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Hydrogeological activities in Peninsular Malaysia and Sarawak

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Abstract: The Geological Survey in Peninsular Malaysia has been involved in groundwater investigations since its inception in 1903. In 1953 investigations under the Perlis Water Supply Scheme resulted in the exploitation of groundwater in Arau. Between 1955-1958 the Department, in collaboration with UNTAA (United Nations Technical Aid Assistance) implemented a regional hydrogeological investigation of the coastal areas of Peninsular Malaysia which resulted in the location of several potential water bearing zones.

During the Third Malaysia Plan (1976-1980) the Department together with the German Hydrogeological Mission successfully completed a programme of investigation in Kelantan, Terengganu, Pahang, Kedah and Perlis. Under the Fourth Malaysia Plan (1981-1985) the Geological Survey embarked on a hydrogeological investigation in Seri Gading, Johor and the Rembau-Tampin-Gemas area, Negeri Sembilan/Melaka.

In Sarawak prior to 1970 the Public Works Department undertook hydrogeological investigation and exploitation in the state. However, since 1975 the Geological Survey has been conducting hydrogeological investigations along the coastal plain. To-date 15 areas have been studied and fresh groundwater has been located in 9 of these areas.

A hydrogeological map of Peninsular Malaysia on a scale of 1:500,000 was published in 1975. The hydrogeological map of Sarawak on the same scale has been compiled and will be published in 1985.

INTRODUCTION

In Malaysia, the bulk of the water used is derived from surface sources. Groundwater constitutes a supplementary component and is used only in areas where a surface source is not readily available. However the importance of groundwater as a source of water has gradually increased especially where demands begin to outstrip surface availability such as in fast-growing urban and industrial centres and in drought-prone areas.

The search for groundwater is the responsibility of the Geological Survey. However it works closely with the Public Works, the Water Boards, and the Drainage and Irrigation Departments because planning and supply of water are their responsibilities.

This paper traces the development of hydrogeological activities in Peninsular Malaysia and Sarawak. It focusses on the work carried out by the Geological Survey, highlights its successes, shows the rate of progress and gives an insight on what is planned for the future.

HYDROGEOLOGICAL SETTINGS IN PENINSULAR MALAYSIA AND SARAWAK

Peninsular Malaysia and Sarawak lie within the tropics and are situated between latitudes $^1/_2°$ and 7° north and longitudes 100° to 115° east (fig. 1) and together occupy 256,300 km^2 or 77% of the total landmass of Malaysia. They are however separated by the South China Sea.

