GEOLOGY AND LANDSLIDE HAZARD ZONATION USING GEOGRAPHIC INFORMATION SYSTEM (GIS) IN CHUCUH PUTERI, KUALA KRAI, KELANTAN

by

BALKIS ARSHILLA BINTI KAMARUL ZAMAN

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

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DECLARATION

I declare that this thesis entitled "GEOLOGY AND LANDSLIDE HAZARD ZONATION USING GEOGRAPHIC INFORMATION SYSTEM (GIS) IN CHUCUH PUTERI, KUALA KRAI, KELANTAN" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :……………………….

Name : BALKIS ARSHILLA BINTI KAMARUL ZAMAN

Date :………………….

APPROVAL

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

Signature	: ……………………………….
Name of Supervisor I	: DR WANI SOFIA BINTI UDIN
Date	: ……………………………….

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

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Geology And Landslide Hazard Zonation Using Geographic Information System (GIS) In Chucuh Puteri, Kuala Krai, Kelantan

ABSTRACT

This research entitled geology and landslide hazard zonation using Geographic Information System (GIS) in Chucuh Puteri, Kuala Krai, Kelantan. The study area isis about 25 km2 which aligned along latitude 5°21'3.90''N to 5°21'2.73''N and longitude from 102°17'21.23''E to 102°17'21.02''E. The aim of this research is to generate geological map of Kampung Chucuh Puteri, Kuala Krai, Kelantan with scale 1: 25 000, to identify the causative parameters that may be triggering a landslide and to produce a Landslide Hazard Zonation (LHZ) map of Kampung Chucuh Puteri, Kuala Krai, Kelantan. The current project's geological mapping is based on fieldwork, which includes taking samples from recently formed outcrops and examining drainage patterns, geomorphological features, and other factors. Granite, granodiorite and quartzite are among the lithological founds at the research area. In order to generate the landslide hazard zonation map, an integrated approach of WOM using GIS technology was applied using several parameters. The parameters were extracted using Digital Elevation Model (DEM) data. An overlay and raster calculation in GIS was used to generate results of landslide hazard map of Kuala Krai. The map which has different classes which was class 1 represents no hazard, class 2 represents a moderate hazard, class 3 represents a medium hazard, class 4 represents a high hazard, and class 5 represents the highest hazard. The factors that caused the landslide were recognised as heavy rainfall intensity. As a conclusion, the ability to identify landslides will provide society with a better knowledge and understanding of landslide mechanisms, as well as a better prevention of the most likely failure area that has high prone landslide for future planning.

Geologi dan Zon Bahaya Tanah Runtuh Menggunakan Sistem Maklumat Geografi (GIS) Di Chucuh Puteri, Kuala Krai, Kelantan

ABSTRAK

Penyelidikan ini bertajuk Geologi dan Zon Bahaya Tanah Runtuh menggunakan Sistem Maklumat Geografi (GIS) Di Chucuh Puteri, Kuala Krai, Kelantan. Kawasan kajian adalah kira-kira 25 km2 yang sejajar sepanjang latitud 5°21'3.90''U hingga 5°21'2.73''U dan longitud dari 102°17'21.23''E hingga 102°17'21.02''E. Penyelidikan ini bertujuan untuk menghasilkan peta geologi Kampung Chucuh Puteri, Kuala Krai, Kelantan dengan skala 1: 25 000, untuk mengenal pasti parameter penyebab yang boleh mencetuskan kejadian tanah runtuh dan menghasilkan peta Zon Bahaya Tanah Runtuh Kampung Chucuh Puteri, Kuala Krai, Kelantan. Pemetaan geologi projek semasa adalah berdasarkan kerja lapangan, yang termasuk mengambil sampel daripada singkapan yang terbentuk baru-baru ini dan meneliti corak saliran, ciri geomorfologi dan faktor lain. Granit, granodiorit dan kuarzit adalah antara penemuan litologi di kawasan penyelidikan. Bagi menghasilkan peta zonasi bahaya tanah runtuh, pendekatan bersepadu WOM menggunakan teknologi GIS telah digunakan menggunakan beberapa parameter. Parameter telah diekstrak menggunakan data Digital Elevation Model (DEM). Pengiraan tindanan dan raster dalam GIS digunakan untuk menjana keputusan peta bahaya tanah runtuh Kuala Krai. Peta yang mempunyai kelas berbeza iaitu kelas 1 tidak mewakili bahaya, kelas 2 mewakili bahaya sederhana, kelas 3 mewakili bahaya sederhana, kelas 4 mewakili bahaya tinggi, dan kelas 5 mewakili bahaya tertinggi. Faktor-faktor yang menyebabkan tanah runtuh telah diiktiraf sebagai intensiti hujan lebat. Kesimpulannya, keupayaan untuk mengenal pasti tanah runtuh akan menyediakan masyarakat dengan pengetahuan dan pemahaman yang lebih baik tentang mekanisme tanah runtuh, serta pencegahan yang lebih baik terhadap kawasan yang berkemungkinan besar kegagalan yang mempunyai tanah runtuh yang tinggi untuk perancangan masa depan

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

DEM	Digital Elevation Model
GIS	Geographical Information System
GPS	Global Positioning System
USGS	US Geological Suervey Earth Resources and Science Centre
WOM	Weighted Overlay Methods

LIST OF SYMBOLS

°	Degree
%	Percentage
’	Minutes
”	Second

CHAPTER 1

INTRODUCTION

1.1. General Background

This research project entitled “Geology and Landslide Hazard Zonation Using Geographic Information System (GIS) in Chucuh Puteri, Kuala Krai, Kelantan”. This study is a primarily concerned with the geology of the region and landslide hazard zonation. According to the Geological Survey Ireland Department of the Environment (2023), Geological mapping involves a geologist conducting fieldwork to gather geological information about exposed rocks. This includes identifying boundaries between different rock types and structures, such as faults, and observing any signs of deformation. The data is typically collected through mapping, field observation, and sampling, in order to better understand the geology and geologic history of a given area. Understanding the nature of the underlying rocks in a region is the cornerstone of all geologically-related studies, therefore mapping is not limited to mineral exploration. It is a crucial stage in many investigations.

This research aims to create a geological map and a landslide hazard zonation map of Kampung Chucuh Puteri in Kuala Krai, Kelantan, using a scale of 1:25,000. Additionally, the research seeks to identify the causative factors of landslides in the area. To accomplish this, fieldwork methods such as mapping, observation, and sampling are utilized. Various mapping tools are employed in order to conduct the geological mapping and different parameters of the area are studied. This included identifying the location of rock outcrops, recording the strike and dip of the outcrop, determining rock type and its sedimentary structure, and other relevant information. Samples will also be collected for further laboratory analysis such as petrographic and thin section research to understand the geology of the area.

Although Malaysia is not a mountainous nation, slope collapses and landslides are a common occurrence here. In general, Malaysia does not have major earthquakes; but large-scale landslides still exist and are mostly caused by gravity and heavy, continuous rains. As the rate of land development and human activity increases, losses from landslides and other effects of ground movements are escalating significantly. Since the 1980s, rapid urbanization in Malaysia has made strategic and appropriate low-lying places for development increasingly scarce (Qasim et al., 2013).

A geologic hazard or geohazard is an undesirable geology state that has the potential to cause extensive property and life loss such as landslides which constitute major geological hazard that occurs widespread, causing extensive damages and casualties all over the world. During severe monsoon rainfall, several landslides occur annually in the Kelantan River valley in Peninsular Malaysia. In the Kelantan River watershed, flooding and accompanying landslides caused substantial damage to cattle, agricultural produce, residences, and businesses, (Beiranvand & Hashim, 2016).

Geographical Information Systems (GIS) have become significant tools for assessing the risk of landslides because it may be used to reduce the impact of disasters through preparatory actions. GIS can incorporate data from a range of sources in addition to giving information on land use and urban planning in a variety of ways. Improved mapping and analysis, faster and more intense access, more information acquisition efficacy, and higher service quality are just a few examples. GIS software can create detailed maps with a wealth of information. As stated by Forkuo & Asiedu (2010), GIS software-generated maps would make it easier to spot potential dangers. Furthermore, the hazard mapping component of GIS software is assisting in the creation of a community vulnerability inventory.

1.2. Study Area

1.2.1. Location

According to Department of Town and Country Planning Peninsular Malaysia, (2011), Kuala Krai has a total area of 227,670.01 hectares and become the second largest region in Kelantan after Gua Musang. The research area concentrates on the rural region of Kampung Chucuh Puteri, Kuala Krai which encompasses about 25 km^2 of the total area. It aligned from latitude 5°21'3.90"N to 5°21'2.73"N and longitude from 102°17'21.23"E to 102°17'21.02"E. Based on the Google E , the study area is easy to access (Figure 1.1).

The geological mapping in the study area is easy to perform as it has a lot of resident's roads that can be accessed using 4 by 4 or by foot. The research region is also at risk of flooding, especially in the area that is close to the Kelantan River, which may also be causing landslides. In addition to human activities, landslides in the Kuala Krai district are exacerbated by human settlements in the area. Figure 1.2 represents base map of the study area.

Figure 1. 1: Location of study area in Google Earth Pro.

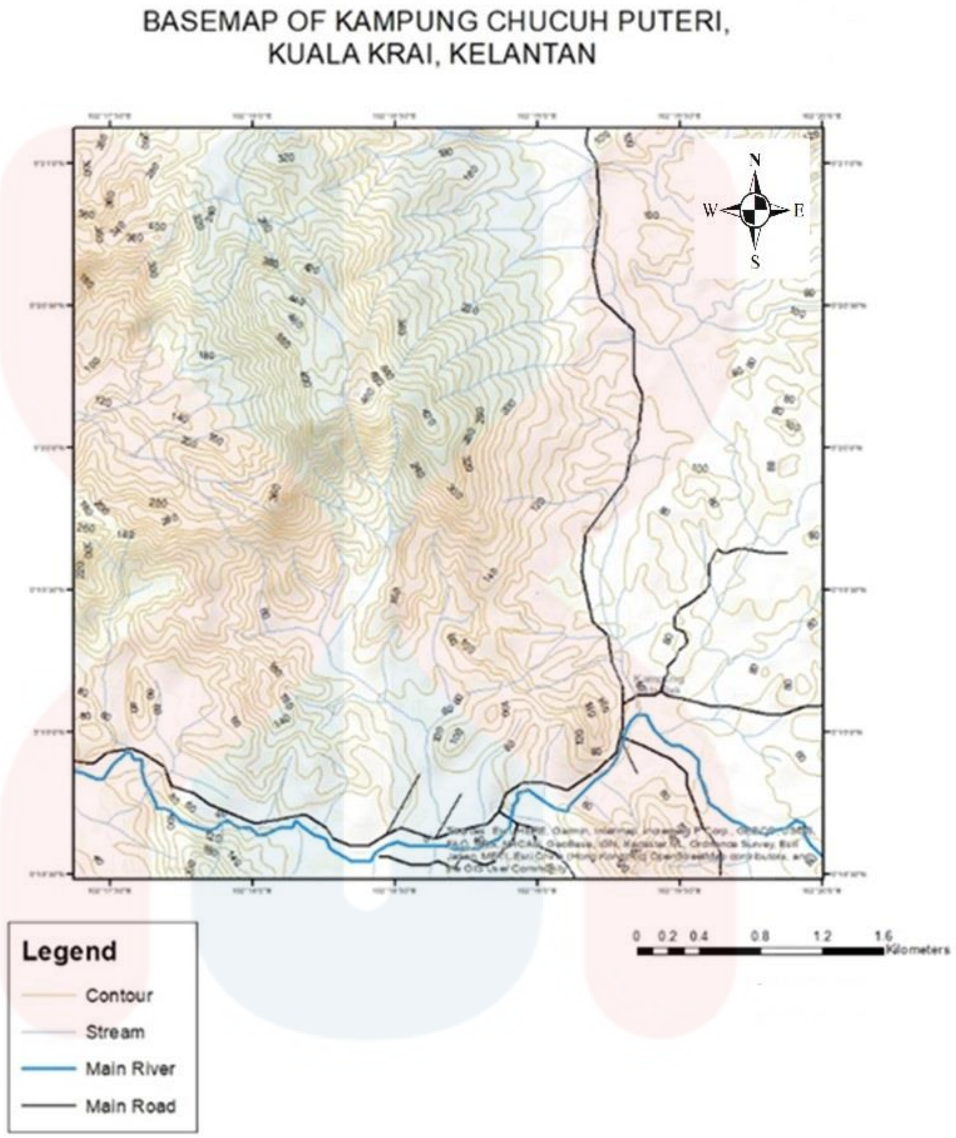


Figure 1. 2: Base map of study area.

1.2.2. Road Accessibility

Kuala Krai's town is in the coterminous Kuala Krai District in southern-central Kelantan, Malaysia. The research area of Kg Chuchuh Puteri is easily accessible due to the area's developed and varied transportation network. Some remote areas can be reached by car and motorbike through a local road. From Universiti Malaysia Kelantan, Jeli to Chucuh Puteri, Kuala Krai Kelantan, it takes around 1 hour and 47 minutes to reach the destination via Lebuhraya Timur Barat Route 4 as indicated in Figure 1.3.

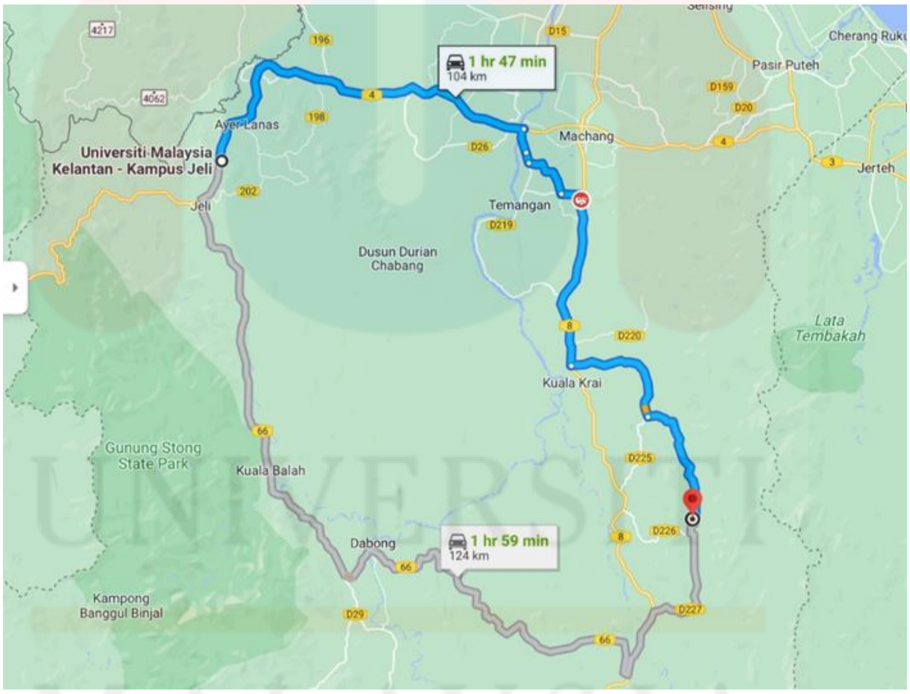


Figure 1. 3: Route from UMK Jeli to study area via driving.

1.2.3. Demography

According to Official Portal of Kuala Krai District Council, (2015), Kuala Krai Province is the second largest province in Kelantan after Gua Musang Province. The area of Kuala Krai Province is $2,329km^2$ or 910 square miles on the borders with Machang Province in the North and Gua Musang Province in the South. The total population of people in Kuala Krai in year 2020 is 105,007 people (Kuala Krai Background (2015).

1.2.4. Landuse

The study area is primarily characterized by a mix of land uses, including secondary forests, rubber and oil palm plantations, agricultural land, and permanent reserve forests. Additionally, there are several indications of development in the area, such as the presence of infrastructure like hospitals, libraries, schools, and commercial areas in Kuala Krai, which were not be found in other rural locations.

1.2.5. Sosial Economic

Agriculture provides the most significant source of revenue in the study area. At the period, rubber manufacturing was becoming increasingly significant throughout Malaysia, and many rubber-tree plantations were established in this area. Later, oil palm plantations were established in the territory, some of which replaced rubber. Most of the people who live in the area are either self-employed or work as laborer.

1.3. Problem Statement

In the studied area, there is one previous researcher nearby the study area. The study for geology of Guchil, Kuala Krai, Kelantan was carried out approximately 25 km ^{2} in and around Guchil. Preliminary research and field studies conducted to produce geological map of Guchil, Kuala krai, Kelantan. Based on the field study carried, carbonaceous mudstone interbedded with greywacke sandstone, shale and ignimbrite distribution of rock found in thay study. The study was carried out in the year of 2021 by R Krishnan et al 2021. The Guchil location is nearby Kampung Chucuh Puteri and there are no updates on geological information about 3 years.

There were some problems statements that needed to be highlighted in this study. Geological data in the study area was incomplete and have less information regarding the geomorphological aspect. Through the geological mapping and observation, the geological map of the study area can be updated.

