GEOLOGY OF SUNGAI SUBONG, GUA MUSANG KELANTAN AND GROUNDWATER POTENTIAL IN HARDROCK BY USING ELECTRICAL RESISTIVITY IMAGING METHOD AT KUALA SELANGOR, SELANGOR.

By

NURUL AWATIF BINTI GHAZALI

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

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UNIVERSITI MALAYSIA KELANTAN

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APPENDIX U

DECLARATION

I declare that this thesis entitled "GEOLOGY OF SUNGAI SUBONG, GUA MUSANG KELANTAN AND GROUNDWATER POTENTIAL IN HARDROCK BY USING ELECTRICAL RESISTIVITY IMAGING METHOD AT KUALA SELANGOR, SELANGOR" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature for any other degree.

Signature : ______________________________

Name : ______________________________

Date : ______________________________

APPENDIX V

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Geology of Sungai Subong, Gua Musang Kelantan And Groundwater Potential in Hardrock by Using Electrical Resistivity Imaging Method at Kuala Selangor, Selangor

ABSTRACT

This study was conducted to access general geology in Sungai Subong, Gua Musang Kelantan and to access the groundwater potential in hard rock at Bestari Jaya, Kuala Selangor, Selangor. The study of groundwater potential is operated by using resistivity survey in selected location. The main objectives of the study were to produce an updated geological map of Sungai Subong in scale of 1:25,000 and to identify the potential groundwater in hard rock at Bestari Jaya, Kuala Selangor, Selangor by based on resistivity value and chargeability value. In study area at Bestari Jaya, Kuala Selangor, Selangor, there are five pole-dipole survey line of resistivity method has been conducted. The data was recorded using ABEM Terrameter SAS 1000. Based on geological mapping and study, there are some aspects such as the geomorphology, lithology, structural geology and historical geology of the study area have been identified. The study area consists of lowland, low hill and hill landform in term of geomorphology. The lithologies found in study area are Permian to Triassic metasediment and sedimentary rock, Tertiary acid intrusive rock and Quaternary to Recent alluvium units. The result showed that the low resistivity region can be found in all of the survey lines. High resistivity values of hard rock such as schist and slate associated with low resistivity value of sandy clay soils.

Geologi Sungai Subong, Gua Musang Kelantan dan Potensi Air Bawah Tanah Dalam Batuan Keras dengan Menggunakan Kaedah Pengimejan Keberintangan Elektrik di Kuala Selangor, Selangor.

ABSTRAK

Kajian ini dijalankan untuk mengakses geologi umum di Sungai Subong, Gua Musang Kelantan dan untuk mengakses potensi air bawah tanah dalam batuan keras di Bestari Jaya, Kuala Selangor, Selangor. Kajian potensi air bawah tanah dikendalikan dengan menggunakan tinjauan keberintangan di lokasi terpilih. Objektif utama kajian ini adalah untuk menghasilkan peta geologi Sungai Subong yang telah dikemas kini dalam skala 1: 25,000 dan mengenal pasti potensi air bawah tanah di batuan keras di Bestari Jaya, Kuala Selangor, Selangor berdasarkan nilai keberintangan dan nilai cas. Di kawasan kajian di Bestari Jaya, Kuala Selangor, Selangor, terdapat lima baris tinjauan keberintangan telah dilakukan dengan menggunakan susunan 'pole-dipole'. Data direkodkan menggunakan ABEM Terrameter SAS 1000. Berdasarkan pemetaan dan kajian geologi, terdapat beberapa aspek seperti geomorfologi, litologi, struktur geologi dan sejarah geologi kawasan kajian telah dikenal pasti. Kawasan kajian terdiri dari dataran rendah, rendah dan bentuk muka bumi dari segi geomorfologi. Litologi yang terdapat di kawasan kajian ialah batuan endapan dan separa endapan dari tempoh Permian sehingga Triassic, intrusi batuan berasid dari tempoh Tertiary dan unit alluvium dari tempoh Quaternary sehingga Recent. Hasil kajian menunjukkan bahawa kawasan resistiviti rendah dapat dijumpai di semua garis tinjauan. Nilai resistiviti tinggi batuan keras seperti schist dan slate yang dikaitkan dengan nilai resistiviti rendah tanah liat berpasir.

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CHAPTER 1

INTRODUCTION

1.1 General Background

This study focused on geological mapping and ground water potential in hard rock by using electrical resistivity method. The location for geological mapping is in Sungai Subong, Gua Musang, Kelantan while for groundwater potential in hard rock will be focus on area of Kuala Selangor, Selangor. In term of water supply, world generally consist of 97.2 % saline water in the ocean and the remain percentage are referring to fresh water distributions. Fresh water distributed into some classification such as ice caps, glaciers, groundwater, surface water, soil moisture and water in atmosphere. Groundwater includes water that exist beneath the land surface, held within opening, or pores, of soils and geological information which called aquifer. More specific, groundwater exists at or beneath a surface known as water table. Below the water table, the pores in saturated zone are completely filled with water.

Aquifer is one of the representatives for water abstraction success which is important for infiltration of water resources and need to quantify the validity of unconfined aquifer to obtain the availability of high flow rate of groundwater (Rais Yusoh et al., 2016). Groundwater normally used in many sectors such as for agricultural use, industrial use and domestic use. In middle income country such as Malaysia, agricultural and industrial sectors consume more water supply. Major cities in Malaysia such as Selangor undergoing great population boom as well as urbanization. These phenomena created limited water supply for all uses.

Unconsolidated sedimentary formations like gravel and sand form excellent aquifer but hard rock such as fracture igneous and metamorphic rock also form good aquifer. These shows that lithology plays an important role in identification of type of aquifer. Based on previous study, sedimentary rock and metamorphic rock are the common rock type that distributed in the study area (Charles S. Hutchison and Denis N.K.Tan, 2009). In this study, the groundwater exploration is focused on hard rock such as in metamorphic rock.

Groundwater become one of the main waters supplies if there are shortage of fresh water supply. Therefore, groundwater potential zonation is important for further groundwater supply planning. Subsurface hydrogeological information is needed in order to identify the potential zone of excellent aquifer for groundwater. Geophysical method such as electrical resistivity method become one of useful way for finding groundwater location. It generally provides both 2-D and 3-D electrical resistivity survey in order to produce the subsurface lithology profile. Therefore, this study focused on how the electrical resistivity method is used for finding a good groundwater potential zone in hard rock.

1.2 Study Area

Kelantan is located in north-east of Peninsular Malaysia with coordinates 5°15'N 102°0'E with total area about 17, 100km^2. It shares boundary with Narathiwat Province at the north, with Terengganu state at the south-east, Perak state to the west and Pahang at the southern area. South-China Sea make it contact at the north-east of Kelantan. At the border of Kelantan, the Peninsula's east and west is spreading due to Titiwangsa mountain range formed a natural divider between it and make a peaking at Mount Tahan with 2,187 m elevation.

Sungai Subong is located at Gua Musang which lies within 4°55’N, 101°57’ E. The study area of Sungai Subong covered about 25 Kilometers^2 such in figure 1.1 and 1.2. Point A, B, C and D refer to the edges of the study area and the coordinate can be shown in table 1.1. The distance between study area and Gua Musang main town is about 3 Kilometers. Gua Musang known as town, district and parliamentary constituency that located in southern part of Kelantan. The town consist of railway line from Tumpat to Gemas. Gua Musang is also one of popular tourism place because it near the National Park at Sungai Relau. Gua Musang also has its own way of generating the state economy. Plantation such as rubber tree and oil palm are the great economy generator for the state and also for country. Sungai Subong is included as its area covered mostly with palm oil plantation which taken care by Ladang Subong palm oil office.

Table 1.1: Coordinate of study area in Sungai Subong, Gua Musang, Kelantan.

POINT	COORDINATE
A	Latitude: 4°56'51.49"N Longitude: 101°56'9.47"E
B	Latitude: 4°56'51.49"N Longitude: 101°58'54.98"E
C	Latitude: 4°54'10.35"N Longitude: 101°56'9.47"E
D	Latitude: 4°56'10.35"N Longitude: 101°58'54.98"E

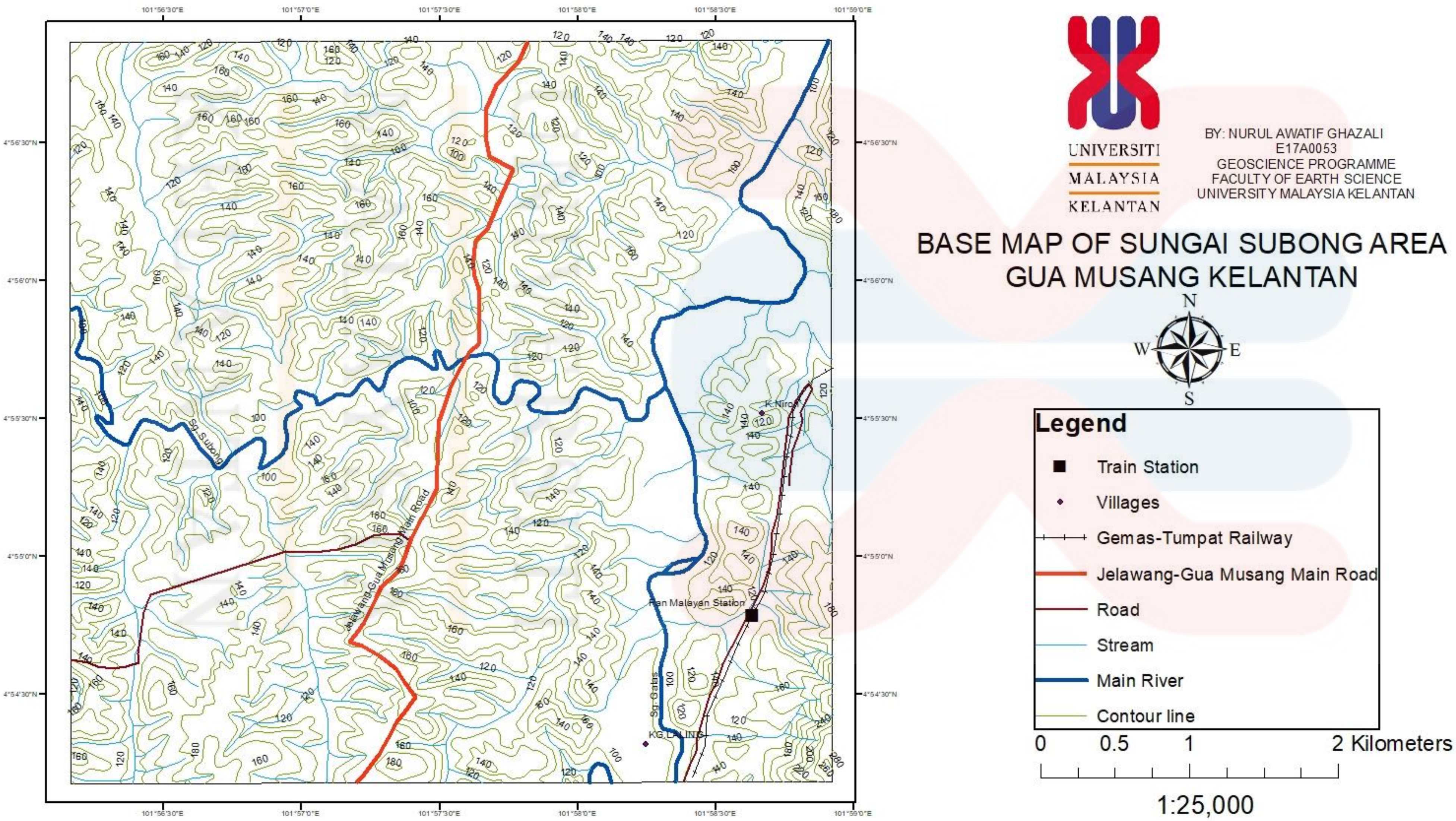


Figure 1.1: Base map of Sungai Subong area

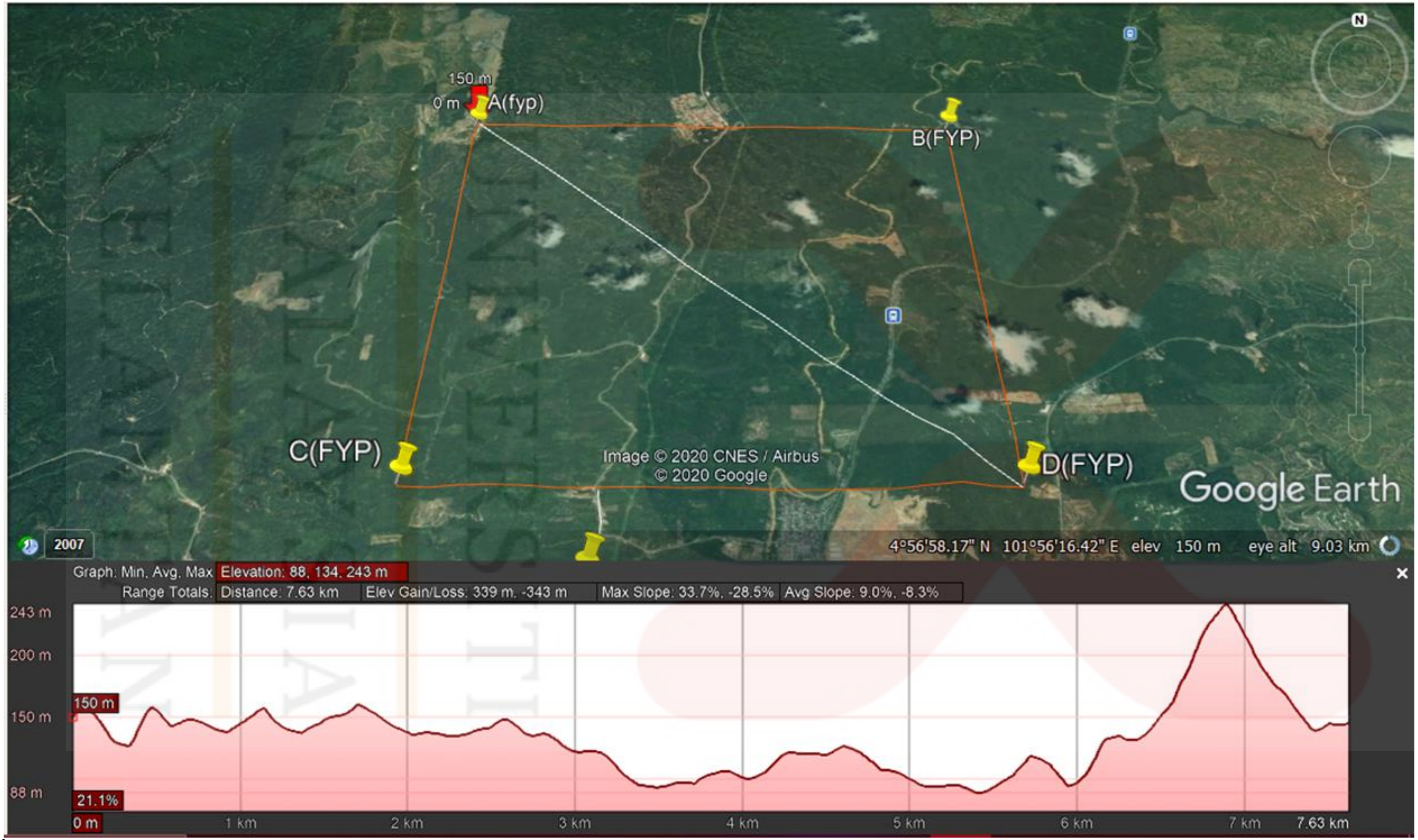


Figure 1.2: Satellite Imagery of Sungai Subong area

Next, for specification of groundwater potential in hard rock, the study area is located at Bestari Jaya, Kuala Selangor, Selangor. Bestari Jaya is a small town and a mukim in Kuala Selangor district. Kuala Selangor is a big town which located at the bay of Selangor River where it drains into the Straits of the Malacca.

The study area lies within 3°20'N, 101°25' E that is located in Bestari Jaya covered about 1.5 Kilometer^2 as in Figure 1.3. Point A, B, C and D refer to the edges of the study area and the coordinate can be shown in table 1.2. The study area is surrounded by palm oil plantation and villages such as Bukit Badong and Jaya Setia Village. The area also located near reserved forest of Bukit Badong. The study area also located near industrial area which named as Suria Industrial area. The distance from the study area to the main town of Bestari Jaya, Batang Berjuntai is about 7 kilometers and about 25 kilometers to the main town of Kuala Selangor.

Table 1.2: Coordinate of the study area in Bestari Jaya, Kuala Selangor, Selangor.

POINT	COORDINATE
A	Latitude: 3°20'55.24''N Longitude: 101°26'19.85''E
B	Latitude: 3°20'55.24''N Longitude: 101°26'35.54''E
C	Latitude: 3°20'33.42''N Longitude: 101°26'19.85''E
D	Latitude: 3°20'33.42''N Longitude: 101°26'35.54''E

Figure 1.3: Satellite imagery of Bestari Jaya study area

1.2.1 Demography

Gua Musang is the largest district in Kelantan state. The total area of the Kelantan is about 7, 979. 77 km^2. Based on socioeconomic report of Kelantan state by Department of Statistic in 2019, there is increased of total population from 2015 to 2019 where there are about 1,760 6000 population in 2015 and about 1, 900 000 in 2019. In 2019, the number of male populations in Kelantan state is greater than female population where there are about 1 million male and 0.9 million females. Based on nationality, there are about 97.4% of the population are Malaysian while other 2.6% are not Malaysian. In scope of Gua Musang district, the total population in 2019 is about 116.2 thousand. This population growth and the growth rate annual population of Gua Musang district can be observed in table 1.3 along with other districts. Based on Gua Musang district council in 2010, the dominant ethnic in this ethnic is Malay ethnic which has the highest percentage. This can be observed in pie chart in figure 1.4 which show the percentage distribution of population base on ethnicity.

Table 1.3: Population by district in Kelantan State

District	Population ('000)		Annual rate of growth (%)	Area (Hectare)
	2018	2019		
Bachok	162.5	165.8	2.0	27,951
Kota Bharu	596.9	608.6	1.9	40,326
Machang	113.6	115.9	2.0	52,851
Pasir Mas	231.8	23.4	2.0	57,238
Pasir Putih	143.1	146.0	2.0	42,494
Tanah Merah	149.2	152.1	1.9	88,414
Tumpat	187.3	190.9	1.9	18,000
Gua Musang	113.9	116.2	2.1	821,430
Kuala Krai	135.2	137.9	1.9	22,871
Jeli	50.9	51.9	2.0	133,048

(Source: Department of Statistic, Malaysia, 2019)

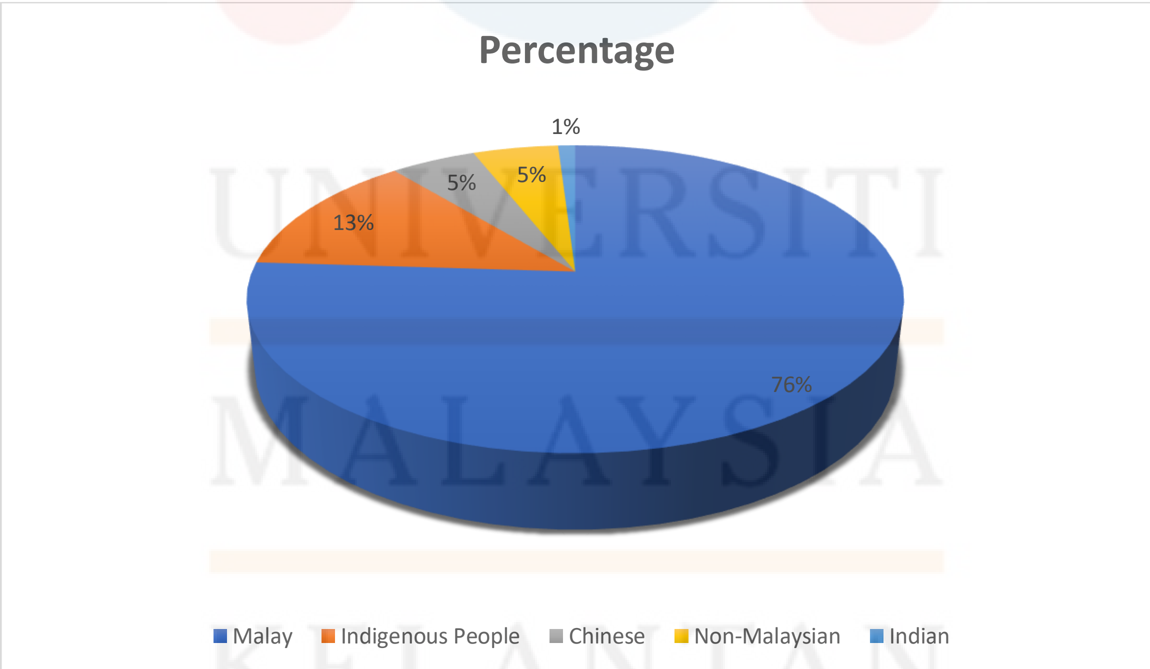


Figure 1.4 Demographic chart of Gua Musang based on ethnics in 2010
(Source: District Council of Gua Musang Portal, 2010)

For Selangor, the total area of the state is about 8104 km^2. Based on socioeconomic report of Selangor state by Department of Statistic in 2019, Total population of in Selangor increasing from 2015 to 2019 where there are about 6.18 million in 2015 and about 6.51 million in 2019. The ration between female and male in Selangor state remain same from 2015 to 2019 with ratio of 108 males for every 100 females. Based on nationality, there are about 90.4% of the population are Malaysian while other 9.6% are not Malaysian. In scope of Kuala Selangor, the total population in 2019 is about 255.6 thousand. This population growth and the growth rate annual population of Kuala Selangor district can be observed in table 1.4 along with other districts.

Table 1.4: Population by district in Selangor State

District	Population ('000)		Annual rate of growth (%)
	2018	**2019**	
Gombak	815.1	828.8	1.7
Klang	1,025.0	1,040.9	1.5
Kuala Langat	270.1	274.7	1.7
Kuala Selangor	251.2	255.6	1.7
Petaling	2,157.0	2,190.7	1.5
Sabak Bernam	126.1	128.3	1.7
Sepang	256.9	261.3	1.7
Ulu Langat	1,370.3	1,392.0	1.6
Ulu Selangor	237.6	241.7	1.7

(Source: Department of Statistic, Malaysia, 2019)

1.2.2 Accessibility

Gua Musang district become one of important town in Kelantan as it connects some route from northern part of Kelantan and also from other state such as Perak, Pahang and Terengganu. Sungai Subong located near the highway of Gua Musang-Jelawang. The highway basically connects Dabong at the north and Gua Musang at the southern part of Kelantan. The study area in Sungai Subong can be access by using this highway which the distance between Gua Musang Town and the study area are about 3 km. The study area also can be access by unpaved road which connected the small village in the study area such as in figure 1.5 and figure 1.6. As the study area covered by rubber tree and palm oil plantation, it can be access by unpaved and paved road which normally can be used by cars, motorcycle and 4-wheel drive car or truck.

