ASSESSMENT VARIABILITY OF ANNUAL DAILY MAXIMUM RAINFALL OF KELANTAN, MALAYSIA

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ASSESSMENT VARIABILITY OF ANNUAL DAILY MAXIMUM RAINFALL OF KELANTAN, MALAYSIA

SITI MAIZATUL ASHIKIN BINTI SHAH BAHRIM

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

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JUNE 2015

SUPERVISOR'S DECLARATION

I hereby declare that I have read this Final Year Project Report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of B. Eng. (Hons.) Civil Engineering

Signature : ....

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Date : 3 JULY 2015

STUDENT'S DECLARATION

I hereby declare that this Final Year Project Report entitled "Assessment Variability of Annual Daily Maximum Rainfall of Kelantan, Malaysia" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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DEDICATION

Every challenging work needs self-efforts as well as guidance from the elders especially to those who are very close to our heart.

I dedicate this thesis, to my parents Mr Shah Baharim Bin Shah Abu Bakar and Mrs Siti Aminah Binti Sheikh Mohamad

They have taught me that the best kind of knowledge to have is that

which is learned for its own sake.

It is their unconditional loves that motivate me to set higher targets and never give up.

My humble effort I dedicate to my supervisor who I greatly indebted,

Dr. Mohamad Idris bin Ali. Thank you for all your kind advices and constant source of knowledge and inspiration.

ACKNOWLEDGEMENT

بسم الله الرحمن الرحيم

Praise be to Almighty Allah for His Guidance and Blessing

Which without, life is meaningless

In the process of completing this research, many people have generously given their time and effort to help. First and foremost, I would like to express my deep gratitude to my supervisor; Dr. Mohamad Idris bin Ali for his constructive comments and helpful decisions on my work, throughout my project paper.

I owe my deepest gratitude to my beloved parents, for their caring and never ending encouragement. The dedication also goes to my siblings, as well as my best friends who supported me along the way for this study. Lastly, I offer my regards and blessing to all those who supported me in any respect during the completion of the project paper.

ABSTRACT

Kelantan is one of the areas in Peninsular Malaysia that often vulnerable with a big flood and affected all local mains road. This situation prevents the help and rescue to get the flooding area. The main objectives of this study were to assess variability of annual daily maximum rainfall, to analysis annual rainfall, annual monthly maximum rainfall and annual daily maximum rainfall and to estimate expected return periods of extreme rainfall events of Kelantan, Malaysia for the period of 1998 to 2013. This study uses rainfall data derived from Tropical Rainfall Measuring Mission (TRMM) satellite-based rainfall data. The rainfall data from TRMM satellite-based for each major city in Kelantan were retrieved using Geographical Information System (GIS) technique. This study was focus on rainfall characteristics of major cities in Kelantan (Gua Musang, Kuala Krai, Jeli, Pasir Puteh, Bachok, Kota Bharu, Tumpat, Machang, Pasir Mas and Tanah Merah). Descriptive statistical analysis was conducted on annual rainfall, annual monthly and daily maximum rainfall. Gumbel distribution function was applied to estimate return periods of extreme rainfall events. It was found that annual daily maximum rainfall for Pasir Putih, Kelantan is 616.13 mm which had a return period of 100 years was the highest maximum annual daily rainfall estimated. For future, the result from this study could be used as a guideline in planning and designing any infrastructure in Kelantan, Malaysia.

ABSTRAK

Kelantan merupakan salah satu kawasan di Semenanjung Malaysia yang sering terdedah dengan banjir besar dan menjejaskan jalan-jalan utama tempatan. Kejadian ini menyebabkan kegagalan bantuan dan menyelamat untuk sampai di kawasan tersebut. Objektif utama kajian ini adalah untuk menilai kepelbagaian curahan hujan maksimum harian tahunan, analisis curahan hujan tahunan, curahan hujan tahunan maksimum bulanan dan curahan hujan maksimum harian tahunan dan untuk menganggarkan tempoh ulangan yang dijangka untuk peristiwa hujan luar biasa di Kelantan, Malaysia untuk tempoh masa 1998 - 2013. Kajian ini menggunakan data curahan hujan yang diperolehi daripada data imej satelit *Tropical Rainfall Measuring Mission* (*TRMM*). Data curahan hujan dari *TRMM* bagi setiap bandar utama di Kelantan telah diambil menggunakan teknik *Geographical Information System* (*GIS*). Kajian ini memberi tumpuan kepada ciri-ciri curahan hujan di bandar-bandar utama di Kelantan (Gua Musang, Kuala Krai, Jeli, Pasir Puteh, Bachok, Kota Bharu, Tumpat, Machang, Pasir Mas dan Tanah Merah). Analisis statistik deskriptif telah dijalankan ke atas curahan hujan tahunan, curahan hujan tahunan maksimum bulanan dan curahan hujan tahunan maksimum harian. Fungsi Taburan Gumbel telah digunakan untuk menganggarkan tempoh ulangan peristiwa curahan hujan luar biasa. Didapati bahawa curahan hujan maksimum harian tahunan bagi Pasir Putih, Kelantan adalah 616.13 mm yang mempunyai tempoh masa 100 tahun, adalah anggaran curahan hujan harian tahunan yang tertinggi. Pada masa depan, hasil daripada kajian ini boleh digunakan sebagai panduan dalam perancangan dan rekabentuk infrastruktur di Kelantan, Malaysia.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The weather in Malaysia is characterised by two monsoon regimes, namely, the Southwest Monsoon from late May to September, and the Northeast Monsoon from November to March. The Northeast Monsoon brings heavy rainfall, particularly to the east coast states of Peninsular Malaysia (Kelantan, Terengganu, Pahang and East Johor) and western Sarawak, whereas the Southwest Monsoon normally signifies relatively drier weather. The transition period in between the monsoons is known as the intermonsoon period.

The 2014–2015 Malaysia floods hit Malaysia from 15 December 2014 – 3 January 2015. More than 200,000 people affected while 21 killed on the floods (www.thestar.com). This flood has been described as the worst floods in decades. Kelantan were the worst recorded. Due to its geographical characteristics which are in east coast state, unplanned urbanization, and proximity to the South China Sea, Kota Bharu has become extremely vulnerable monsoon floods every year. The water level of Sungai Kelantan at Tambatan DiRaja, which has a danger level of 25 metres, reached 34.17 metres in December, 2014 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 (Richard Devis, 2015)

The floods had covered the main roads to Kelantan and make it difficult for the help and rescue process. Apart from that, the government's losses from floods in several states across Malaysia are estimated to cost up to RM2 billion that comprise damaged public infrastructure such as roads and bridges. The recent floods also give a huge damage to Keretapi Tanah Melayu Berhad (KTMB) railway infrastructure which includes damage to railway quarters, signalling, tracks, locomotives, machinery, and rolling stock (www.thestar.com). This is because all infrastructures were designed based on the 50 years back probability rainfall pattern data. The uncertain climate changes cause the maximum rainfall increase then more water would flow to rivers. That is when the rivers overflow; causing major flood that resulted in millions in damages, not to mention lost lives and destroyed homes.

1.2 PROBLEM STATEMENT

The flood in 2014 occurred in Kelantan was the worst in Malaysia and have destroyed and damaged almost all the infrastructure such as bridges, road and drainages. Most major routes have been planned and designed by the intensity of extreme rainfall historical data. Due to global climate change, characteristics of rainfall (intensity, depth, spatial and temporal) change. Therefore, this study aim to come out with the latest estimated extreme rainfall data for each major city in Kelantan so that it can be used in future infrastructure design.

1.3 OBJECTIVES OF STUDY

The study main focus was to assess variability of annual daily maximum rainfall of Kelantan Malaysia, for the period of 16 years (Jan 1998 - Dec 2013). The specific of this study are as follows:

i. To analysis annual rainfall, annual monthly maximum rainfall and annual daily maximum rainfall
ii. To estimate expected return periods of extreme rainfall events

1.4 SCOPE OF STUDY

This study was limited to rainfall data for 16 years starting from January 1998 until December 2013 of main cities in Kelantan, Malaysia (Fig.1.1). This study uses rainfall data derived from satellite image data Tropical Rainfall Measuring Mission (TRMM). Literature review found that many previous researches using such data, and easily obtained from the public domain. Method uses for data analysis are Descriptive Statistical Analysis and Gumbel Distribution Function to obtain the return periods.

Figure 1.1 : Kelantan Study Area
Source : www.malaysia-today.net

1.5 SIGNIFICANT OF STUDY

The return period and probability of expected extreme daily rainfall provides appropriate information for engineer to design any structure that can accommodate with high rainfall intensity.

1.6 THESIS STRUCTURE

This report consists of five chapters. Chapter one comprises the introduction section. Background of study, problem statement, objectives of study, scope of study and lastly significant of study are included. In chapter two, it comprises related and suitable literature reviews for the research. Chapter three will explained the research methodology used to collect rainfall data from satellite-based data. The data will then be analysed to get the maximum value and the annual value. The result obtained is presented and discussed in chapter 4. Finally, chapter five comprises the conclusion of the overall chapter and relates some recommendation for future work in the research field.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The hydrological cycle is a balance process among precipitation, evaporation, and all the steps in between. This process powered by energy from the sun, continuous exchange of moisture between the oceans, the atmosphere and the land. Evaporation is the process by which water changes from a liquid to a gas whether it is from oceans, seas, and other bodies of water (lake, rivers, streams) provides nearly 90% of the moisture in atmosphere. Another 10% remaining is released by plants through transpiration. In addition, a very small portion of water vapor enters the atmosphere through sublimation, the process by which water changes directly from a solid (ice or snow) to a gas. The gradual shrinking of snow banks in cases when the temperature remains below freezing results from sublimation. Together, evaporation, transpiration, and sublimation, plus volcanic emissions, account for almost all the water vapor in the atmosphere that is not inserted through human activities. While evaporation from the oceans is the primary vehicle for driving the surface-to-atmosphere portion of the hydrologic cycle, transpiration is also significant. For example, a cornfield 1 acre in size can transpire as much as 4,000 gallons of water every day. Then the water vapor will condensed and produced precipitation such as rain, snow, sleet and hail which are the primary mechanism for transporting water from atmosphere back to the Earth's surface (Fig 2.1).

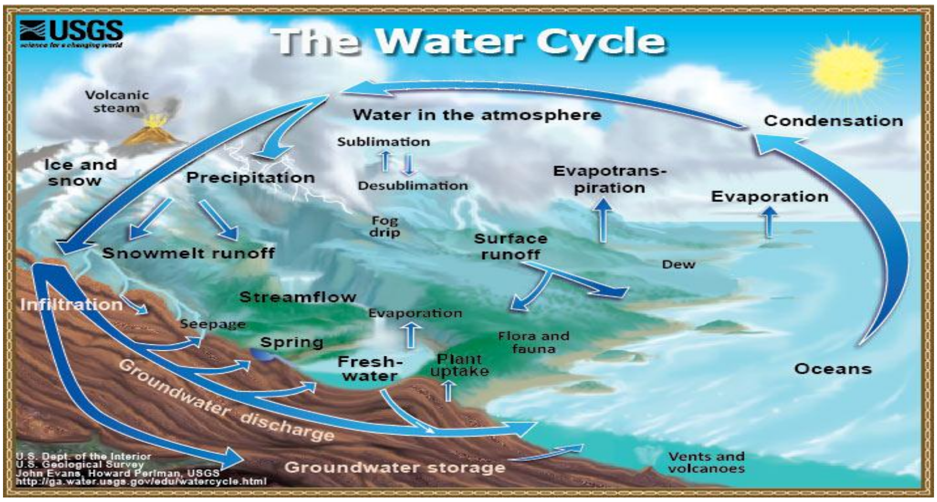

Figure 2.1 Hydrology Cycle

Source : www.water.epa.gov

However, changes in the amount of rain falling during storms provide evidence that the water cycle is already being affected. Over the past 50 years, the amount of rain falling during the most intense 1 percent of storms increased by almost 20 percent. Warmer winter temperatures cause more precipitation to fall as rain rather than snow. Furthermore, rising temperatures cause snow to begin melting earlier in the year and rising the sea level which causes for flood. Changes in global atmospheric circulation patterns accompany La Niña and are responsible for weather extremes in various parts of the world that are typically opposite to those associated with El Niño. These patterns result from colder than normal ocean temperatures inhibiting the formation of rain-producing clouds over the eastern equatorial Pacific region while at the same time enhancing rainfall over the western equatorial Pacific region (Indonesia, Malaysia and northern Australia.) These patterns affect the position and intensity (weakening) of jet streams and the behaviour of storms outside of the tropics in both the Northern and Southern hemispheres.

As most people are well aware, the immediate impacts of flooding include loss of human life, damage to property, destruction of crops, loss of livestock, and deterioration of health conditions owing to waterborne diseases. As communication links and infrastructure such as power plants, roads and bridges are damaged and disrupted, some economic activities may come to a standstill, people are forced to leave their homes and normal life is disrupted.

Damage to infrastructure causes long-term impacts, such as disruptions to supplies of clean water, wastewater treatment, electricity, transport, communication, education and health care. Loss of livelihoods, reduction in purchasing power and loss of land value in the floodplains can leave communities economically vulnerable.

2.2 STUDY AREA

2.2.1 Location

Kelantan is located at east coast of peninsular Malaysia with latitude of 06°10'N and longitude of 102°20'E. The study area include main cities in Kelantan which are Gua Musang, Kuala Krai, Jeli, Pasir Puteh, Bachok, Kota Bharu, Tumpat, Machang, Pasir Mas and Tanah Merah Kota Bharu is one of the main districts in Kelantan and become the capital city of Kelantan which was the main location of commercial centre and state management office. Kelantan River Basin is selected as a pilot area because it represents typical basins and flood plains that are prone to annual monsoon floods in Malaysia. Kelantan River is the major river in Kelantan state and emerges at the confluence of the Galas river and Lebir river near Kuala Krai and meanders over the coastal plain until it finally reached into the South China Sea, about 12 km north of Kota Bahru. The main reach of the Kelantan River has some further larger tributaries downstream. The basin covers 85 percent of the state's surface area. The river only drops 10 meters from the coast up to Guillemard Bridge with the distance of 60 km. The main river comprises of seven major Subcatchments (Kota Bahru, Gullimard, Pergau, Kuala Krai, Galas, Lebir and Nenggiri) that covers a drainage area of 13,170 km. Four major cities are located along the river are Kota Bahru, Pasir Mas, Tumpat and Kuala Krai.

