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CHARACTERISTICS OF GROUNDWATER FROM FRACTURED HARDROCKS IN WEST COAST OF PENINSULAR MALAYSIA

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TABLE OF CONTENTS

		Page
ACKNOWLEDGMENTS		iii
LIST OF TABLES		vii
LIST OF FIGURES		ix
LIST OF ABBREVIATIONS		x
ABSTRACT		xi
ABSTRAK		xiii
CHAPTER		
I	**INTRODUCTION**	1
	Overview of Groundwater Potential and Usage in Malaysia	2
	Objectives of The Study	5
II	**LITERATURE REVIEW**	6
	Groundwater Origin and Hydrologic Cycle	6
	Porosity	13
	Specific Yield	15
	Storage Coefficient	16
	Transmissivity	17
	Hydraulic Conductivity	17
	Groundwater Recharge	18
	Chemical Constituents In Atmospheric Precipitation	19
	Groundwater Characteristics In General	21
	Water Chemistry and Its Relation With Aquifer Materials	26
	Origin of The Chemical Constituents of Groundwater	28
	Physical and Chemical Characteristics of Groundwater	28
	pH	30
	Total Dissolved Solids	30
	Hardness	31
	Colour	32
	Turbidity	32
	Conductivity	33
	Calcium	33
	Magnesium	34
	Sodium	34
	Potassium	35

	Bicarbonate	35
	Chloride	35
	Sulphate	36
	Iron	36
	Fluoride	37
	Rockforming Minerals	38
	Silicates	38
	Non-Silicates Minerals	39
	General Chemical Compositions of Rocks	40
	Igneous Rocks	40
	Sedimentary Rocks	41
	Metamorphic Rocks	41
	Weathering Processes of Rock Forming Minerals in Tropical Environment	42
III	**METHODS AND MATERIALS**	45
	Study Area	45
	Geomorphology	
	Climate and Rainfall	51
	Geology	52
	Drilling and Tubewell Construction	56
	Diameter and Depth	56
	Drilling Method	56
	Casings (Outer casing and tubewell casing)	58
	Tubewell Design	59
	Screen Slot and Gravel Pack	59
	Aquifer Capacity Estimation	60
	Development	61
	Pumping Test	61
	Water Sampling and Chemical Analysis	62
	Sampling	62
	Chemical Analysis	62
	Data Analysis	65
IV	**RESULTS AND DISCUSSION**	69
	Groundwater Usage	69
	Tubewell Characteristics	70
	Well Depth	71
	Fracture Zone	72
	Weathered Zone and Static Water Level	82
	Discharge Rate	82
	Physical Characteristics of Groundwater From Metasedimentary and Granite	83
	pH	83
	Conductivity	88
	Total Dissolved Solids	90
	Color and Turbidity	91

Chemical Characteristics... 92
Bicarbonate... 92
Calcium and Magnesium... 99
Sodium and Potassium.. 101
Chloride and Sulfate.. 101
Fluoride... 103
Hardness... 103
Iron.. 106
Hydrochemical Facies.. 109
Calcium Bicarbonate Water.. 114
Sodium Bicarbonate Water... 114
Magnesium Bicarbonate Water....................................... 115
Sodium Adsorption Ratio (SAR) and Salinity............................ 115

V **CONCLUSIONS AND RECOMMENDATIONS**.................. 120

REFERENCES 124

APPENDICES

A-1 Piper Diagrams for Water From Metasedimentary Aquifers......... 128
A-2 Piper Diagrams for Water From Granitic Aquifers....................... 132
B-1 Stiff Diagrams for Water From Metasedimentary Aquifers......... 138
B-2 Stiff Diagrams for Water From Granitic Aquifers........................ 152
C-1 Wilcox Diagrams showing classification of irrigation waters based on Sodium Adsorption Ratio (SAR) and Conductivity (Metasedimentary)... 183
C-2 Wilcox Diagrams showing classification of irrigation waters based on Sodium Adsorption Ratio (SAR) and Conductivity (Granitic)... 187

