GEOLOGY AND DELINEATION OF GROUNDWATER POTENTIAL ZONE USING ELECTRICAL RESISTIVITY METHOD IN KAMPUNG PULAU LAYAK, DABONG

by

NUR SYAMIMI BINTI JUMARI

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

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2019

APPROVAL

“I hereby declare that I/ we have read this thesis and in ouropinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience) with Honors”

Signature : ______________________________

Name of Supervisor : Dr. MOHAMMAD MUQTADA ALI KHAN

Date : 17 JANUARY 2019

DECLARATION

I declare that this thesis entitled "GEOLOGY AND DELINEATION OF GROUNDWATER POTENTIAL ZONE USING ELECTRICAL RESISTIVITY METHOD IN KAMPUNG PULAU LAYAK, DABONG" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ____________________________

Name : NUR SYAMIMI BINTI JUMARI

Date : 17 JANUARY 2019

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TABLE OF CONTENTS

NO.	LIST OF TABLE	PAGE
1.1	Total population in Kelantan in year 2010 (%)	8
1.2	Total Population of Kuala Krai in Year 2010 (%)	9
1.3	Categorization of Rainfall Intensity	10
3.1	Materials and Equipment required	30
3.2	Chargeability of some common rocks and soil materials	34
3.3	Resistivity of some common rocks and soil materials	35
4.1	Coordinates of observation and sampling station	40
4.2	Class of contour elevation	44
4.3	Weathering Grade Classification	54
4.4	Stratigraphic column of study area	57
4.5	Composition mineral in Phyllite	59
4.7	Composition of mineral in Andesite	63
5.1	The coordinate of three electrodes used in survey line 1	73
5.2	The coordinate of three electrodes used in survey line 2	76
5.3	The coordinate of three electrodes used in survey line 3	80

NO.	LIST OF FIGURE	PAGE
1.1	Base Map view from Kelantan	4
1.2	Base Map of Study Area	5
1.3	Main road	7
1.4	Unpaved road	7
1.5	T- junction from Jeli	7
1.6	T- junction from Dabong.	7
1.7	Demographic chart of Kelantan in Year 2010	9
1.8	Hytograph of Dabong per month	11
2.1	Geology Map of Kelantan	17
2.2	Common arrays used in resistivity surveys**.**	25
2.3	Example of Resistivity Imaging	26
27	Resistivity and conductivity distribution	26
3.1	Flow chart of the research.	29
3.2	Cutting and sectioning process	37
3.3	Polishing process	37
3.4	ABEM Terrameter LS Toolbox software	38
4.1	Traverse and outcrop observation map of study	41
4.2	Rubber Plantation	42
4.3	Oil Palm Plantation	42
4.4	Land use in study area	43
4.5	2D Topography map of study area	46
4.6	Types of drainage pattern	47
4.7	Galas River as the main river.	48
4.8	Drainage pattern map	49
4.9	Biological and Chemical (Oxidation) weathering on sandstone.	51
4.10	Physical weathering (Exfoliation) on schist.	52
4.11	Physical weathering (Exfoliation) on schist.	52
4.12	Biological weathering on sandstone.	53
4.13	Weathered rock turn into soil (Grade IV).	53
4.14	Geological map	56

GEOLOGY AND DELINEATION OF GROUNDWATER POTENTIAL ZONE USING ELECTRICAL RESISTIVITY METHOD IN KAMPUNG PULAU LAYAK

ABSTRACT

Abstract: The present study conducted in Kampung Pulau Layak, Dabong. This research focused on produce geological map of the study area on 1:25,000 scale and to delineate the existence of groundwater potential zone. The community in this area is depends on the surface water and in future, there may be water shortage. Geological mapping conducted through many fieldwork and sampling. The lithologies were updated in geological map which shows the distribution of phyllite, schist and shale. For electrical resistivity, there are three locations selected for electrical resistivity survey. The first location used pole-dipole electrode configuration while the other two lines use Schlumberger electrode configuration. The resistivity data of three lines were collected by using ABEM Terrameter LS1 and later analysed by using RES2DINV software. The results showed that there is fractured zone in survey line 1 and survey line 2 showed a layer assumed as fracture aquifer while line 3, water in weathered zone. The method shows reliability for identifying groundwater potential zone in the study area. The findings of this research will be useful in future for practitioners for references.

Keywords: Dabong, electrical resistivity survey, potential groundwater, geological map

GEOLOGI DAN MENGENAL PASTI ZON POTENSI AIR BAWAH TANAH MENGGUNAKAN KAEDAH KERINTANGAN ELEKTRIK DI KAMPUNG PULAU LAYAK

ABSTRAK

Abstrak: Kajian yang dijalankan di Kampung Pulau Layak, Dabong. Kajian ini memberi tumpuan kepada menghasilkan peta geologi kawasan kajian pada skala 1: 25,000 dan untuk menggambarkan kewujudan zon potensi air bawah tanah. Masyarakat di kawasan ini bergantung kepada air permukaan dan pada masa akan datang, mungkin ada kekurangan air. Pemetaan geologi yang dijalankan melalui banyak kerja lapangan dan pensampelan. Litiologi telah dikemaskini dalam peta geologi yang menunjukkan pengedaran phyllite, schist dan syal. Untuk ketahanan elektrik, terdapat tiga lokasi yang dipilih untuk tinjauan kerintangan elektrik. Lokasi pertama menggunakan konfigurasi elektrod tiang polar sementara dua baris lain menggunakan konfigurasi elektrod Schlumberger. Data resistiviti tiga garisan dikumpulkan dengan menggunakan ABEM Terrameter LS1 dan kemudian dianalisis dengan menggunakan perisian RES2DINV. Hasil kajian menunjukkan bahawa terdapat zon patah dalam garis kaji selidik 1 dan garis kaji selidik 2 menunjukkan lapisan yang dianggap sebagai akuifer pecah manakala garis 3, air dalam zon cuaca. Kaedah ini menunjukkan kebolehpercayaan untuk mengenal pasti zon potensi air bawah tanah di kawasan kajian. Penemuan kajian ini akan berguna pada masa akan datang untuk pengamal rujukan.

Kata kunci: Dabong, kajian kerintangan elektrik, potensi air bawah tanah, peta geologi

CHAPTER 1

INTRODUCTION

1.1 General Background

According to Monroe, 2007, water that founds in cracks of rocks, sediment and soil under the Earth’s surface is called groundwater. It is stored in and moves slowly through geologic formations of soil, sand, and rocks called aquifers that connects with rivers, streams, lakes, and wetlands and it also feeds trees and vegetation. The main source of groundwater is the ocean but other sources of it can also be water infiltrating from streams, lakes, swamps, artificial recharge ponds and water treatment system. Geophysical investigations are used to figure out to what is directly below the surface, other different investigation can be stretch out to the depth of 10's of meters or more. In term of environmental, geophysics is the study and investigation of subsurface site characterization of the geology, geological structure, groundwater, contamination, and human artifacts of the Earth's subsurface by using non-obtrusive technologies (Environmental and Engineering Geophysical Society, 2018).

Keeping the importance of groundwater, the present research is mainly focusing on geology and identifying the groundwater potential zones using electrical resistivity imaging method in parts of Dabong, Kuala Krai, Kelantan. The electrical resistivity imaging is mapping the contrasts in the electrical properties of geologic materials which can show variations in lithology, water content, pore-water chemistry, and the presence of buried debris. This involves transmitting an electric current into the ground between two terminals and estimating the voltage between two other electrodes. This method is used because it is easy to use and most suitable technique for identifying aquifers in the complex geological areas.

Groundwater is an important sources for agriculture, industry and domestic use. Nowadays, the needs of population in the world and industrial is increasing, therefore, the demand for water, especially groundwater will grow. New groundwater sources will need to be located and must be preserve from pollution and overuse as it is very useful and significant for future generation. In Kelantan, groundwater becomes one of the important resources for various uses. Groundwater usage is mostly from the well use in rural place. According to Idrus A.S.et al., 2014, the total percentage of population that used public water supply was about 65% which include household that use 2 sources of water supply from public utilities and alternative source of water supply such as groundwater and gravity feed system while the other 35% completely depends on the alternative source of water supply. Moreover, the pressure of the water supply by the government or pipe water is not enough to reach the houses of the villagers. This is one of the reasons why the groundwater potential needs to explore for future use.

1.2 Study Area

Kelantan is one of the state in Malaysia. The capital city of Kelantan is Kota Bharu and it is located in the north-east part of Peninsular Malaysia. The total area of Kelantan is 15,099 km^2 and consists of ten districts which are Bachok, Gua Musang, Jeli, Kota

Bharu, Kuala Krai, Machang, Pasir Mas, Pasir Puteh, Tanah Merah and Tumpat. The coordinate for Kuala Krai district is N 5° 31' 50.93”, E 102°12'6.66" with the elevation of 35.45 m above the mean sea level. Kuala Krai District has an area of 2329 km^2.

1.2.1 Location

Generally, lithology of Kelantan is dominant with granite and limestone and minor in argillite unit. However, these rocks are not evenly distributed throughout the Kelantan. The study area for this research is conducted in Dabong. It is located in the district of Kuala Krai, Kelantan. Dabong is a small town in Kuala Krai District, Kelantan, Malaysia. It has a railway station and famous with Gua Ikan or Fish Cave which situated nearby on the Galas River. In the figure 1, the east side shown it is totally covered with forest and rubber tree but there is also railway and main street. While on the west side shown that there is a few of villages and river. The study area is 25 km^2 where the latitude and longitude are mark at four different points which are N5°21'17.477" E102°0'6.99", N5°21'17.521" E102°2'50.234", N5°18'36.492" E102°2'50.555", and N5°18'37.017" E102°0'6.177" as shown in Figure 1.1 and 1.2. In this study area, the highest elevation point is 320 m and the lowest elevation in this area is 40 m.

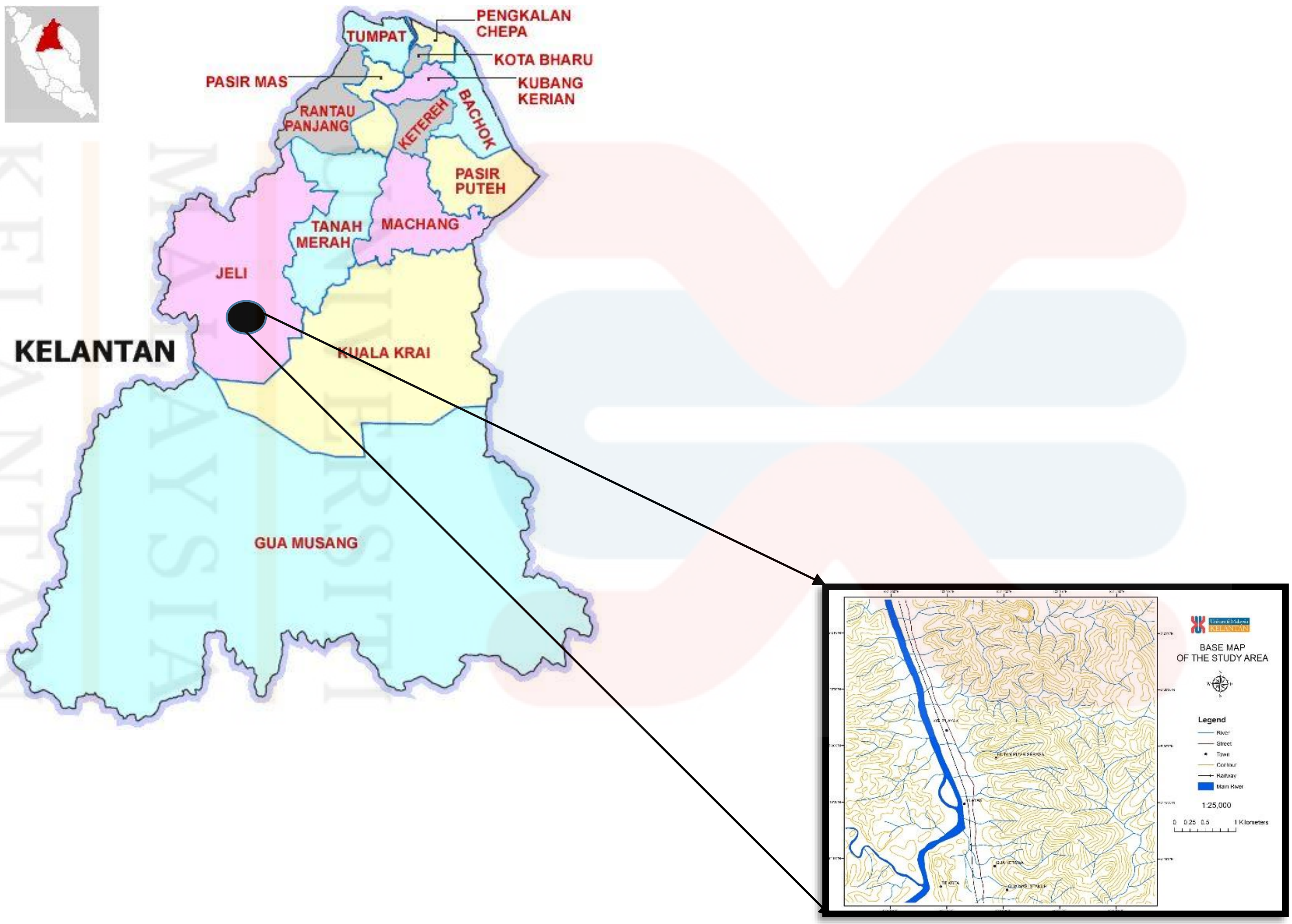


Figure 1.1: Base map view from Kelantan

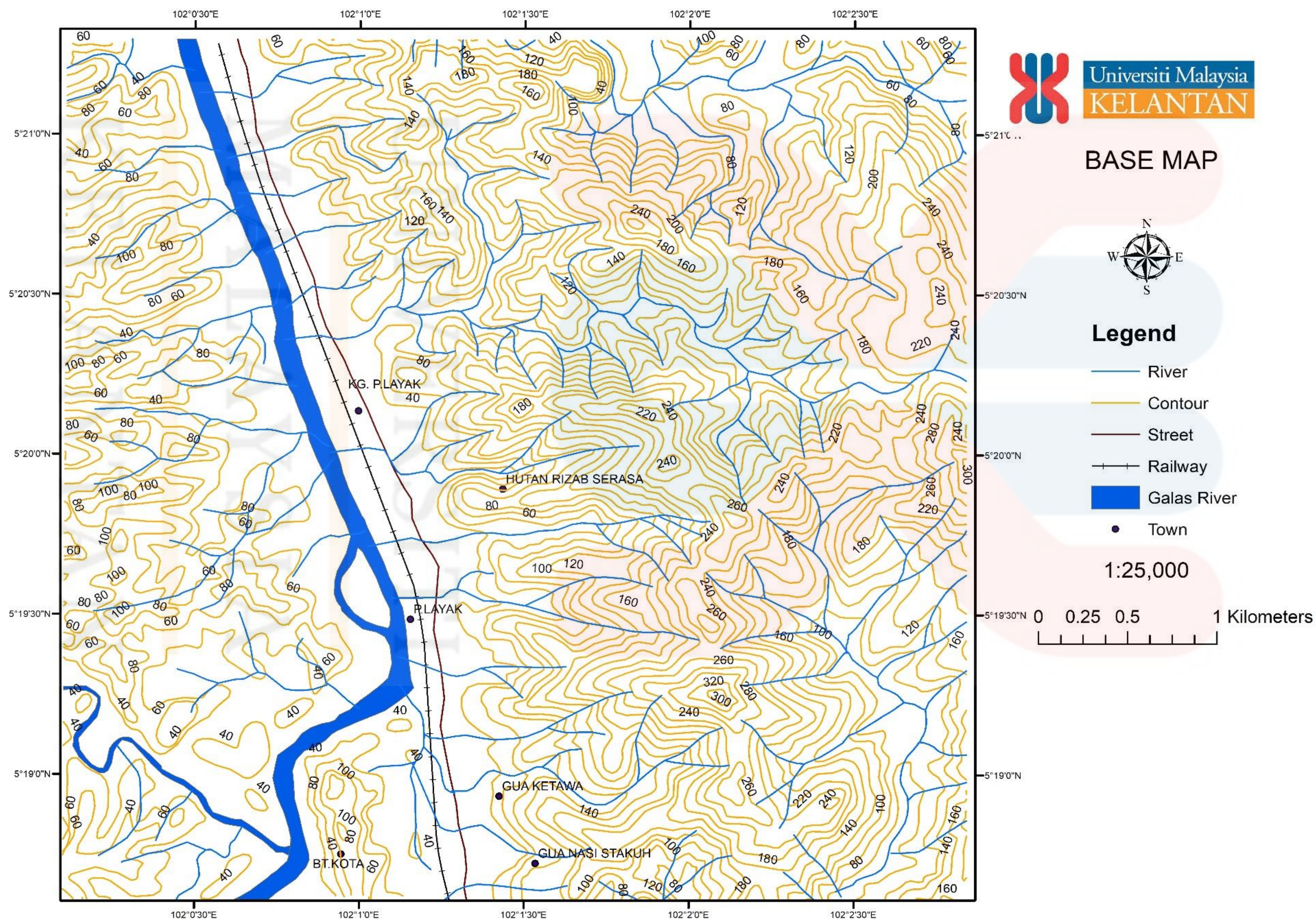


Figure 1.2: Base Map of Study Area

1.2.2 Road Connection and Accessibility

Dabong has a road called Jalan Dabong–Gua Musang or mostly known as Kelantan state route D29. This road is a major road in Kelantan, Malaysia. The road connects Dabong in the north to Gua Musang in the south. It is a longest state road in Kelantan. It also connected with several main roads such as from Jeli, Kuala Krai and Gua Musang.There are many types of transportations mode that can accessible the road in Dabong including public transport. For the rocky and unpaved road in rubber tree plantation area, it usually accessed by Hilux. Nevertheless, the area can still be access by using car and motorcycle. The unpaved road mostly found in the small village.

In the study area, the accessibility of Kampung Pulau Layak can be found along the road as shown in Figure 1.3. This road is the only main paved road for the villagers. The journey to the Jalan Dabong-Gua Musang must go through Dabong where there is a T-junction as shown in Figure 1.4 and Figure 1.3, then turn left if from Jeli and turn right if from Dabong. The unpaved road in Figure 1.4 are usually found in the rubber plantation area which can accessed by using motorcycle or Hilux.

