Geology & Landslide Susceptibility Mapping by Using GIS Application, within Sg. Ketil region, Gua Musang, Kelantan.

By

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A report presented in accomplishment of the essential for the degree of Bachelor of Applied Science (Geoscience) with Honours

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2021

DECLARATION

I declare that this thesis entitled **"GEOLOGY & LANDSLIDE SUSCEPTIBILITY MAPPING BY USING GIS APPLICATION, WITHIN SG. KETIL REGION, GUA MUSANG, KELANTAN"** has been composed by myself and that the work has not be submitted for any other degree or professional qualification. I confirm that the work submitted is my own except as cited in reference.

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APPROVAL

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

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GEOLOGY & LANDSLIDE SUSCEPTIBILITY MAPPING BY USING GIS APPLICATION, WITHIN SUNGAI KETIL REGION, GUA MUSANG, KELANTAN.

ABSTRACT

Sungai Ketil region which is situated within Gua Musang, Kelantan encompassing a region of 25 km^2 where in close proximity to latitude 4˚50'45.0" N to 4˚53'0.0" N and longitudes 102˚0'52.0" E – 101˚58'30.0" E, specifically in the south eastern direction within Gua Musang district. The purpose of this study is to update a geological map of the study area with a scale of 1: 25,000, to identify the zones within the study area which is vulnerable towards landslides and to produce a landslide susceptibility map in Sg. Ketil region in Gua Musang, Kelantan. Involved parameters are analysed based on the geological condition of the study area. This research discusses on the geomorphology, stratigraphy, structural geology, and historical geology of the study area. The region of Sg. Ketil is bounded within the Gua Musang district, Kelantan where it is involving in Gua Musang formation, one of the formation that embodied in the Central Belt of Peninsular Malaysia. Four lithology units are identified in the study area. The instability of slope may be influenced by the slope, aspect, rainfall intensity of a region, type of lithology, drainage density, structural factors as well as the land use of an area. Weighted Overlay Method (WOM) is a practical technique which enables the calculation of several parameters that are being integrated together in form of raster data set. It is a simple tool incorporated within ArcGIS software which provides a comprehensive result and is easier to operate. This assessment presents a landslide susceptibility zonation map which shows the region which is vulnerable towards landslide. It is categorizing as either low, moderate to high susceptibility towards landslide occurrences. In conclusion, discernment towards the structural mechanism is crucial to ensure the safety of a region and to prevent any unavoidable events.

Keywords: GIS, hazard, landslide susceptibility, WOM, Sg. Ketil, Gua Musang.

GEOLOGI & KERENTANAN TANAH RUNTUH MENGGUNAKAN APLIKASI GIS, DALAM KAWASAN SG. KETIL, GUA MUSANG, KELANTAN.

ABSTRAK

Sungai Ketil merupakan sebuah kawasan yang berada di dalam daerah Gua Musang, Kelantan. Kawasan dengan koordinat latitud 4˚50’45.0” N hingga 4˚53’0.0” N dan longitud 102˚0’52.0” E – 101˚58’30.0” E, merangkumi luas 25 km^2, berada dalam lingkungan timur laut di dalam daerah Gua Musang. Kajian yang dijalankan bertujuan untuk mengemas kini peta geologi kawasan kajian dengan skala 1:25, 000. Selain itu, mengenal pasti kawasan – kawasan yang terdedah terhadap kejadian tanah runtuh seterusnya, dapat menghasilkan peta zonasi kawasan yang terdedah terhadap bencana alam tersebut. Parameter yang terlibat dalam menjalankan kajian ini dianalisis terlebih dahulu mberdasarkan keadaan geologi kawasan kajian. Kajian ini turut membincangkan geomorfologi, stratigrafi, geologi struktur, dan geologi sejarah kawasan kajian. Kawasan Sungai Ketil dilingkari daerah Gua Musang, dimana ianya terlibat dalam formasi Gua Musang yang juga berada dalam jasad “Cental Belt” di semenanjung Malaysia. Empat unit lithology telah ditentukan di dalam kawasan kajian. Ketidakstabilan cerun mungkin dipengaruhi oleh cerun, arah cerun, taburan curahan hujan, jenis batuan, ketumpatan saliran factor struktur begitu juga dengan penggunaan tanah di sesuatu kawasan. *Weighted Overlay Method* merupakan sebauh teknik yang membenarkan pengiraan gabungan daripada beberapa parameter yang dalam bentuk data set raster. Ia merupakan penggunaan yang ringkas di dalam perisian ArcGIS di mana ia dapat memberikan hasil yang mudah difahami and mudah untuk dilaksanakan. Hasil daripada kajian ini, sebuah map dihasilkan untuk menunjukkan kerentanan sesuatu kawasan terhadap tanah runtuh. Klasifikasi kawasan di kategorikan mengikut kawasan dengan kadar rendah, sederhana dan tinggi terhadap kejadian tanah runtuh. Secara konklusinya, pemahaman yang mendalam terhadap struktur mekanisma begitu penting untuk memastikan kemaslahatan sesebuah kawasan selain untuk mengelak kejadian tidak diingini.

Kata Kunci: GIS, bencana, kerentanan terhadap tanah runtuh, WOM, Sg. Ketil, Gua Musang.

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LIST OF ABBREVIATION

DEM	Digital Elevation Method
GEP	Google Earth Pro
GIS	Geographical Information System
JKR	Jabatan Kerja Raya
JMG	Jabatan Mineral & Geosains Malaysia
JPKN	Jabatan Pertanian Negeri Kelantan
LSM	Landslide Susceptibility Map
NDVI	Normalized difference vegetation index
OLI	Operational Land Imagery
SRTM	Shuttle Radar Topography Mission
TIN	Triangular irregular networks
TIRS	Thermal Infrared Sensor
USGS	United States Geological Survey Earth Explorer

WOM	Weighted Overlay Method

LIST OF SYMBOL

°	**Degree**
×	Multiplication
%	Percentage

CHAPTER 1

INTRODUCTION

1.1 General Background

Sungai (Sg.) Ketil region is an agricultural land within Gua Musang district. This land is embedded with oil palm plantation by Chin Teck Plantation Berhad (Chin Teck). The Chin Teck's vital business is the oil palms cultivation, and acts as the predominant supplier of fresh fruit bunches, palm kernel and crude palm oil in Malaysia.

This agricultural region is majorly comprising of low land area, however, there is region with high land and is challenging to access. High terrain may develop towards risky hazard such as landslide with steeper slope, along with unstable Earth's material. Landslides in Malaysia has reported approximately 26 cases since 1993 until 2014.

Reported by The Star on 2019, the major landslide event that has occurred in the history are Highland Tower, Ulu Kelang (1993), Bukit Antarabangsa, Ampang (1999), and Bukit Lanjan, Kuala Lumpur (2014). Approximately, total of 2.8 landslide occurrences per year on average, while 1.7 from them are the cases causing fatalities and loss of properties.

Landslide events have result in severe impact towards the economy. Based on Rahman (2017), it is reported that Malaysia has recorded approximately RM 4.28 billion, loss due to landslides in economy sector since 1973 until 2007. Thus, hazard assessment and mitigation measure should be done to ensure low potential of disaster event.

1.2 Study Area

1.2.1 Location

The Sg. Ketil region is situated at southeast part of Gua Musang district, Kelantan and exactly within the northeast Chin Teck Farm area. The area was covered by 5 km x 5 km with total of 25 km^2 from latitude (4˚50’45.0” – 4˚53’0.0” N) and longitudes (102˚0’52.0” – 101˚58’30.0” E) by 5 km x 5 km (Figure 1.1).

Drainage System

The main drainage feature in the study area is Ketil River at 4° 53' north, 101° 58' east, across Gua Musang town. It is next to Gua Batu Boh and close to Chindai river at southern part, specifically flowing in south-east direction from its main tribute which is Galas River.

It has the length of 4.81km and elevation of 94 metres (308 feet). It acts as the main source for irrigation to the lands and crops around the estates in Gua Musang region including Chin Teck Farm, as well as other estate such as Ann Lin Lee farm and Chua farm.

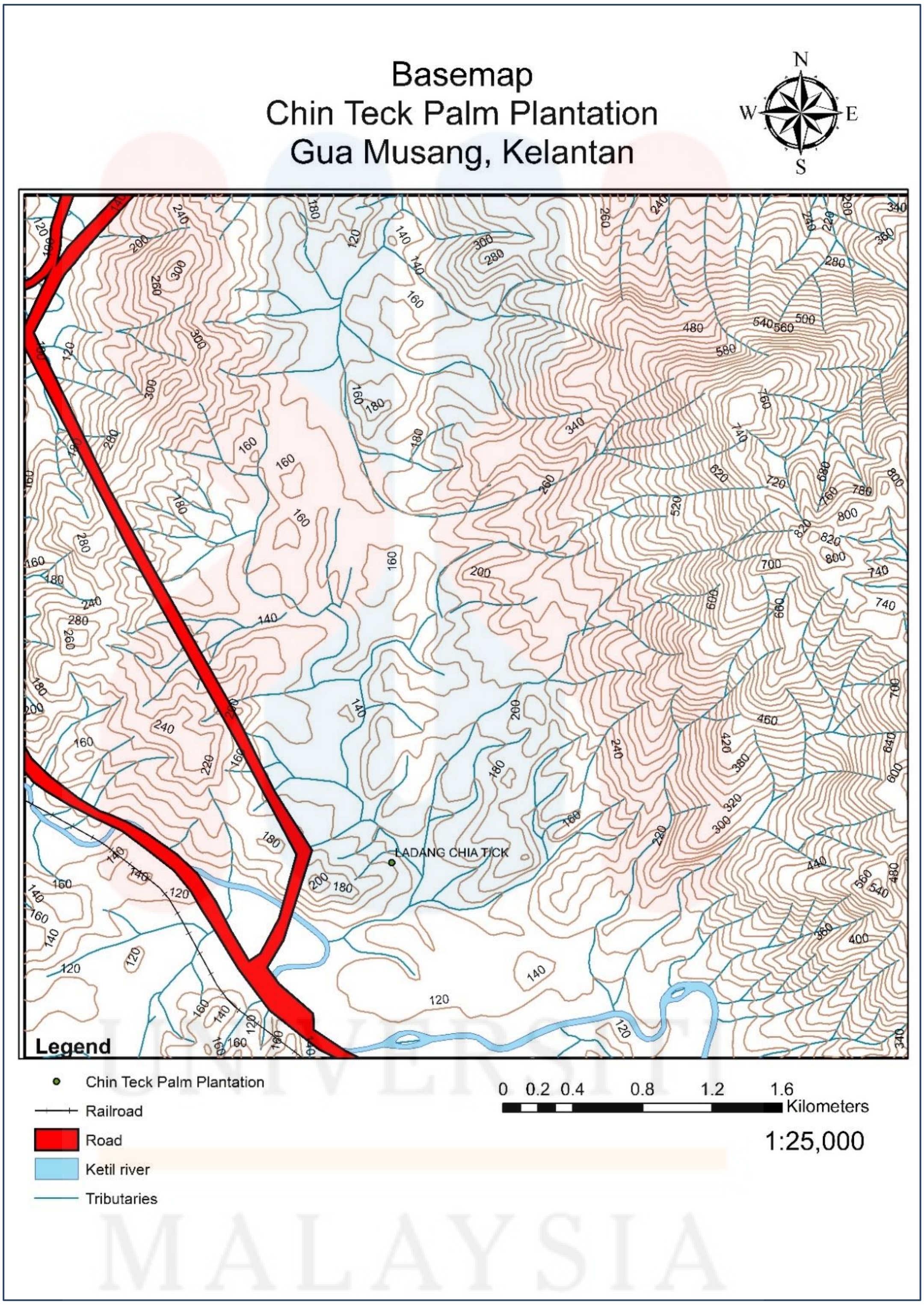


Figure 1.1: Base Map of study area

1.2.2 Accessibility

According to Raizan (2017), there are two main road connecting the Ketil subdistrict with the external main road. The first internal plantation road, is connecting the plantation with the Gua Musang town and the Kota Bharu – Gua Musang Highway at the northern part.

The road is passing along with the Ketil River. The second road is connecting the plantation with Industry Road on the west part. This road is connected with the main Kuala Lumpur – Gua Musang Highway.

Next, the plantation road is located around the plantation area. It is accessible by using transportation such as motorcycle and cars, but, is not suitable to travel when in wet condition due to rainfall. However, it can still be accessed by four wheels' vehicles.

1.2.3 Demography

According to Department of Statistic Malaysia, in 2018, this state has recorded approximately 1.9 million people. By referring to the past research by Syafiqa (2020), the ranking population of "Jajahan Gua Musang" is led by Galas district, which has recorded approximately 31,814. After that, it is followed by Chiku district; 26,251.

Lastly, Bertam; 16,923 people. Kelantan has variety in ethnics similar to other states in Malaysia, however, it is dominant with Kelantanese Malays, '*Orang Asli',* then it is followed by Malaysian Chinese and a little of Malaysia Indian. There are numerous factors that has been the caused for population distribution in Kelantan state.

These factors may be due to the size of district, economic opportunities that develop by time, and the territory as well. All these may contribute to the migration into this district. By referring to Table 1.1 below, it represents the table of populations in Kelantan state. Community in Gua Musang made up about 6.06% of the overall population in Kelantan state in from 2018, with increment of 0.02% since 2017.

Table 1.1: Total Population in Kelantan state from 2017 until 2018

District	Year	
	2017	2018
Bachok	159, 300	162, 500
Kota Bharu	585, 300	590, 900
Machang	111, 400	113, 600
Pasir Mas	227, 300	231, 800
Pasir Puteh	142, 100	143, 100
Tanah Merah	146, 300	149, 200
Tumpat	183, 600	187, 300
Gua Musang	111, 500	113, 900
Kuala Krai	132, 600	135, 200
Jeli	49, 800	50, 800
Total	1, 849, 200	1, 878, 300

(Source: Department of Statistic Malaysia)

1.2.4 Land use

Land use is defined as the regions that are being modified by humans for the purpose of development to meet the requirement for the human race to evolve, (Fraanje, 2018).

In Gua Musang region, it is observed that, this district is well facilitating with good infrastructure and good transportation network. Gua Musang region comprises settlements, with efficient paved road and highways.

Gua Musang region is also a business area, where it has several developing towns. Besides, the agricultural activities around Gua Musang area contributes to the economy development. Taken from the website Global Forest Watch, (2020), rubber is the largest plantation in this region, spanning 96.4 kilo hectares which is 12% of land area, while, oil palm plantation covers about 55.8 kilo hectares , which is 6.94% of the land area.

By using Google Earth Pro software, through the satellite imagery, the study area, comprises 40% of high elevated hill, while, 60% of the remaining is covered with land use which is majorly agricultural. The highest elevation in this region is 700 m at eastern region. It is located near with recreational hill, Bukit Monyet (840 m).

According to (Raizan, 2017), the plantation does not only consist the oil palm tree, however, there is rubber plant tree as well. Besides, there is no village found but settlement of the workers' home.

1.2.5 Social Economic

Gua Musang district has been developing and has undergo urbanization. This region specifically consists of business area, which has provided domestic needs for the people living around. This region is high in agricultural activities as it consists large acres of plantation; rubber tree plantation and oil palm plantation.

The study area is being covered mostly with oil palm plantation. Other than that, Gua Musang has been blessed with various natural and aesthetic landform including karst topography and variety beauty of natures, which is good for tourism sector.

1.3 Problem Statement

Firstly, there is lack of information about the research area in term of geological mapping as there was only one research found to be referred, which was published in 2014 by Hazmira from similar field site.

Next, there is lack of geological data in the research area as the geological map provided by Jabatan Mineral & Geosains Malaysia (JMG) has not been updated to recent year, while the one that is available online currently is from 2012.

The study area is majorly covered with agriculture; this may trigger to landslide due to the type of Earth's material in the study area. Furthermore, the contact between low region and high region in study area shows the potential of landslide, thus, there might be possibilities for landslide to occur in those region.

Plus, from past research in similar study area, there is no data or information regarding landslide susceptibility mappings in that area to provide landslide mitigation measures.

1.4 Objective

1. To update geologic map of Ketil sub - district with a scale of 1:25,000.

2. To identify potential landslide area within Ketil sub – district.

3. To produce landslide susceptibility map of Ketil sub - district.

1.5 Scope of study

The scope of this study is covering on geological mapping in order to study the geology within the study area with the aid of spatial data and statistical data collection. The data can be obtained through websites that provides available online and free data or any government agencies.

Generally, this research will not involve mapping tools and methodologies related to geological mapping and no field data will be involved for data collection. In spatial mapping, the GIS based application, ArcGIS 10.3 by ESRI will be used to run the process in order.

Next, the study is focusing on the potential of landslide hazard that may occur within the study area. Furthermore, the study area is highly covered with agriculture activities, which may contribute to the mass movement due to type of Earth's material in this area, especially at the region showing contact between high and low land.

Firstly, thematic maps that relate to the parameters involved will be processed as the preparation for the landslide susceptibility map. This process will be run by using GIS based application in ArcGIS.

Next, Weighted Overlay Method is one of the approach is ArcGIS application to run the process for the landslide susceptibility map production. The potential of landslide will be rank from the lowest to the highest potential accordingly.

1.6 Significance of study

The importance of this study is to update the geological map of the study area to recent year. Plus, it can also be useful to the government bodies or professional department such as construction company, engineers, or even mining company.

Geological map can be used for future references since it provides primary source of information regarding the geology within the study area. It is useful for the development and planning of land use as well as to avoid from hazard event.

Next, in landslide susceptibility mapping, it is beneficial for the government bodies, decision makers, planners, and the authorities such as *Jabatan Kerja Raya* (JKR) to detect and locate the high risk region, which may not suitable for development.

As well as, to alert any professional departments for future land use planning. Furthermore, this will help them to perform their work efficiently by quick action to repair affected areas or the region showing signs of landslide occurrences.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss on the regional geology and tectonic setting, stratigraphy, structural geology, and historical geology of Gua Musang region where the research area lies within. After that, it will further review on landslide susceptibility mapping studies and the approaches that will be used in this research.

2.2 Regional Geology and Tectonic Setting

The research area, Ketil subdistrict lies within Gua Musang formation. It is a formation extended from South Kelantan to North Pahang embodied argillite, carbonate, and pyroclastic facies around its region. The southeast region of Kelantan exposes carbonate bodies forming eccentric karst topography.

The karst topography consists of North-South trending hills of limestone as well as pavements (Aw, 1990). The age of the rocks are described to be around Middle Permian – Late Triassic, (Yin, 1965). Gua Musang formation is included in Permo-Triassic formation of Central Belt Peninsular Malaysia.

Lee Chai Peng et al., (2004) summarizes, Central Belt forms a continuous north to south trending belt, extended beyond the international boundaries, involving Gua Musang formation up until Thailand (north), to Jurong formation in Singapore (south).

2.3 Stratigraphy

In this research, the southern part of the study area intersects with upper region of study area from past research made by Hazmira, (2013). This represents similar lithology. It is found that, the lithology of the study area consists of limestone, acid intrusive, interbedded sandstone, shale and siltstone.

Also, there are phyllite, slate and shale with subordinate sandstone and schist as well, (Hazmira, 2013). Ketil subdistrict involves in Gua Musang formation. Work done by Yin, (1965), recorded that Gua Musang formation has dated from Middle Permian to Late Triassic.

The boundary of this formation extended up to northern part of Kelantan and down to the north of Pahang state. The upper part of this formation interfingers with Semantan formation, Telong formation and Gunung Rabong formation.

Gua Musang formation is dominant with argillaceous and calcareous rock, there are many karst landforms can be seen around Gua Musang. Other than that, there are layer of rocks interbedded with volcanic and arenaceous rocks.

Next, based on the research made by Khoo et al., (1983), Burton and C.K, (1973), and Yin, (1965), there are plenty of fossils found in Gua Musang region, representing shallow marine environment and once associated with active volcanic activity. Mostly found are brachiopods, algae and bivalve.

2.4 Structural Geology

Gua Musang town, in the southernmost of Kelantan, lies close to Lebir Fault zone in southwest direction. Landform of carbonate rock and its behaviour has been highly influenced by fault and joints, (Hazmira, 2013).