Figure 1.5: Paved road to Gua Subong
(Coordinate: 04°55'03.18" N, 101°57'23.46" E)
(Source: Street view from Google Earth Pro, 2020)

Figure 1.6: Junction of unpaved road in rubber tree and palm oil plantation area.
(Coordinate: 04°55'19.18" N, 101°57'28.01" E)
(Source: Street view from Google Earth Pro, 2020)

1.2.3 Land use

As Gua Musang is the biggest district in Kelantan with area of 821,430 hectare, there are big different of population number throughout the year. Increasing of populations in the district become the main factor that impact the land use in Gua Musang. Increasing of number of population cause increasing of the land use of Gua Musang District. Land in Gua Musang mainly covered by reserve or natural forest. In 2010, there are about 538 kilo hectares of natural or reserve forest covered the district. Due to high demand of land use in the district, Gua Musang lost about 12.6 kilo hectare of its natural forest in 2019 in order to give opportunity for other sectors to develop such as agriculture, urban and mining (Kelantan Forestry Department, 2019).

In the study area, there are several distribution of land uses has been observed based on satellite imagery and literature review. Based on figure 1.7, the land use of the study area can be clearly observed. Plantation become the dominant sector that actively run in the study area where it covered about 95% of the study area. The plantation activity can be divided into two which are rubber tree and palm oil plantation. The other 5% of the land use by other sectors such as natural forest, road construction, grove and farm.

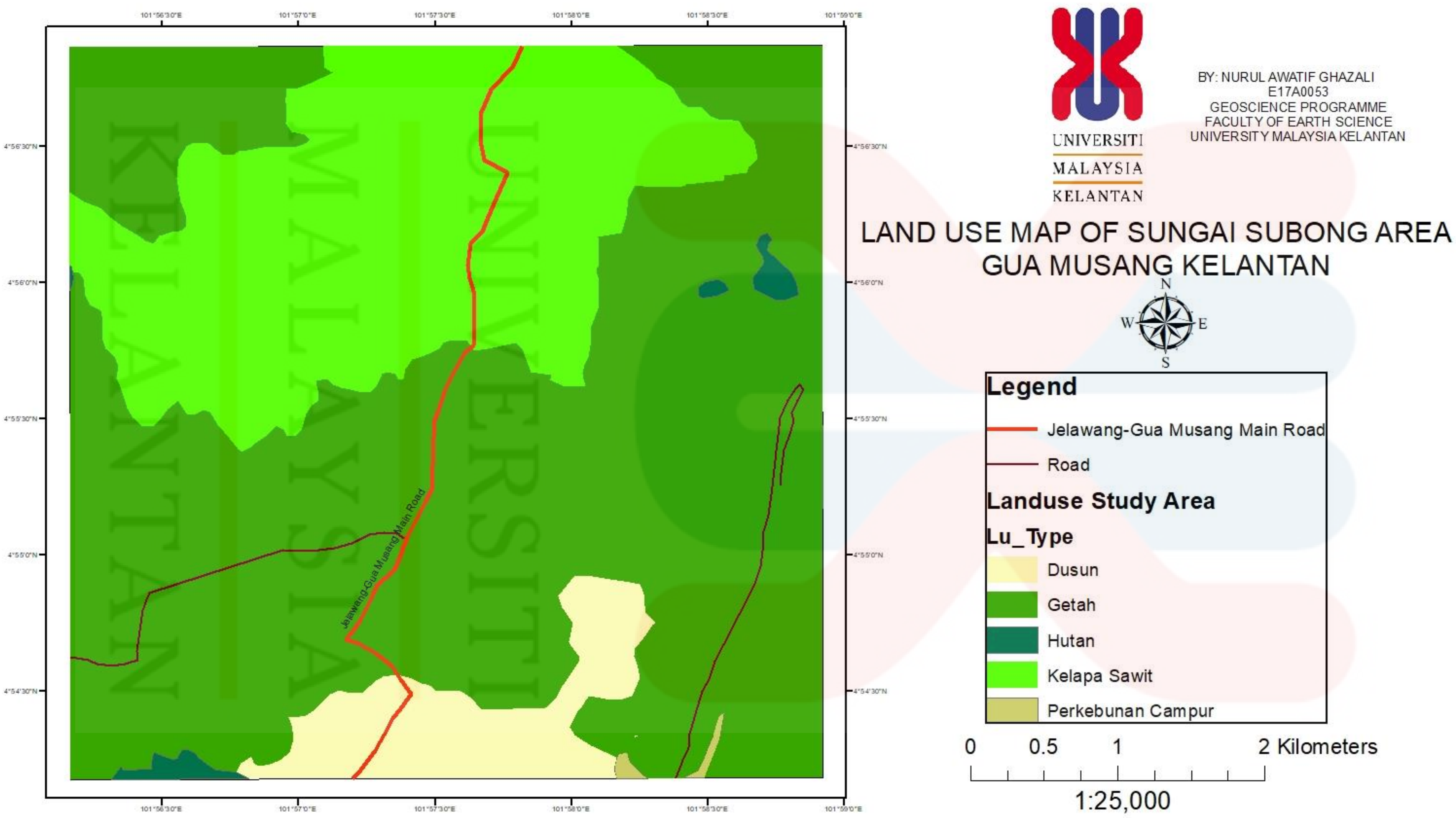


Figure 1.7: Land use map of Sungai Subong study area

1.2.4 Social Economic

Social economic of a place can be related to the domestic output of the state. Based on socioeconomic report by Department of Statistic of Kelantan state in 2019, there are few sectors that contributed such as plantation, manufacture, mining and quarry, service and also construction. In 2019, Kelantan undergone about 5.3% of economic growth based on the report. Based on study area in Sungai Subong, plantation become the main activity that contributed to the social economic. Economy of plantation sector in Gua Musang normally being controlled and managed by two main agencies which are KESEDAR and FELDA. Both of the agencies manage and controlled the development of rubber tree and palm oil plantation in Gua Musang including the plantation in study area. As the study area are dominant in plantation activity, most of the resident basically involved in plantation activity as farmer and also manufacture worker that related to plantation production.

1.3 Problem Statement

For problem statement, geological map is important for gathering information of various geological features. Generally, it represents the distribution of different type of rocks as well as geological structure such as faults and fold. For geological mapping study area which is Sungai Subong, Gua Musang Kelantan, there are no updated geological map has been provided in previous few years. Therefore, this study focused on updating geological map of study area based on interpretation of GIS and Remote sensing methods.

Next, groundwater exploration related to the shortage of fresh water supply. This exploration will not only help in identification of groundwater location but will help in future planning for clean water resources in order to avoid any limitation or demand in next few years. Fresh water resources become limited due to many problems such as increase in population, industrialization, pollution of surface water and climate changes that led to drought condition. These issues happen in certain places of Malaysia particularly in Selangor, Kuala Lumpur, Johor Baharu and Pulau Pinang (Saimy & Raji, 2015). In this study, area in Selangor state will be focused on. In Selangor, there are few studies that focus on systematic basins by the Mineral and Geoscience Department (JMG) of Selangor state. Surface water resources growing limited due to factor such as exposure to pollution and decreasing in water quality itself. In 2016, Jabatan Meteorologi Malaysia stated that Selangor undergone the great water shortage problem due to climate change that led to minor El Nino phenomenon in many areas including in Bestari Jaya, Kuala Selangor. Before it happens, Selangor state government had prepared many ways to face up the problems including groundwater exploration. The exploration continues until now but there are limited groundwater studies in certain places such as in Bestari Jaya, Kuala Selangor. Other than that, the study area is under urbanization as a lot of residential area being build. The potential for the water supply shortage may be high due to increase of population. Therefore, this study also intended to identify the groundwater potential zones in hard rock at study area by using electrical resistivity method of geophysics from the secondary data sources. About more than 5 survey lines will be generated in this study.

1.4 Research Objectives

The focuses of this study are to update the geological map of Sungai Subong, Gua Musang, Kelantan and to identify the groundwater potential zone in hard rock at Bestari Jaya, Kuala Selangor. Therefore, the objectives of this study are:

1. To generate geological map of Sungai Subong, Gua Musang Kelantan with the scale of 1:25000.
2. To identify the potential groundwater in hard rock at Bestari Jaya, Kuala Selangor, Selangor by using electrical resistivity method (ERI) based on resistivity value and chargeability value.

1.5 Scope of Study

This study focused on geological mapping in Sungai Subong, Gua Musang, Kelantan and groundwater potential in hard rock by using Electrical Resistivity Imaging (ERI) method at Kuala Selangor, Selangor. For geological mapping in study area, some aspects have been updated such as the lithology, the geological structures, the geomorphology, land use area, stratigraphy and correlation of study area in order to produce a complete geological map.

For groundwater potential in hard rock, 2-Dimension electrical resistivity imaging (ERI) by geophysical method used. It carried out with a multi-electrode meter which is ABEM SAS 1000 terrameter. The resistivity data has been used in this study is from raw secondary data provided by Dr Hamzah Bin Hussin from University Malaysia Kelantan.

For ERI survey, a pair of current electrodes worked as it allows the electric current flow into Earth while the current and potential electrodes are arranged in a linear array. 2-Dimension electrical imaging survey consist of many types of electrode configurations such as pole-pole array, pole dipole array, dipole-dipole array, wenner array, schlumberger array and wenner-schlumberger array. In this study, the pole-dipole array is used to obtain the subsurface resistivity information. The data from study area has been processed by using inversion software which is RES2DINV. The interpretation included the resistivity, conductivity and subsurface depth.

1.6 Significant of Study

This groundwater exploration can be benefits to many sides such as government and society. As the study area are consist of hard rock compared to other area in Selangor state which dominantly covered by alluvial aquifer, so it may be hard to obtain sufficient groundwater. But this becomes one of the efficient ways to prevent any shortage of clean water supply in the future. This research can become a helpful reference for the state government to obtain information about groundwater locations. As for the society, the risk for them to face any water supply problem may be reduce as the groundwater locations in hard rock will be study in this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter generally consist of some precious studies and research projects that have been conduct by other researcher which related to this research both in Sungai Subong, Gua Musang Kelantan and Bestari Jaya, Kuala Selangor, Selangor. Previous studies and researches from all the researcher may help in process of gathering geological information that related to the study areas. This chapter comprises the relationship of previous studies and researches toward the regional geology and setting, lithostratigraphy, stratigraphy, structural geology and historical geology of Sungai Subong and Bestari Jaya. This chapter also shows the relationship of some previous studies and researches toward the geophysical investigation that related to Bestari Jaya study area.

2.2 Regional Geology and Tectonic Setting

In this study, the area of Gua Musang and Kuala Selangor are involved. Geological mapping is needed in order to produce an update geological map. Both mapping and groundwater exploration involves the detail study of regional geology. This is because regional geology gives a big impact in both studies in this research. Other than that, tectonic setting become the main influence for geology, stratigraphy, structural geology and historical geology of an area.

Peninsular Malaysia has its own unique tectonic setting. There is major event which is collision of plates occur that resulting the formation of Peninsular Malaysia. Based on Malsia-Thailand Border Joint Geological Survey Committee in 2006, the collision involved between two blocks which are Sinoburmalaya to the west and Eastmal-Indosinia to the east. This major event become the main factor to the deformation of Malay-Thai Peninsular.

Based on Metcalf in 2013, Peninsular Malaysia divided into three types of belt which are Western belt of Peninsular Malaysia, Central Belt of Peninsular Malaysia and lastly Eastern Belt of Peninsular Malaysia. Each of the belt in Peninsular Malaysia can be characterized based on their different identity in geology, stratigraphy, structural and evolution. Western Belt can be related with Sibumasu Terrane. In Early Permian, the Sibumasu Terrane migrate from the N-W Australian Gondwana margin. While for Central and Eastern Belt can be related to the Sukhotai Arc that are form on Indochina. Both Eastern and Central belt form derived from the subduction of Sibumasu during Early Devonian. During Early Triassic, the Paleo-Tethys Ocean has been completely subducted as Sibumasu Terrane docked into Indochina.

Those three belts are basically composed of granitic rock, sedimentary rock and also few areas of crystalline metamorphic rock. Gua Musang located in Eastern Belt of Peninsular Malaysia while Bestari Jaya, Kuala Selangor, Selangor located in Western Belt of Peninsular Malaysia. The general geology of Gua Musang basically can be related to Gua Musang formation, Telong formation, Nilam Marble and Airing Formation.

2.3 Stratigraphy

The stratigraphy of Gua Musang can be related to Gua Musang Group. Based on Kamal Roslan Mohamed in 2016, Gua Musang Group included the Gua Musang formation, Aring Formation, Telong formation and Nilam marble formation. Gua Musang Group are newly proposed stratigraphic units as they reflect the lateral facies changes among them. Some of them consist of similar lithology such as Middle Permian to Late Triassic argillite, carbonate and pyroclastic/volcanic facies with Gua Musang formation (Yin, 1965). With these similarities in lithology characteristic, therefore the formations are proposed to be in same group which is Gua Musang Group such in Figure 2.1.

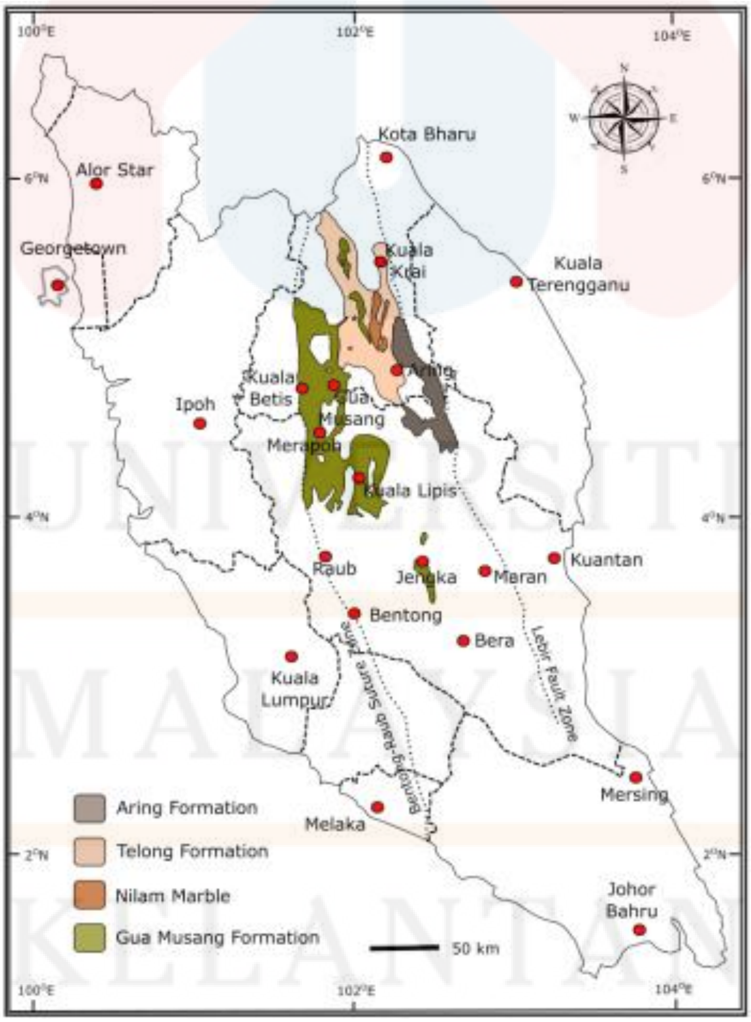


Figure 2.1: Distribution of Gua Musang Group. Modified from Mohamed (1995)

Based on study by Kamal Roslan Mohamed in 2016, the characteristic of formations in Gua Musang group are modified from Lee in 2004. For example, Gua Musang formation age around Middle Permian to Late Triassic. The common lithologies of this formation are argillaceous and calcareous interbedded with volcanic materials. There is also minor existence of arenaceous rocks. Based on the lithologies, it can be assumed that the depositional environment of the formation is at shallow marine with active volcanic activity. Telong formation aged from Permian to Late Triassic. The lower boundary of the formation overly Gua Musang Formation. The common rocks found in this formation are argillite associated with some tuff materials. This also indicated the shallow marine with occasional pyroclastic of the depositional environment. Nilam marble consist of calcitic marble interbedded with tuff and argillite. It also aged around Permian to Late Triassic as the lower part made contact with Aring Formation and Upper part made contact with Telong Formation. Lastly, the Aring formation aged around Carboniferous to early Triassic. The common rocks exist in this formation are basal dolomite marble, tuff, calcareous argillite and limestone.

Next, the stratigraphy of Kuala Selangor is referred to Geology map of Selangor by Mineral and Geoscience Department of Selangor state in 2005. Based on geological map in Figure 2.2, Kuala Selangor mostly covered with rocks that aged in Quaternary and Silurian-Ordovician. In the western side of Kuala Selangor, most of the rock found are from Quaternary age such as marine and continental deposits. For example, clay, silt, sand and peat with minor gravel are distributed in that area. In eastern area of Kuala Selangor such as Bestari Jaya, the age of rocks is from Ordovician to Silurian. The common rocks found are with harder characteristic such as schist, phyllite and limestone. There are also minor intercalations of sandstone and volcanic.

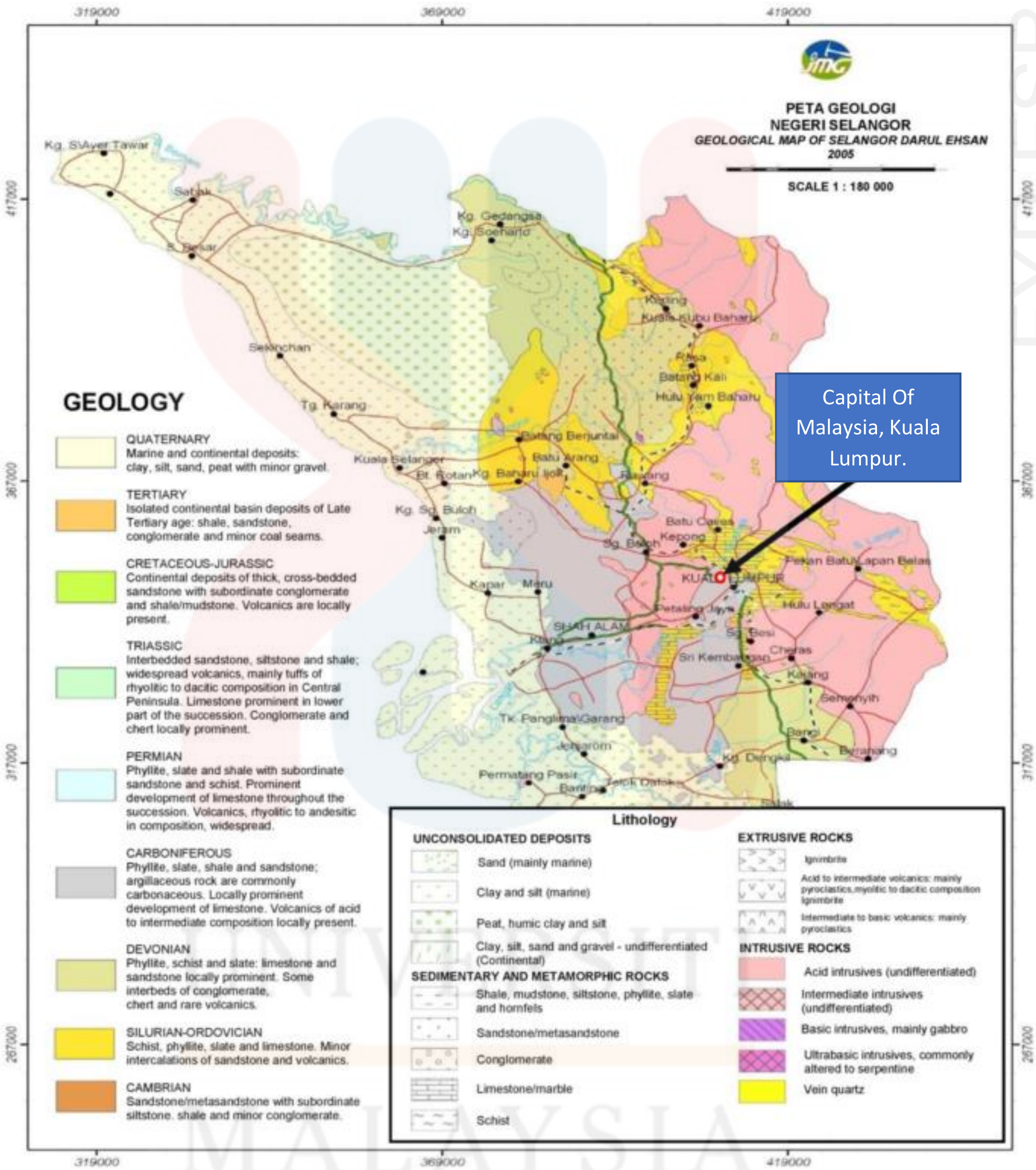


Figure 2.2: Modified Geological Map of Kuala Selangor (JMG 2005)

2.4 Structural Geology

In general, the dominant structural trend in Kelantan is along the N-S to NW-SE direction that happen from post-orogenic phase (Ghani,2009). The Main Range Granite is located along the western margin of the Bentong–Raub Suture Zone (BRSZ) and extends north to Thailand (Schwartz et al., 1995 and Metcalfe, 2000). The north–south-trending Bentong–Raub extends from Thailand through Raub and Bentong to the east of Malacca, Peninsular Malaysia. The BRSZ is characterized by a series of parallel topographic north–south-trending lineaments and the presence of small bodies of mafic to ultramafic rocks that are commonly serpentinite (Tan, 1996). The Lebir Fault Zone is located in the eastern part of Kelantan state such in figure 2.3, which is one of the major lineaments in Peninsular Malaysia and considered to be post-Cretaceous and a sinistral strike-slip fault (Tjia, 1989 and Harun, 2002).

