CHAPTER IV

ENVIRONMENTAL GEOLOGY

It is apparent that both Chon Buri and Rayong areas are the important targets of development for the Eastarn part of Thailand. At the present moment, urban and industrial growth and development have a tendency to occur along a predictable pattern of the past records and constraints that affected the growth.

The present investigation is envisioned that the application of earth sciences information will be of great assistant for the future prospect of development in this area. The environmental geological study specified involves having a thorough knowledge of geological resources as well as their capabilities and limitations for orderly development to stimulate effective urban and industrial growth in order to maintain a healthy living environment. The following discussion is intended to provide a pictorial and graphical presentation including explanation and data on various aspects of geology required for the development planning.

4.1 Physiographical Setting

4.1.1 Climatology

The studied area has a tropical rain forest climate with average annual rainfall of 1,370 millimeters and average temperature of approximately

27.9°C. The rainfall in the area is more abundant and well distributed than that of the Central Plain of Thailand. The seasons change according to the influence of the monsoon directions and they can be classified as follows:

(a) The northeast monsoon season, or the cold season, lasts from November to Febuary.

(b) The summer, or hot season, lasts 3 months, extending from March to May. It is the period of first time monsoon direction changes of the year.

(b) The southwest monsoon season is between June and September. During this period, the monsoon passes over the area and bring moisture from the sea to produce torrential rains. Therefore, this period is the rainy season which usually extends to October.

(d) The second time of monsoon-changed season lasts for only a short period. It is usually starting from October to the beginning of November that the southwest monsoon changes to be the northeast monsoon and the weather is cool down.

For the wind velocity at Chon Buri and Sattahip, there is a meteorological station to keep record throughout the year. The value is between 5-10 knots and directions vary from north, south, east northeast, southwest and west-southwest. The effect of the southwest monsoon at Sattahip is more dominant than of Chon Buri while the northeast monsoon has more influence to Chon Buri than that of Sattahip. For the southwest monsoon, the velocity is generally more than 9 knots, and actives between June and September that makes the rain widely spread in June to October. At Siracha and Chon Buri, the maximum rainfall is about 300 millimeters in September whereas 288 millimeters is the maximum rainfall in September at Sattahip and Rayong.

During October and January, the Northeast monsoon passes through the area with average velocity of 6.5 knots. It comes with a relatively dry and cool weather bringing the mean temperature down to 25-26°C in December and January. The mean minimum temperature falls within the range of 20-22°C at Chon Buri - Sattahip and about 23°C at Rayong.

In summer the highest mean temperature of 30°C and its mean maximum, 35°C, is prevailing in April.

The relative humidity of the area is reversely proportional to the rate of evaporation. The lowest relative humidity is 66-70% in December, and the highest is 80-83% in September and October when the rain is heaviest. The highest rate of evaporation is ranging from 98 to 112 millimeters in December and the lowest ranges from 48 to 55 millimeters in September and October.

However, the climate is locally varied on account of the differences in topography and landforms as well as the areal extent of the adjacent sea where the monsoon passing through prior reaching the coast. Therefore, rainfall in the relatively flat coastal plain eastern part of Rayong is heavier than that in Chon Buri and Sattahip. Besides, the areas adjacent to the coast in front of the mountain range and highland appear to have higher moisture content than those further inland. The climatological data of Chon Buri and Sattahip is presented in Table 4.1.1 and Figure 4.1.1.

4.1.2 Drainage of the Studied Area

The studied area is drained by numerous short streams and one river owing to the characteristics of the morphology which comprises of highland, mountainous area, narrow coastal plain and small flood-plain. Rayong river is that one river of about 20 kilometers long and the rest are intermittent streams which are alive in wet season and abandoned in dry season.

The studied area is divided into 3 catchment basins, namely, Rayong Basin, Chon Buri Basin and Bang Pakong Basin (Figure 4.1.2). Most of them illustrate the dendritic drainage pattern with three different flow directions. Their extents and characteristics are as follows:

(a) Rayong Basin covers the central part of the studied area between the granitic batholith of Khao Khieo, Khao Chom Phu and Khao Khrok and gneissic rocks of Khao Khun In - Khao Taphao Kuam range including the Rayong coastal zone. Most of the streams within the basin discharge southwardly to the Gulf of Thailand and the main stream is Rayong River.

(b) Chon Buri Basin is the coastal area expressing as the narrow strip, 15-17 kilometers wide extending from Chon Buri Township to Amphoe Sattahip. The basin is drained by a number of short-intermittent streams

Table 4.1.1 Climate in Chon Buri and Sattahip for the period 1951-1975.

Station CHONBURI
Index Station 48 459
Latitude 13° 22′ N.
Longitude 100° 59′ E.

Elevation of station above MSL. 3.00 meters
Height of barometer above MSL. 4.22 meters
Height of thermometer above ground 1.50 meters
Height of wind vane above ground 12.00 meters
Height of raingauge 0.56 meters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Pressure (+ 1000 or 900 mbs.)													
Mean	12.56	11.20	10.22	08.83	07.25	06.73	06.92	06.93	07.76	09.68	11.62	12.52	09.30
Ext. Max.	25.28	20.65	19.68	18.00	14.29	13.39	14.99	13.49	15.79	17.79	21.09	21.89	25.28
Ext. Min.	03.74	03.04	02.44	01.14	99.44	97.44	99.74	99.44	98.74	99.49	04.27	03.50	97.44
Mean daily range	4.57	4.66	4.69	4.61	4.27	3.65	3.48	3.76	4.22	4.41	4.29	4.43	4.25
Temperature (°C.)													
Mean	25.9	27.4	28.8	29.6	29.3	28.9	28.6	28.3	27.9	27.3	26.7	25.8	27.9
Mean Max.	31.3	32.1	33.2	34.1	33.3	32.5	31.9	31.6	31.2	31.3	31.1	31.0	32.0
Mean Min.	20.1	22.4	24.2	25.4	25.4	25.5	25.0	24.9	24.4	23.8	22.1	20.3	23.6
Ext. Max.	36.2	36.6	37.0	38.0	37.8	37.1	35.5	34.7	34.4	34.8	35.2	36.1	38.0
Ext. Min.	9.9	16.5	17.5	20.4	21.2	21.0	20.5	20.9	20.6	18.2	14.2	12.0	9.9
Relative Humidity (%)													
Mean	67.0	71.0	71.0	71.0	75.0	75.0	75.0	76.0	80.0	80.0	73.0	66.0	73.0
Mean Max.	85.0	88.2	87.8	87.6	88.8	87.6	88.5	90.0	92.3	93.0	89.5	85.1	88.6
Mean Min.	52.0	56.2	56.6	56.7	60.8	61.8	62.9	64.0	67.1	56.7	57.2	50.1	59.3
Ext. Min.	20.0	25.0	23.0	29.0	32.0	42.0	43.0	45.0	46.0	42.0	29.0	22.0	20.0
Dew Point (°C.)													
Mean	18.6	21.2	22.6	23.8	24.2	23.8	23.5	23.6	23.8	23.4	21.0	18.6	22.3
Evaporation (mm.)													
Mean – Piché	109.4	91.3	101.6	96.2	79.6	83.3	79.7	73.6	54.2	59.5	87.2	111.6	1027.2
– Pan						No	Observation						
Cloudiness (0–8)													
Mean	3.9	3.8	4.0	4.7	6.1	6.5	6.7	6.9	6.7	5.8	4.5	3.6	5.2
Visibility (Km.)													
0700 L.S.T.	6.9	6.4	7.1	8.6	10.7	11.2	10.7	10.2	9.7	9.3	8.2	7.6	8.9
Mean	8.0	7.8	8.2	9.8	11.7	12.2	11.7	11.2	10.7	10.3	9.8	9.1	10.0
Wind (Knots)													
Prevailing wind	E	S	S	S	S	S	S	S	S	NE	NE	NE	–
Mean Wind Speed	6.4	7.0	7.1	6.4	5.9	7.1	6.6	6.5	5.3	5.0	6.2	6.6	–
Max. Wind Speed	40 NE	36 S,SW	37 NNE, SW	50 ENE	47 S.W, NW	55 SW,W	55 SW	55 SW	60 W	63 S	40 NE,S	37 NE	–
Rainfall (mm.)													
Mean	12.6	22.1	40.9	77.9	166.5	118.8	168.0	166.3	302.0	230.1	64.1	10.1	1379.4
Mean rainy days	1.7	3.4	4.8	8.2	15.2	15.0	16.9	19.6	20.0	17.6	6.7	1.6	130.7
Greatest in 24 hr.	37.7	92.1	103.4	74.7	126.2	65.4	110.6	131.0	124.2	145.4	91.8	37.7	145.4
Day/Year	18/75	25/58	13/54	23/47	11/54	23/72	22/51	27/71	26/63	14/52	4/75	1/70	14/52
Number of days with													
Haze	27.2	24.6	25.2	16.6	3.6	2.5	1.1	2.7	2.1	5.8	16.2	21.6	149.2
Fog	2.9	3.3	2.2	0.7	0.3	0.0	0.4	0.2	0.6	0.6	1.6	1.1	13.9
Hail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thunderstorm	0.7	3.2	6.6	15.4	15.9	7.7	7.7	7.9	11.0	11.0	3.8	0.7	91.6
Squall	0.0	0.0	0.0	0.4	0.1	0.4	0.0	0.0	0.0	0.1	0.0	0.2	1.2

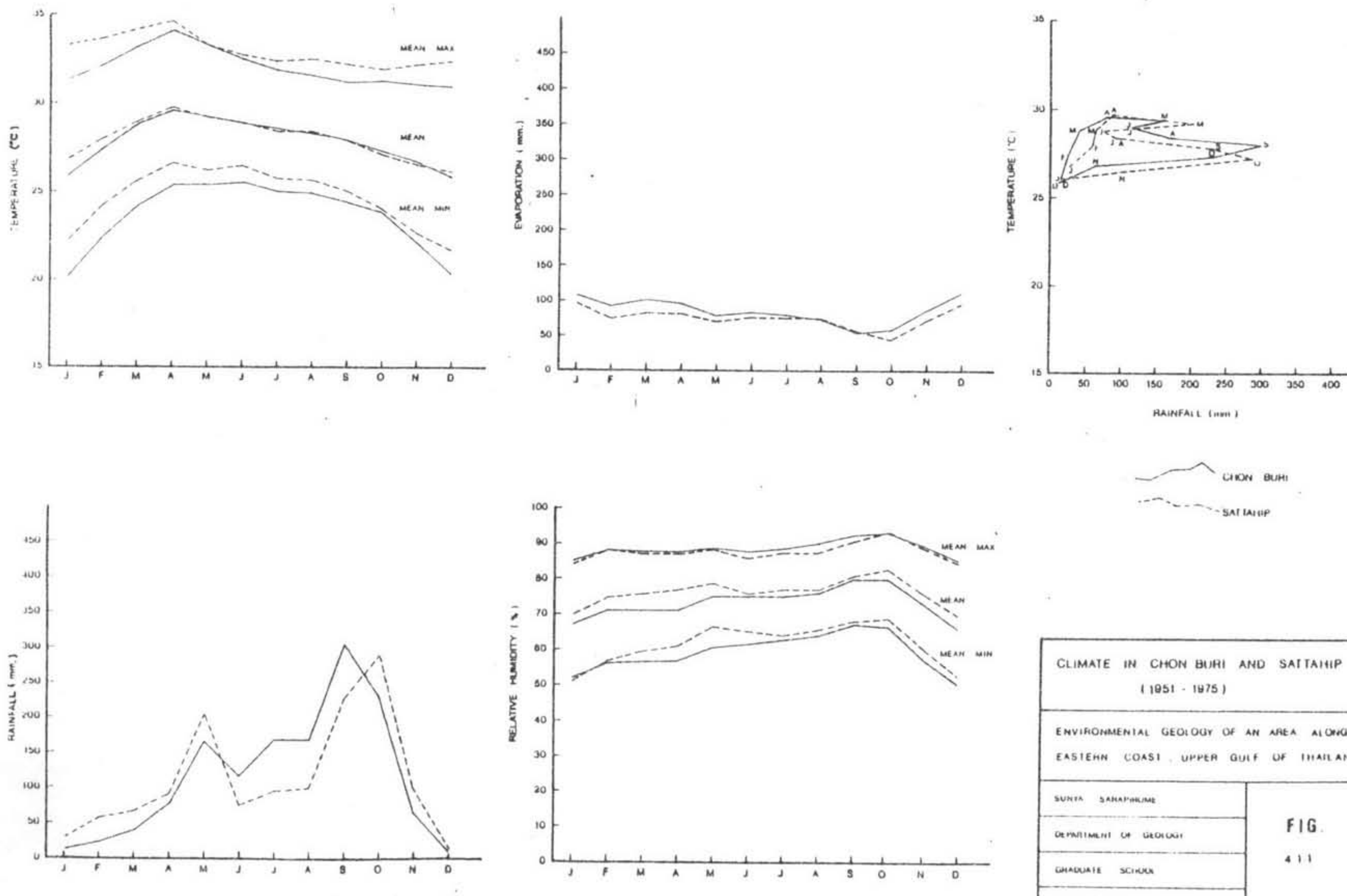
Remark : 1. Pressure 1953 – 1975
2. Evaporation 1954 – 1975

Table 4.1.1 (cont.)

Station SATTAHIP
Index Station 48 477
Latitude 12° 41' N.
Longitude 100° 59' E.

Elevation of station above MSL. 16.00 meters
Height of barometer above MSL. 18.00 meters
Height of thermometer above ground 1.35 meters
Height of wind vane above ground 12.00 meters
Height of raingauge 0.73 meters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Pressure (+ 1000 or 900 mbs.)													
Mean	12.81	11.76	10.98	09.59	07.99	07.66	07.74	07.80	08.48	10.20	11.56	12.59	09.93
Ext. Max.	21.37	20.27	18.04	17.97	14.62	13.84	13.64	13.77	14.63	16.84	18.62	20.27	21.37
Ext. Min.	06.17	05.47	04.68	02.02	01.54	00.27	00.93	00.76	00.67	99.64	95.52	05.66	96.52
Mean daily range	3.74	3.83	3.93	3.95	3.66	3.08	2.99	3.22	3.84	3.90	3.74	3.71	3.63
Temperature (°C.)													
Mean	26.7	27.9	28.9	29.7	29.2	28.9	28.4	28.4	27.9	27.1	26.5	26.1	27.9
Mean Max.	33.2	33.6	34.1	34.6	33.3	32.7	32.4	32.5	32.2	31.9	32.2	32.4	32.9
Mean Min.	22.1	24.2	25.6	26.5	26.2	26.4	25.7	25.6	25.0	24.0	22.6	21.6	21.6
Ext. Max.	39.0	39.4	39.5	40.5	40.5	37.2	37.8	37.2	37.4	36.2	37.4	38.3	40.5
Ext. Min.	12.3	16.8	18.7	21.0	21.5	20.9	19.0	21.5	19.0	19.5	15.0	12.8	12.3
Relative Humidity (%)													
Mean	70.0	75.0	76.0	77.0	79.0	76.0	77.0	77.0	81.0	83.0	76.0	70.0	76.0
Mean Max.	84.2	88.2	87.6	87.3	88.8	86.0	87.4	87.6	90.7	93.3	89.0	84.7	87.9
Mean Min.	51.2	57.0	59.9	61.1	66.6	65.5	64.2	65.9	68.3	69.1	60.7	53.0	61.9
Ext. Min.	25.0	17.0	29.0	33.0	43.0	43.0	47.0	48.0	45.0	38.0	28.0	21.0	17.0
Dew Point (°C.)													
Mean	20.2	22.7	24.0	24.9	24.9	24.3	24.0	23.9	24.2	23.8	21.9	20.0	23.2
Evaporation (mm.)													
Mean – Piché	98.0	75.9	84.2	83.6	73.1	79.4	77.7	76.6	59.9	47.2	73.9	97.1	926.6
– Pan						No	Observation						
Cloudiness (0–8)													
Mean	3.9	4.1	4.3	4.9	6.4	6.5	6.8	6.9	6.9	6.0	4.8	3.7	5.4
Visibility (Km.)													
0700 L.S.T.	7.8	7.8	8.1	9.6	10.6	11.2	10.9	10.8	10.6	9.8	9.8	9.3	9.7
Mean	8.6	8.3	8.6	10.0	11.0	11.4	11.1	11.3	11.0	10.4	10.4	9.9	10.2
Wind (Knots)													
Prevailing wind	N	S	S	S	S,SW	SW	SW	WSW	WSW	N	N	N	–
Mean Wind Speed	6.0	6.8	7.4	7.2	7.2	9.8	9.4	9.1	7.4	5.8	6.8	7.1	–
Max. Wind Speed	35 N	36 NE	48 SE	46 ESE	57 NW	58 WSW	52 W	52 W	49 WNW	59 W	73 NNW	40 N	–
Rainfall (mm.)													
Mean	28.4	56.8	66.2	90.9	205.5	76.4	95.8	99.7	226.1	288.4	99.7	17.1	1351.0
Mean rainy days	2.7	4.7	5.0	7.8	13.8	10.9	13.8	13.5	16.6	17.5	8.8	2.0	117.1
Greatest in 24 hr.	53.2	117.6	116.1	108.7	170.0	62.8	155.0	89.7	107.7	302.7	319.6	87.0	319.6
Day/Year	26/73	27/68	22/70	28/71	4/71	17/72	22/51	25/65	23/63	22/52	30/70	1/70	30/70
Number of days with													
Haze	20.6	15.6	16.1	3.6	0.9	1.0	1.8	2.2	1.1	4.3	8.8	16.1	97.1
Fog	5.8	4.9	3.4	2.0	0.5	0.8	0.7	0.6	0.7	1.3	1.9	3.4	26.0
Hail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
Thunderstorm	0.7	1.4	3.5	7.7	10.3	3.8	3.9	3.7	8.3	10.2	4.8	1.0	59.3
Squall	0.0	0.1	0.2	0.4	0.2	0.4	0.4	0.2	0.2	0.1	0.1	0.0	2.3



CLIMATE IN CHON BURI AND SATTAHIP
(1951 - 1975)

ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND

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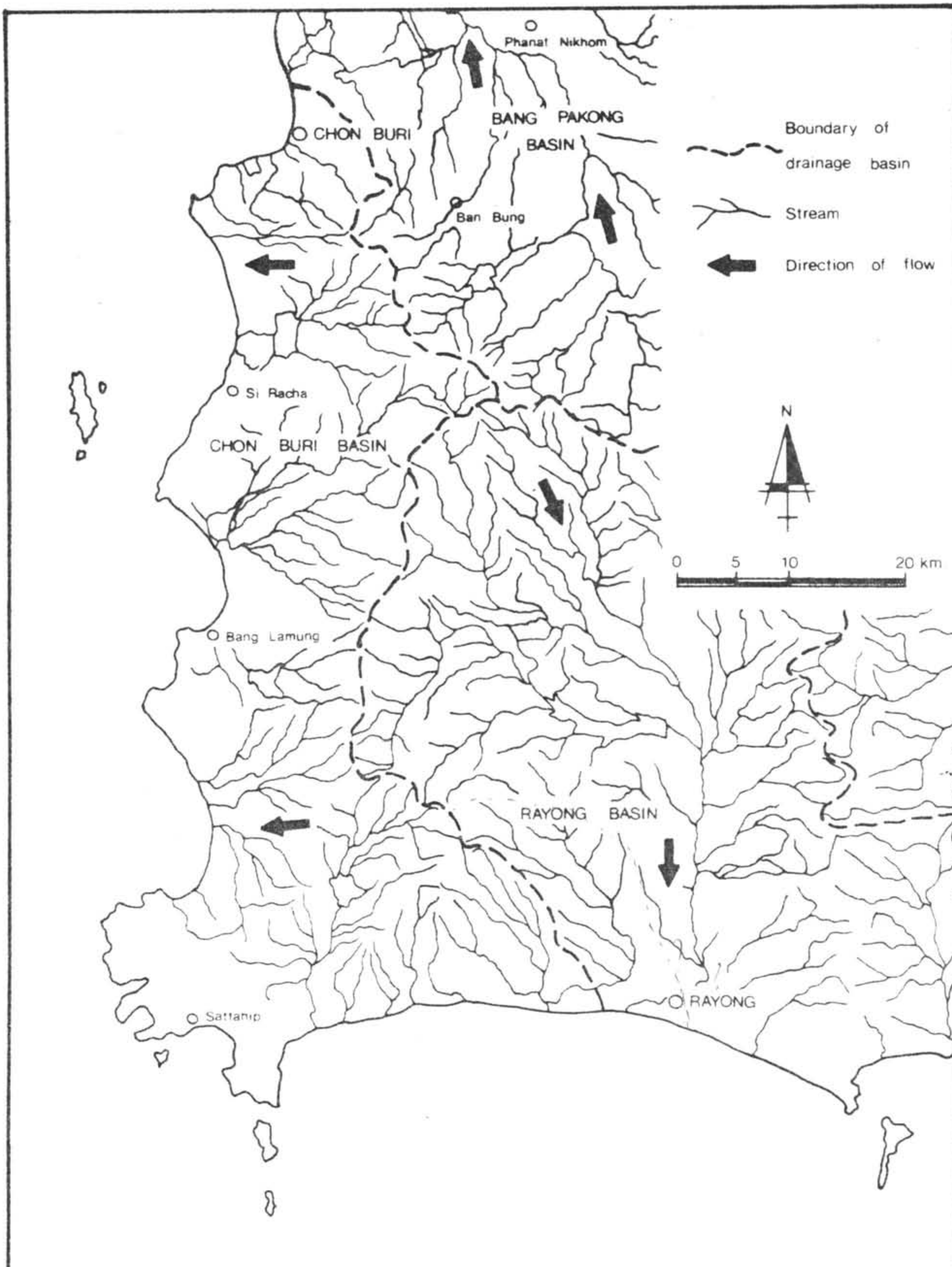
FIG. 4.11



THE DRAINAGE CHARACTERISTICS WITHIN THE STUDIED AREA	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND	
DEPARTMENT OF GEOLOGY, GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	SUNYA SARAPIROME	FIG. 4.1.2

which westwardly flow into the Inner Gulf at Ao Chon Buri, Ao Bangsaen, Ao Bang Lamung and Ao Bang Sare.

