GEOLOGY AND LANDSLIDE POTENTIAL ANALYSIS USING GEOGRAPHIC INFORMATION SYSTEM(GIS) IN KAMPUNG KALAI, JELI, KELANTAN

by

MUHAMMAD AMAR BIN ABDULLAH

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

FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN

2023

DECLARATION

I declare that this thesis entitled **"GEOLOGY AND LANDSLIDE POTENTIAL ANALYSIS USING GEOGRAPHIC INFORMATION SYSTEM(GIS) IN KAMPUNG KALAI, 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 AMAR BIN ABDULLAH

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"

Signature : ……………………………........

Name of Supervisor : DR. WANI SOFIA BINTI UDIN

Date : ………………………………..

Signature : ……………………………........

Name of Co-Supervisor : DR. MOHD SYAKIR BIN SULAIMAN

Date - …………………………………….

ACKNOWLEDGMENT

First of all, Alhamdulillah all praise is to Allah the Almighty, due to his blessing, my journey of final year project was easier and simplified with good health, new knowledge and loving people who surround me from beginning towards the end of this research. I would like to express my gratitude to both of my parents, En Abdullah bin Mohd Amin and Pn Zamilah Tulai binti Mohd Nor and also my family members who's always supporting me mentally, physically and financially. They are always believing and support of me in everything I do. Their prayers are always with me.

I would like to express my deepest gratitude to my supervisor, Dr Wani Sofia binti Udin, my thesis advisor, for her unwavering support and encouragement throughout the entire process of researching and writing this thesis. I grateful for all the time she has dedicated to my work that keeps on guiding me throughout the entire project since FYP 1 till now. She also keeps me on the right track in order to complete the project. Furthermore, I would want to thank Dr. Syakir bin Sulaiman, my co-supervisor, for constantly listening to all of my difficulties and teaching me about geological mapping, as well as guiding me in doing map.

Finally, my dearest love and appreciation to all of my friends especially to my close friends that give supports and help throughout the thesis completion, Nur Ariessa binti Zulfakar, Muhammad Farhan bin Sukri, Adeel Hakeem Bin Ahmad Sayuthy, Ahmad Rieeshi Iman Bin Mazri, Abdullah Abbas Bin Musa, Tengku Muhammad Huzairullah bin Tengku Muda Asseri, Afiq Akmal bin Ramli, and Saif Danisy bin Zaidi. Next, I also would like to thank my mapping partner Kaz Nezhan bin Khalib, Muhd Afif Zaafarani and Muhammad Che Ros bin Mohammed that lend me his motorcycle, show routes in the study area and everyone that involved directly or indirectly in this research project. Thank you once again.

Geology And Landslide Potential Analysis Using Geographic Information System (GIS) In Kampung Kalai, Jeli, Kelantan

ABSTRACT

Kampung Kalai is in the district of Jeli, Kelantan and dominated by small community. The study area covers 32km^2 which aligned within latitude 5°46'44.96"N to 5°42'24.58"N and longitude 101°44'26.51"E to 101°42'16.53"E. Kampung Kalai's landscape is plain areas and slightly hilly areas. The highest elevation is 680 meters, and the lowest elevation is 40 meters respectively found near Gunung Reng. In the research study, landslides often occur at the highest elevation due to the effects of gravity. This study aims to generate the geological map of Kampung Kalai, Jeli, Kelantan with scale 1: 25 000. The factors that triggered the landslide risk potential at Kampung Kalai were also analysed. Geological mapping for the present project relies on fieldwork, including collecting samples from fresh outcrops and observing geomorphological features, drainage patterns, and others. Lithological findings in Kampung Kalai are schist, meta quartz rich granitoid and meta mudrock that ranging from the Triassic to the Carboniferous eras. Faults and folds were also found during structural trends recorded in rocks. Geological map was generated using GIS-based platform that processed all field data, including petrographic analysis. For landslides potential study, a raster-based GIS was used to generate thematic maps of six (6) variables including lithology, slope, aspect, lineament density, land use, and drainage density. The final output of landslide potential analysis map was created in ArcGIS using the Weightage Overlay Method (WOM). The results classify the potential map into three zones: low (50%), moderate (50-75%), and high (>75%). It was determined that the landslide happened due to the lithology and the slope. As a conclusion, this research gives accurate identification of the most likely failure spots within a landslide-prone zone.

Geologi dan Analisis Potensi Tanah Runtuh Menggunakan Sistem Maklumat Geografi (GIS) Di Kampung Kalai, Jeli, Kelantan

ABSTRAK

Kampung Kalai terletak di daerah Jeli, Kelantan dan didominasi oleh masyarakat kecil. Kawasan kajian meliputi 32km2 yang diselaraskan dalam latitud 5°46'44.96''U hingga 5°42'24.58''N dan longitud 101°44'26.51''E hingga 101°42'16.53''E. Landskap Kampung Kalai adalah kawasan dataran dan kawasan berbukit sedikit. Ketinggian tertinggi ialah 680 meter, dan ketinggian terendah masing-masing ialah 40 meter ditemui berhampiran Gunung Reng. Dalam kajian penyelidikan, tanah runtuh sering berlaku pada ketinggian yang paling tinggi akibat kesan graviti. Kajian ini bertujuan untuk menjana peta geologi Kampung Kalai, Jeli, Kelantan dengan skala 1: 25 000. Faktor-faktor yang mencetuskan potensi risiko tanah runtuh di Kampung Kalai turut dianalisis. Pemetaan geologi untuk projek ini bergantung kepada kerja lapangan, termasuk mengumpul sampel daripada singkapan segar dan memerhati ciri geomorfologi, corak saliran, dan lain-lain. Penemuan litologi di Kampung Kalai ialah sekis, granitoid kaya kuarza meta dan batu lumpur meta yang terdiri daripada era Triassic hingga Carboniferous. Sesar dan lipatan juga ditemui semasa aliran struktur yang direkodkan dalam batuan. Peta geologi dijana menggunakan platform berasaskan GIS yang memproses semua data lapangan, termasuk analisis petrografi. Untuk kajian potensi tanah runtuh, GIS berasaskan raster digunakan untuk menjana peta tematik enam (6) pembolehubah termasuk litologi, cerun, aspek, ketumpatan lineamen, guna tanah dan kepadatan saliran. Output akhir peta analisis potensi tanah runtuh telah dibuat dalam ArcGIS menggunakan Kaedah Timbunan Berat (WOM). Hasilnya mengklasifikasikan peta berpotensi kepada tiga zon: rendah (50%), sederhana (50-75%) dan tinggi (>75%). Telah ditentukan bahawa tanah runtuh berlaku disebabkan oleh litologi dan cerun. Sebagai kesimpulan, penyelidikan ini memberikan pengenalan tepat bagi bintik-bintik kegagalan yang paling berkemungkinan dalam zon yang terdedah kepada tanah runtuh.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DEM	Digital Elevation Model
GPS	Global Positioning System
WOM	Weighted Overlay Method
GIS	Geographical Information System
USGS	US Geological Survey Earth Resources and Science Center

CHAPTER 1

INTRODUCTION

1.1 General Background

Geologic mapping is a highly interpretive, scientific method for producing a variety of map products for a variety of purposes, such as assessing ground-water quality and contamination risks, forecasting earthquake, volcano, and landslide hazards, characterising energy and mineral resources and extraction costs, siting waste repositories, land management and land-use planning, and general education (David, 2004). There are three distinct ways in accomplishing a geological map such as following contacts, traversing, and exposure mapping. Traversing technique is used for observing outcrops along a patch to identify a variety of lithologies prevalent in the region by using Global Positioning System (GPS). This technique helps in completely covering the ground. According to David (2004), a geologic mapper's primary goal is to identify the composition and structure of geologic materials at both surface and deep levels of the Earth's crust using symbols and colours.

Geo-hazards or natural hazards that were caused by geological features and processes, create major risks to people, property, the natural and built environment (Lacasse et al., 2010). Most landslides in tropical nations like Malaysia were caused by heavy rain. There have been several cases when landslides have seriously threatened transportation infrastructure, environmental management, and tourism.

Landslides have become more common in developed regions of Malaysia because of the growing construction on hill slopes. Most Malaysia's landslides that caused the greatest damage happened on man-made slopes. Landslides are one of the most common natural catastrophes in Malaysia's mountainous locations. Even in populated places, landslides often occur especially during the rainy season (Mukhlisin et al., 2010).

Geographic Information Systems (GIS) has been an effective tool for conducting efficient analyses in the study of geologic hazards. GIS technology has the potential to be a powerful tool for spatial study and prediction of landslide hazards. Environmental data can now more efficiently collect, modify, and analyse environmental data on the potential of landslides. GIS was used to examine and assess the dangers of landslides. GIS is a comprehensive tool for collecting, storing, retrieving, analysing, and displaying geographical data from the real world (Mukhlisin et al., 2010).

It is essential to identify areas that are prone to landslides and create a geological map of the study area for the purpose of protecting people and preserving the integrity of local and national economies. Having an understanding of the types and distribution of soil and rock in an area can assist in identifying areas that are at risk and in making informed land-use planning and development decisions. Additionally, recognizing the location of previous landslides can aid in identifying potential future hazards. This geological map and the determination of landslide-susceptible zones are two of the most often studied hazard management topics. Using these maps, government agencies, planners, decision makers, and local landowners may come up with emergency plans to limit the damage to infrastructure and people's lives that might otherwise result (Kavzoglu et al., 2014).

1.2 Study Area

1.2.1 Location

The research take place in Kampung Kalai, Jeli which is characterized by small villages and agriculture activities. Kampung Kalai is in the Batu Melintang subdistrict and about 30 km from Jeli town. It is located in the northwest of the state of Kelantan, near to the Thailand border. The study area covers 32km^2 which aligned along from latitude 5°46'44.96"N to 5°42'24.58"N and longitude from 101°44'26.51"E to 101°42'16.53"E as shown in Figure 1.1. The landscape is plain areas and slightly hilly where the highest elevation is 680 meters, and the lowest elevation is 40 meters respectively found near Gunung Reng.

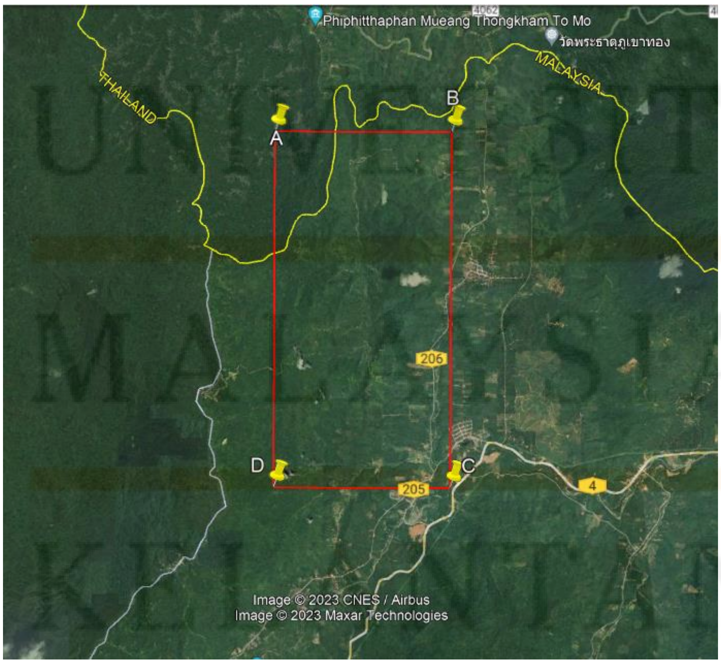


Figure 1.1: The satellite imagery of Kampung Kalai, Jeli, Kelantan (Source: Google Earth Pro).

Gunung Reng is an isolated, exposed limestone hill in low-lying areas. It also has a stunning geological landscape and unique geological characteristics that give geoheritage assets such as recreational and cultural advantages. Most low-lying regions are used for agricultural reasons. This study area also has main river in Kelantan which is Tadoh River. The research study area also has geomorphologically an undulating topography. The area covers by agriculture and settlement areas. Figure 1.2 shows the basemap of Kampung Kalai, Jeli, Kelantan.

1.2.2 Road Connection

Road connection and accessibility to Kampung Kalai is mostly situated in the central and western regions of the study area due to mining activity. The distance between UMK Jeli and Kampung Kalai is 24 kilometres which anticipated travel time almost 30 minutes. Most of the roads are paved, however there are a few unpaved roads or small trails in the rural regions where plantations, such as rubber plantations, are located. Because the area is predominantly filled with rubber and palm oil plantations, the primary road was used for daily tasks such as gathering rubber plant goods. In general, most part of the research study where easily accessible which vehicle can past through for economic and social purposes. However, there were certain aspects of the study that could not be access due to high elevation in the study area. The road access from UMK campus Jeli to the research location is shown in Figure 1.3.

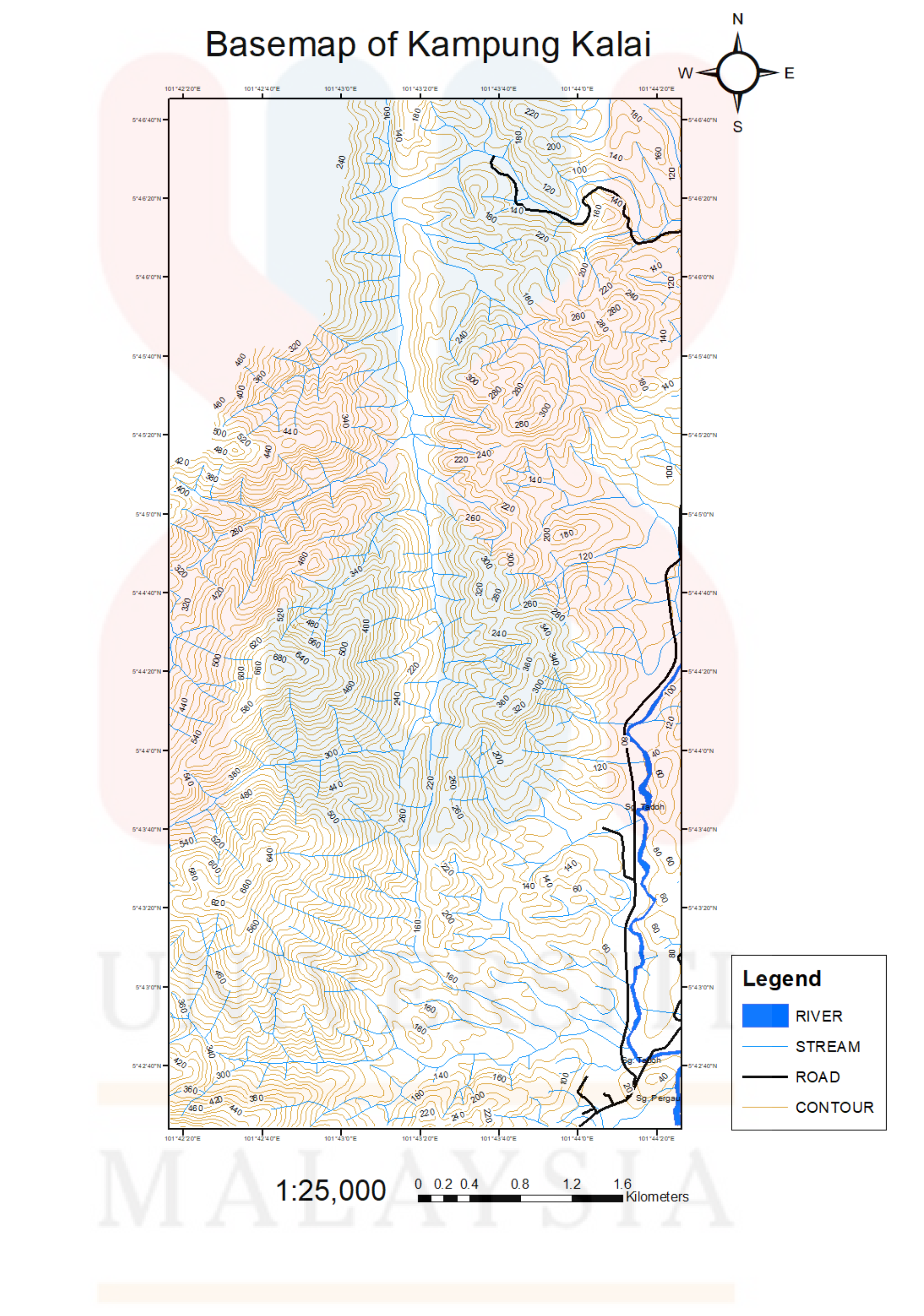


Figure 1.2: Basemap of Kampung Kalai, Jeli, Kelantan.

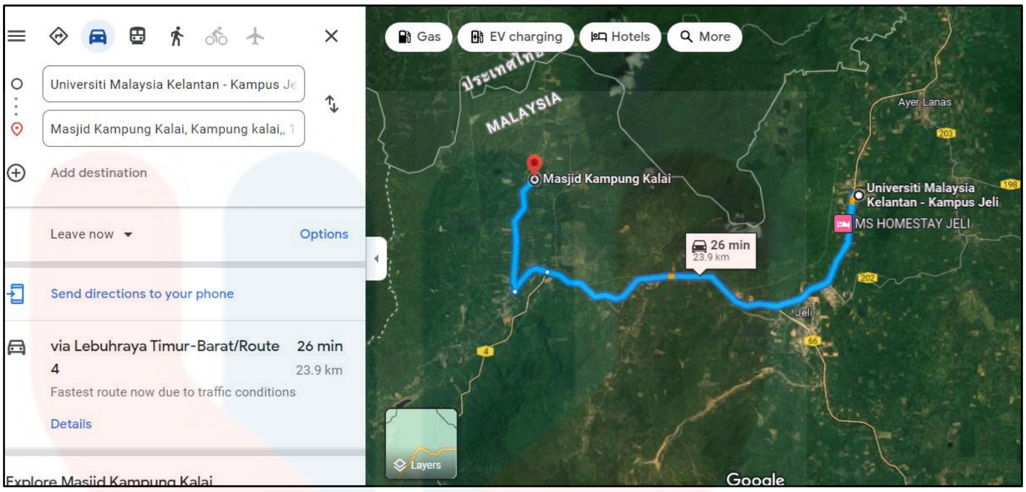


Figure 1.3: Road accessibility to the research study.

1.2.3 Demography

In 2022, the population of Jeli is estimated to reach 78,952 including all ages, sexualities, and races. The majority of Malaysians are of mixed ethnic backgrounds (Bumiputera, Chinese, Indian, and others), as reported by the department of statistical Malaysia. Malay people, known as Bumiputera, make up the largest ethnic group in the country. The percentage ages classes also show that the vast majority of Jeli's residents are under the age of 15 - 64 years old with 65.8%, with the elderly making up a much smaller proportion of the population between age of 65 years old and above. The total population estimate for Jeli, Kelantan is shown in Table 1.1.

