GEOLOGY AND EXPLORATION OF GROUNDWATER POTENTIAL IN HARD ROCK USING RESISTIVITY METHOD (ERI) AT UMK, JELI, KELANTAN.

by,

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

FACULTY OF EARTH SCIENCE

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2021

DECLARATION

I declare that this thesis "Geology and Exploration of Groundwater Potential in Hard Rock using Resistivity Method (ERI) at UMK, Jeli, Kelantan", is the result of own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date: ____

APPROVAL

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

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GEOLOGY AND EXPLORATION OF GROUNDWATER POTENTIAL IN HARD ROCK USING RESISTIVITY METHOD (ERI) AT UNIVERSITI MALAYSIA KELANTAN, JELI.

ABSTRACT

The location of study area is at Universiti Malaysia Kelantan (UMK), Jeli. There are two main objectives of this research, to produce an updated geological map of study area with the scale of 1:25 000. Next, to identify the potential of groundwater in hard rock using resistivity method (ERI) in order to fulfill the demands of water supply for the use in future. For geological mapping, the geomorphology, lithology and geological structure were identified. There are two major lithologic unit that can be identified in the study area. It is composed of meta-sedimentary rock which consist of phyllite from the Telong Formation and granite intrusion from Triassic Period. Mostly the study area is dominated by weathered granitic rock. A Schlumberger configuration arrays were used with 41 electrodes and 200 meters spread length through four survey lines in the study area. The data was recorded using ABEM Terrameter LS. A two-dimensional (2D) resistivity data pseudo section is produced with clear resistivity image which indicate the groundwater potential at certain depth in fractured zone of granitic bedrock.

Keywords: UMK Jeli Campus, geology, groundwater potential, Electrical resistivity, survey

GEOLOGI DAN EKSPLORASI POTENSI AIR GROUND DI HARD ROCK MENGGUNAKAN KAEDAH RESISTIVITI (ERI) DI UNIVERSITI MALAYSIA KELANTAN, JELI.

ABSTRAK

Lokasi kawasan kajian adalah di Universiti Malaysia Kelantan (UMK), Jeli. Terdapat dua objektif utama penyelidikan ini, untuk menghasilkan peta geologi kawasan kajian yang dikemas kini dengan skala 1:25 000. Seterusnya, untuk mengenal pasti potensi air tanah dalam batuan keras menggunakan kaedah resistiviti (ERI) untuk memenuhi permintaan bekalan air untuk penggunaannya di masa depan. Untuk pemetaan geologi, geomorfologi, litologi dan struktur geologi dikenal pasti. Terdapat dua unit litologi utama yang dapat dikenal pasti di kawasan kajian. Batu ini terdiri dari batuan meta-sedimen yang terdiri dari filit dari Formasi Telong dan pencerobohan granit dari Zaman Trias. Sebahagian besar kawasan kajian dikuasai oleh batu granit yang sudah lapuk. Susunan konfigurasi Schlumberger digunakan dengan 41 elektrod dan panjang penyebaran 200-meter melalui empat garis tinjauan di kawasan kajian. Data direkodkan menggunakan ABEM Terrameter LS. Bahagian pseudo data resistiviti dua dimensi (2D) dihasilkan dengan gambar resistiviti yang jelas yang menunjukkan potensi air bawah tanah pada kedalaman tertentu di zon retak batuan dasar granit.
Kata kunci: Kampus UMK Jeli, geologi, potensi air bawah tanah, Ketahanan elektrik, tinjauan

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LIST OF ABBREVIATIONS

GIS	Geographic Information System
GPS	Global Positioning System
Km	Kilometer
Km^2	Kilometer per square
msec	Milisecond
N	North
S	South
W	West
E	East

CHAPTER 1

INTRODUCTION

1.1 General Background

According to (Muhammad Izzudin Syakir et al, 2020) , about 1.5 billion more than around the world depend on the groundwater for the usage of agriculture and consumption industrialization. Groundwater are deposited through the pore spaces, cracks, joints and fractures on a rock body. The movement of soil and groundwater in rocks depends on the shape and size of the hydraulic characteristics. In general, groundwater supplies are determined by three distinct types which are aquiclude, aquifers and aquitard. Groundwater can be found in any rock types such as igneous, sedimentary or metamorphic rock. For sedimentary rocks, groundwater is deposited in the pore areas between the grain with high porosity and high permeability. On the other hand, for igneous and metamorphic rocks, groundwater is found in fracture zone. The fracture would open up a gap that allows groundwater to pass in and settle along the fracture of the rocks in space (Nur Syazana binti Md Saliman, 2020).

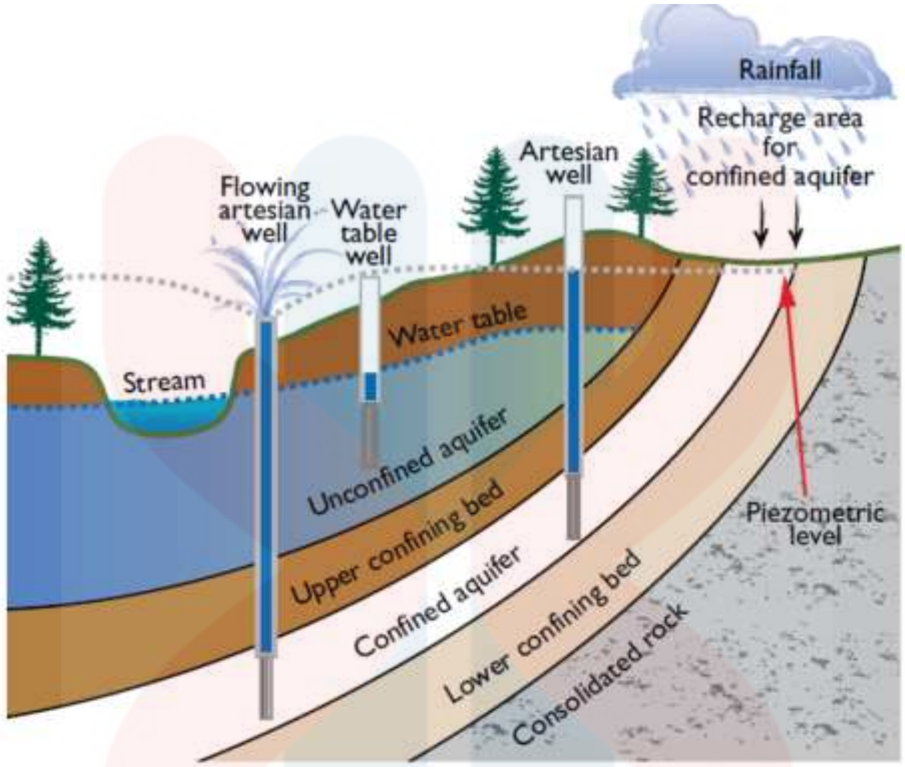

Figure 1.1: Types of aquifers.

(Source: National Groundwater Association)

An aquifer can be defined as the highly permeable or a porous saturated formation. It not only stores water, but also provides ample water and recognizes it groundwater resources. There are few examples including sandstone, conglomerate, unconsolidated sand, gravel, limestone fractures and basalt fractures. Aquitard, like shale and clay, is a partially saturated formation that allows water to move through it but does not have ample water relative to aquifers.

Groundwater can be defined as water that exist in soil beneath the earth surface in the zone of saturation. Meanwhile, the water table is called the upper surface of the saturated region. The water table typically divides the region of groundwater underneath the surface from the capillary fringe or aeration zone. It flows and fills the pores and fractures in underground elements such as gravel, sand, mud or other rocks.

Generally, groundwater passing from recharge zones to discharge zones with varying lengths of flow can enter surface water (SW). The surface water resources are usually depending on the regional precipitation or rainfall which may lead to lost by layer of soils or fractures that interact with groundwater system. There can be several ways of contact between groundwater and surface water. If the surface water flows to the groundwater system, it is called a losing stream, while it is called a winning stream if the surface water moves away from the groundwater system.

Groundwater flowing through the fractures in hard rocks is suitable for electromagnetic surveys defined as very low frequency (VLF). Commonly, in the northern portion of Peninsular Malaysia, because of the small magnitude of VLF anomalies and the shallow structure interpreted from the resistivity results, the fracture areas are shallow (S.P. Sharma and V.C. Baranwal, 2005).

Geophysical method such as electrical resistivity survey has been widely used in groundwater research due to the strong association between electrical characteristics, geology and the fluid content. It is widely used depends on its physical criteria for example the permeability, porosity, transmissivity, specific yield, hydraulic conductivity and specific storage.

Electrical Resistivity Imaging (ERI) or Electrical Resistivity Tomography (ERT) is commonly used to locate the presence of groundwater discovery, sinkholes detection, bedrock depth and thickness determination, mapping faults, and line analysis and landfill lateral extent. The system of electrical resistivity assists in the calculation of apparent soil and rock resistivity. Due to its versatility at various depths for different purposes, it is commonly used. The consistency of analysis of data is rapid.

Electrical resistivity imaging (ERI) was also used to obtain the conditions of the field. The findings indicate a variance and phenomenon that can be associated with various types of rocks, based on the previous analysis at Banding Island. According to (Giao et al., 2003), an initiative by geophysicists and geotechnical engineers shows that soil research is advanced. The ERI approach involves either two or three dimensions of a large area on the ground surface.

According to (S.P. Sharma and V.C. Baranwal, 2005) groundwater can be located in the cracks or the fractures embedded in the rock body in hard rock areas. The amount of groundwater is depending on fractures and their connectivity with each other. By using sounding from Schlumberger, a variation of depth by resistivity can be determine. In addition, due to its resistivity, the VLF system produces a greater depth of penetration in the hard rock regions. The VLF data also can perform a sounding resistivity, assess the required of strike direction. Therefore, a combination of VLF soundings and Dc resistivity has a potential to success (Alvin K. Benson, Kelly L. Payne, 1997).

1.2 Study Area

Kelantan is situated at north-eastern part of Peninsular Malaysia with approximately area of 15, 022 km. Basically, Kelantan is grouped into ten district which are Kota Bharu, Machang, Tanah Merah, Tumpat, Pasir Mas, Jeli, Pasir Puteh, Bachok, Gua Musang, Kuala Krai. Kota Bharu is the capital city of Kelantan. Among the ten districts, one district has been chosen as study area which is Jeli. Jeli is situated in the western region of Kelantan. It is similar to Malaysia's Kelantan-Perak State border and the international border between Malaysia and Thailand (Dony Adriansyah Nazaruddin et al., 2015). Even though the research area is situated in a rural area however, there are development nowadays that rapidly progress and under new constructions in order to fulfill needs of people in that area.

Universiti Malaysia Kelantan (UMK) is chosen as the study area of this final year project (FYP). It is including in a part of Jeli district. The study area is located between altitude of N 05° 42' 28.00’’ to N 05° 45' 30.00" and latitude of E 101° 50' 30.00" to E 101° 53' 30.00" as shown as in Figure 1.2 above. The study area covered approximately about 25 km^2 which is included several institutions such as University Malaysia Kelantan (Jeli), Sekolah Kebangsaan Gemang and Politeknik Jeli. There are also several villages in the research area such as Kampung Gemang Lama, Kampung Lakota, Kampung Bukit Susun, Kampung Chelagi, and Kampung Gemang Lama. Jeli is bounded by few districts including the state of Perak in the west, Thailand in the north, Tanah Merah in the north-east, and Kuala Krai in the south-east. There are also many unpaved roads that connected the villagers to the plantation area since the study area is situated in a rural setting.

To add, geomorphology of the study area is composed of hilly area and forest. The main activities in this area is agriculture. People in the Jeli district mainly work as rubber tappers and rubber tree plantations that belong to local people. Jeli district also can be accessed via East-West Highway which is 70km from the capital city of Kota Bharu.

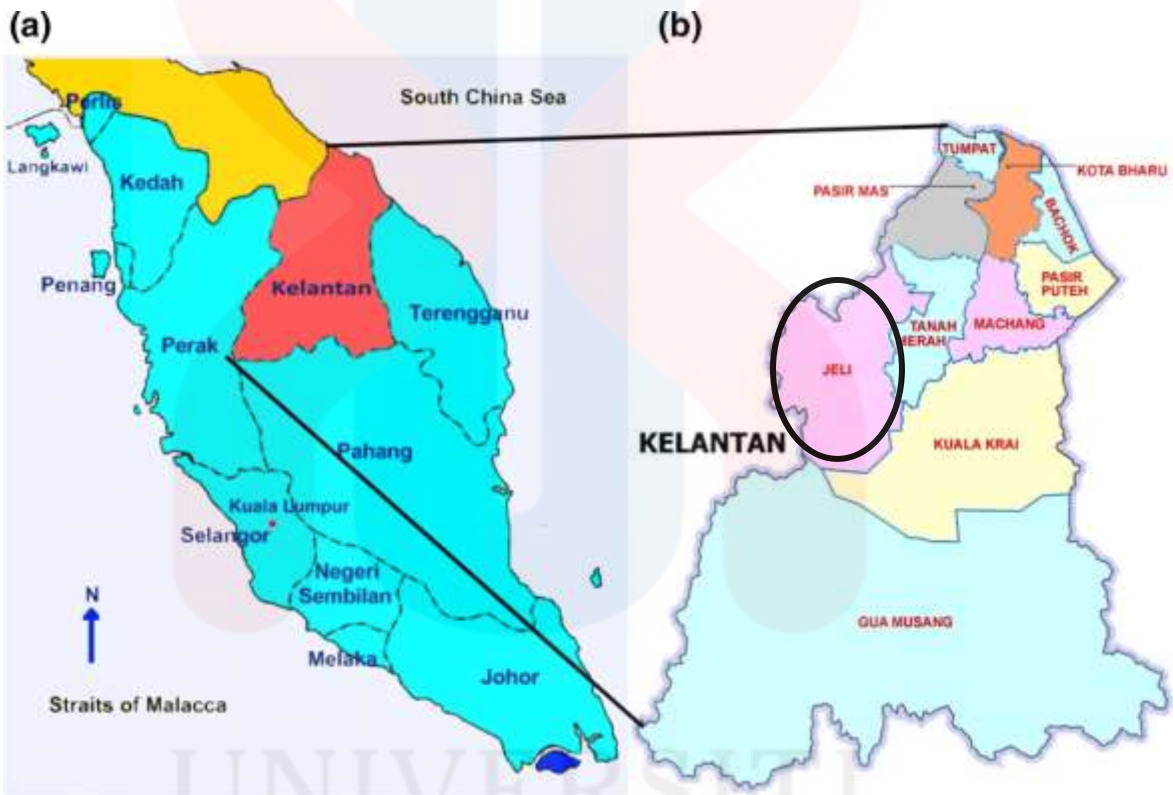

Figure 1.2: Map of Kelantan and map of study area.

(Source: Mohd Rohaizat Abdul Wahab, 2020)

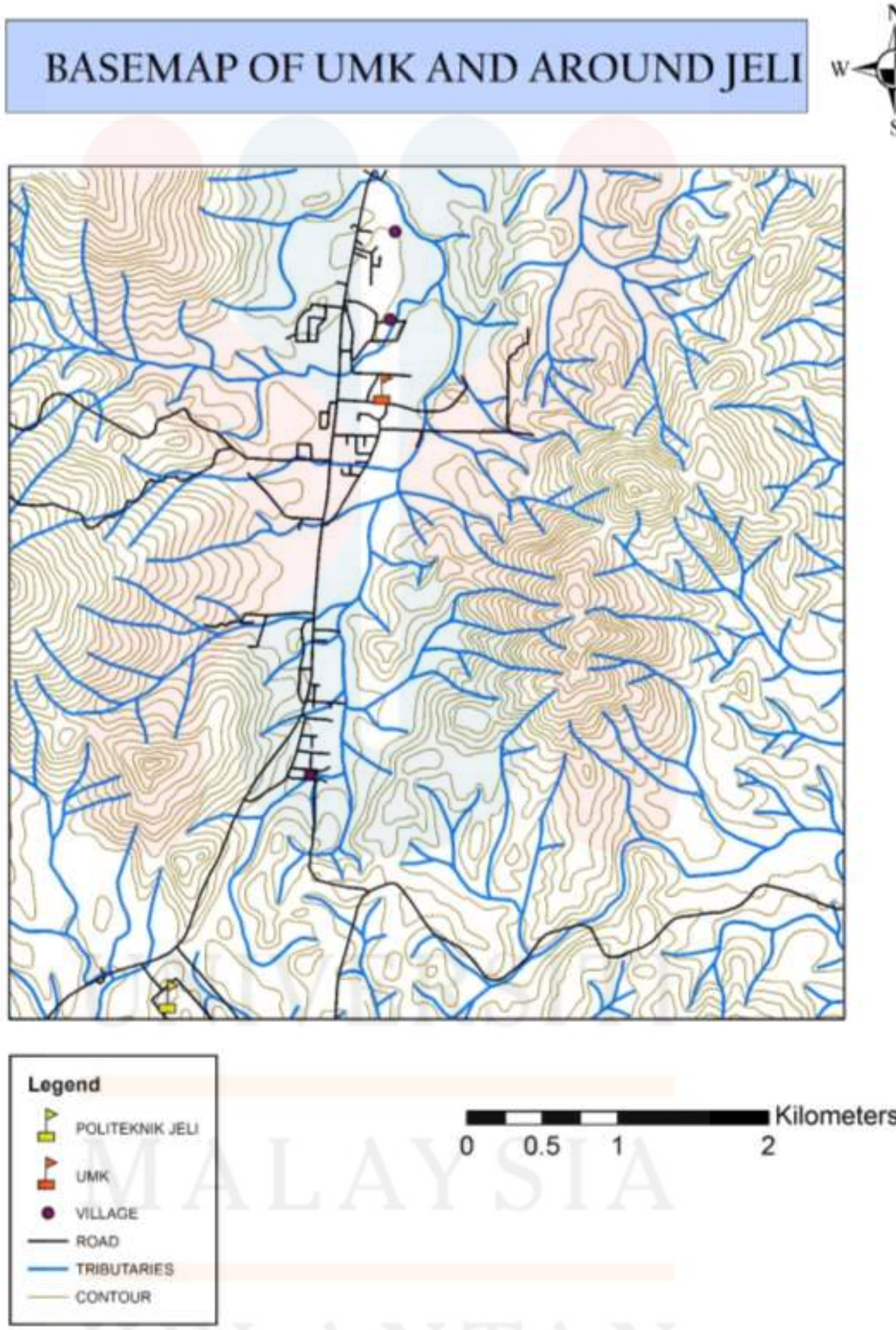

Figure 1.3: Base map of study area.

1.2.1 Location

Generally, there are many rock resources in Kelantan such as granite, limestone and minor argillite. However, in Jeli district limestone is not well distributed due to the occurrences is mainly distributed in southern area of Kelantan which is Gua Musang area. Besides that, at the eastern and western part of Jeli, there are common with granitic rock unit. The total of study area is approximately 25km^2 or 5 x 5 km with several village and housing.

