GEOLOGY AND LANDSLIDE SUSCEPTIBILITY ANALYSIS IN KAMPUNG RENOK BARU, GUA MUSANG, KELANTAN.

By

NUR SYARIENNA BINTI RAZMI

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DECLARATION

I declare that this thesis entitled "Geology and Landslide Susceptibility Analysis in Kampung Renok Baru, Gua Musang, Kelantan" is the result if 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.

Signature :……………………..

Name : NUR SYARIENNA BINTI RAZMI

Date :………………………

APPROVAL

"I hereby declare that I have read this thesis and in our opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Applied Science (Geosciences) with Honours".

Signature : ……………………...........

Name of Supervisor : DR WANI SOFIA BINTI UDIN

Date : ………………………

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Geology and Landslide Susceptibility Analysis in Kampung Renok Baru, Gua Musang, Kelantan

ABSTRACT

This research was covered with $25km^2$ area which aligned along latitude 4°55'15.0" N, 4°57'55.0" N, longitude of 102° 1'45.15" E, 102° 4'25.30" E. This study was carried out due to there is only big scale research and less information regarding geomorphological and stratigraphy aspects in study area. Also, landslide susceptibility analysis was conducted because of previous research not providing detail factors affecting landslide susceptibility and the map of hazardous areas. The purpose of this research is to produce geological map of study area in the scale of 1:25000, to generate landslide susceptibility map of study area with the scale of 1:25,000 and to determine factors triggered landslide and mitigation step in study area. This research involves study of geomorphology, lithological, stratigraphy, historical geology and structural geology. Furthermore, this study was carried out using remote sensing, online interpretation with helped of secondary data, producing map and then analysis each map integrated with Geographic Information System (GIS). This study area made up of two main formation which are Telong formation and Merapoh Limestone that consist of pyroclastic unit, metasedimentary unit and limestone unit respectively. The parameters that triggered to occurrence of landslide were identified such as slope, aspect, lithology, land use, drainage density and distance from road. The landslide susceptibility map was generated using Weighted Overlay Method (WOM) in ArcGIS. The landslide susceptibility map was produced and showed three zones classes of landslide vulnerability area which are low, moderate and high zones, where study area covered with low susceptibility of landslide so the probability of landslide to occur is low. Besides, the external factors triggered to landslide phenomena were determined which are rainfall intensity and anthropogenic activities. As a conclusion, all the research objectives were achieved and this research leading to greater awareness on the landslide occurrence of study area.

Geologi dan Kerentanan Tanah Runtuh Di Kampung Renok Baru, Gua Musang, Kelantan

ABSTRAK

Kajian ini diliputi dengan luas 25km^2 yang selaras sepanjang garis lintang 4 ° 55'15.0 "N, 4 ° 57'55.0" N, garis bujur 102 ° 1'45.15 "E, 102 ° 4'25.30" E. Kajian ini dijalankan kerana hanya ada kajian berskala besar dan kurang maklumat mengenai aspek geomorfologi dan stratigrafi di kawasan kajian. Juga, analisis kerentanan tanah runtuh dilakukan kerana kajian sebelumnya tidak memberikan faktor terperinci yang mempengaruhi kerentanan tanah runtuh dan peta kawasan berbahaya. Tujuan kajian ini adalah untuk menghasilkan peta geologi kawasan kajian dalam skala 1: 25000, untuk menjana peta kerentanan tanah runtuh di kawasan kajian dengan skala 1: 25,000 dan untuk menentukan faktor-faktor yang menyebabkan tanah runtuh dan langkah mitigasi di kawasan kajian. Kajian ini melibatkan kajian geomorfologi, litologi, stratigrafi, geologi sejarah dan geologi struktur. Selanjutnya, kajian ini dilakukan dengan menggunakan penginderaan jauh, pentafsiran dalam talian dengan bantuan data sekunder, menghasilkan peta dan kemudian menganalisis setiap peta yang diintegrasikan dengan Sistem Maklumat Geografi (GIS). Kawasan kajian ini terdiri dari dua formasi utama iaitu formasi Telong dan Merapoh Limestone yang masing-masing terdiri dari unit piroklastik, unit metasediment dan unit batu kapur. Parameter yang menyebabkan terjadinya tanah runtuh dikenal pasti seperti cerun, aspek, litologi, penggunaan tanah, kepadatan saliran dan jarak dari jalan. Peta kerentanan tanah runtuh dihasilkan menggunakan Kaedah Pelapisan Berwajaran (WOM) di ArcGIS. Peta kerentanan tanah runtuh dihasilkan dan menunjukkan tiga zon kelas kawasan kerentanan tanah runtuh iaitu zon rendah, sederhana dan tinggi di mana kawasan kajian dilitupi dengan kerentanan tanah runtuh rendah sehingga kebarangkalian kejadian tanah runtuh adalah rendah. Selain itu, faktor luaran yang menyebabkan fenomena tanah runtuh ditentukan iaitu intensiti hujan dan aktiviti antropogenik. Kesimpulannya, semua objektif kajian tercapai dan kajian ini membawa kepada kesedaran yang lebih besar mengenai kejadian tanah runtuh di kawasan kajian.

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LIST OF ABBREVIATIONS

DEM	Digital Elevation Model
DSSM	Department of Surveying and Mapping Malaysia
E	East
FELDA	Federal Land Development Authority
GIS	Geographic Information System
JMG	Department of Mineral and Geoscience
KESEDAR	Lembaga Kemajuan Kelantan Selatan
KM	Kilometre
N	North
NW	North West
S	South
STRM	Shuttle Radar Topography Mission
USGS	United States Geological Survey
WOM	Weighted Overlay Method
W	West

LIST OF SYMBOLS

%	Percentage
σ	Shear stress
′	Minutes
″	Seconds
°	Degree

CHAPTER 1

INTRODUCTION

1.1 General Background

Geology can be defined as scientific study of the earth, the internal and external forms and processes of earth. To be more precise, it is the study of structure, nature and history of planet. According to Balasubramanian (2017), geology can be divided into physical geology and historical geology. The physical geology deals with Earth's materials, like minerals, rocks and processes within earth and on its surface while historical geology more focuses on the evolution and origin of life in Earth such as continents, oceans, atmosphere and all the ecosystems. The geological studies include all the study on lithology, geological structures, geomorphology, stratigraphy and also sedimentology of the area study.

Landslide is one of the main natural disasters happen around the world especially in mountain areas. The landslide due to the high intensity of rainfalls is unavoidable occurred and nowadays human activities such as deforestation and road buildings had triggered these landslide phenomena to occur (Taib et al., 2017). Several landslides occur during heavy monsoon rainfall in Kelantan river basin as well as in Gua Musang (Hashim et al., 2017). It involves the movement of land surface in different scales including from small landslide phenomenon to huge and regional scale.

There are several types of landslide existed such as rock fall, debris flows and deep slope failure. In Malaysia, landslide phenomenon affects many aspects especially for settlements and structures that support natural resources, transportation and tourism (Pradan & Lee, 2010).

According to Hashim et al., (2017), there are several factors that lead to landslide hazard such as slope, aspect, drainage density, land cover and precipitation and distance to road. All these factors were extracted from remote sensing data and image interpretation by using Analytical Hierarchy Process (AHP) approach.

This research is about to determine landslide susceptibility in Kampung Renok Baru where this area is exposed to several factors that triggered landslide like erosion and rock fall. This is because erosion and rock fall usually occur when rainfall dissolves soil particle and carries them off the slope which can cause landslide. There is also no vegetation in some slope to control erosion through gripping the ground and hold water in the soils. Besides, the landscape and topography in some area of study area is hilly and located at steep slope. Due to that, that are few reason regarding to this landslide susceptibility analysis conduct in the Kampung Renok Baru. Lastly, the study area located along the highway Gua Musang – Kota Bharu, so that might lead to the landslide hazard events.

1.2 Study Area

Gua Musang lies within 4º 53’ 00” N,101º 58’ 0”E located in the south of Kelantan, Malaysia, bordered by the state of Pahang to the south, Terengganu to the east, Perak to the west and on the edge of the central spine of hills and forests as shown in Figure 1.1. Gua Musang is surrounded by limestone hills and caves formed by Gua Musang formation. Gua Musang that also means “Cave of the Civet”. It is named from the geo-art of the civet found in the massive limestone towers above it. Gua Musang is referring to the exposure of rock between ages of Middle Permian to Upper Triassic (Mohamed et al., 2016).

Figure 1.1: Kelantan map

Kelantan is located at the longitude 101º 20’ to 102º 4’E and latitude 4º 33’ to 6º 14’N which is placed at the north-eastern corner of Peninsular Malaysia as shown in Figure 1.1. It shares boundaries with west Perak, south Pahang and east Terengganu and it borders Thailand to the north-west with coastline of 71 km fronting the South China Sea to the north. Kelantan covers an area of 15022 square km.

1.2.1 Location

Kampung Renok Baru is located in Gua Musang which aligned along latitude 4°55’15.0” N, 4°57’55.0” N, longitude of 102° 1’45.15” E, 102° 4’25.30” E as shown in Figure 1.2. The landscape in the state of Kelantan has been divided into four types which are mountainous areas, hilly areas, plain areas and coastal areas (Pour & Hashim, 2017). Thus, Kampung Renok Baru’s landscape is plain areas and slightly hilly areas with 100 m to 300 m of elevation. This study area can be accessed by road or Highway of Gua Musang – Kota Bharu. The area covers by agriculture, town and settlement areas. Then, there are several types of agriculture activities at the study area which are rubber plantation and pam oil plantation.

1.2.2 Road

The study area is located in Gua Musang, Kelantan along the Highway of Gua Musang – Kota Bharu which can be accessed by road. It takes 131 km to reach from UMK Jeli to Kampung Renok Baru with time estimation is about 1 hours and 56 minutes. After that, there are also some alternatives road or small road to reach into the whole study area.

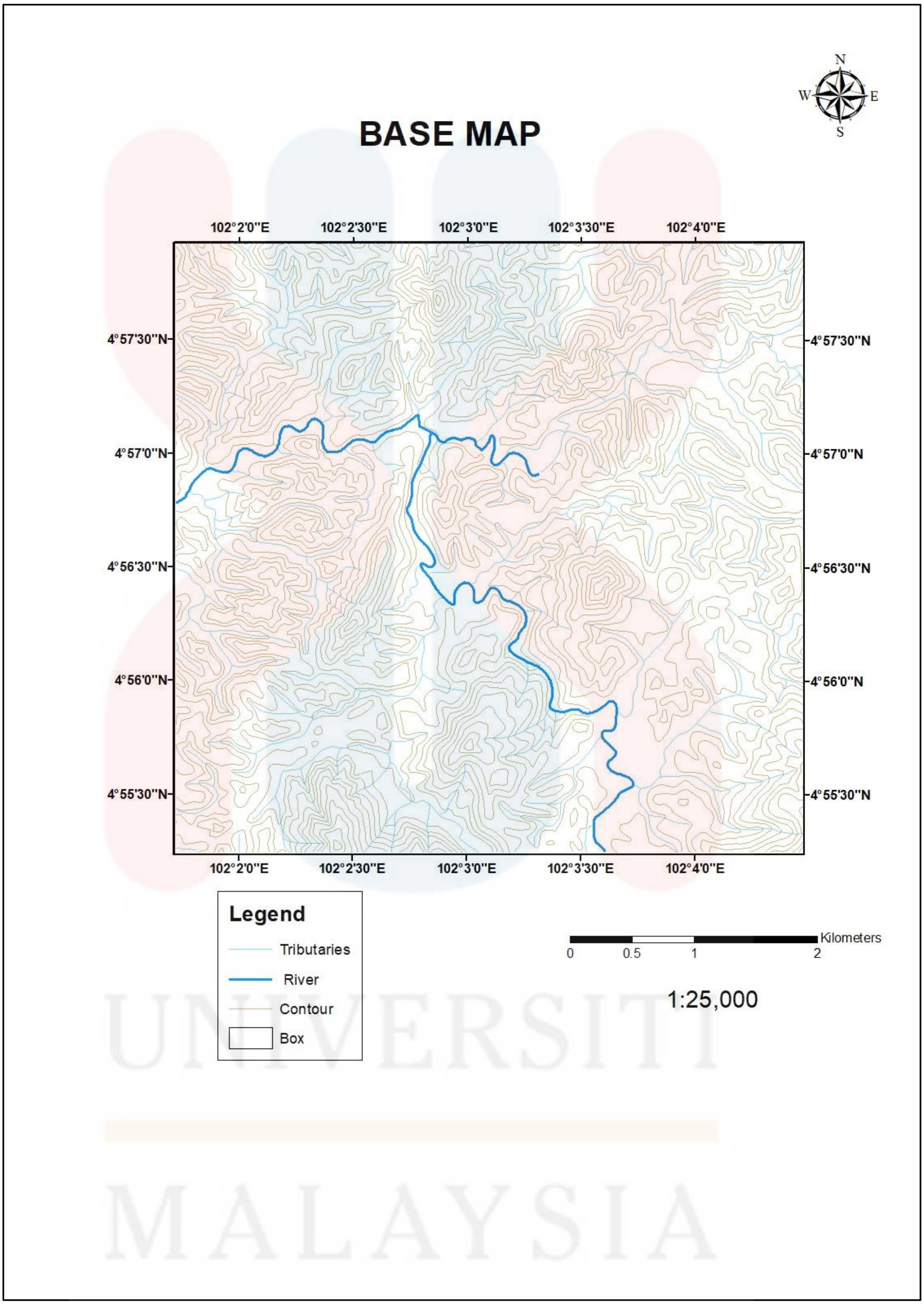


Figure 1.2: Base map of Kampung Renok Baru, Gua Musang.

1.2.3 Demography

According to Department of Statistics Malaysia, total population of Gua Musang in 2019 is 116,200 peoples. Table 1.1 shows the population at Gua Musang in 2017 until 2019. The growth of population in this district can be identified annually as the increases of development in agriculture sector, business sector, hospitality sectors and marketing sectors that require job opportunities for residents in Gua Musang.

Table 1.1: Population in Gua Musang
(Source: Department of Statistics Malaysia, 2019)

District	Year		
	2017	**2018**	**2019**
Gua Musang	111,500	113,900	116,200

1.2.4 Landuse

Landuse involve variety of areas. For example, rural areas which are landuse that commonly include agricultures and forestry areas while for urban areas involving areas of towns, industry and residential areas. Landuse also influence the human activities and jobs in the area. Landuse in Gua Musang is mainly covered by forests, oil palm and rubber plantations and also some paddy area. However, due to rapid growth of population, the area also becomes more widely developed so the landuse of Gua Musang also change rapidly by years. In the study area, the main landuse are oil palm and rubber plantation, forestry and also moderately settlement area.

1.2.5 Social economic

Ongoing development in Gua Musang shows positive impacts to the local residents in terms of job opportunities in several sectors. However in Kampung Renok Baru, the main socio economic still remain in agricultural sector either oil palm plantations or rubber plantation. Both plantations are under agency of Felda and KESEDAR. Besides, few local residents run their own business such as grocery store and restaurants within the study area.

1.3 Problem Statements

There are several limitations on geological information in the geological map of Gua Musang. As there is only big scale research and less information regarding geomorphological and stratigraphy aspects. Hence, these limitations resulted in difficulties of governments and researchers to gather their references for their development and research. Thus, this research is conducting in order to produce updated geological map of study area with scale 1:25,000 and then able to provide others researcher use as references in the future.

Landslide hazard always related to the failure of slopes that sometimes happen due to urbanization on unstable land. These past years, heavy monsoon rainfalls in Kelantan Basin River influence the landslide to occur. Landslide hazard lead to destroy livestock, agriculture produce, homes and business in Kampung Renok Baru, Gua Musang. This sudden phenomenon is hard to predict and there is no time to avoid its damages. Thus, the government of Malaysia is implementing the need for local planning authorities to include the landslide analysis in all planning and process development measures, particularly in hilly terrain areas.

So far, there is few research and studies had been conducted in Gua Musang in order to predict the landslide activities. Works by Hashim et al., (2017) showed the studies were conducted in big scale. Thus, good preparation was taken to avoid the possibility of landslide phenomenon at the area where the chances is high because landslide hazard influence by the rainfall that occur gradually. The previous landslide maps have several limitations such as researchers are not providing the detail factors affecting landslide susceptibility and the map of hazardous areas. This study is conducted based on image interpretation and Geographic Information System (GIS) method to analyse the landslide factor and the landslide susceptibility in study area.

1.4 Objectives

The objectives of study are listed as follows:

1. To produce geological map of the Kampung Renok Baru, Gua Musang in the scale of 1:25,000.
2. To generate landslide susceptibility map of Kampung Renok Baru, Gua Musang with the scale of 1:25,000.
3. To determine factors triggered landslide and mitigation step in Kampung Renok Baru, Gua Musang.

