GEOLOGY AND FLOOD HAZARD ANALYSIS BY USING GIS OF KUALA KRAI TOWN, KUALA KRAI, KELANTAN

by

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Name of Program) with Honours

FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA
KELANTAN

2021

DECLARATION

I declare that this thesis entitled "**GEOLOGY AND FLOOD HAZARD ANALYSIS BY USING GIS OF KUALA KRAI TOWN, KUALA KRAI, KELANTAN**" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

"I/We hereby declare that I/we have read this thesis and in our opinion this thesis is sufficient in term of scope and quality for the award of the Bachelor of Applied Science (Geoscience) with Honours"

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ACKNOWLEDGMENT

Alhamdulillah, first of all I would like to thank to Allah for giving me strength and able to complete this Final Year Project (FYP) titled of Geology and Flood Hazard Analysis by Using GIS of Kuala Krai Town, Kuala Krai, Kelantan. I would like to thank to Dr Noorzamzarina Binti Sulaiman as a coordinator of FYP of Faculty of Earth Science for giving me such valuable opportunity to carry out this FYP.

Furthermore, I would like to express my deepest appreciation to my supervisor, Dr Noorzamzarina Binti Sulaiman throughout making this FYP for her encouragement, advice, patience and willing to share her expertise and knowledge until this FYP can be complete successfully. It is an honor to work under her supervision. Besides, I would like to thank to Ir Arham Muchtar Achmad Bahar that giving the study area of FYP and an advice to all students if had problems. Pak Arham gave a lot of knowledge and helps in guiding me especially in geological study area and in achieve my objectives in making this FYP. For my beloved parents, Roslan bin Lat and Siti Zalina binti Shaari, I would like to thank for their love, support and motivation as they giving me strength to work hard and can complete my project.

Moreover, I would like to thank to my friends who helped me during making this FYP in terms of time, energy and sharing their knowledge especially Nur Amanina ‘Izzati binti Mohamad Rusok, Nur Syakirah binti Murat, and Nur Suhadah binti Mohd Hisham. Special thanks to my best friends, Fatin Athirah binti Mohd Zin and Mohamad Hafiz bin Zaini for their support, knowledge and their time when I needed. The special one, thanks to my senior Geoscience, Nur Alya Shalina binti Ross Kenedy for her support, help, guidance and knowledge sharing to me in complete this FYP. Without their help, I would not able to complete the research.

Lastly, thank you to all my classmates as they also help me in commenting and giving nice idea in this final year project research.

GEOLOGY AND FLOOD HAZARD ANALYSIS BY USING GIS OF KUALA KRAI TOW, KUALA KRAI, KELANTAN

ABSTRACT

The research study is about Geology and Flood Hazard Analysis by Using GIS of Kuala Krai Town, Kuala Krai, Kelantan within the coordinate of 5°:30’46.58” N to 5°:33’30.16” N latitude and 102°:10’17.83” E to 102°:13’0.11” E longitude with the map of scale 1:25 000. The total of study area needs to do the research is 25 km^2. The objective of this research is to update the geological map, identify the factors that cause flood hazard and producing flood hazard map of the study area. Geological map was update by doing the analysis of secondary data such as terrain map and by previous research. Flood hazard map is important to determine the flood zone area either high or low water level in order to overcome and reduce the risk of flooding. The method used in producing flood hazard map is by using Weighted Overlay Method (WOM) in ArcGIS Software which it overlay all parameters uses in this research according to the influences of the study area. All parameters need to convert in raster data first before overlay method was carried out. The result shows the flood hazard map was categorized into different class which is high, medium, low and very low of water level to differentiate the degree of risk in the study area. This is important to inform and increase awareness of the people in the area about the dangerous of flooding. The factors of flood hazard are the annually raining heavily that naturally occur especially when northeast monsoon seasons within November to March time. Furthermore, it is also due to logging activities that causes water to drain fast into rivers especially in Sungai Kelantan.

Keywords: Geographic Information System (GIS), flood hazard map, flood zone, Weighted Overlay Method (WOM)

GEOLOGI DAN ANALISIS BENCANA BANJIR MENGGUNAKAN GIS DI BANDAR KUALA KRAI, KUALA KRAI, KELANTAN

ABSTRACT

Kajian ini adalah mengenai Analisis Bencana Banjir Menggunakan GIS Di Bandar Kuala Krai, Kuala Krai, Kelantan di mana koordinat 5°:30’46.58” N hingga 5°:33’30.16” N latitude dan 102°:10’17.83” E hingga 102°:13’0.11” E longitud dengan peta skala 1:25 000. Jumlah kawasan kajian yang perlu dilakukan ialah 25 km². Objektif penyelidikan ini ialah untuk mengemas kini peta geologi, mengenal pasti faktor-faktor yang menyebabkan bahaya banjir dan menghasilkan peta bahaya banjir di kawasan kajian. Peta geologi dikemas kini dengan melakukan analisis data sekunder seperti peta medan dan oleh kajian sebelumnya. Peta bencana banjir untuk menentukan kawasan zon banjir sama ada paras air tinggi atau rendah untuk mengatasi dan mengurangkan risiko banjir. Kaedah yang digunakan dalam menghasilkan peta bencana banjir adalah dengan menggunakan Weighted Overlay Method (WOM) dalam ArcGIS software yang mana ia melapisi semua parameter yang digunakan dalam penyelidikan ini mengikut pengaruh kawasan kajian. Semua parameter perlu dikonversi dalam data raster terlebih dahulu sebelum kaedah overlay dilakukan. Hasil kajian menunjukkan peta bencana banjir dikategorikan ke dalam kelas yang berbeza iaitu tinggi, sederhana, rendah dan sangat rendah paras air untuk membezakan tahap risiko di kawasan kajian. Ini penting untuk memberi maklumat dang meningkatkan kesedaran masyarakat di kawasan itu mengenai bahaya banjir. Faktor analisis banjir adalah disebabkan berlakunya hujan lebat tahunan secara semula jadi terutama ketika musim tengkujuh timur laut pada waktu November hingga Mac. Tambahan pula, ia juga disebabkan oleh aktiviti pembalakan yang menyebabkan air cepat mengalir ke sungai terutamanya di Sungai Kelantan.

Kata kunci: Sistem maklumat geografi, peta bencana banjir, zon banjir, Kaedah Overlay Berat

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LIST OF ABBREVIATIONS

GIS = Geographical Information System

GPS = Global Positioning System

IUGS = International Union of Geological Society

JPJ = Road Transport Department Malaysia

WOM = Weighted Overlay Method

JPS = Jabatan Pengairan dan Saliran

LIST OF SYMBOLS

%	Percentage
°	Degree
'	Minute
"	Second

CHAPTER 1

INTRODUCTION

1.1 General Background

Geology is the study of the Earth, the materials of which it is made, the structure of those materials, and the processes acting upon them. An essential part of geology is the study of how Earth's materials, structures, processes and organisms have changed over time (King H.M, 2005). The title of this research is ‘Geology and Flood Hazard Analysis of Kuala Krai, Kelantan. This research will be focus on the general geology in the study area. It also includes the geology and flood mapping in the area with the specification of the research which is ‘Flood Hazard Analysis’.

Hazard is a natural phenomenon that might cause negative effect to humans and also the surrounding of us including the environment. It can be categorized into two which are geological and biological hazards. There are many types of hazard that normally occurred such as flood, landslide, earthquake, sinkhole and others. The structural geology, geomorphology, stratigraphy and sedimentology will be included in the geological part to observe and get the data of Kuala Krai, Kelantan.

Flood is a common word that people always hear due to the many cases that happened in many countries including Malaysia, especially in Kelantan. The region experienced flooding annually due to the geographical characteristic of the country itself which adjacent to the coast of South China Sea. It is caused by an abundance of rains especially during the northeast monsoon seasons occurring from November to March.

The flooding occurs rapidly when rainwater is high enough and discharged increasingly into the channel. When the water increased due to heavy and prolonged rain, it surged into the tributaries of Galas River and Lebir River. Then, it will flow to the main Kelantan River until it causes to overspill the banks surrounding Dabong, Gua Musang, Manik Urai and Kuala Krai.

Therefore, this research will conduct to understand general geology of the study area, factors of flood hazard that cause the impact of a disaster to the community and the area.

1.2 Study Area

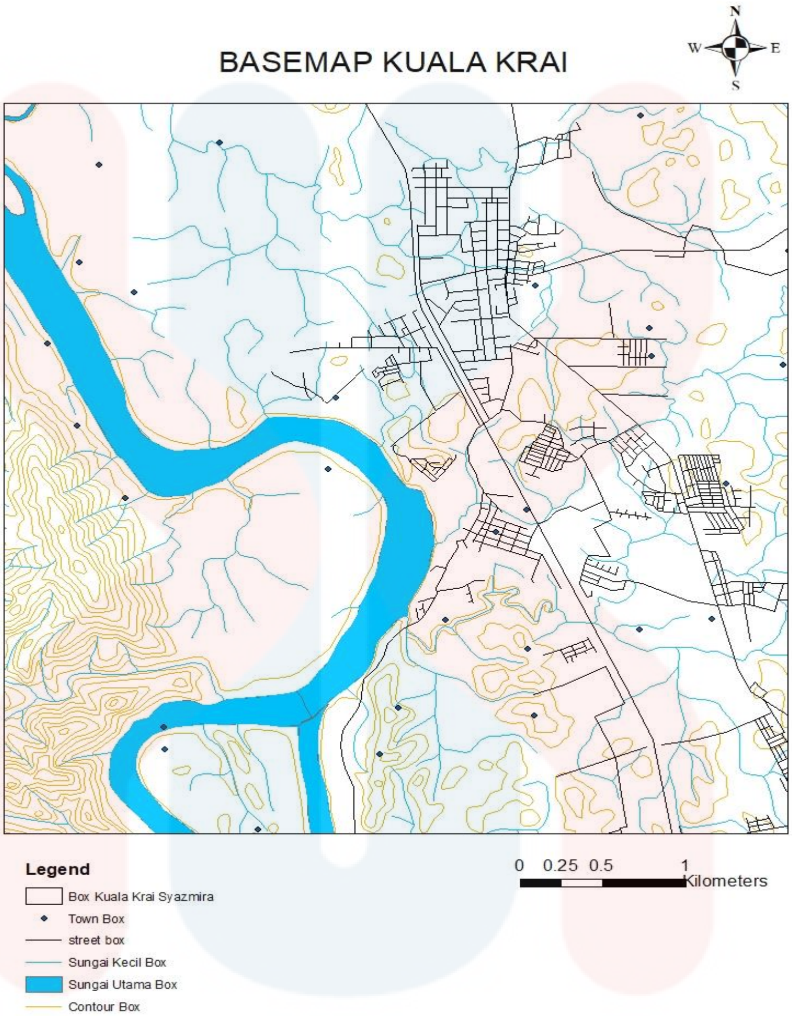

Figure 1.1: Location of the study area

Based on Figure 1.1 above, the map shows the basemap and location of study area in Kuala Krai. For this research which is geology and flood hazard analysis of Kuala Krai, Kelantan, the study area will be cover near the area of Kuala Krai town which connects with people around the district.

a. **Location**

The location is located in Kuala Krai town which located in central region of Kelantan and known as the second largest district after Gua Musang. Kuala Krai is bordering with Machang in the North and Gua Musang in the South, while the East is adjacent to the Terengganu and Jeli is in the West. Historically, Kuala Krai known as Kuala Lebir. The location of the study area is marked with the four points in the edge of the box which is between 5°:30’46.58” N to 5°:33’30.16” N latitude and 102°:10’17.83” E to 102°:13’0.11” E longitude. The area of the location is 25 km^2 wide. The highest is located in the west part of the box where it is the only hill in the location of the study area.

Based on Figure 1.1, at the center and South West part of the location, there is a main river which is Kelantan River that become source to the nearest village. The town and village are situated at the North East of the study area.

The study area is suitable to conduct this research which is general geology and flood hazard analysis as the area is high probability to undergo flood especially in the village area that near to the main Kelantan river. It has lots of village around Kuala Krai district and human activities also one of the main factors that cause the flooding in the area. Therefore, the significant of this study is help in update the data geology of Kuala Krai, Kelantan and can avoid flood hazard that can be dangerous to people who live in the study area.

b. Road connection

Based on figure 1.2, the figure shows the main roads that can be used or can access to go to Kuala Krai' location. Two main roads, which is Federal Route 8 and Kota Bharu-Kuala Krai Expressway that used to access the location. Firstly, Federal Route 8 also known Kuala Lumpur-Kota Bharu, is a 402.7 km federal highway in Malaysia. It connects Bentong in the south to Kota Bharu in the north. Secondly is Kota Bharu-Kuala Krai Expressway and also known as People's Expressway. It is a 73-kilometre (45mi) expressway connecting the city of Kota Bharu and Kuala Krai in Kelantan.

As the study area is located near to the city of Kuala Krai, therefore, it is easier to access this area because there are many transportations can be used by taking cars, bus and train. Besides, there is also a boat service that can help to cross the Kelantan River as it is deep river.

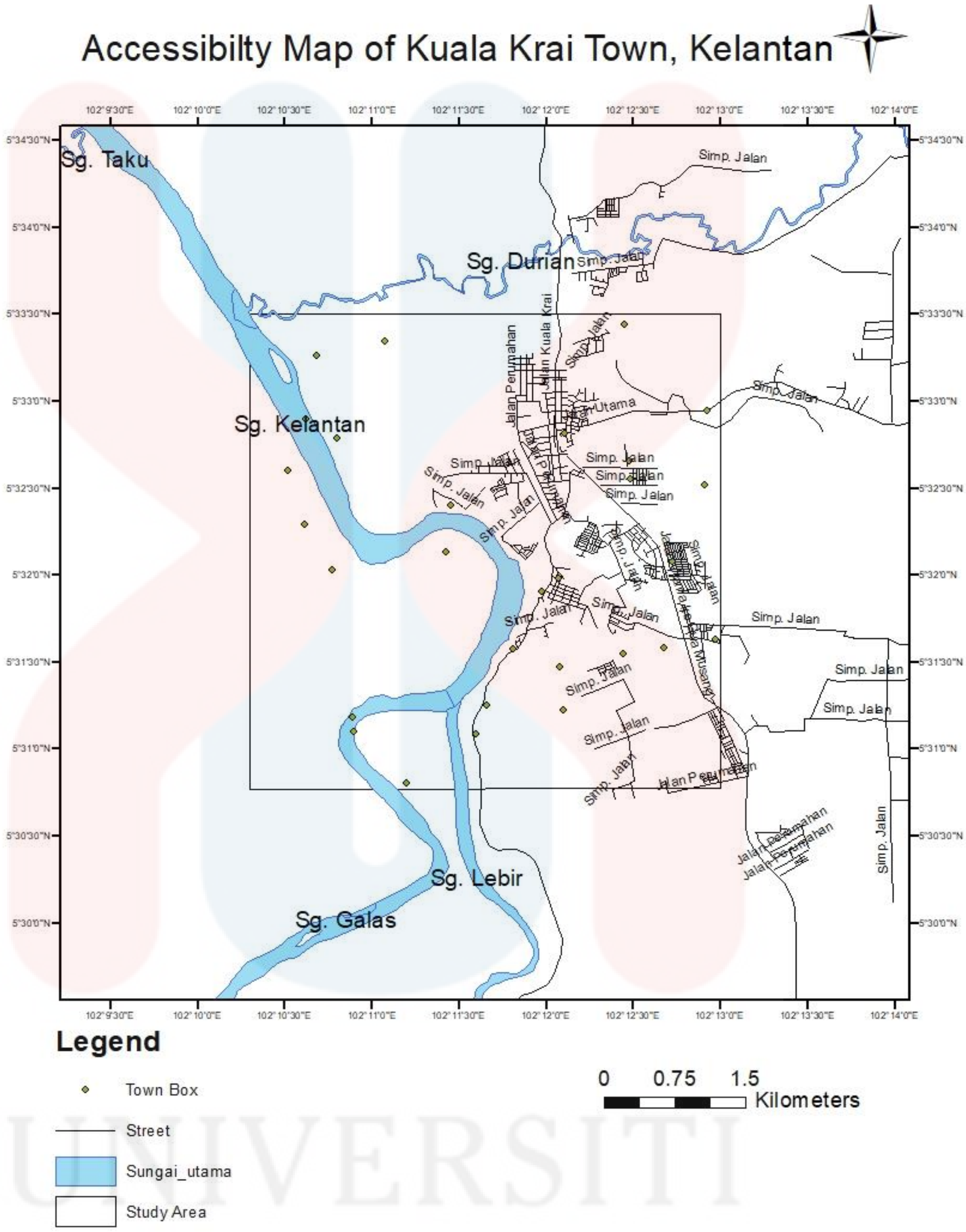

Figure 1.2: The accessibility map of Kuala Krai Town, Kuala Krai, Kelantan

c. Demography

Kuala Krai District is a second largest after Gua Musang with an area of 2329 km^2 with three sub district area which is Olak Jeram, Batu Mengkebang, and Dabong. Olak Jeram (757.6 km^2) with 67 villages, Batu Mengkebang (726.9 km^2) with 122 villages and lastly Dabong (844.5 km^2) with 27 villages.

d. Land use

Land use is the process that involve the management and modification of natural environment into the new built environment. It might take a long time to undergo the process as land use by human has a long of history which is about 10 thousand years ago. The modification of natural environment consists of the total arrangements, activities, and input that people undertake in a certain land type.

Based on Figure 1.3, the land use in Kuala Krai area mostly used by rural and urban developments as the area is near to the town and village. It can be seen development in Kuala Krai today such as infrastructure of hospital, public library, schools, shopping places and others places that growing up well. Besides, the land use in Kuala Krai also used for agricultural activities.

The major use of land is considered as agriculture as half of the world's habitable land is used for it. The extensive land use has a major impact on the earth's environment as it reduces wilderness and threatens biodiversity.

In this location of study area, most of the land use area is covered with plantation areas such as palm oil and rubber tree plantation area. Besides in the north east area is covered with city area.

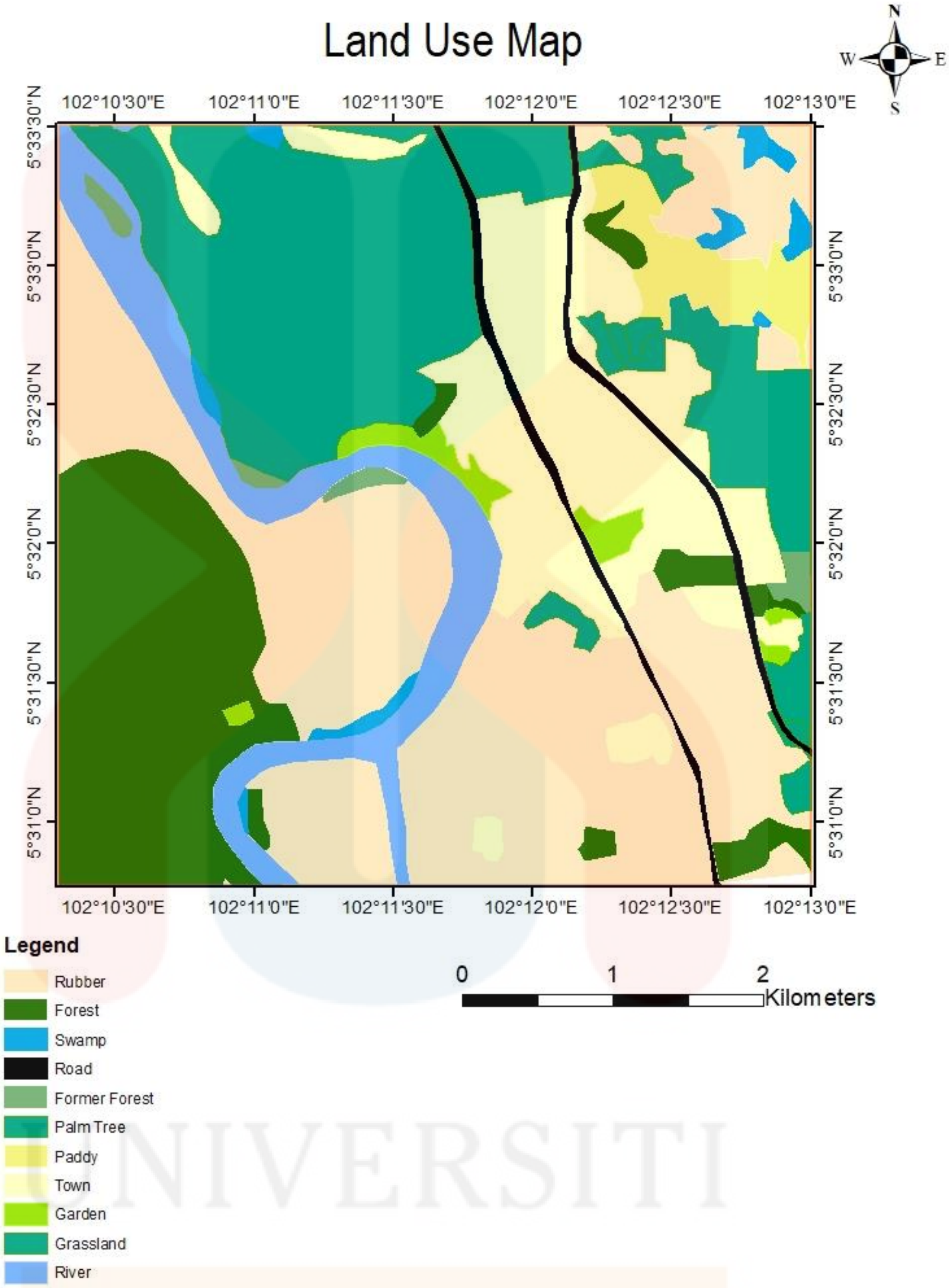

Figure 1.3: Land use map of study area.

e. Social Economic

The foremost social economic generate income in the location of study area is most from agricultural activities and also from government servant or self-employed. Government sector is a large and consist of several residents such as state or local government and all units of central which it can provide many facilities to people. Furthermore, from figure 1.3, most people in the area working as contractor or labourer due to the study area that near to the palm oil in the north area and rubber tree plantation in the south area in the location.

1.3 Problem Statement

Generally, flood hazard is one of the well-known hazards because it can occur everywhere either naturally or not. In this research, the location needs to be study is in Kuala Krai, Kelantan as the flood that occurred in this country is experienced flooding annually due to the main factor which is rainfall during rainy season during the northeast monsoon seasons occurring from November to March.

Besides, the geological factors are one of the main factors. Flooding can be interpreting through geological maps, and it can explain why flooding will not possibly occur in every part of a valley floor.

Even though, the flood occurs annually in Kelantan region, the effects caused by the flood cannot be reduced or decreased. Therefore, this research will conduct to know the factors that cause the impact of disaster to the community and the area. By producing the geological map, the flooding that occurred in the area can be explained will more details. The flood hazard map also will be produced. Hopefully, this will help in overcome and reduce the problems in the study area in the future.

1.4 Objective

This research is going to be conduct based on a few objectives which are:

I. To update the geological map of the study area in 1:25000 scale measurement.

II. To determine the parameter of flood hazard analysis.

III. To produce a flood hazard map by identifying the flood zones in the study area.

1.5 Expected outcome

From this research, hopefully it will help to update the latest geological map of the study area and also the specification of a flood hazard map. The interpretation of geological mapping and method use in the specification will be very detailed, especially in updating the latest data by using GIS method, map information, secondary data and also from previous research. This study also can be able to identify the factors that cause flood hazard in the study area. As an outcome, flood hazard map will be produced to identify the flood zones in the study area. It might help to inform and increase awareness of the people in the area in order to reduce their social-economic impacts as flooding is a threat to life.