Table 1.1: Estimation of population in Jeli 2022 (Source: DOSM, 2022)

Population	
Total	78,952
Citizen	76,917
Non-Citizen	2,035
Male	39,726
Female	39,226
Age classes (%)	
14 years and below	28.7
15 - 64 years	65.8
65 years and above	5.5
18 years and above	62.8
Ethnicity (%)	
Bumiputra	99.37
Chinese	0.22
Indian	0.23
Others	0.18

1.2.4 Land use

Beside the rubber and palm oil plantations, there are also other local fruit plantation such as banana are being planted on a limited scale for domestic use by Kampung Kalai residents. The land use in Kampung Kalai comprises of road infrastructure, plantation development, and a small space for human settlement such as mosque, housing area, shop, school, and numerous others. The landform also affects the social and economic well-being of the people who live and work within the village and in the plantation zone.

1.2.5 Social Economic

The agricultural activity has the greatest social and economic impact on the residents of the Jeli and Kampung Kalai surroundings. Most of the the region's economy is dependent on rubber tapping and palm plantation. In addition, the study area has a variety of shops, including a grocery store, auto services, and a restaurant. The residents of Batu Melintang also may purchase local vegetables, fruits, and raw materials at the grocery shop or wet market owned by the residents of Kampung Kalai. The study region is mostly composed of rubber and palm oil plantations. This research topic area focuses on the traditional economic activities of Malay residents, such as agriculture and carpentry.

1.3 Problem Statement

The study area is in Kampung Kalai, Jeli Kelantan, Malaysia. The absence of a current geological map is a factor in the study being carried out. Due to the recent changes in geological conditions in the study area, an updated geological map is necessary.

Landslides are a serious natural disaster that cause loss of life and property as well as environmental harm. Landslide can happen in many ways because of both natural and human causes. Certain parameters such as vulnerable soils, excessive rainfall, drainage pattern, height of contour may lead to landslides that are particularly dangerous. Landslides may become more common in the future because of population growth, infrastructural expansion, and increased forestry and agricultural activity on sloping terrain. Due to constantly experiencing significant climate changes, hot and humid tropical weather with relatively high humidity which may raise the danger of forest deaths and forest fires. It can increase in number and severity of landslides (Forbes et al., 2012).

This area is also affected by the Northeast Monsoon which usually starts from October to March. Extremely heavy rain falls in the eastern states of Peninsular Malaysia during the Northeast Monsoon. The likelihood of natural disasters like landslides and floods in Kelantan is increased during this season due to recorded rainfall. Landslide vulnerability in that area has become one of the geohazard to consider. More research is needed to help the local society and recognise the potential landslide risk in the research zone to protect people's lives and property from landslides in the research study.

1.4 Objectives

The research's goals are as follows:

1. To produce a geological map of Kampung Kalai, Jeli in 1:25000 scale
2. To identify the causes of landslides in the study area
3. To generate landslide hazard zonation (LHZ) map of Kampung Kalai

1.5 Scope of Study

The geological mapping included traversing and mapping in the study area to learn more about the study area’s features. The total area for this research is 32 km². The traverse is used to discover about the area's lithology, stratigraphy, and geomorphology. Geological mapping also includes sampling where the samples of igneous and metamorphic rock are gathered from the study area for use in petrographic laboratories as thin section material. Several tools and equipment are utilized throughout the traversing and sampling parts of this research, including a Brunton compass, a Jumbo hammer, a hand lens, tapes, and a Global Positioning System (GPS). Most field observations, such as collecting samples from fresh outcrops, noting structural trends in rocks, and noting the lineament in the research region, rely heavily on geological maps.

This research involved ArcGIS software in map production. ArcGIS is a software suite used for geographic information system (GIS) analysis and mapping. It is composed of four main components: a geographic information model for representing real-world elements, a data storage component for managing and storing geographic information in files or databases, and various tools for analyzing and visualizing the data. With the use of four primary components, ArcGIS may be used to create, edit, manipulate, map, analyse, and share geospatial datasets, as well as store and manage data. Before traverse, the information provided by ArcGIS can assist in doing preliminary research on the study area. ArcGIS makes it simple to collect, crowdsource, store, access, and share any data in an efficient and secure way.

This research also includes a map of the study area's landslide hazard assessment. GIS analysis was used to construct landslide risk maps using the Weighted Overlay Method (WOM), which contains raster-based GIS characteristics such as the slope, quantity of rainfall on the land, type of soil in the area, elevation, human activities lithology, and secondary data (Shit et al., 2016). Rainfall data was obtained from the United States Geological Survey (USGS) website. The intensity of the rainfall was collected from the USGS as part of the data used in the analysis of landslide potential in the study area. Data and information were gathered from a variety of sources in order to complete the research. Primary data include traverse, slope, land usage, and land cover area while the drainage system data was provided by the Department of Drainage and Irrigation (JPS).

1.6 Significance of Study

This study provides current geological characteristics in the study area, as well as the most recent geological and geomorphological component. Identifying landslides and creating a landslide hazard map are critical actions that may help disaster planners, local governments, and decision-makers (Kavzoglu et al., 2014). With the accuracy of landslide map, it can benefit the local resident, disaster planner, contractor, and decision makers to considerate before deciding their activities such as agricultural activity and development especially near Kampung Kalai, Jeli, Kelantan.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter summarises the most important findings from prior research conducted in and around the study region. Geology, tectonics, stratigraphy, structural geology, and the history of Kelantan's geology are all discussed in this chapter, as well as the possibility of landslides occurring. Besides, the topic also focuses on the study's interest of GIS application and WOM for landslide hazard potential analysis. A more detailed description elements that contribute to landslides such as slope, land use, drainage, elevation, and lithology is also included.

2.2 Regional Geology and Tectonic Setting

The geological map of Kelantan is presented in Figure 2.1. According to the research, Peninsular Malaysia is made up of two distinct tectonic blocks or terranes. These were formed during the Late Triassic period, with the Sibumasu Terrane located in the west and the Sukhothai Arc situated in the east. This was found by studying the research conducted by Metcalfe in 2013. The Kelantan River is the principal river in the area, flowing across the coastal plain and into the South China Sea. Along the north–south direction of the state of Kelantan, different types of rocks, such as igneous, sedimentary, and metamorphic rocks, are spread out. Sedimentary and metasedimentary rocks, granitic rocks, extrusive rocks known as volcanic rocks, and unconsolidated sediments are common in this region (Figure 2.1).

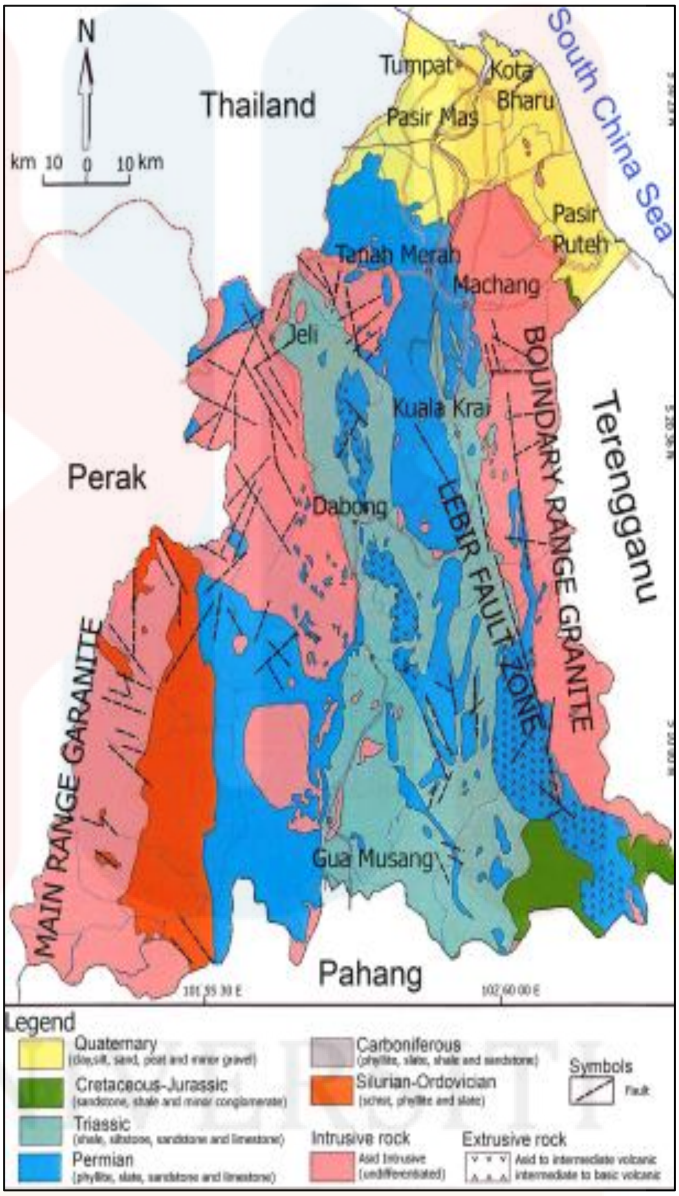


Figure 2.1: Geologic map of the Kelantan state (modified from Department of Minerals and Geoscience Malaysia, 2003).

Unique geological features include the faulting and jointing of granitic rocks and the folding, faulting, and jointing of sedimentary rocks. The regions of West and East Kelantan are primarily composed of granitic rocks, which include the Main Range granite in the West and the Boundary Range granite in the East (Rahman & Mohamed, 2001). The Main Range Granite stretches from western Kelantan to the Perak, Pahang, and Thailand borders. From the post-orogenic era, the major structural direction of Kelantan is N–S to NW–SE (Ghani, 2009). At the western boundary of the Bentong–Raub Suture Zone, the Main Range Granite goes north all the way to Thailand (Schwartz et al., 1995). The Bentong-Raub Suture is a geological feature that extends from Thailand, passing through Raub and Bentong, before reaching the eastern side of Malacca in Peninsular Malaysia. It is approximately 13 kilometers wide. The Bentong–Raub Suture Zone is made up of serpentinite mafic to ultramafic rocks and a series of parallel north-to-south topographic lines. The Lebir Fault Zone (Figure 2.1) is a post-Cretaceous sinistral strike-slip fault located in the eastern part of Kelantan state. The dominant structural trend in Kelantan is from the post-orogenic age and runs from north to south. The Lebir Fault Zone is an important lineament in Peninsular Malaysia that is believed to be a post-Cretaceous sinistral strike-slip fault (Pour & Hashim, 2017).

This landscape, which is part of the Strong Migmatite Complex, is composed of granite and schist from the Main Range. In the centre and east of the area, the terrain is level. Throughout the Palaeozoic and Mesozoic eras, tectonic activity in Peninsular Malaysia was largely responsible for land mass faulting and folding. Localized structures in sedimentary rocks include folds, joints, and faults, as well as joints and faults in granitic rocks (Department of Mineral and Geoscience Malaysia,2003).

Kelantan is situated in the eastern region of Peninsular Malaysia, and it is composed of a central zone of sedimentary and metasedimentary rocks. The area is surrounded by granite formations on the east and west specifically the Boundary Range Granite and the Main Range Granite respectively. This geological formation is a characteristic of the region according to the geologic research of Kelantan. The Ulu Lalat (Senting) batholith, the Stong Igneous Complex, and the Kemahang Pluton are the most prominent granitic intrusives in the middle section. The regional geology north of Pahang is dominated by areas of granite and country rock that run north-south. In the western and central regions of Kelantan, the geologic belts extend in a northward direction, and reach into southern Thailand. Meanwhile, the eastern portion of Kelantan is characterized by the Sungai Kelantan alluvial plain, which overlies the Boundary Range Granite (Goh et al. 2006).

The Lower Paleozoic rocks are exposed in a zone that runs in a north-south direction, from the foothills of the Main Range to Sungai Nenggiri. These rocks mainly consist of metapelites, which have intercalations of arenaceous and calcareous material. However, Amphibolite and serpentinite are rare. The information is based on the study by Goh et al., 2006. Peninsular Malaysia is situated in the eastern section of the Eurasian Plate, within the northern subduction zones of the Sunda Arc. The geology of the region has been divided into two different tectono-stratigraphic terranes, which is represented in Figure 2.2 (the Sunda Shelf and the Sibumasu terranes). The Permo-Triassic Island arc system encircles the Eurasian plate (Kamar Shah Ariffin, 2012).

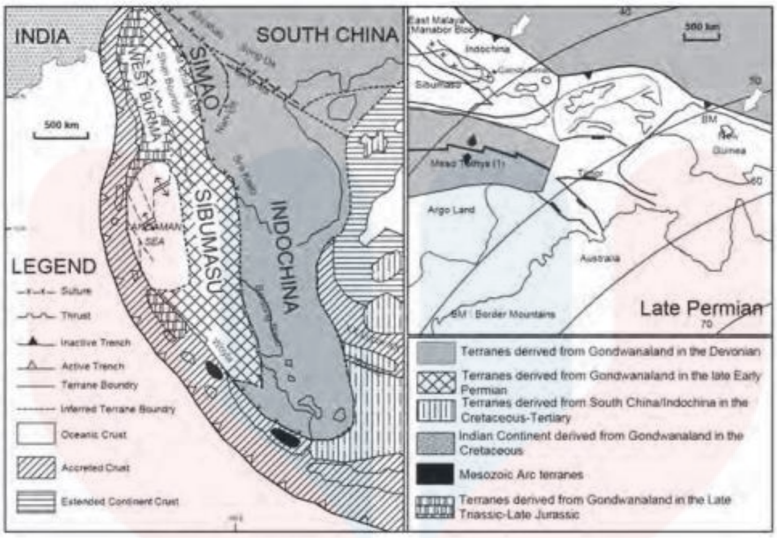


Figure 2.2: Late Permian distribution of Southeast Asian continent blocks, fragments, terrenes and principal sutures together with palaeogeography showing the location of Shan-Thai, east Malaya/Indochina, and Raub-Bentong Suture (modified after Metcalfe, 2002).

The figure 2.3 illustrates the origin of the Central Belt as a complex of accretionary rocks located east of the Bentong Suture line. This formation is the result of tectonic process that caused the accretion of various rock type, which resulted in the formation of the Central Belt. The Raub-Bentong Suture Zone was produced because of the collisions between these two plates. A collision structure formed major N-S or NW-SW trending left slip faults, dilational Riedal and subsidiary shears, and many splays related to these faults (Kamar Shah Ariffin, 2012).

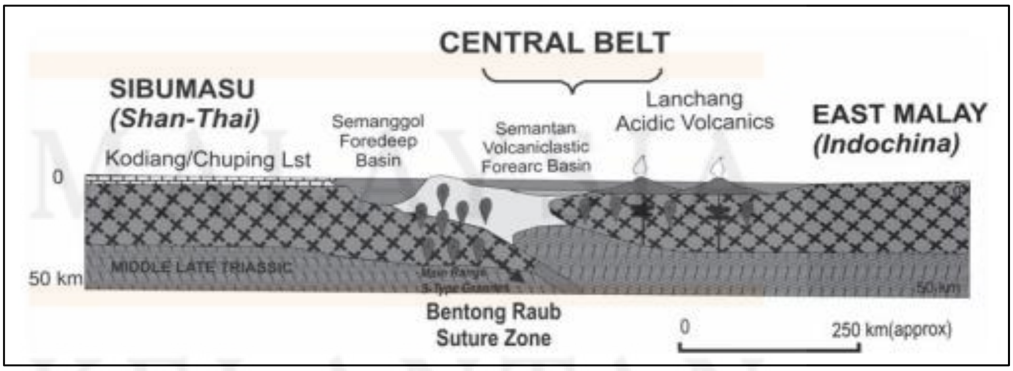


Figure 2.3: Central Belt to the east of Bentung-Raub Suture line was formed as an accretionary complex in the Middle-Late Triassic (modified after Metcalfe, 2000).

2.3 Stratigraphy

The Jeli district is located at the base of Peninsular Malaysia's Main Range. The range is mostly made of granitic rocks, with a few pockets of sedimentary and metasedimentary rocks. The Main Range granite is located west of Kelantan and extends to the state borders of Perak and Pahang. According to Kelantan geology, the Jeli region's geology may be separated into three main categories (Department of Minerals and Geoscience Malaysia, 2003). The Gunong Rabong Formation is a Triassic sedimentary rock. It is made up of shale, siltstone, sandstone, and limestone. The geology of the study area is composed of several rock types. The first is metamorphic rocks, such as phyllite, slate, and schist. These are part of the "Gua Musang Formation" of Permian sedimentary rocks. Additionally, the formation contains sandstone and limestone. Lastly, there are granitic rocks that are acid intrusives (Adriansyah et al., 2015).

According to Tanot et al (2001), Kelantan is separated into four geographical regions such as highland areas, hilly regions, flat regions, and coastal regions. This landscape develops in the area's western and northern regions, and it consists of mountain ridges and valleys (Adriansyah et al., 2015). Faulting and folding in Peninsular Malaysia are mostly the result of tectonic activity that occurring throughout the Paleozoic and Mesozoic eras. folding, joining, and faulting in granitic rocks are examples of specific features in sedimentary rocks (Department of Minerals and Geoscience Malaysia, 2003). In Kelantan, the most common structural orientation is north-south to northwest-southeast. However, the dominant local structures in the Jeli region are northwest-southeast and northeast-southwest orientations (Adriansyah et al., 2015).

2.4 Structural Geology

Structural geology is the study of all geological properties that happened during the development of rocks. Tectonic processes, sediment deposition, and energy force are all variables that contribute to the creation of structural geology. The structural geology of rock may change before, during, or after its development. Faulting is an essential feature of structural geology that may impact mankind by causing natural disasters such as earthquakes. These features, including their orientations, distributions, measurements, and community influence, may be detected, and analysed using geological mapping.

The state of Kelantan is in northern Peninsular Malaysia. Perak and Kedah form the state's northern, eastern, and southern borders, while Thailand and Terengganu form the state's northern and eastern borders. The Gua Musang Formation in state of Kelantan has a wide variety of structural variations, as described in this study. Kelantan is comprised of the West Kelantan Olistostrom, Taku Schist, and Gua Musang Formation. The igneous rocks of Kelantan consist of granite, diorite porphyry, andesite, ignimbrite, and dolerite. The state of Kelantan was structurally constrained by the olistostrom in the west and the Lebir Fault Zone in the east (GSM Warta Geologi, 2010).