(c) The catchment basin which covers the northeastern part of the studied area is the lower part of Bang Pokong Basin. It is also drained by intermittent streams to the north direction and joining Bang Pakong River.

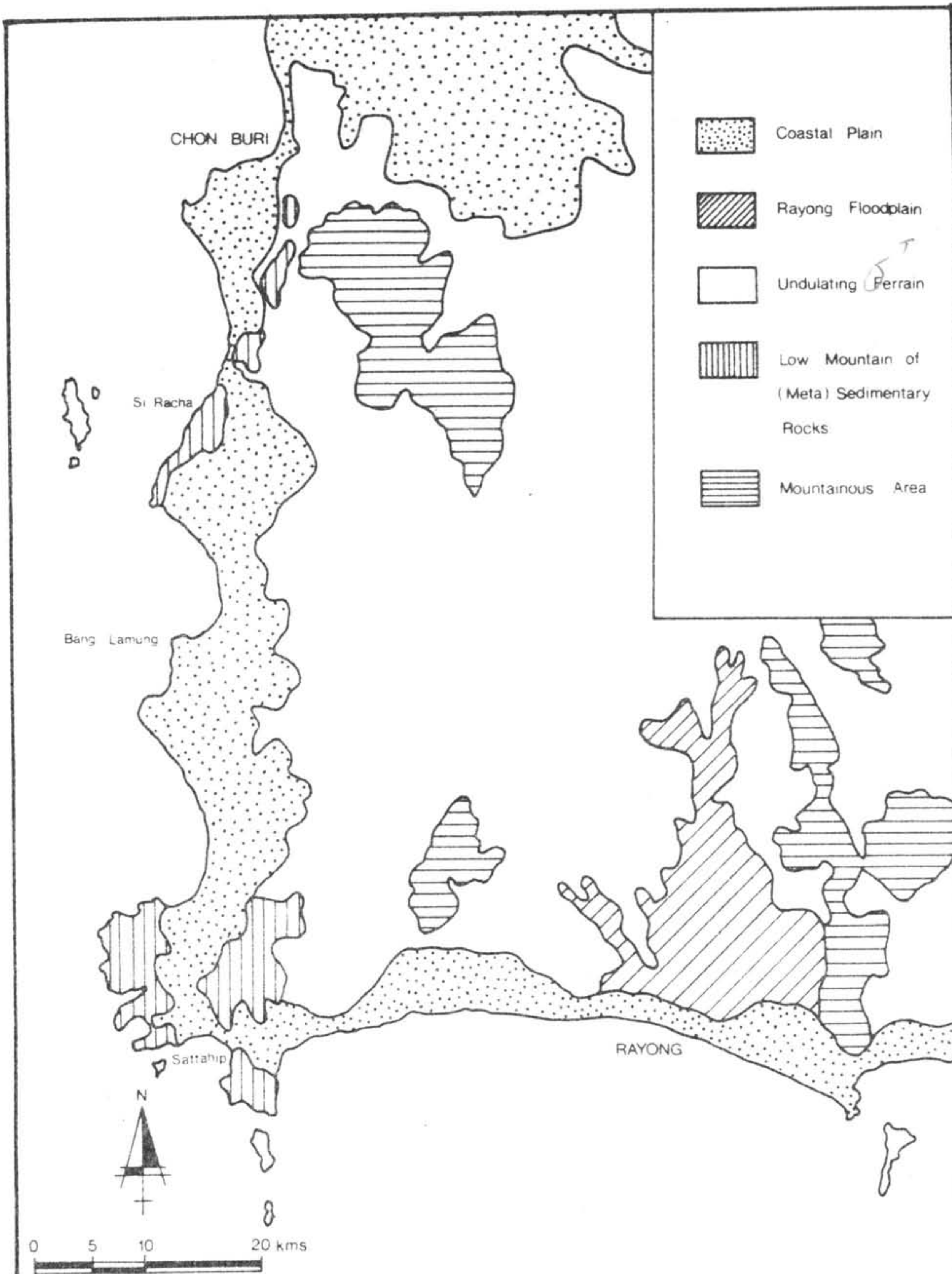
Within the studied area, forest-lands of the granitic mountain ranges of Khao Khieo and Khao Chom Phu including the gneissic rocks of Khao Khun In - Khao Taphao Kwam play an important role in continued supplying and regulating the surface runoff to the adjacent drainage basins.

4.1.3 Geomorphology

The studied area is comprised of low and high mountains ranges, highland, hills, valleys, coastal plains, floodplains. They are conveniently described in terms of 5 physiographic provinces (Figure 4.1.3).

4.1.3.1 Coastal Plain

Coastal plain is the area that closely relates to the marine activities, such as, beaches and tidal flats. This area occupies the western and southern coastline of studied area as long strips. However, the coastal plain between Chon Buri and Sattahip is irregular in size and shape bordering several bays alternated with hills of metasedimentary rocks. The plain in the northern part of Khao Khieo (in the vicinity of



GEOMORPHOLOGIC UNITS WITHIN THE STUDIED AREA

ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND

DEPARTMENT OF GEOLOGY, GRADUATE SCHOOL CHULALONGKORN UNIVERSITY | SUNYA SARAPIROME | FIG. 4.1.3

Amphoe Ban Bung and Amphoe Phanat Nikhom) and narrow strips in southern coast extending from Ban Kong Phet to Ban Phe are also included in this one. The elevation of this area is usually not over than 40 meters above the mean sea level, with slope of about 0-5 per cent.

4.1.3.2 Rayong Floodplain

This physiographic province occupies relatively small areal extent in the studied area. This is basically due to the lack of the well developed streams and rivers. Generally, the topography of studied area is rather mountainous with only afew small and short stream of youth stage developed.

The floodplain is confined to the Rayong river. It starts from the north at Amphoe Ban Khai and flows southwardly to the sea at Ban Pak Klong, Amphoe Muang Rayong where the sand spits occur. The area extends approximately 10 kilometers in length with the maximum width of about 8 kilometers. The elevation of this province is about 20 meters above the mean sea level with slope of approximately 0-2 per cent. Both sides of this province are narrow strips of terrace deposits without conspicuous feature.

4.1.3.3 Undulating Terrain

This province occupies relatively larger part of approximately 50-60 per cent of the studied area. The terrain is predominantly developed in the central part extending from the south of Khao Khieo and Khao Chomphu to the coastline adjacent to Rayong floodplain and

Khao Suan mountain ragne in the east. In this province, there are some low granitic mountains and hills distributed as the trend extending from Khao Chomphu in the southwardly and south-southwestwardly directions. Dominant characters of undulating terrain are wave-like topography of irregular elevation with only small relief. The directions of channel course in this province are diversified. This type of physiographic province is usually developed in prolonged weathered terrain of homogeneous rocks. Lateritic beds are commonly found at depths between the ground surface and the bed rock in some part of the area particularly in the high relief region.

The elevation of the province is ranging from 40-200 meters above the mean sea level with slope of about 2-10 per cent.

4.1.3.4 Low Mountain of (meta) Sedimentary Rocks

This province scatteringly distributed along the coastline between Chon Buri and Laem Chabang as well as cluster around Amphoe Sattahip. These hills and low mountains are mainly composed of metasedimentary rocks. The relative age is older than Khao Khieo and Khao Chomphu granites, which are believed to partly responsible for the metamorphism of overlying sediments. Almost all of the metasediments form low mountains and hills because they are relatively more resistant to chemical tropical weathering as compare with granitic rocks. Along the coastline, they are confined to the area of headland, such as, Laem Chabang, Laem Pattaya, Laem Kham, etc. The metasediments roofpendent play an important role in protecting the underlying granite to weathering and erosion particularly at the headlands. In the areas where metasediments are absent, the granitic rocks have been intensely weathered and eroded. As a consequence, almost all the bay regions along the headland are developed.

Khao Choeng Thian, Khao Phu, Khao Yai Li, Khao Krok Tabak and Khao Chalak, in the vicinity of Bang Phra reservoir, connect with the range of Khao Yai, Khao Phoe Bai, Khao Laem Chabang at Siracha. This mountain range is in north-northeast direction which is also parallel to the regional strike of country rocks and dipping to west. Around Amphoe Sattahip, this province is consisting of many small reticulate valleys. Country rocks exhibit complex folding of more than one episode and their attitude of the bedding planes are generally confused. However, the main strike direction is in the north/south direction and generally dipping to the east. The area in western and southern sides of Sukhumvit road starting from Laem Kham to U-Taphao Airport is the Royal Thai Navy reserved area, so the field investigation programme and data acquisition are prohibited.

The elevation of this province is between 100-300 meters above the mean sea level and the slope is about 5-35 per cent.

4.1.3.5 Mountainous Area

The mountainous area obviously exhibits in the north and east sections of the studied area. In the north, pluton of acidic rock intruded and formed the dome-shaped with its peaks at Khao Khieo and

Khao Chomphu. The peaks are gradually sloping down to the undulating terrain in the central part of the area and elevated again at Khao Khrok mountain range northeast of U-Taphao Airport. North of these peaks, the slope is suddenly changed to the relatively flat coastal plane. Khao Khieo is located approximately 10 kilometers away from the nearest coastline occupying some parts of 3 amphoe in Chon Buri, namely, eastern part of Amphoe Muang Chon Buri, sonthern part of Amphoe Ban Bung, northern and eastern part of Amphoe Siracha. It is the greatest and highest mountain of the studied area with the peak height of 798 meters above the mean sea level. Khao Chomphu is also a high mountain with the peak height of 725 meters above the mean sea level. The area of Khao Khieo and Khao Chomphu has general slope about 15-40 per cent.

In the eastern section of the studied area, this province is characterized by the mountain range of gneissic rocks in the north/south trend with several peaks, for instance, Khao Khun In, Khao Thasoa, Khao Saba, Khao Tha Chud and etc. Their peak heights are varied in the range of 300-700 meters above the mean sea level with slope of about 15-35 per cent.

4.1.4 Slope

Among the various factors, the information about slope steepness is considerable important in land management. It can provide the critical restricting factors for land-use planning which are particularly pertinent in the cases of transport and agriculture. In addition, the slope characters coupled with the nature of materials and vegetation that cover the area can be used in the assessment on the potential of slope failure or its stabiliby. Slope map is one of a valuable tool ading in selecting where the building pads and transportation route should be situated and where the limit in physical ability of heavy equipment used in cultivation is limited. In economic aspect, without considering the slope character of areas used for those activities, the time and money will be wastefully lost. Besides, the slope character may be used as the parameter to permit or regulate development on hill side areas while the minimizing water runoff and soil erosion problems are in need. Some critical slopes are given in Table 4.1.4 which base on a review of available data by Crofts (1973).

In the present investigation, the slope character is classified, according to the suggestion of Crofts, into 5 categories of: 0-2 %, 2-5 %, 5-10 %, 10-20 % and 20 + %. The slope map of the studied area is illustrated in Plate 4.1.4. The area with land slope of 2 per cent or less covers about 33 per cent of the studied area. The flattest slope are mainly developed on the Rayong floodplain and the coastal plain. Besides, they occur as isolated areas on the highland. This category of landslope on the plains are usually subject to flooding, poorly drained and generally have a relatively high water table. Soil stability is generally good excluding the tidal flat.

The area with slope of 2 to 5 per cent constitutes approximalely 43 per cent of the studied area. It is predominantly restricted on the gentle to undulating terrains that cover main part of the studied area.

Table 4.1.4 Critical Slope Categories.

Steepness per cent	Critical for
1	International airport runways
2	Main-line passenger and freight rail transport
	Maximum for loaded commercial vehicles without speed reduction
	Local aerodrome runways
	Free ploughing and cultivation
	Below 2 per cent-flooding and drainage problems in site development
4	Major roads
5	Agricultural machinery for weeding, seeding
	Soil erosion begins to become a problem
	Land development (constructional) difficult above 5 per cent
8	Housing, roads
	Excessive slope for general development
	Intensive camp and picnic areas
9	Absolute maximum for railways
10	Heavy agricultural machinery
	Large-scale industrial site development
15	Site development
	Standard wheeled tractor
20	Two-way ploughing
	Combine harvesting
	Housing-site development
25	Crop rotations
	Loading trailers
	Recreational paths and trails

Source : Crofts (1973).

The drainage is relatively good with a rather high degree of soil erosion as sheetwash owing to the loose surficial sediments as well as the cultivation of cassava in almost all of this land. The sediments of streams and rivers are deposited and the valleys are filled.

The landslope of 5-10 per cent covers about 11 per cent of the studied area. The areal extent of this slope class is generally associated with the footslope of hilly and mountainous land. It is indicated that integrated deposition from slopewash, runoff and streams should be predominantly occurred. The texture of sediment particularly regarding grain size is usually composed of rock cobble, boulder mixed with sand, silt and clay. However, the erosion still be intensively active particularly to the fine-grained sediments on nonvegetated land of granitic and gneissic mountainous area.

The area with slope between 10 and 20 per cent covers about 8 per cent of the studied area. They mainly occur on the midslope of the mountainous and hilly area. Generally, they are the highly susceptible to erosion particulary by means of gullying if the plant cover is removed. In this slope category, the erosion process plays a significant role while the deposition process is believed to be absent. Therefore, the thickness of soil cover or depth to bed rock on this land is comparatively thin. Fortunately, almost all of this land is covered by forest except that of Khao Khrok mountain range which may be susceptible to erosion owing to the deforestation of the area.

The area with slope excess 20 per cent, the steepest category, covers about 5 per cent of the studied area. They mainly occur on the granitic and gneissic mountainous area as well as isolated patches hilly area of sedimentary terrain. This slope category land will, undoubtedly, create numerous problems on development largely due to the slope stability. If the area with high slope is disturbed by construction processes or forest removal, widespread failure is highly probable. Besides, there is a high potentials of rockfall occuring on the metasedimentary mountainous area facing the sea. The wave erosion increases their steepness of the cliff and rockfall is consequently intensified. Khao Laem Chabang is an example of this case. In granitic and gneissic mountainous area, the problems of erosion and rock fall are insignificant due to the relatively dense vegetative cover.

So far there has been no report of the hazard from slope failure within the studied area. This is probably due to the following reasons: the slope character of the studied area is generally less susceptible to slope failure; there is no evidence of serious earthquake occurring in the area; the human activities are presently intensive on the gentle slope land while on the steep slope land is preserved for forestation; and human activities have never been yet disturbed to the equilibrium of slope. These activites include undercutting by construction processes, rising of groundwater table along the banks of a reservoir to trigger slope failure, and devegetation on the land of forest cover.

4.1.5 Existing Land Use and Land Cover within the Studied Area

The meaning of land use and land cover are not quite similar but their concepts are closely related and in many cases, including the present investigation, have been interchangeably. The land use means "man's activities on land which are directedly related to the land" (Clawson and Stewart, 1965), while, the land cover, on the other hand, describes "the vegetational and artificial construction covering the land surface" (Burley, 1961). The existing information concerning both land use and land cover is needed in the regional development planning and management. More or less, it is believed that one of the prime prerequisites for better use of land is information on existing land use patterns and changes in land use through time.

The land use and land cover classification system employed in this investigation (Table 4.1.5) is dealing with the more generalized first and second levels of categories. This is modified after Anderson, Hardy, Roach and Witmer (1976). Generally, these levels of classification should be mostly suitable for regional development planning with respect to the natural factors. Within the studied area, the modification of land use and land cover information in part of Chon Buri based largely on the original data within the land-use map of Chon Buri (1979) whereas in part of Rayong, data are based on the land-use map of the Central Plain of Thailand (1974). The investigations of both areas are undertaken by the Land Classification Division, Land Development Department. The land-use and land-cover map of the studied area is illustrated in Plate 4.1.5

Table 4.1.5 Land use and land cover classification system within the studied area.

Level I	Level II
1. Urban or buit-up land	11. Residential
	12. Comercial and services
	13. Industrial
	14. Transportation and communications
	15. Institutional land
2. Agricultural land	21. Field crop land
	22. Perennial crop land (and horticultural land)
	23. Confined feeding operation
	24. Paddy land
	25. Mixed agricultural land
3. Rangeland	31. Tropical grass and unimproved pasture and rangeland.
	32. Shrub rangeland
4. Forest land	41. Deciduous forest land
	42. Evergreen forest land
5. Water	51. Reservoirs
6. Wetland	61. Forested wetland
	62. Nonforested wetland
7. Barren land	71. Dry salt flat
	72. Idle land, beaches and sand dunes

Table 4.1.5 cont.

Level I	Level II
8. Mixed categories land	81. Field crop land and tropical grass rangeland
	82. Field crop land and shrub rangeland
	83. Field crop land and deciduous forest land
	84. Perennial crop land and tropical grass rangeland
	85. Paddy land and tropical grass rangeland
	86. Paddy land and shrub rangeland.

Following to the Table 4.1.5 and Plate 4.1.5, there are 8 and 25 categories of first and second level, respectively. They are described in more detail in the foregoing passage.

The urban or built-up land is comprised of areas of intensive use with much of the land covered by structures. Included in this categories are cities, towns, villages, strip development along high way, transportation and communication facilities, and area such as those occupied by institutional, industrial and commercial complexes. The urban land occupied about 5 per cent of the studied area. Its prominent feature shows as the discontinuous strip along the coastline as well as along Sukumvit road and the Rayong floodplain. In addition, the built-up land it distributed as villages and estates on the highland. On the western coast, Chon Buri, it seems to be more concentrated than any other parts.

Among the first level of the land-use categories within the studied area, the agricultural land covers the widest extent which is approximately 81 per cent of the area. This category can be divided into 5 classes of the second level, notobly, field crop land, perennial crop land, confine feeding operation, paddy land, and the mixed agricultural land. The agricultural land is mainly represented by the field crop land of particularly cassava cultivation excluding the extreme east of the studied area where the land is characterized by rubber plantation and fruit orchards cultivation. However, the other types of agricultural land are found scatteringly, such as the orchards of mango, coconut, banana and etc. are usually cultivated in the lower land where the moisture is higher. The paddy land is mainly present in Rayong floodplain and covering parts of the western plain as strips along the streams further landward beyond beaches and dunes. The confine feeding operation within the studied area is predominantly the poultry farms which are generally scatteringly cover relatively small areas in the vicinity of Chon Buri township, Ban Bung and Phanat Nikhom. The mixed agricultural lands include perennial and field crop, perennial crop and paddy field, as well as field crop and paddy field. This class of land is difficult to separate from each other.

The rangeland has been defined as land where the potential natural vegetation is predominantly tropical grasses, shrubs and unimproved pasture. The aereal extent is approximately 0.5 per cent of the studied area. The rangelands dispersely cover relatively smaller areas around the up-stream side of reservoirs as well as some parts of the coastline.

