ANALYSIS OF LAG TIME FOR DECEMBER 2014 FLOOD INCCIDENT IN KELANTAN RIVER BASIN, MALAYSIA

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ANALYSIS OF LAG TIME FOR DECEMBER 2014 FLOOD INCCIDENT IN KELANTAN RIVER BASIN, MALAYSIA

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Thesis submitted in partial fulfilment of the requirements for award of the degree of Bachelor of Civil Engineering (Hons)

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DEDICATION

Families, friends and teachers are the compass that guides us.
My humble efforts are dedicated to them.

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In the name of Allah, the Most Gracious and the Most Merciful,

Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this thesis. My immense gratitude goes to my supervisor, Dr. Mohamad Idris bin Ali for his commitment and tolerance throughout the time it took me to complete this research. His continuous guidance and constant support has made this research possible.

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ABSTRACT

Kelantan River Basin is highly vulnerable to the risk of flood. Frequent flooding can cause a lot of cost property damages and losses of lives. December 2014 flood event was on an unprecedented scale due to extreme rain rate rainfall. The water level increase rapidly and the local people do not expected the situation become worst. These research focus of analysing lag time, (Δt) for flood event in Kelantan River Basin occurred during the end of December 2014 (from 20 until 31). The research area covered the area that effected during the flood event; Gua Musang, Kuala Krai, Tanah Merah, Pasir Mas and Kota Bharu. In this research, Auto-estimator method was used to derived hourly rain rate satellite-based rainfall data from satellite image of top of cloud temperature data taken from the public domain meanwhile the water level data obtained from Department of Irrigation & Drainage (DID).In addition, rain gauge hourly rainfall from DID also taken for comparison against satellite-based rainfall data. The estimated value and measured value shows a very good agreement (r = 0.905 to 0.99). The regression line fitted through origin has a slope of 0.811 to 1.134 the dataset. In this research there are three places to measure the water level starts from the upstream basin; Tangga Krai, Jambatan Guillemard and Tambatan DiRaja. From the analysis of the time series graphs of rainfall and river water levels show a lag time between the occurrence of first extreme rainfall in the upstream with water rising to the level of danger were 3,9 and 28 hours in Tangga Krai, Jambatan Guillemard and Tambatan DiRaja, respectively. Neglecting the lag time between rainfall and water level rise to dangerous level at Tangga Krai, it found that the lag time between the water level of danger at Tangga Krai and Jambatan Guillemard, also between Tangga Krai and Tambatan DiRaja were 6 and 17 hour. It comparable with DID records. On top of that, the satellite-based data from public domain able to be used for the flood forecasting in future will give benefit to relevant parties in future to ensure the systematic planning in flood management system.

ABSTRAK

Lembangan Sungai Kelantan amat terdedah kepada risiko banjir. Banjir yang kerap boleh menyebabkan banyak kerosakan harta benda dan kehilangan nyawa. Banjir pada Disember 2014 dikatakan berada di dalam skala yang belum pernah berlaku sebelum ini dan disebabkan oleh kadar hujan melampau hujan. Paras air meningkat dengan cepat dan penduduk tidak menjangka keadaan menjadi teruk. Tumpuan penyelidikan ini adalah untuk menganalisis masa lag, (Δt) bagi kejadian banjir di Lembangan Sungai Kelantan yang berlaku pada akhir Disember 2014 (dari 20 hingga 31). Kawasan kajian meliputi kawasan yang terjejas teruk semasa kejadian banjir; Gua Musang, Kuala Krai, Tanah Merah, Pasir Mas dan Kota Bharu. Dalam kajian ini, kaedah *Auto-estimator* digunakan untuk mendapatkan data hujan berasaskan satelit. Kadar hujan setiap jam yang diperolehi daripada imej satelit dari data suhu awan yang diambil dari domain awam, sementara itu data paras air yang diperolehi daripada Jabatan Pengairan dan Saliran (JPS). Di samping itu, data hujan setiap jam dari JPS juga diambil untuk perbandingan terhadap data hujan berasaskan satelit. Data yang dianggar dan data diukur menunjukkan perbandingan yang sangat baik (r = 0.905 - 0.99). Garis regresi melalui titik asal menunjukkan kecerunan 0.811-1.134 dataset. Dalam kajian ini terdapat tiga tempat untuk mengukur paras air bermula dari lembangan hulu; Tangga Krai, Jambatan Guillemard dan Tambatan DiRaja. Daripada analisis graf siri masa hujan dan air sungai peringkat menunjukkan jarak masa antara berlakunya hujan lebat pertama di hulu sungai dengan air yang semakin meningkat ke tahap yang bahaya adalah selama 3, 9 dan 28 jam di Tangga Krai, Jambatan Guillemard dan Tambatan DiRaja. Dengan mengabaikan jarak masa di antara hujan dan paras air meningkat ke tahap berbahaya di Tangga Krai, didapati bahawa jarak masa di antara paras air bahaya di Tangga Krai dan Jambatan Guillemard, juga antara Tangga Krai dan Tambatan DiRaja adalah selama 6 dan 17 jam. Data ini selari dengan JPS rekod. Selain itu, data yang berasaskan satelit dari domain awam dapat digunakan untuk ramalan banjir pada masa akan datang akan memberi manfaat kepada pihak yang berkaitan pada masa akan datang bagi memastikan perancangan yang sistematik dalam sistem pengurusan banjir.

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Δt	Lag Time

LIST OF ABBREVIATIONS

TRMM	Tropical Rainfall Measuring Mission
DID	Department of Irrigation and Drainage Malaysia
JPS	Jabatan Pengaliran & Saliran Malaysia
BH	Berita Harian
UM	Utusan Malaysia
NSC	National Security Council
TSD	The Sun Daily
PR	Precipitation Radar

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Flood defined as a situation where water flows exceed the carrying capacity of a river resulting in overflows over the river banks (Goh, 1981). Another definition of a flood is considered to be unusually high stage of the river. It is often described as that stage at which the stream channel becomes filled and above which it overflows its banks (Saul, 1992). Normally, this overflow happens when heavy rain takes place non-stop for a long period time at certain location. It will cause place that usually dries be overflow with water. It situation may also bring death and properties damage. 90% of population who affected by natural hazards are subjected to flood (Haider, 2006)

The most devastating natural disaster experienced in Malaysia is flood. The flooding of Malaysian rivers is mainly due to the high amount of rainfall in river basins. Malaysia is a tropical country, receiving more than 2 500mm of rain annually. There are total of 189 river basins with the main channels flowing directly to the South China Sea throughout Malaysia, including Sabah and Sarawak (89 of the river basins are in Peninsula Malaysia, 78 in Sabah and 22 in Sarawak), and 85 of them are prone to recurrent flooding. The estimated area vulnerable to flood disaster is approximately 9% of the total Malaysia area, and is affecting almost 4.82 million people which is around 22% of the total population of the country (DID, 2009).

In Malaysia history prior December2014 flood incident, the massive flood occurred in 1886, 1967, 1971, 2007, and 2008 and lately this situation has continuously worsened. One of the severest is the December 2006 and January 2007 floods, the rescue and recovery departments has learn a lot of experiences as a results of these floods (Barton, 1994, Drabek, 1995, Ewen et al., 2007 and Tompkins et al., 2008).

Kelantan on the other hand has faced a number of severe floods over several past years and its vulnerability to these resulted from the rapid urban development of the Kelantan. The flood incident in December 2014 was the worst (Figure 1.1) The impacts of river flooding are even more damaging and effect economic activities and the livelihoods of people in the area.

Figure 1.1: Flood in Kelantan

Source: zulkarnainh.wordpress.com (2015)

1.2 PROBLEM STATEMENT

Flooding is a natural event, and no matter how hard a government or society tried to minimize or to stop it completely (FRMP 2012). Due to unexpected flood in December 2014, the villagers that lived in effected area do not have enough time to move to the higher place since the transportation cannot be used and the main roads also inundation with water. The situations become worst during 25 December 2014 when water level increase rapidly at the downstream area such as Pasir Mas and Kota Bharu. During that period most of the locals at the downstream area did not expected the increasing of water level will cause flood at their area.

In December 2014 due to extreme rainfall rate, flood event hit almost 90 percent of Kelantan state; only a few district in Kelantan did not affected with the flood. Figures 1.2 to 1.6 are some of the articles from the local newspaper about flood in Kelantan. The articles show the difficulty faces by the villagers during the flood occur. The daily activities were disturbed and it causes a huge amount of losses. Due to the high water level and strong current flow, some of the affected area not able connected and the aid not able extended to the victim. It is necessity for flood forecasting in a practical way to save lives and property. The possibility of satellite-based rainfall data from public domain to be use together with water level data from DID to determine the lag time of between extreme rainfall rate and increasing of water level should be study.

Banjir landa Jeli, Tanah Merah

897 mangsa daripada 194 keluarga dipindahkan ke pusat pemindahan

Figure 1.2 Flood Article (Berita Harian, Dec. 2014)

Banjir di Kuala Krai paling buruk dalam sejarah

UTUSANKELANTAN@UTUSAN.COM.MY | 25 Disember 2014 11:48 PM

KUALA KRAI 25 Dis. - Paling teruk dalam sejarah. Itu yang dapat disimpulkan apabila ramai penduduk di Kuala Krai terperangkap selepas kediaman mereka dinaiki air hingga setinggi tiang elektrik.

Malah, difahamkan ada antara mangsa terputus bekalan makanan dan perhubungan sejak beberapa hari lalu.

Bermula kelmarin, pelbagai kiriman mesej melalui aplikasi Whatsapp dikirimkan oleh mangsa merayu bantuan.

Namun, hari ini tidak banyak lagi kiriman mesej seperti itu diterima mungkin disebabkan bateri telefon bimbit milik mangsa sudah kehabisan dan bekalan elektrik yang terputus.

Sehingga kini, masih terdapat dalam kalangan penduduk khususnya di Manek Urai menanti bantuan daripada pasukan keselamatan bagi menyelamatkan mereka termasuk di pusat-pusat pemindahan yang ditenggelami air.

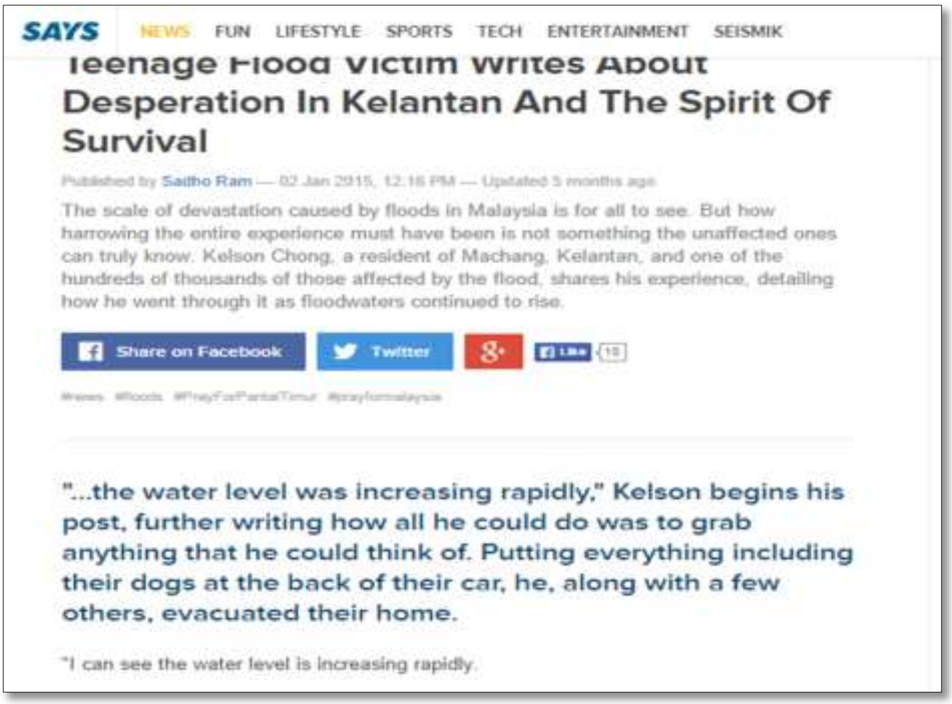
Figure 1.3 Flood Article (Utusan, Dec. 2014)

MALAYSIA

Floods in Kelantan subside, but victims' troubles far from over

When the floods came surging into Kampung Kuala Kelai, Pasir Mas, in the east coast state of Kelantan, on Wednesday, most villagers waded through the deep water to get to the nearest relief centre, but Rohana Dollah, 45, and her family ended up sleeping in their car for the next four nights instead.

Figure 1.4 Flood Article (MalaysiaKini, Dec. 2014)



SAYS NEWS FUN LIFESTYLE SPORTS TECH ENTERTAINMENT SEISMIK

Teenage Flood Victim Writes About Desperation In Kelantan And The Spirit Of Survival

Published by Sadho Ram — 02 Jan 2015, 12:16 PM — Updated 5 months ago

The scale of devastation caused by floods in Malaysia is for all to see. But how harrowing the entire experience must have been is not something the unaffected ones can truly know. Kelson Chong, a resident of Machang, Kelantan, and one of the hundreds of thousands of those affected by the flood, shares his experience, detailing how he went through it as floodwaters continued to rise.

Share on Facebook Twitter

"...the water level was increasing rapidly," Kelson begins his post, further writing how all he could do was to grab anything that he could think of. Putting everything including their dogs at the back of their car, he, along with a few others, evacuated their home.

"I can see the water level is increasing rapidly.

Figure 1.5 Flood Article (Says, Dec. 2014)

Utusan ONLINE Mobile LIVE

Berita Video Rencana Hiburan Bisnes Pendidikan Sains & Teknologi Gaya Hidup Sukan Lain-lain

TERKINI UTAMA NASIONAL POLITIK PARLIMEN WILAYAH LUAR NEGARA JENAYAH MAHKAMAH KOMUNITI NAHAS & BENCANA

Banjir: Kelantan bakal lumpuh

Gua Musang, Kuala Krai terputus hubungan darat

24 Disember 2014 2:10 AM

KOTA BHARU 23 Dis. - n egeri ini bakal lumpuh sepenuhnya. Itu gambaran yang kepada situasi banjir yang melanda negeri ini.

Keadaan tersebut ekoran daripada bahagian Kelantan Selatan iaitu daerah Gua Musang dan Kuala Krai yang ditenggelami air dan terputus hubungan darat.

Malah operasi untuk menghantar bantuan melalui udara ke Gua Musang pada hari ini tidak dapat dilakukan kerana cuaca buruk.

Bandar Lama di Gua Musang seperti sebuah pulau dan 13 orang nyaris maut apabila bot penyelamat terbalik ketika membawa mereka keluar dari kawasan sekitar Resort Kesedar Inn.

Pada masa sama, bahagian utara negeri ini terutama daerah Kota Bharu, Bachok dan Pasir Puteh pula diancam fenomena air pasang besar.

Hujan lebat yang turun di bahagian selatan sejak beberapa hari lalu menyebabkan sebahagian besar daerah Kuala Krai dan Gua Musang, termasuk kawasan yang tidak pernah terjejas sebelum ini mula dinaiki air.

Laluan Lebuh Raya Timur-Barat dari Jeli ke Gorik, Perak ditutup kepada semua kenderaan berikutan tanah runtuh di Kilometer 66 malam ini.

Berikutan itu, beberapa sungai utama di negeri ini iaitu Sungai Galas, Dabong; Sungai Lebir, Tualang; Sungai Golok, Rantau Panjang dan Sungai Kelantan terus meningkat melebihi paras bahaya.

Menurut Jabatan Meteorologi Malaysia, hujan lebat dijangka berterusan sehingga 28 Disember ini.

Figure 1.6 Flood Article (Utusan Online, Dec. 2014)

1.3 OBJECTIVES OF STUDY

The main objective of the study was to analyse of lag time for December 2014 flood incident in Kelantan River Basin. To achieve the main objective of this study, there were specific objectives to accomplish as follow;

1. To estimate and validate satellite-based rainfall data, and
2. To analyse lag time (Δ t), of rainfall incident with the water level at Kelantan River Basin.

1.4 SCOPE OF STUDY

This study was limited to the following:

a. The study area was limited to affected areas along Kelantan River Basin during flood in December 2014 which is Gua Musang, Kuala Krai, Tanah Merah, Pasir Mas and Kota Bharu (Fig 1.7).
b. The period of study was limited from 20 December until 31 December 2014.
c. Satellite based rainfall data downloaded from public domain were used as hour-rainfall data
d. The water level data and onsite rainfall data obtained from Department of Irrigation & Drainage Malaysia

1.5 STUDY AREA

Kelantan River Basin is located in the north eastern part of Peninsular Malaysia. The river is about 248 km long and drains an area of 13,100 km2, occupying more than 85% of the State of Kelantan. It divides into the Galas and Lebir Rivers near Kuala Krai, about 100 km from the river mouth. The Kelantan River system flows northward passing through such major towns as Kuala Krai, Tanah Merah, Pasir Mas and Kota Bharu, before finally discharging into the South China Sea (Figure 1.7).

The basin has an annual rainfall of about 2,500 mm much of which occurs during the North-East Monsoon between mid-October and mid-January. The mean annual temperature at Kota Bharu is 27.5° C with mean relative humidity of 81%. The mean flow of the Kelantan River measured at Guillemard Bridge is 557.5 m3/s (DID, 2009).

December 2014, Kelantan experience the heavy flood. The flood was known as “Bah Kuning” (*yellow flood*) as the brown and muddy coloured of water. As much as 255 mm (10 inches) of rain fall in 24 hours between December 21 and 22 in the east coast states, according to the (MMD, 2014). It had further worsened the flood in the states. On December 23, the Malaysian Meteorological Department issued a high level warning of heavy rain in parts of peninsular Malaysia. Adding to that, the high tide phenomenon which are influenced by the moon were also identified as one of the major contributors for the heavy flood in December 2014.

The area which damage from the flood event was covered near to the major rives at the east coast of Peninsular Malaysia. The area along Kelantan River system which is Kuala Krai, Tanah Merah, Pasir Mas and Kota Bharu effected badly during flood incident in December 2014. The National Security Council reports that the total number of displaced flood victims around the 158,476 (MKN, 2014).