The Gua Musang Formation is mostly found in the Malaysian state of Kelantan. The Gua Musang Formation's major fold runs north to south and up to the north-northwest. South-south eastward Granite intrusion and diorite-pyrophyllite created the northern part of this major NE-SW trending fold. The dextral fault, which strikes N30-45°E and dips 60-70° to the southeast, and the sinistral fault, which strikes N330-340°E and dips 60-80° to the east-northeast-southwest, are the principal faults in the Gua Musang Formation. The Gua Musang Formation formed the confined and strongly folded zone next to the main fault, which was bordered by an igneous granite intrusion. In order to see the intrusion of diorite-pyrophyllite in the NE-SW direction, the major fold of the Gua Musang Formation must be inclined. The major compression that created the Gua Musang Formation's folding and faulting occurred between WNW-ESE and ENE-WSW (GSM Warta Geologi, 2010).

2.5 Historical Geology

The Gua Musang formation was discovered by Yin (1965) in South Kelantan and North Pahang. Carbonate and pyroclastic/volcanic facies were present from the Middle Permian up to the Late Triassic. Carbonate-argillite-volcanic Perm-Triassic sequences are now often characterised as such in northern Peninsular Malaysia. Argillite-carbonate-volcanic rocks have been reclassified because to its widespread occurrence in northern Central Belt. The Aring Formation, for instance, is called for lithologies found in Felda Aring, while the Telong Formation is named for lithologies identified in Sungai Telong (Mohamed et al., 2016). According to Mohamed and Leman (1994), these lateral facies changes may be grouped together if the sediments were deposited in the shallow marine environment of the Gua Musang platform during the Permo-Triassic period (1995). The integration of these strata is vital because to the significant sedimentological and paleontological connections between them.

According to the geology of Kelantan, the Jeli district is composed of three primary rock types: Triassic sedimentary rocks (Gunong Rabong Formation) are composed of shale, siltstone, sandstone, and limestone. Permian sedimentary rocks (Gua Musang Formation) are composed of phyllite, slate, sandstone, and limestone (acid intrusive). The terrain is steepest to the west and north of the region. This terrain consists of the Strong Migmatite Complex, granite from the Main Range, and schist. The terrain in the centre and east of the area is flat. During the Paleozoic and Mesozoic eras, Peninsular Malaysia's tectonic activity altered the faults and folds of the landmass. In sedimentary rocks, there are folds, joints, and faults; in granitic rocks, there are joints and faults. In Kelantan, the predominant building orientations are north-south and northwest-southeast. In contrast, the principal local structures may be situated along NW-SE and NE-SW orientations in the Jeli area. The hydroelectric Sultan Ismail Petra Power Facility, often known as the Pergau Dam, is located near Jeli, Kelantan. Pergau Power Station in Malaysia is the nation's second-largest hydroelectric capacity installation (Sulaiman et al., 2020).

2.6 Landslide

Landslides are mass movements of soil or rock that include shear displacement along one or more visible or reasonably inferred slip surfaces. Identifying landslide-prone locations is critical for ensuring human safety and avoiding severe economic consequences at the local, regional, and national levels (Kavzoglu et al., 2014). To limit the damage caused by landslides, it is necessary to evaluate the factors that contribute to landslides. These variables include geology, geomorphology, land use and cover, rainfall, seismicity, and human impacts (Raghuvanshi et al., 2017). According to landslide research, the combination of these characteristics might cause an area to be susceptible to landslides. To predict potential landslides, it is useful to analyse these factors (Chimidi et al., 2017). Landslide hazard maps must be accurate to reduce losses of life and property damage (Kavzoglu et al., 2014).

2.7 Causative factors of landslide

The distance from the road, land use, slope, and distance from the river are all contributing factors in the Cameron Highlands (Talffi et al., 2000). In the study region, the slope has shown the most critical parameters controlling mass motions. Works by Syafril et al. (2020) have shown lithology, soil type, slope, aspect, land use, and drainage are contributing elements to the occurrence of landslides in Kampung Chas and Kuala Betis as well as Gua Musang. During the 2014 flood, significant rains changed the vegetation in the area, resulting in landslides. Lastly, according to Roslee et al. (2017), the Karak highway, which links Genting Sempah to Bentong, Pahang, has eight causative factors, including land use, drainage, structural, soil, lithology, and geomorphology. The major triggering factors, such as excessive rainfall and massive land use change.

2.8 Factors trigger landslide

Several factors have been identified in previous research that trigger landslide occurrence. In order to comprehend the general applicability of each cause for constructing the landslide hazard zonation, it is necessary to study lithology, slope, drainage, lineament, land use, and aspect.

2.8.1 Slope

According to prior studies, the slope is one of the primary causes of landslide occurrences (Talffi et al., 2000). Almost all landslides are triggered by many factors. Slope movement occurs when forces pushing downslope, mostly due to gravity, exceed the strength of the earth's components that make up the slope. On slopes that are on the verge of movement by rainfall, human disturbance, or any combination of these factors may trigger a landslide.

2.8.2 Land use

Changes in land use and land cover come from deforestation, road construction slope ruptures, and steep slopes that increase the frequency of unstable slopes (Reichenbach et al., 2014). Other factors, such as land cover, can influence the distribution of landslides. Slope instability is caused by changes in land cover, which affect the geological structure of the hills.

2.8.3 Aspect

In the research study, landslide may occur if the slope is exposed by heavy rainfall that can tigger landslide occurrences. On some slopes, the quantity of sunshine and the intensity of the rain might also influence a landslide. Hillsides with heavy rainfall, for example, are more vulnerable to landslides because the soil on these hills becomes saturated more rapidly, increasing the pressure within the pores. Saturation capacity is influenced by lithology, land cover, and soil type.

2.8.4 Lithology

In addition, the type of lithology in the region may influence the frequency of landslides. Many factors may lead to landslides, including changes in the strength and permeability of rocks and soils due to lithological and structural differences (Pradhan and Lee, 2010). The mineralogy, physical and chemical properties of the rock have a role in landslides.

2.8.5 Lineament

Geological structural features, such as discontinuities seen as lineaments in satellite images, often have a role in determining the probability of landslides. When the strength of the slope material has been weakened, leading to potential slope collapse, a lineament may indicate a plane of weakness.

2.8.6 Drainage

Streams reduce toe erosion and may also have an indirect impact on slope stabilisation through increased soil pore pressure by saturating the soil before the water level rises, playing an important role in slope stability. Increasing drainage rates quickens surface flow and decreases water absorption by the soil (Mezughi et al., 2012). Substantial penetration occurs on the slopes that border highly permeable streams, such as alluvium. An ArcGIS tool called Line Density Analyzer was used to create the drainage density map.

2.9 GIS Method in Landslide Analysis

A weighted overlay is a method of modelling suitability in which each component is assigned ranks and weights. In order to control the impact of various factors in the appropriateness model, assigning a weight to each raster during the overlay process is useful. With the weighted overlay method, numerous raster layers are used to create a mapping overlay, with each layer being assigned a weight according to its significance. Weighted overlay is a straightforward bivariate statistical method that provides weights based on the relationship between landslide causal factors and landslide frequency. Based on their relationship to the frequency of landslides, causal variables are assigned numerical weightings (Pardeshi et al., 2013). Using a bivariate discriminant function for ranking and weighting landslide explanatory elements as shown in Equation (2.1), a landslide susceptibility map may be generated with efficiency (Nagarajan et al. 2000). This study applied the weight overlay method to construct maps of landslide hazard zone delineation since it is an effective technique. It is based on the causative variables associated with the frequency of landfill landslides in the study area (Shit et al., 2016). Weighted Overlay Model was used to integrate all themed maps (WOM).

$$s = \frac{\sum w_i s_{ij}}{\sum w_i}$$

(Equation 2.1)

Thus, (Wi) is the factor map weight, and (Sij) is the factor map spatial class weight. The spatial unit value of the resulting map is then calculated (S). Since then, the Weight Overlay Method for constructing a Landslide Hazard Zonation map has been incorporated in the GIS software. The LHZ map was then created by overlaid the layer.

The final landslide hazard map depicts the observed geographical distribution of significant landslide hazard causing factors in the study region. The larger the weight or rating assigned to a cause or its related class, the more frequently landslides will occur. The landslide hazard zonation map can provide many values class ranges that are classified into five classes, including no hazard, low hazard, medium hazard, high hazard, and very high hazard. On the landslide hazard zonation map, these five danger zones are distinguished by colour distinctions based on places with a high risk for landslides.

In the study by Roslee, R et al. (2017), the weighted overlay method was applied to determine the quality of landslides on the Genting Sempah to Bentong Highway in Pahang. The same method and calculation process was used for all parameter maps. It was found that slope gradient was the main contributor to landslides, with other factors like land use, distance from drainage, distance from lineament, soil type, and geomorphology also playing a role. The weighted overlay method was used to create a landslide inventory map with five levels of landslide susceptibility: very low (10%), low (50%), medium (15%), high (15%), and very high (10%). The study found that the majority of the area had low landslide susceptibility.

Udin et al. (2021) also analyzed landslide susceptibility in Aring, Gua Musang, Kelantan. The study used a Digital Elevation Model (DEM) to assess the impact of aspect, slope, elevation, and drainage density, while the lithology was determined from a geological map and lineaments were calculated using satellite data. The Weighted Overlay Method (WOM) was used to integrate these weighted causative factor maps into a Geographic Information System (GIS). The resulting landslide susceptibility map was divided into three categories: low hazard (class 1), medium hazard (class 2), and high hazard (class 3).

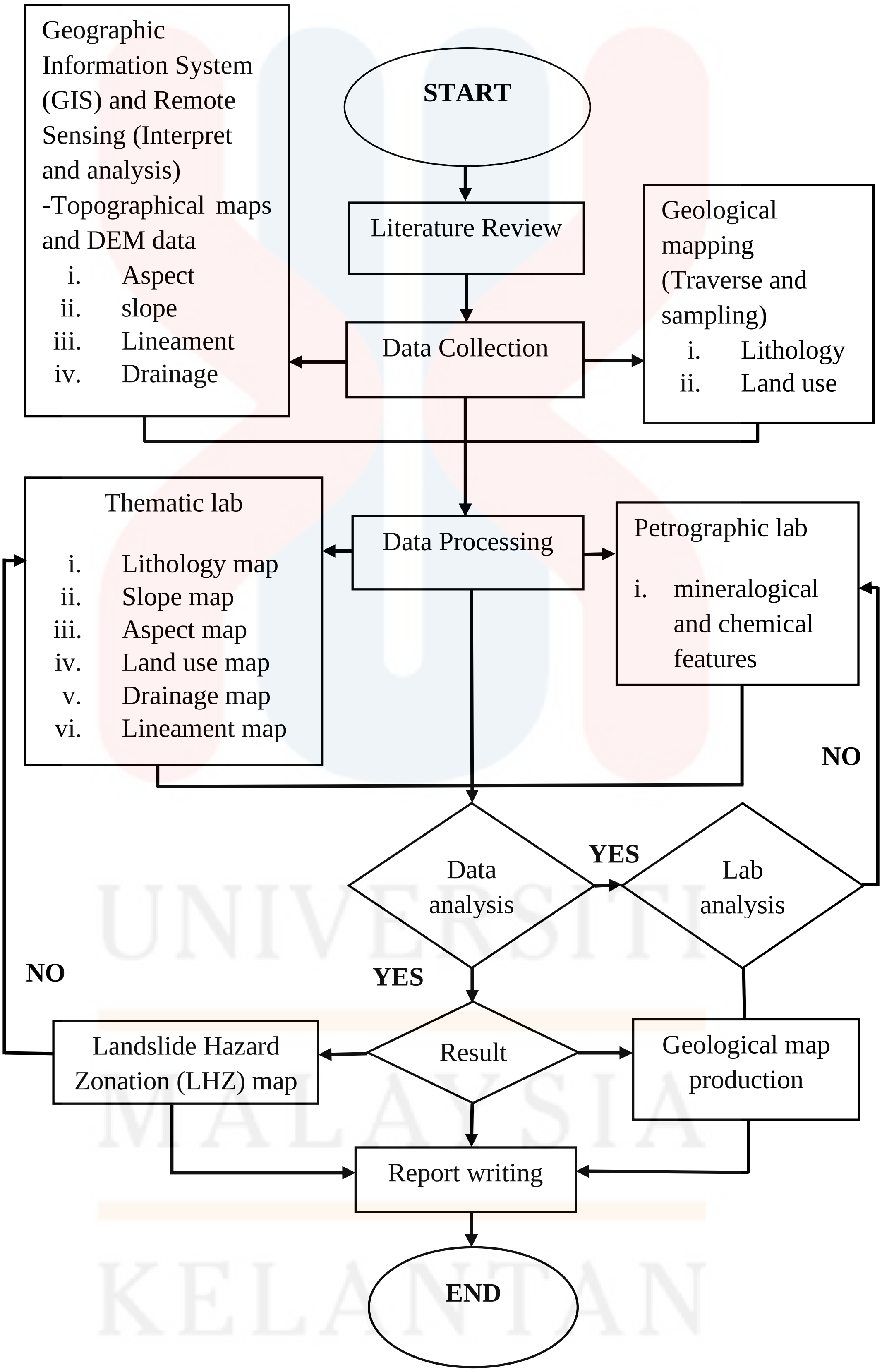
CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

For geological interpretation and landslide risk assessment, a variety of materials and procedures were used to complete data collection and analysis. There are two classifications for materials. The first category consists of journals, articles, books, previous research, and the Internet. This material is a compilation of study-related information sources. The second category contains fieldwork-related equipment. The approach includes preliminary investigations, field research, laboratory work, data processing, data analysis, and interpretation. The result should be easier when use the proper techniques and methodologies. The overall research methodologies are indicated in Figure 3.1.

Figure 3.1: Research flow chart for landslide potential analysis.



3.2 Materials

Prior to formal interpretation, geological mapping was performed using a topographic map to record coordinates, strikes and dips, traverse in the field, and explore area facts and information. The Garmin Portable Global Positioning System (GPS) plays a key role in this research since it is used to identify, locate, and provide positional and structural data during geological mapping and site observations. Besides, Brunton compass was used to navigate and obtain physical measurement during geological mapping. After that, a field tool like a pick-head geological hammer was used to shatter the outcrop while doing sampling. Rock samples were collected using plastic samples for laboratory test. The sizes of the outcrops and river profiles were determined using a 50 ft measuring tape. 01 'Mol' is a hydrochloric acid (HCL) solution that was used to detect limestone or other carbonate-containing rocks. Finally, a hand lens with a magnification of x10 is helpful for identifying minerals when observing lithology. All these materials are available and can be borrowed from Earth Science Faculty in Geoscience department.

3.2.1 Digital Elevation Model (DEM)

The slope, aspect, and drainage density maps were created using DEM data from 23.9.2014. Due to the fact that this data was gathered and collected from the USGS, it must be reconstructed from raw data such as contour data and elevation. This DEM data was used to generate a map of landforms and identify probable landslide zones. Table 3.1 provides 2014 Digital Elevation Data with a resolution of 30 metres.

Table 3.1: Shows properties of DEM used in this study (Source: United States Geological Survey).

Technical properties	**Data type** **Digital Elevation Model**
	Year 2014
Source	USGS
Spatial resolution	30 metre
Area	Jeli
Coordinates	5 , 101
Output format	GeoTIFF 1 Arc-second

a) Topography map

Digital elevation model (DEM) was used to generate topographic map. Contour development is a multi-step procedure that defines how contours are created and where the feature class is stored. The name of the contour feature class that produces the contour intervals, as well as the database where the layer is kept, must be specified. Certain characteristics are automatically inserted and filled in when a contour feature class is generated, depending on the fields provided using the Contour Field Options tool. A feature code, a contour type, and an attribute providing the elevation value are all included in these fields.

b) Land use Map

Land use of the study area can be mapped out from geological mapping and derived from DEM data. This data may be used to analysis the region's land usage at Kampung Kalai.

c) Lineament Map

Lineament patterns are created by drawing the lineament contour that is reflected in DEM reliefs in three dimensions. After each area has been defined, the azimuth measurements, alignment length, and number of lineaments are obtained. When calculating the total number of lineaments, azimuth is used (Fajri et al., 2019).

d) Slope map

Using DEM data, this research area's slope was determined. The slope angle was then utilised to assign a grade. The slope approach may be used to calculate the slope of a raster sheet by defining the slope in each pixel.

e) Drainage density map

Drainage density is an important aspect of the study area, because it impacts the relationship between drainage density and the rate of erosion. This relationship is affected by the primary mechanism of hill slope transport, whether through landslides or runoff erosion threshold. Using digital elevation model (DEM) data obtained from the USGS website, a drainage density map was generated. The study area's drainage pattern was also identified through this process.

f) Aspect Map

The aspect map was also generated using DEM data obtained from the website of the USGS.

3.2.2 Geological Map

The study region's geological map was created at a scale of 1:25,000 and includes all geological characteristics. The lithology, contour, major river, rocks border, stream, geological structure, strike and dip, and coordinates of the research region are all included. A cross section of the research zone between two locations is also included on the geological map.

a) Lithology Map

During the geological mapping of the study area, samples of the different rock types were collected to study the lithology of the region. By examining the rocks and the boundaries between them, a lithology map was created. The information gathered during field observations were plotted and recorded to create the map.

3.3 Methodology

3.3.1 Preliminary Studies

Before starting the research, all relevant information including preliminary study on how to perform the research was gathered and comprehended. To learn more about the landslide hazard potential in the study area, an article evaluation of existing research in the area was conducted. It is crucial and important since it requires brainstorming and a general understanding of what must be done. These studies have provided information on a variety of aspects of the study area's structure, history, lithology, and geological formation.

3.3.2 Field studies

In order to evaluate the study's features, geological mapping was carried out. To figure out the causes of landslide, it is important to find out the structural geology, lithology, weathering, and geomorphology of the study area. Structure analysis is carried out by following the lineament on a topographic map while identify the geomorphology around the research study and selecting the fresh samples of rock for further examination in petrographic. The strike and dip data were measured to gather important data.

Primary data was collected from geological mapping while secondary data was gathered from the previous topographical and historical geology study in that area. A field study was conducted to gather all significant information on previous landslide operations in the region. Additionally, it assists in the evaluation of numerous causative factor maps created during pre-field work. At the completion of the mapping, a geological map was designed.

A technique known as "traversing" is a means of controlling the flow of research all the way through a particular field of study. In addition to this, it is a strategy for providing a comprehensive covering of the region. A traverse is created by moving from one spot on the map to another and then mapping the geology along the way. Plotting and recording field measurements may be accomplished using a variety of methods.