The forest lands mainly occupy the mountainous areas and lessly on the beaches with the total coverage of approximately 9.6 per cent of the studied area. They can be divided into 2 classes of the second level, namely, deciduous forest and evergreen forest. Most of them are deciduous forest on the mountainous and hilly areas whereas the other is the pine plantation on beaches. In addition, the forest land within the studied area seems to decrease in areal extent with time due to the ever-increasing need of cultivated area, and illegal deforestation is widely practice.

The areal extent of water lands or the land covered by reservoir within the studied area are about 0.8 per cent and this figure tends to be increased in the future as a result of the censtruction of Nong Kho reservoir in the vicinity of Siracha, including the several other reservoirs which have already been planned to be constructed in the near future. Those ones include Nong Pla Lai, Klong Yai and Khlong Thup Ma projects which their total design storage are 178 million cubic meters. In addition, the area cover by Ban Bung reservoir will be expanded from the storage capacity of 2 million cubic meters to 10 million cubic meters. The expansion planning, starting in 1982, is undertaken by Japan International Cooperation Agency (JICA). Besides, the small lakes or ponds within the studied area particular on the extreme north and the vicinity of Amphoe Phan Thong are present. But they are too small to delineate on the map.

Wetlands are those areas where the water table is at, near, or above the land surface for a significant part of most years. In the wetland, the aquatic or hydrophytic vegetation such as nipa and mangrove are usually established despite the fact that some marshes and the shallow margin of river estuary may be nonvegetated. The wetlands cover approximately 1.2 per cent of the studied area. They are frequently associated with topographic lows or the depression area, for instance, the actived and/or the old tidal flat in the north and south of Chon Buri township, the shallow margin of Khao Sam Muk Bay and of Rayong estuary including the scattered marshes and swamps along the coast of Rayong Bay. Unfortunately, the tidal flat south of Chon Buri township has just been artificially filled for supporting the need of unban land.

Barren land is the land of limited ability to support life and in which less than one-third of the area has vegetation or other cover. This type of land covers about 0.3 per cent of the studied area. They exist as the dry salt flats that are closely related to the tidal flat in the north of Chon Buri township. Besides, they appear as narrow strips along the beach at Laem Chabang, and behind the mountains at Laem Kham.

According to the unability on individual separation of the areas which are used and covered by various categories, the mixed categories land, the first level category, is designated with 6 classes of the second level, namely, field crop and troprical grass rangeland, field crop and shrub rangeland, field crop and deciduous forest land, perennial crop and tropical grass rangeland, paddy land and tropical grass rangeland, and finally, paddy land and shrub rangeland. They scatteringly occupy as patches of diversified size and shape with approximately 1.6 per cent of the total studied area.

4.2 Geological Setting of the Studied Area

The geological setting of the area in the foregoing passage is essentially compiled from a relatively limited information of previous investigations and additional data obtained from the present field survey.

The prominent feature of the area is revealed by a large batholith of acid rock which occupies the mountainous terrains, the gently sloping hills and also the undulating terrains of the central part. With reference to the radiometric age determination, this acid rock is regared as belonging to the range of Upper Triassic to Lower Jurassic (NEDECO, 1971) or 220 $\pm$ 13 ma. of Rb/Sr age (Suensilpong et al., 1981). The granite batholith is believed to intrude into the older Palaeozoic rocks which inturn exhibit a core of east and west folded flanks of a major anticlinal structure. Contact metamorphism is widely present in the region. From the geological map and report of Nakinbodee and his colleaques (1976), the east flank is underlain by the north/south trending of inferred Precambrian gneisses and schists as well as the unconformable overlying Permo-Carboniferous sedimentary sequences. The latter is particularly exposed on the southeastern corner of the studied area, and comprises predominantly of conglomerate, tuffaceous shale, chert, and red sandstone, mudstone and pebbly sandstone. The west flank, on the other hand, is covered by relatively thin remnants of older sedimentary rocks which were subjected to both regional and contact metamorphisms, now forming the sequence of sedimentary rocks and their metasedimentary and metamorphic equivalents. These rocks are essentially folded and interbeded sandstone, siltstone, quartzite, shale, mudstone, chert, slate, slaty shale, phyllite, phyllitic shale and quartz (mica) schist; mainly intercalated with calc-silicate rocks, hornfels, marble, dolomitic marble, banded or laminated crystalline and argillaceous limestone. On the bases of lithological similarity and additional fossil content, especially of limestone at Ko Si Chang, the sequence is, therefore, more likely to be considered as belonging to Ordovician age.

The rest of the area, however, is covered dominantly by Quaternary alluvial and terrace deposits.

Structurally, the large granite batholith displays as a core of folding of older rocks, as distinguished from a major anticlinal structure across its east and west flanks. The north/south trending of mostly dipping east inferred Precambrian rocks and the unconformable overlying sedimentary and metasedimentary sequences further east are exposed on the east flank. Lying on the west flank are the remnants north-northeast and north/south trendings of folded sedimentary and their metasedimentary and metamorphic equivalents, most probably of Ordovician age. Most of these rocks in the northern part dip westward whilst those in the southern part with intense folds having regional north/south striking are observed. Unconformities are obviously obscured mainly because of erosion and weathering, and are subsequently concealed by the younger sediments. Faults are presumably widely present. In the northern part of Amphoe Klaeng area it might possibly be a large weak zone, as deduced from the distributions of post Permian faults associated with the discontinuous exposures of granite intrusions from Khao Hin Son, Amphoe Phanom Sarakham, Changwat Chachoengsao southward to Khao Chamao, Amphoe Klaeng, Changwat Rayong. The sketched generalized geological map of the studied area is compiled and illustrated on Plate 4.2.1.

The geological history, based partly on Nakinbodee et al. (1976) and partly modified by the present investigation, can be deduced as follows:

The sedimentary record began in Ordovician time which was restricted mostly to the western part of the studied area. The sediments are principally clastics with subordinate nonclastics of both bedded chert and carbonate rocks, now forming relatively thin remnants of sedimentary rocks and their metamorphic equivalents. The younger Palaeozoic depositions were thought to commence in Silurian period and probably continued throughout the closing period in Carboniferous. These clastic and carbonate sediments were deposited on the gneiss and schist Precambrian (?) basement apparently exposed in the eastward for beyond the studied area which now forming thick Silurian-Devonian metamorphic and Carboniferous clastic-carbonate sequences.

During the period of Carboniferous the area might be affected by the Hercynian orogeny possibly during Middle Carboniferous, resulting in foldings and regional metamorphism of the pre-existing rocks, Subsequently, part of the area was subsided and invaded by sea, accompanied by deposition of the clastic and carbonate sequences of the Permo-Carboniferous and Permian ages, especially in the eastern portion of the studied area. The depositions were then interrupted by the Indosinian orogeny which took place during Upper Triassic-Lower Jurassic, causing extensive granite intrusion and its associated volcanic episode. There exist, however, no records of Mesozoic and Tertiary depositions within this area. The final record was the formation of Quaternary alluvial, terrace and coastal deposits which, in the present day, cover most of the northern, western and southern coastal parts of the studied area.

4.2.1 Precambrian (?) Basement Complex

The oldest rocks in the eastern part of Thailand, which are also exposed mostly in the eastern part of the studied area, are exclusively, metamorphic rocks. They consist essentially of gneisses, amphibolites, calc-silicate rocks, quartz-mica and quartz-kyanite schists. Gneisses commonly form mountain ranges with north/south and northwest/southeast trendings, notably, Khao Khun In., Khao Urang, Khao Na Yak, Khao Nguang Chang, Khao Tha Chut and Khao Taphao Khwam. In contrast, schists are dominantly exposed as hills oriented approximately parallel to the gneissic trends.

Numerous investigations regarding to the Precambrian rocks were carried out by many workers. Buravas (1948) recognized the Precambrian gneisses and schists on the basis of their higher grade of metamorphism, as compared with the known "old age" rocks. Brown et al. (1951) described the Precambrian gneissic rocks in Chon Buri and Rayong provinces as forming extensive outcrops of orthogneisses, consisting of banded micaceous granites with conspicuous augen or porphyroblasts of feldspars. Buravas (1959) commented that Phanom Sarakham schists, gneisses and schists, granite, granite gneisses and gneissic granites as well as the Si Chang Limestone and Si Racha Quartzite fall within the Precambrian

Units. Subsequently, most of these rocks have been remapped by Javanaphet (1969) and they have been designated as belonging to the Palaeozoic rocks, ones are of pre-Permian age and the others are Silurian-Devonian rocks. Based primarily on the lithological map of this region prepared by Siriphokakit and Wongsawat (1972), it is revealed that the areal extents of gneisses and schists in the vicinity of Chon Buri and Rayong provinces are not large or continuous as indicated by Brown et al. (1951). Workman (1972) pointed out that the high-grade metamorphic rocks-gneisses and crystalline schists - collectively make up what may be called the basement complex which is probably Precambrian, but some of the less strongly metamorphosed members may be of Lower Palaeozoic age. In addition, Workman has proposed the term for rocks in this area as 'Cholburi massif' consisting of quartzo-feldspathic gneisses, migmatites and granites of various kinds. He emphasized, however, that within and marginal to the granite-gneiss area are bands of low-grade metasedimentary rocks which are placed in the Lower Palaeozoic. Suwanasing (1973) mentioned that there exists Precambrian gneiss and schist in this studied area, especially biotite-muscovite paragneisses and associated mica-schist in forms of injected bodies in many places.

However, Campbell (1975) postulated that the term "basement complex" is closely related to Precambrian rocks but not all basement complexes exposures are made of 100 per cent of Precambrian rocks. Many of large bodies include igneous rock derived from Carboniferous and younger intrusive events have locally been incorperated into the basement complex. Neither can it be said that all of the metamorphism producing the gneisses and schists of the basement complex took place in Precambrian times.

As reported by Nakinbodee et al. (1976), the inferred Precambrian rocks are considered to be existed in this present studied area. Their trends are north/south and northwest/southeast, extending from Phanom Sarakham occupying most of the mountain ranges in the eastern part of Khao Khieo southward to Ban Phe coastline, ending at Ko Samet. They comprise mostly of biotite gneiss, orthogneiss, hornblende-biotite gneiss, amphibolite, quartz-mica and quartz-mica-kyanite schists including pyroxene-garnet granulite.

4.2.2 Palaeozoic Sedimentary Rocks and Their Metamorphic Equivalents

The exposed Palaeozoic sedimentary, metasedimentary and metamorphic rocks are restricted mostly to the western part of the area under consideration, especially along the coastline between Chon Buri and Sattahip. Less extents are those exposed on the offshore islands westward. Only a limited portion of Permo - Carboniferous rocks are reported to extend to the southeast extremity. Interbedded sequence of quartzite, quartz-schist, sandstone, siltstone, metasandstone and siltstone, slate, slaty shale, phyllite, phyllitic shale and mudstone; occasionally intercalated by calc-silicate rock, spotted slate hornfels marble, dolomitic marble, dolomitic and argillaceous-flaser limestone charactenizes the rock units on this western part. This sequence is more likely believed to be Ordovician in age on the basis of lithological similarity, particularly of argillaceous-flaser limestone, as compared to the known Ordovician limestone elsewhere in the country. Moreover, the nautiloid Multicameroceras (?) sp. in limestone found by Nakinbodee et al. (1976) at Ko Si Chang indicates the age of Lower to Middle Ordovician (?). In addition, Workman (1972) stressed that the crystalline dolomitic limestone at Ko Si Chang is speculatively correlated with Ordovician limestone of the Thai-Malay peninsula, and proposed also that phyllite, quartzite and limestone which are associated with the so-called 'Cholburi massif' which appear to be partly folded into it might belong to the Lower Palaeozoic age.

The question has been arisen when Nakinbodee and his colleaques mapped this region. They found the fusuline fossil Pseudofusulina of regularis in limestone which is interbedded with fine-grained sandstone, chert and shale at Khao Rewadi, nearby Bang Phra Reservoir (5135 II (131604)). This fossil indicates that the limestone ranges in age from Upper carboniferous to Lower Permian. This led Salyapongse, in his one of the other criteria, to conclude that this sequence should characterize part of the Permo-Carboniferous rocks (personal communication). However, he also pointed out that the Cambrian sequence should feasibly be included in this metasediment unit but it is not possible to delineate its boundary and those of the Ordovician rocks. His assumption is accordingly that those of the older facies comprising more sandstone and quartzite should probably be the Cambrian rocks whereas those consisting of some carbonate facies should possibly be the Ordovician rocks.

The tentative lithological columnar sections shown in Plate 4.2.2 represent the regional stratigraphy of the investigated area, as being drawn from Ko Si Chang, Khao Choeng Thian-Khao Laem Chabang range and in the vicinity of Sattahip area.

In conclusion, evidences from the previous investigations and the present investigation for the sequence of rocks that exposed along the Chon Buri - Sattahip coastal belt reveal that the age of these rocks is still problematic and debatable. The reason for this is due largely to the extremely rare fossil content in character coupled with the metamorphism which inturned masking the relative age determination.

4.2.3 Quaternary Deposits

The Quaternary deposits in the studied area are composed predominantly of unconsolidated clastic sediments of fluvial and marine origins. Most of these sediments are deposited in the intermontane and coastal plains which are flat to slightly rolling in nature.

The lower part of the sequence is characterized by high and low terrace deposits, laterite, gravel, sand, silt and clay of both fluvial and marine origins. The upper part comprises mainly alluvium and beach sand which are practically found on the active flood plains of larger rivers and on the recent beaches respectively. The latter type is relatively more limited in areal extent as compared with the former.

4.2.4 Triassic Granites

The batholith of granites is largely exposed in the central part of the studied area, now forming high mountains, for instances, Khao Khieo, Khao Chomphu, Khao Kata Khwam, Khao Chom Hae and Khao Khrok. The exposures are also sporadically distributed. The intrusion of granite into the Palaeozoic rocks west of the batholith is apparent along the Chon Buri - Sattahip coastal belt.

This granite is characterized by coarse-grained porphyritic texture of adamellite type. In the central part of the batholith it appears to be more porphyritic and leucocratic as compared with those in the marginal zone. Locally, xenoliths of various sizes have been reported. Its contact to the country rocks is obvious at Khao Chi Chan in the vicinity of Sattahip area, and it indicates that the granite was in the condition of very low temperature when intruded.

The age of this granite had long been questioned but recently radiometric age determination seems likely to solve the problem. It is originally indicated on the geological map of Thailand, scale 1:1,000,000 (Javanaphet, 1969) that this granite is in the age of Carboniferous. Whole rock Rb/Sr and K/Ar ages as determined by Burton and Bignell (1969) of the two-mica adamellite from Khao Taphao Khwam are 272 ± 14 my. and 72 ± 3 my. respectively. This locality, is unfortunately not fall within the granite batholith in this discussion. They concluded, however, that the Rb/Sr age determination is believable to indicate the orignal intrusion. The report of NEDECO (1971) regarded this batholith as in the range Upper Triassic to Lower Jurassic. Thanasuthipitak (1978) reviewed that the granitic rocks in this region are of Carboniferous and Triassic ages. Lately, Suensilpong et al. (1981) attributed, on the basis of radiometric age dating, this granite batholith to the age of Triassic.

Nevertheless, with regard to the age of this granite batholith most of the recent studies tend to believe that it is more likely to be the Triassic age. It is convinced according to some proposals that there might have two phases of intrusion to form this batholith, viz. in Triassic and in Carboniferous. The author conceivably agrees with the discussions of NEDECO (1971) and Suansilpong et al. (1981).

4.3 Mineral Resoures

Considering the potential mineral resources within the studied area, it is unfortunately low as compared with any other region in Thailand. However, the potential mineral resources in neighbouring areas are very promising. The possibilities of exploiting diversified mineral resources in neighbouring areas to meet the raw material demand of existing and future industries within Chon Buri and Rayong area are most feasible. Therefore, an attempt has been made in this study to present not only mineral resources within the studied area, but also to incorporate all other mineral resources in neighbouring area wherever the mobilization of these resources is possible. In this study, the mineral resources are classified into 4 groups, notably, metallic minerals, non-metallic minerals, construction materials and fossil fuels. Detailed discussion regarding this matter is presented in the foregoing section and illustrated in Plate 4.3.

4.3.1 Previous Investigations

In 1959, Agocs of Aero Service Corporation presented the preliminary and tentative interpretation report including supplementary report on qualitative analysis of aeromagnetic survey of three area, namely, north central-Loei or Chiang Khan central-Nakhon Sawan and in south central Chachoengsao. After the aerogeophysical survey, the Thai Geological Survey, Royal Department of Mines (1959) carried out investigations on the occurrence of ferro-magnetic mineral deposits at Cha Choengsao and Chon Buri provinces. Suwanasing (1963) prepared the report on geochemical exploration of tin in granite mountain ranges of Chon Buri, Rayong and Chanthaburi. These mountains are Khao Khieo, Khao Cha-Mao, Khao Sa-Bab including Khao Soi Dao Nua and Khao Soi Dao Tai, located in Chon Buri, Rayong and Chanthaburi, respectively. From the analytical results, he concluded that these areas show promising values of tin for further detailed surveys. In the year 1972, Phungrasami and Wasuwanich carried out the investigations on clay deposits in Nakhorn Nayok, Prachinburi, Saraburi, Chon Buri, Rayong, Chanthaburi and Trat. This report is very meaningful for ceramic industry. Suwanasing (1973) presented the report on geology and mineral deposits of the Eastern Thailand. Suwanasing (1976), Japakasetr and Workman (1978), and Japakasetr (1978) conducted the investigations on evaporite deposits with particular emphases on rock salt and potash, of Northeastern Thailand. They presented the distribution and natural occurences of rock salt and potash minerals within the area, and some probable reserves will be evaluated after the drilling programme. Besides, several other reports on local investigations on geology and mineral deposits are available.

4.3.2 Metallic Minerals

The metallic minerals include iron, antimony, copper, gold, manganese, molybdenum, tin, nickle and lead. Almost all of these metallic mineral deposits are found outside the studied area particularly in the north, northeast and the east. It is noted that these mineral deposits are reported on the bases of preliminary mineral exploration programmes, detailed study on each of these deposits remains to be investigated. Existing information on the prospect of each metallic mineral is as follows:

4.3.2.1 Iron Deposits

There is only one known iron deposit at Khao Chi-On in the studied area, whereas the other 22 deposits are found in neighbouring areas, particularly in the vicinity of the border zones between Chachoengsao/Prachinburi and Rayong/Chanthaburi provinces. At the present stage of knowledge, all these deposits are small and sporadically distributed. They are mainly contact metasomatic and residual lateritic in origin. However, deposits of other origins, namely, float ore, metamorphic, hydrothermal, etc. are also reported. Most of the iron ores occur in the forms of magnetite and hematite.

In the future, there is a programme to set up iron and steel plants within the studied area using imported iron ores in the initial stage. However, the local iron deposits could possibly be developed in the future to reduce the large tonnages of imported iron ores.

Detailed information on iron deposits within the studied area and relevant neighbouring areas is summarized and tabulated in Table 4.3.2.1.

4.3.2.2 Antimony Deposits

Despite the fact that there is no antimony deposit within the studied area, 5 economic deposits and one subeconomic deposit are found

Table .4.3.2.1 The iron deposits within the studied area and the neighbouring areas.

