Perfomance of Stormwater Drainage System through Dry Detention Pond for Medium Size Housing Development using InfoWorks CS (Case Study: Kota Damansara, Selangor, Malaysia)

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ABSTRACT
This paper explains the performance of the stormwater drainage system through Dry Detention Pond for medium size housing development using InfoWorks Collection System (InfoWorks CS) in Kota Damansara, Selangor, Malaysia. The total catchment area is approximately 428 hectare comprises the majority of housing areas and shops. Hydrology and hydraulic data are collected for the model calibration and verification. The sensitivity of each parameter is tested and the effectiveness of the dry detention pond is evaluated using the calibrated model. Research found that the existing pond is function well and could perform well up to the design rainfall of 100 year ARI as suggested in Urban Stormwater Management Manual for Malaysia (MSMA). The current drainage system is functioning well and no recommendation on improvement is needed. Under the scenario of land use changed in the upstream of the catchment, the dry detention pond could also perform up to 100 year ARI. However, runoff gets quicker to reach the peak by 80 minutes for 50 year ARI and 70 minutes for 100 year ARI. It is recommended that the construction of detention pond needs to be further encouraged for any new housing development to control water quantity.

KEYWORD
Dry detention pond; numerical modelling; urban stormwater management; Urban Stormwater Management Manual for Malaysia (MSMA); InfoWorks CS

INTRODUCTION
Since the last 30 years, Malaysia developed rapidly leading water quantity and water quality issues to occur progressively. Flooding is one of the major issues and the scenario is worsening if improper drainage systems were implemented. In urban areas like Kuala Lumpur and Penang, improper urban stormwater drainage has been treated as one of the causes of the flash flood. The Drainage and Irrigation Department, Malaysia (DID) publish the Urban Stormwater Management Manual for Malaysia (MSMA) in 2000 to promote the Best Management Practices (BMPs) (DID, 2000). BMPs aims to manage stormwater quantity and quality which involve construction of detention and retention facilities such as dry and wet detention ponds, infiltration, groundwater recharge, porous pavements for infiltration, swales, and provision of rough surface to retard flow reaching the watercourse and to decrease the peak flow of runoff. This study is to evaluate the design guides under MSMA specifically on the performance of the Dry Detention Pond using numerical modeling approach through InfoWorks CS software.

The research site (Figure 1) is located at Kota Damansara, Selangor which is about 10 kilometres from Sungai Buloh, North-South Highway tol. Tambul River, 3.5 kilometres in length is the main stream flowing in the pond, tributary of Sungai Damansara to the South. This study focus on the dry detention pond (Figure 2) situated in Section 6, Kota Damansara, Selangor built in 1996. The total catchment area contributing to the retention pond in Section 6 are comprises of areas in Section 5, 6, 7, 10 and 11 covered total of approximately 428 hectares. The catchment area is further distributed into numerous sub-catchments to study the behaviours of rainfall-runoff to the ponds. The topography of the project area is hilly to undulating. The project area rises from 21.72 to 202 metres above mean sea level. The nearest road is Jalan Cecawi 6/27 on the left bank of detention pond (Figure 2) with ground level of 28 metres above mean sea level.

For this research project, the research objectives are as follow:

- To study the hydrology and hydraulic parameters of the catchment
- To research on the performance of the existing detention pond
- To predict the performance of the existing detention pond in future development

