak flow attenuation of stormwater for existing buildings. There were three types of subsurface on-site detention/retention systems being constructed namely Modular Storage Tank at Hydrology Laboratory (Figure 2), Loose Rock Infiltration Tank at Jaya Hostel (Figure 3) and Modular Infiltration Tank at Multi-purpose Hall (Figure 4). Even though the design of these subsurface tank systems were carried out in early 1999 before the new urban stormwater management manual has been introduced, the main objective of this project is in line with the direction the new stormwater management manual.

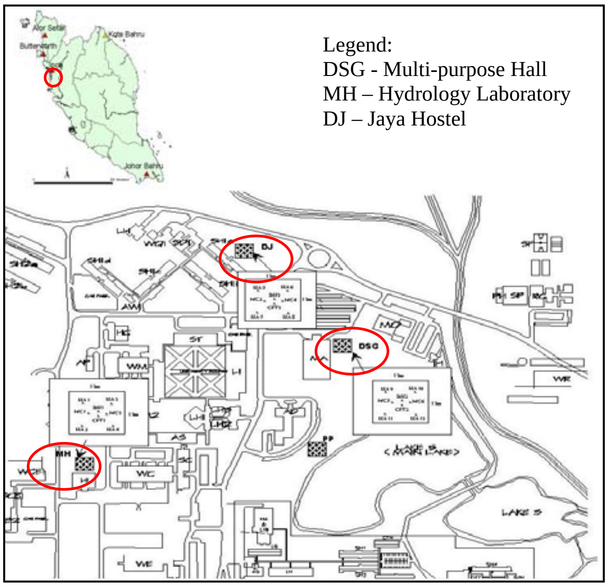

Figure 1 Project Location.

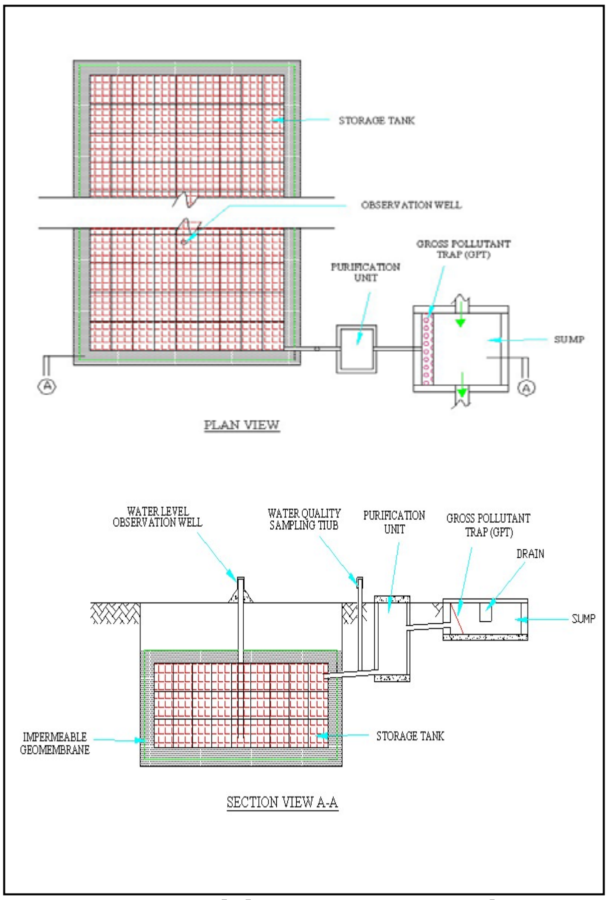

Figure 2 Modular Storage Tank at Hydrology Laboratory.

