



Universiti Malaysia
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**GEOLOGICAL LANDSLIDE SUSCEPTIBILITY
ASSESSMENT USING GEOGRAPHIC
INFORMATION SYSTEM (GIS) AT KAMPUNG
RENYOK, JELI**

By

MUHAMMAD FARHAN BIN MOHD SUKRI

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

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2023

DECLARATION

I declare that this thesis entitled “Geological Landslide Susceptibility Assessment Using Geographic Information System (GIS) At Kampung Renyok, Jeli, 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.

Signature :

Name : MUHAMMAD FARHAN BIN MOHD SUKRI

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APPROVAL

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

Signature :

Name of Supervisor : ROHAZAINI BINTI MUHAMMAD JAMIL

Date :



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Geological Landslide Susceptibility Assessment Using Geographic Information System (Gis) At Kampung Renyok, Jeli

ABSTRACT

Nowadays, a landslide tragedy is becoming a typical occurrence and a major source of concern across the world. In Malaysia, since this country experiences year-round heavy rainfall due to its tropical climate, it contributes a major reason to landslides including in Kelantan. Therefore, Kampung Renyok, in Jeli district, Kelantan has been chosen to perform a landslide study. The study area is aligned along latitude $5^{\circ}35'20.00''\text{N}$ to $5^{\circ}32'40.00''\text{N}$ and longitude $101^{\circ}53'00''\text{E}$ to $101^{\circ}55'20.00''\text{E}$ in Kampung Renyok and covers about 25km^2 . The purpose of this research is to produce a geological map of the study area on the scale of 1:25000, to determine triggering factors to landslide and eventually to generate landslide susceptibility map. Geomorphology, lithology, stratigraphy, historical geology, and structural geology are also studied in this research. Additionally, this study has made use of remote sensing, online basemap interpretation, and a Geographic Information System (GIS) to interpret each resultant maps. During mapping, the distribution of rocks found in the study area is mainly slate rock and minor quartz-rich granitoid rock. Quartz-rich granitoid rock are found in areas with higher elevation hills while slate rock is found in areas with lower elevation hills. The highest peak with a height of 220m from mean sea level is a hill formed from intrusion of granitoid. Meanwhile, for landslide study, parameters such as slope, aspect, lithology, land use, drainage density, and lineament density were identified as the criteria that caused the occurrence of landslides. Most of the data was extracted by using Digital Elevation Model (DEM). The landslide susceptibility map was created in ArcGIS using ModelBuilder tool. Finally, the landslide susceptibility map was produced and shown three zones of landslide vulnerability area, which are low, moderate, and high. As a result, the majority of this research region is covered with moderate susceptibility of landslide, thus the risk of landslide occurring is considered as moderate in Kampung Renyok, Jeli.

Keywords: Landslide, Parameters, ModelBuilder, Kampung Renyok, Geographic Information System (GIS), Petrographic analysis.

Geologi Dan Penilaian Kecenderungan Tanah Runtuh Menggunakan Sistem

Maklumat Geografi (GIS) Di Kampung Renyok, Jeli

ABSTRAK

Kini, tragedi tanah runtuh menjadi perkara biasa dan menjadi punca kebimbangan utama di seluruh dunia. Di Malaysia, memandangkan negara ini mengalami hujan lebat sepanjang tahun kerana iklim tropika, ia menyumbang punca utama tanah runtuh termasuk di Kelantan. Oleh itu, Kampung Renyok, di daerah Jeli, Kelantan telah dipilih untuk melakukan kajian tanah runtuh. Kawasan kajian dijajarkan di sepanjang latitud $5^{\circ}35'20.00''\text{U}$ hingga $5^{\circ}32'40.00''\text{N}$ dan longitud $101^{\circ}53'00''\text{E}$ hingga $101^{\circ}55'20.00''\text{T}$ di Kampung Renyok dan meliputi kira-kira 25km^2 . Tujuan penyelidikan ini adalah untuk menghasilkan peta geologi kawasan kajian dalam skala 1:25000, untuk menentukan faktor pencetus kepada tanah runtuh dan akhirnya menjana peta kerentanan tanah runtuh. Geomorfologi, litologi, stratigrafi, geologi sejarah, dan geologi struktur turut dikaji dalam penyelidikan ini. Selain itu, kajian ini telah menggunakan penderiaan jauh, tafsiran peta asas dalam talian, Sistem Maklumat Geografi (GIS) untuk mentafsir setiap peta yang terhasil. Semasa pemetaan, taburan batuan yang terdapat di kawasan kajian ialah batuan sabak dan batuan granitoid yang kaya dengan kuarza. Batuan granitoid yang kaya dengan kuarza ditemui di kawasan yang mempunyai ketinggian bukit yang lebih tinggi manakala batuan sabak ditemui di kawasan yang mempunyai ketinggian bukit yang lebih rendah. Puncak tertinggi dengan ketinggian 220m dari paras laut purata ialah bukit yang terbentuk daripada pencerobohan granitoid. Manakala bagi kajian tanah runtuh, parameter seperti kecerunan, aspek, litologi, guna tanah, ketumpatan saliran, dan ketumpatan lineamen dikenal pasti sebagai kriteria yang menyebabkan berlakunya tanah runtuh. Kebanyakan data telah diekstrak dengan menggunakan Digital Elevation Model (DEM). Peta kerentanan tanah runtuh telah dibuat dalam ArcGIS menggunakan alat ModelBuilder. Akhirnya, peta kerentanan tanah runtuh telah dihasilkan dan ditunjukkan tiga zon kawasan mudah runtuh tanah runtuh, iaitu rendah, sederhana dan tinggi. Hasilnya, majoriti kawasan penyelidikan ini dilitupi dengan kerentanan tanah runtuh yang sederhana, justeru risiko tanah runtuh dianggap sederhana di Kampung Renyok, Jeli.

Kata kunci: Tanah Runtuh, Parameter, Pembina Model, Kampung Renyok, Sistem Maklumat Geografi (GIS), Analisis petrografi.

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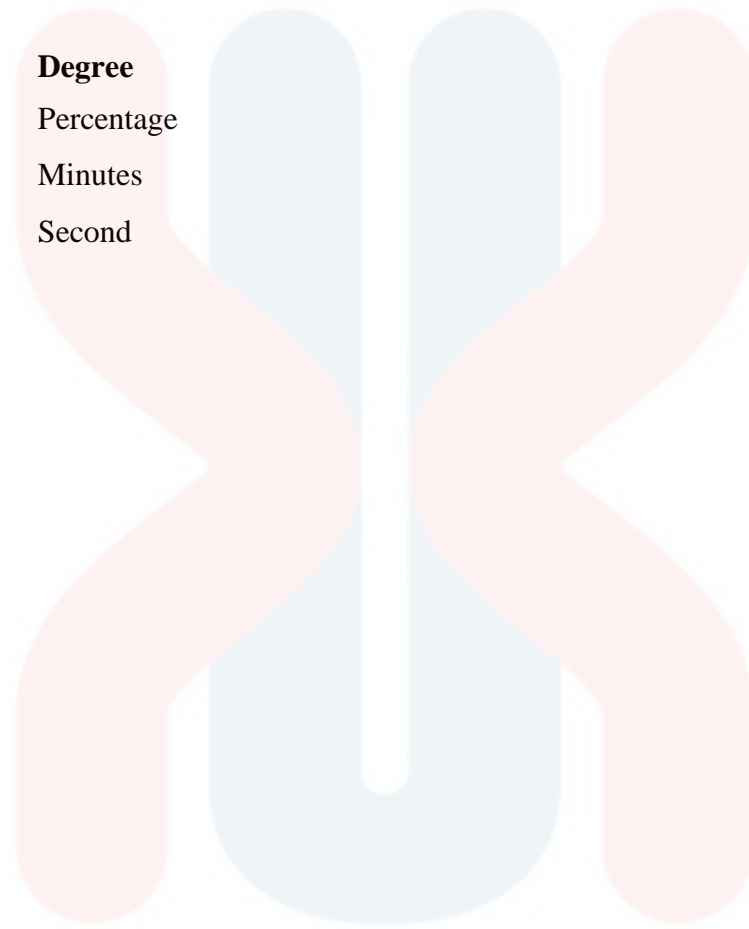
LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
DEM	Digital Elevation Model
GPS	Global Positioning System
GIS	Geographical Information System
USGS	US Geological Survey Earth Resources and Science Centre
WOM	Weighted Overlay Method

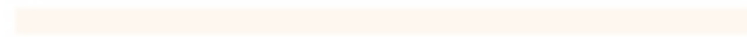
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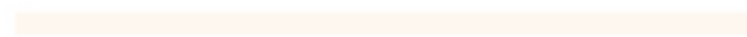
°	Degree
%	Percentage
'	Minutes
”	Second



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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Geology is the scientific study of the earth's interior and outward features and processes, as well as its interactions with other planets and their atmospheres. Specifically, it's the study of the planet's structure, nature, and history. It is possible to separate geology into physical and historic geology. For example, physical geology focuses on Earth's resources like minerals and rocks, whereas historical geology focuses more on the development of Earth's continents, seas, atmosphere, and all its many ecosystems, as well as the origins of life on Earth. The study of the area's lithology, geological formations, geomorphology, stratigraphy, and sedimentology are all included in the geological investigation (Balasubramanian, 2017).

Natural disasters like landslides may be deadly and ruin lives and property. The occurrence of landslides is common in nations like Malaysia, which are tropical. In the country's highlands, it's a major roadblock to future growth. These landslides are often shallow rainfall-induced landslides that occur on steep hills and highlands after heavy rains in the monsoon season (Mezughhi et al., 2011). A wide variety of landslides have occurred, including rockslides, debris flows, and profound slope failures. Landslide phenomena has a wide range of impacts in Malaysia, particularly on natural resources, transportation, and tourist infrastructure (Pradhan & Lee, 2010).

Hashim's et al., 2017 research on landslide susceptibility in Kelantan has indicated that slope, aspect, soil, lithology, and precipitation quantities are the primary

triggers for landslides. According to the report, precipitation amounts are a major cause of landslides. Flooding in Kelantan, Malaysia, in 2014 was exacerbated by the uneven distribution of rainfall. In addition, land use and development along slopes have become the second most significant contributors to landslide activity. Landslides may also be caused by human activity, such as illegal logging in the forest, agricultural operations, and construction on the slope.

Data may be collected, stored, retrieved, modelled, and manipulated with the use of Geographic Information Systems (GIS). Landslide susceptibility mapping relies heavily on GIS systems because of their ability to combine remote sensing and global positioning systems. Analytical and combinational capabilities of Geographic Information Systems (GIS) have allowed the development of approaches used in the evaluation of landslide risk (Mezughli et al., 2011).

Landslide susceptibility near Kampung Renyok, which is exposed to several conditions that might lead to landslides, is the focus of this study. The Kampung Renyok area consists of hills that are likely to have high slope areas. The increasing rainfall in the area will make the soil dissolve and lose hold, which in turn causes the surrounding soil to collapse. In addition, land use around the area is used for agriculture such as cultivation. Human activities like this can significantly affect how stable a slope or cliff is, increasing the chances of slope collapses. This will endanger the residents around the area where they will not be aware when it will happen. Thus, landslide susceptibility mapping will be conducted in the designated study area to mitigate the landslide hazard.

1.2 Study Area

The town of Jeli (5.7007° N, 101.8432° E) on Peninsular Malaysia's west coast, is often referred to as the state of Kelantan's entryway. For those travelling from the East Coast to the West Coast through the East-West highway system, it has become a convenient rest stop. The Jeli – Dabong highway connects the district of Jeli with the rest of Southern Kelantan. The district of Jeli is well situated for strategic growth, bordering Thailand to the north, Tanah Merah to the east, Kuala Krai and Gua Musang to the south, and the state of Perak to the west. The district's capital, Jeli, is around 98 kilometers from Kota Bharu through the East-West route. Hilly terrain with lush woods and rivers covers 82% of the district's area. Sungai Pergau, Sungai Renyok, Sungai Suda, and Sungai Balah are some of the prominent rivers in the region (Jeli District Council, 2019). In addition, the elevation ranges from 90 to 500 meters.

On the north-eastern part of Peninsular Malaysia, Kelantan is situated at $101^{\circ} 20'$ to $101^{\circ} 4'E$, and $4^{\circ} 33'$ to $6^{\circ} 14'N$ longitudes. It is bordered to the west by Perak, to the south by Pahang, and to the east by Terengganu, and to the north-west by Thailand, having a 71-kilometer coastline facing the South China Sea. The total land area of Kelantan is 15022 square kilometers.

1.2.1 Location

Study area is in Kampung Renyok, Jeli as shown in Figure 1.1 with coordinates 5.5812 ° N, 101.8828 ° E. Located 20 km from Pekan Dabong Kuala Krai, 145 km from Kota Bharu City Centre with a total population of 980 people. Agriculture in the area such as rubber, oil palm, bananas, vegetables are cultivated there.

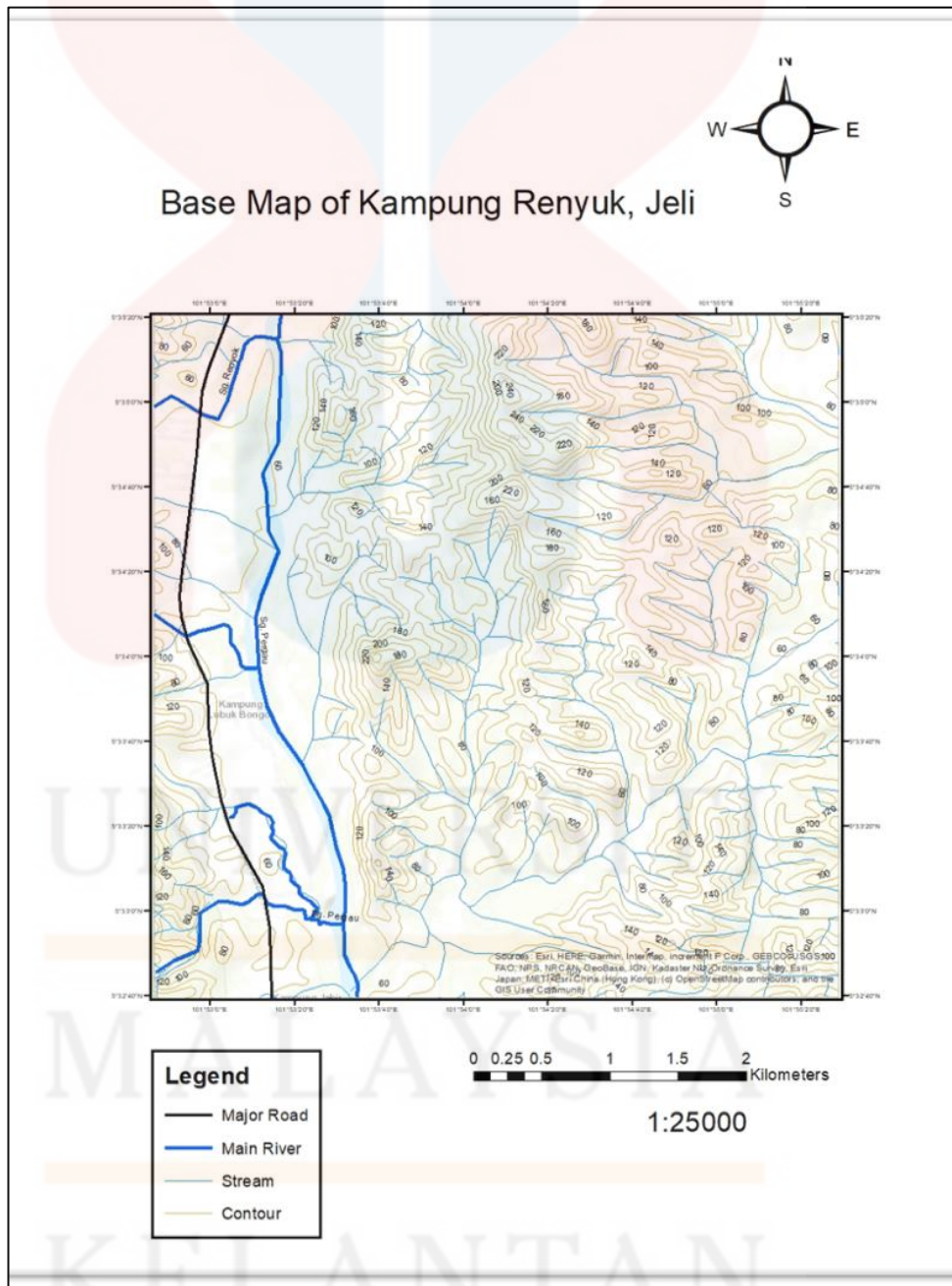


Figure 1.2: **Map of study area** (Sources: Base Map in ArcGIS).

1.2.2 Road

The study area is in Kampung Renyok, Kelantan. It is along the road that goes from Sg Sam to Dabong to Jeli. From UMK Jeli to Kampung Renyok is about 21.2 km and should take about 21 minutes. After that, there are other roads or small roads that can be used to get to the whole study area.

1.2.3 Demography

The Malaysian Department of Statistics says that there will be 54,656 people living in Jeli in 2020. Graph 1.1 shows how many people lived in the Jeli area from 2000 to 2020. The area of Jeli is 1,330 km², and there are 41.09 people per km². The number of people living in this district is growing every year because the agriculture, business, hospitality, and marketing sectors are all growing and need more people to work.

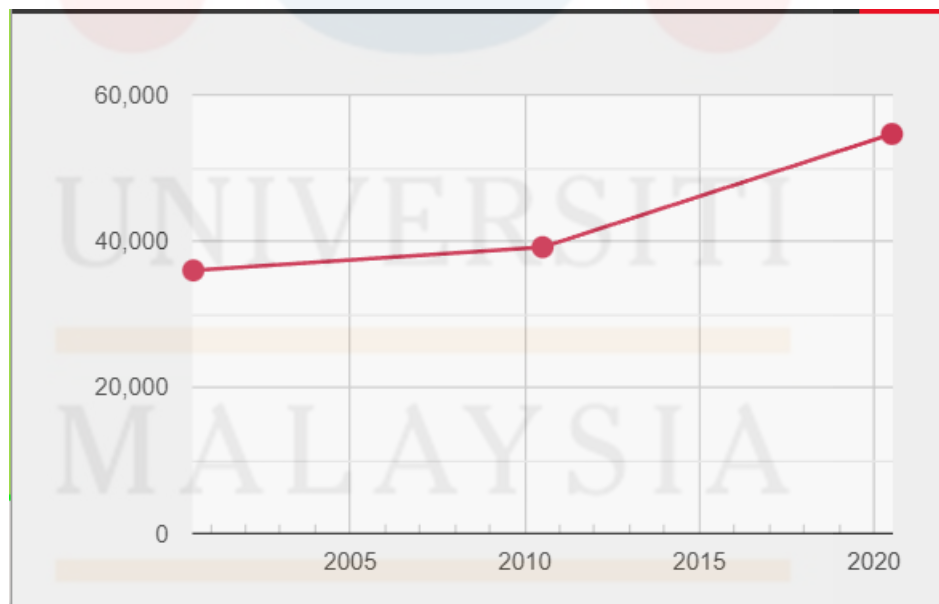


Figure 1.3: Population range in Jeli from year 2000 to 2020 (Source: Department of Statistics Malaysia, 2020).