Location				Ore association	Type of deposit	Grade and Reserve	Development and Production	References	Remarks
Ref. no.	Area	Geographic Lat./Long.	Map. Ref.						
Fe 1	Khao Thup-Kwai, Huai Pong, Khok Samrong, Lopburi	14° 58' 50" N/ 100° 39' 30"	5138 IV	magnetite and hematite	contact metasomatic deposit occurs at the contact of a poorly exposed quartz diorite - granodiorite	8 million tons	Open cast mine production not exceeding 100 tons per day	(26)	
Fe 2	Khao Wong, Khok-Kratiem, Lopburi	14° 53' 40" N/ 100° 44' 00" E	5138 IV	magnetite, hematite, Pb minerals, malachite	contact meta somatic deposit, occurs as a dike of 500 m. long and 15 m wide at contact of a diorite or granodiorite with limestone	250,000 tons; 59 % Fe	No information	(8), (26)	
Fe 3	Amphoe Muang, Prachantakham, Prachinburi	14° 02' 20' N/ 101° 24' 50" E	5237 II	lateritic iron ore	laterite deposit of about 8 m. thick located in on old terrace	13.5 million tons, 15-40 % Fe, 17-43 % SiO_2, 12-13 % Al_2O_3; 8.12 million tons not specified	No information	(26)	
Fe 4	Nong Wa En, Si Mahaphoe Prachinburi	13° 48' 34" N/ 101° 37' 44" E	5336 IV	lateritic iron ore	laterite deposit of about 24 feet thick and covered area about 100 square metres	1,618,500 tons containing Fe = 33.59-41.35 % Ni = 0.02-0.97 % Cr = 0.82-2.24 % Al = 3.56-13.45 %	No information	(20)	
Fe 5	Nong Krathum, Si Mahaphoe Prachinburi	13° 47' 40" N/ 101° 45' 25" E	5336 IV	lateritic iron ore	residual concentration of iron from the underlying serpentinite which was found at depth of 16 feet below the iron deposit	641,657 tons of on Fe content 29.24 %	No information	(20)	
Fe 6	Mo Din Daeng, Ban Bu-Phai, King Amphoe Na Dee, Prachinburi	14° 21' 05" N/ 101° 15' 40" E	5337 I	magnetite and limonite	It is hydrothermal and contact metasomatic deposit. Iron rich mineralized solution, from granodiorite and diorite which intruded in Permian sedimentary rock, entered along fractures of country rocks.	iron ore with more than 65 % Fe, 250,000 metrictons	explored by magnetic geophysic survey, pitting and trenching	(15)	

Table 4.3.2.1 (cont.)

Location				Ore association	Type of deposit	Grade and Reserve	Development and Production	References	Remarks
Ref. no.	Area	Geographic Lat./Long.	Map. Ref.						
Fe 7	Noen Hai, Plaeng Yao, Bang Khla, Chachoengsao	13° 35.2' N/ 101° 19.3' E	5236 II	magnetite and hematite associated with pyrite, serpentine	The ore body is of irregular shape, occurs in schist and covering area about 22,400 m^2	Proven ore reserve of 454, 272 tons	No information	(20)	
Fe 8	Nong Bond, Plaeng Yao, Bang Khla, Chachoengsao	13° 31' 32" N/ 101° 22' 41" E	5236 II	magnetite and hematite	It is the sedimentary iron layers of 5-10 in thick in the mica-schist, gneiss and quartzite with some marble	The proved ore reserve is 6.2 million metrictons with average 57.9 % Fe	No information	(20), (26), (27)	
Fe 9	Lad Kro Thing, Phanom-Sarakham, Chachoengsao	13° 35.20' N/ 101° 26.30' E	5236 II	lateritic iron ore with hematite and limonite	It is iron laterite with small pockets and lenses of hematite and limonite	2.5-2.8 million tons of Fe content 25-35 %	No information	(26)	
Fe 10	Nong Sai Ting, Phanom-Sarakham, Chachoengsao	13° 28.6' N/ 101°.28' E	5235 I	magnetite	Magnetite occurs along the schistosity in a "Magnetite schist"	Possible reserve is 5,000 tons	No information	(20)	
Fe 11	Khao Chi On, Sattahip, Chon Buri	12° 46' 00" N/ 100° 58' 00" E	5134 I	magnetic hematite	Shales and limestones have been folded and faulted and subsequently intruded by a gneissoid granite and a aplitic granite. The iron ores occur along a fault plane striking N-S	56,000 tons with Fe content of 52.9-68.37 %	completed survey, temporarily stopped mining	(26)	
Fe 12	Khao Din Daeng, Khao Sra Ta Phrom, Ban Prok Fa, Tha Boonmee, Phanat-Nikhom, Chon Buri	13° 26.6' N/ 101° 25' E	5235 I	magnetite associated with calcium-magnesium silicates.	Muscovite schist with minor bands of granular quartzite are intruded by aplitic dikes. The ore is said to be formed by contact metamorphism	Probable reserve of 485,114 tons; Fe = 64 %, SiO_2 = 0.26-20.9 %	No information	(20)	
Fe 13	Ban Noen Hin, Bo Thong, Phanat Nikhom, Chon Buri	13° 29' N/ 101° 16.55' E	5235 I	magnetite	Magnetite occurs in light brown shale covering an area of about 10,000 m^2	No information	explored by magneto-meter	(20)	
Fe 14	Nong Mai Kaen, Phanat-Nikhom, Chon Buri	13° 25' 10" N/ 101° 30' 10" E	5335 IV	magnetite	Floating ore scatteringly exist on the hill covering an area of 50 x 10 square metres	iron ore with 50-55 % Fe	No information	(7)	
Fe 15	Ban Cham-Khlor, Klaeng, Rayong	12° 48.45' N/ 101° 45.50' E	5334 I	hematite	Floating ore	No information	No information	(20)	

Table 4.3.2.1 (cont.)

Location				Ore association	Type of deposit	Grade and Reserve	Development and Production	References	Remarks
Ref. no.	Area	Geographic Lat./Long.	Map. Ref.						
Fe 16	Khao Thup Klang, Noen Somboon, Klaeng Rayong	12° 46.4" N/ 101° 45.7' E	5334 I	hematite	The iron mineralization occurs as fine grained hematite along the laminations in white quartzite.	No information	Prospect	(20)	
Fe 17	Khao Ta Sao Wai Mia, Wang Pra-du, Ban Kaeng, Thamai, Chanthaburi	12° 57' N/ 101° 52.7' E	5334 I	magnetite with hematite and limonite	Mesozoic granite intrudes Paleozoic limestones and Mesozoic sandstones. The deposit is found overlying a quartzite of Mesozoic sandstones	144 metrictons, average Fe content 61.44 %	Prospect	(20)	
Fe 18	Khao Loi, Amphoe Muang, Rayong .	12° 48' 45" N/ 101° 27' 10" E	5234 I	hematite	Float ore scattered on the hill covering and area of 1 x 2 square kilometres	No information	No information	(7)	
Fe 19	Ban Sang-Kha-Rock, Kra-Chet, Rayong	12° 45' 40" N/ 101° 28' 30" E	5234 I	hematite	hematite is found in mica-schist covering an area of 50 x 10 square metres	iron ore with 40-50 % Fe	No information	(7)	
Fe 20	Khao Ta Nok, Tha Mai, Chanthaburi	12° 41.50' N/ 102° 04.40' E	5434 III	hematite	Hydrothermal quartz-hematite veins are described to cut through a coarse grained granite	No information	Prospect	(28)	
Fe 21	Khao Ta Plai, Ban Pa-Tong, Chanthaburi	13° 08' 10" N/ 102° 10' 20" E	5435 III	magnetite and hematite	Hydrothermal deposit as pockets in the interbedded of shale and sandstone; and floating ore covers an area of 2,000 square metres.	iron ore with 61.61 % Fe, specific gravity 4.37, 46,000 metric-tons	It has been evaluated by geophysical methods and drilling.	(4)	
Fe 22	Ban Chang Wang, Pong Namron, Chanthaburi	13° 01' 35" N/ 102° 23' 20" E	5435 II	magnetite, hematite, malachite and azurite	Contact metamorphic and hydrothermal vein deposit in sandstone and shale including floating ore on 500 m^2-area	iron ore with 61.35 % Fe, spec. gravity 4.38 50,000 metrictons	It has been explored by magnetic geophysical survey and a drilling program.	(5)	
Fe 23	Khao Som, Ban Chang Wang, Pong Namron, Chanthaburi	13° 02' 45" N/	5435 II	hematite	Hydrothermal vein deposit. It occurs as veinlets in quartz vein which cut through sedimentary rocks	iron ore with 53.60 % Fe, spec. gravity 4.12, 10,000 metrictons	It has been explored by magnetic geophysical survey and surface mapping	(2)	

in neighbouring areas of Chon Buri, Rayong, Chanthaburi and Saraburi. All of the antimony deposits are of hydrothermal origin and the antimony ores are in the forms of stibnite and stibiconit. It is interesting to note that almost all of the antimony deposits are aligned in the north-northwest/ south-southeast zone extending from the border of Rayong and Chanthaburi to Bo Thong, Chon Buri in the north. At the present moment, economic exploitation of these deposits have been carried out despite the fact that illegal mining activities have been wide spreadly reported. Detailed exploration programme on these antimony deposits have been obstructed by the inaccessibility to the area due to the security problem on illegal local influences.

Detailed information on these antimony deposits within the neighbouring areas is summarized and presented in Table 4.3.2.2.

4.3.2.3 Copper Deposits

All of the copper deposits are found entirely outside the studied area in Nakhon Rachasima, Chachoengsao and Lopburi. The genesis of these copper deposits are magmatic and metamorphic types where copper ores occur in the forms of malachite, chalcopyrite, azurite, cuprite and native copper. Very little has been done in terms of detailed investigation of these deposits.

The information of these copper deposits is summarized and tabulated in Table 4.3.2.3.

4.3.2.4 Gold Deposits

Within the studied area, the only gold deposit has been reported at Ko Lan in the form of beach deposit. The other 3 deposits are found outside the studied area in the vicinity of Prachinburi, Chon Buri and

Table 4.3.2.2 The antimony deposits within the Neighbouring areas.

Location				Ore association	Type of deposit	Grade and Reserve	Development and Production	References	Remarks
Ref. no.	Area	Geographic Lat./Long.	Map. Ref.						
Sb 1	Khao Khaao-Khao Khok Chang, Phu-Khae, Saraburi	14° 41' 40" N/ 100° 51' 28" E	5138 II	stibnite	Only information available shows that stibnite occurs in a Middle Permian limestones	No information	No information	(1)	
Sb 2	Khao Yai, Bo Thong, Chon Buri	13° 17' 00" N/ 101° 39' 40" E	5335 IV	stibnite and stibiconite	The ore are mainly placer deposits in creek including hydrothermal solution appearing in slate and sandstones in places	No information	No information	(9), (27)	
Sb 3	Khao Cha-Ang-On, Bo Thong, Phanat Nikhom, Chon Buri	13° 14' 30" N/ 101° 35' 30" E	5335 III	stibnite and stibiconite	The main ore deposit is formed by float material ranging in size from 1-150 cm. and covering an area of 200 x 1,000 m. No information about the primary deposit is available.	inferred 125,000 tons of ore in float material	Prospecting	(1), (10)	
Sb 4	Khao Wong, boundary of Tha Mai, Chanthaburi and Klaeng, Rayong	12° 52' 44" N/ 101° 49' 30" E	5334 I	stibnite and stibiconite	Hydrothermal vein deposit formed especially in limestone, structural control as faultzone	No information	Surface scrapping and hand picking	(1)	
Sb 5	Khao Nam Tok and the neighbouring area, boundary of Tha Mai, Chanthaburi and Klaeng, Rayong	12° 53' 38" N/ 101° 43' 54" E	5334 I	stibnite and stibiconite	hydrothermal vein deposit in the interbedded limestone, sandstone and shales. It is controlled by joint and faultzones.	No information	Surface scrapping and hand picking	(14)	
Sb 6	Khao Tha-Lai and Khao Ma-Mia, Tha Mai Chanthaburi	12° 55' 40" N/ 101° 53' 45" E	5334 I	stibnite and stibiconite	Most of the ore materials are found as float on the slopes and related to granite which intruded to sedimentary rocks.	No information	Surface scrapping	(3)	

Table 4.3.2.3 The copper deposits within the neighbouring area.

Location				Ore association	Type of deposit	Grade and Reserve	Development and Production	References	Remarks
Ref. no.	Area	Geographic Lat./Long.	Map. Ref.						
Cu 1	Khao Phra Bath Noi, Khok Kra Thiam, Lopburi	14° 54' 45" N/ 100° 40' 47" E	5138 IV	malachite, azurite, hematite	A granite is observed cross-cutting the limestone country rock and the ore occurs in two brecciated zones each about 6 metres wide. The mineralization is structurally controlled	No information	No information	(23)	
Cu 2	Kha Nong Phra, Pak Chong, Khorat	14° 39' N/ 101° 18' E	5238 II	malachite, azurite chalcopyrite	The copper minerals occur in quartz vein which is cutting through a brecciated zone in a weathered granite.	Cu content of vein approximately 4 %	No information	(23)	
Cu 3	Chan Thuk, Nong Chan Pak Chong, Khorat	14° 46' 35" N/ 101° 28' 25" E	5238 I	Chalcopyrite, malachite and azurite	The ore occurs in a quartz vein which is cutting through a syenite	Cu content 3 %	No information	(23), (18)	
Cu 4	Bo Hin Riang, Pak Chong, Khorat	14° 45' 48" N/ 101° 28' E	5238 I	malachite associated with iron and manganese oxides	Malachite coated in parts of quartz vein which is cutting through mica schist.	No information	No information	(23)	
Cu 5	60 Mine, Khu Yai Mee, Phanom Sarakham, Chachoengsao	13° 38' 45" N/ 101° 27' 30" E	5236 II	Native copper, cuprite, azurite and chalcopyrite.	The copper minerals occur in a mica schist where the mineralization is probably weak zone, syn-depositional or metamorphism	Cu content 0.65-3 %	It has been worked on by pitting	(11)	
Cu 6	Khao Ta Cheed, Khao Ma Pha, Khao Din, Khao Nam Yod, Phanom Sarakham, Chachoengsao	13° 36'- 13° 38' N/ 101° 20' - 101° 25' E	5236 II	chalcopyrite, cuprite, native copper and malachite	The ore seems to occur dessiminated in beds of 10-30 cm and related to quartz vein which intrudes in mica schist	Cu content 1-3 %	No information	(23)	

Rayong where they occur as contact metasomatic deposit, hydrothermal quartz-gold veins and associated stream bed placers, and streambed placers, respectively. Almost all of gold deposits are small and considered to be subeconomic for large scale exploitation. However, panning by local people in these areas have been carried out for a certain period of time. The only gold deposit at Kabinburi, Prachinburi had been successfully exploited during 1954-1957 with 57,842.27 grams of gold metal being produced. At the present moment, none of these deposits has been systematically developed.

The information regarding these gold deposits is summarized and presented in Table 4.3.2.4.

4.3.2.5 Manganese Deposits

The only manganese deposit in the studied area is at Ko Khram where the manganese ores, pyrolusite and psilomelane, occur as sedimentary origin. Besides, the other 2 deposits at Klaeng, Rayong are hydrothermal and sedimentary origins with pyrolusite as the only ore mineral. Some detailed investigations on manganese deposits have been carried out at Ko Khram, Chon Buri and in the vicinity of Ban Ra-Ok, Klaeng, Rayong. The information on these 3 manganese deposits is summarized and presented in Table 4.3.2.5.

4.3.2.6 Molybdenum Deposits

Two molybdenum deposits have been found in the vicinity of Chanthaburi outside the studied area, at Ban Nam Khun and Khao Kra-Chom, Ma-Kham, Chanthaburi. At both deposits, the molybdenum ore occurs as molybdenite in the joints and micro-faults in the granite and associated country rocks. The economic potential of these two molybdenum deposits is considered to be

Table 4.3.2.4 The gold deposits within the studied area and neighbouring areas.

Location				Ore association	Type of deposit	Grade and Reserve	Development and Production	References	Remarks
Ref. no.	Area	Geographic Lat./Long.	Map. Ref.						
Au 1	Bo Thong, Kabin Buri, Prachin Buri	14° 57' 33" N/ 101° 50' 05" E	5336 I	native gold associated with limonite	The gold occurs in porous quartz veins and white sand-stone	No information	Pitting	(24), (19), (21)	
Au 2	Khao Hin Rong, Khao Bo Thong, King Amphoe Bo Thong, Chon Buri	13° 06' - 13° 12' N/ 101° 22' - 101° 30'	5235 II	gold	Hydrothermal quartz gold veins and associated streambed placers. The primary veins seem to be controlled by faults.	No information	Panning	(16), (9)	
Au 3	Laem Haad Thian, Ko Lan, Chon Buri	12° 55' 10" N/ 100° 46' 08" E	5134 I	gold associated with pyrite	Beach deposits, containing nuggets, associated with slates overlain by quartzite	No information	Panning	(12)	
Au 4	Khao Chuk, Klaeng, Rayong	12° 51' 50" N/ 101° 45' 55" E	5334 I	gold	Gold is found in streambed placer deposits probably derived from quartz veins which occur intercalated in shale and schist.	No information	Panning	(12)	

Table 4.3.2.5 The manganese deposits within the studied area and neighbouring areas.

Location				Ore association	Type of deposit	Grade and Reserve	Development and Production	References	Remarks
Ref. no.	Area	Geographic Lat./Long.	Map. Ref.						
Mn 1	Ko Khram, Chon Buri	12° 41' 59" N/ 100° 47' 15" E	5134 II	Pyrolusite and psilomelane and some iron minerals.	The manganese ore occurs in fractures and in beds of sandstone. It also occurs as thick coatings on boulders on the beach.	5,000,000 metrictons	Fitting	(6), (22)	
Mn 2	Ban Sam Nak Thong, Klaeng, Rayong	12° 55' N/ 101° 30' E	5334 IV	Pyrolusite and some iron minerals.	The ores are found in fractures in a phyllite which contains diabase intrusions along fractures. The origin of the deposit is reported to be hydrothermal.	Deposit restricted to a narrow area	No information	(17)	
Mn 3	3 km. from Ban Ra-Ok and Khao Chamao, Klaeng, Rayong	12° 53' 20" N/ 101° 46' 45" E	5334 I	pyrolusite	Boulders of secondary manganese oxides, pyrolusite, occur along a low hill crest. Those boulders have apparently been derived from underlying manganiferrous shales or slate.	The secondary ore contains about 44.40 % Mn. The manganiferrous shale or slate contain about 24.20 % Mn. The deposit area is about 30 m x 150 m.	No information	(27)	

subeconomic. The information of these molybdenum deposits is summarized and presented in Table 4.3.2.6.

4.3.2.7. Tin Deposits

The geochemical exploration for tin in stream sediments of the granite terranes, namely, Khao Khieo, Khao Cha-Mao, Khao Sa-Bab including Khao Soi Dao Nua and Khao Soi Dao Tai reveals interesting anomaly high tin concentrating areas. Besides, cassiterite in significant quantities appear at Khao Klaet, Tha Mai, Chanthaburi. However, the only successful tin development is from beach placer deposit at Map Ta-Pud, Rayong Bay. It is interesting to note that several economic heavy minerals have been reported in the beach placer deposit of Rayong area where active tin mine is in operation. It is believed that some of the granite batholiths in the areas previously mentioned are the primary sources of tin and other heavy minerals.

Detailed information on tin and heavy mineral deposits at Rayong Bay is summarized and presented in Table 4.3.2.7.

4.3.2.8 Nickel Deposits

Two lateritic nickle deposits have been reported in the vicinity of Nong Wa En and Nong Krathum in Ban Tha Kradan Nok, Ban Nong Kham, Simahaphoe, Prachinburi and Ban Makham, Chanthaburi. These deposits are the residual weathered products of the underlying surpentinite bed rock. For the deposit of Ban Nong Kham, Simahaphoe, Prachinburi, the nickel is concentrated in the weathered serpentinite zone with average 4.2 meters thick and the nickle content is as much as 1.07 % in the area of 0.15 square kilometer. For the deposit of Ban

Table 4.3.2.6 The molybdenum deposits within the neighbouring areas.

Location				Ore association	Type of deposit	Grade and Reserve	Development and Production	References	Remarks
Ref. no.	Area	Geographic Lat./Long	Map. Ref.						
Mo 1	Ban Nam Khun, Ma-Kham, Chanthaburi	12° 55' 30" N/ 102° 2' 7" E	5434 IV	molybdenite associated with pyrite	Mineralization takes place along joints and micro-fault in the graywacke as well as along joints in the biotite granite which intrudes the graywacke.	submarginal	It has been evaluated by geo-physical methods and by drilling	(11), (13) (25)	
Mo 2	Khao Kra Chom, Ma Kham, Chanthaburi	12° 58' 50" N/ 102° 00' 55" E	5434 IV	molybdenite associated with pyrite	Mineralization occurs along joints and micro-fault of biotite granite.	No information	prospecting stage	(13)	

Table 4.3.2.7 The tin deposits within the studied area and the neighbouring areas.

