DEVELOPMENT OF FLOOD HAZARD MAP FOR JOHOR RIVER BASIN

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ABSTRACT

Over many parts of the world, the large-scale atmospheric circulations and anomalies have been shown to have a significant impact on seasonal weather. Malaysia with seasonal monsoons of Southwest and Northeast Monsoons is located in the South East Asia. In December 2006 and January 2007, the Northeast Monsoon had brings heavy rain through series of continuous extreme storms that caused a devastating floods in the northern region of Peninsular Malaysia particularly to Kota Tinggi, Johor. The storms had occurred in two separate phases in late December 2006 and early January 2007 with a total precipitation in four days exceeding twice of the monthly rainfall in which some places recorded a higher number. The 2006 average rainfall return period is 50-years while the later gave more than 100-years return period. The disaster had caused more than 100,000 people evacuated from the residents due to rising flood water. The 2006 flood depth is recorded as 2.3 m and the 2007 flood depth is given as 2.75 m. Flood hazard maps allows quantification of what is at risk of being flooded, such as the number of houses or businesses. This helps to identify the scale of emergency and clean-up operations. The creation of flood hazard maps in give the information for the area prone to the flood should promote greater awareness of the risk of flooding. The objectives of this study are to develop a river model for Johor River by using InfoWorks RS for future prediction and simulation, and to produce the flood hazard map for Johor River Basin. The river modeling of Johor River has been done using InfoWorks RS software. 147 cross-sections have been used to model Johor River. The manning coefficient, n was used the method of trial and error then determined to be in range of 0.035 to 0.20. Results from the modeling indicated water surface profiles that showed river bank overflows along with some of the parameters such as flow, water level, and velocity for 50 and 100 ARI along Johor River. The flood hazard map had generated

using 1-D and 2-D modeling. 2-D modeling flood hazard map has obtained and the velocity variation and also the flow direction included in these flood hazard map. Combined or hybrid 1-D and 2-D modeling is now and the way forward in river and flood modeling. By using 1-D simulation to identify location of flooding and 2-D to investigate direction and depth of flood flows in specific areas.

ABSTRAK

Kebanyakan bahagian di atas muka bumi ini, pengedaran dan perubahan atmosferik telah memberi kesan yang penting pada cuaca bermusim.Malaysia dengan musim monsun barat daya dan timur laut terletak di dalam Asia Tenggara.Pada Disember 2006 dan Januari 2007, monsoon timur laut telah membawa hujan lebat melalui ribut selanjar yang keterlaluan menyebabkan banjir yang membinasakan di rantau Semenanjung Malaysia terutama di Kota Tinggi, Johor. Ribut telah berlaku dalam dua fasa berasingan iaitu pada penghujung Disember 2006 dan awal Januari 2007 dengan satu pemendakan keseluruhan dalam empat hari melebihi dua kali hujan bulanan di mana beberapa tempat mempunyai rekod hujan yang lebih besar. Pada tahun 2006 purata taburan hujan tahunan berkala ialah 50 tahun manakala ia akan memberi lebih daripada 100 tahun. Bencana telah menyebabkan lebih daripada 100,000 orang penduduk-penduduk dipindahkan disebabkan oleh air banjir meningkat. Pada tahun 2006 banjir kedalaman direkodkan sebagai 2.3 m dan 2007 kedalaman banjir diberi sebagai 2.75 m. Peta bahaya banjir akan membolehkan kuantifikasi bilangan rumah atau kawasan perniagaan yang mempunyai risiko banjir. Ini akan membantu mengenal pasti skala kecemasan dan operasi pembersihan. Penghasilan peta bahaya banjir harus menggalakkan kesedaran tentang risiko banjir dengan memberi maklumat kawasan yang berisiko banjir. Objektif bagi kajian ini adalah untuk membangunkan model sungai bagi Sungai Johor menggunakan InfoWorks RS untuk ramalan dan simulasi masa depan,melaksanakan analisa hidraulik Sungai Johor dan menghasilkan peta bahaya banjir bagi Sungai Johor. Permodelan hidrodinamik sungai di Kota Tinggi telah dibuat menggunakan perisian InfoWorks RS. 147 keratan rentas telah digunakan untuk pemodelan Sungai Johor. Pekali manning, n telah diselaraskan dengan kaedah cuba dan ubah dan ditentukan sebagai dalam lingkungan 0.035 dan 0.20. Keputusan daripada permodelan yang menunjukkan profil permukaan air dengan tebing sungai yang melimpah bersama-sama

dengan beberapa parameter seperti aliran, paras air, dan halaju untuk 50 dan 100 ARI di sepanjang Sungai Johor. Peta bahaya banjir telah dijana menggunakan permodelan 1-D dan 2-D. Penggabungan permodelan 1-D dan 2-D adalah carakini dan di masa hadapan bagi permodelan sungai dan banjir. Dengan menggunakan simulasi 1-D adalah untuk mengenal pasti lokasi banjir dan 2-D untuk menyiasat arah dan kedalaman aliran banjir di kawasan-kawasan tertentu.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	:	cross-sectional area (m^2)
CN	:	Curve Number
d	:	duration
D	:	flood depth (m)
DEM	:	Digital Elevation Model
DID	:	Department of Drainage and Irrigation
DOA	:	Department of Agriculture, Malaysia
DTM	:	Digital Terrain Maps
g	:	acceleration due to the gravity
GIS	:	Geographic Information System
HEC-GeoRAS	:	Hydrologic Engineering Centre-Geographic River Analysis System
HEC-HMS	:	Hydrologic Engineering Centre- Hydrologic Modeling System
HEC-RAS	:	Hydrologic Engineering Centre- River Analysis System
HP1 and HP11	:	Hydrological Procedure
i	:	rainfall intensity
IDF	:	Intensity-Duration-Frequency
IPCC	:	Intergovernmental Panel on Climate Change
NEXRAD	:	Next-Generation Radar
NRCS	:	Natural Resources Conservation Service
Q	:	flow rate (m^3/s)

SCS	:	Soil Conservation Service
S_f	:	friction slope
S_0	:	channel bed slope
T	:	return period
Tc	:	time of concentration
Tp	:	time to peak
Tuflow	:	Two-dimensional Unsteady FLOW
x	:	distance along the channel (m)
y	:	water depth (m)
1-D	:	1-Dimensional
2-D	:	2-Dimensional
η	:	manning roughness value

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CHAPTER 1: INTRODUCTION

1.1 Background

Floods will be the meaning of many things for many people due to their profession that they are dealing with. It will represents terror and unlimited suffering to the poorer village people who are caught in the swirling mud laden waters. It will means suffering in indirect ways to the urban people because of disruptions of communication due to breaching of embankments, roads, railways, culverts and other essential supplies (Qasim, Qasim, Shrestha, Khan, & Tun, 2016). Floods means additional expenditure for rescue, relief, rehabilitation measures and damages to national properties including losses of crops, domesticated animals and human lives for the government.

It will calls for a need to the planning commission and other planning bodies to provide rules and regulations whereby land prone to floods can be identified for proper utilization and to insurance people it represents a challenge of how to underwrite flood damages. Furthermore, in general it will represents a natural phenomenon on which millions of money are spent annually for providing protection against floods to all the citizens of a flood affected country. Flood risk management strategies attempt to prevent peak discharges from causing disasters by implementing a combination of measures that enables a region to cope with flood waves (Bruijin, 2005).

Floods impacts is all the effects a flood has on its environment starting from the moment the water inundates dry land until full recovery has occurred. There is a wide variety of positive and negative flood impacts, such as increased fertility of agricultural land, damage to houses and other buildings, loss of life, loss of jobs or income, disruption of the network of social contacts and interruption of normal access to education, health and food services. All these different flood impacts can be categorized based on whether the effect is positive or negative, the link with the flood, the location where damage occurs and the possibility to express the damage in monetary values (Parker, Green, & Thompson, 1987),(Green, Parker, & Tunstall, 2000).

However, the country of Malaysia its cover an area of 330400 sq. km comprising of two regions, namely Peninsular Malaysia and the States of Sabah and Sarawak. Situated just north of the equator, it experiences a tropical monsoon climate (Abdullah, Muhammad, Julien, Ariffin, & Shafie, 2016). The average annual rainfall is estimated at 2420 mm for Peninsular Malaysia, 2630 mm for Sabah and 3830 mm for Sarawak. The bulk of the surface water resources are derived from the South West Monsoon (from May to August) and the North East Monsoon (November to February).

The topography of Peninsular Malaysia is characterized by a central spine (with ground elevations of up to 2000 meters above mean sea level) which slopes steeply to the relatively flatter undulating coastal plains on the eastern and western sides. In the states of Sabah and Sarawak, a similar terrain exists but the higher grounds are found in the interior along a northeast-southwest direction, bordering the boundary with Indonesia. There are more than 150 river systems in the country (Liu & Chan, 2003). The river courses are relatively short with steep gradients in the upper stretches and comparatively flat and meandering stretches in the lower reaches. Flood flows are therefore transient in the upper reaches but increase in duration and intensity towards the coastal plains. The bulk of the population is concentrated in towns and villages situated in river valleys and coastal plains and hence are prone to flood damage.

Furthermore, flooding is perhaps the only significant natural hazard in Malaysia. Malaysia is fortunate that it is not affected by typhoon and earthquake. The severity of flooding is also considered mild when compared to other countries in the region.

Despite this, the problem has escalated over the years as the country becomes more developed. Since 1960, the country has experienced major floods in the years 1967, 1971, 1973, 1979, 1983, 1993 and 1995 (Gasim, Toriman, & Abdullahi, 2014). It has been estimated that some 29000 km^2 or 9% of the total land area are flood prone, affecting more than 2.7 million people or about 15% of the total population (Abidin & Unit, 2004). Figure 1.1 shows the flood prone areas in the country (Abidin & Unit, 2004). However, there is very little reliable data on flood loss or damage. The National Water Resources Study (1982) has estimated average annual flood damage at RM100 million for the year of 1982 price levels (Vincent & Ali, 2005) but this figure likely to be a gross under estimate as a result of rapid socio-economic development in the past decade which has led to significant increase in land and property prices (Hiew, 1996).

Figure 1.1: Flood prone areas Peninsular Malaysia (Abidin & Unit, 2004)

Recently, the flood control alternatives is showcase a number of technological advances in the field of hydrology and floodplain management including NEXRAD, GIS and the HEC`s Next Generation software programs HEC-HMS, HEC-RAS and

HEC-GeoRAS (Chu & Steinman, 2009). These tools continue to make the task of modeling flood control options and determining the effects of floodplain management decisions much easier and more accurate. HEC-HMS and HEC-RAS have taken existing software programs and made them highly visual, easy to use and included much needed data management tools. GIS continues to prove itself an amazingly well suited platform for the display and analysis of the spatially linked data that plays a pivotal role in hydrologic analysis (Philip, Wayne, & Baxter, 2002).

While flood modeling is a fairly recent practice, attempts to understand and manage the mechanisms at work in floodplains have been made for at least six millennia. The recent development in computational flood modeling has enabled engineers to step away from the tried and tested "hold or break" approach and its tendency to promote overly engineered structures (Turner, Colby, Csontos, & Batten, 2013). Various computational flood models have been developed in recent years either 1-Dimension (1D) models (flood levels measured in the channel) and 2-Dimension (2D) models (flood depth measured for the extent of the floodplain). HEC-RAS, the Hydraulic Engineering Centre model, is currently among the most popular if only because it is available for free. Other models such as TUFLOW combine 1-D and 2-D components to derive flood depth in the floodplain. So far the focus has been on mapping tidal and fluvial flood events but the 2007 flood events in the United Kingdom have shifted the emphasis onto the impact of surface water flooding (Colby & Dobson, 2010).

1.2 Problem Statement

Flood disasters in the humid tropics region and their impact to human and environment have continued to increase despite improved ability to monitor the phenomena. Hence, managing of flood disasters is now essential in many Asian countries. According to IPCC (2001) (Thomas et al., 2004), the effects of climate change can aggravate flood disasters related to sea level rises, increase in the frequency or intensity of extreme precipitation and alteration of flood regimes in river basin. Due to that, severe flood have occurred across Malaysia recently which also caused millions of ringgit damage to physical property as well as causing death to some extent (Liu & Chan, 2003).

Bandar Kota Tinggi, the administrative centre of Kota Tinggi District is developing rapidly. The town's immediate surroundings being located within low lying riverine area and river plain, is often subject to intermittent flooding caused by heavy tropical rainfall and effects of high spring tides (Abdullah et al., 2016). One of the major constraints to development in Kota Tinggi is the flooding from the Johor River and its tributaries.

In the last big flood, the rainfall intensity recorded in Kota Tinggi station for a period of 24 hours and 48 hours is 205mm and 335mm respectively (Saudi, Juahir, Azid, & Azaman, 2015). The rainfall intensity recorded is more than 50 years returning period. This rainfall intensity recorded which contributed by the continuous heavy rain for a few days cause the water overflow in Sungai Johor River basin area of 2000 km ^{2}.

According to expert such as Assoc. Prof. Dr. Sobri Harun from UTM Skudai in Utusan Malaysia, January 31 2007 edition, he was confident that caused of flooding in Kota Tinggi is due to heavy water comes down from mountains of Gunung Tahan to Linggiu River. He also added that Linggiu River still don't have one large dam to accommodate monsoon rain.

Two events of big flood has drowned the entire city of Kota Tinggi with depth of more than 3 meters and resulted in a total of 13200 residents have been transferred to the 36 temporary transfer outlets. There are many infrastructure affected as the main roads submerged in the water and the link also has been cut off for the helpers to get there. Areas which hit by the flood are Kampung Rantau Panjang, Kampung

Semanggar, Kampung Baru Sungai Telor, Kampung Batu 25, Kampung Sungai Berangan, Kampung Sri Jaya, Kampung Tembioh, Kampung Kelantan, Kampung Panti, Taman Mawai, Taman Kota Jaya dan Kampung Makam (Bhd, 2009).

Hence, the State Department of Drainage and Irrigation (DID) proposed some of floods control projects to reduce the flood effects within Kota Tinggi such as retaining Johor River erosion, Kota Tinggi urban drainage master plan study, deepen the river, build embankment and upgrading the drainage system (Air, 2006). In addition to that, the flood warning system stations telemetry has been installed at several locations in Johor River, Rantau Panjang, Ulu Sebol and Bukit Besar.

In despite of the two major floods, in a scale of 50 and 100 years returning period within a month occurred in Kota Tinggi has been an eye opener for this problem. The estimation of runoff and flow rates of river is important to predict flooding in future. Thus, it is important to come out with flood hazard assessment so that the flood hazard map can be produced for the use of authority in Kota Tinggi and the residents itself. Besides, it is expected that this flood hazard assessment is hope to increase the awareness of residents and authority toward flood disaster in future. It is expected that the method for flood control and storm water management that can be most effective and economic can be implemented for the mutual interest.

1.3 Objectives

This dissertation is aims to develop a river model and flood hazard map based on hydrological and hydraulic analysis. The main objectives for the dissertation are stated as follow:

1) To develop a river model for Johor River by using InfoWorks RS for future prediction and simulation.
2) To produce the flood hazard map for the Johor River Basin.

1.4 Scope of works

This research work following the flooding events at Johor River basin. Based on the events, the river model and flood hazard map had been developed. The areas prone to flooding had been distinguished.

1.5 Overview of Thesis Chapters

This study consists of five chapters. It includes the general about flooding in Malaysia, the detail meaning of flood, the software of InfoWorks RS, result, analysis and conclusion. Chapter 1 introduces the background, problem definition in the area, and the objectives of this task for general overview. Chapter 2 comprises on variety of literature materials regarding the task which has been conducted before. Chapter 3 will discuss about the methodology that need to be done in order to do the river flood modeling using InfoWorks RS as the medium software. This chapter comprises about preparation phase, data collection phase, execution and verification phase and flood hazard mapping phase. Chapter 4 discusses the results of river flood model in Kota Tinggi area with the standard calibration. The flood hazard map is presented in this section for the selected time of return period. The final chapter, Chapter 5 will give the conclusion on river flood modeling that has been carried out using InfoWorks RS. It concludes the results of study through the most comprehensive form and related to the main objectives.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter presents literature reviews regarding on flood phenomenon, flood in hydrology aspect, the role of flood maps and flood hazard maps. This chapter also briefly describes on the previous works on flood modeling and the overview of the hydraulic modeling software used in this study which is InfoWorks RS. Background of the proposed case study is also discussed at the end of this chapter.

2.2 Flood Phenomenon

2.2.1 Flood definition

There are many perspective of flood definition. According to (Leopold, 1997), flooding is a natural and recurring event for a river or stream. Flooding is a result of heavy or continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of rivers, streams, and coastal areas. This causes a watercourse to overflow its banks onto adjacent lands. Floodplains are, in general, those lands most subject to recurring floods, situated adjacent to rivers and streams. Floodplains are therefore "flood-prone" and hazardous to development activities if the vulnerability of those activities exceeds an acceptable level. Most simply, a flood-plain is defined as a strip of relatively smooth land bordering a stream and overflowed at a time of high water.

Floods are usually described in terms of their statistical frequency. A "100-year flood" or "100-year floodplain" describes an event or an area subject to a 1% probability of a certain size flood occurring in any given year. For example, Figure 2.1 shows this frequency in terms of flood levels and floodplains. This concept does not mean such a flood will occur only once in one hundred years (Segura-Beltrán et al., 2016). Whether or not it occurs in a given year has no bearing on the fact that there is still a 1% chance of a similar occurrence in the following year. Since floodplains can be mapped, the boundary of the 100-year flood is commonly used in floodplain mitigation programs to identify areas where the risk of flooding is significant. Any other statistical frequency of a flood event may be chosen depending on the degree of risk that is selected for evaluation example 5-year, 20-year, 50-year, 500-year floodplain (Norén, Hedelin, Nyberg, & Bishop, 2016).

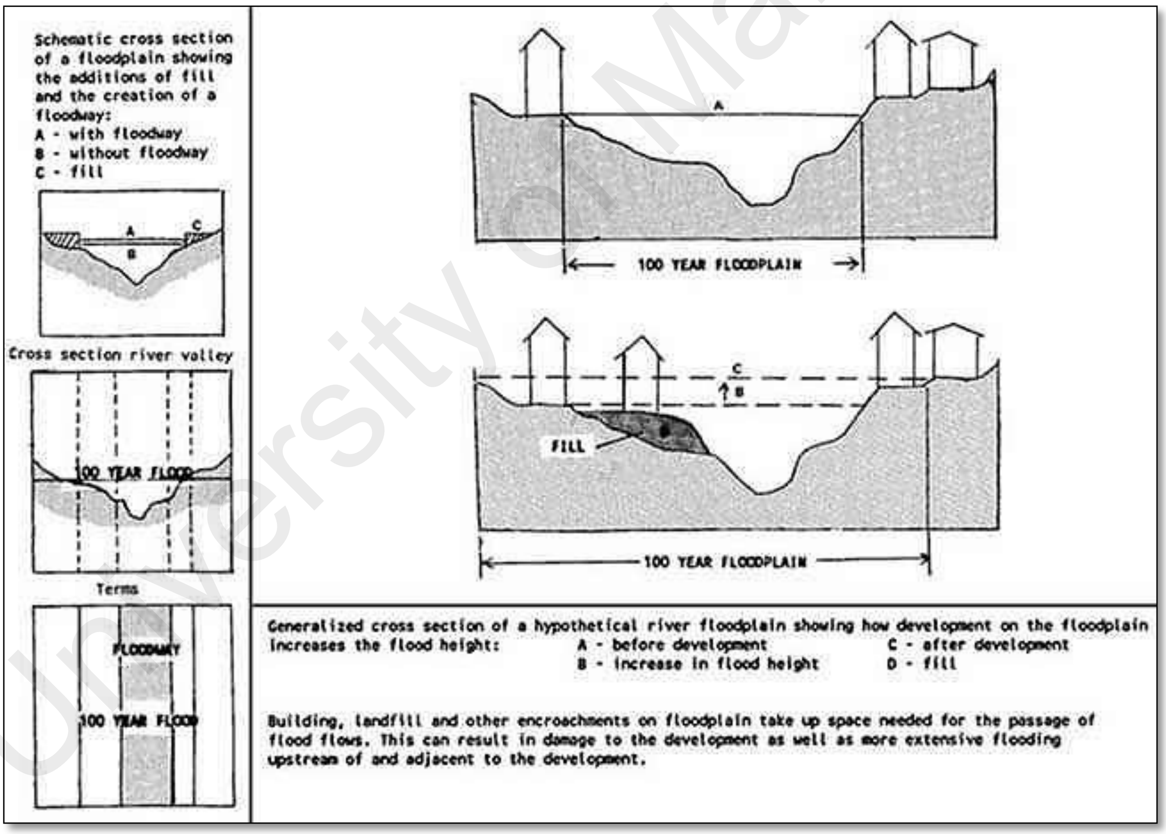


Figure 2.1: The frequency of flood levels and floodplains (Bender, 1991)

Moreover, flooding is considered to be a phenomenon associated with an unusually high stage or flow over land or coastal area, which results in serious detrimental effects. When rain falls on earth an astonishingly huge amount of water is involved. Small rainstorms usually do not cause a flood but when a storm caused by cyclonic depression occurs it may cause a flood, due to precipitation of huge volume of water. Generally, within the banks of river channels there is a great deal of space capable of holding water (Ghosh, 1997).

2.2.2 Types of flood

There are many types of flood in this world. The types are such as flash flood, river flood, coastal flood, pluvial flood, urban flood, muddy flood, estuarine flood and other types of flood. The following is the explanation about the types of flood as stated above.

2.2.2.1 Flash floods

It is defined as floods which occur within six hours of the beginning of heavy rainfall, and are usually associated with cloud bursts, storms and cyclones requiring rapid localized warning and immediate response if damage is to be mitigated. In case of flash floods, warning for timely evacuation may not always be possible (Middelmann-Fernandes, 2010).

2.2.2.2River floods

It is the floods are caused by precipitation over large catchment's areas. These floods normally build up slowly or seasonally and may continue for days or weeks as compared to flash floods. Rainfall over an extended period and an extended area can cause major rivers to overflow their banks. The water can cover enormous areas. Downstream areas may be affected, even when they didn't receive much rain themselves. With large rivers the process is relatively slow (Vincendon et al., 2016).

2.2.2.3 Coastal floods

Coastal flood is some floods are associated with the cyclonic activities like hurricanes, tropical cyclone etc. Catastrophic flooding is often aggravated by wind-induced storm surges along the coast. Simply put a coastal flood is when the coast is flooded by the sea. The cause of such a surge is a severe storm. The storm wind pushes the water up and creates high waves. A storm is formed in a low pressure area, as you may know. An interesting fact is that beneath a low pressure area the sea level is higher (Colby & Dobson, 2010).

2.2.2.4 Urban floods

Flooding in urban areas can be caused by flash floods, or coastal floods, or river floods, but there is also a specific flood type that is called urban flooding. Urban flooding is specific in the fact that the cause is a lack of drainage in an urban area. As there is little open soil that can be used for water storage nearly all the precipitation needs to be transport to surface water or the sewage system. High intensity rainfall can cause flooding when the city sewage system and draining canals do not have the necessary capacity to drain away the amounts of rain that are falling. Water may even enter the sewage system in one place and then get deposited somewhere else in the city on the streets (Abebe, 2005).

2.2.2.5 Ponding floods

Ponding or pluvial floods is a type of flooding that can happen in relatively flat areas. Rain water falling in an area is normally stored in the ground, in canals or lakes, or is drained away, or pumped out. When more rainwater enters a water system than can be stored, or can leave the system, flooding occurs. In this case, rain is the source of the flood and not water coming from a river, but water on its way to the river (Yu & Coulthard, 2015). That's why it is also called "pluvial flood".

2.2.2.6 Other types of flood

Floods can occur if water accumulates across an impermeable surface and cannot rapidly dissipate. Then, a series of storms will move over the same area. Dam and building beavers can flood low-lying urban and rural areas, often causing significant damage (Zhou, Liu, Zhong, & Cai, 2016).

Estuarine flood is commonly caused by a combination of sea tidal surges caused by storm-force winds. A storm surge, from either a tropical cyclone or an extra tropical cyclone, falls within this category. Catastrophic flood is caused by a significant and unexpected event e.g. dam breakage, or as a result of another hazard (Schroeder et al., 2016).

Muddy flood is generated by run off on crop land. It is also produced by an accumulation of runoff generated on cropland. Sediments are then detached by runoff and carried as suspended matter or bed load. Muddy runoff is more likely detected when it reaches inhabited areas. Muddy floods are therefore a hill slope process, and confusion with mudflows produced by mass movements should be avoided (Middelmann-Fernandes, 2010).

2.2.3 Mechanism of flood

Flooding is a natural and inevitable process. Floods occur when a river*'s* channel cannot hold all the water rain supplied to it by the catchment or watershed (the area the river drains). The Figure 2.2 shows the illustration of the mechanism of flood for flooding situation after the rainfall 1 in x year storm.

Flood plains are low areas subject to flooding from time to time. Most floodplains are adjacent to rivers, lakes and seas. The extent of flooded land depends on the magnitude of the flood event. Flood plains are designated by the size of the flood that will cover them, so the term 1 in 1 Year flood plain describes the land covered by the 1 in 1 year flood, similarly the 10 year flood plain is the area covered by the 1 in 10 year flood, and the 100 year flood plain is the area covered by the 1 in 100 year flood. The likelihood of a property flooding varies depending on how high it is above a river, property within a 10 year flood plain could expect to subject to flooding once every ten years (Norén et al., 2016; OIKOS, 2010).

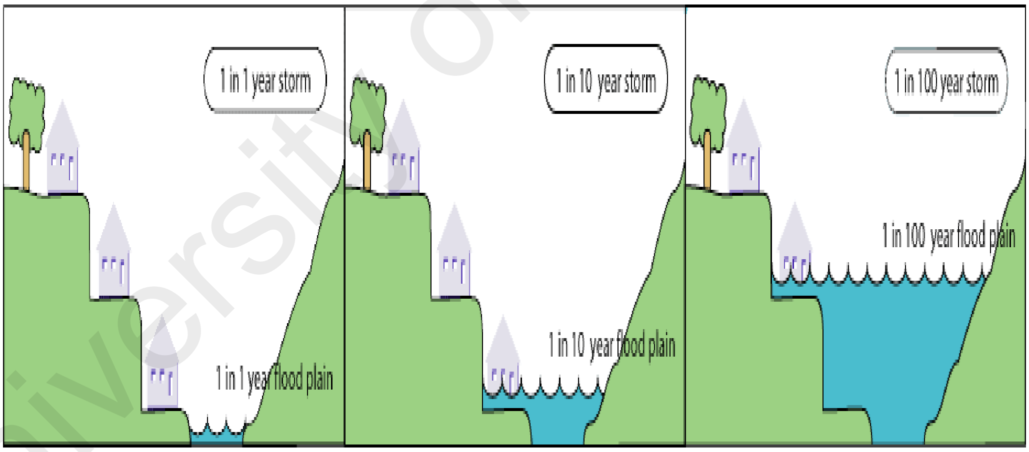


Figure 2.2: The location when the flooding occurs for 1 in x year storm (Norén et al., 2016)

2.2.4 Factors affecting flood

Heavy monsoonal and convectional rainfall, flat topography on both coasts, heavy siltation of rivers, and human activities have all contributed to high flood risk. Risk is increasing because flood characteristics are changing due to rapid urbanization of catchments (Meesuk, Vojinovic, Mynett, & Abdullah, 2015). Deforestation and other environmentally damaging human land uses have also significantly altered hydrological parameters. Research has revealed that significant water yield increases occur after deforestation, and that commercial logging resulted in significant increases in storm flow volume and initial discharge (Liu & Chan, 2003). Other human activities such as tin mining have also contributed to flooding. Climatic change inducing sea level rise may also be an important flood inducing mechanism which can increase future flood risk.