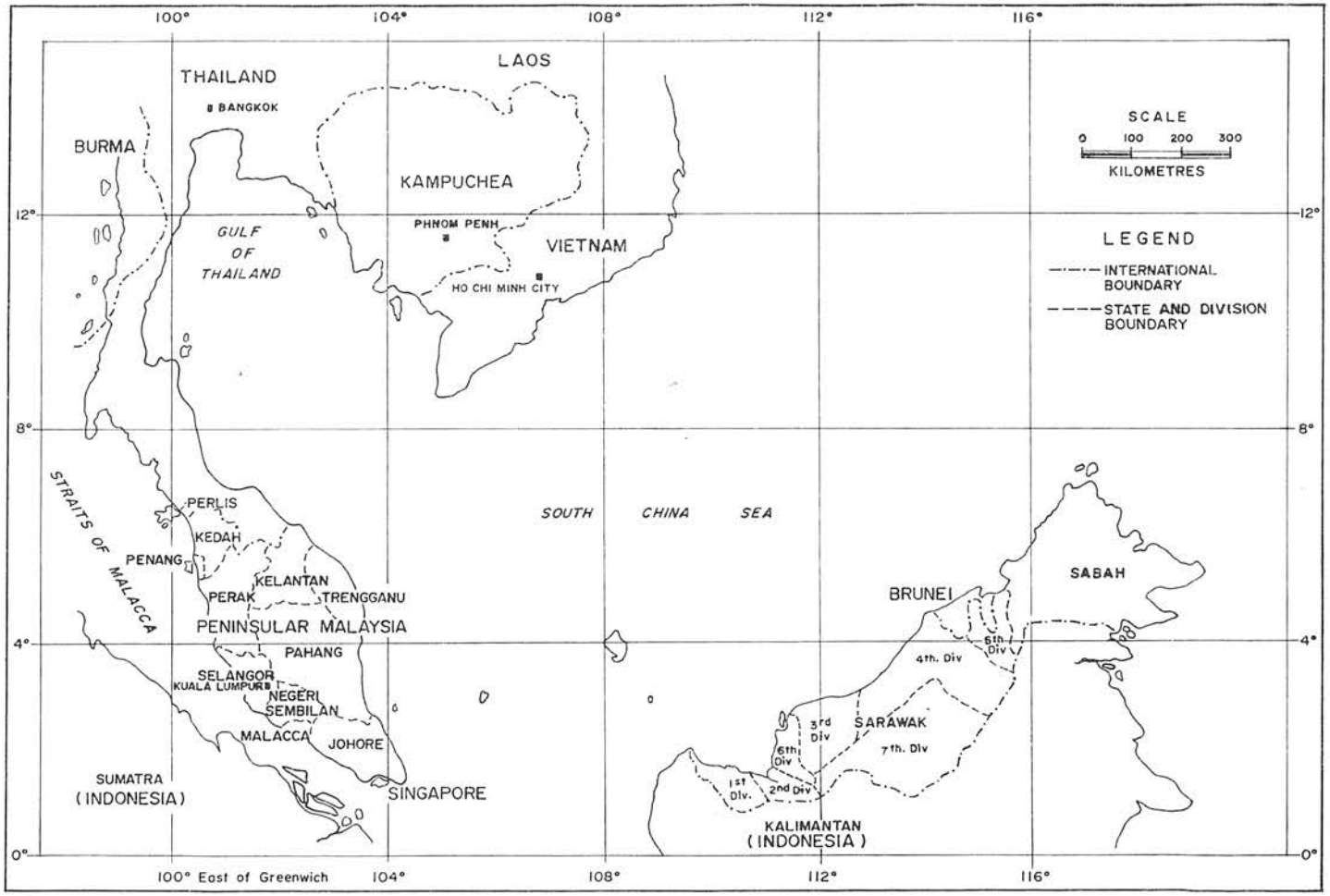


Fig. 1. Location map of Peninsular Malaysia and Sarawak

Because of their geographical locations both the areas come under the influence of two distinct surface winds, namely the Southwest and Northeast Monsoons from May to August and from November to February respectively (fig. 2). The average annual rainfall in Peninsular Malaysia is 2630 mm and in Sarawak is considerably higher at 3836 mm.

Based on the present knowledge of the hydrogeology of Peninsular Malaysia, the groundwater occurrence and potential are more conveniently discussed in terms of rock types. The groundwater prospects can be broadly grouped into four main categories (fig. 3).

The most promising aquifers are found within the Quaternary alluvium. Generally, the yield from wells in these areas exceeds 25 m^3/hr if sandy or gravelly horizons are present. However, the yield per well can exceed 100 m^3/hr, as was obtained in the alluvium in Kelantan and Terengganu. The alluvial aquifers on the East Coast are generally more extensive both laterally and vertically, and are considered to have the highest potential for groundwater development. The aquifers, generally composed of sand and gravel, vary from only a few metres to several tens of metres thick. On the West Coast, the Quaternary alluvium contains a high proportion of clay, particularly in the States of Kedah and Johore. In addition in many of these localities, the groundwater is found to be saline.

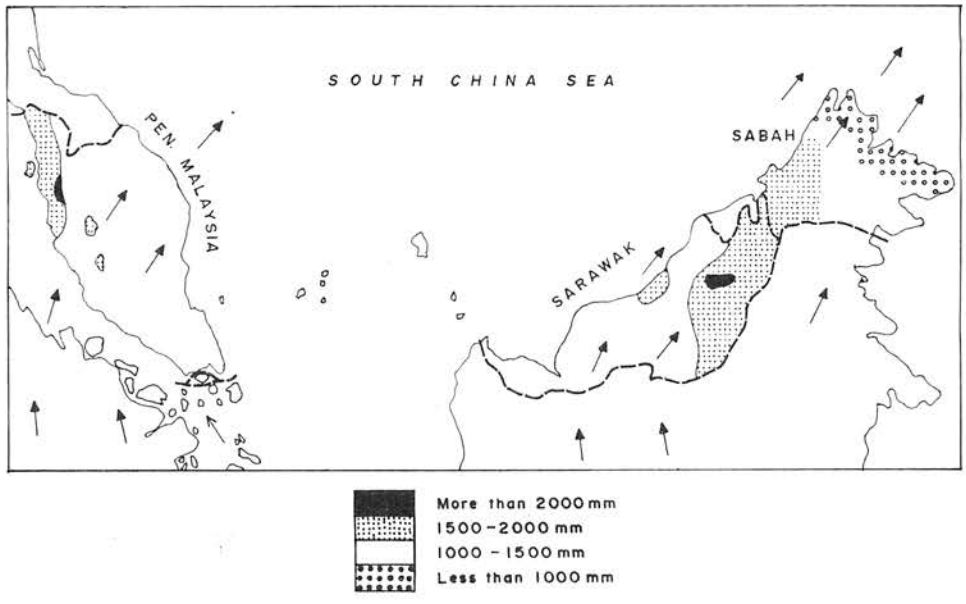
The carbonate rocks also contain important aquifers. However, their distributions are more localised. They are restricted mainly to Perlis, North Kedah, Perak, Selangor and parts of Kelantan. Most of the production wells are located in the karstified carbonate rocks in particular in the Permian limestone in Perlis where yields of more than 65 m^3/hr have been obtained.

The rest of the Peninsular, which are underlain by sedimentary and volcanic rocks, have limited groundwater potential. These rocks are only important locally and provide small amounts of groundwater for domestic purposes. The primary porosity is generally not significant, and the groundwater occurrence is usually related to the fractured zones that are present. Locally, the rocks may be metamorphosed, thereby further decreasing their groundwater-bearing capacity.

The granitic rocks cover a major portion of the surface area. In general, they have limited potential for groundwater development. Some groundwater however can be exploited from the weathered or fractured zones.

Geologically, Sarawak can divided into 2 distinct regions — west Sarawak and central-north Sarawak. In west Sarawak the main rock types are shales, sandstones, conglomerates, limestones, with volcanic rocks and wide-spread igneous rocks of different ages from Carbo-Permian to Miocene. In central-north Sarawak, the main rock types are sandstones, greywackes, shales, phyllites, slates and minor amounts of conglomerates, limestones, and volcanic rocks ranging in age from Late Cretaceous to Pliocene.

