FYP FSB

GEOLOGICAL MAPPING IN GUA MUSANG AND EVALUATION OF SEAWATER INTRUSION IN SHALLOW AQUIFER OF KEMUMIN, KOTA BHARU USING INTEGRATED GEOPHYSICAL & GEOCHEMICAL METHODS

By

ATHIRAH BINTI TARIQ UMAR

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

FACULTY OF EARTH SCIENCE

UNIVERSITI MALAYSIA KELANTAN

2019

UNIVERSITI MALAYSIA KELANTAN

FYP FSB

DECLARATION

I declare that this thesis entitled “Geological Mapping In Gua Musang and Evaluation of Seawater Intrusion In Shallow Aquifer of Kemumin, Kota Bharu Using Integrated Geophysical & Geochemical Methods” is the results of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree,

Signature :

Name : ATHIRAH BINTI TARIQ UMAR

Date :

UNIVERSITI
MALAYSIA
KELANTAN

FYP FSB

APPROVAL

"I hereby declare that I have read this thesis entitled "Geological Mapping In Gua Musang and Evaluation of Seawater Intrusion In Shallow Aquifer of Kemumin, Kota Bharu Using Integrated Geophysical & Geochemical Methods" and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Applied Science (Geoscience) with Honours"

Signature : …………………………….........

Name of Supervisor I : DR. MOHAMMAD MUQTADA ALI KHAN

Date : ………………………………..

UNIVERSITI
MALAYSIA
KELANTAN

ACKNOWLEDGEMENT

First and foremost, I would like to express greatest gratitude to Allah Almighty who enabled me to complete my thesis smoothly.

Then, I have to thank my supervisor, Dr Muqtada Ali Khan. Without his help and dedicated involvement in each step throughout the process, this thesis would have never been accomplished. I would like to thank him for the support and understanding over these past years.

I would also like to express my gratitude to laboratory assistants of Universiti Malaysia Kelantan for their endless help regarding laboratory matters. Without their help, my thesis would be in hiatus. Their huge contribution in finishing this thesis would be remembered to the end.

Besides academic support, I have a lot of people to thank for listening to and tolerate me over the duration of doing the final year project. I would also like to show my gratitude and appreciation for my friends who has been a great help throughout the whole process; Nur Syazana Md Saliman, Anis Syahira Mohd Mozli, Aimie Aisyah Othman, Muhammad Khairul Hakim Mohd Helmi, Thilageswwaran,a/l Vellu and Nariendiran a/l Mohan.

Most importantly, none of this could have happened without my beloved family. My parents, Tariq Umar Mohamed and Harryati Rofik including my siblings who offered their encouragement and support all the times. Being kind and supportive to me over the years has been a great help on moral support. This thesis stands as a proof to all of the unconditional love and encouragement.

FYP FSB

UNIVERSITI MALAYSIA KELANTAN

GEOLOGICAL MAPPING IN GUA MUSANG AND EVALUATION OF SEAWATER INTRUSION IN SHALLOW AQUIFER OF KEMUMIN, KOTA BHARU USING INTEGRATED GEOPHYSICAL & GEOCHEMICAL METHODS

FYP FSB

ABSTRACT

This study focus on geological mapping of Lojing, Gua Musang and evaluation of seawater intrusion in shallow aquifer of Kemumin, Kota Bharu that is located near the shoreline using integrated geophysical and geochemical methods. Geological map was produced on 1 : 25,000 scale by conducting traversing, field observation and petrographic study. Lithology mainly composed of mudstone, quartzite and alluvium unit in the study area. Meanwhile, seawater intrusion in shallow aquifers can pose serious issue as it can be considered as contamination of groundwater. Therefore, integrated approach is applied using Electrical Resistivity Imaging (ERI) method was used by using ABEM Terrameter LS of 200 meter line with 41 electrodes and 5 meter spacing to produce a 2D imaging of the subsurface using RES2DINV software. The aforementioned method than was integrated with in situ geochemical analysis to gather data with the parameters such as pH, temperature, salinity, turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and Electrical Conductivity (EC) and laboratory analysis such as Atomic Absorption Spectroscopy (AAS) and titration analysis in five well locations. A total of three survey line were conducted by applying Wenner, Schlumberger and Pole-dipole array. Based on resistivity profile, only two locations of survey line showing seawater intrusion at approximately 5 to 20 meter depth. Meanwhile, all the groundwater samples are safe to use as the graphical data was compared with the National Guideline of Raw Water Quality Standards by Ministry of Health Malaysia. From the chemical result, samples collected near the shoreline (AT1, AT3, AT7 and AT8) show high salinity value.

Keyword: Sea Water Intrusion, Shallow Aquifer, Geological Mapping, Kemumin, Kelantan

UNIVERSITI MALAYSIA KELANTAN

PEMETAAN GEOLOGI DI GUA MUSANG DAN PENILAIAN PENCEROBOHAN AIR LAUT DALAM AKUIFER CETEK DI KEMUMIN, KOTA BHARU MENGGUNAKAN INTEGRASI KAEDAH GEOFIZIKAL & GEOKIMIA

ABSTRAK

Kajian ini memberi tumpuan kepada pemetaan geologi Lojing, Gua Musang dan penilaian pencerobohan air laut di akuifer cetek Kemumin, Kota Bharu yang terletak berhampiran garis pantai menggunakan kaedah geofizik dan geologi bersepadu. Peta geologi dihasilkan pada skala 1: 25,000 dengan melakukan perjalanan, pemerhatian lapangan dan kajian petrografi. Lithology terutamanya terdiri daripada mudstone, quartzite dan unit alluvium di kawasan kajian. Sementara itu, pencerobohan air laut dalam akuifer cetek boleh menimbulkan isu yang serius kerana ia boleh dianggap sebagai pencemaran air bawah tanah. Oleh itu, pendekatan bersepadu yang digunakan menggunakan kaedah Pengimejan Ketahanan Elektrik (ERI) telah digunakan dengan menggunakan ABEM Terrameter LS dengan garis 200 meter dengan 41 elektrod dan jarak 5 meter untuk menghasilkan pengimejan 2D bawah permukaan menggunakan perisian RES2DINV. Kaedah yang disebutkan di atas disepadukan dengan analisis geokimia in situ untuk mengumpul data dengan parameter seperti pH, suhu, salinitas, kekeruhan, Total Solved Solids (TDS), Total Suspended Solids (TSS) dan Electrical Conductivity (EC) sebagai Spektroskopi Penyerapan Atom (AAS) dan analisis titrasi di lima lokasi yang baik. Sebanyak tiga garis kaji selidik dijalankan dengan menggunakan array Wenner, Schlumberger dan Pole-dipole. Berdasarkan profil rintangan, hanya dua lokasi kaji selidik yang menunjukkan pencerobohan air laut di kedalaman kira-kira 5 hingga 20 meter. Sementara itu, semua sampel air bawah tanah adalah selamat untuk digunakan kerana data grafik dibandingkan dengan Standard Kualiti Air Mentah Kebangsaan oleh Kementerian Kesihatan Malaysia. Dari hasil kimia, sampel yang dikumpulkan berhampiran garis pantai (AT1, AT3, AT7 dan AT8) menunjukkan nilai kemasinan yang tinggi.

Kata Kunci: Pencerobohan Air Laut, Akuifer Cetek, Pemetaan Geologi, Kemumin, Kelantan

FYP FSB

UNIVERSITI MALAYSIA KELANTAN

FYP FSB

TABLE OF CONTENT

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

LIST OF TABLES

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

LIST OF FIGURES

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
AKSB	Air Kelantan Sdn. Bhd.
EC	Electrical Conductivity
ERI	Electrical Resistivity Imaging
GPS	Global Positioning System
IP	Induced Potential
MLD	Millions of Liter per Day
MOH	Ministry of Health Malaysia
ORP	Oxidation-Reduction Potential
SP	Self -Potential
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
WHO	World Health Organization

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

LIST OF SYMBOLS / UNITS

%	Percentage
Z	Depth of freshwater below sea level
ρ	Density
ρ_a	Apparent resistivity
Ω	Ohm unit
σ_1	Major tectonic force
$°C$	Degree Celcius
µS	Micro Siemens
<	Less than
mg	Milligram per litre
NTU	Nephelometric Turbidity Unit
ppt	Parts per thousand

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Water plays a key role in nature and one of life's fundamental striving requirements. Moreover, water is needed for any progressive labour and the need to develop a community whether small or large. Nowadays, the important way on how we approach the subject of water especially on how we use it and its sustainability has become increasingly convoluted due to population growth, urbanization and industrialization. Any improvement and development can majorly be affected either directly or indirectly with how we exploit water usage (Hinrichsen, 2007).

Generally speaking, nearly two-thirds of the world's population lives 400 km inland from the ocean shores, an area that only accounts for 10 percent of the complete surface of the earth (Hinrichsen, 2007). These coastal areas, in addition to surface water such as lakes and rivers, rely mostly on groundwater as their primary source of freshwater supply for agricultural, industrial and domestic reasons. Groundwater can be a better substitute from surface water if it's not profitable and it has less exposure to contamination in a particular area, and if it has enough supply and ideal quality.

Based on the information supplied by the Malaysian Statistics Department, the climate in our country is tropical and receives more than 2,800 mm of rainfall per year which is a great contributor in recharging the groundwater supply beneath the water table. Thus, making the

FYP FSB

groundwater storage quantity up to 5,000 billion m^3 (Tawnie et al, 2016). Currently, the northern part of Kelantan uses groundwater as the main source of water supply for domestic use or irrigation purposes. Kota Bharu district is coastal area which particularly known as the area that undergoes on of the most developed that undergoes a lot of changes over time right after Malaysia were liberated from the British colonialism with increasing industrialisation, urbanisation and population growth. These development including the rise in need for water consumption may largely contribute to exploitation and uncontrolled usage that can cause contamination to the aquifers.

Seawater intrusion is a type of groundwater contamination especially near the shorelines area or coastal aquifers by interfering its chemical equilibrium and physical properties. In another words, it is the subsurface movement of seawater or saline water into freshwater aquifer caused by a lengthened changes in coastal groundwater levels due to extraction or pumping, climate variations, land-use change or sea-level fluctuations. These freshwater supply in coastal aquifers is very vulnerable to deterioration because of its close distance to seawater combined with the extreme water demands from the ever increasing population densities in coastal zones. The essential hindering impacts of seawater intrusion are decrease in the accessible freshwater supply volume and tainting of production wells, whereby under 1% of seawater (approximately 250 mg/L chloride according to WHO, 2010) renders freshwater unsuitable for drinking (Werner et al, 2010).

For this particular case, there are various methods/techniques that can be used to detect these groundwater contaminations. Geophysical methods and geochemical methods are the technique that is commonly used for the investigation of the contaminant.

FYP FSB

1.2 Problem Statements

Climate change and extreme weathering can alter the geomorphological settings of an area. Therefore, it is important for further research and field assessment is needed to be conducted to provide fresh, updated information on the geological settings of the affected area. Natural phenomenon driven by climate change and global warming may have altered the local condition of the soils, causing a high rate of weathering and mass transportation of sediments thus exposing more fresh outcrops or covering a large area of earth surface with different type of sediment. For an instance, the major flood on 2014 that occurred in Malaysia, as Kelantan was one of the state that was largely impacted, causes a huge swath of sand mixed with other sediments to be transported to another area inland right after the flood subsided.

High development rates in populace, expanding water utilization, and water contamination are among the variables which are putting weight on water assets. Thus, any new advancement of water assets and enhancement in water administrations ought to be discovered instantly to take care of the expanding water demand. Interferences in administrations and different disappointments in water industry are a dubious issue in Kelantan. The ninth Malaysia Plan expresses that Kelantan is positioned thirteenth in Malaysia dependent on advancement composite file by state and an expansive offer of the populace lives in country regions. A couple of states which are less created in Malaysia battle to enhance water inclusion for the most part in provincial territories including Kelantan. Currently, total groundwater consumption is 134 MLD, which represents about 41% of total water production in the water treatment plants of AKSB. The 2.5 percent increase per year suggests that demand for potable groundwater would be around 210 MLD in 2020, rising to 270 MLD in 2030 (Rainhill Consulting Sdn. Bhd., 2011).

FYP FSB

Nowadays, there is an excessive rate of groundwater pumping for domestic and industrial usage in Kelantan due to high demand that causes the over. Groundwater pumping may reduce the quantity of fresh water flowing into coastal discharge fields by enabling salt water to be drawn into coastal aquifer freshwater zones owing to the imbalance in water flow gradient. Therefore, the amount of fresh water stored in the aquifers is decreased (Barlow, 2003). Due to this, it is imperative to monitor the seawater intrusion into freshwater aquifer as it causes a decline in the quality of the groundwater according to appropriate standard usage.

1.3 Objectives

- To produce a geological map of Gua Musang, Kelantan using the scale of 1 : 25,000.
- To evaluate the seawater intrusion into groundwater based on the 2D imaging of resistivity data.
- To analyse coastal groundwater quality of shallow domestic wells.

1.4 Study Area

For this research, the study area is important to be determined in order to conduct the assessment and research purposes in accordance to its suitability with the research title.

1.4.1 Location

The study area which is the area to be conducted of the geological mapping and petrographic studies is situated in Gua Musang district, which covers 25 km^2 near the indigenous village community of Kuala Betis, and Sungai Beruk travel through the middle of the box at $4°50' N, 101°47' E$ with elevation of 178 m which can be seen based on Figure 1.2.

FYP FSB

Gua Musang is located in southern Kelantan, Malaysia, a city, neighborhood and parliamentary constituency. It's Kelantan's biggest district. The district of Gua Musang is bordered on the south by the state of Pahang, on the east by Terengganu, on the west by Perak and on the north by the districts of Kuala Krai and Jeli. It is about 140 km south of the state capital, Kota Bharu, a tiny railway town.

The study area in which Electrical Resistivity Imaging (ERI) survey and in-situ hydrochemical analysis to be conducted is situated in Kota Bharu district, based on Figure 1.3, in the north-eastern part of Peninsular Malaysia, and lies near the mouth of the Kelantan River at 6°8′N 102°15′E and is situated at elevation 10 meters above sea level thus making it very close to the shoreline. The north-eastern Malaysian city is close to the Thailand border. Based on what can be observed on the map, the specific study area located in Kemumin, the north-east part of Kota Bharu is in the coastal area with a few popular beaches among the locals.

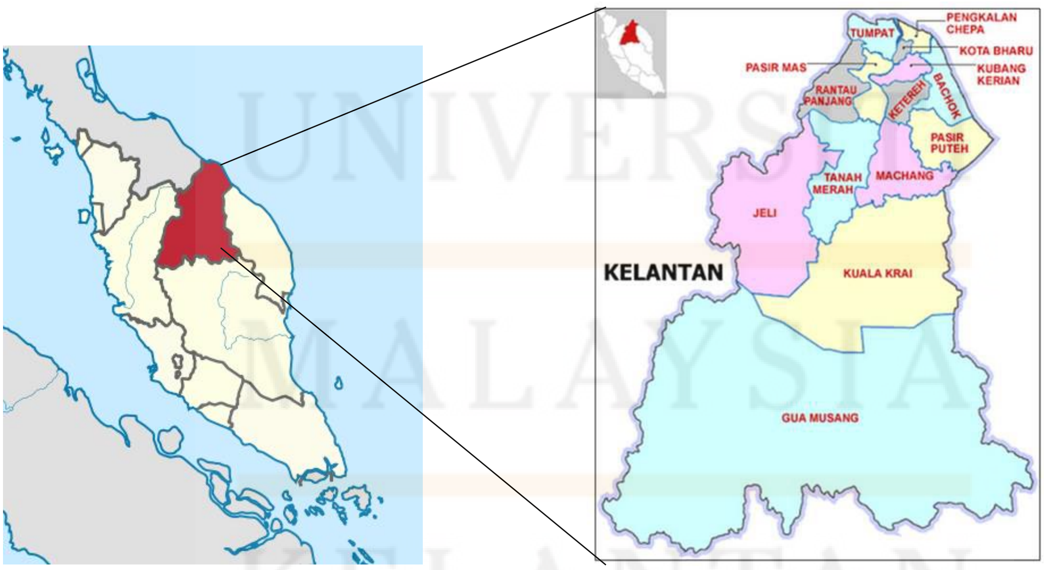


Figure 1.1: Map of Kelantans' districts distribution in Semenanjung Malaysia.

FYP FSB

FYP FSB

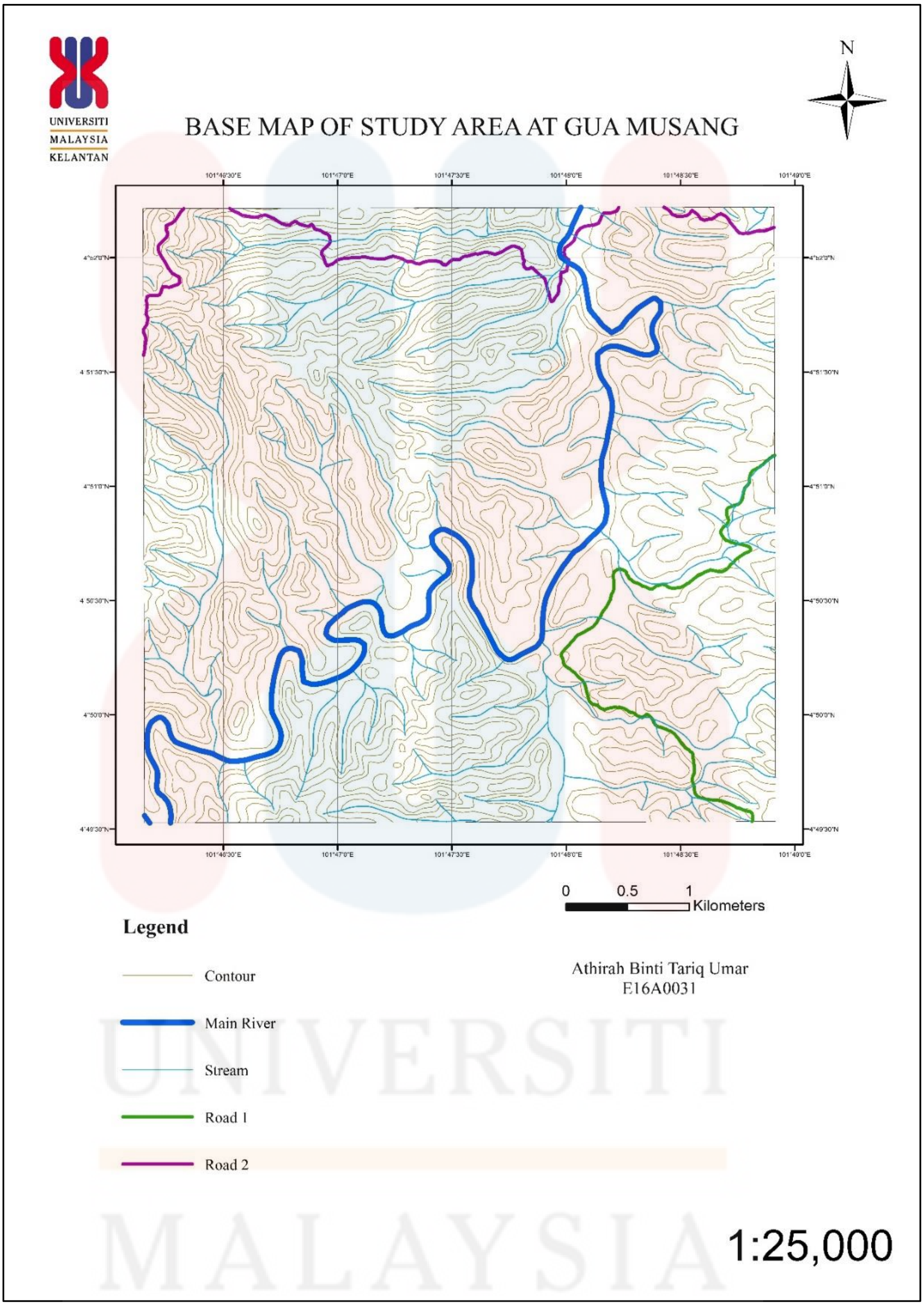


Figure 1.2: Base map of study area in Gua Musang, Kelantan for geological mapping

UNIVERSITI
MALAYSIA
KELANTAN

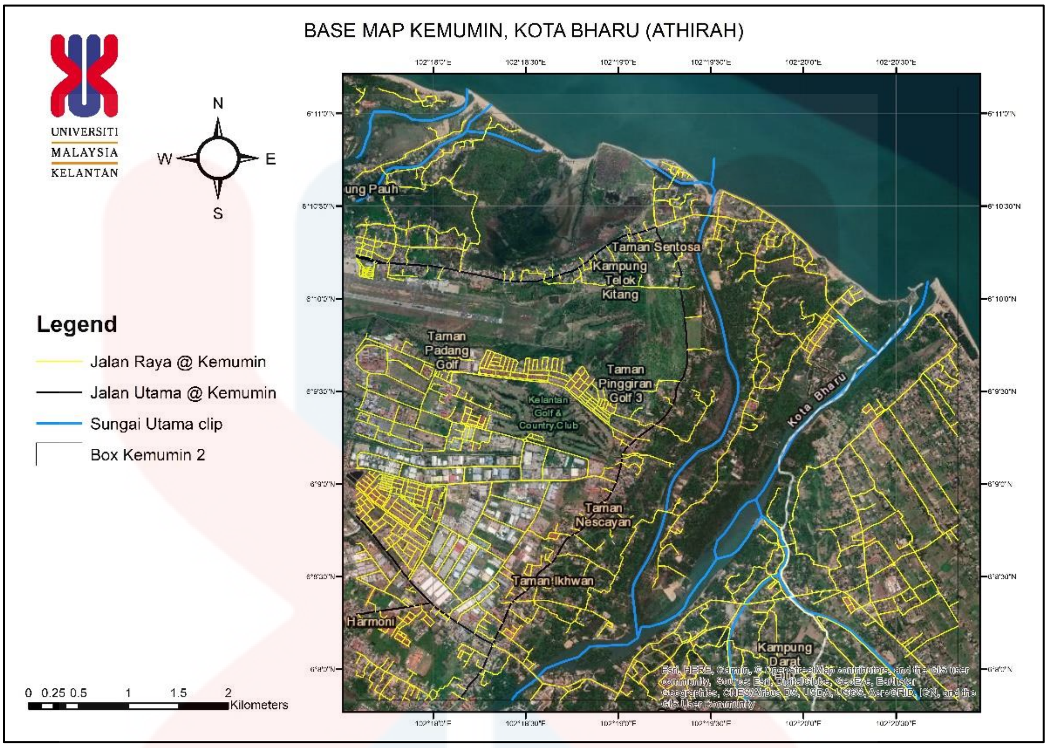


Figure 1.3: Base map of Kemumin, Kota Bharu for seawater intrusion evaluation

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

1.4.2 Demography

According to the data from Department of Statistics Malaysia, total population in Kelantan state is approximately 1.86 million people with citizens in Gua Musang and Kota Bharu total population of 90,057 people and 491,237 people respectively.

Besides that, major ethnics group in Kota Bharu is Malay including other indigenous that populated the district, with approximately 94.6% and followed by Chinese, Indians and other group of about 5.4%.

Moreover, major ethnics group in Gua Musang is Malay including other indigenous that populated the district, with approximately 94.6% and followed by Chinese, Indians and other group of about 5.4%.