LIST OF TABLES

TABLES			Page
1		Chemical Constituents In μEq/L of Atmospheric Precipitation In Petaling Jaya and Cameron Highlands, Malaysia..................	20
2		Typical Analysis of Groundwater From Different Rock Types...	24
3		Some of The Dissolved Inorganic Constituents In Groundwater Classified According To Relative Abundance.............................	25
4		WHO Drinking Water Quality Standards, 1963..........................	29
5		Parameters and Method of Analysis of This Study....................	68
6		Characteristics For Tubewells In Metasedimentary Rocks..........	73
	A.	Metasedimentary Wells In Johor..	73
	B.	Metasedimentary Wells In Perak..	73
	C.	Metasedimentary Wells In Kedah...	73
	D.	Metasedimentary Wells In Melaka...	74
	E.	Metasedimentary Wells In Selangor...	75
	F.	Metasedimentary Wells In Negeri Sembilan..............................	76
7		Characteristics For Tubewells In Granitic Aquifer......................	77
	A.	Granitic Wells In Kedah..	77
	B.	Granitic Wells In Selangor...	77
	C.	Granitic Wells In Negeri Sembilan...	77
	D.	Granitic Wells In Penang...	78
	E.	Granitic Wells Melaka..	78
	F.	Granitic Wells In Perak...	79
	G.	Granitic Wells In Johor...	80
8		Physical Characteristics of Groundwater From Metasedimentary Aquifer..	84
9		Physical Characteristics of Groundwater From Granitic Aquifer	86
10		Major Ions of Groundwater From Metasedimentary Aquifer In mg/l...	93
11		Major Ions Of Groundwater From Granitic Aquifer In mg/l......	95

12 Groundwater Hardness For Granite And Metasedimentary Rocks.. 104

13 Iron Contents In Water From Granite And Metasedimentary Aquifer.. 107

14 Water Type For Granite And Metasedimentary Aquifers........... 110

LIST OF FIGURES

FIGURE		Page
1	Hydrologic Cycle	7
2	Schematic Representation of Major Hydrochemical Process In The Soil Areas	9
3	Hydrogeological Map of Peninsular Malaysia	11
4	Groundwater Exists In The Underground In Two Major Environments: Unconfined and Confined	12
5	Location of The Study Area	53
6	Tubewell Construction and Design	57
7	Depth of Wells For Metasedimentary and Granitic Aquifers	71
8	Number of Wells In Three pH Ranges	88
9	Relationship Between Total Dissolved Solids (TDS) and Conductivity of Groundwater From (a) Metasedimentary and (b) Granitic Aquifers	89
10	Number of Wells In Five Ranges of Conductivity Level	90
11	Number of Wells In Five Ranges of Total Dissolved Solids Concentration	91
12	Distribution of Ca + Mg Vs HCO3 In meq/l of Groundwater From (a) Metasedimentary and (b) Granite	97
13	Distribution of Na + K Vs HCO3 In meq/l For Groundwater From (a) Metasedimentary and (b) Granite	98
14	Mineral Composition of Igneous Rocks	102
15	Water Facies For Granite and Metasedimentary Groundwater In West Coast of Peninsular Malaysia	112
16	Classification of Irrigation Waters Based On SAR And Conductivity	116

LIST OF ABBREVIATIONS

APHA	:	American Public Health Association
AWWA	:	American Water Works Association
GSM	:	Geological Survey of Malaysia
IHP	:	International Hydrologic Program
USDA	:	United States Department of Agriculture
USEPA	:	United States Environmental Protection Agency
AAS	:	Atomic Adsorption Spectrophotometer
fac.	:	factory
Ind.	:	Industry
Well Ident.	:	Well Identification
Max.	:	Maximum
Kg.	:	Kampung
Spg.	:	Simpang
Bkt.	:	Bukit
Btg.	:	Batang
Sg.	:	Sungai

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science.