Along the coastal plain Quaternary alluvium are present. Useful aquifers are found in the alluvium. The most important aquifers are the shallow unconfined aquifers which occur as sand and gravel lenses of limited thickness (3 to 15 m) and lateral extension within the predominantly clayey alluvium. These aquifers generally yield 12 m^3/hr per well. In two



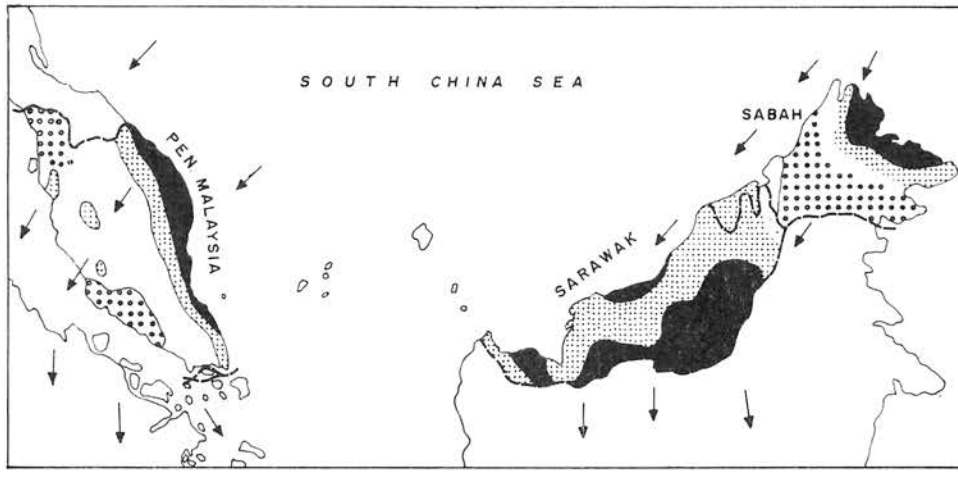


Fig. 2a. Southwest Monsoon (May to August).
Fig. 2b. Northeast Monsoon (November to February).

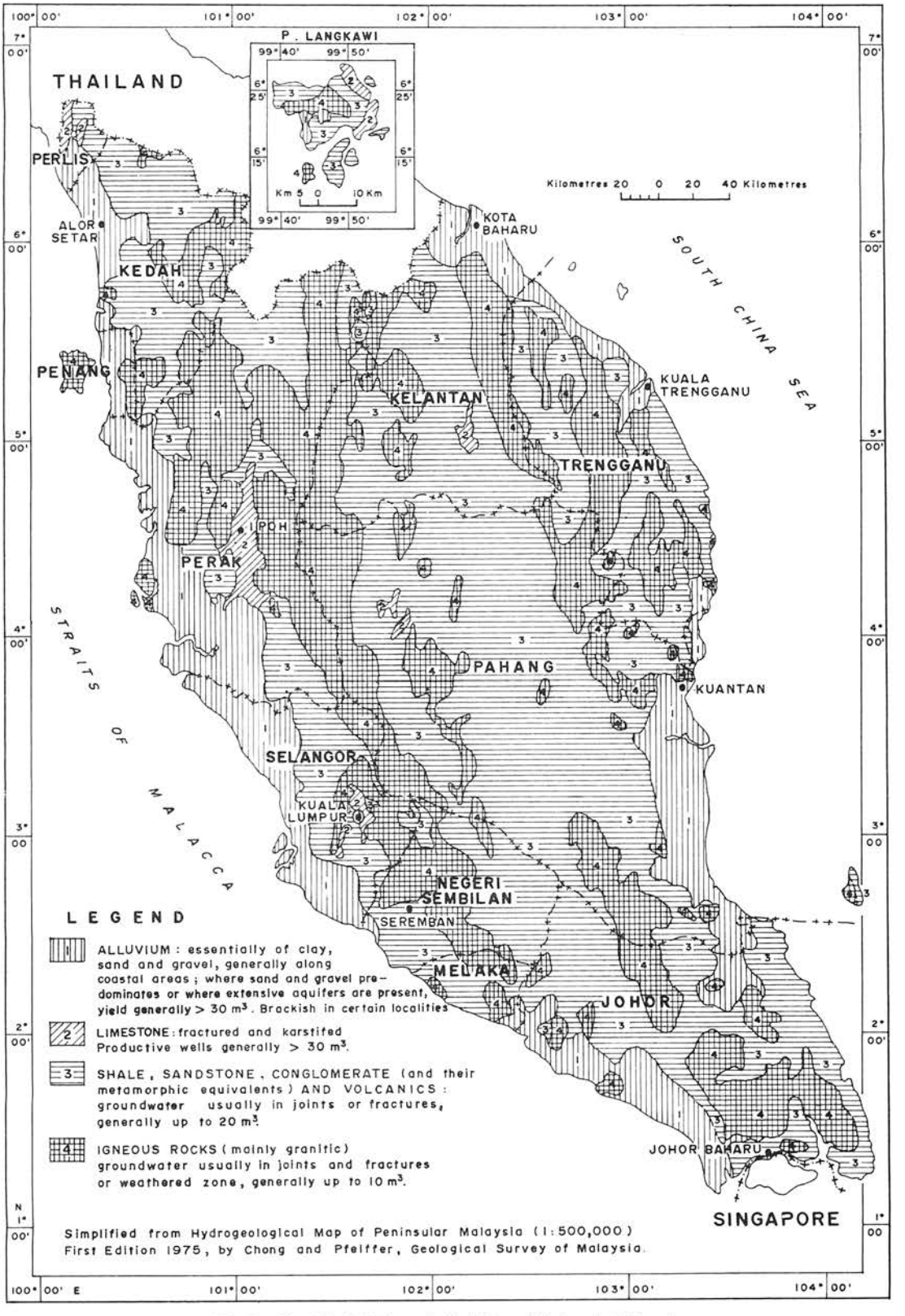


Fig. 3. Simplified Hydrogeological Map of Peninsular Malaysia.

places in the Rajang delta, confined alluvial aquifers which can produce up to 36 m^3/hr per well have also been located.

