PATTERN OF FLOODING IN KELANTAN DUE TO EXTREME RAINFALL AND TIDAL PHENOMENON

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

Malaysia is one of the countries that experiences the flood phenomenon. Every year, the east coast of Malaysia experiences the northeast monsoon season which brings episodes of extreme rainfall and causes floods. The season starts in November until early March. Flooding that occurred in Kelantan in 2014 was the biggest flood that hit Malaysia and this led to huge losses and endangered people's life. Thus, a flood simulation system needs to be conducted as an early precaution to address the flood phenomena. This research analysed a simulation of flood pattern over a period of seven years using ArcGIS software to obtain the area and volume of potential flooding. The area involved in this research is adjacent to a tidal station located in Geting, Kelantan. Besides, other areas included in the research were Keretapi Tumpat station, Department of Irrigation and Drainage (DID) Kota Bharu Store, Chabang Tiga Pendek and Pump House Salor. These area were considered by identifying the pattern of rainfall distribution within these areas using interpolating method. Besides, the water level and streamflow station at Guillemard Bridge of Kelantan river and Lebir river were included in this research to develop the relationship between water level, streamflow and tidal activity with flood occurrence. The methodology comprised three main specific parts which is the generation of flood depth, floodplain areas and simulation of floodplain region, relationship between water level and streamflow and simulation of tidal phenomena in Kelantan. Data used in the research is Digital Elevation Model (DEM) and boundaries of Kelantan state. These data were digitized to combine all the data including cross-section data of Kelantan river to generate the floodplain areas and simulation of flood phenomenon. This research focused on the effect of tidal phenomena and extreme rainfall towards flood occurrence. Other than that, astronomical factors were studied where the distance of the moon to the earth affects tidal activities. The positions of the moon near to the earth caused high tides at that time. During the flooding in year 2014, Malaysia experienced a new moon phenomena and this caused high tides and contributed to the major flood occurrence. Interpolation method resulted in patterns of rainfall distribution that were different every year but the highest rainfall distribution frequently happened at the area of Pump House Salor. Plotted graph showed that water level and streamflow had a linear relationship which had the highest value of data that occured in 2014. This was shown through the simulation of flooding for the year 2014 and the results showed that the biggest potential areas of flooding were at Guillemard Bridge of Kelantan river and Lebir river with a total area of 126,459,291 m^2 and total volume of 1,369,390,421 m^3. The findings have shown that the use of flood simulation can be used to monitor flood activities where the potential areas of flooding can be identified based on the data related to extreme rainfall, water level, streamflow and tidal activities in the future. Based on these flood simulations, the value of the water level that can cause flooding in a specific area can be identified and can be serve as an early precaution for the community and authorities to prepare for the flood as this can reduce the loss of property and save many lives.

ABSTRAK

Malaysia adalah salah satu negara yang mengalami fenomena banjir. Setiap tahun, pantai timur Malaysia mengalami musim monsun timur laut yang membawa episod hujan lebat dan menyebabkan banjir. Musim ini bermula pada bulan November hingga awal Mac. Banjir yang berlaku di Kelantan pada 2014 adalah banjir terbesar yang melanda Malaysia dan menyebabkan kerugian besar dan membahayakan orang awam. Oleh itu, sistem simulasi banjir perlu dilakukan sebagai langkah awal berjaga-jaga untuk menangani fenomena banjir. Kajian ini menganalisis simulasi corak banjir dalam tempoh tujuh tahun dengan menggunakan perisian ArcGIS untuk mendapatkan keluasan dan isipadu kawasan yang berpotensi mengalami banjir. Kawasan yang terlibat dalam penyelidikan ini adalah bersebelahan dengan stesen pasang surut yang terletak di Geting, Kelantan. Di samping itu, kawasan lain yang terlibat dalam kajian ini ialah stesen Keretapi Tumpat, Stor Jabatan Pengairan dan Saliran Kota Bharu, Chabang Tiga Pendek dan Rumah Pam Salor. Kawasan ini juga dipertimbangkan dengan mengenal pasti corak taburan hujan dalam bidang ini menggunakan kaedah interpolasi. Selain itu, stesen aras air dan halaju air di Jambatan Guillemard Sungai Kelantan dan Sungai Lebir dimasukkan dalam kajian ini untuk melihat hubungkait antara aras air, halaju air dan aktiviti pasang surut dengan kejadian banjir. Metodologi terdiri daripada tiga bahagian khusus utama iaitu penjanaan kedalaman banjir, kawasan banjir dan simulasi kejadian banjir, hubungkait antara aras air dan halaju air dan simulasi fenomena pasang surut di Kelantan. Data yang digunakan dalam penyelidikan ialah Model Permukaan Berdigit (DEM) dan data sempadan Kelantan. Data-data ini didigitkan untuk menggabungkan semua data termasuk data keratan rentas Sungai Kelantan untuk menjana kawasan banjir dan simulasi fenomena banjir. Kajian ini menumpukan kepada kesan fenomena pasang surut dan hujan lebat terhadap kejadian banjir. Selain itu, faktor astronomi juga dikaji di mana jarak bulan ke bumi mempengaruhi aktiviti pasang surut. Kedudukan bulan yang terdekat dengan bumi menyebabkan pasang surut tinggi pada waktu itu. Semasa banjir pada tahun 2014, Malaysia mengalami fenomena bulan baru dan ini menyebabkan pasang surut yang tinggi dan menyumbang kepada kejadian banjir besar. Kaedah interpolasi menghasilkan corak taburan hujan yang berbeza setiap tahun tetapi taburan hujan tertinggi sering berlaku di kawasan Rumah Pam Salor. Graf terplot dalam kajian menunjukkan paras air dan aliran sungai mempunyai hubungan linear yang mempunyai nilai tertinggi data yang berlaku pada tahun 2014. Ini ditunjukkan melalui simulasi banjir untuk tahun 2014 dan keputusan menunjukkan bahawa kawasan yang paling besar banjir adalah di Jambatan Guillemard Sungai Kelantan dan Sungai Lebir dengan keluasan 126,459,291m² dan jumlah keseluruhan 1,369,390,421m³. Dapatan telah menunjukkan bahawa penggunaan simulasi banjir boleh digunakan untuk memantau aktiviti banjir di mana kawasan yang berpotensi mengalami banjir dapat dikenal pasti berdasarkan data yang berkaitan dengan hujan lebat, aras air, halaju air dan aktiviti pasang surut pada masa akan datang. Berdasarkan simulasi banjir ini, nilai aras air yang boleh menyebabkan banjir di kawasan tertentu dapat dikenal pasti dan boleh berfungsi sebagai langkah berjaga-jaga awal bagi masyarakat dan pihak berkuasa untuk menghadapi banjir kerana ini dapat mengurangkan kehilangan harta benda dan menyelamatkan banyak nyawa.

