GEOLOGY AND GEOHERITAGE POTENTIAL VALUE OF KARST AT KAMPUNG SUNGAI KEPA, GUA MUSANG, KELANTAN FOR CONSERVATION AND GEOTOURISM

By

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APPROVAL

"I hereby declare that I have read this thesis and in our opinion this thesis is sufficient I term of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience) with Honours".

Signature :

Name of Supervisor I :

Date :

DECLARATION

I declare that this thesis entitled "GEOLOGY AND GEOHERITAGE POTENTIAL VALUE OF KARST AT KAMPUNG SUNGAI KEPA, GUA MUSANG, KELANTAN FOR CONSERVATION AND GEOTOURISM" 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 in candidate of any other degree.

Signature :

Name : SYAHMI SAJIDAH BINTI SURADI

Date :

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ABSTRACT

Kampung Sungai Kepa possess many unique geological features with karst landscape as the dominant features along with the presence of other geological structures. Rapid development at the study area had causes it geological features to exposed to threats. This study area is located at N 4°50'11.6", E102°00'15.2" in Gua Musang District, Kelantan with 5km × 5 km and surrounded with karst features and oil palm plantations. The highest elevation of topography at the study area is 600 meter while the lowest is 200 meters. This research focusses on the general geology and geoheritage potential value of karst at Ladang Chin Teck. The objectives of this research are i) to generate a detail geological map, ii) derive a detail geodiversity map index and iii) determine its geoheritage elements. ArcGIS Software are used in this research to process and generated the maps. Next, DEM data was used to generate the detail geological map of the study area by processing, analyzing and interpretation to obtain the information. There are four types of lithology rock units found at the study area which are alluvial, limestone, metasedimentary rock, and acid intrusion of granite. As for the geodiversity map index, geodiversity assessment method was used by dividing the geodiversity into several partial indices. Geoheritage potential value of the study area are determined from the value of geodiversity occurrence. Based on the assessment, the karst limestone held high geodiversity value, thus also high in geoheritage values. Recommendation are included for conservation of the geological heritage features and geotourism purposes. It is important to preserve and maintain the geological heritage from the threat of rapid development and to ensure the longevity of the place.

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ABSTRAK

Kampung Sungai Kepa memiliki banyak ciri geologi yang unik dengan landskap karst sebagai ciri dominan dengan kehadiran struktur geologi yang lain. Perkembangan yang pesat di kawasan kajian menyebabkan ciri geologi terdedah kepada ancaman. Kawasan kajian ini terletak di N 4 ° 50'11.6 ", E102 ° 00'15.2" di Daerah Gua Musang, Kelantan dengan keluasan 5km × 5 km dan dikelilingi dengan karst dan ladang kelapa sawit. Ketinggian tertinggi kawasan kajian ialah 600 meter manakala yang paling rendah ialah 200 meter. Objektif kajian ini adalah untuk i) menghasilkan peta geologi terperinci, ii) memperolehi peta indeks geodiversiti terperinci dan iii) menentukan elemen geoheritage kawasan kajian. Perisian ArcGIS digunakan dalam kajian ini untuk memproses dan menghasilkan peta. Seterusnya, data DEM digunakan untuk menghasilkan peta geologi terperinci kawasan kajian dengan memproses, menganalisis dan menafsirkan untuk mendapatkan maklumat tersebut. Terdapat empat jenis unit batuan litologi yang terdapat di kawasan kajian iaitu aluvial, batu kapur, batuan metasedimen, dan terjahan granit berasid. Bagi indeks peta geodiversiti, kaedah penilaian geodiversiti digunakan dengan membahagikan kepelbagaian geodiversiti menjadi beberapa indeks separa. Nilai potensi geologi warisan kawasan kajian ditentukan dari nilai kejadian geodiversiti. Berdasarkan penilaian, batu kapur karst memiliki nilai geodiversiti yang tinggi, seterusnya mengandungin nilai geologi warisan yang tinggi. Cadangan disertakan untuk pemuliharaan ciri warisan geologi dan tujuan geotourism. Penting untuk memelihara dan mengekalkan warisan geologi dari ancaman pembangunan pesat dan untuk memastikan umur panjang tempat itu.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DEM	Data Elevation Model
E	East
GIS	Geographic Information System
N	North
S	South
USGS	United States Geological Survey
W	West

LIST OF SYMBOLS

%	Percentage
º	Degree
′	Minutes
″	Seconds

CHAPTER 1

INTRODUCTION

1.1 General Background

Geological heritage is one of the geology branches that proposed the applied scientific field, which mainly focused on distinctive and represent the geological site. This geological heritage field research that related to Earth Science is held in Kampung Sungai Kepa, Gua Musang, Kelantan. This research aims to study the general geology and geoheritage by identifying the geological heritage resources and values that exist in the study area and its potential for conservation and geotourism by using geodiversity assessment method.

Geology focuses on the study of Earth Science that deals with the physical, structure and substances of Earth related to processes acting on them and their formation history. Geology deals with Earth's surface and its origin, composition, structure and indirectly the Earth's inhabitants. Generally, geology branches include petrology, minerology, physical geology, geomorphology, stratigraphy, geological engineering, and hydrogeology.

Geological map is defined as a specially purpose map that shows the variation of geological features that distribute in Earth or a specific study area. The geological map will represent the distribution of different types of rocks, lithology boundaries and other geological structures, for example structural features such as faulting and folding and bedding planes. The different rock units will be shown in different colors and symbology. Degrees of contour lines are also including in the geological map that shows the subsurface topographic trends in strata.

Geological heritage is defined as natural geological or any geomorphological features related to geodiversity and geoconservation that possess educational, scientific, aesthetic, recreational, cultural, historical and any other additional values such as economic and functional values. This geological heritage values provide further insight into the geological process that results into evolution and formation of today's Earth.

Geological heritage is also a fundamental part of natural heritage that contain special places and features, which is important in understanding the history of Earth, as it covers varieties of rocks, minerals, fossil, features and geological landscape. Plus, geoheritage is important in representing conservation and geotourism development.

There are many components of geological characteristic in Malaysia that formed rare naturally beautiful landscape, features, different type of rocks, minerals and fossil that are formed through a long and complex geological process through time in history. Malaysia is recorded to have naturally rich hilly natures, mountains, seas, rivers, and caves mainly calcareous karst that varied through a different location.

Peninsular of Malaysia can be classified into three longitudinal belts which are Eastern, Central and Western Belt according to their geological characteristic. Kelantan State, which is in Central Belt of Peninsular Malaysia has many beautiful and interesting geological features that make up good geological sites, with geoheritage values and are driven towards the potential of conservation geotourism.

Gua Musang, on the other hand, located at the Southern region of Kelantan State is dominantly composed of Permian-Triassic clastic, volcanic and limestones. Gua Musang is a major district that has its own attractiveness due to numerous limestone karst or also known as karts topography. It held diverse flora and fauna, and geological features that have geological values. Moreover, the karst limestone uniqueness shows many geological heritage values such as scientific value, aesthetic, recreational when observed from its geological side. The Figure 1.1 shows the map of Kelantan State and Gua Musang District.

The study area, Kampung Sungai Kepa, Gua Musang is located in the area of karst limestone caves. This area was mostly covered with karst limestone caves and high elevation karst. This sudy required to generate a detailed geological map of the study area, Kampung Sungai Kepa, Gua Musang with the scale of 1:25000 and deriving a detail geodiversity map index of the study area with a scale of 1:25000. From the maps generate, geological features and site that has potential for conservation and geotourism development in Gua Musang can be determine.

Figure 1.1: Map of Kelantan that shows the study area of Gua Musang District. (Source: Zuliskandar, 2019)

1.2 Study Area

This research is held in Kampung Sungai Kepa, in Gua Musang District, Kelantan. This research will be conducted at study area that covers approximately 25 kilometer per square, with 5 kilometer × 5 kilometers.

1.2.1 Location

The study area is located at N 4°50'11.6", E102°00'15.2". Kampung Sungai Kepa is the small villages with the presence of Ladang Chin Teck as cultivation of oil palms processing that are in Mukim of Ketil, Gua Musang District, Kelantan. Moreover, this box of study area is surrounded by heavy palm plantation, rubber plantation and karst limestones. The lowest elevation of the study area are 200 meters while the highest elevation is approximately 600 meters. Geological features such as river, Sungai Ketil, streams, and contours can be seen in base map of study area (Figure 1.2).

Figure 1.2: Base map of study area.

1.2.2 Road Connection

Gua Musang is located in southern part of Kelantan State, with Pahang State at south, Perak to the west, and Terengganu to the east. There is a road connection that connect Gua Musang to Kuala Lumpur through Kuala Lumpur-Gua Musang Highway, which known as Lebuhraya Pantai Timur (LPT). Merapoh-Gua Musang road can be used to access Gua Musang. The box of study area can also be access from Dabong-Gua Musang road and Kuala Krai- Gua Musang road. The box of study area can be access easily but the usage of four-wheel drive car can give a better access.

1.2.3 Demography

Kelantan State whole area are 17,100 kilometers per square with total of 2.001 million population, recorded in 2018 by 'Jabatan Perangkaan Malaysia.' Kelantan State shares the borders with Perak at the west, Pahang in south and Terengganu is in east. Kelantan consisted of ten district which are Jeli, Kota Bharu, Tumpat, Pasir Mas, Gua Musang, Tanah Merah, Machang, Pasir Puteh, Bachok, and Kuala Krai.

In Kelantan State, there are many main streams that include Sungai Lebir, Sungai Golok, Sungai Pengkalan Datu, Sungai Nenggiri, Sungai Kelantan, Sungai Kemasin, Sungai Pergau, Sungai Semerak, and Sungai Pengkalan Chepa. As Kelantan also shares the border with Thailand, Kelantan had gain influenced from Thailand traditions and customs that help to make Kelantan's culture different from other states in Kelantan.

Based on 2018 data, there are approximately 1.9 million with 1.0 million man and 0.9 woman recorded. From the table 1.1, it shows that the population in Gua Musang district is changing from 113 900 to 113 200. This rate of population is however control by several factor such as death and moving out.

Table 1.1: Total population in Kelantan State according to district (Source: Poket Stats Negeri Kelantan ST1 2020. (2020)).

District	**Year**	
	2018	2019
Bachok	162 500	165 800
Kota Bharu	596 900	608 600
Machang	113 600	115 900
Pasir Mas	233 000	236 400
Pasir Puteh	143 100	146 000
Tanah Merah	149 200	152 200
Tumpat	187 300	190 900
Gua Musang	113 900	116 200
Kuala Krai	135 200	137 800
Jeli	50 800	51 900
Total	1 743 400	1 742 400

1.2.4 Land Use

Land uses explain about the function of land that is used and land use of a place varied from one area another. According to Internet Geography, 2020, housing and industry are cities and towns land use which is in urban areas, while in rural areas, farming and forestry can be classified as countryside land use.

Land use that involves in the study area are dominated by rubber plantation and palm plantation as the Ladang Chin Teck at the study area are palm plantation estate. As time changes and the economic improvement of Gua Musang district occured, the land use of the area changes. In overall, the land use of the study area is dominated by rubber plantation, palm plantation and forest land.

1.2.5 Social Economic

As Gua Musang undergoes rapid changes and development, it shows a positive impact to the local people and towards the outsider as more job opportunities are provided and open for them.

In the study area, the main economic are consisted of palm plantation and rubber plantation. At Ladang Chin Teck, the palm plantation is well developed thus offers many job vacancies to the local people and outside to work whether in the factory or the estate. The rubber plantation at the study area also contribute to the economic development for the Gua Musang District.

1.3 Problem Statement

Few problems arise concerning the study area such as there is no detail geological map of the study area. The research in this field at the study area is consider as new and need to be carry out to overcome the issue of lacking in the information about the general geology and geological heritage elements that exist in Gua Musang District. Thus, a detail geological map and identification of geological heritage element need to be done with more effort and detail in study.

Next, in the study area, many karst limestone features are expected to fulfill the geological heritage value, but the karst limestone was not well expose to the public and even the local does not aware of the values that it held. However, this karst limestone can attract the local people and foreign visitors with the proper promotion and exposure. This research must be conducted to identify the study area geological features and geological heritage values that it held.

1.4 Objectives

The main objectives of this research:

1. To generate a detail geological map of Kampung Sungai Kepa, Gua Musang with the scale of 1:25000.
2. To derive a detail geodiversity map index of Kampung Sungai Kepa, Gua Musang with the scale of 1:25000.
3. To determine the geoheritage elements that has potential for geotourism development in Kampung Sugai Kepa, Gua Musang.

1.5 Scope of Study

Scope of the study is concern in generating a detail geological map of the study area and data interpretation is carry out to obtain the data. The geological data needed to construct a detail geological map are structural geology, geomorphology, lithology, hydrogeology, minerals and pedology data of the study area. This detail geological map can be construct using ArcGIS software.

Next, this research also focusses on determining the geological heritage element that guide toward conserving the nature and geological heritage value in Gua Musang, Kelantan. This geological heritage element also involves biodiversity and geodiversity as it also component of geology. In geology perspective view, geological heritage helps in giving data and information regarding geological history, formation and occurrence based on geological structure and features that are found.

1.6 Significant of Study

This research is conduct for three purposes which is to generate a detail geological map of Kampung Sungai Kepa, Gua Musang with the scale of 1:25000 and derive a detail geodiversity map of the study area with the scale of 1:25000. From the geological map and geological map produce, geological heritage elements that have potential for geotourism development in Kampung Sungai Kepa, Gua Musang can be determine.

It is important to generate a detail geological map and geodiversity map of an area by referring to the secondary data and previous research that consisted of geological features, geomorphological, lithological, hydrogeology, minerals and pedological that based on the geodiversity indices.

Geoheritage term is applied to geologically characterized the site or area based on scientific, educational, recreational, aesthetic, and cultural value. By knowing it potential for geotourism development, it helps to raise the awareness of geroheitage occurrence for the public and local community. Understanding the context of geoheritage will directly and indirectly benefit the local, national, and global communities from the full range by conducting this research. As for conservation, the benefits include tourism attraction and cultural and spiritual values.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review is crucial part in research as the purpose is to identify the theoretical and scientific knowledge, making it easier and for better understanding in the research paper. Literature review available from the varieties of sources such as journals, articles, book, internet websites, and any other scientific resources that related and relevant to certain issue of the study area as theory.

Geology is defined as the study of Earth's evolution from the past to the future, that involves the geological history, process and formation that shape into nowadays features. In general, geological studies related with the collection of data from previous studies, books, and scientific journal and articles. Information that related with the geology of study area is collected to provide a better understanding for research paper.

2.2 Regional Geology and Tectonic Setting

Malaysia is part of mainland of Southeast Asia country that consists of Peninsular Malaysia and Sarawak and Sabah State are on Borneo Island at the northern edges part (Moen, 2020). According to Hutchison (2014), Peninsular Malaysia is part of Eurasian plate while Sundaland is the south-eastern part of Asia.

Geologically, Peninsular Malaysia can be classified into three longitudinal belts, Eastern, Central and Western belt, which each longitudinal belt has its own geological characteristic. The Western Belt of Peninsular Malaysia forms part of Sibumasu Terrane, which was derived from North-West Australian Gondwana margin during late Permian. At the same time, Eastern and Central Belt represent Sukothai Arc which are constructed in Late Carboniferous-Early Permian on the Indochina Block margin. Back-arc spreading during Permian had separated this arc from Indochina Block (Metcalfe, 2013). Generally, Peninsular is part of Eastern Malaysia and tectonic stratigraphic terrain of Sibumasu.

Kelantan is situated on the central belt of Peninsular Malaysia, where significant structural zones have appeared known as Bentong-Raub Suture Zone. This Bentong-Raub Suture Zone is one of the major structural zones in Sundaland, Southeast Asia. Genetically, this related to sediment hosted/orogenic gold deposits associated with the major lineament in central belt of Peninsular Malaysia (Pour, 2016). It is well exposed to road-cuts along Bentong-Raub Road, Karak Highway, and Gua Musang-Cameron Highland Road. The Bentong-Raub suture is roughly 13 kilometer broad of deformed rocks consisting of phyllite, schist, meta-sedimentary rocks, cherts, sandstone, mélange, and olistostrome (Tjia, 1996).

The general geological map of Kelantan is shown in Figure 2.1. Based on the geological map of Kelantan, it shows that the lithology of Kelantan varied as it consisted of multiples rocks such as igneous, sedimentary, and metamorphic rocks. These rocks are identified in North-South trend pattern of Kelantan state. These three types of rocks are classified according to their region that consists of granite rock, extrusive rocks, unconsolidated sediments, sedimentary rock, and meta-sedimentary rocks. The rocks are dominated by igneous rock. Localization of joint and fault geological features in sedimentary rocks and distribution of granite rocks in western

Main Range Granite and eastern borders of Kelantan State's Boundary Range Granite are recorded (Department of Minerals and Geoscience Malaysia, 2003).

