PEJABAT KREATIVITI & PENGURUSAN PENYELIDIKAN (RCMO)
CANSELORI
UNIVERSITI SAINS MALAYSIA

Laporan Akhir Projek Penyelidikan Jangka Pendek

1). Nama Penyelidik : Dr. Hj Ismail Abustan

Nama Penyelidik – Penyelidik Lain (Jika berkaiatan) : **Dr. Hjh. Nabsiah Abdul Wahid**
Cik Mahyun Ab Wahab

i) Jangkamasa Projek:

Projek diluluskan untuk jangkamasa 1 tahun iaitu dari 1 Nov 01 sehingga 31 Oktober 2002. Tambahan selama 6 bulan telah diluluskan sehingga 30 April 2003.

ii) **Belanjawan :** Peruntukan yang diluluskan ialah RM 18,008.00

2) Pusat Pengajian /Pusat/Unit : Pusat Pengajian Kejuruteraan Awam

3) Tajuk Projek: ***Permodelan berkomputer: Alternatif Pengurusan Sistem Saliran Bandar***

(a) Objektfe Kajian

Menjalankan kajian terperinci tentang keupayaan ('realible' dan 'accurate') 4 perisian komputer yang boleh digunapakai di Malaysia untuk merekabentuk saliran bandar.

(b) **Kaed*ah (Methodology)***

Keadaan sebenar sistem saliran kawasan bandar didapati dari peta topo (Siri L 808, Data Digital Terhad, Jabatan Ukur & Pemetaam Malaysia). Peta digital ini memberi petunjuk yang tepat kepada penyelidik memandangkan sistem saliran kawasan bandar adalah kompleks. Kawasan ini akan dipecahkan mengikut 'homogeneity' dan peratus kawasan berturan.

Cerapan data hujan dan kadaralir yang telah dijalankan oleh pihak JPS untuk dua kawasan penyelidikan (Sg. Kerayong dan Taman Mayang) tersebut akan dimuaturun menggunakan program TEDIDA® di Bahagian Hidrologi, Jabatan Pengairan dan Saliran, Jalan Ampang. Cerapan data hujan dan kadar alir yang singkat diperlukan dalam kajian ini. Dalam kajian terdahulu (Abustan et al dan Desa et al) pengunaan data yang berjulat 2 minit memberi keputusan memuaskan. Oleh itu julat yang sama akan diguna pakai. Justeru itu pengambilan data secara CD Rom adalah amat perlu. 'Calibration' dan 'validation' perisian komputer yang dicadangkan adalah seperti berikut (a)SWMM (b)InfoWork (c) Heasted Method dan (d) MIDUSS. Perisian (a) dan (b) terdapat di USM. Manakala perisian (c) dan (d) memenuhi kreteria yang telah dibincangkan secara terperinci oleh Abustan (2001).

(c) Keputusan

Dalam kajian yang dijalankan, perisian SWMM, InfoWork dan Heasted Method telah dijalankan dengan jayanya. Perisisan MIDUSS tidak dapat dijalankan kerana harganya di pasaran mencecah RM35,000.00 dari agen tunggal di Malaysian. Perisian InfoWoks telah dibeli dengan harga RM5100.00 khas untuk kegunaan penyelidikan sahaja.

Keputusan kajian merumuskan SWMM and InfoWork amta sesuai digunapakai di Malaysia. Manakala Heasted Method lebih menumpukan pada kaedah reka bentuk. Data input yang digunakan dalam menjalankan simulasi perisian Heasted Method hanya memerlukan hujan rekabentuk. Jenis sistem saliran yang standad sahaja (i.e triprizod, circular, etc) tidak termasuk 'irregular channel; menyukarkan proses permodelan. Oleh itu, perisian Heasted Method diguna pakai dalam proses calibrasi sahaja. Tambahan pula, kadar kehilangan dalam perisian tersebut menggunakan 'SCS Curve' tidak terdapat dan digunapakai di Malaysia.

Perisian InfoWorkmemerlukan data yang komprehensive untuk diletakkan dala 'Global Data'. Perisian ini memerlukan ahli yang terlatik dan mahir dalam perisian tersebut. Harganya yang agak mahal juga akan menjadikan perisian ini tidak mendapat perhatian penyelidik dan perekabentuk di Malaysia. Untuk versi komersial harganya mencecah RM40,000.00. Dalam kajian terperinci perbandingan InfoWork dan SWMM, didapati kedua-dua perisian tersebut memberikan keputusan yang memberansangkan. Kedua-dua perisian memberi nilai 'relative error' (RE) di bawah 10% semasa proses calibrasi dan nilai RE tidak melebihi 15% dalam proses validasi. Keputusan ini meyakinkan penggunaan perisian tersebut yang belum pernah dijalankan untuk keadaan di Malaysia.

Kajian ini juga telah dilanjutkan dan mendapat peruntukan IRPA (6012810) iaitu 'Development of Stormwater Management Model (SWMM)' sebanyak RM163,000.00. Dalam projek tersebut objektif utama adalah untuk membangunkan perisian yang mempunyai ciri-ciri yang penting untuk kawasan hujan tropika lembab seperti Malaysia.

Attribute penting dalam simulasi permodelan berkomputer adalah seperti berikut (menurut turutan):

1) kawasan tidak telap
2) lebar kawasan sub tadahan
3) 'depression storage' atau kehilangan lengkuk
4) kekasaran Manning n di kawasan tidak telap
5) kekasaran Manning n untuk sistem saliran
6) kadar penyusupan Horton iaitu f_o dan f_c

Nilai kawasan tidak telap dapat dikenalpasti dengan dua cara. Cara pertama hádala dengan plotan jumlah kedalaman hujan melawan jumlah air larian. Plot ini dapat mengenalpasti nilai peratus tidak telap dan nilai kehilangan awal (iaitu termasuk juga 'depression storan'). Cara kedua adalah dengan menggunakan peta digital. Cara ini lebih meyakinkan tetapi perlu peta terkini. Pihak Jabatan Pemetaan tidak menjalankan aktiviti pemetaan setiap tahun. Oleh itu peta yang diterima agak lama iaitu kurang lebih 5 tahun. Untuk kajian ini peta tahun 2000 digunapakai.

Nilai kawasan tudak telap merupakan faktor utama. Ini membuktikan pembangunan akan meningkatkan jumlah kadaralir dan nilai puncak kadaralir. Manakala lebar kawasan sub tadahan mempengaruhi nilai puncak kadaralair dan masa puncak. 'Depression storage' atau kehilangan lengkuk adalah nilai kehilangan hidrologi yang utama. Untuk kawasan tidak telap nilai ini adalah kecil (1.5 – 2.5 mm) manakala untuk kawasan telap nilainya mencecah 5.0 – 7.5 mm. Attribut yang lain memainkan peranan kecil dalam simulasi perisian SWMM dan InfoWorks.

(d) Hasil *(Outcome)*

Dalam dapatan kajian, penyelidik telah berjaya:

1. mengenalpasti keupayaan perisian yang berpotensi untuk digunapakai di Malaysia.
2. mengetahui attribut-attribut penting yang dapat digunakan untuk pengurusan sistem saliran bandar secara bersepadu dan sempurna

4) a) Penemuan Projek/Abstrak

(Perlu disediakan makluman di antara 100 – 200 perkataan di dalam Bahasa Malaysia dan Bahasa Inggeris. Ini kemudiannya akan dimuatkan ke dlam Laporan Tahunan Bahagian Penyelidikan & Pembangunan sebagai satu cara untuk menyampaikan dapatan projek tuan/puan kepada pihak Universiti).

Bahasa Malaysia

Perbandingan antara data cerapan dan simulasi untuk jumlah aliran dan puncak aliran ditunjukkan di Jadual 1. Hidrograph dan plot taburan telah digunakan untuk menganalisa keupayaan dan kebolehgunaan model untuk empat peristiwa. Didapati plot taburan untuk data cerapan dan simulasi adalah baik. Jadual 2 menunjukkan penentukuran model menggunakan kaedah statistic juga memberi keputusan yang baik

Dari keputusan tersebut, bolehlah diputuskan bahawa proses penentukuran telah berjaya.. Nilai R^2 adalah diantara 0.83 dan 0.94 telah dicapai dari plot taburan yang dijalankan antara nilai cerapan dan nilai simulasi. Disamping itu juga, analisa selanjutnya menggunakan kaedah 't-Test' tambah meyakinkan keputusan penentukuran yang telah dijalankan (rujuk Jadual 2). Kaedah RMSE yang kecil nilainya juga dapat meyakinkan bahawa proses penetukuran telah berjaya.

Table 1 : Comparison between observed and simulated data.

Event	Observed Depth (mm)	Simulated Depth (mm)	Observed Peak (m^3/s)	Simulated Peak (m^3/s)
18 Nov. 98	12.6	10.3	8.8	8.4
30 Dec. 98	25.0	22.0	21.6	22.2
1 Jan. 99	7.0	7.1	11.8	10.8
15 Jan 99	8.5	7.6	10.6	10.6

Table 2 : The statistical "Goodness-of-fit" test for model performance

Event	R^2	Volume |RE|	Peak |RE|	RMSE (m^3/s)	t-Test
18 Nov. 98	0.88	0.2	0.1	1.07	0.015
30 Dec. 98	0.94	0.12	0.03	1.97	0.116
1 Jan. 99	0.83	0.02	0.1	1.25	0.494
15 Jan 99	0.93	0.12	0.01	1.03	0.194

Dari analisa keberkesanana (sensitivity analysis), didapati parameter yang memberi impak yang amat ketara terhadap jumlah kadaralir adalah lapisan berturap dan 'depression storage'. Memandangkan peratusan kawasan tidak telap adalah sama, oleh itu dalam proses penetukuran, 'depression storage' di agap sebagai parameter pembolehubah.

Penentukuran terhadap aliran puncak memerlukan lebih banyak parameter sebagai pembolehubah. Didapati, Manning n tidak begitu sensitive terhadap puncak aliran. Parameter yang sensitive adalah kawasan tidak telap, lebar sub-tadahan dan 'depression storage'.

Keputuran tersebut bolehlah disimpulkan seperti berikut:

- 'Shape of the hydrographs' meperlihatkan padanan baik nilai cerapan dan simulasi.
- Magnitud puncak aliran juga memperlihatkan padanan baik, ralat kurang dari 10%
- Jumlah kadaralir juga menghasilkan padanan yang baik, ralat kurang dari 15%.

Bahasa Inggeris

A comparison of the computed runoff depth with observed runoff depth is shown in Table 2. It can be concluded that the calibration processes for stormwater quantity were successful. Regression coefficient (R^2) values ranging from 0.83 to 0.94 were obtained for the scatter plot (relationship) between observed and simulated data. A t-Test indicated statistically significant differences in only one event (18^{th} Nov. 98) (Table 2).

Hydrographs and scatter plots were used to evaluate the model performance for the four events. It can be seen from the plot of observed flows against model predicted flows, that a very good match has been obtained.

In addition, data used in this study were tested using normality tests before the authors embarked on any statistical analysis. As the results for these tests shown that the data were normally distributed, therefore an equal variance t- test was carried out (Table 2).

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From sensitivity analysis, it was found that the parameters with the greatest impact on the depth of runoff were the impervious percentage and the impervious depression storage. Since the percentage impervious was held constant and not varied between events, only impervious depression storage could be varied for calibration of the runoff depth.

Calibration of the peak flows was more difficult than of the runoff depth because more parameters had to be adjusted. For example, in calibrating runoff depth, the Manning's *n* was not sensitive, whereas in calibrating peak flows, this parameter was sensitive as well as the impervious percentage and depression storage. In addition, time to peak or hydrograph response of a catchment is related to the spatial and temporal pattern in rainfall events. As suggested by Ball (1994), an adequate representation of rainfall over the catchment is required to match time to peak.

In the visual comparison, the overall shape of the hydrographs shows a good match. It is also supported further by the RMSE values for all events, which are small.

The following conclusions regarding the model calibration can therefore be made:

- The overall shape of the hydrographs shows a good match.
- The magnitude of the peak flows shows a good match, to within 10%
- The total volume of the hydrograph shows a good match, to within 15%.
- The time of the initial increase in flows (rising limb of the hydrograph) has been successfully reproduced.

