DETERMINING THE EFFECTIVENESS OF TASIK HARAPAN AND TASIK AMAN AS FLOOD PONDS AT UNIVERSITI SAINS MALAYSIA

ARNIZA FITRI

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By:

ARNIZA FITRI

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LIST OF ABBREVIATIONS

ARI	Annual Return Period
BMPs	Best Management Practices
DEM	Digital Elevation Model
DID	Department of Irrigation and Drainage
DOS	Disk Operation System
EDM	Electronic Distance Measurement
EPA	Environment Protection Agency
ESRI	Environmental Systems Research Institute
FORTRAN	Formula Translation
GIS	Geographic Information System
GUI	Graphical User Interface
HEC	Hydrologic Engineering Centers
HEC-HMS	Hydrologic Engineering Centers – Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Centers – River Analysis System
HSG	Hydrologic Soil Group
IDF	Intensity Duration Frequency
MSMA	Manual Saliran Mesra Alam/Urban Stormwater Management Manual
NRCS	Natural Resources Conservation Service
RS	River Station
SCS	Soil Conservation Service
SWMM	Storm Water Management Model
TIN	Triangular Irregular Network

TR	Technical Release
US	United State
USDA	United Department of Agriculture
USM	Universiti Sains Malaysia
WinTR-55	Small Watershed Hydrology Technical Report-55

LIST OF SYMBOLS

Roman Symbols

A	Area
C	Contraction and expansion coefficient
CN	Curve Number
Fr	Froude number
F_f	Force due to external friction
g	Gravitational acceleration
he	Energy head loss
hL	Energy head loss
Ia	Initial abstraction
L	Length
n	Manning roughness
p	Rainfall
P	Perimeter
P	Hydrologic pressure force
q	Runoff
q_p	Peak flow
Q	Discharge
r	Average return period
R	Hydraulic radius
s	Maximum potential retention
S	Slope

T	Time
T_c	Time of concentration
T_p	Time for peak flow
v	Velocity
W_x	Force due to weight in the x direction
x	Distance
y	Water depth
z	Elevation head

Greek Symbol

ϕ	Flow partitioned
α	Velocity weighting coefficient
ρ	Density of water
Δv_x	Change on velocity

LIST OF SPECIFIC NAMES

Tasik	Lake
Jabatan	Department
Pembangunan	Development
Sungai	River

MENENTUKAN KEBERKESANAN TASIK HARAPAN DAN TASIK AMAN SEBAGAI KOLAM TAKUNGAN BANJIR DI KAMPUS INDUK UNIVERSITI SAINS MALAYSIA

ABSTRAK

Banjir adalah bencana semula jadi biasa di Malaysia yang dicetuskan oleh kejadian hujan lebat. Urbanisasi yang meningkatkan pembinaan kawasan berturap seterusnya meningkatkan air larian permukaan dan mengurangkan masa tumpuan. Ini meningkatkan magnitud banjir dan oleh itu membawa kepada masalah banjir yang lebih besar seperti yang berlaku di kawasan Kampus Induk USM. Kampus Induk USM telah mengalami masalah banjir sejak pembangunannya pada tahun 1971. Tasik Harapan dan Tasik Aman yang telah dibina pada tahun 1990 sebagai kolam rekreasi telah juga berfungsi sebagai kolam banjir. Malangnya, masalah banjir masih berlaku secara berterusan. Oleh itu, keberkesanan Tasik Harapan dan Tasik Aman untuk mengurangkan masalah banjir perlu dikaji dan punca-punca masalah banjir di kawasan Kampus Induk USM perlu diselidiki.

HEC-RAS hidraulik model digunakan untuk membandingkan kelakuan banjir daripada beberapa kes. Sebagai sokongan, ArcView-GIS dan model hidrologi WinTR-55 juga telah digunakan dalam kajian ini. ArcView-GIS digunakan untuk menyediakan data geometric yang diperlukan oleh HEC-RAS model dan mempersiapkan data input yang diperlukan oleh WinTR-55. WinTR-55 digunakan untuk menyediakan hidrograf aliran masuk yang berguna sebagai batasan keadaan

oleh HEC-RAS model dimana pada analisis hidrologik, ini meliputi perbandingan antara MSMA, Yip (2002) dan hujan pada Talian Besar Sg. Pinang.

