Potential and Effectiveness of Rainwater Harvesting in Enhancing the Effectiveness of On-Site Detention (ROSD) Facilities in Controlling Surface Runoff at Taman Wangsa Melawati, Kuala Lumpur

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Flash flood is becoming more prevalent nowadays in big cities in Malaysia. Rapid and uncontrolled development projects aggravate the problem. . Lack of space for the construction of flood mitigation facilities has prompted authorities to look for other solutions for flood control. One of the approaches is to regulate flow at the upstream area. That is why this study area (Taman Wangsa Melawati), which is located at the upstream of Klang river basin was selected for the study. Taman Wangsa Melawati catchment, which drains to Sg. Gisir is used in this study to evaluate the impacts of RROSD design for storm water management at a small scale. The catchment is fully developed where 83 percent of the area is covered by impervious surfaces. The RROSD with a total storage capacity of 5.0 cubic meter located at one of the houses. 3.3 cubic meter is for rainwater storage, while 1.7 cubic meter is for flood storage. The ROSD was evaluated in its efficiency in reducing peak flow from roof runoff. The cumulative impact of peak flow reduction at the outlet was also evaluated, if each of the houses was equipped with this facility. XP-SWMM model was used to quantify the cumulative reduction of peak flow by the usage of multiple ROSD in the study area. The model was calibrated prior to its application of various hypothetical scenarios. Outflow from the ROSD is released automatically through pipe outlets to the receiving drain. The result shows that the existing ROSD design performs satisfactorily at individual house level, though it did not comply with the PSD limit as set by MASMA. However, the performance was not extendable to the catchment level. The fact that the percentage of overall peak flow reduction at the outlet is below the percentage of reduction of individual ROSD shows that the cumulative effect has reduced the performance of the ROSD. The result shows that, it is best to place the ROSD at the end of each street rather than at a single house. Storm water reuse for this ROSD provides another potential in not only in reducing peak flow but also in reducing storm water volume. Result from data collection at this house shows that about 3.4 m^3 of storm water were reduced from entering the receiving drain in a month. If every house within the area is equipped with ROSD, significant volume of runoff (823 m^3/month) is prevented from flowing to the outlet. This will help alleviate the problem of cumulative effect at the outlet.

Keyword: Flash Flood, On-Site Detention, XP-SWMM, Laurenson's Method, Cumulative Effect and Forecasting and Mitigation.

1.0 Introduction

Flash flood is becoming more like a common phenomenon nowadays in big cities in Malaysia especially Kuala Lumpur. Flash flood rarely causes death but it causes extensive damage to properties and inconvenience to resident of the city. This problem has somehow become more critical over the years when more physical development taking place in the upstream area of the river basin. Despite of numerous flood mitigation projects within the river basin, the flash flood problem still exists. These projects such as river widening, deepening and raising bund level are merely providing short-term solution. Therefore, new approach needs to be adopted in order to provide long term solution, while continuing with the ongoing flood mitigation project to overcome the existing flash flood problem. The approach by DID to implement the new drainage manual (MASMA) is a step in the right direction in providing long-term solution towards solving this problem. The new approach is to introduce control measures at the source of the problem. One of the controls at source approach that can be applied to help reduce flash flood is the On-site Detention (ROSD) method. The outflow from an ROSD has to comply with the criteria specified by the authorities also known as Permissible Site Discharge (PSD). To achieve the PSD limit, the design of the Site Storage Requirement (SSR) should be adequate to take various design storms. In that study, an experimental above ground storage tank was constructed in one of the link houses in the study area to capture surface runoff from roof. The runoff from that lot was stored temporarily in the storage tank and released gradually to the receiving drain. The effectiveness of the ROSD tank depends on the peak flow reduction under various durations and return period. An urban storm water model (XP-SWMM) was used to simulate the peak flow reduction for a single house and other hypothetical conditions.

1.1 Study Objectives

1) To calibrate and validate rainfall-runoff model (XP-SWMM) for the

Taman Wangsa Melawati catchment.