Table 1.1: Total population by ethnic group

District	**Malaysian citizens**				**Non-Malaysian citizens**	**Total**
	Bumiputera	**Chinese**	**Indian**	**Others**		
Kota Bharu	434,917	22,444	1,320	1,199	8,558	90,057
Gua Musang	76,823	3,870	350	161	4,985	491,237

(Source: Department of Statistics Malaysia, 2010)

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

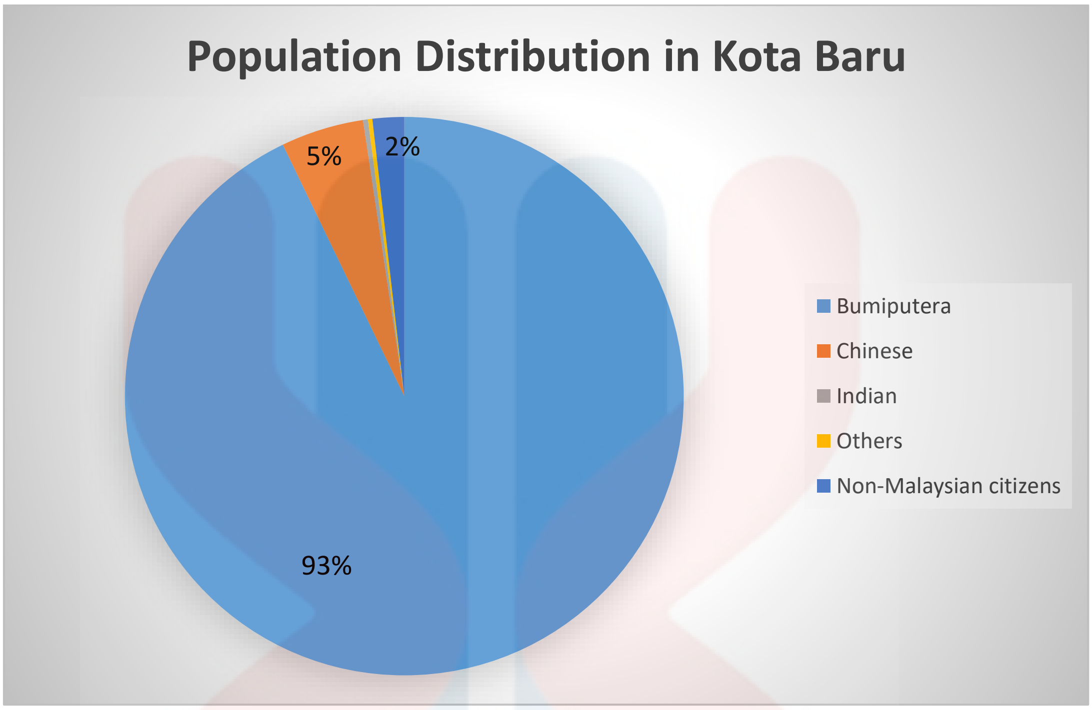


Figure 1.4: Total population by ethnic group in Kota Bharu

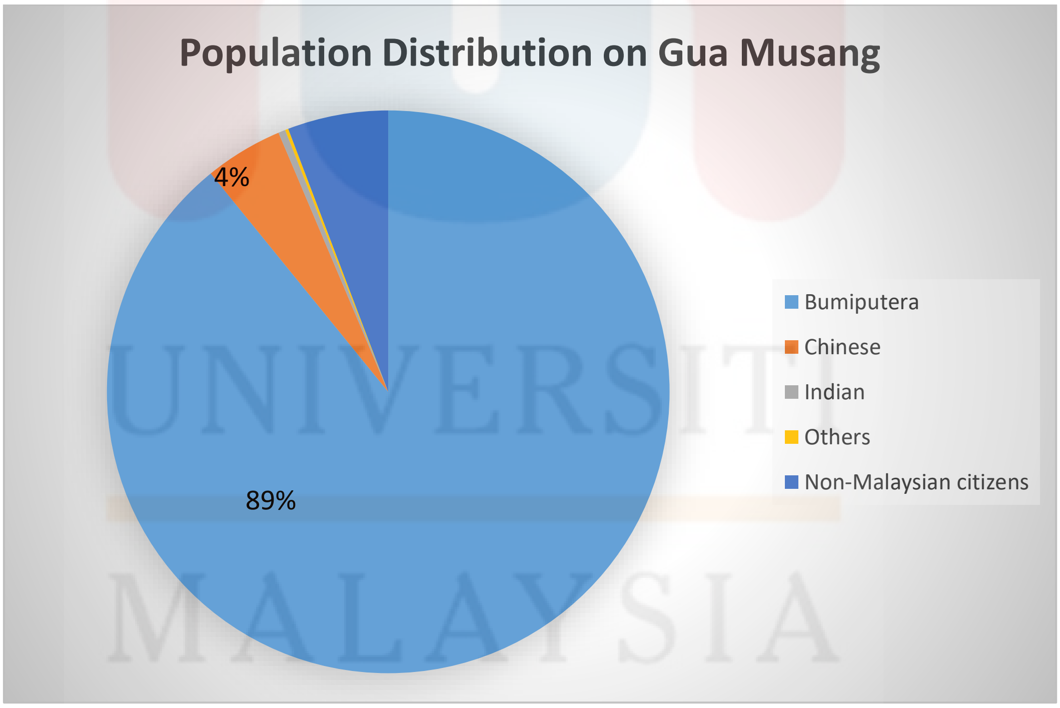


Figure 1.5: Total population by ethnic group in Gua Musang

(Source: Department of Statistics Malaysia, 2010)

FYP FSB

1.4.3 Rainfall Distribution

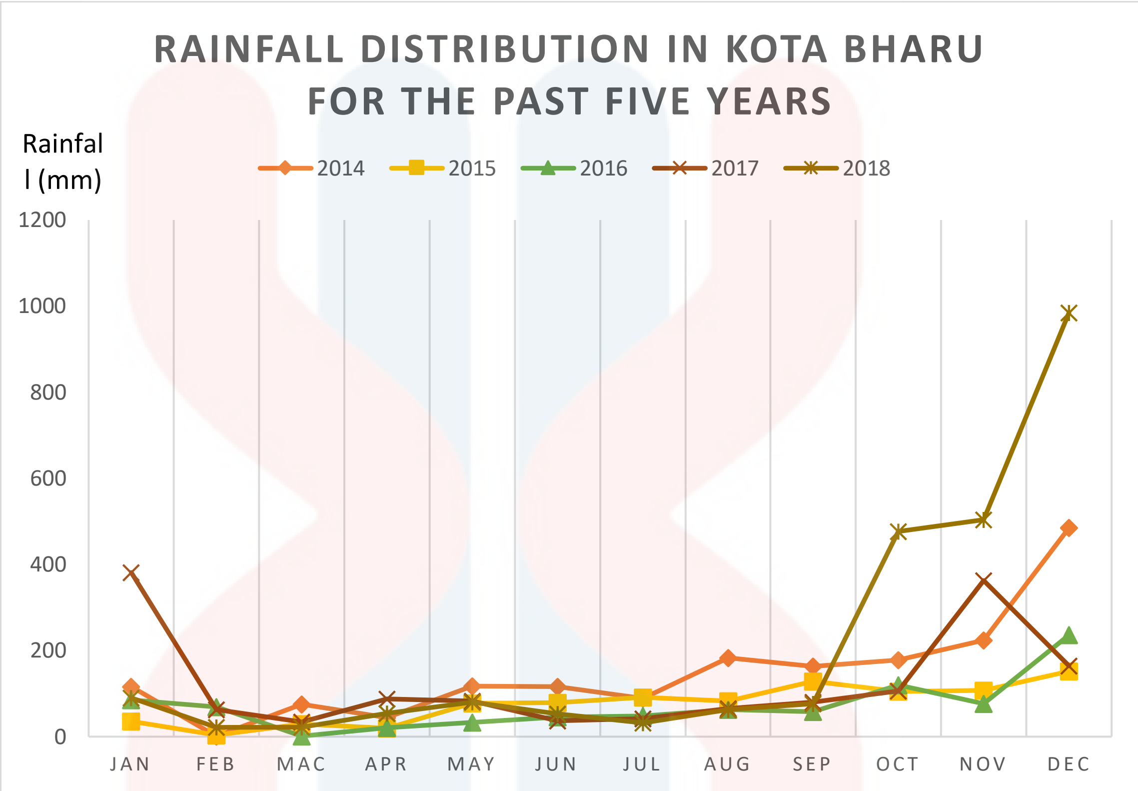


Figure 1.6: Rainfall distribution in Kota Bharu, Kelantan

Table 1.2: Rainfall distribution in Kota Bharu, Kelantan

	Year	**Month**												**Total**
		Jan	**Feb**	**Mac**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**(mm)**
Rainfall (mm)	2014	115.1	1.0	75.0	44.7	117.2	116.5	88.6	183.0	163.08	178.5	224.2	484.7	1,791.58
	2015	35.4	3.7	28.9	19.5	77.7	79.0	91.4	82.4	128.5	105.4	107.9	151.8	911.6
	2016	85.1	69.1	1.3	20.6	32.6	45.1	48.4	62.9	58.41	119.5	76.5	236.0	855.51
	2017	381.2	63.3	34.1	88.2	83.1	36.5	42.3	65.4	80.5	106.4	362.4	164.4	1,507.8
	2018	90.7	21.6	22.0	53.6	80.1	52.6	31.6	63.1	75.9	476.7	503.4	984.6	2,455.9

FYP FSB

Based on Figure 1.6, heavy rainy season's falls in the months of January, September, October, November and December for the past five years (2014 – 2018). On average, the highest precipitation (or the wettest month) is on December. Meanwhile, the lowest precipitation (or the driest month) is on February. Generally, the Kelantan state undergoes monsoon season starting from October until December. This was shown by the high amount of precipitation around those months compared to February until August. Therefore, the average amount of annual precipitation is 999.9 mm. Precipitation is one of the most essential way to recharge groundwater as it infiltrates the soil. This may balance the water table of the aquifer in order to maintain the amount of groundwater storage.

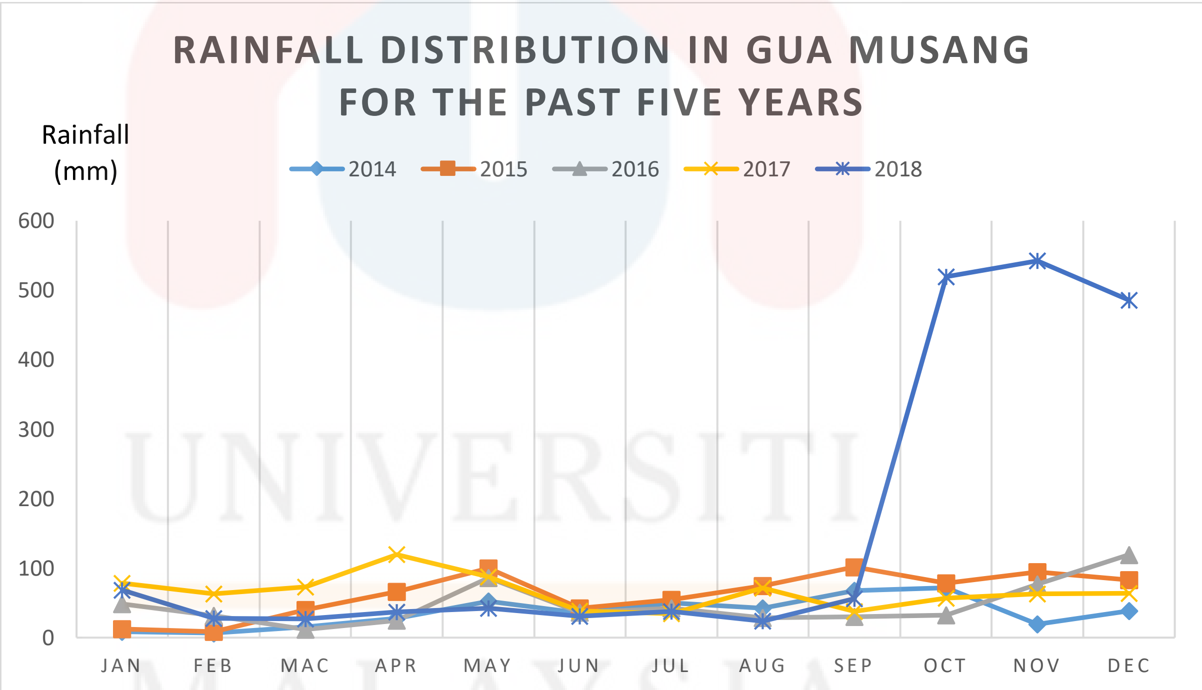


Figure 1.7: Rainfall Distribution in Gua Musang, Kelantan

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

Table 1.3: Rainfall distribution in Gua Musang, Kelantan

	Year	**Month**												**Total**
		Jan	**Feb**	**Mac**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**(mm)**
Rainfall (mm)	2014	8.54	6.65	15.69	27.55	52.07	35.37	49.87	42.24	67.45	71.75	19.56	38.42	419.47
	2015	12.67	8.52	39.86	65.89	99.79	42.2	54.4	74.44	101.65	78.51	94.25	82.62	754.8
	2016	48.48	31.72	11.79	24.78	86.32	36.18	42.67	28.75	30.28	32.51	76.49		569.37
	2017	78.61	63.01	72.94	119.52	87.21	38.67	34.45	71.63	37.57	56.69	62.67		786.99
	2018	68.28	28.09	26.83	36.75	42.06	30.93	37.74	23.69	55.77	519.3	542.3	485.8	119.4
														64.02

Gua Musang has a tropical climate, thus the rainfall in Gua Musang is significant, with precipitation even during the driest month. Based on Figure 1.7, rainy season's falls in the months of September, October, November and December. On average, the highest precipitation (or the wettest month) is on December. Meanwhile, the lowest precipitation (or the driest month) is on February. However, in the year 2018, there was a large peak in the rainfall amount from September until December indicating an unusual high amount of rainfall.

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

1.4.3 Land use

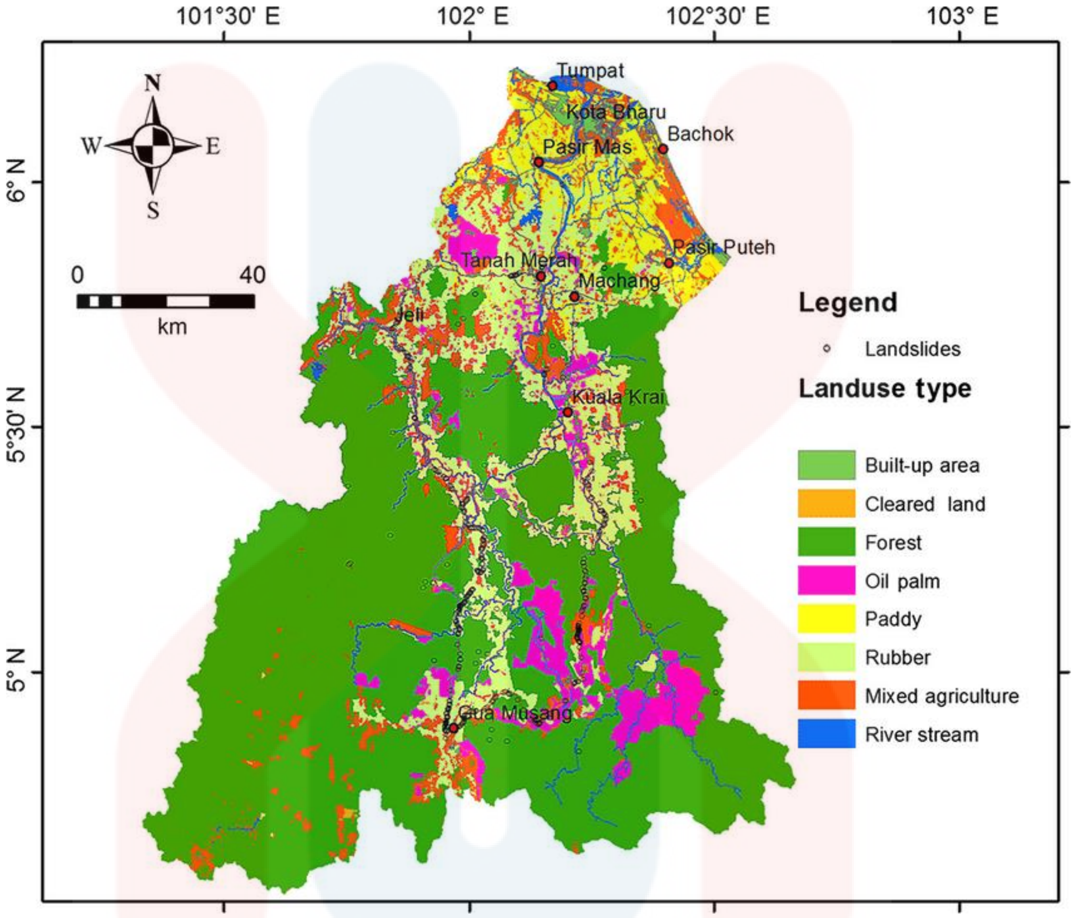


Figure 1.8: Land use/cover map of Kelantan (Pour, Amin & Hashim, Mazlan, 2017)

Based on Figure 1.8, total area of Kelantan state is approximately 17,100 km^2. Land use in Kelantan can be divided into two which are built up areas and non-built up areas. Built up areas cover about 35% indicated by the colour light green, orange, pink, yellow and mint green while non-built up areas cover about 65% shown in green. Built up areas are dominated by residential area, cleared land for future developments and agricultural activities. Meanwhile, non-built up areas are dominated by forests and jungles.

FYP FSB

1.4.4 Social Economic

Based on Lim, 2019, social economics can be defined as a type of economics that focuses on the relationship between social behaviour and economics. It inspects how social standards, morals, rising prevalent feelings, and other social theories impact customer conduct and shape open purchasing patterns. It utilizes history, recent developments, legislative issues, and other sociologies to anticipate potential outcomes from changes to society or the economy.

1.4.5 Road Connection/Accessibility

The study area in Kemumin, Kota Bharu can be easily access as well-developed roads are available. There are three types of roads in Kota Bharu that are interconnected between federal roads, state roads and small roads. This road connection was used by the people in Kemumin to access from one place to another.

The study area in Gua Musang has.moderate access as off-road vehicles are required to reach inside the study site. This is mostly because almost 60% of palm oil plantation covers the area and about 20% are difficult to access due to forest reserves area.

1.5 Expected Outcomes

By the end of this research, a latest and most recent geological map of Kuala Betis/Gua Musang area can be produced along with the identification of seawater intrusion in Kemumin, Kota Bharu.

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

1.6 Scope of Study

The scope of this research was to conduct the geological mapping in Gua Musang including investigate the petrographic properties of rock samples collected from fresh outcrops. Besides that, an electrical resistivity imaging (ERI) was conducted in a large area located in Kemumin, Kota Bharu to evaluate the seawater intrusion including other method to justify the resistivity result; water sampling from domestic groundwater well in shallow aquifer to record the in-situ chemical parameters. Lastly, hydrochemical analysis which includes the analysis of trace elements to detect the presence of chemical element in the groundwater was done in the laboratory.

1.7 Significance of Study

By conducting this research, the detailed analysis of general geology and structural geology of the area at Gua Musang and Kota Bharu will be useful to other geologists as a reference for further research including for development projects or for proper utilization of resources and many other geological purposes. This study helps in shallow aquifers along the coastline as seawater intrusion can easily occurred and one of the most common occurrences in groundwater contamination. This survey is one of the important way so as to reinforce the authorities to step up their methods in preventing the subsidence to occur in order to prevent further intrusion. Early actions may save cost and time. Lastly, this study also useful for future companies that might want to drill new wells in suitable locations to avoid future problems.

FYP FSB

CHAPTER 2

LITERATURE REVIEW

2.1 Regional Geology & Stratigraphy

Based on Hutchison 2009, Peninsular Malaysia is an integral part of the Eurasian Plate, the South-East Asian part of which is known as Sundaland. Kelantan is one of the state located in Malaysia, positioned at the north-east part of the Peninsular Malaysia, and covering an area of 15,099 km^2 with Thailand as the border in the north, Pahang to the south, Terengganu to the south-east and Perak to the west. Ten administrative states formed the state of Kelantan; Gua Musang, Kota Bharu, Kuala Krai, Tanah Merah, Bachok, Machang, Pasir Mas, Tumpat and Jeli (Ranhill Consulting Sdn. Bhd. 2011). The geological formation of Kelantan can be split into three main chronological era; Palaeozoic, Mesozoic and Cenozoic (Figure 2.1).

2.1.1 Palaeozoic

Some main formation in Kelantan located as part of the central zone; Gua Musang formation, Aring formation and Taku Schist. Gua Musang formation located in the southern portion of Kelantan consisting of calcareous-argillaceous series of crystalline calcareous with interbedded argillites, plus of sandstone and volcanics. This formation is the flanking equivalent of the Aring formation with estimation of 650 m in thickness for the unit in south Kelantan, dated from Late Carboniferous to Triassic age (Yee, 1983).

UNIVERSITI MALAYSIA KELANTAN
FYP FSB

Furthermore, there is the Aring formation in Sungai Aring area, also located at the south of Kelantan with the formation estimated to be 3,000 metres thick consists of predominantly of pyroclastics, minor lavas, dolomitic marble and argillite. The formation is thought to be dated to the range from Late Carboniferous to Early Triassic, an indication of the current fossils (Yee, 1983).

Meanwhile, Taku schist-an elongated body extending from the Thai border close Tanah Merah to the main west of Kelantan near Manik Urai, uncertain as its origin remains a dispute among geologists (Yee, 1983).

2.1.2 Mesozoic

The Mesozoic System in Peninsular Malaysia is distributed as separate basins, one on each side of the Main Range. The larger one is a continuous outcrop along the central belt of the Peninsular, stretching from the north of Kelantan to the south of Johor. The formations located at the axial belt which positioned in the Kelantan state is Aring formation, Gua Musang formation and Gagau group, dated from Permian to Triassic is dominated by carbonates with volcanics interbed and shallow marine clastics sediments.

2.1.3 Cenozoic

Cenozoic formation in Kelantan is primarily represented by the sedimentary deposits of the Quaternary. This quaternary sedimentary deposit generally covers Kelantan's northern part and consists of unconsolidated and semi-consolidated rocks, gravel, sand, silt and clay. The coastal area, the inland plain as well as the infilled valleys are underpinned by these sediments.

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

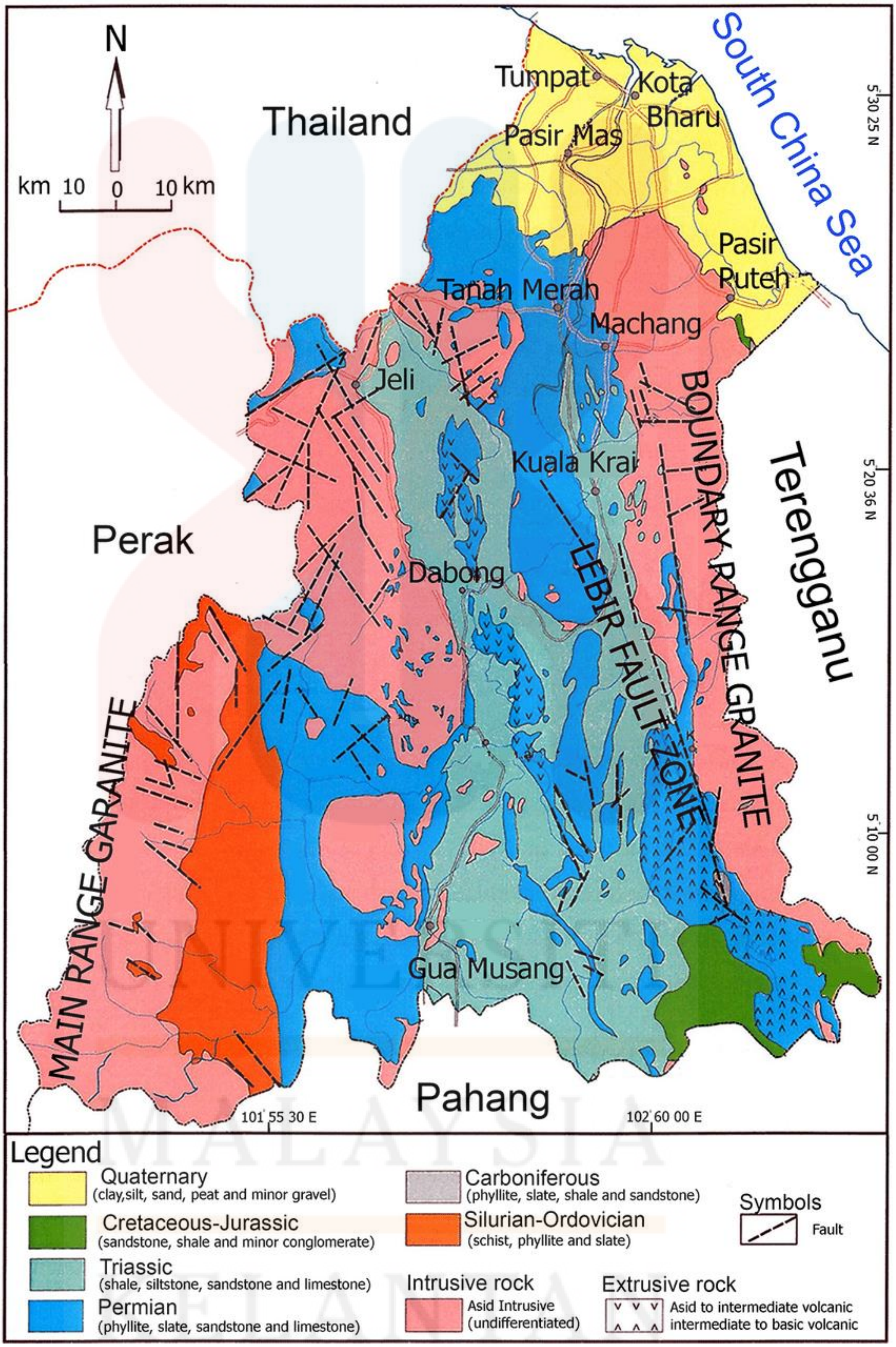


Figure 2.1: Geological map of Kelantan state (Pour, Amin & Hashim, Mazlan, 2017)

FYP FSB

2.2 Stratigraphy

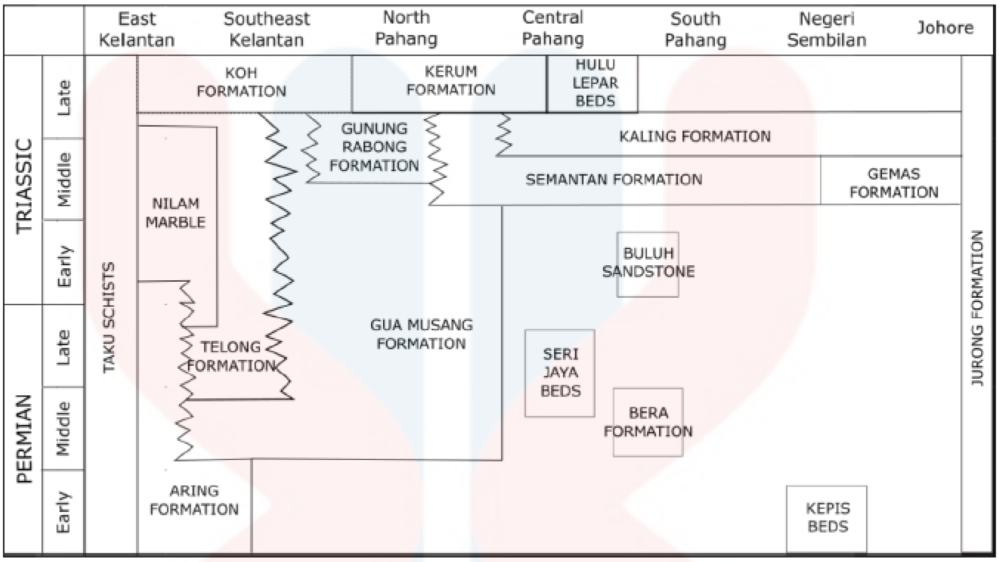


Figure 2.2: Permo-Triassic stratigraphic correlation chart of Central Belt Peninsular Malaysia which includes formations in Kelantan. Modified from Metcalfe & Hussin (1995)

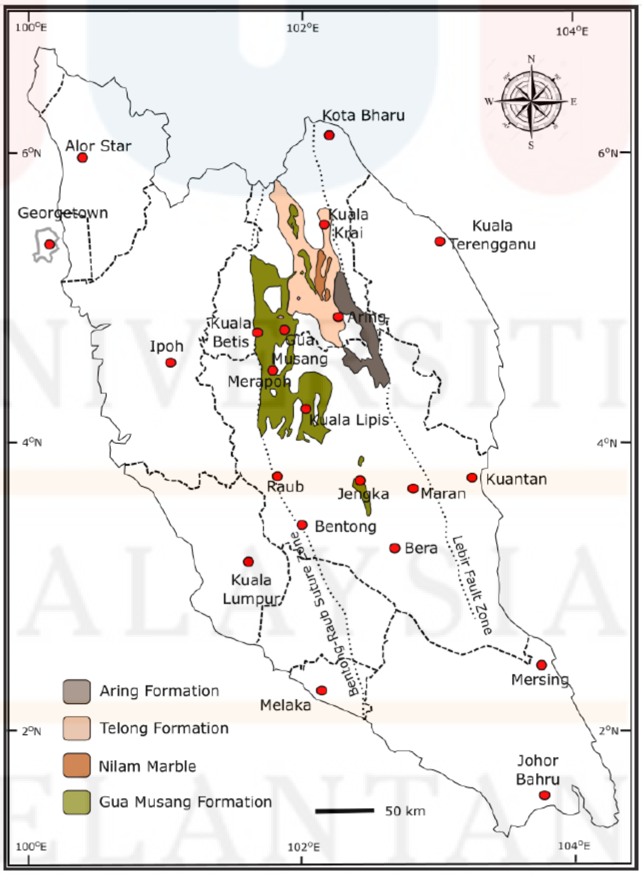


Figure 2.3: Distribution of the Gua Musang Group. Modified from Mohamed (1995).