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Chairman: Dr. Shaharin Ibrahim

Faculty: Science and Environmental Studies

The thesis examines on the chemical characteristics of groundwater found in granitic and metasedimentary rocks of the West Coast of Peninsular Malaysia. A total of 133 tubewells having diameter 20 cm were studied. The wells were drilled to a depth between 100 to 200 m. The top 20 to 40 m of the wells were cased, followed by 60 to 80 m 0f slotted casing. The remaining depth of the wells was left open. The present study shows that the quality is mostly fresh with average pH and conductivity around 6.5 and 200 µS/cm respectively. The total dissolved solids range between less than 100 mg/l to more than 200 mg/l with average of a bout 120 mg/l. The groundwater is classified as soft to hard water because the hardness ranges between 12 mg/l to 180 mg/l. the groundwater facies was found to be Calcium Bicarbonate, Magnesium Bicarbonate and Sodium Bicarbonate

water. Calcium and Magnesium in metasedimentary water have average of about 17 mg/l and 21 mg/l, respectively. For granite, the average of Ca and Mg is 8.75 mg/l and 2.85 mg/l. The amount of iron content can be as high as 15 mg/l with average of 1.5 mg/l. More than 50% of the groundwater samples exceeds the limit of iron for drinking water of 0.3 mg/l. Fluoride concentration is generally low with average 0f 1.0 mg/l. However, groundwater from granite can reach the level of Fluoride to 11.5 mg/l. the groundwater is classified as medium to low salinity hazard and low in sodium; therefore it is suitable for irrigation.

The thesis also examined the production capability of the hardrock aquifers. The top 20 m was mainly in the residual soil and weathered part of the rock. Fresh hardrocks were normally encountered at depth more than 40 m. the static water level or water table in the study area were found to be less than 20 m deep. Four of the wells were outflowing automatically above the well head casings, which was constructed about 0.5 m above ground. High discharge rates up to 800 m^3/well/day were encountered from wells that penetrated major fracture zones. Average discharge rate for metasedimentary and granite aquifers were 400 m^3/well/day and 300 m^3/well/day, respectively and the drawdown is generally less than 50 m from the ground level. The wells were drilled for various purposes such as for rubber, latex, textiles and mineral water bottling factories, poultry and agricultural activities and domestic water supply.

Abstrak tesis ini dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk mendapatkan Ijazah Master Sains

CIRI-CIRI AIR BAWAH TANAH DARI BATUAN KEKAR DI PANTAI BARAT SEMENANJUNG MALAYSIA

Oleh

RAJA ZAINARIAH BINTI RAJA AZIE

Ogos 1997

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Tesis ini mengkaji kandungan kimia air bawah tanah yang terdapat di dalam batuan granit dan sedimen. Sebanyak 133 telaga tiub berdiameter 20 cm telah diperiksa dan digerudi sehingga kedalaman 100 hingga 200 m. Pada 20 hingga 40 m bahagian atas telaga ditutup diikuti dengan pemasangan selonsong pada kedalaman 60 hingga 80 m dan bahagian selebihnya dibiarkan terbuka. Kajian ini mendapati kualiti air pada umumnya adalah baik dengan purata pH dan kekonduksian di sekitar 6.5 dan 200 µS/cm. Jumlah pepejal terlarut berjulat di antara kurang dari 100 mg/l dan lebih daripada 200 mg/l dengan purata 120 mg/l. Air bawah tanah yang dikaji diklasifikasikan sebagai air lembut sehinggalah keras kerana kadar kekerasannya berjulat di antara 12 mg/l ke 180 mg/l. Fasis air bawah tanah yang ditemui ialah Kalsium Bikarbonat, Magnesium Bikarbonat dan Sodium Bikarbonat. Kandungan Kalsium dan Magnesium di dalam air dari

metasedimen masing-masing berpurata 17 mg/l dan 21 mg/l. Bagi batuan granit, purata Ca dan Mg ialah 8.75 mg/l dan 2.85 mg/l. Kadar kandungan Besi boleh mencapai setinggi 15 mg/l dengan purata 1.5 mg/l. Lebih 50% dari sampel air bawah tanah yang dikaji, kandungan Besi melebihi limit untuk air minuman iaitu 0.3 mg/l. Kandungan Florida umumnya adalah rendah dengan purata 1.0 mg/l. Kandungan Florida di dalam air dari batuan granit boleh mencecah sehingga 11.5 mg/l. Air bawah tanah yang dikaji diklasifikasikan sebagai sederhana ke rendah tahap kemasinan dan rendah kandungan Sodium. Oleh itu ianya sesuai untuk digunakan sebagai pengairan tanaman.