2.2.2 Climate

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 March which develops in conjunction with cold air outbreaks from Siberia produce heavy rains which often cause severe floods along the east coast states of Kelantan, Terengganu, Pahang and East Johor in Peninsular Malaysia, and in the state of Sarawak in East Malaysia. During this season, most states experience monthly rainfall minimum (typically 100 - 150 mm). This is attributed to relatively stable atmospheric conditions in the equatorial region. In particular, the dry condition in Peninsular Malaysia is accentuated by the rain shadow effect of the Sumatran mountain range.

2.3 FLOOD EVENTS IN STUDY AREA

2.3.1 Historical Flood Events

Floods in the study area are mainly causes by heavy rainfall brought by the monsoon and categorize as annual flood as it occurs every year during the monsoon season. The study area faces Northeast monsoon from November to March every year. The Northeast monsoon brings heavy rain to east coast states of Peninsular Malaysia and western Sarawak, whereas the Southwest monsoon normally signifies relatively drier weather. Due to its geographical characteristics, unplanned urbanization and proximity to the South China Sea, Kota Bharu has become extremely vulnerable to monsoon flood every year. Severe flooding occurred in 1926 and 1967. In the 1967 floods 84% of the Kelantan population (537,000 people) were badly affected. Some 125,000 people were evacuated and 38 drowned. Some of other recorded flood experiences in study area occur in 1983, 1986, 1988, 1993, 2001, 2003, and 2004. The unprecedented in November 2004 which was triggered by monsoon, has been described as one of the worst natural flood in the history of Kota Bharu other than the latest flood in 2015 with more than people 200,000 affected while 21 killed on the floods.

The highest number of deaths was recorded as 21 in recent event 2015 with the number of evacuees of 200,000 causing monetary loss of US$ 5.27 million. The second highest monetary damage occurred in 1993 with value of US$ 2.22 million. The recorded historical floods, that the number of evacuees was always 100 or above which implies that those floods were severe. According to the past records intensive precipitations have become more frequent and more severe which cause frequent floods. Thus, a flood early warning system is essential to provide sufficient time for the authorities to evacuate the downstream communities to safer places and take necessary measures to protect physical properties in vulnerable areas.

2.4 HYDROLOGY DATA FOR INFRASTRUCTURE DESIGN

2.4.1 Rainfall Characteristics

Three main characteristics of rainfall are its amount, frequency and intensity, the values of which vary from place to place, day to day, month to month and also year to year. Precise knowledge of these three main characteristics is essential for planning its full utilization. A soil has a definite and limited water intake rate and moisture holding capacity. Hence greater quantities as well as intensities of rainfall normally reduce the effective fraction, increasing run-off and lessening infiltration. Similarly, uneven distribution decreases the extent of effective rainfall while an even spread enhances it. A well distributed rainfall in frequent light showers is more conducive to crop growth than heavy downpours. For example, annual rainfall is lower than 100 mm in the Middle Eastern desert countries, so it may all become effective. In countries like India and Pakistan, intensity, frequency and amount are high daring July and August and hence the effective fraction is very low. From November to April, however, most of the rainfall is effective in these countries due to its low intensity, frequency and amount.

Moreover, this rainfall characteristic analysis can also be used by engineers and planner to design infrastructures, roads and bridges to specification that will maintain their accessibility and longevity. Knowing the historical size of floods and frequencies helps governments plan where to put business, hospitals, homes and dams for flood mitigation needs. The infrastructure is designed based on the intensity and the frequency of historical hydrology data. The existing infrastructure may not be able to withstand the extreme flood and collapse or damage due to climate changes.

2.4.2 Return Periods

A return period or also known as a recurrence is an estimate of the likelihood of an event, such as an earthquake, flood or a river discharge flow to occur. It is a statistical measurement typically based on historic data denoting the average recurrence interval over an extended period of time, and is usually used for risk analysis. For example is to decide whether a project should be allowed to go forward in a zone of a certain risk, or to design structures to withstand an event with a certain return period.

The following analysis assumes that the probability of the event occurring does not vary over time and is independent of past events. When dealing with structure design expectations, the return period is useful in calculating the riskiness of the structure. The probability of at least one event that exceeds design limits during the expected life of the structure is the complement of the probability that no events occur which exceed design limits.

2.5 DETERMINATION OF RAINFALL BY USING SATELLITE IMAGE DATA.

The study focuses on the needs of developing a technique which can be used to determine the quantity of rainfall with the right information and cheaper cost to retrieve. Since 1970s, much effort was made to determine the data from satellite image data (Barrett, 1993). The main importance of estimating data by using satellite image data is to provide information regarding to events, the number and data distribution for the field of meteorological, climatological, hydrological and hydrological sciences (Levzzani et al., 2001). The ability of satellite image for estimating data depends on the position of the satellite and the type of sensor used.

Generally, the distribution of information and the number of data from satellite image data can be obtained by either indirectly or directly from the sources (Arkin and Ardanuy, 1989; Barrett, 1993; Levzzani et al., 2002). The observation is done directly by using passive sensors. Rain particle is the main factor of the decreased in upwelling at passive micro frequency wave. Passive sensor traced the microwave energy absorbed and dispersed by the rain particle and changes the information to estimated rate of particles by comparing with the level of radiation from the surface of the Earth. Passive microwave sensor mounted on low satellite orbit caused the derived rainfall information to have scarcity in temporal and spatial resolution; although the information given is reliable (Barrett, 1993). Indirect observation is done by using empirical relationships of temporal and spatial variability between the covered clouds that has a value of lower temperature threshold and rainfall particle. The surface temperature of cloud is obtained by infra-red radiation emitted by the clouds (Levzzani et al.,2002 and Dingman, 2002). An infra-red wave sensor which installed on geostationary satellites at high orbital position, giving a good temporal resolution of rainfall distribution, but the information about rainfall distribution is less effective (Barrett, 1993)

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter describes the phases involved in achieving the study objectives. There were FOUR (4) phases, namely; i) Data collecting, ii) Pre-processing of Data, iii) Processing, and iv) Result and analysis (Fig 3.1). The first part will be explaining about how all the data needed being collected. The second part, pre-processing performed on the data obtained before processing data can be applied. As for the third part, explained how to publish the Descriptive Statistical Analysis and Gumbel Distribution Function analysis. While the results and analyses are described in CHAPTER 4.

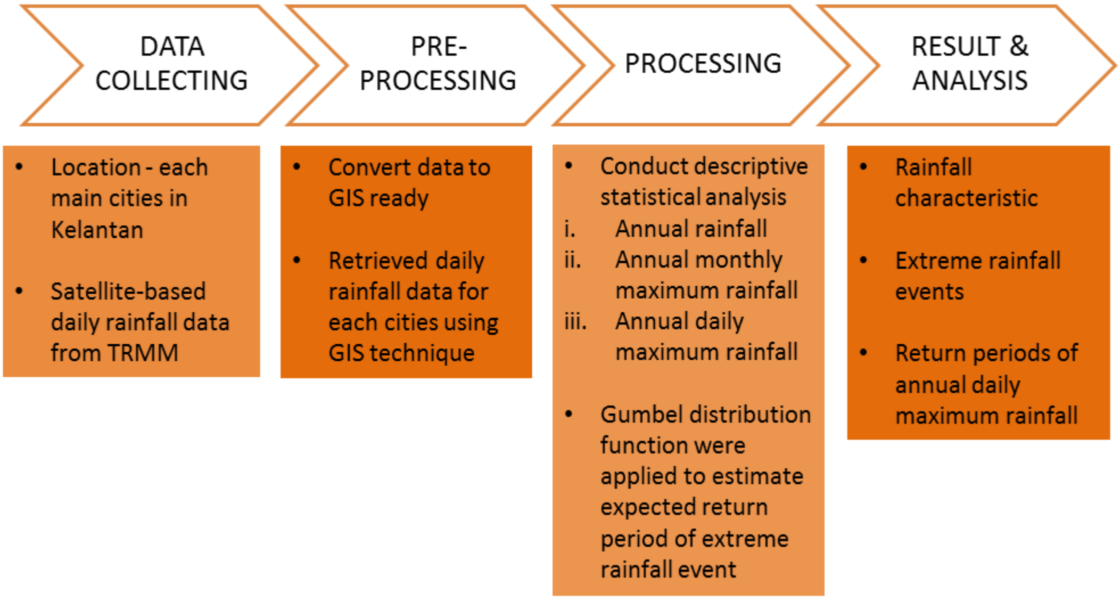

Figure 3.1 : Flow Chart of Methodology

3.2 DATA COLLECTING

The rainfall data is collected from satellite-based TRMM daily for 16 years (Jan 1998 – Dec 2013). Satellite-based rainfall data is the main source for this study. The data is about all around the world including the study area.

3.2.1 TRMM Satellite Image Data

Satellite-based TRMM rainfall data were obtained from public domain archives (NASA). This archive database has provided a wide range of rainfall data products processed with various types of algorithms in form of the distribution of daily rainfall data, monthly and rainfall rates at intervals of three hours, since 1998 until present. To complete this study, the TRMM satellite image data derived by 3B42 V7 algorithm or also known as TRMM Multi-Satellite Precipitation (TMPA) were used (Figure 3.2).

TMPA satellite image rainfall data provided by the archive database was in the form of raster data model. The data series can be obtained with only downloading cost for the user. For the purpose of this study, there were 1,860 data files downloaded for study period July 2009 to June 2014. It is known to be the best standard product (Huffman et al., 2007). However, calibration and validation process need to be done.

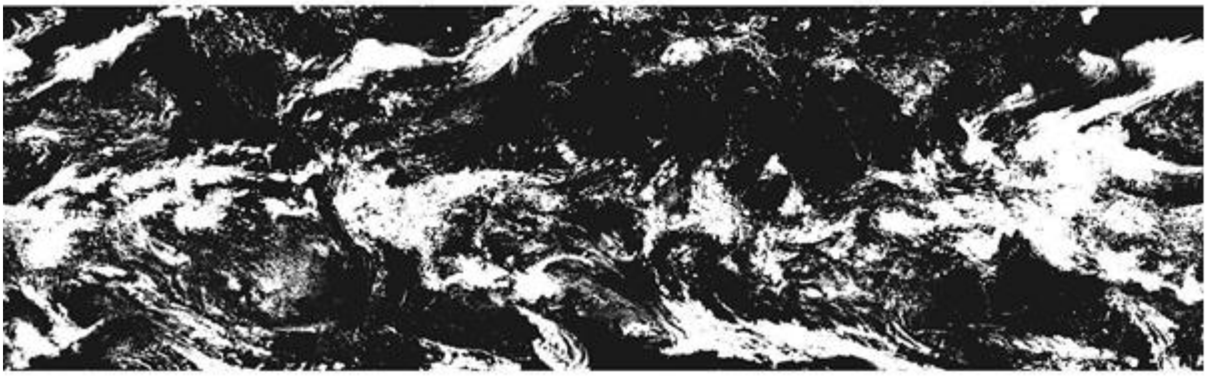

Figure 3.2 : Satellite Data Image in TIFF Format including the Study Area

3.2.2 Map of Study Area

Figure 3-3 shows a map of the study area which is the main cities in Kelantan, Malaysia.

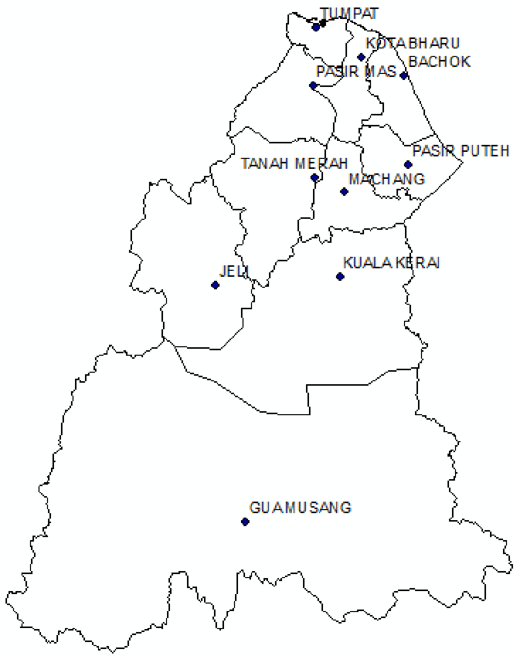

Figure 3.3 : Study Area.

3.3 PRE-PROCESSING

Pre- processing of data was done before all the data can be used in can be used in the processing process.

3.4 PREPARATION OF SATELLITE DATABASE IMAGE

To carry out the analysis, variability of annual daily maximum rainfall of Kelantan, satellite-based data need to be converted into GIS-ready data. All respective 16 years daily data are exported into raster data to enable it for processing with Geographical Information System (GIS) software.