FYP FSB

Gua Musang formation in South Kelantan-North Pahang was mapped to describe the argillite, carbonate and pyroclastic / volcanic facies of Middle Permian to Late Triassic within the Gua Musang region. Now, in the southern portion of the Central Belt Peninsular Malaysia, the word has been loosely used for almost all Permo-Triaasic carbonate-argillite-volcanic sequences. The suggested group of Gua Musang involves the present development of Gua Musang, Aring formation, Telong formation and Nilam marble (Figure 2.3). Based on lithological units, the groupings of listed structures within the same group divide the fresh formations (Mohamed, Mohamed Joeharry, Leman, & Ali, 2016).

2.3 Structural Geology

Structural geology, scientific discipline of large and small scale rock deformation. The study's scope ranges from sub microscopic crystal lattice defects to Earth's crust fault structures and folding systems.

Structural geology techniques are almost as varied as those of the entire geological sciences. Small-scale structural characteristics can be explored using the same general methods used in petrology, where segments of rock mounted on glass slides are very thin ground and then polarized microscopes are examined. The field geology methods are used on a bigger scale. These include plotting the orientation of faults, joints, cleavage, and tiny folds of structural characteristics. In most cases, the goal is to interpret the structure below the surface using surface information. Where mountains, continents, ocean basins and other large-scale characteristics are involved, the methods used are mainly those of geophysics and include the use of magnetic, seismological and gravitational techniques. In addition, since the processes that lead

FYP FSB

rocks to deform can rarely be immediately observed, they need to be studied using computer models in which they are mathematically represented (The Editors of Encyclopedia Britannica, 2018).

2.4 Historical Geology

Inside the heart of Sundaland lies the Malay Peninsula. The region is underlined by two north-south trending basement terranes juxtaposed by Palaeo Tethys ' closure along the Raub-Bentong Suture during the Permo-Triassic. To the south, the Sibumasu terrane originating from Gondwana is dominated by Cambro-Ordovician and Permian cool-water faunas. The Indochina terrane, east of the suture zone, includes completely distinct hot water faunas that testify to its near-equatorial place as part of the Cathaysian continent during much of the Permian (Southeast Asia Research Group, 2016).

The Thai-Malay Peninsular's basement rocks are intruded in various ways by the SE Asian Tin Belt's mesozoic granitoids, located during subduction-related orogenesis. These granite rocks, commonly separated into the Western, Main and Eastern Provinces, dominate the geology of the region by as much as 50%. There are also mesozoic sediments and metamorphics, particularly in the southwest and up the center of the island as part of a north-south trending belt. Cenozoic rocks are visibly absent from the peninsula, except on the tight coastal plane for reservoirs. The Cenozoic is commonly suggested as a moment of creation and thus erosion, with cenozoic material intended for the big sedimentary basins surrounding the peninsula (Southeast Asia Research Group, 2016).

FYP FSB

2.5 Hydrogeology & Groundwater Occurrences

Hydrogeology sees how water interacts with geographical frameworks. Be that as it may, there is a whole other world to hydrogeology than wet rocks. Water is an imperative regular asset for individuals all around the globe - regardless of whether it is funnelled to homes or extracted from wells. Understanding where it is and how it moves under the ground is basic in securing this asset. In spite of the fact that numerous pieces of the globe have copious wellsprings of water and satisfactory precipitation, there are still places where the main source is underground water. Based on Singah & Gupta 2010, hydrogeology is a topical and increasing topic as the water resources of the earth have become scarcer and more susceptible, whether surface or underground. More than half of the continent's ground region is coated with low permeability tough rocks.

Based on a statement from Sefie et. al., 2015, groundwater is the world's largest attainable freshwater supply and an important resource for irrigation purposes, drinking water supply and industrial purposes including global food security. Generally, one third of the human population are dependent on groundwater for drinking. The anthropogenic factors, geology of an area and the degree of chemical weathering of different rock types can affect the chemistry of groundwater.

Groundwater is water that exists in the pore spaces and cracks in rocks and residue underneath the Earth's surface. It begins as precipitation or snow, and afterward travels through the rocks and soils into the groundwater framework, where it in the end advances back to the surface streams, lakes, or seas. Besides that, hydrogeologists also use the term 'groundwater' to indicate the water present in the zone of saturation or partially saturated layers above the water table beneath the earth's

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

surface. In this particular zone, all interstices are filled with water under hydrostatic pressure that extends from the upper surface down to underlying impermeable rock or strata. However, the saturation zone may extends slightly above the water table due to the capillary action. In another words, water located at the saturation zone can also be called phreatic water.

A geographical structure completely immersed by water, equipped for creating adequate amounts of water that can be financially utilized and created, is known as aquifer. All aquifers have two basic characteristics – its ability to store groundwater and a capacity for the flow of groundwater – depending on the geological formations. The most noteworthy components of the hydrogeological decent variety of aquifer types are; (1) major variety of aquifer unit stockpiling limit (storativity) between unconsolidated granular sediments and much solidified cracked rocks, and (2) wide variety in aquifer immersed thickness between various depositional types, bringing about a wide scope of transmissivity or groundwater flow potential (Foster & Chilton, 2003).

UNIVERSITI
MALAYSIA
KELANTAN
FYP FSB

2.5.1 Sea Water Intrusion

Intrusion of saline water is a notable problem that is often discovered around the globe in coastal aquifers. Intrusion of saline water is the actuated progression of seawater into freshwater aquifers primarily caused by enhancement of groundwater near the shoreline. Where groundwater is siphoned from aquifers in a pressure-driven connection with the ocean, heightened inclinations can trigger salt water motion from the ocean to a well, rendering the freshwater unusable. In general, groundwater flows from high groundwater (hydraulic head) to low groundwater regions. This natural freshwater movement towards the ocean prevents salt water from entering coastal aquifers of freshwater (Barlow, 2003).

Since freshwater is less dense salt water, typically freshwater floats on top. The limit between salt water and freshwater isn't unrecognizable; the zone of dispersion, transition zone, or salt-water interface is briny with freshwater and seawater mixed together. Normally, freshwater from recharger area and inland aquifer flow to the sea or coastal discharge areas. This natural movement basically prevents salt water from entering freshwater coastal aquifers (Barlow, 2003). Ghyben-Herzberg principle can explain quantitatively on the relation between freshwater aquifer and seawater movement beneath the surface in this phenomenon.

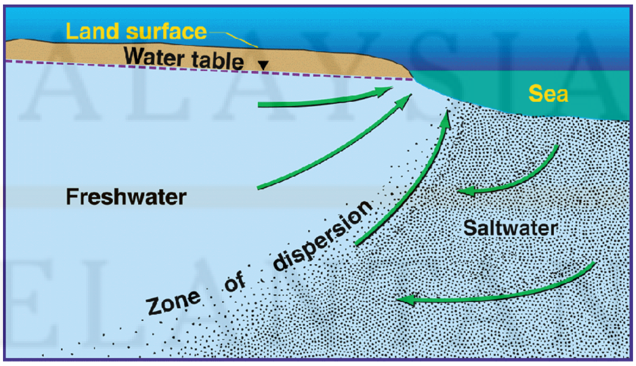


Figure 2.4: Idealized sketch of movement of freshwater and salt water in unconfined coastal aquifer (Water Resources - USGS)

Under hydrostatic circumstances, the Ghyzen-Herzberg Relation (saltwater intrusion) assumes the weight of a unit column of freshwater stretching from the water table to the salt-water border is balanced by a unit column of salt water stretching from sea level to that same interface point. There are also 40 units of fresh water below sea level for each unit of groundwater above sea level. (Solints Canada Ltd.).

2.5.2 Hydrogeology of Kelantan

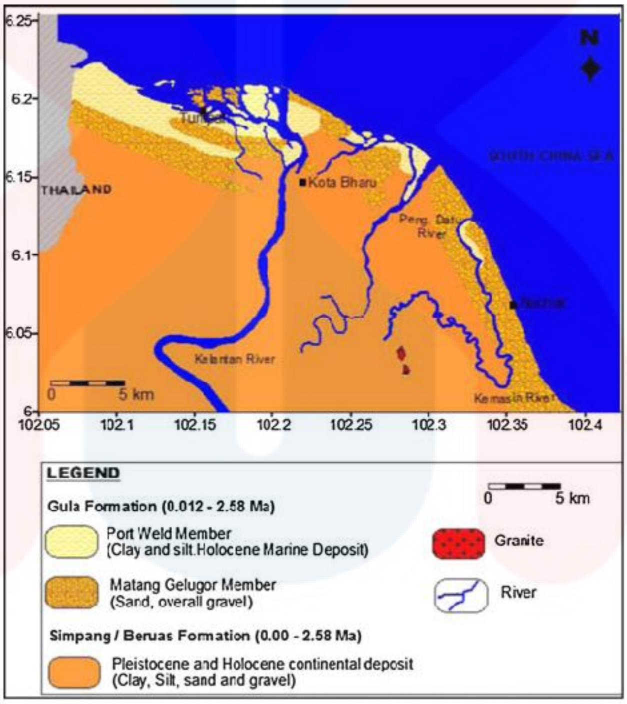


Figure 2.5: Geological Map of North Kelantan (Hussin et al, 2013)

In north Kelantan (Figure 2.5), alluvial aquifers can be found in most groundwater wells that locals has been developing for groundwater extraction wells. According to Wan Muhamad Tahir et. al., alluvial aquifer (quaternary sediments) has been an important source of groundwater for domestic purposes, irrigation for agriculture and industrial purposes. These alluvial aquifers consist of shallow sand and gravel deposits that may change unexpectedly both horizontally and vertically because of their depositional history. Alluvial aquifers are best known for its abundant yield

FYP FSB

and shallow well depths, generally lies in between 5 to 15 metres beneath the surface. In most places, the groundwater inside these shallow aquifers is fresh and of appropriate quality but its local iron concentration can be in the range of 0.85 mg/L to 10.95 mg/L (Tan & Singh, 1989). However, their high porosity and shallow depths make them especially powerless against limits in water level changes because of occasional varieties in precipitation. The lack or absence impermeable (confining) layer above the alluvial layer makes these aquifers especially vulnerable to contamination from the land surface.

Surface water and groundwater connected pretty closely due to its alluvial settings. Since most of alluvial aquifers are unconfined, the groundwater surface (water table) can change abruptly depends on the variation of precipitation and river levels. In spite of that, alluvial aquifers are important sources for moderate-to-large water supplies and can provide valuable water supplies for local communities in the state.

2.6 Electrical Resistivity Imaging (ERI) survey

There are many different methods that can be applied to explore, evaluate and investigate groundwater beneath the surface. Geophysical survey is one of the best sub-methods under the subsurface investigation. Geophysical surveys are methods that use ground-based physical sensing techniques to produce a specific image or a general map of an area. These methods are known for its non-invasive and non-destructive ways, important to preserve the condition of the biodiversity and environment of the selected site for surveying (Perone, 2019). This technique is very crucial in mapping

FYP FSB

groundwater resources, monitoring groundwater contaminations and evaluating water quality beneath the surface (Shishaye & Abdi, 2016).

The technique of resistivity originated in the 1920s on the basis of the Schlumberger siblings ' job. The principal endeavour to quantify electrical resistivity of soils was made toward the end of the nineteenth century by utilizing two-electrode method. In any case, the outcome utilizing this procedure is exceptionally inconsistent and uncertain. In 1912, Conrad Schlumberger recorded the very first equipotential curves using very basic machinery at his estate near Caen in Normandy and at the iron mines nearby. This methods results in its ability to detect metal ores and revealing features of the subsurface structure including boundaries of beddings and the dipping of the formation layers.

Forward a few years after Conrad's discovery, Frank Wenner proposed that a linear array of four similarly spaced electrodes would minimize soil-electrode contact complications based on work of Schlumberger if current-induced electrodes and potential-measuring electrodes are separated in space accordingly. Since that time, all electrical resistivity methods that has been applied in geophysics are based on the standard four-electrode principle (Neugeo, 2018). This kind of arrangement known as array, affect the depth of the investigation, resolution, sensitivity and the addition of noise into each measurement (Asry et. al, 2012).

Electrical resistivity is a major physical property of any material. It is the impedance of electrical flow stream through that material. Electrical soil and rock resistivity is an aspect of the texture of the material, porosity, pore fluid resistivity, and strong formation and saturation. Since tills, fluvial and lacustrine dregs, bedrock, and structural appearances, for example, deficiencies, are relied upon to display enormous

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

differentiations in such properties, electrical resistivity ought to be appropriate to settling structural features and interfered bedrock in unconsolidated sediments. Electrical resistivity surveys have been used in mining, geotechnical studies and hydrogeological studies for many centuries (Asry et. al, 2012).

Information from resistivity studies are usually displayed and translated as estimations of apparent resistivity, ρ_a. Apparent resistivity is defined as the resistivity of an electrically homogeneous and isotropic half-space that would deliberately connect the potential difference to the applied current for a particular course of action and terminal separation. An equation that gives the obvious resistivity in terms of the applied current, the distribution of potential and the arrangement of electrodes can be reached through a single current electrode examination of the potential distribution. Superposition can detect the impact of an electrode pair (or any other mixture).

If the electrode carries a particular current, I, measured in amperes (a), the potential at any point in the medium or on the boundary is given by:

$$U = \rho \frac{I}{2\pi r}$$

Where,

U = potential, in V,

ρ = resistivity of the medium,

r = distance from the electrode.

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

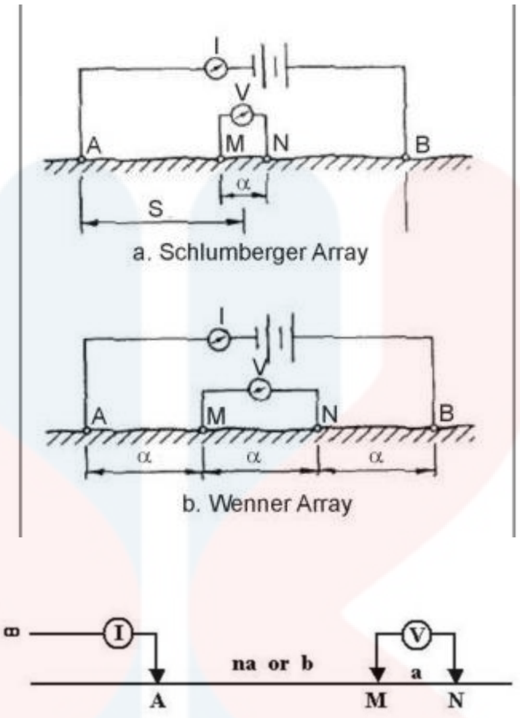
The types of electrode configurations that are most commonly used; Schlumberger, Wenner and dipole-dipole with pros and cons of its own, appropriate to different kind of conditions. The Schlumberger and Wenner arrays accommodate electrodes that were stuck to the soil to secure direct contact with the ground. Horizontal and vertical changes in resistivity can be estimated by progressively moving the whole cluster over the field or basically by keeping potential cathodes foxed while the current electrodes are spread out. It can be a bit time consuming but it can administer enough data with accuracy.

In Schlumberger array configuration, the current electrodes to inject the electricity into the ground are positioned equidistant from the centre of the array. The potential electrodes are located between current electrodes at equidistant from the centre of the configuration. Meanwhile in Wenner array, the potential electrodes is positioned in between the current electrodes in a straight line with the current electrodes in equidistant with each other.

In comparison, the Pole-Dipole array is similar to the dipole-dipole array, but the pole-dipole array is used when the surveyor needs to look deep within a cross-section of the Earth. In comparison, the Pole-Dipole array is similar to the dipole-dipole array, but the pole-dipole array is used when the surveyor needs to look deep within a cross-section of the Earth.

The Schlumberger array has a few advantages compared to using other configurations. They usually have better resolution, more sampling depth and less time-consuming field deployment than the Wenner array (Hassan, Rai & Anekwe, 2017).

FYP FSB



c. Pole-dipole Array

Figure 2.6: Different type of arrangement in electrical resistivity method

2.7 Previous Studies & Research

Based on a previous research conducted by Iqroufa et. al (2010), at Carey Island situated in Selangor, a number of variables may influence the quality of groundwater aquifers, such as contamination by intrusion of salt water or poisonous industrial chemical waste, thereby generating the need for appropriate techniques of tracking the magnitude of such harm to the environment. The emergence of quick computing techniques allowed a wide use of the tomography of electrical resistivity for environmental reasons. By using the electrical resistivity method, the subsurface salinity distribution can be monitored in the coastal alluvial aquifer. Then, the data processed were analysed and correlated with the available boreholes data. The pictures of resistivity provided helpful data on saltwater body geometry. The intrusion of saltwater was detected at a shallow depth of about 10 m and extended to over 40 m. Resistivity information were consistent and showed excellent correlation with cross

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

sections of the lithological borehole, demonstrating the effectiveness of mixing the two techniques in solving environmental issues.

Based on another previous from Samsudin et al, 2007, an integrated hydrogeochemical and geophysical methods have been used to study the salinity of groundwater aquifers along the north Kelantan coastal zone. Analysis of major groundwater ion content was conducted for the hydrogeochemical investigation, and further chemical parameters such as pH and total dissolved solids were also determined. To determine the characteristics of the subsurface and groundwater contained within the aquifers, both geoelectric resistivity soundings and seismic reflection surveys have been conducted for the geophysical study. The pH values range from 6.2 to 6.8, which indicates a slight acidic groundwater in the study area. The interface between fresh and saltwater in the first aquifer is generally located directly in the coastal area with an average concentration of about 15.8 mg/l and high geoelectrical resistivity ([45 ohm m), but for the second aquifer, both hydrogeochemical and geoelectric resistivity results indicate that the interface between fresh water and saltwater is located as far as 6 km from the shore resulted in brackish, with chloride concentration ranging from 500 mg/l to 3,600 mg/l and very low geoelectrical resistivity (\45 ohm m) as well as high concentration of total dissolved solids ([1,000 mg/l). The substantial amount of chloride ions initially shows that the salinity of the groundwater in the second aquifer is likely caused by seawater intrusion. This result suggests that the brackish water in the second aquifer probably originates from ancient seawater that was trapped in the sediments for a long period of time, rather than a direct intrusion of the seawater.

Another previous study discusses to what extent chloride (Cl) content is compared with the National Drinking Water Quality Standard 1983, which states that

FYP FSB

the permitted Cl content is 250 mg / l, intrusion of seawater into a well in the research area. The three-year groundwater Cl concentration data were used to observe the 1990, 1999 and 2011 differences. Cl's parameter has been used to identify the area having a critical intrusion. Pengkalan Chepa and Tanjung Mas are the two areas which were observed in this study. The most problematic wells are all located in Tanjung Mas as all the Cl content from the data from the three years exceed the National Drinking Water Standard 1983. For KB 5, the Cl content in the ground water is too extreme with the reading 1,485 mg/l in the 1990 and increased to1,778 mg/l (1999), but decreased to 1485 mg/l in 2011 but still exceed the National Drinking Water Standard 1983 (Mohd Kamal et al, 2015).

FYP FSB

UNIVERSITI
MALAYSIA
KELANTAN

CHAPTER 3

MATERIALS & METHODOLOGY

3.1 Introduction

Methodology is the most important part in conducting research for it explain the step-by-step procedure that is done with appropriate materials during preliminary studies, fieldwork studies and laboratory analysis. The materials are prepared accordingly with the supervision of lab assistants and supervisor-in-charge. The methodology of this particular research can be divided into a few phase that includes:

i. Preliminary studies
ii. Field assessment
iii. Laboratory analysis
iv. Software application

The flow chart of research methodology are given in Figure 3.1.

FYP FSB

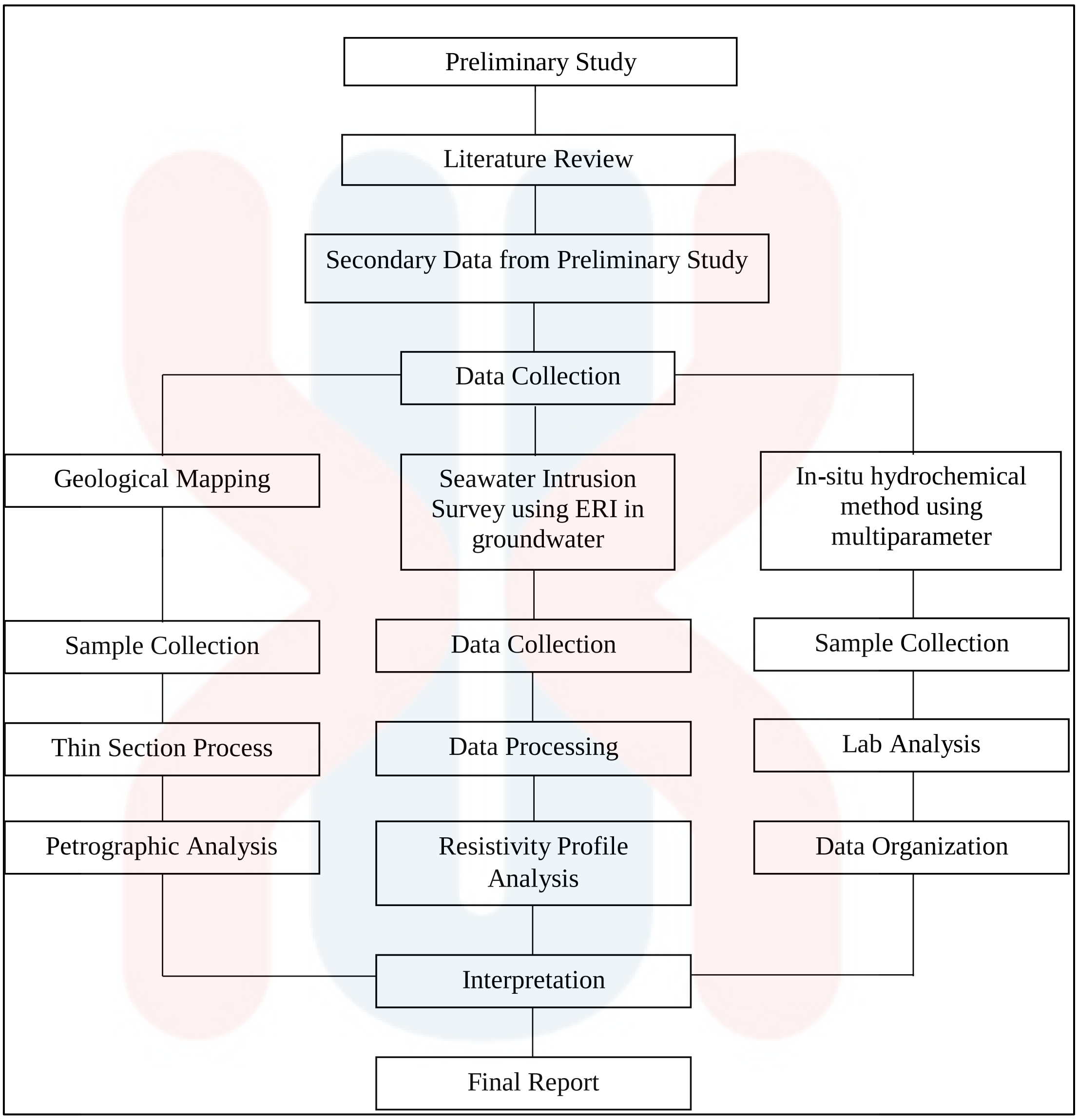


Figure 3.1: Overall flowchart

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

3.2 Materials & Equipment

Below is the list of materials which was needed for conducting several procedures in order to complete this study.

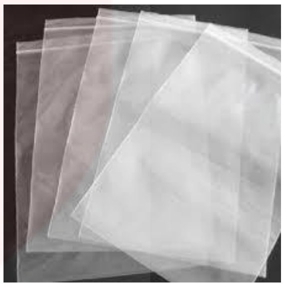
Table 3.1: List of materials/equipment with its function

Material	Function	Picture
Geological hammer	Used to break outcrop to collect fresh samples.	
Global Positioning System (GPS)	Help in locating any location by coordinate system using satellites connection, determine the elevation of the pinpoint location and managing the track of the journey.	
ABEM Terrameter LS	Equipped with data acquisition system for self potential (SP), resistivity and time-domain induced polarization (IP) by injecting electric current to the earth subsurface.	

