GEOLOGY AND EVALUATION SEA WATER INTRUSION IN SHALLOW AQUIFERS USING HYDROCHEMISTRY IN TUMPAT, KELANTAN

NUR DIYANA ANIS BT MD SUHAIMIN

FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN

2017

NUR DIYANA ANIS
BT MD SUHAIMIN

B. App.Sc. (GEOSCIENCE) with Hons.

2017

GEOLOGY AND EVALUATION SEA WATER INTRUSION IN SHALLOW AQUIFERS USING HYDROCHEMISTRY IN TUMPAT, KELANTAN

by

NUR DIYANA ANIS BT MD SUHAIMIN

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

FACULTY OF EARTH SCIENCE

UNIVERSITI MALAYSIA KELANTAN

2017

DECLARATION

I hereby certified that the work embodied in this thesis is the results of the original research and has not been submitted and accepted for any degree of any other universities or institutions.

☐	OPEN ACCESS	I agree that my report is to be made immediately available as hardcopy or online open access (full
☐	CONFIDENTIAL	(Contains confidential information under the Official secret act 1972)*
☐	RESTRICTED	(Contains restricted information as specific by the organization where research was done)*

I acknowledge that Universiti Malaysia Kelantan reserves the right as follows.

1. The report is the property of Universiti Malaysia Kelantan.
2. The library of Universiti Malaysia Kelantan has the right to make copies for the purpose of research only.
3. The library has the right to make copies of the thesis for the academic exchange.

Certified by :

__________________________ __________________________

Name :	Name :
Matric Number :	Date :
Date	

Note : * If the report is CONFIDENTIAL or RESTRICTED, please attach the letter from the organization stating the period and reasons for confidentiality and restriction.

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 for your support and understanding over these past years.

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

Besides academic support, I have a lot of peoples to thank for listening to and tolerate to me over the years. I would like to should my gratitude and appreciation for their friendship. Solehah Abd Rahman, Noor Syahila Salleh, and Nurul Suhada Mhd Sukri have been sincerely gives all their personal and professional support during the time I spent at the university. For many memorable evenings out and in, I must thank everyone above as well as Norshabira Noradlan and Nur Zulaikha Jamani.

Most importantly, none of this could have happened without my beloved family. My parents, Md Suhaimin Muhamad and Azizah Awang and my siblings who offered their encouragement all the times. Being kind and supportive to me over the years. Every time, I have went through some ups and downs in the past four years. Every time I was ready to quit. All of you did not let me and I am forever grateful. This thesis stands as a proof to your unconditional love and encouragement.

Geology And Evaluation Of Seawater Intrusion In Shallow Aquifers Using Hydrochemistry In Tumpat, Kelantan

ABSTRACT

The study is about geology and evaluation of seawater intrusion in shallow aquifers using hydrochemistry in Tumpat, Kelantan. Intrusion of seawater in shallow aquifers is very serious issue as it can be one of the source of groundwater contamination. Water samples which 14 groundwater samples from different wells and 1 river water sample were collected and analysed for pH, temperature, total dissolved solids (TDS), electrical conductivity (EC), turbidity and salinity by using multiparameter and portable turbidity meter. Meanwhile calcium, sodium, magnesium, iron, potassium, chloride, bicarbonate and sulphate were analyzed through atomic absorption spectroscopy analysis, gravimetric analysis and titration analysis. Sea water intrusion evaluated by using the result obtained from the analysis of water samples. The result showed 2 type facies of shallow aquifers which were sodium-bicarbonate and calcium-magnesium-bicarbonate which determined by Piper Trilinear diagram. Meanwhile, all groundwater samples lied within normal groundwater zone based on a graph of chloride against electrical conductivity. The data for geology of Tumpat, Kelantan obtained from alluvium mapping, geomorphological mapping and investigation of soil. New geological map produced by ArcGIS software based on the geological data.

Keyword : Sea water intrusion, coastal aquifer, Tumpat

Geologi dan Penilaian Pencerobohan Air Laut dalam Akuifer Cetek Menggunakan Sains Kimia Air di Tumpat, Kelantan

ABSTRAK

Kajian ini memperihalkan geologi dan penilaian pencerobohan air laut ke dalam akuifer cetek menggunakan sains kimia air di Tumpat, Kelantan. Pencerobohan air laut merupakan isu yang sangat serius kerana ianya boleh menjadikan salah satu punca pencemaran air bawah tanah. Sampel air terdiri daripada 14 sampel air bawah tanah dari telaga yang berlainan dan 1 sampel air sungai diambil dan dianalisis untuk mendapatkan nilai pH, suhu, jumlah pepejal terlarut, konduktiviti, kekeruhan dan kemasinan dengan menggunakan multiparameter dan meter kekeruhan mudah alih. Manakala kalsium, sodium, magnesium, ferum, potasium, klorida, bikarbonat dan sulfur dianalisis melalui serapan atom spektroskopi, gravimetrik analisis dan titrat analisis. Pencerobohan air laut dinilai menggunakan hasil yang didapati daripada analisis air sample. Hasil analisis menunjukkan 2 jenis fasies akuifer cetek iaitu sodium-bikarbonat dan kalsium-magnesium-bikarbinat akuifer sebagaimana ditentukan oleh rajah Piper Trilinear. Sementara itu, semua sampel air tanah dikategori di dalam zon air bawah tanah normal berdasarkan graf diantara khlorida dan konduktivitu. Data geologi untuk Tumpat, Kelantan diperolehi daripada pemetaan aluvium, pemetaan geomorfologi dan penyiasatan sampel tanah. Satu peta baru geologi dihasilkan menggunakan perisian ArcGIS berdasarkan data geologi tersebut.

Kata kunci : Pencerobohan air laut, akuifer di kawasan pantai, Tumpat

TABLE OF CONTENT

CONTENT	PAGE
DECLARATION	**ii**
ACKNOWLEDGEMENT	**iii**
ABSTRACT	**iv**
ABSTRAK	**v**
TABLE OF CONTENTS	**vi**
LIST OF TABLES	**xi**
LIST OF FIGURES	**xiii**
LIST OF ABBREVIATIONS	**xv**
LIST OF SYMBOLS	**xvi**
CHAPTER 1 : INTRODUCTION	
1.1 General background	1
1.2 Problem statement	2
1.3 Research objectives	3
1.4 Study area	3
1.4.1 Location	3
1.4.2 Demography	5
1.4.3 Rainfall	7
1.4.4 Landuse	8
1.4.5 Social economic	11
1.4.6 Road connection	12
1.5 Scope of study	13

1.6 Research importance 13

CHAPTER 2 : LITERATURE REVIEW

2.1 Regional geology and Tectonic Settings 15

2.1.1 Palezoic 15

2.1.2 Mesozoic 15

2.1.3 Cenozoic 16

2.2 Stratigraphy 16

2.2.1 Cenozoic stratigraphy 16

2.3 Hydrogeology 17

2.3.1 Occurence of groundwater 17

2.4 Sea water intrusion 19

2.5 Contamination of ground water 21

2.6 Hydrochemistry 21

2.6.1 Physical parameter(in-situ parameter) 22

2.6.2 Chemical parameter 22

CHAPTER 3 : MATERIALS AND METHODS

3.1 Introduction 23

3.2 Materials 25

3.3 Methods 28

3.3.1 Preliminary study 28

3.3.2 Field studies 28

- Geomorphological study 28
- Water sampling 29
- Soil sampling 30

3.3.3 Laboratory works 31

- Hydrochemical analysis 31
- Grain size analysis 32

3.3.4 Data processing 32

3.3.5 Data analysis and interpretation 32

- Piper Trilinear diagram 32
- Maps 32

CHAPTER 4 : GENERAL GEOLOGY

4.1 Introduction 34

4.2 Geomorphology 34

4.2.1 Topography 34

4.2.2 Drainage pattern 35

4.2.3 Coastal Geomorphology 37

- Delta 37

4.3 Alluvium mapping 40

4.4 Soil analysis 41

4.4.1 Soil classification 51

4.4.2 Soil profile 52

4.5 Quaternary stratigraphic 59

CHAPTER 5 : EVALUATION OF SEA WATER INTRUSION INTO SHALLOW AQUIFERS USING HYDROCHEMISTRY IN TUMPAT KELANTAN

5.1 Introduction 61

5.2 Physical parameters of water samples around Tumpat, Kelantan 64

5.2.1 pH 65

5.2.2 Total Dissolved Solids (TDS) 66

5.2.3 Electrical Conductivity (EC) 67

5.2.4 Turbidity 69

5.2.5 Salinity 70

5.3 Chemical parameters of water samples around Tumpat, Kelantan 71

5.3.1 Calcium, Ca^{2+} 72

5.3.2 Magnesium, Mg^{2+} 73

5.3.3 Potassium, K^{+} 74

5.3.4 Sodium, Na^{+} 75

5.3.5 Iron, Fe^{+} 76

5.3.6 Bicarbonate, HCO^{3-} 77

5.3.7 Chloride, Cl^{-} 78

5.3.8 Sulphate,SO_4^{2-} 79

5.4 Groundwater Classification 81

5.4.1 Piper Trilinear diagram 81

5.4.2 Chloride concentration vs Electrical conductivity graph 85

CHAPTER 6 : CONCLUSION AND RECOMMENDATION

6.1 Conclusion 87

6.2 Recommendation 88

REFERENCES 89

APPENDICES 93

LIST OF TABLES

No	TITLE	PAGE
1.1	Total population by ethnic group	5
1.2	Annual rainfall	7
1.3	Land use in Tumpat District	9
3.1	List of materials/equipments	25
3.2	List of materials/equipments with function	26
3.3	A list of physical parameter with instruments	30
3.4	List of methods used in hydrochemical analysis	31
4.1	Topographic unit versus mean elevation standard of the study area	35
4.2	Sampling location around study area	41
4.3	Diameter of soil particles and Wentworth size class	41
4.4	The result of a mechanical analysis test on a soil sample in Kg Berangan Masjid	43
4.5	The result of a mechanical analysis test on a soil sample in Kg Bharu Nelayan	44
4.6	The result of a mechanical analysis test on a soil sample in Kg Kok Keli	45
4.7	The result of a mechanical analysis test on a soil sample in Kg Tanjung Duff	46
4.8	The result of a mechanical analysis test on a soil sample in Kg Jubakar Pantai	47

4.9 Uniformity coefficient among 5 soil samples 51

4.10 Soil profile at Kg Berangan Masjid 53

4.11 Soil profile at Kg Bharu Nelayan 54

4.12 Soil profile at Kg Kok Keli 55

4.13 Soil profile at Kg Tanjung Duff 56

4.14 Soil profile at Kg Jubakar Pantai 57

5.1 National Guidelines of Raw Water Quality Standard 62

5.2 Sampling location around Tumpat, Kelantan 62

5.3 Physical parameters of water samples around Tumpat, Kelantan 64

5.4 Classification of TDS for groundwater 66

5.5 Classification of electrical conductivity for suitability of water for certain purpose 68

5.6 Chemical parameters of water samples around Tumpat, Kelantan 71

5.7 National Guidelines of Raw Water Quality Standard from MOH and Drinking Water Standard from WHO with concentration of water samples around Tumpat, Kelantan 80

5.8 Conversion Factors for Chemical Equivalence 81

5.9 Cation and Anion Concentration in Percentage Values (%) 82

LIST OF FIGURES

No.	TITLE	PAGE
1.1	Base Map of study area	4
1.2	Total population by ethnic group in Tumpat	6
1.3	Precipitation/Rainfall around Tumpat, Kelantan	7
1.4	Percentages of land use in Tumpat	8
1.5	Land use map of study area	10
1.6	Road Connection in study area	12
2.1	Idealized sketch of fresh and sea water groundwater in unconfined coastal aquifer	19
2.2	Flow pattern of fresh water and saltwater in aquifer	20
3.1	Overall flowchart	24
3.2	Piper diagram	33
4.1	Drainage pattern in study area	36
4.2	River island or delta around study area	38
4.3	Natural levees along the river channels	38
4.4	Image of distributaries due to deltas	39
4.5	Traverse map around study area	40
4.6	Soil sampling location around study area	42
4.7	Graph of particles size distribution in Kg Berangan Masjid	48
4.8	Graph of particles size distribution in Kg Bharu Nelayan	48
4.9	Graph of particles size distribution in Kg Kok Keli	49
4.10	Graph of particles size distribution in Kg Tanjung Duff	49

4.11	Graph of particles size distribution in Kg Jubakar Pantai	50
4.12	Geological Map of study area	58
4.13	Geology map of North Kelantan	60
5.1	Sampling location map around study area	63
5.2	pH value of water samples around Tumpat, Kelantan	65
5.3	Total dissolved solids (TDS) of water samples around Tumpat, Kelantan	66
5.4	Electrical conductivity (EC) of water samples around Tumpat, Kelantan	67
5.5	Turbidity of water sample around Tumpat, Kelantan	69
5.6	Salinity of water samples around Tumpat, Kelantan	70
5.7	Calcium ions concentration around Tumpat, Kelantan	72
5.8	Magnesium ions concentration around Tumpat, Kelantan	73
5.9	Potassium ions concentration around Tumpat, Kelantan	74
5.10	Sodium ions concentration around Tumpat, Kelantan	75
5.11	Iron ions concentration around Tumpat, Kelantan	76
5.12	Bicarbonate ions concentration around Tumpat, Kelantan	77
5.13	Chloride ions concentration around Tumpat, Kelantan	78
5.14	Sulphate ions concentration around Tumpat, Kelantan	79
5.15	The Distribution of ions of samples in study area in Piper Trilenear Diagram	83
5.16	A graph of chloride concentration against electrical conductivity	85

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
bcm	billion cubic metres
DID	Department Of Irrigation And Drainage
E	east
EC	Electrical Conductivity
GPS	Global Positioning System
Kg	Kampung/ Village
m^3/h	cubic meter per hour
meq/L	miliequivalent per Litre
mg/L	milligrams per Litre
mm	millimetres
MOH	Ministry of Health
N	north
NTU	Nephelometric Turbidity Units
ssp	subspecies
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
SME	Small and Medium Entrepreneurs
µS/cm	micro Siemens per centimeter
vs	versus

LIST OF SYMBOLS

%	percentage
”	second (in coordinate system)
’	minute (in coordinate system)
°	degree
° C	degree Celcius
Na^{+}	Sodium
K^{+}	Potassium
Mg^{2+}	Magnesium
Ca^{2+}	Calcium
Fe^{+}	Iron
$SO4^{2-}$	Sulphate
HCO^{3-}	Bicarbonate
Cl^{-}	Chloride

CHAPTER 1

INTRODUCTION

1.1 General background

With an average annual rainfall which is 2420 mm, Malaysia is estimated to have approximately 63 billion cubic metres (bcm) of groundwater storage. Groundwater in Malaysia accounts for over 90 % of the country's water resources(Kura et al., 2015). Currently, groundwater is a major source of water supply in several state in Malaysia such as Kelantan and Selangor. According to Samsudin et al. (2008), in Kelantan especially at north part, water supply from groundwater become main source. Generally, water especially groundwater is used for domestic use, agriculture activities and industrial activities around the world (Arslan,2013). Tumpat district is coastal area which particularly known as the area that undergoes changes over the century with increasing industrialisation, urbanisation and population growth. Rapid population growth, extensive industrialisation and agriculture can cause the increase demand of water and contamination to the aquifer (Jeevanandam et al., 2007)

Occurrence of seawater intrusion start when the seawater displaces or mixes with groundwater in the shallow aquifers. This phenomenon commonly occurs in shallow aquifers which are in close proximity to the sea (Todds & Mays, 2005). There is a possibility sea water intrusion into shallow aquifer of Tumpat as it is coastal area .Excessive mixing of sea water will cause chemical and physical properties of the freshwater in the aquifer will become brackish and salty (Mohd Kamal et al., 2015).

For the study of groundwater, there are various methods/techniques that can be used. Geophysical techniques, geochemical techniques and a combination between geophysical and geochemical techniques are the techniques that commonly used by the previous researcher.For example, previous study from Samsudin et al. (2008) used a technique that combine both the geophysical and geochemical techniques to investigate about the salinity of the groundwater.

1.2 Problem statement

Generally seawater intrusion is a natural process but this process can be exacerbated by human activities. Human activities such as over-exploitation of groundwater can be one of the reason of sea water intrusion. Sea water intrusion can affect the quality and quantity of fresh groundwater in shallow aquifers as sea water is one of contamination source for groundwater. At study area, most of local residents use water supply that come from groundwater for irrigation, domestic use and industrial activity. Deterioration of groundwater in terms of quality and quantity due to intrusion sea water in shallow aquifer, consequently, will give effect to agriculture activity as well as human health.

1.3 Research objectives

1. To prepare an alluvium map of Tumpat, Kelantan .
2. To evaluate sea water intrusion at the shallow aquifers.
3. To identify the groundwater type by using Piper diagram.

1.4 Study area

1.4.1 Location

The study area is situated in Tumpat district, northern part of Kelantan. The study area is lies between latitude 6° 8’ 53.46”E until 6° 12’ 42.12”E and longitude 102° 7’ 48.6”N until 102° 13’ 45.36”N. Based on the base map, at the north side is coastal area which bounded by the South China Sea. Kelantan river on the east part of study area while to the west is bounded by Pengkalan Kubor. Wakaf Bharu at the south, marks the border of study area. (Figure 1.1). In Tumpat district, there are many plains and hundreds of river islands which suitable and has potential for tourism purpose.

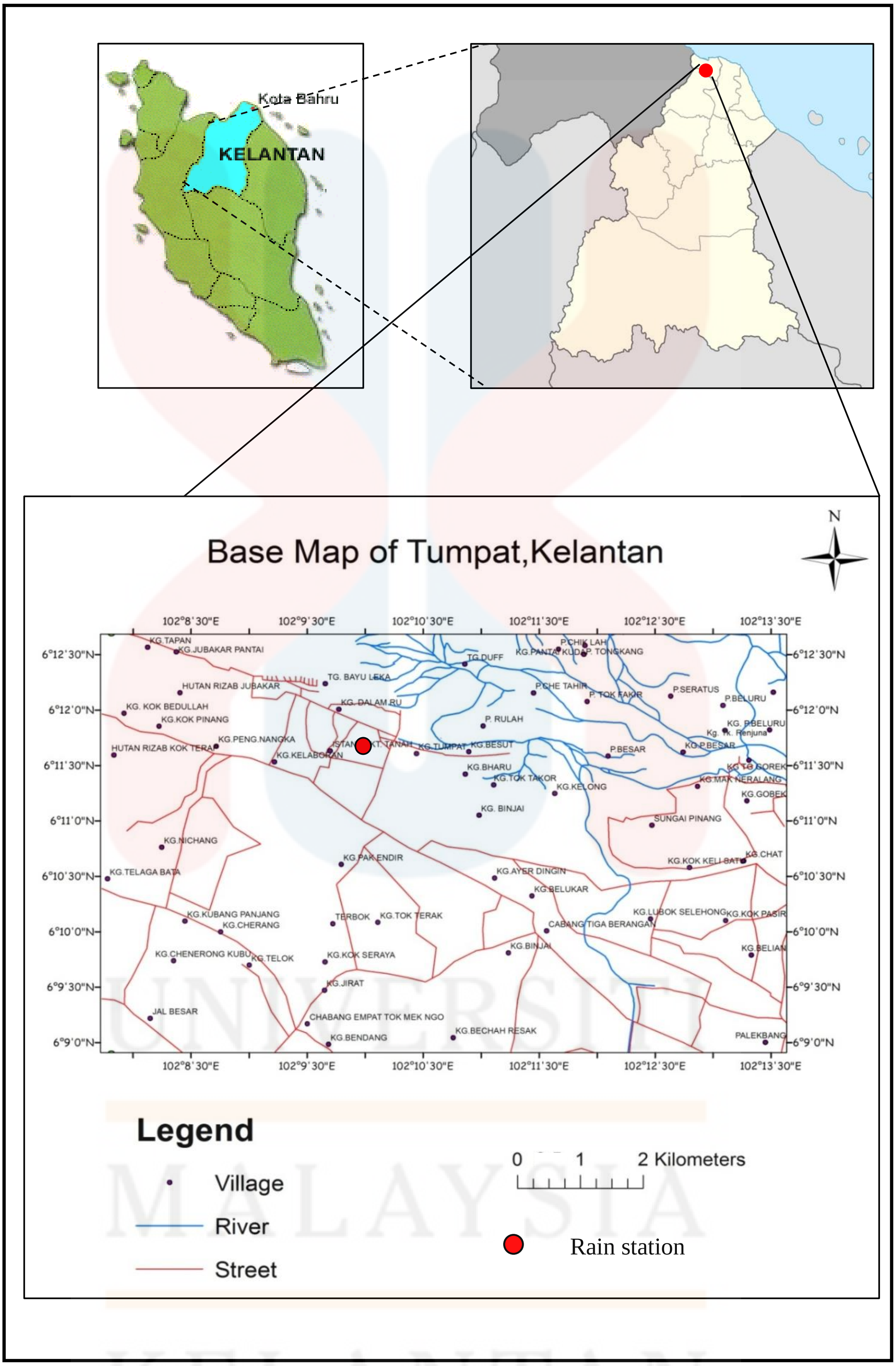


Figure 1.1 : Base Map of study area in Tumpat

1.4.2 Demography

According the data from Local Authority Area and State of Malaysia, total population in Tumpat is 8916 peoples (Table 1.1). Major ethnic group that populated in Tumpat is Malay, approximately 96 % and followed by Chinese, Indian and others about 4% (Figure 1.2)

Table 1.1 : Total population by ethnic group

Sub-district/Mukim	Warganegara Malaysia/Malaysian citizens				Bukan warganegara Malaysia/Non-Malaysian citizens	Jumlah/ Total
	Bumiputera	Cina/ Chinese	India/ Indian	Lain-lain/ Others		
Tumpat	8554	276	23	18	45	8916

(Source : Local Authority Area and State of Malaysia, 2010)

.

