GEOLOGY AND LANDSLIDE SUSCEPTIBILITY MAPPING USING GEOGRAPHIC INFORMATION SYSTEM (GIS) AT ARING 5, GUA MUSANG, KELANTAN

by

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A report submitted in fulfilment of the requirement for the degree of Bachelor of Applied Science (Geoscience) with Honours

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DECLARATION

I declare that this thesis entitled **"Geology and Landslide Susceptibility Mapping Using Geographic Information System (GIS) at Aring 5 Gua Musang, 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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Date : ______________________________

APPROVAL

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

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Date : ………………………………….

Signature : ………………………………........

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GEOLOGY AND LANDSLIDE SUSCEPTIBILITY MAPPING USING GEOGRAPHIC INFORMATION SYSTEM (GIS) AT ARING 5, GUA MUSANG

ABSTRACT

Abstract: Research was conducted at Felda Aring 5, Gua Musang, Kelantan that was approximately 25km² and the coordinate of the research area is 4° 51' 26.0''N longitude to 102° 18' 48.8''E at the latitude. The purpose of this study is to update the geological map of this study area in the scale of 1:25000, determine landslide susceptibility factors and analyse the landslide susceptibility analysis at the study area using the ArcGIS software. The study area composed of three main lithological unit that is interbedded shale, slate and phyllite unit, tuff unit and also interbedded mudstone unit. Based on the weightage overlay method in the ArcGIS software, the susceptibility of landslide in the research area was determined. Eight parameters have been chosen in determining the landslide susceptibility that is slope, lineament density, the type of lithology, vegetation, aspect, land use, drainage density and also soil cover in the research area. The weightage and score for each parameter had been assigned based on the references from the previous study. Eight maps from each of the parameters have been produced and in the end the landslide susceptibility map of the study area was made by overlaying all of the eight maps. The zone of the susceptibility was divided into three that is the low susceptibility zone, moderate susceptibility zone and also the high susceptibility zone.

Keywords: Weightage, ArcGIS, Landslide Susceptibility, Weighted Overlay Method

GEOLOGI DAN KERENTANAN TANAH RUNTUH MENGGUNAKAN SISTEM MAKLUMAT GEOGRAFI DI ARING 5, GUA MUSANG

ABSTRAK

Abstrak: Penyelidikan dilakukan di Felda Aring 5, Gua Musang, Kelantan yang berukuran kira-kira 25km² dan koordinat kawasan penyelidikan ialah 4 ° 51 '26.0'N bujur hingga 102 ° 18' 48.8'E di garis lintang. Tujuan kajian ini adalah untuk mengemas kini peta geologi kawasan kajian ini dalam skala 1: 25000, menentukan faktor kerentanan tanah runtuh dan menganalisis analisis kerentanan tanah runtuh di kawasan kajian menggunakan perisian ArcGIS. Kawasan kajian terdiri daripada tiga unit litologi utama yang terdiri daripada unit serpih, batu tulis dan phyllite, unit tuff dan juga unit batu lumpur. Berdasarkan kaedah overlay berat dalam perisian ArcGIS, kerentanan tanah runtuh di kawasan penyelidikan telah ditentukan. Lapan parameter telah dipilih dalam menentukan kerentanan tanah runtuh yaitu cerun, kepadatan garis garis, jenis litologi, tumbuh-tumbuhan, aspek, penggunaan tanah, kepadatan saliran dan juga penutup tanah di wilayah penelitian. Berat dan skor untuk setiap parameter telah ditentukan berdasarkan rujukan dari kajian sebelumnya. Lapan peta dari setiap parameter telah dihasilkan dan pada akhirnya peta kerentanan tanah runtuh di kawasan kajian dibuat dengan melapisi semua lapan peta. Zon kerentanan dibahagikan kepada tiga iaitu zon kerentanan rendah, zon kerentanan sederhana dan juga zon kerentanan tinggi.

Kata kunci: Pemberat, ArcGIS, Kerentanan Terhadap Tanah Runtuh, Kaedah‘Overlay’ Berwajaran

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LIST OF ABBREVIATIONS

km²	Kilometer square
mm	Millimeter
GIS	Geographical Information System
NE - SW	Northeast - Southwest
E – W	East - West
N - S	North - South
GPS	Global Positioning System
E	East
S	South
M	meter
Cm	Centimeter
Wi	Weightage
Sij	Score

LIST OF SYMBOLS

%	Percentage
>	Greater than
<	Less than
ºC	Degree Celsius
º	Degree
×	Multiplication
Σ	Sum
ϭ	Sigma

CHAPTER 1

INTRODUCTION

1.1 General Background

The occurrence of steep slopes is followed by road construction. As a result, the number of slopes is raised and the slopes are widely distributed throughout the regional area as roads are developed in hilly terrain. The present of the rock-cut slope actually depends largely on geological characteristics, such as the discontinuity of the composition of the rock. The slope collapse will then cause the settlement to landslide and cause a disaster. Geographical Information System (GIS) could be an efficient way of analysing the landslide zonation that are widely scattered in the regional area. The research is about the "Geology and Landslide Susceptibility Using Geographical Information System at Aring 5, Gua Musang, Kelantan". Commonly landslide can be occurring at the urban area and Aring 5 which consist of rural area at Gua Musang which is prone to potential landslide.

Landslide is the movement of rock mass which consist of rock, debris or earth down a slope. The Landslide is one of the geohazards that can be listed as natural disasters. It happens when gravitational and other types of shear stresses within a slope exceed the shear strengths of the material forming the slope. It can happen normally, but at a slow speed. The natural distribution of land may be modified by human actions or changes in land use. Perhaps more than one form of movement happens in a single landslide. According to Nagle, G. (1998), landslide is any perceptible down slope movement of mass bedrock, regolith, or both. Landslide is one of the most common natural hazards that occur after earthquake, most of the cases reported worldwide. However, this effect can be caused by the high rainfall rate and the high seismic activity.

The Geographic Information System (GIS) has been widely used as a valuable tool for processing geographic data in recent years. The major advantage of using GIS is that it is possible to store all geographical features associated to a single location in the form of a digitized map, which can then be scanned, updated and revised. Information of the local area and also of the national scale can also be used, such as geographical and geological details of the regional area, which can be easily analysed.

The aim of the research to identify and evaluate the landslide susceptibility mapping using Geographical Information System (GIS) in Aring 5, Gua Musang Kelantan. The susceptibility area assessment was conducted after the formation of a landslide susceptibility map. The landslide is created to produce the susceptibility map, such as slope, lithology, slope, aspect, vegetation, land use and drainage density, was used to trigger landslide parameters. In GIS, an overlay and raster calculation was then implemented to achieve the predicted landslide susceptibility map result. The estimation of the vulnerability of landslides is a conditional probability dependent on time and spatial frequency and severity of landslides or a given geo-environmental environment. The GIS software is used in the development of landslide susceptibility maps, as this software is used in data collection and interpretation of landslide susceptibility maps. Landslide assessment can be studied using the Weighted Overlay Method (WOM) to avoid this landslide occurrence in order to reduce the landslide risk in the relevant study area.

1.2 Study Area

1.2.1 Location

This research is carried out at the state of Kelantan which is situated at South Part of Kelantan. Aring 5, Gua Musang is located in the southwest of Kelantan, 51 km from Gua Musang Town that is accessible via Jalan Gua Musang. The study area is mainly located at Kampung Batu, Aring 5, Gua Musang, Kelantan with coverage area of 25 km^2 (5 x 5) km^2. The areas were surrounded with the oil palm plantation along the main road of Aring 4, Gua Musang with the maximum elevation about 140m.

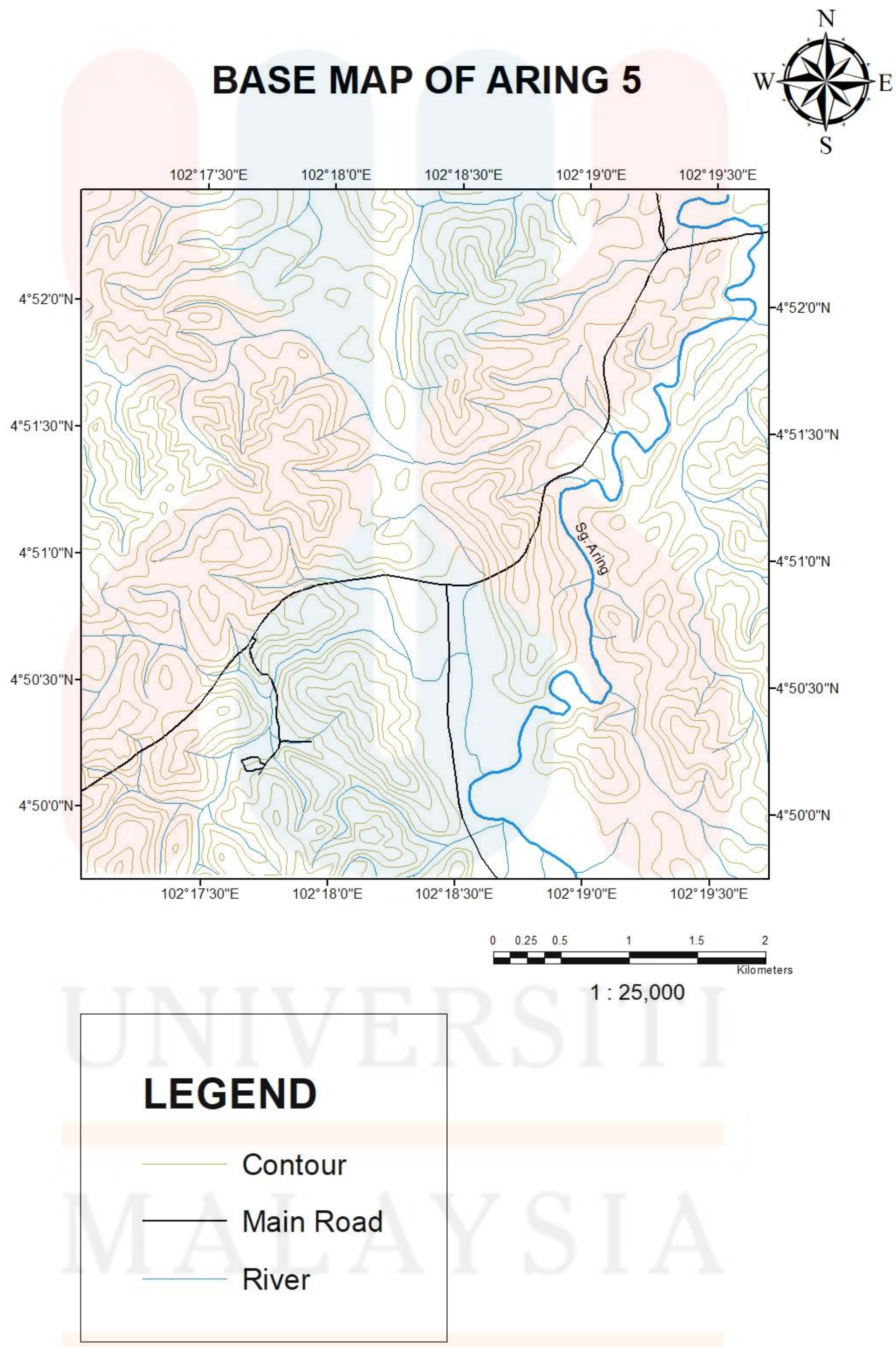


Figure1.1: Basemap of study area at Aring 5, Gua Musang, Kelantan

1.2.2 Accessibility

The study area which is at Felda Aring 5, Gua Musang can be accessed through the main road which area East-West Highway and also Gerik-Jeli Highway. This research area also can be accessed through the road of Kuala Berang to Chiku which the road will passed through Jalan Aring 5 and Jalan Aring 8. Jalan Aring 5 wil be the road which across the box from north-east to south- west which is connected with the highway to Gua Musang.

In order to reach Gua Musang City from Aring 5 need 44 minutes to reach when used the main road of Aring 5 and Highway Gua Musang – Kota Bharu. The road connection provided easy accessibility when performing geological mapping in the study field. There are a variety of roads which can be reached by cars and motorcycles, but some roads are accessible only by motorcycle. Figure 1.3 below shows the route from Felda Aring 5 to Gua Musang City which takes 45 minutes which is about 54 kilometres.

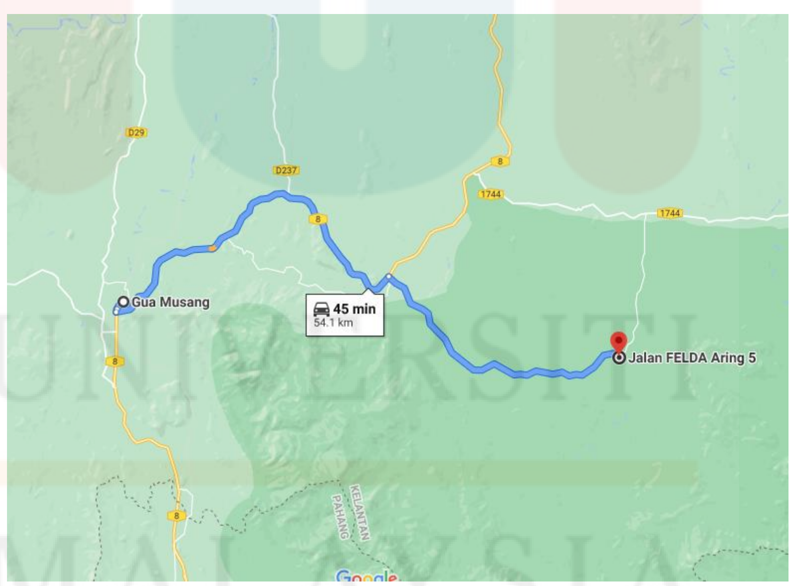


Figure 1.2: shows the route from Gua Musang City to Felda Aring 5, Gua Musang (sources: Google Maps, 2020)

Lebuhraya Kota Bharu- Gua Musang is the main road from Kota Bharu and also the main road to Kuala Lumpur. It easily to accessible due to the research area located near the main road from Jalan Felda Aring 5 as shows in figure 1.4 below. The Main road of Aring 5 only used by the villagers and also the farmer which the road surrounded with oil palm plantation as shows in the figure 1.5 below.

Figure 1.3: shows the main road from Kota Bharu to Gua Musang (sources: Google Maps, 2020)

Figure 1.4: shows the junction of road between Highway Kota Bharu- Gua Musang with Jalan Felda Aring 5(sources: Google Maps, 2020)

There is just one major road in the study area, while the other roads are all tiny rhoades. Figure 1.4 shows the main road link in the area of Jalan Felda Aring, which links Gua Musang Town in Kelantan with Kuala Berang Town in Terengganu. This main road is used mainly by villagers to connect other places and to carry out their daily activities. As most Felda Aring residents work for the oil palm industry, this road is also the main road linking them to the oil palm plantation. The main road is paved, but the road linking Kuala Berang remains unpaved and under construction.

The path branching towards the north direction in Figure 1.4 is going to Felda Aring10. The road to the east is expected to go to Kuala Berang, but the road to Felda Aring 10 is the alternate route to Kuala Berang, as the road to the east is still under development.

However, since the road is unpaved and consists of small rocky pebbles, the road is not used by many persons.

1.2.3 Demography

Information on the population density in Kelantan was collected from the Malaysian Department of Statistics. The Department of Statistics Malaysia (2010) has divided the distribution of population by districts in Kelantan. The distribution of people in the district of Gua Musang, Kelantan, is shown in Table 1. The district of Gua Musang is further subdivided into seven major divisions. They are Batu Papan. Bertam, Chegar Bongor, Gua Musang, Kerinting, Limau Kasturi, Paya Tupai, and the rest are the remaining areas of the Majlis Daerah Gua Musang.

The total number of Majlis Daerah Gua Musang citizens is 86,189. Gua Musang is a resident of two major classes, Malaysian and Non-Malaysian as shown in table 1.1. There are 81,204 total Malaysian people, made up of Bumiputera and Non Bumiputera. The overall number of Bumiputera residents in the Gua Musang district is 76,823, consisting of 64,253 Malays and 12,570 other Bumiputera residents. The Malaysian citizen also consists of citizens of Non-Bumiputera, including 3,870 Chinese, 350 Indians, and 161 others. The non-Malaysian citizens in the Gua Musang district recorded a number of 4,985 people.

The district of Gua Musang is governed by caste, based on population figures. This is accompanied by other ethnic groups of the Bumiputera, who are clustered in the Bumiputera, and most of the people of Gua Musang comprise primarily of the remaining Malay. In Gua Musang, the number of non-Malaysian people is more than that of the Chinese population in this district. It is accompanied by Indians, while the population of minorities in the district of Gua Musang includes other Non Bumiputera ethnic.

Table 1.1: The distribution of population according to ethnic of Gua Musang district in 2010

Jajahan/ Local authority area	Total	Malaysia Citizen								Non-Malaysian Citizen
		Total	Bumiputra			Chinese	Indian	Others		
			Total	Malay	Others					
M.D. Gua Musang	**86,169**	**81,204**	**76,823**	**64,253**	**12,570**	**3,870**	**350**	**161**		**4,985**
Batu Papan	2,594	2,543	1,520	1,512	8	883	132	8		51
Bertam	1,142	1,133	1,131	1,131	-	1	1	-		9
Chegar Bongor	494	426	398	398	-	24	-	4		68
Gua Musang	18,420	17,775	15,373	15,285	88	2,217	155	30		645
Kerinting	157	144	128	128	-	1	15	-		13
Limau Kasturi	975	905	893	893	-	5	-	7		70
Paya Tupai	337	325	325	325	-	-	-	-		12
Remainder of M.D	**62,070**	**57,953**	**57,055**	**44,581**	**12,474**	**739**	**47**	**112**		**4,117**

(Source: Department of Statistic Malaysia, 2010)

1.2.4 Land use

The total area of the Gua Musang district is 7979.77 km2, which is the largest district in Kelantan. The research area's land is primarily used in the palm oil plantation sector of agriculture. Land use is regulated by FELDA's organisation in the research field. FELDA is a federal department responsible for managing the resettlement of rural poor people to newly established areas and arranging cash crops for smallholder farms. Atoms of the settelment research are thoroughly coordinated and produced by FELDA.