2) To apply the calibrated model for hypothetical simulation (design storm without ROSD within the study area)
3) To apply the calibrated model for hypothetical simulation (design storm with ROSD at various land use within the study area)

1.2 Scope of Work

To achieve this objective, the following scope of work will be performed;

1) Collect and collate rainfall and streamflow data
2) Determination of catchment characteristics
3) Determination of hydrologic parameters and hydraulic characteristics of the study area
4) Calibration of hydrologic and hydraulic parameters of the rainfall-runoff model
5) Application of the calibrated model for various hypothetical simulation of the study area. The hypothetical simulation includes application of design storm to the calibrated model for the study area assuming that there is no flood detention structure (ROSD). The other scenario involves the application of the same design storm to the study area but this time it is assumed that the study area is equipped with flood detention structure (ROSD). It is assumed that each terrace house is equipped with an ROSD with the detention storage volume of about 1.7 cubic meter. The other land use within the study area is also equipped with ROSD. For example, it is proposed that the shop houses are equipped with a single ROSD with storage volume of about 10 cubic meter, surau with the ROSD storage volume of 10 cubic meter, kindergarten with detention storage volume of 20 cubic meter and a community rain water tank (RWT) with a storage volume of about 40 cubic meter for the park. However, the storage for playground and kindergarten are not feasible due to lack of space and height. The storage for the surau and park is more suitable due to the availability of ample space and its elevation being slightly higher than the

receiving drain.

1.3 Methodology

The methodology used in this study is to collect field data and to use these data for the process of calibration of the hydrologic and hydraulic parameters that are used for the selected computer model. The calibrated XP-SWMM rainfall-runoff model will be used in this study to estimate surface runoff at the outlet. Observed rainfall and streamflow data will be collected during storm events at the outlet of the catchment. Flow rating curve will also be established at the outlet using the recorded water level and flow. Field infiltration parameter will also be measured at the site using double ring infiltrometer. The approach used in this study is to use a calibrated model to simulate the surface runoff from roof to the storage tank and later on route the flow through the storage tank to the outlet. The outflow to the receiving drain will be combined with surface runoff flow from the road. The model will determine the effectiveness of the existing above ground storage (ROSD) tank in regulating surface runoff from a typical residential. The design storms considered in this study are 15, 30, 60 and 120 minute storm durations of 10, 50 and 100 year ARI. Rainfall intensity and duration will be derived using the polynomial equation for Kuala Lumpur. The effective rainfall will be transformed in to storm flow hydrograph using Laurenson's method. The generated storm flow hydrograph serves as an input to the storage routing model. The process of calibration of hydrologic parameters requires observed storm and stream flow data. These data need to be collected at site.

1.4 Monitoring Instruments

Observed field data are required for the calibration and validation of model parameters. The data required for these processes are rainfall and stream flow data. The instruments that are necessary for the collection of these data are flow meter and rain gage. One automatic rain gage will be installed at the outlet while the other one was already installed on the roof of one of the houses in the study area. (No 46, Jln Wangsa Siaga 1). **Figure 1.3.1** shows the proposed location of the equipments to be installed in the study area. Flow meter is to measure stream flow while rain gage is to measure rainfall. A flow meter was placed at a location, which represents the outlet of the study area. The automatic water level recorder with data logger was installed at the outlet of the catchment. The shape of the monsoon drain is rectangle with a semi circle drain for dry weather flow. The shape and size of the drain is shown in **Figure 1.3.1.1**. Double ring infiltrometer will be used to determine Horton infiltration parameters for the pervious area such as the playing field.