1.2.4 Land use

There are many different types of land uses. A frequent land use in rural regions is agricultural, whereas in urban areas, the predominant land use is a mix of commercial and residential development. The human activities and occupations in the region are likewise affected by land use. Forests, oil palm plantations, and rubber plantations occupy the majority of Jeli's land. Jeli's land use has also changed dramatically throughout the years owing to the fast population increase in the region. Oil palm and rubber plantations, forests, and a little amount of population are the primary land uses in the study region.

1.2.5 Social Economic

Development in Jeli has a good effect on the local population in terms of employment prospects in a variety of industries. For the time being, oil palm and rubber plantations are the primary economic drivers of Kampung Renyok. Felda and KESEDAR are in charge of both plantations. In addition, there are only a few small businesses owned by local inhabitants in the study area, such as a grocery shop and a restaurant.

1.3 Problem Statement

The geological map of Jeli has significant shortcomings in terms of geological knowledge (Baharudin, 2021). The lacking information are geomorphological and stratigraphic elements. Due to these shortcomings, governments and scholars found it difficult to collect references for their ongoing development and study. Thus, this study

is being carried out to develop an updated 1:25,000 geological map of the study region, which may be used as a reference for future researchers.

This study is conducted in Jeli, Kelantan state, Malaysia. From October through March, the Northeast Monsoon is a common occurrence in this region. In Kelantan, heavy rains at this time of year may cause natural disasters including landslides and floods. As a result, many people have been urged to immediately leave their houses during the flooding. There is a need to emphasize the paucity of research on the landslide danger in that specific area. The landslide will occur and destroy the community if effective strategic planning and mitigation of landslides are not implemented. Consequently, quick action is needed to protect the lives and property of the people in the vicinity from the dangers of landslides.

There has been very little research or study done in Jeli to recently to better predict landslide activity. To prevent a landslide in the region where the risk is greatest, careful planning was done ahead of time to minimize the likelihood of a landslide. It's not clear what elements contribute to landslide susceptibility and where the most dangerous locations are located on prior landslide maps. Landslide susceptibility and landslide factor is analyzed using WOM method and model builder within GIS environment.

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1.4 Objectives

1. To produce geological map of the Kampung Renyok, Jeli in the scale of 1:25,000.
2. To determine landslide triggering factors in Kampung Renyok, Jeli.
3. To generate landslide susceptibility map of Kampung Renyok, Jeli by using ModelBuilder tool in ArcGIS

1.5 Scope of Study

Geological and landslide analyses are the two main areas of investigation in this study. A geology map and a landslide susceptibility map are the results. For the geological map, the interpretation of the research area's geological characteristics is used to make the map. Devices such as a laptop and scanner were utilized to produce the map. This study is only focused on 25 km² of Kampung Renyok region Jeli.

Using the Weighted Overlay Methods (WOM) approach, Model Builder tool within GIS, the landslide susceptibility map for Kampung Renyok was created. Remote sensing data from the US Geological Survey Earth Resource and Science Center (USGS) and Digital Elevation Model (DEM). All these secondary data were digitally gathered within GIS environment.

1.6 Significance of Study

This study contributes to the current knowledge on the geology of Kampung Renyok, Jeli. It is thus possible to apply the information gathered in this study for future land use planning in Kampung Renyok, including settlement and urbanization zones. It is also possible for others to utilize this study as a reference.

To assess the region at risk for landslides, the landslide susceptibility map must be created. Therefore, this study may serve as a guide for governments and the public in the event of a landslide, identifying areas that are vulnerable to landslides and recommending mitigating measures. When deciding on new development and building in the study area, the government should exercise more prudence, while the villages may take preventative measures in the event of excessive rainfall or a shift in the monsoon. Thus, human mortalities may be minimized, and public awareness will rise as a result.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter examines the current literature on geological and landslide research. Due to earlier research, this study is possible to perform and concentrate on the specific section with clarity. Several causes, including plate movement and the stresses exerted on the crust's area, are responsible for shaping the region's geology.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia is segmented into three zones that trend either north or south, and each of these zones is split into three divisions. The Western Belt, the Eastern Belt, and the Central Belt of Peninsular Malaysia are the names given to these three distinct regions. Jeli may be found in the middle of Peninsular Malaysia's Central belt. The Bentong-Raub Suture was created as a consequence of the collision between the Sibumasu and Indochina terrains (Metcalf, 2000). The Sibumasu plate is where Peninsular Malaysia may be found. In general, Peninsular Malaysia is separated into two blocks by the Bentong-Raub suture. The western half of Peninsular Malaysia is a component of the Sibumasu blocks, while the eastern part of Peninsular Malaysia is a part of the Indochina block (Metcalf, 2000). Both Sibumasu and Indochina may trace their roots back to Gondwanaland (Metcalf, 2000). The geological formation that can be seen in Figure 2.1 may be found in the state of Kelantan.

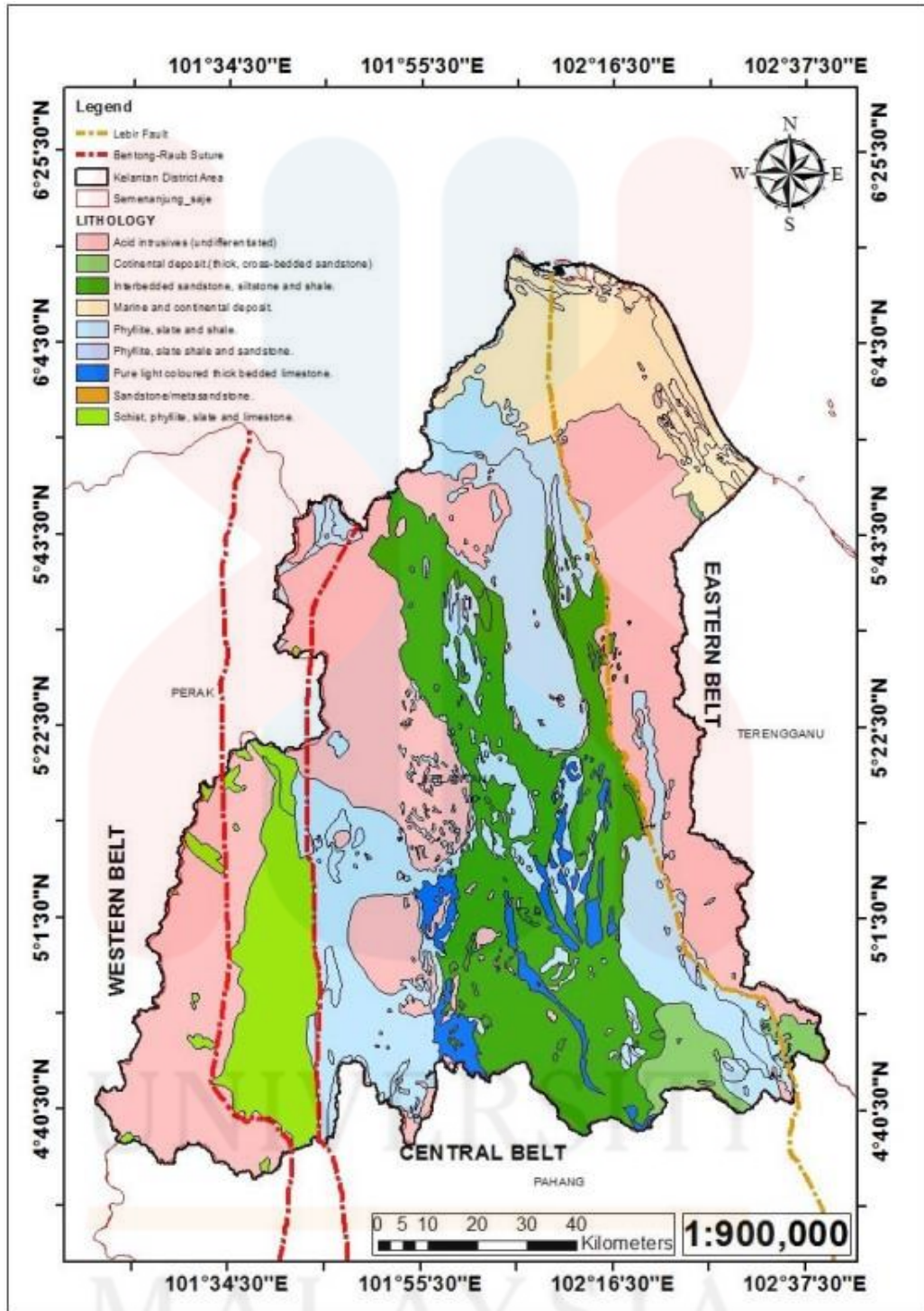


Figure 2.1: Regional Geology map of Kelantan (Source: Patah et al., 2021).

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The geology and tectonic setting of Peninsula Malaysia is characterized by its location in the Sunda Shelf, a region of the Southeast Asian landmass that experienced significant geological and tectonic activity throughout its history. This has resulted in the formation of a diverse range of geological features, including volcanic islands, sedimentary basins, and structural mountains (Laj, 2006).

The peninsula is composed of a series of crustal blocks that have been affected by various tectonic processes, such as collision, accretion, and extension (Hafidz et al., 2013). The northern region of the peninsula is dominated by the Main Range, a series of metamorphic and igneous rocks that were formed during the late Mesozoic and early Cenozoic eras (Laj, 2006). The central region of the peninsula is characterized by a series of sedimentary basins, including the central graben and the West Coast Basin, which contain vast reserves of oil and natural gas (Hafidz et al., 2013).

The southern region of the peninsula is dominated by the Neogene volcanic islands, including Pulau Tioman, Pulau Sibul, and Pulau Besar (Laj, 2006). These islands are believed to have formed as a result of the subduction of the Indian Plate beneath the Sunda Plate (Hafidz et al., 2013).

The tectonic setting of Peninsula Malaysia is dominated by the collision of the Indo-Australian Plate and the Eurasian Plate, which has resulted in the formation of several geological features, including the Sunda Trench, the Sumatra Fault, and the Malacca Strait (Nazarudin, A., & Chen, H., 2017). The Sunda Trench marks the boundary between the two plates and is a site of active subduction, where the Indo-Australian Plate is being forced beneath the Eurasian Plate. The Sumatra Fault is a major strike-slip fault that runs through the region and has been responsible for several large earthquakes, including the 2004 Indian Ocean earthquake and tsunami that

affecting Malaysia. The Malacca Strait is a narrow waterway that separates the Malay Peninsula from Sumatra (Nazarudin, A., & Chen, H., 2017).

2.3 Stratigraphy

Stratigraphy refers to the study of rock layers and their distribution in an area. In Malaysia, the stratigraphy is diverse and complex, with a range of rock formations that have been formed over millions of years. These rock formations include ancient sedimentary rocks, volcanic rocks, and metamorphic rocks (Zamri, et al., 2008).

The oldest rock formations in Malaysia date back to the Permian period, around 300 million years ago. These rocks are primarily composed of sandstone, shale, and coal. Over time, new layers of rock were added, including volcanic rocks that were formed during the Cenozoic era. These volcanic rocks are particularly abundant in central and eastern Malaysia (Hafidz, et al., 2006).

The stratigraphy of Malaysia has significant implications for the country's economic development, as the rock formations contain important minerals such as coal, oil, and gas. These minerals are crucial for the country's energy production and have been instrumental in driving the country's economic growth (Zamri, et al., 2008).

The stratigraphy of Kelantan is composed of seven different strata, which are referred to as the Aring Formation, the Taku Schist, the Gua Musang Formation, the Telong Formation, the Gunung Rabong Formation, the Koh Formation, and the Badong Conglomerate respectively. The Aring Formation and the Taku Schist both have an age that corresponds to the Paleozoic period, but the ages of the other five formations correspond to the Mesozoic period. The Gua Musang formation is in the south of the state of Kelantan, and it went all the way to the north of Kelantan and the

north of Pahang. Gua Musang dates to the Middle Permian to the Upper Triassic (Mohamed et al., 2016). Fossils of pelecypods and ammonoids have been found in Gua Musang, which proves their ages and shows how long ago they lived (Khoo, 1983).

The Jeli district is in Peninsular Malaysia, at the foot of the Main Range. Most of the rocks in the range are granitic, but there are a few pockets of sedimentary and metasedimentary rocks. The Main Range granite is in the western part of Kelantan, just west of where the state boundaries of Perak and Pahang encounter. Based on the general geology of Kelantan by Department of Minerals and Geoscience Malaysia (2003), Jeli district is made up of three types of rocks: (1) Triassic sedimentary rocks (Gunong Rabong Formation), which are made up of shale, siltstone, sandstone, and limestone; (2) Permian sedimentary rocks (Gua Musang Formation), which are made up of phyllite, slate, sandstone, and limestone; and (3) Granitic rocks (acid intrusive).

2.4 Structural Geology

Peninsular Malaysia is stretched in a north-northwesterly direction, which is also comparable to the pattern of its longitudinal extent (Hutchison & Tan, 1989). Structures on the surface of the Peninsular determined its northwest via the north-eastern direction pattern and subsequently its north-northwest strike direction. In the northwestern part of the Peninsula, the Permian folding has been seen (Khoo and Tan, 1983).

Rocks in the central belt were thought to have developed their one-of-a-kind western and eastern vergences as a result of the overall eastern-western compression that was associated with the collision of the Late Triassic crust (Hutchison & Tan,

1989). The structural grain of Peninsular Malaysia eventually included massive faults that were filled with enormous multi-phase quartz dykes. This grain lies in the northwest-southeast area of the country (Hutchison & Tan, 1989).

There are four distinct kinds of topography that may be found in the state of Kelantan, and they are as follows: (1) mountainous regions; (2) hilly areas; (3) plain areas; and (4) coastal areas (Nazaruddin, 2015). The western and northern portions of the district are characterised by their mountainous terrain. The Stong Migmatite Complex, granite from the Main Range, and schist make up this region's environment. The majority of the district's interior, particularly its central and eastern part, has a flat environment. Tectonic events that occurred in Peninsular Malaysia throughout the Paleozoic and Mesozoic eras primarily contributed to the construction of faulting and folding on the land mass. Folding, jointing, and faulting are some of the localised features that have been discovered in the sedimentary rocks, while jointing and faulting have been seen in the granitic rocks (Department of Minerals and Geoscience Malaysia (2003). The most common local building patterns in Kelantan run along north-south and northwest-southeast orientations. Nevertheless, the NW-SE and NE-SW orientations are the most important in terms of local structure in the Jeli district.

Another study, "Structure and Tectonics of the Malay Peninsula, Peninsular Malaysia" (Hamdan et al., 2007) looked at the structural and tectonic evolution of the peninsula and found that it is characterized by a complex network of faults, folds, and other geological features that have been shaped by both tectonic activity and erosional processes.

2.5 Historical Geology

The historical geology of Kelantan, Malaysia, refers to the study of the geological events and processes that have shaped the geology of the region over time. The geology of Kelantan is diverse and includes sedimentary rock formations, volcanic rocks, and intrusive igneous rocks (Ahmad & Ismail, 2018). The region was also affected by tectonic movements and metamorphic processes that caused the formation of folded and faulted rock structures (Ahmad & Ismail, 2018). In addition, the area experienced several phases of volcanic activity, including the eruption of basaltic and andesitic lavas (Ahmad & Ismail, 2018). Metcalfe (2013) says that as the Paleo Tethys Ocean and the Sibumasu plate slid sideways under the Indochina plate, a highly deformed accretionary continues to grow. So, the shallow marine platform of Gua Musang is where the argillocarbonate sediments were laid down. The volcanic rock around Gua Musang also came from a nearby volcanic arc. From the Permian to the Early Triassic, sediments began to build up in the shallow seas of Gua Musang.

Hutchison and Tan (1989) say that the central part of Peninsular Malaysia is a shallow platform next to a system of islands made from continental crust. They found that there was a lot of limestone and volcanic arcs growing above sea level. Aside from this, it was mostly part of the convergent margin from the Viséan to the Late Triassic. The uplift and collision happened at the end of the Triassic.

Hutchison and Tan (1989) defined an extensional graben as the Central zone, which is bounded to the west by major faults along the Bentong-Raub line and to the east by the Lebir Fault Zone. Next, in the Permian age, a major normal fault started along the Bentong-Raub line and the Lebir Fault Zone. This caused a graben to form in 2 to 3 km of marine Triassic-like Semantan Formation, while 1.5 to 2 km of Jurassic-Early Cretaceous-age continental sediments formed what is called the Gagau Group.

2.6 Research Specification

2.6.1 Landslide

A landslide, also known as a landslip, is a mass movement of rock, rubble, earth, or soil that occurs on a slope (soil being a mixture of earth and debris). Whenever the shear stress (resistance to shearing) inside a slope is greater than the shear strength (resistance to gravity shear), landslides occur (Meng, 2022). In mountainous areas across the globe, landslides have been recognized as a significant natural catastrophe. (Hussain et al., 2019).

Landslides are the result of a complex interplay between geological lithology, structure (e.g., fractural zones, faults, and joints), elevation, slope, aspect, river, regolith, soil, land cover, rainfall, roads, and housing development. These criteria have been studied and effectively implemented by Djukem et al. (2020). As a result, this study needs to investigate these geographical characteristics in order to achieve the goals of this research. The various factors that contribute to landslides have been extensively studied in the geological and geomorphological literature. Some of the key factors that affect landslides include:

- **Geology:** The type, structure, and composition of the rock and soil can greatly impact the stability of slopes and the likelihood of landslides (Varnes, 1984).
- **Topography:** Slopes that are steep or irregular can increase the gravitational force acting on the slope and increase the risk of landslides (Cruden & Varnes, 1996).
- **Hydrology:** The presence of groundwater and surface water can weaken slopes and trigger landslides, particularly if the soil or rock mass becomes saturated (Cruden & Varnes, 1996).