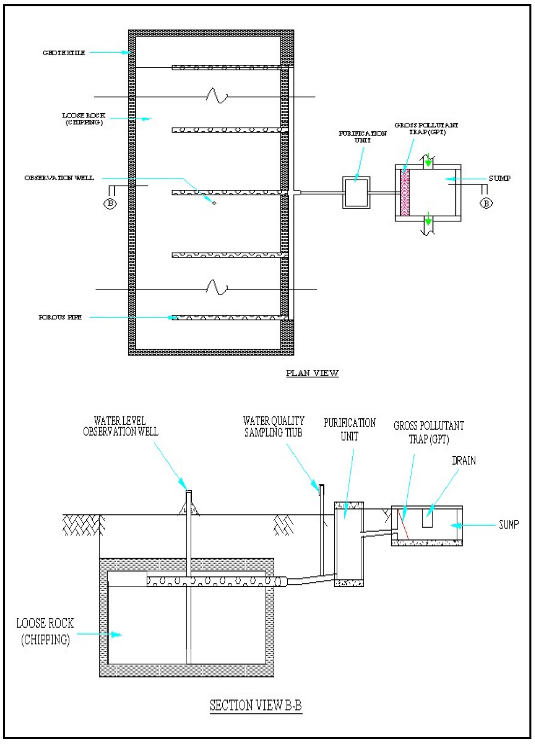

Figure 3 Loose Rock Infiltration Tank at Jaya Hostel.

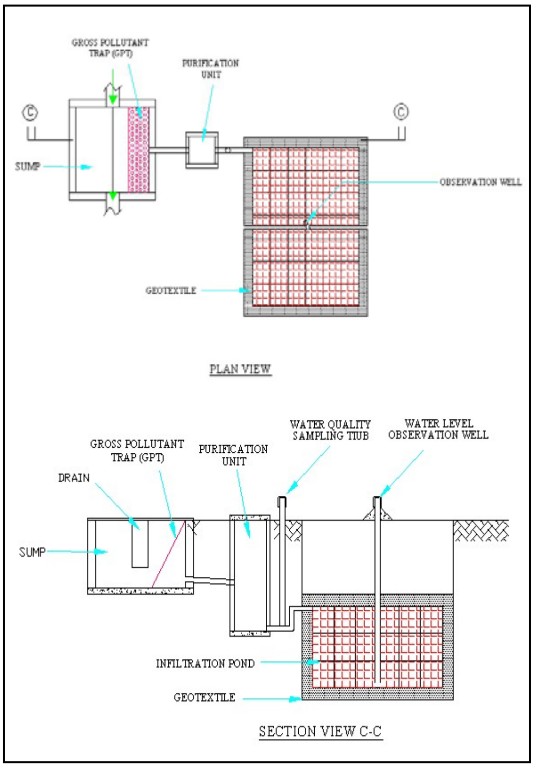

Figure 4 Modular Infiltration Tank at Multi-purpose Hall.

Since the absence of the new stromwater management manual at the beginning of the project, these systems were designed based on criteria recommended in the previous design guideline (DID, 1975), Atlantis Water Management Engineering Design Manual (Atlantis, 1998) and Infiltration Drainage – Manual of Good Practice (CIRIA, 1996). These criteria are adopted for tank system design based on each particular site condition such as soil strata in surrounding medium, infiltration capacity and ground water level.

The coverage catchment areas are $1296m^2$, $1125m^2$ and $2500m^2$ respectively for three study sites i.e. Hydrology Laboratory, Jaya Hostel and Multi-purpose Hall.

3 Subsurface Tank System

The systems were designed as detention (Modular Storage Tank) or retention (Loose Rock Infiltration Tank and Modular Infiltration Tank) storage facilities. The flow was diverted from channel into storage tanks by uPVC pipe which was connected between sump and subsurface storage tanks. The outflow from the channel was regulated by control structure which consists of sump and uPVC pipe. The details of sump is shown in Table 1. There were two cases of control structures being studied during this project as tabulated in Table 2.

Table 1 Details of Sump

Parameter	Location		
	Hydrology Laboratory	Jaya Hostel	Multi-purpose Hall
Length (m)	1.68	1.55	1.70
Width (m)	1.68	1.55	1.70
Depth (m)	0.4	0.5	1.1
Distance of uPVC pipe from Sump Invert (mm)	50	50	50
Distance of Outlet Channel from Sump Invert (mm)	70	195	335

Table 2 Details of uPVC Pipe for Two Cases.