Given that some errors could exist in the observed data, it is considered that, overall, a satisfactory model calibration has been achieved for this rainfall event. More detailed calibration and testing will be carried out. Future work will include investigation of runoff response with respect to rainfall dynamics and implementation of best management practices.

b) Senaraikan kata kunci yang digunakan di dalam abstrak:

Bahasa Malaysia	**Bahasa Inggeris**
Urban runoff	**Air larian bandar**
Best Management Practices	**Amalan pengurusan terbaik**
Peak flow	**Aliran puncak**
Time to peak	**Masa Puncak**

5) Output dan Faedah Projek

(a) Penerbitan (termasuk laporan/kertas seminar)

(Sila nyatakan jenis, tajuk, pengarang, tahun terbitan dan di mana telah diterbitkan/ dibentangkan)

1. **Abustan, I.**, Santosa, B and Abdul Wahid, N. (2002), "Using USM_SWMM And USMTools In The Modeling Of Stormwater Runoff In Urban Watershed Management", *International Conference on Urban Hydrology (ICUH 2002)*, Eds. Mohd Nor et. al 16-18 October, Kuala Lumpur MIHP-UNESCO-HTC_WMO, pp. 204- 221. BA BBK 25375
2. **Abustan, I**, Desa, M.N.M, Abdul Wahid, N.(2002), 'Testing the suitability of SWMM as alternative management practices in Malaysia : the cases of four catchments', Eds. Desa M., Shahar and Sarvamudthy, *International Symposium on Comparative Regional Hydrology and Mission for IHP Phase VI of UNESCO, IHP-VI Technical Document in Hydrology No. 1, UNESCO Jakarta Office*, Kuala Lumpur, pp. 25 – 34. BABBK 25376
3. **Abustan, I**, Desa, M.N.M, and Abdul Wahid, N., (2001) 'SWMM Modeling for a Small Catchment in Kuala Lumpur' *Fresh Perspective on Hydrology and Water Resources in Southeast Asia and the Pasific* edited by M Paul Mosley, IHP-V Technical Document in Hydrology, UNESCO Jakarta Office 21-24 Nov. 2001, Christchurch, New Zealand, pp166 -172 . BABBK 30809

(b) Faedah-Faedah Lain Seperti Perkembangaan Produk, Prospek Komersialisasi Dan Pendaftaran Paten.

(Jika ada dan jika perlu , sila gunakan kertas berasingan)

Penemuan proses penentukuran untuk keadaan di Malaysia dapan meyakinkan pihak yang terlibat dalam kajian dan rekabentuk sumber air menggunakan kaedah berkomputer. Setakat ini hanya satu kajian ini yang dijalankan secara intensif untuk menentukan parameter yang sesuai untuk digunapakai di negara yang mempunyai kadar hujan yang amat tinggi seperti Malaysia. Oleh itu lebih banyak kajian lanjut terhadap permodelan berkomputer amat perlu untuk memberi gambaran sebenar keadaan saliran di seluruh Malaysia.

(c) Latihan Gunatenaga Manusia

(i) Pelajar Pasca-siswazah :

Dua orang pelajar Ijazah Sarjana sedang menghasilkan thesis PhD dan MSc yang berkaitan dengan kajian.

1. Budi Santosa (Peyelia Bersama) *Integrated Assessment for Flood Management and Water Resource Sustainability in Tidal Lowland Urban Watershed*
2. Mahyun Ab. Wahab (Penyelia Utama) *Urban Drainage modeling incoperation with GIS application*

(ii) Pelajar siswazah :

Lima projek tahun akhir telah dijalankan sepanjang kajian ini:

1. Lye Chee Weng, 2002, *The stormwater simulation in Taman Mayang Selatan (Kuala Lumpur) by CUHP/SWMM model.*
2. Krishna Veni a/p Demado, 2002, *Simulation of CUHP model in Taman Mayang Selatan (Kuala Lumpur).*
3. Lee Woei Khang, 2002, *Flood Control Study in Sungai Permatang Rawa, Daerah Seberang Perai Tengah, Pulau Pinang.*
4. Puay How Tion, 2001, *The stormwater simulation in Taman Mayang Selatan (Kuala Lumpur) by SWMM model.*
5. Ooi Cheng Leong, 2001, *Sensitivity analysis in stormwater management model (SWMM).*

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SWMM MODELING FOR A SMALL CATCHMENT IN KUALA LUMPUR

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ABSTRACT

The accurate estimation of model parameters of existing distributed, physically based urban stormwater models requires considerable work to establish model credibility. Research carried out on urban rainfall-runoff processes using computer models in the humid tropics region is still inadequate (Desa M., 1999). Noting this, the authors have taken the initiative to examine the capability and reliability of popular generalized computer models such as Storm Water Management Model (SWMM), HydroWorks and HEC in humid tropic condition such as Malaysia. However, in this paper, only the performance of SWMM is discussed.

The catchment studied is about 174 ha and consists of a mixed development with an average impervious surface value of approximately 60 to 80 percent. The catchment has 15 high resolution automatic rain gauges in an area of only 26 km^2 (Desa M., 1997). Calibration of SWMM has been performed using available information such as conduits/channel lengths, slopes, land uses and catchment slope, etc. Delineation of drainage areas and separation of impervious and pervious surfaces were achieved using existing maps. Initial losses, depression storages and infiltration parameters were estimated during calibration.

Desa M. et al. (1999) reported that the initial calibration results of SWMM were promising. A good correlation between the simulated and the observed results was found. The findings from this study showed support for Desa M. et al.'s (1999) results. What is found is that the SWMM model is capable and reliable in simulating local hydrological conditions for a fully developed urban area. The "goodness-of-fit" measures in calibration used in this study also support the ability of the model.

1. INTRODUCTION

Urban drainage systems are sensitive to the complex and interrelated dynamics of rainfall and pollutant loads from various land uses. To provide an understanding of rainfall-runoff processes, a model should be calibrated to mimic real hydrological conditions in the catchment. Adjusting model parameters is essential to minimize prediction errors, since surface runoff varies in response to the characteristics of the catchment. It is well known that models are an imperfect representation of reality. However, the model representation can be worse if there are errors in the model's structure and errors associated with model parameters or input data. Therefore, in most applications, a model must be guided into a useful tool by calibration and validation. As a guide, Nix (1994) stated that a model should:

- be able to reproduce the behaviour of an urban watershed, and,
- be precise (precision being in terms of reproducibility, which is strongly related to uncertainty or random errors).

Implementation of SWMM to simulate the response of a catchment involves the collection and analysis of a considerable volume of data. While SWMM is sufficiently flexible to enable a variety of modeling approaches, the success of the model simulations is related to the quality of the data used for the simulations. Consequently, it is worthwhile spending additional time verifying the accuracy of the database prior to the commencement of modeling.

According to Desa M. *et al.* (1999), research carried out on urban rainfall-runoff processes using computer models in the humid tropics region is still inadequate. Thus, in this study the authors take the initiative to examine the capability and reliability of popular generalized computer models such as Storm Water Management Model (SWMM), HydroWorks and HEC in humid tropic conditions such those as Malaysia. However, this paper only outlines the performance of SWMM in detail.

2. STUDY AREA

Taman Mayang was chosen as the catchment location to apply SWMM because it is already a fully developed urban area. The size of Taman Mayang is 174 ha upstream of a gauging station located at the catchment outlet. It is located to the northwest of Petaling Jaya and approximately 3km. southeast of the Sultan Abdul Aziz Shah Airport. Housing areas within this catchment include SS-2, SS-3, SS-4, SS-5, SS-25 and SS-21. The detail catchment land use and drainage layout is shown in Figure 1. The percentages of land use within the Taman Mayang catchment are presented in Table 1. Housing occupies the majority of the area (75%).

Table 1: The percentage of landuse within the Taman Mayang catchment

Landuse Type	Percentage of Area Occupied (%)
Terrace house area	51
Banglo house area	24
Open space	21
Industrial area	3
LRT Putra station area	1

The main drainage system for Taman Mayang flows to the west, out to Sungai Kayu Ara. The gauging station is located at MA 2 in the drainage system. Five auto-recording rain gauges with tipping bucket resolution of 0.2 mm to 0.5 mm and 1 auto-recording river level gauge plus 26 manual staff gauges have been installed.

The following sections of the paper describe the data requirement, calibration processes and error analysis in further detail.

3. DATA AVAILABILITY AND PARAMETER SELECTION

A significant amount of data describing both the drainage systems within the Taman Mayang catchment and the observed flows of the drainage systems were gathered. Collected data are summarised as follows:

- Drainage system data, including the actual physical details of the urban drainage network layout, conduit sizes, shapes, gradients and roughness values.
- Catchment area surface data, including the size and general nature of all contributing areas and percentage impervious values.

- Observed rainfall data and flow data, collected on the catchment for a number of different rainfall events.

For operation of SWMM in a catchment modelling system, two alternative forms of control parameters are the measured parameters and the inferred parameters as shown in Table 2. In general, the values of inferred parameters are considered those that need to be adjusted during calibration, while measured parameters are assumed error free during the calibration process. These parameters are influenced by many factors related to the characteristics of the sub-catchment.

Table 2: Control parameters in SWMM (Runoff Block)

Measured Parameters	Inferred Block
Rainfall depth	Sub-catchment width
Sub-catchment area and slope	Max and min infiltration
Catchment characteristics (landuse, soil type)	Decay rate of infiltration
	Manning's roughness
Drainage system (pipe dimension, type, size, slope)	Depression storage
	Conduit roughness coefficient

The model performs best in urbanised areas with impervious drainage, although it has been widely used elsewhere. Quantity simulations are enhanced by the calibration/verification process, but can be expected to resemble measured data fairly accurately if good information is known about area, imperviousness and rainfall. In a study in Penang (northern part of Malaysia) by the authors, SWMM was found to perform well for the Relau catchment (75% urbanized) but behaved poorly for the Air Terjun catchment (10% urbanized).

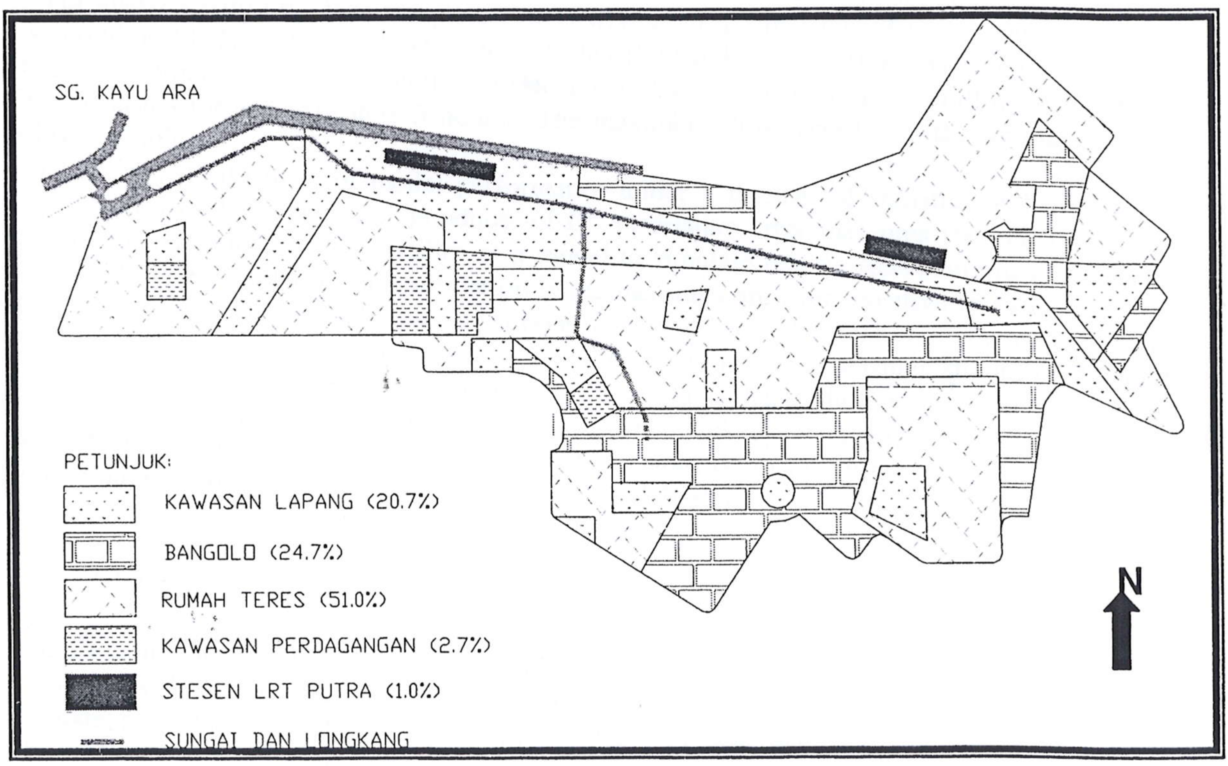

Figure 1: Percentage landuse for Taman Mayang catchment

4. CALIBRATION PROCEDURES AND ERROR ANALYSIS

A review of the literature identified various ways to calibrate SWMM. Nix (1994), for example, suggested the following technique that represents a general three-part prescription for calibration of a model. These steps which can be applied to calibration of SWMM are:

- Adjust the runoff 'depth' or 'volume'. It is probably better to first adjust those parameters that have the most effect on runoff depths. Without a fairly accurate representation of the runoff depth, the process of adjusting parameters that affect peak flows and hydrograph shapes will be much more difficult.
- Adjust the hydrograph 'peak and shape' (assuming that hydrograph simulation is desired). The peak and shape of the runoff event or events should be adjusted after the simulated runoff depths are found to fit with the observed data. However, the effect of changing the value of one of these parameters may alter the runoff depth results to some degree that may lead to some readjustment of the other parameters.
- Adjust the water quality parameters. A model that is not calibrated for quantity cannot produce reliable quality results. Therefore, parameters responsible for generating pollutant loads and their transport through the watershed should be adjusted after calibrating the quantity parameters.

Calibration is an iterative process. For example, while calibrating a model to one event, the adjustment of 'peak and shape' parameters will likely require readjustment of the depth parameters. 'Calibrated' parameters for a second event will probably not agree with those of the first event. All of this inevitably leads to compromise final parameter values that produce model results that probably fit no one event extremely well but most of the observed data reasonably well. As Abustan (1997) emphasised, a model is considered to have a 'reasonable' fit or be 'reasonably well calibrated' when it reproduces the system or catchment behaviour well enough to meet the modeling objectives.

For analysis purposes, four complete events were used in this study. These events were those that occurred on 18th Nov. 1998, 30th Dec.1998, 1st Jan 1999 and 15th Jan. 1999 to calibrate the model. The heaviest storm event occurred on the 30 December 1998 and had a peak rainfall intensity of 132 mm/hr and lasted for approximately 3 hours. The maximum flow recorded at the drainage system outfall was 23 m^3/s.

Frequently, evaluations of model performance utilise a number of statistics and techniques. Usually included in these tools are "goodness-of-fit" or relative error measures (bounded statistics, between 0.0 and 1.0) to assess the ability of a model to simulate reality. According to Legates and McCabe (1999), the correlation and correlation-based measures are over-sensitive to extreme values (outliers) and are insensitive to additive and proportional differences between model simulations and observations. They suggested that the correlation and correlation-based measures should not be used alone to assess the goodness-of-fit of a hydrologic model and that additional evaluation measures (such as summary statistics and absolute error measures) should supplement model evaluation tools. Following their comments, therefore, in this study, the evaluation of model performance is based on the correlation measure (R^2) and absolute error measures (RMSE).

5. RESULTS

The model's calibration results are presented in Figure 2. Hydrographs and scatter plots were used to evaluate the model performance for the four events. It can be seen from the plot of observed flows against model predicted flows, that a very good match has been obtained.

In addition, data used in this study were tested using normality tests before the authors embarked on any statistical analysis. As the results for these tests shown that the data were normally distributed, therefore an equal variance t- test was carried out (Table 4).

Table 3 : Comparison between observed and simulated data.

Event	Observed Depth (mm)	Simulated Depth (mm)	Observed Peak (m^3/s)	Simulated Peak (m^3/s)
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15 Jan 99	0.93	0.12	0.01	1.03	0.194

From sensitivity analysis, it was found that the parameters with the greatest impact on the depth of runoff were the impervious percentage and the impervious depression storage. Since the percentage impervious was held constant and not varied between events, only impervious depression storage could be varied for calibration of the runoff depth.

Calibration of the peak flows was more difficult than of the runoff depth because more parameters had to be adjusted. For example, in calibrating runoff depth, the Manning's *n* was not sensitive, whereas in calibrating peak flows, this parameter was sensitive as well as the impervious percentage and depression storage. In addition, time to peak or hydrograph response of a catchment is related to the spatial and temporal pattern in rainfall events. As suggested by Ball (1994), an adequate representation of rainfall over the catchment is required to match time to peak.

A comparison of the computed runoff depth with observed runoff depth is shown in Table 3. It can be concluded that the calibration processes for stormwater quantity were successful. Regression coefficient (R^2) values ranging from 0.83 to 0.94 were obtained for the scatter plot (relationship) between observed and simulated data. A t-Test indicated statistically significant differences in only one event (18th Nov. 98) (Table 4).

In the visual comparison, the overall shape of the hydrographs shows a good match. It is also supported further by the RMSE values for all events, which are small.

6. CONCLUSIONS

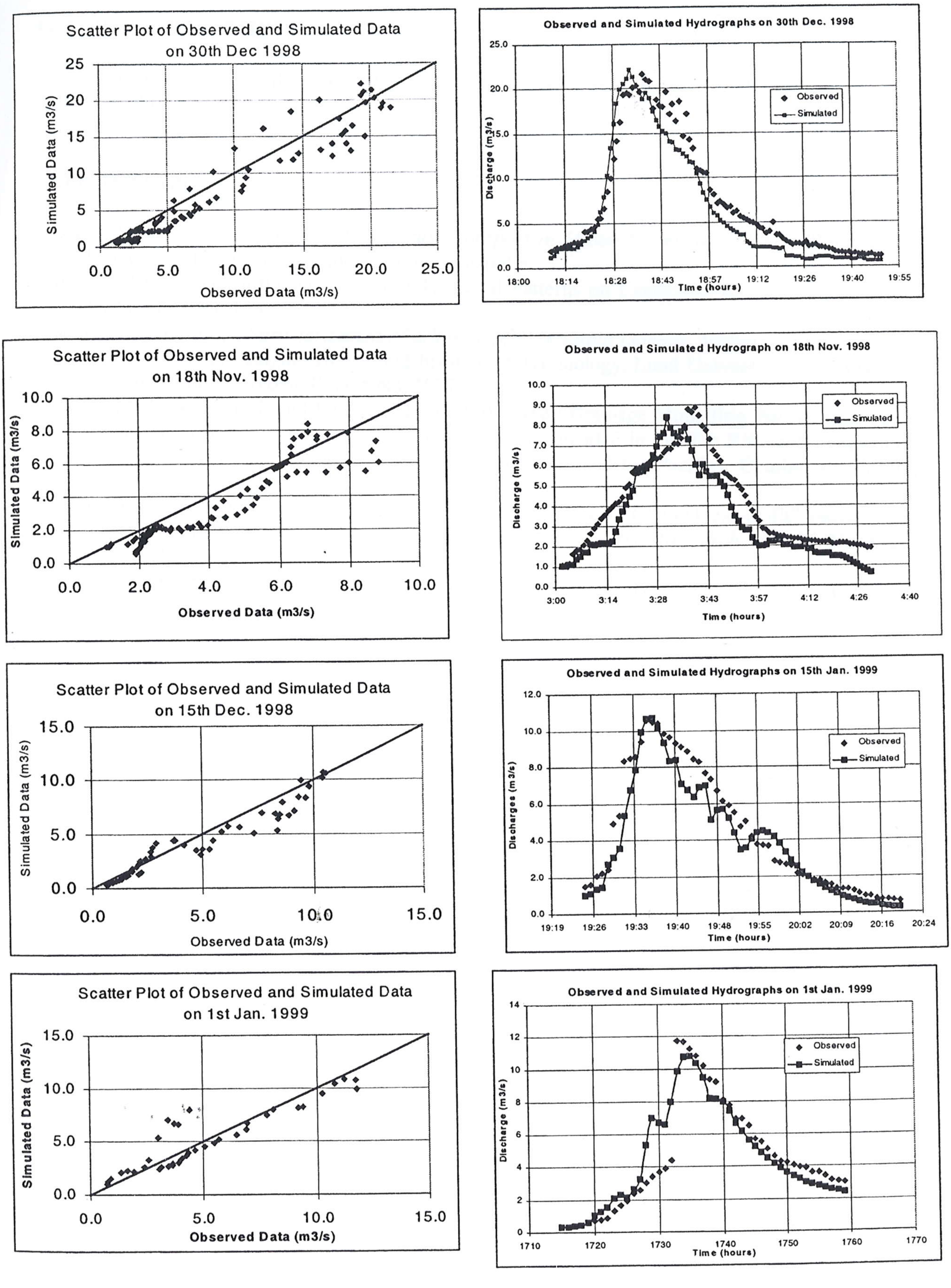
The following conclusions regarding the model calibration can therefore be made:

- The overall shape of the hydrographs shows a good match.
- The magnitude of the peak flows shows a good match, to within 10%
- The total volume of the hydrograph shows a good match, to within 20%.
- The time of the initial increase in flows (rising limb of the hydrograph) has been successfully reproduced.

Given that some errors could exist in the observed data, it is considered that, overall, a satisfactory model calibration has been achieved for this rainfall event.

More detailed calibration and testing will be carried out. Future work will include investigation of runoff response with respect to rainfall dynamics and implementation of best management practices.

Figure 2 : Observed and simulated hydrographs and scatter plots of observed and simulated data for the four events.



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Using usm_swmm and tools in the modeling of stormwater runoff in urban watershed

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Abstract Stormwater Management Model (SWMM) has been developed continuously over the past three decades. To be part of this continual development, Universiti Sains Malaysia has developed a USM_SWMM model to simplify data input requirement that can be applied to urban watershed to suit the humid tropic condition Malaysia is in. This way, the set up for data input for SWMM will not be time intensive and tedious anymore. In addition, Universiti Sains Malaysia has been developing the USMTools that can link USM_SWMM logic with ArcView extension that has both window interface and user friendly format. The data input processes can be simplified by integrating the information in a Geographic Information System (GIS) to create the datafiles required to run the model. Apart from preparing for data input, USMTools have the ability to view the simulation outputs in a graphical format. As such, this user friendly format is very useful in assisting authorities, planners, and designers in their decision making activities. A case study for Taman Sri Rambai, Penang indicates that USM_SWMM model and USMTools are efficient and effective tools in gathering and storing data, creating datafiles, and displaying modelling outputs.

Keywords SWMM, USM_SWMM, USMTools, runoff, urban hydrology, urban watershed, GIS

INTRODUCTION

It is well known that urbanization within a drainage basin tends to increase peak discharge to decrease the time taken for the flood discharge to reach its peak, and to increase the volume of runoff. Brun and Band (2000) found that land use change in urbanizing watersheds has significant impacts on hydrologic processes. In addition, Campana and Tucci (2001) indicate that floods that occur more frequently and the increase of flood flows can cause greater public damage.

Inadequate information about drainage patterns is the most common cause of failure of stormwater drains, roads, and built up structures. Therefore drainage patterns are an important consideration in planning, designing, and building roads, stormwater drains and other structures. In most instances, planning without drainage in mind can cause failure or extensive damage to property including the stormwater drains which channel the water away. With the advent of various modelling and Geographic Information Systems (GIS) tools, this problem can be averted.

A GIS is a user defined system of hardware, software, data, and procedures designed to present analysis, management, manipulation, and display of spatially referenced data in an accessible and user friendly format (Barber *et al*, 1994). GIS in combination with appropriate rainfall-runoff models provide ideal tools for the analysis and management of urban stormwater. Several researchers have utilized GIS in urban watershed modeling including Berry and Sailor (1987), Meyer *et al* (1993), Barber *et al* (1994), Haubner and Joeres (1996), Kyung-sook and Ball (1999), and, Brun and Band (2000).