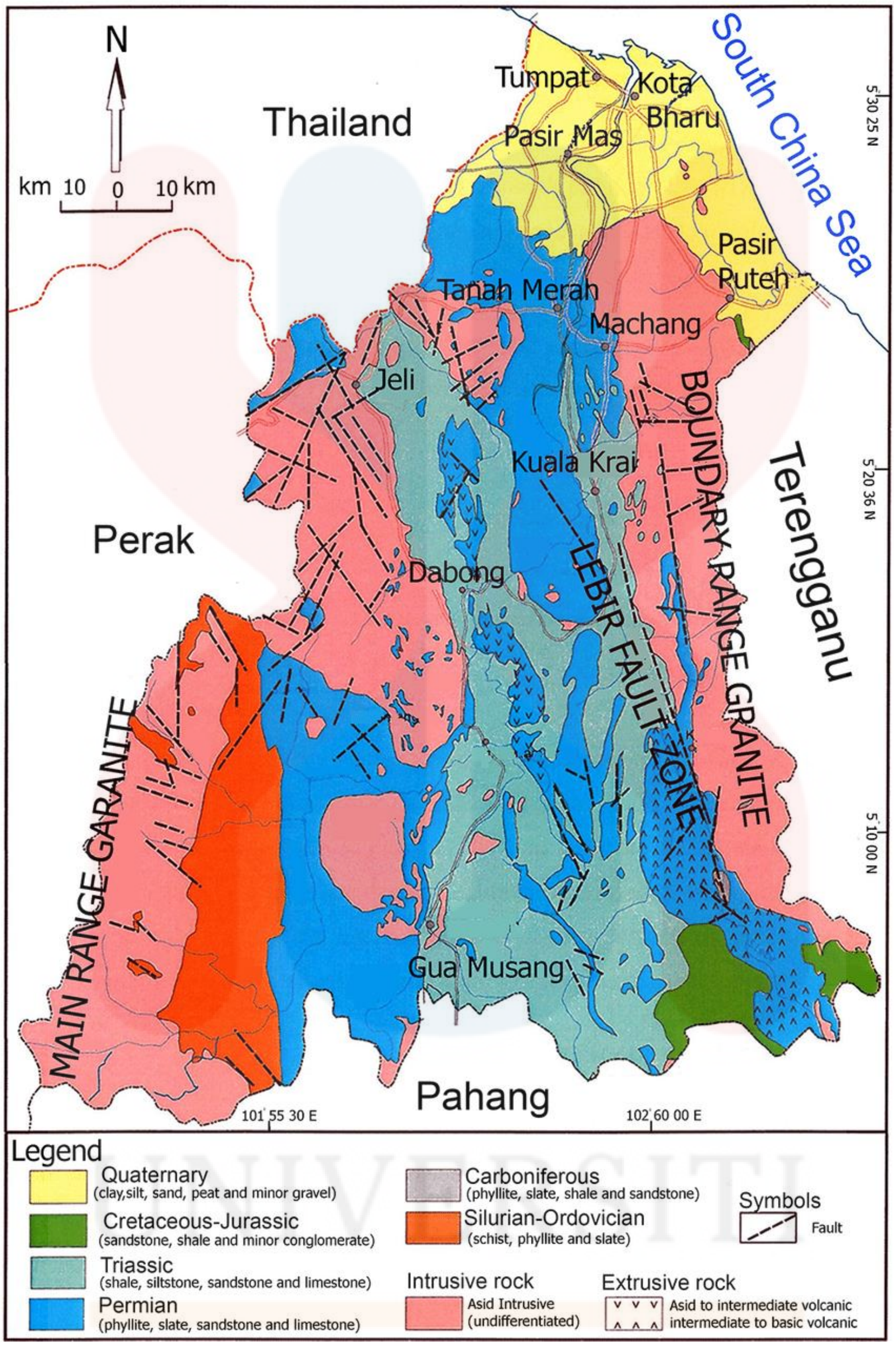


Figure 2.3: Geological Map of Kelantan state (Tjia,1989 & Harun, 2002)

For Bestari Jaya, the structural geology plays an important role in the stratigraphy of the study area. As Bestari Jaya located in eastern part of Kuala Selangor, the type of rock is harder than the rocks in the western part of Kuala Selangor. This can be related to the Main Range Granite which located near the eastern part of Kuala Selangor. The study area also located near to Kuala Lumpur-Kota Tinggi fault zone that cutting across the Main Range

Granite in northwest direction and the faulting also extend across the Kuala Lumpur toward the Straits of Malacca (T.T. Khoo &B.K. Tan, 1983). The Main Range Granite form in the western belt as the main intrusive body. As the study area bordering with The Main Range Granite and the fault zone, the rocks in the study area undergone metamorphism. This can be proved by the existence of metamorphic rocks such as schist, phyllite and limestone.

2.5 Historical Geology

During Permian to Triassic, Gua Musang undergo its own tectonic setting based on figure 2.4. During Early Permian, accretionary complex formed as Paleo-Tethys Ocean were subducted. Thick argillite and volcanic were deposited adjacent to Indochina volcanic arc. During Middle to Late Permian, Thick argillites and volcanics created shallow marine Gua Musang platform favorable for carbonate development and the current Gua Musang Formation started to develop. Volcanism also occur during this age and forearc basin started to subside. During Early Triassic, Forearc subsidence deepened in Gua Musang platform, creating more space for carbonate-argillite-volcanic deposition. Paleo-Tethys Ocean had been completely subducted as Sibumasu docked into Indochina. During Middle to Late Triassic age, sloping subduction of Sibumasu help the process of basin segmentation on the subsiding Gua Musang platform which creating the deep marine Semantan-Gemas basin. Bestari Jaya located in the Western Belt of Peninsular Malaysia. According to Metcalfe in 2013, the Western belt of Malaysia represent the Sibumasu Terrane separated from the NW Australian Gondwana margin during Early Permian period which also during the event of the opening of Meso-Tethys.

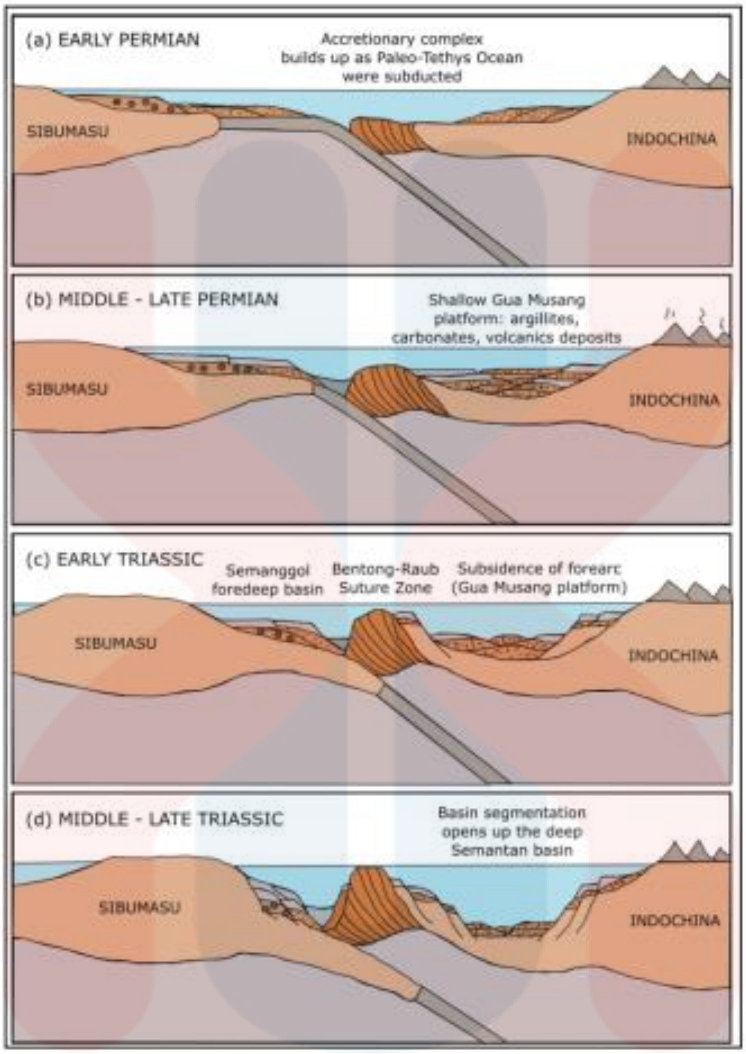


Figure 2.4: Tectonic setting during Permian to Triassic age. (Kamal Roslan Mohamed, 2016)

2.6 Research Specification

There are some researches has been done for groundwater potential in Kuala Selangor. In term of hydrogeological, Bestari Jaya are included in Selangor Basin. JMG has carried out hydrogeological investigation at Kuala Selangor. The study area covered about 400 km^2 that included the area of Kuala Selangor to Bestari Jaya and also part of Tanjung Karang (JMG, 2000). In the study, the result show that Kuala Selangor consist of both alluvium and hard rock aquifer. In details, the area consists of Quaternary alluvium and meta sediment from Devonian-Ordovician-Silurian age. This can be related to geological map in Figure 2.2. In 2017, a hydrogeological investigation is done which covered the Selangor basin. Well drilling and geophysical technique has been done in many locations including Bestari Jaya. In the study, alluvial aquifer detected in coastal area while toward eastern direction meta sediment and metamorphic aquifers (Hidayu Abu Hassan, 2017) are exist as in figure 2.5.

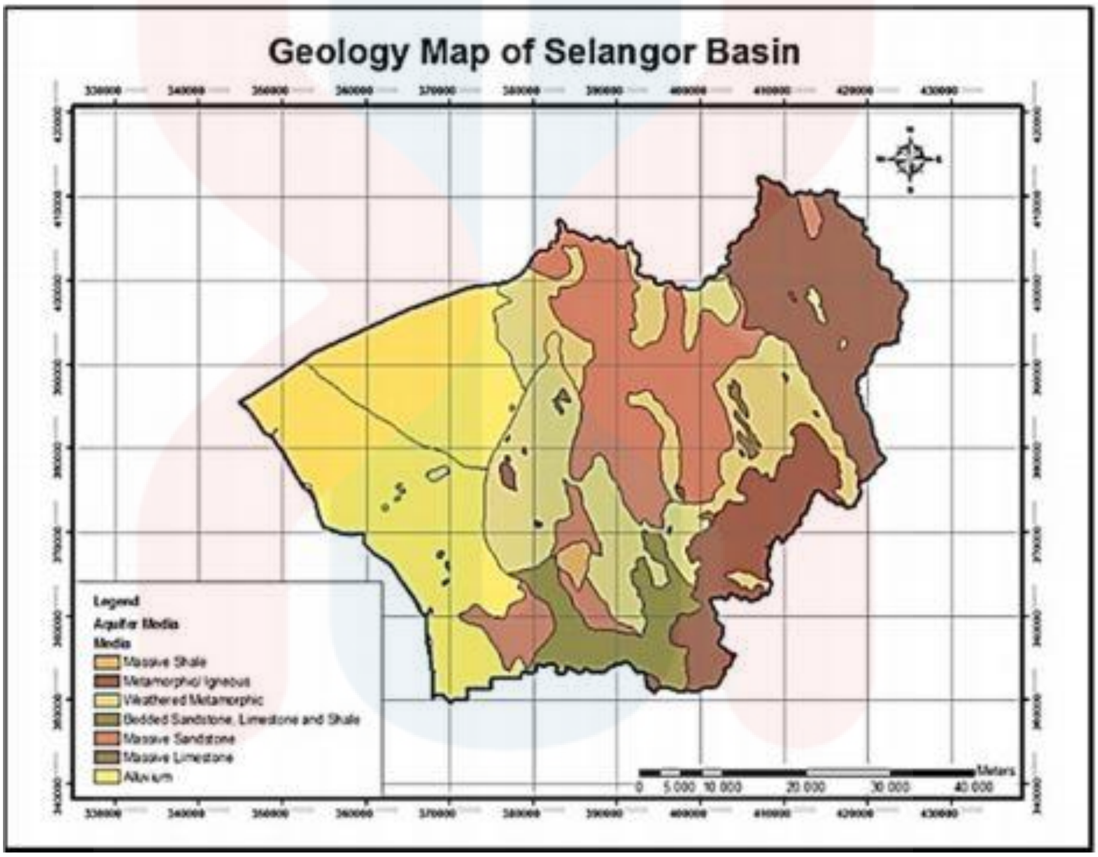


Figure 2.5: Geology map of Selangor Basin (Hidayu Abu Hassan, 2017)

2.6.1 Groundwater

Based on H.M Raghunath in his book in 2006, it is stated that our world covered by 97.2% of oceans water while the remain 2.8% covered by the fresh water. The fresh water then can be divided into two categories where 2.2% are surface water and the remain 0.6% are groundwater. Due to existence of groundwater in greater depth, about only 0.25% of groundwater can be explore economically by using developing drilling technology.

Groundwater refers to any fresh water that flow from the surface of soil or vadose zone into the saturation zone. The freshwater origin from other runoff or rain water which infiltrated through the ground and filled the space between sediment particle and cracks in rocks. The groundwater continues it infiltration process until it reached impermeable or impenetrable layer of rock. The groundwater will flow and remain through bodies of permeable rock and sediment which known as aquifer. In general, the groundwater resources led by contribution of precipitation process in hydrogeological cycle such in figure 2.6 Groundwater also undergo inflow and outflow process. Inflow refers to recharge process or adding of water into the zone of saturation while outflow refer to discharge process or removal of water from the zone of saturation zone toward streams, river or lakes.

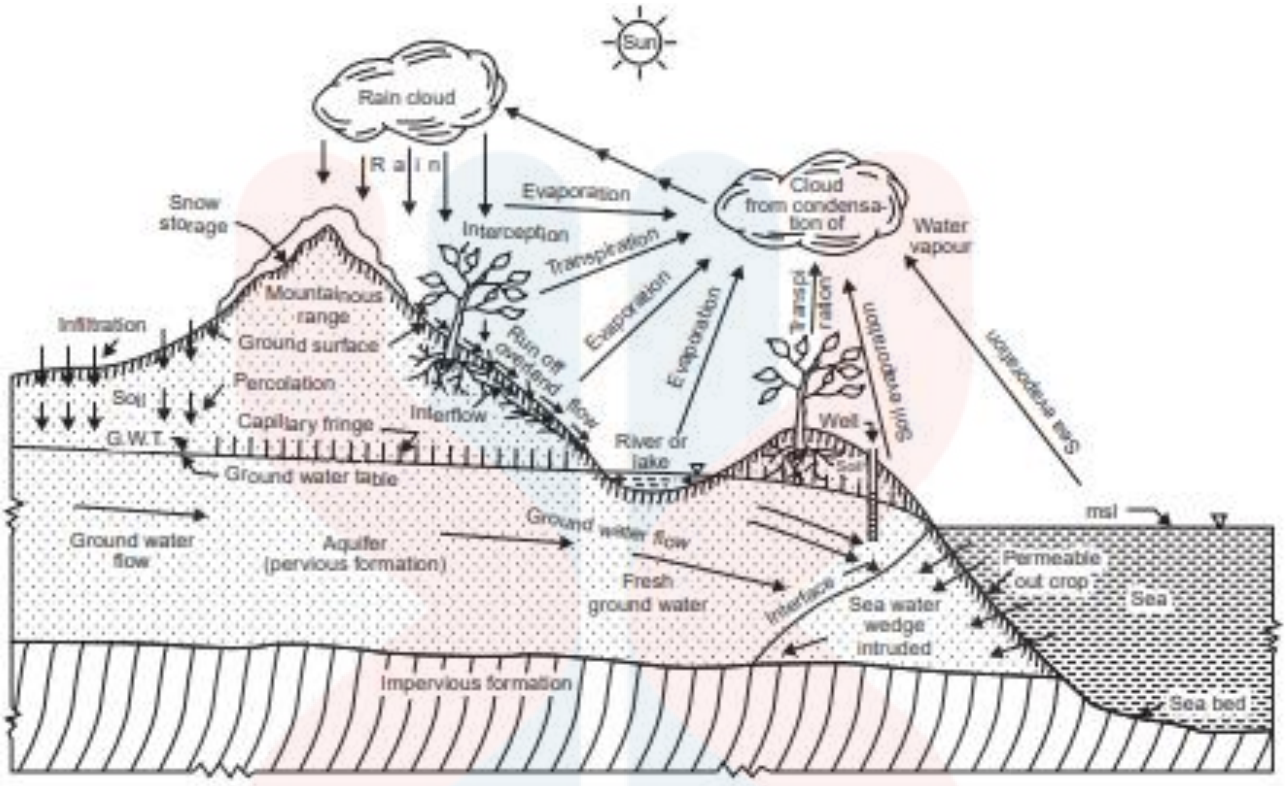


Figure 2.6: Principle of hydrologic cycle.
(Source: H.M Raghunath in 2006)

2.6.2 Aquifer

Aquifer refers to body of saturated rock or any layer of geological formation where the water from vadose zone easily to flow according to factor of permeability and porosity. Generally, aquifer can be divided into two main categories which are confined and unconfined aquifer.

Based on M.S. Javaid and S.A. Khan in 2018, confined aquifer or also known as Artesian aquifer refers to any zone of saturation zone where the water has been accumulated and the zone of saturation is trapped by impermeable rock layer or rock bodies at the top and at the bottom. As the permeable rock layer is underlain by two impermeable rock, the pressure of the confined aquifer is stated to be greater than the atmospheric pressure.

Next, unconfined aquifer generally different from the confined aquifer. Compare to confined aquifer, unconfined aquifer generally found near the surface of the Earth and there no impermeable layer of rock or clay overlay at the top of the aquifer even though they normally overlay above any impermeable layer of rock or clay (M.S. Javaid et.al, 2018). Water table become the upper boundary of groundwater in the unconfined aquifer. As unconfined aquifer does not have any impermeable layer of rock at the top, the groundwater in unconfined aquifer tend to become more venerable and exposed to any contamination from surface pollution. Perched aquifer such as in figure 2.7, refer to special case of unconfined aquifer. Perched aquifer form when there is impermeable layer of rock either aquiclude or aquitard exist above the main water table or main aquifer but still located below the Earth Surface. Groundwater that infiltrated mound above the impermeable layer in order to create the perched aquifer. The amount of groundwater that mound in perched aquifer normally in small quantity and highly variable in time based on some factors such as climate condition or the size of impermeable layer of rock itself.

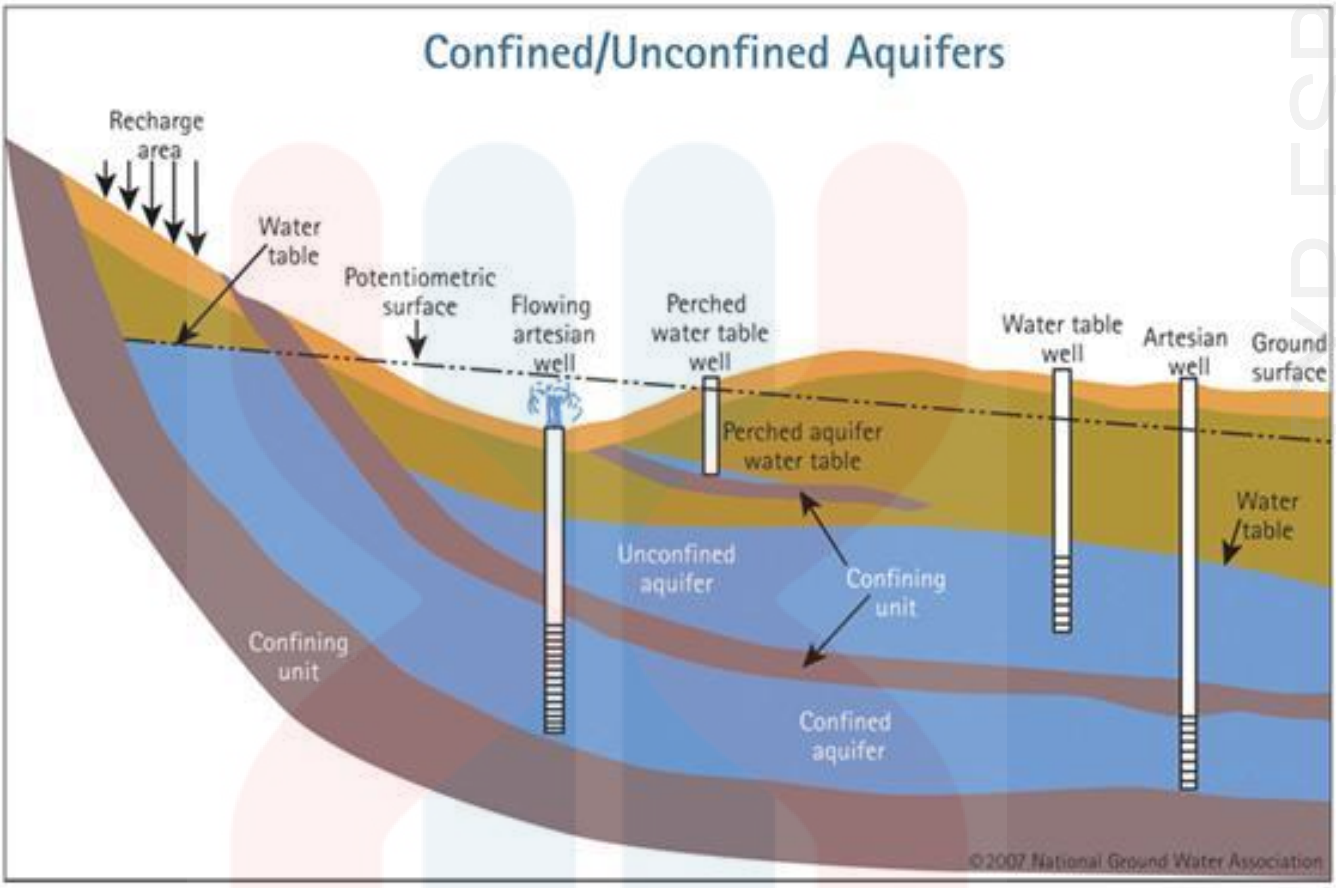


Figure 2.7: Type of aquifers
(Source: National Ground Water Association, 2007)

2.6.3 Potential of Groundwater

Groundwater refers to any water that flow or infiltrated through the vadose zone toward the zone of saturation or layer of permeable rock in order to filled the interconnected pores below the water table. Groundwater potential refer to process of investigation in order to locate any existence of groundwater in the subsurface of the study area. The groundwater potential can be related to the nature and distribution of aquifer and aquitard in the study area. In this matter, lithology, stratigraphy and structural geology give greater impact to the formation of aquifer and the aquitards. Based on R. Allan Freeze and John A. Cherry in 1979, lithology play an important role as each type of rock has their own characteristic such as the mineralization, the grain size and the grain packing of the sediment or the rocks. Stratigraphy describe the correlation between those type of rocks, beds and formation of an area. In term of structural geology, the structural features contributed in the formation of aquifer and aquitard as it produced from the deformation process that occur after deposition or crystallization happen. The aspect such as lithology, stratigraphy and structural feature can be investigated by various method. One of the methods is by using Electrical resistivity imaging (ERI). The absolute value of ground resistivity should be analyses in order to identify the existence of groundwater in an area. According to Keller and Frischknecht in 1966, the characteristic of groundwater in the rock and soil is summarized by using Archie's Law. In 2003, Bernard stated in his study that low resistivity anomaly will be targeted specific for hard rock environment. In opposite, high resistivity anomaly will be targeted in clayish or salty environment.