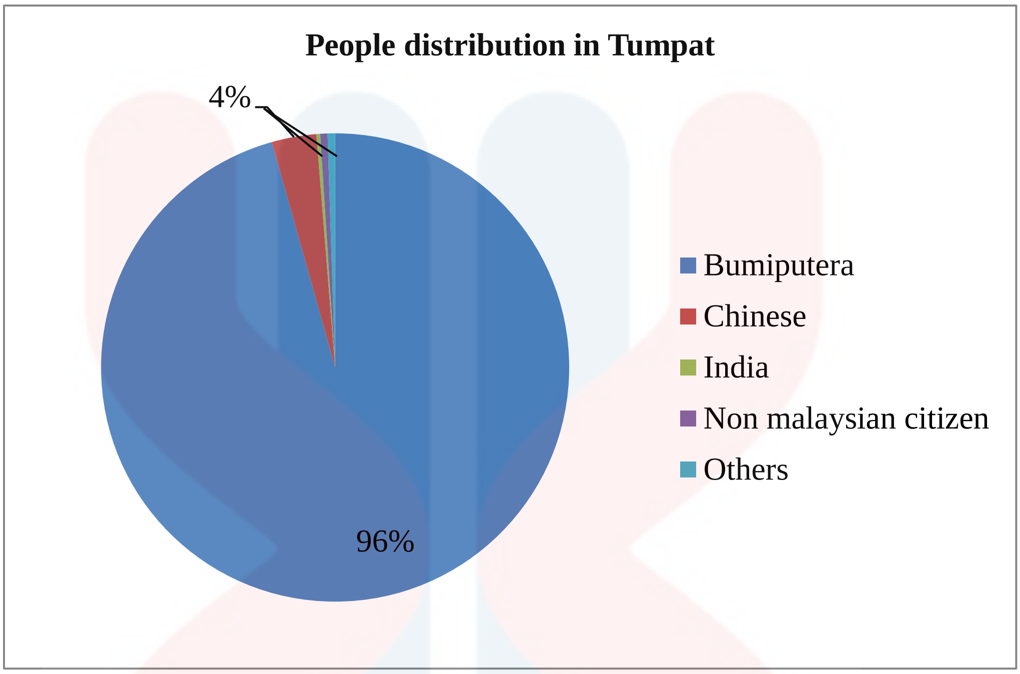


Figure 1.2 : Total population by ethnic group in Tumpat

(Source : Local Authority Area and State of Malaysia, 2010)

1.4.3 Rainfall

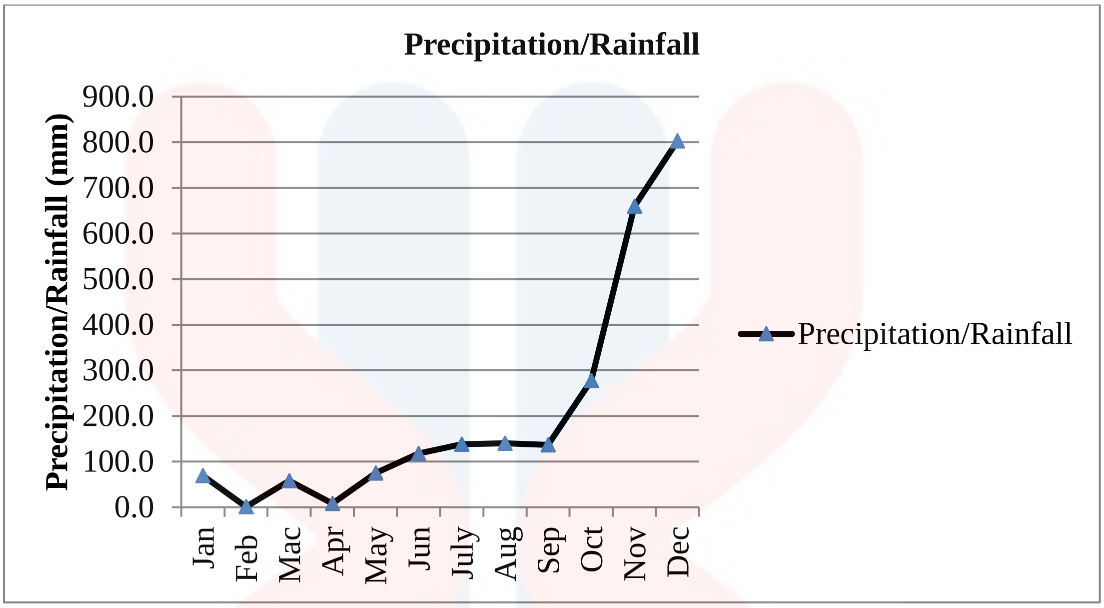


Figure 1.3 : Precipitation/Rainfall around Tumpat, Kelantan

Table 1.2 : Annual rainfall

JAN	FEB	MAR	APR	MEI	JUN	JULAI	OGOS	SEP	OKT	NOV	DEC	TOTAL AMOUNT (mm)
69.0	1.0	58.0	8.0	75.0	118.0	138.0	140.0	137.0	278.0	660.0	803.0	2485.0

(Source : Department of Irrigation and Drainage, 2014)

Figure 1.3 ilustrated the distribution of rainfall or precipitation in Tumpat, Kelantan. The highest precipitation is in December which is 803.0 mm and the lowest precipitation is in February which is 1.0 mm. Generally, Kelantan has monsoon season starting from October until December. Thus, precipitation in October, November and December shows high amount of precipitation. Precipitation by rainfall is very essential to groundwater as through precipitation, groundwater in aquifers can be recharged. Thus, groundwater content may be increase then can fulfill the water demand. The data of precipitation is obtained from Pengkalan Nangka, Tumpat station of Department of Irrigation and Drainage.

1.4.4 Landuse

Total area of Tumpat is approximately 18,111.15 hectares. Land use in Tumpat divided into 2 which are built up areas and non built up areas. Built up areas cover about 4520.65 hectares which is 24.96 % while non built up areas cover 13590.50 hectares which is 75.04% (Figure 1.4). Built up areas dominated by residential areas with 15.93% which is about 2883.72 hectares followed by transportation which is 611.92 hectares (3.38%). Non built up areas dominated by agricultural areas with 60.25% which 10912.81 hectares of coverage. Besides, water bodies is covered about 1585.06 hectares (8.75%) of non built up areas (Table 1.3).

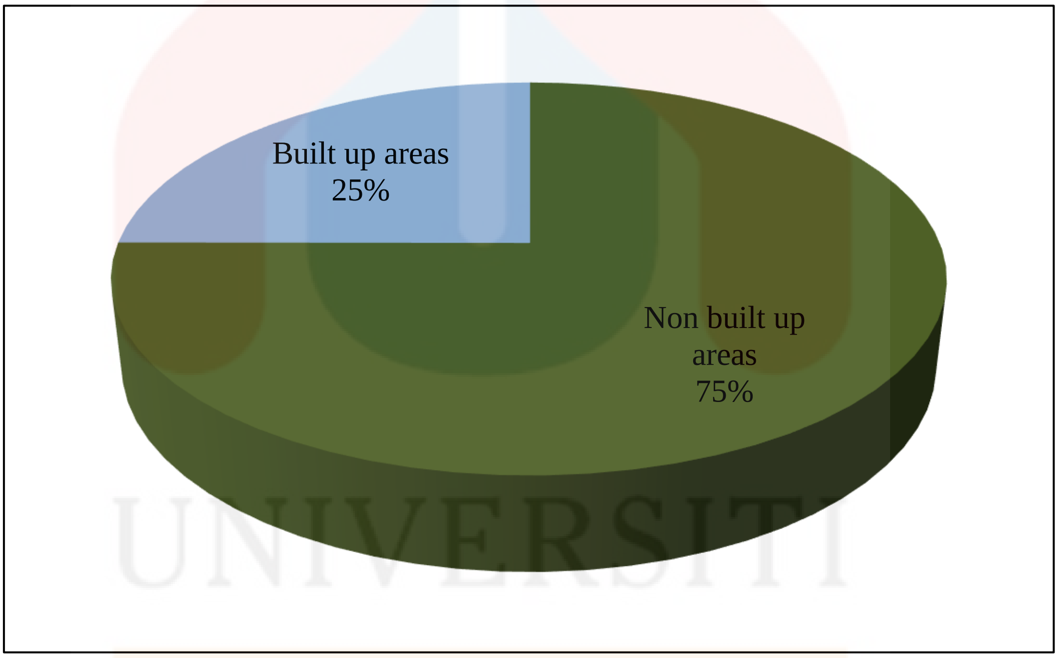


Figure 1.4 : Percentages of land use in Tumpat

Table 1.3 : Land Use in Tumpat District

Landuse	Areas (Hectares)	Percentage (%)
Built up areas	4520.65	24.96
a) Residential	2883.72	15.93
b) Business and service	74.75	0.41
c) Industrial	55.08	0.30
d) Institution and facility	312.28	1.73
e) Recreation	57.54	0.34
f) Infrastructures and utility	525.36	2.90
g) Transportation	611.92	3.38
Non-bulit up areas	13590.50	75.04
a) Agricultural	10912.81	60.25
b) Empty land	917.05	5.06
c) Poultry and aquaculture	116.96	0.65
d) Water bodies	1585.06	8.75
e) Beaches	51.07	0.28
f) Forests	7.55	0.04

(Source : Department of Town and Country Planning of Kelantan,2009)

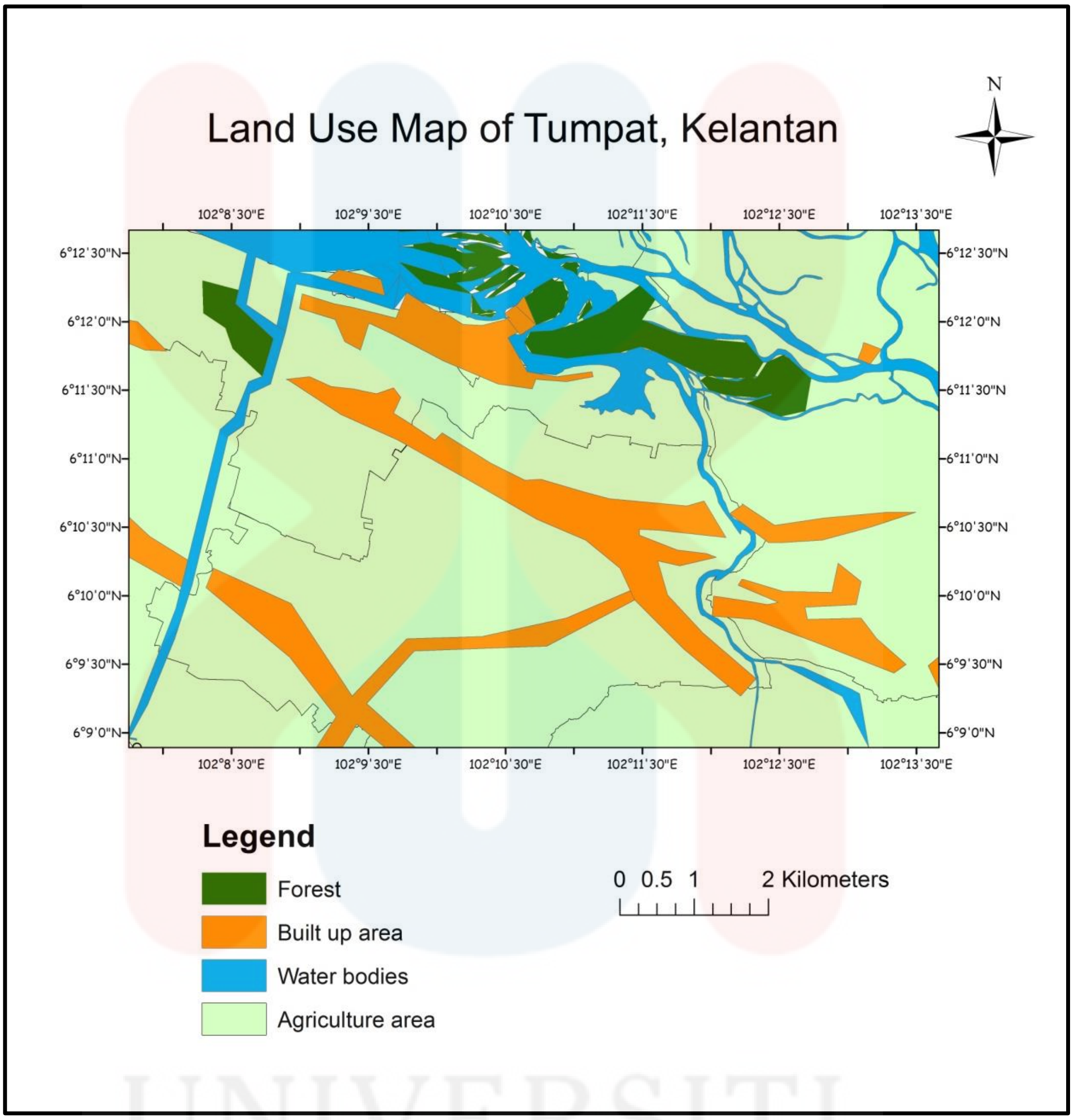


Figure 1.5 : Land use map of study area

1.4.5 Social Economic

Social economic refer to the activities performed by the society based on their local economic. In Tumpat, there are two main sectors that mostly local peoples involved which are business and agriculture sector.

Business sector in Tumpat varies, depending on local speciality and production of raw materials. Mostly business activities are in the small and medium scale or known as Small and Medium Entrpreneurs (SME) business. SME business varied from fishery product, food product, batik, woodcraft product and silverware manucfacture. Generally, each product usually become iconic signature in their location respectively.

Next is agriculture and agro-based sector, which sub-divided into several sector such as poultry , aquaculture and fishery. As Tumpat is one of places that consist fertile soil due to presence of Kelantan deltas, there are a lot of crops and plant have being cultivated such as paddy, maize, sugarcane , tapioca and rubber.

For fishery sector, apart Tok Bali in Pasir Puteh, Tumpat also known popular stop centre as there are variety types of seafood can be found. Besides that, there are a lot breeder of freshwater species such as “keli” or “patin” in Tumpat. The availability of small and big scaled of ditches or irrigation channels which suitable habitat for the freshwater species increase the number of breeders.

1.4.6 Road Connection/Accessibility

Approximately 18 kilometres from Kota Bahru, study area is easy to access as there is well-developed roads. There are three types of roads in Tumpat which are federal road, state road and small road which interconnected each other. Peoples in Tumpat used this road connection to access from one place to other places. Only peoples that settle on the river islands must use boats to access to the mainland for daily activities.

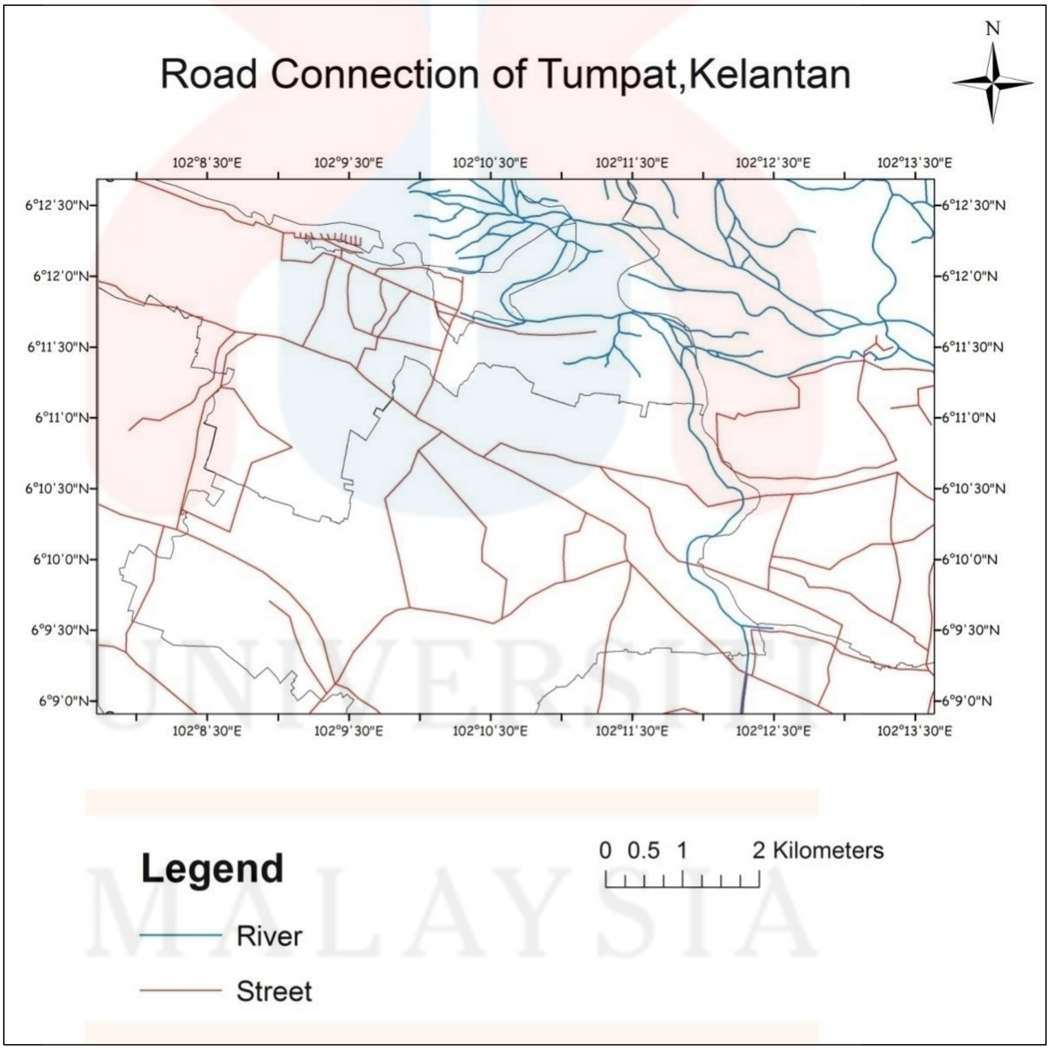


Figure 1.6 : Road Connection of Tumpat, Kelantan

1.5 Scope of study

This study will focus on hydrochemical analysis which include analysis of major cations and anions and analysis of trace elements to know the presence of chemical element in the groundwater. In-situ parameter of water sample also will be recorded. Moreover, analysis of sea water will be conducted to evaluate sea water intrusion. Furthermore, sieving analysis for the soil sample also will be conducted in this study. In addition, soil profile of 100 centimetres will be prepared to see physical characteristics. Lastly, geomorphological study of the study area will be done to know the type of landform present in study areas. All these must be done in order to know the status of the shallow groundwater of the study area.

1.6 Research importance

As the demand for the fresh groundwater increase continuously, it is very importance to check the status of the groundwater in the aquifers from time to timeto ensure the groundwater is safe,no contamination for the domestic use and irrigation.The evaluation of seawater intrusion should be done especially in shallow aquifers along the coastline as seawater is the most common source of contamination in the groundwater.This evaluation is an important step, so that enforcement party can prepare the methods for controlling the seawater intrusion. Early remedial action for this phenomenon can save cost of the remediation and time.Plus, this study also useful for the planner/driller to drill the suitable wells in suitable locations.

At the end, this research can give knowledge of society on the importance of groundwater. Plus, they can to manage the fresh groundwater of the coastal region for their own benefits. Groundwater is one of the valuable resources for us, therefore the conservation of this resources is our responsibility in order to protect the sustainability for the future generation.

CHAPTER 2

LITERATURE REVIEW

2.1 Regional Geology & Tectonic Setting

Kelantan is a part of the Peninsular Malaysia, located in the northeastern cornerof Peninsular Malaysia. All explanation about geological data of Kelantan has been compiled in the book Geology of Peninsular Malaysia by Hutchison & Tan (2009). The geological formation of Kelantan can be sub-divided into three main chronology which are Paleozoic, Mesozoic and Cenozoic.

2.1.1 Paleozoic

The Upper Paleozoic formation in Kelantan was comprised of Gua Musang Formation and Aring Formation in the south of Kelantan while the Taku Schist is in eastern of Kelantan. The Upper Paleozoic formation is dominated by argillaceous and volcanic facies while the rest belong to calcareous and arenaceous facies (Hutchison & Tan,2009).

2.1.2 Mesozoic

The Mesozoic formation is dominant in the central belt that form continuous north – south trending belt extending beyond the international boundaries with Thailand (Gua Musang Formation) in the north and Singapore (Jurong Formation) in the south. The Gua Musang, Aring and Gunong Rabong formations, aged Permian – Triassic is dominated by shallow marine clastics and carbonates with volcanic interbeds (Hutchison & Tan,2009).

2.1.3 Cenozoic

In Kelantan, Cenozoic formation is primarily represented by the Quaternary sedimentary deposits. This Quaternary sedimentary deposits generally cover the northern part of Kelantan and it is comprised of unconsolidated and semiconsolidated of boulders, gravel, sand, silt and clay. These sediments underlie the coastal area, inland plain as well as infilled valleys (Hutchison & Tan,2009).

2.2 Stratigraphy

2.2.1 Cenozoic Stratigraphy

Cenozoic stratigraphy represented by the Quaternary Period sedimentary deposits. In Kelantan, Quaternary sedimentary deposits can be found at the northern part.This deposits consists of unconsolidated and semiconsolidated of boulders, gravel, sand, silt and clay. These sediments also known as “alluvium”(Hutchison & Tan, 2009). This sediments have thickness about 25 metres inland and up to 200 metres towards the coast (Samsudin et al.,2008). The granite lies as the bedrock and the Quaternary sediments overlie it. Northern Kelantan has an alluvium delta and coastal plain stretch about 40 kilometres in length and 10 kilometres in width on its coast which covered the whole area of Kota Bharu and Bachok district and part of Pasir Mas and Tumpat district (Samsudin et al., 2008; Sefie et al., 2015).

2.3 Hydrogeology

Hydrogeolgy is combination between two words hydrology and geology. Hydrogeology involves study of occurrence, distribution, movement and geological interaction of water in the Earth' crust. Based on Madi (2010), groundwater is used to cover more than 90% consumer need.

2.3.1 Occurence of groundwater

Groundwater is defined as water beneath the earth surface which the water fill all the pores and fractures of soil and rocks. Generally,groundwater can be stored in two types aquifers which are alluvial aquifers and hard rock aquifers (Samsudin et al., 2008). According to Kura et al. (2015) and Heng (2004), the alluvial aquifers with the 30-50 m^3/h of hydraulic conductivity, are the most productive aquifers compared to the hard rock aquifers. These alluvial aquifers can be found along the coastline of the east-coast states in Peninsular Malaysia which are Kelantan, Terengganu and Pahang (Heng, 2004). In Kelantan, the alluvial aquifers can be found in the northern region of Kelantan .

According to Heng (2004), hard rock aquifers are comprised of three types of aquifers based on the rock types which are limestone aquifers, sedimentary and volcanic aquifers and lastly is fractured crystalline igneous rocks aquifers. For limestone aquifers, the yield of the well is up to 30 m^3/h/well. The groundwater quality is good but total dissolved solid is at the moderate to high level due to the soluble bicarbonates from the dissolution process of limestone itself. Mostly, this type of aquifers can be found in the Kedah, Perlis and Perak (Heng,2004). Sedimentary and volcanic rocks aquifers generally represented by fractued sandstone, quartzite, conglomerate and all volcanic rocks. Well from sedimentary and volcanic rocks can yield approximately from 5 m^3/hr/well until 20 m^3/hr/well. This type of aquifer distributed in Kedah, Selangor, Johor, Sarawak and Sabah and the quality of water is at medium to good level (Heng,2004). Lastly, fractured crystalline igneous rocks aquifers can be found in Kedah, Selangor, Johor, Melaka and Negeri Sembilan. Among all type of aquifers, the wells from fractured crystalline igneous rocks aquifers have least water yield, only up to 10 m^3/hr/well. The water quality of this aquifers is good to excellent with the present of low total dissolved solids (Heng,2004)

In terms of system, groundwater can be divided into shallow groundwater and deep groundwater. Previous study from Heng et al.(1989) stated that shallow aquifers or known as 1st aquifers made up from sand and gravel that extends from the ground level or from the base of the surface clay down to the next major clay bed. Generally,the shallow aquifers lies between 5 to 15 metres of depth below ground surface. It can be unconfined and confined by the surface clay or aquitard. Most places exploited shallow groundwateras it contained with fresh groundwater but iron concentration can be in the range of 0.85 mg/L to 10.95 mg/L depends on the areas.The shallow groundwater is the most exploited source in the Kelantan groundwater basin (Heng et al., 1989).

Deep groundwater is a aquifers that situated beneath the shallow groundwater. There are three main aquifer intervals have been found and recognised as the 2nd, 3rd and 4th aquifers respectively. The water in the 2nd aquifer is brackish while the 3rd aquifer which lies between 45 to 130 metres depth contains the better quality water and thus has been developed at Tanjong Mas. At the 4th aquifers, the water has been found to be saline (Heng et al., 1989).

2.4 Sea Water Intrusion

Sea water intrusion generally occurs when fresh groundwater are pumped out from the aquifers especially coastal aquifers, then results in declining groundwater levels and facilitating lateral and/or vertical migration of sea water into the aquifers. This will causing a great changes towards groundwater quality (Kumar et al., 2015). Ghyben-Herzberg principle can explain the relation between fresh groundwater and sea water in this phenomenon.

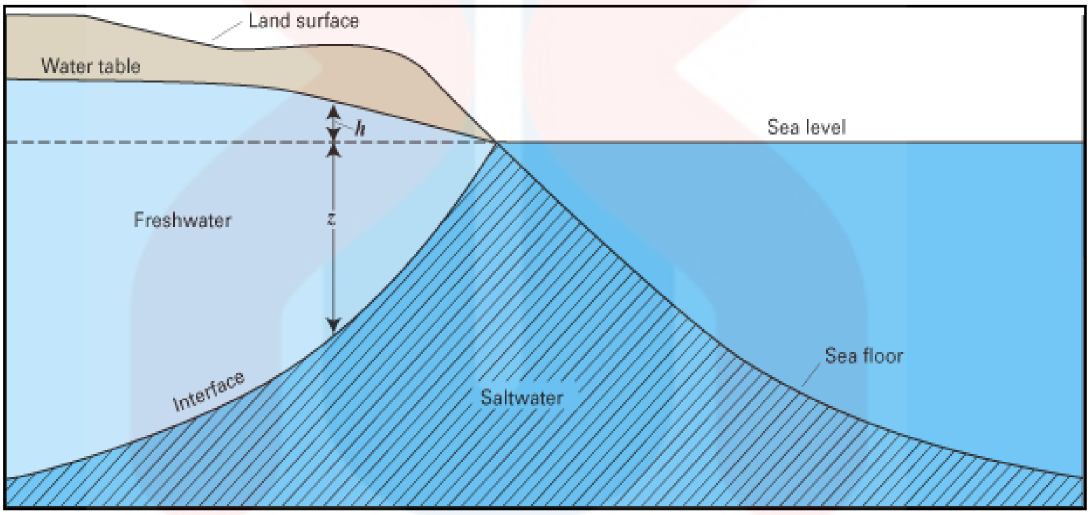


Figure 2.1 : Idealized sketch of fresh and sea water groundwater in unconfined coastal aquifer.(Saltwater intrusion, n.d.)