Figure 1.3: Main road

Figure 1.4: Unpaved road

Figure 1.5: T-junction from Jeli.

Figure 1.6: T- junction from Dabon

1.2.3 Demography

According to research from the State Department of Statistics showed that in Kelantan, the total number of people is approximated at 1,539,601 in 2010 and Table 1.1 belows shows Kuala Krai the the total of people distribution is 109,461. In Table 1.2, it can be observed that the total population in Dabong increased from 11,131 to 13,173. The slow rate of growth is due to slow pace of development in the area. A pie chart of the population in Dabong based on ethnic in 2010 is shown in Figure 1.7.

Table 1.1: Total population in Kelantan in year 2010 (%) (Source: Department of Statistic Malaysia)

State and District	Population in Year 2010
Kelantan	1,539,601
Kota Bharu	491,237
Machang	93,087
Pasir Mas	189,292
Pasir Puteh	117,383
Tanah Merah	121,319
Tumpat	153,976
Bachok	133,152
Gua Musang	90,057
Kuala Krai	**109,461**
Jeli	40,637

Table 1.2: Total Population of Kuala Krai in Year 2010 (%) (Source: Department of Statistic Malaysia)

District and Mukim	**Population in Year 2010**
Kuala Krai	109,461
Dabong	**13,173**
Olak Jeram	27,486
Batu mengkebang	63,575

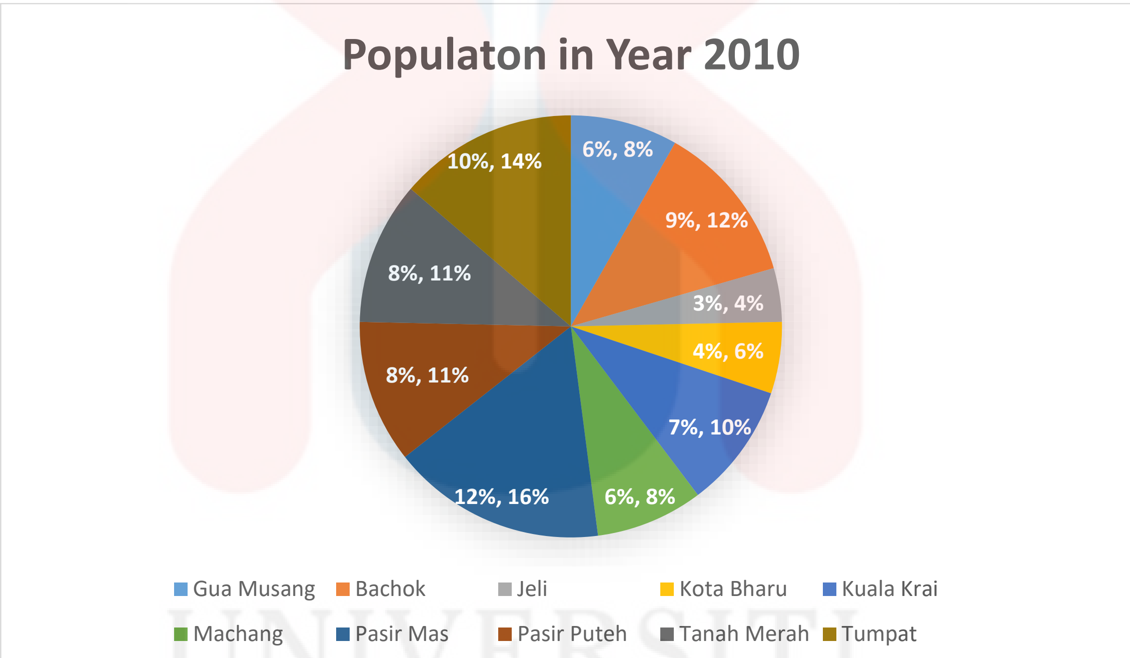


Figure 1.7: Demographic chart of Kelantan in Year 2010 (%) (Source: Department of Statistic Malaysia)

1.2.4 Land Use

According to Rancangan Struktur Kelantan, 2012, in Kelantan, type of land use can dived into residential area, industry, agriculture, forest and others. For Kuala Krai, the land use type is mainly a forest, followed by agriculture and residential area. However, in Dabong, the land is mainly use for a rubber tree plantation, oil palm plantation and then forest.

1.2.5 Social Economic

In Kelantan, it has a chiefly agrarian economy dominated by rice, rubber and tobacco. Another importance economic activity is fishing along its 96-kilometre coastline. Cottage industries which employ traditional skills in handicraft production such as batik, woodcarving and songket weaving are also evident. As mentioned, Dabong main plantation is rubber tree and it is run by the local cultivator. This area also has stall and restaurant so that people can find what food they want rather than cook by themselves. In the study area, mostly still covered by forest. This area still not develop well due to the lack of basic thing such as clinic and public administration.

1.2.6 Rainfall

The climate in Dabong is tropical. It is a city with notable rainfall. Figure 1.8 below showed hydrograph in Dabong per month. According to research in Department of Irrigation and Drainage Malaysia, 2018, the categorization rainfall intensity in Table 1.3 in Dabong per month. The least amount of rainfall occurs in February and the average in this month is 87 mm. Most precipitation falls in December, with an average of 348 mm.

Table 1.3: Categorization of Rainfall Intensity. (Source: Department of Irrigation and Drainage Malaysia)

Category of Intensity	Light Rain	Moderately Rain	Heavy Rain	Very Heavy Rain
Rainfall (mm)	1-10	11-30	31-60	> 60

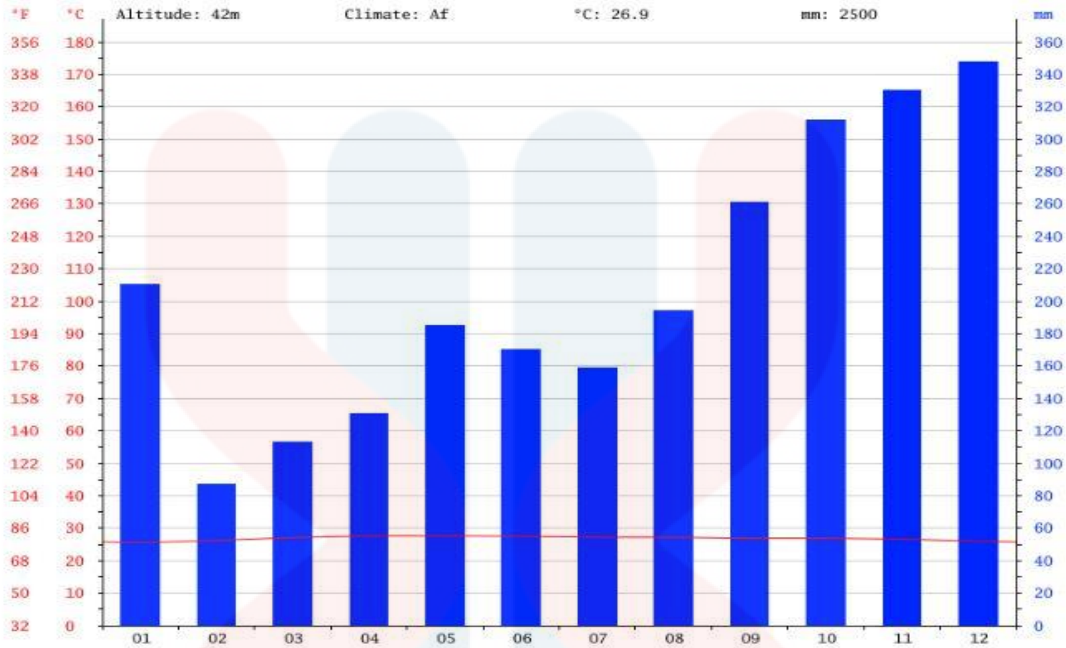


Figure 1.8: Hydrograph of Dabong per month. (Source: Climata-data-org)

1.3 Problem Statement

According to National Economic Planning Unit, 2006, there are many problems in Kelantan's water industry which show low water supply coverage, the highest Non-Revenue Water (NRW) rate in the country, low production capacity and a low quantity of water supply. The study area is a place where the community totally depends on surface water for daily use. It is afraid that the surface water will be not enough for future community use. That why, it is necessary to find new groundwater sources. Another reason is because groundwater is simple and cheap to treat to fine drinking water and has stable quality and quantity all year. The discovery of the new source of groundwater also can alleviate the burden of water supply problem in Kelantan. In the future, the groundwater may use as one of the main water supply to the state. Due to this reason, the investigation to be carried out to determine groundwater potential zones in the area.

1.4 Objectives

1. To produce geological map of the study area to 1:25,000 scale.
2. To identify the existence of groundwater potential zone by using electrical resistivity imaging method.

1.5 Scope of Study

The scope of study for this research were focused on identifying the potential zones of groundwater in Kelantan, specifically in Kampun Pulau Layak in Dabong. The research was be done by using the electrical resistivity method. Electrical resistivity imaging method is one of the geophysical methods that has been used widely in the hydrological investigation. The criteria for establishing the line was choosing based on the advantages of each configuration array. The criteria of choosing the area that were in identifying groundwater were structural geology, geomorphology and lithology. The limitation for using this method is it will only use ABEM Terrameter SAS 4000 and no other instrument involves. For geological mapping, the study of geomorphology and type of rock were carried out but it was only covers the part of Kuala Balah because of the limitation of the time.

1.6 Significance of Study

This research study will give a lot of advantages to people in Kelantan especially the community of Kampung Pulau Layak. It can benefits by fulfill the requirement of the community by providing clean water to them. Furthermore, for the government, it will help to resolve the water supply problem occurs in Kelantan. Next, groundwater is a limited availability, which means decentralized infrastructure and cause short transmission costs. The updated geological map which can be used by other researcher and organization for future plan and further investigation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter basically explains about the data that collected from past research regarding the general geology and the specifications.

2.2 Regional Geology and Tectonic Setting

Based on mineralization, peninsular Malaysia divided into a Central, Eastern and Western Belts (Scrivenor, 1928). The boundary between the Central and Western Belts is Granite while the western foothills of the elongate granitic plutons of Terengganu, Pahang, and Johor become the boundary to Central and Eastern Belts. According to Hutchison, 1975, the line named Bentong-Raub line is the boundary of the Central and Western Belts. This boundary was drawn by the occurring of serpentinite bodies in the rock formations that form the eastern foothills of the Main Range Granite. Another interpretation state that the serpentinite occurrences in Peninsular Malaysia define two linear zones which is one on the eastern side and the other one is on the western side of the Central Belt (Tan B. K., 1981a). This show that the three belt still has no clear decision on how to delineate them although the three belts are apparent.

Kelantan state is one of the states in Peninsular Malaysia. According to MacDonald, 1967, the central zone in Kelantan consists of sedimentary and metasedimentary rocks which encircled granites of the Main Range and Boundary Range on west and east respectively. Within the central zone, there are windows of granitic intrusives, the more prominent of these being the UIu Lalat (Senting) batholith, the Stong Igneous Complex and the Kemahang pluton. These belts of granite and country rocks have a north-south trend. The belts continue northward into south Thailand for west and central Kelantan, while in the east the Boundary Range granite is overlain by the coastal alluvial flat of Sungai Kelantan. According to C. S. Hutchison, 2009, Dabong area is a part of the Stong Migmatite Complex. It was formed by three units of rocks which are Berangkat Tonalite, Noring Granite and Kenerong Leucogranite (Singh et al., 1984).

2.3 Stratigraphy

Dabong is included in the injection of the migmatite from Stong Migmatite Complex. It consists of granitoids which has three plutonic components. The components area Berangkat Tonalite, Kenerong Leucogranite and pink Noring Granite. The metamorphic rocks of the migmatite complexes are of high amphibolites facies. The data are often conflicting and their tectonic significance often assigned with insufficient evidence (Searle and Morley, 2011). The migmatite complex forms mountainous country recline about 8 km west of the railway towns of Kemubu and Dabong. The migmatite of the Stong Complex and related Central Belt granitoids lie east of the Bentong-Raub Line.

2.4 Structural Geology

There are three plutonic components of granitoids in Stong Migmatite Complex (Singh et al., 1984). The earliest two phases are Berangkat Tonalite and Kenerong Leucogranite. The third phase is the distinctive pink Noring Granite that undeformed. According to Cobbing et al., 1992, it is believed Berangkat Tonalite is a coarse grey K-feldspar megacrystic biotite-hornblende tonalite that locally is highly deformed and the pink Noring Granite is an undeformed megacrystic biotite-hornblende granite while Noring Granite also intrudes the earlier Kenerong Leucogranite. The Stong is an injection migmatite of great complexity which form a granitoid-metamorphic rock relationship. The three main type of migmatite are agmatite, venite and nebulite. Agmatite is an angular enclaves of darker gneiss and schist that surrounded by more homogenous granitic materials. Venite is a discrete layer and patches of granitic material occur in schist while nebulite is a more complete mixing of granitic material and schist. It is more homogenous but consists of schlieren (Hutchison, 2009).

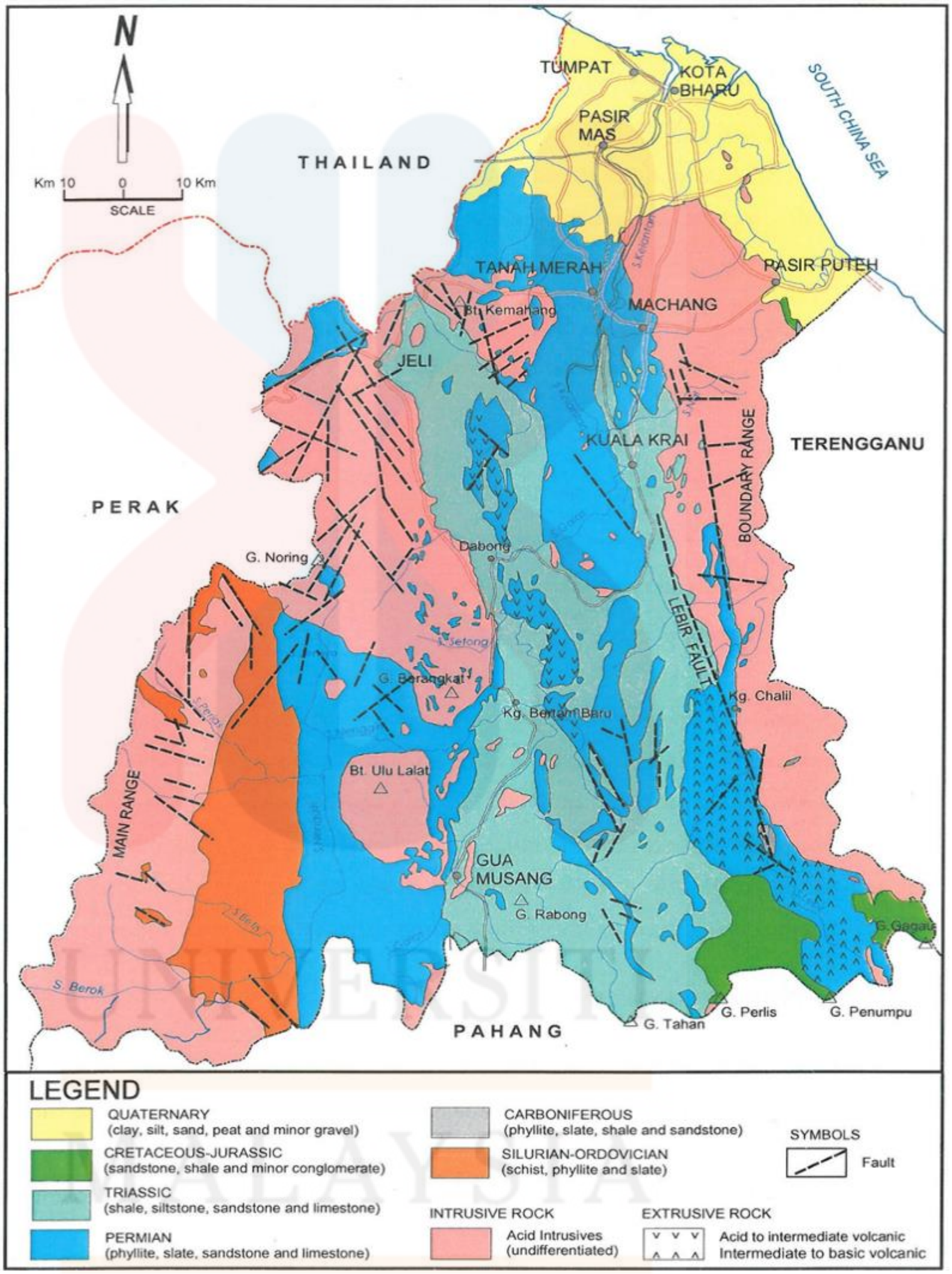


Figure 2.1**:** Geology Map of Kelantan. (Source: Department of Minerals and Geoscience Malaysia, 2003).

2.5 Historical Geology

The study area of Dabong is included in Stong Migmatite Complex. The associated plutonic rocks are both Late Triassic and Late Cretaceous–Palaeocene. There are three plutonic components (Singh et al., 1984). The earliest two phases are Berangkat Tonalite and Kenerong Leucogranite. Both are in part highly deformed in a manner similar to that of the marginal country rocks. Next, the third phase ofthe distinctive pink Noring Granite is undeformed. The Berangkat Tonalite, at the southern end, is a megacrystic biotite-hornblende tonalite that locally is highly deformed. The tonalite is cut by the Kenerong leuco-microgranite. Moreover, the oldest rocks in the state are of Lower Paleozoic age mainly metapelites with lesser volcanic fragmentals and minor arenaceous and calcareous intercalations (MacDonald, 1967). On the eastern side, predominantly Permian volcanic-sedimentary rocks occur extensively and it overlying uncomfortably, the Lower Paleozoic sequence in southwest Kelantan. The rock that dominates central north Kelantan is Taku Schist with definite pre-Triassic age. Triassic rocks are confined and mainly argillo-arenaceous sediments with intercalated volcanics and limestone as shown in Figure 2.1. The Jurassic-Cretaceous continental rocks is the youngest rock of Kelantan which overlie the Boundary Range Granite and Triassic sediments in the Gunung Gagau area and to the west in the Gunung Perlis and Gunung Pemumpu area. This sequence consists of conglomerate overlain by sandstone with sporadic volcanic intercalations (Rishworth, 1974).