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LIST OF ABBREVIATIONS

MOSTI	-	Ministry of Science, Technology and Innovation
GIS	-	Geographic Information System
AVHRR	-	Advanced Very High Resolution Radiometer
ArcGIS	-	Architecture Geographic Information System
DID	-	The Department of Irrigation and Drainage
JUPEM	-	The Department of Survey and Mapping Malaysia
HAT	-	Higher Astronomical Tides
STD DEV	-	Standard Deviation (σ)
HEC-RAS	-	Hydrologic Engineering Center's River Analysis System
u-TAPS	-	UTM Tidal Analysis and Prediction Software (μ-TAPS)
NOAA	-	National Oceanic and Atmospheric Administration
M_2	-	Principal Lunar Semidiurnal Constituent
S_2	-	Principal Solar Semidiurnal Constituent
K_1	-	Lunisolar Diurnal Constituent
O_1	-	Lunar Diurnal Constituent
IPCC	-	Intergovernmental Panel on Climate Change
GIS	-	Geographic Information System
DEM	-	Digital Elevation Model
XS	-	Cross-section
TIN	-	Triangular Irregular Networks
USGS	-	U.S. Geological Survey
HEC-GeoRAS	-	Hydrological Engineering Centre – Geospatial River Analysis System
IDW	-	Inverse Distance Weighting
ESRI	-	Environmental Systems Research Institute
MC	-	Maritime Continent
ENSO	-	El-Nino Southern Oscillation
QBO	-	Quasi-Biennial Oscillation
MJO	-	Madden-Julian Oscillation
OLR	-	Outgoing Longwave Radiation

T2m	-	Surface Air Temperature
RRI	-	Rainfall Runoff Inundation
MFB	-	Mean Field Bias
HLB	-	Hourly Local Bias
CAPPI	-	Constant Altitude Plan Position Indicator
CMIP5	-	Coupled Model Intercomparison Project phase 5
AMIP	-	Atmospheric Model Intercomparison Project
NEM	-	Northeast Monsoon
WNP	-	Western North Pacific Ocean
BV	-	Borneo Vortex
MJO	-	Madden-Julian Oscillation
IOD	-	Indian Ocean Dipole
GCMs	-	General Circulation Models
ED	-	Euclidean Distance
CID	-	Complexity-Invariant
COR	-	Correlation
IP	-	Integrated Periodogram
ETCCDI	-	Expert Team for Climate Change Detection and Indices
NHRCM	-	Non-Hydrostatic Regional Climate Model
COBE	-	Centennial in situ Observation Based Estimates
MFC	-	Moisture Flux Convergence

LIST OF SYMBOLS

F	-	The Amplitude Ratio of Tidal Constituents
HK1	-	The Amplitude of Luni-Solar Declinational
HO1	-	The Amplitude of Principal Lunar Declinational
HM2	-	The Amplitude of Principal Lunar
HS2	-	The Amplitude of Principal Solar
σ	-	Standard Deviation

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Natural disasters often hit Malaysia and it is unavoidable phenomena. Flood disaster is one of the natural hazards that frequently hit Malaysia. Flood disaster has become familiar in Malaysia. According to Ministry of Energy, Science, Technology, Environment and Climate Change, MESTECC (2013), every year, Malaysia experience the northeast monsoon season usually commence in early November until the end of March. During the northeast monsoon season, the bare area such as the East Coast of Peninsular Malaysia, western Sarawak and the northeast coast of Sabah experienced some episodes of continuous rain which resulted in increased water levels and excessive water that caused flooding in certain areas. The flood prone area in east coast of Peninsular Malaysia consisting of Pahang, Kelantan and Terengganu.

East Coast of Peninsular Malaysia region such as Kelantan, Terengganu and Pahang experienced an episode of heavy rain during the northeast monsoon. This research focus on the area of Kelantan which is Sungai Kelantan with the main source of water and its climate position always faced with the northeast monsoon that contributes to the occurrence of heavy rainfall, said Dr Wan Nik Wan Yusof (2015), the Director of Centre for Strategic Study, Kelantan on their website. Kelantan embraces flood event annually, but in different level of flooding which the worst in the year 2014/2015. The northeast Kelantan state which faces the South China Sea, especially the area of Pasir Putih, Bachok, Kota Bharu and Tumpat caused Kelantan experienced monsoon every year usually from November until end of March. Northeast monsoon season known as the monsoon season among people of Kelantan because of heavy rain that caused flooding in that area.

Flood disaster becomes a common phenomenon in Malaysia. Floods occur due to the sequence of natural and human factors (Pradhan and Youssef, 2011). Human factors such as the expanding of urban development that affect the changing of hydrological characteristics and can disrupt the balance of an ecosystem in a basin (Mohmadisa Hashim *et al.*, 2012). The poor drainage system combine with other local factors also contribute to the occurrence of flood phenomenon. Heavy rainfalls during the northeast monsoon season have a huge impact in terms of various aspects of life people in the area of the East Coast of Peninsular Malaysia (Chan, 1995). However, rainfall is also important to agriculture system in Malaysia. Every year, Malaysia exposure to the flood phenomenon during northeast monsoon season, but recently, Malaysia experience major flood phenomena in year 2014/2015. Flood phenomenon occurs in the year 2014/2015 were the biggest floods happen in Malaysia and cause a great harm in the area of East Coast of Peninsular Malaysia.

Floods phenomenon negatively affect the surrounding area which floods can endanger the lives of residents and caused a lot of damage to land, property and public infrastructure. Flooding phenomenon is costly due to the economic lost. Therefore, to control these losses, early identification of flood risk is a step that must be taken by considering at the pattern of flood events that occurring in Kelantan. The level of flood occurring in Kelantan was different each year. Based on the pattern of flood events, precautionary measures can be taken to overcome the flood phenomenon.