Next, the lack of study regarding the landslide hazard of that particular area become one of the issue that needs to be highlighted. Due to the improper of strategic planning and mitigation of landslide, the landslide will easily occur and harm the community. Therefore, landslide hazard zonation techniques can be implementing to come out with a proper mitigation and prevention.

Landslides occur due to the combination of internal and external triggering factors. The lack of past research about the landslide hazard zonation in the study area tend to become the problem and difficulties. The landslide will easily occur because of poor strategic planning and mitigation of the landslide. As a result, the susceptibility of people's lives and property to landslides in the region need quick action (Syafril et.al, 2020).

It is critical to construct a new map in order to stay current in terms of landslide potential area. The advantages of conducting geological mapping on the landslide study are to always be prepared for potential geohazards that may occur specifically on the study area because Kelantan is one of the states in Malaysia that experiences monsoon, which may have an even greater impact on potential landslide incidents. Works by Hashim et al (2017), have shown that the combination of satellite remote sensing with GIS techniques are among useful approaches for mapping landslides and identifying high potential risk and vulnerable zones in tropical environments.

1.4. Objective

The objectives of the research are as follows:

1. To generate geological map of Kampung Chucuh Puteri, Kuala Krai, Kelantan with scale 1: 25 000.
2. To identify the causative factor that may be triggering a landslide.
3. To produce a Landslide Hazard Zonation (LHZ) map of Kampung Chucuh Puteri, Kuala Krai, Kelantan.

1.5. Scope of Study

The Weighted Overlay Map method is a GIS-based technique that combines multiple layers of data, each representing a specific variable, to create a single composite map that shows the spatial distribution of the hazard. This method is often used for creating a landslide hazard map, as it allows for the integration of various data sources, including topography, geology, soil type, vegetation cover, and precipitation, to produce a comprehensive and accurate assessment of the hazard.

Compared to other methods, the Weighted Overlay Map method offers several advantages. One advantage is that it allows for the incorporation of multiple factors that contribute to landslide hazards, which can help to create a more nuanced and accurate hazard map. Additionally, the method allows for the use of different weighting schemes to assign relative importance to each variable based on their perceived significance in contributing to the hazard.

Other methods for creating a landslide hazard map may include statistical analysis, empirical models, or expert knowledge-based approaches. However, these methods may not account for the complex interactions between multiple variables and may be limited by the availability and quality of data.

Ultimately, the choice of method for creating a landslide hazard map will depend on the specific research question, the type and quality of available data, and the suitability of the method for the research objectives. The Weighted Overlay Map method is one of several methods that can be used for creating a landslide hazard map and may be the most appropriate for certain research questions and data availability.

Additionally, this study presents a map that illustrates the zone of potential landslide hazards in the study area. The process of creating this map involved using GIS and the Weighted Overlay Method to analysed parameters like slope, aspect, land use, drainage density and elevation. This information, including the elevation, slope and land use data, were gathered from the United States Geological Survey (USGS) as secondary data.

There are several reasons why one might choose to use USGS (United States Geological Survey) data as a secondary data source. One reason is that USGS is a highly reputable and established organization with a long history of collecting and providing accurate geospatial data. Additionally, USGS data is often freely available and easily accessible to the public, making it a convenient and cost-effective option for researchers.

It's worth noting that while USGS data is generally considered to be highly accurate, it's important to carefully evaluate any secondary data source to ensure that it's appropriate for your specific research needs. Different government agencies may collect and report data differently, and there may be limitations or biases in the data that could affect its accuracy or applicability to your research.

1.6. Significance of Study

The updated geological map and potential landslide map can be beneficial to a variety of individuals and organizations. Some potential benefits include future academics and researchers may use the updated geological and potential landslide maps as a source of information for conducting their own research on the geology and hazards in the area. This could help to expand knowledge on the geological and geohazard characteristics of the region, Local authorities such as JMG (Department of Minerals and Geoscience), JKR (Public Works Department), and JPBD (Department of Town and Country Planning) may use the updated geological and potential landslide maps to inform land-use planning and development decisions.

These maps could help local authorities to identify areas that are vulnerable to landslides and adjust development plans accordingly, potentially reducing the risk of damage or loss of life from landslides. State governments could benefit from the updated geological and potential landslide maps in a similar way to local authorities. These maps could be used to inform land-use planning, infrastructure development, and emergency preparedness efforts.

Overall, the updated geological and potential landslide maps can provide valuable information for a wide range of individuals and organizations, potentially leading to more informed decision-making and improved safety in the area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, a summary of prior research in the study area or similar studies conducted by other researchers is presented. The purpose of the literature review is to provide rationale for the methods and techniques that will be employed in this study. Additionally, this chapter provides an overview of the regional geology of Chucuh Puteri, Kuala Krai, including details about stratigraphy and structural geology, as well as a detailed examination of the landslides in the area.

2.2 Regional Setting and Tectonic Setting

Kuala Krai is a town located in the state of Kelantan in northeastern Peninsular Malaysia. Geologically, the area is part of the Sunda Block, which is a stable continental block that includes most of mainland Southeast Asia. The tectonic setting of Kuala Krai is relatively stable, with no active plate boundaries or significant seismic activity in the area. The region is characterized by low seismic activity, and no major earthquakes or volcanic eruptions have been recorded in the area in recent history (Pour and Hashim, 2015).

The local geology of Kuala Krai is dominated by sedimentary rocks, which were deposited during the Mesozoic and Cenozoic eras. The oldest rocks in the area are Permian to Triassic in age and consist of sandstones, shales, and conglomerates. These rocks are overlain by Jurassic to Cretaceous sandstones and shales, which are the primary source rocks for oil and gas in the region. Quaternary alluvial deposits, which are relatively recent in age, are also present in the area and form the fertile floodplains along the Krai River (Bakhshipour et al., 2013).

In summary, Kuala Krai is located within the stable Sunda Block, and is characterized by low seismic activity and a geology dominated by Mesozoic and Cenozoic sedimentary rocks (Pour and Hashim, 2015). The western tin belt, the central gold belt, and the eastern tin belt were all based on stratigraphy and mineralization.

According to Metcalfe (2016), the Malay Peninsula is divided into three north-south belts based on major distinctions in stratigraphy, structure, magmatism, geophysical signals, Western, Central, and Eastern belts. The Central and Eastern Belts form the Sukhothai Arc, which was developed during the Late Carboniferous to Early Permian along the Indochina Block's southeastern edge. Peninsular Malaysia is located on the Sibumasu plate and is separated into two blocks by the Bentong-Raub suture, with the western portion belonging to the Sibumasu blocks and the eastern portion to the Indochina blocks (Bakhshipour et al., 2013).

According to Khoo and Tan (1983), the three planned subdivisions are Western Belt, Central Belt, and Eastern Belt. Following that, Khoo and Tan divided the island into two distinct sections known as the Kinta-Malacca sector and the northwest sector.

According to Tjia et al. (1974). The Peninsula has four structural domains: northwest, west, central, and eastern. The following are the four regions: The eastern and central belts are separated by the Lebir Fault zone, while the central and western bands are separated by the Hutchison Bentong-Raub line. The eastern and central belts are geographically separated from one another.

2.3 Stratigraphy

According to Goh et.al., (2006), the Main Range Granite of the Stong Complex includes the existence of the Dabong area with intrusive igneous rocks, sedimentary rocks, and metamorphic rocks nearby. The Dabong area is located in Kelantan's southernmost section. Lower Paleozoic rocks (west portion of southern Kelantan), Permian-Triassic rocks (middle part of southern Kelantan), and Jurassic-Carbonaceous rocks make up the southern section of Kelantan (eastern part of southern Kelantan). The Stong Complex, located north of Dabong, is made up of three plutonic components (in descending age order): Berangkat Tonalite, Kenerong Micro-granite, and Noring Granite. Both the first and second components of Berangkat Tonalite and Kenerong Micro-granite are severely foliated and distorted. Berangkat Tonalite, Noring Granite, and Kenerong Leucogranite are the three lithodemic units that make up the Stong Complex.

2.4 Structural Geology

Goh et.al., (2006) stated that the Main Range Granite of the Stong Complex includes the existence of the Dabong area with intrusive igneous rocks, sedimentary rocks, and metamorphic rocks nearby. The Dabong area is located in Kelantan's southernmost section. Lower Paleozoic rocks (west portion of southern Kelantan), Permian-Triassic rocks (middle part of southern Kelantan), and Jurassic-Carbonaceous rocks make up the southern section of Kelantan (eastern part of southern Kelantan). The Stong Complex, located north of Dabong, is made up of three plutonic components (in descending age order): Berangkat Tonalite, Kenerong Micro-granite, and Noring Granite. Both the first and second components of Berangkat Tonalite and Kenerong Micro-granite are severely foliated and distorted

As mentioned by Gobbett (1973), the overall pattern of Gua Musang's major tectonics mimics the minor effects, which include tight concentric folds, asymmetric, recumbent, and overfolds. Minor faults occurred with a northward tendency. The strata are structurally oriented north to northwest. It is made up of several parts

2.5 Historical Geology

A significant portion of the Peninsula's newly created landmass was raised during the start of the Mesozoic Era and exposed to the atmosphere. Two examples are Kodiang-Semanggol in the northern depocenter and Gua Musang in the central depocenter and Semantan were founded on naval sedimentation (Gobbett, 1974).

The former was erected on the Upper Palaeozoic Sibumasu continent and was the sole one. In the Late Palaeozoic, there was a huge marine deposition region. The

Gua Musang-Semantan depocenter was expanded and relocated to East Malaya's Upper Peninsula. The Paleozoic shelfs. During the Triassic period, in the Gua Musang-Semantan depocenter, tuff and associated lava and tuffaceous siliciclastic and the presence of conglomerate indicates that volcanic activity and basinal instability were involved during the basin's lifetime Turbidite accumulations have resulted in the deepest parts of the Gua Musang-I, geologists refer to the rocks as flysch, (Gobbett,1973).

The Stong Complex is made up of three granitic masses that are found in Permian metamorphic, metasedimentary, and meta-volcanic rocks. Taku Schist's formation is separated from the overlaying rocks by a belt of greenschist facies phyllite, marble, and metavolcanic rocks. The fossils discovered in these rocks may be lost as a result of metamorphism. However, the greenschist facies of the Gua Musang Formation, which possesses lithology that is essentially identical to that of the Stong Complex, suggests that the time is Permian to Lower Triassic. The presence of major marble formations in the series suggests a link to the Gua Musang Formation, which occurs directly to the south. Dabong, about 10 kilometers distant, has limestone hills that are part of the Gua Musang Limestone Aggregates.

2.6 Research Specification

2.6.1 Landslide

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

Haque et al., (2016) clearly described that landslide phenomena are a significant natural hazard frequently caused by intense rainfall and powerful earthquakes. Landslides pose a significant threat to human life and the natural environment, as well as commercial and public infrastructure, and have a substantial economic impact.

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

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

Landslides are generally caused by elements that trigger geohazards, such as geomorphology parameters, where structures with greater structure, such as hills and mountains, may have potential landslides compared to low land area. Aside from that, the variables of soil erosion caused by extreme rainfall contribute to unsaturated soils breaking apart as a result of the high intensity and extended rainfall (Gerome, 2009).

2.6.2 Landslide Hazard Zonation

Based on the research by Mohd Shariffuddin & Sofia Udin, (2020), The characteristics that caused the landslide to occur were established, and the landslide susceptibility map was created in ArcGIS software using the Weightage Overlay Method (WOM). The susceptibility map was divided into three zones based on the results: low, moderate, and high. Heavy rainfall intensity and an earthquake were recognized as the factors that caused the landslide. The capacity to detect landslide susceptibility leads to a better understanding of landslide mechanisms for the research region, allowing for a more accurate identification of the most likely failure sites within a landslide-prone area.

Landslides are the most destructive geological hazard in the hilly regions. There must be a systematic approach to land-slide mitigation and management. Landslide appraisal and zonation procedures have been developed over the past few decades. It's possible to divide these methods into qualitative and quantitative approaches in broad strokes. In contrast to quantitative approaches, which include statistical, artificial intelligence, and deterministic techniques, qualitative approaches include geomorphological study. Landslide susceptibility can be predicted quantitatively by using real-world data and their interpretations. The subjectivity inherent in qualitative methods is likewise dispelled by quantitative methods. Each of these methods can consider a variety of elements and employ a variety of methods for evaluating and analyzing those factors (Shano et al., 2020)

Based on Norhisham and Roslee, (2019), among the factors that contribute to geohazards, including slope gradient, elevation, topographic curvature, flow accumulation, and drainage distance, were retrieved from the topographic database, while land use, precipitation, soil types, and soil properties were obtained from various agencies. Several areas are deemed vulnerable in the study area. Future development planning can utilize the landslide susceptibility map to give a few structural controls that can be implemented, such as land use planning and hazard zoning. The findings can serve as a resource for consulting firms, planning agencies, and local governments engaged in risk management, land-use zoning, and risk mitigation efforts

For landslide studies, it is commonly considered that the combination of these elements may cause landslides in a particular location. Evaluation of these parameters and their relationship with historical landslides in a region may therefore serve as a foundation for predicting future landslides (Chimidi et al., 2017). These strategies should take into account distinct causal variables and employs distinct methods for factor assessment and analysis.

2.6.3 GIS Application in Landslide Hazard Zonation (LHZ)

GIS has been proven to be more useful for spatially evaluating landslide distribution by superimposing maps of elements influencing landslide incidence. In the construction of landslide susceptibility maps, remote sensing and GIS are crucial analytical tools for this danger (LHZ). GIS is a computer-based technique for mapping and interpreting events and objects on Earth.

According to works by Syafril et al. in 2020, the Weighted Overlay Method (WOM) was applied using GIS to create a landslide hazard zonation map. The causes of landslides were evaluated and superimposed on the map. The data used were extracted from Digital Elevation Model (DEM) The study revealed that the area is classified into five hazard zones, with class 1 indicating no hazard, class 2 indicating moderate hazard, class 3 indicating a medium hazard, class 4 indicating a high hazard, and class 5 indicating the highest hazard. According to the landslide hazard zonation map, the study area had a low hazard of landslide and a low probability of landslides occurring.

According to a study by Udin and Razmi in 2022, the Weighted Overlay Method (WOM) was applied in conjunction with GIS to research landslides in Kampung Renok Baru, Gua Musang. The research calculated the density of landslides caused by each identified factor, and created a generic prediction to rate the likelihood of landslides caused by these factors in similar settings. The causative factors were then integrated and weighted to construct a landslide susceptibility map, which was divided into three categories based on the level of hazard: minimal, medium, and severe. The resulting map can be used by decision makers to plan land use and mitigate the risk of landslides in the area.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This section discussed the various materials and procedures utilized to accomplish this research. Every information and data collection collected through geological mapping and field survey were recorded, and all outcrop photographs were used as references. The flowchart of overall research methodology is indicated in Figure 3.1.

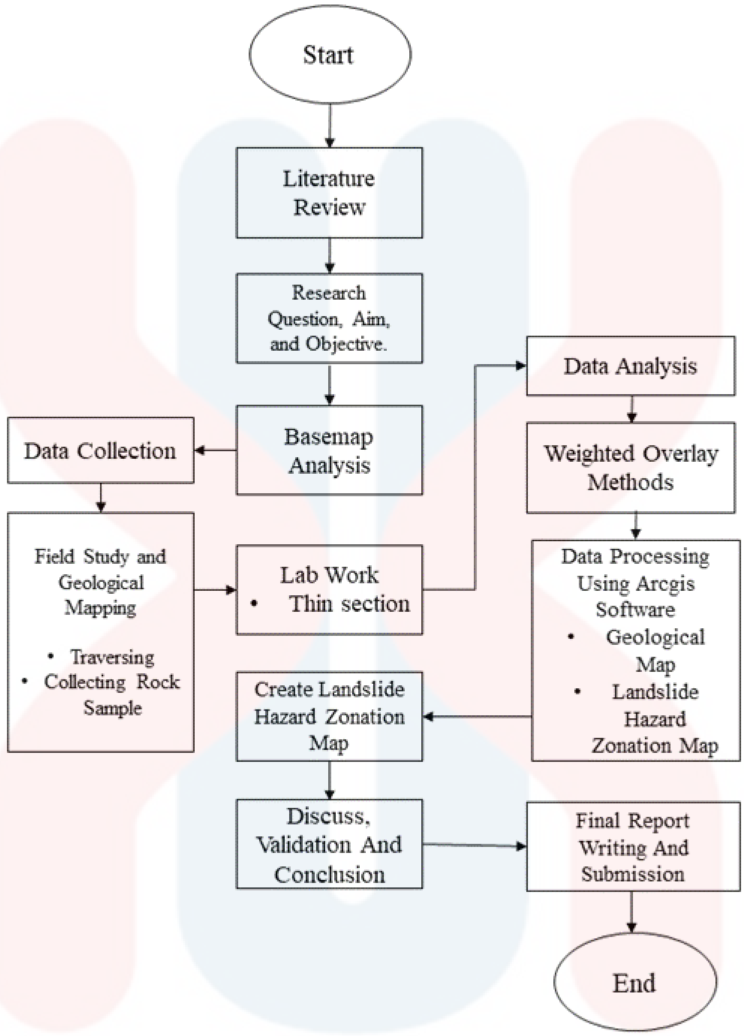


Figure 3. 1: Flowchart of overall research methodology.