1.5 Scope of study

This study focused into two parts which are geological analysis and landslide analysis. The outcomes are in the forms of geological map and landslide susceptibility map. For the geological map, it is produced after making interpretation in order to identify the geological features of study area. During interpretation, hardware such as laptop, scanner, printer and hard disk were used.

For landslide hazard assessment of Kampung Renok Baru, the landslide susceptibility map is produced using WOM method integrated with GIS and also remote sensing techniques. The secondary data like rainfall intensity of Kampung Renok Baru was collected from Jabatan Pengairan dan Saliran (JPS) and US Geological Survey Earth Resource and Science Center (USGS).

1.6 Significance of study

This research provides better and new information especially on geological information of Kampung Renok Baru, Gua Musang. So, the data collection also be used for future landuse planning of Kampung Renok Baru such as settlement and urbanization areas. Moreover, others researchers also can use this research as their reference.

Then, by producing the landslide susceptibility map, the potential area to landslide can be determined. Therefore, this research can provide area that prone to landslide and mitigation steps for governments and people as a guide during the occurrence of landslide. For example, government be more aware during decide new development and construction in study area while villagers also can take precaution steps if there is heavy rainfall or change in monsoon. Due to that, the loss of human life can be reduced and public awareness among the people will be increased.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discuss on existing literature on geological and landslide studies. From the previous research, this research study is able to clearly conduct and focus on the particular part. In addition, the geology of the region is form due to the several factors that affecting for example plate movement and forces that exerted on the crust's region.

2.2 Regional Geology and Tectonic Setting

There are three division of Peninsular Malaysia which is divided into three north-south-trending zones. These zones are known as Western, Eastern and Central Belt of Peninsular Malaysia. Gua Musang is located at Central belt of Peninsular Malaysia. The collision of Sibumasu and Indochina terrains results in the formation of Bentong-Raub Suture (Metcalfe, 2000). Peninsular Malaysia lies on the Sibumasu plate. Generally, Peninsular Malaysia is divided into two blocks which are Bentong-Raub suture, the western part belongs to Sibumasu blocks, meanwhile the eastern parts belongs to Indochina block (Metcalfe,2000). Sibumasu and Indochina both originated from Gondwanaland (Metcalfe, 2000). Figure 2.1 refers to the geological structure in Kelantan State.

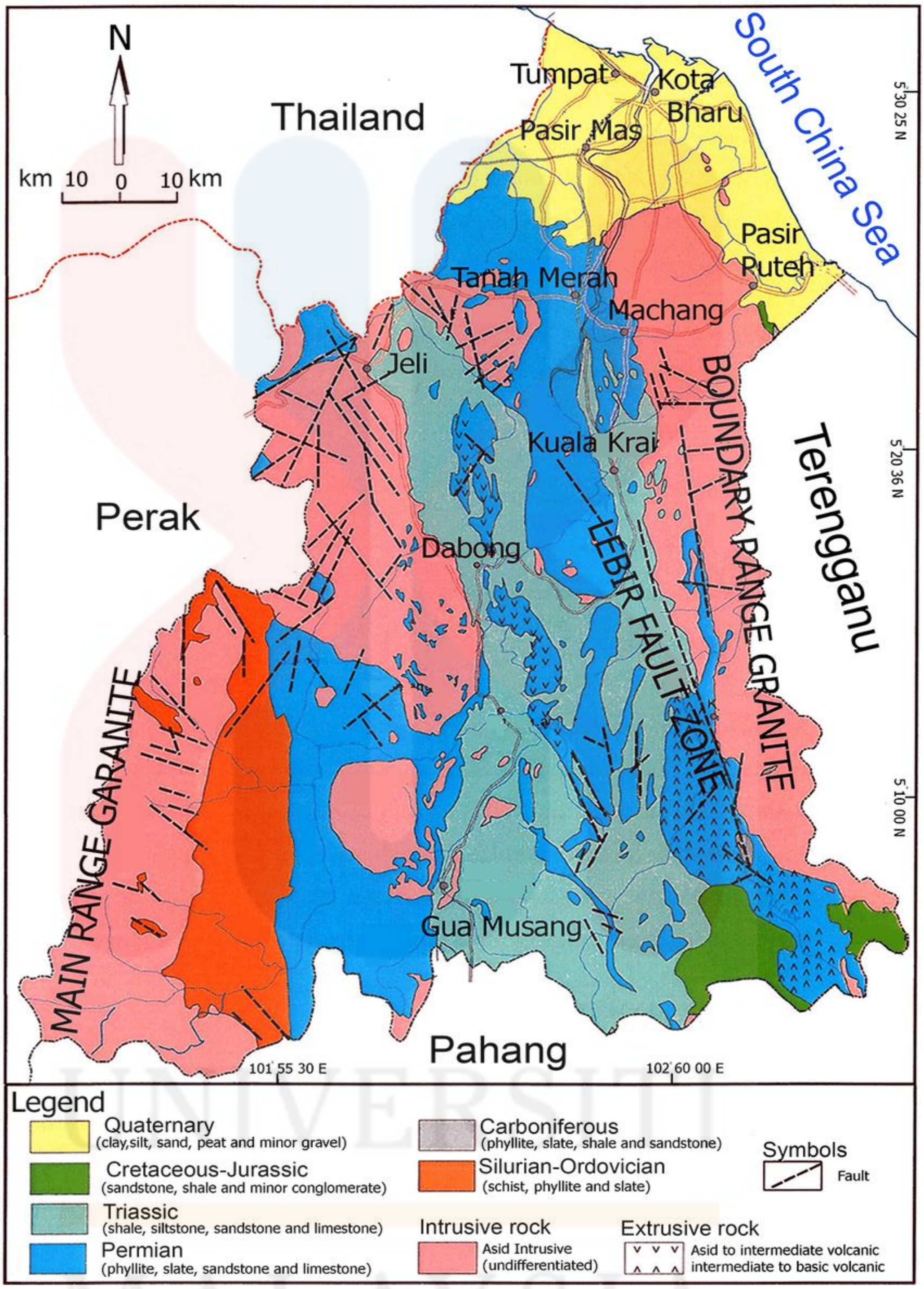


Figure 2.1: Geological map of Kelantan (Source: Department of Minerals and Geoscience Malaysia (2003) Quarry Resource Planning for the State of Kelantan. Osborne & Chappel Sdn. Bhd)

2.3 Stratigraphy

There are seven formations that made up in stratigraphy of Kelantan which are Aring Formation, Taku Schist, Gua Musang Formation, Telong Formation, Gunung Rabong Formation, Koh Formation and Badong Conglomerate. The age of Aring Formation and Taku Schist were formed on Paleozoic era, while the other five formations ages were during the Mesozoic era. For this research, only Gua Musang formation will be discussed. Gua Musang formation is located in South of Kelantan state that extended to North Kelantan and North Pahang. Ranges of Gua Musang age are from Middle Permian to Upper Triassic (Mohamed et al., 2016). The findings of fossils of the pelecypods and ammonoid in Gua Musang have been proven and indicates the ages of formation (Khoo, 1983).

Furthermore, Koh formation overlying the upper boundary of the formation but lower boundary of the formation is not been identified. The upper section of Gua Musang formation is state to be interfingering with Semantan Formation, extending downwards to the Pahang state. Moreover, Gua Musang formation is correlate with Telong Formation and Gunung Rabong Formation. For the lithology of this formation, it is dominant with argillaceous and calcareous rocks. Then, the lithologies are interbedded with volcanic and arenaceous rocks. Based on the research made by Yin (1965), Burton (1973a), Khoo et al (1983), Gua musang shows that it deposited from shallow marine environment and associated with active volcanic activity due to there are abundance fossils found in Gua Musang region. The common fossil found such as the brachiopods, algae and bivalve.

2.4 Structural Geology

Peninsular Malaysia is extended north-northwest and similar to its longitudinal pattern as well (Hutchison &Tan 1989). The surface of structures defined Peninsular's northwest through the north-eastern direction pattern and then north-north-west strike. The Permian folding has been noticed in the northwest region of Peninsular (Khoo and Tan, 1983).

The unique western and eastern vergences observed by the central belt rocks were perceived as a consequence of the general eastern-western compression correlated with the collision of the Late Triassic crust (Hutchison & Tan, 1989). Eventually, Peninsular Malaysia's structural grain, which is in the NW-SE region, also involved major faults that were filled with large multi-phase quartz dykes (Hutchison & Tan, 1989).

Kelantan is located at northern of Peninsular Malaysia. The Gua Musang Formation is primarily divided in the state of Kelantan. Because of the occurrence of Gua Musang Formation's main fold in the middle part north-south up to north-northwest- south-southeast. In the northern area of this main fold terned toward NE-SW by granite intrusion and diorite pophire. In fact, dekstral and sinistral faults with dipping 60° -70° to SE and 60° -80 ° to ENE-WSW are the major fault at Gua Musang. First, the shape of Gua Musang formed firmly folding and was extremely compact in the region bounded by igneous granite and close the central fault. Because of the primary compression towards between WNW-ESE up to ENE-WSW, thus, the folding and fault of Gua Musang formation formed (Setiawan & Abdullah, 2010).

2.5 Historical Geology

According to Metcalfe (2013), a highly deformed accretionary continues to grow as the Paleo Tethys Ocean andthe Sibumasu plate were obliquely subducted under the Indochina plate. Thus, the depositional of argillocarbonate sediments were occurred with the shallow marine platform of Gua Musang. The nearby of volcanic arc also supplied the volcanic rock around the Gua Musang. Finally, the progressed of sedimentation of shallow marine in Gua Musang started from Permian to the Early Triassic.

Hutchison & Tan (1989) defines that the Central region of Peninsular Malaysia to be a shallow platform nearby to an island arc system formed on continental crust. They identified that above the sea level abundant of limestone and submarine volcanic arcs grew. Apart from this, throughout of Visean to Late Triassic mostly part of convergent margin. The uplift and collision occurred during Triassic for final events.

Hutchison & Tan (1989) stated the Central zone bounded to the west by major faults along the Bentong-Raub line and to the east by the Lebir Fault Zone as an extensional graben. Next, in the Permian age the beginning of major normal fault which happened along the Bentong-Raub line and Lebir Fault Zone developed a graben in 2 to 3 km of marine Triassic like Semantan Formation while 1.5 - 2 km continental sediments of Jurassic Early Cretaceous age deposited and known as a Gagau Group.

2.6 Research specification

2.6.1 Landslide

A landslide is a rock, soil, or debris fall down a sloping portion of ground. Landslides are caused by storms, earthquakes, volcanoes or other causes forcing the slope to become unstable (Stanley, 2014)**.** Landslide is characterized as the motion of a mass of soil, rubble, or ground down the slope, when the shear stress exceeds the material's shear power (Cruden, 1991). Landslide have been identified as a major natural disaster all over the world and mainly in hilly zones (Hussain, G et al., 2019).

2.6.2 Landslide Susceptibility

Landslide susceptibility defined as the likelihood of a landslide happening in an region based on the circumstances of the surrounding landscape, determining location of landslides are likely to happen (Reichenbach et al., 2018). Next, it is significant concern partly because its geospatial research offers a valuable method for preparing, handling disasters and reducing hazards (Vojtekova, 2020)

2.6.3 Type of landslides

It is significant to differentiate the types of landslides relative to rate of slope movements. According to Cruden & Varnes (1992), there are several types of landslide movements. Table 2.1 shows the classification of landslides according to Varnes' classification.

Table 2.1: The classification of landslide according to Varnes' Classification

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly coarse	Predominantly fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow (deep creep)	Debris flow (soil creep)	Earth flow
COMPLEX		Combination of two or more principal types of movement		

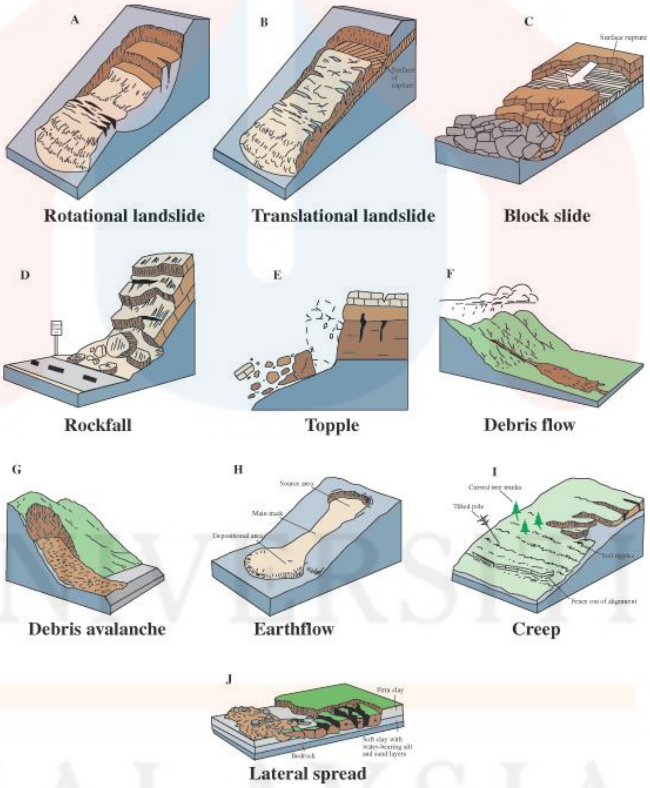


Figure 2.2: Types of landslides

a) Falling

Falling refers to the sudden movements of masses of geological materials that are removed from either steep slopes or cliffs, such as rocks and boulders. From Figure 2.2, the rock fall indicate the falling movement occur. In addition, separation happens between discontinuities such as fractures, joints, and bedding planes, and free-fall, flipping, and spinning happens in motion. Then, gravity, mechanical weathering and the presence of interstitial water have a strong influence on falls (Highland, 2004).

b) Toppling

The toppling failures or known as topple in Figure 2.2 are characterized by the forward movement of a unit or units at some critical point, below the structure, by the pressure and forces imposed by adjacent units or by the crack fluids (Highland, 2004).

c) Sliding

According to Highland (2004), there are two types of sliding movements which are rotational slides and translational slides. For rotational slide, it is a slide in which the top of the break is bent concavely upwards and the slide motion rotates uniformly along an axis similar to the surface of the earth and transverses around the slide. Meanwhile, translational slide is the landslide mass in this form of slide travels over approximately planar surface with no movement or reverse tilting. A block slide is a translational slide in which the moving mass consists of one unit or a few similarly connected units traveling downward as a fairly coherent mass. Both movements can be clearly referred to Figure 2.2.

d) Spreading

Lateral spreads are typically occur on very gentle slopes or flat plains as shown in Figure 2.2. The prevailing mode of motion is lateral contraction followed by cracks of the shear or the tensile. The breakdown is triggered by liquefaction, the mechanism of converting moist, weak, cohesion less sediments commonly usually sands and silts from a firm to a liquefied state (Highland, 2004).

This failure is typically caused by sudden ground motion, such as the one encountered during an earthquake, but may also be induced artificially. Then, spreading laterally on shallow slopes in fine grained materials is typically radical. The failure immediately begins in a tiny place and rapidly spreads out. Moreover, the initial loss is always a depression but movement happens with no obvious cause in certain materials. The combining two or three of these types of landslides is known as a complex landfall (Highland, 2004).

e) Flowing

Flowing movements of landslide basically can be divided into some types also which are debris flow, debris avalanche, earthflow, mudflow and creep can be refer in Figure 2.2. Firstly, debris flow, a debris flow is a process of rapid mass movement in which a mixture of loose soils, rocks, organic matters, air and water move like a slurry flowing downhill. Due to heavy precipitation, debris floods are usually triggered by extreme surface-water movement, which erodes and transport loose soils or rocks on steep cliff. Debris flows are often generally propelled from certain types of landslides that occur on steep slopes which filled of silt and sand materials.

Secondly, debris avalanche is a combination of relatively quick to incredibly rapid debris flows. Earthflows have the distinctive form of an hourglass. The fluid on the slope liquefies and flows down, creating a pool at the head or drop. The flow of water is elongated, and typically happens on intermediate slopes and under saturated environments in fine-grained materials or clay rocks. There may also be dried flow of granular dust. Next, a mudflow is an earthflow composed of soil that is moist enough to flow quickly and includes at least 50 per cent of particles of sand, silt and clay content (Highland, 2004).

Creep is the gradual, steady, imperceptible downward movement of slope-forming soil or rock. Movements are induced by enough shear stress to create irreversible deformation but too low to trigger shear failure. Also, creep is marked by bent tree trunks, angled fences or retaining walls, inclined poles or fences, and slight ripples or ridges on the ground (Highland, 2004).

2.6.4 Factors trigger landslide

There are several identified factors that cause the occurrences of landslide in Kampung Renok Baru, Gua Musang such as slope, aspect, lithology, distance to drainage, distance to road, land cover, and precipitation.

a) Slope

According to Mezughi et al., (2012), in the slope analysis, the primary factor used is slope angle. Then, it also used in generating landslide susceptibility map where it influences the occurrences landslide hazard. Slope angle can be classified into 6 classes based on Geology Society Malaysia. Table 2.2 refers to the slope angle while Table 2.3 refers to the slope direction.