Roughly, the initial warning of flood events can be predicted based on the amount of rainfall, water level, streamflow and tidal data. Early warning on floods events is important so that people are well prepared to face the flood events as well as early preparations to cope with the floods that hit the East Coast of Peninsular Malaysia every year. The role of Geographic Information System (GIS) in flood simulation has become multifaceted and recently use GIS as a platform to implement the early flood warning system. According to the previous research, there are many research on flood simulation using GIS (Farajzadeh, 2002; Pradhan, 2009; Billa *et al*., 2011; Pradhan *et al*., 2011; Masoud *et al*., 2012; Lee *et al*., 2012; Nawawi *et al*., 2012; Youssef *et al*., 2015) and there are also studies that applied probability in

Advanced Very High Resolution Radiometer (AVHRR) data to evaluate precipitation due to the temperature of cloud (Billa *et al*., 2005). The statistical analysis of linear regression and non-parametric analysis have been used to see the trends of rainfall in other areas (Mohmadisa Hashim *et al*., 2012). Most of the previous research used rainfall data in order to create a flood simulation. The results of several surveys of reading, not many studies found that taking tidal behavior towards flood phenomenon.

Based on the previous research by Nicholls (2002), the analysis considers the flood impacts of sea level rise based on a consistent set of scenarios of global mean sea level rise, the changing of coastal populations and flood defence standard. Sea level rise will lead to an increase in flooding in the future where more people will face the flood phenomenon. Measures of adjustment with sea level rise must be taken in order to face sea level rising in the future. These results indicate that an increase in sea level can be a significant problem if it is ignored and should be considered in terms of climate change such as rainfall.

Sea level rise in Malaysia was predicted to be higher due to the local climate change and topographical conditions. Low-lying areas with a high population and socioeconomic activities are at risk of floods. Nowadays, people are more aware about the global daily temperature is increasing and this phenomenon where one of the factors contributing to the natural disaster such as floods. This temperature increase will have many negative effects such as increased intensity of rain events, storms, floods, and rising sea levels. Tidal measurement is required in order to analyse the sea level trend (Yan *et al*., 2004; Erol, 2011; Pytharouli and Stiros, 2012). Pytharouli and Stiros (2012) stated that the astronomical tide refers to the oscillation of the sea level as a clarification of numerous periodic effects that leads to a periodic and predictable signal.

The tide of events also played a role in the flood phenomenon. During the biggest flood occurs in 2014/2015 in the northeast monsoon season, Malaysia also

experienced a new moon phenomenon at the same time. The new moon is a phenomenon where the moon is close to the earth that cause a high tides. Senior Meteorological Officer, National Weather Centre, Meteorological Department, Dr. Mohd. Hisham Mohd Anip said in an Utusan Online, December 23, 2014, floodwaters seen hard to get out because of its new moon phenomenon that led to the region experiencing high tides.

There are also other factors that contribute to the occurrence of floods in Kelantan. According to Dr Mohd Hisham Mohd Anip, Senior Meteorology Officer of Malaysian Meteorological Department, floods experienced in Malaysia become worse because of the northeast monsoon winds consistently across the South China Sea to Malaysia starting from November 2014 to March 2015. This floods was difficult to recede due to the astronomical factor which is Malaysia experiencing the new moon phase at that time. New moon phase is the phase where the moon is closer to the earth that caused the earth experienced the spring tides at the same time. Spring Tides phenomenon is a condition which is earth experienced the highest tide at full moon phase and new moon phase. Floods phenomena in Malaysia worsened by a factor of rainfall increase, which is Kelantan, experiencing the rainy season at the same time.

Tide events occured due to the moon and the sun as their individual gravitational pull the water on earth towards them (Mohd Razali Mahmud *et al*., 2006). The big spring tides occur when the moon experience the full moon and new moon phase. The position of the earth, moon and the sun are roughly in one line in full moon and new moon phases. The gravitational forces of the moon and sun are working together and have a greater magnetic influence on the water resulting the bigger wave or bulge.

This research investigated the floods that hit in Kelantan due to several factors. Among the factors associated with the floods caused by the northeast monsoon that hit the east coast of Malaysia. In addition, the occurrence of spring

tides also contributed to the major flood occurs in Kelantan on 2014/2015. During the major floods happen during 2014/2015, Malaysia also experienced a new moon phase where the earth, moon and sun position are in one line and cause a strong gravitational pull of the moon and the sun in the same direction.

This research was focus on the impact of the tidal phenomenon on flooding, while taking into account the rainfall in the vicinity of Kelantan. This research was made to see the pattern of flood events that occurring in Kelantan for a certain period of time. Flood events that occur before 2014/2015 were also considered to see the difference in the level of floods occurring in Kelantan. Tidal data in area of Kelantan is also taken into account to see the impact of tidal events on flood in Kelantan. The purpose of the tidal data is to see the difference in sea level change before and after a flood. Based on the differences, the amount of rainfall that cause flooding to be happen was identify and also observation of the tidal behavior towards flood phenomenon. The pattern of flood events was analyse based on rainfall data, water level data, streamflow data and tidal data. These all data were involved some of the areas of Kelantan. According to the flood pattern in this research, preliminary monitoring of flood events can be made in terms of total rainfall, water levels, streamflow and tides. All these data is important so that people are more cautious with the rising water level due to the rainfall, which exceeding the average annual rainfall during flood occurrence in the year 2014/2015. Total annual rainfall is important to people as it affects various human activities such as agriculture, fisheries and tourism. All this data analysis can be used to monitor the flood so that the phenomenon of flood can be detect early as the precautionary measures to deal with floods phenomena. The simulation of this flood phenomenon was using ArcGIS software with the function that can be performing in this research.

1.2 Problem Statement

Flood often occurs each year in Malaysia, especially in the east coast of Malaysia. Floods that occur every year due to the northeast monsoon winds that

brings a heavy rain starting from November until March. This research focused on the east coast area of Kelantan. Floods that occur every year give a different effect on the certain region where the worst effects appears to be occurring in 2014/2015. The flood that occurs every year is not systematic. Therefore, the analysis pattern of the flood is important so that people in that area will be alert and prepare to overcome the flood. The floods that occurred in 2014/2015 were the biggest flood ever happened in Malaysia. Major floods occurred due to the combination of several factors such as the tidal occurrence, extreme rainfall, and astronomical factor such as new moon and full moon phase. Flood occurs in 2014/2015 become worse due to the Malaysia experienced a new moon phase at the same time flood occurs. The result of a combination of these factors led to a major flood occurred in year 2014/2015. Therefore, by using ArcGIS software, the pattern of the flood events year by year can be seen and focused with further research on tides and extreme rainfall. These data were taken into account to produce an animated picture of flood events that occur every year in Kelantan.