Tesis ini juga mengkaji kebolehan pengeluaran air oleh akuifer batuan keras. Di 20 m bahagian atas telaga terdapat bahagian terluluhawa dan tanah asal. Batuan segar selalunya dijumpai pada kedalaman lebih dari 40 m. Kedalaman aras mata air statik di kawasan kajian didapati kurang dari 20 m. Empat buah telaga didapati mengalir dengan sendiri melebihi dari kepala telaga yang dibina lebih kurang 0.5 m di atas tanah. Pengeluaran air yang tinggi sehingga 800 m^3/telaga/hari ditemui pada telaga yang telah menembusi zon kekear yang besar. Purata kadar pengeluaran bagi akuifer metasedimen dan granit ialah masing-masing 400 m^3/telaga/hari dan surutan umumnya kurang dari 50 m dari paras bumi. Telaga-telaga ini digerudi untuk berbagai tujuan seperti digunakan untuk kilang getah, kain, pembotolan air mineral, penternakan, pertanian dan pembekalan perumahan.

CHAPTER I

INTRODUCTION

Groundwater is a major source of clean drinking water all over the world. It has been an important resource especially in the dry part of the world including North America and European continent. Groundwater has been used in Malaysia for many centuries (Ang, 1994). However the usage was mainly limited to the shallow or unconfined aquifers using dug wells. Deep tubewells in coarse sand aquifers were developed in the past 20 years for water supply of coastal town such as Kota Bharu (Sofner,1989). Recent development in well drilling is driven by the development of industries and population growth. Factory such as textile manufacturer, rubber factory and quarry are beginning to use groundwater as supplement to surface water. Groundwater is also used in fish hatchery and farming, livestock and agricultural activities and in domestic usage (Bouwer, 1979). Mineral water industries are also tapping groundwater but the quantity is relatively small. The role that groundwater has played in the development of mankind is immeasurable. The use of groundwater has been increasing and because of this, groundwater has tended to be utilised in a disorderly manner. This is due to increasing population and industries, urbanisation, agriculture, production and manufacturing sectors. As a result, many places in the world suffer from a depletion or pollution of groundwater, intrusion of saline water and occurrence of land subsidence. These plight have brought about serious consequences not only to living conditions but also to basic infrastructures as well.

Malaysia is fortunate to have high rate of precipitation and is thus blessed with abundant surface water resources as such that in the past people are generally not interested in groundwater. However, increasing water demand coupled with unsteady supply of surface (river) water has directed much attention of the people to groundwater. The question on the use of groundwater is beginning to become an important topic of discussion in the society, both the public and business communities. Even the Department of Environment, Ministry of Science and Technology, Malaysia is taking initiatives to establish a groundwater monitoring and reporting network so that the status of the quality and beneficial uses of the resource is fully appreciated. The utilisation and development of groundwater in Malaysia require proper evaluation of its quality and sustainability. Even though present groundwater use is limited as compared to its potential, a greater awareness of groundwater potential for domestic, agriculture and industrial water supply can be expected. This will lead to increase in demand; and the development of groundwater will result in groundwater abstraction from consolidated or hardrock aquifers.

Overview of Groundwater Potential and Usage in Malaysia

The total annual water use in Malaysia is about 11.6 billion m^3/year, of which some 1.7 billion m^3/year or 15% is from groundwater (Ang, 1994). At present, the utilisation of groundwater for agricultural purposes is in the middle stage of development (GSM, 1992). The Drainage and Irrigation Department (D.I.D) has successfully carried out a pilot project at Meranti, Kelantan, to demonstrate the conjunctive use of groundwater with surface water for the irrigation of paddy and other seasonal crops during off-seasons. Groundwater is also being developed for irrigation at Kampung Kandis, Bachok, Kelantan, and at Banggol Katong, Terengganu, in connection with the resettlement scheme for fishermen (GSM, 1992). Apart from these, recently completed water resources studies suggested the use of groundwater to meet the demand for irrigation and domestic water supply in the States of Kedah and Perlis, Kemasin-Semerak area in Kelantan, and Terengganu river basins (Sofner, 1989).