2.6 Hydrogeology

According to Fitts, 2013, there are many different kind of issues occurred that groundwater might respond to nowadays. One of the issues is water supply where its wells for drinking water, irrigation and industrial purposes are drilled after assembling data on the hydrogeology on the region. Test wells are drilled and hydraulic testing is done to estimate the long-terms discharge capacity. The water chemistry is checked to make sure that the water is suited for its intended purposes. Next is water resource management. Management of groundwater resources area is important area of practice since groundwater reservoirs cross property lines and political boundaries. Particularly in areas with large regional aquifers, difficult decisions must be determine about who allowed to pump water, where wells located and others. Surface water projects including dams, diversion of irrigation and sewer systems have an impact on groundwater levels and quality, so it should be carefully considered.

Since its establishment in 1903, the Geological Survey in Peninsular Malaysia has been involved in groundwater investigations. According to Chong, 1986, in 1975, a hydrogeological map of the Peninsular Malaysia on the scale of 1:500,000 was published. The hydrogeological map was a compilation of four main aspects which are lithology, structural geology, topography, and available borehole and well data. The hydrogeological map has become useful especially for students and hydrogeologists in the understanding of the general features and characteristics of the groundwater occurrence in Peninsular Malaysia. During the Third Malaysia Plan (1976-1980) the Department in cooperate with the German Hydrogeological Mission successfully completed the project in the east coast states of Kelantan, Terengganu, and Pahang. This project include hydrogeological exploration and geophysical studies.

The investigation of hydrological was done in Northern Kelantan to estimate the groundwater resource or water supply that is needed. The result shown shallow aquifer is the most suitable for development as it has good quality water, gets recharged readily and wells are shallow making a low cost for construction and pumping. The third aquifer is also suitable because it can be used for development at selected localities as it has water of acceptable salinity (10-65 mg/l). Both aquifer will be proposed to utilize to provide water supplies and requirement in the (Tan F. C., 1986).

2.7 Research Specification

2.7.1 Electrical Resistivity Imaging

In 1920, Schlumberger brother had work to develop the resistivity method. It is generally used for quantitative interpretation and conventional sounding in the next 60 years. For the technique, the point in the middle of the electrode array remain fixed, yet the spacing between the two terminals is increased to gain more data on the deeper sections of the subsurface (Barker, 1981). Electrical resistivity imaging (ERI) is a multi-electrode profiling method that records hundreds of subsurface data points. According to Barker, 2002, electrical imaging is a surveying technique for an area of complex geology where the use of resistivity sounding and other techniques are unsuitable for providing detailed subsurface information in a limited area. Moreover, the electrical resistivity imaging technique is a geophysical technique that often used for determine the earth subsurface condition such as the subsurface thickness, rock structure, groundwater flow and aquifer, groundwater salinity and mineral exploration (Reynolds 1997). The method will produced a colored two-dimensional cross section of the earth. The most well-known geophysical method is resistivity method as far as groundwater explorations is concerned. However the method as such has not developed much in the last two decades (Barker, 1981). Some others of examples are such as for bedrock fracture zones, fault zones, delineating tunnels and cavernous zones, characterizing landfills, contamination plumes, and archeological investigations.

According to Ibrahim et al, 2003, electrical resistivity surveys are normally carried out with multi-electrode system. The surveys use a number of electrodes from 25 to 100 deployed in a straight line with constant spacing, connected to a multicore cable. In traditional way of resistivity surveys is used four equidistant electrodes in a standard configuration. A man-made source of electrical current is uses by the direct current resistivity method where it is injected into the earth through grounded electrodes. The second pair of electrodes will measure resulting potential field along the ground. The voltage is converted into a resistivity value representing average ground resistivity between the electrodes. Electrical earthing and soil corrosivity testing is part of the typical applications. The electrode pairs that transmitting and receiving are referred to as dipoles. By varying the unit length of the dipoles as well as the distance between them, the horizontal and vertical distribution of electrical properties can be recorded. This technique can produce a 2D profile of subsurface condition base on the resistivity value of subsurface materials (Okpoli, 2013). The resistivity profile only cannot give a factual data of groundwater flow because the profile is in two dimensional only. A borehole must construct at the potential zone of groundwater, if needed to get the groundwater flow and velocity. The ERI method has its own limitation that needed to be taken. One of them is the proposed line must be situated to avoid large underground metallic pipes electric lines, grounded fencing, and overhead power lines. Next, the depth of investigation is approximately 20% - 25% of the total line length. It should be notice that the resolution of the resistivity method decreases with increasing depth. This is due to the systematic widening of the dipoles. The highest resolution and most accurate depth conversion is provided in the upper 30% of the modeled cross section where the resolution is 1/3 the electrode spacing. In addition, to vastly improve the modeling is by tying lines into existing borehole data.

2.7.2 Resistivity Array

The resistivity is normally measure by carried out four electrodes set equidistant along a line. The four electrode arrangement are called as arrays. An electrode configuration or array is the arrangement of electrodes for resistivity surveys whiles geometric factors are numerical multipliers defined by the positions of the electrodes relative to one another. It will influence the depth of investigation, sensitivity, resolution and the incorporation of noise into each apparent resistivity measurement (Loke, 2006). There are five type of array using for resistivity method which are Wenner array, Schlumberger array, pole-pole array, pole-dipole array and dipole-dipole array. Each type of array has their own benefits and limitations. The best advantages for depth penetration and signal amplitude is pole-dipole while for the field set up, Wenner and Schlumberger array are the best choices. In Figure 2.2, it shows the common arrays used in resistivity surveys and their geometric factors**.**

First and foremost, the common array used is Wenner array. It has a linear course of equally spaced electrodes. The array works by moving electrodes along the profile for lateral resistivity measurements or increasing the electrode spacing about a fixed point for resistivity variation 22 with depth. It is very effective in fixing horizontal structures which sensitive to vertical changes in the subsurface but less effective when it comes to the resolution of vertical structures that less sensitive to horizontal changes. The Wenner array is very widely used and supported by a vast amount of interpretational literature and computer packages. He also portrays it as the establishment stone on which all the array types have been developed (Milsom, 2003).

Secondly is Schlumberger array. This type of array has unevenly separated electrodes with the potential electrodes in the center and the current electrodes at the extreme ends. The two potential electrodes has a much smaller distance compared the distance between a current electrode and a potential electrode. It is suitable for depth sounding because when determining resistivity variations, only the current electrodes are moved. The current electrode spacing is increased symmetrically about the center of the spread whiles the potential electrodes remain settled. In any case, when the current electrodes are too spacious, the potential 23 electrode spacing should be increase for quality readings. According to Milsom, (2013), the Schlumberger array penetrates deeper and resolves vertical structures better than the Wenner.

Thirdly, the dipole-dipole array has the current pair of electrodes on one side and the potential pair on the opposite side of the profile line. It is sensitive to horizontal changes which resolving vertical structures in the subsurface but less sensitive to vertical changes that resolving horizontal structures. This array has low signal strength. By varying 'n' information can be acquired at different depths. General idea state that the bigger the value of 'n', the deeper the penetration of the current paths sampled. The double dipole array 24 is commonly used for induced polarization (IP) because the complete separation of the current and voltage circuits reduces the vulnerability of inductive noise.

The fourth type of array is pole-dipole array. The arrangement of the array is one current electrode is placed at such an extreme distance from the other three which it is considered to be at infinity. This array has higher signal strength than the dipole-dipole. It produces asymmetric anomalies that are consequently more difficult to interpret than those produced by symmetric arrays (Milsom, 2003). Peaks are displaced from the center of conductive or chargeable bodies and electrode positions have to be recorded with particular care (Loke, 2001).

Last but not least, pole-pole array. Ideal array of it only consists of one current and one potential electrode. The two-electrode array has the second current electrode and second potential electrode must be placed far away from the other two. However, the distance is not more than twenty times the separation between the first current and potential electrodes. The array has the widest horizontal coverage and the deepest depth of investigation but with a very poor resolution. According to Milsom, (2003), this array is very popular in archaeological work because it can easily be carried out by one person.

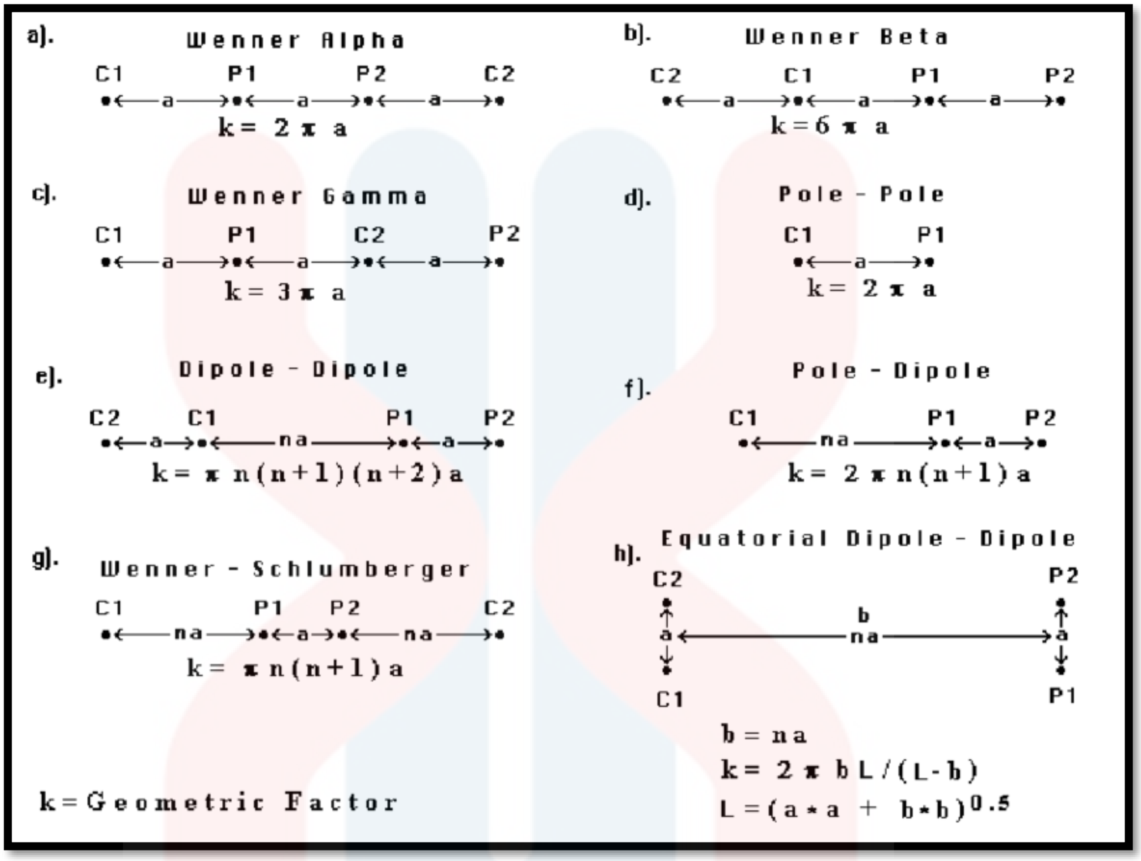


Figure 2.2: Common arrays used in resistivity surveys**.**

2.7.3 Groundwater Potential

ERI survey is a non-destructive method which carried out basically to determine the subsurface resistivity distribution by making measurements on the ground surface (Zeinab Asry, 2012). Nevertheless, it could be considered as sustainable technique due to preservation of environment during data acquisition. After the process of research using the ERI is carried out, the imaging will be generated from spread line. Figure 2.3 below showed the example of resistivity imaging. The absolute value of the ground resistivity must be known in order to identify the presence of groundwater in the study area from the imaging. Next, from the value, it can be compared with the Figure 2.4.

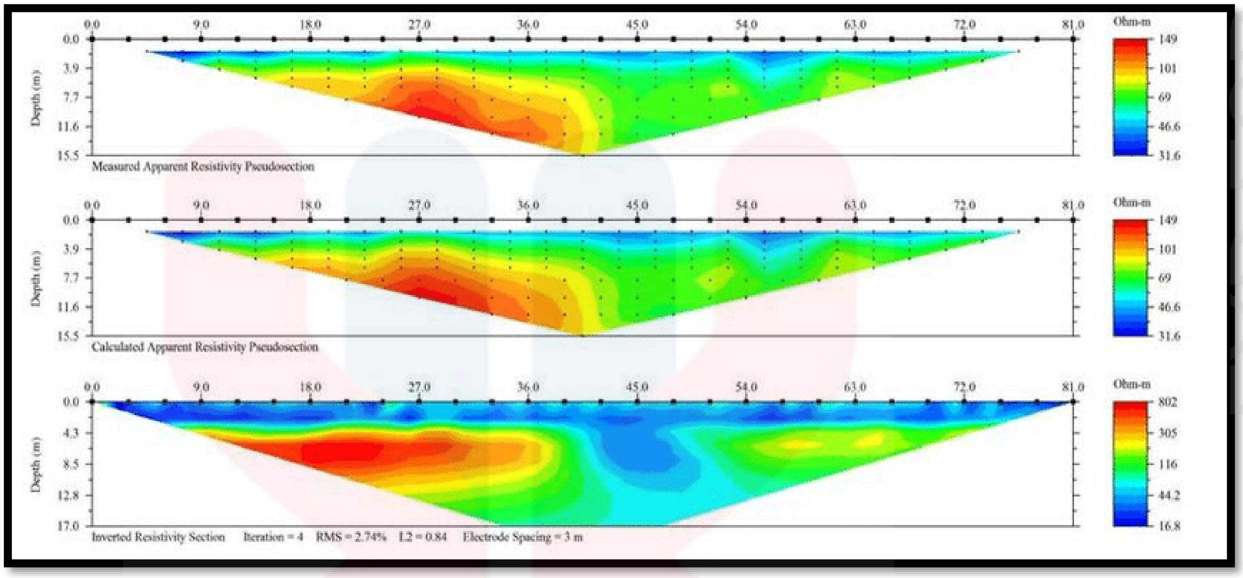


Figure 2.3: Example of Resistivity Imaging

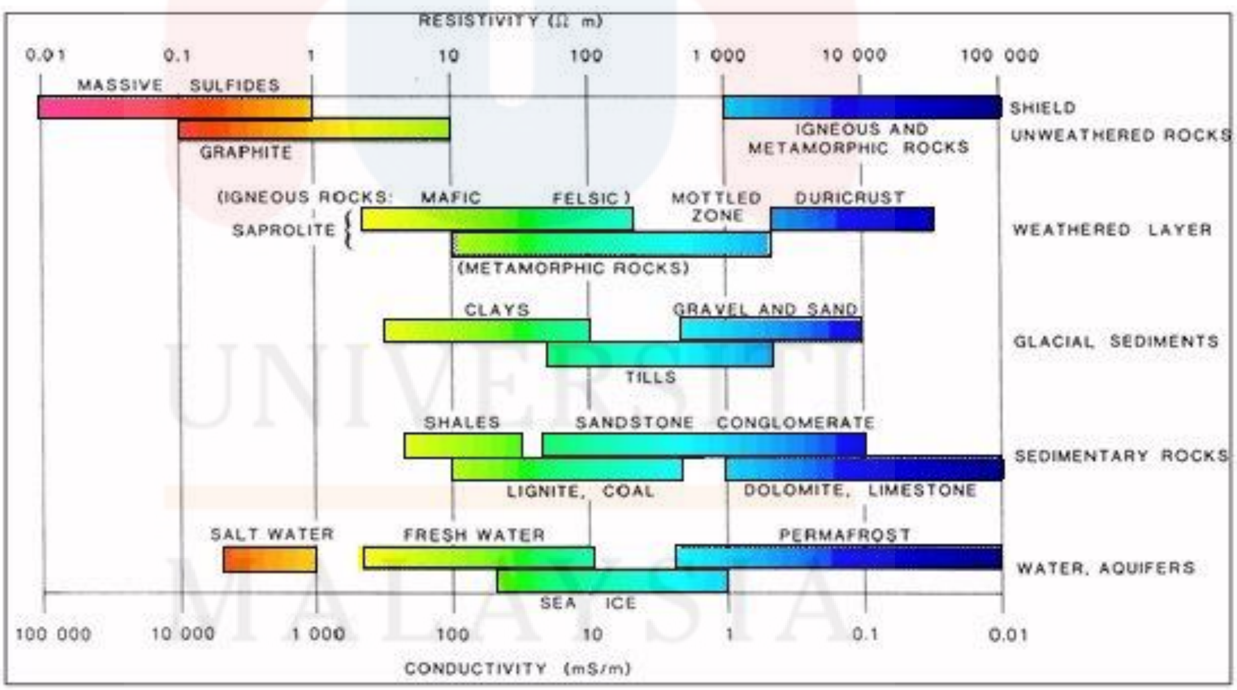


Figure 2.4: Resistivity and conductivity distribution. (Source: Palacky, 1987).

2.7.4 Previous Study

The identifying of potential zones of groundwater by using electrical resistivity imaging has been done in Malaysia. According to (Zeinab Asry, 2012), the study of electrical resistivity imaging surveys have been conducted in Sg. Udang, Melaka. The field survey was carried out along four profiles that allocate a continuous coverage of the resistivity imaging below the surface. From this study, the resistivity image has been used to identify unsaturated and saturated layer of subsurface in the study area. Next, the determination of groundwater potential area using the method of electrical resistivity was located in Jenderam Hilir, Dengkil, Selangor. The survey was done by executing seven resistivity lines by using different electrode spacing accordingly to space availability at study area. Generally, the result showed, the study areas in Dengkil has a good potential to become water supply sources in the future (Rais Yusoh, 2016). In Kelantan, the survey for potential groundwater exploration in Ayer Lanas, Jeli District. The Schlumberger array with a maximum electrode spread of 200 m was conducted by employing three resistivity survey lines. This result of this study showed that the study area has potential groundwater resources which exist in the alluvium and the weathered granite (Dony et al., 2016). In the study area chosen of Dabong, there is still no geophysical study conducted there.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This chapter will discuss about the materials and methods that will be used to achieve the objectives of this research. Materials and equipment to be required are listed in Table 3.1 and the main steps of methods are given in research flow chart showed in Figure 3.1.