Location				Ore association	Type of deposit	Grade and Reserve	Development and Production	References	Remarks
Ref. no.	Area	Geographic Lat./Long.	Map. Ref.						
Sn 1	Map Ta Pud, Rayong Bay	12° 40' 30" N/ 101° 05' - 101° 10' E	5234 III	cassiterite and other heavy minerals	They are found in the granitic wash which spread out over the beach. They are considerably concentrated by waves.	The tin potential is a promising one	placer mining	(27)	
Sn 2	Khao Klaet, Tha Mai, Chanthaburi	12° 42' 30" N/ 102° 02' 25" E	5434 III	cassiterite	The tin occurs in the alluvium and granite wash which formed a continuous sheet around the mountain, especially on the western side.	The tin potential is a promising one	No information	(27)	

Makham, Chanthaburi, geochemical and geophysical exploration reveal that the nickle content of 2.6 per cent in the nickeliferrous laterite covering the area of 400 x 200 square metres (Suwanasing, 1973). Both deposits are small in size and are considered to be subeconomic. The detailed information is presented in Table 4.3.2.1 under the heading Fe 4 and Fe 5

4.3.2.9 Lead Deposit

The only lead deposit within neighbouring area of the present investigation is at Kha Kra Pom and Khao Hin-dad, Ban Bung, Chon Buri. The deposit is characterized by hills consisting of schist which are cut across by quartz veins. Geochemical investigation reveals interesting anomalies of copper, lead and zinc, but unfortunately no further detailed information is available.

4.3.3 Nonmetallic Minerals

The nonmetallic minerals include clay, precious and semiprecious stones, silica sand, dickite, feldspars, barite, potash, rock salt and carbonate potentials. Despite the fact that many of these nonmetallic mineral deposits are located outside the studied area, it is however feasible to develop these resources to meet the industrial demand of raw materials in the area. Furthermore, the plan to mobilize some of these deposits, namely, rock salt and potash as raw materials input for heavy industries at Sattahip - Rayong area has been drawn up and the implementation is expected to be carried out in a very near future.

On this basis, the scope of nonmetallic mineral potential in this study has covered areas not only earlier specified, but also relevant neighbouring area particulary northeastern Thailand

4.3.3.1 Clay Deposits

The clay deposits covered in this study are essentially kaolinite and illite which will be utilized in ceramic industries and as the filler material. The most two important clusters of clay deposits are located in the vicinity of Nakhon Nayok - Prachinburi and the boundary of Rayong - Chanthaburi. There are altogether 7 kaolinite deposits in Nakhon Nayok - Prachinburi area where all of them are residual and/or transported weathered products of felsic extrusives and intrusives. In contrast, the other 9 clay deposits in the vicinity of Royong - Chantaburi boundary are essentially composed of kaolinite and illite of relatively diversified sources rocks, notably, schists, feldspathic sandstone siltstone and granite. The economic production of these clay deposits are almost exclusively limited to those of Nakhon Nayok - Prachinburi area. It is noted that detailed investigations have been carried out for all deposits. The characteristics of clay in each of these deposits are summarized and presented in Table 4.3.3.1.

4.3.3.2 Precious and Semiprecious Stones

The precious and semiprecious stones present in the neighbouring area of the study include corundum, garnet and topaz. The deposits are believed to be mainly in the forms of colluvium, eluvium and alluvium of

Table 4.3.3.1 The characteristics of clay deposits within the studied area and the neighbouring areas.

Ref. no.	Location			Type of Deposit	Reserve (tons)		Chemical Composition												Color after firing				Firing shrinkage (%)				Water absorbtion				1	2	3	4		5	Mineralogy	Uses as raw material for	Remarks
	Area	Geographic Lat./Long.	Map Ref. (1:50,000)				SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	TiO_2	H_2O^+	H_2O^-	Ig. loss	1,000°C	1,100°C	1,200°C	Brightness	1,000°C	1,100°C	1,200°C	1,300°C	1,000°C	1,100°C	1,200°C	1,300°C				4.1	4.2				
C 1	Khao Ka-rieng, Ban Kiriwan Amphoe Muang, Nakhon Nayok	14° 14' 35" N/ 101° 16' 50" E	5237 II	residual clay and transported clay which derived from feldspar in rhyolite.	-	* +	63.4 51.06	25.96 33.60	0.70 2.57	0.02 0.01	0.06 0.18	1.30 1.56	0.10 0.11	0.10 0.05	0.01 0.18	8.29 9.26	0.17 -	8.27 10.69	white	white	white	73.1	1.01	4.09	8.59	-	33.98	29.59	21.21	-	-	74.51	-	6.58×10^{-6}	4.52×10^{-6}	58.7	Kaolinite and illite	white ware ceramics	can be used after dressing
C 2	Ban Khlong Suaton, Hin Tung, Nakhorn Nayok.	14° 15' 35" N/ 101° 18' 20" E	5237 I	transported and residual clay derived from feldspar in rhyolite	> 40,000	* +	69.50 56.20	20.18 26.12	1.32 4.7	0.11 0.09	0.10 0.39	0.58 1.05	2.04 0.14	0.02 0.02	0.31 0.51	5.40 7.76	0.00 -	5.48 9.55	-	-	white	65.3	-	-	-	-	-	-	-	-	-	-	-	-	-	43.7	Kaolinite	stone wares	too rich in iron and titanium
C 3	Ban Khok Mai-Lai, Amphoe Muang, Prachinburi	14° 08' 00" N/ 101° 18' 10" E, 14° 08' 15" N/ 101° 18' 40" E	5237 II	There are 3 types of clay in these 2 deposits :																																			under mining operation
				yellow type, > 2.5 m. thick, leached residual clay of volcanic rocks		* +	73.0 54.77	17.0 29.3	2.0 2.79	0.1 0.03	Trace 0.41	0.6 0.30	 0.35	- 0.05	- 1.05	- 10.77	- -	7.2 11.65	white	white	pale yellow	-	3.28	5.09	12.22	-	31.57	29.76	11.12	-	31	181.34	-	3.5×10^{-6}	4.41×10^{-6}	65.20	Kaolinite	refractory bricks, wall & floor tiles.	
				white type, > 3m. thick, transported clay derived from granitic rock	> 40,000	+	46.1	33.6	1.70	3.2	2.1	0.6		-	-	-	-	12.7	white	white-yellow	milky white	63.4	11.6	11.8	18.4	23.2	29.4	28.6	10.3	12.6	34	115	55.4	5.45×10^{-6}	4.7×10^{-6}	-	Kaolinite	Wall & floor tiles, insulators.	
				black type, 0.35-1.5 m. thick, transported clay which associated with carbonaceous matter.	> 5,000,000	+	58.08	23.61	3.53	0.06	0.46	2.45	0.55	0.006	0.96	7.64	-	9.4	-	reddish brown and pink	-	-	-	16.50	-	-	-	-	-	-	-	123.0	14.18	-	-	95.44	Kaolinite, illite	Wall & floor tiles.	
C 4	Ban Nong Yai, Noen-Hom, Amphoe Muang, Prachinburi	14° 11' 25" N/ 101° 19' 35" E	5237 II	transported clay which derived from weathered granite	-	+	51.1	32.0	2.4	1.6	1.1	0.2		-	-	-	-	11.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		refractory	too rich in iron
C 5	Ban Nahinlad, Pak-Pli, Nakhom Nayok	14° 10' 20" N/ 101° 20' 25" E	5237 II	might be transported clay which derived from rhyolite	-	+	60.38	23.25	3.14	0.02	0.54	2.79	0.48	0.01	0.57	6.91	-	8.68	-	-	-	52.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Kaolinite	stone wares, refractory brick	too rich in iron and alkalies
C 6	Ban Ko Ta Môi, Phoe Ngam, Prachantakham, Prachinburi	14° 10' 35" N/ 101° 30' 50" E	5337 III	transported clay derived from, weathered feldspathic sandstone.	-	*	69.97	23.97	1.89	0.01	0.36	1.30	0.17	0.01	0.69	6.77	-	7.67	-	-	yellowish-gray	61.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Kaolinite	stone wares	too rich in iron
C 7	Ban Kon Ao, Na Klua, Bang Lamung, Chon Buri	12° 58' 10" N/ 100° 53' 55" E	5134 I	transported clay derived from weathered feldspathic quartzite and granite	> 100,000	* +	66.40 48.90	22.30 35.50	1.70 2.10	2.40 0.45	0.61 0.27	- 0.48	- 	- -	- -	- -	- -	6.7 12.30	yellowish	yellow	yellow to grayish white	66.6	10.0	11.2	19.6	21.0	26.2	24.1	6.6	2.5	-	173.3	-	-	-	42.09	Kaolinite	colored ware ceramics, refractory brick.	semi ball clay, high plasticity (under mining)
C 8	East of Khao Thup Klang, Kong Din, Klaeng, Rayong	12° 45' 55" N/ 101° 46' 45" E	5334 I	transported and residual clay derived from weathered	-	+	61.49	26.05	1.78	0.02	0.15	2.32	0.46	0.00	0.64	5.35	-	6.87	-	-	milky white to pale brown	73.2	-	-	14.2	-	-	-	-	-	-	-	-	-	-	31.3	Kaolinite, illite	colored floor and wall tiles.	too rich in iron and alkalies, too small amount of clay
C 9	Ban Cham Makok, Kong Din, Klaeng, Rayong	12° 48' 15" N/ 101° 47' 05" E	5334 I	residual clay derived from weathered schists.	huge amount	*	62.13	26.53	1.92	0.02	0.06	2.39	0.35	0.01	0.78	5.12	0.05	5.71	white	white	pale yellow	46.75	-	-	-	-	-	-	-	-	-	58.49	-	15.25×10^{-6}	6.35×10^{-6}	98.19	illite; kaolinite	colored wall tiles and roof tiles.	
C 10	Khao Lamphuan, Kong Din, Klaeng, Rayong	12° 50' 15" N/ 101° 47' 20" E	5334 I	residual clay derived from weathered schists	-	+	65.57	21.76	1.48	1.35	0.27	3.77	0.54	0.00	1.04	4.17	-	4.71	white	white	white	74.25	0.09	2.24	6.93	-	44.25	39.08	25.39	-	-	17.03	-	4.47×10^{-6}	5.05×10^{-6}	90.84	Kaolinite, illite	white ware ceramics and additives.	

Table 4.3.3.1 (cont.)

Ref. no.	Location: Area	Location: Geographic Lat./Long.	Location: Map Ref. (1:50,000)	Type of Deposit	Reserve (tons)
C 11	Khao Bo Paeng, Ban Na, Klaeng, Rayong	12° 53' 45" N/ 101° 42' 30" E	5334 IV	transported clay derived from feldspathic siltstone and schists	-
C 12	Ban Noen Din Dang and Ban Khlong Kha, Noen Kho, Klaeng, Rayong	12° 44' 05" N/ 101° 35' 35" E	5334 III	transported clay derived from siltstone and schists, thicker than 2 m.	-
		12° 44' 10" N/ 101° 36' 00" E	5334 III		-
C 13	Khao Dun, Nong Sai, Chang Kham, Thamai, Chanthaburi	12° 40' 50" N/ 101° 49' 00" E	5334 II	residual and transported clay might be derived from schists	-
C 14	Ban Sam Nad, Wang Tanod, Thamai, Chanthaburi	12° 45' 30" N/ 101° 57' 50" E	5334 I	transported clay derived from weathered schists, approximately 1 m. thick.	-
C 15	Ban Pa Daeng, Khamong, Thammi, Chathaburi	12° 36' 10" N/ 101° 59' 00" E	5334 II	transported clay derived from weather schists, thick than 1 m.	-
C 16	Ban Kwian Hak, Khlung, Chanthaburi	12° 28' 05" N/ 102° 12' 10" E	5433 IV	transported clay derived from weathered granite	-
C 17	Ban Ta Kang, Amphoe Muang, Trad	12° 13' 45" N/ 102° 37' 55" E	5533 III	transported clay derived from weathered sandstone	> 2,000,000
C 18	Ban Laem Sai, Cham Rak, Amphoe Muang, Trad	12° 12' 10" N/ 102° 39' 50" E	5533 III	transported clay derived from weathered sandstone	-

Ref. no.		Chemical Composition: SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	TiO_2	H_2O^+	H_2O^-	Ig. loss
C 11	+	73.6	20.70	1.30	1.40	0.22	-	-	-	-	-	-	2.8
C 12	+	46.62	38.55	0.37	0.16	0.29	0.04	0.07	0.03	0.77	12.6	-	12.52
	*	46.35	36.68	2.65	0.01	0.08	0.59	0.07	0.07	0.61	12.19	-	13.27
C 13	*	68.96	21.80	0.63	0.02	0.04	2.20	0.55	0.005	0.78	4.93	0.05	4.94
	+	62.57	25.21	1.50	0.02	0.30	3.68	0.58	0.00	0.97	4.80	-	5.76
C 14	*	75.61	16.79	0.73	0.00	0.02	1.04	0.43	0.005	0.67	4.19	0.05	4.47
	+	69.21	19.65	1.22	0.04	0.23	3.30	0.58	0.00	0.84	4.50	-	5.20
C 15	*	66.47	25.80	0.22	0.04	0.03	1.76	0.51	0.03	0.50	4.39	0.14	4.64
C 16	+	49.20	35.00	1.60	0.87	0.12	-	-	-	-	-	-	13.1
C 17	*	81.02	13.52	0.40	0.14	0.03	0.96	0.11	0.03	0.23	3.27	0.13	3.60
	+	70.79	18.77	1.44	0.05	0.39	2.90	0.18	0.001	0.69	4.51	-	5.42
C 18	+	63.11	24.08	1.11	0.04	0.44	4.22	0.35	0.00	1.16	5.43	-	6.19

Ref. no.	Color after firing: 1,000°C	1,100°C	1,200°C	Brightness	Firing shrinkage (%): 1,000°C	1,100°C	1,200°C	1,300°C	Water absorbtion: 1,000°C	1,100°C	1,200°C	1,300°C	1	2	3	4: 4.1	4.2	5	Mineralogy	Uses as raw material for	Remarks
C 11	white	white	white	76.1	3.2	3.3	9.2	-	21.0	20.4	14.5	-	-	-	-	-	-	86.0	quartz, mica	white ware ceramics	comparatively low in stickness
C 12	-	-	yellowish white	66.2	-	-	20.0	-	-	-	-	-	-	-	-	-	-	-	Kaolinite	white ware ceramics	rich in alumina and low in iron and alkalies
									-	-	-	-	-	-	-	-	-	-			
C 13	pale pink	white	white	63.50	- 0.76	1.68	8.80	-	36.04	30.50	13.47	-	-	20.55	-	15.7 x 10^{-6}	7.05 x 10^{-6}	99.23	illite and kaolinite	wall tiles and roof tiles	clay layer is not so thick
C 14	white	white	pale brown	52.50	- 1.71	1.04	6.39	-	23.96	17.72	6.16	-	-	165.78	-	15.6 x 10^{-6}	7.26 x 10^{-6}	92.60	illite and kaolinite	wall tiles and roof tiles	
C 15	white	white	pale brown	41.25	- 0.89	3.11	13.01	-	30.43	21.92	0.28	-	-	58.19	-	16.6 x 10^{-6}	6.88 x 10^{-6}	95.30	illite and kaolinite	wall tiles and roof tiles	
C 16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	stone wares	
C 17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Kaolinite	stone wares	
C 18	white	white	pale brown	48.00	0.00	4.65	12.79	-	31.00	21.33	1.81	-	-	57.59	-	11.73 x 10^{-6}	6.73 x 10^{-6}	98.61	Kaolinite	wall tiles anf floor tiles	

* raw clay

\+ dressed clay

1. Retractoriness (Orton Cone)
2. Modulus of rupture (Average at green condition - lb/in^2)
3. Apparent porosity (% after firing at 1,100°C)
4. Coefficient of Thermal Expansion
   - 4.1 raw clay
   - 4.2 fired clay (at 1,200°C)
5. Grain size - % pass 100 mesh sieve

basaltic origin which are usually vesicular, alkaline basalt/basanitoid group (Vichit, Vudhichativanich and Hansawek, 1978). There are altogether 10 deposits in the vicinity of Chanthaburi and Trat and almost all of them have been exploited domestically and semiindustrially for quite a considerable long period of time. However, certain exploitation has been illegally carried out. The largest deposit appears to be at Bo Rai and Nong Bon, Amphoe Bo Rai, Trat where red corundum or ruby have been found in large quantity with minor amount of garnet. Other deposits, namely, Na Wong, Bo Wen, Tok Phrom, Khao Noi and Bo I Rem of Amphoe Khlung, Chathaburi the association of ruby, blue andgreen sapphires are exploited. Besides, there are several other small deposits of a variety of sapphire, zircon, garnet, ruby in the vicinity of Amphoe Tha Mai, Chanthaburi. Detailed information of these deposits are summarized and tabulated in Table 4.3.3.2.

It is important to note that these precious and semiprecious stones deposits are relatively large in areal extent as well as high in terms of gem quality and quantity. It is considered to be one of the most valuable mineral resources of the country from the economic point of view. Unfortunately, the roles of the Thai Government in promoting the exploitation of this resouce in the proper manner as well as the controlling of illegal mining and government's royalty system have been neglected. The economic lost regarding this matter is therefore considered to be enormous for the country as a whole.

Table 4.3.3.2 The gem deposits within the neighbouring areas.

Location				Type of Gemstones	Type of Deposit and Extent	Mining Method
Ref. no.	Area	Geographic Lat./Long.	Map References			
G 1	Bo Rai, Amphoe Bo Rai, Trat	12° 34' 20" N/ 102° 32' 15" E	5534 III	Ruby	They are placer deposits of alluviums, eluviums and colluviums of basalts which exposed in east and northeast directions of the deposits. They are flat terrains and low hills with covering an area approximately 70 square kilometers.	Ground sluicing, pumping mine. Dressing under jig and hand sorting.
G 2	Bong Bon, Bo Rai, Trat	12° 40' 35" N/ 102° 27' 50" E	5434 II	Ruby, garnet	The deposits are locate in intermontain valley with trending north/south, covering an area about 10 square kilometers. They are placer deposits of colluviums and eluviums of basalt and forming as lateritic soil that underlied by sandstone and shale.	Ground sluicing, pumping mine. Dressing under jig and hand sorting.
G 3	Na Wong, Khlung, Chanthaburi	12° 31' 40" N/ 102° 23' 50" E	5434 II	Ruby, blue and green sapphires.	They are placer deposits of colluviums and eluviums of basalt that form as lateritic soil, covering an area of 9 square kilometers.	Ground sluicing, pumping mine. Dressing under jig and hand sorting.
G 4	Bo Wen, Khlung, Chanthaburi	12° 40' 25" N/ 102° 19' 40" E	5434 II	Ruby, blue and green sapphires.	The deposits are existed in lateritic soil, valley fill deposit which derived from basalt. The trend of valley is north-northwest.	Ground sluicing, pumping mine. Dressing under jig and hand sorting.
G 5	Tok Phrom, Khlung, Chanthaburi	12° 37' 15" N/ 102° 19' 30" E	5434 II	Ruby, blue and green sapphires.	The gem deposits appeared in lateritic soil, valley fill deposit, and along slope edge of weathered basalt, covering an area of approximately 3 square kilometers	Ground sluicing and pumping mine. Dressing by jig and hand sorting.
G 6	Khao Noi, Khlung, Chanthaburi	12° 39' 30" N/ 102° 23' 20" E	5434 II	Ruby	The gem deposits are partly distributed in lateritic soil, valley fill deposit, which derived from weathered basalt. That valley has a trend of north-northwest direction.	Small sclaled ground sluicing mine, and panning by man power.
G 7	Bo I-Rem, Khlung, Chanthaburi	12° 34' 40" N/ 102° 20' 55" E	5434 II	Blue and green sapphires, ruby	The gem deposit is found in lateritic soil on the slope edge of weathered basalt.	Ground sluicing and pumping mine. Dressing by jig and hand sorting.
G 8	Khao Phloi Waen, Tha Mai, Chanthaburi	12° 36' 25" N/ 102° 02' 40" E	5434 III	green, blue and yellow sapphires, zircon including garnet	The deposit occurs as placer deposit of weathered basalt. It is believed to be volcanic plug.	Domestic mining practice, panning.
G 9	Khao Wua, Tha Mai, Chanthaburi	12° 37' 35" N/ 102° 02' 55" E	5434 III	green, blue and yellow sapphires, zircon including garnet	The deposit occurs as placer deposit of weathered basalt.	Domestic mining practice, panning
G 10	Bang Ka Cha, Tha Mai, Chanthaburi	12° 35' 10" N/ 102° 03' 35" E	5434 III	green, blue and yellow sapphires, zircon including garnet.	The deposit occurs as placer deposit of weathered basalt.	Domestic mining practice, panning

After Vichit, Vudhichati and Hansawek (1978);

Sirinawin (1981) - Personnal communication

4.3.3.3 silica sand

There are 5 known deposits of silica sand which are entirely located outside of the studied area, namely, Amphoe Klaeng and Ko Samet /Changwat Rayong, Amphoe Thamai and Khlung/Changwat Chanthaburi including Amphoe Muang and Khlong Yai/Changwat Trat. These deposits had been investigated by Triyarn (1972). It is reported that most of them are beach deposit locating at the present near-shore zone. The source rocks which supply the high quality quartz sand sediments are considered to be the Mesozoic sandstones in the vicinity of each deposit. They are transported to the present depositional environments which are under the influences of waves, currents and tides in reworking and sorting of these deposits. Consequently, these sand sediments are usaually characterized by their well-sorted and clean properties. Finally, the leaching process is responsible in moving out the organic matters, iron content and finer fraction. The quality and quantity of the silica sand deposits are believed to be commercially significant in supporting the glass and ceramic industries. The detailed in formation is summarized and presented in Table 4.3.3.3.