In previous study, Batang Berjuntai or Bestari Jaya are classified in Selangor Basin (Nur Hidayu Abu Hassan et.al, 2017). In the study, Selangor Basin consist of some main geological formation such as alluvium, sedimentary and metamorphic rock. These lithologies controlled the type of aquifer in the study area. In previous study in 2002 by Dzazali Ayob and Ho Choon Seng, alluvial aquifer exist in Selangor Basin as saline water detected about 3 to 5 kilometers from the coastline. Toward eastern part of Kuala Selangor, metamorphic rock aquifer that contain fresh water is identified.

Each type of water has it own characteristic and the resistivity value. Table 2.1 shows the relationship between different type of water and their resistivity value.

Table 2.1: Resistivity values based on different type of water.

Type of Water	Resistivity Value (Ωm)
Precipitation	30-1000
Surface water in igneous rock environment	30-500
Surface water in sedimentary rock environment	10-100
Groundwater in igneous rock environment	30-150
Groundwater in sedimentary rock environment	>1
Sea water	0-20
Drinking water	>1.8
Water for irrigation and stock watering (Maximum salt content 0.25%)	>0.65

(Sources: Rosli Saad and Edy Tonnizam, 2012)

2.6.4 Resistivity Method

Electrical resistivity imaging method which also known as ERI method is one of geophysical method that involved in subsurface investigation. It can be described as a non-destructive geophysical method. This electrical method can be operated or run in two ways either passive technique and active technique. In this research, active technique has been used which is known as DC Resistivity method. This method tends to measure the electrical potential that associated with the subsurface electrical current flow that are generated by a direct current (DC).

The resistivity method consists of some types of array configuration in field survey. In 1999, Loke state that type of structure to be mapped, sensitivity of the resistivity meter and the background noise level become the aspects that controlled the suitable type of array configuration will be used. Based on Berkeley Course in Applied Geophysics of University of California, there are about five main types of array configuration in resistivity method. The configuration can be known as Pole-pole, Pole dipole, Wenner, Schlumberger and Dipole-dipole array configuration. All of the configuration focus on the aim to gather or measure the apparent resistivity but differ in their four-electrode scheme.

Firstly, pole-pole refer to array configuration where the each one of current and potential electrode is been placed so far until they measured at infinity such as in figure 2.8. Due to the maximum distance between the potential electrodes, this will increase the amount of telluric noise that will affect the quality of apparent resistivity. The apparent resistivity for this array configuration can be determine such as in figure 2.9.

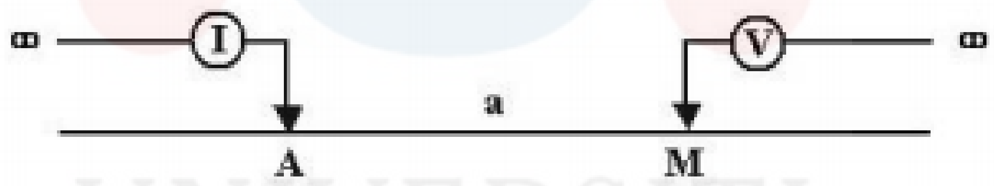


Figure 2.8: The cofiguration of pole-pole array.
(Source: Berkeley Course in Applied Geophysics of University of California, 2018)

$$\rho_A = \frac{V}{I} 2\pi a$$

Figure 2.9: The formular of apparent resistivity for pole-pole array.
(Source: Berkeley Course in Applied Geophysics of University of California, 2018)

Dipole-Dipole array configuration may be differ from pole-pole array configuration. It is very well known as the most suitable configuration in site investigation especially for large study area. In figure 2.10, the different in scheme can be observed. The current and the voltage dipole spacing is identical and the spacing between current and voltage is an interger multiple of a. The apparent resistivity of dipole-dipole array is shown in figure 2.11.

Figure 2.10: The cofiguration of dipole-dipole array.
(Source: Berkeley Course in Applied Geophysics of University of California, 2018)

$$\rho_A = \frac{V}{I} \pi \, a \, n(n+1)(n+2).$$

Figure 2.11: The formular of apparent resistivity for dipole-dipole array.
(Source: Berkeley Course in Applied Geophysics of University of California, 2018)

Pole-dipole array is a hybrid configuration from pole-pole and dipole-dipole array configuration. Normally, one of the current electrode is considered as infinity in this array. This hybrid inprove some of the aspect such as it has good horizontal coverage. The scheme of the array is shown in figure 2.12 and the apparent resistivity is shown in figure 2.13.

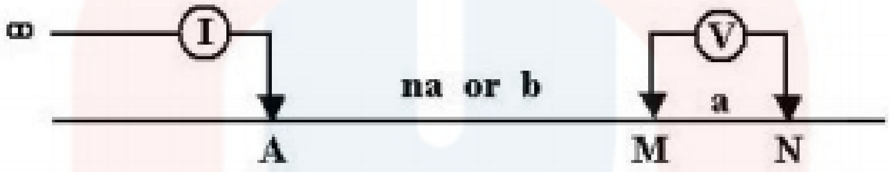


Figure 2.12: The cofiguration of pole-dipole array.
(Source: Berkeley Course in Applied Geophysics of University of California, 2018)

$$\rho_A = 2\pi \frac{b(a+b)}{a} \frac{V}{I}$$

Figure 2.13: The formular of apparent resistivity for pole-dipole array.
(Source: Berkeley Course in Applied Geophysics of University of California, 2018)

Next, Wenner array configuration involve four collinear and equally spaced electrode. The four electrodes refer to two electrode which function as current electrodes and the other two electrodes act as potential electrodes. The spacing between all the electrodes is same, a such in figure 2.14. The formula in figure 2.15 help in determine the apparent resistivity of the Wenner array.

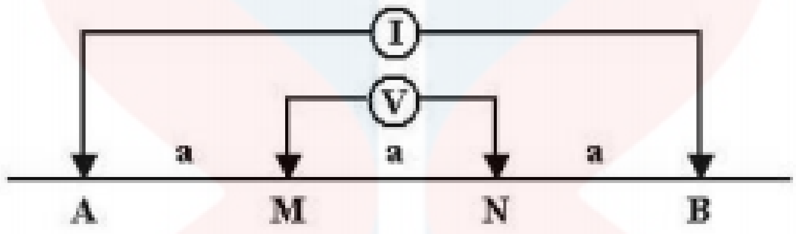


Figure 2.14: The cofiguration of Wenner array.
(Source: Berkeley Course in Applied Geophysics of University of California, 2018)

$$\rho_A = 2\pi\, a \frac{V}{I}$$

Figure 2.15: The formular of apparent resistivity for Wenner array.
(Source: Berkeley Course in Applied Geophysics of University of California, 2018)

Schlumberger is classified as one of the first array in 1920' and still being used until nowadays. The configuration of this array explain that the potential electrodes are placed at the center with a small spacing between them, typically less than one fifth of distance between 2 current electrodes. This array has a better quality of resolution and also improve the depth coverage. This array also known for it convenient in field work as it reduces the time consume for the operation. The configuration can be observed in figure 2.16 and the apparent resistivity can be observed in figure 2.17.

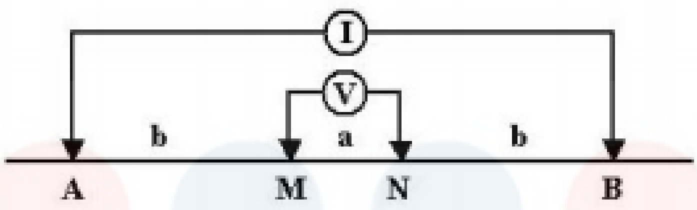


Figure 2.16: The cofiguration of Schlumberger array.
(Source: Berkeley Course in Applied Geophysics of University of California, 2018)

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

Figure 2.17: The formular of apparent resistivity for schlumberger array.
(Source: Berkeley Course in Applied Geophysics of University of California, 2018)

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

This chapter is focusing on the materials and method that need to use during the research. These materials and methods are involved in all stages such as in preliminary study, data processing data analysis and interpretation.

Preliminary study involves the initial exploration and investigation of the study area before the research is start. This stage can help researcher to understand the study area in order to estimate the further works to be done in next stage.

Field study involve collecting of raw data which related to the research study that undergo outside the laboratory or the workplace. In this study, the raw data is collected by secondary data.

Data processing is a stage where the raw data collection must be translated into useable information. This will include some process such as input data, retrieve verify, store, organize or analyse. Most of the raw data need to be translate by using computational method so that it can be a useable information.

The data analyse and interpretation involve in reading and reviewing of translated raw data in order to produce the finding, discussion, conclusion, implication and significance of the research.

3.2 Materials

Materials that involved in this study are electrical resistivity imaging secondary data, ArcMap 10.3 software, Google Earth Pro software, ABEM SAS 1000 terrameter (in secondary data) and RES2DINV software.

ArcMap 10.3 is a series of software in geographic system (GIS) method that use for any work that involving maps and geographic. Google Earth Pro is a geospatial software that shows and display a real virtual globe in order to help the process of analyse and capture any geographical data. ABEM SAS 1000 Terrameter is a geophysical instrument that play multiple role such as it can measure both the resistivity and the induces polarization (IP) simultaneously. This can reduce the time taken in fieldwork as well as the research cost.

3.3 Methodologies

There are some methods that has been used in both studies especially for preliminary study stage, field study stage, data processing stage and lastly, data interpretation stage.

3.3.1 Preliminary studies

In this study, the research initial conducted to make the overview and identify that the evaluation able to cover the focus area. Firstly, Google Earth which provide the detailed geographic information of study area like location and also able to provide terrain map. The preliminary information such as road assessment, settlement, plantation can be obtained by observation in the Google Earth Pro. The information such as landform can also be observed by the elevation profile in Google Earth Pro. The elevation profile will provide the maximum elevation, maximum elevation and the dimension of study area. This will help to identify the landform of study area based on landform classification. For example, each landform such as valley, lowland, low hill, hill and mountains have their own maximum and minimum elevation. These studies help the researcher to understand their study area and help for any consideration based on any limitation found. ArcMap 10.3 able to provide the base map of the study area before start the mapping activity of study area. A perfect base map of study area can be produced as the base map from ArcMap 10.3 will be match with imagery map from Google Earth. If there any difference in the location of the features from both maps, the difference can be edit and save in the ArcMap 10.3. The map must include all the compulsory elements such as title, the author information, legendary, the north arrow, the scale and the gridline of the coordinate. The perfect base map will be extract in form of jpg format from the ArcMap software.

3.3.2 Field Study

In this study, the physical field work will not be conduct directly. For the specification, secondary data will be obtained from the secondary data of ERI method. In this geophysical method, normally more than 5 lines of array will be conducted. This study will involve pole-dipole array configuration because it will give a good vertical and horizontal coverage of subsurface. It also not sensitive to telluric noise signal and it has low signal strength. Telluric signal related to the current that exits due to the variation in Earth's magnetic field. This cause by the collaboration of the solar wind that known as charged particle and the ionosphere. In this study, 41 electrodes will be used.

For each resistivity line, 41 electrodes will be pegged on the ground surface with minimum 2 meters for spacing between the electrodes. The total length of each line can be assumed as 200 meters. Among all the electrodes involved, there are 4 active electrodes will be selected. This is because pole-dipole will select 4 active electrodes which are 2 current electrodes and 2 potential electrodes. One of the current electrodes is installed at an "effective infinity" distance, which is approximately five to ten times the survey depth. The other current electrode is placed in the area of the two potential electrodes such in figure 3.1. Figure 3.1 shows that A indicates current electrodes while M and N indicate potential electrodes. The electrodes will be connected with a multi-electrode resistivity meter which is ABEM Terrameter SAS 1000 instruments. Among all the electrodes involved, there are 4 active electrodes will be selected. After the whole instrument set up, the ABEM Terrameter SAS 1000 will be turn on. In the 'RECORD MANAGER' menu, the operator can select the measuring mode self-potential, resistivity or IP. The record will be update automatically when a new record is defined. For each line, the procedure will be repeat for an accurate data.

During the field investigation for groundwater potential in hard rock, there are some steps and warning should be alert by the user. The Terrameter transmitted voltages and current via the cables and electrodes. The operator needs to take more cautious and responsible to take control of the ABEM SAS Terrameter. If the equipment has set up and the current connected, it is important to avoid any individual or animal to get in touch with those connectors and cables. The operator needs to avoid or stop doing the fieldwork during bad weather such as rainy day or thunderstorm. Any lighting or high voltage sources during bad weathering can damage the instruments. Even though the lightning come from miles away, it can still conduct about hundreds of volts into the long cable. This may invite harm for both the operator and the equipment. The operator also needs to make sure overheating of the Terrameter does not occur. Overheating may destroy the instruments but it surely will halt and disturb the measuring process. In order to avoid overheating, there are few steps that need to follow. Firstly, the instruments must not operate in direct sunlight. Try to use any device or tools to keep the instrument in shade. Secondly, the instrument must be operated in open space in order to allow the air circulate smoothly and freely. If overheating occurs, the operator needs to turn off the equipment in order to prevent any damage.

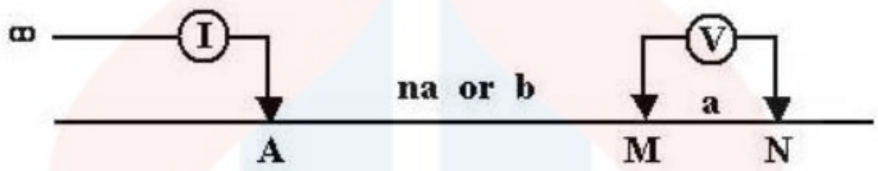


Figure 3.1: Pole-Dipole electrode array where A indicates current electrodes while M and N indicate potential electrodes. (Derived from Smith,1986)

3.3.3 Data Processing

For geological mapping, the data gathering involve the data collection from secondary data. The detailed shapefile for Sungai Subong will be obtain from Secondary data. For example, shapefile such as lithology map, contour, river map, land use map, weathering, lineament and another shapefile needed. The shapefiles will be transfer into ArcMap 10.3 in order to update the base map from previous preliminary studies. The shapefile data can be added into the layer by the 'Add data' button. The updated base map then will be match with satellite imagery by Google Earth Pro in order to check any differences in each feature. If there any differences of the feature, the edit tool must be use. If there any addition of feature, the new shapefile data will create in the 'Catalog' tools. Then, the type of new feature must be selected such as whether it is polygon, polyline or line features.

For groundwater potential in hard rock, the RES2DINV software will be install. In order to connect the Terrameter and PC computer or laptop devices, it is needed to setting the terrameter into communication mode which can be found in Record Manager Menu. Then, click the stop sign. Program Selection Screen will appear. Then, choose the RS232 Communication. Then in RES2DINV software, press the toolbar to invoke the "Import Data" menu. All file in the terrameter will be display. The file saved from the field will be choose. Then the import button will be selected and the data will be import from terrameter into the PC or laptop device.

3.3.4 Data Analysis and Interpretation

For geological map, the interpretation will be based on the base map from secondary data gathering. With updated base map from ArcMap 10.3, there are many things can be observed. Firstly, the accessibility in the study area can be observed by all the road. The distances from any settlement, town or other facilities can be assume. Settlement in the study will be observe so that all facilities can be included in the map such as housing area and factories. Forestry can be observed by the land use shapefile whether there are any forest, plantation or mining area. Traverse will be done both in ArcMap 10.3 and Google Earth pro but it will little bit different in the accuracy from direct field traverse. Geomorphologic classification will be produced base on drainage pattern and fluvial system shapefile. For example, biological, physical and chemical weathering rate will be related to the drainage pattern. As drainage pattern more complicated, then the rate of weathering will be high. It can also can be obtain in the elevation profile provide in the Google Earth Pro. The elevation will help in geomorphology classification such as valley, lowland, flat, low hill, hill or mountains. Normally, river can be found in the valley area which normally with elevation below 100 meters above the sea level. Above 100 meters to 250 meters, the landform can be classified into lowland or low hill. Next, for elevation above 300 meters, the landform can be classified into the hill area. For lithostratigraphy aspect, the rocks will be differentiated whether it younger or older rocks. This can be interpreted by satellite imagery in Google Earth Pro and ArcMap or literature review from previous study of Sungai Subong and the Bestari Jaya. The same interpretation stage also can be applied on identification of rocks type or lithology of study area. Landform can also interpret the type of rocks. For example, the landform with elevation below 300 meters and rich of plantation normally represent the area of sedimentary rocks. The landform with higher elevation such as mountainous area normally consists of igneous rocks. This is because the intrusion of igneous body usually forms a mountain area. Igneous rocks also have high resistant minerals such as quartz and feldspar. Therefore, the rock undergo low weathering process and it maintain the elevation of the area. Lastly, structural geology will be interpreted by using shapefile from ArcMap and also Google Earth Pro. Lineament shapefile will help in identification of many structural features such as vein, fault and fold. For example, feature such as cutting or discontinuous of straight river indicated the present of faulting. The existence of special features such as continuous springs and the waterfall also indicates the present of fault activities. As for the fold, the landform that show any tilted or folding structure such as Cuesta and Hogback may indicates the fold activities. This features also can be identified base on dip and strike data obtain by the satellite imagery. Thus, if there any clear structure, then a principal stress can be study.

For groundwater potential in hard rock, the use of the RES2DINV essentially involves the reading of the field data, inversion of the data using least square inversion procedure to get the true resistivity and the true depth of the field resistivity image. Topographic corrections to account for variations in the surface elevation are also included in RES2DINV. Basically, the data from these surveys are commonly arranged and contoured in the form of a pseudo section which gives an appropriate picture of the subsurface resistivity (Loke et al., 2003). The electrical resistivity will be represented in ohm.m or Ω.m and also in ρ such in Figure 3.2. The apparent resistivity in figure 3.2 can be related to the figure of 3.1. The ρ_A in the formula represent the apparent resistivity. The spacing in the pole-dipole array normally described in integer multiples of voltage electrode which symbol of 'b' in both figure 3.1 and 3.2. The potential electrode spacing are represent in 'a', the voltage represents in 'V' and the current represent in 'I'.

$$\rho_A = 2\pi \frac{b(a+b)}{a} \frac{V}{I}$$

Figure 3.2: Apparent resistivity of pole-dipole array configuration.

The electrical resistivity data in the RES2DINV will be process to form resistivity 2-Dimension graph which will show the resistivity of each line subsurface materials. Basically, igneous and metamorphic rocks have high resistivity value compare to sedimentary rock. The resistivity of groundwater ranges from 10 to 100 ohm.m such in figure 3.3 (Loke, 2013). As in literature review, the possible type of rocks in the study area are majorly come from metamorphic rocks such as schist, phyllite and limestone that form during Ordovician to Silurian period. Therefore, the expected resistivity of the rock can be identified in the chart in both figure 3.3 and figure 3.4.

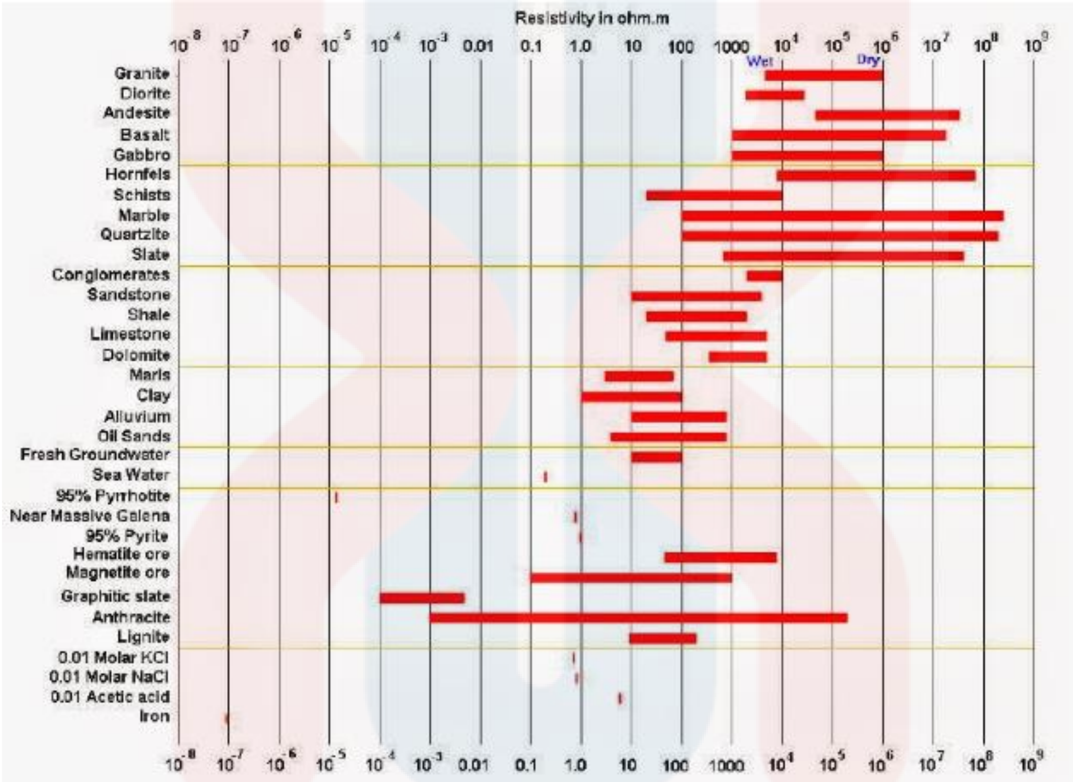


Figure 3.3: Resistivity chart of rocks and other earth material. (Loke,2013)

Next, conductivity related to resistivity of the rocks or earth materials. Soil and rocks normally composed of silicate minerals which act as insulator, meaning they have low electrical conductivity such in figure 3.4. With all this references, the potential of groundwater in hard rock will be analyse and identify.