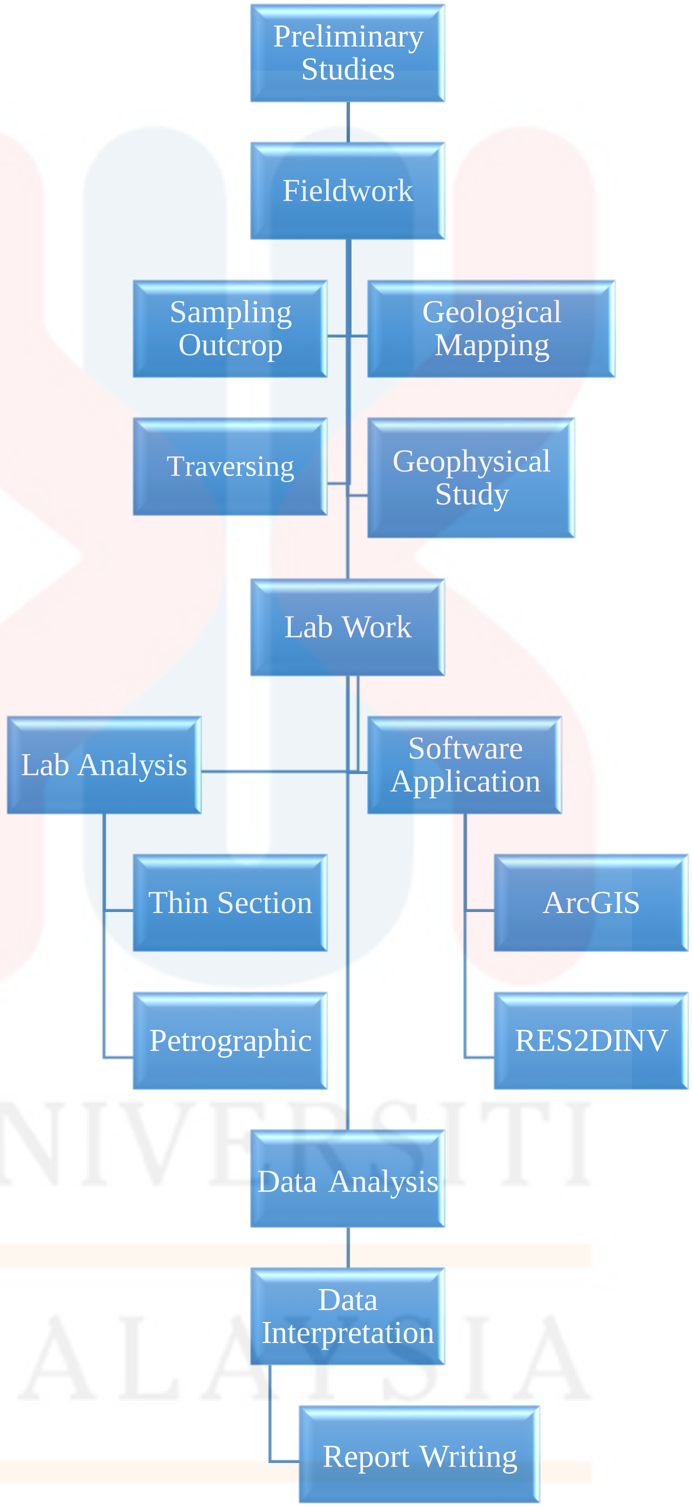
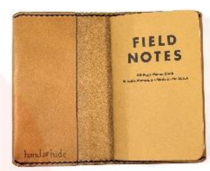
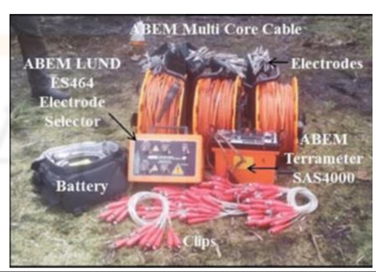


Figure 3.1: Flow chart of the research.

3.2 Materials/Equipment

Table 3.1: Materials and Equipment required.

Materials and Equipment	Uses	Picture
Pen and Marker	Pen is use to write down all the data and information in the notebook. Marker is use to write name for rock sample on the sample bag.	
Field Notebook	It is to keep down data observation and other information from the fields.	
Base Map	Aid as a reference for traversing the study area.	
Suunto compass	Compass is used to determine direction, identify strike and dip direction and measuring inclination in the field.	
Chisel or Tip-point hammer	Hammer is used to break the rock for sampling during mapping.	
Measuring tape	The tape is used for taking the measurement of lithologies, thickness of bed and structures.	

Global positioning system (GPS)	GPS is used to locate the position, marking lithologies, tracking structures, measuring elevation and sampling position.	
Hand Lens	It is used to analyse the rock before further research in the laboratory for a thin section. It is done by observing the minerals characteristics and grains sizes or crystal size on rocks that hardly views by naked eyes.	
Sample bag	Sample bag is used to keep the rock sample from the field.	
Digital Camera	It is used to capture the picture of structures and rocks with scale for report writing.	
1mol HCl	HCl acid is used to determine the carbonate rock. A bubble gas will produce when HCl is reacts with carbonate rock.	
ABEM Terrameter SAS 4000 Electrodes and Cable	ABEM Terrameter SAS is a highly competent and flexible solution for near surface investigations as it is able to measure in 3 modes which are resistivity, induced polarization (IP) and self-potential (SP). Resistivity mode is used for this survey. Electrodes is a conductor planted into the ground through which current is passed, or which is	

	used to measure the voltage caused by the current while cable has a number of independent wires within it.	
Thin Section Machine	It is for re-sectioning and thinning a variety of samples, such as rocks, ceramics, glass and minerals, to perform materials characterization.	
Petrographic Microscope	A petrographic microscope is to identify mineral by used for observing a series of characteristics in a mineral that reflect its properties.	

3.3 Methods

The main steps of this research is showing in the flowchart in Figure 3.1.

3.3.1 Preliminary study

Before starting a research, a preliminary study has been done in order to achieve a better understanding on the geology of the study area and basic concept of research specification. Preliminary study help to narrow the topic, to inspire and for gaining research ideas. Preliminary study is an initial research of issues related to a proposed quality review or evaluation. This study is carried out by collecting the basic information about the study area chosen and related to the title project. This information needed was found in both conventional and unconventional ways. For conventional way, it was found in internet, suitable journal, and articles and published paper in the library. It was served as the references in conducting the research. Ideas and information that generated through talking, consulting and surveying were considered as unconventional ways. This ways was used as one of the method in improving the writing to become better.

3.3.2 Field Studies

The method of fieldwork is important and compulsory to gather data of the study area. For this field study, the research focused on two parts which are geological part and the research specification which are identifying groundwater potential using ERI method in Dabong. Firstly, field study in geological parts includes geological mapping, observing, traversing, and sampling. From this, the information about data at the study area such as type of lithology, geomorphology, topography, drainage pattern and structures were known. The coverage of study area is limit according to the procedure which is 25 kilometer per square. Geological field mapping is process of identifying all the geological aspects of the study area with the purpose to prepare a geological report and detailed map. For traversing, a full observations, sketching and take coordinates was done to make a traverse map. The geological map showed various type of lithology, structures, and geological formations. While the sampling method is all about collecting different geological material, for example fresh rocks, or outcrop of the study area from small to large volume. Rock sampling is a method of sampling. It was done carefully by breaking a fresh rock without altering it using the hammer.

Secondly, the research specification which are identifying groundwater potential using ERI method. In geophysical study, the determination for location of ERI method had been done. The chosen location for resistivity line was based on geomorphology, structural geology and lithology. Based on geomorphology, it must be pick near the river at mountainous area or clean area without any disturbance. For structural geology, make a line at area which has many structure and highly fracture. The lithology of the study area must be known to identify the type of porosity and permeability. ERI is an active geophysical method that measures the electrical potential differences by injecting electric current. The measurement of resistivity are normally carried out with four electrodes set equidistant along a line. According to Loke, 2006, the arrangement of four electrodes will affects four aspects which the depth of investigation, sensitivity, resolution and the incorporation of noise into each apparent of resistivity measurement. The equipment use for the research is specification using ABEM Terrameter SAS4000 at Dabong, Kuala Krai. This machine is specific use only for resistivity subsurface investigation. Table 3.1 and 3.2 showed the charge ability and resistivity for common rocks and soil materials in ohm meter.

Table 3.2: Chargeability of some common rocks and soil materials. (Source: Telford et al., 1990)

Material	Chargeability (ms)
Ground water	0
Alluvium	1 – 4
Gravels	3 – 9
Precambrian volcanics	8 – 20
Precambrian gneisses	6 – 30
Schists	5 – 20
Sandstones	3 – 12
Argillites	3 – 10
Quartzites	5 – 12

Table 3.1.: Resistivity of some common rocks and soil materials. (Source: Loke, 1999)

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

The configuration array used in this research study is two types which are Pole-Dipole array and Schlumberger array. According to Loke, 2001, pole-dipole configuration array is chosen because it has good horizontal coverage and it is not sensitive telluric noise. It also an asymmetrical array (Figure 2.1) and the apparent resistivity anomalies over symmetrical in the pseudosection are asymmetrical. For this research, pole-dipole used a remote electrode known as the C2 electrode which should be placed enough far from the survey line. The second line chosen is Schlumberger configuration array. This is because it needed a fewer electrodes needed to be for sounding. The array also have good resolution, greater probing death and less time-consuming.

3.3.3 Laboratory Work

In laboratory work, it focused on petrography section. Petrography is a geological process by doing thin section. During mapping, rock or outcrop we collected from sampling must be undergoing thin section process to determine the mineral constituents, porosity and other factor that are influenced dissolution of the rock. In petrographic analysis, the classification of rocks will be obtain by doing a detail description on mineral content textural relationships within the rock. In laboratory analysis, a thin section machine and petrographic microscope will be used.

There are three steps in thin section technique. Firstly is cutting and sectioning as shown in Figure 3.2 where the rock sample is cut into the definite size with the given thickness. The sectioning process used to provide the exposed surface of interest rock. Next is grinding. Grinding is performed to remove deformation induced in sectioning and to planar grind. The rock sample must be crush smoothly using a horizontal diamond impregnated diamond wheel. The saw marks will remove while doing as little grinding to get a flat surface before it is cemented and gluing into a glass slide. Last step is in Figure 3.3 which is polishing. Polishing is a way to remove the final deformation during grinding process. The sample will be moved on rotary motion with a glass slide. The sample will be examined by using transmitted light before it undergoes polishing session. Lastly, view the sample under polarized microscopy to observe the mineral composition.

Figure 3.2: Cutting and sectioning process

Figure 3.3: Polishing process

3.3.4 Data Processing

In GIS application of ArcGis, it integrated and analyzed all of the data that had been collected in the field, then the coordinate will be digitized in the application. This will produce a better updated geological map with great accuracy. Other geological data obtained such as joint, fold and fault used GeoRose and Stereonet software by plotting the value of the joint and strike and dip. Next, by using software RES2DINV, a 2D Resistivity will be calculated. After that, the variations in the electrical properties will be interpret.

3.3.5 Data Analysis and Interpretation

After data processing, an analysis and interpretation was done. The important method of creating a geological map is geological mapping. Geologic maps showed the distribution of different types of rock and geologic structures such as faults, foliation, lineation and folds. From this maps it might helped in identifying groundwater aquifers and can also aid in locating water-supply wells. Next, petrography analysis described the minerals content and textural relationships within the rock samples while thin section gave a detailed analysis of minerals which to help in understanding the origin of rocks. The final data of ERI derived from apparent resistivity values after inversion process using RES2DINV. Before that, the data will be process in ABEM Terrameter LS Toolbox software as shown in Figure 3.4 for completing the data. The scale of resistivity values of the ERI was standardized in order to make the visualization and interpretation process easier.

Figure 3.4: ABEM Terrameter LS Toolbox software

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

In this chapter, it discussed the geological aspects such as geomorphology, lithostratigraphy and structural geology of the study area. The geomorphology is detailed in topography, landform, weathering, watershed and weathering process. For lithostratigraphy, it is about hand specimen of rock sample and the petrography analysis while stratigraphy need cross section and stratigraphy column for the detail in law of superposition, age and origin of rock. Structural geology cover vein, joint, fold and fault of the area. In addition, the historical geology of the area is also has been discussed and described.

4.1.1 Traverses and Observations

All data are gathered by field observation and geological mapping. These are done in ordered to have a better understanding on the study area. In Figure 4.1, the traverse map and observation of outcrops is shown. The figure clearly shown the locations where sampling and observation point are done respectively. Table 4.1 showed the coordinates which the observation and sampling station are made.

Table 4.1: Coordinates of observation and sampling station.

Point	Coordinate
Observation Point	102°1'42.84"E 5°20'42.488"N
	102°1'53.585"E 5°20'42.51"N
	102°1'8.167"E 5°18'52.791"N
	102°1'3.148"E 5°20'8.654"N
Sampling Point	102°1'55.096"E 5°20'39.067"N
	102°1'52.092"E 5°20'36.907"N
	102°1'59.976"E 5°21'10.09"N
	102°1'5.404"E 5°18'44.776"N
	102°0'56.245"E 5°20'20.111"N
	102°1'11.34"E 5°20'12.919"N

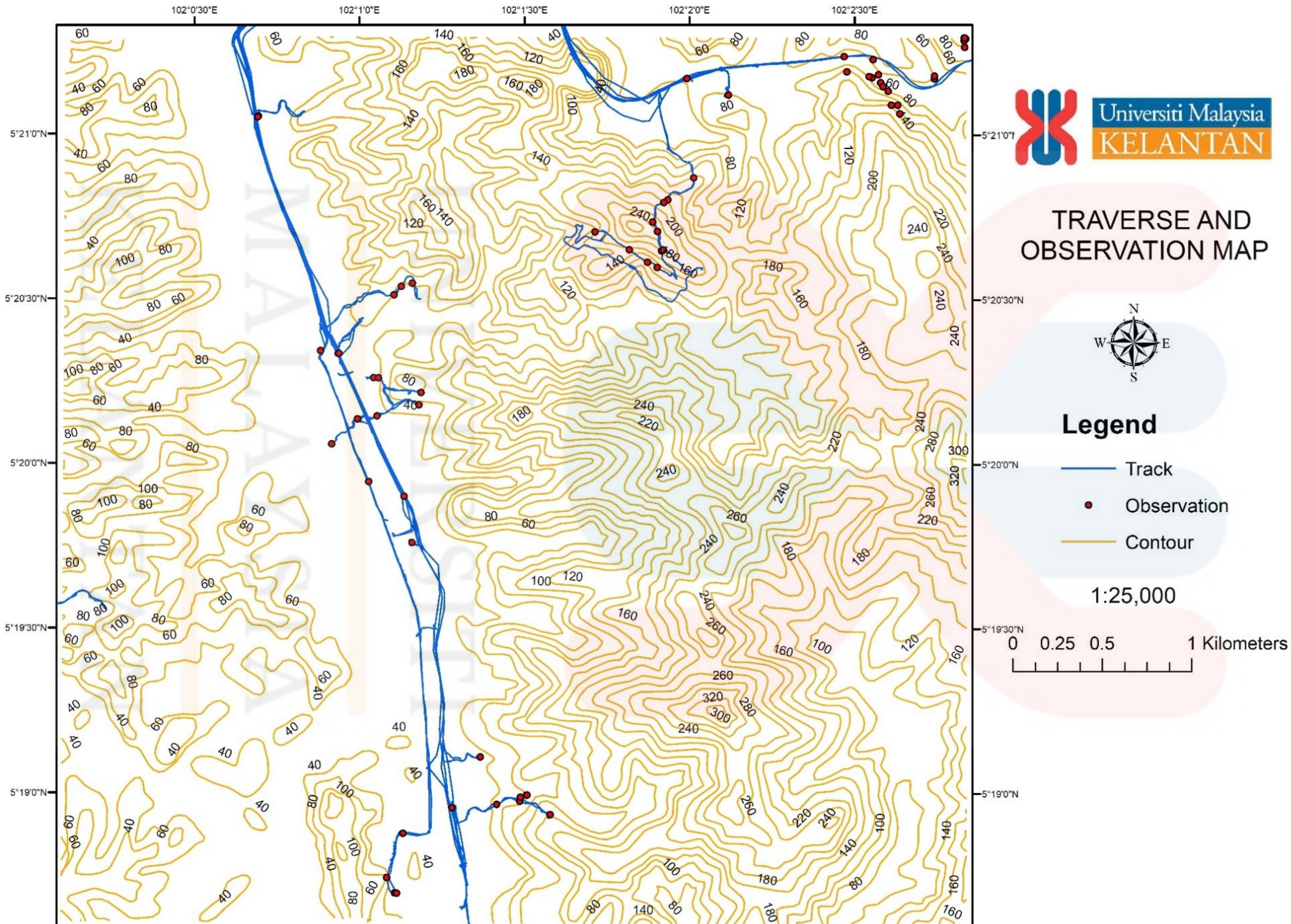


Figure 4.1: Traverse and outcrop observation map of study

4.1.2 Landuse and Settlement

In the study area, there are forestry and mixed agriculture of oil palm and rubber plantation, as shown in Figure 4.4. On the most western part of the study area is mostly a forest while the eastern part is a reserve forest called Hutan Rizab Serasa where under constitutional protection. The eastern part also mainly consist of oil palm plantation (Figure 4.3). The study area near the main road at the west have a vegetation of rubber plantation along the road (Figure 4.2). The resident's areas mainly situated at the western region of the study area as the main road is located there. As mention in Table 1.2, the total population in Dabong increased from 11,131 to 13,173. Nevertheless, the population along Jalan Kemubu-Dabong is sparsely populated. Most of people there working as rubber tapper or working at oil palm plantation.

