EFFECT OF IMPERVIOUS SURFACE ON PEAK DISCHARGE AND RUNOFF VOLUME

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2020

DEDICATION

This project report is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time. My beloved wife and children for strength, moral support and to all my family for willingness guide me to complete this thesis.

ACKNOWLEDGEMENT

In preparing this project report, 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 master project supervisor, Dr. Noraliani binti Alias, for encouragement, guidance, critics and friendship. I am also very thankful to my panel Dr. Shamila binti Azman and Dr. Mohamad Hidayat bin Jamal for their guidance, advices and motivation. Without their continued support and interest, this project report would not have been the same as presented here.

I am also indebted to Dr. Lim Foo Huat, Mr. Marcus Yang Hai Hwee and Ms. Nurul Hidayah binti Ruslan from Angkasa Consulting Services Sdn. Bhd for sharing information and guidance for successful of the hydrological model of this study. I am also wish thanks to all personnel from Department of Irrigation and Drainage Malaysia especially Ir. Roslina binti Yusop, Mr. Roslan bin Sukimin, Mr. Mohammad Hafiz bin Kamaluddin, Mr. Abu Salim bin Abd Aziz and Mr. Mohd Syhrizan bin Mat Ghani for providing the hydrological data regarding with this project report. I also would like to thanks the Public Service Department of Malaysia for their financial support.

My fellow postgraduate student should also be recognised 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 member mostly my wife, Nuraida binti Sanin and children, Harith Eimran, Hezrey Eizlan, Lily and Hanash Eilhami for their support and encouragement.

ABSTRACT

Urbanization processes increase the area of impervious surface in a catchment due to alteration of pervious surface. As a result, the urbanization processes will affect the rainfall-runoff process as higher surface runoff volume will be generated. Therefore, this study was carried in order to determine peak discharge and runoff volume for Golok River Basin. In this study HEC-HMS hydrological engineering modelling was used to simulate the rainfall-runoff process of Golok River basin. In order to compute peak discharge and runoff volume, the initial and constant rate, Snyder's Synthetic unit hydrograph, constant monthly base flow and Muskingum routing were chosen. The model parameters were calibrated using 1981 historical major events observed streamflow data. Calibrated model parameters was validated by using 1982 historical major events observed streamflow data. A statistical test for hydrological model efficiency, Nash and Sutcliffe (NSE) was employed to check the efficiency of calibration and validation process. The results found that values of NSE of 0.681 and 0.643 for calibration and validation respectively. The model calibration was found to be good and meanwhile it was satisfactory for validation. Calibrated and validate parameters then were used to determine the peak discharge and runoff volume for 5, 10, 50 and 100 years Average Recurrence Interval (ARI) for different percentage of impervious surface. The simulation results were then compared to the 2003 peak discharge and runoff volume. The result of this study proved that peak discharge and runoff volume of Golok River basin were increased as the impervious surface increased.

ABSTRAK

Proses pembandaran meningkatkan kawasan permukaan telap dalam satu kawasan tadahan disebabkan oleh perubahan peningkatan pada permukaan tak tedap. Oleh yang demikian, proses pembandaran menyebabkan proses air larian terjejas hasil daripada isipadu air larian permukaan yang tinggi. Lantaran itu, kajian ini dijalankan bagi menentukan puncak luahan dan isipadu air larian untuk kawasan tadahan Sungai Golok. Dalam kajian ini model kejuruteraan HEC-HMS telah digunakan bagi menjalankan proses simulasi hubungan antara hujan dan air larian di kawasan tadahan Sungai Golok. Bagi mengira puncak luahan dan isipadu air larian, kaedah awalan dan kadar malar, unit hidrograf sintetik Snyder, aliran dasar malar bulanan dan kaedah Muskingum *routing* telah dipilih. Parameter model telah dikalibrasi menggunakan data cerapan luahan tahun 1981. Parameter yang telah dikalibrasi kemudiannya melalui proses validasi menggunakan data cerapan luahan tahun 1982. Ujian statistik Nash-Sutcliffe (NSE) telah digunakan bagi menilai kecekapan model terhadap proses kalibrasi dan validasi. Hasil ujian statistik NSE menunjukkan nilai 0.681 bagi proses kalibrasi dan 0.643 bagi proses validasi. Proses kalibrasi model didapati baik dam proses validasi adalah memuaskan. Parameter model yang telah melalui proses kalibrasi dan validasi digunakan untuk menentukan puncak luahan dan isipadu air larian bagi *Average Recurrence Interval* (ARI) 5, 10, 50 dan 100 untuk permukaan kedap yang berbeza. Hasil simulasi model dibandingkan dengan hasil simulasi puncak luahan dan isipadu air larian bagi tahun 2003. Hasil kajian ini membuktikan puncak luahan dan isipadu air larian meningkat apabila permukaan telap bertambah.