This research point towards to appraise the effect combination of tides and extreme rainfall towards flood phenomena. This research focused on rainfall data, water level, streamflow that were acquired from The Department of Irrigation and Drainage (DID) while tidal data from The Department of Survey and Mapping Malaysia (JUPEM). The online web base maps of Kelantan were used through the ArcGIS software. This research is conduct to analyse the pattern of sea level rise before and during flood occurred and see the increasing value of Higher Astronomical Tides (HAT) and Standard Deviation (σ) in the future due to the occurrence of flood phenomena. Standard Deviation (σ) is important to see the changing of raw tidal data and tidal prediction through tidal analysis. Based on the standard deviation (σ) value, it can be analysed the quality of the data which is less value standard deviation (σ) represent the clean data. The tidal data processing and analysis is carry out for tidal prediction while produce the value of HAT and Standard Deviation (σ) to see the differences between the raw tidal data and harmonic analysis that generate from tidal processing. The differences in sea level changes before and after the floods phenomena can be seen and based on the differences of the sea level, the amount of rainfall that can cause the flood can be

identify. In this research, by using the ArcGIS software, the simulation of the flood movement can be seen by taking into account rainfall data, water level, streamflow and tidal data while the flood pattern year by year can be seen.

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1.3 Research Questions

Research questions of this research are as follows:

(a) How the combination of tidal phenomenon, changes and extreme rainfall can contribute to the flood in Malaysia?

(b) How does the differences in rainfall patterns every year contributed to the floods phenomena?

(c) How does the level of floods phenomena can be monitored in ArcGIS in terms of climate change due to the rainfall patterns and sea level rise?

1.4 Objectives of Research

The aim of this research is to generate the level of water rise during the flood phenomenon based on the value of depth obtain by assigning the cross-sectional data riverbank of Kelantan and water level data while taking into account the streamflow. The objectives of this research are stated as follows:

(a) To identify which area of Kelantan experience the highest amount of rainfall during major flood in 2014/2015.

(b) To develop the interrelationship between the rainfall data, water level, streamflow and tidal activity with flood occurrence.

(c) To analyse the depth of the water rise in the event of floods using ArcGIS 10.3 software based on the cross-sectional data riverbank of Kelantan with water level and streamflow data.

1.5 Significant of Research

At the end of December 2014, a series of floods have occurred in Southeast Asia and South Asia which also involved Malaysia. The flooding continued from December until January 2015. The floods hit several states in Malaysia especially in areas of east coast. The floods that happen caused by the several factors such as climate change regarding to the rainfall, change of temperature, shifting wind and the terrain in that areas. This research will focus on several factors such as rainfall, tide phenomena, climate change and the terrain in that area in order to see the pattern of the water level changes. Based on previous research, the small global rise in sea level could give significant disadvantageous impacts if there is no adaptive response (Nicholls, 1999). It is important to study about the patterns of water level changes to give an early warning if the water level in that area exceeds the normal level. There are several areas that are involved in this research such as Kelantan which is experiencing the worst floods in Malaysia.

The floods will certainly give an impact on the environment and the destruction of civilian property in the area. In addition, floods also give impact due to the damage of the infrastructure such as roads, bridges, school and so on. The damage still need to be repair as the development in that area is important. The process of repairing the damage requires a long period and involves high cost. According to Flood Disaster Committee Chairman in Utusan Online on 2 January 2015, Datuk Seri Mustapa Mohamed, the cost of repairs in the state of Kelantan increased by millions of ringgit regarding to the damage of infrastructure and agriculture in the area of Kuala Krai, Tumpat, Gua Musang, Tanah Merah and Pasir Mas. It involves the big amount of cost. This research is important because the

pattern of the flood events can be seen over a long period of time and can help to provide an initial picture of the level of flood events based on the amount of rainfall, water level, streamflow and tidal data. It also can be of help as an early preparation to face the flood phenomena so that the cost of lost can be reduced.

Based on this research, the value of depth water rise of flood events can be seen using the ArcGIS software. By using rainfall data, water level, streamflow and tidal data, the simulation of flood events can be seen based on the spread of water in the involved region area in Kelantan. Based on the spread of flooding, the relationship between water level and streamflow can be seen which is the highest value of streamflow causes the increasing of water speed and sudden increase of water in a short time. The pattern of the flood events can be used to give an early warning which is initial picture about the level of flood that occurs in the future and planning the way to be taken to cope with flooding in Kelantan. This pattern of the floods occurrence has been made based on the factors taken into account such as volume of rainfall, water level, streamflow and tidal water level. Based on the simulation of flood events, the pattern of the floods occur in Kelantan can be seen year by year. In addition, this research also helps to provides more understanding of the factors that could cause major flooding occurs in Kelantan.

1.6 Scope of Study

Scopes of study in this research are divided according to a certain stages in order to achieve the objectives stated in the previous Section. The scope of the study is divided into several stages such as theoretical study, data collection, data processing and analysis of the data.

First stage of this scope is study the theory of climate change occur in Malaysia as heavy rains that occur caused to an average annual rainfall exceeds the

normal value that led to the flood occurrence. Theoretical study is about tide events related to astronomical factors such as position of moon and sun towards earth that influencing the tide events that contribute to the flood occurrence. In addition, understanding the theory of the sea level rise also taken into account because of rising water level also one of the factors led to the occurrence of floods.

The second stage in scope of study is data analysing. The data related to this research was collected at the Department of Survey and Mapping Malaysia (JUPEM) and the Department of Irrigation and Drainage (DID). There are several data that selected in this research such as the volume of rainfall, streamflow, water level and tidal data. However, this research used data only from 2009 to 2014 to see the patterns of flood occurrence at Jambatan Gullemard, Sungai Kelantan and Sungai Lebir. The data used until 2014 is to look at the major changes of flood phenomena compared to the previous year and thus could prove that major floods occurred in 2014. In addition, the data obtained in this research were limited until 2014 on rainfall data, water level data and streamflow where major floods occurred in 2014. The data such as the volume of rainfall, streamflow and water level is suitable to be used to see the rising pattern of the water floods. Tidal station involved in this research in Kelantan at east coast area of Malaysia. Based on the water level data including with cross-sectional data, the depth value of water rise during flood occurrence was determined and simulation of water level rise during flood occurrence was created from year 2009 until 2014 in order to generate the flood pattern that happen in Kelantan. The simulation of flood pattern was created using the application of ArcScene in ArcGIS software.

The last stage in this research is data analysing. Based on the data used in this research, simulation of flood was developed within six years data so that the flood pattern can be observe year after year within the selection data used from 2009 until 2014. ArcScene application in ArcGIS software was used to create the flood simulation that one may use to observe the movement of the floods water in Kelantan. This simulation of flood pattern can be used as guideline for an early

caution the occurrence of the flood phenomena based on the occurrence of the previous flood. The data involved in this research to produce the simulation of flood such as cross-sectional data riverbank of Kelantan, streamflow data and water level data were included into the ArcGIS software by using ArcScene application. This simulation of flood can be used as guidance to help monitoring the floods and aware with the presence of the flood in future. Based on this depth determination, the amount of water level and streamflow which may cause flooding can be identified.