Figure 4.2: Rubber Plantation

Figure 4.3: Oil Palm Plantation

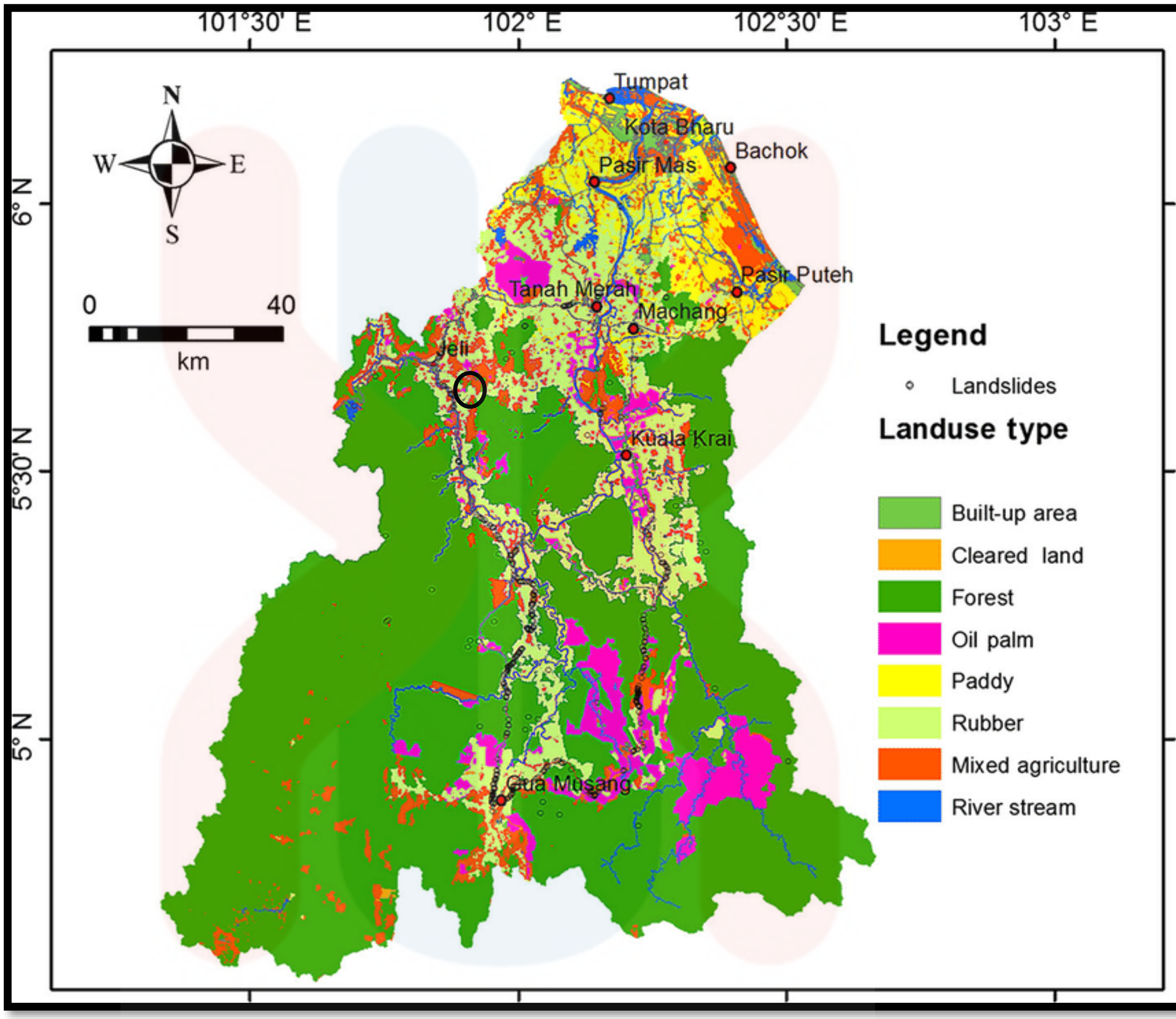


Figure 4.4: Land use map of Kelantan

4.2 Geomorphology

Geomorphology is study about the shape of earth surface and process that occurs since the earth was first formed until now. The importance of geomorphology are to understand process of geomorphological of various environment, to identify natural and hazard, and also to identify various landform feature and landscapes. In this study area, the geomorphology defined the landform and its origin and evolutions that have been occurred in the past.

4.2.1 Topography

Topography is used to describe the shape and features of the earth's surface. It referred to all the physical attributes of a land surfaces include changes in the surface such as mountains, valley and rivers. The natural feature of the earth's surface is called land form. There are several types of landforms which are valley, canyon, island, plain and hills.

The Figure 4.5 shown the topographic view in 2D of the study area. From the elevation of contour shown in Table 4.2, it can be noticed that the study area is divided into two types of landform which are hill and plain landform. The classified of landform is according to the class of contour elevation in Table 4.2 sourced from Van Zuidam.

Table 4.2: Class of contour elevation (Van Zuidam, 1985)

ELEVATION OF COUNTOUR	**LANDFORM**	**STUDY AREA**
< 50 meter	Plain	Plain
50 meter – 100 meter	Interior plain	↓
100 meter – 200 meter	Low hill	↓
200 meter – 500 meter	Hill	Hill
500 meter – 1,500 meter	High hill	
1,500 meter – 3,000 meter	Mountain	
> 3,000 meter	High mountain	

According to the 2D map of the study area in Figure 4.5, the elevation of contour shown that the elevation is between 40 until 320 meter where 320 meter is the highest elevation while 40 meter is the lowest elevation from the sea level. The eastern part of the study area is mostly consist of hill landform. The hill area is referred to the reserved forest that covered mostly by cultivation of rubber and oil palm plantation. Moreover, the western part is consist of plain landform which referred to village area of Kampung Pulau Layak. There is an abrupt change in pattern of elevation located around karst landform which is limestone hill. The elevation range for karst landform is 40 meter 60 meter.

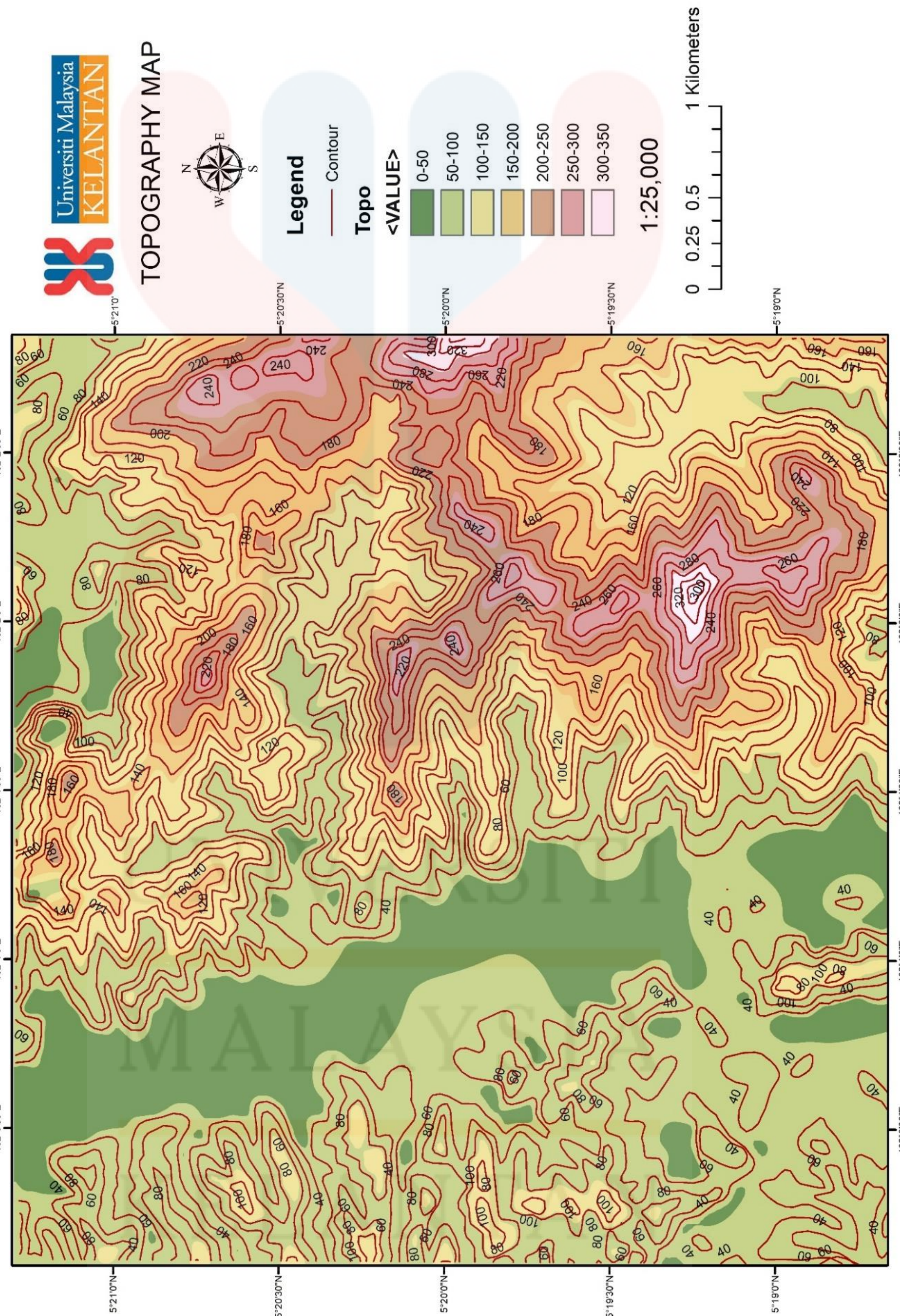


Figure 4.5: 2D Topography map of study area

4.2.2 Drainage Pattern

Drainage pattern is the river system in geomorphology. The pattern is made by tributaries and formed by streams, lakes or rivers that usually regulated by the topography and geology of an area. Drainage pattern is essentially a function of basin geology, climate, developmental history, and slope. Basin pattern usually give the first indication to understanding the geology of the area. There are several types of drainage pattern such as dendritic, parallel and others as shown in Figure 4.6.

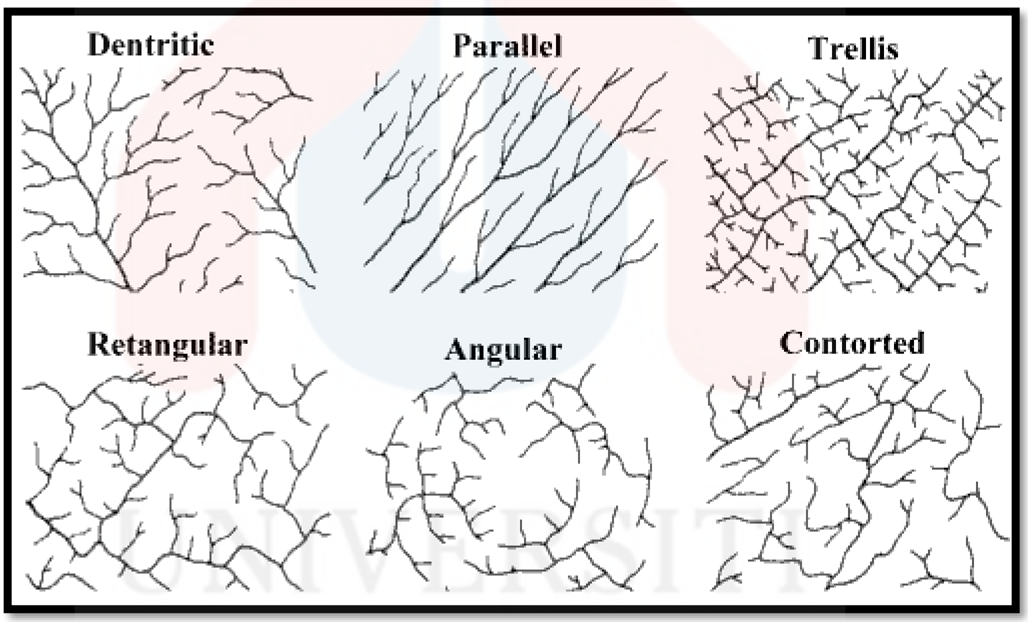


Figure 4.6: Types of drainage pattern (Source: Thonbury, 1969)

In the research study area, there are Galas River as a main river as shown in Figure 4.8. Based on the Figure 4.9, the drainage pattern map shown drainage pattern of river. The circle part in the drainage showed the dendritic type of drainage. There is only one watershed for the area as all small river that flow towards the Galas River. On the drainage map, the rounded shape on the map have the most obvious dendritic pattern. The pattern is random and have irregular tree-like branching tributaries of many directions and almost at any angle. Both rivers have some order that joined them together and tributaries to main river of Sungai Galas.

Figure 4.8: Galas River as the main river.

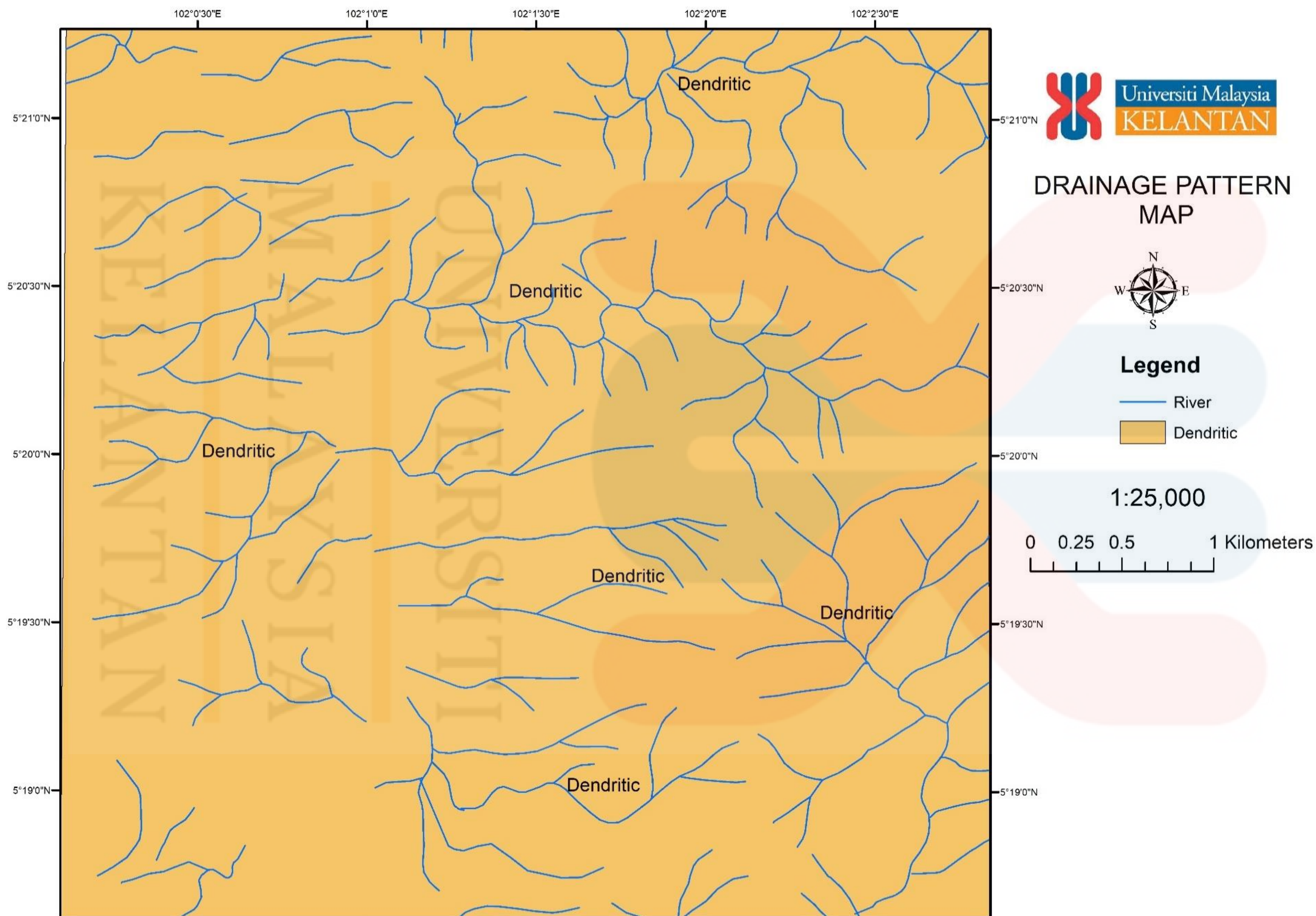


Figure 4.8: Drainage pattern map

4.2.3 Weathering

Weathering is a natural process that breaks down the rock, soil and its mineral content into smaller pieces and can be transported by agents of erosion such as water or gravity. Generally, there are several factor which control the rates of weathering such as properties of parent rocks, climate and soil. There are three types of weathering which are physical, chemical and biological weathering.

Physical weathering is related to the breakup of rocks into small pieces and fragment without changing the chemistry in parent rock. The weathering is caused by the factors of changing in temperature, water and glacial materials. There are many types of physical weathering, but the main two are exfoliation and freeze-thaw. Figure 4.9 and Figure 4.10 showed the physical weathering with the type of exfoliation in the study area. Exfoliation cause the rock of sandstone to crack and break into pieces as is highly resistance. For schist, itt is lowly resistance, it break into smaller pieces and as its crystal sizes can be very small, it had causing a rapid weathering

For chemical weathering, it changes the composition of rocks through chemical mechanism of carbonation, hydration or oxidation. The process is steady and continuous process as the mineralogy of the rock adapts to new changing in the surrounding. Oxidation occurred in the study area can be observed on the Figure 4.9. Oxidation changes the color of the mineral as it react the rock minerals with oxygen. The colour of rock is red or rust colored is because of commonly known mineral iron. As the sandstone is exposed openly especially to sunlight and rain, it easily oxidized as water react with the substance in the rock which is iron or iron minerals and form oxides which is result in weathering.

Biological weathering is the weakening and disintegration of rock by plants, animals and microbes. Biological weathering is important to create nutrient rich soil and allows for plants and trees to grow which eventually makes life on Earth is possible. In Figure 4.9 and Figure 4.12, the crack and joint that caused on the rock had led to the tree to grow there and it eventually separate the rock.

Based on the weathering grade classification by Paul (2016), there are six grades in total of describing the degree of weathering of a rock. The classifying is generally based on the field observation of the rock condition. In the study area, most of the outcrop and rock have been undergoes process of weathering which causing a hard time in finding fresh rock. Figure 4.13 showed the weathered rock that have been turned into soil. The highest grading identified in the research area is V, the highly weathered type. The Table 4.3 showed a description on weathering grade classification by Paul (2006).