The carbonate rocks also contain important aquifers. However, these rocks have restricted distributions; the Jurassic-Cretaceous limestones are found only in the 1st Division whereas the Oligocene-Miocene limestones occur in localised areas in the 4th and 5th Divisions.

Sedimentary, metamorphic and volcanic rocks cover the major portion of the State. However, these rocks have limited groundwater potential and are only important locally. Primary porosity in these rocks is insignificant and any groundwater occurrence is usually related to secondary porosity, such as joints, fractures, shears, fisures, faults and cleavages, and the weathered zones. The Lower Tertiary sedimentary rocks at Sarikei and Binatang gave yields of between 12-18 m^3/hr per well and those at Simanggang yields of up to 11 m^3/hr. In the Kuching area, aquifers found in the Palaeozoic and Mesozoic sedimentary and metamorphic rocks gave yields which generally do not exceed 18 m^3/hr per well.

The intrusive igneous rocks are mainly restricted to the 1st and 2nd Divisions and have very limited groudwater potential. Locally, groundwater may be present in the weathered or fractured zones of these rocks.

HYDROGEOLOGICAL ACTIVITIES PENINSULAR MALAYSIA

The Geological Survey has been involved in groundwater investigations since its inception in 1903. Advice and information pertaining to groundwater resources had, and is still being made available to various departments and agencies in addition to the various estates and private individuals. Assistance rendered include the selection of borehole sites, identification of rock samples, geologic loggings, subsurface geophysical investigations, drillings, pumping tests and water quality analyses.

The Department was active during the period 1953-57 when it initiated investigations into the groundwater potential of Perlis, under the Perlis Water Supply Scheme. A total of 18 percussion wells, and more than 40 exploration boreholes were sunk. This resulted in the development of the karst aquifer within the limestone in Arau.

Between 1955-58, the Department in collaboration with the United Nations Technical Aid Assistance (UNTAA), implemented a regional hydrogeological investigation of the coastal regions of Peninsular Malaysia. As a result of this investigation, several potential waterbearing zones were located. The most important of these was the discovery of the underground source in the Dindings district in Perak.

A Hydrogeology Section was formally established in the Geological Survey in 1971 following the increase in demand for piped water-supply as a result of rapid industrial growth, land development and population growth. Furthermore, prolonged seasonal droughts and river pollution problems have imposed a heavy constraint on the traditional sources of surface water. The first task of the Section was the preparation of a hydrogeological map. The hydrogeological map of the Peninsular Malaysia on the scale of 1:500,000 was published in

1975. The hydrogeological map was a compilation based on considerations of four main aspects, namely

(1) Lithology: this was based to a large extent on the geological map of the country, published by the Geological Survey in 1973. Consideration was given to the lithological differences, and areal distributions of the main rock types.

(2) Structural/Tectonic elements: Consideration was given to the occurrence and degree of fracturing, jointing, and other factors that contribute to secondary porosity in the rock formations.

(3) Topography: consideration was given to its influence on the flow of groundwater.

(4) Available borehole and well data.

In addition to the above, stream flows, isohytes, reservoir locations and their capacities, hot springs, tidal gauging stations, and major surface-water divides are also depicted in the map.

The hydrogeological map has been useful in that it has contributed significantly towards the understanding of the general features and characteristics of the groundwater occurrence in Peninsular Malaysia. It serves as a valuable source of information to both students of hydrogeology and practicing hydrogeologists involved in groundwater investigations in Peninsular Malaysia and has been utilised as a reference for the preparation, planning and implementation of subsequent hydrogeological programmes. Among the major ones that have been completed or are in the process of implementation are the following (fig. 4):

1. Malaysian-German Hydrogeological Mission Project

The project was undertaken from 1974-77 by the Geological Survey with technical assistance from the Federal Republic of Germany. The project involved the sinking of more than 240 exploration boreholes and test wells in the coastal alluvial areas in the east coast States of Kelantan, Terengganu and Pahang.

The results of this study revealed that the alluvium in the Kelantan delta has a maximum thickness of 200 m or possibly more. Generally four aquiferous layers can be delineated. The thickness of these aquifers varies from place to place. The groundwater in the first and third aquifers is fresh and is being exploited. Presently groundwater is tapped from 5 centres in the delta area for the supply of Kota Bharu town. A total of 40,050 m^3/day are produced from these centres.

TABLE I
GROUNDWATER SUPPLY IN THE KELANTAN DELTA AREA.

Location	No. of wells	Present Abstraction
Kampong Putih	13	26000 m^3/d
Kubang Kerian	3	6600 m^3/d
Pintu Geng	3	3300 m^3/d
Tanjung Mas	3	2900 m^3/d
Pengkalan Chepa	9	1250 m^3/d

