HYDROLOGICAL STUDY AND ESTIMATING FLOW RATE OF SUNGAI LEBIR, KUALA KRAI, KELANTAN

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ABSTRACT

Flood is a common natural disaster that exists in almost every part of the world. One of the most affected town in the year 2014 is Manek Urai. Manek Urai is a small town located about 25 kilometres from Kuala Krai town in Kelantan state. The downpour lasted over 48 hours with continues heavy rainfall during the monsoon period. In just a short time, Sungai Galas overflowed and submerged the old town of Gua Musang and the surrounding villages including Manek Urai through Sungai Lebir. The scenario became even worst from year to year. In this research, the catchment area of Sungai Lebir is selected. Thus, this study was carried out to estimate the flow rate of Sungai Lebir and analyse the rainfall data using seven selected hydrology stations in Sungai Lebir catchment. Flood is difficult to avoid. Hence, it is appropriate to carry out forecasting and take precaution in future. HEC-HMS was used in order to estimate the flow rate by analysing rainfall data which acquired from Department of Irrigation Drainage (DID). By creating the river model based on the actual data and satellite image, the true phenomenon of what is really happened can be understood.

ABSTRAK

Banjir merupakan bencana alam yang biasa yang wujud di hampir setiap bahagian dunia. Salah satu bandar yang paling terjejas pada tahun 2014 adalah Manek Urai. Manek Urai adalah sebuah bandar kecil yang terletak kira-kira 25 kilometer dari bandar Kuala Krai di negeri Kelantan. Pada musim tengkujuh yang lepas, hujan lebat berterusan selama lebih 48 jam telah menyebabkan kawasan sekeliling di tengelami air. Dalam masa yang singkat, air daripada Sungai Galas melimpah dan menenggelami bandar lama Gua Musang dan kampung-kampung sekitarnya termasuk Manek Urai melalui Sungai Lebir. Senario ini menjadi lebih teruk dari tahun ke tahun. Dalam kajian ini, kawasan tadahan Sungai Lebir dipilih. Kajian ini dijalankan untuk menganggar kadar aliran Sungai Lebir dan menganalisis data hujan menggunakan tujuh stesen hidrologi yang dipilih di kawasan tadahan Sungai Lebir. Banjir adalah sukar untuk dielakkan. Oleh itu, adalah wajar untuk menjalankan ramalan dan mengambil langkah berjaga-jaga pada masa depan. HEC-HMS telah digunakan untuk menganggarkan kadar aliran dengan menganalisis data hujan yang diperolehi daripada Jabatan Pengairan dan Saliran (JPS). Dengan mewujudkan model sungai berdasarkan data sebenar dan imej satelit, fenomena sebenar apa yang sebenarnya berlaku boleh difahami.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Flood is an overflow of a large amount of water beyond its normal limits. It is also can be refer to the inflow of the tide or the backflow of the river; which occurs at the location where the rivers meet. From a geological perspective, floods are natural consequences of stream flow in a continually changing environment. The streams receive most of their water input from precipitation and the amount that falling in drainage basin varies from day to day. Based on the role of precipitation, the amount and time which precipitation takes places is not constant for any given area. Overall, the water cycle is a balanced system and the reason for the flood to occur is a large amount of precipitation, causing the river/ basin to overflow due to not efficient cross section of the river itself. As the amount of water is increase, the stream must adjust its velocity and cross section in order to form a balance. The discharge increase as more water is added through rainfall, tributary streams, or from the groundwater seeping into the stream resulting in floods due to increase of width, depth and velocity of streams (Ismail DID, 2009).

1.2 PROBLEM STATEMENT

In terms of geography, the Kuala Krai city lies on the outskirts of Sg.Kelantan and only a few kilometers downstream from the confluence of Sungai Nenggiri and Sungai Lebir as mentioned in the early history of Kelantan. The population of Kuala Krai territory was 117,800. For the past few years Kuala Krai has faced with flood.

The territory contains the confluence of two major rivers, the Lebir and Galas, to form the Kelantan River. One of the most affected town in the year 2014 is Manek Urai. Manek Urai is a small town in Kelantan state. The town is located about 25 kilometers from Kuala Krai town.

The downpour in Ulu Kelantan, which covers Gua Musang and Kuala Krai, lasted over 48 hours. It brought to life the fears of the residents of Gua Musang that was inundated on 22 Dec 2014.In just a short time, Sungai Galas overflowed and submerged the old town of Gua Musang and the surrounding villages including Manek Urai through Sungai Lebir. Figure 1.1 shows the Manek Urai area affected by flood. The water rose two to five meters, crippling the entire area. Although the people of Kelantan have annually endured devastating floods, 2014 was on an unprecedented scale.