3.3.3 Laboratory work

Samples and data were collected within study area for petrographic purposes. Petrographic testing is the use of microscopes to evaluate samples of rock to determine their mineralogical and chemical features. Petrographic testing samples might be obtained from lump samples or cores (Collins, 2019). In this study, thin section was used to analyze acquired data for mineral identification and rock type analysis. As a result, accurate data was obtained by doing laboratory work due to the presence of a mineral that cannot be seen with the naked eye.

3.3.4 Data Collection

Measurements of bedding strike and dip, cleavage, foliation, and joints are the most important factors in geological mapping. During the field measurement, different structures are analyzed, specimens are collected, and images are taken. Using photographs, sketches, and written descriptions all data, it makes more easier for every type of information that was accessible, including the changes in rock type and structural features of the outcrop seen.

During site observations, rock sampling is described by measuring features and the data was recorded in the notebook. The first appearance of the ground, the colour of the rock, and the observable qualities of the hand specimen, both with and without a hand lens was described. Their texture and grain size were also takes into consideration. A certain amount of rock samples was stored and labelled in the plastic sample, followed by laboratory task for analyzing these specimens.

Landslide hazard zonation is strongly linked to spatial data such as topography, geology, and land cover, and GIS is a strong tool for analysing geographical data. Geospatial data may be gathered, stored, and analysed using a GIS. Several prospects for a more comprehensive and timely assessment of landslide hazard zonation have opened as computers have become more widely available in the previous several decades (Chandra et al., 2002). GIS was used to gather, manage, and analyse data that combines a wide variety of data types. It analyses geography and visualises data using maps and 3D sceneries. GIS is a good choice for landslide modelling because of its ability to handle large data sets. Geographic data from the actual world may be collected and stored using this extensive collection of tools. GIS was used to build LHZ and geological maps.

3.3.5 Data analysis

A Digital Elevation Model (DEM) for the study area was created using elevation data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). The slope and aspect chart were created by using the ASTERDEM. As an outcome, the drainage map was constructed with the help of the topographical sheet and confirmed using DEM data. ArcGIS software was used to generate a digital point database. There had been a spatial overlay study between the landslide danger zone and one of the thematic layers (Shit et al., 2016).

The information was gathered during the ground investigation and derived from topographical map. Geological maps and meteorological data were used to calculate a precise weighted score for each causative factor and their appropriate subclasses. Finally, the thematic layers were evaluated and ranked according to the geographical correlation between factors and region’s landslide damage (Shit et al., 2016).

The hazard map of the study area was generated by assigning a weight of 1 to 5 causative factors. The hazard index classification of landslides is divided into five categories: no hazard (NH), low hazard (LH), medium hazard (MH), high hazard (HH), and very high hazard (VHH) (Syafril et al., 2020). All thematic maps were combined using WOM. Using WOM analysis, these weighted factors maps had been linked into a GIS platform to generate a susceptibility landslide hazard zonation (LHZ) map. The weighted overlay approach is a simple, effective, and easy tool for analysing possible landslide regions (Erener and Uzgun, 2008).

An update geological map of Kampung Kalai, Jeli in a scale of 1:25000 is the final output of the research. Geological maps would provide the lithology information, such as the distribution of various rock types and the locations of geologic features like faults and folds. In addition, a LHZ map was also created at the end this research by referring to hazard index classification of landslide. From this LHZ map, it would give a cleared visual and prediction of for landslide event to occur at particular studied were by providing an early exposure and awareness based on the colour indicator provided in map.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This study area is specified in Kampung Kalai which located at Batu Melintang, Jeli. This chapter would focus on the general geology of the research region. The general geology of Kampung Kalai, as well as major geological features like as geomorphology, lithostratigraphy, structural geology, and historical geology, will be discussed in this chapter. The geological structures discovered in the study area were studied and analysed in structural geology, while historical geology discovered the history of that specific location. The geological mapping method was used to gather data in the field. Then, in the study area, a geological map was constructed that represented the rock unit distribution, rock type, geological characteristics, and age-rock correlation.

4.1.1 Accessibility

Batu Melintang is a sub-district on the north-eastern route between Grik and Kota Bharu that provides access to this main highway. A trip from UMK Jeli to Masjid Kampug Kalai would take around 26 minutes and cover the roughly 23.9 km distance. The whole research area is accessible by foot or car through a variety of routes, including paved and unpaved roads.

4.1.2 Settlement

This study area's main settlement is Kampung Kalai. According to Google Earth interpretation, Kampung Kalai's settlement pattern can be separated into two categories which area nucleated pattern and linear pattern. The buildings in a nucleated settlement are clustered, linked by roads, and resemble a nearer cluster of residences. For the linear settlement pattern, houses from a straight line following the road network as the major road in the study area.

4.1.3 Forestry

The forestry located to the west of my study area consisted of forest. In addition, this area covered by oil palm and rubber plantations. Forestry and vegetation also have an impact on human activities and employment chances. The majority of residents in Kampung Kalai have their own estates, which contribute to the community's income.

4.2 Geomorphology

Geomorphology is the study of landforms and landform evolution. In order to conduct geomorphological assessments in the study area, topographic map analysis and ground observation from the summits of hills were used. The study area's peaks provide views of Gunung Reng, a large, exposed limestone hill in low-lying regions that may be seen from the summits of Kampung Kalai hill (Figure 4.1). Using these two methods, data on the landform, drainage, contour pattern, and weathering were acquired. Depending on topography, the geomorphology has different elevations, which is an indicator of how water flows from high to low elevation. During the last earth formation event, various tectonic activity occurred in different locations, resulting in a variety of landforms. This geomorphological study provides further information on the topography of the area under study and its surroundings.

Figure 4.1: Geomorphology of the study area.

4.2.1 Geomorphologic classification

Landforms are the topographical characteristics that make up the terrain. Two distinct kinds of landforms with distinct lithologies may be identified in the researched region. Frequently, steep terrain is composed of metamorphic rock. In mountainous regions, igneous rocks such as granite are often found in tight contours, indicating places at high elevations. Different landform types in a location generate distinct lithologies and elevations based on classification type in Table 4.1.

Table 4.1: Classification of landform (Source: T. Listyani R.A., 2019).

Landform	**Elevation (m)**
Land	0-50
Low hill	50-200
Hill	200-500
Mountainous	500-1000

Figure 4.2 shows the elevation map of the study area. There are three different colours depict the different elevations of each landform area. For the red colour, the landform type is mountainous, and the predominant lithology is granite, an igneous rock. Next, the colour yellow depicts a sloping landform (hilly area) in the study area.

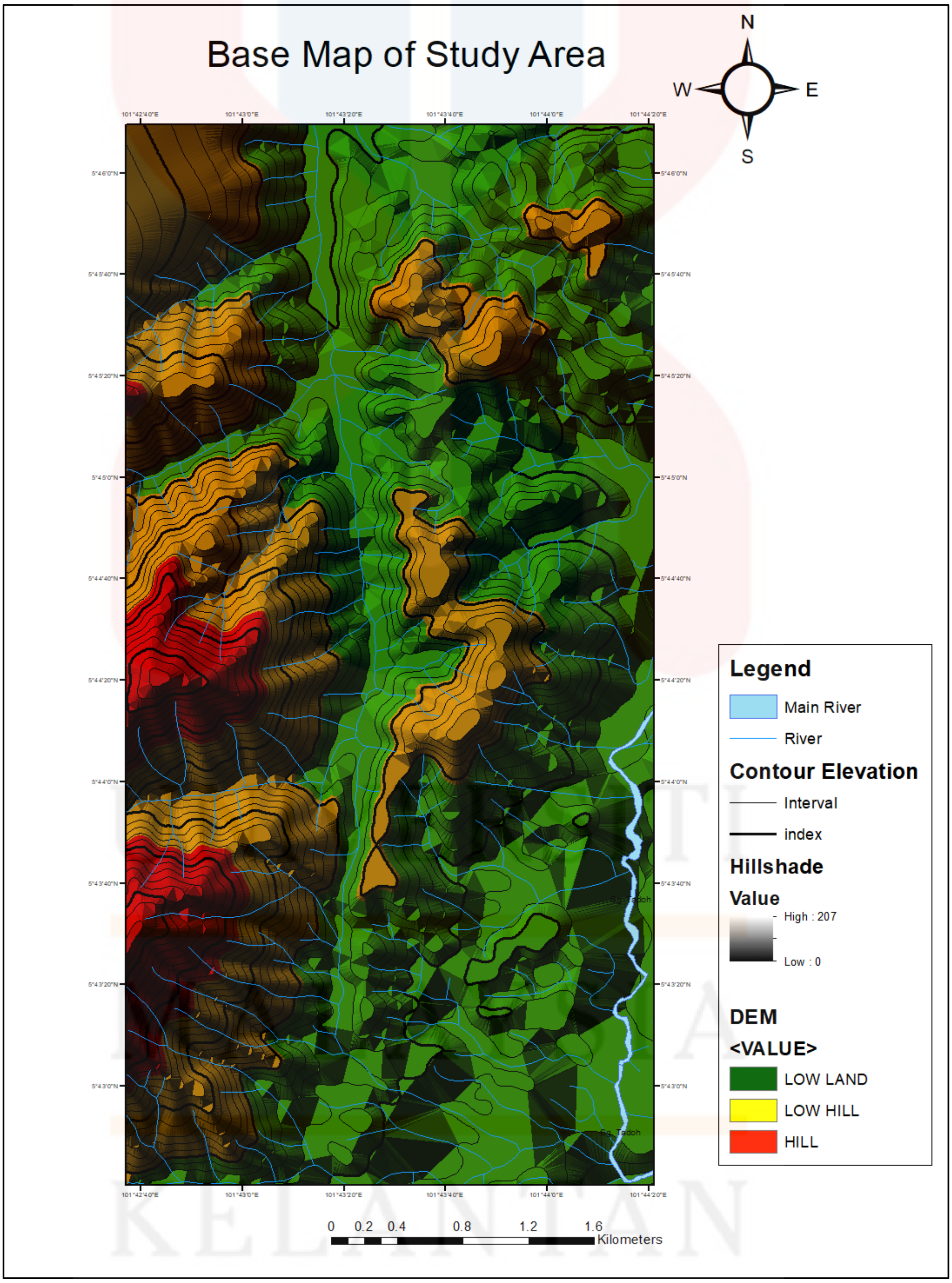


Figure 4.2: The elevation map of study area.

The mountainous landscape is mostly forested and planted, with rubber plantations dominating. Most of the hilly slopes is covered with palm and rubber plantations. Typically, igneous rocks have a greater elevation than metamorphic rocks. This is because igneous rock is more resistant to weathering process and not easily erode by the weathering process compared to metamorphic rock. Igneous rocks are the result of tectonic activity, which is volcanic activity. It is an intrusion of igneous triggered by tectonic action.

4.2.2 Weathering

Several outcrops are weathered in the study area. The process where rocks undergo physical, chemical, and biological processes is known as weathering. Biological and physical processes dominate the weathering at the study area. The most hilly area's rock mass is exposed to the sun. The daily cycle of expansion and contraction weakens the rock's surface, causing it to crack and shatter into smaller fragments. Physically weathering may be seen on the outcrop shown in Figure 4.3. Several outcrops are weathered in the study area. Over millions of years, persistent hot and wet weather causes physical weathering, which may break down rock into smaller fragments and eventually soil. The biological weathering caused by the river outcrop is shown in Figure 4.4. On the rock's surface, lichens and algae create a weak acid that converts some minerals into clay.

Figure 4.3: The physical weathering of an outcrop.

Figure 4.4: The biological weathering of an outcrop.

4.2.3 Drainage pattern

The study location is encircled by multiple rivers, including the Tadoh River, which serves as the primary river, and its tributaries. The Tadoh River is located in the Kampung Kalai, Batu Melintang, Jeli district. The pattern, which reflects the many rocks and geological formations in a region eroded by streams throughout time, is characteristic of a landscape that has been shaped by water flow. The erosion of the drainage pattern may be influenced by variations in the slope, rock resistance, structures, and geological history of the surrounding area.

In general, the drainage pattern of the study area may be split into parallel and dendritic river patterns. Figure 4.5 displays the two drainage patterns at the area, which is shown in distinct colours. Red represents the dendritic pattern of drainage, which closely matches the branching pattern of tree roots, while blue represents the parallel pattern of drainage. Dendritic patterns form in areas where the rock (or unconsolidated material) underneath the stream lacks a clear structure or fabric and may be eroded in any direction. Examples include granite, gneiss, volcanic rock, and unfolded sedimentary rock.

Parallel pattern is a pattern that is formed by steep slopes with some relief. The steep slopes cause the streams to be fast and straight, with few tributaries that all flow in the same direction. There are parallel drainage patterns when there is a steep surface slope. A parallel pattern may also develop in regions with parallel, elongated formations, such as protruding resistant rock bands. This may be seen in the study area, where the parallel pattern stream is situated on a steep slope.

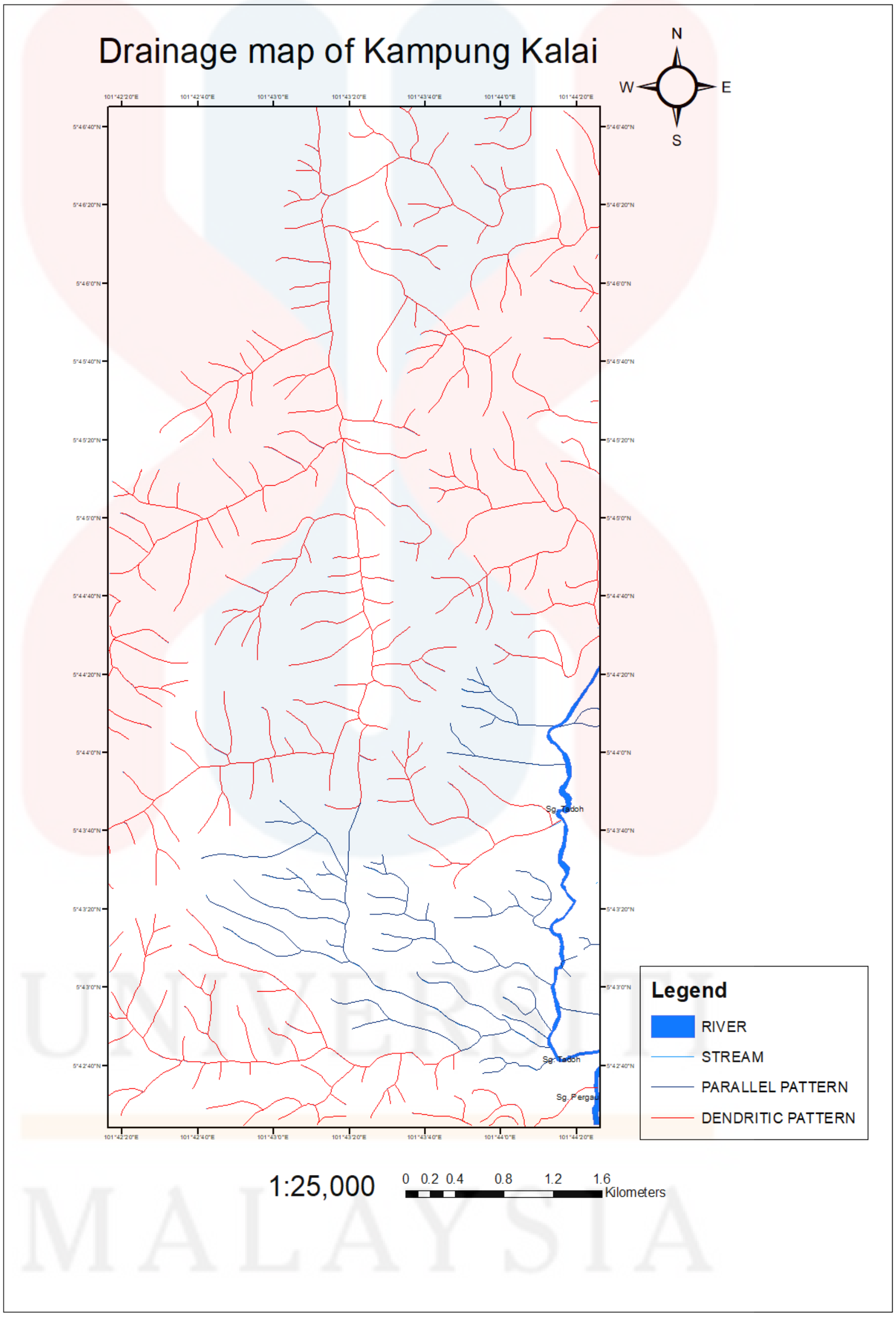


Figure 4.5: The drainage map of study area.

4.3 Lithostratigraphy

The part of stratigraphy involved classifying and identifying the rocks of the Earth based on their lithology and stratigraphic correlations. The lithology units provide information on mineral composition, colour, texture, and grain size. In lithostratigraphy, the lithology of each rock formation component that is included in the strata, as well as its stratigraphic position, forms a component of rock body classification. Igneous and metamorphic are dominants in the study area, with a small proportion of metasedimentary. Each lithology's characteristics are the result of a multitude of geological processes and deposition settings that occurred in the past. These studies are important for establishing chronological sequences of geographical activities occurring in that research area.

4.3.1 Lithostratigraphy position

Classification of rock masses into units according to their lithologic characteristics and stratigraphic connections. It consists of two prominent rock groups. The geology of the Kampung Kalai region consists mostly of metamorphic and igneous rocks, with just a bit of metasedimentary rocks. Consequently, the attributes of each rock in the research area are characterised by several criteria that is developed via the analysis of the study. According to the lithology map, pink colour represents intrusion granite and light green represents metasedimentary rock, which are most common in the Kampung Kalai region. According to past studies on the Jeli formation, the study area is underlain by the Telong Formation (late Permian to Triassic in age) and the Mangga Formation (aged Triassic to Cretaceous). The Manga Formation was formed from low-grade metamorphic sequences comprising arenaceous, argillaceous, pyroclastic, and calcareous rocks. The rocks that make up the Telong Formation may be classified as either argillite, metavolcanic, or metasedimentary (Sulaiman et al., 2022). Intrusive rock, rocks from the Triassic and Permian periods, rocks from the Carboniferous period, and quaternary alluvium make up the lithologies of District Jeli (Table 4.2). Kampung Kalai has rocks with ages from the Triassic to the Carboniferous, including the Telong formation and Mangga formation. In the research region, metamorphic rocks cover more than 50 % of the area. The Kampung Kalai region is situated on metamorphosed metasedimentary rock and is in proximity to areas of granite intrusion.