1.2.5 Social economic

Much of the residents of Felda Aring 4 and 5 are involved in agricultural activities. Although the research area is largely covered by the oil palm plantation, most of the residents involve of the oil palm industry. Besides that, some of the people employed in the rubber estate, the government launched FELDA and KESEDAR to raise living standards in social growth and minimize poverty among citizens. Meanwhile, Felda Aring 4 and 5 are engaged in or linked to oil palm plantation and there are also some residents who operate business, such as restaurants, grocery stores and other businesses. Some educated residents work outside the city, such as the nearby Gua Musang Region, whether working for government or private industry.

1.3 Problem Statement

It is the absence of researchers who performed the analysis at Felda Aring 5 based on the previous study about assessment of landslide susceptibility in the Gua Musang region. This is because the landslide is a huge danger to the communities and will cause the settlement region to lose properties. Since Aring 5 is a rural area, which is the main social economy of agriculture, this area is susceptible to landslide hazards.

This research is focused on landslide susceptibility assessment at the study area at Aring 5, Gua Musang, Kelantan and the significance that can be highlighted by this research proposal. First of all, the research is generally to generate the geological map of the study area which is situated along the road of Aring 5 in the scale of 1:25000 by using map interpretation in terms of lineament analysis structural geology, stratigraphy, geomorphology and lithology from the previous research.

. The research area was located at the main road of Felda Aring 5 which connected with Gua Musang highway. This main road is used by the local people and agriculture activity which is palm oil plantation where a lot of them used this road. Thus the cut slope was highly potential to fall due to the unstable slope since the cutting slope along the road of Felda Aring 5.Because of the climate, added the high weathering factor for the Aring 5 region, rendering the rock slope highly probable to fail. The continuous weathering process also increases the landslide potential particularly in places where the weathering rate is high. Structural geology, such as joint and fracture, has a significant effect on the frequency of landslide. Structural geology can cause brittle rock deformation that is very normal in rock and can affect rock stability.

A geological survey and data information on the geological features collected from secondary data from previous researchers can be undertaken via this research analysis, the map can be interpreted and then analyzed using GIS application. Thus, it is feasible to create a modern updated landslide susceptibility assessment map.

1.4 Objectives

1. To generate the geological map of research area in the scale of 1:25000 using map interpretation

2. To determine landslide susceptibility factors at Aring 5, Gua Musang Kelantan

3. To produce landslide susceptibility map at Aring 5, Gua Musang Kelantan.

1.5 Scope of the Study

This research concern in generating the geological map at the research area located at Aring 4, Gua Musang Kelantan after the preliminary studies are being carried out based on previous research and using secondary data from various source to produce the actual data in the form of structural geology, stratigraphy, geomorphology and others. These areas consist of the cut slope area along the main road of Kampung Batu, Aring 5 Gua Musang Kelantan.

Furthermore, this research also focuses on data interpretation and determines the landslide susceptibility assessment at the study area. The data collected in terms of secondary data and raster data will be analysing using ArcGIS 10.2. ArcGIS tools in terms of Weighted Overlay Method (WOM) are used to generate slope susceptibility map in order to shows the area which could be potential landslide. By the data analysis, the map of landslide susceptibility zonation map can be generated which the place of the study area consist of 3 classes which are low, medium and high hazard of landslide.

1.6 Significant of Study

The significance of this research is to produce the updated geological maps with the scale of 1:25000 and to determine the landslide susceptibility at the study area located at Kampung Batu, Aring 5 Gua Musang, Kelantan.It is crucial to generate the geological maps by providing the latest outcome of the lithology, geological structure and geomorphology as the Earth is dynamic, and changes over time using suitable secondary data and based on the previous studies. In addition, this study will have certain advantages for communities to take precautions against landslides through the development of landslide susceptibility assessment maps. This will also decrease the incidence of the danger of landslides.

CHAPTER 2

LITERATURE REVIEW

1.1 Introduction

This chapter included all previous studies and research conducted by other researchers. With the analysis and review of all such articles, it is possible to obtain general knowledge on geology in the study field. This included regional geology and tectonic setting, structural geology, stratigraphy, sedimentology and historical geology of the area.

1.2 Regional Geology and Tectonic Setting

1.2.1 Regional Geology

Peninsular Malaysia can be split into three longitudinal belts Western, Central and Eastern Europe, each of which has its own distinctive features and its own Goological development. On the basis of mineralization, Scrivenor (1982) suggested the division of the peninsular into the central gold belt between the tin belts to the east and west, which is split into the current Central, Eastern and Western Belts. The geographical geological map of Kelantan is seen in Figure 2.1.

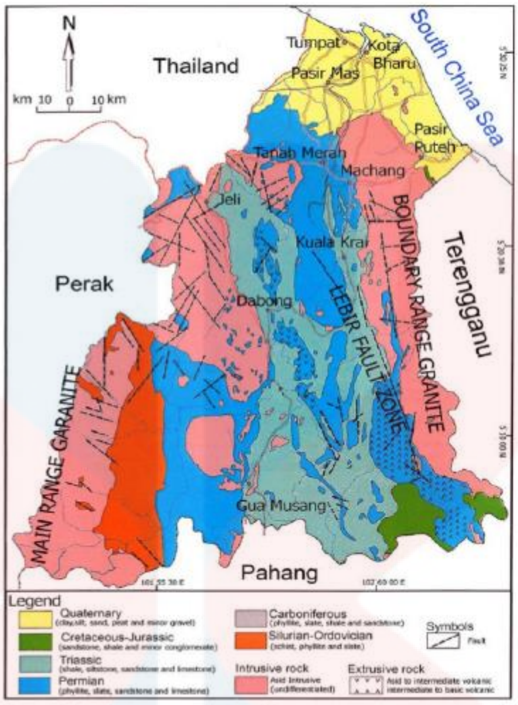


Figure 2.1: Shows the regional geological map ok Kelantan

Source: International Journal of Geoscience

The regional geology of Kelantan primarily comprises of sedimentary and metasedimentary rock. On the western and eastern part, it is surrounded by granite of the Main Range and Boundary Range. The regional geology of Kelantan is connected with regional geology of north Pahang, where it is a continuation with granite belts and the country rocks. Meanwhile in the western and central part of Kelantan, the belt elongates northward into the southern part of Thailand. However, at the eastern part of Kelantan, the coastal alluvium of Sungai Kelantan overlaid the Boundary Range Granite.

In the state of Kelantan, the oldest rock formation that has been identified is during the Lower Palaeozoic age. This rock formation extends eastward, reaching to Sungai Nenggiri, where the foothill of the Main Range is bounded by the trending belt. Generally, the rocks that presents are mostly metapelites, and minor volcanic fragments, arenaceous and calcareous intercalations. As recorded by MacDonald (1967), there is also amphibolite and serpentinite can be found, but the occurrences are quite t hin on the ground, which is minor to be discovered.

On the eastern part, it is dominantly distributed by volcanic-sedimentary rocks of Permian age, while on the central-north of Kelantan, it is dominated by the Taku

Schist formation. This formation ages in Triassic, which comprises argillo - arenaceous sediments with interjected of volcanic and limestone (MacDonald, 1967).

According to Kamal Roslan (2006), The southern Kelantan arc can be split into four regions, such as Kuala Betis, Gua Musang, Aring and Gunung Gagau. The research of importance is situated in the region within the central belt of Peninsular Malaysia. Based on Aw (1990), there are four units of the Gua Musang Group called Aring Formation, Telong Formation, Nilam Marble Formation and Koh Formation. The classification of the formations mentioned is grouped into the same group on the basis of the lithological unit.

One part of the Gua Musang Group is the Aring Formation. The root of the forming of Aring is the name of Sungai Aring, south of Kelantan. It is estimated that this formation is about 3000 m thick and consisting primarily of pyroclastics, minor lavas, dolomitic marble and argillite. As dated by foraminifera and bivalves, the age of this formation is from Late Carboniferous to Early Triassic. During tectonic upper contact with Telong Formation and even K Formation, the lower boundary of Aring Formation is unexposed.

The regional map of Ahmad Rosli Othman and Mohd Shafeea Leman (2012) shows that the central Kelantan is generally part of the Eastern Triassic Rocks Zone (Figure 2.2). In Aring Formation, Aw (1990) recorded that a number of fossils were found, mainly index fossils that suggest the age of marine Triassic rocks in Peninsular Malaysia. The ammonoid assemblages found are of high value, particularly in their position as Triassic good age indicators (Ahmad Rosli Othman & Mohd Shafeea Leman, 2010). The Aring region is considered to have the most abundant Triassic fossils within the Central Belt in Peninsular Malaysia, based on these index fossils (Dony Adriansyah Nazaruddin, 2014). The findings support the notion that the Aring region that can be compared to the Triassic Lampang-Phrae Basin on the Sukhorthai Terrain of the Shan-Thai Block belongs to the Cathaysian domain on the basis of correlation (Ahmad Rosli Othman & Mohd Shafeea Leman, 2010).

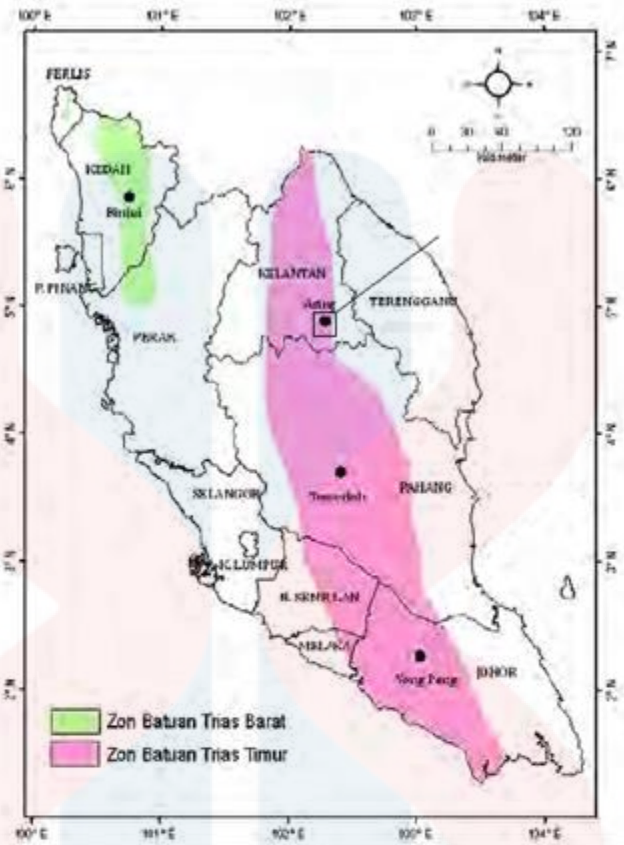


Figure 2.2: Regional map showing the study area located in Eastern Triassic Rocks Zone (Ahmad Rosli Othman & Mohd. Shafeea Leman, 2012).

1.2.2 Tectonic Setting

Metcalfe (2000) split Peninsular Malaysia into three north-south regions, namely the Western, Central and Eastern Belts, based on variations in stratigraphy, mineralization, formations, geology and rock distribution (Kamal Roslan et. al., undated). The Central Belt of Peninsular Malaysia covers most parts of the state of Kelantan. The eastern Peninsular of Malaysia, situated east of Bentong-Raub Suture, was considered to be part of the "East Malaya Block," now known as the southward extension of the Indochina terrane, and has a separate tectonostratigraphy and evolution to the Sibumasu terrane (Metcalfe, 2000).

Bentong-Raub Suture Region on the evidence of serpentinite and other metabasic bodies within the zone is perceived as a subduction plate-margin (Tjia, 1996). The Bentong-Raub Suture Zone is assumed to originate from the northward subduction of the Late Palaeozoic Palaeo-Tethys Ocean under Indochina and the Triassic collision of the Sibumasu Terrane with Indochina (Metcalfe, 2000). Given the uncertainties of the subduction period, the structure of the lithosphere below the Central Belt and the volcanism associated with subduction, it is still unclear whether the subduction was westward or in the opposite direction (Tjia, 1996). As East Malaya was attached to the Indochina plate, Sibumasu was derived from Gondwana, and they were split from Devonian to Permian by the Palaeo-Tethys Ocean. During the Triassic period, Palaeo-Tethys was completely closed, leaving only a small portion preserved in blocks of oceanic sedimentary rocks such as cherts, visible in a few locations along the roads of Bentong-Raub and Gua Musang-Cameron Highland (Jasin, 2013). These studies revealed that melange exposure is one of the essential characteristics of the Bentong-Raub Suture Zone formation, which demonstrates the properties of breccia with known fragments, including sandstone, mudstone and schistone ("Blog Rasmi Jabatan Mineral dan Geosains Malaysia," 2013).

The eastern foothills of the Main Range bounded on its west and Lebir Fault formed its eastern border in the north, down to the west of the Dohol Formation in the south. The central belt ranges from Kelantan to Johor (Hutchinson & Tan, 2009). Based on the evidence that the granitoid bodies of the Eastern Belt were part of the Titiwangsa granitoid complex divided more than a hundred kilometers by the rifting, the Central belt was interpreted to represent an aborted rift (Tjia, 1996).

Central East Malaya" refers to the part of Malaya which extends through central Pahang and eastern Negeri Sembilan from South Kelantan to central eastern Johor." Aring Formation is characterized by submarine sedimentation that lasted over the entire Permian from Late Carboniferous until the Early Triassic (Aw, 1990).

1.3 Startigraphy

Accordinmg to Aw (1990), named after Sungai Telong, invented the Telong Formation when he mapped the region of Sungai Aring further south of Kelantan. The location of the Telong Formation type is along Sungai Telong, a Sungai Aring tributary and upper reaches, after which the unit is called (Khoo, 1983). Telong Formation is thought to have triggered the Carnian of the Upper Triassic in uncertain Permian (Aw, 1990). The thickness of Telong Formation is estimated to be more than 1000 m, and consists mostly of argillite sequences along with some tuff (Mohd ShafeeaLeman, 2004).

In Stratigraphic Lexicon of Malaysia, Mohd Shafeea Leman (2004) reported from Aw (1990) that, based on fossil records of pelecypods, ammonoids, gastropods and brachiopods (Dony Adriansyah Nazaruddin, 2014), Telong Formation started in Late Permian until Late Triassic. The Telong Formation disproportionately overlaps the Taku Schist, which consists of rocks of potentially Carboniferous age that are medium to high grade metamorphism (The Malaysian and Thai Working Groups, 2006). This composition consists mostly of argillite and marble with thin tuff and andesite (Dony Adriansyah, 2014), mostly slate and phyllite low-grade metamorphosed rocks, with small hornfels (Dony Adriansyah, 2014) (The Malaysian and Thai Working Groups, 2006). This formation is associated with the Sokor Formation since both successions specifically show basin instability owing to igneous activity during the process of deposition (The Malaysian and Thai Working Groups. 2006). The Telong Formation is more dominant in deeper marine turbiditic sediments (Mohd Shafeea Leman, 2004).

The Gunong Rabong Formation in the west disproportionately overlaps the Gua Musang Formation. Late Scythian was dated to the thick limestone sequence of the top of the Gua Musang Formation (Aw, 1990). Therefore, evidence from Gua Musang and Aring shows that a time of non-deposition during the Anisian period took place. Telong Formation originated in Ladinian, according to Khoo (1983), and ended in Carnian of the Triassic (Figure 2.3).

The ammonoid assemblage suggests that the rocks are from the Middle-Late Triassic (240-220 million years ago) and belong to the Tethyan Province, Zakaria Hussain et al. (2008) stated (Dony Adriansyah Nazaruddin, 2014). The Gua Musang Formation unconformely overlaps the Telong Formation, creating the lower boundary and the Koh Formation unconformely overlaps the upper boundary, defining the upper boundary (Khoo, 1983). The Telong Formation correlates laterally to the formation of Semantan and Gunung Rabung (Mohd Shafeea Leman, 2004). The Permo-Triassic Telong formation can be compared chronostratigraphically with the Permo-Triassic Ai Ba Lo formation in Thailand (The Malaysian and Thai Working Groups, 2006). The thickness of the Telong Formation is over 1000 m and consists of a series of argillite primarily associated with some tuff (Mohd Shafeea Leman, 2004).