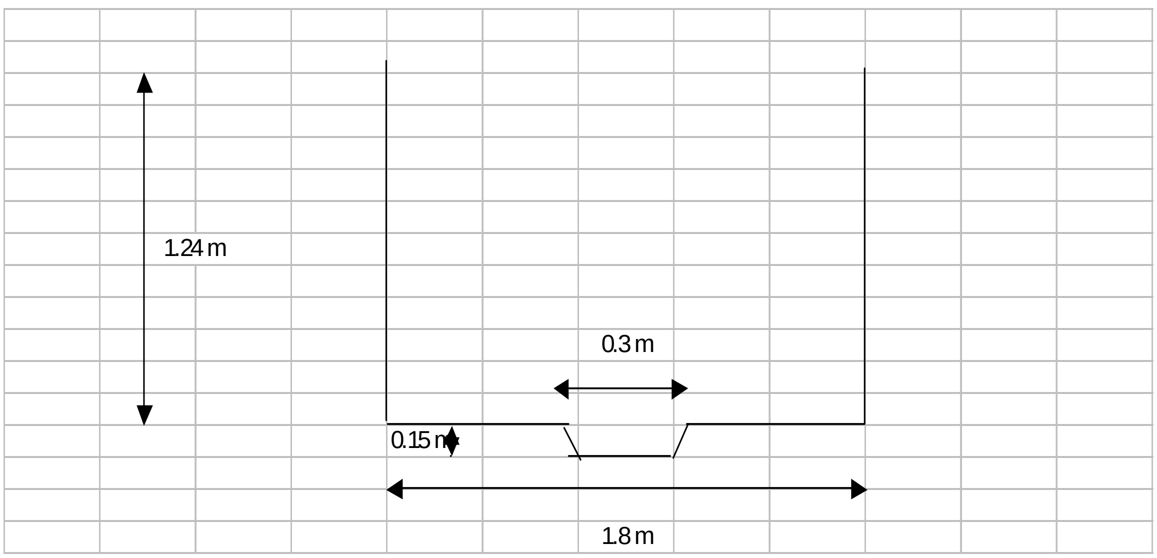


Figure 1.3.1.1: River Cross Section at the Outlet

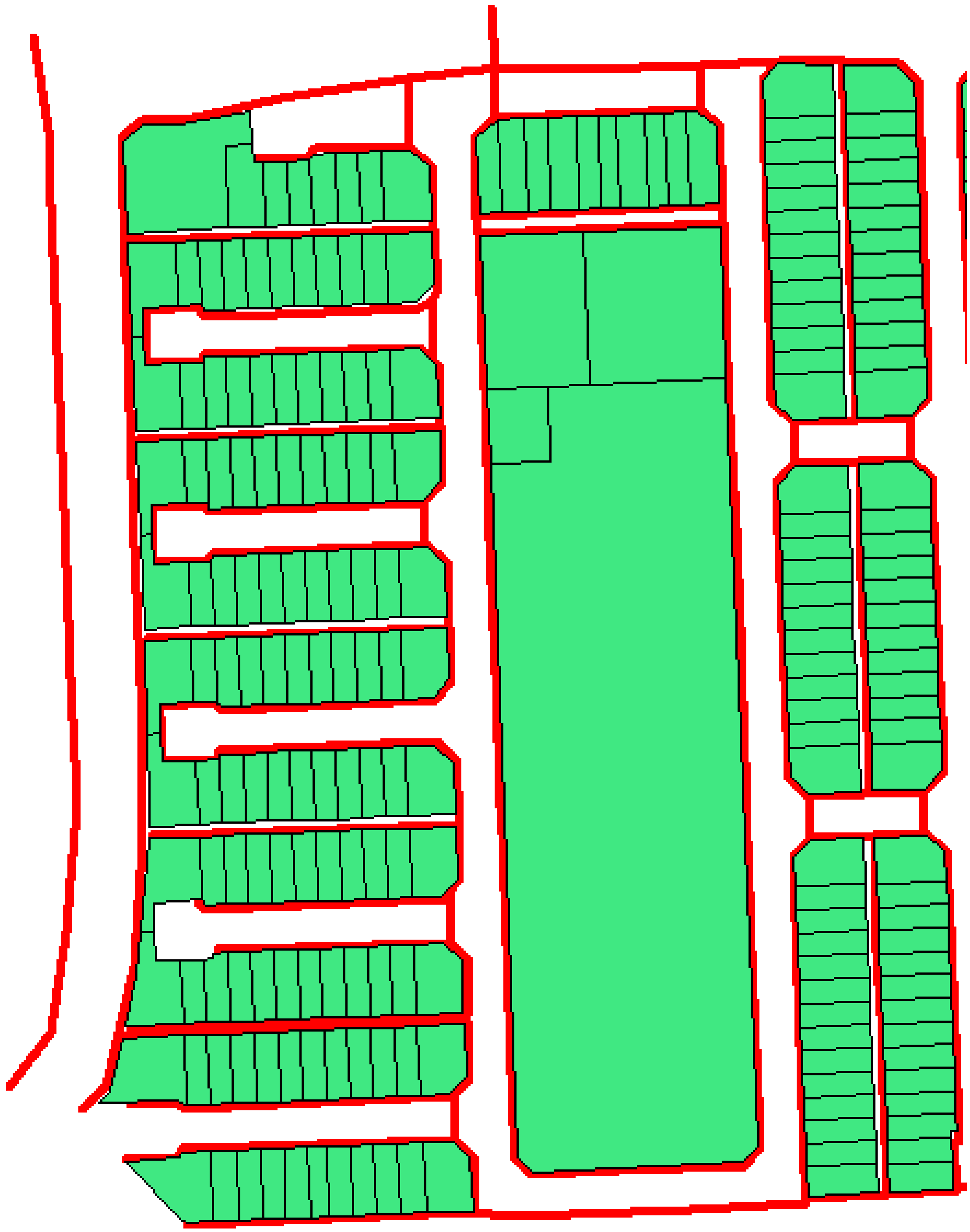


Figure 1.3.1: Location of Rain Gauges and Water Level Station

2.0 Study Area

The study area is a residential area located in the upstream part of Sg. Klang river basin called Taman Wangsa Melawati. This housing area is sandwich between Taman Permata and Wangsa Melawati. This housing area drains surface runoff flow to Sg. Gisir, which is a tributary of Sg. Klang. Location of the study area is shown in **Figure 2.1**. The catchment area covers Persiaran Wangsa Melawati on the north, Jalan Wangsa Melawati 4 in the south, Jalan Wangsa Melawati 1 on the east and Jalan Wangsa Siaga 1 on the west. The pentagon shape catchment area covers an area of **7.6 hectares**.

2.1.1 Land Cover

Land cover in this catchment is predominantly residential area. The residential area consists primarily of link double story houses, shop houses, surau, children playground and a kindergarten. The breakdown of different land cover and the area it occupies are listed in **Table 2.1.1** and shown in **Figure 2.1.1**. Most of the area is covered with impervious area. It occupies about **83 percent** of the catchment area.

Table 2.1.1: Land Cover and its Area

Land Cover	Numbers	Area (m^2)	Percentage (%)
Double Storey House	242	31504	43.9
Double Story Shop House	10	1505	2.1
Park/Lawn	1	12484	17.4
Surau	1	1414	1.97
Play Ground	1	312	0.43
Kindergarten	1	1059	1.48
Roads	1	23515	32.7
Total		**71793**	**100**

2.1.2 Topography And Drainage

Topography in the catchment area is relatively flat. The topography ranges from 67.8 m at the upstream area and 58.8 m at the outlet. Ground level and invert level in the drainage system are measured at site. Drain invert level shows that certain section of the drainage system is affected by accumulation of sediment.

The drainage system in this area is a typical traditional type of drainage system where runoff is being disposed at the earliest possible. Runoff from roof flows straight to the receiving drain through gutter and perimeter drain. Runoff from roof and roadside combines in the roadside drain and later on flows to the main drain at the outlet. Layout of the drainage system, flow direction and catchment outlet is shown in **Figure 2.1.2.** Flow inside the drain is basically gravity flow. Drains in the study area are basically made of concrete drain with concrete cover on top of it. Information on the drains such as drain sizes, length and slopes are measured at site, which serves as an input to SWMM model.