AN OVERVIEW OF HYDROLOGICAL MODELS

Computer models have been used to simulate the behaviour of aquatic systems since the mid 1960s. Models capable of simulating storm water quality and quantity appeared in the earlier 1970s and were developed primarily by US government agencies, such as the US EPA, US Army Corps, USGS and etc. Since then, a number of urban watershed models have been developed. These models vary from very simple conceptual models to complex hydraulic models.

The basic concepts of the hydrological models are hydrological cycle and equilibrium equation. The hydrological cycle begins with precipitation. Precipitation in the form of rain falling on the land surface is subject to evaporation and initial loss due to interception by vegetation. The excess rainfall is available for infiltration, overland flow and depression storage. Depression storages are small pores and depressions on the land surface, which temporarily store water. Infiltrated water may flow through the upper layer of the soil that is generally the unsaturated zone of the soil, or flow deeper into the soil reaching the groundwater, or saturated zone. Water, which has infiltrated the soil and moves through the unsaturated zone and later becomes surface water, is known as interflow. In some urban stormwater models, sub-surface flows are not modelled. One reason why sub-surface hydrology is not included in some urban stormwater models is that a large proportion of the urban catchment is impervious, with little or no sub-surface flows.

Nix (1994) uses three categories- (i) simple, (ii) simple routing and (iii) complex routing models to categorise models. Each category has different demands on data input and computing resources and provides results at different time scales and spatial resolution. In simple models, no routing is performed, little data is required, calculations are not repetitive and a computer may not be required to perform the calculations. These models provide very little detail of the behaviour of the flow. In general, these models are used to provide long-term averages or peak values. The second category model generates runoff hydrographs at one point, or relatively few points in a watershed, and allows some simple routing of flow through channels and storage basin. These are usually designed to simulate watershed behaviour over long periods. This feature allows the user to estimate the characteristics of many runoff events over long periods. The last category model is capable to route flows through gutters, channels, and sewers and producing hydrograph at various locations in the urban watershed. They can be used for simulating single-event or continuous simulation. One of the better-known models of this type is the US EPA Storm Water Management Model or SWMM (Huber and Dickinson, 1988).

In order to perform effective management of urban drainage networks, accurate models are needed, which must be capable of simulating and predicting the water flow in the main sections of the network (Ball and Abustan, 2000). Zarriello (1998) compared nine uncalibrated runoff model to observed flows in two small urban watersheds. In addition, Zoppou (2001) reviews twelve models for simulating storm water quantity and quality in an urban environment. These models have been categorised in terms of their functionality, accessibility, water quantity and quality components included in the model and their temporal and spatial scale. Both studies indicate that SWMM has more advantage than other models with high percentage of modelling accuracy.

USEPA SWMM

SWMM as described by Huber and Dickinson (1988) is a large, complex urban stormwater model that is capable for simulating the movement of rainfall from the ground surface, through pipe/channel network, facilities and finally to receiving water. The model can be used to simulate a single event or continuous event.

It has been developed and continously improved since 1971 through the resources of the USEPA and others. The SWMM was one of the first efforts to develop comprehensive hydrological modeling software. Since it has been continuously funded by the USEPA, and not a commercial firm, SWMM was intended to be used by public freely for hydrologists familiar with the complex problem of surface and subsurface water flows. Numerous people have contributed to SWMM over the past three decades (especially under USEPA, Wayne Huber and Camp, Dresser & McKee) and it is available for free from public domain for SWMM version 4.4h.

SWMM is divided into several blocks (Huber and Dickinson, 1988). The major blocks are the RUNOFF, TRANSPORT, STORAGE/TREATMENT and EXTRAN are known as computational blocks. They are responsible for the hydrological and hydraulic calculations. Others perform various auxiliary functions, and are known as service blocks such as EXECUTIVE, STATISTICAL, RAIN, TEMP, GRAPH and COMBINE.

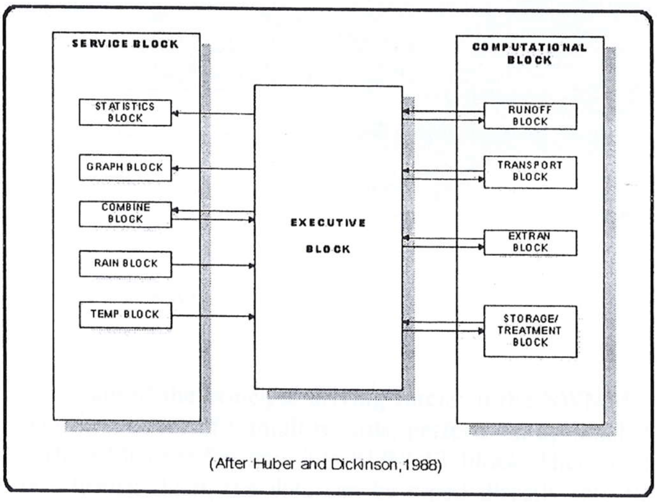

Figure 1 : The schematic diagram of SWMM Blocks (Huber and Dickinson, 1988)

USM_SWMM: Simplification and User Friendly USEPA SWMM

SWMM needs many data input parameters in order to simulate/run the program whereas data sources are limited in the urban watershed- particularly in humid tropic region (Desa *et al.*, 1999). Due to this limitation, USM develops USM_SWMM to simplify and create a user friendly mode for data input preparation into the USEPA SWMM version 4.4h.

In USM_SWMM, the USEPA SWMM version 4.4h. is simplied by reducing the number of blocks used without affecting the reliability of the model. As such, this has reduced computing time of the program and simplify data input format. Only three main blocks are utilised- RAIN, RUNOFF and

EXTRAN to simulate the quantity of stormwater for urban watershed in USM_SWMM (refer to Figure 2)

USM_SWMM consists of "RAIN block input data", "RUNOFF block input data", "EXTRAN block input data", "View data", "Run SWMM", "Extract", "View Graph", "Parameter Optimisation" and "Operational Optimisation". The first three subprograms can be used to edit the data input. They will transfer data to ASCII format automatically so that the data can be read by USEPA SWMM. "View data" can be used to view ASCII format data (use notepad) and revise the data input. "Run SWMM" is used to run the SWMM. "Extract" is used to extract the output of the Extran block. The subprogram will show error, warning, overflow and continuity error, and create three files (inflow, flow and elevation) that will be used by "View Graph". "Parameter Optimisation" is used to calibrate the model.

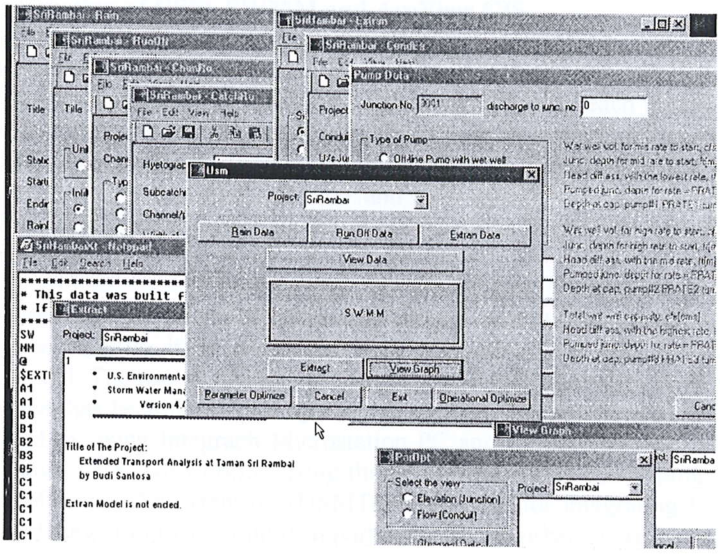

Figure 2: The Control Panel of USM_SWMM

RAIN Block. Rainfall data is one of the principal driving forces in the SWMM. The purpose of the RAIN block is to read long time series of rainfall records, perform an optional storm event analysis and generate a rainfall interface file used for input into RUNOFF block. There are three ways how one can fill in the rainfall data format. First, the data can be typed directly into the RUNOFF Block. Second, the data can be utilized using the ASCII free formatted text file containing two informations, i.e time and rainfall value for each line. The third method which is new, enables the rain data to be generated from IDF equations provided by MSMA (Manual Saliran Mesra Alam).

RUNOFF Block. The RUNOFF block generates surface runoff in response to rainfall. The watershed is divided into a number of subwatershed and each watershed should be relatively homogenous (the physical characteristic should be consistent). Dividing the watershed into a large number of subwatersheds implies that each is probably very homogenous (Nix, 1994). The concept of surface runoff used by the RUNOFF block is quite simple. The principle of this block is that each subwatershed surface is treated as a non linear reservoir with a single inflow.

There are several discharges, this includes infiltration, evaporation and surface runoff. The capacity of this reservoir is the maximum depression storage (the maximum storage provided by ponding, surface wetting, and interception). Surface runoff occurs only when the depth of water in this reservoir exceeds the maximum depression storage.

EXTRAN Block. The EXTRAN block is a hydraulic flow routing model for channel/conduit. The block receives hydrograph input at a specific junction by interfacing file transfer from from RUNOFF Block and/or by direct user input. The block that uses the complete Saint-Venant equations performs dynamic routing of stormwater flows throughout the major storm drainage system to the points of outfall to the receiving water system (Huber and Dickinson, 1988). It will simulate branched or looped networks, backwater due to tidal or nontidal conditions, free surface flow, pressure flow or surcharge, flow reversals, flow transfer by weirs, orifices and pumping facilities, and storage facilities at on or off line. Simulation output takes the form of water surface elevations and discharge at selected system locations.

USMTools: The Integration of USM_SWMM and ArcView GIS

The relationship/interaction between USM_SWMM and USMTools is shown in Figure 3. USMTools is called from ArcView to find required parameters such as coordinate of each junction, length of each conduit, subcatchment area, width of each subcathment and percent of impervious of each subcatchment. USMTools can also be used to show the advance graphical results of inflow graph, water surface elevation graph at certain junction and flow graph at certain conduit and indicate flooded junction. The USM_SWMM program can be called from USMTools extension or from start menu program windows.

The creation of required data input for SWMM is very intensive and time consuming. Thus, Barber et al (1994) suggested to simplify it by integrating the information in a GIS to create the datafiles required to run the model. The use of Arc/Info GIS as pre- and post- possessor to EPA SWMM in the UNIX operating system has been developed by Cera et al (1996). Barber et al (1994) then integrated both GIS and SWMM by using Integraph Microstation PC and Oracle database. The researchers in Universiti Sains Malaysia are also working using the same principle in developing an ArcView GIS extension called USMTools. The extension (USMTools) is used for integrating USM_SWMM and ArcView GIS for modeling stormwater runoff in particular for the urban areas. In the study, ArcView has been selected because it is a sophisticated desktop mapping software which promises to bring the power of GIS to the average PC user (Shamsi, 1996).

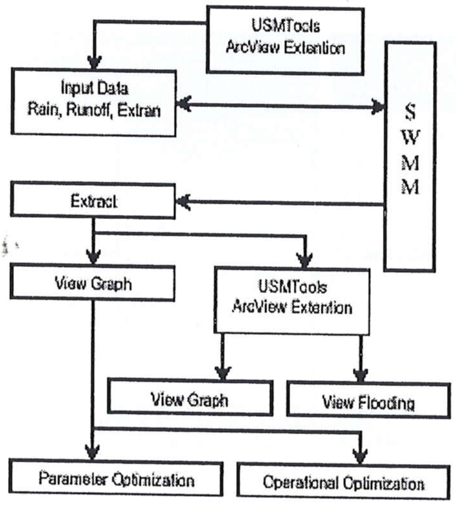

Figure 3. Schematic interaction between USM_SWMM.and USMTools

There are three goals for developing the USMTools. The first goal is to organize the data input to describe the drainage basin into a database. This is accomplished by creating a logical database format and user-friendly forms, displaying the RUNOFF and EXTRAN blocks data information. Data entry and review for each database table were accomplished by creating user-friendly screen forms. For maximum flexibility, the forms are designed to be consistent with the USEPA SWMM model. Some physical parameters that are required as data input, such as length of the conduits, junction coordinates, width of the subcatchment, and percent impervious, can be derived by using USMTools. The second goal is to create interface datafiles as an ASCII text file in order to use USEPA SWMM "engine". Finally, the goal is to develop user friendly graphically results display through the ArcView GIS for a more comprehensive decision support system.The drainage conveyance system capacities, design flows, and inadequacies can be displayed on the drainage schematic. The extension of USMTools can provide user friendly graphically result display facilities.

