Assessment of the Climate Change Impact on a Dry Detention Pond at Kota Damansara, Malaysia

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ABSTRACT
Global warming and climate change have captured more public concern in the recent years. In Malaysia, studies found that extreme water events such as floods and droughts have shown significant changes in intensity and frequency of their occurrences. An initiative has been undertaken to study the performance of the dry detention pond in controlling water quantity under the impact of climate change by using numerical modelling approaches for the research site at Kota Damansara, Malaysia. InfoWorks collection system was applied to develop drainage system model. The collected hydrologic, hydraulic data, soil parameter and cross sections of main drains were among the essential inputs for modelling. The developed model was then validated, calibrated and verified to achieve certain level of confidence for further simulations and analysis. A comparison was carried out to predict the impact of climate change for various return periods on the detention pond. The study indicated the capability of using numerical approaches in predicting the impacts of climate change under different return periods. From the prediction finding, it was expected that a proper development planning could probably be achieved to manage and minimise the possible impacts of climate change.

KEYWORDS
Climate change, dry detention pond, rainfall, numerical model, curve number

INTRODUCTION
Global warming and climate change have captured more concern globally and locally these recent years. Many severe impacts of climate change would be mediated on water resources in different regions globally as reported in Stern Review (2006). In Malaysia, extreme water events encompass both the floods and droughts have shown significant changes in intensity and frequency of occurrences (MMD, 2009). A study embarked by NAHRIM (2006) similarly found that there will be an increase in average annual air temperature for 1.5 ºC during 2025 to 2034 and 2041to 2050, which relative to records from years of 1984 to 1993. Apart, there will be an increase of 10% in average annual rainfall in Kelantan, Terengganu and Pahang, a decrease of 5% in average annual rainfall for Selangor and Johore while an increase in extremes future river flows with future flood flows having an increase from 11% to 43% and future low flows having a decrease ranging from 31% to 93%.

Based on these findings, an initiative has been taken to predict the performance of the existing dry detention pond in controlling water quantity under the impact of land use change (Liew et al. 2009 and Liew et al. 2012) and this study is extended to predict the performance of the dry detention pond under the climate change impact through numerical modelling approaches.

RESEARCH SITE

The research site (as shown in Figure 1) is located at Kota Damansara, Selangor which is about 10 kilometres from Sungai Buloh. Tambul River is the main stream flowing into the pond and connectedwith a small tributary of Damansara River. This study focuses on the dry detention pond built in 1996 with an area of 6.55 hectares (see Figure 2) is situated in Section 6, Kota Damansara. The total catchment area contributing to the detention pond in Section 6 is comprised of areas in Section 5, 6, 7, 10 and 11 covers a total of approximately 428 hectares. The catchment area is further distributed into numerous sub-catchments to study the behaviours of rainfall-runoff in 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 (see Figure 2) with ground level of 28 metres above mean sea level.