Table 2.2: Classes of Slope angle

Classes of slope	Type of classes
0° – 5°	Very gentle
5° – 10°	Gentle
10° – 20°	Moderate
20°– 30°	Moderately steep
30° – 35°	Steep
> 35°	Very steep

Table 2.3: Classes of slope direction

Slope direction
North
South
East
West
North-east
North-west
South-west
South-east

b) Aspect

When the slope in the study area is affected by heavy rainfall, it can contribute to the occurrences of landslide. It also influenced by other factors such as soil thickness, flora distribution and degree of water saturation (Mezughi et al., 2012). Furthermore, the intensity of rain and amount of sun might be effect the landslide in some slope, for example hills that receive excessive rainfall are considered more vulnerable to landslides as the soils of these hills hit saturation earlier, resulting in increased water pressure from the pore. This considered as climatic aspect. The saturation capacity also depend on few factors like soil type, lithology and land cover.

c) Land use

The variations in land cover influence the spatial distribution of landslides along with other parameters for conditioning. The geological condition of the hills is influenced by changes in the land cover, resulting in instability at the slope.

d) Drainage density

Streams play a major role in the slope's stabilization by saturating the soil before the water level allows soil pore pressure to increase which may also have a direct effect on the slope's stabilization as a consequence of toe erosion. The greater the drainage rate, the lower the water penetration into the soil, and the higher the surface flow movement (Mezughi et al., 2012). Penetration usually happens on slopes next to extremely permeable streams, such as alluvium. Drainage topographic maps were digitized to create a drainage density map in this analysis, and a drainage density map was measured using the line density analyst extension on ArcGIS.

e) Distance from road

The landslides hazards mostly spread on the roads and on the slopes of the road sides. This occurs as a result of cutting the toe of steep slopes and filling along the road are common human activities in hilly areas, which increase the area susceptible to landslides. The hazard of landslides were scattered mainly on the roads and slopes of the road sides. This happens as a consequence of cutting the toe of steep slopes and filling along the path are typical human actions in hilly areas, raising the landslide-prone environment (Mezughi et al., 2012). For this analysis, the road distance map was created by digitizing the road network from a topographic map and rendering a buffer upside down to calculate the road's effect on the slope's stability.

f) Lithology

Lithology also can be a fundamental role in phenomena of landslide. The mineral content in the rock also effect the resistance of rock. As the more resistance rock able to withstand the forces compared to weaker and less resistance of rock. Different type of lithology have different resistance and different level of vulnerability in landslide.

g) Rainfall

The rainfall is the primary cause that causes natural activity landslides. Then, rainfall also is the primary trigger factor in the area where after heavy rainfall most of the landslides occurred. Thus, during the monsoon season and after heavy precipitation events, streams undergo high-energy floods and major discharges, and are the main cause of mud and debris floods. Based on past research, the maximum rainfall recorded in the Gua Musang is 9584.10 mm on 2014 (Hashim et al., 2017).

2.6.5 Past Research on Landslide

Malaysia is not a precipitous country which mountains and hills are less than 25% of the terrain where the slope collapses and landslides are a common occurrence (Qasim et al., 2013). Likely, Malaysia did not suffer major earthquakes except for Sabah but large-scale landslides still exist and mainly gravity-induced, combined with intense and sustained rainfall. There are several major series of landslide occurrence that happened in Malaysia include landslide in Ringlet in Cameron

Highlands, Sandakan in Sabah and Bukit Antarabangsa in Ulu Klang, Selangor. According to Haliza & Jabil, 2017 stated the collapse of Highland Tower in Ulu Klang which including 14 –storey blocks collapsed with 48 deaths in 1993 was the most tragic landslide occurred at Malaysia. In 1999, major scale of landslide happened at Bukit Antarabangsa where affected the access road to the residential area and the loss cost approximately 5.4 million (Akter. A et al., 2019). After that. Petley, D (2019) mentioned that the major landslide occurred in Genting Highlands as accumulation of soils and debris from high elevation has left the channel and flowed down the road. This happened due to three hours of major rainstorm in Genting Highlands.

Kelantan is located in the north-east corner of Peninsular Malaysia. This state will experiences northeast monsoon usually at the end of the year around October till March. Others east coast states such Terengganu and Pahang also will involve with this monsoon. The previous research in Kelantan by Hashim et al., (2017) concluded that the heavy rainfall in Kelantan had influences landslide events with various size using remote sensing data integrated with GIS approach.

Based on past research by Gahgah et al.,(2009) were studied about landslide zonation along Cameron Highlands – Gua Musang road had determined that five classes of potential landslide zone which very low hazard (17.27%), low hazard zone (39.35%), medium hazard zone (25.1%), high hazard zone (15.35%) and very high hazard zone (2.93%). The findings of the research were checked through landslide inventory using available aerial photo and field mapping showed that the slope and elevation have the most influence on landslide hazard.

2.6.6 Remote sensing and GIS Application

Remote sensing is a method used to observe surface of the planet and the surface of the earth without direct contact. It records reflected or released of electromagnetic energy by the earth's surface (Aggarawal, S, 2003). This techniques allow images of the earth's surface to be taken in different wavelength of the electromagnetic spectrum (EMS) and known as remote sensing imagery or satellite image. The remote sensing imagery has many uses for land use and land cover mapping, geomorphological studies, urban planning and many more.

A Geographic Information System (GIS) is a computer system used to analysis and manage spatial data. The word geographic indicate the locations of data items that can be calculated which is in geographical coordinates forms. While, the word information itself implies the data in GIS are organized to produce useful knowledge such coloured maps and images even so tables, statistical graphics and many more. System refers to GIS has many and different functions in order to organize the data either in vector or raster. (Xie, 2014)

Extracting important spatial details regarding the risk of landslides is an essential part of the hazard assessment. Remote Sensing (RS) data combined with the Geographical Information System (GIS) is known to be powerful tools for spatial information generation and processing.

The previous research was determined landslide location by tracking changes of vegetation pixel data using Landsat 8 images that obtained prior and past December 2014 (Hashim et al., 2017). During flood hazard on December 2014 in Kelantan river basin, the researcher used all the data from the geohazard of remote sensing and integrated with GIS analysis for produce map, detect and characterize occurrence of landslide in Kelantan.

According to Pradhan, B., 2010, he used remote sensing and GIS tools in analysing landslide events in Penang, Cameron and Selangor. There were ten parameters used during the research such as lope, aspect, curvature, lithology, soil type, land cover and distance from lineaments. The land cover and vegetation index were mapped using SPOT 5 and Landsat TM satellite imagery respectively. After calculation and validation, the maps are then generated using multiple parameters using multivariate logistic model.

Research by Roslee, R et al., 2017, focused on identified the landslide prone area and then construct Landslide Sucesptibility Level (LSL) map using weighted overlay method (WOM) along with GIS and remote sensing methods. Their study area located along Karak Highway which is connects Genting Sempah to Bentong, Pahang and use parameters such as slope, geomorphology, lithology, aspect, geological structure and many more. The topographic database used to generate parameters influence landslide such as slope, aspect, topographic curvature and distance from drainage. Meanwhile, the geologic database used to retrieve the geomorphology, geology structure and lithology parameters. Parameters like land use and soil types of study area generated using SPOT satellite image. All those parameters were overlaid and classified into landslide susceptibility classes from very low to very high classes. Hence, the possibility of landslide occurrence in study area depend on the susceptibility classes. Lastly, the researchers concluded where the changing of soil intensity and land were led to landslide events that had triggered by heavy rainfall.

2.6.7 Past Research on Landslide using Weighted Overlay Method

The weighted overlay approach is an easy bivariate method, straightforward and adequate methodology for evaluating potential land-slide area. Next, this method able to identify weights depend on relationship landslide causative factors with the frequency of landslide in study area (Shit et al., 2016). Moreover, WOM method also most innovative method in making multi criteria decision systems. Furthermore, this method will be ranked the parameters according to its importance. After that, the calculation in this method also simple. In order to build a map of landslide susceptibility, overlay of raster layers need to use with all the influencing factors. Then, all layers were combined using the overlay weighted method based on equation below.

$$S = \frac{\sum Wi\ Si\ j}{\sum Wi},$$

Where W_i is the weight of *i* th factor, S_{ij} represents subclass weight of *j* th factor and S is the spatial unit of the final map.

The research conducted by Roslee, R et al., (2017) used the weighted overlay method to determine the differences in qualitative of landslide occurrences at the study area. In all the parameter maps, the analysis and calculation processes in the research is similar. There was concluded that the weightage value showed the most causative factor which influenced landslide occurrences was slope gradient among others causative factors such as land use, distance from drainage, distance from lineament, soil lithology and geomorphology. From the combination of parameter maps, the landslide inventory map of study area able to produce using WOM which consist of five classes of landslide susceptibility level along the Genting Sempah to Bentong Highway such as very low (10 %), low (50 %), medium (15 %), high (15 %) and very high (10 %). As a result, the study area is mainly covered with low landslide susceptibility level.

Works by Basharat et al., (2016) also determine the occurrences of landslide in NW Himalaya, Pakistan derived using WOM. The landslide susceptibility map classified the study area into very high, high, moderate, and low of susceptible zones. After that, the susceptibility mapping findings were confirmed using the occurrence of landslides and the findings of the verification showed 76% accuracy. Then, the validated findings showed strong agreement between the frequency of landslides and created map of area susceptibility.

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

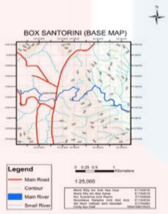
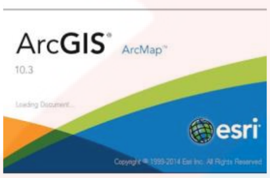
This chapter describe on the materials and method that were used to obtain results in geological parts and landslide analysis. Both analysis used GIS application in order to produce maps.

3.2 Materials

There are several tools that were used in the research study as listed in the Table 3.1.

Table 3.1: List of research materials

Materials	**Function**
Laptop 	To operate all the research study. For example, writing research paper, generate map.
Scanner 	To scan all the documents and images.
Printer	To print out the report and maps.

Hard disk 	To store and backup the secondary data and report.
Base map 	To provide the background details necessary for orient the location of map.
ArcGIS 10.3 	To process all the data and produce maps such as geological map and landslide inventory map.

In order to produce map of landslide susceptibility, the secondary data such as topographic map, rainfall map and satellite imagery were used. All of the data were collected from USGS, Google Earth Pro, and Department of Drainage & Irrigation (JPS) in the digital form.

3.3 Methodology

3.3.1 Preliminary studies

Before the research start, the study on the overview and evaluation on the study area is needed in terms of geological and landslide information. The satellite image also required as it able to capture geomorphology and can spot deformation related to tectonic movements and landslide area. The study on related journal, article and book is really important in order to gain knowledge about the historical, structural, lithology and occurrences of past landslide in the study area.

3.3.2 Secondary data

a) Land use

Landsat images dated 12.2008 (-path 127, row 057) and Landsat images dated 12.2016 (-path 127, row 057) were used to determine the land cover variations for Kampung Renok Baru, Gua Musang. Table 3.2 shows the characteristics of satellite imageries for determining land cover changes.

Table 3.2: Landsat data for land cover changes.
(Source: Google Earth)

Technical properties	**Data type Landsat satellite images**	
	Year 2008	**Year 2016**
Source	Google Earth	Google Earth
Spatial resolution	30 meter	30 meter
Path / Row	127/ 056	127 / 056
Projection	UTM	UTM
Datum	WGS84	WGS84

b) Digital elevation model (DEM)

DEM data dated 11.11.2010 was used to create the slope, aspect and drainage density maps. This data was gathered from USGS, so it has to be built from raw data like contour data and elevation which is not directly from existing map. This DEM data was used to create landform map and identify the occurrences of landslide sites. Table 3.3 shows the DEM data of Gua Musang.

Table 3.3: DEM data in Gua Musang, Kelantan
(Source: United States Geological Survey)

Technical properties	Data type Digital elevation Model	
	Year 2014	**Year 2019**
Source	USGS	USGS
Spatial resolution	30 meter	30 meter
Area	Gua Musang	Gua Musang

c) Rainfall

Rainfall data is able to support the parameter of landslide due to these data will shows the rainfall intensity in Gua Musang. The data from year 2015 and 2019 specifically in Gua Musang. Table 3.4 shows yearly precipitation data in Gua Musang, Kelantan.

Table 3.4: Rainfall data in Gua Musang, Kelantan
(**S**ource: Jabatan Pengairan dan Saliran (JPS))

Technical properties	Data type Rainfall	
	Year 2015	**Year 2019**
Source	JPS	JPS
Area	Gua Musang	Gua Musang

3.3.3 Data processing

This subsection discuss on steps to generate geological map as well as parameters map and also landslide susceptibility map using ArcGIS10.3.

a) Geological map

In order to generate geological map of study area, lithology and structural geology data is needed which was collected from previous study. Then, the data collection was then inserted into ArcGIS and processed using the tools in the software. Moreover, in order to create full geological map, the cross section of study area also need to be constructed using CorelDraw. Lastly, the cross section needs to add into the geological map in ArcGIS. Thus, the geological map of study area can be generated.

b) Thematic map

There are six parameters have been selected for the study area which are distance from road, slope, aspect, land use, lithology and drainage density. The parameters map of study area also was created in ArcGIS software. Each parameters map was generated by availability of various remote sensing data and also different type of multi-temporal. After all the secondary data of parameters have been obtained, the data collection was undergone processing using the specific tools in Arc Toolbox of ArcGIS 10.3.

c) Landslide susceptibility map using Weighted Overlay Method (WOM)

Landslide susceptibility map of study area was generated using WOM based on parameters of slope, aspect, distance to road, land use, lithology and drainage density. There are several steps need to follow. First step is rasterization. All the parameter converted from vector to raster using ArcGIS 10.3. Followed by reclassification. The parameters basically reclassified using reclassify tool in ArcGIS. After that, Weighted overlay method for generating landslide map was selected. As the raster were weighted, a rating scheme used to rate each parameters and their classes were assigned as numerical values as shown in Table 3.5. The evaluation for parameters and classes must in scale such as the landslide evaluate by using scale from 1 to 3. The scale 1 is the least potential to landslide area while the very high landslide prone area is 3. The raster parameters were overlaid and ranked by referring to its importance and total influence are required to be 100%. Table 3.5 shows the parameters are classified into various classes and also give a weightage and rating according to the selected criteria. While, Table 3.6 shows the landslide index classification with class name. Table 3.7 shows reclassify data set with influence.

Table 3.5: The weightage, class and rating for causative factors (Awawdeh, M. M et al., 2018)

Causative factors	Weightage	Class	Rating
Slope	9	0° – 5° 5° – 10° 10° – 20° 20°– 30° 30° – 35° > 35°	1 2 3 4 5 6
Aspect	8	Flat South North Northeast Southeast East West Southwest Northwest	0 5 1 2 4 3 7 6 8
Lithology	6	Limestone Metasedimentary rock Tuff Alluvium	5 6 7 3
Distance to road	8	Very low risk Low risk Moderately risk High Very high risk	1 2 3 4 5
Land use	5	Forestry Plantation Housing area	1 4 3
Drainage density	7	Low Moderate High	1 2 3

Table 3.6: The landslide susceptibility index classification and their landslide class name (Bappaditya Koley et al., 2020)

Landslide susceptibility class	Landslide susceptibility index classification	Landslide susceptibility class name
1	2-3	Low
2	3.01- 4	Moderate
3	4.01- 5	High

Table 3.7: The reclassify data set with influence

Raster Datasets	Influence
Lithology : Pyroclastic rock (Tuff) Limestone Metasedimentary rock (Phyllite, Slate, Shale) Alluvium	10
Slope : 0° – 5° - Very gentle 5° – 10° - Gentle 10° – 20° - Moderate 20°– 30° - Moderately steep 30° – 35° - Steep > 35° - Very steep	25
Aspect: Flat South North Northeast Southeast East West Southwest Northwest	20
Land use: Forestry Plantation Housing area	10

Raster Datasets	Influence
Drainage density: Low Moderate High	15
Distance from road: Very low risk Low risk Moderately risk High risk Very high risk	20
TOTAL	100

3.3.4 Data analysis and interpretation

ArcGIS 10.3 software able to combine data obtained from geological data and landslide data in order to produce geological and landslide susceptibility maps using WOM. From both maps, the interpretation is able to conduct. The research is relying on the interpretation and secondary data from Google Earth, USGS and JPS. This interpretation based on satellite image performed by visual interpretation using computer aided software. ArcGIS 10.3 software was used because of this software had advantages in terms of interpretation visually. Other than that, this software also have the capabilities of digital image processing, visualization of three dimensional, modelling and other visual techniques that helps researcher to complete their research. All the various dataset need to gather and overlays from vector and raster data to produce new information of geological interpretation of study area.