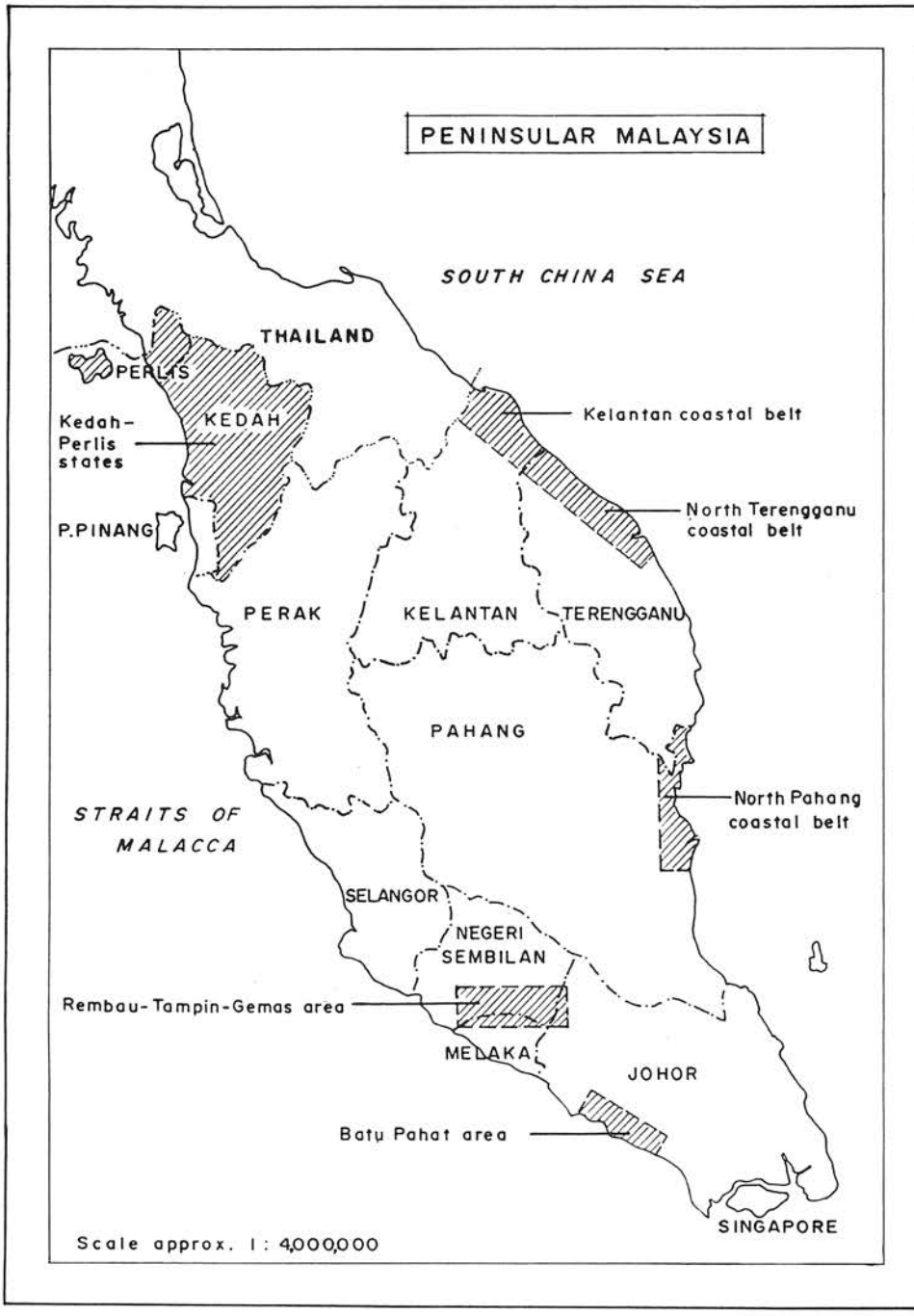


Fig. 4. Areas where detailed hydrogeological investigations have been undertaken since 1975.

In the Kuala Terengganu delta region the alluvium was found to vary from a few metres to 50 m but is generally between 20 to 25 m in thickness. In the southern sector of the plain there is only one aquifer. In the northern sector two distinct aquifers can be delineated.

(a) First aquifer:
Generally between 5-15 m thick, average thickness 10 m.

(b) Second aquifer:
Between 3-15 m thick average thickness 7 m.

A well field has been developed at Kampung Kepong and is producing 11,000 m^3/d from 6 wells.

The investigation in the Kuantan port area in Pahang between Kampong Cherating and Kampong Karang reveals the alluvium thickness to vary from a few metres to 25 m at the centre of the allluvium plain. In general only one aquifer can be delineated but locally, due to the occurrence of silt and clay interbeds, the alluvium may appear to contain two or more aquifers. The discovery of this aquifer has led to its exploitation. At present 1,000 m^3/d of groundwater is abstracted from two production wells at Sungai Ular.

2. Kedah-Perlis Groundwater investigation project

This investigation was part of the overall water resources study undertaken by the Government of Malaysia between 1978-1983. A total of 262 wells were drilled which, except on Langkawi island, were mainly directed to the hard rock regions in the two States. The investigation revealed no extensive aquifer system but found useful groundwater in the limestone areas, the Bukit Arang Coal Beds, the alluvium deposits in Langkawi and in the fractured zones of siltstones and sandstones.

The immediate benefit of the project was the conversion of some of the exploration wells into production wells. The proposal was to implement the followings:

North Kedah

To abstract 3,500 m^3/d of water from 15 wells in the area bounded by Pokok Sena, Padang Sanai and Sungai Tiang to supply the needs of 58 villages.

Perlis

To abstract 17,000 m^3/d of water from 17 wells to boost the supplies in the existing distribution system in the area between Arau, Kampong Bukit Keteri and Kurong Batang.

Langkawi

To abstract 500 m^3/d of water from 4 wells to ease water shortages in Kuah and Kisap and to abstract 3,300 m^3/d of water from a group of 16 wells in the Sungai Melaka basin east of Padang Masirat to ease the medium term shortage of the island as a whole.