2.1.3 Existing On-Site Detention Storage Tank

An above ground storage tank was installed at one of double story house to capture runoff from the roof and discharge it to the receiving drain. The roof area that contributes flow to the above ground storage tank is about 60 meter square. Outflow from the storage tank is through primary and secondary outlet. However, the primary outlet is normally closed. The above ground storage tank was designed for dual purpose, which is for rainwater reuse and for flood flow detention. **Figure 2.1.3** shows the conceptual design of the storage tank. About 3300 liter of storage is allocated for rainwater reuse (bottom portion), while 1700 liter is for detention storage (top portion). The storage tank measures about 11 feet long, 4 feet wide and 3 feet deep. The storage tank has two outlets for the purpose of flood detention control facilities. Primary outlet is through a 2 inch PVC pipe with a control valve. However, the secondary outlet is a 3-inch PVC pipe without any control valve. Primary outlet is located slightly above the rainwater reuse storage level. Secondary outlet is located 45 cm above the rainwater reuse storage level.

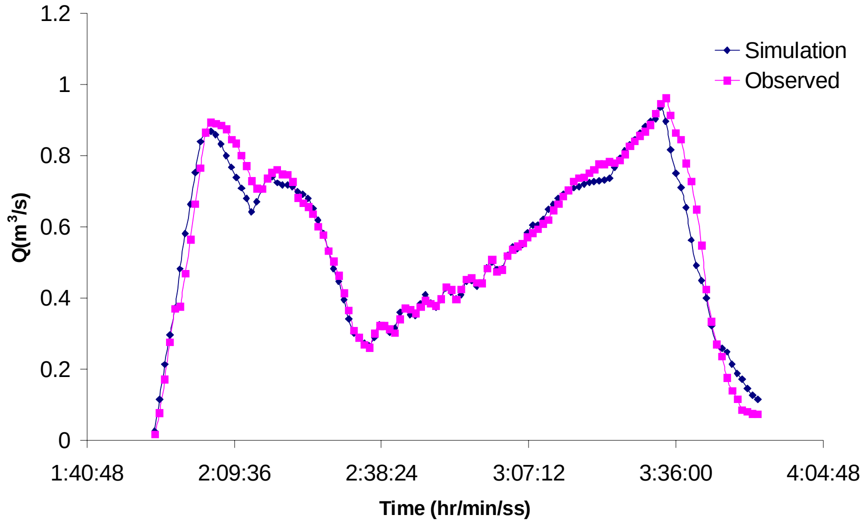
3.0 Result and Analyses

XP-SWMM was used in this study to determine the effectiveness of ROSD in regulating flow from an urbanized catchment area. In order to ensure reliability of the simulation result, the model has to be calibrated first. The model was mainly calibrated for its hydrologic parameter especially the transformation parameters using Laurensons method (B and n).

3.3 Model Calibration

Al though the data collection period was for 6 months, not much quality data were collected during that period. The collection program did not proceed smoothly as it was plagued with problem at site such as vandalism and technical problem. Therefore, we were quite fortunate to obtain one complete storm event over the data collection program for the purpose of calibration. The recorded storm event (**27th February 2005**) and recorded water level were used for the calibration process of catchment routing parameters.

The calibration process is the process of adjusting the catchment routing parameters so that the simulated flow hydrograph is similar to the observed flow hydrograph. The similarities between the simulated and observed flow hydrograph result is measured through an efficiency index. From the calibration process, using the 27th February 2005 event, the results shows good correlations as presented in a graphical form (**Figure 3.3.1**). The efficiency Index (EI) for the calibration results shows good correlation that is about **96.34 %**.