According to the Sinar Harian 6 January 2015, the “mud flood” was from the hilly region of Ulu Kelantan, following the massive clearing of forest for oil palm plantations and vegetable farming. According to the source, it was the cause of the steep and sudden rise in water level, contributing to what was now dubbed as a ‘tsunami over land’.

Figure 1.1: Manek Urai Area Affected by flood 2014

Source: (http://www.bharian.com.my/node/25984)

1.3 OBJECTIVES

In order to make this study successful, two objectives have been determined. It works as a guide line so that the outcomes of this study can be easily achieved. The objectives are,

- To analyse hydrological data of Sungai Lebir for critical river sections.
- To estimate the flow rate of the water catchment area of Sungai Lebir using HEC-HMS.

1.4 SCOPE OF WORK

The scopes of study have been determined in order to ensure that literature study is focusing on certain fields only. The limitations of this study are listed below.

1. The study area is focused on Sungai Lebir catchment area because Manek Urai is one of its sub basin.

2. The method used is simulating the river using gathered data from local authorities. A river network was established using the Google satellite images data and the analysis were carried out using HEC-HMS. The simulating process was conducted to estimate the flow rate at out flow and compare with the stream flow data.

3. A calculation using the 50 years of design rainfall (50 years ARI) and the 100 years of design rainfall (100 years ARI) are compared. Calculation is done using Intensity Duration Frequency Curve and Intensity Duration Frequency Polynomial equation.

1.5 THE IMPORTANCE OF THE STUDY

River simulating is the best option to study the behaviours of flood and what are the influenced factors. By creating the river model based on the actual data and satellite image, the true phenomenon of what is really happened can be understood.

The limitation of human activities along the flood plain area could be established after a river simulating was conducted. Through this study, the effect of rainfall to the flood occurrences and behaviours could be determined. Thus, for the future, the appropriate early solution could be implemented for a certain types of rainfall. This increase the public awareness of the next flood event by predicting based on the rainfall behaviours.

CHAPTER 2

LITERATURE REVIEWS

2.1 INTRODUCTION

Malaysia is an equatorial climate country with having wet and dry seasons every year. There are two types of wet seasons occurs in the peninsular Malaysia; Southwest Monsoon that affect west coast of peninsular Malaysia and Northeast monsoon that affected east coast of peninsular Malaysia (also known as "musim tengkujuh"). In Malaysia, river play an important role since its usage approaching 98% compare to ground water, 2% in daily activities (Ismail, 2009). The heavy seasonal rains and strong winds have affected most parts of Malaysia since mid-December 2014 and continue until early January 2015.

The rains caused severe flooding in the East Coast area including Terengganu, Pahang, and Kelantan states. Kelantan experiences floods due to the heavy rain falls which highest recorded at 507mm as reported in The Sun Daily, 9 January 2015. More than 160,000 people have been evacuated since the onset of the flooding and at least 10 people were confirmed dead.

Reports state that roads in the flood affected states have been inundated, especially in Kelantan, where 16 roads in six districts have been closed due to the rising water levels from three main rivers which are Sungai Lebir, Sungai Kelantan and Sungai Golok. Electricity supply was suspended and water sources were affected. The majority of houses and buildings were submerged by the flood waters in the three states (Malaysian Red Crescent Society, 2014).

2.2 WATER CYCLE

Theoretically, flood is caused by an excess amount of rainfall in a long direction. The ideal percentage of a water cycle balance in order to balance the ecosystem to avoid flood is clearly highlighted and as long as Malaysia is on the line, the flood can be avoided. However, there are several factors that causing the water balance system is disturbed. Since Malaysia received a few numbers of rainfalls annually, the water source condition is usually affected by weather conditions and natural water cycle (Strathler et. al, 1997). The water in the earth surface is evaporated to the atmosphere as a vapour and the group of water vapour in the atmosphere produced clouds which finally condensed and precipitate to the earth as rainfall. This process is known as precipitation (Syukri, 2009).

