PERPUSTAKAAN UMP
0000092339

STUDY OF RAINFALL – RUNOFF RELATIONSHIP FOR LANGAT RIVER WATERSHED BY USING HEC - HMS

MUHAMMAD HAFIZUDDIN BIN MD RASIB

Report submitted in fulfilment of the requirements
for the award of the degree of
Bachelor of Civil Engineering (Hons.)

Faculty Of Civil Engineering And Earth Resources
UNIVERSITI MALAYSIA PAHANG

JULY 2014

ABSTRACT

In this era, we always heard about a flood problems occurrence in Malaysia. Malaysia is a country that subjected to flood problems because it was surrounded by South China Sea. In Malaysia, there are some places that have serious flood problems which is a state near with South China Sea such as in Terengganu, Johor and Selangor. Langat River was located near with Selangor and it is connected to the South China Sea. The places near with Langat River always had a flood problem in every year. The thesis is conducted to stimulate the precipitation-runoff processes of dendritic watershed systems. The thesis also prepared validation and verification of HEC- HMS (hydrological model) to recorded data. After these two objectives of study were completed, the appropriate model for flood hydrograph prediction is produce. From the model, hopefully it will help to make a decision to prevent a flood problem. HEC-HMS is a tool to produce a number of hydrologic modeling inputs. It also can be used to recognize the rainfall- runoff relationship of Langat River in a certain period. From the rainfall data, a hydrograph of Langat River can be obtained by using analysis of relationship between rainfall and runoff. This hydrograph are used for studies of urban drainage and flow forecasting. So, it can be guidance to people along Langat River aware about flood problems and also can be flood control management in Langat River. By referring to Root Mean Square Error (RMSE), as the value is near to zero, it is considered as the best fit. The RMSE value obtained for **Figure 4.2**, **Figure 4.13**, **Figure 4.14** and **Figure 4.25** are 0.256 m^3/s, 0.346 m^3/s, 1.121 m^3/s and 0.319 m^3/s respectively. As for conclusion, SCS Unit Hydrograph method can be used for simulation in Langat River basin.

ABSTRAK

Dalam era ini, kita sentiasa mendengar mengenai kejadian masalah banjir di Malaysia. Malaysia adalah sebuah negara yang selalu terjadi masalah banjir kerana ia dikelilingi oleh Laut China Selatan. Di Malaysia, terdapat beberapa tempat yang mempunyai masalah banjir yang sangat serius seperti di Terengganu, Johor dan Selangor kerana terletak berhampiran dengan Laut China Selatan. Sungai Langat terletak berhampiran dengan Selangor dan ia disambungkan ke Laut China Selatan. Tempat-tempat yang berhampiran dengan Sungai Langat sentiasa mempunyai masalah banjir di setiap tahun. Kajian ini dijalankan untuk merangsang proses pemendakan-air larian sistem tadahan air . Kajian ini juga disediakan pengesahan HEC-HMS (model hidrologi) untuk data direkodkan. Selepas kedua-dua objektif kajian telah siap dibina, model yang sesuai untuk ramalan hidrograf banjir dapat dihasilkan. Dari model, mudah-mudahan ia akan dapat membantu untuk membuat keputusan bagi mengelakkan masalah banjir. HEC-HMS adalah alat untuk menghasilkan beberapa input pemodelan hidrologi. Ia juga boleh digunakan untuk mengenali hubungan hujan-air larian daripada Sungai Langat dalam tempoh masa yang tertentu. Daripada data hujan, hidrograf Sungai Langat boleh didapati dengan menggunakan analisis hubungan antara hujan dan air larian. Hidrograf ini digunakan untuk kajian saliran bandar dan ramalan aliran. Jadi, ia boleh menjadi panduan kepada orang yang tinggal di sepanjang Sungai Langat sedar tentang masalah banjir dan juga boleh menjadi pengurusan kawalan banjir di Sungai Langat. Dengan merujuk kepada Root Mean Square Error (RMSE) jika nilai ini dekat dengan sifar, ia dianggap sebagai yang terbaik. Nilai RMSE diperolehi untuk **Rajah 4.2**, **Rajah 4.13**, **Rajah 4.14** dan **Rajah 4.25** adalah 0.256 m^3/s, 0.346 m^3/s, 1.121 m^3/s dan 0.319 m^3/s . Untuk kesimpulan, kaedah SCS Unit Hidrograf boleh digunakan untuk menjalankan simulasi di lembangan Sungai Langat.