Parameter	Location		
	Hydrology Laboratory	Jaya Hostel	Multi-purpose Hall
Case 1 (original design)			
Size	3"	3"	3"
Slope	5%	5%	5%
Capacity (m^3/s)	0.0085	0.0085	0.0085
Case 2 (modified design)			
Size	2 nos 6"	6"	2 nos 6"
Slope	5%	5%	5%
Capacity (m^3/s)	0.104	0.052	0.104

The construction of these systems took approxiametely half a month for each system from end of 1999 to early of 2000. The construction procedure includes excavation for storage tank, sand bedding, installation of modular tank or loose rock tank, sand filling, backfilling and turfing. The anxillary works of the system are pipe connections, installation of purification unit and control structure.

The data of rainfall and water flow at inlet and outlet channels were retrieved from automatic data collection system. SIGMA 950AV which is integrated with the rain gauge and area-velocity flow probe was installed as the main device of the data collection system. Data collection was carried out for a 15-month duration (July 2000 to September 2000) which covers dry and wet seasons in West Peninsular Malaysia.

4 Result and Analysis

The results of this study are summarised in Figures 5 to 7 for three different study sites in this project. Two cases of control structures known as Case 1 and Case 2 were considered as elaborated above with the latter case had increased flow capacity into storage tank. The performance of the system is measured by the percentage of flow reduction as given in y-axis while x-axis denotes the channel flow at inlet channel. The difference of inlet and outlet channel flow is considered as flow reduction.

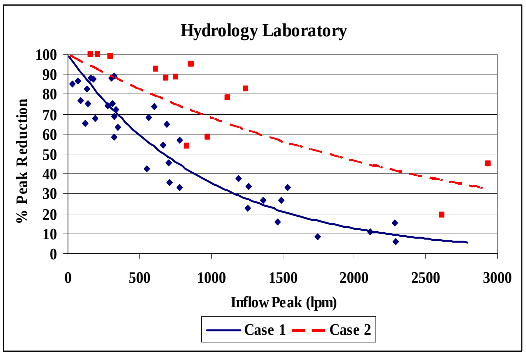

Figure 5 Hydrology Laboratary.

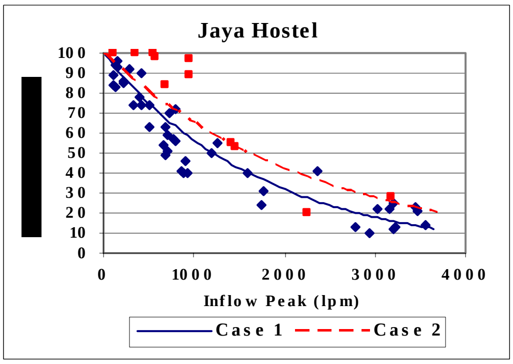

Figure 6 Jaya Hostel.

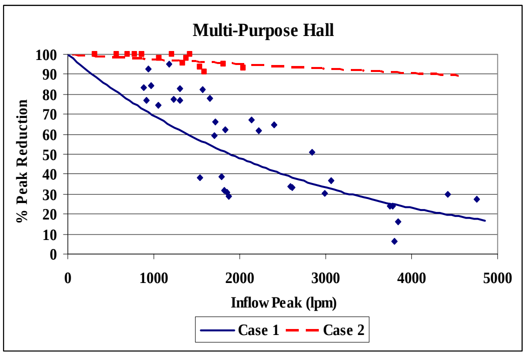

Figure 7 Multi-purpose Hall

The performance of the system is clearly related to the characteristic of the control structure. From the results, Multi-purpose Hall has the highest percentage of peak flow reduction followed by Jaya Hostel and Hydrology Laboratory. The peak flow attenuation is propotional to the storage volume below the outlet channel invert in the sump as given in Table 1. The system at Multi-purpose Hall has 0.97m^3

detention volume compared to Jaya Hostel and Hydrology Laboratory with 0.47 m^3 and 0.20 m^3 respectively before the runoff starts flowing out from the sump providing that the subsurface storage is not full and the distance between uPVC pipe invert and sump invert are the same for all these systems.