Hasil simulasi dari empat Kes pertama (Kes 1 kepada Kes 4) menunjukkan bahawa Tasik Harapan dan Tasik Aman adalah berkesan untuk mengurangkan paras banjir, manakala Tasik Aman ditemukan lebih berkesan dalam mengurangkan paras banjir daripada Tasik Harapan. Malangnya, walaupun Tasik Harapan dan Tasik Aman berkesan dalam mengurangkan paras banjir, mereka tidak dapat menyelesaikan masalah banjir di kawasan Kampus Induk USM. Seterusnya, berdasarkan hasil simualsi dari Kes 5 kepada Kes 12, ini dapat disimpulkan bahwa kejadian banjir di Kampus Induk USM secara ketara dipengaruhi oleh pembentung-pembentung yang terletak pada akhir bagian dari sistem sungai gambir terutama pembentung 2. Selepas simulasi tambahan (Kes 13) yang mana dengan memperbesar dimensi dari pembentung 1 and 2 untuk menjadi sama dengan dimensi pembentung 3 dilakukan, hasil simulasi menunjukkan bahawa paras-paras banjir dapat dikurangi secara ketara.

DETERMINING THE EFFECTIVENESS OF TASIK HARAPAN AND TASIK AMAN AS FLOOD PONDS AT UNIVERSITI SAINS MALAYSIA

ABSTRACT

Flooding is a common natural disaster in Malaysia triggered by heavy rainfall. Urbanization that increases the construction of paved areas, subsequently raise surface runoff and reduce time of concentration. It increases flood magnitude and so that leads to greater flood problems as what has happened at Universiti Sains Malaysia (USM) Main Campus area. USM Main Campus Malaysia has experienced flood problems since its development in 1971. Tasik Harapan and Tasik Aman were constructed in 1990 as recreation ponds and have also functioned as flood ponds. Unfortunately, the flood problem still occurs persistently. Thus, the effectiveness of Tasik Harapan and Tasik Aman in reducing the flood problems need to be investigated and the causes of flood events at USM Main Campus need to be evaluated.

HEC-RAS hydraulic model was used to compare the behavior of flood profiles from several conditions. To support the study, ArcView-GIS and WinTR-55 hydrologic model also have been used. ArcView-GIS is used to develop geometric data files require by HEC-RAS model and prepare input data required by WinTR-55. WinTR-55 model is used to generate inflow hydrographs required as boundary condition by HEC-RAS model simulation where in the hydrologic

analysis, it includes the comparison among MSMA, Yip (2002) and Taliair Besar Sg. Pinang rainfall.

The modeling results from first four performed conditions (Case 1 to Case 4) show that Tasik Harapan and Tasik Aman are effective in reducing the flood water levels while Tasik Aman is found to be more effective in reducing the flood levels than Tasik Harapan. Unfortunately, although both Lakes are effective in reducing the flood levels, they cannot solve the flood problems at USM Main Campus. Furthermore, based on simulation result from Case 5 to Case 12, it can be concluded that flooding at USM Main Campus are significantly influenced by the culverts located at the end of Sungai Gambir reach especially culvert 2. After an additional simulation (case 13) which enlarges culverts 1 and 2 dimensions to be same with culvert 3 dimension was carried out, the result show that flood water levels is reduced quite considerably.

CHAPTER 1

INTRODUCTION

1.1 Flood Introduction

Flood can be defined as a temporary overflowing of water that exceed bankfull limitation and would have detrimental effect on life and properties (Bogdnivic, 2001 and Likens, 2010). It is a certain phenomenon which occurs inevitably (Walesh, 1989).

Floods might be triggered by heavy and prolonged rainfall, the downstream blocking of the river/drainage channels, abnormally high tides/tidal waves and reducing of floodplain areas (Mark et al., 2004; Lindeburg, 2009; Varikoden et al., 2011). Mark et al., (2004) stated that most cities in the world including South/South East Asia often have more severe flood problems during heavy rainstorm because of much heavier local rainfall and lower drainage standard. Besides, altering rural areas to become urban areas dramatically increase rates of runoff from rainfall and subsequently increase severity of flooding (Smith and Ward, 1998; Akan and Houghtalen, 2003; Cameroni et al., 2005; Ab. Hasan et al., 2009; Jacobson, 2011 and Suriya and Mudgal, 2011). It is because urban areas increase the construction of paved area, decreases surface infiltration capacity and reduces times of concentration of runoff.

Floods can be categorized as disrupting, damaging or devastating (Lindeburg, 2009). Floods may be categorized as disrupting if floods have depth approximately less than 30 cm and causes inconveniences for people nearby while floods with depths more than 30 cm may be categorized as damaging if floods soak environment with low flow velocities and as devastating if floods wash its downstream properties with high flow velocities (Lindeburg, 2009).

Flood is a natural disaster which cannot be prevented; however there are many techniques that can be done to mitigate its consequences including implementation of structural flood defense measures and non structural flood management (Walesh, 1989; Smith and Ward, 1998; Plate, 2002; Cullingworth and Nadin, 2003; Plate, 2007). Structural flood defense involves construction of detention and retention ponds, stormwater drainage, dam and reservoir while non-structural flood management includes insurance and emergency planning.