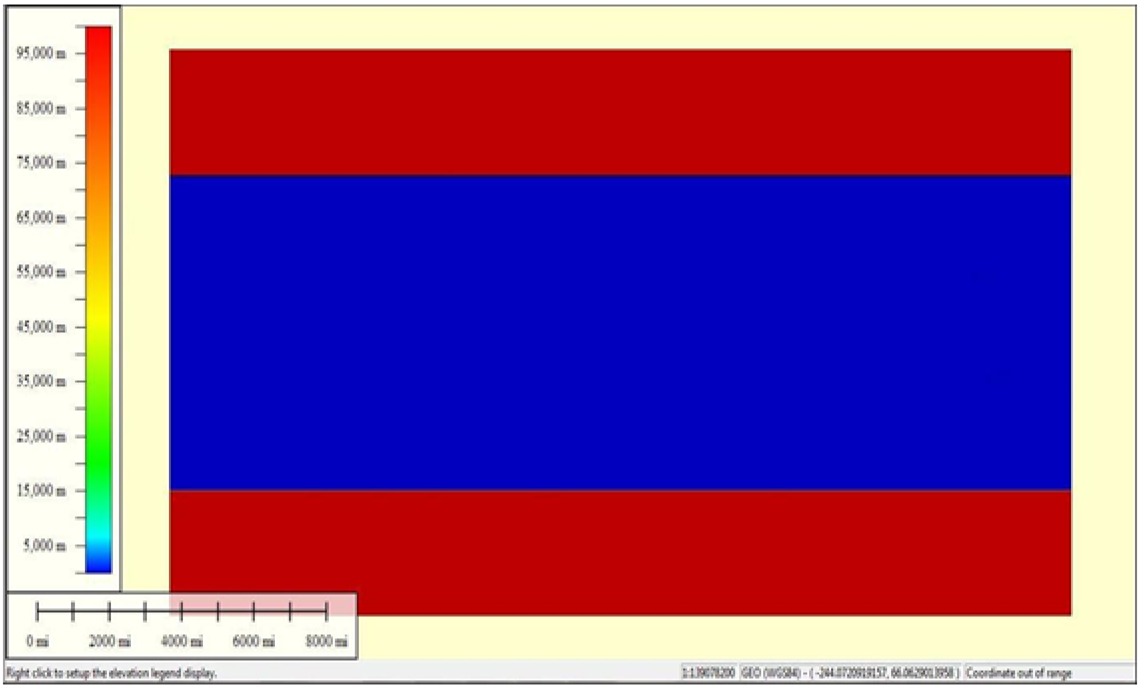

Figure 3.4 : Satellite-based Data Exported into Raster Image by Using Software

3.5 PROCESSING

The following data will then be transferred to ArcGis software for duplication and manipulation techniques.

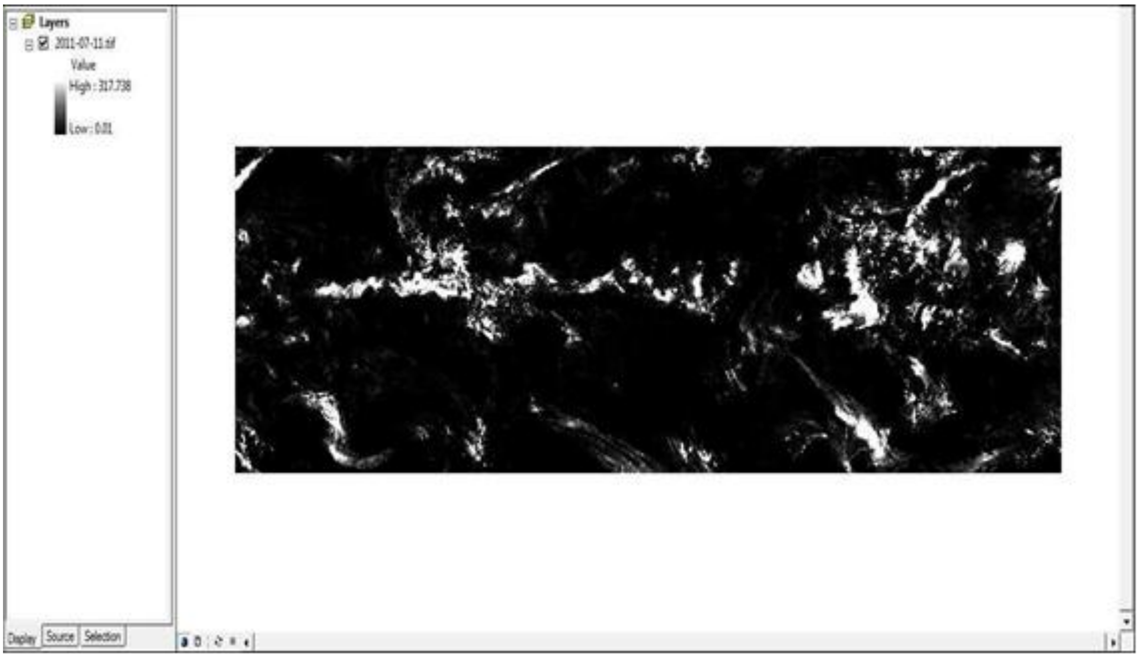

Figure 3.5 : ArcGis Satellite-based Data in Raster Image

The following data were then clipped for the limited study area.

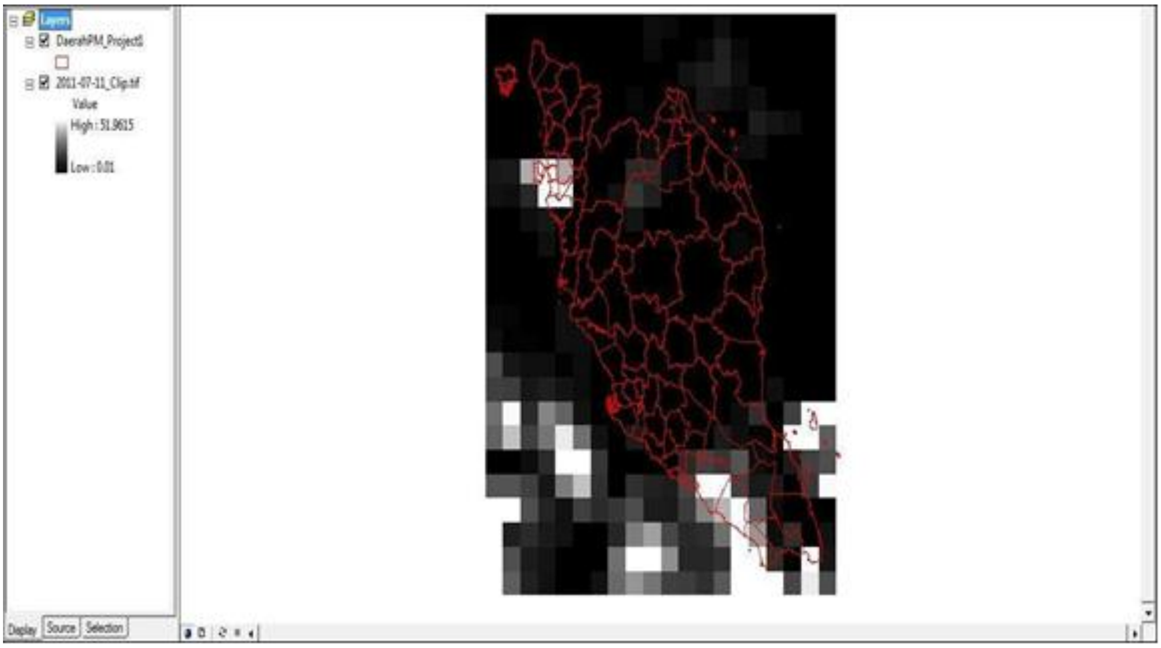

Figure 3.6 : Clipped ArcGis Satellite-based Data in Raster Image.

The following clipped will produced attributes on rainfall distribution data.

Table 3.1 : Attributes of Rainfall Distribution Data.

FID_	ID	BANDAR	RASTERVALU
<Null>	0	JOHOR BAHRU	13.362605
<Null>	0	PONTIAN	4.1185
<Null>	0	KOTA TINGGI	33.043415
<Null>	0	MERSING	0.01
<Null>	0	BATU PAHAT	7.762021
<Null>	0	MUAR	17.532718
<Null>	0	SEGAMAT	0.01
<Null>	0	KLUANG	1.454005
<Null>	0	ROMPIN	0.284982
<Null>	0	PEKAN	0.771489
<Null>	0	KUANTAN	4.1185
<Null>	0	MARAN	7.762021
<Null>	0	BERA	0.01
<Null>	0	BENTONG	14.62886
<Null>	0	TEMERLOH	0.01
<Null>	0	RAUB	68.177337
<Null>	0	KUALA LIPIS	41.436538
<Null>	0	JERANTUT	1.665501
<Null>	0	CAMERON HIGHLAND	43.355392
<Null>	0	KEMAMAN	1.907763
<Null>	0	DUNGUN	0.01
<Null>	0	MARANG	4.30922
<Null>	0	HULU TERENGGANU	14.62886
<Null>	0	KUALA TERENGGAN	0.01
<Null>	0	SETIU	0.01
<Null>	0	BESUT	8.121466
<Null>	0	GUA MUSANG	8.497558
<Null>	0	KUALA KERAI	4.717567
<Null>	0	JELI	7.418484
<Null>	0	MACHANG	0.737344
<Null>	0	PASIR PUTEH	1.389652
<Null>	0	BACHOK	1.742629
<Null>	0	KOTA BHARU	1.742629
<Null>	0	TUMPAT	1.454005
<Null>	0	PASIR MAS	1.454005
<Null>	0	TANAH MERAH	0.737344

All attributes will be transferred to Microsoft Excel together to analyse the Descriptive Statistical and the Gumbel Distribution Function.

3.5.1 Descriptive Statistical

Descriptive statistics are used to describe the basic features of the data in a study. They provide simple summaries about the sample and the measures. Together with simple graphics analysis, they form the basis of virtually every quantitative analysis of data.

Descriptive statistics are typically distinguished from inferential statistics. With descriptive statistics you are simply describing what is or what the data shows. With inferential statistics, you are trying to reach conclusions that extend beyond the immediate data alone. In this study, we conducted descriptive statistical analysis for three types of data: i) annual rainfall, ii) annual daily maximum rainfall and iii) annual monthly maximum rainfall. Descriptive statistics deals with organization and summary of large scale data. It includes tables, graphs and numbers to present raw data (Ott and Longnecker, 2010). We applied descriptive statistics to rainfall data to examine its central tendency (mean, median and mode) and variability (standard deviation). The various statistical moments used in this study are given below:

First moment (mean):

$$\bar{y} = \frac{\Sigma y_i}{n}$$

Second moment (variance):

$$s^2 = \frac{\Sigma (y_i - \bar{y})^2}{n - 1}$$

Table 3.2 : Annual Rainfall Data (1998-2013)

	DEPTH (mm)									
YEAR/TOWN	GUA MUSANG	KUALA KERAI	JELI	MACHANG	PASIR PUTEH	BACHOK	KOTA BHARU	TUMPAT	PASIR MAS	TANAH MERAH
1998	2269.8805	2566.256099	2403.323528	2381.359391	2438.632598	2603.939959	2603.939959	2506.424585	2506.424585	2381.329391
1999	3337.379	3455.975	3265.393	3560.159	3693.128	3708.343	3708.111	3681.665	3682.252	3560.776
2000	3009.105	3178.992	2920.02	3230.449	3236.654	3428.906	3427.93	3297.179	3303.043	3235.472
2001	2862.002	3146.504	2772.104	2974.119	2938.469	2681.865	2681.324	2817.114	2808.122	2971.703
2002	2357.085	2330.915	2097.093	2222.209	2203.996	2271.511	2271.511	2194.768	2194.768	2222.209
2003	2923.584253	3300.933365	2953.042648	3020.42319	3032.985653	2748.846018	2748.846018	2706.599433	2706.599433	3020.42319
2004	2569.61	2999.161	2767.892	2599.106	2595.402	2299.502	2292.191	2169.669	2166.2	2596.714
2005	2565.044	3103.672	2775.237	2951.427	2979.456	2655.012	2655.012	2663.428	2663.428	2951.427
2006	2940.839	2946.537	2763.272	2732.938	2763.119	2361.163	2357.123	2453.942	2447.792	2728.312
2007	3003.252	3293.442	3048.733	2937.604	2802.74	2263.772	2263.772	2321.336	2321.336	2937.604
2008	2624.99	2951.029	2717.196	2781.489	3310.83	3389.349	3389.349	3118	3118	2781.399
2009	2960.167	2598.702	3176.917	2433.352	2845.46	2500.346	2500.346	2509.029	2472.855	2433.352
2010	2833.758	2961	2860.787	2926.153	2877.488	2849.289	2849.289	2795.744	2795.744	2926.153
2011	3056.607	4076.98	3565.107	4129.385	3997.483	3676.439	3676.439	3949.153	3949.153	4129.385
2012	2985.432	2862.154	2834.376	2996.19	3108.917	2972.866	2972.866	2991.197	2991.197	2996.18
2013	3943.188	4841.681	4342.249	3904.197	3555.055	2950.684	2950.684	3009.16	3009.16	3904.197
TOTAL	46241.92275	50613.93346	47262.74218	47780.55958	48379.81525	45361.83298	45348.73298	45184.40802	45136.07402	47776.63558
MIN	2269.8805	2330.915	2097.093	2222.209	2203.996	2263.772	2263.772	2169.669	2166.2	2222.209
MAX	3943.188	4841.681	4342.249	4129.385	3997.483	3708.343	3708.111	3949.153	3949.153	4129.385
MEAN	2890.120172	3163.370842	2953.921386	2986.284974	3023.738453	2835.114561	2834.295811	2824.025501	2821.004626	2986.039724
STANDARD DEVIATION	394.3632748	599.7829788	497.3355035	520.1484084	461.2027222	486.2866079	486.9937121	505.1930908	507.8182421	520.6318038
KURTOSIS	2.578984346	3.499334006	3.628798352	0.545971978	0.253584515	-0.752979589	-0.755893174	0.339624463	0.304192465	0.534518866
SKEWNESS	0.981664031	1.585464599	1.306589492	0.83965497	0.418928119	0.635748147	0.631672933	0.839907371	0.839303895	0.83865921

Table 3.3 : Annual Daily Maximum Rainfall Data (1998-2013)