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

Multi-parameter	Used for measuring physical parameters of in situ hydrochemical analysis such as temperature, pH value and electrical conductivity.	
Turbidity meter	Used for measuring turbidity value of water samples.	
TSS portable meter	Used to measure the Total Suspended Solids (TSS) in water samples.	
Salinity handheld meter	Used to water quality testing and salinity measurement.	

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

Sampling bottles & sampling bag	Used to store collected water samples from site and fresh rock samples.	 
Optical microscope	To analyse and study the petrography of the thin section of rock samples	
ArcGIS & RES2DINV software	ArcGIS - Creating and using maps, compiling geographic data, analysing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database.	ArcGIS

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

	RES2DINV - To interpolate and interpret field data of electrical geophysical prospecting (2D sounding) of electrical resistivity (conductivity) and induced polarization.	

3.3 Methods

3.3.1 Preliminary Studies

Preliminary studies include desk study, collection of basic literature and preparation of base map. The basic literature such as books, article journals, previous reports and researches that related to the research topic were collected and all these should be read for a better understandings of the concept involved, background of study area and the groundwater status in study area. The topographic map also needs to be studied and analysed to provide initial information of the study area such as elevations, landforms, land use and coordinates. These base map will be prepared by using the ArcGIS software to use as reference during the fieldwork.

3.3.2 Field Studies

- Geological mapping

During fieldwork which is the geological mapping part of the research will mainly base on collection of a few rock samples from fresh outcrops, observing and recording the structural trends in rocks including other field observations such as

FYP FSB

geomorphological features, drainage pattern, landforms, land usage, lithologic units and others. The collected rock samples will be used for petrographic study of the rock properties.

For geological mapping conducted in Gua Musang, there are a few specified methods to gather data using different type of equipment and tools. The required equipment and tools are copies of base map, GPS, compass, geological hammer, hand lens, measuring tape, sampling bags and HCL solution.

Field assessment or investigation is an important part in doing the geological mapping, to understand and analyse the general geology of the Kuala Betis/Gua Musang area. By referring to the base map produced using ArcGIS software including topographical, terrain, land use and other maps, the first part of the research requires an overall mapping the selected area. Some of the steps required during geological mapping to gather geological data involve traversing, sampling, and recording data appropriately. During traversing or mapping inside the study area, some of the type of data that was collected are type of rock found, trend and structural analysis, and investigating lineament in the area. The Garmin GPS and compass has been used during traversing and sampling to record the exact time and location. The compass is important to measure strike and dip of the outcrop. Not to mention, the collected fresh rock samples will be taken back for laboratory analysis to identify its facies and mineral types. Last but not least, each checkpoint of collected data was recorded in digital form for safekeeping and management.

- Electrical Resistivity Imaging (ERI) survey

The ERI survey will be needed for this investigation in evaluating seawater intrusion on shallow coastal aquifer. An integrated approach using Electrical

FYP FSB

Resistivity Imaging (ERI) survey will be used in this approach in Kemumin, Kota Bharu to interpret the resistivity value of the subsurface using specialised equipment provided. Some of the equipment needed to do the Electrical Resistivity Imaging (ERI) survey at the selected site are the ABEM Terrameter LS, 12 V battery, stainless steel electrodes, electrode jumper, multi-core cable and measuring tape.

Each survey line by using 200 metres multi-core cable are placed perpendicular to the shoreline in five different locations in the Kemunin, Kota Bharu area, thus there are total of five survey lines conducted. The site selected is based on the accessibility to set up the equipment without too much obstacles. The topography and the morphology of the area should also be considered to investigate the resistivity of the coastal shallow aquifers. Among the configurations that can be used with the ABEM Terrameter LS set-up, the Wenner-Schlumberger, Wenner and Pole-Dipole configurations are chosen for the survey.

The field set-up for the ABEM Terrameter LS equipments are positioned as the image below in Figure. First and foremost, the Multi-core cable A and B are placed on a horizontal line accordingly with the ABEM Terrameter LS at the centre. Each of the multi-core cable length used were 100 metres each.

FYP FSB

UNIVERSITI MALAYSIA KELANTAN

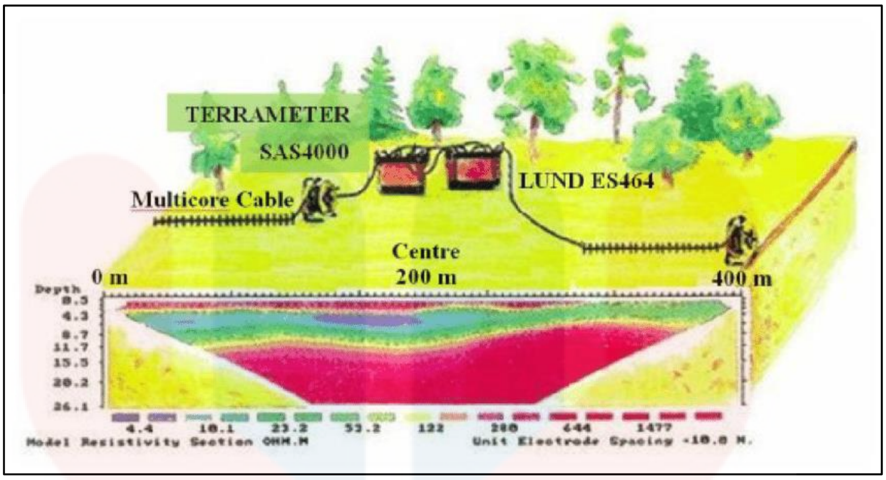


Figure 3.2: A spread for one survey line

A total of 41 electrodes were planted firmly into the ground with an equidistant of metres between each electrode. Then, both heads of the multi-core cable is connected to the ABEM Terrameter LS that was also connected to a battery as the power source. Make sure that the battery has sufficient capacity for multiple usage in the surveys.

The ABEM Terrameter LS is used to record the resistivity data as part of the geophysic analysis of the subsurface. After the equipment has been properly set up, the ABEM Terrameter LS will be powered up using the battery and it takes a few minutes before the interface of the machine turned on. Then, the selected Wenner-Schlumberger configuration has been set-up as per instruction before the machine begin to inject electricity current, channelling through the 41 electrodes into the subsurface. The instrument measured the resulting voltage differences at potential electrodes. Then, the apparent resistivity is then calculated.

The calculated resistivity values taken by the instrument are not the true resistivity of the soil beneath. Therefore, inversion of calculated apparent resistivity values must be made using the RES2DINV software to determine its true resistivity value. The data then will be presented in the form of a 2D imaging.

- Groundwater sampling

Eight groundwater samples were collected uniformly from domestic groundwater wells at the selected area of Kemumin, Kota Bharu. The in-situ hydrochemical analysis was performed directly in order to collect a few physical parameters to analyse its chemical properties such as EC, TDS, TSS, temperature, pH, turbidity, salinity and ORP. The instrument involved are multi-parameter, TSS portable meter, turbidity meter and salinity handheld meter. It is important that the data were recorded into fieldwork notes. Then, these water samples were kept inside sampling bottles; one bottle for water sample only and another bottle was filled with acidified water sample for trace elements. The acidified water sample was mixed with nitric acid (HNO_3) to slow down the absorption of metals to the bottle's wall and its biological activities. This technique is implied to these water samples for bringing it back for laboratory analysis.

3.3.3 Laboratory Works

- Atomic Absorption Spectroscopy (AAS) Analysis

Atomic Absorption Spectroscopy is a very common technique used in samples to detect metals and metalloids. Over 62 elements can be analyzed including the trace elements required for this study which is copper (Cu^{2+}), manganese (Mn^{2+}), sodium (Na^{+}), iron (Fe^{2+}) and potassium (K^{+}). It also measures the concentration of some elements in the sample water. This technique essentially uses the theory that atomizer-generated free atoms (gas) will absorb radiation at specific frequencies. AAS quantifies the removal of atoms in the gaseous state from the earth. The atoms absorb

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

ultraviolet or visible light, and transition to higher levels of electrical energy. The concentration of the analyte is determined from the amount ingested. Concentration measurements are usually calculated from a working curve after the instrument has been calibrated with established concentration levels.

A monochromator is used to choose the particular wavelength of light that the sample receives and to rule out other wavelengths. Selecting the particular light allows the chosen element to be decided in the presence of others. The unknown concentration of an element in a solution is calculated with a calibration curve.

The instrument is calibrated using several known concentration solutions. The absorbance of each known solution is measured and a concentration-vs-absorbance calibration curve is then plotted. The sample solution is fed into the instrument, and measure the element's absorbance in this solution. Then, the element's unknown concentration is calculated from the calibration curve. Figure 3.3 shows the AAS instrument used for this research and more can be refer in appendices.

Figure 3.3: Atomic Absorption Spectroscopy (AAS) instrument

FYP FSB

- Titration analysis

This method determines the chloride ion concentration of a solution by titration with silver nitrate. As the silver nitrate solution is slowly added, a precipitate of silver chloride forms. The end point of the titration occurs when all the chloride ions are precipitated. Then additional silver ions react with the chromate ions of the indicator, potassium chromate, to form a red-brown precipitate of silver chromate. This method is used to determine the chloride ion concentration of water samples from domestic wells in shallow aquifer. Below are the calculation for chloride ion concentration;

$$\text{Chloride, mg/L} = \frac{(ml \times N) of\ AgNO_3 \times 1000 \times 35.5}{ml\ of\ sample}$$

- Thin section analysis

Fresh rock samples that were collected from outcrops at field in Kuala Betis/Gua Musang are needed to be processed into thin section using special equipment in the laboratory. This technique is important to study the petrography of the rock samples by observing the thin section under the optical microscope, based on its mineral content to identify the rock type specifically. The details of the procedure can be refer in Appendices.

3.3.4 Data Processing

Two software-based applications are used for processing all the data collected during field assessment. Firstly, ArcGIS is used to process and produce geological map with geographic information. Second software is the RES2DINV. It is a computer program that can analyse resistivity data obtained and stored in the ABEM Terrameter LS. Then, the process data will be represented in a 2D imaging to interpret the bedrock

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

layers and determining the transition zone between freshwater aquifer and seawater flow.

3.3.5 Data Analysis and Interpretation

- Geological map

There are several type of maps that was produced based on the collected geological data form field assessment. Some of these produce shows drainage pattern, traverse map, topography map, land-use map and geological map. The ArcGIS software will be used to produce the maps.

- 2D Imaging Data

In order to identify between soils and groundwater from resistivity measurement using ABEM Terrameter LS, the resistivity value of each component will be presented with different colour and values accordingly. These resistivity value should be correlated with the table of resistivity values for selected soils, water bodies and materials.

Table 3.2: Resistivity and conductivity value of selected soils and water. Modified after Loke 1999.

Material	**Resistivity $(\Omega - m)$**	**Conductivity $(\Omega - m)^{-1}$**
Clay	1 – 100	1 – 0.01
Alluvium	10 – 800	1.25×10^{-3} – 1.7×10^{-3}
Fresh water	10 – 100	0.01 – 0.1
Sea water	0.15	6.7

FYP FSB

Table 3.3: Interpretation of resistivity value for the study area.

Resistivity value	Material	Indicator
< 20 Ωm	Seawater	Dark blue colour
50 - 150 Ωm	Fresh water	Turquoise – green colour
➢ 1,000 Ωm	Hard layer (rock)	Red – purple colour

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

CHAPTER 4

GENERAL GEOLOGY AND

GEOLOGICAL MAPPING IN LOJING, GUA MUSANG

4.1 Introduction

This chapter include mainly geological process such as weathering, landforms, rock types, stratigraphic geology and geomorphology of the study area.

4.2 Background of Study

4.2.1 Land use

The main land usage in the study area is mostly plantation farming such as rubber trees, palm oil trees and other type of farming. There are also small part of the study area in the southern part was mostly covered by thick, tropical forests that is part of the Sungai Berok Forest Reserve. Figure 4.1 shows the palm oil plantation in Liziz Plantation area,

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

Figure 4.1: Soil used in most of the study area are for palm oil plantation

4.2.2 Social economic

There is a palm oil plantation processing factory near the study area, thus indicating that the area is mostly covered with palm oil plantations and other crops planted by the company as well as the main economy sources of study area. There are also smaller agriculture activities done by local villagers that owned very small area of private-owned land that scattered across the study area. Figure 4.2 shows the palm oil tress inside the plantation area.

Figure 4.2: Most of the study area are developed for palm oil tress plantation

FYP FSB

4.2.3 Road connection

The study area in Gua Musang has.moderate access as off-road vehicles are required to reach inside the study site. This is mostly because almost 60% of palm oil plantation covers the area and about 20% are difficult to access due to forest reserves area. In order to reach the middle of the study area, one needs to be access by using plantation road which is unpaved as it usually is used by the plantation workers to circulate around the plantation farm. Moreover, bad weather can also affecting the road. If heavy rains occur, the unpaved road can be too slippery for off road vehicle. Figure 4.3 and Figure 4.4 below shows some of the main road, plantation road and unpaved road at the study area.

Figure 4.3: Unpaved road of the study area located at north side of the box

Figure 4.4: Entrance into the study area accessible from the main road, Jalan Gua Musang – Cameron Highland

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

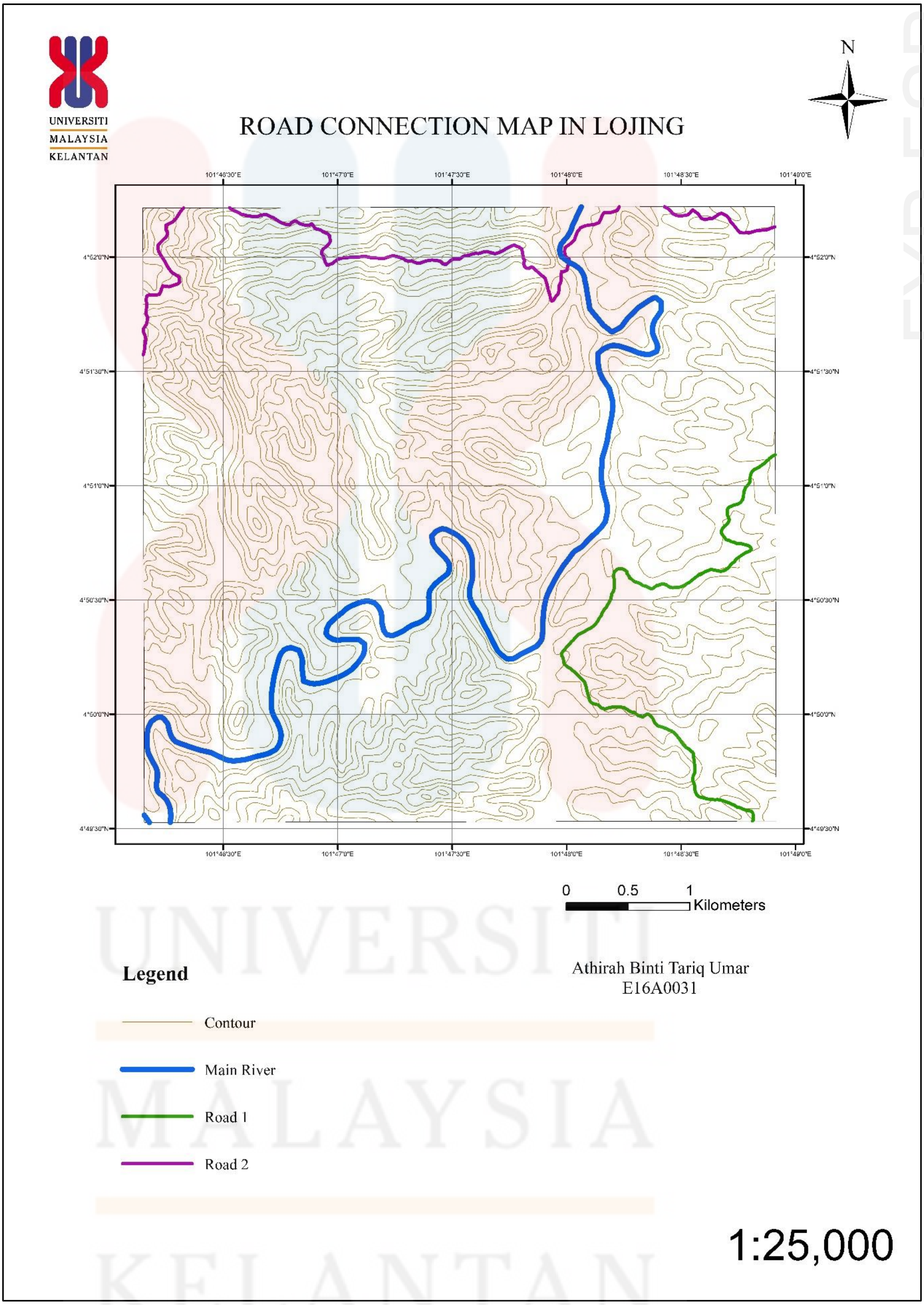


Figure 4.5: Road connection map in Lojing

FYP FSB

4.3 Geomorphologic Process

4.3.1 Topography

The topography of the study area showed elevation ranged from 140 metres to 380 metres. The highest elevation was inside the Liziz Plantation area which was 380 metres whereas the lowest elevation was at 140 metres in which the main river inside the study area located – Sungai Berok. Based on Table 4.1, topographic unit of study area was hilly and mountainous area.

Table 4.1: Topographic unit versus Mean Elevation Standard of the study area

Topographic Unit	Mean Elevation above sea level (m)	Category of Study Area	Percentage
Low lying	Less than 15		
Rolling	16 – 30		
Undulating	31 – 75		
Hilly	76 – 300	Study area	95%
Mountains	More than 301	Study area	5%

(Source: Hutchinson & Tan, 2009)

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

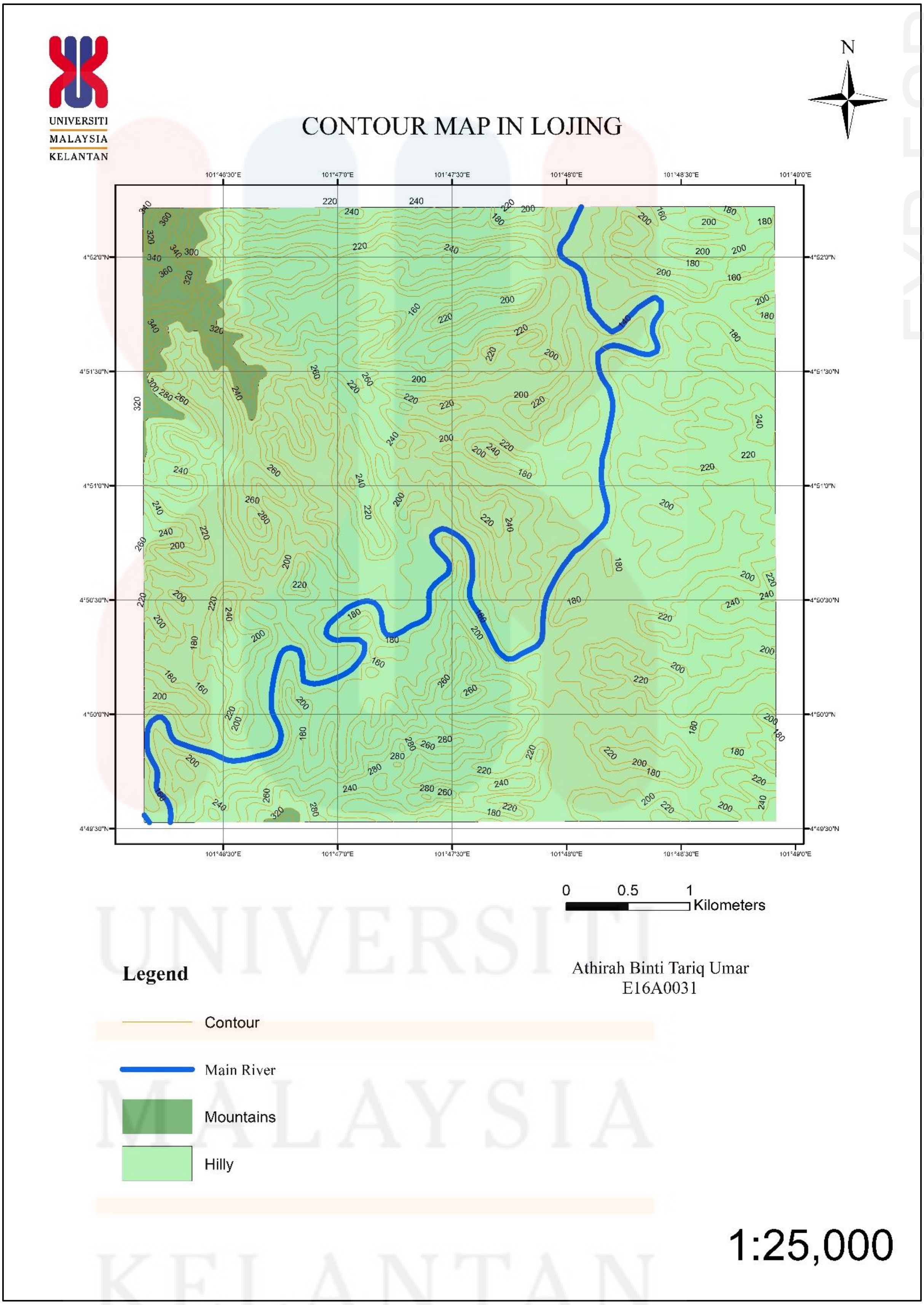


Figure 4.6: Contour map in Lojing

4.3.2 Drainage Pattern

Drainage pattern a pattern produced by stream erosion over time that shows characteristics of the type of rocks and geological structures in a landscape area drained by streams. The topography of the land governs them, whether a particular region is dominated by hard or soft rocks, and the gradient of the land (Geology In, 2014).

In the study area, there is a large river that is Sungai Berok which the native considers as the main river as all small streams finally joined to this river. The stream's drainage system is mostly a dendritic pattern. The most common dendritic patterns form in areas where the type of rock (or unconsolidated material) underneath the stream has no specific fabric or structure and can be eroded in all directions equally easily (Geology In, 2014). Dendritic drainage pattern (Figure 4.9) is a tree-like pattern consisting of tributary branching and a main stream. Usually, dendritic pattern developed in regions with homogeneous lithologies, with horizontal or very gentle dip. For the direction of the tributaries, there is no apparent control towards it due to the similar resistance to the weathering of the subsurface geology. In the study area, there is typically the presence of the same hard rock lithology and uniform structure to form dendritic pattern. Figure 4.7 below shows the view of the main river at the river bank.

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

Figure 4.7: The main river at study area called Sungai Berok

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

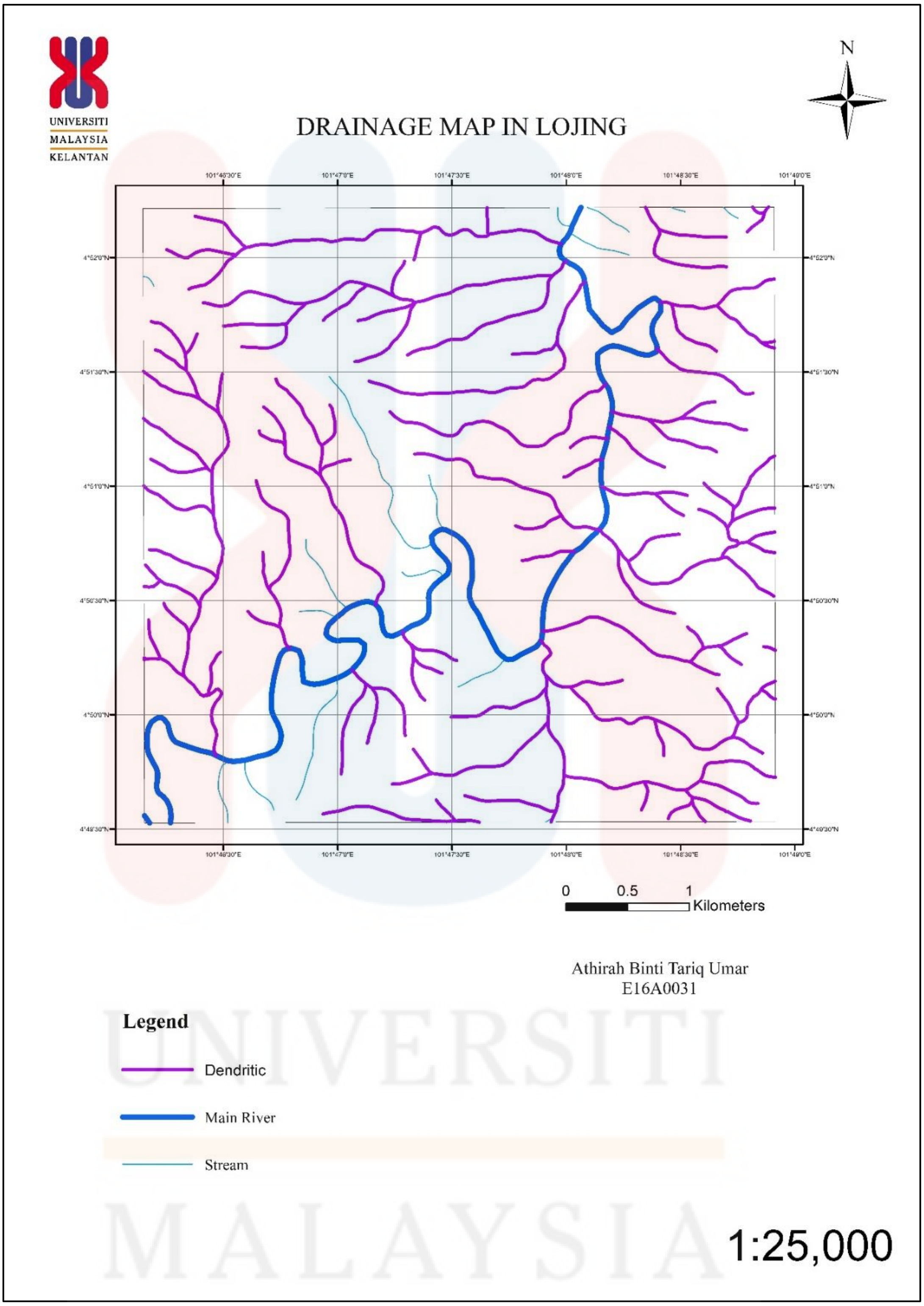


Figure 4.8: Drainage map in Lojing

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

4.3.3 Weathering process

Weathering process is rock breakdown by mechanical breakdown and chemical breakdown. Most rocks begin to decline when they are exposed to the lower temperatures and pressures on the surface of the Earth and brought into contact with air, water and organisms. The process tends to be self-reinforcing: weathering weakens the rocks, making them more permeable, making them more vulnerable to erosion agents (Huggett, 2011). Weathering can occur at the original location where the bedrock is exposed, or in rock material that has been eroded, transported and deposited thousands of kilometres away from its original source.