1.2 Research Background

Universiti Sains Malaysia (USM) Main Campus, Pulau Pinang, Malaysia with location as shown in Figure 1.1 has experienced flood problems since its development in 1971 (Teh et al., 2006; Friends of Tasik Harapan, 2010). Based on a study carried out by Teh et al., (2006) through comparison of peak flows before and after USM Main Campus development, it can be suspected that flood problems are triggered by the heavy local rainfall on monsoon season and the increased of surface runoff induced by urbanization plus expansion of USM Main Campus from an army barrack to a modern campus (Figure 1.2).

Figure 1.1 Location Map of Universiti Sains Malaysia (USM) Main Campus

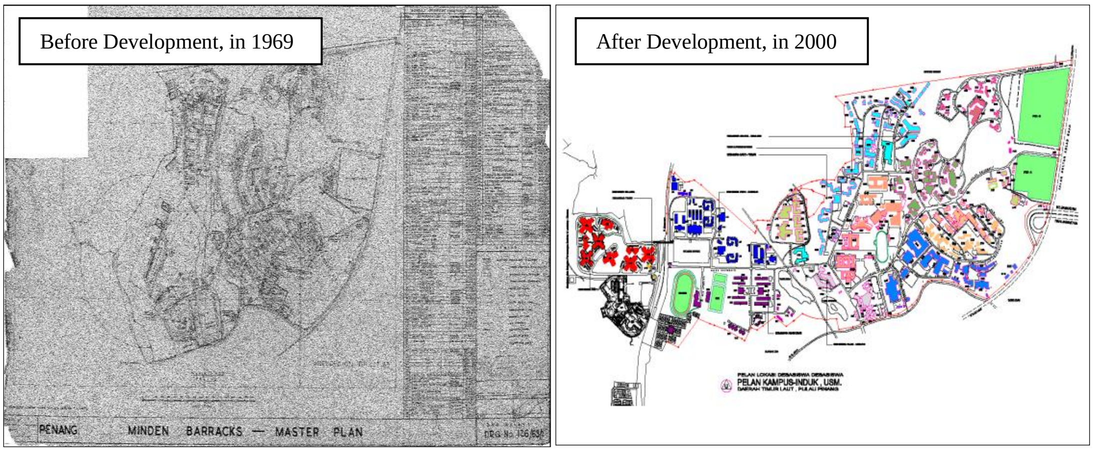

Figure 1.2 Expansion of USM Main Campus from an army barrack to a modern campus (Jabatan Pembangunan of USM Main Campus, 2000)

As informed by Jabatan Pembangunan of USM Main Campus (2011), Tasik Harapan and Tasik Aman were constructed inside the campus in 1990 as recreation ponds. Both ponds have also functioned as flood retention ponds to reduce the flood problems by storing a part of runoff, allowing them to be infiltrated into the soil and releasing them slowly to downstream (Teh et al., 2006). Unfortunately, the flood problems still occur persistently. Figure 1.3 shows one of the flood events that inundating the area adjoining Sungai Gambir in USM Main Campus. Therefore, the effectiveness of Tasik Harapan and Tasik Aman in reducing flood problems need to be investigated and the causes of flood problems in USM Main Campus area need to be evaluated.

Figure 1.3 Flood event on 9th July 2010 at Sungai Gambir reach located around Tasik Harapan and Tasik Aman surrounding (Friend of Tasik Harapan, 2010)

It might not be easy to determine precise causes of flood problems on particular area by manual calculation, but it can be investigated by using simulation of hydraulic modeling. Hydrologic Engineering Centers - River Analysis System (HEC-RAS) was used in this study to simulate flood water surface profiles for investigating the effectiveness of Tasik Harapan and Tasik Aman in reducing flood problems and evaluating the possible causes of flood events at USM Main Campus area in order to resolve the flood problems.

1.3 Problem Statement

The flood problems in USM Main Campus area have become main issue since its development in 1971 (The et al., 2006; Friend of Tasik Harapan, 2010). Those flood events caused inconvenience to students staying nearby. Therefore, this research study needs to be carried out to investigate possible causes of flood in the study area, so that the flood problems can be solved.

1.4 Research Objectives

The objectives of this research are:

1) To investigate the effectiveness of the Tasik Harapan and Tasik Aman as flood ponds by using 1 dimensional hydraulic model.
2) To evaluate the possible causes of flood problems at USM Main Campus area.

1.5 Scope of Research Study

This study was carried out at 666 m length of Sungai Gambir reach inside the campus which receives the runoff flow from catchment area approximately 310.074 ha. The Sungai Gambir reach was connected to Tasik Harapan and Tasik Aman, 5 major inlets and culverts. Floodplain areas considered in this study are approximately 4-10m from River bank or Lakes bank.