This interpretation is able to describe the morphological features of study area, which identify the type of landforms, and group into classes of geomorphology.

The main keys of image interpretation are pattern, relief, drainage, shape and vegetation of study area. Then, different landform describe different rock types. In addition, the lineaments also able to indicate structure such as folds and faults.

The parameters such as slope, aspect, drainage density and distance from road were produced by using DEM. While, land use and lithology were digitized based on satellite image and topographic map. After all the raster input were weighted, the landslide susceptibility map produced. Hence, the map showed the landslide susceptibility area with susceptibility level and scale of 1 to 3. The distribution of high susceptible to low susceptible zones of landslide to occur display in the map. Lastly, the map of susceptibility landslide also can be used in land use planning in study area such as avoiding any construction and development near the high susceptible area. Figure 3.1 indicates the flowchart of overall research methodology.

3.3.5 Research Flowchart

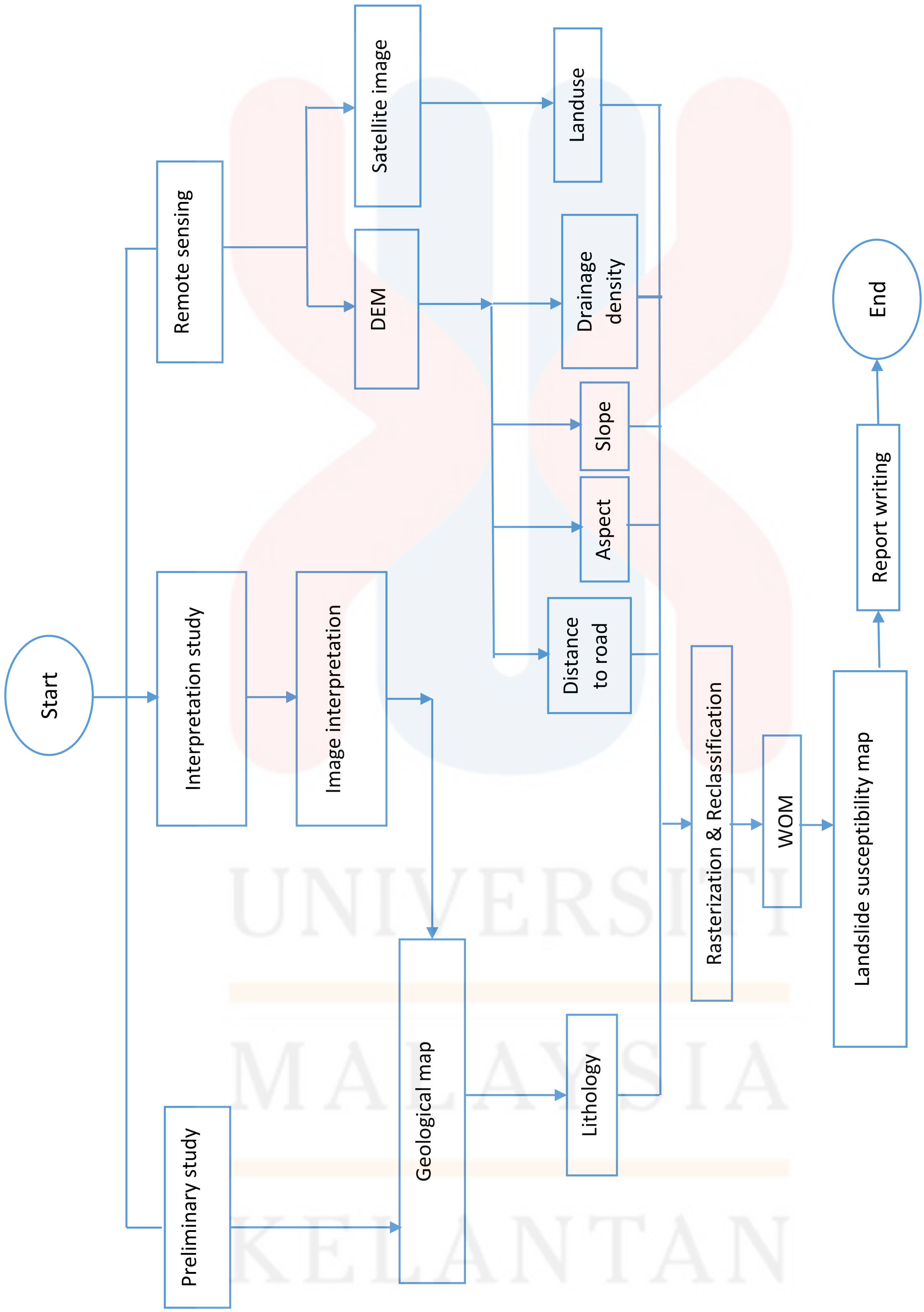


Figure 3.1: Research flowchart

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

General geology basically discussed about information, data collection and analysis of the research. It is include geomorphology, stratigraphy, lithology, structural geology and also historical geology. All of the data had been obtained and gathered from secondary data and past research. Then, a geological map was produced which showed the rock unit distribution, type of rocks, the geological structures and the correlation between age and rock in the study area.

4.1.1 Accessibility

The study area is located along the Highway of Gua Musang – Kota Bharu which can be accessed by this main highway. The distance from UMK Jeli to Kampung Renok Baru is about 131 km and took around 1 hour and 56 minutes driving. Furthermore, there are also some alternatives roads like paved and unpaved road to reach into the whole study area by foot and by vehicle.

4.1.2 Settlement

The settlement area in this study area is Kampung Renok Baru. Based on interpretation from Google Earth, the settlement pattern in Kampung Renok Baru can be classified into two which are nucleated and linear settlement pattern. Nucleated pattern defined as a grouping of many houses that closely together and often concentrated around common center of village like road junction. While, linear pattern shows houses form a straight line, following the road network in the study area.

4.1.3 Forestry

In the study area, the forestry that located at the south was made up by forest which is Permanent Forest Reserve of Gunung Rabong, Gua Musang. Besides, this study area also covered by oil palm and rubber plantation. Both plantations are under agency of Felda and KESEDAR. The forestry and vegetation also influence the human activities and jobs opportunities in the area. Mostly, residents in Kampung Renok Baru have their own estate and also working with management of Felda.

4.2 Geomorphology

Geomorphology is the study of the Earth's surface landforms, their mechanisms, shape, and sediments. Landforms are formed by erosion or deposition, as rock and sediment are eroded away by these earth-surface processes and transported and deposited in various areas. The various climatic conditions contain different types of soil. In geomorphology, landform or morphology, there are three facets which are constitution, as chemical and physical properties defined by material product variables. Then, structure where the size and shape was described by geometry variables and the mass flow which the rates of flow described by such mass flow variables as discharge, precipitation rate, and evaporation rate.

4.2.1 Geomorphologic classification

Generally in the study area, the geomorphology or landform is divided into two types which are land and hilly areas as shown in Figure 4.1. The differences of lithology normally indicate different types of landforms. Mostly, the study area covered by metasedimentary rock such as phyllite, slate, shale which in land to low hill areas. However, study area also consists of limestone in land until hill areas and some tuff in the hill areas. The landform classification can be classified by elevation based on Van Zuidam, 1985 as shown in Table 4.1.

Table 4.1: Classification of landform

Landform	Elevation (m)
Land	50 – 100
Low hill	100 – 200
Hill	200 – 500

(Source: Van Zuidam, 1985)

4.2.2 Drainage pattern

Drainage pattern is the arrangement that refers to spatial connections between main rivers and tributaries on surface of the Earth. The patterns were created by the erosion of streams over time, which shows the features of the kind of rocks and geological formations in a landscape area drained by streams. Then, the erosion of drainage pattern may affected by the differences in slope, rock resistance, structures and geological background of the environment. Dendritic, radial, parallel, subparallel and rectangular are examples of types of drainage pattern.

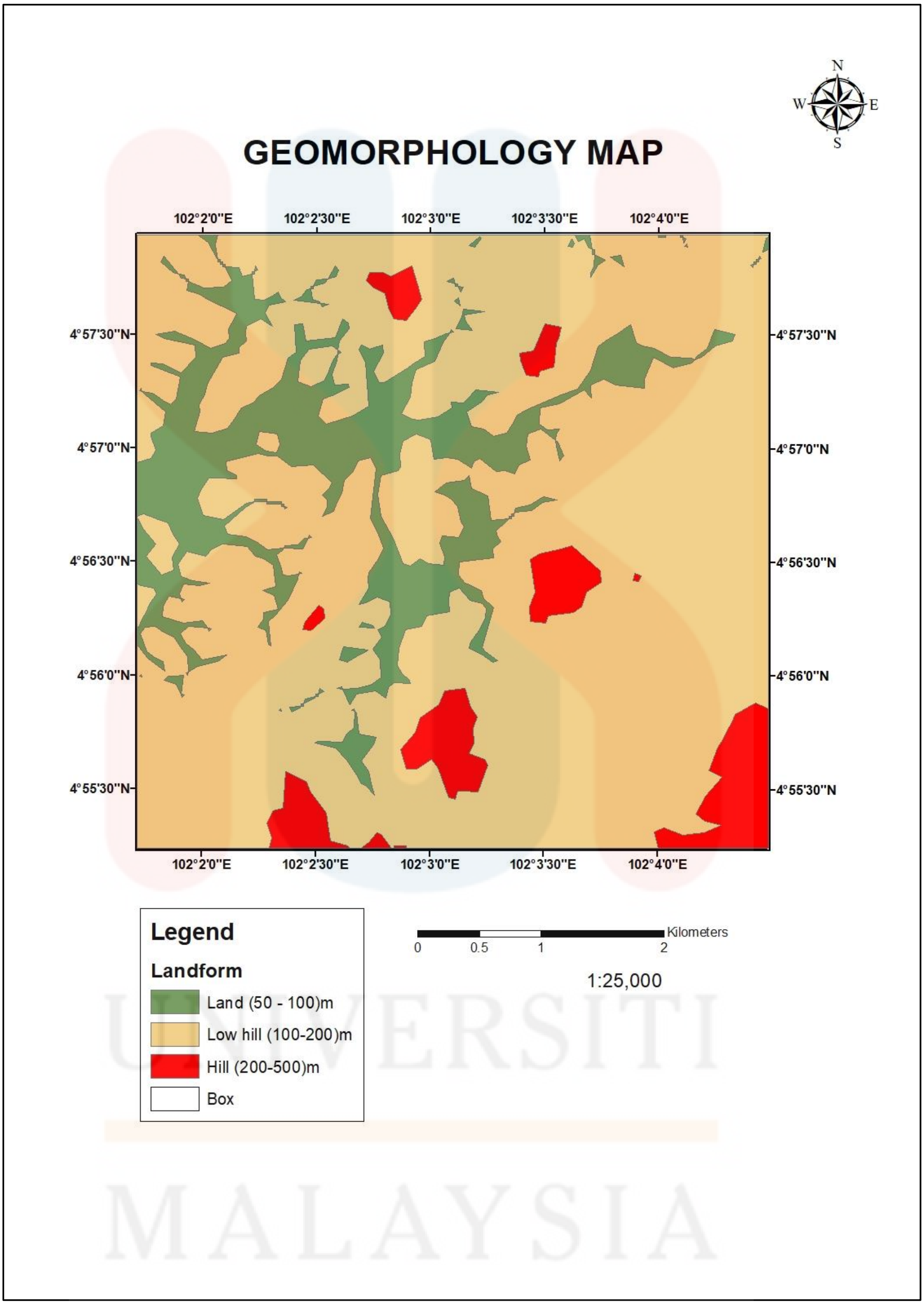


Figure 4.1: Geomorphology map of study area

There are several types of drainage pattern which can be identified in study area which are dendritic, radial, parallel and subparallel. Dendritic is one of most common pattern which treelike pattern composed of branches of tributaries and a main river that randomly developed. The lithology belongs to this pattern usually homogenous material. The subsurface geology has a common resistance to weathering, but there is no apparent control over the path of the tributaries. Dendritic area consist of the distribution of metasedimentary rocks. The geological importance of this pattern is the forms of rocks should be impervious and non-porous.

Radial is formed around a central elevated point. It is composed of streams that radiating outwards from the central peak. This pattern commonly found on tops of mountains and some geological features typically associated with radial drainage are domes and laccoliths. In the study area, the lithologies found at radial pattern were tuff and metasedimentary rock.

Parallel pattern is characterized based on major streams trending in the same direction. Commonly, tributaries join the main stream at same angle. Parallel rivers are indicative of uniformly sloping topography. Besides, subparallel pattern. It is same as parallel pattern but it consist more branches or tributaries compare to parallel. Both pattern made up of metasedimentary rocks. The tributaries of both drainage patterns showed the existence of major fault that cuts through it as it a steeply folded bedrock region. The drainage pattern map of study area is shown in Figure 4.2.

4.3 Lithostratigraphy

Lithostratigraphy is the study of sequence of rock strata based on lithology. (Henrich, R, 2014). The lithology units also include characteristics like mineral composition, colour, and texture and also grain size. It is also a sub discipline in stratigraphy. The main researches are on geochronology, comparative geology and petrology.

There are three main types of lithologies in study area. The lithologies were divided into Telong formation which made up of tuff and metasedimentary rocks while Merapoh Limestone that consists of limestone. These three lithologies were interfingering in age of Middle Permain to Late Triassic.

As a conclusion, the metasedimentary was the oldest rocks in the study area and then some tuff were deposited on the metasedimentary rock. However, the Merapoh limestone also start deposited same age as metasedimentary rock and then some tuff also were deposited on the limestone. It seems that some tuff was older than limestone and vice versa. For alluvium, this unit of rock was the youngest rock as the age in quaternary and the alluvium deposited always occurred and happened. Table 4.2 shows the stratigraphic column of study area.

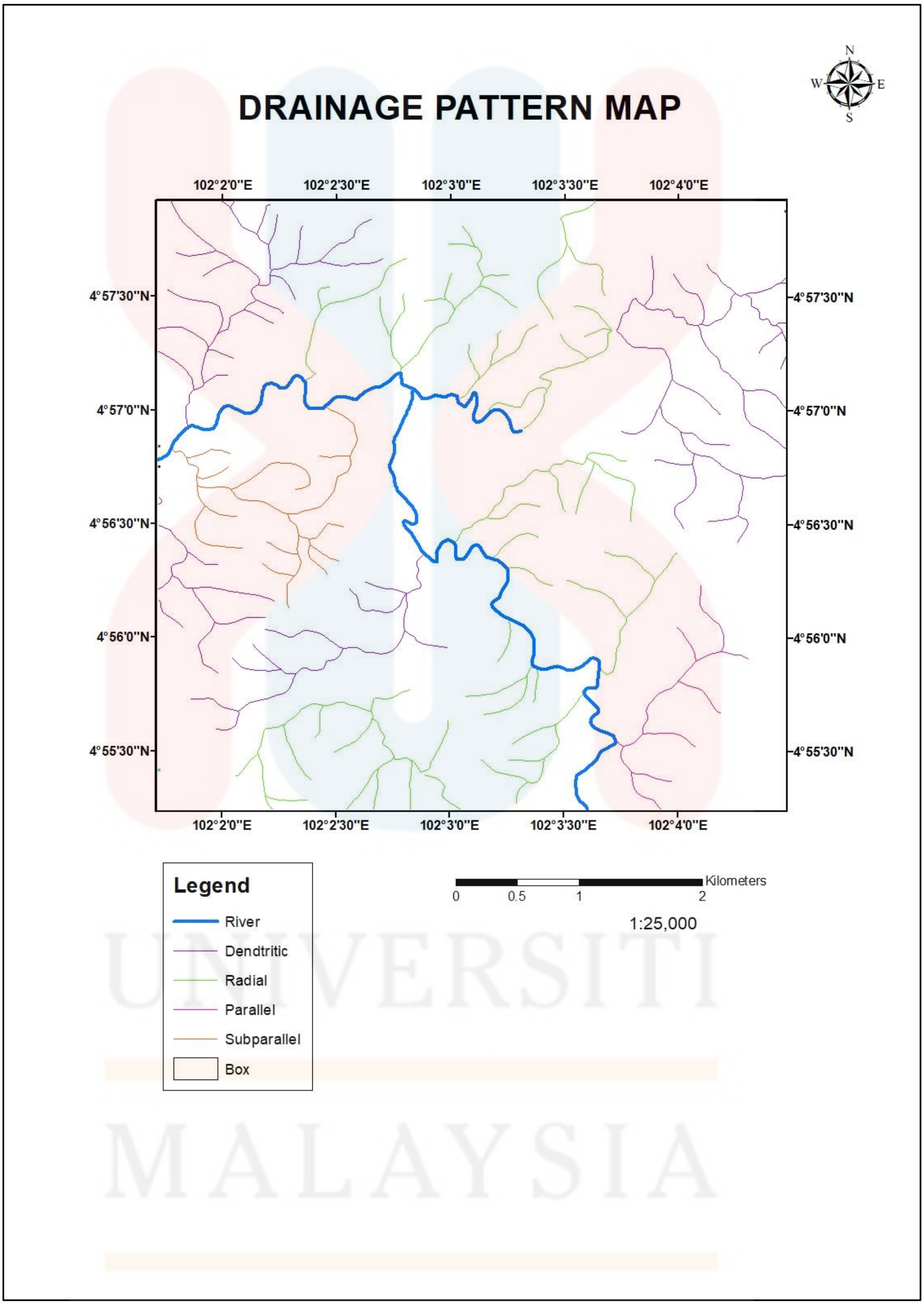
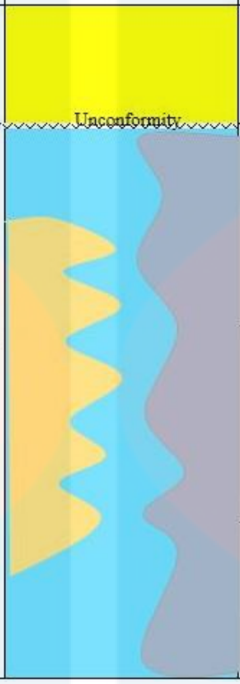


Figure 4.2: Drainage pattern map of study area

4.3.1 Lithostratigraphy Position

Table 4.2: Lithostratigraphy column of study area

Era	Period	Formation	Lithology	Lithology unit	Description
Cenozoic	Quaternary	-		Alluvium	Made up of sand, silt, clay and gravel that deposited at the river due to erosion.
Palaeozoic to Mesozoic	Middle Permian to Late Triassic	Merapoh Limestone & Telong formation		Limestone	Made up of calcium carbonate ($CaCO_3$). Deposited during shallow marine environment. From Merapoh Limestone.
				Pyroclastic rock (Tuff)	Known as pyroclastic materials and made up from volcanic ash that ejected from a vent during volcanic eruption.
				Metasedimentary rock (Phyllite/ Slate/ Shale)	Sedimentary rock that undergo metamorphism process due to high pressure and temperature.

