GEOLOGY AND EVALUATION OF GROUNDWATER SOURCES USING ELECTRICAL RESISTIVITY IMAGING (ERI) IN LOJING, GUA MUSANG

by

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

FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN

2020

DECLARATION

I declare that this thesis entitled “Geology and Evaluation of Groundwater Sources Using Electrical Resistivity Imaging (ERI) in Lojing, Gua Musang” is the results of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

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Date :

APPROVAL

"I hereby declare that I have read this thesis entitled "Geology and Evaluation of Groundwater Sources Using Electrical Resistivity Imaging (ERI) in Lojing, Gua Musang" and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Applied Science (Geoscience) with Honours"

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Date	: ………………………………..

ACKNOWLEDGEMENT

In the name of God the Most Gracious and the Most Merciful

I would like to dedicate my gratitude to my current supervisor Dr Noorzamzarina binti Sulaiman and also my previous supervisor Madam 'Ainaa' Mardhiyah binti Hassin for the guidance and advices given throughout my thesis journey. I would also delighted to give my most appreciation to Pak Arham, Sir Syakir and lab assistant, Cik Din for assisting me with my mapping activity and my specification .

Most special thanks and appreciation goes to Nur Syafiqa binti Mohd Sabari, Thilageswaran a/l M.Velu, Muhammad Khairul Hakim bin Helmi, Nur Alya Shalina binti Ross Kenedy, Luqman Hakim Al-Hafiz bin Saari, Muhammad Amir bin Mat Nuri and Muhammad Afif Aflah bin Mohd Yusri for their helps throughout the 3 weeks of mapping in term of physical and mental until I can complete my mapping to the end.

Not forget also to my ERI team Anis Syahira binti Mohd Mozli , Athirah binti Tariq Umar, Aimie Aisyah binti Othman, Muhammad Khairul Hakim bin Helmi, Thilageswaran a/l M.Velu, Nariendiran a/l Mohan and Ahmad Shafie bin Kamarin that has help me a lot in completing my specification from taking the data at field until processing data.

Last but not least, I also owe my deepest gratitude to my family especially my mother and father for all their endless help and support they have given to me in the term of moral support and financial support. A huge appreciation to all my classmates who have always been my strength throughout the four years of study in Universiti Malaysia Kelantan and also thank you to who directly and indirectly has help me throughout my final year project journey. Thank you very much.

GEOLOGY AND EVALUATION OF GROUNDWATER SOURCES USING ELECTRICAL RESISTIVITY IMAGING (ERI) IN LOJING, GUA MUSANG

ABSTRACT

Lithology of the study area is metamorphic rock which is schist and the parent rock for schist is sedimentary rock. Schist has a characteristic that not suitable for groundwater accumulation between grains, therefore the groundwater may located at the fracture zone. Based on the lithology, this final year project has been conducted to evaluate the possibility of groundwater existence using Electrical Resistivity Imaging (ERI) method. In Kelantan, it used both groundwater and surface water treatment as their main resources for daily uses. However, continuous extraction of groundwater can causes depletion and continuous contamination of river can reduce the quality of water treatment. Therefore, new sources of groundwater is needed to support the water storage. To determine the potential of groundwater in the study area, a geophysical survey using Electrical Resistivity Imaging (ERI) method has been conducted. Based on the results of the ERI, the study area is a high potential of groundwater that located in the subsurface. ERI results shows that the subsurface consist of low resistivity material such sedimentary that can store groundwater in a large volume. As a conclusion, the lithology of this study area can be a zone for groundwater accumulation.

GEOLOGI DAN PENILAIAN SUMBER AIR TANAH MENGGUNAKAN PENGIMEJAN KEBERINTANGAN ELEKTRIK DI LOJING, GUA MUSANG

ABSTRAK

Litiologi di kawasan kajian adalah batuan metamorf yang mana ialah syis dan batu induk untuk syis adalah batuan sedimen. Syis mempunyai ciri yang tidak sesuai untuk pengumpulan air bawah tanah antara bijirin, oleh itu air bawah tanah boleh terletak di zon patah. Berdasarkan lithologi, projek akhir tahun ini telah dijalankan untuk menilai kemungkinan keberadaan air bawah tanah menggunakan kaedah Pengimejan Keberintangan Elektrik (ERI). Di Kelantan, ia menggunakan kedua-dua rawatan air bawah tanah dan air dipermukaan sebagai sumber utama mereka untuk kegunaan harian. Walau bagaimanapun, pengeluaran berterusan air tanah boleh menyebabkan kekurangan dan pencemaran berterusan sungai dapat mengurangkan kualiti rawatan air. Oleh itu, sumber air bawah tanah baru diperlukan untuk menyokong penyimpanan air. Untuk menentukan potensi air bawah tanah di kawasan kajian, kaji selidik geofizik menggunakan kaedah Pengimejan Keberintangan Elektrik (ERI) telah dijalankan. Berdasarkan hasil ERI, kawasan kajian adalah potensi air bawah tanah yang tinggi yang terletak di permukaan bawah tanah. Hasil ERI menunjukkan bahawa permukaan bawah tanah terdiri daripada bahan resistensi rendah sedimen sedemikian yang dapat menyimpan air bawah tanah dalam jumlah besar. Sebagai kesimpulan, lithologi kawasan kajian ini boleh menjadi zon untuk pengumpulan air bawah tanah.

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CHAPTER 1

INTRODUCTION

1.1 General Background

Study area is located in the state of Kelantan which placed at the eastern part of Peninsular Malaysia. Malaysia is a country with a climate of humid type throughout the year and east part of Peninsular Malaysia or also known as East Coast. They are influenced by northeastern monsoon that starts from November and ends in March. Since Kelantan is one of the states that located at the east coast, Kelantan also influenced by the north eastern monsoon and causing the state to become very humid and has a high rate of rainfall distribution at the end of every year. The high rate of rainfall distribution in Kelantan may lead to the possibility of groundwater potential in Gua Musang, Kelantan as groundwater can naturally occur by rain and water surface.

Groundwater is water that accumulates and occur naturally beneath the earth surface. Groundwater can be found in any type of rocks either sedimentary, igneous or metamorphic rock. In sedimentary, groundwater is accumulated in the pore spaces between the grain that has high porosity and high permeability. Meanwhile, in igneous and metamorphic rocks, groundwater can be found in the fracture zone. The fracture will have a space opening that allows groundwater to move in and accumulate in the space along the fracture of the rocks. Groundwater will recharge naturally by rain and surface water that will seep down in the pore spaces between grains and crack of rocks beneath the surface until it reaches the water tables of the aquifer.

In finding the groundwater located beneath the earth surface, one of the methods in geophysical techniques will be used which is Electrical Resistivity Imaging (ERI) method. ERI will be used to detect and map the sub surfaces materials based on the resistivity values. The basic principle of the resistivity is about how strong the materials under the sub surfaces can resist the current that is injected into the ground. From the resistivity value, the lithology of the sub surfaces can be determined because every material has different resistivity values.

This thesis study will cover structure, rock identification based on the texture and minerals, geomorphology, sedimentology, and stratigraphy. Meanwhile, groundwater evaluation will be determined by using geophysical survey.

1.2 Study Area

1.2.1 Location

Kelantan is one of state in Malaysia that located in north-east of Peninsular Malaysia. There are Narathiwat of Thailand at the north of Kelantan, Perak state at the west of Kelantan and Terengganu at the south-east of Kelantan. Coastal area of Kelantan are faced South China Sea. Kelantan state are divided into ten major districts – Kota Baharu, Pasir Mas, Tumpat, Pasir Puteh, Bachok, Kuala Krai, Machang, Tanah Merah, Jeli and Gua Musang. Gua Musang is located at the southern part of Kelantan and it is the largest district among others in Kelantan with total area are 7,979.77 km^2. In the western part of Gua Musang district, there is sub-district of Lojing that has been chosen as location for study area.

The study area in sub-district of Lojing, Gua Musang are near with the Kelantan – Pahang border in the east and also near with the Orang Asli Lojing Berhad Cooperative. The total area of the study area is 25 km^2 which is 5 km by 5 km. These study area isolated area and far from town. There is no housing area either in the study area or outside around the stud area. There is main river that crosses the box of the study area horizontally. Figure 1.1 and 1.2 show the location of the study area in Gua Musang, Kelantan. Figure 1.3 shows the base map of the study area in Lojing, Gua Musang.

Figure 1.1: Map of Malaysia (Source: World Map, 2017)

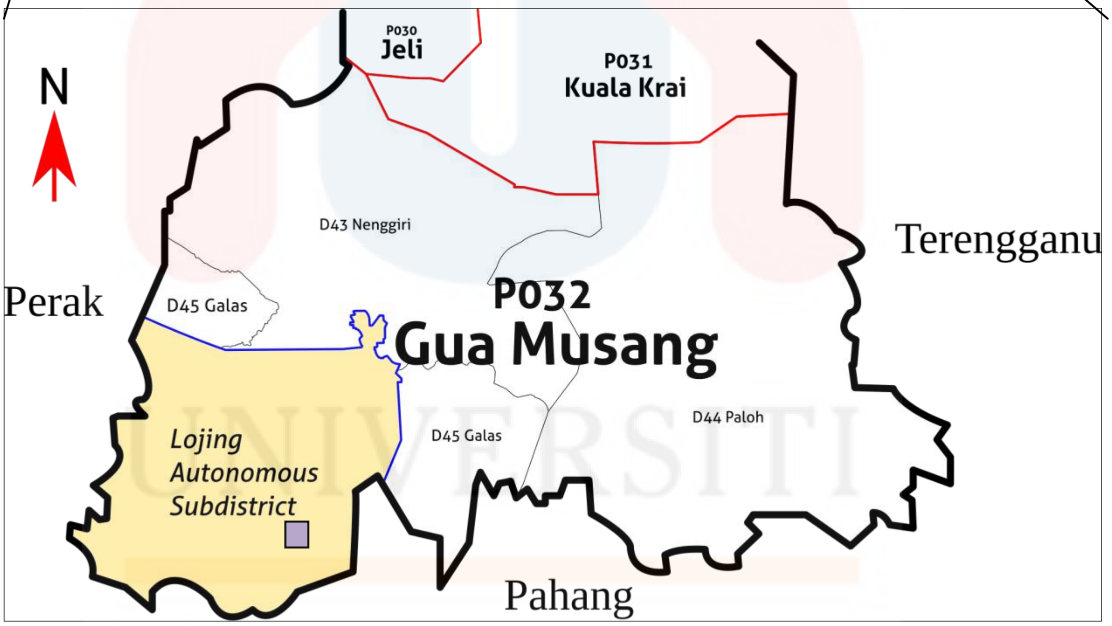


Figure 1.2: Map of Gua Musang District in Kelantan (Source: Wikipedia, 2019)

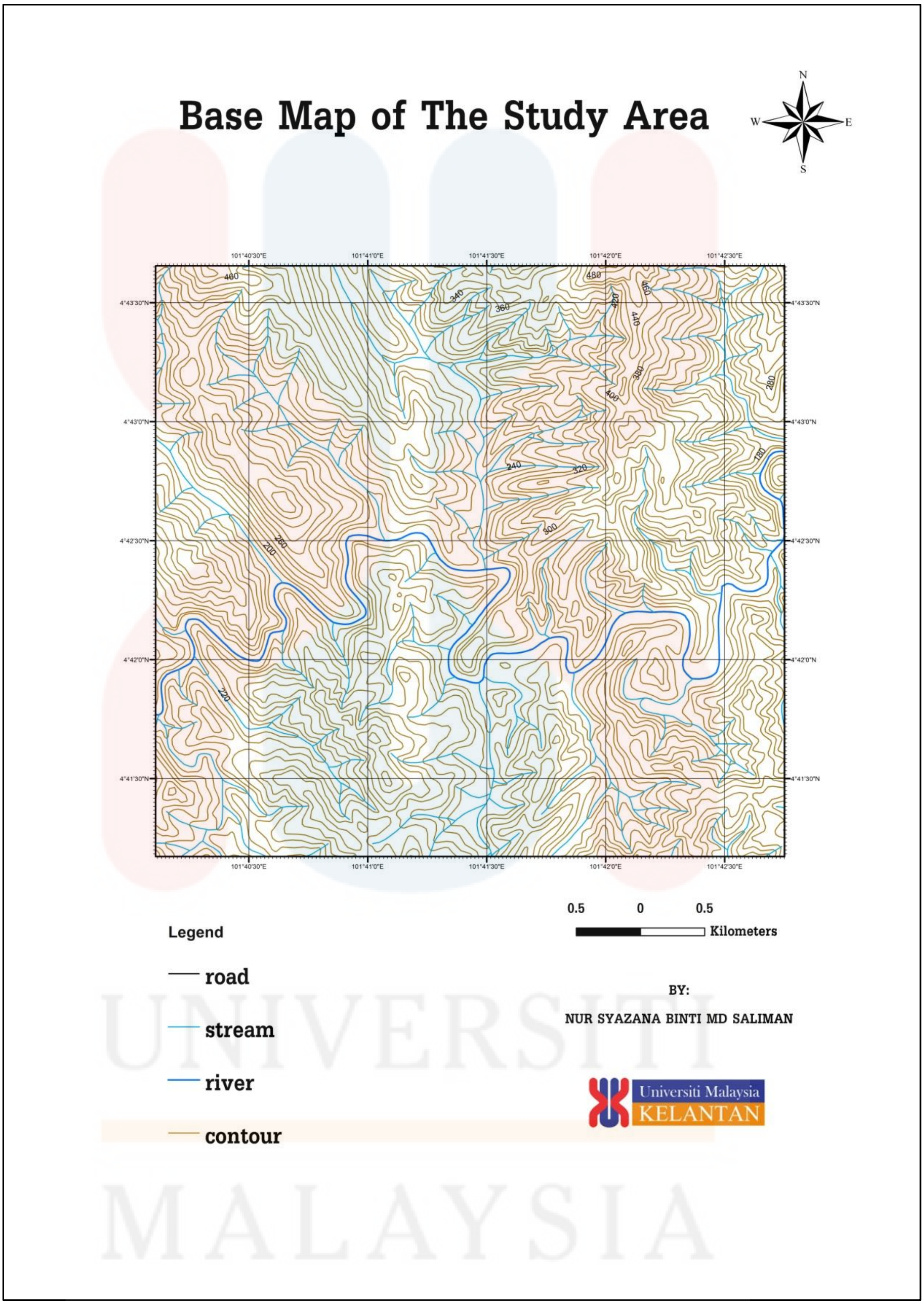


Figure 1.3: Base map of the study area in Lojing

1.2.2 Demography

Based data from Department of Statistics Malaysia in ‘Population Distribution and Basic Demographic Characteristics 2010’, the population density of Kelantan are 102 per km^2 which is not too high as in Wilayah Persekutuan Kuala Lumpur, Pulau Pinang and Wilayah Persekutuan Putrajaya. For the population distribution by state in Malaysia, Kelantan are rank in the 9th place with population 1.54 millions in 2010 and estimated to be increase to 1.86 millions in 2018. In the term of ethnic group, Kelantan state are dominated by Malays and other indigenous (Bumiputera) which 95.7% followed by Chinese 3.4% Indian 0.3% and Others 0.6%.

Kelantan is a state that rich in cultural heritage, starting from language, food until lifestyle that are unique and become as an attraction towards outsider or tourists either from Malaysia itself or other country. This attraction somehow has increase the population of the state because occurrence of mix marriage between outsider and Kelantan people. Figure 1.4 shows the population density in Kelantan and Figure 1.5 shows the population distribution by state in Malaysia.

Table 1.1 shows the population distribution in Kelantan between year 2000 and 2010. Based on the table, it showing an increasing population from 2000 until 2010 in every district in Kelantan. Table 1.2 and Figure 1.6 show the total population based on their ethnics and the percentage in Kelantan in 2010.

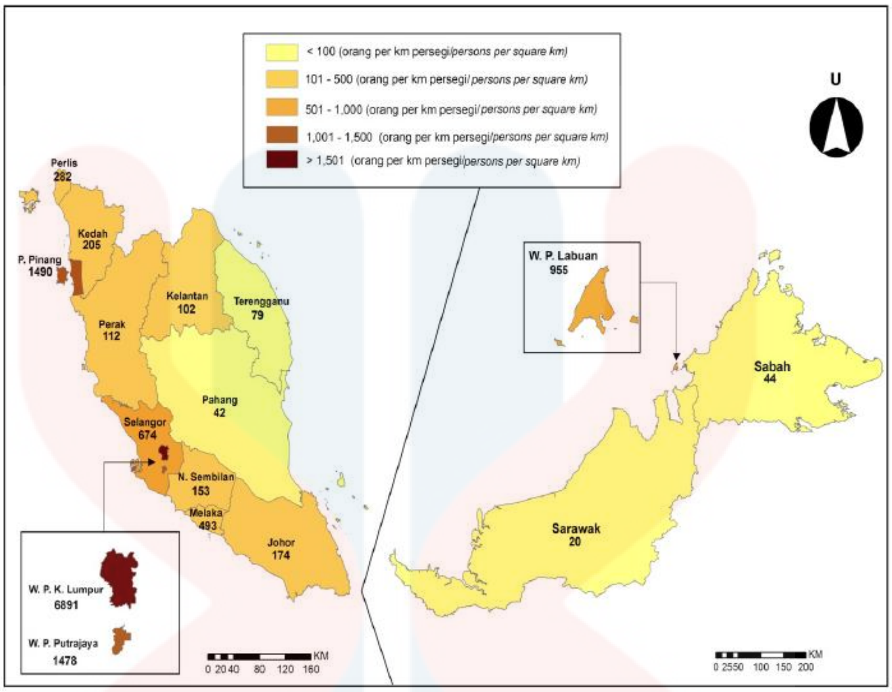


Figure 1.4: Population Density in Kelantan (Source: Department of Statistics Malaysia, 2010)

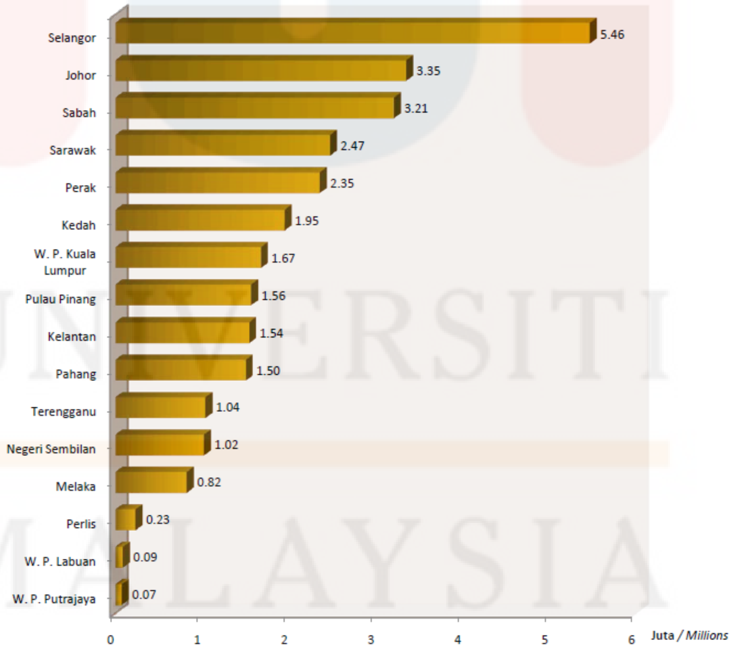


Figure 1.5: Population Distribution by State in Malaysia 2010
(Source: Department of Statistics Malaysia, 2010)

Table 1.1: Population Distribution in Kelantan district in 2000 and 2010

NAME	STATUS	POPULATION (Census 2000)	POPULATION (Census 2010)
Malaysia	**State**	**1,313,014**	**1,539,601**
Bachok	District	111,040	133,152
Gua Musang	District	76,655	90,057
Jeli	District	36,512	40,637
Kota Baharu	District	406,662	491,237
Kuala Krai	District	93,550	109,461
Machang	District	79,032	93,087
Pasir Mas	District	165,126	189,292
Pasir Puteh	District	106,138	117,383
Tanah Merah	District	103,487	121,319
Tumpat	District	134,812	153,976
Malaysia	**Federation**	**23,274,690**	**28,334,135**

(Source: Department of Statistics Malaysia, 2010)

Table 1.2: Ethnics group in Kelantan 2010

Ethnic Group in Kelantan State (Census 2010)	
Malay & other Indigenous (Bumiputera)	1,378,352
Chinese	48,787
Indian	3,658
Other group	8,843

(Source: Department of Statistics Malaysia, 2010)

Specifically in Gua Musang, the population in 2010 are approximately 90,100 peoples compared in 2000 where the population are approximately 76,700 people. Gua Musang is a district that famous with indigenous ethnics. In Gua Musang, the population of Malay and indigenous ethnic are make up to 94.6% which approximately 76,800 of the total ethnics in Gua Musang. Table 1.3 and Figure 1.7 shows the total population based on their ethnics and the percentage in Gua Musang in 2010.