3.4 Application of the Calibrated Model

The calibrated model was applied to the three different hypothetical scenarios as described earlier in the methodology of the study. The playing field will be divided in to two sections, one flowing to the receiving drain node called Park 1 and Park 2 as shown in **Figure 2.1.3**. Each node was provided with a storage volume of 20 meter cube each. It is assumed that the field is 100 percent pervious and the soil type is clay soils. The calibrated SWMM model was used to simulate the impact of flow reduction at the outlet of the catchment due to the installation of ROSD. The peak flow reductions from a single house with ROSD for the 30 minute storm events ranges from **48 to 66 %** for10, 50 and 100 year ARI.

3.4.1 Scenario 1 (S1): Without ROSD

In the first scenario, it is assumed that there is no ROSD within any land use of the study area. Road area covers about **32.7 %** of the total catchment area. It is also assumed that half of the road will generate runoff to each node with an equivalent surface area of about **33 m²**. The average catchment area for each house is assumed to be 150 square meter. The simulated peak flow at the outlet of each street for different storm events with various ARI and storm duration is shown in **Table 3.4.1**.

Table 3.4.1: Simulated Peak Flow (m^3/s) at Outlet of Each Street Without Storage

	15 Minute Storm Duration			30 Minute Storm Duration		
	10 Yr	50 Yr	100 Yr	10 Yr	50 Yr	100 Yr
Street 1	0.29	0.325	0.35	0.276	0.325	0.35
Street 2a	0.16	0.12	0.134	0.094	0.112	0.124
Street 2b	0.38	0.41	0.44	0.36	0.42	0.45
Park N Shop House	1.25	1.55	2.05	1.1	1.32	1.45
Street 3	0.66	0.155	0.17	0.11	0.19	0.145
Outlet	2.15	2.5	2.8	1.92	2.3	2.5

	60 Minute Storm Duration			120 Minute Storm Duration		
	10 Yr	50 Yr	100 Yr	10 Yr	50 Yr	100 Yr
Street 1	0.245	0.29	0.305	0.17	0.37	0.37
Street 2a	0.086	0.102	0.108	0.049	0.145	0.17
Street 2b	0.33	0.38	0.39	0.23	0.47	0.48
Park N Shop House	0.99	1.2	1.3	0.52	1.9	2.1
Street 3	0.185	0.12	0.132	0.052	0.19	0.21
Outlet	1.75	2.05	2.2	1.04	3	3.3

3.4.2 Scenario 2 (S2): With ROSD (Houses Only)

In the second scenario, it is assumed that the generated surface runoff is to flow to an ROSD before entering the receiving drain. It is assumed that each house has a single ROSD with a storage volume of about 1.7 meter cube. The number of houses assumed to be installed with this ROSD is 242 houses with a total storage volume of **411 meter cube**. The comparison of generated peak flow hydrograph to each street outlet is shown in **Table 3.4.2**, while **Table 3.4.2a** shows the peak flow reduction in percentage. The result shows that the percentage of peak flow reduction at the outlet of each street is quite consistent (**about 25 percent**). The percentage of peak flow reduction at the outlet of the catchment (**about 22 percent**) is however less than the reduction for a single house (**about 50 percent**). This shows that the position of the ROSD that is in parallel position did not reduce peak flow satisfactorily at the end of each street and at the outlet. The result also shows that the position of ROSD's on **Street 3** produces the least peak flow reduction **(–3 to 29 percent)**.

Table 3.4.2: Comparison of Simulated Peak Flow (m^3/s) at Outlet of Each Street With Storage at Houses Only and Without Storage

	Without Any Storage (S1)			With Storage (House Only) (S2)		
	30 Minute Storm Duration			30 Minute Storm Duration		
	10 Yr	50 Yr	100 Yr	10 Yr	50 Yr	100 Yr
Street 1	0.276	0.325	0.35	0.218	0.24	0.245
Street 2a	0.094	0.112	0.124	0.0717	0.078	0.086
Street 2b	0.36	0.42	0.45	0.2465	0.27	0.285
Park N Shop House	1.1	1.32	1.45	1.1	1.32	1.45
Street 3	0.11	0.19	0.145	0.111	0.134	0.15
Outlet	1.92	2.3	2.5	1.52	1.75	1.95