- **Climate:** Extreme weather events such as heavy rainfall, snowmelt, and heat can increase the weight of soil or rock masses and trigger landslides (Cruden & Varnes, 1996).
- **Human activities:** Human activities such as deforestation, mining, construction, and land use changes can disrupt the stability of slopes and increase the risk of landslides (Cruden & Varnes, 1996).
- **Earthquakes:** Strong earthquakes can cause soil and rock masses to shift and trigger landslides, particularly in areas with steep slopes and unstable geology (Cruden & Varnes, 1996).
- **Geomorphology:** The shape, size, and orientation of the slope can impact its stability and the likelihood of landslides (Cruden & Varnes, 1996).

2.6.2 Landslide Susceptibility

According to Reichenbach et al., 2018, an area's landslide susceptibility is a measure of how probable it is for a landslide to occur there given the local topographical conditions. The risk of landslides occurring mapping or zonation is the process of dividing the terrain into zones that have a varying risk of landslides occurring. The landslide deposit's geographical distribution, size, position, and displacement are all part of this analysis (Varnes, 1981). Geographical study of landslide susceptibility is significant because it may be used for disaster preparedness, emergency response, and risk reduction (Vojteková, 2020).

2.6.3 Types of Landslides

The word "landslide" is used to describe a wide range of events that lead to the downward and outward movement of slope-forming materials like rock, soil, man-made fill, or a mix of these. The materials can move by falling, toppling, sliding, spreading, or flowing (Cruden & Varnes, 1996). Table 2.1 displays the Varnes categorization of landslides.

Table 2.1: Varnes’s Classification of Landslides.

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

Rocks and boulders that are loosely attached to cliffs or steep slopes are known as "falls" because of their sudden mobility. Free-falling, bouncing, and rolling are all ways in which a rock can move in the absence of a fracture, joint, or bedding plane. gravity, mechanical weathering, and interstitial water all have a role in the formation of falls. Toppling failures are different because a unit or units rotate forward around a pivot point that is below or low in the unit. This happens because of gravity and forces from other units or fluids in cracks.

There are two main kinds of slides: those that turn and those that move. Rotational slide: This type of slide has a surface that breaks off that is curved up and

inward, and the slide moves around an axis that runs parallel to the ground and across the slide. In a translational slide, the mass of the landslide moves along a roughly flat surface without much turning or tilting backward. A block slide is a translational slide in which the moving mass is made up of a single unit or a few closely related units that move downslope as a relatively coherent mass.

Lateral spreads occur on mild slopes or level ground. Lateral extension with shear or tensile fractures is the major movement. Liquefaction causes the failure by turning saturated, loose, cohesionless sediments (typically sands and silts) into a liquid. Rapid ground motion, such as during an earthquake, generally triggers failure, but it may also be created intentionally. When bedrock or soil sits atop liquefiable material, the higher units may fracture and extend, sink, translate, twist, disintegrate, or liquefy and flow. Fine-grained materials spread laterally on shallow slopes. A tiny failure spread quickly. Some materials move for no apparent cause, while others slump. Complex landslides include two or more categories.

2.6.4 Remote Sensing & Geographic Information System (GIS) Applications

GIS data may be gathered using a variety of techniques, one of which is remote sensing. In the absence of any physical touch, remote sensors gather data from things on the planet. By measuring the radiation reflected from the earth, they are often installed on satellites or aero planes. Since its inception, remote sensing technology has grown to be more widespread, more precise, and more affordable.

A Geographic Information System or GIS is a computer system that is used for the analysis and management of geographical data. The term "geographic" refers to the locations of data points whose coordinates may be determined. When it comes to

GIS, the term "information" indicates that the data are structured in a way that yields usable information like colored maps or pictures as well as tables and statistical visualizations. In order to arrange data in vector or raster formats, the GIS system offers many and varied functionalities (Wang & Xie, 2018).

2.6.5 ModelBuilder

ModelBuilder is a language for building geoprocessing workflows that is based on graphical programming. The spatial analysis and data management tasks can be automated and recorded with geoprocessing models. In ModelBuilder, users can make and change geoprocessing models. A model is shown as a diagram that links together sequences of processes and geoprocessing tools. The output of one process is used as the input for another process (ArGIS Pro, 2022).

One or more geoprocessing processes may be shown in the model diagram. A tool and the values it specify make up each procedure (e.g., input and output data, reclassification table). There are various symbols used to represent the model components in the ModelBuilder interface, including inputs (geographic data, values, or SQL expressions), outputs (geographic data or values generated when the model runs), tools (operations to be performed on the input data), connecting arrows that indicate the processing sequence, and text labels to explain the model. The geoprocessing tools may be ready-to-use ArcGIS system tools, scripts written in Python or other COM-compliant languages, or embedded models in the case of complicated operations. In order to build a model, just simply place model components into the Model Builder window, link them with arrows, and then drag and drop the model pieces into the correct order. Before executing a model, the user must specify

the model's parameters. Wizards, layout setup, drag-and-drop tools, property sheets, and the ability to save the complete model as an XML file or script are just a few of the ModelBuilder's other features (ESRI, 2000).

2.6.6 Weighted Overlay Methods (WOM)

Weighted overlay is a technique where different input values are evaluated in the same environment and only the integer raster data can be used. Hence, floating point raster data must be reclassified to form integer raster values before the operation. Different input values are assessed in the same context using a method called weighted overlay. It is necessary to sort each characteristic in a layer from most appropriate to least appropriate before using a weighted overlay approach. The next stage is to assign points to each class, with the most appropriate class receiving the most points. As the level of appropriateness declines, so do the class points. Restrictions should be placed on areas that are unsuitable and the scale should be lowered to reflect this. Only integer raster data may be utilized in weighted overlay. As a result, before performing the procedure, floating point raster data must be classed as integer raster values. A weighted overlay operation was utilized to select the groupings of data that would be used in the same process (Cabuk, et, 2010).

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

Detailed explanations of the tools and techniques used to gather data for geological studies and landslide analyses are provided in this chapter. Maps were created using a GIS tool in both studies.

3.2 Materials

The material used in achieving the objectives of this study is GIS software. GIS software is used as a medium for collecting information obtained in the study area. GPS or known as Global Positioning System, is also used to mark the area when mapping the study area. DEM software is used as a device to create 2D models in the study area with the help of satellites.

3.2.1 Geological Mapping

Primary data will be obtained through geological mapping at the study area to identify the geomorphology, geological structure, stratigraphy, and lithology of rocks in the study area. Equipment such as compass, hammer and notebook are used when doing geology mapping. The compass is used to measure the orientation of geological structures, during mapping in the field, to analyze the geometry of bedding planes, joints, and/or metamorphic foliations and lineation in the study area. Next, a hammer is used to take rock samples for the purpose of studying rock types for petrography

analysis thin section. The use of notebooks in the field is very important to record the various data and geological information identified. All data obtained during the mapping will be inserted into ArcGIS to generate a geological map of the area.

3.2.2 Landslide Susceptibility Mapping

Secondary data such as topography maps, rainfall maps, and satellite photos were gathered to obtain slope, aspect, land use, drainage density and lineament data. All the data will be combined to create a landslide susceptibility map as shown in Figure 3.1. Information was gathered digitally from many sources, including the USGS, Google Earth Pro, and Digital Elevation Model (DEM).

3.3 Methodology

3.3.1 Preliminary Studies

Before beginning any research, it is necessary to do a geological and landslide survey and appraisal of the subject region. A picture from space is also needed to capture geomorphology and identify deformation caused by tectonic activity and landslides. Studying relevant journals, articles, and books is critical to understanding the history, structure, lithology, and occurrences of prior landslides in the region under investigation.

3.3.2 Geological Mapping

The main methodology of conducting geological mapping is by doing traverse. Through this traverse activity, various geological information will be obtained. Before traverse is conducted, preliminary study will be made such as journal article reading

and google earth interpretation to understand the history, structure, lithology, and drainage pattern of the study area. Rock composition and rock type can be identified using petrography analysis after field sampling. Joint, fault, strike and dip data will also be collected during the fieldwork activity. Drainage patterns in the study area will be analysed to identify the type of drainage pattern.

3.3.3 Landslide Susceptibility Mapping

ModelBuilder program in ArcGIS will be used to overlay landslide parameters data using WOM method in order to generate landslide susceptibility map. This map will be used to make an interpretation of landslide susceptibility index. This study relies on secondary sources such as from Google Earth, USGS, and JPS data. Prior to do overlay process using WOM, AHP technique by Saaty (1980) were used to identify the weightage of the six (6) possible landslide susceptibility parameters; slope, aspect, lineament density, lithology, drainage density, and land use.

3.3.4 Laboratory Work

In order to determine the minerals, present and the kind of rock present at the site of the research, an analysis of the samples and data acquired there will be performed using the thin section technique. The most accurate information, such as the mineral that is invisible to the naked eye, can only be obtained in a laboratory setting.

3.3.5 Data Processing

The processes required to build a geology map, parameters map, and landslide susceptibility map using ModelBuilder in ArcGIS are discussed in this part.

a) Geological Map

Data on the lithology and structural geology of the research region were gathered during a prior study and are required for the generation of a geological map of the area under investigation. The data collection was then imported into ArcGIS, where it was processed with the help of the many tools that come included with the program.

b) Thematic Map

Lineament, slope, aspect, land use, lithology, and drainage density have been chosen as the research area's six characteristics, respectively. These are the parameters that have been selected. ArcGIS was also used in the production of the map depicting the characteristics of the research region. The availability of a wide variety of remote sensing data and a variety of different types of multi-temporal data were used to produce each parameter map. After obtaining all of the secondary data for the parameters, the data collection was processed with the help of the particular tools, one of which was called ModelBuilder, which is located in the Arc Toolbox of ArcGIS 10.3.

3.3.6 Data Analysis and Interpretation

a) Petrography Analysis for Geological Mapping

Petrographic analysis will be performed to identify the mineral and the percentage of its constituent minerals through a polarized microscope. The description of the macroscopic properties of the rock, such as fabric, colour, grain size, and other significant qualities that can be visually viewed in hand specimens, is frequently included in the analysis. The purpose of this analysis is to provide more accurate information about the types of rocks found in the study area. Rock identification during mapping will be compared with the petrography analysis results.

b) Landslide Susceptibility Analysis

By using AHP, evaluation and weighting of criteria are based on their relative relevance by using paired comparisons and expert opinion. Then, experts' judgements will be used to give score values and weights, define priority factors, and indicate landslide risk levels. The weighted overlay method (WOM) will be used to derive the landslide susceptibility index. All identified parameters will be used as input to be processed in the ModelBuilder tool to eventually produce a landslide susceptibility map. In this study, possible landslide susceptibility parameters that will be studied are slope, aspect, lineament, drainage density, lithology, and land use. Scale of 0-3 susceptibility level will be showed in the landslide susceptibility area. The scale consists of no landslide occurrence, low, moderate, and high.

3.3.7 Research Flow Chart

A research flow chart is a diagram that outlines the steps in a research process. It provides a visual representation of the different stages involved in conducting a research project, from defining the research question to presenting the results. Figure 3.1 show research flow chart of study area.

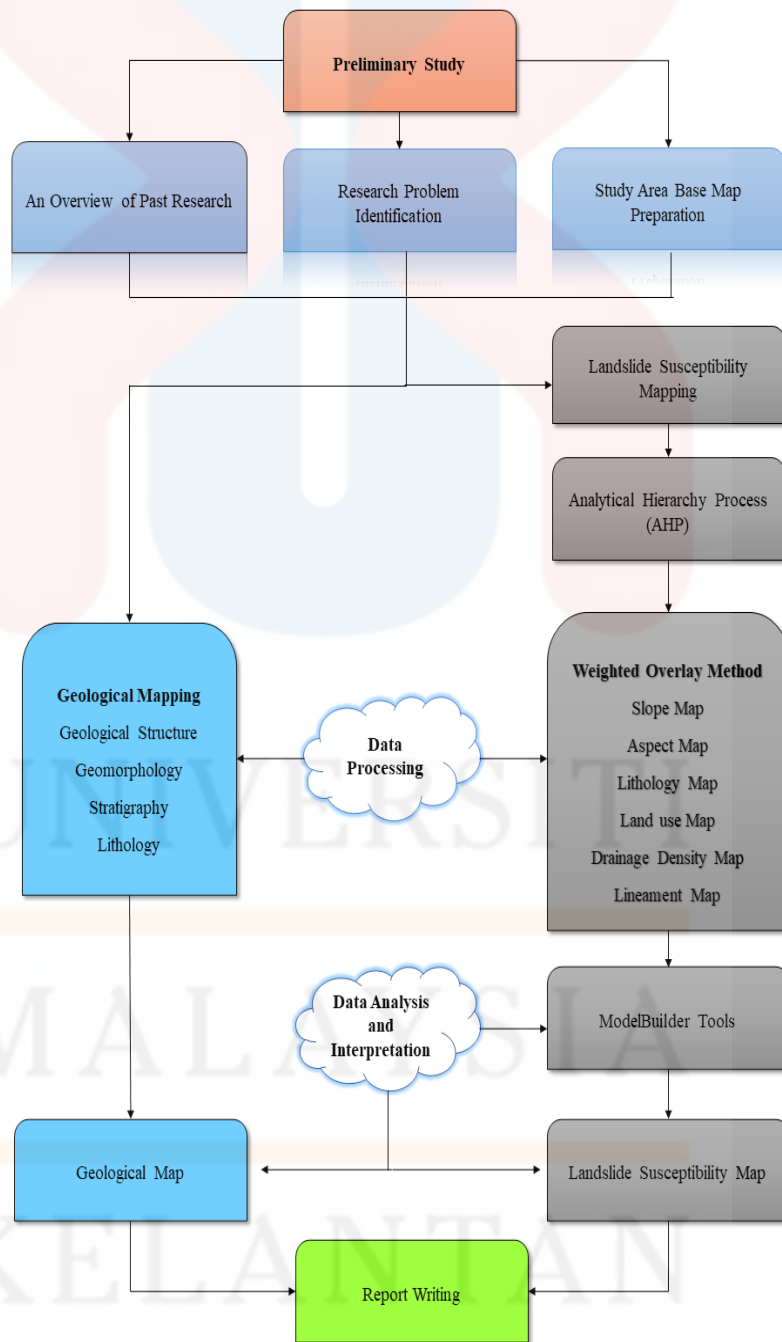


Figure 3.1: Research flow chart of study.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

In general geology, the subjects of information, data gathering, and the analysis of studies were the key focuses of attention. This topic draws from several subfields within geology, including geomorphology, stratigraphy, lithology, structural geology, and historical geology, among others. Secondary sources and previously conducted research were mined for all of the information that was compiled. Following that, a geological map was created to depict the position of various rock units, the types of rocks that are there, the geological structures, and the age-rock correlations in the region that was the subject of the inquiry.

4.1.1 Accessibility

This major roadway provides access to the study area, which is located along the Jalan Sg Sam - Dabong - Jeli. The driving distance between UMK Jeli and Kampung Renyok is approximately 21 kilometers and takes around 21 minutes. 80 percent of the research area is located on the right side of the map (east), across the Sg Pergau region, which must be traversed to reach the study area. The river is typically crossed by boat or sampan, and the journey by Jalan Jambatan Jerimbong takes 1 hour and 2 minutes for 44 kilometers using paved and unpaved road.

4.1.2 Settlement

In the vicinity of this research site is a community known as Kampung Renyok. The settlement pattern of Kampung Renyok may be broken down into two categories, which are known as the nucleated settlement pattern and the linear settlement pattern, according to an interpretation of Google Earth. A nucleated pattern is a collection of many residences that are close to one another and frequently focused around a common centre of the village such as a road intersection. The linear pattern, on the other hand, displays the dwellings as forming a line that is parallel to the road network in the study region. SMK Jeli (2) was established as the primary educational institution for the people of Kampung Renyok and the neighbouring settlements.

4.1.3 Forestry

In the study region, the western forest was comprised of forests belonging to Dabong's Gunung Stong State Park. In addition, this research area contains oil palm and rubber plantations. Oil palm plantations are administered by FIMA, whilst rubber plantations are primarily cultivated by locals. Most inhabitants in Kampung Renyok have their own estate and work with FIMA management. Forestry and vegetation have an impact on human activities and employment prospects in the region.

4.2 Geomorphology

Geomorphology is the study of landforms formed by erosion, weathering, deposition, transport, and tectonic processes. It is science that studies the history and character of the earth's surface. In essence, landforms reflect the interaction between the tectonic structure of the Earth, its atmosphere, and the biota they support. However,

both the earth and the sky undergo continuous changes to which landforms and land-forming processes respond, and the feedback generated by these processes influence both the framework and the atmosphere. Thus, the surface of the Earth is deployed as a system of solids, liquids, and gases in which change is a common denominator.

4.2.1 Geomorphology Classification

In general, the research area's geomorphology or landform consists of three distinct types: low land, low hill, and hill areas. Typically, variances in lithology suggest distinct types of landforms. Covering much of the study area are metasedimentary rocks such as slate, phyllite, mudstone, and shale, which are found in low-lying to low-hill regions. However, the research area also includes granitoid in lowland and hilly regions.

Table 4.1: Landform Classification by Van Zuidam, 1985.

