GEOLOGY AND DETECTION OF GROUNDWATER POTENTIAL USING AHP IN KUALA KRAI, KELANTAN

by

SARAH SYAZWANI BINTI HISHAM

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

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DECLARATION

I declare that this thesis entitled "Geology and Detection of Groundwater Potential Using AHP in Kuala Krai, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : SARAH SYAZWANI BINTI HISHAM

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APPROVAL

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

Signature :

Name of Supervisor 1:

Date :

Signature :

Name of Supervisor 2:

Date :

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Geology and Detection of Groundwater Potential Using AHP in Kuala Krai, Kelantan

ABSTRACT

Groundwater is the major source in Kelantan which consumes 70% of the water supply. The rapid development in the field such as population, urbanization, agriculture, and industry has led to an increase water supply demand. This study was conducted at Kuala Krai, Kelantan within latitude 5”36’30˚ to 5”33’50˚ N and longitude 102”8’25˚ to 102”11’10˚ E. The main objectives of this study are to generate a geological map of the study area with a scale of 1:25000 using GIS and delineate a new source of groundwater potential zone using Analytical Hierarchy Process (AHP) method. The lithology of the study area was identified by schist, ignimbrite, interbedded sandstone, siltstone and silt, and alluvium. Seven thematic layers were used to produce groundwater potential map which included lithology, geomorphology, land use, slope, drainage density, rainfall density, and soil type. Each of the thematic layers was given a weightage through AHP technique. The outcome of this research study had obtained the groundwater potential map into four classes which are poor, moderate, and good.

Geologi dan Pengesanan Potensi Air Bawah Tanah Menggunakan AHP di Kuala Krai, Kelantan

ABSTRAK

Air bawah tanah merupakan sumber utama di Kelantan yang menggunakan sebanyak 70% bekalan air. Perkembangan pesat dalam bidang seperti populasi, urbanisasi, pertanian, dan industri telah menyebabkan peningkatan permintaan terhadap bekalan air. Kajian ini telah dilakukan di Kuala Krai, Kelantan dalam latitud 5"36'30˚ hingga 5"33'50˚ N dan longitud 102"8'25˚ hingga 102"11'10˚ E. Objektif utama kajian ini adalah untuk menghasilkan peta geologi kawasan kajian dengan skala 1:25000 mengunakan teknik GIS dan mengesani sumber air bawah tanah baru yang terdapat di kawasan kajian menggunakan teknik Analisis Hierarki Proses (AHP). Litologi kawasan kajian dilitupi oleh batuan syis, batuan ignimbrit, batupasir yang saling berlapis dengan batulodak dan syal dan juga batuan aluvium. Tujuh lapisan tematik digunakan untuk menghasilkan peta potensi air bawah tanah yang terdiri daripada litologi, geomorfologi, gunatanah, cerun, kepadatan saliran, taburan hujan, dan jenis tanah. Setiap lapisan tematik diberi nilai dengan menggunakan teknik AHP. Hasil kajian ini ialah dimana peta potensi air bawah tanah dibahagikan kepada tiga kelas iaitu, kurang, sederhana, dan baik.

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LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
DEM	Digital Elevation Model
DID	Department of Irrigation and Drainage
DOA	Department of Agriculture
EIA	Environmental Impact Assessment
ERI	Electrical Resistivity Imaging
GDP	Gross Domestic Product
GIS	Geographic Information System
GSM	Geological Society of Malaysia
IDW	Inverse Distance Weighted
MCDA	Multi-Criteria Decision Analysis
RM	Ringgit Malaysia
SRTM	Shuttle Radar Topography Mission
UM	University of Malaysia

LIST OF SYMBOLS

%	Percentage
km	Kilometre
km^2	Square Kilometre
m	Metres
mm	Millimetres
$^{\circ}$	Degree
>	Greater than
<	Less thans

CHAPTER 1

INTRODUCTION

1.1 General Background

Kelantan state is located at the north-eastern corner of Peninsular Malaysia. The distribution of rock types in this region are divided into four types which are granitic rocks, volcanic rocks, sedimentary and metasedimentary rocks, and unconsolidated sediments (Pour & Hashim, 2016). Goh, Teh, & Wan Hassan (2006) described that Kelantan was covered by sedimentary and metasedimentary rocks in the central zone which bordered by Main Range and Boundary Range granites in the west and east respectively. Based on the geological map, the rock in the study area is in the Permian age which mainly from sedimentary/metasedimentary and volcanic rocks.

Groundwater is a valuable resource to the worldwide that occur almost everywhere under the Earth`s surface. It is not just provides us source of drinking water but essential to the sustainability of agriculture and industry (Tarbuck, Lutgens, & Tasa, 2014). Groundwater is known as alternative way for resolving existing water shortages supply. Groundwater can be described as water filling the space, cavities, pores and cracks in the soil, rocks or regolites below the surface of the earth (Isnain & Akhir, 2017).

In Malaysia, not more than 10% of the total use originates from the groundwater resources. The need of groundwater for domestic purposes is very limited to rural and remote areas where there is no availability of piped water. Different in Kelantan, over 70% of the public water supply is used (Nazaruddin et al., 2017). Hussin, Yusoff, & Raksmey, (2020), also reported that Malaysia only used 3% of groundwater resource but in Kelantan, groundwater is the main source of water supply and the demand is still risen until now which consumes 70%. Groundwater resource in Kelantan has been used since 1935. This shows that the demand of water supply is very high especially at the rural areas. About 94 production wells has been managed to abstract for the water supply in the Kelantan (Tawnie, Sefie, & Suratman, 2011).

In order to fulfil the demand, there seemed to be indiscriminate to extract the groundwater resources (Prasad et al., 2008). Lack of knowledge about the groundwater resources become hard to extract where it occurs in a complex subsurface formation and its hidden in nature (Nagarajan & Singh, 2009).

The implementation of Geographic Information System (GIS) techniques followed by field observations is very effective method for the mapping and exploration of groundwater. This study has been a great of interest to the scientific community over the last decade and a lot of researchers have used this technique in their studies (Isnain & Akhir, 2017). Nampak, Pradhan, & Manap, (2014) expressed that GIS is the best method for managing large quantities of spatial data which usually utilize in decision-making in a variety of field, including geology and environmental management. The data that are processed in the GIS can be produced the map of potential groundwater of the study area.

1.2 Study Area

In the sub-topic of study area is discussed about location, road connection, demography, land use, and social economic that conducted at Kuala Krai, Kelantan. The distance from Kuala Krai city to the study area is 11.9 km which take 17 minutes by car.

1.2.1 Location

The study area in the Figure 1.1 is located at the north of the Kuala Krai bounded near to the Machang and Tanah Merah district. It lies between latitude 5˚36’30’’ to 5˚33’50’’ N and longitude 102˚8’25’’ to 102˚11’10’’ E. The box of the study area is covered only 25 km^2 of Kuala Krai area. It is surrounded by many hills and rivers such as Kelantan River and Nal River. Nal River is the division of the main river which is Kelantan River. The highest elevation of the study area is 120 m. Figure 1.2 displays the base map of the study area where consists of different type of features such as main road, railroad, river, and villages.

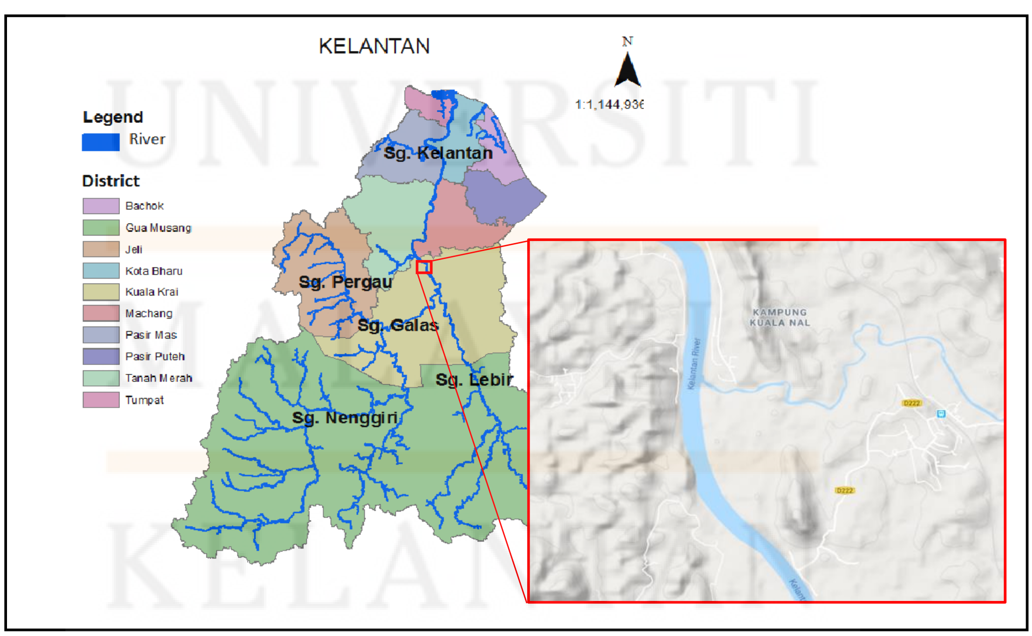

Figure 1.1: Location of the study area within latitude 5˚36’30’’ to 5˚33’50’’ N and longitude 102˚8’25’’ to 102˚11’10’’ E.

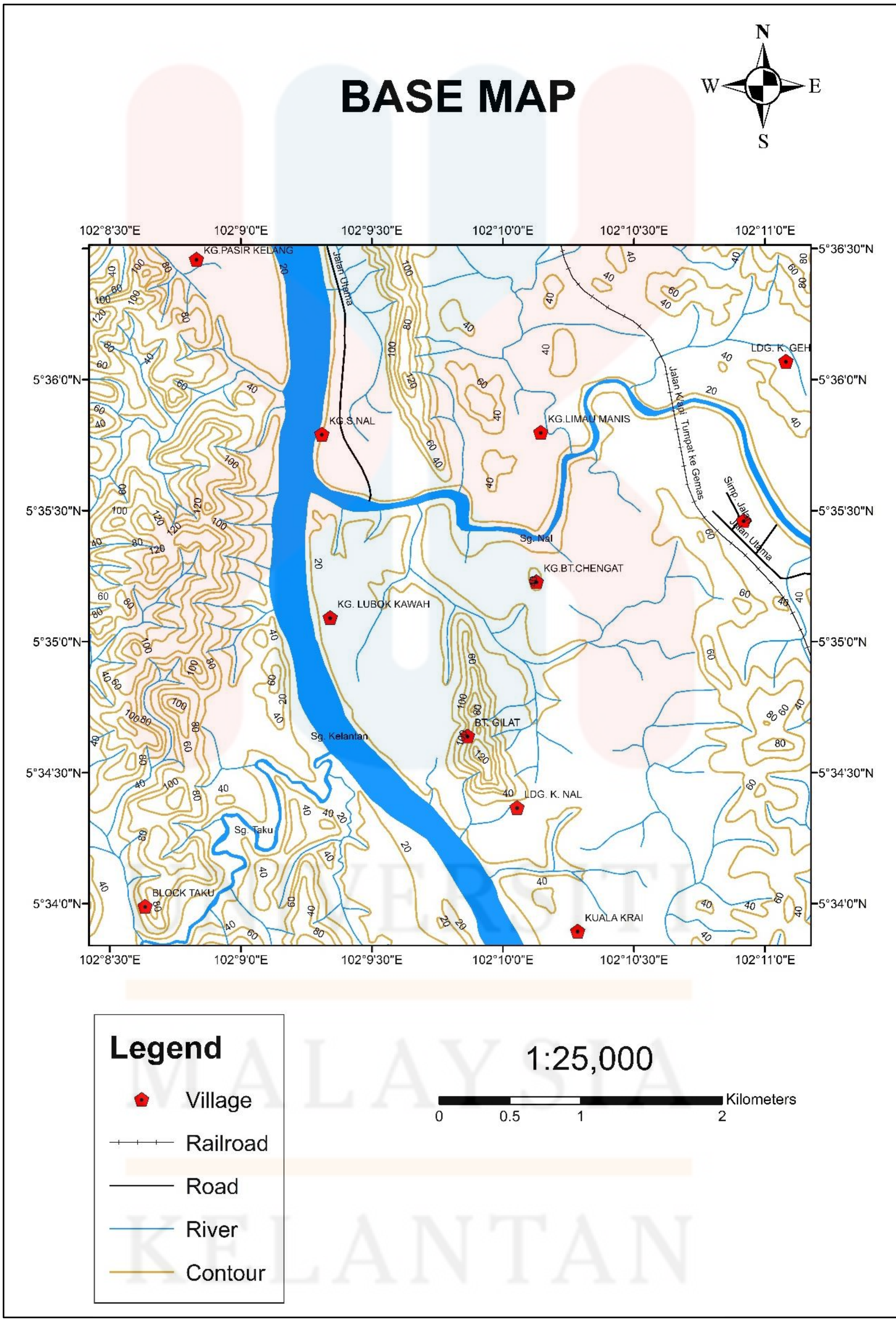

Figure 1.2: Base map of the study area

1.2.2 Road Connection / Accessibility

Transport mobility is important in defining the accessibility of services and facilities for the population. Kuala Krai has an extensive transportation system of public transportation that has a good and well-developed highway. Kota Bharu - Gua Musang Highways, Sungai Sam - Dabong -Jeli road, and Timur - Barat Highway are the main road to reach the study area. The distance between the study area and Kota Bharu city is around 1 hour 14 minutes through Kota Bharu - Gua Musang Highways by car and motorcycle. While the distance from UMK Jeli to the study area takes 1 hour 12 minutes through Timur-Barat Highways by car and motorcycle.

1.2.3 Demography

Kuala Krai has a total area of around 2,287 km^2. Kuala Krai District can be divided into three Mukim (sub-district) which are Batu Mengkebang, Dabong, and Olak Jeram. Batu Mengkebang has the highest population while Olak Jeram is the lowest in 2010 (Citypopulation.de, 2020). The study area is situated in the Batu Mengkebang. The population in Kuala Krai District was 113,900 in 2018 and increase to 137,800 in 2019. The statistic concludes that the male is dominant with 71,300 compared to female with 66,500 in 2019 (Department of Statistics Malaysia, 2020). The population of the ethnic group is mostly dominated by Malay following with Chinese and Indian (Citypopulation.de, 2020). Transport links had become developed during the 20^{th} century causing people to migrate to the Kuala Krai to take advantage of the plentiful land which can use for farming (Jabatan Pendaftaran Negara, 2018).

1.2.4 Land use

In 1984, the development of land-use in the Kelantan basin was not complex compared to nowadays where mostly of land-use patterns are covered with rubber, coconut, oil palm, vegetables. The land use pattern in Kelantan began to be complex in 1997 largely due to the lifestyle change of the people in the Kelantan Basin which experienced technological development that leads to large scale agricultural activities (Samsurijan et al., 2018). Kelantan land use mainly dominated by forest which covered 645250.48 hectares of the land in Kelantan especially in the area of Gua Musang. It is followed by second largest land use which is agriculture that covered 254729.18 hectares. Agriculture is the main economic activity in Kelantan which mostly in the field such as paddy, rubber and tobacco products (Zaman & Mustapha, 2016).

Table 1.1: Land use type in Kelantan Watershed

Land use type	Area (ha)	% of watershed area
Forest	645250.48	66.14
Agriculture	254729.18	29.38
Water Bodies	1682.65	0.17
Bare Land	9180.95	0.94
Grassland	4638.42	0.48
Urban	86.14	0.01
Open land	214.5	0.02

(Source: Zaman & Mustapha, 2016)

1.2.5 Social Economic

According to the Department of Statistics Malaysia, (2020), the social-economic growth in Kelantan is driven into five categories which are agriculture, manufacturing, mining & quarrying, construction, and services. Based on the statistic in the Figure 1.3, the gross domestic product (GDP) has recorded that the rate of economic growth was about 2.6%. It is showed that mining & quarrying were the most contribution to this economic growth and the lowest was in manufacturing. The rate of economic growth in Kelantan had experienced a recession from 2015 to 2018 with the value from 5% to 2.6% but the value of economic growth had increased from RM21.4 billion to RM24.1 billion. The employment in Kelantan was reported where the total of working people was around 7 million with the rate of labor participation 58.9%.