4.3.2 Unit explanation

a) Metasedimentary rock

Metasedimentary rock is type of rock that first formed through the deposition and solidification of sediment or called as sedimentary rock. After that, the rock remained buried underneath subsequent rock and was exposed to high stresses and temperatures or process called metamorphism, allowing the rock to recrystallize. Thus, the rock will become metasedimentary rock. The distribution metasedimentary rocks in study area are shale, phyllite and slate from Telong Formation. Phyllite classified as medium to low grade metamorphism while slate is low grade of metamorphism.

b) Limestone

Limestone is a sedimentary rock that composed of calcium carbonate ($CaCO_3$) in the form of mineral calcite. It is usually an organic sedimentary rock that forms from the accumulation of shell, coral, algal, and debris. This limestone facies represented by thick successions of carbonate forming limestone hills or called as karst limestone. Then, the distribution of limestone in study area is from Merapoh Limestone.

c) Tuff

Tuff is an igneous rock, where rock made of volcanic ash has been expelled through air after volcanic eruption. Since ejection and deposition, the ash is lithified into a solid rock. From previous research, there are two type of tuff which is lapilli tuff and fine grain tuff. However, during this research there is no evidence for occurrence of both tuffs. Thus, it had been classified generally as tuff rock which is from Telong Formation.

d) Alluvium

Alluvium is made up of sand, silt, clay and gravel that deposited at the river due to erosion and deposition. It is typically more widely formed in the lower part of the river, creating floodplains and deltas, but can be deposited at any place where the river overflows its banks. The alluvium in study area deposited at the main river which is Sungai Asap. This alluvium is really young in terms of age where is in Quaternary age and also young in depositional material as depositional and erosion processes always occurred and changed the structure of the river. Also, the floodplains area also can be found in the main river. The lithology of study area shown in Figure 4. 3.

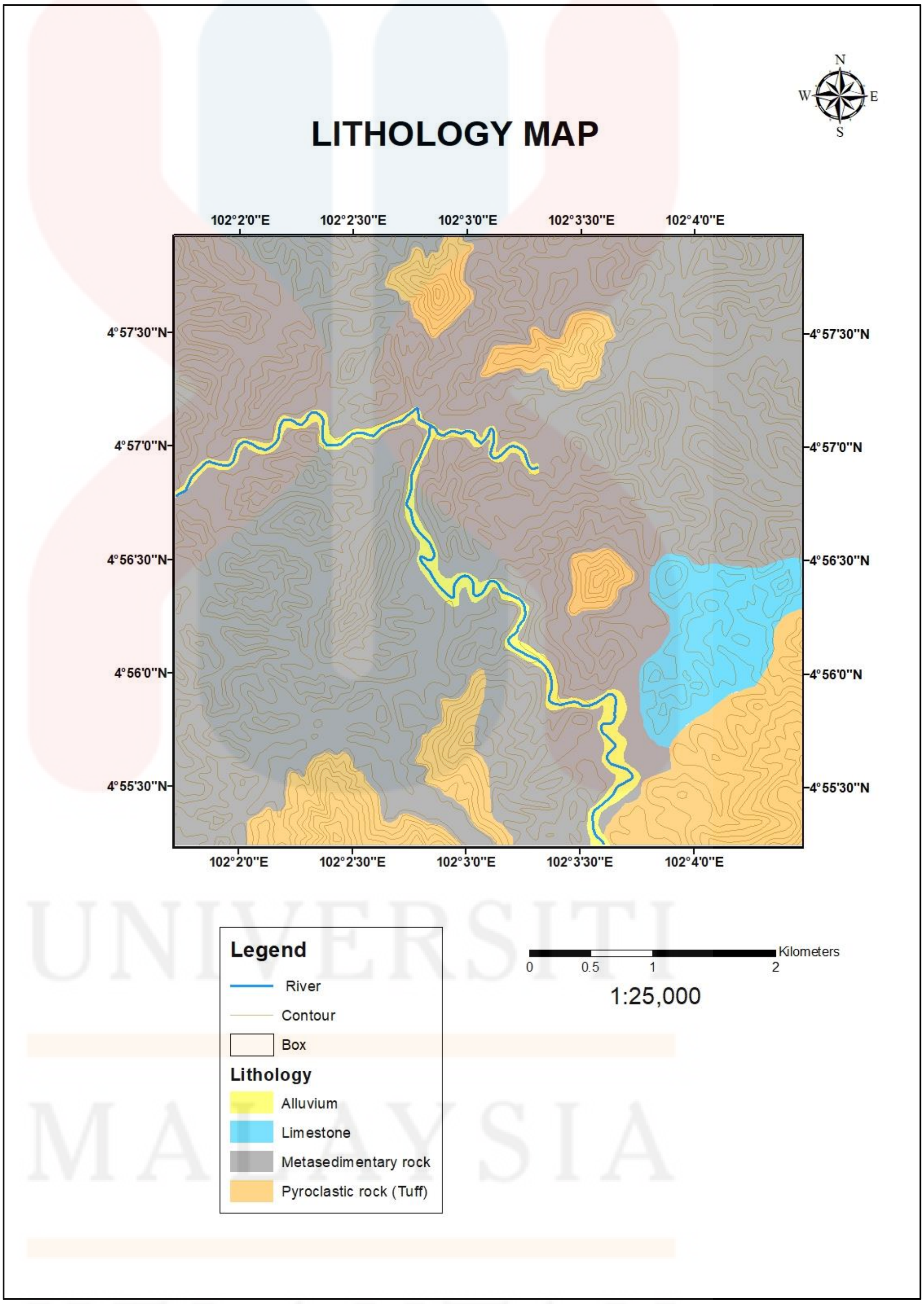


Figure 4.3: Lithology map of study area

4.4 Structural geology

Structural geology is the study of three-dimensional structure of large rock formations, their surfaces, and the structure inside rock units to learn about their origin of tectonic motions, historical seismic processes, and conditions that may have deformed them. Thus, the date of structural geology formed can be determined. Furthermore, structural geology is used to measures the stress field that resulted in the observed strain and geometry. Besides, the structural evolution on a particular area due to plate tectonics can be understood. The structural analysis for this study area was done by interpretation of satellite images and aerial photos such as terrain map from Google Earth Pro. The geological structures of the research area were identified in details for further interpretation. Based on online interpretation, the lineament map was generated.

4.4.1 Lineament analysis

Lineaments provide information about the geological structure in the study area. Commonly, lineaments can be seen through linear or straight line from satellite image, topographic map or terrain map. Therefore, the terrain surface which indicates the structural geology in study area is faulting and other structures. Furthermore, lineaments also can be divided into two types which are negative and positive lineaments. The negative lineaments represent the valley and river while the positive lineaments represent the ridge in the area.

During preliminary study, this analysis was done in order to locate geological structures such as faulting. Figure 4.4 and 4.5 shows the lineament map of study area.

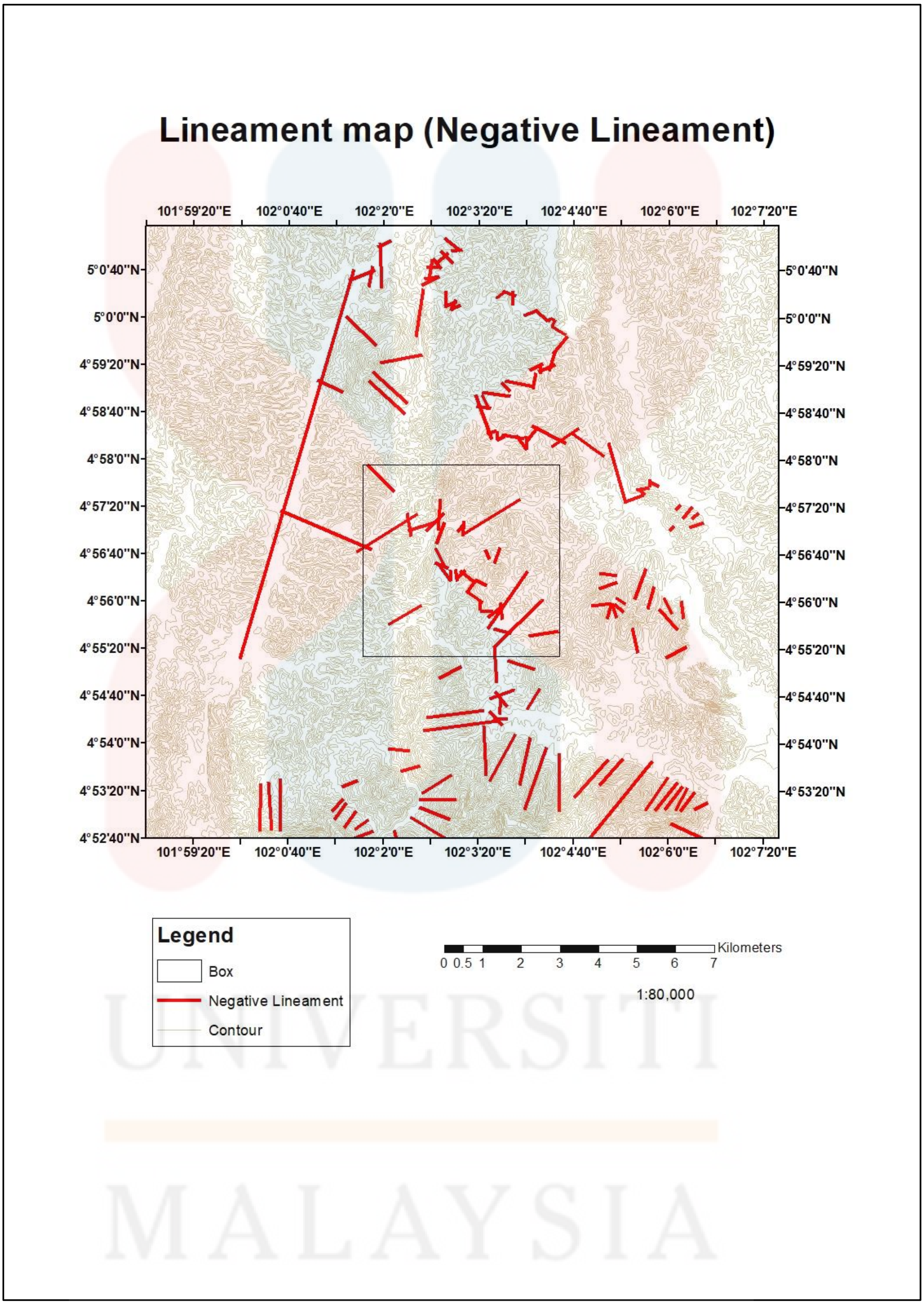


Figure 4.4: Lineament map (Negative) of study area

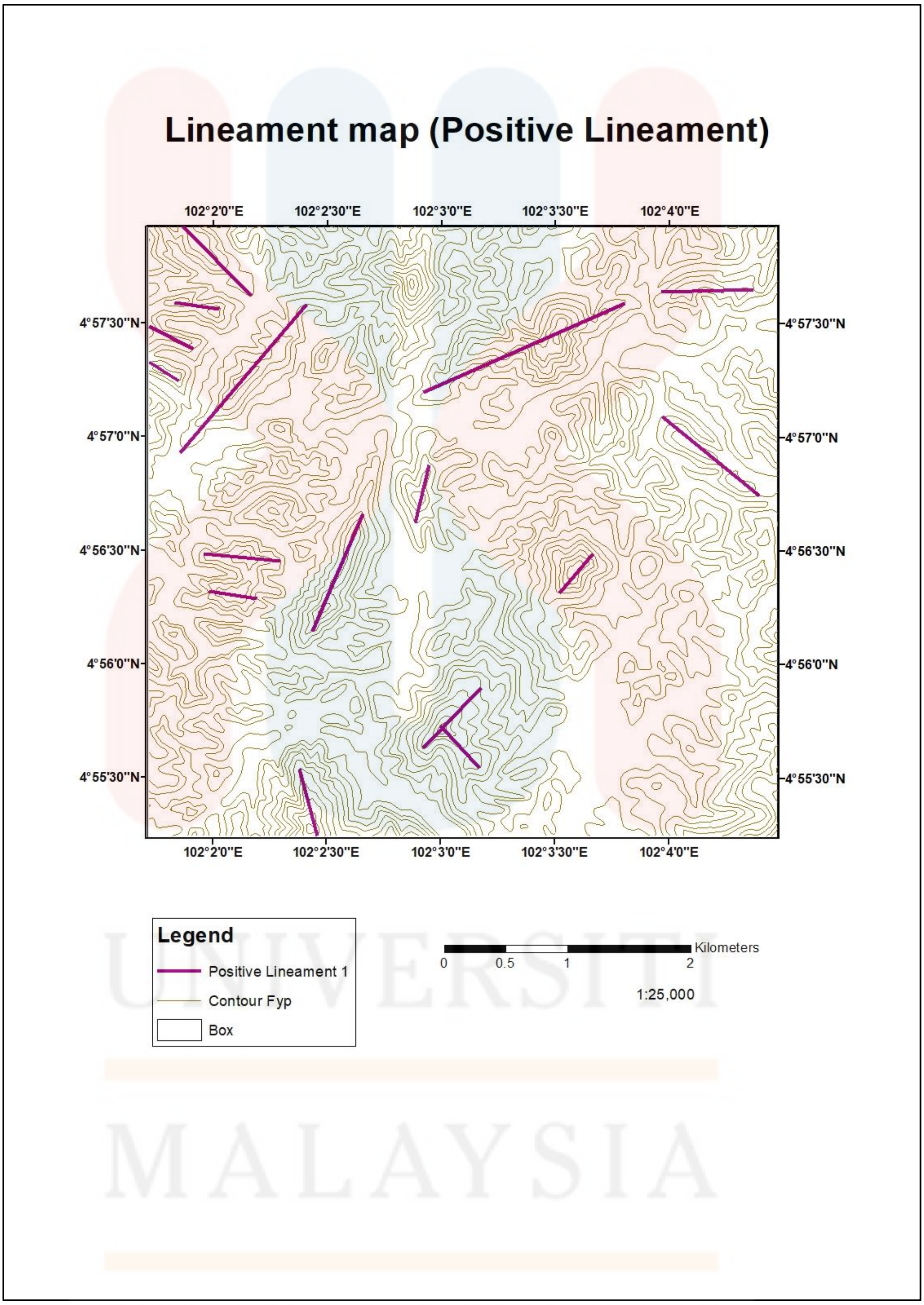


Figure 4.5: Lineament map (Positive) of study area

4.4.2 Fault

Fault is a crack or fracture between rocks. This fracture split into two parallel rock blocks that have pushed past each other due to stress. Usually, faults occurred because of the movement of tectonic plates. The movement of blocks defined the distinct kinds of faults and stress either ductile or brittle. There are three basic type of fault which are normal fault, reverse fault and transform fault. Subdivision of faulting also has strike slip fault, oblique fault and dip-strike fault.