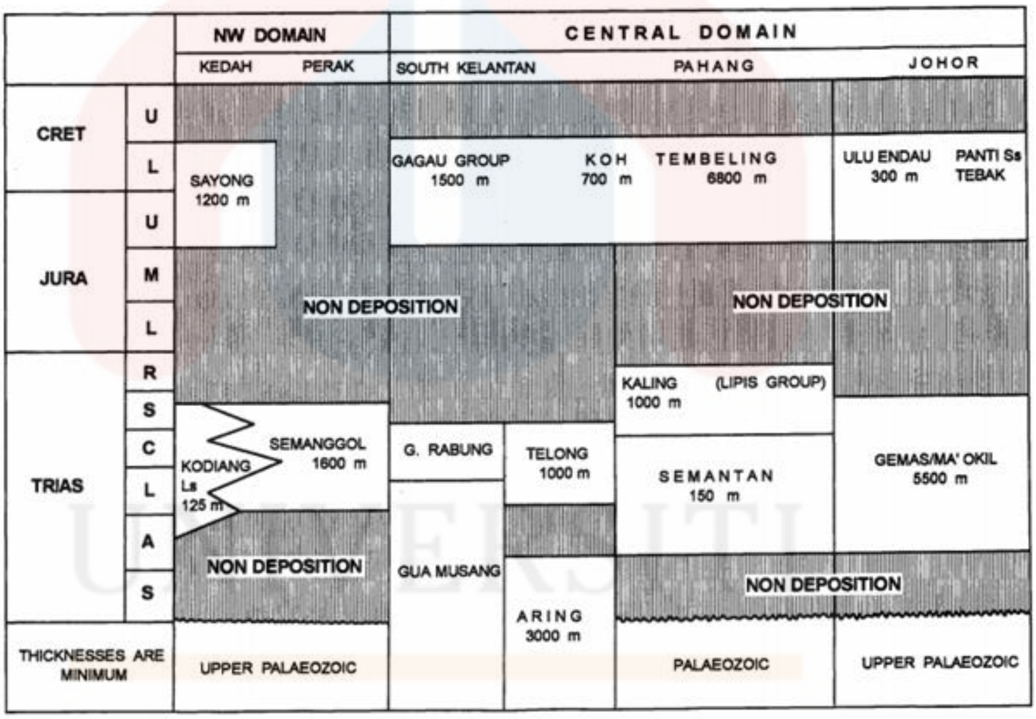


Figure 2.3: Mesozoic stratigraphy of Peninsular Malaysia (Tjia, 1996).

1.4 Structural Geology

In the Central Belt where Kelantan state is located, it consists of a major fault that trends north-south. lt has also been discussed that some of the faults elongated into Thailand. In the western pan, there is a presence of major fault of Karak -Kelau that trends north-sout h (Tija, 1972). At the north, there is Lebir Fault that goes after the Lebir Valley, which the structure is developed during pre-late Triassic.

1.5 Historical Geology

The Aring area has abundance of fossil, which mainly from Triassic fossil that can be found in the Central Belt of Peninsular Malaysia. In Aring, the Triassic age of ammonoids has been recorded, which is written in report by Sato (1964). The age of rock formation during Triassic is determined by the index fossils. The age of the fossils is mostly Middle Triassic, and has been discovered within mudstone of Telong Formation.

1.6 Landslide

Landslide is a natural hazard that happens regularly in the world's mountainous region, causing destruction and property of life. In terms of the number of deaths, Landslide ranked 5th among the top ten most notable disasters in 2010. Landslides can occur due to favorable landscape conditions, which are further exacerbated by heavy precipitation, human activities and earthquakes (Bonaventura, 2010). It can lead to a lot of loss and injury. It is estimated that about 600 people are killed per year worldwide due to slope collapse (Aleotti and Chowdhury, 1999). Malaysia is one of the most vulnerable country experiences with the natural hazard like flash flood and landslide and preparation and mitigation not well prepared and not functioning well.

There are many types of landslides dependent on the Varnes Slope Movement Classification (Varnes, D. J., 1978). Landslide can be divided into two, namely the form of substance and the type of movement. The substance type can be categorized as rock, earth, soil mud and debris as seen in Table 2.1.

The main criteria used in the classification are the type of movement primarily and type of the material secondarily. Types of movement are divided into five main groups; falls, topples, slides, spreads, and flows. A sixth group, complex slope movements, includes the chief criteria used in the classification are the type of movement primarily and type of material secondarily. Types of movement are divided into five main groups; falls, topples, slides, spreads, and flows. A sixth group, complex slope movements, includes combinations of two or more of the other five types. Materials are divided into two classes: rock and engineering soil; soil is further divided into debris and earth. Some of the various combinations of movements and materials are shown in Table 2.1. The type of both movement and materials may vary from place to place or from time to time, and nearly continuous gradation may exist in both. Therefore, a rigid classification is neither practical nor desirable. (Varnes, 1978)

Table 2.1: Classification of landslide

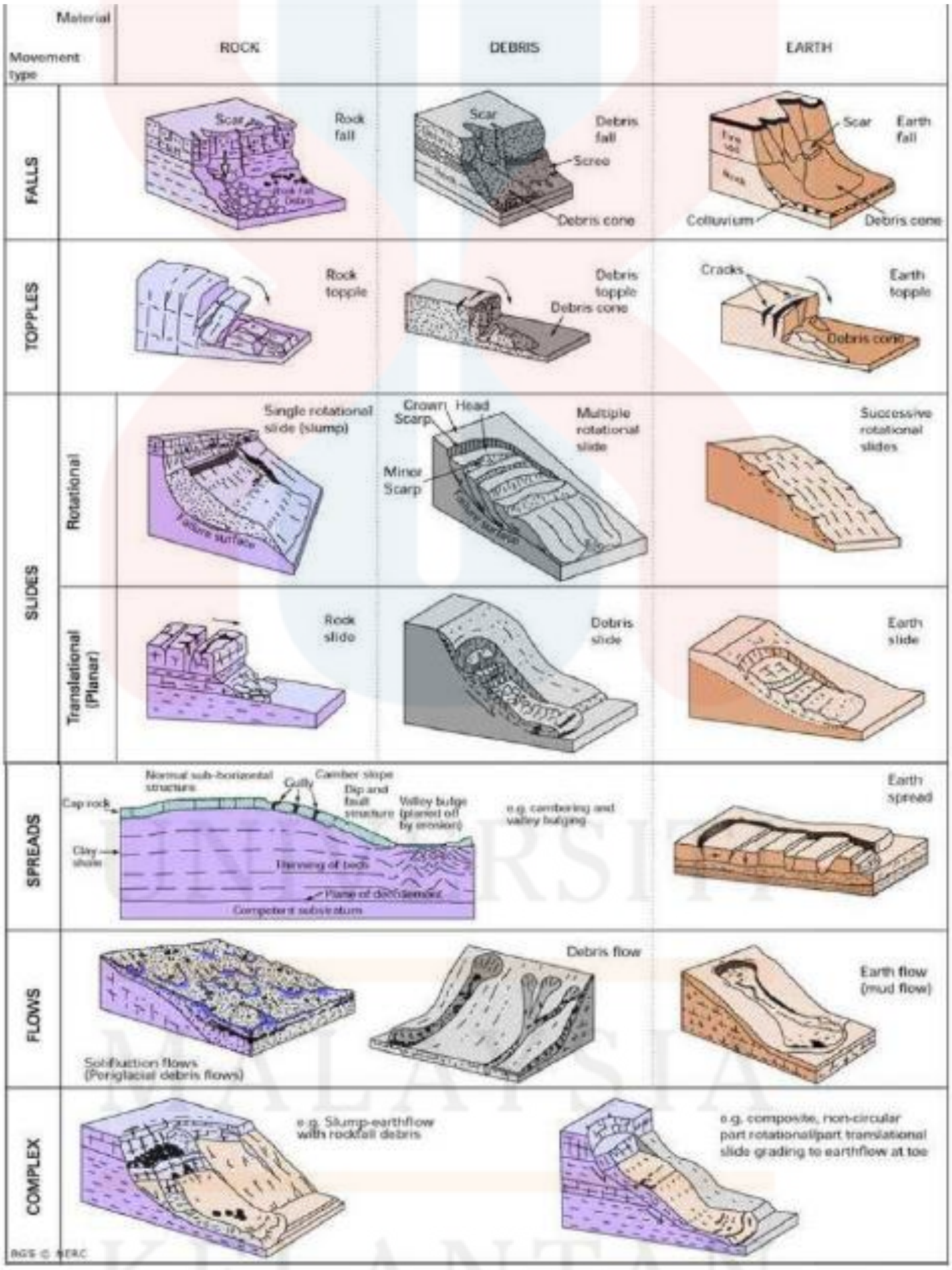
Type of Movement			TYPE OF MATERIAL		
			BEDROCK	Engineering Soil	
				Predominantly coarse	Predominantly fine
FALLS			Rock Fall	Debris Fall	Earth Fall
TOPPLES			Rock Topple	Debris Topple	Earth Topple
SLIDES	Rotational	Few Unit	Rock Slump	Debris Slump	Earth Slump
	Translational		Rock block slide	Debris block slide	Earth block slide
		Many Unit	Rock slide	Debris slide	Earth slide
LITERALLY SPREAD			Rock Spread	Debris Spread	Earth Spread
FLOWS			Rock Flow (deep creep)	Debris Flow (Soil Creep)	Earth Flow (Soil creep)
COMPLEX			Combination of two or more principal type of movement		

Source: Varnes (1978)

For the movement mechanism, flow-like landslide often begins as a slide, forming a rupture surface, but then continues moving over a long distance. The term "landslide source volume" or "landslide source" is defined here as the volume between the rupture surface and the pre-sliding ground surface. It is the volume of initial movement, from which the landslide mass issues onto a flow path. For the second mechanism, material type, the distinction between "debris" and "earth" materials is based on the percentage content of coarse material. "Earth" has less than 20 percent of gravel and coarser clasts whiles "debris" has more (Hungr et al, 2001).

Table 2.2 displays the distinct forms of landslide movements according to the Varnes Slope Movement Classification. There are 6 types of rock or boulder motions that have caused landslides to occur.

Table 2.2: Distinct types of landslide movement (Varnes, 1978)



1.7 Application of GIS in Landslide Susceptibility

The Geographic Information System (GIS) is a computer system used to map and analyze things that exist and events that occur on the surface of the earth. Geographical means the positioning of data objects in the context of coordinate systems. The term information itself refers to the data's information or attribute. The data can be shown in any colored charts, graphics, graphs, models or more. The method relates to how the data is handled and structured.

In generating landslide susceptibility maps, several techniques can be used in GIS methods. The spatial data was arranged in GIS SPRING software from the previous research (Câmara et al., 1996) and calculations related to the computation of probabilistic methods performed using MATLAB software (MATLAB, 2016). It is possible to assess the slope weakness by generating a research area slope inclination chart by conducting both methods.

In their area of research, Shahabi & Hashim (2015) used the GIS-based statistical model to produce landslide susceptibility mapping using GIS and remote sensing knowledge. Their Cameron Highlands research area uses parameters such as fault, SPOT 5, WorldView-1 image, and the distance between roads extracted using SAR data. The maps are then built between variables defined using multiple models, including analytical hierarchy method (AHP), weighted linear combination (WLC) and multi-criteria spatial assessment (SMCE) models, after estimation and determination.

To build a landslide hazard zoning map along Genting Sempah to the Bentong district, Pahang, Rodeano et al. (2017) used the Weightage Overlay Approach (WOM) and Landslide Susceptibility Level (LSL) map. The most causative variables such as land usage, irrigation, line size, soil lithology and geomorphology are weighted by the analysis. These parameters were obtained from the topographic database and graded from very low to high levels of vulnerability to landslides, indicating the potential occurrence of landslides in the study field. By changing the surface and soil intensity, heavy rainfall caused the landslide. Of all the data, the method of layering was weighted by raster input.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Introduction

This section discussed various materials and methodologies used to carry out this analysis. Both data and data collections collected from the geological mapping and field survey were registered as guides with all the image of the outcrop. Methodology is a series of actions taken to accomplish a certain function or to attain a goal where the tools are any instruments or machinery used to perform the work. In this work, the technique is split into four parts: qualitative review, systemic modeling, kinematic analysis and report writing. There are several apparatuses required on the basis of the methodological requirements.

3.2 Materials

Materials are appliances, lab instruments, tools or processing software that has specific functions for the certain method used in research. In geological research, apparatus and materials are undeniably compulsory for conducting studies.

3.2.1 Processing Software

1) Software
   ArcGIS software is necessary for digitizing geological map and produce landslide susceptibility map of the research area.

2) Stereonet 10.0 software
   Stereonet is a plotting program that is displaying a variety of geological data on a hemisphere graph. This software enables to us display those geological data for further Structural analysis.

3) Satellite Imagery

Used as the references in generating map using GIS software and digitizing the map to provide different type of map

3.2.2 Materials for Landslide Susceptibility Map

The secondary data set of topographical data, the Digital Elevation Model (DEM), and satellite imagery are important for generating the landslide susceptibility map. From secondary data gained from agencies and geological mapping, causative factor maps such as lithology map, soil map, drainage map, land use map, slope map, aspect map and NDVI map are derived.

a) Lithology map

During the geological mapping, the lithologies of the study area were compiled. The lithology was defined by analyzing the rocks and their borders. The knowledge reported in the field is plotted out and the lithology chart is created as the observation was done.

b) Slope map

The degree of the slope can be defined by measuring the slope during geological mapping or extracting it from theoretical satellite data. Dependent on its angle, it shows the slope distributions. The slope is defined using Zuidam classification, 1985.

c) Aspect map

An aspect map is a map indicating the direction and degree of steepness of a terrain slope. It was created from the USGS website in ArcGIS as well.

d) Land use map

The land use of the research area can be mapped and extracted from a satellite image from geological imaging. The data gained from the Landsat image of the Google Earth Pro.

e) Drainage density map

The drainage density map from the USGS satellite picture from the USGS websites was designed. It is very significant as the density of the drainage is proportional to the mean rate of erosion. The sediment carried by the hill slope influences the runoff erosion process.

3.3 Method

In geological mapping, a geological map was developed for field observation and image processing. The USGS satellite images were collected in the year 2018. It is possible to define the variations in slope, dimension and drainage density. By doing this, the weighted parameter and causative factor in the research area will assess the possible landslide area in the near future.

The DEM map, slope map, aspect map and drainage density map were developed using ArcGIS software to calculate the distribution from the parameter used. As for the final product, the field of vulnerability to landslides was created and evaluation was completed. From secondary data set, a Weighted Overlay Model solution was used and translated into a raster using the ArcMap reclassification function. The map was then weighted.

3.3.1 Preliminary Study

Before conduct the research at Aring 5, Kelantan researcher must study and get a good grasp of the condition at the study area in order to achieve the objective of the research. Studies on previous research and journal with the help of the references book to provide the importance information and point which might be useful for the research in order to get the general idea. In terms of geological map, topographic map can be made and used as a direction for the researcher before conducting the research and also to determine important data needed in terms of secondary data to achieve the objective. The study of type of rock and its formation with some geological structure is importance in making 1:25000 geological maps as a first objective of the study. For the scope of slope failure analysis, the terrain map is useful to identify suspected slope which have a potential of failure. Lineament analysis is importance in identifying the outcrop and steep slope which is potential to failure.

3.3.2 Data collection

Data collection is important for this research which is about the geological map of study area and also the specification regarding the landslide study. The data needed in this research include the secondary data from the previous research or satellite imagery data and other related data for specification of the research. All of these data can be obtained from other previous research such as article, journal, educational book and internet. Some of them need from the agencies such as JUPEM and USGS website. These data is importance as a basic requirement for this research.

3.3.3 Data Processing

a) Methods for landslide susceptibility area

During the process of generating geological map, satellite image data were applied to the data collected in relation to the existing landslide occurring in the study area. With respect to their sub groups, the more accurate weighted score of and parameter and factor activated was developed.

b) Evaluation of causative factors that triggered landslide to occur

In the assessment of causative factors that cause landslides to occur, eight parameters such as lithology, slope, drainage density, land use, aspect, lineament density, soil cover and vegetation were considered. The frequency of landslides typically happens because of these variables, so all sorts of data in the research area such as dimension and historical landslides were obtained during the geological mapping.

c) Landslide susceptibility map

The Weightage Overlay Method was used for the landslide susceptibility map development. Satellite data and geological mapping data collection data, as well as the parameters concerned, were mapped. It was then transformed into raster-based details. Using a ranking system in which all those variables and their classes were placed as numerical values, the raster was weighted and scored. The landslide was measured on a scale of 1 to 5. As seen in Table 3.1, scale 1 is the least landslide-prone area, while 5 is the very high risk area for landslides. The percentage of all raster-based data was weighted based on its meaning. It is important for the total raster influences to be 100 percent.

Table 3.1: The landslide susceptibility classes with its percentage

Landslide Susceptibility classes	Percentage of landslide pixels	Percentage of class area
Very low	4.65	18.28
Low	7.31	19.04
Moderate	15.09	25.63
High	34.86	25.66
Very high	38.09	11.39
Total	100.00	100.00

(Sources: Champati P. R. and Santosh K. S., 2007)

3.3.4 Data Analysis and Interpretation

The geological map that requires geological interpretation from satellite imagery and secondary data in the general geological aspect, where all the geological features and elements have been observed and documented. The imaginary satellite data was contrasted with the collection of geological survey and data interpretation. In the observation of the satellite data interpretation, review of data was carried out to correct the outdated one.

The polygon layer of parameters used, such as slope, vegetation, drainage density and aspect, were created by using the DEM. From all the data, layering techniques were weighted by raster input. The weight assessment was carried out using reclassifying tools in ArcMap based on the reclassified weight. The landslide susceptibility map was generated as a consequence.

Results from the methods of weighted overlay indicate the most vulnerable area to landslides with a scale of 1 to 5 and susceptibility groups. The landslide assessment was conducted to demonstrate that the distribution of high potential to low landslide potential was most likely to occur. In order to avoid any development of infrastructure or houses near the high susceptibility region, the landslide susceptibility map may be used as an indication.

3.3.5 Report Writing

Report writing consists of the documentation of the whole research. The report consist the geological map of the study area and the entire geological characteristic such as geomorphology, stratigraphy and structural geology. The report also includes the result of landslide susceptibility study and remedy to prevent the hazards of landslide hazard. All the data that have been analysed and interpreted were compiled and written in the report. The report is divided into 6 chapters.