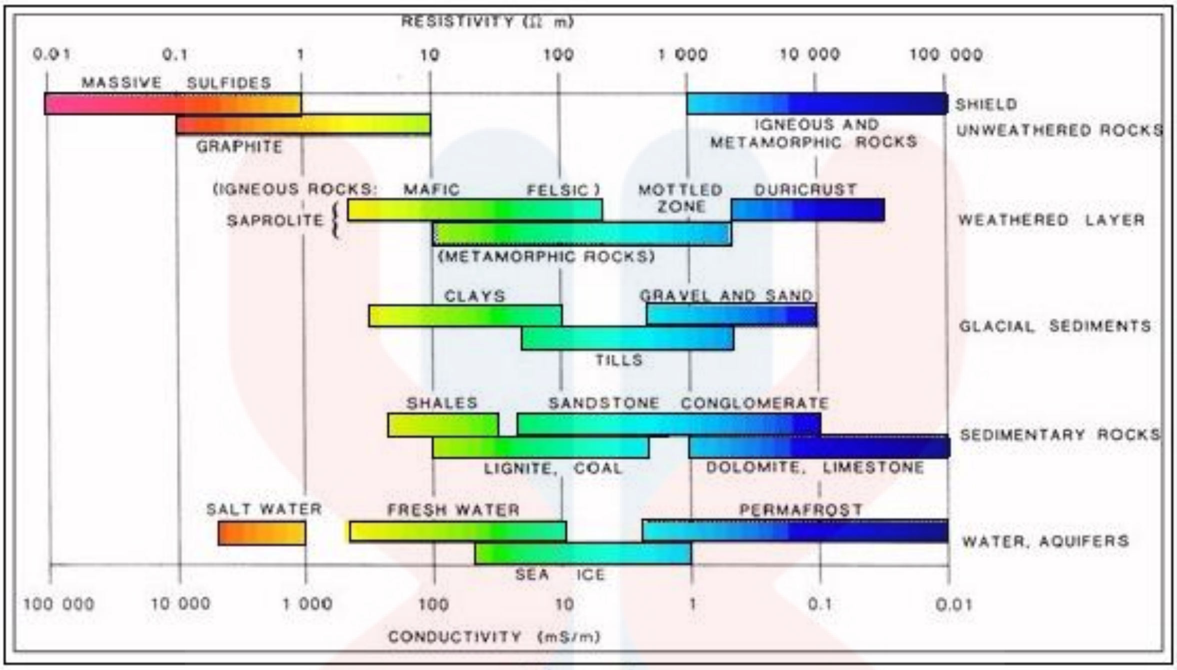


Figure 3.4: Resistivity and conductivity value of earth materials (adapted from Palacky, 1987).

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

General geology involved an investigation or survey which related to geology and Earth Science. The geology of Sungai Subong area Gua Musang, Kelantan are made up of the Gua Musang Formation which developed during Late Permian to Late Triassic. Geology of the study area are focused on the geomorphology, lithostratigraphy and structural geology. Geomorphology describe on how the landform contributed to the geology of study area based on the topography and the drainage pattern. Lithostratigraphy describe in detail each of the rock unit that exist in the study area. The description involves the age of the rock, the petrology of the rock and the other aspects. Structural geology describes on how the deformation activity in the study area affect the rock unit. Lineament plays an important role in deformation activity identification.

4.1.1 Accessibility

Sungai Subong located in the biggest district in Kelantan, which is Gua Musang District. The study area located about 3 kilometres from the main town of Gua Musang Kelantan. The main access to this study area by Jelawang-Gua Musang Highway. The highway connected the main town of Gua Musang and Jelawang. As the study area is covered by palm oil and rubber tree plantation, there are another small road that existed in the study area which included both paved and unpaved road. At the western part of the study area, there are small paved road that contructed in ordert o connect the main Jelawang-Gua Musang Highway to Gua Subong and Ladang Subong Office. At the eastern part of the study area, there are small village road built along the railway. This road become the main access for small village such as Kampung Niroh and Kampung Laling such shown in figure 4.1.

4.1.2 Settlement

The study area consists of two main villages which located at the southern-east part of the map in figure 4.1 The villages are knows as Kampung Niroh and Kampung Laling. Alongside the road that connected to Ladang Subong Office, there are also small settlement. The population of the study area basically dominant by Malay race as most of them worker in rubber tree and palm oil plantation sector.

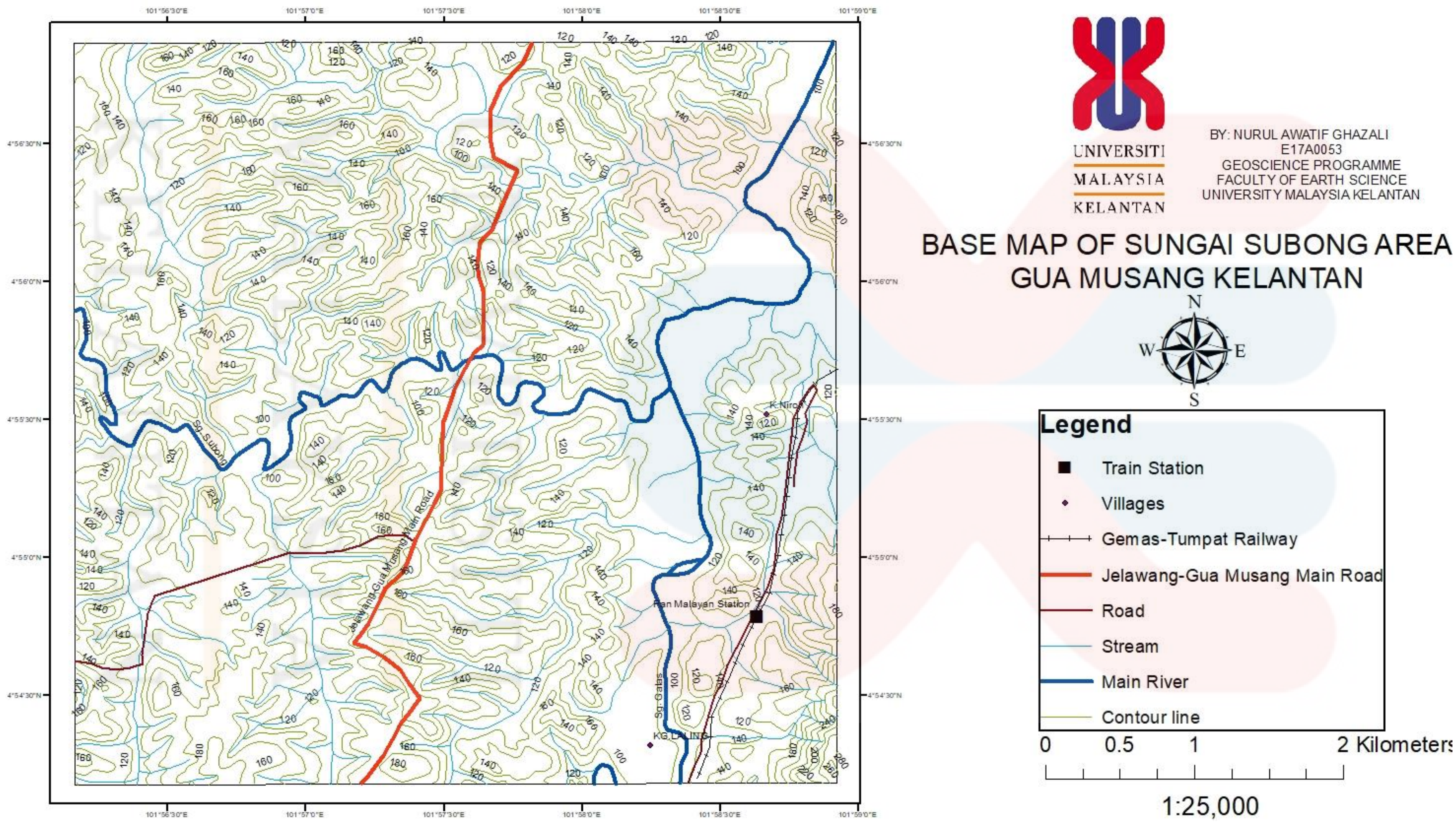


Figure 4.1 Base map of Sungai Subong study area

4.2 Geomorphology

Geomorphology represent the branch of geology that play an important role as it will help to give an overview and information on the existing landscape of the study area. It involves on study of landforms, process, evolution and their formation which may involve physical, chemical or biological process. Geomorphology can be related to the landform and the drainage pattern that exist in the study area. Drainage pattern analysis is one result form process of geomorphology. Drainage pattern that distributed on Earth Surface controlled by the hill slope, the lithology and its thickness, the geological structure, intensity and vegetation type and also nature condition. Landform refers to the Earth surface shape which usually created by process such as tectonic activity where any movement of the plate beneath the surface can create features such as mountains and hill.

4.2.1 Topography

In the study area, the landforms are identified by topography analysis in ArcMap 10.3. The Digital Elevation Model (DEM) help in process of conversion topography to raster. With this step, the landform can be obtained by the help of contour shapefile from DEM. The landform then classified by using theory of Van Zuidam in 1985 such as in table where the relationship between absolute elevation and morphography aspect is shown. Analysis show that the minimum elevation of the study area about 86.95 meters while the maximum elevation in the study area about 274.73 meters. Based on table 4.1 and geomorphological map in figure 4.2, the study area consists of 3 classes of morphograpgy which are low land, low hill and hill.

Low land refers to any elevation with range between 50 to 100 meters. It is also the area where it has higher elevation than the elevation in alluvial plain, stream and river. In the study area, low land can be observed in area where the major lithology is alluvium and also located in certain valley.

Low hill refers to any elevation with range between 100 to 200 meters. It is also representing the area with higher elevation than the elevation in low land. Based on the analysis, the low hill can be observed as the area that consist of higher slope and valley. This can be shown in figure. The area also represents the area where the lithology are sedimentary and metasedimentary rocks.

Hill refers to any area with elevation range between 200 and 500 meters. It is also representing the area that the slope is steeper than lowland and low hill but less steep than mountainous area. Based on the geomorphological map in figure 4.2 and figure 4.3, the hill can be identified in S-E direction. The hill can be related to its lithology where the rock type is igneous rock. Igneous rock tends to have high resistance minerals such as quartz, feldspar and mica. These minerals help the rock to maintain its shape and reduce the erosion process.

Table 4.1: Relationship between absolute elevation and morphography aspect.

Absolute Elevation (meters)	Morphography Aspects
<50	Low valley
50-100	Low land
100-200	Low hill
200-500	Hill
500-1500	High Hill
1500-3000	Mountain
>3000	High mountain

(Sources: Van Zuidam, 1985)

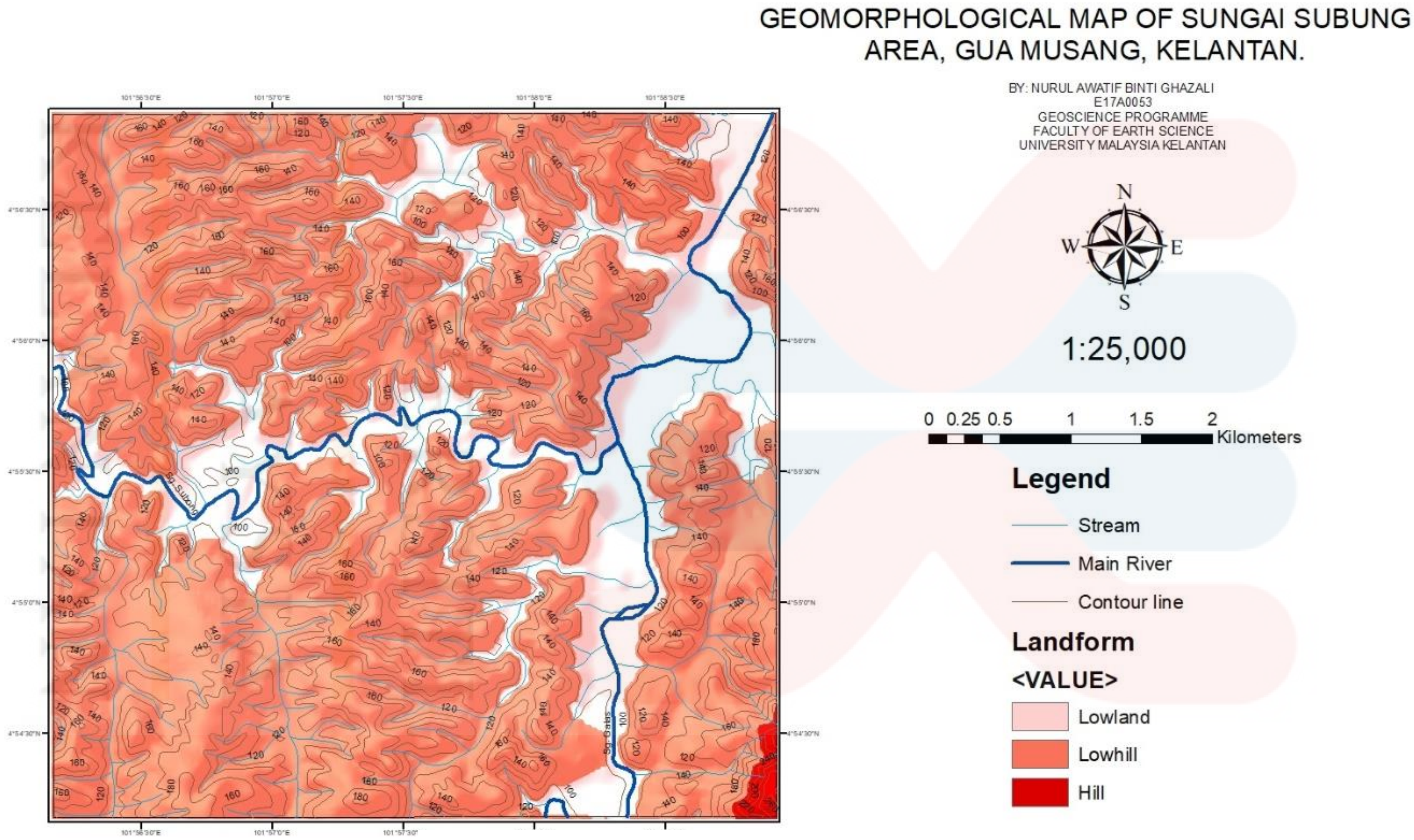


Figure 4.2: Geomorphological map pf Sungai Subong study area

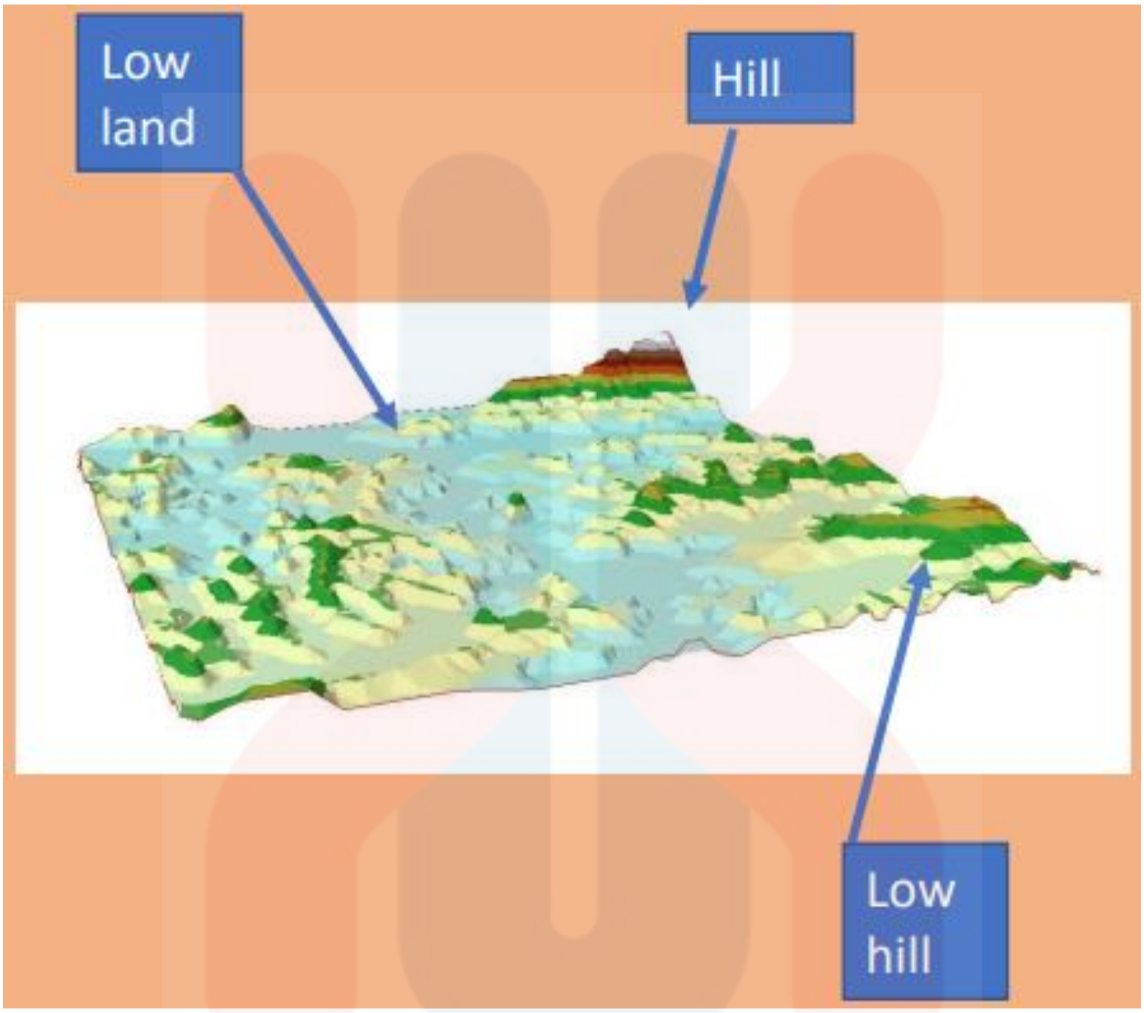


Figure 4.3: The arc scene analysis of the study area with landform.

4.2.2 Drainage Pattern

Drainage pattern origin from process of tectonic and weathering produced valleys for water flow. Drainage pattern may relate to the lithology of the area, erosion condition and the historical geology of the study area. Drainage pattern has been analysed by using software such as ArcMap 10.3. The stream and the river have been updated by suing the georeferenced such as Google Earth Pro software. Based on figure 4.4, the study area consists of 3 types of drainage patterns such as dendritic drainage pattern, parallel drainage pattern and sub-parallel drainage pattern based on theory of Van Zuidam in 1985.

Firstly, dendritic drainage pattern refers to any flow pattern that distributed in branched that spread in shady tree. The drainage pattern usually refers to area where the lithology consists of plain relief sedimentary rock layer. Usually in this area, the rock can be easily eroded in all direction. Based on morphometry analysis, the area that consist of dendritic drainage pattern located at the northern part of study area.

Secondly, parallel drainage system refers to any flow pattern that distributed mostly in low hill area where the slope is moderate and consist of some relief. Due to this aspect, the stream is straight and some of tributaries in that area may flow in the same direction. It is also can be found in landform that consist of elongated shape such as ridges. Based on drainage system map in figure, this type of drainage system operates in area where the lithology is mostly covered of sedimentary rock. The water flow from area with steeper slope into the valley then flow into the main river.

Next, sub-parallel drainage system can be similar to parallel drainage system but there are some differences can be observed. Sub-parallel drainage system refers to any water flow in parallel way but more into certain angle. Normally, the first order tributaries usually nearly parallel to second order tributaries. In the study area, this type of drainage system can be observed in metasedimentary rock. Where the area also has elongated shape landform such as ridges.

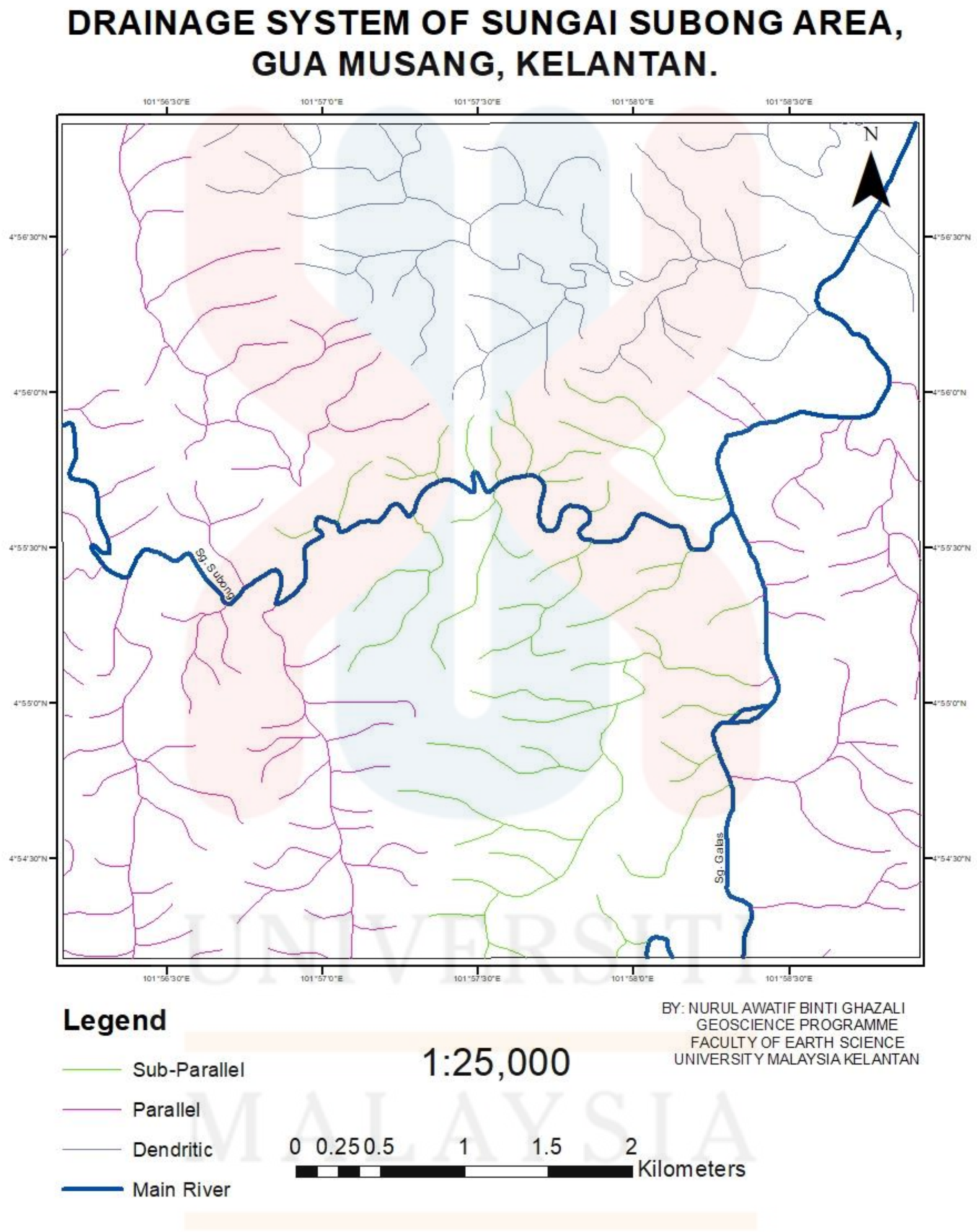


Figure 4.4: Drainage system map of Sungai Subong area, Gua Musang, Kelantan.