1.6 Scope of Study

This research will focus on the geology of Kuala Krai, Kelantan especially in the town area of Kuala Krai. This study will be done through the interpretation of the study area by using some software such as Google Earth, GIS software with the help of secondary data and previous research. Besides, this study area focusing on flood hazard analysis by doing a map that shows an area that exposed to flood hazards. This map will categorize into low, medium and high of water depth in the area.

1.7 Significance of Study

The significance of the study is to improve the previous research of the study area especially for the geological part. It will help in update the data geology of Kuala Krai, Kelantan which it will help the community in the area. This is important especially, to solve the geological problems such as floods in the present and future. This research will focus on the flood hazard analysis of Kuala Krai, Kelantan since the area annually experienced flooding. To prevent this hazard, more research needs to be done by doing the interpretation from secondary data and previous research. This research hopefully would be very beneficial and give awareness to the community in the area about flood hazards to overcome this problem. This is important to the people as the study area is in a rural area and village area. The resident was lack in awareness and knowledge of the geological hazards.

Flood hazard map will produce which is to inform the communities about the flooding in the study area. It also helps people in the study area to find more about the local flood risk that occurred annually in Kuala Krai, Kelantan. So, it might help people in the area to overcome the effect of the flood. Furthermore, this map also can be used as a reference for people, flood management or government in the present or future in order to reduce or improve the problems that relate with the flood hazard.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, all previous research will comprise with details to relate with the research study that were carried out. The important contents must be including in the literature review such are objective, problems and method that have been used previously. With the studies and all these researches, it will help in collect all of the general geology information of the study area in Kuala Krai, Kelantan. The aim of this research is to study about geology and flood hazard analysis by using GIS of Kuala Krai, Kelantan. It is related with the basic of regional geology of Kuala Krai, Kelantan. Therefore, the geological study is important as an indicator to identify the type of rock, rock distribution, and geological structure in the study area. These data help in produce geological map on the study area. All contents from the secondary data such as journals, articles and others would contribute as reference to this research. In this discussion, it will discuss more on the investigation by previous researchers regarding the study area of Kuala Krai district and the title of the research.

2.2 Regional Geology and Tectonic Setting

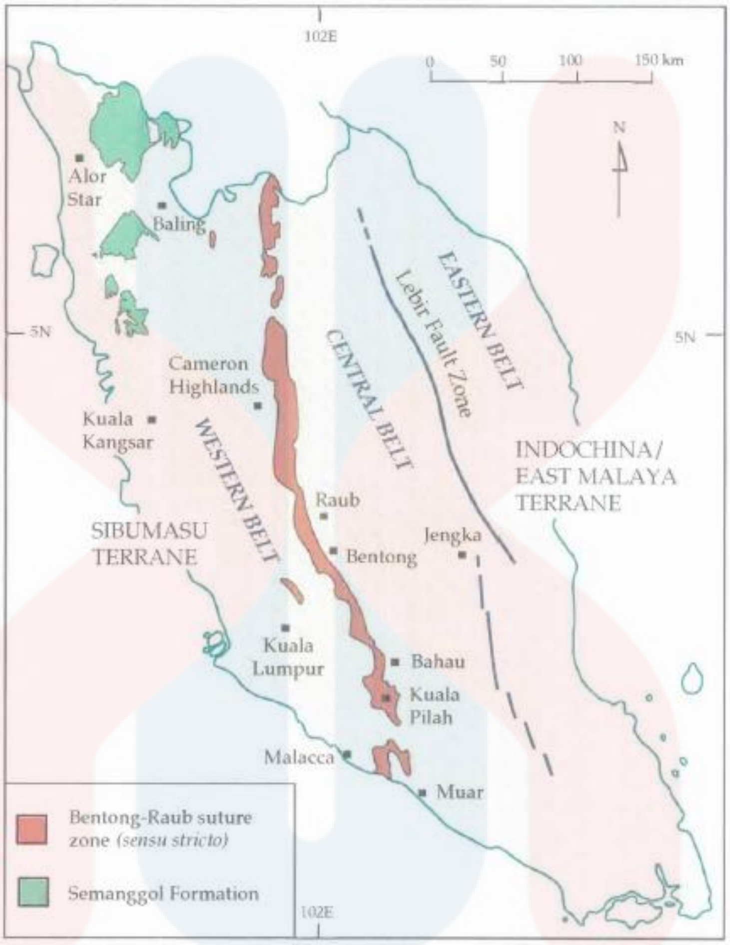

Figure 2.1: Map of Peninsular Malaysia which divided into Sibumasu and Indochina, divided by Bentong-Raub suture zone and Semanggol Formation of northwest Peninsular Malaysia. (Western, Central and Eastern Belt terminology after Khoo and Tan, 1983).

Based on Figure 2.1, Peninsular Malaysia has divided into two continental terrances where the Western part is called Sibumasu and Eastern part is Indochina or East Malaya, which were assembled by the Late Triassic (Pour and Hashim, 2015). Bentong-Raub Suture zone separate the two of these continental terrances. It was divided into three longitudinal belts on the basis of stratigraphy, mineralisation, a western tin belt, a central gold belt, and eastern tin belt.

Khoo and Tan (1983) proposed a threefold subdivision which is Western Belt, Central Belt and Eastern Belt. Then, Khoo and Tan further with division of two regions which is northwest sector and Kinta-Malacca sector. Four structural domains within Peninsula were recognised by Tija and Harun (1972) which is Northwest, West, Central and Eastern. With all the above statement, Lebir Fault zone is known as the boundary between eastern and central belts while boundary between central and western belts is taken as Bentong-Raub line of Hutchison (1975).

2.3 Stratigraphy

Stratigraphy is defined as the branch of geology that involved with the order and position of layering strata and their relationship to the geological time scale. Sedimentary and layered volcanic rocks was used primarily in this study. In Eastern Belt of Peninsular Malaysia, the older sediments exist are essentially Carboniferous and Permian clastics, limestones and volcanics. There is also occurring of schist but only in a low grade. The evident for Triassic sediments occurring is too lack. Unconformable on the older Carboniferous and Permian sediments are continental deposits of Jurassic until Cretaceous age such as the Gagau Group.

Geology of Kuala Krai covered by most rock Formation of Gua Musang and Taku Schist and granite Stong Complex in the western part.

2.4 Structural Geology

The Taku Schists appear to have undergone a phase of recumbent folding coeval with metamorphism and another phase of open folding after the complex has been metamorphosed. The late folding resulted in the complex forming a plunging antiformal structure with a north-south fold axis. This phase of late folding may be coeval with the folding of the Tekai Group. The Tekai Group has been folded into open broad folds with limbs dipping gently. The fold axes are north-south similar to the Taku Schists antiform.

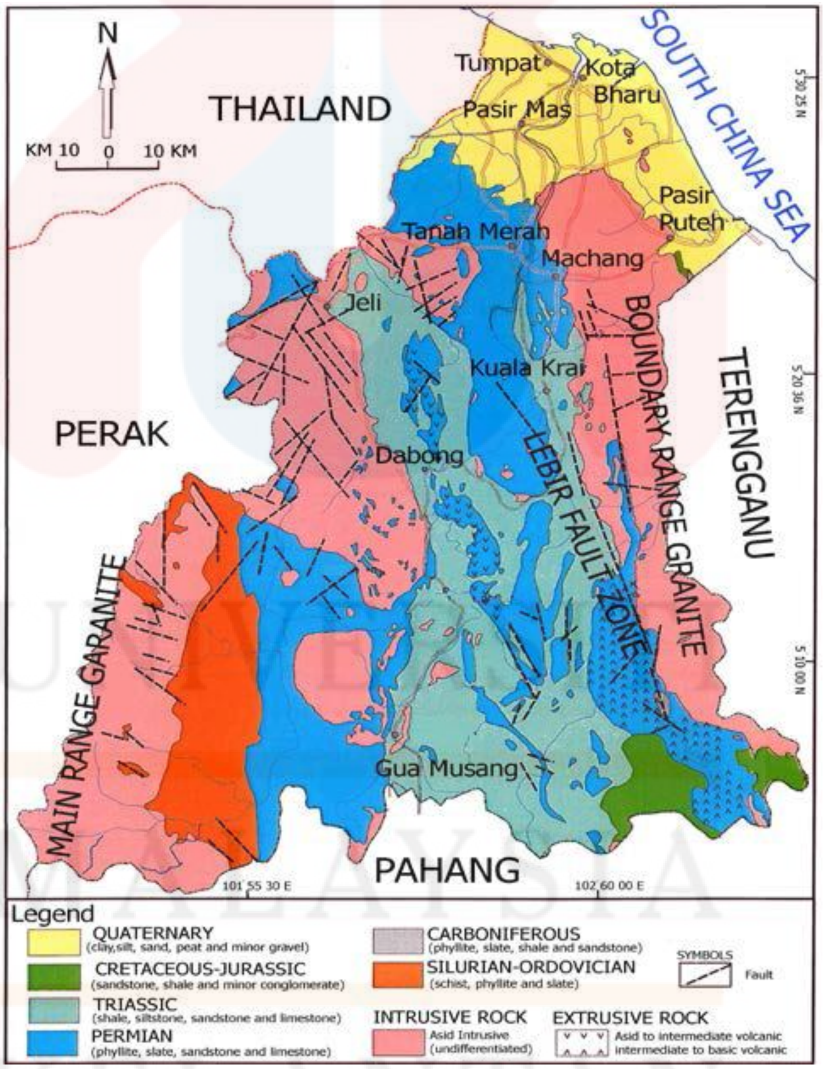

Figure 2.2: Geologic map of the Kelantan state (sources modified from Department of Minerals and Geoscience Malaysia, 2003).

The rocks of the Central Belt bordering the Main Range Granite are also metamorphics such as politic schist phyllites and amphibole schist. In Central Belt area, the Taku Schist in north Kelantan, known as the largest tract of regional metamorphic rocks. If the low grades phyllites bordering the Taku Schist are including, the terrain is much larger. According to MacDonald (1967), an occurrence of serpentinite has also been reported in the Late Triassic. As the Taku Schists have been metamorphosed in the Late Triassic, it must evidently be an older series of rocks.

Based on Figure 2.3, there are about four types of rocks in Kelantan region which is granitic rock, sedimentary or metasedimentary rock, extrusive rock (volcanic rock), and unconsolidated sediment. There are also existing of the faulting and joint in the granitic rocks and folding, faulting and joint in the sedimentary rock. Granitic rocks are distributed in the west (the Main Range granite) and east borders (the Boundary Range granite) of the state of Kelantan (Department of Minerals and Geoscience Malaysia, 2003).

2.5 Historical Geology

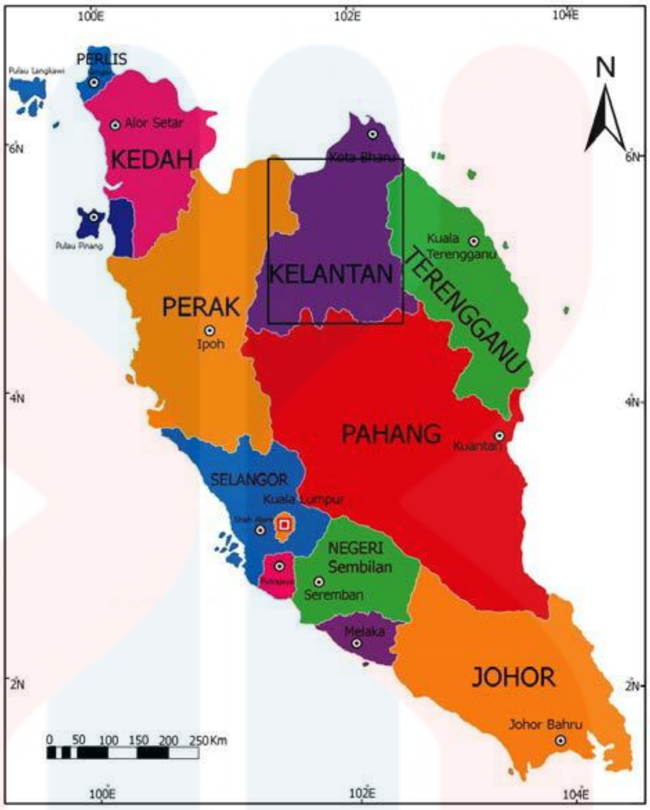

Figure 2.3: Location of Kelantan State in Peninsular Malaysia.

Kelantan is located in the North-Eastern-corner of Peninsular Malaysia (Figure 2.2). Kelantan river is the major river in the region and appear at the convergence of the Galas river and Lebir River. The location is near with Kuala Krai district area and meanders over the coastal plain until it finally degrades into the South China Sea. Kelantan river basin covers 923 km2, which is about 85% of the Kelantan state's surface area. It is composed of flat slope to moderately sloping areas in northern part and steep scraps and high slopes in the southern part of the river basin. A wide variety of rocks consisting of igneous, sedimentary and metamorphic rocks are distributed in a north-south trend in the Kelantan state.

Kuala Krai is one of the districts in Kelantan and known as the second largest district after Gua Musang. Kuala Krai is bordering with Machang in the North and Gua Musang in the South, while the East is adjacent to the Terengganu and Jeli is in the West. Historically, Kuala Krai known as Kuala Lebir.

2.6 Flood

Malaysia is a very prone to flood risk due to the several factors in the area. There are two factors which is physical and human geography which these two relate to each other. The physical factor such as topography and drainage while human geography such as settlement and land use caused the combination of natural and human factors has cause types of floods such as monsoon and tidal (Chan, 1998). Among all the disasters that occurred in Malaysia, floods are consider as the disaster and most frequent and bring the greatest damage annually in Malaysia.

There are two types of floods which is flash flood and monsoon flood. The annual heavy monsoon rain produces about more 3000mm and such a large flood prone area, high flood risk and occurs mostly in the flat lands area.

Monsoon and flash floods are the most severe climate-related natural disasters in Malaysia, with a flood prone area of about 29,000 km2 affecting more than 4.82 million people (22% of the population) and inflicting annual damage of USD 298.29 million (Asian Disaster Reduction Centre (2005) Mitigation and Management of Flood Disasters in Malaysia. In Malaysia, flood that occurs annually can cause damage especially to human and property. This phenomenon known as “normal floods” because it is seasonal monsoon floods that occurred mostly in November to March whereby the water does not normally exceed the stilt height of traditional malay house.

Kelantan experienced flooding annually due to the geographical characteristic of the country itself which adjacent to the coast of South China Sea. It is caused by an abundance of rains especially during the northeast monsoon seasons occurring from November to March and caused flooding until it is high enough and discharged increasingly into the channel especially in Kuala Krai district area (Chan, 1997).

2.6.1 Flood hazard mapping

Flood map is important in order to determine the flood-prone areas. It creates accessible charts and maps in identify and determine the risk of flooding areas and helps prioritize mitigation and efforts of the people in the area (Bapulu & Sinha, 2005). Hopefully, this map will help in increase awareness of people about flooding in the study area by find out more about the flood, how to prevent it and the correct precautions for this problem.

Besides, this map also purposes to increase awareness of the likelihood of flooding among the public, local authorities, and others. They also encourage people living and working in flood-prone areas to find out more about the local flood risk and to take appropriate action. (International Training Program on Total Disaster Risk Management, 2003).

2.6.2 Rainfall Distribution

Climate in Malaysia is equatorial due to the location of Asian located in the North of the equator such as hot, humid, and rainy throughout the year. Then, Monsoon regime occurred and cause rains phenomenon as Malaysia was surrounded by the sea, and there is no real dry season.

Rainfall is a frequent phenomenon and abundant throughout the year. In fact, to find an area lower than 2000 millimetres (79 inches) per year, or month when lower than 100 mm (4 inches) are difficult hard. However, the area that is not too high is possible to find, although they are not the same everywhere. In addition, the rains, as is generally the case in tropical countries, are quite erratic from year to year. The monsoons cause precipitation to occurs more and frequent in the areas directly exposed to the winds especially between mid-October and January. The main area that affecting is the east coast of Peninsular Malaysia and the north-east coast of Borneo which the northeast monsoon prevails. Besides, southwest monsoon occurred between June and September, which, in Malaysia, usually produces weaker effects.

The northeast monsoon directly affects the east coast of Peninsular Malaysia, from 2500 to 3000 mm (98 to 118 inches) of rainfall per year. In November and December, the abundant of rains occurred when they even exceed 500 mm (20 in) per month. Generally, December is the month for raining season which can further until January, especially in central and southern part, and during some years, even in the northern one.

2.6.3 Geographical Information System (GIS)

GIS analysis may lead to high quality of information in the context of complete analysis strategy by using spatial and non-spatial data. GIS utilization began to expand during the 1970s, primarily still using mainframe-based approaches. Although begun during the 1960s, the Harvard Laboratory for Computer Graphics and Spatial Analysis was one of the main academic groups focusing on developing mapping software for broader distribution during the 1970s (Chrisman, 2005).

To produce flood map, ArcGis software is used in determine the flood map by using the weighted overlay method in Gis tools (WOM) by giving weighting and scoring for each parameter. This method is function to overlay all the parameters which influence the flooding based on the consideration of the effect of each parameter on flooding. There are few types of parameters need to be in detail investigation such as flow accumulation, rainfall intensity, land use, slope, elevation, and geology of the area. According to Suhardiman (2012), in GIS analysis part, the weight for each thematic map is depend on the possibility of flooding that affected by each geographical parameter.

Furthermore, scoring is also important in giving score to each class in parameter as it depends on the influence of the class on events. The greater the effect on the events, the higher the score of the parameter (Anas Sudijono, 2007). The total influence of the parameters needs to be 100% according to the influence of the class. The value of influence can be higher or lower based on the parameter itself on the study area. Giving values for each parameter is the same, namely 1-5, while weighting depends on the influence of each parameter which has the greatest factor in the level of flood vulnerability (Matondang J.P, 2013). In the end flood hazard map will produced by using Weighted Overlay Method in GIS with the show of different water level zonation of the study area which is low, medium and high-water level.

2.6.4 Flood hazard mapping methodologies

I. Geological-geomorphological

The arrangement and types of landforms was use in this method and deposits generated during or after the flood event. By using this method, the geomorphologically active areas can be delimit within the stream channel and its banks, and therefore areas prone to flood inundation within the framework of the stream's natural dynamics, their qualitative flood frequency, and even infer the order of the magnitude of certain parameters such as depth, velocity and transported sediment load. These techniques are gaining strength as this method is the only one that consider natural phenomena very difficult to model compared to the other techniques such as avulsion, sediment transport, channel migration, and take into account natural developments of the fluvial system.

II. Hydrological method

In this hydrological method, the characterisation of these abnormal discharges with respect to the time. For example, establishing the flood hydrograph corresponding to the event, will be of fundamental importance. The flood's elements such as peak discharge, rising limb, falling limb, and lag time can be study from this hydrograph. This hydrograph also can determine the components such as surface runoff, direct runoff, and subsurface runoff, base flow, and characteristics times, in relation to the corresponding hyetograph, and then assign an occurrence probability to it.

There are many methods for the hydrological study of floods, ranging from the full characterisation of the hydrograph to the determination of only one of its parameters, such as peak discharge. This main study on this method is to distinguish between two general groups of methods. It helps in analyse a past flood through streamflow data, and those aiming to estimate the streamflow of future floods or hypothetical situations (design flood) based on indirect data from past floods (geological-geomorphological marks or impacts), or by analysing precipitation and/or streamflow data recorded during other floods.

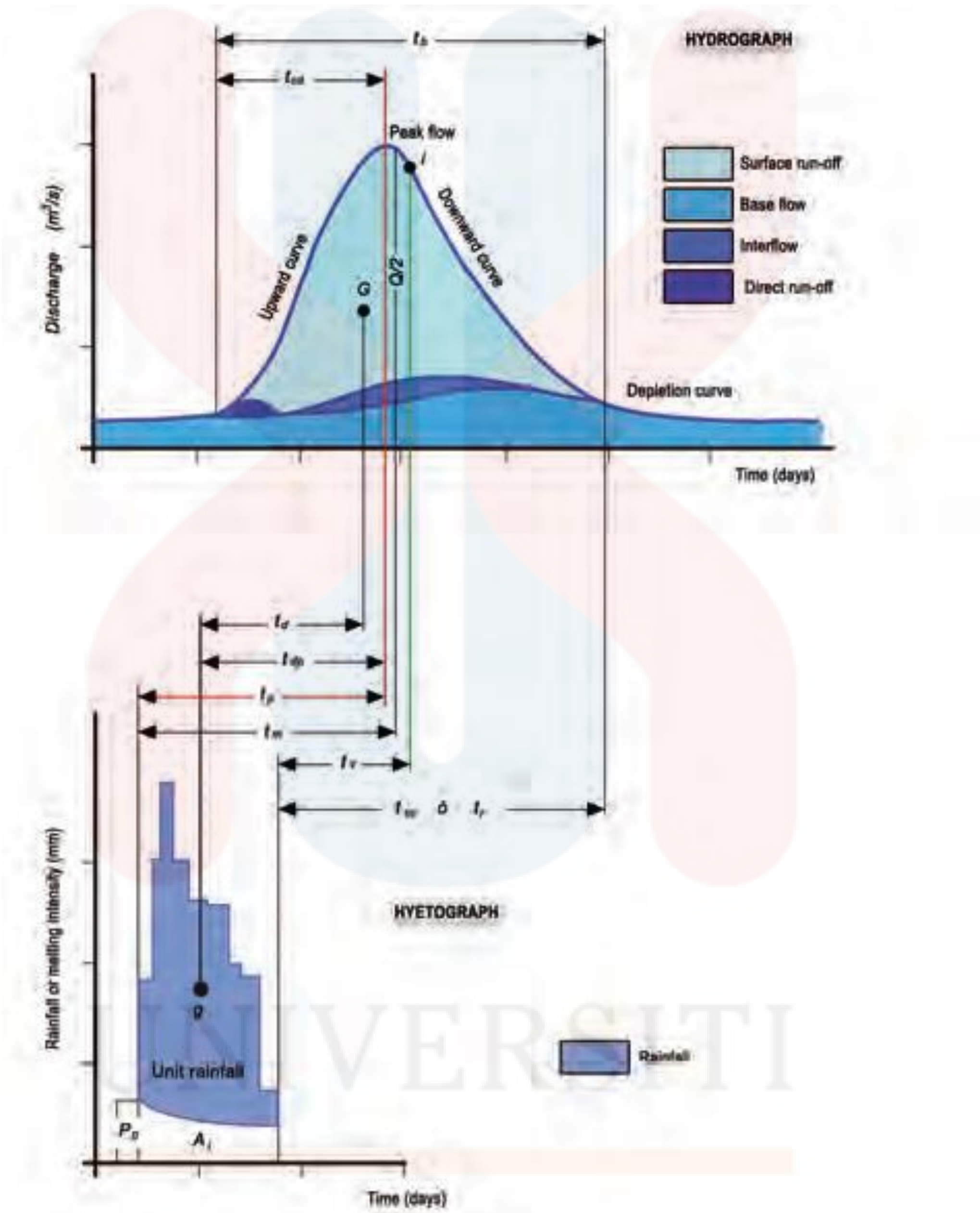

Figure 2.4: Relationship between the rainfall hyetograph and the hydrograph of the flood it generates, the components, elements and characteristic times (Based on Díez-Herrero, 2002 and Díez and Pedraza, 1996).

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Introduction

In this chapter, materials and methodology are important to do the research in order to make sure the research can be done smoothly. In general geology, geological of study area was identify to update the new data of the map by using secondary data such as articles, journal, books and other reference. Secondary data also help in fulfil the specification study which is flood hazard analysis in the study area. Therefore, secondary data is needed in the research by collecting it from any related sources such as articles, journals, and agencies.

