

DEVELOPMENT SOIL PARAMETERS  
FOR HYDROLOGIC MODELLING IN UPPER SUNGAI MUAR

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A project report submitted in fulfillment of the  
requirements for the award of the degree of  
Master of Engineering (Civil - Hydrology and Water Resources)

Faculty of Civil Engineering  
Universiti Teknologi Malaysia

NOVEMBER 2010

*Dedicated to...*

*Atjhenese Tsunami Victims,*

*26 December 2004*

## **ACKNOWLEDGEMENT**

### **In the name of Allah, Most gracious, Most merciful**

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor En. Kamarul Azlan B. Mohd Nasir, for encouragement, guidance, critics and friendship. I am also very thankful to my panels Asoc. Professor Dr. Md Hazarat Ali, Mr. Muhammad Nasir Hanapi and Ms. Noor Yazmeen Farhan Haron for their advices and motivation. Without their continued support and interest, this thesis would not have been the same as presented here.

I am greatly thankful to Universiti Teknologi Malaysia (UTM) for the carriage of my Master study. Librarians at UTM, also deserve special thanks for their assistance in supplying the relevant literatures.

My fellow postgraduate students should also be recognized for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members.

## ABSTRACT

In order to solve most of the engineering problems, application of computer modeling has become the best alternative. Therefore, computer model Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) version 3.3 was selected to model hydrologic responses for Muar River at Buloh Kasap Station. Moreover, it is critical to develop a set of eligible and sufficient data which is compatible with the model application. The objective of this study is to develop and validate the Soil Moisture Accounting (SMA) model parameters prior to its adoption for the Muar River at Buloh Kasap, using its new continuous simulation capabilities. The model can assist water engineer to meet their need of providing national benefits such as flood control, navigation, water supply, irrigation, and other purposes. Not only can the model takes full advantage of the available data but also maximizes the accuracy of modeling in future. HEC-HMS data input requires data of rainfall and discharge ( $\text{m}^3/\text{s}$ ) which was acquired from Department of Irrigation and Drainage (D.I.D) and spatial databases such as Land Use Land Cover (LULC) and Hydrologic Soil Groups Map of Peninsular Malaysia (HSGMPM) which was acquired from Department of Agriculture. This study requires the development of 18 soil moisture accounting model parameters, soil conservation service – curve number (SCS – CN) and stream flow recession analysis. Most of these data input were derived from manipulation of land use, soil map, and topography data using Geographic Information System (GIS). The developed parameters were calibrated using rainfall data (11<sup>th</sup> September 2005 until 31<sup>st</sup> July 2006) to determine their accuracy, and verified against another continuous rainfall event starting from 13<sup>th</sup> September 2001 until 05<sup>th</sup> June 2002. By comparing the SMA parameters before and after calibration it was found that five SMA parameters did not deviate more than 50 percent and had an average deviation of 35 percent. The adjusted calibration process result shows a few simulated peaks closer to the observed peaks, for calibration process there are four out of ten peak events close to observed peaks with an efficiency index for the calibration process of 0.8. Meanwhile the efficiency index for validation process is about minus 0.2 percent, where excessively simulated peak flows lower than the observed flow, these values show about more than 50 percent of deviation among simulation and observed flow.

## ABSTRAK

Aplikasi pemodelan komputer telah menjadi alternatif terbaik dalam menyelesaikan sebahagian besar masalah yang melibatkan kebanyakan isu kejuteraan. Lantarannya, untuk kajian ini, model komputer Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) versi 3.3 telah dipilih untuk memodelkan respon hidrologi terhadap Sungai Muar yang terletak di lembangan Sungai Buluh Kasap. Dalam membangunkan model komputer ini, ia adalah penting untuk mendapatkan satu set data yang mencukupi dan bersesuaian dengan aplikasi model. Justeru itu, objektif kajian ini adalah untuk membangunkan dan mengesahkan kaedah-kaedah parametersasi bagi menganggarkan parameter model SMA yang digunapakai untuk Sungai Muar dengan keupayaan simulasi selanjarnya yang baru, terutamanya dalam membantu jurutera air untuk memenuhi keperluan bagi menyediakan kawalan banjir untuk kerajaan, pelayaran, bekalan air, pengairan, dan tujuan lain dimana ia bukan sahaja mengambil kelebihan terhadap data sedia ada, tetapi juga memaksimumkan ketepatan model dalam memperagakannya pada masa hadapan. Permodelan HEC-HMS ini memerlukan data curahan dan data pelepasan ( $\text{m}^3/\text{s}$ ) yang diperolehi daripada Jabatan Pengairan dan Saliran (JPS) manakala data ruang diperolehi dari pangkalan data Land-Use Land-Cover (LULC) dan pemetaan hidrologi kumpulan tanah bagi semenanjung Malaysia, (HSGMPM) yang mana kedua-duanya diperolehi dari Jabatan Pertanian Malaysia. Berdasarkan parameter-parameter input, kajian ini dibangunkan untuk menunjukkan pembangunan 18 parameter model lembapan tanah yang mengambil kira parameter model yang diterbitkan menggunakan kombinasi perkhidmatan pemuliharaan tanah – curve number (SCS – CN), yang boleh didapati secara terbuka dalam tema Sistem Maklumat Geografi (Geographic Information System) dan analisis kemerosotan aliran sungai. Parameter yang dibangunkan ini kemudiannya dibandingkan dengan data curahan hujan dari 11 September 2005 hingga 31 Julai 2006 untuk mengenalpasti ketepatannya dan ditentusahkan terhadap data hujan berterusan dari 13 September 2001 sehingga 5 Jun 2002. Melalui perbandingan parameter SMA sebelum dan selepas kalibrasi, didapati bahawa terdapat lima parameter SMA yang tidak tidak menyimpang lebih daripada 50 peratus dan mempunyai satu sisihan purata 35 peratus. Keputusan untuk proses kalibrasi yang dilaraskan menunjukkan terdapat sedikit puncak simulasi yang hampir dengan yang diperhatikan. Untuk proses kalibrasi, terdapat 4 dari 10 peristiwa puncak yang hampir dengan puncak yang diperolehi dengan indeks kecekapan sebanyak 0.8 terhadap proses kalibrasi ini. Sementara itu indeks kecekapan untuk proses pengesahan adalah lebih kurang negatif 0.2 peratus, di mana secara melampau, ia mensimulasikan aliran-aliran puncak lebih rendah daripada aliran yang diperhatikan (observe). Nilai-nilai ini menunjukkan terdapat lebih daripada 50 peratus sisihan antara simulasi dan aliran yang direkod.