TABLE OF CONTENTS

		Page
SUPERVISOR'S DECLARATION		ii
STUDENT'S DECLARATION		iii
DEDICATION		iv
ACKNOWLEDGMENTS		v
ABSTRACT		vi
ABSTRAK		vii
TABLE OF CONTENTS		viii
LIST OF FIGURES		xi
LIST OF TABLES		xiv
LIST OF SYMBOLS		xv
LIST OF ABBREVIATIONS		xvi
CHAPTER 1	**INTRODUCTION**	
1.1	Background of Study	1
1.2	Problem Statement	3
1.3	Objectives of Study	4
1.4	Scopes of Study	4
1.5	Significance of Study	5
CHAPTER 2	**LITERATURE REVIEW**	
2.1	Introduction	6
2.2	Principle of Hydrology	6
2.2.1	Watershed	6
2.2.2	Land Use	8
2.2.3	Unit Hydrograph	8
2.2.3.1	Snyder's Synthetic Unit Hydrograph	9
2.2.3.2	SCS Method	10

	2.2.3.3	Clark Method	11
2.3	Rainfall – Runoff Model		13
2.4	HEC – HMS Software		15
	2.4.1	HEC – HMS Components	15
	2.4.2	Precipitation for Modeling with HEC - HMS	16
2.5	Root Mean Square Error (RMSE)		17

CHAPTER 3 RESEARCH METHODOLOGY

3.1	Introduction		19
3.2	Data Collection		21
	3.2.1	Rainfall Data	21
	3.2.2	Stream Flow Data	22
3.3	Application of HEC – HMS Software		22
3.4	Calibration, Validation and Verification Model		23
	3.4.1	Calibration Process	23
	3.4.2	Validation and Verification Process	23
3.5	Appropriate Model		24

CHAPTER 4 RESULT AND DISCUSSION

4.1	Introduction		25
4.2	HEC - HMS		25
4.3	Hydrograph		27
	4.3.1	Hydrograph for Station Sg Lui at Kg Lui (3118445)	27
	4.3.2	Hydrograph for Station Sg Langat at Kajang (2917401)	36
4.4	Evaluation of the Model through Root Mean Square Error (RMSE)		44

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1	Introduction	45
5.2	Conclusions	45

5.3 Recommendations 46

REFERENCES 47

APPENDICES 49

A Location of RF and SF Stations 49

B1 Data for RF 2917112 50

B2 Data for RF 3017108 51

B3 Data for RF 3118103 52

B4 Data for RF 3119001 53

B5 Data for RF 3119104 54

B6 Data for SF 2917401 55

B7 Data for SF 3118445 56

LIST OF FIGURES

Figure No.	Title	Page
1.1	Flood prone areas in Peninsular Malaysia	2
1.2	Flood prone areas in Sabah and Sarawak	3
1.3	Map of Langat River basin in Peninsular Malaysia	5
2.1	The hydrologic cycle	7
2.2	Rainfall-runoff process included in the event model structure	14
3.1	Flow chart diagram	20
3.2	Rainfall stations at Langat River Basin	21
3.3	Example of gauging stations	22
4.1	HEC – HMS layout model	26
4.2	Hydrograph for Sg Lui,Kg Lui discharge station in January 2013	27
4.3	Hydrograph for Sg Lui,Kg Lui discharge station in February 2013	28
4.4	Hydrograph for Sg Lui,Kg Lui discharge station in March 2013	29
4.5	Hydrograph for Sg Lui,Kg Lui discharge station in April 2013	29
4.6	Hydrograph for Sg Lui,Kg Lui discharge station in May 2013	30
4.7	Hydrograph for Sg Lui,Kg Lui discharge station in June 2013	31
4.8	Hydrograph for Sg Lui,Kg Lui discharge station in July 2013	31

4.9	Hydrograph for Sg Lui,Kg Lui discharge station in August 2013	32
4.10	Hydrograph for Sg Lui,Kg Lui discharge station in September 2013	33
4.11	Hydrograph for Sg Lui,Kg Lui discharge station in October 2013	33
4.12	Hydrograph for Sg Lui,Kg Lui discharge station in November 2013	34
4.13	Hydrograph for Sg Lui,Kg Lui discharge station in December 2013	35
4.14	Hydrograph for Sg Langat, Kajang discharge station in January 2013	36
4.15	Hydrograph for Sg Langat, Kajang discharge station in February 2013	37
4.16	Hydrograph for Sg Langat, Kajang discharge station in March 2013	37
4.17	Hydrograph for Sg Langat, Kajang discharge station in April 2013	38
4.18	Hydrograph for Sg Langat, Kajang discharge station in May 2013	39
4.19	Hydrograph for Sg Langat, Kajang discharge station in June 2013	39
4.20	Hydrograph for Sg Langat, Kajang discharge station in July 2013	40
4.21	Hydrograph for Sg Langat, Kajang discharge station in August 2013	41
4.22	Hydrograph for Sg Langat, Kajang discharge station in September 2013	41
4.23	Hydrograph for Sg Langat, Kajang discharge station in October 2013	42
4.24	Hydrograph for Sg Langat, Kajang discharge station in November 2013	43