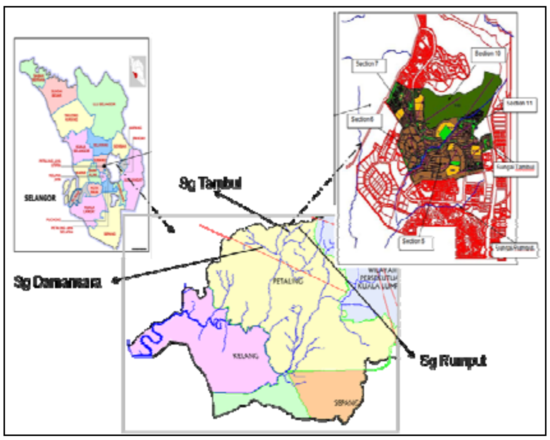

Figure 1: Location of Site

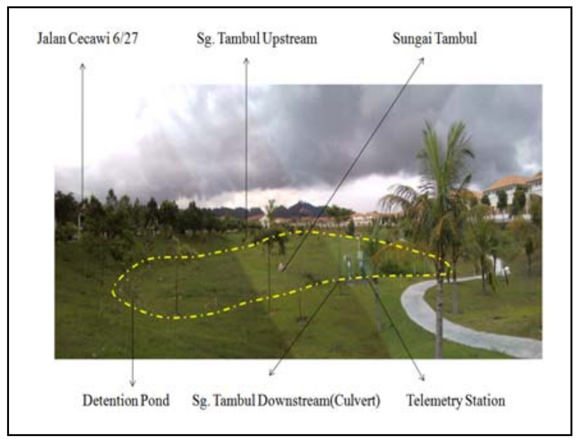

Figure 2: Location of Dry Detention Pond

METHODS

Data Collection

Data needed for model development comprises of hydrology data (rainfall, catchment characteristic, soil type, hydrologic soil groups and etc.) and the hydraulic data (water level, river cross sections, discharge, channel manning roughness coefficient etc). The subcatchments are digitised from contour map generated using LIDAR Image as explained by Hassan (2005) on the appropriateness to obtained catchment manually as the catchment characteristic is basically flat terrain and it is therefore quite difficult to delineate automatically through GIS software. Curve Number (CN) for each catchment is also determine using Remote Sensing and Geographic Information System (GIS) method recommended by Misha and Babu (submitted).

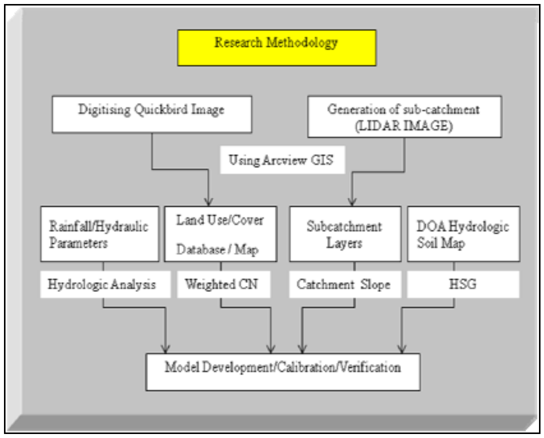

Figure 3: Data Collection

Model Development

The model development involved the creating of subcatchments using GIS subcatchment data as base map, generation of nodes to represent the sump and the link to represent the drains according to the drainage surveyed data. Data collected such as land use cover and soil map are important data to be included into the model developed.

With today's advances in computer Technology, many cities in the developing countries start building computer models to study the drainage or sewer system, for instance by using MOUSE (Mark et al., 1997), MIKE (Smith, 2007, Majewski, 2008), InfoWorks (Swan et al., 1999 and Leow et al., 2008) and the SWMM Models (Guo, 2001 and Jang et al., 2007). InfoWorks CS version 8.5 is used in developing Kota Damansara Drainage System Model (Figure 4). InfoWorks CS can supports up to four different system types (wastewater, stormwater, combined or other) within any one model. It can also support the import and export of data and maximum results to specific layers in ArcView GIS, ArcInfo or MapInfo (Wallingford Software, 2008).

The United States Soil Conservation Service (SCS) Curve Number Method or SCS Model is choosen for rainfall-runoff model in the model. It is observed that SCS Model is quick to produce results and can also easily be updated as the land use or land cover changes could be rapidly applied to ungaged catchment (Tsheko, 2006, Mishra and Babu, submitted and Leow et al., 2008).