Table 4.2: Lithostratigraphy column of Kampung Kalai

ERA	PERIOD	UNIT/ FORMATION	DESCRIPTION	LITHOLOGY
Cenozoic	Quarternary	Alluvium	Stream, flood plain, fluvial and swamp formed	
Mesozoic	Triassic	Intrusive Granite	Meta quartz rich granitoid	
		Telong Formation	Schist, mica schist and schistose rock	
Palaeozoic	Permian	Mangga Formation	Metasedimentary rock (Meta mudrock, shale, slate, phyllite)	
	Carboniferous			

4.3.2 Unit explanation

The research area is at Kampung Kalai, Batu Melintang. Kampung Kalai is a Mangga formation and Telong formation. The Mangga Formation is a low-grade metamorphic sequence made up of four facies which are argillaceous, arenaceous, pyroclastic, and calcareous. In addition to prior research, geological examinations in the region have shown essentially comparable results. In addition, field observations were used to identify and classify rocks in Kampung Kalai.

a. Intrusive granite

Based on the lithological features that predominate the lateral lithology of the research region, the granite unit was determined to be the dominant geological formation. The northwest part of the study area is dominated by granitoid units. In addition, the granitoid rock units in the study area intrude onto the metasedimentary rock. Granite is typically found at higher elevations and rivers that flow downhill. Kemahang granite covers on the western side of the research area may be mapped out. The granite occurs as a batholith, which is often found as a north-south running mountain range. At the base of the mountain, large granite boulders can be found near the granite outcrops, as a result of erosion and transportation. The found granite was mostly grey to black in colour, medium to coarse-grained that was made up of large mineral granules.

The study area has a high presence of quartz veins. Additionally, the area has several granite outcrops situated in the northwest of the study area. The strength of quartz crystals, a common mineral in igneous rocks, results in the steepness of contour lines in this area. Due to weathering and plant cover, it was difficult to detect spectacular igneous outcrops in the eastern section of the study region. However, boulders were numerous. Sometimes, xenoliths may also be found in this granitic granite. According to Malaysian and Thai working groups, Kemahang granite is an I-type granite. In the region of study, granites containing alkali feldspar and quartz-rich granitoids are the most prevalent forms.

b. Metasedimentary

Metasedimentary rock was sedimentary rock that had begun the metamorphic process. Sedimentary rocks with a layered bedding structure are the result of this process. The sedimentary rock in the research region is undergoing metamorphosis due to igneous intrusion, altering its physical characteristics due to changes in temperature and pressure that alter the mineral composition. Following this, the rock was re-crystallized by being exposed to high pressures and temperatures, a process known as metamorphism. This rock will transform into metasedimentary rock. The elevation of the metasedimentary rock was lower than the elevation of the granite unit.

c. Metamorphic rock

The area of Kampung Kalai is primarily composed of a particular type of metamorphic rock known as meta-argillite. Meta-argillite rocks are made up of different types of rock materials that have undergone metamorphism, such as siliceous shale, slate, phyllite, metasiltstone, and hornfels. These rocks are the results of heating and pressurizing of the original sedimentary rock types, which cause them to change in physical and chemical properties. Phyllite is classified as having low to moderate metamorphism, while slate has low metamorphism. Phyllite is often classified as a grey to dark grey rock. Quartz-mica schist, quartz-mica-garnet schist, and quartz-mica-graphite schist are all types of minor metasiltstone and schist that make up the arenaceous unit.

d. Alluvium

Alluvium is made up of various sedimentary rocks and soils, such as clay, silt, sand, and gravel. Sediment is the unconsolidated detrital material deposited in the stream bed, floodplain, delta, or as a cone or fan at the foot of a slope by a river, stream, or other moving body of water. Alluvium from the study area deposited into the Kampung Kalai river from the surrounding foothill mountains and main river which is Sungai Tadoh (Figure 4.6). The river structure is continually being influenced by depositional and erosive processes, this alluvium is relatively new, both in terms of age where is in Quarternary age and of depositional material.

Figure 4.6: Variation of rock transported and deposited along the river.

4.3.3 Petrographic Analysis

I. Meta quartz rich granitoid

Figure 4.7 represents outcrop and hand specimen of meta quartz rich granitoid found at the study area.

Figure 4.7: Outcrop and hand specimen of meta quartz rich granitoid at the study area.

Rock description: The colour of the rock is white, grey, and black. Quartz, microclin, and muscovite constitute the mineral composition. The mineral is visible to the naked eye and has a phaneritic consistency.

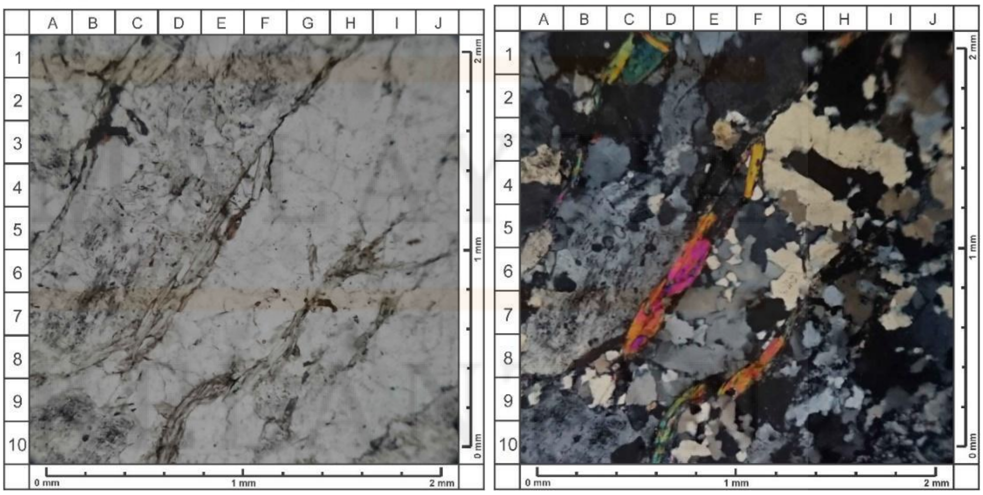


Figure 4.8: PPL (Left), XPL (Right).

Microscopic observation:

Massive structure, phaneric texture with just little foliation, and coarse to medium-sized minerals were seen at 10x magnification and 5x objective magnification, respectively (Figure 4.8). It is a meta-igneous rock characterised by a lack of foliation and by interlocking and parallel mineral groups.

Mineral composition:

Quartz (J3) – PPL is characterised by a colourless absorption colour, low relief, no pleochroism, anhedral crystal structure, and no cleavage. The interference colour in XPL is grey - white of order 1, with undulating dark corners and no twinning.

Microclin (A10) – The presence of sericite was detected. PPL has a monoclinic cleavage and a subhedral - anhedral crystal structure, and it absorbs light without imparting any colour. XPL has a greyish white interference colour of order 1, a slanted black angle, and polysynthetic twinning.

Muscovite (D7) – Under PPL absorption, the crystal takes on a reddish hue, while also showing moderate relief, significant pleochroism, a crystal shape that ranges from subhedral to euhedral, and a cleavage in one direction. XPL has a yellow-orange interference colour without any dark-angle twinning in parallel.

Opaque Mineral (C1) – PPL has a euhedral-anhedral crystal structure, a black absorption colour, a low relief, and no pleochroism. In the first black order of XPL colour interference, there is no twinning.

II. Schist

Figure 4.9 shows outcrop and hand specimen of schist at the study area.

Figure 4.9: Outcrop and hand specimen of schist at the study area.

Rock description: Schist is a metamorphic rock characterised by medium-sized grains. Silver and grey are very common in the rock's colour. With the naked eye, the reflected light causes schists to look very sparkling and glossy.

Figure 4.10: PPL (Left), XPL (Right).

Microscopic observation:

Foliated structure (schistose), crystalloblastic (nematoblastic) texture, grain size of 0.556 - 0.25 mm, and strong sorting were seen at 10x magnification and 5x objective magnification.

Mineral composition:

Quartz (D1) – PPL has a colourless absorption colour, low relief, no pleochroism, anhedral crystal structure, and no cleavage. The interference colour in XPL is grey - white of order 1.

Muscovite (H1) – PPL absorption shows a reddish colour in the crystal, which also shows considerable relief, strong pleochroism, a subhedral to euhedral crystal shape, and a cleavage in one direction. Because there is no parallel dark angle twinning, the interference colour in XPL is an orange yellow of order 3.

Opaque Mineral (I1) – PPL has a black absorption colour, a low relief, no pleochroism, and a euhedral - anhedral crystal structure. No twinning exists in XPL colour interference black order 1.

III. Meta Mudrock

Figure 4.11 refers to outcrop and hand specimen of meta mudrock in the study area.

Figure 4.11: Outcrop and hand specimen of meta mudrock at the study area.

Rock description: Meta mudrocks are a type of metamorphosed siliciclastic sedimentary rock whose mineral grains are not visible to the human eye. According to this figure, the colour of meta mudrock varies from grey to black and seems dull since it does not reflect light.

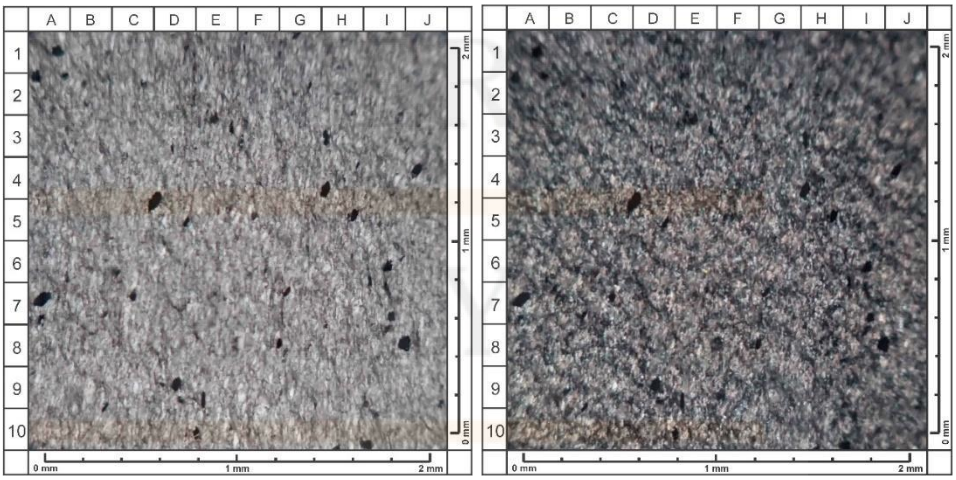


Figure 4.12: PPL (Left), XPL (Right).

Microscopic observation:

The observations, made at 10x magnification and 5x objective magnification, showed a large structure with significant foliation, texture (with grains ranging in size from 1/256 to 1/24 mm), good sorting, and open packing. Despite the apparent parallel mineral orientations, no foliated structures have evolved in this meta-sedimentary rock.

Mineral composition:

Quartz (C9) – PPL has a colourless absorption colour, low relief, no pleochroism, anhedral crystal structure, and no cleavage. The interference colour in XPL is grey - white of order 1, the dark corners are undulating, and there is no twinning.

Silica Clay (J1) – The colour of absorption at PPL is colourless - brown. The interference colour of XPL is a dark grey to black hue. It consists of micro-sized silicate particles.

Opaque Mineral (A1) – The crystal structure of PPL is euhedral with an anhedral symmetry, and it has a black absorption colour, a low relief, and no pleochroism. There is no twinning in the XPL black order of colour interference.

4.4 Structural Geology

The study of all geological features caused by plate motion is known as structural geology. The motion of plates is controlled by the tectonic activity deep inside the Earth. Bedding, joints, and folds are all examples of geological features. These structures were then explored further. Understanding the past tectonic activity, previous geological events, and the setting in which the rock was deformed is made easier with the help of structural geology. Rock deformation and morphologies may be attributed to a certain stress field, which can be determined with the use of structural analysis. For early interpretation, structural geologists use GIS processing from lineament analysis, interpretation of geological maps, and identification of folds, faults, and joints in the field. The geological structure of the research region was defined in detail for future analysis. Using online interpretation, the lineament map was produced.

4.4.1 Fault

When rock strata shift or move apart due to tectonic forces, a fault forms. Lineaments added to topographic maps or photos of hill shades help visualise linear faulting features, making it easy to identify where the largest faults are located. The three types of faults are normal faults, reversal faults, and strike-slip faults. An assumption of faulting was constructed based on the discovered lineament. The lineament map illustrates the location of the major fault in the study region. Geological mapping was employed for on the ground observations to back up the presumption. The research region revealed many indicators of faulting occurrence.

An analysis in the study area revealed the presence of a minor strike-slip fault located near the top of a hill (as shown in Figure 4.13). Strike-slip faults are classified into two types: sinistral and dextral. In this particular case, it was identified the fault as a sinistral strike-slip fault, indicating that the blocks on opposite sides of the fault moved in opposite leftward direction due to the lateral shifting of the blocks as the fault ruptured. Sinistral faults refer to left-lateral movement while dextral faults refer to right-lateral movement of the blocks. This faulting interpret is based on random mapping.

Figure 4.13: Strike slip fault in the study area.

4.4.2 Fold

A fold is created when a force acts on ductile rock. Even when pushed to great stress, the rock's ductile nature prevented it from shattering and instead caused it to fold. When temperature and pressure are high, fold development often occurs in the metamorphic zone. Figure 4.14 shows a drag fold discovered in the study area. The drag fold is a great kinematic indicator of fault displacement.

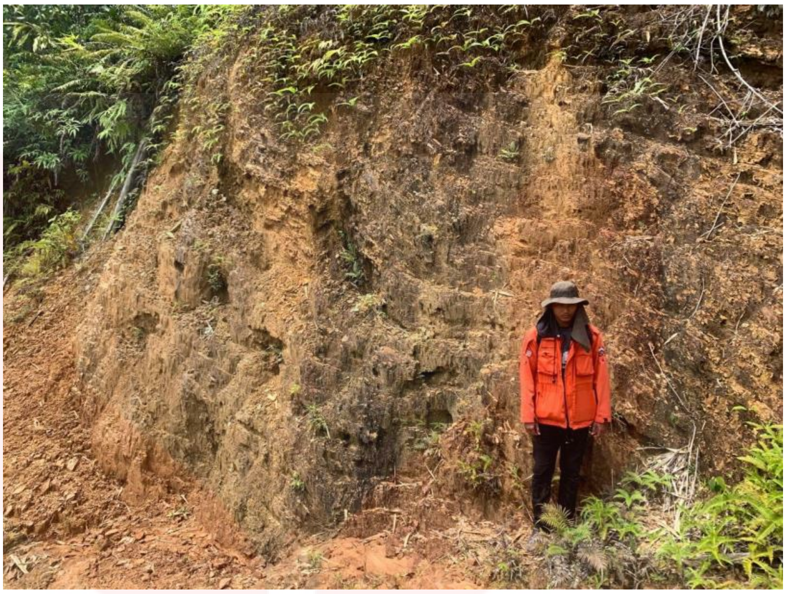


Figure 4.14: Drag fold in the study area.

4.4.3 Mechanism of structure

Erosion and tectonic movement were two of the structural processes detected in the research region. Tectonic activity has also been correlated to the study of lineament and contour structure. Lineament was analysed to determine the presence of both positive and negative lineament. Lineament may be positive in the form of bedding, as seen in ridges and ranges, or negative in the form of a fault or joint, as seen in valleys and rivers. The analysis of the strikes was recorded, and a rose diagram was made to show the results. The strike reading is then used to generate a rose diagram, which depicts the prevailing forces in the region under study. This strike reading is shown in Table 4.3.

Table 4.3: Reading of strike.

STRIKE				
27	47	74	340	23
12	35	323	334	331
326	253	305	1	40
57	31	92	57	355
57	60	50	40	86
113	252	265	59	49
36	27	246	24	210
13	345	344	287	330
37	328	355	141	29
302	329	47	60	21
315	327	320	73	178
135	64	347	245	279

The rose diagram is shown in Figure 4.15. A Rose diagram is a representation of the force of the research area. Compressive stress caused the fault to form in the study region. The rose diagram was made using GeoRose.

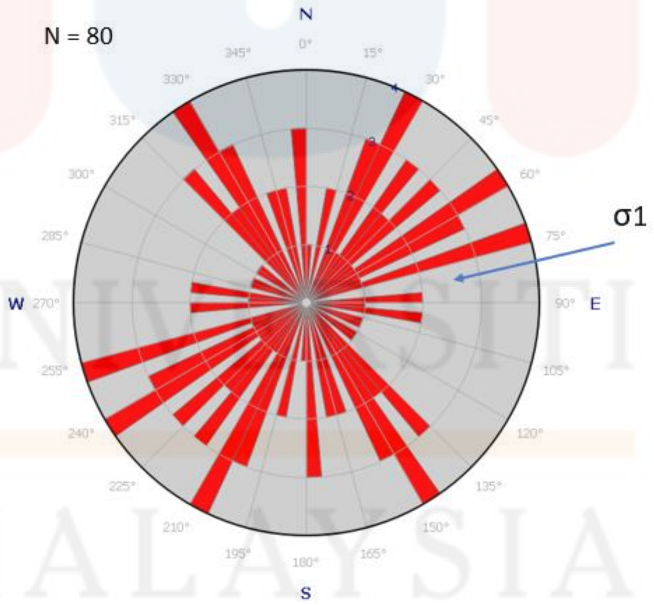


Figure 4.15: Lineament analysis from strike.

4.5 Historical Geology

Peninsular Malaysia is divided into east, middle, and west belts. It formed because of the Indochina and Sibumasu plates colliding and subducting. Jeli sits in the centre belt, where various hydrothermal activity has occurred. Plate collisions have resulted in the formation of various mineralisations and structural geology. Quartz dykes and igneous stocks with a north-south trend intruded the area's rocks, particularly in the Kalai region. The relationship between contact metamorphism caused by igneous intrusions and late-stage mineralization. Eastern part of study area contains the Mangga formation, a sedimentary and low-grade metamorphic rock sequence. The Mangga formation probably originated between the Carboniferous and the Permian eras. It has been found that meta greywacke and meta-argillite lie among low metamorphic arenaceous and argillaceous layers (Malaysian & Groups, 2006).

Permian–Triassic clastic, and volcanic compose the centre belt. Igneous intrusion and convergent processes changed the majority of the belt's body. The western section of the research region has intruded Kemahang granite. The youngest rock in the region of research is Kemahang granite, which is thought to have formed during the Triassic. Ore minerals rich in gold are crystallised in the region because hydrothermal activity is amplified by the intrusion, which in turn deforms the other lithology. The rock formation is thought to be a skarn deposit formed by hydrothermal action in the carbonates rock group. Quaternary period weathering and erosion processes produced unconsolidated, loose sediments over long periods of time. In areas of shearing and contact, localized deformation and mild metamorphism occurred, altering the original rock and creating metamorphic rocks. This process can also lead to the formation of various structural features and mineral deposits, as described in studies by Malaysian & Groups (2006). Figure 4.16 shows the geological map of Kampung Kalai.