CHAPTER 4

GENERAL GEOLOGY AND STARTIGRAPHY

4.1 INTRODUCTION

For this chapter, general geology and stratigraphy describes the geological process occur at the research area Felda Aring 5, Gua Musang Kelantan. The research on general geology includes the study on geomorphology which is the process that produces deformation and made up the shape and landform of a particular area situated at Felda Aring 5, Gua Musang. From the geomorphological process will shows the deformations include the drainage system and also weathering process which differentiate into three main types which are biological weathering, physical weathering and chemical weath

ering. For the geographical study in this chapter will cover the people distribution, social economic and road connection.

For the stratigraphy and lithostratigraphy, it would include the study of lithology of the research area, lithostartigraphy and petrographic study of the rock and mineral content which the sources from the previous study. The thin section for the rock will indicate the lithology of the study area carried out with the interpretation of the analysis to determine the rock unit formed. It can be used in determining the type of lithology in order to constructing the geological map of the research area. Beside, mineral content on the sample and its behaviour will represent the formation of rock unit.

For the structural geology, the geological structures were determine through the landsat image and supported by the lineament analysis of the research area. The changes on its position of the contour line indicate the movement of the surface which can be seen through the landsat image. The lineament analysis will be done by constructing the line based on the valley and ridge and differentiate the direction of line. Throughout the geological structure, the direction of force can be identified and the structure formed can be determined. Besides, the historical geology of the study area will be discussed which can include of the historical formation, lithology and deformation.

The information stated in this chapter can be obtained from the previous research at the study area beside the satellite from various sources include terrain map and also satellite imagery. Terrain map and satellite imagery data will be interpreted with the support from the previous research at Aring 5, Gua Musang Kelantan. Geographical features will be interpret through the observation from the terrain map include the index contour. The interpretation of rock at the study area can be done by overlying the formation map of Gua Musang from the Jabatan Mineral dan Geosains (JMG). For this area which is Aring 5 was lying on the Telong formation which shows the sedimentary facies occur at the entire place of the research box. The boundary of the rock will be determining using V rule and lineament analysis. Satellite image from Google Street view can determine the weathering process occur at the research area. It will be supported by the previous research data to confirm the rock formation at the study area include the geological age of the rock. As the geological mapping cannot be done for the research, the terrain analysis will support the data from the interpretation of the contour line and the difference in the contour shape. With the previous study data at the study area it will differentiate the rock type and also supported the interpretation data from formation map of Telong Formation. Thus, it cannot surely confirm the boundary and rock formation exist at the research area as geological mapping cannot be done.

4.2 GEOMORPHOLOGY

Geomorphological processes are the geological processes that shaped the structure and shape of a particular region. Geomorphology consists of numerous geomorphological units and the distribution of geomorphological units in the study region. Geomorphological processes may include mountain orogeny, elevation, mountain bending and several different processes that have arisen due to tectonic forces. A variety of forms of investigation should be used in the geomorphology analysis of the study field. The first stage is the identification of the morphology or orthography of the research field. This can be achieved by specifying the geomorphological units that are present in the relevant field of analysis. The analysis from the topographic map and the ground observation from the peak can determine the type of landform, drainage and contour pattern. The example of major landform includes mountain, hills, plateau, and plains are the example of the major landform. The endogenic and exogenic process made up the difference in the type of landform formed at the surface of the earth.

4.2.1 GEOMORPHOLOGIC CLASSIFICATION

Geomorphology classification can be categorized and explain the nature, origin and the development of landform to form the specific geomorphological features which undergo geomorphological process and deformation. These classifications can be classified on its origin and development in terms of process, on its own general structure and shape in terms of landform and also depends on measurement of its dimension and characteristic (morphometry).

In terms of landform in the research area, the landform divided into three type of landform which is low laying plain, low hill and hill. The different type of landform formed at the research area which indicates different in lithology. The entire parts of the research area consist of sedimentary facies. But the east part of the research area is tuff interbedded. The sedimentary facies include of mudstone, sandstone, and interbedded of shale, and phyllite which dominant facies in Gua Musang and Telong Formation (Kamal Roslan et all, 2016). The landform classification can be classified by the elevation above the sea level as shown in Table 4.1.

Table 4.1: Landform classification

Relief / Landform	Elevation (m)
Low Lying Plain	5 – 100
Low Hill	100 - 200
Hill	200 – 500

(Sources: Van Zuidam, 1985)

Low lying plain of the research area is as shown in Figure 4.2 which observed through Landsat image of Google Earth. From the figure 4.2 which at the coordinate of 4° 83’ 43.0’’N, 102° 31’ 38.7’’E shows the low lying plain and it can be seen through the Landsat Image. From the observation of aerial photography shows the plantation area. Low hill of the research area is as shown in Figure 4.3 which consists of some hill with the elevation not more than 200 meter. Most of the place at the research area consists of the low hill. The landform classification for hill which the elevation between 200 meter to 500 meter only can be seen at the small part of the area as shown in Figure 4.4.

The Classification of landform is shown in Figure 4.5 which is landform map consist of all the geomorphology classification. The main river in the research area is Sungai Aring which is the one of geomorphology features which flows from the south to the north of the box.it connected with the other river and formed drainage system.

4.2.2 DRAINAGE PATTERN

In geomorphology, a drainage system is the pattern formed by the streams, rivers and lakes in a given drainage basin. A method of drainage depends on the structure and relief of the terrain over which it passes. They are governed by the earth's topography, whether a particular area is occupied by hard or soft rocks, and the gradient of the soil.

The topographic area from which a stream receives runoff by flow and groundwater flow is a drainage basin. Drainage basins are separated from each other by a watershed called topographical barriers. Many of the stream tributaries that flow to some point along the stream system are represented as a watershed. The number, scale, and shape of drainage basins located in a region varies, and the bigger the topographic map, the more knowledge is available about the drainage basin.

The Sungai Aring, which flows from south to north of the study city, is the main river in this area. Using evaporation, deposition, and streamflow, drainage basins lose water and sediment. In a drainage basin, a few variables affect the supply, production and transport of sediment and water. Topography, condition of soil, type of bedrock, climate, and canopy of vegetation are the influences. The design of the pattern of stream channels also affects those factors.

There are two types of drainage patterns that can be recognized from the drainage map in Figure 4.1**.** The drainage in the sample area consists of a dendritic structure and a contorted or deranged pattern. A disrupted structure evolves as a result of the disturbance of the pre-existing drainage cycle, typically due to geological disruption. The system may evolve from a dendritic pattern that was altered when overwhelmed by the glacier.

The dendritic pattern, which occupies much of the area in Figure 4.1**,** is another drainage pattern that can be seen here. There are several contributing streams in dendritic systems that are analogous to the roots of a tree, which are all fused together into the main river's tributaries. At low angles, dendritic system tributaries meet and branch in spontaneous, free-like patterns. In V-shaped valleys, they form where the river channel follows the terrain's slope. They typically form on approximately planar surfaces, even on impermeable and non-porous rock forms, with consistently erodible rocks or sediments. They develop in places such as sandstone or shale with plain and uniform bedrock.

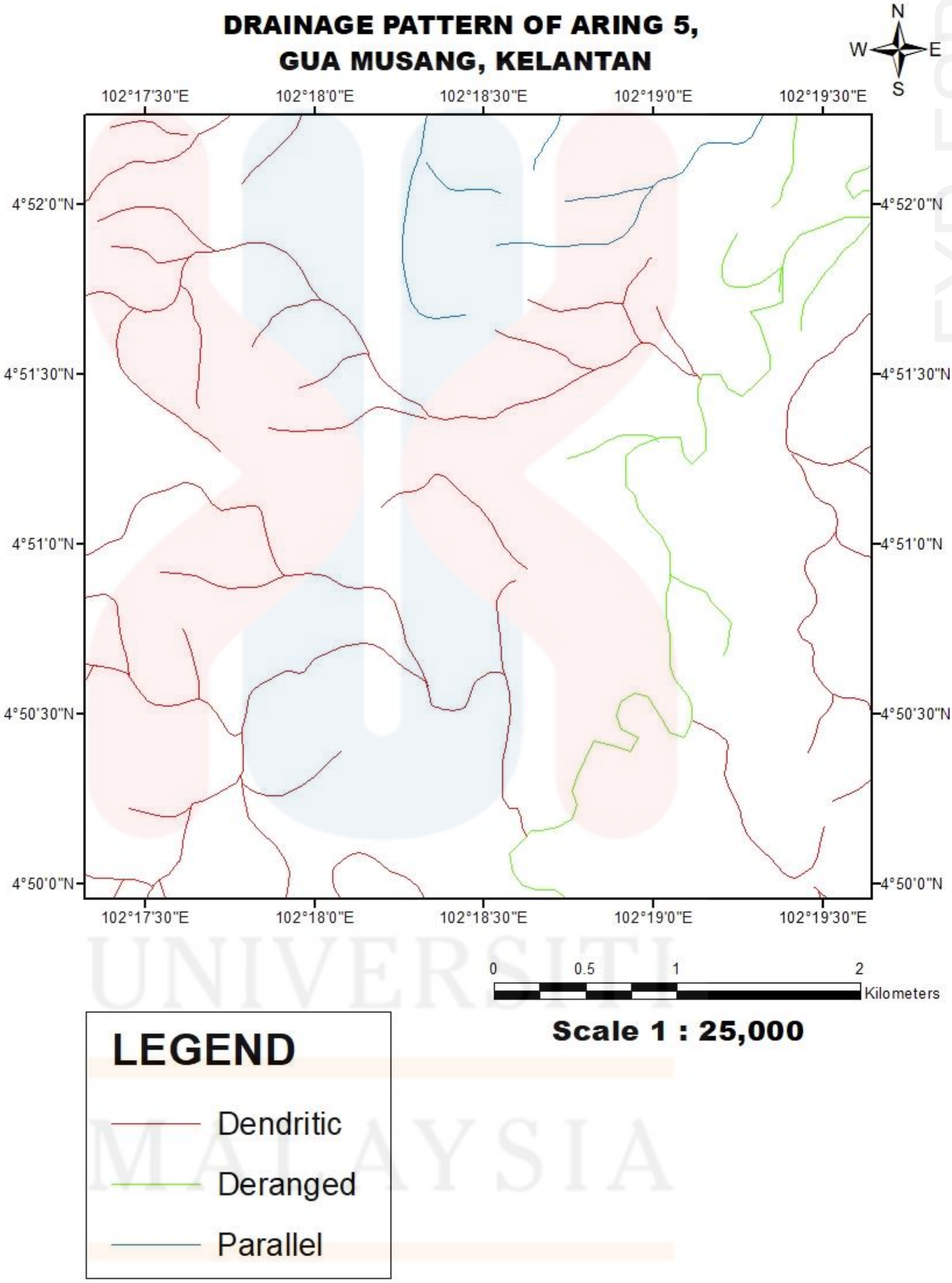


Figure 4.1: Drainage pattern map of the research area

4.3 LITHOSTARTIGRAPHY

According to Bates and Jackson (1980) stated that lithology refers to the study and description of the physical characteristic of rocks, particularly in hand specimen and outcrop. The lithology shows the colour, grain size, mineral content and type of rock presence at the sentences area. Stratigraphy can be defining as the study of the rock strata, their relative and absolute ages, and relationship between strata. From the used of stratigraphy, it is usefull to identify past environment exist on the earth about million years ago referring to the physical characteristic which can be observe through the rock including the structural geology and its deformation which change the shape of the earth surface. Then, lithostratigraphy can be one of the brench of stratigraphy field which the relationship between the rock strata to observe their actual ages which it can be identified on the rock lithology at the sentences places.

There are 3 lithology in the research area which are tuff unit, interbedded mudstone unit and interbedded shale, slate and phyllite which known as a sedimentary facies which is dominated by argillite in Gua Musang Formation and Aring Formation. The lithology can be divided into formation which is Telong Formation and that include tuff, interbedded mudstone and interbedded shale, slate and phyllite.

Telong Formation was introduced by Aw (1990), named after Sungai Telong when he mapped the Sungai Aring area further south of Kelantan. Telong Formation type locality is along Sungai Telong, a tributary and the upper reaches of Sungai Aring, after which the unit is named (Khoo, 1983). It is believed that Telong Formation initiated in unknown Permian to Carnian of the Upper Triassic (Aw, 1990). The thickness of Telong Formation is known to be more than 1000 m, and is made up of sequence of predominantly argillite associated with some tuff (Mohd ShafeeaLeman, 2004). The research area consists of the Permo –Triassic which the rock comprises of age from Permian to the Triassic. The Permian rock which include phyllite, sandstone, limestone and slate. Then, the Triassic rock consists of sandstone, siltstone, shale and limestone. According to Aw (1990), in southern Kelantan, the Triassic lies conformably on Permian. The research area can be observed as the dominantly sedimentary rock comprises dominantly of agilities. From the interpretation from the satellite data and past research, the types of lithology that are found in the research area are interbedded tuff, interbedded mudstone and sandstone, and interbedded shale, slate and phyllite.

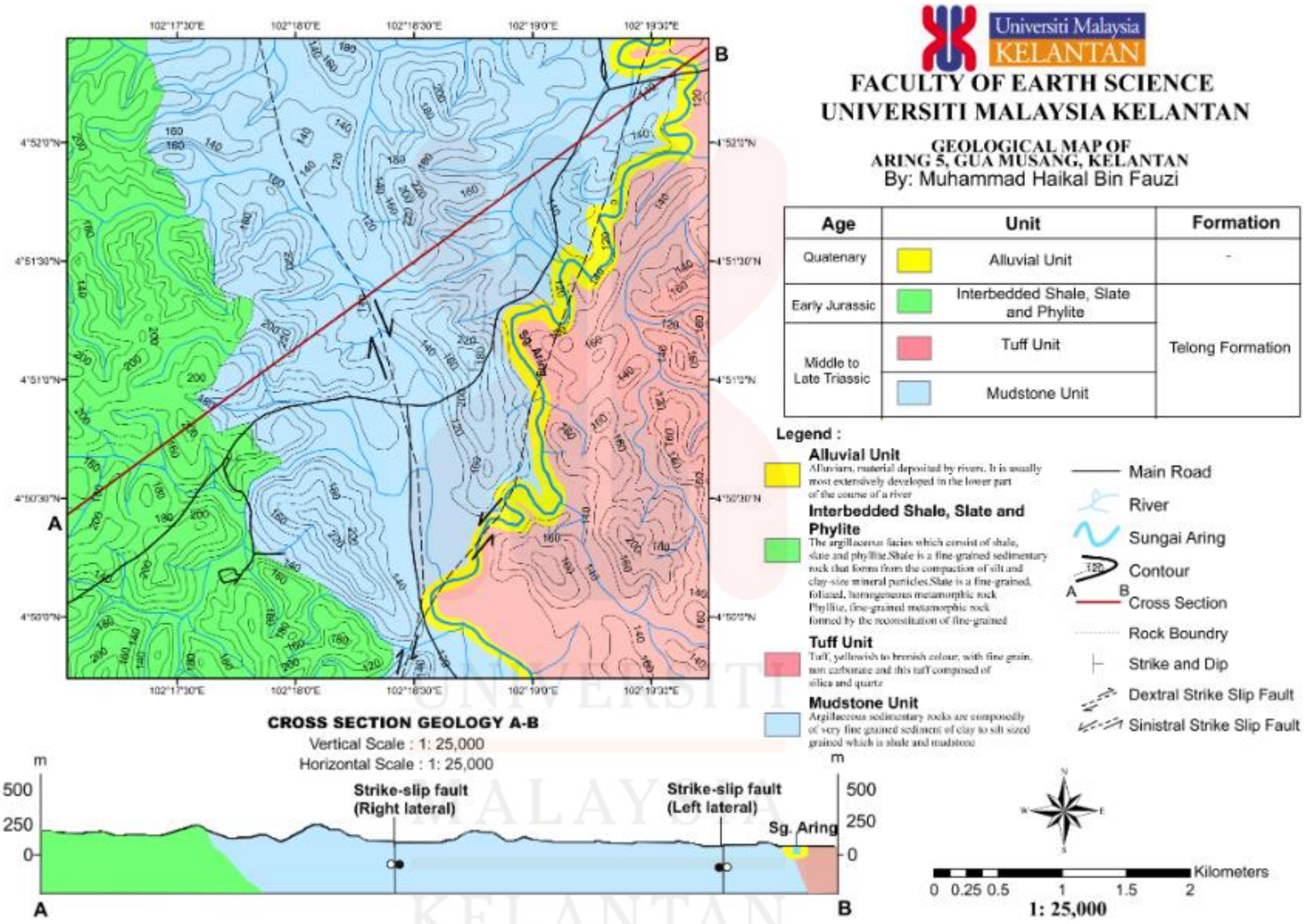


Figure 4.2: Geological map of research area

Table 4.2: The Lithostratigraphy of the research area

Era	Period	Epoch	Formation	Unit
Mesozoic	Jurassic	Early Jurassic	Telong Formation	Interbedded shale, slate and phyllite (Aw,1990)
	Triassic	Middle to Late Triassic		Tuff Unit
				Mudstone Unit

4.3.1 Argillaceous Units

Argillaceous sedimentary rock can be found at the research area, Aring 5, Gua Musang Kelantan. Argillaceous sedimentary rocks are composedly of very fine grained sediment of clay to silt sized grained which is shale and mudstone. The argillaceous sedimentary rock can be found at the entire area at the research area. The argillaceous facies which consist of shale, siltstone, mudstone, slate and phyllite are the dominant facies in Gua Musang and Telong Formation and it also occurs interbeds or lenses in the Aring Formation and Nilam Marble (Kamal Roslan Mohamed et. all, 2016). Shale is a sedimentary rock which is a sedimentary facies at Telong Formation is consisting of flakes of clay mineral with compaction of mainly mud and clay with smaller fraction of silt sized particle. The research area can be classifying as a dominated argillaceous rock, mainly shale. Mostly the colour of the shale shows from grey to dark grey. In past research, most of the shale outcrop found at the Aring 5, Gua Musang found in planar bedding and some of the outcrop were slightly folded.

