



**GEOLOGY AND LANDSLIDE SUSCEPTIBILITY  
MAPPING USING GEOGRAPHIC  
INFORMATION SYSTEM (GIS) AT KAMPUNG  
SUNGAI TERAH, GUA MUSANG, KELANTAN**

by

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

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**FACULTY OF EARTH SCIENCE  
UNIVERSITY MALAYSIA KELANTAN**

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2023

## DECLARATION

I declare that this thesis entitled “**GEOLOGY AND LANDSLIDE SUSCEPTIBILITY MAPPING USING GEOGRAPHIC INFORMATION SYSTEM (GIS) AT KAMPUNG SUNGAI TERAH, GUA MUSANG, KELANTAN**” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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**APPROVAL**

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

Signature : .....

Name of Supervisor I : DR HAMZAH BIN HUSSIN

Date : .....



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Finally, I'd want to give a shout-out to my parents and the rest of my family, as well as the friends who have been so instrumental in my four years at Universiti Malaysia Kelantan and the completion of this project.

This thesis is the product of an academic investigation of the rise of GIS software, which promises to improve mapping both now and in the future. This piece of writing is an attempt at scientific contribution; perhaps, it will prove to be something we can all utilise. This argument, I am well aware, is not ideal. Since the goal is to improve the quality and utility of this thesis, feedback and recommendations are welcome.

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## **Geology And Landslide Susceptibility Mapping Using Geographic Information (GIS) at Kampung Sungai Terah, Gua Musang, Kelantan**

### **ABSTRACT**

Kampung Sungai Terah, Gua Musang Kelantan, in Peninsular Malaysia's Central Belt, hosted the study. The research area's latitude and longitude are 4 '55' 4.97" N and 4 '52' 20.14". This research updates the 1:25,000 geological map of the study region. Landslide susceptibility is an estimate of where landslide will occur. This research's geological mapping included fieldwork, rock sampling, analysing geological structures, and studying geomorphological characteristics and drainage patterns. Field observation included geomorphology drawing and drainage pattern GIS software created the geological and thematic maps from the data. This region is 25% urban, 50% mountainous, and 25% plain, at an elevation of 100-200m. The studied region contains rectangular and dendritic drainage patterns from Galas River tributaries. Fluvial and denudational landform origins are studied. This Middle Permian-Middle Triassic silt is from the Gua Musang Formation. This region has igneous, metamorphic, and sedimentary rock. The research region has quartz-rich granitoid, limestone, slate, and phyllite. Geomorphology, stratigraphy, structural geology, and historical geology of the studied region are examined. There are few types of rock found at the study area which is granite, phyllite, slate and limestone. Weightage Overlay Method (WOM) in ArcGIS software created the landslide susceptibility map using the landslide's characteristics. The susceptibility map revealed low, moderate, and high zones within 25km<sup>2</sup> area. The research area's mountainous terrain made slope the biggest landslide threat. In conclusion, detecting landslide susceptibility improves research area knowledge of landslide processes and helps identify the most probable failure locations in landslide-prone areas.

Keywords: GIS, Landslide Susceptibility, Weightage Overlay Method, Gua Musang

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## Geologi dan Kerentanan Tanah Runtuh Menggunakan Sistem Maklumat Geografi (GIS) di Kampung Sungai Terah, Gua Musang, Kelantan

### ABSTRAK

Kampung Sungai Terah, Gua Musang Kelantan, di Semenanjung Malaysia “Central Belt”, merupakan Kawasan kajian. Latitud dan longitud kawasan kajian ialah 4 '55' 4.97" N dan 4 '52' 20.14". Penyelidikan ini mengemas kini peta geologi 1:25,000 kawasan kajian. Kajian ini memetakan 25 km<sup>2</sup> geologi kawasan Jalan Jelawang–Gua Musang Kelantan. Pemetaan geologi penyelidikan ini termasuk kerja lapangan, termasuk mengumpul sampel batu, menganalisis struktur geologi, dan mengkaji ciri geomorfologi dan corak saliran. Pemerhatian lapangan termasuk lukisan geomorfologi, corak saliran, dan geologi sejarah kawasan penyelidikan. Perisian GIS mencipta peta geologi dan tematik daripada data. Wilayah ini adalah 25% bandar, 50% pergunungan, dan 25% dataran, pada ketinggian 100-200m. Kawasan yang dikaji mengandungi pola saliran segi empat tepat dan dendritik dari anak sungai Galas. Asal-usul bentuk muka bumi fluvial dan denudasional dikaji. Kelodak Permian Tengah-Trias Tengah ini adalah dari Formasi Gua Musang. Rantau ini mempunyai batuan igneus, metamorfik, dan enapan. Petrografi menemui mineral dan batuan. Kawasan penyelidikan mempunyai granit, batu kapur, batu tulis, dan phyllite yang kaya dengan kuarza. Geomorfologi, stratigrafi, geologi struktur, dan geologi sejarah wilayah yang dikaji diperiksa. Terdapat beberapa jenis batuan yang dijumpai seperti granit, phyllite, slate dan batu kapur. Weightage Overlay Method (WOM) dalam perisian ArcGIS mencipta peta kerentanan tanah runtuh menggunakan ciri-ciri tanah runtuh. Peta kerentanan mendedahkan zon rendah, sederhana dan tinggi dalam kawasan 25km<sup>2</sup>. Kawasan pergunungan di kawasan penyelidikan menjadikan cerun ancaman tanah runtuh terbesar. Kesimpulannya, pengesanan kerentanan tanah runtuh meningkatkan pengetahuan kawasan penyelidikan tentang proses tanah runtuh dan membantu mengenal pasti lokasi kegagalan yang paling berkemungkinan di kawasan rawan tanah runtuh.

**Kata Kunci:** GIS, Kaedah Perlapisan Berwajaran, Kerentanan Tanah Runtuh, Gua Musang

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#### LIST OF ABBREVIATION

DEM	Digital Elevation Model
GIS	Geographical Information System
GPS	Global Positioning System
USGS	US Geological Survey Earth Resources and Science Centre



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**LIST OF SYMBOLS**

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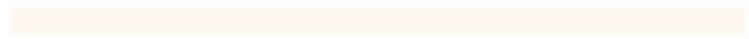
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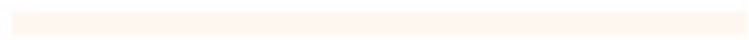
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## CHAPTER 1

### INTRODUCTION

#### 1.1 General Background

Geology is the study of the Earth, its components, their structure, and the processes that shape them. An essential aspect of geology is the investigation of the earth's material, structure, mechanisms and living things have altered over time. Title for this research is Geology and Landslide Susceptibility Mapping Using Geographic Information System (GIS) at Kampung Sungai Terah, Gua Musang, Kelantan. The research will focus on the general geology in the study area. It also includes on the geology and landslide mapping in the area with the research specification, 'Landslide Susceptibility Mapping'.

Hazard is a natural phenomenon that might cause negative effects on humans and also surrounding us, including the environment. It can be categorised into two, which are geological and biological hazards. Many hazards normally occur, such as landslides, floods, earthquakes, sinkholes and others. The structural geology, geomorphology, stratigraphy and sedimentology will be included in the geological part to observe and get the data in Gua Musang, Kelantan.

Landslides are one of the world's most common natural problems, especially in mountainous places resulting in substantial injury and loss of life, property and infrastructure damage. A landslide is generally defined as the movement of soil or

rocks down due to gravity forces. In Malaysia, landslides are shallow, small-scale failures triggered by surface infiltration or erosion during rainfall (Department of Public Works, 2006).

Various triggering conditions, such as severe or prolonged precipitation, earthquakes and anthropogenic activities, can produce landslides. The type of landslide flowing, slide, topple or fall can be combined with two or more movements. In the study area, rainfall intensity and earthquakes are the main factors that trigger yearly landslides.

Excessive rainfall can trigger a landslide, especially in areas with thick and weathered soil. When the rain pours intensely and fills the porosity and void in the soil, it leaves an excessive amount of water that slides through the bedrock, causing a landslide. Clay with high plasticity leading to high pore pressure in the soil with a small shear angle will cause a landslide (Arifianti & Yukni, 2015).

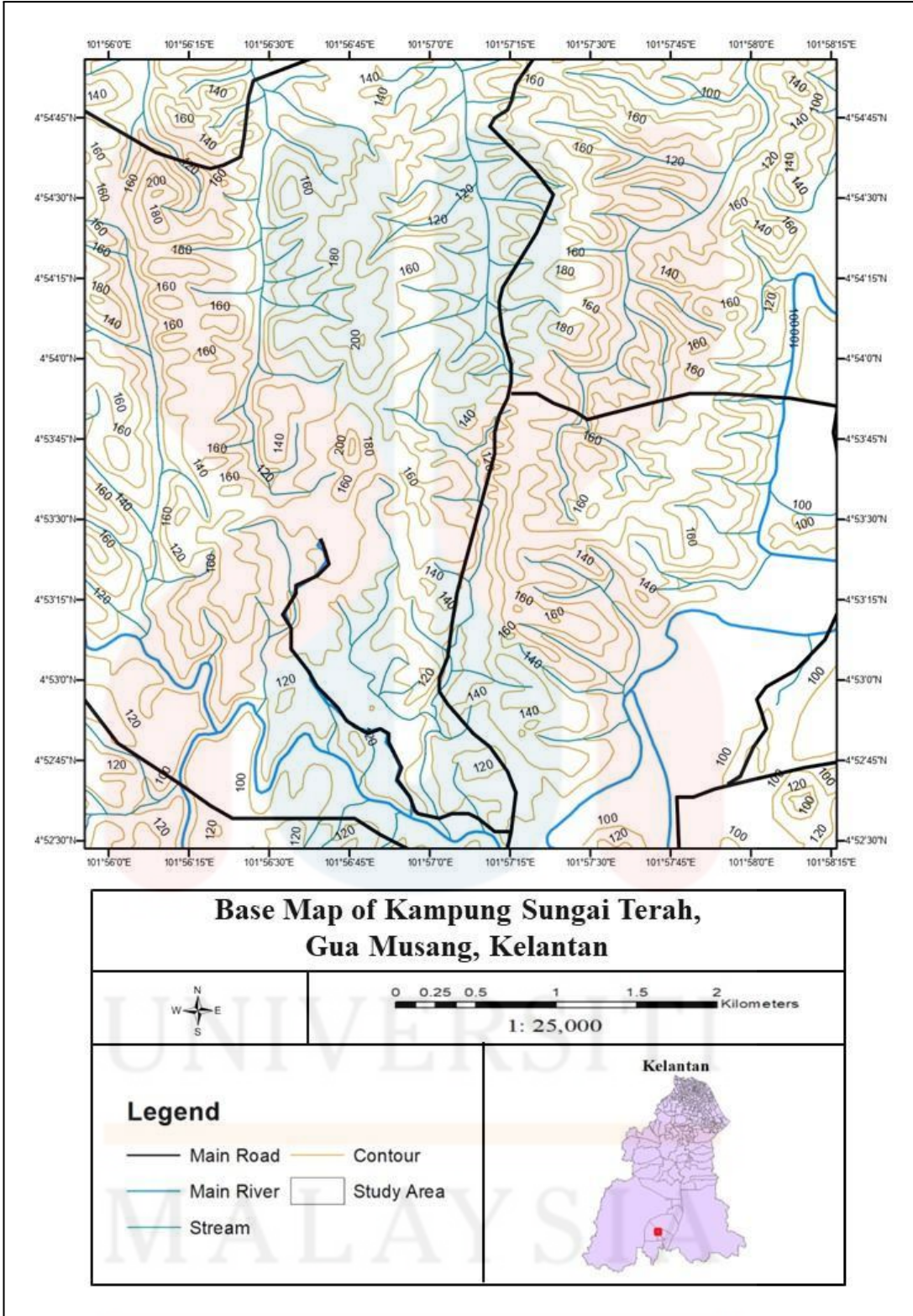
Therefore, this research is conducted to understand the general geology of the study area and factors of landslides that cause the impact of a disaster on the community and the area.

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## 1.2 Study Area

The research mainly focuses on geological mapping in Kampung Sungai Terah, Gua Musang, Kelantan (Figure 1. 1). The total study area is approximately 25 km<sup>2</sup> using measurement dimension of 5km×5km, within the coordinate ranging from latitude 4° 55' 4.97" N to 4° 52' 20.14"N and the longitude 101° 55' 47.07"E to the 101° 58' 25.69"E. This region has a mountainous, hilly, and flat topography. From this chapter, road accessibility, land use, location, demography and social economics were discussed.



**Figure 1.1:** Base Map of Kampung Sungai Terah, Gua Musang, Kelantan

### **1.2.1 Location**

Gua Musang located in the central region of Kelantan is the largest district in the state and is bordered by Pahang to the south, Terengganu to the east, Perak to the west, and Kuala Krai and Jeli to the north. The research area is relevant for conducting this study, because the area is prone to landslide, particularly in the village area near the main road of Jalan Jelawang – Gua Musang.

### **1.2.2 Road Accessibility**

The primary routes that may be travelled on or that provide access to Gua Musang's location are depicted in Figure 1.1. The location can be reached through major roads: Jalan Jelawang – Gua Musang. The town is stated in KTM East Coast Line, which runs from Tumpat near the Thai border to Gemas in Negeri Sembilan. Because the study location is close to the city of Gua Musang, it is simply to get to because there are various transportation options available, including vehicles, buses, and trains.

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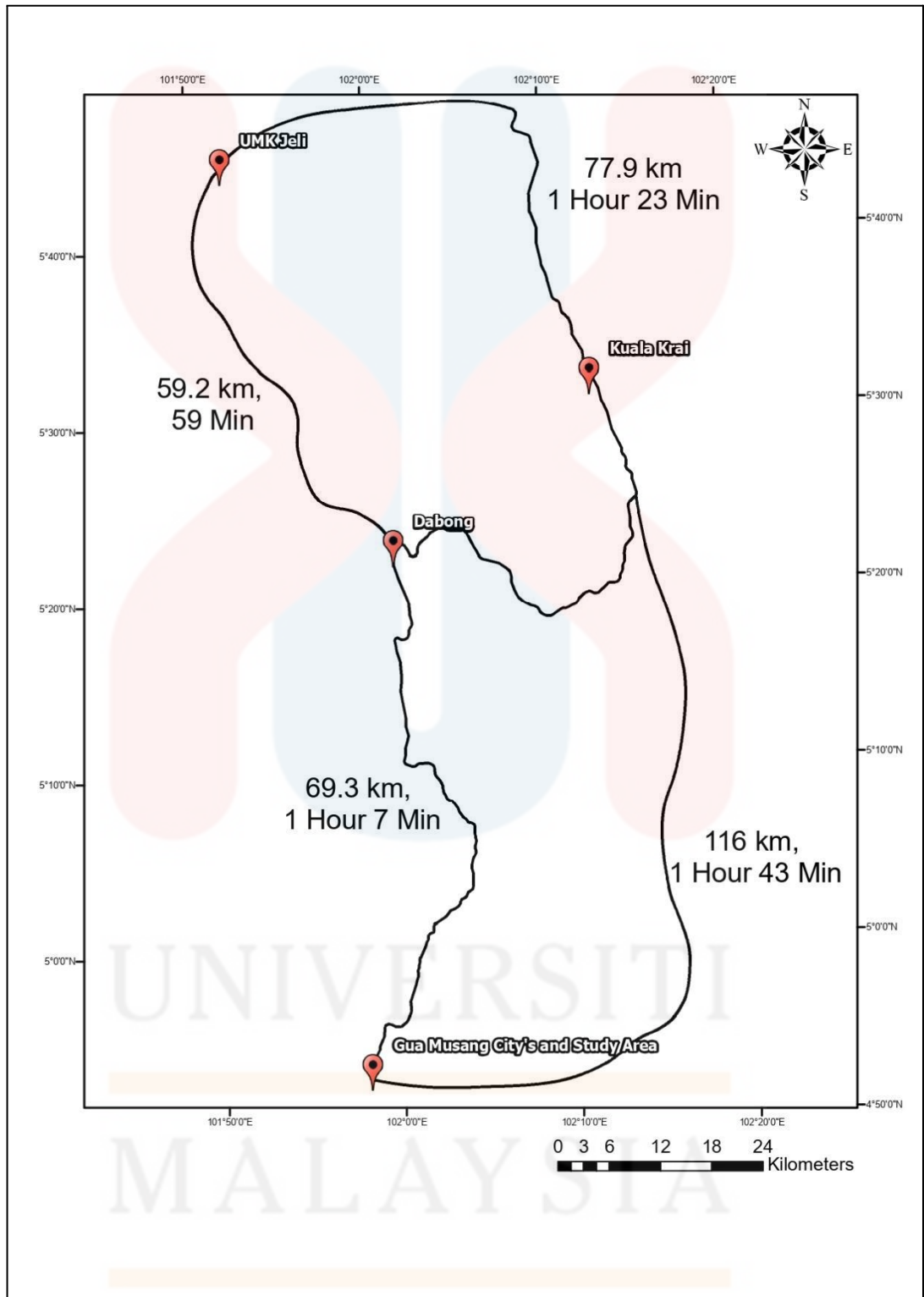


Figure 1.2: Accessibility Map to Study Area

### 1.2.3 Demography

Gua Musang is Kelantan's largest district and has a total area of 6,662 km<sup>2</sup> and divided into three sub-districts: Galas, Bertam Baharu, and Chiku. Galas (404.3 km<sup>2</sup>) contains 8,944 population, Bertam Baharu (4,187km<sup>2</sup>) contains 24, 469 population, and Chiku (3,060.4 km<sup>2</sup>) contains 27, 627 population (Department of Statistics Malaysia, 2022).

### 1.2.4 Land Use

The process of controlling and altering the natural environment in order to make way for a new constructed environment is referred to as land use. It may take a long time to complete. The overall arrangements, activities, and input that people undertake in a specific land type constitute natural environment alteration. The land use in Gua Musang is dominated by rural and urban development's due to its proximity to the town and village. Gua Musang has made significant progress as evidenced by the thriving hospital facilities, public libraries, schools, shopping malls, and other locations.