3.2 Materials and equipment

a) Google Earth

Known as computer program which represent 3D effect of Earth based on satellite imagery. Enable user to see landscape from various angle as it is superimposing aerial photography, satellite images and GIS data onto a 3D globe.

b) ArcGIS Software

ArcGis is important to produce the base map of the study area. All secondary data will transfer to the Arc Gis software to produce geological and flood hazard map of the study area. Flood hazard map are producing by using Weighted Overlay Method tool in ArcGIS software.

c) Website

Website such as United States Geological Survey (USGS) dan Jabatan Pengaliran dan Saliran (JPS), is use to get the secondary data such as digital elevation model (DEM), flow accumulation, slope and rainfall data.

3.3 Methodology

Methodology is important as it will explain more details how this research is going with the help of materials given as a secondary data. Secondary data and previous research also help in the interpretation of the geological part of study area and specification in flood hazard analysis. Figure 3.1, research of flowchart method below shows the overall of methodology in this research starting from preliminary study until report writing.

RESEARCH FLOWCHART

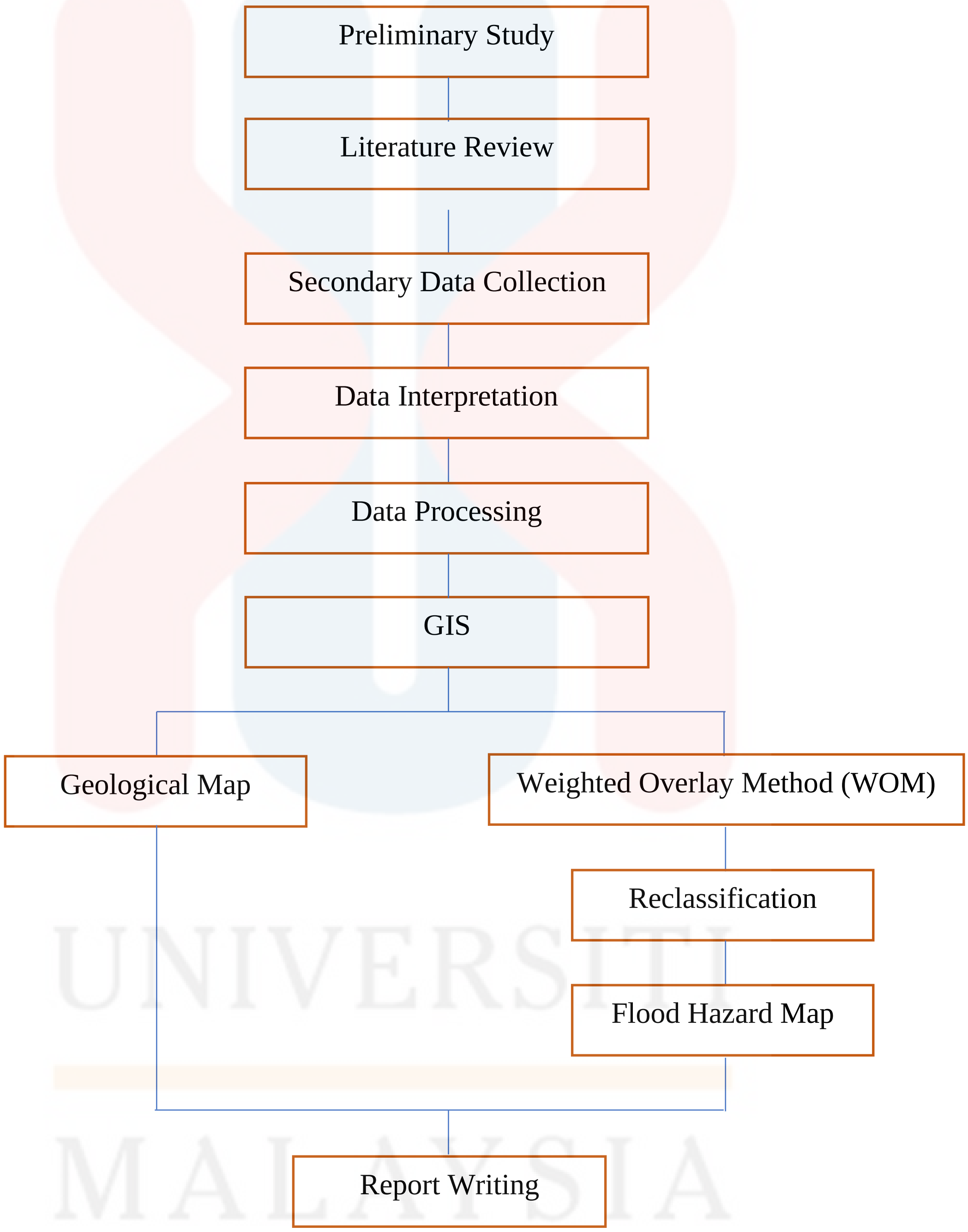

Figure 3.1: Research flowchart method

3.3.1 Preliminary study

Previous research needs to be understood properly in making research study because in this phase, research was started by studying literature review that related to the background study. Previous articles, journal and other report of flood hazard are important for a researcher to find the information. Data acquired from articles, website or books were example of the sources in studying literature review. The preliminary study also very helpful as it gives an overview about the study area and helps researcher in getting the idea to conduct the research. Besides, the data from the base map also can be obtained such as lineament and geomorphology by using the ArcGis software.

3.3.2 Data Collection

In this discussion, data collection is really needed to do the research in the study area and specification. Type of data needed in this research are involved from secondary data either in a part of geological mapping data or in specification of flood hazard analysis. Secondary data can be obtained from previous research such as articles, journal, book and internet. Some of the data need from agencies such as Jabatan Pengaliran dan Saliran (JPS) for rainfall data. Furthermore, some of it can be obtained from USGS website to get such as digital elevation model (DEM). From DEM, other thematic map was generated. Data are basic requirement to do the analysis process of geology and flood hazard analysis of study area which is Kuala Krai, Kelantan.

3.3.3 Data Processing

All secondary data either in geological data or flood data that have been collect are process by using specific software such as ArcGis. These data needed in order to update and produce the new geological map of the study area. The flood map also produced by collecting all the parameters data such as flow accumulation, rainfall intensity, land use, slope, elevation, distance from drainage network and geology of the study area. Then, all the parameters data will process in ArcGIS software by using weighted overlay method tool (WOM). Weighted overlay method is important procedure in GIS (Geographic Information System) as it helps in able one map graphics on another map graphic to produce flood hazard map. It is to ensure one parameter of the map will overlay with another parameter until it produces level of flood zonation on the flood hazard map which is low, medium, and high level.

3.3.4 Data Analysis and Interpretation

In this part, all secondary data obtained will analysed and interpret. GIS also was used to produce flood hazard map to extract out the information with more details to be explained. The lineament interpretation was done by analyse the positive and negative lineament in terrain map and google maps. Flood hazard map was produced by generating and interpret all the parameters such as flow accumulation, elevation, slope, land use and lithology data. Then the hyetograph and hydrograph data was used to interpret the water level of flood that occurred in the study area.

3.3.5 Report Writing

Report writing is compulsory for the documentation and for the evidence in the whole research. It is shown that all data of the research in the study area was recorded completely. The report must include of the geological mapping result which consists of geological map of study area and geological characteristics such as geomorphology, structural geology and stratigraphy. The report also includes the result of specification of study area which is flood hazard analysis of Kuala Krai, Kelantan.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

General geology is a chapter that describing all the subtopics such as geomorphology, lithostratigraphy, structural geology and historical geology. All the information regarding to the geology of the study area were analysed by previous research and data collections. This information required in update the latest observation of geology area and formed the rock unit with the structure involved. Geological map was produced as the final outcome from all geological data that have been collected. Based on previous land use data of the study area on Figure 1.3, the study area mostly covered with plantation area which is palm oil and rubber tree.

a) Brief Content

Geomorphology is defined as the Earth's physical land surface features and its landforms which categorized into rivers, hills, plains, beaches, sand dunes, and others. Geomorphology investigated the landform of the study area and the process that act and form it. Form, process and interrelationships between them are central to understanding the origin and development of landform. In this chapter, geomorphology explained is divided into several subtopics which is geomorphologic classification, weathering, and drainage pattern.

Lithostratigraphy is a subtopic of stratigraphy, the geological science that associated with rock strata and relative stratigraphic positions.

b) Accessibility

Accessibility is the ability to enter, approach or to reach the location of study area by several ways. Based on Figure 4.1 below, the accessibility map shows there are many types of connections can be access or reach by the people to go to the Kuala Krai Town area by using roads and river as their main route. The location of study area is quite strategic and the road connections is in good condition as it is located in the town area that fully with facilities and well development.

The study area is located at Kuala Krai town with 5°:30'46.58" N to 5°:33'30.16" N latitude and 102°:10'17.83" E to 102°:13'0.11" E longitude. This study area is accessible by main road connection from Kota Bharu heading to Gua Musang, Kuala Lumpur and others. Figure 4.2 shows the main road of Kuala Krai Town, Kuala Krai, Kelantan that have been use by many people as it is the main route in the area.

Besides, from Figure 4.3 below, there is also train railway at the middle part of study area in Kuala Krai town which the train railway heading from Tumpat to Gemas station. This facility will help residents to move from one location to another. The study area can be accessed by four-wheel drive, car, motorcycle, or walking through unpaved road of certain area such as palm oil plantation, farm and forest. Figure 4.4 shows the main river, Sungai Kelantan that use by people which this river divides into the Galas and Lebir rivers.

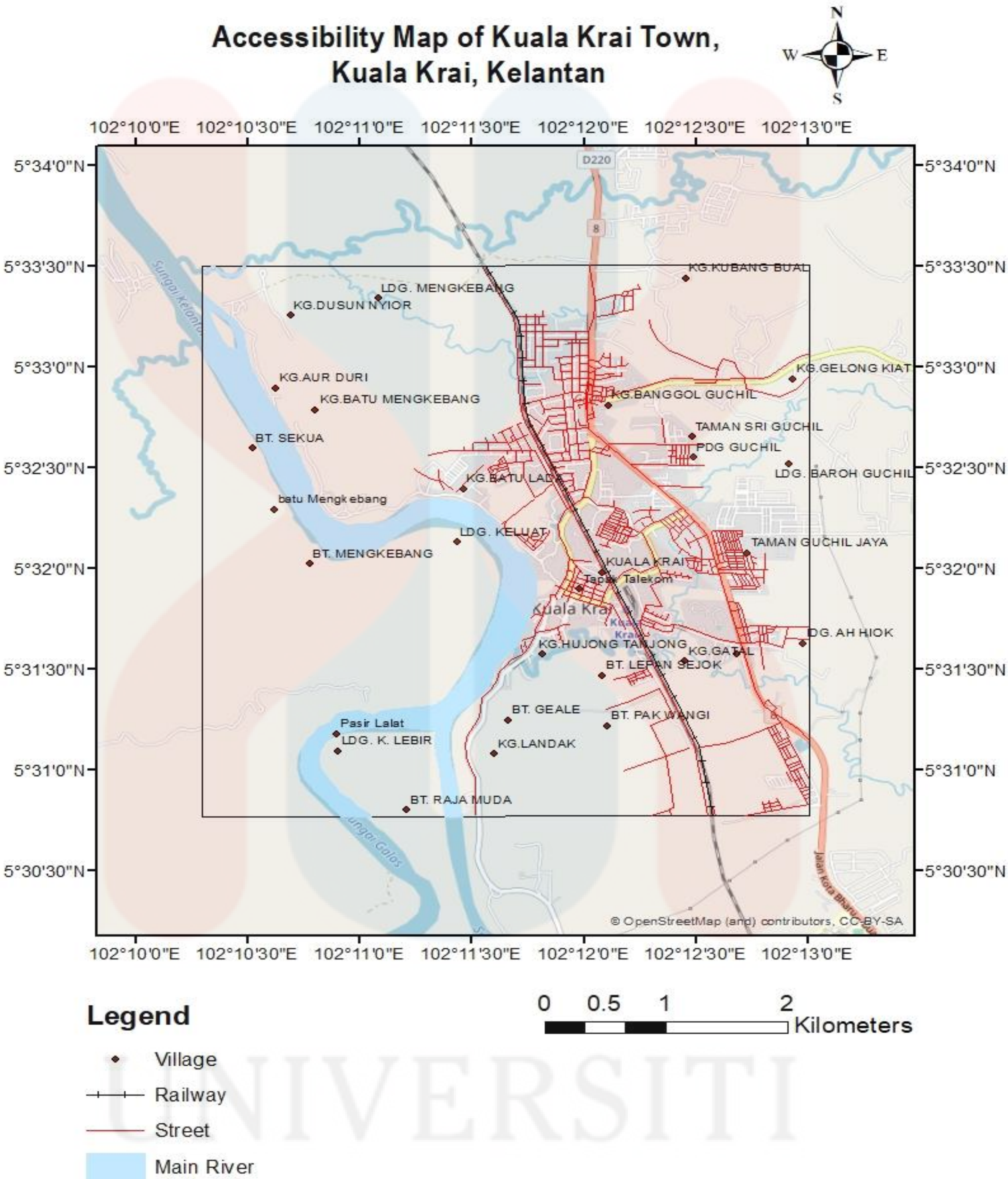

Figure 4.1: Accessibility Map of Kuala Krai Town, Kuala Krai, Kelantan

Figure 4.2: The main road of Kuala Krai Town, Kuala Krai, Kelantan (Source: Google Image, 2005)

Figure 4.3: The Train Station in Kuala Krai Town, Kuala Krai, Kelantan

(Source: Google Image, 2011)

Figure 4.4: The main river, Sungai Kelantan River in Kuala Krai, Kelantan

(Source: Google Image, 2016)

c) Settlement

The Settlement of Kuala Krai town is big and large area as it is located in town area. The settlement in the study area include the Kuala Krai town, Kampong Banggol Guchil and Taman Guchil Jaya. Therefore, Figure 4.5 below shows there are many residents stay in the area which the total estimation population of Kuala Krai in 2020 is 19, 573.

Figure 4.5: The population of Kuala Krai town, Kuala Krai, Kelantan.

(Source: https://www.citypopulation.de/en/malaysia/admin/kelantan/0309__kuala_krai/)

d) Forestry and vegetation

Based on the land use map on figure 1.3, forestry and vegetation are a plantation and growing plants around that can be seen clearly and it is major activities that residents around the Kuala Krai town doing for their economic. There are many types of vegetation in Kuala Krai town area which is rubber tree, swamp, forest, paddy, garden, grassland and palm tree.

4.2 Geomorphology

Geomorphology is deriving from three Greek words which is the Earth, form and discourse. Therefore, it is known as a discourse on Earth forms. Geomorphology is the study of Earth's physical land-surface and its landforms which can be divided into rivers, hills, plains, beaches, sand and others. In geomorphology, all landforms and other processes that occurred was investigated to understand the origin and development of landforms that relates between them.

a) Geomorphologic Classification

Geomorphologic classification defined as categorization and explanation details of nature, origin and occurrence of the landforms. Geomorphic classification is divided into four components systems. There are Geomorphic process, landform, morphometry and geomorphic generation. The Earth's surface topography formed due to physical and chemical process by geological forces such as endogenic, exogenic and extraterrestrial processes. They include processes of transformation and transfer associated with weathering, gravity, water, wind, and ice.

The geomorphological development of Peninsular Malaysia has been influenced by these regional events and its-present day landforms thus result in part from its prolonged sub-aerial exposure throughout the Tertiary period, with the predominance of weathering and erosion. Besides, The Peninsula also effect by global climate and sea-level changes of the Quaternary period, during which time, depositional processes were dominant, especially in coastal areas.

Topography is study of the shapes of the land surfaces and their characteristics with details in elevation data in digital form (DEM). According to Raj (2009), the topographic units based on mean elevations divided into five. Table 4.1 below shows the topographic unit based on mean elevations.

Table 4.1: Topographic unit based on mean elevations

Source: Raj (2009)

	Topographic unit	Mean Elevation (m above sea level)
1	Low lying	<15
2	Rolling	16-30
3	Undulating	31-75
4	Hilly	76-300
5	Mountainous	> 301

Based on the table 4.1 above, the geomorphologies of Kuala Krai consist of several topographic unit starting from low lying, rolling, undulating and hilly elevation. Figure 4.6 below shows the landform map of Kuala Krai Town, Kuala Krai, Kelantan which classified the landform into rolling, undulating, and hilly according to the elevation in the area.

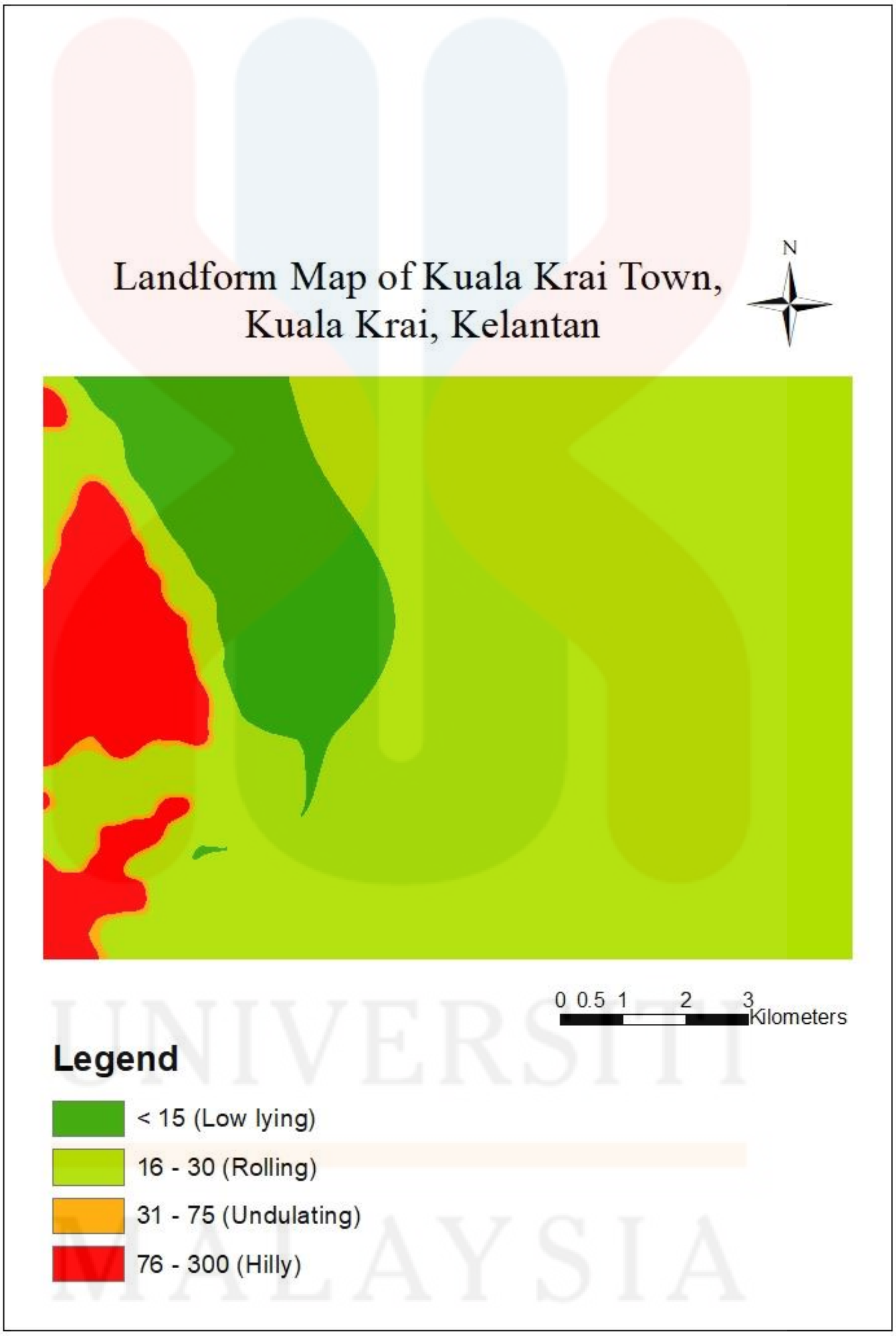

Figure 4.6: Landform map of Kuala Krai town Kelantan.

b) Drainage Pattern

Drainage pattern is important especially when interpreting data in GIS and terrain analysis. In geomorphology, drainage pattern referred as river system which formed by streams, rivers and lakes in a drainage basin which connect and relates with each other. In GIS system, river networks stored as a line segments with geographical coordinates and topographical relationships. The networks help in observe different patterns and relate to the other geographical factors. According to Charlton (2008), there are many factors in drainage basin that helps to cover the influence input, output and transport of sediment and water such as topography, types of soils, bedrock type, climate and vegetation.

In GIS, the drainage system can be digitized manually or extracted from the Digital Elevation Model (DEM) by computing the flow direction and accumulation on the terrain (Mark, 1984; Tarboton et al., 1991, 1997; Vogt et al., 2003; Nardi et al., 2008; Florinsky, 2009; Ortega and Rueda, 2010). Drainage pattern important because it provides fundamental hydrological and morphological partition of river basins into fluvial areas and hillslopes. Ritter (2003) stated there are seven types of drainage patterns which is dendritic, parallel, trellis, rectangular, radial, centripetal and reticulate patterns.

Based on the list given, there is only one type of drainage pattern which is dendritic pattern. The figure 4.7 shows the dendritic pattern in the study area. Lambert (1998) stated the dendritic pattern is the most common form of river system and the river system, tributaries of a main river join together in a shape liked tree. Based on the study area, the lithology found of dendritic pattern is interbedded sand stone, siltstone and shale which this type of drainage pattern obviously occurred in sedimentary rock area.

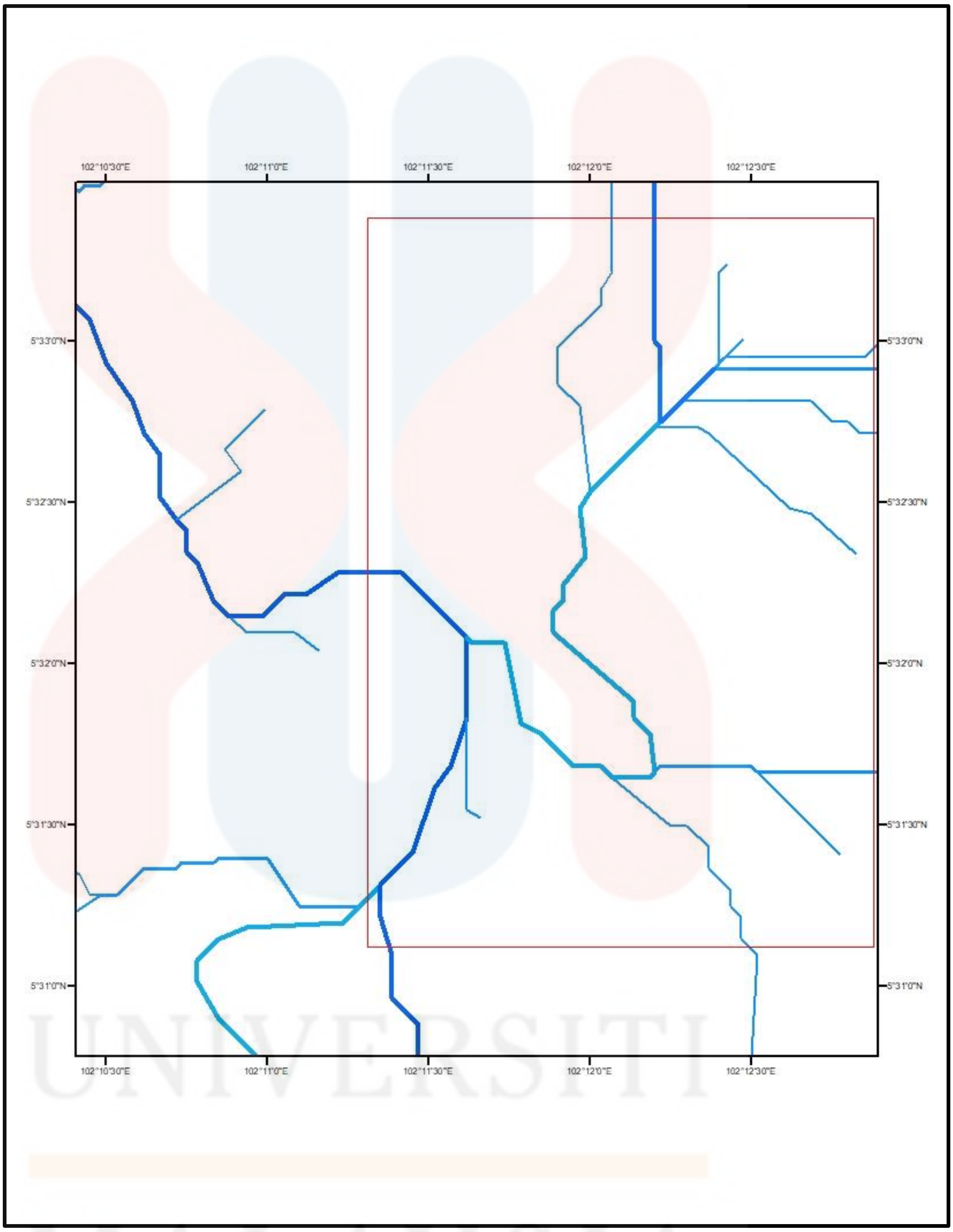

Figure 4.7: The dendritic pattern in the study area.