1.7 Research Methodology

The overall view of this research is shown on the chart below:

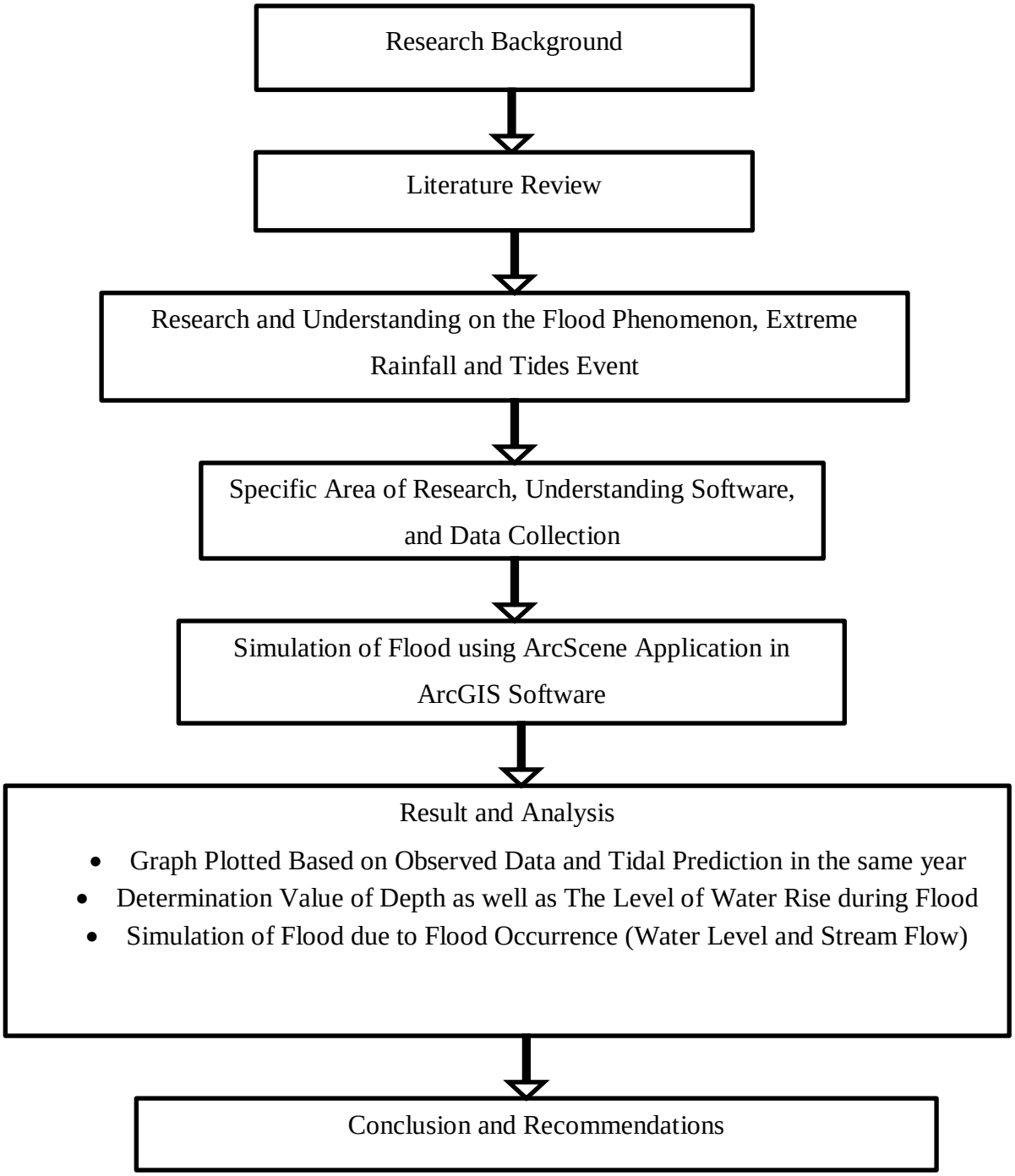

Figure 1.1 Brief of methodology

(a) Literature Review

Literature reviews were conducted to understand more on the phenomenon of Floods, Climate Change and Tides event. Literature review involves the study about understanding the relation of the tides event and climate change on flood occurrence in Malaysia. Previous research will be used as a reference in understanding more on the phenomenon of Floods, Extreme Rainfall and Tides event. Other than that, literature review can contribute to give ideas for a further improvement and also help to achieve the objective.

(b) Research and Understanding on the Flood Phenomenon, Climate Change and Tides Event

This stage involves the research to a further understanding of the theories and concept of the climate change and tides event which related to Flood Phenomenon on how much it can gives influence to the flood phenomenon occur in Malaysia. This research focused on the major floods occurs in 2014/2015. This theories and concept also involves the relationship between the risings of the sea level with flood phenomenon due to the extreme rainfall that happen in Malaysia.

(c) Choosing the Suitable Area, Choosing Software and Data Collection

At this stage, the selection of research areas, software selection and data collection were conducted. The research area selected is around Kelantan area which involves rainfall stations, water levels, streamflow and tidal stations. The collection of these data is done by retrieving existing raw data from related departments. In software selection, ArcGIS software were selected to produce simulation of flood by using ArcScene. ArcScene is an application in ArcGIS specifically designed to process the animation of the water flow using the cross-sectional data riverbank of Kelantan that generate from Hydrologic Engineering Centre's River Analysis System (HEC-RAS).

Besides that, Microsoft Excel 2010 is used to produce graphs for analysis purpose, whereas μ-TAPS software is used for tidal processing.

(d) Data Processing (Tidal Data) and Simulation of Flood using ArcScene Application in ArcGIS Software

Hydrological data used in this research such as rainfall, water level and streamflow obtained from Department of Irrigation and Drainage. Simulation of flood was created based on cross-sectional data riverbank of Kelantan including the water level data. This simulation of flood was created based on this data to see the relationship between the data that contributes towards the occurrence of flood events. In addition, tidal data is also taken into account to see the graph comparison between the observed tidal data and tidal prediction in the same year.

(e) Result and Analysis

Based on the simulation of flood, the value of depth water obtained to see the level of water rise during flood occurrence. This Section also discusses the analysis of the level of water increase when floods occur due to increasing volume of rainfall, water levels and streamflow due to the rainy season in Kelantan. In addition, the graph comparison between observed tidal data and tidal prediction were plotted in the same year to see the level of tide during flood occurrence. High tides can cause river difficult to flow out and cause the water to rise around the river and contribute to the flood occurrence.

