UNIVERSITI PUTRA MALAYSIA

APPLICATION OF RORB RAINFALL-RUNOFF MODEL TO URBAN AND RURAL CATCHMENTS

CHOO EE LI.

APPLICATION OF RORB RAINFALL-RUNOFF MODEL TO URBAN AND RURAL CATCHMENTS

By

CHOO EE LI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

March 2004

DEDICATION

To my beloved family especially my parents, for their continual support, patience, love and care, which finally make this happened.

To GOD, from the bottom of my heart thank you for your love and blessings of perseverance and patience…

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of the requirements for the degree of Master of Science

APPLICATION OF RORB RAINFALL-RUNOFF MODEL TO URBAN AND RURAL CATCHMENTS

By

CHOO EE LI

March 2004

Chairman : Abdul Halim bin Ghazali, Ph.D.

Faculty : Engineering

Over the years, many have realised the growing importance of water and its resources to sustain industrial and community development and most importantly life in all forms. However, excess of uncontrolled surface runoff could lead to flooding and potential damages in properties and loss of life. As a result, the field of hydrology and hydraulic has become a growing importance. With the current technology, various software programs are developed to assist in the analysis and study of water resources management and flood mitigation. Amongst them is the Rainfall-Runoff Routing Model which was widely used in Australia. It has also been used in some of the catchments' studies and flood mitigation projects in Malaysia, mostly to perform flood routing and estimation.

The primary aim of the study is to assess the suitability of RORB model for application to catchments in Malaysia. It is used to simulate the rainfall-runoff routing process of two characteristically different catchments namely Sg Klang Basin at Tun Perak Bridge and Sg Bernam Basin at South Kinta Consolidated

Bridge. The former is highly urbanised and located in Wilayah Persekutuan while the latter is considerably rural and encompasses both Perak and Selangor states.

The setting up of the model begins with subdividing the catchment into various subcatchments based on catchment topography, river system and drainage divides which are then modelled by a series of links and nodes, which represent the reaches of flow and subcatchments respectively. Next, the various input parameters such as subcatchment area and landuse condition, channel type, length and slope, fraction imperviousness, rainfall and streamflow data are defined and determined. All these are compiled in an input data file which is written in Fortran language following a specific sequence of command codes for running of the model simulations.

The catchment modelling is performed up to the calibration and verification stage using 4 storm events; 2 each for calibration and verification respectively. These events are identified based on available past 3 to 40 years of rainfall and streamflow records collected from Department of Irrigation and Drainage Malaysia. The best fit model parameters, m and k_c, are determined and the results of the generated runoff hydrographs are compared to the observed hydrographs.

The model is areally distributed, nonlinear, and has a linear or non-linear storage relationship between storage S and outflow discharge Q which is given as:

$$S = k_c k_r Q^m$$

where k_c and m are the catchment parameters determined by trial and error fitting while k_r is relative delay applicable to individual reach storage calculated based on any unit of indicator of storage delay time. Two units of indicator, namely flow length and flow time, are adopted separately in 1st Model Setup and 2nd Model Setup to ascertain the sensitivity of these two units to the model and its results.

This study concludes that the application of RORB model is relatively user friendly. Also, the model is less complicated in its application as it does not involve too many input parameters leading to less assumption to be made. This is an advantage in view of the inherent problem of data inadequacy and poor quality of recorded data. In addition, there are only two model parameters, m and k_c, to determine because of the simplified approach to the rainfall-runoff process.

The study also showed that RORB model is applicable to both urban and rural catchments. The overall results indicated variations of less than 10% between the generated and observed runoff discharges and volumes, which is of acceptable limitation. However, it is also shown SKC catchment has a higher variation than Tun Perak catchment. This is most possibly due to the fact that SKC catchment has a very much bigger catchment area about 10 times greater than Tun Perak catchment. This results in larger propagated errors or discrepancies in the modelling. But overall, the peak times and shape of the runoff hydrographs are generally matching between the observed and generated. Finally, the model is also not sensitive to the types of indicator used for relative storage delay time as the maximum variations in the results between the two model setups are 2%.

In conclusion, RORB is an acceptable model which provides a reasonably good simulation of the rainfall-runoff process in a catchment.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

APPLIKASI MODEL HUJAN-LARIAN RORB KE ATAS KAWASAN-KAWASAN TADAHAN BANDAR DAN DESA.

Oleh

CHOO EE LI

Mac 2004

Pengerusi : Abdul Halim bin Ghazali, Ph.D.