4.3 Lithostratigraphy

a) Stratigraphy

Stratigraphy is study of geology that relate with study of rock layers (strata) and layering (stratification). Kuala Krai consists various type of rocks but based on the previous geological mapping conducted by Halim (2017) and Kamaruzaman (2018) in the study area, the rocks found are sandstone, siltstone and shale, ignimbrite, alluvium and schist. The rock layers have been determined from younger to oldest which is alluvium, ignimbrite, interbedded sandstone, siltstone and shale, and the last is schist. Table 4.2 below shows the stratigraphy column based on study area.

Table 4.2: Stratigraphy column of study area

EON	ERA	PERIOD	LITHOLOGY	FORMATION	DESCRIPTION-
Phanerozoic	Cenozoic	Quaternary	Alluvium	-	The alluvium contains various type of sediment which is coarse soil and fine grain. The area used for plantation and settlement.
	Mesozoic	Jurassic	Ignimbrite	Temangan dyke	Intrusive rock.
		Triassic	Interbedded sandstone, siltstone and shale	Telong Formation	Interbedded of sandstone, siltstone and shale. These clastic sedimentary rocks deposited in shallow marine environment.
	Paleozoic	Permian	Schist	Taku Schist	The Permian Taku Schist had been metamorphosed to medium grade metamorphic rocks.

From the table 4.2 above, the stratigraphic column of the study area is important in determined the age of the rock unit and to describe the relationship between strata and stratigraphic column in the location. As a theory, this stratigraphic column known as law of superposition which the sequence layers of sedimentary rock start from the oldest at the bottom of layering rock while the younger one is at the top of layering rock.

Figured 4.8 shows geological map which shows the elevation , cross section and lithology rocks in the study area. From the figure, lithology of the study area consists of alluvium, ignimbrite, interbedded sandstone, siltstone and shale, and schist. Different lithology is represented with different colours. The dominant rock in the study area is sedimentary rock which is interbedded sandstone, siltstone and shale in the Kuala Krai Town area.

Geological map was producing by using the spatial data set such as terrain map, by comparing with paper map of Geological Society of Malaysia, shapefile data, remote sensing image and other previous research. The color of the geological map was according to the color of lithology in United States Geological Survey (USGS) website.

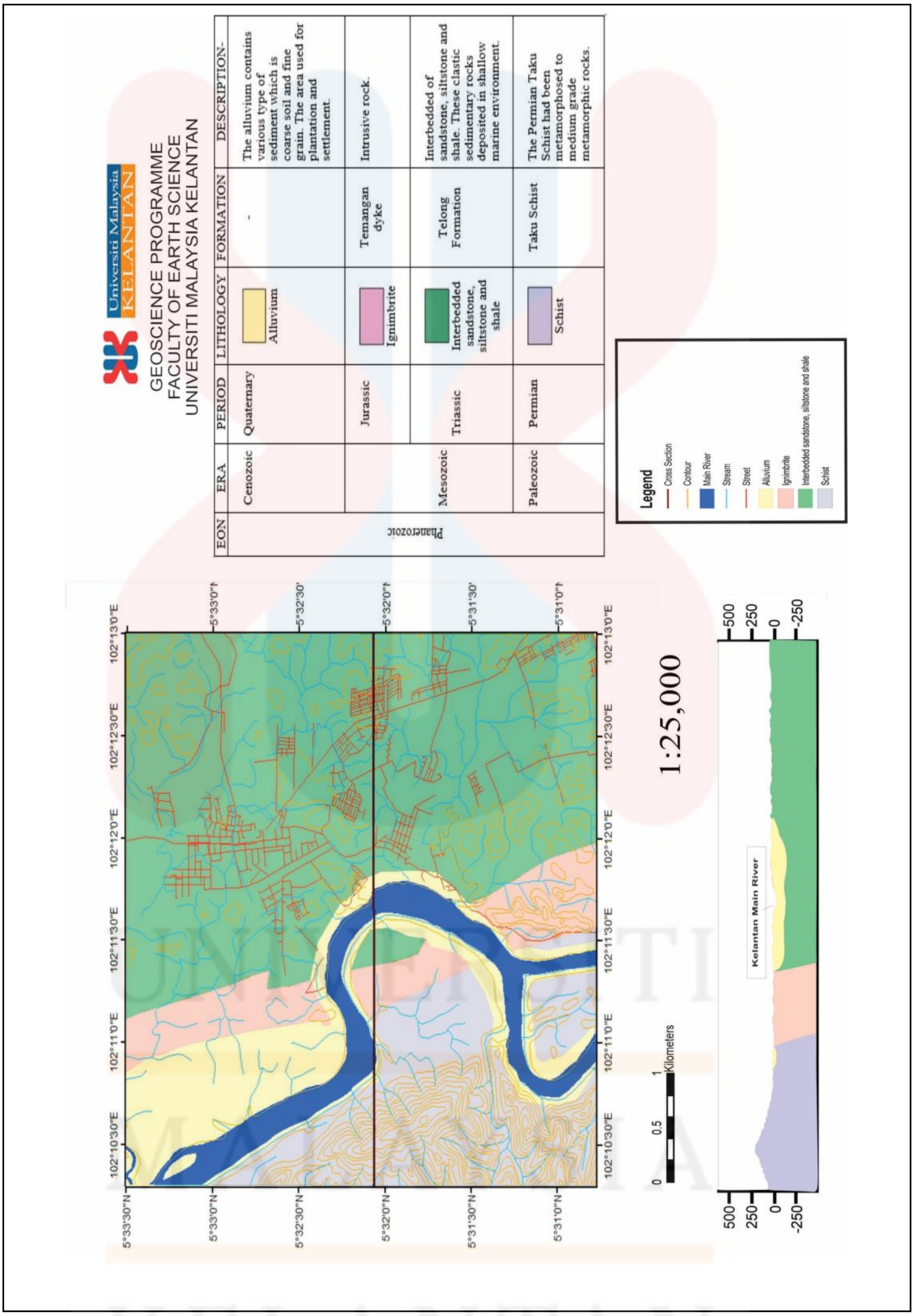

Figure 4.8: Geological map of the study area

b) Unit Explanation

Based on the figure 4.8, the geological map shows the lithology of the study area which is alluvium, ignimbrite, interbedded sandstone, siltstone and shale, and schist.

a) Alluvium

Alluvium is a deposit of clay, silt, and sand left by flowing floodwater in a river valley or delta, usually it produces fertile soil. In study area, the alluvium was located alongside of Kelantan River. Mostly alluvium is loose, unconsolidated soil or sediment due to the erosion process, reshaped by water in some form and re deposited in non-marine setting.

Alluvium is made up of many materials from fine particles of silt and clay and other larger particles of sand and gravel. It is called as alluvial deposit when alluvial material is deposited or cemented into lithological unit or other term is lithified. From previous geological mapping carried out by Kamaruzaman M.F (2018), figure 4.9 shows the alluvium was found along the road of Taman Sri Guchil.

Figure 4.9: Alluvium can be seen along the road of Taman Sri Guchil.

(Source: Kamaruzaman M.F, 2018)

b) Ignimbrite

Ignimbrite is pumice -dominated pyroclastic flow deposit formed from the cooling of pyroclastic material which this event occurred due to the ejection from an explosive volcanic eruption. Ignimbrite is a variety of hardened tuff. Based on previous geological mapping carried out by Halim N.A (2017), ignimbrite was found at the locality near the Pasir Lalat area, Mengkebang Hill area, and near the middle of Kelantan River.

The first locality is Pasir Lalat area which located beside the main river, Kelantan River and at the other site of the outcrop was a forest area. The figure 4.10 below shows the ignimbrite outcrop that have been found in the study area.

Figure 4.10: Ignimbrite Outcrop at near Pasir Lalat, Kuala Krai, Kelantan

(Source: Halim N.A, 2017)

Ignimbrite at near Pasir Lalat Kuala Krai was taken for the analysis. The colour of the ignimbrite is beige in colour. The texture of this ignimbrite sample is porphyritic which mean their crystal are visible to the naked eyes which is known as phenocryst and the crystal was set in a very fine grain which is groundmass. The grain size of this ignimbrite is medium to fine grain. Figure 4.11 shows the hand specimen of Ignimbrite at Pasir Lalat, Kuala Krai, Kelantan.

Figure 4.11: Hand specimen of Ignimbrite at Pasir Lalat, Kuala Krai, Kelantan

(Source: Halim N.A, 2017)

Second locality of Ignimbrite is at Mengkebang Hill area. Kuala Krai, Kelantan. The coordinate where this ignimbrite was found is N 05º 32’ 07.7”, E 102º 10’ 44.6” which located at middle of rubber plantation and above the hills where the two large outcrops have been found. Figure 4.12 below shows the Ignimbrite outcrop at the study area.

Figure 4.12: Ignimbrite at Mengkebang Hill, Kuala Krai, Kelantan

(Source: Halim N.A, 2017)

Figure 4.13: Hand specimen of ignimbrite at Mengkebang Hill, Kuala Krai, Kelantan

(Source: Halim N.A, 2017)

From Figure 4.13, the hand specimen of ignimbrite in Mengkebang Hill show the color is beige with medium to fine grain size. The texture of this Ignimbrite sample is porphyritic which mean their crystal are visible to the naked eyes which is known as phenocryst and the crystal was set in a very fine grain which is groundmass.

Last locality of the ignimbrite near the middle of Kelantan River which the coordinates is N 05º 32’ 18.0”, E 102º 10’ 44.7” with the elevation of the station is 20 meters. The figure 4.14 and 4.15 below shows the locality of the Ignimbrite.

Figure 4.14: Ignimbrite at middle of Kelantan River, Kuala Krai, Kelantan (Source: Halim N.A, 2017)

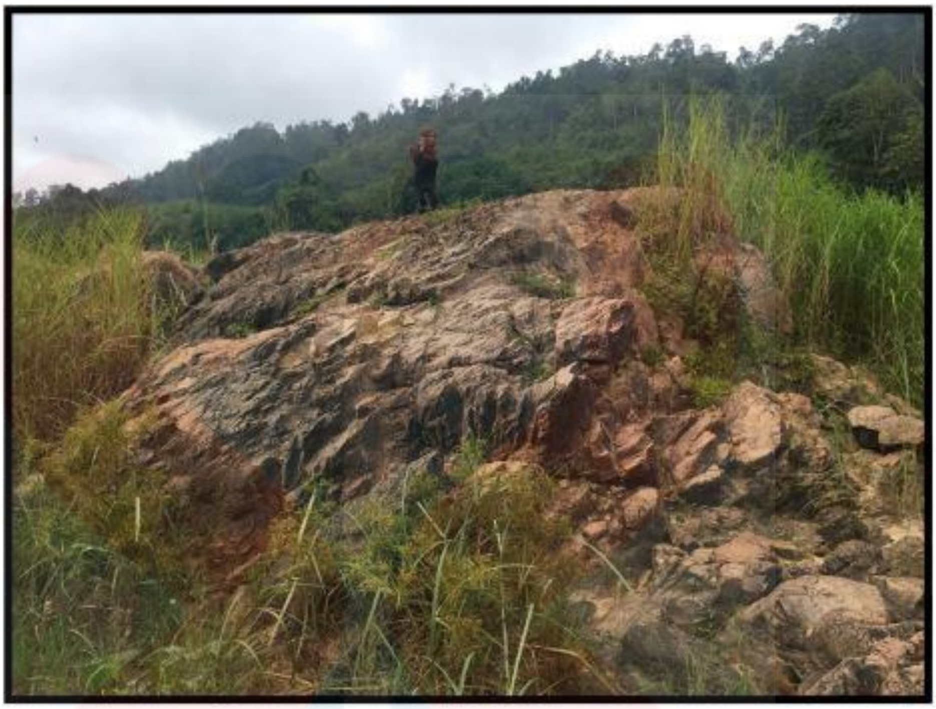

Figure 4.15: Ignimbrite at middle of Kelantan River, Kuala Krai, Kelantan

(Source: Halim N.A, 2017)

c) Interbedded sandstone, siltstone and shale

Based on the previous geological mapping carried out by Kamaruzaman M.F (2018), the outcrop and hand specimen of interbedded sandstone, siltstone and shale was found in this study area.

I. Sandstone

Sandstone is sedimentary rock consisting of sand sized grains of mineral, rock or organic material. It includes cementing material which holds the together the sand grains and may contain a matrix of silt or clay sized particles that occupy space between sand grains. From Figure 4.16 and Figure 4.17 in Kuala Krai Town, most of the sandstones have various shades of red due to the iron oxide and the colour like rust.

Figure 4.16: Sandstone sample taken from the study area (Source: Kamaruzaman M.F, 2018)

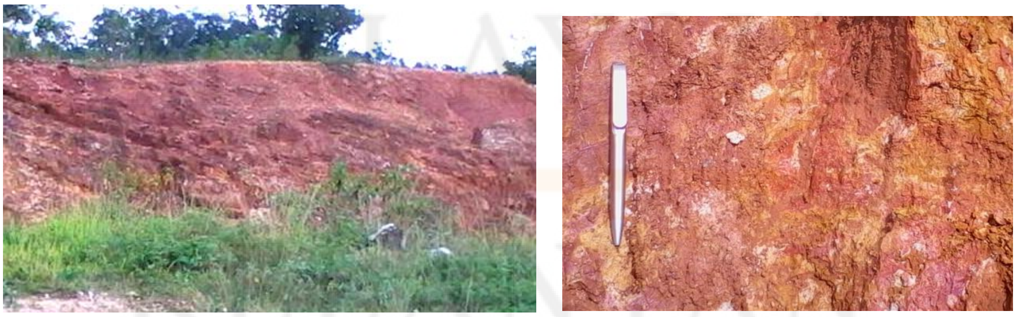

Figure 4.17: Sandstone found near Taman Sri Guchil (Source: Kamaruzaman M.F, 2018)

II. Siltstone

Siltstone is sedimentary rock that composed mostly of silt. It is a type of mudrock with a low mineral content of clay, which can be differentiated from shale by its lack of fissility.

Silt may occur as a soil (often mixed with sand or clay) or as sediment mixed in suspension with water (also known as a suspended load) and soil in a body of water such as a river. It may also exist as soil deposited at the bottom of a water body, like mudflows from landslides. Silt usually has a floury feel when dry, and a slippery feel when wet. Silt can be visually observed with a hand lens.

Siltstone is differentiated by having a major of silt, not clay. Based on Figure 4.1.8, the texture of this siltstone was very fine and same through the grain. The yellow brownish colour shows that the rock undergoes high rate of weathering.

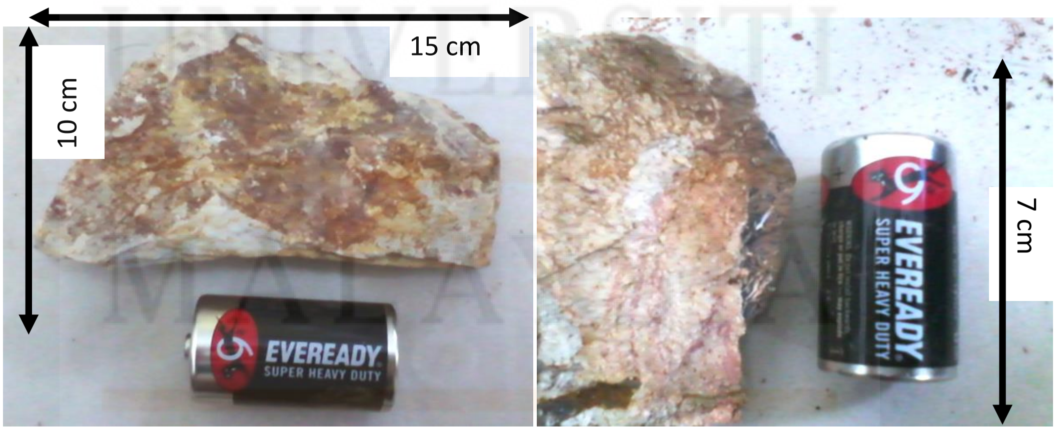

Figure 4.18: The sample of siltstone taken from study area (Source: Kamaruzaman M.F, 2018)

III. Shale

Shale is a fine-grained sedimentary rock formed by the compaction of silt and clay-size mineral particles that we know as mud. This composition puts shale in a grouping of sedimentary rocks knows as mudstones. Shale is distinct from other mudstones because it is fissile and laminate.

Based on previous geological mapping carried out by Kamaruzaman M.F (2018), mudstone was found in the area of Taman Sri Guchil which near to residential area. Mud rocks such as mudstone and shale have a major of 65% of all sedimentary rocks. Mudstone is seeming to be hardened clay depends on the occurrences it was formed, the cracks or fissures may occur too.

Figure 4.19: Sample of mudstone in the study area

(Source: Kamaruzaman M.F, 2018)

Based on Figure 4.19, the color of mudstone is grey to blackish color and the grain size is very fined and brittle.

4.4 Structural Geology

In this part, the detail analysis of lineament was carried out by using GeoRose software. Lineament is known as linear feature in a landscape which is an expression of an underlying geological structure such as a fault. It can interpret by using the topography and terrain map which it will appear as a structure of hills, valley, a straight coastline or indeed a combination of these features. The Figure 4.20 below shows the lineament interpretation of terrain map from Google maps.

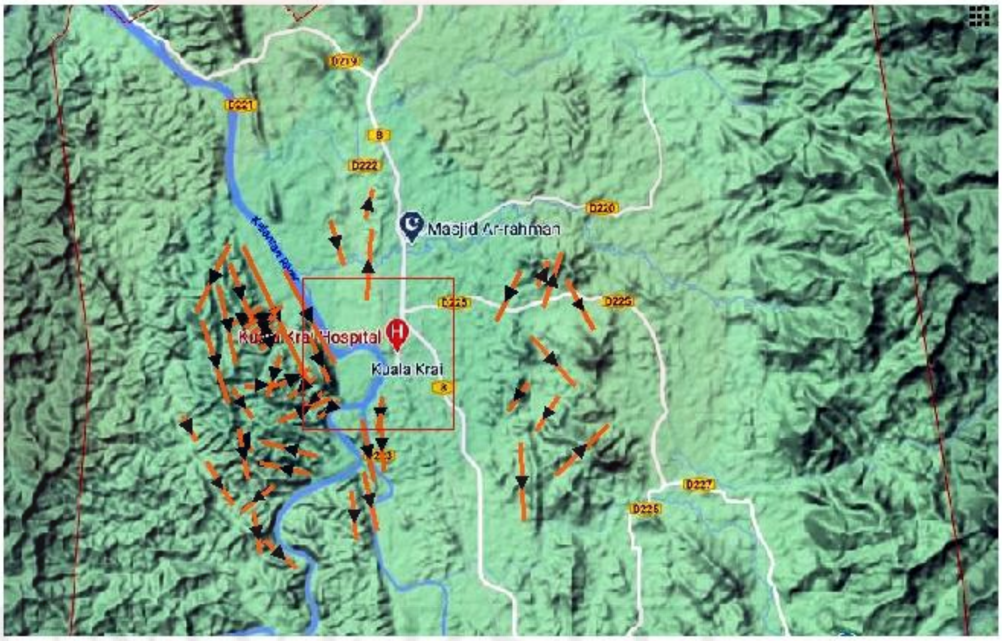

Figure 4.20: Lineament interpretation of terrain map from Google maps

Then, the data in lineament map was used to produce rose diagram that are shown in the Figure 4.21 below. From the rose diagram, the biggest forces are coming from the north-east and south west which is the longest petal of the rose diagram.

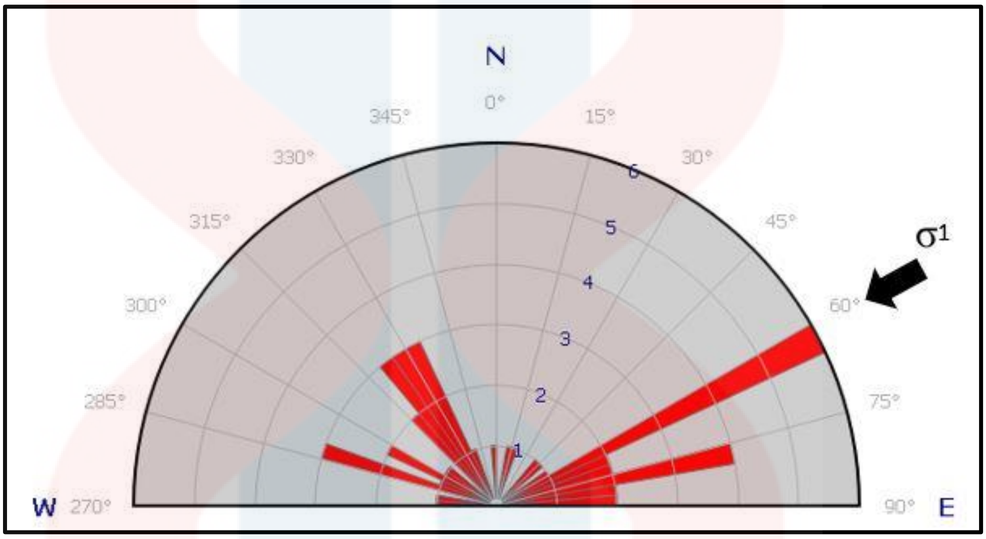

Figure 4.21: Rose diagram of the study area located at the north part

4.5 Historical Geology

From the study area, it can be said that the historical geology of this area is in the age of Permian, Triassic, Jurassic and Quaternary. This can be seen clearly from the stratigraphy of the Kuala Krai Town, Kuala Krai, Kelantan.

The locality of Kuala Krai is said as lower area or lower altitude which the major lithology of study area is received deposited material such as sand, silt and clay and the area is near to the resident's area such as Taman Sri Guchil.

Telong Formation consists of interbedded sandstone, siltstone and shale which these clastic sedimentary rocks deposited in shallow marine environment.