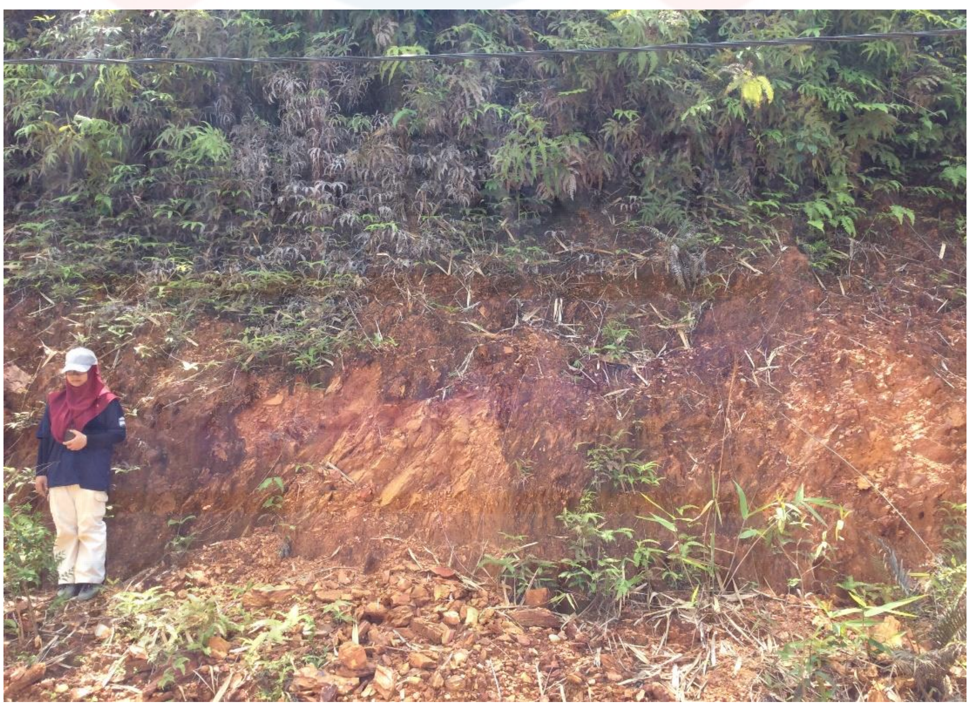


Figure 4.9: Biological and Chemical (Oxidation) weathering on sandstone.

Figure 4.10: Physical weathering (Exfoliation) on schist

Figure 4.11: Physical weathering (Exfoliation) on schist.

Figure 4.12: Biological weathering on sandstone.

Figure 4.13: Weathered rock turn into soil (Grade IV).

Table 4.3: Weathering Grade Classification. (Source: Paul, 2006)

Term	**Description**	**Grade**
Fresh	No visible sign of material weathering.	IA
Fairly Weathered	Discolouration on major discontinuity surface.	IB
Slightly Weathered	Discolouration indicates weathering of rock material and discontinuity of surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker than its fresh condition.	II
Moderately Weathered	Less than half of the rock material is decomposed and disintegrates to soil. Fresh of discoloured rock is present either as a continuous frame work or as core stones.	III
Highly Weathered	More than half of the rock is decomposed and disintegrated to soil. Fresh or discoloured rock is present either as a discontinuous frame work or core stones.	IV
Completely Weathered	All rock material is decomposed and disintegrated to soil. The original mass structure is largely intact.	V
Residual Soil	All rock material is converted to soil. The VI mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

4.3 Lithostratigraphy

Lithostratography is the study of strata or layer and classify of bodies rock based on observable lithological properties on the strata and their relative stratigraphic relations. The basic units of geologic mapping are lithostratigraphic unit. The unit may consist igneous, metamorphic or sedimentary rocks. These lithostratographic unit are defined and identified by observable physical features the time span they represent, inferred geologic and formation.

In the study area, there are two hierarchies of lithostratigraphy which are formation and member. From the observation of lithology and according to past study, it is determined that the study area is Gua Musang Formation and Taku Schist. The geological map is shown in Figure 4.14.

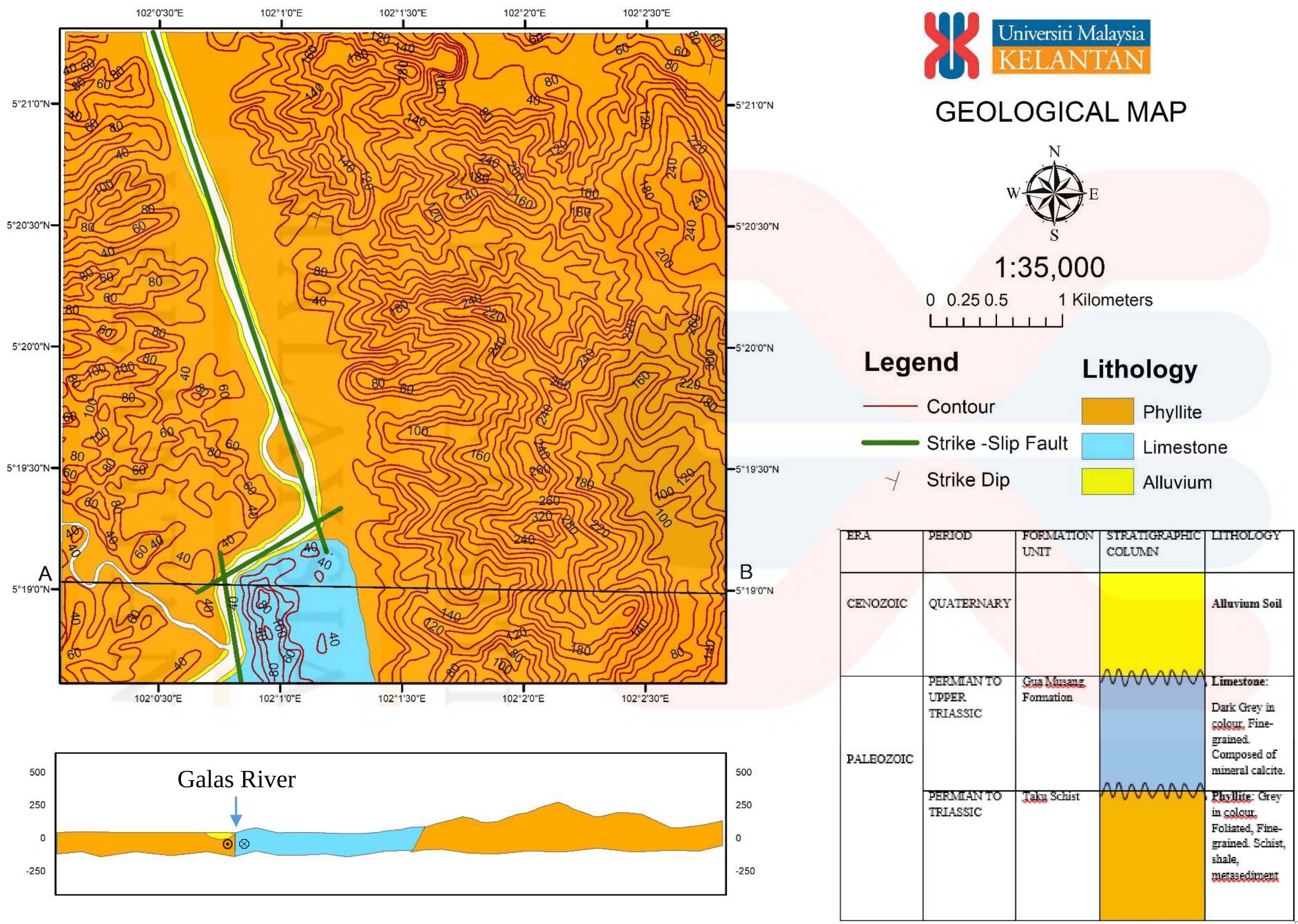


Figure 4.14: Geological map

4.3.1 Stratigraphic Position

Stratigraphy position or column is used to present measured geologic sequences as a figure. It usually arranged the sequenced of rocks unit with the youngest rock unit at the top while the oldest rock unit at bottom. In the study area, the argillaceous rocks which are phyllite, slate and shale are the oldest unit with Permian to Triassic period. At Permian to Upper Triassic, limestone started to deposit has become the youngest unit of the stratigraphy column. In Table 4.4, it shown detailed information about stratigraphy column at the study area.

Table 4.4: Stratigraphic column of study area

ERA	PERIOD	FORMATION UNIT	STRATIGRAPHIC COLUMN	LITHOLOGY
CENOZOIC	QUATERNARY			**Alluvium Soil**
PALEOZOIC	PERMIAN TO UPPER TRIASSIC	Gua Musang Formation		**Limestone:** Dark Grey in colour, Fine-grained. Composed of mineral calcite.
	PERMIAN TO TRIASSIC	Taku Schist		**Phyllite:** Grey in colour, Foliated, Fine-grained. Schist, shale, metasediment

4.3.2 Phyllite

Phyllite unit is the most covered with 80% of total in the study area. Figure 4.15 showed phyllite outcrop. The outcrop is found along the road in a forest beside the main road. The outcrop seen to undergo exfoliation and well exposed to the surrounding and became weathered. Phyllite is a foliated rock with low-graded metamorphic. It can be formed when sedimentary rock are buried and mildly altered by regional metamorphism.

In the study area, the phyllite outcrop showed a reddish-brown color and have a crinkled foliation surface. Figure 4.16 showed the hand specimen of phyllite. The colour of phyllite is usually black to gray or light greenish gray. So, the color of the outcrop had undergone chemical weathering of oxidation which cause it to change to red color. The common minerals of phyllite are quartz, muscovite, plagioclase and biotite. The phyllite under the thin section in Figure 4.17 showed mineral contain as shown in Table 4.5.

Figure 4.15: Phyllite Outcrop

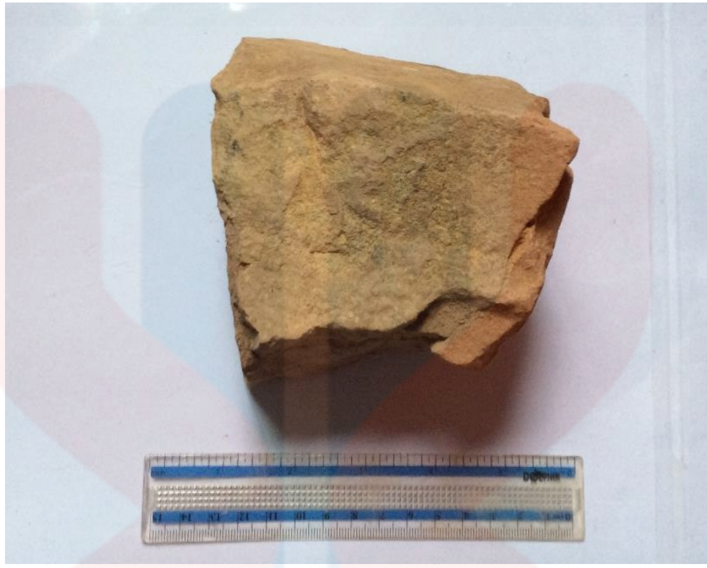
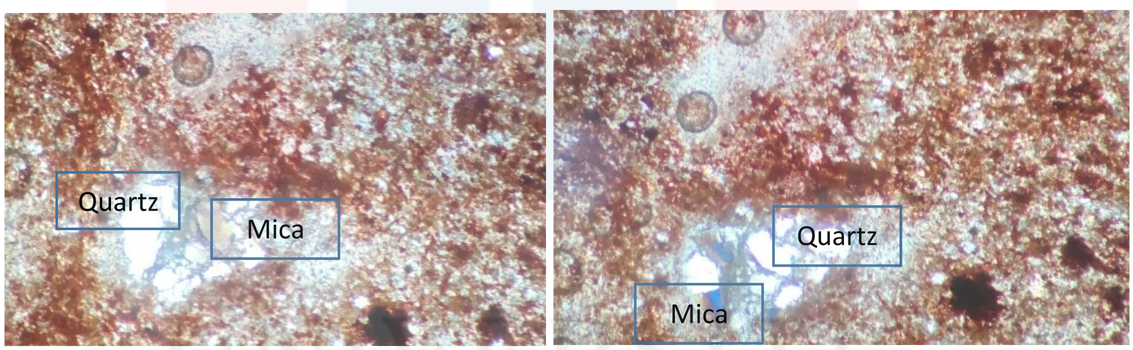


Figure 4.16: Phyllite hand specimen



PPL

Figure 4.17: Phyllite under thin section.

XPL

Table 4.5: Composition mineral in Phyllite

Composition of Mineral	Description of Optical Mineralogy (Magnification 10x)
Quartz	Colourless under PPL, low relief, low first order bf, wavy extension angle
Mica	Colourless under PPL, low-moderate relief, high bf, parallel extension angle

4.3.3 Schist

Schist unit can be found mostly at the oil palm plantation of the eastern part of the map. In Figure 4.18 and Figure 4.19, it showed the outcrop and hand specimen of schist. It can be seen in the figure that the outcrop had undergoes excavation due cutting of the hill for oil palm plantation. Schist is a foliated metamorphic rock that exposed to moderate level of heat and pressure. It usually forms when sedimentary rocks such as shale and mudstones undergoes compressive forces, heat and chemical activity on a continental side of convergent plate boundary.

Figure 4.18: Schist Outcrop

Figure 4.19: Schist hand specimen

4.3.4 Limestone

Limestone unit in the study area can be found in the southern part of the study area. Limestone is a sedimentary rock which mainly composed by calcium carbonate mineral. It commonly forms in warm, shallow marine water. Limestone forms from the accumulation shell, coral and foraminifera. When there is solubility in dilute acidic groundwater, the karst landform and caves were formed. The limestone is easily to dilute when it is in weak acid solution and in water.

The limestone in Figure 4.20 can be found along the unpaved road between the main road and Galas River. The limestone is actually a karst near to an abandoned quarry of hematite. The color of limestone in the study area is light gray and some exhibit dark gray in color due to weathering process. It may contain impurities such as sand, iron oxides and other minerals.

Figure 4.20: Limestone Outcrop

4.3.5 Andesite

Andesite unit is found on the west part of the study area. Figure 4.21 showed the hand sample of Andesite which found in the river. The Andesite had already undergoes metamorphism as it already showed characteristic of small foliation.

Andesite is a fined-grained, extrusive rocks and have a light to dark gray in color. Andesite consist of rich mineral in plagiofeldspar and also contain biotite, pyroxene, or pyroxene. Moreover, andesite usually does not contain mineral of quartz or olivine. In thin section of Figure 4.22 below showed the mineral of clinopyroxene (cpx) and biotite.

Figure 4.21: Andesite hand sample

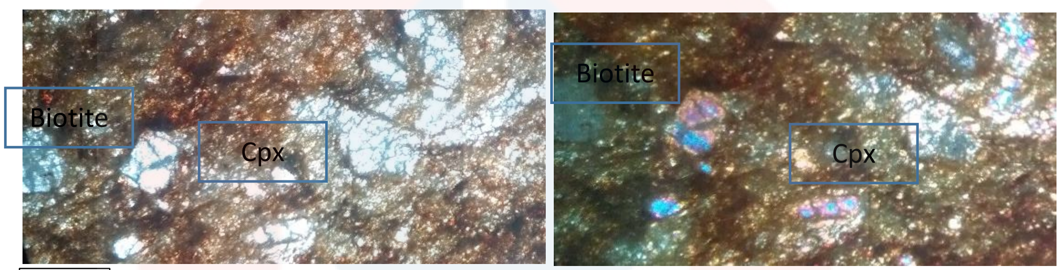


Figure 4.22: Andesite under thin section

Table 4.6: Composition of mineral in Andesite.

Composition of Mineral	Description of Optical Mineralogy (Magnification 10x)
Biotite	Dark colored under PPL, low-moderate relief, very-highly bf, parallel extension angle.
Clinopyroxene	Brightly colored under PPL,high relief, highly bf, high extension angle

4.4 Structural Geology

Structural geology is the study of three dimensional distribution of rocks, their surfaces and the composition of the inside. This is to understand the area's tectonic history, past geological environments and events which contributed to change and deform. The techniques used involved plotting orientation of such structural features such as faults, joints and folds. From the information gathered on surface, the structure beneath the surface can be interpreted.

4.4.1 Lineament Analysis

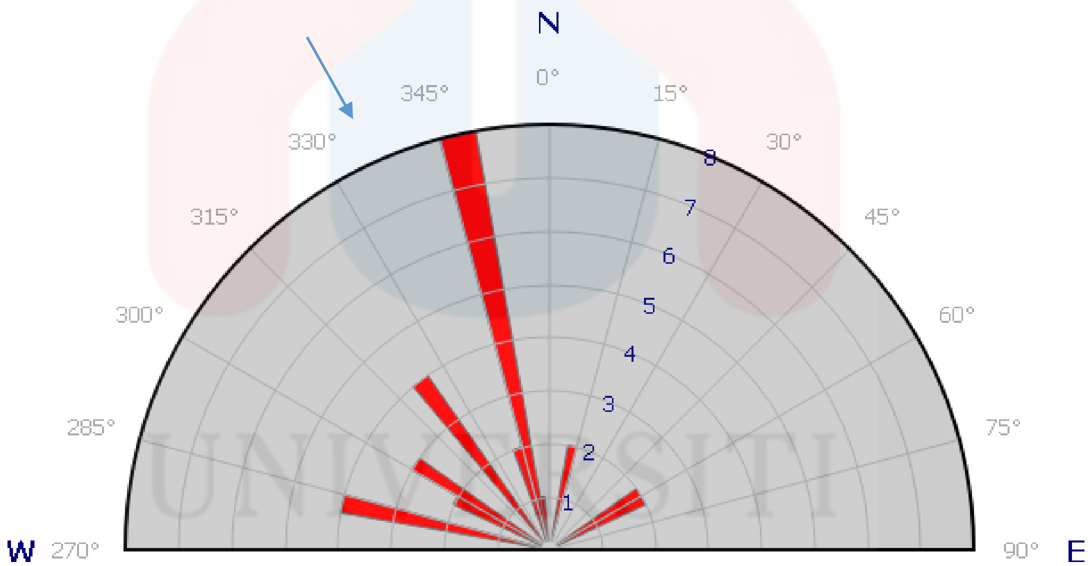


Figure 4.23: Lineament rose diagram for study area.

Figure 4.23 showed the reading of lineament rose diagram in study area. In Figure 4.24 showed the map of lineament in study area. The reading for the lineament is attached at Appendix 1. Based on the orientations of lineaments shown in figure above, it indicates stress, σ_1 in the direction of N 325° W of the study area.