Furthermore, land in Gua Musang is used for agricultural purposes. Agriculture is the most important land use, accounting for half of the habitable land on Earth. Extensive land usage has a significant effect on the planet's ecology, as it diminishes wildness and endangers biodiversity. The majority of the land use area in

this research region is covered by plantation areas such as palm oil and rubber tree plantation areas.

### **1.2.5 Sosial Economic**

The primary source of social economic income in the research area is agriculture, as well as government employees and self-employment. The government sector is large and includes numerous residents such as state or local government and all units of federal government that can give many services to people. Furthermore, most people in the area work as contractors or labourer's due to the study area's proximity to palm oil plantations in the north and rubber tree plantations in the south.

### **1.3 Problem Statement**

Many countries worldwide with severe heavy rains, tsunamis, hurricanes or volcanic eruptions, causing unforeseen landslides. These natural disasters have devastating effects on people and economics. The landslide has reoccurred in some areas in Gua Musang, Kelantan. As a result, the landslide destroyed many properties and left the town in a challenging situation.

This results in economic disruptions since transportation and urban activities are disrupted. Aside from natural disasters, landslides can also be caused by human actions. Many factors, such as climate change, deforestation, and land overuse, can also contribute to developing landslide-prone areas.

#### **1.4 Objective**

The objectives of the research are as follows:

- I. To generate geological map of Kampung Sungai Terah, Gua Musang, Kelantan with scale 1: 25 000.
- II. To determine the landslide distribution in the study area
- III. To produce a Landslide Susceptibility map of Kampung Sungai Terah, Gua Musang, Kelantan.

#### **1.5 Scope of Study**

This project focuses on creating a geological map of 25 km<sup>2</sup> in the Jalan Jelawang – Gua Musang region of Kelantan. To gather geological information about the research region, geological mapping and observation must be performed. The field data is utilised to construct a geological map of the area under study.

The Weighted Overlay Method (WOM) is used in GIS raster-based analysis to create the landslide susceptibility map. The landslide susceptibility map has been produced by using the parameters such as lithology, slope, and topographical maps and the Data Elevation Model (DEM).

#### **1.6 Significance of Study**

The findings from the study may benefit other researchers. They can use the outcomes from this study as their reference and get information for future research.

This study is also helpful in producing a new geological map of the study area. Recent findings of geologic features can explain how geological processes occur in the study area.

The critical slope is identified by creating a landslide susceptibility map. By achieving and giving accessible, continuous, and precise information regarding the incidence of landslides, the solution to the landslide disaster can be established (Shahabi & Hashim, 2015). The precision of the maps of landslide susceptibility is crucial and can prevent the loss of life and property.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

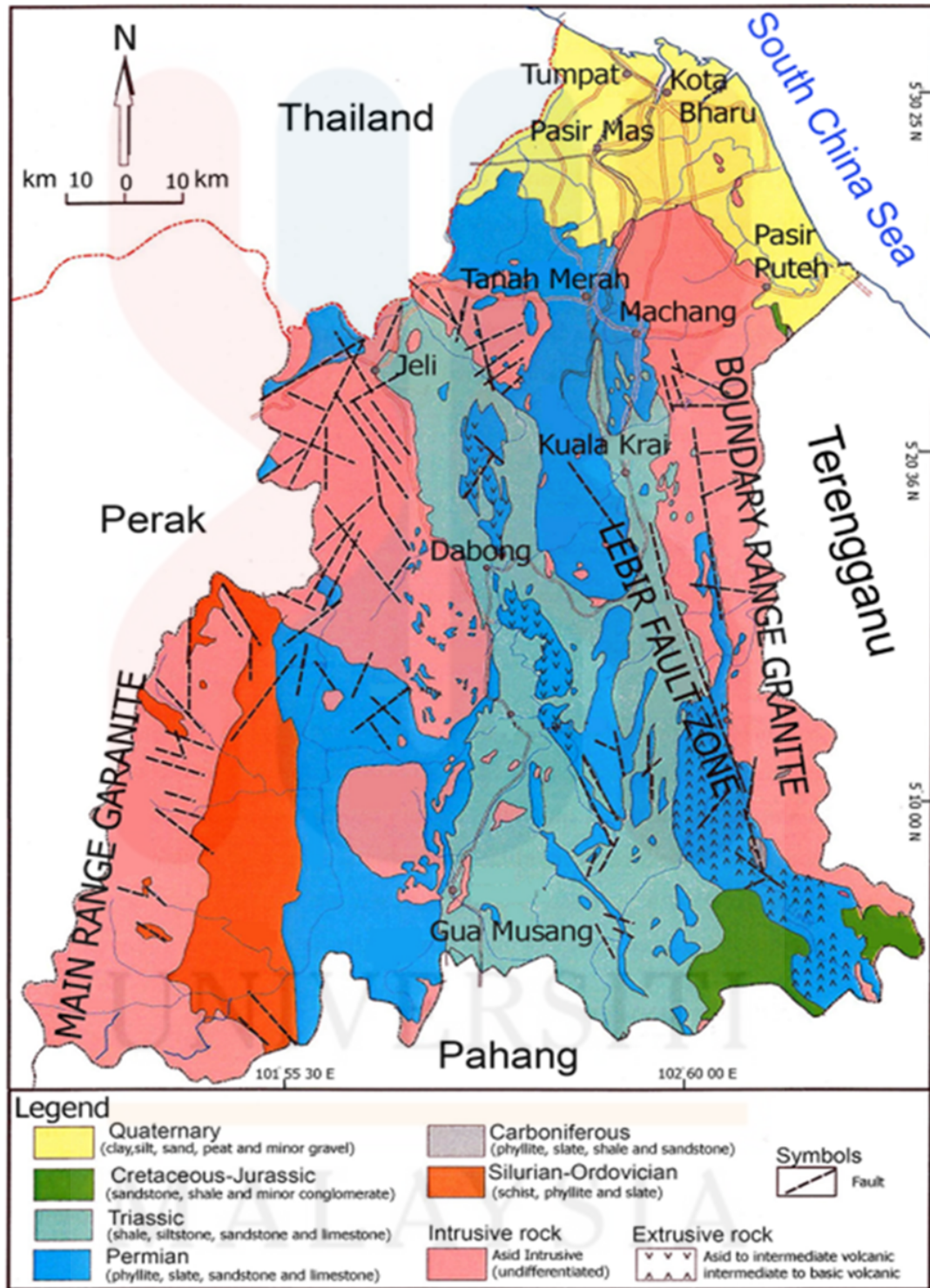
This chapter addresses the literature review in context of the early study findings. The purpose of the literature review is to provide support for the methodologies and processes that can aid in this study. This project seeks to map the geology and landslide susceptibility of Kampung Sungai Terah, Gua Musang, Kelantan, using GIS. Determining the kind of rock, rock distribution, and geological structure of the studied region demands a geological investigation. These data contribute to the creation of a geological map of the research region. This debate will focus on the research conducted by past scholars in the Kampung Sungai Terah, Gua Musang, Kelantan study region.

#### 2.2 Regional Setting and Tectonic Setting

As part of Sundaland's Southeast Asian continental core, Peninsular Malaysia is situated. The Late Triassic assembled the Sibumasu Terrane in the west and the Sukhothai Arc in the east into a single tectonic block (Metcalf, 2013). Located in the north-eastern Peninsula of Malaysia, the state of Kelantan is a Malaysian federal territory.

The Kelantan River is the region's main river. It begins in Kuala Krai at the confluence of the Galas and Lebir rivers and meanders over the coastal plain until it reaches the South China Sea. It consists of flat to moderately sloping sections in the north, steep cuts, and high slopes in the south (Pradhan et al., 2009). The state of Kelantan has north–south distribution of igneous, sedimentary, and metamorphic rocks. Granitic rocks, sedimentary rocks, metasedimentary rocks, and extrusive rocks (volcanic rocks) are the four types of rocks that are typically categorised in this region. Unconsolidated sediments round out the list (Figure 2.1).

Faulting and jointing can be found in granitic rocks, while folding and faulting are present in sedimentary rocks. These are localised geological phenomena. Granitic rocks may be found along both the western (known as the Main Range granite) and eastern (known as the Boundary Range granite) boundaries of the state of Kelantan (Rahman and Mohamed, 2001; Department of Minerals and Geoscience Malaysia, 2003; Heng et al., 2006).



**Figure 2. 1:** Geologic map of Kelantan state

(Source: Modified from Department of Minerals and Geoscience, Malaysia, 2003)

### **2.3 Regional Geology and Tectonic Setting of Gua Musang**

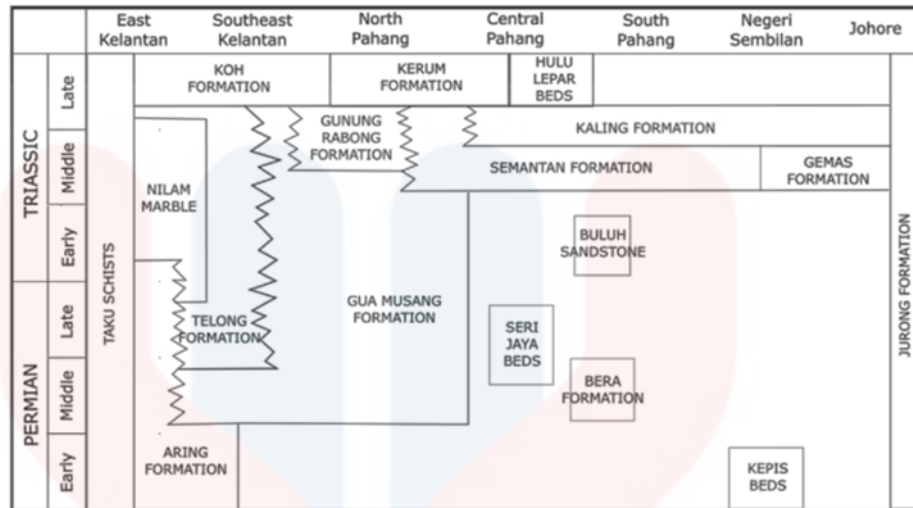
The town of Gua Musang was found in the middle of Peninsular Malaysia's Central Belt. Peninsular Malaysia is split in two by the conspicuous North–South Paleo–Tethys Bentong–Raub suture. On the western side of the peninsula is the Sibumasu block, while on the eastern side is the Indochina block, sometimes known as East Malaya (Hutchison, 2014).

### **2.4 Stratigraphy of Kelantan**

There are 2 to 3 kilometres of Triassic marine sediments in the Central Belt of Peninsular Malaysia, after which there are 1.5 to 2 kilometres worth of continental layers ranging from the Jurassic to the Early Cretaceous. Limestone, siltstone, olistostrome, and conglomerate calcareous sediments are found on the margins of the graben in the Early Triassic sedimentary rock (Metcalf, 1989). Sediments from the Permian Period have been discovered in many rivers in the Kelantan state of Malaysia. These rivers include the Sungai Lebir, Sungai Aring, Sungai Relai, Sungai Paloh, and Sungai Badong (Fontaine, 2002). Youngest rocks in Kelantan are continental rocks that range in age from the Jurassic to the Cretaceous. It sits above the Boundary Range Granite, the Triassic deposits of the Gunung region, and the western mountains of Gunung Perlis and Gunung Pemumpu. Sandstone lies on top of the conglomerate, and volcanic rock intercalations occur here and there throughout the stages.

Kelantan is composed of three different types of rock, or "facies": argillaceous, carbonate, and volcanic/pyroclastic. Shale, siltstone, mudstone, slate, and phyllite are all examples of the Argillaceous facies, and they can be found in abundance in the Gua Musang and Telong formations, as well as in the interbeds and lenses of the Nilam marble. Nilam marble, the Gua Musang formation, and beds or lenses within the Telong and Aring formations are all dominated by carbonate, common facies. (Yee, 1983). In other formations analysed, the volcanic facies are interlayered with carbonate and argillite and are dominant in the Aring Formation. The Gua Musang Formation is found in the Central Belt's Gua Musang-Semantan depocenter, located east of the Bentong-Raub Suture. Crystalline limestone is interbedded with thin strata of shale, tuff, chert nodules, and subordinate sandstone and is volcanic in the Gua Musang Formation. The structure of the formation may be seen, including bedding, cross-lamination, and oolites (Hutchison & Tan, 2009).

The Gua Musang Formation comprises calcareous and argillaceous rocks, lava flows, arenite, and pyroclastic material (Yin, 1965). They are a type of platform facies that are found in shallow water. In the Gua Musang Formation, calcareous rocks make up most of the available facies. Burton (1973) estimates that limestone makes up approximately 80 percent of all the rocks in the Gua Musang Merapoh region. Most Triassic limestone is found as blocks or lenses embedded among shale and olistoliths.



**Figure 2. 2:** Permo - Triassic stratigraphic correlation chart of Central Bet Peninsular – Malaysia.

### 2.5 Structural Geology of Gua Musang

According to Ghani (2000), faulting and folding were the immediate effects of tectonic activity Peninsular Malaysia, between the Palaeozoic and Mesozoic, geographically. In sedimentary and igneous rock, faulting and folding were seen as confined structures consisting of folding, jointing, and faulting.

According to Gobbett & Hutchison (1973), the major tectonics of Gua Musang have an overall pattern that is similar to the minor effects consisting of tight concentric folds, asymmetry, recumbent and overfolds. The minor faults generally oriented north to south. The structural layers are aligned in a north-to-northwest direction. It consists of a series of tight folds with no obvious anticlinal or synclinal tendencies along the axis. The lithology and bed thickness both play a role in the

range of folding intensity, measured in degrees. The stratigraphy of the Aring, Telong, and Nilam Marble formations are depicted in Figure 2.3.

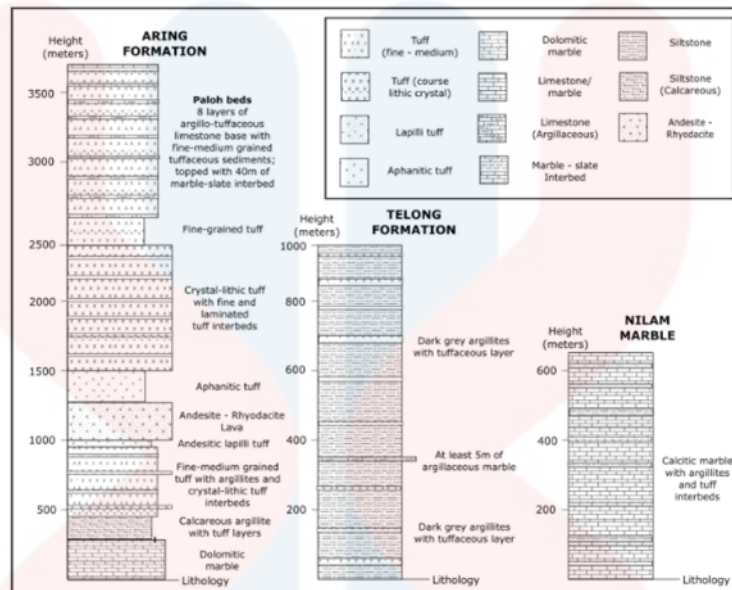


Figure 2. 3: Stratigraphical column of Aring, Telong and Nilam Marble formation.

## 2.6 Historical Geology of Kelantan

Kelantan is situated in the Central Basin, which has the rocks that were formed the most recently. Most Upper Palaeozoic sediments are marine Permian strata in the Central Belt in linear belts flanking Mesozoic deposits (Farhafiezah, 2017). The sediments from the Triassic epoch began to build in the basin. Only fine-grain marine sediment is deposited early in the deposition process, after which further coarse-grained sediments from the continent were deposited throughout the Jurassic and Cretaceous eras (Metcalf, 1989).

In the Malay Basin, strike-slip fault movement in the sinistral direction took place during the Permian era, which resulted in crustal expansion (Tjia, 1994). Graben, pull-apart basins, and the Central Basin were all born as a direct consequence of this process. The basin started to fill up with sediments that dated back to the Triassic period. Early on in the deposition process, only marine sediments with very fine grains are formed, and then, beginning in the Jurassic period and continuing through the Cretaceous period, coarser continental sediments are produced (Metcalf, 1989). Furthermore, Hutchison and Tan (2009) said that Paloh is composed of a Triassic argillic-tuffaceous limestone unit, indicating that Paloh is a part of the Central Basin.

According to Hashim, (2017), North-eastern Malaysia and southern Thailand have experienced significant floods as a result of the North-east monsoon's record-breaking rainfall from December 21–24, 2014, which was estimated to have been as much as 250mm. In addition to flooding, these heavy rains have caused significant landslides, namely on highland slopes in the upper stream sections of the Kelantan River Basin. Landslides of varying sizes occur frequently and are dispersed over the highlands of upper stream areas because the majority of the highland consists of weakly worn geological features consisting of sedimentary and metamorphic rocks.

Haque et al., (2016) clearly described that landslide phenomena are a significant natural hazard frequently caused by intense rainfall and powerful earthquakes. Landslides pose a significant threat to human life and the natural

environment, as well as commercial and public infrastructure, and have a substantial economic impact.

Hashim et al. (2017) report that human activities such as altering the landscape through cut-and-fill operations, extracting minerals, and clearing forests are a major contributor to the occurrence of landslides. Accurately identifying areas at risk for landslides through the use of satellite remote sensing data and GIS analysis is crucial for effectively assessing hazard and reducing risk, which is a pressing need when it comes to managing landslide occurrence zones.

