Faculty of Engineering

HYDROLOGIC MODELING WITH HEC-HMS: SUNGAI SARAWAK KANAN BASIN

Sakinah Dahrawi Edrus

Bachelor of Engineering with Honours
(Civil Engineering)
2004

Universiti Malaysia Sarawak
Kota Samarahan

fk

BORANG PENYERAHAN TESIS

Judul: HYDROLOGIC MODELING WITH HEC-HMS :
FOR SUNGAI SARAWAK KANAN BASIN

SESI PENGAJIAN: 2000 - 2004

Saya SAKINAH DAHRAWI EDRUS
(HURUF BESAR)

mengaku membenarkan tesis ini disimpan di Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dengan syarat-syarat kegunaan seperti berikut:

1. Hakmilik kertas projek adalah di bawah nama penulis melainkan penulisan sebagai projek bersama dan dibiayai oleh UNIMAS, hakmiliknya adalah kepunyaan UNIMAS.
2. Naskhah salinan di dalam bentuk kertas atau mikro hanya boleh dibuat dengan kebenaran bertulis daripada penulis.
3. Pusat Khidmat Maklumat Akademik, UNIMAS dibenarkan membuat salinan untuk pengajian mereka.
4. Kertas projek hanya boleh diterbitkan dengan kebenaran penulis. Bayaran royalti adalah mengikut kadar yang dipersetujui kelak.
5. * Saya membenarkan/tidak membenarkan Perpustakaan membuat salinan kertas projek ini sebagai bahan pertukaran di antara institusi pengajian tinggi.
6. ** Sila tandakan (✓)

[ ] SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972).

[ ] TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan).

[3] TIDAK TERHAD

Disahkan oleh

(TANDATANGAN PENULIS)

(TANDATANGAN PENYELIA)

Alamat tetap: NO. 41, KPG. TUPONG BATU,
93050 KUCHING, SARAWAK.

PROF. SALIM SAID

Tarikh: 1/4/04

Tarikh: 1/04/04

CATATAN * **Potong yang tidak berkenaan.**
** **Jika Kertas Projek ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/ organisasi berkenaan dengan menyertakan sekali tempoh kertas projek. Ini perlu dikelaskan sebagai SULIT atau TERHAD.**

This Final Year Project attached here:

Title	:	Hydrologic Modeling With HEC-HMS: Sungai Sarawak Kanan Basin
Author's Name	:	Sakinah Bt. Dahrawi Edrus
Matric Number	:	5414

Has been read and approved by:

Prof. Salim B. Said
(Supervisor)

1/04/04
(Date)

HYDROLOGIC MODELING WITH HEC-HMS: SUNGAI SARAWAK KANAN BASIN

SAKINAH DAHRAWI EDRUS

This project is submitted in partial fulfillment of
the requirements for the degree of Bachelor of Engineering with Honours
(Civil Engineering)

Faculty of Engineering
UNIVERSITY MALAYSIA SARAWAK
2004

Dedicated to my beloved family

ACKNOWLEDGEMENT

I would like to express my invaluable appreciation and thanks to my beloved parents, my beloved sister and brothers for their encouragement and understanding throughout my studies in Universiti Malaysia Sarawak (UNIMAS).

I would also like to thank the project supervisor, Professor Salim Said for his cooperation. Also not to forget, the staffs of Department of Irrigation and Drainage (D.I.D), Hydrology Branch for their contribution in providing the hydrological data required for this project.

Finally, I would also like to take this opportunity to express my special thanks to all my colleagues and housemates who are kindly sharing their knowledge in completing this project. Thanks are also extended to all Engineering staff and lecturers for their guidance and help.