Table 1.1: Coordinate of study area at UMK, Jeli, Kelantan

Point	Coordinate
A	N 05° 42' 28.00" E 101° 50' 30.00"
B	N 05° 42' 28.00" E 101° 53' 30.00"
C	N 05° 45' 30.00" E 101° 53' 30.00"
D	N 05° 45' 30.00" E 101° 50' 30.00"

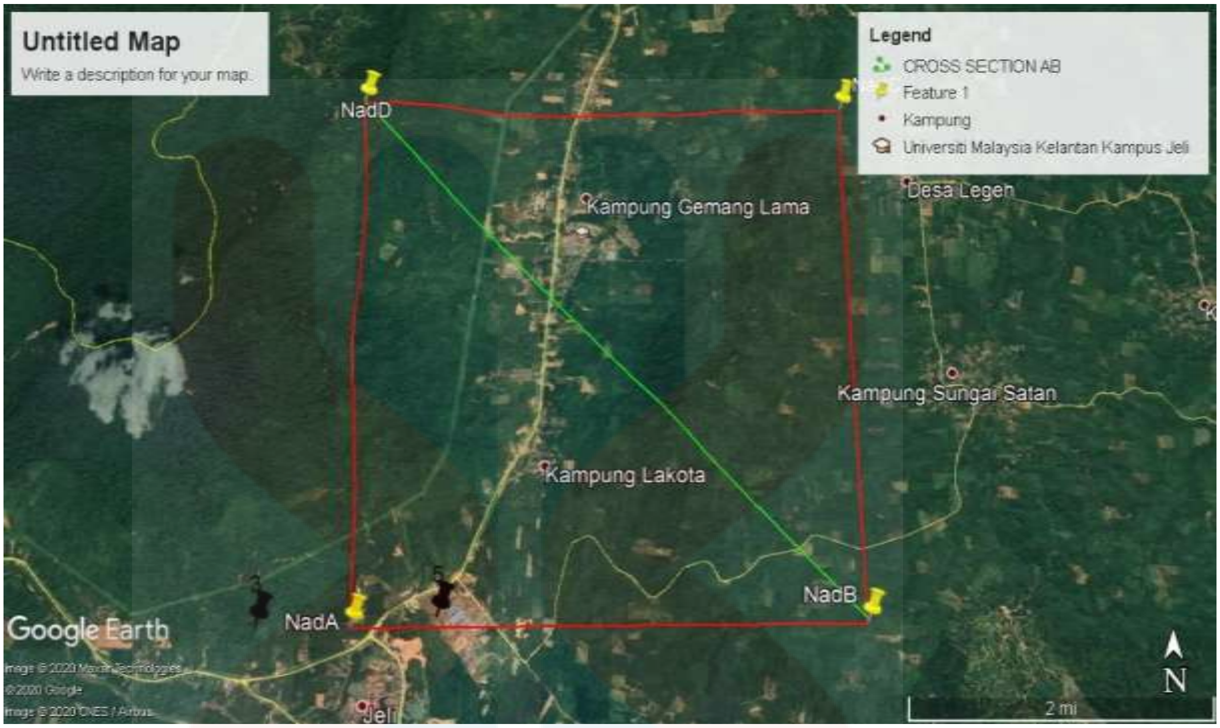

Figure 1.4: Map of study area.

(Source: Google Earth Pro, 2020)

1.2.2 Road Connection/ Accessibility

District of Jeli is located in an area near the highway that can be accessed through the East-West Highway. There are many accessibilities to Jeli which mainly by highway that connecting Jeli district with Gerik, Perak, and all the way west to Kedah or Penang, east to Tanah Merah, and on to Pasir Puteh. The highway is also recognized as East-West Highway. It can be accessed by many forms of mode transportation, including the public transport as the area is situated near the city and it is also consisting of many educational areas such as Politeknik Jeli and Sekolah Kebangsaan Jeli.

Even so, Jeli district is an urban area that consisting of rubber tree plantation and farming area. The unpaved road is linked between the plantation area and villagers and can only be accessed through Hilux or motorcycles which are the location is well distributed in the town of Jeli.

1.2.3 Demography

In 'Population Distribution and Basic Demographic Characteristics 2010', Department of Statistics Malaysia, it can be stated that the population in Jeli district is increasing from 36,512 in 2000 to 40,637 in 2010 as shown in Table 1.2. The increasing is may be due to rapid development in the district that may also bring some mitigation to the population district. In addition, figures 4 show an illustration of pie chart in Jeli district by ethnics in 2010. The highest percentage of ethnics is dominated by Malay with 99.50% followed by Chinese 0.20%, Indian 0.10% and lastly other ethnics 0.09%.

Table 1.2: Population in Kelantan by district.

Name	**Population (Cencus 2010)**	**Population (Cencus 2000)**
Bachok	133, 152	111, 040
Gua Musang	90, 057	76, 655
Jeli	40,637	36,512
Kota Bharu	491,237	406,662
Kuala Krai	109,461	93,550
Machang	93,087	79,032
Pasir Mas	189,292	165,126
Pasir Puteh	117,383	106,138
Tanah Merah	121,319	103,487
Tumpat	153,976	134,812
Total	28, 334, 135	23, 274, 690

(Source: Department of Statistics Malaysia, 2011)

1.2.4 Land Use

Table 1.3 below illustrates the percentage of land use in the state of Kelantan in 2018 with the total hectare is 1,143,197.321. The highest percentage of land use distribution is in the forest area with 63.8% of the percentage, followed by agriculture with 28% and water body is 1.8% from the total percentage. The least percentage of land use in Kelantan state is for beach with 0.03% followed by mixed development with 0.05% of the total percentage.

Table 1.3: Percentage of land use in Kelantan state in 2018

No.	Land Use	Area (hec)	Percentage (%)
1.	Water body	27, 175.516	1.776
2.	Forest	976, 482.969	63.821
3.	Industry	1,359.269	0.089
4.	Infrastructure & Utilities	1, 203.411	0.079
5.	Institutions & Facilities	7, 118.731	0.465
6.	Commercial	1, 195.487	0.078
7.	Beach	458.618	0.030
8.	Mixed Development	828.890	0.054
9.	Transportation	13, 778.723	0.901
10.	Agriculture	428, 427.436	28.001
11.	Housing	41,181.383	2.692
12.	Empty land	29,261.986	1.913
13.	Open Space & Recreation	1,553.792	0.102

(Source: Jabatan Perangkaan Malaysia, 2010)

1.2.5 Social Economic

The most area in Jeli district is covered by rubber tree plantation and followed by forest and agriculture area. To add, the most of residents in Jeli district work as a farmer, rubber tappers and manufactures for some farm production. The rubber tree plantation is usually belonging to the local people. In UMK itself, these agriculture activities had greater influence on the socio-economic and caused the rapid development in the district for the past decade. There are also many rapid developments in housing area construction progress in order to fulfill the society demand in Jeli district area.

Figure 1.5: (A) Rubber tree plantation. (B) Agriculture in Agropark UMK.

(Source: Nur Fatin Idayu bt Ismail, 2019)

1.3 Problem Statement

Jeli is the developing district of Kelantan, which, due to rapid growth of its population that result in increasing of building planning in the area. A perfect preparation is important in order to prevent any catastrophe in the development process. The most important thing is the source of water which it is a needed in our daily life. In addition, groundwater not only important for human needs, but it also for agriculture used such as farming and cultivation process.

This indicates that the need for clean water resources is very important right in the Jeli region, where growth is increasing rapidly from time to time. This shows that the increasing population in an area gives huge impact on its groundwater supply too. Besides that, this analysis also aims to update the geological chart to a scale of 1:25 000. A certain area may be changes due to the rapid development that occur such as cross cutting and many other reasons. Hence, with the updated map of current situation, it may be useful to other researchers' purpose in future.

1.4 Objectives

As seen below, this analysis has two main objectives:

i. To update the geological map of study area with a scale of 1:25 000 of Universiti Malaysia Kelantan (UMK) and surrounding area.

ii. To investigate the potential of groundwater in granitic rock mass at Universiti Malaysia Kelantan (UMK) using resistivity method.

1.5 Scope of Study

For the study field, there are two research approaches, which are interpretation of geological mapping and geophysical survey. The field of research includes about 5km x 5km which is about 35 km^2 in total dimension. The aim of this research is to determine groundwater potential in the mass of granitic hard rock located in Universiti Malaysia Kelantan (UMK) by using electrical resistivity survey. Interpretation for geological mapping includes identifying the rock boundary, geomorphology of study area, its lithology, structural geology present and drainage trend in the region of the study. These are all interpreted by the use of applications such as ArcGIS and Google Earth, as well as USGS info. Besides that, a literature review from the past research also is used in order to gives strong evidence on the interpretation. The scope of the analysis focuses more on the potential of groundwater in crystalline granitic bedrock for geophysical surveys which is the objectives is to identify the subsurface condition, water flowing in bedrock, porosity and its permeability. In order to interpret the resistivity data in the study area, RES2DInv software is used.

1.6 Significance of Study

This research study will give benefit to many people especially other researchers which they can use this study as reference and get information for better improvements in future research. A new geological map of study area can also be producing with more new updated information about the geology of study area and its formation which can be used by other researcher for future plan. A new finding of geologic features can help people to have better understanding about the geological processes that occurs in an area. Groundwater is hardly found in granitic rock because of its porosity and permeability is low. Groundwater is a basic need for human being and it is very essential and becomes a big demand either from UMK student, UMK staff or the community that need clean water for daily used. Thus, this study can fulfill their desire for fresh and clean water which is more suitable for daily used and health. Lastly, this study will also give benefit to jobless community which a labor worker might be needed in order to construct new well design. In the nutshell, this study will give better improvement for inhabitant in the surrounding area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The geological component of the UMK, Jeli, Kelantan is discussed in this section with its surrounding area, with additional formation about using resistivity method in determine the groundwater potential exploration in hard rock mass body. The discussion includes the regional geology, plate tectonic setting, stratigraphy, structural geology and groundwater potential determination. The sources might be coming from past journal, articles, books, previous thesis and internet sources.

2.2 Regional Geology and Tectonic Setting

Peninsula Malaysia was formed from a collision between the western side of Sinoburmalaya and the east side of the Eastmal-Indosinia block. According to (Charles S.Hutchinson, 2007), Peninsula Malaysia is a part of Eurasian plate, which known as Sundaland. Peninsula Malaysia is divided into The Western Stable Shelf, Main Range Belt, Central Graben, and Eastern Belt which are the four major tectonic occurrences. These belts are categorized based on its geological formation, mineralization content, stratigraphy and its structure (Charles S. Hutchinson, 2014).

On the Thai-Malay Peninsula, the Paleo-Tethys Inthanon Suture Zone stretches southwards across the Gulf of Thailand to the broader Bentong-Raub Suture Zone. The southern equivalence of the Sukhothai Island-Arc system is known to be defined by the East Malaya Terrane in the Malaysian Peninsula, which also consists of Perm-Triassic I-Type granitoids. Following the pre-existing Paleozoic and Mesozoic fabrics (Morley et al., 2004), the Cenozoic opening of the Thai Gulf of the Malay Basin possibly set East Malaya apart from South-East Asia's mainland.

The Malay Peninsula's Bentong-Raub Suture Zone is the largest Paleo-Tethys ocean basin and forms the border between the Sibumasu Terrane to the west and the Sukhothai Arc to the east. The suture contains radiolarian oceanic cherts ranging from Devonian to Upper Permian in age. Schists and phyllites reflect the continental margin-slope deposits of Sibumasu incorporated during subduction into the accretionary complex.

In Southeast Asia, Indochina Terrane and Sibumasu Terrane is two major continental masses. Along the belt of convergence between the Sibumasu and Indochina, both sub-parallel suture zones can be recognized. The Paleo-Tethys is a broad suture zone representing an accretionary extension and the other is a narrow suture zone representing a closed basin of the back arc. Both of these sutures are less parallel to each other and form an island arc (Masatoshi Sone & I. Metcalfe, 2008).

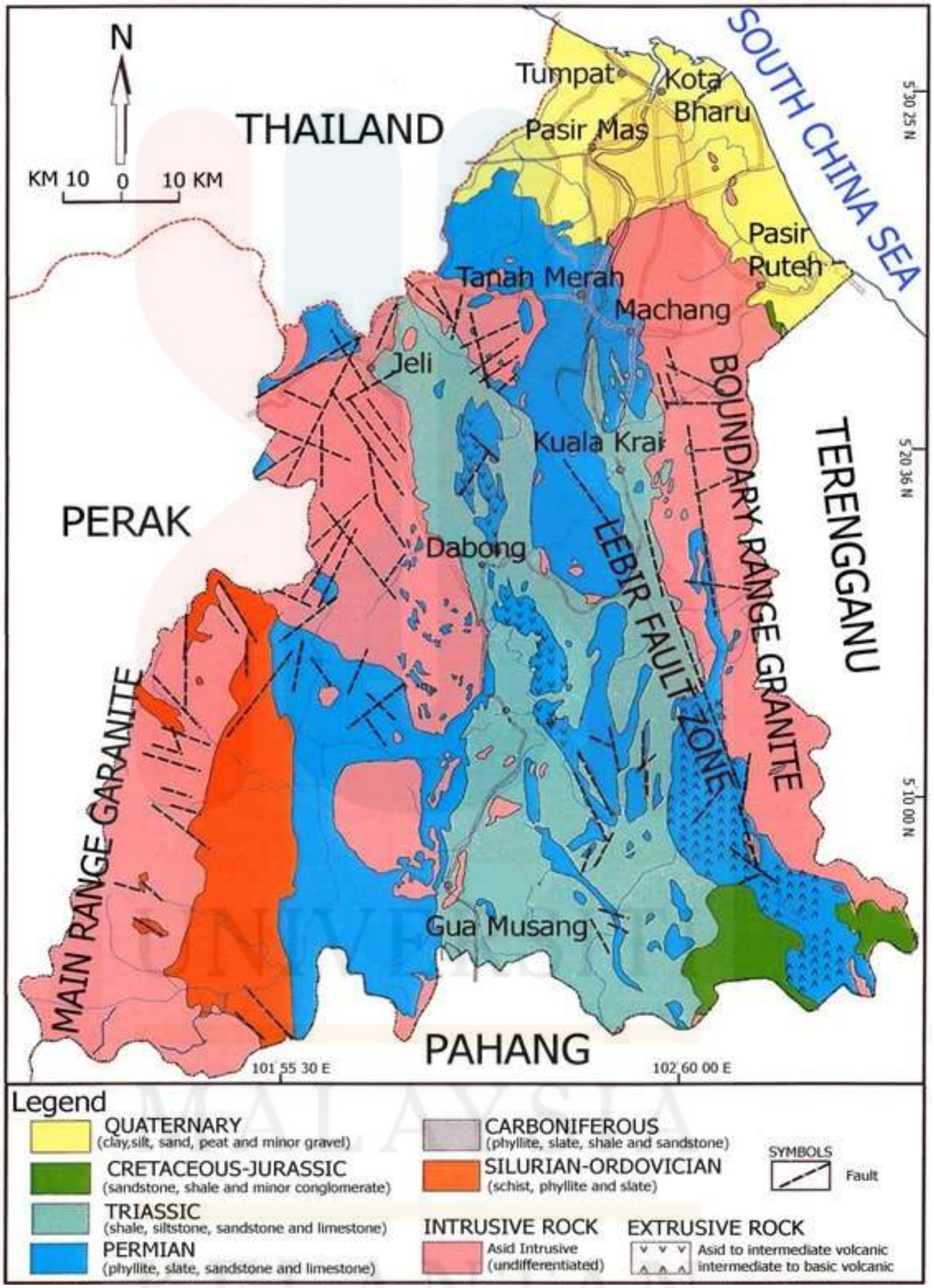

Figure 2.1: Geologic map of Kelantan state

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

2.2.1 Regional Geology of Kelantan

Kelantan lies in the Central Belt and consists of sedimentary and metasedimentary rocks, bordered by the Main Range Granite from the west and Boundary Range Granite from the east. Between the central zone, there are a present of granitic intrusive which more prominent at Ulu Lalat (Senting) batholith, the Stong Igneous Complex and the Kemahang pluton. At the north-south of Kelantan, these belts continually to the north Pahang's northern regional geology. The belts continue northwards to the south of Thailand on the western and central side of Kelantan.

According to (Macdonald, 1983), the oldest is in the Lower Paleozoic Period, with the belt bordering the Main Range Granite foothills and spreading eastward to Sungai Nenggirii. The Triassic rocks mainly confined to the central and south of Kelantan and usually dominated by argillo-arenaceous sediments with intercalated volcanic and limestones (Macdonald, 1983). The Jurassic-Cretaceous is identified as the youngest rocks that overlies in the continental rocks of Granite and Triassic sediment boundaries in the Gunung Gagau zone between Kelantan, Pahang and Terengganu, west of Gunung Perlis and west of Gunung Pemumpu. All of these sequences consist of conglomerate that overlain with sandstone.

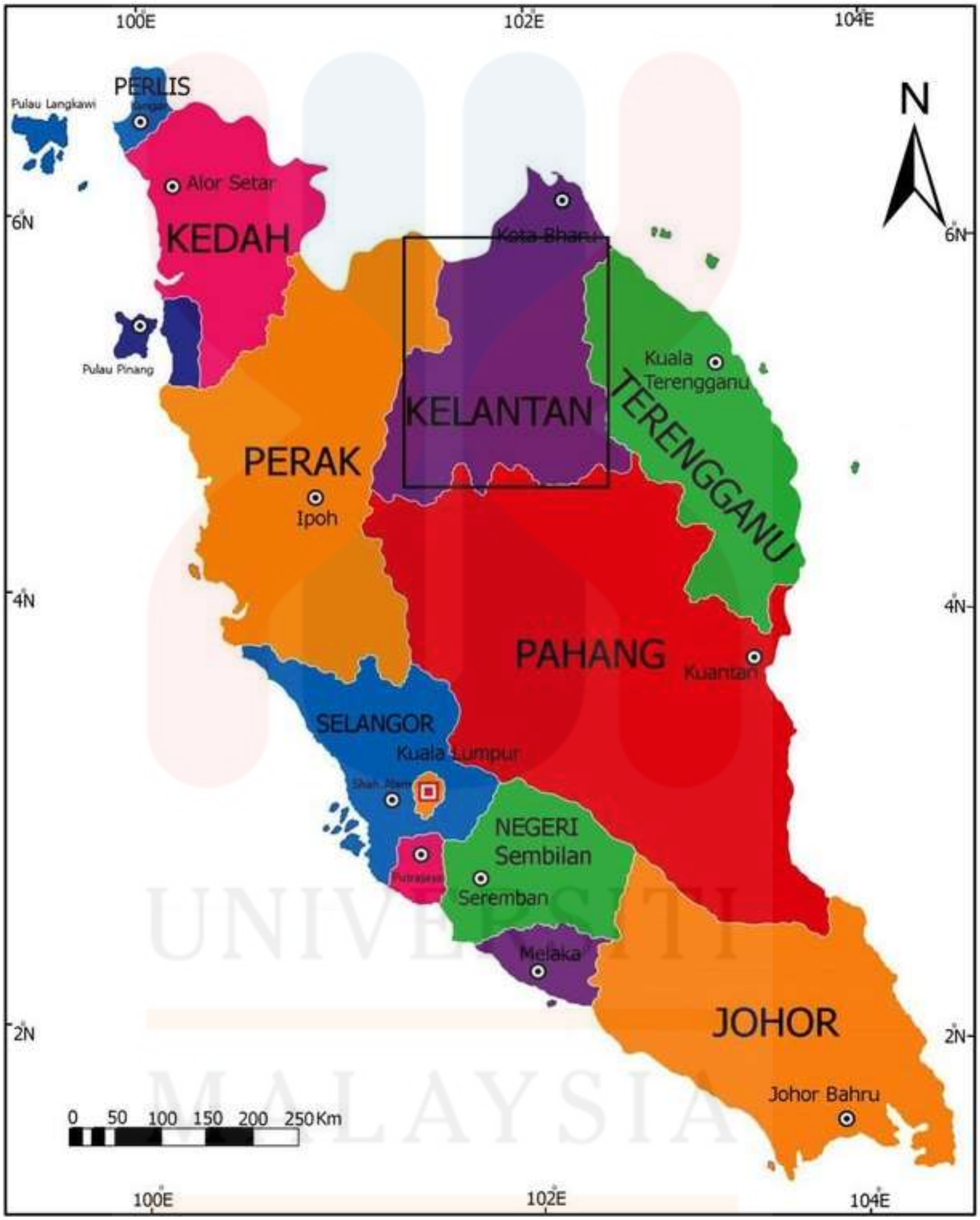

Figure 2.2: Location of Kelantan state in Peninsula Malaysia.