1.2.3 Land Use

The total area of Kelantan state is 15,100 km^2 and the state are divided into 10 districts and 1 sub-districts. Table 1.4 show the total area every districts and one sub-district in Kelantan. Among all the 10 districts, Gua Musang is the largest district which make the total area up to 8,104.1 km^2. The total area of the Gua Musang district is sum up between Gua Musang district and Lojing sub-district that has been placed under Gua Musang district.

Based on data in the Table 1.5 that taken from the Department of Town and Country Planning, it shows that 63.8% of the total land area in Kelantan state are dominated by forest and followed by 28% of the total land area are for agriculture section. The percentage of the land use continue dropping to the 2.7% for the housing area, 1.9% of empty land and 1.8% of the land use for water body. Table 1.6 show the total area of land used specifically in the district of Gua Musang.

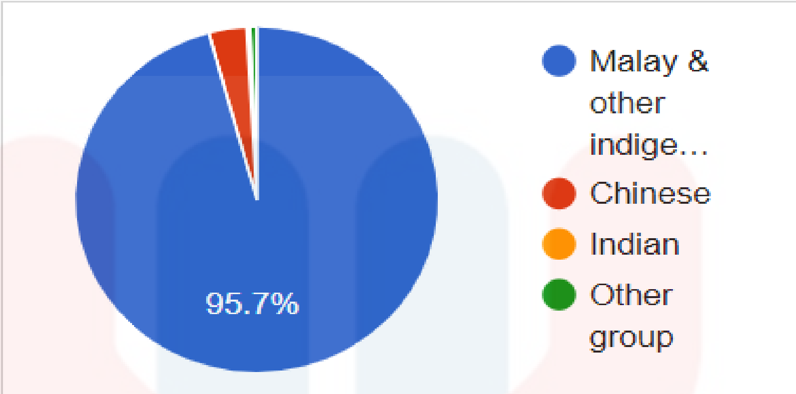


Figure 1.6: Percentage of ethnics group in Kelantan 2010
(Source: Department of Statistics Malaysia, 2010)

Table 1.3: Ethnics in Gua Musang District in 2010

Ethnic Group in Gua Musang District (Census 2010)	
Malay & other Indigenous (Bumiputera)	76,823
Chinese	3,870
Indian	350
Other group	161

(Source: Department of Statistics Malaysia, 2010)

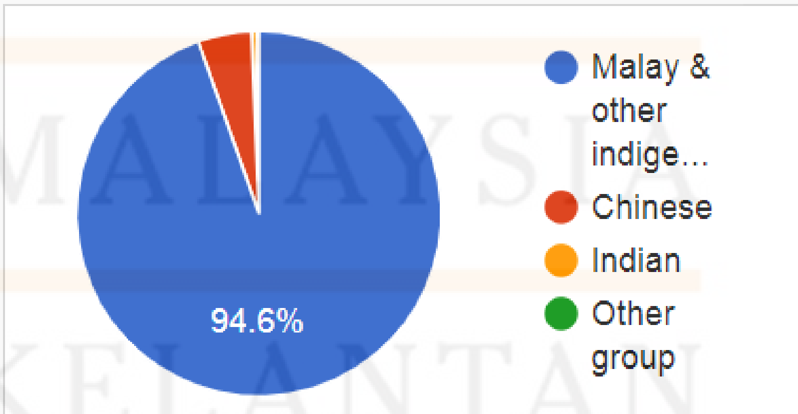


Figure 1.7: Percentage of ethnics in Gua Musang district in 2010
(Source: Department of Statistics Malaysia, 2010)

Table 1.4: Total of district area in Kelantan

NO	DISTRICT	DISTRICT AREA (km^2)
1	Kota Baharu	406.2
2	Kuala Krai	2,224.8
3	Machang	543.8
4	Pasir Mas	574.6
5	Pasir Puteh	432.5
6	Tanah Merah	867.6
7	Jeli	1,328.7
8	Bachok	264.2
9	Tumpat	165.7
10	Gua Musang	6,287.1
11	Lojing	1,817.0

(Source: Department of Town and Country Planning Malaysia, 2018)

Table 1.5: 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: Department of Town and Country Planning Malaysia, 2018)

Table 1.6: Percentage of land use in Gua Musang district in 2018

No.	Land Use	Area (hec)	Percentage (%)
1	Water Body	4,940.227	0.608
2	Forest	695,450.733	85.564
3	Industry	155.166	0.019
4	Infrastructure & Utilities	23.493	0.003
5	Institutions & Facilities	693.714	0.085
6	Commercial	93.683	0.012
7	Beach	0.000	0.000
8	Mixed Development	647.418	0.080
9	Transportation	2,468.969	0.304
10	Agriculture	106,540.677	13.108
11	Housing	1,220.591	0.150
12	Empty Land	353.284	0.043
13	Open Space & Recreation	193.475	0.024

(Source: Department of Town and Country Planning Malaysia, 2018)

In Gua Musang district, the higher land used are forest with 85.6% and agriculture with 13.1%. The third higher land used is water body with percentage 0.6% from the total land area in Gua Musang district. Due to the low development process and also because of the type of landform that are hilly area in Gua Musang, it is normal if the percentage of land use is dominated by forest, agriculture and water body. Meanwhile for the agriculture land use, the main type of agriculture are palm oil plantation and rubber trees plantation.

1.2.4 Social Economic

Based on the amount of the land use in Kelantan, the type of social economic already can be predicted which is high in agriculture sector due to high percentage of land use in agriculture. However, services sector are higher than agriculture sector which make the service sector are the first rank followed by agriculture sector in second rank and manufacturing sector in the third rank for social economic in Kelantan state. Figure 1.8 below shows the percentage of every sector in Kelantan for 2015.

Figure 1.9 is showing the Gross Domestic Product (GDP) in Kelantan by Sector in 2016. In 2016, the figure shows an increasing value for the construction sector which is increase 0.5% from 1.8% in 2015 to 2.3% in 2016. Increasing in the value for construction sector, shows that Kelantan state are in the development process along this one year. While construction sector are in the process of rising, others sector are maintaining their position which service sector are 66.4%, agriculture 24.6%, mining 1.3% and manufacturing 5.4%.

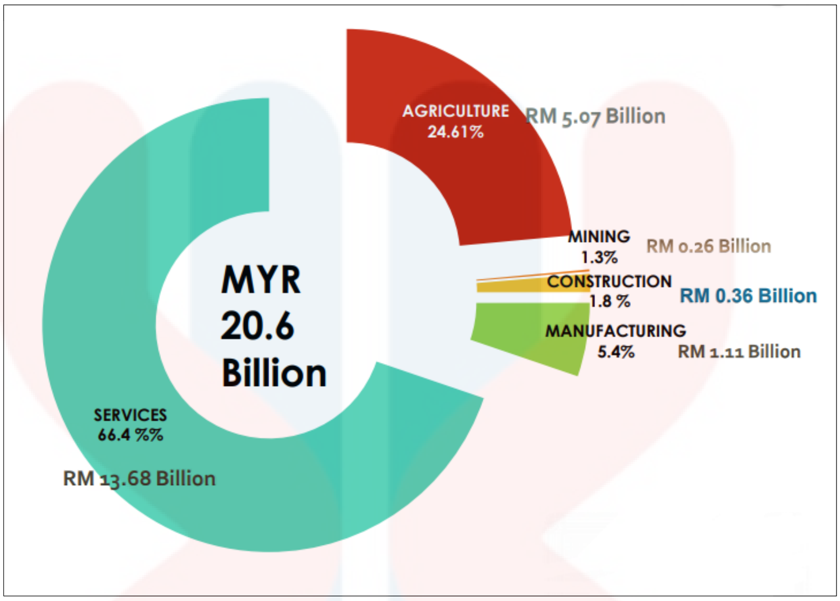


Figure 1.8: Percentage of social economic based on the sector in Kelantan in 2015
(Source: Department of Statistics Malaysia, 2015)

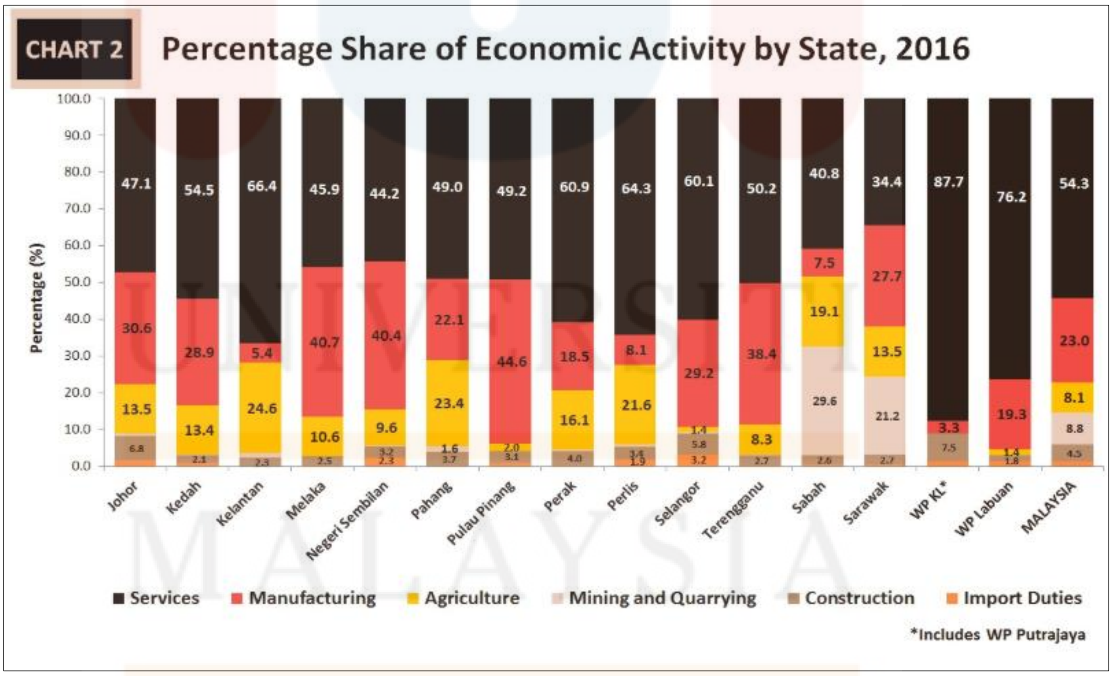


Figure 1.9: Percentage of social economic by State in Malaysia 2016
(Source: Department of Statistics Malaysia, 2016)

1.2.5 Accessibility

Accessibility in the Lojing sub-district are only provide by a major highway from Gua Musang to Cameron Highland, while the left and right side of the highway only provide by plantation area and forest. Meanwhile accessibility for the study area is a bit difficult because the location of the study area is located far from the Gua Musang – Cameron Highland highway. There are only a few unpaved road in the palm oil plantation area that can be accessed by transportation, while the others small unpaved road only can be accessed by walking. Figure 1.10 shows the accessibility of the study area.

Figure 1.10: Accessibility of the study area

1.3 Problem Statement

The existence of the geological map of Gua Musang needs to be updated because Gua Musang has undergone massive construction. Many areas have been exposed and the rock needs to be identified. Therefore, Gua Musang has been chosen to be the study area of this research.

Kelantan general state used groundwater as their main water resources for the community. Meanwhile, in Lojing which is a rural area are in Gua Musang are using river treatment as their main water source. However, due to the increase in the population in Lojing, the demand for water also increase which will influence the production of water from river treatment processes. If there is a possibility of groundwater existence in Lojing, this will help to support the source of water that main from the river treatment to support the increase of the population.

1.4 Objectives

The main objectives of this research are:

1) To produce a geological map of study area in scale 1:25,000
2) To evaluate the possibility of groundwater existence using Electrical Resistivity Imaging (ERI) method.

1.5 Scope of Study

Geological mapping of Gua Musang involves major knowledge of geological structure, petrology, sedimentology and stratigraphy in the field. This knowledge will be applied the most during the observation in the field.

Meanwhile in the exploration of groundwater more focus on the geophysics field. Understanding how to interpret the data from the survey is the basic needed in undergo this geophysical survey. Some calculation also involves in determine the exact and the true data that obtain during the field before finalising the survey finding.

1.6 Significant of Study

This research not only limited to update the geological map of Gua Musang, is also can bring new founding of structure, fossils or others that can become something new during the mapping. Furthermore, determination of the earth movement and the process from the past can be made based on the observation from the field. Prediction of geohazard can also be made from the observation for the precaution in the future. Moreover for the groundwater exploration, continuation of groundwater production can be sustained if new existence of groundwater are found in Lojing, Gua Musang. Therefore, we can overcome the issue of lack of clean water towards population in Kelantan.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Malaysia is a country that rich with geology from an ancient age which is in range of million years ago. Malaysia is bound with Thailnd in the north, Singapore in the south and Indonesia in the east and west. Peninsular Malaysia is forming from collision between Sibumasu Block at the western part of Peninsular and East Malaya Block at the eastern part of Peninsular.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia is divided into three major belts which is western belts, central belt and eastern belt. All these three major belts are characterised by different stratigraphy. In Western Belt consist state of Perlis, Kedah, Perak, Selangor, West of Kelantan and Pahang, half of Negeri Sembilan and Malacca. At the upper part of Western Belt also, there are Northwestern Domain that located at the north-west of Peninsular Malaysia. Based on the geological time scale, stratigraphy in the age range of Paleozoic Era are rich in the Western Belt. The most interesting stratigraphic that showing the complete sequence of Palaeozoic Era that ranging from

Cambrian to Permian can be found at Langkawi UNESCO Global Geopark, Kedah that located in the Northwestern Domain of Western Belt.

For Eastern Belt, the age is approximately older than Central Belt because the age of Eastern Belt ranges from Carboniferous to Permian, meanwhile for Central Belt the age Carboniferous to Triassic. State that located in this Eastern Belt is East of Kelantan, Terengganu, East of Pahang and East of Johor. Kuantan Group in Pahang, Seri Jaya Beds and Kambing Beds in Terengganu are sediments in the age of Carboniferous. Meanwhile for Central Belt, the belt is stretches from Kelantan to Johor. In the Central Belt there are state of Middle part of Kelantan, middle part of Pahang, East part of Negeri Sembilan and West to Middle part of Johor. The age of stratigraphy unit in this belt are from Carboniferous of Palaeozoic until Triassic of Mesozoic.

In western part of Central Belt, there are Aring Formations in South Kelantan, Taku Schist in East Kelantan and rock from Upper Palaeozoic age in Gua Musang. The lithology from the age of Upper Palaeozoic has the lithology of argillaceous strata and volcanic rocks. In a shallow marine environment, there is deposition of arenaceous and calcareous sediments with intermittent submarine volcanism. The deposition process are starting from Upper Carboniferous and peaking in Permian to Triassic. In the Central Belt also, there are Bentong – Raub Suture that extend from Cheroh, southwards through the Bentong and Raub and continue towards Kuala Pilah. The Bentong – Raub suture was shown trending south-east from vicinity of Gunung Ledang (Hutchison, 1975).

2.3 Stratigraphy

Gua Musang, Kelantan are located in the Central Belt of Peninsular Malaysia that stretches from Kelantan to Johor. In the western part of the Central Belt are Upper Palaeozoic rocks of the Gua Musang and Aring Formations in south Kelantan and Taku Schist in east Kelantan (Charles & Denis, 2009). Mapped by Yin (1965) the Gua Musang Formation estimated to be 650 m thick, is made up of crystalline limestone, interbedded with thin beds of shale, tuff, chert nodules and subordinate sandstone and volcanics. Calcitic limestone with light grey colour is hard, non-porous, brittle and splintery. Limestone that often recrystallised will have grey to black colour and minimum amounts of carbonaceous, argillaceous and pyroclastic impurities will present in the recrystallisation limestone.

The thin bedded, laminated and fissile shaleis usually grey in colour but it is black when carbonaceous. It is occasionally associated with dark-grey to black bedded chert (Hutchison, 2000). Foo (1983) stated that the argillaceous sandstone is fine to medium grained with angular quartz in a matrix of limonitic or carbonaceous clay. Volcanic in Gua Musang Formation are vary from rhyolitic to andesitic and include tuff, lava flows and agglomerate. Based on Gobbett (1973) lava flows are very subordinate. Flow banded spherulitic rhyolite trachyte, trachyandesite, and andesite lavas are associated with shale and water-deposited tuff and probably were extruded on the sea floor.

To the west of Gua Musang town, in Kuala Betis area, rocks similar to and identified as the Gua Musang Formation overlie a conglomerate-sandstone sequence conformably (Aw, 1974; Abdul Rahim *et al.*, 1994). This sequence known as the Gunong Ayam conglomerate is interpreted as a basal conglomerate (Aw, 1974) and most likely represents the oldest unit of the Gua Musang Formation (Aw,1974;

Abdul Rahim *et al.*, 1994). The calcareous rocks become the most extensive facies of the Gua Musang Formation with widespread development in Middle Permian and Triassic times (Yin, 1965). Limestone in Gua Musang are estimated constitutes about 80% of the total rocks exposed in the Gua Musang – Merapoh area but decreased rapidly towards the north and south (Burton, 1973a). Figure 2.1 shows the distribution of Gua Musang Formation in Gua Musang.

2.4 Structural Geology

In the Central Belt of Peninsular Malaysia, there are major fault which is Bentong–Raub Suture Zone that separate the Western Belt from the Central Belt (Hutchison, 1973d). Formation of Bentong–Raub Suture is due to the collision between Sibumasu Block and East Malaya (Indochina) Block that age ranges early Late Devonian until Middle Permian. Figure 2.2 below show the location of Bentong-Raub Suture from the south of Thailand border until the Straits of Malacca.