The fault that was interpreted in study area is sinistral strike slip fault. This strike slip fault is vertical fractures where the blocks moved horizontally. Sinistral strike slip fault determined if the side moves oppositely to the left, this fault also known as left- lateral strike slip fault. The interpretation of this faulting interpret is based on analyzing lineament analysis data. Then, the readings of strike were plotted in rose diagram in Figure 4.6.

4.4.3 Mechanism of structure

From the lineament analysis, the reading of strike recorded and plotted in the rose diagram. The rose diagram indicate the forces in the study area using the strike reading. Table 3.3 shows the reading of strike.

a) Negative Lineament

Table 4.3: Reading of strike

STRIKE						
47	35	358	80	67	2	54
5	58	288	70	11	357	38
324	352	83	0	358	1	50
354	81	83	23	65	36	73
350	356	358	66	38	41	45
72	72	11	275	37	35	306
5	321	19	321	60	54	69

STRIKE						
52	7	0	48	295	69	65
285	88	39	315	302	69	281
59	319	33	84	89	352	325
314	58	41	308	58	334	358
349	68	40	70	73	318	
43	345	62	277	277	349	
308	340	79	308	336	20	
305	312	313	302	20	16	
20	32	295	17	339	316	
41	288	8	83	296	80	
34	83	63	340	276	9	
46	83	11	16	358	298	

From the rose diagram in Figure 4.6, the direction of force indicates a sinistral strike slip left lateral motion. The fault formed in the study area due to the compressional stress. So, the study area consists of shear fractures.

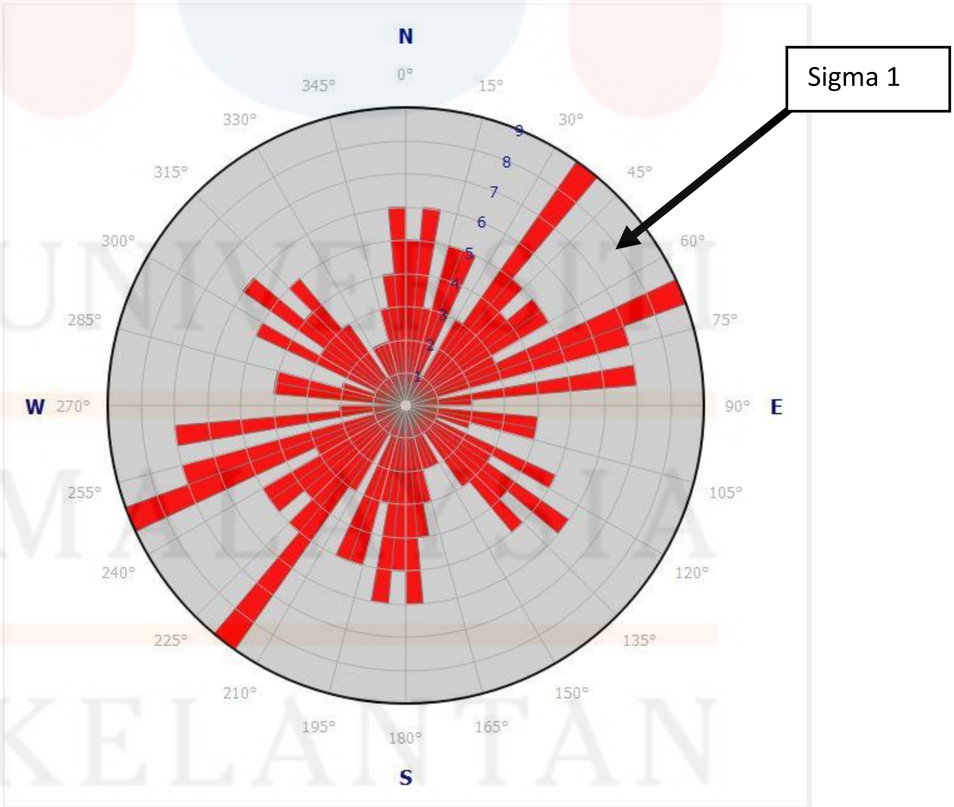
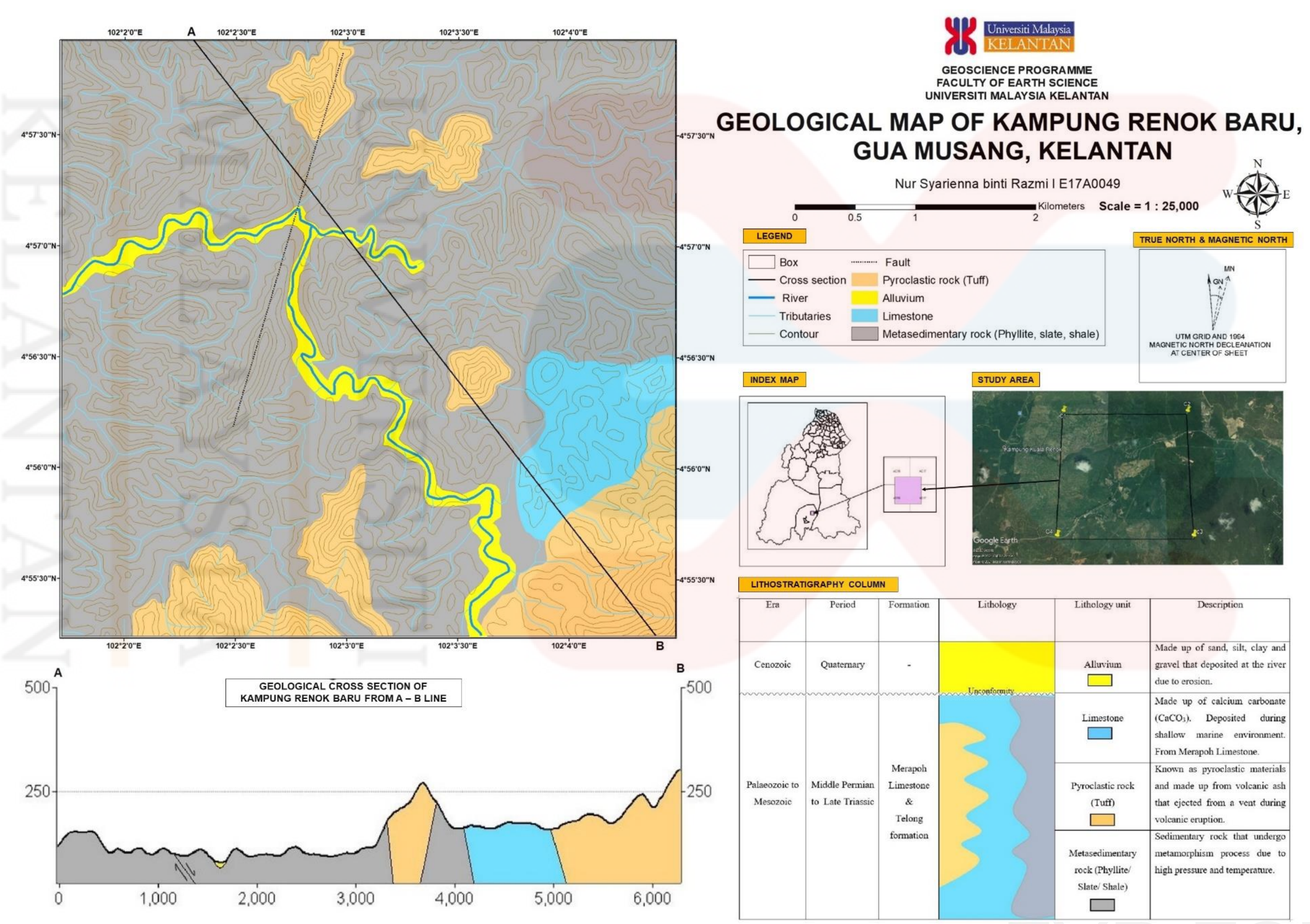


Figure 4.6: Rose diagram indicate sinistral strike slip fault

4.5 Historical geology

A highly deformed accretionary continues to grow as the Paleo Tethys Ocean and the Sibumasu plate were subducted under the Indochina plate. Thus, the depositional of argillocarbonate sediments were occurred with the shallow marine platform of Gua Musang. The nearby of volcanic arc also supplied the volcanic rock around the Gua Musang. Finally, the progressed of sedimentation of shallow marine in Gua Musang started from Permian to the Early Triassic (Metcalfe, 2013).

Hence, the study area covered by Telong formation which age from Middle Permian to Late Triassic is made up of argillite associated with some tuff and turbidities (Mohamed et al., 2016). The distribution of sedimentary rock in study area also had been identified as limestone unit that made up by Merapoh Limestone which also from Middle Permian to Late Triassic age. Figure 4.7 shows the geological map of study area when interpretation study is completed.



Era	Period	Formation	Lithology	Lithology unit	Description
Cenozoic	Quaternary	-		Alluvium	Made up of sand, silt, clay and gravel that deposited at the river due to erosion.
Palaeozoic to Mesozoic	Middle Permian to Late Triassic	Merapoh Limestone & Telong formation		Limestone	Made up of calcium carbonate ($CaCO_3$). Deposited during shallow marine environment. From Merapoh Limestone.
				Pyroclastic rock (Tuff)	Known as pyroclastic materials and made up from volcanic ash that ejected from a vent during volcanic eruption.
				Metasedimentary rock (Phyllite/ Slate/ Shale)	Sedimentary rock that undergo metamorphism process due to high pressure and temperature.

Figure 4.7: Geological map of study area

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY ANALYSIS

5.1 Introduction

In this chapter, the research based on specification which is landslide susceptibility in study area was analyzed and determined. The landslide susceptibility map was generated using ArcGIS 10.3 software. There were six parameters used in order to identify the landslide causative factors such as lithology, slope, aspect, land use, drainage density and distance from road. The parameters were generated using DEM STRM data year 2019. The average weightage for each parameters were used to determine the landslide susceptibility in the study area.

5.2 Evaluation of parameters

There were six parameters used in conducting this research. Table 5.1 shows the parameters involved.

Table 5.1: The parameter of causative factor

No	Parameter
1	Lithology
2	Slope
3	Aspect
4	Land use
5	Drainage density
6	Distance from road

5.2.1 Lithology

Lithology map was derived from geological map in order to determine the occurrence of landslide in the study area. Differences in lithology play an importance role as each lithology have high or low vulnerability to the landslide hazard. Moreover, the lithology and formation condition able to differentiate the features of rock. Next, the two formations that made up in study area are Merapoh Limestone and Telong Formation. Figure 5.1 shows the lithology map of study area.

Based on Figure 5.1, about 80% of study area covered by metasedimentary rock, 15% covered by tuff, limestone and alluvium made up about 3% and 2% respectively. The vulnerability to landslide had been rating for each lithology by referring to Table 3.5. The region that covered with alluvium had the highest potential area to occurrence of landslide while limestone area can be said as the lowest landslide prone area among others lithology in study area. In addition, the potential landslide hazards in metasedimentary rock and tuff determined as moderately prone to landslide as rating for both distribution is in between limestone and alluvium.

5.2.2 Slope

Slope is one of most major causative factor that influences the occurrence of landslide in the study area. The erosion or landslide occurred down a slope due to loss of strength of soil and rock. The study area was divided into three categories of landform which are land, low hill and hill. Figure 5.2 shows the slope map of study area.

As mentioned before the slope was classified by Geological Society Malaysia (GSM) and is divided into five classes. As shown in Table 3.2, the weighting value for slopes is the highest among other causative factors because slopes have the greatest influence in landslide hazards. Meanwhile, the slope score will increase as the slope level increases. However, the validation for occurrence of landslide and the slope prone to landslide that might be happened cannot be determined in the specific area. It is due to limitation of data which is based on interpretation using secondary data and no validation in field. Refer to Figure 5.2, most of the study area has an angle between 10° to 20° which is consider as moderate slope. While, very steep slope with angle is more than 35° has the least covered area.

5.2.3 Aspect

Aspect is an indirect factor affecting the vulnerability of slope. The aspect map also was generated from DEM data. The aspect map showed the slope direction of ground with respect to North for a terrain and this map was divided into nine classification of slope direction. As various direction of slope map associated with various impact of gravitational force. Figure 5.3 shows the aspect map of study area.

5.2.4 Land use

Land use map were generated from secondary data collected from USGS. Figure 5.4 represents the land use map in study area. The study area mostly covered by forestry and plantation however there was also nucleated and linear patterns of settlement area occupied with population of villagers at Kampung Renok Baru. The potential of landslide commonly occurred in plantation while forestry and housing area that near to steep slope also might be affected if landslide hazard happened.

5.2.5 Drainage density

A drainage density map was produced also from DEM data with the additional support of satellite imageries. Importantly, the closeness of the slopes to the stream networks is seem to be another significant factor that affects the stability of the slopes. Streams play a role in the stability of the slope by penetrating the soil until the water level creates a rise in soil pore pressure and can also have an effect on the stability of the slope as a result of toe erosion. In addition, the higher the drainage density the lower of water penetration into soil and the movement surface flow also become faster (Cevik & Topal, 2003).

As shown in Figure 5.5, the drainage density in study area was classified into three equal intervals. The moderate drainage density occupied the most of area in study area followed by the low drainage density and then the high drainage density occupied the sloping and river area. Normally, penetration occurs on slopes nearest to streams with high permeability, such as alluvium (Mezughi et al, 2012). Thus, a drainage density map in Figure 5.5 shows the high steams density were occupied at the nearest area to the streams and the deposition place of alluvium.

5.2.6 Distance from road

There were many landslide hazard occurred close to the road. Due to the study area located along Highway Gua Musang – Kota Bharu, so this became one of the reasons why distance from road parameter was selected in this research. The cutting of road affected the instability of slope along the highway. However, the proof of accurate area for landslide occurred in study area unable to reveal due to insufficient data as no confirmation in the field.

The distance from road map was produced as shown in Figure 5.6. Moreover, the intervals for distance from road were divided into five classes. The most proximity distance to road shows the high tendency for occurrence of landslide rather than far distance but it also depends on others parameters that can triggered to landslide.