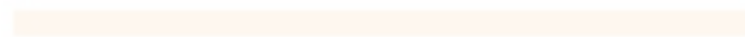
All continents contain landslides, which play a significant role in the evolution of landscapes. In many regions of the world, they also pose a significant risk. Despite their significance, landslide maps were estimated to cover less than 1 percent of the landmass slopes, and there is a lack of systematic information on the type, abundance, and distribution of landslides (Guzzetti et al., 2012). In order to document the extent of landslide phenomena in a region, investigation of the distribution, types, pattern, recurrence, and statistics of slope failures is needed. Besides, it is essential to create landslide maps for the purpose of determining landslide susceptibility, hazard, vulnerability, and risk, as well as examine the evolution of landscapes dominated by mass-wasting processes (Shano et al., 2020).

Landslides are generally caused by elements that trigger geohazards, such as geomorphology parameters, where structures with greater structure, such as hills and mountains, may have potential landslides compared to low land area. Aside from that, the variables of soil erosion caused by extreme rainfall contribute to unsaturated

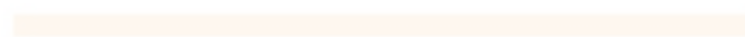
soils breaking apart as a result of the high intensity and extended rainfall (Gerome, 2009).



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## **2.7 Landslide Susceptibility Mapping using GIS**

### **2.7.1 Landslide Definition**

Loss of life and property can be caused by landslides, which typically occur in mountainous regions. At number five on the list of worst natural disasters of 2010, landslides are a severe threat. Intense precipitation, human interference, or earthquakes can amplify the potential for landslides on land that is already sloped in a favourable direction (Bonaventura, 2010). It has the potential to cause significant harm and loss. Slope failure is expected to kill almost 600 individuals worldwide (Aleotti & Chowdhury, 1999)

### **2.7.2 Types of Landslides**

In the Varnes Classification of Slope Movement, landslides are categorised based on their degree of danger (Varnes, 1978). One can classify landslides by the materials they are made of, and another by the way they move. Rock, Earth, dirt, muck, and rubbish are the several kinds of materials listed in Table 2.1. As can be seen in Table 2.2, there are five kinematically unique forms of slope movement: falling, toppling, sliding, spreading, and flowing.

Varnes' Classification of Slope Movement, as seen in Figure 2.4, identifies four unique landslide movements. To put it simply, landslides can be caused by six distinct forms of rock or boulder movement.

**Table 2. 1:**Varnes classification of slope movement

Type of Material	Description
Rock	Hard or firm mass that was intact and its natural position before any movement occur.
Soil	Aggregate of solid particles, which generally of minerals and rocks. It can be transported or formed by weathering of rock.
Earth	Materials in which 80% or more of the particles are less than 2mm, the upper limit of sand sized particles.
Mud	Materials in which 80% or more of the particles are less than 0.06mm in sized which the upper limit of silt sized particles.
Debris	Containing significant proportion of course materials, 20 to 80% of particles are larger than 2mm.

(Source: Varnes,1987)

**Table 2. 2:** Types of landslides

Type of Movement		Types of Materials		
		Bedrock	Engineering Soils	
			Predominantly Course	Predominantly Fine
Falls		Rock fall	Debris fall	Earth fall
Topples		Rock topples	Debris topple	Earth topples
Slides	Rotational	Rock slide	Debris slide	Earth slide
	Translational			
Lateral spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flow	Debris flow	Earth flow
Complex		Confirmation of two or more principal types of movement		

(Source: Varnes, 1987)

Material		ROCK	DEBRIS	EARTH
Movement type	FALLS			
	TOPPLES			
SLIDES	Rotational			
	Translational (Planar)			
SPREADS				
FLOWS				
COMPLEX				

Figure 2. 4: Distinct landslide movement

### 2.7.3 Significant Causes of Landslide

Many landslides are natural phenomena that occur without any human intervention. Landslides have also been caused by human actions aimed at rendering the land suitable for various purposes. Landslides can be caused by external or internal factors (Table 2.3).

Landslide cases in Gua Musang have been documented virtually every year, and it is no longer a new event. Many publications and studies have been published to examine this geohazard. This is because landslides can be extremely dangerous, especially when they occur in densely populated areas such as a housing development or a highway.

The majority of landslides are caused by elements that trigger geohazards, such as geomorphology parameters, where structures with a higher structure, such as hills and mountains, are more susceptible to landslides than low land areas. Aside from that, the variables of soil erosion due to heavy rainfall also contribute to unsaturated soils beginning to disintegrate because of the high intensity and duration of rainfall (Gerome, 2009).

Soil erosion is the movement of the soil's uppermost layer, which causes the soil to decay and fall apart. The intense, prolonged rainfall is a result of the monsoon "Timur Laut," which typically occurs from September to December, the very last part of the year. Aside from this, the overall amount of precipitation is one of the variables that can influence landslides, as the depth of shallow landslides is often less than 3 to 5 metres. When shallow landslides are sufficiently wet, they can travel quickly and be very mobile across great distances. Frequent causes of shallow landslides and debris floods are strong precipitation, with estimated rainfall rates in the tens of millimetres per hour.

**Table 2. 3:** Causes of landslide

<b>External Causes</b>	<b>Internal Causes</b>
Undercutting of the foot of the hill slope due to river erosion, quarrying, excavation for canals and roads, etc.	Increase in pore water pressure.
External loads such as buildings, reservoirs, highway traffic, stockpiles of rocks, accumulation of alluvium on slopes, etc.	Reduction in cohesive strength caused by progressive laterization.
Increase in unit weight of slope material due to increased water content	Hair cracks due to alternate swelling and shrinkage from tension
Vibrations due to earthquakes, blasting, traffic, etc., causing increase in shearing stresses	Presence of faults, joints, bedding planes, cleavage etc., and their orientation
Anthropic changes caused by deforestation	Freezing and thawing of rocks and soils
Undermining caused by tunneling, collapse of underground caverns, seepage erosion, etc.	Material properties such as compressive strength, shearing strength, etc., of earth material

(Source: Prasad, 2017)

#### 2.7.4 GIS Application in Landslide Susceptibility Mapping

A Geographical Information System, sometimes known as a GIS, is a computer system that may be used to map and analyse occurrences and features on the Earth's surface. The term geographical refers to the locations of the data objects, which are expressed through coordinate systems. The information itself is referred to as the information or attribute of the data when the word information is used. The information may be presented in various formats, including but not limited to

coloured maps, graphics, tables, models, and many others. The term system refers to managing and structuring the data. How the various parts that go into making up GIS go about their business (Carrara, 1991).

Shahabi and Hashim (2015) applied a GIS-based statistical model to generate landslide susceptibility mapping utilising GIS and remote sensing data in their study area at Central Zab basin, Iran. Their research region is Iran, and they employ parameters such as fault, SPOT 5, WorldView-1 image, and distance between roads generated from SAR data. After computation and determination, the maps are built between the identified factors using a variety of models, such as the analytical hierarchy process (AHP), weighted linear combination (WLC), and multicriteria spatial evaluation (SMCE). There were ten parameters that were taken into consideration, including slope, aspect, elevation, lithology, the normalised difference vegetation index (NDVI), land cover, precipitation, and distance to fault, distance to drainage, and distance to road.

Rodeano et al. (2017) produced a landslide hazard zoning map along the Genting Sempah to Bentong area in Pahang using the Weightage Overlay Method (WOM). The study gives the most significant importance to the factors considered to be the most causal, such as land use, drainage, distance from lineament, soil lithology, and geomorphology. These parameters were extracted from the topographic database and then classified into landslide susceptibility levels ranging from extremely low to high. These levels reflect the likelihood that a landslide will occur in the area that is being studied. The intensity of the land and soil was altered

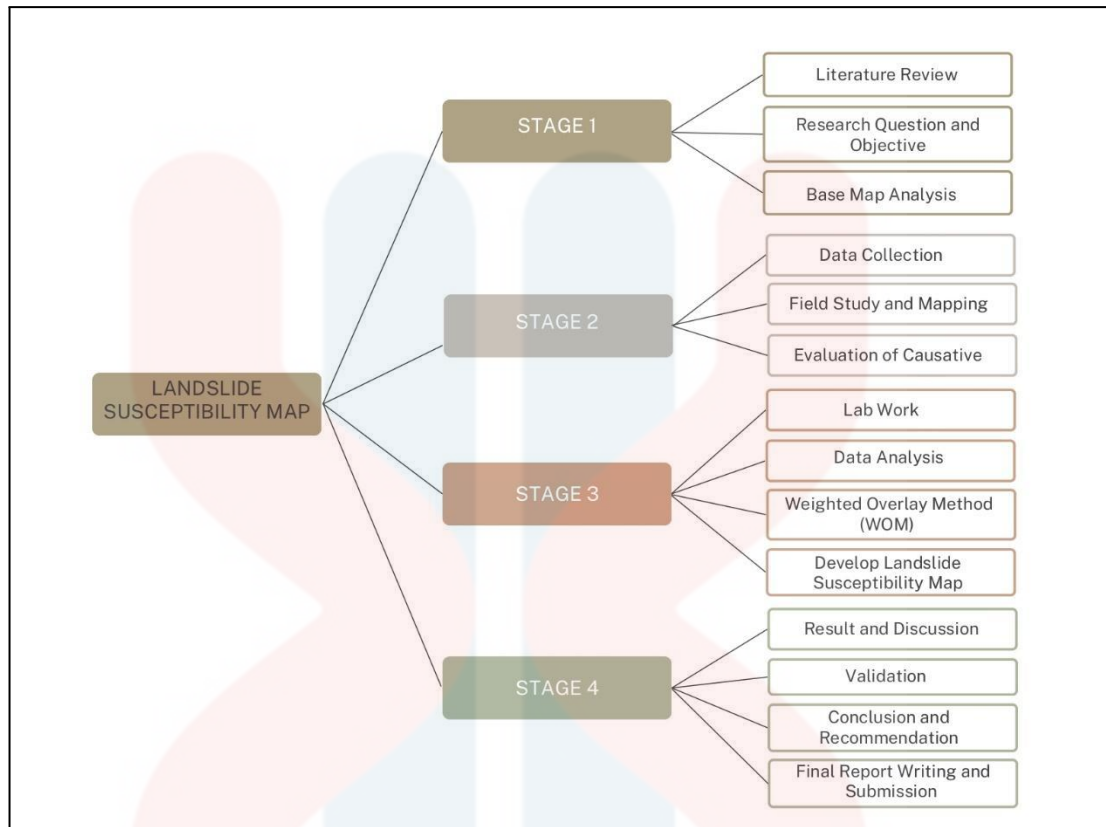
due to the landslide's cause, which were caused by heavy rainfall. The layering method via raster input was weighted using all available data.

## **CHAPTER 3**

### **MATERIALS AND METHODS**

#### **3.1 Introduction**

This section discusses the materials utilised and how the research is carried out before, during, and after the field. A topographic map, GPS, compass, a geological hammer, hydrochloric acid solution (HCl), stationery, digital camera, field notebook, measuring tape, hand lens, and sample bags are all required for the field.



**Figure 3. 1:** Research Flow Chart

### 3.2 Materials

A few materials will be used in geological mapping and landslide susceptibility assessment. The mapping equipment is needed in geological mapping scopes, such as a hammer, compass, measuring tape, HCL, hand lens, and GPS.

The topographical data, the Digital Elevation Model (DEM), and satellite images to produce the landslide susceptibility map are essential. The maps of causative factors, such as lithology, slope, aspect, land use and drainage density are extracted from source data from agencies and geological mapping.

### **3.3 Methodology**

#### **3.3.1. Preliminary Studies**

Before starting the research, all preliminary information was obtained and fully understood. Reviewing of previous research was done in the study area or research related to the landslide susceptibility to gain extra knowledge about the present study. A variety of research techniques were used to develop a landslide susceptibility map. The Geographical Information System (GIS) were generating the landslide hazard zonation map using the Weighted Overlay Method (WOM).

All relevant data for landslide hazard evaluation are gathered from primary and secondary sources to build the landslide susceptibility map. Secondary data collection of topographical maps, satellite pictures, and Digital Elevation Model (DEM) data is gathered before the fieldwork. It is significant and crucial since it includes in brainstorming and surface understanding of what should be done. As a result of this, the structural composition, history, lithology, and formation of the area under investigation are all well known

#### **3.3.2 Field Studies**

##### **i. Geological Mapping**

Geological mapping was conducted to analyse the study's features. To figure out the causes of flood, it is important to find out the structural geology, weathering,

and geomorphology of the study area. Primary data was collected from geological mapping while secondary data was gathered from the previous geology study in that area. A field study was conducted to gather all significant information on previous flood 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.

## **ii. Landslide Mapping**

Landslide identification and preparation process landslide geohazard inventory maps are strongly influenced by several factors, among which are associated with the source documents (e.g., scale, spatial resolution, date), type and the size of the landslide, as well as the skills of the specialists involved. Possible slope failure depends on strength, cohesion, and inner friction angle. Geological history (consolidation, erosion, diagenetic processes, in situ stresses, and weathering) influences soil mechanical (shear strength) attributes.

In rock masses, mechanical behaviour is determined by the strength of the discontinuities, so the entire rock depends on its degree of fracturing and the materials and discontinuities within it. The behaviour of a resistant rock mass depends on its discontinuities, lithology, and geological development. The shear strength of weak surfaces relies on nature and origin, persistence, spacing, roughness, type and thickness of infill, and water. The landslide survey form is needed in order to create these landslide maps (Tajul Anuar Jamaluddin, 1990).

### 3.3.3 Laboratory Work

In petrological research, the minerals are identified from one another based on the characteristics of the rock's texture, clast, matrix, twinning, and crystals. Sample preparation aims to determine the type/name of rocks in the study area. Minerals are identified in petrological research by the matrix and crystal characteristics. Laboratory research was conducted on the rock samples acquired in the field. The rock samples were cut into smaller pieces. After that, a grinding and polishing operation was carried out. It appeared as a thin section after a few grinding sessions.

The rock sample is thinly sliced to be examined under the microscope. The texture of the rock was analysed using a polarised microscope. The thin section is used to observe the rocks under the polarised microscope to determine the mineral content based on the mineral's properties and the texture type. Fresh samples were used because it can show better mineral characteristics. A weathered rock might affect the result of the thin section.

### 3.3.4 Data Processing

Data from fieldwork and laboratory observation were processed. Data processing is as follows:

#### a. Structural Data

Data were processed using statical methods to determine the direction of the stresses. The statistical method is used to examine plane orientations (joints, fractures, and faults) in a stereographic projection or stereonet.

**b. Geomorphological Data**

Data were processed using ArcGIS to determine the type of landform. The determination of the landform is based on the contour interval generated/obtained from the topographic map. Landform-type classification is referred to based on the classification system using different scales of Tpl (Jennes et al., 2011).

**c. Lithology**

To determine rock types based on mineral content using an appropriate classification system. For example, igneous rock using QAP and the Folk Classification for sedimentary rock.

**i. Evaluation of Causative Factors Triggered Landslide**

The following five key causative components were evaluated during the current research for landslide hazard evaluation: slope angle, aspect, drainage

density, land use and lithology. These cause factors were addressed based on recent landslide observations and their likely contribution to slope instability in the area.

**a. Slope**

The slope is derived from Digital Elevation Model (DEM) with 30 m resolution for this research investigation. The slope is subsequently classified based on its slope degree. Previous landslide slopes are compared to the current result. The slope map depicts slope distributions depending on angles. The slope angles are classified into six groups.

**Table 3. 1:** Slope Classification

No.	Class	Description
1.	0-5°	Very Gentle
2.	5-10°	Gentle
3.	10-15°	Moderate
4.	15-25°	Moderately Steep
5.	25-35°	Steep
6.	>35°	Very Steep

(Source: Van Zuidam, 1985)

**b. Aspect**

An aspect map displays both the direction and the slope of a landscape. As a result, it is an important issue in the analysis and creation of landslide susceptibility maps. The aspect map is created using satellite image data from the US Geological Survey Earth Resources Observations and Science Center (USGS). An aspect map is a map that depicts the direction of a terrain's ground slope concerning the north. The aspect map is generated using the Digital Elevation Map (DEM) with 30 m resolution data as well. The aspect map is classified into ten slope directions that face north.

**c. Drainage Density**

The drainage density map was generated using a USGS satellite picture downloaded from the USGS website. The drainage pattern in the research region was determined. The stream density map is critical for establishing the fluvial network in the research region.

**d. Land Use**

The study area's land use was mapped out using geological mapping and Landsat-5 images from 2011 to 2021. The information comes from the PLANMalaysia Official Portal and U.S. Geological Survey (USGS).

**e. Lithology**

During the geological mapping, the lithologies of the study area were collected. The lithology was determined by observing the rocks and their boundaries. Following the observation, the data collected in the field is mapped out and used to create a lithology map.

### **3.3.5 Data Analysis and Interpretation**

In the general geology aspect, the geological mapping that includes the traversing and sampling is a severe matter where all the geological characteristics and elements are observed and recorded. The data from the satellite imagery was compared with the collection of data from geological surveys and mapping. The data was analysed during the observation of the research area to update the outdated one.

All data collected was analysed and evaluated. GIS was also used to create a landslide susceptibility map in order to extract facts that needed to be explained further. The landslide susceptibility map was constructed by collecting and evaluating data on all landslide-related factors, such as slope angle, elevation, aspect, drainage density, land use and lithology.

ArcGIS software was used to produce the update for the geological map of the Gua Musang area, which is on a scale of  $5 \times 5$  kilometres. An updated geological map of the research region was created using the geological data that was collected through geological mapping. This map included information on dipping, lithology, rock boundaries, and rock deformation.

The DEM was used to create a raster layer containing information about the slope, aspect, drainage density, and lithology. Layering techniques were weighted by raster input from the collected data. Using ArcMap's reclassify features, the original weight was recalculated, and then the resulting weight was used to evaluate the data. As a result, the landslide susceptibility map was generated.

The most vulnerable areas to landslides are displayed using a scale from 1 to 5 and different classes using weighted overlay techniques. The probability of a landslide occurring ranged from highest in the most vulnerable areas to lowest in the least vulnerable areas, as revealed by the assessment. The landslide susceptibility map can be used as an indicator to prevent any construction of houses or other buildings in areas with a high risk of landslides.