In Kelantan, Bentong-Raub Suture is exposed 20 km wide with zone of deformed rocks along the Highway of Gua Musang–Cameron Highland. Rocks within the suture are divided into at least 7 tectonic units (Tjia & Syed Sheikh, 1996). Tjia & Syed Sheikh (1996) also suggested that the repeated occurrences of the tectonic units suggest that they formed an imbricated structure. Zones of sub-vertical to steep northeasterly-dipping reverse to dextral-reverse phyllonites or mylonites, striking NW–SE , separate each imbricated unit and steep southwesterly-dipping reverse dextralfaults cut across the units, suggesting the imbrication was due to dextral transpression (Mustaffa, 1994c).

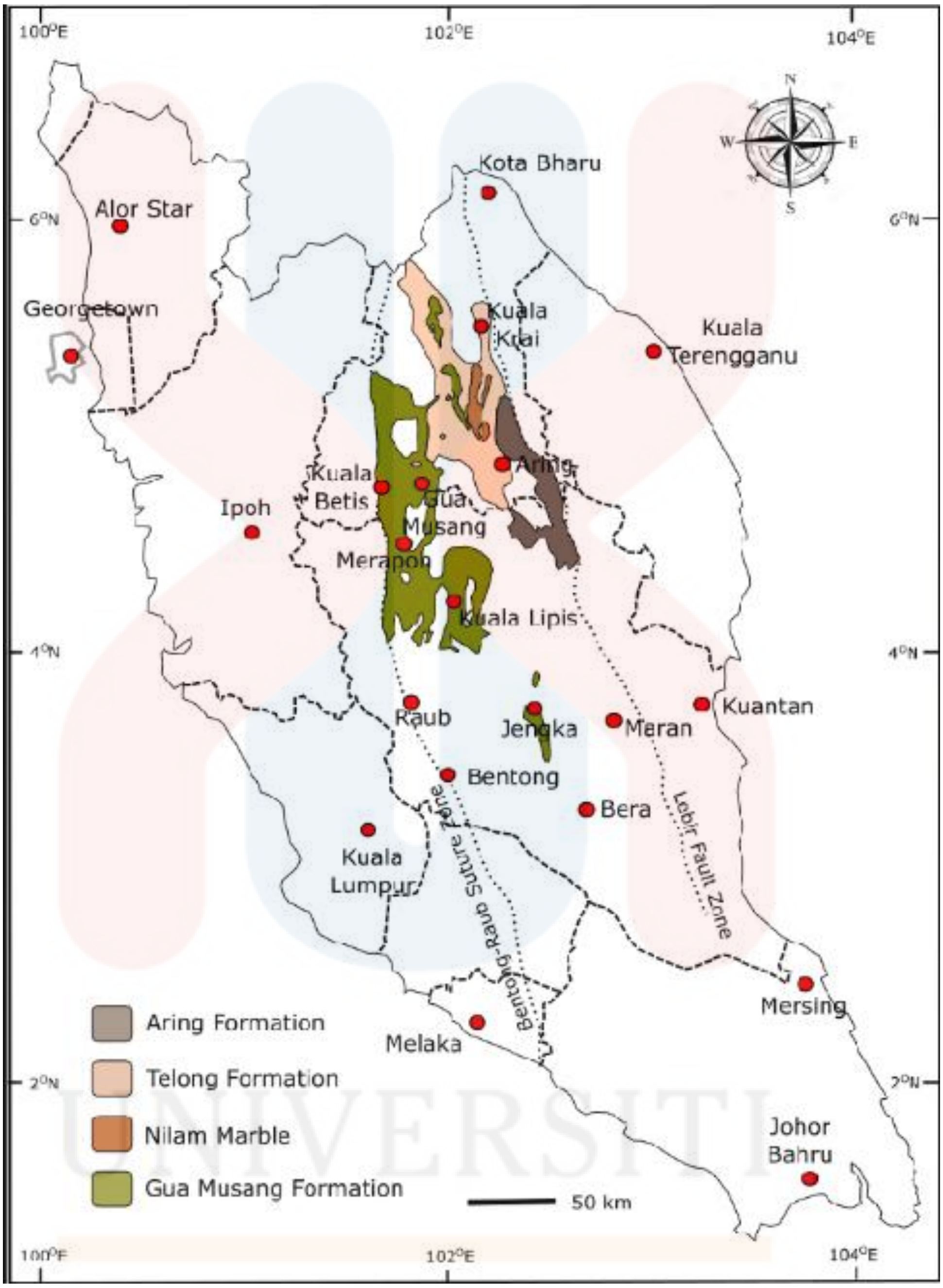


Figure 2.1: Distribution of Gua Musang Formation in Gua Musang (Source: Mohamed, 1995)

Figure 2.2: Location of Bentong-Raub Suture (Source: Basir Jasin, 2013)

At the western boundary of the Bentong–Raub Suture, there are network of dykes and sills that proved the western boundary is a zone of granitoid injection complex. The sills are variably deformed; some were sheared together with the country rock, exhibiting N–S dextral mylonitic zones (Charles & Denis, 2009). Detailed structural studies of the deformation within the Bentong–Raub Suture Zone show that the suture zone had undergone progressive transpressive deformation (Mustaffa, 1994c; Jatmika & Ibrahim Abdullah, 2003). The deformation started with dextral followed by sinistral transpression and the latest involved dextral N–S strike-slip faulting (Charles & Denis, 2009).

2.5 Historical Geology

During the period of Carboniferous, East Malaya was attached with Indochina plate and Sibumasu attached with Gondwana; become a part of Cimmerian plate. However since Devonian until Permian, Sibumasu and East Malaya blocks were separated by an ocean become Palaeo-Tethys. During Triassic, the Palaeo-Tethys was completely closured. Meanwhile the Gua Musang Formation are starting to form at the age of Middle Permian and continue forming until the age of Upper Triassic (Mohd Shafeea Leman, 1993 and 2004).

2.6 Groundwater

Groundwater is a natural occurring water that form under the subsurface causes by the water from surface that act as recharges agent for the groundwater. Approximately 22% of the Earth's total freshwater is the groundwater and it comprises of about 97% of all liquid freshwater available which is used for human consumption (Foster, 1998). Groundwater is the continual availability and good natural quality makes it a significant source of water supply for both rural and urban areas of any country (Todd and Mays, 2005).

Groundwater can be found at alluvial plain due to its naturally good capacity of recharging the groundwater. Alluvial plain is a large area of flat land surface that forming from the deposition of sediment such as sand, silt and clay. The sediments are coming from the highland that has erode due to weathering process, then transport by water flowing to the lowland and deposited over time until the sediments increase and forming alluvial soil.

In Kelantan, it used both groundwater and surface water as their water resources. In urban area it more to groundwater uses for the resources and for rural area it use surface water for the water sources. The uses of both resources are to sustain the of water resources. Beneath the surface, there are two zones of groundwater which is unsaturated zone and saturated zone.

In unsaturated zone, the pore spaces between grains are partially saturated with water and air. Meanwhile, in saturated zone, the pore spaces are totally saturated with water. Figure below show the difference between unsaturated zone and saturated zone of groundwater. Water table is the approximate upper surface of the saturated zone. Figure 2.3 show the position of unsaturated zone and saturated zone in groundwater.

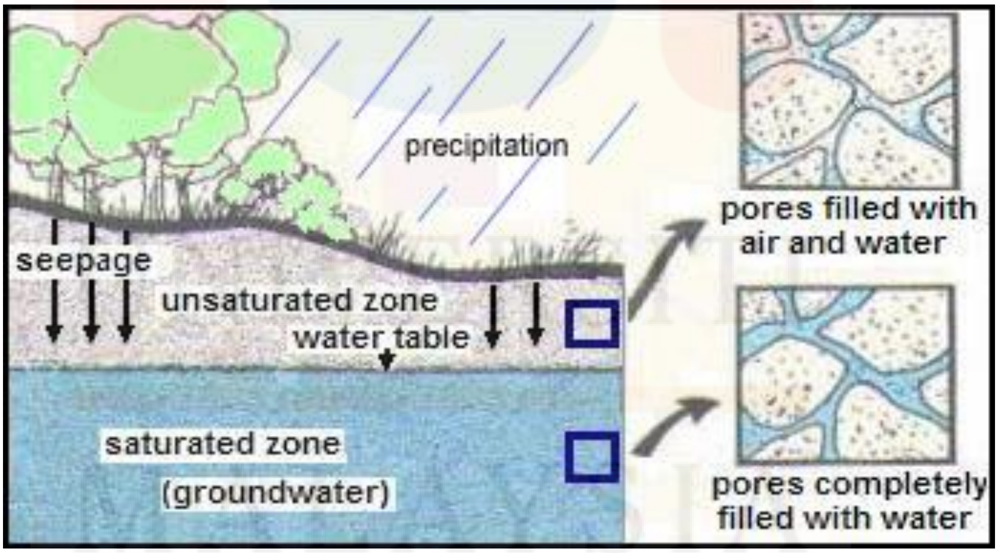


Figure 2.3: Position of unsaturated zone and saturated zone in groundwater
(Source: Nebraska Water Center)

2.7 Electrical Resistivity Imaging (ERI)

There are two types of investigation to identify the potential of groundwater – surface investigation and subsurface investigation. Electrical Resistivity Imaging (ERI) is the another methods in geophysical survey that categorized under surface investigation for groundwater exploration. Electrical resistivity method surveying is based on the principal that the distribution of electrical potential in the ground around a current-carrying electrode depends on the electrical resistivity and distribution of the surrounding soils and rocks.

In the resistivity method, there are five type of electrode configuration for the resistivity method – Wenner, Schlumberger, Dipole-dipole, Pole-dipole and Pole-pole. Table 2.1 below is showing the value of resistivity for different type of materials that will be use in electrical resistivity method to determine the type of material under the subsurface.

Among the five configuration, Wenner array are the simplest array that are placed in a line with equal spacing between each electrodes. Wenner array consist of four electrodes which is A, M, N and B. The outer electrodes which is A and B are current electrodes, meanwhile the inner electrodes which is M and N are potential electrodes. With the Wenner array, the resistivity of subsurface layers is found by increasing the distance between the electrodes while maintaining the location of the center point of the array and detection of horizontal changes of resistivity is achieved by moving the four electrodes across the surface while maintaining constant electrode separation (Hasan, 2017). Figure 2.4 below shows the configuration of Wenner array.

Table 2.1: Resistivity value for different materials

Material	Resistivity (Ωm)	Conductivity (mS/m)
Igneous & 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 & Waters		
Clay	1 – 100	0.01 – 1
Alluvium	10 – 800	$1.25x10^{-3}$ – 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: Fadel, M.A.M. *et al.* 2016)

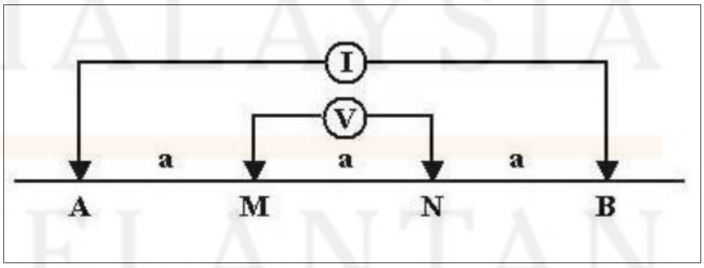


Figure 2.4: Wenner array (Source: Langeo, 2016)

Schlumberger configuration also consist of four electrodes which electrodes A and B that located at the outer are known as current electrodes and electrodes M and N that located at the inner are known as potential electrodes. The distance of inner electrodes M and N are placed close together. With the Schlumberger array, for each measurement the current electrodes A and B are moved outward to a greater separation throughout the survey, while the potential electrodes M and N stay in the same position until the observed voltage becomes too small to measure (Hasan, 2017). Figure 2.5 below shows the electrode configuration of Schlumberger.

Dipole-dipole array is consists of two sets of electrodes, AB and MN. Pair of electrodes A and B are current electrode also known as source and pair of electrodes M and N are potential electrode also known as receiver. A dipole is a pair of oppositely charged electrodes that are so close together that the electric field seems to form a single electric field rather than a field from two different electric poles (Hasan, 2017). The convention for a dipole-dipole electrode array is to maintain an equal distance for both the current and the potential electrodes. Figure 2.6 shows the dipole-dipole array.

Pole-dipole array is used when the surveyor needs to see deep within a cross section of the earth and the achievable depth is based entirely on the distance between the two electrodes, the dipole and the pole (Hasan, 2017). Array of pole-dipole are commonly and most often used for the exploration of mineral and ore. In pole-dipole array, one of the current electrodes is placed at an “effective infinity” which approximately five to ten times of the survey depth and the other current electrodes are placed in the region of two potential electrodes (Langeo, 2016). Figure below show the pole-dipole array configuration. Figure 2.7 shows the electrode configuration of pole-dipole.

In pole-pole survey, one of the current electrodes and one of the potential electrodes are installed far away that they can be considered at infinity. The four electrodes in pole-pole array are arranged so that the distance between the transmitter (A&B) dipole and the receiver (M&N) dipole is small in comparison and the distance ought to be 10% of the A&B dipole (Hasan, 2017). However, pole-pole array are required large space between the electrodes because the two electrodes of infinity need to be place far out in opposite directions. Figure 2.8 shows the array of pole-pole.

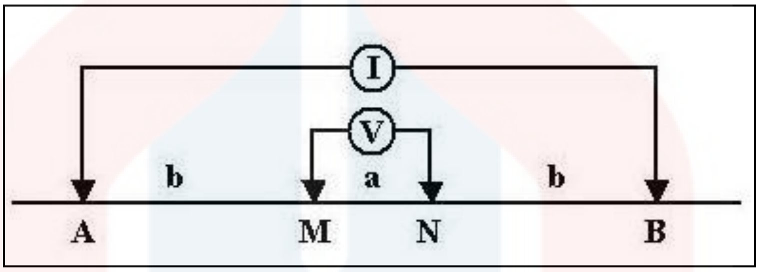


Figure 2.5: Schlumberger array (Source: Langeo, 2016)

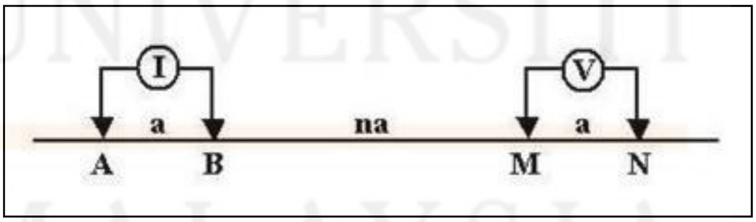


Figure 2.6: Dipole-dipole array (Source: Langeo, 2016)

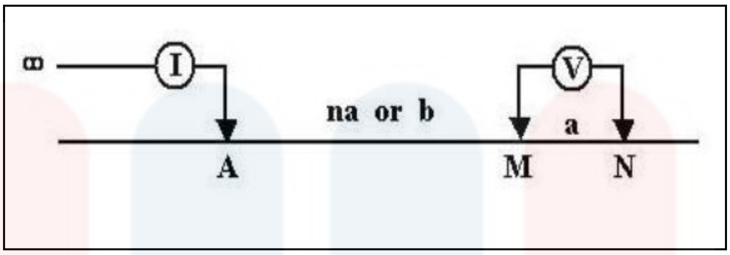


Figure 2.7: Pole-dipole array (Source: Langeo, 2016)

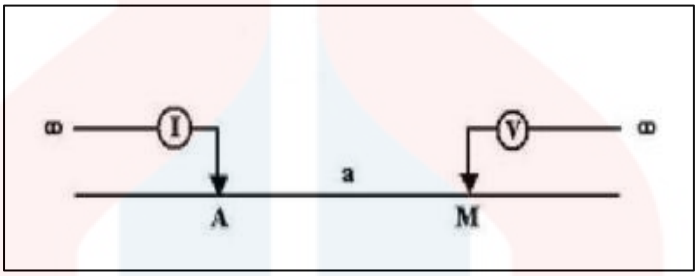


Figure 2.8: Pole-pole array (Source: Langeo, 2016)

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

In this section, both material and method consist of two major part which is geological mapping for general geology and evaluation of groundwater for the specification. Both part using a different type of materials and methods in the process of gaining the data for the result observation. In geological mapping, materials use are the same as basic mapping which is Global Positioning System (GPS), compass, a geological hammer, hand lens and a bottle of HCl. For the method, all geologists using the same methods in the field which rock from the field will be brought back for further observation in determining the composition and the type of rocks.

As for the evaluation of groundwater that more focus on using geophysical survey techniques, the method used is one of the methods in geophysics which is Electrical Resistivity Imaging (ERI). The materials used are the resistivity meter model of ABEM LS-1, 41 electrodes, 200 m cables take out, power supply and crocodile clips. For this survey, the type of electrode configuration that is using is the type of Schlumberger. Electrode configuration of Schlumberger is being chosen in this survey because it captures more resistivity data of subsurface during the survey compare to Wenner type of electrode configuration. More resistivity data obtained from the survey, high accuracy of results can be produced during the data processing.

3.2 Materials

There are two categories of materials that will be use in this geological mapping and geophysical survey. For categories of geological mapping, the materials use are common which is geological hammer, Global Positioning System (GPS), compass, hand lens, plastic sample and a bottle of hydrochloric acid. Hydrochloric acid is usually taken in a small size of bottle because it only use a few drop of hydrochloric acid in testing the presence of calcite in the rocks. When hydrochloric acid react and produce bubbles after being dropped, it indicate that there are presence of calcite in the rock. Table 3.1 shows the materials and the uses of the materials.

Meanwhile for geophysical survey, it involved the use of materials in 2D Electrical Resistivity Imaging method. The materials includes are ABEM Terrameter LS-1, 41 electrodes, power supply, 200m of cable ‘take-out’ and 42 connector. Figure 3.1 shows the materials that will be used to undergo the electrical resistivity survey. Table 3.2 shows the uses of the materials.

Table 3.1: Materials and the uses in the geological mapping

MATERIALS	USES
 **Geological Hammer**	Geological hammer will be use to break the rock from outcrop. Rock that want to be make as sample that needed for identification must be fresh and less weathered.
 **Global Positioning System (GPS)**	GPS will be use to identify the location of certain area in the field. Certain position that take as observation point or important point will be mark in the GPS.
 **Compass**	Compass are use to determine the bearing of the outcrop and measure the reading of strike and dip. In determine the position of the North, compass also will be use.
 **Hand Lens**	Hand lens is a small magnifying glass that use to take a closer look at rocks in the field. By using hand lens we can identify tiny minerals and fossils in the rocks. Minerals that usually being identify by hand lens are minerals in igneous rocks.