Industrial use of groundwater is yet to be documented. The most beneficial use is in industries in which potable water quality is not required. Presently, many factories in the Klang Valley, Selangor/ Kuala Lumpur and the Kinta Valley, Perak, have started using groundwater as an additional source of water supply. Current groundwater abstraction points are mostly drawing water from coastal alluvial aquifers, and only about 10% from hardrock aquifers (Ang, 1994). At present no government agency is responsible for monitoring the use of groundwater.

Deep groundwater is less susceptible to contaminants. The quality of such groundwater is influenced by its parent materials which sometimes can affect the Concentrations of some parameters in the water such as iron, sulphide, fluoride, hardness, total dissolved solids and pH. Groundwater is not pure water because it usually contains dissolved mineral ions, which can affect the usefulness of groundwater for various purposes. Certain parameters can present in excessive amounts or higher than the limit or standard set by World Health Organisation (WHO). Therefore several methods of treatment may be necessary to change, remove or reduce the excess minerals or constituents before the water can be used for its intended purposes. Some of the dissolved minerals are essential for good health but others if abundant can cause problem such as door and stain. In other instance, the presence of low concentration of fluoride in drinking water is beneficial because it reduces tooth decay, however at higher levels mottling of the teeth or fluorosis occurs. For this reason it is important to know the characteristics of the groundwater before it to can be used either for domestic, industry, agriculture or livestock activities. To achieve these ends WHO has set different standard of water quality for different usage.

The present study will form part of the base line data to the groundwater characteristics and hydrogeochemistry in Malaysia.

Objectives of The Study

There are three main objectives of this study:

1. To identify the physico-chemical characteristics of groundwater from granitic and metasedimentary rocks in the West Coast of Peninsular Malaysia.
2. To determine the hydrochemical facies of the water.
3. To determine the potential yield of the hardrock aquifers.

CHAPTER II

LITERATURE REVIEW

Groundwater definition according to Bouwer (1978) is that portion of the water beneath the earth surface that can be collected with wells, tunnels or drainage or that flows naturally to the earth's surface through seep or springs. Not all underground water is groundwater. Bouwer described that true groundwater is reached only when water begins to flow freely into the hole or well. What distinguishes groundwater from other underground water is its atmospheric pressure. Since the air in the hole is at atmospheric pressure, the pressure in the groundwater must be above atmospheric pressure.

Groundwater Origin and Hydrologic Cycle

Water in its various forms has simulation like chicken and egg. We could not tell which comes first and which is last. Hydrologic cycle plays an important role in explaining the origin of groundwater. The cycle is illustrated in Figure 1. The inflow to the hydrologic system arrives as precipitation, while the outflow takes place as streamflow or run-off. The most important process is when the precipitation is delivered to streams by overland flow and interflow or also known as subsurface flow