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LIST OF ABBREVIATIONS

ADAB	-	Australian Development Assistant Bureau
ARI	-	Average Recurrence Interval
DID	-	Department of Irrigation and Drainage
HEC-DSS	-	Hydrological Engineering Centre-Data Storage System
HEC-HMS	-	Hydrological Engineering Centre-Hydrological Modeling System
HEC-RAS	-	Hydrological Engineering Centre-River Analysis System
hr	-	hour
IDW	-	Inverse Distance Weighted
JUPEM	-	Jabatan Ukur dan Pemetaan Malaysia
KESBAN	-	Keselamatan dan Pembangunan
km	-	kilometer
km^2		square kilometre
m		meter
mm		millimetre
m^3		cubic meter
m^3/s		cubic meter per second
NSE		Nash and Sutcliffe Efficiency
SCS		Soil Conservation Services
USACE		United States Army of Civil Engineer
USGS		United States of Geological Survey

LIST OF SYMBOLS

∞	-	Infinity
E	-	Nash-Sutcliffe efficiency
R^2	-	Coefficient of determination
d	-	Index of agreement
O	-	Observed values
P	-	Predicted values

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CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia is known as a tropical country that has an equatorial climate with a constant high temperature and high relative humidity. Department of Irrigation and Drainage Malaysia, DID (2012) reported that the annual average rainfall is 2,500 mm for Peninsular Malaysia, 2,560 mm for Sabah, and 3,640 mm for Sarawak. The east coast of Peninsular Malaysia and the coastal regions of Sabah and Sarawak recorded the heaviest precipitation.

According to DID (2009), there are 189 river systems in Malaysia, which flow directly to the sea; 89 are located in Peninsular Malaysia, 78 in Sabah, and 22 in Sarawak. 85 of them are prone to frequent flooding. In general, all states in Malaysia experienced flooding in the year 2014, 2015, 2016, and 2017 (DID, 2018). In the year 2016 and 2017, Selangor experienced the most frequent flood with a total of 115 flood events, while Perlis was the least affected by only 2 cases.

Besides, DID (2018) also defines floods as frequent occurrences and common natural disasters that can cause property damage and even loss of life. Flooding can occur due to various factors such as heavy rainfall, high tide, obstruction in the drainage system, and shallow river problems. Also, rapid development and uncontrolled human activities can have a significant influence on urban flooding, at the same time, worsening the flood disaster.

1.2 Problem Statement

Kelantan is one of the states that frequently experiences floods particularly, during the Northeast Monsoon season from November to Mac. According to Aminah *et al*., (2016), Sungai Nenggiri, Sungai Galas, Sungai Pergau, Sungai Kelantan, Sungai Golok, Sungai Kemasin, Sungai Pengkalan Chepa, Sungai Pengkalan Datu, and Sungai Semerak are the flood-prone rivers in Kelantan. Golok River, for instance, experienced severe flooding in 2011 and 2012, in areas of Rantau Panjang (DID, 2013).

According to DID (2013), Rantau Panjang streamflow station recorded a 10m increase in water level as a result of heavy rainfall with high intensity, exceeding the flood danger level at 9.0m. In order to minimize property damage and loss of life caused by flooding at Golok River, a study on the hydrological characteristic of the river catchment need to be done. The hydrological models such as rainfall-runoff models can be carried out by using open sources software such as Hydrologic Engineering Centre-Hydrological Modeling System (HEC-HMS) developed by the United States of Army Corps of Engineers (USACE).

Therefore, this study is carried out, in order to investigate the impact of different percentages of impervious surface for different average recurrence interval (ARI).

1.3 Objective of Study

The main objectives of this study are listed as follows:

1. To develop a Golok River basin hydrological model using HEC-HMS.
2. To calibrate and validate the observed and simulation hydrograph from Golok River basin hydrological model.

3. To estimate peak discharge, runoff volume with different percentages of impervious surface with different years ARI.

1.4 Scope of Study

The main scope of this study is to estimate the peak discharge and runoff volume using HEC-HMS hydrological model for Golok River basin. This study also involved the calibration and validation process of the model to ensure it is reliable and accurate. The model then used to simulate various scenario of events using 5%, 10%, 20%, 30%, 40%, 50% and actual land-use impervious surface percentages with 5, 10, 50 and 100 years ARI.

Since the river basin is shared between Malaysia and Thailand, it is hard to get sufficient data from Thailand, particularly the catchment characteristics and hydraulic and hydrological data. As a result, the selected data for this study were obtained solely from the DID, Malaysia.

1.5 Significance of Study

The significance of this study is the application of open-source software for rainfall-runoff modelling of the selected river basin to predict the peak discharge and runoff volume for different events and scenarios. The results from this study can be utilized by DID Malaysia for flood forecasting. Flood forecasting system can be integrated with an early warning system for evacuation planning of residents in flood-affected areas.

This study can also be beneficial for local government in terms of planning and monitoring the land development and agriculture activities at the selected river basin. A proper plan and monitoring system will guarantee integrated and holistic management of the Golok River basin, which can ensure sufficient existing resources for future development along the Golok River basin.

1.6 Structure of Thesis

This study of rainfall-runoff modeling is categorized accordingly by chapters. It consists of five research structures from chapter one until chapter five.

1.6.1 Chapter One

The first chapter explained the outline of the study. This chapter gave a brief explanation of the study background, objectives of study, scope of study and the significant of the study.

1.6.2 Chapter Two

The second chapter explained how factual information has supported this study. It consists of the literature review and theoretical frameworks that have been done by others. This chapter also explained the viewpoints of other authors regarding the study area in general and presented their particular perspective in a logical manner.

1.6.3 Chapter Three

The third chapter discussed the methodology of this research work. It explained the study process and issued existing problems faced in the research philosophy. Moreover, this chapter contained the study frameworks and methods for the data collection.

1.6.4 Chapter Four

This chapter defined the results from the simulation modelling of this study and were presented in a graphical and data tabulation. The result of simulation was categorized in different percentages of impervious with different years of ARI.

The chapter also comprised of the discussion of the results and analysis. This chapter played a critical role by complying every objectives outlined in the beginning of this study.

1.6.5 Chapter Five

The last chapter concluded all the work and summarized the level of achievement based on the objectives of this study. The conclusion acknowledged the limitations of the study and proposed future studies according to limitation addressed.

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