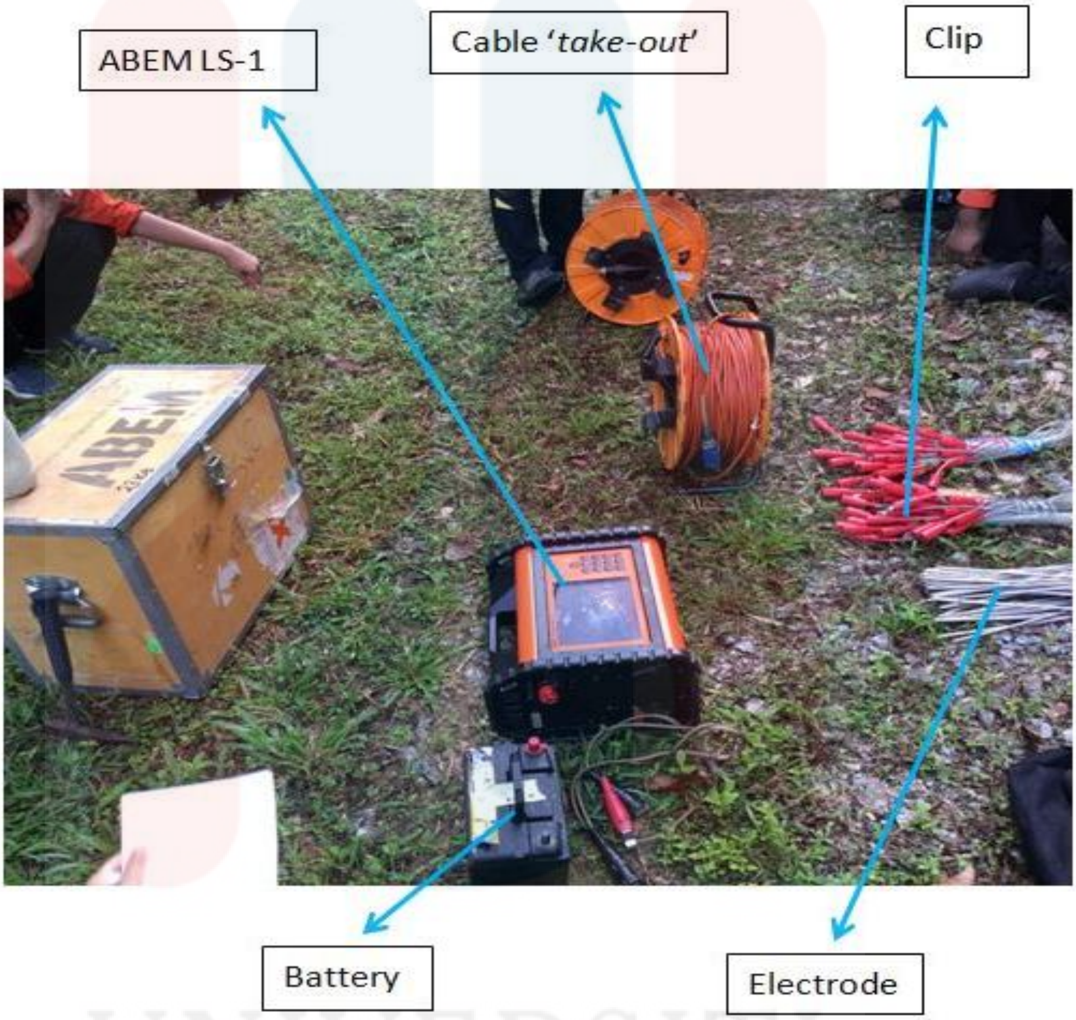


Figure 3.1: Materials of ERI for the geophysical survey

Table 3.2: Material and the uses in geophysical survey

MATERIALS	USES
 **ABEM resistivity terrameter**	ABEM Terrameter are resistivity meter that use to measure, collect and display the data that obtain from the subsurface.
 **Electrical cable**	Electrical cable are a medium for electrical current to flow through after being release from resistivity meter.
 **Clips**	This clip are act as a connector to let the electrical current to flow through from the cable electric to the electrodes.
 **Electrodes**	Electrodes is a medium to let the electrical current that flow through the cable to be injected into the subsurface.
 **Power supply**	Power supply act as a battery to the resistivity meter for it to function well.

3.3 Methodology

3.3.1 Preliminary Study

Preliminary study is the main method that conducted before going to the field area. Preliminary study is consists of geology study of the study area. The information of the study area can be gained from many source such internet, journals and books. The existing geology information of the study area are form the previous researches that has been done by geologists. Other than study the geology of the study area, preparation of base map also being made before going to the study area. Base map are the necessary thing to bring along in during the geological mapping.

3.3.2 Field Studies

Field studies for this research are focus in two major part which is geological mapping and groundwater evaluation. Both studies are conducted in the area of Lojing, Gua Musang. In general geology, traversing and mapping are conducted in the area to study the lithology, morphology, structure and stratigraphy of the study area. Morphology is conducted in the high elevation area that included in the box of the study area. For early observation in determine the lithology in the field, hand lens and a bottle of HCl are used to determine the mineral composition that can be seen by naked eyes. To further the observation, fresh rock from outcrop will be obtained using geological hammer and bring back to proceed with laboratory rock which is thin section processes. Rock sample that had undergone thin section process will be observed under microscope to identify tiny and micro minerals that cannot be seen by naked eye.

In groundwater evaluation, it more focus on geophysical techniques. One of the method in geophysical techniques that will be used in evaluate the groundwater are Electrical Resistivity Imaging (ERI). This survey conducted in five lines. The length of the survey is 200 m in straight line with 41 electrodes. Resistivity meter with type of ABEM are placed in the middle of the 200 m straight line, which mean 100 m line will be at the left side of ABEM and another 100 m at the right side of ABEM. The spacing between electrodes for 200 m lines is 5 m. The type of array used is Wenner, Schlumberger and Pole-Dipole. When the ERI are ready to be run, electrical current from ABEM will be inject into the ground via electrode that has been planted into the surface during the set-up. Resistivity reading of subsurface will appear on the screen of ABEM.

3.3.3 Laboratory Work

Laboratory work is involvement of petrographic thin section process for rock. Rock sample that collect from the field will undergo thin section process to make it into a glass slide size to be use for detail observation under microscope. Petrographic thin section process include the step of cut the rock, frost the glass slide, cement the sample to slide and grind the section on thin section machine. After the sample of the rock can be obtain into glass slide size, tiny minerals that cannot be seen by naked eye will be identify under microscope.

Thin section process is starting from the preparation of the glass slide. The glass slide that used must be flat to ensure the rock section has a constant thickness. Then proceed with the frosting the glass slide. The glass slide must be frosted to make it flat and roughen the surface for epoxy to bind well. The process continue with cutting the slab. Using the slab saw, the slab of the sample is cut along the marked line.

Due to the small size of thin section, the size of the slab also need to be reduced become slightly smaller than the thin section. The size of the slab being reduced by cutting the chip using a special rock-cutting blade. The chip then gluing to the slide by placing it on the hot plates and mix well the approximately 2 grams of epoxy with 1 gram of hardener. When the chip already glued to the slide, the chip are cutting out from the slide and grinding the slide until get the correct thickness.

3.3.4 Data Processing

In the data processing method, it involve the use of software in processing the data before being analyse. Software use in this method are GeoRose, ArcGIS, Terrameter, RES2DINV, Global Mapper and Corel Draw. GeoRose, ArcGIS, Global Mapper and Corel Draw is use in processing data for geological mapping, while Terrameter and RES2DINV are specifically use in processing data from geophysical survey. The final result that obtain after the data processing will be analyse to be interpreted. Figure 3.2 shows the flow process for the Final Year Project.

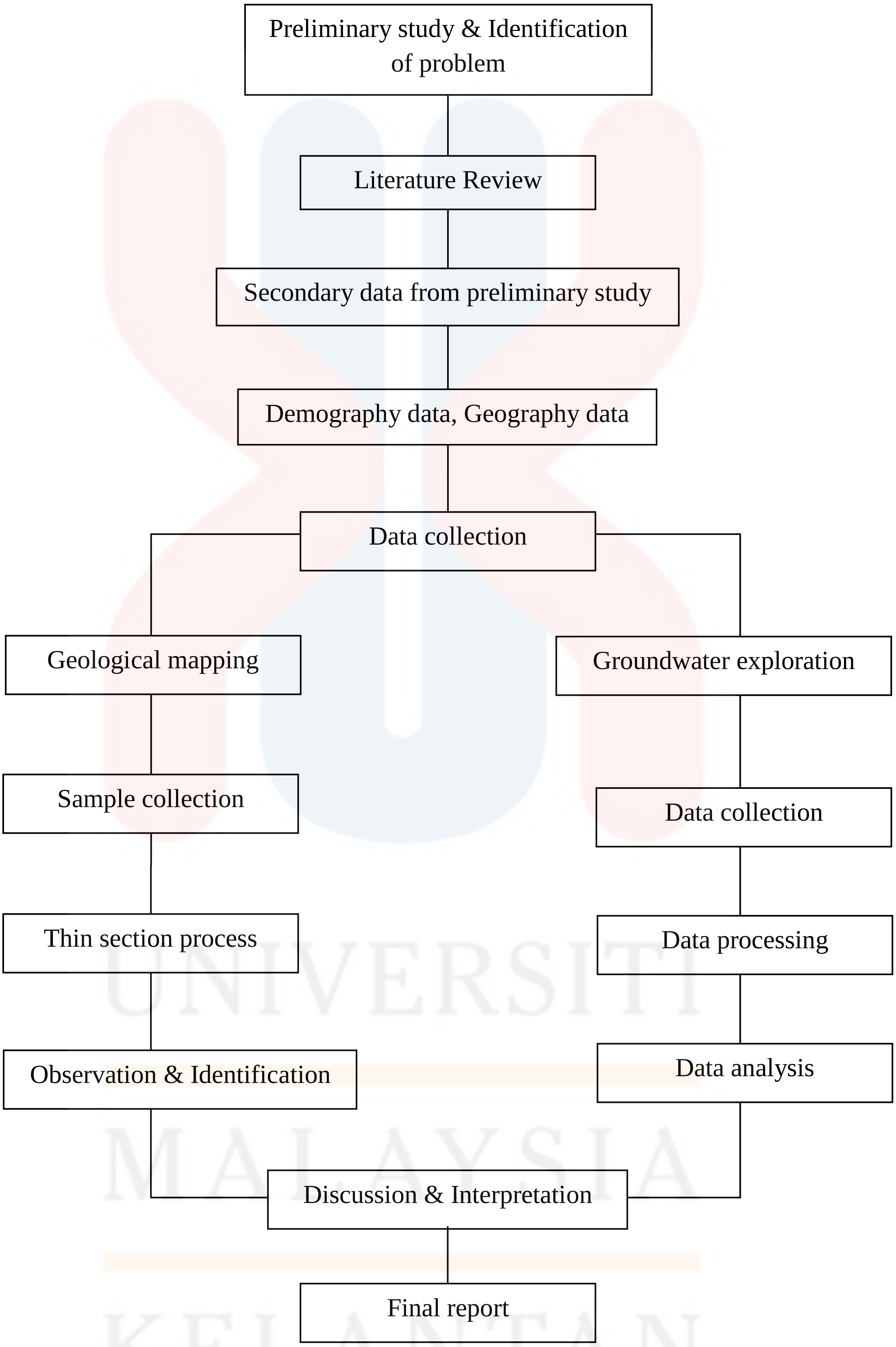


Figure 3.2: Flow process of Final Year Project

CHAPTER 4

GEOLOGY

4.1 Introduction

Geology is the section that explains about the information that gained from the mapping activities. Mapping activities are starting from the preliminary studies from previous research, books, journals, online information and others. Mapping activities in geology consist of geomorphology, stratigraphy, structural geology and historical geology that will be discussed in this chapter. These components were studied before the mapping and during the mapping activities.

In order to complete the general geology of the study area, two weeks of mapping are needed. The study area is divided into three distinct region which 50 percent of the study area are dominated by palm oil plantation that located at the west part of the study area. Another 30 percent is consists of abandon palm oil plantation that located at the north-eastern of the study area and the remaining 20 percent are reserved forest that located at the south-eastern part of the study area.

The main accessibility to the study area is through the Gua Musang – Cameron Highland Highway that leading to Tanah Rata. Meanwhile in the study area, most of the place can only be accessed by unpaved road that interconnected the study area. Certain areas are difficult to access especially the reserved forest due to thick forest and wild animals. Another reason that certain area are difficult to access because of the owner permission, road blocked by landslide and steep areas.

There are no settlements or residential area that can be located in the study area as the study area only consist of palm oil plantation and reserved forest. The only settlement that exist in the study area are office and quarters for workers of the palm oil plantation. The nearest settlement that located around the study area is Pos Blau that 20 km away from the study area.

Figure 4.1 shows the traverse map of the study area during the 14 days of mapping. From the map it can be estimated that almost 80% of the study area has been covered although it is difficult to access.

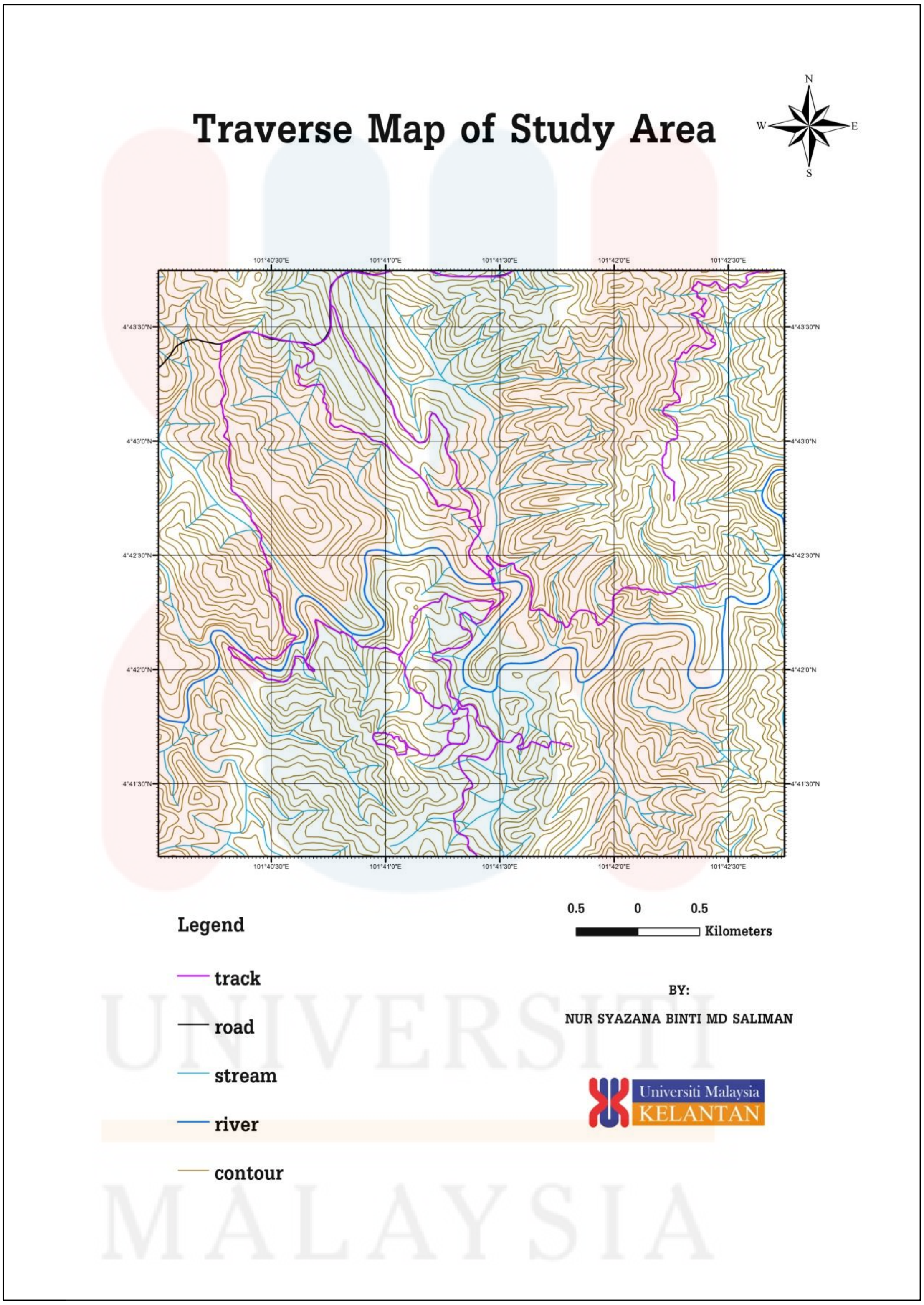


Figure 4.1: Traverse map of the study area

4.2 Geomorphology

Geomorphology is the study of Earth's physical land-surface features, its landform such as rivers, hills, plains, beaches, sand dunes and others. Geomorphology investigates landforms and the process that created them. Form, process and the interrelationship between them are central to understanding the origin and development of landforms (Huggett, 2011).

The formation and deformation of landforms on the surface of the earth are a continuous process with assisted by continuous influence of external (exogenic) and internal (endogenic) forces. Understanding the geomorphological process is important to interpret the evolution or the ancient process that cause the current event to occur. This topic will discusses more on geomorphologic classification, weathering, drainage pattern, mass movement and vegetation in study area.

4.2.1 Geomorphologic Classification

The geomorphological classifications are classified based on the type of landforms – mountain, hilly, valley, plains and alluvium. Landform formed due to the endogenic process, exogenic process and extra-terrestrial process. Endogenic processes are geological process that occurred beneath the earth surface such plate tectonic, volcanism and earthquake. Endogenic processes are triggered by the energy from the earth interior causing it to move and forming many major landform features. Exogenic procesess are geological phenomena that occur near or on the earth surface. These processes are involving weathering, erosion, deposition and transportation that makes the surface erode away.

Figure 4.2 shows the geomorphological map of the study area that consist of high hills, low hills, hills and alluvium. Hills landform had covered approximately 85% from the total extent of study area caused hills landform to become the dominant type of landform in the study area. The elevation for hills landform are range from 200 m until 500 m. Hills landform in study area are used for oil palm plantation, reserved forest and abandoned plantation. Due to the uses of the hills for plantation, several mass wasting were found at the slope of the hills. This mass wasting were stimulate by the hill cut slope that disturbed the compaction between grains caused it to lose their strength. Figure 4.3 shows example of mass wasting in the study area.

Hill landforms are separated to the upper and below part of the study area by alluvium plains located mainly along the main river of Sg. Brooke. The alluvium plain of main river area bordered by two sides of low hills with elevation range from 100 m until 200 m. Figure 4.4 and 4.5 show the geomorphology of the study area from elevation 400 m. Table 4.1 shows the relation between absolute altitude and morphography by Van Zuidam.