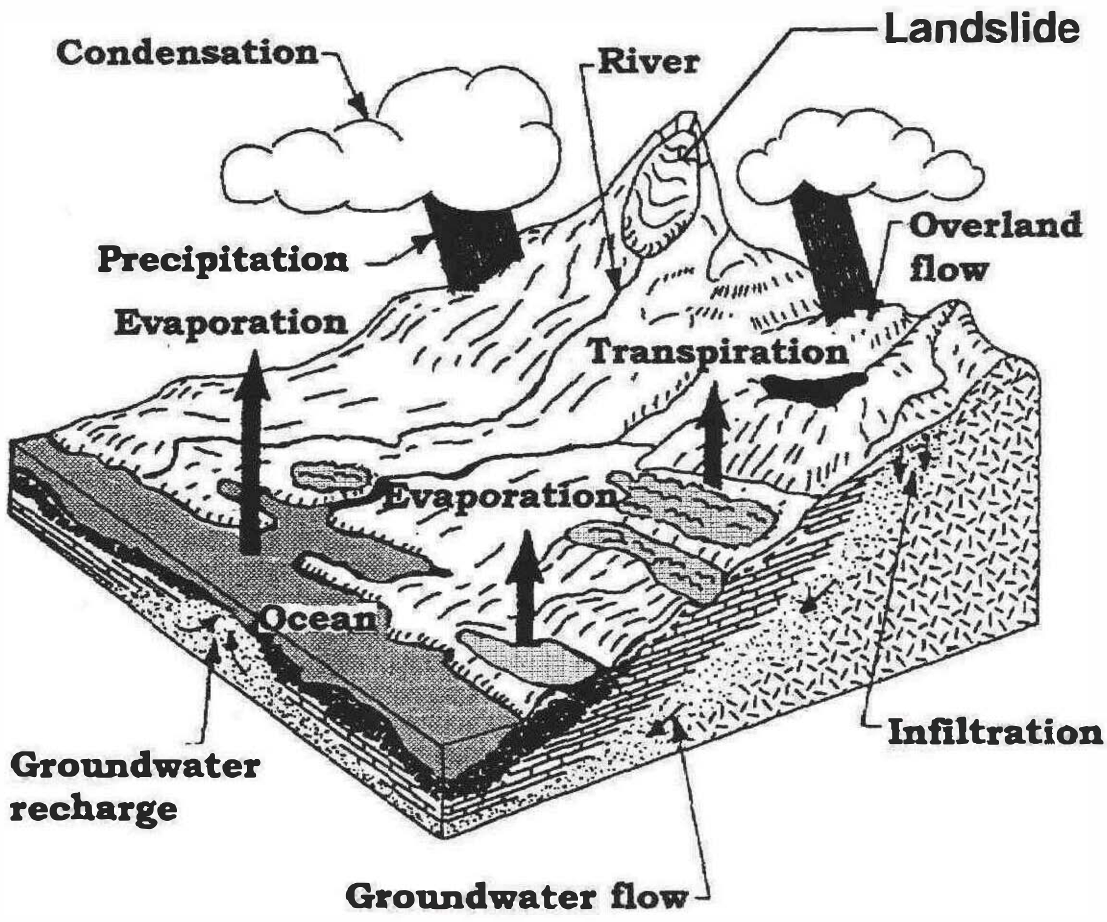

Figure 1. Hydrologic Cycle
(Source : Freeze and Cherry, 1979)

and baseflow; following infiltration into soil. Subsurface flow will not only flow horizontally but it will also flow vertically. Various factors influence water quality in each stage of hydrologic cycle. During rainfall, the rain will react with soluble particles and gases in the atmosphere. Hence, when it reaches the landsurface it is not devoid of chemicals. The water will infiltrate or seep through the soil into flow system in the underlying geologic materials.

The soil zone will alter the chemistry of the water as infiltration occurs; and also by the effects of geochemical processes. Soil zone, which is also known as zone of aeration, has the strongest influence on the chemistry of water that infiltrates through it (Freeze and Cherry, 1979). This is where the soil water belt, intermediate belt and weathering zone are located (Figure 2). Water that has infiltrated the soil deeply enough will reach the zone of saturation which is the groundwater storage that supplies water to the wells. The thickness of the zone of saturation varies from a few meter to hundreds of meter below the earth surface. Factors that determine its thickness are the geology, the availability of pores or openings in the formations, the recharge and the movement of water within the zone from areas of recharge toward the points of discharge.