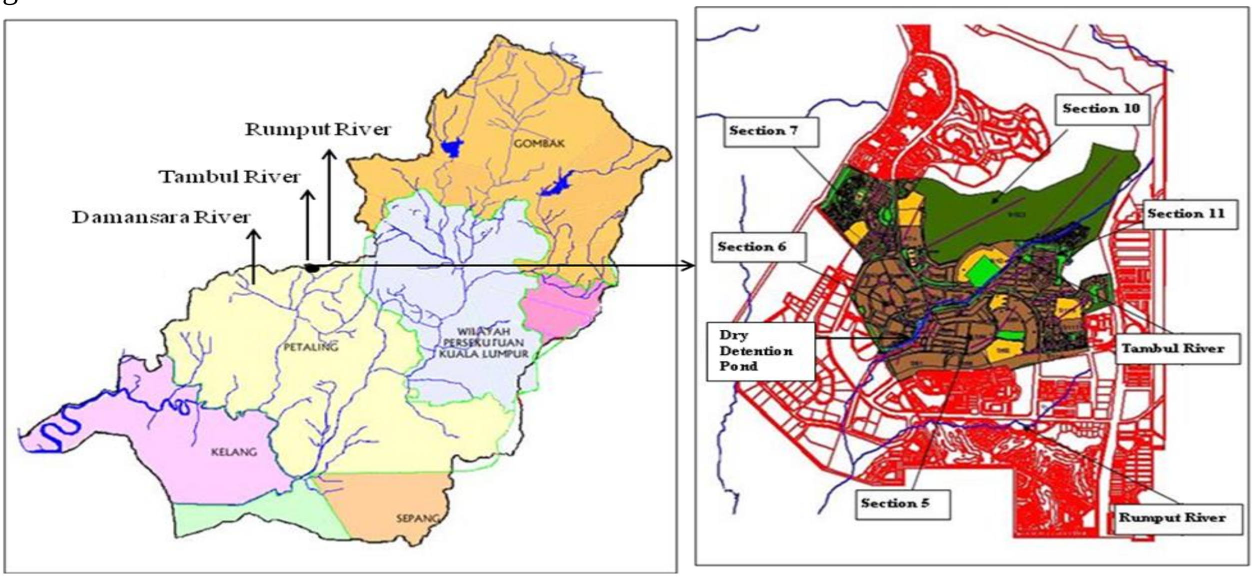

Figure 1. Location of study area

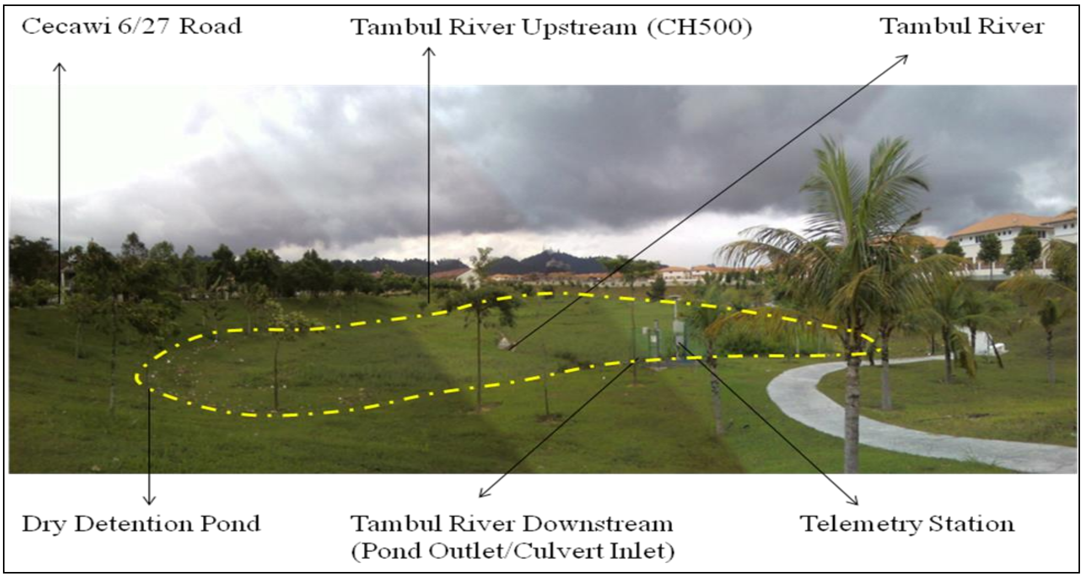

Figure 2. Dry detention pond at study area

METHODOLOGY

InfoWorks Collection System (CS) is applied to develop the one-dimensional (1-D) Kota Damansara Drainage System Model. The software can support up to four different system types (e.g. wastewater, stormwater, combined, etc.) within any one model. It can also support the import and export of data with maximum results to specific layers in Geographic Information System (GIS) format, ArcInfo or MapInfo (Wallingford Software, 2008).

The collected hydrologic data (i.e. rainfall), hydraulic data (i.e. water level), soil parameter and cross sections of main drains are among the important inputs for modelling. The model set-up involved the delineation of sub-catchments, generation of nodes to represent the sump and the link to represent the drains. Information on landuse, soil properties and Curve Number (CN) for each sub-catchment has been obtained from the processing of landuse data in GIS environment. Hydrologic data for the future hydro-climate condition (during 2025-2034 and 2041-2050) are readily available and were retrieved online from NAHRIM future hydro-climate database.