This study focused on determining the effectiveness of Tasik Harapan and Tasik Aman in reducing the flood problems and evaluated the possible causes of the flood events at USM Main Campus area. It was done by comparing the simulation of flood profiles from several performed conditions using HEC-RAS hydraulic model. Primarily, the flood profiles of actual condition were simulated for all inflow hydrographs produced by WinTR-55 model using rainfall data from design rainfall method based on MSMA and 1999 -2011's recorded rainfall data at Taliair Besar Sg. Pinang station. Further, they were compared to observed flood profiles recorded on 9th July 2010 and 8th May 2011 in order to select the suitable inflow hydrograph for the study area. Further, the rest performed conditions were simulated using selected hydrograph and analyzed.

1.6 Thesis Outline

This thesis is organized in six chapters. Chapter 1 is the introduction. This chapter gives general description about flood and introduces briefly the research study includes research background, problems statement, objectives and scope of works.

Chapter 2 is the literature review. This chapter contains literatures that are relevant with research study includes flooding in Malaysia, hydrologic and hydraulic models and GIS application in flood assessment.

Chapter 3 is research methodology. This chapter provides a description of the study area which includes Sungai Gambir, Tasik Harapan, Tasik Aman, and Culverts. It also explores the methods applied in order to complete the research study which includes data collection, data analysis by using ArcView-GIS and hydrologic model

(WinTR-55 model); and flood profile simulations by using hydraulic model (HEC-RAS model).

Chapter 4 is data collection and data analysis. This chapter explained the detail data analyses that have been done to provide input data required by WinTR-55 hydrologic model and HEC-RAS hydraulic model.

Chapter 5 is the generating inflow hydrographs using WinTR-55 model. This Chapter discusses the detail procedures used by WinTR-55 model to obtain inflow hydrographs required by model simulation as its boundary condition.

Chapter 6 is the flood profile simulation using HEC-RAS model. This chapter discusses the detail steps to simulate flood profiles using HEC-RAS model. The simulation results were further analyzed and discussed in order to achieve the objective of the research study.

Chapter 7 presents the conclusion and recommendations for the future study.

CHAPTER 2

LITERATURE REVIEW

2.1 Flooding in Malaysia

Malaysia is one of the developing countries in South East Asia that undergo urbanization and industrialization rapidly. This country receive an average annual rainfall of about 2500 mm or more which varies spatially and temporally (DID, 2000; Julien et al., 2010). In fact, Malaysia has a long history of flood events (Loi, 1996; Chan et al., 2004; DID, 2007). It became significant natural disaster here among others such as earthquake and tsunamis (Chan, 1997; DID, 2007; Hussein et al., 2007).

2.1.1 Flood Causes

Basically, flooding in Malaysia is caused by heavy local rainfall during monsoon season (DID, 2000; DID, 2007; Toriman et al., 2009; Varikoden et al., 2011). Further, human activities such as urbanization, vegetation removal and soil disturbances have caused significant changes in climate, soil condition and land cover which caused the increase in frequency and magnitude of flooding (Nik, 1988; DID, 2007; Eisenbies et al., 2007; Toriman et al., 2009; Julien et al., 2010). Urbanization increases the runoff rates by decreasing surface infiltration capacity (Toriman et al., 2009; Julien et al., 2010), climate changes cause changes in atmospheric circulation that affects local alteration in precipitation frequency (Smith and Ward, 1998) and land cover changes significantly affects soil infiltration capacity and soil water retention (Wahl et al., 2003).

2.1.2 Flood Damages

The occurrences of flood events in the world have caused many damages (Walesh, 1989; Smith and Ward, 1998; Hussein et al., 2007; Qi and Altinakar, 2011b). Walesh (1989) classified flood damages into direct and indirect form. Direct damages are caused by physical contact between object/material with floodwater such as loss of human lives, physical damage to property and cost of complete restoration; and indirect damage mean damages as a consequence of direct damage such as disruption of traffic & trade, cost of temporary evacuation and increased hazard vulnerability of survivor.

Flood events in Malaysia have resulted to loss of lives and damage to crops, livestock, property and public infrastructure (Chan, 1997; DID, 2007; Wing, 2005). Descriptions of several flood damages that have been recorded in Malaysia were summarized in Table 2.1. However, flood events in 1971 and 2006-2007 have been listed by DID (2007) as the major flood events due to caused the most serious damage. One of the flood events that have been experienced in 1971 and 2006-2007 are presented in Figure 2.1 and Figure 2.2.