4.25	Hydrograph for Sg Langat, Kajang discharge station in December 2013	43

LIST OF TABLES

Table No.	Title	Page
2.1	Summary of major land use types in Langat River basin	8
2.2	Runoff volume models	15
2.3	Direct runoff models	15
2.4	Base flow models	16
2.5	Routing models	16
2.6	Precipitation field monitoring options	17
3.1	Parameter used in the HEC-HMS	23
4.1	Rainfall stations	26
4.2	Stream flow stations	27

LIST OF SYMBOLS

Q	Discharge
Q_{obs}	Observed discharge
Q_{sim}	Simulated discharge
LU	Land use
CN	Curve number
T_R	Time of rise
B	Time of fall
D	Duration
Vol	Volume
%	Percentage

LIST OF ABBREVIATIONS

JPS	Jabatan Pengairan dan Saliran
DID	Department of Irrigation and Drainage
HEC-HMS	Hydrologic Modeling System
HEC-DSS	Data Storage System
RF	Rainfall Station
SF	Streamflow Station

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Malaysia flood disaster is a phenomenon that always happens almost every year. It often occurs due to the inability of existing drainage systems are unable to cope with the flow rate and volume of runoff water that exceeds the level of the outlet such as drains and rivers.

Increasingly rapid development is also a major cause of flooding. This is because the surface flow slowed down as a result of changes in land use (from impervious surfaces such as forest to impervious surfaces such as concrete, cement and asphalt) watercourses are blocked, decreasing the ability of the river through the deposition of silt and convective storm event great.

Floods cause a lot of damage to the property and threatening residents. In all areas, drains constructed to allow for rain runoff and waste water to prevent flooding. Unplanned development also causes flooding. However, in recent years, flooding is deeply disturbing. Ineffectiveness of irrigation and drainage system is the main cause contributing to flooding problems in our country.