4.3.3.4 Dickite

Dickite, $Al_4(Si_4O_{10})_3(OH)_{12}.3H_2O$, is a mineral of Phyllosilicate group in the monoclinic crystal system. Its origin is closely related to hydrothermal replacement in acidic volcanic rock such as rhyolite. Dickite is similar to kaolinite in structure and chemical composition but is less important in constituting most of clay deposits. It can be

4.3.3.3 The silica sand deposits within the neighbouring areas.

Location: Area	Location: Geographic Lat./Long.	Location: Map References (1:50,000)	Type of deposit	Reserve (tons)	Physical property: Color	Physical property: Roundness	Physical property: Sorting	Chemical Composition (%): SiO_2	Chemical Composition (%): Fe_2O_3	Chemical Composition (%): Al_2O_3	Chemical Composition (%): CaO	Chemical Composition (%): MgO	Chemical Composition (%): Ig. loss	Grain Size Distribution, Wt. % passing on mesh no.: + 20	20	40	60	80	100	Recommend uses
Ban Chak Phong, Klaeng, Rayong	12° 29' 30" N/ 101° 36' 07" E	-	Beach deposit with thickness over 2 meters, silica sand is derived from the Mesozoic sandstone of adjacent area and transported by fluvial process, Deposit and sorting by waves. Leaching is the final process	prooved : 500,000, probable : millions of tons.	pinkish gray (5 YR 8/1)	angular to subangular	well sorted	99.[illegible]	0.11	0.02	0.04	0.02	0.09	-	99.73	96.25	50.32	20.81	10.66	glass and ceramic industries
Ban Bong Sai, Tha Mai, Chanthaburi	12° 40' 12" N/ 101° 49' 05" E	-	Its appearance is in the same character as S1	No in formation	grayish orange pink (5 YR 7/2)	angular to sub angular	well sorted	99.14	0.16	0.29	0.01	0.02	0.21	-	99.65	98.12	95.34	76.46	42.16	glass and ceramic industries
Ban Bob, Khlung, Chanthaburi	12° 19' 30" N/ 102° 15' 05" E	-	It is considered to be old beach deposit which is closely related to tidal marsh deposit. Clay and iron may deteriorate its quality.	over 2 million	pale yellowish brown	angular to sub angular	poorly sorted	99.38	0.13	0.04	0.02	0.02	0.23	-	99.73	96.25	50.32	20.81	10.66	glass and ceramic industries
Amphoe Muang and Khlong Yai, Trat	12° 04' 42" N/ 102° 42' 55" E to 11° 48' 22" N/ 102° 46' 22" E	-	Beach deposit which sand sediments are derived from the Mesozoic sandstone of Khao Ban Thad.	1,700,000	pinkish gray to light pinkish gray (5 YR 8/1 to 5 YR 9/1)	angular to subangular	well sorted													glass and ceramic industries
- Ban Laem Klad								99.5	0.07	0.17	0.01	0.02	0.22	-	97.47	83.75	62.12	46.69	38.71	
- Khao Lan								99.32	0.06	0.13	0.01	0.02	0.17	0.58	99.95	94.33	86.76	54.22	28.71	
- Ban Mai Rood								99.40	0.10	0.25	0.02	0.009	0.20	-	98.11	52.69	18.09	7.43	3.68	

distinguished from kaolinite by differential thermal and x-ray analyses. Generally, dickite can be used as raw materials in refractory bricks, saggar, electrical porcelains, pottery, mosaic tile, wall tile and white cement as well as filler in rubber and paint industries.

The 3 dickite deposits are located outside the studied area in the nighbourhood of Saraburi and Nakhon Nayok. However, the largest deposit is in Nakhon Nayok, Khao Cha Ngok, where dickite occurs from hydrothermal replacement in rhyolite under the fracture control and the economic exploitation of this deposit has been carried out. For the other 2 deposits at Saraburi, dickite are found in relatively smaller quantity and lower in grade. Detailed description of these 3 deposits are summarized in Table 4.3.3.4. In addition, the chemical composition and firing property of different grades of dickite at Khao Cha Ngok deposit are presented in Table 4.3.3.4 a.

4.3.3.5 Feldspar

The only feldspar deposit (Fl) is located within the studied area at Khao Noen Kraprok, lat. 12° 45' 50" N/ long. 101° 04' 55" E, Map Ta Pud, Rayong. The feldspar occurs in the form of microcline intergrowth with quartz in the pegmatite. Economic development of this feldspar deposit for ceramic raw material has been reported.

4.3.3.6 Barite

The only barite deposit (Ba 1) within the studied area at Khao Phlu Ta Luang, Sattahip, Chon Buri. It occurs as a very small, lense

Table 4.3.3.4 The dickite deposits within the neighbouring areas.

	Location			Type of Deposit	Reserve	Development and Production	Uses
Ref. no.	Area	Geographic Lat./Long.	Map Reference				
D 1	Khao Cha Ngok, Nakhon Nayok	14° 17' 45" N/ 101° 09' 45" E	5237 IV	The deposit occurs as replacement of hydrothermal solution in rhyolite with fracture control. The dickite can be classified into 3 commercial grades as A, B and C	No information (It is believed to be high potential of large reserve)	quarrying	Ceramic industries, tiles, refractory; white cement
D 2	Khao Phu Phang, Ban Cha-Om, Saraburi	14° 25' 40" N/ 101° 04' 50" E	5237 IV	The deposit occurs as hydrothermal replacement in rhyolite with fracture control	No information	quarrying	Ceramic industries, white cement
D 3	Khao Mai Nual, Ban Cha-Om, Saraburi	14° 25' N/ 101° 05' 50" E	5237 IV	The deposit occur as hydrothermal replacement in rhyolite with fracture control	No information	quarrying	Ceramic industries, white cement

Table 4.3.3.4-a The chemical composition and firing property of different grades of dickite, Khao Cha Ngok deposit.

Grade	Chemical Composition					Firing 1,250°C
	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	Ig.loss	
Khao Cha Ngok						
A	45.67	38.24	0.22	0.10	14.61	SK33 *
B	59.07	27.96	0.04	0.10	11.36	SK31 *
C (gray)	85.63	9.42	0.07	0.07	4.64	- *
C (white)	93.19	4.03	0.04	0.13	1.85	- *

* not melt.

shaped, deposit of cavity filling type in slaty shale and chert. The deposit is small in quantity and subeconomic to develop under the present knowledge after a reconnaissance survey.

4.3.3.7 Potash and Rock salt.

Originally, the rock salt beds and potash minerals were discovered during the drilling program me for groundwater in Northeast Thailand since 1955. The exploration programme has shown that rock salt and potash deposits are present in two evaporatic basin in the rocks of Khorat Group covering an area of approximately 50,000 square kilometres. Subsequently, a preliminary drilling programme for potash over a four-years period with 63 bore holes scattered throughout the basins were carried out. Besides, additional 33 bore holes with relatively closer spacing were drilled under a feasibility study on the Rock Salt and Soda Ash Project.

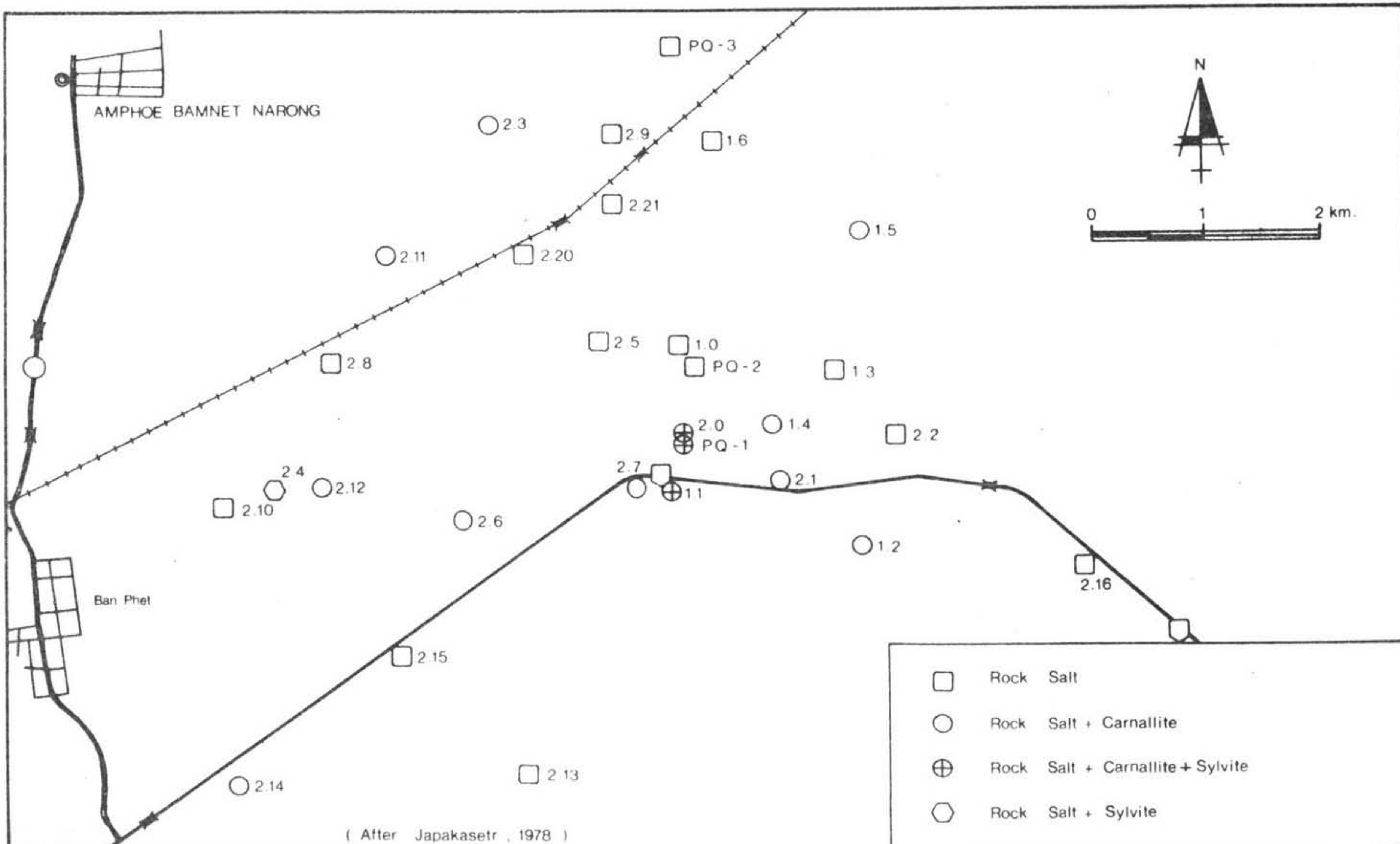
As a result of this preliminary investigation of potash in northeastern Thailand, it is indicated that evaporitic minerals mainly halite, carnallite, sylvite and trachyhydrite with minor amount of gypsum and anhydrite are present in the rocks of Mahasarakham Formation of Khorat Group. Altogether 3 evaporitic cycles consisting essentially of rock salt have been reported with potash minerals in the upper part of the lowest cycle. The thickest section of the lowest evaporite cycle is 437 meters. The common potash minerals is carnallite with high grade, K_2O greater than 14 %, have been found in several locations, namely, Bamnet Narong, Udon, Nong Khai and other provinces. However, an economic deposit has not yet been identified. Sylvite has been reported to be only scattering locally. From the economic and mining point of view, it is more economical to produce sylvite with its relatively higher potash content than carnallite which require a more expensive leaching and crystallization processes to separate the potash. However, the potash deposits of Northeastern Thailand appear to be the shallowest and thickest zone of carnallite and probably sylvite as compared with similar deposits in other countries.

Among the subsurface rock salt deposits in Northeastern Thailand, namely, at Chaiyaphum, Nakhon Ratchasima, Mahasarakham, Yasothon, Ubon Ratchathani and Udon Thani, the deposit at Bamnet Narong, Chaiyaphum is the largest and most economic one. The drilled hole locations of potash and rock salt deposit at Bamnet Narong/Chaiyaphum and Non Sung/Nakhon Ratchasima are illustrated in Figure 4.3.3.7-a and 4.3.3.7-b, respectively. The drilling log information of both localities are also summarized and presented in Table 4.3.3.7.

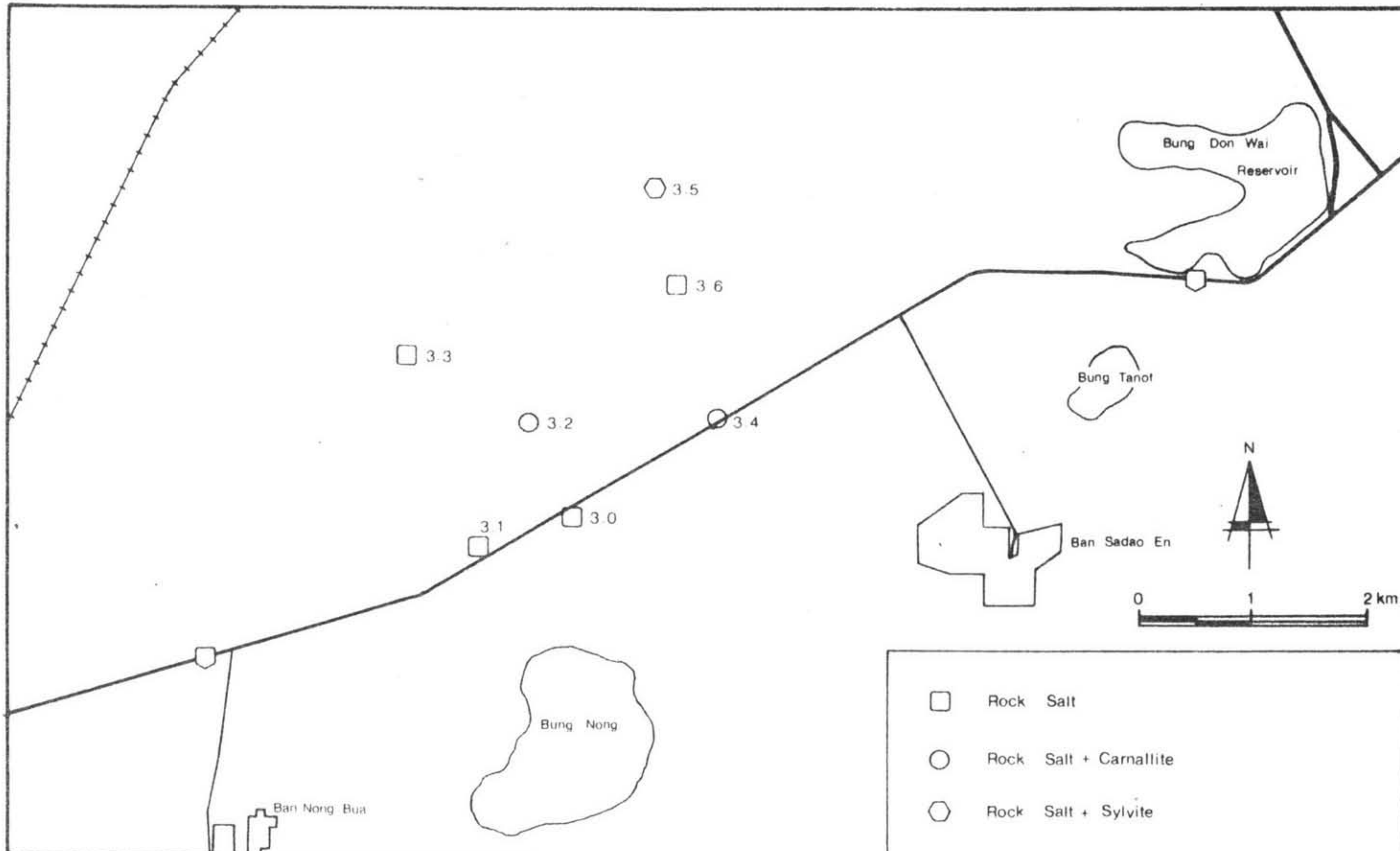
4.3.3.8 Marls and Carbonate Rock

a) Marl

According to various definitions and as old-fashioned name, the term "marl" has various meanings. Pettijohn (1957) explained that marls, proper, is semifriable mixtures of clay minerals and lime carbonate. The better-indurated rocks of like composition are marlstones or marlite and are more correctly an earthy or impure limestone rather



LOCATION OF DRILL HOLE, BAMNET NARONG DISTRICT	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND	SUNYA SARAPIROME DEPARTMENT OF GEOLOGY GRADUATE SCHOOL CHULALONGKORN UNIVERSITY, 1982	FIG. 4.3.3.7 - a



LOCATION OF DRILL HOLE, NON SUNG DISTRICT	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND	SUNYA SARAPIROME DEPARTMENT OF GEOLOGY GRADUATE SCHOOL CHULALONGKORN UNIVERSITY, 1982	FIG. 4.3.3.7 - b

Table 4.3.3.7 The depth interval and thickness of rock salt and potash at Bamnet Narong and Non Sung District.

Hole No.	Location			Rock Salt						Potash			
	Area	Geographic Lat/Long	Map Reference	Upper Bed		Middle Bed		Lower Bed		Carnellite		Sylvite	
				Depth Interval (ft.)	Thickness (ft.)	Depth Interval (ft.)	Thickness (ft.)	Depth Interval (ft.)	Thickness (ft.)	Depth Interval (ft.)	Thickness (ft.)	Depth Interval (ft.)	Thickness (ft.)
	Bamnet Narong District Chaiyaphum Province												
1.1	Ban Tan	15° 27' 55" N/ 101° 44' 20" E	5339 IV	-	-	182'-372'	190	485.0-987.5	502.5	400.7-485	84.3	394'-400.7	6.7
1.2	Wat Hua Thalae	15° 27' 40" N/ 101° 45' 20" E	5339 I	-	-	315.0-695.0	380	835.2-1160.8	325.6	745.9-835.2	89.3	-	-
1.3	Wat Hua Hung	15° 28' 30" N/ 101° 45' 10" E	5339 I	-	-	-	-	197.8-1079.6	881.8	-	-	-	-
1.4	Ban Tan	15° 28' 15" N/ 101° 44' 50" E	5339 IV	393.5-436.8	43.3	579.5-795.2	215.7	882.0-1051.0	169.0	838.7-882.0	43.3	-	-
1.5	Wat Pa Samakki Tham	15° 29' 10" N/ 101° 45' 20" E	5339 I	-	-	-	353.4	-	327.3	-	97.2	-	-
1.6	Wat Sarika	15° 29' 35" N/ 101° 44' 30" E	5339 IV	-	-	-	-	191.9-926.1	734.2	-	-	-	-
2.0	Ban Tan	15° 28' 10" N/ 101° 44' 25"	5339 IV	-	-	176.0-370.4	194.4	579.8-825.0	249.2(+)	446.4-575.8	129.4	443.4-446.4	3
2.1	Ban Tan (Hole was abandoned in potash horizon)	15° 28' 00" N/ 101° 44' 50" E	5339 IV	-	-	235.5-572.6	337.1	?	?	626.0-651.0	25(+)	-	-
2.3	Ban Hin Tang	15° 29' 40" N/ 101° 43' 25" E	5339 IV	-	-	224.0-408.0	184	515.0-715.0	200	487.8-515.0	27.2	-	-
2.4	Ban Khok Fack	15° 27' 55" N/ 101° 42' 20" E	5339 IV	-	-	235.0-338.5	103.5	416.0-603.0	187.2	-	-	399.5-416.2	16.7
2.5	Ban Kloi-Ban Tan	15° 28' 35" N/ 101° 44' 00" E	5339 IV	-	-	-	-	220.4-730.0	509.6(+)	-	-	-	-
2.6	Ban Khok Sawang	15° 27' 45" N/ 101° 43' 15" E	5339 IV	-	-	217.0-384.0	167	482.0-724.2	242.2	451.2-481.3	30.1	481.3-482.0	0.7
2.7	Ban Tan	15° 28' 00" N/ 101° 44' 10" E	5339 IV	-	-	191.5-356.7	165.2	483.0-750.0	267(+)	375.0-483.0	180	-	-
2.8	Ban Kloi	15° 28' 35" N/ 101° 42' 40" E	5339 IV	-	-	-	-	291.0-602.1	311.1	-	-	-	-

Table 4.3.3.7 (cont.)