USM_SWMM and USMTools Application

The USM_SWMM and USMTools have been used in two catchments for verification purposes, Taman Mayang Selatan, Kuala Lumpur and Taman Sri Rambai, Penang. This paper only describes the latter study.

Taman Sri Rambai (Phase 2, 3 and 4), Seberang Perai, Penang, was chosen as the urban watershed to apply both the USM_SWMM and USMTools. This watershed is a fully developed urban area with a catchment area of about 70 ha. The boundaries of the watershed are Cross Drain No. 2 in the north, Cross Drain No. 3 in the south, Parit 4 (Parit 4 is an extension of the Sungai Permatang Rawa) in the west and Sungai Rambai in the east. Originally, the watershed was a swamp area. Due to rapid urbanization, this area has been developed into residential and commercial areas without proper consideration on river basin and urban drainage management USM (2000). Rainfall data records from the Permatang Rawa station (station no. 5304046) has been used in the simulation. The detail characteristic of the watershed were derived from the USM (2000) study. Drainage layout was taken from the digital survey plan supplied by the Majlis Perbandaran Seberang Perai. Some sample of the simulation results are shown in Figure 4.

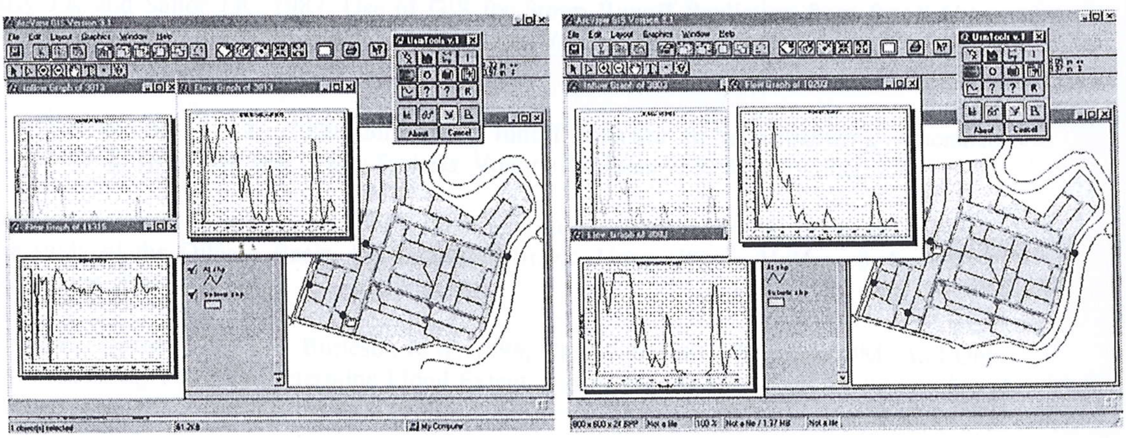

Figure 4. Application of USMTools for Simulation at Taman Sri Rambai, Penang.

CONCLUSION

ArcView GIS with the integration of SWMM model provide ideal tools for the analysis and management of urban stormwater. The results from the study concerning Taman Sri Rambai, Seberang Perai Tengah, Penang, indicates that USM_SWMM and USMTools are efficient and effective in gathering and storing data, creating datafiles, and displaying modelling results. The overall process of creating the datafiles was simplified with the use of the form application. As a result, efforts could be focused on the analysis of the drainage system and as such, many more alternatives could be evaluated. In addition, inaccurate or erroneous data could be identified within the GIS user friendly graphical format. The graphical display of the modelling results also provide an easy and effective means of analyzing the drainage system and identifying flooding locations and system inadequacies. Finally, with the location maintaining the modelling information within their GIS, future master plans will benefit from the up-to-date information.

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Testing the suitability of SWMM as alternative management practices in Malaysia: the cases of four catchments

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Abstract To date, research carried out on urban rainfall-runoff processes using computer models in the humid tropics region is still inadequate. This is due to one having to ensure accurate estimation of model parameters of existing distributed physical based urban stormwater models to establish model credibility. In this article, the capability and reliability of a popular generalized computer model called StormWater Management Model (SWMM) in humid tropic condition such as Malaysia is examined.

Taman Mayang and Sungai Kerayung (in Kuala Lumpur) and Sungai Relau and Sungai Air Terjun (in Penang) were chosen as catchments in this study. The size of the catchments ranges from 1.72 to 52km^2 and consist of a mixed development/land uses. Calibration of SWMM was performed using available information such as conduits/channel lengths, slopes, land uses and catchment slope, etc. Delineation of drainage areas and separation of impervious and pervious surfaces were achieved using existing maps. Initial losses, depression storages, infiltration parameters and other were estimated during calibration.

The study found good results in terms of runoff depth, peak flow and hydrograph shape between the simulated and the observed data. This implies that SWMM is suitable to be used as alternative management practices in managing water resources in humid tropic condition such as Malaysia.

Keywords Stormwater Management Model (SWMM), distributed physical model, urban drainage, alternative management practices.

INTRODUCTION

This paper reviews Storm Water Management Model (SWMM), an alternative numerical model for the simulation of the quantity of stormwater runoff from catchments especially in an urban environment. As a deterministic model, SWMM is capable of simulating all aspects of the urban hydrologic cycle in terms of the quantity and quality of surface runoff, its transport through the drainage network, the storage and treatment applied to it, and any receiving water effects. Hence, there are many advantages in using it for planning, design and operational purposes (Huber and Dickinson, 1988). In addition, it has been employed in many studies in US, Canada and Australia (*e.g.* Donigian and Huber, 1991; Ball, 1992; Abustan 1997, Ball and Abustan 2000).

Urban drainage systems are sensitive to the complex and interrelated dynamics of rainfall from various land uses. To provide an understanding of rainfall-runoff processes, a model should be calibrated to mimic real hydrological conditions in the catchment. Adjusting model parameters is essential to minimize prediction errors, since surface runoff varies in response to the characteristics of the catchment. It is well known that models are an imperfect representation of reality. However, the model representation can be worse if there are errors in the model's structure and errors associated with model parameters or input data. Therefore, in most applications, a model must be guided into a useful tool by calibration and validation. As a guide, Nix (1994) stated that a model should:

- be able to reproduce the behavior of an urban watershed, and,
- be precise (precision being in terms of reproducibility, which is strongly related to uncertainty or random errors).

Implementation of SWMM to simulate the response of a catchment involves the collection and analysis of a considerable volume of data (refer Table 3). While SWMM is sufficiently flexible to enable a variety of modeling approaches, the success of the model simulations is strongly related to the availability and the quality of data used in the simulations. Thus, one is suggested to spend more time to verify the accuracy of the database prior to the commencement of modeling.

STUDY AREAS

Four (4) catchments had been identified based on the availability and the quality of data that can be used for simulation of SWMM.

Taman Mayang was chosen as the catchment location to apply SWMM because the catchment had been previously studied and it had been identified as an experimental urban catchment (Desa M, 1997). The size of Taman Mayang is 1.74 km^2. It is a fully developed urban area located to the northwest of Petaling Jaya and approximately 3km. southeast of the Sultan Abdul Aziz Shah Airport. Housing areas within this catchment include SS-2, SS-3, SS-4, SS-5, SS-25 and SS-21. The detail catchment land use and drainage layout is shown in Figure 1. The percentages of land use within the Taman Mayang catchment are presented in Table 1. Housing occupies 75% of the area. The gauging station is located at MA 2 in the drainage system. Five auto-recording rain gauges with tipping bucket resolution of 0.2 mm to 0.5 mm and 1 auto-recording river level gauge have been installed.

Landuse Type	Percentage of Area Occupied (%)
Terrace house area	51
Bungalow house area	24
Open space	21
Industrial area	3
LRT Putra station area	1

Table 1. The percentage of landuse within the Taman Mayang catchment

Sungai Kerayong catchment covers an area of 52 km^2 and is a major tributary of Sungai Klang. It is subdivided into 8 sub catchments. A major portion (60%) of these sub catchments is extensively urbanized areas and the rest in the outer urban area. The percentage of impervious areas in these sub catchments are presented in Table 2. There are 5 monitoring station to record the water level and rainfall depth throughout of the catchment.

Subcatchment	Area (km^2)	% Impervious
Cheras	8.83	40
Hulu Langat	4.79	40
Ampang	6.54	60
Kampung Pandan	7.02	60
Shemelin	9.44	50
Seri Petaling	5.01	30
Taman Desa	7.55	60
Kelang Lama	7.55	60

Table 2: Subcatchment areas and percentage impervious areas of Sungai Kerayong Catchment (E.M Yahya et al. 1998)

Another study area selected is a small catchment for the Sungai Air Terjun which is located at the Penang Hill; Penang with a size of 4.98 km^2. It is a part of the Penang Forest Reserve, which is under constant pressure for various agricultural activities and urban developments. At present, the land uses are 92% natural forest, 6.4% scrubland, 0.3 % agriculture and 1.3% are residential, commercial and recreational land (Rainis *et al*, 1998). A temporary gauging station was set up by School of Humanities, USM under supervision of Dr. Wan Ruslan Ismail (Ismail 1995).

Sungai Relau catchment, the fourth study area is also located in Penang Island. It is an urban catchment with an area of 10.87 km^2. The catchment is in the process of urbanization. The main land uses are residential and commercial. High density residential area is located in the lower part of the catchment whereas hotels, bungalows and low-density residential area are located in the upper part of the catchment. According to Ismail (1994), urbanized areas consist of 80 percent of the total catchment. A temporary gauging station was also set up by School of Humanities, USM (Ismail 1995).

DATA AVAILABILITY AND PARAMETER SELECTION

A significant amount of data describing both the drainage systems and the observed flows of the drainage systems were gathered. Collected data are summarised as follows:

- Drainage system data, including the actual physical details of the urban drainage network layout, conduit sizes, shapes, gradients and roughness values.
- Catchment data, including the size and general nature of all contributing areas (land uses) and percentage impervious values.
- Observed rainfall data and flow data, collected on the catchment for a number of different rainfall events.

For operation of SWMM in a catchment modelling system, two alternative forms of control parameters are the measured parameters and the inferred parameters as shown in Table 3. In general, the values of inferred parameters are considered those that need to be adjusted during calibration, while measured parameters are assumed error free during the calibration process. These parameters are influenced by many factors related to the characteristics of the sub-catchment.

Measured Parameters	Inferred Block
Rainfall depth Sub-catchment area and slope Catchment characteristics (land use, soil type) Drainage system (pipe dimension, type, size, slope)	Sub-catchment width Max and min infiltration Decay rate of infiltration Manning's roughness Depression storage Conduit roughness coefficient

Table 3. Control parameters in SWMM (RUNOFF Block)

The model performs best in urbanised areas with impervious drainage, although it has been widely used elsewhere. Quantity simulations are enhanced by the calibration/verification process, but can be expected to resemble measured data fairly accurately if good information is known about area, imperviousness and rainfall.

CALIBRATION PROCEDURES AND ERROR ANALYSIS

A review of the literature identified various ways to calibrate SWMM. Nix (1994) and Abustan (1997), for example, suggested the following technique that represents a general three-part prescription for calibration of a model. These steps which can be applied to calibration of SWMM are:

- Adjust the runoff 'depth' or 'volume'. It is probably better to first adjust those parameters that have the most effect on runoff depths. Without a fairly accurate representation of the runoff depth, the process of adjusting parameters that affect peak flows and hydrograph shapes will be much more difficult.
- Adjust the hydrograph 'peak and shape' (assuming that hydrograph simulation is desired). The peak and shape of the runoff event or events should be adjusted after the simulated runoff depths are found to fit with the observed data. However, the effect of changing the value of one of these parameters may alter the runoff depth results to some degree that may lead to some readjustment of the other parameters.
- Adjust the water quality parameters. A model that is not calibrated for quantity cannot produce reliable quality results. Therefore, parameters responsible for generating pollutant loads and their transport through the watershed should be adjusted after calibrating the quantity parameters.