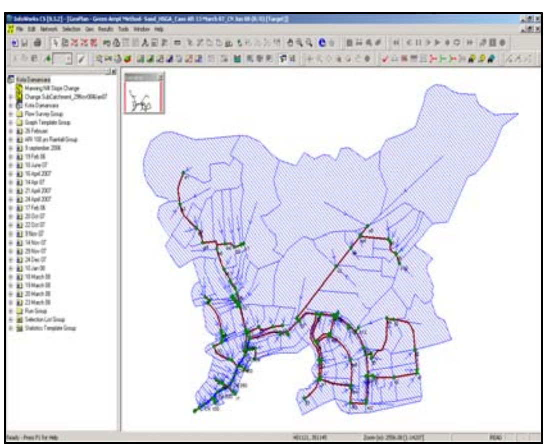

Figure 4: Kota Damansara Urban Drainage System Models

Model Calibration and Verification

Methods (2003) stated that any hydraulic model should be calibrated to the greatest degree of accuracy and verification is desirable step following completion of the calibration step. The model developed earlier are then calibrated and verified for further simulation and analyses.

For model calibration, event on 20 October 2007 (8 year ARI) and 29 November 2007 (2 year ARI) were tested while for model verification, three events on 26 February 2006 (25 year ARI), 9 September 2006 (4 year ARI) and 19 March 2008 (1 month ARI) were used. Table 1 show the observed and simulated result at Detention Pond for all events. Since the calibrated and verified models gave satisfactory mean square errors, it could be furthered used to assess the performance of existing detention pond and to predict the future performance of the detention pond under land use changed condition. The results of model calibration and verification are illustrate in Table 1.

Table 1: Results of Model Calibration and Verification

Event	Peak Water Level (meter)			Peak Flow (m^3/s)			Difference Time to Peak (min)			r2
	Observed	Simulated	Differences	Observed	Simulated	Differences	Observed	Simulated	Differences	
20 October 2007 (Calibration)	3.92	3.784	0.136 (2.5%)	28.381	32.007	3.626 (12.78%)	16:25	16:31	6	0.957
29 November 2007 (Calibration)	2.24	2.216	0.024 (1.1%)	10.994	14.089	3.095 (12.78%)	18:32	18:45	13	0.927
26 February 2006 (Verification)	3.470	3.626	0.156 (4.5%)	22.41	30.50	8.09 (36.1%)	05:03	05:06	3	0.984
9 September 2006 (Verification)	3.220	3.202	0.022 (0.7%)	20.43	25.82	5.39 (26.4%)	15:54	16:09	15	0.907
19 March 2008 (Verification)	1.61	1.458	0.152 (9.4%)	3.252	2.912	0.34 (10.5%)	16:15	16:20	5	0.905

RESULTS AND DISCUSSION

Catchment Characteristic

The land use within the catchment area are grouped under four main categories namely Bungalow or Schools, Impervious (Housing or Shops), Fields (Landscape or Open Space) and Pervious (Forest or Ponds) where more than 50% of it are impervious area (Figure 5). It is found that the hydrologic soil groups within the catchment are the combination of Group A and C and Group B. The soil are mostly Yellowish grey silty sand with infiltration rate of 12 mm/hr. The average catchment slope is 0.027, normal water depth is 9 centimetres, average velocity and flow is 0.56 m/s and 0.09 m^3/s respectively. Channel Manning's n coefficient is 0.011.