ABSTRACT

Rainfall intensity and duration are the major driving force for rainfall-runoff processes, followed by the watershed characteristics that translate the rainfall input into the output hydrograph at the outlet. The Hydrologic Modeling System HEC-HMS is a simulation model that is designed to simulate the rainfall-runoff single storms event. A rainfall-runoff model for the upper part of the Sungai Sarawak Kanan basin is developed for prediction of peak flow of outflow hydrograph. Prediction of flood peak is important so that necessary safety and protection measures can be carried out for important hydraulic structures such as bridges, culverts and embankments. Preparation for implementing this single-event simulation model begins with a watershed subdivision into two subbasins. The computation proceeds from the most remote upstream subbasin in a downstream direction. Input data like the rainfall and discharge data for the model are obtained from Department of Irrigation and Drainage (D.I.D). The three selected storm, November 2000 (3 hours) storm, September 2001 (5 hours) storm and December 2001 (2 hours) storm are analyzed. Suitable methods for computing precipitation losses, synthetic unit hydrograph and baseflow are selected for the analysis. The average precipitations over the study area are determined by using the Thiessen polygon method. The baseflow calculation for separating the direct runoff from baseflow is done by the exponential recession method, and then the hydrologic losses such as infiltration and interception are computed with the Φ–index method. By using the Snyder's Synthetic Unit Hydrograph method, rainfall excess is converted to surface runoff. Finally, the selected storms from the model are then calibrated and the results from each are compared. The Φ –index method gives values of losses that ranging from 1.22 to 11.15 mm/hr. The result of calibrated values of Snyder's coefficient, C_t varies from 1.85 to 2.0. Meanwhile the result of peaking coefficient, C_p varied from 0.10 to 0.65. Based on the result, Snyder's proposed values of C_t and C_p are not quite applicable to the upper part of Sungai Sarawak Kanan Basin. The result also indicate that the basin poses greater storage capability and it is a little less steep from Snyder's original study area which is the Appalachian Highlands of the eastern United States. The values of the observed peak flow for the November 2000 (3 hours) storm is 180 m^3/s, for September 2001 (5 hours) storm is 57.5 m^3/s and for December 2001 (2 hours) storm is 47.1 m^3/s. Meanwhile, the values of the simulated peak flow from the outflow hydrograph for the November 2000 (3 hours) storm, September 2001 (5 hours) storm and December 2001 (2 hours) storm are 179.87 m^3/s, 57.502 m^3/s and 47.126 m^3/s respectively. It shows that the simulated and observed peak flows are almost similar with less than 1% of error.

ABSTRAK

Keaamatan dan jangkamasa hujan ialah kekuatan utama untuk proses kerpasan-larian, diikuti oleh ciri-ciri kawasan tadahan yang menukarkan input hujan kepada hidrograf output. Hydrologic Modeling System HEC-HMS ialah satu model untuk menganalisa kerpasan-larian dari rekod kerpasan ribut. Satu model kerpasan-larian bagi bahagian atas kawasan tadahan Sungai Sarawak Kanan dihasilkan untuk menganggar hidrograf kepasan dan kerpasan tertinggi. Anggaran kerpasan banjir tertinggi adalah sangat mustahak supaya langkah-langkah keselamatan dapat diambil untuk melindungi srtuktur-struktur yang penting seperti jambatan, pembentung dan tambak. Data untuk input seperti data hujan dan data kadar alir sungai telah diambil dari Jabatan Saliran Air (J.P.S) dan tiga curahan ribut iaitu November 2000 (3 jam), curahan ribut September 2001 (5 jam) and curahan ribut Disember 2001 telah dipilih untuk dianalisa. Kaedah-kaedah yang sesuai untuk mengira kehilangan hidrologi, unit hydrograph dan aliran dasar telah dipilih untuk analisa. Purata bagi ukur dalam curahan sesuatu kawasan dihasilkan melalui kaedah segibanyak Thiessen. Penilaian aliran dasar tadahan untuk mengasingkan aliran dasar dan air larian dibuat dengan kaedah kecerunan malar dan diikuti kehilangan hidrologi seperti resapan telah dikira dengan menggunakan kaedah index-Φ. Dengan menggunakan kaedah unit hidrograf Snyder, hujan berkesan akan ditukarkan kepada air larian permukaan. Curahan-curahan ribut untuk model bahagian atas kawasan tadahan Sungai Sarawak Kanan akan melalui proses penentu-ukuran dan keputusan analisa akan dibandingkan. Hasil nilai kehilangan hidrologi yang diperolehi adalah 1.22 sehingga 11.15 mm/jam. Nilai keputusan dari proses penentu-ukuran bagi pekali Snyder, C_t ialah di antara 1.85 sehingga 2.0. Manakala nilai bagi aliran puncak, C_p pula ialah di antara 0.1 sehingga 0.65. Berdasarkan keputusan yang telah diperolehi, didapati nilai bagi C_p dan C_t yang telah dicadangkan oleh Snyder adalah kurang sesuai bagi kawasan tadahan Sungai Sarawak Kanan. Bahagian atas Sungai Sarawak Kanan mempunyai keupayaan takungan yang lebih besar dan mempunyai kecerunan yang sedikit rendah dari kawasan kajian Snyder iaitu di pergunungan Appalachian yang terletak di timur Amerika Syarikat. Nilai paras ukuran air maksimum yang sebenar ialah 180 m^3/s untuk curahan ribut November 2000 (3 jam), 57.5 m^3/s untuk curahan ribut September 2001 (5 jam) dan 47.1 m^3/s untuk curahan ribut Disember 2001 (2 jam). Nilai paras ukuran air maksimum yang telah dianggarkan bagi curahan ribut November 2000 (3 jam), curahan ribut September 2001 (5 jam) and curahan ribut Disember 2001 (2 jam) adalah 179.87m^3/s, 57.502 m^3/s and 47.126 m^3/s masing-masing. Ini menunjukkan nilai paras ukuran air maksimum yang sebenar dan anggaran adalah hampir sama dengan perbezaan kurang dari 1%.