Geological features such as fault and joint are often found in granitic rocks, while fault, fold, joint are found in sedimentary rocks. Gua Musang has formed the compact and develop strong folding in the region enclosed with intrusion of igneous granite and close by with the main fault.

Major fold in Gua Musang is located at centre region heading north-south up to north- northwest–south-southeast. There is granite intrusion of the main fold at northern part, and diorite porphyry heading to NE-SW.

Gua Musang embedded in the Cental Belt zone, where the eastern end is neighbouring to Lebir fault trace, sinistral strike-slip fault from post Cretaceous. It is one of the main lineaments found in Peninsular Malaysia, (Tjia, 1992).

Figure 2.1 is representing the type of lithology and the geological age as it evolves. As shown in the geological map of Kelantan state, Gua Musang region is dominated with shale, siltstone, sandstone and limestone where they have been evolving in Triassic and the phyllite, slate, sandstone and limestone since Permian age.

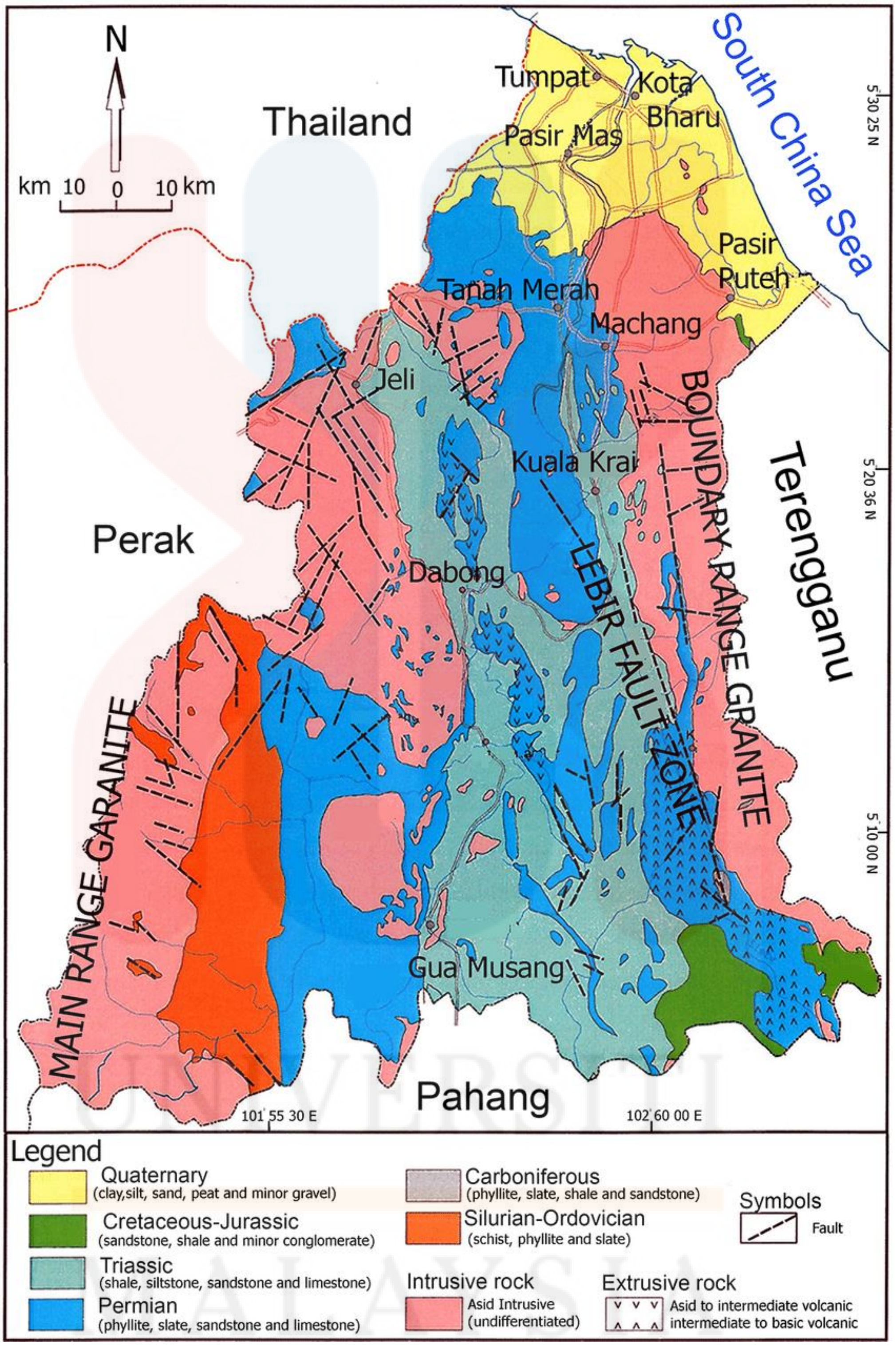


Figure 2.1: The geological map of Kelantan state.

(Source: Nazaruddin et al., 2014)

2.5 Historical Geology

Mohamed et al., (2016) discusses on fore arc basin subsidence and segmentation model of Permo - Triassic Indosinian Orogeny within Paleo-Tethys Seaway of the Central Belt. In early Permian, accretionary complex developed during the subduction of Paleo-Tethys Ocean.

Gua Musang platform was developed in middle - late Permian. Concurrently, the environment was compatible for benthic fauna and carbonate development. It was developed in the east, where the current Gua Musang formation. Consequently, fore arc basin subsided when volcanism peaks.

In early Triassic, the fore arc subsidence concentrated the Gua Musang platform, a compatible space for deposition of carbonate-argillite-volcanism. When Sibumasu docked into Indochina, PaleoTethys ocean has subducted completely. This has eventually encouraged the basin segmentation process on subsiding Gua Musang platform.

2.6 Landslide

2.6.1 Definition

Landslide is the natural hazard event occurring due to the integration of the type of Earth's materials and their movements. Type of materials can be rocks, debris and Earth's materials. Landslide is influenced right by gravitational force. It incorporates five modes in movement of slope; topples, falls, slides, flows, spreads and complex. Nefeslioglu & Sonmez, (2008) states that landslide gives huge impact in affinity to the environment and human life, as well as to the worldwide.

2.6.2 Type of Landslides

Landslide are assemblage of landforms constructed by the Earth material such as rock or soil moving downslope due to the gravity attraction. It is generally described as "Mass wasting" by previous researchers, which indicates any motion that moving with any kind of movement mode and causing disaster to the environment later on. Figure 2.2 shows the general form in graphical features of landslides. Next, the variation type of landslides, including material types and its movement is further discussed in Figure 2.3.

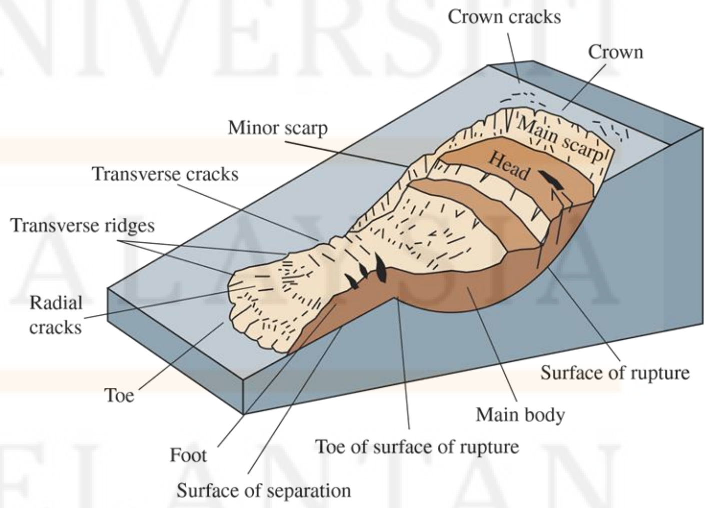


Figure 2.2: Graphical features of landslides.

(Source: Varnes, (1978); Varnes and Cruden, (1996))

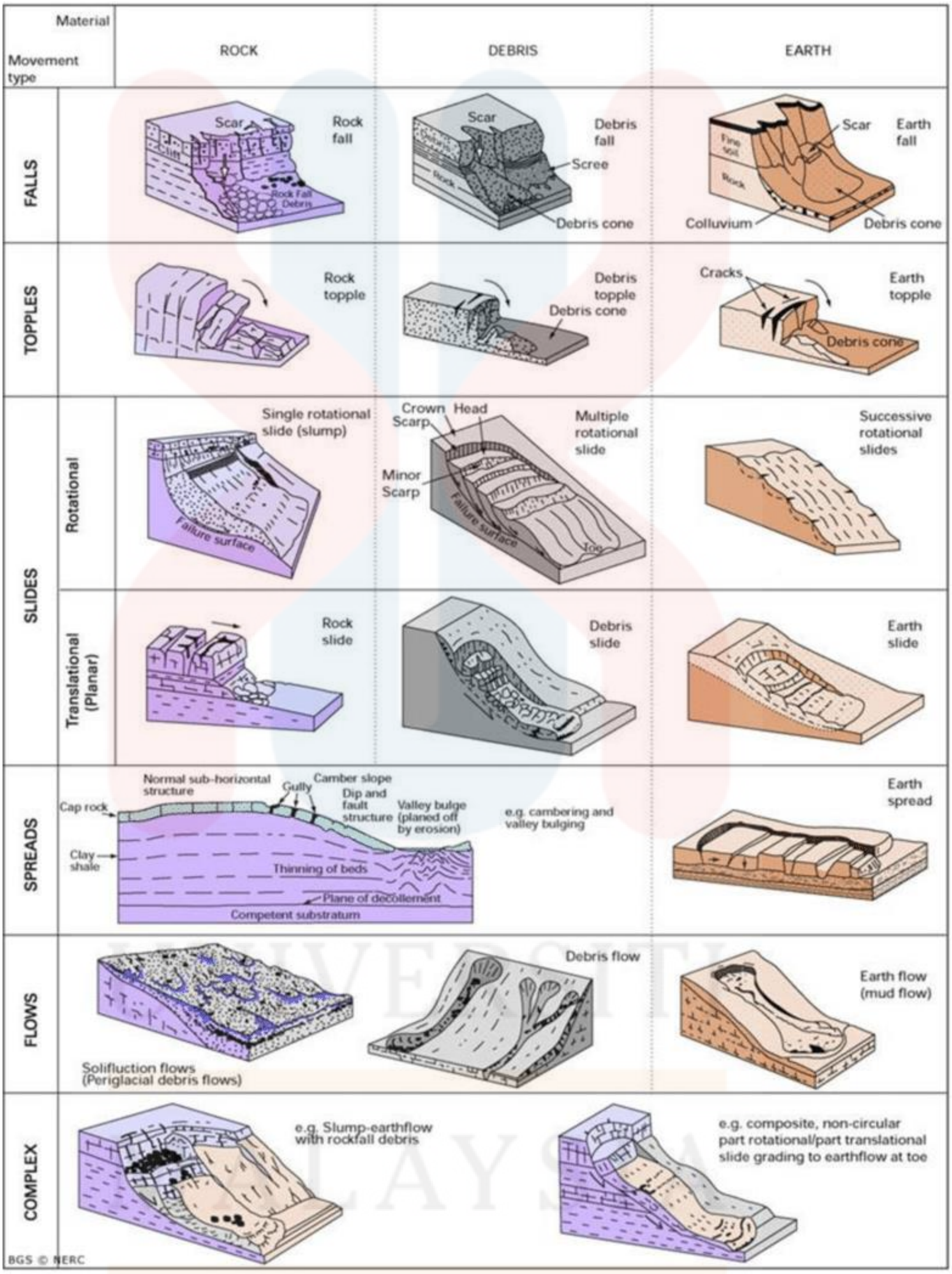


Figure 2.3: Landslide classification according to the type of materials and their movement.

(Source: Varnes, (1978); Varnes and Cruden, (1996)) Landslide or mass movement are not new to the world. Varnes (1978) & Varnes and Cruden, (1996) in their writings have explained on variety type of landslide and mass movement. There is slide, falls, topples, flows and lateral spread. Each of these categories are distinct to one another based on the type of Earth's material and their movement.

Figure 2.3 represents the concept on landslide classification according to the type of material and its movement. From Varnes, (1978) in his writing on *"Slope movement types and processes, in Schuster"*, shares the various categories of landslides.

Falls may consist of rock or boulder being detached from cliffs and slopes moving downwards in abrupt motion. On the other hand, topples happen when motion failure of the unit in forward rotation due to gravity influence, and is supported by force of units next to it, there might be due to the fluid content in cracks.

Next, slides. There are three types of slides; rotational landslide, translational landslide, and block slide. Rotational landslide occurs when the rupture surface is facing upward in concave.

Its motion is rough and transverse across slides. Next, the motion of translational landslide is moving on a rough plane and tilting backwards, whereas, block slide is similar to translational slide, however, it moves with single unit downslopes as correlative coherent mass.

After that, lateral spread. It is regularly present on gentle slope or flat terrain. It is usually moving in lateral extension due to tensile fractures. Usually it occurs when ground is shaking rapidly such as earthquake. Besides, it can also occur when upper units mobilized on loose or liquefy material.

Next, flows are divided into several types such as, debris flow, debris avalanche, earthflow, mudflow and creep. Debris flow is mass movement due to intense flow of surface water that cause erosion of loose soil, organic matter, or rocks with water down a slope. Existence of debris fan at mouth of gullies is often related with steep-gullies and debris flow deposit.

Debris avalanche; variety debris flow from rapid to extremely rapid debris flow due to high steep slope. Next, earthflow is often discovered with the shape of hour glass. Loose material precipitates down in slope and settles down at foothill. Fine-grained composition is found in the elongated flow, while clay-bearing rock in saturated condition or moderate slopes.

Additional type for flow is creep. Generally, it moves in steady down slopes along with loose soil or rocks due to shear stress that capable of forming permanent deformation, nevertheless, unable to cause shear failure. There are several types of creeps; seasonal, continuous, and progressive.

In seasonal, soil moves due to climate changes affecting moisture of soil and its temperature, whereas, continuous creeps happen when the shear stress overreaches the material strength. In progressive creep, the slope hit the failure limit. Commonly, it is identified by tilted poles, bulkhead or any sign of soil ripples.

Apart from these categories, there is also a complex type of landslide, it involves one motion followed by several types of movement.

2.6.3 Factors that trigger landslide

In southeast Asia, it is recorded that frequent landslides events occur at steep hill slopes. Several factors influencing the excessive precipitation intensities, seasonally dry periods, and instable soil that leads to erosion of loose material in hillsides (Douglas, 1999). Next, slopes, aspects, soil, fault, roads, land use, NDVI, and rivers also influence landslide risk (Hashim et al., 2018); (Pradhan et al., 2017).

2.6.3.1 Internal Factors

a. Lithology

It is essential to include lithology as common factors for hillslope erosion, as it may affect the slope stability due to the effect towards the composition, texture, and weathering degree. Besides, slope lithology determines the susceptibility to failure (Pradhan et al., 2017).

b. Structural Features

The interconnection between slopes and discontinuities plays vital role specifically in rock slopes in order to perceive the mechanism of failure. Discontinuities that may exists in the study area are such joints, faults, folds, bedding and shear zones in the slopes.

Other than that, distance of the slope to the major fault or lineaments may give a great impact to the landslide activity (Shahabi & Hashim, 2015); (Kanungo et al., 2009).

c. Slope

According to (Pradhan et al., 2017), landslide events happen when slope of hills unable to withstand the gravity force. Shear stress on slope increases when disturbance is either caused by natural or man-made induce. Besides, slope inclination influence hydraulic continuity as well (Saadatkhah et al., 2014). Variation of geomorphological factors, such as slope are prone to landslide compared to aspects (Hashim et al., 2018)

e. Hydrogeology Conditions

The hydrogeological conditions signify the drainage network and distribution nature of surface and sub-surface water; these components also play vital role for landslide occurrences as the erosional occurs on the slopes due to excessive surface run-off through drainages (Hashim et al., 2018). Drainage density functions to estimate the precipitation evacuation by small catchment base. It is a convenient and practical technique for hazard mitigation (Hasegawa S. et al., 2013).

2.6.3.2 External Factors

a. Climate/Precipitation

The change in geographic pattern influenced by the climatic pattern as the locations that are prone towards landslides occurrence are the area which predisposed towards high rainfall in tropical and sub-tropical climatic region**.**

The precipitation data will be prepared using the last 10 years (2009- 2019) of historical rainfall data in Kelantan region, specifically in Gua Musang region from Jabatan Pengairan dan Saliran Negeri Kelantan (JPNS, Kelantan).

b. Land Use Change

By referring to (Hashim et al., 2018), landslide event may occur due to active illegal logging activities. Natural forest cover may have been demolished and result in exposed steep slopes to erosion (Pradhan et al., 2012).

c. Unplanned Construction

Work done by (Pradhan et al., 2017) states that poor in planning, management and improper construction leads to landslide issues relates to the soil and rock strength. Other than that, (Pradhan et al., 2012) has mentioned that construction within dense jungle may cause a great impact and lead to erosion or landslide event.

2.6.4 Landslide Susceptibility Mapping

Assessment on landslide hazard and risk mitigation can be accomplished efficiently by providing precise information regarding the region and its potential zones for landslide occurrences (Hashim et al., 2018).

Firstly, it functions as a guide for decision making, especially to engineers and planners. For example, to find the most suitable area or to prevent hazard potential area (Norbert Simon, 2017).

More from Norbert Simon (2017), the products can also be used as a basic data in land use planning and slope management. The information of investigated region can assist them to prevent or to mitigate landslide hazard by providing sufficient information about the history of landslide occurrences in that region.

Besides, the information covering from terrain to slope and is very useful to predict the fertility loss of soil due to slope failure (Saadatkhah et al., 2014). So, these will assist them to propose suitable engineering techniques in the construction processes after investigating the remedial measurement.

It is to prevent or minimize landslide issues especially in the region of high to very high zone which prone to landslide. (Basharat et al., 2016). Consequently, a precise landslide susceptibility mapping activity is beneficial to large range of users in providing useful information for hazard assessment purpose or for regional development later (Shahabi & Hashim, 2015).

In landslide susceptibility analysis, the first thing to consider is to construct a spatial database with the causative factors involved in the study area (Mersha and Meten, 2020). Triggering factors to landslide may vary from one case to another, it depends on the environmental factors as well.

Thus, investigating the previous research has become a crucial phase before selecting the triggering factors of the research area. This will further be affecting the development of database (Panahi et al., 2020).

Database development in landslide susceptibility analysis will integrate the information from previous research, amount of data availability and also field knowledge (Khosravi et al., 2016).

From (Pradhan et al., 2017), landslide event has been investigated from its related factors, thus, it is expected that future hazard may happen again due to past condition. Also, risk in planning or further development of the region could be avoided if a precise and accurate assessment is done by concerning to the parameters involved.

Most of many cases of landslide events are due to combination of several parameters to the triggering factors, even though, there are several cases which were influenced by only one major factor.

Investigation on past research on the study area in term of the nature or environment, and data availability will determine the triggering factors involved. “Present is the key to the past” which implies that future event may occur under similar conditions in term of geology, geomorphology, hydrogeology and climatic condition of a region.

Thus, past landslide cases may be used as a guide, which would be more helpful in landslide susceptibility assessment in order to mitigate the landslide potential. From Kanungo et al., (2009), climatic change and unexpected pressure on land may influence the aggressive and unpredictable behaviour of external causative factors with past events.

In order to process landslide susceptibility analysis on landslide prone area, Stanley & Kirschbaum, (2017) state, it involves the integration of common characteristics in explanatory variables, modelling approach and its resolution.

From Prayudi et al., (2020), the zones of landslide vulnerability can be determined with using tools and techniques which involve calculation by using ArcMap 10.3 software, it is specifically known as raster calculator method. For example, "Weighted Overlay Method (WOM)".

Involved parameters will be converted in raster form first, after that, the calculation is performed. From the work done by Mersha and Meten, (2020), firstly, the weights of causative factors will be calculated subsequently for evaluation. The weights are calculated based on the relationship between landslide and its causative factors.