(Source: Amin Beiranvand Pour & Mazlan Hashim, 2017)

2.2.2 Regional Geology of Jeli

The Jeli district is located on the backbone of the Malaysian peninsula at the foot of the Main Range Granite. The Main Range consists of mainly granitic rocks with sedimentary and metasedimentary rocks from many provinces. The Main Range Granite is situated west of Kelantan, along the western side of the border between Perak and Pahang.

According to Department of Minerals and Geoscience Malaysia, the general geology of the Jeli district typically consists of three types of rock consisting of shale, siltstone, sandstone, and limestone, which are Triassic sedimentary rocks (Gunung Rabong Formation). Next, the phyllite, slate, sandstone and limestone Permian sedimentary rocks (Gua Musang Formation). Lastly, granitic rocks (intrusive acid), (Sulaiman et al., 2020).

Based on the geomorphology aspect, state of Jeli can be divided into four forms of landscape: mountainous, hilly, plain, and coastal regions. The landscape also included the Main Range Granite, Migmatite Stong Complex and schist, (Dony Adriansyah Nazaruddin, 2017). Tectonic activities in Peninsular Malaysia affect faulting and folding formation during the Paleozoic and Mesozoic periods, mainly involving the land mass. Local structures involve folding, jointing, and faulting of sedimentary rock and jointing and faulting of granitic rock.

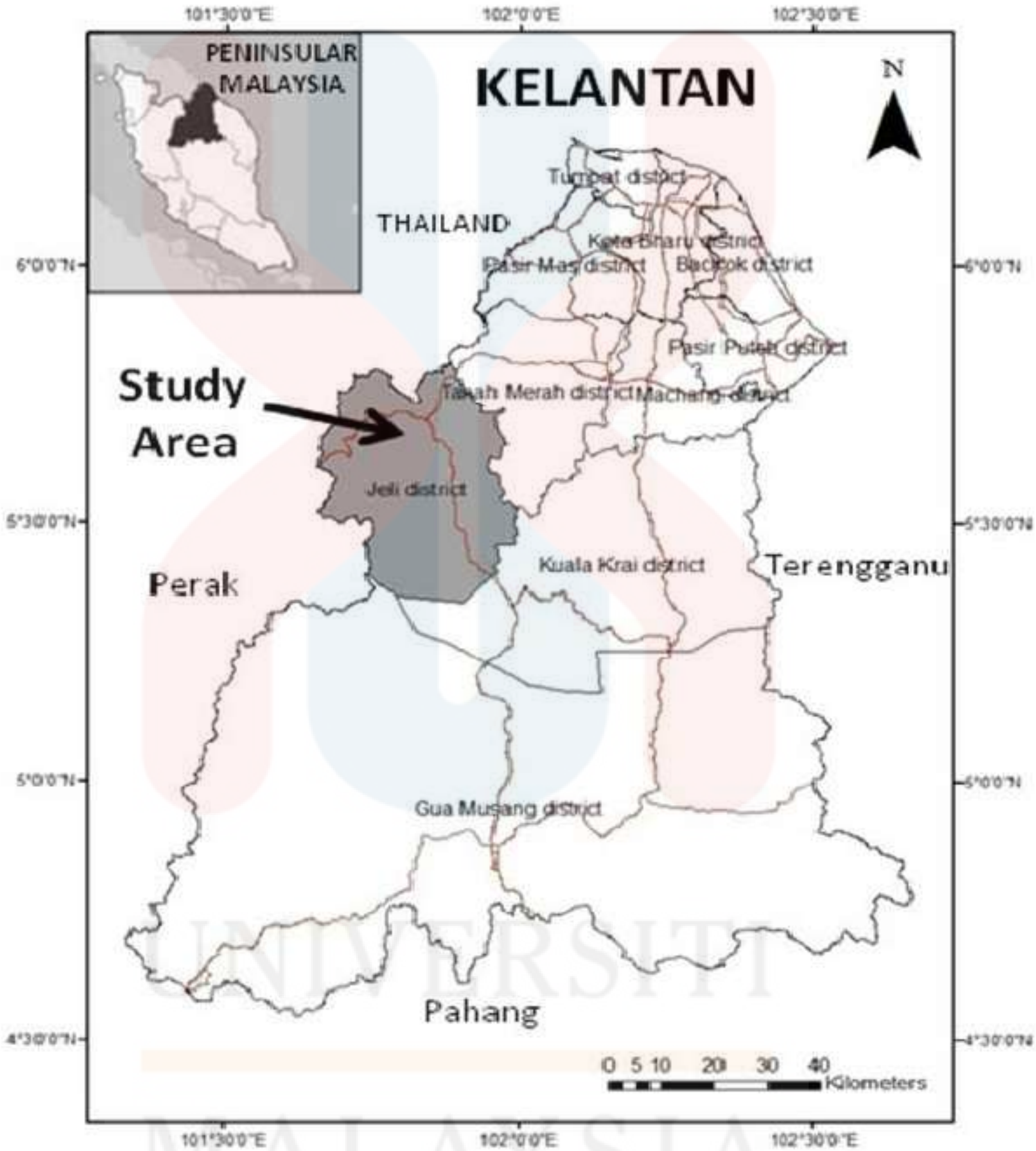

Figure 2.3: Location of Jeli district situated in western part of Kelantan state.

(Source: Dony Adriansyah Nazaruddin, 2017)

2.3 Stratigraphy

Stratigraphy can be defined as the study of a geology branch that related to rock layers and layering. The interpretation can be made by determining the sequence of rock and its physical characteristics. According to previous research from (Chu Ling Heng, 2006), Kelantan is one of the state that located near the border of Thailand. In Jeli, there are few formations that can be recognized including The Formation of the Gula, Telong Formation, Formation of the Mangga, Tiang Schist, and Formation of the Taku Schist. The origin of the Gula Formation comes from the Quaternary period marine deposit and is known as the youngest formation compared to the others. Next, the oldest formation is Taku Schist relative to the other formation, which is from Devonian to Silurian period. According to Mangga Formation, the type of outcrop can be said as it were exposed until Sungai Machang that spread out to the southwards of Kampung Gunung in Batu Melintang area.

There is some fossil found which is bivalves and foraminifera in the age about Permian-Triassic. It is found under the south transect area with the same lithology. The Taku Schist Formation that exposed in Sungai Galas area is well distributed to Tanah Merah and back to Kemahang Granite through Sungai Sokor at Kuala Bertam before it passing Ulu Sungai Taku. The Taku Schist Formation consist of metamorphic rock that same as Mangga Formation with the age about Carbonaceous-Permian. The Telong Formation that exposed at Kampung Legeh are extends to the eastwards to Tanah Merah and composed of mainly argillite, low grade meta-sedimentary rock and meta-volcanic rocks. There are four facies that can be found which are argillaceous, arenaceous, calcareous and volcanic facies with no present of fossil. The Kemahang Granite that forms mountainous range from east west of Jeli town spreading into Sukhirin range in Thailand.

For Malaysia, Kemahang Granite covers area such as Bukit Jeli, Bukit Kemahang, Bukit Kusial and several small hills as showed in the Figure 2.4.

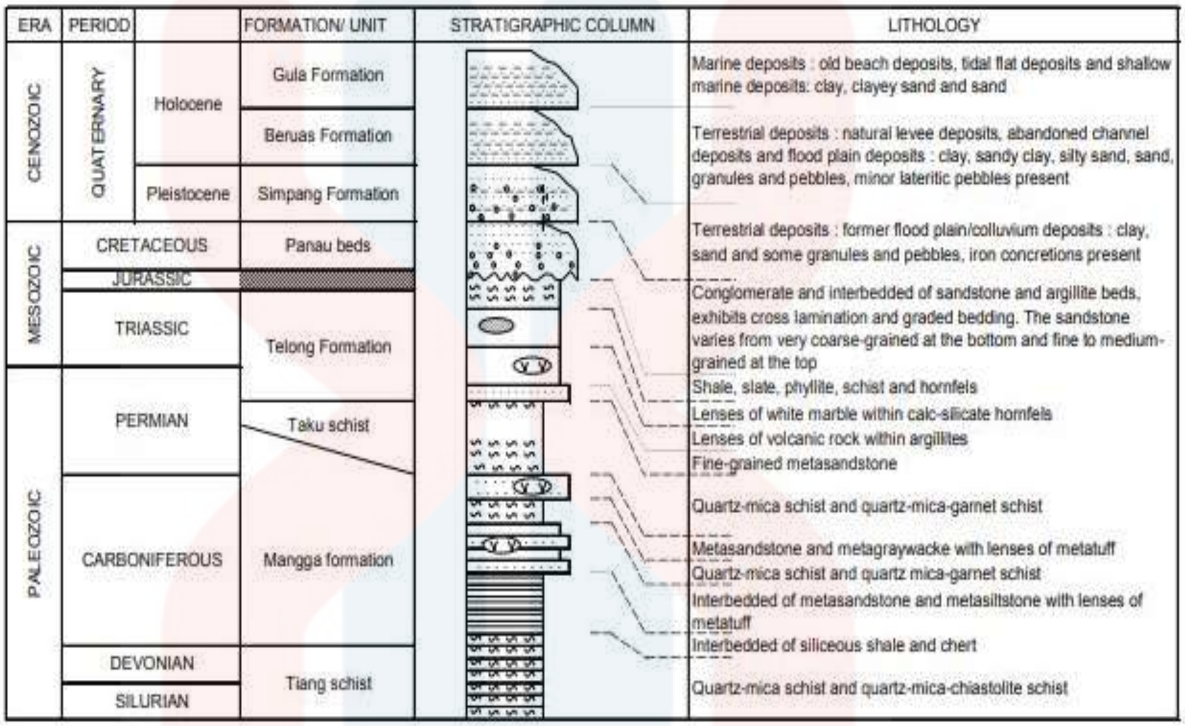

Figure 2.4: A schematic stratigraphic column of Batu Melintang-Sungai Kolok Transect area in Malaysia.

(Source: Chu Ling Heng, 2006)

2.4 Structural Geology

Structural geology can be characterized as the analysis of the three-dimensional distribution of large rock bodies and their surface, including the identification of positive and negative line reading in the field of study (Citra et al., 2012). From the lineament reading, the interpretation of structural geology that present at the study area can be identify. For example, fault structure is present in a linear feature of landscape. Besides that, another structure such as dykes, fracture zones, shear zones and igneous intrusion can also give interpretation to a lineament. A line is usually fault-aligned, a sequence of fault or fold-aligned hills that can be separated. A fault line can be found, particularly in the area of Jeli and Tanah Merah, based on the figure.

Geology of the Batu Melintang-Sungai Kolok Transect area along the Malaysia-Thailand border reported that the fault can varies in fractures, sheared or mylonitic rocks and can be found along the major fault for example Long-Kolok fault (NE-SW), Pergau fault (NE-SW), Kalai-To Mo fault (N-S) and Ka To Bu Yong fault. The fold present in the transect area is a pre-orogeny sedimentary type which is A variety of synclines and anticlines comprise the folded one. The folding is characterized by strong, asymmetric and open folds that in the sedimentary rock can lead to repetition and reversal formation.

A small-scale structure can also be recognized in the transect area which is tight folding, parallel folding and fault. The rock sequence that consists of moderate to steep dips can be found in Tiang Schist and Mangga Formation. The present of faulting and folding are recognized between the age of Triassic to Cretaceous due to the granite intrusions. The trending fold is mainly in the direction of NW-SE and N-S, which is a sub-parallel to the long axis of the Malay Peninsula, and with different dip angles, the most dipping on the bedding planes is in the east direction.

2.5 Historical Geology

Jeli is one of the districts in the northern part of Kelantan State, consisting of several formation that can be identify through the previous research. Centered on the analysis of the Batu Melintang-Sungai Kolok Transect region along the border between Malaysia and Thailand, Jeli are near with the border of Thailand. There are few formations in Jeli area including Gula Formation, Kemahang Granite, Telong Formation, Mangga Formation, Tiang Schist and Taku Schist formation. Based on the research, Kemahang Granite is identified as the youngest formation among the other which forms a mountainous range of east west of Jeli town which is then spreading into Sukhirin range in Thailand. In Malaysia, Kemahang Granite covers area such as Bukit Jeli, Bukit Kemahang, Bukit Kusial and several small hills. The Taku Schist is classified as the oldest rock sequence with age between Carbonaceous-Permian that exposed along the main river of Sungai Galas while in Kampung Legeh, the Telong Formation is exposed and stretches to the west of Tanah Merah.

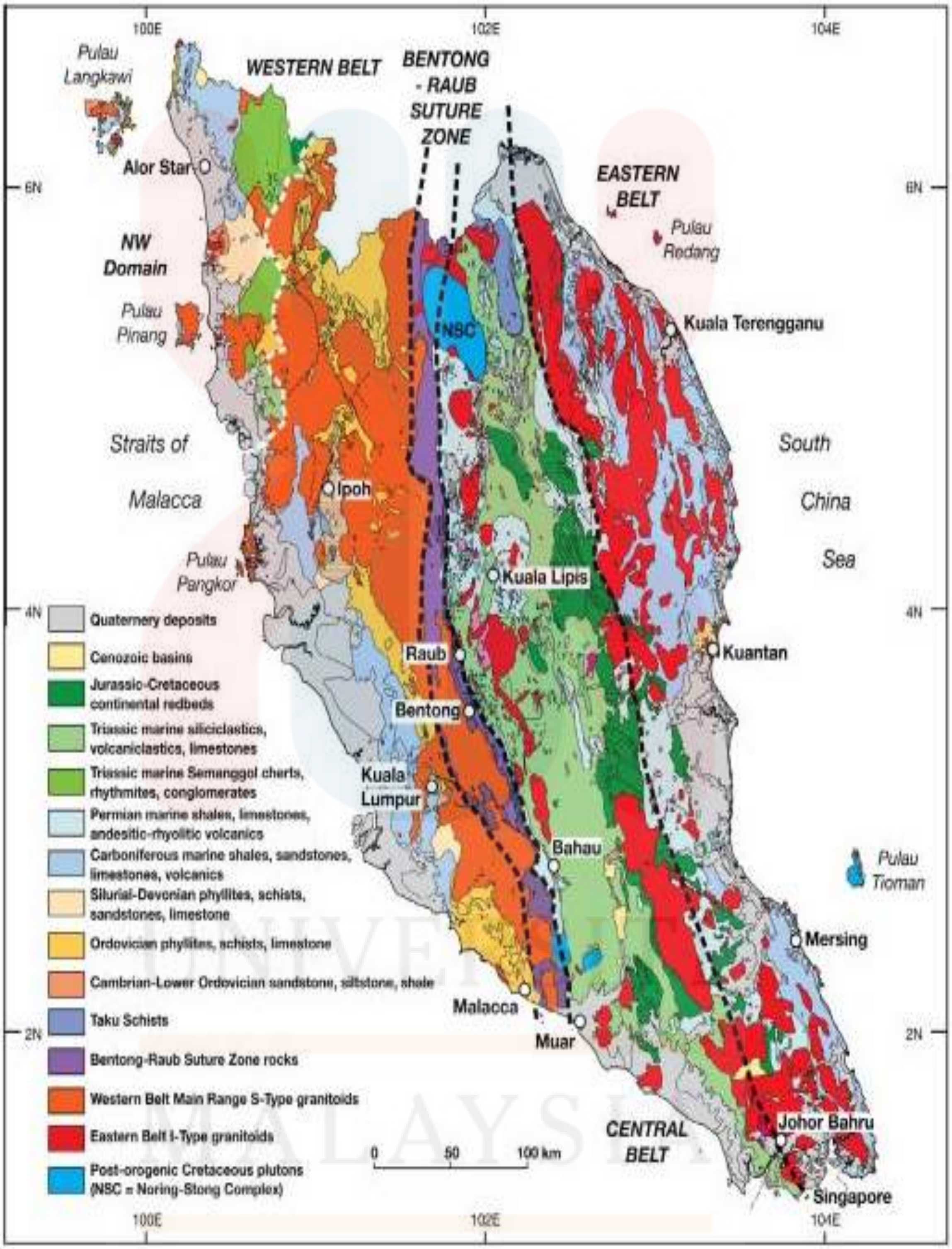

Figure 2.5: Geological map of Malay Peninsula

(Source: Metcalfe, 2013)

2.6 Research Specification

2.6.1 Groundwater Aquifer

In soil pore spaces and rock formation fractures, the Earth system consisted of around 95 percent fresh water is exists beneath the Earth's surface. Water is basic needs of living things including in human life, ecosystem and agriculture used. The water body van be found in many parts of the earth such as rivers, lakes, oceans, polar ice and rainfall. In the Lower Kelantan Basin, there are about 75 percent of the state population who rely more on groundwater services for daily supply, agriculture and industrial activities. Approximately about 146 million liters per day (MLD) of groundwater consumed in 2009 and estimated that the rate will increase by 2.5% per year (Sefie et al., 2015).

According to (Bernard-Jannin et al., 2017), determination of groundwater potential is by knowing its absolute value of the ground resistivity. The anomaly results in low resistivity in granitic rocks that are hard rock, whereas fresh water results in high resistivity in an artificial or saline climate.

The groundwater movement in the subsurface layer are depends on its characteristics of the subsurface formation such as aquifers, aquitard, aquiclude and aquifuge. Aquifer referred to good permeability and porosity formation to allow the water to flow to the well or spring in sufficient quantities. Aquitard referred to the formation of low to medium permeability that is not sufficient to allow the water to pass. Aquiclude can be defined as the formation with high porosity but low permeability while the aquifuge referred to the formation called as bedrock that did not have good permeability and porosity. The groundwater also can exist in fracture zone and soil.

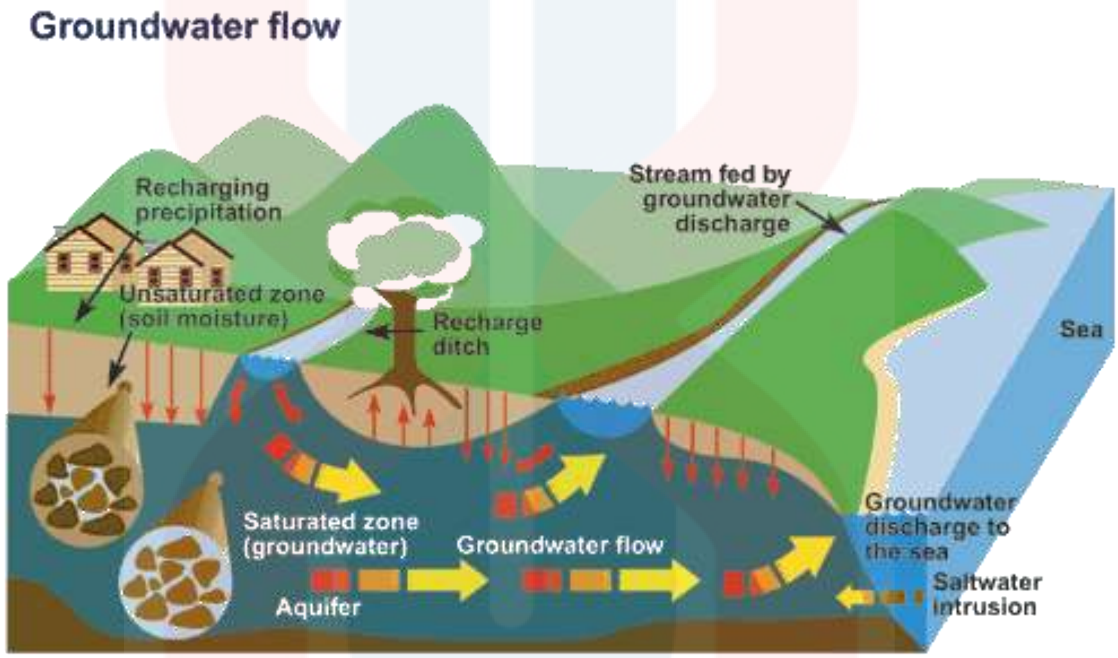

Figure 2.6: Groundwater flows.