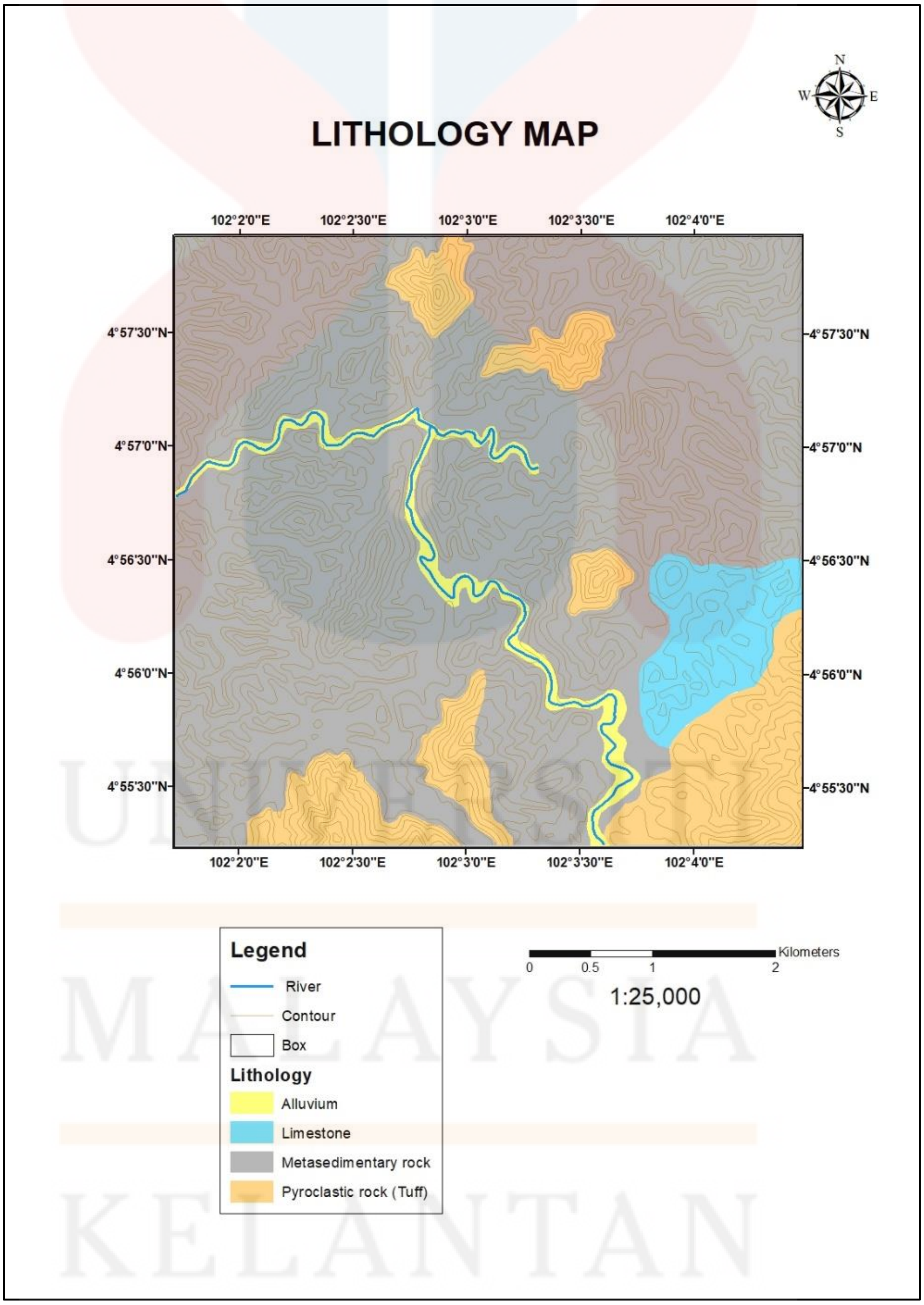


Figure 5.1: Lithology map of study area

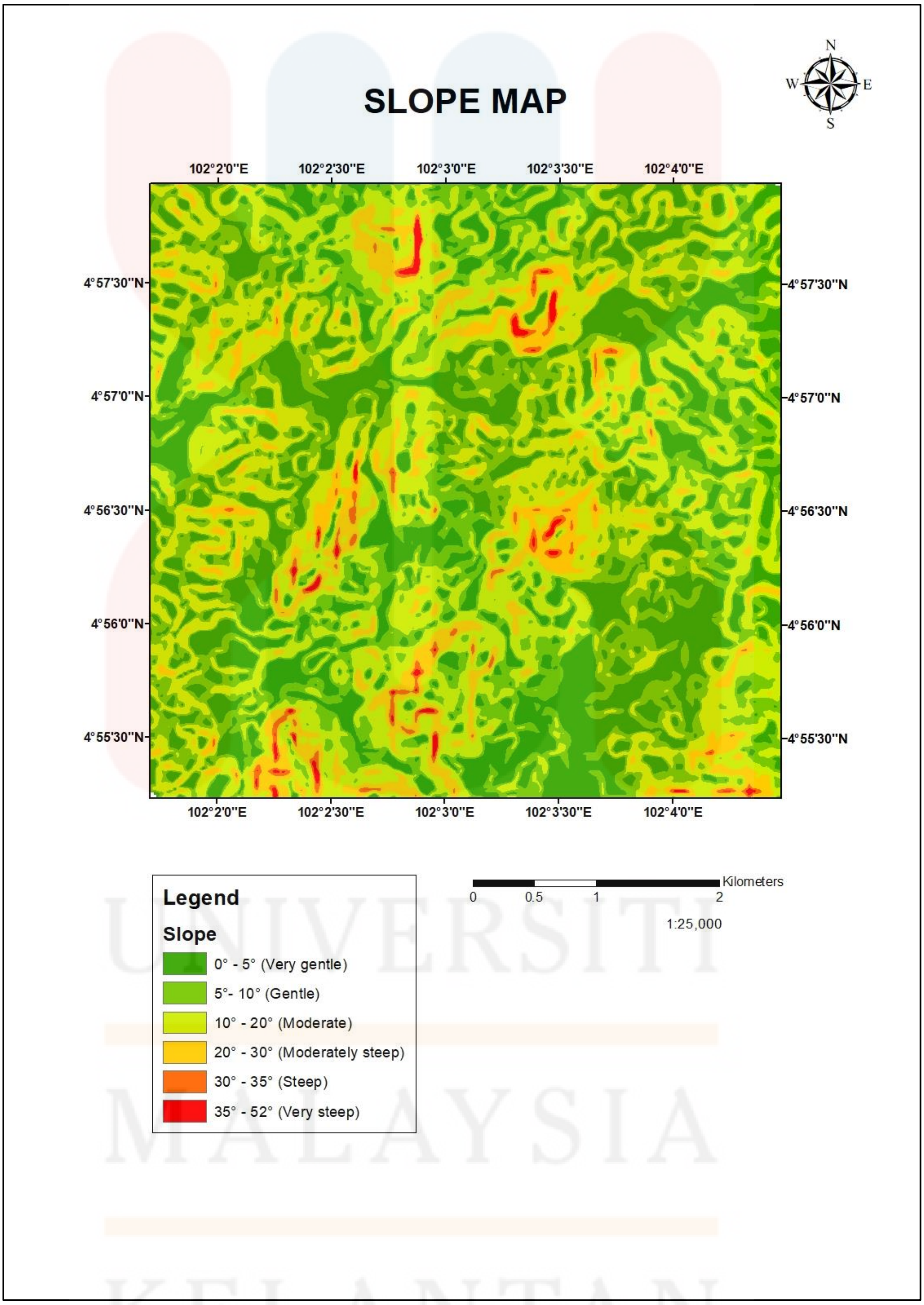


Figure 5.2: Slope map of study area

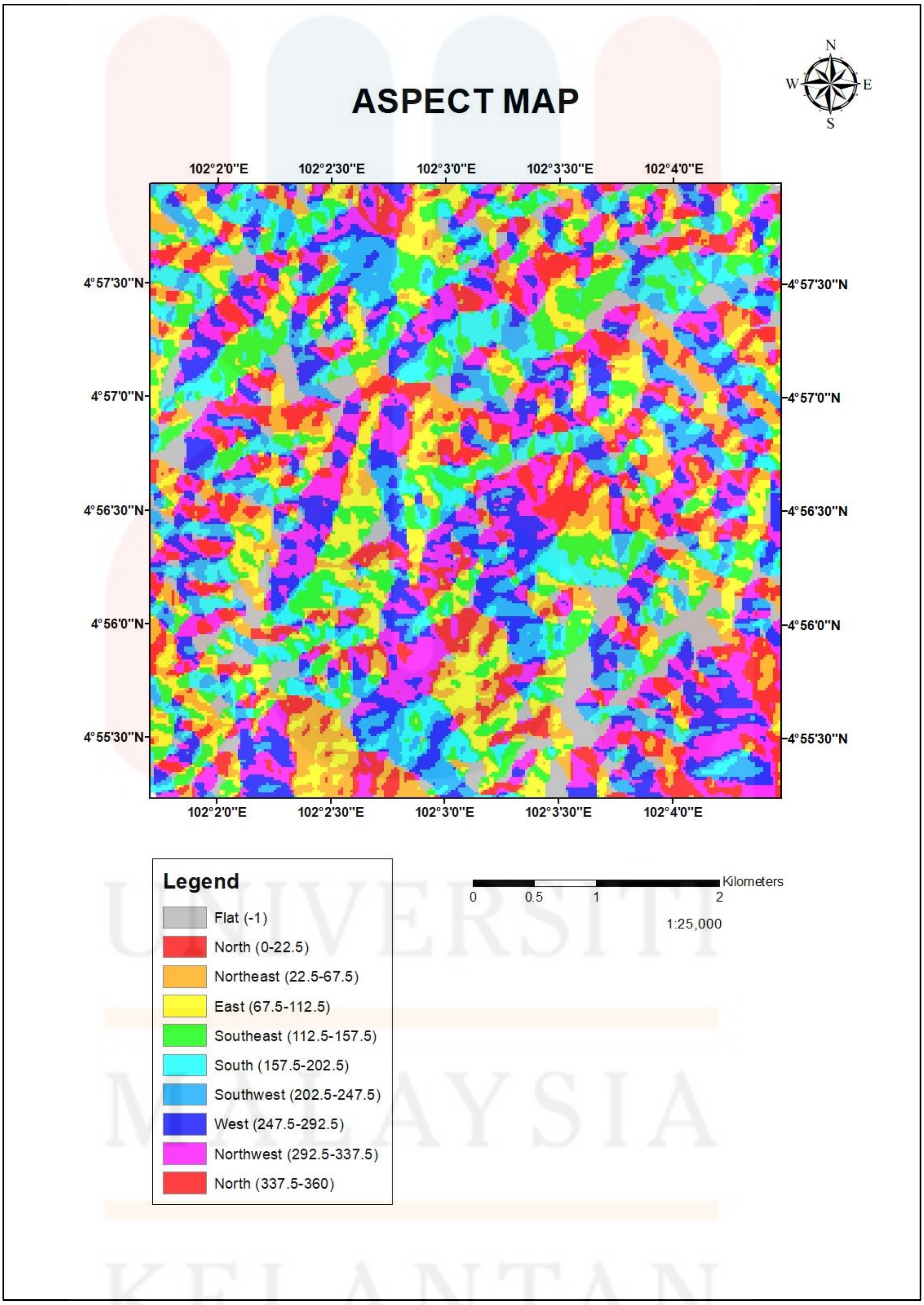


Figure 5.3: Aspect map of study area

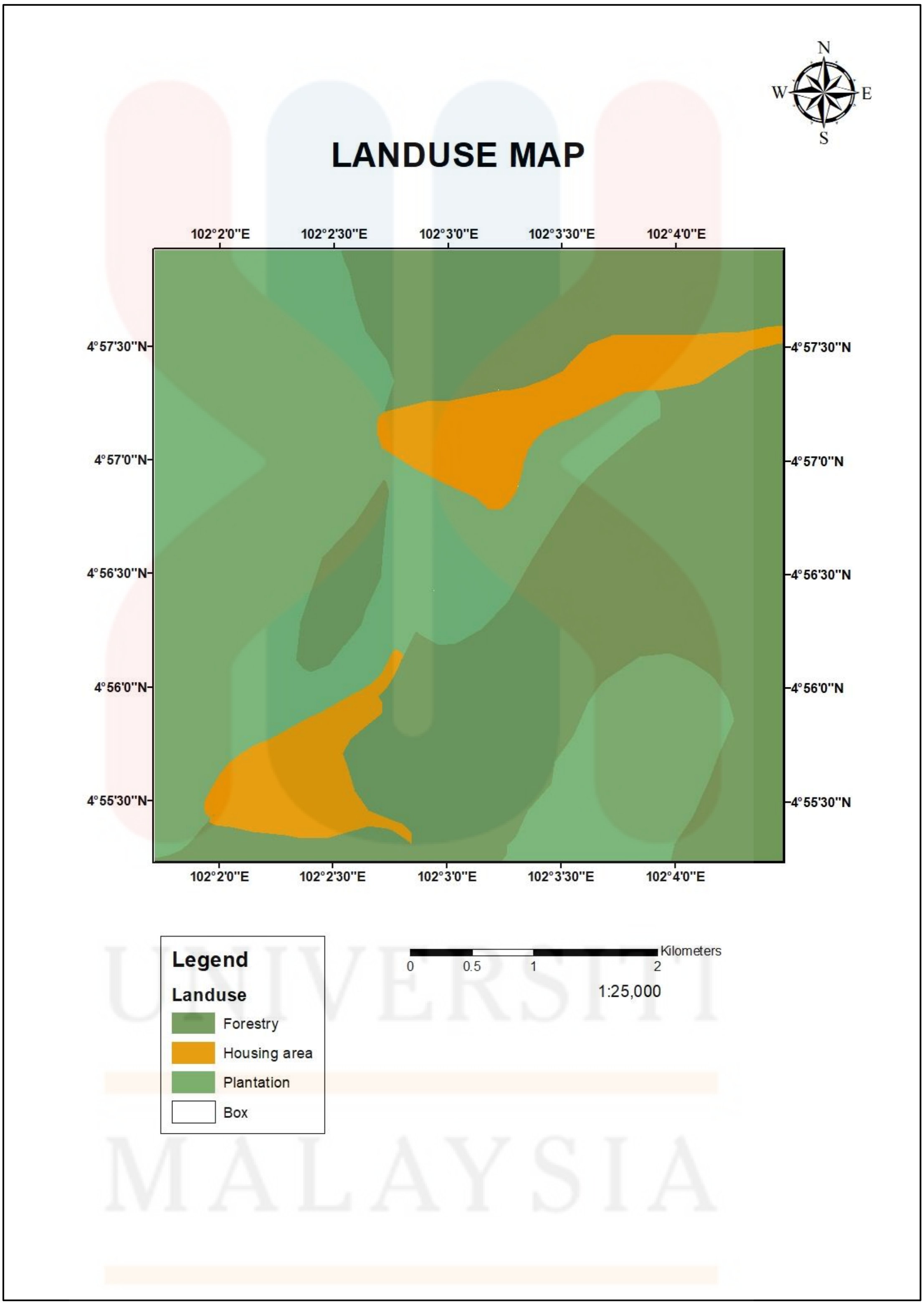


Figure 5.4: Landuse map of study area

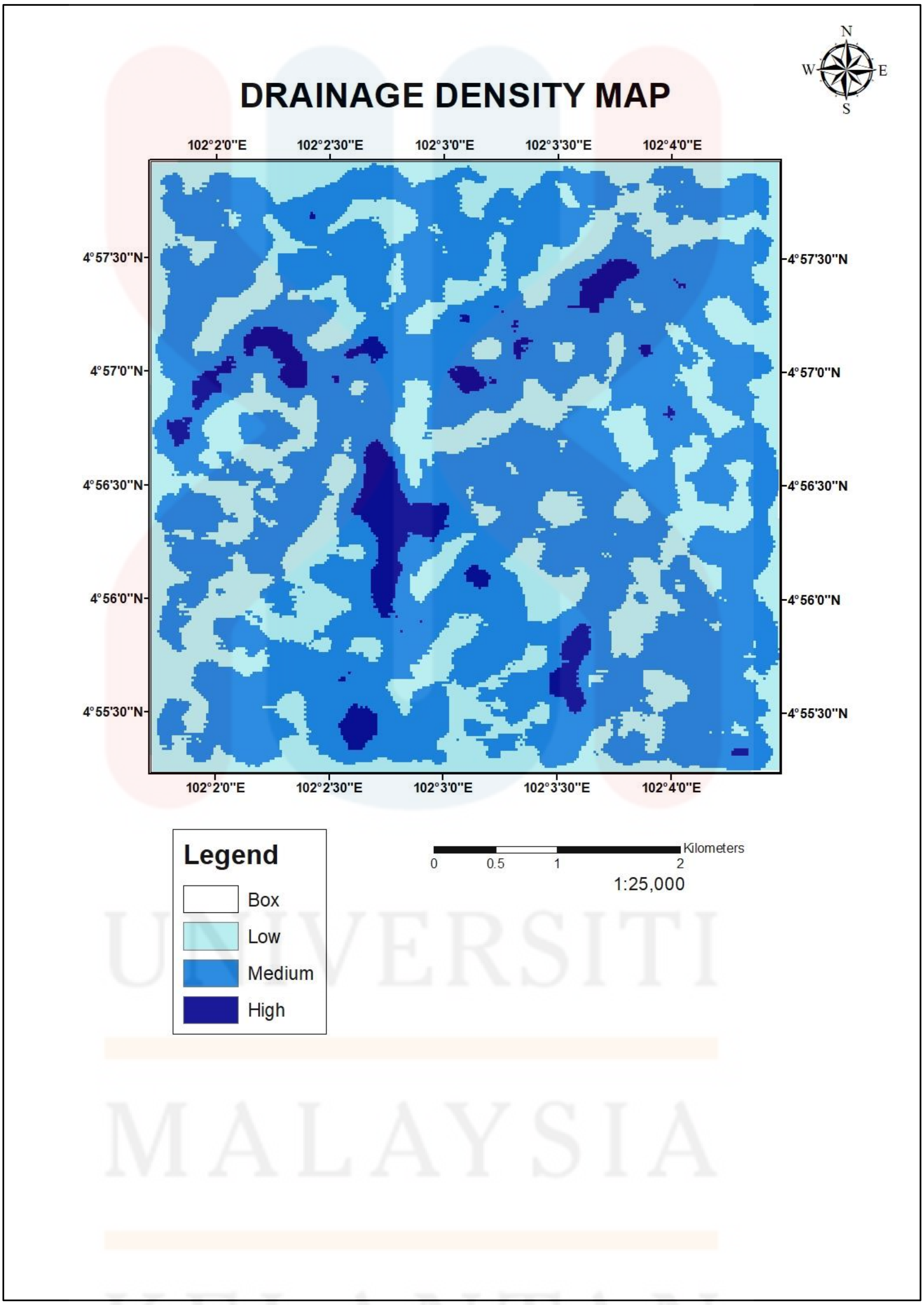


Figure 5.5: Drainage density map of study area

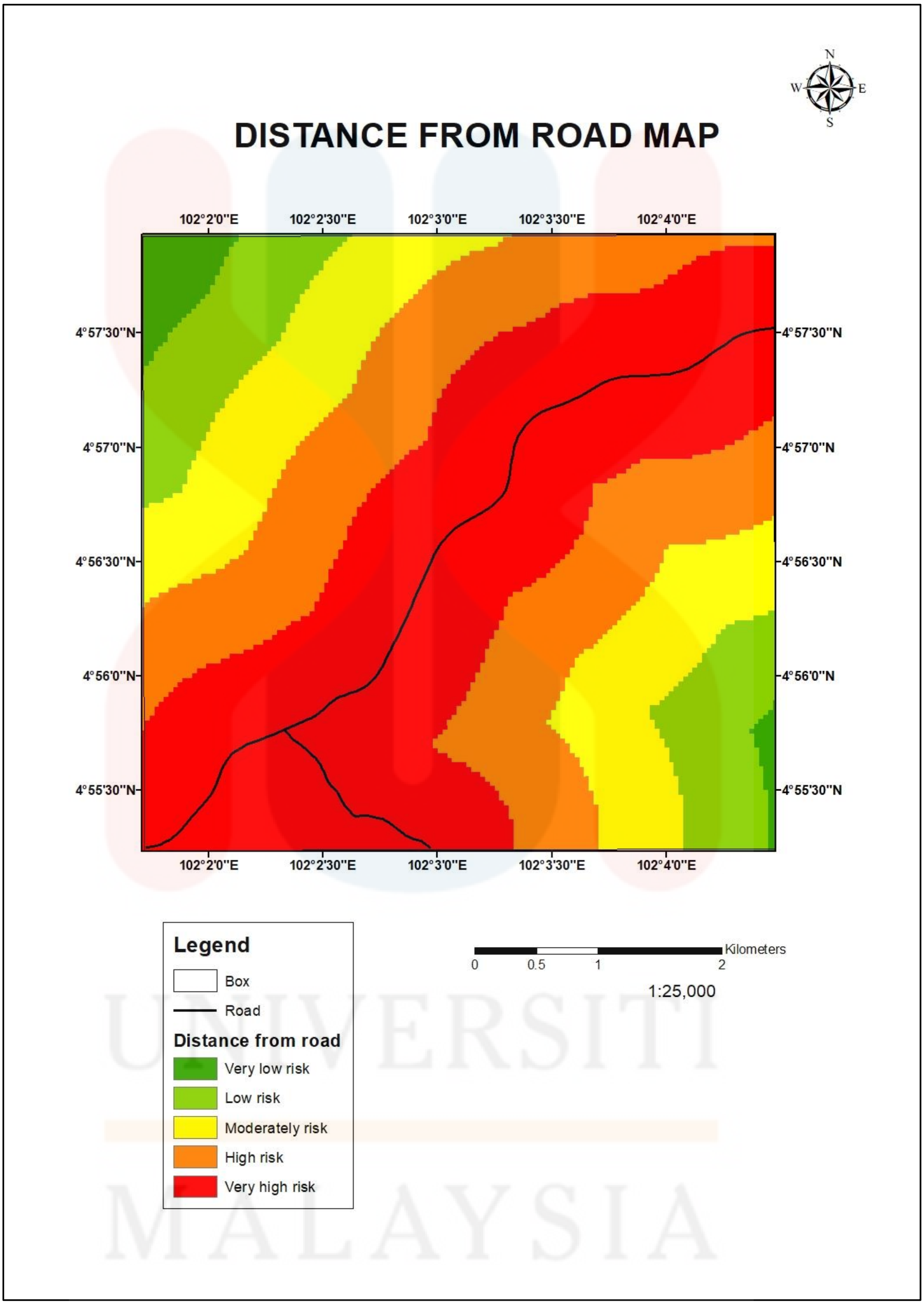


Figure 5.6: Distance from road

5.3 External factors triggered landslide

There are many external factors that can cause landslide in the study area every year such as rainfall and anthropogenic activities. Excessive water accumulation can affect landslides or erosion especially in areas of soil and rocks that are sloping and weathering. When rainfall continuously poured and the waters fill up the porosity and fractures between soil and rocks, the high amount of water content in soil at the particular area that already loss strength causing landslide. Hilly areas with weathered soils and poor terrain condition leading to high potential of landslide (Habibah et al, 2013). Table 5.2 shows the rainfall distribution data in Gua Musang starting from 2015 until 2019, which is collected from Jabatan Pengairan dan Saliran (JPS), Malaysia.

Table 5.2: The rainfall distribution in Gua Musang from 2015 until 2019

Months	Rainfall Distribution (mm)				
	2015	2016	2017	2018	2019
January	102	112	376	279.5	71
February	13.5	148	80	29.5	39.5
March	59	2	79	135.5	231
April	88.5	149.5	64.5	66	53
May	299	65	431	7	217.5
June	112	276	214.5	79	165.5
July	121.5	207.5	152.5	150	172.5
August	314.5	156	340	94	216
September	246.5	181.5	227.5	402.5	272
October	220	188.5	403	305.5	285
November	258	214.5	344	274	306.5
December	219	139	293	317.5	-
Average	171.125	153.2917	250.4167	178.3333	184.5

(Source: Jabatan Pengairan dan Saliran (JPS), Malaysia, 2020)

Within five years, the rainfall distribution is higher in September to December annually the highest average of rainfall intensity is recorded in year 2017. Therefore, landslide in Malaysia and Gua Musang usually happen during experiences of wettest season as high intensity of rainfall poured and affected the steep slope with weathered materials. Moreover, the driest season is in March between 2015 until 2017. While in the year of 2018 and 2019, the driest season during May and April respectively. Then, year of 2016 recorded the driest season among the five years. Drought season causes a decrease in the number of water resources to less affect the phenomenon of landslides in the study area.

An anthropogenic activity defined as an effect that resulting from human activities. This activity is a contributing factor to landslides. Construction of roads without proper grading of slopes will disrupt old landslides and poor planning of drainage patterns will be affected by landslide hazards. Deforestation usually occurs because the land is converted into other uses such as for plantations. Thus, there were many human made that affect the environment and causes the landslide occur in study area. Even so, this anthropogenic activities caused to landslides can be mitigated.

5.4 Landslide Susceptibility Analysis

A map of study area that susceptible to landslide was produced by overlaying all selected parameter in three classification of zone which is low, moderate and high area. The parameters used were converted into raster data before processing the map. The landslide susceptibility map was generated using weighted overlay method in ArcGIS platform. The parameters chosen for landslide causative factor are lithology, slope, aspect, land use, drainage density and distance from road by referring to previous study. The parameters have assigned with each weightage and the sum of all parameters must be equal to 100% and then used the formula for WOM as shown in Equation 5.1:

$$S = \frac{\sum Wi\ Si\ j}{\sum Wi} \text{...(Equation 5.1)}$$

The raster data of causative factors were reclassified the weightage based on works by Awawdeh et al, (2018). In order to produce landslide susceptibility map, the reclassify process and the value of influence for each parameter play an important role.

Figure 5.7 shows the landslide susceptibility map of Kampung Renok Baru. From the map, the study area were divided into three classes. The class 1 is for low susceptibility, class 2 for moderate susceptibility and class 3 for high susceptibility. Based on the landslide susceptibility map that were generated, the low susceptibility towards landslide covered major of study area with 53%. About 34% of study area covered by moderate susceptibility to landslide while 13% covered by high susceptibility area to landslide hazard.

In landslide vulnerability analysis, slopes, aspects and distances from roads are identified as parameters that have a higher influence. The steeper the slope, the greater the chance of a landslide occurring in this area-as well as the nearest distance to the road. These parameters are interconnected and affect landslides as slope cuts in road areas become more serious. There were instability slope nearest the road area. These also effect the strength of rocks and soil due to road construction along the highway in study area.

Drainage density moderately influence the landslide hazard. Then, land use and lithology parameter had classified as the lower influence to landslide. However, all external parameters and factors triggered by landslide phenomena are important in landslide analysis in the study area. Table 5.3 shows the classes of susceptibility for landslide in study area.

Table 5.3: Susceptibility of landslide phenomena in study area

Susceptibility class	Risk	Area Percentage (%)	Area (km^2)
Low	0 – 50%	53	13.25
Moderate	50 – 75%	34	8.50
High	>75%	13	3.25

From the landslide susceptibility map above, the landslide is more prone on the hilly region and along the road due to high elevation and steep slope respectively. Hence, this conclude the reason of study area dominant with low susceptibility to landslide.

5.5 Mitigation Step

The mitigation step in landslide hazards need to be implemented in the area that high to vulnerability of this hazard. Therefore, landslides can be reduced or avoided and increase public awareness about landslides among residents in Kampung Renok Baru.