In term of comparison for Case 1 and Case 2, it is obviously found that the performance of Case 2 is better than Case 1. Case 2 with higher capacity of uPVC pipe due to either increase the pipe nominal diameter size or pipe quantity gives improvement of peak flow attenuation by 28.6%, 14.5%, 58.3% at peak nflow of 2500 liter per minute (lpm) for Hydrology Laboratory, Jaya Hostel and Multi-purpose Hall respectively.

Figures 8 and 9 illustrate the relationship for storage depth versus duration of rainfall for retention storage tanks. Three rainfall events (8, 9 and 10 January 2001) are being compared. The characteristic of these rainfall events are given in Table 3 and Table 4.

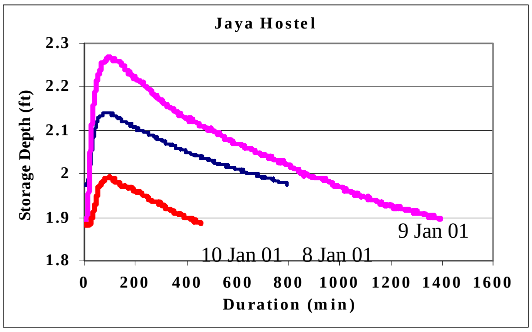

Figure 8 Storage Depth of Loose Rock Infiltration Tank.

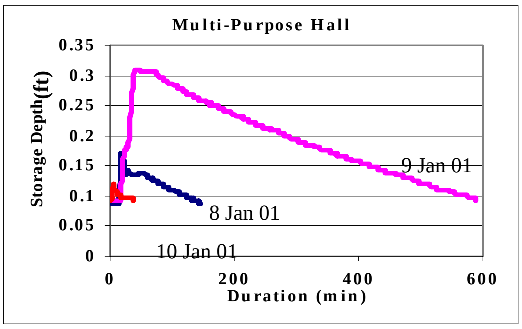

Figure 9 Storage Depth of Modular Infiltration Tank

Table 3 Rainfall Characteristic for Loose Rock Infiltration Tank

Date	Rainfall Depth (mm)	Rainfall Duration (min)	Inlet Peak Flow (lpm)
8 Jan 01	6.04	40	111.6
9 Jan 01	12.44	24	517.8
10Jan 01	5.25	65	83.5

Table 4 Rainfall Characteristic for Modular Infiltration Tank

Date	Rainfall Depth (mm)	Rainfall Duration (min)	Inlet Peak Flow (lpm)
8Jan 01	6.79	38	1352.7
9Jan 01	14.95	34	2217.2
10Jan01	4.75	47	739.3

The time to empty the storage tank is governed by the characteristic of the surrounding soil. Soil classification and infiltration tests were carried out in these sites to determine the soil characteristics. The results show that the soil adjacent to Multi-purpose Hall and Jaya Hostel are classified as silty sand to coarse sand with high permeability with infiltration coefficient of 0.084m/hr and 0.018m/hr respectively.

Generally, loose rock infiltration tank requires longer empty time and larger storage tank compared to modular infiltration tank to cater for the same event even though it has smaller peak flow in this study.

The relationship in Figures 8 and 9 can be represented in term of volume versus event duration as depicted in Figures 10 and 11. Comparison of inflow volume and storage volume at a particular time was made. Inflow volume is calculated from the difference of inlet and outlet flow at every interval of 1 minute while storage volume is calculated from recorded water level in the storage tank. The difference between inflow and storage volume is resulted by the outflow through infiltration process. Modular infiltration tank at Multi-purpose Hall records significant reduction for these volume differences due to its higher infiltration rate at surrounding soil and larger effective area for infiltration occurred compared to loose rock infiltration tank at Jaya Hostel. This also indicates that the actual required storage volume can be reduced if the characteristic of the surrounding soil is known.