Table 2.1 Description of flood damages recorded at Malaysia in 1971-2011

Flood Event		Flood damages	Sources
Year	Place		
1971	Kuala Lumpur, Kuala Lipis, Selangor, Penang and Kuching	Loss of RM 200 million, and 61 people died	DID, 2007
1979	Peninsular Malaysia	7 people died and 23898 people were evacuated	Chan, 1995
1982	Peninsular Malaysia	8 people died and 9893 people were evacuated	Chan, 1995
1984	Batu Pahat	Loss of RM 20.3 million and 8400 people were evacuated	Chan, 1995
1988	Peninsular Malaysia and Kelantan	Loss of 33 million, 56 people died and 137555 people were evacuated	Chan, 1995
1993	Peninsular Malaysia	22 people died and17 people were evacuated	Chan, 1995
1995	Georgetown and Kuala Lumpur	Damage to crop, livestock, public structure and properties (amount is not available)	Chan, 1997
2004	Penang	54 people died	Billa et al., 2006
2006-2007	Johor, Peninsular Malaysia, Melaka, Negeri Sembilan and Pahang	Loss of RM 1.5 billion, 18 people died and 110 people were evacuated	DID, 2007
2010	Kedah and Perlis	More than 3000 people were evacuated	Thestar online (http://thestar.com.my/news/story)
2011	Johor, Batu Tinggi, Negeri Sembilan, Pahang and Sabah	3 people died and 46000 people were wvacuated	Thestar online (http://thestar.com.my/news/story)

Figure 2.1 Flooding at Kuala Lumpur, Malaysia in 1971
(Wikipedia, 2011)

Figure 2.2 Flooding at Johor, Malaysia in 2006-2007
(Shafie, 2009)

2.1.3 Flood Mitigations

Flood mitigation is an effort to reduce flood damages to a minimum cost (Brody et al., 2011). Many attempts have been done in order to reduce flood damages in the world including flood forecasting, flood warning and implementation of both structural and non-structural measures (Smith and Ward, 1998; Plate, 2002; Plate, 2007).

In Malaysia, Department of Irrigation and Drainage (DID) have been tasked to plan and implement urban drainage work of both structural and non-structural as flood mitigation and management program since 1971. In 1975, DID successfully published the first urban drainage manual "Planning and design procedure No.1: Urban drainage Design Standard and Procedure for Malaysia”. This first urban manual has been a guideline in planning and designing the urban drainages in the whole of Malaysia for around 25 years (Loi, 1996; DID, 2007).

Unfortunately, the increase in flood magnitude and frequency due to urbanization have caused conventional drainage system to be no longer an effective way in solving flood problems (Zakaria et al., 2004; DID, 2007). Therefore, DID have taken a proactive step by publishing the Urban Stormwater Management Manual for Malaysia (MSMA) in year 2000 to promote the Best Management Practices (BMPs) (DID, 2000). BMPs aim to manage storm water quantity and quality. It is targeted to achieve zero development impact contribution and preserve the natural river flow carrying capacity (DID, 2000). It involves construction of detention and retention facilities such as dry and wet detention ponds; infiltration; groundwater recharge; swales; engineering swales, provision of rough surface, dam and levee.

Applications of ponds and levees as Best Management Practices in flood mitigation effort have been proposed widespread in Malaysia such as a retention pond that has been proposed for Sarawak River Sub-basin (Bustami et al., 2009) and a levee that has been proposed for Muda River, Malaysia (Julien et al., 2010) and Sarawak River (Mah et al., 2010). Further, pond was found quite effective in reducing the flood level (Bustami et at., 2009).

2.2 Hydrologic Modeling

Hydrologic impact assessment is necessary for planning, analyzing and designing various hydraulic components (Jang et al., 2007). Since the stormwater gages information are rarely available in the particular area especially on small urban stream and computer models have given the quick way in system information, the hydrologic computer models have been used by engineers worldwide (Akan and Houghtalen, 2003).

Historically, hydrologic models were developed by US Government Agencies in 1970. One of those models is Environment Protection Agency - Storm Water Management Model (EPA-SWMM) (Zoppou, 2001). From that time onwards, the hydrologic models have become an interesting discussion by academic institutions, government departments and engineering consultants which pared way to develop many new hydrologic models applied currently (Jacobson, 2011). For information purposes about the hydrologic models that have been used worldwide, Singh and Woolhiser (2002) described more than 60 hydrological models used in general. They noted HEC-HMS model as a standard model considered by private sector in the United States for the design of drainage systems and quantifying the effect of land-use change on flooding. In addition, Elliott and Trowsdate (2007) also has identified approximately 40 hydrological models and listed 10 of them to be compared while Jacobson (2011) summarized 7 hydrologic models widely used by engineers as shown in the Table 2.2 and listed WinTR-55 as a common hydrological model used to analyze the hydrology for small watersheds.