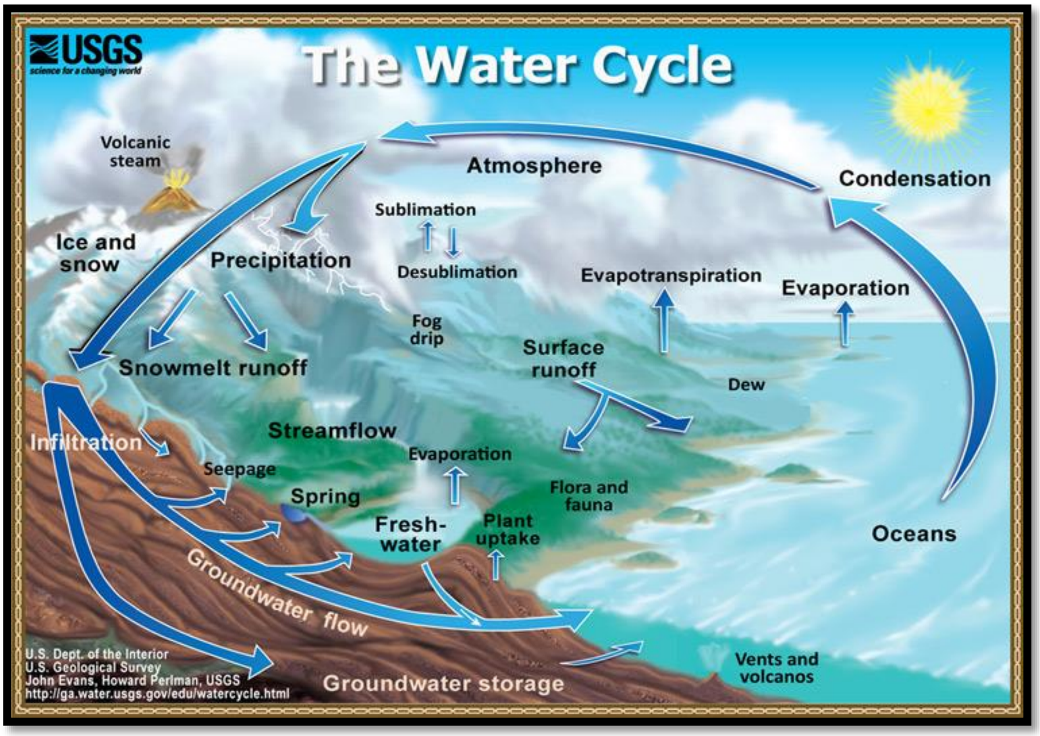

Figure 2.1: The water cycle

Source: (Strathler, 1997)

2.3 FACTORS AFFECTING FLOOD

Floods are natural consequences of stream flow in a continually changing environment. The streams receive water from precipitation and the amount of rainfall varies from day to day. The amount and time which precipitation takes places is not constant for any given area. In Malaysia, river is known as a number one water resource. In fact, there are several town and residential area widely developed in the flood plain area which is known as a hazardous area because of its potential to be flood by water.

2.3.1 Precipitation

Several factors have been listed down for affecting flood. The main factor that caused flood is precipitation. For a short duration of rainfall in a small watershed, flood also can be occurred. The danger accompanying is a high-water velocity which can results in extremely large flood. From the rainfall (precipitation) results, the runoff can be identified using available evaporation data as a catalyzer (Walter and Francis, 2005). When the stream flow for a catchment is combined with the precipitation, flood event will occur. The evapotranspiration and evaporation has little influence of water balance at daily time scale compare to rainfall (L.Siriwardena et.al, 2005).

2.3.2 Urbanization

Urbanization also listed as one of the factors that affecting flood. Theoretically, the percentage rate of runoff increase due to urbanization because of the rate of infiltration is limited when certain section is covered with concrete. CN, also called as a curve number, is a percentage of constant runoff coefficients (value from 0 – 100%). The more CN value means the more urbanization in that area and the less number of infiltration which results in increasing surface runoff. The CN value also provides an indication of the watershed’s water retention capacity (Gaume et.al, 2003).

2.3.3 River Cross Section

Others factor that affect the flood is river cross section. The value of discharge is varying with channel width, depth and gradient. Flows get deeper and faster as a discharge increase. In the other words, the flood power is depended on the river section. During heavy rainfall, the stage and discharge increase and the depth of flow are assumed to be negligible since the width-depth ratio is too small. The rates of change in mean depth and velocity are greater than change in width Thus, the increase in discharge is directly proportional to the depth which influences the river to flow in high velocity and causing overflow or in the other words, flood. The fact is, the river is more effective with depth compare to the width (Vishwas et. al, 2002).

2.4 RIVER CATCHMENT

The river catchment, or drainage basin as all the land from the mountain to seashore, drained by a single river and its tributaries. Catchment areas vary greatly in size. A big river may have a catchment area of several thousand square kilometers, whereas a smaller tributary will have a catchment area of only a few hectares (L.Siriwardena et. al, 2005).

2.5 CATCHMENT FACTORS

The catchment is the most significant factor determining the amount or like hood of flooding. Catchment factors are;

- Topography shape
- Size
- Soil type
- Land use

Catchment topography and shape can be determined as the time taken for rain to reach the river. Catchment size, soil type and development determine the amount of water to reach river (Vishwas et. al, 2002).