Table 3.4.2a: Comparison of Peak Flow Reduction (%) at Outlet of Each Street With Storage at Houses Only and Without Storage

	% Reduction of Peak Flow (S1)		
	10 Yr	50 Yr	100 Yr
Street 1	21	26	30
Street 2a	24	30	31
Street 2b	32	36	37
Park N Shop House	0	0	0

Street 3	-1	29	-3
Outlet	21	24	22

3.4.3 Scenario 3 (S3): With Storage (Houses, Surau and Park)

In the third scenario, it is assumed that the generated surface runoff hydrograph flows directly to the drainage system with ROSD for houses, surau and park. The comparisons of simulated peak flow hydrograph at the outlet of each street for different storm events is shown in **Table 3.4.3,** and **Table 3.4.3a** shows the comparison of peak flow reduction in percentage for each street. The comparison of peak flow reductions at the outlet (with (**S3**) and without ROSD (**S1**)) for these storm events is about **70 %** for 30 minute storm. The percentage of peak flow reduction at the catchment outlet shows significant increase from **Scenario 2 (S2)** to **Scenario 3 (S3)**. The peak flow reduction has increased from about **24 % (S2)** to about **70 % (S3)**. The main contribution of the peak flow reduction comes from the storages provided for the park and surau. The total combine storage provided by surau and park is **60 meter** cube as compared to storage provided by houses that is **411** meter cube. These storages are located at the end of each street of this land use. This further strengthened the conclusion that the storages need to be positioned strategically in order to achieve maximum result.

Table 3.4.3: Comparison of Simulated Peak Flow (m^3/s) at Outlet of Each Street With Storage (House, Park & Surau) and Without Storage

	Without Any Storage (S1)			With Storage (House ,Park, & Shop House) (S3)		
	30 Minute Storm Duration			30 Minute Storm Duration		
	10 Yr	50 Yr	100 Yr	10 Yr	50 Yr	100 Yr
Street 1	0.276	0.325	0.35	0.207	0.23	0.26
Street 2a	0.094	0.112	0.124	0.0684	0.076	0.086
Street 2b	0.36	0.42	0.45	0.2445	0.272	0.295
Park N Shop House	1.1	1.32	1.45	0.14	0.158	0.175
Street 3	0.11	0.19	0.145	0.111	0.134	0.15
Outlet	1.92	2.3	2.5	0.624	0.68	0.76

Table 3.4.3a: Comparison of Peak Flow Reduction (%) at Outlet of Each Street With and Without Storage at Houses Only

	% Reduction of Peak Flow (S3)		
	10 Yr	50 Yr	100 Yr
Street 1	25	29	26
Street 2a	27	32	31
Street 2b	32	35	34
Park N Shop House	87	88	88
Street 3	-1	29	-3
Outlet	68	70	70

The total peak flow reduction at the outlet with ROSD installed at every house can be considered unsatisfactory due to small percentage **(24 percent**) of peak flow reduction. The study also shows that the effectiveness of a network of ROSD decreases at watershed scale. This approach does not consider any reduction of runoff volume, since all runoff volume will eventually be released though pipe outlet. The fact that the runoff volume has increased to about **100 percent** (**1955 liter to 3820 liter**) from pre development level was not addressed carefully. The focus of the design is only to reduce surface run off peak flow, and not the surface runoff volume for each ROSD. Rainwater harvesting from the ROSD could help reduce surface runoff volume. The design has also not taken in to any consideration of the effects of the timing release from other ROSD to the total outflow at the outlet. The automatic release from each ROSD, in an un-coordinated manner, provides little or no control at all to the total outflow at the outlet.