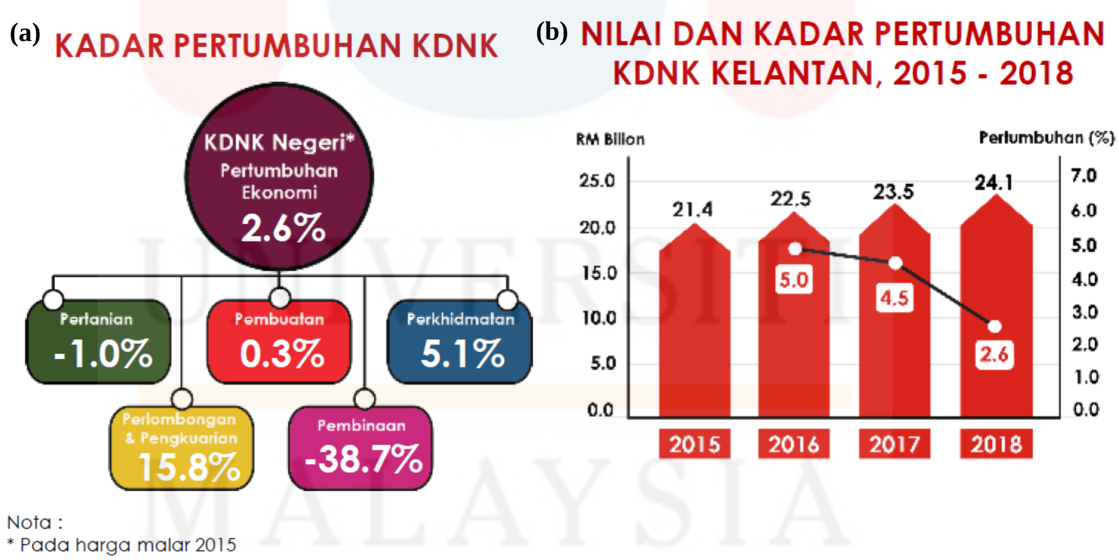

Figure 1.3: (a) The rate of gross domestic product (GDP) growth (b) The value and rate of gross domestic product (GDP) growth from 2015 to 2018 (Department of Statistics Malaysia, 2020).

1.3 Problem Statement

About 70% of the land-use in the study area is covered with lowlands. This area has a gentle slope where it is more suitable for groundwater exploration. But not many people do the exploration due to the lack of research and financial constraint.

Rapid development in different type of fields such as population, urbanization, agriculture, and industry has led to high demand for water supply in which needs to exploit groundwater resources (Prasad et al., 2008). This is because these factors can lead to both the quality and quantity of underlying groundwater systems. Malaysia is still lacking the use of groundwater supply and has not been exploited in any major way except Kelantan where constitutes 70% of the total groundwater supply. Most of the states use surface water to meet their water demands. Groundwater is being widely undervalued, extracted inefficiently, and improperly protected (Mazrali, 2016). Having difficulty locating exactly the groundwater potential and unplanned groundwater withdrawal will result in random drilling of well that leads to failure. In that case, the use of the GIS technique is very effective to delineate the groundwater potential zones.

In Malaysia, groundwater can be a hot issue when it comes to drought periods (Nampak et al., 2014). The activity of groundwater exploitation becomes extremely active to meet the high demand. Thus, a need to understand the groundwater conditions is required to conserve groundwater resources.

1.4 Objectives

The objectives of this research are conducted as follows:

1. To generate a geological map of the study area with a scale of 1:25,000 using GIS
2. To delineate a new source of groundwater potential zone that present in the study area based on thematic data analysis.

1.5 Scope of Study

The scope of study for this research area was conducted at the Batu Mengkebang, Kuala Krai, Kelantan specifically at Bukit Gilat. The box of the mapping area is covered 5×5 km per square of the Batu Mengkebang area. The generated geological map with a scale of 1:25,000 was produced by using ArcGIS software. A topographic map is another material that can be used as an aid for generating a geological map. Geological mapping was conducted by collecting secondary data that can be from previous research, Minerals and Geoscience Department (JMG) Malaysia, and the State Department of Survey and Mapping (JUPEM). Description about geomorphology, petrology, and geology of the environment were carried out in the study area to study geological history and reveal the major distribution of rock units. Type of rocks in the study area were analyzed by getting secondary data from the previous research.

Groundwater potential had been studied at the Kuala Krai district which in the rural area. The description for the groundwater field was included geohydrology and petrology. Thematic maps that include lithology, rainfall, slope steepness, drainage density, soil types, land use, and geomorphology had been analyzed to predict groundwater potential zones.

1.6 Significance of Study

The significance of this study can be a benefit for local government and private company to improve their service and be able to resolve the water supply-demand and provide clean water to the residents. It is important to ensure the quality of water meets the Water Quality Standard Water Materials for safe drinking water.

Extensive hydrogeological investigation can provide information for the community and create awareness in developing sustainable groundwater management to avoid the random drilling of bore wells.

Moreover, all the recorded groundwater data can be used for groundwater exploitation in developing a better planning to assess, monitor, and conserve groundwater resources. By applying this research study, it will provide a reference for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is focused on geological aspect and research specification in Kuala Krai, Kelantan. The geological aspect is covered on regional geology, tectonic setting, stratigraphy, structural and history geology. For research specification, reviewing about groundwater potential, water supply and Analytical Hierarchy Process (AHP) method at the study area.

Kelantan state is situated in the northeast of Peninsular Malaysia, which is bounded with Thailand in the north, South China Sea in the northeast, Terengganu in the east, Pahang in the south and Perak in the west. The area of the Kelantan state is 15 040 km^2 with the population 1.89 million based on the statistic in 2019 (Department of Statistics Malaysia, 2020a). Kelantan state consists of ten districts that includes Kota Bharu, Tumpat, Pasir Mas, Bachok, Pasir Puteh, Kuala Krai, Machang, Tanah Merah, Jeli and Gua Musang. Kuala Krai has three mukims or sub-districts including Batu Mengkebang, Dabong, and Olak Jeram (Citypopulation.de, 2020).

2.2 Regional Geology and Tectonic Setting

According to Metcalfe, (2013) Peninsula Malaysia is a one of the Sundaland`s Southeast Asian continental core. It constitutes two tectonic fragments where in the west is Sibumasu Terrane and in the east is Sukhothai Arc or can be called as East Malaya Block. In the Late Triassic, these two tectonic fragments had become assemble in one continent. Peninsula Malaysia can be divided into three north-south belts consisting the Western, Central, and Eastern belts that come from the Northwest Australian Gondwana margin in the late Early. The Western Belt was formed from the part of Sibumasu Terrane in the late Early Permian while the Central and Eastern Belts were part of the Sukhotai Arc in the Late Carboniferous-Early Permian that come from the Indochina Block. In between the Sibumasu Terrane and Sukhothai Arc, formed the Bentong-Raub suture zone in the central Peninsula Malaysia. The continental blocks of Southeast Asia were experienced three episodes of rifting, separation and northward drifts creating three ocean basins that included, the Palaeo-Tethys in the Devonian-Triassic, Meso-Tethys in the late Early Permian-Late Cretaceous and Ceno-Tethys in the Late Jurassic-Late Cretaceous. The Bentong-Raub suture was described as the main Palaeo-Tethys ocean basin.

This was supported by Hutchison, (2014), where the Bentong-Raub and Chiang Mai sutures were interpreted as the main Paleo-Tethys suture that occupied the eastern foothills of the Main Range. The Bentong-Raub suture zone broadens southwards from Cheroh, through the Raub and Bentong zones and towards Kuala Pilah in the south. Bentong-Raub was known by a number of names such as Bentong-Raub Line and Bentong-Raub “medial Malaya” line (Spiller, 1997). The boundary between the Central and Western Belts to be the eastern foothills of the Main Range Granite and been covering with the occurrences of serpentinite bodies in the rock formations that make it called as

Bentong-Raub suture. The western foothills of the elongate granitic that occupied the Terengganu, Pahang and Johor were the boundary between the Central and Eastern Belts (Khoo & Tan, 1983).

Kelantan state mostly covered with mountainous zones which related to the Main Range Granite located in the west and Boundary Range Granite located in the east of the state. (Pour & Hashim, 2016). Pour & Hashim, (2017) also described that the Main Range Granite was placed in the west had stretched along western Kelantan to the Perak, Pahang and Thailand boundaries. Goh, Teh, & Wan Hassan, (2006) stated the Boundary Range Granite intruded onto Kelantan in the eastern part causing a Skarn formation throughout the contact zones. The landform in Kelantan state had been classified into four categories which composed of mountainous, hilly, plain, and coastal areas. Mount Chama has the highest point of 2171 metres in the Kelantan state which located in the district of Gua Musang which near to the border of the state of Perak (Pour & Hashim, 2017). Kelantan state has many large and small limestone hills and ridges in the south-eastern part that rises all of a sudden due to the extensive alluvial plain from the Sungai Galas flows. These occurrences have the same series with Ulu Pahang which contains the Cherual Range. There are quartzite and shale hills between these limestone hills and the Main Range, which are a common feature in Pahang where they are recognized as the Main Range Foothills (Savage, 1925). Nuraiteng Tee Abdullah (2009) described that between Gua Musang in the north to Gua Panjang in the south, the calcareous rocks form N-S trending karstic hills.

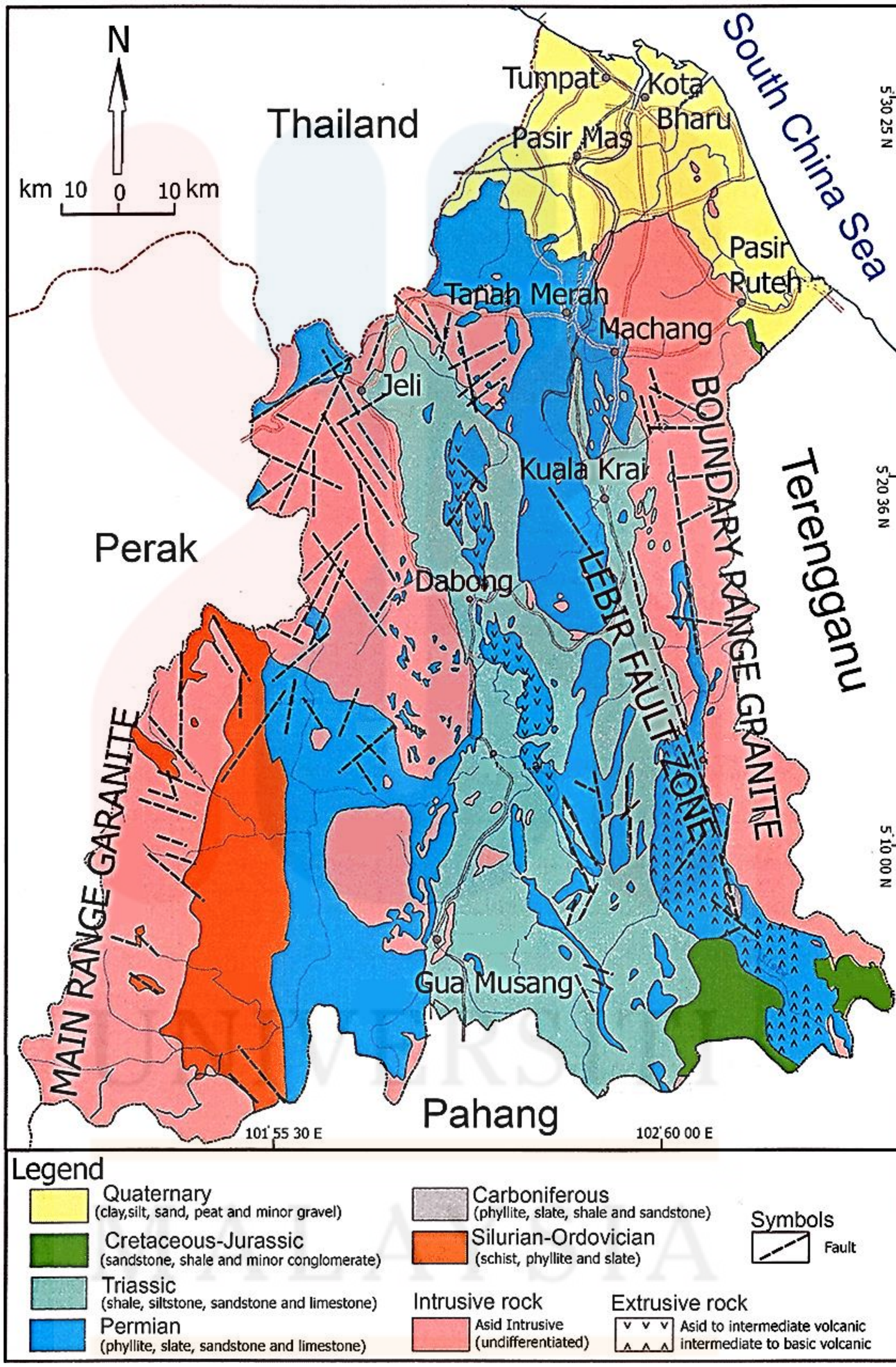

Figure 1.1: Geology map of Kelantan

2.3 Stratigraphy

Sibumasu Terrane has the old dated clastic rocks in the Middle Cambrian to Early Ordovician period which occupying the Machinchang and Jerai formation in northwestern Peninsular Malaysia (Metcalfe, 2013). The Indochina /East Malaya is characterized by an abundance of Carboniferous-Permian clastic and volcanic rocks (Spiller, 1997). Spiller, (1997) and Khoo & Tan, (1983) described that the Western Belt part in the northwest sector of Peninsula Malaysia is comprised of Kedah, north Perak and Langkawi-Perlis. The Lower Palaeozoic of the Upper Cambrian arenaceous Machinchang Formation in the Langkawi-Perlis region was succeeded in a conformable with the Setul Formation in the Ordovician-Silurian period which was predominantly limestone with detrital bands. The Machinchang Formation is the oldest known sedimentary deposit in Peninsula Malaysia that consists of 3000 metres of clastic deposits. It formed from the interlayered graded siltstones and mudstones interbedded with clayey sandstones by coarsening upward sequently. The Setul Formation was identified on the eastern side of Langkawi Island and on the mainland in Kedah and Perlis. It was formed large areas of mountainous region and the spectacular Langkawi Islands karst topography which made up of fossiliferous detrital rocks. The red mudstones were the base of the occurrence of the Singa Formation which consisted of mudstone, sandstone and ooccasional rather thin horizons of pebbly mudstones. The Singa Formation was assumed in the Carboniferous period while following with Chuping Formation in the Permian that composed of fossiliferous limestone.

Spiller, (1997) also discussed that in the Kedah mainland, the oldest strata is the Jerai Formation which was correlated with the Machinchang Formation on the basis of structural and lithological grounds. It composed of two units, lower schist series and upper arenaceous series. Also, Mahang Formation was discovered in central and south Kedah that consists of shale, mudstone, siltstone, and radiolarian chert. In the north Perak, south Kedah and in central to north Kedah had been exposed with the fault bounded Semanggol Formation. According to Khoo & Tan, (1983), it contains of marine Triassic arenaceous and argillaceous rocks with chert bands and also had turbidite characteristics.

The Central Belt has rock sequences mostly consisted of Perman-Triassic marine carbonates, shale, volcaniclastics and andesitic volcanics rocks (Metcalfe, 2013). The oldest rocks were found at the border of the eastern flank of the Main Range Granite (Khoo & Tan, 1983). The distribution of rocks in the Central Belts were classified in various group such as Raub Group, Gua Musang Formation, Kepis Formation, Semantan Formation and Tembeling Formation. The Raub Group has Carboniferous-Permian rocks which composed of limestone, calcareous shale, and acid pyroclastic rocks. It has correlation with the Kepis Formation. The Gua Musang formation is commonly contained of argillaceous rocks with interbedded limestone and volcanic pyroclastic rocks. The Kepis formation can be described as a sequence of carbonaceous shale, siltstone, mudstone and sandstone with minor conglomerate and local limestone. The Semantan formation is consisted of a thick sequence of acid to andesitic volcaniclastics and mudstone with minor conglomerate and limestone while for Tembeling Formation is composed of thick sequence of continental redbeds (Spiller, 1997).

The Eastern Belt is commonly contained of Carboniferous and Permian clastic, limestone and volcanic which in the category of Kuantan Group and Gagau Group (Khoo & Tan, 1983).

Kelantan has four types of rocks, including granite rock, sedimentary/ meta-sedimentary rocks, volcanic rocks and unconsolidated sediments (Pour & Hashim, 2016, 2017). Goh et al., (2006) described Kelantan is a central zone of sedimentary and metasedimentary rocks bordered on the western and eastern Main Range and Boundary Range granites. Within the Central zone, there were windows of granitic intrusives, where mostly occurred in the Ulu Lalat (Senting) batholith, the Stong Igneous Complex and the Kemahang pluton. The granitic mass was spread from the north Kelantan alluvial plain to latitude 4˚50`N which close to the Gunong Gagau (Senathi Rajah, Chand, & Singh, 1977).

2.4 Structural Geology

Geologically, Peninsula Malaysia elongated parallel to its structural trend in the direction of north to northwest. Tectonic transport directions in Peninsula Malaysia was generally to the west, except for the Central Belt which in the east vergence. The Northernwest - Southerneast structural grain of Peninsula Malaysia had major faults, commonly filled with major multi-phase quartz dykes. As example in the Klang Gates which may had experienced subsequent wrench movements. East Malaya has three main phases of deformation in Upper Palaeozoic and Lower Mesozoic rocks. Upper Palaeozoic strata was extensively folded along axes that primarily strike NNW to the north. Late Triassic to Jurassic Indosinian Orogeny had experienced deformation of strata, which also included the continental Permian strata (Spiller, 1997). Metcalfe (2013) also clarified that the Palaeozoic rocks of the Malay Peninsula had a multiply deformed, exhibit refolded folds, and typically exhibit three stages of folding. This involve Permian rocks in the Bentong-Raub suture zone, Middle Triassic, and younger strata in the Peninsula Malaya and between folded Permian strata and Triassic marine and Jurassic continental sediments in the Central and Eastern Belts.