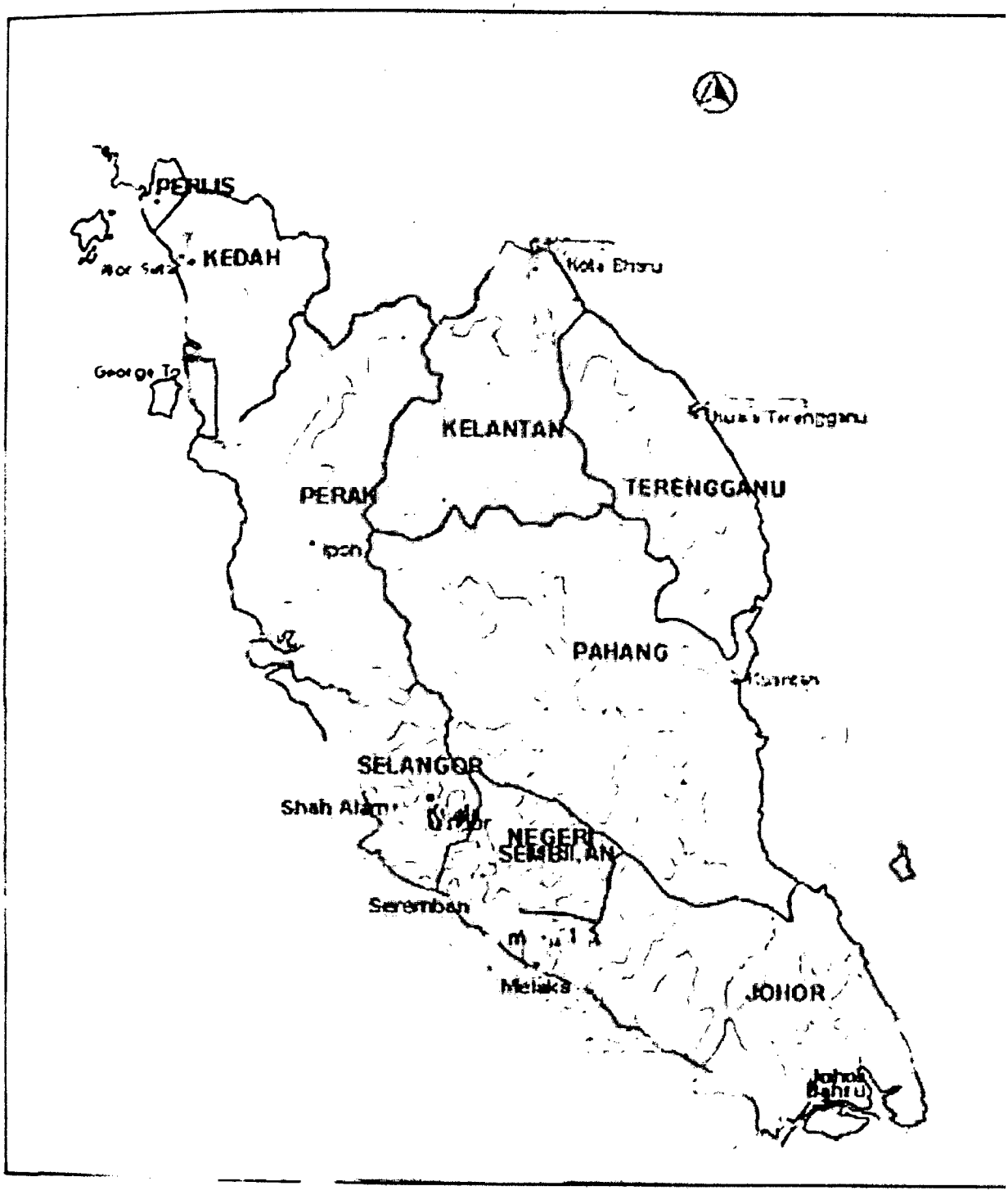

Figure 1.1: Flood prone areas in Peninsular Malaysia

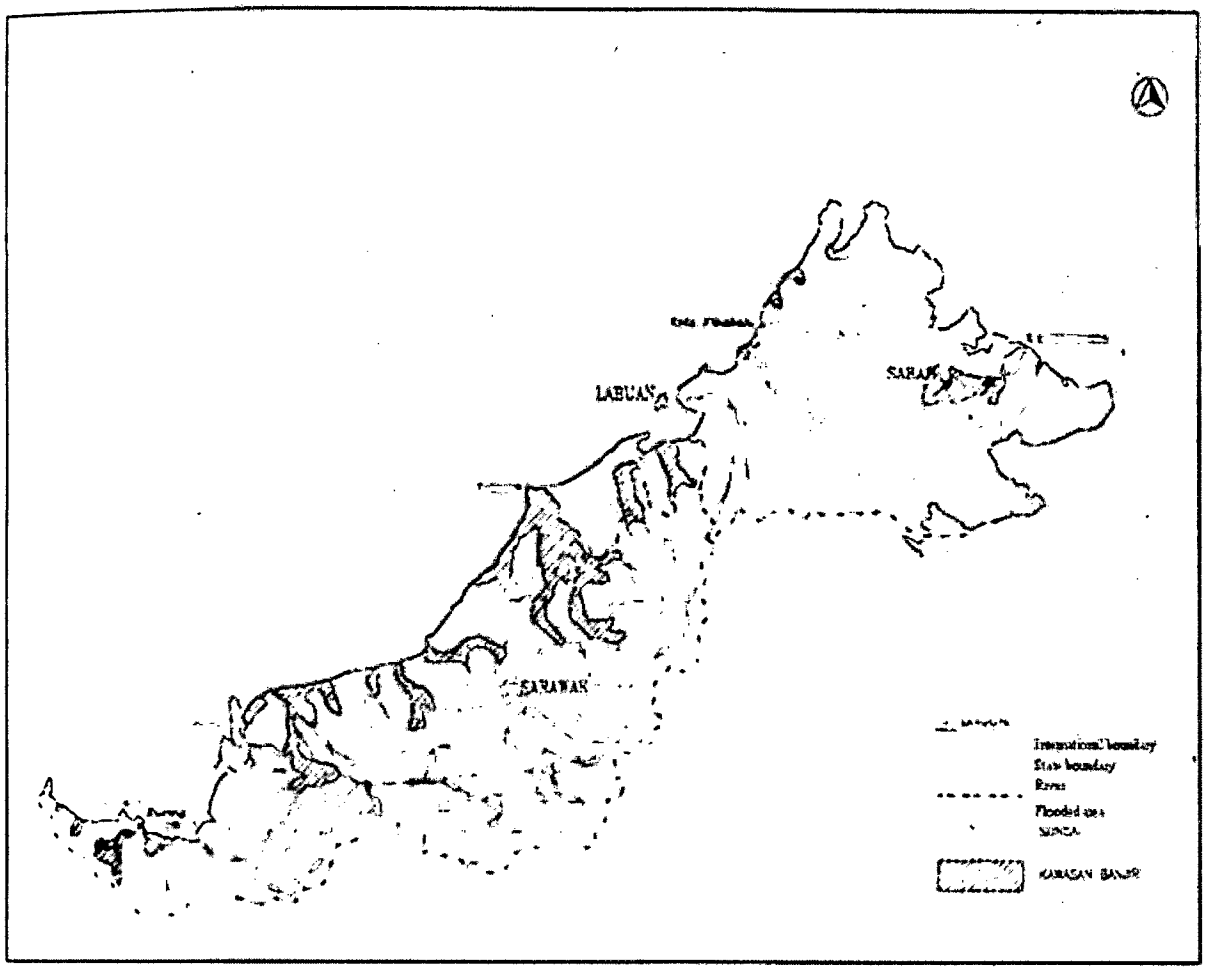

Figure 1.2: Flood prone areas in Sabah and Sarawak

1.2 PROBLEM STATEMENT

Flooding is the most significant natural hazard in Malaysia. Malaysia covers an area of 330,400 km^2 consists two regions that is the state of Sabah and Sarawak and Peninsular Malaysia. Malaysia has experienced major floods from the years 1960 to 2003. Malaysia also is a tropical country and which is subjected to flooding in both the urban and rural areas.

Flood modelling can help to reduce the impacts of flood hazard by taking extra precautions. The Langat River is located in the state of Selangor, Malaysia and it is subjected to regular flooding. Flooding is still the most significant natural hazard in Malaysia and the problem has escalated over the years as the country becomes more developed. The average annual flood damage cost is estimated to be RM100 million.

Therefore, prediction of flood levels for different frequencies will help to reduce flood damages and in checking the effectiveness of flood mitigation measures, namely the channel improvement as a solution for flood control.

1.3 OBJECTIVES OF STUDY

The objectives of this study are:

- To simulate the precipitation-runoff processes of dendritic watershed systems.
- To do validation and verification of HEC- HMS (hydrological model) to recorded data.
- To determine the appropriate model for flood hydrograph prediction.

1.4 SCOPES OF STUDY

The area of this study is conducted in Langat River because the frequently of flooding. In fact, the Langat River is one of the most important rivers in Malaysia. Many town having very large population like Kajang, Dengkil, Sepang and Cheras are located along the river bank.

The Langat River Basin occupies the south and south- eastern parts of the state of Selangor Darul Ehsan. Langat River has a total catchment area 1987.8 km^2, 78 km long and 20 km to 51.5 km wide. Pahang- Selangor borders as the source of Langat River due to its hilly terrain that reaching up to 1500 m above mean sea level.

In this study, the HEC-HMS is used to recognize the rainfall- runoff relationship of Langat River in a certain period. HEC- HMS also as a tool to produce a number of hydrologic modeling inputs. The hydrograph of Langat River can be obtained by using analysis of relationship between rainfall and runoff. Hydrographs produced by the program are used for studies of urban drainage and flow forecasting.