(Source: Government of Canada, 2013)

2.6.2 Groundwater in Hard Rock

Geophysical techniques such as electrical electromagnetic, magnetic, and seismic have been widely used in groundwater studies, especially in the study of aquifer geometry, electrical sub-surface conductivity, intrusive body mapping, and basement depth (Chandra et al., 2008). Geophysical approaches are also easier, more cost-effective and faster compared to other techniques. Geoelectric resistivity method is one type of geoelectric method that use for the studies of underground properties to investigate the subsurface conditions. The physical quantities measured in this system are the resistance of the rock type due to the potential field and current under the surface of the earth (Islami, 2019).

As reported by (Chandra et al., 2008), generally, hard rock granite aquifers cover just the first few meters below the subsurface layer. The composite aquifer of stratified layers such as the deep weathering is normally believed to consists of mother rock (Lachassagne et al., 2011). The fissured layer is usually defined by two sets of sub-horizontal and sub-vertical fissures, while the density decreases with depth and assumes the composite aquifer's transmissive function. The degree of interconnectivity of the fissures also decreases as the density of the fissure decreases rapidly with depth. The aerial size of the aquifer is thus found to be very large, but when the water level stays at a shallow level, when lateral inhomogeneities are decreased, the aquifer is divided into small aquifer zones (Chandra et al., 2008).

In the analysis of heterogeneous hard-rock aquifers, there are many methods used for the detection of groundwater in hard rock, such as the Magnetic Resonance Sounding (MRS) technique. The technique enables the classification of two-dimensional subsurface structures with fair accuracy when the scale of the subsurface anomaly is equal to or greater than the MRS loop. Nevertheless, the broken portion of hard-rock aquifers with low effective porosity (<0.5 percent) cannot be resolved using the MRS unit. (Legchenko et al., 2006).

2.6.3 Resistivity in Groundwater Exploration

The electrical resistivity method is more preferable method in determining the groundwater exploration. Electric resistivity surveys map the subsurface structure by making electrical measurements near the ground surface. Two electrodes inject an electrical current into the soil and calculate the voltage difference between two other electrodes. Potential difference measurements at various locations of the current and potential electrodes are converted into apparent resistivity by these values and then the data set is reversed. There are several parameters for ground resistivity such as the quality of minerals and fluids, porosity, permeability and level of saturation in rock (Letters, 2003). For several years, geophysics has played a useful role in such investigations, and advances in instruments and the development of better methods have resulted in an extension of its applications (Asry et al., 2012). On the one hand, the high rate of urbanization and The urgent need for natural resources and the non-invasive nature of geophysical methods such as geo-electrics, very low frequency (VLF) and induced polarization (IP) electromagnetic methods, which are capable of providing information on large areas (Sunmonu et al., 2017). As reported by (Dony Adriansyah Nazaruddin et al., 2016), a reliable and accurate approach to determining potentially desirable groundwater acquisition zones in the study region is the combination of geological mapping and multi-electrode resistivity surveys.

Generally, site investigation for ground instability assessment was based on borehole data exploration method. However, there are several limitations are identified using borehole data thus, a geophysical methods is used for solving the problems since it is low cost and able to covers more area over time (Abidin et al., 2017).

For ground surface materials, a 2D electrical resistivity method is typically used to calculate the apparent electrical resistivity. These electrical resistivity surveys include injection of electric current into the subsurface between two electrodes and the possible variations between two other potential electrodes are measured. This technique was used to determine the anomalies of subsurface resistivity and has recently become famous for investigating the movement of water in the vadose region (Asry et al., 2012).

Electrical resistivity imaging has become a popular method for the production of multi-electrode resistivity equipment and techniques for data acquisition in near-surface geophysical surveys. The configuration of Schlumberger was used in this research with electrode spacing for each is 5m. The length of the survey line is 200m with the depth penetration about 30m. as reported by (Olakunle & Olakunle, 2012), groundwater faced a lot of uncertainties. In no small amount, the right exploration techniques in delineation of subsurface water-bearing formation can eliminate, minimize or avoid these uncertainties entirely.

For this research, a Schlumberger configuration is used with the line of survey is 200m long. The spacing of each electrode is 5m with the depth of survey is about 30m. By increasing the movement of the entire array across the field, the potential electrodes can be measured or fixed by lateral and vertical changes in resistivity while the current electrodes are distributed. Four collinear electrodes make up with the Schlumberger configuration. The outer two electrodes are the current electrodes (source) and the inner two electrodes are the potential (receiver) electrodes. There are some advantages in using Schlumberger array such as only necessary to transfer fewer electrodes and the cable length for the prospective electrodes is shorter. Schlumberger soundings typically have higher resolution, greater testing depth and less time-consuming deployment of fields.

$$\rho_A = \frac{V}{I}\pi\frac{b\left(b+a\right)}{a} \approx \frac{V}{I}\pi\frac{b^2}{a} \quad \text{if } a << b$$

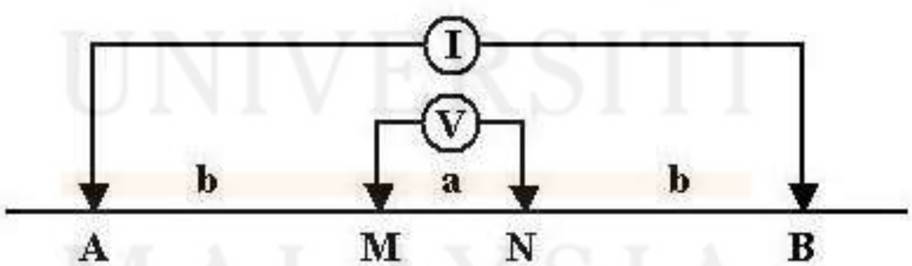

Figure 2.7: Schlumberger array and apparent resistivity.

(Source: M. H. Loke, 2000)

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

In order to complete this Geological Mapping and Slope Failure Investigation Research Study using the Resistivity Method (ERI) at the University of Malaysia Kelantan (UMK) Jeli, Kelantan, certain materials and methods are used and performed to meet the specified goals. Methods such as preliminary research, data processing and analysis and interpretation of data are used.

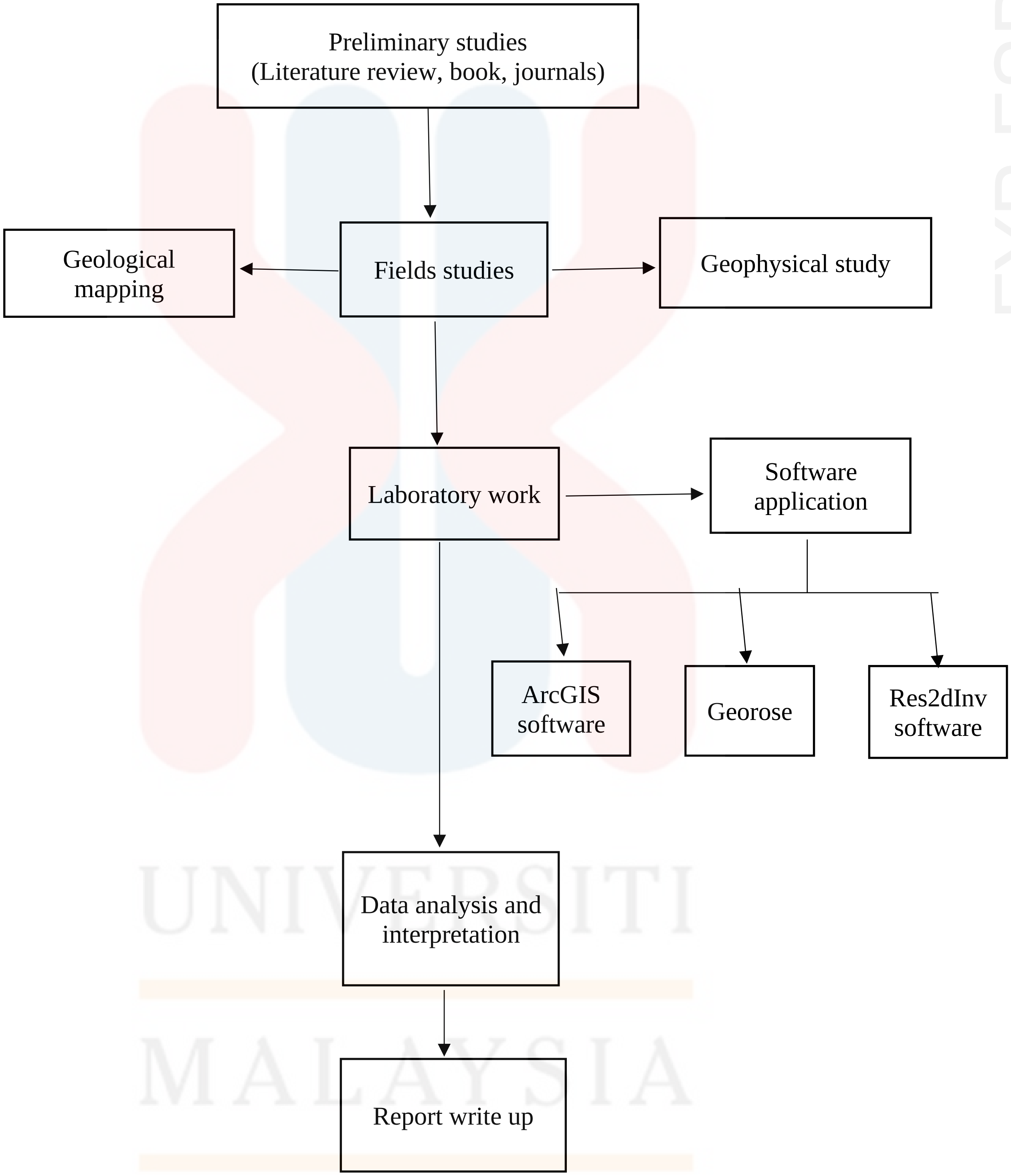

Figure 3.1: Flow chart of research.

3.2 Materials

3.2.1 Materials for Geologic Interpretation

There are many materials and tools that are used in geological mapping to collect data. It lists the materials and software as follows:

Table 3.2:List of materials and software used.

NO	MATERIALS AND SOFTWARE	USES
1	ArcGIS software	It is used to produce the elevation map and contour and the boundary lithology of the study area.
2	Microsoft excel	It is used for data tabulation and report writing.
3	Google Earth Pro	Determination of the geological map by satellite picture.
4	RES2Dinv	It is used to interpret knowledge regarding resistivity.
5	JMG data	It is used on a scale of 1:25000 to make a geological map.
6	CorelDraw	Used to labelling the pseudo section.

3.3. Methodology

Methodology is an important technique that must be included in a research study. It will describe things related to the action that must be taken in order to investigate the research problem. The method that used t identify the methods is including to select the process, to know how the data is collected and analyzed in order to have better understanding about the research problem. Generally, there are four components of research methodologies that had been run in this research:

a) Preliminary studies
b) Processing data
c) Analysis data
d) Report writing

3.3.1 Preliminary Studies

A preliminary analysis is an initial exploration of the problems associated with a research study proposal. It will allow investigators to have a clearer understanding of the issue. Reviewing prior research to study the problems relevant to it and using it as a guide to construct a new study is an important move that can be taken. In order to determine the achievable research gaps in the field of analysis, literature review may be transparent to the issue and extend the information about the subject addressed. In this stage, a previous study area map or any satellite image available from the previous researcher is also gathered and separated based on its priority. More features such as historical geology, tectonic environment, methodology used, structural geology and stratigraphy can also be studied and understood.

For determination of groundwater, a geophysical method is used to investigate the potential of groundwater in UMK, Jeli, Kelantan. The result from the survey lines on different locations will be correlate in order to identify the resistivity value for subsurface conditions at study area. The table shows a resistivity value for some common rocks, mineral and metals. For this research study, a Schlumberger configuration is used. It is chosen due to its criteria that more suitable on the study area hence it less sensitive voltmeter are required. A multi-electrode resistivity survey is used by using ABEM Terrameter LS with 200m long of each survey and 41 stainless steel electrodes with straight line position is used. A 5 meter of constant spacing is used from one electrode to another spreading about 200-meter length. There are four survey line for this research study. The suitable location for each survey lines is chosen based on its geomorphology condition, its open space and topography. The data is then processed using Terrameter LS Toolbox and RES2DIN software.

3.3.2 Processing Data

Data from the resistivity survey line will be processed using multiple tools, such as Google Earth Pro, ArcGIS, RES2Dinv and CorelDraw, in this report. Data processing can be characterized as a series of actions to be performed on a data in an acceptable output to verify, organize, transform or extract data. Data analysis, on the other hand, requires behavior and processes that can assist in explaining evidence, establishing theories and testing hypotheses. Firstly, the data will be processed using Georose software for linear reading. Basically, based on the reading of data, it can produce a strike and dip path. The degree of inclination indicates where the trajectory is going. Next, in most processes, ArcGIS software is used to generate data, including geological map updating, data interpretation and data analysis.

Resistivity data was analysed using RES2DINV operated software with nine common options at the top of the screen. The input data file must in a "file." Format. The measures taken during the processing of resistivity data using the RES2DINV programme were the following procedures.

i. Picked File Data from the Reads menu.

ii. Bad date points have been exterminated from the Edit menu. Using a notepad or other text editor, negative values or values that were too big were edited (Figure 3.2). A Feature to exterminate bad datum points was used to remove more bad data value by clicking the mouse when the cursor at the points of those was not in line

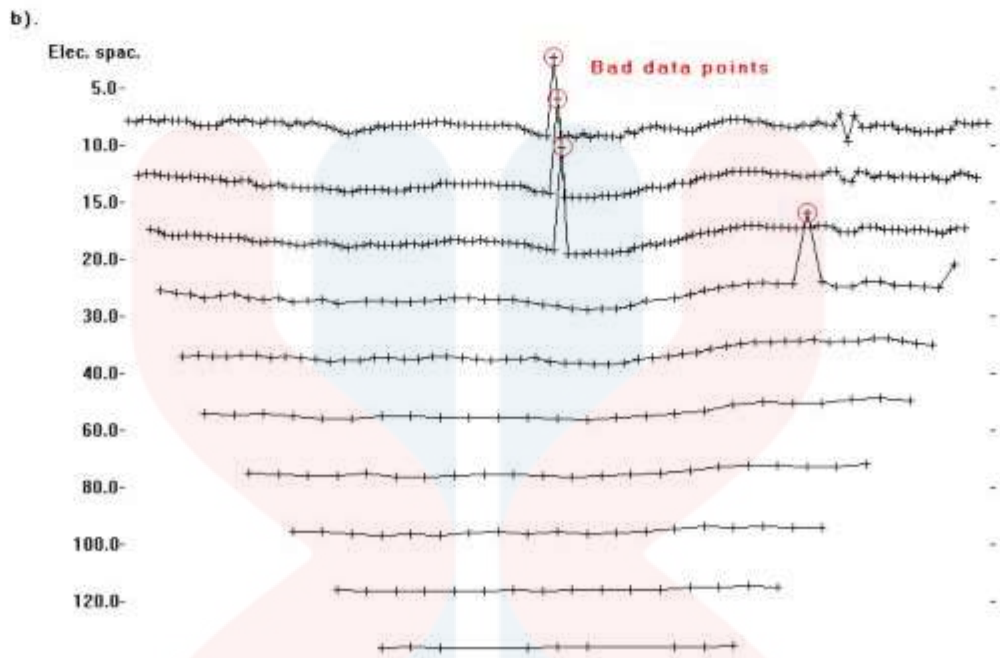

Figure 3.2: Exterminate bad data points.

iii. The Change menu was also used to change the resistivity data by selecting the number of iterations required, while the applications of the damping factor, mesh refinement, convergence limit, and model resistivity values were set according to whether the data set was too high or too low.

iv. Next, Inversion menu is chosen to begin the process of data inversion.

v. The change was made using the robust inversion technique from the menu by smoothing the resistivity model.

vi. To reduce the RMS (Root Mean Square) error that affects the inversion process and the construction of model resistivity data, the RMS error statistics menu was chosen. Resistivity data in the form of rectangular blocks (Figure7) were adjusted and recalculated in order to create a pseudo-section of resistivity. This method involves recalculating and observing pseudo cross-sectional field-based resistivity values before producing a pseudo count (calculated pseudo-section) that is very close to the actual field data. For the purpose of quantitative interpretation, the inverse model resistivity sections were created from pseudo count.

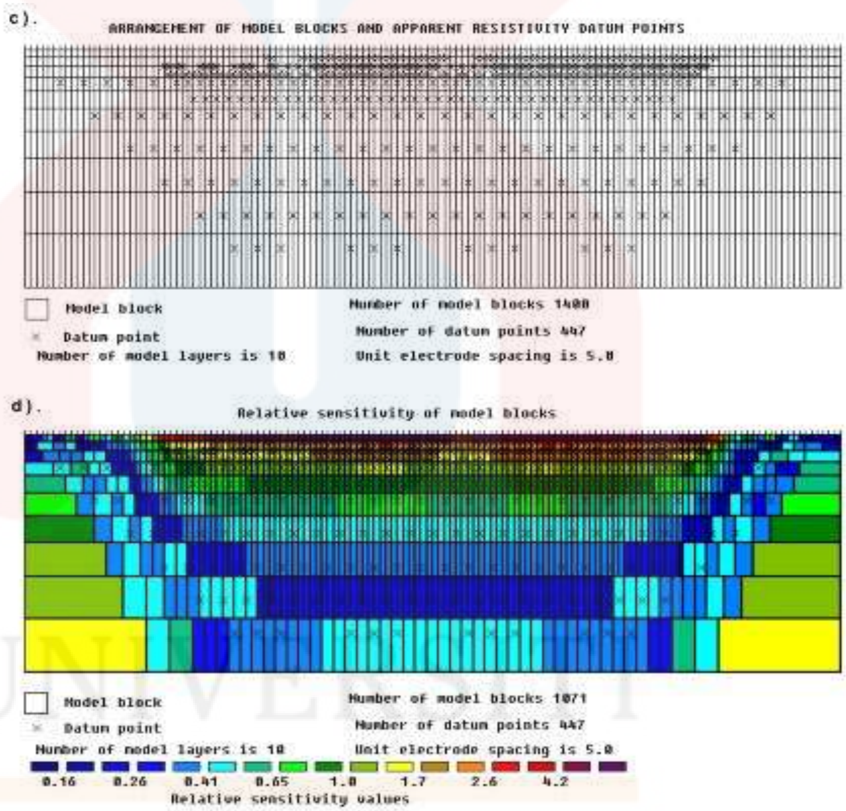

Figure 3.3: Resistivity data in rectangular blocks.

vii. The show display menu was selected to display the real resistivity model after the inversion phase was completed.