The equation Ghyben-Herzberg principle :

$$Z = \frac{\rho_f}{\rho_s - \rho_f} h$$

where,

ρ_f = Fresh water density

ρ_s = Sea water density

h = Elevation of the water table above sea level

Z = Depth to the fresh – sea water interface below sea level

Based on Ghyben-Herzberg principle, if water table in aquifers lowered by 1 metre, the sea water interface will rise by 40 metres. Regarding freshwater-sea water equilibrium, the water table must lie above sea level and it slope downwards to the sea. Without this two condition, when withdraw of groundwater reduce the water table of freshwater, the intrusion of sea water will occur(Hiscock & Bense, 2014).

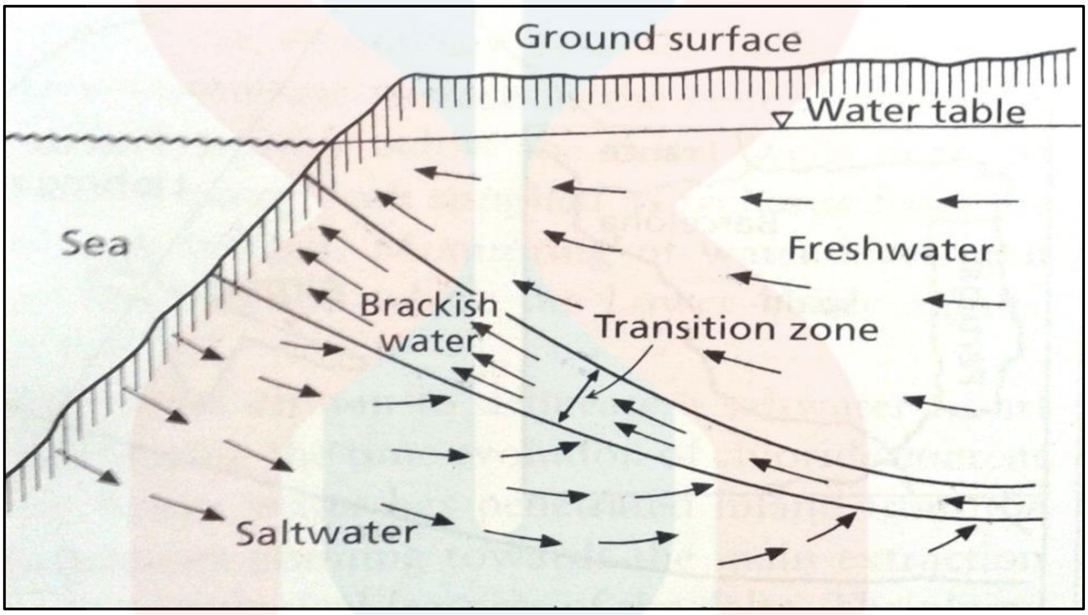


Figure 2.2 : Flow pattern of fresh water and saltwater in aquifer (Hiscock & Bense, 2014).

Based on Figure 2.2, the interface between fresh water and sea water seem sharp but in reality, there is a brackish transition zone of finite thickness that separates freshwater and sea water as shown in the Figure 4. This zone formed from dispersion due to the flow of freshwater with the present of unsteady movement of the interface. Unsteady movement of the interface caused by external factors such as tides, groundwater recharge and pumping wells (Hiscock & Bense, 2014).

Mohd Kamal et al.(2015) and Tajul Baharuddin et al.(2013) are the previous researchers that conducted the study of sea water intrusion in Malaysia. Research area for both study are in Kota Bharu, Kelantan and Carey Island, Selangor.

2.5 Contamination of groundwater

Untreated groundwater may consist contamination whether microbiological contamination and chemical contamination.The types of bacteria that commonly found in water samples are *Coliform, E.coli, Vibrio spp and Salmonella spp.* These bacteria can affect human health as they can cause waterborne disease outbreak such as *Salmonella* outbreak and cholera outbreak (Idrus et al., 2014).

In Kelantan, waterborne disease outbreak which is cholera outbreak had occurred in Tumpat. This outbreak occurred between 13th January and 16th May 1990 with 108 cases reported and 85 carriers identified. During this outbreak, 1 death case reported (Isa et al., 1990)

Ferum, manganese, ammonia, aluminium and nitrate are the chemical that can contaminated groundwater. The quality of the groundwater can be affected by these chemical if they present in high mineral content. Although ferum and manganese are important element that needed by human body but excessive intake also can affect human health (Idrus et al., 2015).

2.6 Hydrochemistry

Hydrochemistry is a study of the chemical composition of water and the laws related to the changes in composition as a result of the chemical, physical and biological processes occurring in the surrounding environment. Hydrochemistry is a combination of both geochemistry and hydrology (Hydrochemistry,n.d.).

For geochemical analysis, the parameters are classified into two types which are physical and chemical parameters (Kura et al., 2015). These parameters are used in the process of characterisation of the groundwater(Samsudin et al., 2008) and to identify ground water chemistry (Jeevanandam et al., 2007). According to the study that conducted by Kura et al. (2015), these parameters also used to understand the hydrochemistry of the areas. At the end, from all data of geochemical analysis, the quality of groundwater can be assessed for drinking, agriculture and industrial purposes (Kumar et al.,2009).

2.6.1 Physical parameter (in-situ parameter)

Electrical conductivity (EC), pH value, total dissolved solid(TDS), temperature, turbidity , oxidation reduction potential(ORP), salinity and dissolved oxygen (DO) are the physical parameter (in-situ parameter).

2.6.2 Chemical parameter

Chemical parameters include major ions and trace elements. Major ions comprised major cations and major anions such as calcium (Ca^+), magnesium (Mg^+), sodium (Na^+), potassium (K^+),sulphate (SO_4^-), chloride (Cl^-) and bicarbonate (HCO_3^-)(Kura *et al.*, 2015). The example of trace elements that may be present are barium (Ba), nickel (Ni), cobalt (Co) and arsenic (Ar). The major ions and trace elements expressed in milligrams per litre(mg/L) (Kumar,2015). According to Sadashivaiah et al.(2008), the chemical parameters of groundwater have a significant part in classifying and assessing the quality of water.

CHAPTER 3

MATERIALS & METHODS

3.1 Introduction

For this chapter, all the materials and methods which used in this study were explained. The materials were prepared and several methods were conducted in laboratory of Universiti Malaysia Kelantan under supervision of lab assisstants and supervisor.

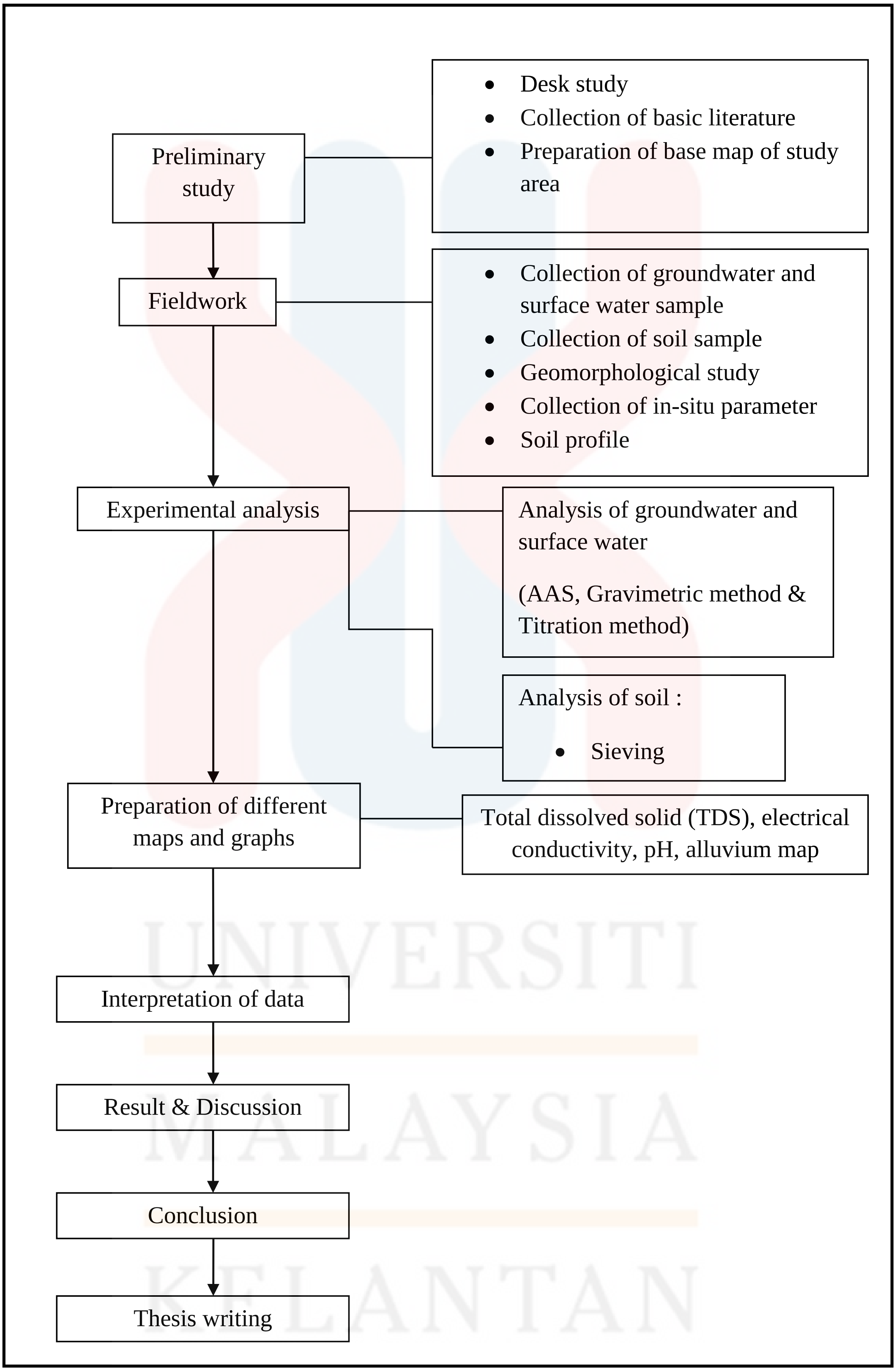


Figure 3.1 : Overall flowchart

3.2 Materials

A list of materials which needed to conduct several methods in completing the study (Table 3.1 and Table 3.2).

Table 3.1 : List of materials/equipments

Method	List of materials/equipments
Preliminary study	ArcGIS software.
Geological mapping and in-situ analysis	Hammer, GPS, compass, sample bags, polyethylene bottles, basemap, multiparameter, turbidity meter , portable total suspended solids (TSS) meter, water level measuring tape, auger, notebook, pencil/marker, camera and reagent/chemical.
Laboratory analysis a. Titration method b. Gravimetric method c. Atomic Absorption Spectroscopy(AAS) method d. Sieving	AAS, Whatman 42 filter paper, beakers, measuring cylinders, burette, sieving machine, several reagents/chemicals, crucible and furnace

Table 3.2 : List of materials/equipments with function

Material	Function	Picture
Hammer	The hammer can be used to break any outcrop.	
Global Positioning System(GPS)	Functions of GPS were to locate any location by coordinate system with the help of satellites, detect the elevation of the location and manage to track the journey.	
Water level measuring tape	Water level measuring tape used for measure water level and depth of well.	
Atomic absorption spectroscopy (AAS)	AAS used for determination of major cations and major anions in water sample.	
Sieving machine	Sieving machine used for grain size analysis for the soil sample.	
Multiparameter	Multiparameter used for measuring insitu parameters of water such as temperature, pH value and electrical conductivity.	

Turbidity meter	Turbidity meter used for measuring the turbidity of water sample.	
Portable TSS meter	Portable TSS meter used to measure total suspended solid in water.	
Auger	Auger used to collect the soil sample.	
Sampling bottle and bag	Sampling bottle and bag used to store water sample and soil sample.	 
Furnace	Furnace used in gravimetric method.	
ArcGIS software	ArcGIS software used in making maps.	

3.3 Methods

3.3.1 Preliminary studies

Preliminary study include desk study, collection of basic literature and preparation of base map. The basic literatures such as books, article journals, reports and proceedings that related to the research topic were collected and all these have been read for better understandings of the concept involved, background of study area and groundwater status in the study area. The study of topographic map also important as it provided information of the study area, for example coordinate value, land use and elevation. Then, preparation of base map of study area by using ArcGIS software. Base map was used as reference during the fieldwork.

3.3.2 Field studies

- **Geomorphological mapping**

Geomorphology mapping is basic technique for producing data base in geomorphological study (Smith & Otto, 2013). Geomorphological maps is a tools to potrays landscape and landforms as well as decsribe subsurface materials. Besides, geomorphological maps can be useful for land management and geomorphological and geological risk management. Other sectors such as landscape ecology, forestry and soil science also use geomorphological map as this map provide baseline data (Paron & Claessens, 2011).

- **Water sampling**

Water samples of groundwater were took from the wells and total number of water samples were 15 samples within 15 locations of sampling. A grid system was used in selecting 15 locations of sampling, therefore the sampling was not focus in one places only but represent all the areas in the study area.

Collection of in-situ/physical parameter which are ph value, EC, TDS, temperature, turbidity, ORP were immediately measured at the location of sampling by using handheld analyzing kits (Kumar et al.,2009). The apparatus that involved for measurement of in-situ/physical parameters were multiparameter, turbidity meter and portable TSS. All the data were recorded in the fieldwork note book. About 1 litre of water sample was collected in each location and water sample was splited into 2 cleaned polyethylene bottles, 500 mL each. One polyethylene bottle was filled with only water sample and another one polyethylene bottles was filled with acidified water sample. Water sample was acidified with nitric acid (HNO3) to slow down the absorption of metals to the bottle's wall and biological activity (Sefie et al, 2015). All water samples were stored at 4°C (Sefie et al, 2015 & Këpuska, 2013) and brought back for hydrochemical analysis.

Table 3.3 : A list of physical parameter with instruments

Parameter	Instruments
pH Temperature Total Dissolved Solids (TDS) Salinity Electrical Conductivity	YSI Multiparameter
Total Suspended Solids (TSS)	TSS Portable Meter
Turbidity	Turbidity meter

- **Soil sampling**

Soil samples were took from 15 location which cover all the areas of the study area. The sample was collected by using auger and the depth of the soil that was digged out precisely 100 centimetres. Each layers might be slightly different from the other above or below it, therefore soil profile was made immediately at the field site to record the characteristics of each soil layer. The soil profile was divide into five section which the section was about 20 centimetres each. The characteristics, for example colour and texture of the soil were recorded in the field note book. All the soil samples were brought back to the lab for analysis.

3.3.3 Laboratory works

- **Hydrochemical analysis**

Hydrochemical parameters were measured major cations and major anions. The major cations that analysed were calcium (Ca^{2+}) magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}) and iron (Fe) while the major anions that analysed were sulphate (SO_4^{2-}), chloride (Cl^{-}) and bicarbonate (HCO_3^{-}). In chemical analysis, there were several method used such as titration method, gravimetric method and AAS method (Table 3.4).

Table 3.4 : List of methods used in hydrochemical analysis

Method	Elements
Titration method	Bicarbonate
	Chloride
Gravimetric method	Sulphate
Atomic Absorption Spectroscopy (AAS) method	Calcium
	Magnesium
	Sodium
	Potassium
	Iron

- **Grain size analysis**

For this study, grain size analysis conducted using sieving method by using sieving machine. In this analysis, the particles of the soil will be separated by the size class. Thus, the particles grain size distribution will be determined.

3.3.4 Data processing

Data and result from field sampling and laboratory works were processing by using several calculation of formulas. Then, several graph and diagram constructed for interpretation of researcher and for understandings of the readers.

3.3.5 Data analysis and interpretation

- **Piper Trilinear Diagram**

The Piper diagram is one of the graphical methods used in the study of groundwater. This diagram suitable to classify the type for groundwater samples which taken from all parts of study area (Kumar et al.,2015;Piper,1944;Kura et al.,2013). Data about major ions in groundwater samples will be used for the preparation of the diagram.

Based on Figure 3.1, there are anion triangle and cation triangle and these triangle will projected into main diamond field in the middle to know the groundwater type of the samples (Kumar,2015).

- **Maps**

Several types of map were produced based on geological data that obtained from field mapping. Drainage pattern map, geological map, topography map and traverse map were the example of maps that will be produced. Software ArcGis was used to produce the maps.

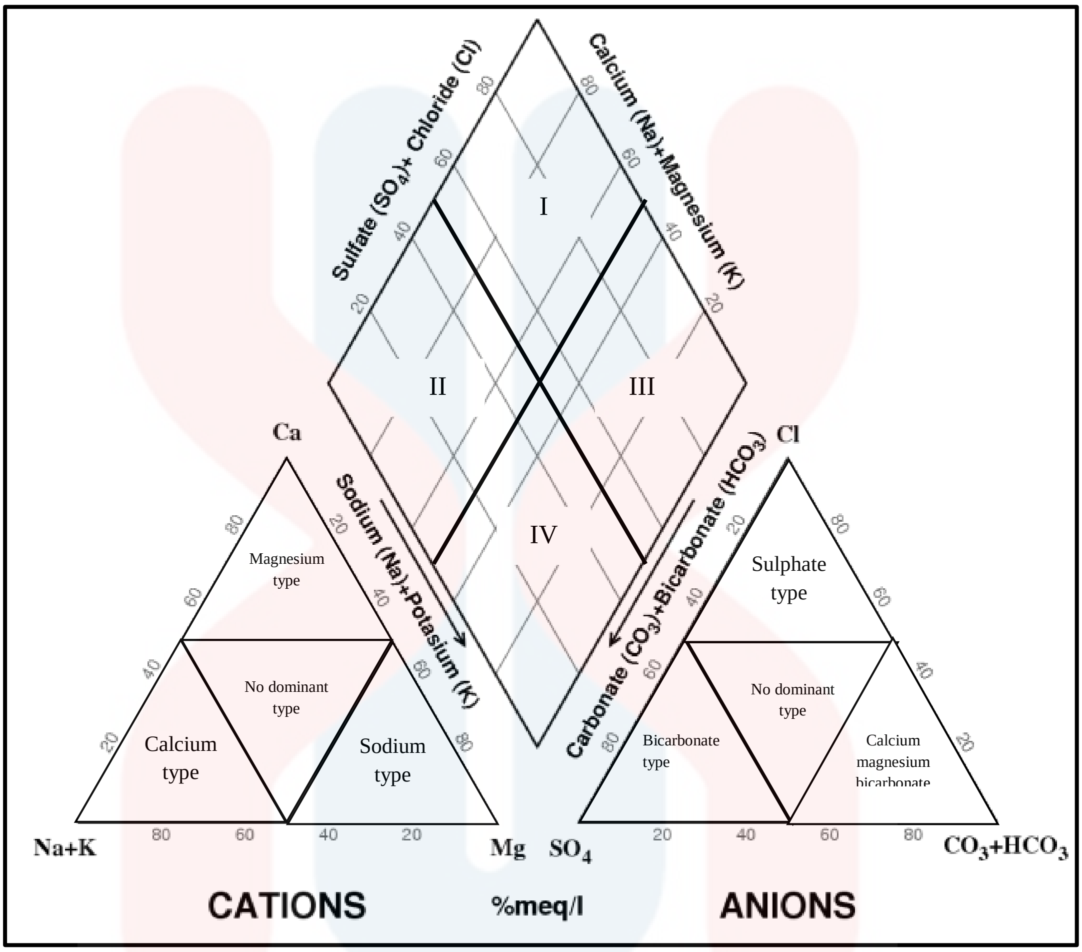


Figure 3.2 : Piper diagram (Prinsip,December 6, 2010)

I – Calcium magnesium sulphate
II – Calcium magnesium bicarbonate
III – Sodium chloride
IV – Sodium bicarbonate

CHAPTER 4

GEOLOGY

4.1 Introduction

There are a few sub topics that will be discussed in this chapter which relate with the geology of study area.

For this chapter, geology basically about geomorphology, alluvium mapping, soil analysis and quaternary stratigraphy. With the ArcGIS, various types of maps were created as a proof.

4.2 Geomorphology

Based on Hugget (2007), geomorphology is the study of Earth's physical land-surface features, in other words, landforms formed on the Earth surface such as rivers, hills, plains, beaches, sand dunes and myriad others.

4.2.1 Topography

The contour of study area, which Tumpat, Kelantan showed elevation ranged from 4 meters to 20 metres. The highest elevation was at Kg Kok Keli which was 22 metres whereas the lowest elevation was at Kg Tanjung Duff which was 1 metre.

Tumpat was one of the district that situated at low elevation area. Based on Table 4.1, topographic unit of study area was low lying and rolling areas.

Table 4.1 : Topographic Unit versus Mean Elevation Standard of the Study Area.

(Hutchinson & Tan, 2009)

Topographic Unit	Mean Elevation above sea level (m)	Category of Study Area
Low Lying	<15	Study Area
Rolling	16-30	Study Area
Undulating	31-75	
Hilly	76-300	
Mountains	>301	

4.2.2 Drainage pattern

Drainage basin is the area that provide water and sediments to the channel of the river. The other term can be used are watershed and catchment. Generally, drainage is bounded by a drainage divide or catchment boundary. The boundary is something that is clearly visible as a ridge in mountainous and hilly areas but can be rather difficult to see in areas of more subdued topography. Drainage basin can form a mosaic across the land surface and varies in size from a few hectares to millions of square kilometres. The pattern of drainage basin usually viewed from the air by the help of aerial photography and satellite (Charlton,2008) . Based on Figure 4.1, the drainage pattern was dendritic pattern.

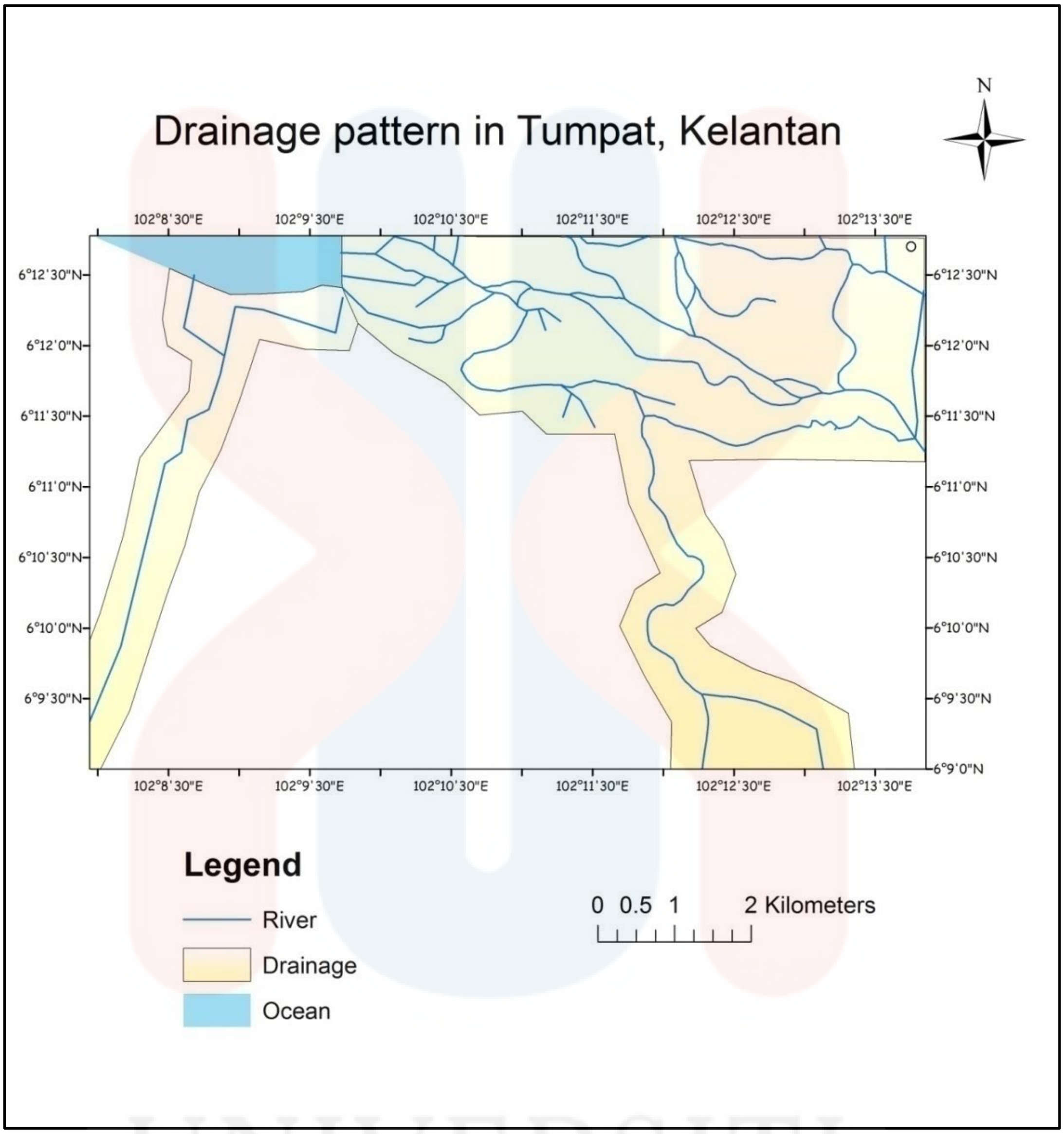


Figure 4.1 : Drainage pattern in study area

4.2.3 Coastal Geomorphology

- **Delta**

According to book of Coastal Geomorphology by Eric Bird, deltas formed where sediments that brought dowm by river and filled the mouths of valleys. This process caused a depositional formation at general outline of the coast. Depositional formation usually protrudes at the outline of the coast. Generally, delta formed when the rate of sediment accumulation at river mouth exceeded the rate of sediment erosion and dispersion by the waves or currents.