In the early phase of deformation of East Malaya block Spiller (1997) stated that this block was an active convergent margin in the late Early Permian. The Eastern zone undergone a phase of regional metamorphism, folding, and uplifting which possibly occurred in the Late Palaeozoic. The Central zone had undergone a Late Triassic uplift that stopped marine sedimentation. Peninsula Malaysia was tectonically stable by the end of the Mesozoic or Early Tertiary period.

The deformation style in Kelantan largely changed from the west to the east. Structural analysis revealed four different parts that included western part of the scene by ductile fabrics, western of the Bentong-Raub Suture Zone affected by brittle deformation, ductile-brittle deformation between Bentong-Raub Suture Zone and Lebir Fault Zone and brittle-ductile fabrics between Lebir Fault Zone and eastern coastal line (Pour & Hashim, 2016). The Lebir Fault Zone is situated in the eastern part of the state of Kelantan which known as the main lineament in the Peninsula Malaysia. Also it was recognized as post Cretaceous and a sinistral strike-slip fault (Pour & Hashim, 2017). Explanation by Spiller, (1997), she said the Lebir Fault formed the boundary between the Central and Eastern Belts of the Peninsula Malaysia.

2.5 Historical Geology

It became a problem to unravel the tectonic history of the Malay Peninsula when there is a limited quality of the geological data available. Most of the information collected to date are limited use for tectonic synthesis and the other causes are the impossibility of mapping complete sequences and studying the field relationships between the different rock units (Khoo & Tan, 1983). The tectonic development of the Malay Peninsula began when the Palaeo-Tethys Ocean was formed causing the East Malaya block along with

South China, North China and Tarim detached from Gondwana in the Early Devonian. The Sibumasu Terrane was formed in one part of the southern Palaeo-Tethys passive margin of Gondwana at this time. In the Permian-Early Triassic, Sibumusu began to collide with the East Malaya. Subduction had ceased by the late Middle Triassic causing the Main Range S-Type granitoids to generate by crustal thickening (Metcalfe, 2013).

Kelantan state's oldest rocks are in the Lower Palaeozoic age, outcropping as a northward trending belt bordering the Main Range foothills and widening eastward to Sungai Nenggiri. On the eastern side of the Kelantan, had occurred extensively by predominantly Permian volcanic-sedimentary rocks and overlying uncomformbly on the south-west Kelantan in the Lower Palaeozoic sequence. In the central and south Kelantan are mainly confined with Triassic rocks. The youngest rocks are in the Jurassic-Cretaceous age which covered the Boundary Range Granite and Triassic sediments in the Gunung Gagau zone that located at the boundary between Kelantan, Terengganu and Pahang until to the west in the Gunung Perlis and Gunung Pemumpu zones (Goh et al., 2006). Based on the Figure 2.2, the age of rock in the study area is within Permian to Triassic which covered by Taku Formation and Telong Formation. The rock units from both formations could be found in the area of Tanah Merah, Kelantan where dominantly covered with argillite, low-grade metamorphic rock (slate and phyllite), and a slight of hornfels (The Malaysian and Thai Working Groups, 2006).

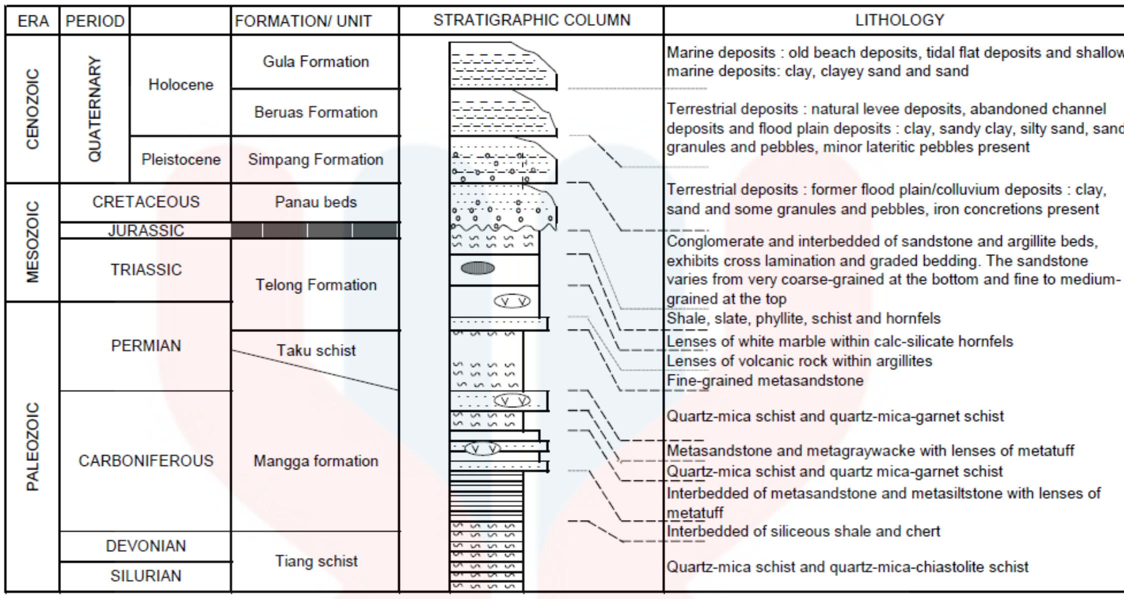

Figure 3.2: Geology map of Kelantan Schematic stratigraphic column of the Batu Melintang-Sungai Kolok Transect area in Malaysia (The Malaysian and Thai Working Groups, 2006)**.**

2.6 Groundwater Potential

Malaysia is a tropical country with an abundance of surface water receiving an average annual rainfall of 3000 mm that always continually recharges the groundwater. The groundwater consumption in Malaysia is about 3% of total use which usually use for domestic purposes, industrial supply and agriculture (Mazrali, 2016). Nazaruddin et al., (2017) also expressed that not more than 10% Malaysia use groundwater resources as water supply. It is mainly use at rural and remote areas where there is limited piped water supply. Kelantan is one of the examples that still facing some water issues, such as poor quality of surface water supply that need to use groundwater resource as water supply. Nampak et al., (2014) highlighted groundwater had been used as a major source of water supply in other states of Malaysia such as Kelantan, Perlis, Terengganu, Pahang, Sarawak, and Sabah.

In Kelantan, the public generally use spring water as a source of water for areas that closer to the hills. There was feedback in Kuala Krai that Leptospirosis is threatened from the water supply. This acute infectious disease is commonly referred to as Rat Urine Disease and can cause death if treatment is not available (AWER, 2011). This show that a need to locate groundwater supply to meet the demand.

In order to locate the potential groundwater field, many researchers used remote sensing and GIS. Thomas Saaty used the application of the GIS and AHP methods in 1980 for higher analytical processes in groundwater fields (Mohd Sahrul Syukri et al., 2021). Agarwal et al. (2013) also applied remote sensing, AHP and GIS method in delineating groundwater potential zone in Unnao district, Uttar Pradesh.

A study from Nampak et al., (2014), a higher elevations, steeper slopes, and convex-concave curvatures may result increase rainfall-runoff levels and decrease penetration thus resulting in lower groundwater potential. Flat surface areas are more suitable for detecting groundwater potential. Higher elevated areas such as mountainous and hilly are considered to be recharge areas, while low and flat areas are as discharge areas (Nazaruddin et al., 2017).

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This chapter is discussed about materials and methods that were used in the research study area. The flow chart in the Figure 3.1 shows a brief outline of the methodologies for the purpose of geological mapping and groundwater potential mapping. Sources of data are from published and unpublished reports, journals, and books. Secondary data are analysed and interpreted by using GIS software to produce map of the study area. Seven parameters for groundwater potential were produced into thematic map and integrated for generating the zones of groundwater potential in the study area.

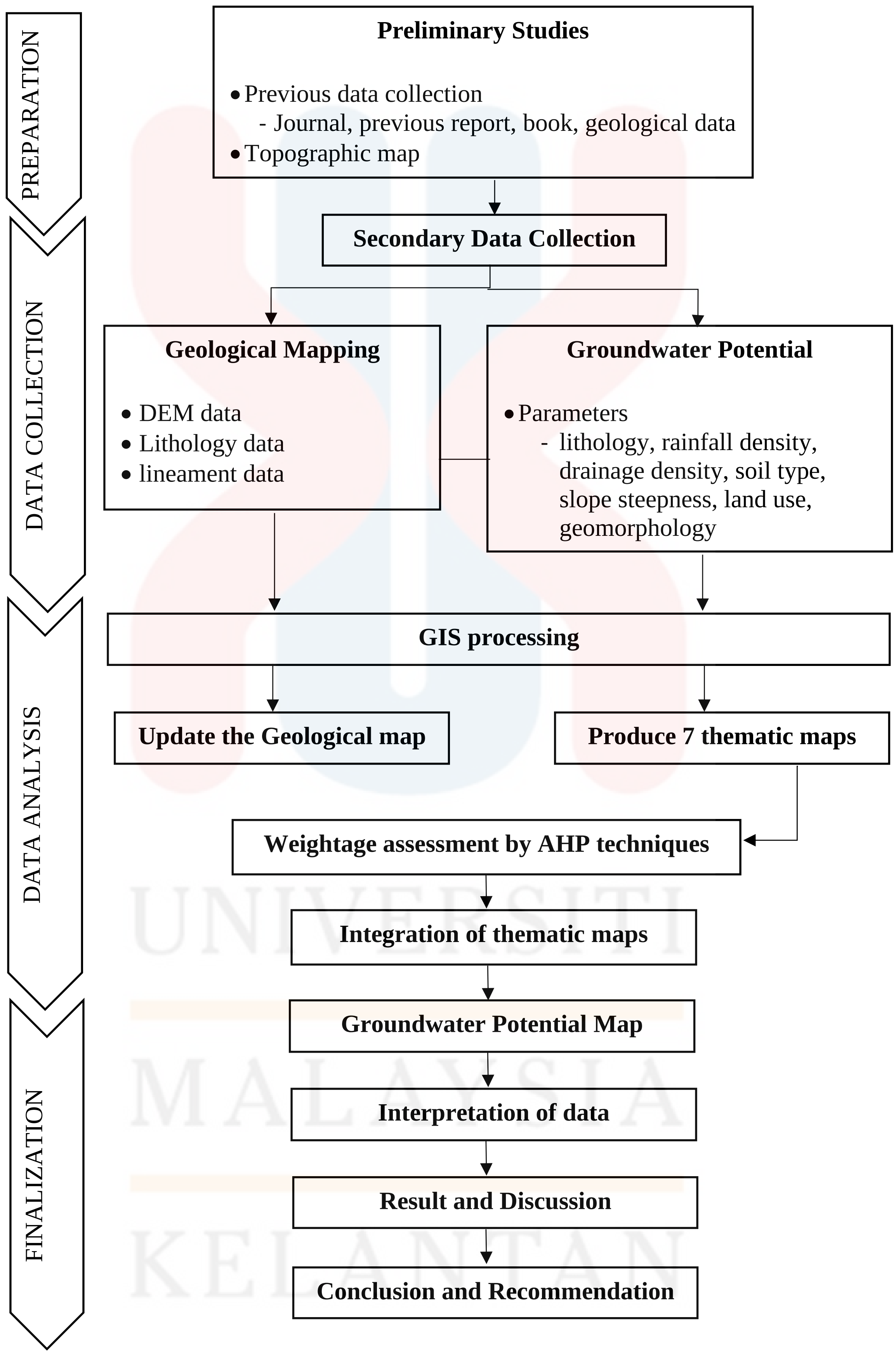

Figure 3.1: Research Flow Chart

3.2 Materials

The materials that used in this research study are topographic map, digital elevation model (DEM), ArcGIS 10.3 software, and GeoRose software. These materials are essential to extract and collect data for the purpose of research project.

3.2.1 Topographic Map

Topographic map is one of the important materials when doing geological mapping. This map represents third dimension by using contour lines to show elevation change on the surface of the earth. The map scale used was 1:25000 to easier plotting down the information. The features on this map may include stream, road, railroad, and village.

3.2.2 Digital Elevation Model (DEM)

DEM is a specialized database which describing the relief of a surface between established elevation points. It is in the format of raster. A rectangular, digital elevation model grid can be generated by interpolating known elevation data from sources such as ground surveys and photogrammetric data capture. It helps in creating 3D landscape visualisation by displaying geological structures, lithologies and landscape morphology. DEM data for the study area was used from Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global that published on 23 September 2014. This DEM data can be assessed from the Earth Explorer website. The DEM data was applied to extract the information such as contour, lineament, and terrain.

3.2.3 ArcGIS

ArcGIS is a GIS tool for mapping and spatial reasoning. The ArcGIS software used in this study is ArcGIS 10.3 version. ArcGIS software was used by many users such as from academic institutions, governments, and private institutions to create and demonstrative ground-breaking research. ArcGIS can create maps where it overlaid by a few layers.

3.2.4 GeoRose

GeoRose is a rose diagram and stereonet plotting application that can plot a rose diagram of structural geology, equal area, and stereonet diagram of equal angle. It has many features and one of them are can generate strike, dip direction and dip angle. Also, it can calculate strike from the dip direction.

3.3 Methodology

Geological and hydrological mapping in this research study involve using a few methods in structural geology, geomorphology, petrology, stratigraphy, and geohydrology. Preliminary mapping was conducted before collecting data by getting a general knowledge of the study area. The collected data was then analysed and interpreted through thematic maps that were generated through ArcGIS software.

3.3.1 Preliminary Studies

A preliminary study is an early stage to get an overview of the knowledge of the research study. The sources were obtained from the previous report, journals, books, and geological data. These sources provided literature and theory methods as for aid to the research study. The purpose of this preliminary study is to create an awareness of the existing knowledge and to identify the research gap (IJSBAR, 2015).

The interpretation of the study area can be analyzed in the form of studying the geological and geomorphological map, making trajectory plan, lineament analysis, and planning for geological mapping. The interpretation is required secondary data like a topographic map, satellite images, regional geological map, land use map, geological research for an area that will be mapped. These secondary data were used to determine landscape and strike/dip of bedding, distribution of rock units or formations, geological structure pattern, and tentative maps (AAPG Wiki, 2015).

3.3.2 Secondary Data Collection

Secondary data was divided into two categories which are geological mapping and groundwater mapping. For geology, the data including DEM, lithology, and lineament are needed to extract and analyse for the purpose of generating geological map.

For groundwater secondary data, the research study needs to use several parameters to generate groundwater potential map. The detection of groundwater potential was conducted by interpreting seven parameters including lithology, geomorphology, drainage density, slope steepness, land use, rainfall density, and soil type.

Both geology and groundwater data can be assessed from the JMG Malaysia, the JUPEM, Department of Irrigation and Drainage (DID), Department of Agriculture (DOA), Earth Explorer, and previous research.

3.3.3 Lithology

Lithology can be influenced both the permeability of aquifer and the distribution of fracture pattern (Isnain & Akhir, 2017). High permeability and high porosity are possibility to have high groundwater potential zones. The lithology data of the study area was obtained from geological map of Peninsular Malaysia by Geological Society of Malaysia (GSM) and University of Malaya (UM) with the scale of 1:1,000,000 that modified in 2008. Other secondary data was from previous study by Nurfatin Che Samat, (2015) and 'Ainaa' Mardhiyah, (2013).

3.3.4 Geomorphology

Geomorphology may reflect a few types of landform and structural features that are related to the occurrence of groundwater. The features can be found in the pediment, inselbergs, buried pediment shallow, buried pediment deep, residual hills, sedimentary plain, and flood respectively (Nagarajan & Singh, 2009). The geomorphology map was obtained based on elevation that extracted from DEM data.

3.3.5 Land use

Standard methods of visual analysis were used to classify the type of land use trend in the study area using secondary data from previous studies or relevant agencies. Agarwal et al., (2013) said vegetation and sandy area are a perfect place to have a good groundwater potential. The land use in the study area was referred to the Agriculture Land Use map of Kuala Krai 2015 by DOA. This map was then georeferenced and digitized to extract the land use in the study area.

3.3.6 Slope

Slope is the rate of change in elevation and is known to be the key influence of the flow of surface water because it causes the water to move. The slope is directly proportional to the runoff which means that the areas with high steep slope, recharge will be lesser (Preeja et al., 2011). The slope map was created from DEM data using Surface tool for slope. The classification of slope classes was used manual classification.

3.3.7 Drainage density

Drainage pattern reflects surface characteristics as well as the formation of the subsurface. The drainage density in the unit of km / km^2 which indicates the closeness of the channel spacing and the nature of the surface material (Prasad et al., 2008). High river density values indicate an area`s high surface runoff and therefore these areas are considered suitable for arresting excessive runoff (Nampak et al., 2014). The drainage density map was prepared using Line Density under Spatial Analyst Tool.

3.3.8 Rainfall

The Peninsular Malaysia has a tropical rainforest climate because it is in the equatorial zone where it is driven by the monsoon regimes of the north-east and south-east. Kelantan is one of the four states affected by climate change in the East Region of Peninsular Malaysia. This can be seen by how the temperature of the atmosphere has risen in this area from 1.75 ° C to 2.69 ° C in the last 40 years, resulting in greater reliability in terms of rainfall and extreme drought (Hussin et al., 2020). The rainfall data of Kelantan was accessed from DID that collected from 2015 to 2019. By summing the daily rainfall data that determined by rainfall stations, monthly total rainfall values were obtained. Similarly, the annual total rainfall data was determined by adding monthly total rainfall data after the missing values had been filled in (Faizah Che Ros et al., 2016). The amount of precipitation can be determined the amount of water that can be percolated into the groundwater system as the main source of recharge (Nampak et al., 2014). Inverse Distance Weighted (IDW) interpolating method was used to generate rainfall map based on location of rainfall station in Kelantan.