**Table 3. 2:** The landslide susceptibility classes with their percentage

<b>Landslide Susceptibility Classes</b>	<b>Percentage of Landslide pixels (%)</b>
High Susceptibility	25 - 50
Moderate Susceptibility	12.5 - 25
Low Susceptibility	6.25 - 12.5
Very Low Susceptibility	0 - 6.25

(Source: Fell, 2008)

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**CHAPTER 4**

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**GENERAL GEOLOGY**

#### **4.1. Introduction**

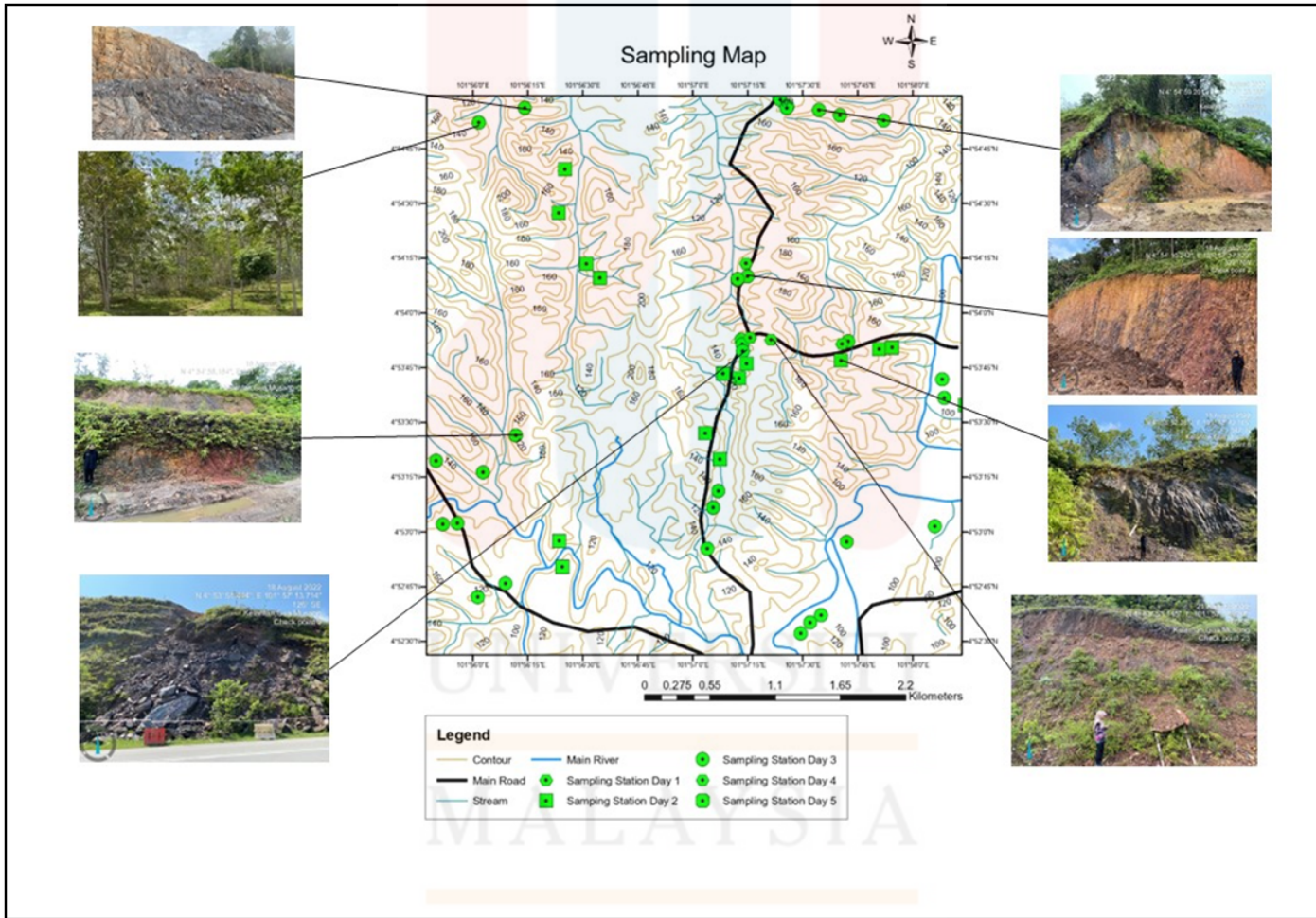
All the specifics of geology, including geomorphology, lithostratigraphy, structural geology, and historical geology, need to be set in a general geology chapter. The information described in this section comes from three sources: a previous study, an assessment of remote sensing data, and the use of a geographic information system.

By comparing and correlating between all previous research studies and also the general knowledge based on the paper, journal and so on where all the data obtained is analysed. This data is necessary for keeping update with the most recent findings in the geology of the region and formed of the rock unit as well as the structural involved. All the geological data collected resulted in a geological map.

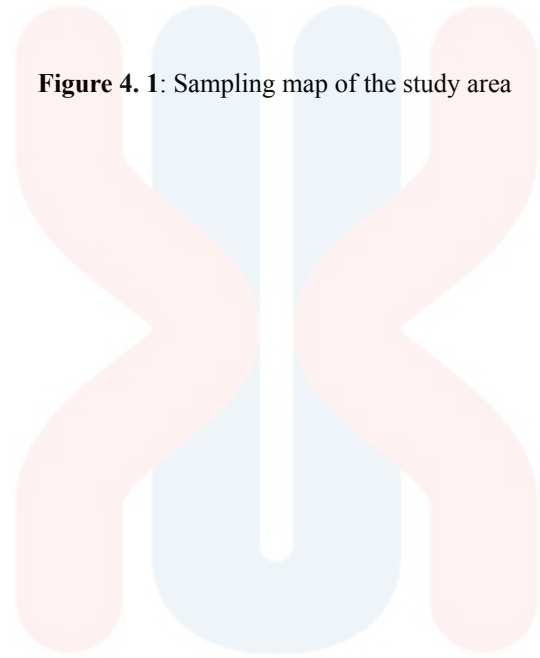
#### **4.2. Observation and Traverse Point**

Traverse planning is accomplished through the observation and interpretation of a remote sensing image before actually heading out into the field. Geological mapping on the study region was done using a variety of methods, including rock sampling and measuring, traversing, and observation for collecting geological data. When it comes to mapping, traversing is one of the many strategies that may be used to follow a variety of contour and lithology patterns. Before entering the field, both the traverse path and the target had been mapped out and confirmed. The entire geological fieldwork process for the area under study takes around 5 days to complete and during that time, geological data is collected.

The map of the sampling station is depicted in Figure 4.1. According to the figure, the position of the outcrop observation in the field is shown in green dot format. A total of 49 coordinated observations and samples were taken in the field within the scope of the study. The entirety of the study area is covered around 70 % of the time overall, with the greatest coverage in the south of the study area, followed by the greatest coverage in the north and west, and the least coverage in the east of the study region. The centre of the research site is inaccessible because of its extremely high elevation and densely packed restricted forest. The plantation roads are nearly inaccessible, and the transverse cannot go because of the dense vegetation and steep slope.



**Figure 4. 1:** Sampling map of the study area



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### **4.3. Geomorphology**

#### **4.3.1. Landform**

The research area is defined as low land to hills with a height between 90 and 247 metres according to Van Zuidam (1985) classification. There are hills in the west and east, and plains in the centre, running from the northeast to the northwest. The research area's scope region includes the origin of fluvial landforms.

According to van Zuidam's classification from 1985, the origin of fluvial landforms can be divided into three categories: flood plain landforms, natural levee landforms, and terrace landforms. At the research area, it is an active floodplain region in the Galas River due to erosion and deposition as well as generated by the action of water redistributes silt equally during frequent flooding. Erosion has flattened out the terrain to the northeast of the study area, removing the interlocking spurs. When a river loses its ability to move material due to flooding, it deposits the debris it has picked up. The material that is deposited and the resulting sand bed both contribute to an increase in the height of the floodplain over the course of time. The floodplain is typically found in areas that are flat and wide, as a result of meanders shifting down the valley.

Lithological controls over landforms produce a large number of variations, and more importantly, these variations may be associated with a wide range of discrete regions ranging in size from a distinct outcrop of a few square metres to areas of uniform rock type extending over hundreds of square kilometres. These

variations can be associated with a wide range of landforms, and these landforms can be associated with a wide range of lithological controls. The research region features denudational hills and has a hilly and undulating topography, with slopes ranging from 15 to 55% and height differences (local relief) ranging from 90 to 247 metres. Additionally, the area is characterised by a lack of valleys. In most cases, the rate of erosion ranges from moderate to low, and it is dependent on the lithology, climate, and human use of the land.



**Figure 4. 2:** View from top at the study area

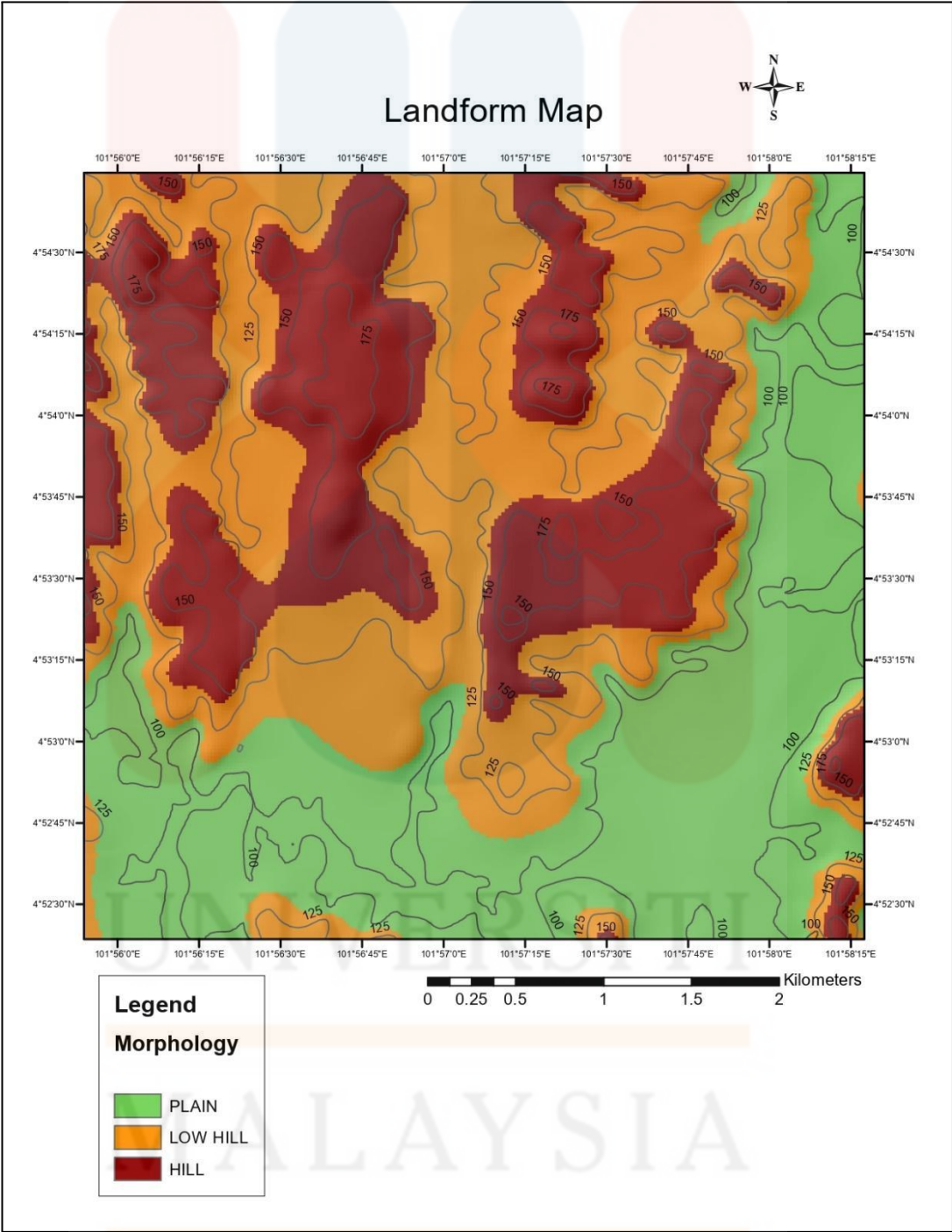


Figure 4. 3: Landform map of the study area

### 4.3.2. Drainage Pattern

The drainage flowing in the study area comprises the Galas River's tributaries, which are located in the northeast and southeast research region. A river that meets another river can form a particular drainage pattern based on the surrounding area's geological conditions. Water flowing from the north-south of the study area, the Galas River has several drainage patterns consisting of the Dendritic, Trellis and Parallel.

The Dendritic pattern usually indicates patterns of a river where tributaries tend to align with the main river. Tributaries lead to the main river with an acute angle. The dendritic pattern model is like a tree with branches and twigs as branches and tributaries. This pattern is usually found in areas with a plain landform or similar rock areas (uniform, homogeneous, and with a wide distribution. Usually, it reflects the resistance of the rock, which is not hard. Interpreted as areas with low relief, horizontal layers, and faults controlled by faults are not developed. Landforms that are influenced by the structure and altered by topographic changes are identified by their drainage patterns. This drainage pattern starts in the middle and takes up about 10% of the study area. It is made up of phyllite and shale in general.

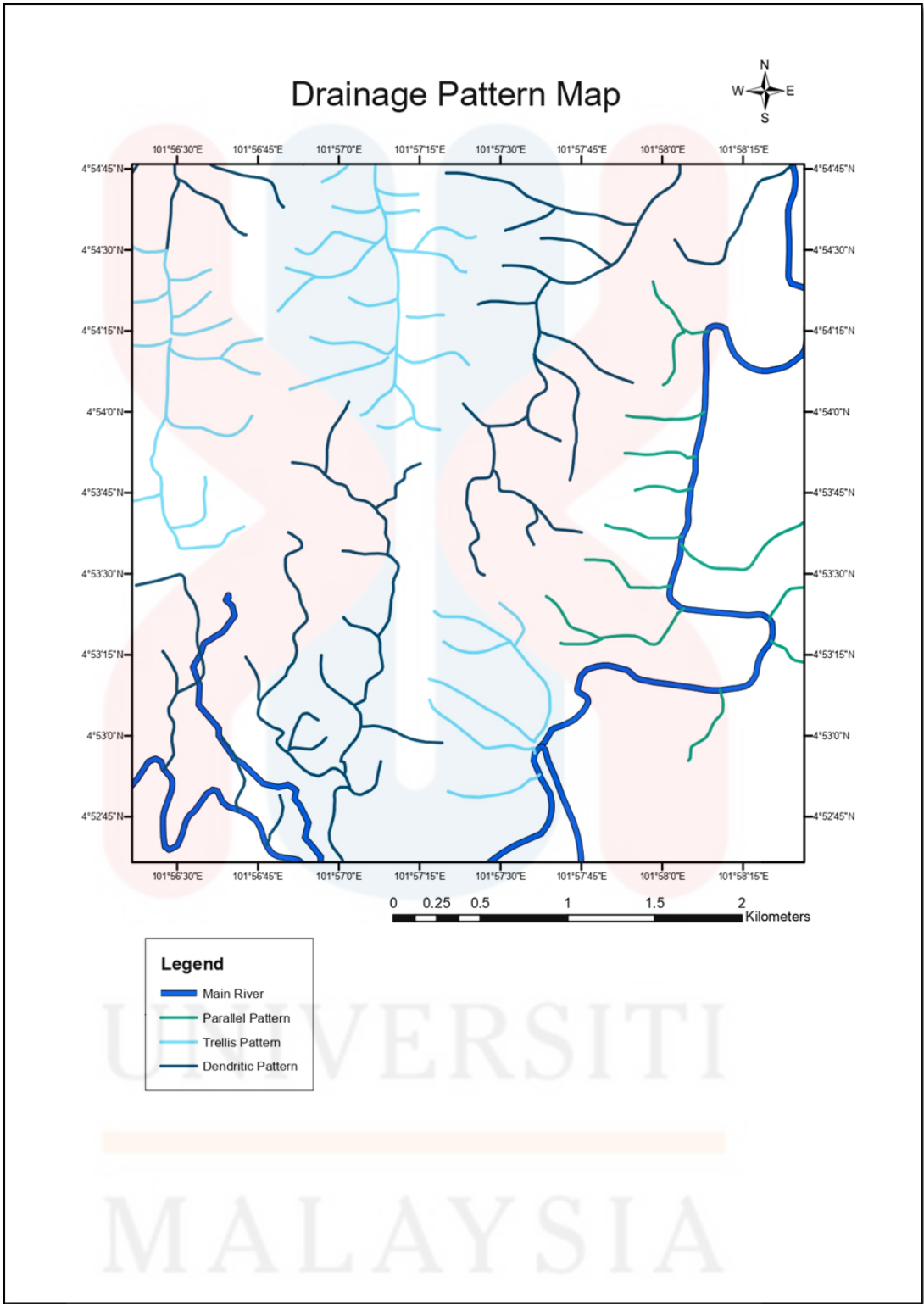


Figure 4. 4: Drainage pattern map of the study area

#### **4.4 Lithostratigraphy**

The superposition of soil layers states that the rocks at the bottom layer are older than the rocks at the top layer unless certain conditions occur. Furthermore, the relative ages of layers in geological strata can be determined using archaeological resources such as fossils. This section only discusses lithostratigraphy, which is the study of various types of rocks and their ages based on rock samples discovered in the research area.

Lithostratigraphy is the study of rock strata, relative and exact ages of rocks, and how layers fit together. Stratigraphy is a method of determining what happened and what the Earth's environment was like by examining the physical qualities of rocks and how the environment changed over time. This is due to the fact that different occurrences may have left distinct markings to be examined.

##### **4.4.1 Stratigraphic Position**

Stratigraphy or lithostratigraphy is when the type of rock in a layer of rocks is used to figure out how old the layer is. Lithostratigraphy was needed to find out how old the area was and what its history was. The stratigraphy of the area was used to sort rocks by their lithology.