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

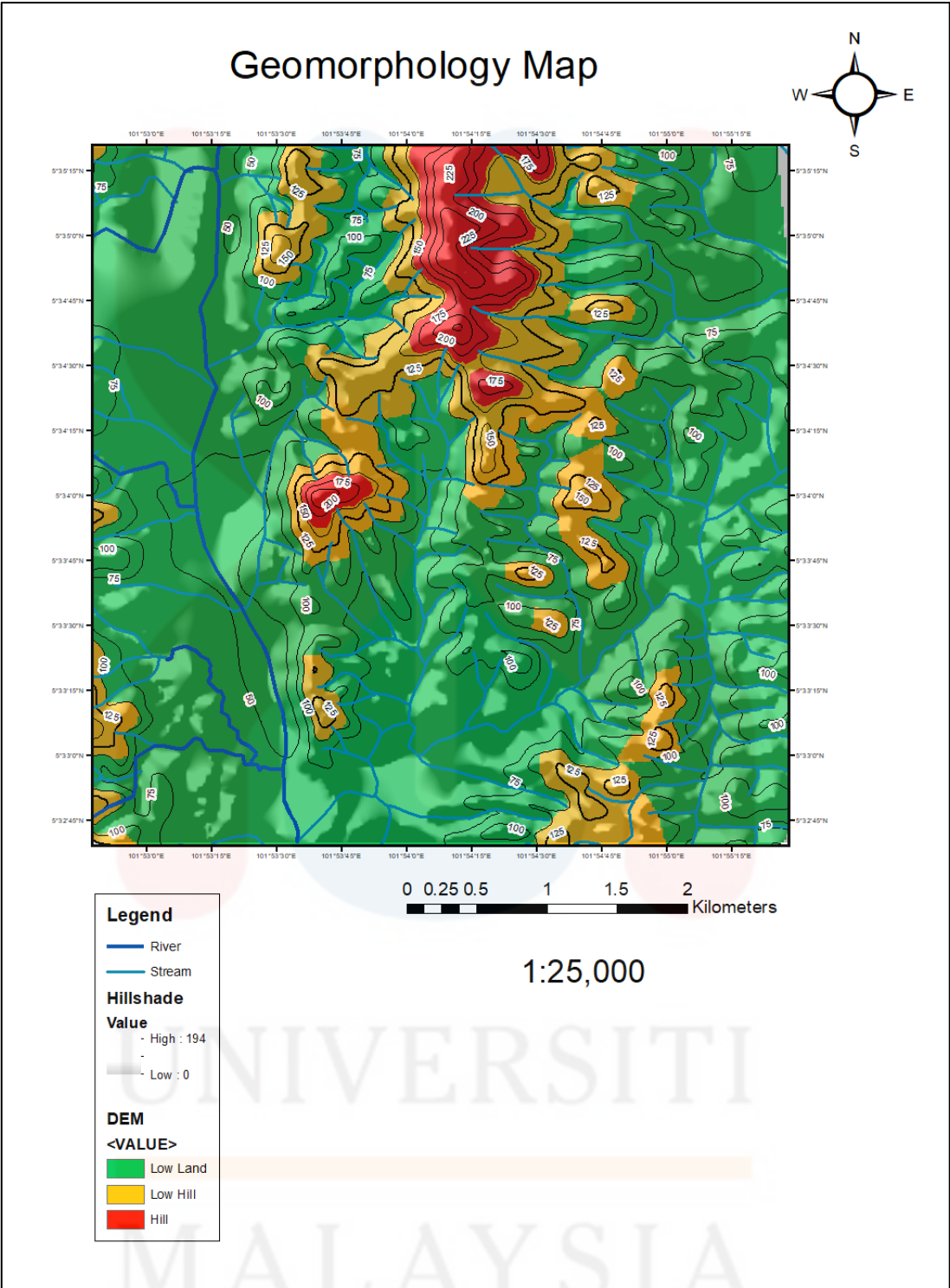


Figure 4.1: Geomorphology map of study area.

4.2.2 Weathering Process

The term "weathering" refers to the process by which rocks are eroded at Earth's surface due to the combined effects of water, temperature extremes, and biological processes. It is not required that rock be removed. Weathering can occur in three different ways: physically, chemically, and biologically. All this weathering may be found in the Kampung Renyok research area.

Physical weathering causes rock to break down, which has ramifications for rock temperature. This method of deteriorating rocks without altering their chemical make-up is known as physical weathering or mechanical weathering. Since most breaking happens along mineral boundaries, physical weathering typically results in silt that is sand-sized or larger. Very fine grains can be produced in large quantities by the physical weathering of fine grained or finely crystalline rock, although most of the sediment from these types of rocks consists of rock pieces known as lithic clasts. Lithic clasts formed by physical weathering might be as little as silts and clays or as massive as boulders and gravel.



Figure 4.2: Physical weathering occurrence in the study area.

During chemical weathering, precipitation reacts with rock minerals to produce clays and soluble salts. To a greater extent, these processes take place in water with a mild acidity. These chemical reactions require water and progress more rapidly in warmer temperatures, therefore warm, humid conditions are ideal. Chemical weathering is the first process in soil formation (particularly hydrolysis and oxidation). Hydrolysis refers to the process by which rock is broken down by acidic water to form clay and soluble salts. Oxidation refers to the process of rock disintegration brought on by oxygen and water, which also gives iron-rich rocks their characteristic rough, worn appearance.



Figure 4.3: Chemical and physical weathering.

Biological weathering is a type of weathering that is brought about by living organisms. When plants and animals decompose, they release chemical acids that cause weathering and contribute to the erosion of rocks and landscapes. This is because plant roots tend to grow into crevices. The roots are growing so rapidly that they are forcing the fissures to widen and deepen. Eventually, even the sturdiest rock can have a stone or two break free.

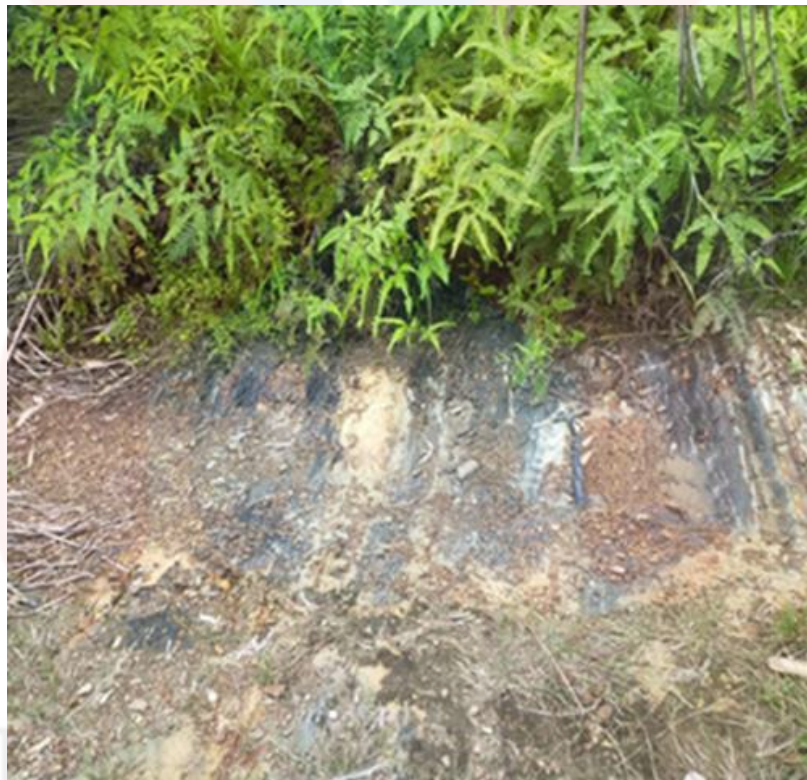


Figure 4.4: Biological weathering in sedimentary rock.

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4.2.3 Drainage Pattern

A drainage pattern is a pattern formed by stream erosion over time, which displays features of the type of rocks and geologic formations in a landscape region drained by streams. It is the pattern generated by streams, rivers, and lakes within a specific drainage basin. They are governed by the geology of the ground, the prevalence of hard or soft rocks in a location, and the slope of the terrain. There are numerous forms of drainage pattern, including dendritic, radial, parallel, subparallel, and rectangular.

There are several types of drainage patterns which can be identified in the study area which are dendritic, parallel, and trellis. Dendritic patterns, which are by far the most prevalent, emerge in regions where the rock (or unconsolidated material) beneath the stream has no structure or fabric and can be eroded in all directions. Examples might be granite and unfolded sedimentary rock. The most frequent form resembles the branching pattern of tree roots. It occurs in locations with uniform subsurface material. In other words, subsurface geology has a comparable resistance to weathering, therefore there appears to be no influence on the course of the tributaries.

Parallel drainage pattern develops where there is significant slope leading up to the surface. In places characterized by a series of parallel and elongated formations, such as outcropping resistant rock bands, a parallel pattern can also emerge. The slope of the surface is typically followed by tributary streams as they spread out in a manner that is similar to parallelism. Sometimes, the presence of a significant fault that slices across an area of sharply folded bedrock can be inferred from the presence of a parallel pattern.

Trellis drainage patterns are usually the result of sedimentary rocks being folded or inclined and subsequently being eroded to varied degrees, with the degree of erosion being proportional to the rocks' resistance. Valleys are formed by down-turned folds known as synclines, and the primary course of the stream is located within these valleys. When they descend the slopes of a series of parallel ridges known as anticlines, smaller tributary streams enter the larger channel at acute angles.

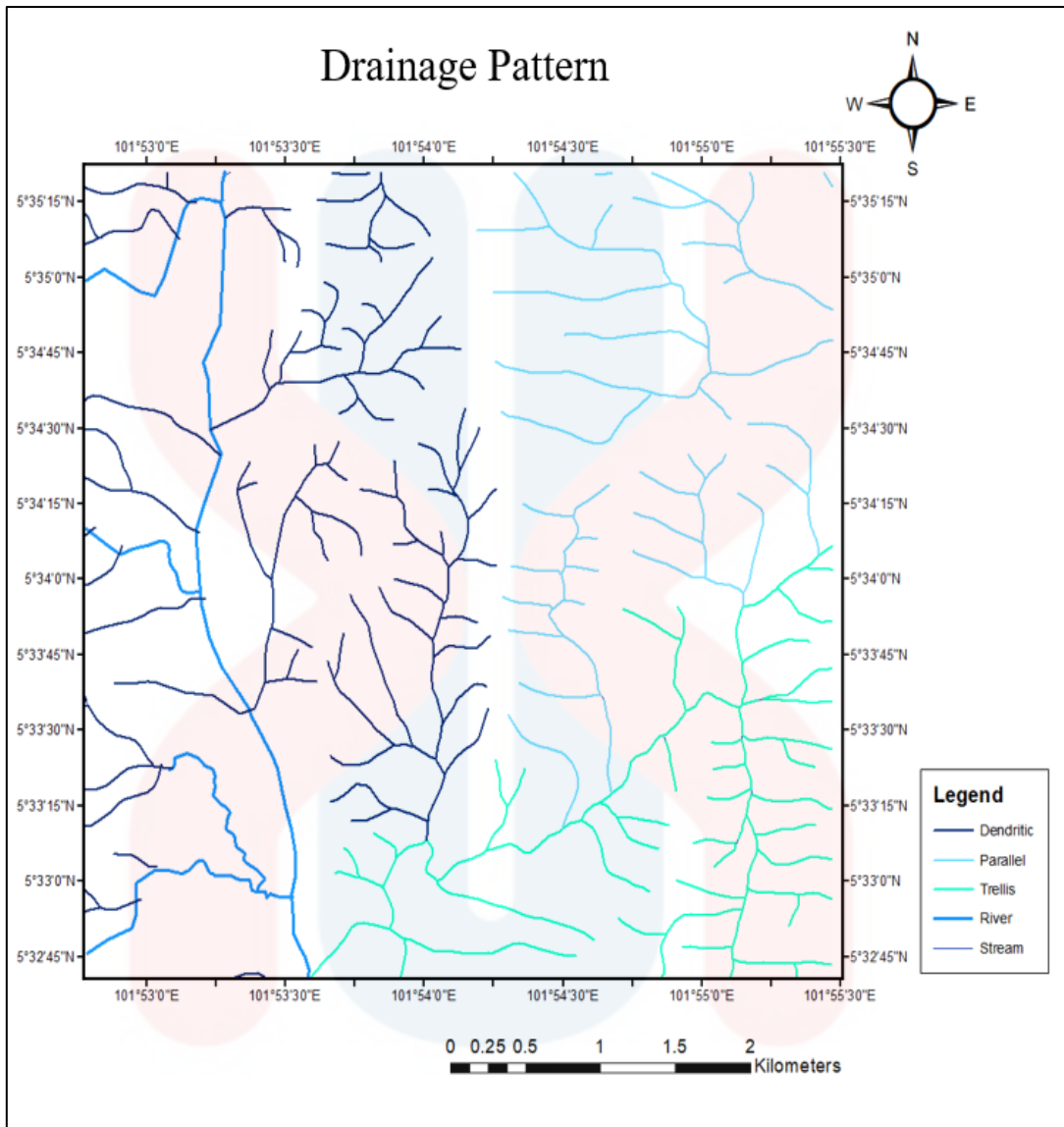


Figure 4.5: Drainage pattern map of the study area.



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4.3 Lithostratigraphy

The study of rock layers, often known as strata, is the focus of the geological science known as stratigraphy. Lithostratigraphy is a sub-discipline of stratigraphy. The subfields of petrology, geochronology, and comparative geology are the primary areas of concentration. When considering the origin of the rock, strata are typically classified as either igneous or sedimentary, respectively.

In the research area, there are two primary types of lithologies. The metasedimentary rocks and granitoid bodies of Noring Granite, Berangkat Tonalite and Kenerong Leucogranite were separated into their respective lithologies. The Stong Complex is composed of the Noring Granite, Berangkat Tonalite and the Kenerong Leucogranite. In between ages of the Late Permian and the Tertiary, these two lithologies were interacting with one another.

The granitoid was the youngest rock that intruded the metasediment, which leads to the conclusion that the metasedimentary rocks were the oldest rocks in the study area. The available evidence suggests that the intense dynamo thermal metamorphism and deformation recorded in both sedimentary and some plutonic rocks resulted from forces generated by the emplacement of the granitic rocks. This idea is supported by the fact that the emplacement of the granitic rocks was recorded in both sets of rocks. At the very least, the most recent phase of the intrusive history of the Stong Complex occurred during the Late Cretaceous period; the ages of the complex's older phases are unknown but fall within the timeframe. Out of the Triassic till the end of the Cretaceous.

STRATIGRAPHY				
STRATIGRAPHY COLUMN				
LITHOLOGY	DESCRIPTION	UNIT	PERIOD	ERA
	The main features consists of quartz and sericite with accessory mineral biotite	Granitoid	Tertiary	Cenozoic
	Mainly consists of slate, shale, phyllite and mudstone	Slate	Permian	Paleozoic



LITHOLOGY COLUMN	
LITHOLOGY	DESCRIPTION
	Kampung Renyok rocks consist of granitoid with composition of quartz (15%), sericite (68%) change from microcline and mafic mineral biotite (15%). There is an interlocking mineral arrangement and parallel mineral directions that have not yet formed a foliation structure.
	Rocks are very brittle and break by fissile because of highly weathered condition affecting and change normal minerals to clays minerals by physical disaggregation and chemical decomposition.

Table 4.2: Lithostratigraphy of the study area.

4.3.1 Unit Explanation

a) Metasedimentary

The first stage in the formation of metasedimentary rock is the deposition and subsequent solidification of sediment, which is why this type of rock is sometimes referred to as sedimentary rock. After that, the rock was re-crystallized because it was subjected to high temperatures and pressures as part of a process known as metamorphism. This caused the rock to remain buried beneath further rock layers. Due to this, the rock will eventually transform into metasedimentary rock. In the research

region, the metasedimentary rocks that are distributed are from the Telong Formation and include mudstone, shale, phyllite, and slate. Slate is considered to have a low grade of metamorphism, whereas phyllite is considered to have a medium to low grade of this process.

b) Quartz Rich Granitoid

The name “granitoid” refers to a broad group of coarse-grained igneous rocks that are mostly composed of quartz, plagioclase, and alkali feldspar. Granitoid is a general term for this group. Granitoids can range from tonalites that are rich in plagioclase to syenites that are rich in alkali, and monzonites that are deficient in quartz to quartzolites that are rich in quartz. Granitic rock and granite are both types of granitoids; however, granite is only one type of granitoid. The terms granite and granitic rock are often used interchangeably for granitoids.

Quartz-rich granitoids can contain varying proportions of quartz, feldspar, and mafic minerals, depending on a number of factors, including the composition of the original magma, the conditions under which the rock solidified, and the subsequent geological processes that the rock has undergone. In some cases, a quartz-rich granitoid may contain lower amounts of quartz and higher amounts of sericite, a fine-grained mica mineral result in the dissolution of quartz and the precipitation of sericite in its place.

4.3.2 Petrography Analysis

The branch of mineralogy known as petrography focuses on providing an in-depth analysis and description of rocks. The study of the appearance of thin, transparent sections of rocks when viewed using a microscope that is equipped with polarizers is a

significant part of the scientific discipline of petrography. The term "petrography analysis" refers to the process of describing the rock minerals by employing microscopic features seen through a polarising or petrographic microscope under lighting conditions that are both plain and crossed polarised.

a) Quartz Rich Granitoid

The observations were carried out with an ocular magnification of 10x and an objective magnification of 5x. Additionally, observations of massive structure, phaneric texture with weak foliation, and coarse mineral size in the medium range were carried out. It is a meta-igneous rock, which may be identified by its apparently interlocking mineral arrangements and parallel mineral direction arrangements, yet there is no foliation structure present in the rock at this time.

Mineral Composition

Quartz (15%)

In PPL show absorption color is colorless, low relief, pleochroism is absent, anhedral crystal form, cleavage is absent. On XPL, the color of gray-white interference is order 1, the angle of darkness is wavy, there is no twinning.

Sericite (68%)

Changes from microcline. In PPL, the absorption color is colorless, low relief, pleochroism is absent, euhedral - anhedral crystal form, 1-way cleavage - absent. On XPL, the interference color is gray-white order 1, parallel darkening angle, twinning is not visible.

Biotite (15%)

On PPL absorption color is brown - greenish, medium relief, strong pleochroism, subhedral - euhedral crystal form, 1-way cleavage. In XPL color interference green - orange order 3, there is no twin parallel darkening angle.

Opaque Mineral (2%)

In PPL, black absorption color, low relief, no pleochroism, euhedral - anhedral crystal form. At XPL, the black interference color of the 1st order, twins do not exist.

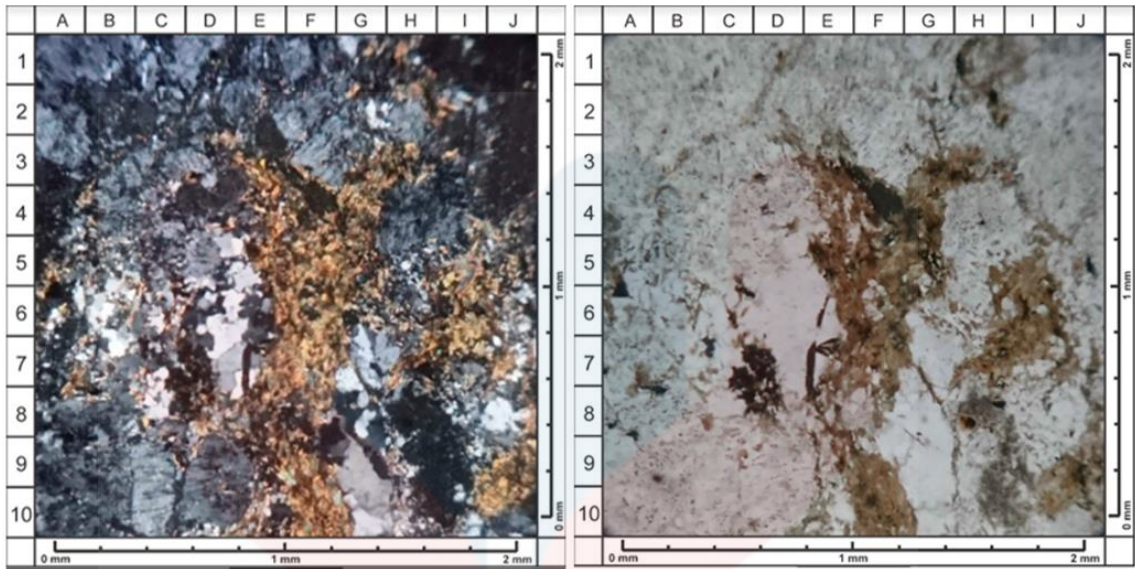


Figure 4.6: Granitoid thin section under XPL and PPL.