Flood reports for the period 1925 to1996 also suggest that flooding has become progressively more frequent, with flash floods mainly affecting the federal capital and Pulau Pinang (Weng Chan, 1997). Flooding magnitudes have also appeared to have increased since the 1970s (a period of rapid economic development) in the east coast states. The physical contexts of floods have, therefore, changed. Together with greater exposure and vulnerability of human populations, they have contributed to increased flood risk. In Malaysia, flood hazards and disasters continue to escalate in frequency and magnitude mainly because humans choose to occupy flood plains, ignore the dangers of such hazard zones, mismanage flood hazards, over develop land and deplete natural resources (e.g. forests and hill slopes) at rates of change which natural systems can neither cope with nor adapt to (Diakakis, Deligiannakis, Pallikarakis, & Skordoulis, 2016; Shafiai & Khalid, 2016).

2.2.5 Flood impacts

Flood impacts can be summarized as all the effects a flood has on its environment starting from the moment the water inundates dry land until full recovery has occurred.

Regular floods usually bring benefits to riverside communities. In the case of regular normal floods, the local economy and ecology are well adapted to the ‘flood pulse’. In regularly flooded inhabited areas agriculture is often important. Agriculture not only uses water but may also benefit from the nutrients in the sediments that are deposited during floods. Furthermore, ‘normal’ floods also help preserve areas of floodplains and replenish lakes and ponds, which in turn support irrigation or fish farming. Other possible advantages of floods are the recharge of shallow aquifers that supply households with drinking water and the flushing of salt from the surface of areas thereby increasing soil fertility (Bruijin, 2005).

Based on the link with the flood, direct and indirect flood impacts can be distinguished. Direct flood impacts are caused by the destructive force of the water, while indirect flood impacts are impacts that result from interruption of economic and social activities (Wicks, Hu, Scott, Chen, & Cheng, 2013). Examples of indirect impacts are production losses of agriculture and industry, loss of income for trade companies, shops and hotels, extra costs for transport due to flooded roads, disruption of family activities and emergency and evacuation costs.

A second distinction can be made between primary, secondary and flood-induced flood impacts depending on the location where damage has occurred (Vincent, 2001). Primary flood impacts are impacts which occur in the flooded area, secondary impacts occur in other areas (e. g. loss of income of companies that sell to or buy from companies in the flooded area). Flood-induced impacts are induced by a threatening flood but cannot be attributed a certain area (e. g. evacuation costs or extra costs of information services).

2.3 Floods in Hydrology Aspect

2.3.1 Rainfall Intensity

The rainfall intensity, (I) is the average rainfall rate in in/hr or mm/hr for a specific rainfall duration and selected frequency. Rain with large intensity generally occurs within a short time. Relation of intensity and time of rainfall which is generally formulated much depends on the parameters of the local conditions (Young & Liu, 2015). The amount of rainfall intensity was different and caused by time and frequency of rainfall events. Some rain intensity formula associated with it was developed as an empirical formula which can be expressed as follows:

$$i = \frac{\alpha(T)}{b(d)} \tag{2.1}$$

IDF relationship is a mathematical relationship between the rainfall intensity i, duration d, and the return period T. As stated by (Philip et al., 2002), the typical IDF relationship for a specific return period can be expressed in the form:

$$i = \frac{\lambda T^{K}}{(d+\theta)^{\eta}} \tag{2.2}$$

where θ and η is parameter to be estimated ($\theta>0$, $0<\eta<1$). Even though the function $\alpha(T)$could be completely determined from any probability distribution function of the maximum rainfall intensities *i(d)*, it was recognized by the oldest relationship as $\alpha(T) = \lambda T^{K}$. A generalized IDF relationship can be written where the parameters θ,η, d, and K can be solved by means of the one-step least squared method using the embedded optimization procedure in MS Excel (Tekleab, Uhlenbrook, Savenije, Mohamed, & Wenninger, 2015).

2.3.2 Generation the Rainfall Data

Furthermore, for the given data rainfall of daily rainfall which is the data have been collected from a rainfall station data, in the case of generate it to hourly rainfall, the NRCS 24-h rainfall distribution can be used. In the rational method the intensity is considered to be uniform over the storm period. Unit hydrograph techniques, however can account for variability of the intensity throughout a storm although the overall depth for a storm will be the same for a given duration for each method (He, Hu, Tian, Ni, & Hu, 2017). Therefore, when using unit hydrograph techniques, a rainfall hyetograph or distribution is determine. The NRCS Type II and III distributions are some of the standard distributions available for use (Jakubcová, Máca, & Pech, 2015).

These two distributions are typically described in either an incremental or accumulative rainfall format usually in 15 minute increments. In addition, they are also considered to be dimensionless. They represent a distribution of one inch of rainfall over a 24-hour period to which a design rainfall depth can be applied. The distribution itself is arranged in a critical pattern with the maximum precipitation period occurring just before the midpoint of the storm (Emmanuel, Andrieu, Leblois, Janey, & Payrastre, 2015).

Table 2.1: NRCS 24-hour Type II and III Rainfall Distributions (Chandwani, Vyas, Agrawal, & Sharma, 2015)

Time, t (hours)	**Fraction of 24-hour rainfall**	
	Type II	Type III
0	0	0
2	0.022	0.02
4	0.048	0.043
6	0.08	0.072
7	0.098	0.089

Table 2.1, continued

Time, t (hours)	Fraction of 24-hour rainfall	
8	0.12	0.115
8.5	0.133	0.13
9	0.147	0.148
9.5	0.163	0.167
9.75	0.172	0.178
10	0.181	0.189
10.5	0.204	0.216
11	0.235	0.25
11.5	0.283	0.298
11.75	0.357	0.339
12	0.663	0.5
12.5	0.735	0.702
13	0.772	0.751
13.5	0.799	0.785
14	0.82	0.811
16	0.88	0.886
20	0.952	0.957
24	1	1

2.4 The role of flood maps

The main purpose of flood map is to gather in one map the hazard-related information for a study area to convey a composite picture of the natural hazards of varying magnitude, frequency, and area of effect. A flood map may also be referred to as a "composite," "synthesized," and "overlay" map. One area may suffer the presence of a number of flood hazards. Using individual maps to convey information on each hazard can be cumbersome and confusing for planners and decision-makers because of their number and their possible differences in area covered, scales, and detail (Matthew M. Linham, 2010).

Many flood hazards can be caused by the same natural event. The inducing or triggering mechanism which can interconnect several hazards can more easily be seen through the use of a flood map (Ali, 2007). Additionally, the effects and impact of a single hazard event, as in the case of volcanoes and earthquakes, include different types of impacts, each having different severities and each affecting different locations. The flood map is an excellent tool to create awareness in mitigating hazard. It becomes a comprehensive analytical tool for assessing vulnerability and risk, especially when combined with the mapping of critical facilities as discussed (B. Pradhan, Shafiee, & Pirasteh, 2009).

River flooding may create substantial infrastructure problems and enormous economic losses in terms of production, as well as significant damage to property and supplies. Significant damage is caused where people increase the risk of flooding through unsuitable housing in high-risk areas or through serious interference in natural processes (Hiew, 1996). Good policy and planning can reduce the exposure to flooding through control of land management and housing development whilst well-designed flood defense schemes will assuage the impact of flooding.

There are many different ways to illustrative the flood map such as flood hazard map and flood risk map. Flood hazard maps include a time frame or likelihood reference. For example, the map below shows the flood hazard map for of Prey Veng, Cambodia with differences inundation depth (Science, 2015).

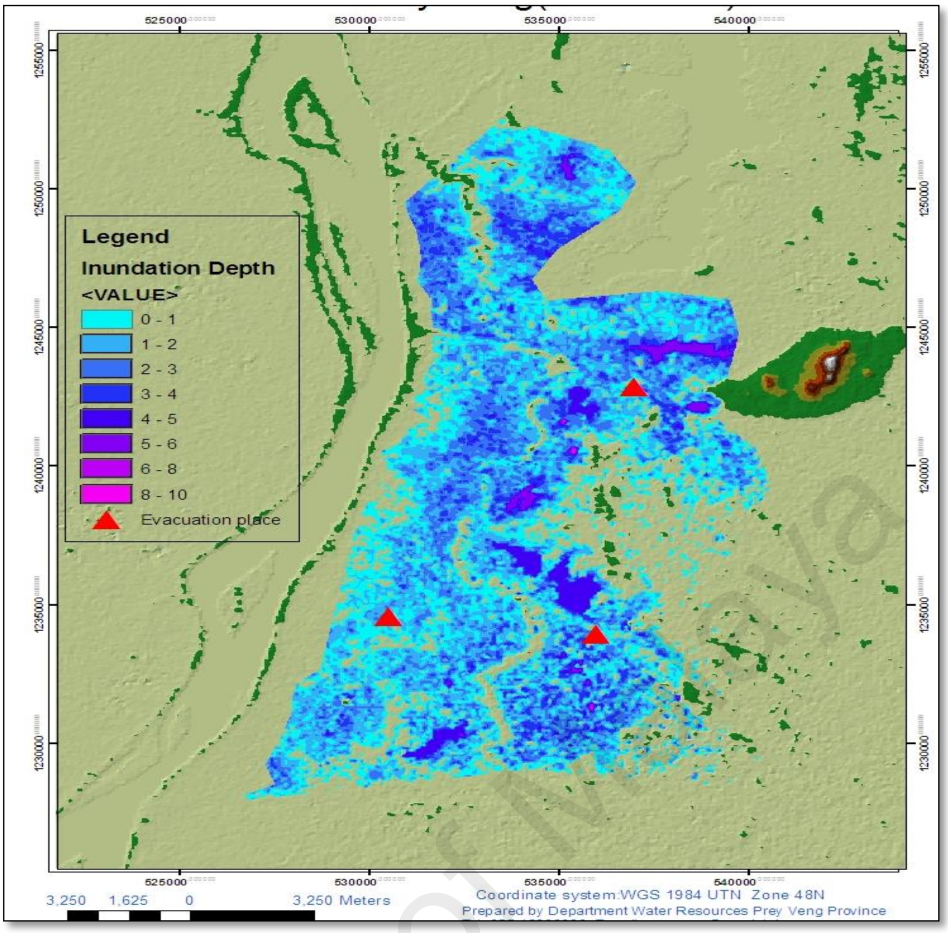


Figure 2.3: Flood hazard map of Prey Veng, Cambodia (JICA, 2008)

Flood risk maps show the consequences of an event with a likelihood scale. The example below shows Westport with 500 year flood risk map with number of buildings per km^2 in a damage state of moderate or greater (Science, 2015; Wang, 2002).

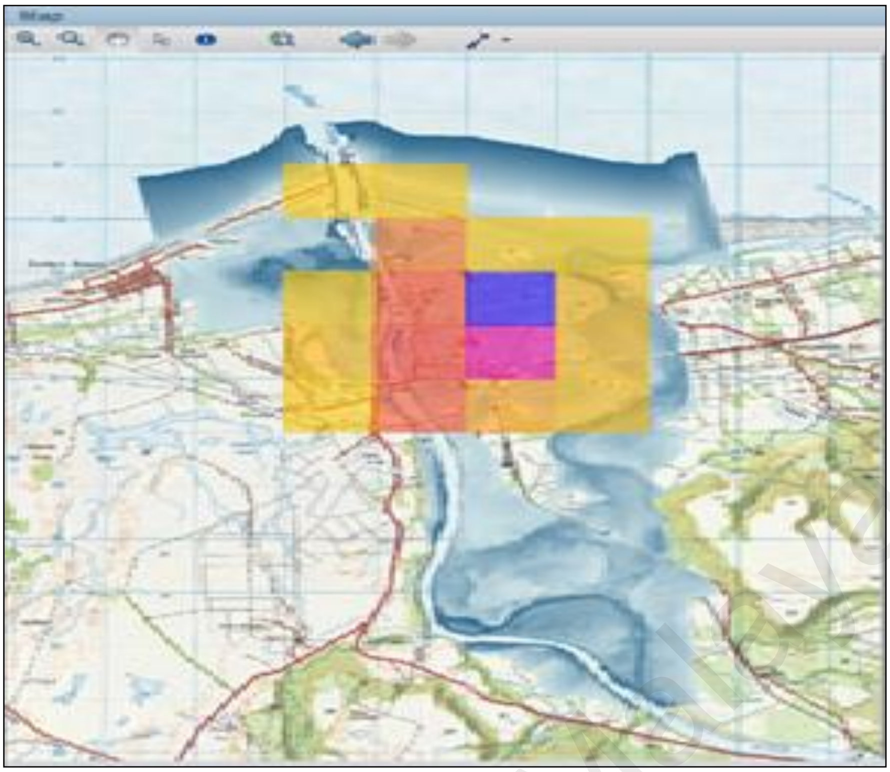


Figure 2.4: Flood risk map of Westport with 500 years return period (Safaripour, Monavari, Zare, Abedi, & Gharagozlou, 2012)

2.5 Flood Hazard Maps

The definition of flood hazard maps are detailed flood plain maps complemented with type of flood, the flood extent, water depths or water level, flow velocity or the relevant water flow direction (Matthew M. Linham, 2010). A number of different approaches for creating flood hazard maps were developed by different states. Some of the water bodies had published a recommendation for creating flood hazard maps which outlines the creation process and contains recommendations on map content, requirements for creating maps, quality management and publishing maps. Some federal states had already made flood hazard maps before the recommendation was published. The first point to clarify is the content of the map that is produced. In Germany water levels and inundations are the most commonly displayed features. The main step of building flood hazard maps should be the collection of necessary data (Prinos, 2009).

Flood hazard maps will allow quantification of what is at risk of being flooded such as the number of houses or businesses. This will help identify the scale of emergency and clean-up operations. The creation of flood hazard maps should promote greater awareness of the risk of flooding. This can be beneficial in encouraging hazard zone residents to prepare for the occurrence of flooding (N. R. Pradhan & Ogden, 2010). In order to achieve this however, local authorities must ensure that emergency procedures are established, and that information about what to do in the event of a flood is made available to the general public. In the longer-term, flood hazard maps can support planning and development by identifying high risk locations and steering development away from these areas. This will help to keep future flood risk down and also encourages sustainable development. In order for this to occur, the consideration of flood hazard maps must be integrated into planning procedures (Matthew M. Linham, 2010).

2.6 Flood Modeling Software

Modeling is essential for the analysis, and especially for the prediction, of the dynamics of urban growth and how this, in turn, will impact back on the environment (e.g. climate change, flood risk). Even less is known about how climate change and floods may affect the urban structure and function. The modeling approach will allow a range of research questions relevant to policy and preparation for sustainable urban development (Meesuk et al., 2015).

First Generation models are essentially 1-D models used with a 2DH grid. These models calculate water level in each flood cell at given output steps and therefore enable the duration of flood to be estimated. In cases where the flood plain is extensive, such models can give poor results, because they do not consider the propagation of floodwater within each cell (Madsen, 2003). InfoWorks RS, InfoWorks CS and ISIS are typical examples of this category of models. InfoWorks RS and InfoWorks CS are available softwares of medium cost, medium accuracy and medium run-time. They are 1D model with 2DH grids, which simulate flood volume propagation. They use Digital Terrain Maps (DTM), time series and overflow discharges as input and produce results of flood depth, flood extent and flood duration. ISIS is software of similar characteristics to the previous models, but of lower accuracy (Prinos, 2009).

Models such as InfoWorks RS, ISIS, as well as Mike 11, HEC-RAS and SOBEK-CF, which solve the one-dimensional St Venant equations, are used to describe flow processes in compact channels. They are applied in the case of design scale modeling which can be of the order of 10s to 100s of km depending on catchment size. Surveyed cross sections of channel and floodplain, upstream discharge hydrographs and downstream stage hydrographs are provided as inputs to the models aforementioned. Water depth and average velocity at each cross section, inundation extent by intersecting predicted water depths with Digital Elevation Models and downstream outflow hydrograph are produced as outputs of the models. First Generation Models also include 1D+ models, which are 1D models plus a storage cell approach to the simulation of floodplain flow. Example models of this category are: Mike 11, HEC-RAS, InfoWorks RS and ISIS. The computation time for 1D and 1D+ models is counted in minutes and minutes to hours, respectively (Prinos, 2009).

Second Generation models are 1D/2DH hybrid models and fully 2D. The models of this category use the St Venant equations to model channel flow, however, a 2D continuity equation is used to approximate flow over the flood plain area (Ranatunga, Tong, & Yang, 2017). The software used for 2D models are such as InfoWorks RS, HYDROF, LISFLOOD-FP, Mike 21, TELEMAC 2D, TUFLOW, SOBEC-OF and Delft-FLS.

2.7 Overview of InfoWorks RS

InfoWorks RS is an integrated network modeling solution for river systems. It can provide data and model management functionality, model build functionality, ISIS flow, hydrology and PDM engines also clearer graphical presentation and analysis (Bustami, Bong, Mah, Hamzah, & Patrick, 2009). So, for modeling the flood which happened in Kota Tinggi, Johor in 2006-2007 InfoWorks RS software would be preferred.

2.7.1 General Information of InfoWorks Program

InfoWorks, Wallingford Software, UK is using to make 1-D hydrodynamic model to estimate the river at river structures such as bridges, dams and sprawler. It also help engineer to simulate the steady flow simulation and flow was not steady also can be combined with GIS and Digital Terrain Model to be developed right to flood plains and combined with maps of the earth to get the flood map (B. Pradhan et al., 2009). However, 1-D only gives the average water velocity and height of water level in cross section. Otherwise, InfoWorks can also be used to investigate the behavior of sediment and water quality (Hasan, 2009).

There are three types of InfoWorks program such as InfoWorks CS, InfoWorks WS and InfoWorks RS. Below are the descriptions about the program.

2.7.1.1 InfoWorks CS

InfoWorks CS is the leading software solution integrating asset and business planning with urban drainage network modeling. It is powerful management system, workgroup model management solution, complete model build and simulation tool and also an integrated solution (Bustami et al., 2009).

2.7.1.2 InfoWorks WS

InfoWorks WS is the leading software solution integrating asset and business planning with water supply and distribution network modeling. It is workgroup model management, model building tools, results interpretation, powerful hydraulic simulation and integrated solution (Bustami et al., 2009).

2.7.1.3 InfoWorks RS

InfoWorks RS is an integrated network modeling solution for river systems. It is data and model management functionality, model build functionality, ISIS flow, hydrology and PDM engines, clearer graphical presentation and analysis and also make master database where all the data associated with stored river (Goodarzi, 2010).

2.7.2 Structure of an InfoWorks Model

In InfoWorks, the mechanisms that make up a model of a river network are divided into three part but very closely related database items.

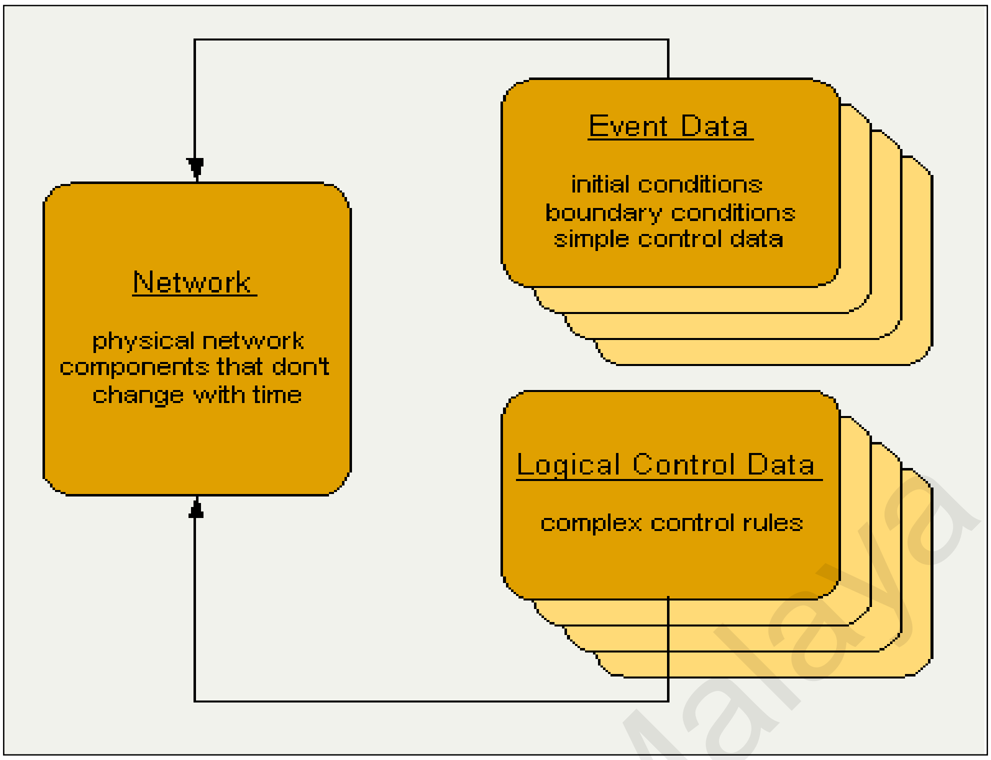


Figure 2.5: Structure of an InfoWorks Model (Goodarzi, 2010)

The Network database item defines all the physical aspects of the network that do not change over the time frame of a reproduction, such as the parameters of abridge or a channel cross section. You make changes to the network by creating different versions of the network (Goodarzi, 2010).

2.8 Background of the Case Study

Johor is located in the southern region of Peninsular Malaysia and administratively divided into eight districts with Johor Bahru serves as its capital state in highly urbanized setting that connects Malaysia to Singapore as an international business hub and port of entry. The close proximity of Kota Tinggi to Johor Bahru which is approximately 42-km north-east of Johor Bahru had been the main factor contributing to its rapid development as part of the Johor Bahru growth corridor (San & Selamat, 2010; Saudi et al., 2015).

The district of Kota Tinggi (Figure 2.6) is located at the east of Johor state with 65% of its border is surrounded by the sea. Kota Tinggi district have an area of 3,500 km^2 (364,399 hectares) and consists of 10 sub-districts (Saudi et al., 2015).

Urbanization in this area is growing rapidly focusing in agricultural activities and housing development with population of more than 200,000 people. The administrative town of this district also was named Kota Tinggi. This study is covered the total catchment area for Johor River Basin.

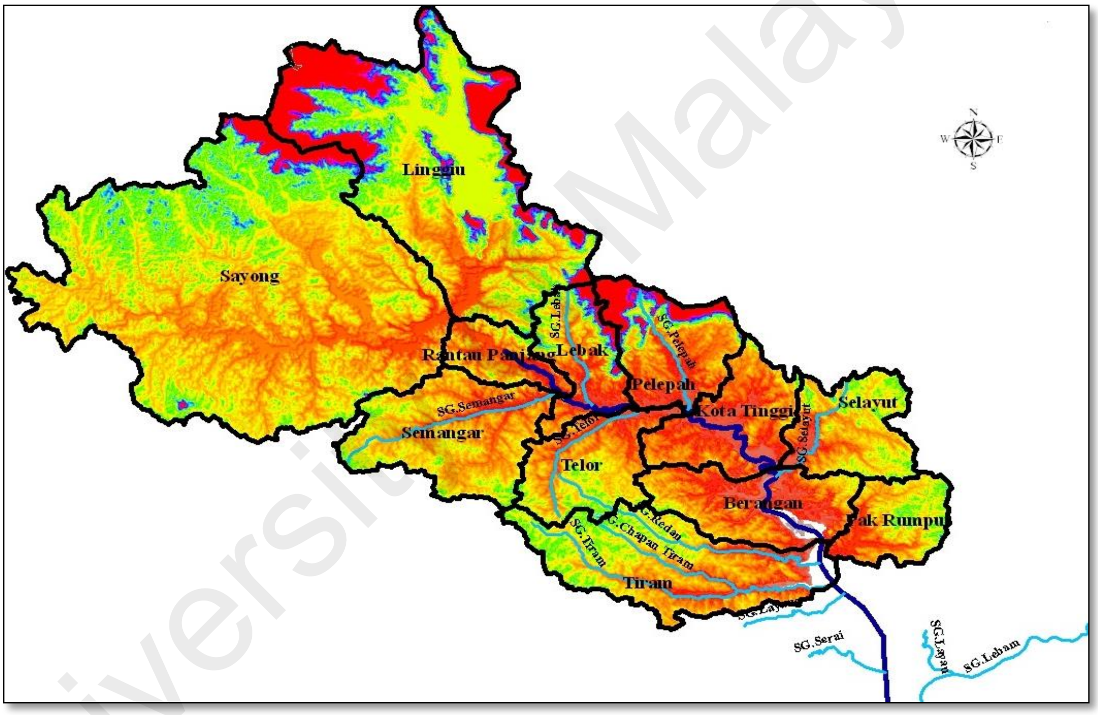


Figure 2.6: Map showing the Kota Tinggi district under state of Johor, Malaysia

Furthermore, regarding to the technical report of Extreme Flood Event: A Case Study on Floods of 2006 and 2007 in Johor, Malaysia by Atikah Shafie, in the period of 19-31 December, 2006 and 12-17 January, 2007; Peninsular Malaysia had been hit by series of storm events generated by Northeast Monsoon that caused severe floods in several states located in the lower half of the Peninsular. The 2006 and 2007 events had caused millions of lost and damages in four states namely Negeri Sembilan, Melaka, Pahang and Johor. So, the flood in Kota Tinggi, Johor is including in this storm events by Northeast Monsoon (Shahidan, Hasan, Abdullah, & Ghani, 2012). This location had the most devastating impact with nearly 100,000 people were evacuated to emergency relief centers mainly due to its geographical characteristics and triggers with the inadequate drainage facilities.

The beginning of heavy rainfall at Kota Tinggi was on 17th December 2006 and continuing for five days until 21st December 2006. The river rising rapidly and it started to fill up the floodplain areas because of the town has low lying area and it is close to the estuaries. The first wave period of the flood here was on 19th -31st December 2006. The duration of the flood approximate to 13 days and 5243 people was the number of the victims in Kota Tinggi (Shafie, 2009). Then, the most of areas has dried out and the relief center had close down on 30th December 2006. The victims had return to their home on 11th January 2007 and the conditions become well with the area are safe to live. However, on 11th January 2007 the state of Johor started to fall continues heavy rain for four days until 14th January 2007 and the second wave period of the flood was on 12th -17th January 2007. Table 2.2 is Kota Tinggi flood chronology for first wave on December 2006 while Table 2.3 is for second wave on January 2007 (Saudi et al., 2015).

Table 2.2: Kota Tinggi flood chronology of December 2006

Calendar of December 2006						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Legend: 17 = The rainy days

First wave of flood

Table 2.3: Kota Tinggi flood chronology of January 2007

Calendar of January 2007						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Legend: 17 = The rainy days

Second wave of flood

Recently, on the year 2011 there was heavy rainfall occurred in Kota Tinggi. The starting of heavy rainfall was on 29th January 2011 and continuing for four days until 1st February 2011. The period of the flooding was on 31st January 2011 until 7th February 2011. The duration of the flood approximate to eight days and 1079 people was the number of the victims from 243 families in Kota Tinggi. The victims had return to their home on 8th February 2011. Table 2.4 is Kota Tinggi flood chronology for January and February 2011 (Shafiai & Khalid, 2016).