Deltas have 2 components which are subaqueous and subaerial components. Subaqueous componets situated below the low tide line that include nearshore sea floor plain. For subaerial components, it situated above the low tide line or above sea level (Bird, 2008).

Bird (2008) explained that subaerial component comprised of a lower and upper delta plain. Some deltas divided the river into distributaries. The upper delta plain built above high tide level by the depositional of alluvial sediment. Generally, the formation of upper delta plain includes natural levees along river channels. Meanwhile, in the lower delta plains, channel of river becomes tidal. These distributaries reached the coast . The area of lower delta plain may contain salt marshes or mangrove swamps.

Figure 4.2 : River island or delta around study area

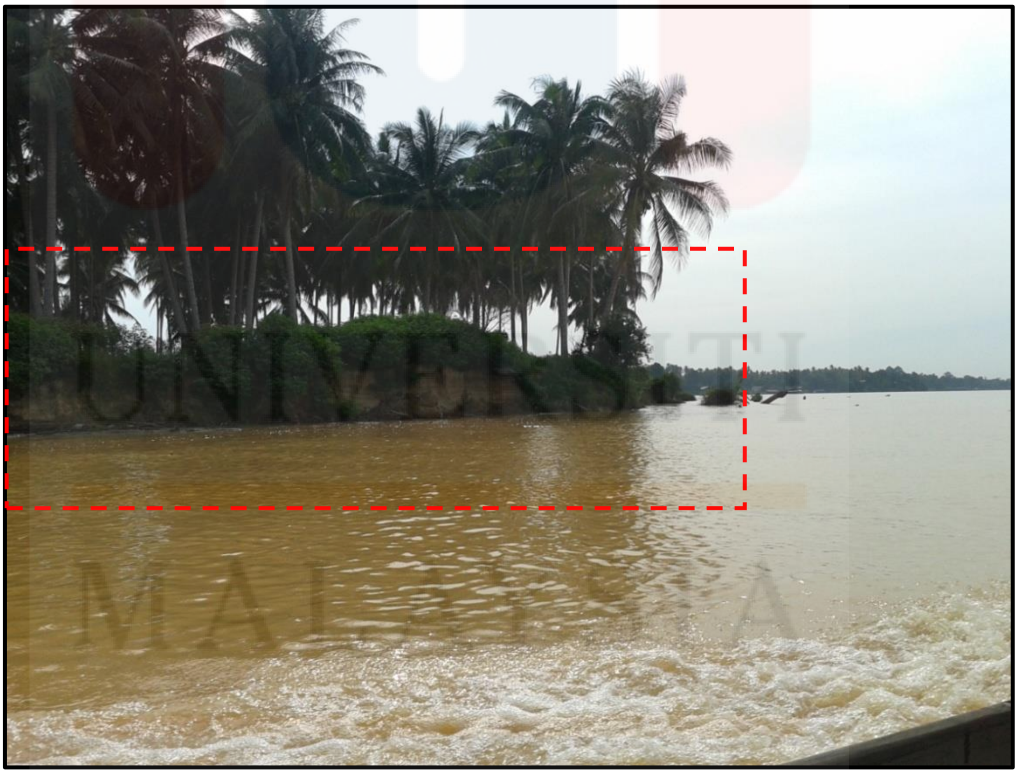


Figure 4.3 : Natural levees along the river channels

Based on geomorphological mapping, study area mostly covered by the upper delta plains. As mentioned by Bird (2008), the natural levees at upper delta plains can be found along the river channel (Figure 4.3). In Figure 4.4, the image showed the distributaries of river due to deltas in the study area.

Figure 4.4 : Image of distributaries due to deltas

4.3 Alluvium mapping

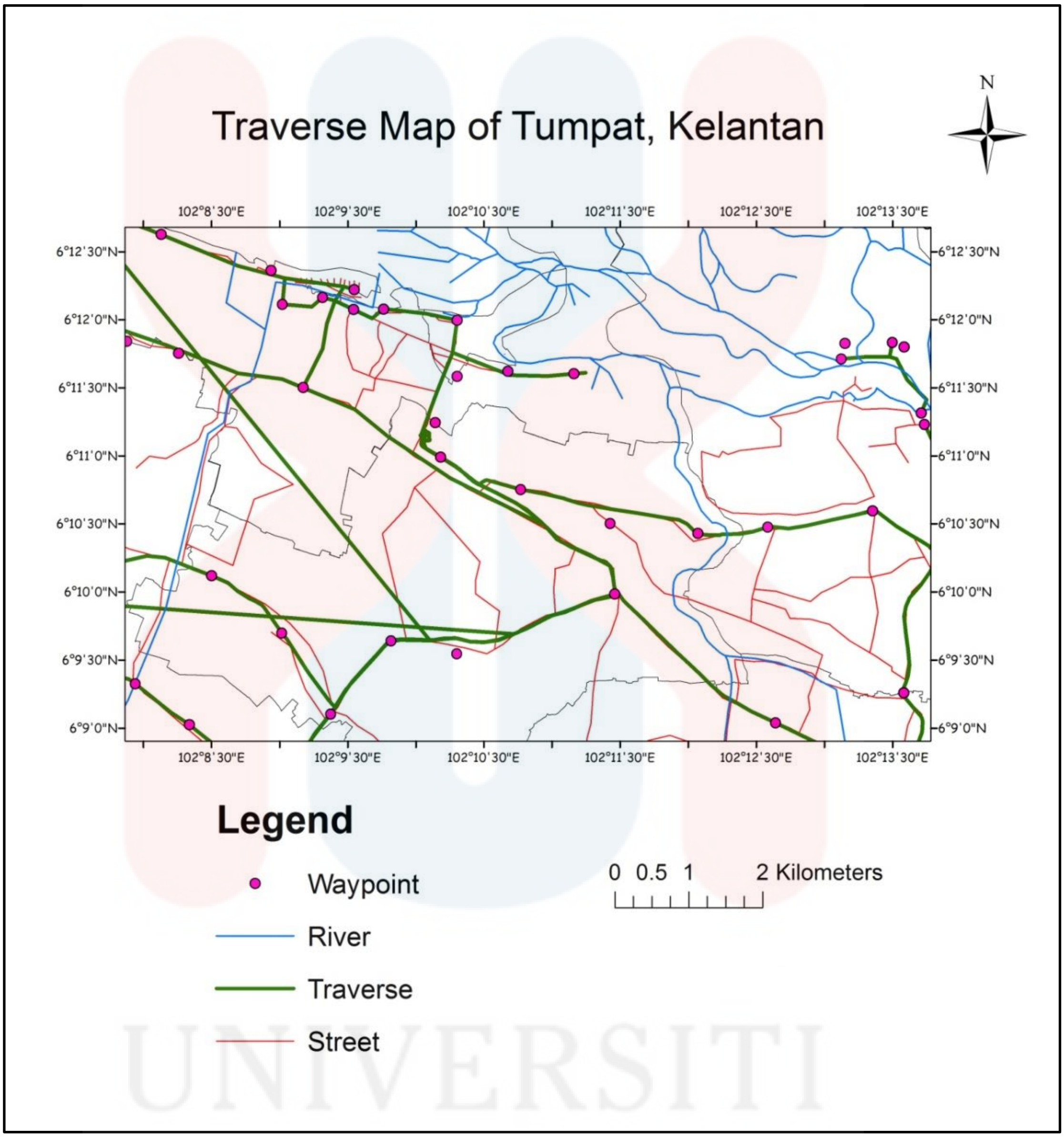


Figure 4.5 : Traverse map around study area

4.4 Soil analysis

For soil analysis, there were 5 soil sample collected around Tumpat, Kelantan which comprised different sizes of grain. Result from mechanical analysis was used for soil classification.

Table 4.2 : Sampling location around study area

No of sample	Type of sample	Location	Latitude/N	Longitude/E
S1	Soil	Kg Berangan Masjid	06° 09' 56.80"	102° 11' 38.6"
S2	Soil	Kg Bharu Nelayan	06° 12' 17.9"	102° 09' 27.5"
S3	Soil	Kg Kok Keli	06° 10' 27.2"	102° 12' 39.7"
S4	Soil	Kg Tangjung Duff	06° 11' 58.4"	102° 10' 42.1"
S5	Soil	Kg Jubakar Pantai	06° 12' 28.9"	102° 08'29.0"

Table 4.3 : Diameter of soil particles and Wentworth size class

Diameter (mm)	Wentworth Size Class	
4096 - 256	Boulder	Gravel
256 - 64	Cobble	
64 - 4	Pebble	
4 - 2	Granule	
2 - 1	Very coarse sand	Sand
1 - 0.5	Coarse sand	
0.5 - 0.25	Medium sand	
0.25 - 0.125	Fine sand	
0.125 - 0.0625	Very find sand	
0.0625 - 0.0313	Coarse silt	Silt
0.0313 - 0.0156	Medium silt	
0.0156 - 0.0078	Fine silt	
0.0078 - 0.0039	Very fine silt	
0.0039 - 0.00006	Clay	Mud

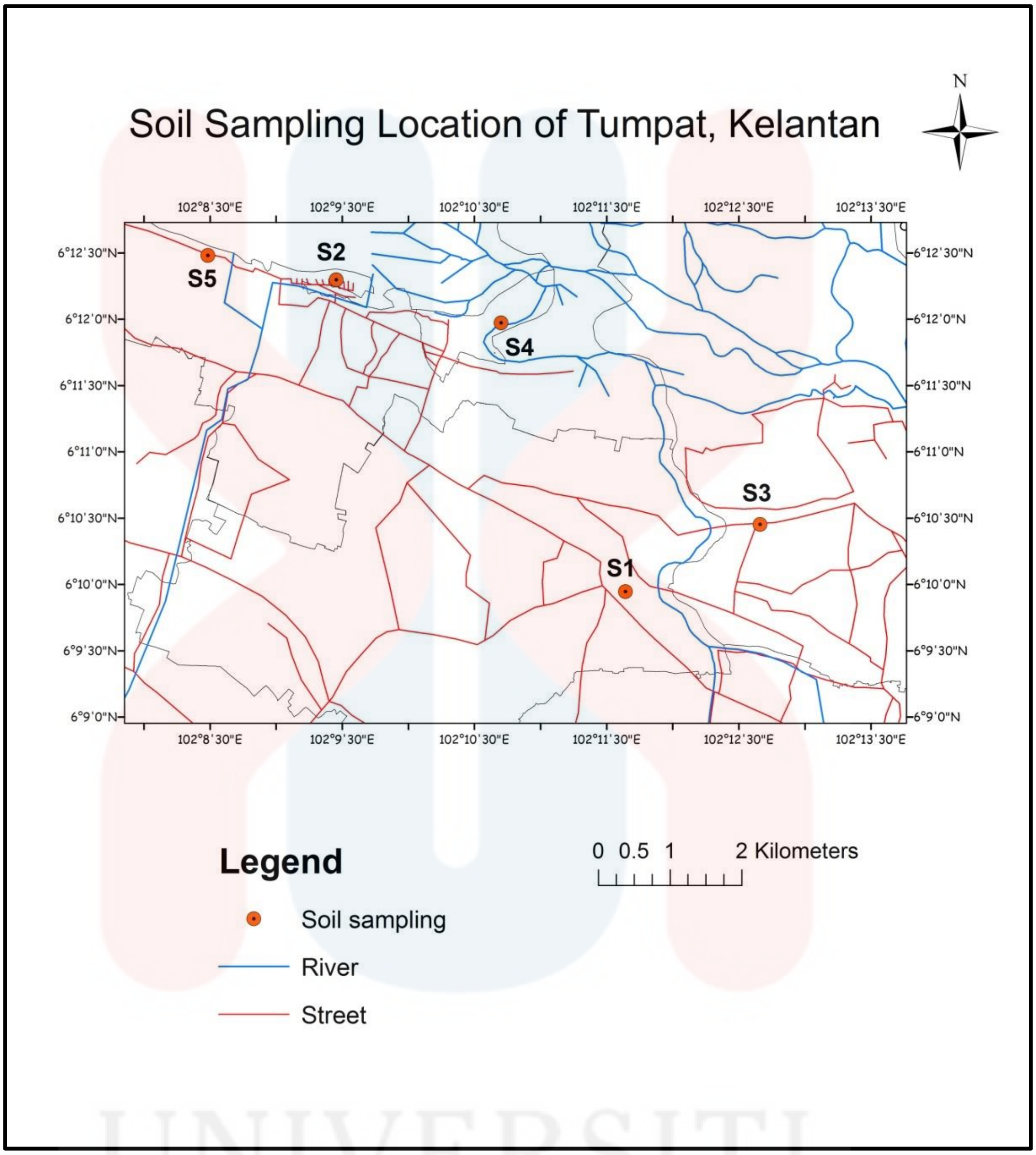


Figure 4.6 : Soil sampling location around Tumpat, Kelantan

Table 4.4 : The result of a mechanical analysis test on a soil sample in Kg Berangan Masjid

SI Sieve Aperture Dimension	Weight of empty sieve	Weight of sample (sieve + soil sample)	Weight retained	Weight retained in percentage	Cumulative weight retained in percentage	Cumulative of passing in percentage	Wentworth size class
2.8 mm	547.5 g	1st : 561.58 g 2nd : 562.02 g	14.3 g	7.2	7.2	93	Gravel
2.0 mm	318.0 g	1st : 394.30 g 2nd : 394.80 g	76.55 g	38.56	45.76	54	Very coarse sand
1.0 mm	510.0 g	1st : 536.89 g 2nd : 537.80 g	27.35 g	13.77	59.53	40	Very coarse sand
0.5 mm	459.5 g	1st : 477.80 g 2nd : 478.30 g	18.55 g	9.34	68.87	31	Coarse sand
0.3 mm	278.0 g	1st : 290.11 g 2nd : 289.70 g	11.91 g	6	74.87	25	Medium sand
0.075 mm	261.5 g	1st : 311.20 g 2nd : 311.44 g	49.82 g	25.1	99.97	0	Very fine sand
			Total : 198.48 g	99.97			

Table 4.5 : The result of a mechanical analysis test on a soil sample in Kg Bharu Nelayan

SI Sieve Aperture Dimension	Weight of empty sieve	Weight of sample (sieve + soil sample)	Weight retained	Weight retained in percentage	Cumulative weight retained in percentage	Cumulative of passing in percentage	Wentworth size class
2.8 mm	547.5 g	1st : 573.00 g 2nd : 572.90 g	25.45 g	10.18	10.18	89.8	Gravel
2.0 mm	318.0 g	1st : 362.54 g 2nd : 363.90 g	45.22 g	18.09	28.27	71.71	Very coarse sand
1.0 mm	510.0 g	1st : 545.77 g 2nd : 543.80 g	34.79 g	13.92	42.19	57.79	Very coarse sand
0.5 mm	459.5 g	1st : 515.11 g 2nd : 515.40 g	55.76 g	22.31	64.5	35.48	Coarse sand
0.3 mm	278.0 g	1st : 338.10 g 2nd : 340.40 g	61.25 g	24.5	89	10.98	Medium sand
0.075 mm	261.5 g	1st : 289.20 g 2nd : 288.70 g	27.45 g	10.98	99.98	0	Very fine sand
			Total : 249.92 g	99.98			

Table 4.6 : The result of a mechanical analysis test on a soil sample in Kg Kok Keli

SI Sieve Aperture Dimension	Weight of empty sieve	Weight of sample (sieve + soil sample)	Weight retained	Weight retained in percentage	Cumulative weight retained in percentage	Cumulative of passing in percentage	Wentworth size class
2.8 mm	547.5 g	1st : 560.51 g 2nd : 560.55 g	13.03 g	6.91	6.91	93.07	Gravel
2.0 mm	318.0 g	1st : 388.80 g 2nd : 387.70 g	70.25 g	37.3	44.21	55.77	Very coarse sand
1.0 mm	510.0 g	1st : 535.50 g 2nd : 534.00 g	24.75 g	13.14	57.35	42.63	Very coarse sand
0.5 mm	459.5 g	1st : 481.30 g 2nd : 481.25 g	21.78 g	11.56	68.91	31.07	Coarse sand
0.3 mm	278.0 g	1st : 288.70 g 2nd : 287.75 g	10.23 g	5.43	74.34	25.64	Medium sand
0.075 mm	261.5 g	1st : 309.20 g 2nd : 310.40 g	48.3 g	25.64	99.98	0	Very fine sand
			Total : 188.34 g	99.98			

Table 4.7 : The result of a mechanical analysis test on a soil sample in Kg Tanjung Duff

SI Sieve Aperture Dimension	Weight of empty sieve	Weight of sample (sieve + soil sample)	Weight retained	Weight retained in percentage	Cumulative weight retained in percentage	Cumulative of passing in percentage	Wentworth size class
2.8 mm	547.5 g	1st :548.50 g 2nd : 549.55 g	1.53 g	0.7	0.7	99.28	Gravel
2.0 mm	318.0 g	1st : 373.00 g 2nd : 373.55 g	55.28 g	25.47	26.17	73.81	Very coarse sand
1.0 mm	510.0 g	1st :511.12 g 2nd : 513.10 g	2.11 g	0.97	27.14	72.84	Very coarse sand
0.5 mm	459.5 g	1st : 504.22 g 2nd : 505.10 g	45.16 g	20.81	47.95	52.08	Coarse sand
0.3 mm	278.0 g	1st : 330.43 g 2nd : 331.80 g	53.12 g	24.48	72.43	27.55	Medium sand
0.075 mm	261.5 g	1st : 322.20 g 2nd : 320.40 g	59.8 g	27.55	99.98	0	Very fine sand
			Total : 217.00 g	99.98			

Table 4.8 : The result of a mechanical analysis test on a soil sample in Kg Jubakar Pantai

SI Sieve Aperture Dimension	Weight of empty sieve	Weight of sample (sieve + soil sample)	Weight retained	Weight retained in percentage	Cumulative weight retained in percentage	Cumulative of passing in percentage	Wentworth size class
2.8 mm	547.5 g	1st : 552.05 g 2nd : 551.45 g	4.25 g	1.72	1.72	98.3	Gravel
2.0 mm	318.0 g	1st : 328.38 g 2nd : 328.55 g	10.47 g	4.26	5.98	94	Very coarse sand
1.0 mm	510.0 g	1st : 570.77 g 2nd : 571.20 g	60.99 g	24.78	30.76	69.2	Very coarse sand
0.5 mm	459.5 g	1st : 515.30 g 2nd : 513.80 g	55.05 g	22.37	53.13	46.9	Coarse sand
0.3 mm	278.0 g	1st : 327.70 g 2nd : 328.90 g	50.3 g	20.44	73.57	26.4	Medium sand
0.075 mm	261.5 g	1st : 327.50 g 2nd : 325.50 g	65 g	26.41	99.98	0	Very fine sand
			Total : 246.06 g	99.98			