The results will be verified later. Generally, triggering factors are not set up to strict guidelines to be used in variety of statistical techniques. However, the factors that are chosen should be measurable and operative based on properties of particular region, (Ayalew & Yamagishi, 2005).

From Norbert Simon (2017), the attributes which were given weightage was summed altogether and was reclassified, this will further generate landslide susceptibility map. The weightages on each attributes are subject to the combination degree of landslide occurrences.

The weightages will undergo processes of calculation and extraction before being converted in to raster map for the phase, analysis. In *WOM*, spatial relationships of each factors will be analysed and the weightages will be summed as a results of landslide susceptibility map.

According to Chen et al., (2017), in landslide susceptibility mapping, there are five (5) categories index to grade from very low (I), low (II), medium (III), high (IV), and very high (V), from high vulnerability zone to landslide to the safest zone.

While, Norbert Simon, (2017) explains, the region with very low to low marks limited potential of landslide to occurs in that region although it comprises strong triggering factors.

For example, climatic changes or extreme land use changes. On the other hand, there is high potential of landslide event in high to very high risk zone even though by being affected by slight presence of weak triggering factors.

CHAPTER 3

MATERIAL & METHODOLOGIES

3.1 Introduction

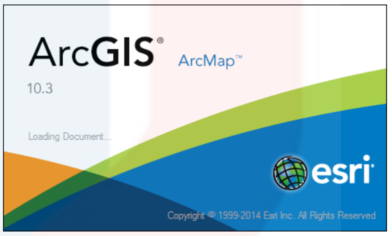
This chapter is discussing on the materials and methods that will be used for the study analysis. This will include software, website, resourceful agencies and the type of data obtained that will be used in further processing until accomplishing the final result.

The methodology section is covering the activities in the preliminary study, data inventory, preparation of data, analysis of data until the thesis production. The results that will be generated will involve the use of secondary data, such as spatial data, statistical data, and by referring to the past researches involved in the study area, to validate the information gathered.

The techniques involve in this study is focusing on the Weighted Overlay Method (WOM) in order to produce a landslide susceptibility assessment within the region of Ketil subdistrict, Gua Musang, Kelantan.

3.2 Materials/Equipment

3.2.1 Software

a.	b.
	
Figure 3.1: Logo of Google Earth Pro (2020).	**Figure 3.2**: Logo of ESRI ArcGIS 10.3 software
Google Earth Pro (GEP) is one of geospatial software application, which has enabled users to obtain free online data, that presents a virtual globe.	ArcMap is the fundamental segment of Esri's ArcGIS suite of geospatial preparing programs, and is utilized essentially to view, create, edit, and analyse geospatial information.
Since GEP is a multi-purpose of Google Earth detail imagery, it is used to observe the location of the study area, to view the geomorphology, and aid in interpretation of lineament analysis while being in remote.	ArcMap software will be used to produce a geological map, thematic maps, landslide susceptibility map and any related maps that will be used in this study. Secondly, weighted overlay tool is one of the processing tools in ArcMap software. It is practical to process the integration of all parameters that will be involved in order to produce a landslide susceptibility map of the study area.

3.2.2 Website

Figure 3.3: Logo of United States Geological Survey (USGS) Earth Explorer.

Figure 3.3 is representing the logo of USGS Earth Explorer website. It is a website that offers free variety of earth imagery beyond geo-spatial data types that can be obtained online. It enables users to navigate on any spatial data, even though, some of them are limited to specific regions and are limited to recent years.

There are various spatial data that are available online with specific resolutions according to their types. In this research, SRTM, a type of digital elevation model data from USGS will be used. The data sets can be searched by entering the coordinates of the study area or upload criteria to obtain an accurate satellite imagery data.

The layer of study area boundary in form of kml or kmz file (criteria) will be uploaded from ArcGIS 10.3 software. In this research, most of the spatial data is obtained from USGS Earth Explorer, then will be used in further process such as in data preparation and data analysis.

3.3 Methodology

The flowchart of the study can be referred to the Figure 3.4 as shown, the flow of the study begins with preliminary study, then, it is followed with the collection of data in the data inventory. Next, the production of updated geological map with a scale of 1:25, 000 of the study area, as well as preparation of thematic map.

Consequently, the production of landslide susceptibility map in data analysis by using a Weighted Overlay Method in ArcMap 10.3, ArcGIS software. Complete analysis and the results are all recorded in the thesis writing.

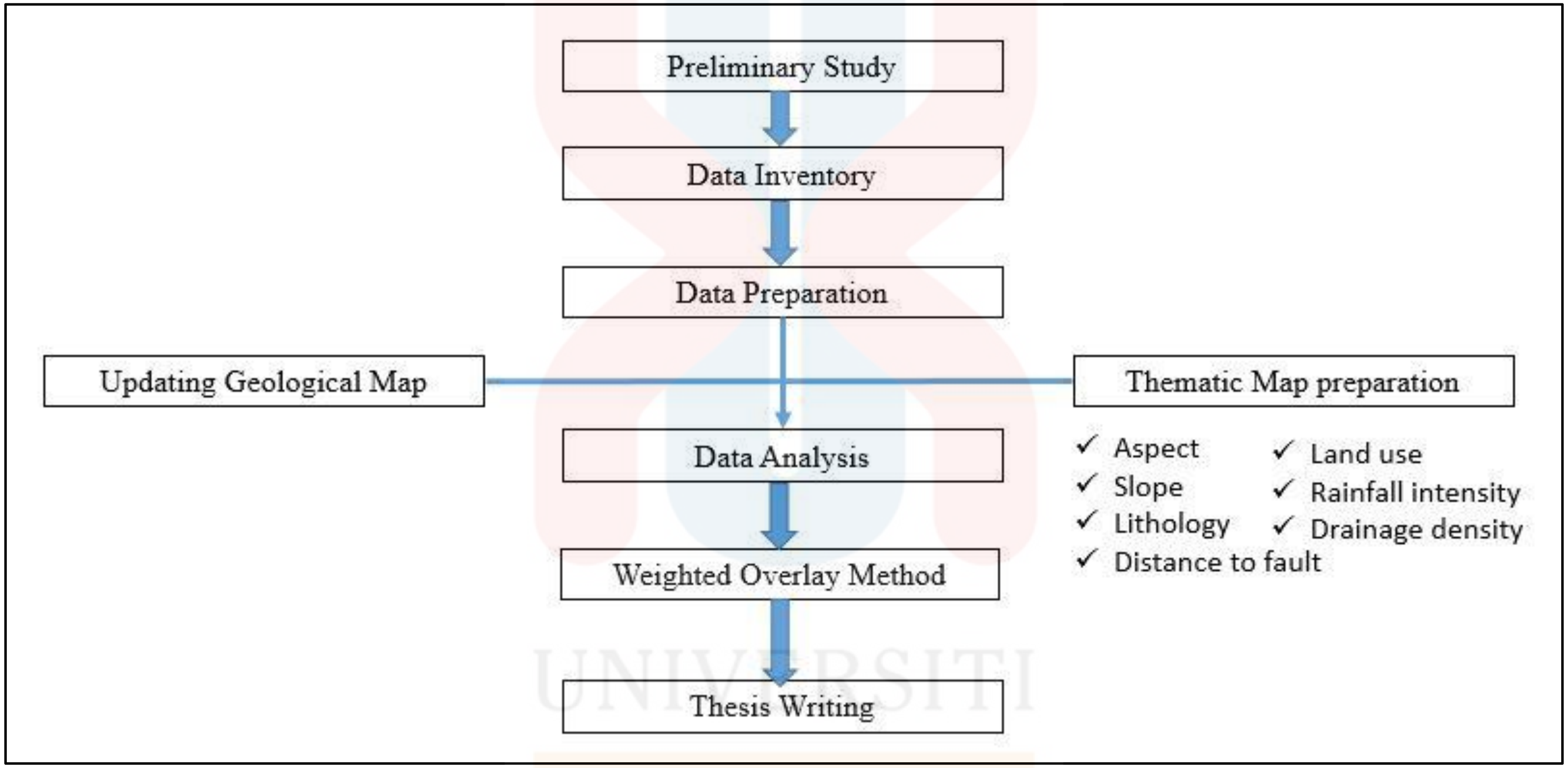


Figure 3.4: Research flowchart

3.3.1 Preliminary studies

Review on the case study and past researches is made to clarify the idea of doing the research. This process has involved number of journals, articles, internet sources, official newsletter from agencies and organizations.

Generally, the preliminary studies in this research, highlighting on the scope of geology and geological mapping of the study area. Next, landslide and its types, landslide susceptibility mapping, and Weighted Overlay Method (WOM) approach in GIS application.

It is done by gathering all the information from previous published literature review. Preliminary study is a crucial phase to enhance the depth of understanding before conducting the research.

3.3.2 Data Inventory

Data inventory is the stage of data collection. There are two types of data that will be used in this research; spatial data and statistical data. Spatial data can be obtained online and is available for free. It can be obtained from any website or portal that provide free data such as USGS Earth Explorer.

In this research, satellite imagery data from USGS Earth Explorer will be used, such as Shuttle Radar Topography Mission (SRTM). Besides that, layer of Digital Elevation Model (DEM) can also be obtained from Google Earth Pro software.

Next, a type of statistical data is obtained from government agency such as Jabatan Pengairan dan Saliran (JPS) for the precipitation data within the region of Gua Musang, Kelantan. Table 3.1 below shows the collection of secondary data that will be used in the next process.

Table 3.1: Data Inventory

Data Type	Source	Year	Resolution
Satellite Imagery	Google Earth Pro	2015	30-m pixel
	USGS Earth Explorer – SRTM	2020	30-m pixel
Topography map	USGS Earth Explorer – SRTM	2020	30-m pixel
Rainfall	(JPS) – Gua Musang Station.	2009-2019	--

3.3.3 Data Preparation

3.3.3.1 Updating Geological Map

Geological map is a special-purpose map to represents different geological features including the lithology units. The first result of this research will be a geological map with a scale of 1:25,000.

It is very useful in providing information for land use planning. Besides, it will be a useful reference for geological hazard mitigation. This geological map is processed by using ESRI ArcGIS ArcMap 10.3. Layers of geological data of the study area are combined.

The lithology boundary of the rock is generated through the interpretation of the satellite imagery by relying on the interpretation of drainage density, observation through geomorphology and terrain analysis of the study area. However, the result from past researcher will be referred as well for precise information.

Linear lines are extrapolated on the processed satellite imagery by referring to the remote sensing analysis of geological structures and fractures of the study area, (C.K. Muthumaniraja, 2019). For the structural features, the lineament is produced by extrapolating the linear lines on the spatial data and this results in the production of both lineament and structural maps.

Lineaments can be extrapolated on the layer of Triangular Irregular Networks (TIN), hillshade maps, or by using the layer of terrain map. TIN map layer is used for lineament interpretation. The positive lineaments are the lines extrapolated on the linear surface of a hill or ridges.

Whereas, the negative lineaments are the linear lines extrapolated along the fractures, valleys or rivers. From this interpretation, the fault lines are being inferred and extrapolated to the area showing linear lines and showing break from the original path of the linear lines.

The result maps for the structural geology are the lineament maps and the structural map representing the inferred fault within the study area. Apart from processing the map technically to extrapolate the lineaments, Google Earth Pro software was also used to validate the analysis by observing the geomorphology of the current study area.

Next, negative lineament values are extracted to be transferred as input values in GeoRose software in order to produce a rose diagram to determine the orientation of the structures collected within the study area.

3.3.3.2 Thematic Map Preparation

A thematic map is a map derived from the integration of base data, such as the region boundaries, coastlines, and places as a reference point for the feature to be mapped. It offers general information regarding spatial patterns.

The collected data are gathered in either shape file or in form of digital raster layer data system and are further processed into different thematic layers. Thematic maps that will involve in this analysis are slope map, aspect map, precipitation map, lithology map, drainage density map, distance to fault map and land use map.

Next, further analysis will be conducted to assign proper input parameters to the most influencing factors which is vulnerable to landslide event, (Muheeb M. Awawdeh et al., 2018). Table 3.2 is showing the weightage and scoring for the parameter in landslide susceptibility analysis by referring to (Roslee et al., 2017).

In this case, each of the parameters are assigned with weightage scores out of 100% marks. In this analysis, slope and rainfall intensity are determined to be the most influencing factors, thus, they are given marks of 20% each. Next, other vital factors include lithology types, drainage density, and distance to fault which are responsible towards instability of slopes

Table 3.2: Weightage and scoring for the parameter in landslide susceptibility analysis.

Parameter	Weightage (%)	Class	Scoring
Slope	20	0˚ – 5˚	1
		5˚ - 10˚	2
		10˚ – 15˚	3
		15˚ – 25˚	4
		25˚ – 35˚	5
		> 35˚	6
Rainfall Intensity	20	High	3
		Moderate	2
		Low	1
Lithology	15	Alluvium	6
		Acid intrusive	1
		Sandstone interbedded with siltstone	5
		Phyllite	3
Drainage density	15	Low	1
		Moderate	2
		High	3
Distance to fault	15	A	5
		B	3
Aspect	10	Flat	1
		North	2
		North East	3
		East	4
		South East	10
		South	8
		South West	9
		West	7
		North West	5
		North	6
Land Use	5	Forest	5
		Plantation	4
		City	1
		Settlement	3
		Road	2

(Source: Roslee et al., 2017)

3.3.4 Data Analysis

3.3.4.1 Weighted Overlay Method (WOM).

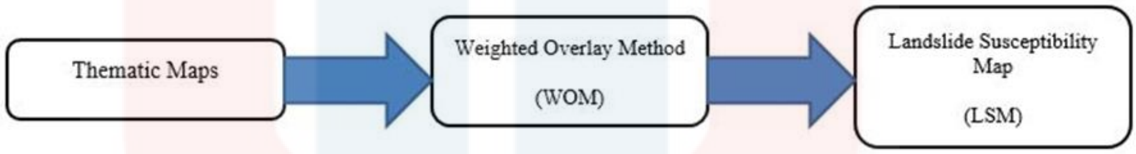


Figure 3.5: Order of landslide susceptibility map production

The purpose of this study is to investigate potential of landslide prone area and to produce landslide susceptibility map in part of Sg. Ketil region by utilizing Weighted Overlay Method (WOM). The process is assimilated with remote sensing techniques and Geographic Information System (GIS). Figure 3.5 shows the brief flow of the process within weighted overlay method for landslide susceptibility zone map production.

This technique is involving several steps such as selection of parameters, database construction, generation and preparation of data layers, numerical ranking assigned to each parameter, landslide event index computation, and verification of landslide model, (Sarkar and Kanungo, 2004)

Detailed process of this technique can be referred to Figure 3.6. It shows the beginning process of WOM which starts with preparation of different types of thematic maps including slope and aspect map which is generated from DEM data, Shuttle Radar Topography Mission (SRTM) layer will be used to generate this into a raster layer.

Next, other thematic maps may involve lithology map, rainfall map, drainage density map, distance to fault map and land use map. The thematic layers are integrated by using WOM to acquire a product of landslide susceptibility map. First step, an evaluation scale will be selected.

It delineates suitability range, scale for default evaluation ranging from 1 to 9 accordingly. An evaluation scale should be entered ascendingly for evaluation scale in WOM. Next, these layer will then be converted into a raster layer before operating the reclassification of the parameters.

The raster row is selected and can be altered accordingly. Next, in order to input another raster, each one of the raster that have been inputted can either be weighted or a percentage influence can be assigned according to its priority.

Reclassification process responsible to assign scorings to each of the attributes for each of the parameters. A complete total influence of all raster should be 100. For final output raster, the cell values obtained will be added. All these process are involved in order to produce a landslide susceptibility map.

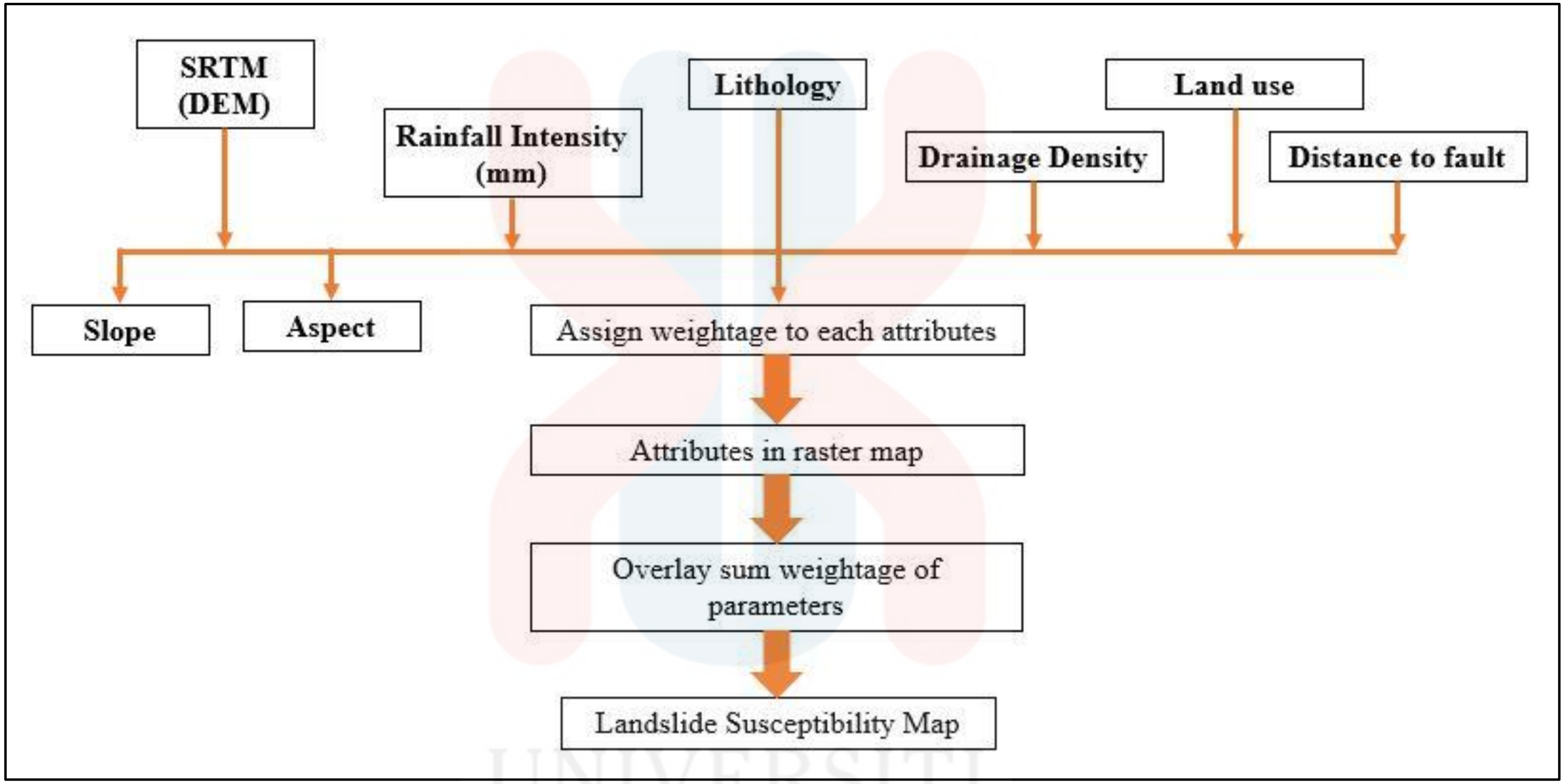


Figure 3.6: Detail process in Weighted Overlay Tool,
in ESRI ArcGIS ArcMap 10.3 software

3.3.4.2 Landslide Susceptibility Map

The next final product of this research will be a landslide susceptibility map with a scale of 1: 25,000. A landslide susceptibility map is a very useful map to identify the regions which are subjected or prone to landslide events.

The region involved is measured from low to high scale by ranking the possibility for landslide occurrences according to the influencing parameters. Landslide susceptibility map estimates the area that may have the potential trigger to landslides.

This is influenced by many factors or the parameters that are taken into account that may trigger to landslide. According to Kanungo et al., (2009), landslide susceptibility map is very useful and is essential for a safer and strategic planning for future development activities.