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## LIST OF SYMBOLS

CN	-	Curve number
$F_i$	-	Test flowrate at the time of i
$K_r^t$	-	Recession constant at time t
$K_r$	-	Recession constant
$K_{rs}$	-	Recession constant for surface storage
$K_{ri}$	-	Recession constant for interflow storage
$K_{rb}$	-	Recession constant for base flow storage
m	-	The percent fit (%)
N	-	Number of data
Q	-	Average observed flowrate
$Q_{\max}$	-	Maximum flow
$Q_{\text{sim},i}$	-	Total hourly simulation flow
$Q_i$	-	The real flowrate at the time of i
$q_t$	-	Average daily flows at future times
$q_0$	-	Initial flow
$q_t$	-	Outflow
r	-	Correlation coefficient, value between $0 < r < 1$
S	-	Soil Storage
$S_t$	-	Groundwater 2 storage volume at time t
$S_{\text{obs},\text{sim}}$	-	Unbiased covariance between observed and simulated
		Stream flow
$SST$	-	The real flowrate change value
$SST$	-	The real flowrate change value flowrate

## LIST OF ABBREVIATIONS

AMC	-	Antecedent Moisture Content
ARC	-	Antecedent Runoff Condition
DEM	-	Digital Elevation Models
DID	-	Department of Irrigation and Drainage
DOA	-	Department of Agriculture
GIS	-	Geographic Information System
HEC-HMS	-	Hydrologic Engineering Center's Hydrologic Modeling System
HSGMPM	-	Hydrologic Soil Groups Map of Peninsular Malaysia
LSD	-	Land Survey Datum
LULC	-	Land Use Land Cover
MRUs	-	Modeling Response Units
PRMS	-	Precipitation-Runoff Modeling System
RORB	-	Runoff Routing Burroughs
RS	-	Remote Sensing
SCS – CN	-	Soil Conservation Service – Curve Number
SMA	-	Soil Moisture Accounting
USDA	-	United States Department of Agriculture
USGS	-	United States Geological Survey

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Introduction**

Soil moisture in hydrologic simulation is a simplified representation of moisture loss cycles in soils. It was derived from a moisture-accounting balance among rainfall, surface runoff, subsurface outflow, actual evaporation, and change in moisture storage. It expresses actual evapotranspiration in terms of root density, soil water retention factor, soil storage capacity and soil water level held by molecular attraction from time to time that water on the surface of soil particle.

Soil moisture contributes to evapotranspiration and basin recharge, but not to total runoff. It has a relationship between the volume of rainfall and surface runoff flow rates. It is a part of the hydrologic processes that controlling the distribution and movement of water on the earth's surface, in the soil, and atmosphere.

Continuous hydrologic simulation is a method based on a seasonal time frame to draw surface runoff activity system that includes soil moisture condition in the watershed, it is widely used to depict hydrologic cycle they involve that the

of surface runoff at point. The method also took into account the portion of rainfall that does not contribute to direct runoff such as interflow and base flow.

The continuous hydrologic simulation model is influenced by many factors such as the contribution to the flow rates. They are; geomorphologic descriptors (e.g., drainage area, slope, channel length, drainage density, and relief ratio), soil property descriptors (e.g., infiltration capacity, field capacity, soil depth, and porosity), land-use and land-cover descriptors (e.g., percent of agriculture, forest, and urban cover), geologic descriptors (e.g., structural geologic properties and lithologic). Many researchers have developed such as a regression method to relate basin descriptors to hydrologic variables, such as peak flow and low flow rates.