3.5 Storm Water Reuse

The ROSD tank was also used for the purpose of storm water reuse such as toilet flushing, washing floors and cars. The observed storm water usage data is recorded from 11th August 2006 until 3rd March 2007. A total of **13.89 m^3** of stormwater was used for toilet flushing within 174 days. The usage for other purposes such as for washing cars, water the plant and wash the porch during that period amounts to about **5.59 m³**. The total combine usage of storm water during the period of study is **19.5 m³.** The average daily and monthly usage of the storm water is estimated to be about **0.11 m³** and **3.36 m³**. If every single house within the study area is assumed to re use similar amount of storm water, significant volume of runoff (823 m³/month) is prevented from flowing to the outlet. This will help alleviate the problem of cumulative flow at the outlet.

The water usage of **0.11 m³** is relatively very small when compared to the average daily storm water volume that is available inside the storage tank which is estimated to be about **4.62 m³**. The percentage of average daily total combine usage of storm water amounts to about **2.42 %** of what is available inside the storage tank. The storage provided for this purpose is **3.3 meter cubic**. The detail result is shown in **Table 3.5**. The result also shows that plenty more of storm water is available but was not used up. This clearly shows that if the usage of the collected storm water is increased, it means that significant volume of storm water is prevented from entering the drainage system. This will contribute significantly in reducing not only peak flow but also flow volume at the outlet if every house is provided with this ROSD tank.

Table 3.5: Volume of Storm Water Reuse for Toilet Flushing

Date	Time	Meter Reading	Volume (m^3)
11/8/2006	0800	262.11	

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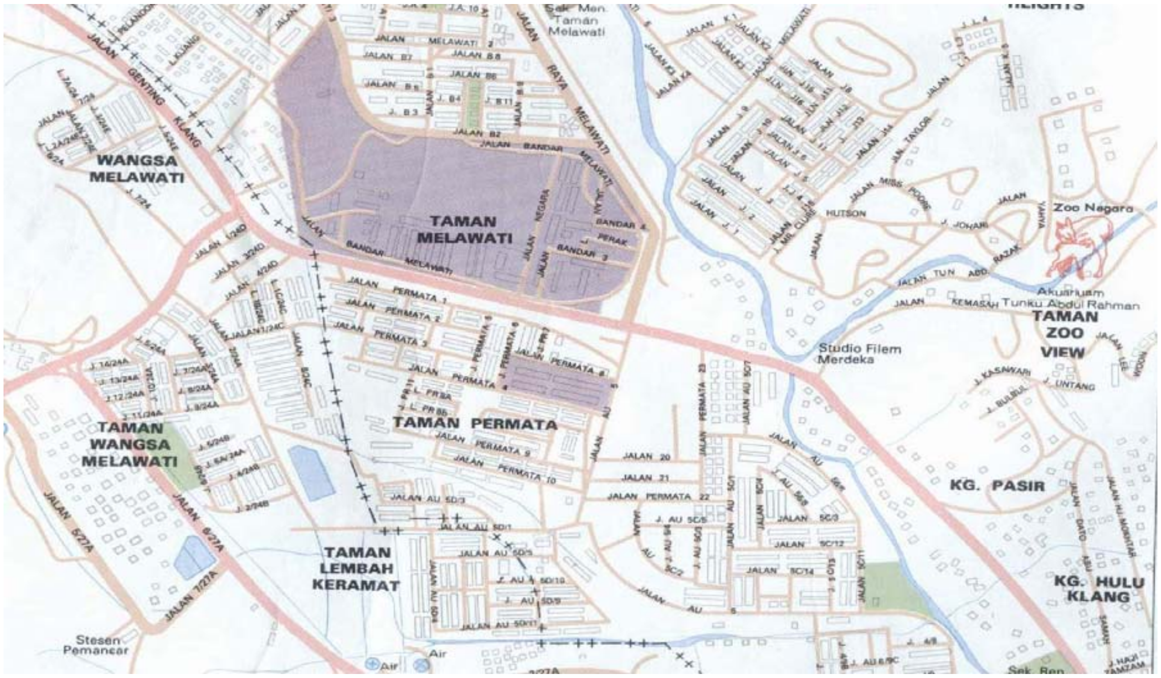

Figure 2.1 : Location of the Study AreaFigure 2.1.3 a : Drain and Conduit Identification Tag