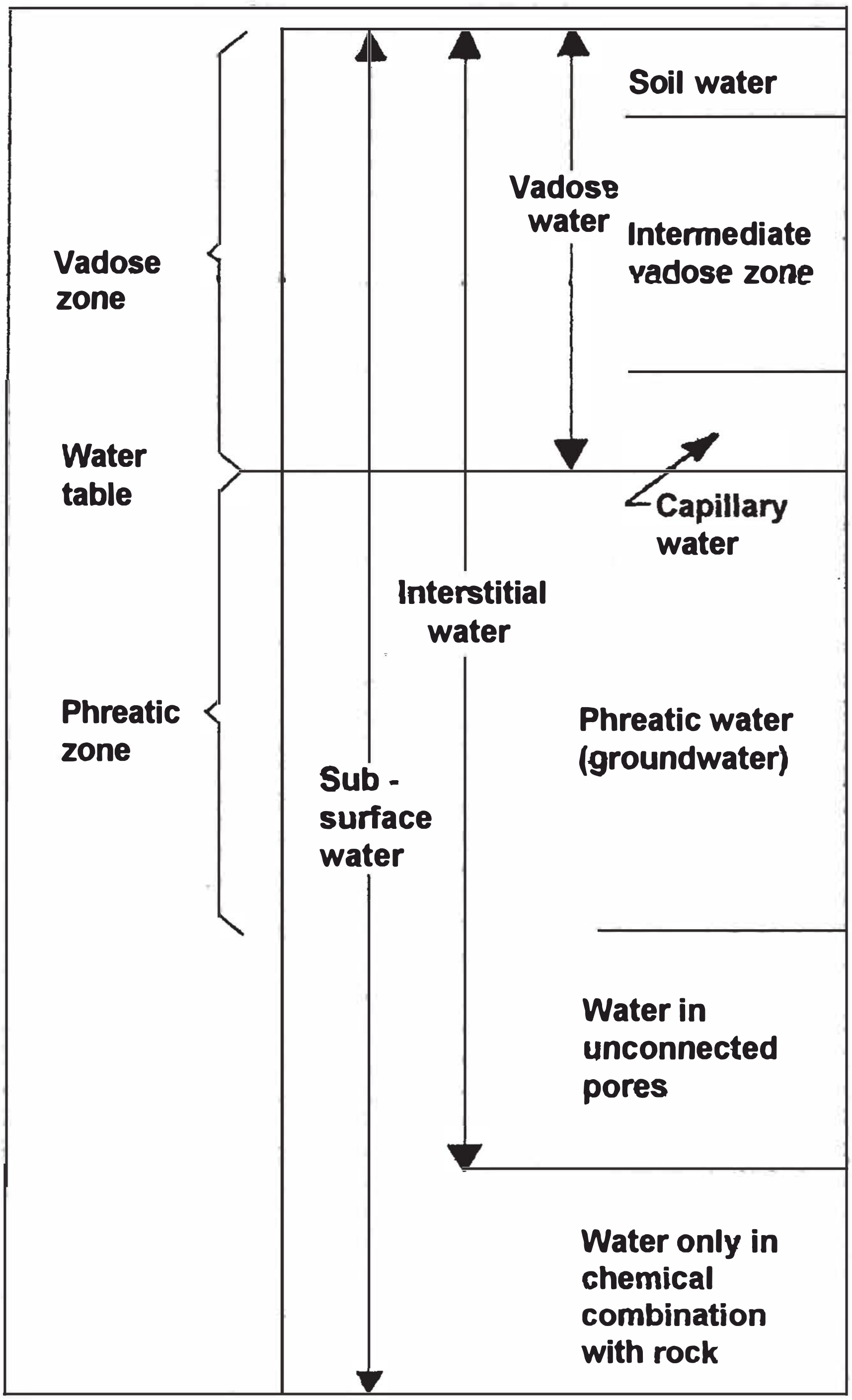

Figure 2 Schematic Representation Of Major Hydrochemical Process In The Soil Areas.
(Source : Driscoll, 1986)

There are four major types of aquifer viz.; alluvial, sedimentary, igneous and metamorphic rock aquifers. An aquifer is a saturated bed formation or group of formation, which yields water in sufficient quantity to be economically useful. Figure 3 shows the four types of aquifers in Peninsular Malaysia. Formations that have some water movement are called aquitard, while those that have no water movement is called aquicludes. On the other hand the terms confined and unconfined aquifers refers to the condition of the water table. If the water table is exposed to the atmosphere, it is unconfined aquifer and if it is isolated from atmosphere, it is called confined aquifer (Figure 4).

Water in the saturated zone is found in rock's opening. Significant amount of water can be found in fractures and joint systems. Typical types of openings found in rocks are as follows:

1. Openings between individual particles in sandstone and gravel formations
2. Crevices, joints, faults and gas holes in igneous and metamorphic rocks.
3. Solution channels, caverns and vugs in limestone and dolomite.