The percentage (%) of the area is computed in the attribute table of the result layer. The “Area” and “Percent” fields are added in the table. The area of the region is calculated by using “Calculate Geometry” tool, whereas, the percentage of the area is computed by using “Field Calculator” tool.

3.3.5 Thesis Writing

Thesis writing is the final phase to document the scope of the research. This thesis is discussing on the scope of geology within the Ketil subdistrict in Gua Musang.

Besides, it is also focusing on the specification of potential regarding landslide occurrences especially in the region which is showing contact within the low land and high land in the study area. This research will further be discussing on the parameters that determines the vulnerability of the landslide occurrences in the study area.

Past researches in term of geology of the study area and the techniques that will be applied will be reviewed in order to make comparison within the information collected while being in remote. After completing the documentation, this thesis will be forwarded to the agencies concerned as an exchanged towards their kindness for granting data resources without charging any fees to the researcher.

This thesis will be useful as a record of the research by using the data provided. Plus, the completion of this thesis is hoped to be useful to the government bodies or professional department in developing the research area in future.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

4.1.1 Introduction

This chapter will be discussing on the geology of Sg. Ketil region in Gua Musang, Kelantan. Being in remote, the information gathered are limited, thus, the result that are being analysed will be validated with the aid of past researches as a guide to interpret the study area precisely.

This chapter will be discussing on general geology relating to basic geology, geomorphology, stratigraphy, structural geology and history geology of the research area. This chapter will present a geological map, cross section of the lithology and the lithostratigraphy column within the study area as the final result for the geology within Sg. Ketil region, Gua Musang, Kelantan as shown in Figure 4.11.

4.1.2 Accessibility.

Figure 4.1 below is taken from the satellite imagery through Google Earth Pro software, showing the number of routes connecting the external region within Gua Musang town to the study area which is clearly located at the southeast region of Gua Musang district.

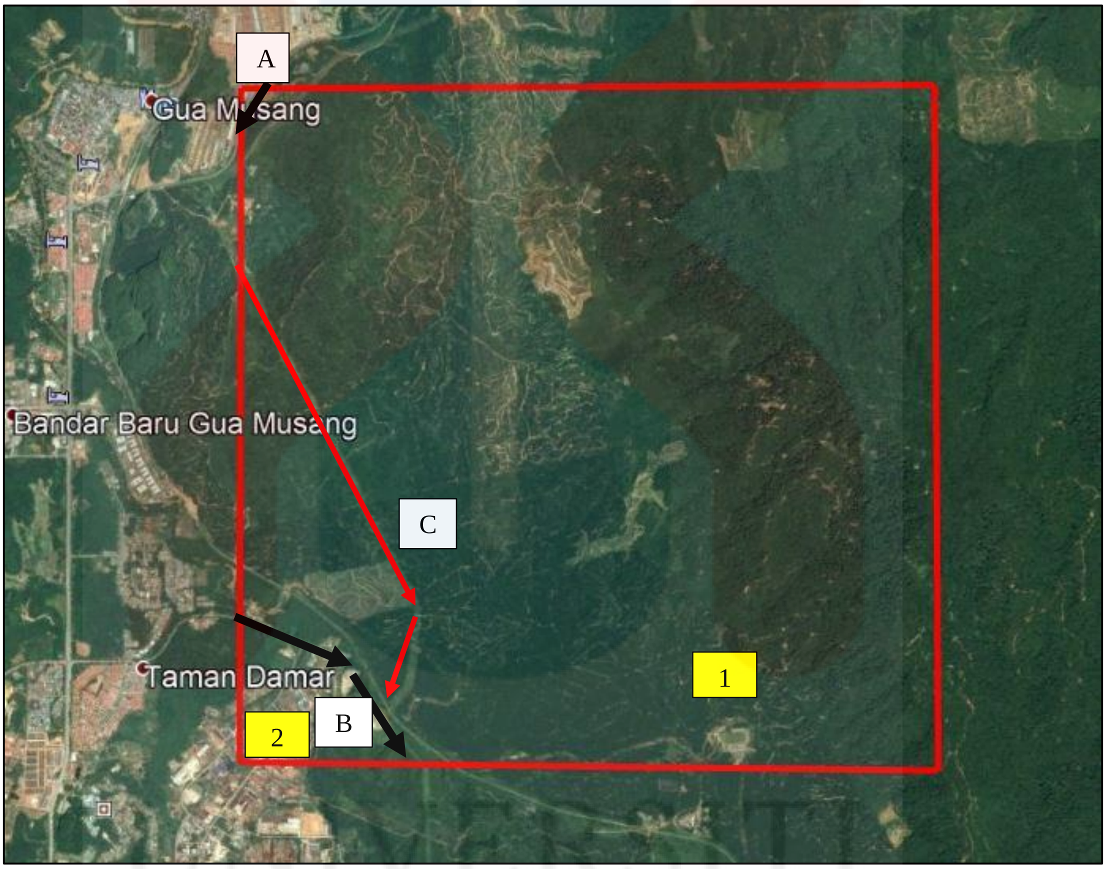


Figure 4.1: Satellite imagery of Gua Musang town to Sg. Ketil region, Gua Musang.

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Table 4.1: Symbol indicator for routes in Sg. Ketil region, Gua Musang Kelantan.

Symbol	Route
→	Main road
→	Farm road

By observing through the satellite imagery in Figure 4.1, there are three roads observed connecting to the study area. According to the indicator in Table 4.1, there are two (2) type of routes observed; Route A and Route B being represented the main road to the study area, Ketil region, Gua Musang, Kelantan. While, Route C is the main farm road connecting one section to another within the large area of Chin Teck Farm.

First, Route A is known as the Federal Route 8, connecting Kuala Lumpur to Kota Bharu highway. It is found in Northwest direction of the study area, specifically at the corner of the study area before entering the region of the palm oil plantation, Chin Teck Farm. Next, Route B is known as "Jalan Industri" within new region of Gua Musang town. This road is connecting the new town of Gua Musang to the study area, specifically at the southwest region.

Lastly, Route C represents the main farm route inside the region of research area. Specific number of roads in other sections of the study area could not be traced accurately since there is no record found for the total number of roads. However, these small roads are interconnecting with one another in the Chin Teck Farm to assist the farmers to reap yield and bring it out of the farm.

4.1.3 Settlement

Table 4.2: Symbol indicator for settlement in Sg. Ketil region, Gua Musang Kelantan.

Symbol	Settlement
1	Settlement of the workers in Chin Teck Farm
2	Settlement or village in Jalan Industri, Gua Musang.

By referring to the Figure 4.1, there is little number of settlement in the study area since most of the land is highly in use for agricultural activity. 40% of the low land area within Sungai Ketil is dominant with the palm oil plantation; Chin Teck Farm.

The settlement of the farm workers consists only 5% of the study area, which is located at a region with coordinate of 4°50'32.0"N 102°00'26.9"E, southern part of the study area. This region is denoting as settlement No. 1. Whereas, 15% of the settlement probably located at southwest region which is specifically known as “Industrial Region” of Gua Musang which is marked with settlement No. 2 as shown in Table 4.2.

4.1.4 Forestry

Within Sungai Ketil region, vegetation covers about 30% of the area in the north-east part. It is a region of high land, consisting hill to high hill which is very limited to access. With its highest elevation, 800 m, it is where Bukit Monyet, a recreational or hiking area is located.

40 % of the land in the study area from north to south especially in the middle region is actively in used for agriculture activities, oil palm plantation as it contributes to the economic factor surrounding Gua Musang region.

4.2 Geomorphology

Astrid et al., (2020) describes geomorphology as the study on the landforms, the relation between the process and its formation. Geomorphologic process affecting the structure of the land due to the modification by geological process.

4.2.1 Geomorphologic Classification

The classification of the landform in the study area is referred according to its absolute height based on (Zuidam, 1985). In general, Zuidam categorizes the geomorphology into seven (7) classification. As shown in Table 4.3, it is representing the relationship between absolute height (m) and its morphology.

According to the Table 4.3 below, the land with elevation below 50 m is concluded as low land. Next, the land with elevation in the range within 50 m to 100 m is classifies as inland low land.

After that, Low hill (100 m to 200 m), hill (200 m to 500 m), and high hill (500 m to 1,500 m). A mountain is described as a land with elevation in the range of 1,500 m to 3,000 m and any elevation greater than this is classifies as high mountain.

Table 4.3: Relationship between absolute height (m) and its morphology.

Absolute height (m)	**Elevation**
< 50	Low Land
50 – 100	Inland Low Land
100 – 200	Low Hill
200 – 500	Hill
500 – 1,500	High Hill
1,500 – 3,000	Mountain
> 3,000	High Mountain

(Source: Zuidam, 1985).

Figure 4.2 shows the geomorphology within the region of Sg. Ketil in Gua Musang, Kelantan. There are three (3) major landform observed, such as low hill, hill and high hill within Sungai Ketil region, Gua Musang. Since the range of elevation within Sg. Ketil region is from 104 m to 860 m approximately. The classification of landform is referring to Zuidam, (1985) in Table 4.2.

The eastward region of Sg. Ketil region is dominant with hill to high hill. It is covering about 40% of the study area with its highest elevation approximately 860 m. The low land to low hill region are covering about 60% of the study area, mostly from the western region to the middle of the study area.

Other than that, the fluvial system in Sungai Ketil region embodied the main river, Ketil river. The type of the river is a meandering river, as there is low structural control and it is flowing over gentle sloping ground of the flat flying area due to low resistance towards the weathering. After all, there is alluvium deposited along the river, as it is formed due to erosion and sediment deposit within the flood plain.

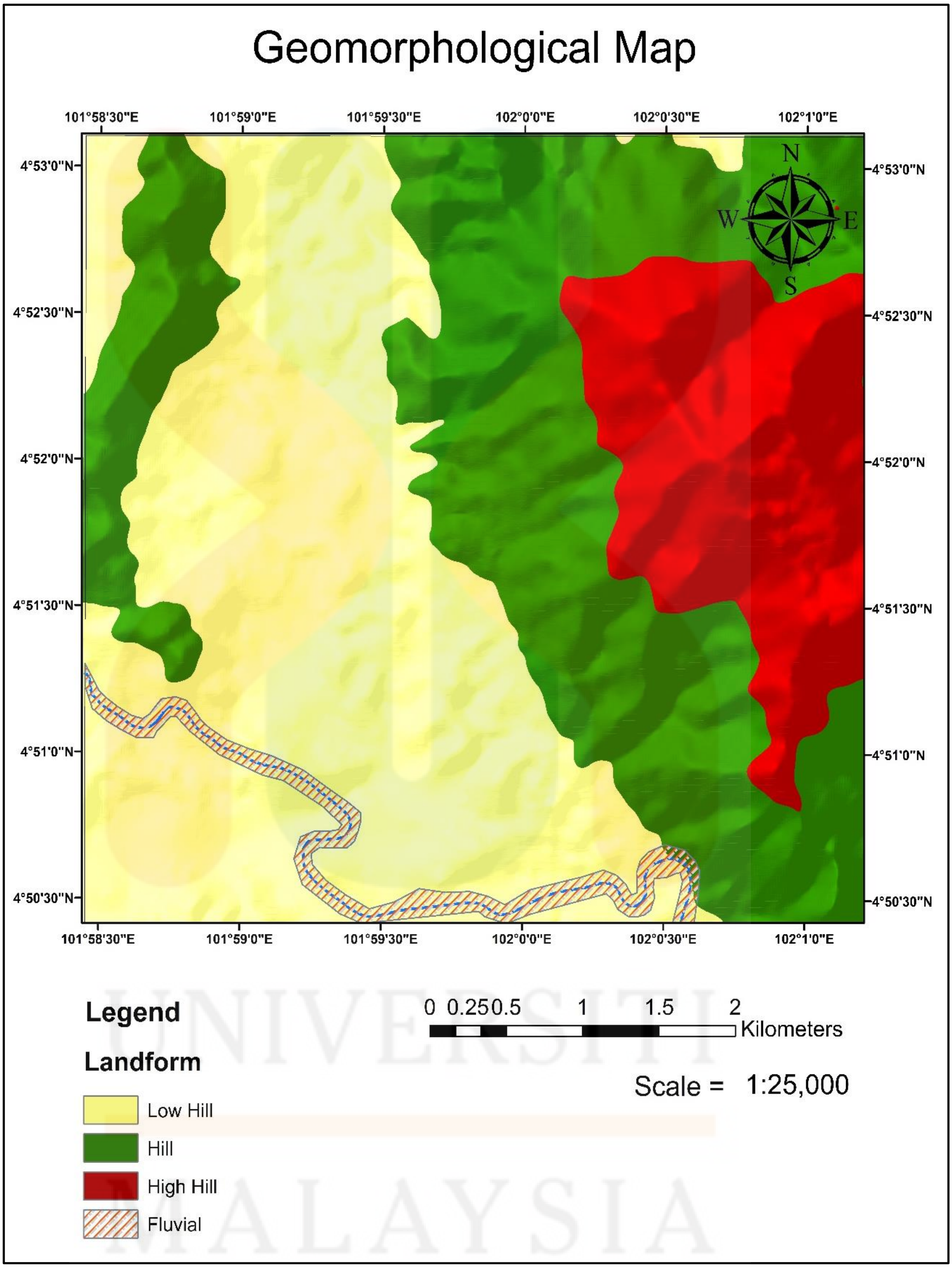

Figure 4.2: Geomorphological Map of Sg. Ketil region, Gua Musang.

4.2.2 Drainage Pattern

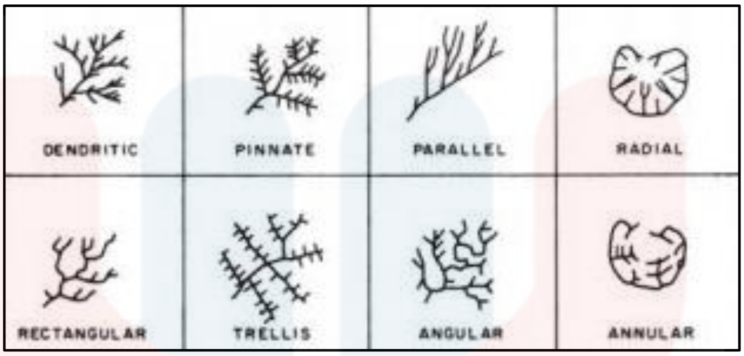

Figure 4.3: Types of drainage pattern
(Source: Howard, 1967; Parvis, 1950)

Figure 4.3 represents the different types of drainage pattern that are being classified by Howard, (1967) and Parvis, (1950). Generally, there are eight (8) types of drainage pattern. There are dendritic, pinnate, parallel, radial, rectangular, trellis, angular, and annular.

In Figure 4.4 below, there are three major pattern identified within the study area; annular pattern, dendritic pattern and subparallel pattern. Annular pattern denotes with yellow colour. Basically, annular pattern is formed when there is presence of igneous intrusion which breaks through the sedimentary rocks and often occurring in eroded zone. This type of pattern is often found in weaker belt.

Next, dendritic pattern. This pattern is dominating the region of flat flying area. This pattern is marked with red colour; it signifies the type of sedimentary rocks which is dominating this region within the middle of the study area. The branching pattern with fine branch shows that this region is easily to erode and it has low structural control. Lastly, the subparallel pattern comprises small river that flows parallel to one another. This can be observed from map, the green colour pattern moves from slope to undulating surface. It is also involving a uniform rock resistance.

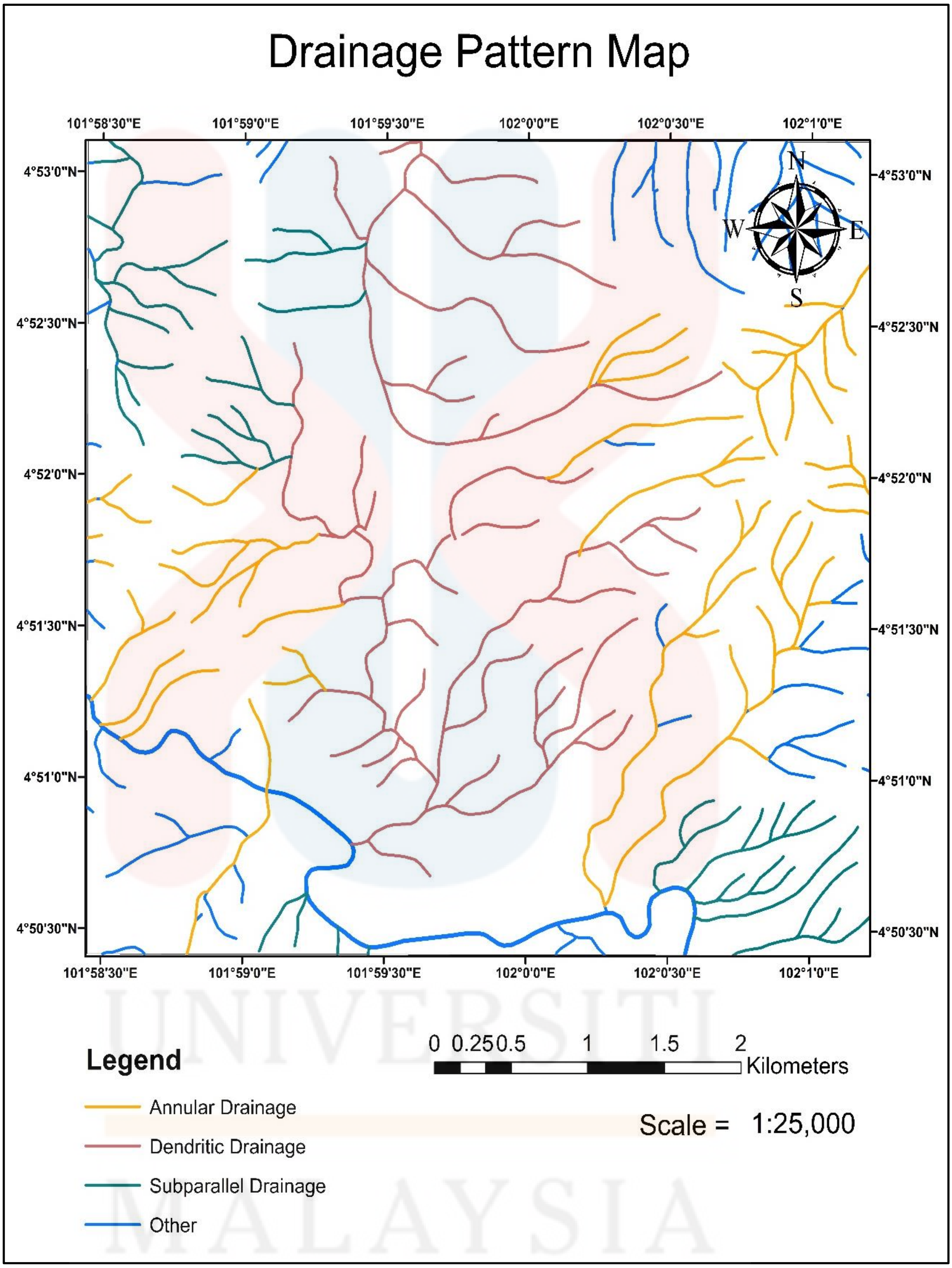

Figure 4.4: Drainage pattern of Sg. Ketil region, Gua Musang.

4.3 Lithostratigraphy

4.3.1 Stratigraphic position

In the region of Sungai Ketil, Gua Musang, Kelantan, the lithology units are divided into four units. The stratigraphic position is arranged in younging upwards order as shown in Table 4.4. These units are all involved in the Gua Musang formation. Firstly, the oldest unit is Phyllite unit which has begun since the Permian period. Next, it is interfingering to the next unit which has developed since the middle Permian to late Triassic.

This unit consisting of sandstone interbedded with siltstone and shale. The hiatus sign in the period section within Middle Permian to Late Triassic and Tertiary period denotes a type of unconformity layer between the sedimentary layer and acid intrusive rock. Lastly, the alluvium unit is overlying the layer of bedrock and it has been evolved since the quaternary period.

Table 4.4: Lithostratigraphy of Sg. Ketil region, Gua Musang, Kelantan.