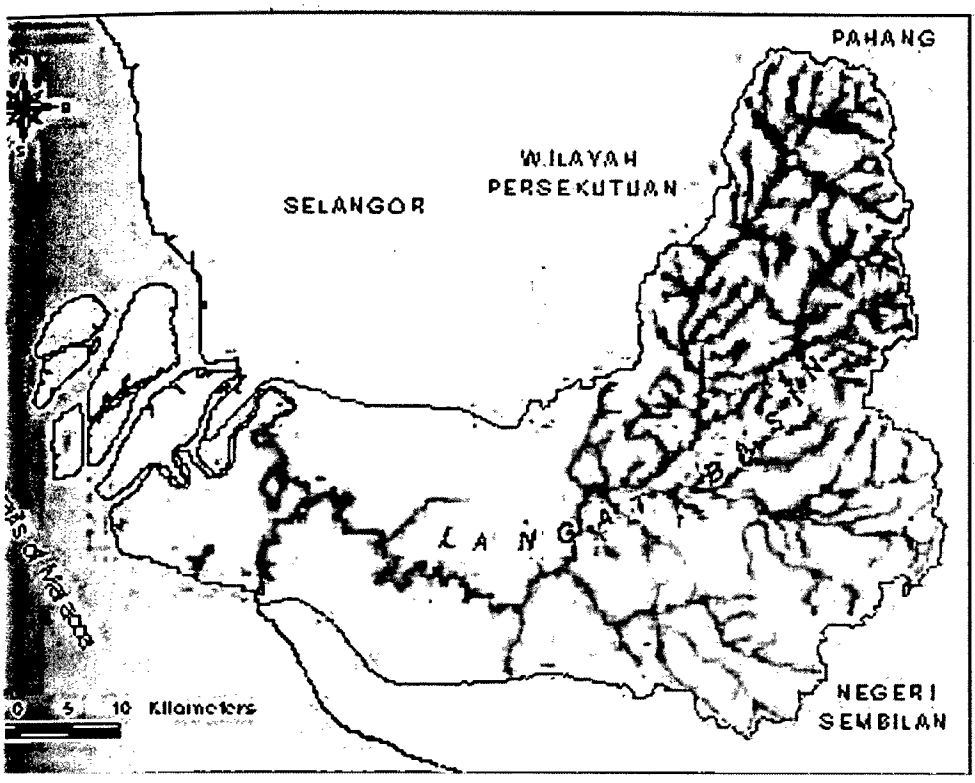

Figure 1.3: Map of Langat River basin in Peninsular Malaysia

1.5 SIGNIFICANCE OF STUDY

Nowadays, Malaysia often occur floods that causing much losses to all parties. Flooding is a phenomenon that happen suddenly has made a difficulty for all parties to be on the alert. In this research, HEC- HMS software can be used for the flood management. It can be done by predict the flood discharge. So, it can prevent many losses to the parties involved. Besides that, the rainfall- runoff model can be determined by using analysis between the rainfall and runoff that can produced a hydrograph. The produced hydrograph can be used for flow forecasting. It also can be used to evaluate the effects of land use-land cover changes, channel modifications and storage additions.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Water is one of the basic needs for human to survive. Nigel (2002) has claimed that people need water for drinking, washing and preparing meals every day, farmers need water to plant vegetation, development and industry need water as a raw material and for cooling agent, river are used as a transportation network and transferring waste to the sea.

Flood in Malaysia is a phenomenon that always happens in every year. According to Lim (1988), the factors that contribute to the flood is localised rainfall, inland flooding due to inadequate drainage, tidal and backwater effects and over spilling of bank due inadequate to river channel capacity. Based on the flood statistics of the National Water Resources Study carried out by the Japanese International Cooperation Agency (1982), it is estimated that 9 % of the total land area suffers from flooding affecting about 2.7 million people.

2.2 PRINCIPLE OF HYDROLOGY

2.2.1 Watershed

Based on study that had be done by New Jersey Department of Environmental Protection, a watershed is the area of land that drains into a body of water such as a river, lake, stream or bay. It is separated from other watersheds by high points in the area such as hills or slopes. It includes not only the waterway itself but also the entire

land area that drains to it. For example, the watershed of a lake would include not only the streams entering that lake but also the land area that drains into those streams and eventually the lake. Drainage basins generally refer to large watersheds that encompass the watersheds of many smaller rivers and streams.

With respect to watershed, the hydrologic cycle refers to the process beginning with the water falling to earth in either liquid or solid form. The captured water is either taken up by vegetation, retained in the soil, or percolates through the soil. The water may enter into springs, streams, rivers, lakes, groundwater reservoirs or the sea. It can return to the atmosphere by evaporating and start the cycle again