3.3.9 Soil Type

The characteristics of soil play a major role in water infiltration. The infiltration rate depends largely on the grain size of the soil (Preeja et al., 2011). Large grain size such as sand and gravel have high porosity compared to silt and clay which are small grain size. Nor Ashikin Shaari et al., (2016) mentioned that the soil is in good condition when the structure is strong, and the surface has continuous pores. This enables rainfall water to enter unhindered during rainfall event that can recharge the groundwater. Soils that have low infiltration show an increase in the total amount of water runoff which may lead to local and regional flooding. The soil map was generated with the aid of Reconnaissance Soil Map of Kuala Krai by DOA with the scale of 1:150,000.

3.3.10 Weightage

In generating groundwater potential map, a decision method was used in this research. AHP was introduced by Saaty in 1980 as a solving social-economic decision method to solve various type of problems. AHP was used when dimensions are independent and it is appropriate to solve problems that involved dependent dimensions (Agarwal et al., 2013). Rahmati et al., (2014) also highlighted that the commonly used in Multi-Criteria Decision Analysis (MCDA) models was the AHP process, which had already used in environmental management. By using AHP process, experts can focus on the relative strength of each of the thematic layers for assessing groundwater potential.

The AHP Excel template by (Goepel, 2013) was used in this research for finding the weighs in each category of groundwater potential parameters. The comparison ratings for each thematic layer was based on Saaty`s 1-9 scale in the table. Using Saaty`s scale 1-9, all the thematic layers were compared to each other in a pairwise comparison matrix as the inputs while the outputs were the relative weights of the thematic layers. Through the use of principal eigenvalue and consistency index, the AHP can captures the concept of uncertainty in decisions (Agarwal et al., 2013; Rahmati et al., 2014).

Table 3.1: The relative importance based on Saaty`s 1-9 scale

Scale	Importance
1	Equal importance
2	Weak
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong importance
8	Very, very strong
9	Extreme importance

3.3.11 Data Analysis and Interpretation

All the collected data were analysed in GIS software to generate geological map and groundwater potential map. The maps need to be georeferenced and digitize first in ArcGIS before export to ArcView to visualize, explore and spatial analysis. The thematic layers such as lithology, hydrogeomorphology, slope, drainage density, land use and soil type were reclassified in the GIS environment. Each of the thematic layers were then assigned to the weightage factor. Weightage factor was used to indicate the influence on the availability of groundwater. Then all the thematic layers were combined for integration using Spatial Analyst tool in ArcGIS software to generate groundwater potential zones.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter is focused on geomorphology, lithostratigraphy, structural geology, and historical geology of study area in Kuala Krai, Kelantan. The accessibility, forestry and settlement are also will be discussed in this chapter.

The geomorphology section is about landform with identification of the fundamental units that can be categorized based on the landscape. The classification of the landform unit was generated into geomorphologic map. The streams and rivers were observed to describe their drainage pattern where their pattern was controlled by the topography of the land.

The lithostratigraphy is determined based on the previous research and regional geology map of Peninsular Malaysia from GSM and UM. The rock unit was explained in detail followed by geological map and cross section.

The structural geology is discussed about structure that have been found such as fault, fold, and joint. Lineament analysis is divided into two types which are positive and negative lineaments. The lineament was analysed through DEM data.

Meanwhile, for the historical geology, it is about geological processes and tectonic occurred based on geological time scale.

4.1.1 Accessibility

Jalan Kuala Nal and Jalan Nal Station are used as the main road connection in the study area. These two roads are mainly used to connect the road to Kuala Krai town, residential areas, and public facilities such as mosques, clinics, schools, mini markets. There is an unpaved road which is mostly used as a road connection to the plantation and forest areas. The railway is covered at the right side of the study area from South-North that cross the Sungai Nal (Nurfatin Che Samat, 2015).

4.1.2 Settlement

The study area was situated in the sub-district of Batu Mengkebang in the Mukim Kuala Nal with a population of 7,002 (Department of Statistics Malaysia, 2010). Batu Mengkebang was inhabited by 122 villages (Majlis Daerah Kuala Krai, 2018) where Kg Batu Jong, Kg Kuala Nal, and Kg Bukit Sireh are the main settlement by villagers of the study area. A long time ago people love to live near a river because they wanted to get fresh water to drink and bathe. The river also was a part of transportation and used to supply agriculture and livestock. In the study area, there is also a group of people living Sungai Kelantan. The distribution of races in the study area is mostly populated with Malay, followed by Chinese and Indian (Nurfatin Che Samat, 2015). Apart from that, many public facilities were built in the study area that made the population even grow.

4.1.3 Forestry

Towns and villages in Kuala Krai were rapidly developed to cater primarily to the agricultural industry. In Malaysia, rubber production had become increasingly important, and many rubber tree plantations had been set up in this region (Jabatan Pendaftaran Negara, 2018). The types of land-use in Bukit Gilat, Kuala Krai in the Figure 4.1 is mostly covered with mixed agriculture, forest and plantation like rubber trees and palm oil trees due to the dominant lowland. Other than that, it has been covered with bare land, builds up, and water body. Adnan, (2010) described that the change in land use in relation to urban growth was gradually changed from the 1970s to the 1990s with 7% growth. After the 1990s, it became a very slow development in the area with just 1.4% growth.

Kuala Krai is the second largest that had high approved Environmental Impact Assessment (EIA) project after Gua Musang. The EIA project was approved during the period 2000 - 2015 where the majority of the project was replanting and new plantations of rubber and oil palm (Samsurijan et al., 2018). This shows the reason why the study area is dominant with rubber and palm oil trees.

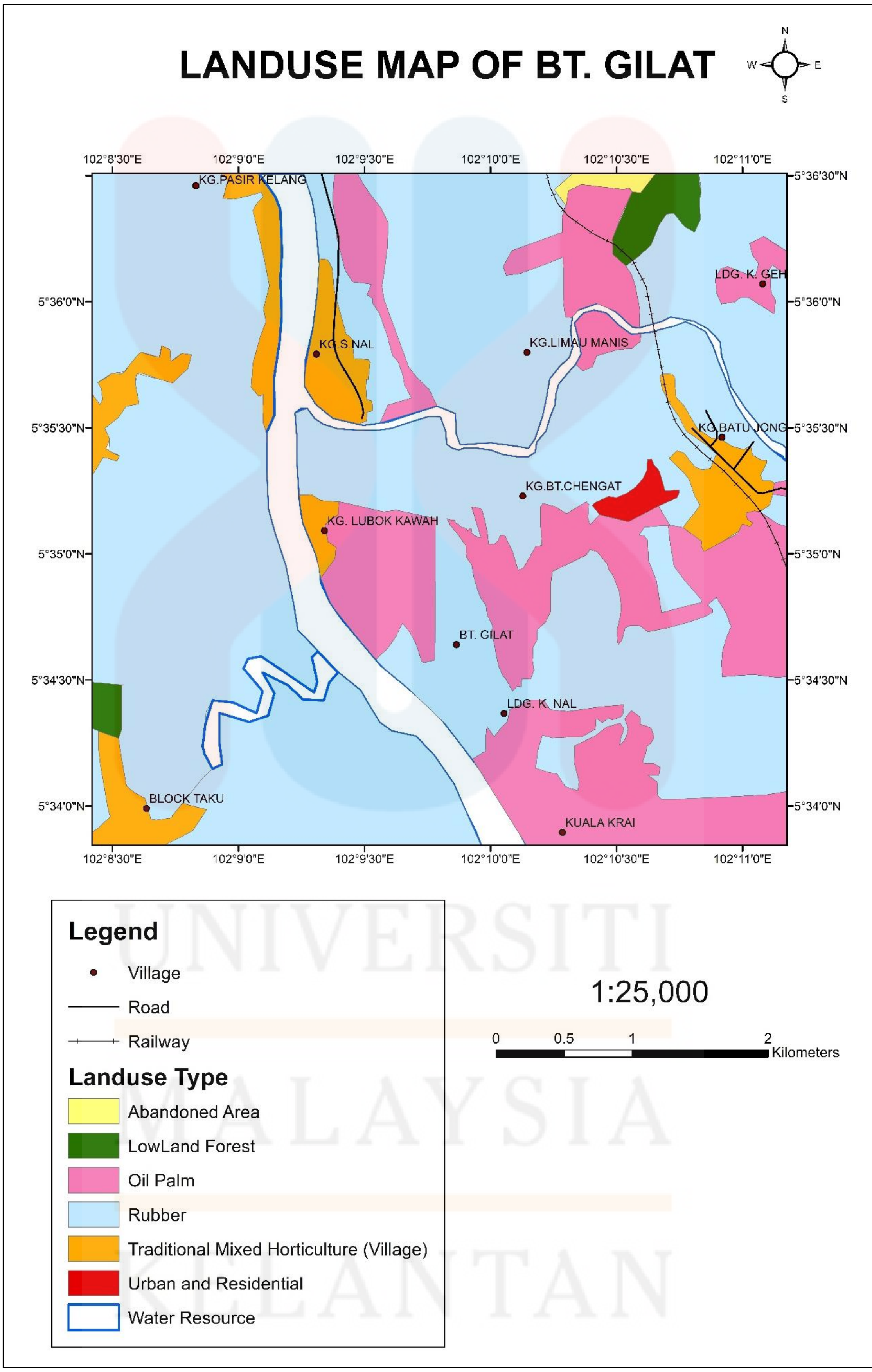

Figure 4:1 Landuse map of Bukit Gilat, Kuala Krai

4.2 Geomorphology

Harvey, (2012) described that the definition of geomorphology is the scientific study of the surface of the Earth`s landforms. The form of landforms can be in various scales, for example, mountain, hill, inselberg, plateau, escarpment, plain, alluvial plain, flood plain, and coastal plain. The processes that generate the landforms include the formation of the relief itself and its alteration through erosion and deposition.

4.2.1 Geomorphologic classification

The types of landforms in the study area are hilly landforms, fluvial landforms, and plains landforms. According to Van Zuidam, (1985), hilly landforms have an elevation between 50 meters until 500 meters on the marine surface and have a slope between 7% until 20 %. The name of hilly was used on dome landforms of intrusion, volcanic hills, karst, and the hill that control by structural. Fluvial landforms were generated by running water, mainly rivers. The fluvial processes entailed erosion, transportation, and deposition of earth materials by running water. The type of alluvial channel in the study area is meandering channels. The meandering channel can be described as where the river flowing over gently sloping ground begin to curve back and forth across the landscape. Plain landforms, where plains are large, flat pieces of land with no drastic changes in the elevation. Plains usually formed sediment from taller landforms such as mountains, erodes and washes downhill. Over time, the sediment built up to create a large, flat plain.

The geomorphology of the study area in the Figure 4.2 had been classified into three classes which are low hills, low hills inland and lowlands. Elevation that has below than 50 m was classified as lowlands and they mostly classified as flat to undulating. 50 to 100 m was categorized as low hills inland and it classified as a undulating to hilly. Low hills have the elevation between 100 to 200 m, and it is in the relief classification of undulating to hilly. The topography of the study area has the highest elevation which is 140 m and the lowest is 20 meters. It is mostly covered with lowlands where the elevation is below than 50 m.

Table 4.1: Relationship of elevation with classification

Elevation (m)	Classification
< 50	LowLands
50 - 100	Low Hills Inlands
100 - 200	Low Hills
200 - 500	Hilly
500 - 1500	High Hills
1500-3000	Mountains
> 3000	High Mountain

(Source: Van Zuidam, 1985)

Table 4.2: Relationship of relief class with slope and elevation

Relief Class	Slope (˚)	Elevation (m)
Flat	0 - 2	<5
Flat to undulating	2 - 4	5 - 25
Undulating	4 - 8	25 - 75
Undulating to hilly	8 - 16	75 - 200
Hilly	16 - 35	200 - 500
Steep mountains	35 -55	500 - 1000
Very steep mountains	>55	>1000

(Source: (Van Zuidam, (1985)

The slope degree of the study area in the Figure 4.3 ranges from 0 to more than 36˚. It had been classified into five categories such as very gentle (0˚ - 3˚), gentle (3˚ - 8˚), moderate (8˚ - 14˚), moderately steep (14˚ - 21˚), and steep (21˚ - 36˚) classes by using natural breaks classification method in GIS environment. The very gentle and gentle slope classes are covered with 58% and 25%. The moderately steep and steep classes are covered about 15% and 3 % landslides area. The slope classification can be referred from Van Zuidam (1985) in the Table 4.3.

Table 4.3: Relationship of slope with classification

Slope (˚)	**Classification**
0 - 2	Flat
2 - 4	Very gentle
4 - 8	Gentle
8 - 16	Moderate
16 - 35	Moderately steep
35 -55	Steep
>55	Very steep

(Source: Van Zuidam, 1985)