Era	Period	Formation	Lithology	Description	Deposition Environment
Cenozoic	Quaternary			Alluvium	Alluvium overlying bedrocks
Palaeozoic to Mesozoic	Tertiary	Gua Musang		Acid intrusive	• Creating marine topographic high for limestone, deposition in shallow marine environment. • Enabling shallow marine fauna to flourish in Central Belt during Permo - Triassic.
	XXXXXXX				
	Middle Permian to Late Triassic			Sandstone interbedded with siltstone & shale	• Covering flat flying area in shallow marine environment. • Exposed to high weathering and erosion.
	Permian			Phyllite	Yin (1965) assigned this rock types into arenaceous facies that deposited in marine environment.

(Source: Mohamed et al., 2016)

4.3.1.1 Lithology

Previous research made by Hazmira in 2013 is overlapping with this research by approximately 60%, which is covering from middle to the southern region of the study area. From Figure 4.5, interpreted lithology data encompasses alluvium, acid intrusive, phyllite, and sandstone interbedded with siltstone. To support this study, previous data from Hazmira (2013) is referred.

The age of the rock ranging from Permian to Quaternary period. From the generated lithology map, sedimentary rock is dominating the flat flying areas within Sungai Ketil region, Gua Musang. The interbedded of sandstone and siltstone is covering about 30% of the study area while the alluvium deposit is inferred along the flood plain of the main river, Sungai Ketil in the southwest region.

Next, a type of metasedimentary rock represents the section of low hill to hill area, signifying greater resistance than those sedimentary rocks in the lower part. To support this interpretation, phyllite sample has been collected within this region by past researcher, Hazmira, (2013).

Lastly, the high hill area in the eastern region is inferred to be acid intrusive. This is supported by the observation on the drainage pattern in this section; annular pattern. Annular pattern signifies there is intrusion of igneous rock breaks through the sedimentary rock and often occurring in the zone with high weathering.

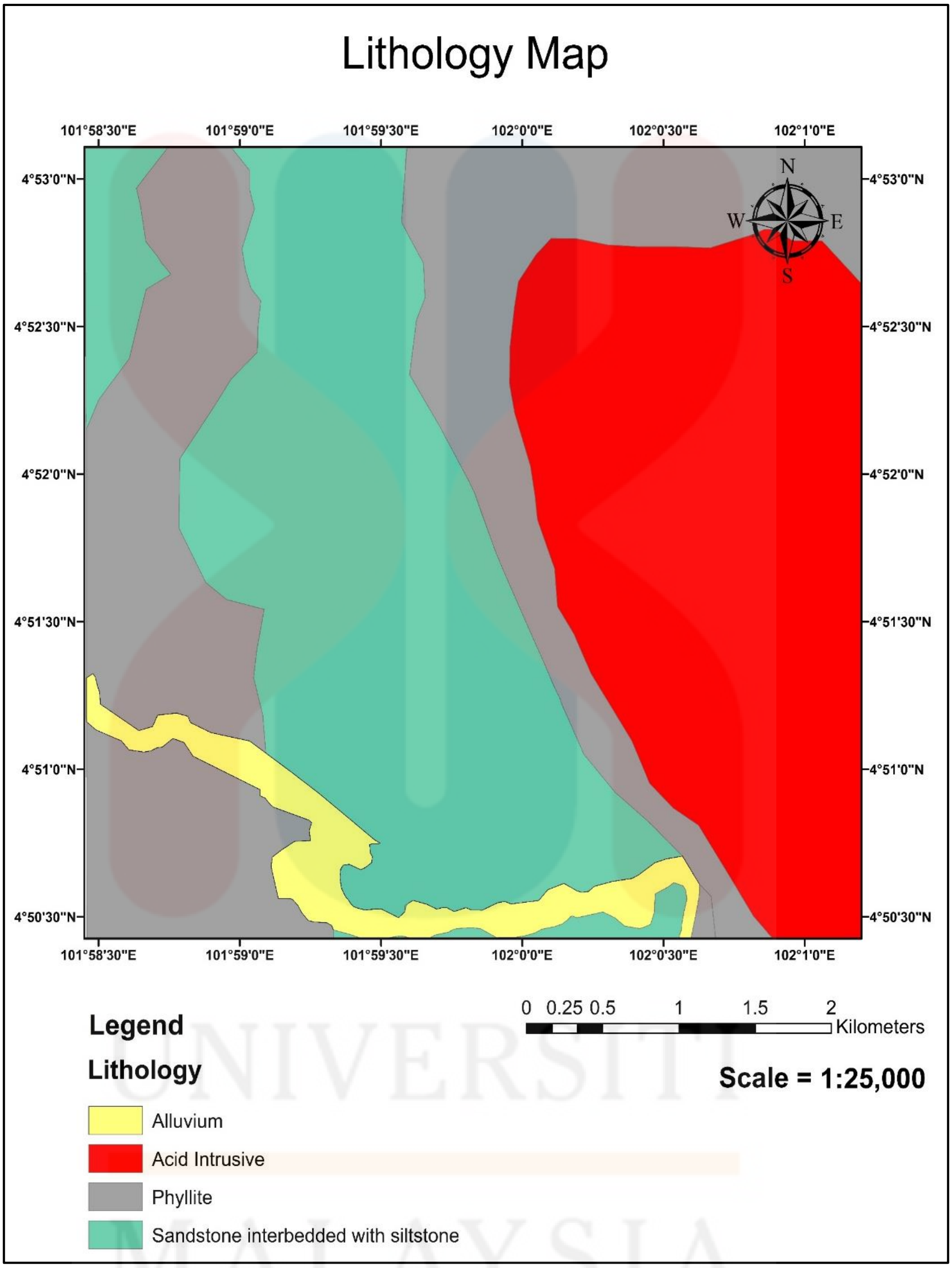

Figure 4.5: Lithology map of Sg Ketil region, Gua Musang.

4.3.2 Unit explanation

Mohamed et al., (2016) discusses on the lithology units encompasses within Gua Musang region and its relation with the Central Belt. The lithology unit involved in this study area are alluvium, sandstone interbedded with siltstone, phyllite and acid intrusive.

4.3.2.1 Phyllite Unit

This rock unit is interpreted and being inferred to occupy the low hill to hill area, especially in the eastern region and the western region of Sg. Ketil. However, Mohamed et al., (2016), Yin (1965), describes this unit to be classified into the unit of arenaceous facies.

It is developed in marine environment. This rock is estimated to be existed since Permian period. Hazmira, (2013) has confirmed her findings of the Phyllite unit in the upper section of the study area covering from low hill to hilly area. She describes the colour of rock to be either reddish to brownish in colour.

4.3.2.2 Sandstone interbedded with siltstone.

The evolution of this rock unit began since Middle Permian to Late Triassic. This lithology unit is covering a wide area within the Sg. Ketil region. It is dominant in the flat flying region, which was once a shallow marine environment in the past.

Sandstone and siltstone is highly exposed to weathering and the structure of these sedimentary rocks are easily to erode. This rock unit is covering the region of north to north west as well as covering in the middle section of the study area. The sample collection found comprises mostly in yellowish colour, (Hazmira, 2013).

4.3.2.3 Acid Intrusive.

This rock unit is inferred to be located at the region of higher elevation such as from hill to high hill area, with closer contour and steeper slope. This is because an igneous rock high in resistance even though being exposed in weathering for a long period.

The age of this rock is estimated to be existing since in the Tertiary period. The development of acid intrusive within Gua Musang has created a high marine topographic for limestone, which once was depositing in the shallow marine environment, (Mohamed et al., 2016).

4.3.2.4 Alluvium.

Alluvium is discussed by Mohamed et al., (2016) to be existed since the Quaternary period. In this study, it is inferred to the region of flood plain along with the main river of the study area, Sungai Ketil. Alluvium is overlying the bedrock since it is transported and being deposited along the flood plain.

4.4 Structural Geology

Primary structures were acquired in the rock mass genesis, while the secondary structures were the results of primary structures deformations, this may happen due to the movement of the plate tectonics. The structural geology that has been involved in this study covering the structures that can be interpreted through the processed satellite imagery such as lineaments and fault lines.

4.4.1 Fault

The Figure 4.6 shows the structural map within the region of Sg. Ketil. There are two faulting lines inferred within the study area from the interpretation through satellite imagery. Interpretation through contour map, terrain map, and TIN layer map shows the dislocated of the blocks, thus, it is inferred as a fault region.

Fault region A is inferred at the foothill of the region within eastward of the study area. It shows dislocation of the blocks and shows potential of a faulting region. Next, Ketil river is a type of a meandering river, it probably has formed in a weak lithology unit and with low structural control.

Different directions of the river flow showing that faulting has occurred in that region, and water is flowing through the cracks which was resulted from discontinuities. Thus, region within Ketil region is inferred as fault region B.

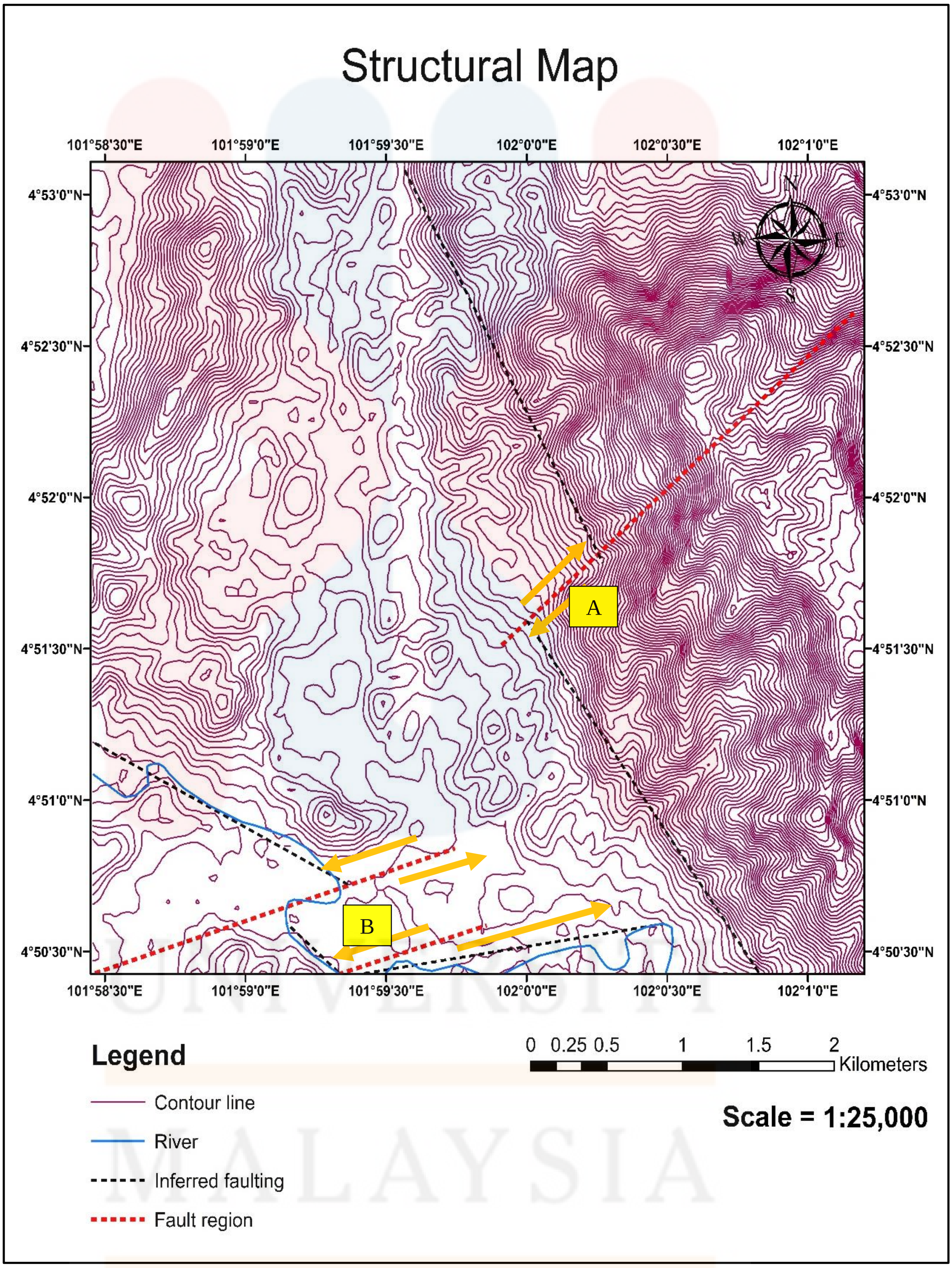

Figure 4.6: Fault map of Sg. Ketil region, Gua Musang.

4.4.2 Mechanism of structure

There are two types of lineaments extracted, positive lineament and negative lineaments. Positive lineaments are described as the bedding which can be identified as ridge or ranges, whereas, negative lineament are described as fault or fractures which can be identified through valleys or rivers, (Ibrahim Komoo, 1989).

A map is produced to show positive lineaments and negative lineaments within the Sg. Ketil region as shown in Figure 4.8. Negative lineament is denoted with red lines, while positive lineament is represented with yellow line on the map.

Measurements from the lineaments extrapolated in the TIN layer represents the type of faults in the study area. Figure 4.8 and Figure 4.9 are constituting the computed lineament measurement from both region, which is also representing faulting in both regions A and B respectively. From Table 4.5, fault in region A is deduced as dextral strike slip fault, while Figure 4.10 is showing the region B as sinistral strike slip fault.

To support this analysis, the direction of the dislocation of blocks are being observed as shown in Figure 4.7, when the block in front of the observer is shifting to the right, then it is dextral strike slip fault, and region A shows similar result. while, Sinistral strike slip fault happens when the block in front of the observer is moving to the left, and the fault in region B shows similar result.

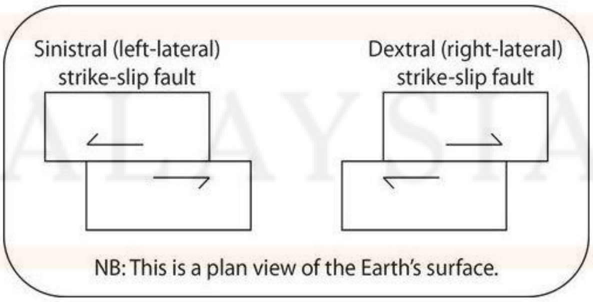

Figure 4.7: Classification of fault type based on its direction of its movement.

(Source: So, 2019)

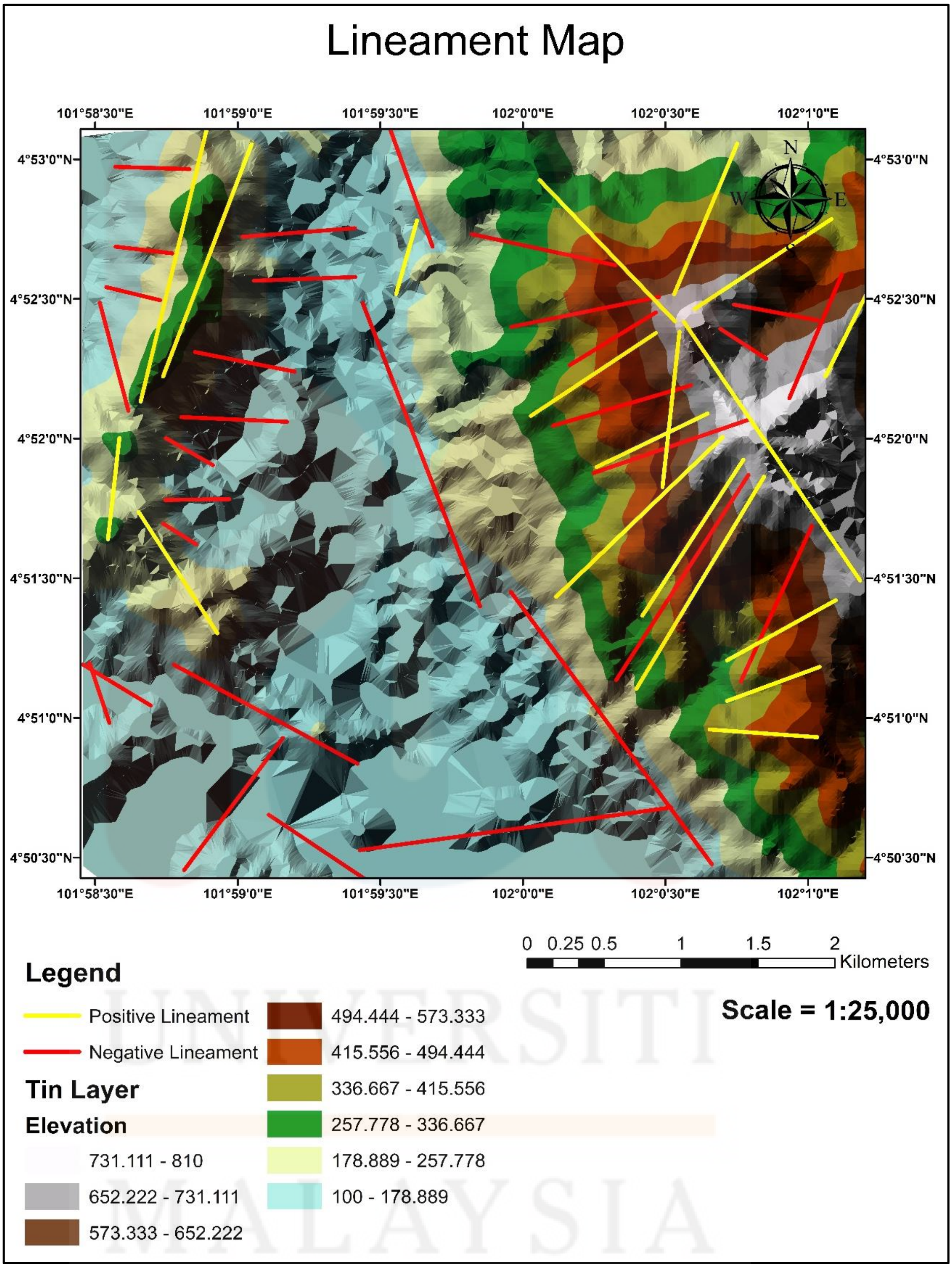

Figure 4.8: Lineaments in Sg. Ketil region, Gua Musang.

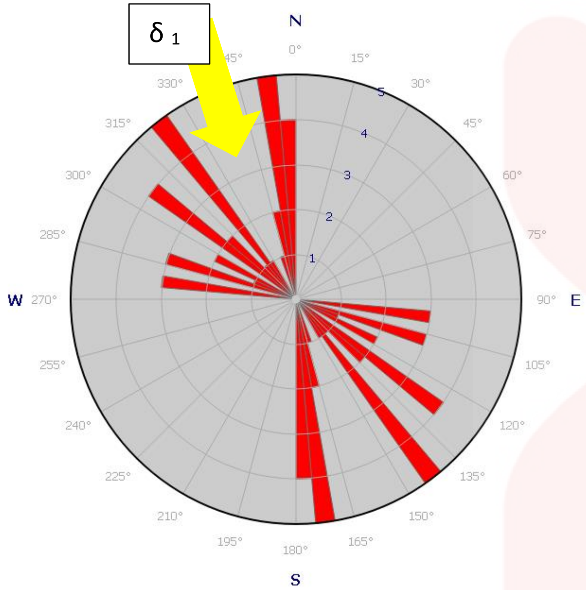

Figure 4.9: Dextral strike slip fault in region A

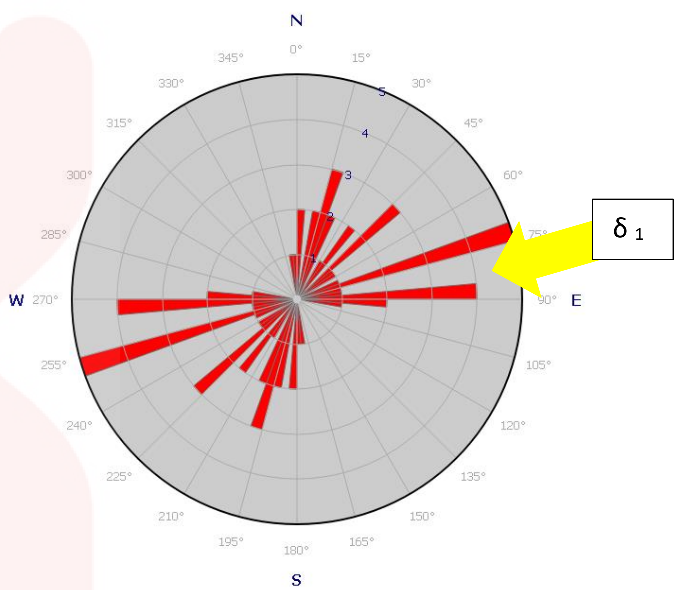

Figure 4.10: Sinistral strike slip fault in the region of region B

Table 4.5: Classification of fault type.