Table 4.1: Relation between absolute altitude and morphography (Van Zuidam, 1985)

ABSOLUTE ALTITUDE (m)	MORPHOGRAPHY
< 50	Lowland
50 – 100	Lowland Interior
100 – 200	Low Hill
200 – 500	Hill
500 – 1,500	High Hill
1,500 – 3,000	Mountains
> 3,000	High mountains

(Source: Van Zuidam, 1985)

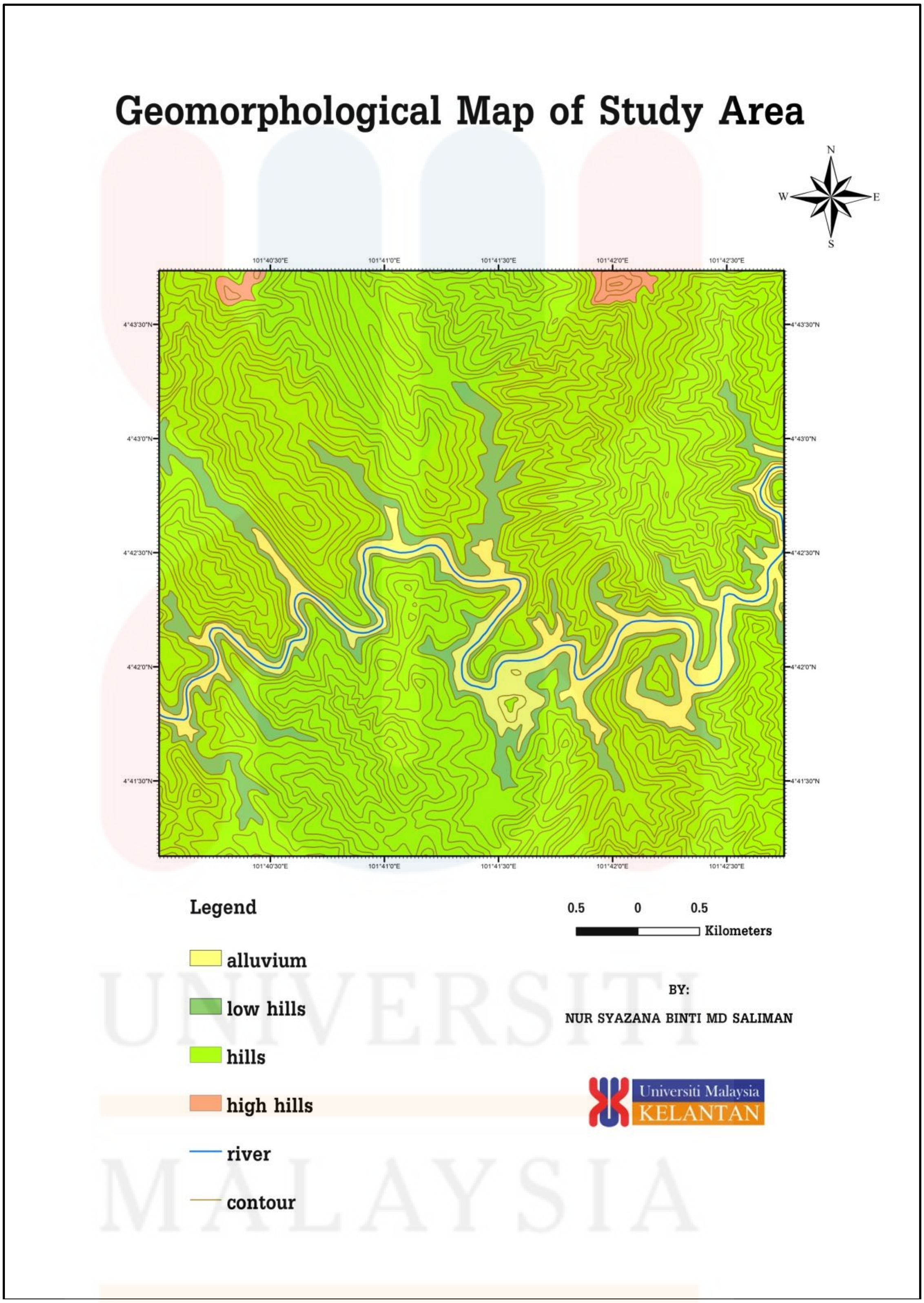


Figure 4.2: Geomorphological map of study area

Figure 4.3: Example of mass wasting in study area

Figure 4.4: Geomorphology view

Figure 4.5: Geomorphology view

4.2.2 Drainage System

Drainage systems are about the pattern formed by the stream, rivers, and lake in a particular drainage basin. Formations of the drainage patterns are dependent on the topography of the land. From the drainage system, it can tell the hardness of the rock in that area either hard or soft rocks, the gradient of the land and the geology of the subsurface. In the view of geomorphologists, streams are a part of drainage basin that receives runoff, throughflow and groundwater flow. Drainage channels are formed when the runoff surfaces are increase and the earth materials are low resistance towards erosion. Meanwhile the textures of the drainage are affected by soil infiltration and the volume of water available in a given period of time to enter the surface. If the soil infiltration is high, fewer drainage channels will develop due to the water soak into the ground. Fewer drainage channels will lead to the formation of coarse-texture for the drainage pattern.

Based on Figure 4.6 it shows that the study area is consist of two types of drainage pattern – rectangular and dendritic. However the study area are dominated by rectangular pattern and followed by dendritic pattern. Rectangular pattern has a change in the stream direction and displaying an almost 90 degree bends between the main streams and their tributaries. Rectangular pattern are associated closely with joint and fault of the subsurface. Joint structure has a characteristics of low resistance towards erosion which giving a chances to the streams to develop along the joints when erosion has advantageously open the joints. Rectangular pattern also associated with massive, intrusive igneous and metamorphic rocks.

Dendritic drainage pattern is a tree-like pattern composed of branching tributaries and a main stream. Dendritic pattern usually develop in regions with homogenous lithologies, horizontal or very gently dipping. For the direction of the tributaries, there is no apparent control towards it due to the similar resistance to the weathering of the subsurface geology. In order to form dendritic pattern, there is usually presence of same lithology of hard rock and uniform structure in study area.

4.2.3 Watershed

Watershed also known as catchment area is an area of land that receives all the water from streams and its tributaries, then accumulate it to a body of water such main river channel in the study area. Watershed are separated normally at the region of highest point such ridge tops that usually will be determine the boundary of a watershed. How and where the water flows will be determined by topography. Figure 4.7 show the watershed in the study area.

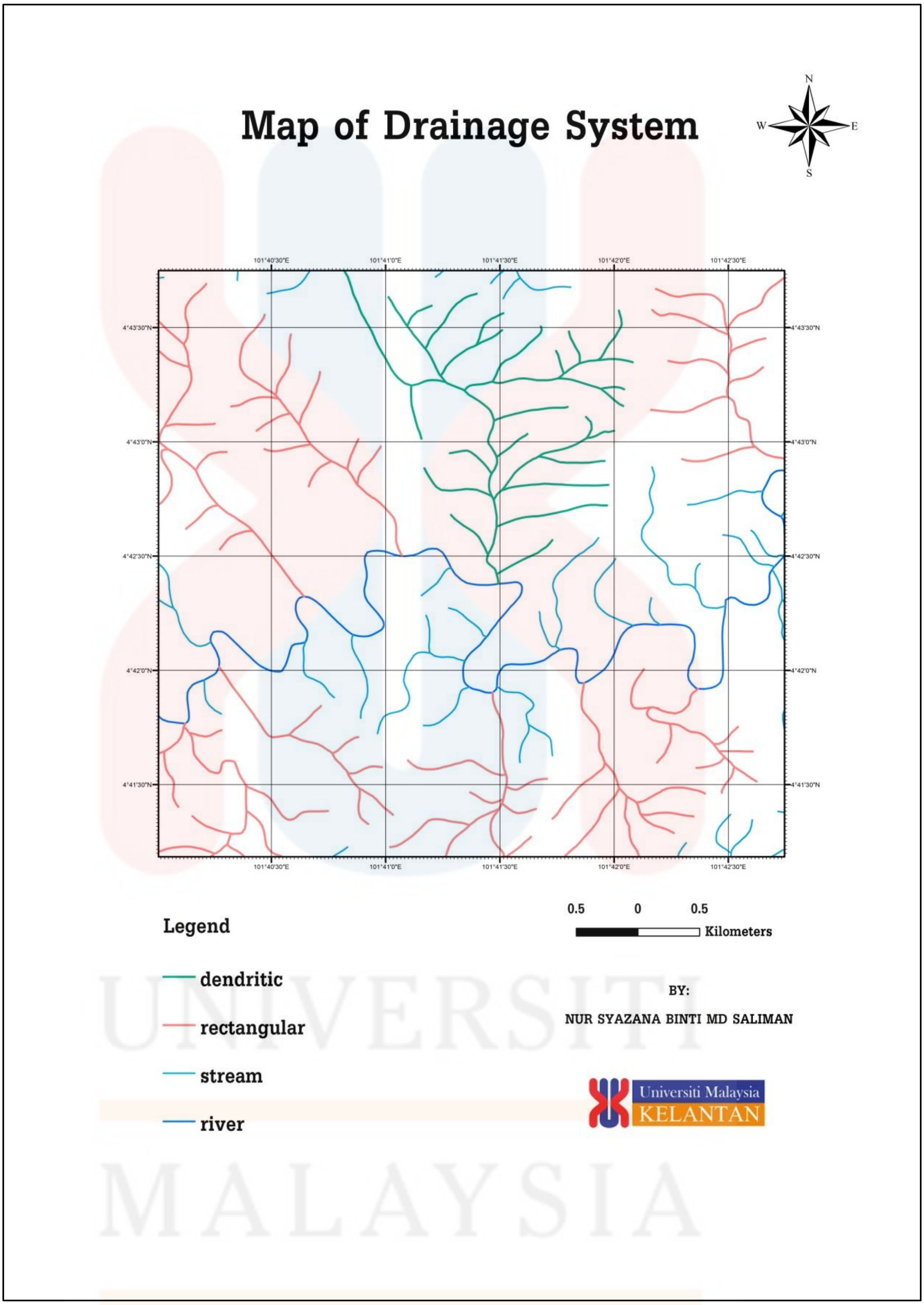


Figure 4.6: Map of drainage system

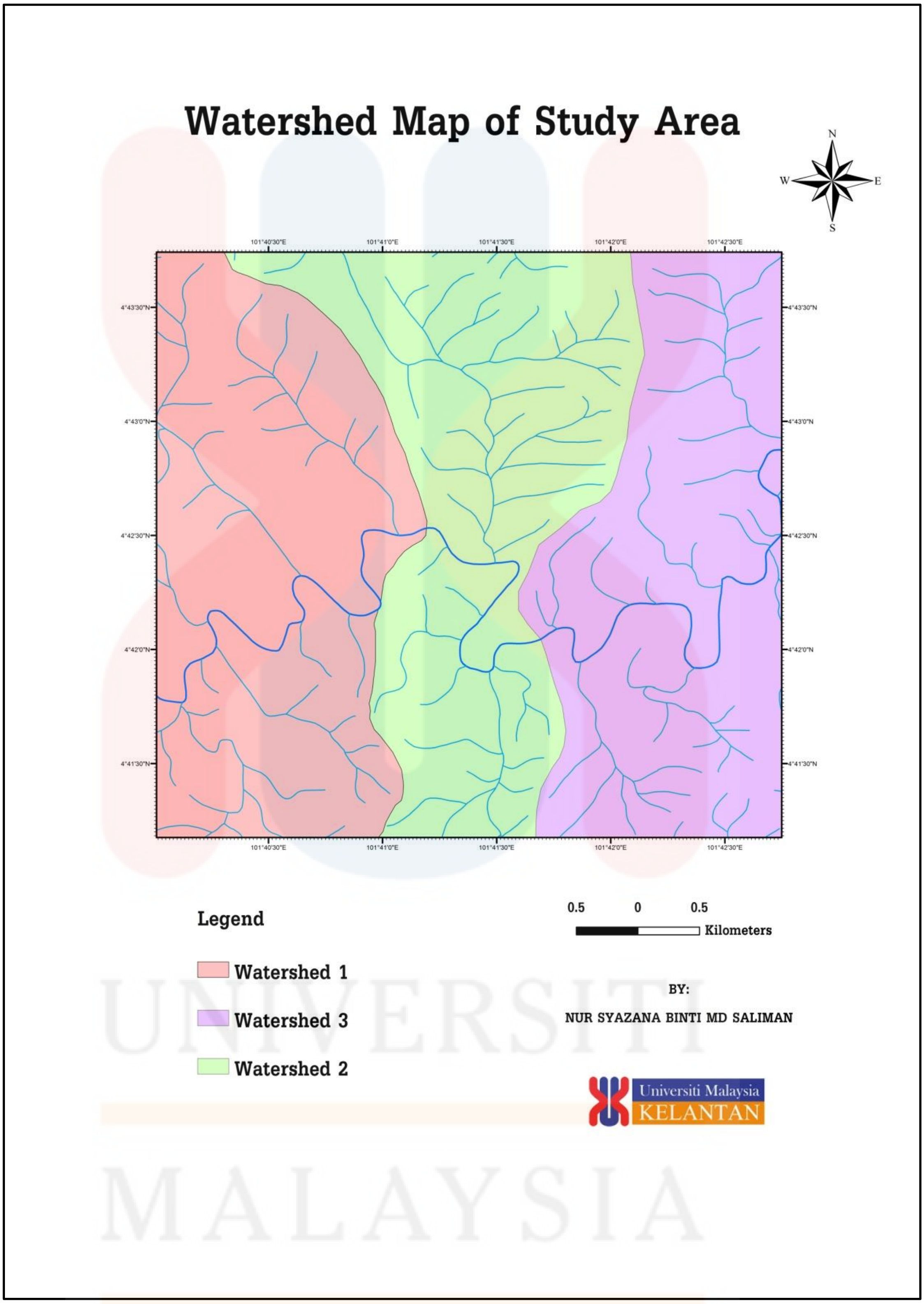


Figure 4.7: Map of watershed in the study area

4.2.4 Weathering

Weathering is the breakdown of rocks by mechanical disintegration and chemical decomposition. Rocks from the subsurface when exposed to the lower temperatures and pressures at the Earth's surface and brought into contact with air, water and organisms, they start to decay. Weathering weakens the rocks and makes them more permeable, so rendering them more vulnerable to removed by agents of erosion and the removal of weathered products exposes more rock to weathering (Huggett, 2011).

Weathering is an *in-situ* process which the occurrence of the weathering in the same place, with little or no movement. Weathering and erosion are the two different processes. Weathering is literally occurs in the same place where the rock placed. Meanwhile, erosion involve the movement of earth materials that being transported by the agents – water, ice, wind, snow, waves and gravity to the other places for deposition process. In weathering process, wind, water, ice and snow are the main important factors that caused weathering to happen. Table 4.2 shows the grade of the weathering and the characteristics of the outcrop.

Table 4.2: Grade of weathering

Grade		Characteristics
VI	Residual Soil	Original rock texture completely destroyed. Can be crumbled by hand and finger pressure into constituent grains.
V	Completely Weathered	Original rock texture preserve, can be crumbled by hand and finger pressure into constituent grains, easily indented by point of geological pick, slakes when immersed in water, completely discoloured compared with fresh rock.
IV	Highly Weathered	Can be broken by hand into smaller pieces, make a dull sound when stuck by geological pick, does not slake when immersed in water, completely discoloured compared with fresh rock.
III	Moderately Weathered	Cannot usually be broken by hand, easily broken by geological hammer. Makes a dull or slight ringing sound when stuck by geological hammer.
II	Slightly Weathered	Not broken easily by geological hammer. Makes a ringing sound when stuck by geo-hammer. Fresh rock colours generally retained but stained near joint surfaces.
I	Fresh	Not broken easily by geological hammer. Makes a ringing sound when stuck by geological hammer, no visible signs of decomposition.

(Source: Geotechnical Engineering Office, 1988)

a) Physical Weathering

Physical weathering is a process that only involve mechanical occurrence of breaking apart larger rock size into smaller size without changing its original chemical composition. Physical weathering is stimulated by temperature, pressure, frost, water and thermal stress. These factors can give mechanical forces through the action of frost wedging, thermal expansion, salt crystal growth and abrasion. Through physical weathering, the surface of the rocks will crack and create an opening to increase the surface area, thus increasing the rate of rock breakdown.

Abrasion is the common physical weathering process that can be found in the study area. Abrasion is the process of wearing away rock particles by erosion of water and wind. Continuously occurrence of these processes will gradually break down the rock exposed surfaces into small sizes. Figure 4.8 shows the example of physical weathering in the study area after the process of the abrasion occur in a long period of time.

b) Chemical Weathering

Chemical weathering is the chemical reaction that involves alteration of the original chemical composition through the process of dissolution, hydrolysis, carbonation and oxidation. In the chemical weathering, the presence of moisture and air are very essential to ensure it work well. These chemical reactions occur when water and air interact chemically with the minerals and rocks causing the original chemical composition to altered forming new chemical contents.

c) Biological Weathering

Biological weathering is causes by the action of animals and plants. Common biological weathering in the study area is caused by plants that grows surrounding the outcrops and on the top parts of rocks forming leeching and discoloured the surface of the rocks. Plants that growth on the top part of outcrops, as it retains most of the water content usually will become the hostile environment for vegetation, bacteria and organisms. The rate of biological weathering acting on the rock will increase, due to the acidic environment of the rock layer. Figure 4.9 shows example of biological weathering in the study area.

4.3 Stratigraphy

Stratigraphy is one of the branch in geology that concerned with the description of layering (stratification) of rock layers (strata), correlation within the lithology and the history interpretation that represented by the stratification of the rock layers. Stratigraphic column of the study area are showed in the vertical distribution with the geological time scale to study the chronological sequence of scattered strata of different places. Based on the law of the superposition, the oldest rock unit will lies at the bottom part and followed by the youngest rock unit that lies at the top. Table 4.3 show the stratigraphy column of the study area.

Figure 4.8: Example of physical weathering in study area

Figure 4.9: Example of biological weathering

Table 4.3: Stratigraphic column

ERA	PERIOD	LITHOLOGY	DESCRIPTION
Mesozoic	Early Triassic – Middle Triassic	Alluvial deposit	Various grain size deposited. Light brown colour.
	E., Late Permian – E., Early Permian	Schist	Medium-grade metamorphism rock with schistose texture.

4.3.1 Rock Unit Explanation

This study area only has one type of rock unit which is schist. Schist is a metamorphic rock with crystalline texture and the grain size are usually medium and can be seen by naked eye. Due to compaction and pressure during the formation of metamorphic rock, schist have a foliation and schistosity structure. However there various colour and type of schist in the study area.

a) Mica Schist

Mica schist is one of the schist rocks that found in the study area (04° 42' 9.62" N and 101° 41' 22.13" E) that abundance with minerals of mica (biotite or muscovite) as their main minerals causing the surface of the rock looked very shiny even with naked eye. The colour of the mica schist are brick red and the hardness of the rocks are low due to the weathering process and vulnerable to split into layers. The rocks are showed foliation structure with strike and dip 337/54. The surfaces of the outcrop are highly weathered causing the colour of the outcrop to change into dark colour and reduce the strength of the rocks. The grade of weathering for this outcrop can be classified into grade V. Figure 4.10 shows the outcrop of mica schist and Figure 4.11 shows the hand sample of the rock from the field. Petrographic analysis for mica schist is not really well due to the wrong cut by the lab assistant which in the thin section it only shows the weathering part. However certain mineral still can be find.

Mica schist also can be found at the coordinate of 04° 42’ 25.6” N and 101° 41’ 35.6” E. The outcrop of this mica schist also has undergone weathering of grade V that causing the change of colour into a little yellow. The surface of the rocks also shiny indicating the abundance of minerals mica. The rocks are compacted and consolidated but low in hardness and can easily broke. The structures of mica schist at this location are hard to identify due to the effect of hill cut slope. Figure 4.12 shows the mica schist outcrop at another location.

b) Dark Mica Schist

This dark mica schist can be found at coordinate 04° 43’ 32.17”N and 101° 42’ 21.71”E, north-eastern part of the study area. The colour of the rock is black with shiny surface that indicate to the abundance of mineral mica. Dark mica schist has a medium hardness that can break by using geological hammer. The reading of strike and dip is 322/65. The outcrop may be affected by chemical weathering based on the rock that feel a bit wet and biological weathering due to the vegetation that surround it. Figure 4.13 shows the outcrop of the dark mica schist and Figure 4.14 shows the sample of hand specimen from the outcrop. Table 4.4 shows the mineralogy description for dark mica schist.