3.2 Materials

In geological mapping, preliminary geological interpretation began with the use of a topographic map to record the location of points of interest in the field, as well as data and information about the research region. Several mapping equipment were used such as tip-point hammer, Brunton compass, HCL, 50-meter measuring tape, GPS, sample plastic and hand lens. To create the Landslide Hazard Zonation (LHZ) map, all relevant data and information for assessing the risk of landslide was acquired from both primary and secondary sources.

3.3.1. Materials for Geological Mapping

The function of fieldwork equipment are as follows:

a. GPS - GPS is a tool that navigate the location and use the map to find route in the study area. GPS accuracy depends on how many satellites work on a different place.

b. Brunton compass - Compass uses to measure the slope, strike and dip reading as it is very important to determine the rock formation and azimuth reading.

c. Tip-point hammer - A tip point hammer was utilized to shatter the rock sample on the exposed outcrop in the study area and also been used as scale to take picture of outcrop

d. Plastic - Plastic sample was used as a carriage for the fresh rock that been break by hammer and bring it back as a sample for study.

e. Meter tape - Meter tape was used to measure the outcrops in the study area.

f. Hand lens - Hand lens was used as the tools to see the mineral composition in a rock that found during the field work.

g. HCL - The limestone rock was tested with hydrochloric acid. When it exhibits the reaction of gas bubbles and fizzy impact on the rock, it determines if it is a carbonate rock.

3.3.1. Materials for Landslide Hazard Zonation Map

ArcGIS is required to create the research area's base map. All secondary data were sent to the ArcGIS software, which was used to create a geology and flood hazard map of the research area. Flood hazard map was created in ArcGIS software using the Weighted Overlay Method tool.

To create the landslide hazard zonation map, it is crucial to collect the secondary data of satellite images, topographic data and Digital Elevation Model (DEM). The secondary data from gain from geological mapping and agencies such as The United States Geological Survey (USGS) were extracted to create the slope and aspect, elevation, drainage, and land cover map.

a. Digital Elevation Model (DEM)

A Digital Elevation Model is employed to examine the relationship between the terrain's geomorphological characteristics and underlying geology. Elevation information was utilized to generate maps of elevation and slope. Figure 3.2 shows High-resolution data, obtained from the Shuttle Radar Topography Mission's was retrieved from the U.S Geological Survey's Earth Explorer website with a horizontal resolution of 30 meters from year 2014. This data was used to compare with the developed DEM for the specific flood plain area under examination

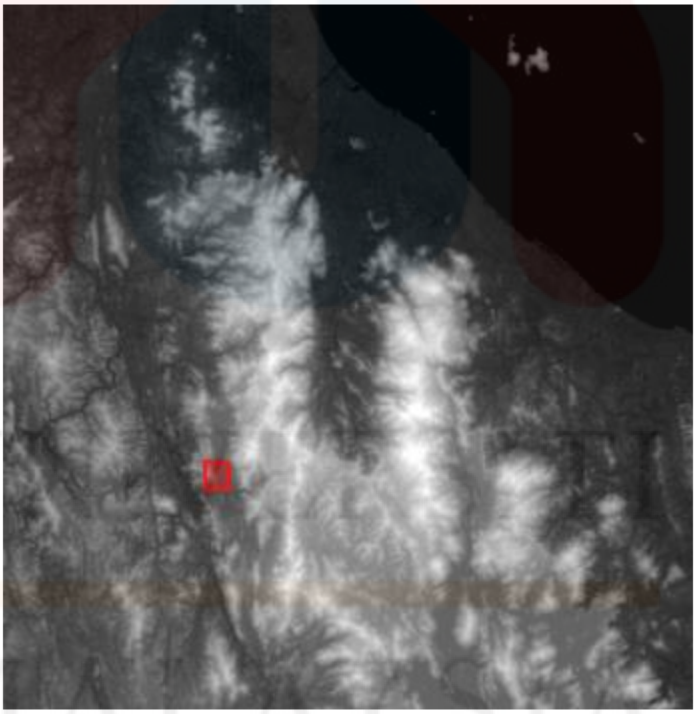


Figure 3. 2: SRTM with red box of study area.

b. Satellite Imageries

Satellite imagery plays a vital role in identifying potential landslides risk areas and monitoring landslides that have occurred. Geologists and scientists use satellite images to analyze the changes in land cover, vegetation, and topography, which are key indicators of a landslide. In this study, satellite imagery was used to produce slope, aspect and land use map. Through satellite imagery, the areas where vegetation is no longer present and assess the risk of landslides can be observed. The satellite imagery was taken from Google Earth Pro 2023 with year of 2019 and 30 meters of resolution. All data that gathered will be processed in ArcGIS software.

c. Topographic map

Topographic maps are important tools for identifying areas at risk of landslides by providing information about the geology and topography of an area. Topographic maps show elevation, contours and landforms, useful for identifying steep slopes susceptible to landslides. Together, these maps can help identify areas at high risk of landslides, enabling targeted risk management and mitigation efforts. The topographic map was created in ArcGIS software and the data is collected from secondary data such as from DEM of the study area.

3.3 Methodology

The geological mapping for this research work was mostly based on fieldwork. This included collecting samples from fresh outcrops, recording structural trends in rocks, and making other field observations like geomorphological features, drainage patterns, and others. All of this field data, including the petrographic studies, was then put into an ArcGIS-based platform and used to make geological and other thematic maps.

For landslide study, an integrated approach of WOM using GIS technology was applied using several parameters. The parameters were extracted using Digital Elevation Model (DEM) data. An overlay and raster calculation in GIS was used to generate final results of landslide hazard map of Kuala Krai which have different classes; class 1 represents no hazard, class 2 represents a moderate hazard, class 3 represents a medium hazard, class 4 represents a high hazard, and class 5 represents the highest hazard.

3.3.1. Preliminary Studies

Before begin the research, all of the necessary information was gathered and thoroughly understood by doing preliminary study. To fill the research gap and determine which data have not yet been studied, existing research data connected to landslide hazard zonation must be evaluated. Research project analysis might be disrupted if the references are not prepared in advance, thus it is essential that they be always remains on track.

3.3.2 Field Studies

For field studies, there are three things to be highlighted which is traversing, sample collecting and conducting interview. As for the traversing, it covers the 5km x 5km of study area. Traversing approach can regulate the observation conducted at an outcrop. Geological data of the area such as structure, joint, faulting at the outcrop were collected. Then, the lithology of the area can be recognized, and it allow the determination causative factor of landslide hazard zonation. Next, sampling process is needed for laboratory work. The fresh rock sample were taken from the outcrop as it can help on determined the formation and lithology of the study area.

3.3.3 Laboratory Work

In petrological studies, minerals are identified based on their texture, clast, matric, twinning, and crystal structure. A lab investigation was done on the rock sample. At first, the rock was cut into smaller pieces. After that, the rock was ground and polished. After being ground a few times, it looked like a thin section. A thin slice of the rock sample is cut so that it can be seen through a microscope. The texture of the rock was looked at with a polarized microscope. Under a polarized microscope, the thin section used to observe the rock. A fresh sample can help make a better observation because minerals are easier to see in a thin slice meanwhile, weathered rock affect the result of the thin section analysis.

3.3.4 Data Processing

a. Methods for Landslide Hazard Zonation Map.

The USGS satellite images were obtained. The satellite image data was used to create a digital point database. On the other hand, information gathered during the site investigations and derived from satellite data were combined to produce a precise weighted score for each causative factor and their respective subclasses.

b. Evaluation of causative factors and landslide distribution.

The following five key causative components were evaluated during the current research of landslide hazard evaluation: slope and aspect, elevation, drainage, and land cover. These cause factors were addressed based on recent landslide observations and their likely contribution to slope instability in the area

c. Landslide hazard zonation map.

The WOM was used for landslide hazard zonation. All the causative factors were mapped and converted into raster from the satellite image and data collection. The raster was then weighted. Table 3.1 shows the landslide hazard zonation classes with its percentage. The evaluation scale must be created, for example, scale 4 being the most landslide hazard area and scale 1 being the least landslide hazard area. Every raster can be weighted by a percentage value based on its importance. The raster's total influence must be equal to 100%. The hazard index is shown in Table 3.2, along with the hazard class name. Finally, validations of the landslide hazard zonation map were performed using field observations.

Table 3. 1: The landslide susceptibility classes with percentage.

Landslide hazard zonation classes	**Percentage of landslide pixels (%)**	**Percentage of class area (%)**
Very low	4.65	12.28
Low	7.31	19.04
Moderate	15.09	25.63
High	34.86	25.66
Very high	38.09	11.39
Total	100.00	100.00

3.3.5 Data Analysis and Interpretation

Geological mapping comprises travelling and sampling and records all geological characteristics and components. To update the research area, data was analyzed. ArcGIS 10.8 was used to update a 5x 5 km geological map of Chucuh Puteri, Kuala Krai, Kelantan. A revised geological map of the research region includes updated geological data such as rock boundary and deformation, lithology, and dip direction.

To create the landslide hazard zonation map, the raster layer of slope and aspect, elevation, drainage, and land cover were all generated using the DEM. Layering approaches were weighted based on raster input from all the data. ArcMap's reclassification tools were used to reclassify the weight for the purposes of this weight assessment.

The final findings in this research are an updated 1:25,000-scale geological map of Chucuh Puteri, Kuala krai, Kelantan. There would be lithology information on geological maps, such as the distribution of various rock types and the positions of geologic features such as faults and folds. In addition, a Landslide Hazard Zonation (LHZ) map was generated at the end of this research using the landslide hazard index classification. This LHZ map would provide a clear visual and prediction for a landslide event to occur at a specific area of study by providing early awareness based on the map's various colors

CHAPTER 4

GENERAL GEOLOGY

4.1. Introduction

These general geology segments include components of geological mapping such as geomorphology, structural geology, stratigraphy, and historical geology of the area under study. By comparing and correlating all the previous research studies, as well as the general knowledge that is based on the paper, journal, and other publications where all of the data that was obtained is analysed.

4.1.1. Brief Content

The study of geomorphology entails research on the surface of the Earth, as well as its drainage, contour pattern, weathering, and the processes that led to the formation and development of the Earth. The topography and drainage pattern are also featured in the research, which is another important aspect.

In the meantime, stratigraphy involves both the process of generating a geological map of the area under study as well as determining the types of lithologies that are present. It is just as essential as being familiar with the historical geology of the area, from which one can learn about the depositional environment and its formations. In structural geology, any geological structure that could be verified at the study area, such as a fault, fault, or other mechanism of structure, could be a head up start to any forces that were exerted on that area. This is because any geological structure that could be verified at the study area is a geological structure. Aside from that, the historical geology of the study area was debated, and it varied from the formation and deformation of the Earth at that location based on the lithologies

4.1.2. Accessibility

Kuala Krai is a town in the Kuala Krai District in southern-central Kelantan, Malaysia. The location of the research region is easily accessible due to the area's developed and varied transportation network. Some remote areas are accessible by car and motorcycle through a local road. From Universiti Malaysia Kelantan, Jeli to Chucuh Puteri, Kuala Krai Kelantan, it takes approximately 1 hour and 47 minutes through Lebuhraya Timur Barat Route to reach the destination.

4.1.3. Settlement

The study area is in the centre of villages which Kampung Kampung Sg. Sok and Kampung Lata Rex. Most villagers are local Malay. The majority of them make a living by tapping rubber and run their own business.

4.1.4. Forestry

The study area is included in Hutan Simpan Lata Rex. The forest in the study area is classified as high - density. This is due to the dense vegetation, which contains a wide range of plant species. Most of the study area consists of plantations, primarily of oil palm trees and rubber trees. In addition, some of the locals in the research area work at the logging factory.

4.2. Geomorphology

Geomorphology is a crucial component in the assessment of geological mapping because it has the potential to characterise the physical structure or characteristics of the Earth's landforms, including rivers, hills, plains, and other landforms. The processes that led to the formation of these kinds of landforms are likewise the subject of study within the research area.

4.2.1. Geomorphologic Classification

Geomorphologic classification is one component of geomorphology that refers to the observation of landforms in the research area. The main landform in the study region is reserved forest and rubber tree-covered hills. A few hills in the research region have been deforested. Furthermore, the elevation and position of surface characteristics were determined.

Topography is the primary focus, and contour lines are crucial features in landform. The contour line is the horizontal line in the imagery that connects all spots with the same elevation value. The maximum height in the research area is 490m, while the lowest is 20m, which falls within the range of a hill. The contour pattern of the research area is close together, indicating that it is a hilly location. There is additional region of low elevation at the right side of the study area.

Other natural features found in the study region include a valley and a stream. Figure 4.1 illustrates the hill that constituted the topography of the study region. Approximately 60% of the study area is covered by hill with rubber tree. Figure 4.3 displays the geomorphology map. The green colours on the map show the low height, which is practically flat area. The orange show the medium elevation area while red colours show the high elevation which is the hilly area and Figure 4.2 shows geomorphology of study area.

Figure 4. 1: Geomorphology of study area

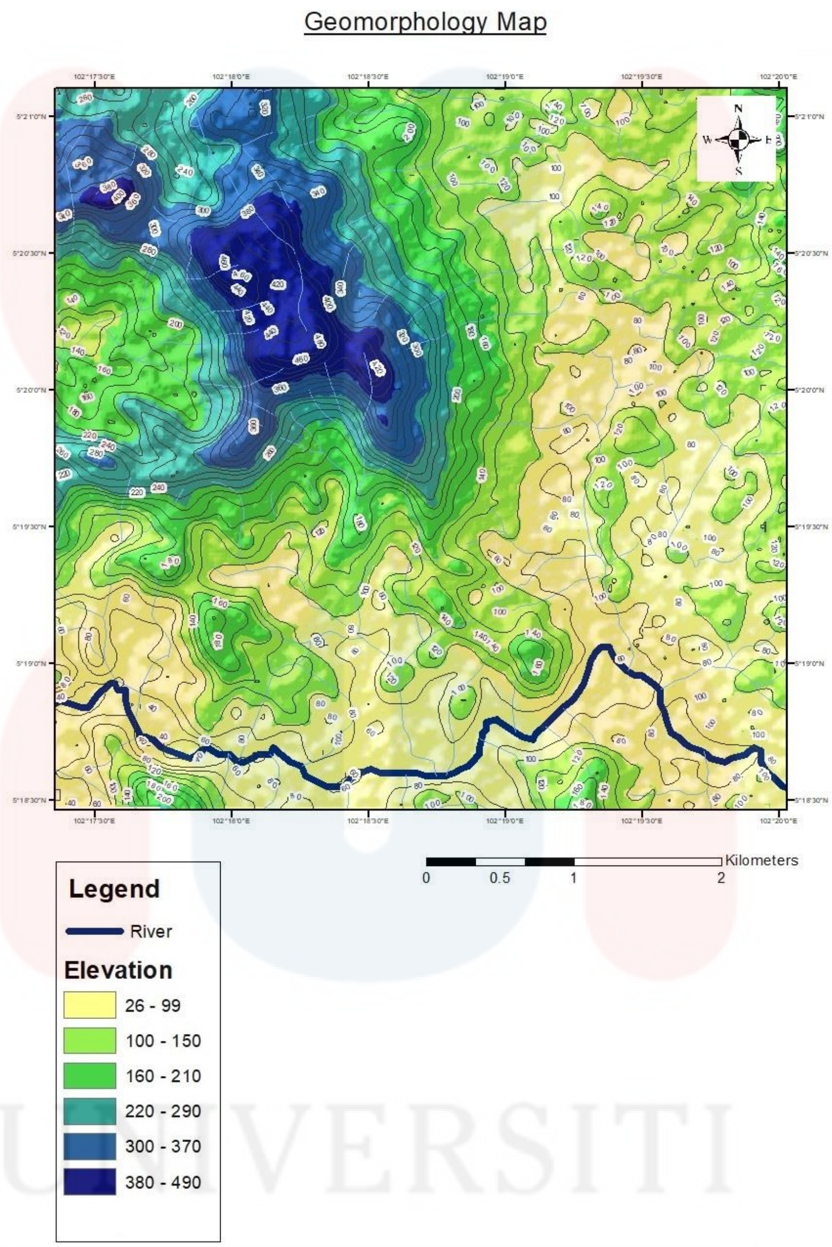


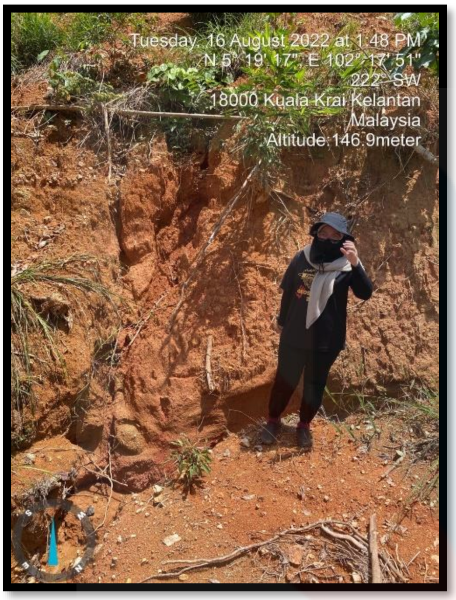
Figure 4. 2: Geomorphology map

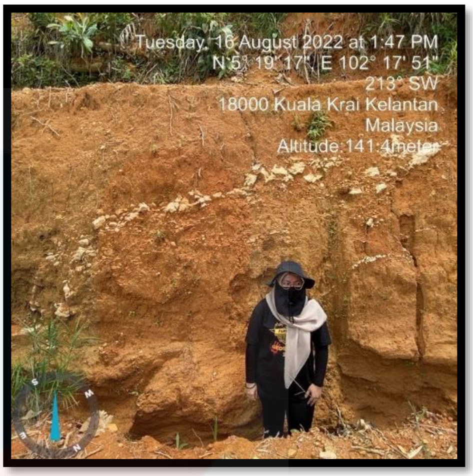
4.2.2. Weathering

Weathering is the physical breakdown and chemical transformation of rocks and minerals at or near the Earth's surface. Landforms on the surface of the earth are mostly impacted by weathering and erosion. Physical, chemical, and biological forces acting on the rock cause weathering. The lithology, climate, terrain, and groundwater are only a few of the variables that have an impact on the pace of weathering. There are three type of weathering which was physical weathering, chemical weathering, and biological weathering.