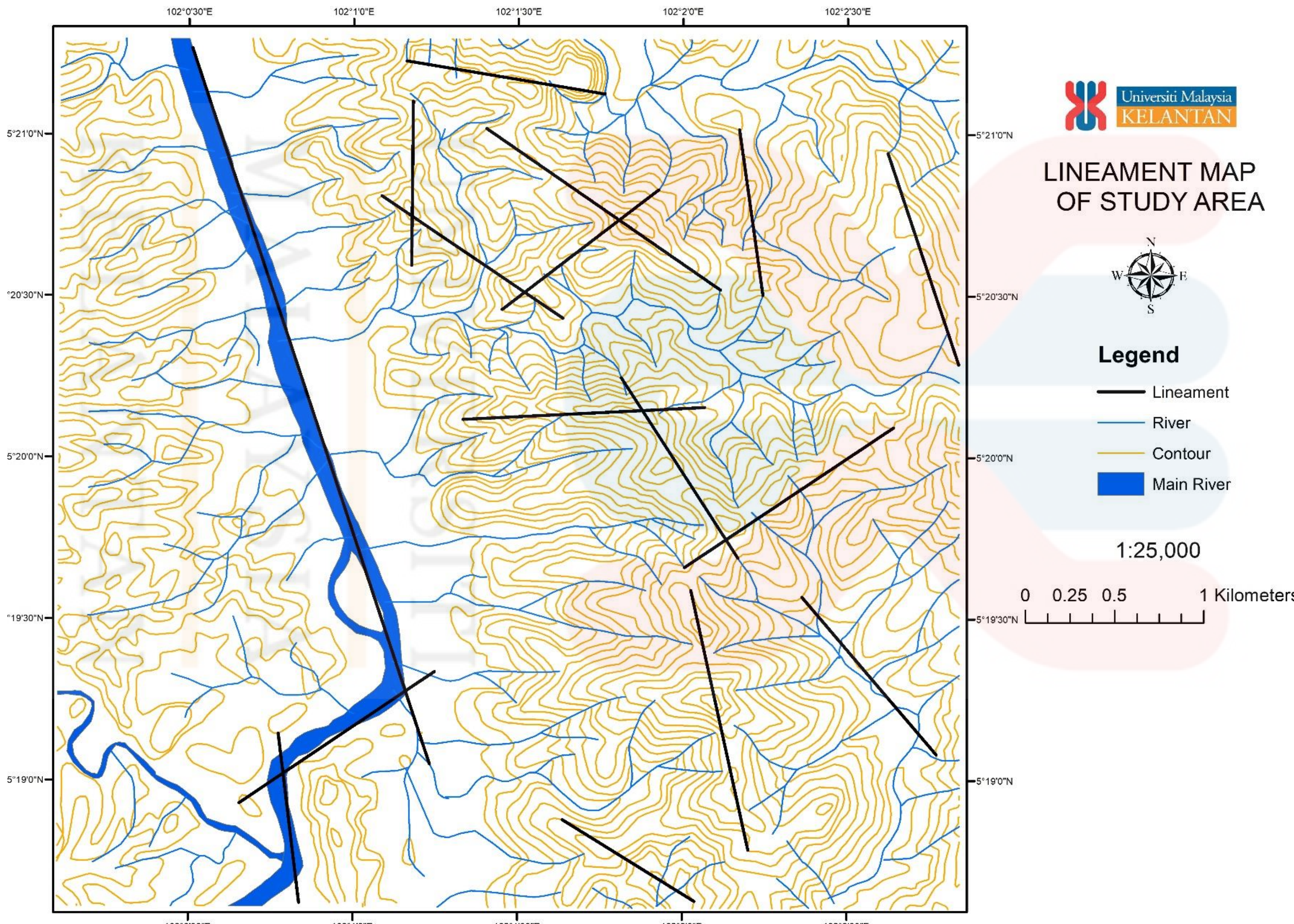


Figure 4.24: Lineament map of study area

4.4.2 Joint

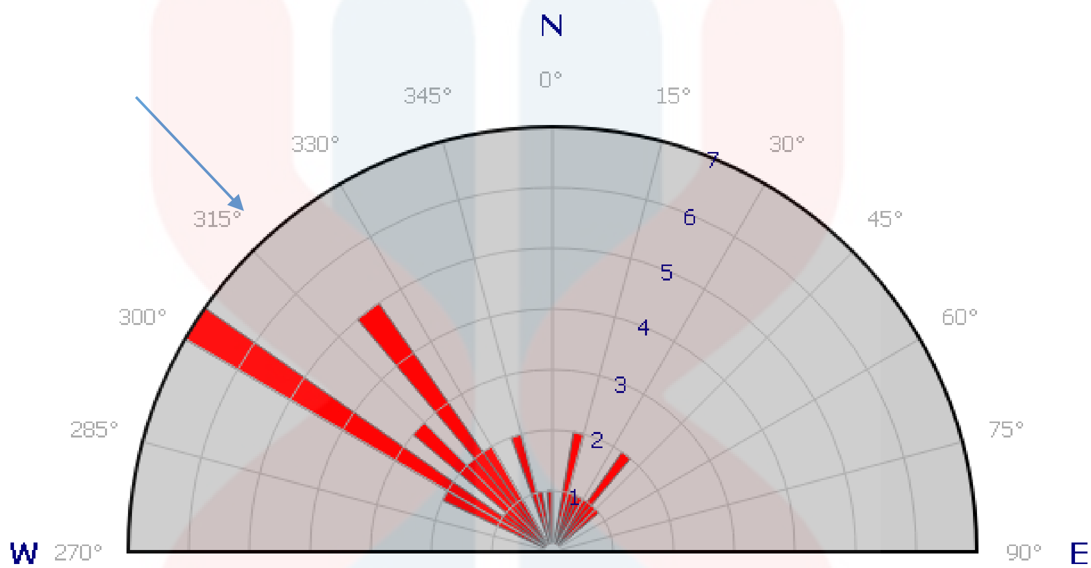


Figure 4.25: Rose diagram for study area.

Joint formed naturally by brittle fracture of a layer or body of rock. Most all type of rock consist of joint. It easily found when rock undergoes weathering process. Figure 4.25 showed the rose diagram of joint analysis in the study area. The orientation of joint is attached as Appendix 1. According to joint analysis of the study area, it cab clearly observed that the major compressional force, $\sigma_{1,}$ is at N 315º W.

4.4.3 Fold Analysis

Fold is a wave in stratified rocks of Earth's crust which formed when rocks deform by bending under compressional stress. Fold can be in vary size from microscopic to mountain-sized fold and it is very common to find a smaller fold within larger fold. Generally, fold is classified according to their axes and appearances in cross section perpendicular to the trend of fold. The axial plane can be in line of vertical, horizontal, or inclined at any intermediate angle. In the study area, the structural geology found is asymmetrical fold as shown in Figure 4.26.

Figure 4.26: Asymmetrical fold at the study area.

4.4.4 Quartz Vein

Quartz vein form when rock undergoes fracture because of pressure exerted by surrounding rocks. Fracture is any discontinuity in displacement and form a deep fissure in the rock. Vein is mineral deposits form when a fracture or fissure at the host rock is filled with mineral material. The minerals constituents is performed by an aqueous solution and deposits through precipitation. Quartz vein formed as the fissure in the rock is filled with quartz which can be seen in Figure 4.27 and Figure 4.28.

Figure 4.27: A line of quartz vein at the study area.

Figure 4.28: A close up of quartz vein.

4.5 Historical Geology

There are two formation for the study area which are the Gua Musang Formation and Taku Schist. For the historical geology of the study area, it started in the Permian where a metamorphism process occurred and formed in the region. The rocks are changing their shape while minerals recrystallize into new orientations or minerals in order to achieve new stability under changes in pressure and temperature. This metamorphism process produced the metamorphic rock such as phyllite, schist and shale.

During Lower Triassic, carbonaceous rock of Gua Musang Formation started to deposit as the limestone karst and at the Upper Triassic, the formation stopped. An exogenous process such as weathering and erosion occurred during Quaternary period and resulted in deposition of alluvium at the study area until nowadays.

CHAPTER 5

ELECTRICAL RESISTIVITY INTERPRETATION

5.1 Introduction

This chapter explains about groundwater potential using electrical resistivity method (ERI). The locations, result and interpretations of each horizontal line are discussed in detail.

5.2 Electrical Resistivity Imaging Survey Line

The total of horizontal line used for electrical resistivity survey in this research survey is three lines. The three survey line is a 200 meter in length and 5.00 meter electrode spacing. For this first survey line, Pole-Dipole configuration array is used. Meanwhile, the survey line 2 and 3 used Schlumberger configuration array. Figure 5.2 showed the location and direction of the three survey lines done in the study area. The area chosen for this research is two which at Jalan Kemubu – Dabong and near Gua Ikan for the each placement of line. These three lines are placed in the direction based on topography presents in the study area. The reason is because groundwater is transport from high elevation to lower elevation areas. Figure 5.1 showed the equipment used in the field. The resistivity section images are produced by programs known as RES2DVINV software.

All of the interpretations are made by comparing the resistivity value from data collected with resistivity values done by previous researchers. The values of resistivity is referred to Figure 3.2.

Figure 5.1: Equipment used in the field.

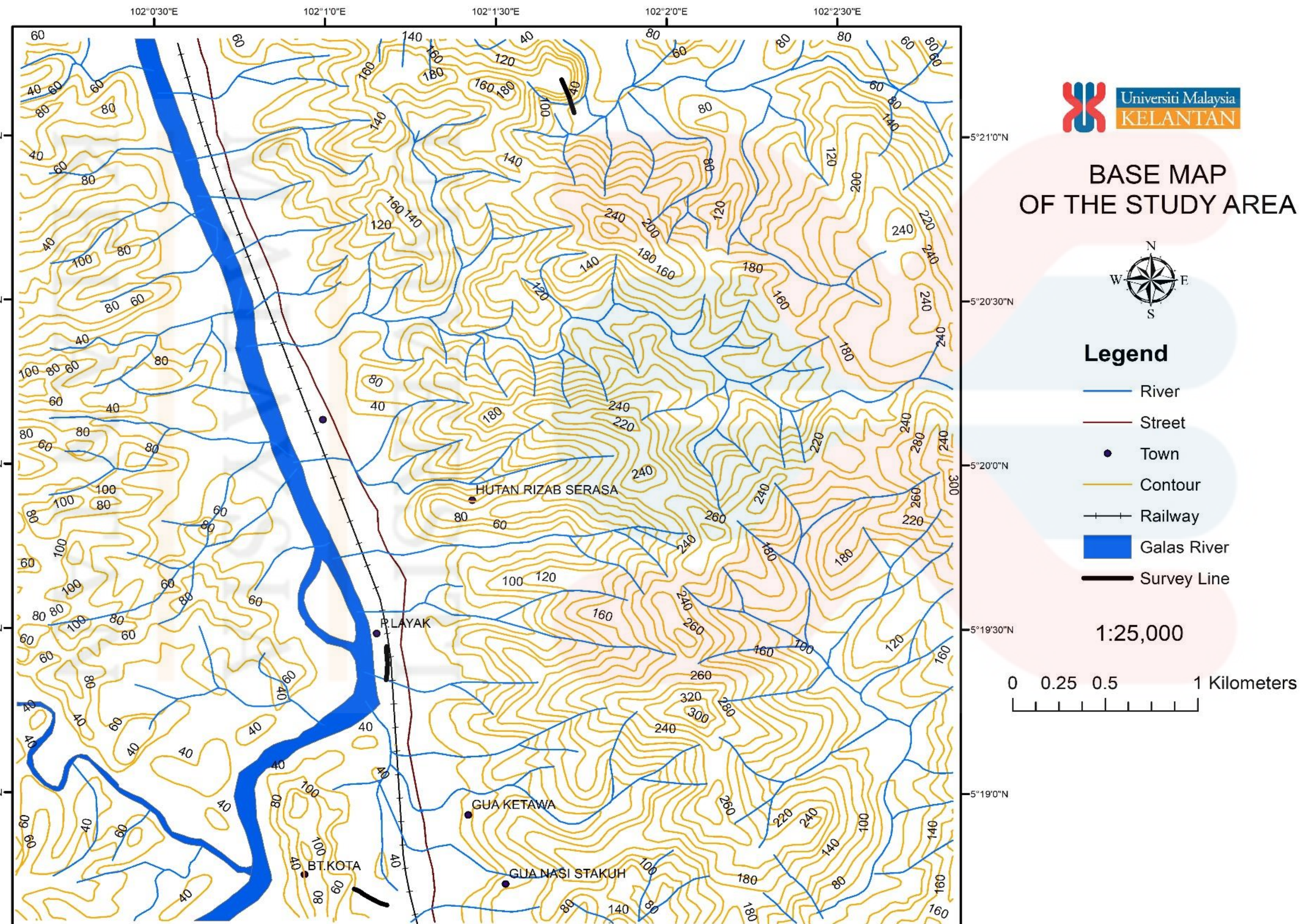


Figure 5.2: Survey line in study area

5.3 Electrical Resistivity Survey Line 1

Table 5.1 showed the coordinate of three electrodes used.

Table 5.1: The coordinate of three electrodes used in survey line 1.

Line	Electrode No.	Latitude	Longitude	Elevation (m)
A	1	N 5°18'39.484"	E 102°1'11.186"	47.0
C (Centre)	21	N 5°18'40.851"	E 102°1'8.295"	44.0
B	41	N 5°18'42.442"	E 102°1'5.453"	50.0

The survey site is an open wide area which with a few plants. For the line B, the area is open space (Figure 5.3) while in line A (Figure 5.4), it is grassy. The center shown in Figure 5.5It is located in a former mining site and near to karst limestone at Jalan Kemubu-Dabong. The location also contain an area that had been digging maybe used as pool and a river. The time of conducting the survey is at 10.45 a.m. with a cloudy and rainy weather.

The result shown in Figure 5.6 showed the elevation of investigation from sea level is -20.0 meter. The root-mean-square errors (RMS) observed in the inverse resistivity model is 13.1% while in chargeability, the root-mean-square errors are much lower with 11.5%. The ranges of resistivity values is standardized for all three survey lines which are from 1.00 Ωm to 2000 Ωm. In addition, same as resistivity values, the chargeability values range is also standardized from 0.100 msec to 30.0 msec.

From the result of resistivity image, a color of green to brown is near to high resistivity values and mostly appeared on the upper part. It showed a medium reading between 30.0 Ωm to 500 Ωm may be refer as weathered rock and alluvium. In the chargeability reading, there is a reading between 1 msec to 2 sec which can be considered to have groundwater value. The highest resistivity reading is between 700 Ωm to 3000 Ωm is at the middle part and indicated by color of from orange to dark purple. The highest resistivity values can be interpreted as limestone bedrock which typically has a high value of resistivity due to it less ability to conduct electricity. The bedrock is assumed to have a displacement where a fault zone may occur. The top soil near to the bedrock is considered to be recharge zone, an area the water may enter. On the bottom part of the resistivity image result, the colors and values are same as the upper part which interpreted as alluvium soil or maybe weathered rock.

Figure 5.3: Line A

Figure 5.4: Line B

Figure 5.5: Centre for survey line 1

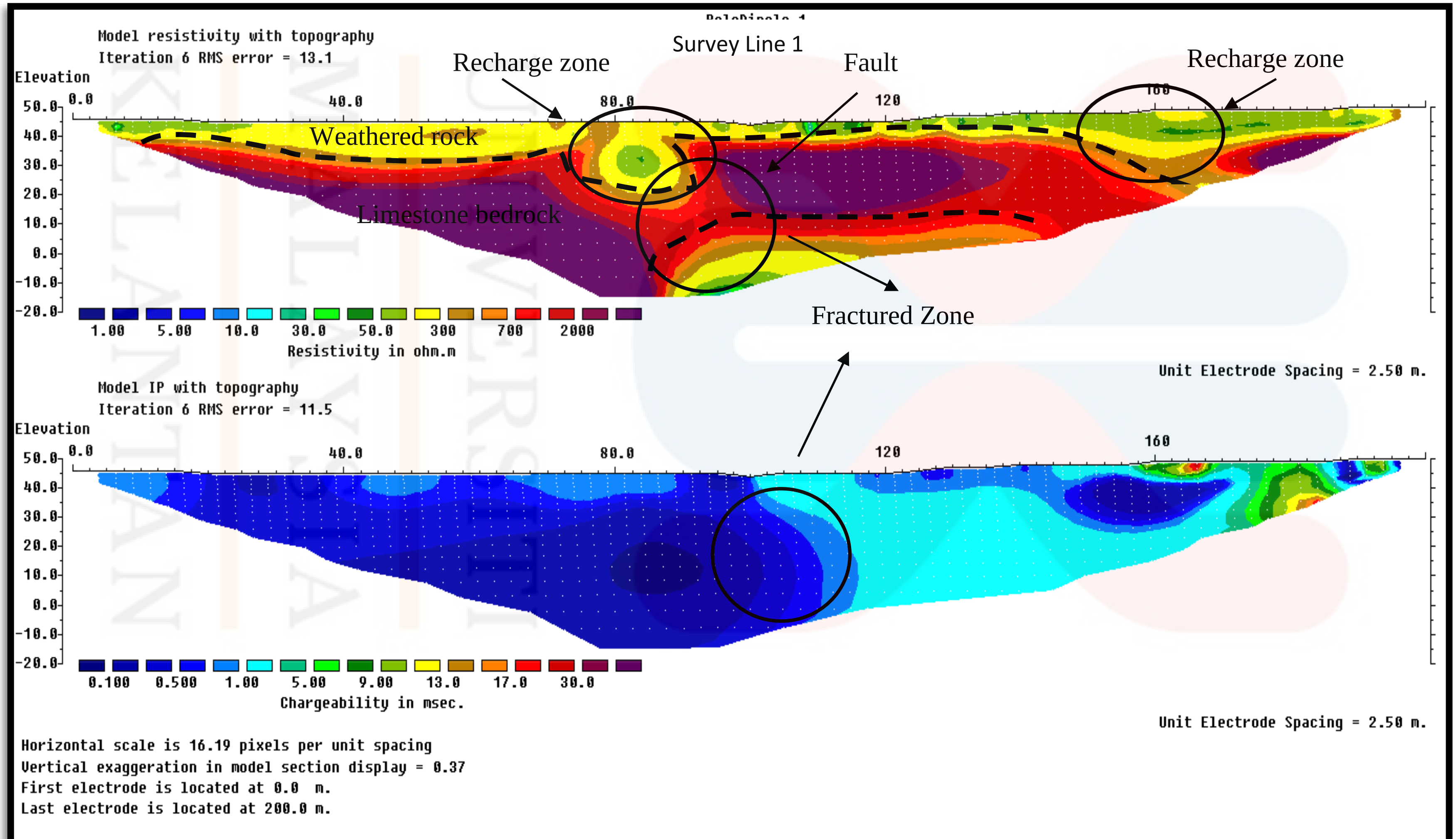


Figure 5.6: Inverse resistivity and chargeability model section for survey line 1

5.4 Electrical Resistivity Survey Line 2

Table 5.2 showed the coordinate of three electrodes used.