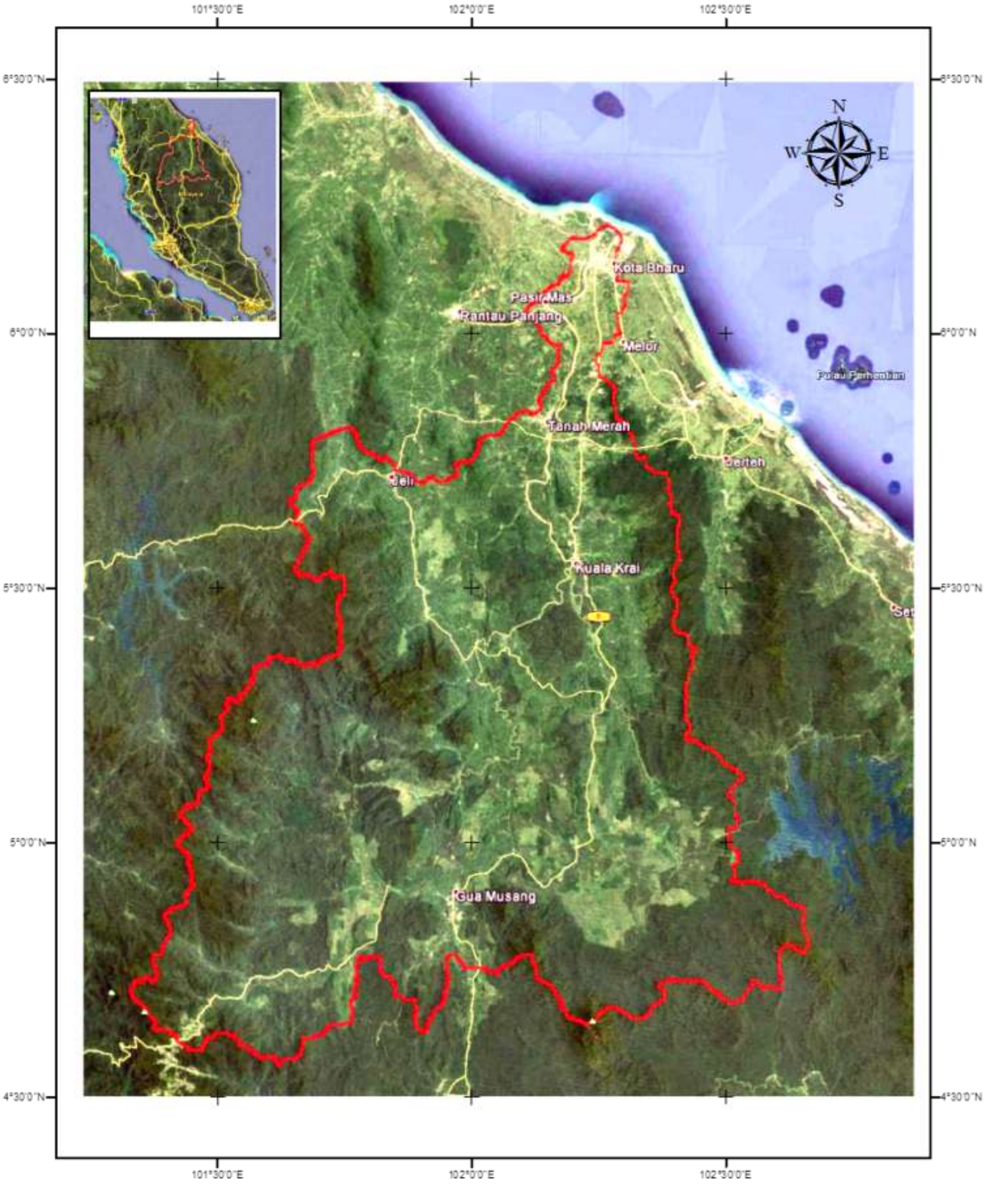


Figure 1.7 The Kelantan River Basin Boundary

1.6 SIGNIFICANCE OF STUDY

From this study, the pattern of the rainfall and the water level at Kelantan River Basin during the flood 2014 incident can be determined. Beside the pattern of time travelling of the flood flow also can be determine. Therefore, the comprehensive planning can be made to ensure all the villagers can be alert to make preparation and planning with any possible of flood incident in future. The data is importance and can be used for the authorized party such as Department of Drainage and Irrigation (DID) or Kelantan State Government for future development.

1.7 THESIS STRUCTURE

This research comprises of five chapters. The first chapter consists of introduction section. It states the background, problem statement, objectives of study, scope of study and lastly the significant of study. For chapter two, the key terms in-purpose for this research are described and also the literature review that related and suitable for this research. Chapter three explains the research methodology for research data collected and the method of data analysis to be employed. For chapter four, the results obtained from study area and year of study were presented and the analysis from the result was discussed. Finally, chapter five comprises the conclusion from the overall chapter and relates some recommendations for future work on research field.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A flood issue is synonym with the community especially for those who live in East Coast area of Peninsular Malaysia which is Kelantan, Terengganu and Pahang state. In Kelantan, flooding is the most devastating natural hazard that usually occurs during end of the year. Flood takes hours or even days to develop, the resident have time to prepare for moving to the higher place. There are many factor causes the flood. The high rainfall intensity, the design of drainage that not enough to support the demand and also the water discharge system that has been disturbed by human activity such as human development and deforestation are several factor that cause the flood.

Over the year, flood leaves a very huge impact and causes suffering to human life and loss of materials and properties. Floods are the most common occurring natural disaster that affects human and its surrounding environment (Gebeyehu, 1989). The flood hazard comprises many aspects including structural and tensional damage, loss of life and property, contamination of food, water and other material, disruption of socio-economic activity including transport and communication, and in some cases the spoiling of agricultural land (Jamaluddin, 1985).

2.2 FLOODS IN KELANTAN

Hydrological Kelantan River Basin is one of the areas in Malaysia that experienced frequent flooding. The major flood episode happen in 1967 caused the area to be declared as Emergency Area as 84 percent of residents of Kelantan State were affected and a lot destruction of basic facilities such as roads and hospitals (Low, 1983; Sham, 1973). The floods that occur in Kelantan in 1967 also known as “Bah Merah” (*red flood*) as the water, which inundated almost all parts of the state, was reddish in colour, a departure from the usual milk tea or brown-coloured water. In a research article by Sham Sani (1974), about 84.0 percent of the population in Kelantan were affected and at least 20.0 percent or 125,000 people had to be moved to safer grounds. Damage was estimated to be in the region of RM 30,000,000.

The National Security Council (NSC) confirmed the massive flood that hit Kelantan was the worst in the history of the state. Water levels of the recent floods superseded the floods of 1967.According to the council’s report, the water level of Sungai Kelantan at Tambatan DiRaja, which has a danger level of 25 metres, reached 34.17 metres last month compared to 29.70 metres in 2004 and 33.61 metres in 1967.The levels at Tangga Krai, which has a danger level of 5 metres, reached 7.03 metres compared to 6.70 metres in 2004 and 6.22 metres in 1967.Kampung Manek Urai, Kampung Manjur and Kampung Karangan in Kelantan as among the worst-hit areas during the floods that inundated the east coast of the peninsula, with houses and villages in ruins.

2.3 CHRONOLOGY OF THE FLOOD IN KELANTAN IN DECEMBER 2014

The New Age (TNA,12 Jan 2015) reported that the torrential rains that began on the 17th of December, 2014, led to flash flooding and forced 3390 people in Kuala Krai, Kelantan, to flee their homes. Later, three days of continuous heavy rain fell from the 21st to the 23rd of December, 2014, in Gua Musang. This was a record-setting rainfall of 1295 mm, equivalent to the amount of rain usually seen in a span of 64 days. As a result, the water levels of three major rivers, the Sungai Galas at Dabong, the Sungai Lebir at Tualang and the Sungai Kelantan, rose drastically above the water levels considered dangerous. Figure 2.1 shows the situations of flood at one of main road at Kuala Krai.

The local newspaper, The Sun Daily (TSD, 5 Jan 2015) has recorded the chronology of the flood at Kelantan started since December, 17 where the low area in Kuala Krai and Machang start affected by floods, the flood evacuees rose to 2,084 people during that day. In December 20, TSD reported that the number of evacuees in Kelantan increasing drastically from 15,002 on December 19 to 19,186. 22 main roads closed in Kelantan with the total evacuees increase to 20,709 people at 84 evacuation centre during December 23.

Figure 2.1 Pam station at Kuala Krai under water during flood

(Source: The Sun Daily, Dec. 2014)

Another local newspaper, Utusan Online (28 December 2014) reported that during December 25, Kelantan state is almost paralyzed when the water of the Sungai Kelantan start overflow into the Kota Bharu city in the afternoon. Even until 10 pm on 24 December, the water flow was getting extremely fast and accelerated at high rate, it has submerged the whole riverbank area of Kelantan River and overflow to the town. The authorities also issued an immediate warning siren and evacuation order to residents in the vicinity. The affected areas are Kampung Kota, Kampung Sireh, Jalan Che Su, Jalan Post Office Lama, Jalan Tok Hakim, Bunut Payung and Tambatan DiRaja (Figure 2.2).

Figure 2.2 The area near to Tambatan DiRaja on December 24.

(Source: Utusan Online, Dec. 2014)

An article from Berita Harian (BH) on December 25, Kuala Krai district was reported totally lost under water on December 25 (Figure 2.3). Almost 500 victims trapped at Sekolah Menengah Kebangsaan Manek Urai, Kuala Krai. The victims have evacuated to the school since 20 December and the water level keeps increasing until it reaches the third level of the school. Bad weather and strong currents flow become the reason for the rescue team failed to do the rescue operation for the victim at the school (Figure 2.4). The total evacuees increase to 30,687 people at 9 districts with 146 evacuation centre opened during December 24.

Figure 2.3 The view of Kuala Krai district on December 25
. (Source: Utusan Online, Dec. 2014)

Figure 2.4 The view of SMK Manek Urai on December 25
. (Source: Utusan Online, Dec. 2014)

On 25 December the situation at Kota Bharu becomes worst when the river water start to overflow to almost area in the city. The water level in Sungai Kelantan at Tambatan DiRaja exceeded the danger level and overflowed caused inundating several low-lying areas in Kota Bharu town. According to TSD, the areas around Jalan Post Office Lama and Kubang Pasu Market were observed to be flooded including the roads, and water level in the river reached 5.91 metres at 10am, exceeding the danger level of 5 metres. Stadium Sultan Muhammad IV and Hospital Raja Perempuan Zainab were one of the most affected areas in Kota Bharu District (Figure 2.5).

Figure 2.5 The view of Stadium Sultan Muhammad IV

(Source: Utusan Online, Dec. 2014)

At the same time the Pasir Mas district is totally cut off with the other district because all the main road were closed due to the high water overflow to the road (Figure 2.6 & 2.7). Rescue boats were unable to traverse the strong currents while the menacing weather made it difficult for helicopters to reach certain locations. The number of evacuees continued to rise with more than 134,139 people at the evacuate centre. The rescue operations become more difficult when the electricity at all affected area have been cut off and limited communication.

BH on 30 December reported that the flood waters start to recede and flood situation improved drastically in Kelantan sending back more evacuees to their homes. Data from Social Welfare Department show the number of evacuees dropped from more than 100,000 people to 81,458 people. Although the flood situation continued to improve, there were still many evacuees at the relief centres as they had lost their homes, or their houses were badly damaged or covered with mud.

Figure 2.6 The riverbank area at Dataran Air Muleh, Pasir Mas

Figure 2.7 The water overflows the riverbank at Dataran Air Muleh, Pasir Mas

2.4 FLOOD ROUTING

Understanding According to Chow, Maidment and Mays (1988), the term flood routing refers to procedures to determine the outflow hydrograph at a point downstream in a river as a function of the inflow hydrograph at a point upstream. As flood waves travel downstream they are attenuated and delayed. That is, the peak flow of the hydrograph decreases and the time base of the hydrograph increases. The shape of the outflow hydrograph depends upon the channel geometry and roughness, bed slope, length of channel reach, and initial and boundary flow conditions. The propagation of flood waves in a channel is a gradually varied unsteady flow process, which is governed by conservation of mass and momentum equations. Brass (1990) agree with the solution of these equations in a distributed manner is referred to as distributed routing of flood waves. When no spatial variability is taken into account and when the channel reach or reservoir is considered as a black box, the corresponding routing procedure is referred to as lumped routing.

Two categories of routing can be recognised which is reservoir routing and channel routing. Reservoir routing is used to determine the peak-flow attenuation that a hydrograph undergoes as it enters a reservoir or other type of storage pool. Input data needed for storage routing include the inflow hydrograph and reservoir characteristics which is storage and outlet facilities. In channel routing, the change in the shape of a hydrograph as it travels down a channel is studied. By considering a channel reach at an input hydrograph at the upstream end, this form of routing aims to predict the flood hydrograph at various sections of the reach. Information on the flood-peak attenuation and the duration of levels obtained by channel routing is of utmost importance in operations and flood protection works.

2.5 SATELLITE-BASED RAINFALL DATA

Warming Measuring rainfall from space appears to be the only cost effective and viable means in estimating regional precipitation and the satellite rainfall products are essential to hydrological and agricultural modelling. Rainfall can be estimated remotely, either from ground-based weather radars or from satellite. Radars are active devices, emitting radiation at wavelengths ranging between 1 and 10 cm, and receiving the echo from targets such as raindrops.

The maximum range of radars is only about 300 km, so offshore coverage is limited. Also, radars are prohibitively expensive in the Third World. With the advent of geostationary weather satellites in the 1960s and 70's, positioned above the equator at 5-6 positions around the globe to provide complete coverage, various techniques have been developed to estimate rainfall from visible and infrared (IR) radiation upwelling from the Earth into space. The higher the cloud albedo, the more droplets and/or ice crystals it contains and the deeper it tends to be, so the more likely rainfall is on the ground. The lower the IR brightness temperature, the higher the cloud top, and the more likely the rainfall.

Research by Prasetia (2012) to validate the satellite data by validate monthly and seasonal rain rates derived from the Tropical Rainfall Measuring Mission Precipitation Radar (PR) over Indonesian region using rain gauge data analysis from 2004 to 2008. The study area employed 20 gauges across Indonesia to monitor three Indonesian regional rainfall types. The validation analysis showed very good correlation with the gauge data of monsoonal type rainfall, high correlation for anti-monsoonal type rainfall.

2.6 AUTO ESTIMATOR METHOD

The Hydro-Estimator (H-E) is a single-channel (11-µm) rain rate algorithm whose origins go all the way back to the semi-automated Interactive Flash Flood Analyzer (IFFA; Scofield 1987) which was originally developed in the late 1970's. According to Vicente et al (1998), many of the IFFA's features were automated into the Auto-Estimator (AET) in the late 1990's, including rainfall rate as a function of IR window brightness temperature which is calibrated against radar and corrections for atmospheric moisture. However, the A-E frequently assigned high rain rates to cold (non-raining) cirrus clouds, leading to the H-E which replaced the A-E in 2002. The H-E assigns rainfall only to pixels that are colder than the average of the surrounding cloudy pixels in order to eliminate cirrus clouds.

2.6.1 Precipitation Rate Equations

The primary feature of the A-E is a fixed relationship between rainfall rate and temperature that was derived from 6800 pairs of collocated IR brightness temperatures and radar rainfall rates from convective cores of mesoscale convective systems (MCS's) for 16 events from March-June 1995 (Vicente et al. 1998). Regression was used to derive the following relationship:

$$R = 1.1183(10^{11}).\exp[-3.6382(10^{-2}).T^{1.2}] \quad \text{(Eq.1)}$$

$$T(K) = T(°C) + 273.15 \quad \text{(Eq.2)}$$

Where:

R = rainfall rate $(mm.h^{-1})$

T = temperature (K)

2.8 SUMMARY

In this chapter, the review of chronology of flood incident during December 20114 already explained. The elaboration of satellite-based rainfall data used and the significant of data validation have been discussed in this chapter.

CHAPTER 3

METHODOLOGY

3.1 METHODOLOGY

The purpose of this study is to analyses the lag time (Δt) for flood incident in Kelantan River Basin. The purposes of this chapter are to

(1) Describe the research methodology of this study,

(2) Explain the sample selection,

(3) Describe the procedure used in collecting the data, and

(4) Provide an explanation of the statistical procedures used to analyse the data.

This chapter explain the methodology of research to accomplish the research objective. There are four (4) main phase for this research which is data collection, pre-processing, process and finally the output of the research (Figure 3.1).