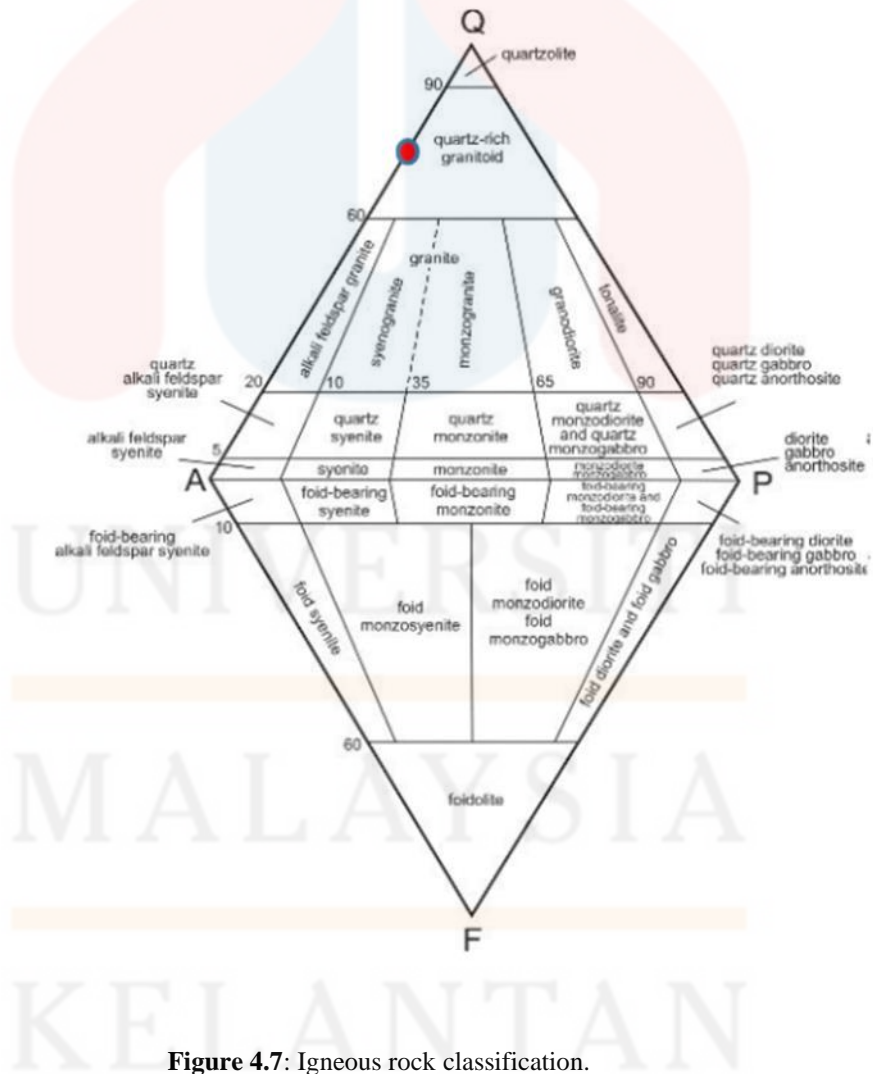


Figure 4.7: Igneous rock classification.

b) Slate

The observation was carried out at 10x ocular magnification and 5x objective magnification and at observation of foliation structure (slaty cleavage), palimpsest texture (blastopellite) including grain size $<1/256 - 1/32$ mm, good sorting.

Mineral Composition**Quartz (1%)**

In PPL, absorption color is colorless, low relief, pleochroism is absent, anhedral crystal form, cleavage is absent. On XPL, the color of gray-white interference is order 1, the angle of darkness is wavy, there is no twinning.

Silicate clay (98%)

At PPL the absorption color is colorless - brown. On XPL the interference color is dark gray - black. Consists of micron-sized silicate material.

Opaque Mineral (1%)

In PPL, black absorption color, low relief, no pleochroism, euhedral - anhedral crystal form. At XPL, the black interference color of the 1st order, twins do not exist.

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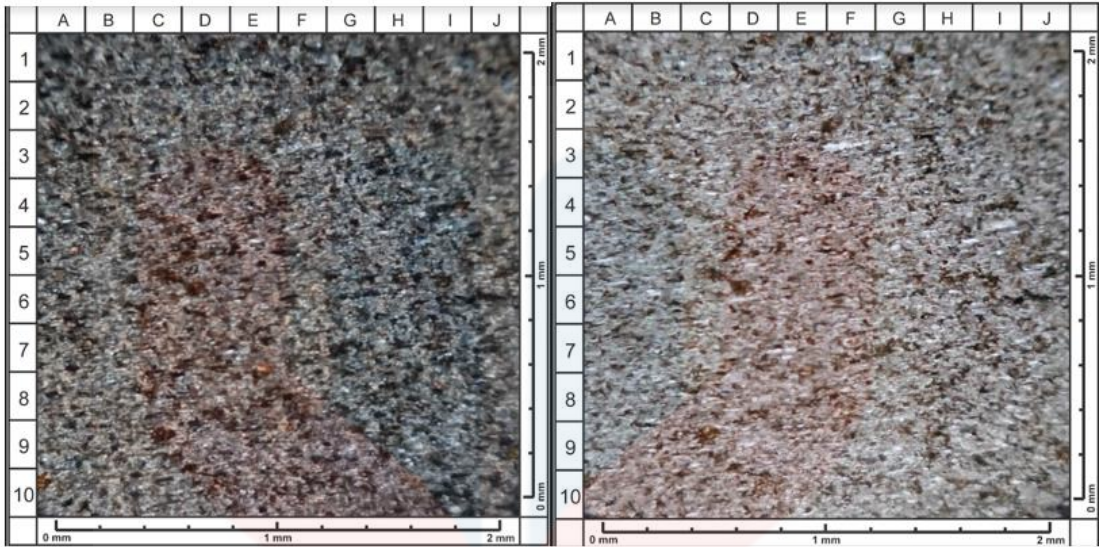


Figure 4.8: Slate thin section under XPL and PPL.

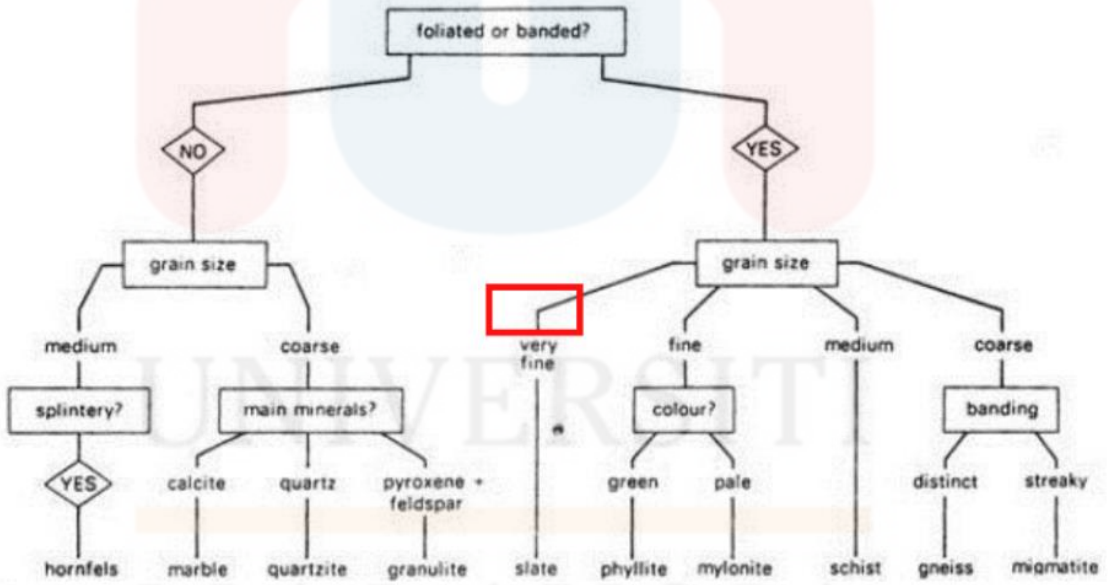


Figure 4.9: Sedimentary rock classification.

4.4 Structural Geology

The study of how rocks deform in response to the stresses that act within the Earth is the focus of a subfield of the science of geology known as structural geology. Rocks and the minerals that make them can adapt to the stresses that are applied to them and maintain a record of these changes by generating genuinely magnificent geological structures such as fractures, faults, and folds. The purpose of doing an examination of geological structures is to learn about the why, how, and when of the Earth's transformation. It is possible to constrain the mechanical laws that control how deformation is taken up by geological materials and to reconstruct the evolution of mountain chains in space and through geological time by means of structural investigations. These investigations can be used to determine how deformation is taken up by geological materials. In addition, structural studies are essential for the creation of contemporary geological maps and cross sections. These are the tools that we use to illustrate how rocks are distributed on the surface of the Earth as well as at depths below it, so it is important that structural studies be conducted. The interpretation of satellite pictures and aerial photography, such as the terrain map from Google Earth Pro, was used to carry out the structural analysis for this research region. In order to facilitate additional interpretation, the geological formations of the research region were mapped out in detail. The lineament map was developed based on interpretations found online.

4.4.1 Lineament Analysis

Lineament analysis also was utilised in the process of assisting in the interpretation of regional structure, assisting in the localization of subterranean structures, and mapping fractures. Lineament analysis can be used in regional syntheses to characterise the structural fabric of a terrane and direct attention to domain boundaries or zones of weakness. Positive lineament and negative lineament are the two categories that fall under the category of lineament. Positive lineament denotes bedding, which can be recognised from ridges or ranges, and negative lineament denotes fault or joint, which can be recognised from valleys or rivers. Both types of lineaments can be found in the rock.

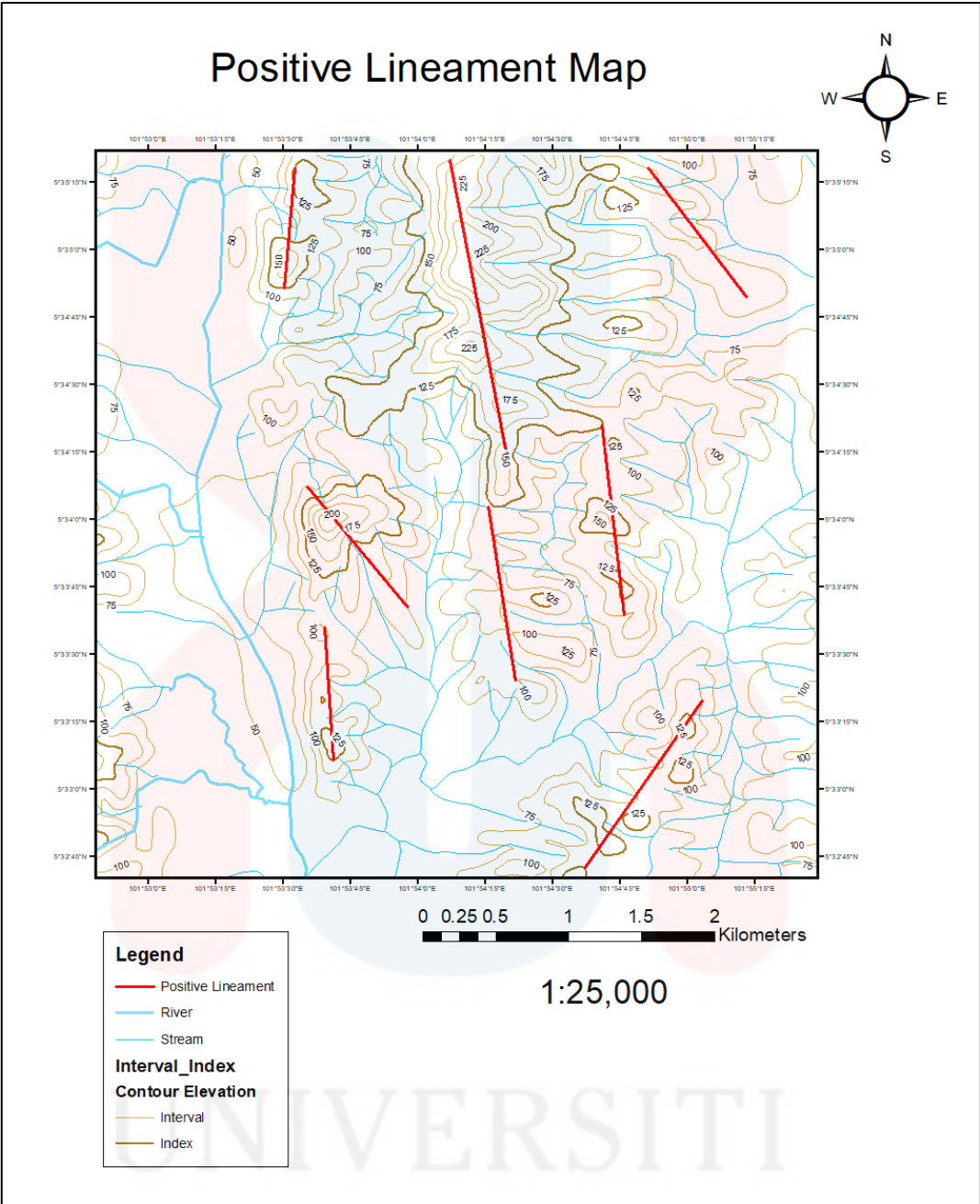


Figure 4.10: Positive lineament map of study area.

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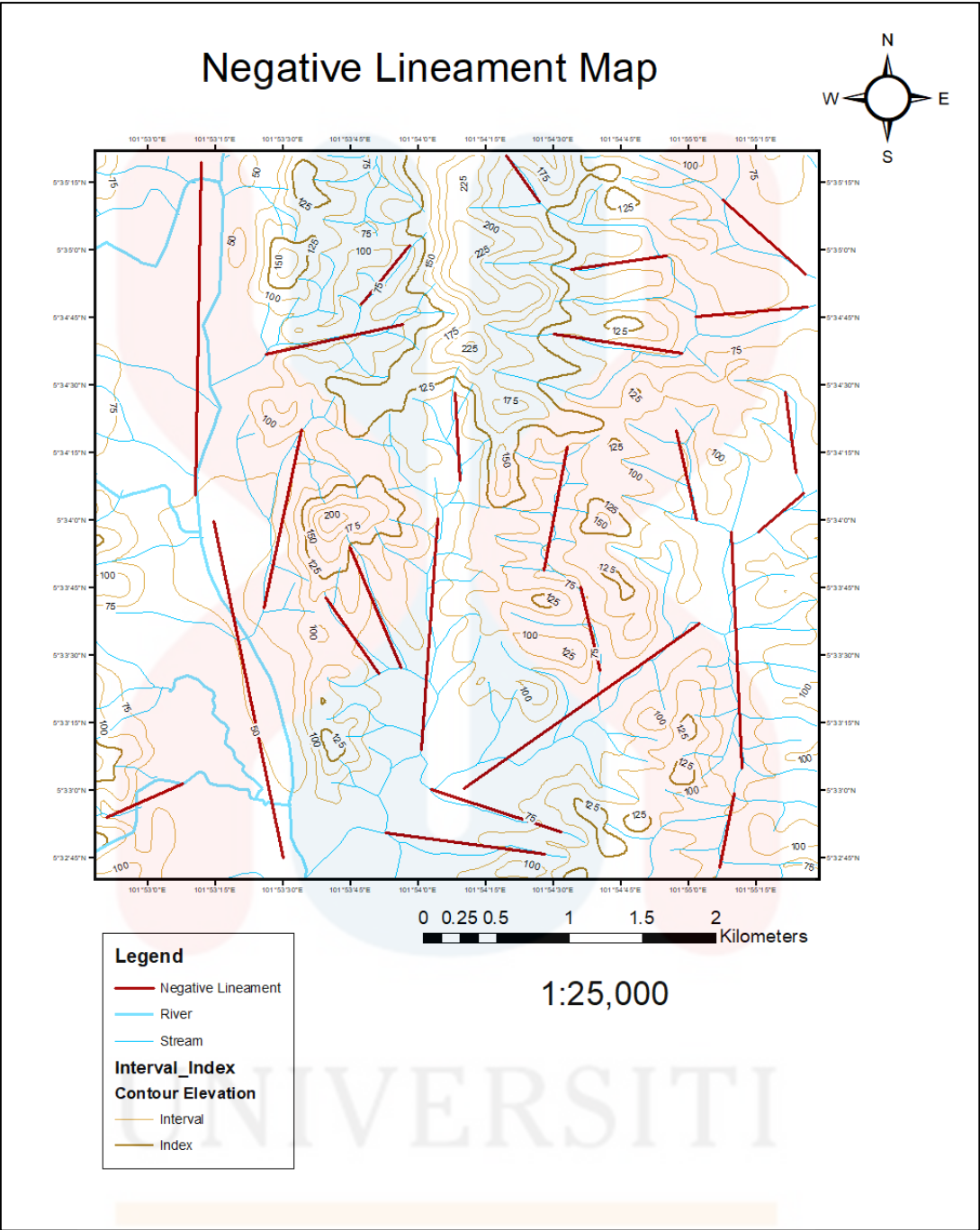


Figure 4.11: Negative lineament map of study area.

4.4.2 Fault

A fracture or zone of fractures that runs between two different blocks of rock is called a fault. The blocks can move in relation to one another according to faults. This movement might take place suddenly, as in the case of an earthquake, or it can take place gradually, as in the case of creep. It's possible for faults to be as short as a few millimetres or as long as thousands of kilometres. Most faults are responsible for producing recurring displacements across geologic time. When an earthquake occurs, the rock on one side of a fault abruptly slips with respect to the rock on the other side of the fault. The surface of the fault can be horizontal or vertical, or even at an arbitrary angle somewhere in between. Normal faults, reverse faults, and transform faults are the three fundamental kinds of faults that can occur in a system. In addition to these, faulting can further be subdivided into strike slip fault, oblique fault, and dip-strike fault.