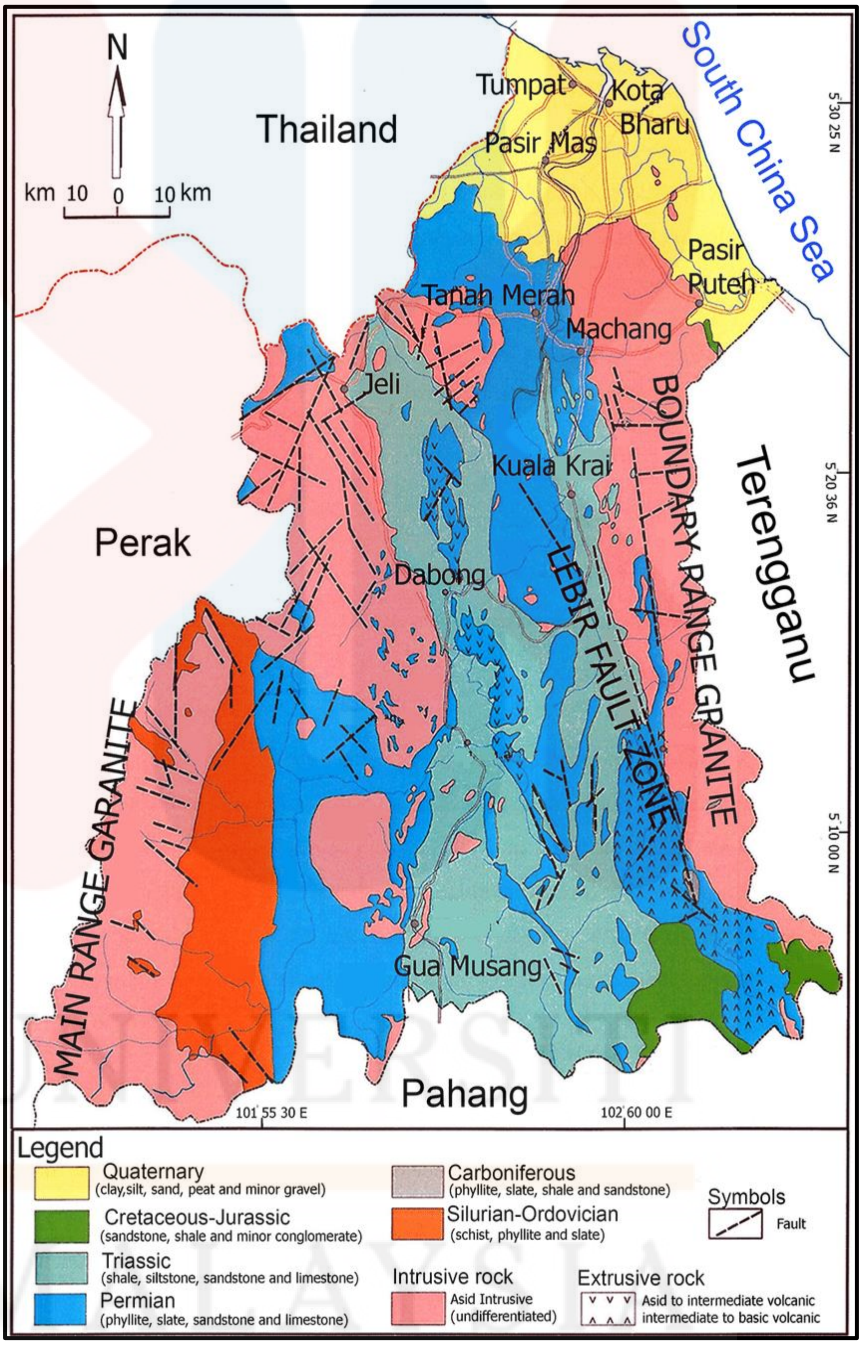

Figure 2.1: General geology map of Kelantan State. (Source: Department of Geoscience Malaysia, 2003).

According to Goh (2006), the regional geology of Kelantan consists of sedimentary central zone and meta-sedimentary rocks bordered on the east and west of Main Ranges Granite and Boundary Ranges Granite respectively. Geomorphologically, the Kelantan state can be divided into four types of landscape which are the hilly areas, mountainous areas, coastal areas, and plain areas. These types of landscape occur in the Gua Musang district except the coastal areas, which form only in the northern part of Kelantan.

There are two formations in Gua Musang area which is the Gua Musang and Gunung Rabong formations. According to Mohamed (2016), Gua Musang Formation consists of calcerous and argillaceous rock intercalated with the volcanic and arenaceous rock. These unit extend from north to south of Kelantan to north of Pahang. Based on the fossils record found by Ichikawa and Yin (1966), the fossils shows Permian to Middle Triassic age. According to Yin (1965), Gunung Rabong overlain Gua Musang Formation and named after Gua Musang town in south of Kelantan. Gunung Rabong Formation consists of predominantly arenaceous bands in Gua Musang area of southern Kelantan. Fossils of *Donella* and *Posidonia* found suggest the age of formation is Middle-Late Triassic.

The study area, Gua Musang is in southern region of Kelantan and it is part of Central Belt. The Central Belt is predominantly composed of Permian-Triassic clastic, volcanic and limestone (Mohamed, 2016). Gua Musang contained unique morphological features and surrounded with karst limestone that has many geological features. Limestone landscape or karst topography is well distributed in Peninsular Malaysia, Sarawak, and Sabah.

Rafferty (2016) defined karst as rocky ground, barren, sinkholes, caves, absence of surface streams and lakes, and underground rivers. Underground water on massive soluble limestone give excavating effect that result to the formation of karst. Karst is landscape form from soluble rocks including limestone, gypsum, and dolomite that undergoes the dissolution process. Almost all surface karst is formed by subsidence, internal drainage, and collapse triggering by development of underlying (Drew, 1999).

Karst Gua Musang undergoes many favorable conditions for the process of karst formation to strongly develop. Rainfall, rich organic acids and abundant of acid area some of the favorable conditions for karst formation. The Gua Musang area and karst of Gua Musang cave is indicators of depositional environment and landscape evolution (Mohamed, 2016).

According to Hutschison (1989), he proposed that Bentong-Raub line as the main tectonic border between Peninsular Malaysia’s western and central belts. The Bentong – Raub Suture Zone stretches from Tomo, southern Thailand through Bentong and Raub to Melaka (Tjia, 1996) which is shown in Figure 2.2. Peninsular Malaysia's Bentong-Raub suture zone is located between the Terrane of Sibumasu and the Terrane of East Malaya (Indochina). The Sibumasu terrane was connected to Cimmeria and the terrane of East Malaya was connected to the Indochina and South China.

Ocean known as Paleo-Tethys divided the blocks of Sibumasu and East Malaya, creating an opening when the North and South China, Tarim plate and Indochina rifted during Devonian. It is known as Indochina, when the Sibumasu terrane collided with Paleo-Tethys, during the Triassic.

The record of radiolarian chert blocks shows the remain of oceanic sediments and this Paleo-Tethys is known ages from Early to Middle Devonians. During Late Devonian, Paleo-Tethys was an ocean with the first chert of *Radiolaria* deposited and it grew larger during the Carboniferous period. In Late Permian, the oceanic crust of Paleo-Tethys collapsed under the East Malaya Terrane and subdued eastward. According to Fontaine (1995), Paleo-Tethys became shallow ocean during Early Triassic period that dominated by scattered calcareous fossils. The closure of Paleo-Tethys and Bentong was completed during the Triassic period and the Bentong-Raub Suture Zone was formed (Fontaine, 1995).

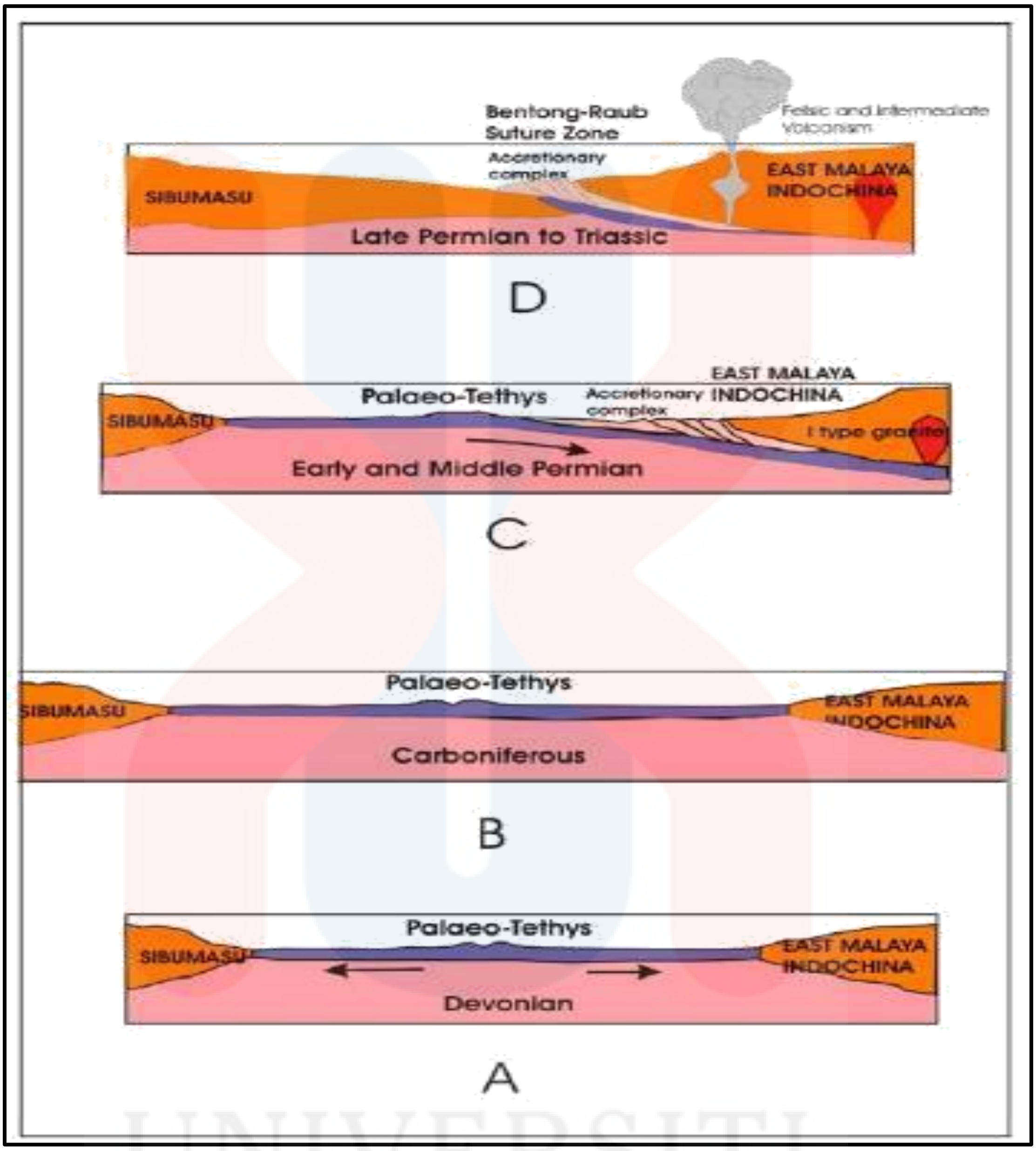

Figure 2.2: The illustration of Evolution of Paleo-Tethys based on the radiolarian cherts. A. Opening of Palaeo-Tethys occurred during Devonian period. B. During Carboniferous, Palaeo-Tethys became wider. C. Palaeo-Tethys were subducted under East Malaya. (Source: Bulletin of the Geological Society of Malaysia, 2013).

2.3 Stratigraphy

Stratigraphy is one of the geology branches that explains about the composition, formation, sequences and includes correlation of stratified rocks and sedimentation of area. (MacLeod, 2020). In Gua Musang, there are two formations which are Gua Musang and Gunung Rabung formations. Gua Musang Fomation consisted of argillaceous and calcareous rock intercalated with volcanic and arenaceous rock in south of Gua Musang (Yin, 1965). Argillaceous and calcareous rock intercalated with volcanic and arenaceous rock occured in the south of Gua Musang to the north of Pahang under Gua Musang Formation. In stratigraphic column, Gunung Rabong Formation is uncomfortably overlain the Gua Musang Formation that consisted of predominantly arenaceous and argillaceous sequences with subordinate calcareous, volcanic and rudaceous bands in southern Gua Musang Kelantan.

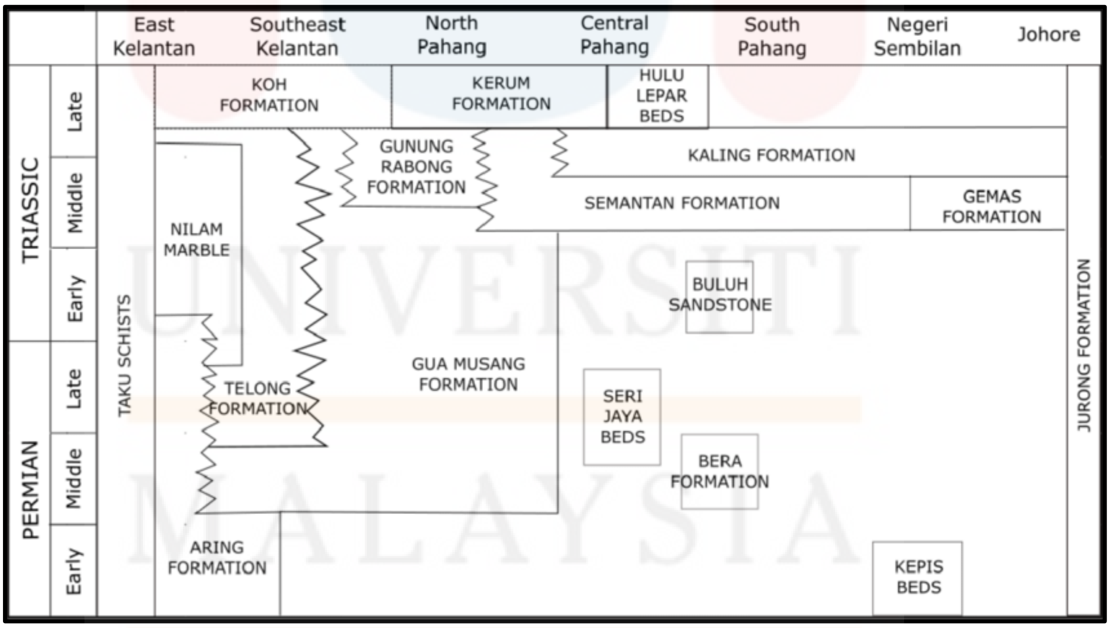

Figure 2.3: Permian-Triassic stratigraphic correlation of Central Belt of Peninsular Malaysia (Source: Modified from Metcalfe and Hussin, 1995).

Correlation between each formation and their occurrence in different state aging from Permian to Triassic age is shown in Figure 2.3. For Taku Schist at central east Kelantan, it appeared from Permian to Triassic or possibly older as the schist correlates along the eastern foothills of Main Range. Aring Formation, south Kelantan age from Upper Carboniferous, whole Permian age to Lower Triassic. It has correlates with Gua Musang Formation in Kelantan Pahang volcanic series in northwest and west Pahang and metasediments in southeast Pahang.

Nilam Marble Formation in southeast Kelantan appeared from Late Permian until Late Triassic. It correlates with Aring Formation and Telong Formation of southeast Kelantan. Next, Koh Formation at southeast Kelantan is laterally equivalent with Tembeling Group that age from Upper Triassic to Jurassic. It is recorded to unconformably overlay the Telong Formation. Telong Formation unconformably overlying the Gua Musang Formation as its lower boundary and unconformably overlay Koh Formation in the upper boundary. It correlated lateral equivalent to Semantan Formation and Gunung Rabung Formation. Gua Musang Formation that age from Middle Permian to Upper Triassic interfingering with Telong Formation, Semantan Formation, and Gunung Rabong Formation.

Gunung Rabong Formation in southeast Kelantan and north Pahang occured from Middle Triassic to Upper Triassic and laterally equivalent to Telong Formation and Semantan Formation. It unconformably overlies the Gua Musang Formation. Kerum Formation that dated at the Late Triassic is overlain by Lanis conglomerate.

2.4 Structural Geology

Kelantan is located at the north-east of Peninsular Malaysia. The compressional force that occurred in the region had caused series of geological event such as fold and fault. According to Khoo (1983), the dominant structure at N-S to NW-SE has formed through the orogenesis process. Orogenic process is the main mechanism and process where the continent mountain was built. The process occurred when the continent plate crumbles and pushed upwards to formed one or more mountain ranges and orogenic belt develops. When involves a collective series of geological process, it is known as orogenesis.

Being positioned at the central belt of Peninsular Malaysia, a significant structural zone has appeared at Kelantan state which is known as Bentong-Raub Suture Zone. Bentong-Raub Suture Zone that present at the Central Belt represent a segment of main Devonian to Middle Triassic Paleo-Tethys ocean that form boundary between Gondwana, derived from Sibumasu and Indochina terranes (Metcalfe, 2000). Paleo-Tethyan oceanic ribbon-bedded cherts preserved in the suture zone range in age from Middle Devonian to Middle Permian, while mélange which includes chert and limestone clasts range in age from Lower Carboniferous to Lower Permian. This Paleo-Tethyan oceanic ribbon-bedded cherts and mélange present indicates that the Paleo-Tethys opened in the Devonian age, when Indochina and other Chinese blocks separated from Gondwana, and closed in the Late Triassic. The suture zone is resulted from northwards subduction of the Paleo-Tethys ocean beneath Indochina in the Late Paleozoic and the Triassic collision of the Sibumasu terrane with under thrusting of Indochina.

2.5 Historical Geology

Gua Musang contain many unique geological features and geomorphological features such as karst limestone and hills area. Karst topography is a landscape often noticeable by surface drainages due to its suspension patterns characteristics. Karst limestone or karst topography are well distributed along Peninsular Malaysia, Sabah, and Sarawak.

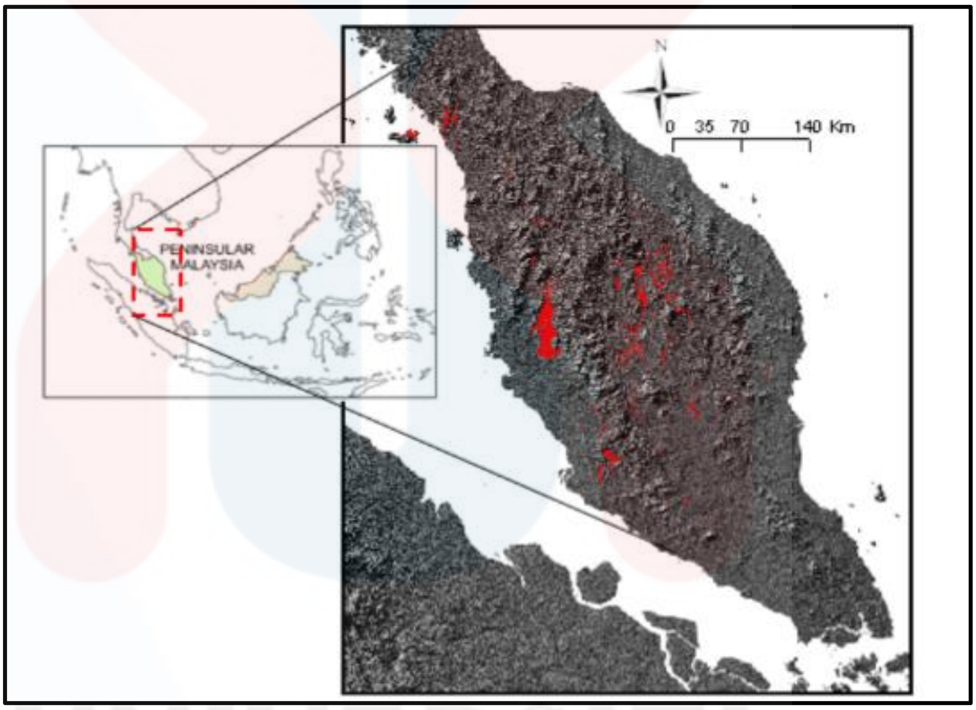

Figure 2.4: Figure shows the distribution of limestone or karst topographic in Peninsular Malaysia (Source: Department of Mineral and Geoscience Malaysia).