Fault	Description
Region A	Dextral strike slip fault
Region B	Sinistral strike slip fault

4.5 Historical Geology

Within the region of Sg. Ketil, there are four (4) types of lithology being identified. These lithology units include alluvium unit, acid intrusive unit, sandstone interbedded with siltstone unit, and phyllite unit which are embedded within Gua Musang formation.

The argillite, carbonate, and volcanic facies as the major units dominating the Gua Musang formation from middle Permian to late Triassic period. Argillaceous series comprises siltstone, phyllite, mudstone, slate, and shale, these series are the dominant facies within the Gua Musang region

The oldest unit in this study is phyllite unit. Phyllite unit is included in argillaceous facies. Fossiliferous facies are more often found in northern region, thus, there no such unit might be found within Sg. Ketil area since no evidence has been found by past researcher, (Hazmira, 2013).

This development of the depositional environment for phyllite is located in a region with warm, quiet, and shallow marine environment which is convenient for the development of argillaceous facies. Next, the sandstone interbedded with siltstone unit might involve in the argillaceous facies as well.

This unit has developed since middle Permian to late Triassic. This unit interfingering into the phyllite units as they come from similar facies. Next, Rhyolitic composition signifies volcanism that has ever happened in the past. It is mostly found on the western part which is closer to the region of Gua Musang to Kuala Lipis.

Particularly in the region covering from southwest Kelantan to northwest Pahang. Whereas, at the eastern side is more dominant with composition of andesitic. Rhyolitic composition is being correlated with the subduction process in the past which has occurred in the middle to upper Triassic period.

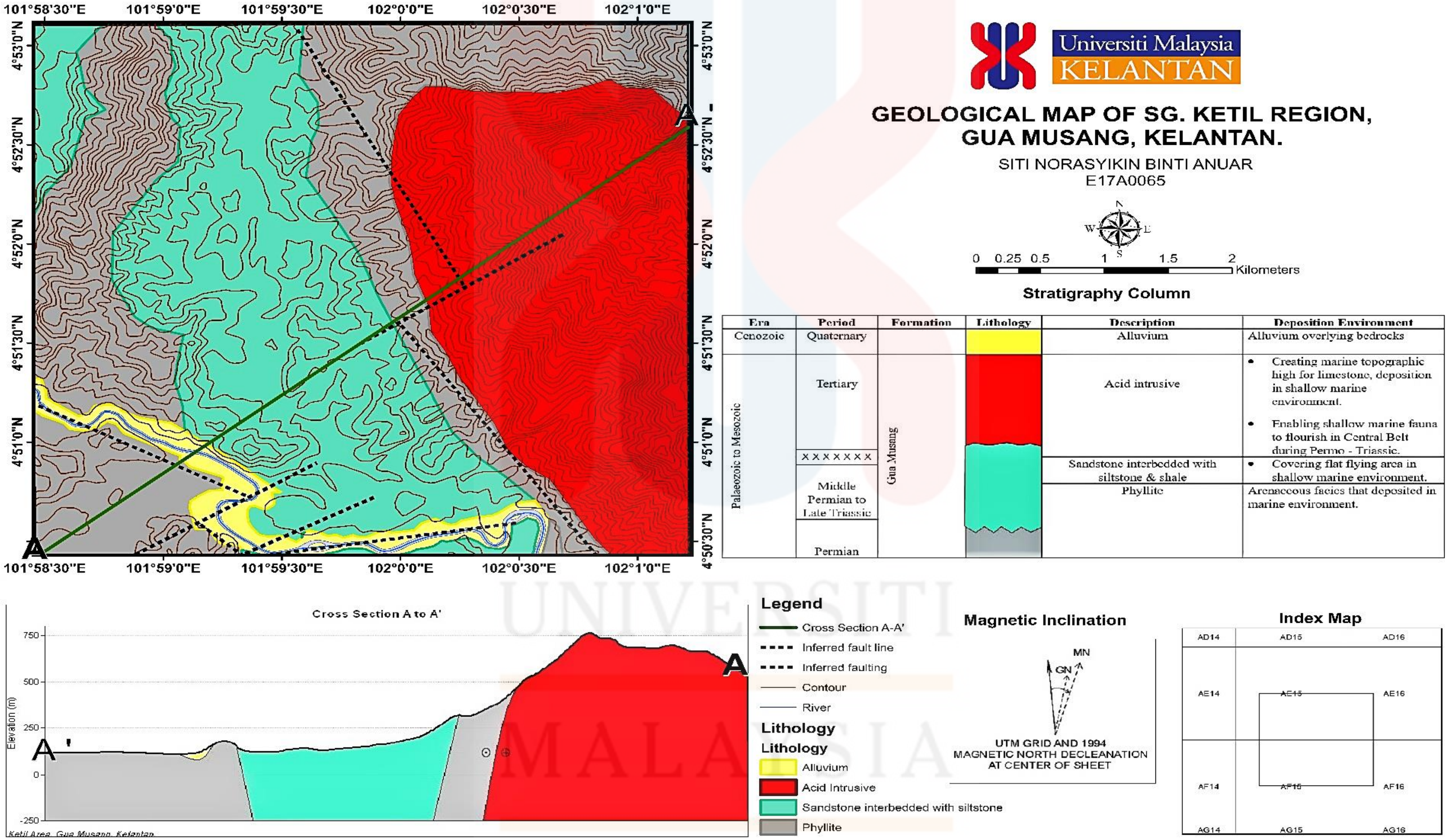

Figure 4.11: Geological Map of the Sg. Ketil region, Gua Musang.

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY ASSESSMENT

5.1 Introduction

Within this chapter, the landslide susceptibility assessment in the region of Sg. Ketil is analysed and processed. This chapter presents the results of thematic maps and landslide susceptibility map of Sg. Ketil region.

Involved parameters includes slope, aspect, lithology, rainfall intensity, drainage density, land use, distance to road, and distance to fault after operating the Weighted Overlay Method (WOM) by overlying the parameters altogether.

5.2 Parameter of Landslide.

Parameters involved in this study for the landslide susceptibility assessment within Sg. Ketil region includes slope, rainfall intensity, lithology unit, drainage density, distance to fault, slope aspect and land use. The weightage assigned to each of the parameters enables to determine and aid to select the area with most vulnerable towards landslides.

5.2.1 Slope

Slope shows the increment in the inclination degree over the horizontal plane to indicate the topography of the region integrated with the steepness which aid in describing the surface runoff. From the generated map in Figure 5.1 shown, it is clearly observed that the eastward region denotes steep to very steep slope especially along the hillside within the ridges. While, the region in southwest only has slight steep slope.

These regions cover about 60% of the study area, whereas, the other comprises very gentle to moderate slope. Slope map is assigned to 20 marks out of 100 mark from all the parameters due to the steepness of a slope within an area is one of the crucial parameter in determining a landslide susceptible region.

The slope map is being classified according to the *Geology Society Malaysia* (GSM) in 2004.There are six (6) classifications of the slope map. gentle, gentle, moderate, moderately steep, steep and very steep. As shown in Table 5.1, the slope is identified with very gentle slope when it has an inclination degree within the range of 0˚ to 5˚.

Next, moderate slope is categorized when the inclination degree achieving a range from 10˚ to 15˚. The steepest or very steep slope is when the inclination degree of the slope is greater than 35˚. The very steep slope is assigned a maximum score out of all the six classifications. Value six (6) is given for the scoring of the very steep slope to show the critical condition for the potential of landslides to occur (Roslee et al., 2017).

Table 5.1: Classification of slope in Sg. Ketil region, Gua Musang.

Class (˚)	**Description**	**Scoring**
0 – 5	Very gentle	1
5 – 10	Gentle	2
10 – 15	Moderate	3
15 – 25	Moderately steep	4
25 – 35	Steep	5
> 35	Very steep	6
Source	(Geological Society Malaysia, 2004)	(Roslee et al., 2017)

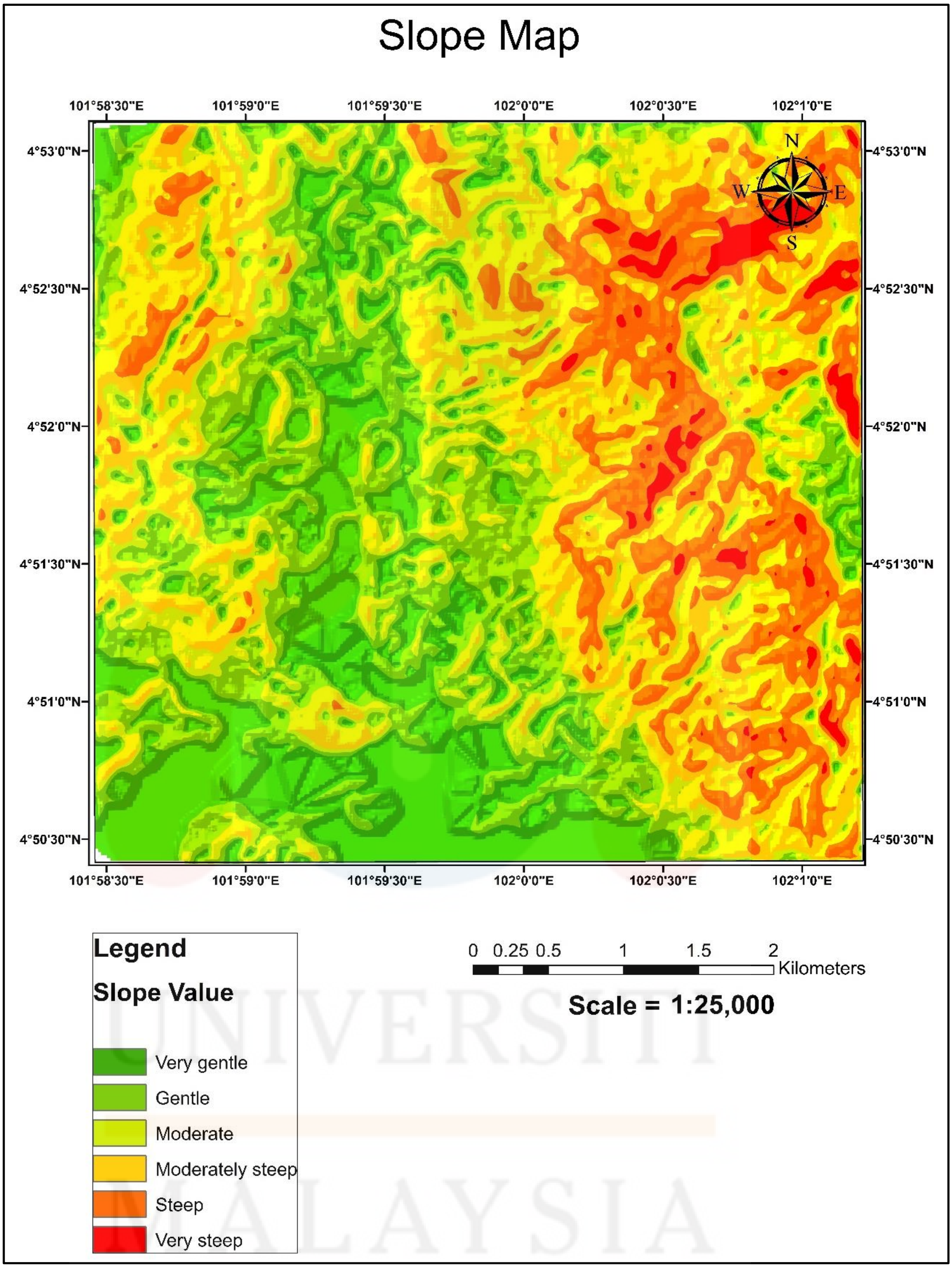

Figure 5.1: Slope Map of Sg. Ketil region, Gua Musang.

5.2.2 Rainfall Intensity

One of the main factors which trigger landslide occurrence is rainfall precipitation. The impact of rainfall precipitation with higher intensities causes the slope stability to decrease due to the infiltration process in inducing landslide, (Habibah Lateh et al., 2013).

Table 5.2 shows the monthly rainfall distribution that was being collected from Jabatan Pengairan dan Saliran Malaysia (2020) in the region of Gua Musang, Kelantan. This information represents data collection of yearly precipitation (mm) within 2015 to 2019. The yearly maximum precipitation data is presented as well to show the maximum amount received throughout the year within 2015 to 2019.

Annual precipitation within Gua Musang district is: 999.9 mm (39.37 in) every year in average. Gua Musang district is receiving an optimum rainfall distribution throughout the year. From the statistical data collected, the months with most wet condition starts from October to December consistently due to the strike of northeast monsoon from October to March every year.

While, minimum rainfall distribution recorded is within the month of Jun to July every year. 2017 denotes the highest amount of average annual maximum precipitation; 53.92 mm within 2015 to 2019.

Table 5.2: Monthly rainfall distribution within station of Gua Musang, Kelantan from 2015 to 2019.

	2015		2016		2017		2018		2019	
Month	**Average (mm)**	**Max (mm)**	**Average (mm)**	**Max (mm)**	**Average (mm)**	**Max (mm)**	**Average (mm)**	**Max (mm)**	**Average (mm)**	**Max (mm)**
Jan	3.40	45.00	3.61	33.00	12.13	80.00	9.32	33.50	2.29	20.00
Feb	0.48	13.00	5.29	48.00	2.86	14.00	1.09	12.00	1.46	12.00
Mar	1.97	24.50	0.06	2.00	2.63	27.50	4.37	63.50	7.45	187.50
Apr	2.95	21.00	5.16	58.50	2.15	24.00	2.20	23.00	1.83	15.50
May	9.65	49.50	2.10	56.50	14.37	94.00	0.23	0.50	7.02	39.00
Jun	3.73	36.50	9.20	59.00	7.15	60.50	2.63	49.00	5.52	40.00
Jul	3.92	28.50	6.69	87.00	4.92	31.50	5.00	50.00	5.56	41.00
Aug	10.15	79.50	5.03	61.00	10.97	52.50	3.03	40.50	7.20	59.00
Sep	8.22	54.50	6.05	33.00	7.84	41.00	13.42	64.00	9.07	44.00
Oct	7.33	45.00	6.08	61.50	13.00	68.50	10.18	56.00	9.19	55.00
Nov	8.60	54.00	7.15	64.00	11.47	74.50	9.13	88.50	16.13	92.50
Dec	7.30	55.00	4.63	68.50	9.45	79.00	10.24	44.00	0.00	0.00
Average annual precipitation (mm)	5.64		5.09		8.24		5.90		6.06	
Average annual max precipitation (mm)	42.17		52.67		53.92		43.71		50.46	

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

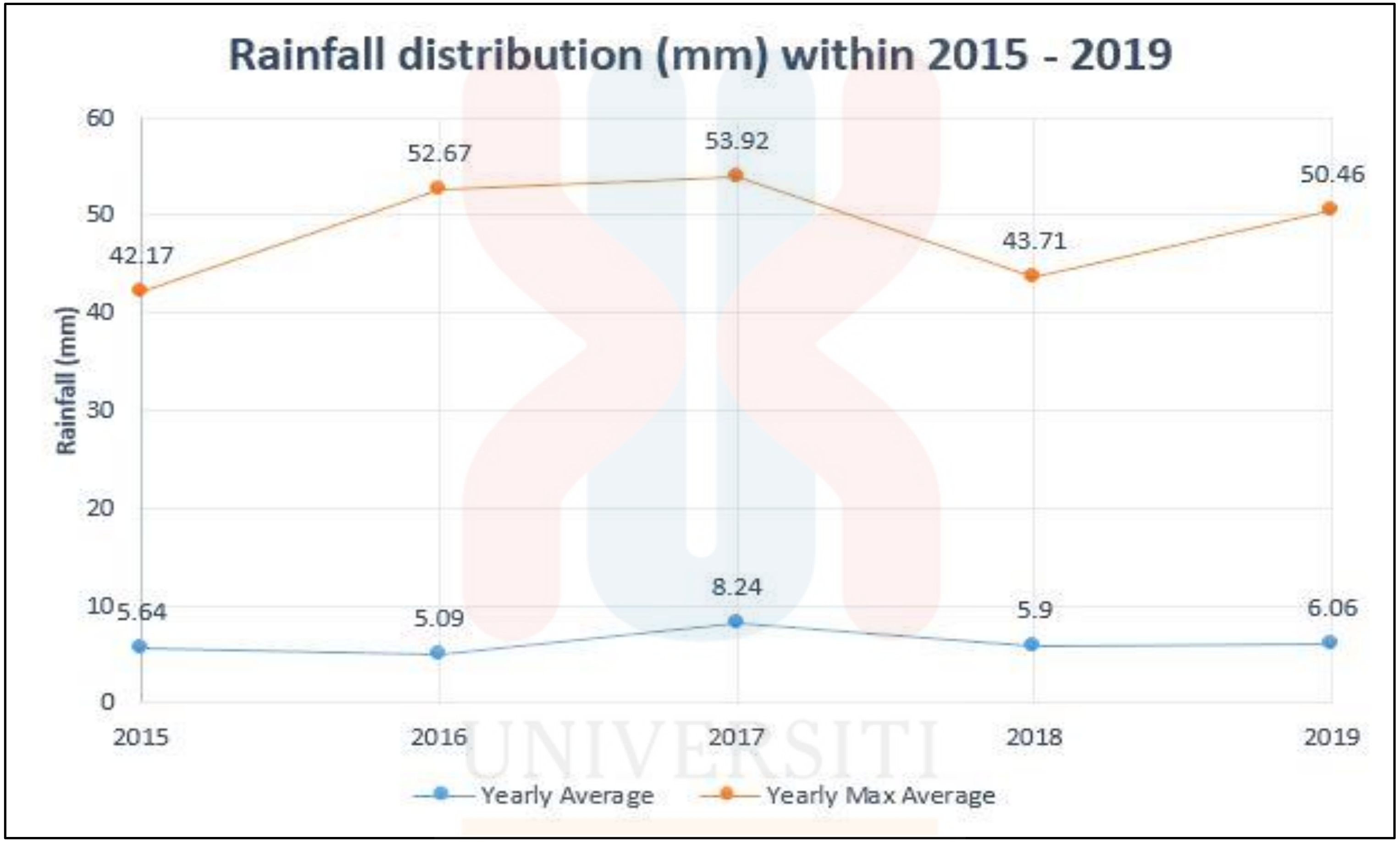

Figure 5.2: Graph of rainfall distribution within 2015 to 2019, Sg Ketil region, Gua Musang, Kelantan.

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

Figure 5.2 represents the graph of average annual precipitation (mm) and the average annual maximum precipitation within 2015 to 2019 from statistical data collected. The blue line represents average annual precipitation while, the orange coloured line denotes the average annual maximum precipitation (mm) in the region of the study area.

From the graph, 2017 shows the highest for both average annual precipitation and average annual maximum precipitation. The highest amount of precipitation collected in the year 2017 is during May (94.00 mm), next the months of October to December, 68.50 mm, 74.50 mm and 79.00 mm respectively.

Figure 5.3 shows the rainfall distribution map of Sg. Ketil region, Gua Musang. The total amount of precipitation collected within a year is in a range of 2341.06 mm to 2355.46 mm. The highest amount of rainfall distribution collected is presented with the violet colour, whereas, light blue colour represents the lowest amount of precipitation collected.

The south region within the Sg. Ketil region shows highest amount of precipitation data collected which is covering approximately 40% of the study area. It is a region which is close to the main river, Ketil river and hilly areas in southeast.