Table 2.2 The commonly used hydrological models and their functionalities (Jacobson, 2011)

Model	Organization or Author	Internet Address	Stated Purpose	Example Model Components (and use)
HSPF (Hydrological Simulation Program-Fortrant)	USGS (US Geological Survey)	http://water.usgs.gov/software/HSPF	Simulation hydrologic and water quality processes for previous and impervious surfaces	Green-Ampt equation (infiltration), Kinematic wave model (overland and channel flow)
HydroCAD	HydroCAD software Solution (LLC)	http://www.hydrocad.net/	Design of urban drainage systems	SCS unit hydrographs and Rational Method (runoff), Muskingum-Cunge method (flow routing)
MIKE Products (e.g. MIKE, SHE, MIKE URBAN)	DHI	http://www.mikebydhi.com/	MIKE SHE models groundwater and surface water, MIKE URBAN models sewers, storm water drainage systems, and overland flow	(Components are product dependent), Dynamic flow equations (St. VEnant), (Channel flow), Muskingum-Chunge method (flow routing), Darcy equation (saturated flow of groundwater)
SWAT (Soil and Water Analysis Tool)	USDA (Department of Agriculture)	http://www.brc.tanus.edu/swat/	A river basin scale model to quantity the impact of land management practices	Green-Ampt method (infiltration), SCS curve number (CN) method runoff, Muskingum method (infiltration)
SWMM (Storm Water Management Model)	US EPA (Environmental Protection Agency)	http://www.epa.gov/ednnrmrl/models/swmm/	A dynamic rainfall runoff simulation model primarily for urban areas	SCS unit hydrographs and Rasional Method (runoff), Horton and Green-Ampt method (infiltration), manning equation (overland flow)
WetSpa (Water and Energy Transfer between Soil, Plants and Atmosphere)	Wang et al., (1997); Liuet al., (2003)	http://code.google.com/p/wetspa/	A GIS based distributed model for flood and water balance simulation on a catchment	Dynamic flow equations (St. Venant), (channel flow), Manning's equation (flow velocity)
WinTR-55	USDA	http://www.wsi.nrcs.usda.gov/products/w2q//h&h/Tools_Models?WinTR55.html	Analysis of the hydrology of small watersheds	SCS unit hydrographs (runoff) Manning's equation (flow velocity)

This thesis will not describe and explore all of the existing hydrologic models, but will give general information for few models described in Table 2.2 and explore one of them used in completing this study.

2.2.1 Storm Water Management Model (SWMM) Model

SWMM has been developed first in 1969-1971 by US Environment Protection Agency (Metcalf and Eddy, 1971). It is designed to simulate the precipitation-runoff processes for single event or continues simulation of runoff quantity and quality (Campbell and Sullivan, 2002; Jang et al., 2007; Rossman, 2009; Sharifan et al., 2010), such as a study carried out by Tsihrintzis and Hamid (1998) that have used SWMM model to simulate the quantity and quality of urban storm water runoff from four relatively small sites in South Florida.

Basically, SWMM is a DOS based model which must create data files before running the model (Akan and Houghtalen, 2003). However, the model has undergone several major upgrades (Huber et al., 1975; Huber et al., 1988). The current SWMM edition is SWMM5. It provides an integrated windows environment for editing input data, running simulation, and viewing the results, unfortunately it is too complex to be used by general public with no modeling experiences (Gironas et al., 2010).

2.2.2 Small Watershed Hydrology (Win-TR55) Model

In 1975, Soil Conservation Service (SCS) has published Technical Release 55 (TR-55) Urban Hydrology in a DOS based model for small watershed as a simplified procedure for calculating the stormwater runoff volume, peak discharge rate and storage volume. Then in 1998 it is revised and completely rewritten which become WinTR-55 as a windows based program where the input and editing windows have substantially improved over the DOS version (Visser and Scheer, 2002; Pitt, 2005; NRCS, 2009).

WinTR-55 model is a distributed hydrological model which has been applied in this study to determine the runoff rates through generating hydrographs for each selected points. Hydrographs produced by this model are based on SCS method. This model is widely accepted, inexpensive, user friendly, flexible and model parameters easily obtained (Jacobson, 2011).

SCS (now is called the Natural Resources Conservation Service (NRCS)) method is one of the unit hydrograph synthetics developed and widely used in United State of America (USA) for engineering practices (USDA, 1985; Walesh, 1989; Campbell and Sullivan, 2002; Green and Nelson, 2002; Akan and Houghtalen, 2003). This method which has been observed as one of rainfall-runoff model that can produce fast results and can be applied to ungaugaed catchment, is depends on the amount of rainfall intensity, synthetic 24-hr rainfall distribution type, curve number (CN) values and time of concentration (Tc) value (Leow et al., 2008; NRCS, 2009).

Basically, CN values are used to determine the approximate amount of direct runoff from a rainfall event in a particular area based on Equation 2.1-2.4 (USDA, 1985). The direct runoff is then transformed into a runoff hydrograph based on travel time (NRCS, 1986) and rainfall distribution.

$$q = \frac{(p - I_a)^2}{(p - I_a) + s} \tag{2.1}$$

$$I_a = 0.2s \tag{2.2}$$

$$s = \frac{1000}{CN} - 10 \tag{2.3}$$

By substituting Ia parameter in Equation 2.1 to become s parameter based on Equation 2.2, the new equation becomes:

$$q = \frac{(p - 0.2s)^2}{p + 0.8s} \tag{2.4}$$

Where:

q = Runoff (mm)

p = Rainfall (mm)

I_a = Initial abstraction, all losses before runoff begins (mm)

s = Maximum potential retention (mm)

CN = Curve Number, have a range from 0 to 100 (NRCS, 1986)

T_p = Time for peak flow (minutes)

T_c = Time of concentration (minutes)

For the rainfall distribution, this model includes four types of regional synthetic 24-hr rainfall distribution that are type I, IA, II, and III as described in Table 2.3.