From Table 4.1, the stratigraphic column of the study area is vital in determining the age of the rock unit and describing the relationship between strata

and stratigraphic. The study area consists of three unit which are limestone unit, phyllite unit and slate unit. Limestone unit is located north east of the study area whereas phyllite and slate distributed mainly in the study area. Granite unit distributed in small – scale at north west of the study area.

**Table 4. 1:** Stratigraphy column of the study area

LITHOLOGY	DESCRIPTION	UNIT	PERIOD	ERA
	Major felsic mineral is quartz with minor mafic minerals such as biotite and chlorite	Granite	Tertiary	Cenozoic
	Mainly consists of minerals silicate clay and oxidize clay with minor quartz mineral, phyllite in brownish color and show medium grade foliation textures.	Phyllite and Slate	Permian	Palaeozoic
	Mainly composed of mineral calcite (CaCO <sub>3</sub> )	Limestone	Permian	Mesozoic

#### 4.4.2. Unit Explanation

##### i. Granite

Granite is found to be a common form of intrusive, felsic, phaneritic textured igneous rock. Granite consists predominantly of minerals such as quartz, mica, feldspar and ferromagnesium. The outcrop was found at the stream (Figure 4.5) and undergone physical weathering because it keeps contact with running water all the time. Due to the slow cooling that can be seen with the visual inspection, most of the mineral grains that formed are big. The most common minerals in granite are made up of crystals that fit together. These minerals include quartz, biotite, and other minerals in small amounts. With the small dark minerals that make up the matrix, the minerals that make up granite give it its grey and white colour.



**Figure 4. 5:** Granite outcrop at study area



Figure 4. 6: The hand specimen of Granite, observed at station sampling day 1.

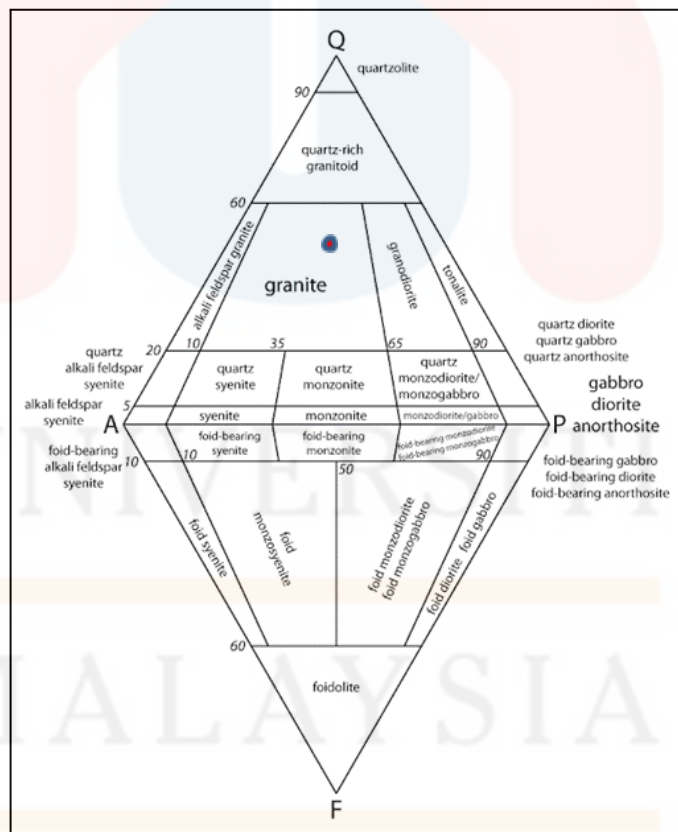


Figure 4. 7: Classification of plutonic rock

LOCATION : N 04°54'11", E 101°56'32"

NAME OF ROCK : Granite

ROCK TYPE : Igneous Rock

CLASSIFICATION : QAPF diagram

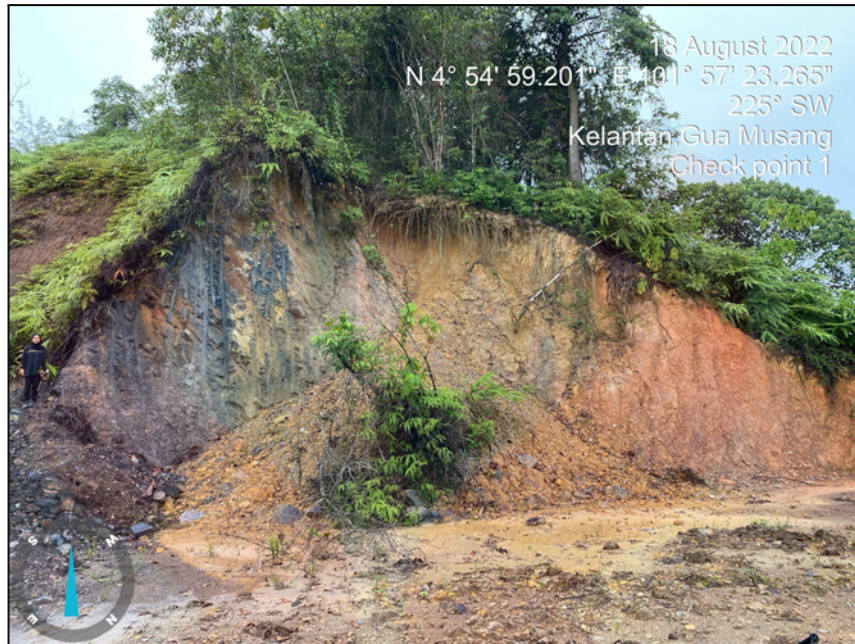
**Table 4. 2:** Petrography analysis for Granite

<p style="text-align: center;">PPL</p>											<p style="text-align: center;">XPL</p>										
Quartz mineral as the major mineral																					
Description of Mineralogy																					
Composition of Mineral				Amount %				Description of Optical Mineralogy													
Quartz				48				<ul style="list-style-type: none"> <li>- Colourless under PPL, low relief, anhedral crystal shape, no cleavage</li> <li>- Under XPL shows gray-white colour, no twin</li> </ul>													
Sericite				20				<ul style="list-style-type: none"> <li>- Colourless under PPL, low relief, euhedral crystal shape</li> <li>- Under XPL shows gray-white colour, no twin</li> </ul>													
Sanidine				10				<ul style="list-style-type: none"> <li>- Colourless under PPL, low relief, subhedral crystal shape</li> <li>- Under XPL shows gray-white colour, carlsbad twin</li> </ul>													

Orthoclase	8	<ul style="list-style-type: none"> <li>- Colourless under PPL, low relief, anhedral crystal shape</li> <li>- Under XPL shows gray-white colour, polysynthetic twinning</li> </ul>
Biotite	2	<ul style="list-style-type: none"> <li>- Greenish brown under PPL, mid relief, strong pleochroism, subhedral crystal shape</li> <li>- Under XPL shows orange-green</li> </ul>

## ii. Phyllite

Meta-sedimentary rocks develop when sedimentary rocks buried beneath the earth are exposed to high temperatures and pressure. The sediment that has been deposited in a specific area then solidifies to form meta-sedimentary rock under high pressure and temperature. The meta-sedimentary identified in the research area was phyllite, which undergoes mild metamorphism in the metamorphic facies. Figure 4.7 depicted a hand specimen of phyllite discovered in the study area. The composition of mineral in phyllite composed of quartz, silica clay and oxide clay.



**Figure 4. 8:** Phyllite outcrop at study area



**Figure 4. 9:** The hand specimen of Phyllite, observed at station sampling day 2.

LOCATION : N 04°59'201", E 101°23"

NAME OF ROCK : Phyllite

ROCK TYPE : Metamorphic Rock

**Table 4. 3:** Petrography analysis for Phyllite

	A	B	C	D	E	F	G	H	I	J		A	B	C	D	E	F	G	H	I	J
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
	PPL										XPL										
Oxide clay mineral as the major mineral																					
Description of Mineralogy																					
<b>Composition of Mineral</b>	<b>Amount %</b>					<b>Description of Optical Mineralogy</b>															
Oxide clay	77					<ul style="list-style-type: none"> <li>- Brown colour under PPL</li> <li>- Under XPL shows brown colour</li> </ul>															
Silicate clay	15					<ul style="list-style-type: none"> <li>- Colourless under PPL, low relief, euhedral crystal shape</li> <li>- Under XPL shows gray-white colour, no twin</li> </ul>															
Quartz	5					<ul style="list-style-type: none"> <li>- Colourless under PPL, low relief, anhedral crystal shape</li> <li>- Under XPL shows gray-white colour</li> </ul>															

iii. Slate

Shale is a fine-grained sedimentary rock formed by the compaction of mineral particles ranging in size from silt to clay. Shale differs from other mudstones in that it is fissile and laminate. Figure 4.9 depicted a hand specimen of slate discovered in the study area. The composition of mineral in slate composed of quartz and silica clay.



**Figure 4. 10:** Shale outcrop at the study area



**Figure 4. 11:** The hand specimen of Slate, observed at station sampling day 2.

LOCATION : N 04°53'52" E 101°57'42"

NAME OF ROCK : Slate

ROCK TYPE : Metamorphic Rock

**Table 4. 4:** Petrography analysis for Slate

PPL											XPL										
Silicate clay mineral as the major mineral																					
Description of Mineralogy																					
Composition of Mineral						Amount %						Description of Optical Mineralogy									
Silicate clay						48						<ul style="list-style-type: none"> <li>- Colourless under PPL</li> <li>- Under XPL shows gray-white colour, consist of silicate material micron – sized</li> </ul>									
Quartz						2						<ul style="list-style-type: none"> <li>- Colourless under PPL, low relief, anhedral crystal shape</li> <li>- Under XPL shows gray-white colour</li> </ul>									

iv. **Limestone**

Limestone is a category of carbonate sedimentary rock composed of calcium carbonate ( $\text{CaCO}_3$ ) derived from the skeletal fragments of marine organisms. Figure 4.11 depicted a hand specimen of slate discovered in the study area. The composition of mineral in slate composed of calcite.



**Figure 4.12:** Limestone outcrop at the study area



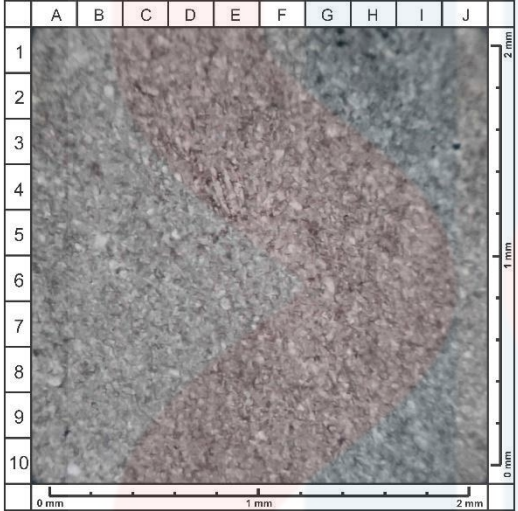
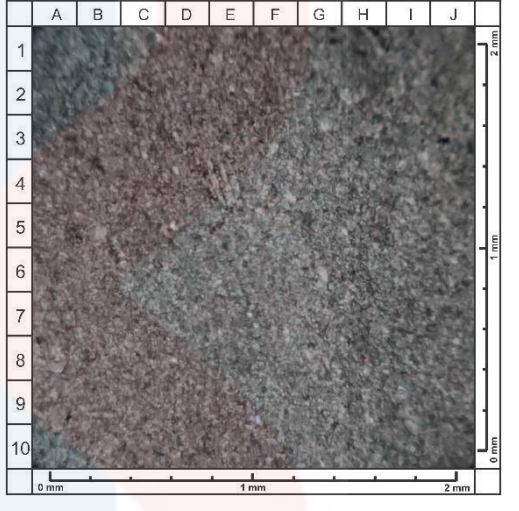
**Figure 4.13:** The hand specimen of Limestone, observed at station sampling day 3.

LOCATION : N 04°53'35", E 101°58'14"

NAME OF ROCK : Limestone

ROCK TYPE : Sedimentary Rock

**Table 4. 5:** Petrography analysis for Limestone

 <p style="text-align: center;"><b>PPL</b></p>	 <p style="text-align: center;"><b>XPL</b></p>	
Calcite mineral as the major mineral		
Description of Mineralogy		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Calcite	99	<ul style="list-style-type: none"> <li>- Colourless under PPL, anhedral crystal shape</li> <li>- Under XPL shows pinkish – green colour</li> </ul>

#### 4.5 Structural Geology

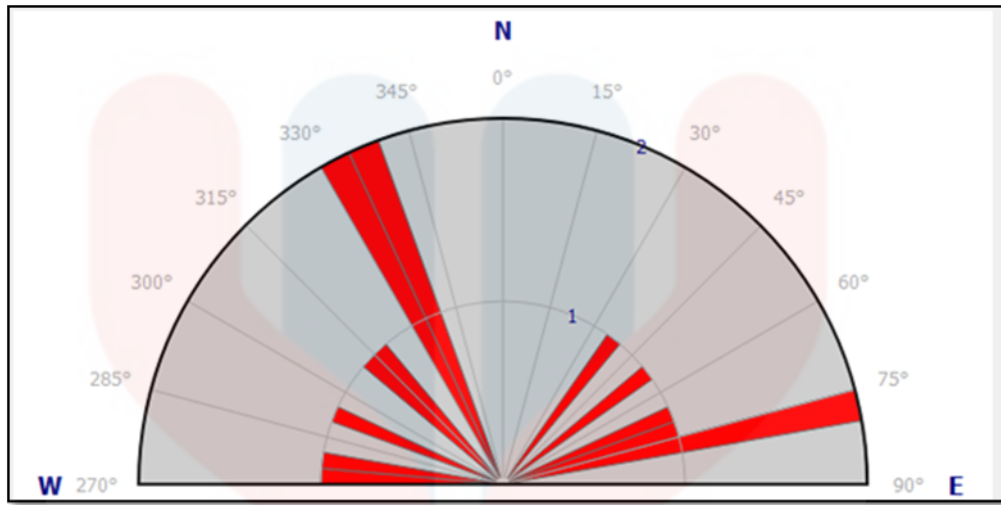
Structural geology is concerned with geological features formed as a result of tectonic movement, which causes deformation. It is critical to investigate the

geometries and the Earth's tectonic activities, as well as the stress and strain of the rock. The history of the Earth can be revealed by understanding structural geology. Faults, folds, joints, bedding, and veins are all caused by deformation. Geological mapping and lineament analysis using a terrain map can be used to detect Earth deformation.

#### **4.5.1 Lineament Analysis**

The lineament analysis based on the DEM-generated topographic map of the study area. Different directions and lengths of the lineaments were discovered. Fault-related lineaments are often created by erosion of the physically weak fault zone or through a succession of geomorphic offsets linked with recent fault movements. As such, a lineament analysis is considered as crucial work for locating and describing faults in a certain area.

In this study, researchers used a DEM-derived shaded relief picture to analyse lineaments and infer larger-scale fault networks or tectonic faults. The DEM itself is derived from digital topographic maps. The interpretations of fault-related geomorphic markers, such as fault-aligned valleys, which are rather visible in a steep mountain terrain, have allowed to map potential fault lineaments. After that, the information from the lineament map was utilised in the creation of the rose diagrams that are presented in Figure 4.13. According to the rose diagram, the strongest forces originate from the north-west and the north-east, which together make up the rose diagram's petal with the longest length.



**Figure 4. 14:** Rose diagram of the study area located at the north part

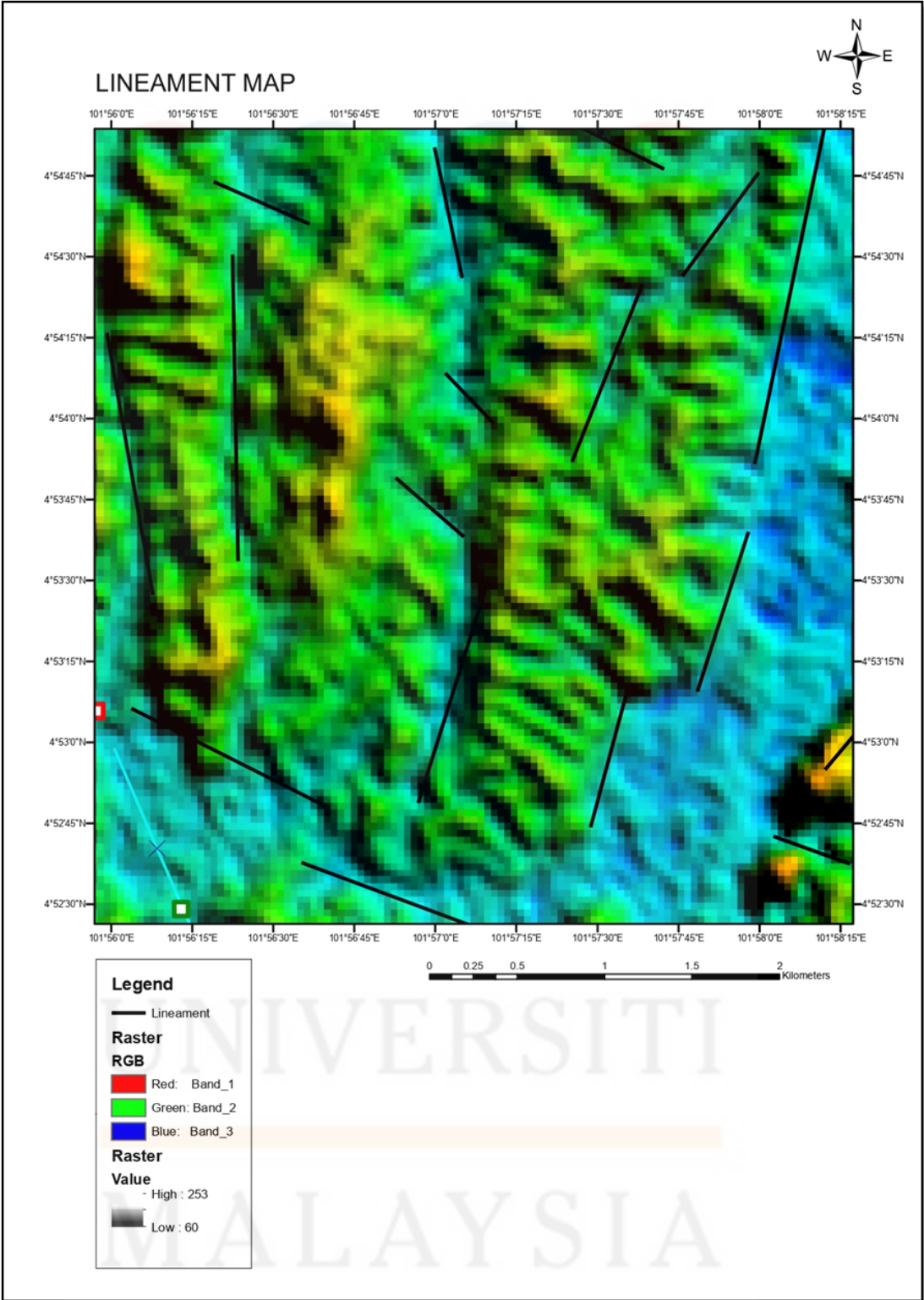


Figure 4. 15 : Lineament map of the study area

#### 4.5.2 Fault

The study conducted in the field revealed that the research region has one faults that found. The fault plane and an assumed hanging footwall that faces the outcrop observation make it simple to identify the fault structure in the field. This allows for easy recognition of the fault structure. It is speculated that the fault is an oblique-slip fault, as seen in Figure 4.16.