2.5.1 Topographical Shape

A topographical map is one that shows the physical features of the land. Besides just showing landforms such as mountains and rivers, the map also shows the elevation changes of the land. Elevation is shown using contour lines. When a contour line is drawn on a map it represents a given elevation. Every point on the map touching the line should be the same elevation. Topography determines the speed which the runoff will reach a river clearly, clearly rain that falls in the steep mountainous area will reach the river faster than flat or gently sloping areas (Vishwas et. al, 2002).

2.5.2 Shape

Shape will contribute to the speed with the runoff reaches a river. A long thin catchment will take longer to drain than a circular catchment (Vishwas et. al, 2002).

2.5.3 Size

Size will help determine the amount of water reaching the river, as the larger the catchment the greater the potential for flooding (Vishwas et. al, 2002).

2.5.4 Soil Type

Soil type will help to determine how much water reaches the river. Certain soil types such as sandy soils are very free draining and rainfall on sandy soil is likely to be absorbed by the ground. However, soils containing clay can be almost impermeable and therefore rainfall on clay soils will run off and contribute to flood volumes (Vishwas et. al, 2002).

2.5.5 Land Used

Land use will contribute to the volume of water reaching the river, in a similar way to clay soils. Rainfall on roofs, pavement and roads will be collected by rivers with no absorption into groundwater (Vishwas et. al, 2002 and L.Siriwardena et. al, 2005).

2.6 RIVER MODELLING

River modelling is a method used to study the flow behavior in the river. This method is also used to predict the reaction of water flow in the construction of hydraulic structures in rivers or human activities whether it's changing the floodplain topography such ad road construction and land reclamation level. Two methods use are, physical modelling and mathematical modelling. Both methods have their own advantages and disadvantages depending on the desired accuracy, time and resources available. It is stated that the physical modelling of floodplain is considered to be unsuitable as the costs of these models is quite high. In this study only the mathematical modelling will be used which will be compared with observations in the field (Handmer, 2001).

2.7 MODELLING AND SIMULATION

Modelling and simulation is a process to form a picture of a real element in the study conducted through analysis of data and information into software used. Simulation is defined as the process of using the system and the existing software, through the process of designing a mathematical model or logical and implementation of computer-based testing of the model. It was implemented with the aim of to develop and expand the use of the real system. This model is particularly useful in analysis and hydraulic design. The computer model is used to enable processed information continuously to achieve a goal. Moreover model also provides a quantitative measure of information processing quality because it can carry out the analysis repeatedly with different variables even with the same set of constants in model.

CHAPTER 3

STUDY AREA

3.1 INTRODUCTION

Southeast Asia has long experienced a monsoon climate with dry and wet seasons. With mean annual rainfall precipitation locally in excess of 5,000mm, the very intense rainstorms in the steep mountains of Malaysia have caused frequent and devastating flash floods. In the valleys, floodwaters spread over very wide flood plains developed for agriculture, predominantly, rice paddies and oil palm. For centuries, residents of Malaysia have built houses on stilts to cope with frequent floods, and longhouses were built along the main rivers. Over the years, a large number of inhabitants have encroached into the flood plain; nowadays, many dwellings are built on the river banks. With cars and housing closer to the ground, flood control is subject to drastic changes. Urbanization also exacerbates flooding problems due to the increased runoff from impervious areas. As a result, the sediment transporting capacity of rivers also increases, thus causing major perturbations to river equilibrium (P. Y. Julien et. al, 2010).

In Malaysia, there are three large basins namely Kelantan River basin, Pahang River basin and Terengganu River basin. These three basins are under monsoon catchment which is affected by the heavy rainfall during Northeast monsoon. Northeast monsoon occurs in November to March while Southwest monsoon occur from May to September. The Kelantan River is known as the flood prone area in Malaysia. Heavy rainfalls increase the water inundation area and affected economic and agriculture sector. There are several factors contributing to flood such as unmanaged drainage system, unpredictable regional weather condition and unplanned development by human activities. Land use and climate change have significant impact on the hydrologic conditions and ecological process of watershed.

Kelantan River basin is one of the major basins in Malaysia. It is located at the North Eastern part of Peninsular Malaysia at latitudes 4° 40' to 6° 12' North and longitude 101° 20' to 102° 20' East .The maximum length and breadth of the catchment are 150km and 140km respectively. The river is about 248km long and drains an area of 13,100km^2, occupying more than 85% of the State of Kelantan. There are six sub-basins in Kelantan River basin namely Galas, Nenggiri, Pergau, Guillemard Bridge, Kuala Krai and Lebir. The entire basin contains large areas of tropical forested mountains, lowland forest and limestone hills. Currently, there are many activities involving land use changes from lowland forest to vegetation and urban area.