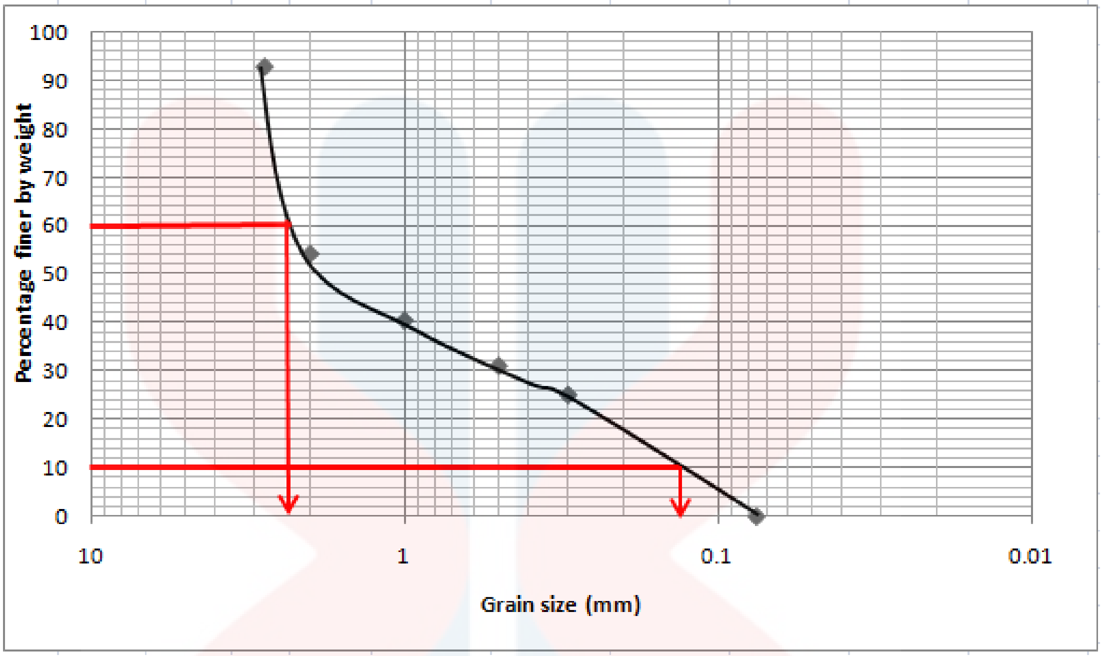


Figure 4.7 : Graph of particles size distribution in Kg Berangan Masjid

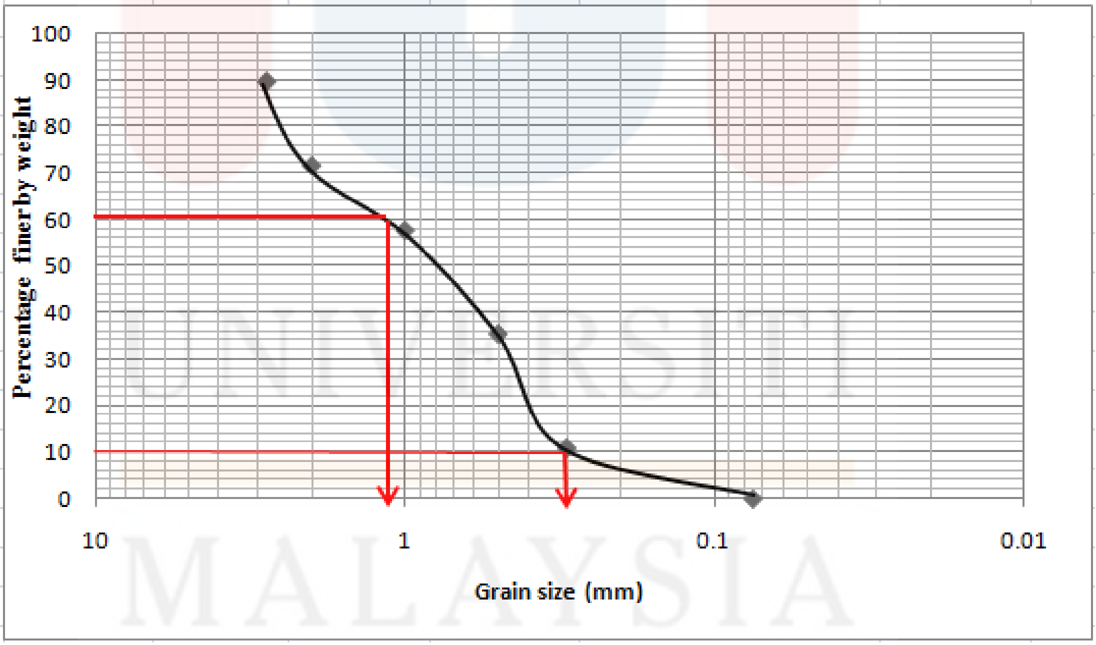


Figure 4.8 : Graph of particles size distribution in Kg Bharu Nelayan

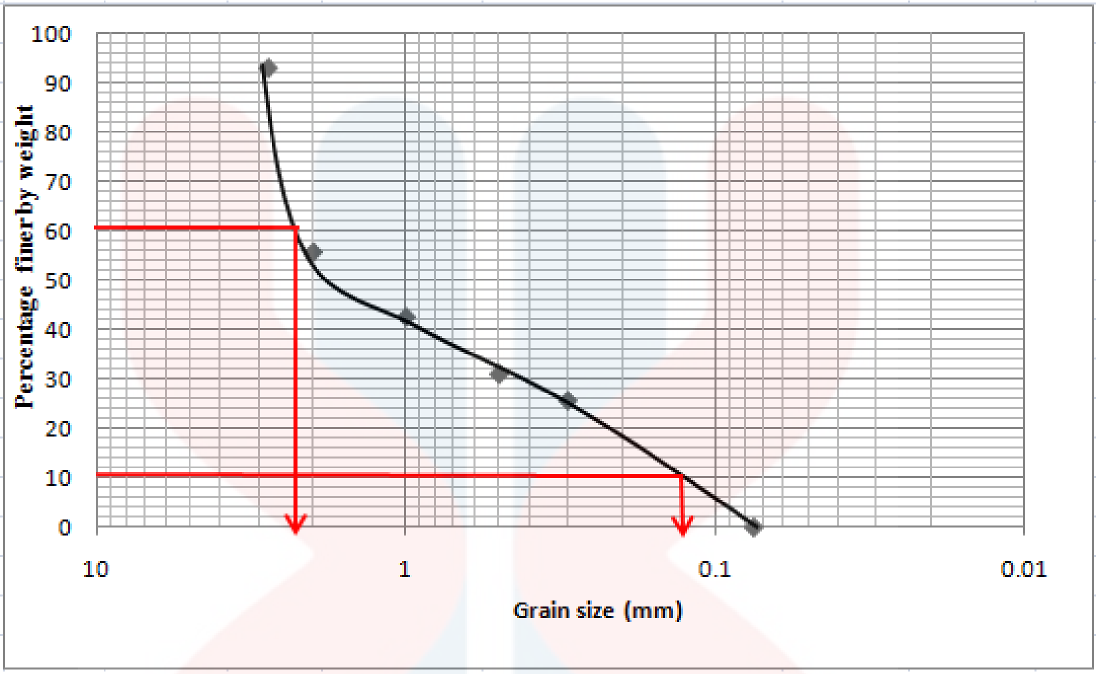


Figure 4.9 : Graph of particles size distribution in Kg Kok Keli

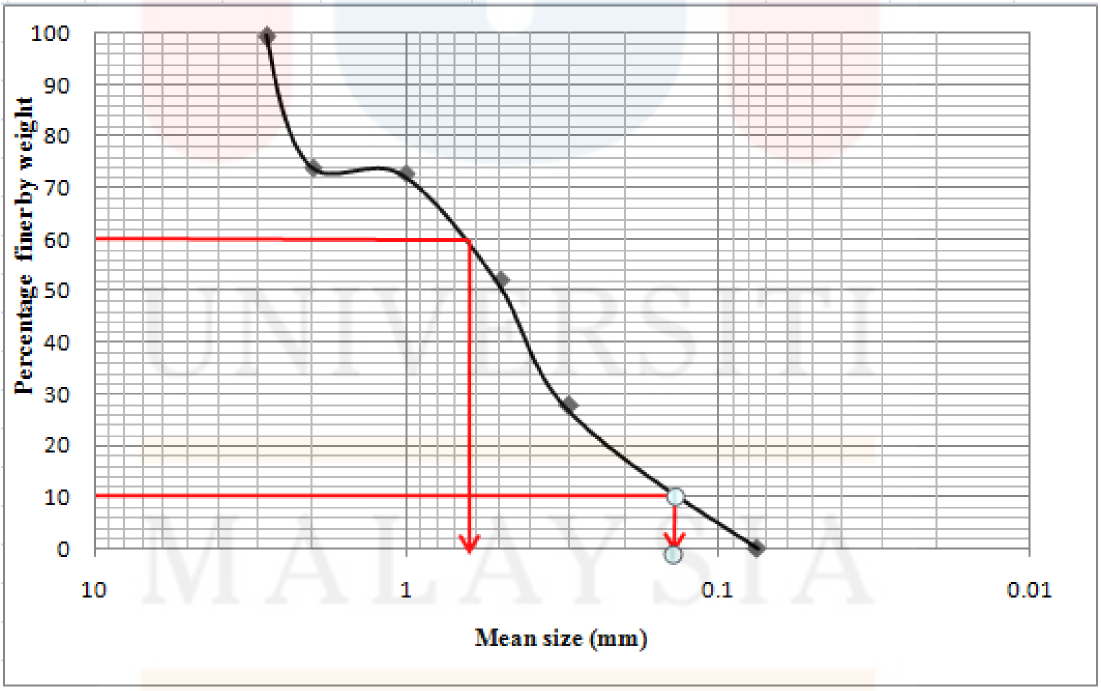


Figure 4.10 : Graph of particles size distribution in Kg Tanjung Duff

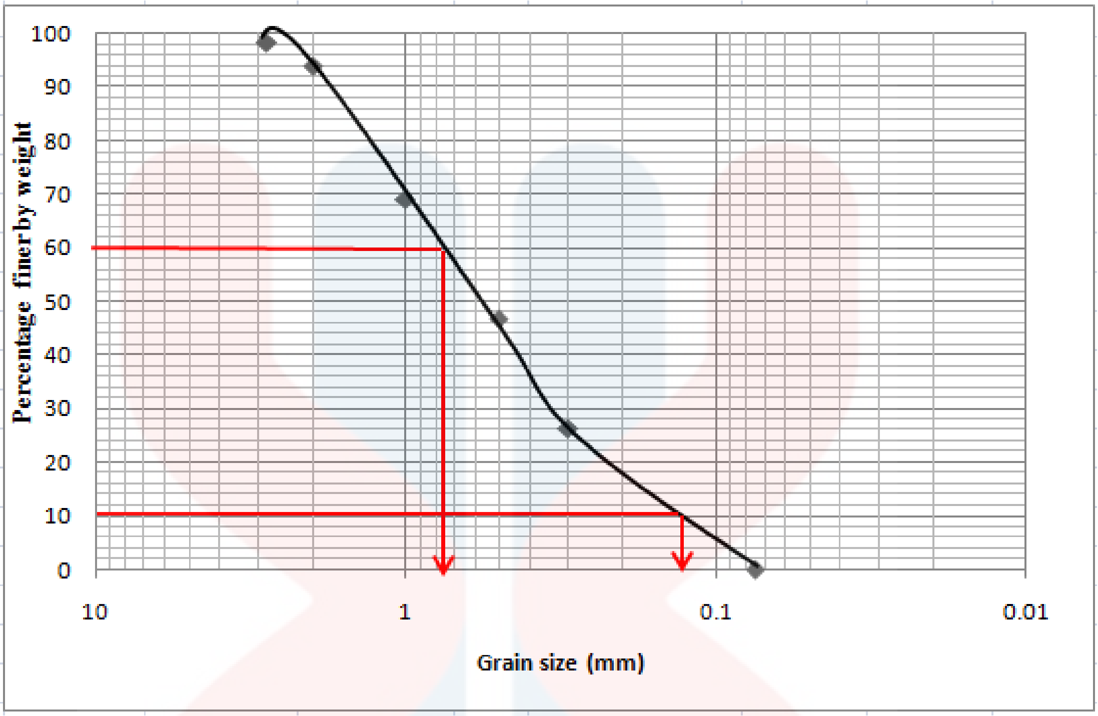


Figure 4.11 : Graph of particles size distribution in Kg Jubakar Pantai

4.4.1 Soil Classification

Basically, grain size distribution is useful for soil classification (Fredlund *et al.*, 2000). Grain size distribution was based on the result from the sieving analysis by using sieving machine. The graphs above were constructed in semilogarithmis paper.

From the grain size distribution, the uniformity coefficient was obtained. The uniformity coefficient is a parameter to measure the sediments whether it is well sorted or poorly sorted (Fetter, 2001). The value of uniformity coefficient was obtained from calculation of formula 4.1.

$$C_u = D_{60}/D_{10} \qquad 4.1$$

C_u was stands for ratio of grain size which is 60 % finer by weight, D_{60} to the grain size which is 10 % finer by weight, D_{10} (Fetter,2001).

Table 4.9 : Uniformity coefficient among 5 soil samples

Location/Soil sample	D_{10}	D_{60}	Uniformity Coefficient , C_u	Sorting
Kg Berangan Masjid/SP1	0.14	2.3	16.4	Poorly sorted
Kg Bharu Nelayan/SP2	0.3	1.02	4.0	Well sorted
Kg KokKeli/SP3	0.14	0.12	0.86	Well sorted
Kg Tanjung Duff/SP4	0.15	0.61	4.07	Good sorted
Kg Jubakar Pantai/SP5	0.13	0.79	6.08	Poorly sorted

A sample with value of C_u below than 4 was classified as well sorted while a sample with value of C_u more than 6 was classified as poorly sorted (Fetter, 2001). SP1 was poorly sorted sediments whereas SP3 was classified as well sorted sediments.

4.4.2 Soil profile

Table 4.10, Table 4.11, Table 4.12, Table 4.13 and Table 4.14 showed soil profile for each location of soil sampling. Soil colour and soil structure were described in all these table. Soil colour was described based on Munsell Soil Color Chart.

Table 4.10 : Soil profile at Kg Berangan Masjid

Picture	Description
	Soil colour : Grey (5/1) Soil structure : Granular 20 cm Soil colour :Reddish brown (5/4) Soil structure : Granular 40 cm Soil colour : Light reddish brown (6/4) Soil structure : Granular 60 cm Soil colour : Reddish yellow (7/8) Soil structure : Granular 80 cm Soil colour : Pink (8/4) Soil structure : Granular

Table 4.11 : Soil profile at Kg Bharu Nelayan

Picture	Description
	Soil colour : Dark grey (4/1) Soil structure : Single grain 20 cm Soil colour :Grey (5/1) Soil structure : Single grain 40 cm Soil colour :Light reddish brown (6/4) Soil structure : Single grain 60 cm Soil colour : Light reddish brown (6/4) Soil structure : Single grain 80 cm Soil colour : Light reddish brown (6/3) Soil structure : Single grain

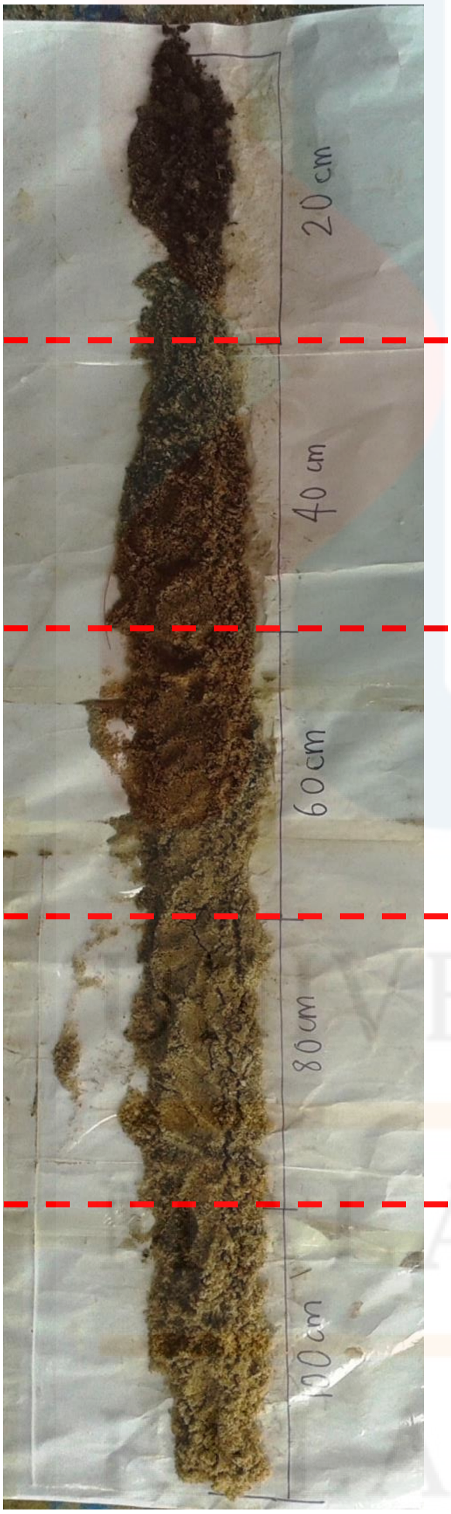
Table 4.12 : Soil profile at Kg Kok Keli

Picture	Description
	Soil colour : Reddish grey (5/2) Soil structure : Granular 20 cm Soil colour :Reddish brown (5/4) Soil structure : Granular 40 cm Soil colour : Light reddish brown (6/4) Soil structure : Granular 60 cm Soil colour : Reddish yellow (7/8) Soil structure : Granular 80 cm Soil colour : Pink (8/4) Soil structure : Granular

Table 4.13 : Soil profile at Kg Tg Duff

Picture	Description
	Soil colour : Reddish grey (5/2) Soil structure : Granular 20 cm Soil colour :Light reddish brown (6/4) Soil structure : Granular 40 cm Soil colour :Reddish yellow (7/6) Soil structure : Granular 60 cm Soil colour : Reddish yellow (7/6) Soil structure : Granular 80 cm Soil colour : Pink (8/4) Soil structure : Granular

Table 4.14 : Soil profile at Kg Jubakar Pantai

Picture	Description
	Soil colour : Dark grey (4/1) Soil structure : Single grain 20 cm Soil colour :Grey (5/1) Soil structure : Single grain 40 cm Soil colour :Light reddish brown (6/4) Soil structure : Single grain 60 cm Soil colour : Light reddish brown (6/4) Soil structure : Single grain 80 cm Soil colour : Light reddish brown (6/4) Soil structure : Single grain

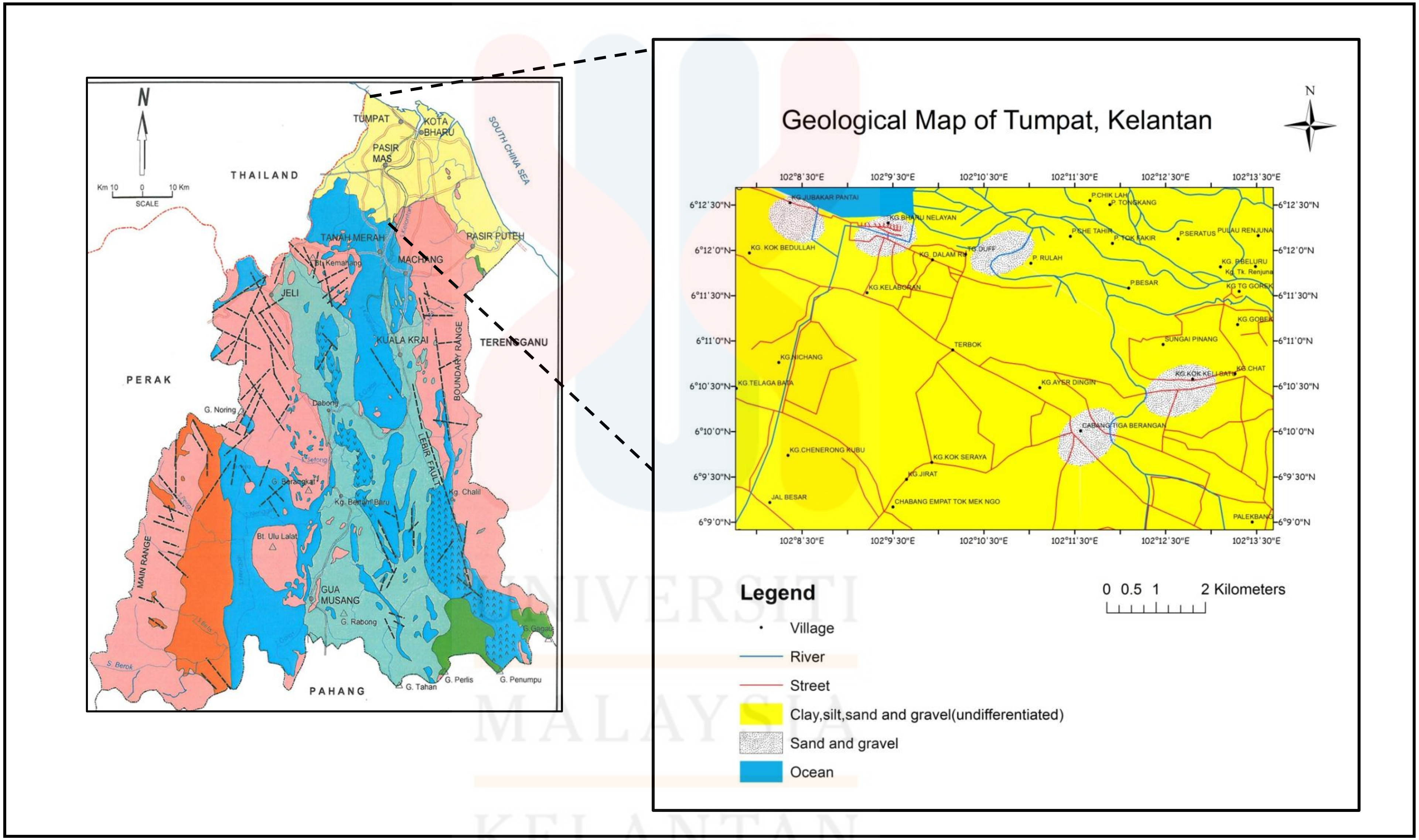


Figure 4.12 : Geological map of study area

4.5 Quaternary stratigraphic

Tumpat, is one of district situated in northern part of Kelantan which covered by Quaternary alluvium deposits. Generally, Quaternary deposits can be divided into two types which are Pleistocene deposit and Holocene deposit based on study from Bosch (1986). Then, the Pleistocene deposits comprised of Simpang Formation meanwhile the Holocene deposit comprised of Gula Formation and Beruas Formation which granite bedrock lied beneath it (Nur Hayati, 2011). Figure ??? showed the geology map of North Kelantan from the study of Nur Hayati (2011) which can be compared with this study in aspect of Quaternary stratigraphic.

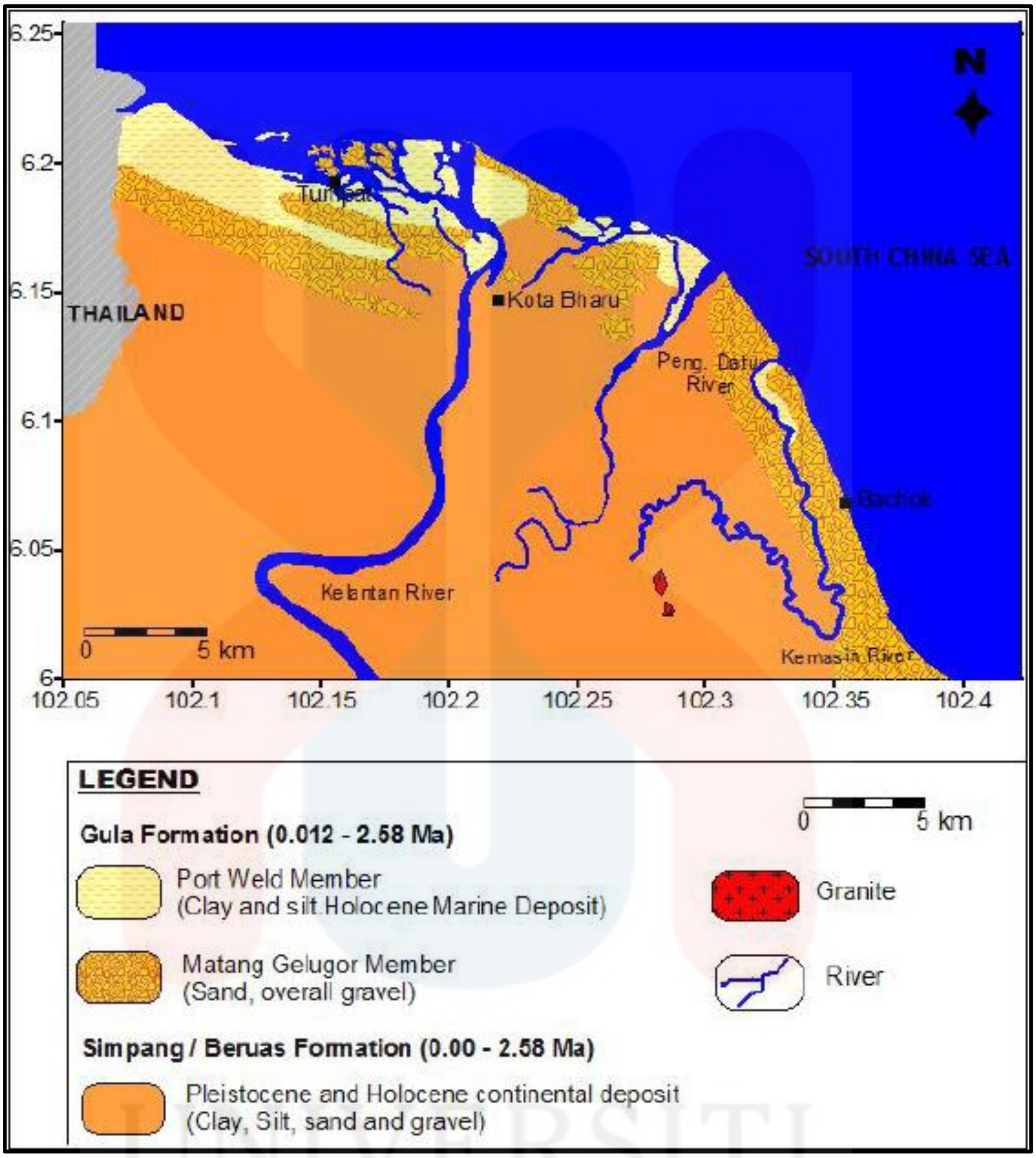


Figure 4.13 : Geology map of North Kelantan

(Source : Nur Hayati, 2011)

CHAPTER 5

EVALUATION SEA WATER INTRUSION INTO SHALLOW AQUIFERS USING HYDROCHEMISTRY IN TUMPAT, KELANTAN

5.1 Introduction

All the result of water samples around Tumpat, Kelantan were tabulated and discussed in this chapter. Basically, the result of water samples mostly groundwater samples shows different values and concentration for each location. The factors which contribute to differences in values and concentration of water samples also discussed in this chapter. At the end, these result then compared with National Guidelines of Raw Water Quality Standard from the Ministry of Health of Malaysia. This standards used as the benchmark to determine the groundwater quality status around Tumpat, Kelantan.