There are three types of weathering that can happen in sedimentary rocks:-

(a) Physical weathering.

(b) Chemical weathering

(c) Biological weathering

a. Physical or Mechanical Weathering

Physical processes are gradually reducing rocks into smaller parts. The decay increases the surface area that is exposed to chemical attack. The main mechanical weathering process that can occur on exposed bedrocks is unloading, heating and cooling thermal stress, as well as swelling and shrinking due to wetting and drying.

One of the major example of physical weathering which can be found in the study area occurred at the mudstone (Figure 4.9). Abrasion is the common physical weathering mechanism to be found in the area of analysis. Abrasion is the process of

FYP FSB

wearing rock particles away by water and wind erosion. Continuous occurrence of these processes will gradually decompose the surfaces exposed to rock into small sizes.

Figure 4.9: Physical weathering of mudstone at one of the outcrop at the study area

b. Chemical Weathering

Weathering involves a huge number of chemical reactions that work together under the full range of climatic conditions on many different types of rock. These are some ofthe rock decomposition's major chemical reactions: carbonation, hydrolysis and hydration.

b

Figure 4.10: Chemical weathering of limestone boulder at the study area

FYP FSB

For examples, carbonisation that occurs in these limestone boulder (Figure 4.10) is the formation of carbonates, the carbonic acid (H2CO3) salts. Within natural environments, carbon dioxide dissolves to form carbonic acid. The reversible reaction mixes water with carbon dioxide to form carbonic acid which dissociates into an ion of hydrogen and a molecule of bicarbonate. Carbonic acid attacks rocks and produces carbonates. Carbonisation dominates the weathering of calcareous rocks (limestones and dolomites) in which calcite or calcium carbonate (CaCO3) is the main mineral. Calcite reacts to form calcium hydrogen carbonate (Ca(HCO3)2) with carbonic acid that is readily dissolved in water unlike calcite.

c. Biological Weathering

Some organisms mechanically or chemically attack rocks, or through a combination of mechanical and chemical processes. Growing in bedding planes and joints, plant roots and especially tree roots have a biomechanical effect – as they grow, mounting pressure may lead to rock fracture. Figure 4.11 below shows biological weathering as the tree roots that caused rock fracture due to its growth.

Figure 4.11: Biological weathering shown by one of the outcrop at study area

FYP FSB

4.4 Field observation and Mapping

4.4.1 Lithostratigraphy

Stratigraphy is one of the geological branches concerned with the description of layering (stratification) of rock layers (strata), lithological correlation and historical interpretation represented by rock layer stratification. In the vertical distribution with the geological time scale, the stratigraphic column of the study area is shown to analyze the chronological sequence of dispersed strata from different places. The oldest rock unit, based on the superposition theorem, lies at the bottom and is preceded by the youngest rock unit at the top. Table 4.2 below shows the stratigraphy column of the study area.

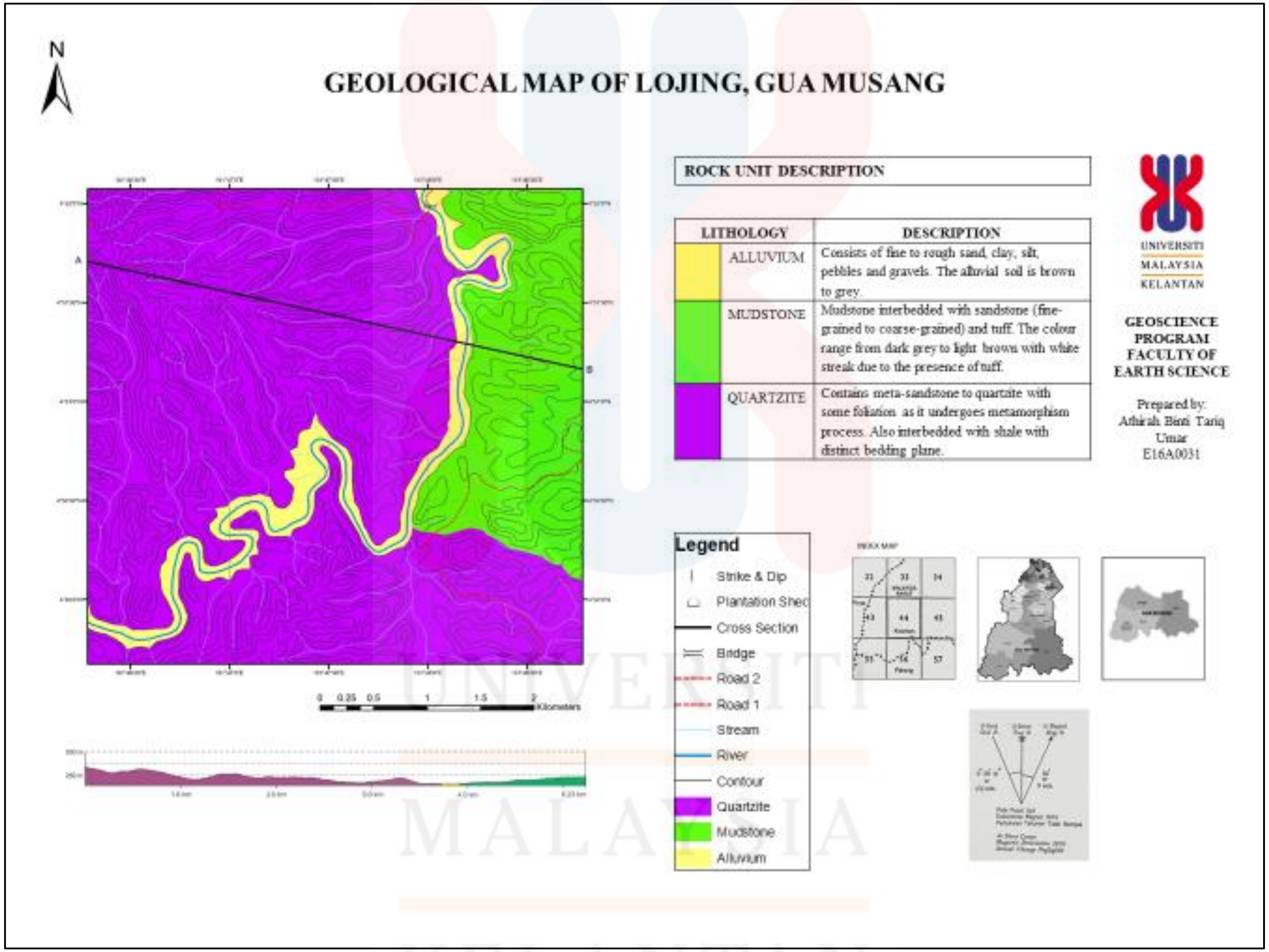
FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

Table 4.2: Stratigraphic column of study area

ERA	PERIOD	UNIT	DESCRIPTION
Cenozoic	Quarternary	Alluvium	Consists of fine to rough sand, clay, silt, pebbles and gravels. The alluvial soil is brown to grey
Mesozoic	Triassic	Mudstone	Mudstone interbedded with sandstone (fine-grained to coarse-grained) and tuff. The colour range from dark grey to light brown with white streak due to the presence of tuff.
Paleozoic	Permian	Quartzite	Contains meta-sandstone to quartzite with some foliation as it undergoes metamorphism process. Also interbedded with shale with distinct bedding plane.

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

FYP FSB



UNIVERSITI MALAYSIA KELANTAN

Figure 4.12: Geological Map of Lojing, Gua Musang

a. Alluvium Unit

The alluvium unit at the study area is the youngest rock unit. Most of the alluvium found at the study area deposited along the main river inside the study area, Sungai Berok that stretches diagonally across the designated box in about 13 kilometres in length. The alluvium unit found at the study area has variable in grain size as they are composed from the smallest grain of sand to gravel size pebbles with the age range in Quaternary period of Holocene epoch. Figure 4.13 And Figure 4.14 below shows the alluvium deposition that mainly occurred at the main river and streams.

Figure 4.13: Alluvium unit at the main river of the study area, Sungai Berok

Figure 4.14: Deposited sediment at one part of channelled river

FYP FSB

b. Mudstone Unit

The lithology unit in mudstone mostly consists of mudstone interbedded with chert and sandstone with some of the outcrop undergoes the process of metamorphism during the Triassic in the Mesozoic era as lamination can be observed from certain outcrops (Figure 4.15). The lamination is an indicator that shows that the formation at the study area undergoes a great amount of pressure with high temperature underneath the crust before it was uplifted above the subsurface.

However, it is quite difficult to distinguish the difference between mudstone and sandstone (Figure 4.16) based on colour due to the highly weathered condition of most of the outcrop found at the study area. In order to distinguish easily between sandstone and mudstone, a few hand specimen were collected for petrographic analysis so that further inspection can be done on the thin section for identification of the minerals. There is a variety of the thickness of the interbedded mudstone with shale and sandstone, where the thickness ranged from 2 cm to 6 cm for the respected lithology.

Figure 4.15: Lamination of mudstone found at one of the outcrop

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

Figure 4.16: Interbedded of mudstone with sandstone and shale

c. Quartzite Unit

The lithology that were included in the quartzite units; sandstone, meta-sandstone, meta-mudstone and quartzite can be found at the site at different phase of metamorphism that formed during the Permian period within the Palaeozoic era. This is the oldest rock unit at the study area. The sandstone and other lithology has variable thickness range from fine to medium grain included coarse-grained sandstone that can be clearly observed by naked eye.

There is no fossil found as mapping was conducted through the study area due to highly weathered factor on the outcrop exposed due to surface runoff by heavy rainfall and human interference as they developed the area for agriculture industry.

Figure 4.17: Sandstone outcrop found at the study area with foliation presence

FYP FSB

Figure 4.18: Quartzite found at one of the stream exposed by water movement

4.4.2 Structural Geology

(a) Lineament analysis

Examination of the lineament applies to positive lineament and negative lineament. The positive lineament was drawn by identifying the study area's ridges and rivers presented the negative lineament (Figure 20). They were measured using a protractor after the identification of both lineaments to obtain the bearing of each lineament. To describe the position of the forces applied to the river and ridge, all the bearings were used to map the Rose diagram.

Figure 4.19: Ridge at the study area

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

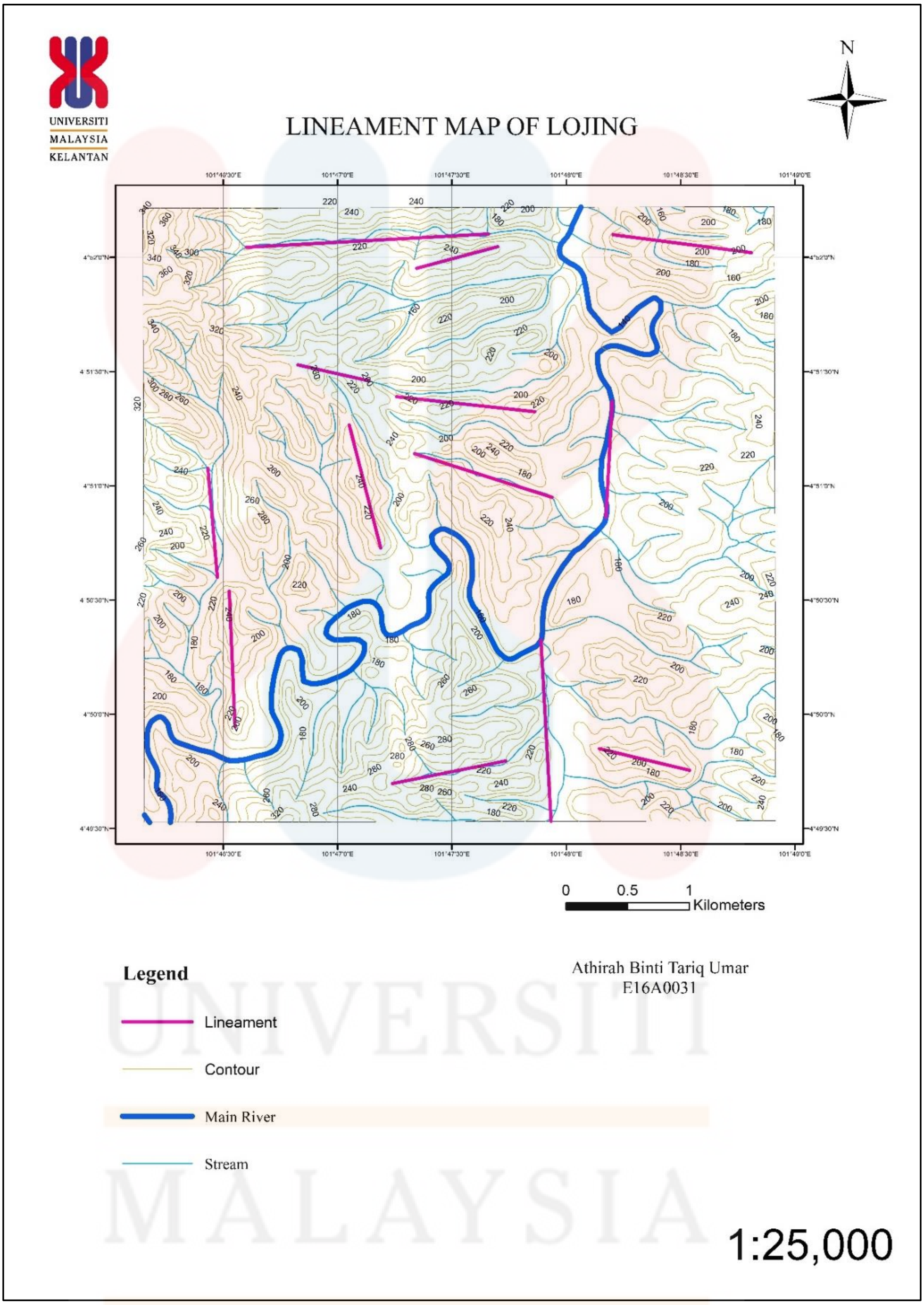


Figure 4.20: Lineament map of Lojing

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

(b) Joint analysis

Crack analysis was done in one location which is at OA72 (Figure 4.22). The total 100 discontinuities were taken at one outcrop with distinct joints that can be observed particularly at one sandstone/mudstone outcrop. A Rose diagram was plotted for the location to determine the magnitude of the major force or σ_1 upon the strata.

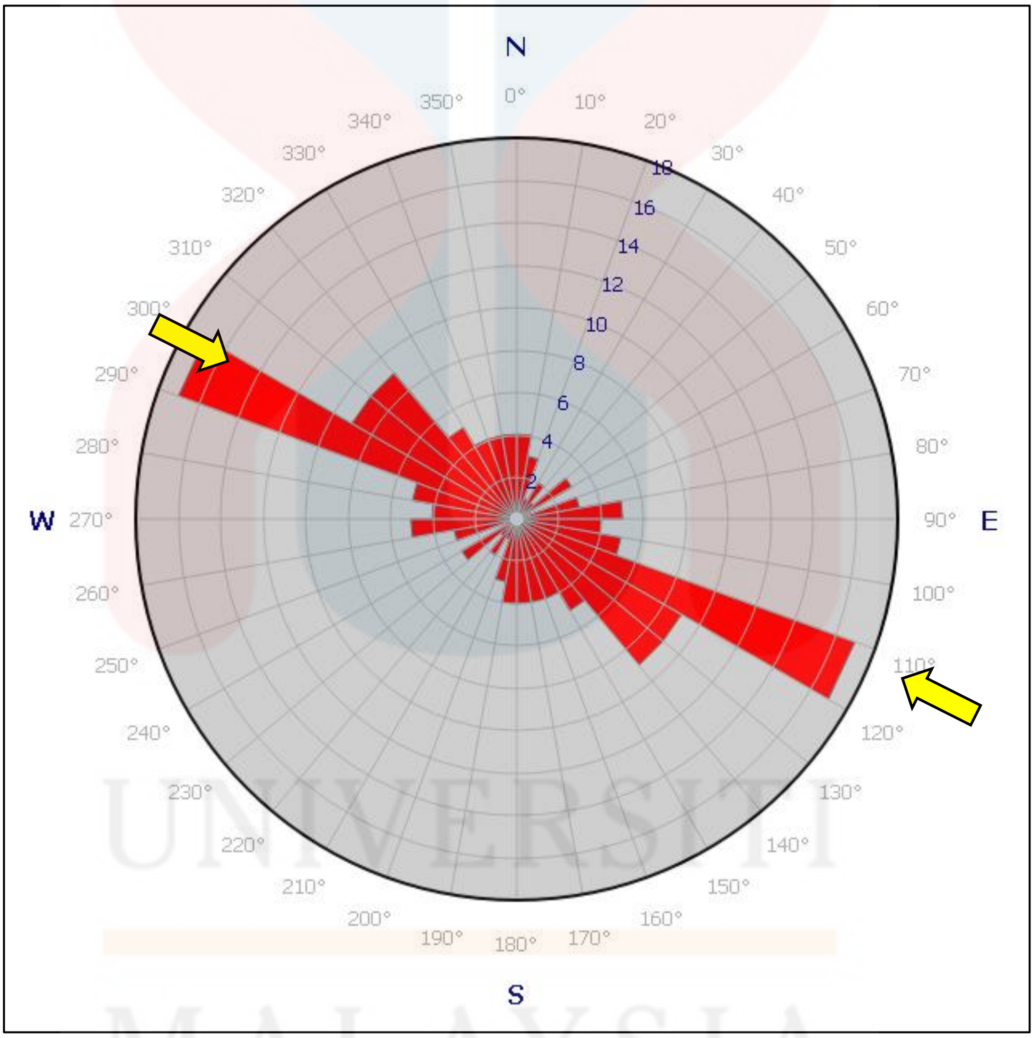


Figure 4.21: Rose diagram of a joint analysis at one of the outcrop

At OA72, major force (σ_1) is from North-West and South-East (Figure 4.21). All these directions indicated in which the tectonic force that may have act upon the formation at the study area that contributes to the presence of discontinuities in certain

FYP FSB

exposed outcrop. The outcrop (Figure 4.) was measured and data was collected to generate the Rose diagram.

In conclusion, the direction of forces applied at the outcrop may originated from the movement of Sibumasu Block and East Malaya Block that formed the Bentong-Raub Suture zone as part of the Gua Musang Formation.

Figure 4.22: Measuring joint data at outcrop OA72

(c) Fault analysis

No major fault structure was observed as most of the outcrop or exposed bedrocks were too weathered and most of the study area were covered with heavy foliage and underbrushes that makes it difficult distinguished any fault structure.

(d) Fold analysis

The folds are determined by gathering strike and dip data along a certain lineament to sketch a rough folding formation by observing the direction and orientation of the bedding found at the outcrop (Figire 4.23 & Figure 4.24). These data

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

are collected to visualised the trough and peak of the fold structure at a bigger picture as minor fold structure are not common inside the study area due to most of the bedding are covered by vegetation and thick forest.

Figure 4.23: Inclined angle of strike and dip at one of the outcrop

Figure 4.24: Different measurement of strike and dip found at this bedding along the same outcrop

FYP FSB

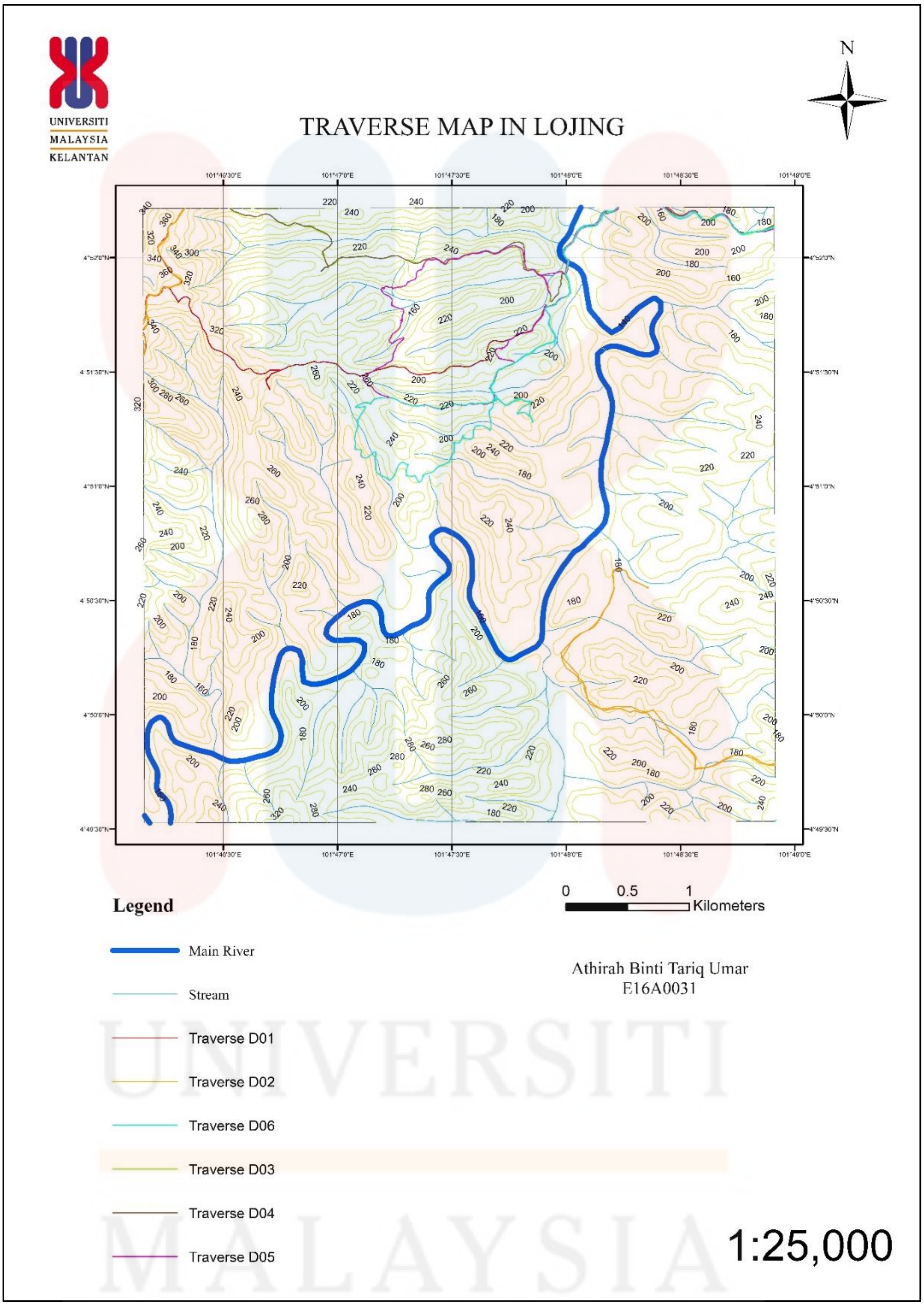


Figure 4.25: Traverse map in Lojing

FYP FSB

4.5 Petrography

Petrographic analysis was conducted on seven thin sections. All of the thin sections represent the Gua Musang Formation but only six thin section samples that can be described and analysed under the microscope. All of these samples were collected in hand specimen and described in accordance each of its classification. These thin sections were used to determine the petrographical characteristics of its source rocks or provenance. A micrometre eyepiece was used to determine the grain size of minerals within each thin section.

a. Sandstone

This thin section of sandstone originated from the hand specimen found at an exposed sandstone outcrop. Based on the observation under the microscope, a lot of discontinuities evidence can be found indicating major tectonic force that acted upon the bedrock. The tectonic force occurred near the location of this lithology cause the formation of metamorphosed sandstone from high temperature and pressure deep beneath the surface.

Figure 4.26: Hand specimen of a sandstone

FYP FSB

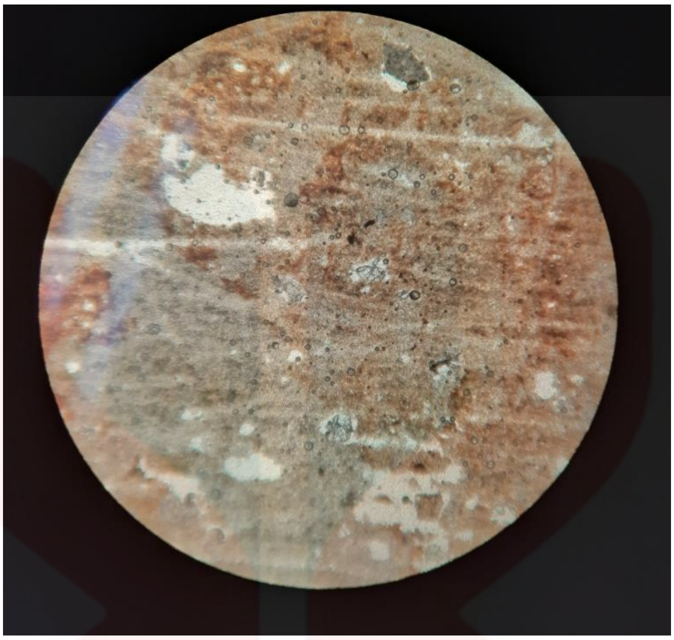


Figure 4.27: Sandstone grain minerals under optical microscope

FYP FSB

UNIVERSITI
MALAYSIA
KELANTAN

CHAPTER 5

EVALUATION OF SEAWATER INTRUSION IN SHALLOW AQUIFER OF KEMUMIN, KOTA BHARU USING ELECTRICAL RESISTIVITY IMAGING (ERI) METHOD & GEOCHEMICAL METHODS

5.1 Introduction

The Electrical Resistivity Imaging (ERI) survey were done around in Kemumin, Kota Bharu data and also in situ chemical parameters data collected to support the results obtained by the ABEM Terrameter LS. This is all part included in the integration of methods used to complete these investigations.