Geomorphologically, the Kelantan state is classified into four types of landscape which are the hilly areas, mountainous areas, coastal areas, and plain areas (Tanot, 2011). All these types of landscapes occurred in Gua Musang district except for the coastal areas that formed only in northern part of Kelantan.

Rock Unit of Kelantan State are divided into severals part which are unconsolidated rock sediments, sedimentary rocks, metasedimentary rock and extrusive igneous rocks such as volcanic rocks, and granite. As for granite in Kelantan State, it is classified into two main bodies which are Boundary Range Granite and Main Range Granite. Main Range Granite was formed in between 200 to 230 million years ago during Late Triassic age (Department of Minerals and Geoscience Malaysia, 2003).

2.6 Geological Heritage

There are distinctive rocks and other valuable Earth materials, wonderful geological landforms, and amazing geological processes everywhere on Earth. These features cause Earth to become more attractive and potentially contain geological heritage (Dony, 2016). Geological heritage or geoheritage is a geological concept which focuses on special, unique, and representative geological features that have geoheritage value (ProGEO, 2011).

High in geoheritage resources, Malaysia is known as one of the countries that actively conserved and developed. According to Komoo (2004), early efforts to conserve geological resources in Malaysia were initiated in the Third Malaysian Plan (1976-1980) by providing for the requirement to protect geological memorials and landscape. The establishment of Malaysia Geological Heritage in 199 shows the start of systematic determinations to endorse the conservation of geological heritage. Most research works were subsequently conducted to study and describe many geo-heritage sites of maintenance and growth.

Geoheritage refer to the geological elements and features that valuable while geotourism is geological tourism based on the Earth's geological heritage. Geotourism is one of the sub-components from the main components of tourism which based on the geological environment (Dowling, 2013).

Having condition like distinctive occurrence, rarity and representativeness of certain geological features required a measurement when identifying the potential site of geological significant (Brocx, 2007). He also classified geological heritage into its scope which are mineralogical site, geomorphological site, hydrogeological site, structural site, petrological site, and others that related to geological characteristic elements.

According to Brocx (2007), geoheritage and geoconservation are concerned and focus with the preservation of Earth Science features and endeavors globally. Globally, this geological heritage focused on the geology and geomorphology, which according to literature important for education, research, tourism, natural resources management, local cultural reasons, and land management.

Notable geologic features considered important for geological heritage preservation that may have scientific values, historic, educational value, aesthetic, or economic value (Halim, 2017) In geology's perspective, landscape is generally related to heritage value which can be divided to several types (Dony, 2016).

According to Joanes (2008), educational and scientific values provide public knowledge on the history of physical development of Earth. Scientific value related to geologic features and landscape, distinctive rock or mineral types or other geologic characteristic that are significant to research and important for geologic records and Earth's history. Almost similar to scientific value, educational related to education such as in educating people regarding the geological sites and features. Scientific value is more systematic and comprehensive compared to educational value. The geological resources have high educational values as it acts as tools to understand geological events that shape the study area and the region in general.

Cultural value related with geological features or landscape that plays role on cultural or historical event in social or local community for past, present, or future societies (Dony, 2016). Based on Mohamed (2016), other additional values such as economic values involve financial values of resources depending on the geological features and landscape or nature. For functional value, it relates with the use of resources of the study area.

2.7 Geological Diversity

According to Athanasios (2016), the concept of geodiversity has been used in various applications such as geological heritage, geoconservation and ecosystem management. Geodiversity acted as the connection between people, culture, and landscape, varieties of component and geological environments, phenomena, and processes that developed them and resulted in showing varieties of rock types, soils, minerals, and fossils that provide Earth's frame of life (Stanley, 2002).

Geodiversity was defined as the natural range diversity of geological such as rocks, minerals, and fossils, soil features, and geomorphological diversity which are landforms and the physical processes involves (Gray, 2004). Gray (2008) added that topographic and hydrographic elements were introduced in the definition of geodiversity.

According to Fernandez (2020), geodiversity is recognized to be intrinsic territorial features that contribute to establishment of geological interest. Geodiversity materializes in geological elements such as outcrop, landscape, and kind of soils which then to be studies and interpreted. Kozlowski (2004) further explain that surface of waters such as rivers and lakes, and the impact of human give influence to the geodiversity.

Various physical properties of surface of Earth become the main factors which influence the local topography of an area. However, this variety of Earth surface's physical property can be identified through the geomorphometric landform information as it provides valuable knowledge regarding the interfered processes that shapes today landscapes, thus producing geodiversity (Benito-Calvo, 2009).

Sharples (2002) also considered the interrelated the properties, system, characters of assemblages, and processes of the geological, soil element, and geomorphological that produce geodiversity.

According to Brilha, (2018), geodiversity assessment can be approached from two perspectives which are qualitative and quantitative. The qualitative perspective relies on knowledge of expert and the geodiversity elements description of a region. Next, the quantitative perspective focus to numerically reflect the spatial variability of the geological elements of a region. This qualitative and quantitative methods founded on numerical analysis, enable one to recognize the diversity and spatial distribution of the geodiversity elements in a region.

Geodiversity index is the total of partial indices which are lithology, geomorphology, pedological, minerals, hydrology and geosites (Fernandez, 2020). From the partial indices, a geodiversity map index and geodiversity map can be derived. As for calculation of geodiversity index, several partial indices were considered which are geomorphological, lithological, speleological, and hydrological.

Geomorphological diversity index is the sum of the relief and hydrographic sub-indices. The relief sub-index results from counting the number of morph-sculptural sub-units and the first- and second-order structural contacts, and represented on a 1:25,000 map of geomorphological units.

Speleological index map calculated the occurrence of karst limestone landscape and caves at the study area which represented on a 1:25,000 speleological map. Another geodiversity index is lithological diversity index which is generated based on the occurrence of the lithology rock unit. The more the rock unit occurrence at the square gird, the score will be higher.

The hydrology index is calculated by the drainage density that shows the hierarchy of rivers. This hydrology index can be defined as the diversity indicator of the water resources in a territory (Fernandez, 2020). According to Brilha (2018), geosites that make up the geoheritage are parts of identified geodiversity with values deserving focus, and attention, and their conservation is important to gain knowledge of the geological history of the area where they crop out.

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

Several materials and method were used to complete the process of geological analysis and interpretation, generating a complete geological map and geodiversity map index of study area thus determining the geoheritage elements for geotourism development in Gua Musang.

3.2 Materials

Digital Elevation Model (DEM) data taken from United States Geological Survey (USGS) was used for processing, analysis, and geological interpretation of the study area. This secondary data then was further processed using the ArcGIS Software.

Table 3.1: List of materials and their function.

Materials	Functions
ArcGIS Software	To generate the geological map at the study area For map analysis and geographic data compilation.
Secondary Data	Data available from other sources and already been used in previous research, Used to carry out further research.

	Secondary data from official authorized: • United States Geological Survey (USGS): - Digital Elevation Mode (DEM)

3.3 Methodologies

3.3.1 Preliminary Study

Preliminary study is the first step that takes place at the early stage of conducting this research as a preparation and collection of data regarding the study area and research. Various sources were referred especially journal, article, books, internet sources and previous research paper. Generally, preliminary research can support this research by emphasizing the general geology settings, geological heritage, and geological diversity of study area.

Before moving on to the next stage of methodology, which is geological processing, analysis and interpretation of secondary data, preliminary study must be resolve by gathering previous published literatures. Information were gained by reviewing journals, articles, books, internet sources and previous research which clarifies more clearly about the study area and act as reference for conducting research.

3.3.2 Data Collection

During data collection stage, secondary data was collected from official authority which was from United States Geological Survey (USGS) as a source. In this research, secondary data was needed to process, analysis and interpret geologically.

For the first map which was geological map, secondary data that was used was Digital Elevation Model (DEM). According to Manap (2009), 3D information from the contour data, aerial photographs and satellite imaginary will provide information in form of DEM. Which this DEM will be useful in interpreting the geomorphology and geological map.

From this DEM data, geomorphological map, landform map, lineament map, watershed and drainage map can be generated. Base map that shows what geological features and lithology rock unit was generated using this DEM data and supported by information from the previous research data.

Derivation of detail geodiversity map for this research required the data from several partial indices which were lithology, geomorphology, hydrology, and speleology map. As for the derivation of geodiversity map, lithology map, geodiversity map, hydrology map and speleology map were generated first. All this geodiversity map can be derived from DEM data.

3.3.3 Data Processing

The secondary data were processed, analyzed, and geologically interpreted to obtain information about the geological study, geodiversity and geoheritage study of research area.

During data processing, the detail geological map with the scale of 1:25000 of the study area and a detail geodiversity map index based on the satellite imaginary images were generated from the secondary data. For the detail geological map, few other maps were generated such as base map, lithology map, geomorphology map, landuse map, watershed map, drainage, and density map. From the partial indices data of geodiversity, several maps were generated first which were lithology index map, geomorphology index map, hydrology index map, and speleology index map. These geomorphology map, hydrology map, lithology map and speleology map then were combined to derive a detail geodiversity map.

The detail geodiversity map index was obtained by the analyzation and geological interpretation of the secondary data through data processing. Pereira (2013) introduced this method and later were improved by Silva (2015) and Araujo and Pereira (2017).

Second objective which is to derive a detail geodiversity map index of the study area, the geodiversity mapping assessment method was used. This method consists of two perspectives which are qualitative and quantitative. The qualitative perspective relies on knowledge of expert and the through the assessment of geodiversity elements description of a region. Qualitative perspective does not generate geodiversity maps as they can be derived from geological maps of the area. This qualitative geodiversity assessment provides data about the geological element's spatial distribution however, geodiversity data variation is not provided.

As for the quantitative perspective, it focusses to numerically reflect the spatial variability of the geological elements of a region. Using numerical analysis of quantitative, identification of diversity and spatial distribution of geodiversity elements in an area can be figured. Using GIS tools, the partial or total geodiversity index is obtained by combining the partial diversity index, showing the concentration of specific geodiversity features in an area.

Geodiversity mapping assessment focus on generating a geodiversity map of the study area using different partial indices. The assessment was proposed by Pereira

(2013) based on the continuous nature of geodiversity where he divided nature into different partial indices of geodiversity and were presented in form of maps of lithology, geomorphology, speleology, and hydrology. All these data were obtained from DEM data derivation and supported from previous research paper.

For each partial index, a regular grid was drawn on the map to define their different units. The size of the grid was decided to be ten grid horizontal and vertical, with same size distribution for each grid. The size of each square of regular grid was drawn respectively same as the base map of study area which were 5 km × 5 km in total area. The sum of the partial indices in each square give the result of geodiversity index per square. All the steps and each partial diversity map index were generated using ArcGIS Software.

Pereira (2013) proposed that in the partial indices map index, the numbers within the square are absolute value of the features represent in map and the legend presented the natural breaks that ranges to five values which are 1 (very low), 2 (low), 3 (medium), 4 (high) and 5 (very high). The geodiversity map indexes the sum up the normalized values obtained from the generated partial indices maps.

To calculate geodiversity index, partial indices involve were geomorphological, lithological, speleological, and hydrological. The geodiversity index map was derived from the sum of all the partial indices for each square and will be classify. The grid map was classified into five classes of geodiversity which were very low (1), low (2), medium (3), high (4) and very high (5).

3.3.4 Data Analysis and Interpretation

When the maps were generated, they were geologically analyzed and interpreted Geologic analysis and interpretation of the maps can be considered generally a two-step process. The first step includes observation, fact-gathering, measurement, and identification of features on the DEM data derivation, in contrasts with second step which involves deductive or inductive mental processing of these data in terms of geologic significance.

For geological analysis and interpretation of data, several factors and element were taken to consideration which were contour topography, slope gradient, water system, associated features, shape, size and other element. Geological analysis and interpretation of the data obtained from DEM data is not same as geological interpretation of field observed data.

Interpretation was based not only on landform but also on photographic differences, drainage patterns, erosion patterns, stream pattern, soil patterns, vegetation patterns, and any other surface expression of underlying geology. Fundamentally, photointerpretation was only applicable to those geologic features that do develop such surface expressions.

For interpretation of the geodiversity map index, the sum of all partial indices for each square were classify by combining all the partial indices map. The grid map of geodiversity map contained five classes of geodiversity which were very low (1), low (2), medium (3), high (4) and very high (5). By knowing the geodiversity value, Gray (2005) classified geodiversity into eight group of elements which are rocks, minerals, fossils, landscape, soil, landform, process and other georesources.

Brocx (2007) explain that geological heritage can be classified based on their scopes such as geomorphological site, mineralogical sites, stratigraphic site, petrological site, structural site, speleological site, and hydrological site. These scopes show further explanation on how geodiversity can be related as geological heritage. As s site contain high geodiversity value, then its geological heritage values will also high. Research Flow Process is shown in illustration of Figure 3.1.

3.3.5 Research Flow Chart

Research Flow Chart

Preliminary Study
- Regional Geology
- Stratigraphy
- Structural Geology
- Historical Geology
- Geological Heritage
- Geological Diversity

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Data Processing
- Geological Map
  - Base Map
  - Geomorphology Map
  - Lithology Map
  - Landuse Map
  - Watershed Map
  - Drainage Map
- Geodiversity Map
  - Geomorphology Map
  - Lithology Map
  - Hydrology Map
  - Speleology Map

↓

Data Collection

↓

Data Analysis and Interpretation
- Observation, fact gathering, measurement and identification of features
- Deductive and inductive process for geologic significance

↓

Full Thesis Writing

Figure 3.1: Illustration of Research Flow Process.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

In this chapter, general geology of the study area is analyzed and discussed based on the data collection and interpretation of secondary data from various official authorities and from previous research. Generally, this chapter explained geological information of the study area that include structural geology, historical geology, geomorphology, lithology, and stratigraphy. All of these data are generated by processing, analyzing and interpretation of secondary data obtained. The main outcome of this chapter is the geological map as it shows the geological features and structure of the study area along with the distribution of lithology rock units. From this, the history and correlation between rocks can be interpreted based on their age and formation.

4.1.1 Accessibility

Gua Musang is situated in the southern part of Kelantan State that shares border with Pahang at the south, Terengganu to the east and Perak to the west. There is a road connection that connect Gua Musang to Kuala Lumpur through Kuala Lumpur-Gua Musang Highway, which known as Lebuhraya Pantai Timur (LPT). Gua Musang can also be access from Merapoh - Gua Musang road. The box of study area can be access from Kuala Krai-Gua Musang road and Dabong - Gua Musang road. The study area can be access through Jalan Industri as the main road that heads toward the industrial town. This road is however off-road and leads to unpaved road. It can be accessed easily by using four-wheel drive car and by walking.

4.1.2 Settlement

As for settlement, this study area is mostly covered with limestone and oil palm plantation. Due to this, it gave positive impact to the local people and toward the outsider as more opportunities are provided and open for them. This causes more people to come and settle down at the Kampung Sungai Kepa, Gua Musang, Kelantan.

4.1.3 Forestry

The study area is surrounded with oil palm plantation with percentage around 30 %. Turned into oil palm plantation and rubber plantation, almost all of forestry of the study area have been irrigated. Furthermore, this oil palm plantation become the major factor that contribute towards the economics of the Kampung Sungai Kepa.

4.2 Geomorphology

Geomorphology is the study related to landforms, processes that formed them, their types and mechanism and sediments at the surface of Earth. This study includes studying the landscape of Earth to study the Earth's surface processes such as ice, water and wind that could formed landscape. Landscape is the physical elements that defined landforms such as hills, mountains, living elements of land cover for example vegetation, water bodies like lakes, rivers and sea, and human elements that covers land use and building structure.

Landforms are natural features of Earth's surface that are naturally formed through deposition and erosion processes. Worn away by Earth surface process, transported, and deposited in different location, rocks and sediments will form varieties of landform depends on the conditions.

4.2.1 Geomorphological classification (geomorphologic unit map)

Geomorphology of the study area is described through topography, weathering processes and drainage pattern that occurred at the study area which also included vegetation, and water morphology. The geomorphology of study area is determined based on processing, analyzing and interpretation of secondary data.

4.2.2 Topography

Topography is the study of forms and naturally physical features of land surfaces of an area. This naturally physical features are hills, mountain, rivers, and valleys. Topography plays major part in geomorphology study as it can be discussed and classified in relation to their different elevation of the study area.

In this part, the elevation of the study area is discussed and analyzed. From topography, landforms types and other characteristics can be distinguished. Historical geology of the study area can also be determined based on the landforms processes and formation.

According to Van Zuidam (1985), topographic system is divided into number of categories which are classified accordingly based on their mean elevations. Table 4.1 shows the class of topographic units with average elevations.

Table 4.1: Classification of topographic units (Van Zuidam, 1985).

Absolute Height (meter)	Morphology Element based on topography
<50	Lowlands
50-100	Inland Lowlands
100-200	Low Hills
200-500	Hills
500-1500	High Hills
1500-3000	Mountains
>3000	High Mountains

All the classification of morphological elements are based on topography which are high mountains, mountains, high hills, hills, low hills, inland lowlands, and lowlands can be analyzed and interpreted based on the contour map of the study area.

The study area is mostly covered with hilly mountains with the highest elevation observed around 600 meters, signaling high hills. This high hill is located at the south part of study area. Elevation of the study area are equally distributed ranging mostly from 300 meters to 600 meters. Generally, Kelantan state can be classified into four types of landscape which are hilly areas, mountainous areas, hilly areas, coastal areas, and plain areas (Tanot,2011). From table 4.1, according to Van Zuidam (1985), landscape of the study area that occurred are plain areas, hilly areas, and mountainous areas.

This study area is classified as limestone plain unit of geomorphology as the area has elevation ranging mostly from 300 meters to 600 meters. The hilly areas are indicated by the present of oil palm plantation estate as it occupied the remaining area from karst geomorphology. Mountainous area in the study area is referring to the peak of karst limestone with 500m elevation.

a. Origin of denudation

According to the geomorphological analysis and interpretation, geomorphology of the study area can be explained through origin of denudation. Denudation involves processes that causes the Earth's surface to be worn away by moving water, wind, ice and by waves. These processes lead to reduction in elevation and formation of landscape and landforms. Denudation is wearing a way of landmass through processes such as mass movement, weathering, erosion, and transportation. Denudation processes result in lowering level of land, exposed rock to be rounded and levelling down the peaks.

Geomorphic unit are classified as residual hill, denudational hill, dissected pediment, linear ridge, and alluvial plain. From interpretation, the hilly areas of the study area can be classified as denudational hilly landform. Denudational hills is a relict hill which already undergone denudation process and in return formed barren rocks or steep sided.