LIST OF CONTENTS

CONTENT		Page
Dedication		ii
Acknowledgement		iii
Abstract		iv
Abstrak		v
List of Contents		vi
List of Tables		ix
List of Figures		x
Notation		xi
Chapter 1.0	**INTRODUCTION**	
	1.1 Flood Level	1
	1.2 Project Description	2
	1.3 Objective	3
Chapter 2.0	**LITERATURE REVIEW**	
	2.1.1 Watershed	5
	2.1.1.1 Basin Characteristics	6

	2.1.2	Rainfall	8
		2.1.2.1 Thiessen Polygon Method	9
	2.1.3	Losses From Rainfall	9
		2.1.3.1 Constant Loss Rate Using ϕ Index	9
	2.1.4	Runoff	10
		2.1.4.1 Surface Runoff	11
		2.1.4.2 Groundwater Flow	11
		2.1.4.3 Direct Runoff	11
		2.1.4.4 Streamflow	12
	2.1.5	Baseflow Recession Method	12
		2.1.6.1 Rainfall Runoff Relationship	14
		2.1.6.2 Stage Discharge Relationship	15
	2.1.7	Unit Hydrograph (UH)	15
		2.1.7.1 Snyder's Synthetic Unit Hydrograph	16
	2.1.8	Runoff Simulation Models	17
	2.2	Data Needed For Simulation	17
	2.3	Model Calibration	19
	2.4	Peak Discharge	20
		2.4.1 Design Flood	21
		2.4.2 Design Flood Computation	22
	2.5	History Of HEC	22
Chapter 3.0	**METHODOLOGY**		
	3.1	Select A Watershed	27

3.2	Collect Data And Selection of Storm For Simulation	28
3.3	Start A Project	29
3.4	Create Gage Data	29
3.5	Enter Basin Model Data	29
3.6	Enter Precipitation Model Data	31
3.7	Enter Control Specification	31
3.8	Create And Execute A "Run"	32
3.9	Calibration Of Time Lag,t_p And Peaking Coefficient,C_p	32
Chapter 4.0	**DATA AND ANALYSIS**	
4.1	Data	34
4.1.1	Watershed Delineation	34
4.1.2	Hourly Precipitation & Discharge Records	35
4.1.3	Hydrologic Parameters For Calibration In Basin Model	35
4.1.4	Thiessen Polygon Areas & Gage Weights for Meteorologic Model	43
4.1.5	Control Specification	44
4.1.6	Parameter Summary	45
4.2	Result And Analysis	46

Chapter 5.0	**DISCUSSION AND RECOMMENDATION**	
	5.1 Thiessen Polygon Method	55
	5.2 The Φ–Index	56
	5.3 Snyder Unit Hydrograph Method	57
	5.4 Further Studies With HEC-HMS	57
Chapter 6.0	**CONCLUSION**	59
References		62
Appendix A	Rainfall And Discharge Data	63
Appendix B	Recession Constant	89
Appendix C	Figures And Procedure	95