3. Seri Gading Groundwater investigation project

The objective of this project was to carry out a detailed study on the subsurface hydrogeological condition and to locate the occurrence of groundwater to supplement the

shortage of potable water for the population in this rural district. The investigation, covering an area of 1500 km^2, was carried out between 1981-1983. A total of 42 exploration boreholes and wells were drilled. The investigation revealed that most of the groundwater in the area is saline but localised fresh groundwater exists in some parts of the alluvium and in areas underlain by weathered granite. Tests indicated that the wells built in these areas can sustain abstraction rates of below 10 m^3/hr and could be used for smallscale development as a supplementary source of potable water supply.

4. Rembau-Tampin-Gemas Groundwater investigation project

This region has experienced periodic shortages of water supply, particularly during the dry season. Most of the surface-water sources that are readily available have already been fully tapped. This investigation was carried out to study the groundwater potential in the consolidated rock formations including shale, volcanics, limestone and granite which underlie the region. The investigation commenced in 1982 and will be completed in 1985. To date a total of 34 wells have been drilled. In all a total of 60 wells will be drilled to evaluate the groundwater potential in the area.

SARAWAK

Prior to 1970, groundwater investigations and exploration were undertaken by the Public Works Department (PWD). The Geological Survey only gave advice during the drilling phase of the investigation. Between 1954 and 1964, the PWD drilled a total of 26 exploration wells in 6 separate areas.

Subsequently, 4 production wells were constructed at Sarikei, 3 at Binatang and 4 at Simanggang. The total depths, yields and drawdowns of these production wells are given in Table III. The 4 wells at Sarikei were in production from 1957 till 1969. Daily production

TABLE II

WATER PRODUCING WELLS IN THE REMBAU-TAMPIN-GEMAS AREA

Locality	Well Number	Abstractable Yield
Army Camp	RTG 1	45 m^3/hr
Army Camp	RTG 4	12 m^3/hr
Army Camp	RTG 5	3 m^3/hr
Army Camp	RTG 9	25 m^3/hr
Army Camp	RTG 10	25 m^3/hr
Gemas Baru	RTG 13	3 m^3/hr
Kampong Tiong	RTG 15	3 m^3/hr
Tanah Pinggir	RTG 17	6.5 m^3/hr
Sungai Geduk	RTG 20	25 m^3/hr
Kawasan KTM	RTG 21	3 m^3/hr
Pasir Besar	RTG 23	25 m^3/hr
Kampong Bangka Hulu	RTG 24	79 m^3/hr
Kampong Bangka Hulu	RTG 26	6.5 m^3/hr

TABLE III

RESULTS OF PRODUCTION WELLS AT SARIKEI, BINATANG AND SIMANGGANG

Location and well number	Depth of well (m)	Yield (m^3/hr)	Drawdown (m)	Screened depth (m)
Sarikei				
No. 1	20.8	14.1	8.9	2.9 - 20.8
No. 2	59.2	18.2	26.2	22.5 - 59.2
No. 3	58.8	12.8	25.0	28.9 - 58.8
No. 5	56.3	14.1	25.9	39.7 - 56.3
Binatang				
No. 1	46.1	15.3	20.7	29.4 - 46.1
No. 2	39.9	16.5	16.8	24.6 - 39.9
No. 3	65.6	15.3	29.4	17.1 - 65.5
Simanggang				
No. 3	61.3	11.4	14.6	n.a.
No. 4	76.3	6.1	33.6	n.a.
No. 6	49.7	49.7	18.9	n.a.
No. 7	67.1	6.4	34.2	n.a.

n.a. = not available

varied from 173 m^3/d in 1959 to 306 m^3/d in 1965 with a record flow of 54.5 m^3/hr (PWD Annual Report). From 1966 onwards, these wells were supplemented by water from surface sources until 1969 when the wells were abandoned. The 3 wells at Binatang were in production from 1957 till 1976. Daily production varied from 81 m^3/d in 1960 to 158 m^3/d in 1965 with a record flow of 41 m^3/hr. They were supplemented by water from surface sources in 1966, and were finally abandoned in 1977. The 4 wells at Simanggang were in production from 1960 to 1972, with daily production varying from 73 m^3/hr in 1960 to 320 m^3/d in 1963 with a record flow of 27 m^3/hr. From 1965, these wells were supplemented by surface sources until 1972 when they were abandoned. Unfortunately, no chemical analyses of the groundwater from these 3 areas are available. Overpumping, poor maintenance, and lack of monitoring resulted in the deterioration of both the wells and the aquifers so that they were eventually abandoned because of salt-water intrusions and low yields.

In 1964, the PWD conducted exploratory drilling for groundwater in the Nonok peninsula, mid-Sadong area, and Kabong area. In the Nonok peninsula, 5 boreholes were drilled to depths varying from 13 m to 22 m. the groundwater encountered was saline with chloride values ranging from 965 to 4,030 ppm. Four boreholes were drilled in the mid-Sadong area to depths of between 14.6 m to 23.8 m. The groundwater encountered was variable from fresh to saline, with chloride values ranging from 13 to 695 ppm. The 4 boreholes at Kabong were drilled to depths of between 7.9 m to 9.7 m and the chloride values of the groundwater varied from 5 to 3,550 ppm. All these 13 exploration boreholes were considered to be unsuccessful and abandoned.

The first systematic hydrogeological investigation was carried out by the Geological Survey, with assistance from the German Hydrogeological Mission, in 1975. To date, a total

of 15 areas were investigated. The locations of these areas are shown in Figure 5. These investigations were concentrated on the coastal plain because the region suffers from extreme water shortage during drought periods. Almost all of the rural population, estimated at about 200,000, in this region depend upon hand-dug shallow wells for their water supply. Existing piped water schemes are, with few exceptions, using surface sources which are unreliable during prolonged droughts, being either affected by sea-water intrusion or drying up completely.