	GUA MUSANG		KUALA KERAI		JELI		MACHANG		PASIR PUTEH		BACHOK		KOTA BHARU		TUMPAT		PASIR MAS		TANAH MERAH	
YEAR	DATE	DEPTH (mm)	DATE	DEPTH (mm)	DATE	DEPTH (mm)	DATE	DEPTH (mm)	DATE	DEPTH (mm)	DATE	DEPTH (mm)	DATE	DEPTH (mm)	DATE	DEPTH (mm)	DATE	DEPTH (mm)	DATE	DEPTH (mm)
1998	28-Dec	59.519737	29-Dec	102.4654	29-Dec	112.17513	6-Dec	176.39801	6-Dec	117.369766	18-Dec	147.182037	18-Dec	147.18204	6-Dec	112.175132	6-Dec	112.17513	6-Dec	176.39801
1999	6-Dec	71.33451	4-Dec	161.12915	4-Dec	102.4654	4-Dec	277.389862	4-Dec	290.23529	13-Dec	290.23529	13-Dec	290.23529	4-Dec	347.847503	4-Dec	347.8475	4-Dec	277.38986
2000	23-Nov	161.12915	23-Nov	265.112915	23-Nov	231.44707	23-Nov	242.164993	23-Nov	221.203506	22-Nov	211.413314	22-Nov	211.41331	23-Nov	176.39801	23-Nov	176.39801	23-Nov	242.16499
2001	18-Jan	122.805023	19-Jan	184.566696	19-Jan	153.99779	14-Jan	134.442153	14-Jan	265.112915	14-Jan	153.997787	14-Jan	153.99779	16-Dec	153.997787	16-Dec	153.99779	14-Jan	134.44215
2002	29-Jul	71.33451	21-Jan	112.175132	21-Jan	71.33451	19-Dec	78.094245	19-Dec	93.59613	6-Nov	140.667938	6-Nov	140.66794	30-Dec	140.667938	30-Dec	140.66794	19-Dec	78.094245
2003	10-Dec	122.805023	10-Dec	277.389862	10-Dec	242.16499	10-Dec	242.164993	10-Dec	231.447067	10-Dec	265.112915	10-Dec	265.11292	10-Dec	277.389862	10-Dec	277.38986	10-Dec	242.16499
2004	30-Jan	140.667938	11-Dec	184.566696	11-Dec	147.18204	29-Nov	128.491912	4-Dec	168.590774	4-Dec	140.667938	4-Dec	140.66794	4-Dec	117.369766	4-Dec	117.36977	29-Nov	128.49191
2005	18-Dec	184.566696	8-Dec	153.997787	23-Dec	117.36977	23-Dec	202.056427	15-Dec	202.056427	15-Dec	265.112915	15-Dec	265.11292	15-Dec	211.413314	15-Dec	211.41331	23-Dec	202.05643
2006	20-Dec	134.442153	26-Sep	147.182037	3-Jan	147.18204	16-Dec	140.667938	3-Jan	140.667938	11-Dec	122.805023	11-Dec	122.80502	3-Jan	117.369766	3-Jan	117.36977	16-Dec	140.66794
2007	7-Jan	176.39801	7-Jan	221.203506	7-Jan	168.59077	7-Jan	168.590774	7-Jan	184.566696	20-Oct	147.182037	20-Oct	147.18204	20-Oct	147.182037	20-Oct	147.18204	7-Jan	168.59077
2008	6-Dec	147.182037	6-Dec	221.203506	6-Dec	193.11366	6-Dec	140.667938	1-Dec	176.39801	24-Jun	231.447067	24-Jun	231.44707	24-Jun	128.491912	24-Jun	128.49191	6-Dec	140.66794
2009	1-Jan	59.519737	1-Dec	231.447067	1-Dec	161.12915	1-Dec	265.112915	1-Dec	290.23529	1-Dec	317.738311	1-Dec	317.73831	1-Dec	242.164993	1-Dec	242.16499	1-Dec	265.11292
2010	30-Dec	65.159889	31-Dec	97.930412	1-Dec	93.59613	31-Dec	112.175132	31-Dec	140.667938	2-Nov	134.442153	2-Nov	134.44215	28-Nov	168.590774	28-Nov	168.59077	31-Dec	112.17513
2011	24-Dec	81.710693	23-Dec	231.447067	23-Dec	153.99779	23-Dec	290.23529	23-Dec	265.112915	23-Dec	211.413314	23-Dec	211.41331	23-Dec	242.164993	23-Dec	242.16499	23-Dec	290.23529
2012	25-Dec	117.369766	25-Dec	211.413314	25-Dec	176.39801	25-Dec	193.113662	25-Dec	231.447067	24-Dec	193.113662	24-Dec	193.11366	24-Dec	231.447067	24-Dec	231.44707	25-Dec	193.11366
2013	4-Dec	153.997787	1-Dec	168.590774	1-Dec	122.80502	5-Dec	184.566696	5-Dec	161.12915	22-Nov	221.203506	22-Nov	221.20351	5-Dec	184.566696	5-Dec	184.5667	5-Dec	184.5667
TOTAL	1869.942659		2971.821321		2394.949265		2976.33294		3179.836879		3193.735207		3193.735207		2999.23755		2999.23755		2976.33294	
MAX	184.566696		277.389862		242.164993		290.23529		290.23529		317.738311		317.738311		347.847503		347.847503		290.23529	
MIN	59.519737		97.930412		71.33451		78.094245		93.59613		122.805023		122.805023		112.175132		112.175132		78.094245	
MEAN	116.8714162		185.7388326		149.6843291		186.0208088		198.7398049		199.6084504		199.6084504		187.4523469		187.4523469		186.0208088	
STANDARD DEVIATION	43.17683929		55.07949931		46.94933014		63.06602632		60.91157099		61.76367036		61.76367036		66.68036805		66.68036805		63.06602632	

Table 3.4 : Annual Monthly Maximum Rainfall Data of Gua Musang

	DEPTH (mm)															
MONTH/YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
JAN	58.35383	298.042937	214.5942	355.5849	108.8438	178.8888	319.0076	64.08734	222.1598	265.4574	148.9249	300.557753	152.8698	291.7933	247.443	252.357
FEB	21.41214	184.499641	169.0895	88.87384	31.49099	132.8412	45.13353	24.85792	221.5794	98.17492	169.2199	221.767128	50.0147	49.72086	141.4062	332.7999
MAR	60.13295	298.263406	319.756	235.2482	104.8464	182.4838	199.7742	145.63	142.3152	221.7819	272.257	243.664075	76.54334	331.8465	233.7523	155.5035
APR	64.62353	276.706155	292.3145	252.5102	232.1478	165.6284	156.9419	141.1168	214.0063	202.5529	122.7211	235.053203	191.5128	175.9092	345.5349	328.9832
MAY	178.2864	269.054174	227.0077	139.2587	161.4426	187.7657	224.1555	263.3371	306.5889	223.4686	252.0126	227.190903	276.3667	257.3921	371.3646	335.1847
JUN	200.4922	195.570839	215.6307	104.1341	245.3428	217.0731	85.9273	191.4879	257.584	201.8232	198.5247	221.787128	300.9911	279.7583	113.4217	297.8247
JUL	200.4922	152.26936	129.2462	103.9191	159.2533	282.3203	178.2143	204.0057	172.8808	257.3819	208.2122	246.324912	365.3199	120.0218	187.5184	281.0925
AUG	273.7122	290.019209	204.3428	247.2623	261.4398	305.3986	200.1302	133.3243	179.2954	188.6926	205.6882	269.302152	235.2445	184.1025	250.1942	314.525
SEP	203.9526	350.797743	268.375	243.6102	263.3325	219.5107	324.6525	180.6091	393.7694	256.253	216.4331	294.29396	248.2594	216.7809	314.2549	432.1288
OCT	327.5637	338.410436	273.0726	398.7312	278.9074	391.6614	342.1314	339.2787	261.8621	363.7872	279.7377	237.524521	208.3379	429.3758	233.4331	456.2175
NOV	277.8029	279.800648	380.0094	320.9064	256.4074	316.5307	225.5482	401.0117	282.3787	264.3681	276.3536	220.491801	402.5674	359.9481	182.1222	336.6869
DEC	368.1258	401.948168	315.6665	371.9627	253.63	343.4816	267.9932	476.2978	286.4193	459.5101	274.905	248.686255	325.7306	359.9581	364.987	419.8844
TOTAL	2234.951	3335.382716	3009.105	2862.002	2357.085	2923.584	2569.61	2565.044	2940.839	3003.252	2624.99	2966.64379	2833.758	3056.607	2985.432	3943.188
MAX	368.1258	401.948168	380.0094	398.7312	278.9074	391.6614	342.1314	476.2978	393.7694	459.5101	279.7377	300.557753	402.5674	429.3758	371.3646	456.2175
MIN	21.41214	152.26936	129.2462	88.87384	31.49099	132.8412	45.13353	24.85792	142.3152	98.17492	122.7211	220.491801	50.0147	49.72086	113.4217	155.5035

Table 3.5 : Annual Monthly Maximum Rainfall Data of Kuala Kerai

	DEPTH (mm)															
MONTH/YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
JAN	170.0416	354.060298	224.1714	516.1971	156.8711	232.6001	373.5956	9.79465	161.4079	361.0247	169.1853	342.734495	175.1458	495.0949	277.092	514.7349
FEB	22.58032	287.83019	115.5852	117.0325	2.430891	95.20581	38.72922	39.38154	375.3739	31.85095	150.2599	167.055589	10.45434	54.39668	54.00317	520.3122
MAR	34.31801	152.93438	333.9738	255.0604	103.2985	167.5063	88.48301	183.9447	79.26488	135.893	115.8797	198.09542	103.8271	549.3909	218.5335	206.5842
APR	18.09946	182.713446	143.3892	136.1088	117.034	110.835	84.44546	67.81044	105.552	116.1175	209.9503	167.493895	70.41348	57.00065	191.3224	354.8465
MAY	202.9367	211.579716	195.1269	219.7101	149.422	178.8255	162.0656	234.742	238.8445	222.0033	228.9462	193.069806	163.766	227.6912	193.6989	349.9061
JUN	179.3618	181.223268	198.7869	121.255	185.4731	226.964	130.6304	239.3382	203.1094	155.3417	294.4434	167.075589	277.6947	225.5078	106.5236	315.2483
JUL	232.9956	155.176276	108.2422	143.736	180.3832	294.518	231.7793	170.7074	331.6725	248.1515	206.0933	168.898915	232.7685	209.9324	190.8095	294.2698
AUG	266.2746	320.655336	171.7089	198.0093	228.9254	240.3078	258.5562	240.9071	210.3566	245.8082	328.6873	252.249983	209.8278	252.1241	259.7692	376.0948
SEP	332.3161	188.154296	292.596	303.1863	243.1771	197.7694	316.0637	293.9946	389.9674	299.3002	261.4865	207.199153	208.5845	250.2861	258.6873	390.6866
OCT	323.5462	300.565964	285.3159	338.7792	266.8748	480.2415	459.2098	342.7429	237.1299	350.447	208.1315	176.384963	320.3081	471.0582	243.5773	473.6891
NOV	199.8205	397.887564	607.6888	308.472	291.157	314.8665	403.3108	448.7437	251.948	169.7357	270.3255	169.789069	545.5956	640.1891	91.21077	462.1682
DEC	583.9553	723.194627	502.4063	488.9574	405.8682	761.2934	452.2925	831.565	361.9102	957.7678	507.6405	397.545942	642.6142	644.3076	776.926	583.1399
TOTAL	2566.246	3455.975361	3178.992	3146.504	2330.915	3300.933	2999.161	3103.672	2946.537	3293.442	2951.029	2607.59282	2961	4076.98	2862.154	4841.681
MAX	583.9553	723.194627	607.6888	516.1971	405.8682	761.2934	459.2098	831.565	389.9674	957.7678	507.6405	397.545942	642.6142	644.3076	776.926	583.1399
MIN	18.09946	152.93438	108.2422	117.0325	2.430891	95.20581	38.72922	9.79465	79.26488	31.85095	115.8797	167.055589	10.45434	54.39668	54.00317	206.5842

Table 3.6 : Annual Monthly Maximum Rainfall Data of Jeli

	DEPTH (mm)															
MONTH/YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
JAN	122.5698	320.882501	222.6937	444.7092	90.35718	161.2824	347.7605	38.06293	195.3019	290.0389	84.61529	373.305718	155.6398	372.7507	279.1885	420.4613
FEB	5.651525	245.721786	110.1724	94.4775	6.459795	71.88209	58.59832	0.28	311.8406	43.84961	186.551	228.031218	51.58582	40.66112	74.00338	470.1111
MAR	28.2731	146.403771	292.8961	220.2702	81.20093	130.9704	99.25805	116.5319	87.69596	153.7807	154.6263	242.636596	70.6708	479.3078	226.9226	166.6667
APR	47.77117	215.106727	203.1962	150.568	152.0611	129.168	110.0336	85.0239	127.9337	127.709	158.8883	230.085834	81.66895	86.84622	268.8851	323.9835
MAY	203.8527	220.103125	186.6514	171.8579	158.7589	163.7658	171.6107	267.0498	262.9165	245.0626	189.3824	242.906332	201.3695	216.3818	211.1873	331.2859
JUN	159.5436	209.685566	176.5746	120.1128	211.1892	207.7868	115.0566	209.2908	224.933	165.7067	292.432	228.051218	238.7951	258.2324	79.33025	297.2118
JUL	247.2486	141.670734	127.8835	143.8121	195.6937	343.0228	219.9914	172.8941	289.4521	258.0665	171.5884	249.709622	260.1439	196.2425	181.8736	275.3825
AUG	266.2746	325.9966	149.2542	165.9567	192.3541	266.2271	242.0103	232.4657	192.2256	233.2069	279.5191	279.152147	239.3914	258.4506	243.7022	370.37
SEP	301.4852	207.608856	300.0563	294.8319	218.8104	186.3547	355.6519	266.0854	338.3156	282.5613	253.9253	278.245814	203.8681	223.9425	285.6337	377.762
OCT	301.6374	309.551978	286.2689	341.4322	246.7745	461.8363	400.2494	326.9034	235.279	338.9435	269.4215	239.502627	316.4366	438.5541	235.9938	455.7164
NOV	187.1064	379.063052	524.309	217.4162	261.4939	307.9781	279.8319	408.2619	228.6361	160.5119	281.337	218.543212	486.5174	496.8635	52.84078	413.5087
DEC	493.453	543.597847	340.0636	406.6595	281.939	522.7683	367.8394	652.3876	268.7422	749.2955	394.9094	377.895806	554.6996	496.8735	694.815	439.7887
TOTAL	2364.867	3265.392543	2920.02	2772.104	2097.093	2953.043	2767.892	2775.237	2763.272	3048.733	2717.196	3188.06614	2860.787	3565.107	2834.376	4342.249
MAX	493.453	543.597847	524.309	444.7092	281.939	522.7683	400.2494	652.3876	338.3156	749.2955	394.9094	377.895806	554.6996	496.8735	694.815	470.1111
MIN	5.651525	141.670734	110.1724	94.4775	6.459795	71.88209	58.59832	0.28	87.69596	43.84961	84.61529	218.543212	51.58582	40.66112	52.84078	166.6667