Tables 5.1 : National Guidelines of Raw Water Quality Standard

Constituents	Permissible limit in MOH 2000
pH	5.5 – 9.0
Total Dissolved Solids (TDS)	1500
Turbidity	1000 NTU
Calcium	200
Magnesium	150
Sodium	200
Potassium	30
Iron	1.0
Chloride	250
Sulphate	250
Bicarbonate	500

(Source : MOH,2000)

Table 5.2 : Sampling location around study area

No of sample	Type of water sample	Location	Latitude/N	Longitude/E	Elevation (metre)
R1	River	River at Tanjung Duff	06° 11' 58.1"	102° 10' 42.1"	1
S1	Groundwater	Kg Tanjung Duff	06° 11' 57.7"	102° 10' 38.8"	1
S2	Groundwater	Kg Bharu Nelayan's mosque	06° 12' 12.9"	102° 09' 30.1"	17
S3	Groundwater	Kg Bharu	06° 12' 15.3"	102° 09' 08.1"	18
S4	Groundwater	Kg Kok Bedullah	06° 11' 54.1"	102° 07' 50.2"	20
S5	Groundwater	Kg Jubakar	06° 12' 28.4"	102° 08' 28.7"	12
S6	Groundwater	Kg Chenerong	06° 09' 21.7"	102° 07' 52.1"	15
S7	Groundwater	Kg Pulau Teluk Renjuna	06° 11' 46.9"	102° 13' 22.5"	17
S8	Groundwater	Kg Pulau Beluru	06° 11' 43.2"	102° 13' 5.07"	17
S9	Groundwater	Kg Chap	06° 10' 34.5"	102° 13' 18.7"	12
S10	Groundwater	Kg Air Dingin	06° 10' 21.3"	102° 11' 10.2"	16
S11	Groundwater	Kg Berangan	06° 09' 56.8"	102° 11' 38.6"	12
S12	Groundwater	Kg Telaga Bata	06° 10' 30.5"	102° 08' 00.6"	10
S13	Groundwater	Kg Dalam Rhu Tumpat	06° 11' 54.0"	102° 09' 57.5"	15
S14	Groundwater	Kg Kok Keli	06° 10'27.2"	102° 12' 39.7"	22

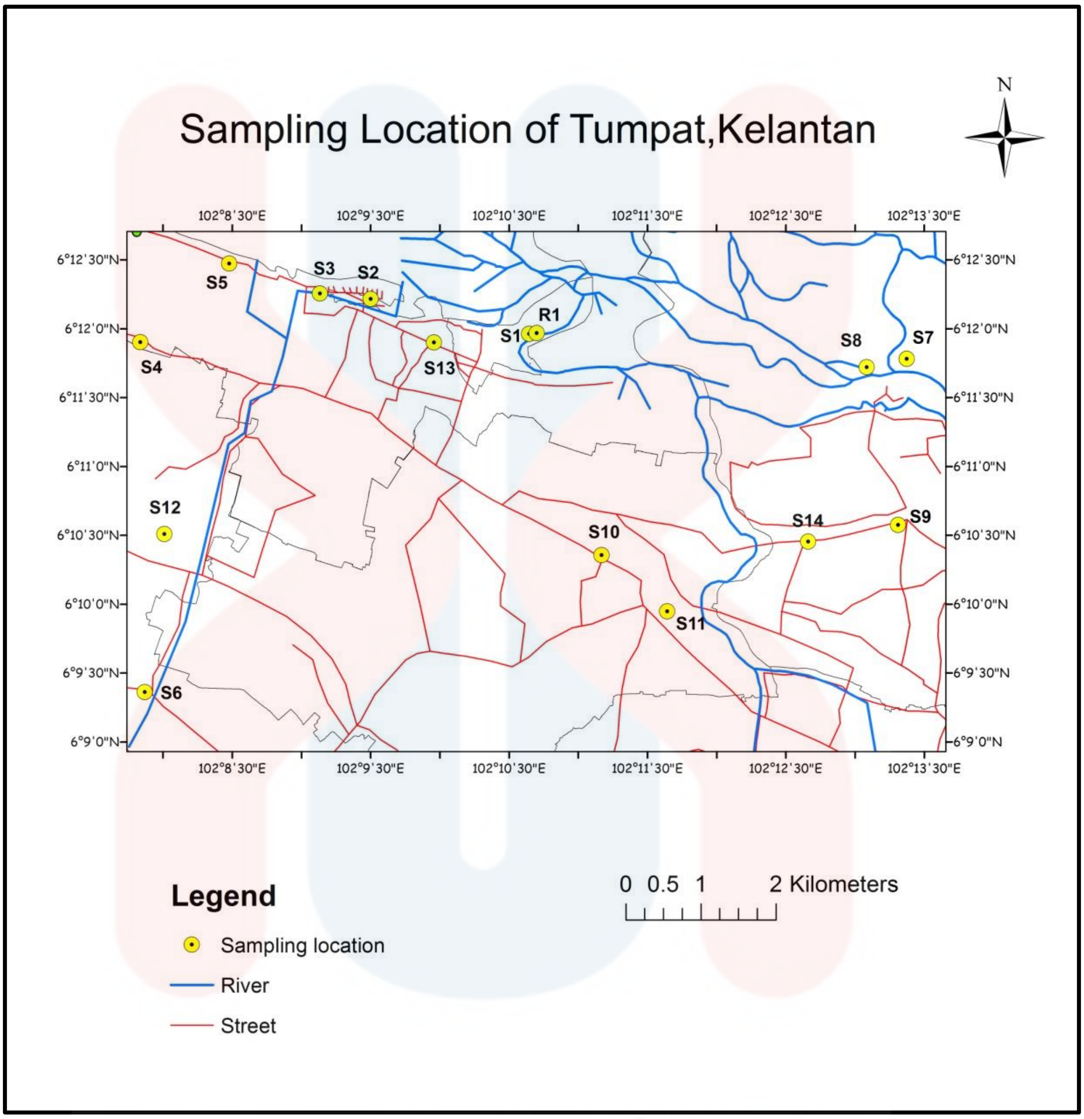


Figure 5.1 : Sampling location around study area

5.2 Physical parameters of water samples around Tumpat, Kelantan.

Table 5.3 : Physical parameters of water samples in study area

Sample	Location name	pH	Temperature, ºC	Total Dissolved Solid (TDS),mg/L	Salinity	Turbidity, (NTU)	Electrical Conductivity (EC), µS/cm
R1	River at Tanjung Duff	6.36	30.47	14070	12.90	9.98	23900
S1	Kg Tanjung Duff	6.94	30.40	143	0.10	0.58	244
S2	Kg Bharu Nelayan's mosque	7.35	29.29	203	0.15	1.25	338
S3	Kg Bharu	6.99	33.65	307	0.22	0.72	550
S4	Kg Kok Bedullah	6.49	28.31	438	0.32	4.34	716
S5	Kg Jubakar	6.84	29.62	69	0.05	3.31	116
S6	Kg Chenerong	6.09	27.94	106	0.08	5.34	172
S7	Kg Pulau Teluk Renjuna	6.86	27.47	128	0.09	4.60	207
S8	Kg Pulau Beluru	6.69	28.05	245	0.18	6.40	798
S9	Kg Chap	6.40	28.53	83	0.06	1.03	137
S10	Kg Air Dingin	6.13	28.60	113	0.08	1.82	185
S11	Kg Berangan	5.96	27.41	155	0.11	0.67	249
S12	Kg Telaga Bata	5.83	34.90	165	0.12	5.50	301
S13	Kg Dalam Rhu Tumpat	6.93	31.37	296	0.17	0.78	396
S14	Kg Kok Keli	6.24	31.26	165	0.12	0.72	285

5.2.1 pH

pH value is important parameter to describe quality of groundwater because pH value can controls the amount and chemical form of solutes in groundwater (Fisher, 2002). pH value generally show whether water samples is acidic or alkaline. Based on Table 5.3, the values for pH ranged from 5.83 to 7.35. S12 showed lowest pH value which is 5.83 whereas S2 showed highest value of pH value which is 7.35. The average of pH value for all water samples was 6.55. Low pH value of S12 may cause by cultivation activities as the location where sample was taken near with paddy cultivation. Cultivation in agricultural over long period may cause soil to be more acidic by nutrient uptake of bases (Knutsson,1994). As water pass through the acidic soil, the water become acidic as well before the water infiltrate into groundwater. The range of pH value from 5.83 to 7.35 is acceptable according to National Guidelines of Raw Water Quality Standard from Ministry of Malaysia (MOH) as shown in Figure 5.2.

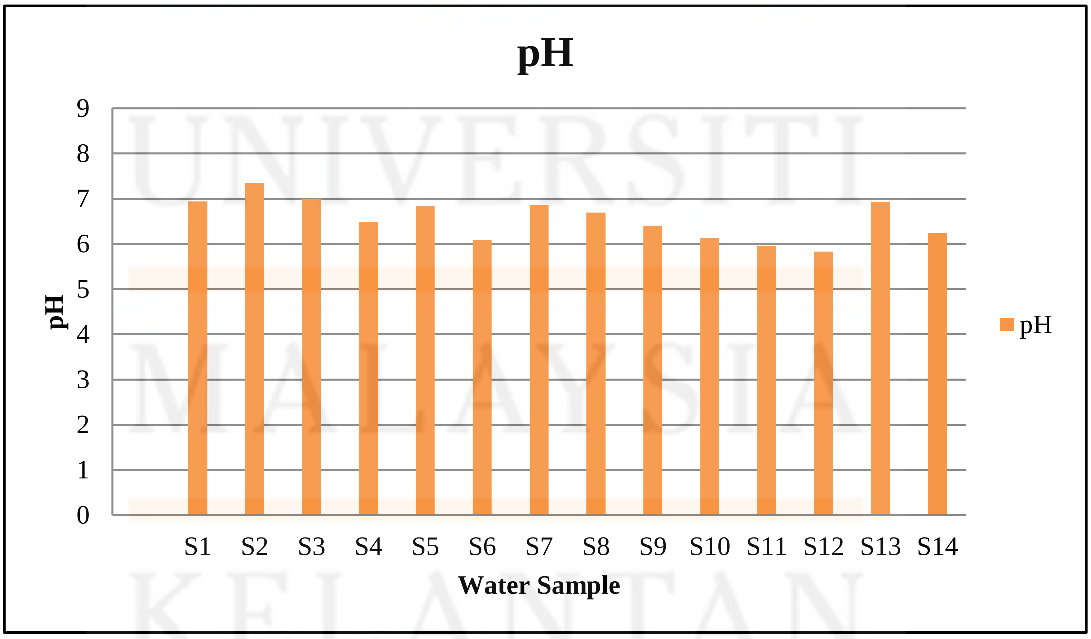


Figure 5.2 : pH value of water samples around Tumpat, Kelantan

5.2.2 Total Dissolved Solids (TDS)

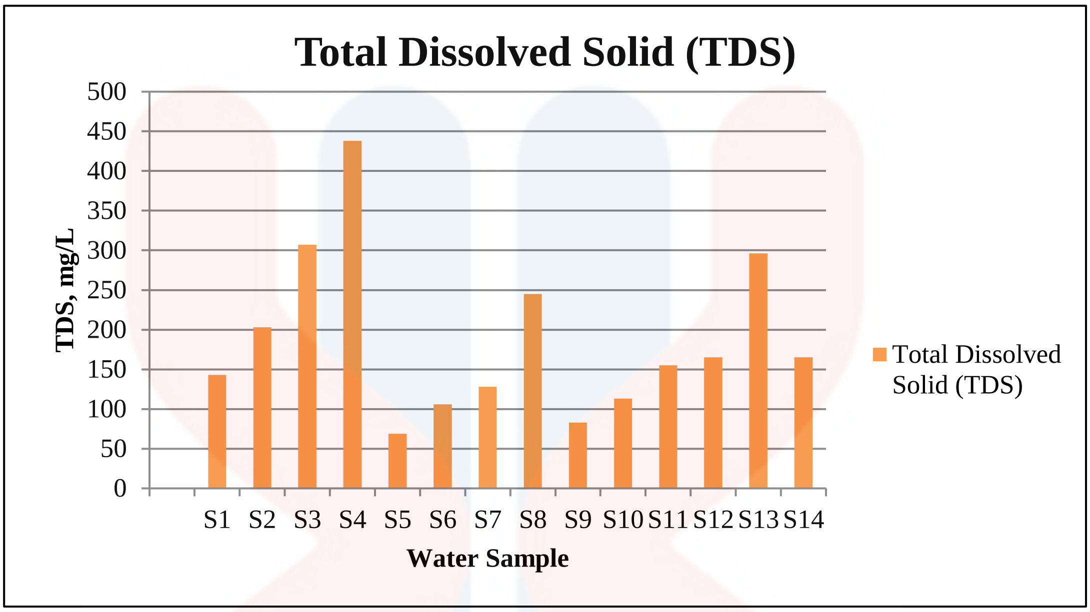


Figure 5.3 : Total dissolved solids (TDS) of water samples around Tumpat, Kelantan

Table 5.4 : Classification of TDS for groundwater (Shahida & Ummatul, 2015)

Categorize	TDS in mg/L	Classification
Freshwater/Non-saline	< 1000	S1 – S14
Slightly saline	1000 – 3000	
Moderately saline	3000 – 10000	
Very saline	>10000	

Total dissolved solids (TDS) of water samples around Tumpat, Kelantan varied from 69 mg/L to 438 mg/L with the average value was 187.5 mg/L and all samples in permissible limit of standard from MOH. Among water samples, S4 had highest value of TDS which is 438 mg/L compared to other samples as shown in Figure 5.3, which may be caused by high content of natural bicarbonates, chlorides, sodium, potassium, magnesium and calcium (Ojol et al.,2012) .The amount of TDS in sample 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 (Nelson, 2002).

According classification of TDS in Table 5.4, all water samples were classified as non-saline or freshwater.

5.2.3 Electrical Conductivity (EC)

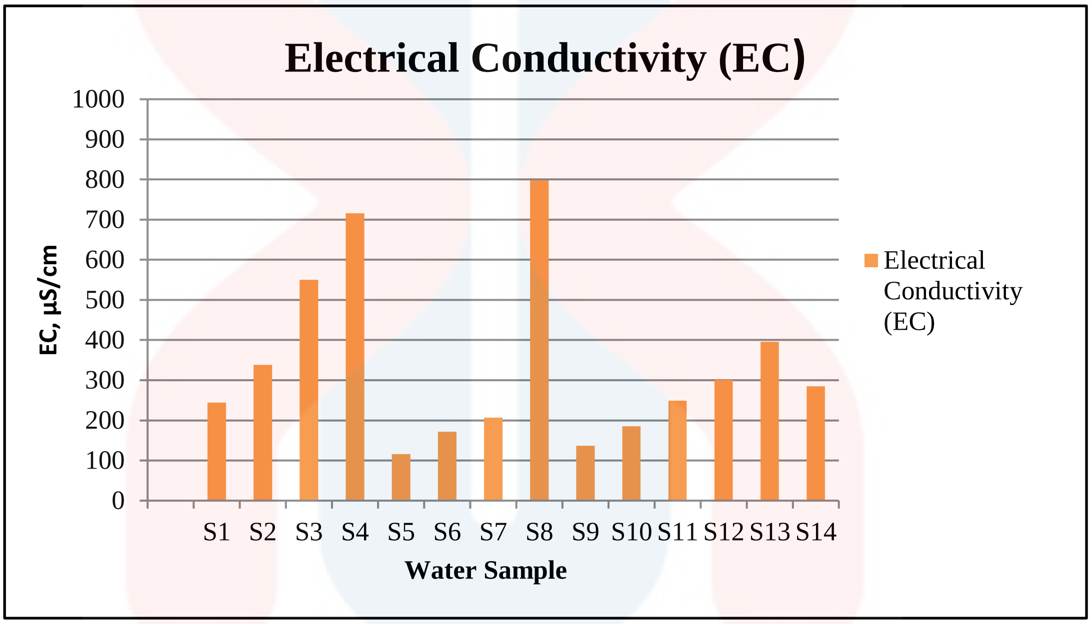


Figure 5.4 : Electrical conductivity (EC) of water samples around Tumpat, Kelantan

Electrical conductivity (EC) in study area recorded from 116 ųS cm^{-1} to 798 ųS cm^{-1}, S8 had highest value of EC whereas S5 had lowest value of EC with overall average for EC values was 355.2 ųS cm^{-1}. EC is a measure of capacity and ability of water to conduct electric current due to presence of dissolved salt in water (Shahida & Ummatul, 2015).Dissolved salts that capable to conduct electric current is sodium chloride (NaCl). Therefore, S8 may had high amount of NaCl.

Table 5.5 : Classification of electrical conductivity for suitability of water for certain purpose (Shahida & Ummatul, 2015)

Classification	EC in ɥS cm^{-1}	Classification
Excellent	< 250	S1, S5, S6, S7, S9, S10
Good	250 - 750	S2, S3, S4, S8, S11, S12, S13, S14
Permissible	750 - 2000	
Doubtful	2000 - 3000	
Unsuitable	>3000	

Suitability of water samples for certain purpose can be referred in Table 5.5. S1, S5, S6, S7, S9 and S10classified as excellent to use for certain purpose as these samples considered low conductivity of water. S2, S3, S4, S8, S11, S12, S13 and S14 classified as good also suitable for all pupose of usage.

5.2.4 Turbidity

Water samples in Tumpat, Kelantan had turbidity ranged from 0.58 to 6.40 NTU with a mean of 2.65 NTU and all the samples within permissible limit which is below 1000 NTU according to MOH standard. Turbidity is a parameter to measure the cloudiness the water. In other words, turbidity of water samples may caused by the presence of suspended material, sized from colloidal to coarse dispersion (Shahida & Ummatul, 2015).

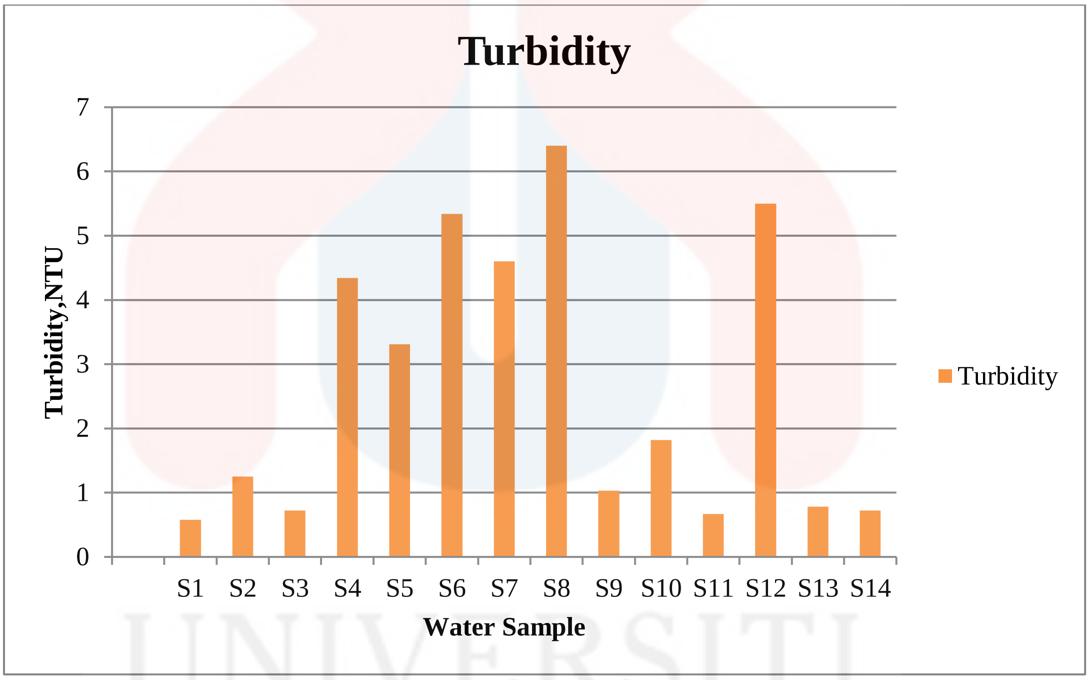


Figure 5.5 : Turbidity of water samples around Tumpat, Kelantan

5.2.5 Salinity

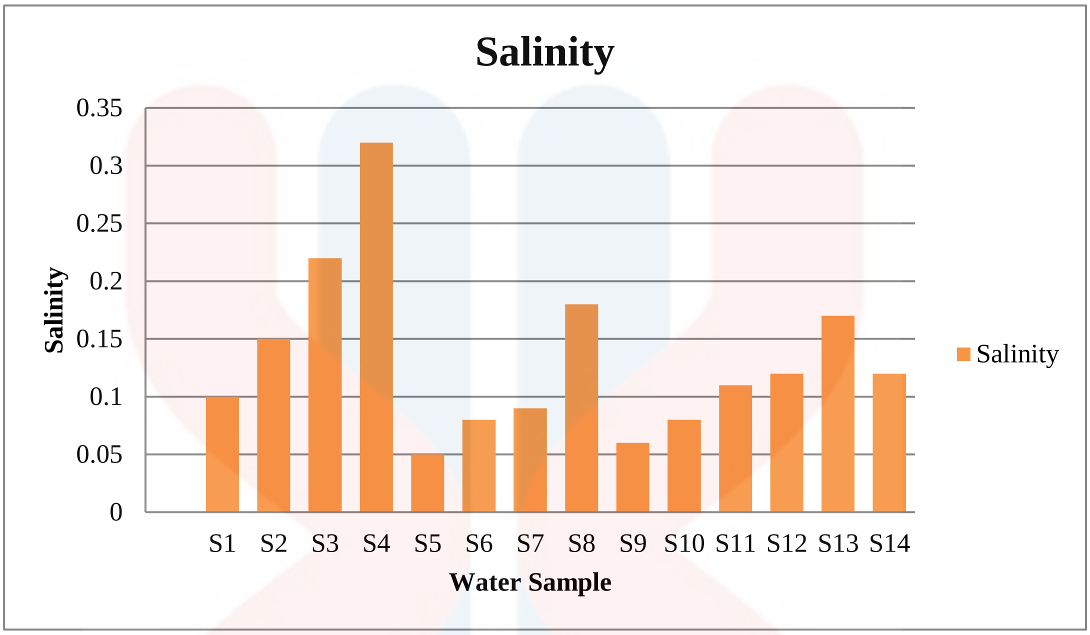


Figure 5.6 : Salinity of water samples around Tumpat, Kelantan

0.32 to 0.05 was the range of salinity values in water samples collected around Tumpat, Kelantan. S4 recorded high value of salinity while S5 recorded low value of salinity with the average of salinity for all samples was 0.13. All water samples showed very low value of salinity.

5.3 Chemical parameters of water samples around Tumpat, Kelantan

Result of chemical parameters of water samples aroun Tumpat, Kelantan was showed in Table 5.6.

Table 5.6 : Chemical parameters of water samples around Tumpat, Kelantan

Sample	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Fe (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	HCO_3^{-} (mg/L)
R1	18.63	17.57	16.87	44.58	1.763	1000	200	490.00
S1	0	2.382	11.81	6.358	1.822	27.69	20.58	240.00
S2	25.34	5.639	15.02	8.788	1.164	54.47	15.64	290.00
S3	10.00	4.473	15.13	9.158	1.599	46.86	19.34	292.5
S4	0	3.501	16.09	11.95	1.890	61.06	3.94	407.50
S5	0.999	1.372	6.154	2.294	2.337	21.30	6.73	142.50
S6	0	2.489	14.13	5.499	2.042	24.85	10.34	237.50
S7	0	5.322	14.95	5.351	3.953	31.95	9.88	292.50
S8	8.767	8.273	15.63	6.053	2.651	63.90	82.3	292.50
S9	0	1.695	12.38	3.462	3.170	26.98	11.54	230.00
S10	0.119	1.435	12.88	5.880	3.189	30.53	5.76	365.00
S11	0	3.856	15.54	8.248	3.272	34.08	6.03	210.00
S12	0	2.911	16.04	5.145	4.004	63.19	45.27	307.50
S13	13.87	5.705	15.07	9.570	3.604	37.63	18.93	507.50
S14	0	2.900	15.49	9.103	3.674	34.79	75.72	407.50

5.3.1 Calcium, Ca^{2+}

Calcium is one of essential alkaline-earth element for life forms. The concentration for calcium ions around Tumpat, Kelantan ranged from 0 mg/L to 25.34 mg/L with overall average concentration was 4.22 mg/L. Based on the Figure 5.8, S2 had highest concentration of calcium ion which is 25.34 mg/L.

For S2 which groundwater enriched with high concentration of calcium ions, the reason may be related with water sources for the groundwater recharge (Schot & Wassen, 1993). As the location of well was approximately 300 metres from the freshwater stream which groundwater may recharged by stream that possible consisted high concentration of calcium ions. Recharging of groundwater by the freshwater stream may contribute to increasement of amount of calcium ions which already present in the wells of S2.