Calibration is an iterative process. For example, while calibrating a model to one event, the adjustment of 'peak and shape' parameters will likely require readjustment of the depth parameters. 'Calibrated' parameters for a second event will probably not agree with those of the first event. All of this inevitably leads to having compromise final parameter values that produce model results that will probably fit no one event extremely well but most of the observed data reasonably well. As Abustan (1997), and Ball and Abustan (2000) emphasized, a model is considered to have a 'reasonable' fit or be 'reasonably well calibrated' when it reproduces the system or catchment behavior well enough to meet the modeling objectives.

Evaluations of model performance utilise a number of statistics and techniques. Usually included in these tools are "goodness-of-fit" or relative error measures (bounded statistics, between 0.0 and 1.0) to assess the ability of a model to simulate reality. The objectives of catchment models are generally to determine runoff depth, peak flow rate, and hydrograph shape and timing. The evaluation criteria for calibrating model parameters are relative error (RE).

Relative Error (RE) $$RE = \frac{Obs. - Sim.}{Obs.}$$

where:
Obs. is observed values
Sim. is simulated values

According to Legates and McCabe (1999), the correlation and correlation-based measures are over-sensitive to extreme values (outliers) and are insensitive to additive and proportional differences between model simulations and observations. They suggested that the correlation and correlation-based measures should not be used alone to assess the goodness-of-fit of a hydrologic model and that additional evaluation measures (such as summary statistics and absolute error measures) should supplement model evaluation tools.

RESULTS

Stormwater Runoff Depth and Peak Flows

The parameters with the greatest impact on the depth of runoff were the impervious percentage and the impervious depression storage. Since the percentage impervious was held constant and not varied between events, only impervious depression storage could be varied for calibration of the runoff depth.

The calibration of the peak flows was more difficult than the runoff depth because more parameters had to be adjusted. For example, in calibrating runoff depth, the Manning's *n* was not sensitive, whereas in calibrating peak flows, this parameter was sensitive as well as the impervious percentage and depression storage. In addition, time to peak or hydrograph response of a catchment is related to the spatial and temporal pattern in rainfall events. As suggested by Ball (1994), an adequate representative of rainfall over the catchment is required to match time to peak.

The SWMM model's calibration results for four (4) catchments in Malaysia are presented in Table 4 through 7. Hydrograph shapes and scatter plots were used to evaluate the model performance for the four catchments (refer Figures 1 through 3). The basic statistical evaluation (relative errors) indicates that the SWMM model can be used effectively in humid tropic condition as Malaysia since values of relative errors of depth and the peak flows were small (refer Table 4 to 7).

In most of the cases, SWMM simulates well especially for the runoff depth. As discuss in the previous section, it is more difficult to estimate peak flow rather than runoff depth. In general, the RE for runoff depth were lest that 15% except on the 3 Aug.93 event for Sg. Air Terjun catchment.

The highest relative error for depth and peak flow occurred on the 3 Aug.93 event for Sg. Air Terjun catchment. It is expected because this catchment is a natural catchment (least develop). It behaves more complex since the loss model in SWMM emphasised on depression storage and infiltration.

Event	Depth (mm)		Peak (m^3/s)		% RE Depth	% RE Peak
	Observed	Simulated	Observed	Simulated		
18 Nov. 98	11.6	10.3	8.8	8.4	11.2	4.54
1 Dec. 98	41.8	35.8	32.4	29.1	14.4	10.2
30 Dec. 98	25.0	22.0	21.6	22.2	12.0	-2.78
1 Jan. 99	7.0	7.1	11.8	10.8	-1.43	8.47
15 Jan 99	8.5	7.6	10.6	10.7	10.6	-1.00

Table 4. Comparison between observed and simulated values and model performance for Taman Mayang

Event	Depth (mm)		Peak (m^3/s)		% RE Depth	% RE Peak
	Observed	Simulated	Observed	Simulated		
25 Oct. 97	13.3	13.1	95.0	96.2	1.50	-1.26
27 Oct. 97	8.75	7.79	43.0	48.1	11.0	-11.9
24 Nov 97	8.77	9.01	40.0	44.8	-2.74	-12.0

Table 5. Comparison between observed and simulated values and model performance for Sungai Kerayong

Event	Depth (mm)		Peak (m^3/s)		% RE Depth	% RE Peak
	Observed	Simulated	Observed	Simulated		
6 Sept 93	2.98	3.05	2.70	3.14	-2.35	-16.3
19 Sept 93	7.94	8.92	7.94	9.28	-12.3	-16.9

Table 6: Comparison between observed and simulated values and model performance for Sungai Relau

Event	Depth (mm)		Peak (m^3/s)		% RE Depth	% RE Peak
	Observed	Simulated	Observed	Simulated		
3 Aug 93	2.40	1.72	0.36	0.46	28.3	-27.8
19 Aug 93	1.90	2.18	0.47	0.49	-14.7	-4.27
23 Aug 93	16.2	13.9	3.55	3.88	14.2	-9.30

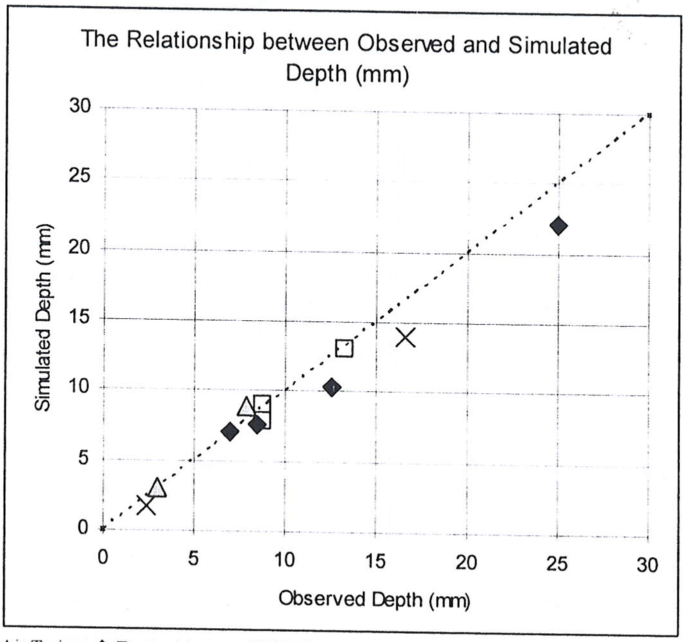
Table 7: Comparison between observed and simulated values and model performance for Sungai Air Terjun

A comparison of the computed runoff depth with observed runoff depth is shown in Figures 1 and 2 for each of the events. It can be seen from the plot of observed flows against model predicted flows, that a very good match has been obtained

Shape of the Hydrograph

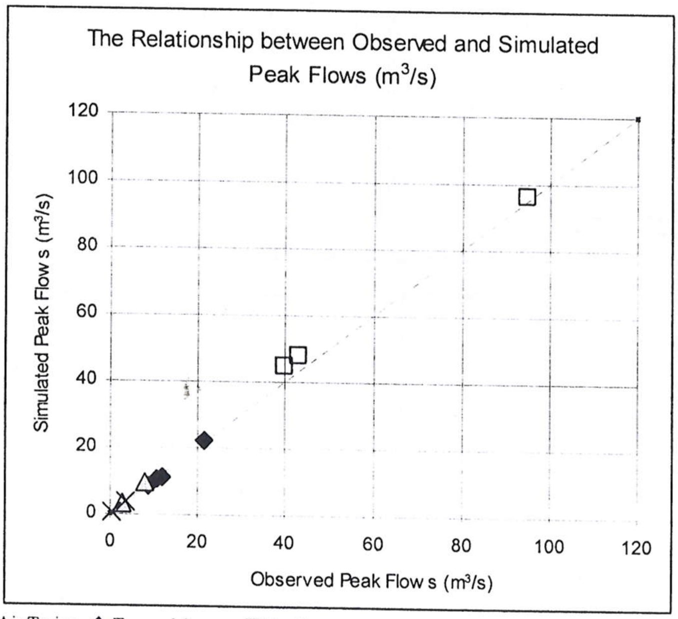
The shape of the hydrograph is very difficult to simulate as it is a combination of runoff depth, peak flow and response time. For a single peak, the shape factor can be determined from the runoff depth and peak flows but it is difficult to justify for multiple peaks.

In the visual comparison, the shape of the hydrograph including the runoff volume (depth) and the peak flow of observed values was compared to the simulated value. In the case of multiple peak flows, the correspondent simulated peaks should be as similar as the observed peaks. Comparisons of the simulated hydrographs with the observed hydrographs for selected events are shown in Figure 3 for the all four catchments. In the visual comparison, the overall shapes of the hydrographs show a good match.



Note : Δ Sg. Relau × Sg. Air Terjun ◆ Taman Mayang □ Sg. Kerayong

Figure 1: A scatter plot of observed and simulated depth values for the four catchments.



Note : Δ Sg. Relau × Sg. Air Terjun ◆ Taman Mayang □ Sg. Kerayong

Figure 2: A scatter plot of observed and simulated peak flow values for the four catchments

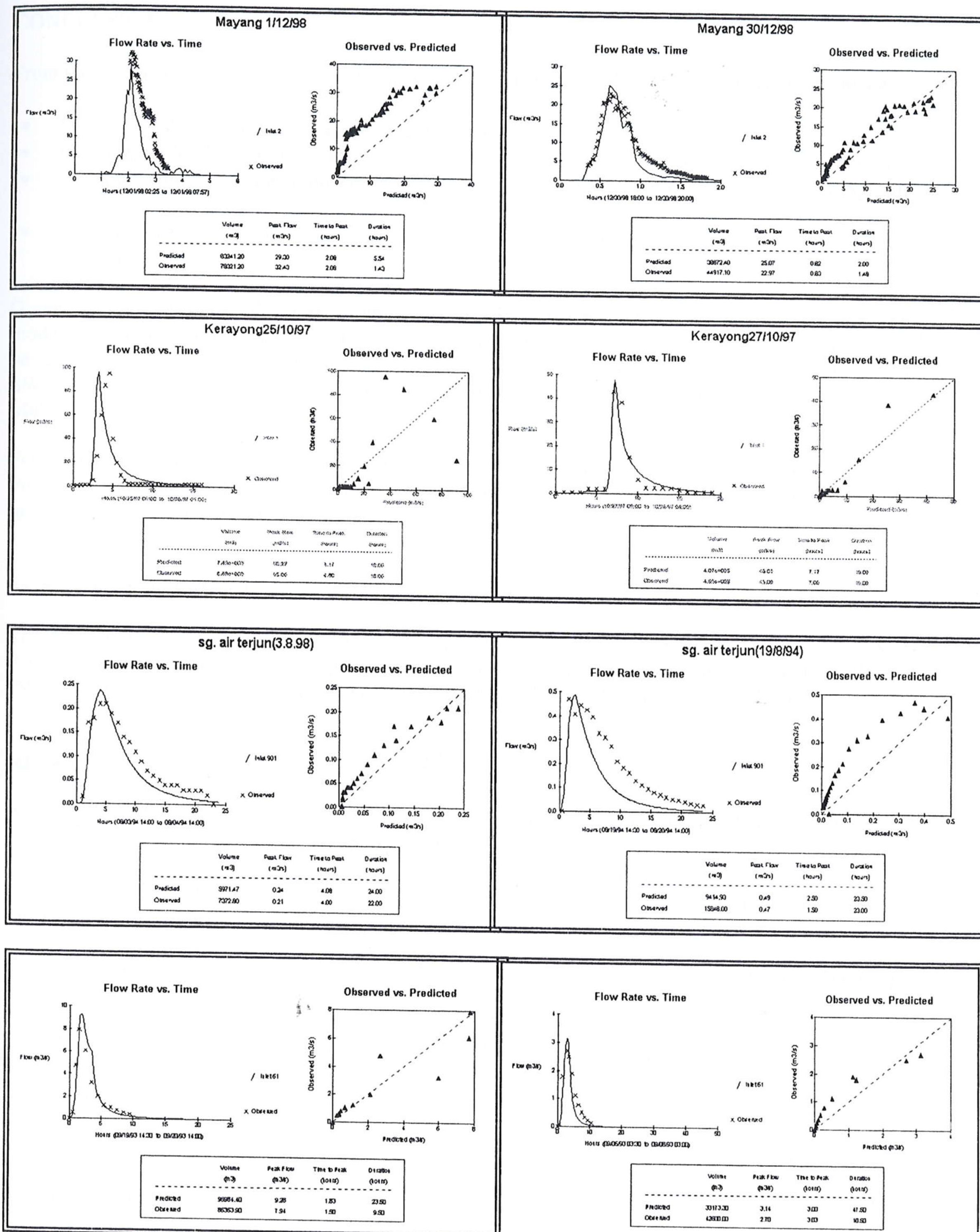


Figure 3: Shape of Hydrographs simulated for the four catchments (Taman Mayang, Sungai Kerayong, Sungai Air Terjun and Sungai Relau)

CONCLUSIONS

From the findings, the following conclusions regarding the model calibration can therefore be made:

- The overall shape of the hydrographs shows a good match.
- The magnitude of the peak flows shows a good match, to within 15% except for Sg. Air Terjun
- The total volume of the hydrograph shows a good match, to within 20% except for Sg. Air Terjun.
- The time of the initial increase in flows (rising limb of the hydrograph) has been successfully reproduced.