Next, the region at the middle section of the study area crossing in northeast and southwest direction shows moderate amount of precipitation distribution. The area which receives lowest rainfall distribution is specifically covering in the northwest direction within the study area.

Since the Gua Musang district is experiencing tropical climate throughout the year, rainfall distribution is vital within Sg. Ketil region. Out of all the parameters involved, rainfall intensity is set with mark of 20 out of 100 as rainfall distribution within a region is responsible towards slope instability.

Within the rainfall intensity classification as in Table 5.3, the region with highest intensity is set with maximum value of 3, and is followed accordingly in descending order for moderate rainfall intensity and low rainfall intensity respectively.

Table 5.3: Classification of rainfall intensity in Sg. Ketil region, Gua Musang.

Classification	**Scoring**
High	3
Moderate	2
Low	1

(Source: Roslee et al., 2017)

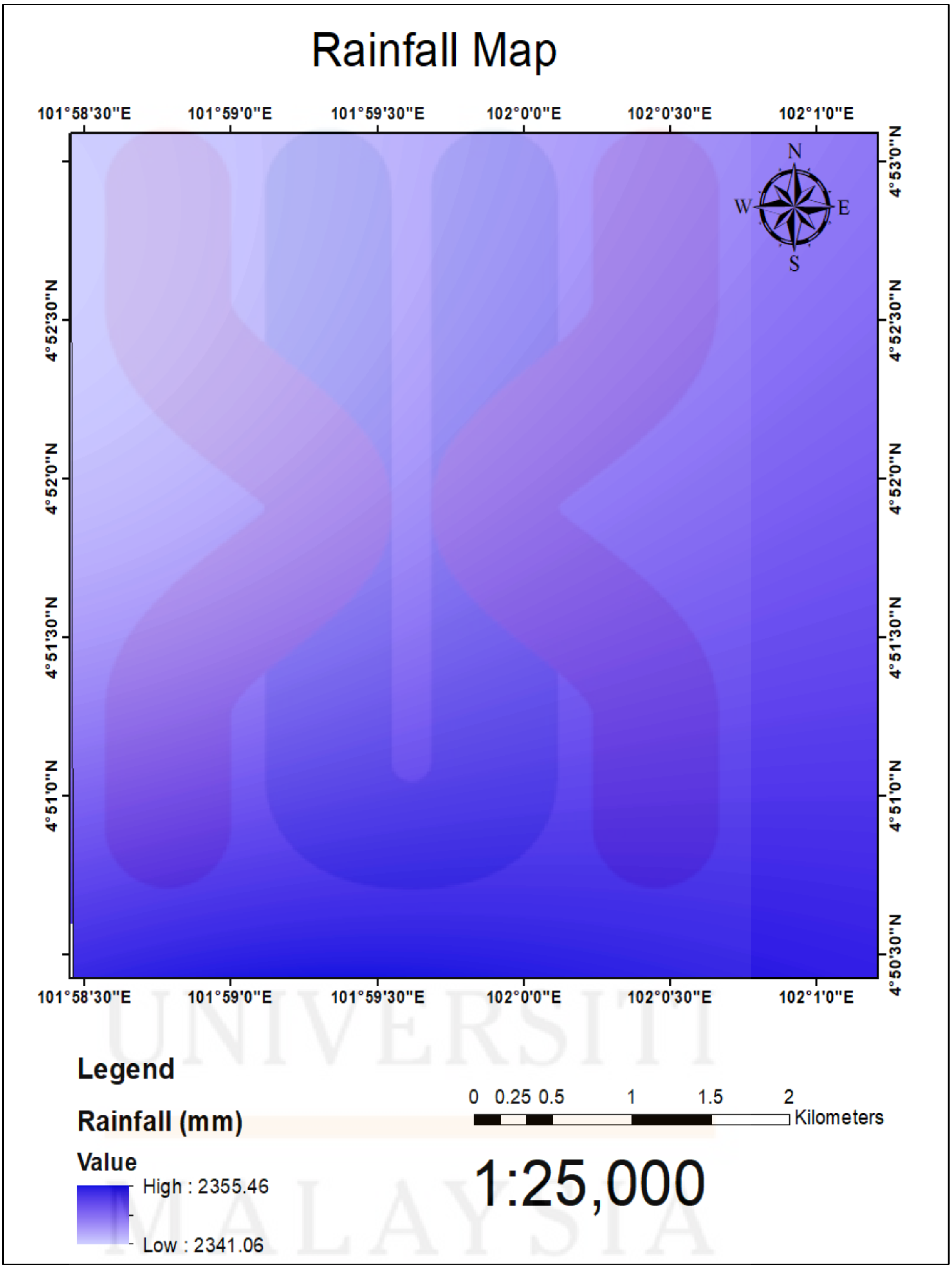

Figure 5.3: Rainfall distribution map of Sg. Ketil region, Gua Musang.

5.2.3 Lithology

Lithology unit means the type of rock involved within the study area. The lithology condition along with its formation identify the properties of soil and rock. Type of rocks involved in a specific region may influence the vulnerability to the landslide occurrences.

By referring to the map shown in Figure 5.4, there are four (4) types of lithology units involve in within the study area. These includes alluvium unit, acid intrusive unit, sandstone interbedded with siltstone unit and phyllite unit. Lithology map was used as one of the parameter towards processing the landslide susceptibility map and is assigned with value of 15% for the weightage score.

The scoring value for each type of rocks is shown in Table 5.4 to identify the region that shows the most susceptible towards landslide. Each type of rock has their own lithological properties. Igneous type rocks and metasedimentary rocks may have greater resistance to weathering compared to those weaker sedimentary rocks which is easier to be affected by erosion and deposition.

Table 5.4: Classification of lithology in Sg. Ketil region, Gua Musang.

Lithology	**Scoring**
Alluvium	6
Acid intrusive	1
Sandstone interbedded with siltstone	5
Phyllite	3

(Source: Malaysian Journal Geosciences, 1(2): 13-19)

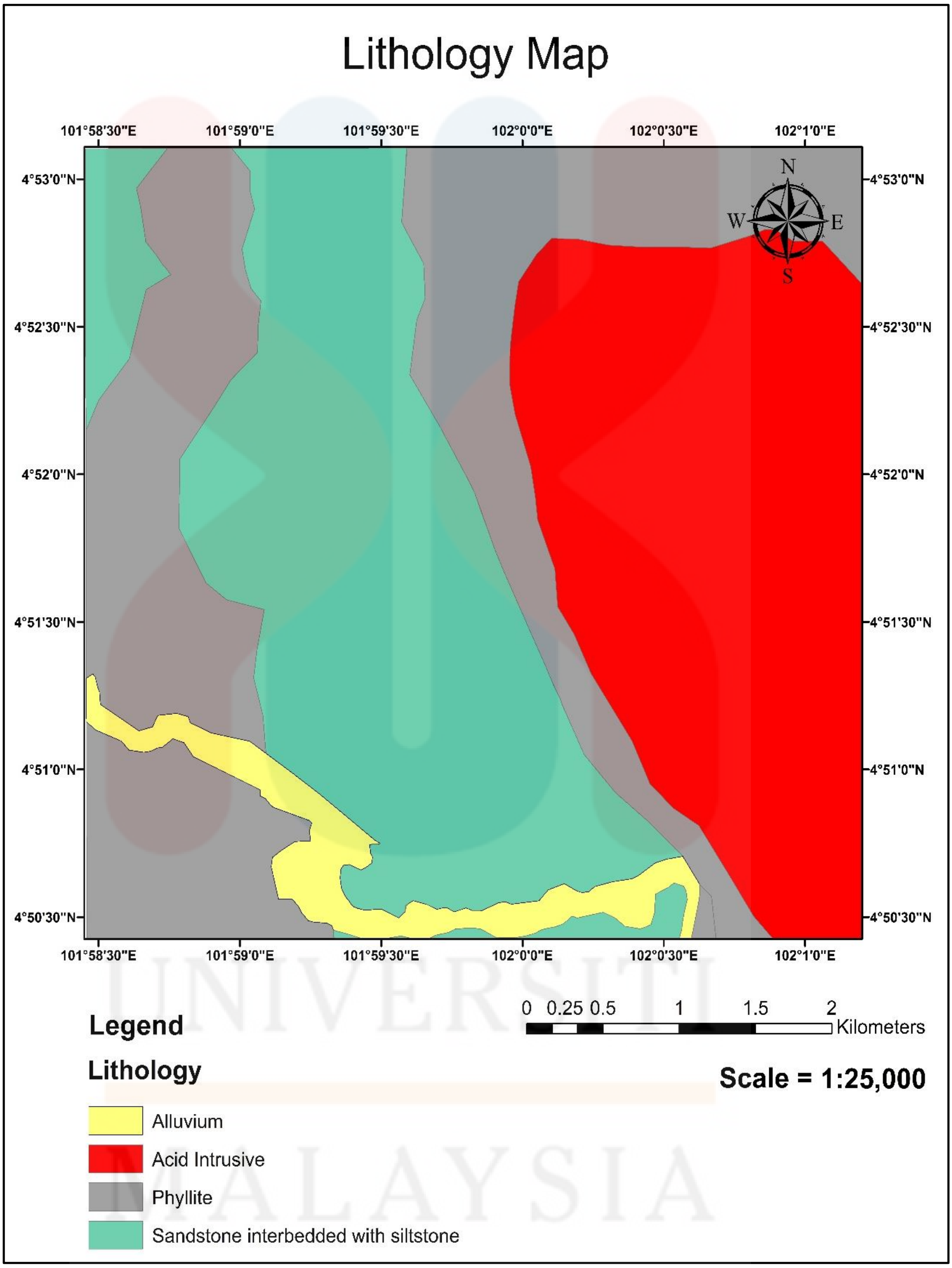

Figure 5.4: Lithology Map of Sg. Ketil region, Gua Musang.

5.2.4 Drainage density

A result map in Figure 5.5 shows the concentration of the drainage density within the study area. The drainage density in the study area is classified as low, moderate to high intensity of drainage density. Generally, the section which shows low intensity of drainage density is the region of high elevation with steep slope as water is travelling down the slope.

The gap within the ridges and valleys is probably managed by the competition between the creep like sediment during the transporting process. It plays a significant role in the process of surface- runoff as it is influencing the torrential flood intensity, the concentration, the sediment load and the water balance within a drainage basin.

This is presumably due to low catchment area within steep slope area, as water is running down the slope and accumulate at a region with gentler slope or low lying areas. This can be observed in the region at eastern section of the map which is dominated with hill to high hill.

On the other hand, the location which is closer to the main river, Ketil river within the southwest region of the study area, has higher intensity of drainage. The region with moderate to high intensity of drainage density is generally located in the flat flying area. Gentler slope enables wider water catchment area especially in the middle region of the study area to the main river or at the foothill area.

The Table 5.5 shows the highest drainage density is assigned as the maximum scoring and the scoring marks are set in descending order for moderate to low drainage density respectively. Among all of the parameters that may triggers to landslide, drainage density is given a mark of 15 out of 100 marks as it is another vital factor responsible towards slope instability after the slope and rainfall intensity parameters.

Table 5.5: Classification of drainage density in Sg. Ketil region, Gua Musang.

Description	**Scoring**
Low	1
Moderate	2
High	3

(Source: Roslee et al., 2017)

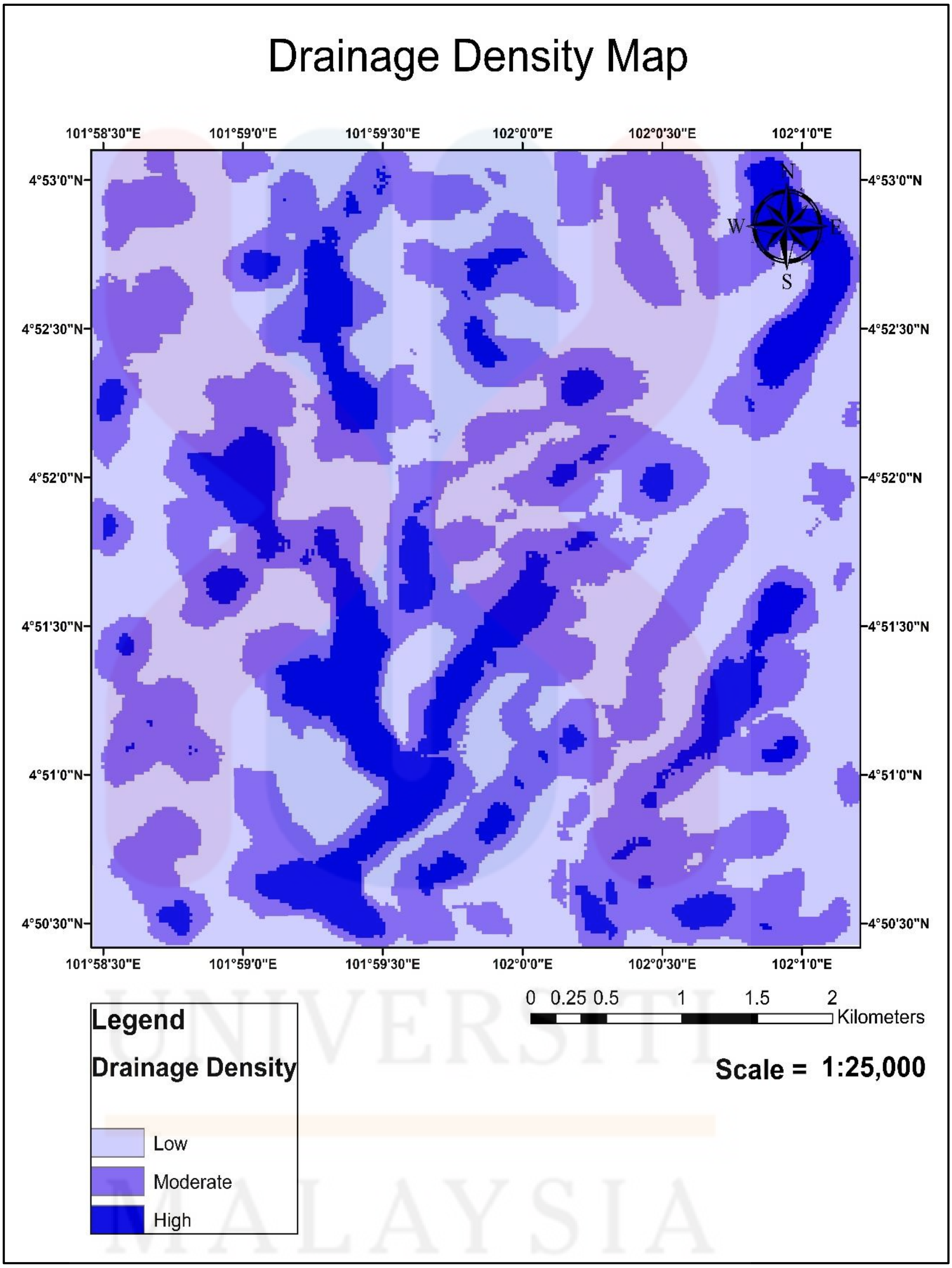

Figure 5.5: Drainage Density of Sg. Ketil region, Gua Musang.

5.2.5 Distance to Fault

Distance to fault may triggers the initialization towards mode of failure. Among of all the parameters, distance to fault map is given a weightage score 15% as faulting region marks a region to be less stable when there is high intensity of discontinuities within an area. Table 5.6 shows the relation between the fault classification and its scoring.

Region A is located within the foothill of the study area, showing dislocation of two blocks of high land. It is specifically situated in the eastward direction of the study area, thus, this region should be focused more since it comprises high land with steeper slopes.

Next, region B represents the fault region which is closer to the main river in southern section of the study area. This region comprises a land with gentler slope than in region A, thus, it is assumed to be less critical than in region A.

A distance to fault map is being generated as shown in Figure 5.6. Fault in region A is given a scoring value greater than in region B. it is considerable since fault in region A happens within the ridge of the high land and it shows the dislocation within the blocks as well.

Table 5.6: Classification of fault region in Sg. Ketil region, Gua Musang.

Fault	Description	Scoring
Region A	Dextral strike slip fault	5
Region B	Sinistral strike slip fault	3

(Source: Roslee et al., 2017)

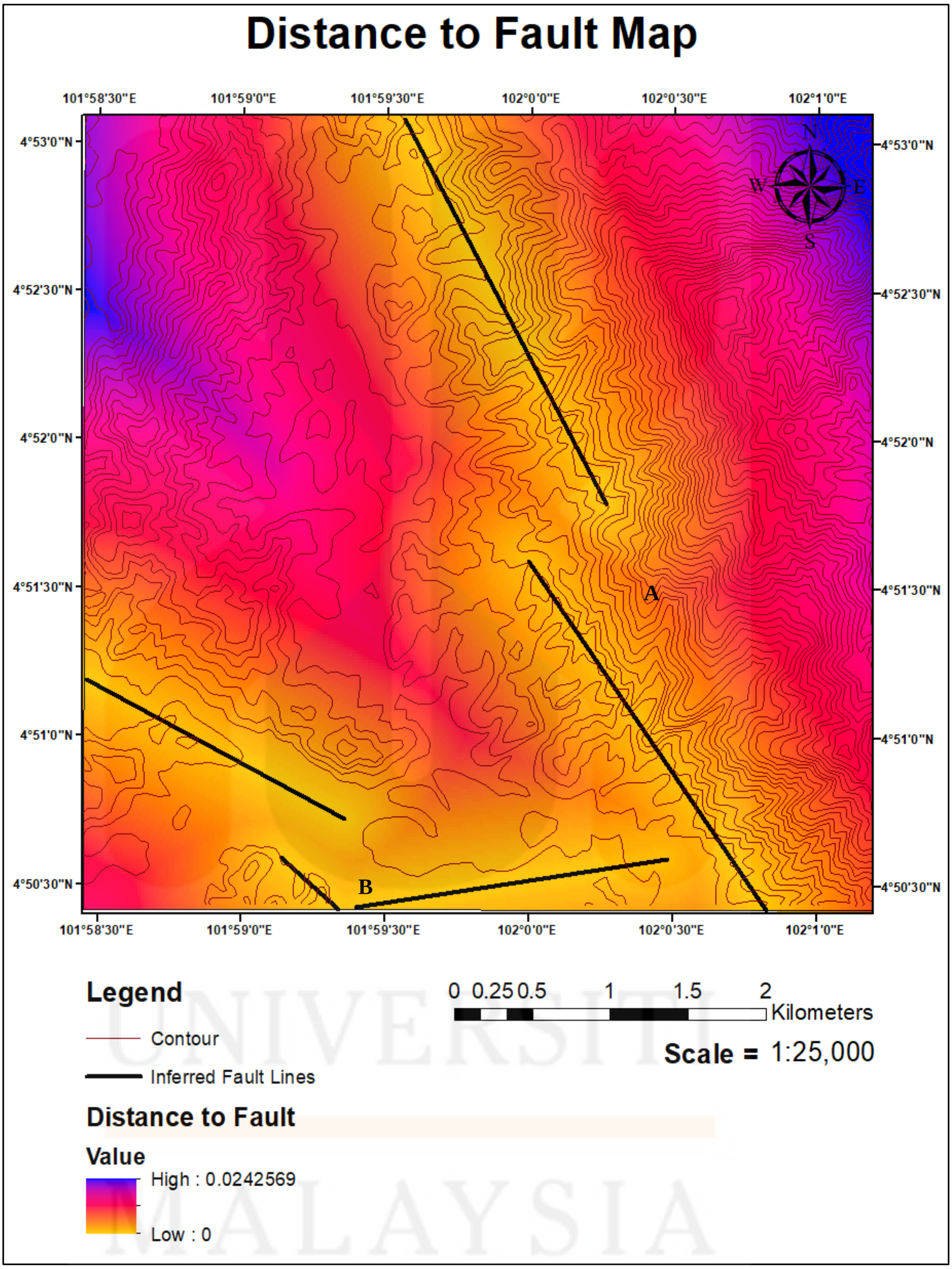

Figure 5.6: Distance to fault of Sg. Ketil region, Gua Musang

5.2.6 Aspect

Aspect map is measured in degrees, starting from 0 (north direction) to 360 (north, completing a full circle), rotating in a counter clockwise direction. It plays a significance value towards influencing vulnerability to landslide. An aspect raster that is generated results in the classes of the slope direction.