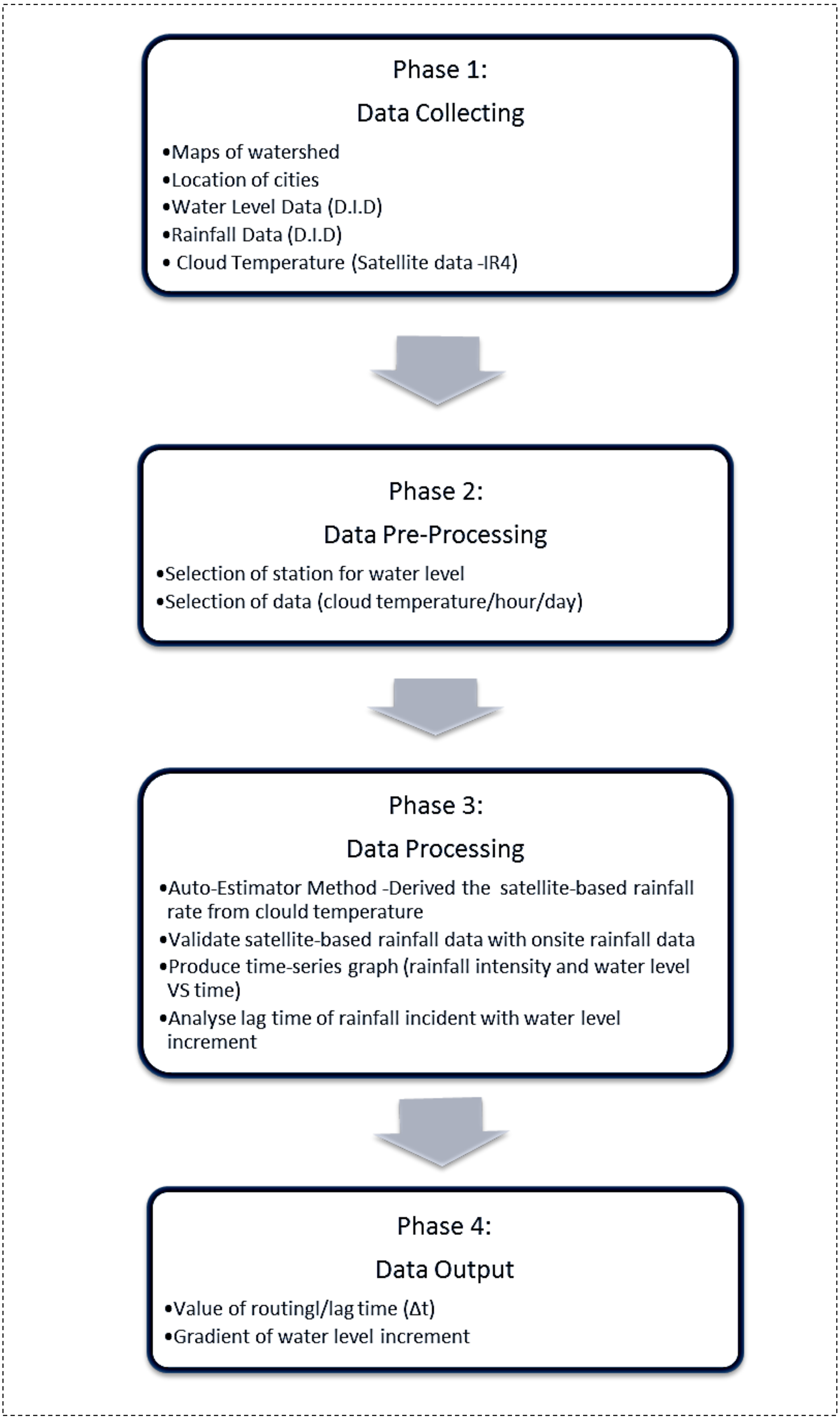


Figure 3.1 Flow diagram of Research Methodology

3.1 Study Area

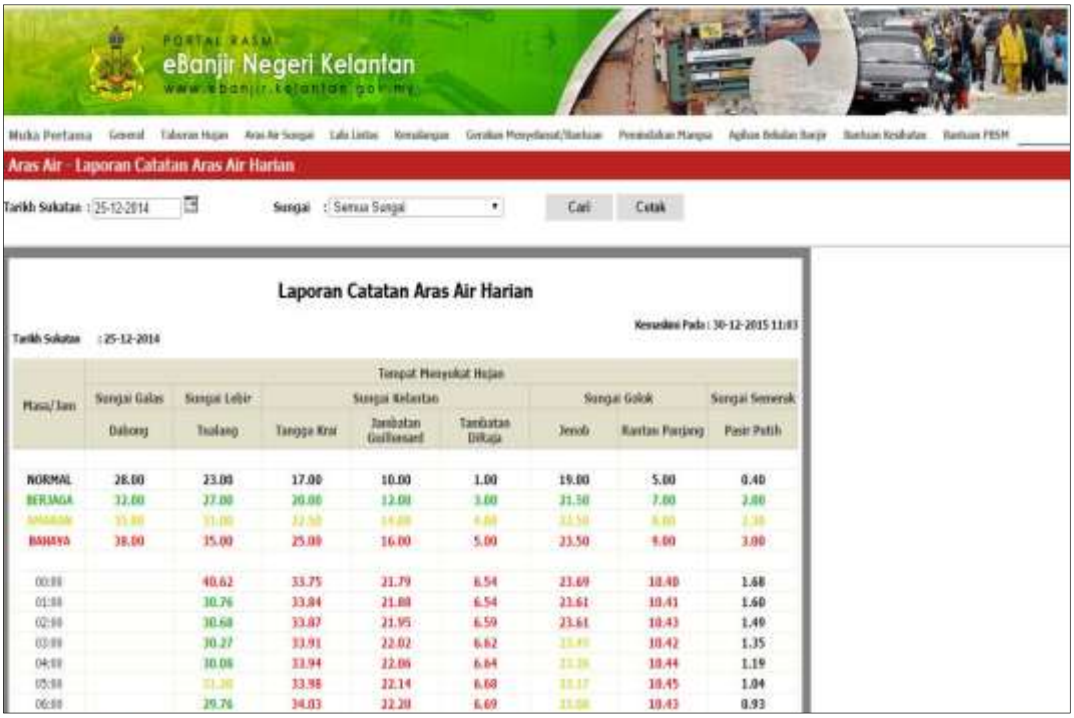
Kelantan has a tropical climate, with temperatures from 21 to 32 °C and intermittent rain throughout the year. The wet season is the east-coast monsoon season from November to January. Kelantan situated in the eastern part of Peninsular Malaysia with the total area 15, 105 km2. The selected study area comprises of five major cities in Kelantan which are Gua Musang, Kuala Krai, Tanah Merah, Pasir Mas and Kota Bharu. The next table shows the population and area of five major cities in Kelantan that related in this study.

Table 3.1: Population and area of major cities in Kelantan

Cities	Population (as of 2010)	Area (sq. miles)
Gua Musang	86,198	8,214.30
Kuala Krai	104,234	2,287.10
Tanah Merah	115,949	884.14
Pasir Mas	180,878	572.38
Kota Bharu	314,964	115.64

3.2 DATA COLLECTING

The water level and on site rainfall data for this study supplied by the Department of Irrigation & Drainage Malaysia (DID). The DID provide dataset of water level and rainfall rate for entire Kelantan state through their online inventory (Figure 3.2 & 3.3).



Laporan Catatan Aras Air Harian

Tarikh Sukatan : 25-12-2014

Kemaskini Pada : 30-12-2015 11:03

Masa/Jam	Sungai Galas	Sungai Lebir	Sungai Kelantan			Sungai Golok		Sungai Semerak
	Dabong	Tualang	Tangga Krai	Jambatan Guillemard	Tambatan Diraja	Jenob	Rantau Panjang	Pasir Putih
NORMAL	28.00	23.00	17.00	10.00	1.00	19.00	5.00	0.40
BERJAGA	32.00	27.00	20.00	12.00	3.00	21.50	7.00	2.00
AMARAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BAHAYA	38.00	35.00	25.00	16.00	5.00	23.50	9.00	3.00
00:00		40.62	33.75	21.79	6.54	23.69	10.40	1.68
01:00		30.76	33.84	21.88	6.54	23.61	10.41	1.60
02:00		30.68	33.87	21.95	6.59	23.61	10.43	1.49
03:00		30.27	33.91	22.02	6.62	[illegible]	10.42	1.35
04:00		30.08	33.94	22.06	6.64	[illegible]	10.44	1.19
05:00		[illegible]	33.98	22.14	6.68	[illegible]	10.45	1.04
06:00		29.76	34.03	22.20	6.69	[illegible]	10.43	0.93

Figure 3.2 Water Level Dataset Retrieved from D.I.D website

(Source: http://ebanjir.kelantan.gov.my/p_parpt03.php)

Figure 3.3 Onsite Rainfall Dataset Retrieved from D.I.D website

(Source: http://ebanjir.kelantan.gov.my/p_thrpt01.php)

The temperatures of cloud for every hour starting from December 20 (00:00) until December 31(23:00) were collected from satellite based data (IR4), (Figure 3.4).

Figure 3.4 The interface of Satellite base Dataset (IR4)

With the advent of geostationary weather satellites in the 1960s and 70's, positioned above the equator at 5-6 positions around the globe to provide complete coverage, various techniques have been developed to estimate rainfall from visible and infrared (IR) radiation upwelling from the Earth into space. The higher the cloud albedo, the more droplets and/or ice crystals it contains and the deeper it tends to be, so the more likely rainfall is on the ground. A combination of both channels works best (Arkin, P.A. and P.E. Ardanuy, 1989).

The visible/IR rain retrieval algorithms work best at low latitudes, because at higher latitudes the view is more slanted, confusion arises with high-albedo surfaces of snow or ice, and deep-convective precipitation is less common. Another problem is incomplete pixel filling for small cumulonimbus clouds (Vicente, G.A., R.A. Scofield & W.P. Menzel 1998)

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3.3 PRE - PROCESSING

The dataset of water level and rainfall rate provide by DID were selected. Only the data from Kelantan River Basin will be selected from the dataset. Table 3.1 were the example of selected data retrieve from DID.

Table 3.2 Selected water level dataset by DID
(21 December 2014)

Time	Sungai Kelantan Flood level station (21-12-2014)		
	(Tangga Krai)	(Jambatan Guillemard)	(Tambatan DiRaja)
00:00	22.71	13.83	3.11
01:00	21.36	13.69	3.33
02:00	21.31	13.66	3.33
03:00	21.31	13.63	3.30
04:00	21.30	13.59	3.27
05:00	21.35	13.56	3.21
06:00	21.38	13.53	3.17
07:00	21.43	13.50	3.14
08:00	21.56	13.48	3.09
09:00	21.64	13.46	3.09
10:00	21.74	13.46	3.07
11:00	21.84	13.46	3.07
12:00	21.89	13.48	3.03
13:00	22.00	13.50	2.97
14:00	22.12	13.54	2.98
15:00	22.16	13.57	2.98
16:00	22.26	13.59	2.91
17:00	22.27	13.63	2.92
18:00	22.36	13.65	2.91
19:00	22.41	13.68	3.00
20:00	22.41	13.70	2.97
21:00	22.50	13.73	3.06
22:00	22.54	13.76	3.07
23:00	22.61	13.79	3.09
NORMAL	17.00	10.00	1.00
CAUTION	20.00	12.00	3.00
WARNING	22.50	14.00	4.00
DANGER	25.00	16.00	5.00

3.4 PROCESSING

3.4.1 Auto-Estimator Method

The Auto-Estimator methods as state in previous chapter 3 were used to derive the rainfall rate for satellite database (IR4). The temperatures of the cloud in Celsius were converted to Kelvin using Eqn 2 as stated in Chapter 3. Then the Eqn 3 will be used to generate the rainfall rate, Table 3.2 show the example of complete processing data. From the complete satellite based rainfall rate data, the time series graph of rainfall versus time was produce and combine together with the time series graph of water level versus time (Chapter 4).

Table 3.3 Rainfall rate using Auto-Estimator method at Gua Musang (20 December 2014)

Date	Time	Temperature (C)	Temperature (K)	$\exp(-3.6828 \times 10^{-2} \times T^{1/2})$	R (mi//h)
20/12/2014	00:00	-20	253.15	5.66745E-13	0.06
	01:00	-20	253.15	5.66745E-13	0.06
	02:00	-30	243.15	2.14582E-12	0.24
	03:00	-55	218.15	5.70191E-11	6.38
	04:00	-65	208.15	2.07446E-10	23.20
	05:00	-65	208.15	2.07446E-10	23.20
	06:00	-60	213.15	1.08923E-10	12.18
	07:00	-60	213.15	1.08923E-10	12.18
	08:00	-65	208.15	2.07446E-10	23.20
	09:00	-65	208.15	2.07446E-10	23.20
	10:00	-70	203.15	3.93867E-10	44.05
	11:00	-70	203.15	3.93867E-10	44.05
	12:00	-65	208.15	2.07446E-10	23.20
	13:00	-60	213.15	1.08923E-10	12.18
	14:00	-55	218.15	5.70191E-11	6.38
	15:00	-35	238.15	4.15842E-12	0.47
	16:00	-20	253.15	5.66745E-13	0.06
	17:00	-15	258.15	2.90106E-13	0.03
	18:00	-15	258.15	2.90106E-13	0.03
	19:00	-15	258.15	2.90106E-13	0.03
	20:00	-10	263.15	1.48114E-13	0.02
	21:00	-	-	-	-
	22:00	-	-	-	-
	23:00	-5	268.15	7.54264E-14	0.01

3.4.2 Statistical Correlation

All the data has been opened in excel to be organized in the form of tables. Statistical Correlation was conducted for the two types of data i) satellite-based rainfall rate and ii) onsite-based rainfall rate. Scatter plot of the data to see any underlying trend in the relationship of rainfall from satellite-based rainfall rate and onsite-based rainfall rate from Department of Irrigation and Drainage (DID). This method is simple to validate the dataset and provides a correlation value (R^2) which is an indication of the strength of relationship. In general, $R^2 > 0$ indicates positive relationship, $R^2 < 0$ indicates negative relationship while $R^2 = 0$ indicates no relationship. The value of R^2 in the range of 0.5 to 1.0 consider as strong relationship.

3.4.3 Descriptive Statistics

After all the data has been opened in excel to be organized in the form of tables and graphs. Descriptive statistics was conducted for the three types of data i) satellite-based rainfall rate and ii) water level data. Graphical analysis of time series graph was used to compare water level and rainfall from satellite based rainfall estimates over selected stations in Kelantan River Basin. This method involved plotting water level and satellite based measurements against time. This method is simple and provides quick visual observation at a given time.

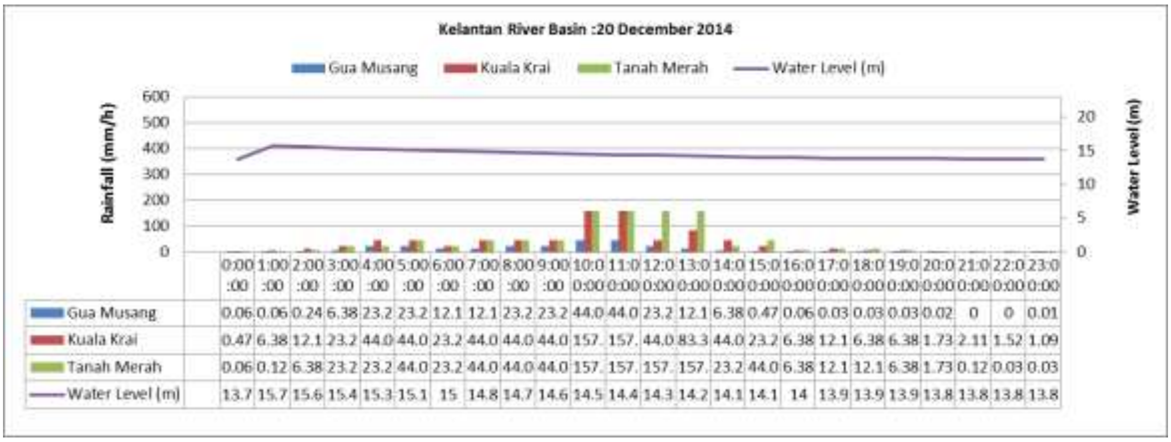

Figure 3.5 Time-series graph for 20 December 2014

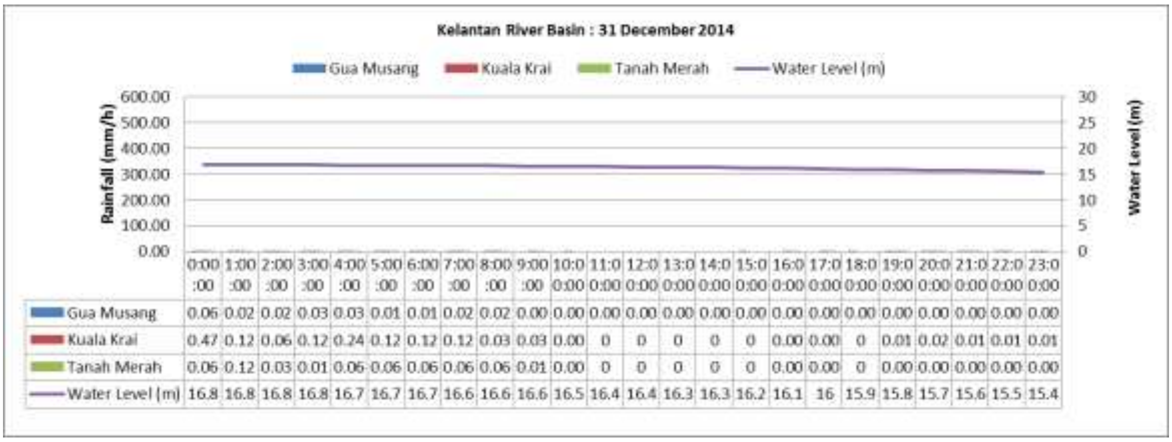

Figure 3.6 Time-series graph for 31 December 2014

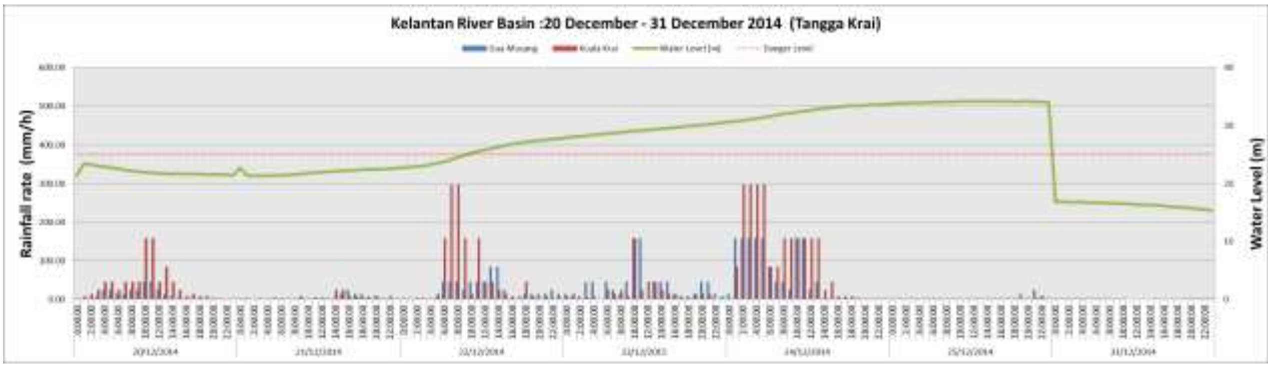

Figure 3.7 Time-series graph for Tangga Krai Flow

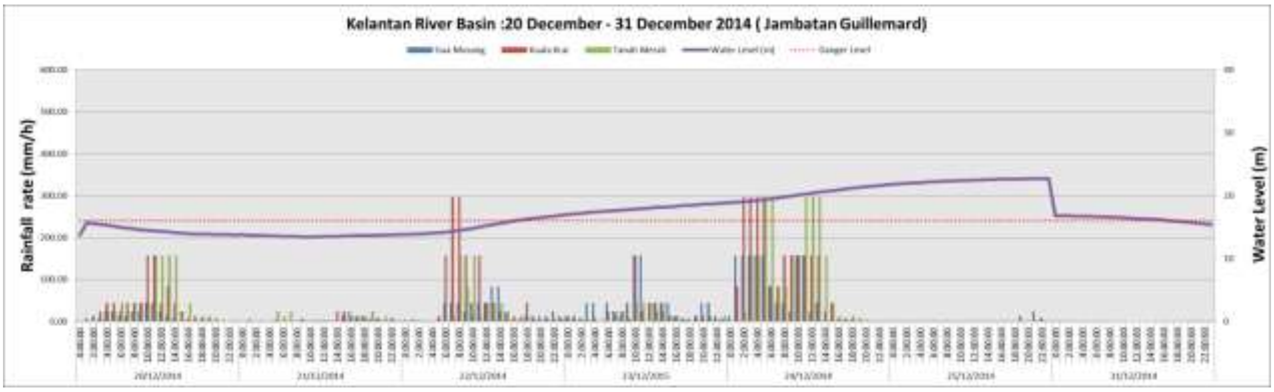

Figure 3.8 Time-series graph for Jambatan Guillemard Flow

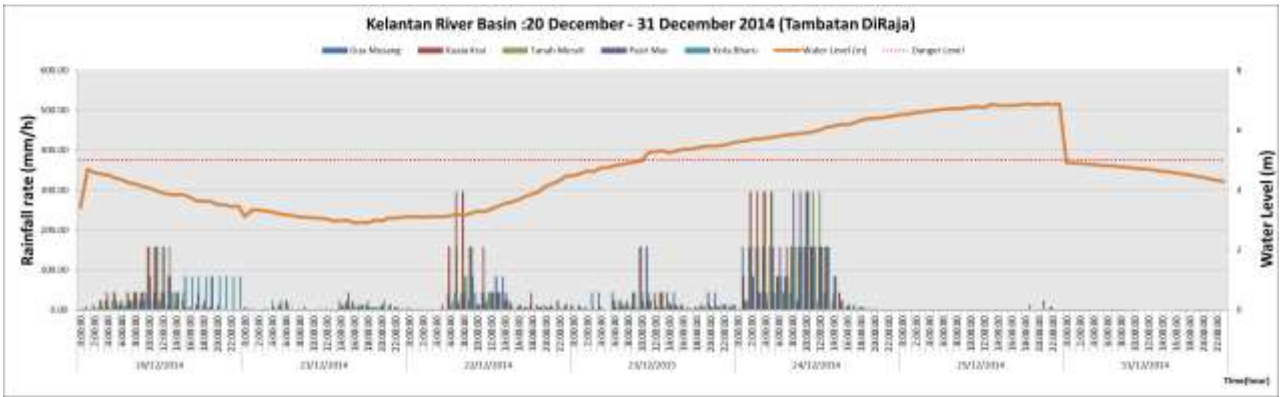

Figure 3.9 Time-series graph for Tambatan DiRaja Flow

3.5 OUTPUT

The final output obtain from the graph was the lag time (Δt) of the flood incident from upstream to downstream of Kelantan River Basin during December 2014 (Chapter 4).