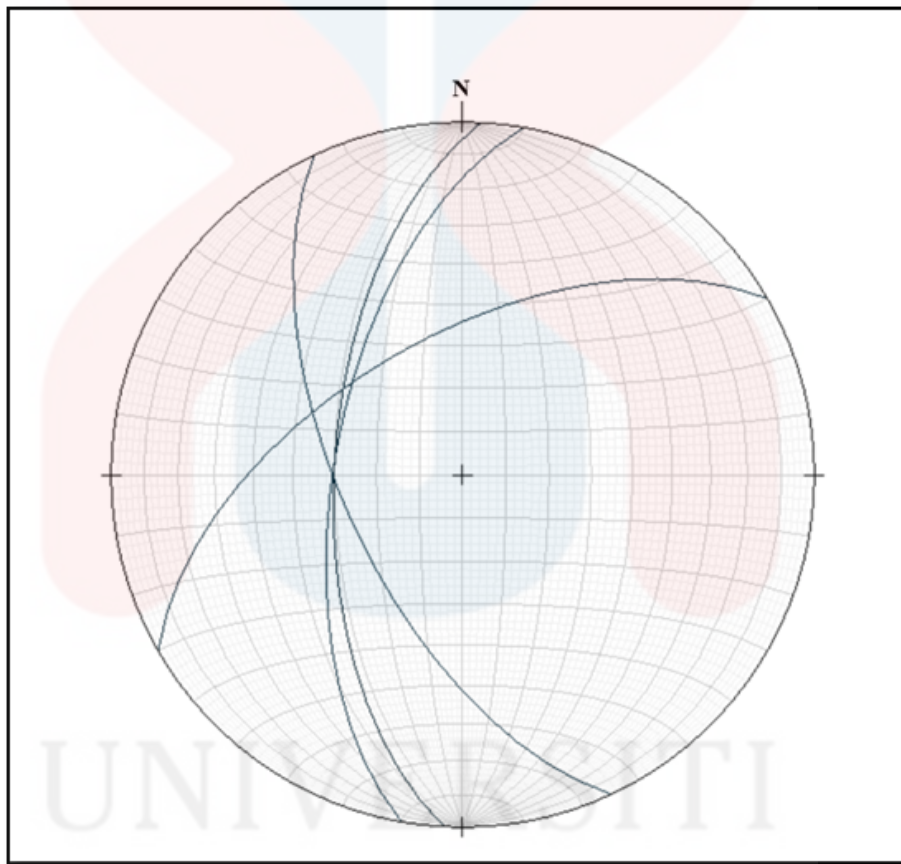
An oblique-slip fault comprises two separate components, the dip-slip component and the strike-slip component. As a result of the fault's movement at an angle across the fault surface, the magnitudes of the component displacements are incredibly close to one another. In addition, because of the existence of faults, it is not easy to quantify the bedding of the rocks. Because of the strong compressional strength and stress exerted between the rocks, the fault has caused the structures of the rocks to shift.



**Figure 4. 16:** Oblique - slip fault at N 4° 53' 00.7", E 101° 57' 28.7"

**Table 4. 6:** Strike and dip reading of fault in the study area

Strike	Dip
183	60
190	60
155	62
240	58
180	50



**Figure 4. 17:** Stereonet plot for fault at the study area

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### 4.5.3 Fold

The fold is a structure that was classified based on their axes' attitude and appearance. It formed because of forces applied to the area that caused deformation. As a result, a flat-lying or other undeformed surface is deformed. The types of fold include anticline, syncline, monocline, chevron, plunging, harmonic and recumbent.

Anticline is a fold that is convex upwards, while syncline is a fold that is concave upwards. Sometimes, the folding is very gentle that the inclination of the strata is hard to be seen and perceptible. In a situation, the strata of the two flanks may be substantially parallel or almost flat. Figure 4.15, shows anticline fold that occurred in the study area. The anticline fold was found on phyllite outcrop. These folds may feature 'limbs' with high (vertical) or shallow (just a few degrees) slopes. Since the anticline's rock layers were flat when they originated and folded down when the strata distorted, the oldest rock is found near the centre of the anticline.



Figure 4. 18: Anticline found at N 4° 54' 10.2\", E 101° 57' 17.89\"/>

**Table 4. 7:** Strike and dip reading of fault in the study area

<b>Strike</b>	<b>Dip</b>
230	80
235	45
206	72
225	70
230	60

#### **4.6 Historical Geology**

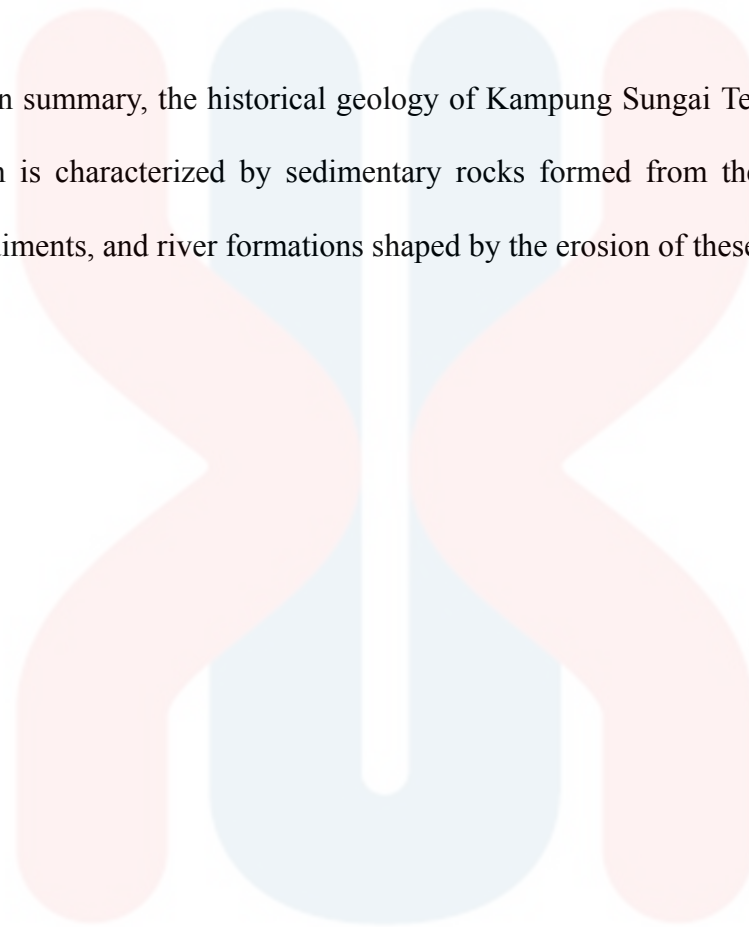
The study area is located in the Malay Peninsula's centre belt. As the Meso-Tethys opened in the late Early Permian, the Sibumasu block to the west of the Bentong-Raub suture evolved from Gondwana (Metcalf, 2013). On the middle Triassic, the Sibumasu block collides with the Indochina block, and then the Sibumasu block is subducted beneath the Indochina block. The collision of two blocks caused the Palaeo-Tethys to close.

The historical geology of Kampung Sungai Terah, Gua Musang, Kelantan is characterized by the presence of sedimentary rocks and river formations. The sedimentary rocks in the area were likely formed from the accumulation of sediments from the nearby river, which over time became compacted and cemented to form solid rock layers.

The river in Kampung Sungai Terah has likely played a significant role in shaping the landscape over the course of its history. Through erosion, the river has carved a channel through the surrounding rock formations and transported sediments to lower elevations. Over time, these sediments may have accumulated along the

banks of the river, contributing to the formation of the sedimentary rocks found in the area today.

In summary, the historical geology of Kampung Sungai Terah, Gua Musang, Kelantan is characterized by sedimentary rocks formed from the accumulation of river sediments, and river formations shaped by the erosion of these rocks over time.



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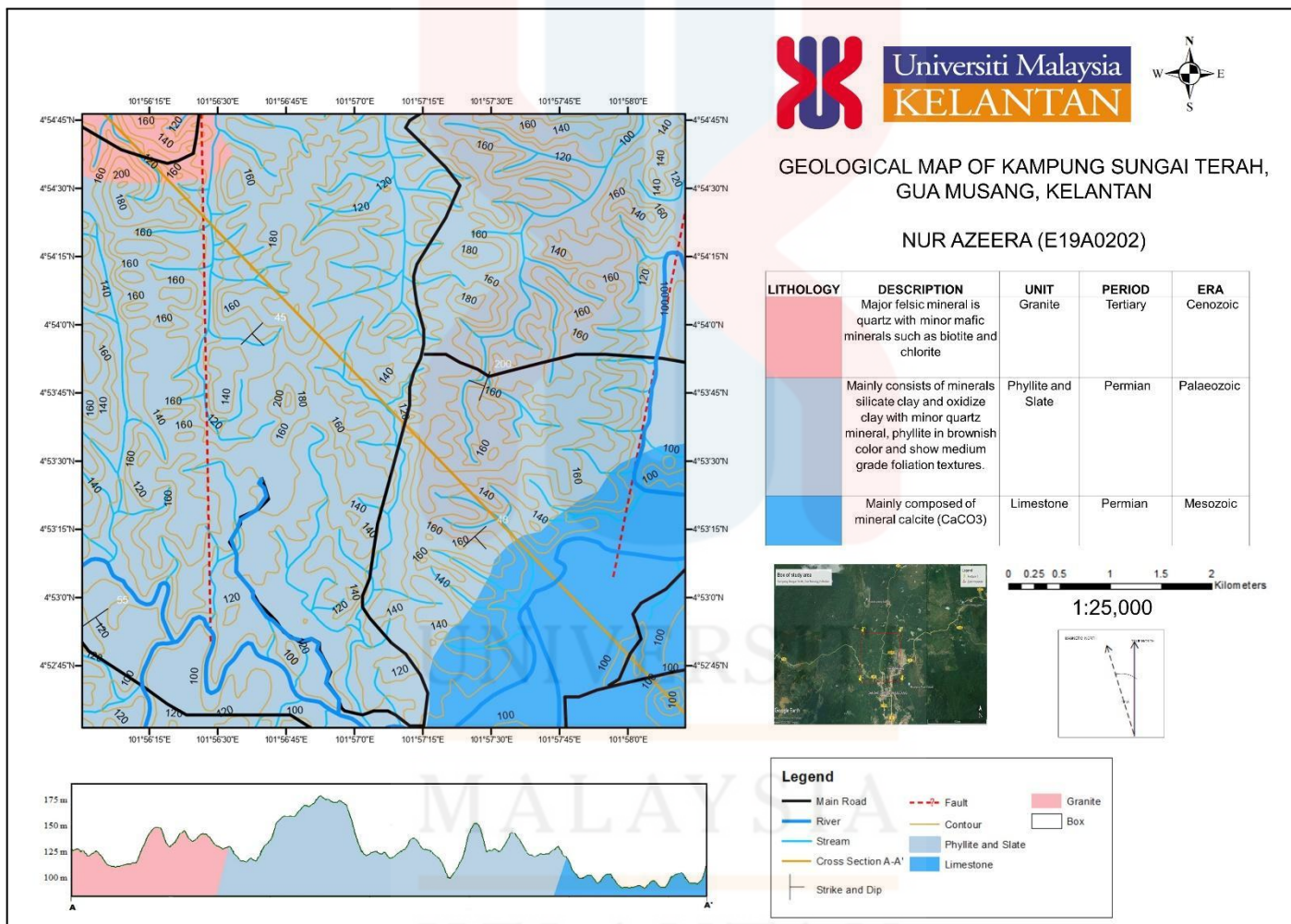


Figure 4. 19: Geological map of the study are

## CHAPTER 5

### LANDSLIDE SUSCEPTIBILITY MAP

#### 5.1 Introduction

The landslide susceptibility assessment was analysed in this section and classified into three classes: low, medium, and high. Using digital elevation model (DEM) data from USGS, thematic maps of each character, such as slope, elevation, aspect, drainage density, and land use were created.

#### 5.2 Field Landslide Mapping

This study's targets required collecting data, creating datasets for landslide inventories, building a database of landslide causal variables, and using WOM to create landslide susceptibility maps and verify them.

##### i. Data Collection

The information used in this research came from a wide variety of sources. These include a topographic map at a scale of 1:25,000 and a Google Earth picture from Google. Also included are DEM data from the USGS, rainfall data from the National Metrological Agency of Malaysia, and a collection of related literatures from published and unpublished research. During fieldwork, mapped landslide inventory on both active landslide and scarp regions is needed, including measuring

their length, width, accumulation zone, and depth (where feasible), and recorded information about land use or human activities, such as farming. The collected field data was processed and analysed in ArcGIS, Microsoft Excel, and ArcGIS in a methodical order after data compilation.

### **5.2.1 Location of Landslide**

A landslide is the downward movement of loose rock, debris, or soil. Soil and rock sliding downslope under the force of gravity is called "mass wasting," and this includes landslides. The phrase "landslide" can refer to any of five different types of slope movement: falling, toppling, sliding, spreading, or flowing. They are further classified by the specific geological substance they consist of (bedrock, debris, or earth). Rock falls and debris flows (sometimes known as mudflows or mudslides) are two prevalent forms of landslides. Several landslides occurred in the study area. But most of the landslide is rock fall (Circular Failure) and rock topple (Toppling Failure). Figure 5.1 show the landslide that occur in the study area.

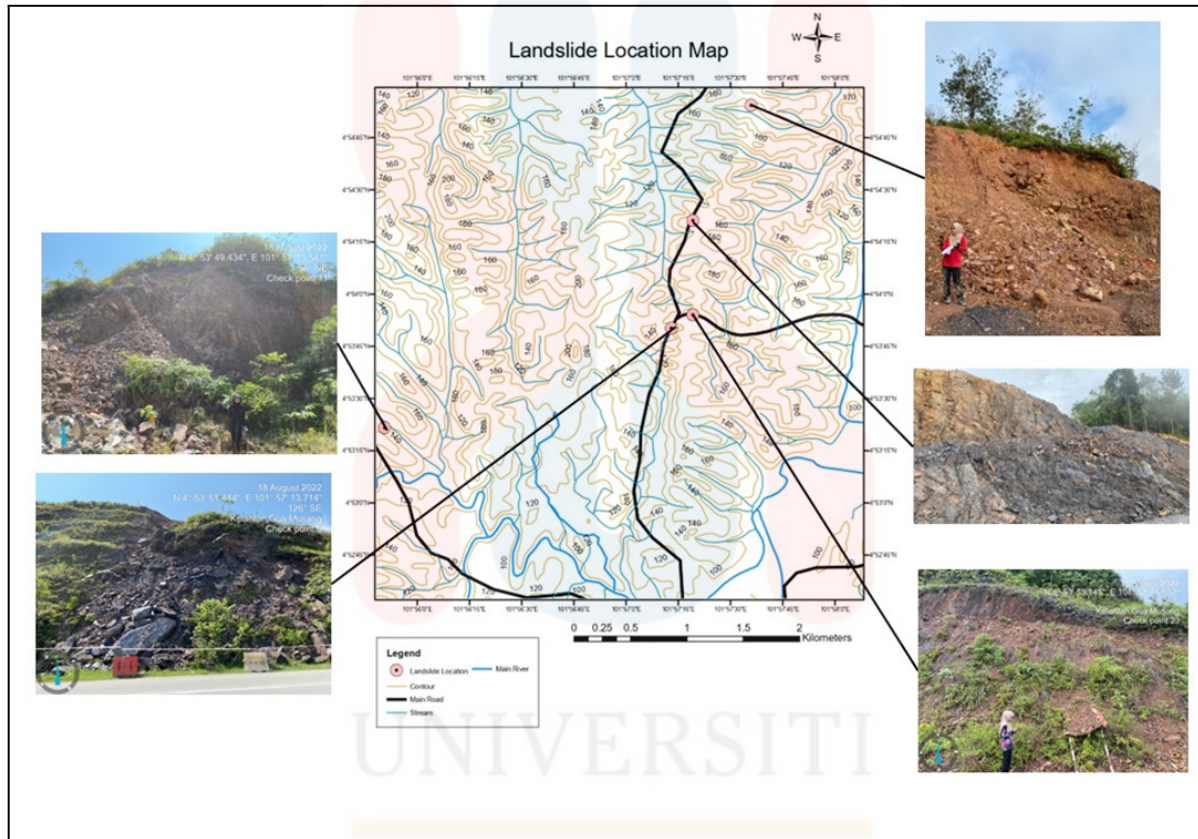


Figure 5. 1: Landslide location map of the study area.