The hilly areas are interpreted as denudational hilly landform as the multiple erosion and weathering process that occurred, causing it form to formed barren rocks and steep sided or karts limestone.

b. Karst morphology

The most dominant landform at the study area belongs to lithology unit of limestone as the limestone unit represent karst geomorphology. Karst landform is usually distinguished by barren and rocky rocks and ground such as sinkholes and caves underground rivers. This landform is formed as massive soluble carbonate-rich rocks such as limestone, dolomite and gypsum which easily dissolved as it undergoes excavating effects of underground water.

Karst topography are formed from underlying soluble rocks that undergoes chemical processes known as dissolution by ground water or surface water. It highly associated with carbonate rocks which are limestone and dolomite or other rocks that highly soluble like rock salt or gypsum.

Based on the present of limestone unit at the study area, it shows that are indeed chemical processes occurred. Limestone is sedimentary rock that mainly consisted of calcium carbonate which are mineral calcite. Ground water or surface water dissolves this calcium carbonate under dissolution process.

The chemical processes of dissolution on the calcium carbonate rocks that occurred at the study area formed a karst landscape in form of cave formation. These chemical processes are influenced by pressure, temperature, and pH and ion concentrations. The acidic rainwater that contains carbon dioxide will chemically react producing carbonic acid. Although a weak acid, it able to react with carbonate mineral in rocks. This process causes the rock to weaken and chemical weathering process occur.

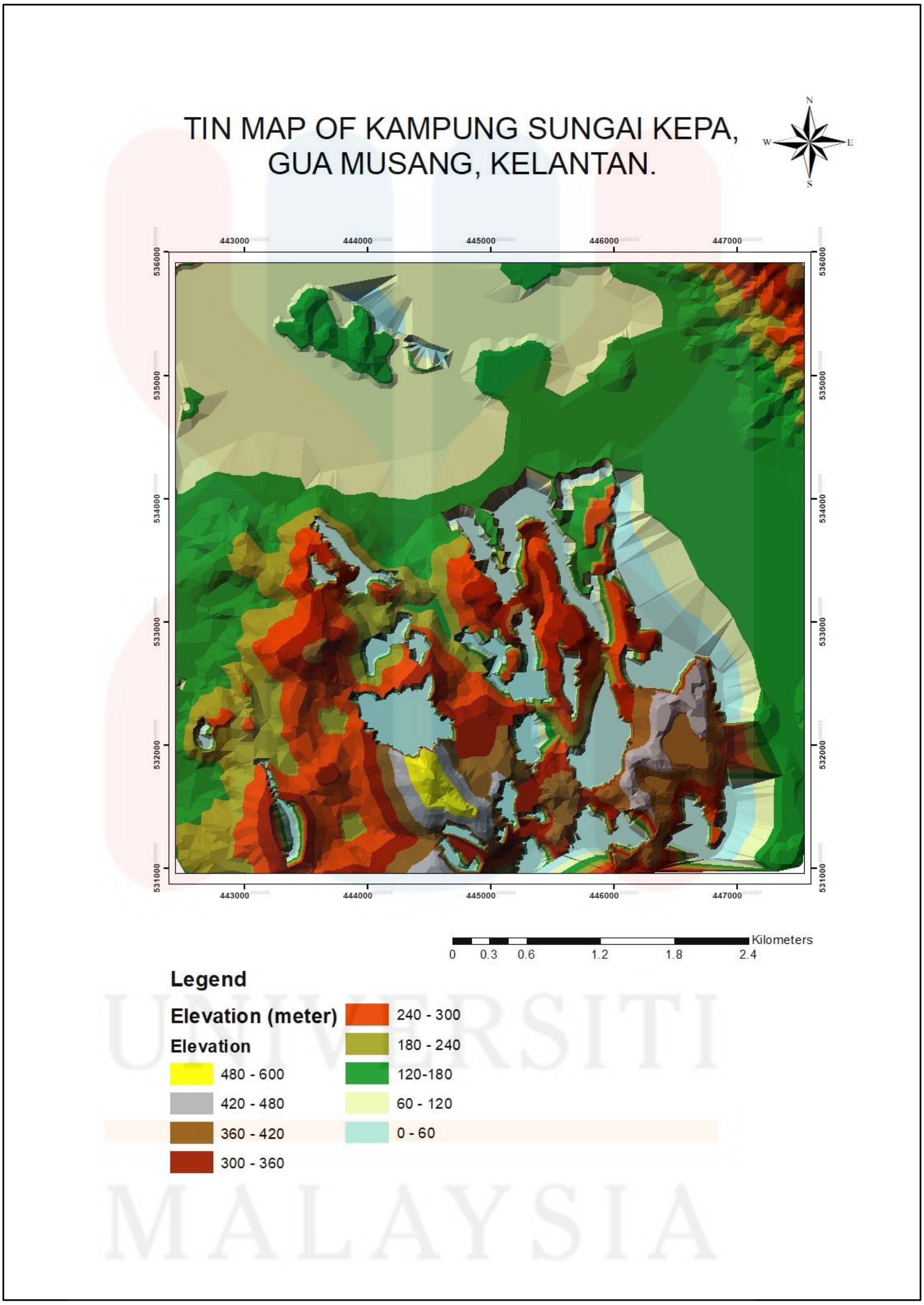

Figure 4.1: Tin map of study area.

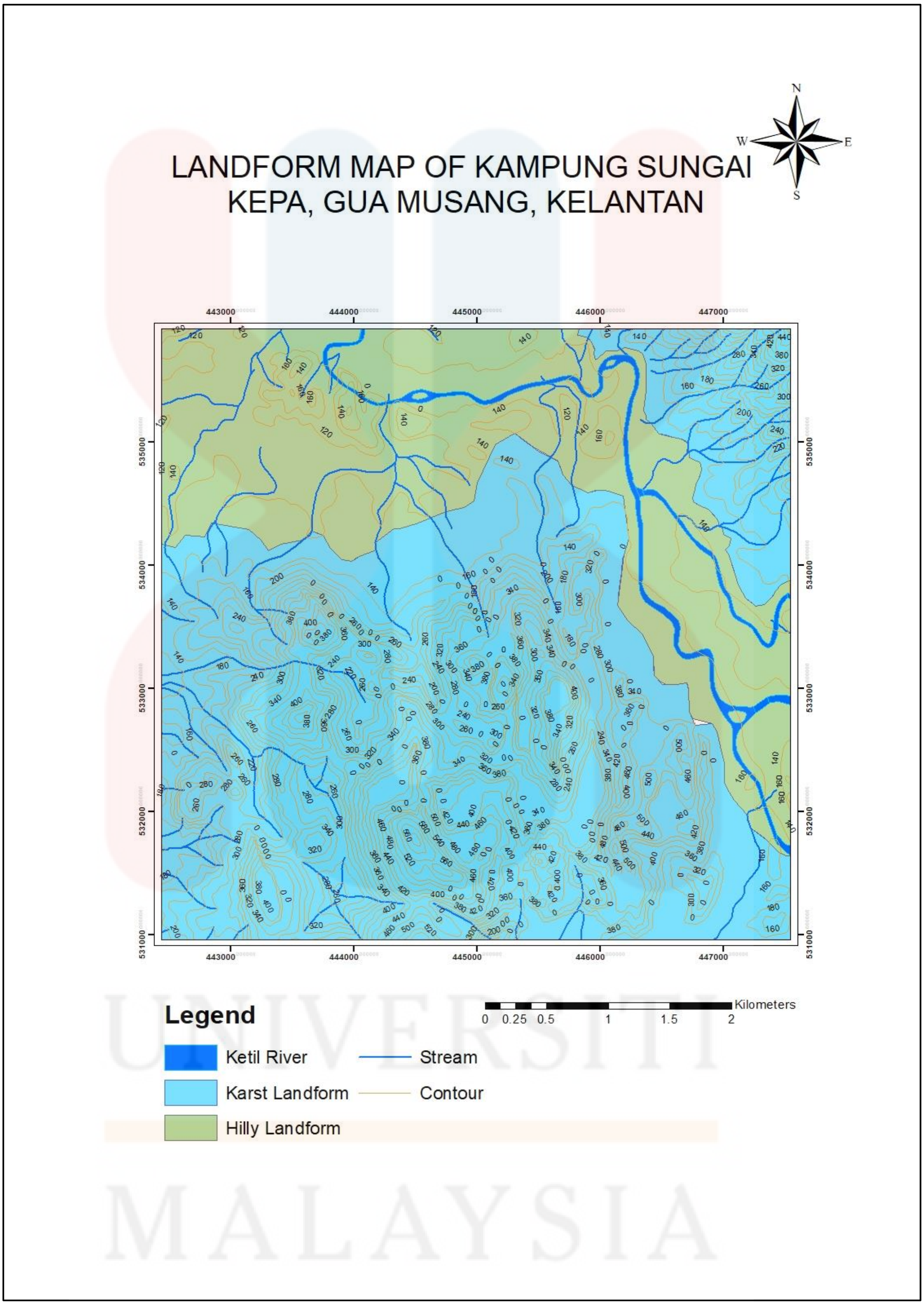

Figure 4.2: Landform map of study area.

4.2.3 Drainage pattern

Drainage pattern or drainage system is the pattern distribution of rivers, streams or lakes based on drainage basin. They are governed by the topography of an area, the lithology unit of an area is whether dominated with soft or hard rocks and also from the gradient of the land. Drainage pattern function as basin geology that indicates structure, lithology and overburden, historical geology formation, and slope. Basin pattern reveals the geology of an area based on their tributaries pattern.

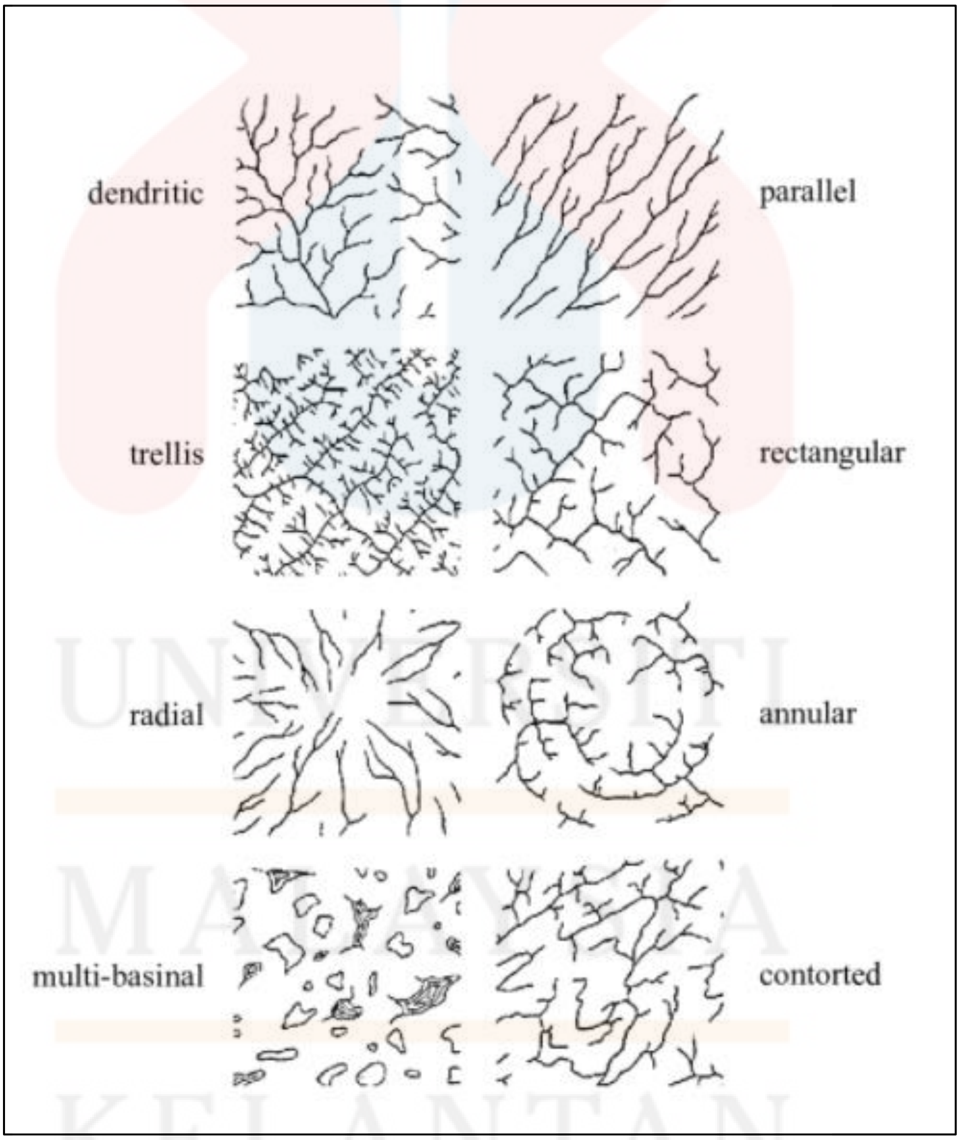

Figure 4.3: Type of drainage pattern (Howard, 1967).

Based on Figure 4.3, drainage system can be classified into several categories of forms of transitions known as drainage patterns which are parallel, dendritic, rectangular, angular, trellis and contorted. Based on analysis and interpretation, there are three types of drainage pattern that are identified at the study area which are dendritic, parallel, and radial. (Figure 4.4)

a. Dendritic pattern

Dendritic pattern is the most common form of drainage pattern and they flow not in straight pattern. This drainage pattern has many sub-tributaries which assembles branch or twig of tree or random which will merge into one main tributaries of main rivers. Dendritic pattern is strongly accordant and follow the land gradient with true dendritic system forms in V-shaped valleys. It can be concluded that the type of rock for dendritic pattern is impervious and non-porous, or flat sedimentary rock.

From the map analysis, the north-west of the study area are covered with dendritic pattern of drainage pattern which the streams are flowing towards the amin river, which is Ketil River. Based on interpretation, type of lithology at this area is metasedimentary rock.

b. Parallel pattern

This type of drainage pattern occurred on common slope which is in linear ranges or rivers that located in between linear series of parallel or elongated landforms. Parallel pattern drainage pattern also follows the natural faults or erosion that occurred at the rock body.

The water flows in straight and swift with little tributaries which all of them flows in the same direction, forming right angle bends. Water in this pattern flows on long, uniform slopes and from the map of the study area, this type of pattern can be found at the North-East part. It might be an indicator for joint or major fault that cut across steep bedrock.

c. Radial pattern

As for radial drainage pattern, the tributaries flow outwards from central high region. This type of drainage system can be found at the lower part of the study area, with small part of area only.

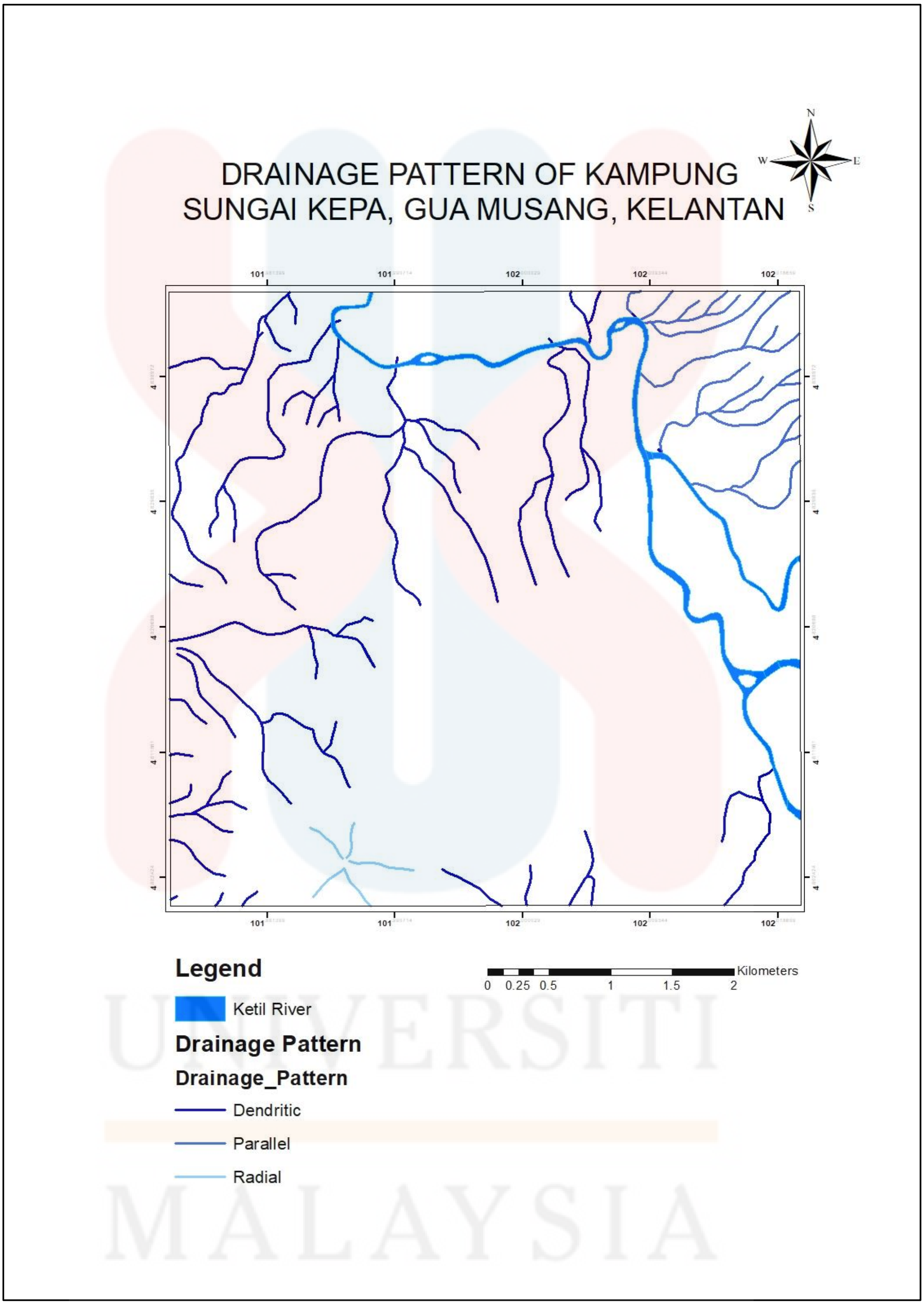

Figure 4.4: Drainage Pattern of study area.

4.3 Lithostratigraphy

In lithostratigraphy, the type of rock units is described and classified according to their stratigraphic characteristics. Lithostratigraphic units are the fundamental part of geological features which the others are geological structure, bedding orientation and many more. The lithology rock unit is determined based on the analysis and interpretation of the contour topography, slope gradient and water system. This will further explain in geological map and stratigraphic column in Figure 4.6 and Table 4.2.