The observed water level is then compared with the simulated results. Model developed was continued to be validated, calibrated and verified to achieve certain level of confident. Figure 3 shows the model for Kota Damansara drainage system. In this study, the calibrated and verified model which has been developed in the previous studies by Liew et al., 2009 and Liew et al. 2012 will be applied for further simulations in order to predict the impact of climate change based on the future hydro-climate data retrieved.

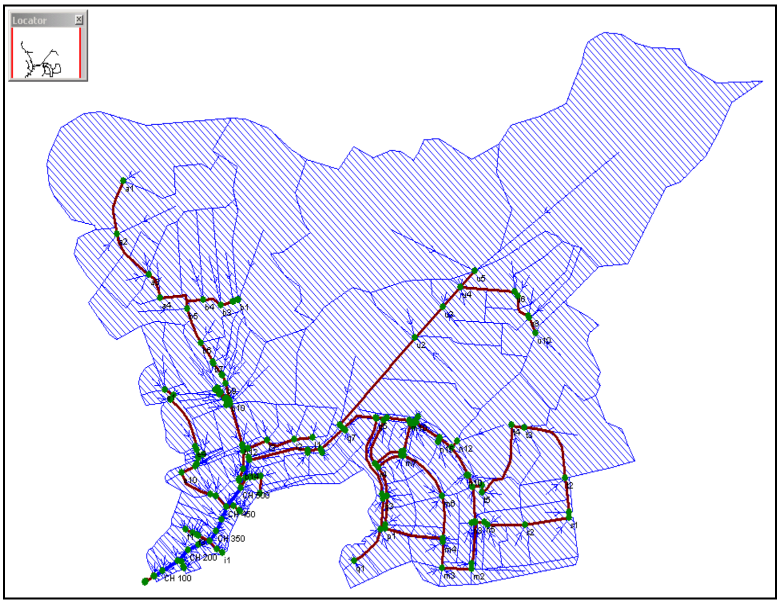

Figure 3. Model of Kota Damansara drainage system

Future Hydro-climate Data Analysis-Frequency Analysis

The Intensity-Duration Frequency (IDF) Curve for future hydro-climate data as shown in Figure 4 is generated using Frequency Analysis, Extreme Value Type I (EVI) as recommended by Chow et al. (1988). Zainal Abidin (1999) also applied this method in his study for catchment with limited data.

The Extreme Value Type I function is as below:

$$F(x) = exp\left[-exp\left(-\frac{x-u}{\propto}\right)\right] \quad -\infty \le x \le \infty \qquad (4.1)$$

Where,

$$\propto = \frac{\sqrt{6}\, s}{\pi} \qquad (4.2)$$

$$u = \bar{x} - 0.5772 \propto \qquad (4.3)$$

$$y = \frac{x-u}{\propto} \qquad (4.4)$$

Substituting the reduced variant into Equation 4.1 yields:

$$F(x) = \exp[-exp(-y)] \qquad (4.5)$$

Solving for y:

$$y = -\ln\left[ln\left(\frac{1}{F(x)}\right)\right] \qquad (4.6)$$

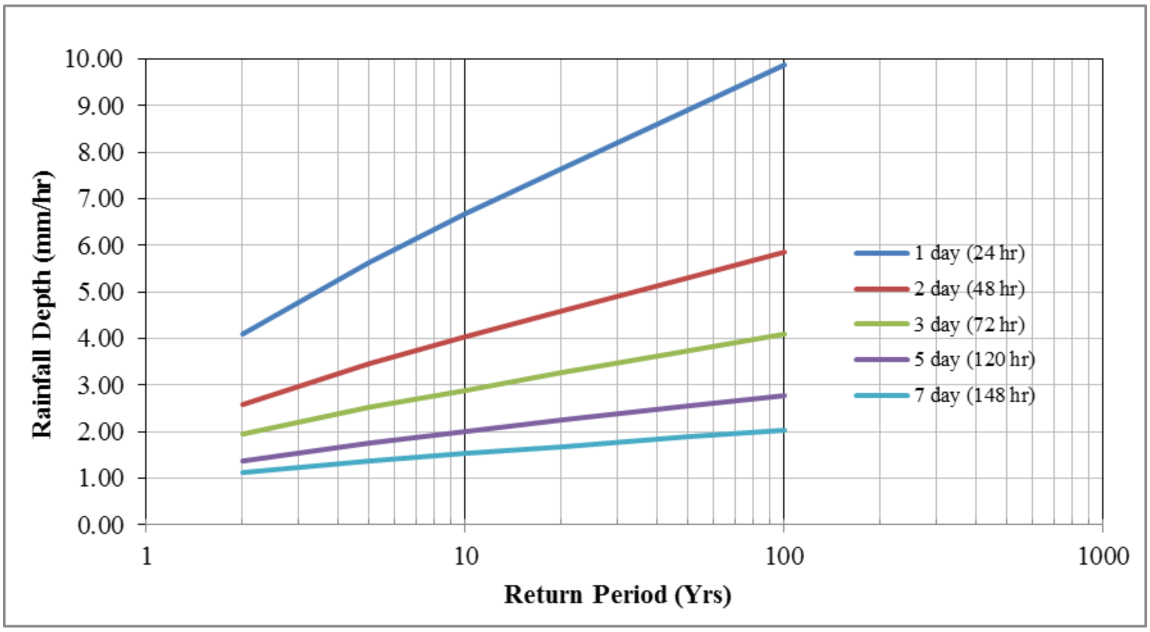

Figure 4. Intensity-Duration Frequency (IDF) Curve for future hydro-climate data

Temporal Distribution of Annual Maximum Rainstorms in Peninsular Malaysia

Hydrological Procedure No.1 (DID, 1994) is referred to the estimation of temporal distribution of Annual Maximum Rainstorms in Peninsular Malaysia. The distribution of rainfall for 24 hours (i.e. 1-Day) duration for the research area is choose for station 3, West Coast as shown in Figures 5 and 6. Table 1 shows the distribution of rainfall for 24 hours in various Return Periods.

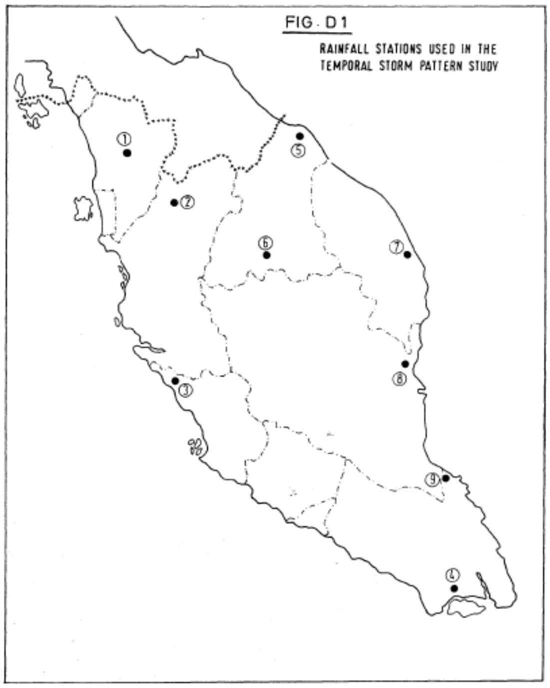

Figure 5. Rainfall stations used in the temporal storm pattern study

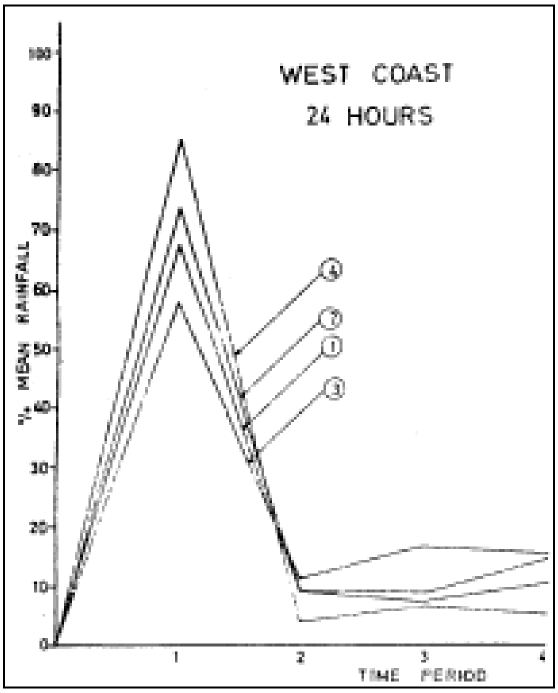

Figure 6. The temporal distributions for the selected stations for West Coast (24 hours)