(f) Conclusion and Recommendations

At the end of the study, the results and analysis of the research are concluded whether they achieved the objectives of the research or not. In addition, the recommendations to further improve the research on flood phenomena for future research are also discussed

1.8 Thesis Layout

This thesis is divided into five chapters with specific description as follow:

(a) Chapter 1 explains about the planning on the research activity and focus more on the research background.

(b) Chapter 2 gives some explanation and understanding on the theory of flood phenomena and tidal behaviour by reviewing the previous research.

(c) Chapter 3 describes the systematic way to conduct the research stage by stage

(d) Chapter 4 discusses based on the objective stated before in chapter 1 and analyse the result from data collection.

(e) Chapter 5 is the conclusion of overall achievement of the objectives and with some recommendations for future research.

REFERENCES

Adiat, A. K., Nawawi, M. N. M., & Abdullah, K. (2012). Integration of Geographic Information System and 2D Imaging to investigate the effects of subsurface conditions on flood occurrence. *Modern Applied Science*, *6*(3), 11.

Ahmad, S. S., & Simonovic, S. P. (2011). A three-dimensional fuzzy methodology for flood risk analysis. *Journal of Flood Risk Management*, *4*(1), 53-74.

Ahmad Jamalluddin bin Shaaban. (2014) NAHRIM R&D Initiatives and Contributions. Malaysia Water Resources Management Forum. *National Hydraulic Research Institute of Malaysia (NAHRIM)*

Alias, N. E., Hazim, M., Chin, W. Y., & Zulkifli, Y. (2016). Rainfall analysis of the Kelantan big yellow flood 2014. *Jurnal Teknologi*, *78*(9-4).

Anisah Aini. "Sistem Informasi Geografis Pengertian dan Aplikasinya."*Artikel Kuliah Sistem Informasi. STMIK AMIKOM. Yogyakarta* (2007).

Arkin, Phillip A. "The relationship between fractional coverage of high cloud and rainfall accumulations during GATE over the B-scale array." *Monthly Weather Review* 107.10 (1979): 1382-1387.

Billa, L., Mansor, S., & Mahmud, A. R. (2011). Pre-flood inundation mapping for flood early warning. *Journal of Flood Risk Management*, *4*(4), 318-327

Billa, L., Mansor, S., & Mahmud, A. R. (2012). Mesoscale grid rainfall estimation from AVHRR and GMS data. *International journal of remote sensing*, *33*(9), 2892-2908.

Billa, L., Mansor, S., Mahmud, A. R., & Ghazali, A. H. (2005). AVHRR data for real-time operational flood forecasting in Malaysia. In *Geo-information for Disaster Management* (pp. 1357-1379). Springer Berlin Heidelberg.

Billa, L., Mansor, S., Mahmud, A. R., & Ghazali, A. H. (2006). Modelling rainfall intensity from NOAA AVHRR data for operational flood forecasting in Malaysia. *International Journal of Remote Sensing*, *27*(23), 5225-5234.

Billa, L., Shattri, M., Rodzi Mahmud, A., & Halim Ghazali, A. (2006). Comprehensive planning and the role of SDSS in flood disaster management in Malaysia. *Disaster Prevention and Management: An International Journal*,*15*(2), 233-240.

Billa, Lawal, Shattri Mansor, and Ahmad Rodzi Mahmud. "Spatial information technology in flood early warning systems: an overview of theory, application and latest developments in Malaysia." *Disaster Prevention and Management: An International Journal* 13, no. 5 (2004): 356-363.

Carl, R. D., & Davis, D. W. (1989). *An Integrated Software Package for Flood Damage Analysis* (No. HEC-TP-125). HYDROLOGIC ENGINEERING CENTER DAVIS CA.

Chan, Y., & Mori, M. (2011, July). Web-based flood monitoring system using Google Earth and 3D GIS. In *Geoscience and Remote Sensing Symposium (IGARSS), 2011 IEEE International* (pp. 1902-1905). IEEE.

Chan, N. W. (2012), 'Impacts of Disasters and Disasters Risk Management in Malaysia: The Case of Floods', in Sawada, Y. and S. Oum (eds.), *Economic and Welfare Impacts of Disasters in East Asia and Policy Responses*. ERIA Research Project Report 2011-8, Jakarta: ERIA. pp.503-551.

Chen K. (2014). Flood: Mapping Flood-Prone Areas in SE Asia. Retrieved 25 June 2016,from http://www.asiainsurancereview.com/Magazine/ReadMagazineArticle

Csanyi, N., & Toth, C. K. (2007). Improvement of lidar data accuracy using lidar-specific ground targets. *Photogrammetric Engineering & Remote Sensing*, *73*(4), 385-396.

Dayang Norazila Awang Bima, 2017. The Impact of Explicit Convection on The Asian Monsoon and The Indian Ocean Wet Bias. Malaysian Meteorological Department., ISBN/ISSN: ISBN: 978-967-5676-93-2

Dr Wan Nik Wan Yussof (2015, June 30). Banjir Kelantan 2014 – Satu Musibah. Pusat Kajian Strategik Kerajaan Negeri Kelantan. Retrieved February 17, 2016, from http://pks.kelantan.gov.my.

East Coast to Experience More Sea Related Issues (4 February 2015). The Star Online.

Erol, S. (2011). Time-Frequency Analyses of Tide-Gauge Sensor Data. *Sensors* 11:3939-3961

Fadila Jasmin Fakaruddin, Yip Weng Sang, Mat Kamaruzaman Mat Adam, Nursalleh K Chang and Muhammad Helmi Abdullah, 2017: Analysis of the Northeast Monsoon 2016/2017. Malaysian Meteorological Department., ISBN/ISSN: ISBN: 978-967-5676-91-8

Farajzadeh, M. (2002, September). Flood susceptibility zonation of drainage basins using remote sensing and GIS, case study area: Gaveh rod Iran. In*Proceeding of international symposium on geographic information systems, Istanbul, Turkey* (pp. 23-26).

Fauziana Ahmad, Mahluddin Sahrin, A.Kamiluddin Ibrahim and Asmadi Abdul Wahab, 2018: Comparasion of CAPPI Height 2km and 1km during Northeast Monsoon Malaysian Meteorological Department., ISBN/ISSN: ISBN: 978-967-5676-96-3

Fauziana Ahmad, Tomoki Ushiyama and Takahiro Sayama, 2017: Determination of Z-R Relationship and Inundation Analysis for Kuantan River Basin. Malaysian Meteorological Department., ISBN/ISSN: ISBN: 978-967-5676-92-5

Fenomena 'new moon' Burukkan Keadaan Banjir (2014, December 23). Utusan Online.