Table 3.7 : Annual Monthly Maximum Rainfall Data of Machang

	DEPTH (mm)															
MONTH/YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
JAN	58.0756	305.751406	208.9944	450.1756	66.77375	202.3003	141.6451	4.4185	145.7074	315.6203	76.48451	246.520995	148.6312	489.8305	293.9898	420.3999
FEB	10.68445	364.631148	143.1312	120.2939	1.791339	88.10591	2.865026	0.28	288.7267	1.077217	105.8777	159.356572	16.28511	26.19278	34.25484	382.3839
MAR	30.04633	102.169359	308.59	258.5057	97.97511	127.4438	50.96955	181.6273	81.46871	133.2339	85.89829	209.067801	91.4179	554.2619	210.0422	125.2422
APR	5.408012	175.596685	168.4801	127.3115	90.49545	83.08062	78.46021	52.57267	96.49672	120.0308	258.472	160.835305	80.30749	32.49175	186.5477	245.6332
MAY	177.6876	213.694356	156.4351	183.7557	154.0058	153.289	156.1427	225.5867	260.2561	220.147	305.1024	166.795056	176.6027	200.9361	202.9329	287.2694
JUN	150.4484	188.768104	190.8877	81.13906	166.6776	202.5985	145.3194	254.6253	228.4518	137.6718	272.3553	159.376572	182.7553	272.7875	104.0758	296.3484
JUL	238.3174	146.080333	130.3322	162.8466	157.7953	288.9629	217.8324	163.1514	296.1375	249.036	268.271	159.386572	216.2165	216.352	220.3465	209.1182
AUG	250.6572	320.467065	179.7152	193.344	205.5225	242.0451	249.3712	207.5335	194.4118	240.555	292.441	199.956734	220.2668	221.9809	234.3345	303.0167
SEP	329.114	168.755826	277.5858	288.321	223.6182	188.8584	335.5792	299.3767	357.0841	334.0324	233.5172	181.301037	235.6363	213.7663	257.1862	282.9664
OCT	316.4306	281.645386	241.6232	324.2254	262.5109	447.7702	451.1737	335.2397	179.8848	318.959	149.2257	159.629082	315.9423	437.613	244.081	388.2456
NOV	221.994	465.992003	697.2488	304.4832	352.5068	323.9116	395.6223	391.2486	264.1309	150.2618	268.0759	206.845094	581.0701	731.5809	67.73109	498.41
DEC	592.4856	826.607082	527.4253	479.7171	442.536	672.0567	374.1252	835.7667	340.1819	716.9791	465.7684	424.518943	661.0209	731.5909	940.6674	465.1634
TOTAL	2381.349	3560.158753	3230.449	2974.119	2222.209	3020.423	2599.106	2951.427	2732.938	2937.604	2781.489	2433.58976	2926.153	4129.385	2996.19	3904.197
MAX	592.4856	826.607082	697.2488	479.7171	442.536	672.0567	451.1737	835.7667	357.0841	716.9791	465.7684	424.518943	661.0209	731.5909	940.6674	498.41
MIN	5.408012	102.169359	130.3322	81.13906	1.791339	83.08062	2.865026	0.28	81.46871	1.077217	76.48451	159.356572	16.28511	26.19278	34.25484	125.2422

Table 3.8 : Annual Monthly Maximum Rainfall Data of Pasir Putih

	DEPTH (mm)															
MONTH/YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
JAN	87.41845	316.100367	166.7003	426.3705	55.34167	153.399	112.5103	2.207763	160.8138	342.4684	99.17765	234.024554	146.9423	460.7939	302.5577	386.0726
FEB	9.544171	430.303676	138.5934	123.0317	0.800042	110.4538	1.344192	37.22882	295.6954	0.974711	161.2353	191.82285	11.93573	23.28836	32.88625	375.3984
MAR	27.25927	80.459935	330.5858	266.7021	93.6134	136.5076	36.93865	192.8526	50.12376	121.0094	76.74788	247.217278	80.38787	606.1895	236.212	104.2744
APR	10.27732	178.737998	173.486	111.8563	80.13274	82.28245	74.99962	46.68952	84.02579	111.0165	351.3518	199.112523	83.65015	28.21492	143.8079	219.8388
MAY	176.5106	210.272456	131.7942	176.3269	129.7565	138.8834	144.5673	201.6028	230.4146	197.4447	369.5039	201.957677	188.3228	170.2584	220.3713	222.5668
JUN	162.7523	180.24977	184.708	117.0031	159.9451	192.0017	133.6161	266.4457	198.7847	146.4297	296.3825	191.84285	147.6371	218.9628	97.07346	227.4412
JUL	205.4947	156.624629	114.3066	143.8687	138.0986	306.0062	133.6161	154.4005	303.9527	243.7608	319.6747	192.430843	222.8306	195.1586	219.2492	176.1198
AUG	243.4591	306.29517	145.4266	196.035	184.0385	220.2941	226.9194	210.5378	197.9666	236.9154	339.0493	263.17736	181.6415	211.9552	204.4612	262.9494
SEP	313.9049	159.534425	275.3508	280.0253	198.892	197.243	306.957	282.9584	364.9567	288.693	306.1775	219.413444	216.3448	195.046	257.6425	245.2163
OCT	326.7893	266.102716	234.4698	249.0751	247.7839	469.8691	496.8515	321.7261	198.1068	325.8324	162.9008	192.346175	277.3438	462.452	304.0821	358.4412
NOV	206.2176	499.441524	754.4375	388.8663	428.732	356.3382	430.5516	413.117	306.8451	157.0893	304.6196	229.60802	597.5546	712.5765	72.28559	522.9113
DEC	668.9949	909.004841	586.7948	459.3082	486.8614	669.7071	417.9948	849.6892	371.4335	631.1057	524.0096	482.506797	722.8972	712.5865	1018.288	453.8245
TOTAL	2438.623	3693.127507	3236.654	2938.469	2203.996	3032.986	2516.866	2979.456	2763.119	2802.74	3310.83	2845.46037	2877.488	3997.483	3108.917	3555.055
MAX	668.9949	909.004841	754.4375	459.3082	486.8614	669.7071	496.8515	849.6892	371.4335	631.1057	524.0096	482.506797	722.8972	712.5865	1018.288	522.9113
MIN	9.544171	80.459935	114.3066	111.8563	0.800042	82.28245	1.344192	2.207763	50.12376	0.974711	76.74788	191.82285	11.93573	23.28836	32.88625	104.2744

Table 3.9 : Annual Monthly Maximum Rainfall Data of Bachok

	DEPTH (mm)															
MONTH/YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
JAN	191.3559	250.630204	143.9706	269.4183	93.78717	159.7344	32.71377	23.13104	121.9199	230.5489	75.48418	140.478627	134.7155	367.2978	208.1419	259.0737
FEB	34.07825	431.911167	109.5993	141.7617	15.04862	73.18249	32.40172	12.94349	90.93962	34.06929	96.35889	175.929718	11.84926	26.76934	41.53237	280.5801
MAR	28.67345	81.95465	378.0133	252.0394	104.6044	138.4441	26.82997	147.86	72.62282	109.8177	60.59446	227.947896	77.07104	660.6794	176.9884	67.20023
APR	4.355142	185.076996	290.2249	126.46	83.85943	59.14528	46.90808	29.24121	45.07506	124.2503	374.7623	183.376527	87.1181	9.344872	183.6002	213.8583
MAY	154.2804	201.395847	107.0235	198.0525	147.6925	144.8023	120.5147	209.0472	269.7289	194.6055	411.8743	177.10921	187.6414	177.3437	163.5262	200.3237
JUN	160.7779	171.231709	173.5553	95.38674	150.4995	173.1394	156.7934	241.0868	207.6194	109.2635	386.4942	175.949718	125.1839	197.5957	74.28015	188.6757
JUL	234.9274	113.872274	143.8571	153.1744	115.6307	280.9298	216.8344	136.8564	254.156	202.6843	358.4049	179.091192	252.3547	178.7803	222.7121	111.4673
AUG	259.5549	261.873584	110.8029	203.4432	154.13	173.616	200.8501	98.33287	152.5562	218.2561	321.2679	183.368202	160.0564	170.4197	199.0499	211.8488
SEP	309.7405	129.399697	277.8535	208.5886	194.6447	169.2147	224.6852	284.2617	277.5098	270.984	297.8618	188.720907	202.388	177.5412	243.447	168.9928
OCT	342.4003	271.986702	187.2497	305.82	207.7288	457.5353	542.833	318.3279	170.8779	369.6396	174.5829	175.968043	257.2543	409.69	237.1502	339.9879
NOV	254.5371	569.777386	877.1617	398.8128	547.6148	417.8516	383.3133	370.2379	374.6821	152.7698	396.4633	200.495072	634.1031	650.4835	102.756	580.9092
DEC	629.2487	1039.232731	629.5944	328.9074	456.2704	501.2507	314.8248	783.6856	323.4753	246.8832	435.1996	491.911353	719.5536	650.4935	1119.682	327.7664
TOTAL	2603.93	3708.342947	3428.906	2681.865	2271.511	2748.846	2299.502	2655.012	2361.163	2263.772	3389.349	2500.34647	2849.289	3676.439	2972.866	2950.684
MAX	629.2487	1039.232731	877.1617	398.8128	547.6148	501.2507	542.833	783.6856	374.6821	369.6396	435.1996	491.911353	719.5536	660.6794	1119.682	580.9092
MIN	4.355142	81.95465	107.0235	95.38674	15.04862	59.14528	26.82997	12.94349	45.07506	34.06929	60.59446	140.478627	11.84926	9.344872	41.53237	67.20023

Table 3.10 : Annual Monthly Maximum Rainfall Data of Kota Bharu

	DEPTH (mm)															
MONTH/YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
JAN	191.3559	250.630204	143.9706	269.4183	93.78717	159.7344	32.71377	23.13104	121.5983	230.5489	75.48418	140.478627	134.7155	367.2978	208.1419	259.0737
FEB	34.07825	431.911167	109.5993	141.7617	15.04862	73.18249	32.40172	12.94349	90.93962	34.06929	96.35889	175.929718	11.84926	26.76934	41.53237	280.5801
MAR	28.67345	81.72307	378.0133	252.0394	104.6044	138.4441	26.82997	147.86	72.62282	109.8177	60.59446	227.947896	77.07104	660.6794	176.9884	67.20023
APR	4.355142	185.076996	290.2249	126.46	83.85943	59.14528	46.90808	29.24121	45.07506	124.2503	374.7623	183.376527	87.1181	9.344872	183.6002	213.8583
MAY	154.2804	201.395847	107.0235	198.0525	147.6925	144.8023	120.5147	209.0472	269.7289	194.6055	411.8743	177.10921	187.6414	177.3437	163.5262	200.3237
JUN	160.7779	171.231709	173.5553	95.38674	150.4995	173.1394	156.7934	241.0868	207.6194	109.2635	386.4942	175.949718	125.1839	197.5957	74.28015	188.6757
JUL	234.9274	113.872274	143.8571	153.3711	115.6307	280.9298	209.5226	136.8564	250.4371	202.6843	358.4049	179.091192	252.3547	178.7803	222.7121	111.4673
AUG	259.5549	261.873584	110.8029	202.7057	154.13	173.616	200.8501	98.33287	152.5562	218.2561	321.2679	183.368202	160.0564	170.4197	199.0499	211.8488
SEP	309.7405	129.399697	277.8535	208.5886	194.6447	169.2147	224.6852	284.2617	277.5098	270.984	297.8618	188.720907	202.388	177.5412	243.447	168.9928
OCT	342.4003	271.986702	187.2497	305.82	207.7288	457.5353	542.833	318.3279	170.8779	369.6396	174.5829	175.968043	257.2543	409.69	237.1502	339.9879
NOV	254.5371	569.777386	878.3088	398.8128	547.6148	417.8516	383.3133	370.2379	374.6821	152.7698	396.4633	200.495072	634.1031	650.4835	102.756	580.9092
DEC	629.2487	1039.232731	627.4713	328.9074	456.2704	501.2507	314.8248	783.6856	323.4753	246.8832	435.1996	491.911353	719.5536	650.4935	1119.682	327.7664
TOTAL	2603.93	3708.111367	3427.93	2681.324	2271.511	2748.846	2292.191	2655.012	2357.123	2263.772	3389.349	2500.34647	2849.289	3676.439	2972.866	2950.684
MAX	629.2487	1039.232731	878.3088	398.8128	547.6148	501.2507	542.833	783.6856	374.6821	369.6396	435.1996	491.911353	719.5536	660.6794	1119.682	580.9092
MIN	4.355142	81.72307	107.0235	95.38674	15.04862	59.14528	26.82997	12.94349	45.07506	34.06929	60.59446	140.478627	11.84926	9.344872	41.53237	67.20023