The Permian Taku Schist is conformably overlain by the Triassic Telong Formation it has been metamorphosed to medium grade metamorphic rocks.

CHAPTER 5

FLOOD HAZARD ANALYSIS BY USING GIS OF KUALA KRAI TOWN, KUALA KRAI, KELANTAN

5.1 Introduction

This chapter explained about the results produced which is flood hazard map of Kuala Krai Town, Kuala Krai, Kelantan. This map will show the results of flood zones area which is low, medium and high-water level by using Weighted Overlay Method in GIS software. There are few parameters will be focused on this chapter to make sure the flood hazard map can be produced.

In 1967, major flood had impact on Kelantan population with the estimation of 70% of the village , or nearly half of the state's population were affected. The largest flood was recorded during 2014, known as "tsunami-like disaster" in which 202,000 victims were displaced. This flood referred as "Bah kuning" due to the yellow-coloured flood because of its high mud content. The chronology of the flood in Kuala Krai began during 17th of December, 2014 and causing flash flood and forced 3390 people in the area.

5.2 The Causes of Flooding

Flooding can occur due to naturally floods or man-made floods. Natural floods are natural disaster and it usually happened when heavy rainfall, storm surge from a tropical cyclone, rapid snowmelt or tsunami in coastal areas. When the accident occurred, the ground becomes too saturated to absorb excess water. When the flood water already absorbed by the soil, the water starts to accumulate on the surface and spread out into the new areas. The flood also may occur when the soil is too dry and the water is hard to be absorbed by soil.

Secondly, man-made flood occurred due to the action by human especially in areas that developed by human where the natural resiliency of ecosystems has been lost. This flood can destroy many facilities, infrastructures, leads to loss of crops, to the spread of waterborne diseases, and affect human life. Floods can also disrupt industry, water supplies, transport, education, wastewater treatment and other economic activities.

In the study area, the major factor that cause the flooding in Kuala Krai, Kelantan is the raining heavily that naturally occur especially when northeast monsoon seasons within November to March time. The geological characteristic of the study area is one of the evidences that show the study area easy to increase the water level or flooding which is by looking at the geomorphology. The geomorphology of the Kuala Krai town, Kuala Krai, Kelantan divided into rolling, undulating and hilly elevation area. The geographical characteristic of the country also causes the influence of flooding to occur which the region adjacent to the coast of South China Sea.

Besides, the other factor that cause serious flooding in Kuala Krai, Kelantan because of unsystematic logging. It is due to the hills in the area become barren due to logging. This causes water to drain fast into rivers especially in Sungai Kelantan. Deforestation is play as important role in flooding by preventing the sediment runoffs and forest hold more water than farms or grasslands. This is because trees support rain into the soil when living and rotting roots make the soil porous by forming a network of well-connected, minuscule channels in the soil. Rainwater seeps into soil with such channels several hundred times faster than it seeps through soil without channels.

The volume of water flowing over the surface after raining occurred will decrease when there is land under tree cover that absorbing rainwater. Thus, the volume of water entering the river and streams decreases. There is an evidence of logging or land clearing cause worst flooding in Kelantan which the alluvial deposits as far 1000m from riverbanks seen post-flood, formation of acres of sandbars in Sungai Kelantan due to accelerated erosion upstream and many satellite images showing soil erosion from cleared forest. According to a study by the Institute of Infrastructure Engineering and Sustainable Management (IIESM) of Malaysia, rainfall increases when land clearing and logging activities affects the hydrologic cycle of rains.

Therefore, it is explaining flood in 2014 occurred when ten of thousands of hectares of forest cleared in the year causing about 40% of the annual rainfall came down within 10 days in the Kelantan region.

5.2.1 Rainfall Distribution

Rainfall distribution is important as an evidence to show the occurrence of floods occurring in the Kuala Krai Town, Kuala Krai, Kelantan. Kelantan occurring flooding annually especially November to March.

Figure 5.1 below shows the information of rainfall distribution at the rain measure stations obtained from Portal of Department of Irrigation and Drainage which this data shows evidence of the cause of floods is due to heavy rain. This rainfall data was recorded in all 13 centers across Kelantan in December 2014 which starting from 17 December to 25 December 2014, indicates rain down continuously in that period. From the duration, the highest total of rainfall distribution recorded from all 13 stations on 17 December 2014 with the amount 2596 mm and the highest rain measure station is at Klusial Tanah Merah station by 414 mm.

Analisis Sukatan Turunan Hujan di Pusat-pusat Sukatan Turunan Hujan Negeri Kelantan, 17-25 Disember 2014														
	Gua Musang		Kuala Krai	Gua Musang	Jeli	Kuala Krai			Tanah Merah	Kota Bharu	Tanah Merah	Pasir Mas	Pasir Puteh	Jumlah
Tarikh	Gunung Gagau	Kg. Aring	Kg. Laloh	Gua Musang	Kg. Jeli	Dabong	Tualang	Kuala Krai	Kusial	Jeti Kastam	Jenob	Rantau Panjang	Pasir Putih	
17/12/2014	164	135	121	85	192	146	127	140	414	223	291	273	285	2596
18/12/2014	71	47	52	7	74	33	45	48	58	101	77	51	77	741
19/12/2014	40	19	1	1	20	12	2	10	22	3	6	1	44	181
20/12/2014	36	19	17	13	106	24	16	38	121	84	110	58	105	747
21/12/2014	302	128	77	65	70	78	82	78	99	32	96	59	23	1189
22/12/2014	478	294	208	212	130	243	227	155	83	12	70	20	29	2161
23/12/2014	515	13	0	116	39	154	164	24	27	5	46	13	4	1120
24/12/2014	159	0	0	0	160	101	112	211	261	40	181	77	60	1362
25/12/2014	32	0	0	0	60	0	8	22	18	6	15	17	10	188
*** sumber: Portal e-Banjir Negeri Kelantan.														

Figure 5.1: Rainfall distribution at the rain measure stations

(Source: Portal of Department of Irrigation and Drainage, 2015)

Then, the rainfall data from 2015 until 2020 was obtained from Jabatan Pengairan dan Saliran (JPS) which includes the nearest station of Kuala Krai Town area. There were two stations that available in the study area which is at 5521050 Ladang Kuala Nal and 5522047 Sek. Men. Teknik Kuala Krai. These two stations contain rainfall information starting from 2015 to 2020.

From the rainfall distribution data obtained from Jabatan Pengairan dan Saliran (JPS) in Figure 5.2, Figure 5.3, Figure 5.4, Figure 5.5, Figure 5.6, and Figure 5.7 from 2014 until 2020, this data shows that monsoon season occurred annually in Kelantan area especially in Kuala Krai, Kelantan due to the geographical factors which is near to the Kelantan River. When the large rivers cannot hold abundant runoff of heavily raining, the capacity of the river is not enough and floods will occur.

Besides, the study area is located in settlement and town area which it is rapid uncontrolled development area. Widespread land and uncontrolled logging activities cause infiltration of water decrease. Then, it will runoff directly to the rivers. Even the land clearing was used for cultivation of oil palm or agricultural crops, the effect of this activities especially in high area will affect soil erosion when raining.

1. Station: Ladang Kuala Nal (5521050)

Figure 5.2 below shows the rainfall distribution data at Ladang Kuala Nal in 2015 which the daily heavily raining in this area started from November to December with the highest value of 152.5 mm compared to the other month which the rainfall distribution around 0 mm until 30 mm.

Year 2015												
Site 5521050 Ldg. Kuala Nal												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		0	0	0	0	0	0	6.5	0	0	0	4
2	?	0	0	0	0	1	0	24.5	0	5.5	10.5	0
3	?	18.5	0	0	0	2.5	19.5	19.5	0.5	0	12	6.5
4	?	1	0	0	0	0	0	0	7.5	0	29.5	0
5	?	0	0	0	0	0	0	21.5	24.5	0	6	0
6	?	1	0	0	0	0	2	4.5	0	0	2.5	12
7	?	0	0	0	0	0	0	0	7	11	1	9.5
8	?	0	0	0	0	0	15.5	3	13	0	2	0.5
9	?	0	0	0	0	0	12	8.5	28.5	17.5	1	2.5
10	?	0	0	0	2.5	0	1	12.5	0.5	0	0.5	0.5
11	?	0	0	21.5	0.5	4	0	2	11.5	0	6	1
12	?	0	0	0	0	58	0	8.5	1.5	2.5	1	3.5
13	?	0	0	0	0	35	6.5	0	0.5	0	0.5	0
14	?	0	0	32.5	24	34.5	0	13	0	0	7	2.5
15	?	0	0	2.5	0	9	0	0	0	0	4	0.5
16	?	0	0	0	45	1	0	0	0	3.5	1.5	0
17	?	0	0	0	0.5	0.5	0	0	0.5	0	8.5	81.5
18	?	0	0	0	0	0	0	11	0	29.5	0.5	11.5
19	?	0	0	2	0	0	0	6	0	0	16	0
20	0	0	0	0	7	0.5	0	0	0.5	0	2.5	0
21	0	0	0	0	0	1	3	0	0	?	23	3.5
22	0	0	0	0	5	0	0	21	53	0	2.5	0
23	0	0	0	0	0	0	0	7.5	0	0	0	7.5
24	0	0	0	0	13	0	0.5	27.5	12.5	0	3.5	0
25	0	0	?	0	22	0	14.5	0	2	0	0.5	4
26	0	0	0	0.5	0	0	8.5	6.5	3	0	16.5	9.5
27	0	0	0	4.5	2.5	0	0.5	0	3	8	75.5	152.5
28	0	0	0	0	0	0	0	0	0	27.5	20.5	57
29	0.5		0	0	0	7	3.5	14.5	10	3.5	6.5	0
30	1		8	5.5	0	0	0	5	0	4	15	0
31	0		8.5		23		28.5	0		2		27.5

Figure 5.2: Rainfall distribution at Ladang Kuala Nal of 2015

(Source: Portal of Department of Irrigation and Drainage, 2020)

Figure 5.3 shows the continues of the heavy rainfall event from November 2015 to 2016. Usually, the monsoon season occurred within November to March but in Figure 5.2, rainfall distribution data in January and February 2016 is not too high compared to November and December of 2015 which it shows around 0 mm to 20 mm. When started in November and December of 2016, these two months shows the increasing of rainfall data which are 38.5 mm in November and 153.5 mm in December.

Year 2016												
Site 5521050 Ldg. Kuala Nal												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	10.5	0	0	0	0	0	0	0	0	0	0	70.5
2	0.5	17	0	0	0	48.5	0	0	1.5	0	9	12.5
3	0	12	0	0	0	0	0	0	0	0	38.5	8
4	0	14.5	0	0	1.5	0	0	0	18.5	56	3.5	2.5
5	0	12	0	0	0	0	3.5	2	0	0	29.5	0.5
6	0	32	0	0	0	27.5	1.5	0	0	0	0	2.5
7	0	1	0	0	0	0	0.5	3	0	50.5	0.5	2
8	0	0.5	0	0	20.5	6	0	0	0.5	36	0	2.5
9	1	0	0	0	0	11.5	0.5	0.5	10.5	0.5	25	0
10	0	0	0	0	0	2.5	0	8	0	5.5	3.5	2
11	0	0	0	0	0	9	6.5	4.5	0	0	26	0.5
12	0	9.5	0	0	0	0	5	38	3	0	8.5	0
13	0.5	4	0	0	0	0	2.5	1.5	0	0	6.5	18
14	5	0	0	0	0	33.5	0	0	56	5.5	1	0
15	1.5	4.5	0	0	3.5	3.5	0.5	0	30	0	17	0
16	0	0	0	0	1	1	19	6.5	0.5	0	9.5	0.5
17	0	2	0	3	0	23.5	0.5	0.5	26.5	0	14.5	0.5
18	0	5.5	0	0	9	0	3.5	0	0	1.5	0.5	1.5
19	0	1.5	0	0	0.5	0	2.5	0.5	11.5	0	6	41.5
20	0	0	0	1	17.5	0	0	0	0	22.5	11	12.5
21	11	0	0	0	0	3.5	2.5	0	15	38	0	1.5
22	11.5	0	0	0	0	0	0	0	0.5	3	0	11
23	0.5	0	0	0	0	3	0.5	0.5	1.5	0.5	0	37
24	1.5	0	0	0	0	2	1.5	2	0.5	0	5	12
25	17.5	2	0	0	0	0	7	0.5	11.5	0	0	0
26	12.5	3.5	0	0	0	25	5	1.5	0	29.5	25	6
27	3.5	15.5	2	0	5	0	?	13.5	0	0	23	6
28	7	12	0	0	41	0	2	2.5	0	9	10	20
29	0.5	0	0	0	5.5	1	0	0.5	0	0.5	13	0.5
30	0		0	0	3	3	0	1	0	2	3.5	153.5
31	0		0		13.5		0	0		15		81

Figure 5.3: Rainfall distribution at Ladang Kuala Nal of 2016

(Source: Portal of Department of Irrigation and Drainage, 2020)

In 2017, the Ladang Kuala Nal station recorded the highest rainfall distribution in early year which is in January with 150.5 mm in the date of 21 January 2017 and at the end of year which is November 2017 with 143 mm as shown in Figure 5.4 below. Usually, the monsoon season started from November to March, but the rainfall data for December 2017 is not higher compared to 2015 and 2016. In other months, only several days that raining was occurred.

Year 2017												
Site 5521050 Ldg. Kuala Nal												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	74.5	0	3	20	0.5	0	10.5	68	0	0	?	15.5
2	119.5	0	9	79	0	12	2.5	0.5	0	15.5	?	5.5
3	36	0	0	6.5	0.5	40.5	19	0.5	0	0	?	0.5
4	10	16.5	0	6.5	0	0	3.5	0	0	2.5	?	40
5	13	0	0	2	0	4.5	19.5	0	0	0	?	8
6	44	0	0	0	6.5	3	0	2	0	0.5	?	0
7	0.5	0	0	3.5	0.5	1.5	22.5	0	0	0	?	59
8	5.5	0	0	0.5	0	0.5	37.5	0	4.5	0	?	4
9	0	0	0	3.5	2	4	0	2	0	26.5	?	3
10	0	3	0	0.5	0.5	0	4	3	19	1.5	?	0
11	0	0.5	0	0	0	15.5	49.5	9	20.5	0.5	?	0
12	0	7	0	0	0	0	1	8.5	0	36	?	0
13	0	0.5	0	0	1.5	0	0	20	28	0	?	0
14	0	10	0	0	12	28	0	53	6.5	0	?	0
15	0	1.5	0	0	0	0.5	0	5.5	74	0	?	0
16	0	0	0	0	0	0	0	8.5	0	0	?	0
17	3.5	0	0	0	0	0	0	0	0	0	?	0
18	11.5	13.5	0	0	34	26.5	0	0	0	0	?	3
19	40	1.5	0	0	20.5	3.5	0	0	0	16	?	0
20	62	0	3	0	0	5	0	0	1	0	?	2
21	150.5	0	22.5	0	8.5	4.5	0	3	2	0	?	2.5
22	10	0	0	5	0.5	0	48	6.5	9.5	14.5	0.5	8
23	23.5	8	0	0	43.5	0	13	1.5	0	2	4	10.5
24	65.5	0.5	0	54	3.5	19	0	3	0	0	14.5	0
25	38.5	1	0	0	0	4	10	27	9	0	27.5	1
26	80	25	25	3.5	0	17	0.5	32.5	19	0	57.5	0.5
27	0.5	1.5	3.5	0	1	1.5	0	0.5	0	0	143	2.5
28	0	4	10	0	2	0	0	2.5	37	5	80	19.5
29	0		6	0	35.5	19.5	44	0	4	?	4.5	12.5
30	0		0	0	0	0	17	0	4	?	40.5	5.5
31	0		0		20.5		1	0		?		19.5

Figure 5.4: Rainfall distribution at Ladang Kuala Nal of 2017

(Source: Portal of Department of Irrigation and Drainage, 2020)

Based on Figure 5.5 below, rainfall distribution in 2018 shows the highest value in December with 98.5 mm while the second highest is 95 mm which only on 1 May 2018. Next, 1 January 2018 shows the third highest data with 80.5 mm while the lowest rainfall distribution data is in February 2018 which is about five days only rains had occurred.

Year 2018												
Site 5521050 Ldg. Kuala Nal												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	80.5	0	0	0	95	25.5	1	0	27	0	27	14.5
2	19	0	0	0	1	0	0	0	0	0	33	18
3	12.5	2	0	0	0	1.5	0	0	61	0	4.5	9
4	0	0	0	0	0	0	0	0	10	0	8.5	25
5	4	0	0	0	0	0	0	0	0	0.5	42.5	23
6	0.5	0	0	0	9.5	0	0	0	2.5	1.5	21.5	14
7	0	0	13.5	16.5	21	34	11.5	0	4.5	10	1	0.5
8	0	0	0	2.5	0	0.5	13.5	0	0	15.5	16	0
9	0	0	4.5	1.5	0	0	26	6	15.5	26.5	0	2.5
10	10	0	0	11	0	4.5	0	0	2.5	3	0	5.5
11	6.5	0	0	25	0	3.5	?	0	4	5.5	0.5	45.5
12	26	0	0	0	0	0	0	0	0.5	4	0.5	98.5
13	7	4	0	0	0	0	0	0	7	0	0.5	24
14	3.5	0	0	24.5	0	0	0	0	26.5	0.5	13.5	20.5
15	0	0	3	0	1.5	0	0	0	0	0	0	52.5
16	4.5	0	3.5	0	0	0	0	0	0.5	0	0	10.5
17	0	0	0	0	0	10.5	2.5	0	32	19	6	25.5
18	0	0	0	0	0	0.5	1	0	0	3	0	2.5
19	5	0	0	0	15.5	0.5	0	13.5	6.5	10	2	1
20	13.5	0	0	0	2.5	28.5	3	27	0	0	20.5	0.5
21	1.5	0	0	0	3	34.5	0.5	8	0	2	0	0
22	1	0	0	0	5.5	0.5	0	18	0	0	0	0
23	11	28	18.5	0	0	21.5	16.5	0	4	0.5	0	0
24	0	1	0.5	0	0	0	5	0	0.5	9	0	0
25	15.5	0	0	7.5	0	10	57.5	4	1	2.5	12	0
26	0.5	0.5	0	4	2	0.5	77.5	0	0	0	?	0
27	0	0	?	0	0	0	4	0	0	2	0	39
28	0	0	0	1.5	0	0	24	4.5	0	0	10.5	0
29	2		0	9	35	49.5	46	0.5	0.5	2.5	17.5	0
30	0		0	0	0	0	0	4.5	0	1.5	26.5	0
31	0		0		16		0.5	33.5		2		2

Figure 5.5: Rainfall distribution at Ladang Kuala Nal of 2018

(Source: Portal of Department of Irrigation and Drainage, 2020)

Figure 5.6 shows rainfall distribution in 2019 which the highest value is 171.5 mm in December. From the data below, it can be seen the heavily rainfall that occurred almost every day is started from September until December 2019. The rainfall distribution in January 2019 is high in the early month which it continuously rain starting from day one until day 18 while it started to slow in day 19.

Year 2019												
Site 5521050 Ldg. Kuala Nal												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	10	0	0	29	0	20.5	0	0	1	0	0	171.5
2	12.5	0.5	0	12	0	6	0	0	5	0	53.5	6.5
3	20.5	7	0	?	0	0	0	0	5	12	5	3
4	42.5	0	0	0	1	2.5	0	0	24.5	0.5	14	0.5
5	0	0	0	0	0.5	32	0	0	0	0	4.5	0.5
6	5	0	0	0	0	24.5	38.5	0	1	2	19.5	0.5
7	2	0	0	1	0	0	0	0	0	5.5	0.5	9
8	1.5	5	0	0	0	8.5	0	0	7.5	2	14.5	10.5
9	10.5	0	0	0	0	0	0	0.5	3.5	0	5.5	0.5
10	2	0	0.5	0	0	0	0	0	0	33	17.5	0
11	1.5	0	0	0	0	4.5	0	49.5	2.5	3	3	0.5
12	14.5	5	0	0	0	0.5	4.5	0.5	2.5	1	3	?
13	0.5	30	0	0.5	7	0	6.5	2	19	0.5	13	5
14	0	0	0	2.5	1	37	20.5	12.5	11	4.5	0.5	22.5
15	0	0	0	0	0	0	0	22.5	0	0	6.5	15.5
16	17.5	0	0	0	0	5	12	0	49.5	0	1.5	11.5
17	24	0	0	0	0	32.5	0	13.5	7	4.5	0	96.5
18	3	0	0	0	6	4.5	44	0	9	0	0	37
19	0	?	0	0	0.5	0	0	0	0	3	9.5	0.5
20	0	0	0	0	0	4	0	9	0	0	2	2.5
21	0	0	0	0	0	4.5	0	0.5	0.5	0.5	19.5	0
22	0	0	0	0	0.5	19	0	0	0	5	22.5	0
23	0	0	0	4.5	0	3.5	0	1.5	0.5	4.5	0	0
24	0	0	0	0	1.5	0	0	21	2	2	10	0
25	0	0	0	0	0	21	0	1	2.5	0	2	0
26	0	0	0	0	0.5	0	0	0	3.5	0.5	19	0
27	0	0	0	56.5	0	0	42.5	2	0	0.5	22.5	0
28	0.5	0	0	0	0	0	0	0.5	1.5	3.5	54	0
29	0.5		0	8	0	0.5	0	1.5	0	2.5	61.5	0
30	0		37	5	0	0	9	0	0	20	68.5	0
31	0		33		19.5		0	0		5		1.5

Figure 5.6: Rainfall distribution at Ladang Kuala Nal of 2019

(Source: Portal of Department of Irrigation and Drainage, 2020)

In 2020, the rainfall distribution data that can be obtained from Jabatan Pengairan dan Saliran only from January to Jun as shown in Figure 5.7. From this period, the rainfall data in Station of Ladang Kuala Nal shows that the most occurrence of rain is in June month with the highest value of 70 mm. The lowest occurrence of rain is on March where only four days that occurred a raining day.

Year 2020						
Site 5521050 Ldg. Kuala Nal						
Day	Jan	Feb	Mar	Apr	May	Jun
1	4.5	1	0	0	6	0.5
2	5.5	0	0	12	2.5	3.5
3	0.5	0	0	0.5	0	0
4	0	0	0	0	0	0.5
5	1	0.5	0	3	0	27.5
6	0.5	0	0	0	0	1.5
7	15	0	0	0	0	53
8	2	0.5	0	0	0	5.5
9	0.5	10	0	0	0.5	70
10	0	79	0	0	24	0.5
11	0	5	0	0	1	0
12	?	42	0	0	1.5	36
13	0	5	0	0	0	0
14	0	0	0	0	1	0
15	0	0	4.5	0	0	0.5
16	0	0	0	0	0	0
17	21.5	21.5	0	4.5	0	3
18	3.5	3	0	0.5	0.5	11
19	8	0	0	0	1.5	19.5
20	2.5	0	0	2.5	17.5	2
21	1	3.5	0	1	0	0.5
22	1.5	1.5	10	8	0	5
23	0	9	0.5	10	3	0
24	0.5	0.5	0	0	0	1
25	0	0	0.5	11	3.5	5
26	0	0	0	1.5	0	6.5
27	0	0	0	4.5	0	0
28	0	0	0	2.5	0	0
29	0	0	0	8	20.5	0
30	0		0	1	2.5	0
31	0		0		33	

Figure 5.7: Rainfall distribution at Ladang Kuala Nal of 2020

(Source: Portal of Department of Irrigation and Drainage, 2020)

From all data of rainfall distributions from Figure 5.1 until Figure 5.7 above, it can be concluded by making an average rainfall distribution graph data of Station of Ladang Kuala Nal as shown in Figure 5.8 below. From the graph in Figure 5.8, the highest rainfall distributions in this station are during November and December months which this month is starting of northeast monsoon season in the Kelantan region.