3.6 SUMMARY

This chapter was describe the methodology of this research, as such describe the procedure used in collecting the data, derived satellite-based rainfall data from temperature of top cloud data from public domain, provide an explanation of the statistical procedures used to analyse the data and produce time series graph of satellite-based rainfall data and water level versus time, so at the end of the research the objective is successfully achieved.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this chapter, all the information from the previous chapter was analysed. Analysis was made of THREE (3) parts, namely i) the reliability of satellite based rainfall data, ii) Lag time change of water level rising to dangerous levels of water level for every DID water level stations, and iii) time lag between the occurrence of extreme rain-rate rainfall with increasing of water level to the dangerous level at DID water level station.

4.2 RELIABILITY SATELLITE-BASED RAINFALL DATA

The daily rainfall accumulations for the measured and the estimated satellite-based rainfall were computed by hourly values. The comparison of satellite-based rainfall data with measure rainfall data was conducted separately for the six days (6) starting from 20 December until 25 December 2014. The comparison from 26 until 30 December 2014 not be able to carried-out because there were no available measure data from DID.

The hourly rainfall data for 20 December has been taken for comparison and found that the estimated value and measured value shows a very good agreement (r = 0.93). The regression line fitted through origin has a slope of 0.811 the dataset (Figure 4.1).

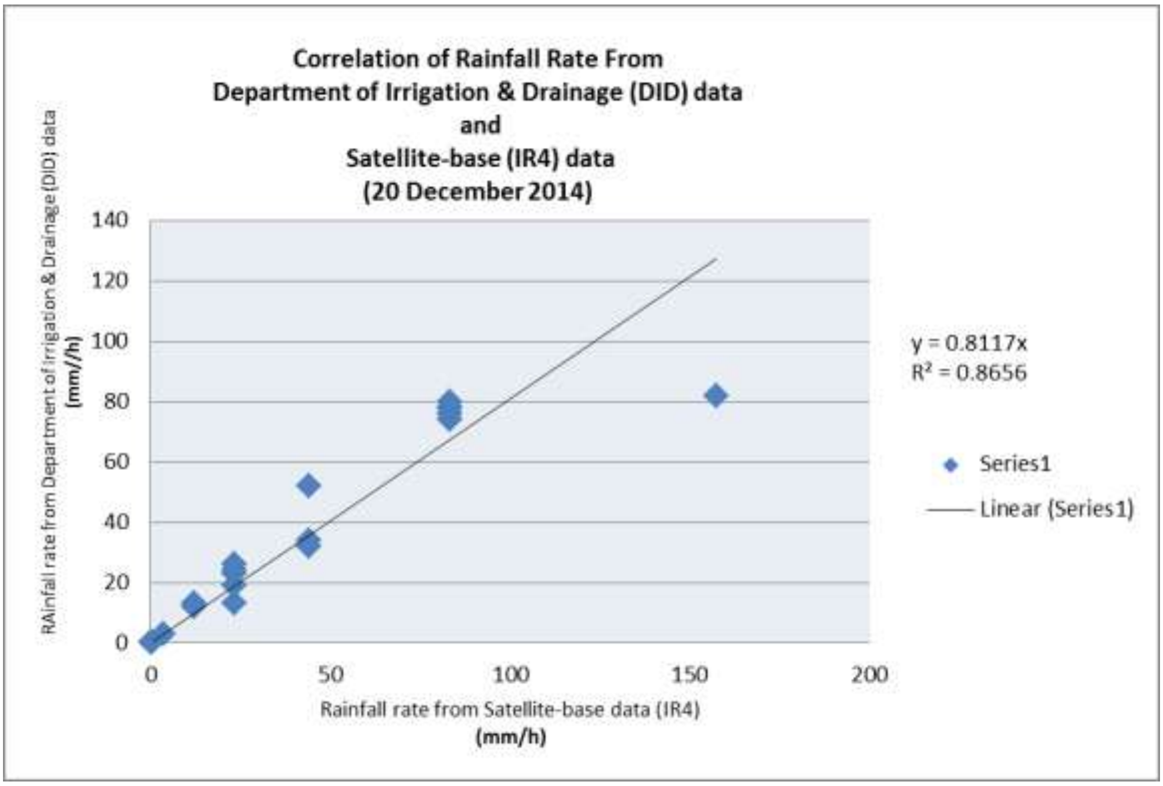

Figure 4.1: Correlation of rainfall rate for 20 December 2014

The hourly rainfall data for 21 December has been taken for comparison and found that the estimated value and measured value shows a very good agreement (r = 0.99). The regression line fitted through origin has a slope of 0.92 the dataset (Figure 4.2).

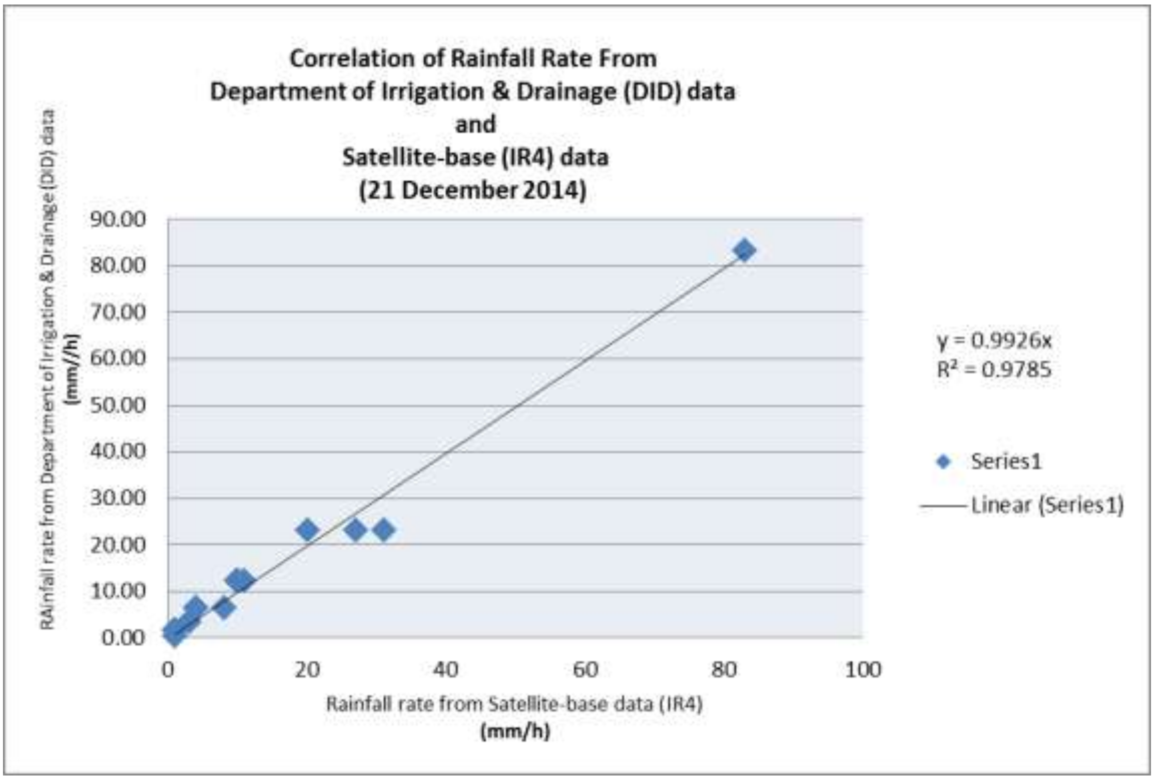

Figure 4.2: Correlation of rainfall rate for 21 December 2014

The hourly rainfall data for 22 December has been taken for comparison and found that the estimated value and measured value shows a very good agreement (r = 0.95). The regression line fitted through origin has a slope of 0.94 the dataset (Figure 4.3).

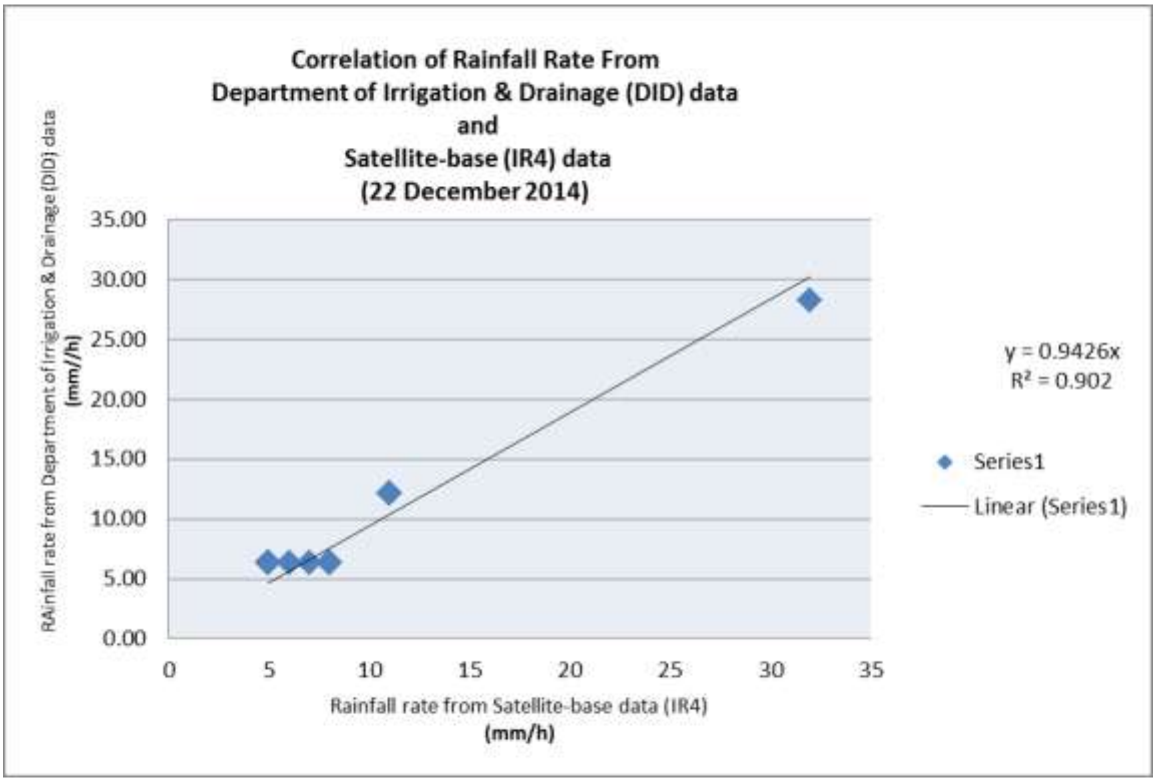

Figure 4.3: Correlation of rainfall rate for 22 December 2014

The hourly rainfall data for 23 December has been taken for comparison and found that the estimated value and measured value shows a very good agreement (r = 0.98). The regression line fitted through origin has a slope of 1.02 the dataset (Figure 4.4).

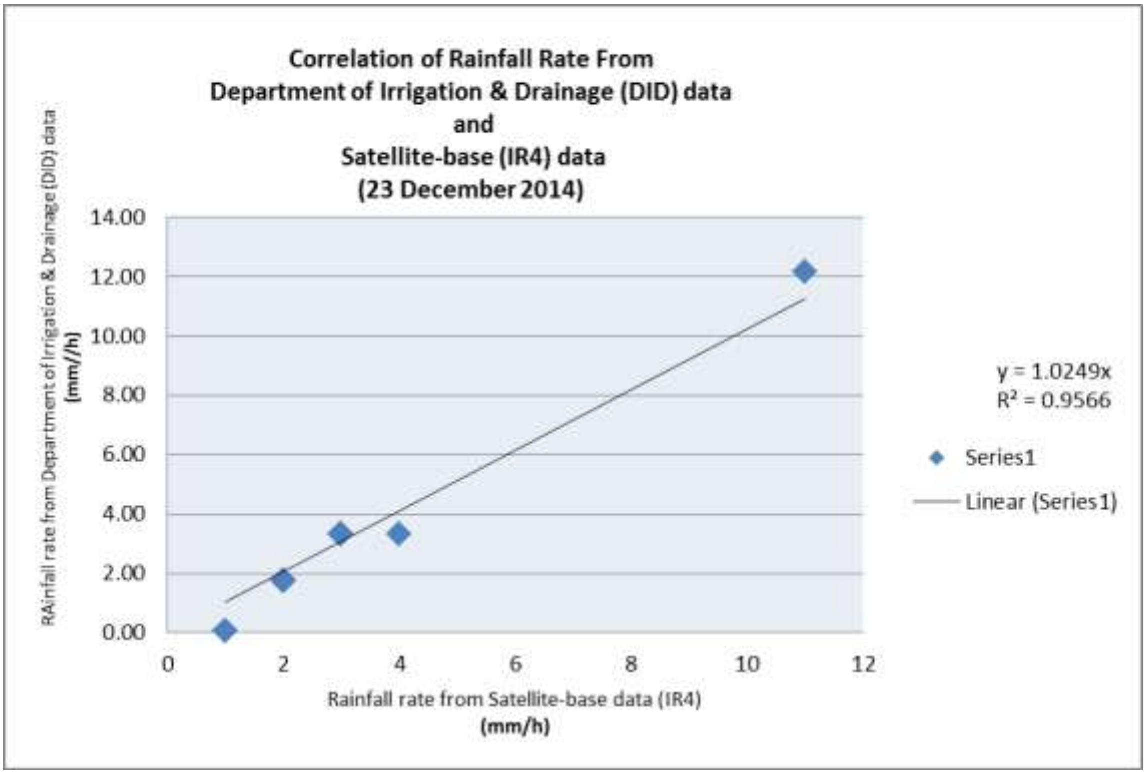

Figure 4.4: Correlation of rainfall rate for 23 December 2014

The hourly rainfall data for 24 December has been taken for comparison and found that the estimated value and measured value shows a very good agreement (r = 0.90). The regression line fitted through origin has a slope of 1.103 the dataset (Figure 4.5).

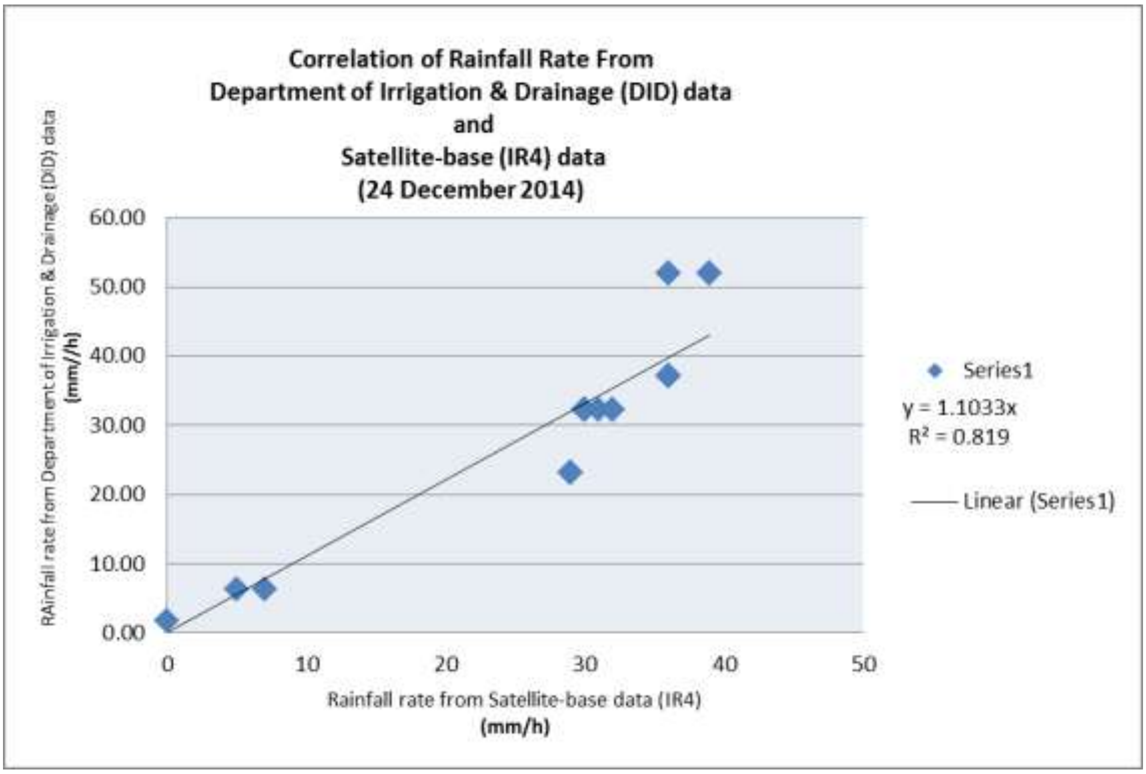

Figure 4.5: Correlation of rainfall rate for 24 December 2014

The hourly rainfall data for 25 December has been taken for comparison and found that the estimated value and measured value shows a very good agreement (r = 0.99). The regression line fitted through origin has a slope of 1.13 the dataset (Figure 4.6).