LIST OF TABLE

Table | Page

4.1	Subbasin Areas	34
4.2	Baseflow Separation For November 2000 (3 Hours) Storm	36
4.3	Baseflow Separation For September 2001 (5 Hours) Storm	37
4.4	Baseflow Separation For December 2001 (2 Hours) Storm	39
4.5	k And Direct Runoff Volume	41
4.6	Direct Runoff Depth And Φ-Index	42
4.7	Thiessen Polygon Areas	43
4.8	Gage Weight Values	44
4.9	Control Specification For Each Storm	44
4.10	Parameter Summary	45
4.11	The Observed And Simulated Peak Discharge	46
4.12	The values of C_p, C_t and t_p	46

LIST OF FIGURES

Figures		Page
1.1	HEC-HMS Model Configuration	3
2.1	Delineation Of Watershed Boundary	6
2.2	Effect Of Catchment Shape On Runoff	7
2.3	Φ Index method	10
2.4	Catchment Rainfall And Runoff Process	13
2.5	Sketch Of An Unit Hydrograph	15
2.6	Concept Of A Model	17
2.7	Schematic Of Calibration Procedure	20
4.1	Rainfall Hyetograph For November 2000 (3 Hours) Storm	49
4.2	Rainfall Hyetograph For September 2001 (5 Hours) Storm	50
4.3	Rainfall Hyetograph For December 2001 (2 Hours) Storm	51
4.1	Result I	52
4.2	Result II	53
4.3	Result III	54

NOTATION

C_p	-	Peaking Coefficient
C_t	-	Basin coefficient
HEC	-	Hydrologic Engineering Center
HMS	-	Hydrologic Modeling System
k	-	Recession constant
L	-	Channel length
L_c	-	Length along channel to point nearest centroid of area
Q	-	Discharge (flow rate)
T	-	Time (hour)
t_p	-	Time lag to peak
UH	-	Unit hydrograph

CHAPTER 1

INTRODUCTION

1.0 General

Many simulation models in hydrology have been developed since 1970s to assist hydrologist in watershed analysis and hydrologic design. Hydrologic simulation models use various equations to describe hydrologic processes. These models have been applied to urban stormwater, drainage design, agriculture drainage, floodplain and watershed hydrology, reservoir design and operation, flood frequency analysis and large river basin management.

1.1 Flood Level

A flood is an unusual high stage of a river that overflows the natural or man made banks spreading water to its flood plains. It is possible to predict the flood peak at a particular place and time by using an appropriate hydrologic simulation model so that the necessary protection measures can be carried out. For design of bridges, culverts, small dams, embankments and barrages, the peak flood discharge is the greatest concern. For design of such important structures, complete flood hydrograph at the site is an important requirement.

1.2 Project Description

The U.S Army Corps of Engineers has designed a series of computer packages that can be used to solve hydrological problems encountered in river valley system. One of the packages is HEC-HMS, which is a Window-based hydrologic model. It is categorized as a mathematical model. HEC-1(HMS) is considered to be the most versatile and most often used hydrologic model. It is designed to be used for the simulation of flood events in watershed and river bank.

A HEC-HMS model for any river basin has basic components for subbasin runoff, channel routing and hydrograph combining. Hydrologic elements are arranged in a dendritic network, and computations are performed in an upstream-to-downstream sequence. Streamflow is generated by precipitation during the storm event and groundwater entering a catchment. A catchment (watershed or river basin) model is a set of mathematical abstractions describing hydrologic cycle, with objective of transforming precipitation into direct runoff by simulation.

This precipitation is converted to runoff using unit hydrograph method that is available in the program. The storm hydrograph is computed or combined from upstream areas, routing is then performed. The result of modeling is the computation of outflow hydrograph at downstream location within the river basin.