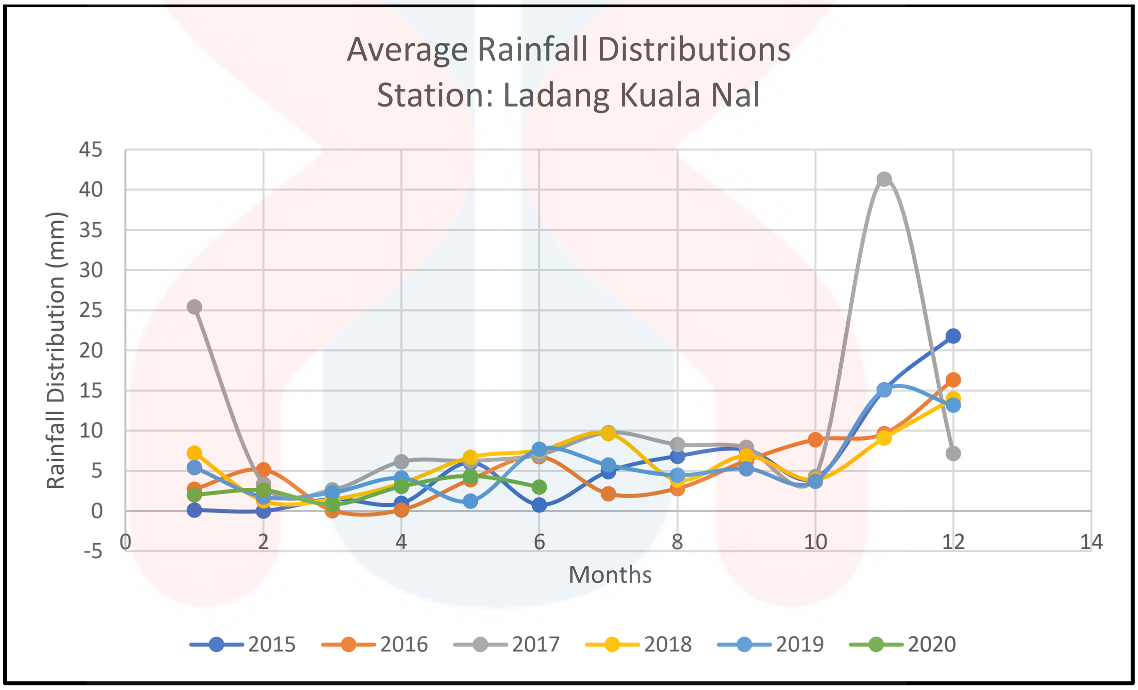

Figure 5.8: Average rainfall distributions at Ladang Kuala Nal of 2015-2020

2. Station: Sek. Men. Teknik Kuala Krai

Second station that near with the Kelantan River is at Sek. Men. Teknik Kuala Krai. Therefore, rainfall distribution data was obtained from Jabatan Pengairan dan Saliran (JPS) to know the increases or decreases of rainfall from year to year as shown in Figure 5.9 until 5.14. Based on Figure 5.9 below, the station of Sek. Men. Teknik Kuala Krai shows the highest rainfall distribution with 178.5 mm while the lowest rainfall distribution data is February.

Year 2015												
Site 5522047 Sek. Men. Teknik Kuala Kerai												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		0	0	0	0	0	0	0	0	0	0	3.5
2	?	0	0	0	0	0	0	22	0	14.5	27	7
3	?	11	0	0	0	10.5	35.5	11	0	0	17.5	18
4	?	1.5	0	0	0	0	0.5	0	1.5	0	64	0.5
5	?	1	0	0	0	0	2.5	14.5	3.5	0	17.5	0.5
6	?	3	0	0	0	0	2.5	5.5	0	3	7	16
7	?	0	0	0	0	0	0	33	0.5	0	2	20
8	?	0	5.5	0	2	0.5	0	12	5.5	0	6	3.5
9	?	0	0	0	0	0	3.5	12	14.5	38	0.5	26
10	?	0	0	0	0	0	4	4.5	0	0	0.5	0.5
11	?	0	0	0.5	0	32	1.5	0.5	12	0	11.5	0
12	?	0	0	0	0	48.5	0	8.5	0	0	2.5	17
13	?	0	0	0	0	4.5	6	0	0	0	3	1
14	?	0	0	21	59	20	6	0.5	0	0.5	0	4
15	?	0	0	8	0	5	0	0	0	0	10.5	0
16	?	0	0	0	56.5	2	0	0	2	0	0.5	0
17	?	0	0	0.5	0.5	0	0	0	0	0	11	82
18	?	0	0	0.5	0	0	0	2.5	0	11.5	0.5	13
19	?	0.5	0	0.5	0	2.5	0	1.5	7.5	0	8	0
20	?	0	0	0	4.5	0	0	0.5	0	0	8	0
21	?	0	0	0	0	0	0.5	0	4	?	26.5	0
22	0	0	0	0	5.5	0	4.5	7	8	0	3.5	0
23	0	0	0	0	0	0	0	26.5	0.5	0	0	15.5
24	0	0	0	1	0.5	0	5	12	30.5	0	3.5	0.5
25	0	0	0	0	8	0	1	0	0.5	0	9.5	0
26	0	0	0.5	4.5	0	0	3	24.5	30.5	1	14	10.5
27	0	0	0	5	3	0	0	0	31	9	64	178.5
28	0	0	0	0	0	0	0	0	0.5	13.5	21.5	85.5
29	5.5		13	0.5	0	0	37	29	1	6.5	10	0
30	0		35.5	52	0	0	0	13.5	0	8	17.5	0.5
31	0		1.5		0		41	0		1.5		31.5

Figure 5.9: Rainfall distribution at Sek. Men. Teknik Kuala Krai of 2015

(Source: Portal of Department of Irrigation and Drainage, 2020)

From Figure 5.10, the rainfall distribution data cannot be determined in November and early December. But, at the end of December month, the rainfall distribution shows highest amount which is 188.5 mm. The lowest rainfall distribution can be seen in March where the study area only had raining one day in that month which is on 27 March 2016.

Year 2016												
Site 5522047 Sek. Men. Teknik Kuala Kerai												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	9.5	0	0	0	0	0	0	0	0	0	?	?
2	0	6.5	0	0	0	49.5	0	0	6	0	?	?
3	0	10	0	0	0	0	0	0	0	0	?	?
4	0	21.5	0	0	0	0.5	0	0	9.5	41.5	?	?
5	0	10.5	0	0	5.5	0	12	1.5	0	0.5	?	?
6	0	22.5	0	0	2	44.5	0.5	0	0	0.5	?	?
7	0	2	0	0	9	0	16	0	0.5	44	?	?
8	0	0	0	0	0	0.5	0.5	0	1.5	13	?	?
9	0	0	0	0	2.5	4	0	1	21	0	?	?
10	0	0	0	0	0	1	0	10	0	0	?	?
11	0	0	0	0	0	2.5	13	6.5	0	?	?	?
12	0	14	0	0	1	0	6.5	3.5	5	0	?	?
13	2	1	0	0	0	0.5	9.5	16.5	0.5	0	?	?
14	8.5	0	0	0	10.5	26.5	0	0	11	9	?	?
15	2	13.5	0	0	4.5	1	0	0	7.5	0	?	?
16	0.5	0.5	0	1.5	0	0	20	15.5	0.5	0.5	?	?
17	0	0	0	1	0	34.5	0	3	4.5	0	?	?
18	0	2	0	0	6	0	10	0.5	0.5	18	?	?
19	0	1	0	0	0	0	22	0	17	0	?	?
20	0	0	0	?	8	0.5	0.5	0	0	36.5	?	1
21	18.5	0	0	0	0	4	0	0	10	?	?	0
22	15.5	0	0	0	0	0.5	1	0	0	?	?	10
23	1	0	0	0	0	0	0.5	0	0.5	?	?	28.5
24	0	?	0	0	0	1.5	2	5	0	?	?	14
25	15	0	0	0	0	0	9.5	3	0	?	?	0.5
26	7.5	4.5	0	0	0	7.5	6	2.5	0	?	?	9.5
27	3	14.5	1	0	11	0	1	21	0	?	?	2.5
28	2.5	1	0	0	53	0	8	4	1.5	?	?	2.5
29	0	0	0	2.5	5.5	1	0	0	0	?	?	1
30	0		0	0	9.5	0	0	0.5	0	?	?	188.5
31	0		0		38.5		0	0		?		80.5

Figure 5.10: Rainfall distribution at Sek. Men. Teknik Kuala Krai of 2016

(Source: Portal of Department of Irrigation and Drainage, 2020)

Figure 5.11 below shows rainfall distribution in year 2017 starting from January to December. The highest amount of rainfall distribution is 148 mm in 27 November while the lowest rainfall distribution occurred in February 2017 which the amount of rainfall in a range of 0 mm to 15 mm.

Year 2017												
Site 5522047 Sek. Men. Teknik Kuala Kerai												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	86.5	0	1.5	28	0.5	0	0	41	16.5	0.5	1	14.5
2	93.5	0	4	94	0	10	0	0	0	19	0	8.5
3	34.5	0.5	0.5	6.5	1	42	8.5	1	0	0	9.5	4
4	4.5	8.5	0	13.5	0	0	6.5	0	0	1	13	36.5
5	16.5	0.5	0	0	0	6	42	0	0	16	77.5	17
6	57.5	0	?	0	11	0.5	4.5	21.5	0	0	9	0
7	27	0	0	0	?	0	9	0	0	7.5	41.5	46.5
8	0	0	0	0	0	0	28.5	0	1.5	0.5	43	4.5
9	0	?	0	4	52	22.5	2	6	0	28	1	0.5
10	0	1.5	0	0.5	0	0	?	3.5	22	20.5	0.5	2.5
11	0	0	0	0	0.5	72	23.5	9	31.5	0	9.5	?
12	0	5	0	4.5	0	0	0.5	46.5	0	46.5	1	0
13	0	3	0	2	5	0	0	0	22.5	0	0	0
14	0	12	0	0	15.5	0	0.5	76	1	0	2.5	0
15	0	3	0	0	0	0	0.5	5.5	23.5	0	0	0
16	0	0.5	0	0	0	0	0	13	0.5	0	6	0
17	10.5	1	0	0	1	0	0	0	0	0	5	12
18	17	13	0	0	7	4	0	0	2	0	0	4
19	56	0.5	0	0	52	3	2	0	0.5	25	0	0
20	64	0	1.5	0	0	6.5	0	1	1	0	0	0.5
21	120	0	17.5	0	45	3.5	0	3.5	0	0	0	4.5
22	20.5	0	0	0	1.5	0	38.5	10	0	9	0.5	19
23	33	2	0	0	11.5	0	0.5	3.5	0	0.5	6.5	18
24	87	0.5	0	21.5	5.5	28	0	2	0	1	27	0
25	32.5	3	0	0.5	0	0	21.5	29.5	0	0.5	29.5	19.5
26	72	14.5	0	0.5	3.5	19	0	26	53	0	53	0.5
27	0.5	1.5	1.5	0.5	0	0	0	0	0	0	148	0.5
28	0	15	14	0	1	0	0	16	2.5	5.5	91.5	13.5
29	0		1	2	18.5	28.5	17.5	0	11.5	1.5	15	35
30	0		2.5	2.5	0	0	12.5	0	7.5	1	40.5	12.5
31	0		0		1.5		1	0		6		13.5

Figure 5.11: Rainfall distribution at Sek. Men. Teknik Kuala Krai 0f 2017

(Source: Portal of Department of Irrigation and Drainage, 2020)

Figure 5.12 below shows the rainfall distribution in year of 2018 which the amount of rainfall distribution not higher as previous year where the amount in range of 0 mm to 50 mm. The higher amount of rainfall distribution is in January and May with 88.5 mm and 100 mm respectively.

Year 2018												
Site 5522047 Sek. Men. Teknik Kuala Kerai												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	88.5	?	0	0	100	14	3	0	11	2	34.5	27
2	18.5	1.5	0	0	7	0	0	0	0.5	0	34.5	23.5
3	18.5	0	0	0	0	0	0	0	30	0	10	10.5
4	0	0.5	0	0	0	0.5	0	0	1	6.5	15	19.5
5	9	0	0	0	0	0	0	0	0	7.5	38.5	15
6	1.5	0	31	0	17.5	0.5	0	0	2.5	0.5	24	12
7	0	0	4	30.5	3.5	0	2.5	0	12.5	9	0.5	20.5
8	0	0	0	2	0	0.5	7	0	0	13.5	2	0
9	0	0	15	11	0	0	10	0	25.5	64	0.5	3
10	7.5	0	0.5	10.5	0	26.5	?	0	11.5	0.5	0	1
11	5.5	0.5	0	25	0	7	0	0	1	7.5	0.5	13
12	33.5	0	0	0	0	0	0	0	0	9	2	67
13	13	2	0	0	10.5	0	0	0	20	0.5	6.5	14
14	2.5	1.5	?	3	0	0	0	0	21.5	0.5	12	18.5
15	0	0	0	0	0	0	0	0	0	0	2.5	51.5
16	0	0	1	0	0	0	0	0	10.5	0	0	12
17	0	0	0.5	0	0	30.5	0	0	34	8	11.5	26.5
18	0	0	0	6	0	0	2	0	0	16.5	0	3.5
19	6.5	1	0	0	7.5	0.5	0	4	4	35.5	0.5	1.5
20	18	0	0	0	0	15	4	11	0	0	27.5	?
21	2	0	0	0	6	4	0	6	0	2	0.5	0
22	0	2	0	0	2.5	0	0	9	0	0	0	0
23	3.5	28	12	0	1.5	46.5	1.5	0	3.5	0	0	0
24	0	0	0	?	0	0	5	1	0	8	0	0
25	0	0	0	0	0	14	0.5	17	0	0	10.5	0
26	0	0	0	24.5	15.5	0	22	0	0	5.5	2.5	0
27	1	0	0	0	0.5	0	1.5	0	0	4	0	37.5
28	0	0	0	10.5	0	0	29	4.5	0	0	1	0.5
29	1		0	5	71.5	24	30.5	12.5	0	1	20.5	0
30	0		0	0	0	0	0	0	0	5	20	0
31	0		0		17.5		1	15		13		4.5

Figure 5.12: Rainfall distribution at Sek. Men. Teknik Kuala Krai of 2018

(Source: Portal of Department of Irrigation and Drainage, 2020)

Rainfall distribution in 2019 in Figure 5.13 below shows the highest value from 28 November until 17 December 2019 which in November there are 76 mm while 183 mm in December month. At the end of December, the rainfall distribution showing the 0 mm in the study area so that the water level of the river might not increase rapidly. The lowest rainfall distribution can be seen in February month where the raining only occurred in a few days which is about seven days only.

Year 2019												
Site 5522047 Sek. Men. Teknik Kuala Kerai												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	10	3.5	0	33	0	25	0	0	2	0	0.5	183
2	16	2	0	12	0	35	0	0	0.5	0	2	18
3	22	8.5	0	0	0	0	0	0	1.5	0	2	2.5
4	1	0	0	0	0.5	40	0	0	0.5	1	2	0.5
5	0	0	0	0	0	19.5	0	0	0	0	2	0.5
6	2.5	0	0	0	1.5	10.5	12	?	0	0	17	1
7	0	0	0	9	0	8.5	0.5	0	0	7	0	4.5
8	25	10	0	0.5	0.5	6.5	0	0	0	2	11	10.5
9	31.5	0.5	0	0	0	0	1.5	1.5	0	7	5	1
10	2.5	0	0.5	0	0	0	0	0	0	4	12	0
11	2	0	0	0	0	16	0	31	0.5	21	1	0
12	11.5	5	0	3.5	0	0.5	0	0	0.5	0	5	0
13	0.5	18	0	0	18	?	5	0	16.5	1	4.5	3.5
14	0	0	0	6	0	21	36	0	11.5	2	6	15
15	0	0	0	0.5	4	0	0	19	0	0.5	18	14.5
16	14	0	0	0	5	5.5	6	0	45.5	5.5	0	20
17	10	0	0	0	1.5	20	0	24.5	11	6	0	68.5
18	5.5	0	?	0	0	6.5	0	0	6	1.5	0	26
19	0	0	0	0	0	0	0	0	0	7.5	0.5	1
20	0	0	0	0	0	14.5	0	2.5	3.5	6.5	2.5	2
21	0	0	0	0	0	2	0	0	0.5	3	8.5	0
22	0	0	0	0	3	21.5	0	26.5	0	4	32	0
23	2	0	0	2.5	0	5.5	3	1.5	0	8.5	0.5	0
24	0.5	0	0	0	29.5	0	0	57.5	0.5	0	9	0
25	0	0	0	?	0.5	33	0	0.5	2	0	2.5	0
26	0	0	0	0	17.5	0	0	0.5	2	2	8	0
27	0	0	0.5	38.5	0	0	24.5	1	0.5	0	44	0
28	0.5	0	12.5	0	0	0	0	0	3	34	70.5	0
29	0		0	1.5	0	12	0	0.5	0	6.5	64	0
30	0		39	0.5	0	0.5	5.5	7	0	2	76	0
31	0		0		3.5		0	0		24.5		0

Figure 5.13: Rainfall distribution at Sek. Men. Teknik Kuala Krai of 2019

(Source: Portal of Department of Irrigation and Drainage, 2020)

Lastly, rainfall distribution data that obtained from Jabatan Pengairan dan Saliran (JPS) in Figure 5.14 was in year 2020 where the data only from month of January until Jun 2020. In 2020, in the duration of January to Jun, there are only two days that shows higher rainfall distribution which on 10 and 12 February with the value of 77 mm and 61.5 mm respectively.

Year 2020						
Site 5522047 Sek. Men. Teknik Kuala Kerai						
Day	Jan	Feb	Mar	Apr	May	Jun
1	5	1.5	0	0	31.5	1.5
2	2.5	0	0	1	16	0
3	1	0	0	14	0	0
4	0	0	0	0	0	0
5	0	1	0	1	0	9.5
6	0	0	0	0	0	0.5
7	5	0	0	0	0	14.5
8	0	0	0	0	0	1
9	0	7.5	0	0	9	0
10	0	77	0	0	9.5	4
11	0	8	0	0	1	0
12	0	61.5	0	0	12	15
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	2
16	0	0	0	3	0	0
17	2.5	15	0	6.5	0	0
18	0	1	0	0	0	3
19	6	0	0	0	18.5	1.5
20	0	0	0	0	9	1
21	1	0.5	0	0	0.5	0
22	0.5	2.5	11	2	0	0
23	0	6.5	15	36	2.5	0
24	0	1	0.5	0	0.5	1.5
25	0	0	0	3	0	?
26	0	0	0	1.5	0	?
27	0	0	0	0	0	?
28	0	0	0	1	0.5	?
29	0	0	0	5	3.5	?
30	0		0	20	32.5	?
31	0		0		5	

Figure 5.14: Rainfall distribution at Sek. Men. Teknik Kuala Krai of 2020

(Source: Portal of Department of Irrigation and Drainage, 2020)

Figure 5.15 below shows the graph of average rainfall distribution in Station of Sek. Men. Teknik Kuala Krai from 2015 to 2020. From the graph, the station recorded the highest amount in November and December annually compared to the other months in every year. Therefore, it is an evidence that the northeast monsoon season occurred within the period and the flood normally happened at that time.

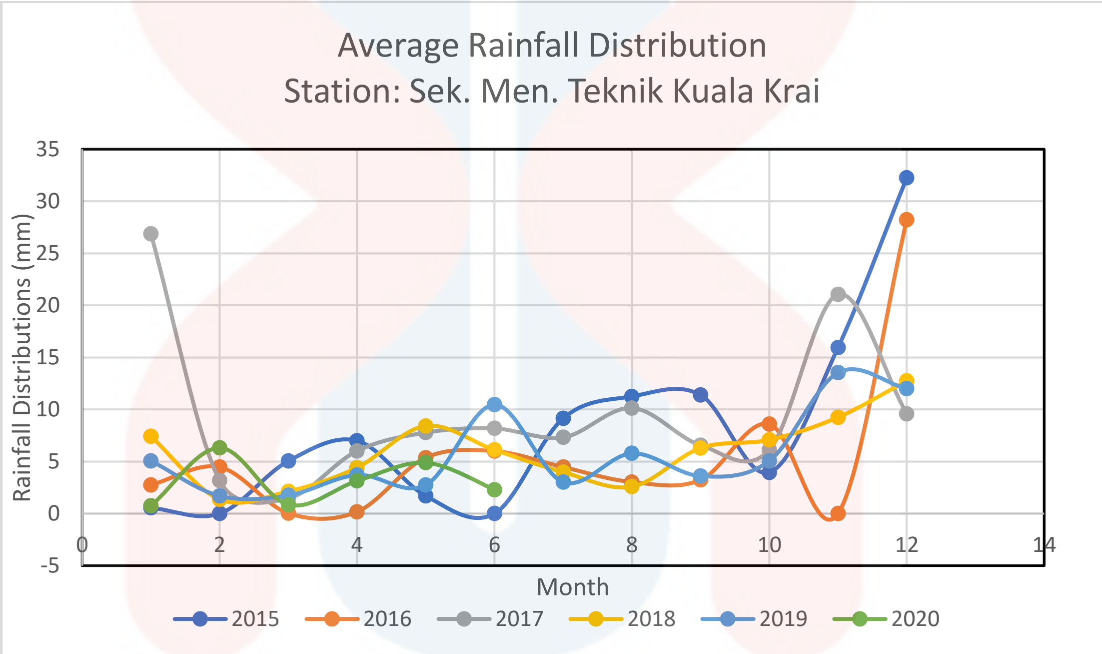

Figure 5.15: Average rainfall distributions at Sek. Men. Teknik Kuala Krai of 2015-2020

5.2.2 Hyetograph of Annual Rainfall at Kuala Krai Town, Kuala Krai, Kelantan

Figure 5.16 and Figure 5.17 below shows hyetograph which represent the distribution of rainfall intensity over time that was translated into a graph at different locations during 2014 flood by Department of Drainage and Irrigation. Generally, these two locations will provide detail information of rainfall distribution in Kuala Krai Town, Kuala Krai, Kelantan.

Figure 5.16 below shows the hyetograph for Kelantan River, Kuala Krai, Kelantan. From the graph, the rainfall distribution started from 14 December 2014 until 26 December 2014 where the highest rainfall distribution was recorded more than 200 mm 24 December 2014. However, the value decreased drastically to 0 mm and then increased again to less than 50 mm on 25 December 2014.