4.3.1 Stratigraphic position

Stratigraphy is branch of geology that related with the study of rock layers succession and rock layering. This stratigraphy column can be used for interpretation in term of geological time scale as it deals with formation, sequences, compositions, and correlation of stratified rocks and sediments.

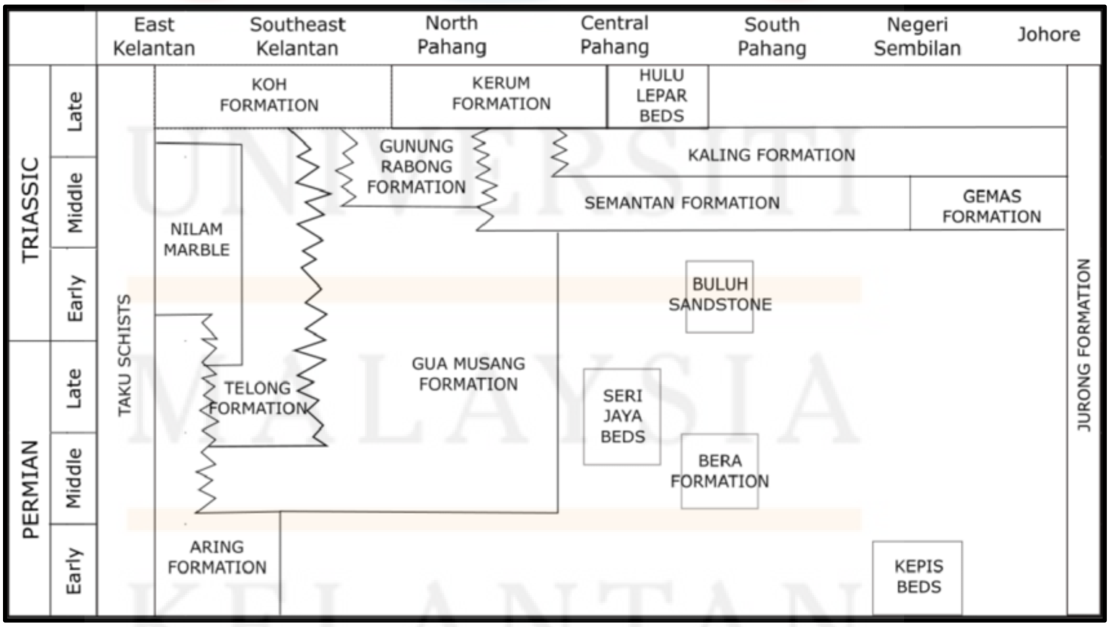

Figure 4.5: Permian-Triassic stratigraphic column of Central Belt of Peninsular Malaysia (Metcalfe & Hussin, 1995).

Based on Figure 4.5, the stratigraphy column shows the general stratigraphy of Central Belt of Peninsular Malaysia with age from Early Permian to Late Triassic. The study area which located near Gua Musang is under Gua Musang Formation. The age of Gua Musang Formation is from Middle Permian to the Late Triassic, sharing border with Aring Formation, Telong Formation and Gunung Rabong Formation with interfingering between them.

Gua Musang Formation is distributed towards Southeast Kelantan until North of Pahang with argillaceous and calcareous rock intercalated with the volcanic and arenaceous rock around Gua Musang area. The argillaceous facies consisted of shale, slate, phyllite, siltstone and mudstone which are dominant facies in Gua Musang Formation and in Telong Formation as they share interfingering borders. However, these facies are not found in large unit at the study area.

As for calcareous facies it mostly composed of calcium carbonate which is common in sedimentary rock limestone. This limestone is deposited from calcareous remains of marine animals or chemically precipitated from the seas as the depositional environment for Gua Musang Formation are also marine deposits. This limestone formed karst morphology as can be analyze based on the topography of the study area.

During the age of Permian towards the late Triassic, Gua Musang undergoes depositional process that resulted to the formation of argillites, carbonates, and volcanic facies. Based on secondary research, argillitic rock, carbonate, and acidic intrusion of South Kelantan to North Pahang are interpreted to occurred during Triassic while marine depositional environment started at early of Permian.

Analyzation and interpretation were made based on the contour topography, gradient of land slope, and the lithology rock unit that can determined at the study area are alluvial, limestone, meta-sedimentary rock and acidic intrusive of granite. Figure 4.6 shows the geological map of the study area.

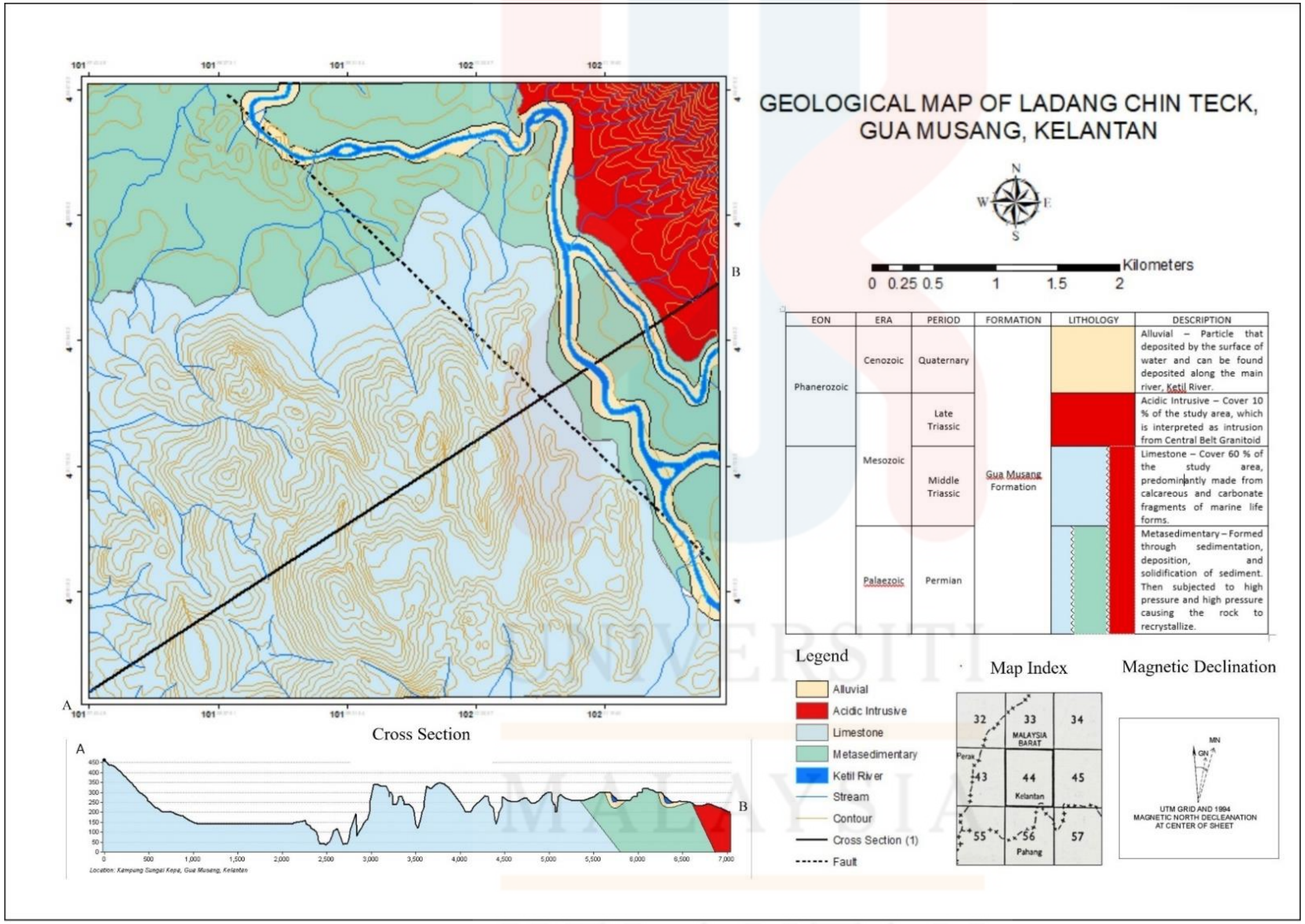

Figure 4.6: Geological map of study area.

Table 4.2: Stratigraphy Column of study area.

EON	ERA	PERIOD	FORMATION	LITHOLOGY	DESCRIPTION
Phanerozoic	Cenozoic	Quaternary	Gua Musang Formation		Alluvial – Particle that deposited by the surface of water and can be found deposited along the main river, Ketil River.
	Mesozoic	Late Triassic			Acidic Intrusive – Cover 10 % of the study area, which is interpreted as intrusion from Central Belt Granitoid
		Middle Triassic			Limestone – Cover 60 % of the study area, predominantly made from calcareous and carbonate fragments of marine life forms.
	Palaezoic	Permian			Metasedimentary – Formed through sedimentation, deposition, and solidification of sediment. Then subjected to high pressure and high pressure causing the rock to recrystallize.

Based on the stratigraphy column, the age of lithology rock unit can be determined and explain further. Metasedimentary rock which are identified as phyllite, shale and slate occur during Permian period. This type of rock is the oldest rock unit found at the study area as depositional proses of marine environment started.

Limestone rock unit occurred due to the marine depositional proses of calcareous and carbonate fragment of marine life forms which took place during Early

Permian until Middle Triassic. Limestone rock unit is the most found rock unit at the study area.

Next, based on previous research, Gua Musang Formation involves in orogenic uplift process during Late Triassic. There is record of volcanic rocks from acidic to andesitic compositions which occur during Permian to Triassic. The intrusion of acidic rock, granitic are said to be biotite-bearing and intrudes the Permian-Triassic sediments.

The youngest lithology rock unit found at the study area are alluvial unit which can be seen present along the main river which is Sungai Ketil. This unit is classified to occur during Quaternary period in the geology time scale.

4.3.2 Unit explanation

a. Metasedimentary unit

Metasedimentary rock is a sedimentary rock that formed through sedimentation, deposition and solidification of sediment then continued with metamorphism. This rock was buried underneath and subjected with high temperature and pressure, causing the sedimentary rock to recrystallize with the development of metamorphic minerals and textures.

This type of rock is sedimentary rock but with foliation or banded texture due to high exposure of temperature and pressure during metamorphism. Although with textures and minerals like metamorphic rocks, it is easy to distinguish metasedimentary rock and metamorphic rocks.

b. Limestone unit

Limestone is a sedimentary rock which predominantly made from calcareous and carbonate fragments of marine life forms, which obey the Gua Musang Formation depositional environment settling. Limestone contains mineral calcite and aragonite with distinctive rock types are calcium carbonate (CaCO3). Water, which is acidic dissolve the limestone rock, changing the chemical composition of limestone thus forming karst landscape. This limestone bedrock formed cavities and soon caves system are created.

From analysis and interpretation, the lower part of the study area is filled with limestone rock unit and considered as dominant rock found in Gua Musang area due to the existence of karst limestone landscape. Almost 60 % of the study area was covered with limestone rock unit. Limestone found are predicted to formed during Early Permian until Late Triassic period.

Dendritic pattern is the most common form of drainage pattern and they flow not in straight pattern. This drainage pattern has many sub-tributaries which assembles branch or twig of tree or random which will merge into one main tributaries of main rivers. Dendritic pattern is strongly accordant and follow the land gradient with true dendritic system forms in V-shaped valleys. It can be concluded that the type of rock for dendritic pattern is impervious and non-porous, or flat sedimentary rock.

From the map analysis, the north-west part of the study area is covered with dendritic pattern of drainage pattern which the streams are flowing towards the amin river, which is Ketil River. Based on interpretation, type of lithology at this area is metasedimentary rock.

c. Acidic intrusive unit

This rock unit covers about 10 % of the study area which located at the North-East part. From the analysis of contour topography, the rock can be characterized as plutonic rock which intrude the country rock. Intrusive rock undergoes crystallization process at great depth, below surface of Earth. It undergoes slow cooling process and producing large crystal minerals.

This intrusive rock are exposed millions or billions year later through few processes such as uplifting, erosion, and mountain-building. This rock intrudes surrounding rock which is known as country rock. This intrusive rock is interpreted and classified as acidic intrusive rock based on the previous research and study handle at the study area. Acidic rocks rich in silica content and contain mineral quartz, feldspar and biotite compared to other intrusive rock. Example of acidic intrusive rocks are granite, microgranite, and rhyolite. Acidic magmas are usually thick, viscous, and thick in form which explain why the grain size are unusually larger compared to basic rocks.

d. Alluvial unit

Alluvial unit are found along the main river which is Ketil River due to the depositional and cementation proses of sediment particles. This rock unit covers only about 5 % of the study area. Alluvial unit consist of sand, clay, silt and gravels and some organic matter which deposited in the riverbeds. The size of this sediment particle highly depends on the speed of the river flow.

4.4 Structural Geology

Structural geology explains about the three-dimensional distribution of large bodies of rock units that related with historical geology, past geological environments and significant events that changed or deformed them. Structural geology is branch of geology that deals with forms, arrangement, structure, and distribution of rocks. Geological structures are formed due to the strong tectonic forces that occurred in Earth. Tectonic forces cause the rock to fold and break, causing faults or rose of mountains. Geological structure useful to utilize estimation of present-day rock geometries that can reveal data about historical stress and strain of rock.

4.4.1 Fault

Fault is a planar fracture or discontinuity in rock volume that occurred with significant displacement, resulted from movement of rock mass. Faults are resulted from the action of plate tectonic forces with boundaries in between them such as subduction zones. Faults are divided into several categories based on the direction of slips, which area strike-slip, dip-slip, and oblique-slip. Fault can also be classified based on their stress into normal fault, reverse fault and thrust fault.

Based on the terrain map (Figure 4.7), faults are identified and analyzed by using lineament analysis. The occurrence of fault in the study area can be determined from this analysis. Lineament is linear feature in landscape that express of underlying geological structure, as it indicates faults, joint or fracture. Lineaments appear as straight water coastline, fault-aligned valley, series of fold or fault aligned hills, or combination of these features.

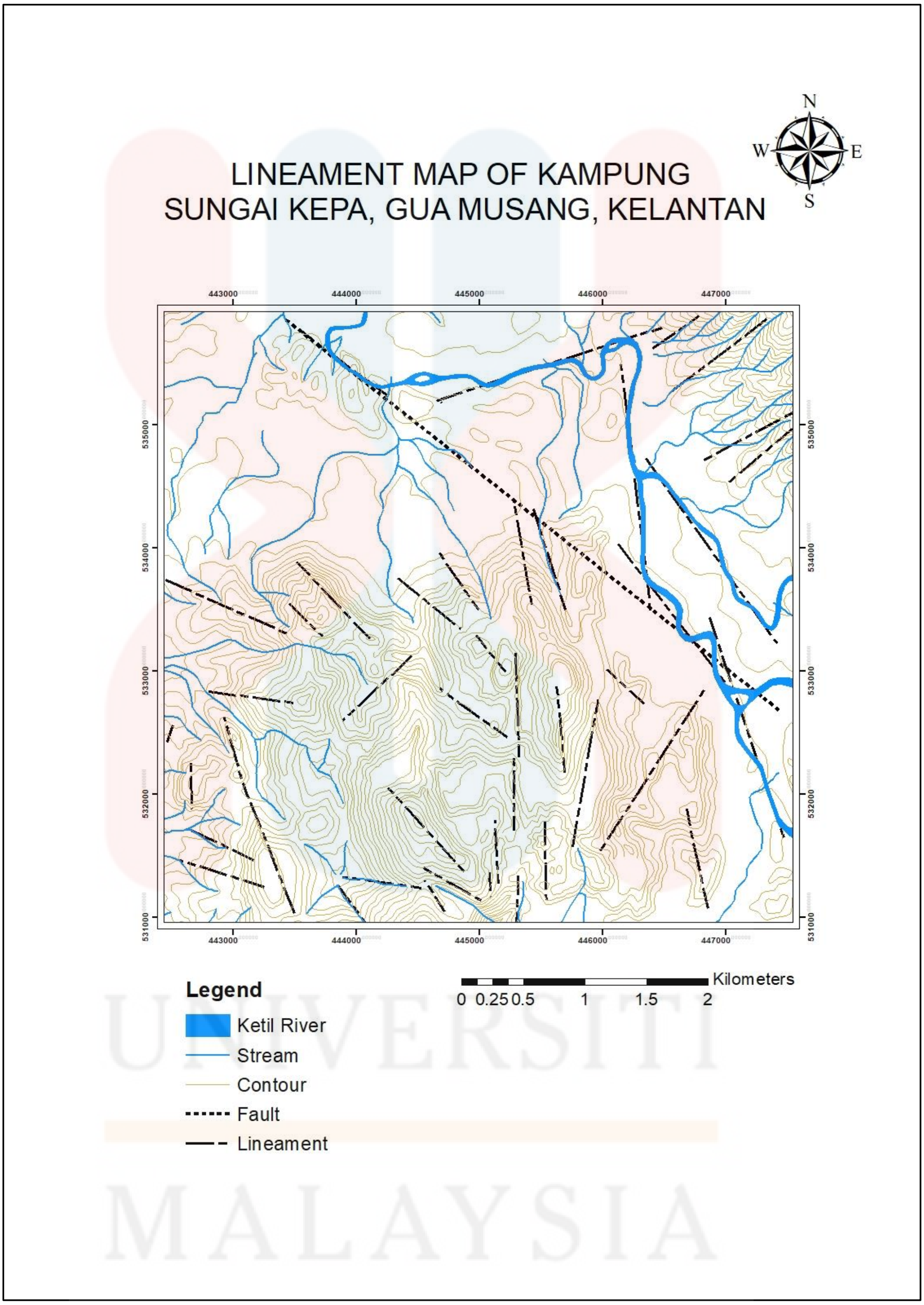

Figure 4.7: Lineament map of study area.

4.4.2 Mechanism of structure

Mechanism of structure of the study area occurred to the processes of uplifting during the plate tectonic movement. Earth's surface is lifted during tectonic movement as force are exerted from crust beneath Earth, forming hilly terrain landscape. Lineament analysis is useful in identifying the geological structure such as fault. To determine the present of fault without going to the field mapping, a lineament analysis method is used.

a. Positive lineament

By referring to the terrain map, positive lineament was determined by measuring angle between the ridge of hills. Figure 4.8 shows the positive lineament map that were generated based on identification of positive lineament at the study area.

b. Negative lineament

The angle of straight line of the valley and the edge of the river can be measured to get the negative lineament of the study area. Based on the rose diagram, the maximum direction came from 30^o and 70^o. The force that applied at the study area were identified as compressional stress as it occurs from two direction causing the rock to undergo fractures. The forces applied were perpendicular to the surface and transmitted through surrounding rock. From this rose diagram, the type of fault identified is sinistral strike-slip fault which the force direction is from left direction.