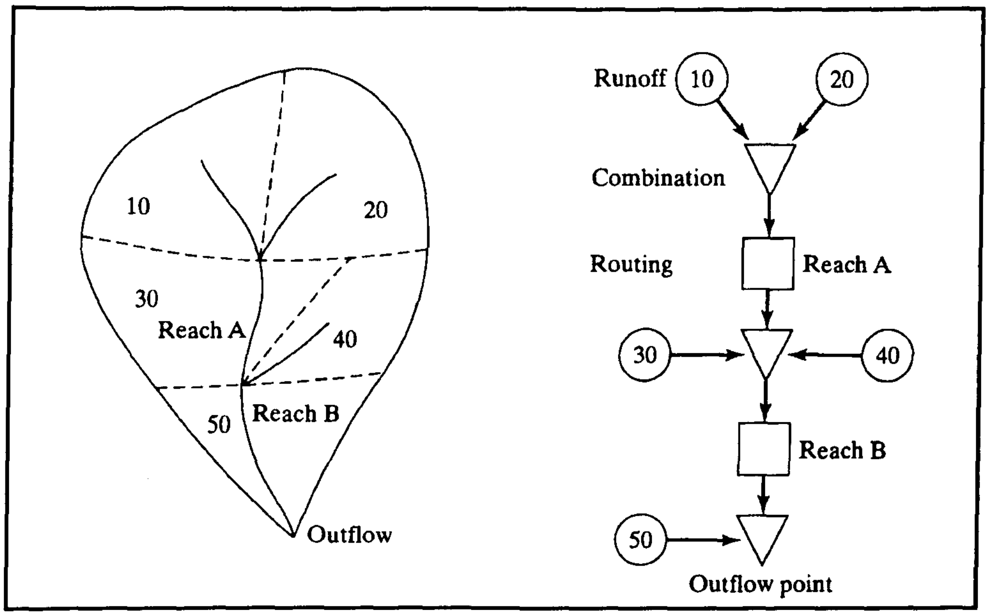

Figure 1.1 HEC-HMS Model Configuration

1.3 Objective

The objectives of this project are :

(i) to develop a rainfall-runoff model for the upper part of Sungai Sarawak Kanan basin which is located in Sungai Sarawak basin by using HEC-HMS model.

(ii) by using model calibration, model parameter values are adjusted until model results match historical data.

(iii) to predict the peak flow for the upper part of Sungai Sarawak Kanan basin by using the Snyder's Synthetic Unit Hydrograph method and model parameters, then compare the peak flow developed to the observed hydrograph.

CHAPTER 2

LITERATURE REVIEW

2.0 General

This chapter discuss briefly about watershed modeling using HEC-HMS.

2.1.1 Watershed

According to McCuen (1989), since big watersheds are made up of many smaller watersheds, it is necessary to define the watershed in terms of a point ; this point is usuallythe location at which the design is being made and is referred to as the watershed "outlet". With respect to the outlet, the watershed consists of all land area that sheds water to the outlet during rainstorm. Using the concept that "water runs downhill", a watershed is defined by all points enclosed within an area from which rain falling at these points will contribute water to the outlet. This is best shown pictorially, as in Figure 2.1. The shaded area of Figure 2.1 represents the watershed for the outlet at point A.

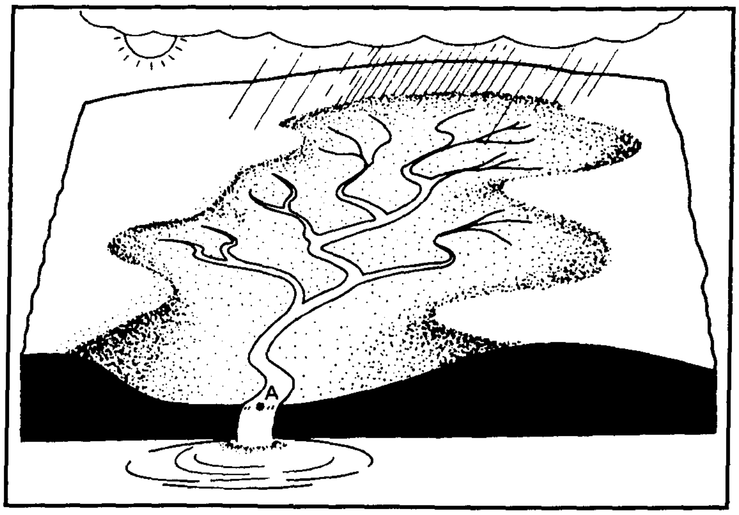

Figure 2.1 Delineation Of Watershed Boundary

2.1.1.1 Basin Characteristics

According to Patra (2001), the features of basin characteristics that can affect runoff from a storm are :

(i) Size

Total runoff from a catchment expressed in depth is independent of the area. Therefore, total volume of precipitation available at a river section is directly proportional to the catchment area and the peak flow can be approximated to the square root of drainage area.