Unfortunately, to model long term hydrologic response parameter values that reflect the effect of soil, slope, and land-use on the hydrologic response are limited. Without a clear understanding, the transition from simple empirical models to physical base hydrological models could not be achieved. One of the draw backs of physical hydrologic models is that it is difficult to identify vegetation, soil texture, and geomorphologically influenced hydrological processes at a different spatial and temporal scale.

In recent years, the need for physically-based hydrologic models has increased to forecast its response throughout a catchment. As a computer became widely used by engineers to model and solve an engineering problem, The US Army Corps for Engineer have demanded models that can easily achieve. A modeling package included in Hydrologic Engineering Center – Hydrologic Modeling Systems (HEC-HMS), which accurately simulate hydrologic descriptors at the one particular watershed using Soil Moisture Accounting (SMA).

Long term simulation model using HEC-HMS Software is applied where by soil moisture accounting (SMA) method was used as a loss rate method. There are other methods used to derive the parameters that are required in SMA model.

Firstly, parameterization using Soil Conservation Service Method uses an arbitrary “curve number” to determine direct runoff. The “curve number” represents the cumulative effects of landscape descriptors that control initial abstractions or water losses that usually correspond to that fraction of precipitation not translated into direct runoff. Initial abstractions include surface depression storage (controlled by land-use and land-cover, soil, and micro-topography), interception (controlled by land-use and land-cover type), and infiltration losses, controlled by soil characteristics.

Secondly, parameterization using spatial data, thus spatial data employs using Geographic Information Systems (GIS). Physically, the method is used to retrieve land-use/soil shapefile data input. The information is used to estimate some of SMA parameters. The data information can be retrieved using GIS such as soil type distribution, soil texture, depth soil, land cover, and land slope. This technique has been used to estimate others parameter in SMA infiltration such as initial number of land use, soil profile, tension zone storage, infiltration, and percolation rates.

Thirdly, parameterize using Streamflow recession analysis method, it was first introduced by Linsley et al. (1958). He identifies the inflection point on the receding limb of a hydrograph where surface flow has stopped contributing to runoff, and the receding limb represents the contribution from interflow and base flow.

In this study Sungai Muar at Buloh Kasap River Basin has been selected as a study area, the simulation process is to test all the parameters estimated, and then



before it is validated using another rainfall data, these result has adjusted in order to get a smaller deviation between simulated flow and observed flow.

## **1.2 Statement of problem**

In hydrologic studies, Soil moisture plays important role in surface runoff estimation. The soil moisture represents the actual storage to store the rainfall before it is converted to a surface runoff. It is important to estimate the soil moisture content to model the hydrologic condition. Hydrograph characteristic influences by the condition of soil moisture use when the storm begins.

The large catchment with impermeable land use will lead to highly surface runoff. However, the catchment with less impermeable land use will affect the amount of surface runoff. It could lead to high surface runoff or less surface runoff. The relationship of rainfall and surface runoff depends on the soil moisture content. The soil moisture condition is given to estimate the soil ability to absorb the amount of rainfall before it needs to be updated regularly due to the conversion to surface runoff. This soil moisture updating could be done by using soil moisture accounting model.

Otherwise, the availability and quality of high resolution data are insufficient (e.g., topography, land-use/covers, soils, rainfall, and flow monitoring data) estimate soil moisture for developing, calibrating, and validating the continuous hydrologic model. Under these circumstances, it is critical to develop an effective modeling strategy that not only takes full advantage of the available data but also maximizes the accuracy of modeling in the future.

### **1.3 Objective of study**

To establish SMA parameters for rural catchment based on the project at locations in order to aid future research with similar topography, land-use/land-cover, and soil.

### **1.4 Scope of the Study**

The scopes of study are:

1. Site visit, a researcher visited few gauging and rainfall stations in Muar River Basin, identified the characteristics of the study area.
2. Data collation, a set of secondary data was collected i.e. hydrological data, Streamflow, rainfall stations coordinate topographic map. This data was gathered from the Department of Irrigation and Drainage (DID) at Jabatan Pengairan dan Saliran, Ampang office centre. Land-use/covers and soils, Data was gathered from Department of Agriculture (DOA).
3. Data processing, selection of rainfall events, imperviousness data from land-use to decide the land use description classification, soil data from the land-soil map to decide soil class. Simulation processing from these data using HEC-HMS. The output results from a simulation process were compared with observed data. Validation processing is justification parameters to verify the reliability of the parameters.

4. Hydrologic modeling, develop comparative results based on a simulation models, the results obtained will be discussed concerning reference to the criteria set before making conclusions.

## **1.5 Significant of Study**

The formation of the soil influences the amount of pore space in the soil features, which in turn affects infiltration, soil moisture retention, and other water movement through the layers. The average soil features may have a pore space of about 45%, with a variation from 30% to 70 % (McCuen, 1998). This study observes soil parameters due to soil characteristic, their ability and changes to absorb and release the water.