4.3.2 Arenaceous Unit

Arenaceous sedimentary rock is clastic sedimentary rocks whose particle sizes range from 2 to 0.06 mm, or if silt is present, to 0.004 mm are included in the arenite rocks. Any arenites consist mostly of fragments of carbonate, in which case they are called calcarenites.

4.4 Structural Geology

Structural geology is concerned with the geological characteristics produced by tectonic activity that allow deformation to occur. It is important to study the geometries and examine the tectonic activities of the Earth, as well as the rock stress and strain. The history of the Earth can be discovered by knowledge of structural geology. Deformation results in the occurrence of fault, fold, joint, bedding and veins. Geological mapping and lineament analysis using a terrain map will detect the deformation of the Earth.

4.4.1 Lineament analysis

Fractures that are directed in various directions are represented by lineaments. A lineament is an early aligned mappable and observable linear characteristic of the surface of the Earth and represents an expression of the geological phenomenon underlying it (O'leary er al. 1976). A line is different from the patterns of adjacent features. A lineament is different from the pattens with adjacent features. A single rose diagram with angles ranging from 0 to 180 can represent the different orientations of lineaments in all directions. The length of each rose petal depends on the frequency of lineaments falling at each angle. Rose diagrams are widely used to represent line orientations because of their interpretation of their situation (Chopra et al, 2009). Figure 4.3 and 4.4 shows the lineament analysis using rose diagramof the research area. Which indicate the structural geology form at the area.

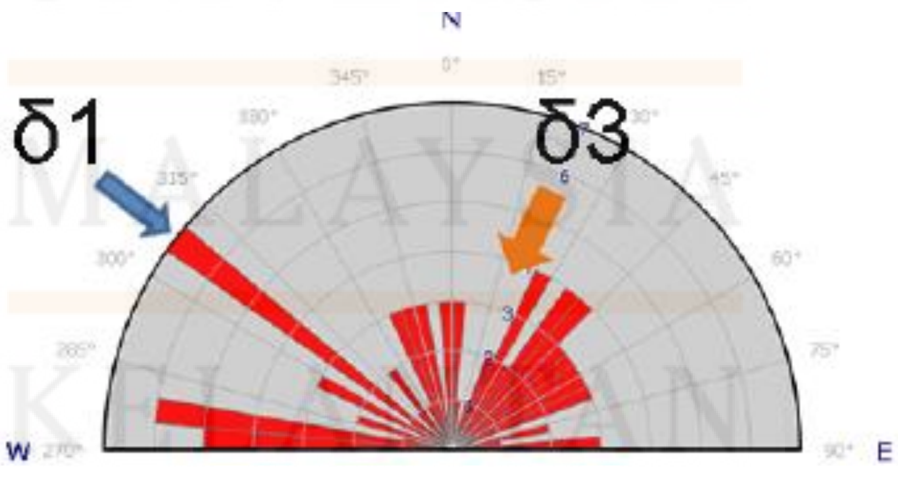


Figure 4.3: Rose diagram of the research area. Sigma 1 at W-N

From the figure 4.3 shows the rose diagram of the study area which the sigma 1 is from west-north. Thus the force is from west-north to the east-south. From the interpretation, the structure geology is presence which is dextral strike slip fault

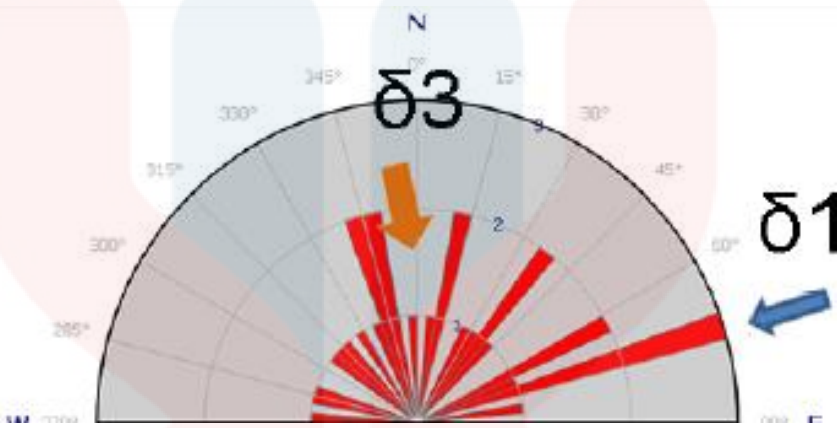


Figure 4.4: Rose diagram of the research area. Sigma 1 at N-E

From the figure 4.4 shows the rose diagram of the study area which the sigma 1 is from north-east. Thus the force is from north-east to the south-west. From the interpretation, the structure geology is presence which is sinistral strike slip fault

4.5 Historical Geology

Peninsular Malaysia is part of the Sundaland Eurasian plate and has split Palaco-Tethys Bentong-Raub suture from north to south into Sibumasu block on the west and East Malay block on the east. We can infer that the age of the rock units varies from Ordovician to Cretaceous, according to the fossil produced by Dony Adriansyah Nazaruddin and Ahmad Rosli Othman (2014) and other research that has been investigated.

There are several small fossils that have been found in the Aring region, Gua Musang, as Dony Adriansyah Nazaruddin and Ahmad Rosli Othman (2014) point out. From Kelantan. Fossil occurrences and presence in Malaysian rocks are uncommon, according to Lee (1992). To date, nearly fossils of small invertebrates and plants as well as trace fossils of past animal activities have been identified.

Most fossils found at this site are from Phylum Mollusca, according to Dony Adriansyah Nazaruddin and Ahmad Rosl Othman (2014). At this location, ammonoids and bivalves were created. This fossils were found in Telong Formation at thin layers of dark grey tuffaceous mudstone In the Middle Triassic, the age of the fossil was estimated.

According to Ahmad Rosin Othman and Mohd Shateca Leman (2008), the creation of Molluse and brachiopod at the research asrea located at Aring 5. Five ammonoid fossil species, such as Ralatonites ef B, were discovered. *Balatonic. Balatonicus Kellnerites amanuensis, Hollandites sp, Dunubites kansa and Acrocordiceras sp. Costatoria pahangensis, C maluvensis* was identified for the fossil of bivalve Ahmad Rosli Othman & Mohd Safeea Leman 2010). The *ovatus neaschizodes. N. (Leviatus) elongatus Langsonella eloigata, Entolatus and Hoernesia magnesimma*.

Telong Formation was age Permian to Upper Triassic according to Lee (2004). It is based on the fossils found including Ammonites sp., Lima sp., cephalopod and Anatomites sp.. The formation consisted mainly of argillite series lithology with some tuff. According to Nuraiteng (2009) suggested that sediment lithology bears close resemblance to the Gua Musang Formation's argillaceous rocks. Telong Formation, which encompasses Gua Musang Formation, is thought to age from Upper Permian to Upper Triassic. The rock sequence of this formation comprises primarily of argillite and marble with thin tuff and andesite. According to Zakaria, Hussain and.al. (2008) The ammonoid assemblage reveals the Early – Late Triassic age (240 – 220 million years ago) and belongs to the Tethian Province (Dony Adriansyah Nazaruddin, 2014).

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY ASSESSMENT

5.1 INTRODUCTION

For this chapter, landslide susceptibility assessment can done and analyse using weigted overlay method (WOM). Based on the research area of Aring 5, Gua Musang, Kelantan, six parameter were used to identify and determine the landslide causative factor such as lithology, slope, aspect, vegetation, land use and drainage density. All those parameter were done and generated form the DEM data provided form USGS website. To determine the landslide susceptibility area, the average weightage score of each parameter were selected. Thus, the landslide susceptibility area can be identifying.

5.2 Parameter of Landslide Causative Factor

The weight of the parameter chosen to determine the vulnerability of landslides is shown in Table 5.1. Rather than using the chosen parameter and weights, the susceptibility of landslides in the study area is calculated using the weighted overlay method. In order to support the result obtained using the weighted overlay method, the actual phenomenon and field condition causing landslide were observed based on the defined parameter, so that the landslide vulnerable area can be calculated.\

Table 5.1: Weightage of parameter of landslide causative factor

No	Parameter	Weightage (Wi)
1	Slope	6
2	Lithology	5
3	Aspect	1
4	Land use	4
5	Drainage density	8
6	Lineament density	7
7	Vegetation	3
8	Soil cover	2

5.2.1 Slope

Landslide can be defined as the movement of mass of rock, debris or earth down a slope. The down-slope motion of the soil and rock was influenced by gravity. Slope is one of the most importance parameter to determine the landslide susceptibility in the research area of Aring 5, Gua Musang, Kelantan. That is because stability is the basis of the the frequency and therefore the strength of the study of hazards. The study area consists of hill and low hill with the presence of cut slope which is located at the main road of Aring 5 Gua Musang. And this undulating landform of this study area highly influence and affected on the degree of the slope. The slope was categorized into six groups according to the Malaysia Slope Classification by the Geology Society Malaysia, as seen in Table 5.2

Table 5.2: Slope classification

No.	Class	Description
1.	0 – 5º	Very gentle
2.	5 – 10º	Gentle
3.	10 – 15º	Moderate
4.	15 – 25º	Moderately steep
5.	25 – 35º	Steep
6.	> 35º	Very steep

(Sources: Geology Society Malaysia, 2004)

From the interpretation from the satellite image, the result can be obtained by the observation of base map which shows the area with high degree, moderate and very gentle of slope which becomes the trigger factor of landslide that can be happen at the research area. It is including the cut slope area along the main road of Aring 5, Gua Musang Kelantan which can be consider as a very steep slope which is more than 35˚ (degree) of slope. Figure 5.2 below shows the slope map generated from

Dem using Geographical Information System (GIS). From the map of slope map showing the high degree of slope which is more than 35˚, medium degree of slope which is moderate and low degree of slope which is very gentle.

To generate the slope map of the study area, the score and weightage are divided into six classes of degree using the slope classification by Geology Society Malaysia (GSM) with the weightage (Wi) used is 6. The slope is one of the trigger factors which influence the landslide occurring at the sentence places. The score can be obtaining by multiplying the weightage of the slope with the area (km²). The score will increase with the increase of the area of the places. But, from the past research prove that the landslide not only occurred on a very steep slope, but it also can be occur on a moderate slope with the presence of the other trigger factor which influence the movement of rock mass which landslide can be occur in a form of rock fall or debris flow.

Table 5.3: Weightage and score for slope generated using Geographical Information System

No	Class	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	0 – 5º	6	1	6
2	5 – 10º	6	2	12
3	10 – 15º	6	3	18
4	15 – 25º	6	4	24
5	25 – 35º	6	5	30
6	> 35º	6	6	36

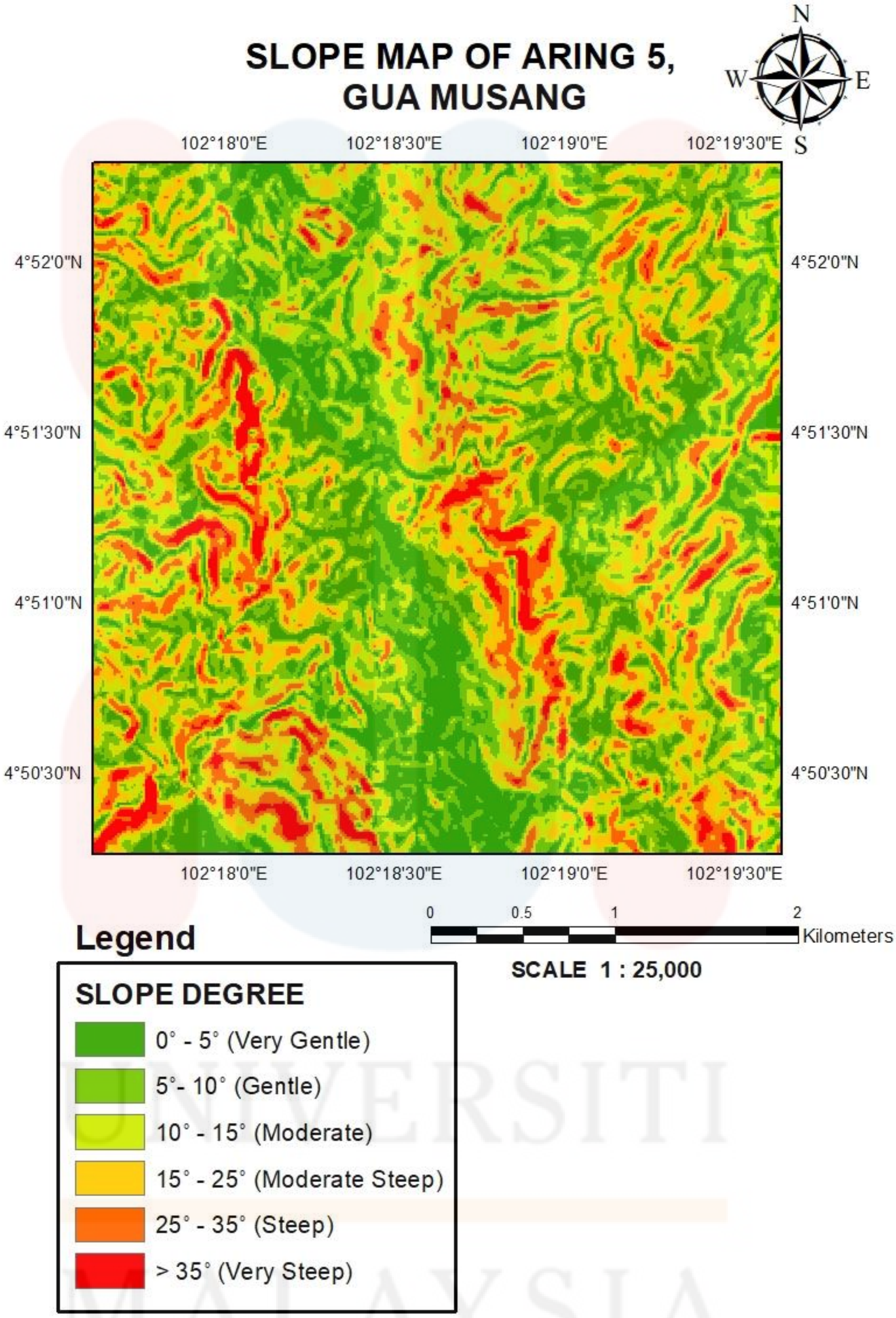


Figure 5.2: shows the slope map of the research area

From the table 5.4 shows the weightage and score for slope generated using Geographical Information System. Weightage used is 6 and slope classification can be concluding from the multiple of weightage with the score. The score is based on the slope classification by Geology Society Malaysia (GSM). 20 percent of the area with very steep slope can be seen through the slope map figure 5.2. It shows the value of influence of landslide with dominantly at the area of cut slope of Jalan Aring 5 and the agriculture area. The development and construction for road as a presence of cut slope along the road give the high vulnerability of landslide. Moderate zone of landslide shows the yellow colour at the slope map in figure 5.2 with approximately 30 percent of the research area. For the very gentle slope result in low potential of landslide and it cover about 50 percent of the area at the research area. However, others factor can be consider for the landslide vulnerability in order to get actual result of landslide vulnerability.

Figure 5.3: shows the steep slope at the research area, Aring 5, Gua Musang Kelantan. (source: Google map, 2020)

The figure was took from the google street view which showing the steep slope presence at the cut-slope along the main road of Aring 5, Gua Musang Kelantan. The steep slope presence due to the construction for road building which resulted the slope failure might be presence. The higher the slope degree the higher the potential of landslide happens at the sentence area.

5.2.2 Lithology

The parameter used in determining the susceptibility of landslide occurrence in the research area was the lithology map. Where the region is prone or vulnerable to landslides, the variations in lithology have played a significant role. The lithological environment and formation distinguish rock and soil characteristics. The formation exist at the study area consist of Telong Formation dividing the lithology unit into three categories which are Interbedded shale, slate and phyllite, tuff unit and interbedded mudstone.

Figure 5.1 shows the lithology of the research area demonstrating that the distribution of lithology is from the oldest to the youngest in the northern to southern areas. The rock formed from Permian to Upper Triassic (Karnian) (Mohd Shafeea Leman, 2004).

Table 5.4: Weightage and score for lithology

No	Lithology Unit	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	Interbedded shale, slate and phyllite	5	4	20
2	Tuff Unit	5	3	15
3	Interbedded mudstone	5	4	20

Figure 5.4 shows the lithology map of the research area consist of three rock unit which are interbedded shale, slate and phyllite, tuff unit and interbedded mudstone unit. The weightage of 5 indicate the landslide potential with the mudstone unit and interbedded shale, slate and phyllite dominantly exist at the research area while alluvial unit can be seen along the main river which is from south to the north of the research box which is Sungai Aring.