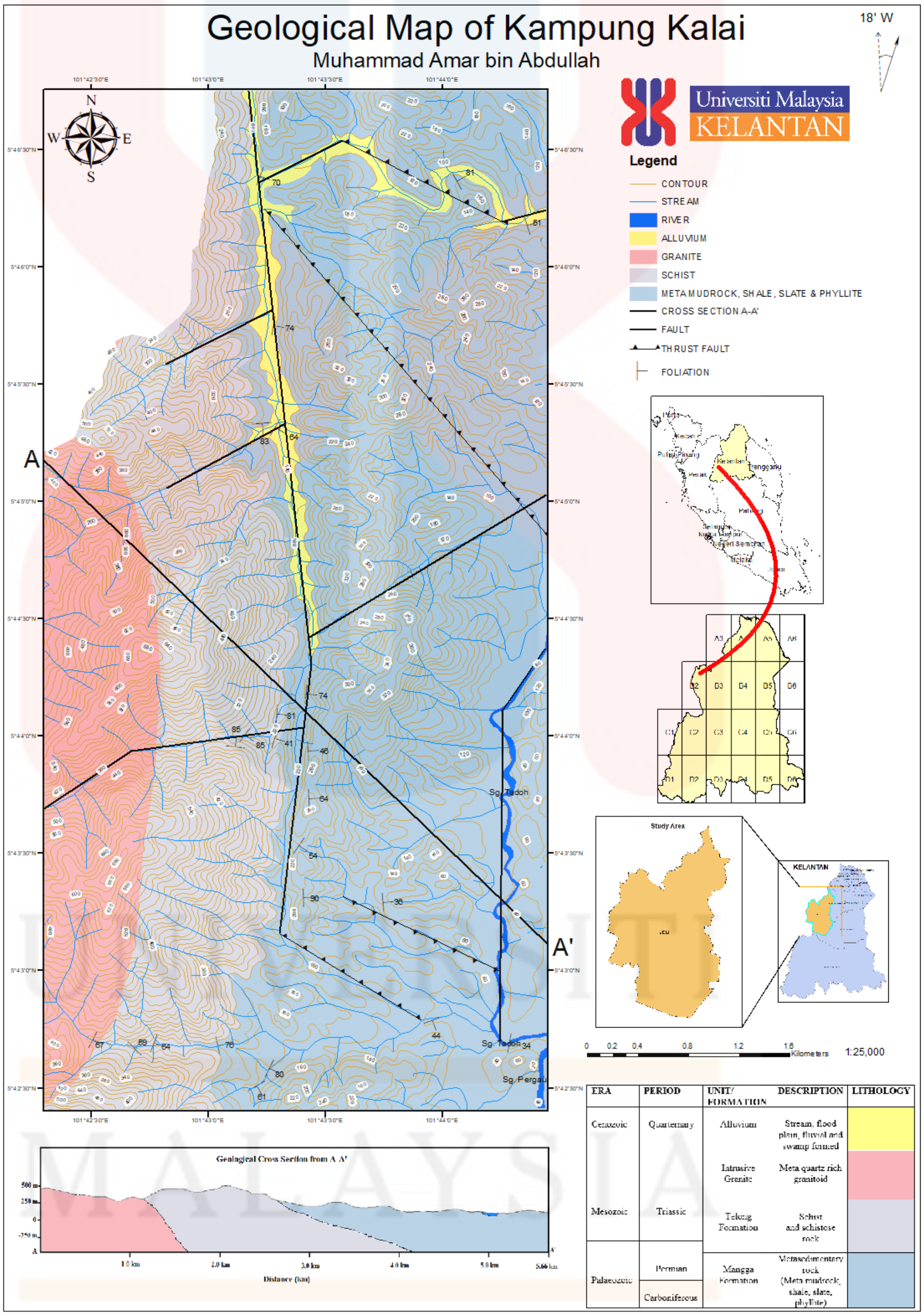


Figure 4.16: Geological map of Kampung Kalai

CHAPTER 5

LANDSLIDE ANALYSIS ASSESMENT

5.1 Introduction

This chapter discussed on landslides potential using GIS analysis. Each relative importance of all six elements were considered in the landslide-prone area of Kampung Kalai, Jeli, Kelantan. The element of geomorphology includes various factors that can influence the potential for landslides, such as lithology (rock types), slope angle, aspect (direction the slope faces), vegetation cover, land use, and drainage density. All of these elements are interrelated and can affect the stability of the slope. Estimate for the year 2022 were calculated using DEM data that was mapped and synthesised. By averaging the importance ratings for each factor, the landslide analysis zone can be identified. According to Jamil et al., (2022), the relative importance of the landslide analysis's constituent parts is shown in Table 5.1.

Table 5. 1: Weightage of landslide analysis factors.

No	Parameter	Weightage (Wi)
1	Lithology	9
2	Lineament density	5
3	Drainage density	7
4	Aspect	8
5	Slope	10
6	Land use	6

5.2 Result and Discussion

5.2.1 Lithology

The lithology map was used to analyze the potential for landslides in the region. Variation in lithology is crucial factor in determining a region whether vulnerable or not to landslides. The lithologic condition and geologic evolution of rocks and soils affect their qualities. Variations in lithology play a critical role in determining whether a location has a high or low risk of landslides. The higher the impact of these variables on a region's vulnerability to erosion and landslides. According to the lithology map, about 45% of the research area was covered by metasedimentary rock, 20% by intrusion granite, 30% by metamorphic rock schist, and 5% by alluvium. Among the analysed lithologies, the alluvium-covered area shown the most potential for landslide occurrences, while the granite zone displayed the least. In addition, the possible landslide dangers in metasedimentary rock have been categorised as being low susceptible to landslides.

The granite unit, schist unit, and meta mudrock unit in the study region are each given a score of 4, 6, and 2, respectively (Table 5.2). Lithology was assigned a weighting of 9 because of its influence on the risk of landslides. The lithology and their distribution are shown in Figure 5.1.

Table 5.2: Weightage and score.

No	Lithology Class	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	Granite	9	4	36
2	Schist	9	6	54
3	Meta Mudrock	9	2	18

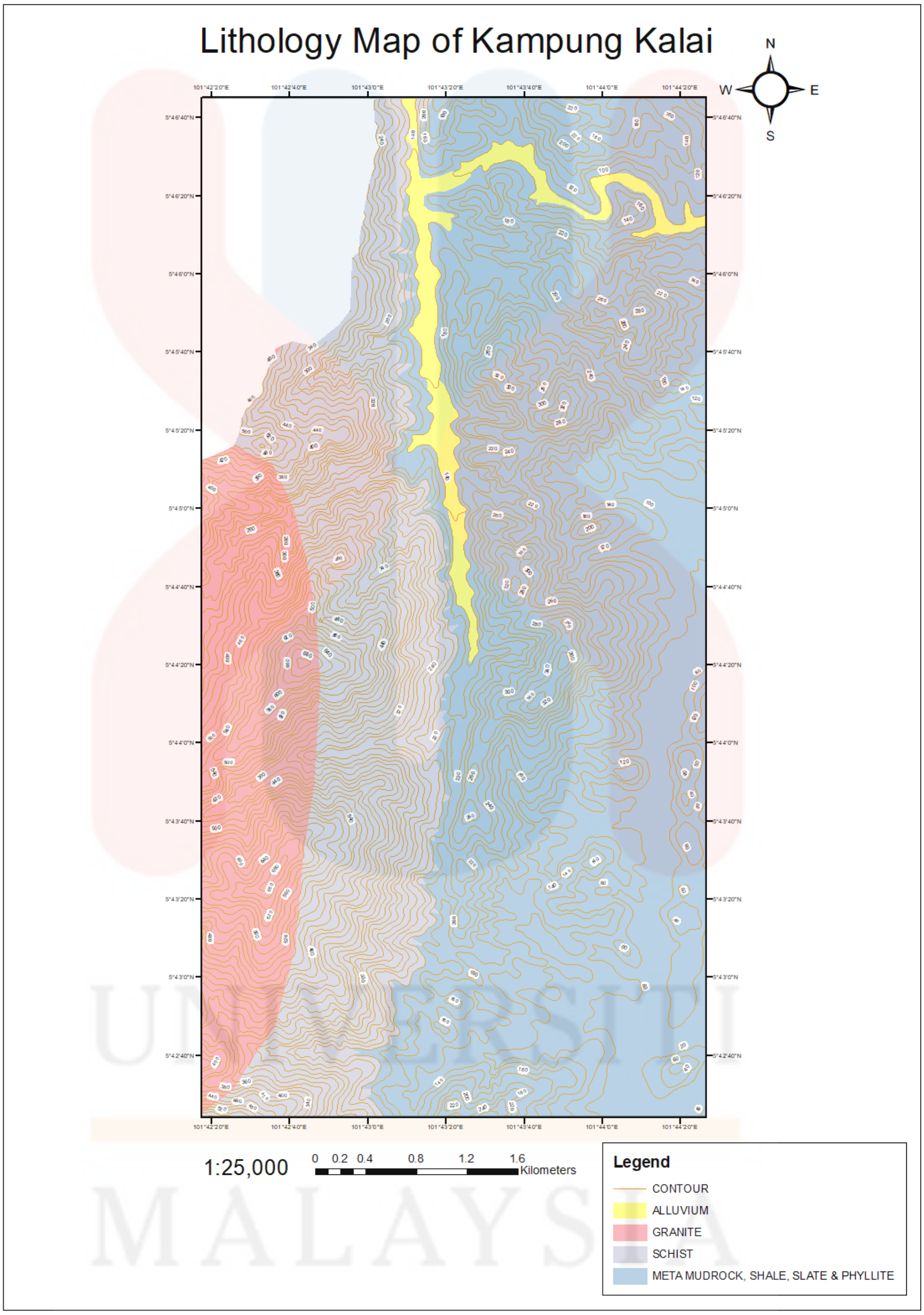


Figure 5.1: Lithology map of the research study.

5.2.2 Aspect

By using DEM, the aspect map was constructed and then split into nine groups depending on the slope's orientation to the north. Variations in gravitational force were linked to the significance of this parameter in influencing the slope's direction. The slope's instability and direction may be evaluated. Anticlockwise rotation is measured from 0 degrees north to 360 degrees south (due to North) (Table 5.3). Figure 5.2 illustrates the aspect map of the study area.

Table 5.3: Slope direction of aspect.

No.	Slope direction	Weightage (Wi)	Score (Sij)	Weightage x Score (WixSij)
1	North-Facing (0 – 22.5)	8	1	8
2	North-East (22.5 – 67.5)	8	3	24
3	East-facing (67.5 – 112.5)	8	5	40
4	South-East (112.5 – 157.5)	8	6	48
5	South-facing (157.5 – 202.5)	8	9	72
6	Southwest-facing (202.5 – 247.5)	8	6	48
7	West-facing (247.5 – 292.5)	8	5	40
8	North-West (292.5 – 337.5)	8	2	16
9	North (337.5 – 360)	8	1	8

5.2.3 Slope

Slope angle is a crucial factor in determining the potential for landslides in the study area. Based on the investigation, it can be inferred that the potential for landslides is closely associated with the slope angle in the study area. Using DEM data, the slope map was produced. According to the standards established by the Geology Society of Malaysia (GSM), there are six distinct types of slope angles, each having a value of 10 scores for weightage (Table 5.5).

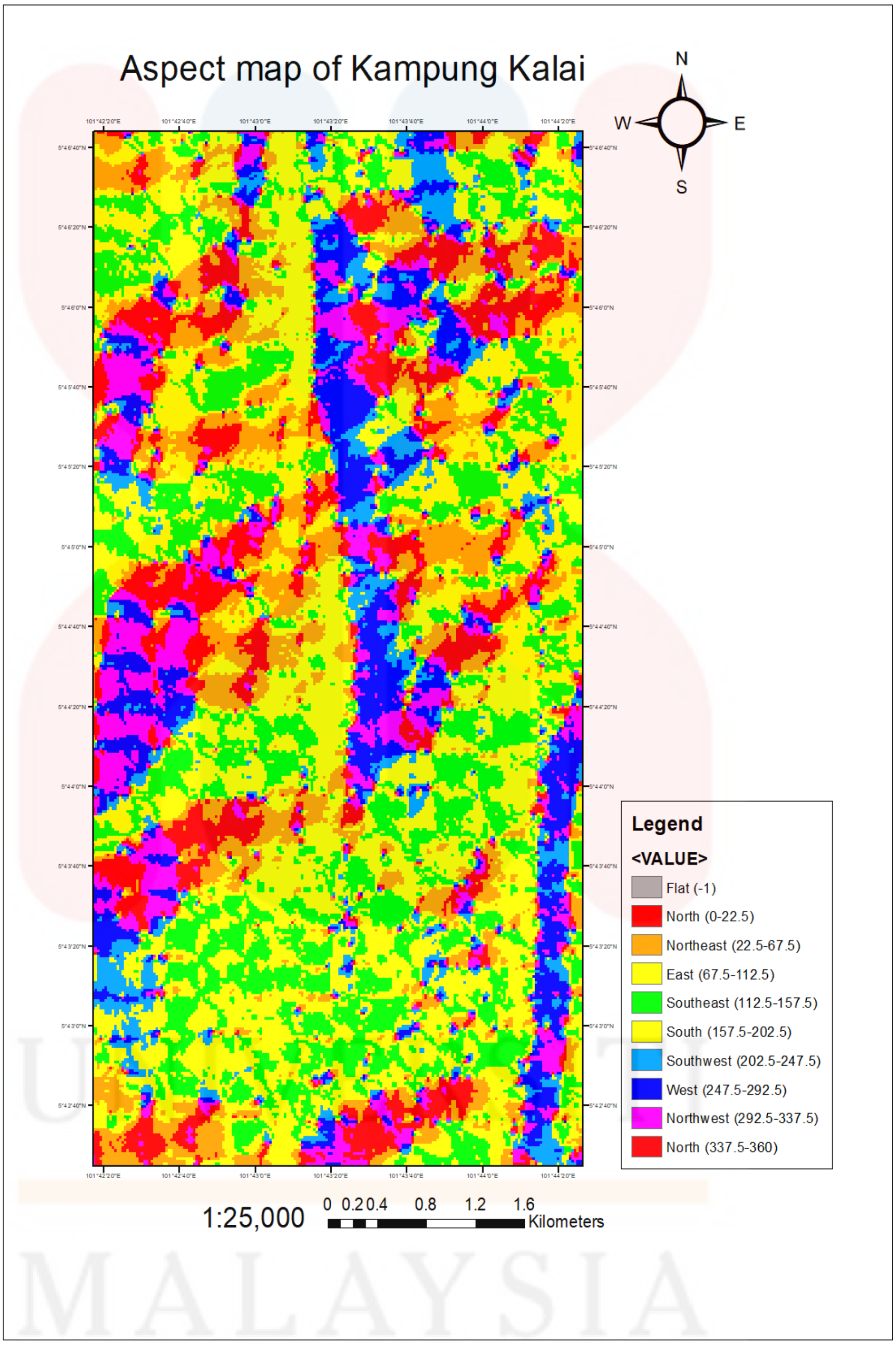


Figure 5.2: Aspect map of study area.

Table 5.4: 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

A landslide occurs when a mass of rock, debris, or soil slides down a slope. Soil and rock were impacted by gravity's force in a downward direction. The erosion or landslide occurred downslope because of weakened soil and rock The downward pressures of a slope result in reduced or weakened strength. The higher the risk that precipitation will run off instead of infiltrating the soil. Moreover, the steeper the slope, the faster the water flows. According to geological mapping, the last landslide happened on both a steep and a moderate slope. Figure 5.4 illustrates the occurrence of a landslide in the location under study, which is located on a gentle slope along the main road of Kampung Kalai.

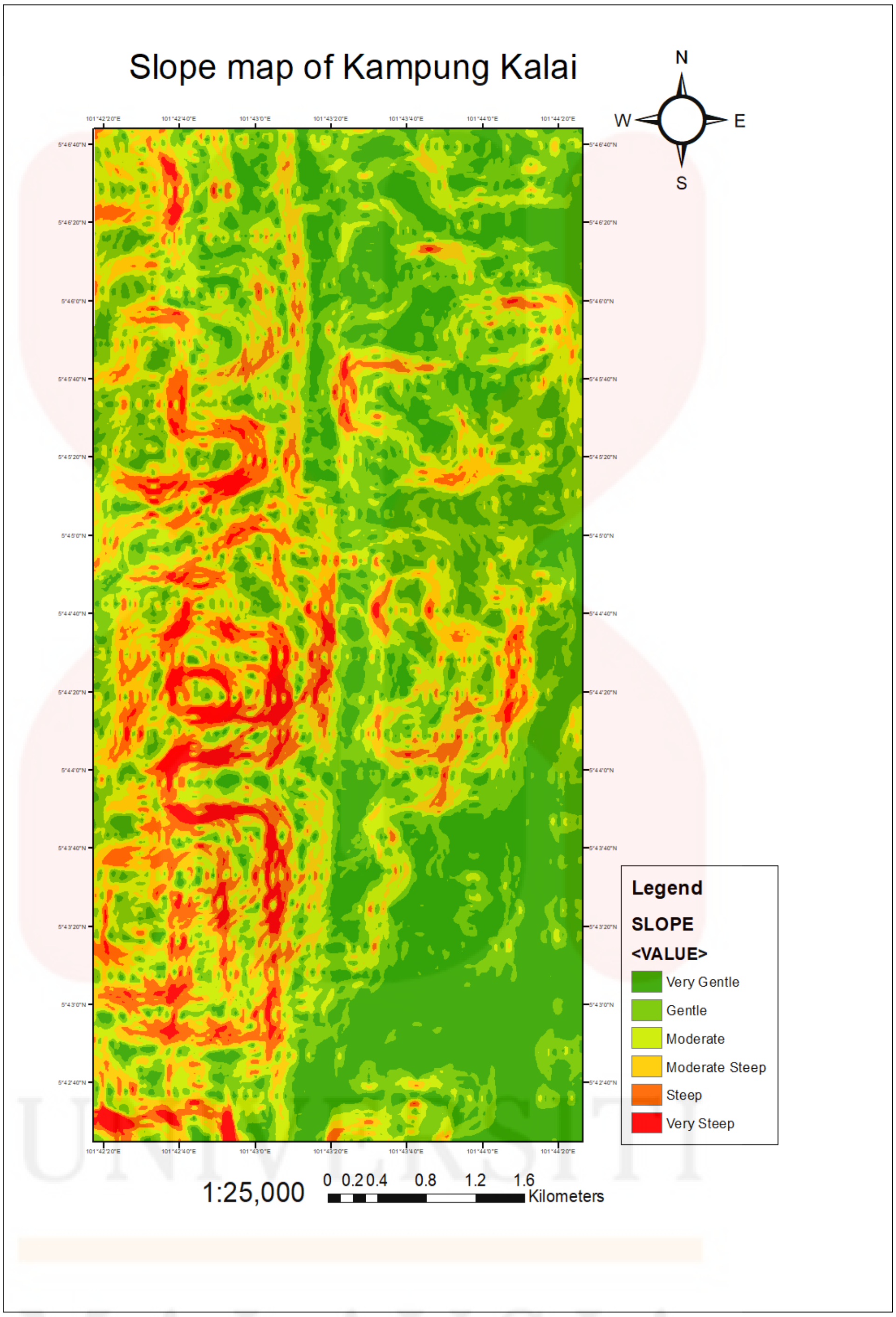


Figure 5.3: Slope map of the study area.