Hai, O. S., Samah, A. A., Chenoli, S. N., Subramaniam, K., & Ahmad Mazuki, M. Y. (2017). Extreme rainstorms that caused devastating flooding across the east coast of Peninsular Malaysia during November and December 2014. *Weather and Forecasting*, *32*(3), 849-872.

Hashim, Mohmadisa, Mohamad Suhaily Yusri Che Ngah, and Nasir Nayan. "Trend hujan jangkamasa panjang dan pengaruhnya terhadap hakisan permukaan: Implikasinya kepada tapak kampus baru Sultan Azlan Shah, Tanjong Malim." *Geografia: Malaysian Journal of Society and Space* 8.2 (2012): 38-51.

Hashim, Mohmadisa, Mohamad Suhaily Yusri Che Ngah, and Nasir Nayan. "Trend hujan jangkamasa panjang dan pengaruhnya terhadap hakisan permukaan: Implikasinya kepada tapak kampus baru Sultan Azlan Shah, Tanjong Malim." *Geografia: Malaysian Journal of Society and Space* 8.2 (2012): 38-51.

Hess, L. L., Melack, J. M., Filoso, S., & Wang, Y. (1995). Delineation of inundated area and vegetation along the Amazon floodplain with the SIR-C synthetic aperture radar. *Geoscience and Remote Sensing, IEEE Transactions on*, *33*(4), 896-904.

Hicks, S. D., & Szabados, M. W. (2006). *Understanding tides*. US Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

Intergovernmental Panel on Climate Change. (2014). Retrieved May 10, 2015, from IPCC Fourth Assesment Report: Climate Change 2007: http://www.ipcc.ch/

Ir. Muhammad bin Kadir *et al.* (25 February 2015*). Laporan Banjir Tahunan 2014/2015*. Jabatan Pengairan dan Saliran Negeri Terengganu.

Jamaluddin, A. F., Tangang, F., Chung, J. X., Juneng, L., Sasaki, H., & Takayabu, I. (2018). Investigating the mechanisms of diurnal rainfall variability over Peninsular Malaysia using the non-hydrostatic regional climate model. *Meteorology and Atmospheric Physics*, *130*(6), 611-633.

Kementerian Tenaga, Sains, Teknologi, Alam Sekitar & Perubahan Iklim, MESTECC (2013). Retrieved September 29, 2015, from Jabatan Meteorologi Malaysia: http://www.met.gov.my/

Keping Chen. (2014) Flood: Mapping Flood-Prone Areas in SE Asia. *Asia Insurance Review*,https://www.asiainsurancereview.com/Magazine/ReadMagazineArticle?aid=34926

Kerugian Lebih 200 Juta, Kemusnahan Kemudahan Asas Akibat Banjir di Kelantan, (2015, January 02). Utusan Online.

Khabar Pahang (January 29, 2015). Retrieved September 29, 2015, from http://khabarpahang.blogspot.my/

Khan, M. M. A., Shaari, N. A. B., Bahar, A. M. A., Baten, M. A., & Nazaruddin, D. A. B. (2014). Flood impact assessment in Kota Bharu, Malaysia: a statistical analysis. *World Applied Sciences Journal*, *32*(4), 626-634

Kia, M. B., Pirasteh, S., Pradhan, B., Mahmud, A. R., Sulaiman, W. N. A., & Moradi, A. (2012). An artificial neural network model for flood simulation using GIS: Johor River Basin, Malaysia. *Environmental Earth Sciences*,*67*(1), 251-264.

Lee, M. J., Kang, J. E., & Jeon, S. (2012, July). Application of frequency ratio model and validation for predictive flooded area susceptibility mapping using GIS. In *Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International* (pp. 895-898). IEEE.

Lian F. W. (2010) Rainwater Harvesting will help Avert Water Crisis. *Laman Berita Malaysia Kini*, https://www.malaysiakini.com/letters/149067

Lian F. W. (2011). Kesan Perubahan Iklim Dan Banjir Kepada Pengguna. Retrieved 25 June 2016, from http://www.konsumerkini.net.my/v1/index.php/berita-terkini/perubahan-iklim/595-kesan-perubahan-iklim-dan-banjir-kepada-pengguna

Lian F. W. (2013). Maklumat Terkini Mengenai Perubahan Iklim. Retrieved 25 June 2016,fromhttp://www.konsumerkini.net.my/v1/index.php/beritaterkini/perubahan-iklim/846-maklumat-terkini-mengenai-perubahan-iklim-2013

Loo, Y. Y., Billa, L., & Singh, A. (2015). Effect of climate change on seasonal monsoon in Asia and its impact on the variability of monsoon rainfall in Southeast Asia. *Geoscience Frontiers*, *6*(6), 817-823.

Mariney Mohd Yusof, Ching G. H., Tengku Adeline Adura Tengku Hamzah, Nureai Kase, Nik Juliana Alias (2011). *Pembangunan Dataran Banjir Lembah Sireh, Kelantan: Isu dan Cabaran*. Persidangan Kebangsaan Masyarakat, Ruang dan Alam Sekitar. 265.

Mohd Hilmi Abdullah (2012). *Pengaruh Fenomena El-Nino dan La-Nina Terhadap Corak Pasang Surut Di Malaysia.* Johor Bharu: Universiti Teknologi Malaysia.

Mohd Hilmi Abdullah, Mohd Razali Mahmud and Nor Ainah Amat (2015). *Variations of Sea Level and Tidal Behaviour during El-Nino and La-Nina: An example of Malaysian Coastline*. Jurnal Teknologi, 107-118.

Mohd Razali Mahmud and Tan Tai Hung (2006). *Tides During Monsoon Season in Peninsular Malaysia*. Universiti Teknologi Malaysia.

Muhammad Isa Ramadhan (2013). Geographic Information System (Gis) In Education.*Universitas Pendidikan Indonesia, Jakarta*

National Oceanic & Atmospheric Administration. (2013, Oct 15). Retrieved May 05, 2015, from Tides & Currents: http://tidesandcurrents.noaa.gov/

Ngah, Mohamad Suhaily Yusri Che, Ian Reid, and Mohmadisa Hashim. "Rainfall Trend Analysis Using 50 Years Historical Data in Newly Developed Catchment in Peninsular Malaysia." *Middle-East Journal of Scientific Research* 11.5 (2012): 668-673.

Nicholls, R. J. (2002). Analysis of global impacts of sea-level rise: a case study of flooding. *Physics and Chemistry of the Earth, Parts A/B/C*, *27*(32), 1455-1466.