In 1975, the areas investigated were the Nonok peninsula, Kampung Bako, and Semariang. During the Third Malaysia Plan period (TMP), explorations for groundwater were carried out in the Kuala Lawas, Kampong Awat-Awat, Punang, Daro, Belawai, Kabong, Tambirat and Bako areas. Under the Fourth Malaysia Plan (FMP), to date, groundwater explorations have been conducted in the Rambungan, Igan, Oya, Judan and Penipah areas. The results of these investigations are summarisd in Table IV.

To date, the Geological Survey has constructed production wells to exploit the groundwater from the shallow alluvial aquifers in 2 of these areas. At Belawai, 42 production wells were constructed to supply 1,000 m^3 of water daily to meet the needs of about 7,000 people in the Belawai-Jerijeh-Rajang area. At Kuala Lawas, 24 production wells were constructed with a total capacity of supplying 360 m^3 of water daily to meet the needs of about 2,000 people in the area.

The aquifer at Kabong will be developed as soon as the land for the catchment area has been acquired. Plans have been drawn up to construct 48 production wells in this aquifer to produce 600 m^3 of water daily to meet the needs of about 4,000 people in the Kabong area.

Under the FMP, the Geological Survey also has plans to assess the groundwater potential of the Sampadi-Sungai Sarawak delta area, the Rajang delta area, and the Serian Volcanics. Due to acute manpower shortage, however, only one of these projects can be carried out at any one time. Up to the end of April, 1983, investigations of the groundwater potential of the Sampadi-Sungai Sarawak delta area were conducted. However, commencing in May, 1983, priority was shifted to the Rajang delta because of the urgent request by the PWD to search for and develop groundwater sources for their rural water supply schemes. Thirteen priority areas, namely Judan, Penipah, Teh/Tabau, Sisak Baru/Lama, Jabunga, Tegak, Penakub, Tekajong, Ska'an/Jamoreng, Paloh, Kuala Matu, Igan and Oya where groundwater is required, have been identified.

To date, preliminary exploration comprising surface mapping, exploratory drilling and water sampling had been completed in the Oya, Judan, Penipah and Igan areas, and unconfined aquifers have been identified in all these 4 places.

Compilation of the Hydrogeological Map of Sarawak on a scale of 1:500,000 has been completed. Publication of the map is expected at the end of 1984 or early 1985. The main features of this map are:

(i) the use of 2 shades of blue to show mainly unconsolidated porous rocks of different productivity,

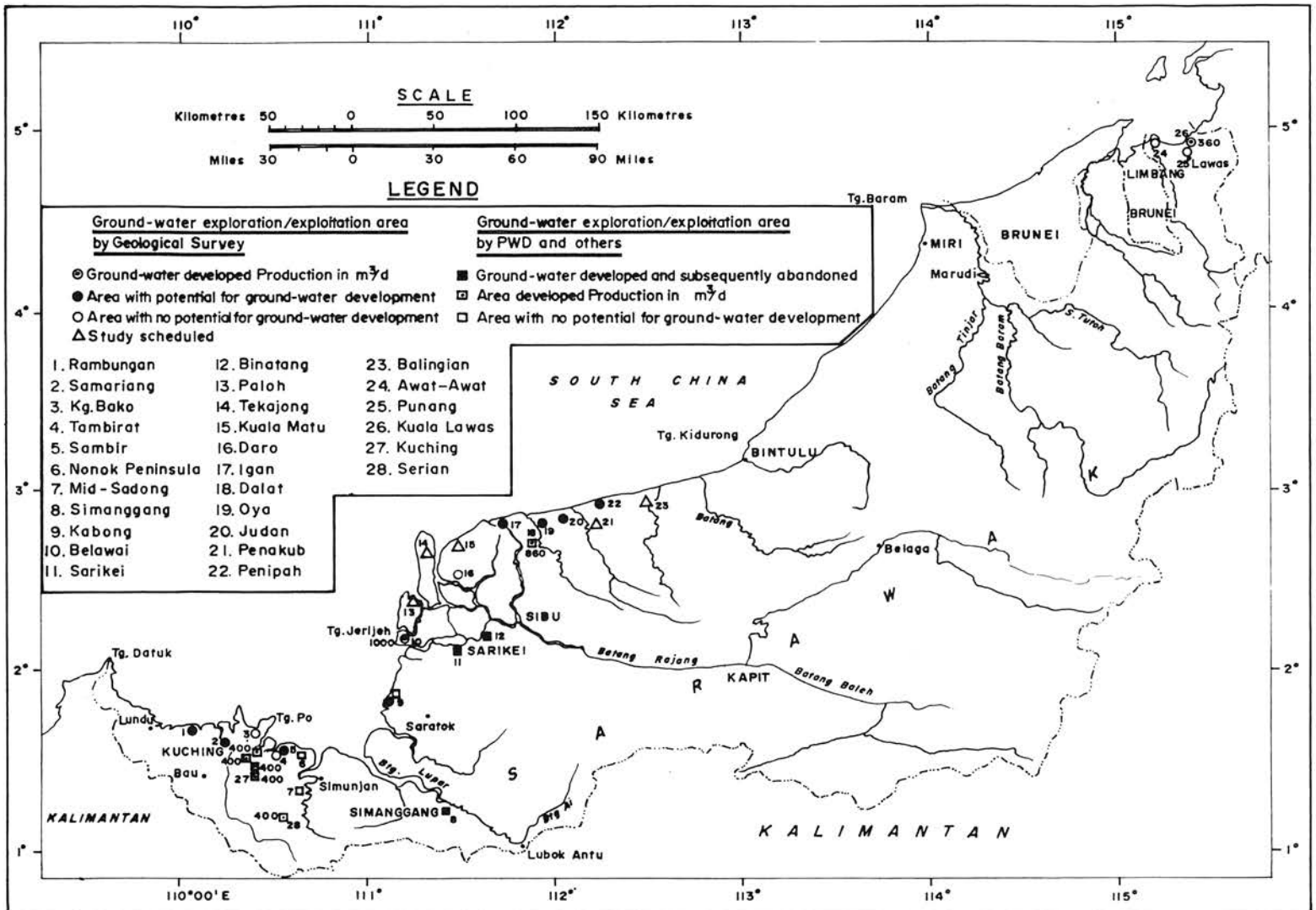


Fig. 5. Location of ground-water exploration and exploitation in Sarawak.