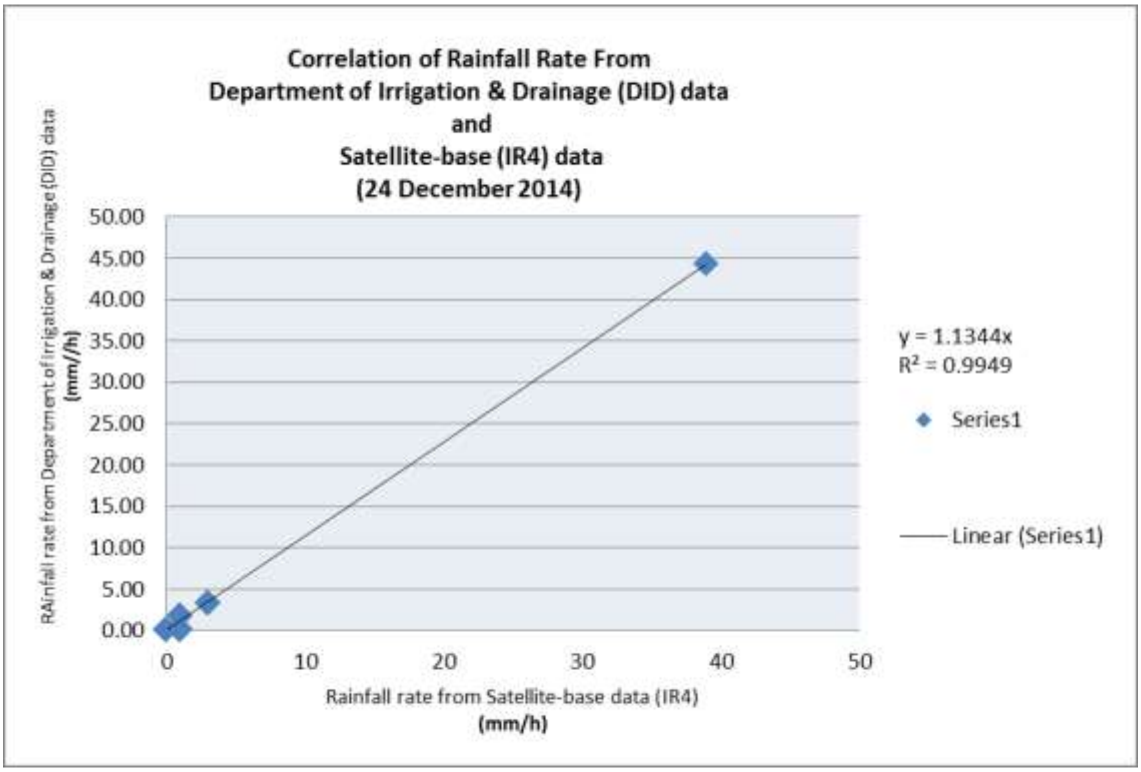

Figure 4.6: Correlation of rainfall rate for 25 December 2014

Linear graphs of single mass curves of cumulated rainfall displayed straight lines in the station used in the study. Furthermore, the coefficient of determination (R^2) was above 0.5 everyday, an indication that more than 50% of gauge rainfall values fitted the linear regression line. Therefore, the data was considered valid and consistent over these stations and thus homogeneous and good for further analysis.

4.3 LAG TIME (∆t) OF WATER LEVEL INCREMENT

The lag time (∆t) of water level at Kelantan River basin is analyse with the illustration of time series graph based on data provided by DID. From the graph, after upstream flows (Tangga Krai) exceed danger level it take about 6 hours for mid-stream area (Jambatan Guillemard) to exceed danger level. 17 hours after Jambatan Guillemard exceed danger level, the downstream area (Tambatan DiRaja) also exceed danger level (Figure 4.7). Starting 31 December 2014, the water level starts to decrease until it reaches back normal level.

The predictions of lag time for the flood happen were very crucial for executed plan or early warning. A disaster usually occurs when people are not prepared for a flood due to the lack of warning system, preparedness and mitigation measure.

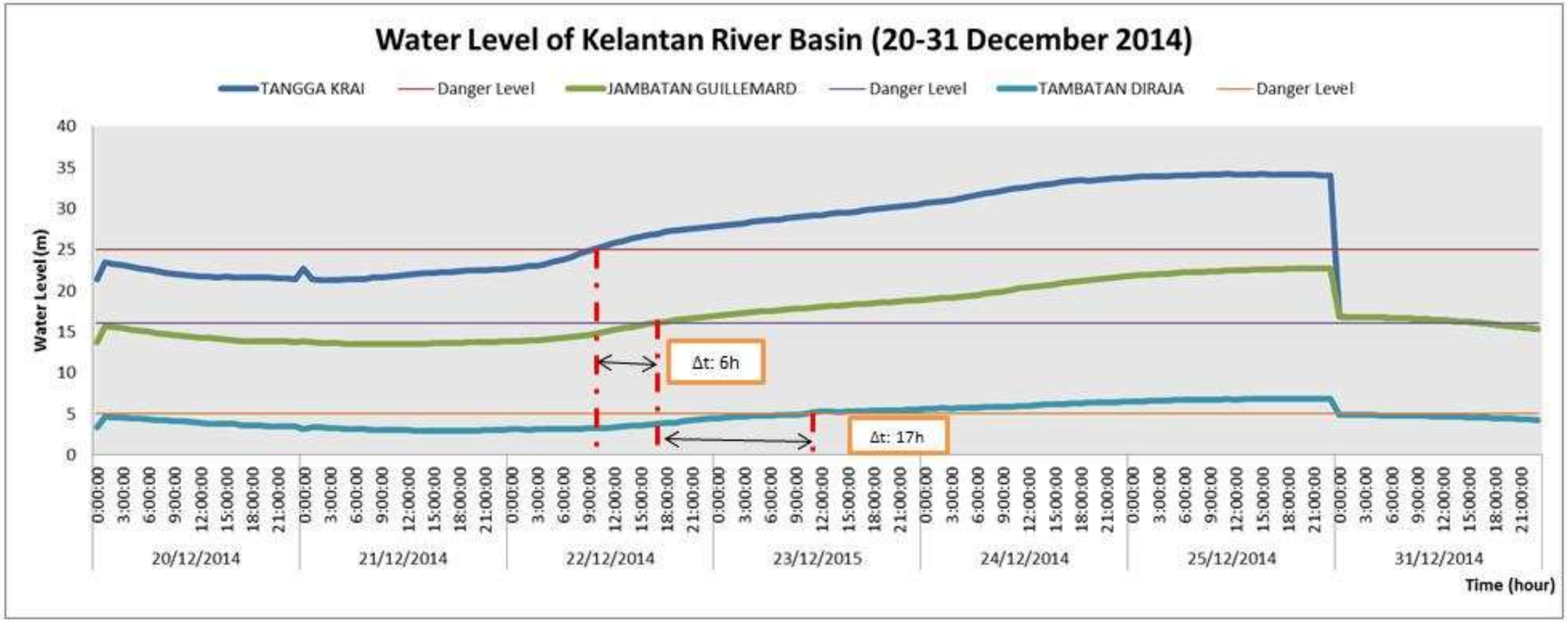

Figure 4.7 Lag time for water level of Kelantan River Basin based on DID dataset

4.4 LAG TIME (∆t) ANALYSIS

4.4.1 Lag time (∆t) of water level in Tangga Krai Flow with the influence of rainfall rate at Gua Musang and Kuala Krai

Tangga Krai located in Kuala Krai District. So the study area for this analysis focuses at Gua Musang and Kuala Krai flow which is the upstream flow of Kelantan River basin. The lag time (∆t) from three type of flow; i) Heavy rainfall to the water level exceed danger level, ii) water level exceed danger level to next heavy rainfall rate and iii) Heavy rainfall to the water level exceed maximum water level is analysed with the time series graph (Figure 4.8). Based on the graph gradient of the flow rate based on the rainfall rate and water level were computed (Table 4.1).

From the graph, the danger level of Tangga Krai is 25.0 meter. On December 22 (07:00), the upstream areas, Gua Musang and Kuala Krai receive a very heavy rainfall and it continues for a few hours. The heavy rain effect the water level rise until it exceeds the danger level at December 22 (10:00) which is 3 hours after the first hour of heavy rain start. The increment of water level for this period is 0.37 m/hour.

Even this upstream area did not receive lot of heavy rain during December 22 (10:00) until December 24 (02:00) the water level keep rise up to 30.8 meter which is more 5 meter from the danger level. It took almost 39 hour from the time of water exceed danger level until the next heavy rainfall. The increment of water level for this period is 0.14 m/hour.

The heavy rainfalls continue starting from December 24 (02:00) for more than 4 hours. The heavy rainfall effect the water levels until it reach the maximum reading for the water level at Tangga Krai. The lag time from the heavy rainfall until the maximum water level is about 33 hours. The increment of water level for this period is 0.1 m/hour. The data from 26 until 30 December 2014 not available because the water level already exceeds the maximum level of the gauge at Tangga Krai station.

Table 4.1 Lag time of Tangga Krai Flow Influence by Gua Musang and Kuala Krai Rainfall Rates

	Tangga Krai Flow		
Type of Flow	Period	Routing Time,Δt	Gradient (m/hour)
Heavy rainfall to Exceed Danger Level	22/12 (0700) to 22/12 (1000)	3 hours	0.37
Exceed Danger Level to Heavy rainfall	22/12 (1100) to 24/12 (0200)	39 hour	0.14
Heavy rainfall to Exceed Max. Level	24/12 (0200) to 25/12 (1100)	33 hour	0.10

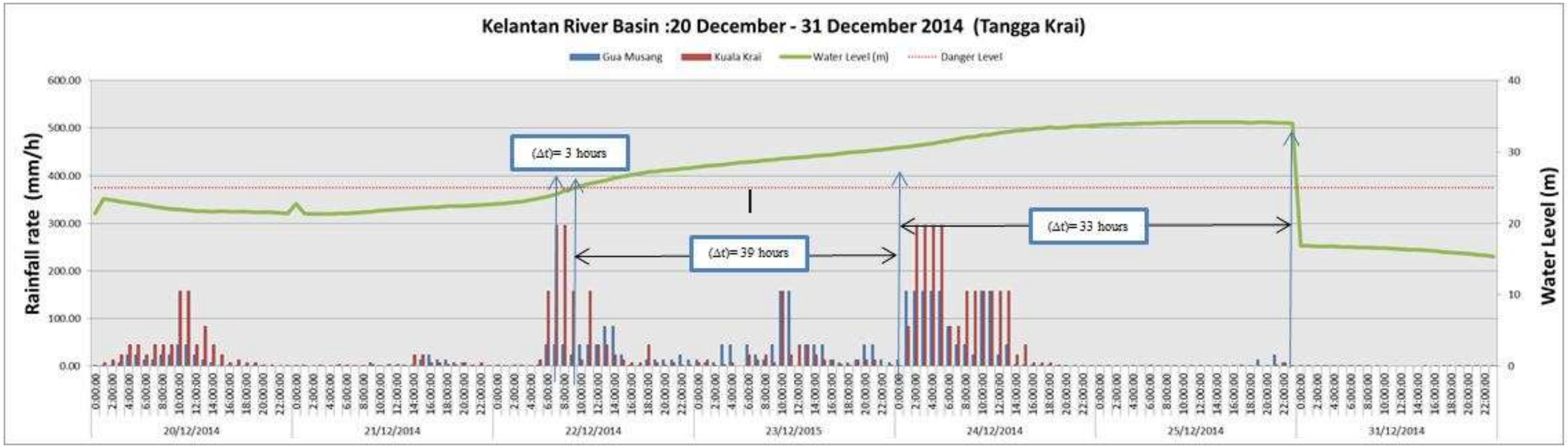

Figure 4.8 Lag Time for Tangga Krai flow

4.4.2 Lag time (∆t) of water level in Jambatan Guillemard Flow with the influence of rainfall rate at Gua Musang ,Kuala Krai and Tanah Merah

Jambatan Guillemard located in Kusial which is one of area in Tanah Merah District. So the study area for this analysis focuses at Gua Musang, Kuala Krai and Tanah Merah flow which is the upstream flow of Kelantan River basin. The lag time (∆t) from three type of flow; i) Heavy rainfall to the water level exceed danger level, ii) water level exceed danger level to next heavy rainfall rate and iii) Heavy rainfall to the water level exceed maximum water level is analysed with the time series graph (Figure 4.9). Based on the graph gradient of the flow rate based on the rainfall rate and water level were computed (Table 4.2).

From the table 4.2 and figure 4.8, the danger level of Jambatan Guillemard is 16.0 meter. On December 22 (07:00), these areas which are Gua Musang, Kuala Krai and Tanah Merah receive a very heavy rainfall and it continues for a few hours. The heavy rain effect the water level rise until it exceeds the danger level at December 22 (18:00) which is 11 hours after the first hour of heavy rain start. The increment of water level for this period is 0.16 m/hour.

Even the upstream area did not receive lot of heavy rain during December 22 (18:00) until December 24 (02:00) the water level keep rise up to 19.1 meter which is more 3 meter from the danger level. It took almost 32 hour from the time of water exceed danger level until the next heavy rainfall. The increment of water level for this period is 0.10 m/hour.

The heavy rainfalls continue starting from December 24 (02:00) for more than 4 hours. The heavy rainfall effect the water levels until it reach the maximum reading for the water level at Tangga Krai. The lag time from the heavy rainfall until the maximum water level is about 45 hours. The increment of water level for this period is 0.08 m/hour.

The data from 26 until 30 December 2014 not available because the water level already exceeds the maximum level of the gauge at Jambatan Guillemard station.

Table 4.2 Routing Time of Jambatan Guillemard Flow Influence by Gua Musang, Kuala Krai and Tanah Merah Rainfall Rates

	Jambatan Guillemard Flow		
Type of Flow	Period	Routing Time,Δt	Gradient (m/hour)
Heavy rainfall to Exceed Danger Level	22/12 (0700) to 22/12 (1800)	11 hours	0.16
Exceed Danger Level to Heavy rainfall	22/12 (1800) to 24/12 (0200)	32 hour	0.10
Heavy rainfall to Exceed Max. Level	24/12 (0200) to 25/12 (2300)	45 hour	0.08

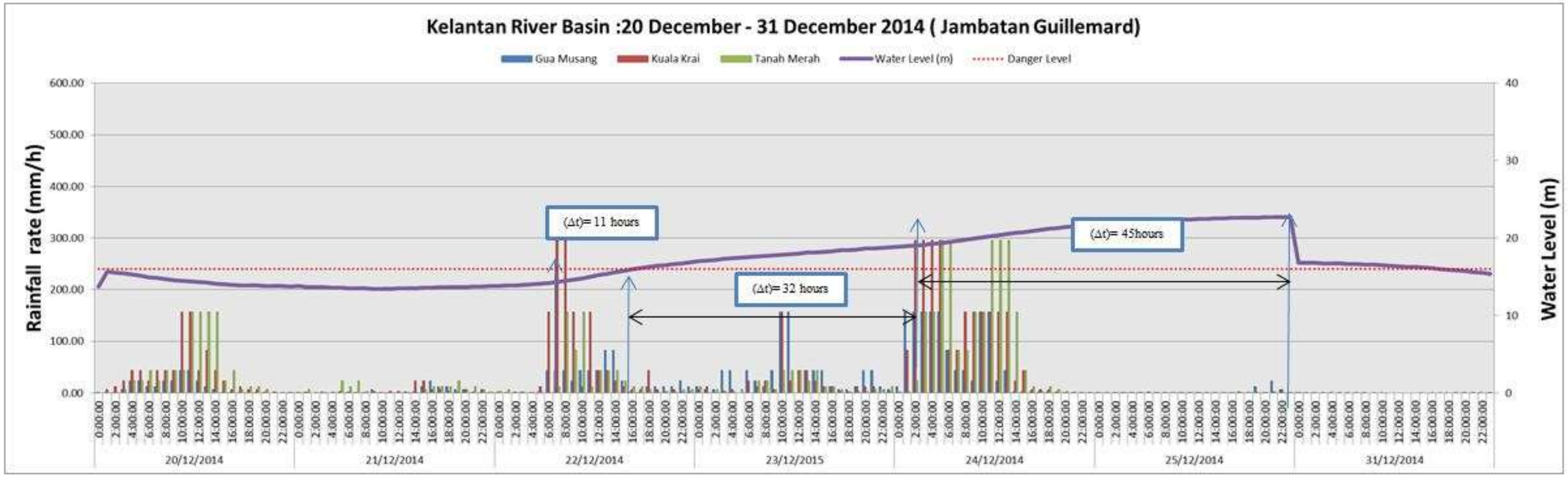

Figure 4.9 Lag Time for Jambatan Guillemard flow

4.4.3 Lag time (∆t) of water level in Tambatan DiRaja Flow with the influence of rainfall rate at Gua Musang ,Kuala Krai, Tanah Merah, Pasir Mas and Kota Bharu

Tambatan DiRaja located in Kota Bharu District. So the study area for this analysis focuses at Gua Musang, Kuala Krai, Tanah Merah, Pasir Mas and Kota Bharu flow which is the downstream flow of Kelantan River basin. The lag time (∆t) from three type of flow; i) Heavy rainfall to the water level exceed danger level, ii) water level exceed danger level to next heavy rainfall rate and iii) Heavy rainfall to the water level exceed maximum water level is analysed with the time series graph (Figure 4.10). Based on the graph gradient of the flow rate based on the rainfall rate and water level were computed (Table 4.3).

From the table 4.3 and figure 4.9, the danger level of Tambatan DiRaja is 5.0 meter. On December 22 (07:00), the upstream areas, Gua Musang and Kuala Krai receive a very heavy rainfall and it continues for a few hours. The heavy rain at upstream effect the water level at downstream area until it exceeds the danger level at December 23 (11:00) which is 28 hours after the upstream area(Tangga Krai) exceed danger level. The increment of water level for this period is 0.08 m/hour.

Even the downstream area did not receive lot of heavy rain during December 23 (11:00) until December 24 (03:00) the water level keep rise up to 5.7 meter which is almost 1 meter from the danger level. It took almost 16 hour from the time of water exceed danger level until the next heavy rainfall. The increment of water level for this period is 0.03 m/hour.

The heavy rainfalls continue starting from December 24 (03:00) for more than 4 hours. The heavy rainfall effect the water levels until it reach the maximum reading for the water level at Tangga Krai. The lag time from the heavy rainfall until the maximum water level is about 44 hours. The increment of water level for this period is 0.01 m/hour.

The data from 26 until 30 December 2014 not available because the water level already exceeds the maximum level of the gauge at Tambatan DiRaja station.