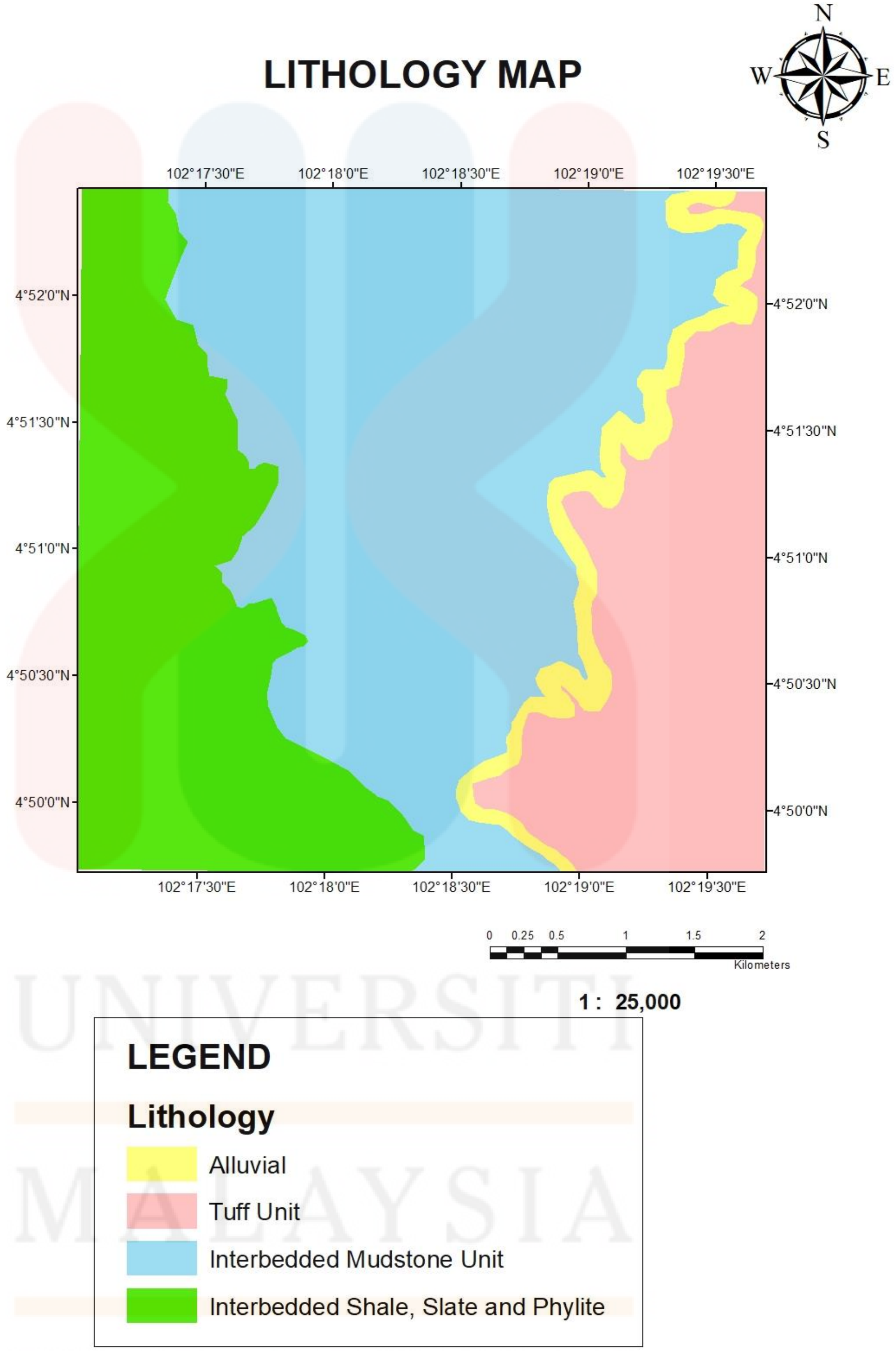


Figure 5.4: Lithology maps of the study area.

5.2.3 Aspect

Aspect map were generated from DEM data from the USGS website. The aspect map was divided into 8 classification of slope direction that due to the North. The parameter was used to observe the position of the slope resulting in variations in gravitational force. The instability and inclination of the slopes can be established. Counter clockwise is calculated in degrees from 0 (North) to 360 (North) degrees (due to North). The slope position of the aspect is shown in Table 5.5 and the aspect chart of the sample area is shown in Figure 5.2.

Table 5.5: Weightage and score for aspect of the research area

No	Slope direction	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	Flat (-1)	1	3	3
2	North (0-22.5)	1	4	4
3	Northeast (22.5-67.5)	1	4	4
4	East (67.5-112.5)	1	5	5
5	Southeast (112.5-157.5)	1	3	3
6	South (157.5-202.5)	1	4	4
7	Southwest (202.5-247.5)	1	4	4
8	West (247.5-292.5)	1	5	5
9	Northwest (292.5-337.5)	1	3	3
10	North (337.5-360)	1	3	3

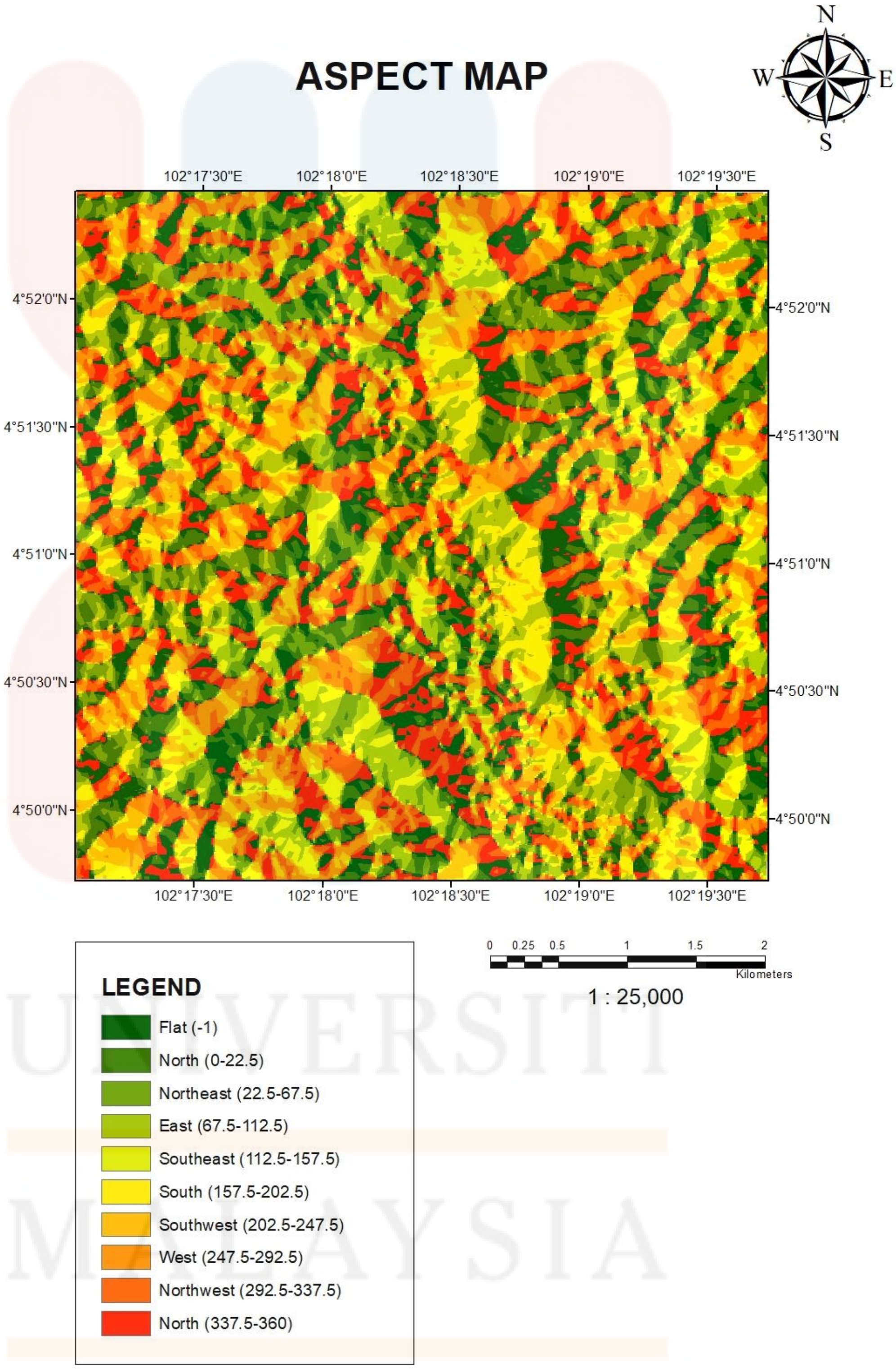


Figure 5.5: Aspect map of the research area

5.2.4 Land use

Land use maps were taken from secondary data obtained from Jabatan Pertanian Negeri Kelantan and observation and interpretation from Landsat image of Google Earth Pro. Most of the land was used for planting, such as palm plantation which is dominated at the research area and some of it was surrounded by forest. In addition, the settlement area with a medium population density is situated in the Aring 5, Gua Musang. The ground cover demonstrates the stability of the slopes.

Table 5.6: Weightage and score for land use and vegetation of the study area

No	Class	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	Forest	4	3	12
2	Palm oil plantation	4	7	28
3	Main Road	4	3	12
4	Lake and river	4	3	12

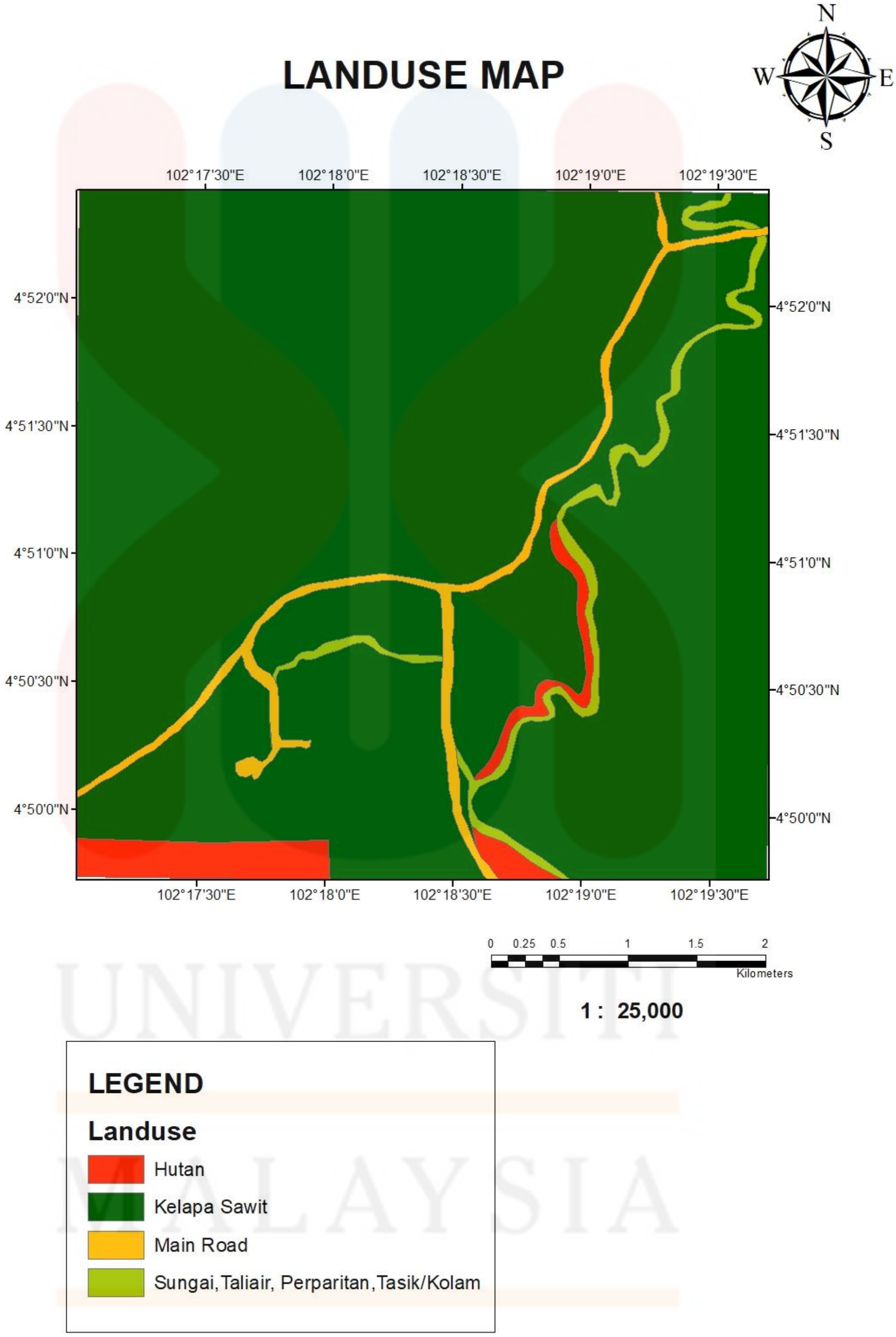


Figure 5.6: The land use map of the research area

5.2.5 Drainage Density

Drainage density corresponds to the total length of the streams and rivers in the drainage basin divided by the total area of the drainage basin. Drainage variation was affected by temperature, topography, soil infiltration, vegetation, and flow density. It is important to decide the river network in the study area. The prone region of landslide to occur can be determined by the level of debris flow and seepage due to rainfall infiltration.

The drainage density map was extracted from ArcGIS's DEM results. The stream length divided by area is drainage density. The drainage density has been graded into three low, moderate and high grades. The high drainage rate suggests the great potential for the incidence of landslides. This is because there is a high degree of soil runoff. The weight and score for drainage density are shown in Table 5.7, while the drainage density chart of the sample area is shown in Figure 5.7.

Table 5.7: Weightage and score for drainage density

No	Drainage Density	Weightage (Wi)	Score (Sij)	Weightage x score (Wi x Sij)
1.	Low	8	5	40
2.	Moderate	8	6	48
3.	High	8	4	32

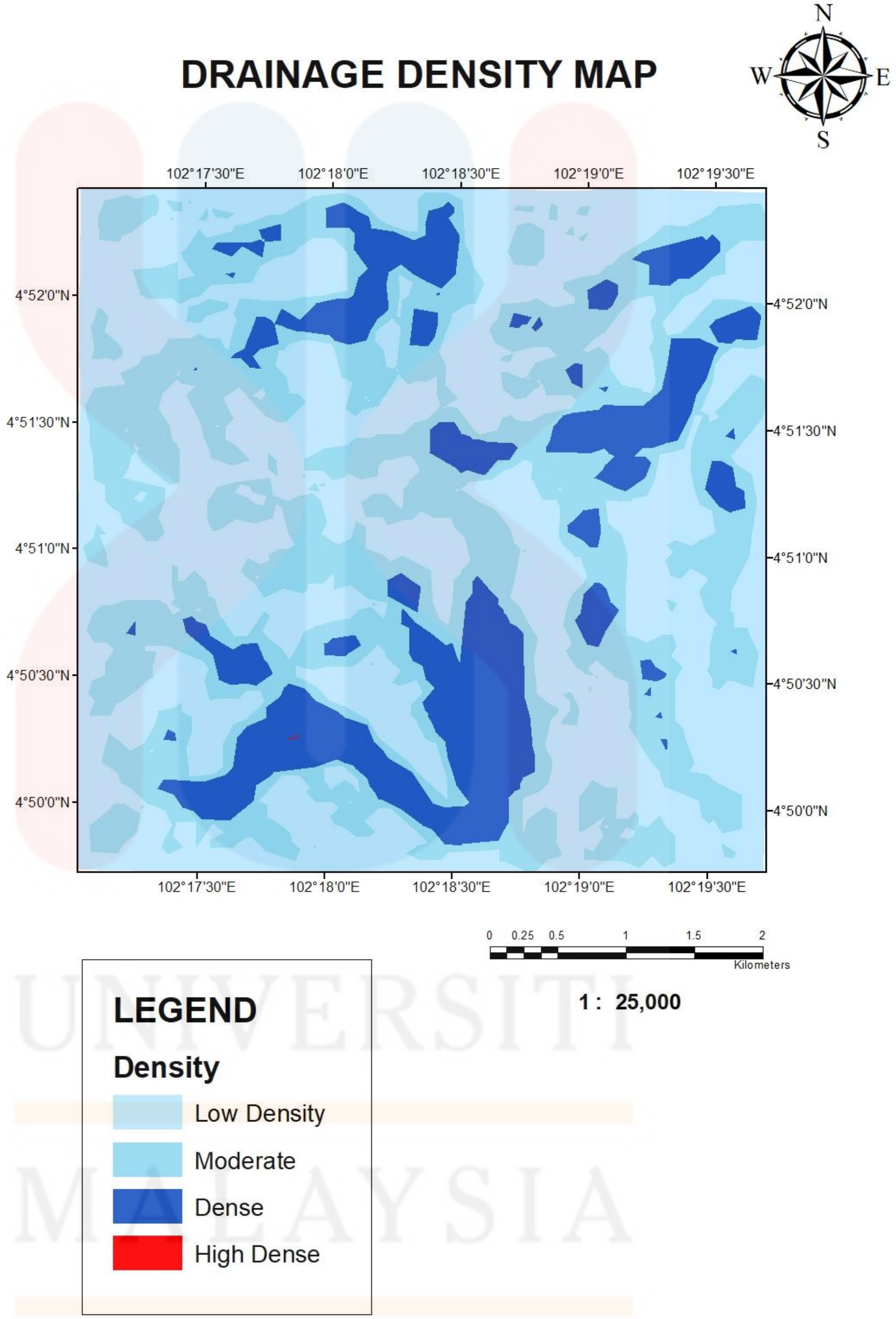


Figure 5.7: Drainage density map

5.2.6 Lineament Density

Lineaments are structurally regulated linear features that can be identified. The alignments are relatively linear. Lineaments suggest that there is a presence of faulting and fracture resulting in increased secondary permeability and porosity. The vulnerability of landslides hazard can be calculated by calculating the density of the lineament. Lineament density map shows in figure 5.9 and Lineament map shows in figure 5.10

There are 3 groups of lineaments that are identified in the study area as low level, moderate group, and even large group. The low group has the lowest effect on landslide vulnerability, while the high group has the highest impact on landslide events. The weighting of the linear density is 9 which will be multiplied by the ranking shown in table 5.8 below.