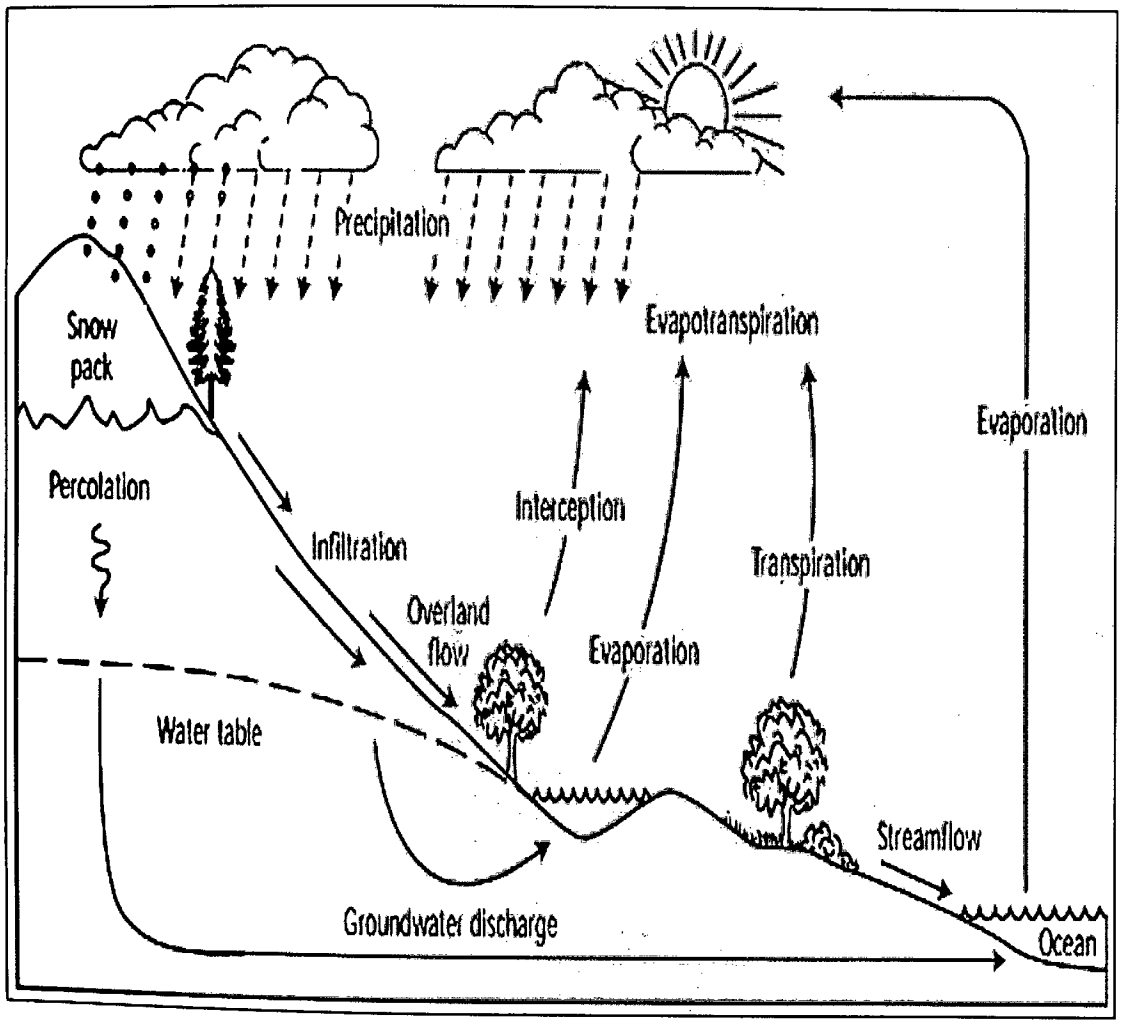

Figure 2.1: The hydrologic cycle

2.2.2 Land Use

According to Wong (2004), land use will change a watershed's response to precipitation. The most common effect is the reduction of infiltration especially on impervious surfaces, which significantly increase erosion, discharge and volume of storm runoff in a watershed. Then again, land development changes the pattern and distribution of runoff where natural flow paths in the watershed will be replaced or supplemented by paved gutters, storm sewers, or other elements of artificial drainage.

Table 2.1: Summary of major land use types in Langat River basin

Major Land Use Type	Area (km^2)	Percentage Of Land Use (%)
Agriculture	1335.57	55.13
Forest	467.80	19.31
Wetland and swamp	308.36	12.73
Urban and built – up areas	150.12	6.20
Mining	38.91	1.61
Others	121.79	5.02
TOTAL	2422.55	100

In general, agriculture and forest are the dominant types of land use in the Langat River Basin. The agriculture is the main land use type (55.13 %), followed by forest (19.31 %) and wetland (12.73 %). Urban and built- up areas only occupy 6.2 % of the land use. Mining (1.61 %) is a relatively minor land use type (Ekhwan et al.,2009).