Firstly, physical weathering is responsible for the disintegration of rocks without chemical alterations. The primary process in physical weathering is abrasion. Weathering physically can happen because of temperature, pressure, frost, etc. For instance, the surface area exposed to chemical action will increase in cracks that are exploited by physical weathering. Additionally, the process of disintegration may be aided by the chemical reaction of minerals in cracks.

Much of the outcrop in the field was weathered. Weathering in the study area is primarily chemical and biological. Malaysia has a high weathering rate because it is located near the equator and has a tropical climate that is hot and humid all year. Figure 4.3(a) shows the chemical weathered outcrop at the study area. This happens as a result of atmospheric chemicals acting directly on the rock surfaces. Tropical, hot, and humid areas are the ones most prone to experience this type of weathering. Figure 4.3(b) displays an outcrop where chemical weathering had broken the outcrop's rocks into tiny pieces and entirely weathered the outcrop grade to residual soil.





(a) **(b)**

Figure 4. 3(a) & (b): The chemical weathered outcrop at the study area.

Lastly, biological weathering occurs when a force or pressure is applied to break rocks apart or degrade the minerals in them. Increasing the exposed surface area of rocks allows other physical factors to accelerate their degradation. If there is water, plants are able to thrive in almost any environment. Growing into the fissures and cracks in rocks and soil, the roots of trees and other plants can organically break down rocks as they do so by growing into them. Figure 4.4 shows the biological weathering occurs at the study area.

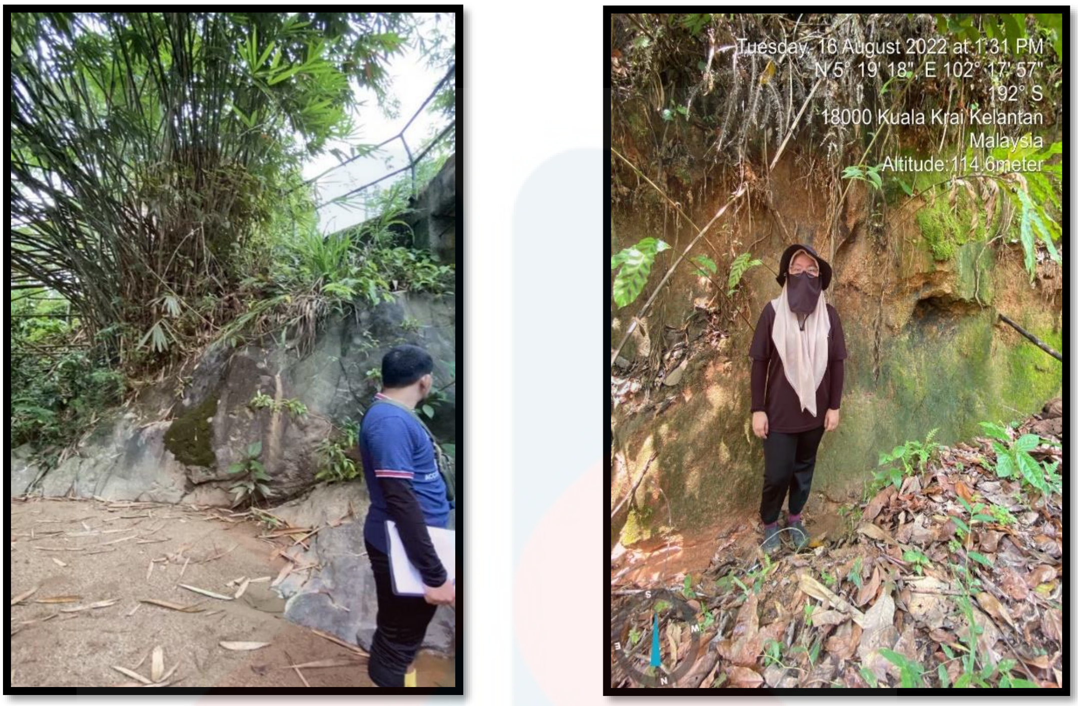


Figure 4. 4: The biological weathered outcrop at the study area

4.2.3. Drainage Pattern

Drainage pattern is another aspect covered in geomorphology. Drainage pattern formed from the flow of streams. These patterns develop because of the landform of the area, whether high or low, the gradient of the area, and the types of rock, whether soft or hard. A high gradient area allows water to flow downward, resulting in drainage patterns, whereas a low gradient area allows water to flow to the reservoir. Meanwhile, when there is soft rock, water flows easily, and where there is hard rock, water flows gradually. There are several sorts of drainage patterns, including dendritic, parallel, rectangular, tells, radial, annual, internal, and contorted.

There are three drainage pattern that have been observe in the study area which was dendritic, sub-dendritic and parallel. Figure 4.5 shows the drainage map at the study area. The dendritic pattern is the most common type of drainage pattern, and it looks like the branches of trees connected together. It came into existence because of the river canal following the slope of the surrounding terrain. The lithology that supports this pattern is composed of a single component over its entirety.

The parallel drainage pattern refers to a network of rivers that are generated by steep slopes that also have some type of relief. Because of the steep slopes, the streams are both quick and straight, and there are a few tributaries that flow in the same direction as the mainstream. When there is a significant slope in the soil, many drainage patterns can begin to evolve all at once. In landform zones that are parallel to one another and elongated, a pattern that is comparable to outcropping resistant rock bands can also be found. The region or ridge of land that divides the water into distinct basins, rivers, or seas is referred to as the watershed. It is possible to think of the watershed as a region. It also includes lakes, reservoirs, rivers, and wetlands, in addition to the groundwater that surrounds these features.

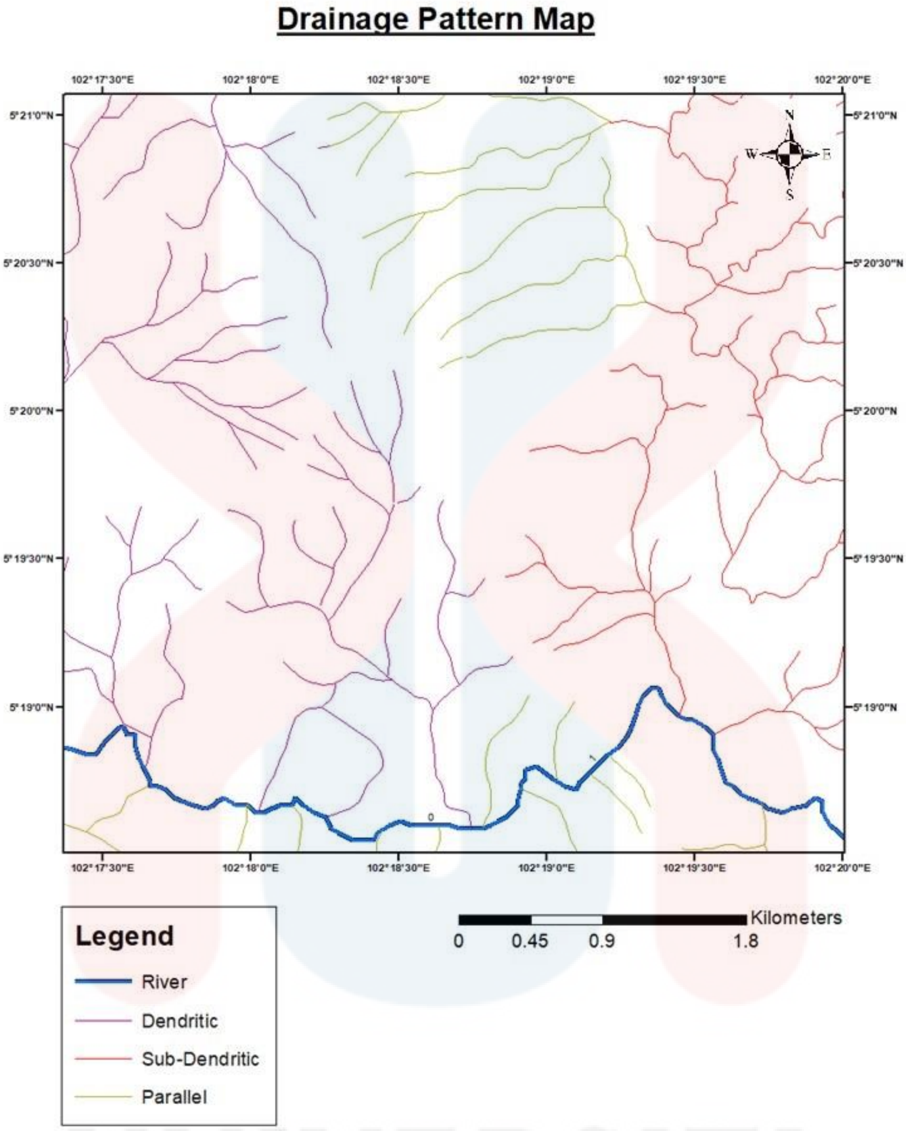


Figure 4. 5: Drainage map of the study area.

4.3. Lithostratigraphy

Stratigraphy is the application of the Law of Superposition to the layers of soil which said that the rocks at the bottom layer are older than the rocks at the top layer unless certain conditions event are occur. Furthermore, the geological strata also can be known the relative ages of layers from the archaeological materials such as fossil. This section only discussed about lithostratigraphy, which is the study of different types of rocks and its age that based on rock samples found in the study area.

Lithostratigraphy is a branch of geology that studies rock strata, relative and exact ages of rocks, and how layers fit together. Stratigraphy is a way to figure out what happened and what the environment was like on Earth by looking at the physical properties of the rocks and how the environment changed over time. This is because different events may have left different marks to be looked at.

Table 4.1 shows the lithostratigraphic units of the study area in the form of a stratigraphic column. The geology and stratigraphy of the study area are shown in a stratigraphic column. It is used to describe the rock unit's vertical position and as a guide for formations and their ages in the study area. A typical stratigraphic column shows the order of the rocks' ages, with the oldest rock at the bottom and the newest rock at the top.

Table 4. 1: The lithostratigraphic unit of the study area.

Era	Period	Formation	Lithology	Description
Palaeozoic	Triassic	Gua Musang Formation		Quartzite
	Permian			Granodiorite
				Granite

4.3.1. Stratigraphy Position

When a layer of rocks is defined by its lithology and closely correlated with age of the strata, this is known as stratigraphy or lithostratigraphy. Lithostratigraphy was required to ascertain the region's age and historical background. According to the local stratigraphy, rocks were classed based on their lithology. Figure 4.6 shows the lithology map of study area.

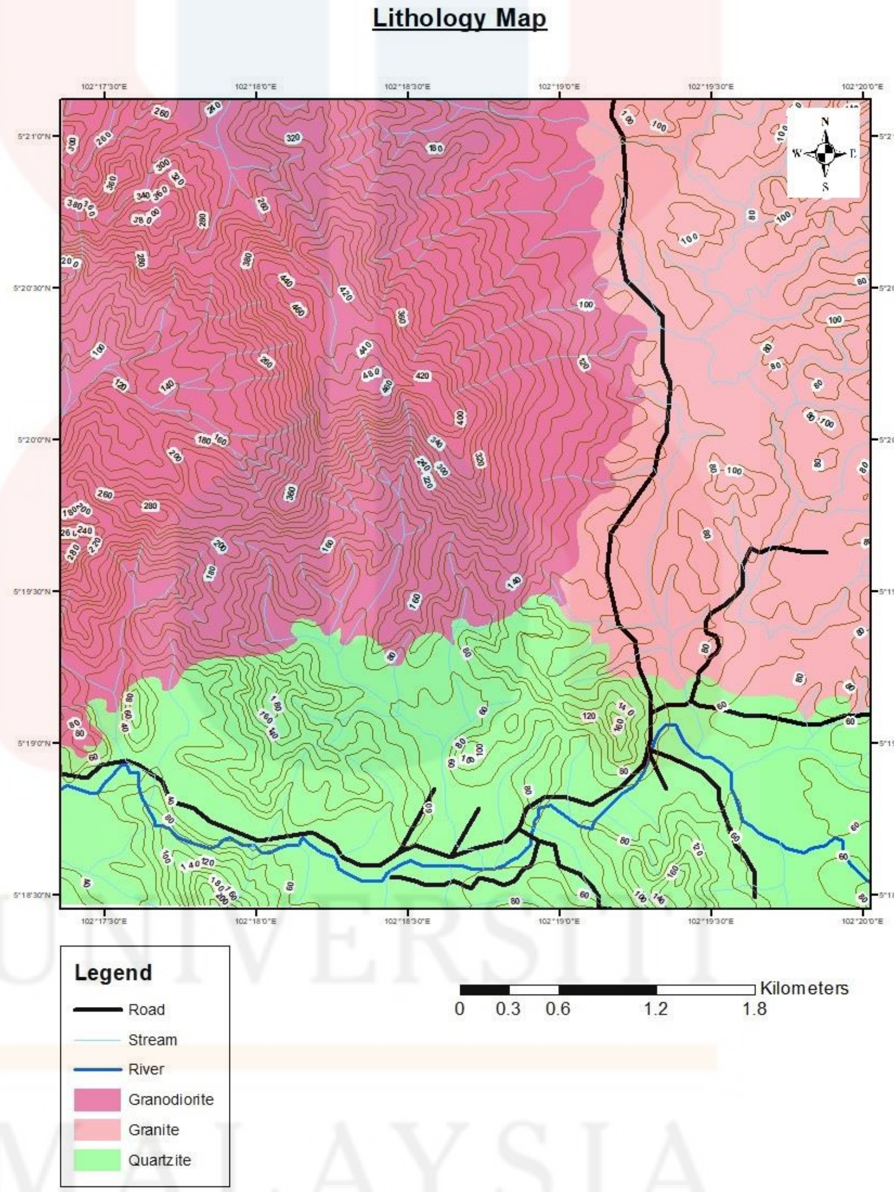


Figure 4. 6: Lithology map of study area.

4.3.2. Unit Explanation

The research region contains three major types of lithologies.

a. Quartzite

Quartzite covered 20% of the study area. It is located at 5.3111° N, 102.3440° E. Quartzite is a type of metamorphic rock that has a granoblastic texture and is compact, hard, non-foliated, medium to coarsely crystalline, and nearly mono-mineral. The process of recrystallization and loss of original forms and contacts of grain under high pressure and high temperature results in the isometric grain shape and their jagged contacts. Pure sandstone, siltstone, and hornfels are examples of sedimentary rocks rich in quartz from which the pure quartzite is formed. It has been found at the eastern part of the study area. Figure 4.7 shows the quartzite outcrop in the study area.

Figure 4. 7: The outcrop of quartzite in the study area.

b. Granite

Granite takes placed in the western part of the study area 40% percent of the study area is covered by granite. This outcrop is located at the coordinates 102°18'3"E, 5°18’3"N. The size of the outcrop is about 4km length and 2km width. The outcrop is located along the river. Figure 4.8 and 4.9 shows the granite outcrop in the study area.

Figure 4. 8: Hand specimen of quartzite.

The unit under the granite lithology is the hornfels. As the hornfels is not mappable under the 1:25000 scales, it was put under the granite unit. The hornfels is the contact between the metasedimentary rocks with the intrusion contact.