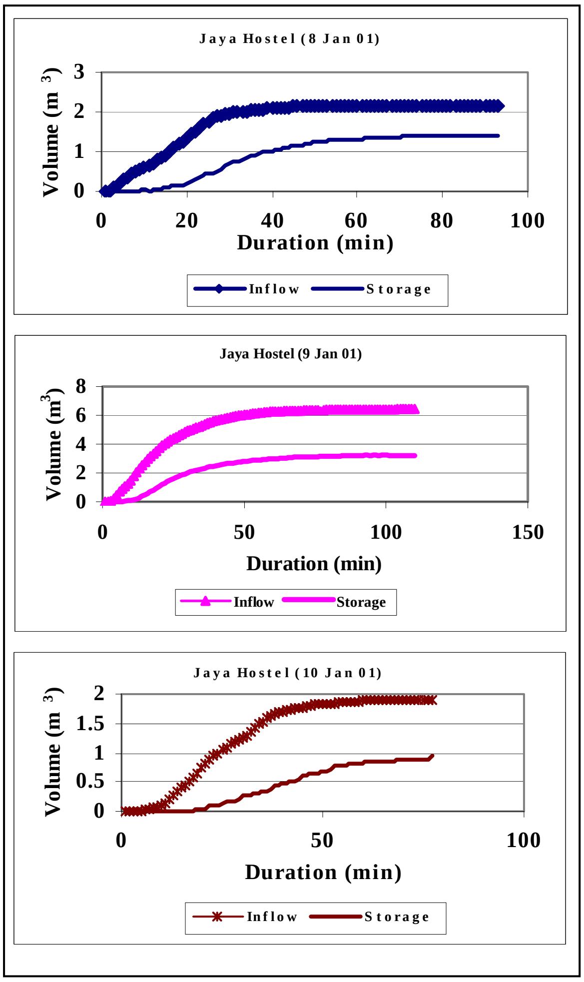

Figure 10 Comparison of Inflow and Storage Volume for Loose Rock Infiltration Tank.

5 Conclusion

The above-shown results are usefull for the designers who involve in designing stormwater detention/retention storage tank systems. The designers should pay attention for the provision of control structure which will affects the performance of the system. Apart from that, the surrounding soil characteristic will influence the sizing of the storage tank required. Therefore, it is important to carried out soil test so that the storage tank provided will be more economic.

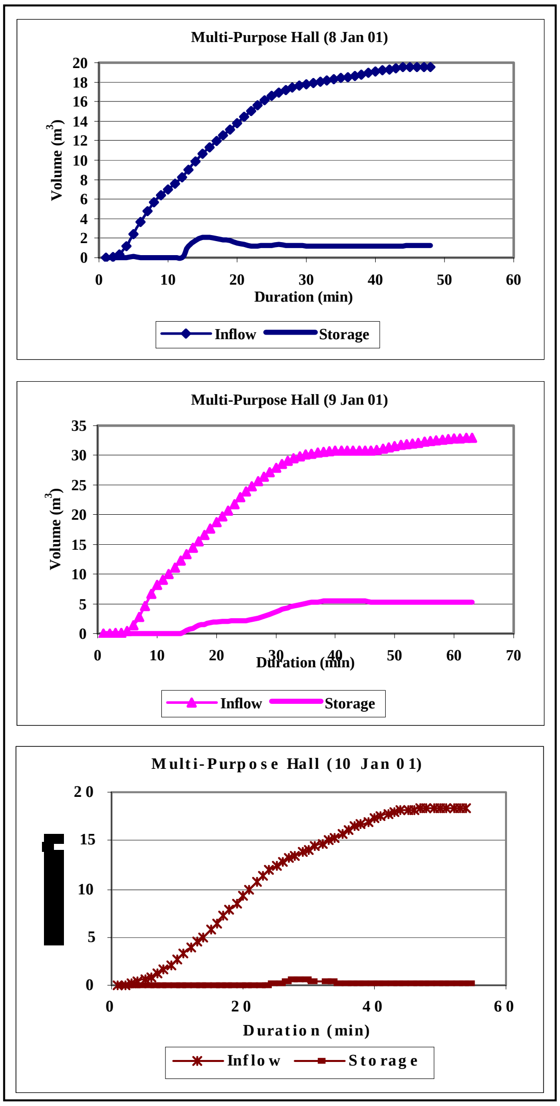

Figure 11 Comparison of Inflow and Storage Volume for Modular Infiltration Tank.

The results can also be utilised as a baseline for designing a similar system with designated flow attenuation rate at the designated average recurrence interval. By adjusting the parameter of control structure, the desired objective of the system can be achieved.

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