The fault identified in the research region is a sinistral strike slip fault. This strike slip fault consists of vertical fractures caused by horizontal block movement. This fault is also known as a left-lateral strike slip fault if it occurs when the side moves in the opposite direction to the left. This faulting interpretation is based on the study of lineament analysis data.

4.4.4 Mechanism of structure

From the study of lineament, the strike reading is recorded and displayed on the rose diagram. Figures 4.12 and 4.13 shown rose diagram data from the positive lineament and negative lineament.

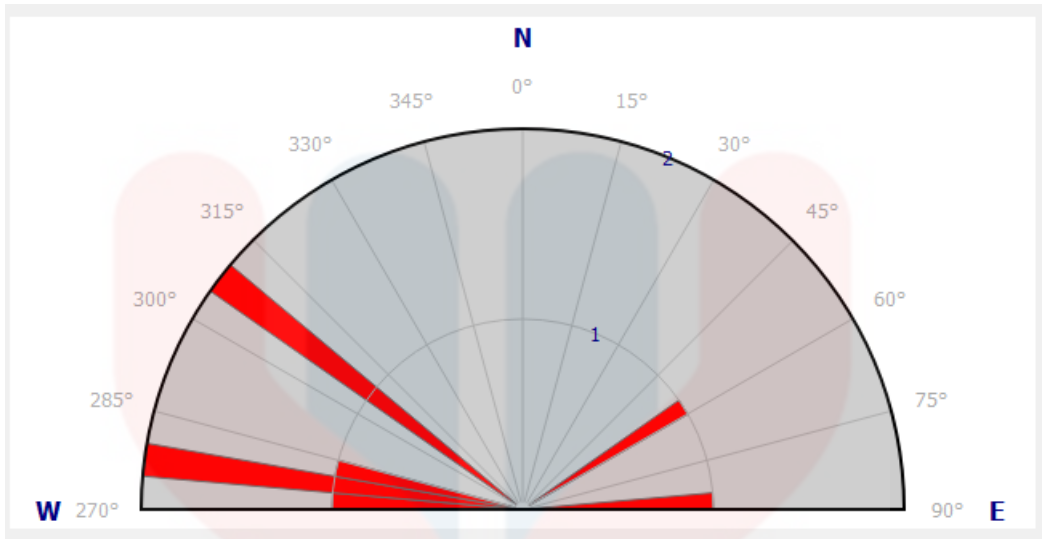


Figure 4.12: Rose diagram for positive lineament analysis.

The tension created by the ridge started between the north-west and south-east, based on the rose diagram Figure 4.12. As a result, the predominant shear is to the right, indicating the deformation direction, which is northwest to southeast. Shear direction for Figure 4.13 show it is in 4 direction which are north-west, south-east, north-east and south-west. This due to compressional stress.

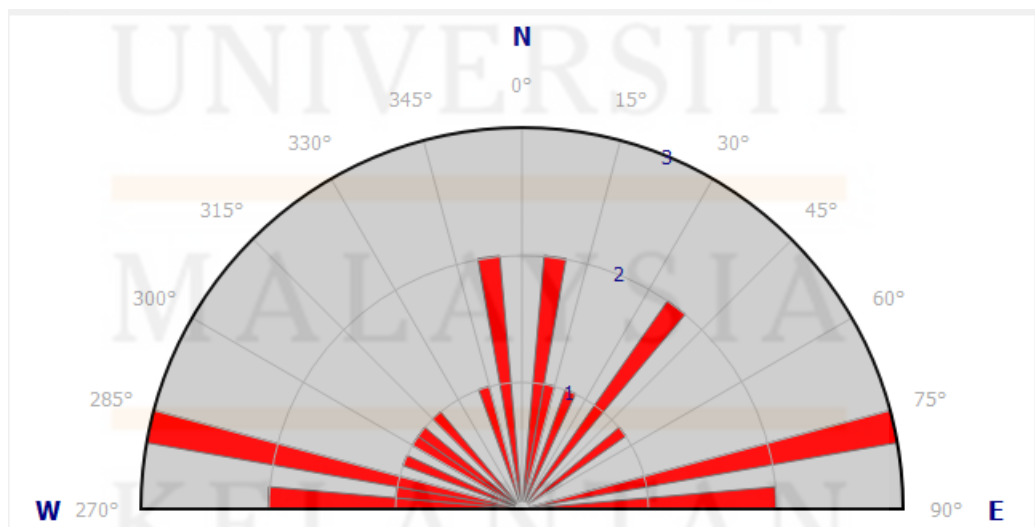


Figure 4.13: Rose diagram for negative lineament analysis.

A joint is a fracture or fissure in a rock mass that causes no discernible movement of the surrounding rock. Joints arise as a result of the stresses and strains that rocks experience as a result of tectonic movements, temperature, pressure, and other causes. They might be solitary or several and can have different orientations and shapes. Joints data was collected and plotted in rose diagram in Figure 4.14 with 135 readings in total. Based on rose diagram, show the force direction is in NW and tension direction is in E

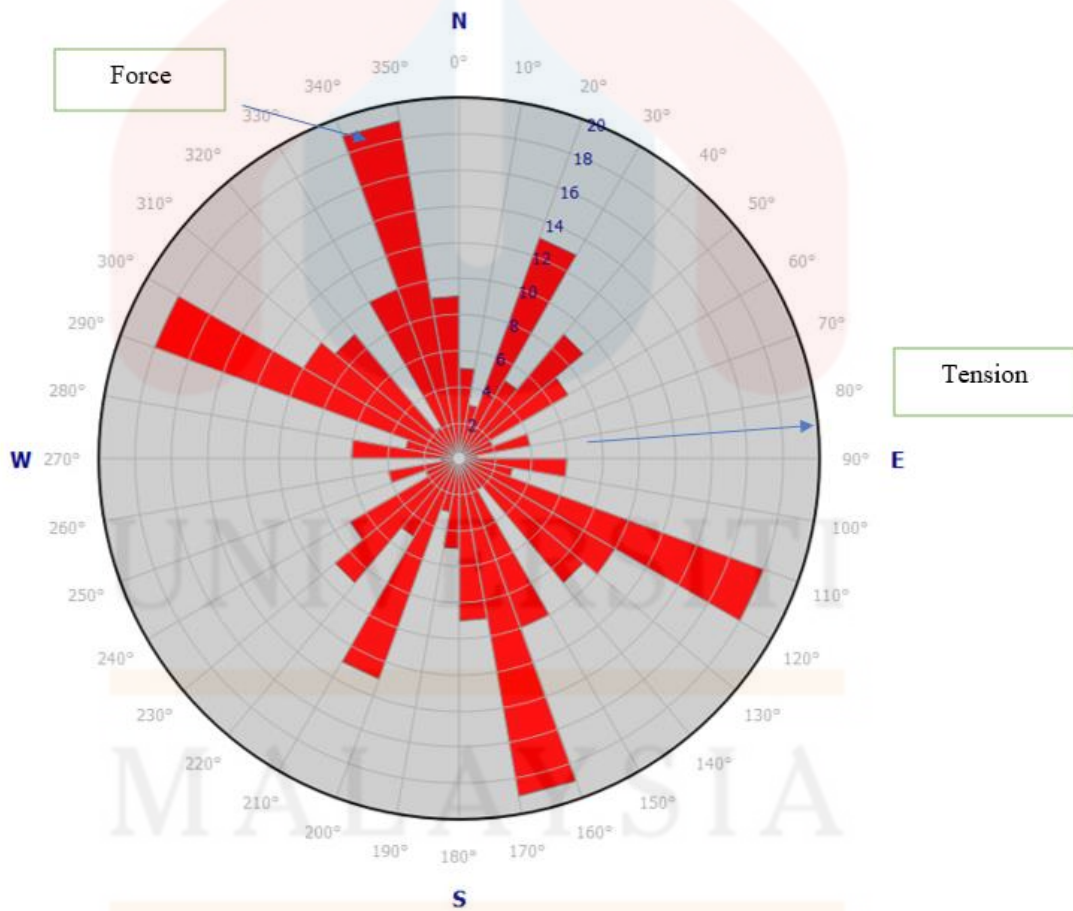


Figure 4.14: Rose diagram for joint analysis.

4.5 Historical Geology

Kampung Renyok area is composed of plutonic and metasedimentary rocks that are a component of the Migmatite Stong Complex. It is in the northern side of the Stong Complex, within the Kenerong Leucogranite plutons. Berangkat Tonalite is the oldest rock, followed by Kenerong Leucogranite, and Noring granite is the youngest rock. During the Permian Period, depositions of shale and mud-rich material began to occur in Kampung Renyok, where tectonic activity was accelerating. This deposition of shale continues until the Early Cretaceous (64-67 million years ago), when igneous intrusion uplift causes the formation of sedimentary rocks. Peninsular Malaysia's landforms are mostly the result of faulting and folding caused by tectonic activity in the Paleozoic and Mesozoic. According to Ibrahim Abdullah et al. (2003), the rock at Kampung Renyok has undergone at least four stages of deformation resulting the production of Kenerong Leucogranite, which consists of sub-parallel stretched leucogranite veins and metasedimentary enclaves.

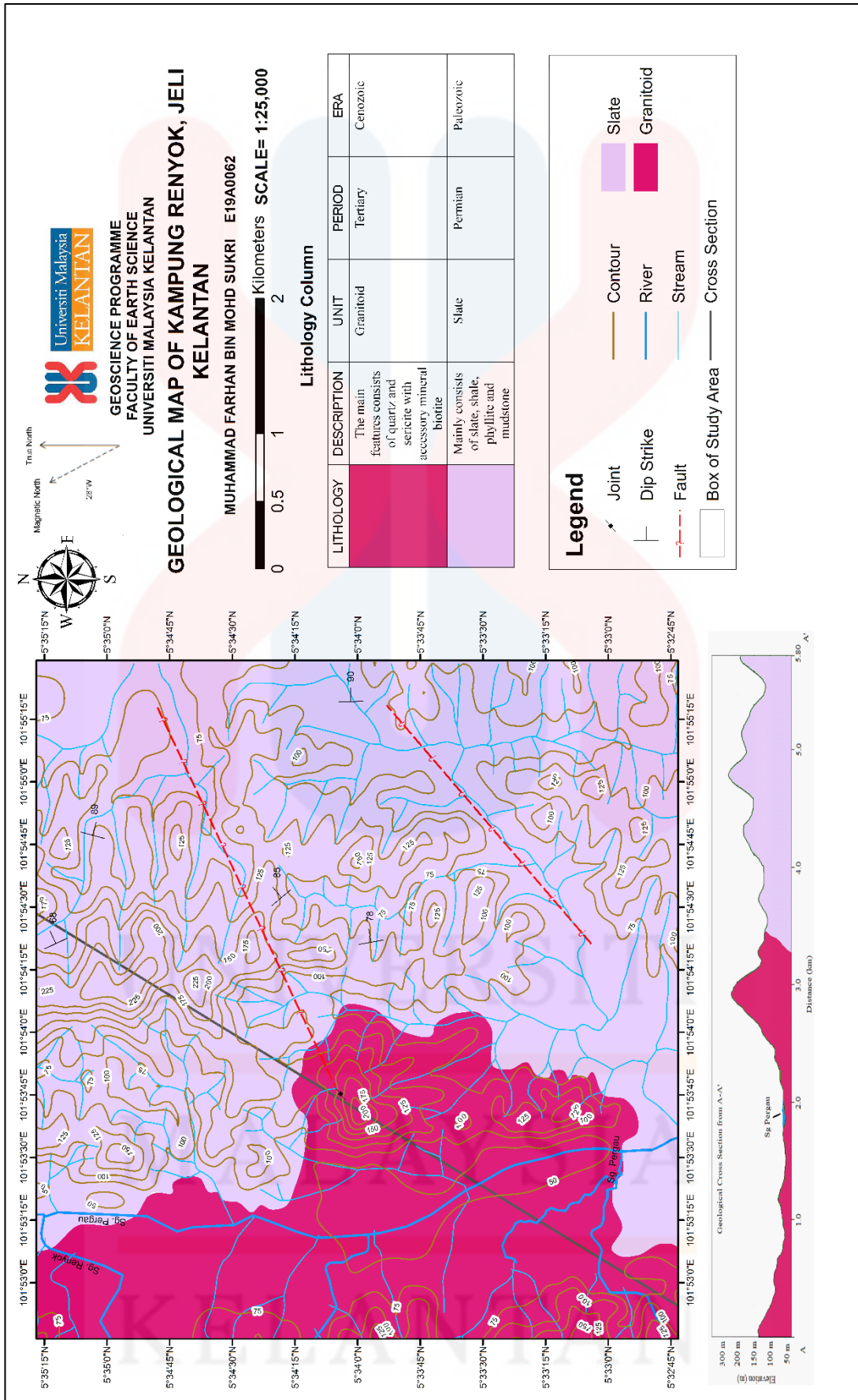


Figure 4.15: Geological map of Kampung Renyok, Jeli, Kelantan.

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY ANALYSIS

5.1 Introduction

In this chapter, the landslide susceptibility mapping in the study area of Kampung Renyok, Jeli is explained in further detail. There are six landslide parameters or causative elements used to assess the landslide susceptibility area. These include the lineament density, slope, aspect, lithology, landuse, and drainage density. The parameters will be manually layered in ModelBuilder using the Weight Overlay Method (WOM). Each parameter will be assigned a weighting score and will be overlay using ArcGIS tools. The distribution of parameter weights is shown in Table 5.1. Therefore, the final map created was the Landslide Susceptibility Map. This final map will depict areas that may be susceptible to landslides.

Table 5.1: The six parameters with weightage distribution.

Parameters	Weightage (W_i)
Lineament Density	9
Slope	10
Aspect	8
Lithology	7
Landuse	6
Drainage Density	5

5.2 Evaluations of Parameters

5.2.1 Lineament Density

The structurally controlled linear characteristics that can be discovered by nearly linear alignments are referred to as lineaments. Lineaments can be found in many different types of structures. In fact, lineaments can provide insight on the presence of faulting and fracture, both of which result in an increase in secondary permeability and porosity. Lineament analysis can be used in regional syntheses to identify the structural fabric of a terrane and direct attention to domain boundaries or zones of weakness. Therefore, the vulnerability to the potential for landslides can be determined by examining and evaluating the density of the lineament. The lineament indicates a weaker area of the landscape, where the strength of the slope material has been diminished, which results in slope failure, which in many cases lead to landslides. Therefore, differentiation in lineament density was a contributing factor in the occurrence of landslides.

In addition, there are three categorizations of lineament that have been identified in the research area, which is in Kampung Renyok. According to Figure 5.1, the value 1 indicates the lowest lineament density followed by value 2 with moderate density while the value 3 indicates the maximum lineament density. The highest group has the most impact on the frequency of landslide occurrences, whilst the lowest group has the least influence on the likelihood of landslide susceptibility. The lineament density weightage was 9, which has been referred to from Shaari M. S., (2019), and is multiplied by the score stated in Table 5.2, while Figure 5.1 displays the lineament density map of the research region.

Table 5.2: Lineament density weightage and score.

Lineament Density	Weightage (Wi)	Score (Sij)	(Wi x Sij)
Low	9	4	72
Moderate	9	6	54
High	9	8	36

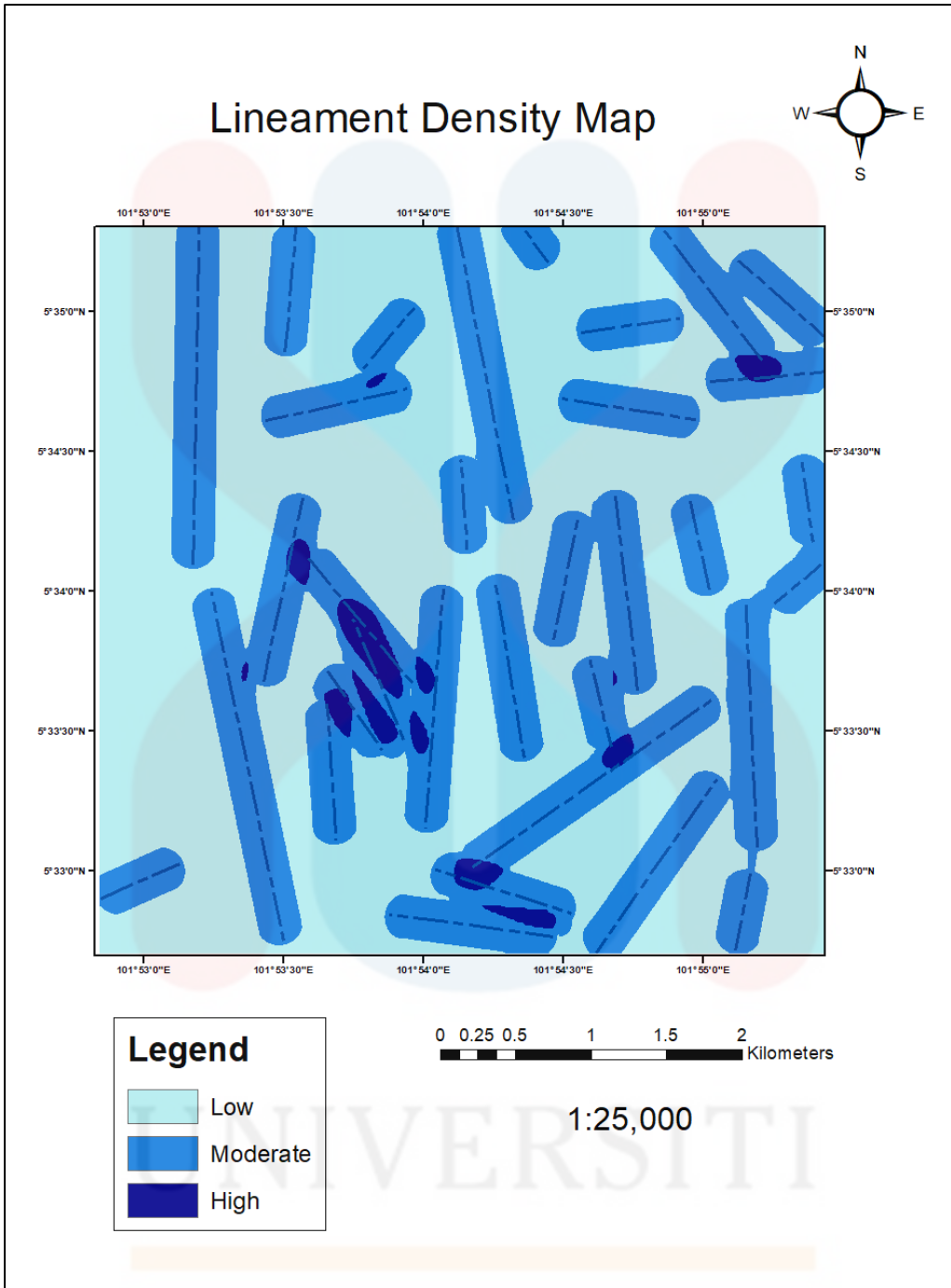


Figure 5.1: Lineament density map of Kampung Renyok.