4.3 Lithostratigraphy

Lithostratigraphy is one of study in stratigraphy which related to Earth Science study that associated with the study of strata and layer of rocks. In this topic, the geochronology, petrology and geology of study area.

In the study area, there are 4 lithologies can be found such as alluvium, intrusive rock, metasedimentary rock and clastic sedimentary rock such in figure. The lithologies in the study area are origin from different age such as Permian to Middle Triassic, Late Triassic and Quaternary to Recent. These lithologies has been observed to follow some law of stratigraphy and are classified as Gua Musang Formation.

During Permian Period of Palaeozoic era, metasediment formed as the forearc basin of the accretionary complex started to subside. In the study area, the metasediment represents the argillaceous facies that consist of shale, siltstone, mudstone, slate and phyllite. Sandstone may also present as it has variety of grain size which from very fine to fine. The slate unit can be found in fine grained size with grey to black colour as there are also existence of foliation. Shale unit normally composed of silt and clay minerals. The colour of this rock unit can be in greyish colour and it is a fined grained size. In the geological map, metasedimentary rock has covered about 75 % of the study area.

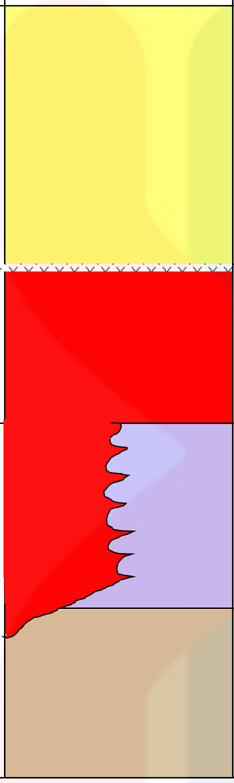
Next, clastic sedimentary rock unit can also be observed in the study area. The clastic sedimentary rocks are made up of some sandstone, siltstone and shale. These lithologies unit form interbedded facies. There are formed during Late Permian to Middle Triassic. The sandstone unit normally has dark red in colour and the composition of sandstone are quartz and feldspar.

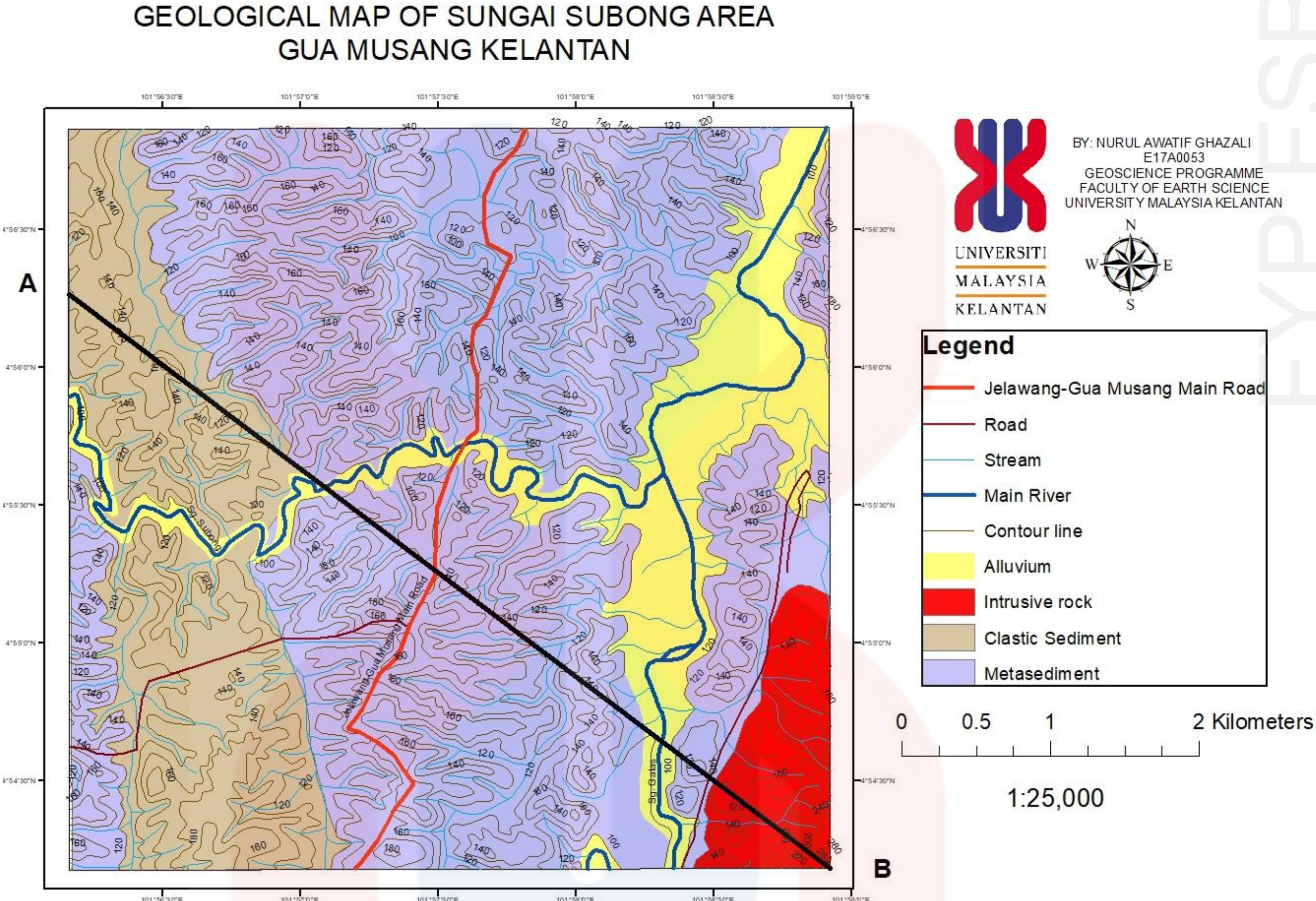
Based on Department of Mineral and Geoscience Kelantan State, the intrusive rock found in the study area is acidic intrusive rock. The rocks are mostly composed of quartz, feldspar and plagioclase. Based on law of stratigraphy which is law of intrusion, the acidic intrusive rock intrudes older rock such as sedimentary and metasedimentary rock. The acidic intrusive rocks intrude during Late Triassic period. Based on Lee in 2009, the volcanic rock in western part of the state near to Gua Musang is more rhyolitic composition compared to intrusive rock in eastern part. In the study area, the acid intrusive rock can be found in the S-E of the geological map. The rocks normally represent the landform with higher elevation because volcanic rock composed of high resistance mineral such as quartz, feldspar and plagioclase. Those mineral help to reduce the rate of erosion thus will maintain the high elevation of the landform.

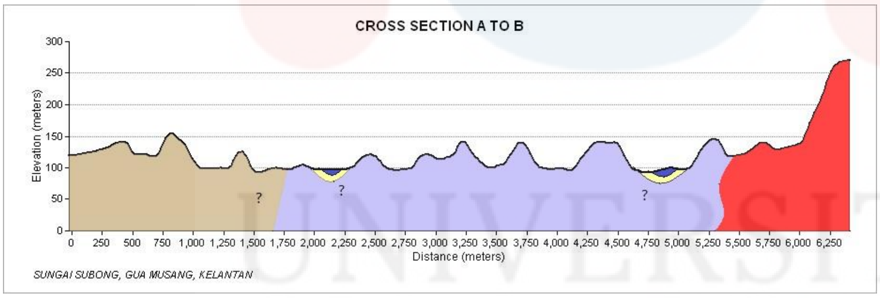
In the study area, alluvium unit can be found in river area. Alluvium unit normally consist of fine particle such as silt, sand gravel. Those particles are not permanent in one area for a long time. Alluvium unit existed during quaternary until present.

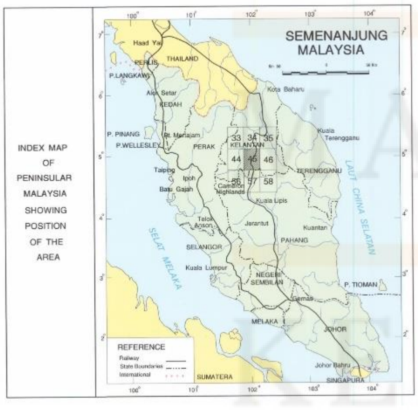
Depositional environment for this study area can be classified as shallow marine environment. Shallow marine environment is warm, calm and quite which suitable form argillite deposition.

Table 4.2: The lithostratigraphy column of Sungai Subong area, Gua Musang, Kelantan.

AGE	LITHOLOGY	LITHOLOGY UNIT	DESCRIPTION
Quaternary to Recent		Alluvium	Deposits of fine particle such as clay, silt and sand along the river valley or delta produced by flowing water. These fine-grained deposits are not permanent in that particular area for a long time
Late Triassic		Intrusive Rock	Acidic intrusive rock such as granite and rhyolite are distributed in the area.
Permian to Middle Triassic		Metasedimentary Rock	Argillaceous facies which consist of shale, siltstone. Mudstone, slate and phyllite. Sandstone also may be varied in grain size which is from very fine to fine.
		Clastic Sedimentary rock	Made up of some sandstone, siltstone and shale. In few areas, these rocks form interbedded facies.







AGE	LITHOLOGY	LITHOLOGY UNIT	DESCRIPTION
Quaternary to Recent		Alluvium	Deposits of fine particle such as clay, silt and sand along the river valley or delta produced by flowing water. These fine-grained deposits are not permanent in that particular area for a long time
Late Triassic		Intrusive Rock	Acidic intrusive rock such as granite and rhyolite are distributed in the area.
Permian to Middle Triassic		Metasedimentary Rock	Argillaceous facies which consist of shale, siltstone. Mudstone, slate and phyllite. Sandstone also may be varied in grain size which is from very fine to fine.
		Clastic Sedimentary rock	Made up of some sandstone, siltstone and shale. In few areas, these rocks form interbedded facies.

Figure 4.5: Geological map of Sungai Subong area, Gua Musang, Kelantan.

4.4 Structural Geology

Structural geology refers to a branch in Earth science study that concern about the deformation of the rocks. It can be large or small scale of deformation process on the surface and subsurface of Earth. The structure may form due to high internal or external forces that may impact the original characteristic of the rocks. Tectonic force may contribute in formation of the structure. Applied force may result in structure such as folding, faulting and many else. Lineament analysis help to identify any deformation base on any linear feature that can be observe in the study area.

Based on Ibrahim Kamoo in 1989, lineament can be classified into 2 types which are positive and negative lineament. Positive lineament is referred to any straight-line feature in the form of bedding which can be represent by the ridges and ranges. For negative lineament, it indicates the existence of faulting or folding based on the valley or rivers that have straight line characters.

The positive and negative lineament has been observed in the study area such as in figure 4.6. Both lineaments type has been identified by using satellite image of software such as Google Map or Google Earth Pro. Some big features such as faulting, ridges, river and valley can be seen clearly by satellite imagery.

The lineament then processed and digitized in software such as ArcMap 10.3 and the direction of the lineament can be obtained. The direction of the lineament then processed Geo Rose software in order to obtain rose diagram. The rose diagram such as in figure 4.7, help in identification of the direction major force that has been applied in the study area.

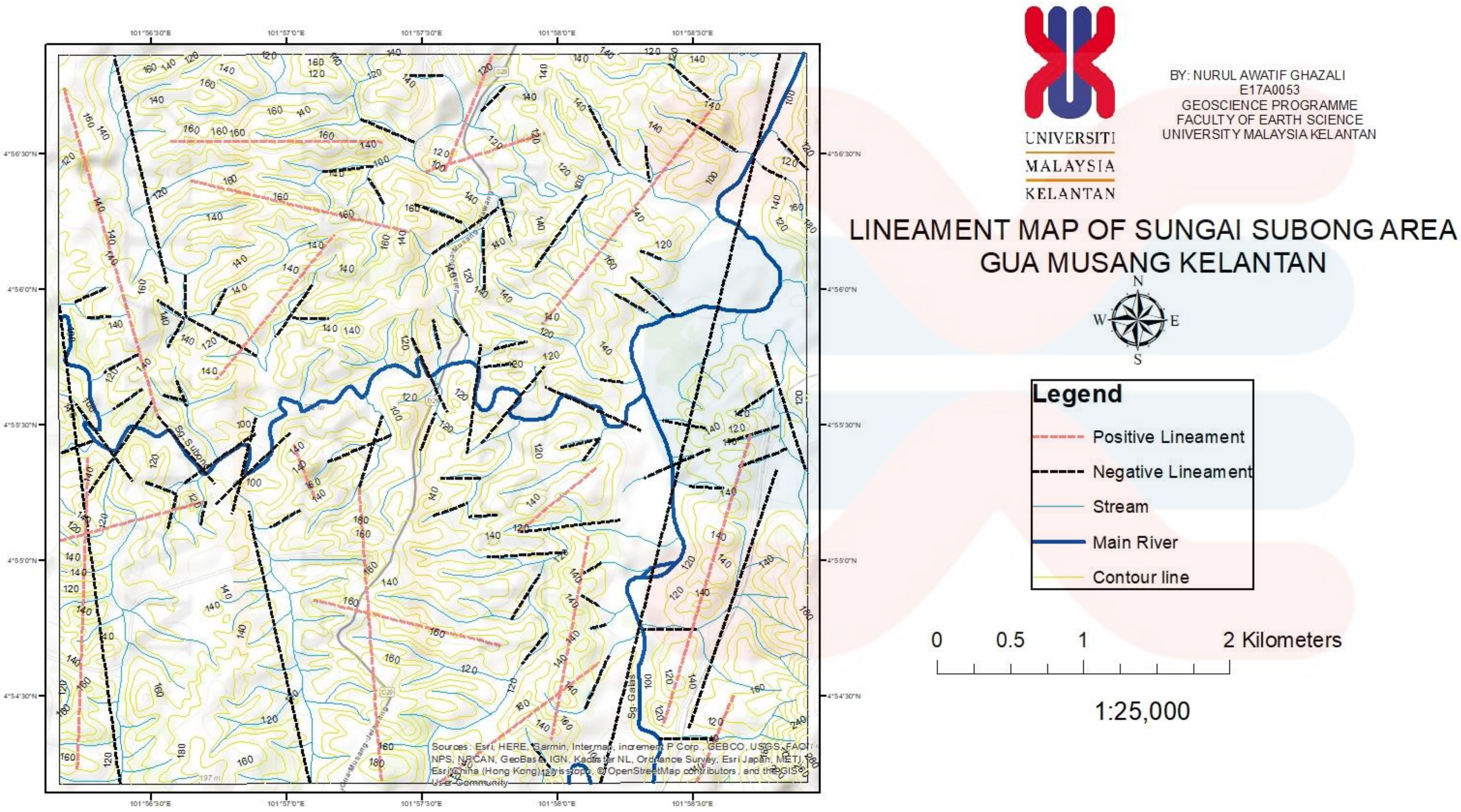


Figure 4.6: Lineament map of Sungai Subong, Gua Musang, Kelantan.

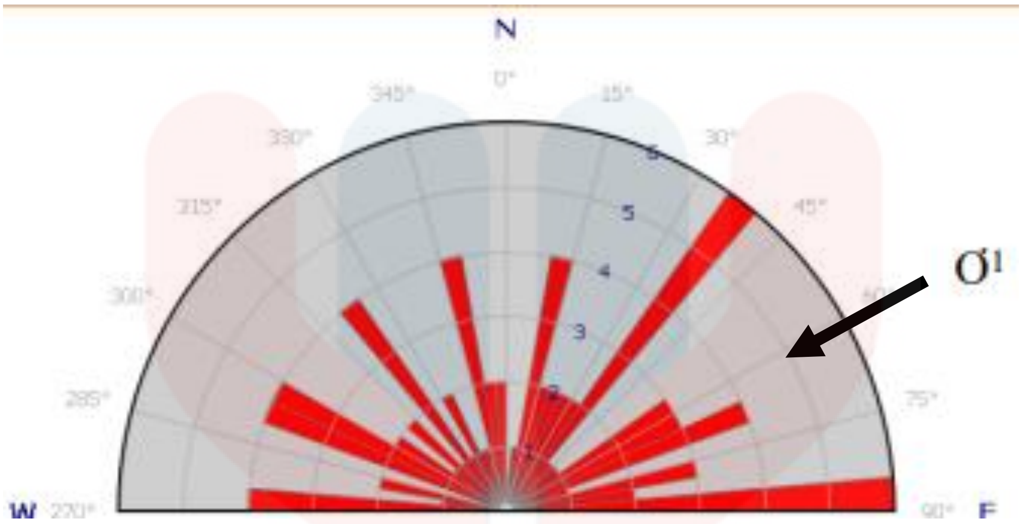


Figure 4.7: Rose diagram based on lineament direction of Sungai Subong Area, Gua Musang, Kelantan.

Based on the rose diagram in figure 4.7, the sigma 1 which represent the largest compressive force applied has strike from N-E direction. Based on the full edition of rode diagram in figure 4.7, the type of fault can be identified. Fault refer to any fracture or area of fracture between 2 blocks of rock. Faults may exist in small scale or either bigger scale such as in kilometre size. This kind of fault refers to any displacement of the far block is toward right when observed from either side.

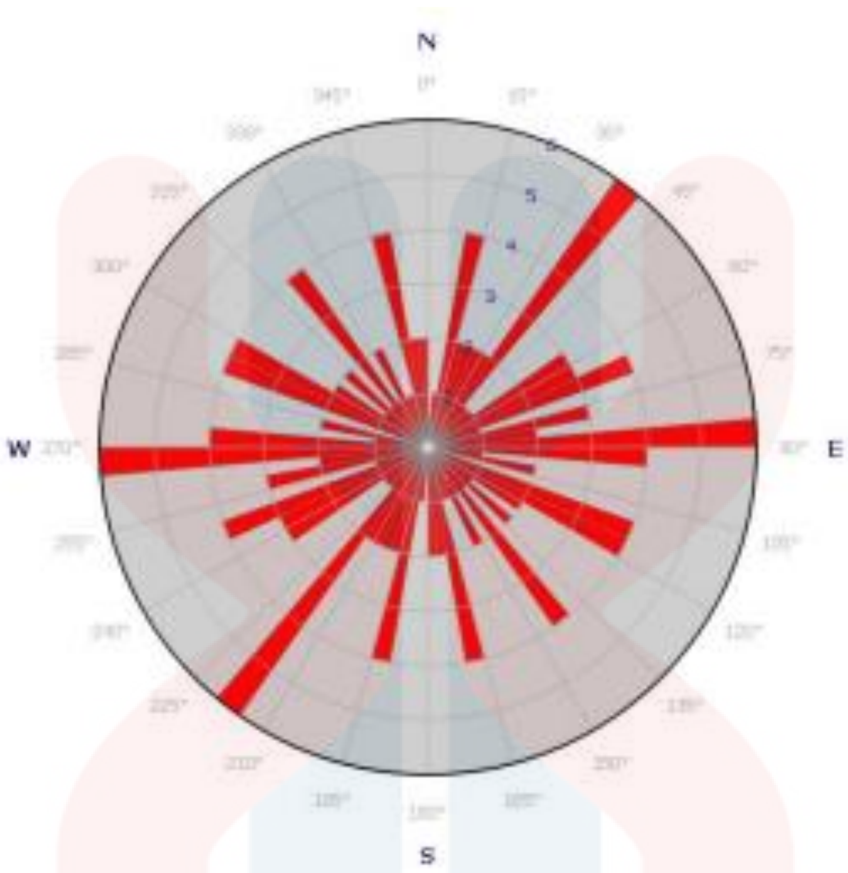


Figure 4.8: Full rose diagram plotted based on Sungai Subong area, Gua Musang, Kelantan.

4.5 Historical Geology

In this study area, the formation of lithologies started in Lower Permian until Quaternary period. During Permian period, low grade metamorphism occurs in this area. Most of the existence sedimentary rocks has altered their characteristic such as their shape and mineralization in order to achieve new equilibrium under sudden different in pressure and temperature. Most of the sedimentary rock formed new low grade metamorphic rock or metasedimentary such as slate and phyllite. This can be related or correlate with the lithologies in Gua musang Formation.

During Triassic period, clastic sedimentary rock is formed when there are process of transportation and sedimentation of sediment into the basin. The clastic sedimentary rock has likely clay-sized sediment.

Later during Tertiary period, there are process of intrusion occur near the study area. This involved the intrusion of acidic magma to form granitic and rhyolitic igneous rock.

Exogenous process such as weathering and erosion continue to happen. During Quaternary Period. This led to deposition of alluvium units especially along the Subong and Galas River.

CHAPTER 5

GROUNDWATER POTENTIAL IN HARDROCK BY USING ERI AT KUALA SELANGOR, SELANGOR.

5.1 Introduction

Electrical resistivity imaging (ERI) method has been introduced to the world in early of 19th century. It involved the evolution of electrical prospecting that predate digital computer. The electrical resistivity imaging is well known as non-destructive geophysical method that focus on subsurface investigation. It focused on the measurement of resistivity of subsurface material in an area. The method has been used in many sectors such as groundwater table investigation, the mapping of bedrock in term of lithology and structure, landfill delineation and also hazard mapping such as sinkhole or void mapping. Electrical resistivity imaging method can produce final result as 2-dimensional (2D) and 3-dimensional (3D) subsurface images. In 2017, Utility Survey Corp stated that electrical resistivity imaging method is different from other method such as Ground Penetrating radar (GPR). ERI may produce a low-resolution result than GPR but ERI produce a result of deeper investigation depth. In Groundwater book by R. Allen Freeze, the resistivity may different according to the lithology, stratigraphy and geological structure. Layer of rock may have a low resistivity if the pore fluid is increase, the salinity of the pore fluid also increases and if the layer of rock contains structural geology such as highly fracture. The resistivity also may decline if the layer of rock has presence of clay mineral. Oppositely, layer of rock may have high resistivity if the pore fluid is removed or decrease, the salinity of water is low. High resistivity rock has low content or presence of clay mineral.

This chapter generally, explain the application of geophysical method for groundwater potential investigation. The method used is electrical resistivity imaging method with pole-dipole array configuration for all the line. All raw data of these survey line is obtained by Dr. Hamzah Bin Hussin, University Malaysia Kelantan.