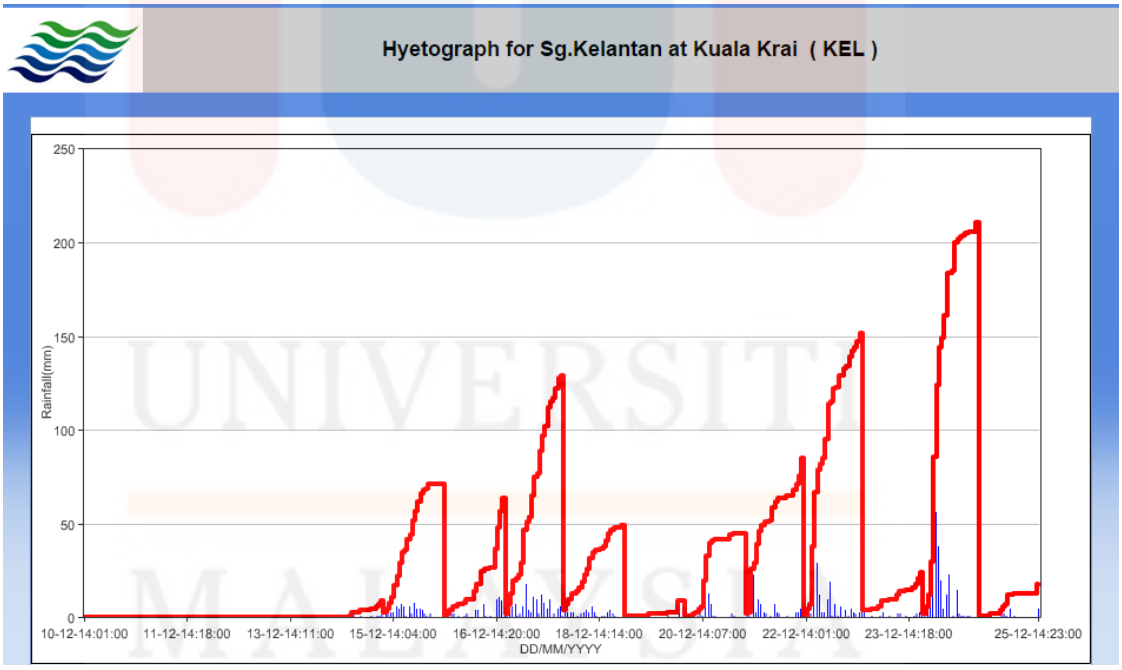

Figure 5.16: Hyetograph of annual rainfall for Kelantan River at Kuala Krai

(Source: http://infobanjir.water.gov.my, 2015)

Figure 5.17 shows the hyetograph of annual rainfall for Galas River at Dabong during 2014 when flood was occurred. From the figure, hyetograph recorded the heavy rainfall starting from 21 December 2014 until 25 December 2014. From 21 December 2014, the hyetograph recorded the highest amount of rainfall distribution which is more than 200 mm at Sungai Galas, Dabong. Then, the value decreased dramatically from more than 200 mm to less than 50 mm for the next day. However, the hyetograph suddenly increases to 150 mmon 23 December 2014 during 23:00 pm and it decreased to less than 100 mm on 24 December 2014.

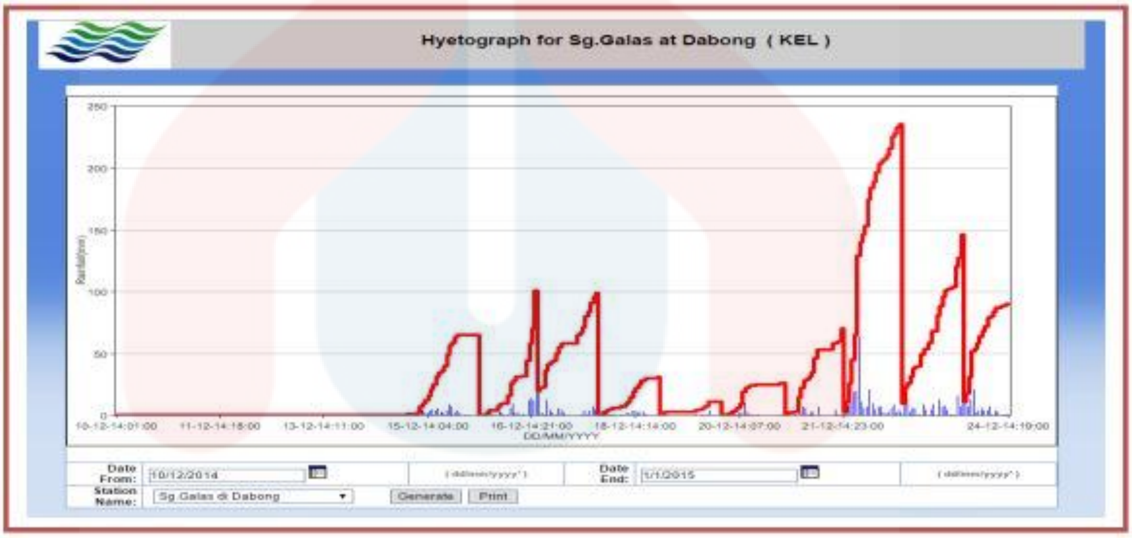

Figure 5.17: Hyetograph of annual rainfall for Galas River at Dabong

(Source: http://infobanjir.water.gov.my, 2015)

5.2.3 River Catchment Area of Kuala Krai Town, Kuala Krai, Kelantan

River catchment is an area of land where water was collected when raining occurred which mostly it bounded by hills. When the water flows across the landscape, it makes its way through the streams and then down into the soil, finally feeding the river. A catchment catches water which falls to earth as precipitation process, and the drainage network channels the water from throughout the catchment to a mouth of a main river.

There are three large basins in Malaysia which Kelantan River basin, Pahang River basin and Terengganu River basin. These three basins are located and grouping under monsoon catchment area which is heavy rainfall is the main factor during the northeast monsoon that occurred in November to March. The Kelantan River is known as the flood prone area in Malaysia. The water inundation area increases due to the heavy rainfall and it affect the agriculture and economic sector. The range of the rainfall in the region starting from 0 mm in the dry season to 1750 mm in the monsoon season. The average runoff of the Kelantan River area is about 500 m^3/s.

Figure 5.18 below shows River Catchment for Kelantan River which located at the North Eastern part of Peninsular Malaysia at latitudes 4° 40' to 6° 12' North and longitude 101° 20' to 102° 20' East. The maximum length and breadth of the catchment are 150km and 140km respectively. The Kelantan River has about 248 kilometres length and drains an area of 13,100km2, that become the backbone to the source of water of the state. There are six-sub basins of Kelantan River named as Galas, Nenggiri, Pergau, Guillemard Bridge, Kuala Krai and Lebir.

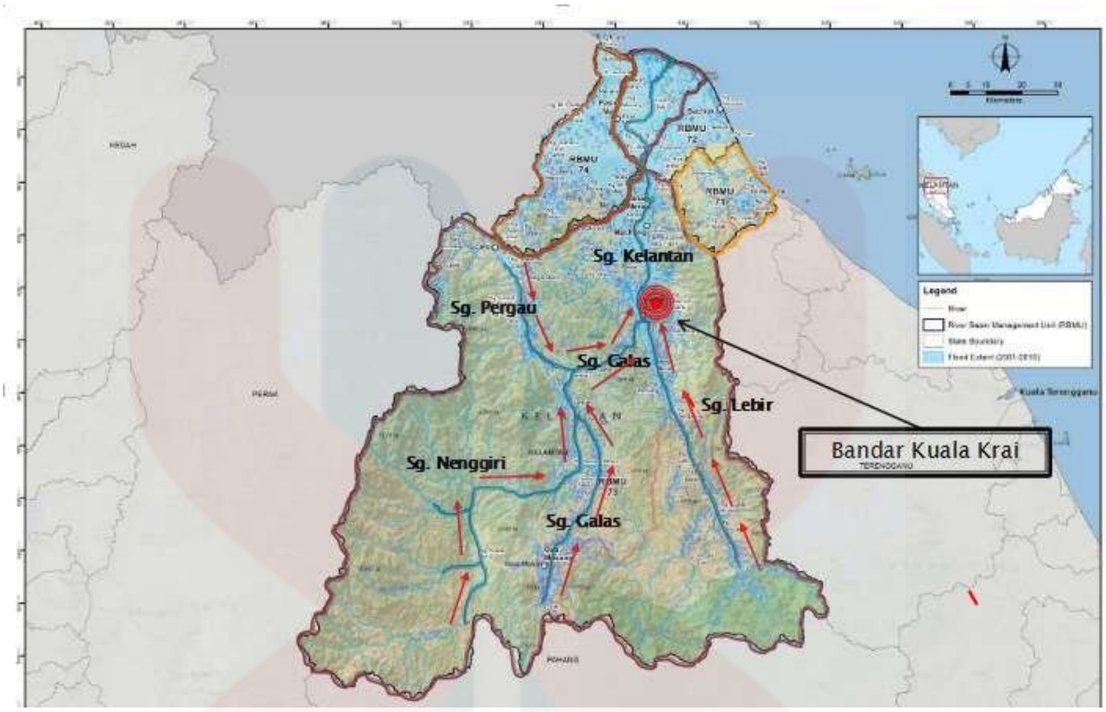

Figure 5.18: River Catchment area that caused 2014 flood in Kuala Krai Town, Kuala Krai, Kelantan (Source: Google Image, 2018)

The main river catchment in the study area is Kelantan River and at the South of the study area consist of two main tributaries which are the Galas River and Lebir River. The Galas River is formed by the junction of the Nenggiri and Pergau Rivers. The Nenggiri River originates in the south western part of the central mountain range (Main Range). The Lebir River originates from the Tahan mountain range. Sungai Lebir catchment area is located in the southern part of the state of Kelantan in the upper most north of Peninsular Malaysia with an approximately total catchment area of 2500km².

5.3 Parameter of Flood Hazard Analysis

There are few parameters needed in flood hazard analysis which the most important flood factor is flow accumulation. Then, follow with second and third parameters which is slope and elevation. Weightage and scoring are needed in each parameter that influences flooding when using Weighted Overlay Method (WOM). It is based on the consideration of the effect of each parameter on flooding. The table below shows the parameter selected in determining the flood hazard analysis by using GIS. The parameter, weightage, class and rating were based on the article of Analysis Of Flood Hazard Zones Using Overlay Method With Figused-Based Scoring Based On Geographic Information Systems (2019).

Table 5.1: Weightage of parameter of flood hazard analysis (Adlyansah et al., 2019)

No	**Parameter**	**Weightage**
1	**Flow Accumulation**	**0.6122**
2	**Elevation**	**0.2944**
3	**Land use**	**0.0697**
4	**Slope**	**0.2944**
5	**Lithology**	**0.0053**

5.3.1 Flow Accumulation

The most important parameter of flood hazard in weighted Overlay Method (WOM) is flow accumulation. Therefore, the weightage of flow accumulation given as 10 because flow accumulation considers as the zone of accumulation of water flow entering a basin. This data was processing through the Dem data, then it was generated until produce flow accumulation map with different types of classes and have a range of values starting from 0 to 31,971.

When the value of flow accumulation is higher, the water accumulated in the area is higher too. Besides, flow accumulation also was influenced by the river order. Therefore, when the order value of the stream or river is high, the flow accumulation is high too. Drainage pattern helps in determine the spread of flow accumulation. Based on the study area, the dendritic pattern of Figure 5.19 show when the area closer to the downstream of the river, the flow accumulation values is greater. Table 5.2 shows the weightage and score for flow accumulation.

Table 5.2: Weightage and rating for flow accumulation (Adlyansah et al., 2019)

No	Range of Flow Accumulation	Weightage	Rating
1	0 - 752	0.6122	1
2	752 - 2633	0.6122	2
3	2633 - 6394	0.6122	3
4	6394 - 15797	0.6122	4
5	15797 - 31971	0.6122	5

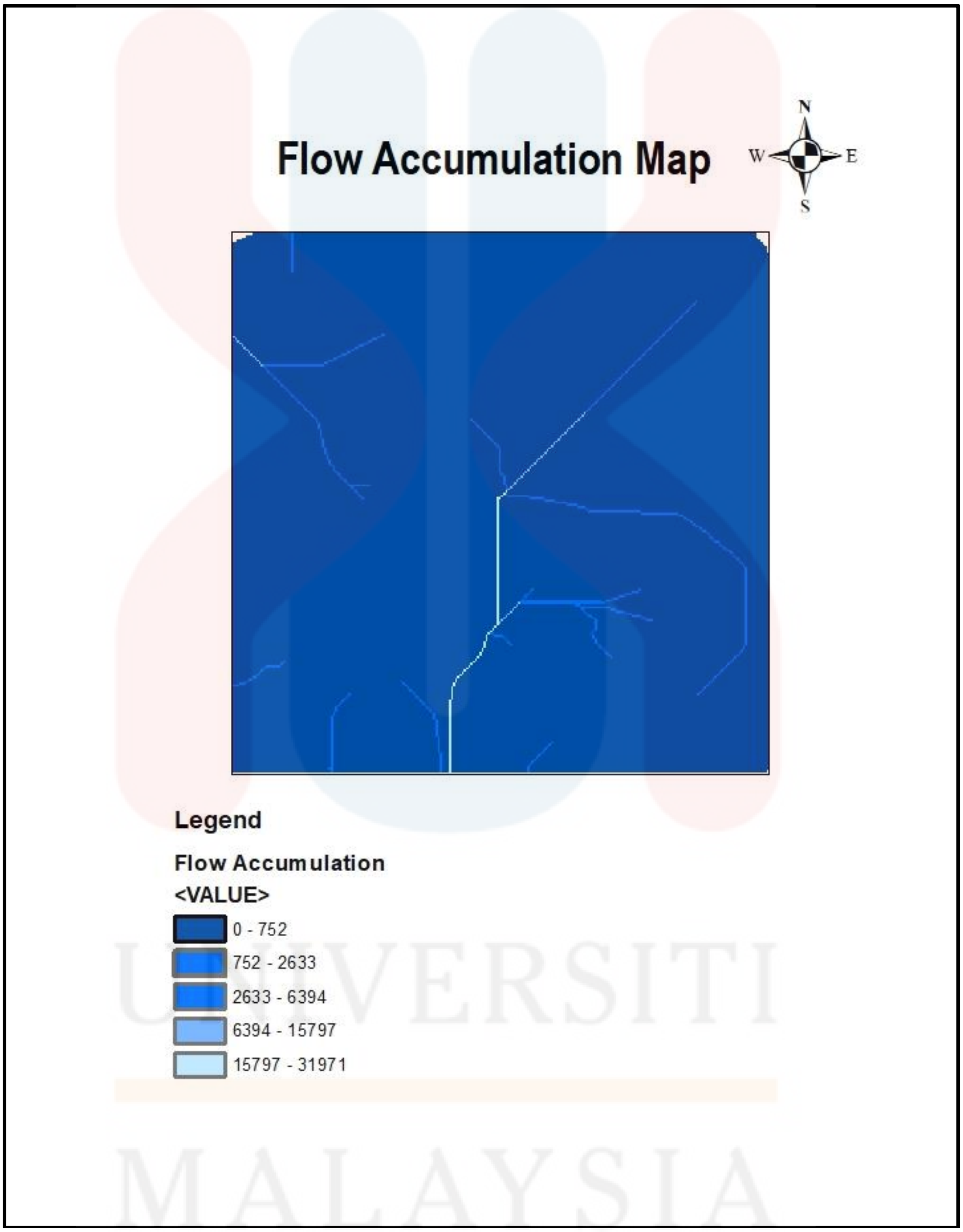

Figure 5.19: Flow Accumulation map of study area

5.3.2 Elevation

The elevation data was processing through Dem data until the elevation map was produced with the range of values 20 m to 240 m. Generally, the potential to become flood is high in the area that have low elevation due to water flowing from high altitude to the lower altitude. Table 5.3 below shows the weightage and score for parameter of elevation. Figure 5.20 shows the elevation map of study area.

Table 5.3: Weightage and rating for elevation (Adlyansah et al., 2019)

No	Elevation Class	Weightage	Rating
1	20 - 50	0.2944	5
2	50 – 80	0.2944	4
3	80 - 120	0.2944	3
4	120- 170	0.2944	2
5	170 - 240	0.2944	1

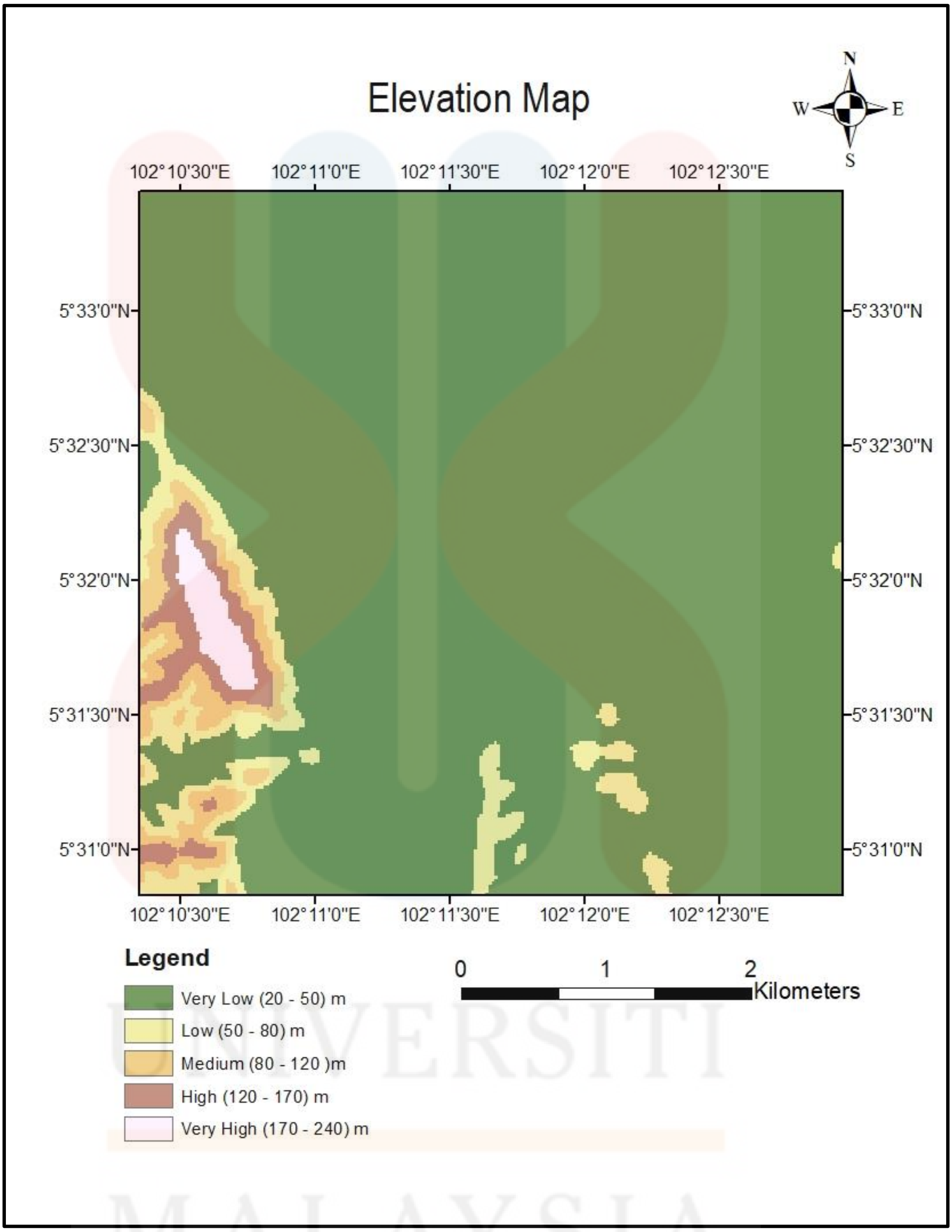

Figure 5.20: Elevation map of study area

5.3.3 Land use

Land use referred to the land serve which describe the area in the study area. It involves the management of natural environment into the built environment. For example, settlements agricultural, forest and lakes. Land use can influence the study area to become flood due to the ability of water infiltration. The data of this parameter was obtained from land use shapefile of geospatial data with the scale of 1: 25000. Land use that has a high degree of similarity has characteristics, namely low infiltration ability that supports flooding. The land will able to infiltrate surface water when there was the presence of dense vegetation such as forest which it was able to reduce the risk of flooding to occur. Table 5.4 below shows the weightage and score for the land use parameter. Figure 5.21 shows the land use map of study area.

Table 5.4: Weightage and rating of land use (Adlyansah et al., 2019)

No	Class	Weightage	Rating
1	River	0.0697	5
2	Weed	0.0697	3
3	Garden	0.0697	3
4	Town	0.0697	4
5	Paddy	0.0697	3
6	Oil palm	0.0697	3
7	Former forest area	0.0697	3
8	Road	0.0697	3
9	Swamp	0.0697	3
10	Forest	0.0697	1
11	Rubber	0.0697	3

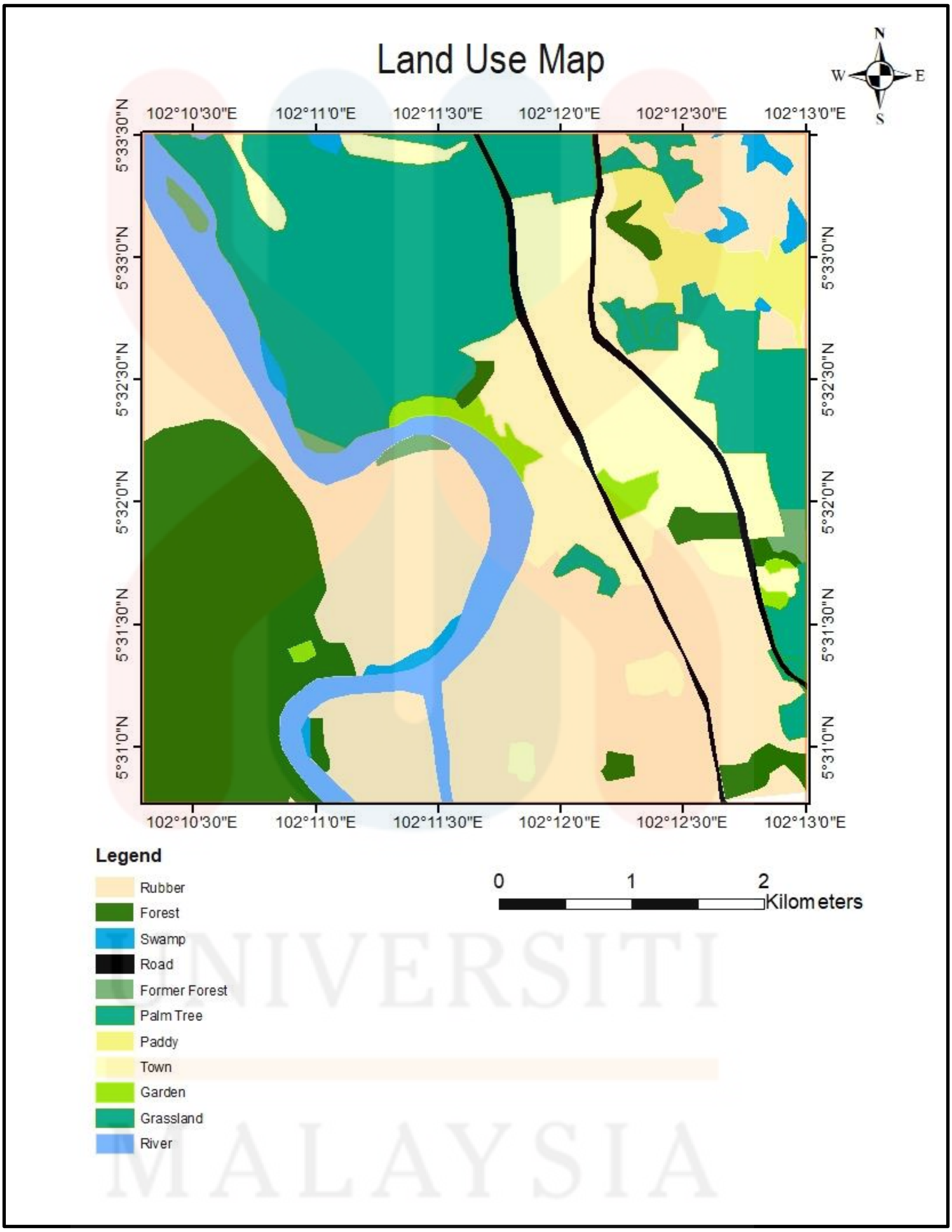

Figure 5.21: Land use map of study area

5.3.4 Slope

The parameter for this slope is generated from Dem data and it uses units of degrees (^{o}). Based on the study area, the slope parameter consists of range values from 0 ^{o} to more than 35 ^{o}. In the West of study area, the steep slope was found with the value more than 35 ^{o}. The majority of Kuala Krai Town, Kuala Krai, Kelantan has a slope range 0 ^{o} to 5 ^{o} which the area is a plain area with low altitude of elevation and have greater flood potential compared to the area that have steep slopes and high altitude of elevation. Table 5.5 below show the weightage and score of slope parameter. Figure 5.22 shows the slope map of study area.