First action is land use planning, where the authorities need to plan the systematic development area in order to avoid occurrence of hazards. For example, mark the areas that prone to landslide hazard and avoid to build up development at

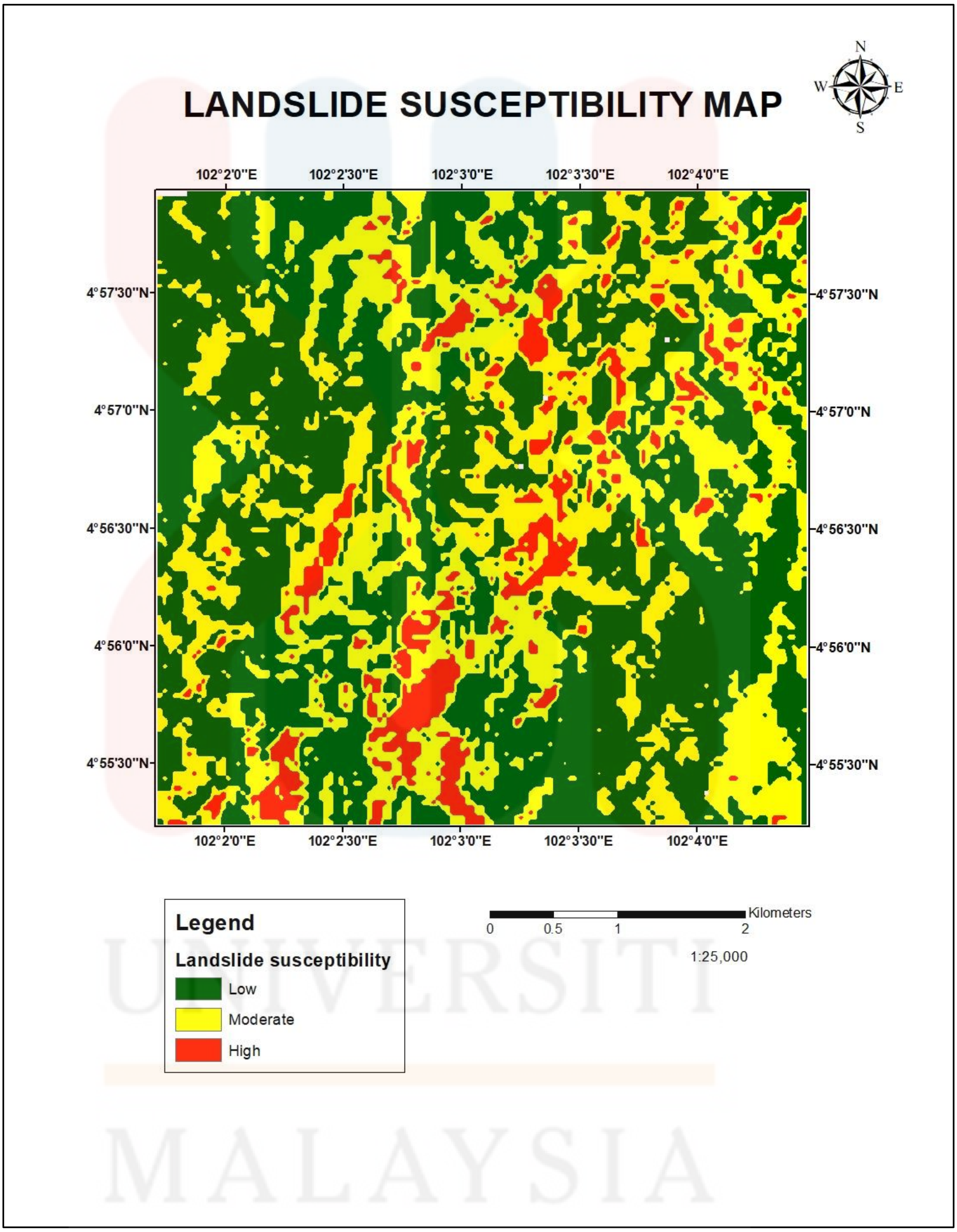


Figure 5.7: Landslide susceptibility map of Kampung Renok Baru

landslide prone area in the future. Therefore, the loss of property can be prevented and safety among the residents in Kampung Renok Baru can be given priority.

The use of method of biotechnical slope stabilization on near surface soil can be applied. This method use plants and vegetation with fast growing and sturdy root system. The roots able to hold the soil compactly together. Furthermore, the vegetation also can help to slow down the rate of water flow in the soil. Thus, soil erosion in the area is able to prevent.

The construction of a thick retaining wall at the end of the slope can be recommended. The retaining wall is used to retain a large amount of soil behind it in sloping area. Then, this wall also helps in stabilize slope in the area. Thus, the landslide hazard is able to avoid and the slope is able to maintain and stabilize. Besides, shotcrete can also be used. High-speed shot concrete on a rebar grid that has been properly and precisely enchanted on the slope surface.

In addition, good drainage is also important in reducing the landslide hazard. Water presence in rocks and soils is one of the main factors that lead to instability of slope. Therefore, the proper drainage need to be built in the place that have potential of erosion. Importantly, the function of drainage to lessen the content of water or pore pressure of the rock or soil. Due to that the effective of stress and shear strength will be increased.

For landslides, the mitigation measures that need to be taken are to clear the blocked drainage channels in the area. This is one of the reasons why landslides occur so the maintenance of certain areas should be done and updated. Then, the debris after erosion needs to be cleaned especially of large boulders from rocks and trees that fall on the road or area. In addition, in case of landslide hazards occur in the study area, the first step is to help the victims involved. For example, give them temporary shelter, food supplies and daily necessities.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

This chapter concludes all the findings from general geology and landslide susceptibility analysis respectively as well as evaluation using GIS and remote sensing method in obtaining result.

As a conclusion, all the research objectives were achieved. The first objective is updating a geological map of Kampung Renok Baru, Gua Musang in scale of 1:25000 by online interpretation and with the aids of secondary data and past research. The lithostratigraphy of area study area were divided into three unit which are pyroclastic rock, metasedimentary rock and limestone. This rock distribution made up of Telong formation and Merapoh Limestone. Based on interpretation there is major fault in study area.

Next for second objective of research as stated in section 1.3, the map of landslide susceptibility of study area with scale 1:25000 was successfully generated using weighted overlay method in ArcGIS software. Thematic maps of slope, aspect, land use, lithology, drainage density and distance from road were overlaid in ArcGIS to generate the landslide zonation map. The DEM data became main sources in order to produce map of each parameter. For lithology map, the land use map were generated based on visual interpretation using topographic map, terrain map and also past research study. While, the land use map obtained from USGS data. The landslide susceptibility map was produced based on the overlay's parameters. The landslide map were divided into three classes which class 1 for low risk, class 2 for moderate risk and class 3 for high risk to landslide. Hence, the study area were prone to landslide potential with 34% of moderate, 13% high and 53% low of susceptibility.

The third objective was achieved as there were several factors influenced occurrence of landslide. Rainfall and anthropogenic activities were identified as external factors that can trigger landslide. However, these both factors not are not overlapped in ArcGIS software. Yet, the rainfall intensity also play an important role in leading to landslide. The main causative factor that lead to landslide in study area is slope.

Mitigation also can be determined as precautions steps in the event of a landslide in the study area. This also reveals that the villagers are more sensitive about this geohazard issue.

6.2 Suggestion

There are some limitations when conducting this research, therefore some suggestions for future research have been identified. Firstly, the need to apply secondary data. For example, lithology data, structure geology data and soil data. This is because when there is a lack of secondary data during online interpretation, the parameters that need to be used should be considered. Therefore, the results may also be inaccurate such as doing geological mapping. The secondary data can be obtained from many agencies like Department of Mineral and Geoscience and Department of Surveying and Mapping Malaysia (DSSM). Hence, the initiative to approach these agencies need to seriously taken in order to get an accurate and better result of the research.

In the specification section, the use of various types of parameters such as plants, soil and height of the study area is helpful to produce better results. This is because different type of parameters used will give different findings. Therefore, the result obtained can be compared between the most influences of parameters that prone to the landslide hazard in study area.

Next, high quality DEM data must be used. If the DEM data used is in low resolution, then the results or images generated in ArcGIS are not clear and sharp enough. The DEM data used in this research are from the large-scale USGS website. No high quality DEM data is provided by the USGS website. Good quality data can be obtained from agencies such as the Department of Mineral and Geoscience. Therefore, steps to approach the agency need to be prepared in conducting research.

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