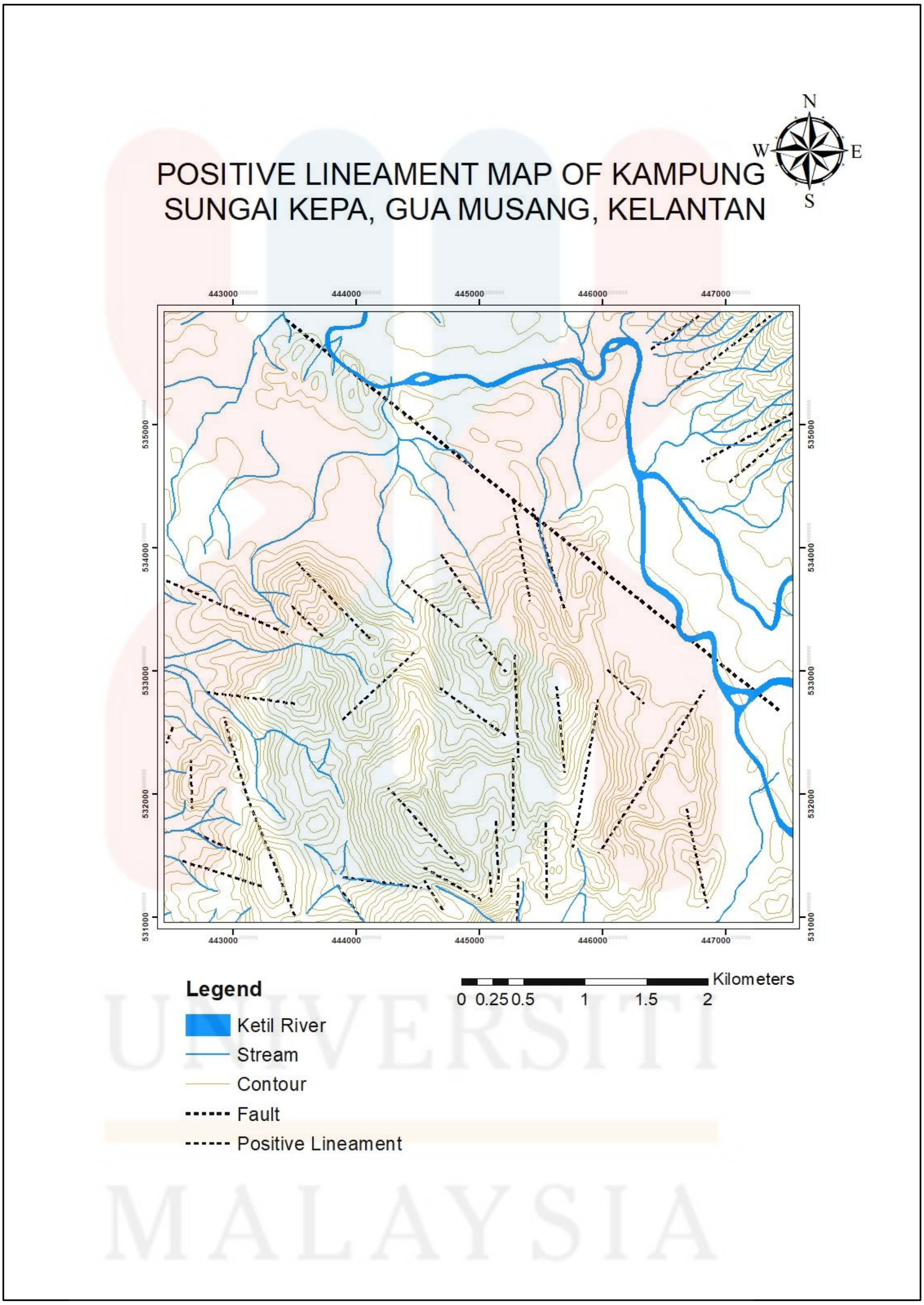

Figure 4.8: Positive lineament of study area.

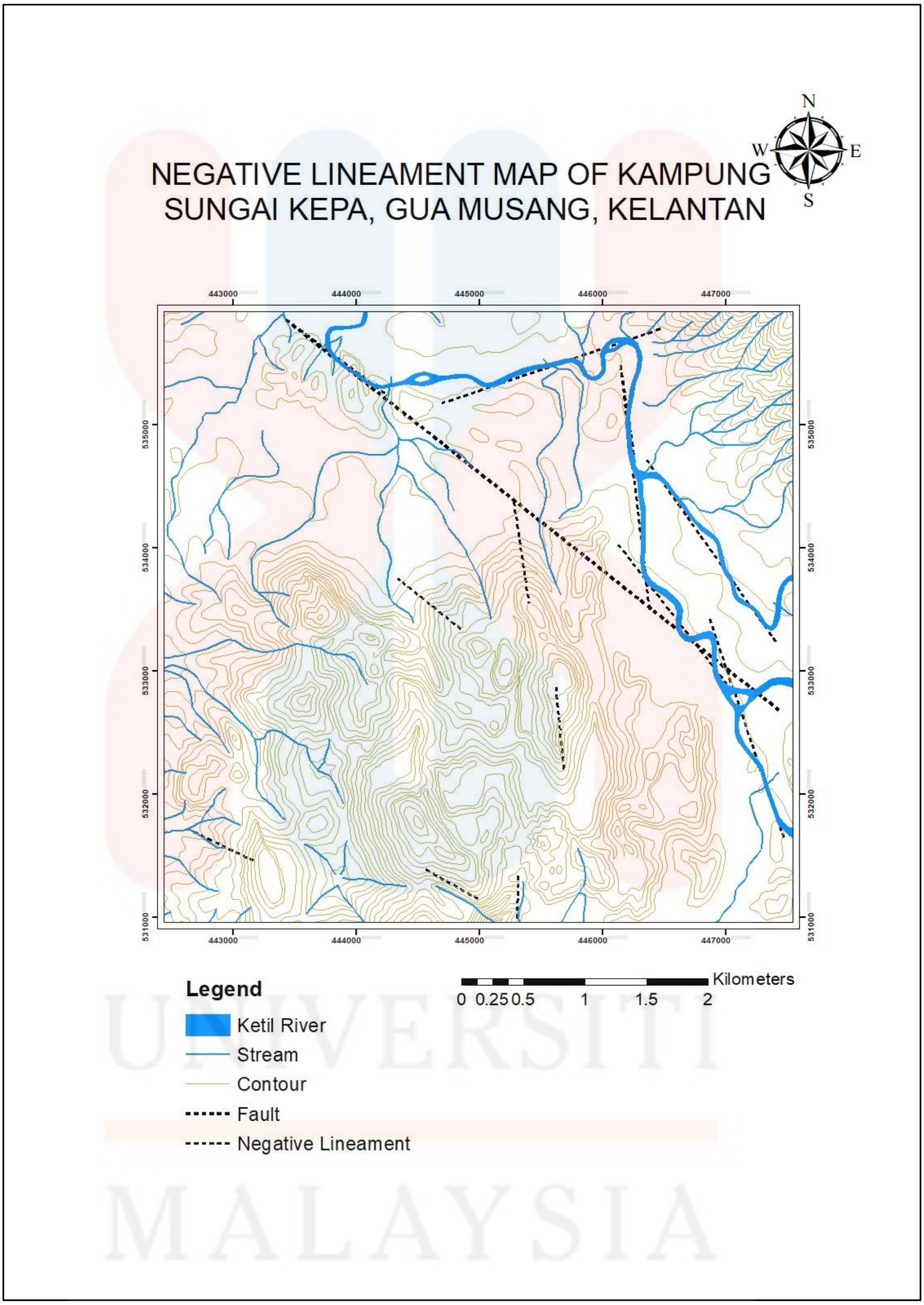

Figure 4.9: Negative lineament map of study area.

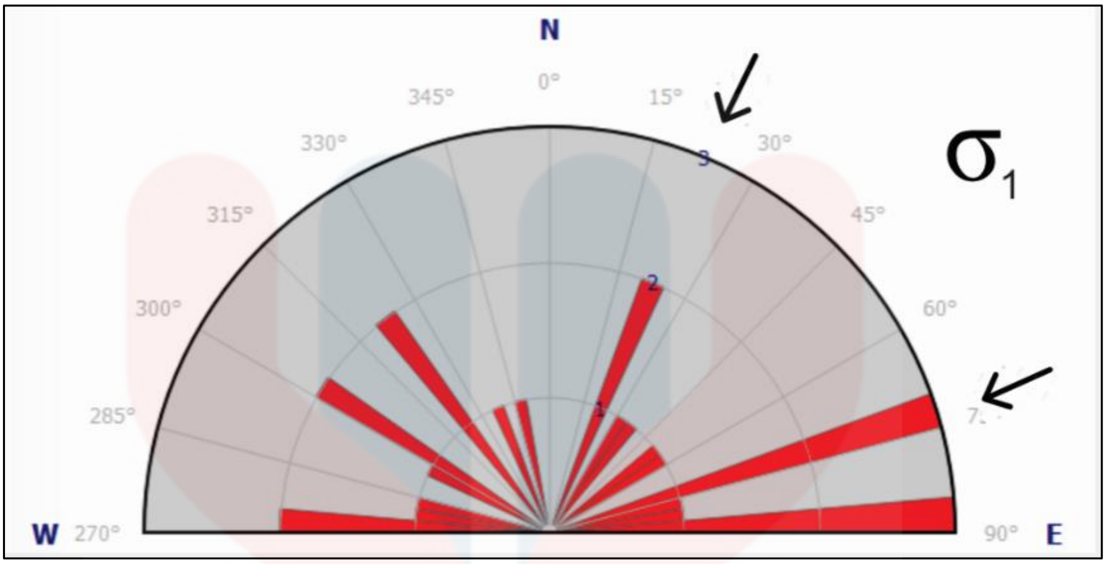

Figure 4.10: Rose diagram of negative lineament of study area.

4.5 Historical Geology

In historical geology, geological processes and formation of the study area are discussed and how the tectonic setting effects the geology of the study area. Kelantan is located on the central belt of Peninsular Malaysia, where significant structural zones have appeared known as Bentong-Raub Suture Zone. This Bentong-Raub Suture Zone is one of the major structural zones in Sundaland, Southeast Asia. Collision between Sibumasu Plate and Indochina Plate occurred during Upper Permian and Upper Triassic.

The historical geology of study area started from Permian age until Late Triassic which falls under Gua Musang Formation. Gua Musang Formation depositional environment is shallow marine shelf with active volcanic activity, which explain the lithology rock units found at the study area. multiples types of lithologies are classified based on their region that consist of granite rock, sedimentary rocks, meta-sedimentary rocks, unconsolidated sediments, and extrusive rock.

At the study area, lithology rocks unit that are found area granite, limestone, meta-sedimentary rock, and acid extrusive rock. However, the dominant rock unit are limestone due to present of karst limestone that covers almost 60% of the study area.

CHAPTER 5

GEOHERITAGE POTENTIAL VALUE OF KARST AT KAMPUNG SUNGAI KEPA, GUA MUSANG, KELANTAN

5.1 Introduction

In this chapter, geological heritage potential value at Kampung Sungai Kepa, Gua Musang, Kelantan is discussed, analyzed, and interpreted. The geological heritage potential value of study area is determined based on the processing, analysis and interpretation of geological features and element that are unique and special. This potential site has distinctive occurrence, rarity and representativeness of certain geological features and element that need to be identified. Geological heritage value can also be access through the geological diversity features, elements, and composition.

5.2 Geoheritage

Geological heritage focus on attractive and unique geological elements and features that are valuable. Geoheritage are also concerned with preservation of Earth elements and features which is globally important for natural resources management, land managements, research, cultural reasons, education, and tourism.

Geologic features contain important values that are valuable for heritage conservation such as scientific values, historical values, aesthetic values, educational values, and economic values. In term of geodiversity, geological heritage can also be classified into lithological site, geomorphological site, hydrogeological site, petrological site, structural site, speleological site, and others geological features site.

5.3 Geodiversity Assessment

Geological diversity assessment method was used and further explained in this chapter as this method had been used for multiple purposes such as geological heritage, ecosystem management and geological conservation. Geodiversity involves natural range with variety of geological environment and element, components, and processes that constitute them making them varied in rock types, minerals, fossils, and soils.

This assessment is divided into two perspectives which are qualitative and quantitative. The qualitative involves knowledge and description of the geodiversity elements of an area or region. As for quantitative, it numerically reflects the variability of the geological elements. Further explain in this chapter, geodiversity map index is constructed for geodiversity assessment.

Geodiversity map index are separated into several partial indices which are lithology, geomorphology, hydrology, and speleology. In this research study, indices that will be used are lithology, geomorphology, speleology, and hydrology. Geodiversity map index will be generated based on the data combined from partial indices.

5.3.1 Lithology Index

For lithology index, a 1:25,000 scale digital-based lithological map of the study area was generated. Lithology is the study of rock unit according to their description of general physical characteristics which is visible at outcrop at area. The physical characteristics of rocks included color, compositions and texture which can be observed at field.

However, in this case, the type of lithology rock unit of the study area is determined based on the processing and analyzing of Digital Elevation Mode (DEM) and supported by previous research paper. The lithology rock unit are also determined by referring to previous research paper.

For each lithology unit, they were classified according to several categories (Figure 5.1) which are lithology rock unit of alluvial, granite, metasedimentary rock, and limestone. Once lithology unit had been classified, ArcGIS Software was used to process the units according to their lithology rock unit.

The lithology rock unit were connected with the grid 10 × 10 shape file and lithology number of occurrences per grid square was calculated. Classification of the unit were done according to their occurrence per grid square by natural breaks classification (Jenks, 1967) which are very low (1), low (2), medium (3), high (4) and very high (5). This is further stated according to legend of Figure 5.2.

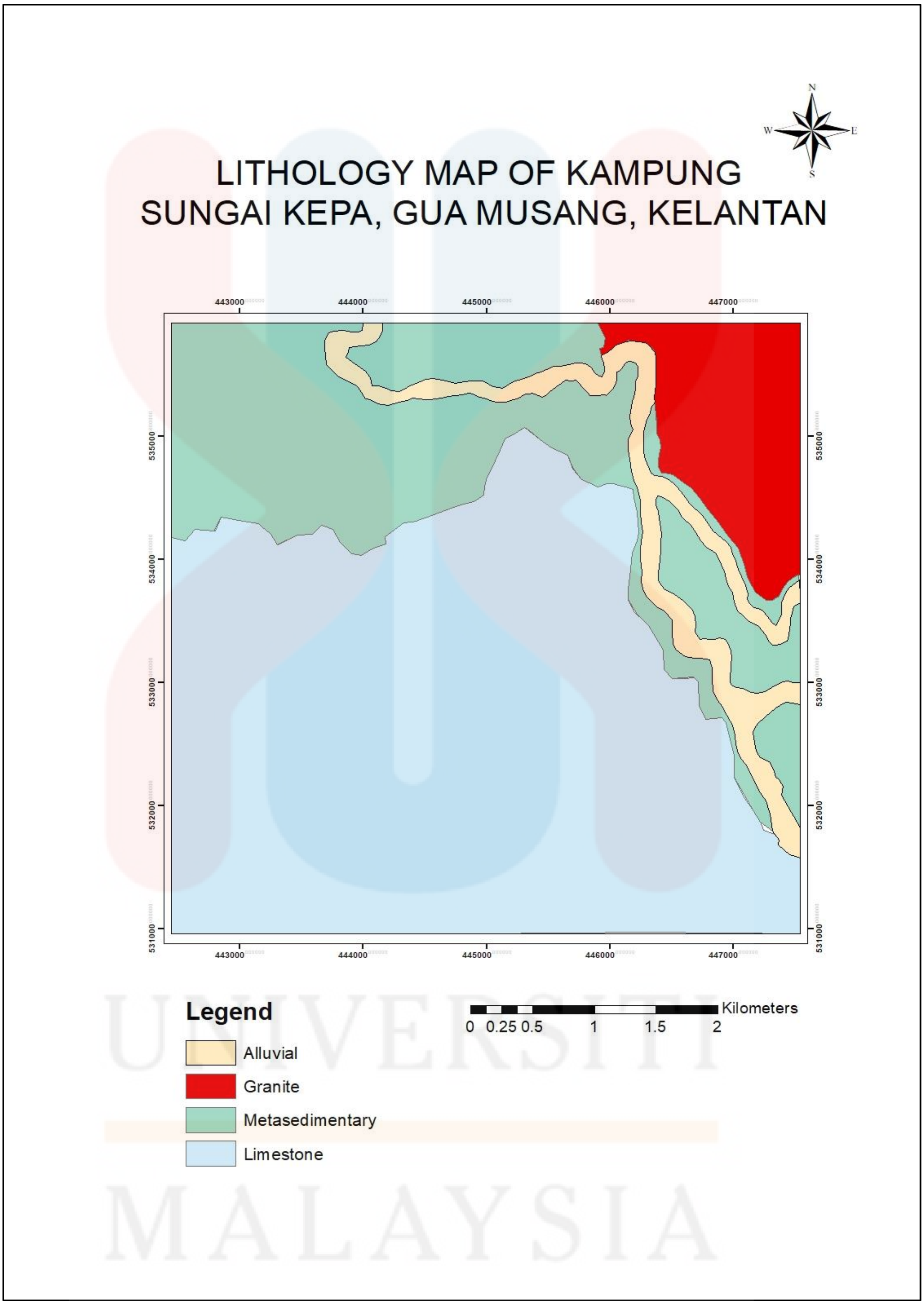

Figure 5.1: Lithology map of study area.