Hole No.	Location: Area	Location: Geographic Lat/Long	Location: Map Reference	Rock Salt: Upper Bed: Depth Interval (ft.)	Upper Bed: Thickness (ft.)	Middle Bed: Depth Interval (ft.)	Middle Bed: Thickness (ft.)	Lower Bed: Depth Intervall (ft.)	Lower Bed: Thickness (ft.)	Potash: Carnellite: Depth Interval (ft.)	Carnellite: Thickness (ft.)	Sylvite: Depth Interval (ft.)	Sylvite: Thicaness (ft.)
2.9	Ban Wang Ka Am-Ban Hin Tang	15° 29' 40" N/ 101° 44' 10" E	5339 IV	-	-	-	-	277.8-606(+)	328.2(+)	-	-	-	-
2.10	500 m.W. of 2.4	15° 27' 55" N/ 101° 42' 10" E	5339 IV	-	-	-	-	289.0-580.1	291.1	-	-	-	-
2.11	Ban Non Thong Lang	15° 29' 05" N/ 101° 42' 50" E	5339 IV	-	-	-	94.3	-	54.6(+)	-	30.9	-	-
2.12	300 m.E. of 2.4	15° 28' 00" N/ 101° 42' 35"	5339 IV	-	-	-	246.3	-	46.3(+)	-	18.8	-	0.8
2.13	Wat Samran, Ban Kum	15° 26' 35" N/ 101° 43' 35"	5339 IV	-	-	-	-	182.7-936.0	753.3	-	-	-	-
2.14	Ban Kut Ta Lat School	15° 26' 35" N/ 101° 42' 10" E	5339 IV	-	-	-	-	285.6-408.3	122.7	-	-	-	-
2.15	Ban Khok Sawang	15° 27' 10" N/ 101° 43' 00" E	5339 IV	-	-	-	-	264.7-781.4	516.7	-	-	-	-
2.16	Ban Nong Yai Nut	15° 27' 30" N/ 101° 46' 25" E	5339 I	-	-	-	-	285.1-1253.7	968.6	-	-	-	-
2.17	Ban Khao Din	-	5339 I	1052-1135.3	83.3	1164.8-1324.0	159.2	1408.0-1510.6	102.6	1381.5-1408.0	26.5	-	-
PQ-1	10 ft S of 2.0	15° 28' 10" N/ 101° 44' 30" E	5339 IV	-	-	178.0-370.4	192.4	575.5-702(+)	126.5	446.8-575.5	128.7	443.5-446.8	3.3
PQ-2	625 m.N. of PQ-1	15° 28' 30" N/ 101° 44' 25" E	5339 IV	-	-	-	-	201.2-701(+)	499.8(+)	-	-	-	-
PQ-3	Ban Wangka Am	15° 30' 05" N/ 101° 44' 20" E	5340 III	-	-	-	-	225.0-705.0	480(+)	-	-	-	-
.	<u>Non Sung District Nakhon Ratchasima Province</u>												
3.0	Km.19 Nakhon Ratchasima -Khon Kaen Highway	15° 04' 35" N/ 102° 13' 40" E	5439 III	-	-	-	-	290.8-672.7	381.9	-	-	-	-
3.1	1 km. W. of 3.0	15° 04' 25" N/ 102° 13' 10" E	5439 III	-	-	-	-	258.1-667.0	408.9(+)	-	-	-	-
3.2	1 km. N. of 3.0	15° 05' 00" N/ 102° 13' 25" E	5439 III	-	-	316.7-376.3	59.6	550.8-719.1	168.3	470.3-550.9	80.6	-	-
3.3	2 km. NW of 3.0	15° 05' 20" N/ 102° 12' 50" E	5439 III	-	-	-	-	285.0-600.0	315(+)	-	-	-	-
3.4	1.5 km. E of 3.0	15° 05' 05" N/ 102° 14' 20" E	5439 III	-	-	330.1-342.5	12.4	544.6-717.2	172.6	466.5-544.6	78.1	-	-
3.5	3 km. NE of 3.0	15° 06' 10" N/ 102° 14' 00" E	5439 III	-	-	-	-	407.1-715(+)	307.9(+)	-	-	-	-
3.6	2 km. NE of 3.0	15° 05' 40" N/ 102° 14' 10" E	5439 III	-	-	-	-	361.0-670.0	310(+)	-	-	-	-

than a shale. Marl has been defined as a rock with 35 to 65 percent carbonate and a complementary content of clay. In addition, Howell (1957) states that marl is an old term of a considerable range of usage. In Coastal Plain geology of the United States it has been used as a name for little indurated sedimentary deposit of a wide range of composition among which are slightly to richy calcareous clay and silt; fine-grained calcareous sands; clays, silts, and sand containing glauconite; and unconsolidated shell deposits. In the interior of the United State the name is used for the calcareous deposits of lakes in which the percentage of calcium carbonate may range from 90 to less than 30 per cent. The name does not connote any particular composition.

The marl is chiefly used as raw material for portland cement in wet process and as soil neutralization. Further more, it can be used as fillers and abrasives.

Despite the fact that there is no marl deposit within the studied area, 2 marl deposits, reported by Kuentag (1979), are located at Amphoe Ban Mo and Amphoe Phra Bhudhabath/Saraburi and in the vicinity of Ban Tha Khae/Lopburi. Both deposits are characterized by white, loose, porous, and tufa-like material with occasional limestone gravel, and carbonate content are more than 90 per cent. Kuentag (1979) suggested that they should rather be called marly limestone. The genesis is believed to be related to the deposition of limestone weathered products around those areas in the beginning of Quaternary period. The chemical composition of both deposits are presented in Table 4.3.3.8-a.

Table 4.3.3.8-a The chemical composition of marls in Saraburi and Lopburi

Localities	Chemical Composition (per cent by weight)							
	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	$MgCO_3$	$CaCO_3$	$MgCO_3 + CaCO_3$
<u>Saraburi</u>								
Nong Bua, Ban Mo	2.57	1.63	0.80	0.14	51.95	0.15	92.71	92.86
, Ban Mo	5.40	1.35	0.73	0.04	51.04	0.43	91.09	91.52
<u>Lopburi</u>								
Irrigational canal, A. Muang	-	-	-	-	51.55	-	92.00	92.00
Tha Khae, A. Muang	-	-	-	-	52.05	-	93.05	93.05

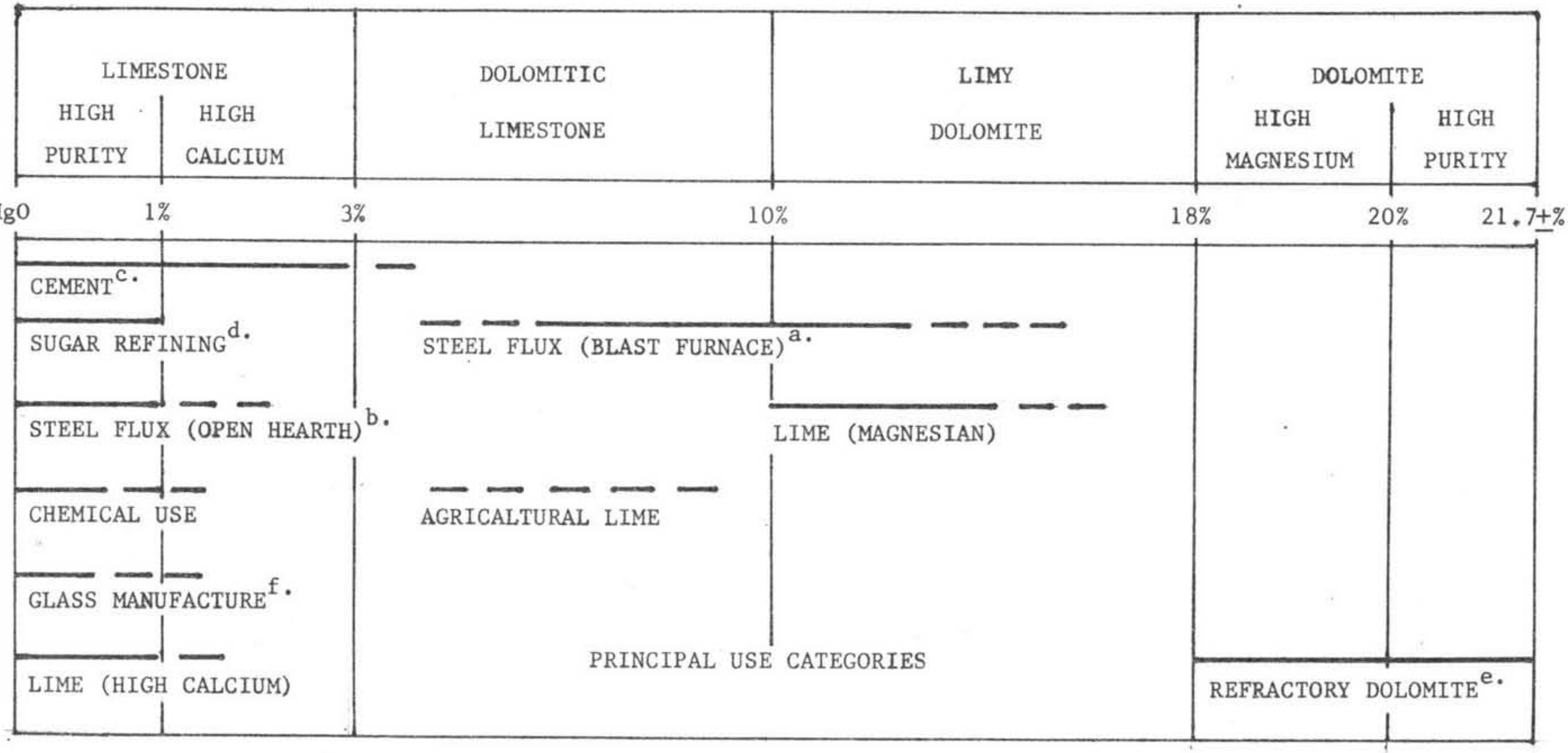
Kuentag (1979).

b) Carbonate rocks

The term "carbonate rock" in this context means of limestone in general including dolomite and marble. The name limestone is limited to sedimentary carbonate rocks which are mainly composed of calcite ($CaCO_3$) and the double salt of calcium and magnesium carbonate ($CaMg(Co_3)_2$), with calcite being the most abundant. Dolomite is sedimentary rock composed mostly of the mineral dolomite ($CaCO_3.MgCO_3$). Marble is a metamorphic rock composed essentially of calcite and/or dolomite.

These carbonate rocks can be used in various industries. They are the basic building blocks of the construction industry, the material from which aggregate, cement, lime and building stones are made. Carbonate rocks and their derived products, are used as fluxes, glass raw material, refractories, fillers, abrasives, soil conditioners, ingredients in a host of chemical processes, and much more. Carbonate rocks as construction materials will be discussed in the next item. For the other uses of carbonate rocks, there are many of the particular specifications for the particular uses. However, Evans (1977) presented the schematic chart, as in Table 4.3.3.8-b showing the nomenclature of carbonate rocks which is based on MgO content and is designated to fit industrial use categories. The chemical contents concerning in these general specifications are CaO, MgO, SiO_2, Fe_2O_3, Al_2O_3, P_2O_5 and total alkalies.

Table 4.3.3.8-b Schematic chart showing the nomenclature of carbonate rocks defined to fit industrial use categories. (After Evans, 1977)



a. SiO_2 < 5%, PREFERABLY < 3%, Al_2O_3 < 2%, P_2O_5 MUST NOT EXCEED TRACE AMOUNTS (i.e. 0.005-0.006%)

b. P_2O_5 MUST NOT EXCEED TRACE AMOUNTS

c. TOTAL ALKALIES < 0.5%

d. SiO_2 < 1.0%, Fe_2O_3 < 0.5%

e. SiO_2, Fe_2O_3 AND Al_2O_3 NOT TO EXCEED 1.0% EACH

f. Fe_2O_3 < 0.05%, PREPERABLY < 0.02%

Within the studied area, the carbonate rock potential is discussed in detailed by Sarapirome and his colleaques (1982). It is noted that carbonate rocks at Khao Chi On, Khao Chi Chan and Ko Sichang are most promising due to their quantities and chemical qualities. Outside the studied area, within the radius of 300 kilometers from the Sattahip deep-seaport, the interesting carbonate potentials are in the vicinity of Saraburi and Lopburi provinces. They can be divided into 2 formations as Khao Khad Formation and Khao Khwang Formation as illustrated in Plate 4.3. Hinthong, et al (1976) reported that Khao Khad Formation comprises of black, very dark to light gray limestone; recrystalline argillaceous limestone and dolomite with nodular and bedded cherts; intercalated shale sandstone and rare volcanics; locally marble and limesilicate rock; common fusulines, corals, brachiopods and algae. Within the area underlain by this formation, Nakhon Luang Cement and Siam Cement factories are located using carbonate rocks as one of the raw materials. Another formation, Khao Khwang, comprises of black, dark and light gray limestone with nodular chert; locally dolomitic and intercalated with few pale brown, greenish-gray shale, tuffaceous sandstone and volcanics; common fusulines, corals, crinoids, brachiopods and algaes. It is interesting to note that no exploitation programme has been undertaken despite the fact that the carbonates from this formation shows relatively high quality. The difficulty on accessibility to the deposit might be the answer of that doubtful case.

The chemical composition of carbonate rocks within the studied area and of Khao Khad Formation are presented in Table 4.3.3.8-c and 4.3.3.8-d, respectively.

Table 4.3.3.8-c Chemical composition of carbonate rocks at Ko Sichang, Khao Chi Chan and Khao Chi On, Sattahip, Chon Bur

Localities	Chemical Composition										Remarks
	H_2O^-	Ig. loss	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5	
Chon Buri											
- Laem Khao Khad line, Ko Sichang	0.21	40.33	5.60	1.28	0.48	0.96	50.70	0.04	0.35	nil.	Composite samp
- Laem Ngoo - Laem Tham Phang line, Ko Sichang	0.31	37.96	8.54	2.10	0.62	1.47	48.18	0.05	0.63	nil.	Composite samp
- Crushed stone at Khao Chi Chan, Sattahip	0.06	32.91	13.56	3.48	1.69	1.81	44.91	0.28	1.07	0.04	Composite samp
- Southwest line of Khao Chi Chan, Sattahip	0.02	18.00	33.22	10.00	3.64	2.80	28.02	0.58	3.55	0.06	Composite samp
- Northeast of Khao Chi On, Sattahip	0.02	37.93	7.48	2.20	1.24	0.97	49.18	0.15	0.63	nil.	
- Middle line of Khao Chi On, Sattahip	0.04	32.06	15.61	3.35	1.33	1.60	44.58	0.23	1.10	nil.	Composite samp
- West line of Khao Chi On, Sattahip	0.10	31.76	15.46	3.46	0.96	0.62	46.32	0.17	0.86	0.01	Composite samp

Source : Chemical Analysis Section, Geological Survey Division, DMR.

Table 4.3.3.8-d Chemical composition of carbonate rocks within Khao Khad Formation.

Localities	Chemical Composition												
	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	H_2O^-	TiO_2	P_2O_5	MnO	SO_3	Ig. loss	FeO	C
<u>Saraburi</u>													
- Khao Wong, Phu Khae	0.65	0.21	0.15	1.07	54.30	0.00	0.00	0.00	0.03	0.00	43.10	-	
- Khao Leow, Phra Bhudhabaht	nil.	nil.	1.57	0.45	53.81	0.40	0.01	0.02	0.05	0.06	42.89	0.32	
- Khao I-Mod, Phra Bhudhabaht	0.24	0.02	0.40	1.66	54.10	0.36	-	-	0.27	-	43.56	-	1.39
- Khao Yai, Phu Khae	0.27	0.15	0.24	1.92	53.07	0.04	nil.	nil.	0.01	-	44.28	-	0.49
- Khao Ngob, Phu Khae	0.31	0.27	0.24	0.82	54.43	0.02	nil.	nil.	0.003	0.01	43.92	-	0.16
- Khao Nok Yoong, Phu Khae	0.47	0.15	0.48	1.64	53.90	0.02	0.02	0.01	0.13	0.02	43.04	-	nil.
- Khao Prong Phrab, Phhra Bhudhabaht	0.15	0.19	0.24	0.74	53.95	0.24	0.03	0.02	0.01	0.01	42.48	-	0.09
- Khao Phat, Phu Khae	0.85	0.01	0.24	0.98	53.95	0.32	0.01	0.01	0.02	nil.	43.45	-	0.95
- Khao Khaao, Phu Khae	0.21	nil.	0.24	0.85	54.34	0.24	nil.	nil.	0.01	nil.	43.66	-	0.05
- Khao Phu Kham, Phra Bhudhabaht	5.35	0.78	0.48	0.36	51.32	0.20	nil.	nil.	0.03	-	38.24	-	0.06
- Khao Ma-Kham Thao, Phu Khae	0.55	0.52	0.72	0.94	53.43	0.20	0.02	0.01	0.00	0.01	43.36	-	0.18

Source : Chemical Analysis Section, Geological Survey Division, DMR.

4.3.4 Construction Materials

Generally, construction materials include crushed stones, sand and gravel, and laterites/lateritic soils. Most of them are natural construction materials. Crushed stones including sand and gravel are aggregates which are commonly used as concrete aggregate, highway and railroad base or ballast materials, graded fill and various industrial uses. The aggregates provide bulk and strength in portland cement concrete, bituminous concrete mixes and also provide special characteristics such as thermal and acoustic insulation, weight, surface texture, abrasion resistance, and impermeability to various concrete products and mixes Most aggregates are relatively inexpensive materials, despite their delivered costs are added. Quantity or rate of consumption is in huge amount, therefore, the mass production could be done for supplying the development projects which will be occurred in the near future.

4.3.4.1 Crushed Stones

For crushed stones, certainly, limestone is the one of most common rock to be used. The requirement of crushed stone is uniform, non porous, and free from chert, organic matters and pyrite. The gradation for particular use can be adjusted to meet the specification by the adjustable processes and equipment in crushing plant. The advantage of fresh limestone is not only tough, sound aggregate, and stand up well in other types of surface, but it is less abrasive to crushing equipment than other commonly used types of stone.

Within the studied area, carbonate potentials for crushed stones are at Khao Chi On, Khao Chi Chan and Ko Sichang. There is one quarry and crushing plant at Khao Chi Chan and more than one quarry at Ko Sichang. Besides, there are rock quarries and crushing plants at Khao Phong Sua, Khao Choeng Thian, Khao Phu and Khao Phlu Ta Luang, but most of them are limited in quantity. Their products are entirely used as aggregates for roads and concretes. NEDECO (1971) reported that the quality and quantity of limestone at Ko Sichang, Khao Chi Chan and Khau Chi On meet the requirement of rubble and breakwater stones for Laem Chabang Deep-Seaport project. In the aspect of dimension stone, the rock must have significant characters, namely, beautiful, uniform and available in blocks. Generally, limestone at Ko Sichang is banded crystalline limestone with the characters suitable for dimension stone. At Khao Chi Chan and Khao Chi On, the rocks are argillaceous-flaser limestone which recrystallized and change to be calc-silicate rocks in part because of the granitic contact at the base. Calc-silicate rocks coupled with argillaceous association which contains plenty of free silica are the problem for using these rocks as dimension stone owing to their high hardness which may cause the difficulty on cutting. Outside the studied area, Khao Khad Formation, there are plenty of rock quarries for crushed stones including one marble factory locating at Khao Ngob. From the geological consideration, it can be said that the carbonate reserves of Khao Khad and Khao Kwang Formations in the vicinity of Saraburi and Lopburi can be excessively supplied to the most of development programmes which will occur within the studied area and/or the neighbouring area.