Table 2.4: Kota Tinggi flood chronology of January 2011 and February 2011

Calendar of January 2011						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Calendar of February 2011						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28					

Legend: 17 = The rainy days

Flood of 2011

2.9 Summary of literature review

River flood is caused by precipitation over large catchment's areas. Heavy monsoonal and convectional rainfall, flat topography on both coasts, heavy siltation of rivers, and human activities have all contributed to high flood risk. The main purpose of flood map is to gather in one map the hazard-related information for a study area to convey a composite picture of the natural hazards of varying magnitude, frequency, and area of effect. Flood hazard maps are detailed flood plain maps complemented with type of flood, the flood extent, water depths or water level, flow velocity or the relevant water flow direction. Thus, it is important to come out with river model and flood hazard assessment so that the flood hazard map can be produced for the use of authority and the residents itself. Besides, it is expected that this flood hazard assessment is hope to increase the awareness of residents and authority toward flood disaster in future.

CHAPTER 3: STUDY AREA AND RESEARCH METHODOLOGY

3.1 Introduction

In this chapter, the methodology and the software used in this research works are explained. The description of the study area has been brief followed by the overview of the methodology. Several phases for this project have been discussed such as preparation phase, data collection phase and execution and verification phase.

For data collection phase, it's covered the data requirement for InfoWorks RS and also the data that have been collected. The steps for river flood modelling for 1-D and 2-D also have been explained in execution and verification phase. The calibration has been done to ensure the model represent the best river flood model. Lastly, the flood hazard map can be developed after all the phases completed.

3.2 Study Area Description

The study area for this dissertation is Kota Tinggi, Johor. The district of Kota Tinggi is located at the east of Johor state with 65% of its border is surrounded by the sea. Kota Tinggi district have an area of 3,500 km^2 (364,399 hectares) and consists of 10 sub-districts. Urbanization in this area is growing rapidly focusing in agricultural activities and housing development with population of more than 200,000 people (Bhd, 2009). The administrative town of this district also was named Kota Tinggi. This study will focus on the total catchment area for Johor River Basin.

3.2.1 Wind flow and Monsoon Rain

The rainfall pattern in Malaysia is influenced by two monsoon regimes, Northeast Monsoon and Southwest Monsoon. The shorter period in between the two monsoons is called Inter-monsoon. Table 3.1 shows the Monsoon regimes in Malaysia.

Table 3.1: Monsoon regimes in Malaysia (Department, 2015)

Monsoon	Period	Characteristics
Northeast	November – March	Winds 10-20 knots up to 30 knots during cold surges period affecting east coast area. Heavy rainfall.
Inter-monsoon	April – May October - November	Frequent period of thunderstorm in afternoon and evening hours with heavy rainfall causing flash flood.
Southwest	May – September	Winds below 15 knots affecting west coast area. Drier weather.

Due to the seasonal prevailing winds, the seasonal variation of rainfall in Peninsular Malaysia can be classified to three categories. The east coast will have maximum rainfall in the months of November to January while June and July are the driest months in most areas. The southwest coastal area however, is much affected by early morning "Sumatras" from May to August. October and November are the months with maximum rainfall and February the month with minimum rainfall. The rest of the Peninsula has distinct two periods of maximum rainfall separated by two periods of minimum rainfall. The primary maximum generally occurs in October to November while the secondary maximum generally occurs in April to May (Abdullah, 2007). Over the north-western region, the primary minimum occurs in January to February with the secondary minimum in June to July while elsewhere the primary minimum occurs in June to July with the secondary minimum in February.

3.2.2 Soil type

The major soil type in Johor is presented in Figure 3.1 from Department of Agriculture, Malaysia (DOA). The dominant soil type in Johor is sedentary soils. These soils cover 53% of the total land area in Johor. These soils can be classified under shallow (less than 50 cm), moderately deep (50- 100 cm) and deep soil (more than 100 cm). These soils also occur on different terrain from the relatively flat areas (0- 2 %) to the hilly areas (> 20%). Most of the industrial and food crops in Johor are grown on sedentary soils (DOA, 2002).

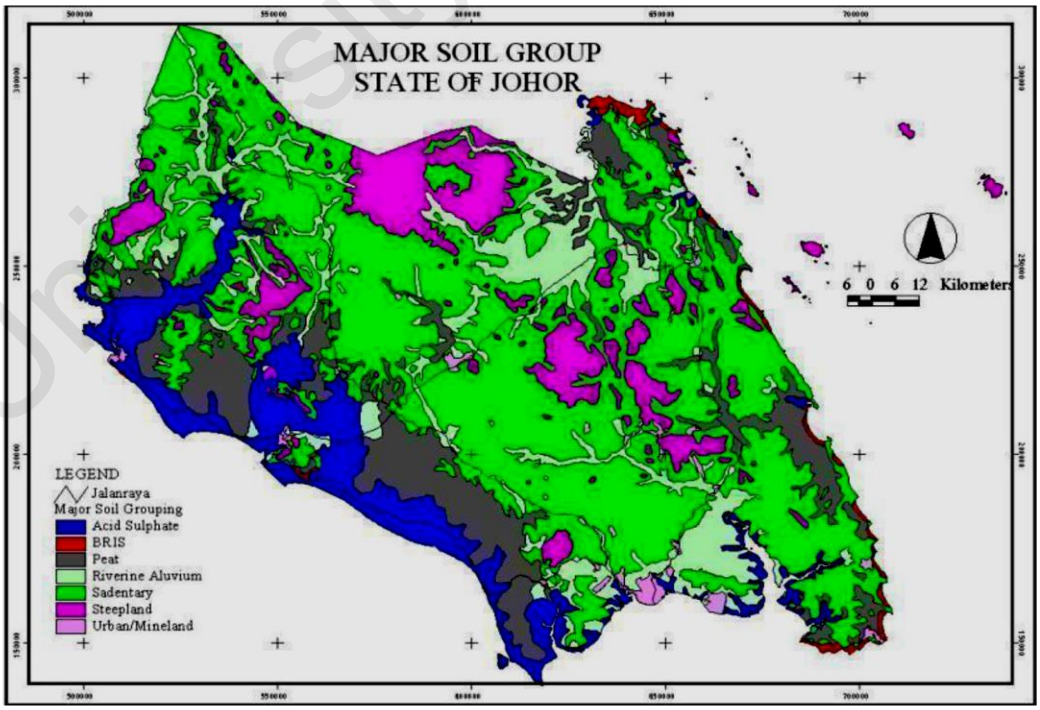


Figure 3.1: Major soil type in Johor (Department of Algriculture, 2002)

3.2.3 Johor River Characteristics

Johor River is approximately 122.7km long with drainage area of 2,636 km^2. It originates from Mt. Gemuruh and flows through the south-eastern part of Johor and finally into the Straits of Johor. The catchment is irregular in shape. The maximum length and width are 80-km and 45-km respectively. About 60% of the catchment is undulating highland rising to a height of 366-m while the remainder is lowland and swampy (Saudi et al., 2015). The highland in the north is mainly jungle. In the south a major portion had been cleared and planted with palm oil and rubber. The highland areas have granite soil cover consisting of fine to coarse sand and clay. The alluvium consists of fine sand and clay. The catchment receives an average annual precipitation of 2,470-mm while the mean annual discharge measured at Rantau Panjang (1,130-km^2) has been 37.5 m3/s during the period1963-1992. The temperature in the basin ranges from 21^0C to 32^0C. Table 3.2 shows the basic data of Johor River (River, 2009).

Table 3.2: Basic Data for Johor River, Malaysia (River, 2009; Saudi et al., 2015)

Location: Central part of south Johor	N $1^0$27' - $1^0$49' E $103^0$42' - $103^0$01'
Area: 2,636 km^2	**Length of main stream**: 122.7 km
Origin: Mt. Gemuruh (109m)	**Highest point**: Mt. Belumut (1,010m)
Outlet: Straits of Johor	**Lowest point**: River mouth (0m)
Main geological features: Intrusive rocks, quaternary, triassic, permian, cretaceous-jurassic, tertiary	
Main tributaries: Sayong, Linggui, Semangar, Tiram, Layang, Lebam	
Main lakes: Nil	
Main reservoirs: Linggui Dam (impounded in 1993: Malaysia-Singapore Treaty)	
Mean annual precipitation: 2470-mm (basin average)	
Mean annual runoff: 37.5 m3/s at Rantau Panjang (1963-1992)	
Population: 230,000	**Main cities**: Kota Tinggi
Landuse: Urban(5.5%), Forest(16.4%), Oil Palm, Other crops (18.5%), waterbody (0.5%), Swamps(11.6%)	

Johor River or Sungai Johor in Malay language is originated from its source of Sungai Layang-layang and Sungai Linggui/Sayong in the upstream before merging to Sungai Johor and flows down southeast to estuarine of Johor Straits. Downstream major tributaries are Sungai Tiram and Sungai Lebam (DID). The highest elevation in the basin based on the available DEM is 600-m and the lowest point is 4 m. Most of the downstream area is covered with wetlands and swampy area (Shafie, 2009). Generally, Johor River is a meandering channel with most of the areas is prone to have neck or chute cut-off with high sedimentation ranging from suspended, to mix as well as bed load sedimentation along the reaches.

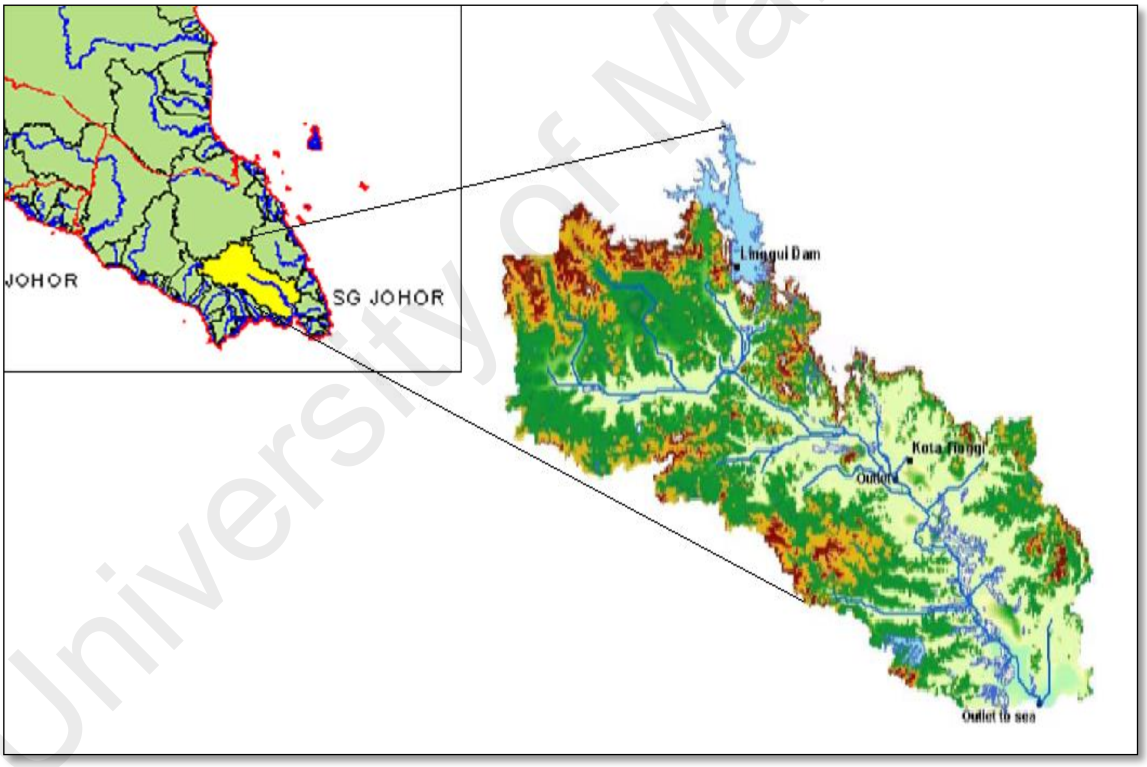


Figure 3.2: Johor River catchment

3.3 Methodology Overview

There are two types of river modeling that can be adapted, which are physical and numerical modeling in order to obtain the flood hazard map. However, in this task, numerical modeling will be used as a medium to obtain the flood hazard mapping for the district of Kota Tinggi, Johor. Numerical modeling is chosen because it is much easier to handle and more cheap in cost (Horritt & Bates, 2002). In numerical modelling, there are several software can be used for this task such as HecRas, Fluvial 12, MIKE 11, InfoWorks RS and etc (Zhang, Madsen, Ridler, Refsgaard, & Jensen, 2015). So, out of all available software in the market, InfoWorks RS will be used as the medium software to complete this task. Generally, the main task need to be done regarding to this topic is river flood modeling and comprised of 4 stages which are preparation phase, data collection phase, execution and verification phase and the last but not least, the hazard mapping phase. The research methodology chart is reflected in Figure 3.3.

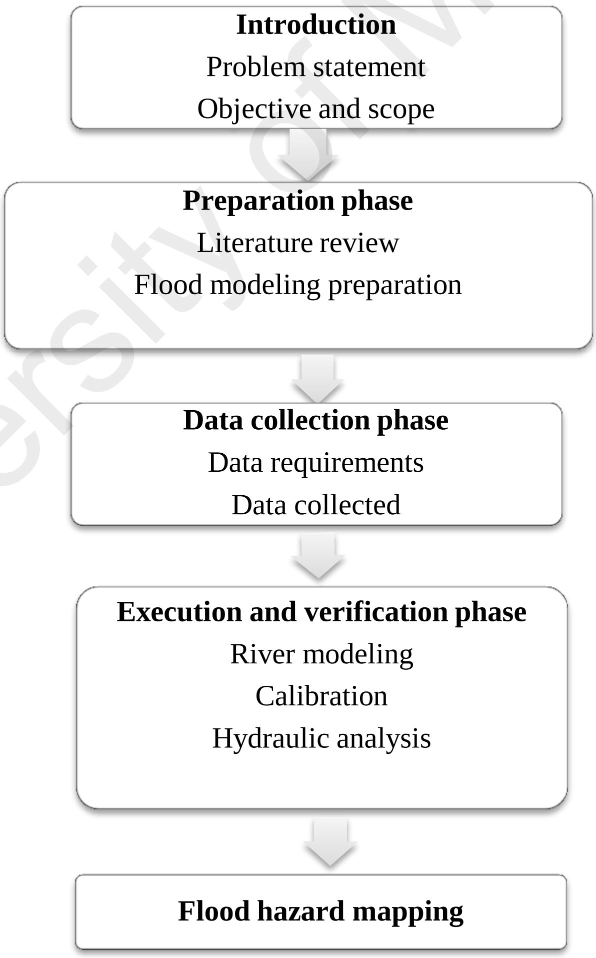


Figure 3.3: Flow chart of the research processes

3.4 Preparation Phase

This phase comprised activities such as literatures study and river flood modeling preparation. Literature study was done along the research. This has been carried out in order to obtain research knowledge and develop the methodology as well. The literature studied mostly deals with flood hazards, GIS modeling, and more specifically InfoWorks RS software. The literature on flood hazard studies includes the causes of flooding, processes and their impact.

In addition, flood hazard assessment is studied as well as the GIS modeling especially to obtain knowledge on the use of hydrological software in a GIS environment. GIS coverage that will be covered are river, contour, road, land use and soil classification whereas the required rainfall data are maximum annual rainfall as well as flood events. GIS coverage is developed for sub-catchments and the time of concentration. Total rainfall, rainfall patterns and rainfall distribution are determined. Rainfall discharge simulations were then run for every sub-catchment which then generates a discharge hydrograph for each sub-catchment (Goodarzi, 2010). Generally the flow chart for river flood modeling given below (Figure 3.4):

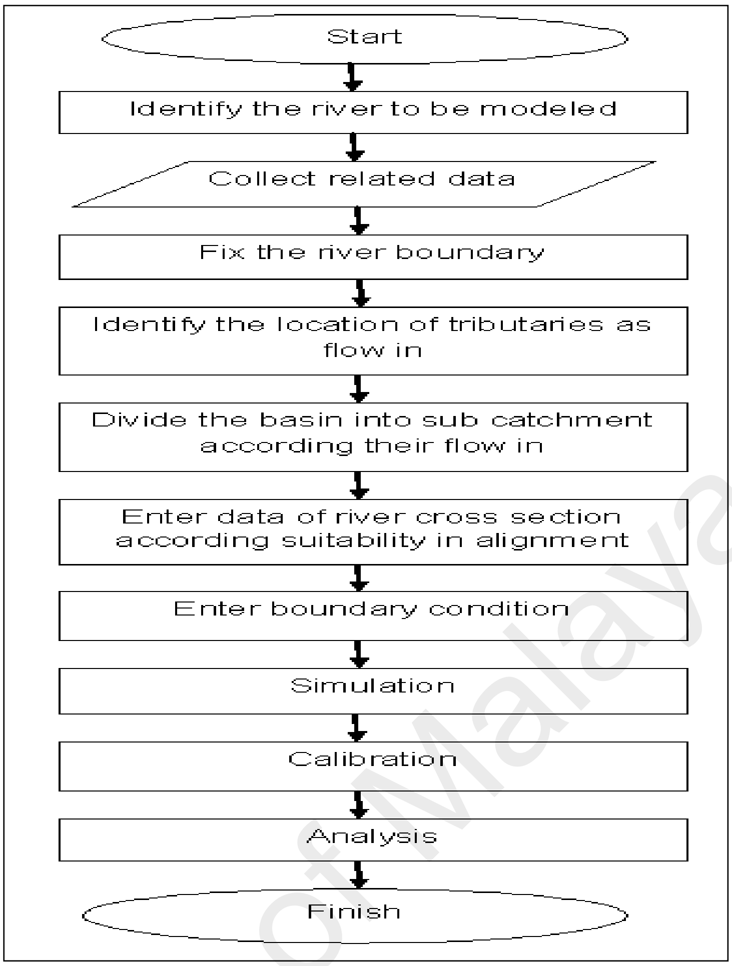


Figure 3.4: Flow of River Flood Modeling Using InfoWorks RS

3.5 Data Collection Phase

Data collection phase included some data that needed to collect and input for modeling the flood using InfoWorks RS. The data collected are using in the model as the model main input, information for the catchment area activity and the hydrology analysis. The table 3.3 shows the data needed for river flood modeling using InfoWorks RS.

Table 3.3: List of the data needed for river flood modeling

No.	Types of Information	Format	Uses	Source
1	Stream Cross section (Distance and Level)	Digital	Model main input	DID
2	Location Plan (Johor River catchment)	Hardcopy	Reference/ hydrology	DID
3	River alignment plan (Nodes along the river)	Digital	Model main input	DID
4	Hydrology data, rainfall data, spill data	Hardcopy or digital	Hydrology analysis	DID
5	Land use map	Digital	Catchment area activity Hydrology analysis	DOA
6	Soil types map	Digital	Hydrology analysis	DOA

3.5.1 Data Requirement for InfoWork RS

3.5.1.1 Input of Hydraulics (Boundary condition)

The cross section point value is inserting for the value of left and right bank. The condition of exact and proposed is both used. The river chainage divided into three levels. For simulation, the important things to insert for modeling the river are cross section, hydraulic structure, discharge and velocity. The boundary condition is needed to determine while input the flow of the river.

There are two part of boundary condition:

a) Upstream boundary condition – Hydrograph discharge Vs Time, Hydrograph Depth Vs Time and Rain-flow Modelling. Rainfall depth and discharge time series has been analyzed.

b) Downstream boundary condition – Discharge Vs Depth, Fix water Level and Tidal Water Level. In InfoWorks RS model, initial condition can be manually input in every cross section and other way is derived from steady flow run.

3.5.1.2 Input of Hydrology

The rainfall-runoff model is the input of hydrology. Hydrograph can be simulated from Hydrological Procedure (HP1 and HP11) by Department of Irrigation and Drainage Malaysia for the modeling using SCS method. Calibration process can be done by predict Tc and Tp value. Then, for the assumption of Tc and Tp, the catchment area should be predicted. It is including the boundary area, length of the river flow, catchment area and the percent of slope. The data needed for each sub-catchment are the length of the river flow, area, SCS curve number and CN value based on use of soil.

3.5.1.3 Input of Tidal Data

Water level should be done referring to Admiralty Chart Datum which is correlated to Land Survey Datum for the calibration of the flooding.

3.5.2 Data Collection

The data collected for InfoWorks RS consist of hydraulic and hydrology data. The data of Johor river tributaries, sub-catchment, sub-basin, rainfall, streamflow station and main river cross section that is used included for proposed and exact data. The magnitude of the major flood occurred at Kota Tinggi was classified as 50 and 100 years returning period.

The hydrological data for the Johor River basin is obtained from Drainage and Irrigation Department (DID), Ampang. The data needed are rainfall data, water level data and stream flow data. The rainfall data which is chosen is the event based data and in hourly form. So, the data of rainfall duration is from 15 December 2006 until 5 January 2007 is taken as the flood event occurred on 19-31 December 2006. The water level and streamflow data are taken from rantau panjang gauging station (Figure 3.5). Apart from that, the coordinate of the rainfall station is taken as the point on GIS map.

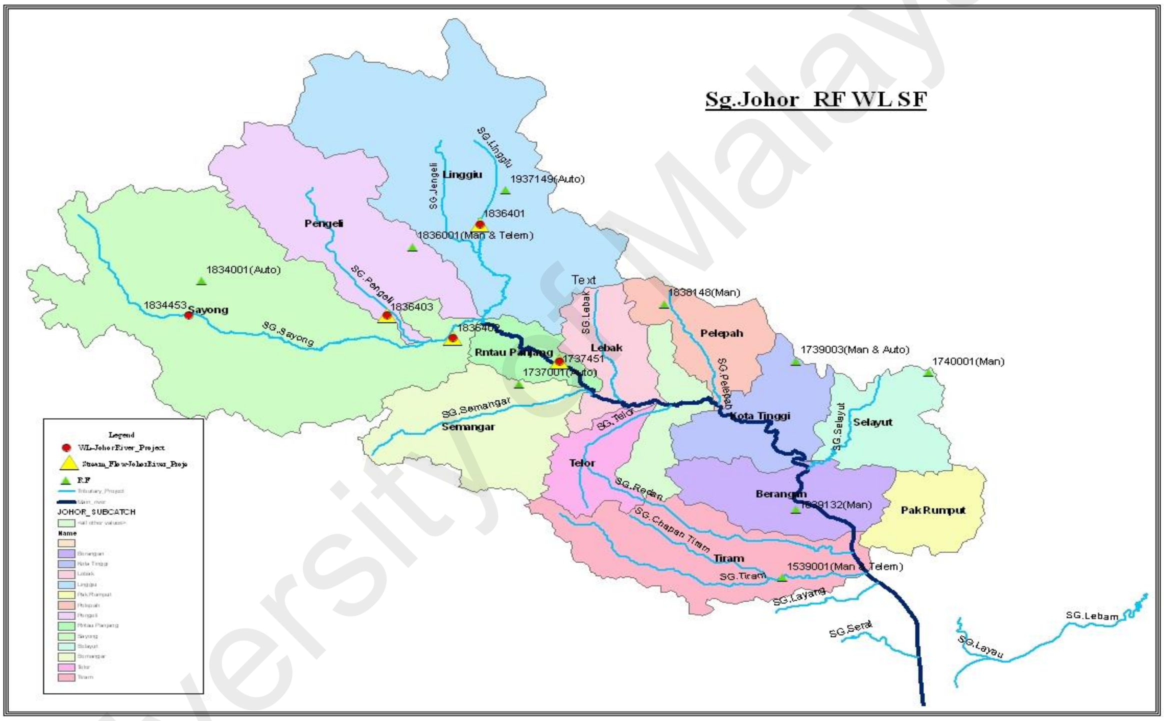


Figure 3.5: Rainfall, Water Level and Streamflow Stations for Johor River

3.6 Execution and Verification Phase (Modelling Phase)

The objective of this phase was to generate the flood map of 2006 flood event and verify it with field observation data. In this phase the geometric data of the study area, i.e. the stream centerline, cross-section cut lines, main channel banks, flow path centerlines and reach lengths values were extracted from the GIS. The ArcGIS program was used to extract the geometric data and export to the InfoWorks RS.This file was then imported in InfoWorks RS model. The correction of geometric data such as adjusting the location of river banks and filtering the number of cross section point then performed in InfoWorks RS model. After the correction, the maximum daily average discharge of year 2006 and the boundary conditions of the simulation were input to simulate the flood event of this year. The results of the simulation were the flood extent and flood depth. The model was then calibrated with the available field data.

3.6.1 Steps for 1-D River Flood Modelling Using InfoWorks RS

1) To start with InfoWorks RS, make sure the requirement data are available. Then, to start the river modelling, the master database must be created first.

2) After the database created, import the GIS files in shapefiles format into the InfoWorks RS. The GIS coordinate format must be in RSO format so that the map is in real scale as on the earth.

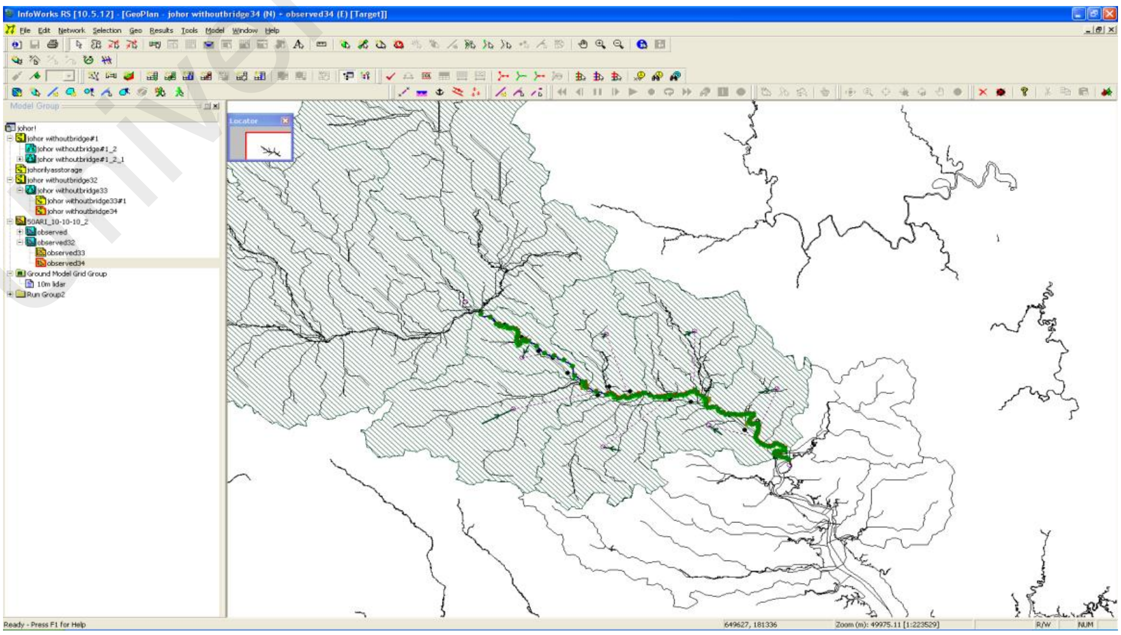


Figure 3.6: The GIS files Imported into InfoWorks RS

3) The cross section of Johor River is keyed in and the nodes will represent as the cross sections. While the cross section distance for every node is only 1000 meters interval and the lines will represent as the distance between cross sections. However, InfoWorks RS has a feature that can interpolate the nodes in between the interval. So, some of the nodes was add up to three nodes within the interval. Hence, the river nodes keyed in within 250 meters interval. The manning roughness coefficient also keyed in with the bed surface coefficient and non-contact surface with water coefficient are 0.035 and 0.2 respectively.