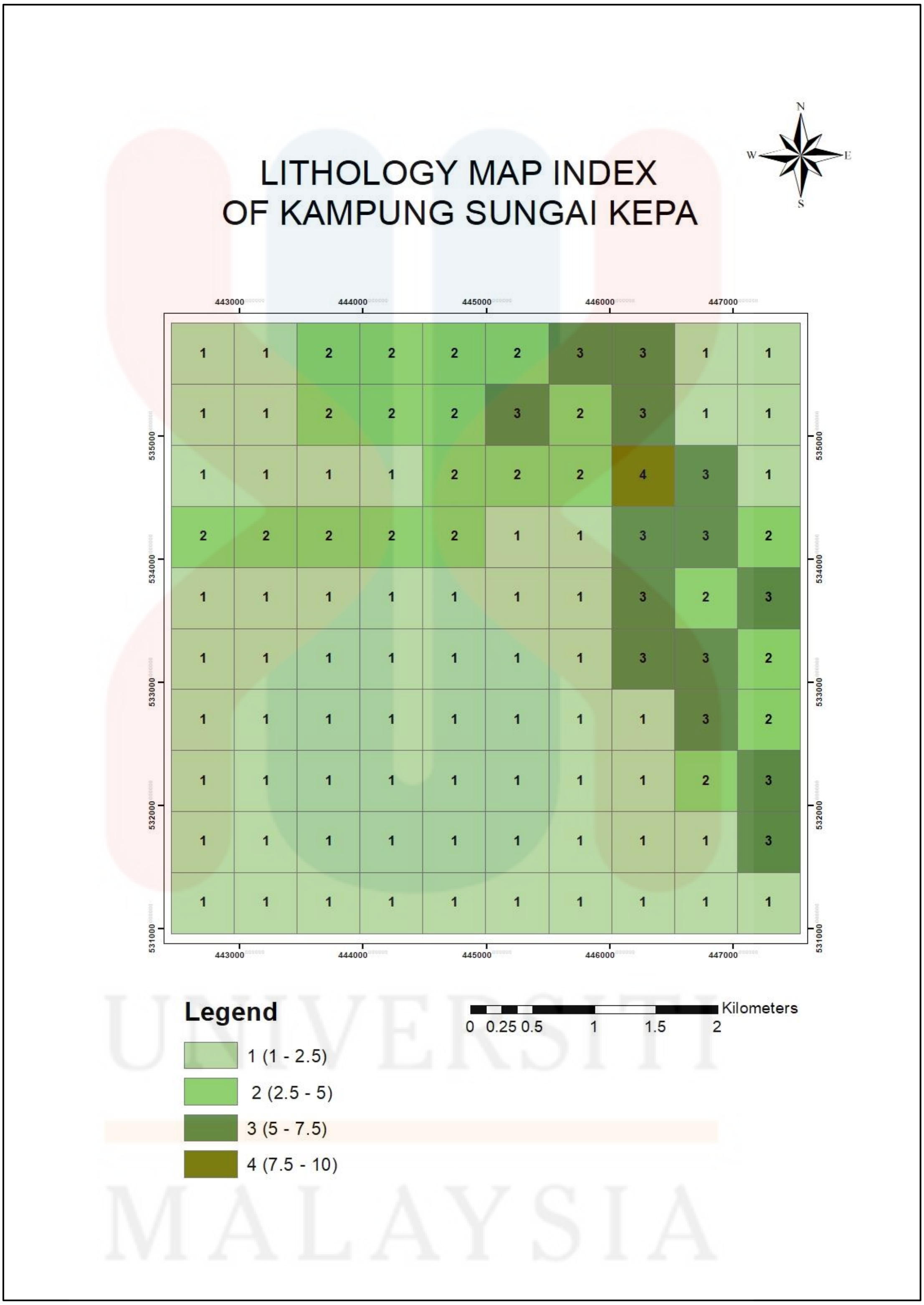

Figure 5.2: Lithology map index of study area.

Lithological diversities of the study area vary in between 1 to 10 points. Squares are classified according to their points with the highest score of 10. The highest part of lithological diversity is label as 4 (7.5 – 10 points) which is in North-East part of the study area. This area contains all the four lithologies that are identified in the study area which are alluvial, granite, metasedimentary and limestone. The grid square contains the highest the point when they have all four rock units in one grid square.

As for the score 3, the points range from 5 to 7.5 which according to the lithology map index were posited from upper to lower part of East area. According to record, this 3 score have alluvial, metasedimentary and granite or limestone in each grid square.

The study area is covered with 75 % percent of 1 score as they only contain one lithology rock unit per grid square that depends on the position located at the study area. The lower part of study area with 1 score is limestone rock unit, the North-West part are metasedimentary rock unit while the North-East are granite.

Through this lithology map index, the highest lithology diversity interpreted are labeled as 4 with points 7.5 to 10 which is only at one grid square. It is identified at eight row and column three.

5.3.2 Geomorphology Index

For geomorphological map index, a 1:25,000 scale digital map of the study area was generated. Geomorphology is related with the Earth's landform, processes that formed them, mechanism, types and the features and element at the surface of Earth. It also involves landforms such as hills, mountains, living elements of land cover, water bodies and other geological features.

This map index was generated from geological landform and water bodies, fluvial data, which were generated from DEM, forming a detail geomorphology map (Figure 5.3). The steps of generating this geomorphology map index is similar as lithology map index. The geomorphological map is arranged in grid square shape file and the occurrences of geodiversity number per unit square are calculated and classified according to their points and score (Figure 5.4).

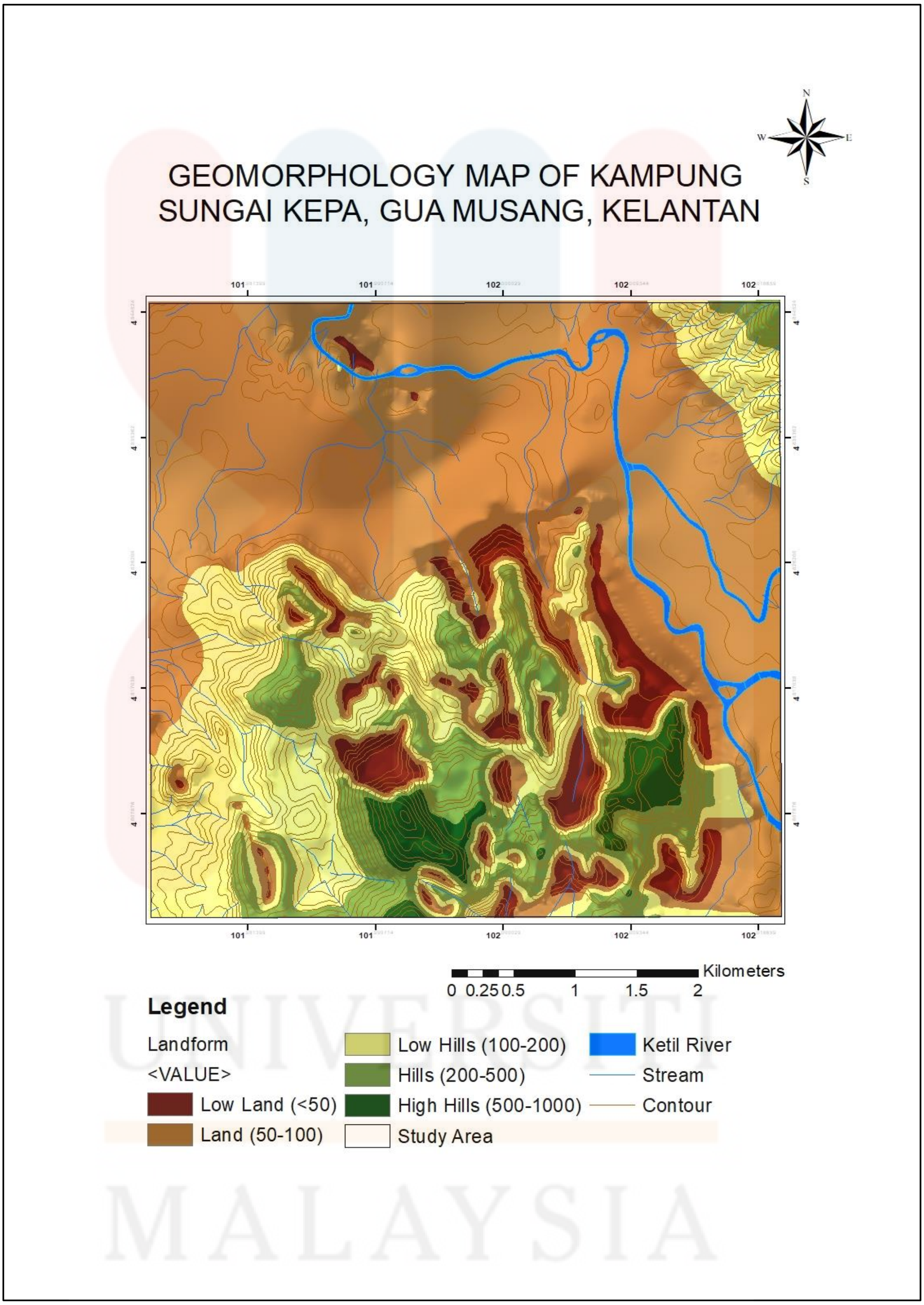

Figure 5.3: Geomorphology map of study area.

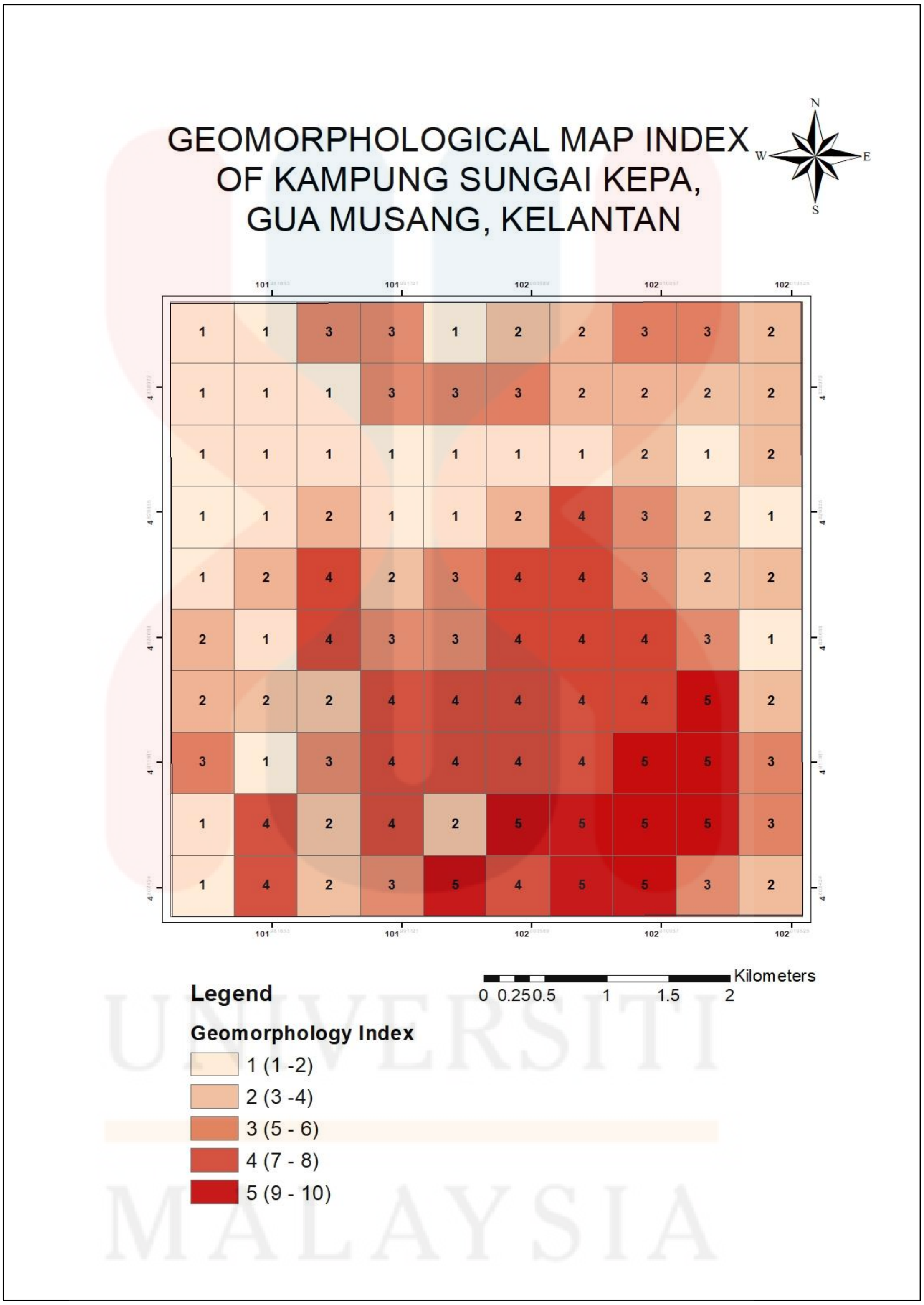

Figure 5.4: Geomorphology map index of study area.

This geomorphology index is classified into 1 until 10 points with the highest point located at South-East of the study area. The highest geomorphology diversity is identified with points 9 to 10, with score 5 (Pereira, 2013). The highest grid square contains many geomorphological elements where the high hills with elevation 500 to 1000 meters are located, with karst limestone landscape, different topography units of hills and terraces and water bodies of alluvial which are the main river of Sungai Ketil. This explain why this part of study area are interpreted as the highest geomorphology diversity unit.

As for the lowest score of 1 with the points value 1 to 2 only consist of one type of topography units of hills which is mostly consisted of land with elevation of only 50 to 100 meters. This grid squares are classified as low geomorphology diversity unit because there is no present of unique landscape or water bodies, thus it is interpreted as normal and plain area of geomorphology unit. The topography units of hills of the grid square are monotonous with homogenous hilly landscape, contributing to the lower score.

5.3.3 Hydrology Index

Hydrology index are calculated through generation of hierarchy of rivers or also known as stream order system. This can be used to indicate the water resources of the study area. This system is used to classified stream segments based on number of tributaries and sub-tributaries of upstream. Stream order in hydrology explain about the hierarchy of streams from headwater or sources to the downstream.

Another 1:25,00 scale map of hydrology map index is generated by taking stream order system into consideration to determine the water resources of the study area. Using DEM, stream order map (Figure 5.5) was established according to Strahler stream order proposed by Strahler, 1952. Rivers or stream with no tributaries are classified as first order stream as it is headwater stream. The second order stream are segment downstream confluence of two coming out from the first order streams. The classification of stream order varied when similar order streams intersect thus producing a high order stream.

To determine the hydrology diversity of the study area, the grid square is given points according to the stream order. Grid square without stream order is given 0-point value as the lowest score and the point are increase according to the occurrence of stream order. The hydrology index is classified into 6 classification which are 0 (0), 1 (1 - 2), 2 (3 - 4), 3 (5 - 6), 4 (7 - 8) and 5 (≥ 9) which stated in legend of Figure 5.6.

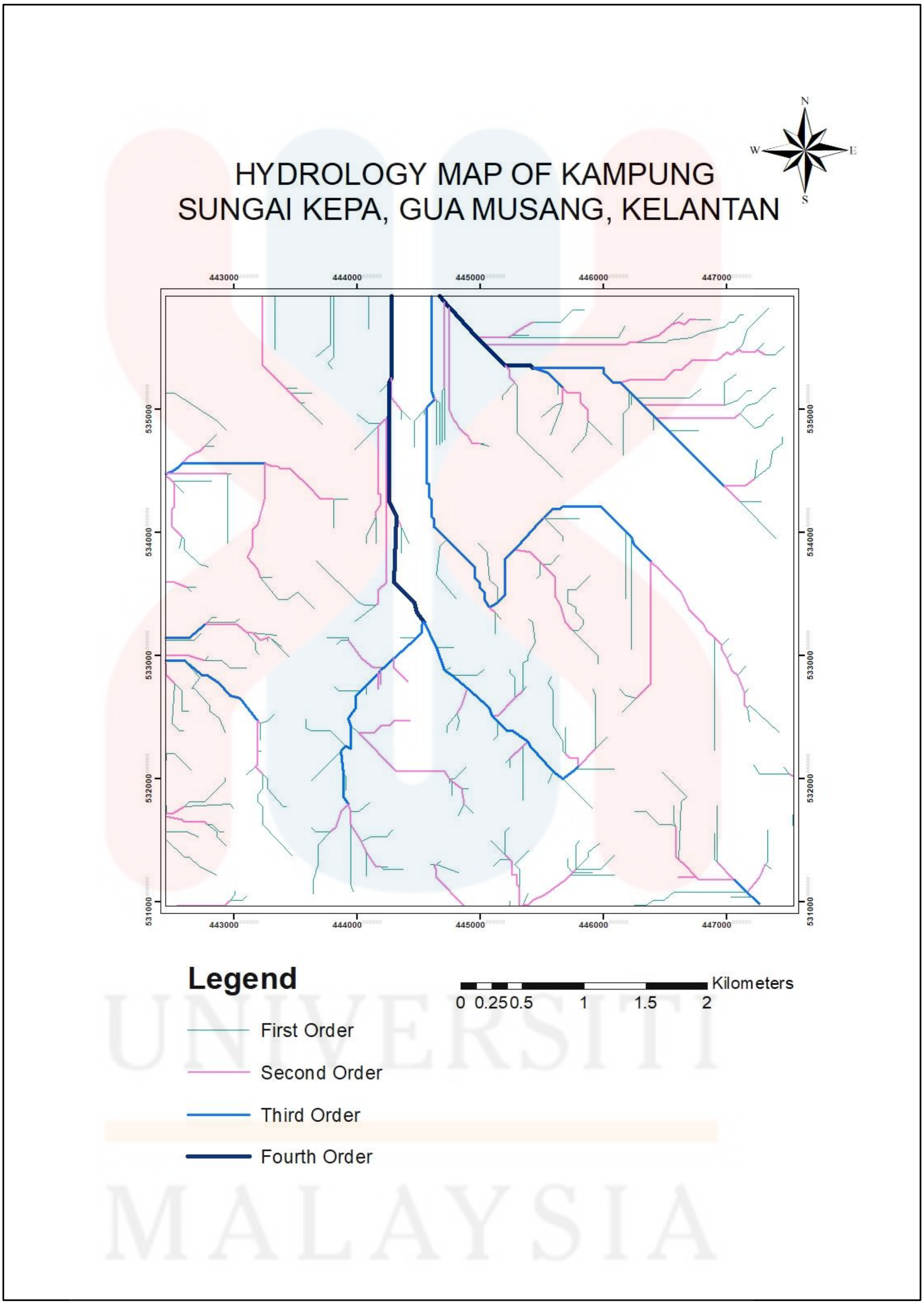

Figure 5.5: Hydrology map of study area.

Figure 5.6: Hydrology map index of study area.

Based on the hydrology map index generated, the highest score is mostly on North towards the center and found scattered to several grid index (Figure 5.6) was the main river, Ketil river are located. This part reaches it maximum hierarchy with the score 5 and point values ranging from 9 and higher than 9. The high score which was located at the grid square containing mostly limestone rock unit can be related with the present of karst limestone as they hold many water bodies due to the present of water aquifers and from the storage of abundant of rainfall.