3.3.3 Analysis Data

To map the subsurface electrical resistivity structure, the electrical resistivity method is used. Several functions, such as porosity, permeability, water saturation and concentration of dissolved solids in pore fluids within the subsurface, are measured in ohm-meters by the geological unit. The current is injected into the ground through surface electrodes in the electrical resistivity phase.

The configuration used is an array of Wenner-Schlumberger with 3-5 survey lines. The length of the electrode cable, with 41 electrodes, is 200 meters long. The approach used in this analysis is the traditional technique using the Wenner array with a parallel and perpendicular resistivity line to the slope face. With an average penetration depth of 20 m to 30 m below the ground surface, the Wenner array with a total profile length of 200 m was used. Using this process, zones with high water content and poor areas could be calculated as low resistivity zones. Due to the restricted space for seismic lines compared with the projected target depth, refraction for the seismic survey could not be used.

An inversion of the calculated apparent resistivity values using a computer programmer was carried out to establish the true subsurface resistivity. Using 2D electrical resistivity imaging or tomography surveys to map areas of moderately complex geology is one of the latest advances in recent years.

Usually, such surveys are conducted using a large number of electrodes linked to a multicore cable. To automatically pick the relevant four electrodes for each measurement, a modern resistivity meter together with an electrode selector device is used

Figure 3.4: Tools for resistivity survey.

1. Storage Box ABEM
2. Battery (Power Resources)
3. Receiver and Transmitter (ABEM Terrameter)
4. Cable for Takeout (ABEM Multi-Core Cable)
5. Battery Connector Cable
6. Clips
7. Electrodes

Figure 3.5: Resistivity value for some common rocks, minerals, chemicals and metals

Material	Resistivity (Ω•m)	Conductivity (Siemen/m)
Igneous and Metamorphic Rocks		
Granite	$5x10^{3} - 10^{6}$	$10^{-6} - 2x10^{-4}$
Basalt	$10^{3} - 10^{6}$	$10^{-6} - 10^{-3}$
Slate	$6x10^{2} - 4x10^{7}$	$2.5x10^{-8} - 1.7x10^{-3}$
Marble	$10^{2} - 2.5x10^{8}$	$4x10^{-9} - 10^{-2}$
Quartzite	$10^{2} - 2x10^{8}$	$5x10^{-9} - 10^{-2}$
Sedimentary Rocks		
Sandstone	$8 - 4x10^{3}$	$2.5x10^{-4} - 0.125$
Shale	$20 - 2x10^{3}$	$5x10^{-4} - 0.05$
Limestone	$50 - 4x10^{2}$	$2.5x10^{-3} - 0.02$
Soils and waters		
Clay	1 - 100	0.01 - 1
Alluvium	10 - 800	$1.25 x10^{-3} - 0.1$
Groundwater (fresh)	10 - 100	0.01 - 0.1
Sea water	0.2	5
Chemicals		
Iron	$9.074x10^{-8}$	$1.102x10^{7}$
0.01 M Potassium chloride	0.708	1.413
0.01 M Sodium chloride	0.843	1.185
0.01 M acetic acid	6.13	0.163
Xylene	$6.998x10^{16}$	$1.429x10^{-17}$

(Source: M.H. Loke, 2000)

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

All geological factors such as geomorphology, stratigraphy, lithostratigraphy, structural geology and historical geology of the area of study will be discussed in this chapter. The mapping is starting from preliminary study from previous research, books, journals, online information and others. All the data from geological mapping interpretation that conducted in the study area is observed for the purpose of better understanding on the historical geology.

4.1.1 Accessibility

Jeli district can be accessed mainly through highway that connect Jeli and Gerik, and Perak, all the way west to Kedah or Penang, and all the way east to Tanah Merah, and all the way to Pasir Puteh. Jeli entrance is divided into three which are from the east through Tanah Merah or Pasir Pueth, from the west through Gerik and from the south through Mempelam, Jelawang or Kuala Krai. It can also be accessed by public transport such as bus or taxi as the location is near the town. However, Jeli area is also known for its urban condition that consists of rubber tree plantation and agriculture area with unpaved road.

4.1.2 Settlement

The study area is located at University Malaysia Kelantan (UMK) and composed of few villages such as Kampung Gemang Lama, Taman Pinggiran UMK, Kampung Bukit Susun, Kampung Legeh and Kampung Lakota. The Jeli district borders the state of Perak to the west, Thailand to the north, the Kuala Krai district to the southeast, and the Tanah Merah district to the northeast.

4.1.3 Forestry or vegetation

Jeli area are mostly covered with forest followed by rubber tree plantation and agricultural area. The total area of Jeli district are about 128,020 hectare and become the third largest district in Kelantan state. The land use is divided into several settlement such as school, forest, plantation, river and road. The primary occupation for the first generation of the inhabitants of Jeli for a living is rubber tapping and other types of plantations. Fortunately, the current generation's career has improved much better due to the proper education system and dedicated teachers sent to this remote region.

4.2 Geomorphology

Geomorphology is defined as the analysis of the earth's surface physical characteristics and their relationship to its geological structures. Geomorphology explains the landform changes in geology, flood plain area, drainage pattern area and watershed which is formed from the flow of rainfall. It also consists of topographic analysis and characteristics due to its various landforms which associated with physical, chemical or biological processes that operating on the surface or the landscape. In the study area, the geomorphology includes the undulating hills which can be found in the study area on the eastern and western part. There are two types of drainage patterns that are dendritic and parallel patterns that can be found in the study field.

4.2.1 Geomorphologic classification

The categorization and definition of the existence, origin and growth of the landforms is a geomorphic classification. It is possible to define a geomorphic unit on the basis of its origin and growth (processes), its general structure and shape (landforms), the measurement of its dimensions and characteristics (morphometry) and the existence and status of overprinting. The geomorphological classification is based on the type of landforms that are undulating hilly areas, flat areas and drainage patterns based on the study region.

The development of landform is due to endogenous, exogenous and extra-terrestrial process. Endogenous process are geological processes such as plate tectonics, volcanism or earthquakes that occurred under the earth's crust. The radiation from the interior of the earth triggers the processes of endogenous which allowing it to shift and forming landforms according its characteristics. Exogenous process is the geological phenomenon that occur near or on the surface of earth. It involves several processes such as weathering, erosion, deposition and transportation. Extra-terrestrial processes are the materials that refers to the natural objects that origin from the outer space. It can be either cosmic dust or meteorites.

The geomorphology in province of analysis are categorized into three groups which are undulating area, flat area and drainage pattern. Generally, in the eastern and western portions of the study area, the undulating area is largely occupied. The undulating area is surrounded by a forested area and composed of reserved forest in the east-south section that made up with altitude of 500m above the sea level which consisting of a granitic rock that extremely resistance towards weathering process. The point tip showed the form and the hill more to the natural mound as the peak of the hill. The slopes are mostly covered by rubber tree plantation.

Table 4.5: Relation between absolute altitude and morphography.

Absolute Altitude (m)	**Morphography**
<50	Lowland
50-100	Inland Lowland
100-200	Low Hills
200-500	Hills
500-1500	High Hills

(Source: Van Zuidam, 1985)

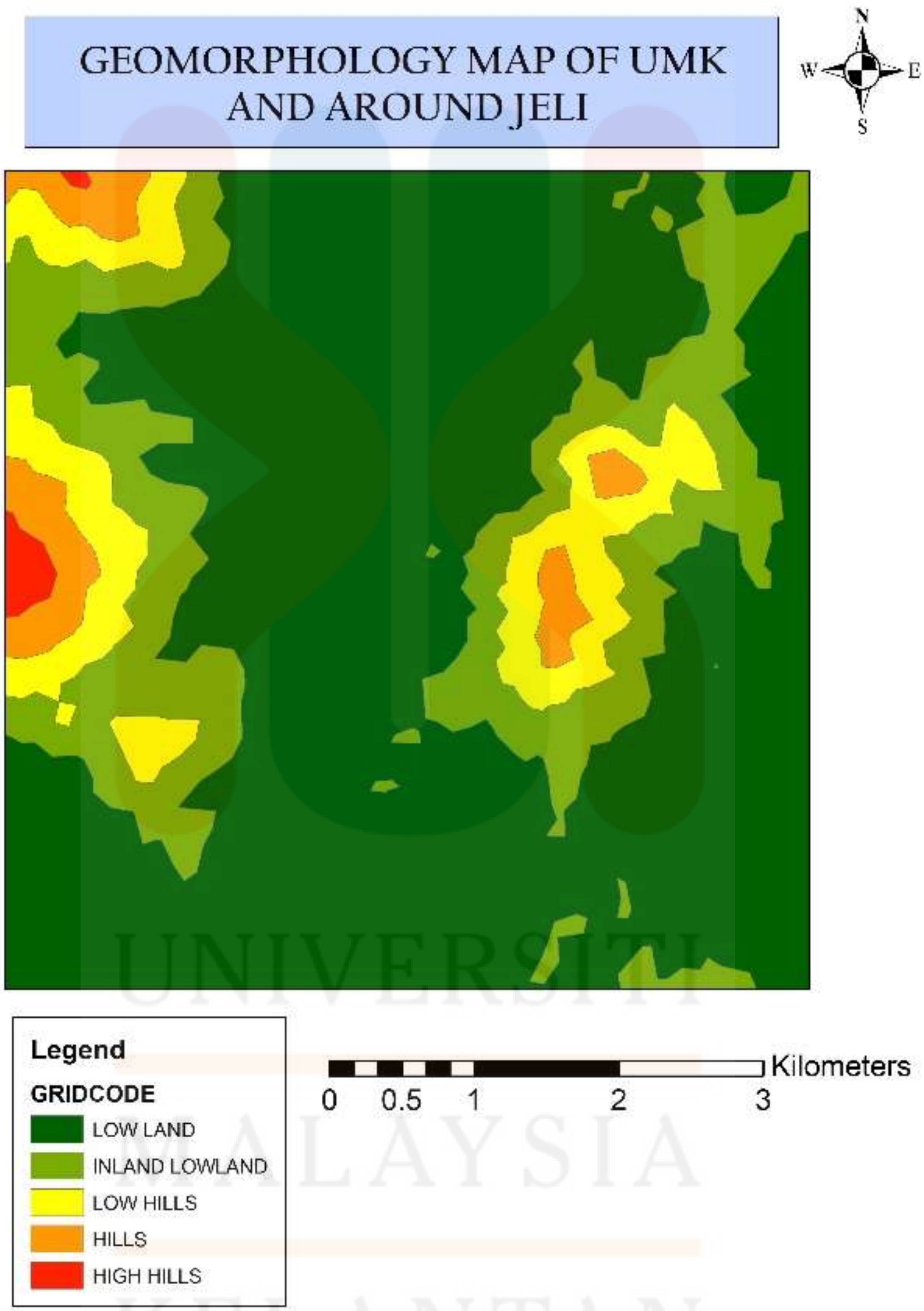

Figure 4.1: A geomorphology map of study area.

To add, through the analysis based on the contour interval and some literature from the past research, there are two types of drainage patterns that are dendritic and parallel patterns that can be found in the study field. Mostly, dendritic pattern can be seen as branching pattern of the tree roots. There are many sub-tributaries that flow into major river tributaries with the movement of water is from the peak of hills to the lower elevation of drainage basin. For parallel pattern, it is mostly occurred by natural faults or erosion processes in a linear series down the slope. The flat region consists in the middle of study area at the lower elevation that composed of meta-sedimentary rock as its lithology. It is referred to the housing area, village and educational institution.

4.2.2 Topography

Basically, topography can be defined as the shape and relief of land. It measures the elevation and the slope percent that change over distance. The study covers about physical features of a lad surface that includes the mountains, hills, valleys, plains, creeks and water bodies.

The physical characteristic of land surface in the study area is hilly areas with the elevation ranging from 300m-500m above the sea level at the eastern and western part and the flat area which ranging from 0-200m above the sea level is located at the center from north to south of the province of regional. The flat area is referred to the town, housing area, villages, educational institution such as University Malaysia Kelantan (UMK), Maktab Rendah Sains Mara (MRSM), Politeknik Jeli, primary school and secondary school.

The highest elevation is around 550 m above sea level in the western and eastern sections of the study area. Based on the analysis of contour pattern, the characteristics of the area is referred to the reserved forest that is covered up by the deep forest. The concentric circle of contour indicating the hills area while the contour line that spaced apart refers to the gentle slope and close-spacing is indicating the steep slopes. The V-shaped contour line indicates the flow of water through the stream beds and narrows the valleys that the V points uphill or upstream. Considered as the high point of the watershed, the point at the uphill of V shaped contours line stop. As the V form is sharper, the valley becomes more pronounced. U-shaped contour lines refer to the lower elevation point downstream formed in the pre-existing V-shaped valley where the U pointing down the ridge is pointing.

4.2.3 Drainage pattern

Drainage pattern can be defined as the study of pattern that created by the stream erosion over time which shows the characteristics of rock and geologic features in the drained areas. It is typically created by a drainage basin of streams, rivers and lakes. The drainage pattern is mostly used to identify the characteristics of rock types, recharge area and potential condition of area. Generally, dendritic, parallel, rectangular, trellis, contorted, and angular are many types of drainage pattern. From the drainage pattern, an interpretation such as hardness of rock, the gradient of land and the geology of the subsurface. Drainage channels can be created when the runoff surfaces are increased and the earth materials have low erosion resistance.

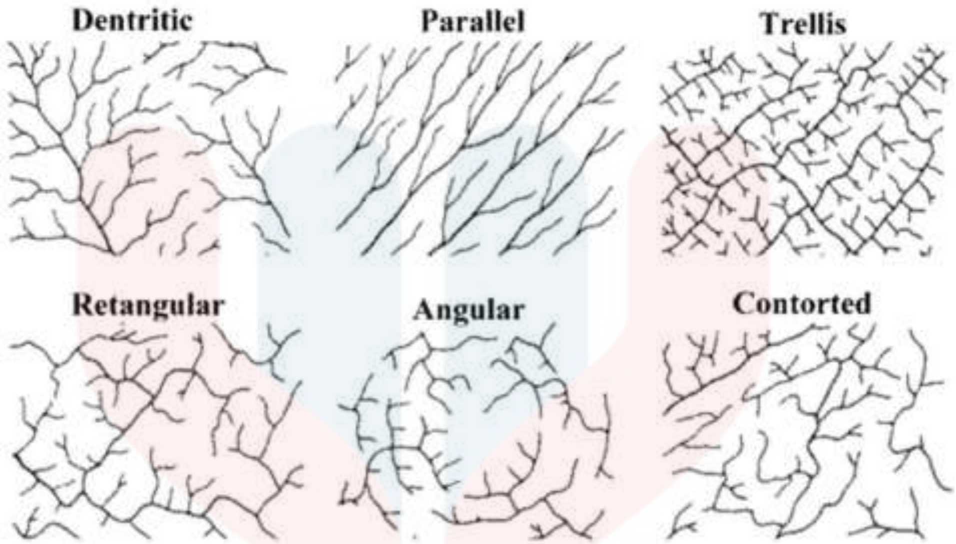

Figure 4.2: Types of drainage pattern.

(Source: William D. Thornbury, 1656)

Based on the Figure 4.3, no main river is present but there are several streams exists and linked to other tributaries like Sungai Gemang, Sungai Keding, Sungai Ayer Putih, Sungai Lanchang, Sungai Buloh and Sungai Ayer Batu Pengas. In addition, in the study region, there are two types of drainage patterns that are dendritic and parallel. Even so, the study area is mostly dominated by dendritic pattern with minor of parallel pattern.

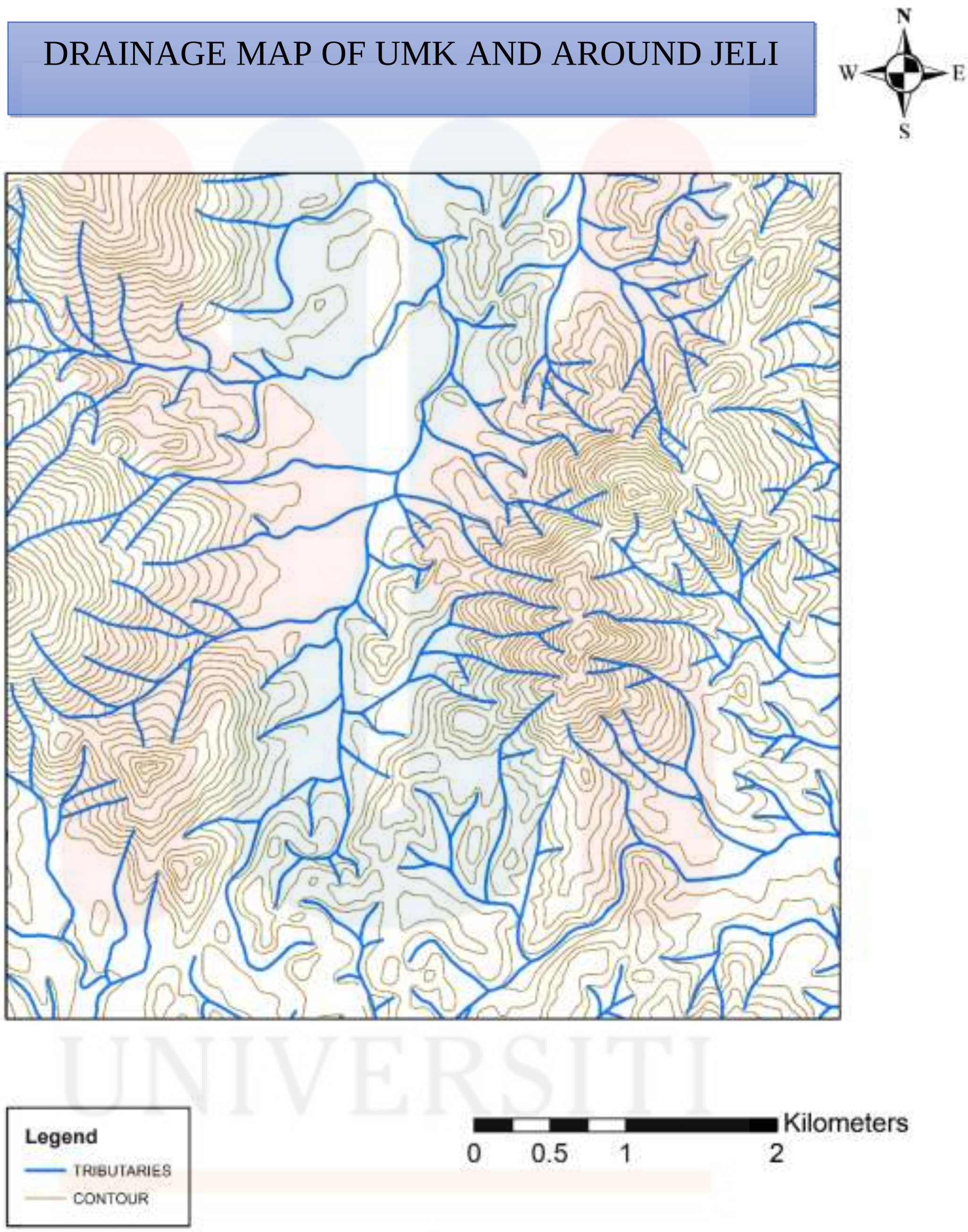

Figure 4.3: Drainage map of study area.