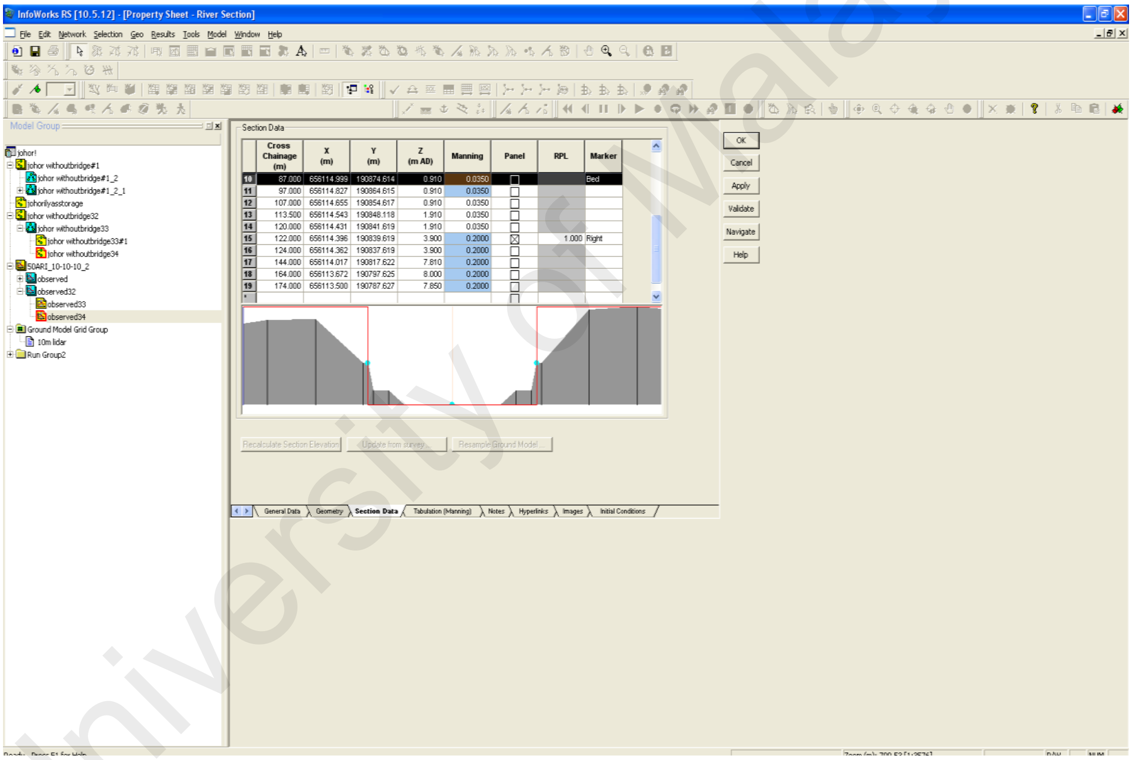


Figure 3.7: The cross section of Johor River (Chainage JHR11000)

4) The sub-catchment areas are digitized using polygon icon. If the sub-catchment areas are given in GIS format, then it is easier to digitize the sub-catchment areas in the map. But in the case when the sub-catchment areas are not given, we need to have contour map from GIS file in order to digitize the sub-catchment area. The boundary node is put inside every sub-catchment and linked to the sub-catchment area.

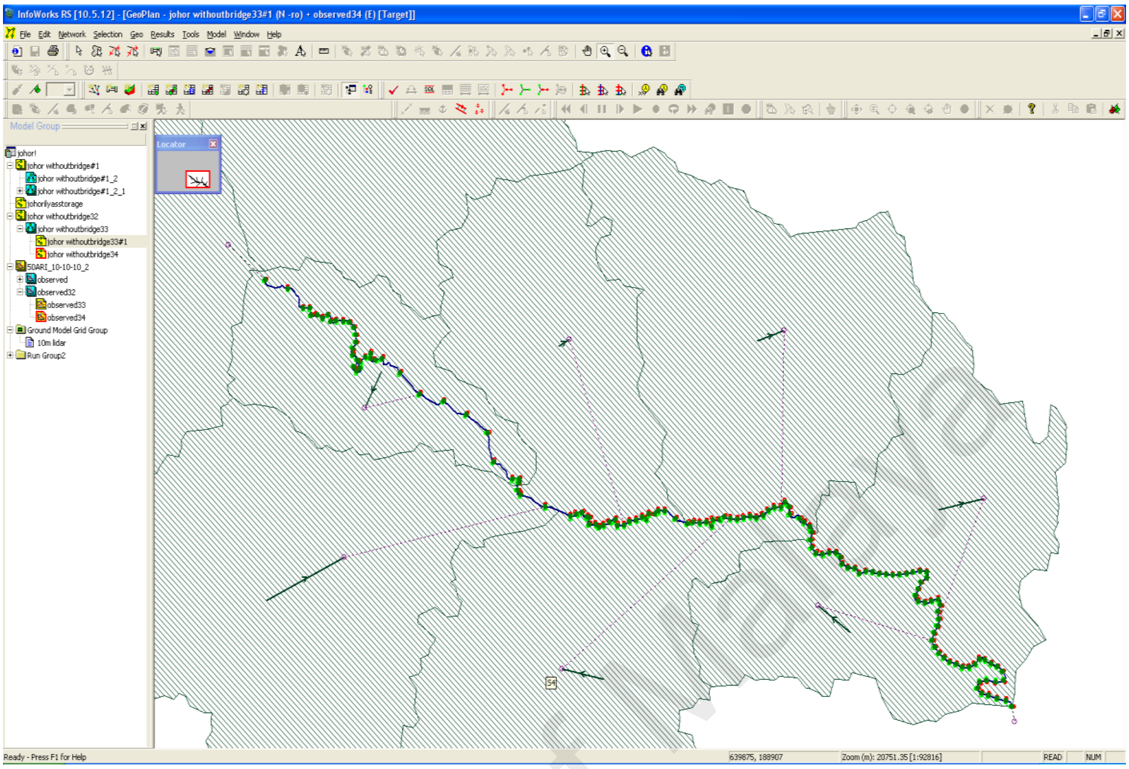


Figure 3.8: The chainage after the river cross section interpolated

5) Then, the hydrology data is keyed in at each boundary node. As the InfoWorks RS has a feature of United State Soil Conservation Services (US SCS). However, the US SCS condition for the Curve Number is set as default which the value is 70.

- The US SCS Method Hydrological Boundary is a hydrological model for determining runoff from rainfall for a sub-catchment using the (US SCS) unit hydrograph method. It is used as an upstream boundary condition.
- The US SCS Boundary requires the input of a Runoff Curve Number (or alternatively the percentage runoff). Runoff Curve Number, CN, determined from a set of tables which are reproduced in the US SCS Method Runoff Curve Numbers topic. The choice of Curve Number depends on an

assessment of the dominant hydrological soil group, the type of land use and antecedent soil moisture conditions.

- The soil of Johor River is sedentary soil and some of the areas are residential and forests area, so the default Curve Number 70 was chosen for this type of soil.

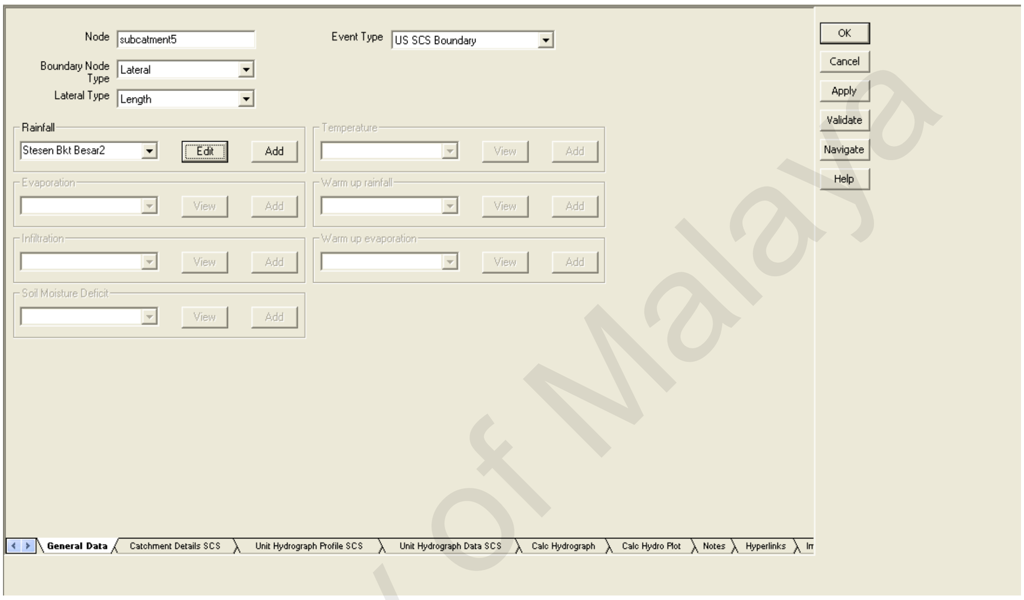


Figure 3.9: The selection of US SCS boundary condition

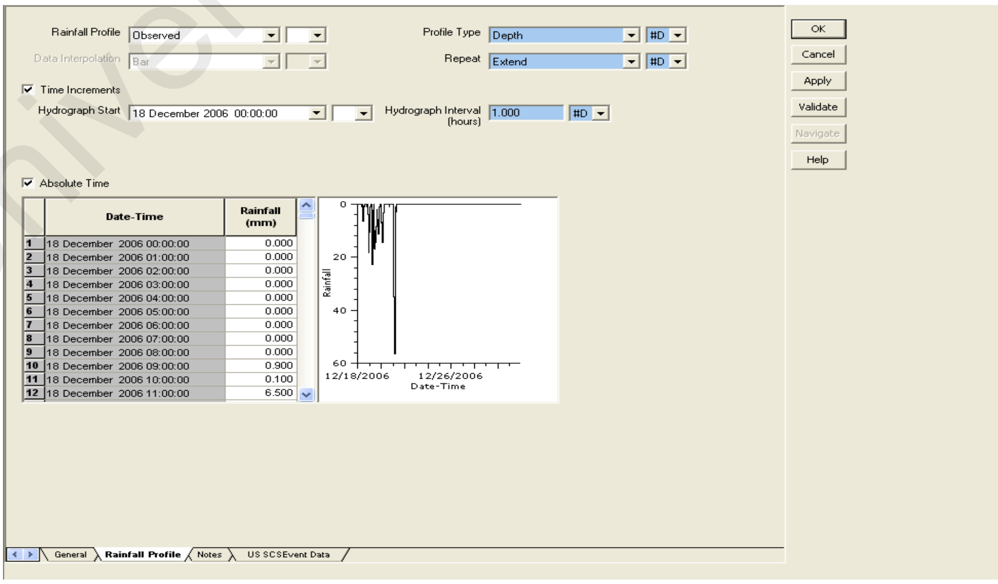


Figure 3.10: The rainfall input data

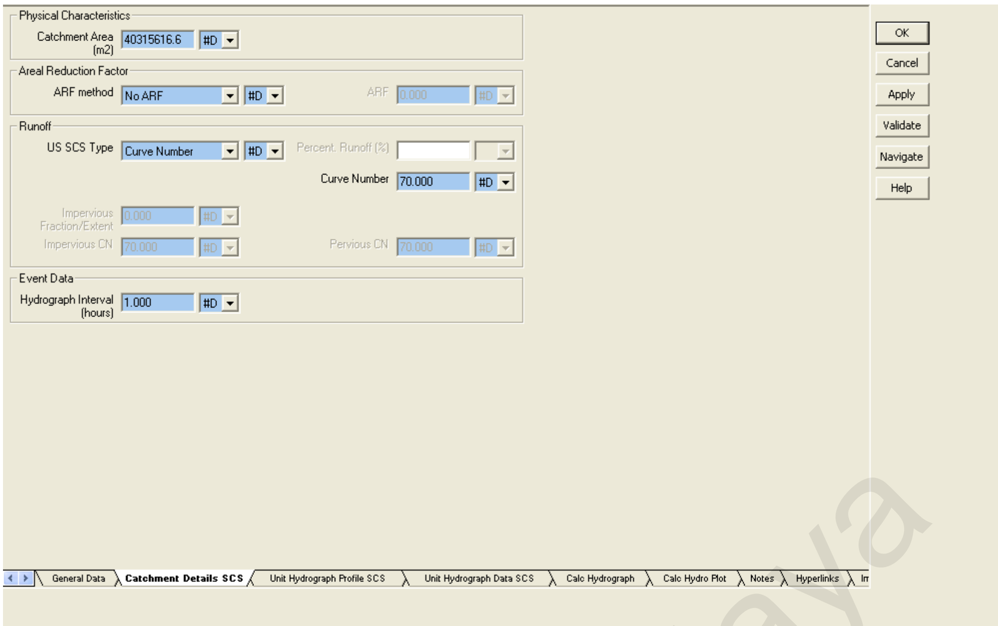


Figure 3.11: The curve number input

6) In the hydrology data input, the time of concentration (Tc) must calculate in order to determine the time of peak (Tp). The time of concentration is the flow travel time from the most hydraulically remote point in the contributing catchment area to the point under study. The concept of time of concentration is important in all methods of flow estimation as it can be assumed that the rainfall occurring during the time of concentration is directly related to flow rate. The time of concentration is often considered to be the sum of the time of travel to inlet plus the time of travel in the stormwater drainage system.

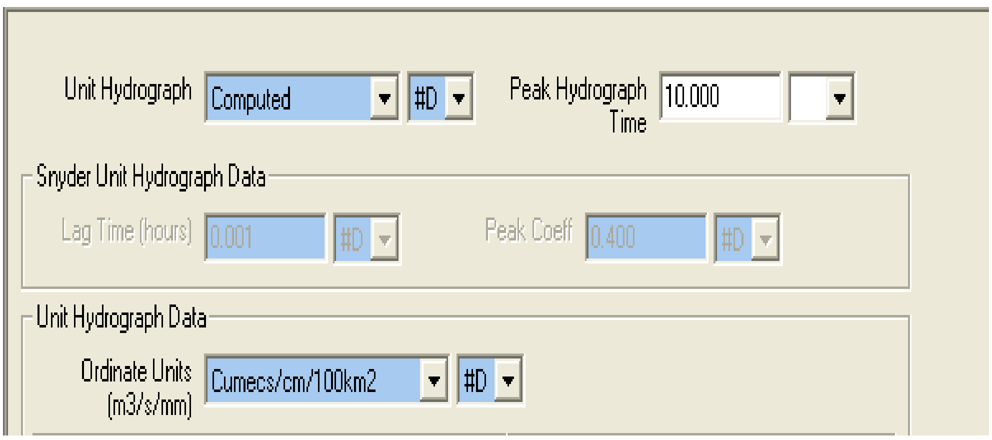


Figure 3.12: The time of peak input

7) The boundary condition for the downstream is keyed in. Normally, the boundary condition selected is tidal wave from the sea. However, in this river modeling the fix water level is used.

8) Before run the model, the validation need to be done for all the data input including the historical data. If there are any errors, the entire data input need to be recheck until there is no error.

9) Next, the model runs in the mode of steady flow. The reasons for running a steady flow simulation are to check the model had been built correctly and able to do simulation then to create initial conditions data to be used for an unsteady flow simulation (Hasan, 2009).

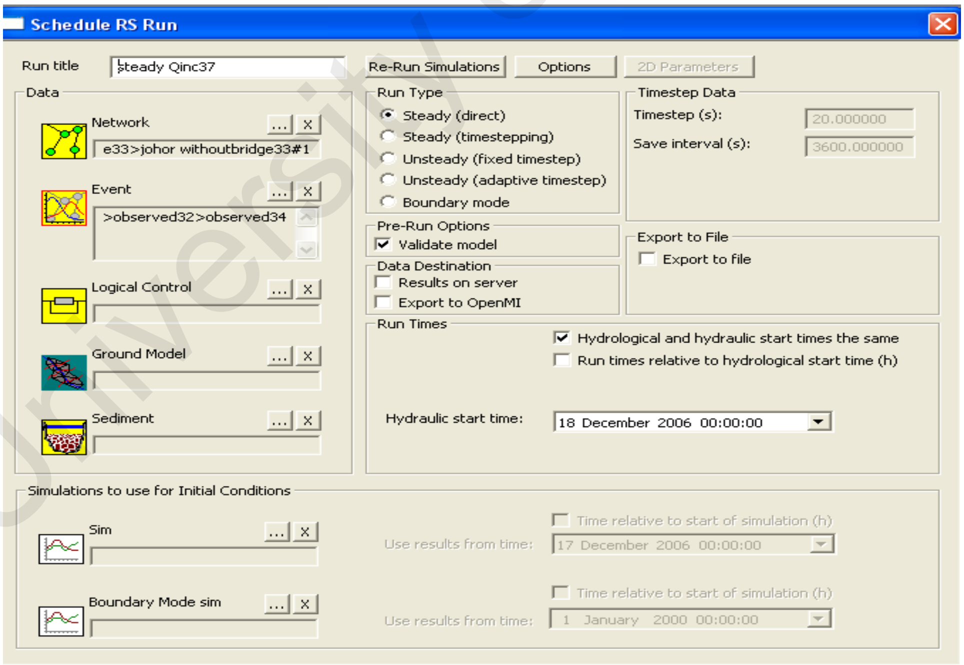


Figure 3.13: Steady flow run

10) Once completed, the model runs in unsteady flow before the result simulation can be used.

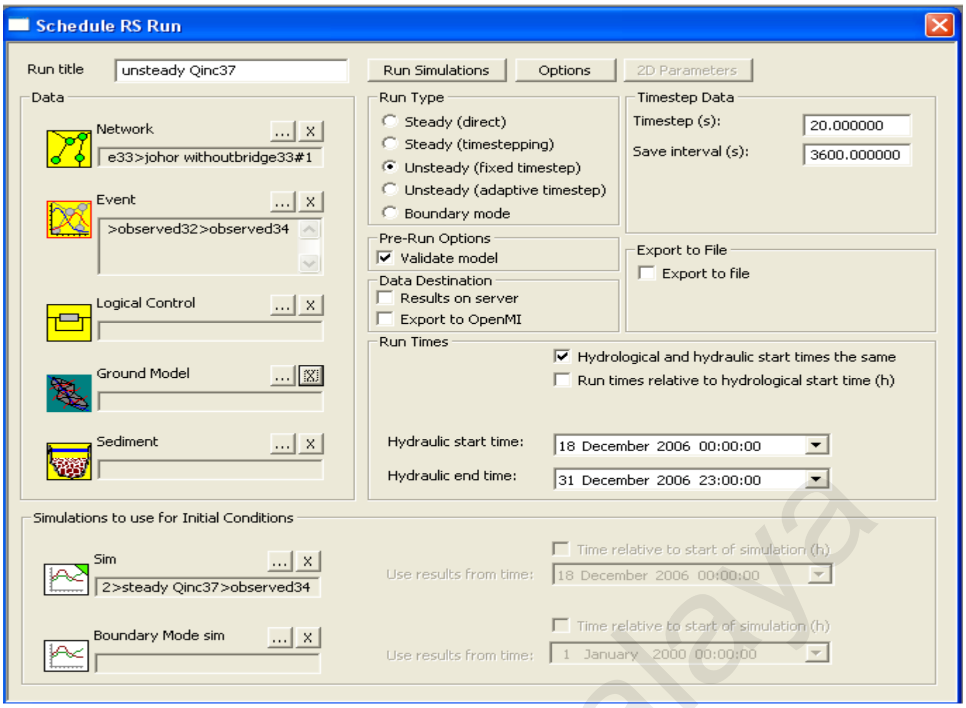


Figure 3.14: Unsteady flow run

11) The process of calibration need to be done as an indicator to the reliability of results.

3.6.2 Steps for 2-D River Flood Modelling Using InfoWorks RS

1) To continue with 2-D model, the spill and polygon need to be inserted. The network of the model still uses the same as 1-D master database.

2) Draw the spill along the river and the type of the cross section is Spill Unit.

Figure 3.15: The spill unit inserted along the river

3) The spill unit properties sheet will appear and refer to section tab that all the elevation are taken from the ground model data.

4) Draw the polygon and connect the spill unit to storage area. The polygon is being created can represent as residential area or the flood storage. Then, validate the network.

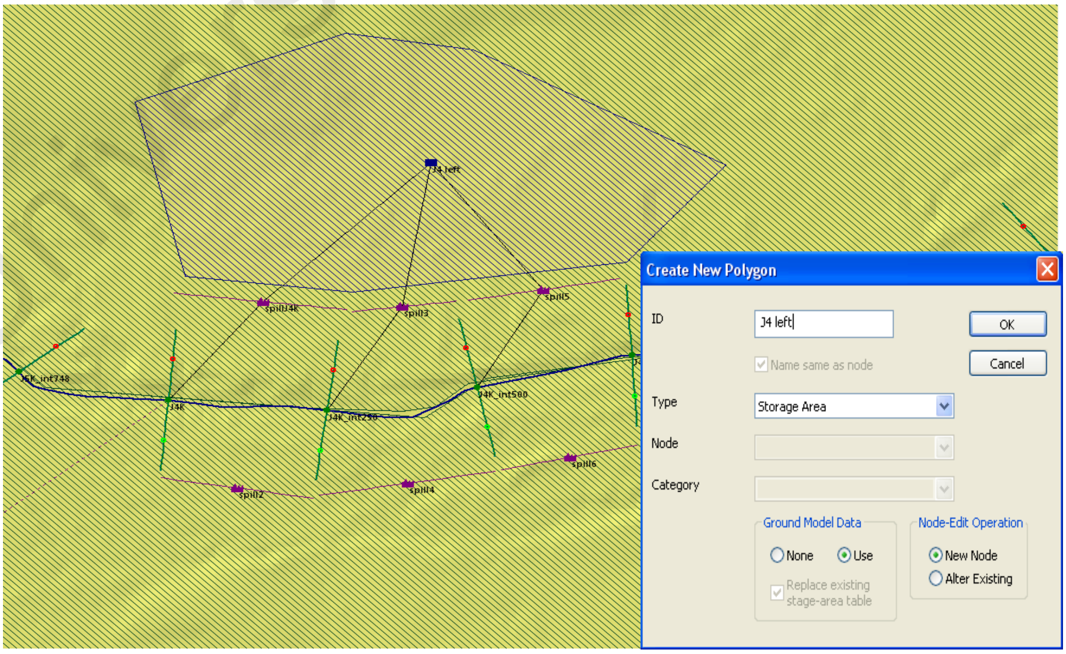


Figure 3.16: The storage area with connected spill link

5) After that, the storage area will be selected and convert to 2D simulation polygons option. The storage will be mesh using the ground model provided. Validate the network and run for unsteady.

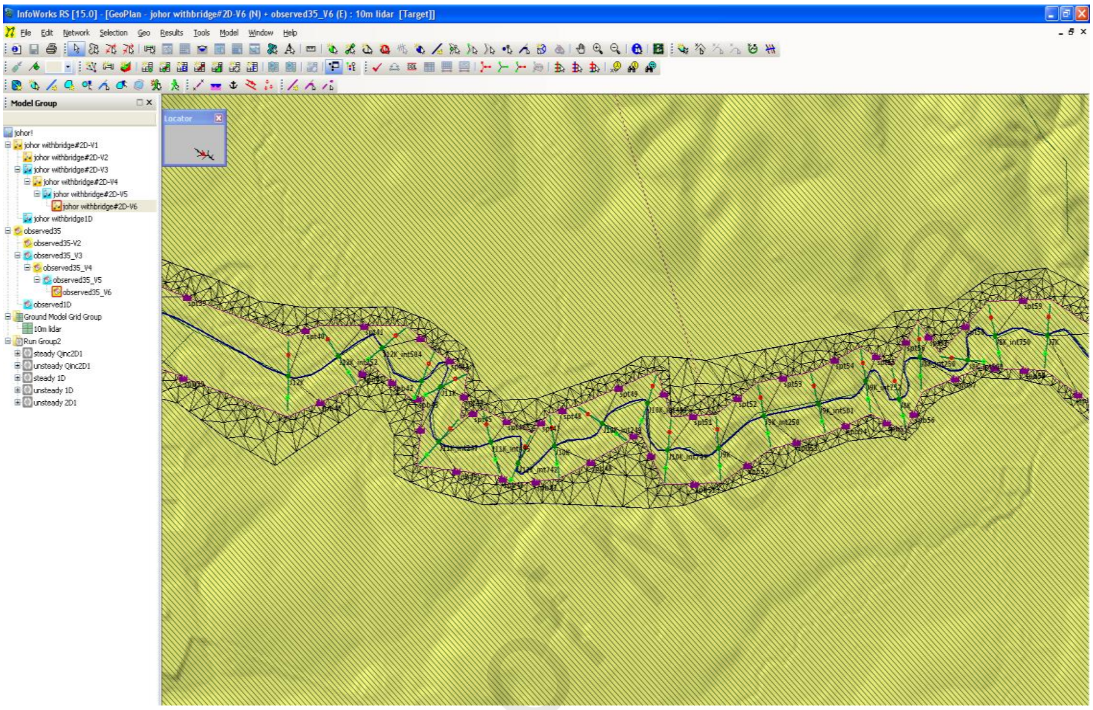


Figure 3.17: The storage area that have been meshed

6) Validate the network and run for unsteady.

3.7 Calibration

Model calibration is adjustment of the parameters of a mathematical or numerical model in order to optimize the agreement between observed data and the model's prediction. Model calibration consists of changing values of model input parameters in an attempt to match field conditions within some acceptable criteria. Before a river model can be used for analysis or design, it needs to be calibrated. This process enables the users to evaluate whether the river model has an acceptable accuracy.

In a simple term, calibration is a process where a designer adjusts parameters and hydraulic coefficients to enable the mathematical model to represent the river system correctly. This is achieved by comparing the simulated flood event to the real flood occurrence. One of the popular approaches is to adjust manning roughness value (η) and hydraulic coefficient such as weir and bridge. For hydrologic model CN value is used to describe land use of the catchment. However it is important to note that calibration can only be done once the physical information of the river system is available. It implies that the correct insertion of river cross section or size of a weir will ensure correct results, thus avoid unnecessary manipulation. Various approaches can be applied to carry out calibration. A good calibration is to compare observed hydrograph at a gauged location with simulated hydrograph (Hasan, 2009).