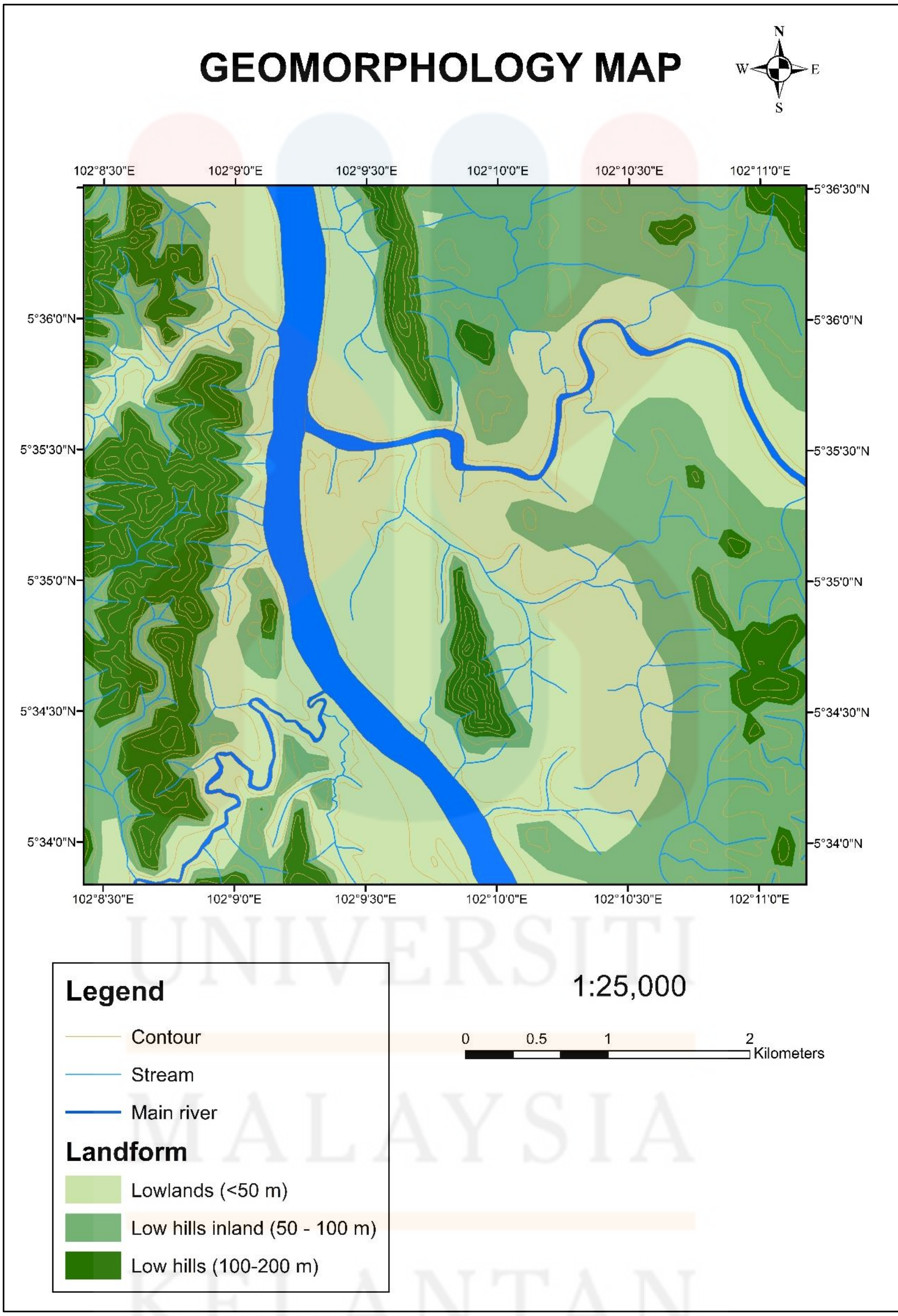

Figure 4.2: Geomorphology map of the study area

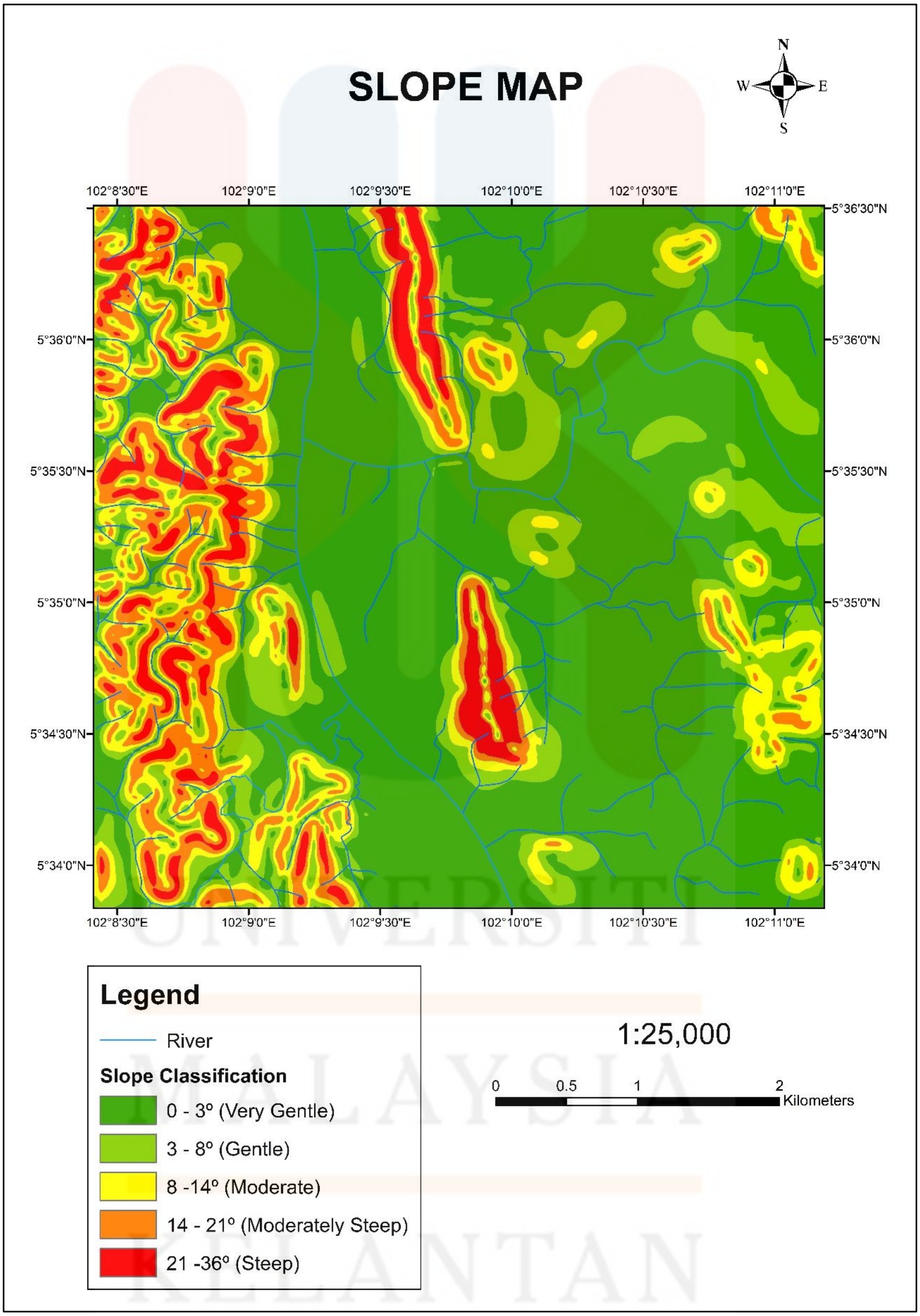

Figure 4.3: Slope map of the study area

4.2.2 Drainage Pattern

In the study area, there are two main river present which are Sungai Kelantan and Sungai Nal. In map view, the arrangement of a river and its tributaries was called a drainage pattern. In certain cases, a drainage pattern may expose the existence and structure of the rocks underneath it. Almost all tributaries that joined into the main stream were flowed at an acute angle, forming a V (or Y) pointing downstream (Plummer, Carlson, & Hammersley, 2016). They were regulated by the topography of the land, either it was hard or soft rocks dominantly at a particular region and the gradient of the land. The drainage pattern was classified based on their shape and texture where it was developed in response to relief and sub-surface geology (Nurfatin Che Samat, 2015).

The drainage patterns can be categorized in several patterns which included dendritic, parallel, trellis, rectangular, radial, centripetal, annular, deranged, and reticulate. It has been identified that in the study area in the Figure 4.6 presents two types of drainage pattern which are dendritic and trellis.

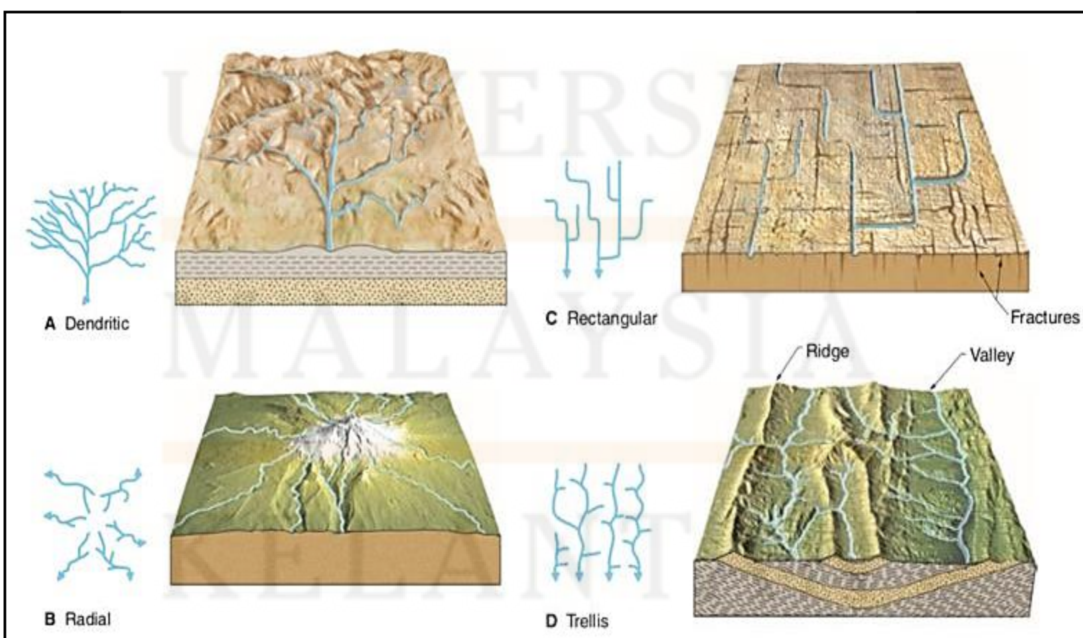

Figure 4.4: Types of drainage patterns (Plummer et al., 2016)

Dendritic drainage pattern in which the pattern looks like tree branches or nerve dendrites. It is the most typical type of pattern which in the category of convergent drainage. It usually formed on systematically erodible rock or regolith. The streams that incise through the underlying rock were controlled by three factors which are 1) the regional base level, 2) stream power, and 3) rock resistance to rock. When facing towards the main stream, the incision changed and steepened, creating a new line of convergent drainage called as drainage subsequent (trellis pattern). A trellis pattern composes of parallel main streams connecting them at right angles with short tributaries. It was formed in an area in which tilted layers of durable rock like sandstone mix with undurable rock like shale (Harvey, 2012; Plummer et al., 2016).

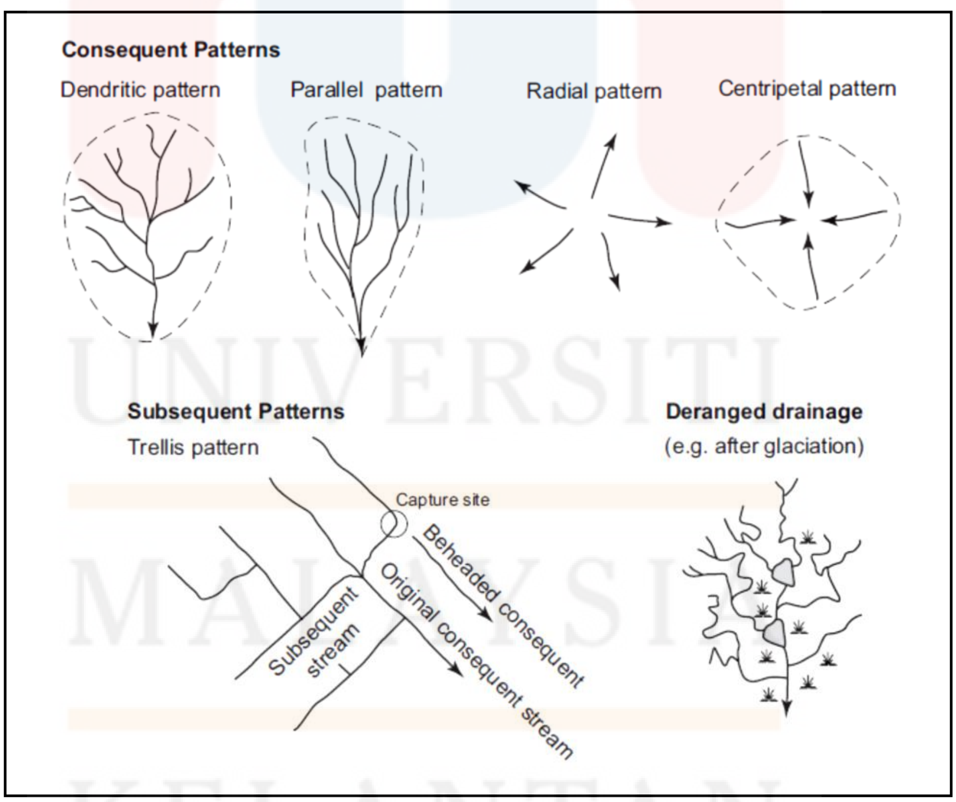

Figure 4.5: Three major group of drainage patterns which are consequent, subsequent and deranged (Harvey, 2012)

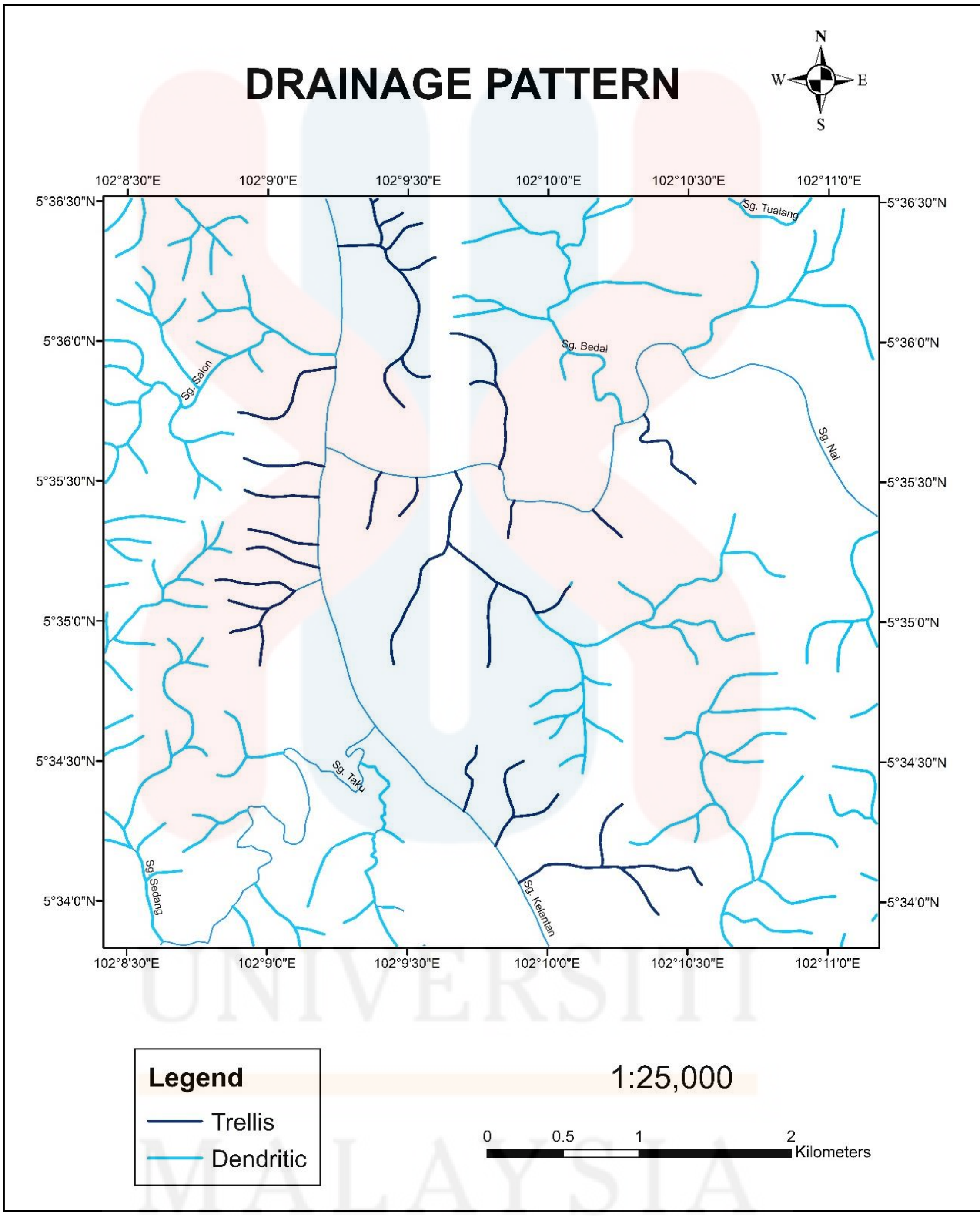

Figure 4.6: Drainage Pattern of study area

4.3 Lithostratigraphy

The lithostratigraphy of the study area was referred from various sources such as previous study, geological map of Peninsular Malaysia from GSM and UM. The lithology of the study area has mostly covered by previous studies from Nurfatin Che Samat, (2015) where about 75% and 50% from 'Ainaa' Mardhiyah, (2013). Based on geological map in 2018 from GSM, the study area is covered by three types of rocks which are schist, ignimbrite and interbedded sandstone, siltstone, and shale.

4.3.1 Stratigraphy

The oldest rock in the study area is schist which in the formation of Taku Schist. It was deposited in Permo-Triassic age. According to the lithology from The Malaysian and Thai Working Groups, (2006), the base of the Taku Schist consists of metasandstone and metagraywacke with lenses of meta-tuff which known as Mangga Formation in the age of Carboniferous. The Taku Schist was then overlain by Telong Formation of the Triassic age containing interbedded sandstone, siltstone, and shale. Temangan dyke or Temangan Ignimbrite of Triassic age was unconformably underlain by the Telong Formation. Aw, (1967), highlighted that the ignimbrite was in contact between the schists and the sedimentary rocks. The ignimbrite formed a prominent ridge, which stretches about 15 miles long and approximately half a mile wide, towards the north south. The youngest rock is alluvium which in the age of quaternary. Basically, this alluvium was deposited near to water source where it consists of clay, silt, and sand.

4.3.2 Schist unit

The name of Taku Schist was taken from Sungai Taku which extended from the Thai border near Tanah Merah to the central east of Kelantan near Manik Urai. The Taku Schist consists predominantly schists of completely crystalline and entirely schistosed. The main rock type is pelitic mica schist which comprised of quartz-mica schist, quartz-mica-garnet schist, and garnet-mica schist. Commonly, the narrow bands of amphibolite schist and even narrower schist band were occurred in the mica schist and presented with rare carbonate schist. Hornfels were found in contact with the body of a granite (Lee, 2009; The Malaysian and Thai Working Groups, 2006). In the previous research from Nurfatin Che Samat, (2015), her findings was a quartz-mica schist with the foliated texture of fine to medium grain size. The color of the schist had mix-colored of white and grey. Quartz and muscovite were presented under the thin section.

4.3.3 Sandstone, siltstone, and shale unit

This unit is under the Formation of Telong. The formation of Telong is consisted mainly of argillite, metasedimentary low-grade and metavolcanic rocks. It had been identified that there are four facies which were argillaceous, arenaceous, calcareous and volcanic facies. The argillaceous facies consisted of slate, phyllite, schist and hornfels, where theirs color were from greenish to reddish grey to black. In the carbonaceous rocks, mostly was a pyrite. For arenaceous facies, they were mainly fine-grained sandstone and metasandstone. The calcareous facies was composed of grey marble which can be seen at Gua Setir on the southwest side of the Transect area (The Malaysian and Thai Working Groups, 2006).

In the findings from 'Ainaa' Mardhiyah, (2013), she had discovered arenaceous and argillaceous facies. The arenaceous facies consisted of sandstone specifically from the types of lithic wacke and greywacke. The minerals in sandstone mainly composed of quartz, feldspar, and lithic fragments. The argillaceous facies were mudstone and shale. Mudstone is commonly consisted of few rock fragments, clay minerals, and silt grade quartz. Shale has very fine-grained size which compacted with clay minerals. Different finding from Nurfatin Che Samat, (2015), she had discovered sandstone that consisted of quartz, plagioclase and orthoclase with clastic texture. The color was in brownish grey. Her hand specimen of shale was in light grey consisting clay minerals, quartz, chert, and feldspar. Siltstone was found in whiteish grey in which finer grained than sandstone but coarser grained than shale. It contained a very little sand and clay.