3.2 SUNGAI LEBIR

Sungai Lebir catchment area is located in the southern part of the state of Kelantan in the upper most north of Peninsular Malaysia with an approximately total catchment area of 2500km^2. The most significant impact mankind due to flooding recently was occurred at Manik Urai Lama. Report from the local people said that the water flow of Sungai Lebir is much stronger than other rivers but doesn’t prove scientifically. However it can be accepted by looking the damages of the houses and bridge along this river. In this research, the catchment area of Sungai Lebir is selected. Figure 3.1 shows the Lebir river catchment.

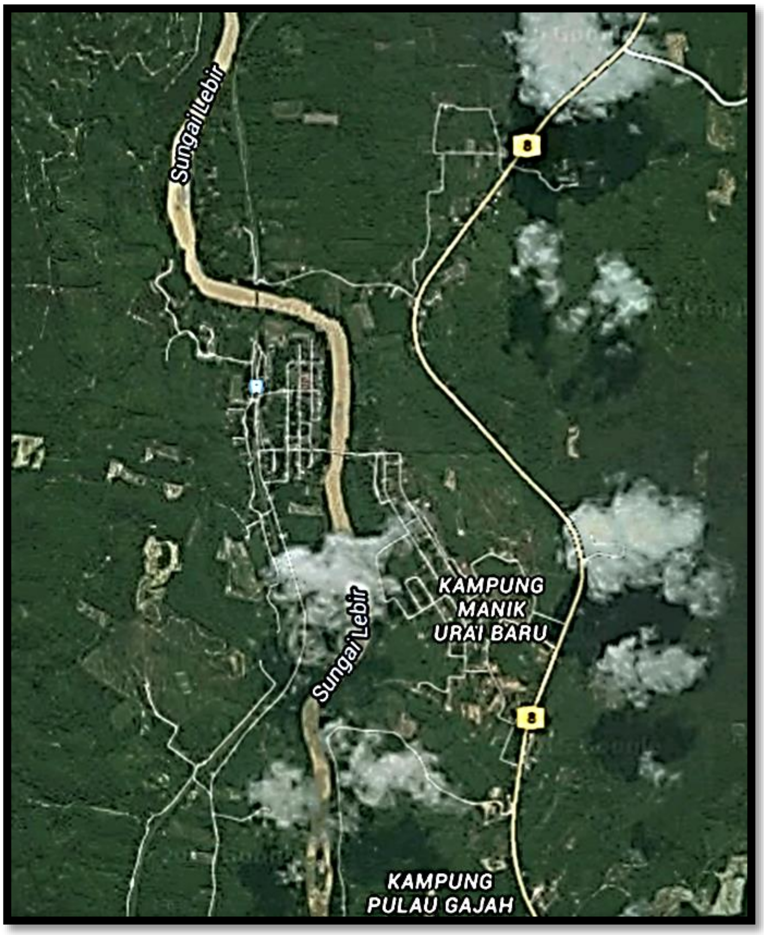

Figure 3.1: Lebir River Catchment and Study Reach for Modeling

Source: Google Map

Sungai Lebir is 91km length and there are 8 tributaries (Sungai Pahi, Sungai Sok, Sungai Rek, Sungai Sam, Sungai Terong, Sungai Miak, Sungai Lebir Kechil and Sungai Paloh) along the river which flow through Manik Urai up to Kuala Krai before ending near Kuala Koh.

3.3 HYDROLOGICAL STATION

In this selected study area, there are two types of hydrological stations data which are used to perform the data analysis. The station consists of rainfall station (RF) and streamflow station (SF).

3.3.1 Rainfall Station

Rainfall data from seven active hydrological stations as shown in table below is used to analyze the rainfall pattern for this study. The data was obtained from Department of Irrigation and Drainage (DID) Kelantan. Three selected active rainfall stations are located downstream of Sungai Lebir. Meanwhile, the other three rainfall stations are located at upstream of Sungai Lebir respectively. There are one rainfall station, Station Keretapi Manek Urai (5322045) which has been closed in October 1963.

Table 3.1: The selected rainfall stations along Sungai Lebir

Station Number	Station Name
5522047	JPS Kuala Krai
5422046	Ladang Lapan Kabu
5322044	Kampung Lalok
4922001	Kg Lebir, Paloh
4923001	Sg Aring
4721001	Upper Chiku
4726001	Gunung Gagau