3.8 Hazard Mapping Phase

Once the model results were verified, the discharge values corresponding to each return period from the frequency analysis in the first phase were input in the model to simulate flood in the same calibrated geometric data and boundary conditions. In this study the discharge for 50 and 100 years were used for flood hazard mapping. Steps for flood mapping are:

1) Create a new TIN and browse DEM file into source

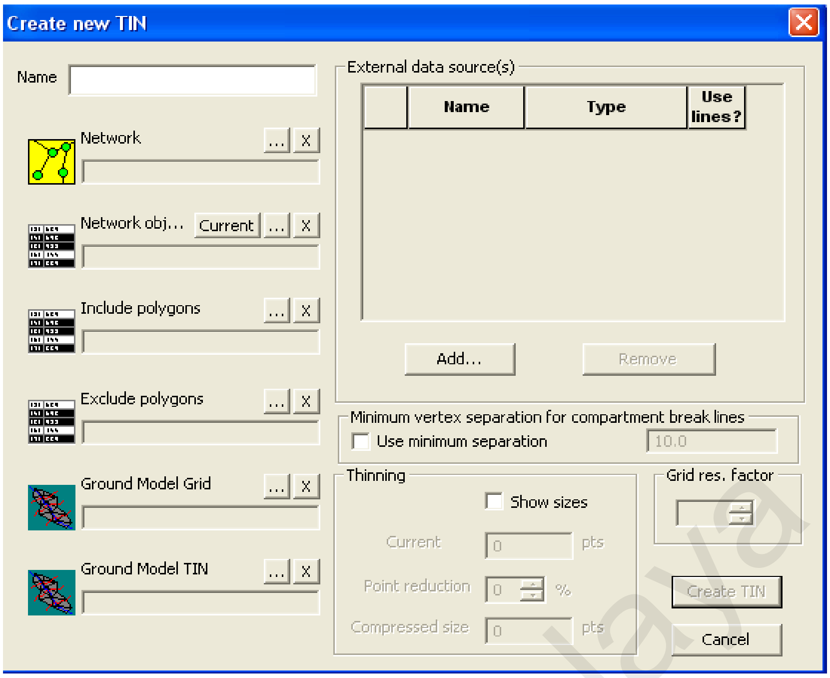


Figure 3.18: Create a new TIN

2) TIN is now created. The Earth surface of Johor River Basin is now visible

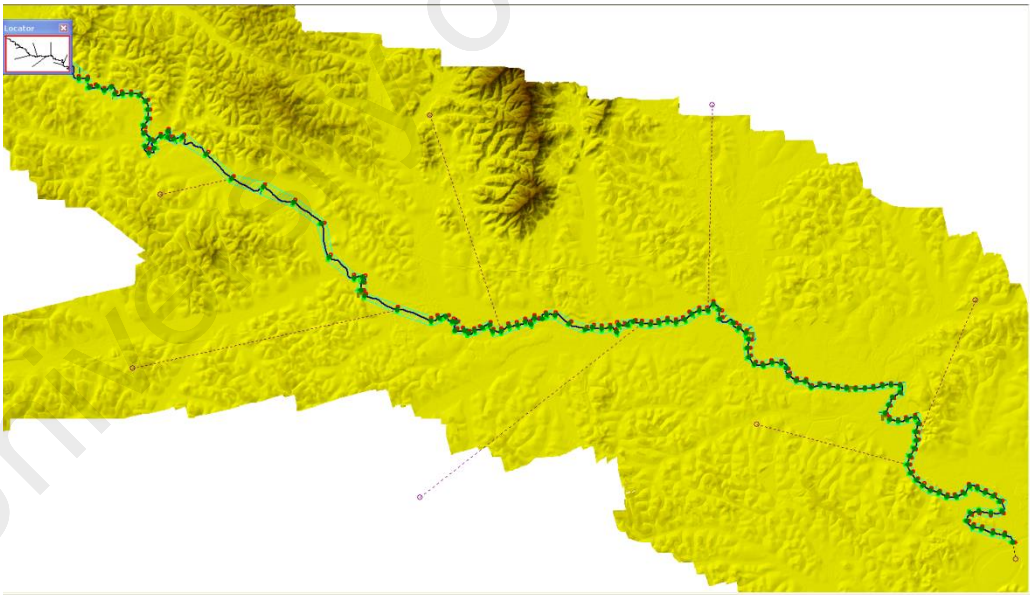


Figure 3.19: Johor River basin TIN

3) Generate flood map by run this model include the TIN file

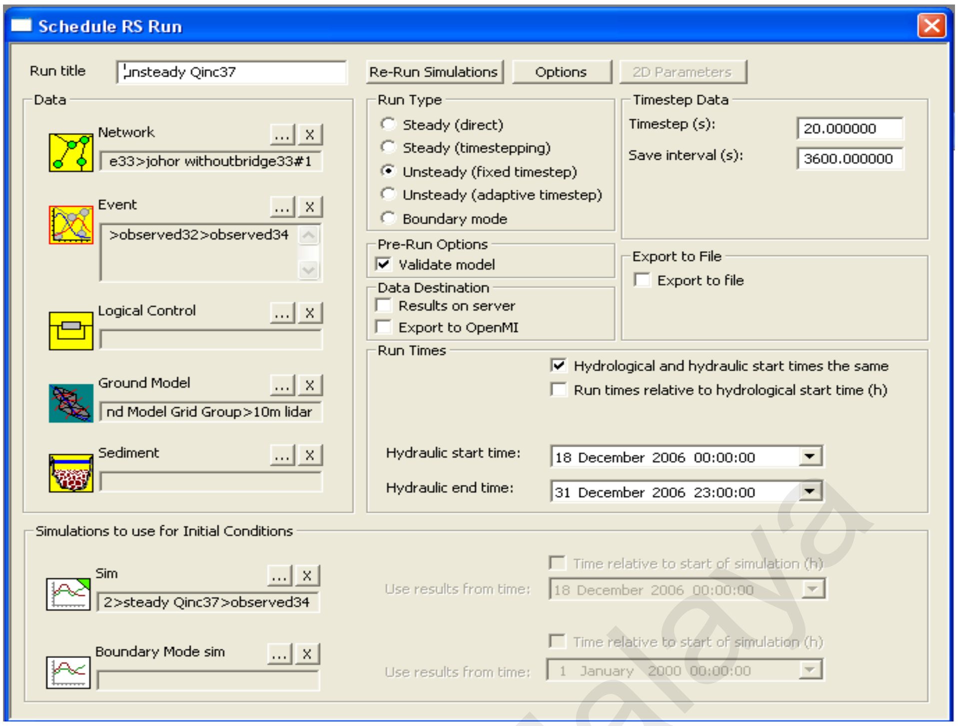


Figure 3.20: Run model for flood mapping

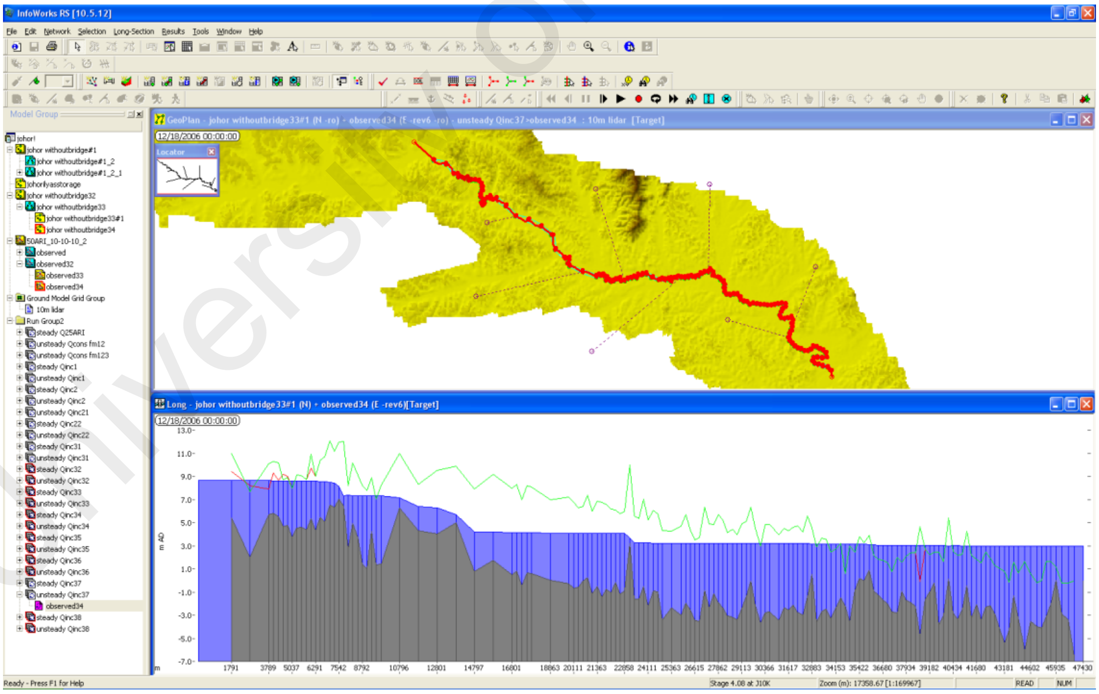


Figure 3.21: River simulation in Long Section

CHAPTER 4: RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussions. The layout and boundary conditions of Johor River model had been discussed. The hydraulic analysis was performed. The flood hazard map is presented in this section for the selected time of return period. The flooding area of Johor River had been determined and the calibration had been done.

4.2 Development of Johor River Model

Moreover, regarding of Johor River model, it is important to know the layout of river, the cross section starting point and cross section end point. In this river modeling, we started from Johor River downstream near the estuary and started with chainage JHR00 and end at chainage J30K. The chainage is separated by 1 km interval and thus 46 cross sections totally need to be keyed in. However, in this river modeling, in order to get more accurate results, InfoWorks RS got a feature where the cross section can be interpolated into 250 m interval. Hence, some of the cross sections in the Johor River layout are 250 m interval from each other. The total of the cross-sections is 147. The manning coefficient, n value was done by trial and error method and determined to be in range of 0.035 to 0.20. The Johor River layout is shown in figure 4.1. The real chainage is indicated in the layout (Figure 4.1).

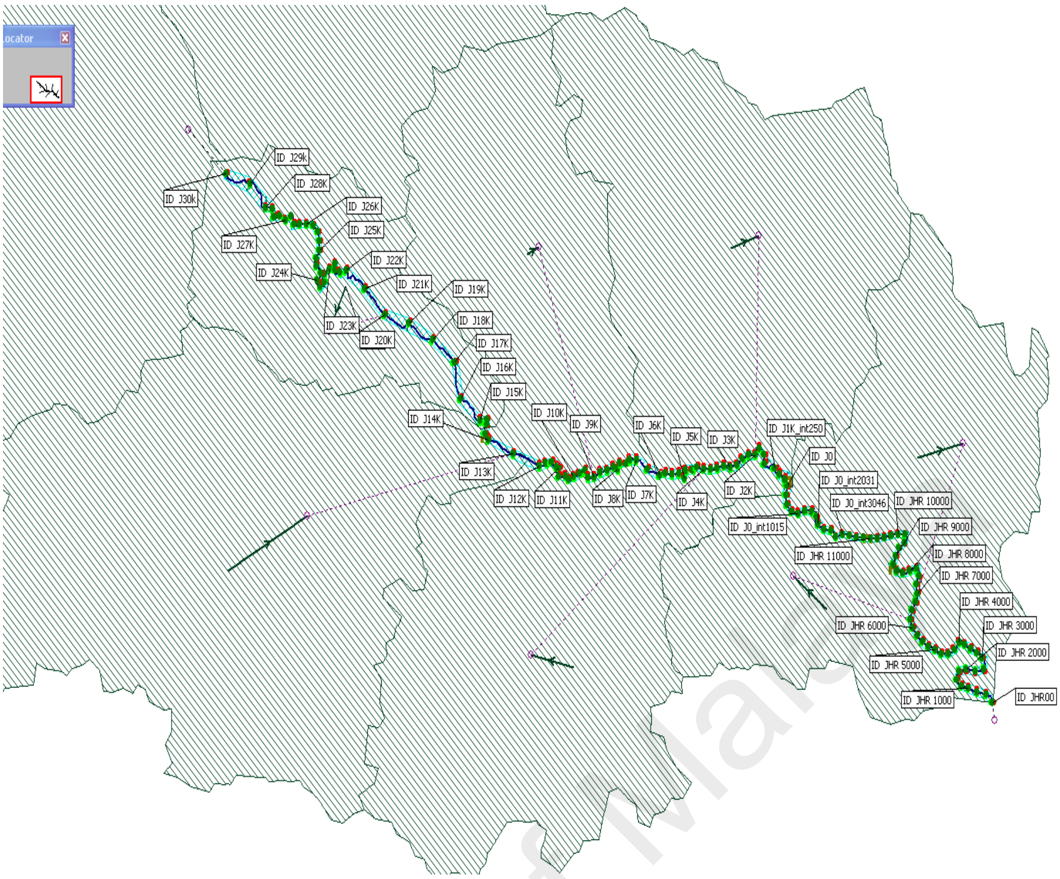


Figure 4.1: Johor river layout

There are six locations of Johor River have been considered for the simulations. Figure 4.2 show the locations starting from the upstream are Rantau Panjang, Lebak, Semangar, Pelepah, Telor and Kota Tinggi. All the locations were chosen based on the main tributaries along Johor River.

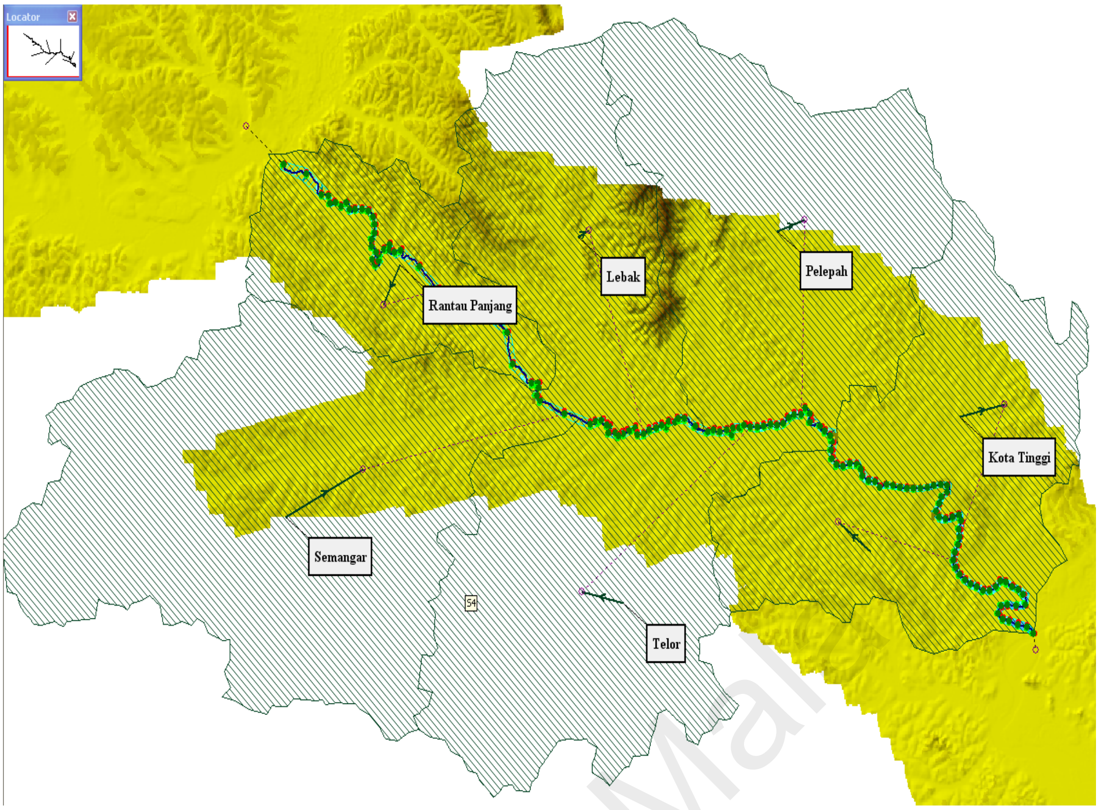


Figure 4.2: The locations along Johor River

There are nine boundary nodes along Johor River including upstream and downstream boundary. The ID of the boundary nodes in InfoWorks RS is such as B1, B2, B3, B4, B7, Subcatchment 5 and B6. The ID of upstream boundary is ‘p’ and for downstream boundary is Seluyut confluence. Every boundary nodes data is the input of Bukit Besar rainfall station data. The data for every chainage, data for every boundary nodes, upstream and downstream boundary data had been attached in the APPENDIX A: Input data for chainage and boundaries.

4.2.1 Hydraulic Analysis

After run InfoWorks RS, the water level in six locations of Johor River has been considered. Rantau Panjang, Semangar, Lebak, Telor, Pelepah and Kota Tinggi are locations the water level is considered. The water level simulation, water level profile, flow and velocity simulation will be shown for the analysis.

4.2.2 Water Level Simulation

The following figures show the water level for 50 ARI for Rantau Panjang and Kota Tinggi during flooding event. The other four locations had been attached in the APPENDIX B: InfoWorks RS Results for 1-D modeling. The top blue line is the maximum water level (Max WL) and the below blue line is the minimum water level (Min WL). Figure 4.3 shows the water level at Rantau Panjang with minimum water level is 6.9 m and maximum water level is 9.9 m. The normal level is 4 m, alert level is 7 m and warning level is 9 m. Figure 4.4 shows the water level at Kota Tinggi with minimum water level is 2.0 m and maximum water level is 7.1 m. The normal level is 1 m, alert level is 2.2 m and warning level is 2.7 m.

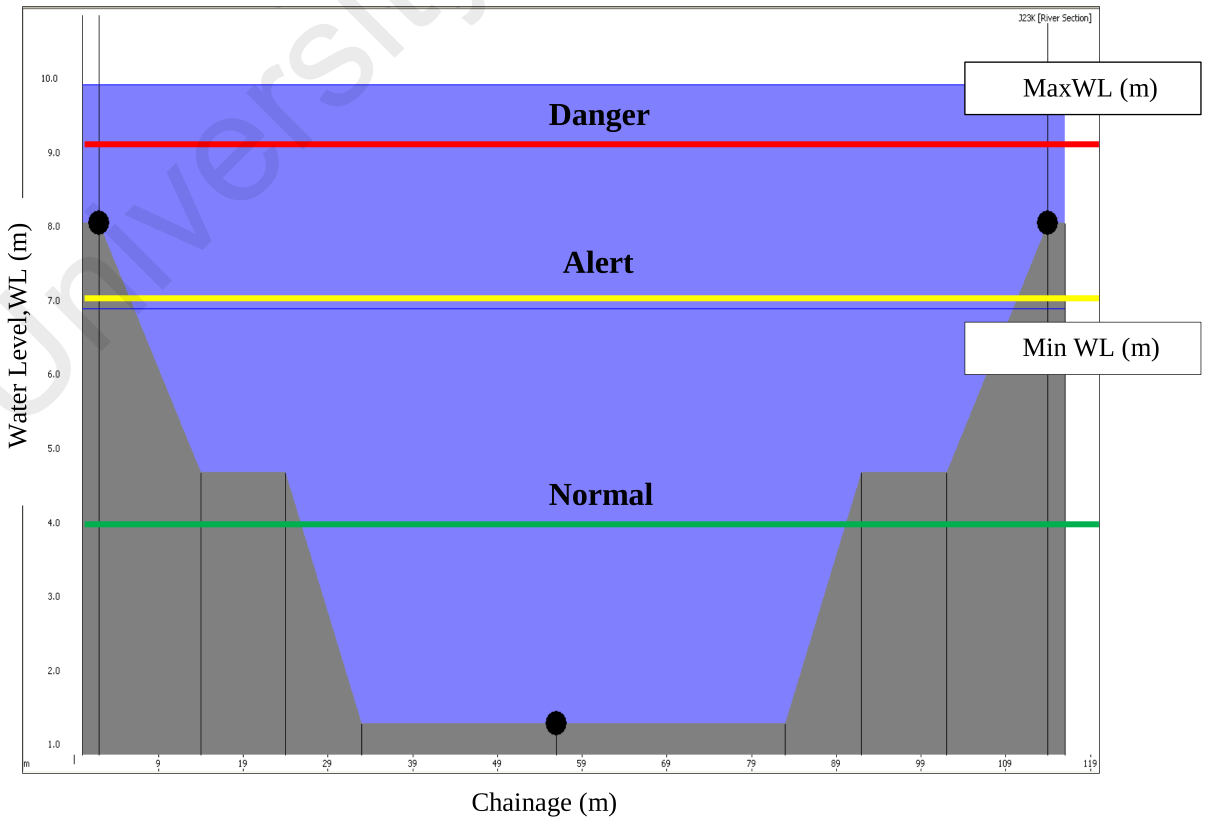


Figure 4.3: Rantau Panjang-50 ARI (J23K)

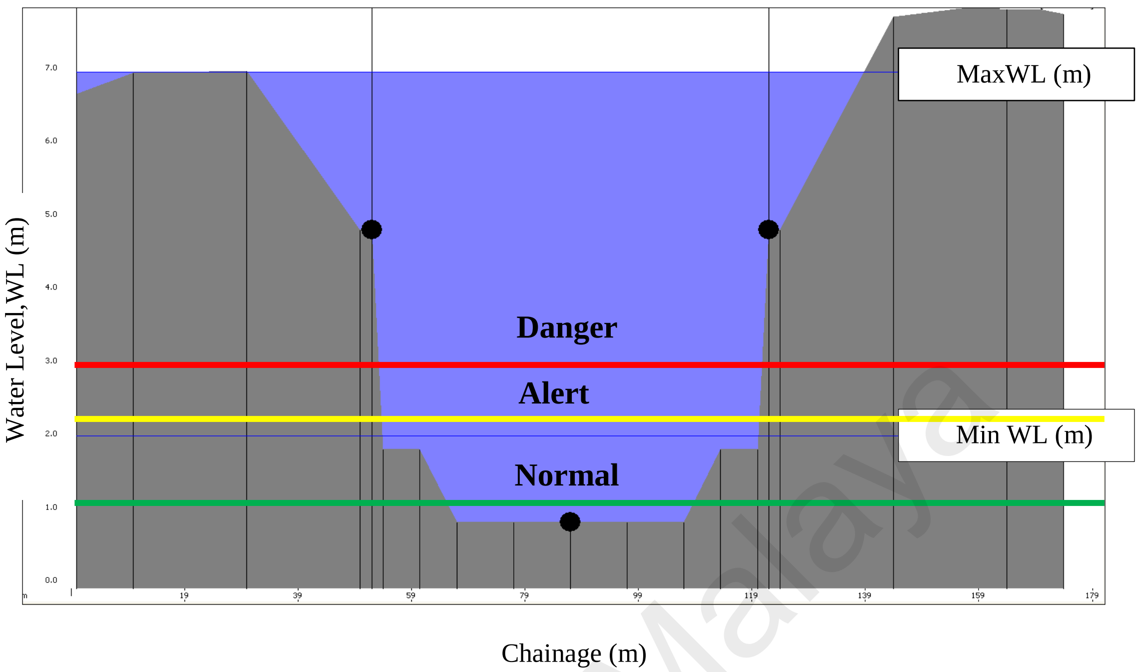
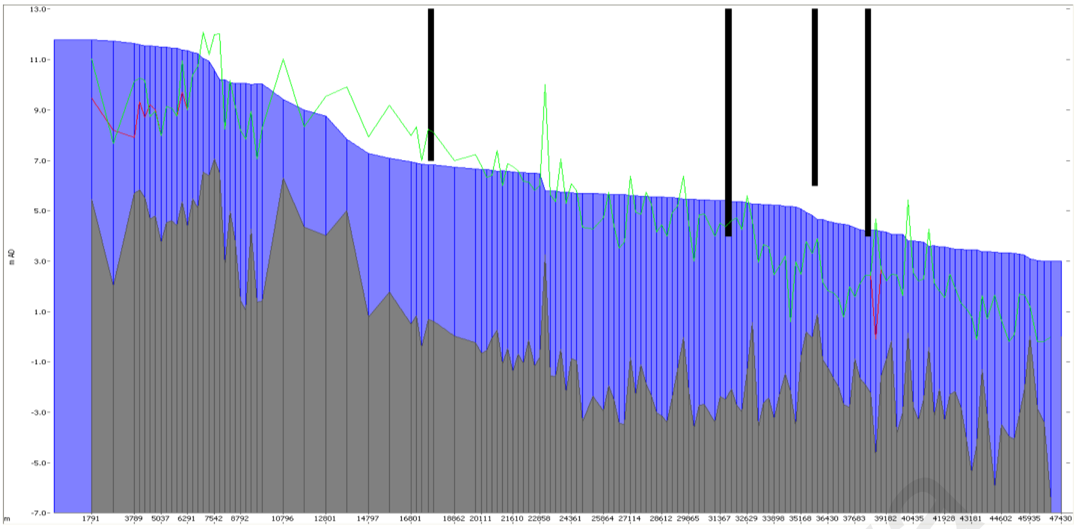


Figure 4.4: Kota Tinggi-50 ARI (JHR11000)

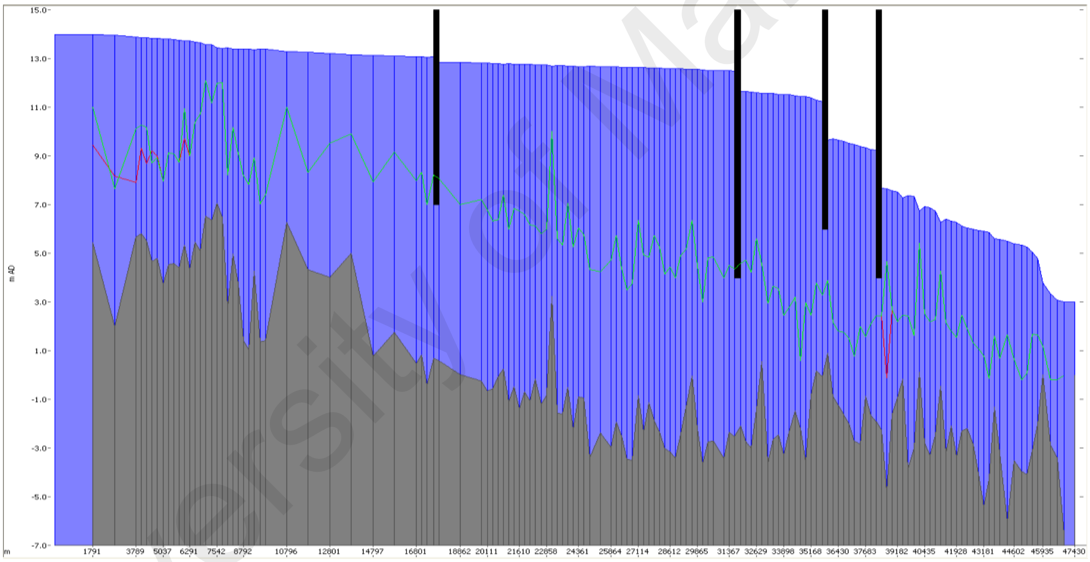
4.2.3 Water Level Profile

Water level modeling has been done for 50 and 100 ARI in Johor River by InfoWorks RS. In the modelling the red line shows the left bank of the river and the green line shows the right bank of the river. Figure 4.5 and Figure 4.6 show the water level from upstream to downstream of Johor River for 50 and 100 ARI respectively. The four vertical black lines represent the bridges inserted along Johor River. The water level for 100 ARI is increasing from 50 ARI water level and it rise near to the top of the bridges. For 100 ARI profile, it shows that all locations along Johor River will be flooded because of the water level is higher than the bank level. The size of flood areas for 100 ARI will be bigger than 50 ARI due to the higher water level that will extent the flooding area. From this observation, the administrative bodies can design the bridges according to this model results.