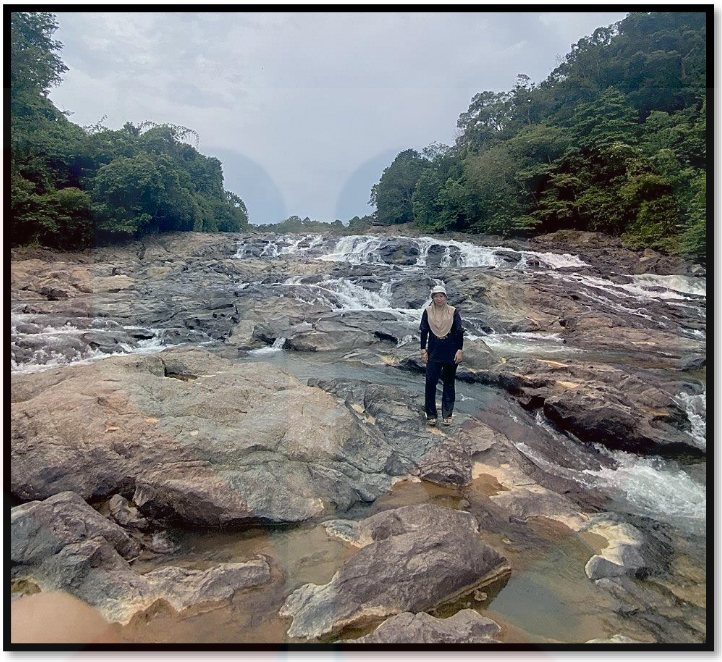


Figure 4. 9: The outcrop of granite in the study area.

Figure 4.11 shows the hand specimen of the granite outcrop. The granite is light grey granite and has a phaneritic texture which is coarse grain. The degree of crystallinity is holocrystalline which the crystal minerals are still in a good shape. The form of individual crystal is subhedral shape.

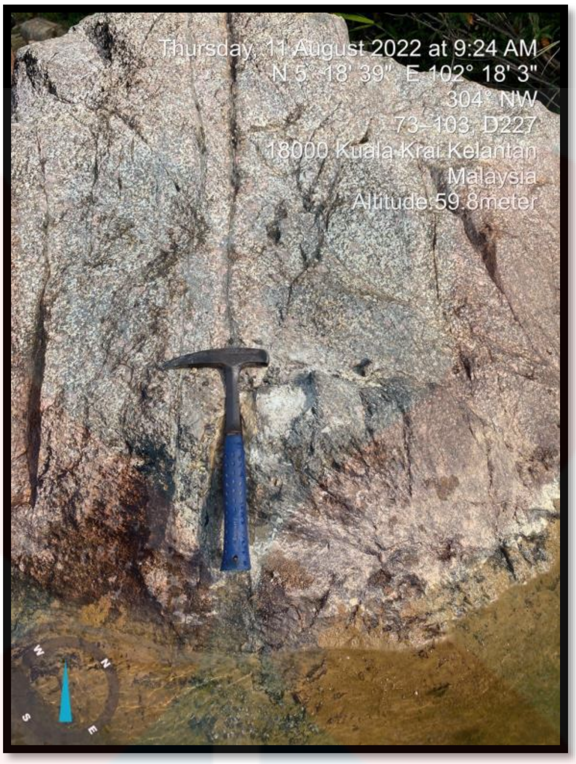


Figure 4. 10: The outcrop of granite in the study area.

Figure 4. 11: Hand specimen of granite in the study area.

c. Granodiorite

Granodiorite take about 40% of the study area. It was found along the Lata Rex River. At the outcrop it contains more quartz compared to quartz at granite. The mineral there are clearly seen using the hand specimen was coarse grain and pinkish colour and easily to identified due to slow cooling. Figure 4.13 shows the hand specimen of granodiorite and Figure 4.12 shows the granodiorite outcrop in the study area.

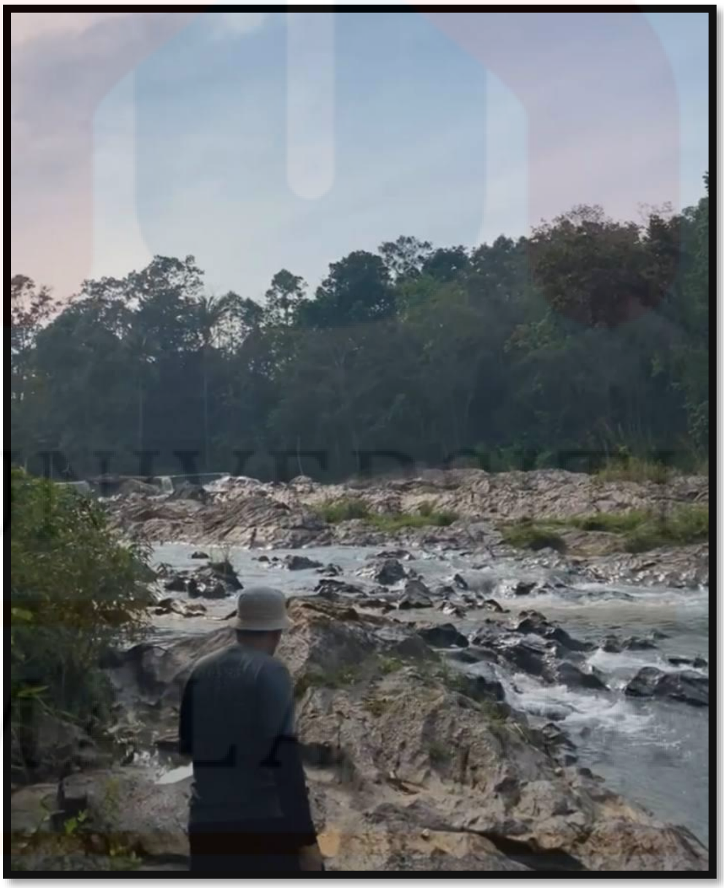


Figure 4. 12: The outcrop of granodiorite in the study area.

Figure 4. 13: Hand specimen of granodiorite in the study area.

Granodiorite and granite are intrusive igneous rocks that share a similar mineral composition. However, they vary in their constituent mineral proportions. Granodiorite, for example, is a coarse-grained rock primarily composed of plagioclase feldspar and quartz, with smaller amounts of other minerals such as biotite and hornblende. In contrast, granite also has a coarse texture, mainly made up of feldspar and quartz. Nevertheless, it contains more alkali feldspar and less plagioclase feldspar than granodiorite, often with higher amounts of biotite and muscovite mica. Therefore, while both rocks share mineral similarities, granodiorite has more plagioclase feldspar, whereas granite contains more alkali feldspar.

4.3.3. Petrography Analysis

Petrographic analysis is a method used to examine the optical and microstructural characteristics of the thin layer of rocks gathered during geological mapping. Two techniques, cross polarisation, and plane polarisation, were used to determine the content and materials of minerals under the microscope. Analyses of petrography characterised the mineral composition, which is difficult to perceive with the naked eye.

Three petrographic analyses were carried out on each of the primary lithology units present in the research site. Petrographic research was performed on hand specimens of granodiorite, granite, and quartzite. The research included cutting thin sections and analysing the rocks.

a. Quartzite

Table 4. 1: Petrographic analysis of quartzite.

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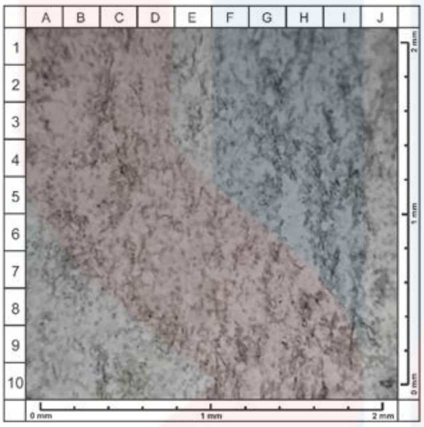
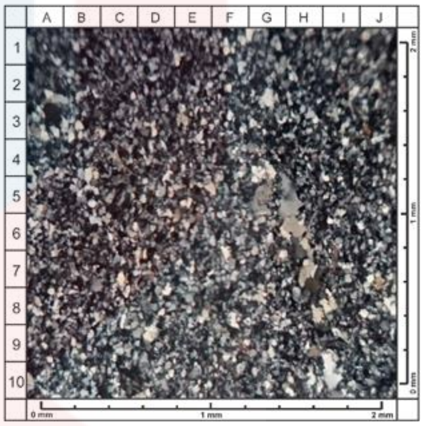
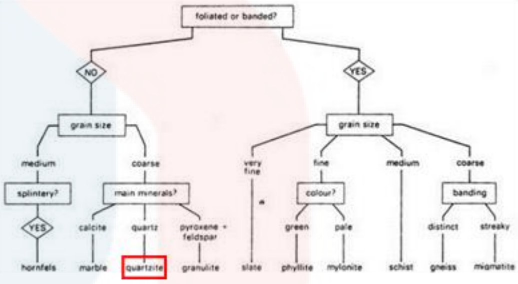
<tr><td colspan="4"></td></tr>
<tr><td>**PPL (*Plane Polarized Light*)**</td><td></td><td>**XPL (*Cross Polarized Light*)**</td><td></td></tr>
<tr><td colspan="2">**Microscopic Observation :**
The observation was carried out at 10x ocular magnification and 5x objective magnification and on the observation of non-foliated (granulose) structures, crystalloblastic (nematoblastic) textures including grain size <1/64 – 1/5 mm, good sorting.

Mineral Composition:
Quartz (A1) – 100%
At PPL the absorption color is colorless, low relief, no pleochroism, anhedral crystal form, no cleavage. In XPL the interference color is order 1 gray – white, the dark corners are wavy, there is no twinning.</td><td colspan="2"></td></tr>
<tr><td colspan="4">**ROCK TYPE QUARTZITE (GILLEN, 1982)**</td></tr>
</table>

b. Granite

Table 4. 2: Petrographic analysis of granite.

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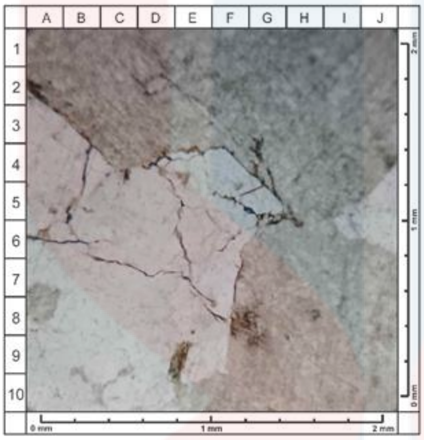
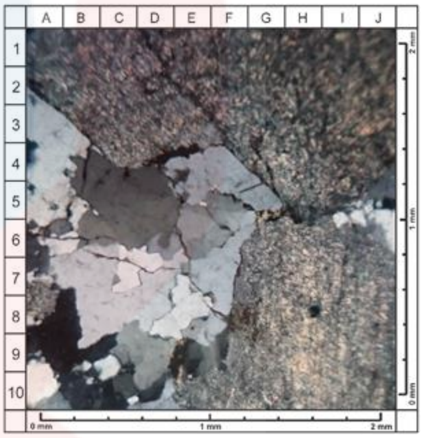
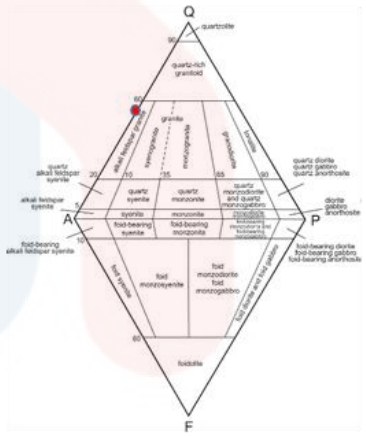
<tr><td colspan="4">CODE SAMPLE: B 03</td></tr>
<tr><td>PPL (Plane Polarized Light)</td><td>
</td><td>XPL (Cross Polarized Light)</td><td>
</td></tr>
<tr><td colspan="2">Microscopic Observation :
The observation was carried out at 10x ocular magnification and 5x objective magnification and on massive structure, faneric texture, coarse-medium mineral size.

Mineral Composition:

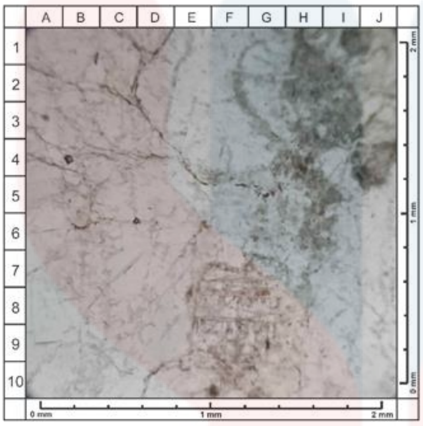
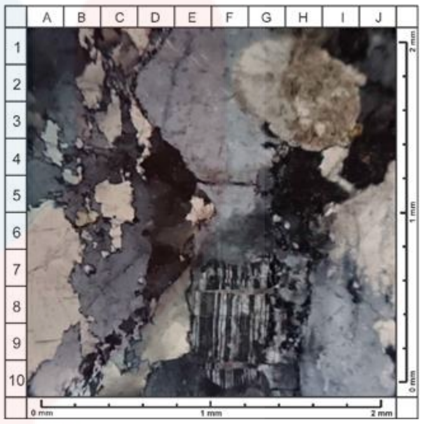
Quartz (A10) – 45%
At PPL the absorption color is colorless, low relief, no pleochroism, anhedral crystal form, no cleavage. In XPL the interference color is order 1 gray – white, the dark corners are wavy, there is no twinning.

Sericite (A1) – 54%
Based on a change from the alkaline mineral feldspar type. At PPL the absorption color is colorless, low relief, no pleochroism, euhedral – anhedral crystal form, 1-way cleavage – absent. In XPL the interference color is order 1 gray – white, the dark corners are parallel, the twins are not visible.

Opaque Mineral (A2) – 1%
At PPL the absorption color is black, low relief, no pleochroism, euhedral – anhedral crystal form. In XPL color interference black order 1, there is no twinning.</td><td colspan="2">
</td></tr>
<tr><td colspan="4">ROCK TYPE: GRANITE</td></tr>
</table>

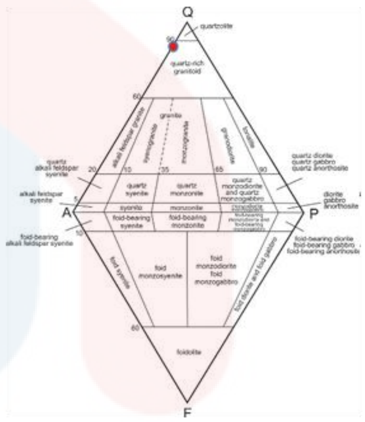
c. Granodiorite

Table 4. 3: Petrographic analysis of granodiorite.

<table>
<tr><td>PPL (Plane Polarized Light)</td><td></td><td>XPL (Cross Polarized Light)</td><td></td></tr>
<tr><td colspan="2">Microscopic Observation :
The observation was carried out at 10x ocular magnification and 5x objective magnification and the observation of massive structure, faneric texture, coarse-medium mineral size.

Mineral Composition:
Anorthoclase (F8) – 10%
In PPL, colorless absorption, low relief, no pleochroism, anhedral crystal form, 1-way cleavage. In XPL the interference color is gray – white order 1, dark angles are parallel – oblique, polysynthetic twinning

Quartz (A7) – 80%
At PPL the absorption color is colorless, low relief, no pleochroism, anhedral crystal form, no cleavage. In XPL the interference color is order 1 gray – white, the dark corners are wavy, there is no twinning.

Sericite (H2) – 10%
At PPL the absorption color is colorless, low relief, no pleochroism, euhedral – anhedral crystal form, 1-way cleavage – absent. In XPL the interference color is order 1 gray – white, the dark corners are parallel, the twins are not visible.</td><td colspan="2"></td></tr>
<tr><td colspan="4">ROCK TYPE: GRANODIORITE</td></tr>
</table>

4.4. Structural Geology

Structural geology is a study of the three-dimensional distribution of significant rock masses, their surfaces, and internal composition. In order to understand the tectonic history, earlier geological settings, and potential causes of changes or deformation to the massive volumes of rock, this is necessary. To identify when the structural features formed, it can also be dated. Exploration for oil and gas, groundwater exploration, building of dams, tunnels, and roads, among other things, could all result from studying structural geology. The structural geology term's fault, fold, joint vein, and crack are examples.

4.4.1. Fault

A fault is a type of geological structure that was created by tectonic activity at the plate boundary. There are three primary types of faults: dip slip, strike slip, and oblique slip. The three types of dip slip fault are a reverse fault, a normal fault, and a thrust fault.

The types of faults that occur in the study area is normal fault. Normal faults occur when the hanging wall is moved down relative to the footwall. It occurs when a tension applied and pulls apart the rock. Figure 4.14 shows the example of normal fault found in along the main road of Lata Rex at the coordinate N05° 18.67', E102° 17.97 which is at the eastern part of the study area.

Figure 4. 14 : Normal fault of study area.