Table 5.5: Weightage and score for slope.

No	Class	Weightage (Wi)	Score (Si)	Weightage x Score (Wi x Sij)
1	0 – 5º	10	1	10
2	5 – 10º	10	2	20
3	10 – 15º	10	3	30
4	15 – 25º	10	4	40
5	25 – 35º	10	5	50
6	> 35º	10	6	60

Figure 5.4: The ongoing landslide along the main road in Kampung Kalai.

5.2.4 Drainage Density

In the GIS analysis, a map of drainage density was created using Digital Elevation Model (DEM) data. This map demonstrated that the drainage density can be an important factor in determining slope stability. Additionally, proximity of the slopes to the stream network was also identified as a key element influencing slope stability. Water from streams seeps into the soil, raising the water table and hence the pore pressure of the soil, both of which contribute to the stability of the slope. The stability of slopes may also be impacted by erosion. Also, both soil water infiltration and surface flow improve with increased drainage density (E. Cevik & Topal, 2003).

The drainage density of a drainage basin is calculated by dividing the total length of streams and rivers by the drainage basin's total surface area. Calculating the drainage density of a stream involves dividing its length by its surface area. The drainage density was classified as low, moderate, or high. (Table 5.6). Climate, terrain, soil infiltration, vegetation, and flux density all have an effect on the drainage variation. It is crucial for constructing a river network in the study area. The amount of debris flow and seepage caused by precipitation infiltration may be used to predict the danger of landslides in a location. A thick drainage system indicates a higher chance of landslides. Figure 5.5 refers to drainage density map of study area.

$$Drainage\ Density = \boldsymbol{Stream\ Length} \,/\, \boldsymbol{Area} \text{ .... } \text{(Equation 5.1)}$$

Table 5.6: Weightage and score for drainage density.

No	Drainage Density	Weightage (Wi)		Score (Sij)	Weightage x Score (WixSij)
1	Low	0 – 543	7	4	28
2	Moderate	544 – 1090	7	6	42
3	High	1100 – 1630	7	8	56

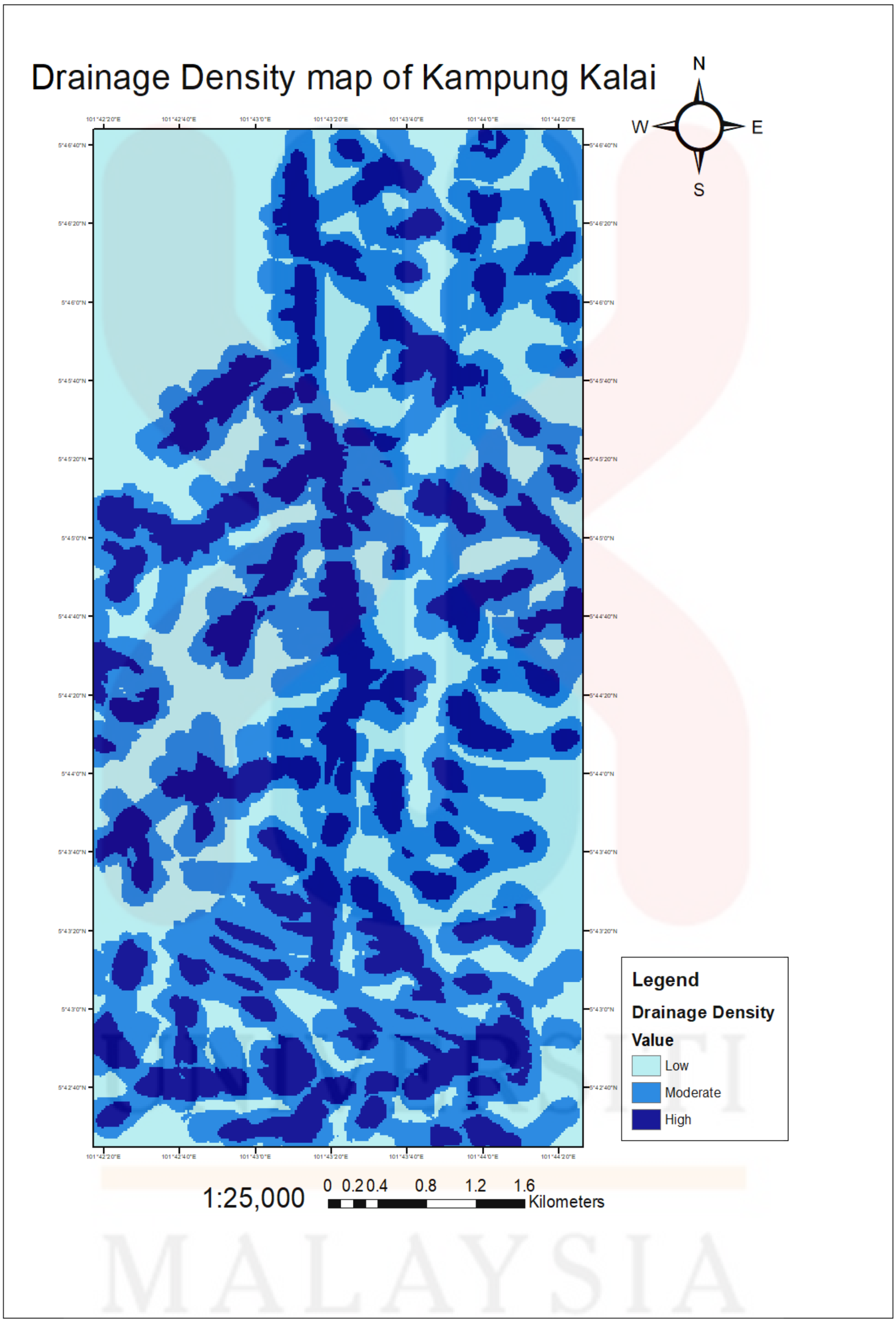


Figure 5.5: Drainage density map of study area.

5.2.5 Lineament density

Lineament is another important feature to consider when evaluating the probability of a landslide. A lineament is a landscape feature that is the linear expression of a geological structure such as a fault, fracture, or joint. Geological surface mapping and topographical mapping information is utilised to comprehend the lineaments. Both faulting and fracture in lineaments increase secondary permeability and porosity (Murasingh & Jha, 2013). The density of the lineament may be used to assess the sensitivity of the landslide threat. There are three distinct kinds of lineament present in the region under study which are low, moderate, and high. The low category has the least influence on the chance of landslides, while the high category has the most impact. The lineament density weightage is five, which is multiplied by the score in Table 5.7. Figure 5.6 depicts the density of lineaments in the analysed area.

Table 5.7: Weightage and Score for lineament density.

No.	Lineament Density		Weightage (Wi)	Score (Sij)	(WixSij)
1	Low	0-220	5	8	40
2	Moderate	220-550	5	6	30
3	High	550-970	5	4	20

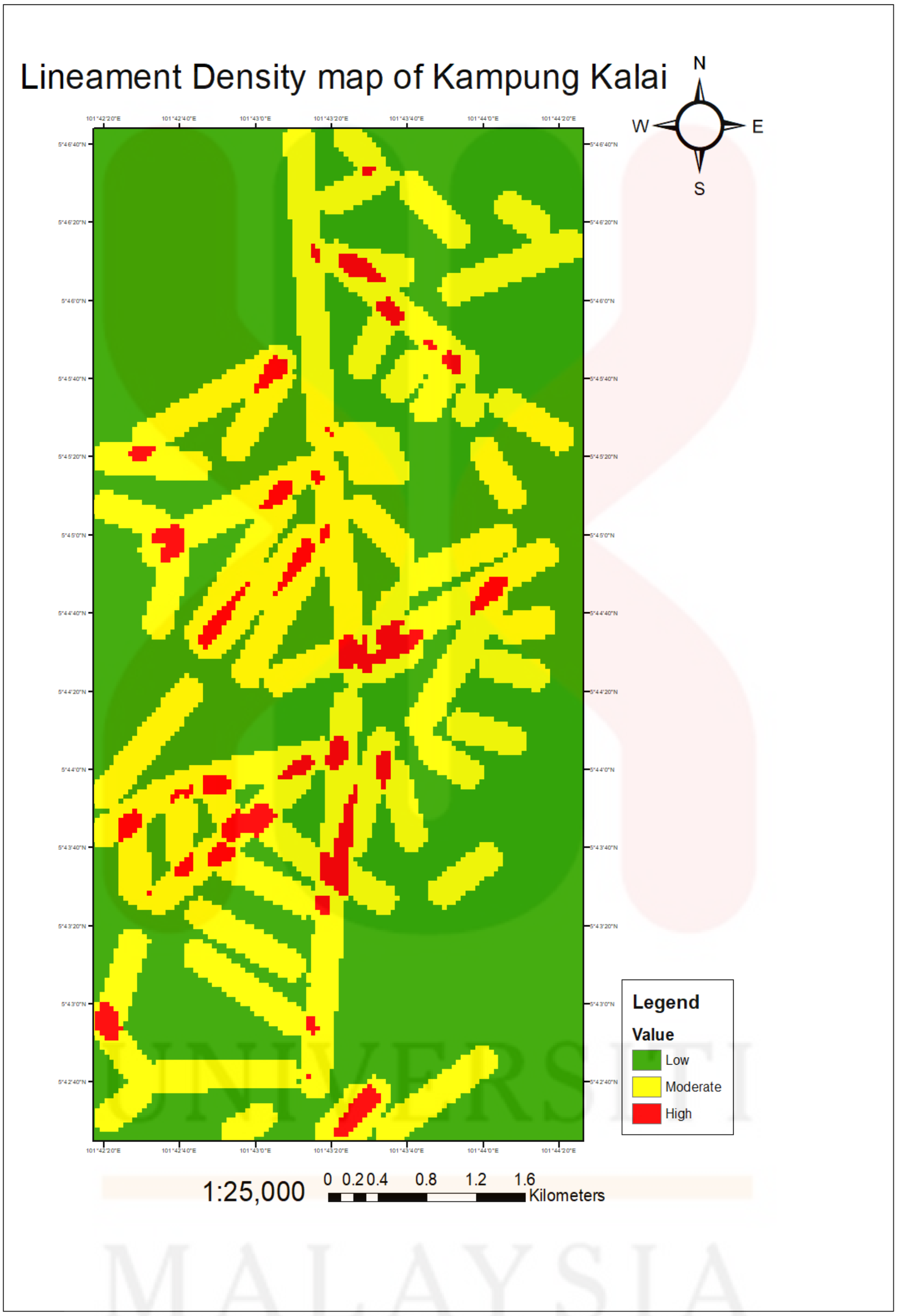


Figure 5.6: Lineament Density of the study area.

5.2.6 Land use

Although Kampung Kalai is a nucleated and linear human village, most of the study area was covered by forest and plantation with a small mining sector. On steep slopes, the risk of landslides is typical in forestry. In addition, landslides may occur near streams and rivers, which might be destroyed if a landslide occurs. The absence of vegetation on the slope and along the road would enhance the effect of rainfall absorption from entering the space between the rocks, so raising the danger of damaged rocks and landslides and enhancing soil strength via root reinforcement. Land use maps of the research area were constructed based on weighting and score indicator (Table 5.8). As represents in Figure 5.7, the area mostly covers by rubber and oil palm plantations, although there are still some forests remaining. The quantity of vegetation on a slope influences the stability of the slope. Human activities might substantially increase the frequency and severity of landslides.

Table 5.8: Weightage and Score for land use.

No.	**Class**	**Weightage (Wi)**	**Score (Sij)**	**Weightage (Wi) x score (Sij)**
1	Plantation	6	4	24
2	Forestry	6	6	36
3	Mining area	6	2	12
4	Settlement area	6	3	18

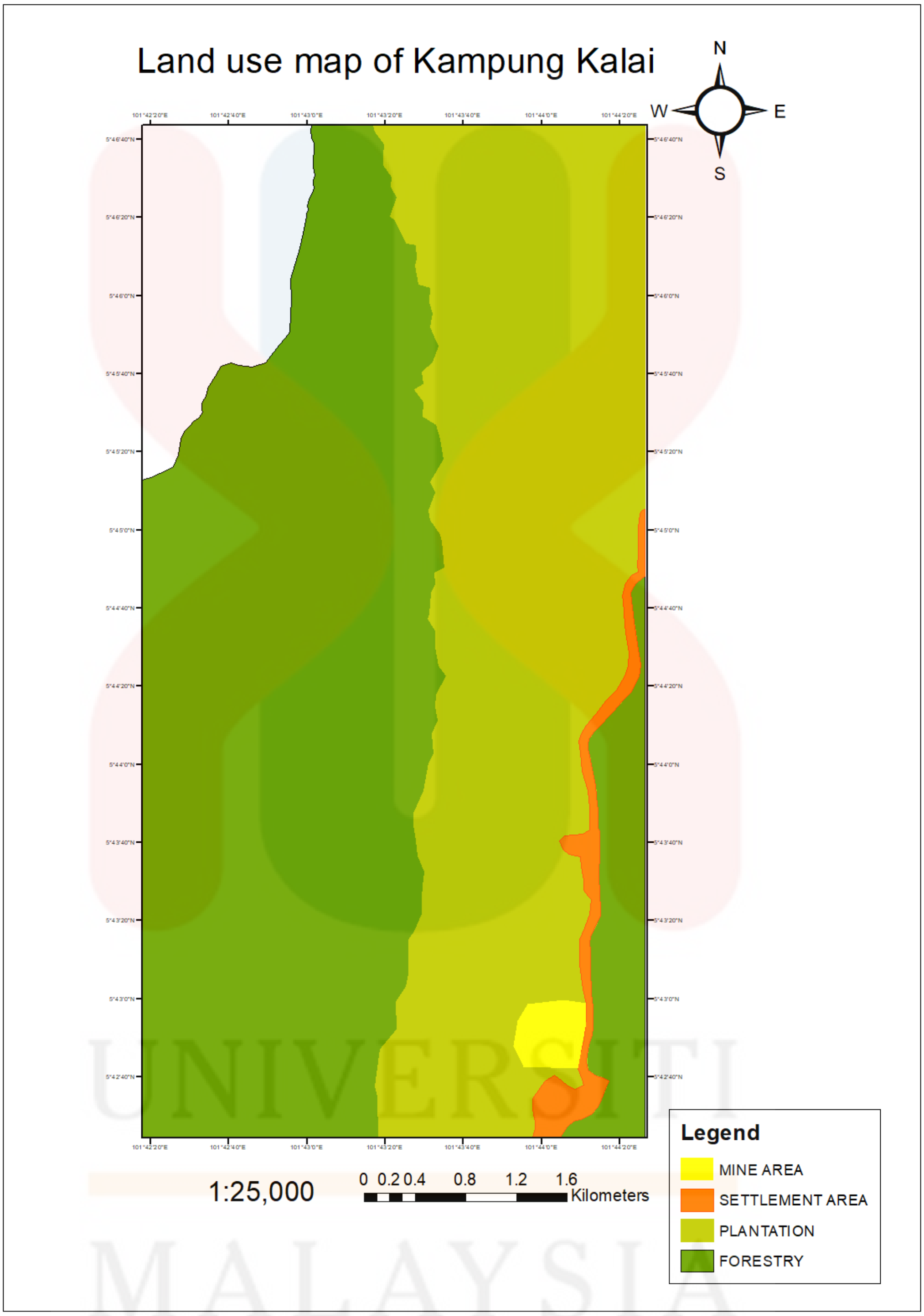


Figure 5.7: Land use of the study area.

5.3 Landslide Potential Analysis

Before developing the potential landslide map, all parameters were converted to raster data sets. Weighting and impact values for each attribute were critical steps after classifying this raster data. The potential for landslides was evaluated on the GIS platform with the help of the weighted overlay index method. Slope, lineament density, lithology, drainage density, aspect, and land use are the six aspects of landslide-causing parameters determined based on previous research. Before using the WOM formula approach specified in Equation 5.2, weights were assigned to these parameters and the total of all factors was set to 100%.

$$S = \frac{\Sigma wisij}{\Sigma wi} \quad \text{.. (Equation 5.2)}$$

The raster data used to determine the weighting of the causative components was reclassified based on works by Awawded et al (2018). Classifying the data is essential for using the weightage overlay approach to build a landslide potential map, as is determining the impact value for each parameter. The reclassified data set is shown in Table 5.9.

Table 5.9: Data reclassification with influence.