Cross Section

Figure 4.5: Long section profile for 50 ARI



Cross Section

Figure 4.6: Long section profile for 100 ARI

The location were affected by the flood along Johor River are Kampung Rantau Panjang, Kampung Semanggar, Kampung Baru Sungai Telor, Kampung Batu 25, Kampung Sungai Berangan, Kampung Sri Jaya, Kampung Tembioh, Kampung Kelantan, Kampung Panti, Taman Mawai, Taman Kota Jaya dan Kampung Makam.

4.2.4 Comparison of simulation results for flow and water level (stage) during 50 and 100 ARI

Figure 4.11 until figure 4.16 show the model simulation results. These results show the comparison of water level and flow during different ARI (50 and 100 years) in different locations. The green lines indicate 100 ARI and the blue line indicate 50 ARI. From the simulation graphs, the results for 100 ARI are higher than 50 ARI results for flow and water level but the pattern of the graphs for both ARIs is the same. The higher result for 100 ARI is due to the amount of flow occurring in the river is higher than 50 ARI.

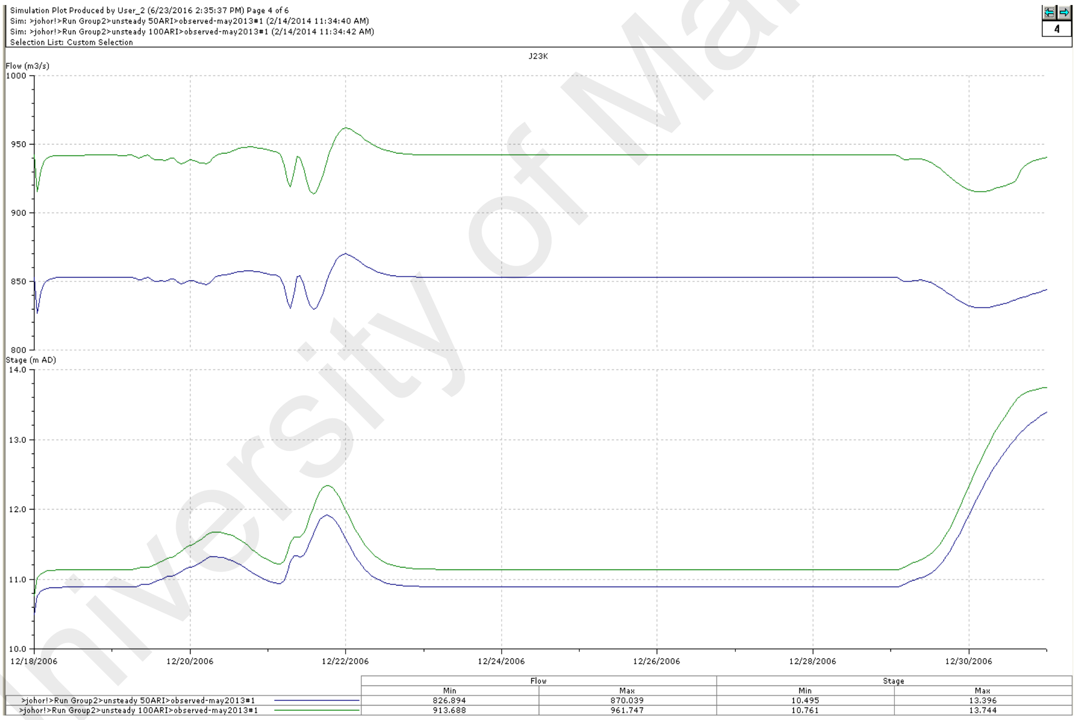


Figure 4.7: Flow and water level comparison for for Rantau Panjang (J23K)

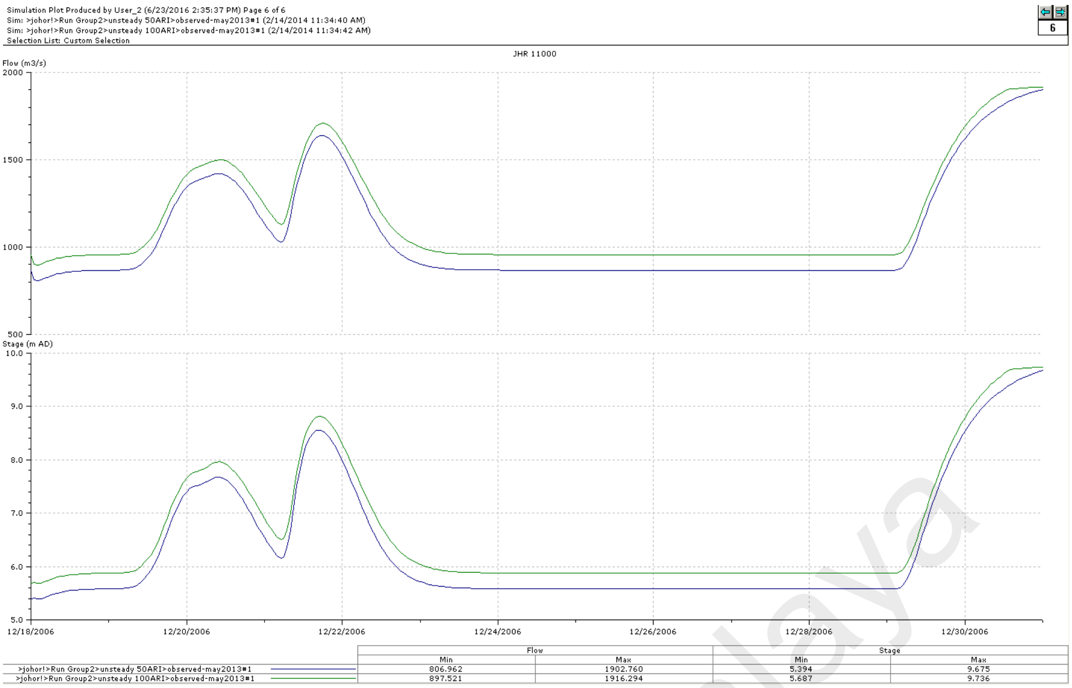


Figure 4.8: Flow and water level comparison for Kota Tinggi (JHR11000)

4.2.5 Velocity and unit flow simulation results from 1-Dimensional (1-D) and 2-Dimensional (2-D) modelling

The following figures show the velocity and unit flow model simulation results. These results show the comparison between 1-D and 2-D modelling of velocity and unit flow. The green lines indicate 2-D modeling and the blue line indicate 1-D modeling. The differences between the simulated velocity and unit flow are generally high and the overall look is not the same. These differences confirm the importance of the roughness parameter in the floodplains of the river.

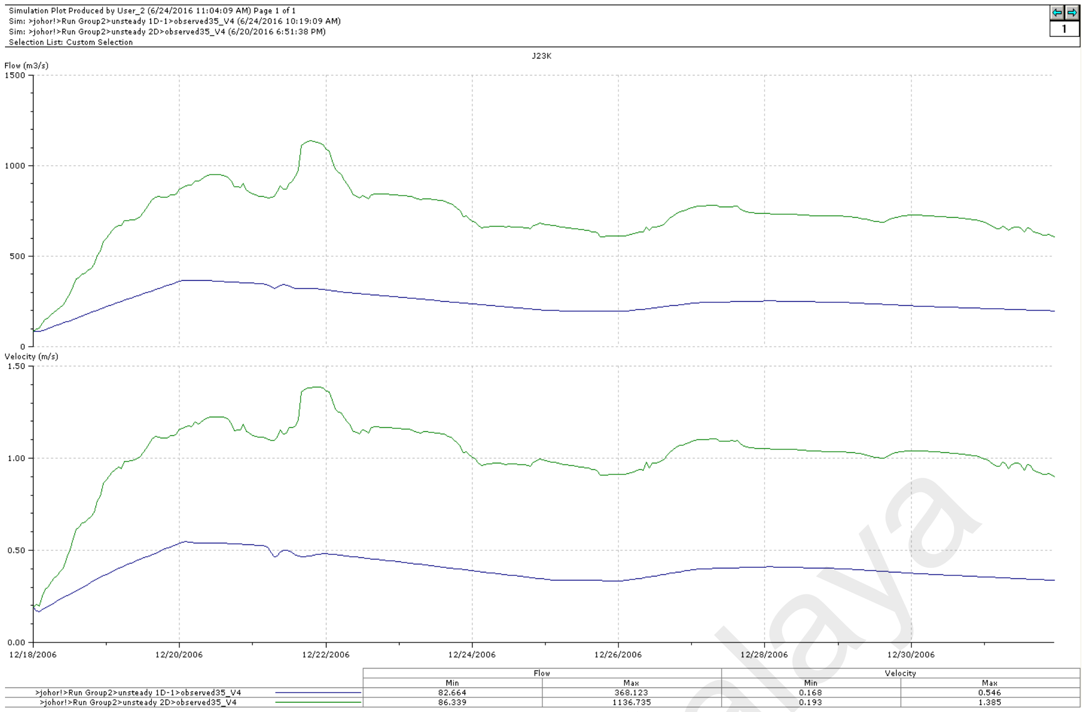


Figure 4.9: Unit flow and velocity comparison for Rantau Panjang (J23K)

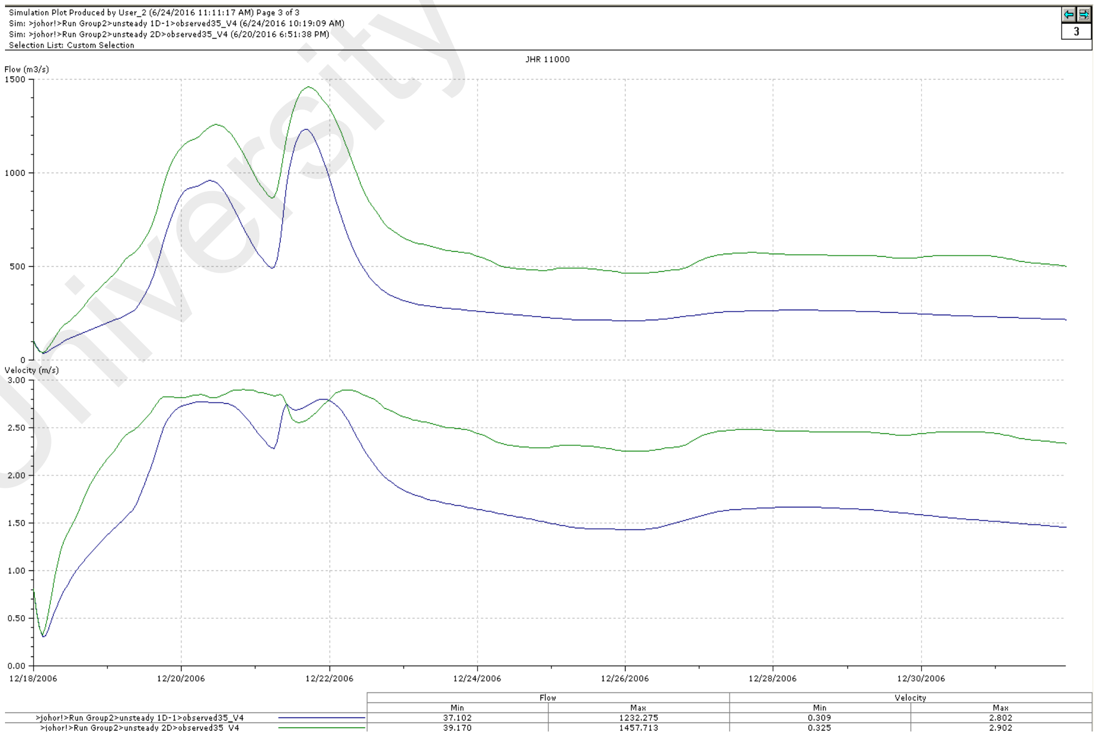


Figure 4.10: Unit flow and velocity comparison for Kota Tinggi (JHR11000)

4.3 Flood Hazard Map

Moreover, after the calibrations have been done, the flood hazard map is produced to give more visualization to the area where the inundation area is determined. In this section, the flood hazard map of Johor River will be shown in two types of modeling views;1-D and 2-D. Figure 4.23 and 4.24 shows 1-D flood map for Johor River before and during flooding respectively. Figure 4.25 and 4.26 shows the zoom in views to Kota Tinggi area flood map before and during flooding respectively. Figure 4.27 and 4.28 shows the 3D view flood map before and during flooding respectively. Figure 4.29 until 4.35 are 2-D flood hazard map of Johor River.

From the flood hazard map, it shows the difference view before flooding and during flooding. The view during flooding shows the water overflows from the normal condition and it shows the flood extent area. The comparison of 1-D and 2-D flood hazard map are 2-D map will give the direction of the velocity and the flooding area will be more accurate than 1-D map.

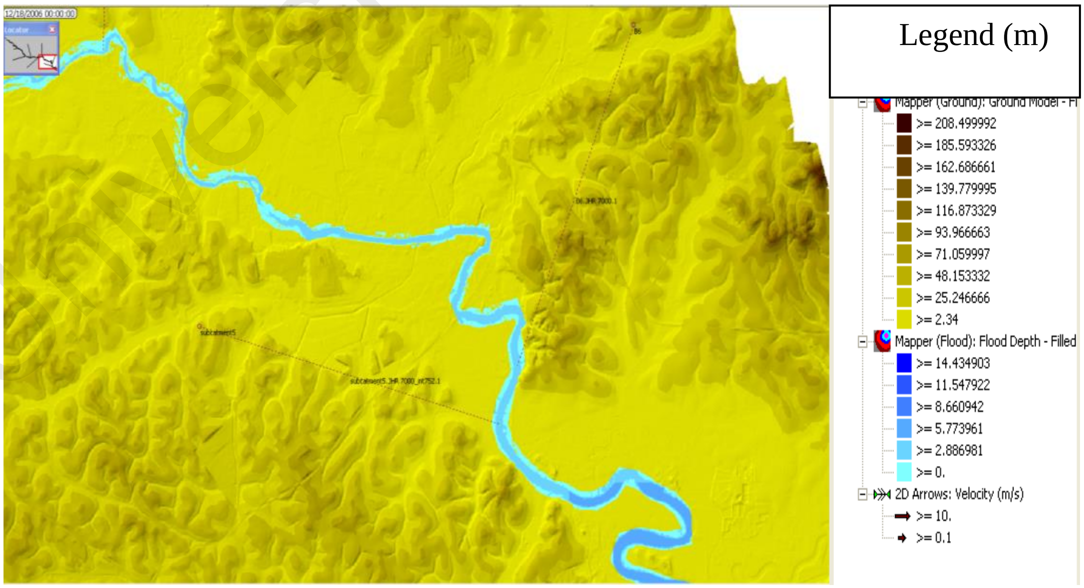


Figure 4.11: 1-D Johor River Flood Map before flooding

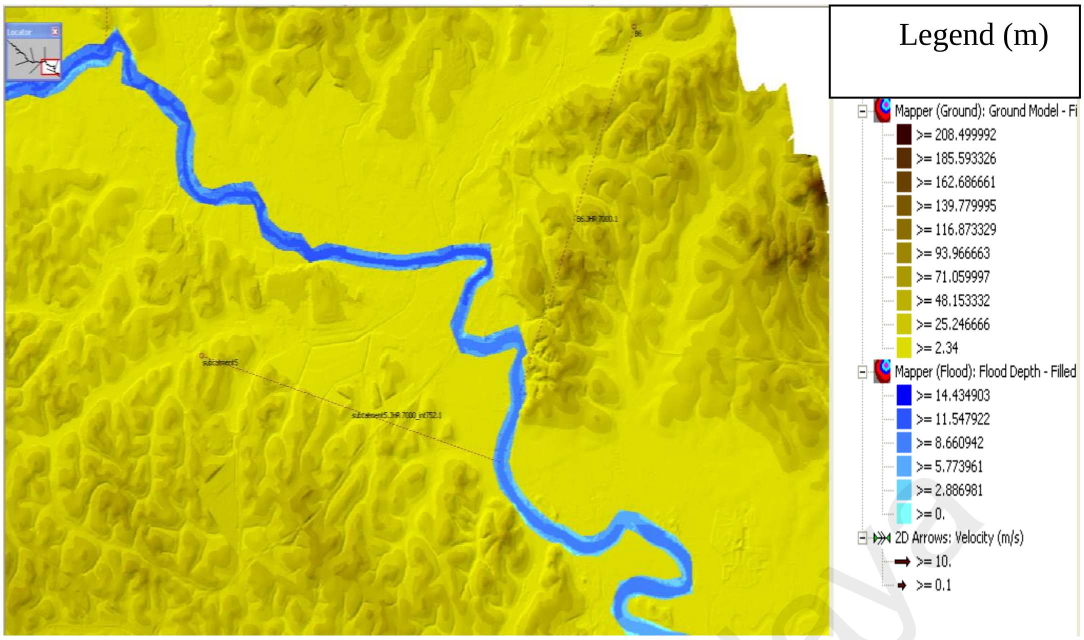


Figure 4.12: 1-D Johor River Flood Map during flooding

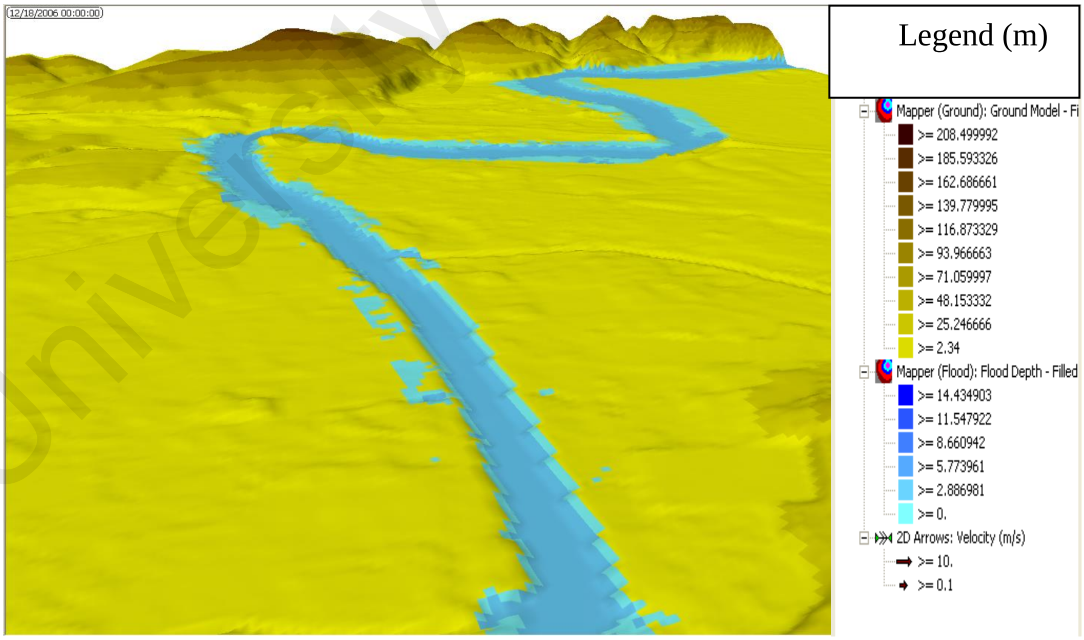


Figure 4.13: Rantau Panjang 3D view Flood Mapping before flooding

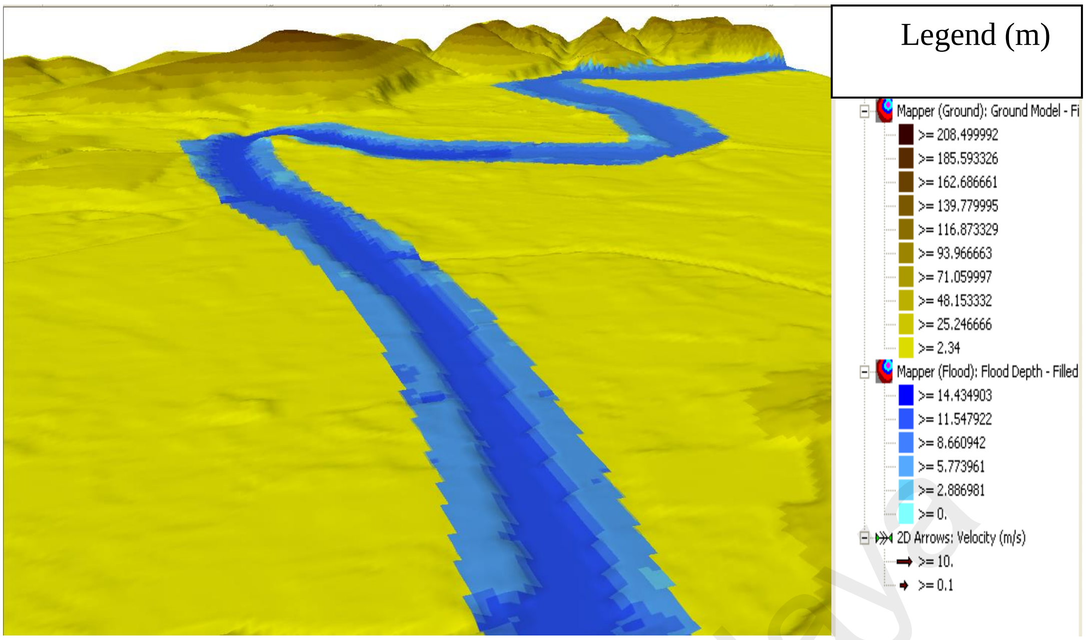


Figure 4.14: Rantau Panjang 3D view Flood Mapping during flooding

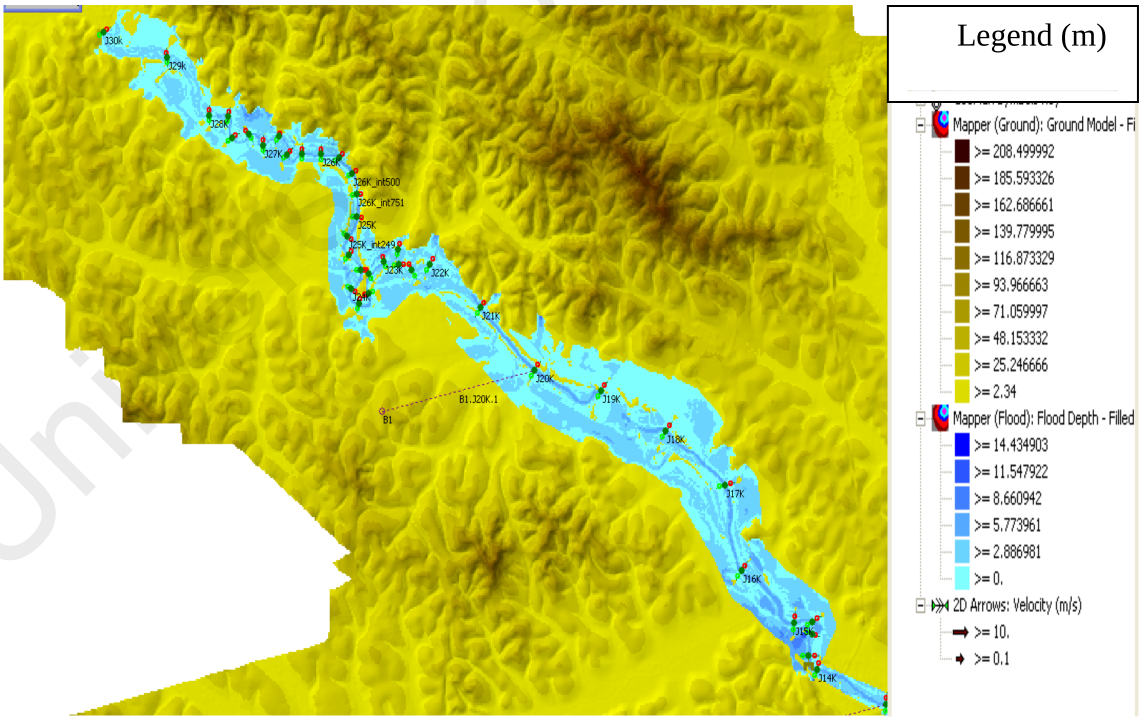


Figure 4.15: 2-D flood hazard map for velocity variation at maximum extent

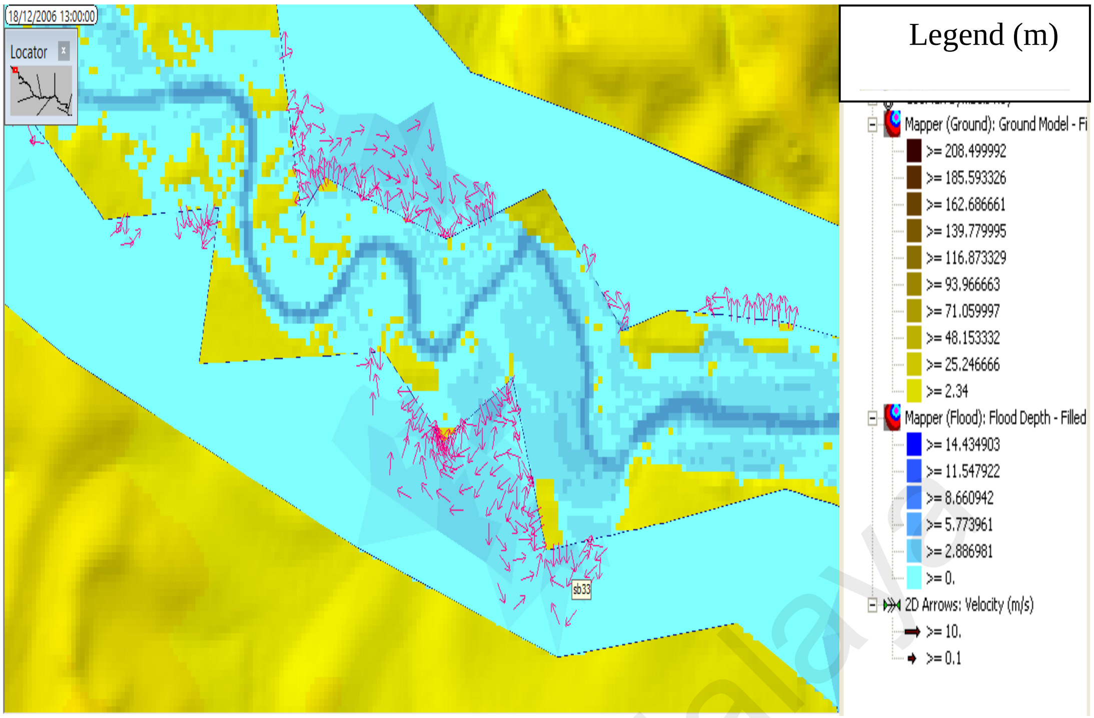


Figure 4.16: Flow direction at 18/12/2006 13:00 hours

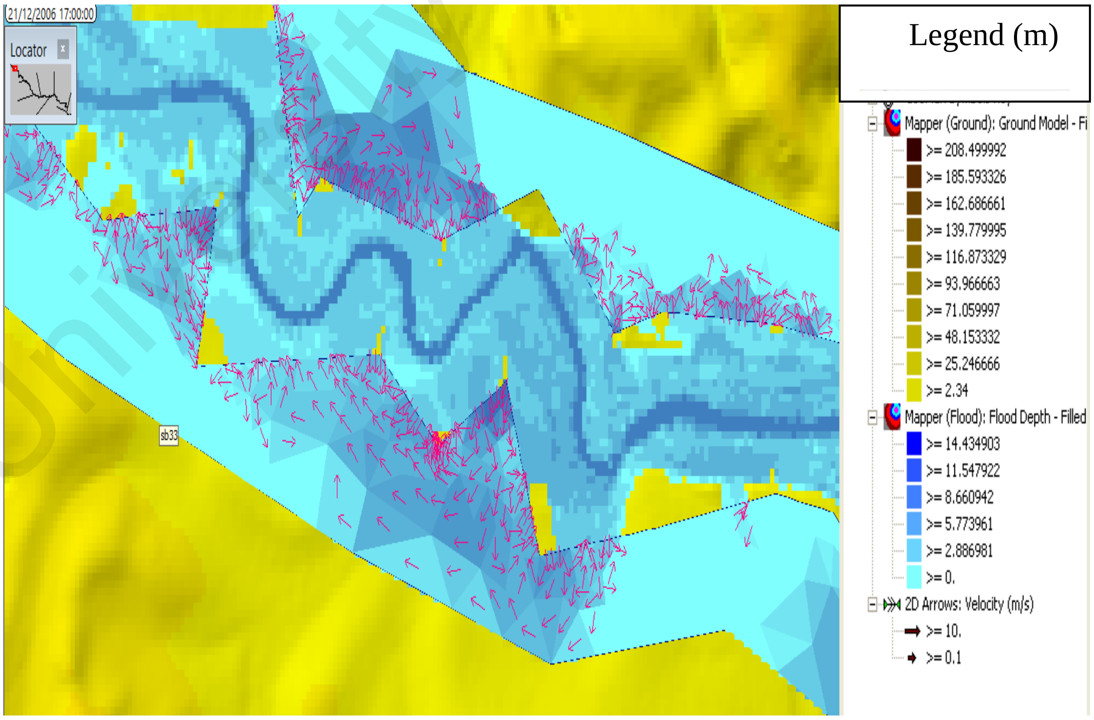


Figure 4.17: Flow direction at 21/12/2006 17:00 hours

4.4 Johor River Flooding Area

Based on the flood hazard map, Rantau Panjang and Kota Tinggi area reach the danger level which is the maximum water level is higher than bank level. Semangar and Lebak area had reach the warning level which is higher than normal level. Then, Telor and Pelepah are just reach alert level which is the water level slightly increasing from the normal level.