### 5.2.2 Causes of Landslide

Multiple factors contribute to nearly every landslide. When downward forces (mostly gravity) surpass the strength of the earth components making up a slope, movement occurs. There are a number of variables that contribute to weak or unstable slopes, including those that amplify the impact of down-slope pressures. Rainfall, fluctuating water levels, stream erosion, shifting ground water, earthquakes, volcanic activity, human disturbance, and other natural and manmade disturbances can all trigger landslides on slopes that are on the edge of sliding. Underwater landslides can be caused by earthquake shaking and other sources. Submarine landslides are the name given to these natural disasters. Tsunamis can be triggered by underwater landslides, having a devastating impact on coastal communities.

Rainfall is the primary cause of landslides in Southeast Asia, and Malaysia receives a lot of rainfall due to its tropical environment. Rainfall in Gua musang, Kelantan, is particularly heavy during the monsoon season (November–March). Based on this phenomenon, the dynamics of the water on the surface and underneath the ground alter, reducing the stability of the slope and increasing the risk of landslides. Dangers to life and property are posed by these occurrences. In the area under investigation, landslides are more common along roads. The landslide was probably caused by poor drainage on the slope and next to the road. Surface fractures are the earliest warning indicator, as seen in Figure 5.2. That's proof that water made its way to the surface. The lack of proper drainage would be the reason. Landslide occurs when water penetrates below the pavement through cracks or openings in the

drainage system. The overflow water in this situation would have drained through the bare soil on the opposite side of the road, down the hill.



**Figure 5. 2:** The tension crack on the Gua Musang road, which shown the sign of slope movement.

### 5.3 Parameter of Landslide Causative Factor

Table 5.1 indicates all parameters and weightage that were used to produce a landslide susceptibility map.

**Table 5. 1:** The parameter of the research study

No.	Parameter	The weightage (Wi)
1.	Slope	9
2.	Aspect	9
3.	Drainage Density	5
4.	Land Use	6
5.	Lithology	7

(Source: Prakash, 2020)

### 5.3.1 Slope

A landslide is a rock, debris or Earth's mass movement down a slope. Gravity affected the down-slope movement of the soil and rock. The effect of down-slope forces leads to low or decreased power. The slope is an important parameter in the study area for evaluating the susceptibility to landslides (Table 5.2).

**Table 5.2: Slope Classification**

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

(Sources: Van Zuidam, 1985)

According Van Zuidam (1985) classifies the slope with ten weighting ratings used to divide the slope weighting and ranking into six categories. This is because the slope aspect has a significant impact on the frequency of landslides. The scores climb as the degree of slope increases.

Table 5.3 shows the weightage of the slope, which has been categorised into six separate classes ranging from 0° to more than 35°. The preceding landslide

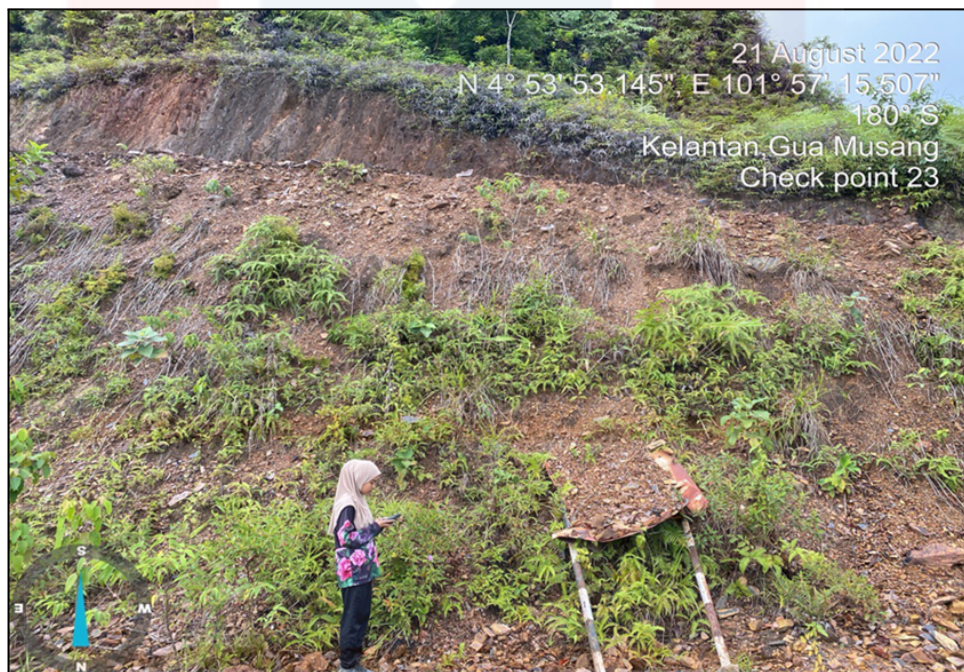
demonstrates that during geological mapping, the landslide occurred not only on a very steep slope but also on a mild slope. This could be related to another setting that was selected. The slope map of the research region is depicted in Figure 5.5.

**Table 5.3:** Weightage and score for slope

No	Class (°)	Weightage ( $W_i$ )	Score ( $S_{ij}$ )	Weightage x Score ( $W_i \times S_{ij}$ )
1.	0-5	9	1	9
2.	5-10	9	2	18
3.	10-15	9	3	27
4.	15-25	9	4	36
5.	25-35	9	5	45
6.	>35	9	6	54



**Figure 5. 3:** Landslide occurred along the major road at checkpoint 9. The size of failure is massive



**Figure 5. 4:** Landslide occurred along the major road at checkpoint 23. The size of failure is massive

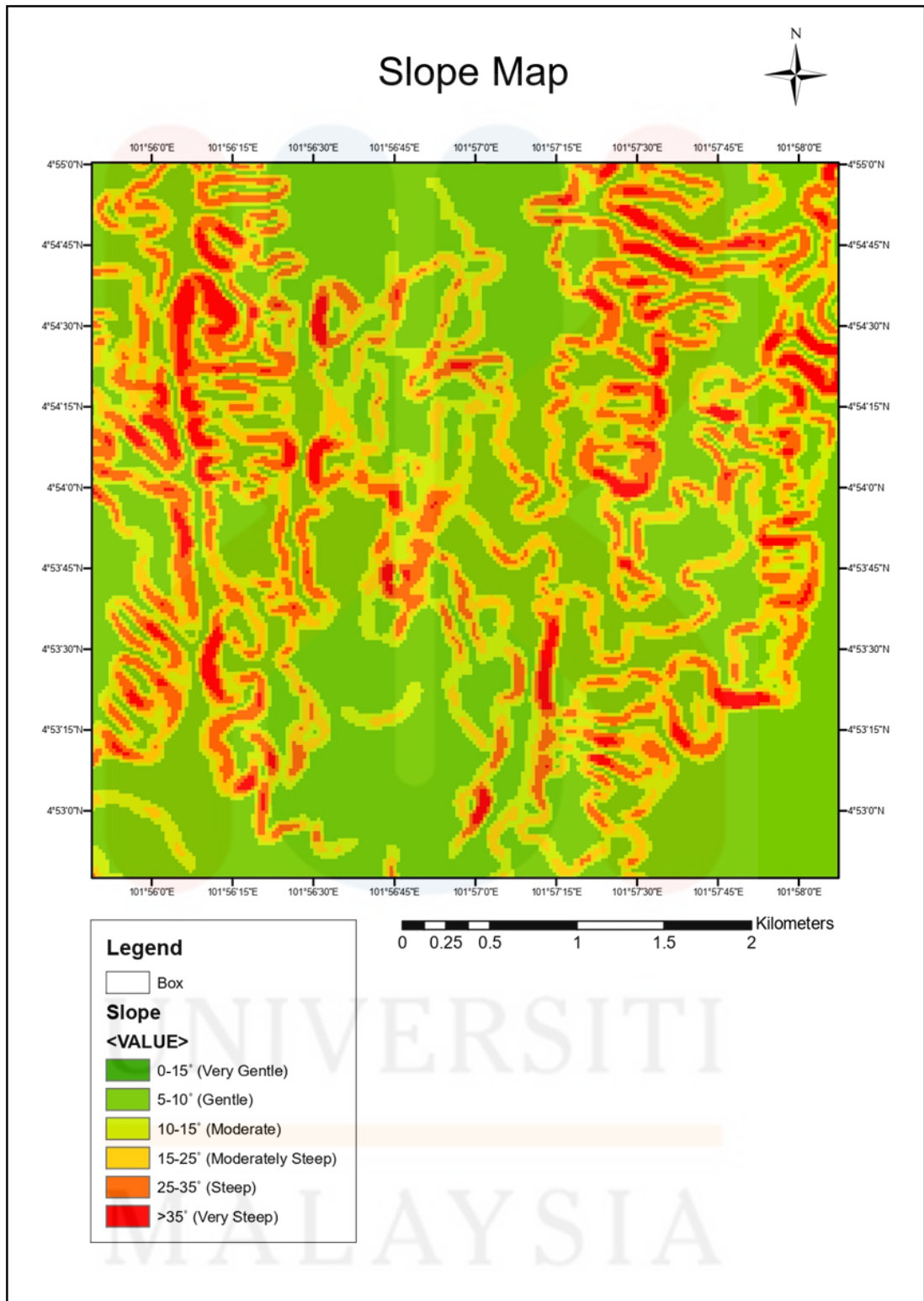


Figure 5. 5: Slope map generated from ArcGIS at the study area

### 5.3.2 Aspect

This map was produced using DEM data, and it is divided into eight different classifications of slope direction based on whether or not it faces north (Table 5.4). In order to detect the slope's orientation and determine the gravitational force that should be applied, the parameter must be implemented so that it can show the direction of the slope. It is measured in an anticlockwise direction starting at 0 degrees in the north and going all the way up to 360 degrees. Aspects of the study area are depicted on the map in Figure 5.6.

**Table 5.4:** Weightage and score for aspect

No	Slope direction	Weightage (Wi)	Score (Sij)	Weightage x Score
1.	Flat (-1)	9	1	9
2.	North (0-22.5)	9	2	18
3.	Northeast (22.5-67.5)	9	3	27
4.	East (67.5-112.5)	9	4	36
5.	Southeast (112.5-157.5)	9	5	45
6.	South (157.5-202.5)	9	6	54
7.	Southwest (202.5-247.5)	9	7	63
8.	West (247.5-292.5)	9	8	72
9.	Northwest (292.5-337.5)	9	9	81
10.	North (337.5-360)	9	10	90

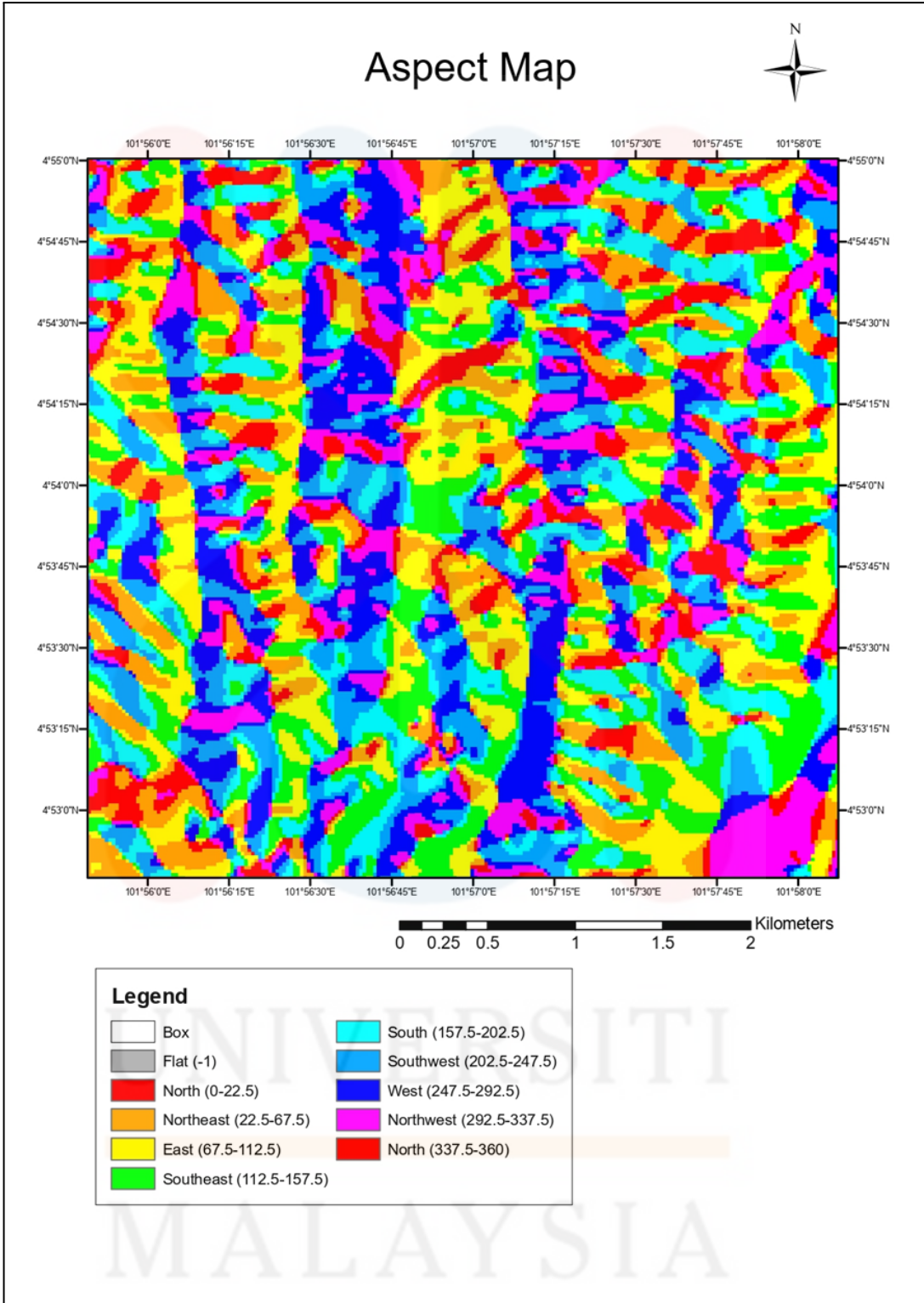


Figure 5. 6: Aspect map generated from ArcGIS at the study area

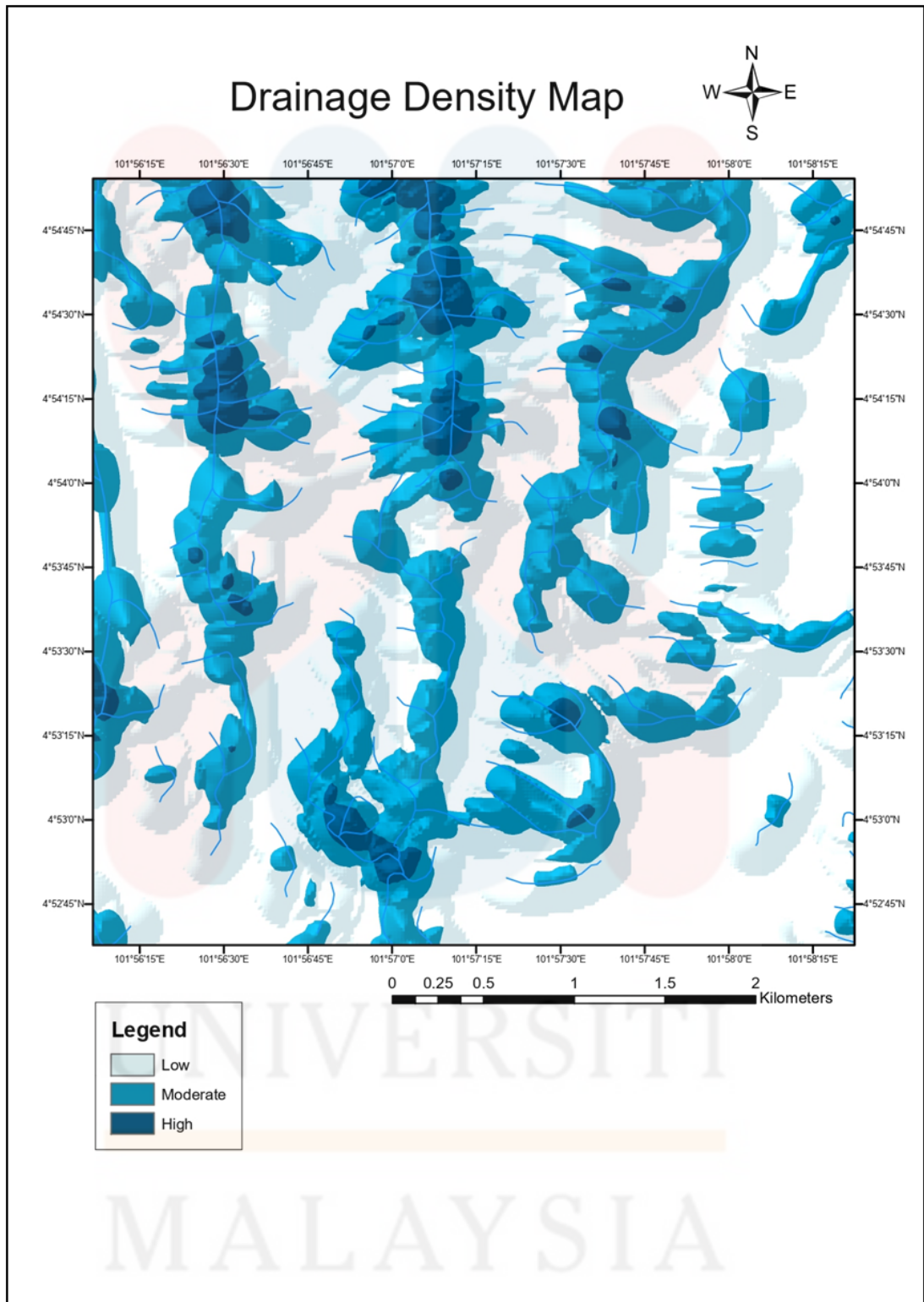
### 5.3.3 Drainage Density

Drainage density can easily be calculated by dividing the total area of the drainage basin by the total length of all streams and rivers within the drainage basin. A multitude of elements, including climate, slope, soil infiltration, vegetation, and flux density, interact in a complicated manner to produce the current drainage variation. It is crucial to determine the network of rivers and streams that traverse the researched region. By evaluating the quantity of debris flow and seepage caused by precipitation penetration, it is possible to identify areas prone to landslides. The drainage system density in a certain region may be determined by summing the lengths of all the channels in that region. This statistic is often expressed as a ratio of channel miles to square miles.