Table 5.8: Weightage and Score (Lineament Density) of the research area

No	Lineament density	Weightage (Wi)	Score (Sij)	Score (Sij)
1	Low	7	8	56
2	Moderate	7	5	35
3	High	7	3	21

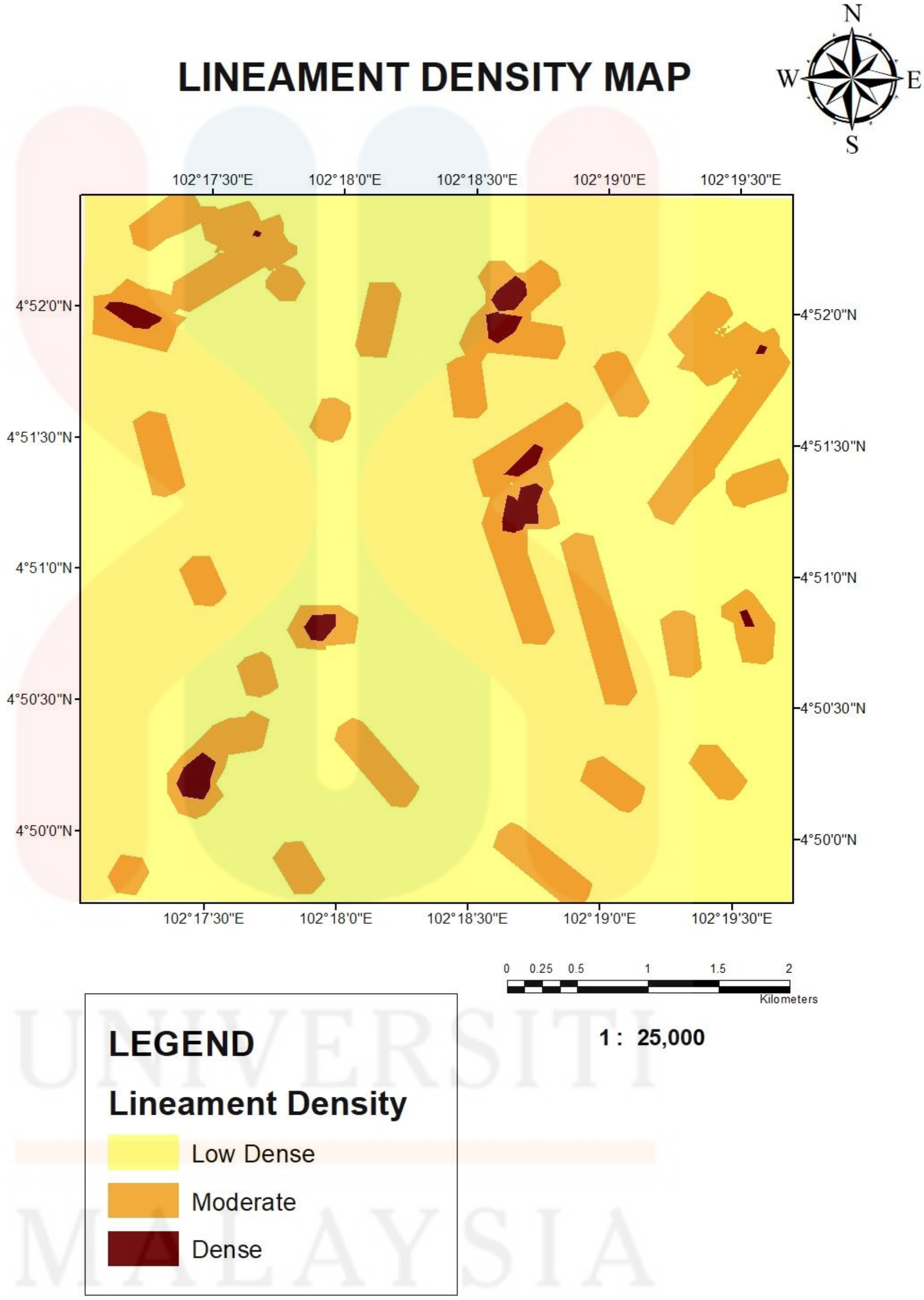


Figure 5.8: Lineament density map of the research area

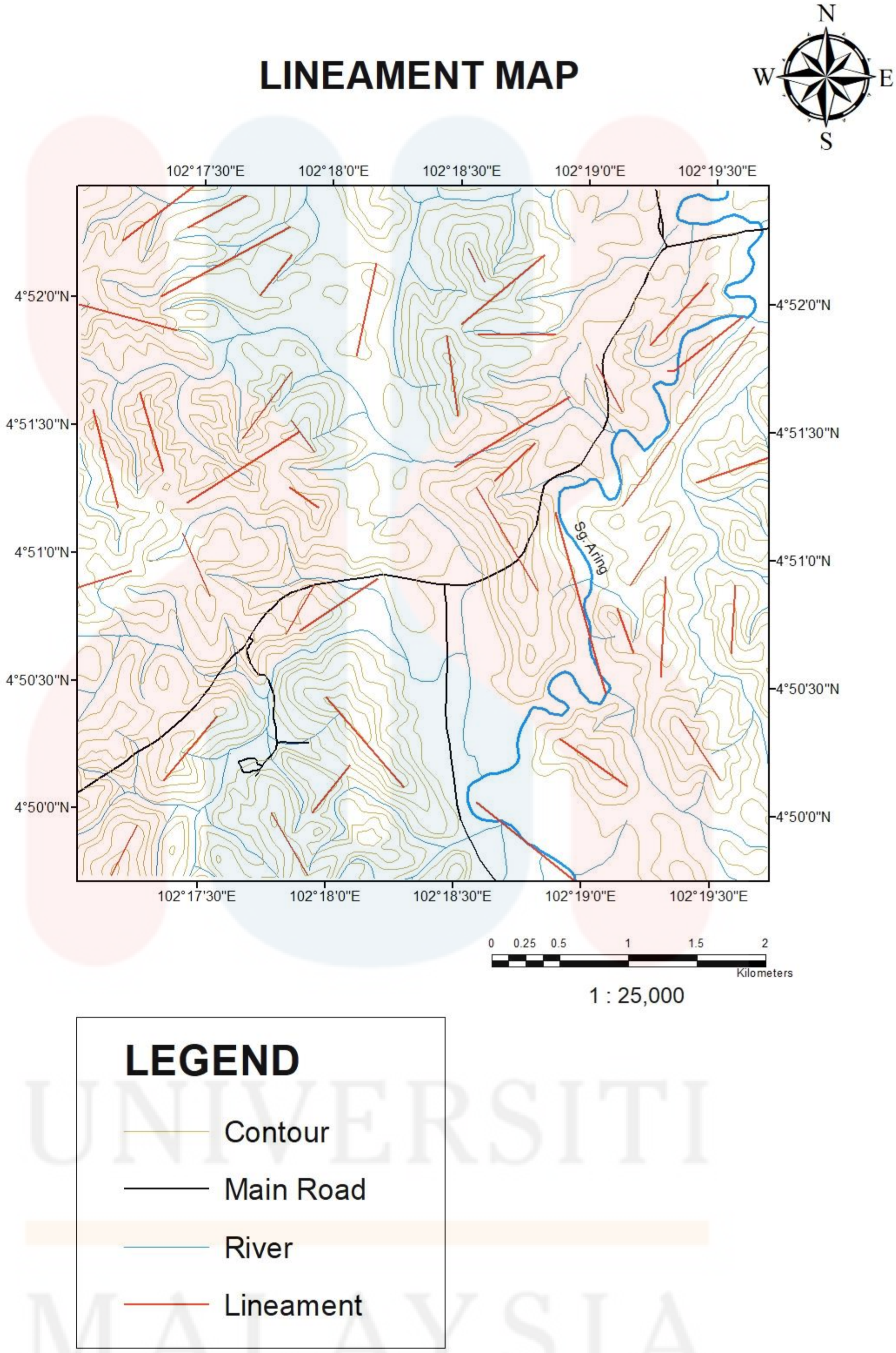


Figure 5.8.1: Lineament map of research area

5.2.7 Vegetation

A map of vegetation is exactly as it looks like a map of vegetation. For any land manager, a vegetation map is essential information about whether the land is maintained for agriculture or forestry or tourism and is applicable to virtually any challenge a land manager needs to face.

From the vegetation map, the density of vegetation can be classified into 3 zones which is low dense, medium and dense. The low dense area commonly consists of small amount of vegetation while the medium and dense consist of large amount of vegetation which shows the palm plantation and forestry at the research area. Low vegetation can increase the landslide susceptibility due to high chances of movement of rock mass along the steep slope which can cause the landslide hazard. Thus, the denser the vegetation, the lower the potential of landslide which can cause negative effect to the people and surrounding.

Table 5.9: Weightage and vegetation of the research area

No	Vegetation	Weightage (Wi)	Score (Sij)	Score (Sij)
1	Low dense	3	2	6
2	Medium	3	5	15
3	dense	3	7	21

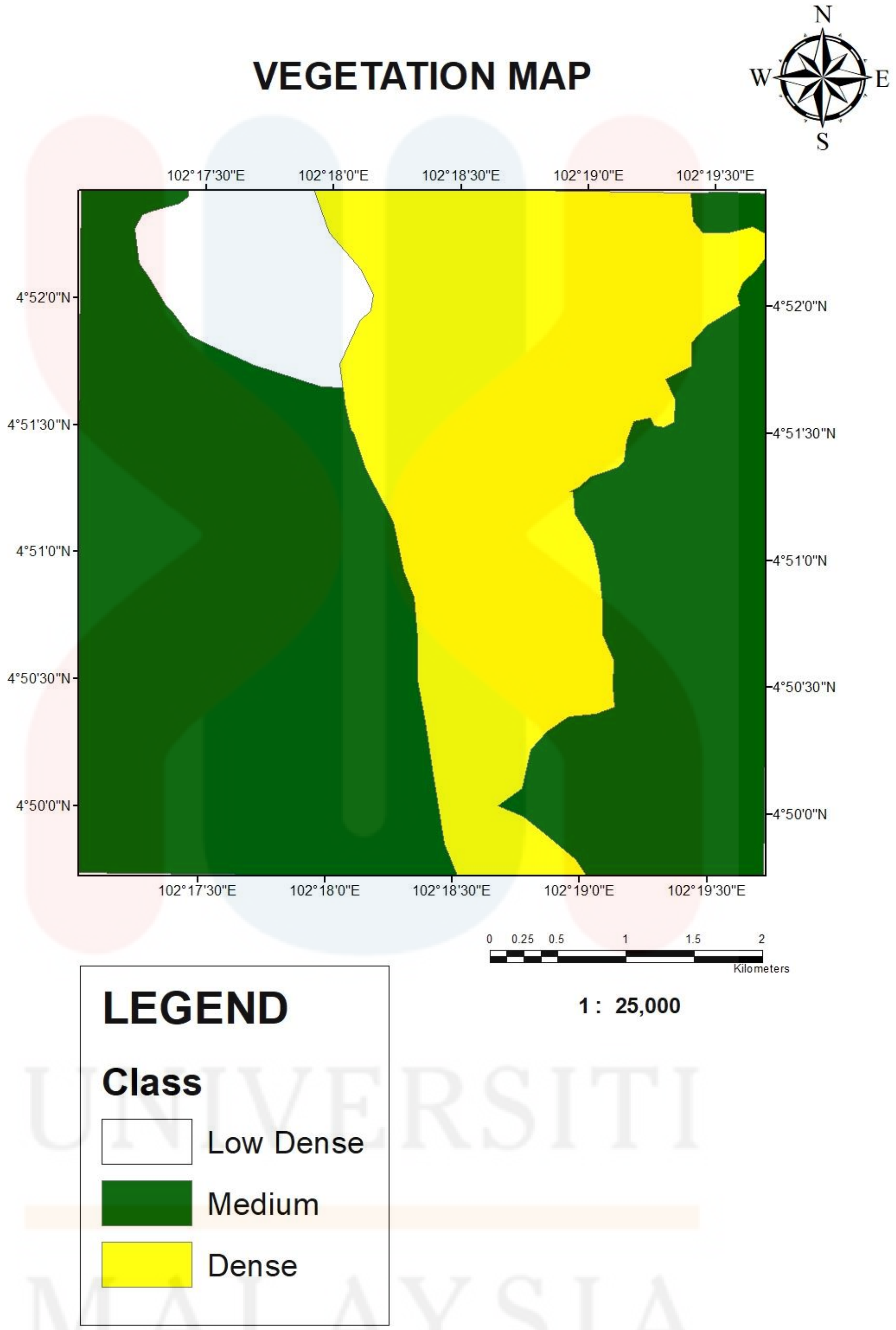


Figure 5.10: Vegetation map of the research area

5.2.8 Soil Cover

The soil type in the area was important because it restricts the amount of water that could be used. The volume of water flooding into the soil in order to penetrate the soil (Nichols and Wong, 2005). The risk of landslides increases as the soil penetration capacity decreases, leading to increases in surface runoff. If the supplied water reaches the capacity for soil penetration, it runs down the slope as runoff on sloping land that can lead to the possibility of landslides (Lowery et al, 1996).

Table 5.10: Weightage and Score (Soil type) of the research area

No	Soil Type	Weightage (Wi)	Score (Sij)	(Wi x Sij)
1	yellow-grey Podzolic soil	2	7	14
2	Lithosols and shallow red-yellow podzolic	2	5	10

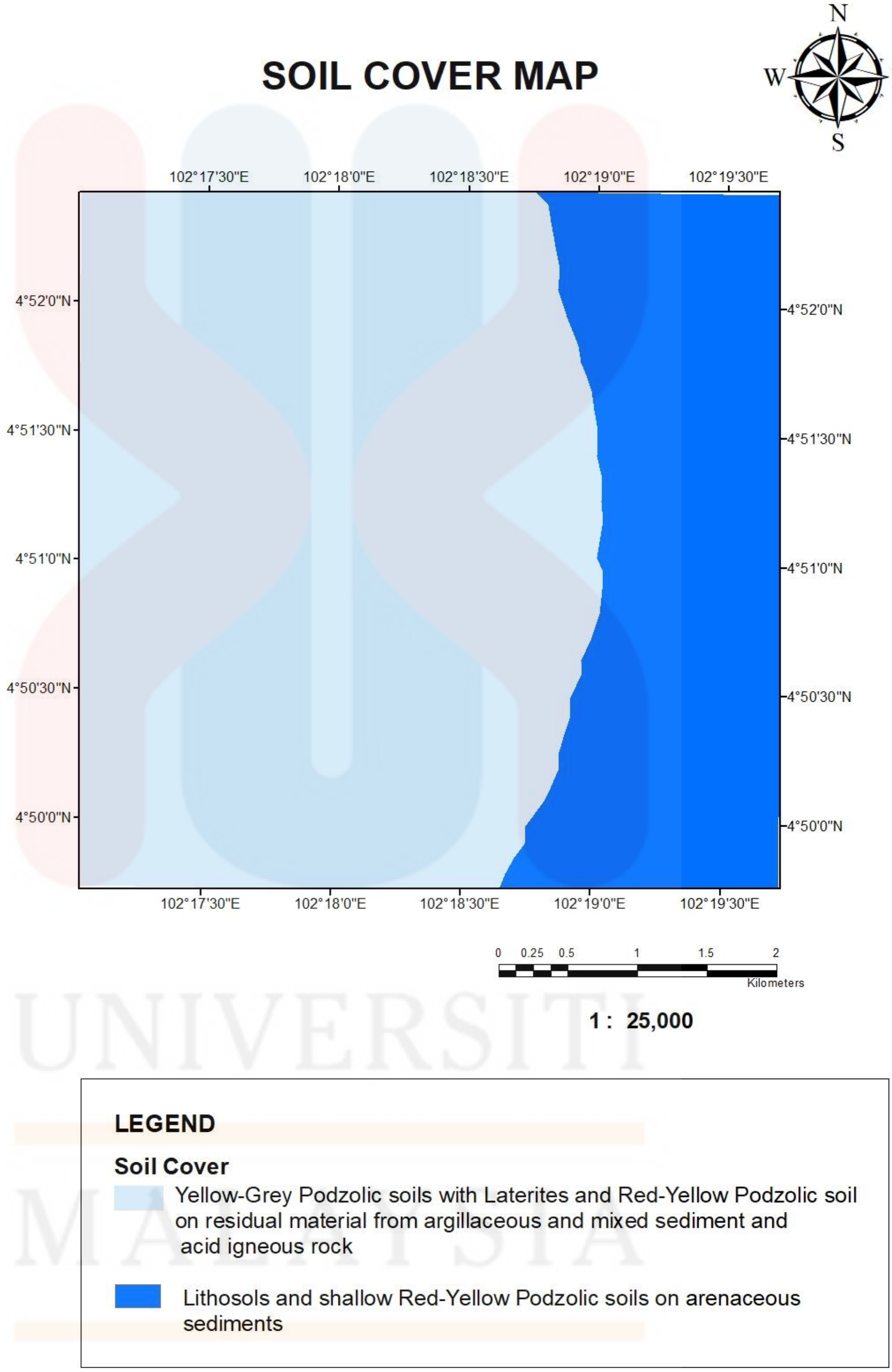


Figure 5.11: Shows the type of soil at the research area

5.3 Factor Triggered Landslide

A variety of factors may be a consideration that caused the landslide. The intensity of rainfall and earthquake is known as the primary factor in the study region that caused landslides to occur every year. Excessive rainfall, especially in an area with dense and weathered soil, may cause landslides. The excessive volume of water that slides through the bedrocks, creating landslide, leaves as rainfall poured intensely and filled the porosity and gap in the soil

Construction of cut slope along main road of Aring 5 can trigger the mass movement of soil and it will cause landslide. Landslide cause destructive natural disaster where the rock mass movement such as rock fall and debris flow cause the disaster. The study area is near to major fault which is Lebir fault. The movement of fault may be less an inch a year but causing landslide due to the movement of the plate.