Table 1. The temporal distribution of rainfall for 24 hours in various Return Periods

Durations	Distribution (%)	Return Period (year)					
		2	5	10	20	50	100
6	58	60.21	70.39	77.13	83.60	91.97	98.25
12	11	11.42	13.35	14.63	15.86	17.44	18.63
18	16	16.61	19.42	21.28	23.06	25.37	27.10
24	15	15.57	18.20	19.95	21.62	23.79	25.41
Total	100	103.81	121.36	132.99	144.14	158.57	169.39

RESULTS AND DISCUSSION

Model Calibration and Verification

For model calibration, three rainfall events on 17th February 2006, 20th October 2007 and 29th November 2007 were calibrated, whereas another four additional events on 26th February 2006, 9th September 2006, 22nd October 2007 and 19th March 2008 were used for verification process. The comparison between the observed and simulated scenarios for both calibrated and verified models showed good agreement and satisfactory for mean square errors (r^2) more than 0.9, thus it could be applied for further simulations. Table 2 and Figure 7 show the results of model calibration and verification with example of the comparison of observed and simulated water level for 20th October 2007 respectively.

Table 2. Results of Model Calibration and Verification (after Liew et al., 2012)

Event	Peak Water Level (meter)			r^2	Peak Flow (m^3/s)			r^2	Difference Time to Peak (min)		
	Observed	Simulated	Differences		Observed	Simulated	Differences		Observed	Simulated	Differences
17 February 2006 (Calibration)	2.12	1.97	0.15 (7.1%)	0.951	10.24	11.42	1.18 (11.35%)	0.931	16:19	16:24	5
20 October 2007 (Calibration)	3.92	3.78	0.14 (3.5%)	0.957	28.38	32.01	3.63 (12.78%)	0.977	16:25	16:31	6
29 November 2007 (Calibration)	2.24	2.22	0.02 (1.1%)	0.927	10.99	14.09	3.10 (28.15%)	0.966	18:32	18:45	13
26 February 2006 (Verification)	3.470	3.63	0.16 (4.5%)	0.984	22.41	30.50	8.09 (36.1%)	0.988	05:03	05:06	3
9 September 2006 (Verification)	3.220	3.20	0.02 (0.7%)	0.907	20.43	25.82	5.39 (26.4%)	0.903	15:54	16:09	15
22 October 2007 (Verification)	2.66	2.56	0.1 (3.8%)	0.986	14.79	17.94	3.15 (21.3%)	0.981	3:39	3:39	0
19 March 2008 (Verification)	1.61	1.46	0.15 (9.4%)	0.905	3.252	2.912	0.34 (10.5%)	0.913	16:15	16:20	5