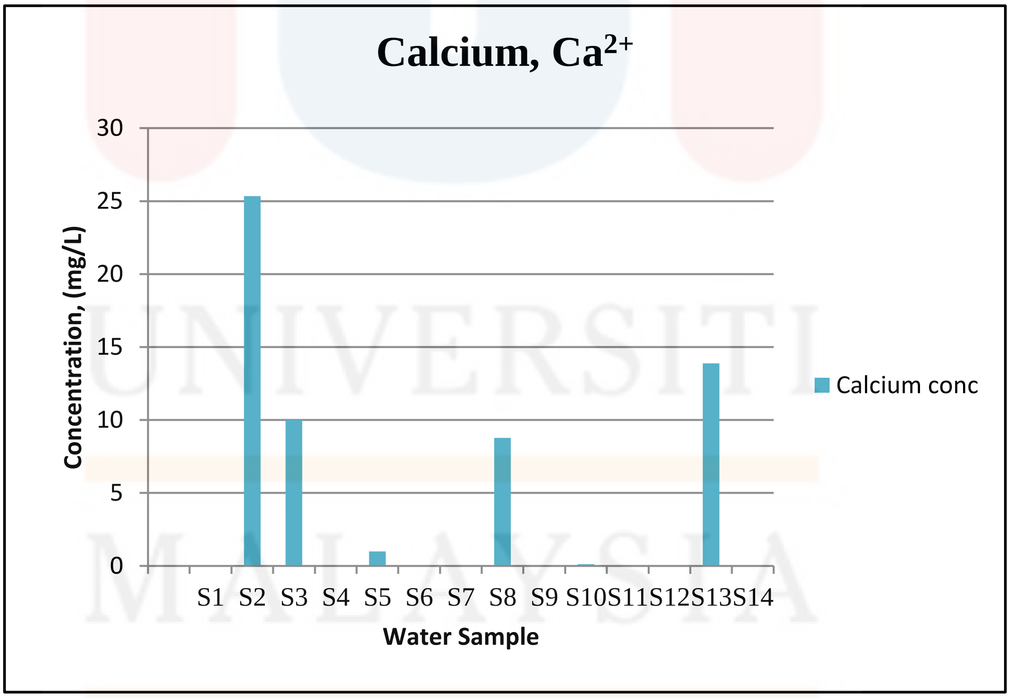


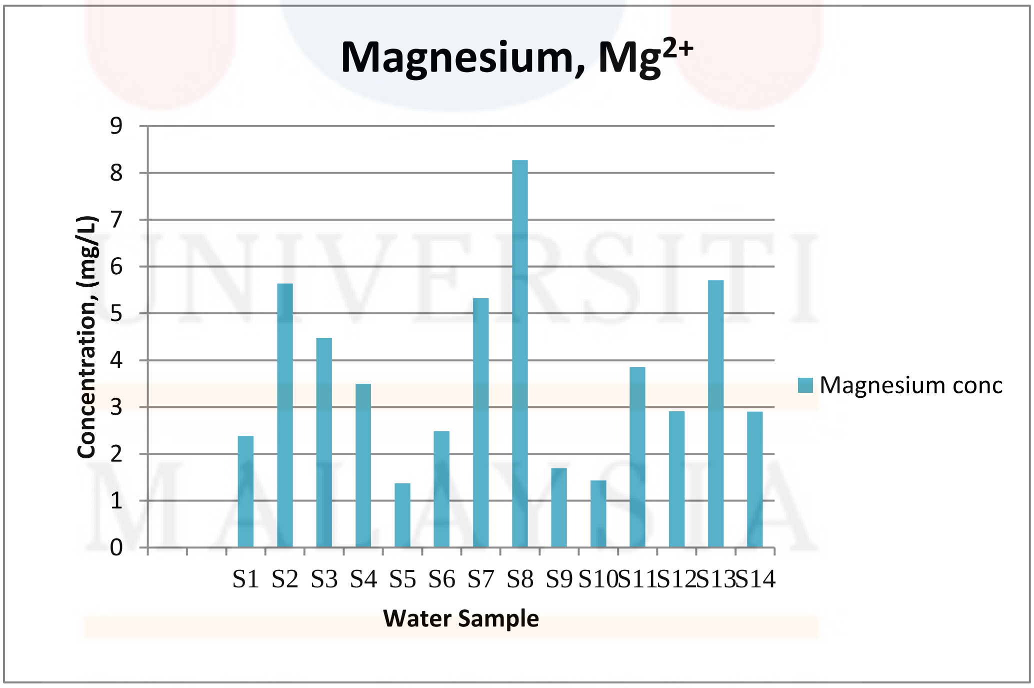
Figure 5.7 : Calcium ions concentration around Tumpat, Kelantan

Based on Figure 5.7, all the samples had calcium ions concentration below than 200 mg/L which all the samples within permissible limit of MOH standard.

5.3.2 Magnesium, Mg^{2+}

From analyzed data, magnesium ions concentration around Tumpat, Kelantan varied from 1.372 mg/L to 8.273 mg/L, S5 had lowest magnesium ions concentration and S9 had highest magnesium ions concentration. S8 had highest magnesium ions concentration which is 8.273 mg/L. That because of dissolution reaction of andesine, chlorite and muscovite. Generally, magnesium is derived from the dissolution of andesine, chlorite and muscovite which make up some parts of the sand and gravel that fill the Kelantan Basin. The rate of dissolution at location of S8 may increased by acid precipitation or acid rain. The average of magnesium ions concentration was 3.71 mg/L. According to MOH, water that contained magnesium ions below than 150 mg/L is suitable and safe for all purposes, which all water samples collected from the well around Tumpat, Kelantan were suitable and safe for all purposes.

Figure 5.8 : Magnesium ions concentration around Tumpat, Kelantan



5.3.3 Potassium, K^+

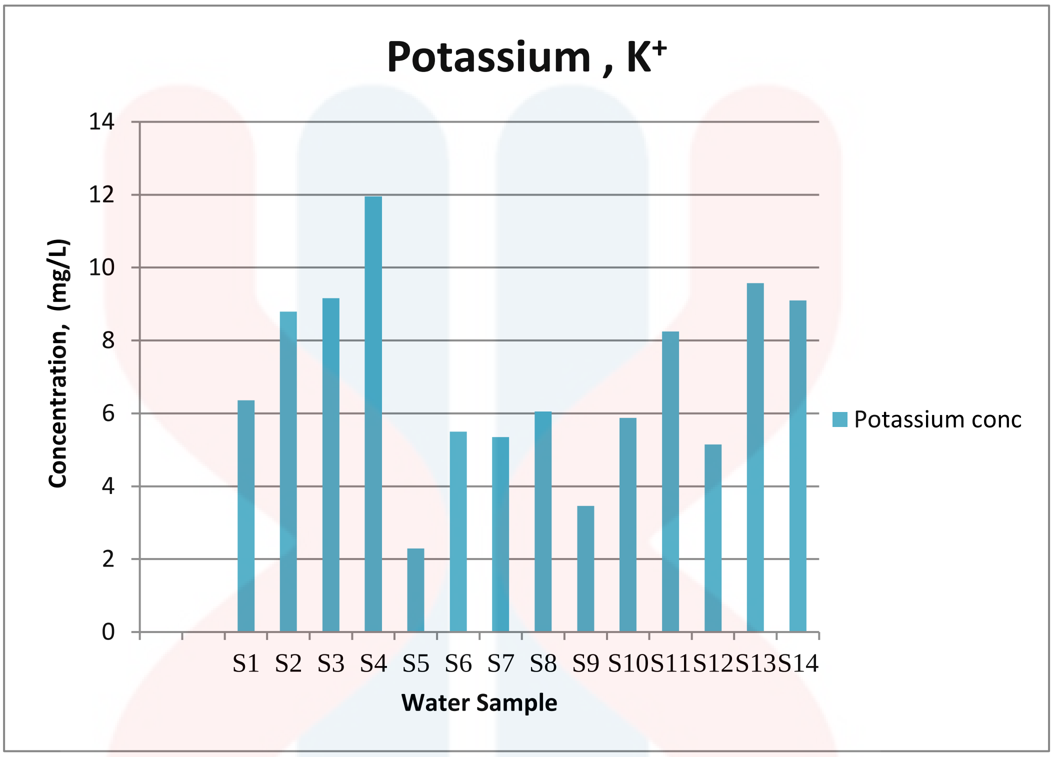


Figure 5.9 : Potassium ions concentration around Tumpat, Kelantan

Analysis of geochemical data showed potassium ions concentration around Tumpat, Kelantan ranged from 2.294 mg/L to 11.95 mg/L with mean value was 6.91 mg/L. S4 recorded highest concentration of potassium ions which is 11.95 mg/L while S5 rcorded lowest concentration of potassium ions which is 2.294 mg/L. Potassium ions originated from the dissolution process of several silicate minerals and clay minerals which present sub surface (Plummer *et al.*, 2003). This explains why S4 recorded high concentration of potassium ions.

All water samples showed concentration of potassium ions below than 30 mg/L, indicates groundwater around Tumpat, Kelantan can be used for human activities, livestock and agriculture activities. This followed standard from MOH.

5.3.4 Sodium, Na^+

Figure 5.10 displayed that range of sodium ions concentration of water samples around Tumpat, Kelantan start from 6.154 mg/L to 16.09 mg/L with overall average was 14.02 mg/L. As shown in the Figure 5.10, S4 had 16.09 mg/L of sodium ions concentration and S5 had 6.154 mg/L of sodium ions concentration. This can be explained by natural cation exchange, reaction of ion exchange on the surfaces of certain clay minerals meanwhile sodium is released to the water in exchange for calcium or magnesium (Plummer *et al*., 2003). As water from precipitation had contact with soil contained sodium, water brought together the solutes enter into the groundwater.

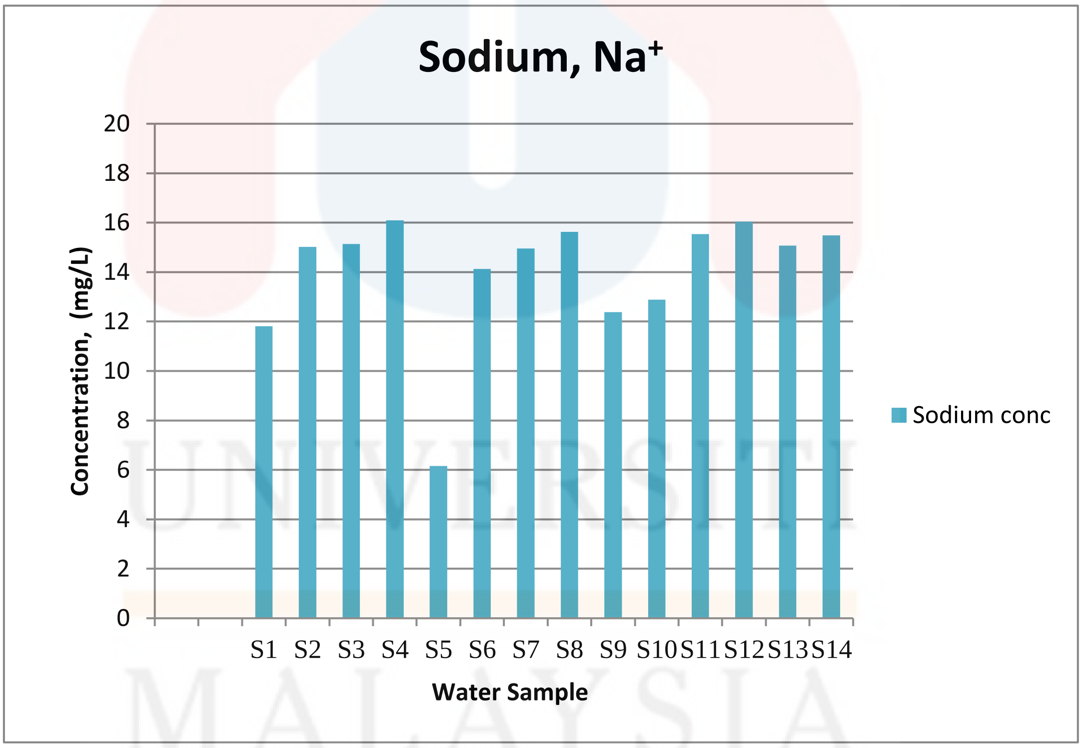


Figure 5.10 : Sodium ions concentration around Tumpat, Kelantan

Permissible limit for sodium ions concentration is below than 200 mg/L. Therefore, all water samples allowed to use to perform daily activities.

5.3.5 Iron, Fe^{+}

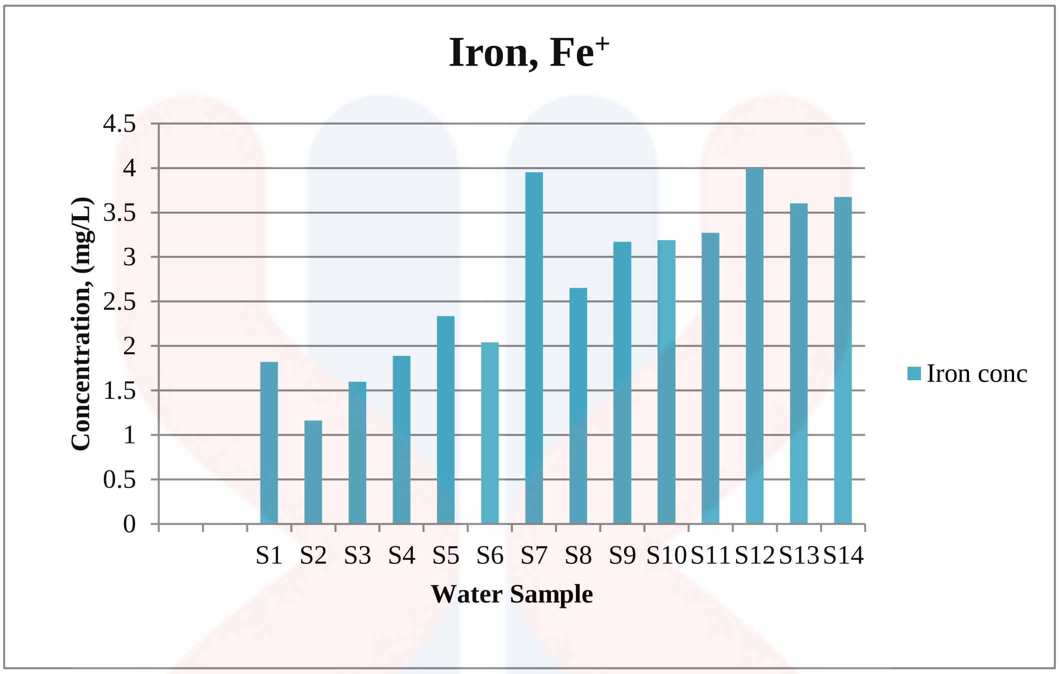


Figure 5.11 : Iron ions concentration around Tumpat, Kelantan

Concentration of iron ions around Tumpat, Kelantan considerably low unlike another ions, which ranged from 1.164 mg/L to 4.004 mg/L. The average of the iron ions concentration was 2.74 mg/L. Figure 5.11 clearly showed that S2 had 1.164 mg/L of iron ions concentration, which the lowest value compared to others and S12 had 4.004 mg/L of iron ions concentration, which highest value compared to others. Amount of iron ions concentration should not more than 1 mg/L in terms of suitability of water for daily purposes as excessive of iron in water can cause stains pipes, laundry and cooking appliances (Todds & Mays, 2005). Based on Figure 5.11, all water samples contained iron ions concentration above the permissible limit.

5.3.6 Bicarbonate, HCO^{3-}

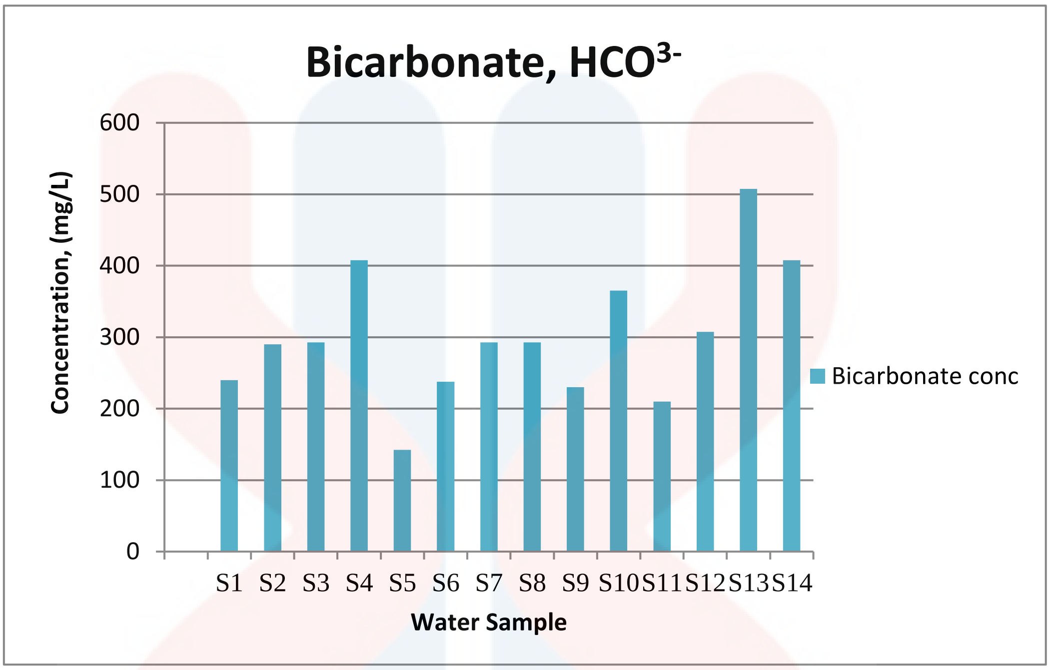


Figure 5.12 : Bicarbonate ions concentration around Tumpat, Kelantan

Result of bicarbonate ions concentration around Tumpat, Kelantan as shown in Figure 5.12 varied from 142.5 mg/L to 507.5 mg/L and the mean value for concentration of bicarbonate ions was 301.60 mg/L. In bicarbonate ions analysis, S13 had high concentration as with S5 had low concentration, 507.5 mg/L and 142.5 mg/L respectively.

As water infiltrates through the soil layer, water tends to dissolve carbon dioxide (CO2) gas that exists in the soil in large quantities because of biological activity. A weak acid is formed when CO2 dissolves in water in the soil zone, Carbonic acid contribute the dissolution of minerals that are exist in the soil which releases solutes such as bicarbonate to the water and causing their concentrations to increase. From these processes, water in the soil zone can obtained certain ions before it reaches the water table (Plummer *et al.*, 2003). This may be the reason of high concentration of bicarbonate ions of S13. The concentration value of S13 had exceed the limit of National Guidelines of Raw Water Quality Standard from the

Ministry of Health of Malaysia as in this guidelines bicarbonate ions in water must be below than 500 mg/L.

5.3.7 Chloride, Cl^-

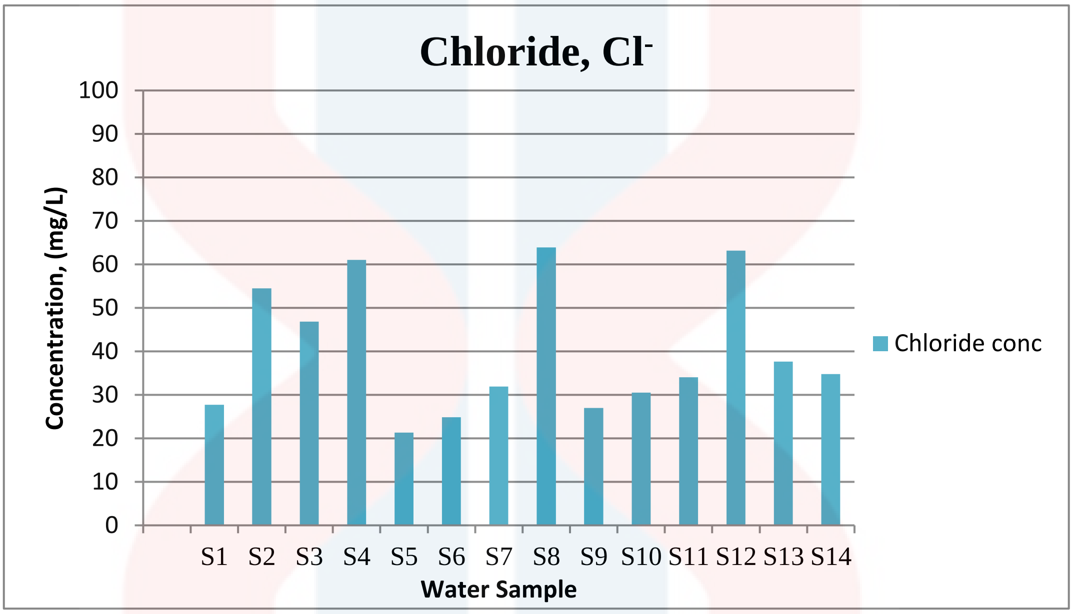


Figure 5.13 : Chloride ions concentration around Tumpat, Kelantan

As ilustrated in Figure 5.13 above, around study area, range of chloride ions concentration initiated at 21.3 mg/L to 63.9 mg/L. The average for chloride concentration is 39.94 mg/L. S6 was at low concentration which is 21.3 mg/L of chloride ions conversely with concentration of chloride ions for S8 soared up to 63.9 mg/L, top the charts. As for chlorine ions , the limit is not more than 250 mg/L in water as excessive chlorine in water imparts a salty taste. Based on Figure 5.13, all the water samples were below than 250 mg/L.

5.3.8 Sulphate, SO_4^{2-}

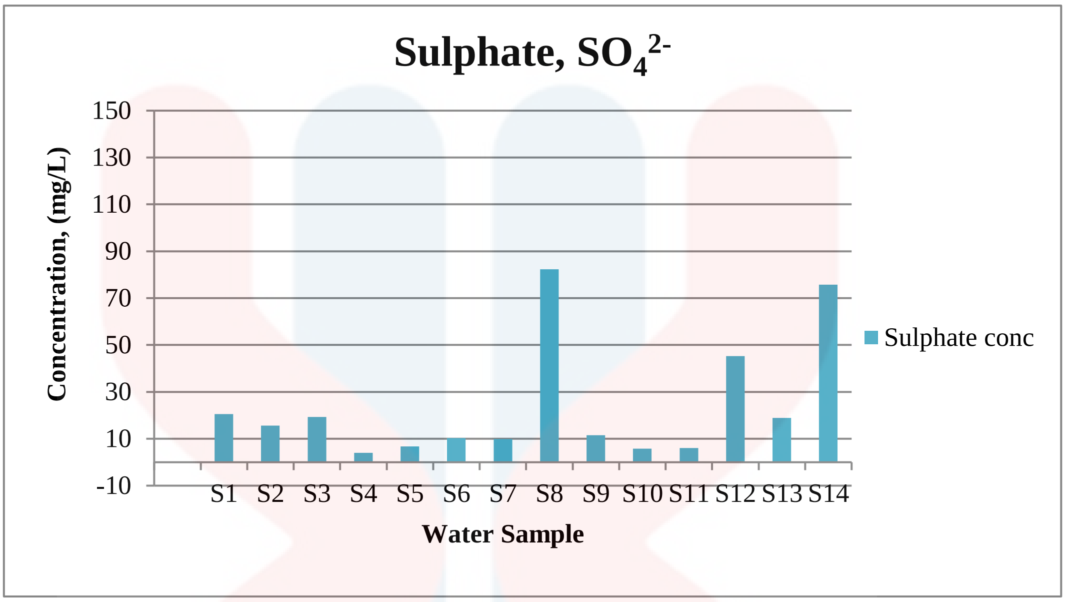


Figure 5.14 : Sulphate ions concentration around Tumpat, Kelantan

Sulphate ions concentration around Tumpat, Kelantan began at low 3.94 mg/L to 82.3 mg/L with the mean value was 23.71 mg/L. Besides natural occuring sulphate ions, other sources of sulphate ions can be from decomposition of organic matter which contribute about 0.1 percent sulfur and usage of sulphate-based fertilizers and pesticides (Minesota Pollution Control Agency). High concentration of sulphate ion of S8 may be caused by effluent discharge from irrigation lands that used fertilisers for the crops. Same with chloride ions, sulphate ions also must not more than 250 mg/L as excessive of sulphate can stains plumbing fixtures and clothes.

Table 5.7 : National Guidelines of Raw Water Quality Standard from MOH and Drinking Water Standard from WHO with concentration of water samples around Tumpat, Kelantan

Parameter	MOH 2000	WHO 2011	Concentration of water samples
pH	5.5 – 9.0	Not stated	5.83 to 7.35
Total Dissolved Solids (TDS)	1500	Not stated	69 mg/L to 438 mg/L
Turbidity	1000	Not stated	0.05 to 6.40
Calcium	200	Not stated	0 mg/L to 25.34 mg/L
Magnesium	150	Not stated	1.372 mg/L to 8.273 mg/L
Sodium	200	200	6.154 mg/L to 16.09 mg/L
Potassium	30	Not stated	2.294 mg/L to 11.95 mg/L
Iron	1.0	Not stated	1.164 mg/L to 4.004 mg/L
Chloride	250	250	21.3 mg/L to 63.9 mg/L
Sulphate	250	500	3.94 mg/L to 82.3 mg/L
Bicarbonate	500	Not stated	142.5 mg/L to 507.5 mg/L

5.4 Groundwater Classification

Based on chemical parameters analysis, distribution of cation and anion can be used to classified groundwater type around Tumpat, Kelantan.