In contrast, grid square with lowest score is identified with 0 score which are sedimentary rock units. The most score recorded is 2 with the point value ranging from 3 to 4 is found scattered at the study area. This grid square contains the most recorded score due to the present of similar stream order and tributaries. Thus, the grid square with score 5 hold the highest hydrology diversity unit while the low score 0 and 1 contain less value of hydrology diversity unit.

5.3.4 Speleology Index

By using the same step as previous geological diversity map index, speleology map index of the study area is generated with scale of 1:25,000. Speleology involves the study and exploration of caves and other features that related to karst along with their structure formation, physical properties, history formation, process of formation which known as speleogenesis and how it undergoes changes over time in speleomorphology.

By referring to the previous research paper, speleology map is generated (Figure 5.7) based on the occurrence of karst limestone landscape and caves at the study area. To determine the speleology diversity value of study area, the grid square with the most occurrence of speleology or the occurrence of caves are calculated and classified according to their scores and point values. For speleology diversity index, scores and point values are classified into six classes. The classes are 0 score with no occurrence of speleology, 1 (1 – 2), 2 (3 – 4), 3(5 – 6), 4 (7 – 8) and 5 (9 – 10).

Based on the speleology map index generated (Figure 5.8), the highest occurrence of speleology is identified to covers the study area almost 60 %. With the point values ranging between 9 to 10, the area is analyzed to be high in speleology values.

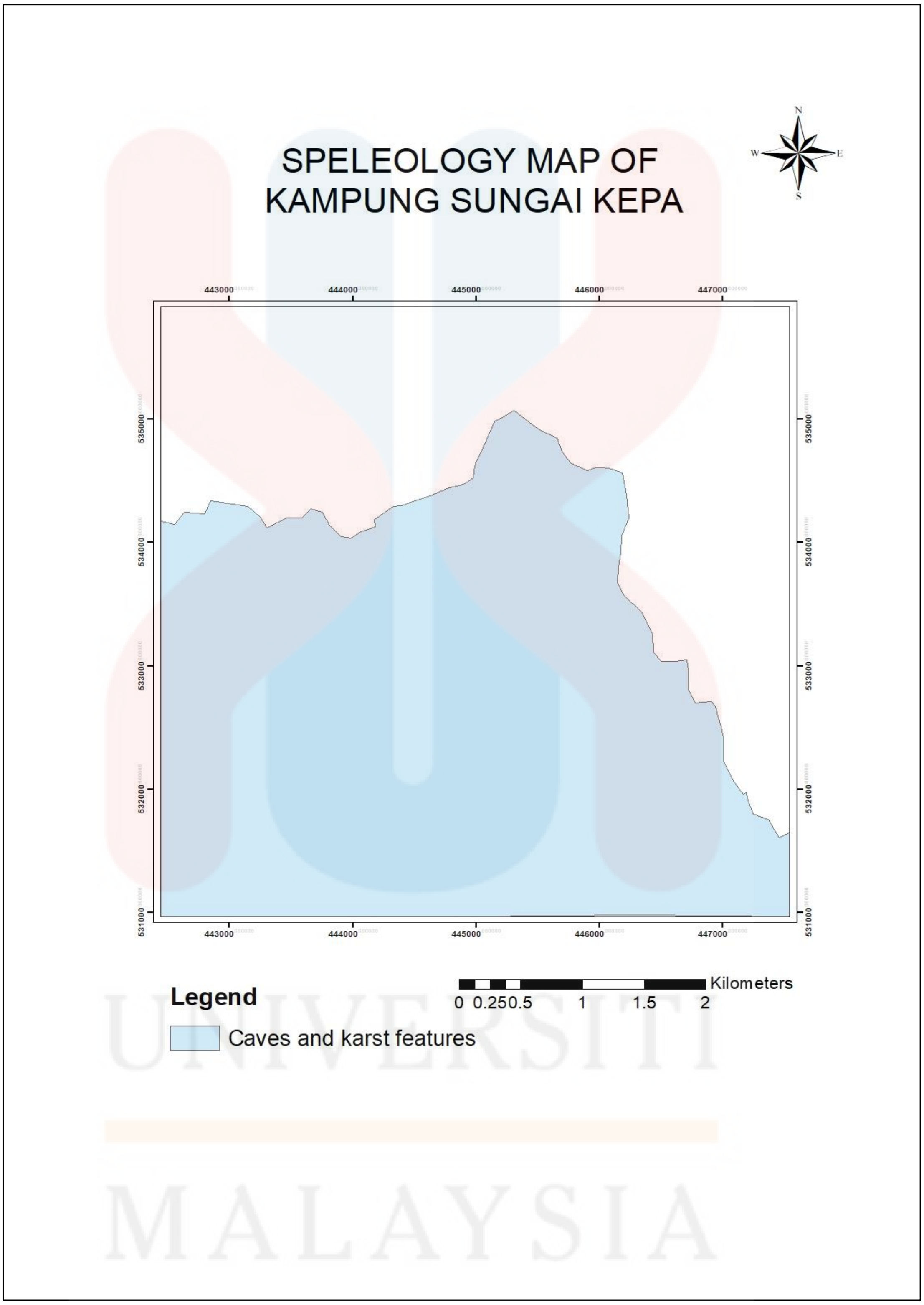

Figure 5.7: Speleology map of study area.

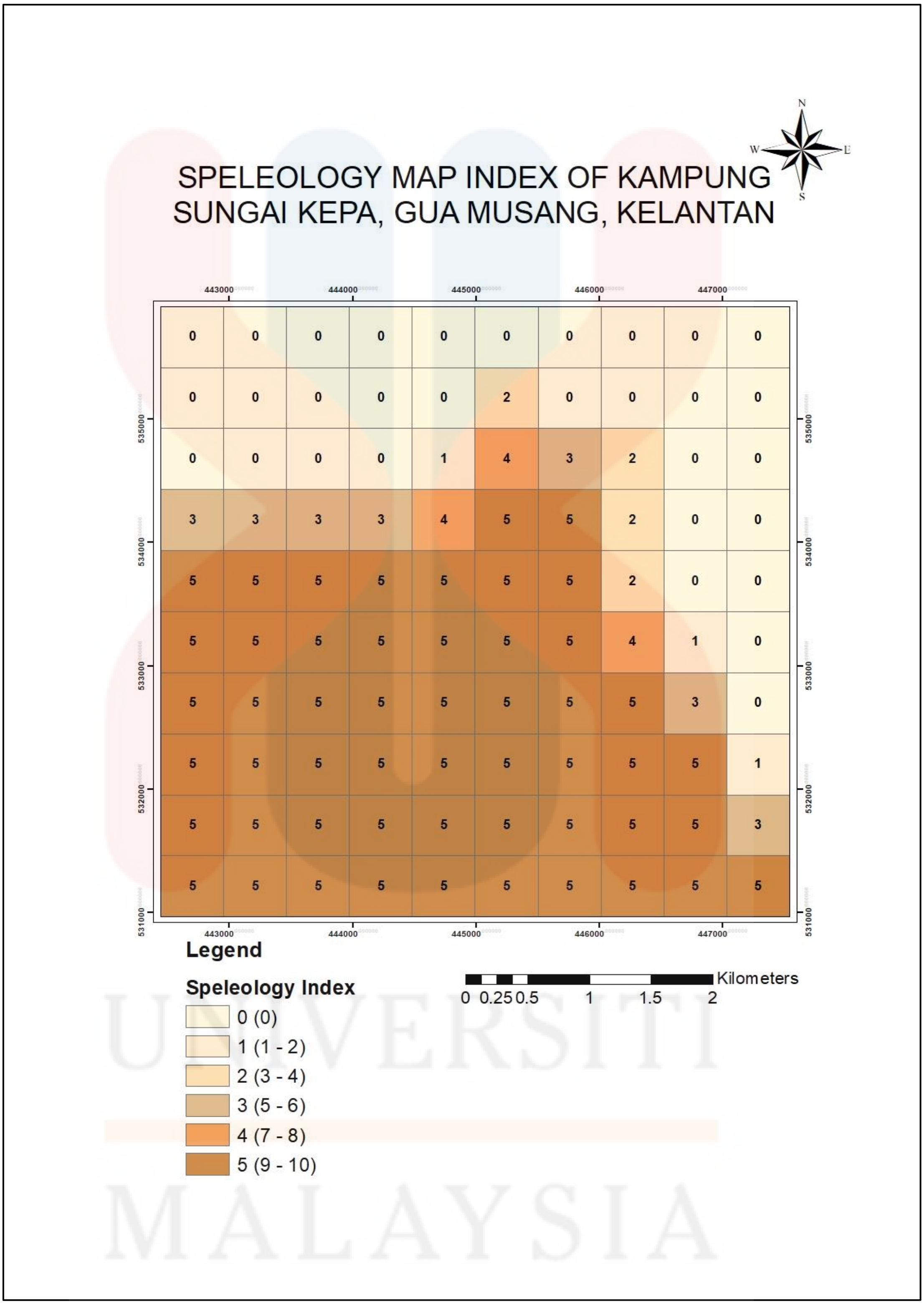

Figure 5.8: Speleology map index of study area.

5.3.5 Geodiversity Index

Derived from the partial indices, a geodiversity index map was generated with the scale 1:25,000 (Figure 5.9). The grid map from the combination of all indices will show the four geodiversity classes which are very low (1), low (2), medium (3), high (4) and very high (5). Obtaining from totaling up all the score values of indices, the lowest score is 2 while the highest is 15. This score is then classified into several classes to determine the grid square with the highest geodiversity.

The grid square with the highest score is label as red, which is based on the map index generated, it contains high geodiversity value of geomorphology and speleology. This red area is the area covered with karst morphology and limestone lithology rock unit, which is the main lithology of the study area. The small, scattered part of red grid square are high in hydrology value as the main river flows around the grid square and lithology value as it held all four lithology of the study area. That explain why the grid square are scattered and not in uniform form.

The lowest geodiversity value is label as dark green as it only contains low score value which ranging from 1 until 3. The lowest geodiversity value is identified to occur at the North-West part of the study area. At this part, there is only occurrence of one lithology rock unit and lowlands with no other geodiversity value.

Thus, the study area is interpreted as the center and downwards part of the study are high in geodiversity value based on the four indices of lithology, geomorphology, hydrology, and speleology index.

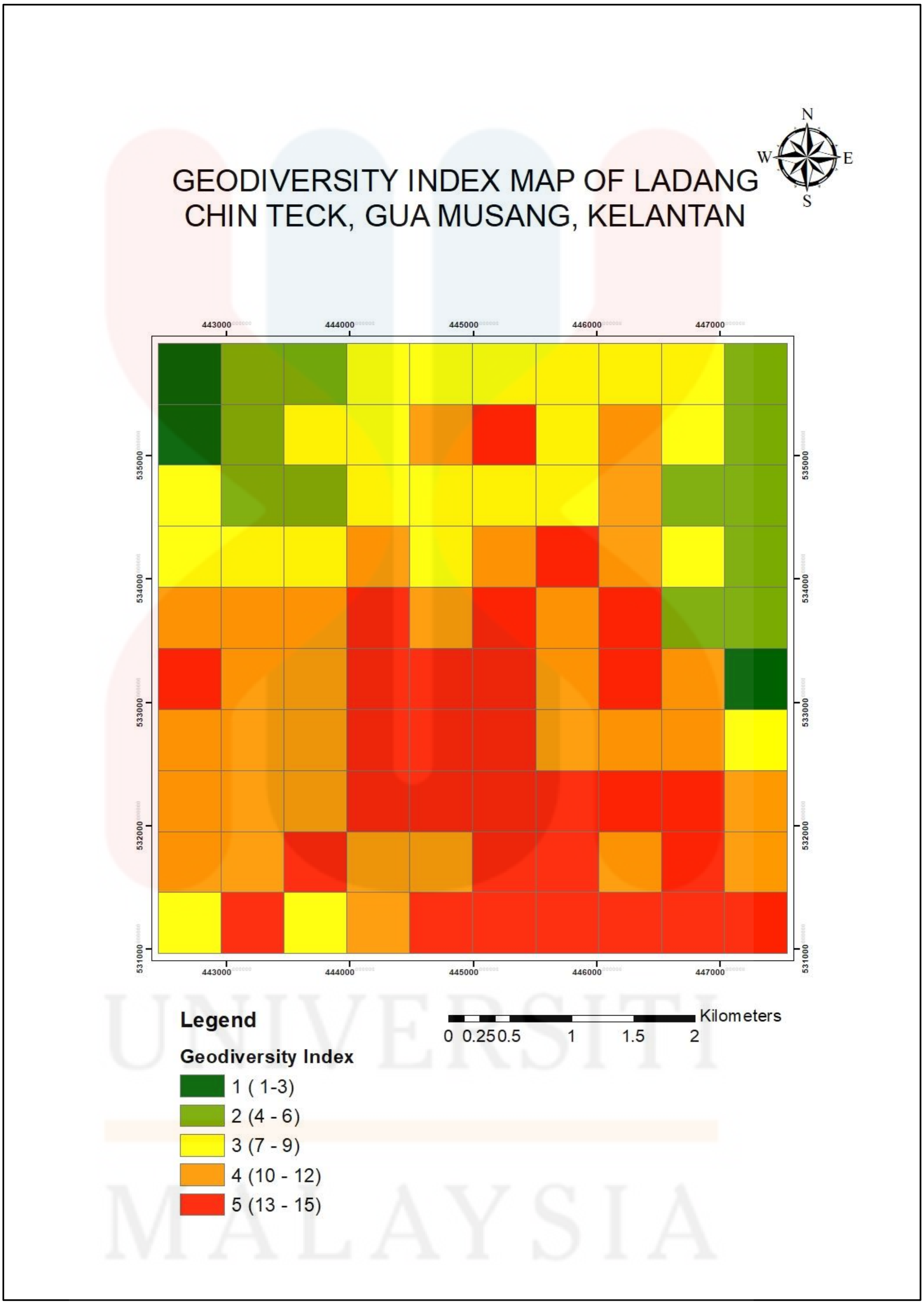

Figure 5.9: Geodiversity map of study area.

5.4 Geoheritage Potential Value

Based on the geodiversity map index generated, it can be used as correlation with geoheritage potential value. Geological heritage can be classified into lithological site, geomorphology site, hydrology site and speleological site. Through this geodiversity assessment method, this high rich geodiversity value of a site at the study area can be identified.

From the lithology map index, the site that high in lithology geodiversity value consisted of three to four lithology at one grid square. As for geomorphology map index, geological features and landform and water bodies are classified under geomorphology of the study area. The most frequent geomorphology value occur at the grid square are assumed to be high in geomorphology value. The one with low geomorphology value means that the site is low and unsuitable for geomorphology site for heritage potential value.

Hydrology map index shows the site with the highest stream order held higher value in hydrology geodiversity value. This indicate that grid square with high value to be hydrological site due to the present of main river or the high stream order. Next, the occurrence of karst landscape or caves at the study area effect the speleology index. The more the occurrence of karst landscape or caves, the geodiversity of the area became higher. From the speleology map index generated, almost 60% of the study area high in value. It indicated that the area as speleological site, thus contain high geological heritage potential due to the present of speleology.

CHAPTER 6

CONCUSION AND SUGGESTIONS

6.1 Conclusion

This research study aims are to generate a detail geological map and to derive a detail geodiversity map index of Kampung Sungai Kepa, Gua Musang with scale of 1:25,000. From these two maps, the geological elements that has potential for geotourism development can be determined. From the preliminary study, data processing, analysis, and interpretation of the contour topography, slope gradient and water system, geological features of the study area can be determined.

The lithology rock unit identified at study area are alluvial, limestone, metasedimentary rock and acidic intrusive of granite. The age of occurrence for these lithologies rock units ranging from Permian to Triassic period. Geomorphology landscape that occurred at the study area are plain areas, hilly areas and mountainous areas which are determined from the topography. There was also structural geology such as fault that been identified from the lineament analysis. From these data, geological map with scale 1:25, 000 able to be generated.

The geological heritage potential value of the study area was determined from the geodiversity index map generated. Geological features held important values that can be access from its geological diversity, thus can be classified into lithological site, geomorphological site, hydrological site, and speleological site. These geological diversities indices were assessed using geodiversity assessment method proposed by Pereira (2013). Each index formed their own geodiversity map index with the scale

1:25,000, which combined and shows the total value of geodiversity of the study area. The area with high geodiversity values correlated with geological heritage thus shows that the study area has geoheritage elements with potential for geotourism development. From the research, conclusion can be made that the study area contains high geological heritage value and have potential for conservation and geotourism.

6.2 Suggestion

The study area that high in geological heritage value are covered with karst limestone that needs more attention as it contains high potential in conservation and geotourism. This region able to attract more people especially tourist with the presence of aesthetic caves that need to be preserved and maintained its heritage values. The research shows that the study area has more geoheritage values from the occurrence of its geodiversity environment.

Conservation and geotourism are incredibly important in making sure that this geological heritage preserved and maintained. It is important to preserve geological heritage because it is part of natural heritage that held its own value for geological research. Geoconservation need to be done to protect the geology of the study area as small damages and threat can give big impacts towards the geological of the place. The study area is in rapid development and the occurrence of the plantation only increase the risk of threat more. The study area that has high potential in geological heritage need to be monitored and the development at the area need planned.

The possible threat for the geological heritage value at the place might cause by human activities of the surrounding areas such as forestry, limestone mining, excavation, construction, and land use. To maintain and preserved the area these rapid development needs a good management planning in order to avoid any development that potentially damaged the geological heritage values. Geologist, official authorities, and educational institutes plays major role in educating people about the importance of this heritage values thus exposing them with the value of conserving geological resources.

As for geotourism, it is defined as tourism which sustains and enhancing the identity of the area at the same time by taking the geology, environment, culture, heritages, and well-being of the residents. Geotourism is part of conservation, dissemination and cherishing the geological history and formation of the place, thus enable people especially tourist to understand the geology of the place. The different view and perspective of the tourist might expose them with the appreciation of the geological heritage. This appreciation of geological heritage might cause them to expand the geological knowledge and its importance to larger scale of people by using new technology.

The geological heritage knowledge and information of an area is often presented in ways that hard for general pubic to understand. The geological knowledge and information need to be easily accessible and intelligibly understood by the public for them to be exposed. The geology of the place can be presented in basic concepts with the combined effort from geologist, experts and educational constitute. The area needs to be developed by not only focusing on the environment and geological heritage but also the cultural, historical, aesthetic values of the place. Furthermore, the involvement of local people and tourist are encouraged as they might help in building local identity for the place and promoting them more towards public. From this, the area, and people around it obtained environmental integrity and benefits along with the sustainable economic development.

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