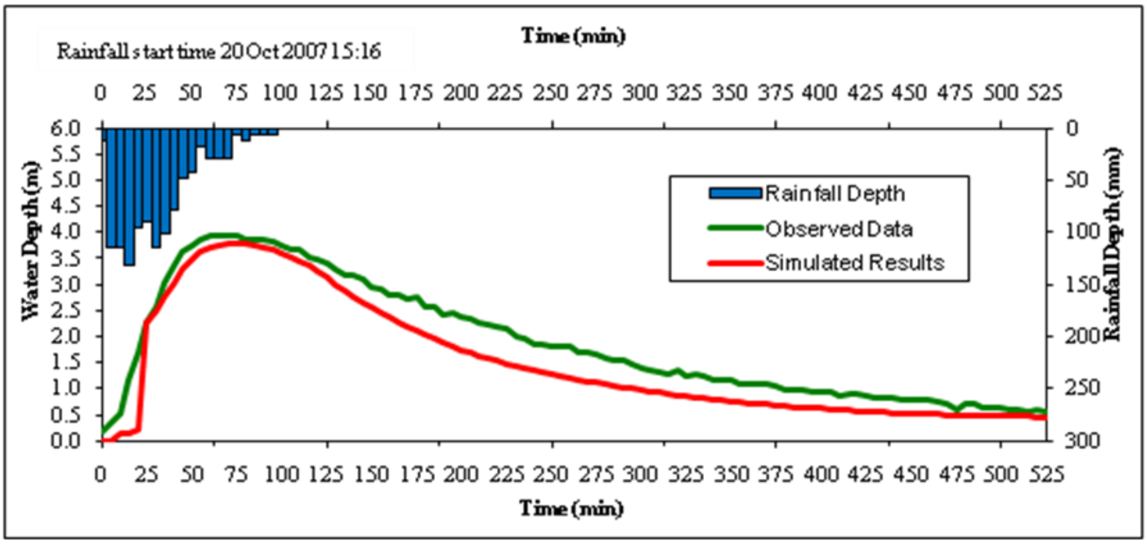

Figure 7. Comparison of observed and simulated water levels for 20th October 2007

Assessment on the Impact of Climate Change

The existing rainfall data are transformed to 1-day rainfall intensity in order to compare with future hydro-climate data for minimum 1-day rainfall duration. The comparison of the rainfall intensity for the existing and impact of climate change condition are as shown in Table 3. It shows an increase trend for 5-, 10-, 20-, 50- and 100-year Average Recurrence Interval (ARI) in rainfall intensity under the impact of climate change but a minimal decrease for 2-year ARI.

Table 3. Comparison of the rainfall intensity for the existing and impact of climate change condition (24 hours duration)

ARI (year)	Existing		Future Climate	
	Rainfall Depth (mm)	Rainfall Intensity (mm/hr)	Rainfall Depth (mm)	Rainfall Intensity (mm/hr)
	1 Day		1 Day	
2	103.81	4.33	98.32	4.10
5	121.36	5.06	135.42	5.64
10	132.99	5.54	159.99	6.67
20	144.14	6.01	183.56	7.65
50	158.57	6.61	214.06	8.92
100	169.39	7.06	236.92	9.87

A comparison has done to relate the existing condition with the impact of climate change scenario for various return periods for the detention pond and results are depicts in Table 4. It shows a slightly increase from 0.10 to 0.59 % in peak water level under the impact of climate change compared to the existing condition for 5-, 10-, 20-, 50- and 100-year ARI.

Table 4. Comparison of maximum water level in percentage for existing condition and under impact of climate change

Return Periods	Peak Water Level		Percentage of Differences (%)
	Existing Condition	Impact of Climate Change	
2	21.903 ↑	21.895	- 0.04
5	21.925	21.947 ↑	+ 0.10
10	21.945	21.987 ↑	+ 0.19
20	21.963	22.045 ↑	+ 0.37
50	21.987	22.087 ↑	+ 0.45
100	22.005	22.136 ↑	+ 0.59
Legend: ↑ = Indicate an increment in water level			

CONCLUSION

The rainfall intensity transformed from short duration storm (i.e. 30 minutes or less) to 1-day provides less intense rainfall condition within the catchment. Thus, water depth and flow produced by the simulation do not represent the actual condition under impact of climate change. Besides this, the catchment is categorized as urban catchment with a shorter time of concentration (i.e. less than 15 minutes). Thus, it is unsuitable to compare the results for a longer duration of time.

It is recommended that a more details future hydro-climate data in shorter duration (i.e. hourly data) instead of daily data are prerequisite to get a better result for a small urban area. Temporal distribution within the catchment also needs to be studied in detail apart by using methods in HP 1 which only suitable for designing rainstorms.

However, despite the data issues, the drainage system model was successfully calibrated and verified, therefore, it indicates the capability of using the existing numerical approaches in predicting the impacts of climate change under different return periods. From the prediction results, it is hopeful that a proper development planning can probably achieved to manage and minimise the possible impacts due to climate change.

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