4.4.2. Fold

Fold formed when there is a force that act on rock that have ductile characteristic. As a result of the ductile nature of the rock, even though there was a significant amount of force acting on the rock, the rock did not fracture but instead folded in on itself. The formation of fold usually takes placed in the zone of metamorphism where the temperature and pressure are high and the rock in the semi-fluid form. Figure 4.15 show anticlines that can be found in the study area. It is located at the coordinates 5°18'40.3"N 102°20'34.1"E.

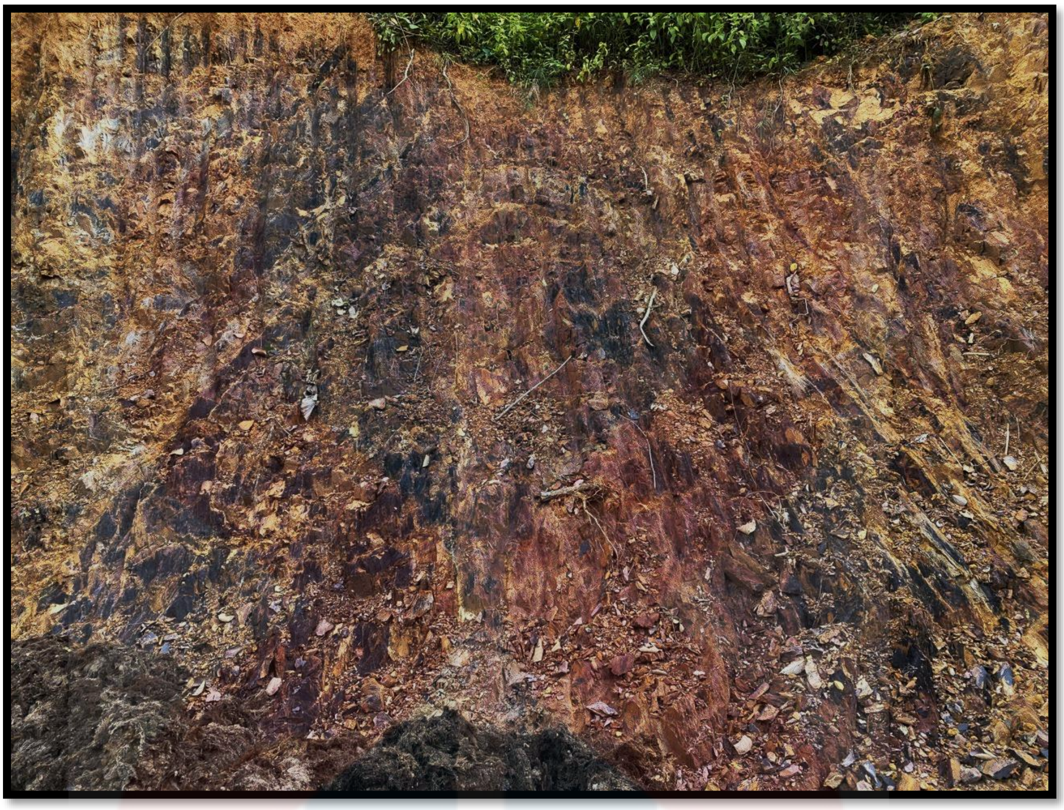


Figure 4. 15: Folds (anticline) in the study area.

4.4.3. Mechanism of Structure

a. Lineament Analysis

Lineament is a feature on the terrain map that looks like a line. Cracknell and Heyes say that lineaments are how fractures, joints, and other linear phenomena show up on the surface of the land. These things can happen anywhere from the land's surface down to possibly great depths.Lineament is one way to find geological structures in the area under study. Before the ground observation, the lineament is looked at. Linear or straight features on the topography map were studied to find geological structures like faults, fractures, and joints.

Figure 4.16 shows the lineament map that was made before the mapping was done. From the lineament map, you can see that there are six straight lines. Not only do the lineaments show things like faulting, but they can also show things like rivers and roads. We looked at the directions of the lineament to figure out the general direction of the forces acting on the study area.

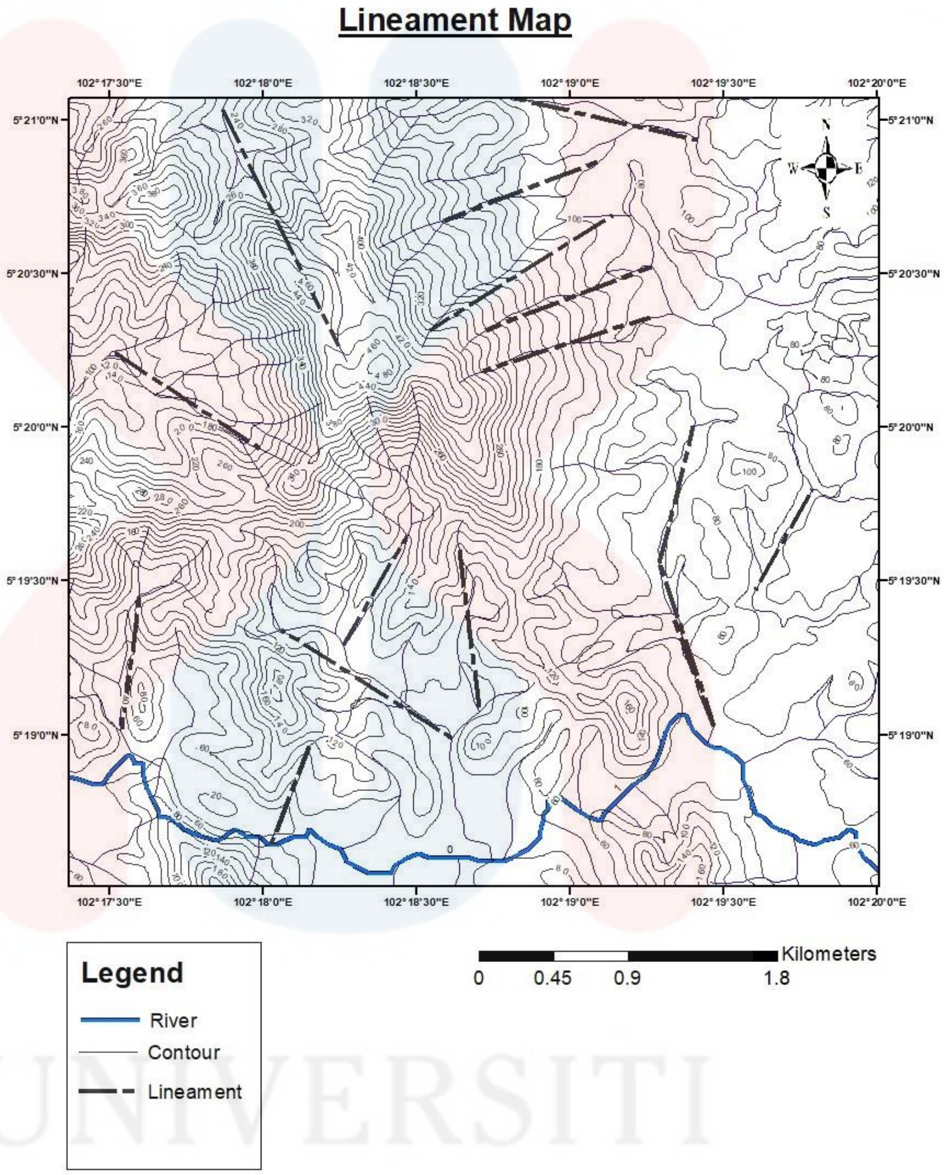


Figure 4. 16: Lineament map of the study area.

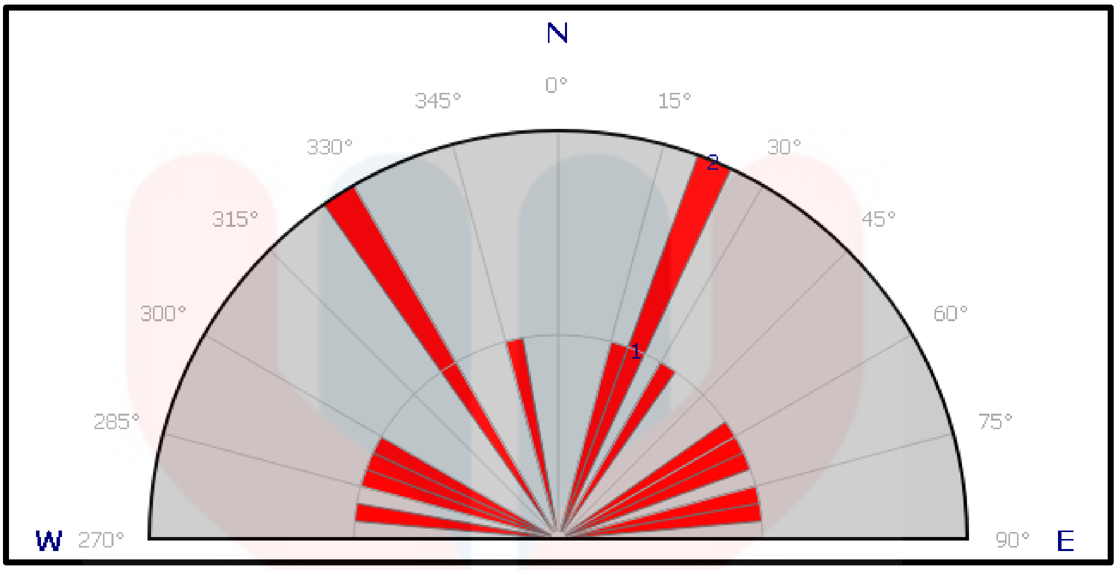


Figure 4. 17: Rose diagram of the lineament analysis.

4.5. Historical Geology

The study area is made up with Taku Schist Formation and Telong Formation. Since there is an intrusion of granite in the study area, this indicates that in the past geologic time, there is an unstable in the earth subsurface. Thus, in order to achieve stability and buoyancy, the magma rises from the subsurface in form of intrusion thus, this rises of magma intrude the metasedimentary rock in the area. Then, mineral start to crystalize as the magma cooling and formed granite. The study area also undergoes regional metamorphism in the past.

This process is due to high temperature and pressure that acts on the metasedimentary rocks. The rise in temperature makes the minerals in the rocks to become unstable. Thus, to achieve stability, the mineral makes a new assemblage and thus showing foliation structure. Geological structures like faults and folds were shaped as a result of the intrusions. Rock composed of hornfels was discovered in the transition zone between the metasedimentary and granite. When sedimentary rock comes into contact with igneous rock, hornfels is the result. Figure 4.45 shows the geological map of the study area.

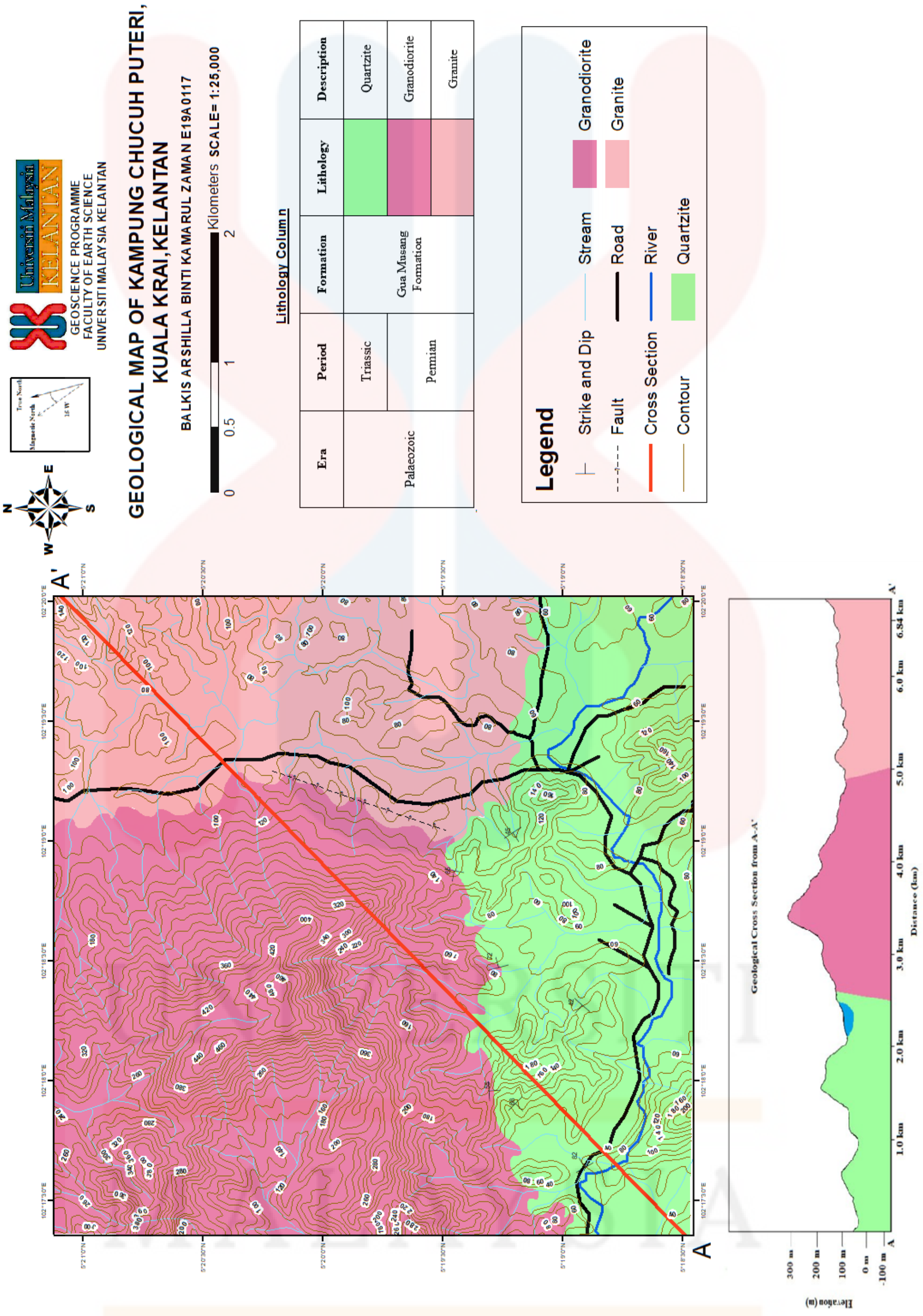


Figure 4. 18: Geological Map of study area.

CHAPTER 5

LANDSLIDE HAZARD ZONATION

5.1. Introduction

This chapter discussed about the production of landslide hazard zonation map using remote sensing and Geographic Information System (GIS) in the study area, Chucuh Puteri, Kuala Krai, Kelantan. The landslide hazard zonation map was generated by using the ArcGIS 10.8 software. Some of the parameters were used in order to generate the map such as slope, aspect, elevation, drainage and land cover which were obtained by using the DEM and satellite image data.

5.2. Parameter of Landslide Causative Factor

The weightage of the parameter selected in determining the landslide susceptibility is shown in Table 5.1.

Table 5. 1: Weightage of landslide causative factor.

No.	Parameter	Description
1.	Slope	25
2.	Aspect	10
3.	Land use	15
4.	Drainage density	25
5.	Elevation	5

Aside from using the selected parameter that weighted using WOM, a field studies were also conducted at several locations where landslides have occurred, which is at a) 102°17’51’’E 5°19’17’’N, b) 102°18’07.8 ’E 5°20’49.7’’N and c) 102°19’1’’E, 5°20’10’’N. Based on the identified parameter, the actual phenomenon and field condition causing the landslide were observed in order to support the result produced by the weighted overlay method, and thus the landslide vulnerable area can be estimated.

5.2.1. Slope

The movement of a mass of rock, debris, or earth down a slope is referred to as a landslide. Gravity influenced the movement of soil and rock downslope. The effect of downslope forces contributes to a reduction in strength. Slope is a critical factor in determining the landslide hazard zone in the study area. Based on the guideline from Geology Society Malaysia, they classified the slope into six categories. Figure 5.1 shows the slope map that was generated from DEM. This is due to the fact that the slope factor has a significant influence on the occurrence of landslides. The degrees of slope have an effect on the ratings, and a steeper slope results in higher scores.

Nevertheless, the geological mapping revealed that the previous landslide occurred not only on a very steep slope but also on a moderate slope. This information was gained from the previous landslide. This was presumably connected to one of the other parameters chosen.