4.3.4 Ignimbrite

From the research study by Aw, (1967), the ignimbrite is a volcanic igneous rock which plugs an old feeding fissure and formed a hard-massive outcrop. The texture of ignimbrite overall was very homogeneous, and there was no noticeable lateral or vertical change. The colour ranges from pink to dark brown in fresh specimens, while greenish-grey in slightly altered rock. In hand specimens, the porphyritic nature was visible, with quartz and feldspar phenocrysts in feldsitic matrix. Some specimens were included shale fragments and some small black lenses of pumiceous content. The ignimbrite comprised three joints, but it was not prominent.

The ignimbrite sample from Nurfatin Che Samat, (2015) was more to pink and grey color. The texture of ignimbrite was porphyry aphanitic with containing quartz and alkali feldspar. It was also associated with accessory mineral like biotite mica. While the ignimbrite sample from 'Ainaa' Mardhiyah, (2013) was in pink color and had aphanitic texture containing embayment shape of quartz and tuff ashes.

4.3.5 Alluvium

The alluvium deposited in the fluvial environment which mostly appeared along the river. In the study area, fluvial deposits were presented along the Sungai Kelantan and Sungai Nal. The fluvial deposits were dominantly with sand, silt, and clay. In some time, pebbles were presented together embedded with sand, silt and clay (Nurfatin Che Samat, 2015).

Table 4.4: Stratigraphy column of the study area

FORMATION	LITHOLOGY	DESCRIPTION
ALLUVIUM		**Alluvium:** Mainly consist of sand, silt, and clay. The depositional environment is fluvial where it can be seen along the river.
TEMANGAN DYKE		**Ignimbrite:** A pumice-dominated pyroclastic flow deposit. Dominated with color in pink and grey. The texture of the rock is porphyry aphanitic with the mineral composition of fine grained glassy matrix and phenocrysts. Most of the minerals are quartz and alkali feldspar.
TELONG FORMATION		**Sandstone, siltstone and shale unit:** Sandstone is mainly composed of quartz, plagioclase and orthoclase with the clastic tecture. The color of the rock is brownish grey. Siltstone is fine grained size which has a mixture of quartz, feldspar, micas and clay minerals. The color is in whitish grey. Shale is very fine grain that composed of mud and mix of clay minerals. It often seen in light grey color. These clastic sedimentary rocks are deposited in shallow marine environment.
TAKU SCHIST		**Schist unit:** It is medium grade metamorphic rock which mainly pelitic that consist of quartz-mica schist. Have a foliated texture with the fine to medium grain size. Their color are mixed color of white and grey. Rich in mineral of quartz and muscovite

(Source: NurFatin, Che Samat, 2017 & \`Ainaa\` Mardhiyah, 2013)

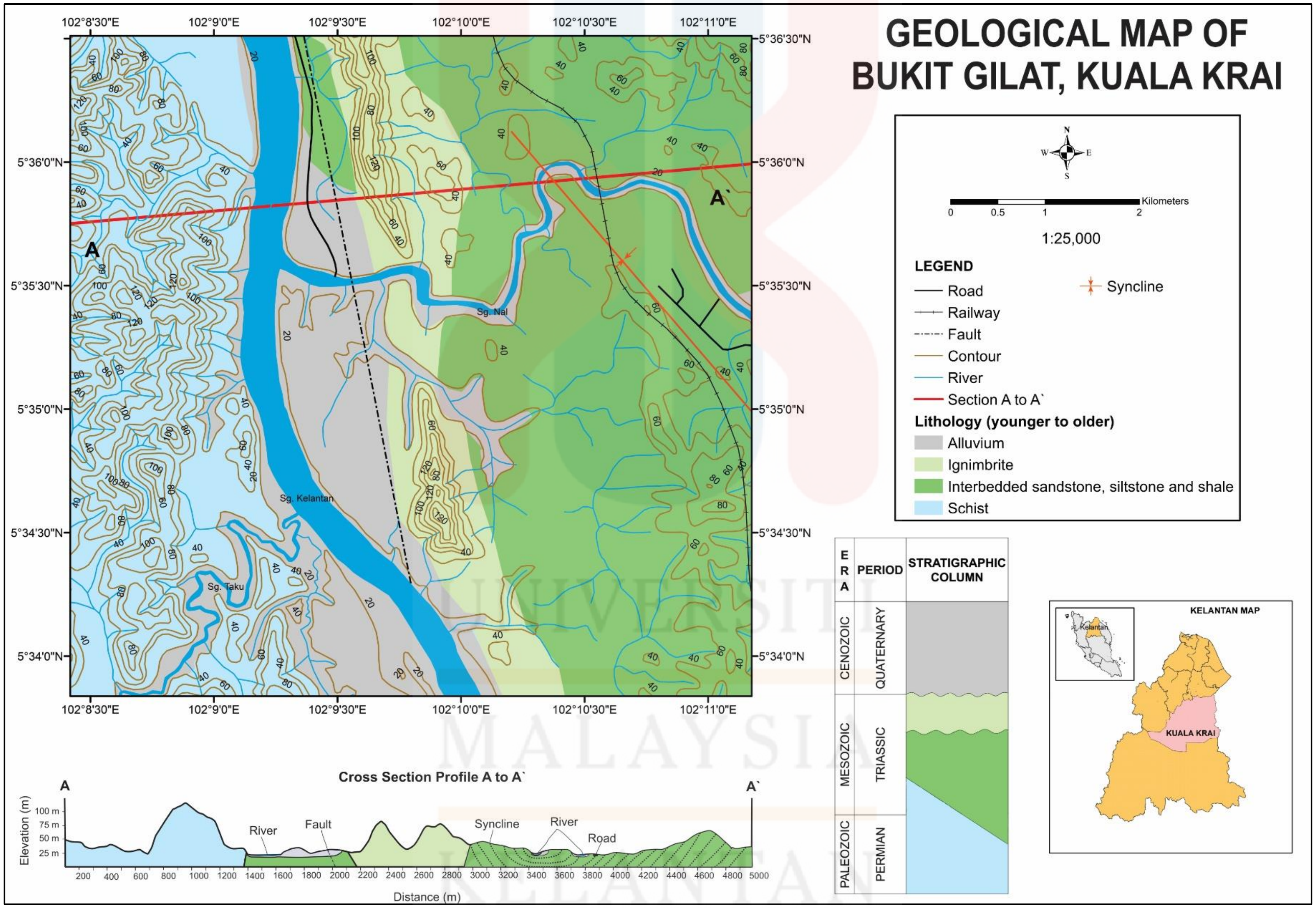

Figure 4.7: Geological map of the study area

4.4 Structural Geology

In the structural geology of the study area, a lineament analysis was identified from the DEM data and drainage pattern. The lineament can be divided into two types which are positive and negative lineaments. The result from lineament analysis was produced into rose diagram by using GeoRose software

4.4.1 Lineament Analysis

Lineaments are commonly considered to be linear features representing discontinuities in geological structure that present in the ground surface and land cover (mainly faults). The extracted lines derived from the discontinuities in the raster picture and drainage pattern. The geomorphological interpretation of the lines drawn depended on the geometrical character of the discontinuities (Šilhavý et al., 2016). Lineament can be either positive or negative lineament.

Positive lineament in the Figure 4.9 is referred to ridge trends or convex edges. Positive lineament was mapped by plotting manually onto DEM data. In delineating lineament, hillshade effect was used on the DEM. This technique was used for producing shaded topographic images of the surface elevations of the Earth. The shaded was came from the reflection of artificial light through a point source of illumination that based on altitude (inclination) and azimuth (declination) (Ramli et al., 2010). A total of 5 positive lineaments had plotted from the DEM data. The strong force in the study area comes from the orientation at NE-SW.

Negative lineament in the Figure 4.10 can be referred as river valley or concave edges. It was mapped by plotting manually onto drainage. It was proposed that the orientation of the drainage pattern need to be interpreted before lineament delineation was undertaken. The main lineament trends based on the drainage patterns (Ramli et al., 2010). About 180 negative lineaments were digitized from the drainage. The negative lineament trends in the study area are strongest at NW-SE.

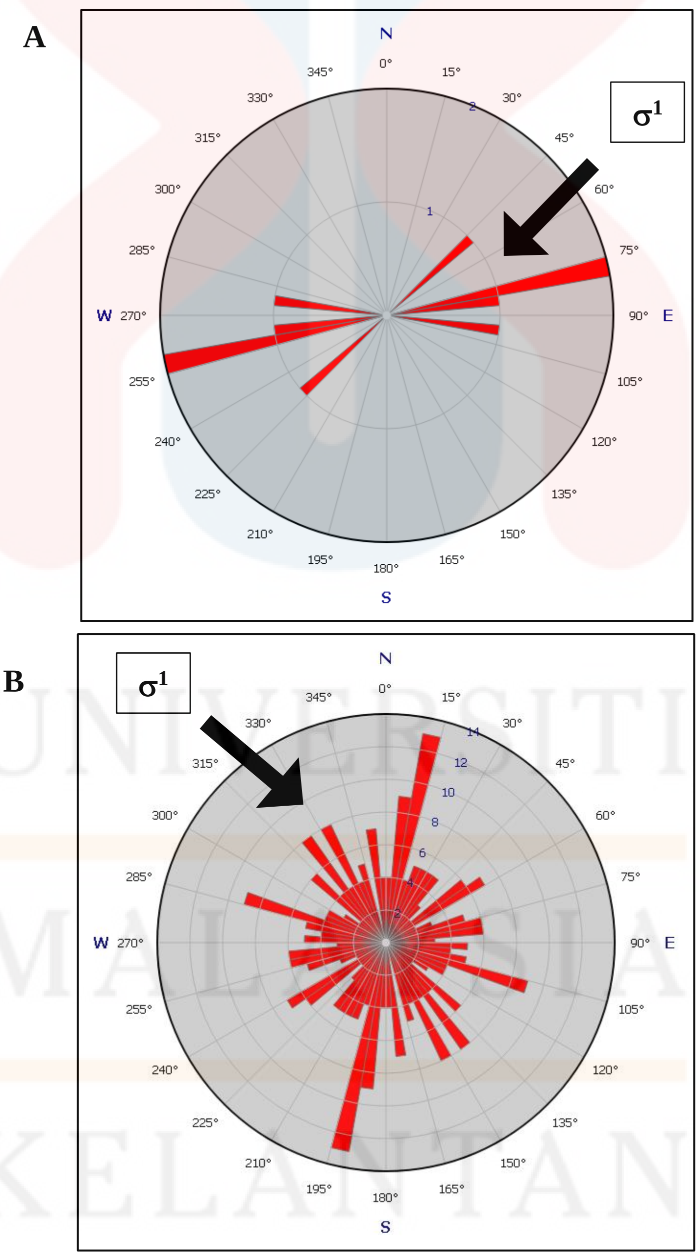

Figure 4.8: A) Positive lineament B) Negative lineament

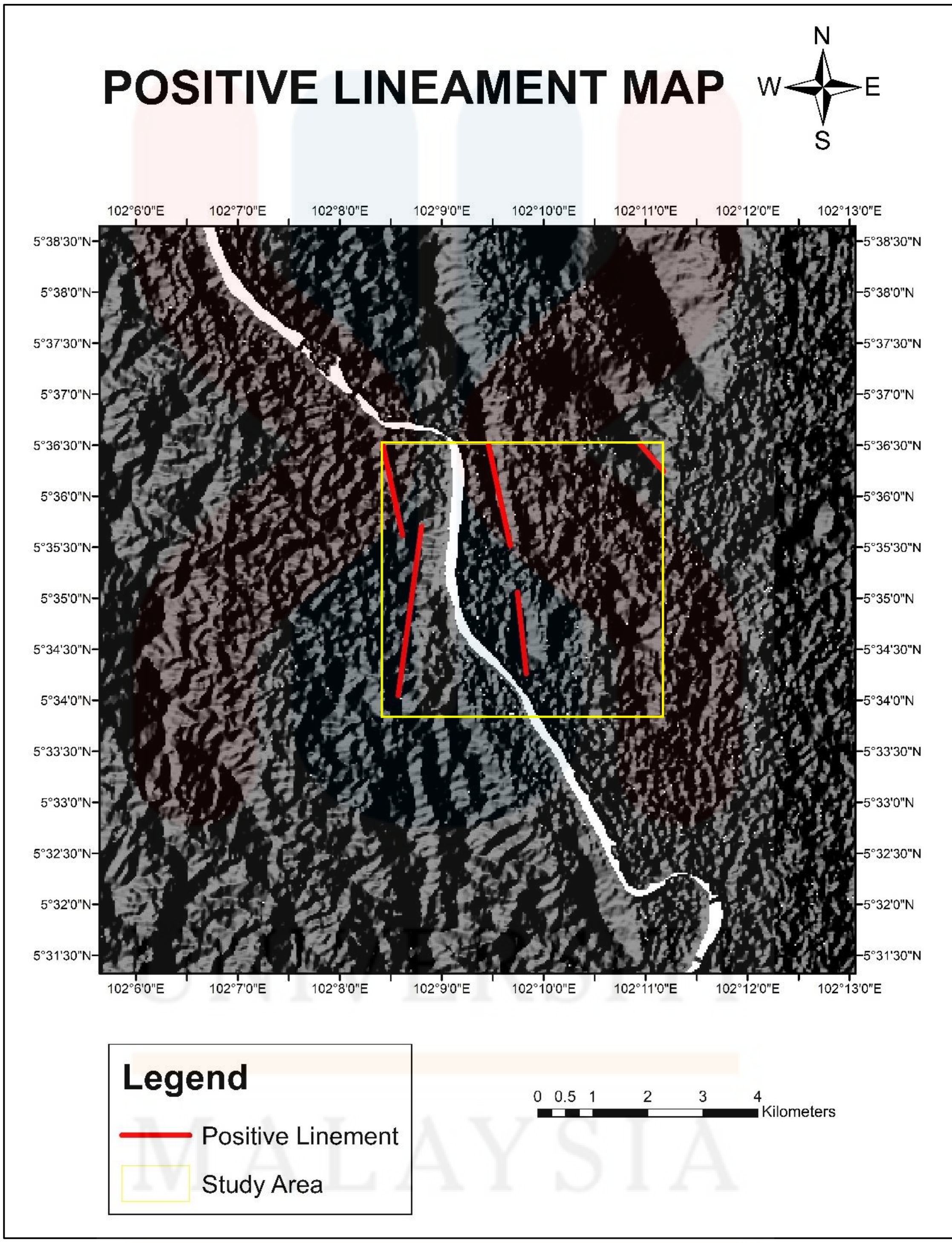

Figure 4.9: Positive lineament map of the study area

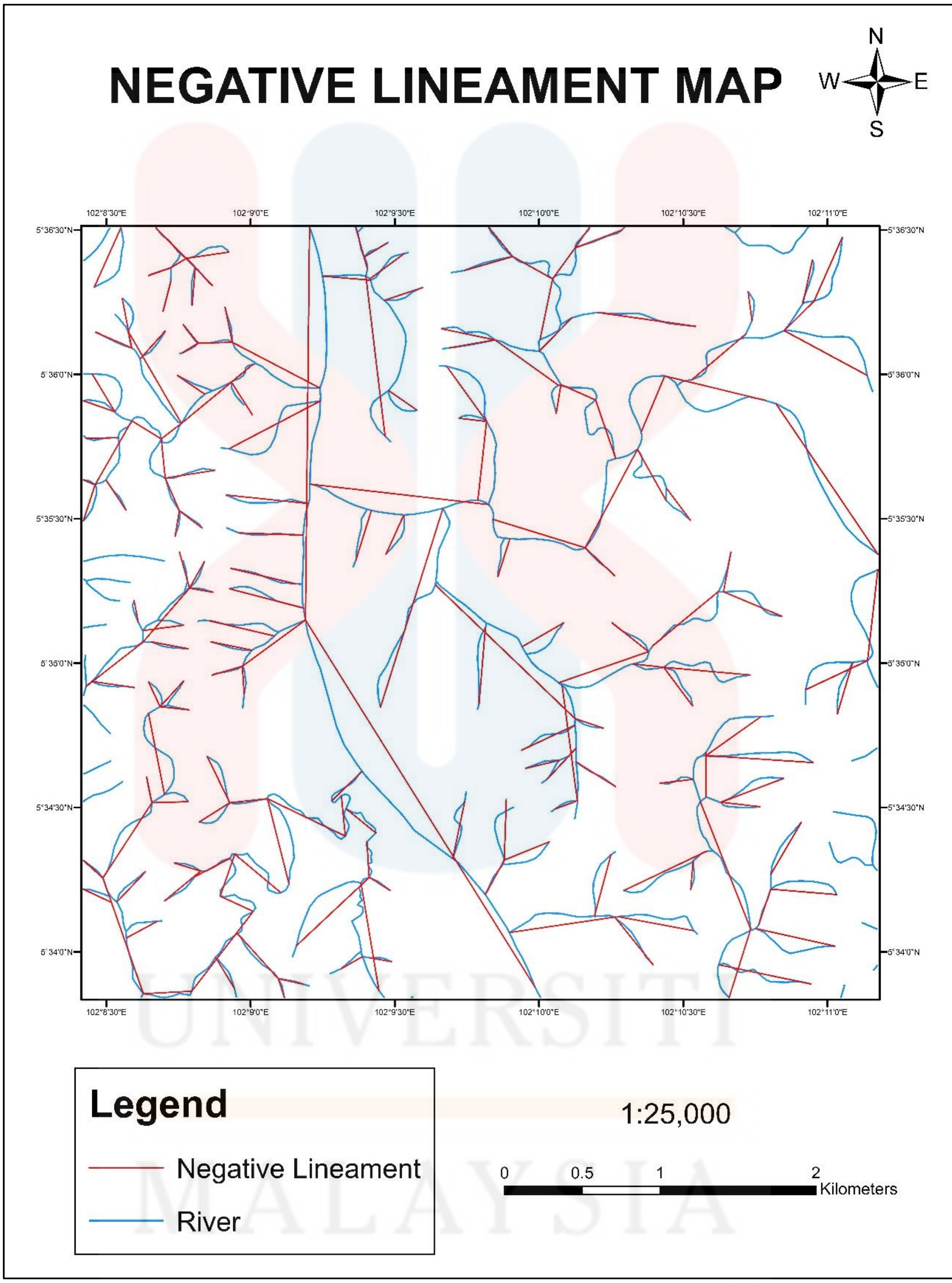

Figure 4.10: Negative lineament map of the study area

4.5 Historical Geology

Taku Schist is an extensive body of prominently from the type of pelitic schist of amphibolite facies, covering an area of more subdued topography than the Stong Complex, was the first to be recognised as a result of dynamothermal or regional metamorphism in Peninsular Malaysia. Another recognition is Taku Schist was the oldest basement rocks of the Peninsula, but it was opposed by other researcher that Taku Schist was occurred in Permo-Triassic age and may include in the part of strata in the age of Carboniferous. Therefore, the period of metamorphism was correlated to the Indosinian Orogeny triggered by the Sibumusu colliding with East Malaya (Hutchison, 2009).