Table 4.3 Routing Time of Tambatan DiRaja Flow Influence by Gua Musang, Kuala Krai , Tanah Merah, Pasir Mas and Kota Bharu Rainfall Rates

	Tambatan DiRaja Flow		
Type of Flow	Period	Routing Time,Δt	Gradient (m/hour)
Heavy rainfall **to** **Exceed Danger Level**	22/12 (0700) to 23/12 (1100)	28 hours	0.08
Exceed Danger Level **to** **Heavy rainfall**	23/12 (1100) to 24/12 (0300)	16 hour	0.03
Heavy rainfall **to** **Exceed Max. Level**	24/12 (0300) to 25/12 (2300)	44 hour	0.03

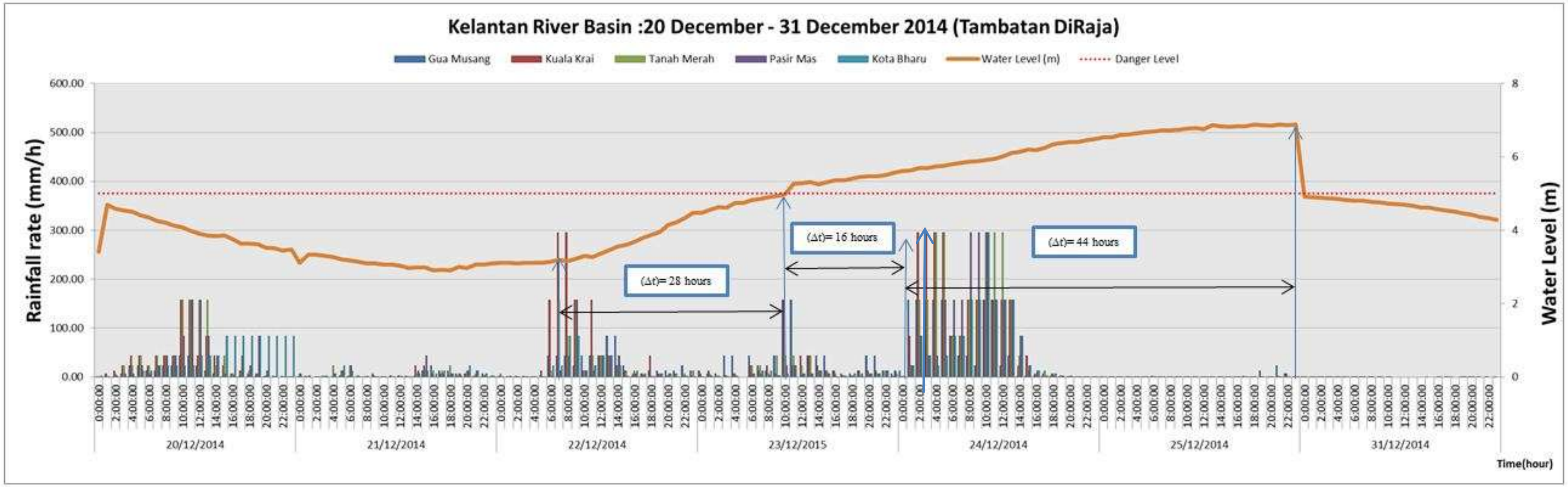

Figure 4.10 Lag Time for Tambatan DiRaja flow

4.5 SUMMARY

In this chapter, the data from previous chapter was analysed in order to accomplish the objective that has been set. Based on analysed data and provided data from DID, the satellite-based rainfall rate with onsite-based rainfall rate were validate. From the graphically illustration of time series graph (satellite-based rainfall data and water level versus time), the objective to determine the lag time of flood incident at Kelantan River Basin in December 2014 was successfully achieved.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This research was carried out in order to determine the la time of flood incident in Kelantan River Basin during December 2014. This chapter will discuss on the conclusion and recommendation for the research. The conclusion of the research need to be evaluated based on the objective of the research. It is very essential in discover and evaluate back the methodology applied for the research could achieve the objective. The recommendation for future researcher in the related field is provided.

The study area was selected along Kelantan River Basin which is the affected area during the flood incident in December 2014.The main objective of this research were to determine the lag time (Δt) of the flood incident from upstream to downstream area of Kelantan River Basin. To achieve the main objective, there were two sub-objective which is i) to validate satellite-based rainfall data and ii) to analyse lag time (Δt), of rainfall incident with the water level at Kelantan River Basin. Auto-estimator method was the method used to determine the satellite-based rainfall rate for this research.

Literature was carried out from various sources. There were several method used by previous researcher to determine the satellite-based rainfall rate. In this study, the simple Auto-Estimator method was selected where the method used the temperature of top cloud from satellite data (IR4). Necessary data which is the onsite-based rainfall data and water level data was obtained from Department of Irrigation and Drainage Malaysia (DID) (Appendix A).

The analysis in this study was carried out using Microsoft Excel. Starting with the converting temperature from Celsius to Kelvin and determining the satellite-based rainfall rate.

In this study, time-series graph of satellite-based rainfall intensity and water level versus time was used to determine the lag time. The satellite-based data and onsite-based data also being validate using statically correlation method.

5.2 EVALUATION FOR OBJECTIVE

Two sub-objectives had been set-up to accomplish the main objective for this study, the objective have been verified and were discussed in previous chapter. Following shows how the objective are conclude

5.2.1 Sub-objective 1: To validate satellite-based rainfall data

Based on the result in chapter four (4), this objective was successfully achieved. From the result, there were good correlation of linear graphs of single mass curves of cumulated rainfall displayed straight lines in stations used in the study. The data was considered valid and consistent over these stations and thus homogeneous and good for further analysis.

5.2.2 Sub-objective 2: To analyse lag time (Δ t), of rainfall incident with the water level at Kelantan River Basin

This objective was also successfully achieved. From the result, the lag time (Δ t), of the flood incident were determined using the time-series graph produced base on the analysed data from chapter three (3).

5.2 Recommendations for future research

To further this research, there are some action plans that can be taken in order to get better results. Some recommendations that can be implemented to further research are:

1. Data collected for this research was downloaded from IR4 satellite. The results of data have been compared with rain-gauge station in order to get more precise result and compare both data to calibrate the data. Instead of using IR4 data, one can also use different type of satellite data like SSM/I or TRMM data to be compared with onsite-based data.

2. Instead of using only one method to get satellite-based rainfall rate, one can also use different approach of method to get the rainfall rate like using Hydro-Estimator with Radar (HE-R), GOES Multi-Spectral Rainfall Algorithm (GMSRA), Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) or Hydro-Estimator (HE) to compare the results.

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APPENDIX A

Daily water level data for Kelantan River Basin

Kemaskini Pada : 11-01-2015 09:07

Tarikh Sukatan : 21-12-2014

Masa/Jam	Water level station							
	Sungai Galas	Sungai Lebir	Sungai Kelantan			Sungai Golok		Sungai Semerak
	Dabong	Tualang	Tangga Krai	Jambatan Guillemard	Tambatan DiRaja	Jenob	Rantau Panjang	Pasir Putih
NORMAL	28.00	23.00	17.00	10.00	1.00	19.00	5.00	0.40
BERJAGA	32.00	27.00	20.00	12.00	3.00	21.50	7.00	2.00
AMARAN	35.00	31.00	22.50	14.00	4.00	22.50	8.00	2.30
BAHAYA	38.00	35.00	25.00	16.00	5.00	23.50	9.00	3.00
00:00	33.10	30.79	22.71	13.83	3.11	22.95	10.40	1.50
01:00	31.68	27.67	21.36	13.69	3.33	23.66	10.21	1.46
02:00	31.75	27.60	21.31	13.66	3.33	23.61	10.23	1.40
03:00	31.85	27.57	21.31	13.63	3.30	23.68	10.22	1.35
04:00	31.93	27.55	21.30	13.59	3.27	23.71	10.25	1.34
05:00	32.00	27.49	21.35	13.56	3.21	23.68	10.25	1.37
06:00	32.05	27.50	21.38	13.53	3.17	23.66	10.25	1.42
07:00	32.10	27.45	21.43	13.50	3.14	23.62	10.25	1.44
08:00	32.15	27.50	21.56	13.48	3.09	23.49	10.27	1.44
09:00	32.17	27.69	21.64	13.46	3.09	23.52	10.29	1.40
10:00	32.20	27.90	21.74	13.46	3.07	23.48	10.29	1.35
11:00	32.19	28.22	21.84	13.46	3.07	23.43	10.29	1.27
12:00	32.19	28.50	21.89	13.48	3.03	23.46	10.32	1.16
13:00	32.22	28.78	22.00	13.50	2.97	23.46	10.33	1.05
14:00	32.28	29.10	22.12	13.54	2.98	23.39	10.33	0.96
15:00	32.37	29.35	22.16	13.57	2.98	23.39	10.34	0.92
16:00	32.48	29.54	22.26	13.59	2.91	23.33	10.35	0.91
17:00	32.61	29.66	22.27	13.63	2.92	23.32	10.36	0.92
18:00	32.73	29.75	22.36	13.65	2.91	23.26	10.35	1.05
19:00	32.84	29.86	22.41	13.68	3.00	23.21	10.34	1.29
20:00	32.94	29.91	22.41	13.70	2.97	23.15	10.37	1.49
21:00	32.97	30.02	22.50	13.73	3.06	23.11	10.39	1.61
22:00	33.03	30.19	22.54	13.76	3.07	22.97	10.38	1.61
23:00	33.06	30.43	22.61	13.79	3.09	22.89	10.38	1.57

Kemaskini Pada : 11-01-2015 09:07

Tarikh Sukatan : 22-12-2014

Masa/Jam	Water level station							
	Sungai Galas	Sungai Lebir	Sungai Kelantan			Sungai Golok		Sungai Semerak
	Dabong	Tualang	Tangga Krai	Jambatan Guillemard	Tambatan DiRaja	Jenob	Rantau Panjang	Pasir Putih
NORMAL	28.00	23.00	17.00	10.00	1.00	19.00	5.00	0.40
BERJAGA	32.00	27.00	20.00	12.00	3.00	21.50	7.00	2.00
AMARAN	35.00	31.00	22.50	14.00	4.00	22.50	8.00	2.30
BAHAYA	38.00	35.00	25.00	16.00	5.00	23.50	9.00	3.00
00:00	33.10	30.79	22.71	13.83	3.11	22.95	10.40	1.50
01:00	33.18	31.04	22.80	13.87	3.11	22.93	10.39	1.43
02:00	33.28	31.34	22.98	13.91	3.10	22.88	10.40	1.42
03:00	33.47	31.69	23.05	13.96	3.11	22.86	10.40	1.41
04:00	33.68	32.07	23.26	14.02	3.12	22.90	10.40	1.40
05:00	34.00	32.56	23.51	14.11	3.12	22.90	10.41	1.38
06:00	34.49	33.14	23.75	14.22	3.15	22.98	10.41	1.35
07:00	35.08	33.77	24.08	14.33	3.19	22.97	10.42	1.31
08:00	35.67	34.48	24.48	14.47	3.16	22.95	10.42	1.31
09:00	36.21	35.04	24.80	14.63	3.22	22.91	10.43	1.30
10:00	36.69	35.53	25.19	14.80	3.30	22.91	10.42	1.25
11:00	37.12	35.98	25.51	14.99	3.27	22.91	10.42	1.17
12:00	37.53	36.43	25.76	15.20	3.36	22.90	10.42	1.08
13:00	37.88	36.74	26.04	15.41	3.46	22.91	10.43	0.98
14:00	38.17	37.07	26.33	15.60	3.55	22.90	10.43	0.95
15:00	38.44	37.33	26.53	15.79	3.60	22.91	10.42	0.96
16:00	38.68	37.53	26.75	15.97	3.68	22.89	10.42	0.98
17:00	38.89	37.71	26.92	16.13	3.80	22.98	10.42	1.05
18:00	39.10	37.84	27.16	16.26	3.87	22.97	10.42	1.16
19:00	39.27	37.96	27.27	16.39	3.96	22.98	10.43	1.38
20:00	39.45	38.09	27.38	16.52	4.15	22.91	10.42	1.56
21:00	39.63	38.22	27.52	16.64	4.22	22.89	10.41	1.75
22:00	39.82	38.35	27.65	16.76	4.33	22.84	10.41	1.81
23:00	39.96	38.48	27.75	16.88	4.47	22.87	10.40	1.79

Kemaskini Pada : 11-01-2015 09:07

Tarikh Sukatan : 23-12-2014

Masa/Jam	Water level station							
	Sungai Galas	Sungai Lebir	Sungai Kelantan			Sungai Golok		Sungai Semerak
	Dabong	Tualang	Tangga Krai	Jambatan Guillemard	Tambatan DiRaja	Jenob	Rantau Panjang	Pasir Putih
NORMAL	28.00	23.00	17.00	10.00	1.00	19.00	5.00	0.40
BERJAGA	32.00	27.00	20.00	12.00	3.00	21.50	7.00	2.00
AMARAN	35.00	31.00	22.50	14.00	4.00	22.50	8.00	2.30
BAHAYA	38.00	35.00	25.00	16.00	5.00	23.50	9.00	3.00
00:00	40.12	38.56	27.87	16.99	4.48	22.88	10.40	1.70
01:00	40.29	38.75	28.00	17.09	4.56	22.92	10.40	1.64
02:00	40.50	38.95	28.11	17.19	4.64	23.01	10.39	1.56
03:00	40.70	39.15	28.21	17.29	4.62	22.95	10.39	1.46
04:00	40.84	39.30	28.35	17.38	4.74	23.07	10.38	1.36
05:00	41.02	39.46	28.47	17.46	4.74	23.01	10.38	1.26
06:00	41.31	39.62	28.56	17.55	4.82	23.02	10.37	1.19
07:00	41.40	39.79	28.66	17.63	4.85	23.09	10.36	1.19
08:00	41.59	39.83	28.83	17.71	4.90	22.95	10.35	1.20
09:00	41.76	40.00	28.91	17.79	4.94	23.02	10.36	1.16
10:00	41.97	40.07	29.02	17.87	4.98	22.98	10.35	1.08
11:00	42.08	40.27	29.10	17.95	5.26	22.87	10.34	1.01
12:00	42.26	40.42	29.20	18.03	5.28	22.82	10.35	0.93
13:00	42.39	40.51	29.32	18.11	5.32	22.76	10.32	0.85
14:00	42.59	40.84	29.47	18.18	5.25	22.71	10.33	0.77
15:00	42.76	41.01	29.52	18.25	5.31	22.63	10.32	0.70
16:00	42.93	41.16	29.63	18.33	5.36	22.56	10.31	0.65
17:00	43.13	41.32	29.76	18.41	5.36	22.47	10.32	0.61
18:00	43.30	41.18	29.89	18.48	5.41	22.44	10.31	0.76
19:00	43.45	40.68	29.96	18.55	5.46	22.34	10.31	1.03
20:00	43.53	40.86	30.10	18.63	5.47	22.30	10.30	1.24
21:00	43.70	40.79	30.24	18.70	5.47	22.26	10.29	1.34
22:00	43.77	40.51	30.32	18.77	5.50	22.26	10.28	1.41
23:00	43.89	40.67	30.47	18.84	5.57	22.26	10.29	1.46

Kemaskini Pada : 11-01-2015 09:07

Tarikh Sukatan : 24-12-2014

Masa/Jam	Water level station							
	Sungai Galas	Sungai Lebir	Sungai Kelantan			Sungai Golok		Sungai Semerak
	Dabong	Tualang	Tangga Krai	Jambatan Guillemard	Tambatan DiRaja	Jenob	Rantau Panjang	Pasir Putih
NORMAL	28.00	23.00	17.00	10.00	1.00	19.00	5.00	0.40
BERJAGA	32.00	27.00	20.00	12.00	3.00	21.50	7.00	2.00
AMARAN	35.00	31.00	22.50	14.00	4.00	22.50	8.00	2.30
BAHAYA	38.00	35.00	25.00	16.00	5.00	23.50	9.00	3.00
00:00	44.01	40.90	30.61	18.92	5.62	22.20	10.29	1.48
01:00	44.16	41.08	30.73	18.99	5.63	22.18	10.27	1.52
02:00	44.27	41.33	30.88	19.07	5.70	22.19	10.28	1.42
03:00	44.44	41.66	31.02	19.15	5.69	22.29	10.28	1.26
04:00	44.66	41.69	31.18	19.23	5.74	22.33	10.28	1.08
05:00	44.79	41.99	31.40	19.33	5.76	22.38	10.28	0.96
06:00	44.98	42.17	31.60	19.46	5.80	22.43	10.28	0.92
07:00	45.14	38.12	31.81	19.61	5.84	22.53	10.28	0.91
08:00	45.39	37.03	32.00	19.77	5.87	22.78	10.27	0.85
09:00	45.52	36.28	32.14	19.92	5.88	23.16	10.29	0.81
10:00	45.65	36.13	32.36	20.09	5.91	23.59	10.28	0.86
11:00	45.74	32.07	32.46	20.26	5.95	24.00	10.29	0.88
12:00	45.89		32.65	20.41	6.01	24.10	10.31	0.98
13:00	45.95	26.46	32.80	20.55	6.11	24.19	10.31	1.11
14:00	46.06		32.94	20.67	6.14	24.29		
15:00	46.14	27.76	33.08	20.79	6.20	24.30	10.31	1.25
16:00	46.47	28.66	33.22	20.92	6.19	24.30	10.33	1.30
17:00	46.32	26.85	33.31	21.04	6.25	24.27	10.33	1.38
18:00	46.31	28.00	33.43	21.17	6.34	24.23	10.33	1.45
19:00	46.39	27.88	33.38	21.28	6.37	24.12	10.34	1.52
20:00		27.57	33.47	21.40	6.41	24.07	10.35	
21:00		30.24	33.58	21.50	6.41	23.98	10.34	1.62
22:00		31.59	33.64	21.61	6.45	23.96	10.37	1.66
23:00		38.86	33.71	21.70	6.49	23.77	10.40	1.68

Kemaskini Pada : 11-01-2015 09:07

Tarikh Sukatan : 25-12-2014

Masa/Jam	Water level station							
	Sungai Galas	Sungai Lebir	Sungai Kelantan			Sungai Golok		Sungai Semerak
	Dabong	Tualang	Tangga Krai	Jambatan Guillemard	Tambatan DiRaja	Jenob	Rantau Panjang	Pasir Putih
NORMAL	28.00	23.00	17.00	10.00	1.00	19.00	5.00	0.40
BERJAGA	32.00	27.00	20.00	12.00	3.00	21.50	7.00	2.00
AMARAN	35.00	31.00	22.50	14.00	4.00	22.50	8.00	2.30
BAHAYA	38.00	35.00	25.00	16.00	5.00	23.50	9.00	3.00
00:00		40.62	33.75	21.79	6.54	23.69	10.40	1.68
01:00		30.76	33.84	21.88	6.54	23.61	10.41	1.60
02:00		30.68	33.87	21.95	6.59	23.61	10.43	1.49
03:00		30.27	33.91	22.02	6.62	23.45	10.42	1.35
04:00		30.08	33.94	22.06	6.64	23.26	10.44	1.19
05:00		31.20	33.98	22.14	6.68	23.17	10.45	1.04
06:00		29.76	34.03	22.20	6.69	23.08	10.43	0.93
07:00		29.90	34.05	22.24	6.73	22.97	10.46	0.86
08:00		30.14	34.07	22.29	6.72	22.95	10.46	0.82
09:00		29.98	34.10	22.35	6.74	22.85	10.46	0.83
10:00		29.92	34.13	22.39	6.77	22.78	10.45	0.80
11:00		29.87	34.17	22.42	6.78	22.80	10.46	0.76
12:00		29.89	34.14	22.46	6.76	22.69	10.46	0.72
13:00		29.84	34.16	22.50	6.86	22.65	10.44	0.68
14:00		29.95	34.15	22.53	6.84	22.60	10.46	0.63
15:00		29.88	34.17	22.56	6.82	22.46	10.45	0.58
16:00		29.92	34.16	22.59	6.84	22.42	10.44	0.52
17:00		29.87	34.14	22.61	6.83	22.34	10.44	0.47
18:00		29.82	34.11	22.63	6.88	22.35	10.41	0.45
19:00		27.72	34.12	22.65	6.86	22.27	10.43	0.50
20:00		33.69	34.12	22.67	6.85	22.23	10.42	0.64
21:00		25.75	34.10	22.69	6.88	22.16	10.40	0.83
22:00		26.38	34.05	22.71	6.86	22.10	10.41	0.95
23:00		31.64	34.03	22.73	6.88	22.06	10.41	1.06