Table 2.3 Description of 24-hr rainfall distribution (NRCS, 1986)

Type	Description
I & IA	Pacific maritime climates with wet winters and dry summers, IA is the least intense rainfall
II	The rest of the country, most intense short duration rainfall
III	Atlantic coastal areas and the Gulf of Mexico where tropical storms with large 24 hour rainstorms occur

2.2.2.1 Curve Number (CN) Determination

Soil Conservation Service (SCS) (now is called the Natural Resources Conservation Service (NRCS)) method determines Curve Number (CN) values based on hydrologic soil condition and landuse as tabulated in Appendix A. Hydrologic soil conditions in this method is classified into four Hydrological Soil Groups (HSG) to indicate the infiltration rate for different soil types that are A, B, C and D. Soil description for the Hydrological Soil Groups (HSG) is summarized in Table 2.4. However, SCS (NRCS) developed CN values based on United State of America (USA) conditions. Nonetheless, Yip (2002) conducted a study for four catchments in Malaysia and has developed correction coefficients for them.

Table 2.4 Soil description for Hydrological Soil Groups (HSG)
(USDA, 1972; TR-55, 1986)

Group	Soil Description
A	Soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission show. Examples are sand, loamy sand or sandy loam.
B	Soils have moderate infiltrations rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately fine to moderately coarse textures and have a moderate rate of water transmission. Examples are silt loam and loam.
C	Soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water soils with moderately fine texture and have a low rate of water transmission. Examples are sandy clay loam.
D	Soils have high runoff potential. They have very low infiltration rate when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with clay layer at or near the surface and have very low rate of water transmission. Examples are clay loam, silty clay loam, sandy clay, silty clay and clay.

The correction coefficients that have been produced by Yip (2002) are summarized in Table 2.5 and further, can be used to estimate runoff for ungauged catchment conditions in Peninsular Malaysia that have similar landuse and physical characteristic such as slope and Hydrologic Soil condition with catchment condition used (Yip, 2002).

Table 2.5 Catchment Conditions and Correction Coefficient for CN Values (Yip, 2002)

No	Catchment Conditions	Correction Coefficient of CN Values
1	The catchment is mixed, that is rural and urban; HSG type is B.	0.600
2	The catchment is mainly urban; HSG type is C	0.716
3	The catchment is predominant by rural that is with plantation and jungle conditions; HSG type is D	0.911
4	The catchment is predominant by rural that is jungle conditions; HSG type is Between B and C.	1.040

2.2.2.2 Time of Concentration Determination

Time of concentration can be defined as total travel time required for runoff to reach watershed outlet. In order to determine the time of concentration, SCS method divides the flow path into sheet flow, shallow concentrated flow and channel flow according to different hydraulic conditions. Sheet flow occurs on the land surface and when the distance of sheet flow is more than 30 m, it is assumed as a shallow concentrated flow. Channel flow occurs within the channels while the cross section can already be surveyed (USDA, 1985; Akan and Houghtalen, 2003; Akan, 2006; NRCS, 2009). Travel time for sheet flow is based on Equation 2.5 and travel time for shallow concentrated and channel flow is based on Equation 2.6 (Akan and Houghtalen, 2003; Akan, 2006). Finally, the total travel time is obtained by summing travel time from sheet flow, shallow concentrated and channel flow.

$$T_1 = \frac{C(nL)^{0.8}}{p^{0.5}S^{0.4}} \qquad (2.5)$$

$$T_2 = T_3 = \frac{L}{3600v} \qquad (2.6)$$

Where:

T_1, T_2, T_3	=	Travel time (hr)
n	=	Effective manning roughness factor
L	=	Flow length (m)
C	=	0.029
P	=	2 years, 24-hr rainfall (cm)
S	=	Slope
v	=	Average flow velocity (m/s)

2.3 Hydraulic Modeling for Flood Assessment

Hydraulic model is a form of mathematical, numerical and physical modeling widely used to investigate the design and operation issues in hydraulic engineering (Ettema, 2000). In flood assessments, hydraulic models have been developed due to increased socioeconomic relevance with river flood studies towards integrated flood risk management concepts (Di Baldassarre et al., 2009). In fact, Hydraulic models have facilitated many researcher, government agencies and private industries in analyzing flood issues. These models might be 1 dimensional or 2 dimensional models. 2D models require more complex representation of topographic data and need process complexity of calculation (Bates and De Roo, 2000). One of 1D models that has been widely used until now is HEC-RAS model (Ab. Hasan et al., 2007;

Brunner, 2008; Julien et al., 2010) while LISFLOOD-FP is known as one of 2D hydraulic models that have been applied (Biancamaria et al., 2009; Bates, 2010).