5.2 Survey Line for Electrical Resistivity Imaging

The study area located in Bestari Jaya, Kuala Selangor, Selangor. The study area surrounds by palm oil plantation and also near to Sungai Selangor Phase 2 water treatment plant. There are also stream that flow at the western part of the study area. The total of survey line for this groundwater potential investigation is five lines. Figure 5.1 shows the study area in Bestari Jaya and the direction of all the five survey lines done in the study area. The study area has been decided because the area is not fully explored by the authorities. The study area also is strategy as there are stream flow near the area and also the study area located in Selangor Basin which the lithologies of the basin consist of Quaternary and Devonian-Silurian-Ordovician rocks. As refer to geological map by Geoscience and Mineral Department of Selangor, the lithology in the study area may age from Devonian Period such in figure 5.2.

RES2DINV software is used in data processing stage in order to produce 2-Dimensional subsurface resistivity investigation.

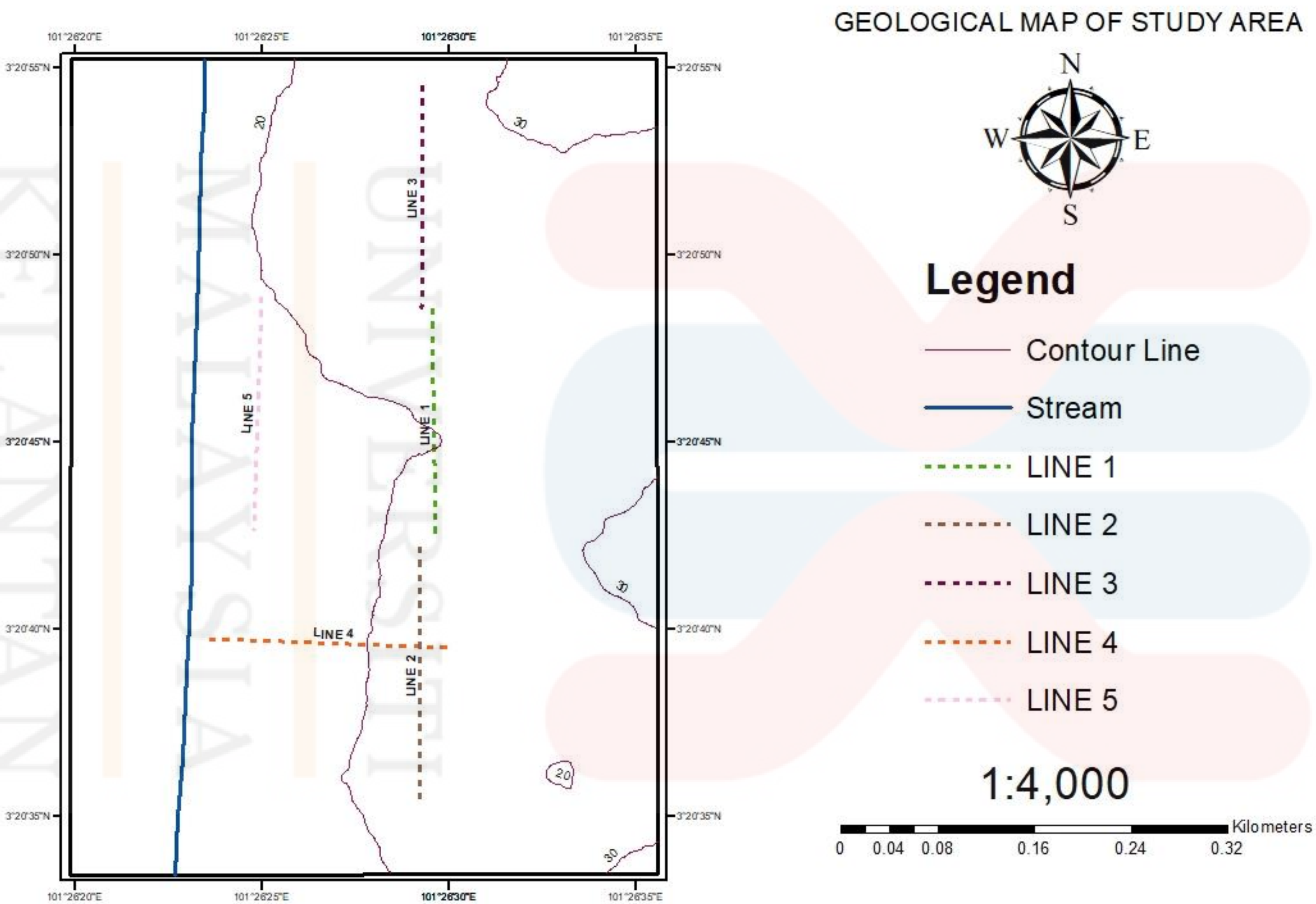


Figure 5.1: Basemap and pole-dipole line lovation in Bestari Jaya study area

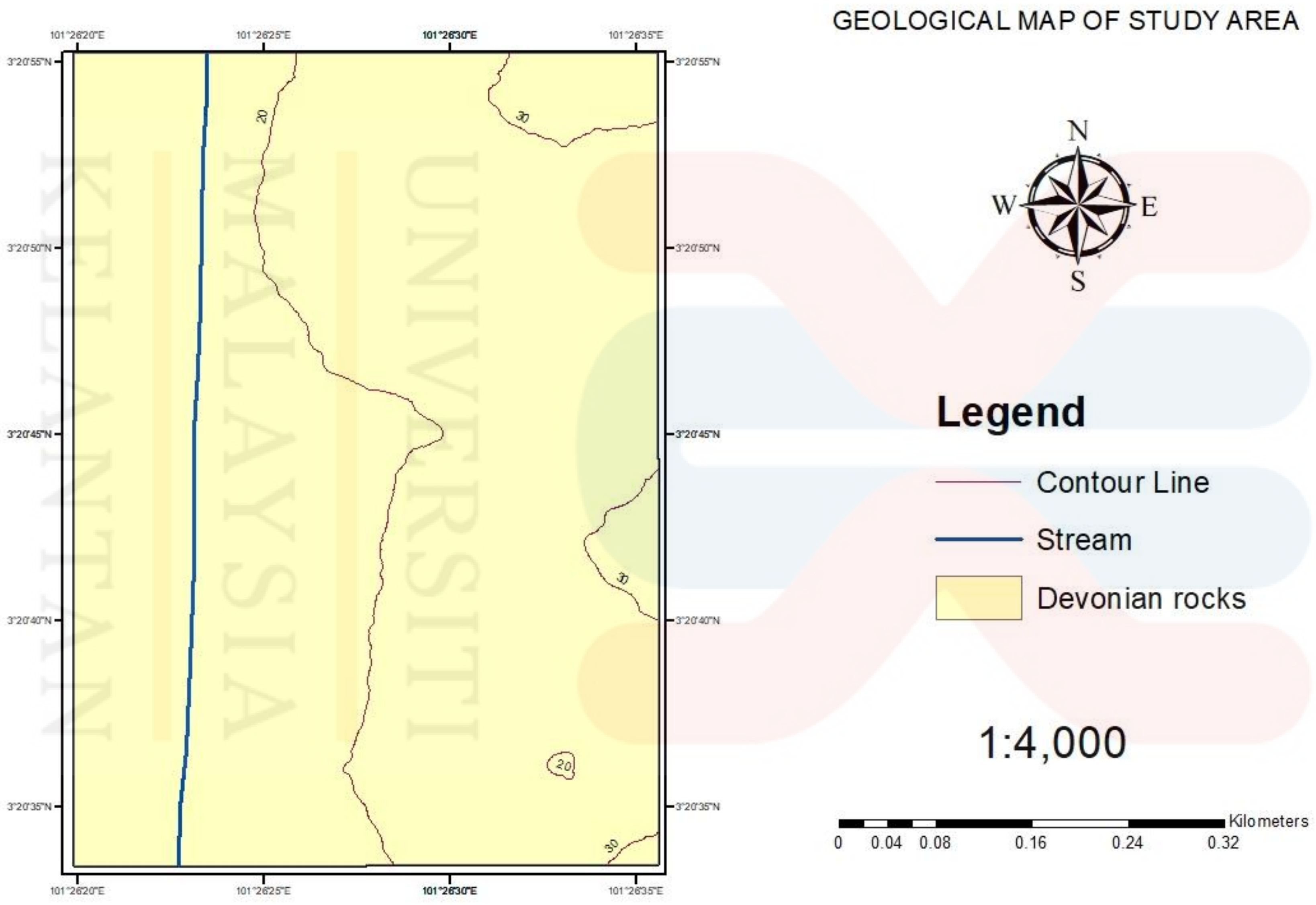


Figure 5.2: Geological map of study area in Bestari Jaya, Kuala Selangor, Selangor.

5.3 Survey Line 1

Line 1 used pole-dipole electrode configuration. The length of the survey line approximately to 200 meters. The spacing between each electrode for those 41 electrodes is about 5 meters apart. The coordinate of the line can be referred as table 5.1.

Table 5.1: Coordinates of Survey line 1

Point	Coordinate
Starting Point	Latitude: 3°20'47.95" Longitude: 101°26'29.68"E
End Point	Latitude: 3°20'41.52"N Longitude: 101°26'29.75"E

The survey line is set up next to a pond is about 200 meters and the survey line is set up in N-S direction such as in figure 5.1. During the field investigation the weather is bright and clear. The condition of the study area of survey line 1 can be shown in figure 5.3 and figure 5.4.

Result of 2-Dimesional subsurface resistivity investigation for survey line 1 has been shown in figure 5.5. Based on the result shown, the effective depth for survey Line 1 is approximately 60.0 meters. The inverse resistivity model in survey line 1 has the root-mean-squares error about 13.7% while the chargeability inverse model for line 1 has the root-mean-square error about 22.5%. This can be observed that chargeability inverse model has greater root-mean-square percentage than resistivity inverse model. The range of resistivity that has been observed in survey line 1 is from 2.27 Ωm to 1143 Ωm. The range of chargeability of subsurface material in survey line 1 are from -38.7 msec to 472 msec. The chargeability inverse model of survey line 1 show the relatively high chargeability anomalies which is around 399 msec.

Based on the result, there are about 3 zone of interpretation can be analysed in the survey line 1. Zone 1 and zone 2 both located about 0 to 30 meters from the Earth surface. Zone 1 consist of the range of resistivity in this zone are from 30 Ωm to 150 Ωm. This region can be interpreted as saturated weathered metamorphic rock. In zone 2, the layer with high resistivity value in range of 470 Ωm to 1143 Ωm can be classified as hard rock which are slate and schist rocks. Zone 2 shows that the metamorphic rocks which is schist started to weathered and the fluid begin to flow in the pore of the rocks. Lastly, zone 3 located at the bottom of resistivity inverse model which about 60 meters depth. The range resistivity of this zone is from 2.27 Ωm to 13.4 Ωm. This zone can be interpreted as saturated sandstone based on the resistivity. The sedimentary rock nicely deposited as layer by layer. There is a bit disturbance in the sedimentary rock layer which may cause by some forces. In zone 3, there are accumulation of groundwater based on the resistivity. Overall, the potential location of groundwater can be found in zone 3 between 30 meters to 60 meters depth.

Figure 5.3: Starting point of Survey line 1
(Source: Dr Hamzah Hussin, 2019)

Figure 5.4: The set-up of survey line 1 from north direction view
(Source: Dr Hamzah Hussin, 2019)

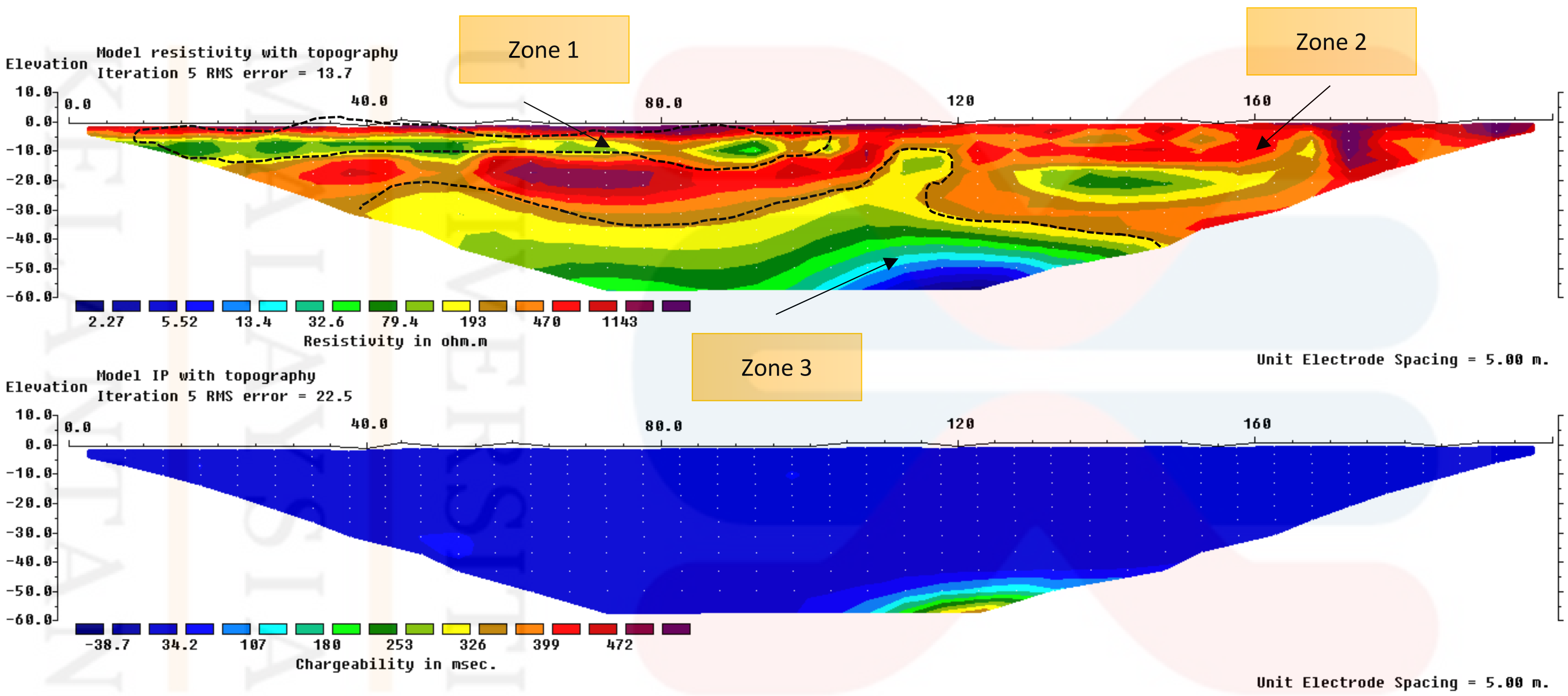


Figure 5.5: Inverse resistivity and chargeability model of survey line 1.

5.4 Survey Line 2

Line 2 used pole-dipole electrode configuration. The length of the survey line approximately to 200 meters. The spacing between each electrode for those 41 electrodes is about 5 meters apart. The coordinate of the line can be referred as table 5.2.

Table 5.2: Coordinates of Survey line 2

Point	Coordinate
Starting Point	Latitude: 3°20'35.11"N Longitude: 101°26'29.23"E
End Point	Latitude: 3°20'41.50"N Longitude: 101°26'29.26"E

The survey line is set up next to a pond is about 200 meters and the survey line is set up in N-S direction such as in figure 5.1. The pond located at the northern part of survey line 2. The line then extends to south direction toward palm oil plantation area. During the field investigation the weather is bright and clear. The condition of the study area of survey line 2 can be shown in figure 5.6 and 5.7

Result of 2-Dimesional subsurface resistivity investigation for survey line 2 has been shown in figure 5.8. Based on the result shown, the effective depth for survey Line 2 is approximately 30 meters. The inverse resistivity model in survey line 2 has the root-mean-squares error about 17.9% while the chargeability inverse model for line 2 has the root-mean-square error about 13.1%. This can be observed that chargeability inverse model has greater root-mean-square percentage than resistivity inverse model. The range of resistivity that has been observed in survey line 2 is from 0.185 Ωm to 1350 Ωm. The range of chargeability of subsurface material in survey line 2 are from -3.61 msec to 195 msec. The chargeability inverse model of survey line 2 show that there are high percentage of layer with chargeability from -3.61 msec to 53.3 msec.

Based on the result, there are about 4 zone of interpretation can be analysed in the survey line 2. Zone 1 and zone 2 both located about 10 to 20 meters from the Earth surface. Zone 1 and zone 2 shows there are type of rock which exist in the form of lenses. The resistivity of rocks in zone 1 and zone 2 is from 100 Ωm to 250 Ωm. In this region, the layer can be classified as saturated sandstone lenses. Zone 1 and zone 2 shows the weathered zone of harder rock such as schist. Zone 3 located at the centre of the survey line. In that zone, there are a rock body that separated both of sandstone lenses. The rock body has high resistivity as shown in figure 5.8 has range of resistivity between 400 Ωm to 1350 Ωm. Therefore, the body of rock can be interpreted as hard rock body which is schist rock boulder that undergo low weathering process. Lastly, zone 4 located at the bottom of resistivity inverse model which about 20 to 30 meters depth. The range resistivity of this zone is from 0.185 Ωm to 100 Ωm. This zone can be interpreted where there is presence of water accumulation. Thus, this zone can be a groundwater potential based on the resistivity. Overall, there are about 80 % of the survey line covered by metamorphic and weathered metamorphic rock and the remain 20% composed of sedimentary rock with certain potential of groundwater. Zone 2 and Zone 4 can be a good groundwater potential based on their resistivity value and the chargeability value which can be shown in figure 5.8.

Figure 5.6: Centre of Survey line 2
(Source: Dr Hamzah Hussin, 2019)

Figure 5.7: Instrument set up of survey line 2 and the condition of survey line.
(Source: Dr Hamzah Hussin, 2019)

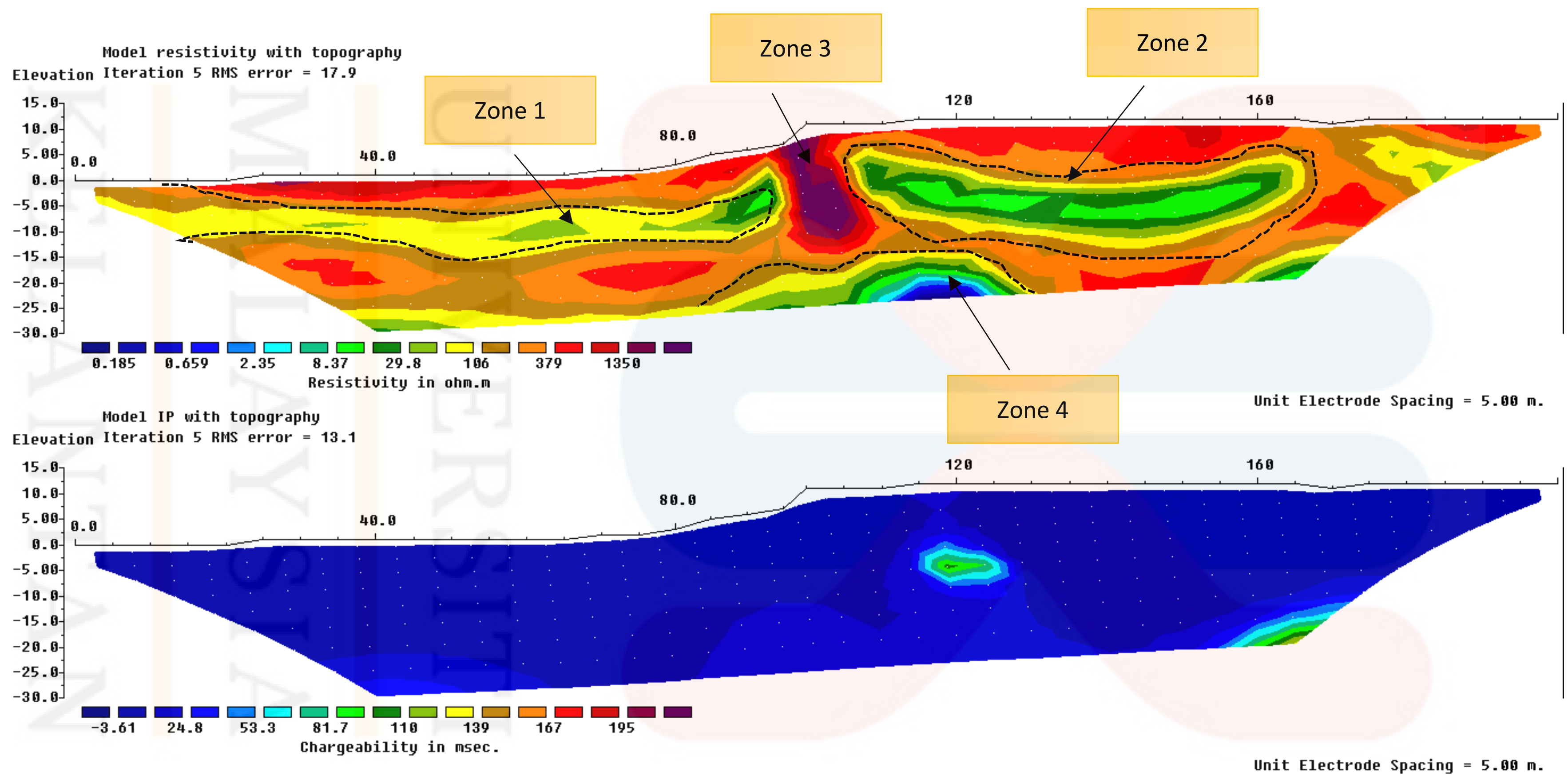


Figure 5.8: Inverse resistivity and chargeability model of survey line 2.

5.5 Survey Line 3

Line 3 used pole-dipole electrode configuration. The length of the survey line approximately to 200 meters. The spacing between each electrode for those 41 electrodes is about 5 meters apart. The coordinate of the line can be referred as table 5.3.

Table 5.3: Coordinates of Survey line 3

Point	Coordinate
Starting Point	Latitude: 3°20'54.45"N Longitude: 101°26'29.48"E
End Point	Latitude: 3°20'47.78"N Longitude: 101°26'29.35"E

The survey line is set up at the upper part of the pond is about 200 meters and the survey line is set up in N-S direction such as in figure 5.1. The pond located at the southern part of survey line 3. The line then extends to north direction toward palm oil plantation area. During the field investigation the weather is bright and clear. The condition of the study area of survey line 3 can be shown in figure 5.9 and 5.10

Result of 2-Dimesional subsurface resistivity investigation for survey line 3 has been shown in figure 5.11. Based on the result shown, the effective depth for survey Line 3 is approximately 45 meters. The inverse resistivity model in survey line 3 has the root-mean-squares error about 29.5% while the chargeability inverse model for line 3 has the root-mean-square error about 5.4%. This can be observed that chargeability inverse model has smaller root-mean-square error percentage than resistivity inverse model. The range of resistivity that has been observed in survey line 3 is from 3.09 Ωm to 2834 Ωm. The range of chargeability of subsurface material in survey line 3 are from 0.00154 msec to 18.8 msec.