5.2.2 Slope

In within scope of this study, slope was identified as one of the most important factors contributing to the incidence of landslides. The weakening of the soil and rock on the slope led to the landslide or erosion that happened further down the slope. The region under research was subdivided into three landform groups, which were land, low hill, and hill, respectively. The degree of slope can have a significant impact on the frequency of landslide occurrences. As the degree of slope increases, the susceptibility to landslide also increases because the force of gravity becomes greater. Furthermore, the steeper the slopes, the less friction force there is in the area, which raises the risk that a landslide will occur.

Flat, very gentle, gentle, moderate, moderately steep, and steep are the six primary slope classifications that are used in this study based on Figure 5.2. This slope classification, on the other hand, is determined by utilising a weightage of 10 and referring to the Malaysia Slope Classification, which was developed by the Geological Society of Malaysia (Table 5.3). This is due to the fact that it exerts a very strong influence on the probability of a landslide taking place. Majority of the west side of the research area is covered by angles ranging from 0° to 2° , which indicates a flat area that is primarily dispersed around Sungai Pergau, the primary river. While on the eastern side of the map of the research area there is a steep slope that has an angle ranging from 20° to 30° covered.

Table 5.3: Slope weightage and score.

Slope Class	Weight (W_i)	Score (S_{ij})	($W_i \times S_{ij}$)
Flat ($0^\circ - 2^\circ$)	10	0	0
Very Gentle ($2^\circ - 5^\circ$)	10	1	10
Gentle ($5^\circ - 10^\circ$)	10	2	20
Moderate ($10^\circ - 15^\circ$)	10	3	30
Moderately Steep ($15^\circ - 20^\circ$)	10	4	40
Steep ($20^\circ - 35^\circ$)	10	5	50

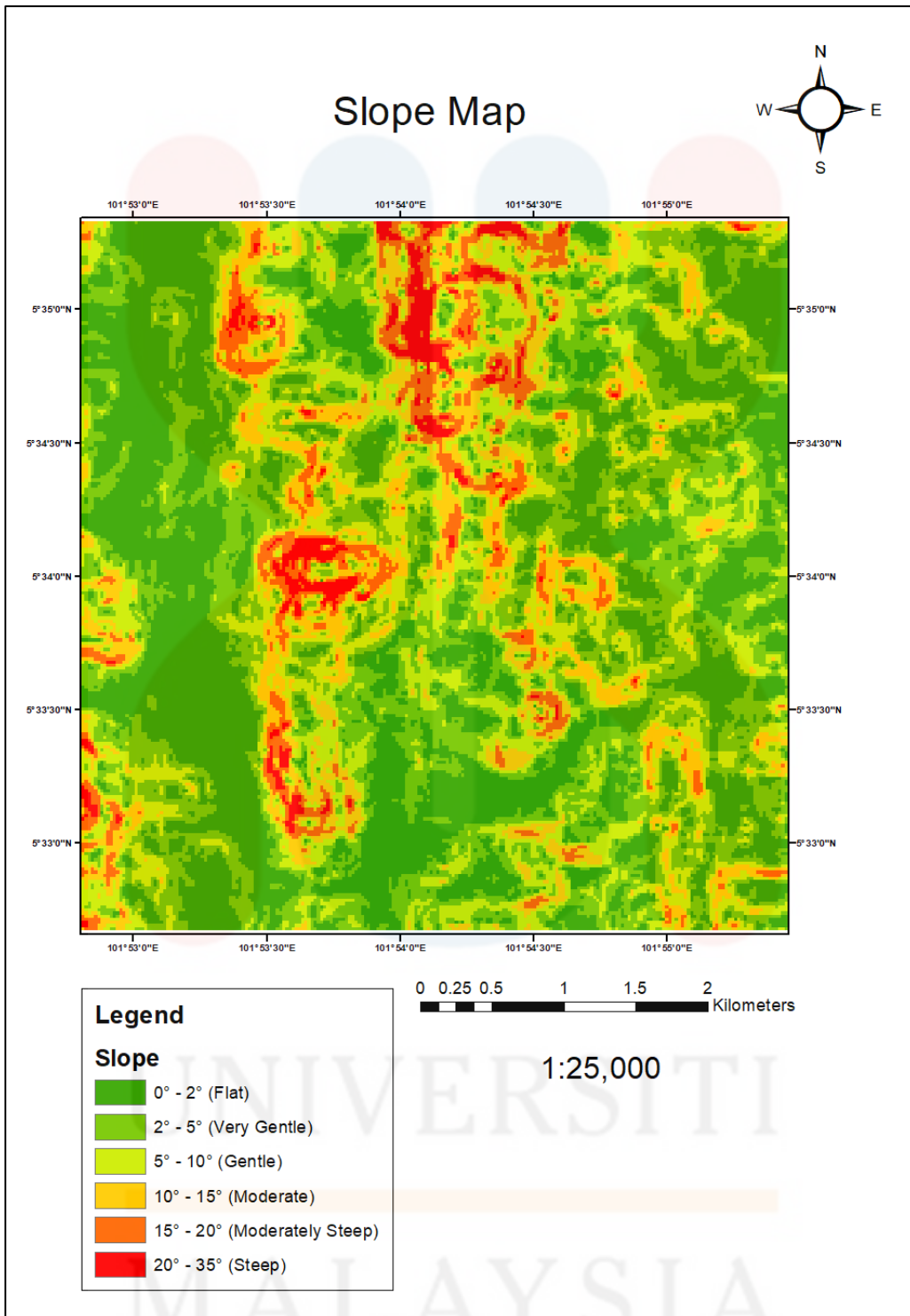


Figure 5.2: Slope map of Kampung Renyok.

5.2.3 Aspect

The vulnerability of a slope can be indirectly affected by factors such as its aspect. The DEM data were used as the basis for the generation of the aspect map. The aspect map displayed the slope direction of the ground in relation to the direction of North for a terrain, and this map was separated into 8 different classifications of slope direction. A variety of different impacts caused by the gravitational force are related with the various directions of slope maps. Because every area affected by a landslide has its own unique morphological structure, it is impossible to generalise about the appearance of the area. In other words, there is no one single factor that contributes to the development of landslides. In most cases, landslides take place in regions that are exposed to more than one direction. The direction and slope of a landscape are simultaneously displayed on an aspect map in the same way. As a result, considering it as a component in the assessment and generation of landslide susceptibility maps is essential.

Table 5.4: Aspect weightage and score.

Slope Direction	Weightage (W_i)	Score (S_{ij})	($W_i \times S_{ij}$)
Northeast	8	3	24
East	8	5	40
Southeast	8	6	48
South	8	9	72
Southwest	8	6	48
West	8	5	40
Northwest	8	2	16
North	8	1	8

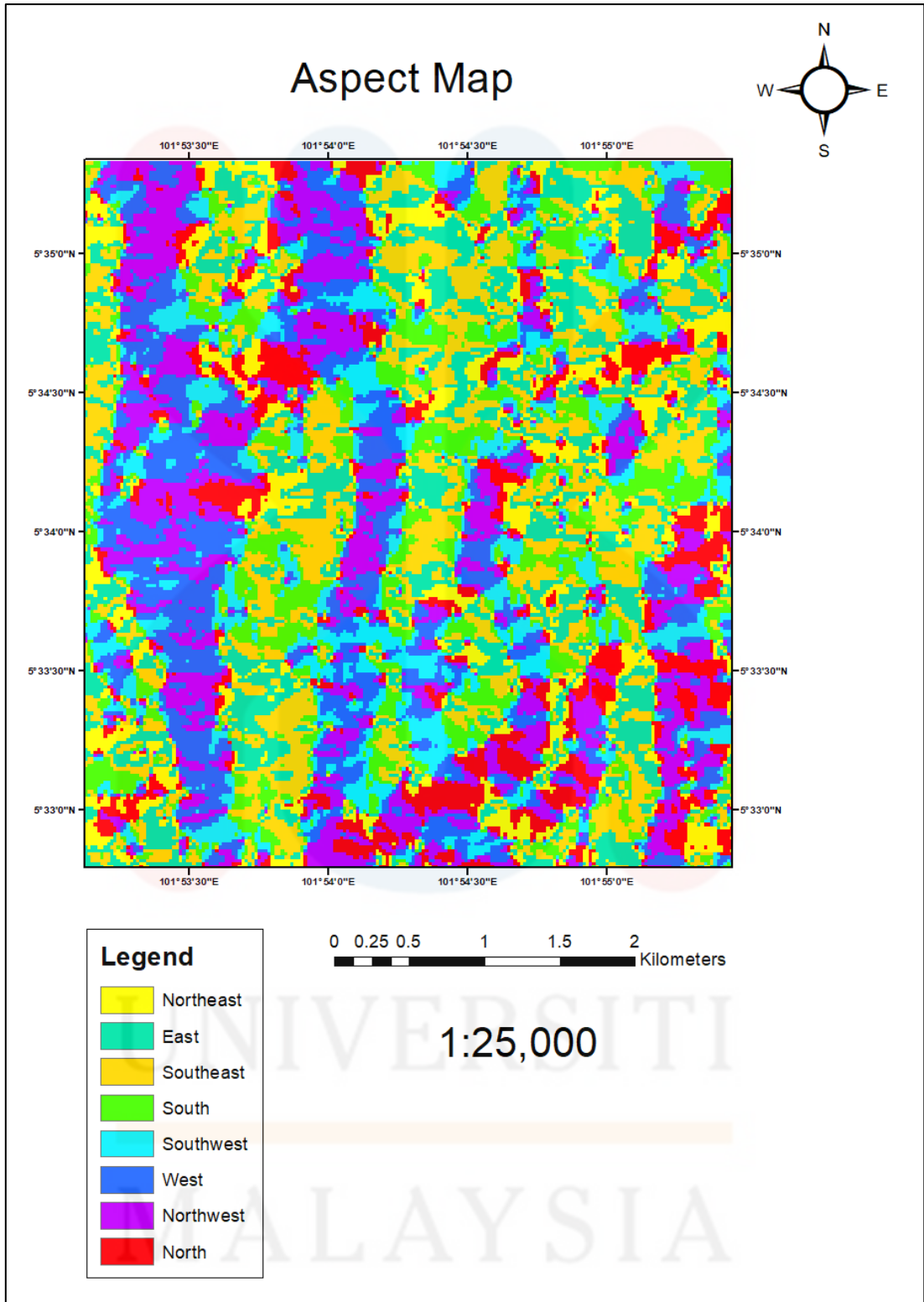


Figure 5.3: Aspect map of Kampung Renyok.

5.2.4 Lithology

In order to ascertain whether landslides are present in the area under investigation, a lithology map was produced using a geological map. Variations in lithology play an important part in the process since different lithologies have varying degrees of susceptibility to the threat posed by landslides. In addition, the characteristics of rocks can be differentiated based on their lithology and formation conditions.

The area that was covered with granitoid rock had the highest potential area to occurrence of landslide due to the weathered condition that results in relatively significant slope instability, and it was also the area that had the most potential area to occurrence of landslide. When compared to the other types of lithology in the research region, the area with metasedimentary rock can be described as having a moderate risk of landslides. Granitoid rock and metasedimentary rock that is predominately slate, with smaller amounts of shale, phyllite, and mudstone make up the two types of lithological units that can be found in area. The lithology category has been given a weighting of 7.

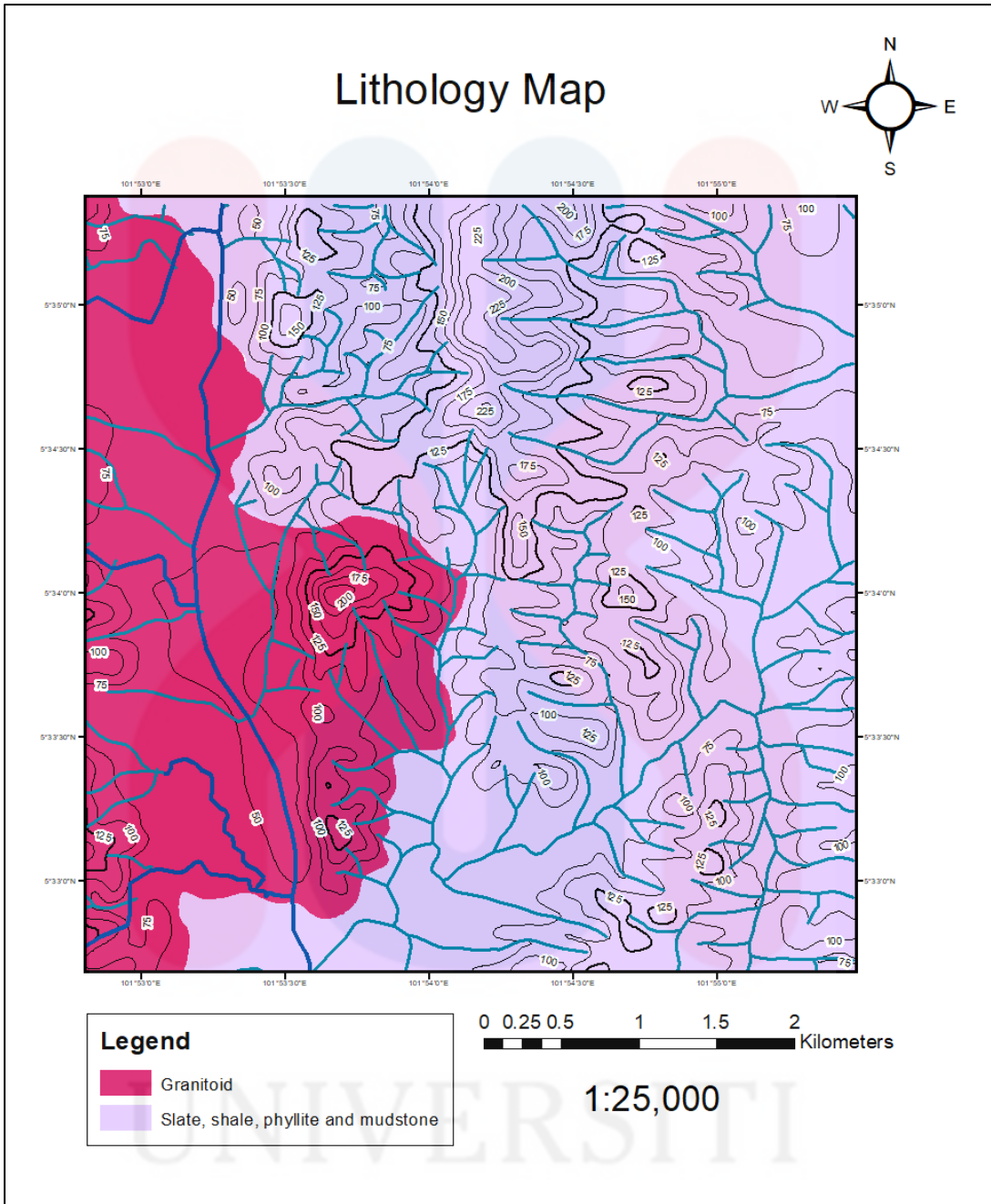


Figure 5.4: Lithology map of Kampung Renyok.

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5.2.5 Land Use

The majority of the land was plain and located at a lower height, and it consisted of grassland, settlement areas, and cropland. The area of the map that is at a moderate elevation is covered by forest land, and a big area of palm oil plantation is located there as well. The area of the map that is at the highest elevation is covered by mixed plantation. The amount of land cover is really one of the factors that can influence how stable the slope is. In addition, the occurrence of landslides can be sped up and will have a substantial impact as a result of human activities such as cutting down trees to construct a structure. This is because human activity creates more instability in the landscape. According to Shaari, M. S. (2019), land use received a weightage of 6.

Table 5.5: Land use weightage and score.

Land use	Weightage (W_i)	Score (S_{ij})	($W_i \times S_{ij}$)
Clear land	6	2	12
Forest	6	1	6
Palm oil	6	4	24
Mix plantation	6	3	18

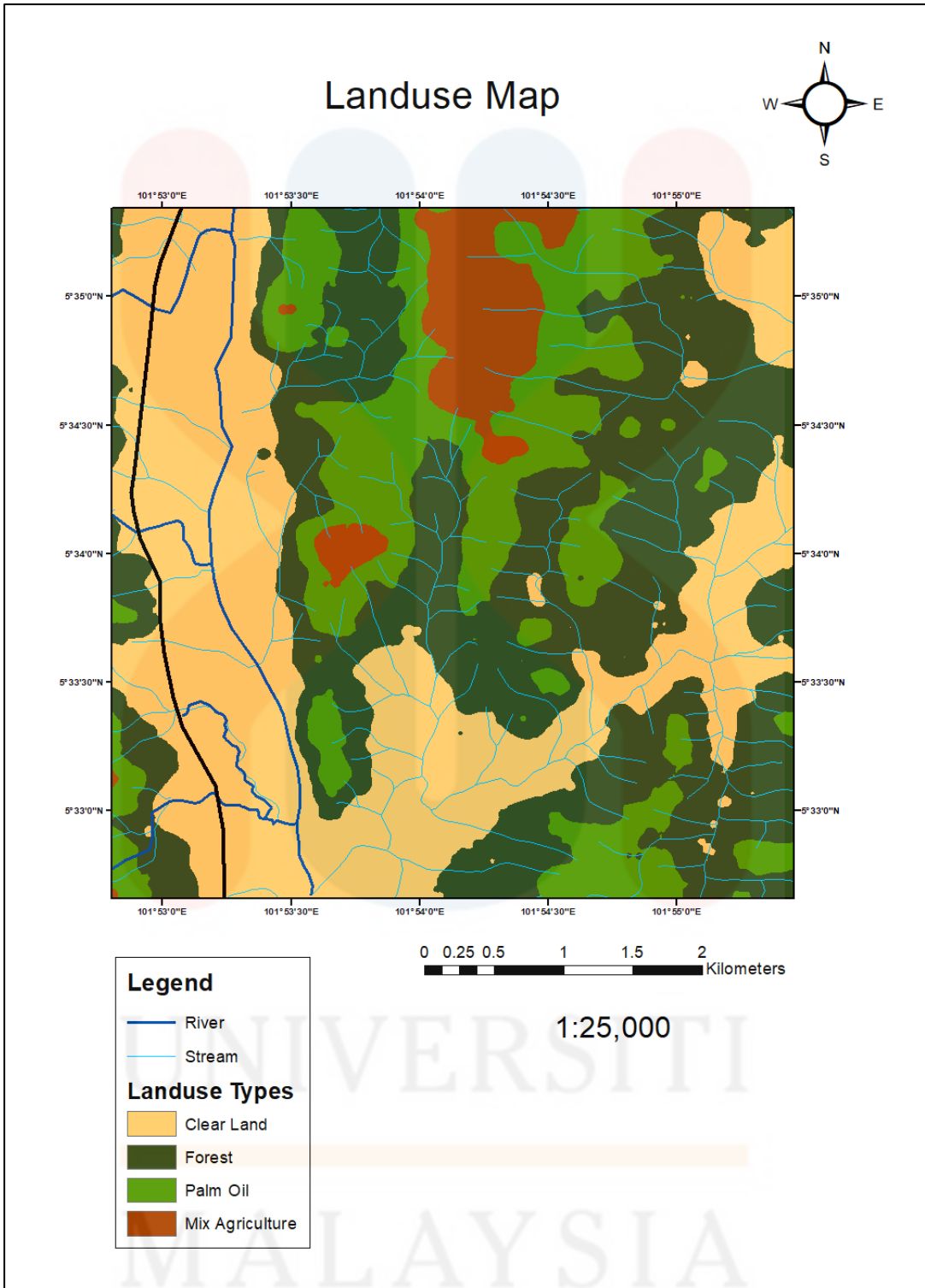


Figure 5.5: Land use map of Kampung Renyok.