4.2.4 Weathering

Weathering is the breakdown processes that caused by mechanical disintegration and chemical composition that effect on a rock or its mineral. A rock can undergo weathering processes due to exposure of surface area to the lower temperature and pressure on the subsurface of earth. The subsurface of rock will start to decay when contact with water, air or organism. The weathering processes change the physical and chemical properties of rocks origin into soils or smaller pieces of rocks called as sediment. Chemical weathering, biological weathering and physical weathering are three types of weathering. Weathering can weaken and makes rock becomes more permeable, making them more vulnerable on removal of erosion agents and weathered materials that exposes more to the weathering. In general, Malaysia is located on the equator line which receives rainfall and warm climate every year. There are few factors can influence the rate of weathering such as material's properties, climate, chemical composition and surface area. Weathering also can be carried by agents such as water, winds, air, animals, atmosphere and plants.

Physical weathering or known as mechanical weathering is the process of breaking apart rocks and crystals without altering their chemical composition by various processes. This type of weathering mainly caused by several factors such as change of temperature, wind, water and glacial materials. The water plunges through rock holes, freezes and spreads, causing more rock breakdowns. The physical weathering gives effects on a smaller section of the same material that is being weathered without alteration of its chemical composition. Because much of the fracturing happens along mineral borders, physical weathering appears to create more sand-sized sediment and larger grains. Fine grained or finely crystalline rock physical weathering may produce abundant very fine grains, but most of the sediments from these types of rocks consist of rock fragments called lithic clasts. From very fine silts and clays to large boulders and gravel, lithic clasts are developed from physical weathering range in size.

Biological weathering is a type of weathering caused by various living organisms' activities. Biological weathering can lead to the further destruction of rocks and rock particles, along with other weathering forms, by making them more vulnerable to other environmental factors, whether biotic or abiotic factors. The release of acid-forming chemicals from animals and plants can cause weathering and lead to the breaking down of rocks and landforms. When the tree roots seep or expand through the cracks or joints, the roots eventually isolate the rock from the most normal biological weathering. This occurred because it exerted pressure on the rocks as the plants grew, which ultimately set the bulk rock apart.

Table 4.6: Types of weathering based on its grade.

Term	Description	Grade
Fresh Fairly weathered	The obvious sign of material weathering is not present. Discoloration on a surface with substantial discontinuity.	IA IB
Weathered slightly	Discoloration suggests rock material weathering and surface discontinuity. By weathering, all the rock material may be discolored and may be much weaker than its new state.	II
Weathered moderately	Less than half of the rock material is broken down and dissolves into the soil. Either as continuous frame work or as core stones, fresh from discolored rock is present.	III
Weathered highly	Less than half of the substance of the rock is broken down and disintegrates into soil. Either as continuous frame work or as core stones, fresh from decolored rock is present.	IV
Weathered completely	It decomposes and disintegrates all rock material into the soil. The composition of the source mass is largely intact.	V
Residual soil	Everything content from rock is transferred to soil. It kills the VI mass structure and the material fiber. There is a great volume transition, but the soil has not been transported substantially.	VI

(Source: M.S. Paul, 2006)

4.3 Lithostratigraphy

Lithostratigraphy can be defined as the geological science related with the development of strata or rock layers where it can be recognized by the physical characteristics of the rock types. It is possible to assess the relative locations of rock units by considering their geometric and physical relationships, showing which beds are older and which beds are younger. The units can be divided into lithostratigraphic terms according to the hierarchical structure of members, formations, and groups that describe rocks.

Based on the objectives, a geological map of the study region with a scale of 1: 25 000 is produces as shown in the figure. It composed of lithology boundary, stratigraphy column and structural geology of the study region. In the region study, the stratigraphy column for lithology was carried out by referring to the formation that the previous researcher had done. In general, there are two kinds of formation found which are Telong Formation and Kemahang Granite. The Telong Formation is referred to meta-sedimentary rock that identifies as phyllite while the Kemahang Granite is referred to the granite unit in the study area. Each lithology unit was then described and discussed in detail, starting with the oldest rock in the strata and followed by the youngest rock units.

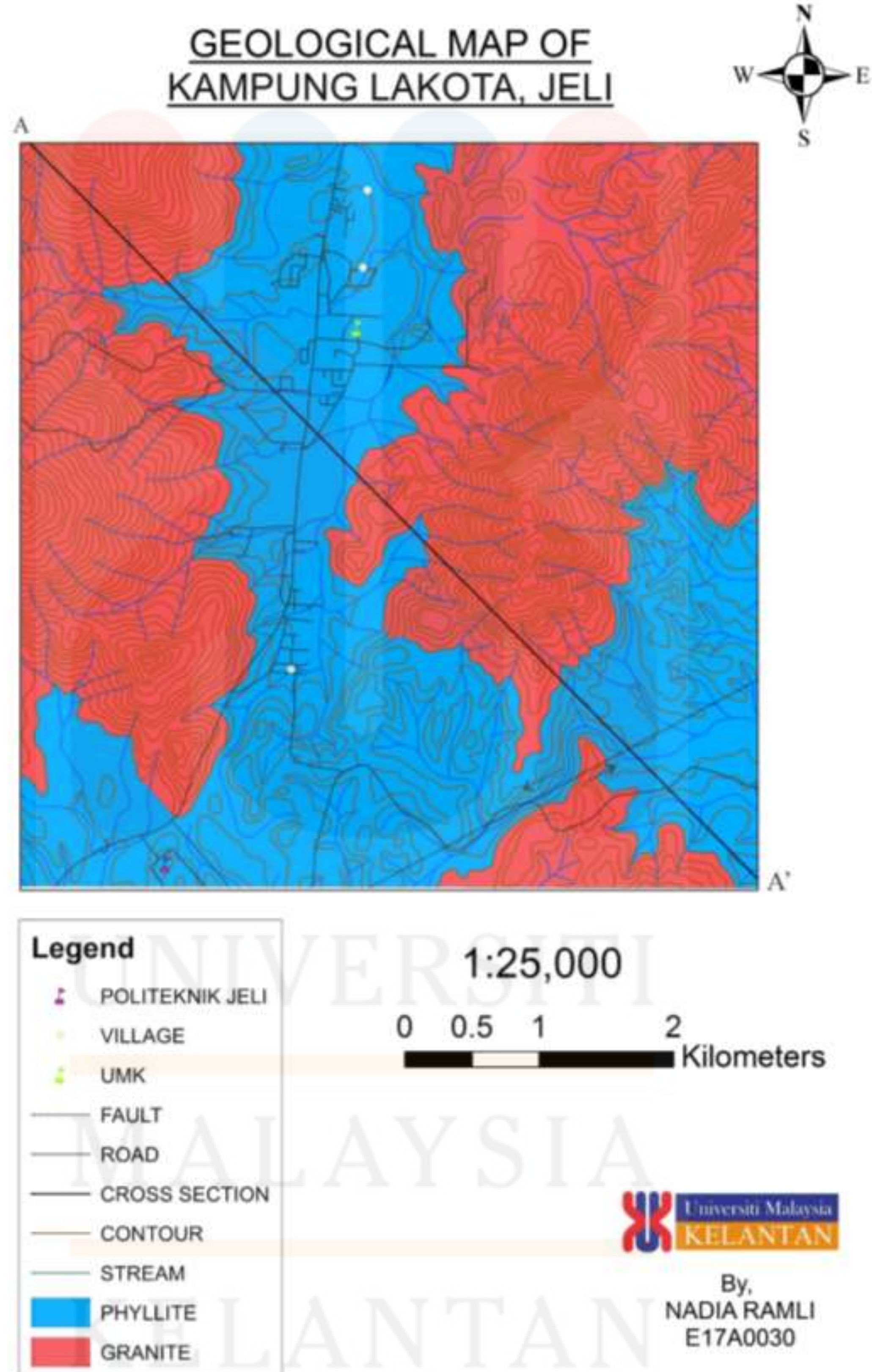

Figure 4.4: Geological map of study area.

4.3.1 Stratigraphic position

Era	Period	Lithology
Mesozoic	Triassic	Granite
Paleozoic	Permian	Phyllite

Figure 4.5: Stratigraphic column for study area.

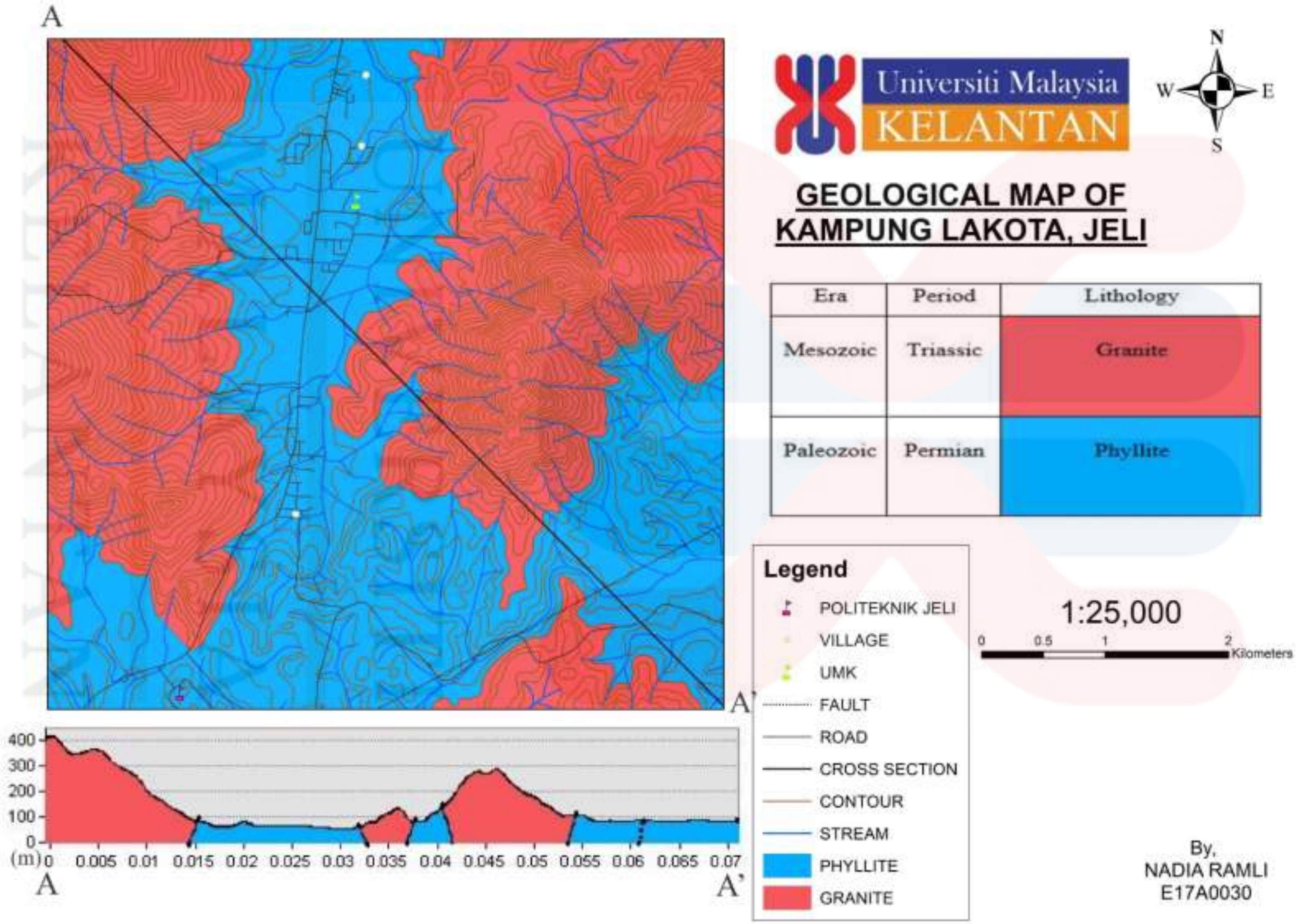

Figure 4 6: Geology and lithology map of study area

4.3.2 Unit explanation

A. Phyllite unit

Based on the study area, in the central region of map there are about 50% of the map is covered by meta-sedimentary rock. The meta-sedimentary rock is formed from deposited sediment that undergo solidification process with influenced of high temperature and pressure. The high pressure and temperature are subjected to the buried sedimentary rock beneath the earth forming meta-sedimentary rock. The type of meta-sedimentary rock that can be identified is referred as phyllite due to its low metamorphism in metamorphic facies.

Figure 4.7: Hand specimen of phyllite unit

(Source: Nur Fatin Idayu bt Ismail, 2019)

Figure 4.7 above shows hand specimen of phyllite unit. Based on the figure, it can be seen that the phyllite consists of phyllite sheen texture on its surface. The observation is made based on the presence of micas that shows a sheet-like structure. The composition of phyllite mineral is such as quartz, plagioclase, muscovite and biotite. This phyllite unit is found at outcrop of coordinate N 05˚ 43’ 55’’ and E 101˚ 51’ 17.5’’.

B. Granite unit

The geological map of the study area consists granite unit that covers approximately about 50% of the study area located at the East and West side. Granite is one of the igneous rocks that usually exposed and more dominant in the ground's surface. The formation of granite is coming from the partial melting of magma conditions with pre-existing rock below the earth's surface located at the mantle or the core followed by cooling and solidification process. There are two conditions of granite under solidification process which are intrusive igneous rock located below the earth surface while extrusive igneous rock is located at the surface of the earth. The condition characteristics between intrusive and extrusive igneous is different based on its characteristics.

Figure 4.8: Hand specimen of granite unit

(Source: Nur Fatin Idayu bt Ismail, 2019)

Figure 4.8 shows hand specimen of granite unit at outcrop with coordinate of N 05˚ 43’ 37’’ and E 101˚ 52’ 2.03’’. All of the granite in the study area is formed from the intrusion state and considered as younger rock unit that formed during Triassic Period.

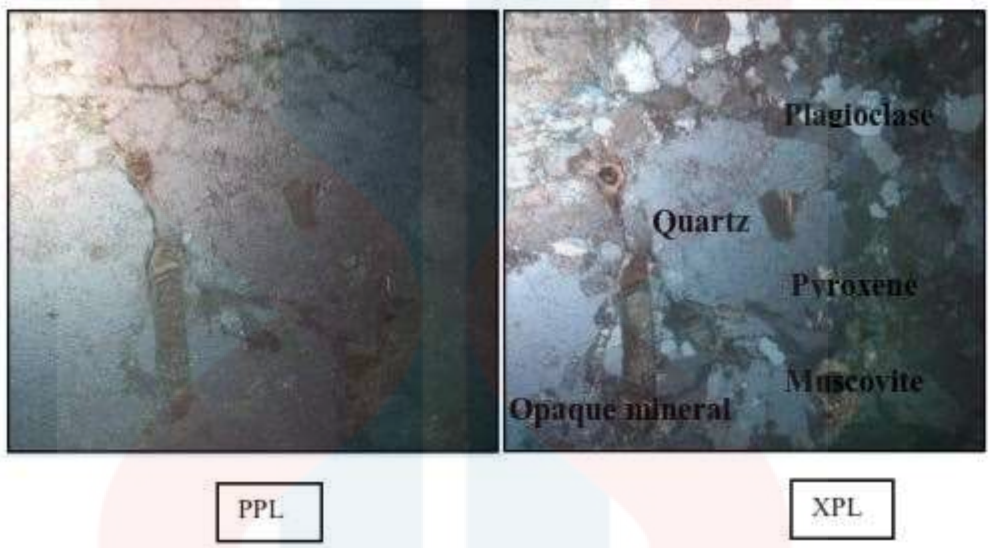

Figure 4.9: Thin section of granite unit under PPL and XPL

(Source: Nur Fatin Idayu bt Ismail, 2019)

Table 4.7: Mineral composition of granite

Microscopic: Contain plagioclase, muscovite with minor pyroxene and opaque mineral Quartz mineral as major mineral		
Description of mineralogy		
Composition of mineral	Amount (%)	Description of optical mineralogy (Magnification 4X)
• Quartz	50	Colorless under PPL, low relief XPL: white
• Plagioclase	20	Twinning present, low relief
• Pyroxene	5	Colorless under PPL, brownish under XPL
• Opaque mineral	5	Cannot transmit light under PPL
• Muscovite	20	Medium relief, medium birefringence

(Source: Nur Fatin Idayu bt Ismail, 2019)

4.4 Structural Geology

According to definition, structural geology is the study of the three-dimensional distribution of rock units, surface areas and internal structure in terms of their histories of deformation, historical geological conditions and events that have led to the occurrence of deformation. All of these can be dated and determine when the structural features are formed. The main purpose of studying structural geology is to determine the deformation that occur is due to stress and strain based on its measurements. The measurements involve usually lineament analysis, folding analysis, faulting analysis and joint analysis.

4.4.1 Fault

A fault is a single fracture or a rupture zone in the crust of the Earth along parallel movement to the fracture or zone has taken place. This occurs because of the forces from plate tectonics acting on the surface of the Earth which then make the fault line align to the ground surface with a fault plane. Generally, there are three types of faults are strike-slip faults, ordinary faults and thrust faults that develops from different type of stress conditions. A fault can be resulted from various forces pushing or pulling on the crust and causing the rocks to slip up down or slide past each other.

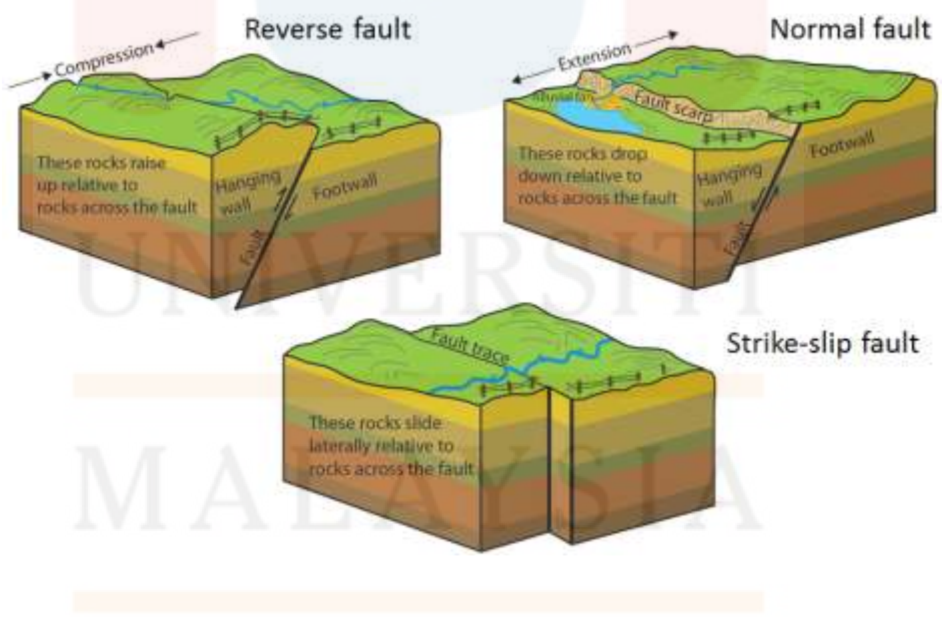

Figure 4.10: Types of fault.

(Source: Steven Earle, 2020)

4.4.2 Lineament analysis

Lineaments can be defined as any linear features that can be found on topographic map that gives the details on the geological structure underlying them. Lineament is one of the most critical features displaying elements of the subsurface or structural weakness, such as faults, and is usually extracted from enhanced image data visual analysis. The structural lineament can typically appear as a fault-aligned valley, a fault plane, fold-aligned hills, a straight coastline, or a combination of these characteristics. Besides that, an igneous intrusion such as dykes can also classified as structural lineaments. In geological or topographic maps, lineaments can be identified through aerial or satellite photograph.

Table 4.8: Lineament reading for study area.