The shape of openings, their size, volume and interconnection play an important part in the hydraulic conductivity of an aquifer.

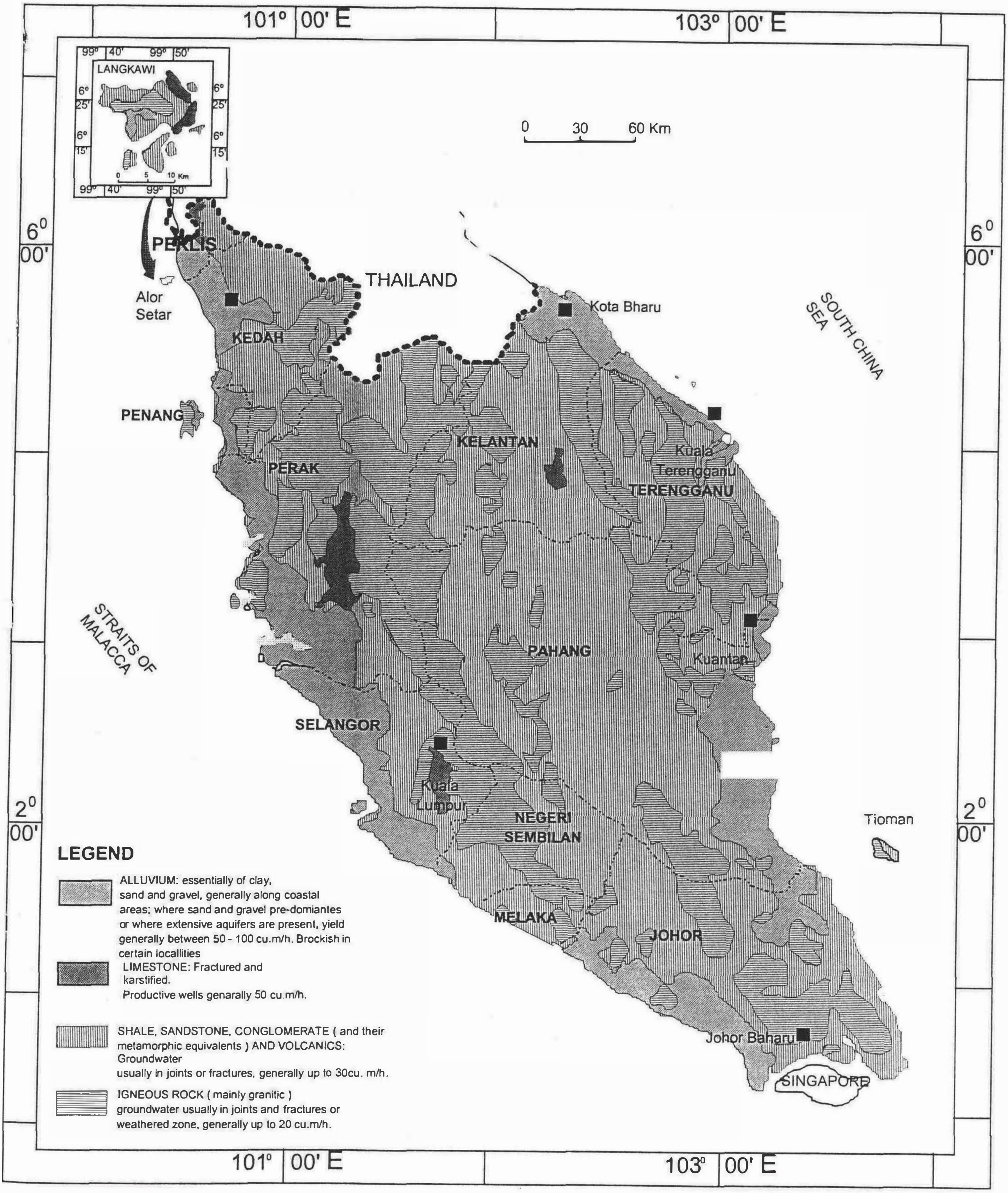

Figure 3. Hydrogeological map of Peninsular Malaysia
(Source: Ang, 1994)