Table 3.11 : Annual Monthly Maximum Rainfall Data of Tumpat

	DEPTH (mm)															
MONTH/YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
JAN	139.2193	224.705365	166.6406	348.4986	86.25337	130.2749	24.20233	15.72541	139.4934	223.1041	57.86782	192.87173	96.01465	434.8192	240.6701	275.5421
FEB	6.567076	410.466308	114.9728	115.4988	4.226415	77.29884	9.752487	1.591497	149.9934	0.28	134.8562	179.443927	0.28	26.25923	16.55748	266.95
MAR	32.90572	96.532976	371.4069	253.6626	87.37912	121.0965	28.39089	151.1449	80.7888	111.0853	69.01779	217.486081	72.0388	624.3978	199.6432	68.04623
APR	1.478748	187.033018	263.4162	122.805	84.54648	28.00286	44.92125	27.28341	59.34012	129.2558	311.614	190.689507	75.1792	9.977248	164.9906	217.9255
MAY	134.9927	210.529694	117.3791	182.3202	139.6383	172.0595	154.6227	214.7597	267.3416	192.955	380.7671	180.917932	177.35	199.1217	197.4224	225.7239
JUN	141.5828	182.739189	162.436	87.4789	156.1314	173.7023	146.1321	239.158	253.5568	108.0075	308.7328	179.463927	138.5624	243.0229	91.94851	209.5738
JUL	290.4067	146.068088	152.6247	172.8078	120.2607	326.1385	208.5401	146.2147	259.2193	203.6425	342.3759	179.615137	268.5239	213.2542	200.9943	151.1244
AUG	249.3173	265.409257	116.6779	209.4263	163.6701	198.4056	209.1168	128.4337	139.6774	221.0056	265.1834	183.773147	164.5932	206.076	215.4112	235.953
SEP	324.717	134.5162	263.5425	246.2781	208.3028	176.5842	199.4117	278.2314	312.5116	300.9091	302.657	197.808556	153.3572	186.6386	236.9153	191.8395
OCT	330.4721	280.414797	193.5462	350.4311	215.3864	414.3693	484.2399	309.8197	157.6199	349.9479	173.7248	179.550085	268.509	427.2602	244.8325	295.8342
NOV	260.777	545.917444	810.1754	318.5937	498.8982	380.3579	401.2035	344.8612	336.5464	138.8044	312.7435	205.74923	674.9569	689.1581	86.50394	518.8876
DEC	593.9782	997.332317	564.3605	409.3129	430.0746	508.309	259.135	806.2042	297.853	342.3388	458.4598	421.660026	706.3792	689.1681	1095.308	351.7598
TOTAL	2506.415	3681.664653	3297.179	2817.114	2194.768	2706.599	2169.669	2663.428	2453.942	2321.336	3118	2509.02929	2795.744	3949.153	2991.197	3009.16
MAX	593.9782	997.332317	810.1754	409.3129	498.8982	508.309	484.2399	806.2042	336.5464	349.9479	458.4598	421.660026	706.3792	689.1681	1095.308	518.8876
MIN	1.478748	96.532976	114.9728	87.4789	4.226415	28.00286	9.752487	1.591497	59.34012	0.28	57.86782	179.443927	0.28	9.977248	16.55748	68.04623

Table 3.12 : Annual Monthly Maximum Rainfall Data of Pasir Mas

	DEPTH (mm)															
MONTH/YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
JAN	139.2193	224.705365	166.6406	348.4986	86.25337	130.2749	24.20233	15.72541	139.4934	223.1041	57.86782	192.87173	96.01465	434.8192	240.6701	275.5421
FEB	6.567076	410.466308	114.9728	115.4988	4.226415	77.29884	9.752487	1.591497	149.9934	0.28	134.8562	179.443927	0.28	26.25923	16.55748	266.95
MAR	32.90572	96.532976	371.4069	253.6626	87.37912	121.0965	28.39089	151.1449	80.7888	111.0853	69.01779	217.486081	72.0388	624.3978	199.6432	68.04623
APR	1.478748	187.033018	263.4162	122.805	84.54648	28.00286	44.92125	27.28341	59.34012	129.2558	311.614	190.689507	75.1792	9.977248	164.9906	217.9255
MAY	134.9927	210.529694	117.3791	182.3202	139.6383	172.0595	154.6227	214.7597	267.3416	192.955	380.7671	180.917932	177.35	199.1217	197.4224	225.7239
JUN	141.5828	182.739189	162.436	87.4789	156.1314	173.7023	146.1321	239.158	253.5568	108.0075	308.7328	179.463927	138.5624	243.0229	91.94851	209.5738
JUL	290.4067	146.068088	152.6247	172.8078	120.2607	326.1385	208.5401	146.2147	259.2193	203.6425	342.3759	179.615137	268.5239	213.2542	200.9943	151.1244
AUG	249.3173	265.409257	116.6779	209.4263	163.6701	198.4056	209.1168	128.4337	139.6774	221.0056	265.1834	183.773147	164.5932	206.076	215.4112	235.953
SEP	324.717	134.5162	263.5425	246.2781	208.3028	176.5842	199.4117	278.2314	312.5116	300.9091	302.657	197.808556	153.3572	186.6386	236.9153	191.8395
OCT	330.4721	280.414797	193.5462	350.4311	215.3864	414.3693	484.2399	309.8197	157.6199	349.9479	173.7248	179.550085	268.509	427.2602	244.8325	295.8342
NOV	260.777	545.917444	810.1754	318.5937	498.8982	380.3579	401.2035	344.8612	336.5464	138.8044	312.7435	205.74923	674.9569	689.1581	86.50394	518.8876
DEC	593.9782	997.332317	564.3605	409.3129	430.0746	508.309	259.135	806.2042	297.853	342.3388	458.4598	421.660026	706.3792	689.1681	1095.308	351.7598
TOTAL	2506.415	3681.664653	3297.179	2817.114	2194.768	2706.599	2169.669	2663.428	2453.942	2321.336	3118	2509.02929	2795.744	3949.153	2991.197	3009.16
MAX	593.9782	997.332317	810.1754	409.3129	498.8982	508.309	484.2399	806.2042	336.5464	349.9479	458.4598	421.660026	706.3792	689.1681	1095.308	518.8876
MIN	1.478748	96.532976	114.9728	87.4789	4.226415	28.00286	9.752487	1.591497	59.34012	0.28	57.86782	179.443927	0.28	9.977248	16.55748	68.04623

Table 3.13 : Annual Monthly Maximum Rainfall Data of Tanah Merah

	DEPTH (mm)															
MONTH/YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
JAN	58.0756	305.751406	208.9944	450.1756	66.77375	202.3003	141.6451	4.4185	145.7074	315.6203	76.48451	246.520995	148.6312	489.8305	293.9898	420.3999
FEB	10.67445	364.631148	143.1312	120.2839	1.791339	88.10591	2.865026	0.28	288.7267	1.077217	105.8777	159.356572	16.28511	26.19278	34.25484	382.3839
MAR	30.03633	102.786188	308.59	258.5057	97.97511	127.4438	50.96955	181.6273	81.46871	133.2339	85.89829	209.067801	91.4179	554.2619	210.0322	125.2422
APR	5.408012	175.596685	168.4801	127.3115	90.49545	83.08062	78.46021	52.57267	96.49672	120.0308	258.462	160.835305	80.30749	32.49175	186.5477	245.6332
MAY	177.6776	213.694356	156.4351	183.7557	154.0058	153.289	156.1427	225.5867	260.2561	220.147	305.0924	166.795056	176.6027	200.9361	202.9329	287.2694
JUN	150.4484	188.768104	190.8877	81.13906	166.6776	202.5985	145.3194	254.6253	228.4518	137.6718	272.3453	159.376572	182.7553	272.7875	104.0758	296.3484
JUL	238.3174	146.080333	130.3322	162.0817	157.7953	288.9629	215.4401	163.1514	291.5108	249.036	268.261	159.386572	216.2165	216.352	220.3465	209.1182
AUG	250.6572	320.467065	179.7152	191.7029	205.5225	242.0451	249.3712	207.5335	194.4118	240.555	292.431	199.956734	220.2668	221.9809	234.3345	303.0167
SEP	329.114	168.755826	277.5858	288.321	223.6182	188.8584	335.5792	299.3767	357.0841	334.0324	233.5072	181.301037	235.6363	213.7663	257.1862	282.9664
OCT	316.4306	281.645386	241.6232	324.2254	262.5109	447.7702	451.1737	335.2397	179.8848	318.959	149.2157	159.3913	315.9423	437.613	244.081	388.2456
NOV	221.994	465.992003	704.1398	304.4832	352.5068	323.9116	395.6223	391.2486	264.1309	150.2618	268.0659	206.845094	581.0701	731.5809	67.73109	498.41
DEC	592.4856	826.607082	525.557	479.7171	442.536	672.0567	374.1252	835.7667	340.1819	716.9791	465.7584	424.518943	661.0209	731.5909	940.6674	465.1634
TOTAL	2381.319	3560.775582	3235.472	2971.703	2222.209	3020.423	2596.714	2951.427	2728.312	2937.604	2781.399	2433.35198	2926.153	4129.385	2996.18	3904.197
MAX	592.4856	826.607082	704.1398	479.7171	442.536	672.0567	451.1737	835.7667	357.0841	716.9791	465.7584	424.518943	661.0209	731.5909	940.6674	498.41
MIN	5.408012	102.786188	130.3322	81.13906	1.791339	83.08062	2.865026	0.28	81.46871	1.077217	76.48451	159.356572	16.28511	26.19278	34.25484	125.2422

3.5.2 Gumbel Distribution Function

The famous statistician Emil Julius Gumbel (1941) was probably, the first person who dealt extreme values of hydrological data in organized way for conducting flood frequency analysis. Traditionally three extreme value distributions: Fréchet, Weibull and Gumbel are commonly used for analysing return periods of annual daily maximum rainfall. Nadarajah and Choi (2007) and Carvalho et al. (2013) expressed the Cumulative Distribution Function of the Generalized Extreme Value (GEV) distribution as:

$$F(x) = \exp\left\{-\left(1+\xi.\frac{x-\mu}{\sigma}\right)^{-1/\xi}\right\} \qquad \ldots(1)$$

for 1 + ξ (x−μ)/σ N 0, where ξ, μ and σ are referred as shape, location and scale parameters respectively. The Eq. (1) is referred as Gumbel distribution for the cases of ξ → 0; the GEV distribution can be expressed as Eq.(2). The probability and return periods of annual daily maximum rainfall were estimated using Eqs. (3) and (4) respectively.

$$F(x) = \exp\left[-\exp\left\{-\left(\frac{x-\mu}{\sigma}\right)\right\}\right] \qquad \ldots(2)$$

$$P(X) = 1 - F(x) \qquad \ldots(3)$$

$$N = \frac{1}{P(x)} \qquad \ldots(4)$$

Where,

x annual daily maximum rainfall,

μ mean of observed annual daily maximum rainfall,

σ standard deviation of observed annual daily maximum rainfall,

F(x) cumulative probability distribution,

P(x) probability distribution,

N return periods of expected annual daily maximum rainfall.

CHAPTER 4

DATA ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the determinations of which were obtained from Chapter 3, is displayed in geographic information systems (GIS). Explanation and analysis of the study results made to three (3) parts, namely; (i) the rainfall characteristic, (ii) the extreme rainfall events and (iii) the return periods of annual daily maximum rainfall of Kelantan, Malaysia

4.2 RAINFALL CHARACTERISTIC

The average maximum annual rainfall for Kelantan is 4069.5 mm while minimum annual daily is 1994.1 mm. From Table 4.1, we can see that from annual rainfall the maximum are major in 2011 which is in Machang, Pasir Puteh, Tumpat, Pasir Mas and Tanah Merah while the minimum rainfall is in 2002 in Kuala Kerai, Jeli, Machang and Pasir Puteh. For the annual monthly rainfall, the maximum recorded are mostly in December which is in northeast monsoon where the highest value recorded is at 1119.682 mm for Bachok and Kota Bharu.

Table 4.1: Annual Maximum Rainfall and Annual Monthly Rainfall

	YEARLY		MONTHLY	
CITY	MAX	MIN	MAX	MIN
GUA MUSANG	3943.18 **2013**	2269.88 **1998**	476.2978 **DEC 05**	278.9073 **OCT 02**
KUALA KERAI	4841.68 **2013**	2330.91 **2002**	957.76776 **DEC 07**	389.96741 **SEPT 06**
JELI	4342.24 **2013**	2097.09 **2002**	749.29548 **DEC 07**	281.93904 **DEC 02**
MACHANG	4129.38 **2011**	2222.2 **2002**	940.66736 **DEC 12**	357.08406 **SEPT 06**
PASIR PUTEH	3997.48 **2011**	2203.99 **2002**	1018.2879 **DEC 12**	371.43347 **DEC 06**
BACHOK	3708.34 **1999**	2263.77 **2007**	1119.682 **DEC 12**	369.63963 **OCT 07**
KOTA BHARU	3708.11 **1999**	2263.77 **2007**	1119.682 **DEC 12**	369.63963 **OCT 07**
TUMPAT	3949.15 **2011**	2169.66 **2004**	1095.3076 **DEC 12**	336.54642 **NOV 06**
PASIR MAS	3949.15 **2011**	2166.2 **2004**	1095.3076 **DEC 12**	336.54642 **NOV 06**
TANAH MERAH	4129.38 **2011**	2222.2 **2004**	940.66736 **DEC 12**	357.08406 **SEPT 06**

4.3 EXTREME RAINFALL

The highest amount of daily rainfall was recorded of 10 main towns in Kelantan is shown in Table 4.2. We can see that extreme rainfall events occurred in year 1999 (347.847503mm) and 2009 (317.738311mm). It is shown that the return period for Kelantan is 10 years. Both maximum recorded in December because of Northeast monsoon. For Bachok and Kota Bharu, they have the same maximum depth because they are close to each other and only 25 km apart. Both towns are exactly located on the coastal area of South China Sea that give the major rainy season in the country during northeast monsoon. Same goes to Tumpat and Pasir Mas, they are 25 km away to each other.

Table 4.2 : Historical Extreme Rainfall Events of Main Cities in Kelantan, Malaysia

CITY	DATE	DEPTH (mm)
GUA MUSANG	18/12/2005	184.566696
KUALA KERAI	10/12/2003	277.389862
JELI	10/12/2003	242.164993
MACHANG	23/12/2011	290.23529
PASIR PUTEH	1/12/2009	290.23529
BACHOK	1/12/2009	317.738311
KOTA BHARU	1/12/2009	317.738311
TUMPAT	4/12/1999	347.847503
PASIR MAS	4/12/1999	347.847503
TANAH MERAH	23/12/2011	290.23529

4.4 RETURN PERIODS OF ANNUAL DAILY MAXIMUM RAINFALL

Kelantan is one of the east coast states of Peninsular Malaysia that always have big flood during Northeast Monsoon. For this study, we take the overturn year for 25, 50 and 100 years ahead for every city in Kelantan. The figures below show the return periods for each city.