An aspect map is given a mark of 10 out of 100 marks in the weightage of parameters. It contributes less as a triggering factor. However, this parameter is included as it signifies the physical direction of slope face. The aspect values can be classified by relying to the angle of the slope with a descriptive direction.

From the aspect map as shown in Figure 5.7, the aspect direction that shows downward facing slope are in southeast (112.5˚ – 157.5˚), southwest (202.5˚ – 247.5˚), south (157.5˚ – 202.5˚), west (247.5˚ - 292.5˚) and north (337.5˚ - 360˚) within the study area. These covers 60% of the region with hill to high hill area at eastward of Sg. Ketil region. Thus, these important aspect directions are assigned as maximum scorings from 10 to 6 marks value in descending order respectively as shown in Table 5.7.

While the rest are assumed to indicate the slope face direction in very gentle slope to moderate slope, and might be less vulnerable towards landslide potential. These include northwest (292.5˚ – 337.5˚), east (67.5˚ – 112.5˚), northeast (22.5˚ – 67.5˚), north (0 – 22.5˚) and flat (-1˚).

Table 5.7: Classification of aspect in Sg. Ketil region, Gua Musang.

Class (˚)	Description	Scoring
-1	Flat	1
0 – 22.5	North	2
22.5 – 67.5	North East	3
67.5 – 112.5	East	4
112.5 – 157.5	South East	10
157.5 – 202.5	South	8
202.5 – 247.5	South West	9
247.5 – 292.5	West	7
292.5 – 337.5	North West	5
337.5 – 360	North	6

(Source: Roslee et al., 2017)

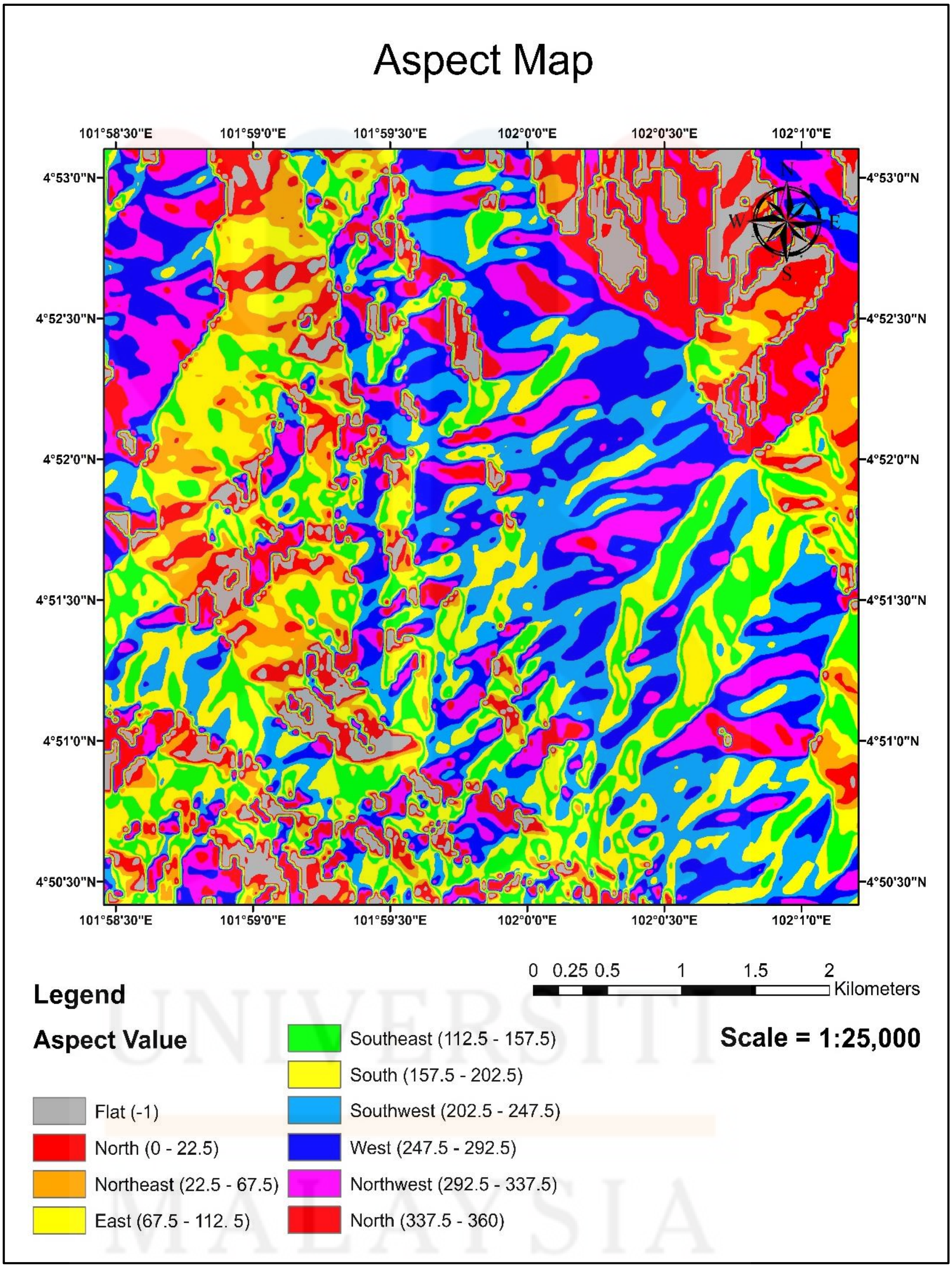

Figure 5.7: Aspect Map of Sg. Ketil region, Gua Musang.

5.2.7 Land Use

Figure 5.8 presents the development within the region of Sg. Ketil, Gua Musang. In the study area, the land is highly in used for agriculture activities which also plays as economic contributor around the Gua Musang region. As observed, the land which is dominant with agriculture activities lies in the flat flying areas from low land to low hill area as it is easier to be accessed to reap the yield.

The undisturbed section is the hill to high hill area which is limited to access in the eastward region. There are nearby town in the region locating at corner of the study area in southwest direction. Little number of settlements within Sg. Ketil region, Gua Musang, are located in the small area of Chin Teck Farm at south region and within "Jalan Industri" in Gua Musang town at southwest region respectively.

Lastly, several roads connecting the external route to the study area includes the main roads of Federal Route 8, *Jalan Industri* of Gua Musang town and the farm road within the study area.

In Table 5.8 below, among all of the classification in land use within the study area, forest is selected as the maximum scoring of 5 as it comprises hill to high hill region, it is followed with plantation, settlement, road and city in descending order respectively.

Table 5.8: Classification of land use in Sg. Ketil region, Gua Musang.

Land Use	Scoring
Forest	5
Plantation	4
City	1
Settlement	3
Road	2

(Source: Malaysian Journal Geosciences, 1(2): 13-19)

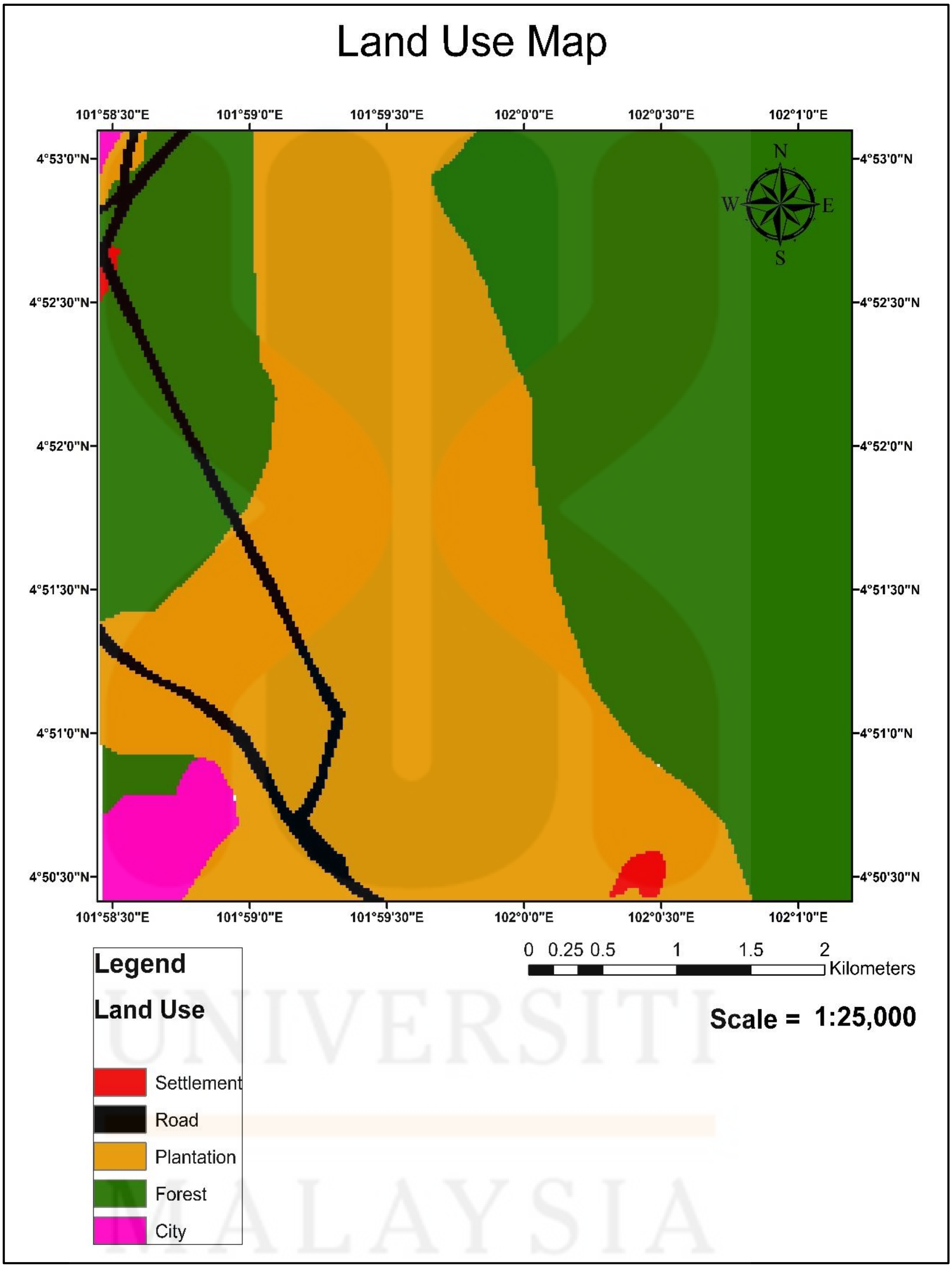

Figure 5.8: Land use map of Sg. Ketil region, Gua Musang.

5.3 Landslide Susceptibility Zonation.

Involved parameters in this analysis are the slope, aspect, drainage density, lithology, and land use map. As shown in Table 5.9, the parameters generated gives a sum of 100 marks for the weightage. The most vital factors are the slope and rainfall intensity with marks of 20 for each respectively.

Next, it is followed with lithology, drainage density, and distance to fault in the study area with weightage 15 marks for each. Other factor includes aspect and land use which contributes marks of 10 and 5 respectively. Reclassification of attributes for each of the parameters aiding the analysis by determining the area which shows the most susceptible towards landslides in the generated map.

Table 5.9: Reclassification of parameters with influence.

Parameter	Weightage (Wi)
Slope	20
Rainfall intensity	20
Lithology	15
Drainage density	15
Distance to fault	15
Aspect	10
Land Use	5

The classification of landslide susceptibility zone is made by referring to Geology Society Malaysia in 2004 as shown in Table 5.10. The result of landslide susceptibility zonation map in Figure 5.9 categorizes the region of the study area into low, medium, and high susceptible to landslide.

The generated map determines the area with high potential of landslides to occur as well as the unaffected region towards the potential failure. Table 5.11 indicates the percentage of the area susceptible to the failures. By referring to the result map shown, the area which shows the high susceptible to landslide is indicating with red colour, medium susceptibility is represented in yellow colour and the low susceptibility is marked with green colour.

As observed, the red colour is concentrated in the hillside of the hilly to high hill area, representing the hillside in the eastern region with steeper slope, high intensity of drainage density, closer to faulting area and weaker type of rock. This indicates that, this region which covers 35% of the study area has high potential for failures to happen.

The land covered in agriculture at middle of the study area shows low susceptible towards landslide approximately covering 30%, except the region which is near with the main river, it shows 5% of area coverage which is vulnerability towards the landslide since it acts as site for drainage accumulation, has weaker type of rocks, and close to inferred faulting area.

Lastly, the low susceptibility zone lies within flat flying area, with gentle slope, and low intensity of drainage density. This region is also concentrate with the built of high resistant rock such as the metasedimentary rock, phyllite covering about 30% of the study area. The low susceptibility zone is mostly covering the western region of Sg. Ketil region near to the cities.

Table 5.10: Classification on landslide susceptible zone.

Landslide Susceptibility Zone	Risk (%)
Low	0 – 50
Medium	50 – 75
High	> 75

(Source: Geological Society Malaysia, 2004)

Table 5.11: Analysis on landslide susceptible zone in Sg. Ketil region, Gua Musang.

Landslide Susceptibility Zone	Percentage area susceptible to landslide (%)	Dominant region
Low	30	Western/NW-SW
Medium	30	Western/NW-SW
High	35	Eastern/NE-SE
	5	South/S

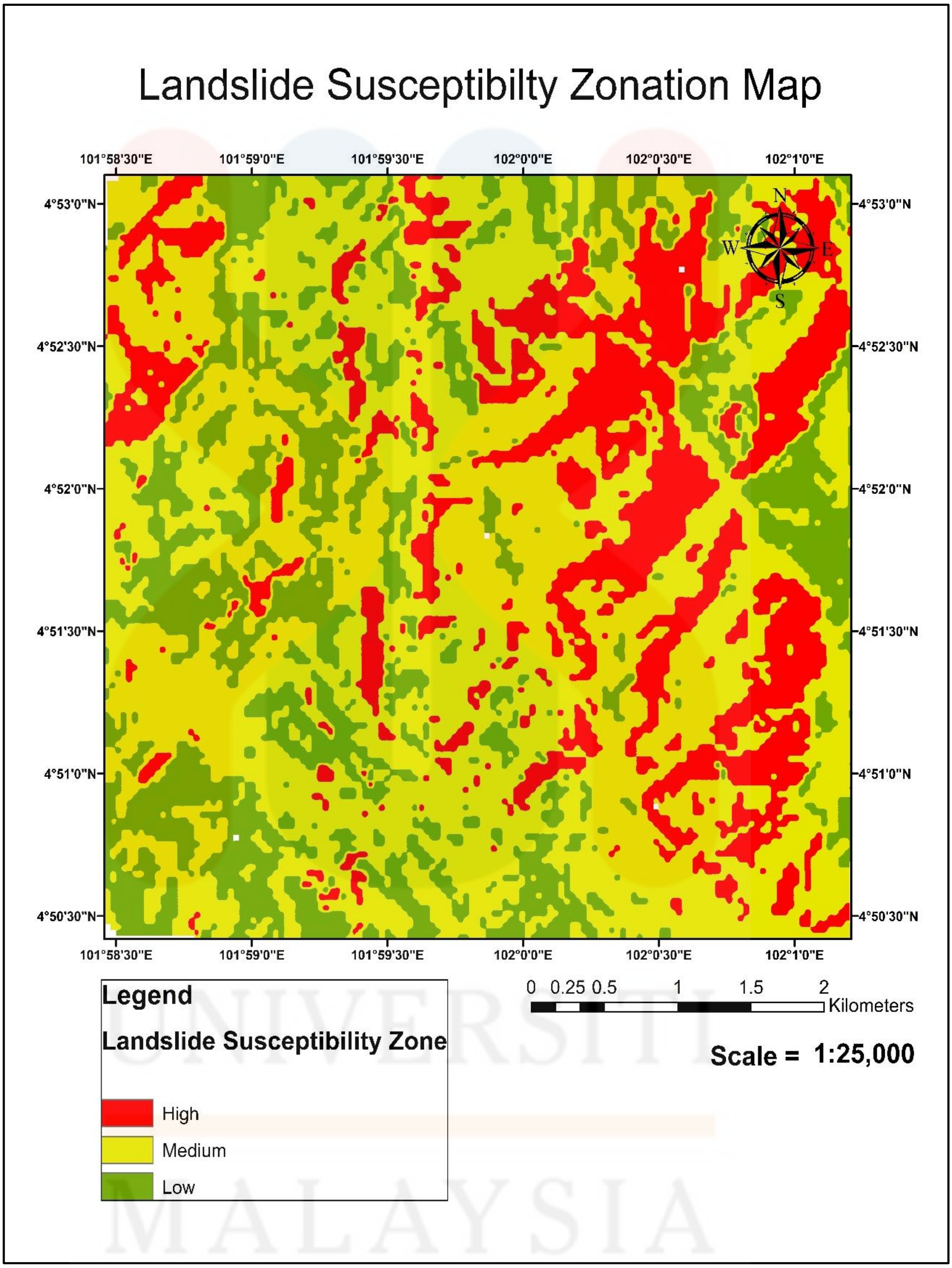

Figure 5.9: Landslide susceptibility zonation of Sg. Ketil region, Gua Musang.

CHAPTER 6

CONCLUSION & RECOMMENDATION

6.1 Conclusion

In conclusion, after conducting this research, a geological map of Sg. Ketil region has successfully being updated with a scale of 1: 25, 000. The lithology types embedded in this research are phyllite, sandstone interbedded with siltstone, and acid intrusive.

This interpretation was developed based on observation through satellite imagery, and was being validate by referring to the past researcher within the same region. The geomorphology assessment, drainage pattern, structural analysis and lithostratigraphy were done through Geographical Information System (GIS) virtual mapping.

As for the research specification, this research revolves around landslide susceptibility analysis within the region of Sg. Ketil. The potential of land which is showing vulnerability towards landslide occurrences in Ketil region is being identified.

The study area has been divided into three (3) classes of landslide zonation, from low, moderate to high susceptibility to landslide event. The most vulnerable to landslide is the region located in the eastern part of the study area, which is the region dominated with hilly area.

The area coverage percentage is covering approximately 40% from the study area, whereas, the region from low to moderate being vulnerable to landslide has areas covering up to 30% for both regions respectively. By operating Weighted Overlay Method (WOM), the parameters involved to operate this analysis includes slope, aspect, drainage density, distance to fault, lithology, and land use.

After conducting this assessment, landslide susceptibility zone is being parted into three main classifications; from low susceptible, moderate susceptible, and to high susceptible towards the hazard. Among of the mentioned parameters, the most influencing factors probably the slope factor.

By counting back, this can be deduced due to the tendency of landslide occurrences when the resisting force has been exceeded. Plus, the high susceptible zone comprises high elevated area with steeper slopes. After all, others parameters are playing their roles in contributing to landslide events.

The landslide susceptibility map of Ketil region in Gua Musang is successfully produced and can be useful to the engineers and any construction companies in order to guide them in future development and planning.

6.2 Recommendation

In the process of conducting this study, there are a lot of challenges and limitation have occurring since the COVID-19 pandemic struck. The most challenging part in this process probably the restriction from conducting physical field survey, thus, result in limitation of primary data collection.

Thus, field investigation should be conducted in order to verify the interpretation made based on virtual mapping through satellite imagery. Field mapping survey includes traverses by visiting the accessible part within the study area, validate the data obtained during preliminary study, collecting rock samples and petrography analysis to confirm lithology unit present, as well as marking the region with geology structures to verify structural features within study area.

On the other hand, in term of research specification, there are limitation in obtaining the secondary data especially for the analysis operation. This is due to complex procedures towards obtaining secondary data from the agencies. Too little number of agencies providing online, accessible and free geo spatial data.

It is advised to make earlier application of the secondary data from the agencies since it takes a long period for the procedure to be processed. Next, increase the variation of parameters that will be used by obeying the geological condition of the study area, since different amount of factors that are used will influence the final results.

It is advised to operate the landslide susceptibility analysis in ArcMap 10.3, ArcGIS software since it has variation of tools which is practical and effective instead of instant operating process and providing clear results.

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