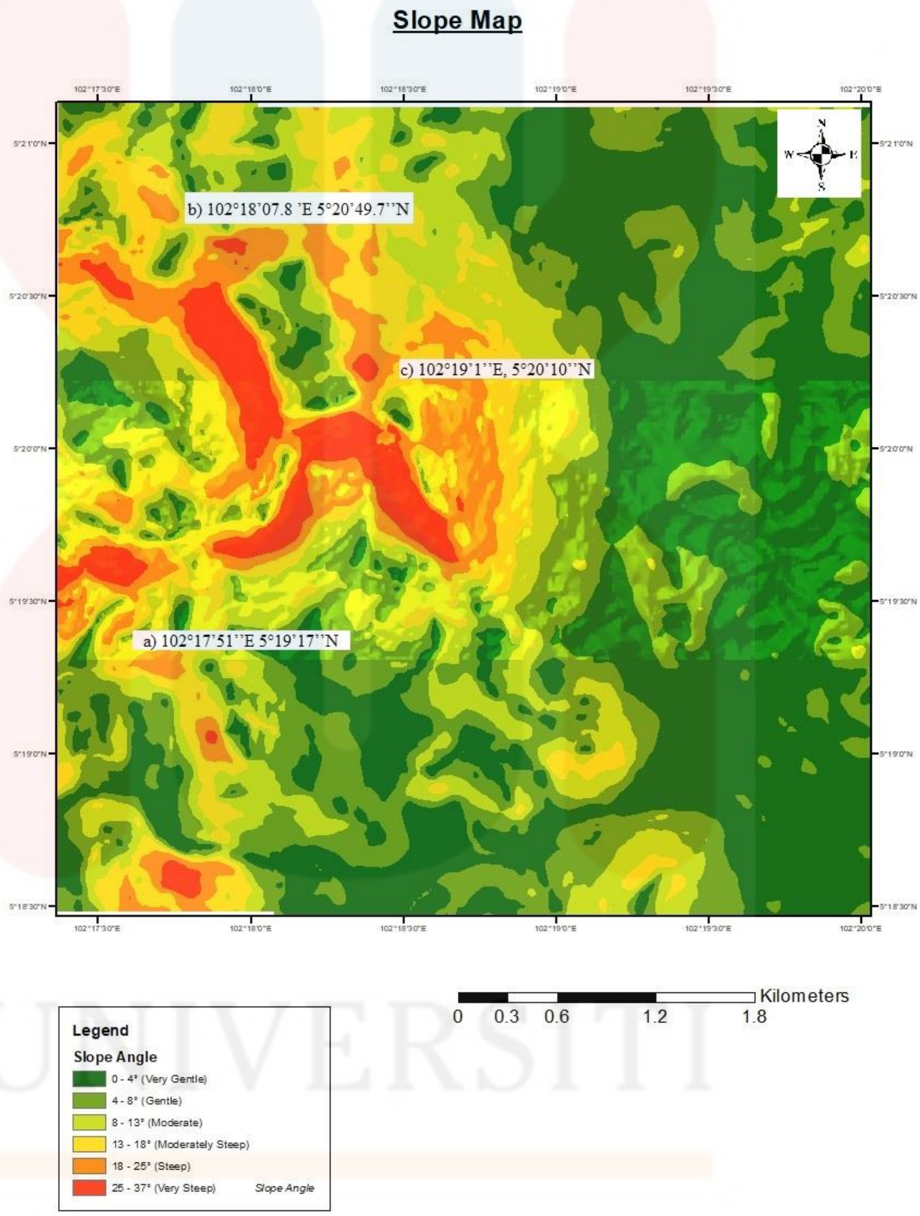


Figure 5. 1: Slope map of the study area with three observation point.

Table 5. 2: Slope classification.

No.	Class	Description
1.	0-4	Very gentle
2.	4-8	Gentle
3.	8-13	Moderate
4.	13-18	Moderate steep
5.	18-25	Steep
6.	25-37	Very steep

Using the slope categorization by Geology Society Malaysia (GSM), the slope's weightage and score are separated into six categories with ten weighting scores.

Table 5. 3: Weightage and score for slope.

No	Class	Weightage (Wi)	Score (sij)	Weightage x score (wi x sij)
1	0-4	10	1	10
2	4-8	10	2	20
3	8-13	10	3	30
4	13-18	10	4	40
5	18-25	10	5	50
6	25-37	10	6	60

Figure 5.2, 5.3 and 5.4 shows the landslide occurred at study area with different elevation which is at a) 102°17’51’’E 5°19’17’’N, b) 102°18’07.8 ’E 5°20’49.7’’N and c) 102°19’1’’E, 5°20’10’’N.

Figure 5. 2: Landslide occurred at location (a) coordinate 102°17’51’’E 5°19’17’’N

Figure 5. 3: Landslide occurred at location b) 102°18’07.8 ’E 5°20’49.7’’N

Figure 5. 4: Landslide occurred at location c) 102°19’1’’E, 5°20’10’’N

5.2.2. Aspect

Aspect maps were created using DEM data. The aspect map was classified into 10 slope direction classifications that are attributed to the North. The parameter was utilised to determine the slope direction, which resulted in changes in gravitational force. The instability and slope orientation may be recognised. It is measured in degrees anticlockwise from 0º (North) to 360º (due to North).

The aspect of a slope, which refers to the compass direction that it faces, can be an important factor in the occurrence of landslides. This is because the amount of solar radiation that a slope receives, and therefore the degree to which it dries out or remains moist, can vary based on its aspect.

For example, slopes that face north tend to receive less direct sunlight and remain cooler and moister than those that face south. This can lead to differences in vegetation growth, soil moisture, and other factors that affect slope stability.

Slope angle is a key factor in determining the likelihood of a landslide. Generally, steeper slopes are more prone to landslides than gentler slopes. The aspect of a slope, which refers to the direction the slope is facing, can also be important in understanding landslide risk. For instance, a north-facing slope may be more susceptible to landslides than a south-facing slope due to differences in sunlight exposure and temperature. Additionally, the elevation of the area is also taken into consideration, as landslides can occur at different elevations depending on the geology, weather, vegetation, and land use. Table 5.4 shows the slope direction of aspect and Figure 5.5 shows the aspect map of the study area.

Table 5. 4: Weightage and score for aspect.

No	Slope direction	Weightage (Wi)	Score (sij)	Weightage x score (wi x sij)
1	Flat (-1)	10	1	10
2	North (0-22.5)	10	2	20
3	Northeast (22.5-67.5)	10	3	30
4	East (67.5 – 112.5)	10	4	40
5	Southeast (112.5- 157.5)	10	5	50
6	South (157.5-202.5)	10	6	60
7	Southwest (202.5- 247.5)	10	7	70
8	West (247.5-292.5)	10	8	80
9.	Northwest (292.5-337.5)	10	9	90
10.	North (337.5-360)	10	10	100

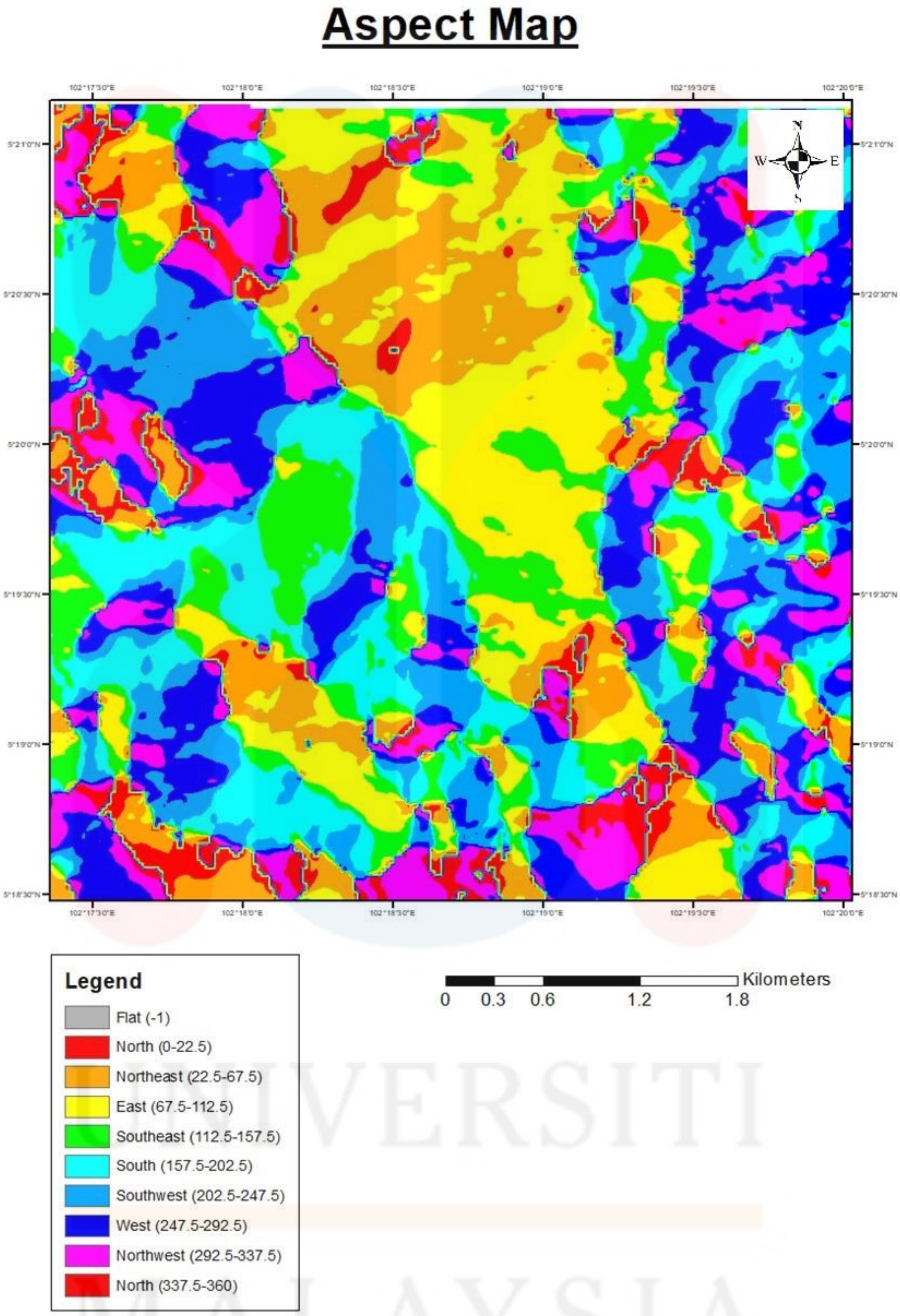


Figure 5. 5: Aspect map of the study area.

5.2.3. Vegetation and landuse

DEM secondary data was used to generate a land cover map. Most of the land was used for agricultural activities like oil palm and rubber tree plantations, while the rest was covered in forests. In addition, the Kampung Chucuh Puteri neighbourhood has been divided up into clear land zones with a medium population density. Slope stability was estimated based on land cover type. Human activities can significantly influence the onset and intensity of landslide. Table 5.5 shows Weightage and score for land use and vegetation and Figure 5.6 shows the land use and landcover map of the study area.

Table 5. 5: Weightage and score for land use and vegetation.

No	Class	Weightage (Wi)	Score (sij)	Weightage x score (wi x sij)
1	Settlement	15	1	15
2	Build-up area	15	2	30
3	Forest	15	3	45
4	Oil palm	15	4	60
5	Rubber	15	5	75
6	Mix Agriculture	15	6	90

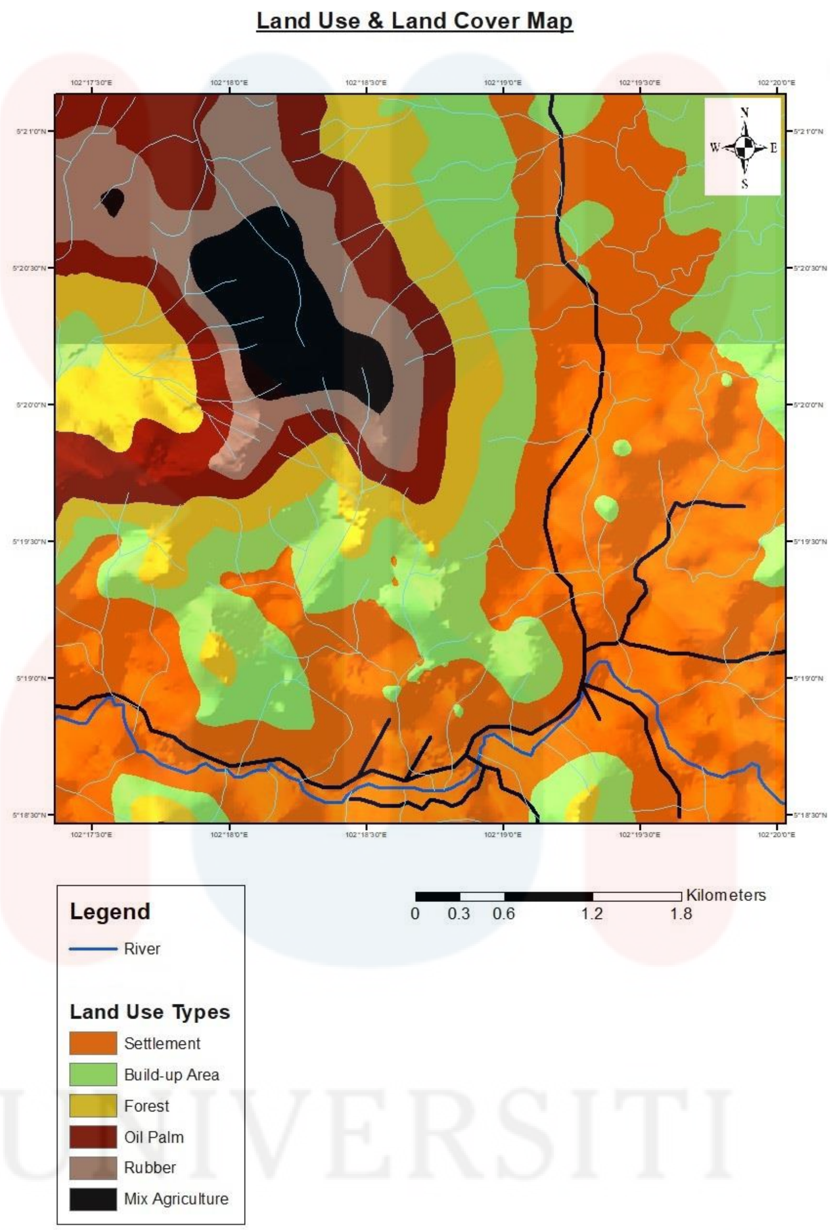


Figure 5. 6: Land use map of the study area.

5.2.4. Drainage Density

Drainage density is defined as the total length of streams and rivers in a drainage basin divided by the drainage basin's total area. Climate, terrain, soil infiltration, vegetation, and flux density all have an impact on drainage variance. It is critical for defining the fluvial network in the research region. The degree of debris flow and seepage owing to rainwater infiltration can be used to assess the susceptible region of a landslide.

The drainage density map was created in ArcGIS using DEM data. The drainage density is calculated by dividing the length of the stream by its area. Drainage density was divided into three categories: low, moderate, and high. A high drainage density suggests a high likelihood of landslide occurrence. This is due to the excessive surface runoff. The drainage density weightage and score are shown in Table 5.6, and the drainage density map of the research region is shown in Figure 5.7.

$$Drainage\ Density = \frac{Stream\ Length}{Area} \quad \text{.. (Equation 5.1)}$$

Table 5. 6: Weightage and score for drainage density.

No	Class		Weightage (Wi)	Score (sij)	Weightage x score (wi x sij)
1	Low	0-4.05	25	1	15
2	Moderate	4.06-8.09	25	2	50
3	High	8.1-12.1	25	3	75

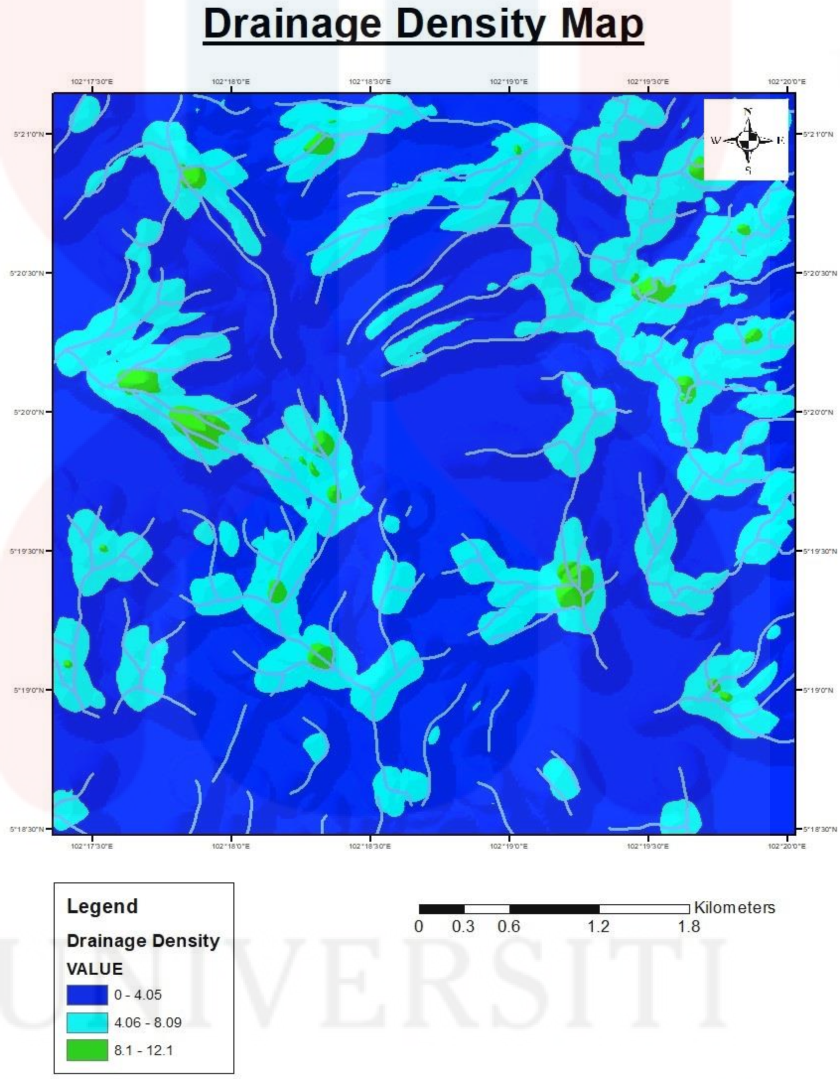


Figure 5. 7: Drainage density map of the study area.