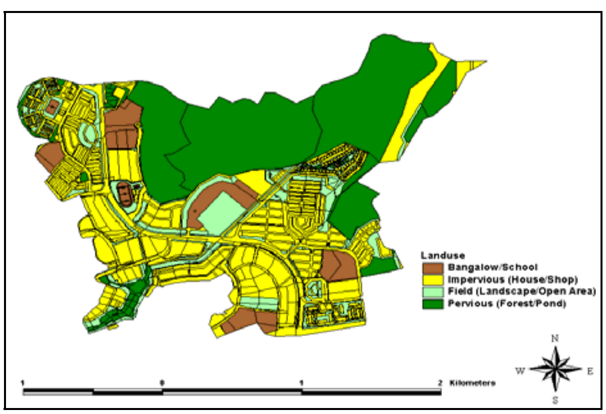

Figure 5: Land Uses within Catchment

Performance of Existing Pond

From the simulation and analysis done, results show 60 minutes duration rainfall gives the highest peak water depth for all design rainfall. Therefore, for evaluating the performance of existing pond, the 60 minutes design rainfall for 2, 10, 50 and 100 year ARI were tested. The comparison of water depth and flow for each ARI of 60 minutes duration was then evaluated (Figure 6 and Figure7). This simulation results show that the water depth for 2 year ARI to 100 year ARI is from 2.261 metres or 23.981 metres above mean sea level to 4.213 metres or 25.933 metres above mean sea level which gives the difference of 1.952 metre (Table 2). For the flow comparison, the results show that the maximum flow simulated for 2 year ARI to 100 year ARI is from 14.554 to 35.908 m^3/s (Table 7.5). It indicate no flooding for both 50 and 100 year ARI on Jalan Cecawi 6/27. It is concluded that the pond is well perform and manage to cater the flow up to 100 year ARI of design rainfall with no flood as designed by Consultant (Ganedra, Ahmad and Associates, 1996) and recommended in MSMA. The present study results confirm the ability in attenuating peak flow as discussed by Ahmad Nasir (2008).

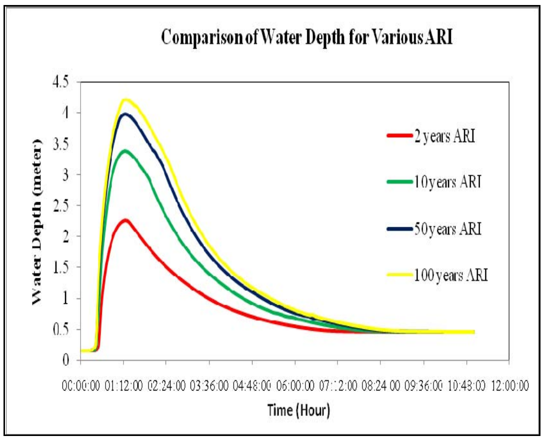

Figure 6: Simulations of Water Depth for Various ARI (2, 10, 50 and 100 year)

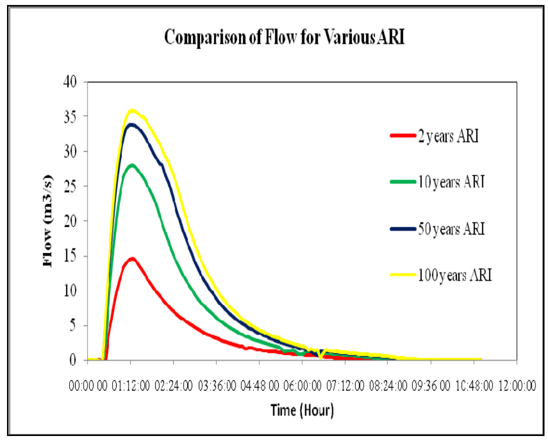

Figure 7: Simulations of Flow for Various ARI (2, 10, 50 and 100 year)

Table 2: Results of Simulations of Water Depth and Flow for Various ARI

Comparison of Peak	ARI (year)			
	2	10	50	100
Water Depth (metre)	2.261	3.384	3.986	4.213
Flow (m^3/s)	14.554	28.020	33.872	35.908

Land Use Change Scenario

Regarding Tsheko (2006), SCS Curve Number method is sensitive to land use changes. Thus, to study the effects of land use change, we assume that the forest area upstream of the catchment is change to pave area where the Curve Number of all upstream forested area are changed to CN = 95. The 100 year ARI gives the highest water depth and flow compared to 2, 10, 25 and 50 year ARI. For all the simulation with various ARI, the maximum water level predicted under the effects of land use change are less than the ground level of Cecawi 6/27 Road nearby Detention Pond (28 metres above mean sea level) and show no flood at the area.