110˚	92˚	20˚	70˚	75˚
130˚	50˚	105˚	63˚	40˚
170˚	145˚	45˚	170˚	91˚
160˚	140˚	120˚	140˚	65˚
30˚	120˚	100˚	110˚	38˚
30˚	91˚	115˚	12˚	60˚
60˚	110˚	62˚	105˚	40˚
60˚	130˚	65˚	120˚	50˚
8˚	178˚	170˚	95˚	88˚

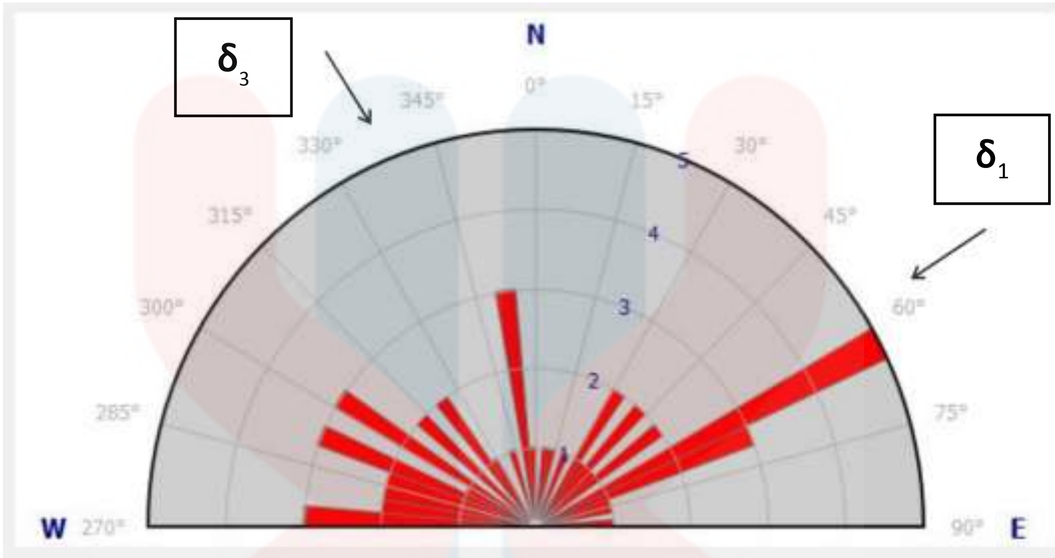

Figure 4.11: Rose diagram for lineament analysis in the study area.

Figure 4.11 above shows a rose diagram for lineament analysis in the study area. From the Figure 4.11 above, it can be observed that the most orientation is lies on sigma 1 which means that the major force is coming from the NE direction. For the sigma 3, it presents the weak force in the study area at NW direction.

To conclude, the lineament analysis in the study area shows that the principle force is mostly from the Northeast direction. Form the observation, it can be said that the most force gives high pressure to the rock that makes it break apart and forming fracture or joint or fault. The fault in this study area is name as sinistral strike slip fault due to the rock is slide laterally across the forces.

4.5 Historical Geology

The historical geology of study area begins in Carbonaceous-Permian Period, where the formation of metamorphic rock in the region because of the high grade of metamorphism phase. In order to achieve the high grade of metamorphism phase, a high temperature and pressure is needed to form the rock. In Permian Period, a low grade of metamorphism process occurs forming meta-sedimentary rock. Under constant pressure and temperature, the rocks formed may be changes in order to achieve their equilibrium. The metamorphism process then results in the formation of phyllite that categorized under Telong Formation.

During the Tertiary Period, an intrusion of acidic magma intruded beneath the study area and created granite intrusion. The granite intrudes in the pre-existing of metamorphic rock forming an orthogenesis derived from the granite. A migmatite rock is formed as the result of the granite intrusion which comes from the combination of igneous and metamorphic rock. The structure of dykes also can be identified from the crack and fracture formed during the intrusion of magma at origin granite rock that exposed to the surface. Lastly, a few structural geologies can be identified in the study area and recognized as the sinistral and dextral strike slip fault, folds and quartz vein.

CHAPTER 5

ELECTRICAL RESISTIVITY IMAGING (ERI)

5.1 Introduction

This chapter generally cover about the result of groundwater potential in hard rock using resistivity method (ERI). The interpretation of each lines is based on the software such as RES2DINV and ABEM Terrameter LS Toolbox. For this research, there are four survey line of Schlumberger configuration that had been done to classify the possible groundwater present in the region of the analysis with 200 meters spread line and 41 electrodes with 5 meters spacing each.

Nowadays, Electrical Resistivity Method (ERI) had been widely used especially in groundwater exploration in order to determine the subsurface conditions through the measuring ground surface. A result of 2D electrical resistivity imaging (ERI) pseudo section is used to classify the potential groundwater in the region of the analysis, based on the apparent resistivity value of ground surface materials.

The interpretation of each line is made based on its geomorphology, lithology and hydrogeologic of subsurface conditions. Based on (M.A.M. Ashraf et al., 2018), it is possible to achieve a hydrogeological characterization of sedimentary formation by defining its collection of aquifer parameters, such as aquifer thickness, extent, and hydraulic conductivity. The presence of a geological fracture zone helps to create a medium for groundwater conduits and to accumulate groundwater. Electrical resistivity method is suitable used for vulnerability studies. This is due to its low resistivity indicated less permeable formations while high resistivity indicated sand permeable formations. The results and interpretation of all resistivity survey that conducted in the study area are explained and discussed in detail.

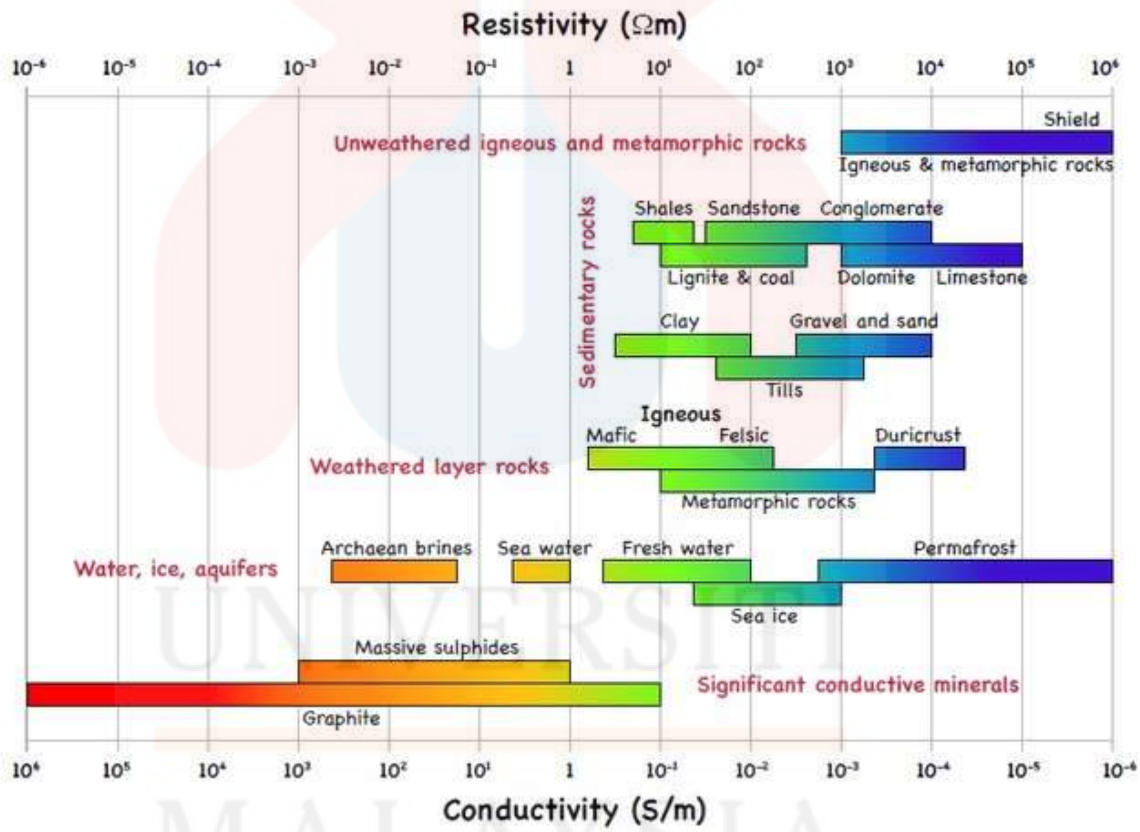

Figure 5.1: Standard resistivity values and conductivity values.

(Source: Yeomans, 2011)

5.2 Location of Resistivity Survey

Four survey line were conducted in different part of UMK Jeli which covers the area of fish pond at Agropark. Figure 5.2 shows location of all survey line and the direction that had been conducted in UMK Jeli in Google Earth images. The survey line is conducted in the morning until evening of 19th November 2020.

The resistivity data that obtained from ABEM Terrameter LS is processed using RES2DINV software. The interpretation of all survey line is made based on the previous literature review of resistivity scale that had been done by other researchers. The earth materials of subsurface conditions resistivity values are done by comparing the resistivity values of earth materials with induced polarization (IP) values that stated from previous researchers. In order to identifying the potential groundwater in granitic hard rock, a comparison between resistivity values and IP values are done.

Figure 5.2: Specification map of all survey line at UMK, Jeli.

(Source: Google Earth image, 2020)

5.3 Result

5.3.1 Line Survey 1

For line survey 1, the length of the survey is 200-meter length with 5 meters of electrode spacing. The type of configuration is Schlumberger. Table 5.1 shows the coordinate of electrode number 1, 21 and 41 that located at the first electrode, middle electrode and last electrode. The line survey is in NE-SW direction.

Table 5.5: Coordinate for Line 1.

Electrode number	Coordinate	Elevation (m)
1	N 05˚ 44’ 47.3’’ E 101˚ 52’ 04.8’’	51
21	N 05˚ 44’ 50.5’’ E 101˚ 52’ 05.5’’	49
41	N 05˚ 44’ 53.8’’ E 101˚ 52’ 06.3’’	47

The line survey is conducted in an open area of fish pond of Agropark area in UMK. The line survey is set up for 200-meter length in the direction of SW-NE between the fish pond. The line survey is started at 9 a.m. (19th November 2020) and the weather is bright and clear. The interpretation is made based on the values of resistivity and chargeability that shown in the pseudo section.

Based on the resistivity and chargeability analysis from Figure 5.4 below, an interpretation of resistivity values can be made. The range of resistivity value from low resistivity to high resistivity are started from 0 Ωm to approximately 3000 Ωm that represented with color from dark blue to dark purple. The chargeability values range from 0.00 msec to approximately 140 msec. The depth of pseudo sections is 35meter from the surface. The root-mean-squares (RMS) errors that observed for line survey 1 in the inverse resistivity pseudo section is 2.5% while for inverse model of chargeability section is 0.0030%.

From the resistivity pseudo section survey line 1, it can be categorized into low resistivity values, medium resistivity values and high resistivity values. The values with high resistivity are around 800 Ωm to 3000 Ωm. The high resistivity values are shown at the bottom of the pseudo section models that represented by brownish orange to light red color. Thus, this is understood to be the fresh granite bedrock. The higher resistivity values mean that the material in the subsurface have less ability to conduct electricity. So, it can be assumed that the higher resistivity values region for line survey 1 have lower ability to conduct electricity. The medium resistivity values can be classified from 200 Ωm to 700 Ωm that represented by from light blue to green and yellow color with the distribution is at the middle layer of the pseudo sections. This section can be interpreted as residual soil with weathered bedrock or loose material that contain high possibility of groundwater potential. Low resistivity values that shown at the top layer of model section have resistivity values less than 200 Ωm. It is represented by dark blue color in the pseudo section. The area can be interpreted as groundwater potential or surface water area. For chargeability pseudo section, it shows that low chargeability which meaning the potential of groundwater is higher in the area.

Figure 5.3: Set up for line survey 1

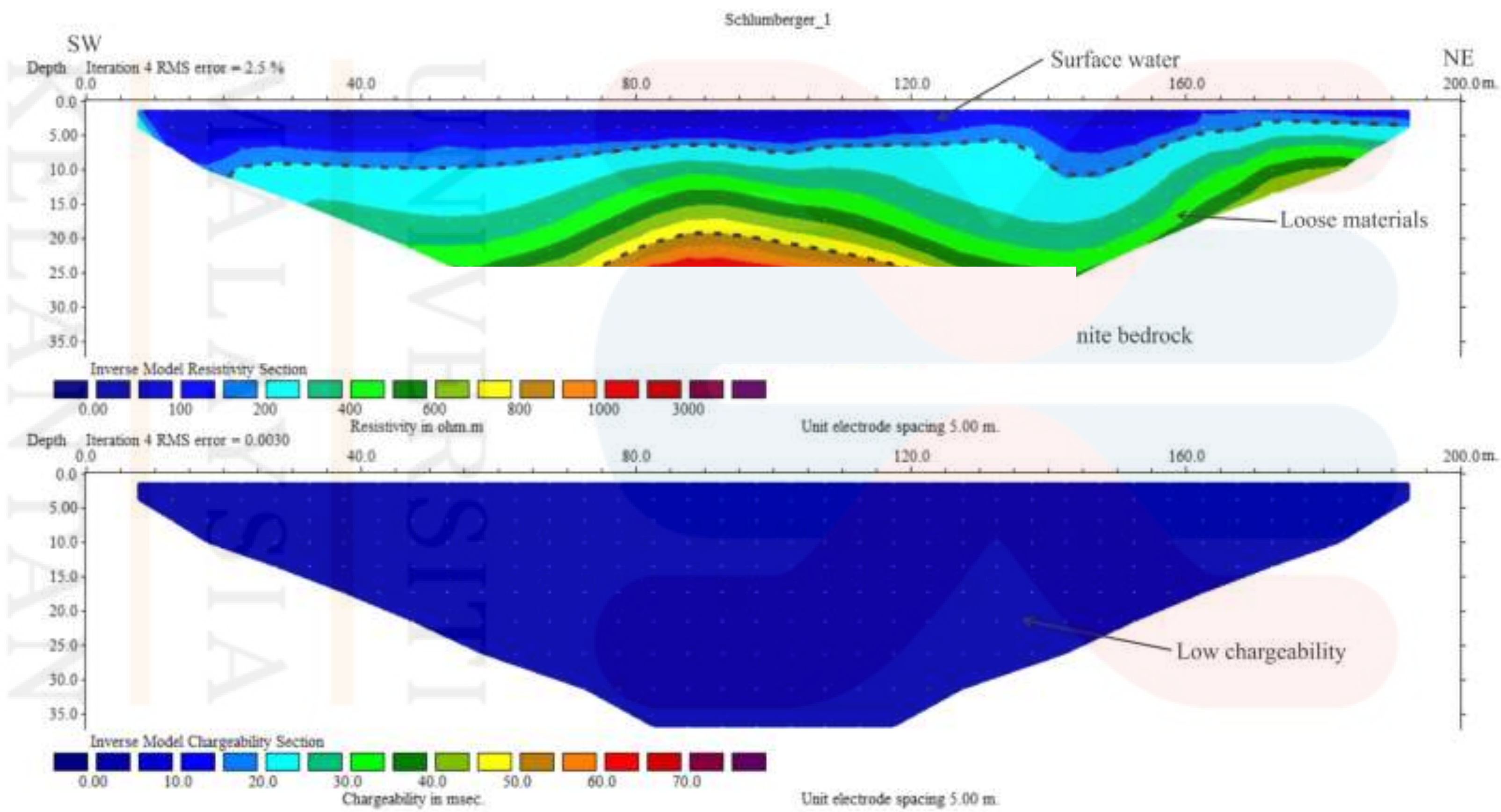

Figure 5.4: Resistivity and chargeability values for survey line 1

5.3.2 Line Survey 2

For survey line 2, the length of the survey line is 200 meters, with electrode spacing of 5 meters. The array type used is the configuration of the Schlumberger array. Table 5.2 below shows the coordinate electrode for number 1, 21 and 41 that located at the first electrode, middle electrode and last electrode. The line survey is at the SW-NE directions.

Table 5.6: Coordinate for line survey 2.

Electrode number	Coordinate	Elevation (m)
1	N 05˚ 44' 46.9'' E 101˚ 52' 01.3''	42
21	N 05˚ 44' 47.8'' E 101˚ 52' 04.4''	44
41	N 05˚ 44' 48.1'' E 101˚ 52' 7.70''	49

Based on the Figure 5.6 below, a resistivity pseudo section and chargeability model section for line 2 is shown with the range of resistivity pseudo section is between 0 Ωm to 4000 Ωm that represented by color of dark blue to light red with the chargeability values is from 0.00 msec to 60.0 msec. The root-mean-square (RMS) for the resistivity pseudo section is 3.0% and for the chargeability section is 2.8%.

From the resistivity pseudo section below, it can be categorized into low resistivity values, medium resistivity values and high resistivity values. The high resistivity values are range from 800 Ωm to 4000 Ωm represented by brownish orange to dark purple color. The high resistivity area can be interpreted as the granite bedrock that have less ability to conduct electric. For the medium resistivity values, the values are 150 Ωm to 700 Ωm. The medium resistivity values region is distributed in the center of pseudo section with the depth about 35.0 meter from the surface area. It can be interpreted as loose material with high possibility of groundwater potential. For low resistivity values, it is less than 150 Ωm that represented by dark blue color and located at depth of 10 meters from the surface is interpreted as the surface water. At depth 15 meters, the low resistivity values can be interpreted as the groundwater potential area. For the chargeability sections, it can be categorized into two which is low chargeability and high chargeability. For low chargeability, the values are less than 5 msec and interpreted as the fractured rock contain fresh water. For high chargeability values the range is between 20.0 msec to 60.0 msec and interpreted as the fresh solid rock zone.