Table 5.5: Weightage and rating of slopes (Adlyansah et al., 2019)

No	Class	Weightage	Rating
1	0 - 5 ^{o}	0.2944	5
2	5 - 10 ^{o}	0.2944	4
3	10 - 15 ^{o}	0.2944	3
4	15 - 25 ^{o}	0.2944	2
5	25 - 35 ^{o}	0.2944	1
6	>35 ^{o}	0.2944	1

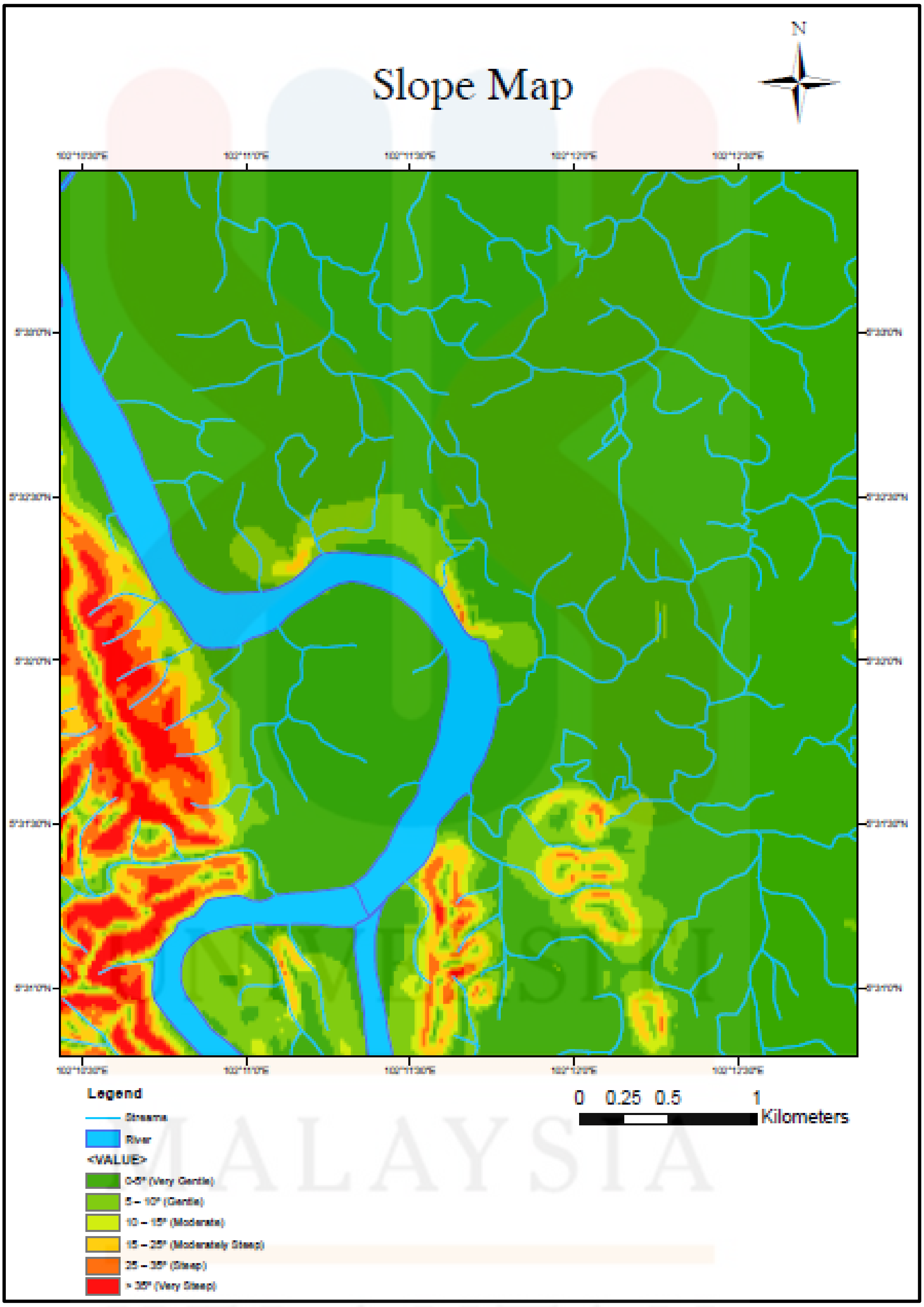

Figure 5.22: Slope map of study area

5.3.5 Lithology

Based on regional stratigraphy in Figure 4.2, the study area included in Temangan dyke, Alluvium Deposition, Telong Formation and Taku schist formation. The lithology in the study area consists of alluvium, ignimbrite, interbedded sandstone, siltstone and shale and the last is schist, with the age of Cenozoic, Mesozoic, and Paleozoic respectively. The source of geological data of Kuala Krai Town comes from the spatial data analysis such as from the terrain map, paper map from Geological Society Malaysia (GSM), previous research and remote sensing image which provides shapefile data.

The lithology in the study area influence the strength of a flood. When the rock is unconsolidated and sediments such as alluvial that permeable will help in support the water, percolation, and groundwater infiltration while impermeable rocks support surface flow. The potential of study area to become flood smaller if the lithology of rock is permeable. The table 5.6 below shows the weightage and score for lithology rock. Figure 5.23 shows the lithology map of study area.

Table 5.6: Weightage and rating of lithology (Adlyansah et al., 2019)

No	Lithology Class	Weightage	Rating
1	Alluvium	0.0053	3
2	Ignimbrite	0.0053	1
3	Schist	0.0053	2
4	Interbedded sandstone, siltstone and shale	0.0053	4

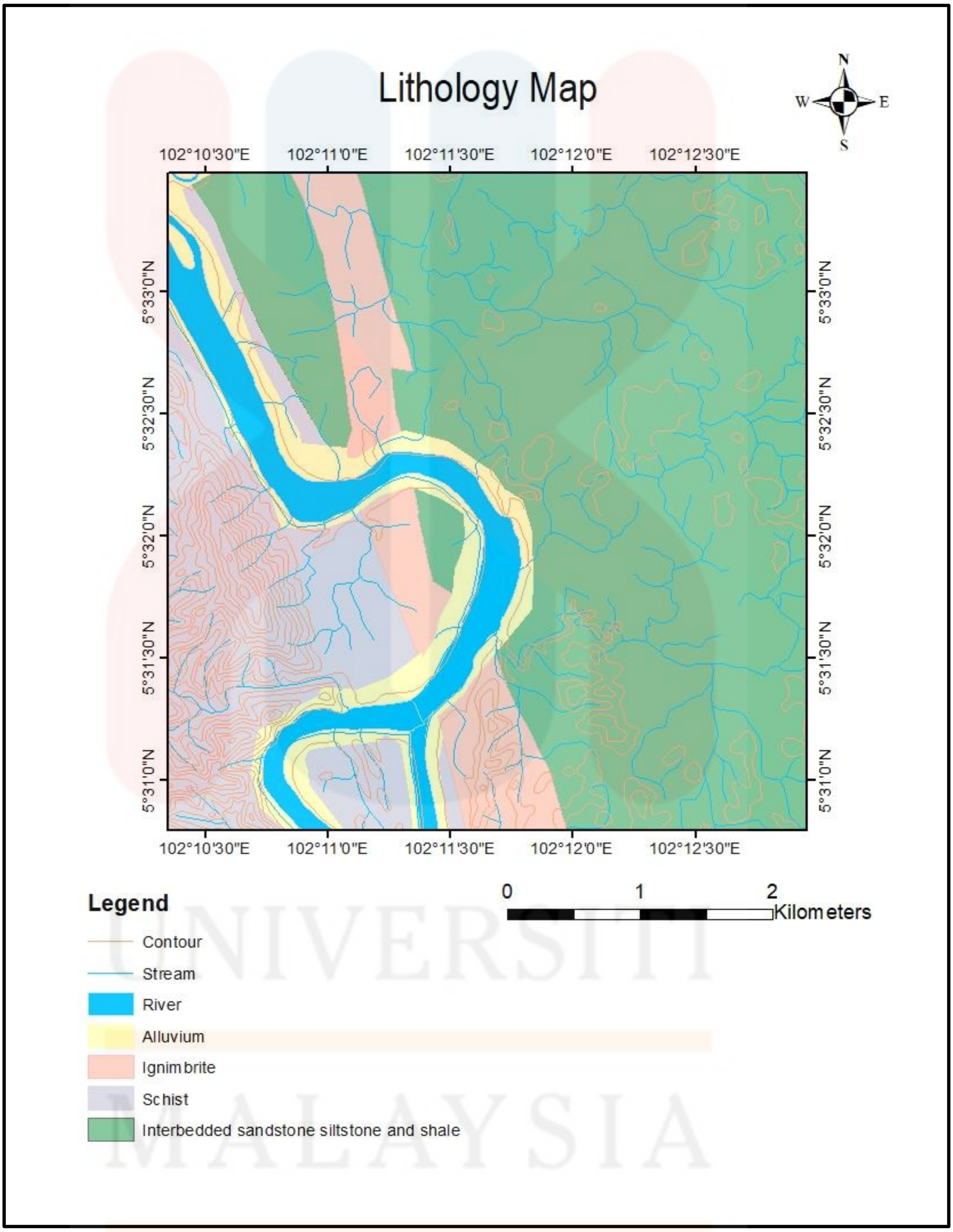

Figure 5.23: Lithology map of study area

5.4 Flood Hazard Map

To produce and generate flood hazard map of Kuala Krai Town, Kuala Krai, Kelantan, each parameter needs to be in raster data before reclassify. Then, all parameters were overlay by using Weighted Overlay Method (WOM) in by using ArcGIS Software. The parameters need to be chosen in this study area are flow accumulation, elevation, land use, slope and lithology. The table 5.7 below shows the reclassify data with the influence of flooding according to each parameter.

Table 5.7: Reclassify data with influence

No	Raster Datasets	Influence
1	**Flow Accumulation** Very Low (0 – 752) Low (752 – 2633) Moderate (2633 – 6394) High (6394 – 15797) Very High (15797 - 31971)	30
2	**Elevation** 20 - 50 50 – 80 80 - 120 120- 170 170 - 240	25
	Land use River Weed	

3	Kebun Town Paddy Oil palm Kawasan cerang Road Swamp Forest Rubber	25
4	**Slope** 0 - 3 3 - 10 10 - 20 20 - 30 30 - 50	10
5	**Lithology** Alluvium Ignimbrite Schist Interbedded sandstone, siltstone and shale	10

In this research, flood hazard map was constructed by overlay all the parameters in ArcGIS Software and the map also refer to the hydrograph data of Kelantan River at Kuala Krai, Kelantan. At the end of the Weighted Overlay Method (WOM), the figure 5.24 shows flood hazard map of Kuala Krai Town, Kuala Krai, Kelantan was produced with the different classes which is high, medium, low and very low of water level. Figure 5.25 shows the hydrograph data of Kelantan River at Kuala Krai, Kelantan that will help in identify the area of flood hazard with the depth of water level.

Flood hazard also refers to the probability of occurrence with a different degree of severity. Thus, the map constructed is divided into three level which area low, medium, and high to differentiate the degree of flood hazard faced by residents. Flood hazard will be emphasized on measurable indicator such as flood depth and flood duration that were obtained from the analysis of hydrograph , and hyetograph. The water level, duration , depth , and exposure are the important physical characteristics that need to analysed together with the response variable to determine the severity of flood occurrence.

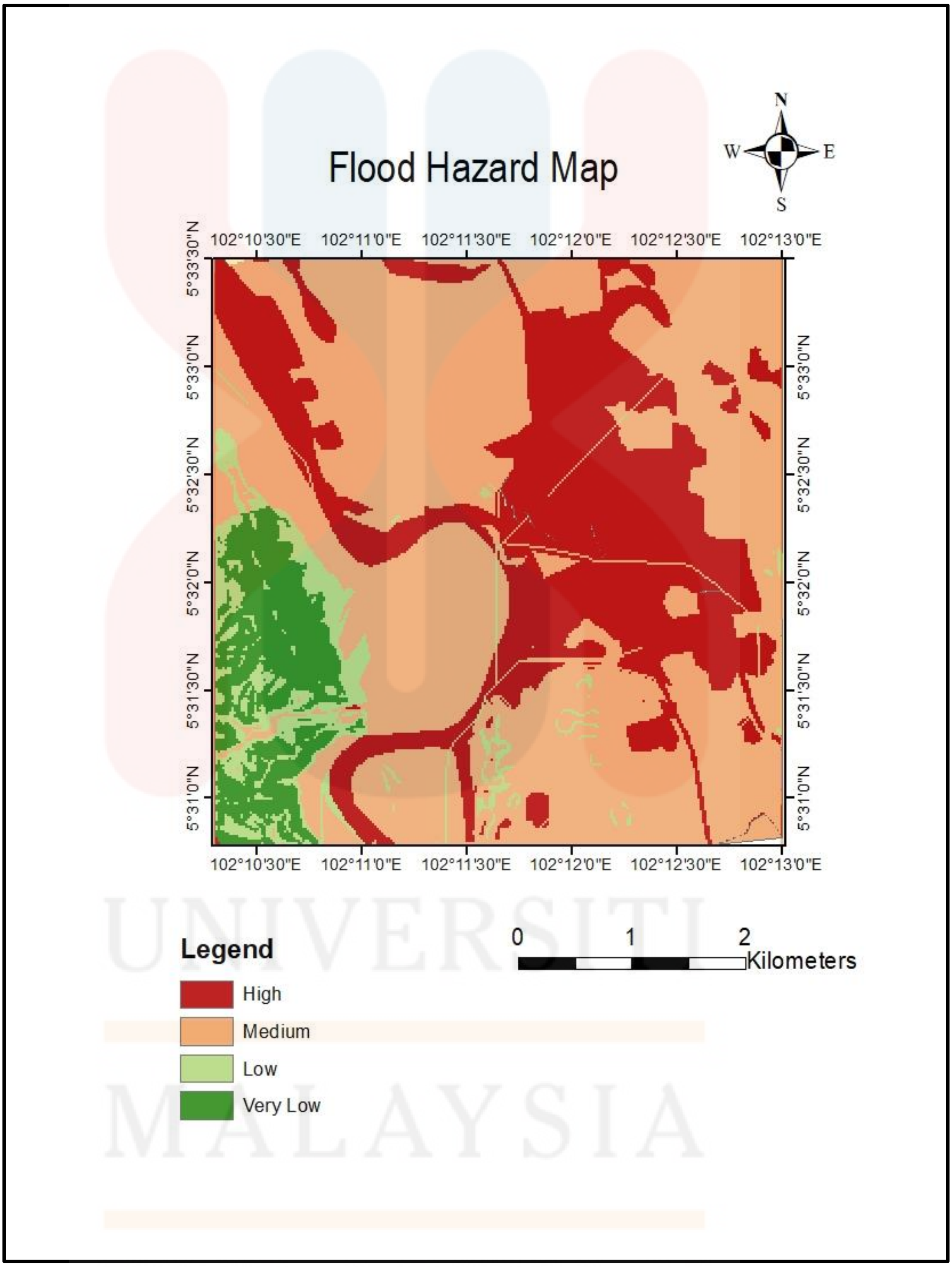

Figure 5.24: Flood hazard map of study area

5.4.1 Hydrograph of Water Depth Level at Kuala Krai Town, Kuala Krai, Kelantan

Figure 5.25 below shows Hydrograph for Kelantan River at Kuala Krai, Kelantan from 16 December 2014 until 1 January 2015 by Flood Info. Generally, the hydrograph below shows the fluctuated water depth along that day. From the graph, it has three types of water level which are danger level, alert level, and normal level with 25.0 m, 22.5 m and 20.0 respectively.

During drought period, smaller stream is often dry, but when heavy rainfall hits the town as in December 2014, all the streams become turbulent bringing down the tremendous amount of sediments and the stream overflow their banks.

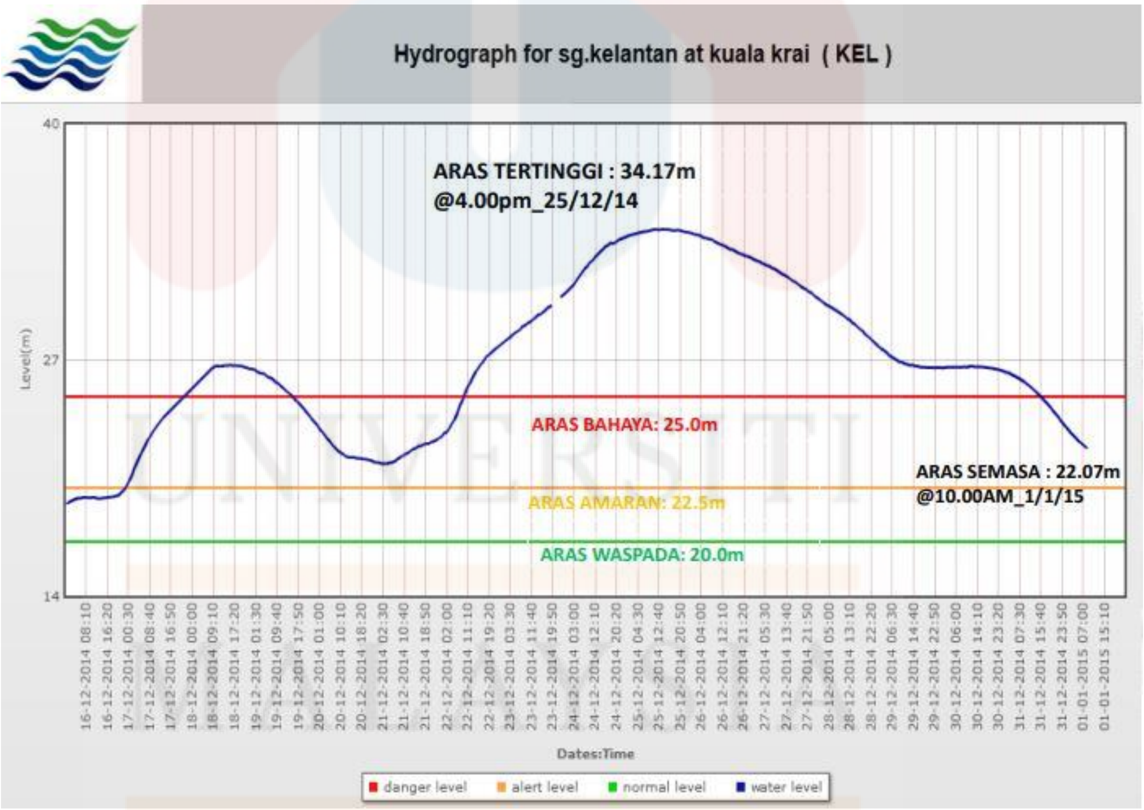

Figure 5.25: Hydrograph for Kelantan River at Kuala Krai, Kelantan

(Source: http://infobanjir.water.gov.my, 2015)

5.5 Flood Hazard Analysis

Flood hazard map was produced by doing the Weighted Overlay Method (WOM) of five parameters which are flow accumulation, elevation, land use, slope and lithology. To support this method, certain criteria was used as main priorities such as depth and duration for this flood hazard. Besides, the figure of hyetograph was used to show the annual rainfall for Kelantan River in 2014 while hydrograph was used to see the water level occurred in the study area.

Based on the analysis, it can be observed that duration is the main component followed by depth in determine the flood hazard analysis in the Kuala Krai Town, Kuala Krai, Kelantan. Duration was referred as water that have been retreated from the flood condition to the normal condition while depth was referred as water depth during the flood event.

Therefore, from Figure 5.24, the flood hazard map of study area and Figure 5.25, hydrograph for Kelantan River at Kuala Krai, Kelantan was related to each other. The flood hazard map shows different flood zone areas which are very low, low, medium and high flood zone. It can be concluded, the area of high flood zone is referred as the danger water level when it started to increase at 25 m and above. From the flood hazard map above, high flood zone area was focused on the Kelantan River and Kuala Krai Town area as the area is at the lowest elevation of 20 m.

For medium of flood zone area, it is considered as warning level when it rises to 22.5 m and above from it. From hydrograph data in Figure 5.25 above, the water level started to increase continuously on 17 December 2014 until it become danger water level on 18 December 2014. In 19 December it suddenly decreases to the warning level again but on 22 December 2014, it increases rapidly to the danger water level.

At 20 m of water level and below of 22.5 m, it was referred as low water level while below 20 m of water level it is identify as very low of water level which this area focusses on low of flood zone areas. From Flood Hazard Map in Figure 5.24, the areas focus on the west of study area which it is forest areas with the elevation of 80 m to 240 m. Forest area normally has ability of water infiltration, thus the presence of dense vegetation increases the ability of land to infiltrate surface water. This causes the areas that have dense vegetation such as forest can reduce the risk of flooding.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, all research objective stated in 1.4 were achieved. A geological map of Kuala Krai Town, Kuala Krai, Kelantan was updated with more details in scale of 1:25000. Lithostratigraphy discussed about lithology of the study area where it is divided into four types which is alluvium, ignimbrite of Temangan dyke, interbedded sandstone, siltstone and shale of Telong Formation and schist of Taku Schist. The stratigraphy position of the formation is discussed where the oldest rock is schist while the youngest rock is alluvium. The highest elevation in the study area is determined which is 240 m in the west area of study area while the lowest elevation or altitude is 20 m especially in Kuala Krai Town location.

The flood hazard map was produced by using five parameters such as flow accumulation, elevation, land use, slope and lithology. These parameters then were reclassified and overlay by using Weighted Overlay Method (WOM) in GIS software. The flood hazard map was generated and classified into low, medium and high flood zone areas. Generally, the study areas have potential to occur flood hazard with 30% high, 50% medium and 20% low. The parameters for flood hazard analysis were discussed and the factors for flood hazard also has been determined.

From the research, the main factors for flood hazard analysis in the study area to occur are rainfall intensity and logging activities.

6.2 Recommendation

As recommendation for the future researcher, I recommend that mapping is important in Geoscience field especially in identifying the result and collecting sample of hand specimen for the evidence to update geological map of study area. The data is too little and not enough just by doing the interpretation from terrain map.

Besides, in order to produce a better result of flood hazard analysis map, it is suggested to select suitable parameters for study area because different parameters will lead to different results. Therefore, this method needs to be understood very well to prepare suitable parameters. For method of producing flood hazard map, I would recommend to try doing another method in order to get more accurate data and for doing the comparison between the current data and the new one. For example, another method is Analytic Hierarchy Process (AHP).

Lastly, flood mitigation help in reduce the flood event by involves the management and control of flood water movement. At least, there are several steps need to take to avoid flooding in Kelantan become worst in the coming years. First, land clearing or logging should be stopped or at least in a control situation. If not, it should be done in a suitable manner. Next, built an infrastructure of water containment at upstream such as dam to hold the water during heavy rainfall and monsoon season. Lastly, Flood can be reduced by doing the silting and deepening of rivers downstream which need to be done aggressively. This action required efforts targeted at the upstream and downstream levels of the Kelantan River basins.

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