Telong Formation was named after the Sungai Telong in which a part of tributary of Sungai Aring area, Kelantan. The Transect area was lacks palaeontological evidence to estimate the age. Thus, based on lithological correlation with related rock units from Gunung Rabung Formation and Semantan Formation, it was believed that the Telong Formation age ranged from Late Permian to Triassic (Peng et al., 2004; The Malaysian and Thai Working Groups, 2006).

Volcanic rocks in the Eastern Belt were more complex than in Western Belt. Temangan ignimbrite was occurred at the eastern margin of the Bentong-Raub Suture which was in the Middle to Upper Permian and Triassic. Andesitic and acidic volcanism occurred in the Late Permian, while acidic volcanism occurred in the Triassic (Ghani, 2009). As the texture of ignimbrite is a tuff flow, it is believed in the Triassic age.

Alluvium is the Quaternary deposit which occurred along the Sungai Kelantan and Sungai Nal. Raj, Tan, & Abdullah, (2009) mentioned that within the wide valley of Sungai Kelantan and its delta, the Simpang Formation was discovered.

CHAPTER 5

GROUNDWATER POTENTIAL ANALYSIS

5.1 Rainfall Map

Rainfall is the primary groundwater recharge source. It is regulated the volume of water that will be required for the groundwater system to percolate (Agarwal et al., 2013). Ladang Kuala Nal rainfall station is the only one that operated on the study area. A graph of annual rainfall of Ladang Kuala Nal rainfall station in Figure 5.1 was produced from 2015 to 2019. The graph shows the study area has a constant rainfall trend. This information has given a benefit where groundwater source in the study area had been constantly recharged during the rainfall event. The rainfall map in Figure 5.2 was grouped into three classes which are 1) <2250 mm, 2) 2250 mm - 2500 mm, and 3) 2500 mm - 2750 mm with the interval 250 mm that was introduced by Musa in 2000 (Manap et al., 2011). The measurement of annual rainfall data in the map was from 2019.

The scale values in the Table 5.1 for rainfall distribution are ranging from 4 to 8. The zone in the study area that received less than 2250 mm was given low scale which indicated as poor groundwater potential. The high scale was given to the zone that receive ranging from 2500 mm to 2750 mm. High rainfall is highly potential to have groundwater source. These scale values were referred based on Manap et al. in 2011.

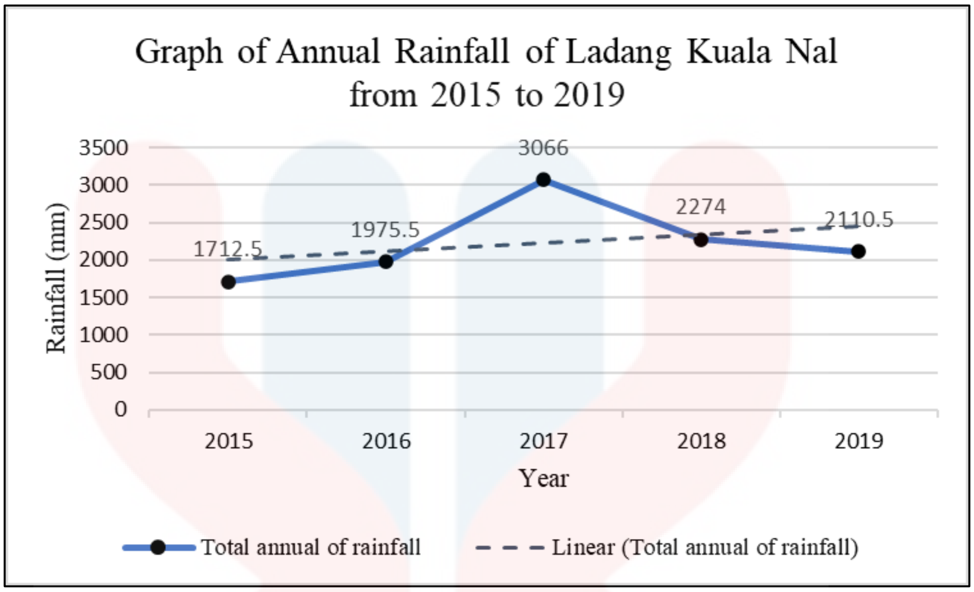

Figure 5.1: Graph of Annual Rainfall of the study area from 2015 to 2019

Table 5.1: Score for rainfall

Rainfall (mm)	Scale Value
< 2250	4
2250 - 2500	6
2500 - 2750	8

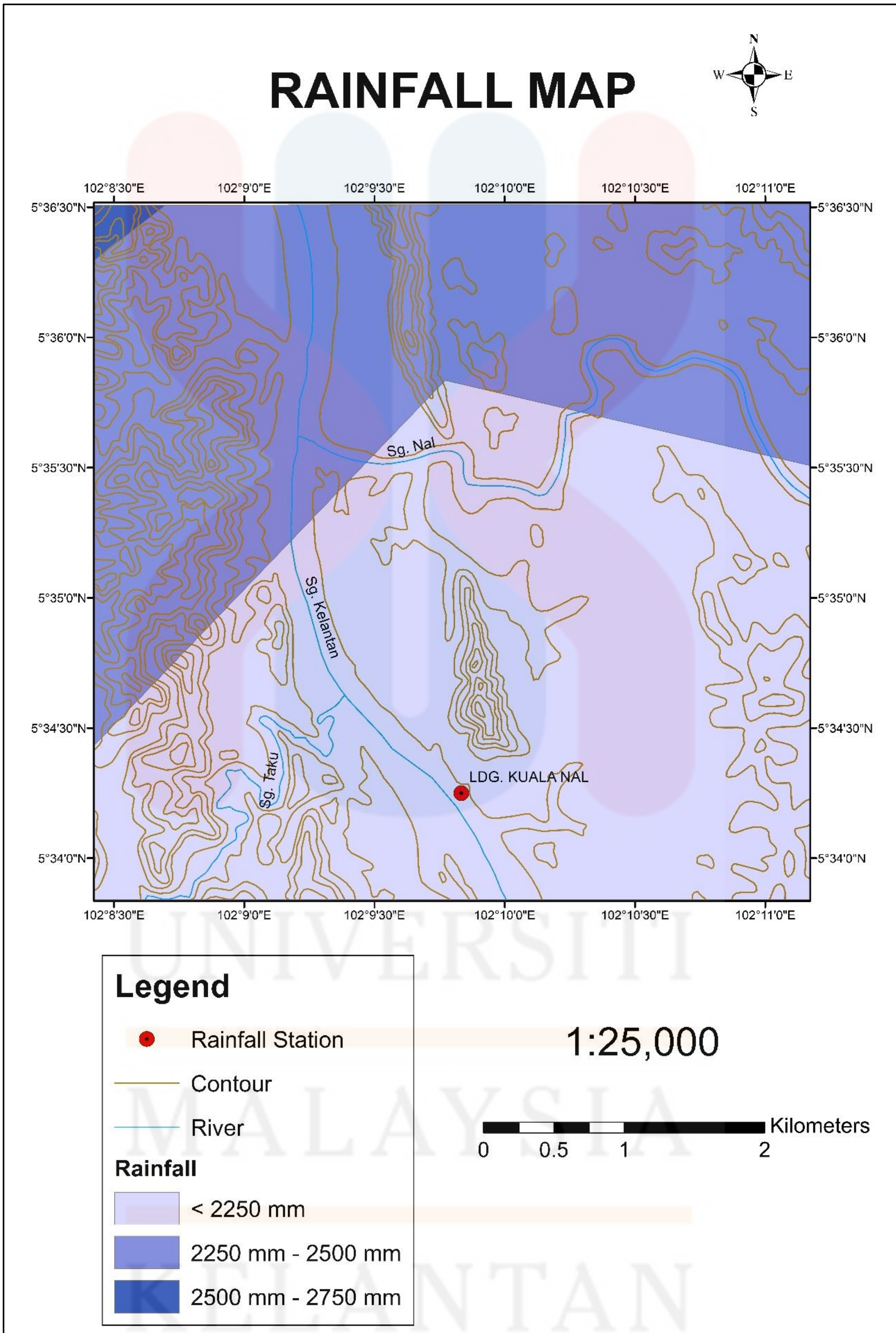

Figure 5.2: Rainfall map of the study area

5.2 Lithology Map

The study area was covered by four types of rocks which are schist, ignimbrite, interbedded sandstone, siltstone and shale, and alluvium. The given scale values for each rock was based on (Manap et al., 2011). Table 5.2 shows schist and ignimbrite were given low scale values because their grain sizes have low porosity and permeability. These types of rock made the groundwater difficult to move and therefore they assumed to have poor groundwater potential. Also, they were located at steep sloping which water cannot be fully trapped in. Alluvium has the highest scale value because it underlain by unconsolidated river-borne sediments. Alluvium consists of sand, silt and sand may easily made the groundwater to move. Furthermore, it was characterized as a gentle sloping where water can be tapped through shallow depth. Thus, this rock has a high potential of groundwater. In the Figure 5.3, schist mostly covered at west of the study area scattered around the low hills while alluvium located near to the water body source.

Table 5.2: Score for lithology

Lithology	Scale Value
Schist	5
Ignimbrite	6
Interbedded sandstone, siltstone, and shale	8
Alluvium	9

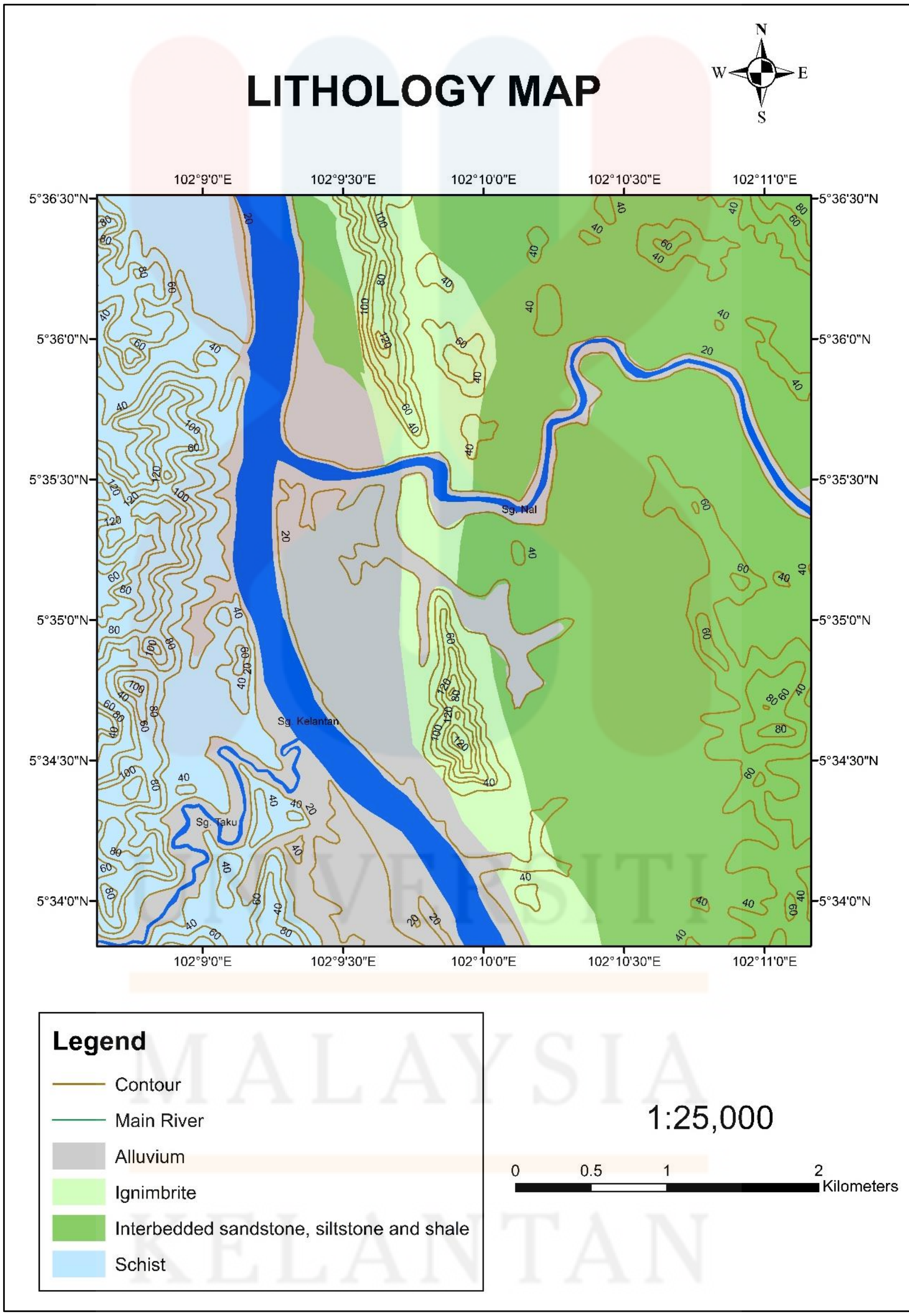

Figure 5.3: Lithology map of the study area

5.3 Geomorphology Map

The topography is an important predictor of groundwater in crystalline rock terrain. Geomorphic imprints can be viewed as a surface markers for sub-surface water conditions (Preeja et al., 2011). In the study area, it had been assorted into three classes which are lowlands, lowlands inland, and low hills. Lowlands were given the highest scale values because they have a low elevation. The lower elevation is characterized as a low slope where it can trap more water than higher elevation. Since this landform has a high-water level surface making it the best landform for high groundwater potential. Low hills were ranked low because they have a high elevation and steep slope which can increase the rate of rainfall runoff and decrease infiltration. Thus, it is possible that this landform is poor groundwater potential.

Table 5.3: Score for geomorphology

Elevation (m)	Geomorphology	Scale Value
<50	Lowlands	9
50 - 100	Lowlands Inland	7
100 - 200	Low Hills	5

5.4 Landuse Map

A multiple type of landuse pattern were identified in the study area namely urban residential, abandoned area, lowland forest, traditional mixed horticulture, rubber, oil palm, and water resource. In the Table 5.4, each of the landuse category was scaled based on the humidity rate. The dry zone had scaled low while aqueous zone scaled high. Water resource has the highest scale values which reveal the very good potential of groundwater. It is followed by vegetation such as traditional mixed horticulture, rubber, and oil palm. Urban and residential, and abandoned had scaled low values, hence it has poor groundwater potential. These given scale values are based on (Manap et al., 2011; Preeja et al., 2011).

Table 5.4: Score for landuse

Landuse	Scale Value
Urban and Residential	1
Abandoned Area	3
Lowland Forest	6
Traditional Mixed Horticulture	8
Rubber	8
Oil palm	8
Water Resource	9

5.5 Slope Map

Slope is a major influencer when controlling the infiltration of groundwater into subsurface. The study area had classified into five classes of slope: a) 0˚ - 3˚, b) 3˚ - 8˚, c) 8˚ - 14˚, d) 14˚ - 21˚, and e) 21˚ - 36˚. In the Table 5.5, the slope area that had classified as very gentle and gentle were ranked higher than the area in the steep slope. This is because lower slope caused slow surface runoff which allowing rainwater to percolate longer. While the higher slope area caused rapid surface runoff which taking less time for percolation of rainwater. Thus, it can be assumed that lower slope has a high groundwater potential. Having a slope more than 21˚ are considered as low groundwater potential. The scale values were referred to the (Preeja et al., 2011).