APPENDIX B

Daily Rainfall data for Jeti Kastam/Tambatan DiRaja

Bil	Station Name	Date	Time	Level(cm)	RF Month(mm)	RF Daily(mm)
1	JETIKASTAM	20/12/2014	0:00	475	799	3
2	JETIKASTAM	20/12/2014	1:00	470	799	0
3	JETIKASTAM	20/12/2014	2:01	459	799	0
4	JETIKASTAM	20/12/2014	3:00	454	799	0
5	JETIKASTAM	20/12/2014	4:00	451	799	0
6	JETIKASTAM	20/12/2014	5:00	441	811	12
7	JETIKASTAM	20/12/2014	6:01	435	812	13
8	JETIKASTAM	20/12/2014	7:00	425	812	13
9	JETIKASTAM	20/12/2014	8:00	420	818	19
10	JETIKASTAM	20/12/2014	9:00	413	822	23
11	JETIKASTAM	20/12/2014	10:00	408	823	24
12	JETIKASTAM	20/12/2014	11:00	398	825	26
13	JETIKASTAM	20/12/2014	12:01	391	831	32
14	JETIKASTAM	20/12/2014	13:01	385	833	34
15	JETIKASTAM	20/12/2014	14:00	384	851	52
16	JETIKASTAM	20/12/2014	15:01	385	873	74
17	JETIKASTAM	20/12/2014	16:00	377	875	76
18	JETIKASTAM	20/12/2014	17:00	371	875	76
19	JETIKASTAM	20/12/2014	18:00	363	877	78
20	JETIKASTAM	20/12/2014	19:00	362	877	78
21	JETIKASTAM	20/12/2014	20:00	352	877	78
22	JETIKASTAM	20/12/2014	21:01	351	877	78
23	JETIKASTAM	20/12/2014	22:00	344	879	80
24	JETIKASTAM	20/12/2014	23:01	348	881	82

Bil	Station Name	Date	Time	Level(cm)	RF Month(mm)	RF Daily(mm)
1	JETIKASTAM	21/12/2014	0:01	342	882	83
2	JETIKASTAM	21/12/2014	1:01	333	883	1
3	JETIKASTAM	21/12/2014	2:00	333	883	1
4	JETIKASTAM	21/12/2014	3:01	330	883	1
5	JETIKASTAM	21/12/2014	4:01	327	883	1
6	JETIKASTAM	21/12/2014	5:01	321	883	1
7	JETIKASTAM	21/12/2014	6:00	317	883	1
8	JETIKASTAM	21/12/2014	7:01	314	885	3
9	JETIKASTAM	21/12/2014	8:00	309	885	3
10	JETIKASTAM	21/12/2014	9:00	309	886	4
11	JETIKASTAM	21/12/2014	10:00	307	886	4
12	JETIKASTAM	21/12/2014	11:01	307	890	8
13	JETIKASTAM	21/12/2014	12:02	303	892	10
14	JETIKASTAM	21/12/2014	13:01	297	892	10
15	JETIKASTAM	21/12/2014	15:02	298	892	10
16	JETIKASTAM	21/12/2014	16:01	291	892	10
17	JETIKASTAM	21/12/2014	17:00	292	892	10
18	JETIKASTAM	21/12/2014	18:00	291	892	10
19	JETIKASTAM	21/12/2014	19:00	300	892	10
20	JETIKASTAM	21/12/2014	20:00	297	893	11
21	JETIKASTAM	21/12/2014	21:00	306	902	20
22	JETIKASTAM	21/12/2014	22:01	307	909	27
23	JETIKASTAM	21/12/2014	23:01	309	913	31
24	JETIKASTAM	20/12/2014	23:01	348	881	82

Bil	Station Name	Date	Time	Level(cm)	RF Month(mm)	RF Daily(mm)
1	JETIKASTAM	22/12/2014	0:00	311	914	32
2	JETIKASTAM	22/12/2014	1:01	311	919	5
3	JETIKASTAM	22/12/2014	2:00	310	919	5
4	JETIKASTAM	22/12/2014	3:00	311	919	5
5	JETIKASTAM	22/12/2014	4:00	312	919	5
6	JETIKASTAM	22/12/2014	5:00	312	919	5
7	JETIKASTAM	22/12/2014	6:00	315	919	5
8	JETIKASTAM	22/12/2014	7:00	319	919	5
9	JETIKASTAM	22/12/2014	8:01	316	919	5
10	JETIKASTAM	22/12/2014	9:00	322	919	5
11	JETIKASTAM	22/12/2014	10:00	330	920	6
12	JETIKASTAM	22/12/2014	11:00	327	921	7
13	JETIKASTAM	22/12/2014	12:01	336	922	8
14	JETIKASTAM	22/12/2014	13:00	346	922	8
15	JETIKASTAM	22/12/2014	14:00	355	922	8
16	JETIKASTAM	22/12/2014	16:00	368	922	8
17	JETIKASTAM	22/12/2014	17:00	380	922	8
18	JETIKASTAM	22/12/2014	18:01	387	922	8
19	JETIKASTAM	22/12/2014	19:00	396	922	8
20	JETIKASTAM	22/12/2014	20:00	415	922	8
21	JETIKASTAM	22/12/2014	21:00	422	925	11
22	JETIKASTAM	22/12/2014	22:01	433	925	11
23	JETIKASTAM	22/12/2014	23:00	447	925	11

Bil	Station Name	Date	Time	Level(cm)	RF Month(mm)	RF Daily(mm)
1	JETIKASTAM	23/12/2014	0:01	448	925	11
2	JETIKASTAM	23/12/2014	1:00	456	926	1
3	JETIKASTAM	23/12/2014	2:00	464	926	1
4	JETIKASTAM	23/12/2014	3:01	462	927	2
5	JETIKASTAM	23/12/2014	4:02	474	927	2
6	JETIKASTAM	23/12/2014	5:02	474	927	2
7	JETIKASTAM	23/12/2014	6:02	482	927	2
8	JETIKASTAM	23/12/2014	7:02	485	927	2
9	JETIKASTAM	23/12/2014	8:02	490	927	2
10	JETIKASTAM	23/12/2014	9:02	494	927	2
11	JETIKASTAM	23/12/2014	10:02	498	927	2
12	JETIKASTAM	23/12/2014	10:50	514	927	2
13	JETIKASTAM	23/12/2014	11:02	526	927	2
14	JETIKASTAM	23/12/2014	12:02	528	927	2
15	JETIKASTAM	23/12/2014	13:02	532	927	2
16	JETIKASTAM	23/12/2014	14:02	525	927	2
17	JETIKASTAM	23/12/2014	15:03	531	927	2
18	JETIKASTAM	23/12/2014	16:01	536	927	2
19	JETIKASTAM	23/12/2014	17:01	536	928	3
20	JETIKASTAM	23/12/2014	18:01	541	928	3
21	JETIKASTAM	23/12/2014	19:01	546	928	3
22	JETIKASTAM	23/12/2014	20:01	547	928	3
23	JETIKASTAM	23/12/2014	21:01	547	928	3
24	JETIKASTAM	23/12/2014	22:01	550	928	3

Bil	**Station Name**	**Date**	**Time**	**Level(cm)**	**RF Month(mm)**	**RF Daily(mm)**
1	JETIKASTAM	24/12/2014	0:01	562	930	5
2	JETIKASTAM	24/12/2014	1:01	563	930	0
3	JETIKASTAM	24/12/2014	2:02	570	937	7
4	JETIKASTAM	24/12/2014	3:02	569	959	29
5	JETIKASTAM	24/12/2014	4:02	574	959	29
6	JETIKASTAM	24/12/2014	5:02	576	959	29
7	JETIKASTAM	24/12/2014	6:02	580	960	30
8	JETIKASTAM	24/12/2014	7:02	584	960	30
9	JETIKASTAM	24/12/2014	8:02	587	960	30
10	JETIKASTAM	24/12/2014	9:02	588	960	30
11	JETIKASTAM	24/12/2014	10:02	591	960	30
12	JETIKASTAM	24/12/2014	11:02	595	960	30
13	JETIKASTAM	24/12/2014	12:02	601	960	30
14	JETIKASTAM	24/12/2014	13:09	612	961	31
15	JETIKASTAM	24/12/2014	14:02	614	962	32
16	JETIKASTAM	24/12/2014	15:02	620	962	32
17	JETIKASTAM	24/12/2014	16:02	619	966	36
18	JETIKASTAM	24/12/2014	17:02	625	966	36
19	JETIKASTAM	24/12/2014	18:02	634	966	36
20	JETIKASTAM	24/12/2014	19:02	637	966	36
21	JETIKASTAM	24/12/2014	20:02	641	966	36
22	JETIKASTAM	24/12/2014	21:02	641	966	36
23	JETIKASTAM	24/12/2014	22:02	645	969	39
24	JETIKASTAM	24/12/2014	23:02	649	969	39

Bil	Station Name	Date	Time	Level(cm)	RF Month(mm)	RF Daily(mm)
1	JETIKASTAM	25/12/2014	0:02	654	969	39
2	JETIKASTAM	25/12/2014	1:02	654	969	0
3	JETIKASTAM	25/12/2014	2:02	659	969	0
4	JETIKASTAM	25/12/2014	3:02	662	969	0
5	JETIKASTAM	25/12/2014	4:02	664	969	0
6	JETIKASTAM	25/12/2014	5:02	668	969	0
7	JETIKASTAM	25/12/2014	6:02	669	970	1
8	JETIKASTAM	25/12/2014	7:02	673	970	1
9	JETIKASTAM	25/12/2014	8:02	672	970	1
10	JETIKASTAM	25/12/2014	9:02	674	970	1
11	JETIKASTAM	25/12/2014	10:02	677	970	1
12	JETIKASTAM	25/12/2014	11:02	678	970	1
13	JETIKASTAM	25/12/2014	12:02	676	970	1
14	JETIKASTAM	25/12/2014	13:02	686	970	1
15	JETIKASTAM	25/12/2014	14:02	684	970	1
16	JETIKASTAM	25/12/2014	15:02	682	970	1
17	JETIKASTAM	25/12/2014	16:02	684	970	1
18	JETIKASTAM	25/12/2014	17:02	683	970	1
19	JETIKASTAM	25/12/2014	18:02	688	970	1
20	JETIKASTAM	25/12/2014	19:02	686	970	1
21	JETIKASTAM	25/12/2014	20:02	685	972	3
22	JETIKASTAM	25/12/2014	21:02	688	972	3
23	JETIKASTAM	25/12/2014	22:02	686	972	3
24	JETIKASTAM	25/12/2014	23:02	688	972	3

APPENDIX C

Satellite-based rainfall & water level data for Tangga Krai Flow

DATE	Time	Gua Musang	Kuala Krai	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
20/12/2014	0:00:00	0.06	0.47	21.38	25	22.5	20	17
	1:00:00	0.06	6.38	23.45	25	22.5	20	17
	2:00:00	0.24	12.18	23.24	25	22.5	20	17
	3:00:00	6.38	23.20	23.06	25	22.5	20	17
	4:00:00	23.20	44.05	22.88	25	22.5	20	17
	5:00:00	23.20	44.05	22.69	25	22.5	20	17
	6:00:00	12.18	23.20	22.53	25	22.5	20	17
	7:00:00	12.18	44.05	22.32	25	22.5	20	17
	8:00:00	23.20	44.05	22.19	25	22.5	20	17
	9:00:00	23.20	44.05	22.02	25	22.5	20	17
	10:00:00	44.05	157.28	21.92	25	22.5	20	17
	11:00:00	44.05	157.28	21.84	25	22.5	20	17
	12:00:00	23.20	44.05	21.72	25	22.5	20	17
	13:00:00	12.18	83.37	21.67	25	22.5	20	17
	14:00:00	6.38	44.05	21.64	25	22.5	20	17
	15:00:00	0.47	23.20	21.66	25	22.5	20	17
	16:00:00	0.06	6.38	21.62	25	22.5	20	17
	17:00:00	0.03	12.18	21.58	25	22.5	20	17
	18:00:00	0.03	6.38	21.58	25	22.5	20	17
	19:00:00	0.03	6.38	21.55	25	22.5	20	17
	20:00:00	0.02	1.73	21.55	25	22.5	20	17
	21:00:00	-	2.11	21.52	25	22.5	20	17
	22:00:00	-	1.52	21.47	25	22.5	20	17
	23:00:00	0.01	1.09	21.4	25	22.5	20	17

DATE	Time	Gua Musang	Kuala Krai	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
21/12/2014	0:00:00	0.12	0.79	22.71	25	22.5	20	17
	1:00:00	1.73	0.57	21.36	25	22.5	20	17
	2:00:00	-	0.41	21.31	25	22.5	20	17
	3:00:00	1.73	0.29	21.31	25	22.5	20	17
	4:00:00	-	0.21	21.3	25	22.5	20	17
	5:00:00	0.06	3.33	21.35	25	22.5	20	17
	6:00:00	0.06	1.73	21.38	25	22.5	20	17
	7:00:00	0.06	0.90	21.43	25	22.5	20	17
	8:00:00	0.03	0.47	21.56	25	22.5	20	17
	9:00:00	6.38	3.33	21.64	25	22.5	20	17
	10:00:00	0.03	0.47	21.74	25	22.5	20	17
	11:00:00	0.12	3.33	21.84	25	22.5	20	17
	12:00:00	0.12	3.33	21.89	25	22.5	20	17
	13:00:00	1.73	0.90	22	25	22.5	20	17
	14:00:00	1.73	23.20	22.12	25	22.5	20	17
	15:00:00	12.18	23.20	22.16	25	22.5	20	17
	16:00:00	23.20	6.38	22.26	25	22.5	20	17
	17:00:00	12.18	6.38	22.27	25	22.5	20	17
	18:00:00	12.18	3.33	22.36	25	22.5	20	17
	19:00:00	6.38	1.73	22.41	25	22.5	20	17
	20:00:00	6.38	6.38	22.41	25	22.5	20	17
	21:00:00	0.90	1.73	22.5	25	22.5	20	17
	22:00:00	0.47	6.38	22.54	25	22.5	20	17
	23:00:00	0.06	0.90	22.61	25	22.5	20	17

DATE	**Time**	**Gua Musang**	**Kuala Krai**	**Water Level (m)**	**Danger Level**	**Warning Level**	**Caution Level**	**Normal Level**
22/12/2014	0:00:00	0.12	1.73	22.71	25	22.5	20	17
	1:00:00	0.06	0.06	22.8	25	22.5	20	17
	2:00:00	0.47	1.73	22.98	25	22.5	20	17
	3:00:00	1.73	0.90	23.05	25	22.5	20	17
	4:00:00	0.12	0.90	23.26	25	22.5	20	17
	5:00:00	1.73	12.18	23.51	25	22.5	20	17
	6:00:00	44.05	157.28	23.75	25	22.5	20	17
	7:00:00	44.05	295.75	24.08	25	22.5	20	17
	8:00:00	44.05	295.75	24.48	25	22.5	20	17
	9:00:00	23.20	157.28	24.8	25	22.5	20	17
	10:00:00	44.05	12.18	25.19	25	22.5	20	17
	11:00:00	44.05	157.28	25.51	25	22.5	20	17
	12:00:00	44.05	44.05	25.76	25	22.5	20	17
	13:00:00	83.37	44.05	26.04	25	22.5	20	17
	14:00:00	83.37	23.20	26.33	25	22.5	20	17
	15:00:00	23.20	12.18	26.53	25	22.5	20	17
	16:00:00	1.73	6.38	26.75	25	22.5	20	17
	17:00:00	0.47	6.38	26.92	25	22.5	20	17
	18:00:00	12.18	44.05	27.16	25	22.5	20	17
	19:00:00	12.18	6.38	27.27	25	22.5	20	17
	20:00:00	12.18	1.73	27.38	25	22.5	20	17
	21:00:00	12.18	6.38	27.52	25	22.5	20	17
	22:00:00	23.20	1.73	27.65	25	22.5	20	17
	23:00:00	12.18	1.73	27.75	25	22.5	20	17

DATE	Time	Gua Musang	Kuala Krai	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
23/12/2015	0:00:00	12.18	6.38	27.87	25	22.5	20	17
	1:00:00	6.38	12.18	28	25	22.5	20	17
	2:00:00	6.38	0.47	28.11	25	22.5	20	17
	3:00:00	44.05	3.33	28.21	25	22.5	20	17
	4:00:00	44.05	6.38	28.35	25	22.5	20	17
	5:00:00	-	-	28.47	25	22.5	20	17
	6:00:00	44.05	23.20	28.56	25	22.5	20	17
	7:00:00	23.20	12.18	28.66	25	22.5	20	17
	8:00:00	12.18	23.20	28.83	25	22.5	20	17
	9:00:00	44.05	6.38	28.91	25	22.5	20	17
	10:00:00	157.28	157.28	29.02	25	22.5	20	17
	11:00:00	157.28	23.20	29.1	25	22.5	20	17
	12:00:00	-	44.05	29.2	25	22.5	20	17
	13:00:00	44.05	44.05	29.32	25	22.5	20	17
	14:00:00	44.05	23.20	29.47	25	22.5	20	17
	15:00:00	44.05	12.18	29.52	25	22.5	20	17
	16:00:00	12.18	12.18	29.63	25	22.5	20	17
	17:00:00	6.38	3.33	29.76	25	22.5	20	17
	18:00:00	6.38	1.73	29.89	25	22.5	20	17
	19:00:00	12.18	12.18	29.96	25	22.5	20	17
	20:00:00	44.05	12.18	30.1	25	22.5	20	17
	21:00:00	44.05	12.18	30.24	25	22.5	20	17
	22:00:00	12.18	0.00	30.32	25	22.5	20	17
	23:00:00	6.38	1.73	30.47	25	22.5	20	17