Figure 4.10: Outcrop of mica schist

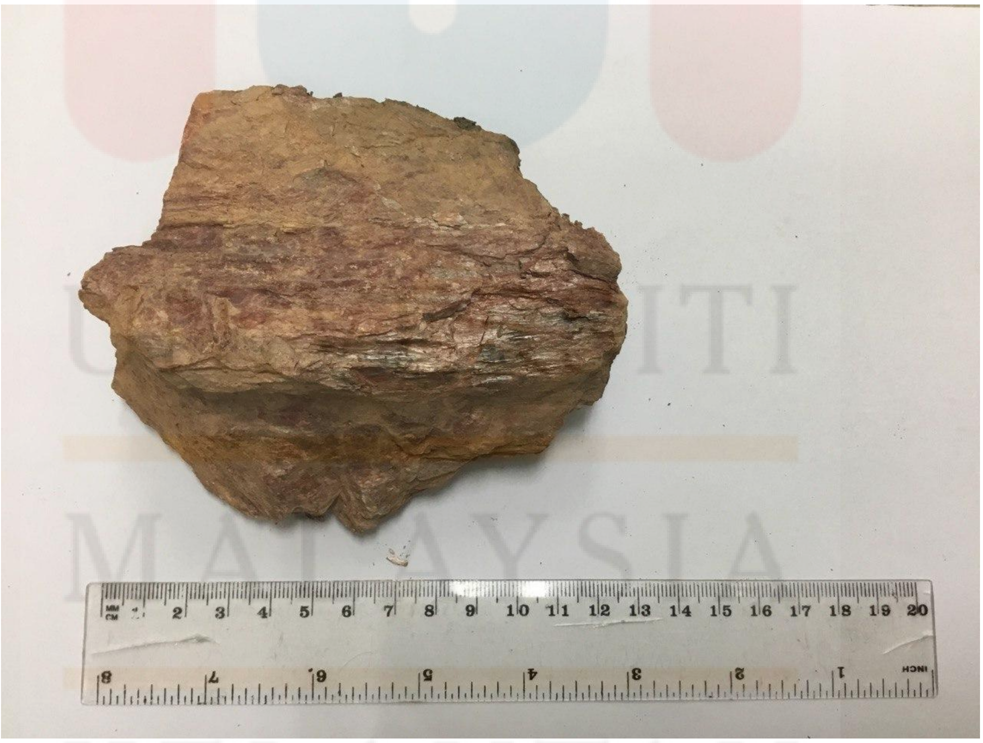


Figure 4.11: Hand sample of mica schist

Figure 4.12: Outcrop of mica schist

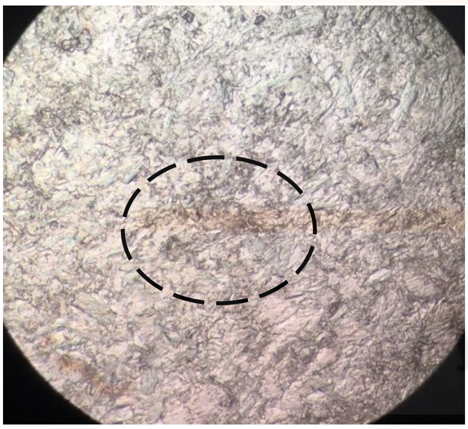
Figure 4.13: Outcrop of dark mica schist

Figure 4.14: Hand specimen of dark mica schist

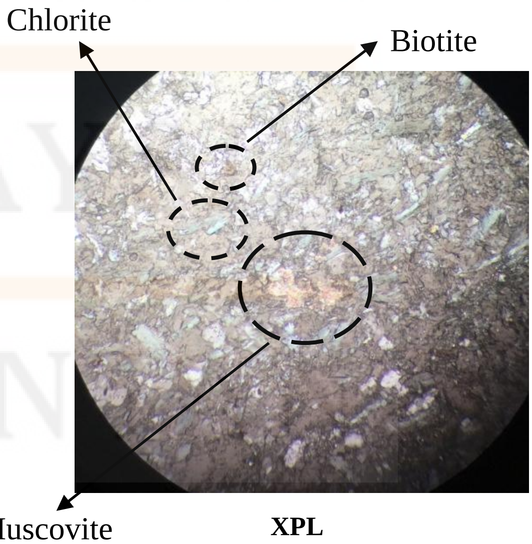
Table 4.4: Mineralogy description of dark mica schist

Mineralogy Description	
Composition of Minerals	**Description**
Chlorite	Chlorite is pleochroic usually colourless, pale green. Twinning is common but often difficult to recognize.
Biotite	Biotite is similar to muscovite, usually dark green and pale brown in colour.
Muscovite	Colour of muscovite is tinted of yellow, violet, green, and browns under the XPL.

Photo: 10x10



PPL



XPL

c) Grey Schist

The second type of rock that found in the study area (04° 42' 2.82" N and 101° 41' 13.05" E) are also schist but grey in colour. The outcrop of grey schist are small and located at the below part of the slope. The hardness of the outcrop is very hard that take several blows to break it for sample collection. Grade II of weathering also indicate that the outcrop only slightly weathered and do not affect the hardness of the rock. These outcrop also showed the structure of lineation and joint. The size of minerals is medium and can be identify by naked eye. Figure 4.15 shows the outcrop of grey schist.

d) Graphite schist

Graphite schist has a luster of submetallic with a little amount of mica and easily break by using hand. The outcrop of this rock located at coordinate 04° 43' 23.26"N and 101° 42' 18.11"E. Although generally the colour of the outcrop surface are black-grey but the colour is a bit red which is hematite. The reading of strike and dip is 319/76. The rock may undergo chemical weathering because there was a water flow near the outcrop. The condition of the outcrop is not very well due to mass movement that cause by water flow movement. Figure 4.16 shows the outcrop of the graphite schist and Figure 4.17 shows the hand sample of graphite schist that has break into pieces. Table 4.5 shows the mineralogy description for graphite schist.

Figure 4.15: Outcrop of grey schist

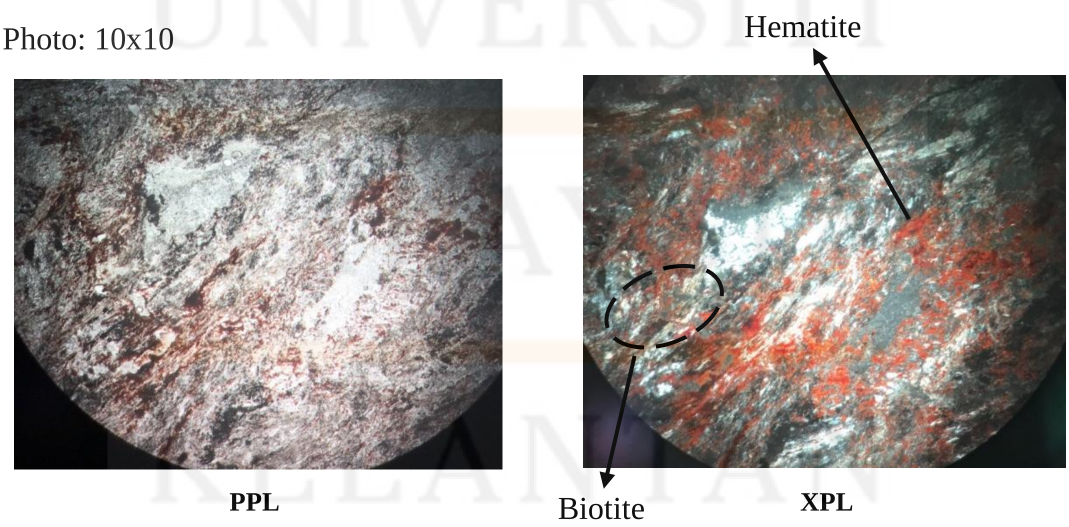
Figure 4.16: Outcrop of graphite schist

Figure 4.17: Pieces of hand specimen for graphite schist

Table 4.5: Mineralogy description of graphite schist

Mineralogy Description	
Composition of Minerals	**Description of Optical Mineralogy**
Hematite	Hematite usually opaque, unless the thin section is thin enough, the colour is reddish under PPL and XPL.
Biotite	Biotite usually dark green, pale brown or black in colour. It similar to muscovite that display high interference colours in XPL.

Photo: 10x10



PPL **XPL**

4.4 Structural Geology

Structural geology are the another branch of geology that concerned with the deformation of rocks as result from the forces of tectonic movements. Structural geology also studied how these structures are formed and how it effects the rocks and the surrounding. Structures were split into two basic groups – ductile and brittle. Ductile structures were formed from the stretching, bending or shortening of rocks that forming folding. Brittle structures formed by breaking or fracturing of the rocks that forming joint and fault. Structural geology also represent past geological environment and deformation histories that can help to predict the evolution of structural geology in particular area.

4.4.1 Foliation

Foliation is the main structures for metamorphic rocks that have been exerted with pressure and high temperature. The direction of the layers can be either parallel with the direction of shear or perpendicular to the higher pressure direction. Formation of foliation was caused by shearing forces or differential pressures that occur when the rocks are buried deep beneath the subsurface of lithosphere. Shearing forces are involving pressures that coming from different direction and push the rock in different sections. Differential pressure are involving pressure from two opposite direction, however pressure from one direction are higher than in others. Figure 4.18 shows the structure of foliation.

4.4.2 Chevron

Chevron is a structure that shaped like fold structures but with sharp hinges and the inter-limb angles are generally 60 degrees or less. Well developed chevron will produce a v-shaped beds. Chevron folding preferentially occurs when the bedding regularly alternates between contrasting competences. Turbidites, characterized by alternating high-competence sandstones and low-competence shales, provide the typical geological setting for chevron folds to occurs (geology page, 2015). Chevron and folds are the common structures in metamorphic rocks, therefore many structures of chevron can be found in this study area. Figure 4.19 shows the structure of chevron.

4.4.3 Vein

Vein is a deposition of mineral that found in rock. Vein occur when there is an opening or fracture at the rock, mineral will deposited in that space and crystallized. Usually type of mineral filling is quartz and calcite. Figure 4.20 shows the filling of quartz minerals in the opening spaced of the rock and crystallized throughout the time.

4.4.4 Joint

Joint is a straight line fracture with a little or no displacement that divide the rock into certain section. Joints are formed from brittle structure as result of compressive stress and physical weathering – exfoliation and unloading. Joint usually occur as sets which each set of joint are parallel to each others. Figure 4.21 shows total joint analysis in the study area by using Georose software. From the rose diagram, the highest forces which is sigma 1 are coming from the north-east side at an angle 60°. Sigma 3 that are always perpendicular to the sigma 1 are coming from north-west side at angle 330°. Joint results are used in understanding the local and regional geology and geomorphology. Figure 4.21 shows the analysis of joint using Georose.

Figure 4.18: Structure of foliation

Figure 4.19: Structure of chevron

Figure 4.20: Small quartz vein in schist rock

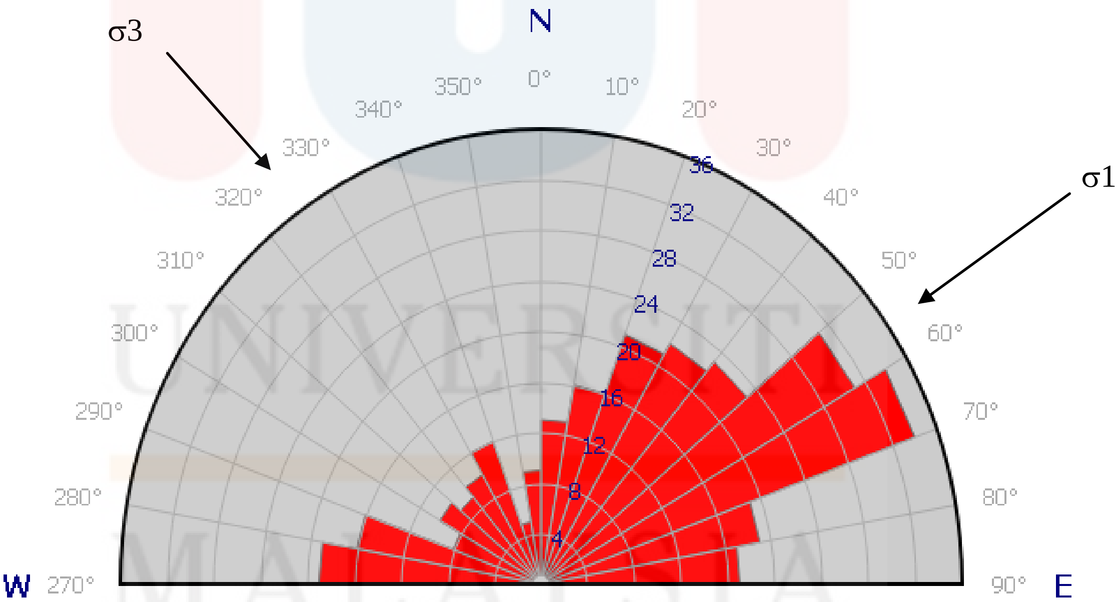


Figure 4.21: Joint analysis

4.5 Historical Geology

Historical geology of the study area started during the Early Permian and ended during Middle Triassic of Bentong – Raub Suture Zone. Based on the finding during the geological mapping, the study area was placed right at the section of schist distribution in Bentong – Raub Zone. Before the formation of Bentong – Raub Suture Zone, the study are were consist of sedimentary rock of mudstone, shale and siltstone. However, due to the collision between Indochina Block and Sibumasu, these sedimentary rock has undergo contact metamorphism that has altered the chemical composition in the sedimentary rock into metamorphic rock. Due to higher temperature and pressure, mineral has change their orientation and aligned it horizontally. This change orientation forming new structure of foliation.

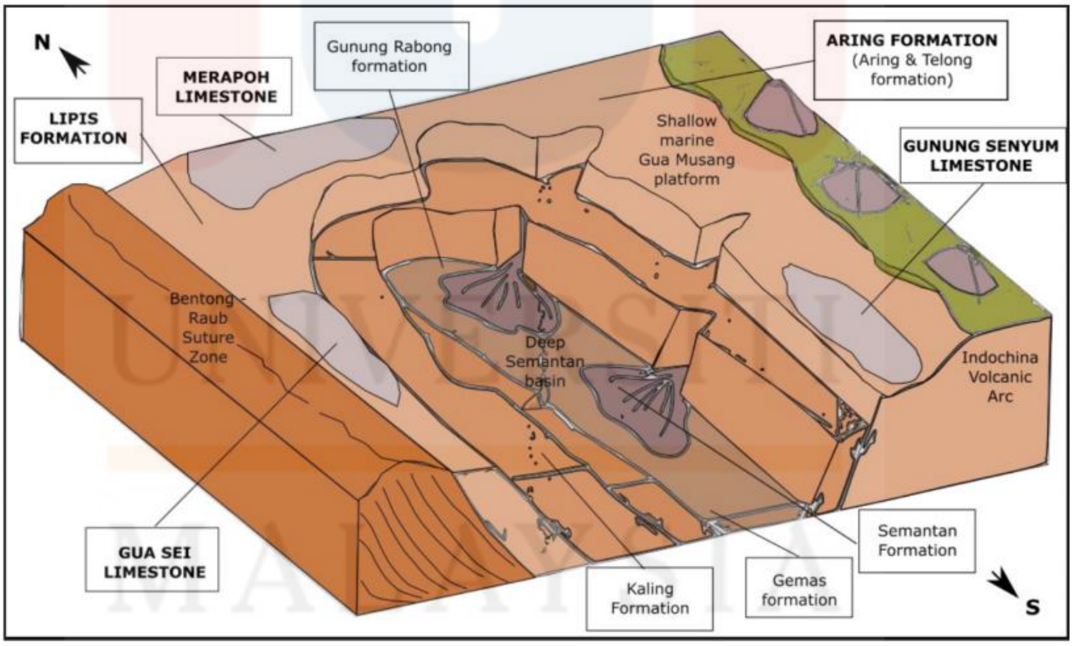


Figure 4.22: Depositional setting during the Middle Triassic

(Source: Bulletin of Geological Society of Malaysia, 2016)

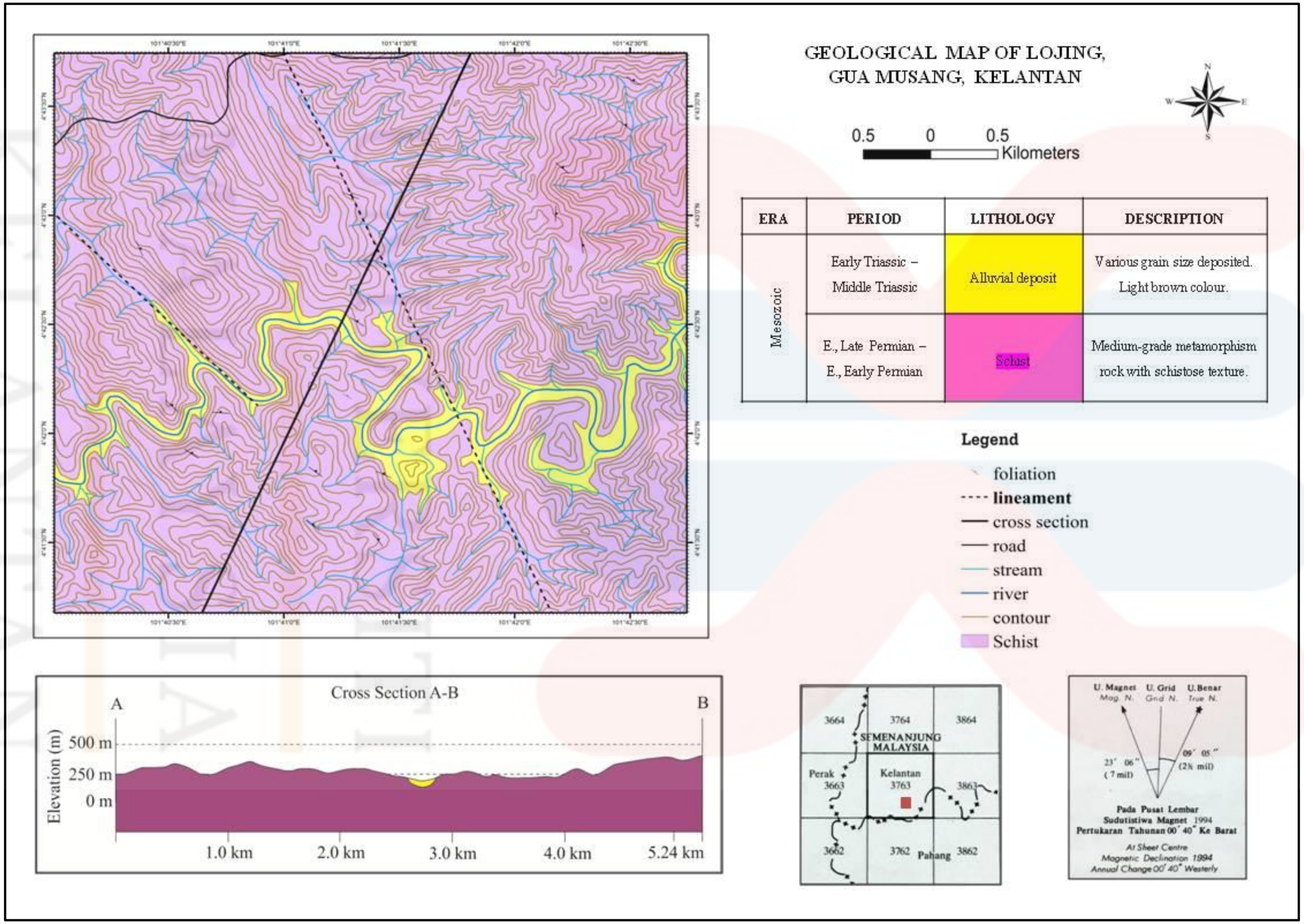


Figure 4.23: Geological map of the study area

CHAPTER 5

GROUNDWATER EVALUATION BY USING ELECTRICAL RESISTIVITY IMAGING

5.1 Introduction

Evaluation of groundwater is used to evaluate whether there are or not existence of groundwater in the hard rock area. In the North Kelantan, there is abundance of groundwater due to the type of landform that is alluvium. Alluvium has the characteristics of unconsolidated materials and can bear water compare to the study area that has the lithology of hard rock. Groundwater in hard rock area only can be found in the fracture area, where there are an opening in the rock that can accumulate and hold water. Existence of groundwater can be monitor by using geophysical survey of Electrical Resistivity Imaging (ERI) method. Electrical Resistivity Imaging method can determine the subsurface material and condition by using the resistivity value as every materials possess different resistivity values. Figure 5.1 shows the standard value of resistivity and conductivity for various types of materials by Palacky.