Given that some errors could exist in the observed data, it is considered that, overall; a satisfactory model calibration has been achieved for these rainfall events. It indicates that the SWMM model can be used as alternative management tools in managing our urban hydrology. It also implies that SWMM is suitable to be used in managing water resources in humid tropic condition such as Malaysia.

For future study, it is recommended that more detailed calibration and testing to be carried out. Future work should include investigation of runoff response with respect to rainfall dynamics and implementation of best management practices.

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SIMULASI AIR LARIAN RIBUT DI TAMAN MAYANG SELATAN (KUALA LUMPUR) DENGAN MODEL CUHP/SWMM

Oleh

Lye Chee Weng

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ABSTRAK

Walaupun konsep penggunaan model komputer dalam kerja rekabentuk hidrologi dan hidraulik telah lama dipraktikkan di luar negara, namun ianya kekal sebagai 'rantai' yang hilang dalam bidang rekabentuk tempatan. Proses urbanisasi yang kian berlaku dan menyebabkan kejadian banjir di bandar-bandar besar pada seluruh Malaysia telan menimbul kembali minat pihak-pihak tertentu dalam konsep pemodelan ini. Apabila digunakan secara berkesan, model komputer bukan sahaja dapat menjimatkan masa namun kos yang dilaburkan. Keputusan tesis ini bagaimanapun menunjukkan kepentingan proses penentuukuran sebelum dapat digunapakai sepenuhnya. Tujuan tesis ini adalah untuk menentukan kesesuaian dan kebolehpercayaan model komputer (CUHP dan SWMM) dalam simulasi air ribut bandar secara kuantitatif. Juga dicadangkan dalam bab 2 pada tesis adalah penggunaan data hujan berterusan. Model CUHP dan UDSWM telah digunakan sebagai perbandingan untuk sebuah kawasan tadahan yang pernah dikaji di Lembah Klang. Walaubagaimanapun, amat dikesali model UDSWM tidak dapat dihubungkait dengan model CUHP dan hanya output terhad sahaja yang mampu dihasilkan. Model CUHP bagaimanapun digunakan untuk mengira hidrograf ribut. Analisis aliran puncak dan isipadu ribut diterangkan dengan lanjut dalam bab ke-6.

PENGHARGAAN

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Bantuan rakan-rakan sekalian dan anggota PPKA juga tidak saya lupakan. Jasa anda sentiasa ku ingatkan.

ISHNA VANI :

ulasi Air Larian Ribut bagi Kawasan Taman Mayang

ABSTRAK

Pendekatan moden yang digunakan untuk mengkaji peristiwa ribut dan air larian secara saintifik dan kuantitatif bagi kawasan tadahan bandar sebenarnya telah berusia lebih dari 100 tahun. Model berkomputer menjadi sebahagian daripada perancangan struktur dan rekabentuk sistem saliran sejak dari pertengahan tahun 1970an lagi. Model ialah suatu proses yang mampu membantu meningkatkan tahap pemahaman mengenai suatu sistem (semulajadi / rekabentuk) dan cara penyelesainnya bagi pelbagai peristiwa ribut. Sebuah model air larian ribut bandar berupaya menyelakukan (simulate) pergerakan air larian ribut dan bahan-bahan terangkut melalui suatu kawasan tadahan bandar sebagai tindak balas (respond) kepada hujan, ciri-ciri fizikal kawasan tadahan serta parameter masukan. Suatu model tidak sempurna tanpa pengesahan model dengan set data yang berlainan. Ini perlu dilakukan sebelum model itu mencapai tahap keboleharapan yang tinggi. Setelah itu, analisis dilakukan dengan membandingkan data sebenar. Tesis ini akan memperbincangkan mengenai 2 model iaitu CUHP dan SWMM versi 4.3 “Windows Interface” sebagai perbandingan.

PENGHARGAAN

Syukur kepada Yang Maha Berkuasa kerana atas rahmat dan berkatnya, laporan projek tahun akhir, dapat saya sudahi dengan jayanya. Dalam menyediakan laporan projek tahun akhir ini, pelbagai masalah dan rintangan terpaksa saya lalui. Namun, atas bantuan dan kerjasama pelbagai pihak yang sudi membantu, kesemua rintangan dan masalah ini dapat diatasi. Penghargaan yang tidak terhingga ingin saya tujukan kepada semua pihak yang telah membantu saya sepanjang menjalankan projek tahun akhir saya.

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KAWALAN BANJIR DI SEKITAR SUNGAI PERMATANG RAWA, DAERAH SEBERANG PERAI TENGAH PULAU PINANG

Oleh

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PENGHARGAAN

Di sini saya ingin mengambil kesempatan untuk menyatakankan setinggi-tinggi penghargaan dan jutaan terima kasih kepada Dr. Ismail Abustan selaku penyelia saya yang sanggup melapangkan masa dan bersusah payah dalam memberi tunjuk ajar, nasihat, dorongan dan bantuan kepada saya dalam projek tahun akhir ini walaupun beliau sibuk dengan urusan harisn dan pejabat. Beliau tidak jemu-jemu memberi bantuan dan panduan, menyediakan maklumat yang berkaitan, memberi idea dan garis panduan yang bernas lagi efektif supaya hasil reka bentuk dan penulisan tesis ini dapat disiapkan dengan sempurna.

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ABSTRAK

Projek tahun akhir ini dilaksanakan dalam kawasan kajian di Sungai Permatang Rawa. Rekod-rekod dan data-data hujan kawasan kajian diperolehi daripada Encik Naser Khan dari Jabatan Pengairan Dan Saliran Pulau Pinang. Tujuan utama projek ini ialah mengawal masalah banjir yang berlaku di sekitar Sungai Permatang Rawa. Antara langkah permulaan yang terlibat ialah menentukan kadar alir rekabentuk ARI 50 tahun dengan menggunakan kaedah Rasional dalam sub-kawasan kajian. Bagi menentukan kadar alir puncak dalam keseluruhan kawasan tadahan Permatang Rawa pula, kaedah Muskingum digunakan sebagai kaedah penghalaan banjir kawasan kajian tersebut. Setelah menentukan jumlah kadar alir puncak dalam kawasan tadahan, langkah seterusnya ialah rekabentuk laluan air bagi Sungai Permatang Rawa supaya dapat menampung kadar alir rekabentuk ARI 50 tahun. Perangkap mendakan dipasang sebagai langkah kawalan kualiti air yang akan mengalir ke dalam Sungai Permatang Rawa. Pembentung *(culvert)* direkabentuk sebagai struktur hidarulik yang merentasi Sungai Permatang Rawa. Selain itu, pengiraan bagi menentukan samada kesan air balik yang berlaku akibat pengecutan saluran penyaliran akan menyebabkan limpahan air pada permukaan jalan dan kawasan sekelilingnya atau tidak juga dilakukan.

TESIS (a)

APLIKASI MODEL HEC-RAS DALAM SIMULASI PROFIL AIR DAN REKABENTUK PENGUBAHSUAIAN KE ATAS SG. PERMATANG RAWA

ONG LIP HEE

56101

PENGHARGAAN

Dalam usaha menyiapkan projek ini, saya ingin mengambil kesempatan ini untuk merakamkan hutang budi saya kepada semua pihak yang telah membantu saya menjayakan projek ini. Pertama sekali, ucapan penghargaan saya adalah kepada penyelia saya, Dr. Ismail Abustan (Pusat Pengajian Kejuruteraan Awam, USM) kerana dedikasi beliau terhadap penyelidikan ini di atas segala pertolongan dan bantuan yang tidak pernah mengenal erti jemu. Dengan adanya bantuan beliau, saya berjaya menyiapkan projek tahun akhir yang menarik ini.

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ONG LIP HEE

(5 Januari 2002)

ABSTRAK

Projek ini adalah untuk mengaplikasikan model HEC-RAS dalam melaksanakan simulasi profil air permukaan bagi sesuatu saliran semula jadi dan meninjau sejauh mana model HEC-RAS dapat memodelkan kawasan tadahan yang diwakili sebagai sesuatu sistem. Dengan kata lain, model ini turut merumuskan keupayaan kapasiti saliran dalam menampung kapasiti air larian yang semakin meningkat. Keputusan analisis menunjukkan kapasiti saliran yang sedia ada gagal dari segi keberkesanan untuk menampung luahan air larian kawasan tadahan berkenaan untuk 50 tahun mahupun 10 tahun yang akan datang. Adalah difahamkan keadaan ini jika dibiarkan berterusan akan mewujudkan kejadian banjir kilat yang tidak menentu terutamanya pada musim tengkujuh. Bagaimanapun, ketidakcukupan saliran tersebut telah diatasi dengan cadangan untuk mereka dan mengubahsuaikannya dengan menggunakan perisian HEC-RAS untuk ribut rekabentuk 50 tahun. Analisis kemudian dijalankan pada model yang telah diubahsuai ini dan keputusan menunjukkan model yang dihasilkan adalah memuaskan. Justeru itu, pelaksanaan saliran yang baru ini telah meningkatkan keupayaan saliran dalam menampung luahan air larian kawasan tadahan tersebut tanpa pelimpahan untuk ribut rekabentuk 50 tahun. Ini secara tidak langsung telah mengatasi masalah banjir kilat yang akan melanda. Akhir sekali, perbandingan juga dijalankan ke atas saliran sedia ada dengan saliran rekabentuk dalam profil air permukaan keratan rentas, didapati keputusan saliran rekabentuk mempunyai keberkesanan yang nyata mengatasi saliran sedia ada mahupun dari segi keupyaan kapasiti saliran ataupun profil air permukaan.

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TESIS

Simulasi Air Larian Ribut Di Taman Mayang Selatan (Kuala Lumpur) Dengan Model SWMM

Puay How Tion
(50663)

ABSTRAK

Salah satu daripada pendekatan baru untuk menganggar, menganalisis dan menilai air larian ribut di kawasan bandar adalah melalui proses pemodelan dan simulasi kawasan tersebut (Sue J. Lin Lewis, 1983). Sebuah model air larian ribut bandar berupaya menyelakukan (simulate) pergerakan air larian ribut dan bahan-bahan terangkut melalui satu kawasan tadahan bandar sebagai tindakbalas (respond) kepada hujan dan ciri-ciri kawasan tadahan tersebut. Ini bermakna sesebuah model itu dapat membantu dalam memahami sistem tersebut yang sukar untuk dilakukan melalui pendekatan lain (Stephen J.Nix 1994). Namun demikian, sebelum sesebuah model itu dapat digunakan untuk menyelakukan sesebuah kawasan tadahan, proses penentukuran (calibration) perlu dilakukan. Proses penentukuran ini melibatkan langkah-langkah pengubahsuaian parameter-parameter hidrologi kawasan tersebut (sebagai contoh, kecerunan, sifat tanah dan nilai kekasaran Manning), sehingga satu set parameter yang dapat menghasilkan keputusan (dalam bentuk hidrograf) yang menghampiri dengan keputusan dari cerapan lapangan diperoleh (Abustan, 1997). Pengesahan model dengan set data yang berlainan perlu dilakukan sebelum model itu mencapai tahap keboleharapan yang tinggi. Dalam kajian ini, 2 buah model air larian ribut bandar digunakan iaitu SWMM dan StormCAD (Haested Methods) untuk menyelakukan satu kawasan bandar di Lembah Klang. Penumpuan kajian adalah kepada model SWMM. Model StormCAD akan digunakan sebagai perbandingan.