TABLE IV

RESULTS OF HYDROGEOLOGICAL INVESTIGATIONS IN THE COASTAL PLAIN

	Location	Number of exploration boreholes	Type of aquifer	Average thickness of aquifer (m)	Water Quality	Remarks
1.	Rambungan	18	Alluvial, unconfined	5	Chlorides content 12 – 920 ppm, average 120 ppm	May be developed
2.	Semariang	1	Alluvial, unconfined	5	Chlorides content 35 ppm	–
3.	Kg. Bako	–	Fractured chert	–	–	–
4.	Sambir	26	Alluvial, unconfined	3.2	chlorides content 18 – 26 ppm	May be developed
5.	Tambirat	–	Peat	2	–	Water supply obtained from drainage of peat.
6.	Kabong	30	Alluvial, unconfined	8	Chlorides content 15 – 40 ppm	Will be developed once land for catchment area is acquired.
7.	Belawai	65	Alluvial, unconfined	12.5	Medium salinity with chloride content 224 – 1,377 ppm	Developed to supply water to Belawai, Jerijeh & Rajang
8.	Daro	25	Alluvial, unconfined	–	Saline with chloride content 2,060-2,370 ppm	–
9.	Igan	55	Alluvial, unconfined	6-10	Chloride content 20 – 180 ppm	May be developed
10.	Oya	38	Alluvial, unconfined	4	Chloride content 20 – 150 ppm	May be developed
11.	Judan	27	Alluvial, unconfined	4.4	Chloride content 30 – 715 ppm, average 200 ppm	May be developed
12.	Penipah	11	Alluvial, unconfined	5	Chloride content 72 – 1330 ppm, average 487 ppm	May be developed
13.	Awat-awat	1	Alluvial, unconfined		Saline	–
14.	Punang	2	Tertiary sandstone		–	–
15.	Kuala Lawas	27	Alluvial, unconfined	4	Chloride 220 ppm	Developed to supply water to Kg Kuala Lawas

(ii) the use of 2 shades of green to show hard rocks of different productivity,

(iii) the use of 2 shades of brown to represent both unconsolidated and hard rocks which contain little or no groundwater,

(iv) symbols to indicate lithology, surface-water divides, gauging stations, water works, boreholes, and some geological features, and

(v) isohytes showing distribution of annual precipitation.

FUTURE PROGRAMME

In Peninsular Malaysia groundwater investigation will form an integral part in all major water supply studies planned by the Government. The Geological Survey will be taking an active role in these projects especially in the proposed national rural water supply study. In areas where groundwater has been located and is being exploited in large quantities e.g. in Kelantan and Terengganu, the Geological Survey will set up a monitoring programme to study the exploitation and management.

Hydrogeological activities in Sarawak will, however, be concentrated in the coastal region of the state. Master plan studies are presently being conducted for the water supply of Kuching, Sibu and Miri by the respective Water Boards. Proposals for conjunctive uses of both groundwater and surface water to meet the needs of these 3 major towns form important aspects in these studies. It is expecteds that exploration for groundwater in these three areas and in the coastal region of the 1st, 2nd, 3rd and 6th Divisions will be carried out in the near future.

CONSTRAINTS AND SOLUTIONS

Basically the main problems faced by the Geological Survey in the field of hydrogeology are lack of funds and the acute shortage of trained manpower. Funds are required not only for the capital layout of equipment but also for operating expenses in conducting the investigation. As to the question of manpower, hydrogeological investigation is a specialised field and appropriate training and experince are required of all personnel at all levels.

The Geological Survey is well aware of the present necessary financial squeeze and agrees that when funds are limited they have to be apportionated according to priority. However, water supply is an essential input in the development of the country. Because the reliance in groundwater for water supply will increase it is essential that groundwater investigations, particularly in the rural areas, be accorded an important priority.

To overcome the problem of shortage of skilled and experienced manpower, the solution is exposure and formal training for the staff. The Geological Survey has achieved a certain amount of success in attaching its staff, mainly geologists and drilling technicians, to consultants involved in government groundwater projects. Efforts are also made to send the new recruits for training courses. For this, it is proposed that the geologists and technicians be given training overseas either through formal courses or through attachment for on-the-job training.

CONCLUSION

Present knowledge of the hydrogeological setting has indicated that the groundwater resources in both Peninsular Malaysia and Sarawak are not extensive. However the demand for groundwater will increase because the Government's push towards industrialization and development under the various 5 year plans has given rise to projection that surface water will be unable to meet all the water demands of industry, agriculture and domestic consumption.

The Geological Survey is responsible for groundwater exploration. In this respect its objective is to carry out a continuing programme of hydrogeological data collection and assessment of the availability of groundwater resources so that groundwater can be effectively and safely exploited for the benefit of the population.

ACKNOWLEDGEMENTS

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