DATE	Time	Gua Musang	Kuala Krai	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
24/12/2014	0:00:00	12.18	0.90	30.61	25	22.5	20	17
	1:00:00	157.28	83.37	30.73	25	22.5	20	17
	2:00:00	157.28	295.75	30.88	25	22.5	20	17
	3:00:00	157.28	295.75	31.02	25	22.5	20	17
	4:00:00	157.28	295.75	31.18	25	22.5	20	17
	5:00:00	157.28	295.75	31.4	25	22.5	20	17
	6:00:00	83.37	83.37	31.6	25	22.5	20	17
	7:00:00	44.05	83.37	31.81	25	22.5	20	17
	8:00:00	44.05	157.28	32	25	22.5	20	17
	9:00:00	23.20	157.28	32.14	25	22.5	20	17
	10:00:00	157.28	157.28	32.36	25	22.5	20	17
	11:00:00	157.28	157.28	32.46	25	22.5	20	17
	12:00:00	23.20	157.28	32.65	25	22.5	20	17
	13:00:00	44.05	157.28	32.8	25	22.5	20	17
	14:00:00	1.73	23.20	32.94	25	22.5	20	17
	15:00:00	1.73	44.05	33.08	25	22.5	20	17
	16:00:00	1.73	6.38	33.22	25	22.5	20	17
	17:00:00	1.73	6.38	33.31	25	22.5	20	17
	18:00:00	1.73	6.38	33.43	25	22.5	20	17
	19:00:00	0.90	1.73	33.38	25	22.5	20	17
	20:00:00	0.06	0.47	33.47	25	22.5	20	17
	21:00:00	0.06	0.47	33.58	25	22.5	20	17
	22:00:00	0.06	0.06	33.64	25	22.5	20	17
	23:00:00	0.02	0.06	33.71	25	22.5	20	17

DATE	Time	Gua Musang	Kuala Krai	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
25/12/2014	0:00:00	0.02	0.06	33.75	25	22.5	20	17
	1:00:00	0.03	0.06	33.84	25	22.5	20	17
	2:00:00	0.03	0.47	33.87	25	22.5	20	17
	3:00:00	0.03	0.06	33.91	25	22.5	20	17
	4:00:00	0.01	0.02	33.94	25	22.5	20	17
	5:00:00	0.90	0.06	33.98	25	22.5	20	17
	6:00:00	0.12	1.73	34.03	25	22.5	20	17
	7:00:00	0.02	0.90	34.05	25	22.5	20	17
	8:00:00	0.03	0.03	34.07	25	22.5	20	17
	9:00:00	0.06	0.03	34.1	25	22.5	20	17
	10:00:00	0.06	0.03	34.13	25	22.5	20	17
	11:00:00	0.06	0.02	34.17	25	22.5	20	17
	12:00:00	0.06	0.02	34.14	25	22.5	20	17
	13:00:00	0.06	0.06	34.16	25	22.5	20	17
	14:00:00	0.03	0.06	34.15	25	22.5	20	17
	15:00:00	0.03	0.06	34.17	25	22.5	20	17
	16:00:00	0.06	0.12	34.16	25	22.5	20	17
	17:00:00	1.73	0.06	34.14	25	22.5	20	17
	18:00:00	0.90	0.01	34.11	25	22.5	20	17
	19:00:00	12.18	0.06	34.12	25	22.5	20	17
	20:00:00	0.90	0.90	34.12	25	22.5	20	17
	21:00:00	23.20	1.73	34.1	25	22.5	20	17
	22:00:00	6.38	6.38	34.05	25	22.5	20	17
	23:00:00	0.90	0.90	34.03	25	22.5	20	17

DATE	Time	Gua Musang	Kuala Krai	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
31/12/2014	0:00:00	0.06	0.47	16.82	25	22.5	20	17
	1:00:00	0.02	0.12	16.8	25	22.5	20	17
	2:00:00	0.02	0.06	16.78	25	22.5	20	17
	3:00:00	0.03	0.12	16.76	25	22.5	20	17
	4:00:00	0.03	0.24	16.73	25	22.5	20	17
	5:00:00	0.01	0.12	16.7	25	22.5	20	17
	6:00:00	0.01	0.12	16.67	25	22.5	20	17
	7:00:00	0.02	0.12	16.63	25	22.5	20	17
	8:00:00	0.02	0.03	16.6	25	22.5	20	17
	9:00:00	-	0.03	16.55	25	22.5	20	17
	10:00:00	-	0.00	16.49	25	22.5	20	17
	11:00:00	-	-	16.44	25	22.5	20	17
	12:00:00	-	-	16.38	25	22.5	20	17
	13:00:00	-	-	16.31	25	22.5	20	17
	14:00:00	-	-	16.25	25	22.5	20	17
	15:00:00	0.00	-	16.18	25	22.5	20	17
	16:00:00	-	0.00	16.1	25	22.5	20	17
	17:00:00	-	0.00	16.01	25	22.5	20	17
	18:00:00	0.00	-	15.92	25	22.5	20	17
	19:00:00	0.00	0.01	15.82	25	22.5	20	17
	20:00:00	0.00	0.02	15.72	25	22.5	20	17
	21:00:00	0.00	0.01	15.61	25	22.5	20	17
	22:00:00	0.00	0.01	15.5	25	22.5	20	17
	23:00:00	0.00	0.01	15.38	25	22.5	20	17

APPENDIX D

Satellited-based rainfall & water level data for Jambatan Guillemard Flow

DATE	Time	Gua Musang	Kuala Krai	Tanah Merah	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
20/12/2014	0:00:00	0.06	0.47	0.06	13.72	16	14	12	10
	1:00:00	0.06	6.38	0.12	15.7	16	14	12	10
	2:00:00	0.24	12.18	6.38	15.56	16	14	12	10
	3:00:00	6.38	23.20	23.20	15.42	16	14	12	10
	4:00:00	23.20	44.05	23.20	15.28	16	14	12	10
	5:00:00	23.20	44.05	44.05	15.13	16	14	12	10
	6:00:00	12.18	23.20	23.20	14.97	16	14	12	10
	7:00:00	12.18	44.05	44.05	14.83	16	14	12	10
	8:00:00	23.20	44.05	44.05	14.69	16	14	12	10
	9:00:00	23.20	44.05	44.05	14.59	16	14	12	10
	10:00:00	44.05	157.28	157.28	14.49	16	14	12	10
	11:00:00	44.05	157.28	157.28	14.41	16	14	12	10
	12:00:00	23.20	44.05	157.28	14.32	16	14	12	10
	13:00:00	12.18	83.37	157.28	14.23	16	14	12	10
	14:00:00	6.38	44.05	23.20	14.14	16	14	12	10
	15:00:00	0.47	23.20	44.05	14.05	16	14	12	10
	16:00:00	0.06	6.38	6.38	13.98	16	14	12	10
	17:00:00	0.03	12.18	12.18	13.89	16	14	12	10
	18:00:00	0.03	6.38	12.18	13.89	16	14	12	10
	19:00:00	0.03	6.38	6.38	13.86	16	14	12	10
	20:00:00	0.02	1.73	1.73	13.83	16	14	12	10
	21:00:00	-	2.11	0.12	13.81	16	14	12	10
	22:00:00	-	1.52	0.03	13.79	16	14	12	10
	23:00:00	0.01	1.09	0.03	13.75	16	14	12	10

DATE	Time	Gua Musang	Kuala Krai	Tanah Merah	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
21/12/2014	0:00:00	0.12	0.79	6.38	13.83	16	14	12	10
	1:00:00	1.73	0.57	0.47	13.69	16	14	12	10
	2:00:00	-	0.41	0.03	13.66	16	14	12	10
	3:00:00	1.73	0.29	1.73	13.63	16	14	12	10
	4:00:00	-	0.21	23.20	13.59	16	14	12	10
	5:00:00	0.06	3.33	12.18	13.56	16	14	12	10
	6:00:00	0.06	1.73	23.20	13.53	16	14	12	10
	7:00:00	0.06	0.90	3.33	13.5	16	14	12	10
	8:00:00	0.03	0.47	1.73	13.48	16	14	12	10
	9:00:00	6.38	3.33	0.90	13.46	16	14	12	10
	10:00:00	0.03	0.47	0.06	13.46	16	14	12	10
	11:00:00	0.12	3.33	0.12	13.46	16	14	12	10
	12:00:00	0.12	3.33	0.47	13.48	16	14	12	10
	13:00:00	1.73	0.90	0.90	13.5	16	14	12	10
	14:00:00	1.73	23.20	6.38	13.54	16	14	12	10
	15:00:00	12.18	23.20	12.18	13.57	16	14	12	10
	16:00:00	23.20	6.38	12.18	13.59	16	14	12	10
	17:00:00	12.18	6.38	12.18	13.63	16	14	12	10
	18:00:00	12.18	3.33	23.20	13.65	16	14	12	10
	19:00:00	6.38	1.73	6.38	13.68	16	14	12	10
	20:00:00	6.38	6.38	12.18	13.7	16	14	12	10
	21:00:00	0.90	1.73	6.38	13.73	16	14	12	10
	22:00:00	0.47	6.38	1.73	13.76	16	14	12	10
	23:00:00	0.06	0.90	3.33	13.79	16	14	12	10

DATE	Time	Gua Musang	Kuala Krai	Tanah Merah	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
22/12/2014	0:00:00	0.12	1.73	6.38	13.83	16	14	12	10
	1:00:00	0.06	0.06	0.47	13.87	16	14	12	10
	2:00:00	0.47	1.73	0.90	13.91	16	14	12	10
	3:00:00	1.73	0.90	0.90	13.96	16	14	12	10
	4:00:00	0.12	0.90	0.06	14.02	16	14	12	10
	5:00:00	1.73	12.18	0.90	14.11	16	14	12	10
	6:00:00	44.05	157.28	12.18	14.22	16	14	12	10
	7:00:00	44.05	295.75	157.28	14.33	16	14	12	10
	8:00:00	44.05	295.75	83.37	14.47	16	14	12	10
	9:00:00	23.20	157.28	157.28	14.63	16	14	12	10
	10:00:00	44.05	12.18	12.18	14.8	16	14	12	10
	11:00:00	44.05	157.28	44.05	14.99	16	14	12	10
	12:00:00	44.05	44.05	44.05	15.2	16	14	12	10
	13:00:00	83.37	44.05	44.05	15.41	16	14	12	10
	14:00:00	83.37	23.20	23.20	15.6	16	14	12	10
	15:00:00	23.20	12.18	12.18	15.79	16	14	12	10
	16:00:00	1.73	6.38	12.18	15.97	16	14	12	10
	17:00:00	0.47	6.38	6.38	16.13	16	14	12	10
	18:00:00	12.18	44.05	1.73	16.26	16	14	12	10
	19:00:00	12.18	6.38	3.33	16.39	16	14	12	10
	20:00:00	12.18	1.73	1.73	16.52	16	14	12	10
	21:00:00	12.18	6.38	6.38	16.64	16	14	12	10
	22:00:00	23.20	1.73	6.38	16.76	16	14	12	10
	23:00:00	12.18	1.73	12.18	16.88	16	14	12	10

DATE	Time	Gua Musang	Kuala Krai	Tanah Merah	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
23/12/2015	0:00:00	12.18	6.38	0.90	16.99	16	14	12	10
	1:00:00	6.38	12.18	6.38	17.09	16	14	12	10
	2:00:00	6.38	0.47	3.33	17.19	16	14	12	10
	3:00:00	44.05	3.33	3.33	17.29	16	14	12	10
	4:00:00	44.05	6.38	6.38	17.38	16	14	12	10
	5:00:00	-	-	-	17.46	16	14	12	10
	6:00:00	44.05	23.20	23.20	17.55	16	14	12	10
	7:00:00	23.20	12.18	23.20	17.63	16	14	12	10
	8:00:00	12.18	23.20	6.38	17.71	16	14	12	10
	9:00:00	44.05	6.38	44.05	17.79	16	14	12	10
	10:00:00	157.28	157.28	44.05	17.87	16	14	12	10
	11:00:00	157.28	23.20	44.05	17.95	16	14	12	10
	12:00:00	-	44.05	23.20	18.03	16	14	12	10
	13:00:00	44.05	44.05	44.05	18.11	16	14	12	10
	14:00:00	44.05	23.20	12.18	18.18	16	14	12	10
	15:00:00	44.05	12.18	12.18	18.25	16	14	12	10
	16:00:00	12.18	12.18	6.38	18.33	16	14	12	10
	17:00:00	6.38	3.33	1.73	18.41	16	14	12	10
	18:00:00	6.38	1.73	3.33	18.48	16	14	12	10
	19:00:00	12.18	12.18	1.73	18.55	16	14	12	10
	20:00:00	44.05	12.18	6.38	18.63	16	14	12	10
	21:00:00	44.05	12.18	6.38	18.7	16	14	12	10
	22:00:00	12.18	0.00	12.18	18.77	16	14	12	10
	23:00:00	6.38	1.73	1.73	18.84	16	14	12	10

DATE	Time	Gua Musang	Kuala Krai	Tanah Merah	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
24/12/2014	0:00:00	12.18	0.90	1.73	18.92	16	14	12	10
	1:00:00	157.28	83.37	23.20	18.99	16	14	12	10
	2:00:00	157.28	295.75	157.28	19.07	16	14	12	10
	3:00:00	157.28	295.75	157.28	19.15	16	14	12	10
	4:00:00	157.28	295.75	295.75	19.23	16	14	12	10
	5:00:00	157.28	295.75	295.75	19.33	16	14	12	10
	6:00:00	83.37	83.37	83.37	19.46	16	14	12	10
	7:00:00	44.05	83.37	83.37	19.61	16	14	12	10
	8:00:00	44.05	157.28	157.28	19.77	16	14	12	10
	9:00:00	23.20	157.28	157.28	19.92	16	14	12	10
	10:00:00	157.28	157.28	295.75	20.09	16	14	12	10
	11:00:00	157.28	157.28	295.75	20.26	16	14	12	10
	12:00:00	23.20	157.28	295.75	20.41	16	14	12	10
	13:00:00	44.05	157.28	157.28	20.55	16	14	12	10
	14:00:00	1.73	23.20	44.05	20.67	16	14	12	10
	15:00:00	1.73	44.05	12.18	20.79	16	14	12	10
	16:00:00	1.73	6.38	3.33	20.92	16	14	12	10
	17:00:00	1.73	6.38	12.18	21.04	16	14	12	10
	18:00:00	1.73	6.38	6.38	21.17	16	14	12	10
	19:00:00	0.90	1.73	3.33	21.28	16	14	12	10
	20:00:00	0.06	0.47	1.73	21.4	16	14	12	10
	21:00:00	0.06	0.47	0.12	21.5	16	14	12	10
	22:00:00	0.06	0.06	0.06	21.61	16	14	12	10
	23:00:00	0.02	0.06	0.06	21.7	16	14	12	10

DATE	Time	Gua Musang	Kuala Krai	Tanah Merah	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
25/12/2014	0:00:00	0.02	0.06	0.06	21.79	16	14	12	10
	1:00:00	0.03	0.06	0.06	21.88	16	14	12	10
	2:00:00	0.03	0.47	0.12	21.95	16	14	12	10
	3:00:00	0.03	0.06	0.12	22.02	16	14	12	10
	4:00:00	0.01	0.02	0.12	22.06	16	14	12	10
	5:00:00	0.90	0.06	0.12	22.14	16	14	12	10
	6:00:00	0.12	1.73	0.47	22.2	16	14	12	10
	7:00:00	0.02	0.90	0.12	22.24	16	14	12	10
	8:00:00	0.03	0.03	0.03	22.29	16	14	12	10
	9:00:00	0.06	0.03	0.03	22.35	16	14	12	10
	10:00:00	0.06	0.03	0.06	22.39	16	14	12	10
	11:00:00	0.06	0.02	0.02	22.42	16	14	12	10
	12:00:00	0.06	0.02	0.03	22.46	16	14	12	10
	13:00:00	0.06	0.06	0.06	22.5	16	14	12	10
	14:00:00	0.03	0.06	0.06	22.53	16	14	12	10
	15:00:00	0.03	0.06	0.12	22.56	16	14	12	10
	16:00:00	0.06	0.12	0.06	22.59	16	14	12	10
	17:00:00	1.73	0.06	0.03	22.61	16	14	12	10
	18:00:00	0.90	0.01	0.12	22.63	16	14	12	10
	19:00:00	12.18	0.06	0.06	22.65	16	14	12	10
	20:00:00	0.90	0.90	0.12	22.67	16	14	12	10
	21:00:00	23.20	1.73	0.12	22.69	16	14	12	10
	22:00:00	6.38	6.38	0.90	22.71	16	14	12	10
	23:00:00	0.90	0.90	0.12	22.73	16	14	12	10

DATE	Time	Gua Musang	Kuala Krai	Tanah Merah	Water Level (m)	Danger Level	Warning Level	Caution Level	Normal Level
31/12/2014	0:00:00	0.06	0.47	0.06	16.82	16	14	12	10
	1:00:00	0.02	0.12	0.12	16.8	16	14	12	10
	2:00:00	0.02	0.06	0.03	16.78	16	14	12	10
	3:00:00	0.03	0.12	0.01	16.76	16	14	12	10
	4:00:00	0.03	0.24	0.06	16.73	16	14	12	10
	5:00:00	0.01	0.12	0.06	16.7	16	14	12	10
	6:00:00	0.01	0.12	0.06	16.67	16	14	12	10
	7:00:00	0.02	0.12	0.06	16.63	16	14	12	10
	8:00:00	0.02	0.03	0.06	16.6	16	14	12	10
	9:00:00	-	0.03	0.01	16.55	16	14	12	10
	10:00:00	-	0.00	-	16.49	16	14	12	10
	11:00:00	-	-	-	16.44	16	14	12	10
	12:00:00	-	-	-	16.38	16	14	12	10
	13:00:00	-	-	-	16.31	16	14	12	10
	14:00:00	-	-	-	16.25	16	14	12	10
	15:00:00	0.00	-	-	16.18	16	14	12	10
	16:00:00	-	0.00	0.00	16.1	16	14	12	10
	17:00:00	-	0.00	0.00	16.01	16	14	12	10
	18:00:00	0.00	-	-	15.92	16	14	12	10
	19:00:00	0.00	0.01	0.00	15.82	16	14	12	10
	20:00:00	0.00	0.02	0.00	15.72	16	14	12	10
	21:00:00	0.00	0.01	0.00	15.61	16	14	12	10
	22:00:00	0.00	0.01	-	15.5	16	14	12	10
	23:00:00	0.00	0.01	-	15.38	16	14	12	10