Based on the result, there are about 2 zones of interpretation can be analysed in the survey line 3. Zone 1 located at near the surface of study area where the depth I about 0 to 25 meters. Based on figure5.11, the upper part of the subsurface covered by bodies or layer of hard characteristic rock. The resistivity ranges in zone 1 is from 300 Ωm to 2834 Ωm. The hard body rock underlain the softer characteristic rock beneath them. At the surface, some of the rock body tend to undergo weathering and erosion as some of the area consist of accumulation of fluid in their pore. Thus, the high resistivity body of rocks can be interpreted as schist and slate rocks based on their resistivity and chargeability. Zone 2 refer to area that located about depth of 24 to 40 meters. The range of resistivity of this zone is between 3.09 Ωm to 400 Ωm. This indicate the zone are dominant by saturated sandy soil. In zone 2, there are presence of potential location for groundwater accumulation between 40 meters to 100 meters from starting point and also between 120 meters to 170 meters from starting point of the survey line. This also based on their chargeability value which between 1.00 msec to 188 msec. Overall, there are about 50 % of the survey line covered by metamorphic and weathered metamorphic rock and the remain 50% composed of sedimentary rock with certain potential of groundwater.

Figure 5.9: The condition of survey line 3
(Source: Dr Hamzah Hussin, 2019)

Figure 5.10: Instrument set up of survey line 3.
(Source: Dr Hamzah Hussin, 2019)

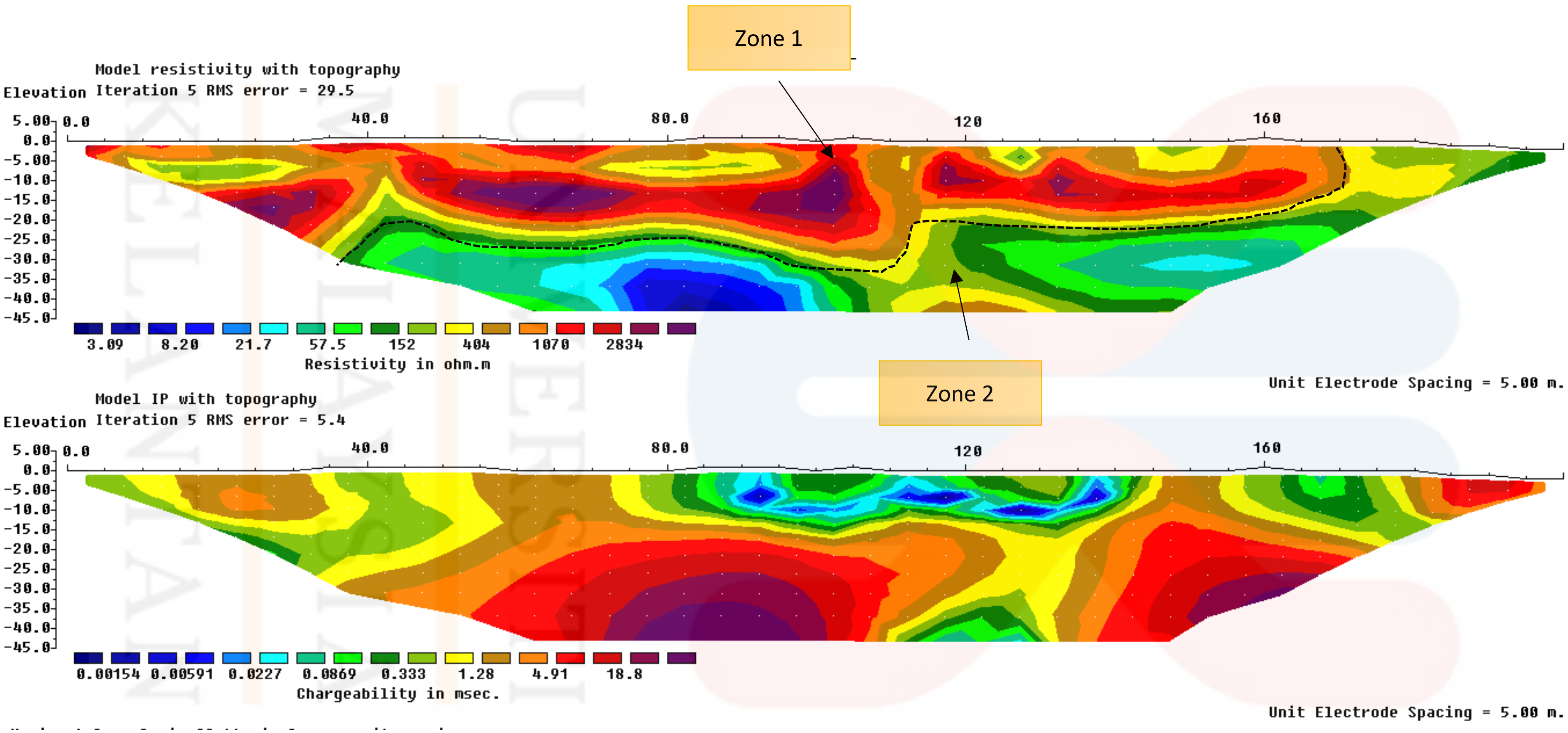


Figure 5.11: Inverse resistivity and chargeability model of survey line 3.

5.6 Survey Line 4

Line 4 used pole-dipole electrode configuration. The length of the survey line approximately to 200 meters. The spacing between each electrode for those 41 electrodes is about 5 meters apart. The coordinate of the line can be referred as table 5.4.

Table 5.4: Coordinates of Survey line 4

Point	Coordinate
Starting Point	Latitude: 3°20'38.79"N Longitude: 101°26'30.07"E
End Point	Latitude: 3°20'39.06"N Longitude: 101°26'23.78"E

The survey line is set up at the southern part of the map is about 200 meters and the survey line is set up in W-E direction such as in figure 5.1. During the field investigation the weather is bright and clear. The condition of the study area of survey line 4 can be shown in figure 5.12 and figure 5.13.

Result of 2-Dimesional subsurface resistivity investigation for survey line 4 has been shown in figure 5.14. Based on the result shown, the effective depth for survey Line 4 is approximately 80.0 meters. The inverse resistivity model in survey line 4 has the root-mean-squares error about 25.4.7% while the chargeability inverse model for line 4 has the root-mean-square error about 12.0%. This can be observed that chargeability inverse model has smaller root-mean-square percentage than resistivity inverse model. The range of resistivity that has been observed in survey line 4 is from 8.72 Ωm to 1672 Ωm. The range of chargeability of subsurface material in survey line 4 are from -34.8 msec to 197 msec. The chargeability inverse model of survey line 1 show the relatively high chargeability anomalies which is around 64.4 msec.

Based on the result, there are about 4 zone of interpretation can be analysed in the survey line 4. Zone 1 located at the depth of 0 to 40 meters from the Earth surface. Zone 1 show a series of rocks that consist of resistivity range from 8.72 Ωm to 372 Ωm. The lithologies for this zone can be classified into sandy-clay soils based on the resistivity range value. In zone 1, there are region at the depth of 20 to 40 meters where the groundwater could be present. This aquifer can be classified into unconfined aquifer as there is no impermeable layer of rock underlay at the top of the surface in zone 1. Zone 2 shows a series of rock that consist of range of resistivity from 18.5 Ωm to 1672 Ωm. Based on the resistivity, there are presence of hard rock at the surface near the centre of survey line which can be classified as schist rocks. Zone 2 also consist of lower resistivity region which located at 20 to 40 meters depth and the distance of the region from the starting point of survey line is about 160 meters to 175 meters. This region show there is an area with slightly high content of fluid in pore as the chargeability of the region is quite high. Thus, ground water could be existing in the region based on the resistivity value. Next, Zone 3 refers to region where there are body of rock that consist of range of resistivity from 300 Ωm to 800 Ωm. Based on the resistivity, the rock in the region can be classified as highly weathered schist. Lastly zone 4 refer to region where the layer of rock located at depth of 20 to 40 meters. The resistivity range for this region is between 40 Ωm to 180 Ωm. According to the resistivity value, the region can refer as sandy clay soil. Based on the 2-Dimesional imaging, line 4 is formed as the harder rock such as schist. Overall, survey line 4 consist of hard rock layer near to centre the surface and there is potential existence of groundwater in zone 1, 2 and 4.

Figure 5.12: Instrument set up of survey line 4.
(Source: Dr Hamzah Hussin, 2019)

Figure 5.13: Condition of survey line 4 area.
(Source: Dr Hamzah Hussin, 2019)

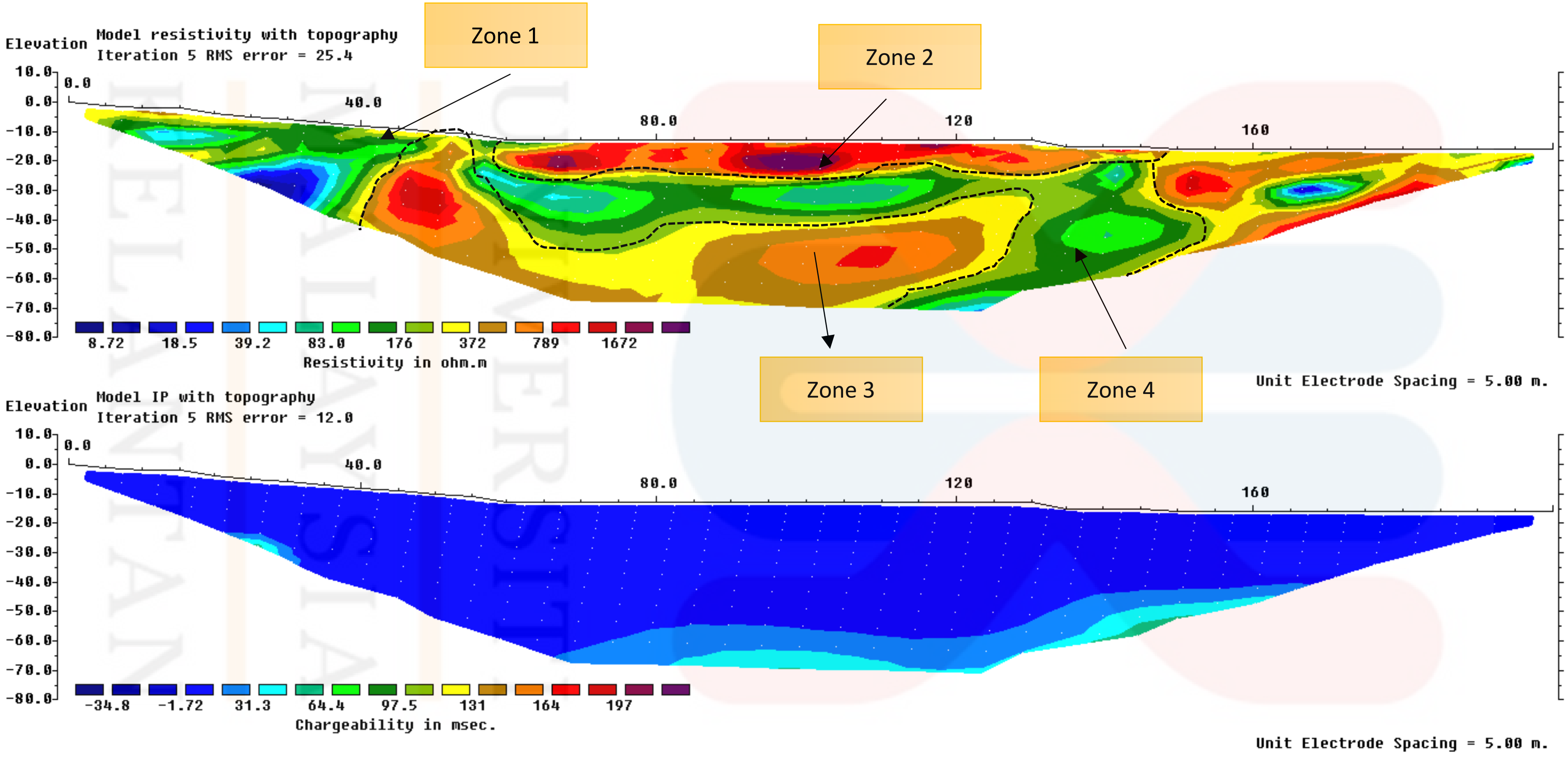


Figure 5.14: Inverse resistivity and chargeability model of survey line 4.

5.7 Survey Line 5

Line 5 used pole-dipole electrode configuration. The length of the survey line approximately to 200 meters. The spacing between each electrode for those 41 electrodes is about 5 meters apart. The coordinate of the line can be referred as table 5.5.

Table 5.5: Coordinates of Survey line 5

Point	Coordinate
Starting Point	Latitude: 3°20'48.25"N Longitude: 101°26'24.98"E
End Point	Latitude: 3°20'41.89"N Longitude: 101°26'24.86"E

The survey line is set up next to a pond is about 200 meters and the survey line is set up in N-S direction such as in figure 5.1. During the field investigation the weather is bright and clear. The condition of the study area of survey line 5 can be shown in figure 5.15 and figure 5.16.

Result of 2-Dimesional subsurface resistivity investigation for survey line 5 has been shown in figure 5.17. Based on the result shown, the effective depth for survey Line 5 is approximately 60.0 meters. The inverse resistivity model in survey line 5 has the root-mean-squares error about 14.2% while the chargeability inverse model for line 5 has the root-mean-square error about 39.7%. This can be observed that chargeability inverse model has greater root-mean-square percentage than resistivity inverse model. The range of resistivity that has been observed in survey line 5 is from 0.837 Ωm to 638 Ωm. The range of chargeability of subsurface material in survey line 5 are from 0.00061 msec to 81.9 msec.

Based on the result, there are about 3 zones of interpretation can be analysed in the survey line 1. Zone 1 located about 0 to 60 meters from the Earth surface. Zone 1 shows the distribution of hard rock which the resistivity value ranges from 250 Ωm to 638 Ωm. Based on the resistivity, the type of rock distributed in this zone can be refer as very highly weathered bedrock which is highly weathered schist. The weathering process contributed to present of some sandy materials which may allow the infiltration of water. Survey line 5 located near to pond and the stream which flow at western part of the study area. This improves the process of water infiltrated toward the sandy area as the fluid filled the pore of the rocks. Zone 2 located at depth of 10.0 to 20 meters where the rock body in that zone has resistivity value vary from 14.4 Ωm to 100 Ωm. According to the resistivity ranges, the region can be referring as saturated sandy clay soil due to high weathering process of the bedrock. The region also can become groundwater potential area as groundwater normally have low resistivity range from 10 Ωm to 100 Ωm due to its character of high conduct electricity. Lastly, zone 3 refer to region that located at the bottom of the survey line which located at depth of 35 to 60 meters. In this zone, the resistivity value ranges from 0.837 Ωm to 100 Ωm as opposite where the zone also has higher chargeability value which from 10.0 msec to 81.9 msec. This zone can be interpreted where there is presence of aquifer as there are water accumulation with 0.837 Ωm to 100 Ωm resistivity value.

Figure 5.15: Instrument set up of survey line 5.
(Source: Dr Hamzah Hussin, 2019)

Figure 5.16: Condition of survey line 5 area.
(Source: Dr Hamzah Hussin, 2019

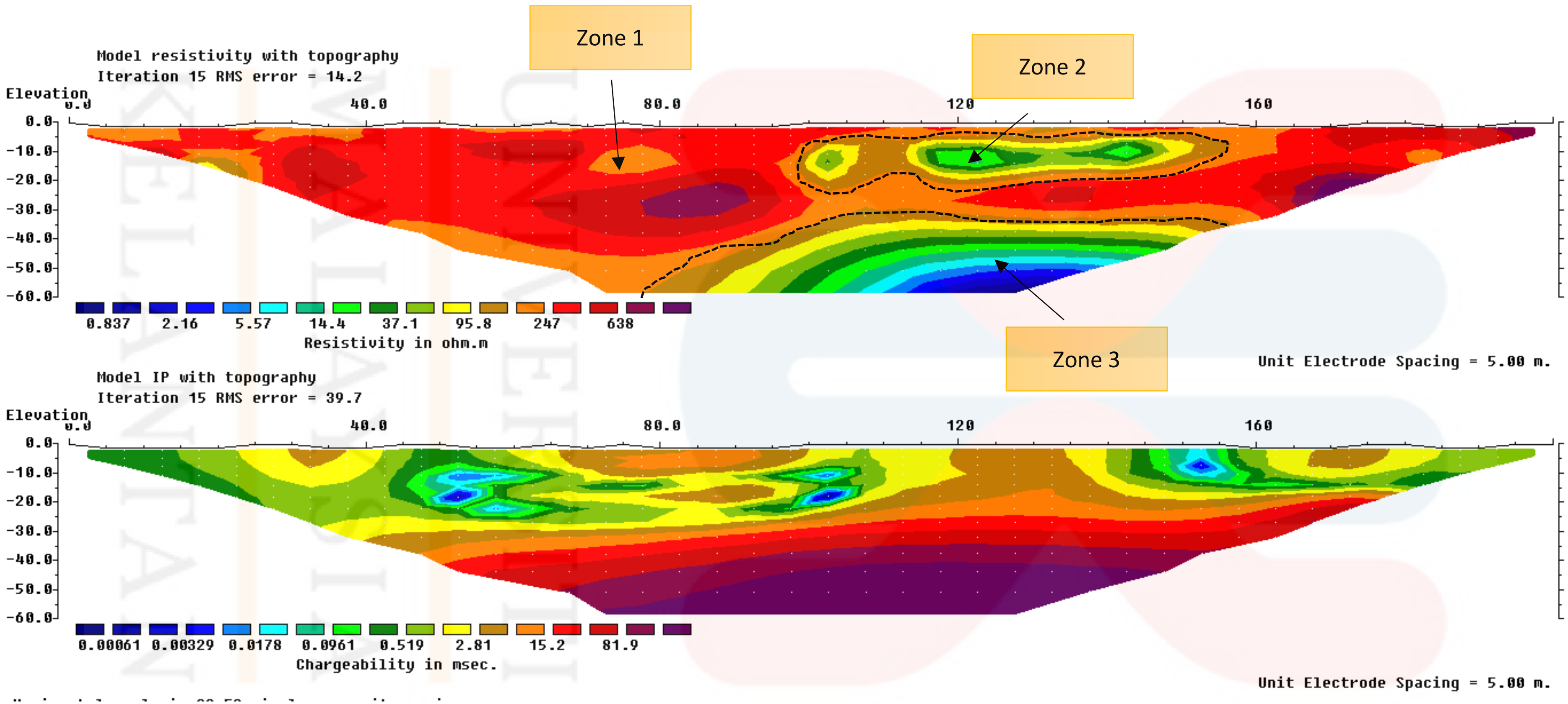


Figure 5.17: Inverse resistivity and chargeability model of survey line 5.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

This chapter will conclude all the results done from the general geology mapping and electrical resistivity survey. From the general geology mapping, it enables to identify the lithologies present in the study area. In the study area, rocks such as granite, phyllite, slate, shale, sandstone and siltstone are found. Each of these rock unit exhibits in different conditions. The metasedimentary rock such as shale, slate and phyllite formed due to metamorphism process under certain pressure and temperature where the sedimentary rock altered their characteristic in order to achieve the equilibrium based on different degree of compaction process. The granite unit in the study area refer to acid intrusion that intrude near the study area. Based on general geological mapping, an updated geological map of Sungai Subong area is produced. This includes the updated in certain aspect such as lithology, structure, and the stratigraphic column.

In chapter 4, the stratigraphic column is made based on correlation of previous study and research. Metasedimentary rock in the study area such as shale, slate and phyllite are listed as oldest rock in Gua Musang formation which specifically formed during Permian period. During Triassic period, the clastic sedimentary rock transported and undergo sedimentation in the basin. Some of clastic sedimentary rock in the study area also formed interbedded layers. During Tertiary period, there are intrusion of acidic intrusive rock near the study area which contributed the distribution of acidic igneous rock. During Quaternary to recent period, process of weathering, erosion and sedimentation occur continuously. This created the alluvium unit in the study area especially in area of Subong and Galas River.

Based on the result obtained from electrical resistivity survey, it indicated that the study area consists of Devonian period rocks such as shist, slate and sandstone. Based on inverse resistivity and chargeability model section, the study area dominantly composed of hard rock such as schist and slate. Based on all survey lines that has been investigated, some potential region of groundwater accumulation can be detect in all of the survey line. The groundwater potential may different in the characteristic of groundwater as certain aquifer may have high salinity compared to another aquifer. The aquifer from the subsurface investigation also vary with depth as some are classified as shallow aquifer and some as deeper aquifer. Survey Line 1 consist of deeper position of potential aquifer. The aquifer overlain by body of hard rock. In survey line 2, the groundwater potential located in zone 4. The aquifer tends to have high composition of clay unit and there also saline water content in the aquifer. Next, survey line 3 is considered as deep groundwater potential and the region also have high composition of clay units. Survey line 4 consist of 3 potential ground water region which in zone 1, 2 and 4. The region can be refer as shallow groundwater potential where the groundwater show varies in resistivity value from 8.72 Ωm to 176 Ωm. Lastly, survey line 5 shows the potential of groundwater located at zone 2 and 3. Aquifer in zone 2 is shallow while aquifer in zone 3 are bit deeper. The aquifer in zone 3 of survey line 5 seem to have intrusion of a bit saline water.

6.2 Recommendation

In future, this thesis can be used as guideline for other student or researcher who would like to conduct a study or project that related to general geological mapping and groundwater exploration in both of the study area, Sungai Subong and Bestari Jaya, Kuala Selangor, Selangor. For mapping, the updated geological map can be used as guideline. However, further study and site investigation need to be performed especially for area that are not been visits in previous study. Site investigation is important as the geological characteristic of specific area is different compared to information from literature review.

For groundwater exploration, the groundwater potential has been identified in all survey lines of this study by using pole-dipole array of Electrical Resistivity Imaging (ERI). However, the existence of groundwater may change based on the availability of water during the exploration process. Further detailed subsurface investigation can be operate in future by using different type of geophysical method. Methods that can be listed for this exploration including Vertical Sounding, horizontal profiling survey and also hydrogeological field investigation. With different result from different method such as mentioned above, this will improve the accuracy of the finding.

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