Table 5.5: Score for slope

Slope (˚)	**Class**	**Scale Value**
0 - 3	Very gentle	9
3 - 8	Gentle	8
8 - 14	Moderate	4
14 - 21	Moderately steep	2
21 - 36	Steep	1

5.6 Drainage Density Map

Drainage density can be described as the closeness of stream channel spacing. It is a measure of all orders per unit area of the total length of the stream segment. Density of drainage is the inverse permeability function. If the rock is low in permeability then the rainfall infiltration will be low which appears accumulated in surface runoff (Magesh, Chandrasekar, & Soundranayagam, 2012). The study area had been grouped into four classes and assigned to 'dry end' (0 - 2 km/km^2), 'low dense' (2 - 4 km/km^2), 'moderately dense' (4 - 6 km/km^2), and 'highly dense' (>8 km/km^2). In the Table 5.6, the high scale value was given to the area with a low drainage density because it has more infiltration and slow surface runoff than high drainage density. This indicates that area has very good potential of groundwater. Area with highly dense was given low scale values due to the greater surface runoff and lower infiltration. Each of these scale values were based on (Preeja et al., 2011). Manap et al., (2011) described that if the drainage density is high, it means that springs are situated near the main stream which allows to the high discharge quantity. The amount and type of precipitation, the intensity and type of vegetation and the ability of soils to absorb rainfall can alter the rate and amount of surface runoff and affect the texture of the drainage in that area.

Table 5.6: Score for drainage density

Drainage Density (km/km^2)	Scale Value
0 - 2	9
2 - 4	8
4 - 6	5
>8	2

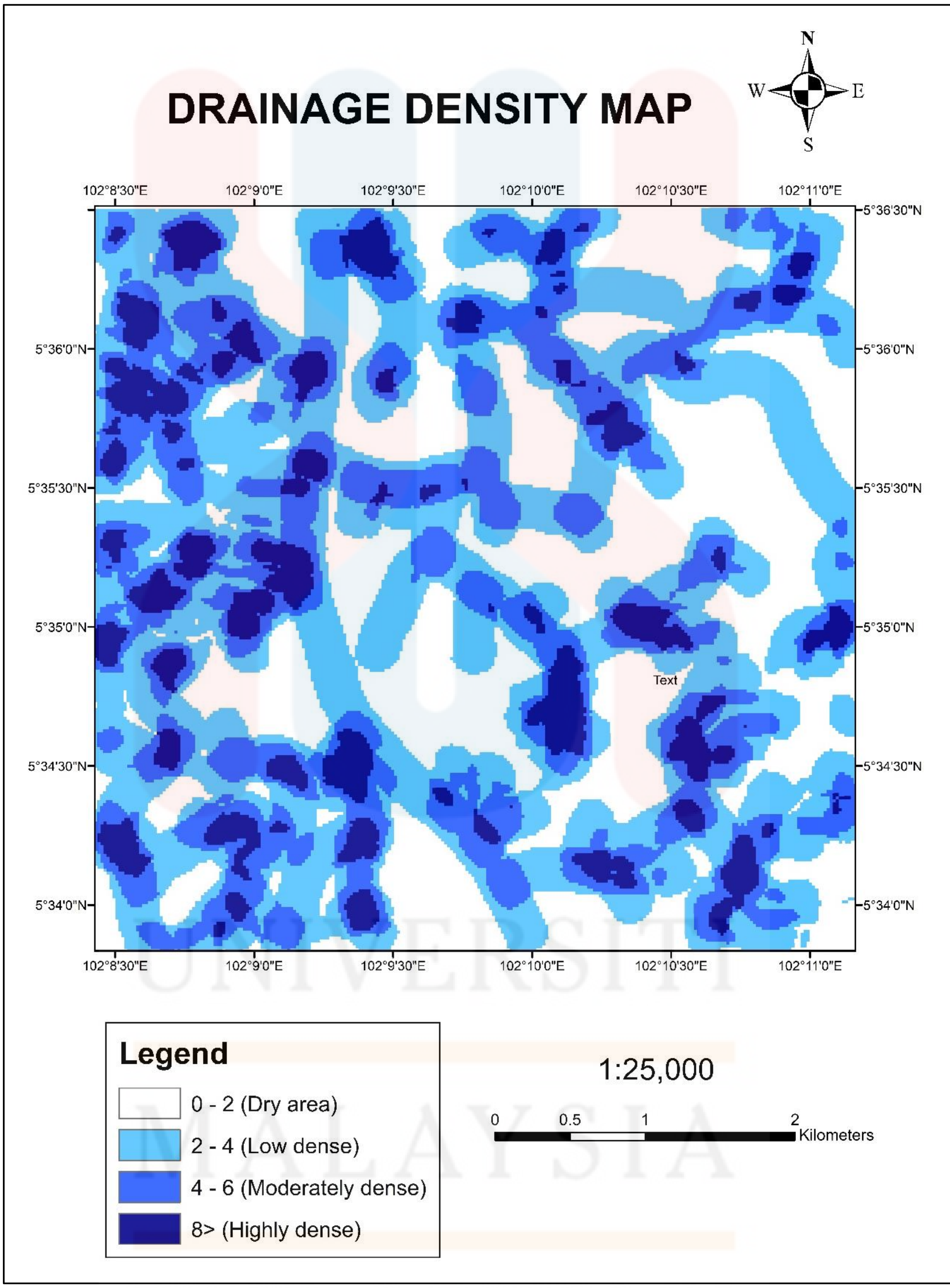

Figure 5.4: Drainage density map of the study area

5.7 Soil Type Map

The data of soil type was extracted from the DOA. The area was covered by three different soil series which are Batang Merbau-Muncung, Durian-Muncung-Bungor, and Segamat-Katung. The soil type for each soil series are described in the Table 5.7. The analysis of the soil type had been revealed that the study area is predominantly covered by loamy, silt loam (Muncung and Durian series), and fine loamy siliceous (Batang Merbau-Muncung series). Durian-Muncung-Bungor series was given the highest score because of their parent rock are from the sedimentary rock. Sedimentary rock has a good porosity and permeability compared to igneous and metamorphic rock. Other than that, loamy soil has moderately low runoff potential.

Table 5.7: The characteristic of soil series

Parent Rock	Soil Series	Soil Type	Permeability	Internal Drainage
Schist and quartzite	Batang Merbau	Fine loamy siliceous	Moderate	Moderately well drained
Argillaceous shale	Muncung	Loamy, silt loam	Good	Well drained
Argillaceous shale	Durian	Loamy, silt loam	Moderate	Moderately well drained
Quartzite and shale	Bungor	Fine sandy clay	Moderate	Well drained
Andesite	Segamat	Clayey	Moderately rapid	Well drained
Diorite and Andesite	Katung	Sandy clay loam	Moderate	Well drained

(Source: Paramananthan, 2000 & Pushparajah & Amin, 1977)

The lower score was given to Batang Merbau-Muncung series because Batang Merbau are from the parent rock of schist. Schist has a poor permeability and porosity due to the interlocking crystals. Thus, it means that it is not suitable for groundwater potential.

Table 5.8: Score for soil series

Soil Series	Scale Value
Batang Merbau-Muncung	1
Durian-Muncung-Bungor	7
Segamat-Katung	5

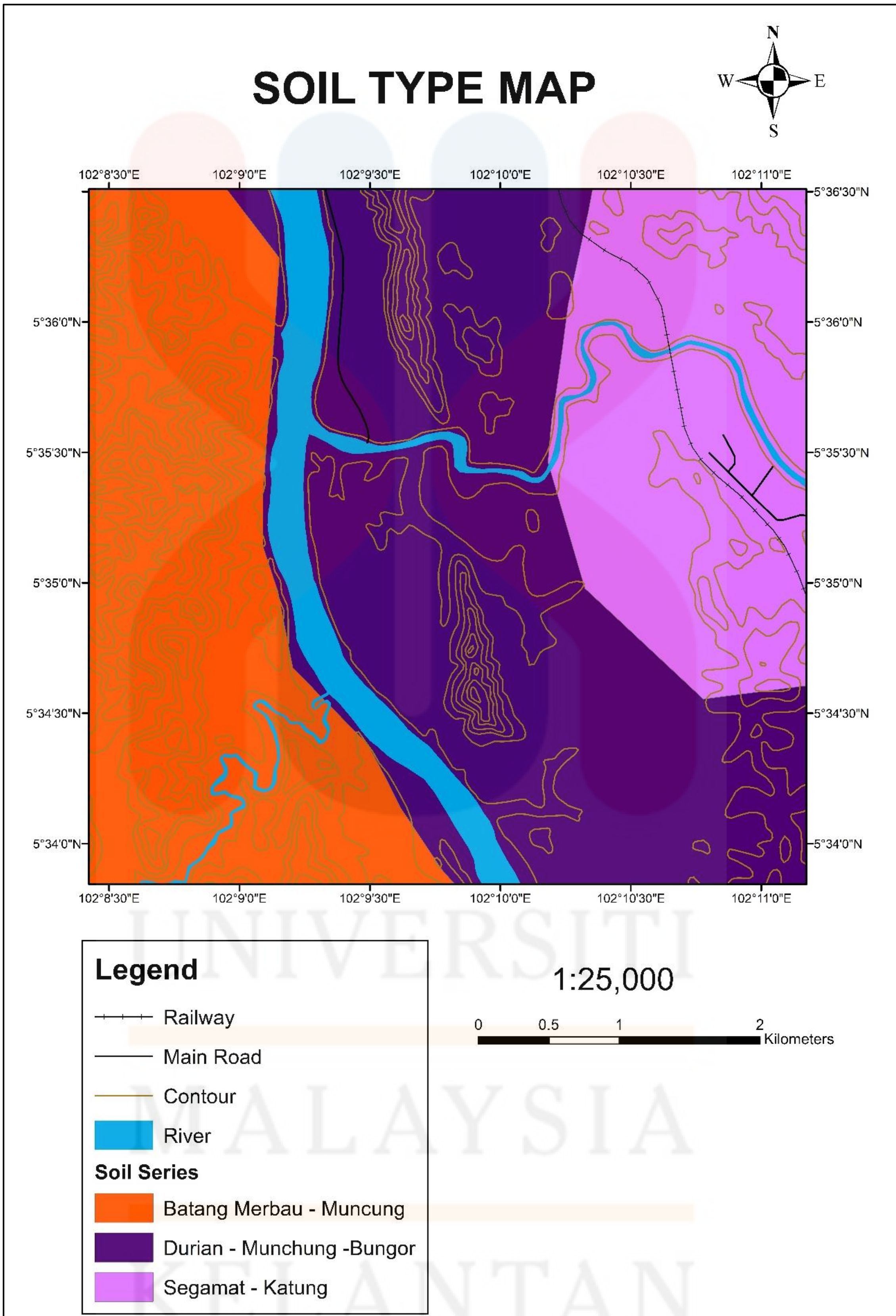

Figure 5.5: Soil map of the study area

5.8 Groundwater Potential Map

In this research study, the groundwater potential map was generated using the GIS software based on AHP technique to support the relative importance of various thematic layers which affecting the groundwater. All thematic maps such as lithology, geomorphology, land use, slope, drainage density, rainfall density and soil type had been reclassified and overlaid using weighted overlay method in the spatial analyst tool. From the analysis, the groundwater potential zones can be divided into three grades which are poor, moderate, and good. Based on the Table 5.9, land use factor was given low score which means it has low importance to groundwater potential. It was followed by other three factors which are drainage density, soil type and slope. Rainfall factor was considered as moderate importance to groundwater potential. Lithology and geomorphology have the most important factor to groundwater potential that help the infiltration ability of the groundwater system. These weightage score are referred to (Agarwal et al., 2013; Manap et al., 2011).

The good groundwater potential in the Figure 5.6 is covered mostly in the eastern of the study area due to the covering major by alluvial plains, low drainage density, low elevation and has slope ranging from 0˚ to 8˚. The western part of the study area is covered by poor groundwater potential because of high elevation, high drainage density, has slope ranging from 14˚ to 36˚ and lithology with low permeability. Nadun et al., (2010) mentioned alluvial plains have a high potential for the existence of groundwater while steeply mountainous are considered as low potential of groundwater.

Table 5.9: Score for thematic maps

Criteria	Weights (%)
Lithology	33
Geomorphology	31
Land use	3
Slope	9
Drainage density	5
Soil type	6
Rainfall	13

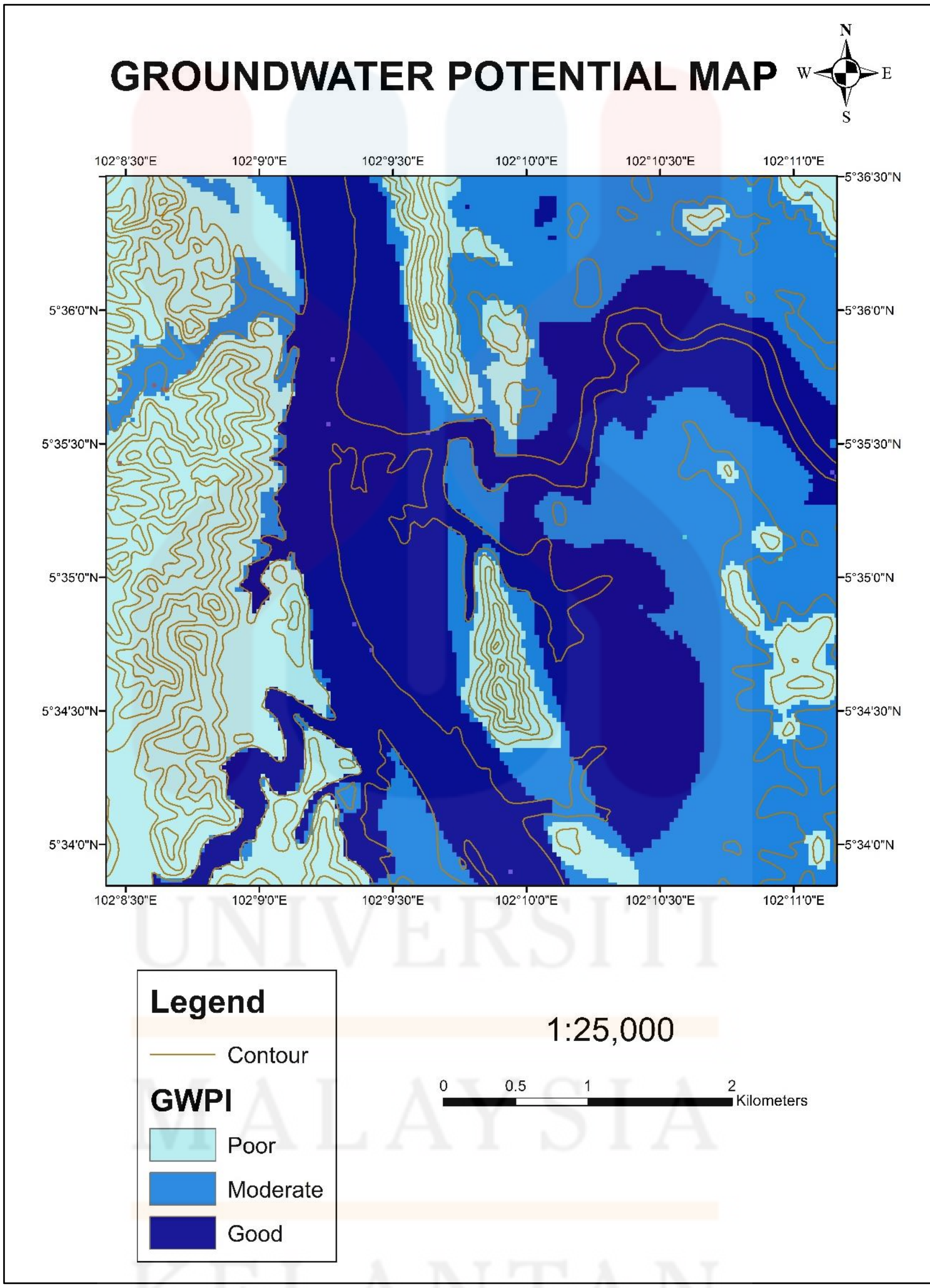

Figure 5.6: Groundwater potential zone of the study area

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

As a conclusion, the objective of this research has been successfully achieved. The geological map with the scale of 1:25000 was generated where four types of rock were identified in the study area. The identified rocks were, schist, ignimbrite, interbedded sandstone, siltstone and shale, and alluvium. This geological map was digitized by using GIS method. The distribution of rocks and new geology structure were updated based on the interpretation and secondary data. Secondary data such as DEM data, topographic maps and conventional data were used to produce seven thematic layers which included lithology, geomorphology, land use, slope, drainage density, rainfall density, and soil type. All the thematic layers were given weightage using AHP technique making it easier to integrate in the ArcGIS software. The groundwater potential zone map of the study area was generated by using weightage overlay method under spatial analyst tools. The result had divided groundwater potential map into three zones that include, poor, moderate, and good. Low elevation, gentle slope, alluvial plains, and vegetation area have high potential of groundwater. The study area is dominant with moderate to good groundwater potential.

6.2 Suggestion

This research study needs to do a further research since it is only based on secondary data. It may not be detailed in rock description and structural geology to support the output data, but the result obtained can be useful for the next research study in evaluation of groundwater exploration. With the updated geological and groundwater potential map, a fieldwork should be done to validate the data. The method used in this research study are generic in nature. Thus, it could be suitably modified or use other method like Electrical Resistivity Imaging (ERI) for the next exploration.

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