(ii) Shape

The shape of the catchment affects the runoff peak in the following way. An elongated catchment has lesser peak than a fan-shaped catchment of same area (Figure 2.2) and has long runoff durations than a fan-shaped catchment

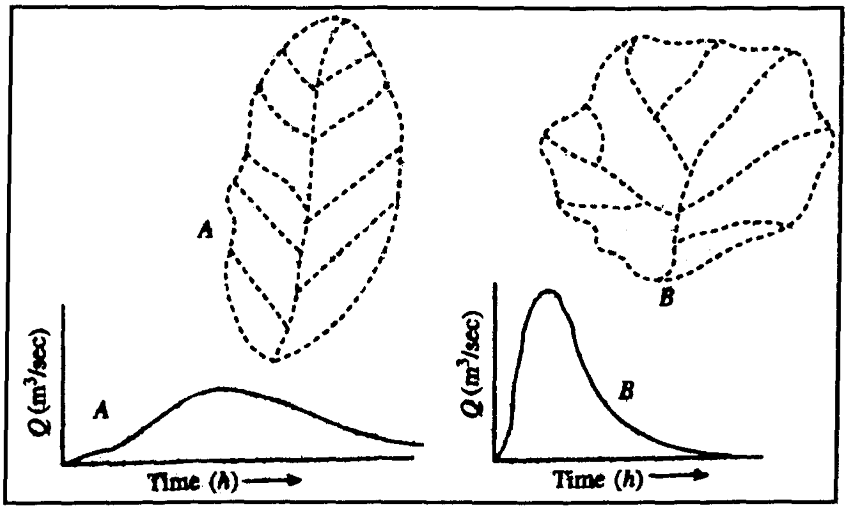

Figure 2.2 Effect Of Catchment Shape On Runoff

(iii) Slope

A catchment having extensive flat area gives rise to low peaks and less runoff whereas a catchment with a steep slope produces high peak flood. Rate of infiltration from a flat catchment is more which affects the velocity of overland flow. Therefore, the time of arrival of peak at the outlet is late and so is the total time period of runoff for such flat shaped catchment.

(vi) Drainage Density

Drainage density, defined as the ratio of total length of all streams of the catchment divided by its area, indicates the drainage efficiency of the basin. The higher the value, the quicker is the runoff and the lesser is the infiltration and other losses. Thus, drainage density :

$$D_d = L_s/A \qquad (2.1)$$

where L_s is the total length (m) of all streams in a basin and A the drainage area in sq.km.

(v) Basin Geology

Basin geology is responsible for the rate of infiltration during a storm. If good aquifer material forms the basin then surface runoff will be less due to increased infiltration, but for a basin composed of impervious materials the runoff will be highly peaked. Presence of faults, fissures and cracks in geological formations results in diversion of storm water to a new location where they terminate.

2.1.2 Rainfall

Rainfall is the liquid form of precipitation; snowfall and hail are the solid forms. In common usage, the word rainfall is often used to refer to precipitation. The essential requirements for precipitation to occur are : (i) moisture in the atmosphere, (ii) presence of nuclei around which condensation of vapour takes place, (iii) dynamic cooling responsible for condensation of water vapour and (iv) precipitation product much reach the ground in some form.

2.1.2.1 Thiessen Polygon Method

Bedient and Huber (2002), stated that predicting watershed response to a given precipitation event often requires knowledge of the average rainfall that occurs over a watershed area in a specified duration. Three basic methods exist to derive areally averaged value from point rainfall data: arithmetic mean, the Thiessen polygon method and the isohyetal method.

2.1.3 Losses From Rainfall

Generally, the catchment has an abstractive capability that acts to reduce total rainfall into effective rainfall. The difference between total rainfall and effective rainfall is the losses or hydrologic abstractions. The hydrologic abstractive capability is a characteristic of the catchment varying with its level of stored moisture. Hydrologic abstractions include interception, infiltration, surface storage.

2.1.3.1 Constant Loss Rate Using ϕ Index

The Φ index is the simplest infiltration method and is calculated by finding the loss difference between gross precipitation and observed surface runoff measured as a hydrograph. The Φ index method assumes that the loss is uniformly distributed across the rainfall pattern.