Ain Shams University
Faculty of Engineering
Irrigation & Hydraulics Department

A Multi-Component Rainfall/Runoff Model for Engineering Applications

A Thesis Submitted for the Partial Fulfillment of the
Master Degree
Civil Engineering - Irrigation & Hydraulics [2018]

By
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2018

بسم الله الرحمن الرحيم

(وَقُلْ رَبِّ زِدْنِي عِلْماً)

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STATEMENT

This thesis is submitted to the Irrigation and Hydraulics Department, Faculty of Engineering, Ain Shams University in the partial fulfillment of the requirements for the Degree of Master in Civil Engineering.

The work in this thesis was carried out in the Irrigation and Hydraulics Department, Faculty of Engineering, Ain Shams University from 2012 to 2018.

No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

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ABSTRACT

The Rainfall/Runoff transformation process is the response of any given watershed in transforming a rainfall event into the corresponding flow hydrograph. This process can be estimated through rainfall and discharge measurements or be simulated through Rainfall/Runoff (Hydrologic) modeling. Generally, as gauged watersheds are not available (especially in arid and semi-arid regions); Hydrologic modeling is the most commonly used approach to simulate the process of rainfall/runoff transformation.

Hydrologic models vary in their degrees of complexity and accuracy. The available hydrologic models can be divided into three major types: Lumped models, Distributed models, and Semi-Distributed models. Lumped models are simple to apply but cannot determine flow hydrographs. On the other hand, distributed models are very complex models that provide high accuracy but still distributed models can not satisfy engineering applications due to the unacceptable runtime taken by some of these models. The semi-distributed models are the most widely used for engineering applications as they are much more accurate than lumped models and at the same time less complex than distributed models. The semi-distributed models are mainly divided into two sub-groups: (1) Network Techniques (e.g., HEC-HMS flood hydrograph package), and (2) Time-Area (TA) techniques. The idea of this research is to blend the powers of the two worlds to develop an accurate and practical model suitable for engineering applications.

In this research, historical and previous studies and researches in the same field are discussed and rainfall-runoff observed data were collected for some of the available gauged watersheds in order to be used in the verification of the results of this research.

The work methodology includes the development of an automated hydrological model using GIS capabilities to analyze terrain raster data and apply hydrologic and hydraulic basics to produce a spatially distributed unit hydrograph for each watershed, in addition to estimating some hydrological parameters for these watersheds (i.e., area, time of concentration & weighted CN values).

The results of the developed model were verified using the collected rainfall-runoff observed data, and then the model is applied to several case studies to show the comparison between the results of the developed model and the results of other practically applied hydrologic models in engineering applications.

The main conclusion from this research is that spatially distributed unit hydrographs are more recommended to be used in hydrologic processes (simulations) as the watershed actual response is better simulated using this technique than the lumped unit hydrographs in the sense of consideration of spatial variation in travel times within the same watershed which affects the resultant shape of the runoff hydrograph and peak discharge value as well.

Keywords: Rainfall\Runoff, Hydrology, Modeling, GIS, Gridded Runoff Hydrograph

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List of Abbreviations

HEC Hydrologic Engineering Center

HMS Hydrologic Modeling System

TA Time Area

SCS Soil Conservation Service

NRCS Natural Resources Conservation Service

CN Curve Number

GIS Geographic Information System

SDUH Spatially Distributed Unit Hydrograph

S.D. Spatially Distributed

T_t Travel time

L or LFP Longest flow path, the distance between the hydraulically most distant point to the outlet

V Average velocity of the water drop between the two points

T_c Time of concentration

S Slope of the longest flow path

Y Average watershed slope

R_i Hydraulic radius at point of interest

A_{i-us} Accumulated area upstream the point of interest

P_{i-e-us} Average excess rainfall depth upstream the point of interest

S_{i-us} Average slope of the watershed upstream the point of interest

V_i Average flow velocity

n_i Average manning's roughness coefficient

S_i Longitudinal slope

T_t Lag time