Nicholls, R. J., & Mimura, N. (1998). Regional issues raised by sea-level rise and their policy implications. *Climate research*, *11*(1), 5-18.

Nicholls, R. J., Hoozemans, F. M., & Marchand, M. (1999). Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. *Global Environmental Change*, *9*, S69-S87.

Noorazuan Md Hashim, Sulong Muhammad, Kadaruddin Aiyub, Norhayati Yahya (2011). *Land Forest Development and Flash Flood Phenomenon: A Case of Sungai Lembing, Pahang*. 155-169.

Nor Aslinda Awang and Mohd Radzi Hamid (2013). *Sea Level Rise in Malaysia.*

Norazuan Md Hashim (2011). Land Forest Development and Flash Flood Phenomenon. 156.

Norlaila Ismail and Changhyun Yoo, 2018: **Statiscal Approach Towards Subseasonal Prediction over Maritime Continent** Malaysian Meteorological Department, ISBN/ISSN: ISBN: 978-967-5676-97-0

O'Hargan, P. (2000). *Tidal Theory.*

Parker, B. B. (2007). *Tidal Analysis and Prediction.* Silver Spring, Maryland: U.S Department of Commerce

Portal Rasmi eBanjir Negeri Kelantan. Retrieved March 24, 2016 from http://ebanjir.kelantan.gov.my/

Pradhan, B. (2010). Flood susceptible mapping and risk area delineation using logistic regression, GIS and remote sensing. *Journal of Spatial Hydrology*, *9*(2).

Pradhan, B., & Youssef, A. M. (2011). A 100-year maximum flood susceptibility mapping using integrated hydrological and hydrodynamic models: Kelantan River Corridor, Malaysia. *Journal of Flood Risk Management*, *4*(3), 189-202.

Pytharouli, S.I., and Stiros, S.C. (2012). Analysis of Short and Discontinuous Tidal Data: A Case Study from the Aegean Sea. *Survey Review* 44(326): 239-246.

Report from Department of Ecology State of Washington, Preparing for a Changing Climate, Washington State's Integrated Climate Response Strategy (2012), 1-5.

Research Body: Rising Sea Levels to Lead to Inundated Coasts in Future. (4 February 2015). The Star Online.

Richard, S., & Walsh, K. J. (2018). The influence of El Niño–Southern Oscillation on boreal winter rainfall over Peninsular Malaysia. *Theoretical and applied climatology*, *134*(1-2), 121-138.

Sharifah Faridah S. M. , 2017: Pengelompokan Corak Taburan Hujan Dengan Kaedah Pengelompokan Siri Masa. Malaysian Meteorological Department., ISBN/ISSN: ISBN: 978-967-5676-95-6

Suhaila, Jamaludin, S. Mohd Deni, WZ Wan Zin, and Abdul Aziz Jemain. "Trends in peninsular Malaysia rainfall data during the southwest monsoon and northeast monsoon seasons: 1975–2004." *Sains Malaysiana* 39, no. 4 (2010): 533-542.

Tangang, F., Farzanmanesh, R., Mirzaei, A., Salimun, E., Jamaluddin, A. F., & Juneng, L. (2017). Characteristics of precipitation extremes in Malaysia associated with El Niño and La Niña events. *International Journal of Climatology*, *37*, 696-716

Tehrany, M. S., Lee, M. J., Pradhan, B., Jebur, M. N., & Lee, S. (2014). Flood susceptibility mapping using integrated bivariate and multivariate statistical models. *Environmental Earth Sciences*, *72*(10), 4001-4015.

The Official Portal for Department of Irrigation and Drainage Malaysia (8 May 2015). The Official Portal for Department of Irrigation and Drainage Malaysia : http://www.water.gov.my/

Toh, Y. Y., Turner, A. G., Johnson, S. J., & Holloway, C. E. (2018). Maritime Continent seasonal climate biases in AMIP experiments of the CMIP5 multimodel ensemble. *Climate dynamics*, *50*(3-4), 777-800.

Tuan Pah Rokiah Syed Hussain and Hamidi Ismail. "Flood Frequency Analysis of Kelantan River Basin, Malaysia." World Applied Sciences Journal 28(12): 1989-1995, 2013.

Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. Doney, R. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville, 2014: Ch. 2: Our Changing Climate. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 19-67. doi:10.7930/J0KW5CXT.

Ward, H. C., Tan, Y. S., Gabey, A. M., Kotthaus, S., & Grimmond, C. B. (2018). Impact of temporal resolution of precipitation forcing data on modelled urban-atmosphere exchanges and surface conditions. *International Journal of Climatology*, *38*(2), 649-662.

Weng Chan, N. (1995). Flood disaster management in Malaysia: an evaluation of the effectiveness of government resettlement schemes.*Disaster Prevention and Management: An International Journal*, *4*(4), 22-29.

Yan, Z., Tsimplis, M.N., and Woolf, D. (2004). Analysis of the Relationship between the North Atlantic Oscillation and Sea-level Changes in Northwest Europe. *International Journal of Climatology*. 24: 743–758.

Youssef, A. M., Pradhan, B., & Hassan, A. M. (2011). Flash flood risk estimation along the St. Katherine road, southern Sinai, Egypt using GIS based morphometry and satellite imagery. *Environmental Earth Sciences*,*62*(3), 611-623.

Youssef, A. M., Sefry, S. A., Pradhan, B., & Alfadail, E. A. (2015). Analysis on causes of flash flood in Jeddah city (Kingdom of Saudi Arabia) of 2009 and 2011 using multi-sensor remote sensing data and GIS. *Geomatics, Natural Hazards and Risk*, 1-25.

LIST OF PUBLICATIONS

Indexed Conference Proceedings

1. **Yusof, N. H. M.**, Mahmud, M. R., & Abdullah, M. H. (2017). Effect of Long Term Tidal Constituents on Mean Sea Level Trend during El-Nino and La-Nina Phenomena. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences **(Indexed by SCOPUS).**

Conference Proceedings

2. **Yusof, N. H. M.** & Mahmud, M. R. (2019). Extreme Rainfall, Streamflow, Water Level and Tidal Phenomenon due to Flooding in Kelantan. International Graduate Conference of Built Environment & Surveying 2019 (GBES 2019)

Indexed Conference Proceedings

3. Abubakar, A. G., Mahmud, M. R., Tang, K. K. W., Hussaini, A. & **Yusof, N. H. M.** (2019). A Review of Modelling Approaches on Tidal Analysis and Prediction. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences **(Indexed by SCOPUS).**