A comparison of water depth and flow for 50 and 100 year ARI under scenarios of before and after land use changed were also evaluated. Refer to Table 3, Figure 8 and Figure 9, the scenario of land use change gives little impact compared to the existing condition as observed only a minor difference from 0.50% to 2.13% of water depth and 0.53% to 2.43% of flow simulated for 2, 10, 50 and 100 year ARI where the 50 year ARI depicts the highest percentage of difference in water depth and flow. However, runoff gets quicker to reach the peak under the land use change scenario by 80 minutes for 50 year ARI and 70 minutes for 100 year ARI. This recommeding that any future development should be fully considered this factor.

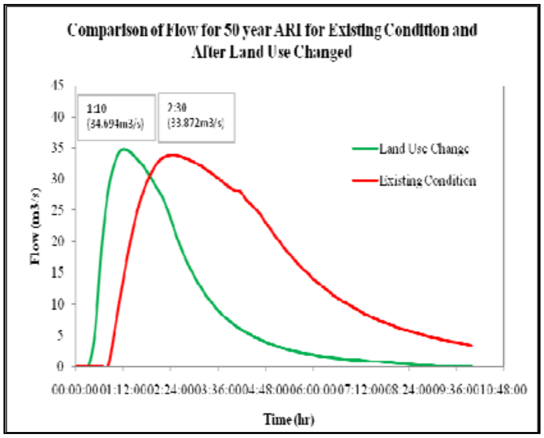

Figure 8: Comparison of Flow for 50 year ARI for Existing Condition and After Land Use Change

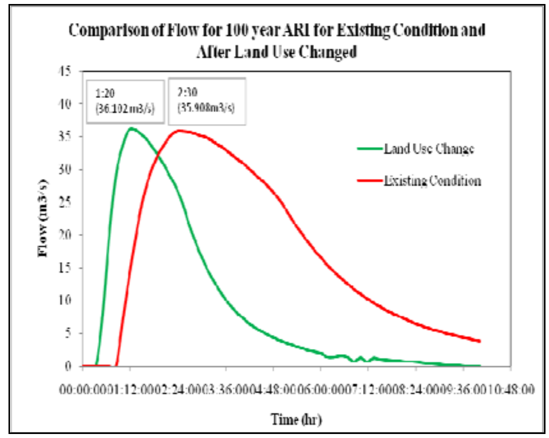

Figure 9: Comparison of Flow for 100 year ARI for Existing Condition and After Land Use Change

Table 3: The Comparison of Water Depth and Flow for Existing Condition and after Land Use Changed

Design Rainfall, ARI (Year)	Existing Condition	Land Use Changed	Existing Condition	Land Use Changed
	Max Water Depth (metre)	Max Water Depth (metre)	Max Flow (m^3/s)	Max Flow (m^3/s)
2	2.261	2.279	14.554	14.773
10	3.384	3.406	28.020	28.274
50	3.986	4.071	33.872	34.694
100	4.213	4.234	35.908	36.102
Design Rainfall, ARI (Year)	% of Difference Water Depth (metre)		% of Difference Flow (m^3/s)	
2	0.80		1.50	
10	0.65		0.91	
50	2.13		2.43	
100	0.50		0.53	

CONCLUSION

The research findings are as follow:

- From the sensitivity test, it is found that CN Value for land use based on hydrologic soil group, soil antecedent moisture content, hydrology loss model, rainfall intensity intervals, drainage properties particularly Manning's n coefficient are the most sensitive parameters
- The existing pond could perform up to 100 year ARI of design rainfall under current condition and effect of land use change with no flooding. It is as recommended in Manual of Stormwater Management of Malaysia (MSMA)

- The current drainage system is functioning well and no recommendation on improvement is required
- Construction of detention pond need to be encouraged for new housing development to control water quantity
- Future development need to consider factor like runoff from catchment area and it should be studied using the numerical approaches to solve problems and ease decision making processes

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