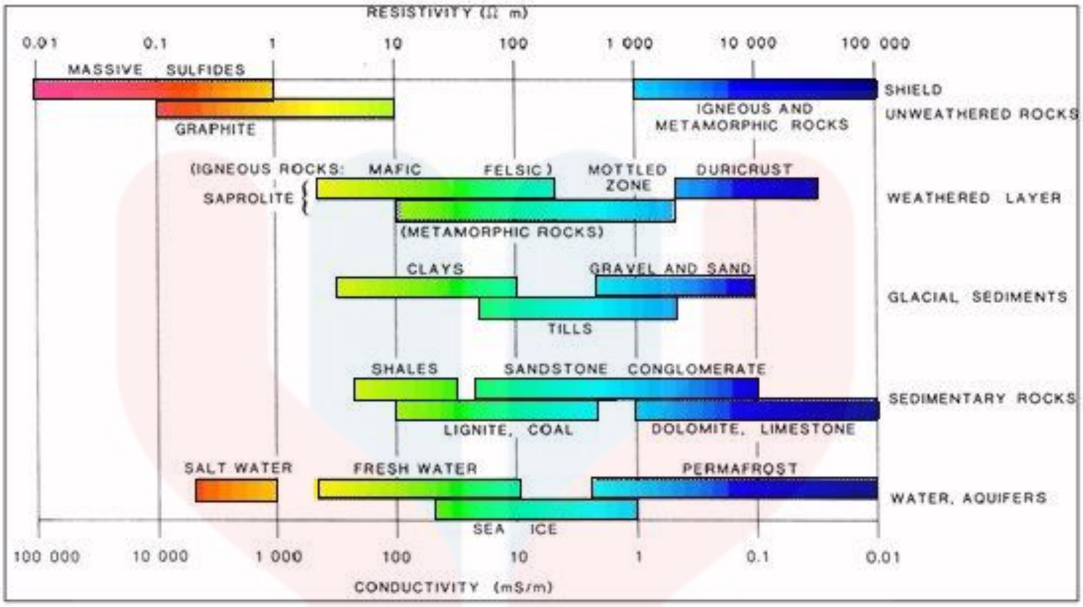


Figure 5.1: Standard Resistivity Value and conductivity
(Source: Palacky, 1988))

5.2 Electrical Resistivity Imaging Survey Line

Five lines of geophysical survey by using Electrical Resistivity Imaging method are done to investigate the existence of groundwater in the study area. Figure 5.2 shows the location of the five lines survey in the study area. These survey lines were chosen mostly based on the lineament . The length of each survey line are 200 m with 42 takeout and the spacing between each takeout are 5 m. The type of electrode configuration used are Wenner array, Schlumberger array and Pole-Dipole array. Survey line that has been processed will be interpret by comparing the resistivity value from the result with the standard actual resistivity value.

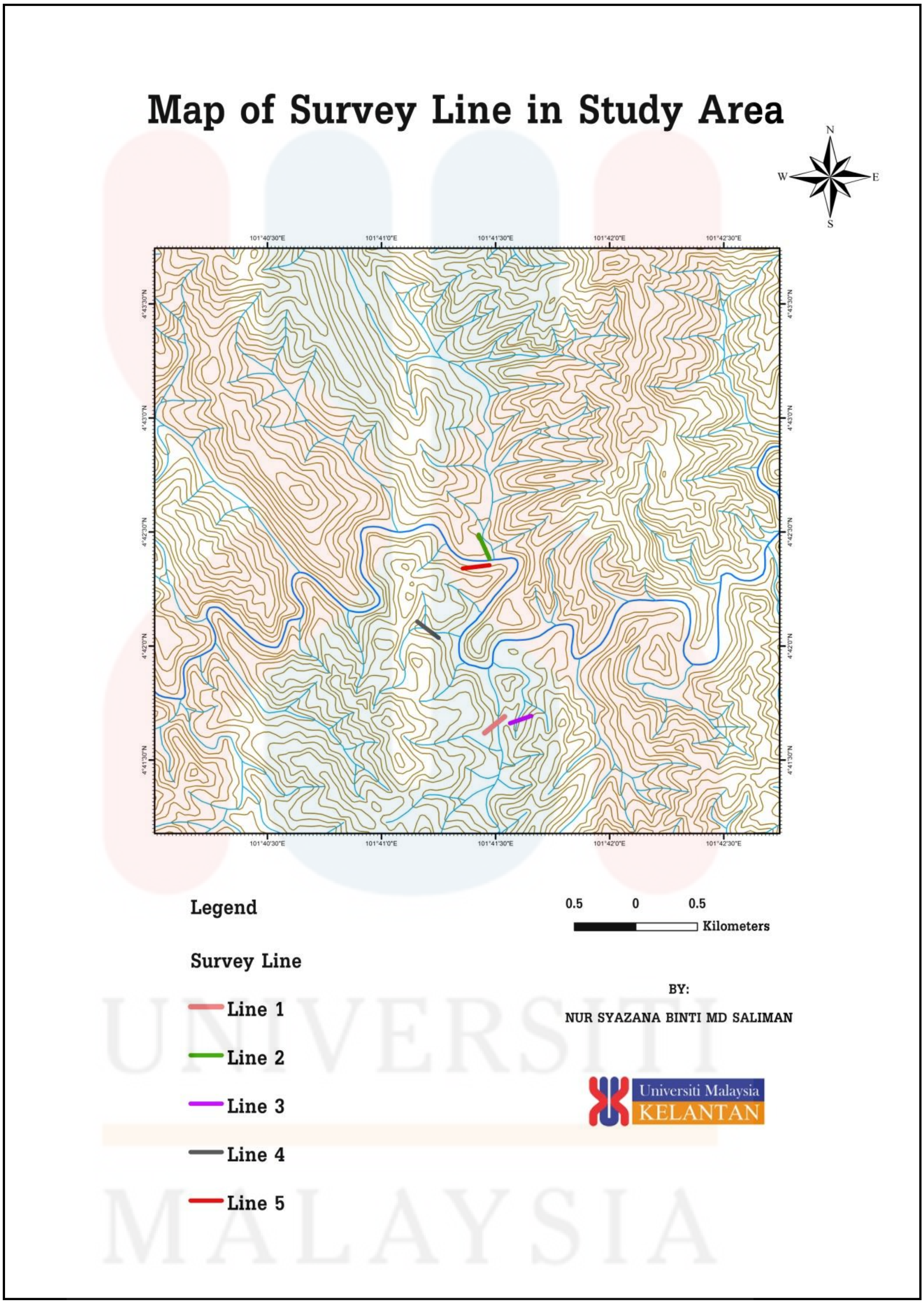


Figure 5.2: Map of survey line

5.2.1 Survey Line 1

The first location of this survey line are located at the lineament with coordinate 04° 41' 38.01" N and 101° 41' 27.78" E. The direction of the survey line are SW-NE and the type of electrode configuration for this line are Pole-Dipole. Table 5.1shows the coordinate for first, centre and last electrode of the survey line. Figure 5.3 and 5.4 shows the set-up of survey line 1.

Table 5.1: Coordinate for first electrode, centre and last electrode

Electrode	Latitude	Longitude	Elevation
1	04° 41' 28.01"N	101° 41' 27.78"E	232 m
21	04° 41' 40.56"N	101° 41' 29.28"E	226 m
41	04° 41' 41.47"N	101° 41' 32.37"E	227 m

Based on Figure 5.5 the total percentage of RMS error is 13.3% for resistivity although many bad datum has been eliminated. Minimum resistivity value in this survey line is 0.5Ωm and the highest is 14,000Ωm with depth more than 30m. Based on the figure 5.5, the pseudosection is divided into three zones – Zone A, Zone B and Zone C. Zone A is a high potential of groundwater with resistivity value below than 200Ωm. For Zone B the range of resistivity value is between 300Ωm until 5,000Ωm which is the standard resistivity value for sedimentary rock such limestone, sandstone and shale. Zone C is for the material with high resistivity value that range between 5,000Ωm until 14,000Ωm. High resistivity value is indicating to the hard materials such granite, slate and quartzite. Potential groundwater for this location is stored in two type – fracture and in sediments. Zone A at the bottom of the pseudosection is stored in sediments while Zone A at the top of pseudosection is stored in fracture.

Figure 5.3: Set-up for survey line 1

Figure 5.4: Set-up for survey line 1

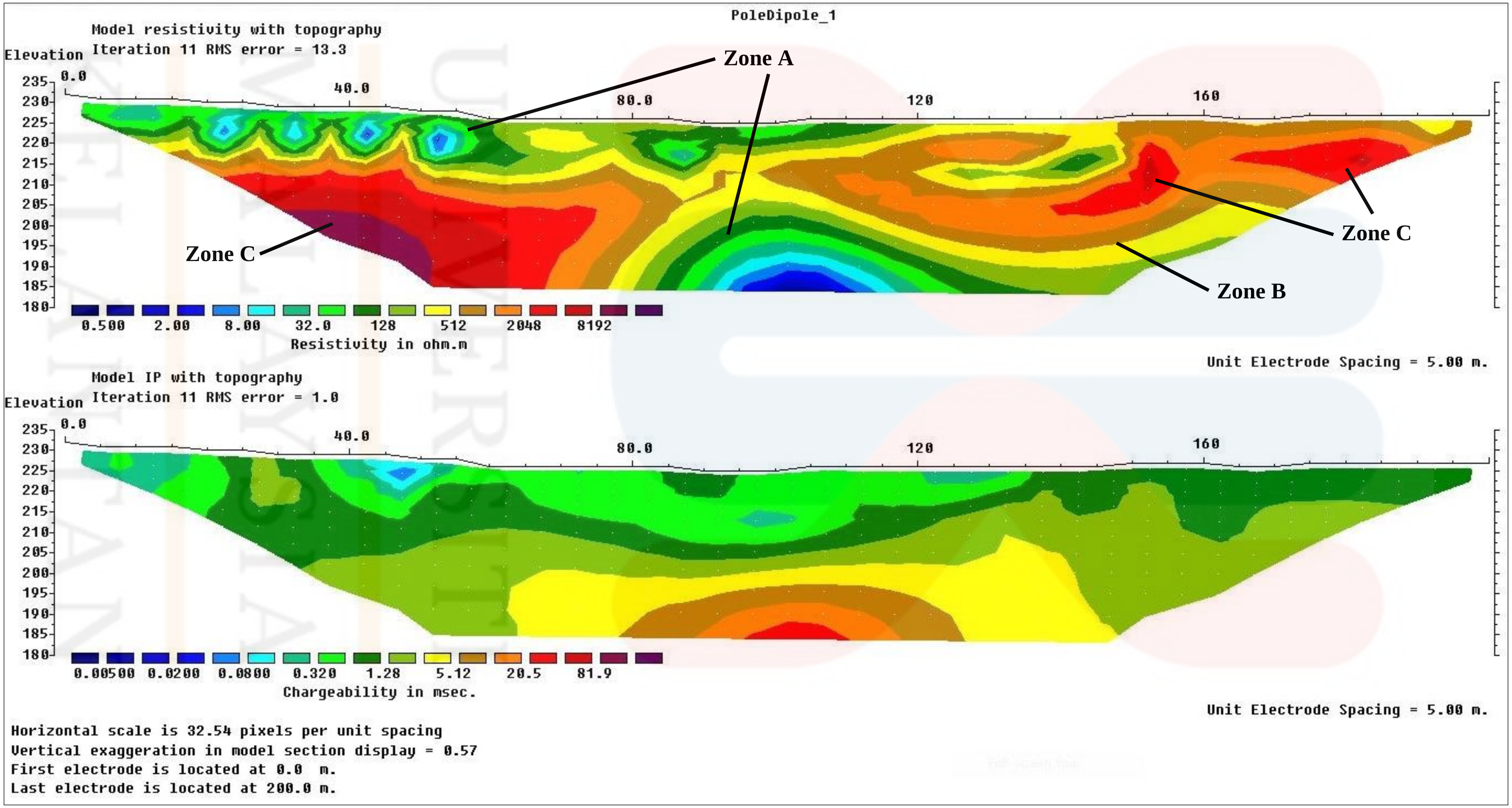


Figure 5.5: Result of survey line 1

5.2.2 Survey Line 2

Second line of the survey are located at stream which also a lineament. This location were chosen because stream that located at lineament can act as recharge source for groundwater, therefore there are high possibility for the existence of groundwater. The coordinate of second location are 04° 42' 26.08"N and 101° 41' 27.56"E and the direction of the second line are N-S. Electrode configuration for this second line are Wenner array. Table 5.2 shows the coordinate for first, centre and last electrode of the survey line. Figure 5.6 and 5.7 shows the set-up for survey line 2.

Table 5.2: Coordinate of first electrode, centre and last electrode.

Electrode	Latitude	Longitude	Elevation
1	04° 42' 28.58"N	101° 41' 25.86"E	207 m
21	04° 42' 26.08"N	101° 41' 27.56"E	205 m
41	04° 42' 23.13"N	101° 41' 28.40"E	209 m

Based on Figure 5.8 total percentage of RMS error is 5.7% with minimum resistivity value 5.0Ωm and the maximum resistivity value is 1,000Ωm. This highest resistivity value is lower than the highest resistivity value for survey line 1. This may due to the location of this survey line that located at the stream and the surrounding of the stream which is wet. Pseudosection of this survey line only divided into two zones – Zone A and Zone B. Range of resistivity value for Zone A is from 0.00Ωm until 200Ωm that indicated to the groundwater. For Zone B, the resistivity value is range between 200Ωm until 1,000Ωm. With maximum depth of penetration that is only 30m, this result shows that there is no hard materials with resistivity value more than 5,000Ωm. Zone B only consist of soft sedimentary rock that has resistivity value low than 1,000Ωm such clay.

Figure 5.6: set-up for survey line 2

Figure 5.7: set-up for survey line 2

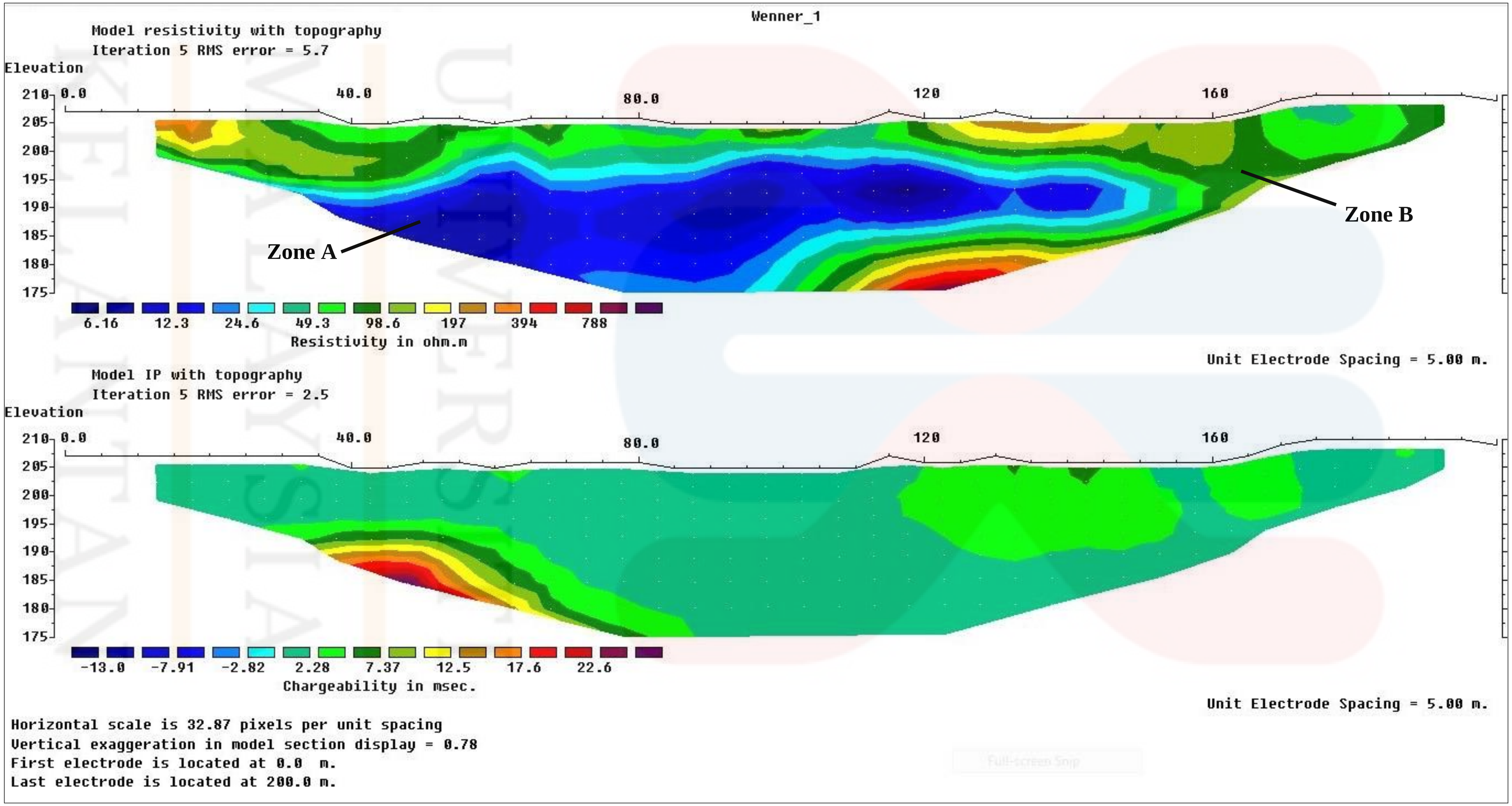


Figure 5.8: Result of survey line 2

5.2.3 Survey Line 3

The third line are located near with the lineament of first survey line at coordinate 04° 41’ 39.29”N and 101° 41’ 36.73”E. The type of electrode configuration used are Schlumberger with line direction W-E. Table 5.3 shows the coordinate of first electrode, centre and last electrode. Figure 5.9 shows the set-up for survey line 3.