Fakulti : Kejuruteraan

Sejak kebelangkangan ini, ramai telah menyedari kepentinganan air dan sumber air untuk menampung pembangunan industri dan masyarakat, serta semua jenis kehidupan. Walaubagaimanapun, kelebihan air permukaan yang tak terkawal akibat hujan lebat mungkin mengakibatkan banjir and seterusnya kerosakan harta dan kehilangan nyawa. Dengan ini kepentingan bidang hidrologi dan hidraul kian meningkat. Kemajuan teknologi kini membolehkan banyak program perisian dihasilkan untuk membantu dalam analisis dan kajian pengurusan sumber air dan tebatan banjir. Antaranya ialah model RORB, iaitu satu program penyaluran hujan-air larian, yang digunakan dengan meluas di Australia. Ia juga telah digunakan untuk penyaluran dan penganggaran luahan banjir dalam beberapa kajian lembangan sungai dan tebatan banjir di Malaysia. Tujuan utama kajian ini adalah untuk mengesahkan kesesuaian model RORB untuk applikasi ke atas kawasan-kawasan tadahan sungai di Malaysia. Ia digunakan untuk simulasi proses penyaluran hujan-air larian bagi dua kawasan tadahan iaitu lembangan Sg Klang di Jambatan Tun Perak dan Sg Bernam di Jambatan Kinta Selatan. Lembangan pertama terletak di

dalam Wilayah Persekutuan manakala lembangan kedua merentasi negeri Perak dan Selangor.

Penyediaan model bermula dengan pembahagian kawasan tadahan kepada beberapa subtadahan berdasarkan topografi kawasan, sistem sungai dan pembahagian saliran dan kemudian dimodelkan sebagai satu siri kait dan nod yang masing-masing mewakili rangkaian aliran dan subtadahan. Kemudian parameter input seperti luas kawasan subtadahan dan keadaan gunatanah, jenis, panjang dan cerun saluran, turutan operasi penyaluran, pecahan kawasan tak telus, data hujan dan aliran sungai ditentukan. Kesemua data tersebut disusun dalam satu fail data input yang ditulis menggunakan bahasa Fortran dan mengikuti jujukan kod arahan yang tertentu untuk simulasi model.

Kawasan tadahan dimodelkan hingga tahap penentukuran dan pengesahan model berdasarkan 4 kejadian hujan yang lepas. Kejadian-kejadian tersebut dikenalpasti daripada 3 hingga 40 tahun rekod hujan dan aliran sungai yang sediada dan terkumpul daripada Jabatan Pengairan dan Saliran Malaysia. Pasangan parameter penyaluran, k_c dan m, yang paling padan ditentukan dan keputusan hasil hidrograf air larian dibandingkan dengan cerapan hidrograf air larian. Model ini berdasarkan luas teragih, bukan linear dan mempunyai hubungan storan linear atau tak linear antara storan S dan luahan Q seperti berikut:

$$S = k_c k_r Q^m$$

di mana k_c and m adalah parameter tadahan yang perlu ditentukan melalui proses padan cuba dan silap manakala k_r ialah masa lengah relatif bagi storan jangkauan individu berdasarkan sebarang unit penunjuk masa lengah storan. Dua unit penunjuk, panjang saluran aliran dan masa lengah, telah digunakan dalam '1st Model Setup' dan '2nd Model Setup' masing-masing untuk mengkaji kepekaan kedua-dua penunjuk ke atas model dan keputusannya.

Kesimpulan kajian ini menunjukkan bahawa model RORB adalah mudah diguna dan kurang rumit dalam aplikasinya kerana ia tidak melibatkan terlalu banyak parameter input. Maka, kurang andaian perlu dibuat dalam penentuan input data. Ini merupakan kebaikan memandangkan ketidaklengkapan dan kekurangan data yang sediaada. Tambahan, hanya dua parameter penyaluran, m dan k_c yang perlu diselaraskan disebabkan konsep proses hujan-air larian yang dipermudahkan.

Kajian ini juga mengesahkan bahawa RORB sesuai digunakan untuk kawasan tadahan berkeadaan bandar dan desa. Secara keseluruhannya, variasi keputusan yang kurang daripada 10% dalam perbandingan keputusan luahan dan isipadu air larian yang dihasilkan dengan rekod yang sediaada adalah boleh diterima. Namun, variasi bagi kawasan tadahan SKC adalah lebih tinggi daripada di Tun Perak. Ini disebabkan luas kawasan tadahan SKC yang 10 kali lebih besar daripada Tun Perak mungkin mengakibatkan perambatan variasi yang lebih tinggi. Pada keseluruhannya, masa puncak dan bentuk hidrograf air larian adalah padan secara amnya di antara hidrograf yang terhasil dan direkodkan. Akhirnya, adalah didapati bahawa model adalah tidak sensitif kepada unit penunjuk bagi masa relatif lengah storan kerana variasi maksimum keputusan antara dua jenis siapan model hanya 2%.

Kesimpulannya, RORB adalah model yang boleh diterima dan dapat memberikan hasil simulasi proses hujan-larian suatu kawasan tadahan yang memuaskan.

ACKNOWLEDGEMENTS

In the course of the Study, many individuals and organisation have lent their time and support to ensure the success of this study. The author thus would like to thank her supervisor Assoc. Prof. Dr. Abdul Halim bin Ghazali for his never-ending patience and guidance throughout the course of this study. Appreciation is also extended to the other supervising committee members, Assoc. Prof. Kwok Chee Yan and Mdm. Badronnisa bin Yusuf for their understanding and support.

The author would also like to express her gratitude to Assoc. Prof. Dr. Aziz F. Eloubaidy, without whom the author would not have the courage to undertake the course of study. His encouragement and advice is highly treasured by the author.