5.2.5 Elevation

Elevation maps are crucial tools for identifying areas at risk of landslides. They provide detailed information about the topography of an area, including the slope angles, aspect, and elevation. This information is used to generate landslide hazard zonation maps, which are used to identify areas that are particularly susceptible to landslides.

Hilly, are very vulnerable to landslide. For the landslide hazard zonation study, an elevation map with a resolution of 30 metres was constructed using data from the Shuttle Radar Topography Mission's (SRTM) Digital Elevation Model (DEM). Figure 5.8 shows the elevation map of study area and able 5.5 shows the weightage and score of the elevation.

Table 5. 7: Weightage and score for elevation.

No	Class	Weightage (Wi)	Score (Sij)	Weightage X Score (Wi x Sij)
1	Low Land	5	4	20
2	Low Hill	5	6	30
3	Hill	5	8	40

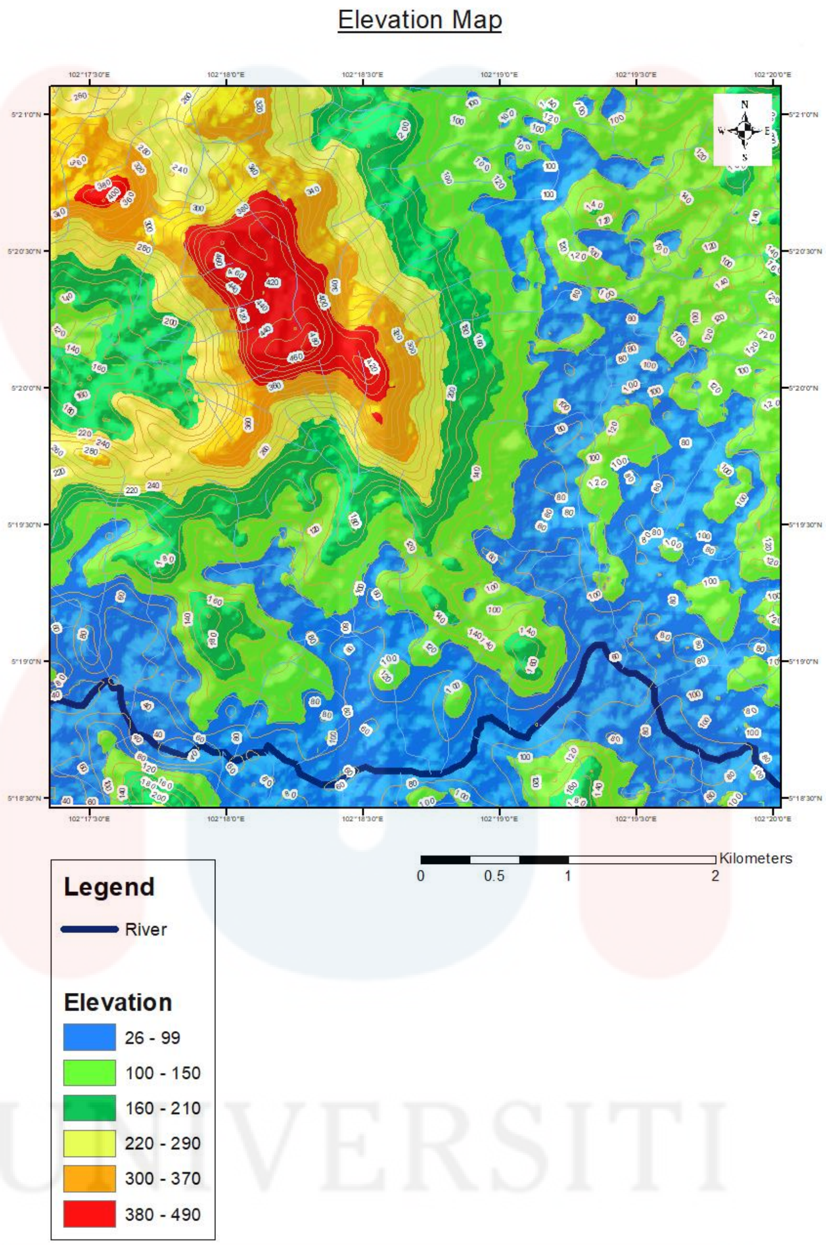


Figure 5. 8: Elevation map of study area

5.3. Reclassify of Raster

Before producing the landslide susceptibility map, all relevant parameters were transformed into raster data sets. The weightage of these raster data was then reclassified. The landslide susceptibility map was created using a GIS software and the weightage overlay method. The lithology, slope, aspect, landuse. drainage density, elevation parameter chosen as landslide causative factors. The parameters were allocated weightages, and the sum of all factors was equal to 100% using the formula stated below.

$$S = \frac{\Sigma wisij}{\Sigma wi}$$

In order to construct the landslide susceptibility map using the weightage overlay method, it is required to reclassify the data. Table 5.7 shows the reclassify data sets.

Table 5. 8: Reclassify data set.

No	Raster Datasets	Influence
1.	Slope (°): Very gentle (0-4) Gentle (4-8) Moderate (8-13) Moderate steep (13-18) Steep (18-25) Very steep (25-37)	20
2.	Aspect: Flat (-1) North (0-22.5) Northeast (22.5-67.5)	10

	East (67.5 – 112.5) Southeast (112.5- 157.5) South (157.5-202.5) Southwest (202.5- 247.5) West (247.5-292.5) Northwest (292.5-337.5) North (337.5-360)	
3.	Landuse: Settlement Build-up area Forest Oil palm Rubber Mix Agriculture	20
4.	Drainage Density: Low (0- 4.05) Moderate (4.06-8.09) High (8.1-12.1)	30
5.	Elevation:	20
Total		100

5.4. Landslide Causative Factor

The primary factor contributing to landslides in the study area is found to be high intensity rainfall. Excessive precipitation, particularly in areas with thick and weathered soil, can cause landslides by filling porous spaces in the ground and leading to excess water that destabilizes the soil and causes movement of earth and rock.

Kuala Krai, Kelantan experiences particularly heavy rainfall during the monsoon season, and this increased precipitation can cause changes in the water levels on and beneath the ground, weakening slopes and increasing the likelihood of landslides. These landslides can pose dangers to both life and property. In the area being studied, landslides are more prevalent along roads and are believed to be caused by poor drainage on and near the roadways. Surface fractures are often the first sign of potential landslides, and the presence of these fractures can indicate that water has reached the surface and that the drainage system is inadequate.

According to data from Malaysia's meteorological agency, September 2020 saw less than 200 millimeters of rainfall in several Peninsular states including Kelantan, Terengganu, Pahang, Malacca, and Negeri Sembilan. Rainfall is expected to increase in November 2020, ranging from 100 to 300 millimeters, and in December 2020, the forecast is for 200 to 700 millimeters of precipitation.

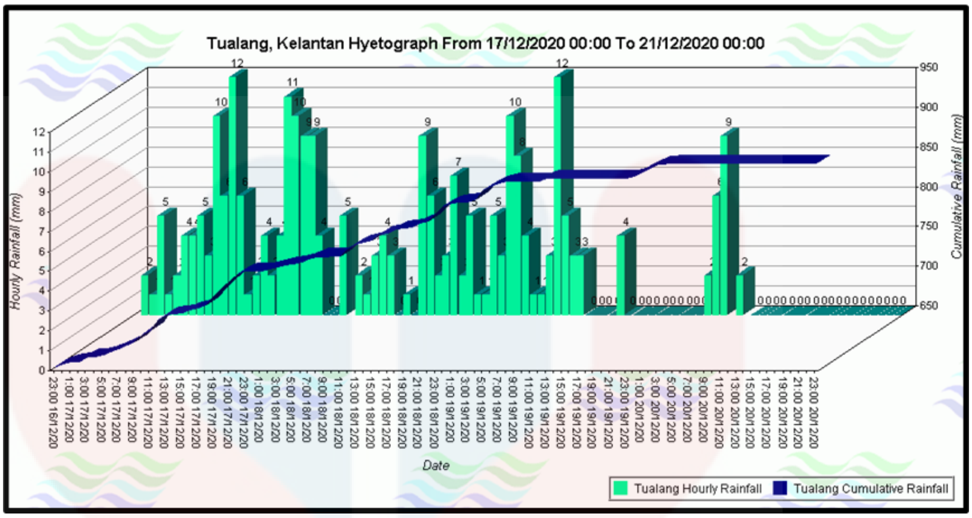


Figure 5. 9: The hyetograph of Tualang

5.5. Landslide Hazard Zonation Map and Evaluation

The weighted overlay approach is one of the methods used to create the landslide hazard zonation map. After reclassifying all data, the parameters were overlaid in ArcGIS using the weighted overlay tools. The software developed the landslide hazard zonation map automatically based on the scale values determined by its significance. Figure 5.8 shows a landslide hazard zonation map created in ArcGIS software using the weighted overlay method.

Based on the landslide hazard zonation map that been generated, the study area was divided into 5 classes. The class 1 is for the no hazard, class 2 is for the low hazard, class 3 is for the medium hazard, class 4 for the high hazard and class 5 is for the highest hazard. From all parameters that been used, the hydrological factors are the most influenced factors that can lead to landslide occurrence.

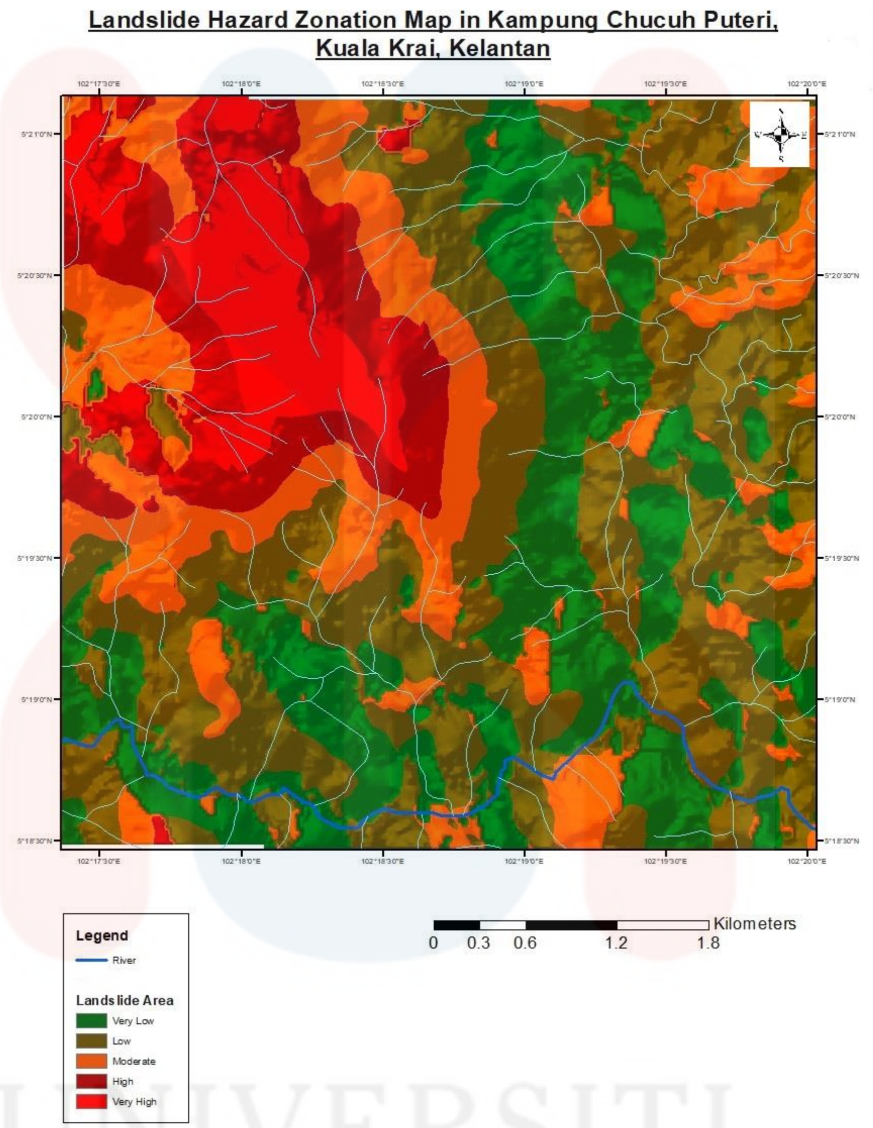


Figure 5. 10: Landslide hazard zonation map of Kampung Chucuh Puteri, Kuala Krai, Kelantan

In landslide susceptibility analysis, slope, lithology, and drainage density are becoming crucially significant characteristics. There is a greater potential for landslides to occur on steeper slopes. As the local rock and soil originated with varying degrees of porosity and void, lithology also is a factor in the landslide.

When a landslide hazard zonation map designates an area as a red zone, it suggests that the location has a high risk or hazard for landslides. However, the classification doesn't necessarily mean that all areas within the red zone are equally dangerous. Several geological, topographical, and weather factors contribute to slope stability, and some areas within the red zone may be more susceptible to landslides than others.

It's also possible that some parts of the red zone may have received their classification based on past or potential landslide activity, even if no recent landslides have occurred there. It's critical to keep in mind that landslide hazard zonation maps are broad-scale assessments of potential landslide risk and not a guarantee of safety. Local conditions and individual circumstances also play a crucial role in determining the risk of landslides, and it's essential to consult with local experts and authorities when assessing the risk of landslides in a specific area.

The occurrence of landslides is moderately affected by vegetation, land use, and aspect factors. However, it is also crucial in landslide analysis in the research region in relation to other parameters and triggering factors. According to the map of landslide susceptibility, the landslide is more prone to occur along rivers and streams. It is probably because of moderate to high stream density. Heavy rains filled the porosity between the soils in the study region. Excessive water flows and causes rotational debris slide when the bottom layer of interflow is bedrock. The breakdown of the land structure caused the earth mass to slide. The landslide was triggered by excessive rains, with location at high elevation and steep slope.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1. Conclusion

This chapter conclude the findings from general geology and landslide hazard zonation and evaluation using GIS and remote sensing. It has been concluded that the objectives of this research study are achieved. The first objective is to produce a geological map of Chucuh Puteri, Kuala Krai Kelantan with 1:25000 scales. All geological aspects including geomorphology, stratigraphy, structural geology, petrography, and historical geology were discussed in chapter 4 in detailed. Generally, the study area was divided into 3 main lithologies which are granite rocks, quartzite rocks, and granodiorite rocks. There are many geological structures that found including major fault, fold, and joint.

The second objective is to determine the causes of landslide occurrence. Hydrological factors are primarily responsible for the occurrence of landslides monsoon due to the climate that raining throughout the year. The flood event also served as the precipitating factors that led to the occurrence of the landslide.

The third objective is achieved by generating a 1:25,000 scale map of landslide hazard zonation. The landslide hazard zonation map was created using the weighted overlay GIS and remote sensing method in ArcGIS software. Several parameters, including vegetation, slopes, aspects, stream density, and elevation were used in order to generate the map. The DEM data which is obtained from the website of the USGS were utilised to generate the selected parameters map.

As a results, the parameters were overlaid by using the weighted overlay method, thus, the landslide hazard zonation were produced. The landslide hazard zonation map was divided into 5 classes. The class 1 is for the no hazard, class 2 is for the low hazard, class 3 is for the medium hazard, class 4 for the high hazard and class 5 is for the highest hazard.

6.2. Suggestion

For the current work, the resulting image not being sharp enough when using the lower quality of data which represents a very low resolution. There isn't any good quality, free data available for download on the USGS website. As for the future research, the use of better-quality DEM data is highly suggested. Any other agencies such as Department of Survey and Mapping Malaysia (JUPEM) and National Geospatial Centre (PGN) can fulfil the demand of high-quality DEM through proper request for education purposes.

The use of other software can be an alternative such as PCI Geomatics or QGIS besides ArcGIS for better interpretation. For geological study, future researchers can create the 3D-topography of the study region using tools like ArcScene to display the changes in vegetation in greater detail. The NDVI values produced by the DEM can be supported by the 3D topography. Utilizing additional software aids in producing more proof to validate the research endeavour.

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