5.2 Location of the Horizontal Lines

Three horizontal lines were selected for the electrical resistivity surveys in this research. All three lines were chosen from close to the shoreline to far from the shoreline to detect the boundaries in where the saline water interface with groundwater. These lines were chosen appropriately according to the vastness of the area, its accessibility and the line must be perpendicular to the shoreline.

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

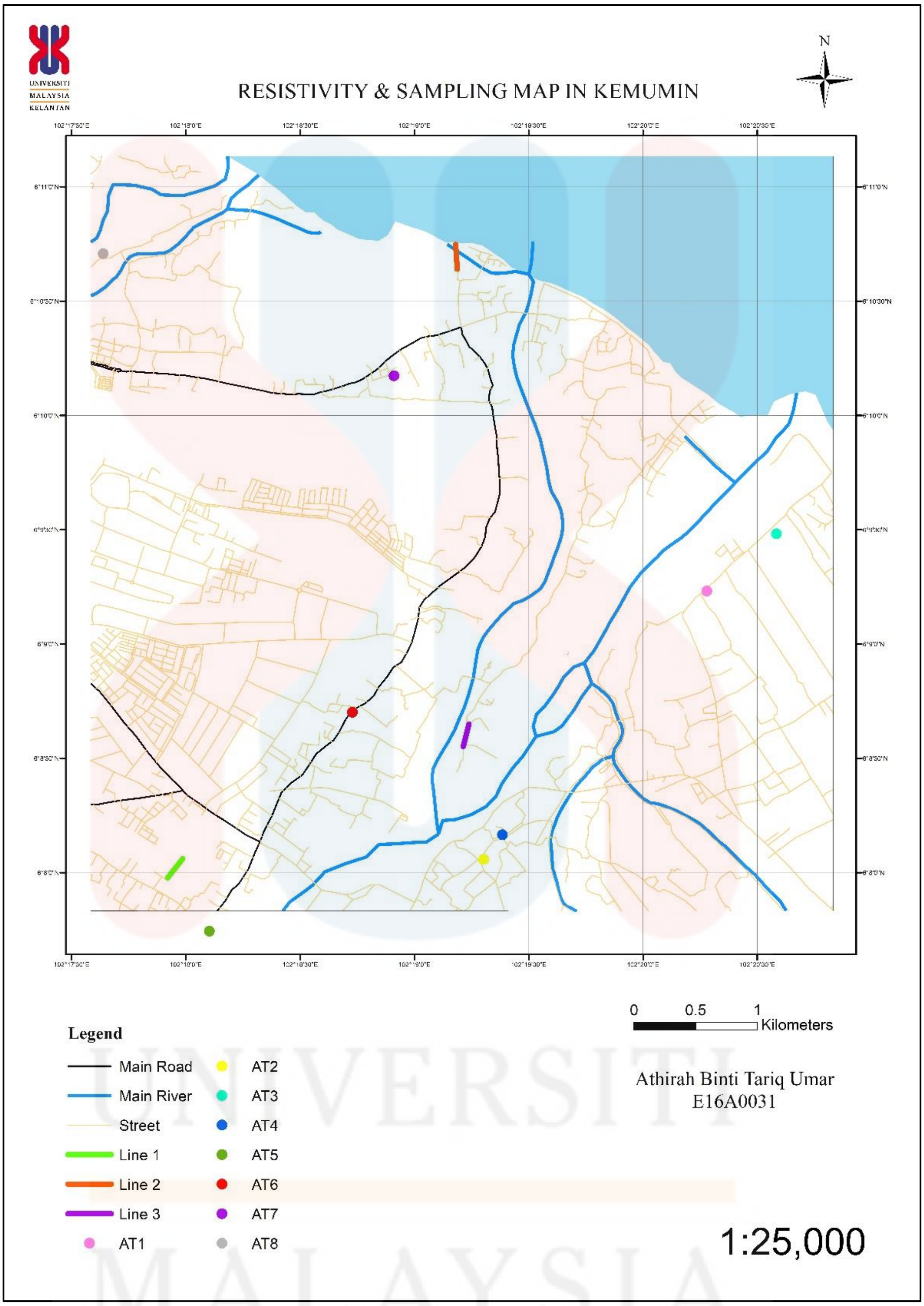


Figure 5.1: Resistivity and sampling map in Kemumin

UNIVERSITI
MALAYSIA
KELANTAN
FYP FSB

5.3 Electrical Resistivity Imaging – Standard resistivity range

In this section, the image produced by RES2DINV software from all three horizontal lines are interpreted and discuss based on Figure 5.2. Interpretations are made by comparing the values of resistivity obtained from previously established researchers from data and resistivity values. The medium resistivity values used by previous researcher from comparison are from the literature review table of resistivity values. Based on Figure below, the 2D imaging can be interpreted according to its colour and values.

Table 5.1: Interpretation of resistivity value for the study area.

Resistivity value	Material	Indicator
< 20 Ωm	Seawater	Dark blue colour
50 - 150 Ωm	Fresh water	Turquoise – green colour
➢ 1,000 Ωm	Hard layer (rock)	Red – purple colour

5.3.1 Survey Line 1

Line 1 is located at N 6.132945, E 102.298665 and elevation of 17 metres above sea level with a length of 200 metres and located about 5 km from the shoreline and near a school. Based on Figure 5.3, the area located surrounded by residential area and paddy field. The selected configuration was pole-dipole array for more depth. The location was quite dry with no stream or river nearby.

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

Table 5.2: Location for Line 1

Name	Coordinate	Distance from shoreline	Resistivity values. Ωm
SMK Panchor	N 6.132945, E 102.298665	5 km	4 – 55, 542

Figure 5.2: SMK Panchor school field

Based on the pseudosection in Figure 5.3, the total percentage of RMS error is 11.6% for resistivity although a lot of bad datum has been eliminated. Minimum resistivity value in this survey line is 3.39 Ωm and the highest value is 55,542 Ωm with depth of about 70 metres. Based on the resistivity value shown, there is saline water presence as the minimum value of resistivity below than 20 Ωm. It means that groundwater already started to turn saline even though the area is far from the shoreline due to high amount of groundwater extraction.

FYP FSB

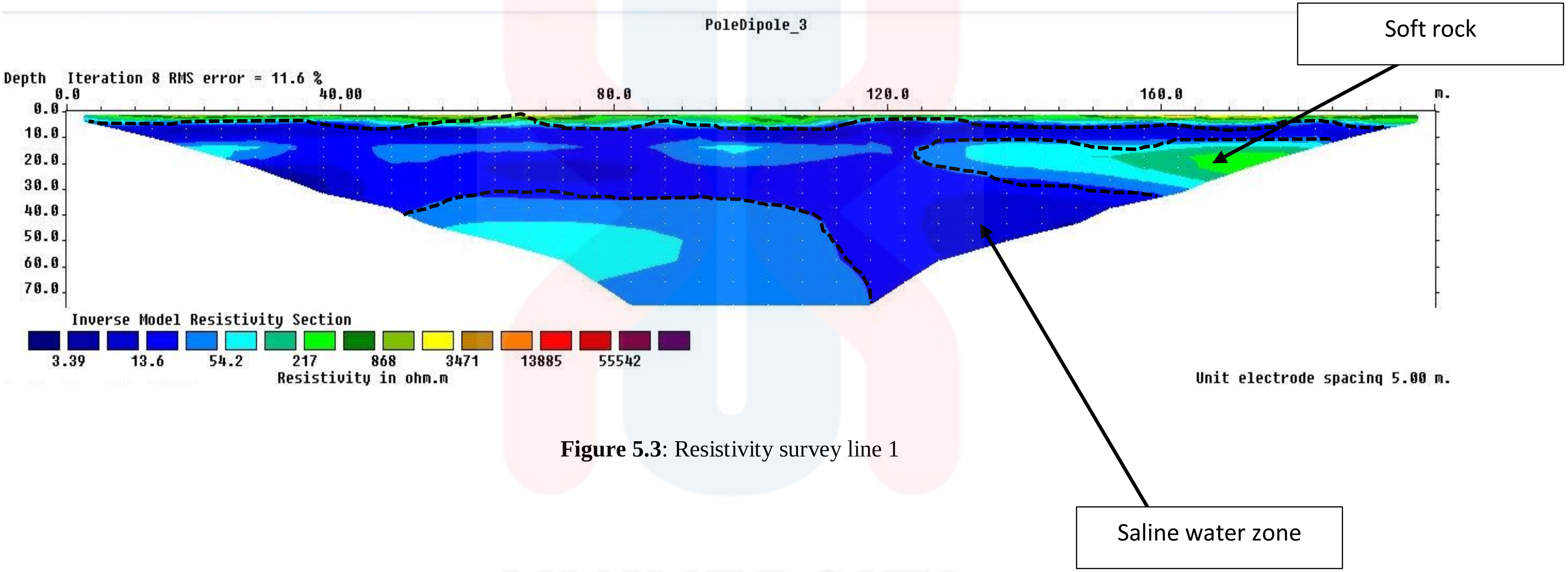


Figure 5.3: Resistivity survey line 1

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

5.3.2 Survey Line 2

Horizontal line 2 is located at N 6.177405, E 102.319807 and elevation of 2 m above sea level with a length of 200 metres. Based on Figure 5.4, the area was very near to the shoreline. The selected configuration was Schlumberger array as the intrusion was predicted to enter freshwater aquifer at a very shallow depth. The resistivity reading of line 2 is interpreted in this area which was Pantai Sabak. The location lithology was mostly sandy with shrubs and small vegetation inside a small village. Survey line 2 located only a few metres from the shoreline.

Table 5.3: Location for line 2

Name	**Coordinate**	**Distance from shoreline**	**Resistivity values. Ωm**
Pantai Sabak	N 6.177405, E 102.319807	2 – 3 m	0.1 – 3,000

Figure 5.4: Line 2 at Pantai Sabak

FYP FSB
KELANTAN

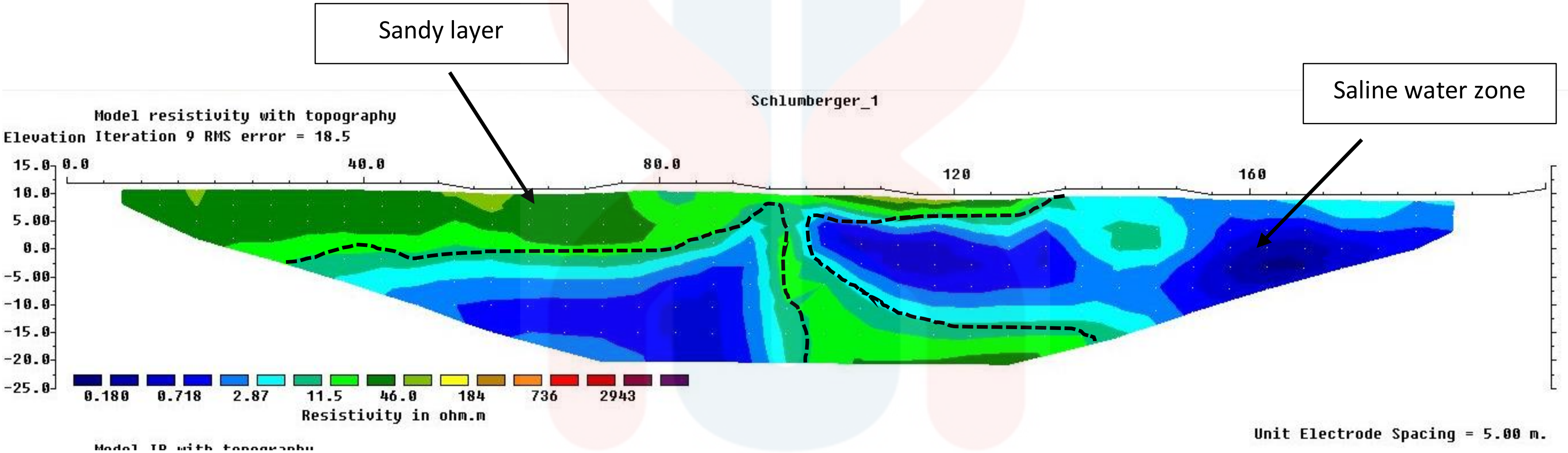


Figure 5.5: Resistivity survey line 2

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

Based on the result, the total percentage of RMS error is 18.5% for resistivity although a lot of bad datum has been eliminated. Minimum resistivity value in this survey line is 0.18 Ωm and the highest value is 2,943 Ωm with depth of about 20 metres. Based on result in Figure 5.4, there is saline water presence as the minimum value of resistivity was below than 20 Ωm. This value indicate the range of saline water intrusion for 0.18 Ωm to less than 20 Ωm. Based on this value, the aquifers are not safe for consumption.

5.3.3 Survey Line 3

Line 3 is located at N 6.14412500, E 102.32062400 and elevation of 7 m above sea level with a length of 200 metres. The area was about 3 km from the shoreline but located beside the main river. The selected configuration was Wenner array. The location was quite wet as the line located close to a fishing recreation area inside a small village as the intrusion was predicted to enter freshwater aquifer at a very shallow depth.

Figure 5.6: Line 3 at Kg Pulau Gajah

FYP FSB

Table 4.4: Location for line 3

Name	Coordinate	Distance from shoreline	Resistivity values. Ωm
Kg Pulau Gajah	N 6.14412500, E 102.32062400	3 km	0.1 – 3,000

Based on the result, the total percentage of RMS error is 15.1% for resistivity. Minimum resistivity value in this survey line is 0.947 Ωm and the highest value is 121 Ωm with depth of about 25 metres. Based on the Figure 5.7, there is small value from 0.947 Ωm shows of saline water presence as the minimum value of resistivity was below than 20 Ωm. v

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

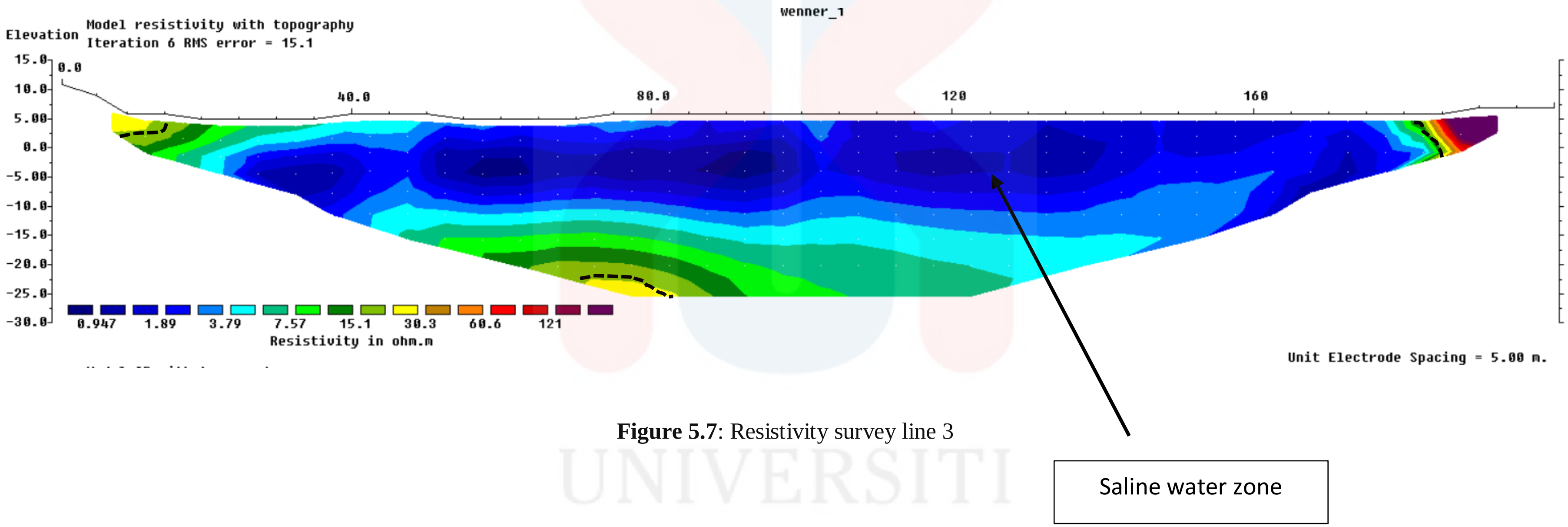


Figure 5.7: Resistivity survey line 3

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

5.4 In Situ Chemical Parameters

All water sample results were tabulated and discussed in this part around Kemumin, Kota Bharu. Essentially, the results of water samples show different values and concentrations for each area, mainly groundwater samples obtained from local wells. Often addressed were the factors that contribute to the disparity in water samples values and concentration. Eventually, this finding was then aligned with the Ministry of Health of Malaysia's National Guidelines of Raw Water Quality Standard. To assess the groundwater quality status around Kemumin, Kota Bharu, and these criteria were used as the benchmark.

Table 5.5: Recommended Raw Water Quality Criteria by Ministry of Health, Malaysia

Constituents	**Permissible limit in Ministry of Health, Malaysia (MOH) in mg/L unless otherwise stated**
pH	5.5 – 9.0
Total Dissolved Solids (TDS)	1500
Turbidity	9 NTU
Calcium	200
Sodium	200
Potassium	30
Iron	1.0
Chloride	250
Manganese	0.2
Copper	1.0
Salinity	0.5 ppt

FYP FSB

Table 5.6: Sampling locations around study area in Kemumin, Kota Bharu

Sample Name	Type of water sample	Location / Time	Latitude, N	Longitude, E	Elevation above sea level	Distance from shoreline
AT1	Boring well	Pulau Gajah/ 9.47 am	6.153852	102.3379	5 m	1.9 km
AT2	Boring well	Kg Pengkalan Datu / 4.05 pm	6.13429	102.321725	9.7 m	4.24 km
AT3	Boring well	Kg Pantai Senok/ 5.00 pm	6.158035	102.343035	14 m	0.9 km
AT4	Dug well	Kampung Sering / 5.53 pm	6.136083	102.323089	5.5 m	4.05 km
AT5	Boring well	SK Panji / 6.25 pm	6.129023	102.301557	9.9 m	5.90 km
AT6	Dug well	Kg Gertak Saku / 7.00 pm	6.145016	102.312147	7.5 m	3.85 km

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

AT7	Dug well	Kg Tebing Tinggi / 7.30 pm	6.169551	102.315189	6.6 m	1.28 km
AT8	Boring well	Masjid Mukim Pulau Panjang / 7.50 pm	6.178448	102.293969	6.0 m	1.15 km

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

Table 5.7: In situ physical parameters of collected water sample in study area of Kemumin, Kota Bharu

Sample	**Location / Time**	**pH range**	**Temperature range, °C**	**Total Dissolved Solids (TDS), mg/L**	**Total Suspended Solids (TSS), mg/L**	**Turbidity range, NTU**	**Salinity range, ppt**	**Electrical Conductivity (EC), µS/cm**
AT1	Pulau Gajah/ 9.47 am	6.75	20.4	453	169	5.67	6.2	99
AT2	Kg Pengkalan Datu / 4.05 pm	7.2	19.7	514	40	4.87	7.2	112
AT3	Kg Pantai Senok/ 5.00 pm	6.52	30.57	103	179	0.47	8.1	159.8
AT4	Kampung Sering / 5.53 pm	5.81	31.24	102	122	9.9	0.1	156.9

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

AT5	SK Panji / 6.25 pm	5.93	33.61	142	135	8.79	0.1	219.6
AT6	Kg Gertak Saku / 7.00 pm	6.19	30.33	321	20	9.99	0.2	494.0
AT7	Kg Tebing Tinggi / 7.30 pm	4.2	31.66	951	178	0.47	5.8	146.2
AT8	Masjid Mukim Pulau Panjang / 7.50 pm	6.54	31.71	156	67	1.86	5.3	241.1

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

5.4.1 pH

Based on Table 5.6, the values for pH ranged from 7.2 to 4.2. AT7 showed the lowest pH value which is 4.2 whereas AT2 showed the highest value of pH which is 7.2. The average of pH value for all water samples was 6.14. The range of pH value from 5.81 to 7.2 is acceptable according to National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.8. The high pH of water sample from AT7 could be due to agricultural activity nearby the locations that may affect the groundwater aquifer as well as clay content in the aquifer.

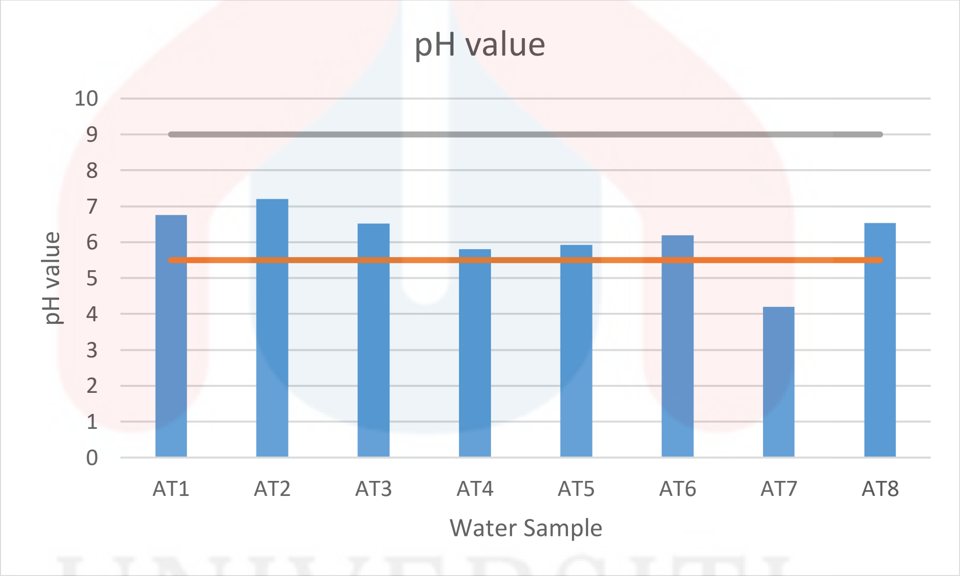


Figure 5.8: pH values of water sample around Kemumin

5.4.2 Total Dissolved Solids (TDS)

Total dissolved solids (TDS) is the term used to describe the inorganic salts and small quantities of organic matter found in water solution. Calcium, magnesium, sodium, and potassium cations and anions of carbonate, hydrogen carbonate, chloride, sulphate, and nitrate are usually the main constituents.

FYP FSB

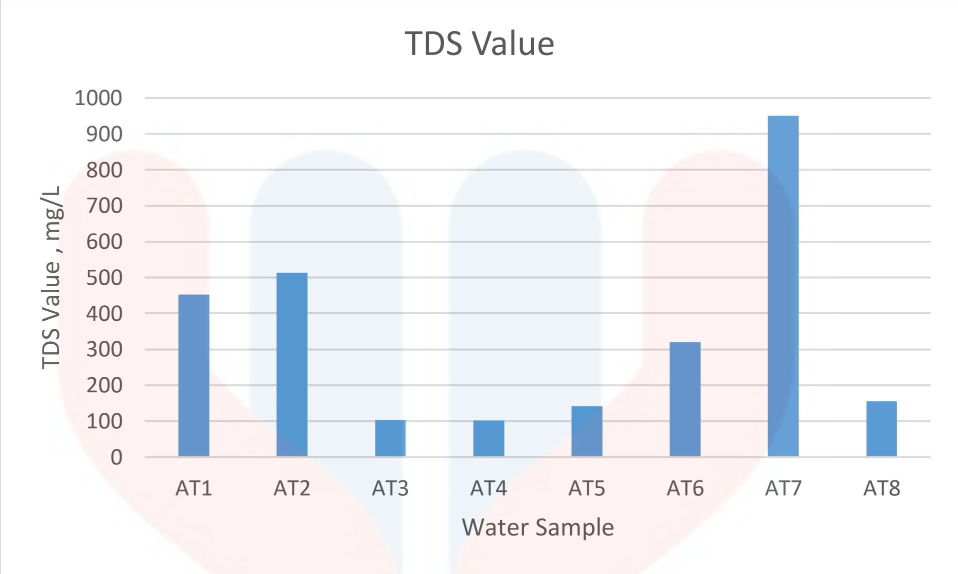


Figure 5.9: Total Dissolved Solids (TDS) values of water sample around Kemumin

Total Dissolved Solids (TDS) of water samples around Kemumin, Kota Bharu varied from 453 mg/L to 514 mg/L with the average value of 362.25 mg/L and all samples within permissible limit of standard from MOH. Among all the collected water samples, AT7 shows the highest value of 514 mg/L compared to other water samples. The amount of TDS in these samples varied may be affected by types of minerals that make up the aquifers, the length of time which water is in contact with the minerals and chemical state of the groundwater.

5.4.3 Electrical Conductivity (EC)

The electrical conductance is the substance's ability to conduct an electrical current. Groundwater conductance is a function of temperature, ion types present, and different ion concentration. Chemically pure water has very low electrical conductivity - it is an excellent insulator. Moreover, as the amount of solutes dissolved decreases, the ability of water to transfer electricity increases. Water with high conductivity in

FYP FSB

pipes and containers may have an unpleasant taste, cause staining, and precipitate size (KGS, 2019).