The vulnerable areas prone to the flood lies within chainage JHR11000 and J23K as Kota Tinggi and Rantau Panjang located there. In this section, it will be focusing on the data used in this InfoWorks RS modelling and results obtained within these areas. All the output data shown are basically from 18 December 2006 until 31 December 2006. The following are the flood analysis for every location.

4.4.1 Chainage JHR 11000 (Kota Tinggi) Flood Analysis

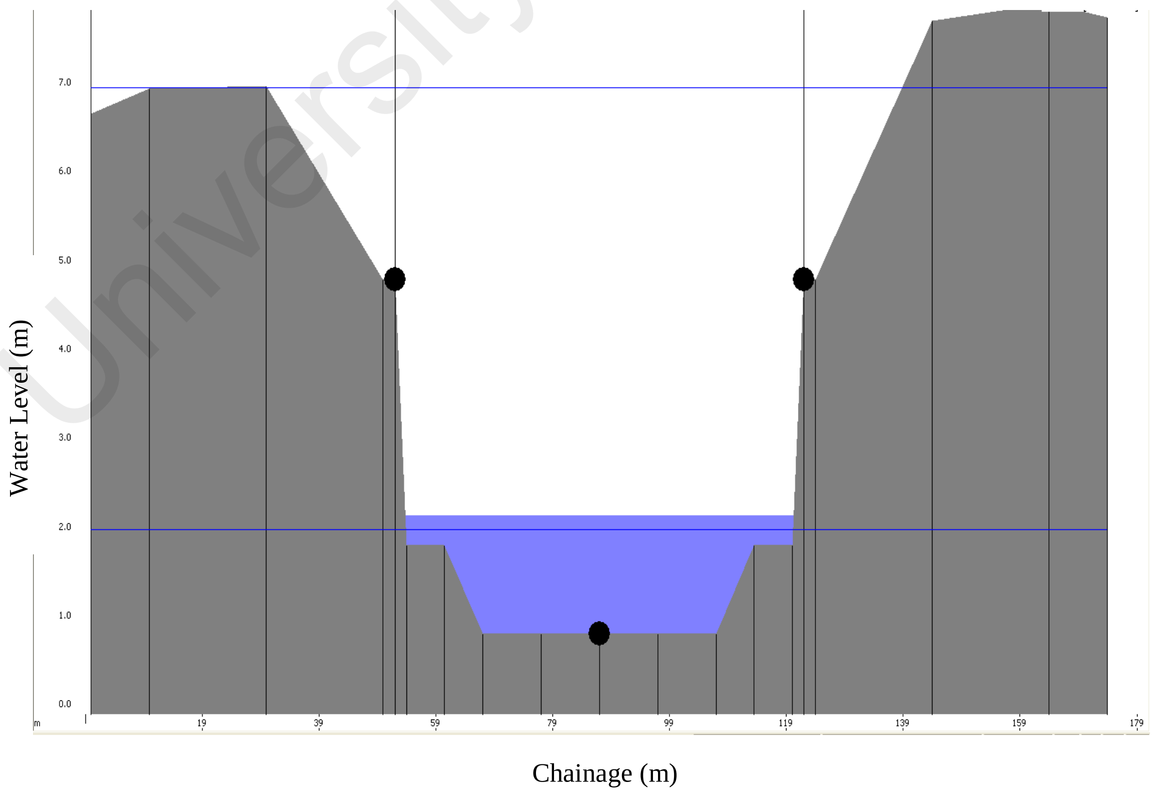


Figure 4.18: Chainage JHR 11000 Cross Section before flooding

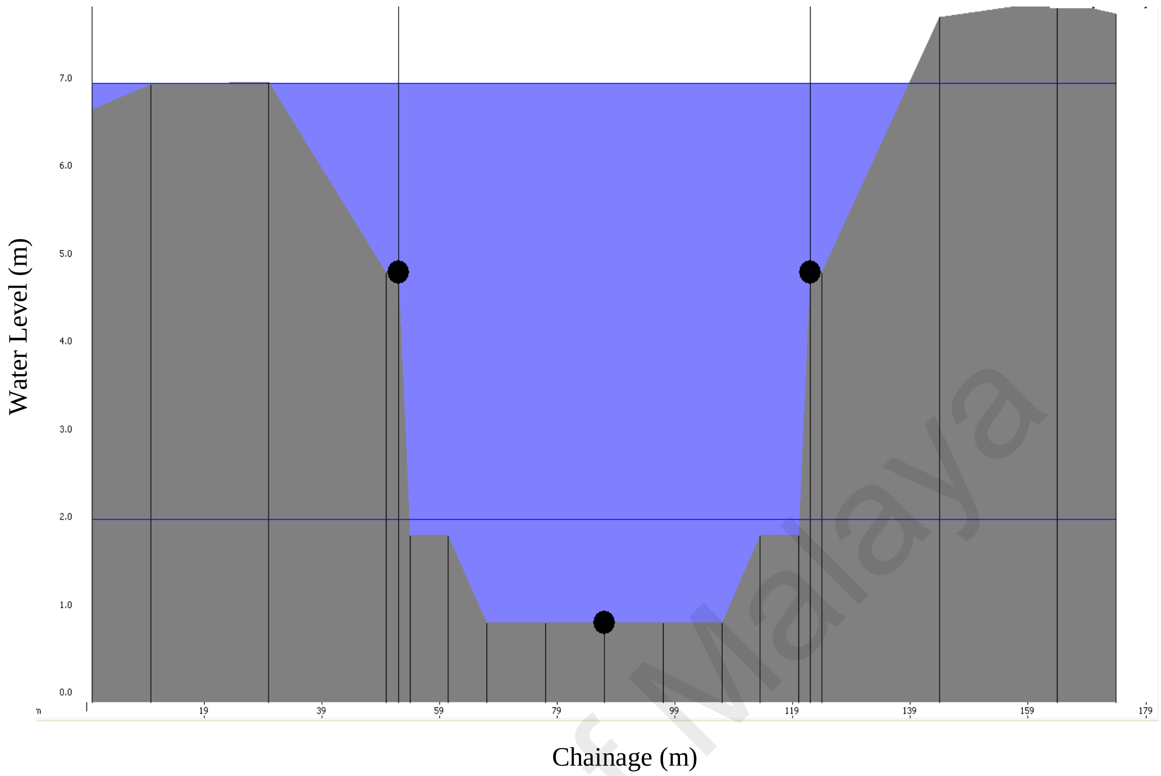


Figure 4.19: Chainage JHR 11000 Cross Section during flooding

The flooding time was started on 21st of December 2006 at 15:00 with the highest water level was 7.054 m and the river bank level was 4.9 m. The flood depth at this chainage was 2.154 m.

4.4.2 Chainage J23K (Rantau Panjang) Flood Analysis

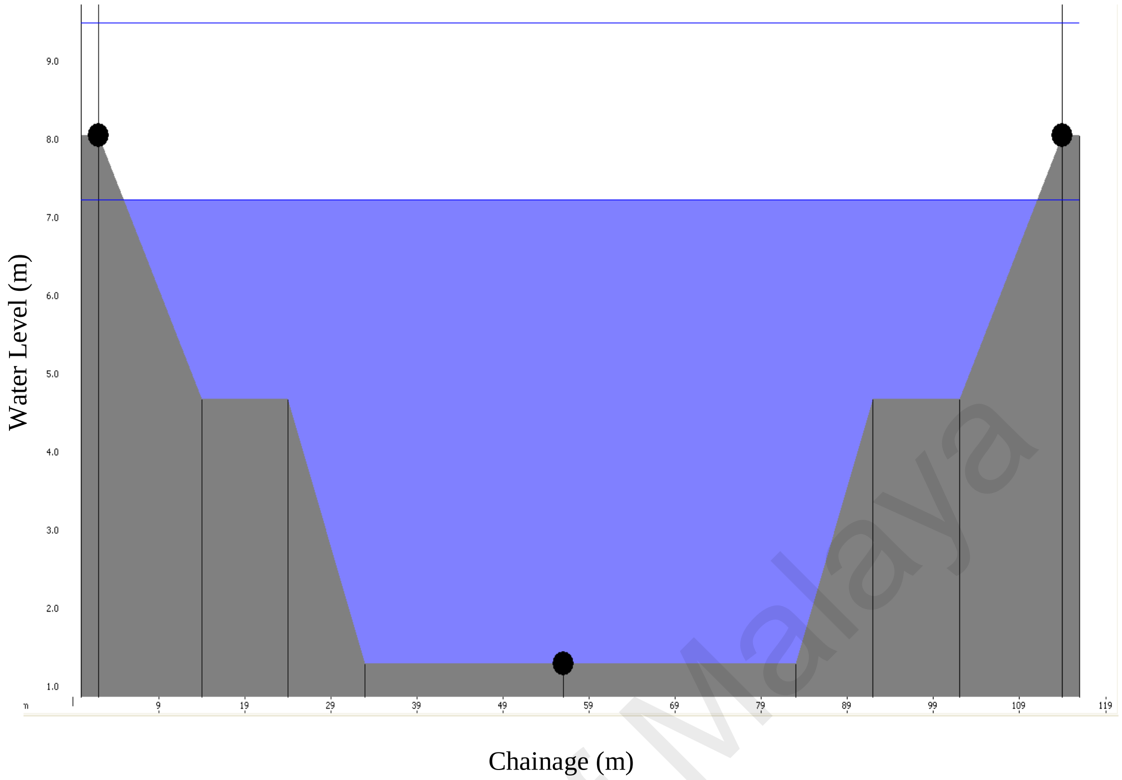


Figure 4.20: Chainage J23K Cross Section before flooding

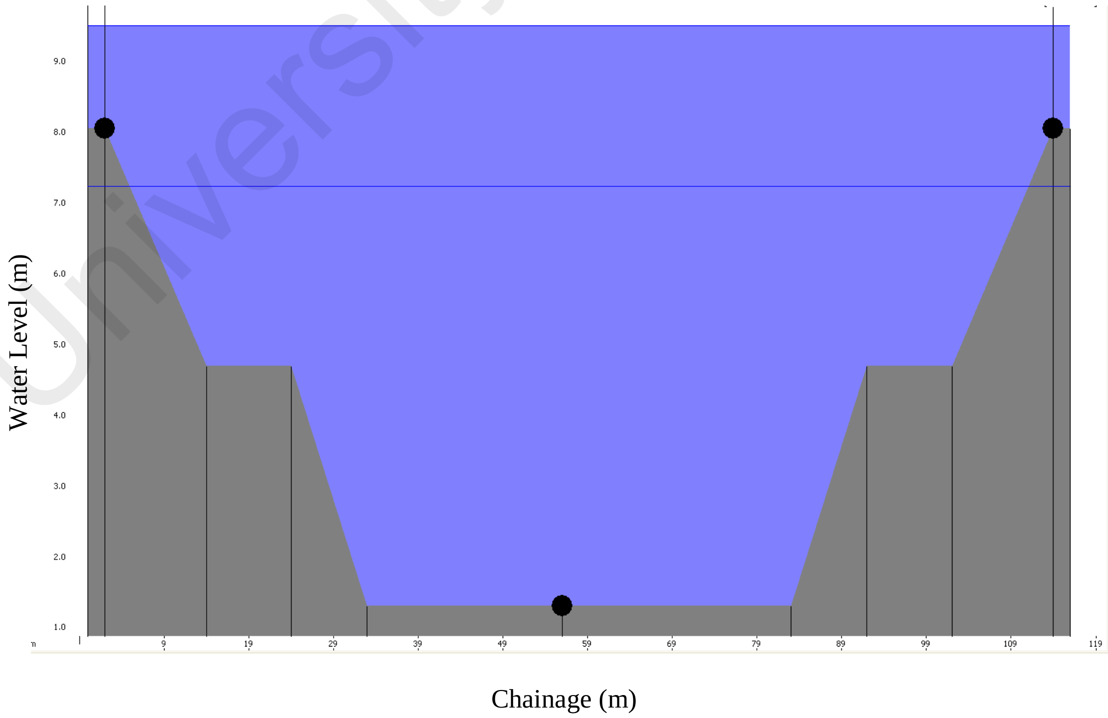


Figure 4.21: Chainage J23K Cross Section during flooding

The flooding time was started on 21st of December 2006 at 8:00 with the highest water level was 9.902 m and the river bank level was 8.94 m. The flood depth at this chainage was 0.962 m.

4.5 Model Calibration

The chainage JHR11000 and J23K as Kota Tinggi and Rantau Panjang are the flooding area in the Johor River layout. Furthermore, the results are focus within this two chainage that lies along Johor River. The output data shown are basically from 18 December 2006 at 0:00 until 31 December 2006 at 23:00. Moreover, the results of steady and unsteady run for this InfoWorks RS are shown for several chainage.

4.5.1 Steady and Unsteady Run Results

The ultimate process in model development is simulation. Simulation will produce result of flow and water level along the river based on input that had entered. A steady and unsteady run result is generating from simulation. Below is the example of the steady and steady run results for grid view.

Table 4.1: The steady run results

12/18/2006 00:00:00

Node	Total Energy (m)	Flow (m3/s)	Froude	Max Total Energy (m)	Max Flow (m3/s)	Max Froude	Max Stage (m AD)	Max State	Max Velocity (m/s)
J0	3.218	101.339	0.030	3.218	101.339	0.030	3.216	0.000	0.173
J0_int1015	3.207	101.339	0.073	3.207	101.339	0.073	3.201	0.000	0.350
J0_int1015_int253	3.203	101.339	0.022	3.203	101.339	0.022	3.202	0.000	0.150
J0_int1015_int507	3.203	101.339	0.028	3.203	101.339	0.028	3.201	0.000	0.189
J0_int1015_int761	3.201	101.339	0.034	3.201	101.339	0.034	3.199	0.000	0.193
J0_int2031	3.199	101.339	0.027	3.199	101.339	0.027	3.198	0.000	0.167
J0_int2031_int253	3.198	101.339	0.038	3.198	101.339	0.038	3.196	0.000	0.200
J0_int2031_int507	3.196	101.339	0.041	3.196	101.339	0.041	3.193	0.000	0.255
J0_int2031_int761	3.194	101.339	0.026	3.194	101.339	0.026	3.193	0.000	0.152
J0_int253	3.216	101.339	0.025	3.216	101.339	0.025	3.215	0.000	0.167
J0_int3046	3.192	101.339	0.032	3.192	101.339	0.032	3.190	0.000	0.214
J0_int3046_int253	3.190	101.339	0.055	3.190	101.339	0.055	3.185	0.000	0.304
J0_int3046_int507	3.179	101.339	0.090	3.179	101.339	0.090	3.168	0.000	0.467
J0_int3046_int761	3.162	101.339	0.083	3.162	101.339	0.083	3.152	0.000	0.449
J0_int507	3.215	101.339	0.024	3.215	101.339	0.024	3.214	0.000	0.161
J0_int761	3.213	101.339	0.041	3.213	101.339	0.041	3.210	0.000	0.242
J10K	4.084	92.339	0.032	4.084	92.339	0.032	4.082	0.000	0.193
J10K_int249	4.083	92.339	0.030	4.083	92.339	0.030	4.081	0.000	0.172
J10K_int499	4.080	92.339	0.036	4.080	92.339	0.036	4.078	0.000	0.206
J10K_int749	4.078	92.339	0.027	4.078	92.339	0.027	4.077	0.000	0.163
J11K	4.092	92.339	0.048	4.092	92.339	0.048	4.089	0.000	0.256
J11K_int247	4.089	92.339	0.031	4.089	92.339	0.031	4.088	0.000	0.163
J11K_int495	4.088	92.339	0.035	4.088	92.339	0.035	4.086	0.000	0.207
J11K_int742	4.086	92.339	0.030	4.086	92.339	0.030	4.084	0.000	0.173
J12K	4.103	92.339	0.040	4.103	92.339	0.040	4.101	0.000	0.217
J12K_int252	4.101	92.339	0.033	4.101	92.339	0.033	4.099	0.000	0.190
J12K_int504	4.099	92.339	0.031	4.099	92.339	0.031	4.097	0.000	0.185
J12K_int756	4.096	92.339	0.038	4.096	92.339	0.038	4.094	0.000	0.207
J13K	4.117	89.339	0.041	4.117	89.339	0.041	4.114	0.000	0.225
J14K	4.135	89.339	0.051	4.135	89.339	0.051	4.131	0.000	0.283
J15K	4.164	89.339	0.048	4.164	89.339	0.048	4.160	0.000	0.272
J15K_int249	4.159	89.339	0.056	4.159	89.339	0.056	4.154	0.000	0.302
J15K_int499	4.150	89.339	0.070	4.150	89.339	0.070	4.144	0.000	0.350
J15K_int749	4.140	89.339	0.053	4.140	89.339	0.053	4.136	0.000	0.291
J16K	4.203	89.339	0.090	4.203	89.339	0.090	4.194	0.000	0.425
J17K	4.245	89.339	0.052	4.245	89.339	0.052	4.241	0.000	0.287
J18K	5.825	89.339	0.565	5.825	89.339	0.565	5.717	0.000	1.453
J19K	6.311	89.339	0.106	6.311	89.339	0.106	6.302	0.000	0.431
J1K_int250	3.221	101.339	0.023	3.221	101.339	0.023	3.220	0.000	0.138
J1K_int500	3.220	101.339	0.028	3.220	101.339	0.028	3.219	0.000	0.168
J1K_int750	3.219	101.339	0.027	3.219	101.339	0.027	3.218	0.000	0.159
J20K	6.399	86.339	0.084	6.399	86.339	0.084	6.393	0.000	0.354
J21K	7.243	86.339	0.395	7.243	86.339	0.395	7.179	0.000	1.117

River Section | Boundary Node

Table 4.2: The unsteady run results

Node	Total Energy (m)	Flow (m3/s)	Froude	Max Total Energy (m)	Max Flow (m3/s)	Max Froude	Max Stage (m AD)	Max State	Max Velocity (m/s)
J0	8.171	1278.656	0.107	8.171	1278.656	0.107	8.144	0.000	0.729
J0_int1015	8.077	1277.131	0.169	8.077	1277.131	0.169	8.014	0.000	1.104
J0_int1015_int253	8.056	1276.778	0.099	8.056	1276.778	0.099	8.027	0.000	0.747
J0_int1015_int507	8.038	1276.391	0.115	8.038	1276.391	0.115	8.003	0.000	0.823
J0_int1015_int761	8.013	1276.054	0.119	8.013	1276.054	0.119	7.967	0.000	0.951
J0_int2031	7.997	1275.728	0.107	7.997	1275.728	0.107	7.965	0.000	0.790
J0_int2031_int253	7.975	1275.369	0.119	7.975	1275.369	0.119	7.938	0.000	0.848
J0_int2031_int507	7.941	1275.026	0.146	7.941	1275.026	0.146	7.892	0.000	0.981
J0_int2031_int761	7.913	1274.734	0.112	7.913	1274.734	0.112	7.869	0.000	0.929
J0_int253	8.155	1278.232	0.110	8.155	1278.232	0.110	8.126	0.000	0.758
J0_int3046	7.883	1274.452	0.149	7.883	1274.452	0.149	7.829	0.000	1.029
J0_int3046_int253	7.833	1274.472	0.194	7.833	1274.472	0.194	7.757	0.000	1.223
J0_int3046_int507	7.722	1274.898	0.330	7.722	1274.898	0.330	7.559	0.000	1.798
J0_int3046_int761	7.605	1275.322	0.324	7.605	1275.322	0.324	7.446	0.000	1.773
J0_int507	8.141	1277.818	0.102	8.141	1277.818	0.102	8.113	0.000	0.735
J0_int761	8.113	1277.451	0.156	8.113	1277.451	0.156	8.055	0.000	1.070
J10K	8.618	725.000	0.095	8.618	725.000	0.095	8.602	0.000	0.629
J10K_int249	8.612	727.097	0.083	8.612	727.097	0.083	8.601	0.000	0.493
J10K_int499	8.603	728.994	0.093	8.603	728.994	0.093	8.587	0.000	0.588
J10K_int749	8.597	730.897	0.074	8.597	730.897	0.074	8.587	0.000	0.464
J11K	8.649	717.713	0.111	8.649	717.713	0.111	8.625	0.000	0.785
J11K_int247	8.642	719.226	0.076	8.642	719.226	0.076	8.633	0.000	0.466
J11K_int495	8.634	721.276	0.101	8.634	721.276	0.101	8.621	0.000	0.597
J11K_int742	8.626	723.133	0.080	8.626	723.133	0.080	8.613	0.000	0.538
J12K	8.684	712.981	0.109	8.684	712.981	0.109	8.669	0.000	0.692
J12K_int252	8.676	714.370	0.099	8.676	714.370	0.099	8.665	0.000	0.568
J12K_int504	8.668	715.614	0.087	8.668	715.614	0.087	8.653	0.000	0.630
J12K_int756	8.661	716.716	0.094	8.661	716.716	0.094	8.647	0.000	0.590
J13K	8.721	581.000	0.110	8.721	581.000	0.110	8.718	374.024	0.687
J14K	8.733	604.676	0.120	8.733	604.676	0.120	8.726	0.000	0.831
J15K	8.749	623.388	0.125	8.749	623.388	0.125	8.745	0.000	0.765
J15K_int249	8.745	618.745	0.129	8.745	618.745	0.129	8.739	0.000	0.885
J15K_int499	8.741	614.683	0.148	8.741	614.683	0.148	8.732	0.000	1.012
J15K_int749	8.736	609.528	0.130	8.736	609.528	0.130	8.731	0.000	0.794
J16K	8.767	640.434	0.171	8.767	640.434	0.171	8.758	0.000	1.099
J17K	8.787	652.797	0.122	8.787	652.797	0.122	8.781	0.000	0.864
J18K	8.863	661.177	0.565	8.863	661.177	0.565	8.836	0.000	1.934
J19K	9.083	670.166	0.191	9.083	670.166	0.191	9.013	0.000	1.195
J1K_int250	8.213	1279.901	0.088	8.213	1279.901	0.088	8.192	0.000	0.643
J1K_int500	8.200	1279.487	0.105	8.200	1279.487	0.105	8.174	0.000	0.714
J1K_int750	8.186	1279.074	0.097	8.186	1279.074	0.097	8.163	0.000	0.686
J20K	9.283	370.775	0.123	9.283	370.775	0.123	9.270	390.257	0.706
J21K	9.459	368.521	0.395	9.459	368.521	0.395	9.414	0.000	1.383

River Section | Boundary Node

4.5.2 Rantau Panjang Station

The model calibration was based on the flood observations on 18 December 2006 at 0:00 until 31 December 2006 at 23:00. The floods data observed were streamflow and water level at Rantau Panjang Station (1737451). The observation data are taken from DID Ampang using Tideda software. Hence, this section will show the graphs of streamflow and water level at Rantau Panjang Station and the calculation of calibration is based on the difference between maximum and minimum value of streamflow and water level. Rantau Panjang station is located at chainage J17K in Johor River layout figures.