2.3.1 LISFLOOD-FP

LISFLOOD-FP is a two dimensional raster inundation model developed primarily for modeling river basin flooding by Bates and De Roo (2000) at the University of Bristol and the newer versions have been able to incorporate coastal flooding simulations (Bates et al., 2005; Bates, 2010).

This model is a coupled 1D/2D hydraulic model. The channel flow is based on the kinematic approximation to the 1D St Venant equations. The floodplain flow are similarly described in terms of continuity and momentum equations over a grid of square cells, and so allows the model to represent 2D dynamic flow fields on the floodplain (Bates and De Roo, 2000; Horritt and Bates, 2002; Bates et al., 2005; Biancamaria et al., 2009). It is used to simulate floodplain inundation in a computationally efficient manner over complex topography (Biancamaria et al., 2009; Bates, 2010) and to calibrate uncertain flood inundation models using remote sensing (Mason et al., 2009).

2.3.2 Hydrologic Engineering Centers - River Analysis System (HEC-RAS) Model

HEC-RAS is a hydraulic model developed to perform one dimensional steady and unsteady water surface profiles and river hydraulics calculations which also considers the impact of any obstruction structures such as bridges, culverts, weirs, spillway and etc at flood plain (Brunner, 2008). It is an excellent model applied for analyzing flood profile and extent of flooding (Ab. Hasan et al., 2007; Brunner, 2008; Julien et al., 2010). Besides supporting steady and unsteady water surface profile calculation, HEC-RAS model is also used for computing movable boundary sediment transport and analyzing the water quality (Brunner, 2008).

2.3.2.1 HEC-RAS Concepts

HEC-RAS model computes water surface profiles from one cross section to the next cross section of schematic stream morphology (Brunner, 2008). The stream morphology is presented by single or several reaches connected by junctions. A reach is composed of cross sections connected together in series called river stations and indicated by numbers.

The river stations were numbered increasingly from downstream to upstream. Each cross section is identified by crossways and elevation coordinates. The numbering of the crossway coordinates begins at the left to the right of the cross section looking toward downstream of the stream. The distance between one cross section to the next cross section is termed reach length. Additionally, ponds and the hydraulic structures such as bridge, culvert etc. can also be added and indicated by polygons (Bruner, 2008). An example of stream schematic in HEC-RAS model is delineated in Figure 2.3.

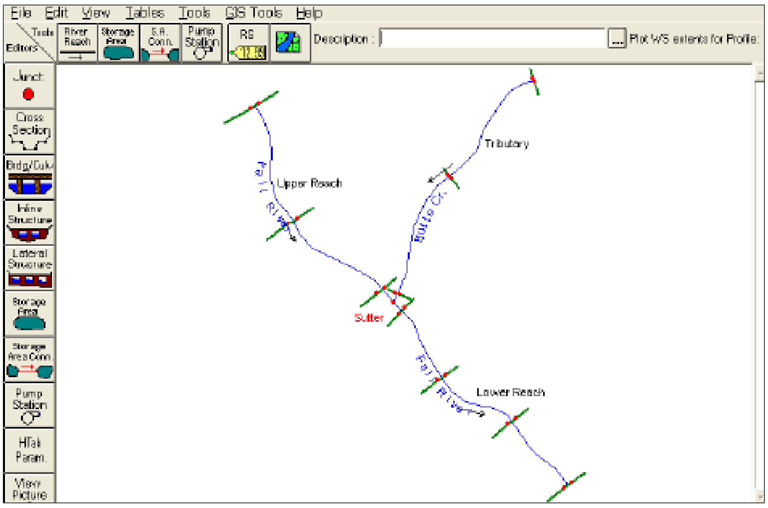

Figure 2.3 The stream schematic in HEC-RAS model (Brunner, 2008)

Basically, this model solves one dimensional Energy Equation in order to compute water surface profiles for steady gradually varied flows. When the rapidly varied flow occurs such as transition flow from subcritical to supercritical and supercritical to subcritical, Momentum Equation is applied. The energy head loss between two cross sections is computed by friction losses and contraction/expansion losses equation written following Equation 2.8 while the coefficients of contraction and expansion is summarized in Table 2.6 (Brunner, 2008).

$$h_e = LS_f + C\left|\frac{\alpha_2 v_2^2}{2g} - \frac{\alpha_1 v_1^2}{2g}\right| \tag{2.8}$$

Where:

h_e = Energy head loss (m)

L = Discharge weighted reach length (m)