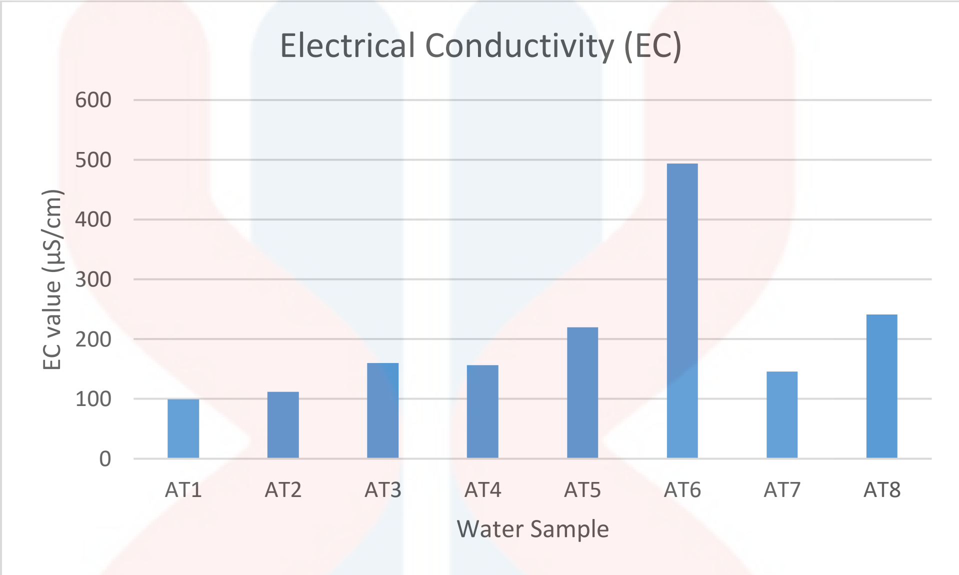


Figure 5.10: Electrical Conductivity (EC) values of water sample around Kemumin

Electrical conductivity (EC) in the study area recorded from 494 **µS** $\boldsymbol{cm^{-1}}$ to 99 **µS** $\boldsymbol{cm^{-1}}$**.** AT6 had the highest value which is 494 **µS** $\boldsymbol{cm^{-1}}$ whereas AT1 99 **µS** $\boldsymbol{cm^{-1}}$ had the lowest value with overall average EC values was 203.6 **µS** $\boldsymbol{cm^{-1}}$**.**

Table 5.8: Classification of electrical conductivity for suitability of water for certain purpose

Classification	**Electrical Conductivity (EC), µS** $\boldsymbol{cm^{-1}}$	**Classification**
Excellent	Less than 250	AT1, AT2, AT3, AT4, AT5, AT7, AT8
Good	250 – 750	AT6
Permissible	750 – 2000	-
Doubtful	2000 – 3000	-
Unsuitable	More than 3000	-

(Source; Shahida & Ummatul, 2015)

FYP FSB

5.4.4 Turbidity

Turbidity is a function of a liquid's relative clarity. It is an optical characteristic of water and is a measure of the amount of light that is absorbed in the liquid when a light is shined through the sample of water. The higher the scattered light frequency, the higher the turbidity. Including clay, silt, very small inorganic and organic matter, algae, dissolved organic compounds, and plankton and other microscopic organisms are substances that cause water to be turbid. Turbidity makes water dark or gloomy (USGS, n.d.).

In drinking water, excessive turbidity or cloudiness is aesthetically unattractive and can also be a health concern. Turbidity may provide pathogens with food and shelter. If not removed, the causes of high turbidity can promote the regeneration of pathogens in the water, leading to outbreaks of waterborne disease (USGS, n.d.). Based on Figure 5.11, AT4 and AT5 shows the highest turbidity value which exceed the permissible limit according to MOH.

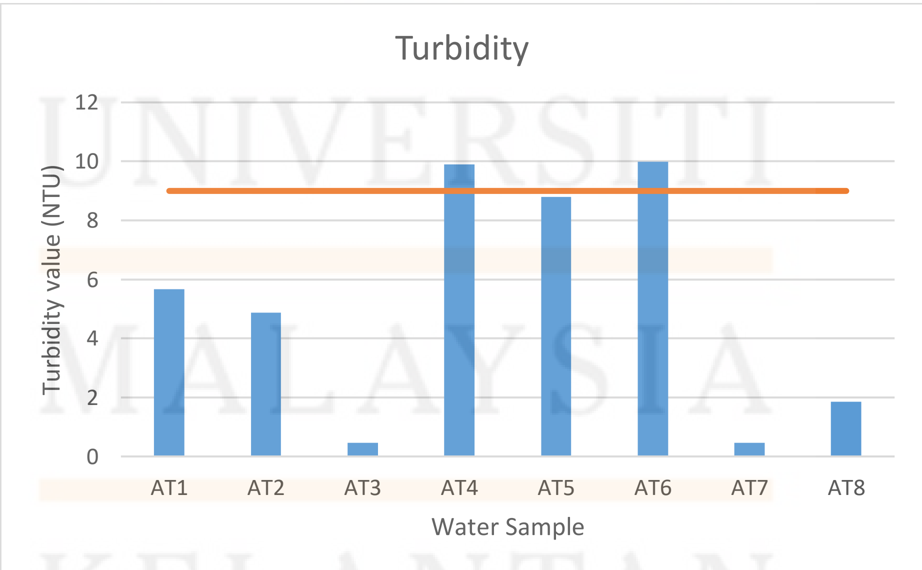


Figure 5.11: Turbidity values of water sample around Kemumin

FYP FSB

5.4.5 Salinity

Salinity refers to the soil or liquid concentration of soluble salts. There are some dissolved salts such as sodium, magnesium and calcium in all natural waters. The most popular of all salts is sodium chloride (table salt); it is the main component of seawater. Salt levels in water affect their suitability for irrigation, storage and household use (Agriculture Victoria, 2018).

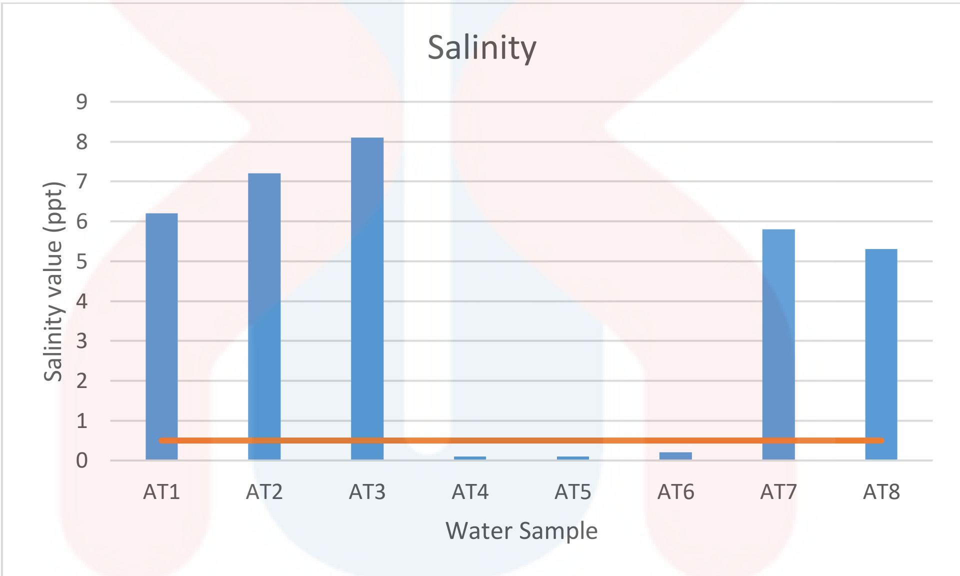


Figure 5.12: Salinity values of water sample around Kemumin

The results shown by the Figure 5.12 indicated that the range of salinity values was from 0.1 to 8.1 ppt. AT3 recorded the highest value of salinity due to its very close distance to the ocean while AT4, AT5 and AT6 recorded the lowest value of salinity which are still within the permissible limit according to MOH.

5.4.6 Total Suspended Solids (TSS)

In the water column, Total Suspended Solids (TSS) are particles greater than 2 microns. Anything less than 2 microns (average size of the filter) is called a solid

FYP FSB

dissolved. Many suspended solids consist of inorganic materials, while bacteria and algae may also contribute to the overall concentration of solids. Observing water clarity is a significant factor in overall suspended solids. The heavier the water is, the less pure the water will be (Fondriest Environmental, Inc., 2014).

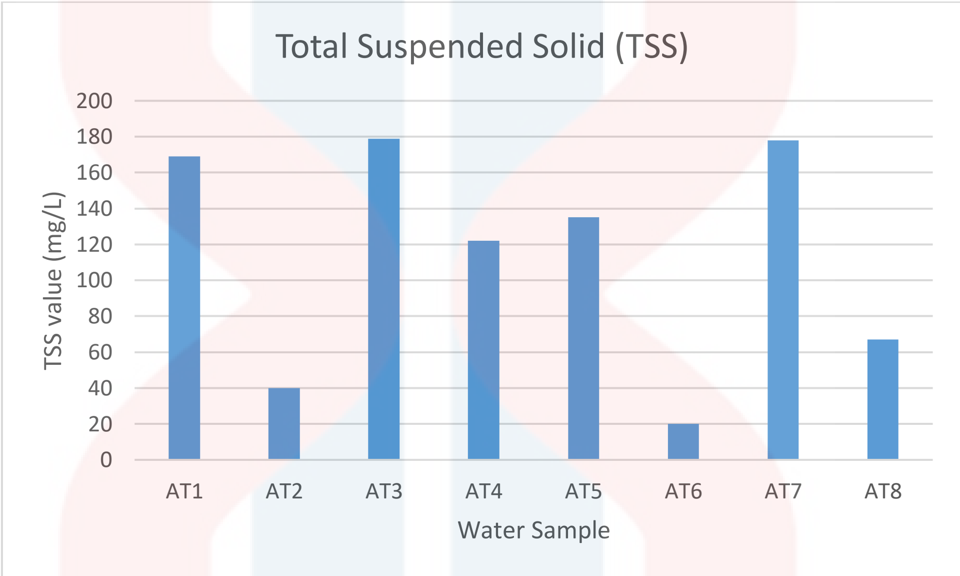


Figure 5.13: Total Suspended Solids (TSS) values of water sample around Kemumin

FYP FSB

UNIVERSITI
MALAYSIA
KELANTAN

5.5 Chemical Parameters of Water Sample

Below are the results obtained from the Atomic Absorption Spectrometer (AAS) that analysed five samples collected around Kemumin, Kota Bharu.

Table 5.9: Chemical parameters of water samples around Kemumin analysed using AAS

Sample	Cu^{2+} (mg/L)	Fe^{2+}/Fe^{3+} (mg/L)	K^{+} (mg/L)	Mn^{2+} (mg/L)	Na^{+} (mg/L)
AT1	0.031	1.384	3.199	0.040	5.360
AT2	0.048	0.718	22.93	0.129	50.26
AT3	0.042	2.650	41.33	0.071	777.2
AT7	0.052	2.168	3.143	0.378	43.74
AT8	0.027	0.267	5.650	0.341	6.889

5.5.1 Copper, Cu^{2+}

Copper is a very common material that occurs naturally in the atmosphere and is spread by natural phenomena throughout the world. By both natural sources and human activities, copper can be released into the environment. Wind-blown dust, rotting trees, forest fires, and sea spray are examples of natural sources (Lenntech BV, 2019).

Some copper compounds can settle and either be attached to water or soil particles. Soluble compounds of copper pose the greatest threat to human health. Generally water-soluble copper compounds occur in the environment following release in agriculture via application (Lenntech BV, 2019). Some of these threats are may cause damage to the stomach and intestines, liver and kidney, high doses of

FYP FSB

anaemia. Besides that, it can gives clothes and fixtures an unpleasant taste and substantial staining. The copper ions also can be called essential trace element but at moderate levels toxic to plants and algae (USGS, n.d.).

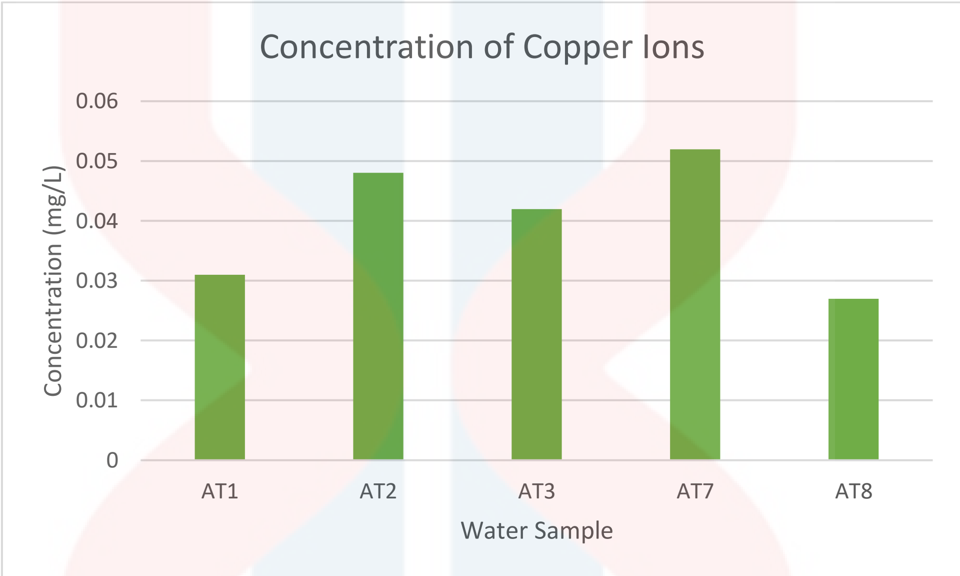


Figure 5.14: Copper ion concentration around Kemumin

The concentration for copper ions which exist as trace elements in groundwater aquifer around Kemumin, Kota Bharu ranged from 0.052 mg/L to 0.027 mg/L with the average concentration of 0.04 mg/L. Based on the Figure 5.14, AT7 had the highest concentration of copper ions which is 0.052 mg/L.

Based on the Figure 5.14, all five samples had copper ions concentration below than 1.0 which is still within the permissible limit of MOH standard.

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

5.5.2 Iron, Fe^{+}

Iron is metallic elements that exist in many rock types. Iron can be found naturally in water, and all living organisms require essential elements in small amounts. In groundwater, iron levels are often higher than in surface waters. The iron occurs naturally in the aquifer, but through the removal of ferrous borehole and hand pump materials, the groundwater levels can be increased (Lenntech BV, 2019).

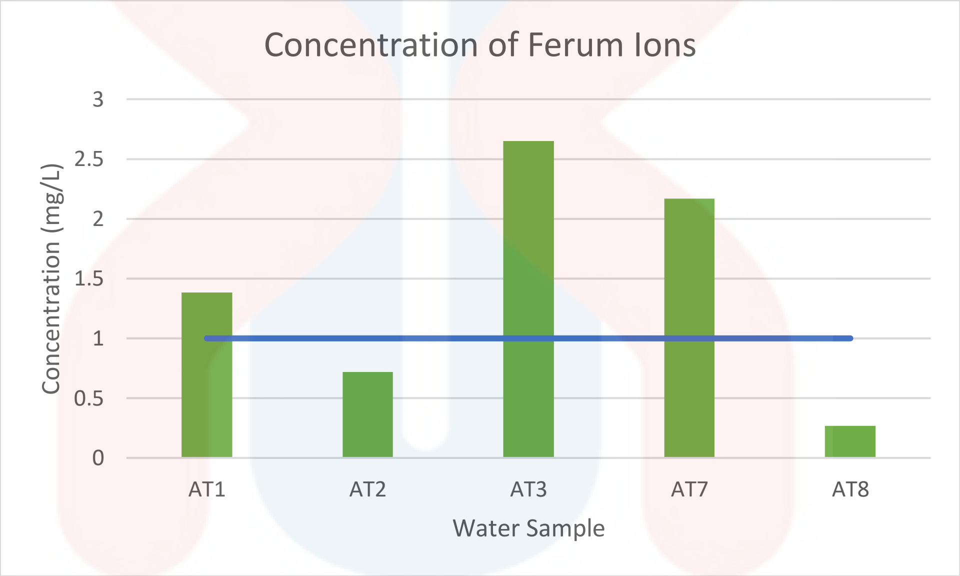


Figure 5.15: Ferum ion concentrations of water sample around Kemumin

Concentrations of iron in study area ranged from 2.65 mg/L to 0.267 mg/L. The average of the iron ions concentration was 1.437 mg/L. Based on Figure 5.15, only water samples collected from AT2 and AT8 contained iron below the permissible limit compared to other sites which exceeds more than 1.0 mg/L. Water sample AT1, AT3 and AT7 exceeds the permissible limit of ferum ion concentration. This could probably due to presence of steel pipes used for plumbing that contaminates the groundwater.

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

5.5.3 Potassium, K^+

Potassium is mostly found in nature as unchanged minerals of silicate and clay. The potassium content is highly dependent on the type of aquifer sediments. This is because, unlike sodium salts, potassium salts are not readily soluble in most rocks in groundwater. Potassium (K) are also present in ancient brines, seawater, some industrial brines, and sewage, dissolved from nearly all rocks and soils (NGWA, 2019).

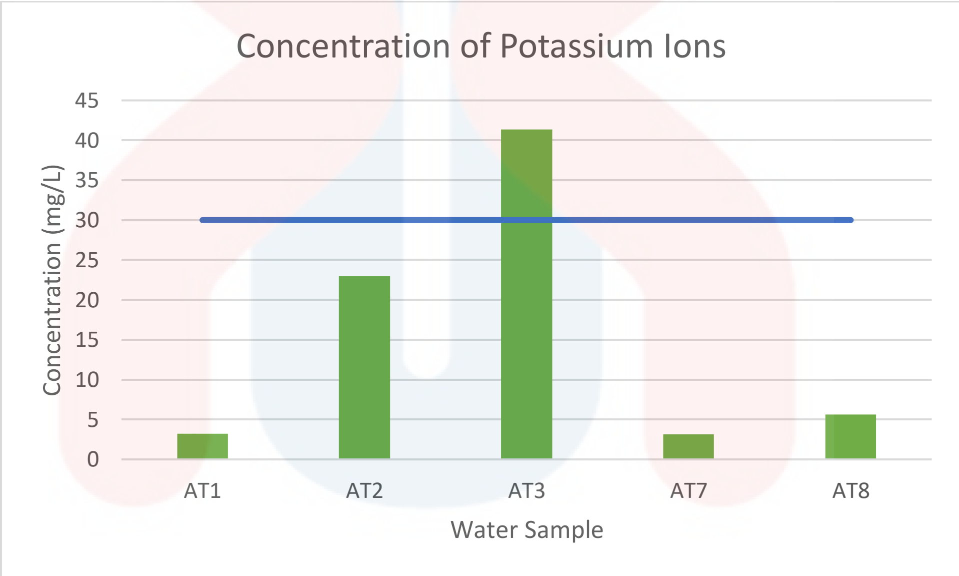


Figure 5.16: Potassium ion concentrations of water sample around Kemumin

Analysis of the geochemical data obtained shown in Figure 5.16, potassium ions concentrations in study area ranged from 3.143 mg/L to 41.33 mg/L with mean value of 15.25 mg/L. AT3 shows the highest concentration of potassium ions of 41.33 mg/L while AT1 recorded the lowest value of potassium ions which is 3.143 mg/L.

All the collected water samples showed concentration of potassium ions indicates that groundwater around the study area can be used for human activities such as domestic usage, agricultural and farming thus following the standard stated by MOH which is below 200 mg/L.

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

5.5.4 Manganese, Mn^{2+}

Manganese is metallic elements that exist in many rock types. Manganese can be found naturally in water, and all living organisms require essential elements in small amounts. In groundwater, manganese levels are often higher than in surface waters. Groundwater comes into contact with these solid materials in the aquifer, dissolving them, releasing their contaminants into the water, like manganese. At concentrations of approximately 0.3 mg / L Mn, the quality of the water may be seriously affected, e.g. water may have a metallic taste, and plumbing fixtures may become widely stained. Dissolved manganese in the water may form black particles and cause similar coloured stains on fixtures.

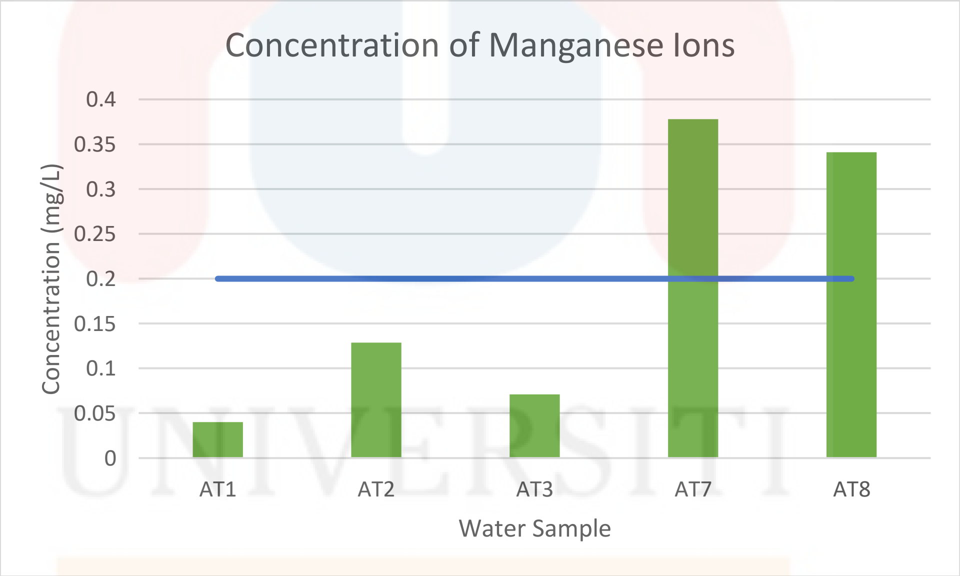


Figure 5.17: Manganese ion concentrations of water sample

Analysis of the geochemical data obtained (Figure 5.17) showed that manganese ions concentrations in study area ranged from 0.04 mg/L to 0.378 mg/L with the mean value of 0.192 mg/L. Sample AT7 and AT8 show high manganese ion concentration which is more than permissible limit and it is not safe for drinking purpose. Other than these two samples, the rest are safe and can be used for drinking

FYP FSB

purpose. The high concentration of manganese ion are probably due to contaminants that seeps into the ground.

5.5.5 Sodium, Na^+

Sodium is a chemical element that is highly soluble and is often present in groundwater. Sodium does not smell in water, but it can be detected at levels of 200 mg / L or more by most people. A rise in sodium above environmental or natural levels in groundwater can result in contamination from point or non-point sources or intrusion of salt water.

Most groundwater contains some sodium because sodium is easily removed from most rocks and soils. There are some common sources of elevated sodium levels that the samples can detect: natural brackish water from aquifers, infiltration of salt water into wells in coastal areas, drainage and rain leaching from landfills from soils rich in sodium or groundwater contamination (The British Columbia Groundwater Association, 2017). However, an excess consumption of sodium contained water can be a health risk factor for those individuals on a low-sodium diet.

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

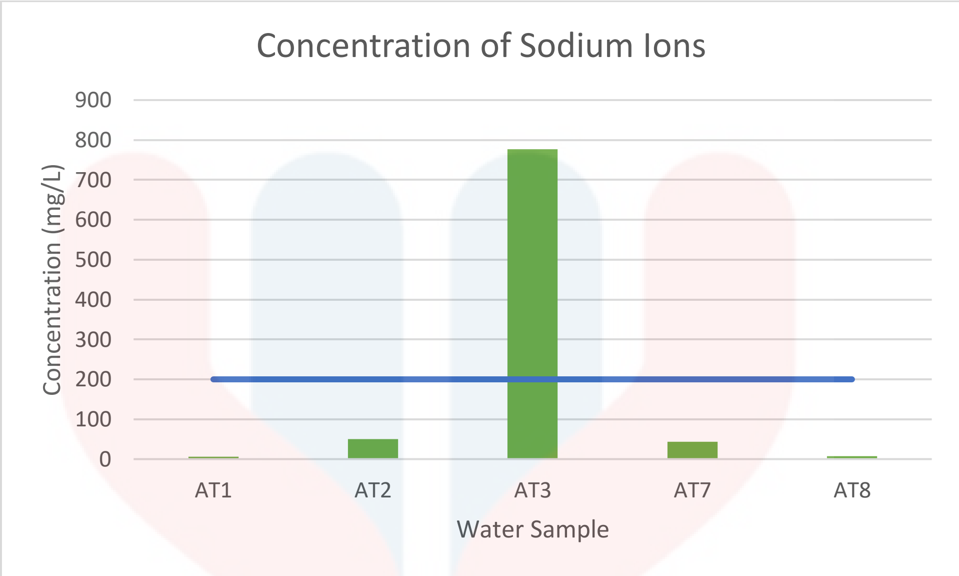


Figure 5.18: Sodium ion concentration of water sample around Kemumin

Figure 5.18 displayed that the range of sodium ions concentration of water samples ranges from 5.36 mg/L to 777.2 mg/L with overall average concentration of 176.69 mg/L of sodium ions. As shown in the Figure %.18, AT3 has the highest value of sodium ions which is 777.2 mg/L which is more than permissible limit that clearly shown seawater intrusion due to its distance with the shoreline. This result also supported by other parameters such as salinity that also show high value in the same sample. Permissible limit for sodium ions concentrations must be below than 200 mg/L. Therefore, all the water samples except the one collected at AT3 are safe to consume by local people around the study area.

5.5.6 Chloride, Cl^{-}

Presence of chloride ions are the one of the best indicators to detect seawater intrusion as the main component of salt water is $NaCl$. Based on Figure 5.19, all the samples are still within the permissible limit which does not exceed 250 mg/L and still safe for consumption.