Plantation industry may be a triggered factor because the landslide due to the terrace for plantation of palm tree can triggered the strength of the soil. It will cause the mass movement with the continuous rain. Most of the research area consists of sedimentary rock which has lower resistance which might increase the potential of landslide. A research of the factor influence landslide such as geological features, design an d also construction error in terms of road building which consist of cut slope and also illegal deforestation.

5.3.1 Previous Investigation of Landslide Study

In Malaysia, landslide can be occur which resulting in large number of huge of economic loss specifically at hilly and mountainous area which has a high degree of slope which is a steep slope which become the triggered factor of landslide occurring. Form the fast development of the building and settlement since year 1980s resulting uncontrolled disaster and geo hazard (Suhaimi Jamaluddin and Ahmad Nadzri Hussein, 2006). The research from Suhaimi Jamaluddin and Ahmad Nadzeri Hussein (2006) have stated that six major landslide have been reported and occurred at Malaysia from the year1993 until 2004.

According to Jamaluddin (2006) Malaysia is not a rash country. the presence of the high intensity of rainfall resulting the existence of the slope failure which can be the factor of landslide occurring. According to Abdullah (2013), Malaysia always experience in facing the geo hazard and disaster which frequent in flooding and landslide hazard. From the statistic of the landslide occur in Kuala Lumpur shows that more than USD 1 billion has been estimated during cases loss of landslide since year 1973**.** Table 5.11 below shows the example of landslide occurring in Kuala Lumpur.

Table 5.11: Example of landslide at Kuala Lumpur and its effect

Date	Location	Type of Lanslide	Number of Death	Notes
December 1993	Ulu Klang	Shallow rotational slide. Heavy rain triggered make the failure of cut slope behind the Highland Tower	48	Cut slope in granitic formation
June 1995	Karak Highway-Genting	Debris flow. Snowball effect debris	22	Natural slope in Metasediment
November 2004	Taman Harmonis, Gombak outskirt of Kuala Lumpur City	Debris flo, sliding/ flowing of debris soil from uphill bungalow project	1	Dumping Area of project ongoing project in meta-sediment formation.
December 2004	Bercham, Ipoh	Rock fall	2	Natural limestone cliff

5.4 Landslide Susceptibility Analysis

Before the landslide susceptibility map can be generated, all selected parameters have been converted into the polygon data collection. The weighting of such polygon data is again reclassified. The landslide susceptibility map was prepared using the GIS application weightage overlay method. Lithology, slope, aspect, vegetation, land use, lineament density, soil cover and drainage density are the parameters of the landslide causative factor selected. The weight parameters were respectively given and the sum of all variables was equal to 100% and the formula was used as shown in Equation 5.2:

$$s = \frac{\sum wisij}{\sum wi} \quad \text{... (Equation 5.1)}$$

Any of the parameters of each weight has been allocated. And it is determined later using the equations shown in the 5.2 equation above. Based on Figure 5.12, it can be found that most of the research area has a moderate landslide susceptibility that occupies around 60% of the study area, and 15% of the study area consists of low landslide hazard susceptibility, while 15% more are extremely susceptible to landslides.

Table 5.12: Susceptibility class of landslide hazard in the study area

Susceptibility Class (Zone)	Risk	Area Percentage (%)
Low	0 – 50%	25
Moderate	50 – 75%	60
High	>75%	15

It is important to reclassify the data in order to generate the landslide susceptibility map using the weightage overlay method. Table 5.14 shows the reclassify data sets.

Table 5.14: The reclassify data with influence

No	Datasets	Influence
1	**Slope:** 0 – 5° 5 – 10° 10 – 15° 15 – 25° 25 – 35° > 35°	15
2	**Lithology:** Interbedded shale, slate and phyllite Tuff Unit Interbedded mudstone	11
3	**Aspect:** Flat (-1) North (0-22.5) Northeast (22.5-67.5) East (67.5-112.5) Southeast (112.5-157.5) South (157.5-202.5) Southwest (202.5-247.5) West (247.5-292.5) Northwest (292.5-337.5) North (337.5-360)	3
4	**Land use:** Forest Palm oil plantation Main Road Lake and river	9
5	**Drainage density:** Low Moderate	22

	High	
6	**Lineament density:** Low Moderate High	20
7	**Vegetation:** Low dense Medium Dense	14
8	**Soil cover:** yellow-grey Podzolic soil Lithosols and shallow red-yellow podzolic	6
	Total	100

In particular, the degree of landslides increased with the decrease in the drainage density and even the density of the lineament. Slope is one of the most critical parameters in the study of landslide vulnerability, as the stability of the slope forms the basis for the occurrence and strength of landslides. The sharper the angle, the more likely it is to be to instability. In fact, the hilly and mountainous areas are more likely to encounter landslides due to higher slopes and this concludes that the research area was dominated by medium susceptibility zones. Moderate vulnerability of landslide implies that there is a large risk of landslides danger if the conditions, such as the slope, have not been properly reduced. Table 5.13 shows susceptibility class of landslide hazard in the study area.

Figure 5.12 shows the landslide susceptibility maps of Felda Aring 5, Gua Musang Kelantan. From the map below, the majority of the study area consists of moderate level of landslide susceptibility with 60% of the research area. While 25%of the research area consist of low susceptibility of landslide and 15% of the research area is high susceptibility of landslide. Most of the high susceptibility of landslide was along the main road of Aring 5 which consists of cut slope. While the others part with the high susceptibility is at the terrace of the palm oil plantation which classified as steep slope with some trigger factor of landslide.

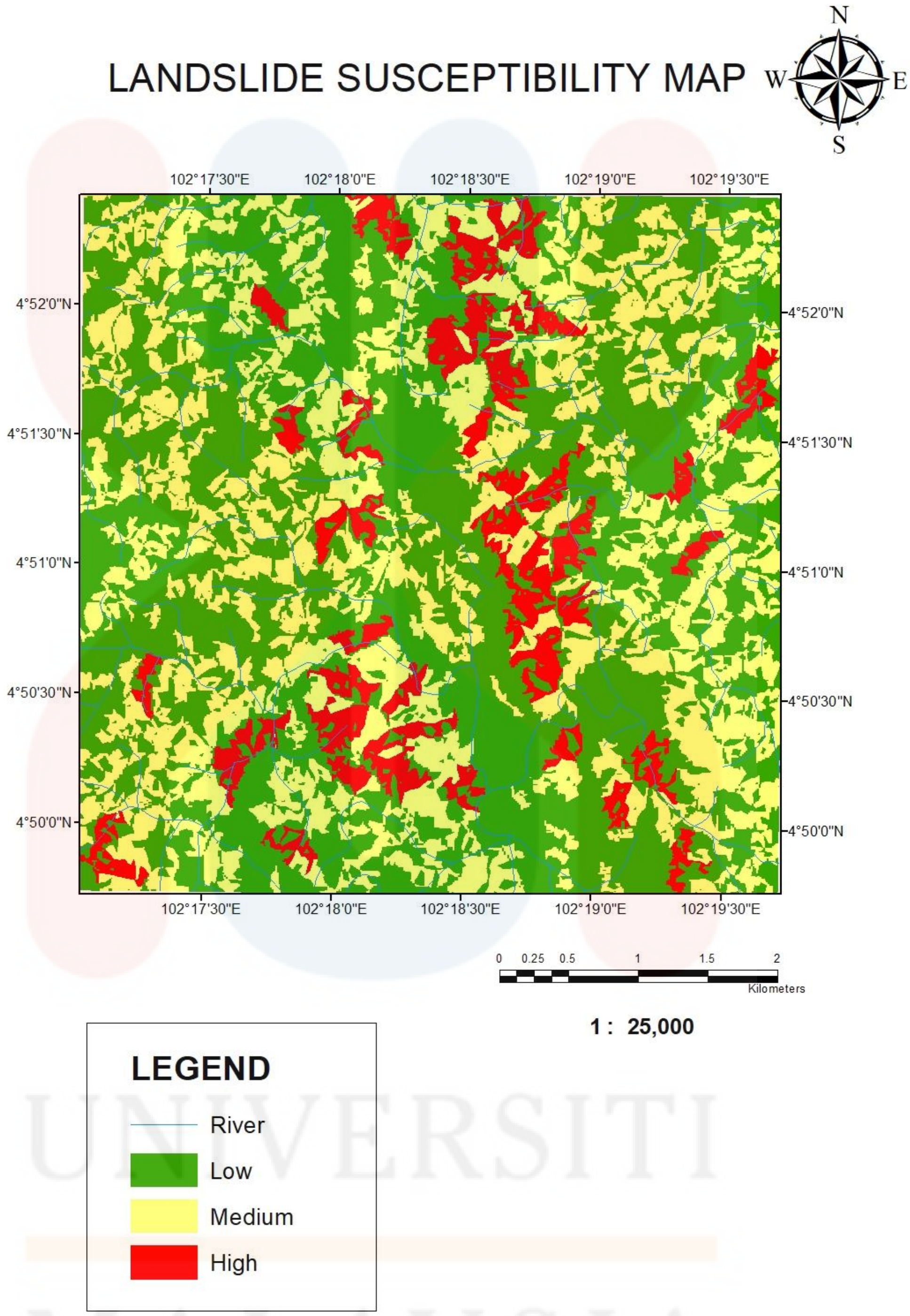


Figure 5.12: Landslide Susceptibility Map of Aring 5, Gua Musang Kelantan

Drainage density, lineament density, slope and lithology play a significant role and become criteria that have a strong effect to landslide occurring. The steeper rate of slope has a greater tendency for landslides to occur. The rising density in the drainage density allows landslide frequencies to occur more frequently due to high porosity and permeability. Steep slope is an importance factor for landslide occurrence. Slope which has greater degree of slope may cause the movement of mass which can cause landslide in terms of rock fall and debris. Lithology also impacts the landslide, since the rock and soil produced in the region have different porosity and void. The intensity of the drainage density indicates that the hydrological factor will cause landslides when much of the high inclination to landslides happens along the river and stream. Vegetation, soil cover, land use and aspect have a moderate impact on the phenomenon of landslides. However, with respect to other parameters and the triggered component, it is at the same time essential for landslide analysis in the study field.

When heavy rainfall occurred in the research area, the porosity between the soils was filled. When the bottom layer of the interflow is dry, the additional volume of water falls and the rotational debris slides. The collapse of the land system caused the earth's mass to slide. Heavy rainfall and earthquake caused a landslide, particularly in the centre part with a high altitude and steep slope.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

As for the conclusion, the geological map of the study was completed. Felda Aring 5 area has been updated to a scale of 1:25000. The lithology was classified into three lithological groups, the interbedded shale, slate and phyllite, the tuff unit and also the interbedded mudstone unit. Structural analysis, geomorphology, drainage pattern and stratigraphy of the research area were obtained by geological interpretation and geological report conducted.

In the research specification, which is the landslide vulnerability mapping a map of the landslide zone map of the Aring 5 region has been created from the study area. It has been classified into three class zones, the low class zone, the moderate class zone and the high class zone. Using the weighted overlay approach on the GIS model, eight parameters were chosen which are slope, linear density, lithology, drainage density, appearance, land use, vegetation and soil cover.

The field of research has generally been divided into three groups of area that Susceptible to danger of landslides with low susceptibility to hazard of landslides, moderate susceptibility to hazard of landslides and even high susceptibility to hazard of landslides. The field has also been categorized into percentages composed of moderate susceptibility, which is 60% of the research area which is the majority of the study area, whereas the low and high susceptibility of the study area is split into 25% and 15% respectively.

In fact, slope is one of the highest influenced by the risk of landslides, based on eight parameters picked, since slope stability is the foundation frequency for the occurrence of the hazard of landslides. The location of the research area on a mountain and hilly area makes it more vulnerable to landslide occurrences.

The lack of awareness of the villagers can be minimized by doing this research as the estimation of the potential susceptibility area has been completed. It will assist all decision-makers, contractors and local authorities in mitigation and disaster preparation, with the accuracy of the map created. In the high-risk area in particular, the determination on every construction may be considered

6.2 Recommendation

For the recommendation for the next research, the geological mapping is the importance part for gaining the data. Geological mapping must be done and must be start earlier in order to gain the data in terms of geological data. It can avoid the problem such as insufficient in the collection of data. Geological mapping cannot be done properly if only use a secondary data and satellite imagery due to incorrect in terms of the interpretation. Field data is importance to determine the actual rock lithology and petrology with the interpretation of stratigraphy of the research area. It is also important to develop general knowledge of geology, which is in the knowledge of mapping and also in another field of geological knowledge such as structural geology and lithology of the study area.

In terms of specification, it is good in the next research to improve the parameter of the research by adding the raining intensity, soil strength, geomorphology and past landslide data. It is because that parameter is a strong trigger factor for landslide occurrence. The various kinds of parameters used will provide different outcomes, so the outcome can be compared to see what parameters most affected the susceptibility of the landslide to the study area.

It was recommended to perform the landslide susceptibility study by using ArcGIS software is a basic software that can assess the vulnerability of landslides in a study field. As for the outcome of the vulnerability of landslides, it is prudent to do the construction properly in the research region as the area has a high probability of landslide hazard occurrences. It is for people's safety and also to avoid the loss of life and property.

REFERENCES

Price D.G. (2009). Engineering Geology Principle and Practice. Springer.

Evans, S.G. (2006). The Formation and Failure of Landslide Dams: An Approach to Risk Assessment, Italian Journal of Engineering Geology and Environment, Special Issue 1 (2006), 15 – 19

Hoek, E.; Bray, J.W. (1981). Rock Slope Engineering, Rev 3rd ed, 548p, The Institute of Mining and Metalurgy, London, UK.

Hoek, E. and Bray, J. W., 1981, Rock Slope Engineering: The Institute of Mining and Metallurgy, London, England, 358 p.

GOODMAN, R. E., 1989, Introduction to Rock Mechanics: John Wiley & Sons, New York, NY 562 p.

Tajul Anuar Jamaluddin. 1990. Geologi kejuruteraan Lebuh raya Timur-Barat penekanan kepada penstabilan cerun. MSc Thesis, Universiti Kebangsaan Malaysia

F.G. Bell, 2007, Basic Environment and Engineering Geology, 28 p and 74 p, British Geological Survey, UK

Tony Waltham, 2001, Basic Environment and Engineering Geology, 2rd edition

Duncan C whyllie and Christopher W Mah, 2004, Rock Slope Engineering; Civil and Mining, 4th edition

Monroe, J. S., & Reed, W. (2006). The Changing Earth, Exploring Geology and Evolution.Monroe James. S, W. R. (2009). Mass Wasting. In In The Changing Earth: Exploring

Geology and Evolution (p. 274). Belmont, USA: CENGAGE Leraning.

Varnes, D. J. (1978a). *Slope Movement, Type and Process*.

Varnes, D. J. (1978b). Slope Movement Types and Processes. *Transportation ResearchBoard Special Report*, (176), 11–33. https://doi.org/In Special report 176:

Landslides: Analysis and Control, Transportation Research Board, Washington, D.C.

Van Zuidam, R. A, (1985). Aerial Photo-Interpretation In Terrain Analysis and Geomorphologic Mapping, Smith Publisher, The Hagus, The Netherlands (Hal-41).

Varnes, D. J. 1978. Slope movement types and processes. In: Special Report 176: Landslides: Analysis and Control (Eds: Schuster, R. L. & Krizek, R. J.). Transportation and Road Research Board, National Academy of Science, Washington D. C., 11-33.

Mohd Hisham, Mohd Muzamil, Akhir, Juhari Mat.Lineament mapping using Landsat TM image in the eastern part of Gua Musang-Cameron Highlandroad. Malaysia.

Mohd Hisham, Mohd Muzamil, Akhir, Juhari Mat.Lineamentmapping usingLandsat TM image in the eastern part of Gua Musang-Cameron Highlandroad. Malaysia.

Punyatoya Patra, (2010. Remote Sensing and Geographical Information System, The Association for Geographical Studies , 1-27.

Gang Piao, Ping Lu, Marco Scaioni, Shuying Xu, Xiaohua Tong, Tian Tian Feng,Hangbin Wu, Wen Chen, Yixiang Tian, Weian Wang, Rongxing Li. (2013), Landslide Investigation with Remote Sensing and Sensor Network: ForSusceptibility Mapping and Scaled-down Simulation towards in situ Sensor Network Design, Remote Sensing, 4319 - 4346.

Richard J. and Lisle. (2011). basic Geological Mapping, Fifth Edition. Wiley Blackwell a John Wiley & Sons, Ltd. Publication.