The drainage density map was generated using the ArcGIS DEM output. Utilizing the ratio of stream length to total land area, drainage density is calculated. The drainage density has been classified into four distinct categories: low, moderate, high, and highest. The large number of drains in the region suggests a greater likelihood of landslides. The considerable amount of surface runoff is the primary source of this issue. Below is Figure 5.7, which displays the area's drainage pattern and is the major subject of this investigation. Based on the study area, density of drainage is larger in damp regions than in arid parts; it approaches zero in flat, sandy desert regions and reaches a maximum in steep, rocky, humid regions.

**Table 5.5:** Weightage and score for drainage density

No	Drainage Density		Weightage ( $W_i$ )	Score ( $S_{ij}$ )	Weightage x score ( $W_i \times S_{ij}$ )
1.	Low	0-84	5	1	5
2.	Moderate	455-145	5	2	10
3.	High	911-207	5	3	15



**Figure 5. 7:** Drainage density map generated from ArcGIS at the study area

### 5.3.4 Land Use

The research area consists of oil palm plantation Figure 5.8, rubber tree plantation Figure 5.9, and forest reserve Figure 5.10. FELDA manages both the rubber tree and oil palm plantations. The mature trees have already produced new oil palms and rubbers. In the rubber plantation region, the dirt road is much narrower than in the oil palm plantation region.

So, motorbike was used by worker to collect the rubber, meanwhile a four-wheel car was driven every day to collect the oil pam. In rubber tree plantation areas, the soil is brown, however in oil palm plantation areas, the soil is darker brown. The majority of plantation outcrops are majorly eroded and embedded in the soil. The forest in the research region is mature and densely forested. Table 5.5 displays the weighting and score for land use, whereas Figure 5.11 depicts the land use map for the research region.



**Figure 5. 8:** The oil palm plantation at the study area



**Figure 5. 9:** Rubber plantation at the study area



**Figure 5. 10:** Thick Forest with matured tree at the study area

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**Table 5.6:** Weightage and score for land use

<b>No</b>	<b>Class</b>	<b>Weightage (<math>W_i</math>)</b>	<b>Score (<math>S_{ij}</math>)</b>	<b>Weightage x Score (<math>W_i \times S_{ij}</math>)</b>
1.	Clear land	6	2	12
2.	Build up area	6	3	18
3.	Oil palm	6	4	24
4.	Rubber	6	3	18
5.	Mix agriculture	6	3	18

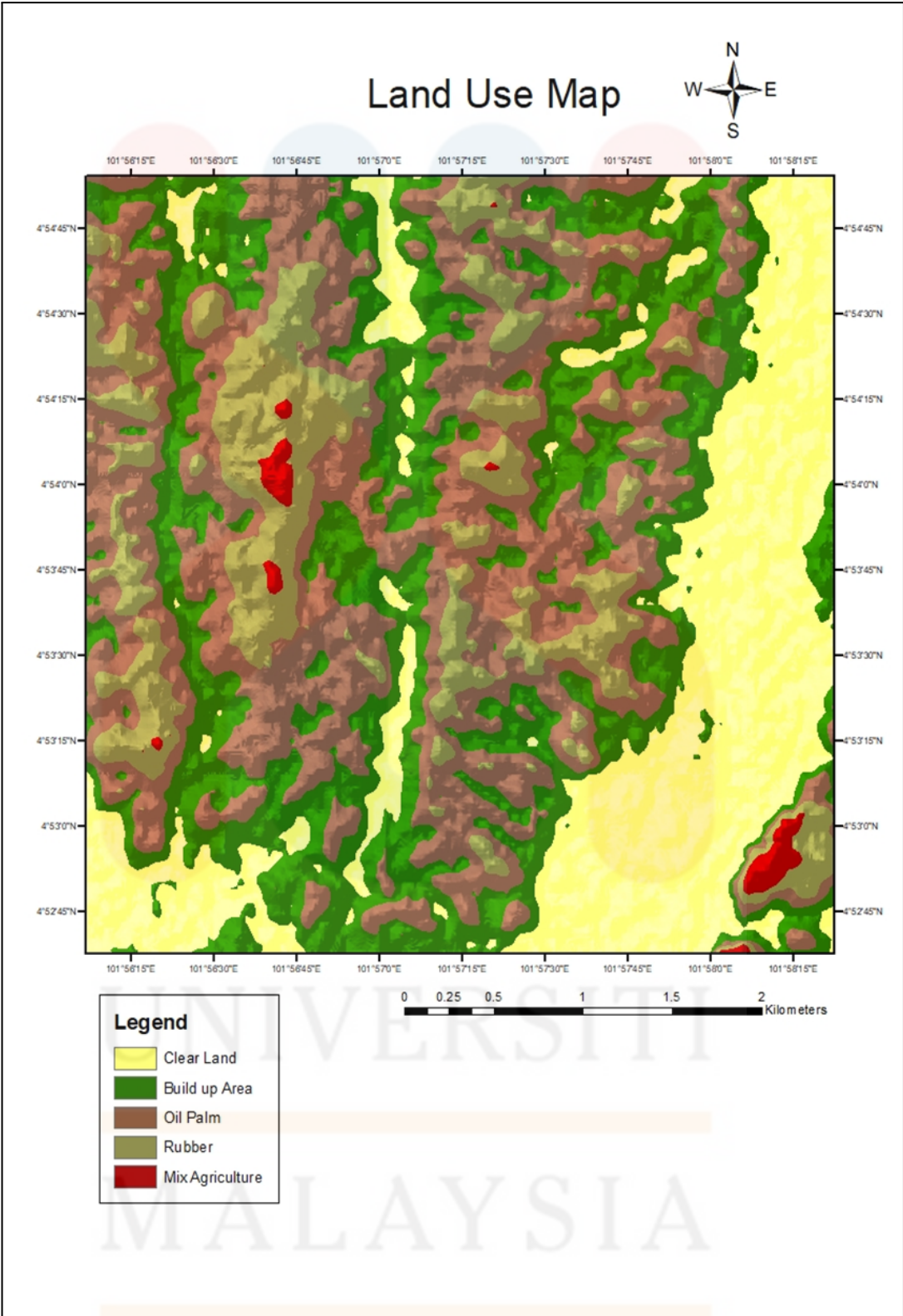


Figure 5. 11: Land use of the study area

### 5.3.5 Lithology

Lithology was one of the parameters utilised to determine the risk of landslide occurrence in the research area. Where a region is susceptible to or prone to landslides, differences in lithology have played a crucial role. The lithological environment and formation differentiate rock and soil characteristics.

In the study area, there are three types of lithologies which are granite, limestone, phyllite and slate, which had been explained earlier in chapter 4. Each of the lithologies does represent the structure and the formation in that area. In this case, all the lithologies overlay in the same formation, which is Gua Musang Formation.

**Table 5.7:** Weightage and score for lithology

No	Lithology Class	Weightage (Wi)	Score (Sij)	Weightage x score (Wi x Sij)
1.	Limestone	7	1	7
2.	Granite	7	3	21
3.	Phyllite and Shale	7	4	28

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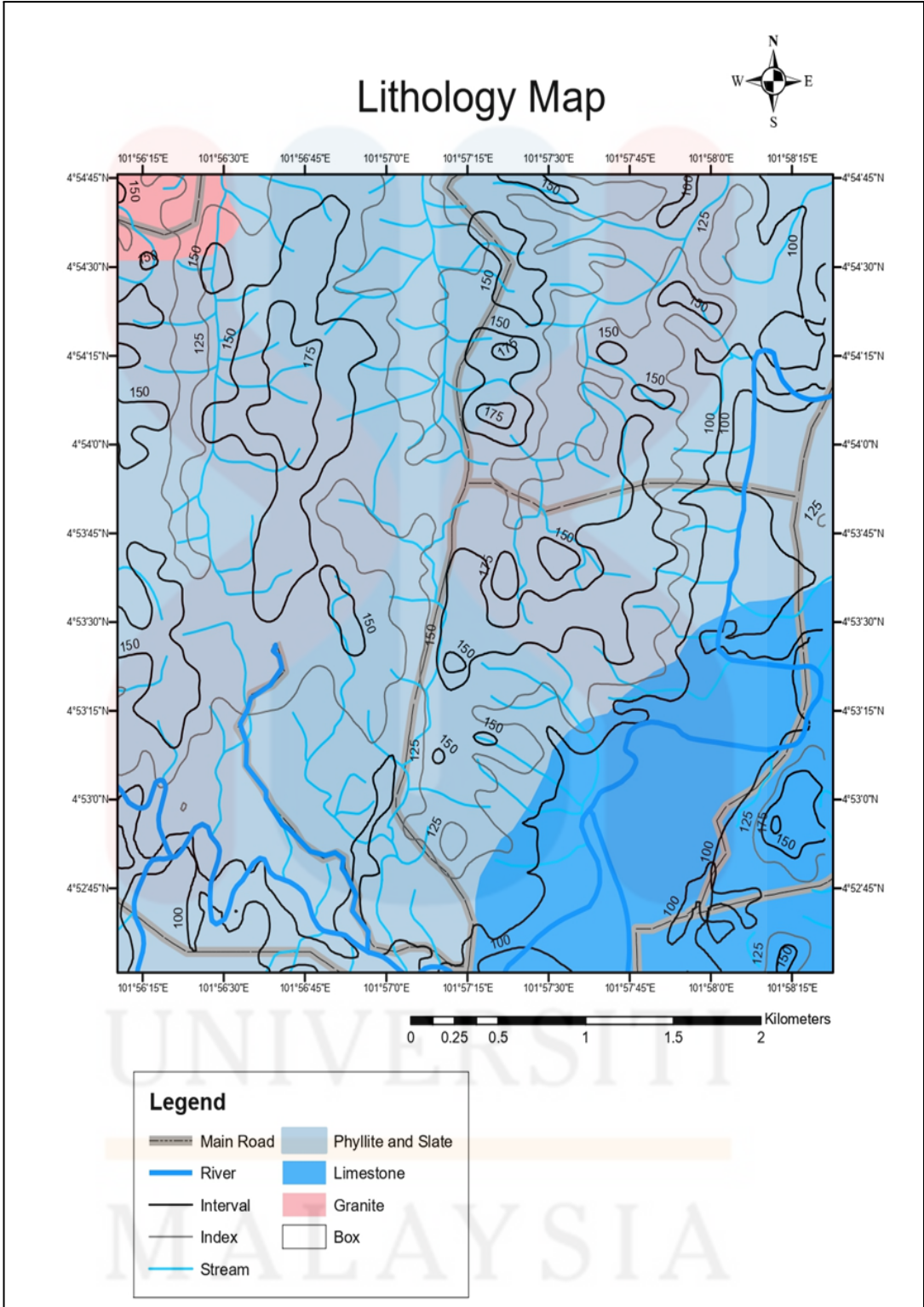


Figure 5. 12: Lithology map of the study area

## 5.2 Landslide Susceptibility Analysis

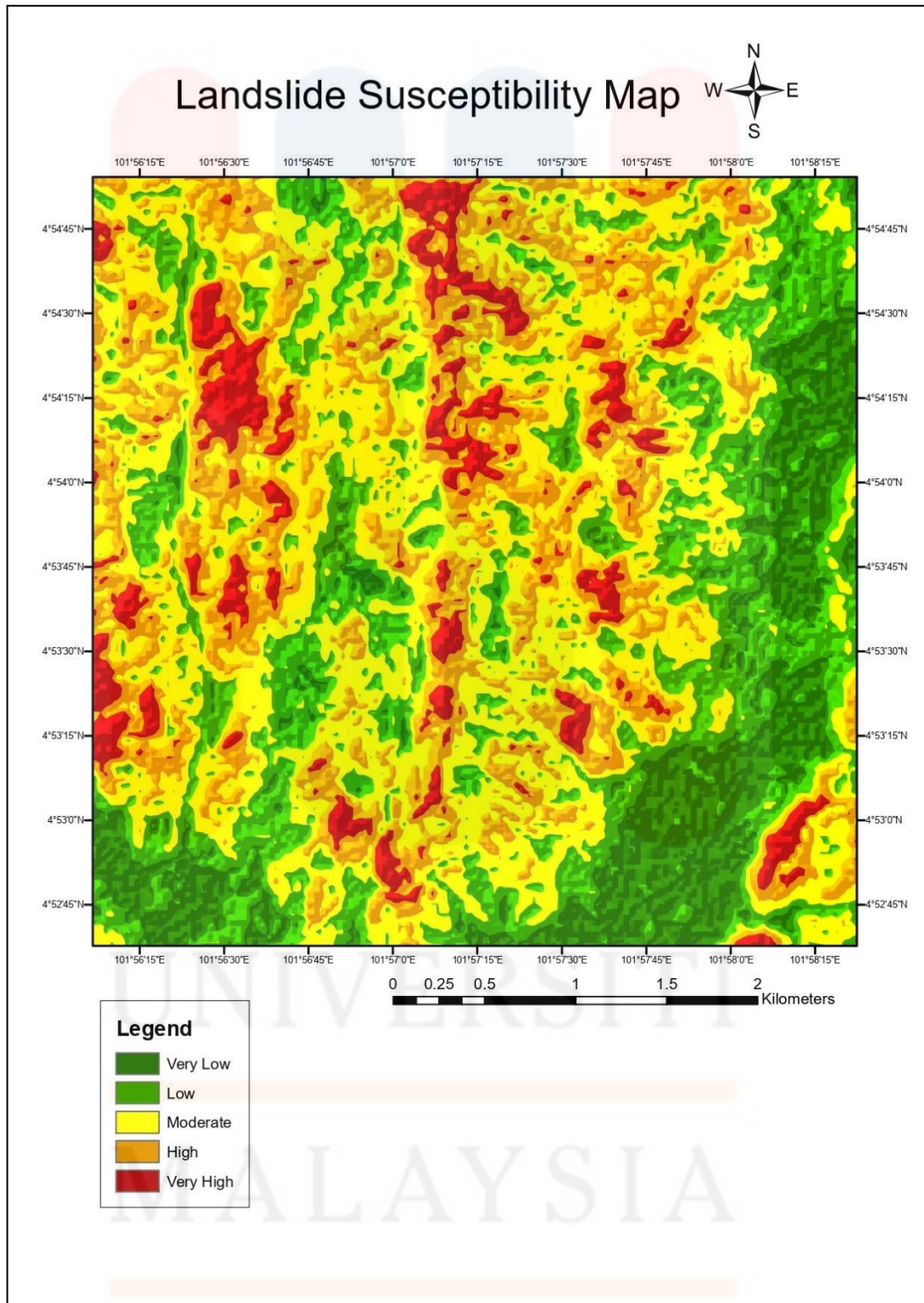
Before creating the landslide susceptibility map, all selected parameters were converted into a raster data set. After then, the weighting of such raster data was reclassified. The landslide susceptibility map was created using the GIS application and the weightage overlay procedure. The parameters are lithology, slope, aspect, and drainage density.

In the study of landslide susceptibility, slope, lithology and drainage density play an important role and become parameters that have a strong effect. The steeper rate of the slope has a greater tendency for landslides to occur. As the rock and soil that formed in the region have distinct porosity and void, the lithology also affects the landslide. Figure 5.13 shows the landslide susceptibility map of the study area based on the data collection on the five parameters raster class.

**Table 5.8:** Susceptibility of landslide hazard in the study area

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

(Source: Prakash, 2020)



**Figure 5. 13:** Landslide susceptibility map of Kampung Sungai Terah area

## CHAPTER 6

### CONCLUSION AND SUGGESTION

#### 6.1 Conclusion

In conclusion, the study does affect Kampung Sungai Terah's, Gua Musang, and Kelantan's landslide risk. The collected data from five distinct sources and fed it into a GIS and remote sensing software. Slope, aspect, lithology, land use, and drainage are all part of the component that is analysed with the WOM technique. With the WOM tool, one of the most popular overlay analysis methodologies to deal with multicriteria issues like site selection and appropriateness models. Each piece of information was verified by drawing connections to the landslide observation checkpoint data.

Very low, low, moderate, high, and very high susceptibilities are present in the study area, with the former two dominating the latter two. Extremely dangerous landslides can occur in the study area due to the high to extremely high vulnerability level. These places tend to be found in areas with a medium amount of vegetation, close to urban centres. First responders, local authorities, and researchers can all benefit from the attention and data provided by the landslide vulnerability map that is created. Preliminary information about the potential spread of landslide hazards in the study area is all that can be gleaned from the resulting landslide susceptibility maps. With regard to regional growth and environmental spatial planning, this map lacks information about the landslide area.

## 6.2 Suggestion

Based on the findings and recommendations from the specification section, future research should take into a broad range of criteria, including vegetation type, official documents of previous landslides, and a detailed geomorphology analysis of the study area. The explanation is that different parameters might produce different results, and by comparing the results, it is possible to determine which parameters had the greatest impact on the landslide risk of the study area.

Higher awareness is required in terrain units with a high potential for landslide disasters or damage to life and property. In addition, the community needs to be educated through training and counselling about landslides and the need for disaster management procedures before, during, and after such a disaster strikes.

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