No	Raster Datasets	Influence (%)
1	**Lithology:** Granite Schist Meta mudrock	25
2	**Slope:** 0-5 º 5-10 º 10-15 º 15-25 º 25-35 º >35 º	25
3	**Aspect:** North - Facing (337.5–22.5) North - East (22.5–67.5) East - facing (67.5–112.5) South - East (112.5–157.5) South - facing (157.5–202.5) Southwest - facing (202.5–247.5) West - facing (247.5–292.5) North - West (292.5–337.5)	10
4	**Drainage density:** Low (0–543) Moderate (544–1090) High (1100–1630)	20
5	**Lineament analysis:** Low (0-220) Moderate (220-550) High (550-970)	10
6	**Land use** Forest Farm Settlement area Mine area	10
TOTAL		100

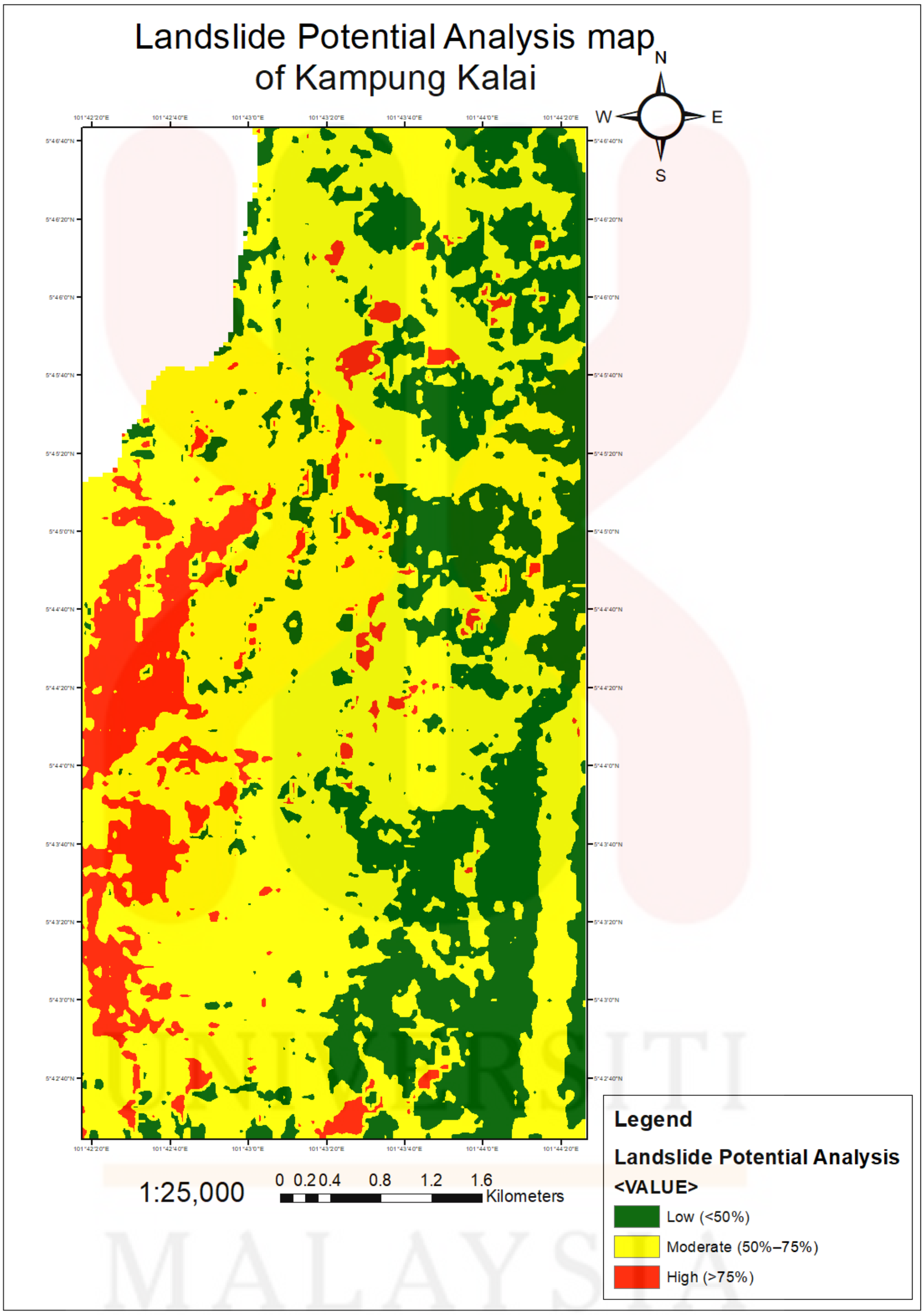


Figure 5.8: Landslide potential analysis map of Kampung Kalai.

Figure 5.8 represents a landslide potential map of the Kampung Kalai area. The map was used to assign a "low," "moderate," or "high" categorization to the study region. It was determined that 34% of the study area was at a low risk for landslides based on the landslide potential map that was created. There is a moderate risk of landslides throughout 53% of the research area, with a severe risk affecting 13% of the area.

There are three main factors to consider while conducting a study on the potential for landslides. Slope, lithology, and drainage density have all become more important in recent years as indicators of landslide potential. The chance of a landslide increases as the slope steepens at this location. Because the rock and soil in that area are porous and void to varying degrees, the lithology of the area also plays a role in the landslide. It has an influence on the stability of rocks and soil because of road development along the main route through Kampung Kalai. Impacts of density and lineament on the landslide phenomena are negligible. Landslide analysis in the research area does not only rely on this factor, but it is of equal relevance when considered with other criteria and circumstances. The landslide potential map shows that landslides are more likely to happen close to watersheds. The stream's moderate to high water density is likely to blame for this phenomenon. Table 5.10 shows the potential of landslide hazard in the study area.

Table 5.10: Potential of landslide hazard in the study area.

Potential Class	**Risk**	**Area Percentage (%)**
Low	0–50%	15
Moderate	50–75%	75
High	>75%	10

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The objective of this chapter is to summarize the results of the assessments conducted using GIS and WOM techniques, as well as the analyses of the geology and potential for landslides in the Kampung Kalai, Jeli region. The goal of the research was to create a detailed geological map of the area at a scale of 1:25,000, and it is noted that all objectives of the research were successfully accomplished. The chapter delves into the different geological aspects of the region, such as its geomorphology, stratigraphy, structural geology, and historical geology. The lithostratigraphy of the area being studied is split into three categories: intrusive granite, metasedimentary rock, and metamorphic rock. The Telong and Mangga formations make up this lithological distribution. There is a north-south fault in the study region, according to the interpretation. Because metasedimentary rocks underlie underneath the area of study, close to the zone of granite intrusion. Numerous geological features, including as faults, folds, joints, and veins, have been uncovered. The causes of the landslide in the Kampung Kalai region were discovered and included as data processing parameters.

The second goal is to identify the causes of landslides. Slope and lithology are the two most crucial factors in triggering landslides. The possibility for landslides in the area under consideration is directly related to the slope angle, as slope totally influences material movement based on gravity. Slopes with steeper gradients have more gravitational and shear forces, which increases material activation at the material of stability. The chance of a landslide has increased. Since the landslide causes the material to either become looser or denser with increasing slope in the research region, lithology is strongly related to slope.

A map depicting the study area's landslide vulnerability was created based on an analysis of the Kampung Kalai landslide potential, which was presented in the specification section. It is now separated into three sections as a low-class (<50%) zone, a moderate-class (50%-75%) zone, and a high-class (>75%) zone. Weightage overlay approach of the GIS platform employed six criteria, including land use, slope density, lineament density, lithology, drainage density, and aspect. The study area has been divided into three groups based on the potential for landslide danger: low, moderate, and high. Specifically, 34% of the area is classified as having low potential for landslides, 53% is considered to have intermediate risk, and 13% is considered to have high potential for landslides.

By analyzing all the six criteria, slope is the most causative factors due to the fact that most landslide risk incidences are caused by unstable slopes. A greater risk of landslides exists in the research area because of its location on a particularly steep and mountainous terrain.

6.2 Recommendation

Geological mapping should begin as soon as possible to help with problems like inadequate data collecting, according to recent studies. Geological information in other fields, such as structural geology and the lithologies of the research area, must also be compiled alongside general mapping knowledge.

In the specification section, a variety of parameters, including rainfall distribution, soil, vegetation, and distance from the road in the research region, are recommended for use in the next study. Various factors lead to varying outcomes, with the most significant characteristics impacting the hazard potential of landslides in the study location.

Furthermore, the requirement of using high-quality DEM data is needed. This is because when low-quality data is utilised, the final image is not clear enough and has a poor resolution. Any other agencies such as Department of Survey and Mapping Malaysia (JUPEM) and National Geospatial Centre (PGN) can fulfil the demand of high-quality DEM through proper channel and application for education purposes.

In addition, the thin section technique of analysing mineral properties requires field studies for more precise findings. Researchers may use the results of mineral studies to learn more about the composition of rocks and the physical factors that contribute to landslides, such as the rock's strength.

REFERENCES

Adriansyah, D., Busu, I., & Programme, G. (2015). Geoheritage as The Basic for Geotourism Development: A Study Case in Jeli District, Kelantan, Malaysia, Geojournal of Tourism and Geosites 15(1):25-43

Awawdeh, M. M., ElMughrabi, M. A., & Atallah, M. Y. (2018). Landslide susceptibility mapping using GIS and weighted overlay method: a case study from North Jordan. Environmental Earth Sciences, 77(21), 732.

Chandra, P., Rajbhandari, L., Monwar Alam, B., & Akther, M. S. (2002). Application of GIS (Geographic Information System) for Landslide Hazard Zonation and Mapping Disaster Prone Area: A Study of Kulekhani Watershed, Nepal (Vol. 1, Issue 1).

Chimidi, G., Raghuvanshi, T. K., & Suryabhagavan, K. v. (2017). Landslide Hazard Evaluation and Zonation in And Around Gimbi Town, Western Ethiopia—A GIS-Based Statistical Approach, Applied Geomatics, 9(4), 219–236.

Collins, M. (2019). Petrographic tests. Concrete Society provides Technical Information,https://www.concrete.org.uk/fingertips-nuggets.asp?cmd=display&id=575

David R. Soller, (2004) McGraw-Hill Yearbook of Science & Technology 2004, pp. 128-130.)

Department of Minerals and Geoscience Malaysia, (2003), Quarry Resource Planning for the State of Kelantan, Osborne & Chappel Sdn. Bhd., Kota Bharu.

Department of Statistics Malaysia Official Portal. (2022). Jeli. Politika. https://politika.my/state/kelantan/jeli

E. Çevik & T. Topal. (2003, July 24). GIS-based landslide susceptibility mapping for a problematic segment of the natural gas pipeline, Hendek (Turkey). SpringerLink. https://link.springer.com/article/10.1007/s00254-003-0838-6

Erener A, Uzgeun HSBD (2008) Analysis on landslide hazard mapping methods: regression models versus weight rating. The international archives of the photogrammetry, remote sensing and spatial sciences, vol. 37 (Part B8), Beijing

Fajri, S., Surtiyono, E., & Nalendra, S. (2019). Lineament analysis of digital elevation model to identification of geological structure in Northern Manna Sub-Basin, Bengkulu. IOP Conference Series: Materials Science and Engineering, 636(1), 012001.

Forbes, K., Broadhead, J., Bischetti, G. B., Brardinoni, F., Dykes, A., Gray, D., Lmaizumi, F., Kuriakose, S. L., Osman, N., Petley, D., Stokes, A., Verbist, B., & Wu, L. H. (2012). Forests and landslides: The role of trees and forests in the prevention of landslides and rehabilitation of landslide-affected areas in Asia Second edition in collaboration with. www.fao.org/

Ghani, A. A. (2009). Plutonism, in: Geology of Peninsular Malaysia, edited by: Hutchison, C. S. and Tan, D. N. K., Geological Society of Malaysia, Kuala Lumpur, 211–232,

Goh Swee Heng, Teh Guan Hoe & Wan Fuad Wan Hassan. (2006). Gold Mineralization and Zonation In The State Of Kelantan. Geological Society of Malaysia Bulletin, 52(June), 129–135. Retrieved from http://www.gsm.org.my/products/702001-100513-PDF.pdf

GSM Warta Geologi. (2010). Abstract: Structural Geology of Gua Musang Formation in Kelantan.

H. Mezughi, T., Akhir, J. M., Rafek, A. G., & Abdullah, I. (2011). Analytical Hierarchy Process Method for Mapping Landslide Susceptibility to an Area along the E-W Highway (Gerik-Jeli), Malaysia. Asian Journal of Earth Sciences, 5(1), 13–24.

Jamil, R. M., Fadzil, F. N., Nawawi, S. A., Nor, A. N. M., Sulaiman, N., Sulaiman, N., & Ibrahim, N. (2022). Landslide Susceptibility Mapping Using Geographic Information System (GIS) in Kuala Balah, Jeli, Kelantan. IOP Conference Series: Earth and Environmental Science, 1102(1).

Kamar Shah Ariffin (2012). Mesothermal Lode Gold Deposit Central Belt Peninsular Malaysia, Earth Sciences,Dr. Imran Ahmad Dar (Ed.), ISBN: 978-953-307-861-8, InTech, http://www.intechopen.com/books/earth-sciences/mesothermal-lode-gold-deposit-c entral-belt-peninsularmalaysia

Kavzoglu, T., Sahin, E. K., & Colkesen, I. (2014). Landslide Susceptibility Mapping Using GIS-Based Multi-Criteria Decision Analysis, Support Vector Machines, And Logistic Regression. Landslides, 11(3), 425–439.

Lacasse, S., Nadim, F., & Kalsnes, B. (2010). Living with Landslide Risk. Geotechnical Engineering Journal of the SEAGS & AGSSEA, 41(4). http://www.engmath.dal.ca/tc32/

Malaysian, T., & Groups, T. W. (2006). Geology of the Batu Melintang- Sungai Kolok transect area along the Malaysia-Thailand boarder. (Malaysian & Groups, 2006)

Metcalfe, I. (2013). Tectonic Evolution of the Malay Peninsula. Journal of Asian Earth Sciences. 76. 195-213. 10.1016/j.jseaes.2012.12.011.

Metcalfe, I. (2000). The Bentong-Raub Suture Zone, Journal of Asian Earth Sciences, 18, pp. 691- 712.

Metcalfe, I. (2002). Permian tectonic framework and palaeogeography of SE Asia, Journal of Asian Earth Sc., 20, pp. 551-566.

Mohamed, K. R., Joeharry, N. A. M., Leman, M. S., & Ali, C. A. (2016). The gua musang group: A newly proposed stratigraphic unit for the permo-triassic sequence of northern central belt, peninsular Malaysia.

Mohamed, K.R. & Leman, M.S., 1994. Formasi Gua Musang: Satu Pemikiran Semula. Warta Geologi, 20(2), 97-99.

Mukhlisin, M., Idris, I., Salazar, A. S., Nizam, K., & Taha, M. R. (2010). GIS Based Landslide Hazard Mapping Prediction in Ulu Klang, Malaysia. ITB Journal of Science, 42 A (2), 163–178.

Murasingh, S., & Jha, R. (2013). Conference Paper: Identification of Groundwater Potential Zones Using Remote Sensing and GIS in A Mine Area of Odisha Water Quality of River using Multispectral Remote Sensing View project low flow View project Identification of Groundwater Potential Zones Using Remote Sensing and GIS in A Mine Area of Odisha.

Nagarajan, R., Roy, A., Vinod Kumar, R. (2000). Landslide Hazard Susceptibility Mapping Based on Terrain and Climatic Factors for Tropical Monsoon Regions. Bull Eng Geol Env 58, 275–287

Pardeshi, S. D., Autade, S. E., & Pardeshi, S. S. (2013). Landslide hazard assessment: recent trends and techniques. SpringerPlus, 2(1), 523.

Pour, A. B., & Hashim, M. (2017). Application of Landsat-8 and ALOS-2 data for structural and landslide hazard mapping in Kelantan, Malaysia. Natural Hazards and Earth System Sciences, 17(7), 1285–1303.

Pradhan, B, S Lee, M F Buchroithner. (2010). Remote sensing and GIS-based landslide susceptibility analysis and its cross-validation in three test areas using a frequency ratio model Photogrammetry Fernerkundung Geoinformation

Rahman, C. A. and Mohamed, K. R. (2001).Pemetaan Awalan Sumber Warisan Geologi Negeri Kelantan, in: Geological Heritage of Malaysia (Geoheritage Mapping and Geosite Characterization), edited by: Komoo, I., Tjia, H. D., and Leman, M. S., LESTARI UMK, Bangi,

Reichenbach, P., Busca, C., Mondini, A. C. and Rossi, M. (2014). The Influence of Land Use Change on Landslide Susceptibility Zonation: The Briga Catchment Test Site (Messina, Italy), Environ. Manage., 54(6), 1372–1384, doi:10.1007/s00267-014-0357-0, 2014.

Roslee, R., Mickey, A. C., Simon, N., & Norhisham, Mohd. N. (2017). Landslide susceptibility analysis lsa using weighted overlay method wom along the genting sempah to bentong highway pahang. Malaysian Journal Geosciences, 1(2), 13–19.

Schwartz, M. O., Rajah, S. S., Askury, A. K., Putthapiban, P., and Djaswadi, S. (1995). The Southeast Asian Tin Belt, Earth Sci. Rev., 38, 95–293

Shit, P. K., Bhunia, G. S., & Maiti, R. (2016). Potential Landslide Susceptibility Mapping Using Weighted Overlay Model (WOM). Modeling Earth Systems and Environment, 2(1).

Sulaiman, M.S, Khan, M.A, Sulaiman, N. and Udin, W.S. (2022). Groundwater Potential Using Electrical Resistivity Imaging In Batu Melintang, Jeli, Kelantan.

Sulaiman, N., Sulaiman, N., Hussin, H., Bahar, A. M. A., & Udin, W. S. (2020, August). Diversification of Igneous Rocks and Geoheritage Values in Pergau, Jeli Kelantan. In IOP Conference Series: Earth and Environmental Science (Vol. 549, No. 1, p. 012020). IOP Publishing.

Syafril, N. S., Udin, W. S., & Achmad Bahar, A. M. (2020). GIS-Based Landslide Hazard Evaluation and Zonation of Kg. Chas, Kuala Betis, Gua Musang, Kelantan. IOP Conference Series: Earth and Environmental Science, 549(1).

T. Listyani R.A. (2019). Criticise of Van Zuidam Classification: A Purpose of LandformUnit. Publikasi Karya Ilmiah Institut Teknologi Nasional Yogyakarta. https://journal.itny.ac.id/index.php/ReTII/article/view/1432/917

Talffi, J. A., & Napiah, A. (2000). Landslide Hazard Zonation Mapping Using Remote Sensing and GIS Techniques. In Geol. Soc. MalaYJia, Bulletin (Vol. 44)

Tanot, U., Ibrahim, K., Hamzah, M., (2001), Pengenalpastian Sumber Warisan Geologi di Negeri Kelantan, In: Ibrahim, K., Tjia, H.D., and Shafeea, M.L. (eds), Geological Heritage of Malaysia (Geoheritage Mapping and Geosite Characterization), LESTARI UMK, Bangi, pp. 111-126.

Tareq H. Mezughi, Juhari Mat Akhir, A. G. R. and I. A. (2012). Asian Journal of Earth Sciences, 5, 13–24. Retrieved from.

Udin, W. S., Yahaya, N. N., & Shariffuddin, S. I. M. (2021). Landslide susceptibility assessment using geographic information system in Aring, Gua Musang, Kelantan. IOP Conference Series: Earth and Environmental Science, 842(1).

Yin, E.H., 1965. Provisional Draft Report on the Geology and Mineral Resources of the Gua Musang Area, Sheet 45, South Kelantan. Geological Survey of Malaysia, 49 pp (unpublished).