2.2.3 Unit Hydrograph

A unit hydrograph is the direct runoff hydrograph produced by a storm of given duration such that the total volume of excess rainfall is 1mm. The ordinates of unit hydrograph indicate the direct runoff flow produced by the watershed for every millimetre of excess rainfall; therefore, the units are m3/sec/mm. The discrete convolution equation allows the calculation of direct runoff for a given excess rainfall, P_m

$$Q_n = \sum_{m=1}^{n \leq M} P_m U_{n=m+1} \quad (2.1)$$

where : n = the number of runoff steps

m = the number of excess rainfall steps.

2.2.3.1 Snyder's Synthetic Unit Hydrograph

The basin lag is:

$$t_p = C_t (L L_c)^{0.3} \quad (2.2)$$

Where : C_t = coefficient ranging from 1.8 to 2.2

L = length of the basin outlet to the basin divide

L_c = length along the main stream to a point nearest the basin centroid.

The peak discharge rate is:

$$Q_p = \frac{640 C_p A}{t^p} \quad (2.3)$$

where : 640 = 2.75 for metric system

C_p = storage coefficient ranging from 0.4 to 0.8 where larger values of C_p are associated with smaller values of C_t

A = the drainage area.

The base time is:

$$T_b = 3 + \frac{t_p}{8} \quad (2.4)$$

For a small watershed, the base time is determined by multiplying t_p by a value ranging from 3 to 5.

- The duration for above equations is:

$$D = t^p/5.5 \tag{2.5}$$

- For other rainfall excess duration, the adjusted basin lag is:

$$t_{p'} = t_p + 0.25(D' - D) \tag{2.6}$$

- . The width equations for 50% and 75% of Q_p are:

$$W_{50} = 770\left(\frac{Q_p}{A}\right)^{-1.08} ; W_{75} = 440\left(\frac{Q_p}{A}\right)^{-1.08} \tag{2.7}$$

where 770 and 440 should be replaced with 2.14 and 1.22 when the metric unit system is used.

2.2.3.2 SCS Method

The hydrograph is represented as a simple triangle with a rainfall duration D, time of rise TR, time of fall B, and peak flow. The volume of direct runoff is:

$$Vol = \frac{Q_p T_R}{2} + \frac{Q_p B}{2} \tag{2.8}$$

From the analysis of historical stream flow data, B = 1.67 TR. So the peak discharge can be expressed as:

$$Q_p = \frac{0.75\ Vol}{T_R} \tag{2.9}$$

The total runoff can be calculated by SCS curve number method.

$$Q(t)=\frac{(P(t)-I_a)^2}{(P(t)-I_a+S)} \quad (2.10)$$

where: $I_a = 0.8$ S. The potential maximum retention S is defined as:

$$S=\frac{1000}{CN}-10 \quad (2.11)$$

where : CN = curve number.

2.2.3.3 Clark Method

By considering the three fundamental equations used in the Muskingum routing method:

$$dS=(I-O)dt \quad (2.12)$$

$$Q=xI+(1-x)o \quad (2.13)$$

$$S=KQ \quad (2.14)$$

where : I = rate of inflow

O = rate of outflow

S = storage in reach or reservoir

Q = weighted flow in the reach, in cfs

x = Muskingum weighting coefficient

K = Muskingum storage coefficient

From these equations, it may be shown that:

$$K = \frac{dS}{dQ} = \frac{(I-O)dt}{xdI+(1-x)dO} \tag{2.15}$$

and

$$O=I-Kx\frac{dI}{dt}-K(1-x)\frac{dO}{dt} \tag{2.16}$$

Solving above equation via a finite difference formulation yields the familiar Muskingum formulation:

$$\frac{O_1+O_2}{2}=\frac{I_1+I_2}{2}-Kx\frac{I_2-I_1}{\Delta t}-K(1-x)\frac{O_2-O_1}{\Delta t} \tag{2.17}$$

Which may be reduce to:

$$O_2=C_0I_2+C_1I_1+C_2O_1 \tag{2.18}$$

where:

$$C_0=-\frac{Kx-0.5\Delta t}{K-Kx+0.5\Delta t} \tag{2.19}$$

$$C_1=-\frac{Kx-0.5\Delta t}{K-Kx+0.5\Delta t} \tag{2.20}$$

$$C_2=\frac{K-Kx-0.5\Delta t}{K-Kx+0.5\Delta t} \tag{2.21}$$

Algebraically C_0, C_1, C_2 sum to 1.0. It is interesting to note that when the inflow has ceased (I = 0.0), the equation reduces to:

$$O=-K\frac{dO}{dt}(1-x) \tag{2.22}$$