Her gratitude also goes out to the Department of Irrigation and Drainage at Ampang for supplying the necessary hydrological data required for the study and its staff under the Unit of Information Management for their kind assistance and helpfulness.

Last but not least, the author would like to convey her heartfelt gratitude to her family and dear friends for their continual advice and support that has carried her through the completion of the project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure		Page

Figure		Page

LIST OF ABBREVIATIONS

CL	Continuing Loss
DCM	Deterministic Conceptual Model
DEM	Deterministic Empirical Model
DID	Department of Irrigation and Drainage, Malaysia
DR	Direct Runoff
F	Fraction Impervious
FC	Penman Open Pan Evaporation
GAWSER	Guelph Agricultural Watershed Storm-Event Runoff
GDEL	Groundwater Store Delay
GSP	Groundwater Store Index
GSU	Groundwater Store Factor
HEC-HMS	Hydrologic Engineering Center – Hydrologic Engineering System
HM	Huggins and Monke
HYMO	Hydrologic Model
HYRROM	Hydrological Rainfall-Runoff Model
ID	Identity
I.H.U.K.	Institute of Hydrology United Kingdom
IL	Initial Loss
IUH	Instantaneous Unit Hydrograph
MSMAM	Manual Saliran Mesra Alam Malaysia
RC	Surface Runoff Partitioning Factor
RDEL	Routing Store Delay
RK	Routing Store Factor

RORB	Rainfall-Runoff Routing Model
RX	Routing Store Index
SCM	Stochastic Conceptual Model
SCS	Soil Conservation Service
SCS TR-20	Soil Conservation Service Technical Report-20
SEM	Stochastic Empirical Model
Sg	Sungai
SKC	South Kinta Consolidated
SMI	Soil Moisture Index
SS	Size of Vegetation and Interception and Surface Detention Store
SSARR	Streamflow Synthesis and Reservoir Regulation
UH	Unit Hydrograph
WAHS	Watershed Hydrology Simulation

CHAPTER 1

INTRODUCTION

1.1 General Background

Water is classified as one of the five essential and fundamental elements found on earth. In fact it is the basis of life to all living things. This being so, it was almost inevitable that the development of water resources preceded any real understanding of their origin and formation. The distribution and availability of water has influenced the development of human society through the course of history. Examples of the earliest influences were the emergence of civilization along rivers like the Nile, Thames, Ganges and etc. In short, throughout centuries, water has remained an important element of the physical environment up to this day. With the ever-continuing growth of global development and population, demand for water has increased greatly in all regions.

In the tropical region, where rainfall occurs all year round with an average annual precipitation of above 2500 mm, an abundance of water is available for many uses, like in the field of industrial, domestic water supply, agriculture and power generation. Furthermore, countries in this region still have a relatively high percentage of undeveloped tropical rain forests and mountains, which is an important source of water and water retention basins which can be utilized to meet the growing demand.

On the other hand, such high precipitation when brought about during intense thunderstorms or prolonged rainfall which is common in the tropical region, if uncontrolled usually results in flooding occurrences. This leads to other disasters such as erosion problems, landslides, structural collapse and etc. Consequently, flooding is one of the more frequent natural disasters in this region and not to be looked lightly upon.

As a result, availability of accurate and reliable methods for estimating and predicting water budget and flood discharge of any particular area is crucial for the purpose of water resources and flood evaluation, planning and management. The efforts will prevent flooding and to ensure efficient and optimum utilization of potential water resources. It is therefore no doubt that research and analysis into the field of hydrology and hydraulics should and has become one of the focuses of community and national development. To date, many technical approaches have been developed to quantify it with watershed modelling being the forefront approach at present.

With the advancement of technology and continual development that changes the catchment characteristics significantly, watershed modelling plays a major role in estimating and predicting runoff flows. With a versatile approach and wide application, modelling enables the rainfall runoff process in a catchment to be analysed and assessed under varying scenarios. The results of the model will allow optimisation of designs for water management measures.

According to Moore (1969), models are used in hydrology for three main purposes namely:

(i) To simplify and generalise a complex reality

(ii) To predict forthcoming hydrological events

(iii) To plan the future use of water resources

And specifically, models are used in hydrology to do the followings:

(i) Increase our understanding of drainage basin processes and the interrelationships between processes and forms.

(ii) Predict drainage basin response to variations in input or catchment characteristics, especially those caused by human activities.

(iii) Explain the interrelationships of the various hydrological phenomena.

(iv) Solve various hydrological and water resource problems.

The hydrologic system synthesis involves selecting an appropriate hydrologic model and testing the operation of the model by analysis (Dooge, 1973). In watershed modeling, models are created for better understanding and to define the responses of hydrologic system for the areas under study, which may then be used to make predictions in a deterministic or probabilistic sense. For natural water resources, many efforts concentrating on the analysis of the physical hydrological system via representing its components and their linkages by conceptual and mathematical relations have already been made. To date, there are a few models of these processes that do not require fitted parameters, for example, a mathematical model,