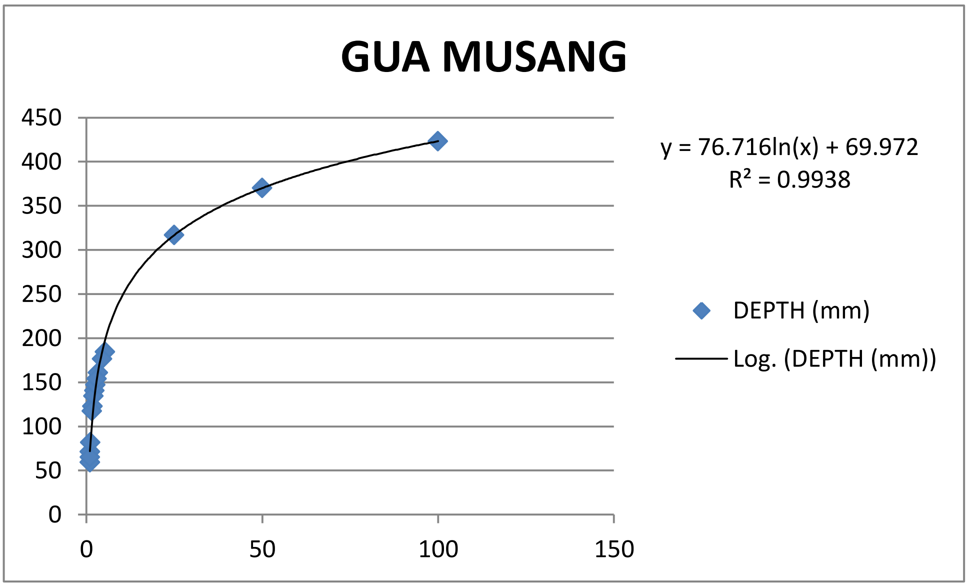

Figure 4.1 : Return Periods of Annual Daily Maximum Rainfall of Gua Musang

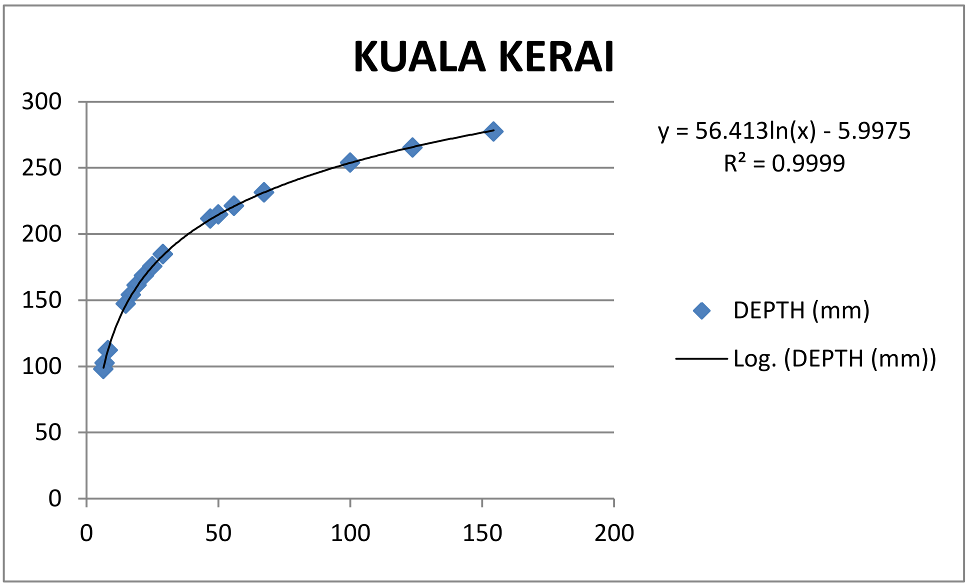

Figure 4.2 : Return Periods of Annual Daily Maximum Rainfall of Kuala Kerai

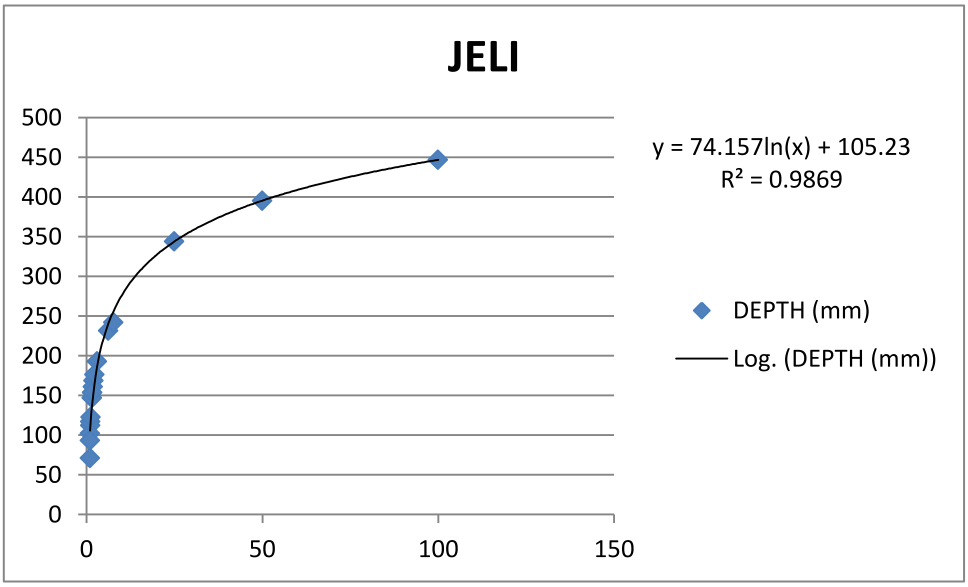

Figure 4.3 : Return Periods of Annual Daily Maximum Rainfall of Jeli

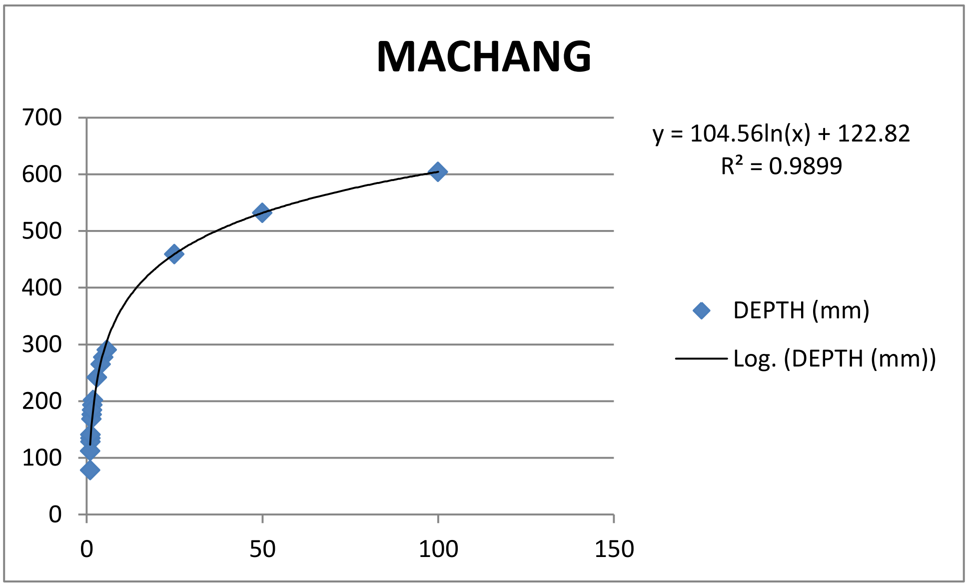

Figure 4.4 : Return Periods of Annual Daily Maximum Rainfall of Machang

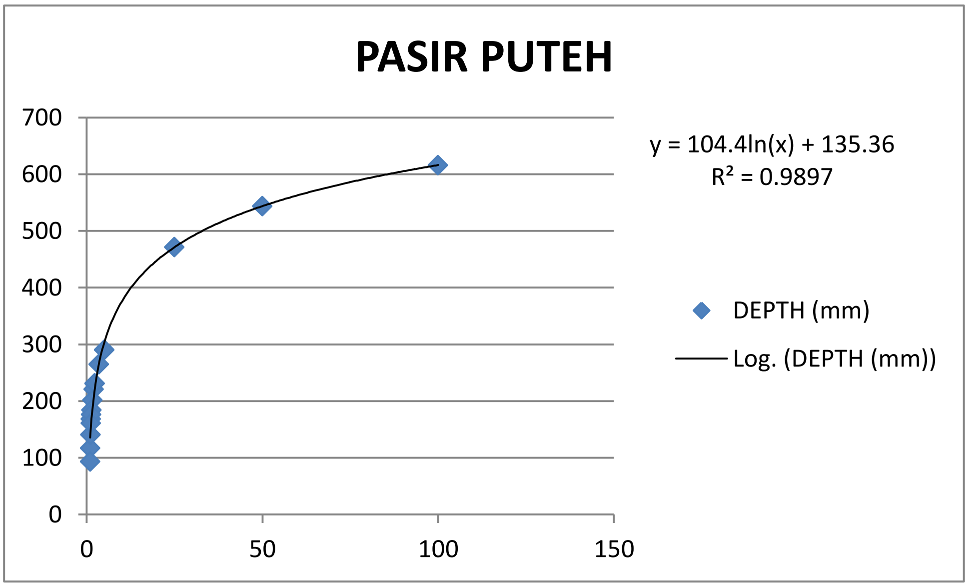

Figure 4.5 : Return Periods of Annual Daily Maximum Rainfall of Pasir Puteh

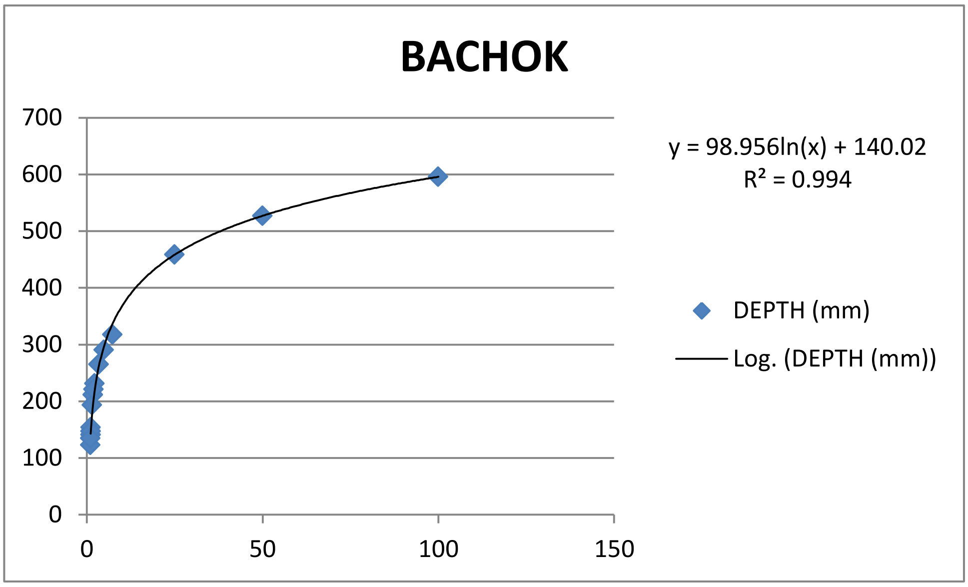

Figure 4.6 : Return Periods of Annual Daily Maximum Rainfall of Bachok

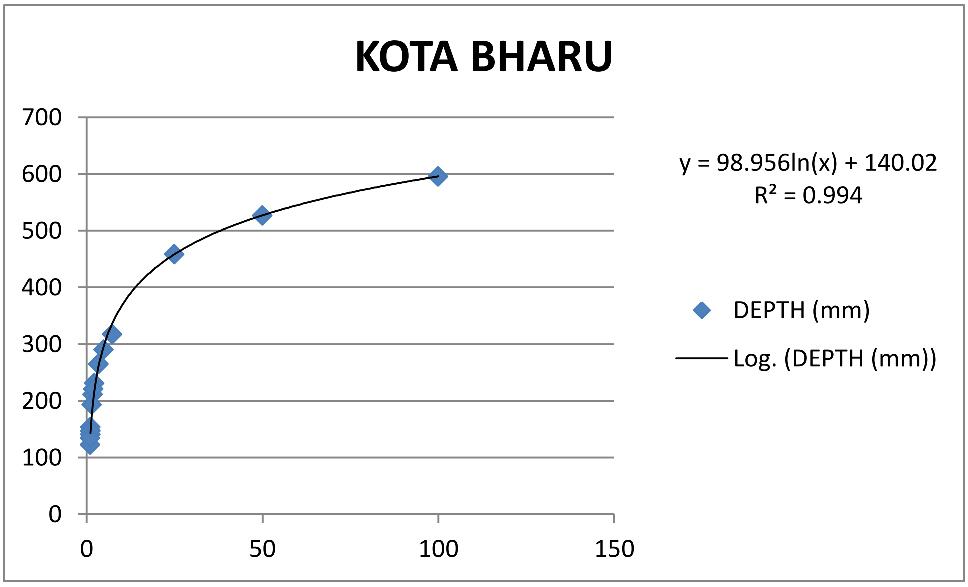

Figure 4.7 : Return Periods of Annual Daily Maximum Rainfall of Kota Bharu

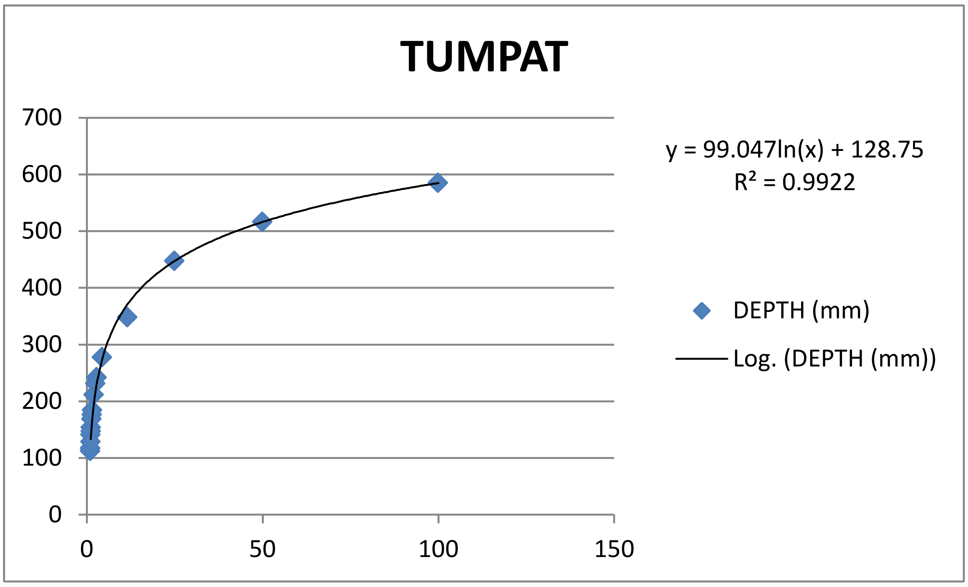

Figure 4.8 : Return periods of annual daily maximum rainfall of Tumpat

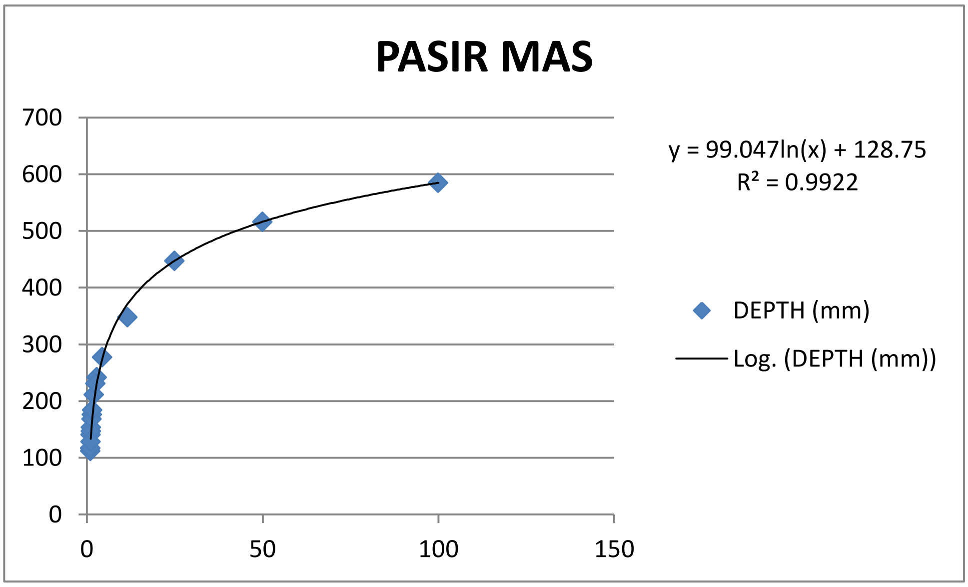

Figure 4.9 : Return Periods of Annual Daily Maximum Rainfall of Pasir Mas

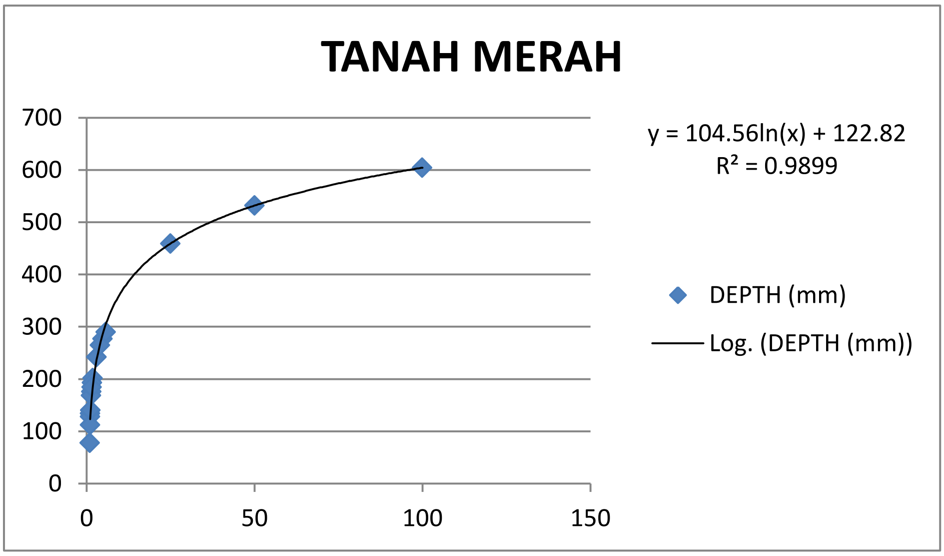

Figure 4.10 : Return Periods of Annual Daily Maximum Rainfall of Tanah Merah

Table 4.3 : The Return Period Table of Annual Daily Maximum Rainfall of Kelantan

TOWN	EQUATION	m	c	R^2	RETURN PERIODS		
					25	50	100
GUA MUSANG	y = 76.716ln(x) + 69.972	76.716	69.972	0.9938	316.911	370.086	423.262
KUALA KRAI	y = 56.413ln(x) + 5.9975	56.413	5.9975	0.9999	175.588	214.691	253.793
JELI	y = 74.157ln(x) + 105.23	74.157	105.23	0.9869	343.932	395.333	446.735
MACHANG	y = 104.56ln(x) + 122.82	104.56	122.82	0.9899	459.395	531.871	604.346
PASIR PUTEH	y = 104.4ln(x) + 135.36	104.4	135.36	0.9897	471.4	543.76	616.129
BACHOK	y = 98.956ln(x) + 140.02	98.956	140.02	0.994	458.547	527.138	595.729
KOTA BHARU	y = 98.956ln(x) + 140.02	98.956	140.02	0.994	458.547	527.138	595.729
TUMPAT	y = 99.047ln(x) + 128.75	99.047	128.75	0.9922	447.566	516.22	584.873
PASIR MAS	y = 99.047ln(x) + 128.75	99.047	128.75	0.9922	447.566	516.22	584.873
TANAH MERAH	y = 104.56ln(x) + 122.82	104.56	122.82	0.9899	459.395	531.871	604.346

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter explicated the conclusion and recommendation for overall of the chapter before in the research. Basically, the conclusion for the study is to express the outcome that based on the objective of the study which was to analysis annual rainfall, annual monthly maximum rainfall and annual daily maximum rainfall, to assess the variability of annual daily maximum rainfall and to estimate expected return periods of extreme rainfall events of Kelantan, Malaysia

5.2 CONCLUSION

The statistically analysis was carried out based on daily rainfall data and converted to monthly basis for 16 consecutive years. The analysis shows the pattern of extreme rainfall events for a particular return period. From the result, any future drainage structure to be designed and constructed in Kelantan should be resilient to extreme rainfall event. The existing system was designed based on historical rainfall data, but surely cannot resist a high intensive short duration rainfall which is expected due to global climate change. The proposed return periods of annual daily maximum rainfall of this study can be used to examine the risk and reliability of the structure design of Kelantan. With that, we can be prepared for the coming flood and minimize the cost of damages. Therefore, the objectives of this study were achieved.

5.3 RECOMMENDATION

A few recommendations can be made in order to improve these studies for future study purpose:

i. Based on the study, TRMM data need to calibrate with the rain-gauge data to obtained more reliable result

ii. This study need to be conduct regularly because of the drastic climate changes.

REFERENCES

Adeyewa, Z. B., and Nakamura, K. (2003). Validation of TRMM Radar Rainfall Data over Major Climatic Regions in Africa. *Journal Climate.* 35, 331–347.

Adler, R. F., Negri, A. J., Keehn, P. R., and Hakkarinen, I. M. (1993). Estimation of Monthly Rainfall over Japan and Surrounding Waters from a Combination of Low-orbit Microwave and Geosynchronous IR Data. *Journal of Applied Meteorology*. 32, 335−356.

Adler, R. F., Kummerow, C., Bolvin, D., Curtis, S., dan Kidd, C. (2003). Status of TRMM Monthly Estimates of Tropical Precipitation. Dlm Cloud Systems, Hurricanes, and TRMM, Meteorology Monograph. *American Meteorology Society*. 51, 223–234.

Ahammed, F. Hewaa, G. A, John R. Argue (2014). Variability of annual daily maximum rainfall of Dhaka, Bangladesh article *Atmospheric Research*; 137,176–182

Almazroui, M. (2011). Calibration of TRMM Rainfall Climatology over Saudi Arabia During 1998-2009. *Atmospheric Researh*. 99, 400-414.

Barret, E. C. (1993). Satellite Rainfall Monitoring for Agrometeorology: Operation Problems, Practices and Prospects. *EARSel. Advances in Remote Sensing*. 2(2): 66-72.