Table 5.2: The coordinate of three electrodes used in survey line 2.

Line	Electrode No.	Latitude	Longitude	Elevation (m)
A	1	N 5°19'26.741"	E 102°1'11.047"	55.0
C (Centre)	21	N 5°19'23.72"	E 102°1'11.181"	57.0
B	41	N 5°19'20.643"	E 102°1'10.822"	55.0

The time conducting for the electrical resistivity survey line 2 was around 12.30 p.m. with a cloudy and rainy day. The location of the survey is near to survey line 1 and the area is done close to main river of Sungai Galas on the west part of horizontal line. The survey line 2 is conducted in forest with only a few electrodes placed in bushy area as shown in Figure 5.7 and 5.8. The center of survey line 2 in Figure 5.9 is placed at open wide area

The elevation of investigation from sea level is 20.0 meter is showed in Figure 5.10. The root-mean-square errors (RMS) observed in the inverse resistivity model is 9.9% while in chargeability, the root-mean-square errors are much lower with 1.1%. The ranges of resistivity values and chargeability is standardized for all three survey lines which are from 1.00 Ωm to 2000 Ωm and from 0.100 msec to 30.0 msec.

For the result of survey line 2 as showed in Figure 5.10, the upper part mainly consisted of the highest resistivity reading between 700 Ωm to 3000 Ωm with the represented color of orange to dark purple but as is on the surface it considered weathered rock. The chargeability showed a value of 0.5 msec to msec that indicated clay and water and 4.00 msec to 9.00 msec that indicated gravels. By refer to value of chargeability, there might be potential zone of fracture as it contain water. The bottom part of the result in the figure also composed of same color and had the highest resistivity values same as the upper part. Both part is interpreted as limestone bedrock and seemed to surround the middle part of the result survey line 2. The medium resistivity reading is between 50 Ωm to 500 Ωm and the color that indicated this values are green to brown which mostly dominated in the middle part. It can be clarified as compacted alluvium soil as it being flanked by the weathered rock and limestone bedrock. The value of chargeability showed 1 msec to 2 msec reading that indicated water potential.

Figure 5.7: Open area with trees and bushes.

Figure 5.8: Line B in bushes area.

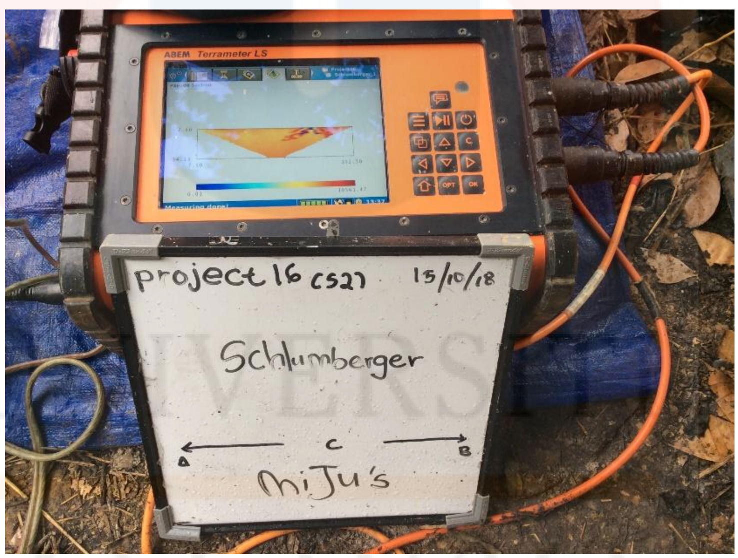


Figure 5.9: Centre of survey line 2

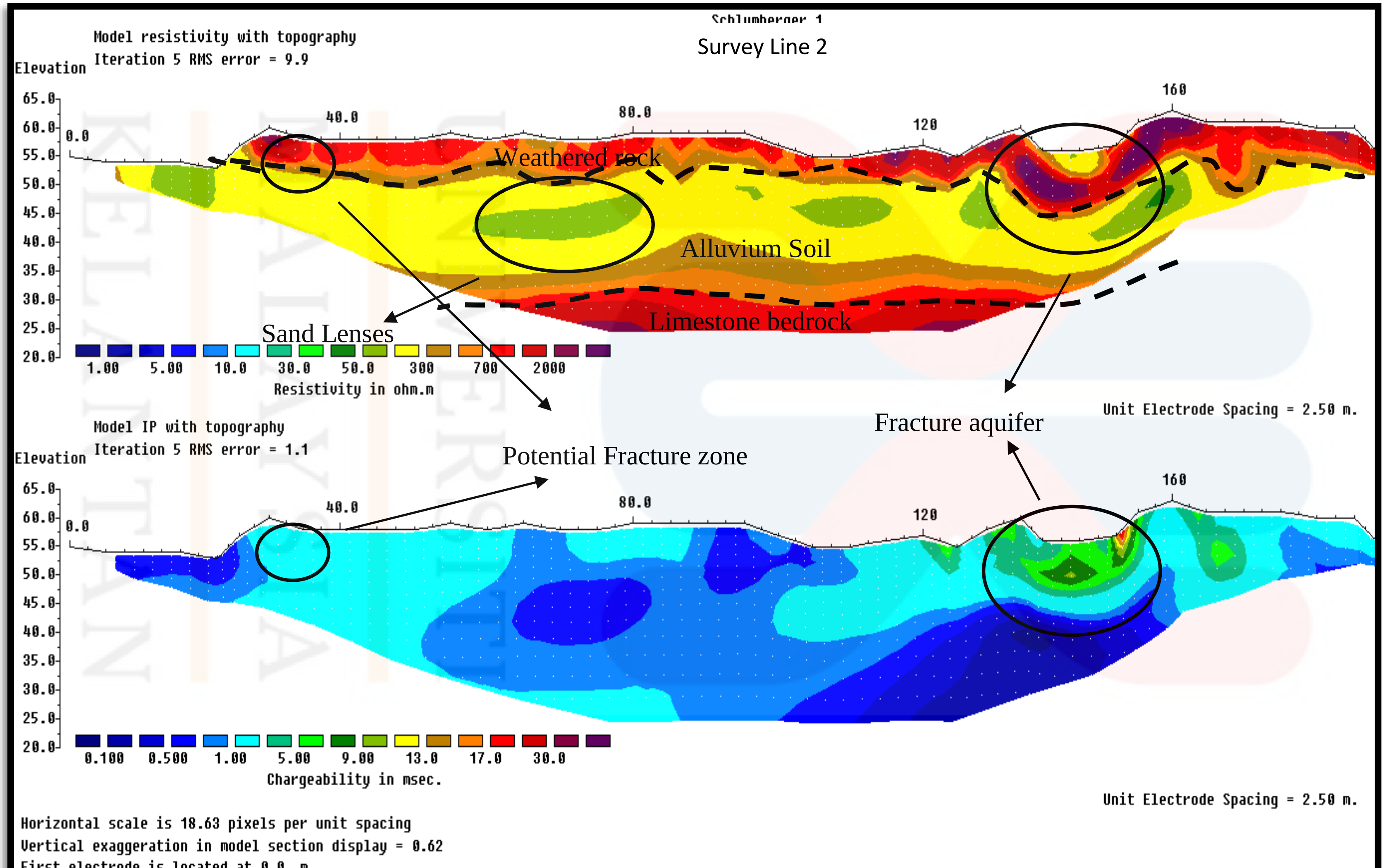


Figure 5.10: Inverse resistivity and chargeability model section for survey line 2

5.5 Electrical Resistivity Survey Line 3

Table 5.3 showed the coordinate of three electrodes used.

Table 5.3: The coordinate of three electrodes used in survey line 3.

Line	Electrode No.	Latitude	Longitude	Elevation (m)
A	1	N5°21'10.365"	E102°1'41.706"E	59.0
C (Centre)	21	N 5°21'7.317"	E 102°1'42.847"	60.0
B	41	N 5°21'4.308"	E 102°1'43.794"	53.0

The area conducted for electrical resistivity survey line 3 is near karst limestone called Gua Keris and Gua Ikan. The time conducting for the electrical resistivity survey line 2 was around 3.15 p.m. (Figure 5.14) with a clear and sunny condition. The survey line 2 is conducted in bushy area as in Figure 5.12 and Figure 5.13 where the only open space area (Figure 5.11) is the placement of center electrode.

The elevation of investigation from sea level is 20.0 meter as showed in Figure 5.15. The root-mean-square errors (RMS) observed in the inverse resistivity model is 5.3%. In chargeability, the value of root-mean-square errors are much lower with 0.82%. The ranges of resistivity values and chargeability is standardized for all three survey lines to have same reading values.

This line 3 is divided into two part. The highest resistivity values showed a reading scale from 700 Ωm to 3000 Ωm. The color represented for values are orange to dark purple where it can be interpreted as a limestone bedrock that has least conductivity. This highest resistivity is distributes half of the resistivity result. Furthermore, the upper part or the other half part of this line 3 has a medium resistivity readings between 60 Ωm to 600 Ωm.

The color indicated the medium resistivity values are green to brown which interpreted as weathered rock. The water potential value from the chargeability of 1 msec to 2 msec can only be found on the middle of upper part at the elevation of 60.0 m to 120.0 m and 125 m to 160.0 m. The overlain between the values of medium resistivity reading with the chargeability of water potential showed that it can be assumed as potential of water on weathered zone.

Figure 5.11: Open area in survey line 3

Figure 5.12: Line A in bushes area

Figure 5.13: Line B in bushes area

Figure 5.14: Centre of survey line 3

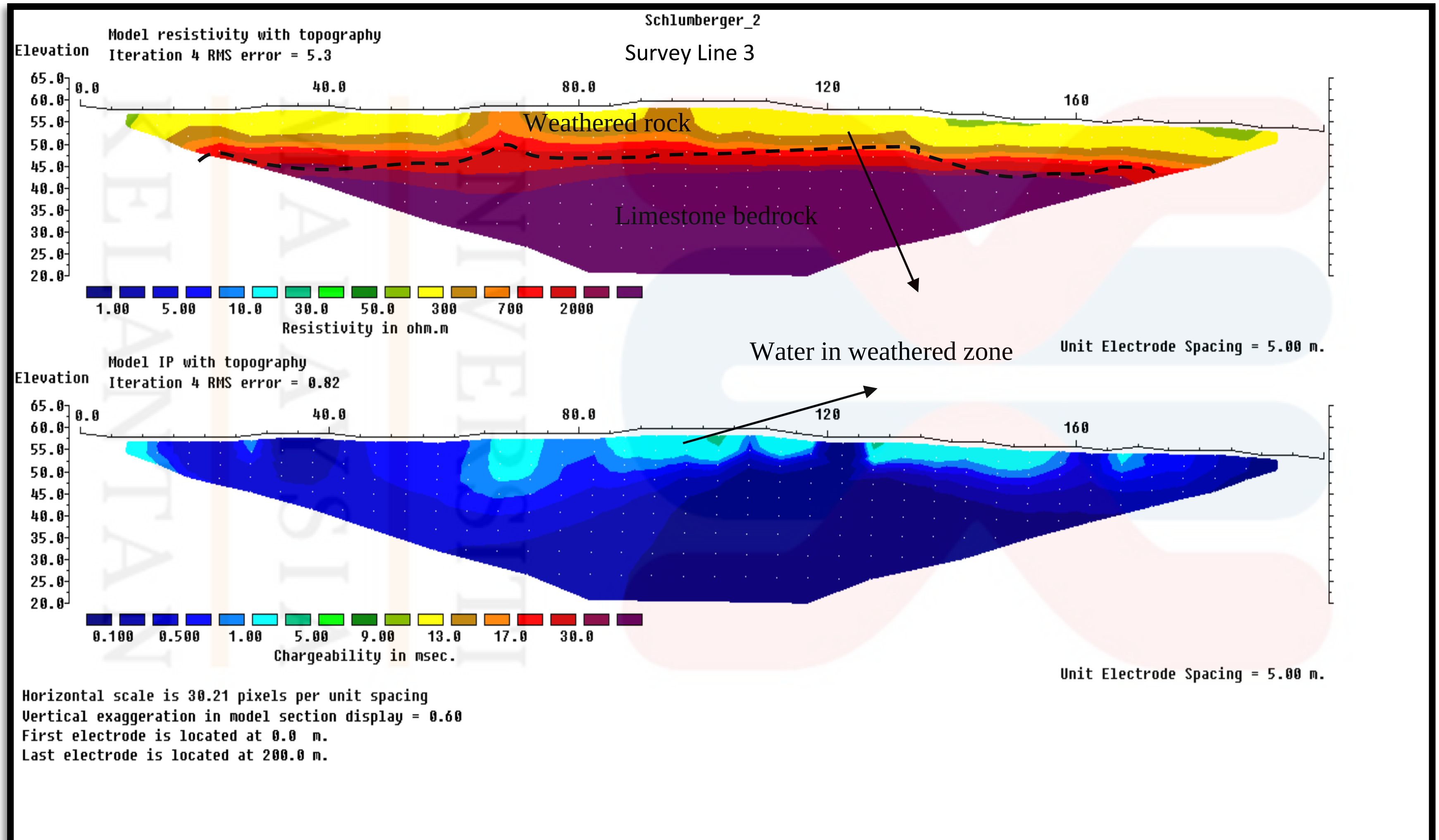


Figure 5.15: Inverse resistivity and chargeability model section for survey line 3

5.6 Discussion

According to the three survey lines, there are relationship between resistivity and conductivity. According to Juanah et al., 2012, induced polarization has a capability in differentiate groundwater from water in clayley soil. The value of chargeability that shows groundwater is 1 msec to 2 msec. According to Azwan et al. (2015), the reading of fracture aquifer is using the combination of resistivity and induced polarization analysis. The induced polarization is read as chargeability. Interpretation for this survey line also use the same method but it is for groundwater potential.

For the three lines, the highest resistivity values is dominated by the limestone bedrock which causing it to have low conductivity. The bedrock is surrounded by alluvium soil and weathered rock which have finer materials on top of layer but at the bottom, it is coarser. The limestone bedrock is assumed to have fractured zone because the shape of the bedrock indicates a fault occurrence exist there. The alluvium soil in survey line 2 can be considered as fracture aquifer as water enter from the ground surface directly through above the aquifer. On the surface of weathered rock, it can considered as potential fracture zone as the chargeability value show contain of water. The alluvium soil has resistivity values between 60 Ωm to 600 Ωm. In survey line 3, it can be assumed the upper part of the surface have potential of water as water can seeps through into weathered rock. For groundwater, it consists of lower resistivity and high conductivity value.

In survey line1, the lithology is assumed as limestone as it near to a karst limestone and small river. It is done opposite from the lineament of Galas River or any structure at the study area. The soil condition is gravel at line A and rock pebble at line B. For survey line 2, it is not far away from the place of survey line 1. The assumed bedrock is also limestone. It is done beside Galas River and followed the lineament of it. The soil is considered as alluvium and weathered rock. The survey line 3 is also done near the karst limestone of Gua Ikan and the surface is considered weathered rock. The area is surrounded by hill of oil palm plantation (Figure 4.3). Both place of survey line 2 and 3 have no sign of structure.

Based on the result of interpretation, from the combination value of resistivity and induced polarization, it assumed that this survey site has a potential groundwater water but in weathered zone, fractured zone and fracture aquifer. The line that has good potential is line 1 and 2 which in fracture and aquifer zone. As a conclusion, the geophysical analysis using electrical resistivity method is useful to detect and determine the potential of groundwater.

CHAPTER 6

CONCLUSION & SUGGESTION

6.1 Conclusion

This chapter will conclude all the results done from general geology mapping to electrical resistivity survey. The first objective of this research is to produce geological map of the study area to 1:25,000 scale. The map was updated by identifying the lithologies and stratigraphy column present in the study area. The structure, geomorphology, lithology and other relate characteristic were identified in the study area. The study area consists of phyllite, schist, limestone and sandstone. In stratigraphic column, phyllite, schist and sandstone are included in Taku Schist while limestone is in the Gua Musang Formation. Andesite is an extrusive igneous which may come from Telong Formation that overlies with Gua Musang Formation. The formation of foliation on andesite has showed that it undergone metamorphism and andesite is not highly distributed in the study area. The structures found were lineament, joint, quartz vein and fold. There was only one type of drainage in the study area which is dendritic pattern. The geomorphology in the area is basically hill and plain landform with karst landform on the southwest of the map.

For the specification research, a geophysical survey known as electrical resistivity method is used. There were two types of configuration array used which are pole-dipole and Schlumberger. The method was conducted by using ABEM Terrameter SAS 4000 with Electrode Selector equipment. For analysis and interpreting result, RES2DINV software was used in this research. Based on the final result and interpretation, it indicates the study area has a potential of groundwater in fracture aquifer, fracture zone and weathered zone by refer to chargerability. According to the three inverse resistivity and chargeability value, all of the three survey lines have high resistivity value of bedrock.

6.2 Suggestion

This successful result of this survey shows the resistivity survey is reliable for identifying groundwater potential zone in the study area. The finding of fracture aquifer and water in weathered zone may relate to groundwater potential. Therefore, this research should be continued for further investigation in the fracture zone, fracture aquifer and in weathered zone. Drilling is one of the method that can be done for more detailed information of the subsurface where both data between drilling logging and resistivity can correlate. This can justify the presence of groundwater potential in the study area. These research and data can be used as a references and guideline for practitioners and other researchers who maybe conduct same method or projects.

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APPENDICES

Appendix 1: Bearing readings for lineament analysis.

No.	Bearing (°)	No.	Bearing(°)	No.	Bearing(°)
1.	165	11.	160	21.	10
2.	60	12.	100	22.	140
3.	170	13.	120	23.	165
4.	165	14.	55	24.	60
5.	140	15.	165	25.	165
6.	140	16.	167	26.	170
7.	100	17.	167	27.	140
8.	10	18.	55	28.	100
9.	100	19.	100	29.	160
10.	115	20.	115	30.	120

Appendix II: Joint reading.

No.	Strike (º)	No.	Strike (º)	No.	Strike (º)
1.	190	11.	124	21.	133
2.	220	12.	126	22.	142
3.	217	13.	130	23.	168
4.	192	14.	122	24.	24
5.	178	15.	124	25.	48
6.	164	16.	146	26.	36
7.	162	17.	208	27.	300
8.	144	18.	212	28.	302
9.	138	19.	198	29.	296
10.	146	20.	140	30.	298