PENGHARGAAN

Syukur kepada Tuhan kerana projek ini dapat disiapkan dalam keadaan yang sempurna setelah mengharungi pelbagai rintangan dan halangan. Selain dari usaha gigih, projek ini tidak akan sempurna bentuknya tanpa pimpinan dan suluhan dari penyelia projek saya, Dr. Ismail Abustan. Ribuan terima kasih saya ucapkan atas bantuan dan nasihat beliau dalam proses penyiapan tesis ini.

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APLIKASI MODEL HEC-RAS DALAM SIMULASI PROFIL AIR DAN REKABENTUK PENGUBAHSUAIAN KE ATAS SG. PERMATANG RAWA

Oleh

ONG LIP HEE

TESIS

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SARJANA MUDA KEJURUTERAAN (KEJURUTERAAN AWAM)

Pusat Pengajian Kejuruteraan Awam
Universiti Sains Malaysia

Januari 2002

ABSTRACT

This project is to apply HEC-RAS model to simulate water surface profile for natural waterways and determine how well HEC-RAS model will response to the watershed. In another word, this model also summarized the potential of waterways capacity to support the increasing of runoff discharge. Analysis results showed that the present waterways capacity is under designed and failed to support urban runoff for the 10 and 50 year events. These phenomenon will easily cause a serious flash flood especially during a rainy season if preventive action is not taken. Therefore, we need to propose a new waterways system to prevent the flash flood. However, the incompetence of waterways capacity has been overcome with the suggestion to design and modify the geometry of present waterways by using HEC-RAS program (Channel Modification) for design storm up to 50 years. Then, analysis result showed that the model that has been modified is satisfactory and competence. Therefore, the propose waterways had improve the waterways potential to support watershed runoff discharge without overflow up to design storm 50 year. Thus, the occurrence of flash flood can be preventing effectively. Lastly, comparison of water surface profile between present waterways and propose waterways using cross section plot in HEC-RAS showed that propose waterways capacity is more effective and competence compare to present waterways capacity at all.

ABSTRAK

Projek ini adalah untuk mengaplikasikan model HEC-RAS dalam melaksanakan simulasi profil air permukaan bagi sesuatu saliran semula jadi dan meninjau sejauh mana model HEC-RAS dapat memodelkan kawasan tadahan yang diwakili sebagai sesuatu sistem. Dengan kata lain, model ini turut merumuskan keupayaan kapasiti saliran dalam menampung kapasiti air larian yang semakin meningkat. Keputusan analisis menunjukkan kapasiti saliran yang sedia ada gagal dari segi keberkesanan untuk menampung luahan air larian kawasan tadahan berkenaan untuk 50 tahun mahupun 10 tahun yang akan datang. Adalah difahamkan keadaan ini jika dibiarkan berterusan akan mewujudkan kejadian banjir kilat yang tidak menentu terutamanya pada musim tengkujuh. Bagaimanapun, ketidakcukupan saliran tersebut telah diatasi dengan cadangan untuk mereka dan mengubahsuaikannya dengan menggunakan perisian HEC-RAS untuk ribut rekabentuk 50 tahun. Analisis kemudian dijalankan pada model yang telah diubahsuai ini dan keputusan menunjukkan model yang dihasilkan adalah memuaskan. Justeru itu, pelaksanaan saliran yang baru ini telah meningkatkan keupayaan saliran dalam menampung luahan air larian kawasan tadahan tersebut tanpa pelimpahan untuk ribut rekabentuk 50 tahun. Ini secara tidak langsung telah mengatasi masalah banjir kilat yang akan melanda. Akhir sekali, perbandingan juga dijalankan ke atas saliran sedia ada dengan saliran rekabentuk dalam profil air permukaan keratan rentas, didapati keputusan saliran rekabentuk mempunyai keberkesanan yang nyata mengatasi saliran sedia ada mahupun dari segi keupyaan kapasiti saliran ataupun profil air permukaan.

URBAN STORMWATER MODELLING IN DAMANSARA CATCHMENT (KUALA LUMPUR)
WITH MODEL USM_SWMM

Oleh

YONG CHI MING

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TESIS

SARJANA MUDA KEJURUTERAAN (KEJURUTERAAN AWAM)

Pusat Pengajian Kejuruteraan Awam
Universiti Sains Malaysia

JAN 2004

ABSTRACT

The aim of this project is to simulate the effectiveness of USM_SWMM that has been developed by Dr.Ismail Abustan and Mr.Budi Santosa for urban areas. Modeling of USM_SWMM in Damansara catchment is carrying out for this project. Overall modeling process will involve data collecting, data preparing and parameter estimating according to subcatchment characteristics. The sensitivity analysis will be determined to ensure the effectiveness and calibration and validation will conducted to determine the effectiveness of the proposed model. Big event and small event will be simulated in this project. Sensitivity analysis were undertaken for both big and small events to determine the sensitivity of surface runoff volume, peak flow and time to peak toward the variation of the model parameter, result shows that percent impervious, width of subcatchment and maximum infiltration rate (Horton) are sensitive parameter. The model was calibrated to get a best match between predicted hydrograph and observed hydrograph. "Trial and error" method had been conduct in adjusting the calibration parameter to have best match with observed hydrograph. Validation had been undertaken to verify the "calibrated" parameters. The evaluation criteria for calibrating model parameters for model are relative error (RE) and absolute relative error (ARE). Discussion for sensitivity of parameters, calibration, and validation has been carry out in this report. The conclusion is USM_SWMM is suitable urban runoff model to do simulation for the surface runoff quantity for Damansara catchment.

ABSTRAK

Projek ini bertujuan untuk menentukan keberkesanan USM_SWMM yang dibangunkan oleh Dr.Ismail dan Mr.Budi Santosa untuk membuat simulasi di kawasan bandar. Simulasi aspek kuantiti air larian bagi subtadahan Damansara yang terletak di lembah Sungai Kayu Ara akan dijalankan untuk tujuan ini. Secara umumnya, proses simulasi melibatkan pengumpulan data, penyediaan data dan pemilihan data berdasarkan kepada ciri-ciri permukaan subtadahan. Analisis kepekaan dijalankan ke atas model subtadahan Damansara untuk menganalisis kepekaan isipadu air larian permukaan, kadar alir puncak dan masa ke puncak terhadap perubahan parameter model. Di dapati peratus permukaan tidak telap, lebar subtadahan dan kadar penyusupan maksimum (Horton) merupakan parameter yang utama. Dua peristiwa iaitu peristiwa besar dan peristiwa kecil telah disimulasi untuk melihat pengaruh sifat hujan ke atas keputusan analisis kepekaan. Penentukuran dijalankan untuk memperolehi satu set parameter model yang dapat menghasilkan korelasi yang baik diantara hidrograf ramalan dengan hidrograf sebenar. Isipadu air larian permukaan, kadar alir puncak dan masa ke puncak merupakan parameter hidrograf yang ditentukur. Analisis statistik dijalankan ke atas parameter hasil penentukuran untuk menilai tahap korelasi antara hidrograf ramalan dan sebenar melalui kaedah ralat relative (RE) dan ralat relative mutlak (ARE). Pengesahan di jalankan untuk menilai keberkesanan parameter yang telah ditentukur. Perbincangan berkaitan dengan keputusan yang didapati untuk analisis kepekaan, penentukuran dan pengesahan di bincangkan dan kesimpulan dibuat di dalam laporan ini. Kesimpulannya ialah USM_SWMM adalah model yang sesuai untuk membuat simulasi air larian permukaan di kawasan Bandar secara berkesan.

USER–FRIENDLY DETENTION POND DESIGN :

DEVELOPMENT USING VISUAL BASIC 6.0

By

Leong Weng Chin

TESIS

This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

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BACHELOR OF ENGINEERING (CIVIL ENGINEERING)

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ABSTRACT

Nowadays, urban development in many developing countries, e.g. Malaysia, has found susceptible to adverse environmental crisis through excessive runoff that leads to the degradation of rivers and lakes. Therefore, this project has been carried out in which effective way to manage stormwater has to be developed. Actually, this project is focused more on the development of community and regional detention pond design using Visual Basic 6.0. In accordance with the guidelines provided in Urban Stormwater Management Manual for Malaysia 'MSMA' (DID, 2000), a computer model had been developed under this final year project. In other words, this model is built specifically to suit the design rainfall in Malaysia. Since the detention pond simulated via this design model is only to cater for large catchment area (80 ha and above), hence, the Time-Area Method is proposed for the estimation of peak inflow and outflow. After attaining both the stage-storage and stage-discharge relationships, Level Pool Routing will then be used in order to determine the peak discharge once a detention pond is designed. This is to ensure that the runoff discharged from the detention pond will not overflow the receiving water downstream. Even the manual calculation had been conducted to have this model checked and complemented. To verify its computation accuracy compared to spreadsheet (EXCEL), this model had been used to design the proposed wet community and regional detention pond located in a development area in *Mukim 6, Daerah Seberang Perai Utara, P. Pinang.* All the inflows, allowable outflows and required detention pond storage computed through this model were proved to be almost the same as that of EXCEL, only the outlet discharge is rather different between the two. As a whole, this model is indeed a helpful tool to do the preliminary design of wet detention pond.

ABSTRAK

Kini, urbanisasi yang giat di banyak negara membangun, termasuk Malaysia, mendatangkan banyak krisis alam sekitar. Ini berlaku akibat lebihan air larian telah menjejaskan kualiti sungai, tasik dan sumber air yang lain. Memandangkan keadaan genting ini, projek tahun akhir ini telah dicadangkan di mana ianya berkisar kepada cara efektif dalam menguruskan air larian. Amnya, projek ini berfokus pada pembangunan model rekabentuk kolam tahanan basah jenis komuniti, dengan menggunakan *Visual Basic 6.0*. Model rekabentuk ini telah dikendalikan mengikut spesifikasi yang tertera dalam Manual Saliran Mesra Alam 'MSMA' (JPS, 2000). Dengan kata lain, model ini dibangunkan agar sesuai dengan keadaan cuaca di Malaysia. Disebabkan simulasi rekabentuk kolam tahanan melalui model ini hanya untuk menampung kawasan tadahan 80 ha dan ke atas, maka Cara Masa-Kawasan dicadangkan untuk menganggarkan aliran masuk puncak dan aliran keluar puncak. Setelah hubungan paras-storan dan paras-buangan ditentukan, *Level-Pool Routing* digunakan untuk mendapatkan aliran keluar puncak dari kolam tahanan. Ini adalah untuk memastikan air yang dilepaskan tidak akan membanjiri kawasan di hilir sungai. Untuk menentukan ketepatan output rekabentuk melalui model ini berbanding dengan *EXCEL*, ianya telah digunakan untuk merekabentuk kolam tahanan basah dalam kawasan pembangunan Mukim 6, Daerah Seberang Perai Utara, P. Pinang. Kadar alir masuk dan kadar alir keluar dibenarkan, serta saiz kolam tahanan yang diperoleh melalui model ini terbukti lebih kurang sama dengan kiraan *EXCEL*. Namun, yang berbeza hanyalah kadar alir keluar daripada kolam tahanan. Secara keseluruhannya, model ini masih merupakan alat yang berkesan semasa membuat rekabentuk awalan untuk kolam tahanan basah.