5.2.6 Drainage Density

Drainage density map was produced using the input from DEM with the help of Google Earth. Importantly, the slopes' proximity to networks of streams seems to be another important factor that affects their stability. The climate and physical features of the drainage basin affect how much water flows out of it. The runoff in a watershed is affected by the soil's permeability and the type of rock underneath. If the ground is hard or exposed, there will be more surface water runoff and more streams. Clay and solid rock are examples of materials that have poor hydraulic conductivities. These types of materials would produce a system with a higher drainage density. Because of the low hydraulic conductivity, very little water is lost through infiltration. Instead, most of the water that enters the system does so in the form of runoff, which can contribute to erosion.

The research area has drainage density that can be categorised as low, moderate, and high on a scale from lowest to highest. The area with the moderate drainage density occupied the largest portion of the research area, which was subsequently followed by the area with the low drainage density and finally the area with the high drainage density. Values of drainage density that are high encourage surface runoff, which indicates an increased potential for landslides. Table 5.6 present weightage and scoring for drainage density and Figure 5.6 represent drainage density map of study area.

Table 5.6: Drainage density weightage and score.

Drainage Density	Weightage (W_i)	Score (S_{ij})	($W_i \times S_{ij}$)
Low	5	4	20
Moderate	5	6	30
High	5	8	40

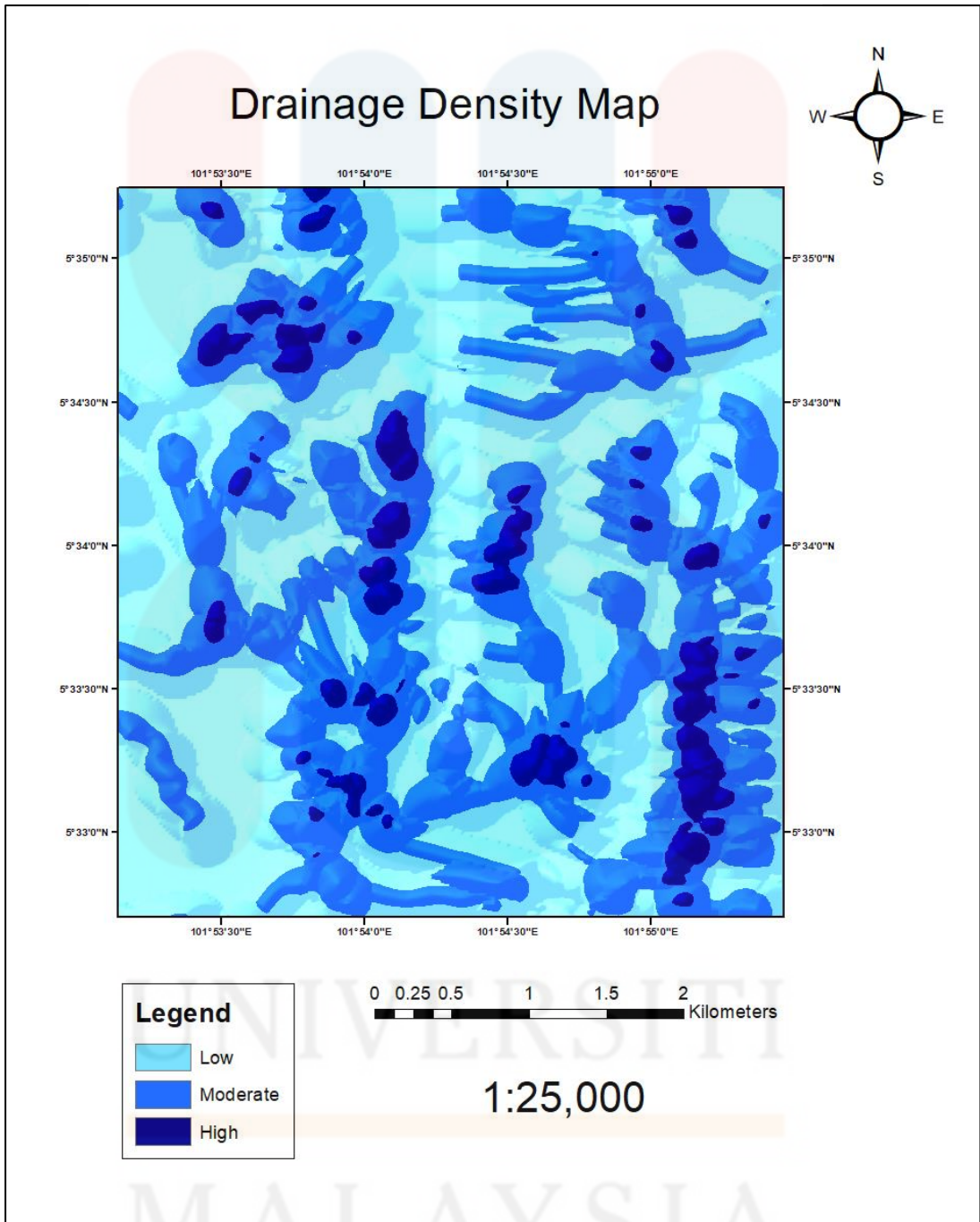


Figure 5.6: Drainage density map of Kampung Renyok.

5.2.7 Landslide Susceptibility map

The final product of this research was a landslide susceptibility map, which was created to highlight landslide-prone areas in 3 categories: low, medium, and high risk. The map was generated by using the ModelBuilder tool provided by the ArcGIS software, which allowed it to determine the landslide prone area. Six parameters were utilised to create this landslide susceptibility map: lineament density, drainage density, slope, aspect, land use, and lithology.

Each parameter has been allocated a weightage value based on its influence on landslide hazards. Before applying the Weight Overlay Method (WOM) in the ModelBuilder application, all six parameters must be reclassified depending on their class. In this stage, the overlay procedure for each parameter must adhere to the weight values supplied to each parameter. After all the data has been overlaid, the model must be run, and the landslide susceptibility map will be generated based on all six parameters and their weight values. Figure 5.7 show model of landslide susceptibility.

According to Figure 5.8, the study area was divided into three zones of landslide susceptibility in the study area, which covered approximately 63% of the area that has moderate susceptibility to landslide, 20% of the study area that is highly susceptible to the landslide, and 17% only that has low susceptibility to the landslide hazard.

In general, slope and aspect are often defined as characteristics that have a greater impact on landslide. Since slope stability provides the foundation for the frequency and intensity of landslide occurrences, it is one of the most essential elements in landslide susceptibility analysis. The higher the slope, the more likely the instability. The hilly and mountainous regions have a higher risk of landslides due to their steeper

slopes, which is why the research area was dominated by a moderate susceptibility area (63%). However, as drainage density and lineament density grow in an area, so does the vulnerability and severity of landslides. Water is a factor that causes landslides because it increases the weight of soil and rock elements. Landslides occurred because of lineament density differentiation because the lineament symbolises a weaker area of the environment in which the stability of the rock mass has been diminished, resulting in slope instability.

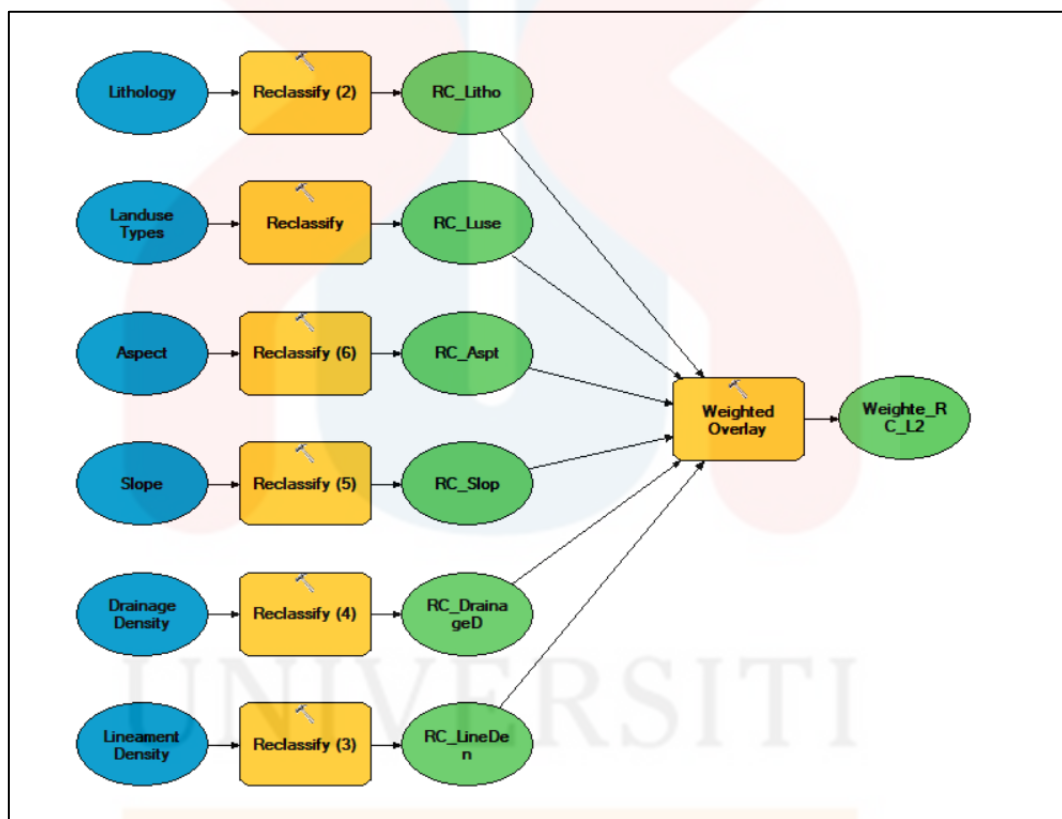


Figure 5.7: Model of landslide susceptibility that was produce using ModelBuilder.

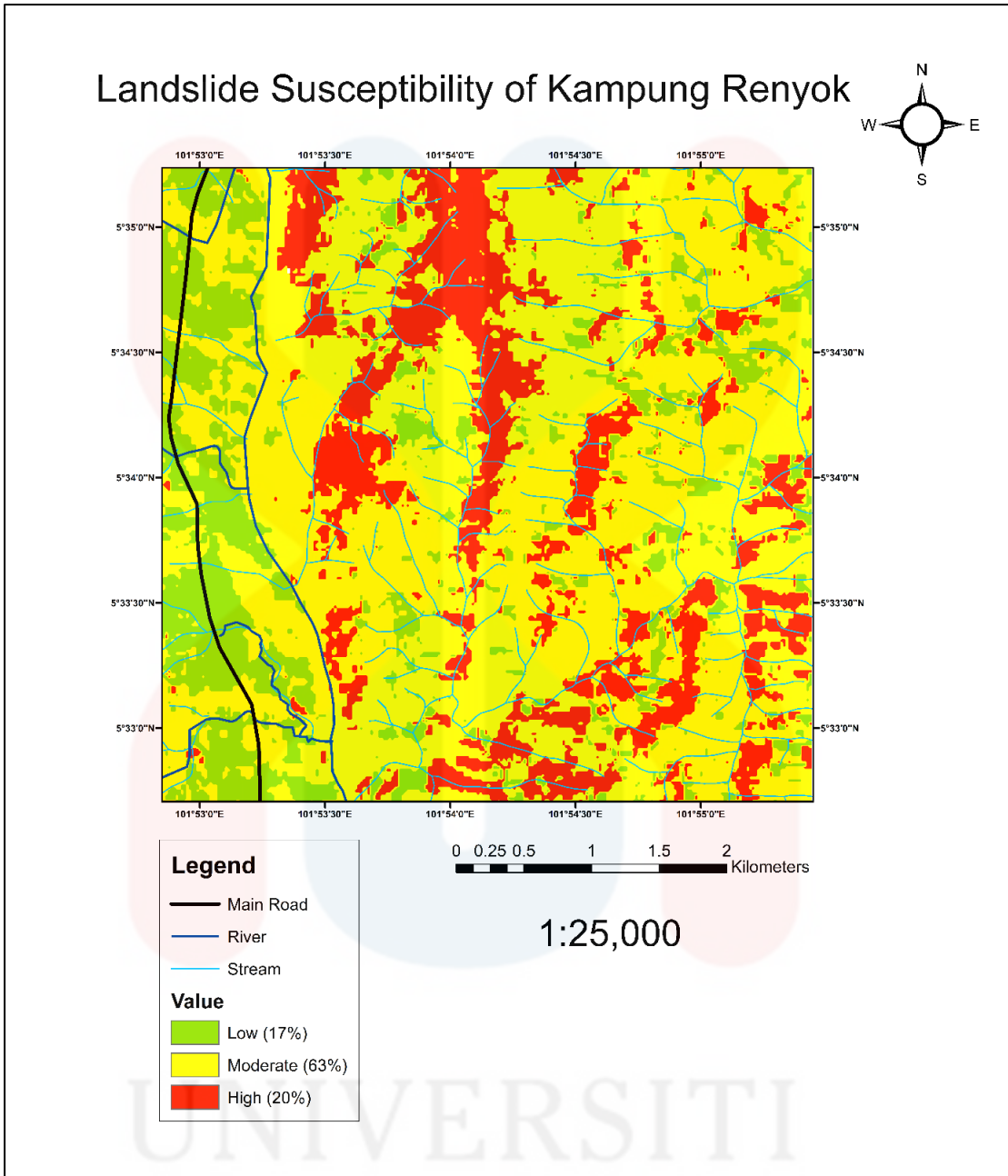


Figure 5.8: Landslide susceptibility map of Kampung Renyok.

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CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This chapter summarises all the findings from the general geology and landslide susceptibility analyses, as well as the evaluation utilising GIS and remote sensing methods to acquire results.

As a result, all the research aims were attained. The main objective is to update a geological map of Kampung Renyok, Jeli at a scale of 1:25000 using online interpretation and secondary data from previous study. The geological map has been created, and geological data and information such as lithology, structural geology, and historical geology have been added.

The research area's lithology was separated into two units: granitoid rock and metasedimentary rock. This rock distribution is comprised of the Stong Migmatite Complex and the Telong formation. Furthermore, there are two periods of lithology units in the research region, such as the oldest unit named permian-aged rock from Telong formation metasedimentary that consists of shale, slate, phyllite, and mudstone. The youngest unit called tertiary-aged intrusive rock from Stong Migmatite Complex. Petrography analysis identified it was granitoid rock.

The second objective was achieved since numerous factors controlled the occurrence of landslides. External variables that might cause landslides to have been recognised as rainfall and anthropogenic activity. However, in ArcGIS software, rainfall elements were not used as parameter because it is quite costly to get the latest

rainfall data. However, rainfall intensity also has a role in landslide formation. The slope is the primary cause of landslides in the studied region.

The third objective was a research specification which was to create a landslide susceptibility map using ModelBuilder in ArcGIS software with identified input which are 6 parameters that possibly affecting landslide susceptibility in study area. The objective has been accomplished since the Landslide susceptibility map has been created as illustrated in Figure 5.8.

Basically, there are 3 different types of areas that are prone to landslide occurrence: low, moderate, and high susceptibility to landslide. The study region was further divided into percentages, with moderate susceptibility representing for 63% of the study area and low and high susceptibility representing for 17% and 20%, respectively. As a result of the high and hilly terrain, landslides are prone to occurring at high to moderate levels in the area. This is because, in general, extreme rainfall events occur at higher elevations, and the water flow carries debris, soils, and rock materials to the lower section of the slope or hills. It is also important to note that hilly terrains have a higher drainage density, which leads to the same problem, especially during the rainy season. Aside from that, hilly terrain has a higher level of slope than the lowland terrain, which may cause a landslide to occur because gravity might create a force that pushes the material downhill.

Additionally, lowland regions are less prone to landslides since their terrain is at a lower level, resulting in slopes that are more gradual or less steep, leading to a reduced gravity impact compared to hilly and mountainous places. Furthermore, drainage density is lower at lower elevations than at higher elevations, putting the region fewer vulnerable to landslides.

6.2 Recommendation

Since there are some limits to this research, several recommendations for additional research have been made. First, there is a requirement to use secondary data. Rainfall data, structural geology data, and soil data are a few examples. So, the criteria that must be utilised should be considered if there is a lack of secondary data throughout online interpretation. As a result, the findings, such as geological mapping, may be erroneous. Many organisations, including the Department of Mineral and Geoscience and the Department of Surveying and Mapping Malaysia, can provide secondary data (DSSM). Therefore, the effort to approach these authorities must be taken seriously in order to obtain an accurate and improved study result.

Aside from that, it is recommended that the landslide susceptibility mapping approach be utilised for landslide research since it is more accurate because the data was obtained and seen in the field. If the parameters used for landslide susceptibility mapping are substantially more than those used in this study, it will be more formal and accurate.

Following that, high-quality DEM data must be applied. When using low-resolution DEM data, the results or pictures created by ArcGIS are not precise and sharp enough. Agencies such as the Department of Mineral and Geoscience can provide high-quality data. As a result, before doing research, actions to approach the agency must be prepared.

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