FYP FSB

Table 5.10: Chloride ion concentration from water sample in study area

Sample	Location	mg/L
AT1	Pulau Gajah	47.85
AT2	Kg Pengkalan Datu	42.6
AT3	Kg Pantai Senok	44.02
AT7	Kg Tebing Tinggi	36.50
AT8	Masjid Mukim Pulau Panjang	49.27

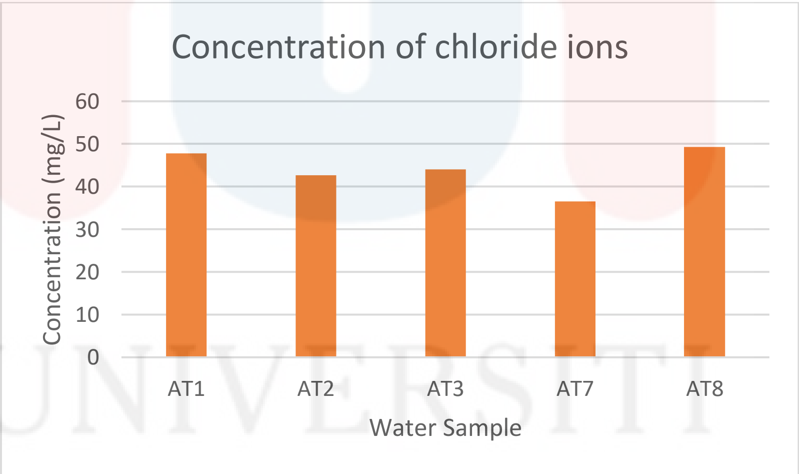


Figure 5.19: Concentration of chloride ions in study area

Based on resistivity data, the result shows there are indicators of seawater intrusion supported by geochemical result from water sample done in-situ and laboratory analysis.

FYP FSB

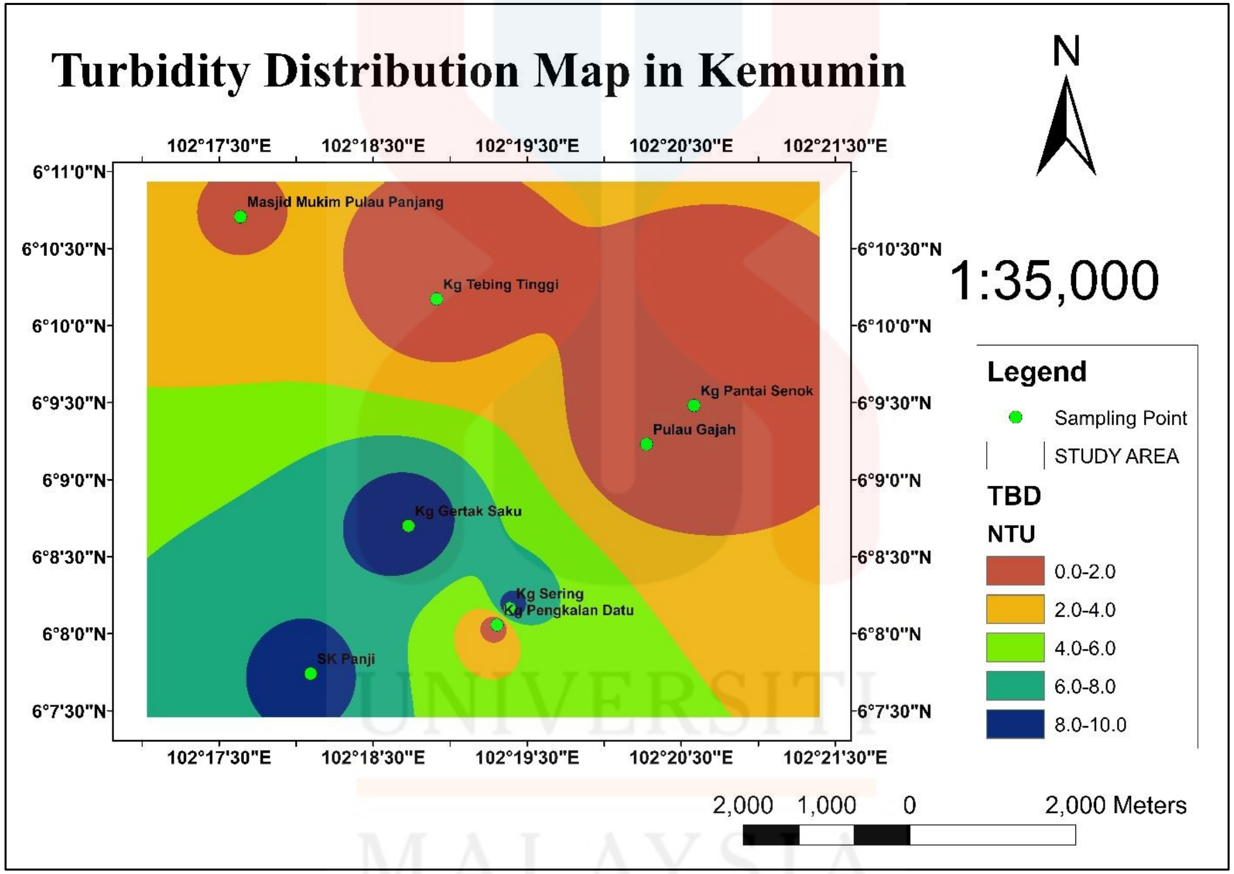


Figure 5.20: Turbidity distribution map in Kemumin

UNIVERSITI MALAYSIA KELANTAN

FYP FSB

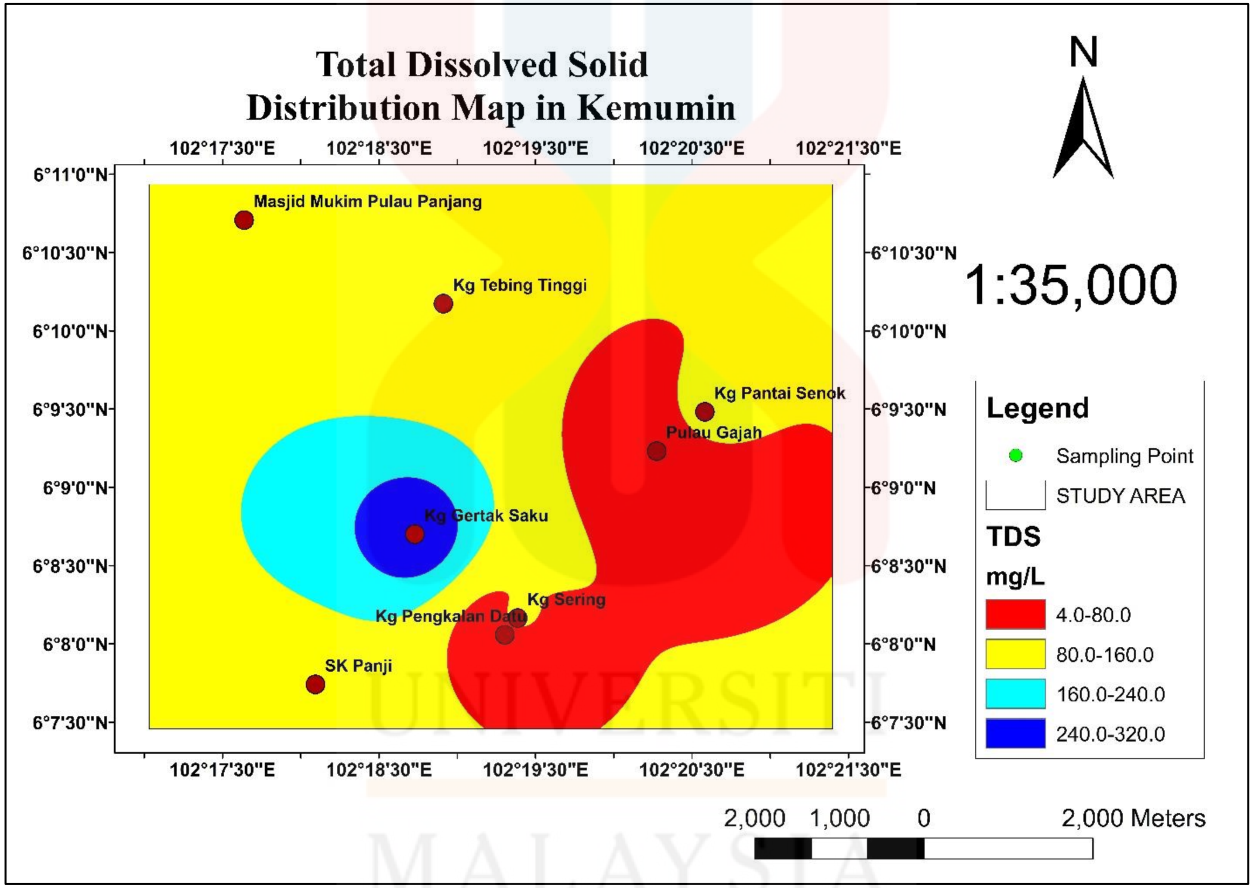


Figure 5.21: Total Dissolved Salid (TDS) distribution map in Kemumin

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

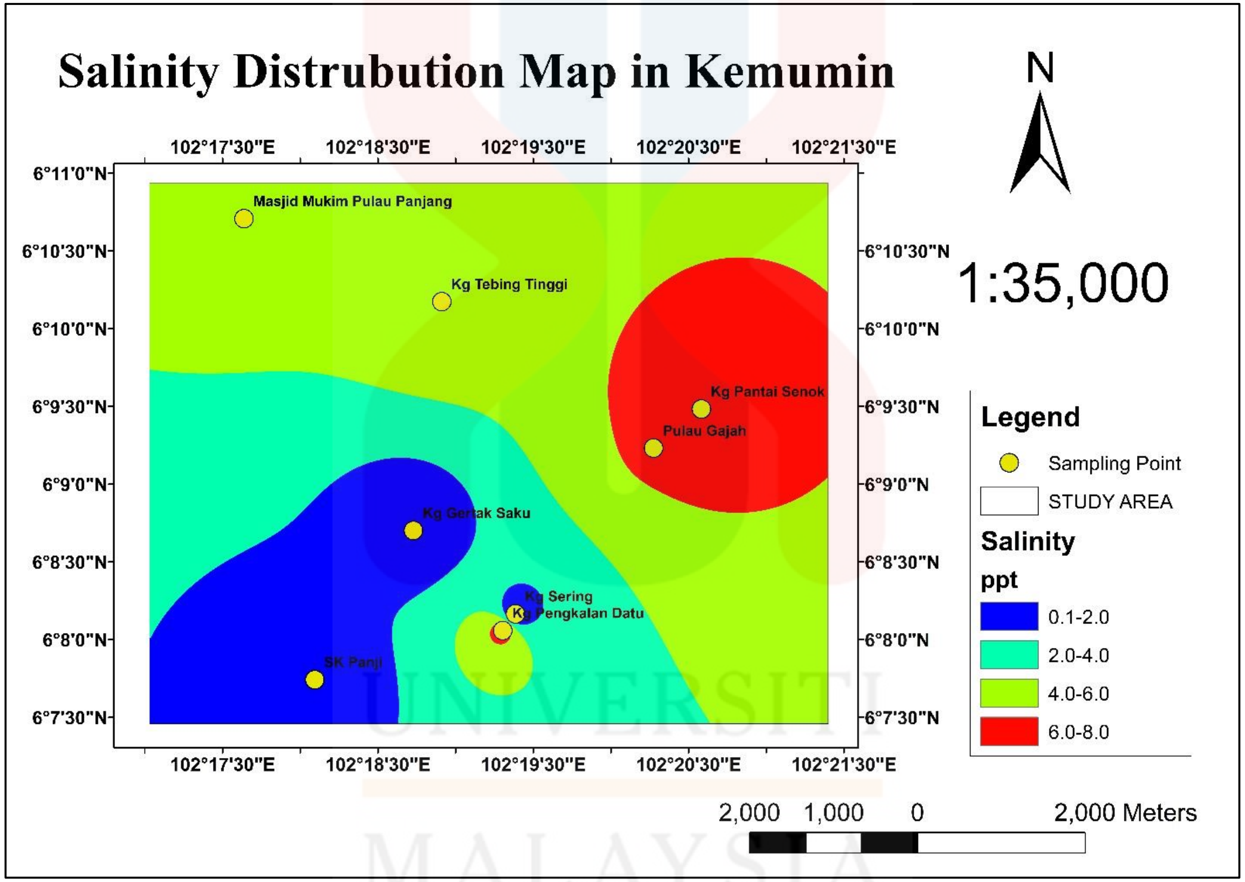


Figure 5.22: Salinity distribution map in Kemumin

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

FYP FSB

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

As conclusion, lithology in area of Gua Musang, Kelantan comprised of very highly weathered sedimentary and meta-sediment rocks such as mudstone, sandstone and quartzite with different phase of metamorphism as lamination and foliation structure were found on exposed outcrop. Meanwhile, a few groundwater samples are not safe and suitable for usage of all purposes in daily life as the data collected was compared to the Guidelines of Raw Water Quality Standard from the Ministry of Health of Malaysia. Based on the result obtained from Electrical Resistivity Imaging (ERI) survey, there is quite the distinct border in which the seawater and freshwater interface occurred at 2 to 3 kilometres from the shoreline.

In conclusion, based on all the indicators, there was seawater that intrudes fresh groundwater aquifer within a few kilometres distance from the shoreline. This statement can be justified by the resistivity profile shown in Survey Line 2 and resistivity survey line 3 show a small amount salinity presence inside its shallow aquifer which can be supported by data collected from nearest groundwater well (sample AT4 and sample AT6).

6.2 Recommendation

For groundwater well users that contained high concentrations of manganese ions and sodium, chloride and other related ions from saline water that intrudes groundwater aquifer that is above the allowable level, it is recommended that the water be treated before use whether it can affect health for domestic or drinking purposes as excess ions can be deteriorating for one's body.

Future research must be carried out again as this phenomenon are dynamic and must be regularly monitored. Groundwater demands will increase and groundwater over pumping will interrupt the coastal line balance between seawater and freshwater interface and contribute to the intrusion of seawater into aquifers. It is advisable for local authorities to control the abstraction of groundwater well to prevent from formation of cone of depression that may lead to seawater intrusion and subsidence due to over extraction done by consumers.

Based on the second indicator which the geochemical analysis is done on site and in laboratory, it is best to say that some of the location that extract groundwater aquifers especially near the shorelines must be monitored regularly by consumer and local governments in order to avoid over pumping or over extraction due to excessive groundwater usage that can cause the formation of depression cone. This will disrupt the freshwater – seawater interface beneath the water table that may contaminate the groundwater resources with hazardous trace elements that will pollute freshwater resources.

FYP FSB

To avoid any parallax error, the electrical resistivity survey and the sampling program must be properly designed and executed, thus increasing the accuracy of the study result. In addition, future researchers will need to increase the sampling point and better developed equipment during the survey. Moreover, the samples collected from the groundwater well must be handled more carefully to avoid any contamination by external environments.

In the future, scientists should use more advanced laboratory tools to better explain the reliability and validity of the study test.

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN

REFERENCES

Agriculture Victoria. (2018, November 30). Measuring the Salinity of Water. Retrieved from Agriculture: http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/salinity/measuring-the-salinity-of-water

Asry, Z., Samsudin, A., Yaacob, W., & Yaakub, J. (2012). Groundwater investigation using electrical resistivity imaging technique at Sg. Udang, Melaka, Malaysia. Bulletin of the Geological Society of Malaysia, 55 - 58.

Barlow, Paul M. 2003. Groundwater in Freshwater-Saltwater Environments of the Atlantic Coast. U.S. Geological Survey Circular: 1262.

Environmental Protection Agency, USA. (2016, May 19). Resistivity Methods. Retrieved May 3, 2019, from https://archive.epa.gov/esd/archive-geophysics/web/html/resistivity_methods.html

EPA South Australia. (2019). EPA South Australia. Retrieved from Salinity: https://www.epa.sa.gov.au/environmental_info/water_quality/threats/salinity

Fondriest Environmental, Inc. (2014, June 13). Fundamentals of Environmental Measurements. Retrieved from Turbidity, Total Suspended Solids and Water Clarity: https://www.fondriest.com/environmental-measurements/parameters/water-quality/turbidity-total-suspended-solids-water-clarity/

Foster, S. S. D., & Chilton, P. J. (2003). Groundwater: the processes and global significance of aquifer degradation. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 358(1440), 1957-1972.

Geology In. (2014, March). Type Of Drainage Patterns. Retrieved from Geology In: http://www.geologyin.com/2014/03/drainage-pattern.html

Hassan, Ami & Md Din, Ami Hassan & Nadzri, Mohd & Md Reba, Mohd Nadzri & Omar, Kamaludin & Rashidi, Mohamad & Razli, Md & Rusli, Noradila. (2015). Land Subsidence Monitoring Using Persistent Scatterer InSAR (PSInSAR) In Kelantan Catchment.

Hassan, E., Rai, J. K., & Anekwe, U. O. (2017). Geoelectrical Survey of Ground Water in Some Parts of Kebbi State Nigeria, a Case Study of Federal Polytechnic Bye-Pass Birnin Kebbi and Magoro Primary Health Center Fakai Local Government. Aliero, Nigeria: Department of Physics, University of Science and Technology.

Hinrichsen, Don. 2007. Ocean Planet in Decline. Available: [online] http://www.peopleandplanet.net/?lid=26188&topic=44&section=35. Accessed: November 7, 2007.

FYP FSB

Huggett, R. J. (2011). Fundamentals of Geomorphology: Third Edition. Oxon: Routledge.

Hussin, Nur & Yusoff, Ismail & Alias, Yatimah & Mohamad, Sharifah & Rahim, Nurul & Ashraf, Muhamad. (2013). Ionic liquid as a medium to remove iron and other metal ions: A case study of the North Kelantan Aquifer, Malaysia. Environmental Earth Sciences. 71. 10.1007/s12665-013-2615-5.

Hutchison, C. S., & Tan, K, D. N. (2009). Geology of Peninsular Malaysia. Kuala Lumpur: Geological Society of Malaysia.

Iqroufa, S., Hashim, R., & Taib, S. (2010). Mapping of Salt-water Intrusion by Geoelectrical Imaging Carey Island. 5th International Symposium on Hydrocarbons & Chemistry (ISHC5).

KGS. (2019). Groundwater-Quality Analyte Descriptions. Retrieved from Kentucky Geological Survey: https://kgs.uky.edu/kgsweb/datasearching/water/analyteDescr.asp

Lenntech BV. (2019). Copper - Cu. Retrieved from LENNTECH: https://www.lenntech.com/periodic/elements/cu.htm

Lenntech BV. (2019). Iron in groundwater. Retrieved from LENNTECH: https://www.lenntech.com/groundwater/iron.htm

Metcalfe, I. & Hussin, A., 1995. Implications of New Biostratigraphic Data for Stratigraphic Correlation of the Permian and Triassic in Peninsular Malaysia. Bulletin of Geological Society of Malaysia, 38, 173–177.

Mohamed, K. R., Mohamed Joeharry, N. A., Leman, M., & Ali, C. (2016). The Gua Musang Group: A newly proposed stratigraphic unit for the Permo-Triassic sequence of Northern Central Belt, Peninsular Malaysia. Bulletin of the Geological Society of Malaysia, 131 - 142.

Mohamed, K.R., 1995. Sabbatical Report. Stratigraphy and Sedimentology of Gua Musang formation and Semantan Formation. Universiti Kebangsaan Malaysia. 71 p.

Mohd Kamal, M. Z. A., Hashim, D. N. M., & Mohd Zin, M. S. B. (2015). Seawater Intrusion In The Ground Water Aquifer In The Kota Bharu District, Kelantan. People: International Journal of Social Sciences, 1(1).

Neugeo Services. (2018, July 17). The History - Resistivity Survey. Retrieved May 2, 2019, from https://www.neugeo.com/article/the-history-resistivity-survey/

NGWA. (2019). Dissolved Mineral Sources and Significance. Retrieved from National Groundwater Association: https://www.ngwa.org/what-is-groundwater/About-groundwater/dissolved-mineral-sources-and-significance

FYP FSB

Peng, K. H. (1983). Mesozoic Stratigraphy In Peninsula Malaysia (pp. 1-14, Rep.). Ipoh, Perak: Geological Survey of Malaysia. Retrieved April 25, 2019, from https://gsm.org.my/file/SCTM_26.pdf.

Perone, J. (2019). Geophysical Surveys: Definition & Methods. Retrieved May 2, 2019, from https://study.com/academy/lesson/geophysical-surveys-definition-methods.html

Pour, Amin & Hashim, Mazlan. (2017). Application of Landsat-8 and ALOS-2 data for structural and landslide hazard mapping in Kelantan, Malaysia. Natural Hazards and Earth System Sciences. 17. 1285-1303. 10.5194/nhess-17-1285-2017.

Ranhill Consulting Sdn. Bhd. (2011). Review Of The National Water Resources Study (2000 - 2050) And Formulation Of National Water Resources Policy (Vol. 10, Kelantan, pp. 1-462, Rep.). Kelantan: Department of Irrigation and Drainage Malaysia. Retrieved April 25, 2019, from https://www.water.gov.my/jps/resources/PDF/Hydrology Publication/Vol10Kelantan.pdf.

Sefie, A., Aris, A. Z., Shamsuddin, M. K. N., Tawnie, I., Suratman, S., Idris, A. N., & Ahmad, W. K. W. (2015). Hydrogeochemistry of groundwater from different aquifer in Lower Kelantan Basin, Kelantan, Malaysia. Procedia Environmental Sciences, 30, 151-156.

Shishaye, H. A., & Abdi, S. (2016). Groundwater Exploration for Water Well Site Locations Using Geophysical Survey Methods. Hydrology: Current Research, 7.

Singhal, B. B. S., & Gupta, R. P. (2010). Applied hydrogeology of fractured rocks. Springer Science & Business Media.

Solinst Canada Ltd. Pump/Recharge Rate Affects Saltwater Intrusion. Retrieved May 11, 2019, from https://www.solinst.com/resources/papers/101c4salt.php

Southeast Asia Research Group. (2016). Peninsular Malaysia Geology and Evolution. Retrieved from Southeast Asia Research Group: http://searg.rhul.ac.uk/current-research/peninsular-malaysia-geology-and-evolution/

Tan, E., & Singh, M. (1989). Groundwater Supply Studies in Northern Kelantan. Geological Society of Malaysia, 14.

Tawnie, I., Sefie, A., Idris, A. N., Shamsuddin, M., & Mohamed, A. (2016, November 28-30). Overview of Groundwater Contamination in Malaysia. SEAWE12. Hanoi, Vietnam.

The British Columbia Groundwater Association. (2017, February). Sodium in Groundwater. Retrieved from Water Stewardship Information Series: https://www.rdn.bc.ca/cms/wpattachments/wpID2284atID3807.pdf

FYP FSB

The Editors of Encyclopedia Britannica. (25 October, 2018). Structural Geology. Retrieved from Encyclopedia Britannica: https://www.britannica.com/science/structural-geology

USGS. Contamination of Groundwater. Retrieved from USGS: https://www.usgs.gov/special-topic/water-science-school/science/contamination-groundwater?qt-science_center_objects=0#qt-science_center_objects

USGS. Turbidity and Water. Retrieved from USGS - Water Science School: https://www.usgs.gov/special-topic/water-science-school/science/turbidity-and-water?qt-science_center_objects=0#qt-science_center_objects

Wan Muhamad Tahir, W. Z., Hussin, N. H., Yusof, I., Mamat, K., Abdul Latif, J., & Demanah, R. (2014). Integrated Assessment Of Groundwater Recharge In The North Kelantan River Basin Using Environmental Water Stable Isotope, Tritium And Chloride Data. University Malaya.

Werner, A. D. (2010). A review of seawater intrusion and its management in Australia. Hydrogeology journal, 18(1), 281-285.

Yee, F. K. (1983).The Palaeozoic Sedimentary Rocks Of Peninsular Malaysia - Stratigraphy And Correlation (pp. 1-19, Rep.). Ipoh, Perak: Geological Survey of Malaysia.

FYP FSB

UNIVERSITI
MALAYSIA
KELANTAN

FYP FSB

APPENDICES

Figure 1: Electrical Resistivity survey

Figure 2: Resistivity cable at one end of the line

Figure 3: Collection of water samples at boring well and dug well

UNIVERSITI MALAYSIA KELANTAN

Figure 3: In situ geochemical analysis of water sample using YSI Multiparameter

Figure 5: Dilution of water sample for AAS

Figure 6: Preparing thin section slide for petrographical analysis

FYP FSB
UNIVERSITI MALAYSIA KELANTAN

FYP FSB

Figure 6: Weighing dry silver nitrate for titration analysis

Figure 7: Preparing apparatus for titration analysis

Figure 8: Water sample with potassium chromate

UNIVERSITI MALAYSIA KELANTAN

Thin Section Analysis

In the laboratory, fresh rock samples collected from the field are produced into a thin section. The following fundamental steps can generally be broken down into the normal thin section manufacturing:

i. Preparing the glass slide

In order for the rock portion to end up with a steady thickness, the glass slide that will be used to glue the rock must be flat. To accomplish this, it is necessary to "frost" the slide, which achieves two objectives. It removes the dense spots on the slide and adjusts the face of the slide to be parallel to the face of the grinding wheel.

ii. Frosting the glass slide

The glass slide is either "frost" or grind to flatten it and roughen the surface so that the epoxy can bind well. Place the slide on the grinder in the same direction to achieve this.

iii. Marking the sample

Where to cut the rock sample must be decided. Usually, the sample will be cut on a plane perpendicular to any planar fabric for rocks that have a fabric. But other orientations may be preferable for specific reasons. A line on the rock should be marked.

iv. Cutting and cleaning the slab

A slab is separated from the stone sample along the row labelled using the slab saw.

v. Cutting the chip

It is necessary to reduce the size of the slab to a smaller size than a thin section. To cut the slab, the trim saw is used. From which part of the slab you want to cut the section you need to closely decide.

vi. Glue the slide to the chip

The slide's frosted side is glued to the ground-down side of the chip. Constant epoxy thickness must be ensured throughout the segment.

vii. Cutting the chip from the slide

Most of the chip will be cut off and a thin slide will be attached.

FYP FSB

viii. Grind the slide to the correct thickness

Much of the rock on the slide needs to be grinding. This has to be done closely as it is the thinnest parts that go wrong.

FYP FSB
UNIVERSITI
MALAYSIA
KELANTAN