Figure 5.5: Set up for line survey 2

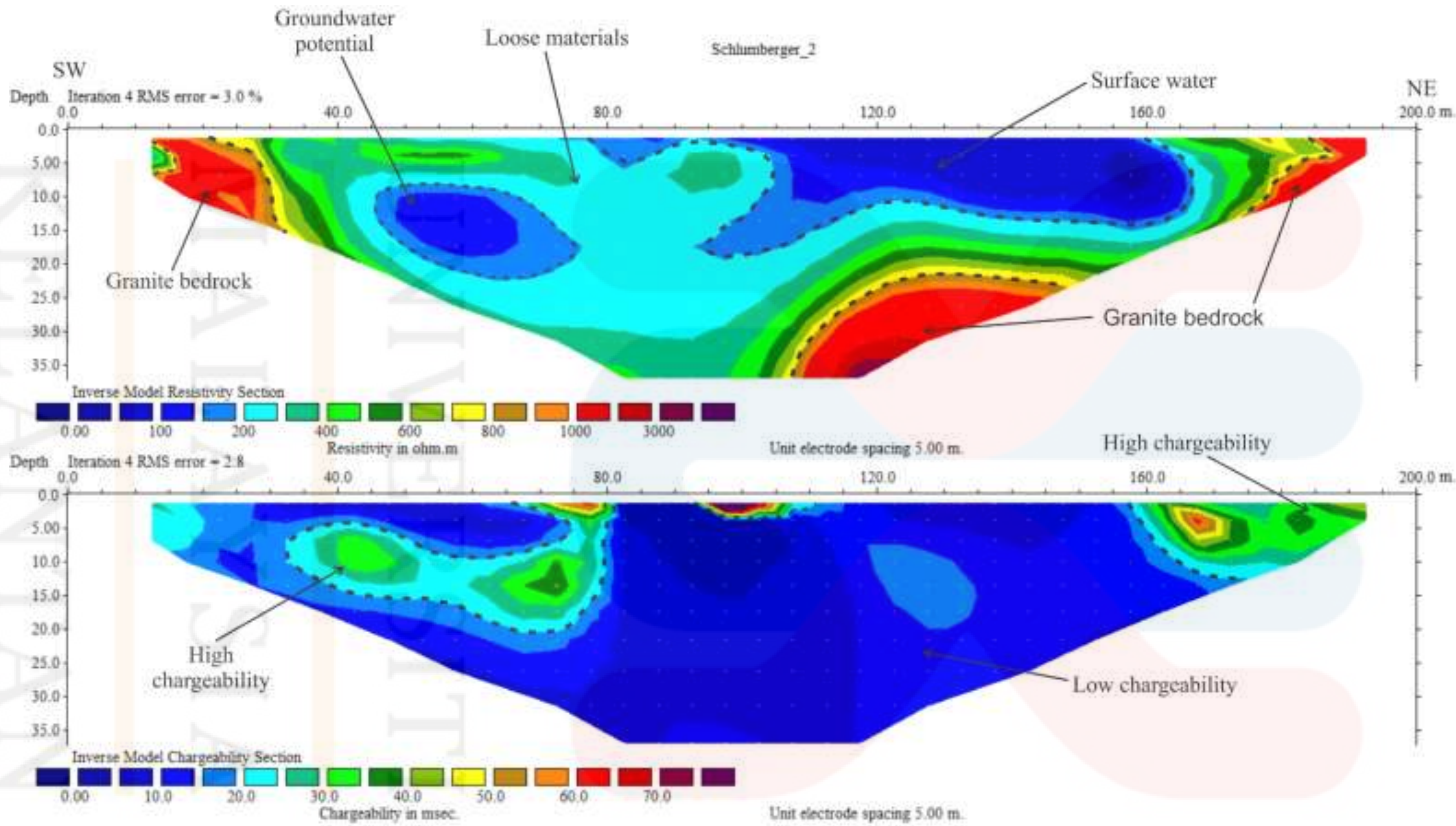

Figure 5.6: Resistivity and chargeability values for survey line 2

5.3.3 Line Survey 3

For survey line 3, the length of the survey line is 200 meters, with electrode spacing of 5 meters. The array type used is the configuration of the Schlumberger array. Table 5.3 below shows the coordinate electrode for number 1, 21 and 41 that located at the first electrode, middle electrode and last electrode. The direction of the survey is at SE-NE direction.

Table 5.7: Coordinate for line survey 3.

Electrode number	Coordinate	Elevation (m)
1	N 05˚ 44’ 47.66’’ E 101˚ 52’ 7.44’’	65
21	N 05˚ 44’ 50.75’’ E 101˚ 52’ 8.14’’	63
41	N 05˚ 44’ 53.69’’ E 101˚ 52’ 8.79’’	60

Figure 5.8 shows the resistivity values and chargeability values for line survey 3 with range of resistivity values is between 600 Ωm to 4000 Ωm that represented by green to dark purple color. The depth of the investigation is 35 meters from the surface area. The root-mean-squares (RMS) observed for resistivity pseudo section is 4.0% and for chargeability values is less than the resistivity pseudo section which is 1.6%.

From the resistivity model section, there are high resistivity values and medium resistivity values that can be identified. The values of high resistivity are range from 1000 Ωm to 4000 Ωm. The values for high resistivity can be seen dominated whole of model section that represented by brownish orange to dark purple color. It can be identified as hard rock granite layer. The higher resistivity values usually indicated the area or materials in the subsurface have less ability to conduct electricity. For chargeability sections, there are low and high chargeability. For low chargeability values, it ranges less than 10 msec and can be interpreted as the fractured area with fresh water content represented by dark blue color. For high chargeability values, the range is between 20 msec to 40 msec and interpreted as the clay material area represented by green to yellow color.

Figure 5.7: Set up for line survey 3

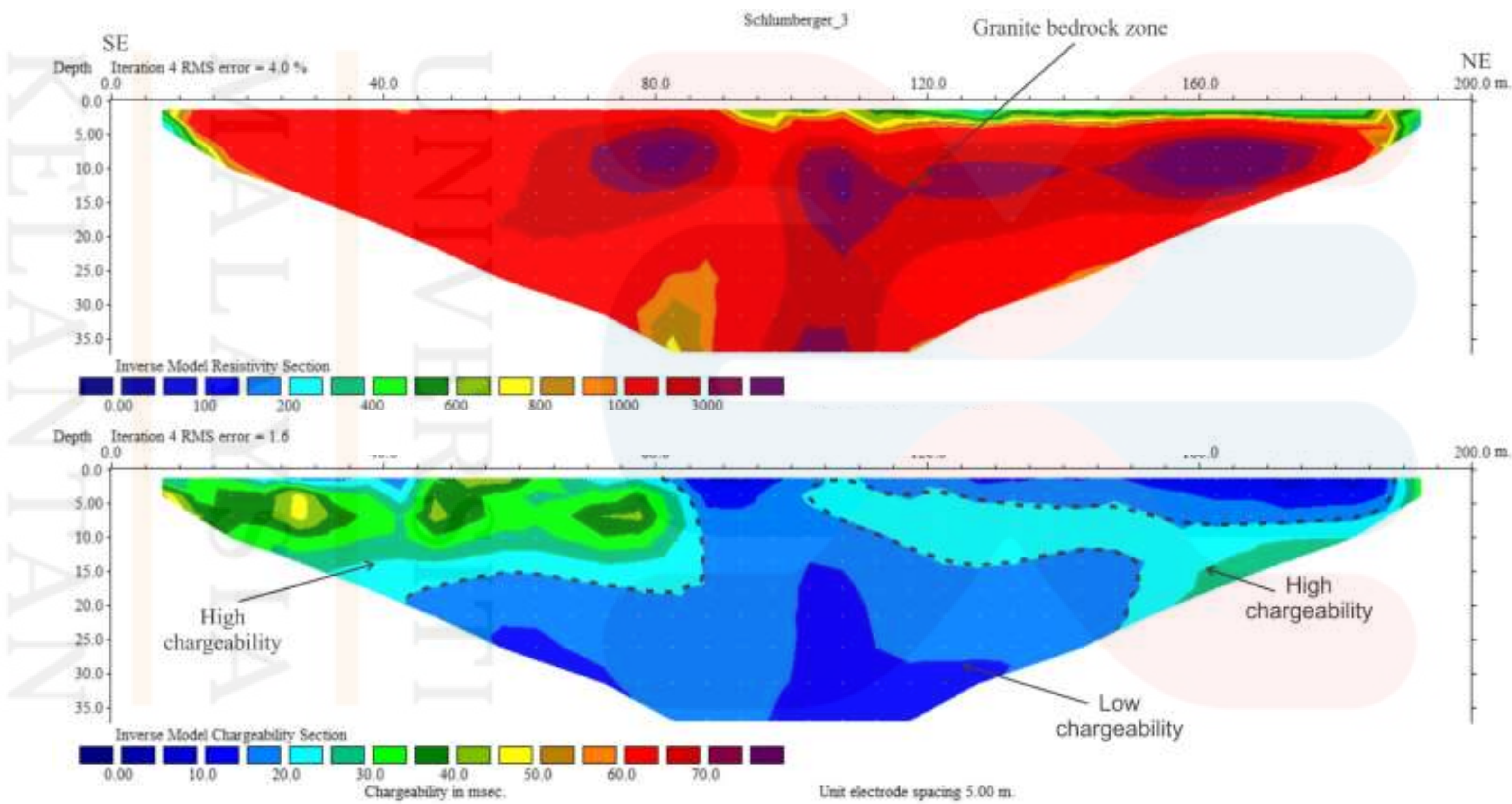

Figure 5.8: Resistivity values and chargeability values for line survey 3.

5.3.4 Line Survey 4

For survey line 4, the length of the survey line is 200 meters, with electrode spacing of 5 meters. The array type used is the configuration of the Schlumberger array. Table 5.4 below shows the coordinate electrode for number 1, 21 and 41 that located at the first electrode, middle electrode and last electrode. The direction of survey line is located at WN-NE direction.

Table 5.8: Coordinate of line survey 4.

Electrode number	Coordinate	Elevation (m)
1	N 05˚ 44’ 53.10’’ E 101˚ 52’ 3.53’’	51
21	N 05˚ 44’ 52.33’’ E 101˚ 52’ 6.73’’	54
41	N 05˚ 44’ 51.55’’ E 101˚ 52’ 9.79’’	72

Figure 5.10 showed a resistivity values and chargeability values of pseudo section for line 4 in the line survey area. The range for this line survey is from 0 Ωm to 4000 Ωm that represented by dark blue to dark purple color in the pseudo section. The depth of pseudo section is 35 meters depth from the surface layer. The root-mean-squares (RMS) for the resistivity values is 4.0% and for chargeability values inverse models is 1.6%, less than the RMS error for resistivity values.

From the resistivity values model section, it can be categorized into low resistivity value, medium resistivity values and high resistivity values. The higher resistivity values are shown in the right part of the model section with depth of 35 meters from surface layer. The values of high resistivity are range from 800 Ωm to 4000 Ωm represented by brownish orange to dark purple color. It can be interpreted as the granite bedrock. The high resistivity values indicate that the material in the subsurface have low ability to conduct electricity. For medium resistivity values, the range is from 200 Ωm to 700 Ωm that represented by light blue to yellow color. It is dominantly distributed from the left to the central part of the model sections with the depth is various up to 35 meters from the surface layer. The values of medium resistivity can be described as the loose material and weathered rock with potential of groundwater. Lastly, the low resistivity values are range less than 100 Ωm represented by dark blue color that located at the center of the pseudo section is interpreted as groundwater potential area while at the surface area it is interpreted as the surface water area. For chargeability values, it is divided into two which are low chargeability and high chargeability. For low chargeability the range is less than 10 msec represented by dark blue color. It can be interpreted as the fractured area with fresh water. For high chargeability, it ranges between 20 msec to 50 msec represented by light blue to yellow color. The area can be interpreted as the fractured area with clay materials content.

Figure 5.9: Set up for line survey 4

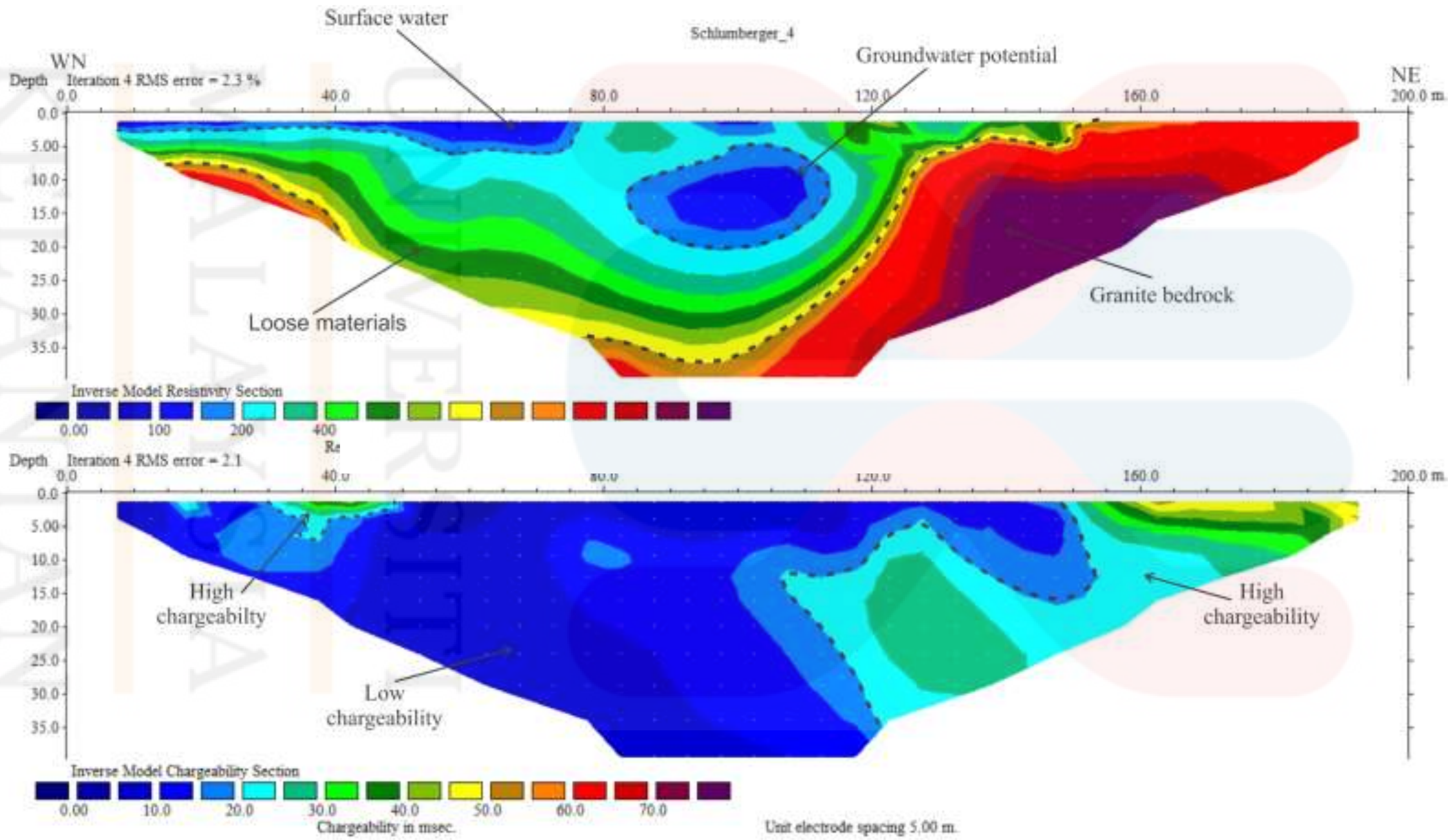

Figure 5.10: Resistivity values and chargeability values for line survey 4.

5.4 Discussion

Most of the study area is covered by granitic rock, particularly in the UMK region, which all of the line survey consists of granite as its bedrock. In the pore spaces and fractures in the rock, groundwater may accumulate. This can be measured by comparing the reading between the values of resistivity and chargeability values. The chargeability value of 1 msec to 2 msec suggested the groundwater value. In order to indicate the presence of groundwater, resistivity values and chargeability values were compared to each other on the basis of the interpretation of the entire survey line. When the resistivity values are high, thus there is low conductivity. This resistivity referred to the capacity of the material to oppose the electrical current flow, while the conductivity referred to the capacity to conduct the electrical current.

The results showed that, based on the resistivity value of the high resistivity region, the medium resistivity area and the lower resistivity area, the study area consists of three resistivity classes based on the electrical resistivity system that operates in the study area. The high resistivity range consists of the resistivity range from 2000 Ωm to more than 5000 Ωm, the hard rock was portrayed by a color of light red to dark purple. The medium resistivity area consists of the resistivity value range from 300 Ωm to 900 Ωm indicating the color between green to brown and weathered granite and residual soil in this zone. For low resistivity values it ranges less than 200 Ωm that represented by dark blue color.

From all the line survey at the study area, the interpretation from resistivity values shows there is a present of groundwater potential in the site area. All the survey line 1, 2, 3, and 4 have groundwater potential when compared the resistivity values and chargeability values. From all the survey line, the water can be assumed existed in formed of confined aquifer as its overlain by hard layer. The survey line 1 have potential groundwater at depth approximately 20 meters from the subsurface while survey line 2 have groundwater potential between 20 meters to 35 meters depth from the surface layer and at the left part of the section model at depth 15 meter from surface layer. For survey line 3, the groundwater potential is estimated at the whole section model with 35 meters depth from the surface layer. Lastly, for line survey 4, the majority of groundwater capacity is in the correct portion of the model section at survey line of 160 meters to 200 meters with depth of 35 meters from the surface layer.

Factor such as weather condition should be considered since resistivity survey is not suitable conducted during rainy days. The survey should be conducted properly in order to get accurate interpretation for the result. When a heavy rainfall present in the site survey, water from the rainfall will be absorbed in soil which will lead t the increase of soil moisture within the soil. This will impact the reading of the resistivity reading as one of the most dominant variables regulating the distribution of resistivity is the soil moisture content. Therefore, prior to running the survey line, the correct timing and weathering should be properly considered. Also, the variables that need to be considered when running the survey line are geomorphology, lithology and structural geology. Geomorphology such as river or pond, while lithology such as granite presented by the fracture is related to groundwater occurrence.

5.5 Conclusion

To conclude, the geophysical approach is the best way to assess the capacity of groundwater in the subsurface region. Geophysical method also is easy to handle and the cost is much cheaper compared to borehole. The survey site consists of groundwater potential depending on the interpretation of model section of each line. For this study, a Schlumberger configuration is used in order to determine groundwater potential in hard rock. The interpretation is made based on the resistivity values reading and the chargeability values reading in the model sections. When a resistivity values increasing and the chargeability values decreasing, it can be interpreted as groundwater potential present in that area. The most groundwater potential in hard rock present is in line survey 3 followed by survey line 4 and the less groundwater potential present in hard rock is survey line 2.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This chapter will cover the part of conclusion and all of the result obtained from the study area and site survey based on its interpretation from geological map and geophysical method using resistivity techniques. Generally, there are two units of lithology in the study area that can be identify based on interpretation of geological map which are granite and metasedimentary rock. The lithology is distributed in the different location on the study area. The granite unit is distributed on the west-east of the study area and covers about 50% of the total area of study area. The granite unit is from Mesozoic Era and Triassic Period that consist of foliated granite, coarse-grained granite and microgranite. Lastly, metasedimentary unit that covers about 50% of the study area. The metasedimentary unit formed from Paleozoic Era and Permian Period that consist of argillite which is a low-grade metasedimentary rock under metamorphism processes.

Stratigraphy column of the area of study developed on the basis of rock lithology correlation with previous researchers. Granite is the oldest unit of rock listed in the research field during Carbonaceous-Permian under the Taku Schist Formation and meta-sedimentary rock is from the Telong formation during the Permian Period. The tectonic events that have occurred in the past can be understood based on the present of different structural geology in the study area. In the study region, geomorphology consisted mainly of the hilly area covered in the eastern and western parts, while the flat area covered in the middle of the study area. The drainage pattern that can be found in the study region consists mainly of a dendritic and sub-rectangular pattern.

Based on the interpretation of geophysical method using electrical resistivity, it can be assumed that the study area consists of groundwater potential that showed in all line survey. Survey line 1 has potential groundwater at a depth of 20 meters, while survey line 2 has groundwater potential at a depth of 20 meters to 35 meters from the surface layer and 15 meters from the surface layer on the left side of the model for the segment. The groundwater potential for survey line 3 is measured at a depth of 35 meters from the surface layer. Finally, for line survey 4, the capacity for groundwater is 160 meters to 200 meters in depth, 35. meters from the surface layer.

6.2 Recommendation

For the purposes of the recommendation, the potential of groundwater is located in the UMK Agropark. For the further analysis, the student is recommended to assess water quality in the presence of groundwater potential in UMK using suitable methods such as pumping testing. It was shown based on the outcome obtained from the ERI survey process. The potential for groundwater can be found at levels ranging from depths of 20 m to 50 m in various locations. However, as the water often stored in the fractured zone, the amount of water cannot be predicted and drilling method is needed to estimate the amount of water in the fractured zone. By using more comprehensive subsurface investigations such as logging and pumping tests, vertical electrical sounding and horizontal profiling geophysical surveys, it is also suggested that the student locate groundwater sources in another section of the study area.

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