5.4.1 Piper Trilinear diagram

Table 5.8 : Conversion Factors for Chemical Equivalence. (Todd, 1976)

Chemical Constituent	Conversion Factor
Bicarbonate, HCO_3^-	0.01639
Chloride, Cl^-	0.02821
Sulfate, SO_4^{2-}	0.02082
Sodium, Na^+	0.04350
Potassium, K^+	0.02557
Calcium, Ca^{2+}	0.04990
Magnesium, Mg^{2+}	0.08226

Table 5.9 : Cation and Anion Concentration in Percentage Values (%)

Sample	Na+K	Ca	Mg	Total	Cl	HCO_3	SO_4	Total
R1	44.10	21.88	34.02	100	69.82	19.88	10.31	100
S1	77.54	0.00	22.46	100	15.19	76.48	8.33	100
S2	33.69	48.51	17.80	100	23.23	71.85	4.92	100
S3	50.72	28.36	20.91	100	20.28	73.54	6.18	100
S4	77.73	0.00	22.27	100	20.30	78.73	0.97	100
S5	66.73	10.19	23.08	100	19.53	75.91	4.55	100
S6	78.67	0.00	21.33	100	14.58	80.95	4.48	100
S7	64.26	0.00	35.74	100	15.27	81.24	3.49	100
S8	42.75	22.40	34.85	100	21.69	57.69	20.62	100
S9	81.81	0.00	18.19	100	15.95	79.01	5.04	100
S10	85.15	0.71	14.14	100	12.37	85.91	1.72	100
S11	73.66	0.00	26.34	100	21.23	76.00	2.77	100
S12	77.59	0.00	22.41	100	22.96	64.91	12.14	100
S13	43.67	33.57	22.76	100	10.86	85.11	4.03	100
S14	79.17	0.00	20.83	100	10.63	72.31	17.07	100

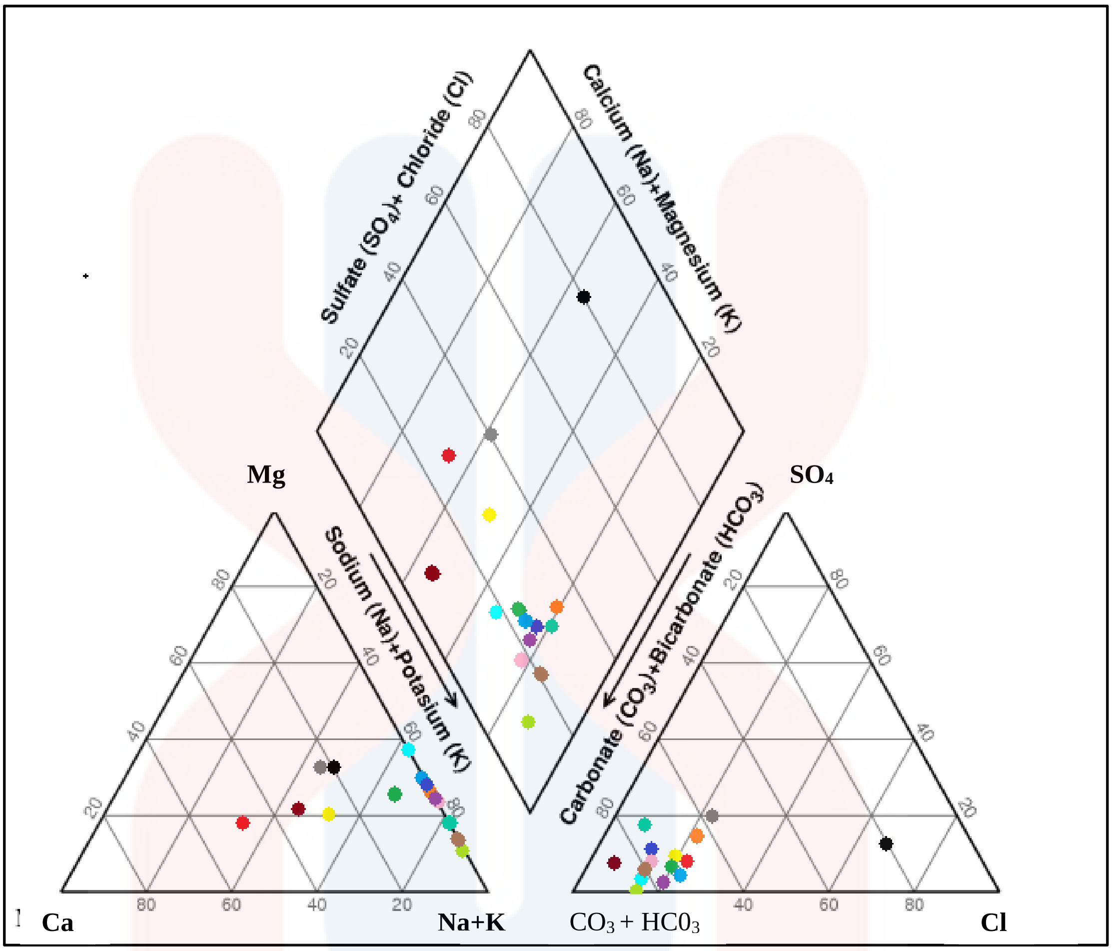


Figure 5.15 : The Distribution of ions of samples in study area in Piper Trilinear Diagram

Legend :

R1
S1
S2
S3
S4
S5
S6
S7
S8
S9
S1
S11
S12
S13
S14

Based on Piper Trilinear diagram in Figure 5.15, for cation content, 11 samples classified as sodium type of groundwater while 4 samples showed no dominant type. For anion content, 14 samples lie in the same type which are bicarbonate type of groundwater except 1 sample which is R1 lie in the calcium-magnesium-bicarbonate of groundwater.

Based on diamond diagram, 11 samples lie within sodium-bicarbonate type of groundwater while other 3 samples categorised as calcium-magnesium-bicarbonate type of groundwater. The last sample which is R1 classified as calcium-magnesium-sulphate type of groundwater. There was no sample classified under sodium-chloride type of groundwater.

Therefore sea water intrusion into shallow aquifers in Tumpat, Kelantan not happened yet.

5.4.2 Chloride concentration vs Electrical conductivity graph

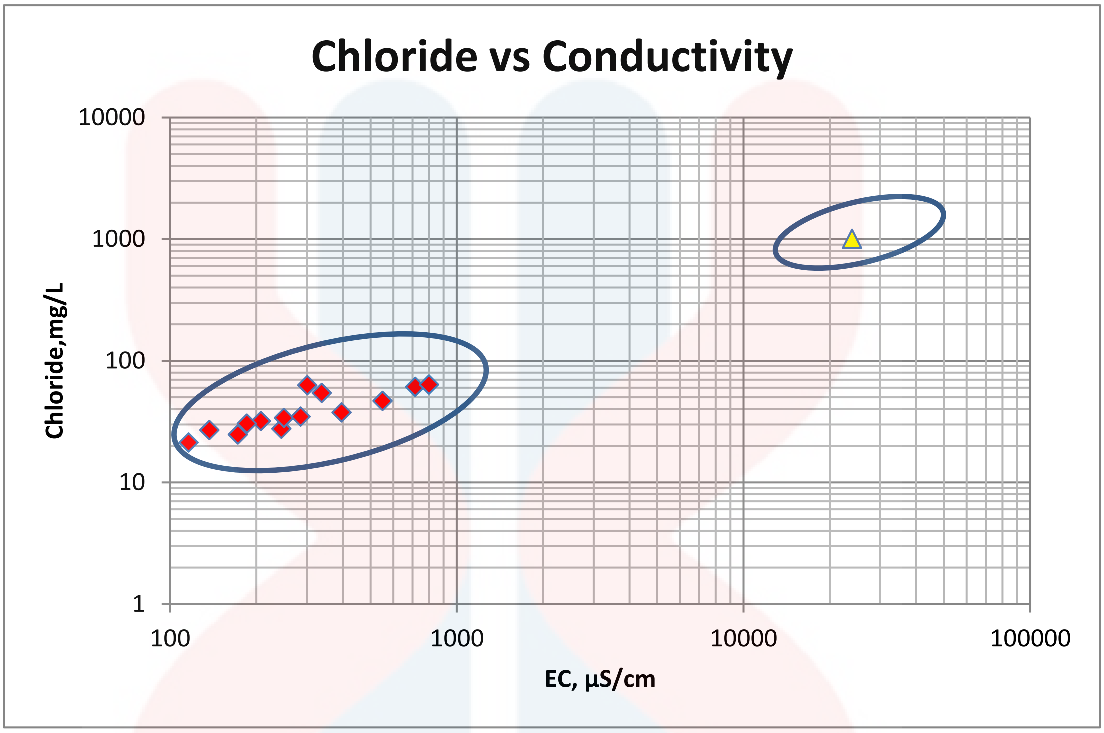


Figure 5.16 : A graph of chloride concentration against electrical conductivity

Legend :

△ River water sample

◆ Groundwater sample

Besides Piper Trilinear diagram, graph in Figure 5.16 also can used in groundwater classification. Value of chloride concentration and electrical conductivity were used in order to construct the graph. According to the graph, all groundwater samples around Tumpat were lied within normal grounwater zone. Meanwhile water sample from river which R1 lied within sea water intrusion zone.

Therefore sea water intrusion into shallow aquifers in Tumpat, Kelantan not happened yet.

CHAPTER 6

CONCLUSION & RECOMMENDATION

6.1 Conclusion

As conclusion, area of Tumpat, Kelantan comprised of Quaternary sediments which lined up by clay,silt, sand and gravel. Groundwater around Tumpat, Kelantan was safe and suitable for usage of all purposes in daily life according to the Guidelines of Raw Water Quality Standard from the Ministry of Health of Malaysia. Based on diamond diagram in Piper Trilinear diagram, 11 samples lie within sodium-bicarbonate type of groundwater while other 3 samples categorised as calcium-magnesium-bicarbonate type of groundwater. The last sample which is R1 classified as calcium-magnesium- sulphate type of groundwater. There was no sample classified under sodium-chloride type of groundwater.

Based on second indicator which chloride vs electrical conductivity graph, all groundwater samples lied within normal groundwater zone and water sample R1 lied within sea water intrusion zone due mixing of freshwater with sea water.

As conclusion, based on both indicators, there was no sea water intrusion into shallow aquifers happened around Tumpat, Kelantan.

6.2 Recommendation

For the users of groundwater that contained high concentration of iron ions which above permissible limit are recommended to filtrate the water before use it for any purposes as excess iron ions can affect the health.

Future research must be conduct again as this phenomenon can happen in just a few years as Tumpat is one of the districts that undergo developing phase. The demands of groundwater will be increase and the overdraw of groundwater will interupt the balance between seawater and freshwater interface along coastal line and contribute to the sea water intrusion in aquifers.

Sampling program must be design properly to avoid any errors and increase the accuracy of the result of the study. Increase the sampling point and bring complete equipments during sampling are suggestion for future researchers. Samples also must be handle in correct ways to avoid any errors.

In future, researchers are suggest to use more sophisticated laboratory instruments to increase the accuracy and precision of the result of the study.

REFERENCES

Arslan,H.(2013). Application of Multivariate Statistical Techniques in the Asessment of Groundwater Quality in Seawater Intrusion Area in Bafra Plain, Turkey. Environmental Monitoring and Asessment, 185(3),2439-2452

Bird, E.(2008). Deltas. In *Coastal Geomorphology* (Second Edit,pp.331-437). JohnWiley & Sons Inc.

Bosch, J.H.A. (1986). Quaternary. In: Hutchison, C.S & Tan, D.N.K., (eds). *Geology of Peninsular Malaysia,* University of Malaya and Geological Society of Malaysia,Kuala Lumpur.

Charlton,R.(2008).Introduction. In *Fundamentals of Fluvial Geomorphology* (First Edit,pp.1-11). Taylor & Francis Group.

Department of Irrigation and Drainage.(2014). Monthly Rainfall Report in Tumpat.Kelantan, Malaysia

Department of Town and Country Planning of Kelantan.(2009).Local Plan of Tumpat for 2020.Kelantan,Malaysia

Fetter, C.W.(2001).Applied Hydrogeology(Fourth Edit).United State of America : Prentice Hall, Inc. New Jersey.

Fisher, R.S.(2002). Groundwater Quality in Kentucky : pH. Kentucky Geological Survey Circular 6

Fredlund, M.D., Fredlund, D.G., & Wilson, G. W.(2000). An equation to represent grain-size distribution. *Can. Geotech. J.,Vol. 37,2*. pp 817-827.

Heng, C. L. (2004). Groundwater utilisation and management in Malaysia. In *Coordinating Committee for Geoscience Programmes in East and Southeast Asia(CCOP)* (pp. 83–93). Tsubuka.

Heng, T. E., Singh, M., & Muhammad, S. (1989). Groundwater supply studies in Northern Kelantan. *Bulletin of the Geological Society of Malaysia, 23*(October), 13–26.

Hiscock, K. M., & Bense, V. F. (2014). *Hydrogeology: Principle and Practice* (Second Edi). John Wiley & Sons Ltd.

Huggett,J.R.(2007). Introducing Landforms And Landscapes. In *Fundamentals of Geomorphology* (Second edit,pp 4-30). Taylor & Francis Group.

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

Hydrochemistry. (n.d.). Retrieved March 11 2016 from http://encyclopedia2. thefree dictionary.com/Hydrochemistry.

Idrus A.S., Fauziah M.N., Hani M.H.,Wan Rohaila W.A., & Wan Mansor H.(2014). Status of Groundwater Contamination in Rural Area , Kelantan. *IOSR Journal of Environmental Science Toxicology and Food Technology*, *8(1)*, 72–80.

Isa, Ab.R.,Othman, W.M.,&Ishak, A.(1990).Cholera Outbreak in Tumpat, Kelantan,*Medical Journal Malaysia*,*45(3)*,187-193.

Jeevanandam, M., Kannan, R., & Srinivasalu, S. (2007). Hydrogeochemistry and Groundwater Quality Assessment of Lower Part of the Ponnaiyar River Basin , Cuddalore District , South India. *Environmental Monitoring Assessment*,132,263–274.

Këpuska, X.(2013). Study of Physico-Chemical Parameters of Water Quality in the Lumbardh Deçani. *Anglisticum Journal (IJLLIS)* , Vol 2, Issue 3, pp 154-158.

Knutsson, G.(1994). Acidification effects on groundwater - prognosis of the risks for the future. In *Future Groundwater Resources at Risk (*Publ. no. 222,).Helsinki.

Kumar, K. S. A., Priju, C. P., & Prasad, N. B. N. (2015). Study on Saline Water Intrusion into the Shallow Coastal Aquifers of Periyar River Basin, Kerala Using Hydrochemical and Electrical Resistivity Methods. *Aquatic Procedia*, *4*(Icwrcoe), 32–40.

Kumar, S.K.,Rammohan, V.,Sahayam, J.D.,& Jeevanandam, M.(2009). Assessment of groundwater quality and hydrogeochemistry of Manimuktha River basin, Tamil Nadu, India, *Environmental Monittoring Assessment*, 159,341–351.

Kura, N. U., Ramli, M. F., Sulaiman, W.N.A., Ibrahim ,S.,& Aris.,A.Z. (2015). An overview of groundwater chemistry studies in Malaysia. *Environmental Science and Pollution Research*, (DECEMBER).

Kura, N.U.,Ramli, M.F.,Sulaiman,W.N.A.,Ibrahim,S.,Aris.A.Z.,& Mustapha,A. (2013).Evaluation of Factors Influencing The Groundwater Chemistry in a Small Tropical Island of Malaysia. *Int. J. Environ. Res. Public Health*, *10*, 1861-1881.

Local Authority Area And State.(2010).Total population by ethnic group. Malaysia

Madi, N. B.(2010). Groundwater Study for Shallow Alluvium Aquifers at Kota Bharu,Kelantan (Master thesis).Retrieved from http:// www.efka.utm.my/ thesis / IMAGES/4MASTER/2009/JHH/nassirbshermadi.pdf.

Minesota Pollution Control Agency : Environmental Outcomes Division.(1999).Sulfate in Minnesota's Ground Water.

Mohd Kamal, M.Z.A., Md Hisham, N., & Mohd Zin, M.S.(2015).Seawater intrusion in the groundwater aquifers in the Kota Bharu, Kelantan. *PEOPLES: International Journal of Social Sciences Special Issue*., 320-327.

Ministry of Health.(2000).National Standard for Drinking Water Quality.Engineering Service Division.Malaysia.

Nelson, D.(2002).Natural Variations in the Composition of Groundwater. Conference from *Groundwater Foundation Annual Meeting*. Oregon.

Nur Hayati, Hussin.(2011). Hydrogeochemical Study and Iron Removal of Groundwater in North Kelantan.(Master thesis).University of Malaya, Malaysia.

Ojo1, O.I., Otieno, F.A.O.,& Ochieng, G.M.(2012). Groundwater: Characteristics, qualities, pollutions and treatments: An overview. *International Journal of Water Resources and Environmental Engineering Vol. 4(6)*, pp. 162-170.

Paron, P.,& Claessens, L. (2011) Makers and users of geomorphological maps.In *Geomorphological Mapping: methods and applications*. Smith MJ, Paron P, Griffiths J (eds.). Elsevier: London, 75-106.

Piper, A.M.(1944).A Graphical Interpretation of Water Analysis.Transactions American Union,25,914-928.

Prinsip pemplotan diagram piper dengan gnuplot (December 6, 2010).Retrieved May 24, 2016, from http://warmada.staff.ugm.ac.id/Graphics/gnuplot/diagram/piper.html.

Plummer, L.N., Laura, M.B.,&Scott, K.A.(2003). How ground-water chemistry helps us understand the aquifer.United State Geological Survey Circular 1222.

Sadashivaiah, C.,Ramakrishnaiah, C.R.,& Ranganna, G.(2008).Hydrochemical Analysis and Evaluation of Groundwater Quality inTumkur Taluk, Karnataka State,India. *International Journal of Environmental Research and Public Health 5(3)*,158-16.

Saltwater intrusion. (n.d.). Retrieved April 18, 2016, from https:/m/en .wikipedia.org/wiki/ Saltwater_intrusion.

Samsudin, A. R., Haryono, A., Hamzah, U., & Rafek, A. G. (2008). Salinity mapping of coastal groundwater aquifers using hydrogeochemical and geophysical methods: A case study from north Kelantan, Malaysia. *Environmental Geology*, *55*(8), 1737–1743.

Schot,P.P.,& Wassen,M.J.(1993). Calcium concentration in wetland groundwater in relation to water source and soil conditiond in the recharge area. *Journal of Hydrology*,*141* pp 197-217.

Sefie, A.,Aris, A.Z.,Samsudin, M.K.N.,Tawnie, I.,Suratman, S.,Idris, A.N.,Saadudin, S.B.,&Wan Ahmad, W.K.(2015).Hydrogeochemistry of Groundwater from Different Aquifer in Lower Kelantan Basin, Kelantan, Malaysia. *Procedia Environmental Sciences*,30,151-156.

Shahida,P.,& Ummatul, F.(2015). Physico-Chemical Analysis Of Groundwater Quality In Aligarh City, Uttar Pradesh. *International Journal of Science and Nature, Vol.6 (3)*, pp 397-405.

Smith, M.J.,&Otto,J.C.(2013). Geomorphological Techniques, *British Society for Geomorphology*, Chap. 2, Sec. 6 .

Tajul Baharuddin, M. F., Taib, S., Hashim, R., Abidin, M. H. Z., & Rahman, N. I. (2013). Assessment of seawater intrusion to the agricultural sustainability at the coastal area of Carey Island, Selangor, Malaysia. *Arabian Journal of Geosciences*, *6*(10), pp 3909–3928.

Todds, D. K., & Mays, L. W. (2005). Irrigation water criteria. In *Groundwater Hydrology* (Third Edit, pp. 347–348). John Wiley&Sons,Inc.

World Health Organization.(2011).Guidelines for Drinking-water Quality. Fourth Edition

APPENDICES

Figure 1 : Collection of soil and water samples

A B

Figure 2 : A shows withdraw of groundwater by pump or engine while B showwithdraw of groundwater by manpower or manually

Figure 3 : One of the river in Tumpat, Kelantan

Total Alkalinity, Carbonates and Bicarbonates

Reagents

A. Hydrochloric acid, 0.1 N

   12 N concentrated HCl is diluted to prepare 1.0 N HCl. Then, 1.0 N HCl is diluted to make 0.1 N HCl.

B. Methyl orange indicators, 0.05%

   0.5 g of methyl orange is dissolved in 100 mL of distilled water.

C. Phenolphthalein indicator

   0.5 g of phenolphthalein is dissolved in 50 mL of 95% ethanol and 50 mL of distilled water is added. Then, 0.05 N CO_2 free NaOH solution is added dropwise until the solution turns taintly pink.

Procedure

1. 100 mL of water sample is took from an erlenmeyer flask and 2 drops of phenolphthalein indicator is added.
2. If the solution remains colourless, PA = 0, and total alkalinity is determined with the step 4.
3. If the colour change to pink after addition of phenolphthalein , the solution is titrated with 0.1 N HCl until the colour disappear at end point. This is phenolphthalein alkalinity (PA).
4. 2-3 drops of methyl orange is added to the sample and continue with the titration until yellow colour is changed to pink at end point. This is total alkalinity (TA).

Calculation

$$PA \text{ as } CaCO_3.mg/l = \frac{(A \times Normality) \text{ of } HCl \times 1000 \times 50}{ml \text{ of sample}}$$

$$TA \text{ as } CaCO_3.mg/l = \frac{(B \times Normality) \text{ of } HCl \times 1000 \times 50}{ml \text{ of sample}}$$

where,

A = ml of HCl used with only phenolphthalein

B = ml of total HCl used with phenolphthalein and methyl orange

PA = phenolphthalein alkalinity

TA = total alkalinity

Chloride

Reagents

A. Silver nitrate, 0.02 N

3.4 g of dried $AgNO_3$ is dissolved in distilled water to prepare 1 litres of solution and the solution is kept in a dark bottle.

B. Potassium chromate, 5%

5 g of K_2CrO_4 is dissolved in 100 mL of distilled water.

Procedure

1. 50 mL of water sample is took from an Erlenmeyer flask and 2 mL of K_2CrO_4 solution is added into water sample.
2. Then, water sample is titrated against 0.02 N $AgNO_3$ until a persistent red tinge appear.

Calculation

$$\text{Chloride, mg} = \frac{(\text{mL x N}) \text{ of } AgNO_3 \text{ x } 1000 \text{ x } 35.5}{\text{mL sample}}$$

Sulphate (Gravimetric method)

Reagents

A. Methyl red indicator

   100 mg of methyl red sodium salt is dissolved in distilled water to prepare 100 mL of solution

B. Hydrochloric acid

   HCl (1÷1)

C. Barium chloride solution

   100 g $BaCl_2.2H_2O$ is dissolved in distilled water to prepare 1 litre of solution. The solution is filtered through a filter paper before use.

D. Silver nitrate – nitric acid reagent

   8.5 g of $AgNO_3$ and 0.5 mL of concentrated HNO_3 is dissolved in distilled water to prepare 500 mL reagent.

Procedure

1. 100 mL of water sample is took and a few drops of methyl red is added. The pH of solution is adjusted to 4.5 – 5.0 by addition of HCl. Then, additional 1 - 2 mL of HCl is added.
2. The solution is boiled and warm $BaCl_2$ solution is added slowly in excess until the precipitation is completed.
3. The precipitates is heated at 80 – 90 ºC for at least 2 hours or more.
4. The precipitate is filtered through ashless filter paper (Whatman no. 42).
5. The precipitate is washed repeatedly with warm distilled water until the filtarte is free from chloride which can be tested with $AgNO_3$ solution. If chloride present, $AgNO_3$ will gives a white turbidity.

6. Then, the filter paper that containing precipitates is dried and it is ignited in a crucible at 800 ºC for 1 hour. The filter paper is cooled in dessicator and weighed to know the weight of precipitate of $BaSO_4$.

Calculation

$$SO4,\ mg/l = \frac{mg\ BaSO4 \times 411.5}{mL\ sample}$$