Brown, J. E. M. (2006). An Analysis of the Performance of Hybrid Infrared and Microwave Satellite Precipitation Algorithms over India and Adjacent Regions. *Remote Sensing Environment*. 101, 63–81.

Chiu, L. S., Liu, Z., Vongsaard, J., Morain, S., Budge, A., Neville, P., dan Bales, C. (2006). Comparison of TRMM and Water District Rain Rates in New Mexico. *Advance Atmospheric Science.* 23, 1–13.

Chokngamwong, R., dan Chiu, L. (2007). Thailand Daily Rainfall and Comparison with TRMM Products. *Journal of Hydrometeorology*. 9, 256-265.

Collischonn, B., Collischonn, W., and Tucci, C.E.M. (2008). Daily Hydrological Modeling in the Amazon Basin Using TRMM Rainfall Estimates. *Journal of Hydrology*. 360, 207–216.

Dingman, S. L. (2002). *Physical Hydrology*. (2nd edition) (pp. 646). New Jersey: Prentice Hall.

Dinku, T., Ceccato, P., Grover-Kopec, E., Lemma, M., Connor, S. J. and Ropelewski, C. F. (2007). Validation of Satellite Rainfall Products Over East
158
Africa's Complex Topography. *International Journal of Remote Sensing.* 28, 1503–1526.

Hamza Varikoden, Samah, A.A., dan Babu, C.A. (2010). Spatial and Temporal Characteristics of Rain Intensity in the Peninsular Malaysia Using TRMM Rain rate. *Journal of Hydrology*. 387, 312–319.

Harris, A., Rahman,S., Hossain, F., Yarborough, L., Bagtzoglou, A.C., dan Easson, G.(2007). Satellite-based Food Modeling Using TRMM-based Rainfall Products. *Sensor*. 7, 3416–3427.

Hazarika, M.K., Kafle,T.P., Sharma, R., Karki, S., Shrestha, R.M., dan Samarakoon, L. (2007). Statistical Approach to Discharge Prediction for Food Forecasts Using TRMM Data. *In: Proceedings of the 5th Annual Mekong Flood Forum.* May 17–18. Ho Chi Minh City, Vietnam.

Huffman, G. J., Adler, R. F., Bolvin, D. T., Gu, G. J., Nelkin, E. J., and Bowman, K. P., et al. (2007). The TRMM Multisatellite Precipitation Analysis (TMPA): Quasi-global, Multiyear Combined-sensor Precipitation Estimates at Fne Scales. *Journal of Hydrometeorology*. 8, 38−55.

Hughes, D., Andersson, L., Wilk, J., dan Savenije, H.H.G. (2006). Regional Calibration of the Pitman Model for the Okavango River. *Journal of Hydrology*. 331(1-2): 30-42.

Islam,M. N., dan Uyeda, H. (2006). TRMM Observed Vertical Structure and Diurnal Variation of Precipitation in South Asia. *Proceeding IGARSS'06.* July 31 – Aug 4. Denver, Colorodo*:IEEE Geoscience and Remote Sensing Society*, 1292–1295.

Islam, M. N. and Uyeda, H. (2007). Use of TRMM in Determining the Climatic Characteristics of Rainfall Over Bangladesh. *Remote Sensing of Environment*. 108, 264–276.

Jamandre, C.A. and Narisma, G. T. (2013). Spatio-temporal Validation of Satellitebased Rainfall Estimates in the Philippines. *Atmospheric Research.*122, 599-608.

JI, Y. and STOCKER, E., 2003, Ground validation of TRMM and AMSU microwaveprecipitation estimates. In Proceedings of the International Geoscience and RemoteSensing Symposium, 21–25 July 2003, Toulouse, France (Piscataway, NJ: IEEE), pp. 3157–3159

JPS (2010). Drought Information for Peninsular Malaysia (Based on Hydrological Analysis).
Jabatan Pengairan dan Saliran Malaysia.

Kummerow, C., Simpson, J., Thiele, O., Barnes, W., Chang, A.T.C., Stocker, E., Adler, R.F., Hou, A., Kakar, R., Wentz, F., Ashcroft, P., Kozu, T., Hong, Y., Okamoto,K., Iguchi, T., Kuroiwa, H., Im, E., Haddad, Z., Huffman, G., Ferrier, B., Olson, W.S., Zipser, E., Smith, E.A., Wilheit, T.T., North, G., Krishnamurti, T., dan Nakamura, K. (2000). The Status of the Tropical Rainfall Measuring Mission (TRMM) After Two Years in Orbit. *Journal of Applied Meteorology*. 39, 1965–1982.

Lgouvardas, K., Kotroni, V., Defer, E., Bousquet, O., 2013. Study of a heavy precipitation event over southern France, in the frame of HYMEX project: observational analysis and model results using assimilation of lightning. Atmos. Res. 134, 45-55

Muhammad Izuan Nadzri and Mazlan Hashim. Validation of Satellite Precipitation Using TRMM Recent Products.

NASA (2010). National Aeronautics and Space Administration.
, Taken from http://neo.sci.gsfc.nasa.gov//Search.html

Nash, J.E. and Sutcliffe, J.V. (1970). River Flow Forecasting Through Conceptual Models Part I — A Discussion of Principles. *Journal of Hydrology. 10(3),* 282-290.

Roongroj Chokngamwong, Long S. Chiu. Thailand Daily Rainfall and Comparison with TRMM Products (26 July 2007).

Saif Ud Din, Ahmad Al Dousari, dan Abdul Nabi Al Ghadban (2017). Sustainable Fresh Water Resources Management in Northern Kuwait – A Remote Sensing View From Raudatain Basin. *International Journal of Applied Earth Observation and Geoinformation*. 9, 21-31.

Sahoo, A. K., Ming Pan, Troy, T. J., Vinukollu, R. K., Sheffield, J. and Wood, E. F. (2011). Reconciling the Global Terrestrial Water Budget Using Satellite Remote Sensing. *Remote Sensing of Environment*. 115, 1850–1865.

Xiang-Hu Li , Qi Zhang, dan Chong-Yu Xu (2012). Suitability of the TRMM Satellite Rainfalls in Driving a Distributed Hydrological Model for Water