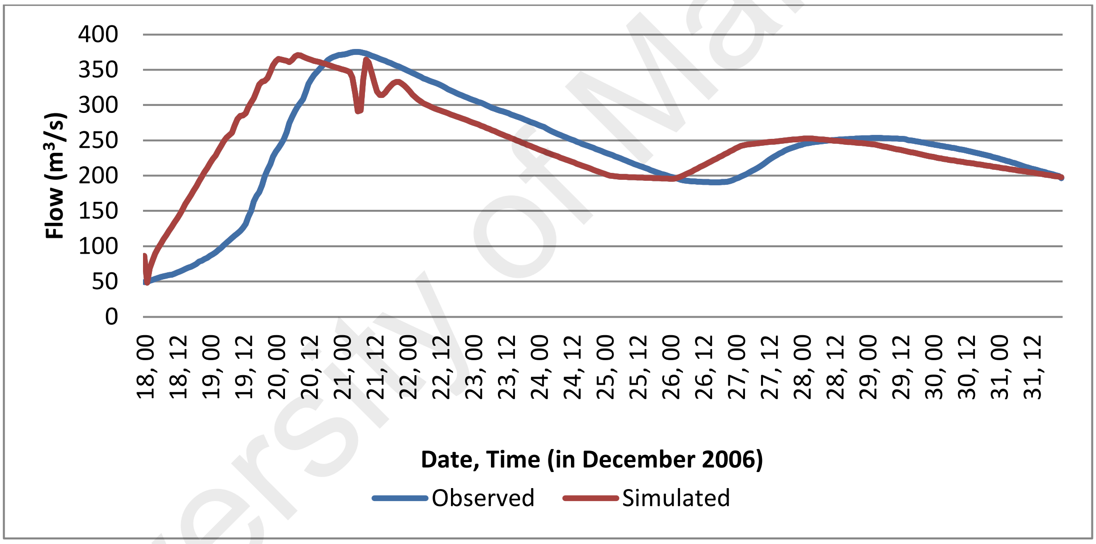


Figure 4.22: Observed and simulated flow rates at Rantau Panjang station

Table 4.3: The percentage error for streamflow

	Maximum Flow (m^3/s)	**Minimum Flow (m^3/s)**
Observed Flow	375.266	49.145
Simulated Flow	370.718	48.330
Difference between observed and simulated	4.548	0.815
Percentage error	**1.21%**	**1.66%**

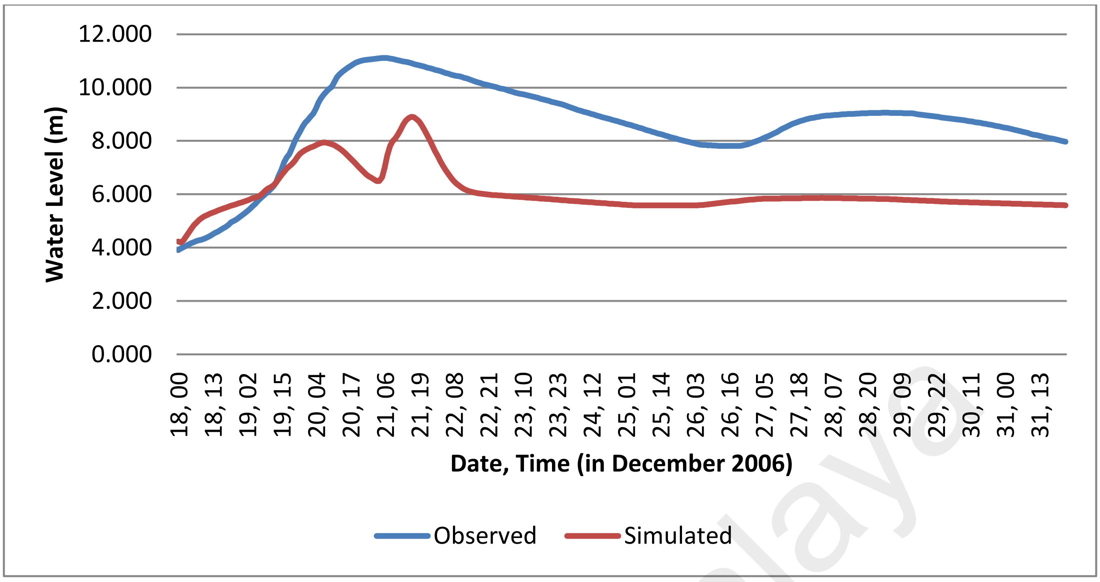


Figure 4.23: Observed and simulated water level at RantauPanjang station

Table 4.4: The percentage error for water level

	Maximum Water Level (m)	**Minimum Water Level (m)**
Observed Water Level	11.109	3.914
Simulated Water Level	8.902	4.197
Difference between observed and simulated	2.207	0.283
Percentage error	**19.87%**	**7.23%**

4.6 Discussion

Based on the results gained, the calibration for the difference in observation and simulated water level at Rantau Panjang Station for the maximum and minimum using Infoworks RS software are 2.207 m and 0.283 m respectively while flow rates are 4.548 m^3/s and 0.815 m^3/s. The percentage error of the maximum water level is 19.87% and minimum water level is 7.23%. These percentages are still in satisfactory and very good status respectively for modeling (Van Liew, Veith, Bosch, & Arnold, 2007).

Meanwhile, the percentage error of the maximum flow rates is just 1.21% and the minimum flow rate is 1.66%. These results are near to the observed data.

In 2-D modeling, the action of fixing the boundary or limits of flood area is simpler than 1-D modeling. 2-D simulation boundaries can be created along the river without knowing exactly where the flooding will occur. However, slow computing time should be expected. In this study, two 2-D simulation boundaries were created along Rantau Panjang area based on 2006 flood event. 2-D meshes in the boundaries were generated within InfoWorks RS using Shewchuk Triangle meshing functionality. Heights at the vertices of the generated mesh elements are calculated by interpolation. 1-D river network nodes and 2-D flood plain meshes were connected using spill units linked to a cross-section node.

A run on the model for 50 and 100 years design return period produced 1-D and 2-D flood hazard map for Johor River basin. Surface velocity information as in Figure 4.15, can be used for further analysis especially in assessing damages done by flood waters and potential hazard to the people affected. Figure 4.16 and Figure 4.17 demonstrate the direction of flood water flow busting out from the river bank at different date and time.

However, the error that might cause the results gain such like that is because the hydrological data used is not adequate as the data retrieved at Department of Irrigation and Drainage (DID) such as rainfall data which requires hourly data. So, for Johor River modelling, the rainfall data for hourly is basically just from SMK Bukit Besar Station (1737001) as the other rainfall station just record daily data and some are not in good condition with no readings recorded because of the damage of the station during the huge flooding. Hence, in this river modelling all the subcatchments are using SMK Bukit Besar Station as their input in rainfall data.

Besides, the mistakes in raw data in shape files contribute to the error occurred in this model. This is because the shape files such as main river data is not in proper alignment compare to the topographic map in such way the river got bend while the drawing in shape file shows the river is straight. As a result, when DEM file inserted in this model, some of the river alignment lie within the land area and thus affecting the flood hazard map.

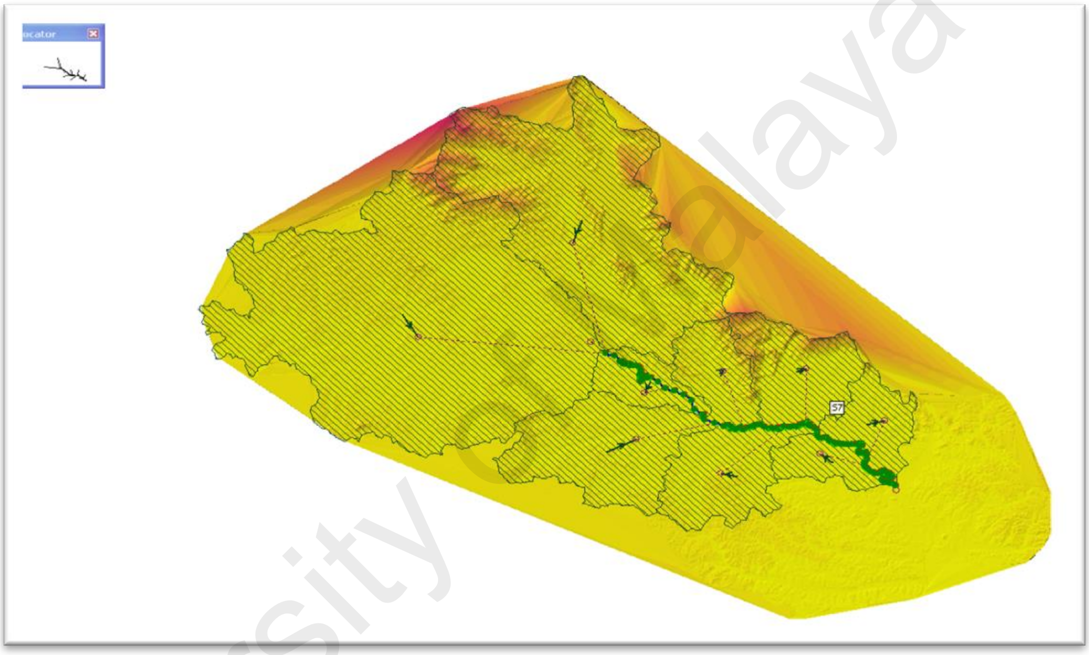


Figure 4.24: Unmatched DEM and river alignment

Furthermore, the most challenging part in doing this task is when the raw data files gained is not suitable for Infoworks RS software. Thus, to overcome this situation, we need to convert files into the format that recognized by Infoworks RS and this data processing consumed a lot of time efforts and always delay the time to finish this river modelling. Other than that, the bridge data also not very accurate and it is just to try for this software. This is the reason that the error occur during adding the bridge at the link of the river.

CHAPTER 5: CONCLUSION

5.1 Conclusions

A river model for Johor River basin has been developed in this research by InfoWorks RS. From the model, the layout of river and cross sections had been determined. The total of the cross sections are 147 and the manning coefficient, n used in range of 0.035 to 0.20. Six locations have been considered for the simulations and nine boundary nodes along Johor River including upstream and downstream boundary.

The hydraulic analysis of Johor River had been performed. Water level has been simulated in right and left bank of the river and investigation some parameters such as flow and velocity were developed by the modeling. Providing some plots and graphs to show the curve of water level for the flow is one of the most important hydrodynamic modeling parameters in this study, because of flood disaster affect location have been shown by this plots.

The flood hazard map has been produced by InfoWorks RS for 1-D and 2-D modeling. The estimation of flood extent area has been done in modeling in order to develop flood mapping for Johor River based on 50 and 100 ARI. The flood hazard map of Johor River, the flood hazard map zoom to Kota Tinggi area and 3D view for 1-D modeling before and during flooding was shown. 2-D modeling flood hazard map of Rantau Panjang has obtained and the velocity variation and also the flow direction included in these flood hazard map. So, the result of InfoWorks RS modeling can be used to propose the flood hazard mapping in Johor River and can be used to make planning about dangerous unit in left and right bank of the river.

Johor River flooding area was determined and it was covered Kota Tinggi and Rantau Panjang area. From the analysis, the flood depths were known for both areas. The steady and unsteady run had been performed. From the calibration, the percentage error for Rantau Panjang for both parameters; water level and flow rates with the percentage less than 20% are in satisfactory and very good status (Van Liew et al., 2007). Therefore, the simulated maximum water elevation and streamflow were acceptable and the result of InfoWorks RS modeling can be used to propose the flood mapping options.

River modeling solution can be very useful solution as assessment and prediction can always be done with sufficient data. This flood hazard map helps the administrative bodies in the area by giving them the ideas on which areas are affected by flood. Further analysis can be done using difference scenarios and various return periods as well as future land use planning to minimize flooding risks. It serves as beneficial planning and design tools for the local authority and community in preparing for evaluation plan.

5.2 Recommendations

Further to this study, some recommendations can be proposed for future work. The recommendations are as follow:

The chainage's distance have been used in this study are 500 m to 1000 m. But for some locations such as town and villages the distance of survey map should be 50 m to calculate the water level and flood extent map with more accuracy.

The real map of Johor River shows there are some sub rivers joined during the way but the survey map didn't attention to this rivers and just concentrate to main river and two upstream, so to provide the correct information of flood extent map the information's detail of this small rivers are necessary.

To calibrate of modeling just one station has been used, so to calibrate more accuracy and validation recommended collecting the data in flood events in another two stations. The data for tidal must be included to get more appropriate results as Kota Tinggi floods affected by the tidal. Hydrological Data must be complete accordingly to get the more reliability results such as the rainfall data needed is in hourly interval. Thus, we need to generate the daily rainfall data into hourly rainfall data. The cross section data must be correctly placed on the map so that the river cross section will not displaced from the origin location. The data of the bridges need to be referring from the department that constructs the bridge at the location. The data that is not accurate will make the simulation have many errors.

As with all models, the accuracy of the results depends on the validity of the equations used to describe the physical processes and the quality and detail of the input data to which the equations are applied. With respect to flood mapping, the following points are particularly important. The hydraulic model must be self-consistent (no intersection of river cross sections for instance) and consistent with both the flood mapping model and the ground model.

The 1-dimensional hydraulic model network must capture all the important characteristics and dynamic behavior of the river and its surrounding flood plains. In particular, the flood mapping does not represent any dynamic process or conserve the volume of water, thus: A low area within a flood compartment will flood or dry at the moment it connects or disconnects with the flooded river channel. If this behavior is unrealistic, the low area must be modeled hydraulically as a storage area located within a separate flood compartment and the stage-area table of this storage area must be a good match to the ground model in the corresponding area. This will be assured if the ground model is used to derive the stage-area table in the first place.

In the hydraulic model, storage areas effectively have a flat surface. If several storage areas are used within a single flood compartment to model flow on the floodplain, the flood map water level in this compartment will vary smoothly across the compartment. Ideally, all river sections and compartment boundaries in the Flood Mapping Model should have corresponding representation as break lines in the Ground Model. If this is not the case, then inaccuracies in the calculated water surface may arise near these lines. The Flood Mapping Model should cover at least the same area as the Ground Model. If the Ground Model has a point lying outside the Flood Mapping Model, then there will be no calculated water levels in the vicinity of that point, both inside and outside the Flood Mapping Model coverage.

REFERENCES

Abdul Jalil, H., Aminuddin, A.G. & Rozi Abdullah. (2006). *Development of Flood Risk Map Using GIS For Sg. Selangor Basin*. Paper presented at the 6th International Conference on ASIA GIS, Universiti Teknologi Malaysia.

Abdullah, Jazuri. (2007). *Distributed runoff simulation of extreme monsoon rainstorms in Malaysia using TREX*. Colorado State University. Libraries.

Abdullah, Jazuri, Muhammad, Nur Shazwani, Julien, Pierre Y, Ariffin, Junaidah, & Shafie, Atikah. (2016). Flood flow simulations and return period calculation for the Kota Tinggi watershed, Malaysia. *Journal of Flood Risk Management*.

Abebe, A.J. & Price, R.K. (2005). Decision support system for urban flood management. *Journal of Hydroinformatics.*, *7*(1), 3-15.

Abidin, Raja Dato'Zaharaton Raja Zainal, & Unit, Economic Planning. (2004). *Water resources management in Malaysia: The way forward.* Paper presented at the Asia Water Conference.

Air, Bahagian Hidrologi dan Sumber. (2006). Ringkasan laporan banjir Disember 2006

Negeri Johor: Jabatan Pengairan dan Saliran, Malaysia.

Ali, Paridah Anun & Anuar. (2007). Preparation of Flood Hazard Maps for Kota

Tinggi Town. Malaysia: Department of Irrigation and Drainage, Malaysia.

Bender, S. (1991). Primer on natural hazard management in integrated regional development planning. *Organization of American States, Department of*

Regional Development and Environment. Executive Secretariat for Economic and Social Affairs, Washington, DC.

Bhd, K&L Jurutera Perunding Sdn. (2009). Kajian Pelan Induk Tebatan Banjir bagi

Lembangan Sungai Johor, Final Report (Vol. 3). Malaysia: Jabatan Pengairan dan Saliran.

Bruijin, K. M. De. (2005). *Resilience and Flood Risk Management: A Systems Approach Applied to Lowland Rivers*. Delft: Delft University Press.

Bustami, Rosmina, Bong, Charles, Mah, Darrien, Hamzah, Afnie, & Patrick, Marina. (2009). Modeling of Flood Mitigation Structures for Sarawak River Sub-basin Using InfoWorks River Simulation (RS). *World Academy of Science Engineering and Technology*, 14-18.

Chandwani, Vinay, Vyas, Sunil Kumar, Agrawal, Vinay, & Sharma, Gunwant. (2015). Soft computing approach for rainfall-runoff modelling: A review. *Aquatic Procedia*, *4*, 1054-1061.

Chu, Xuefeng, & Steinman, Alan. (2009). Event and continuous hydrologic modeling with HEC-HMS. *Journal of Irrigation and Drainage Engineering*, *135*(1), 119-124.

Colby, Jeffrey D, & Dobson, James G. (2010). Flood modeling in the coastal plains and mountains: Analysis of terrain resolution. *Natural Hazards Review, 11*(1), 19-28.

Department, Malaysian Meteorological. (2015). Climate. Retrieved 26/05/2015, 2015, from http://www.met.gov.my/en/web/metmalaysia/climate/generalinformation/malaysia

Department of Algriculture, Malaysia. (2002). *Major Soil Type in Johor*.

Diakakis, Michalis, Deligiannakis, Georgios, Pallikarakis, Aggelos, & Skordoulis, Michalis. (2016). Factors controlling the spatial distribution of flash flooding in the complex environment of a metropolitan urban area. The case of Athens 2013 flash flood event. *International Journal of Disaster Risk Reduction, 18*, 171-180.

Emmanuel, Isabelle, Andrieu, Hervé, Leblois, Etienne, Janey, Nicolas, & Payrastre, Olivier. (2015). Influence of rainfall spatial variability on rainfall–runoff modelling: Benefit of a simulation approach? *Journal of hydrology, 531*, 337-348.

Gasim, Muhammad Barzani, Toriman, Mohd Ekhwan, & Abdullahi, Musa G. (2014). FLOODS IN MALAYSIA Historical Reviews, Causes, Effects and Mitigations Approach. *International Journal of Interdisciplinary Research and Innovations, 2*(4), 59-65.

Ghosh, Some Nath. (1997). *Flood control and drainage engineering*: CRC Press.

Goodarzi, Mohsen Salarpour. (2010). *Flood mapping of Sungai Skudai using infoworks RS.* Universiti Teknologi Malaysia, Faculty of Civil Engineering.

Green, Colin H, Parker, Dennis J, & Tunstall, Sylvia M. (2000). Assessment of flood control and management options. *World Commission on Dams, Cape Town,(http://www/dams. org).*

Hasan, AJ. (2009). River and Floodplain Modelling–A Practical Approach: National Hydraulic Research Institute of Malaysia (NAHRIM).

He, Zhihua, Hu, Hongchang, Tian, Fuqiang, Ni, Guangheng, & Hu, Qingfang. (2017). Correcting the TRMM rainfall product for hydrological modelling in sparsely-gauged mountainous basins. *Hydrological Sciences Journal, 62*(2), 306-318.

Hiew, KL. (1996). *Flood mitigation and flood risk management in Malaysia.* Paper presented at the Proceedings of an International Workshop on Floodplain Risk Management.

Horritt, MS, & Bates, PD. (2002). Evaluation of 1D and 2D numerical models for predicting river flood inundation. *Journal of Hydrology, 268*(1), 87-99.

Jakubcová, Michala, Máca, Petr, & Pech, Pavel. (2015). Parameter estimation in rainfall-runoff modelling using distributed versions of particle swarm optimization algorithm. *Mathematical Problems in Engineering, 2015*.

JICA. (2008). The 5th Flood Hazard Mapping in East/East-Asian Region, 2008 (Training, Trans.): International Centre for water hazard and risk management under the auspices of UNESCO.

Leopold, Luna Bergere. (1997). *Water, rivers, and creeks*: University Science Books.

Liu, Pin-Shuo, & Chan, Ngai Weng. (2003). The Malaysian flood hazard management program. *International Journal of Emergency Management, 1*(3), 205-214.

Madsen, Henrik. (2003). Parameter estimation in distributed hydrological catchment modelling using automatic calibration with multiple objectives. *Advances in water resources, 26*(2), 205-216.

Matthew M. Linham, Robert J. Nicholls. (2010). Flood hazard mapping. Retrieved 11 May 2015 http://www.climatetechwiki.org/content/flood-hazard-mapping

Meesuk, Vorawit, Vojinovic, Zoran, Mynett, Arthur E, & Abdullah, Ahmad F. (2015). Urban flood modelling combining top-view LiDAR data with ground-view SfM observations. *Advances in Water Resources, 75*, 105-117.

Middelmann-Fernandes, MH. (2010). Flood damage estimation beyond stage–damage functions: an Australian example. *Journal of Flood Risk Management, 3*(1), 88-96.

Norén, Viveca, Hedelin, Beatrice, Nyberg, Lars, & Bishop, Kevin. (2016). Flood risk assessment–Practices in flood prone Swedish municipalities. *International Journal of Disaster Risk Reduction, 18*, 206-217.

OIKOS. (2010). Floods Mechanism (Leonardo da Vinci Project). Retrieved 21 March 2012 http://www.e-oikos.net/gmap/eng/FL/Fl.htm

Parker, Dennis J, Green, Colin H, & Thompson, Paul M. (1987). *Urban Flood Protection Benetits: a Project Appraisal Guide*: Gower technical press.

Philip, Bedient B, Wayne, CH, & Baxter, EV. (2002). Hydrology and floodplain analysis: Prentice-Hall, Inc., NJ.

Pradhan, B, Shafiee, M, & Pirasteh, S. (2009). Maximum Flood Prone Area Mapping using RADARSAT Images and GIS: Kelantan River Basin. *International Journal of Geoinformatics, 5*(2).

Pradhan, Nawa Raj, & Ogden, Fred L. (2010). Development of a one-parameter variable source area runoff model for ungauged basins. *Advances in Water Resources, 33*(5), 572-584.

Prinos, P. (2009). Review of flood hazard mapping: University of Athens.

Qasim, Said, Qasim, Mohammad, Shrestha, Rajendra Prasad, Khan, Amir Nawaz, & Tun, Kyawt. (2016). Community resilience to flood hazards in Khyber Pukhthunkhwa province of Pakistan. *International Journal of Disaster Risk Reduction*.

Ranatunga, Thushara, Tong, Susanna TY, & Yang, Y Jeffrey. (2017). An approach to measure parameter sensitivity in watershed hydrological modelling. *Hydrological Sciences Journal, 62*(1), 76-92.

River, Catalogue of. (2009). *Basic data for Johor river, Malaysia*.

Safaripour, Mahsa, Monavari, Masoud, Zare, Mehdi, Abedi, Zahra, & Gharagozlou, Alireza. (2012). Flood Risk Assessment Using GIS (Case Study: Golestan Province, Iran). *Polish Journal of Environmental Studies, 21*(6).

San, Liew Yuk, & Selamat, Z. (2010). Flood hazard mapping using two-dimensional river modelling for Sungai Muar, Johor in. *Colloqium on R & D in Flood Plain Management*, 102-136.

Saudi, Ahmad Shakir Mohd, Juahir, Hafizan, Azid, Azman, & Azaman, Fazureen. (2015). FLOOD RISK INDEX ASSESSMENT IN JOHOR RIVER BASIN. *Malaysian Journal of Analytical Sciences, 19*(5), 991-1000.

Schroeder, Amanda J, Gourley, Jonathan J, Hardy, Jill, Henderson, Jen J, Parhi, Pradipta, Rahmani, Vahid, . . . Taraldsen, Matthew J. (2016). The development of a flash flood severity index. *Journal of Hydrology, 541*, 523-532.

Science, GNS. (2015). General Natural Hazard Guidance. Retrieved 11 May 2015 http://www.gns.cri.nz/Home/RBP/Risk-based-planning/A-toolbox/Setting-the-Scene/General-Natural-Hazard-Guidance/Types-of-maps

Segura-Beltrán, Francisca, Sanchis-Ibor, C, Morales-Hernández, Mario, González-Sanchis, M, Bussi, GIANBATTISTA, & Ortiz, E. (2016). Using post-flood surveys and geomorphologic mapping to evaluate hydrological and hydraulic models: The flash flood of the Girona River (Spain) in 2007. *Journal of Hydrology, 541*, 310-329.

Shafiai, S, & Khalid, MS. (2016). Flood Disaster Management in Malaysia: A Review of Issues of Flood Disaster Relief During and Post-Disaster. *The European Proceedings of Social & Behavioural Sciences EpSBS*.

Shafie, Atikah. (2009). *A Case Study on Floods of 2006 and 2007 in Johor, Malaysia.* Colorado State University.

Shahidan, Noor FN, Hasan, Zorkeflee A, Abdullah, Mohd Z, & Ghani, Aminuddin A. (2012). Mathematical Modelling of Flow and Sediment Pattern at Ijok Intake, Ijok River, Perak, Malaysia. *International Journal of Modelling and Simulation, 32*(3), 165-170.

Tekleab, Sirak, Uhlenbrook, Stefan, Savenije, Hubert HG, Mohamed, Yasir, & Wenninger, Jochen. (2015). Modelling rainfall–runoff processes of the Chemoga and Jedeb meso-scale catchments in the Abay/Upper Blue Nile basin, Ethiopia. *Hydrological Sciences Journal, 60*(11), 2029-2046.

Thomas, Chris D, Cameron, Alison, Green, Rhys E, Bakkenes, Michel, Beaumont, Linda J, Collingham, Yvonne C, . . . Hannah, Lee. (2004). Extinction risk from climate change. *Nature, 427*(6970), 145-148.

Turner, Ashleigh B, Colby, Jeffrey D, Csontos, Ryan M, & Batten, Michael. (2013). Flood modeling using a synthesis of multi-platform LiDAR Data. *Water, 5*(4), 1533-1560.

Van Liew, Michael W, Veith, Tamie L, Bosch, David D, & Arnold, Jeffrey G. (2007). Suitability of SWAT for the conservation effects assessment project: Comparison on USDA agricultural research service watersheds. *Journal of Hydrologic Engineering, 12*(2), 173-189.

Vincendon, Béatrice, Édouard, Simon, Dewaele, Hélène, Ducrocq, Véronique, Lespinas, Franck, Delrieu, Guy, & Anquetin, Sandrine. (2016). Modeling flash floods in southern France for road management purposes. *Journal of Hydrology, 541*, 190-205.

Vincent. (2001). *Kajian Permasalahan Banjir Kilat di KawasanTelipok, Daerah Tuaran, Sabah.* . (Bachelor Degree), Universiti Teknologi Mara, Shah Alam.

Vincent, & Ali, Rozali Mohamed. (2005). *Managing natural wealth: environment and development in Malaysia*: Resources for the Future.

Wang, Yong. (2002). Mapping extent of floods: what we have learned and how we can do better. *Natural Hazards Review, 3*(2), 68-73. doi: http://dx.doi.org/10.1061/(ASCE)1527-6988(2002)3:2(68)

Weng Chan, Ngai. (1997). Increasing flood risk in Malaysia: causes and solutions. *Disaster Prevention and Management: An International Journal, 6*(2), 72-86.

Wicks, JM, Hu, C, Scott, M, Chen, L, & Cheng, X. (2013). A broad scale model for flood simulation in the Taihu Basin, China. *Journal of Flood Risk Management, 6*(1), 33-41.

Young, Chih-Chieh, & Liu, Wen-Cheng. (2015). Prediction and modelling of rainfall–runoff during typhoon events using a physically-based and artificial neural network hybrid model. *Hydrological Sciences Journal, 60*(12), 2102-2116.

Yu, Dapeng, & Coulthard, Tom J. (2015). Evaluating the importance of catchment hydrological parameters for urban surface water flood modelling using a simple hydro-inundation model. *Journal of Hydrology, 524*, 385-400.

Zhang, Donghua, Madsen, Henrik, Ridler, Marc E, Refsgaard, Jens C, & Jensen, Karsten H. (2015). Impact of uncertainty description on assimilating hydraulic head in the MIKE SHE distributed hydrological model. *Advances in Water Resources, 86*, 400-413.

Zhou, Zhengzheng, Liu, Shuguang, Zhong, Guihui, & Cai, Yi. (2016). Flood Disaster and Flood Control Measurements in Shanghai. *Natural Hazards Review*, B5016001.

LIST OF PUBLICATIONS AND PAPERS PRESENTED

Seminar / Conference / Colloquium

1) Faridah Othman, Noor Farahain, Lau Mi Fung and M. K. Mohd Nor (2011). Flood Mapping of Johor River Using InfoWorks River Simulation (RS). Proceedings of Seminar on Integrated & Multidisciplinary Research on Flood Hazard Assessment in Johor,4-6 July 2011, Hotel Permaisuri MITC, Melaka.
2) Faridah Othman and Noor Farahain (2012). Development of Flood Risk Map using InfoWorks for Sungai Johor. Paper presented at the Seminar on River and Drainage 2012, Grand Blue Wave Hotel, Shah Alam, 27 Jun 2012.
3) Faridah Othman and Noor Farahain (2013). One-Dimensional Flood Modeling for Sungai Johor. Paper presented at the Kolokium Penjanaan Peta Hazard Banjir di Malaysia, JPS cawangan Ampang, Kuala Lumpur, 18 Februari 2013.

Journal Paper

1) Faridah Othman, Noor Farahain, Lau Mi Fung and Alaa Eldin M. E (2013). Utilizing GIS and InfoWorks RS in Modelling the Flooding Events for a Tropical River Basin. Applied Mechanics and Materials. (353-356), 2281-2285.
2) Faridah Othman and Noor Farahain (2016). Development of Flood Map for a Tropical River Basin: Case Study of the Johor River, Polish Journal of Enviromental Studies. (Submitted)