Table 5.3: coordinate of first electrode, centre and last electrode

Electrode	Latitude	Longitude	Elevation
1	04° 41’ 39.48”N	101° 41’ 33.82”E	228 m
21	04° 41’ 39.29”N	101° 41’ 36.73”E	223 m
41	04° 41’ 41.14”N	101° 41’ 38.57”E	241 m

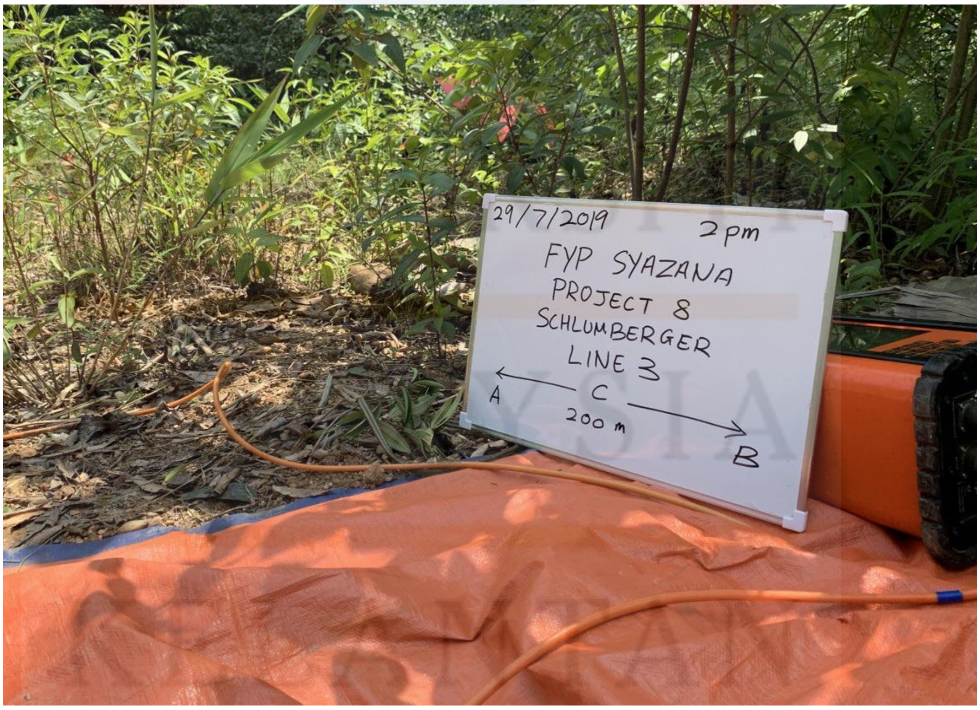


Figure 5.9: set-up for survey line 3

Based on Figure 5.10 the total percentage of RMS error is 5.7% with range of resistivity value is between 30Ωm and 5,000Ωm. Division of zone for this pseudosection is same with the previous which only divide into two zones – Zone A and Zone B. Range of resistivity value for Zone A is between 30Ωm until 200Ωm and the region of the potential groundwater seems divide into top and bottom of pseudosection. The top region of groundwater potential may stored in fracture and also can known as shallow groundwater because near with the surface. Zone B has a range of resistivity value between 300Ωm until 5,000Ωm. This subsurface has a sedimentary rock with resistivity value low than 5,000Ωm such limestone and shale.

5.2.4 Survey Line 4

The forth line is placed with crossing a stream and the coordinate is 04° 42'3.94"N and 101° 41'11.28"E. Stream was chosen because the stream can act as recharge materials for groundwater. Therefore, there were a possibility that there is a groundwater in the area. The type array use is Wenner and the direction of the line survey is SE–NW. Table 5.4 shows the coordinate of first electrode, centre and last electrode. Figure 5.11 shows the set-up for survey line 4.

Table 5.4: Coordinate of first electrode, centre and last electrode

Electrode	Latitude	Longitude	Elevation
1	04° 42' 02.80"N	101° 41' 14.16"E	222 m
21	04° 42' 03.94"N	101° 41' 11.28"E	214 m
41	04° 42' 06.39"N	101° 41' 09.36"E	237 m

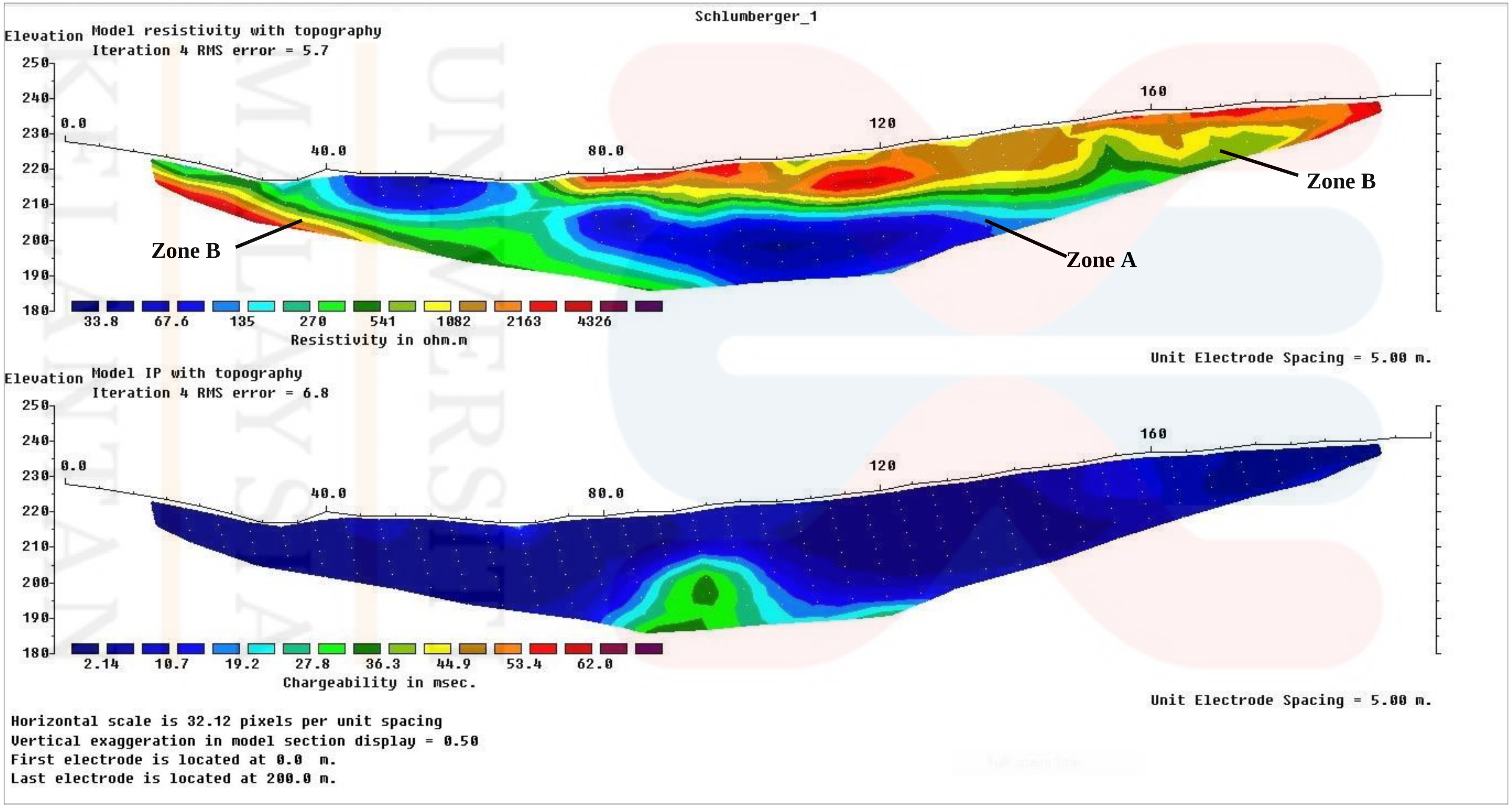


Figure 5.10: Result of survey line 3

Figure 5.11: Set-up for survey line 4

Figure 5.12 shows the total percentage of RMS error is 5.7% with resistivity value range between 30Ωm until 7,000Ωm. This pseudosection also divided into two zone – Zone A and Zone B. Zone A is a zone for potential groundwater and at this location Zone A is located at the top of pseudosection, near the surface. This Zone A may categorize as shallow groundwater because near with the surface. This survey line is lined crossing a stream which may become a reason for the shallow groundwater. Surface water of the stream may act as a recharge for the shallow groundwater. Resistivity value for Zone A is range between 30Ωm until 200Ωm. For Zone B, the resistivity value is range from 200Ωm until 3,000Ωm which indicate that Zone B consist of sedimentary such sandstone and limestone.

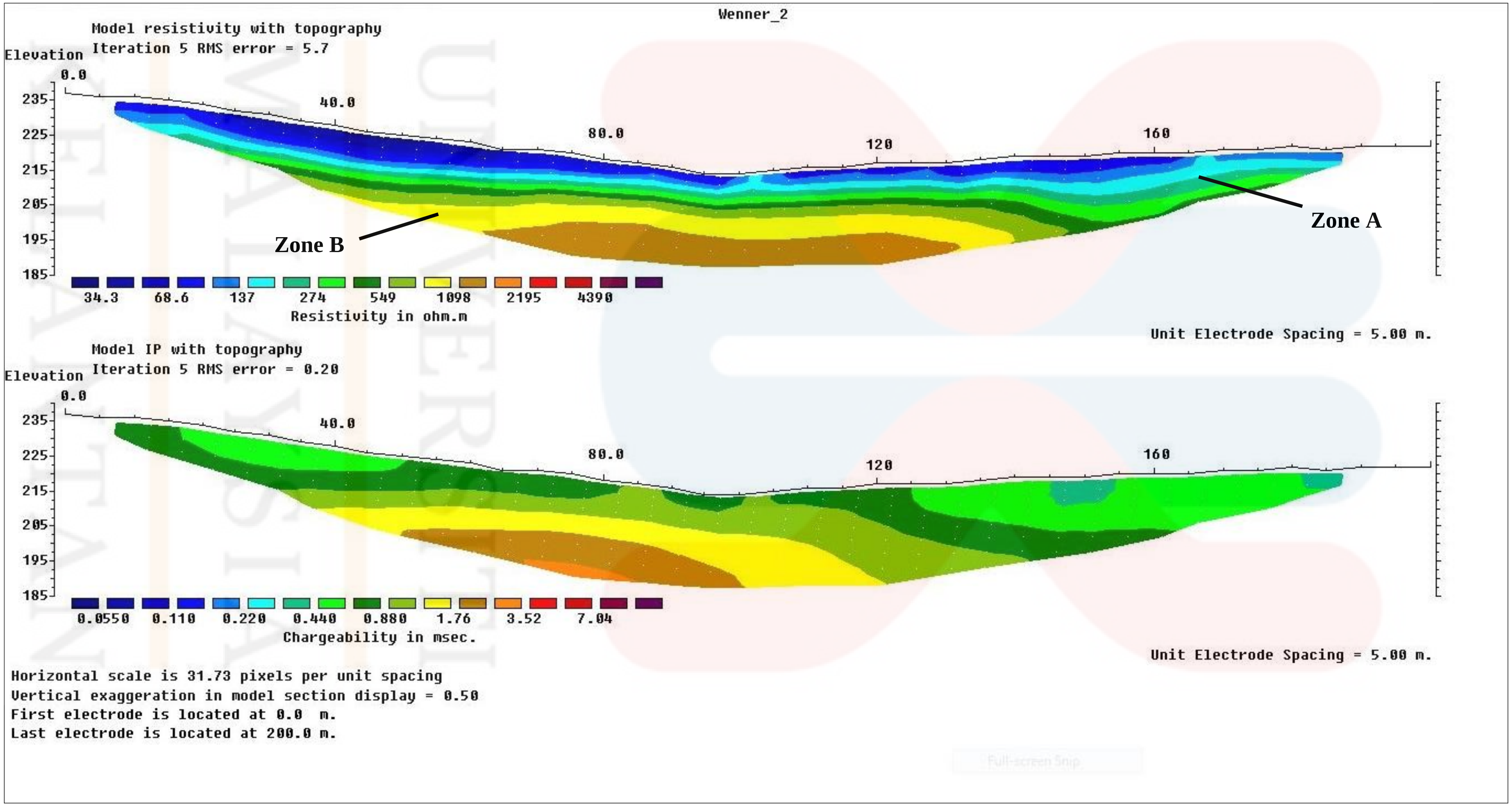


Figure 5.12: result of survey line 4

5.2.5 Survey Line 5

The fifth line is near with the main river, Sg. Berok with coordinate 04° 42’ 20.35”N and 101° 41’ 25.39”E. This fifth line also chosen due to the possibility of the main river act as a recharge material if there is a groundwater. Type of electrode configuration for this line is Pole-Dipole and the direction of the survey line is W–E. Table 5.5 shows the coordinate for first electrode, centre and last electrode. Figure 5.13 shows the set-up for the fifth survey line.

Table 5.5: Coordinate of first electrode, centre and last electrode

Electrode	Latitude	Longitude	Elevation
1	04° 42’ 20.49”N	101° 41’ 22.21”E	215 m
21	04° 42’ 20.35”N	101° 41’ 25.39”E	207 m
41	04° 42’ 21.24”N	101° 41’ 28.50”E	206 m

Figure 5.14 shows the total percentage of RMS error is 18% which is a bit high than the limit with depth of penetration is more than 30m. Minimum resistivity value for this survey line is 3.0Ωm and the maximum resistivity value is 70,000Ωm. The pseudosection of this result is divided into three zones – Zone A, Zone B and Zone C. Zone A has a range of resistivity value between 3.0Ωm until 200Ωm. Potential groundwater of this location is high and may have a lot of groundwater stored at the subsurface. This because of the survey line that lined right beside the main river that can become the reason as the main river act as a recharge agent for the groundwater. Range of resistivity value for the Zone B is between 200Ωm until 5,000Ωm. For this range of resistivity value, Zone B may consist of sedimentary

such sandstone, limestone and shale. Zone C is a zone for hard materials with high resistivity value and for this survey line the highest resistivity value is 70,000Ωm. With this highest resistivity value, Zone C may consist of granite, basalt and quartzite.

Figure 5.13: Set-up for survey line 5

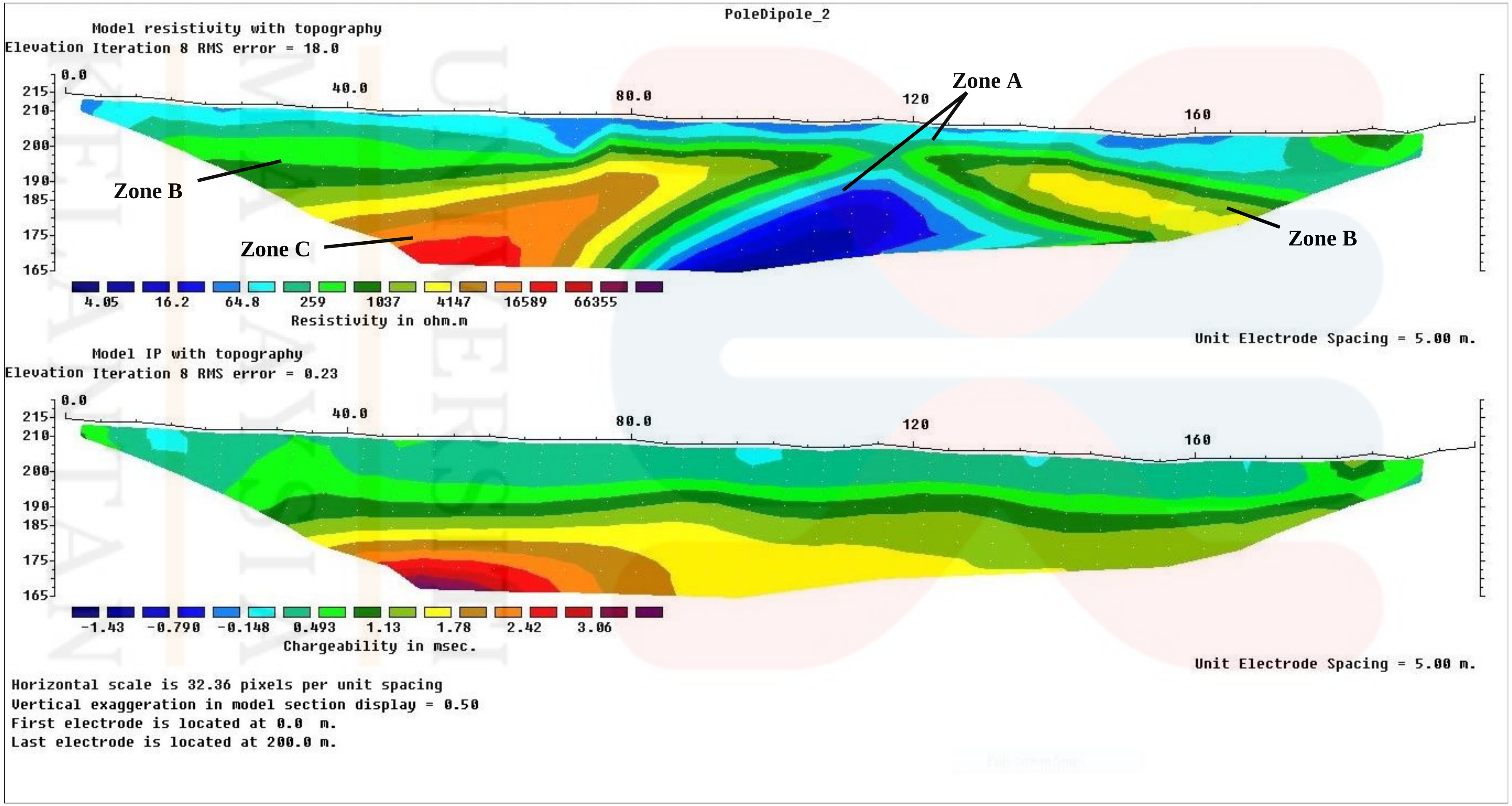


Figure 5.14: result of survey line 5

CHAPTER 6

CONCLUSION AND SUGGESTIONS

6.1 Conclusion

As a conclusion for this Final Year Project, the lithology of the study area are consist of medium grade of metamorphic rock which is schist. However there are various types of schist rock that different in colour and texture. Formation of schist rock occurred during the collision of IndoChina plate and Sibumasu plate that formed Bentong-Raub Suture. The highest external forces that forming the strike of the rock is coming from the north-eastern direction. Based on the geophysical survey using Electrical Resistivity Imaging method has show that the study area is a high potential of groundwater but not in a fracture zone. Result of pseudosection shows that the groundwater zone were accumulate in a large dimensional area.

6.2 Suggestion

This research was able to investigate the groundwater potential in the subsurface for the benefit of the community. Therefore the research should be continued with determine the recharge rate of groundwater and the quality of groundwater. These data can be very useful in the future especially in determination of groundwater contamination due to mining and logging activities. These groundwater can be beneficial for daily uses compare to the surface water that has been contaminated with sediments .

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