Basalt is the important one to be used as crushed stone. It is the dark fine-grained igneous rock essentially composed of plagioclase and ferromagnesian minerals. It has finely crystalline, compact texture, a very tough, sound stone, impervious to weathering. Those characters of basalt are suitable for crushed stone which is commercially called trap or trap rock. However, it usually contaminated by vesicular layers and weathered zone that must be avoided or eliminated during producing.

Unfortunately, there is no basalt within the studied area. They extruded in the southern part of Khorat Plateau extending from Nakhon Ratchasima into Burirum, Surin, Sisaket and Ubon Ratchatani where most of them are located at distant excess 250 kilometers from Sattahip deep-seaport. They generally occur as sheet like flow and are covered with weathered red soil excluding basalts of Burirum and Surin which commonly flow out from volcanic vents and formed a higher relief of volcanic cones. The locations of basalts are illustrated on mineral resources map, Plate. 4.3. Jungyusuk and Sirinawin (1981) studied on detailed petrography and petrochemistry of these basaltic rocks. In the aspect of construction materials, they mentioned that there are many quarries within these basaltic terrain, namely, Ban Thung Chaliang/Nakhon Ratchasima, Khao Kradong and Phu Phra Angkhan/Burirum, and Khao Phanom swai/Surin, including Ban Non Thong and Phu Fai/Sisaket. In addition, they suggested that the lower part of basalt at Khao Kradong and diabase at Phu Fai could be used as dimension stone rather than as crushed stone which is lower in commercial value. Besides, basaltic rocks are exposed within the vicinity of Chanthaburi but almost all of them are strongly weathered. Therefore, they are not expected to be the potential of construction material, and in contrast, gem stone potential seems to be highly attractive within this basaltic area.

4.3.4.2 Sand and Gravel

In order to discuss the sand and gravel intelligently, it is necessary to define sand and gravel. The Wentworth classification, accepted by geologists, presented that the material ranging in grain size from 1/16 to 2 millimeters is termed "sand", and the coarser material is gravel. However, "sand" as most often used by industry is not sand in an engineering or geological sense but should be called "natural fine aggregate". The expression "fine aggregate" is preferable to "sand" because the fine aggregate includes grain size which, according to engineering or geological classification, are defined as pebble or grit size. Natural fine aggregate is distinguished from manufactured fine aggregate in that the manufactured material is crushed and screen to produce the required sizes and natural fine aggregate is only screen or pre-processed use. In the present investigation, only natural fine aggregate within the studied area will be discussed.

Sand and gravel is used in asphaltic and portland cement concretes, as subbase for pavements, as fill where good drainage is needed (such as around structures), and for many other uses. The chief use of them is aggregate in portland cement concrete, since it contains 80 to 85 per cent aggregate by weight.

The ideal sand and gravel deposit is one that consist of clean, hard, sound, inert particles that are present in quantity in wide range of size grades. Stream, flowing at high volume and velocity, are the dominant agents in the formation of commercial sand and gravel deposits. Sand and gravel of this orgin are found in bars and channel deposits, terrace, and alluvial fans.

The specifications controlling the qualities of sand and gravel are highly variable depending upon the specifying agency, the availability of materials, and the purpose for which the aggregate is to be used. Specifications are normally concerned with : the chemical reactivity; without salts present; the resistance to abrasion and impact; gradations; and miscellaneous deleterious constituents. Water absorption, specific gravity, colour, strength in fabricate concrete, and other characteristics of sand and gravel may be important in particular areas or for particular purposes. Besides, the haulage distances between the area of planned development project and crushed stones as well as sand and gravel deposits should be as short as possible.

Within the studied area, 6 existing sand deposits for construction industry have been reported. The 3 sand deposits occurred as the old beach deposits at Ban Ang Sila, Laem Chabang and about 4-kilometer distance east of Rayong township; 2 point bar deposits of Rayong River (Khlong Yai) at 3 and 11 kilometer distances north of Ban Khai; and only one alluvial fan deposit north of Khao Khieo in the vicinity of Ban Suan Nam Tok east of Chon Buri township. Most of them are illustrated in Figure 4.3.4. It is believed that their quantities are extensive. The gradation of each deposit, excluding the alluvium fan deposit, have been tested by Vallentine, Laurie & Davies, R.O.P. (1977) and they are presented in Table 4.3.4.2

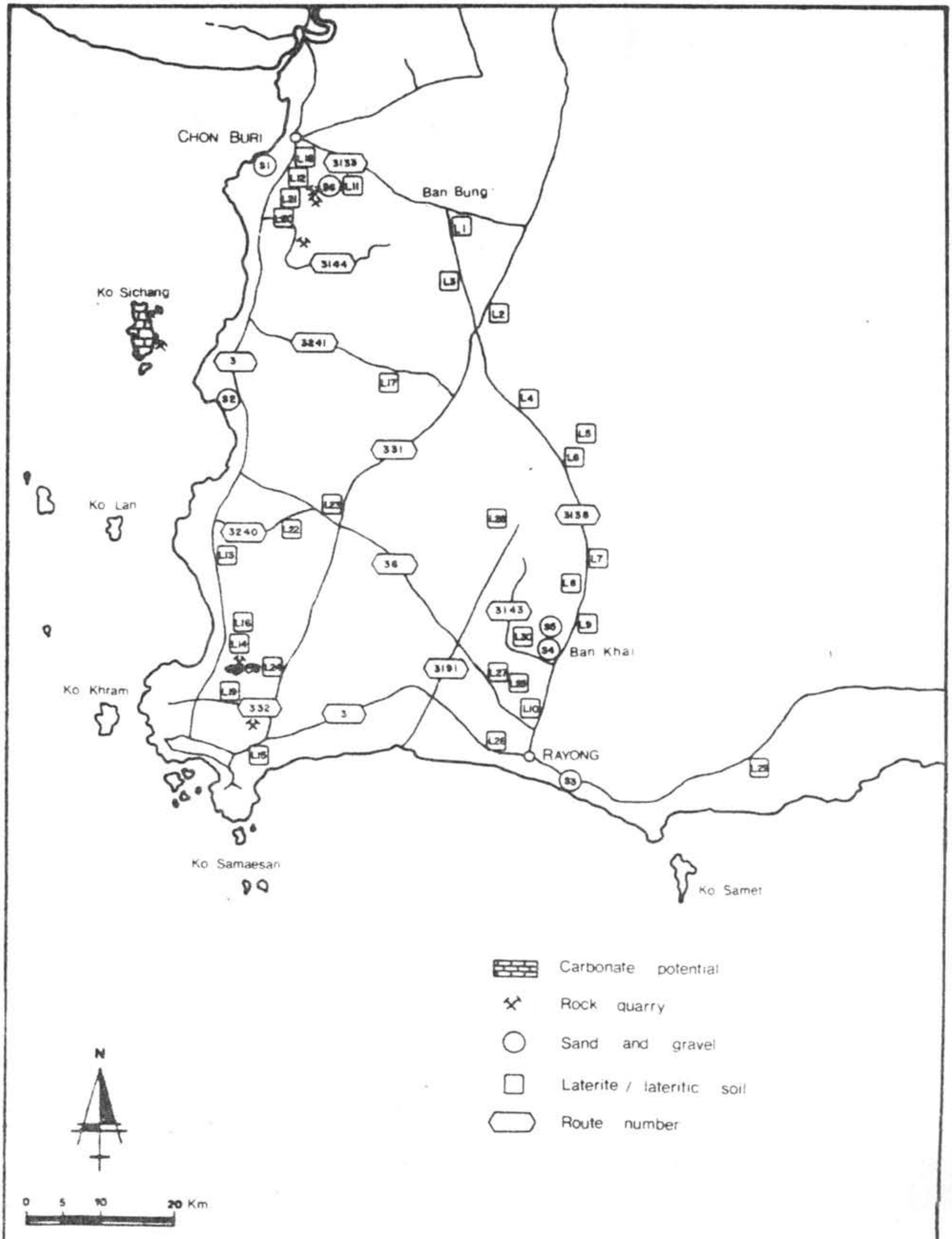
4.3.4.3 Laterites/Lateritic Soils

Laterite is a porous, indurated, concretionary material which is usually red to reddish brown in colour. Furthermore, laterite, as described by Persons (1970), is a naturally occuring material possessing certain chemical characteristics which, after desiccation, hardens irreversibly. According to de Medina, the identification of laterite lateritic soil and nonlateritic materials as presented in Table 4.3.4.3-a iron oxide composing in those materials.

Table 4.3.4.3-a Identification of laterite, lateritic soil and nonlateritic materials.

$$Kr = \frac{\%SiO_2/60}{\%Al_2O_3/102 + \%Fe_2O_3/160}$$

	Kr
Nonlateritic soil	>2.00
Lateritic soil	1.33-2.00
Laterite	<1.33



CONSTRUCTION MATERIALS.	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND

DEPARTMENT OF GEOLOGY, GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	BUNYA SARAPIROME	FIG. 4.3.4

Table 4.3.4.2 The gradation of sand and gravel deposits within the studied area.

Ref. No.	LOCATION	SIEVE ANALYSIS % PASSING								
		26 mm	19 mm	9.5 mm	4.75 mm	1.2 mm	0.42 mm	0.3 mm	0.15 mm	0.07 mm
S - 1	3 km West of Km 100 Highway 3, Ang Sila			100	98.5	46.4		6.8	2.5	1.3
S - 2	1.5 km West of Km 127 Highway 3, Laem Chabang			100	99.9	62.7		3.8	1.1	0.3
	1.5 km West of Km 127 Highway 3, Laem Chabang			100	99.4	70.9		8.2	1.5	0.6
	1.5 km West of Km 127 Highway 3, Laem Chabang			100	99.1	48.5		4.2	0.6	0.3
S - 3	700 m. right of Km 224 Highway 3			100	99.5	62.0		4.0	1.3	0.4
S - 4	3 km North of Ban Khai		100	99.5	98.0	35.1	9.3		2.0	0.7
	3 km North of Ban Khai		100	99.2	97.8	53.6	14.2		0.3	0.2
	3 km North of Ban Khai			100	98.0	49.0	11.4		0.1	
	3 km North of Ban Khai			100	99.8	61.2	16.4		1.1	0.3
	3 km North of Ban Khai			100	96.4	59.5	22.9		1.0	0.1
	3 km North of Ban Khai			100	98.3	50.9	15.4		0.6	0.2
	3 km North of Ban Khai			100	97.4	39.8	5.9		0.4	0.1
	3 km North of Ban Khai			100	99.2	59.3	11.6		0.4	0.1
S - 5	11 km North of Ban Khai				100	71.9	14.1		0.7	0.2
	11 km North of Ban Khai			100	99.8	69.9	21.7		1.9	0.9
	11 km North of Ban Khai				100	77.6	29.4		1.3	0.4

However, Persons (1970) suggested that there are 3 types of laterite commonly encountered in a tropical climate. The name of these types describe their physical appearance.

a) Wormhole laterite (vermicular) is a massive concretionary formation with an iron-rich matrix and slaggy or wormhole-like appearance.

b) Pellet laterite (oolitic) consists of fine soil grains which are cemented by iron oxide into pellet-shaped particles. These pellets may be loosely consolidated or unconsolidated.

c) The third type of laterite is a "soft-doughy" material which harden irreversibly upon exposure to alternate wetting and drying.

Wormhole and pellets laterite will also become irreversibly harder and more stable upon exposure to alternate wetting and drying. This unique property supplements the physical properties to make these two types of laterite desirable construction materials and an important group in the tropical soil family.

Laterite is found in the soil profiles of sparsely vegetated and rolling to roughly dissected terrain. It is formed through the action of minerals from weathered various rock types which are carried into the subsoil stratum by a fluctuating ground water table.

Laterite is often confused with lateritic soil simply because the physical appearances and chemical properties are so similar. Lateritic soils vary in type from poorly graded sands to highly plastic clays and vary in colour from a red to a reddish brown. Although lateritic soils also harden upon drying, they soften readily upon wetting. The lateritic soils are finer grained materials than laterite and behave accordingly. An important physical difference between a laterite and lateritic soils, is that a laterite has a gravel component but a lateritic soil does not.

Laterite is mostly suitable as subbase and shoulder of road, subbase of airfield and the course for a medium traffic road. It is excellent as a fill material and compacted fill in earth dams used for impounding water. Blocks cut from laterite can be used effectively as building material.

Within the studied area, laterite and lateritic soil closely related to granitic residuum and terrace deposits. Considering the topography and geology, they are favourable for laterite formation. Almost all of laterite deposits used are located in undulating terrain and foot slope where granitic rocks are underlain at the base. Some of the laterite deposits including a limited number of weathered rocks, have been used as soil aggregate for subbase and shoulder of road, are illustrated in Figure 4.3.4 Cercerning the potential, it can be said that laterite and lateritic soil resources are abundant in this area.

Considering the engineering uses of laterite and lateritic soils, the significant properties should be tested, namely, gradation, Atteberg limit (liquid limit, plastic limit and plastic index), compaction test, and California Bearing Ratio (CBR). Vallentine, Laurie & Davies, R.O.P. (1977) provided engineering properties of laterite deposits with reference numbers of L-1 to L-10 and are presented in Table 4.3.4.3-b. The laterite deposits of reference numbers L-11 to L-30 are to be tested by Chachoengsao Highway Engineering Division, Highway Department and are presented in Table 4.3.4.3-c

4.3.5 Fossil Fuels

Due to the fact that the studied area is a part of the Eastern Coast, Upper Gulf of Thailand, therefore, it must be directly affected to the exploration and development of petroleum prospect whithin the Gulf of Thailand. The result of various industrial projects are planned to launch within the studied area rely mostly on the promising of petroleum prospect since 1977. From many exploratory wells, it is found that almost all of the discovered petroleum is in the forms of natural gas and the condensates. These petroleum products which will be piped up at Map Ta Pud, Rayong can be used as the significant fuel for the power generating plant and other heavy industrial projects, namely, soda ash, steel and sponge irons, fertilizers projects and etc. Undoubtedly, many of chain industries will be launched after these heavy industrial projects enjoy the benefit. Besides being used as direct fuel, natural gas can also be seperated or processed for its products which can be further utilised for various other purposes. As mentioned, the use of natural gas is universal and particularly as energy resource for the industrial purposes. It can be said that natural gas is the

Table 4.3.4.3-b Engineering properties of laterite and lateritic soil, tested by Vallentine, Laurine & Davies R.O.P. (1977)

Ref. No.	LOCATION (Start from Ban Bung)	UNIFIED SOIL CLASSIF.	SIEVE ANALYSIS % PASSING											Atterberg Limit			Modified Compt. Test		Lab. CBR	
			51 mm	39 mm	26 mm	19 mm	9.5 mm	2.4 mm	4.75 mm	1.3 mm	0.42 mm	0.15 mm	0.075 mm	LL	PL	PI	MDD gm/cc	OMD %	at 95 % rd	Swell %
L - 1	200 m. north of Km 4 + 100 of route no.3138	GC			100	96	88	70	50	43	38	36	34	46	24	22	2.03	10.6	15.5	.88
L - 2a	100 m. east of rout no.331, 1 Km. from Km. 19 + 400 of route no.3138	GC				100	99	88	57	39	29	25	23	39	23	16	2.07	8.2	25.3	.07
L - 2b	100 m. east of rout no.331, 1 Km. from Km. 19 + 400 of route no.3138	GC				100	99	92	60	41	28	22	20	27	16	11	2.11	6.0	53.0	-
L - 3	100 m. right of Km. 14 + 450 of route no.3138	GC			100	99	97	88	54	32	21	17	14	36	23	13	2.07	6.8	43.3	-
L - 4	100 m. left of Km. 35 + 200 of route no.3138	GC			100	96	79	63	46	35	24	18	15	23	15	8	2.21	6.9	36.7	-
L - 5	3 Km. left of Km. 35 + 800 of route no.3138	GC		100	95	88	74	56	34	27	21	18	15	27	17	10	2.16	6.2	37.0	.01
L - 6	300 m. left of Km. 38 + 700 of route no.3138	GC		100	97	95	91	80	43	35	28	24	22	34	19	15	2.16	7.0	46.5	.04*
L - 7	300 m. left of Km. 52 + 350 of route no.3138	GM	100	94	90	88	82	66	48	44	40	37	35	48	31	17	1.93	12.6	18.5	.98
L - 8	2 Km. right of Km. 52 + 950 of route no.3138	GC-GM		100	97	93	85	78	63	51	43	39	37	47	27	20	1.97	11.9	19.3	.34
L - 9	1 Km. left of Km. 57 + 550 of route no.3138	GM		100	98	95	78	56	42	36	31	28	26	47	29	18	2.04	11.1	31.7	12
L - 10	1 Km. right of Km. 74 of route no.3138	GC		100	99	88	72	58	46	39	32	28	26	33	20	13	1.91	11.8	30.3	.08

Table 4.3.4.3-c Engineering properties of some laterite deposits, tested by Chachoengsao Highway Envineering Division, Highway Department.

Ref. no.	LOCATION	SIEVE ANALYSIS % PASSING										Atterberg limit			Standard Proctor		Lab. C.B.R.	
		2"	1½"	1"	3/4"	½"	3/8"	4#	10#	40#	200#	LL	PL	PI	Opt Mc %	Dry density	C.B.R.	Swell %
L - 11	5 Km. right of Km. 7 + 000 of route no.3133		100.0	99.1	98.9	98.7	98.2	80.2	46.3	26.3	17.2	21.0	16.7	4.3				
L - 12	2 Km. left of Km. 99 + 100 of route no.3	100.0	99.4	88.9	81.4	69.0	60.3	38.4	28.5	17.2	12.4	34.6	25.9	8.9				
L - 13	3 Km. left of Km. 149 + 700 of route no.3	100.0	92.5	90.8	86.0	77.6	72.3	50.9	25.2	14.4	9.5	30.7	21.7	9.0				
L - 14	1 Km. left of Km. 162 + 950 of route no.3	100.0	99.2	98.3	91.9	85.8	82.2	61.6	39.7	23.5	16.2	28.6	23.9	4.7				
L - 15	1 Km. right of Km. 182 + 800 of route no.3	100.0	95.2	88.2	81.6	70.6	60.8	30.5	19.3	12.7	9.8	20.4	13.8	6.6				
L - 16	1 Km. left of Km. 159 + 100 of route no.3	100.0	98.1	93.9	89.3	83.9	80.3	58.1	36.9	21.5	16.6	34.7	23.9	10.8				
L - 17	1 Km. right of Km. 18 + 900 of route no.3241	100.0	-	97.6	94.7	89.9	85.8	67.9	50.7	25.8	14.9	25.7	19.7	6.0				
L - 18	5 Km. left of Km. 98 + 100 of route no.3		100.0	98.3	96.8	94.2	92.1	82.4	55.9	26.7	14.2	18.8	14.5	4.3				
L - 19	500 m. left of Km. 2 + 400 of route no.332		100.0	98.6	96.6	93.5	91.1	61.9	34.9	20.2	14.6	27.6	18.9	8.7				
L - 20	2 Km. left of Km. 3 + 500 of route no.3144	100.0	98.8	39.6	82.3	72.3	65.9	46.9	34.5	25.1	19.6	28.6	23.0	5.6				
L - 21	2.5 Km. left of Km. 3 + 050 of route no.3144	100.0	97.4	39.5	83.5	73.9	66.5	45.5	34.1	25.6	19.3	35.3	23.3	12.0				
L - 22	Right of Km. 7 + 000 of route no.3240														7.3	2.159	55.5	0.666
L - 23	150 m. right of Km. 13 + 000 of route no.3240		100.0	97.2	93.3	87.2	80.4	48.8	25.4	14.0	10.0	19.5	16.0	3.5				
L - 24	500 m. left of Km. 5 + 300 of route no.331	100.0	-	86.6	81.2	71.4	62.9	37.6	25.8	18.5	13.5	28.2	22.6	5.6				
L - 25	3 Km. left of Km. 48 + 900 of route no.36														16.3	1.910	28.0	0.67
L - 26	500 m. left of Km. 19 + 200 of route no.3191														7.7	2.146	49.0	0.599
L - 27	1 Km. left of Km. 46 + 600 of route no.36														6.9	2.180	67.0	0.33
L - 28	100 m. left of Km. 213 + 300 of route no.3														8.4	2.217	65.4	-
L - 29	250 m. right of Km. 250 + 800 of route no.3														11.3	2.069	73.4	0.3
L - 30	1.2 Km. right of Km. 8 + 590 of route no.3143	100.0	87.0	68.8	61.8	51.7	45.7	30.1	16.7	11.2	8.5	25.3	17.2	8.1				

key to the direction of Thailand's industrial development strategy.

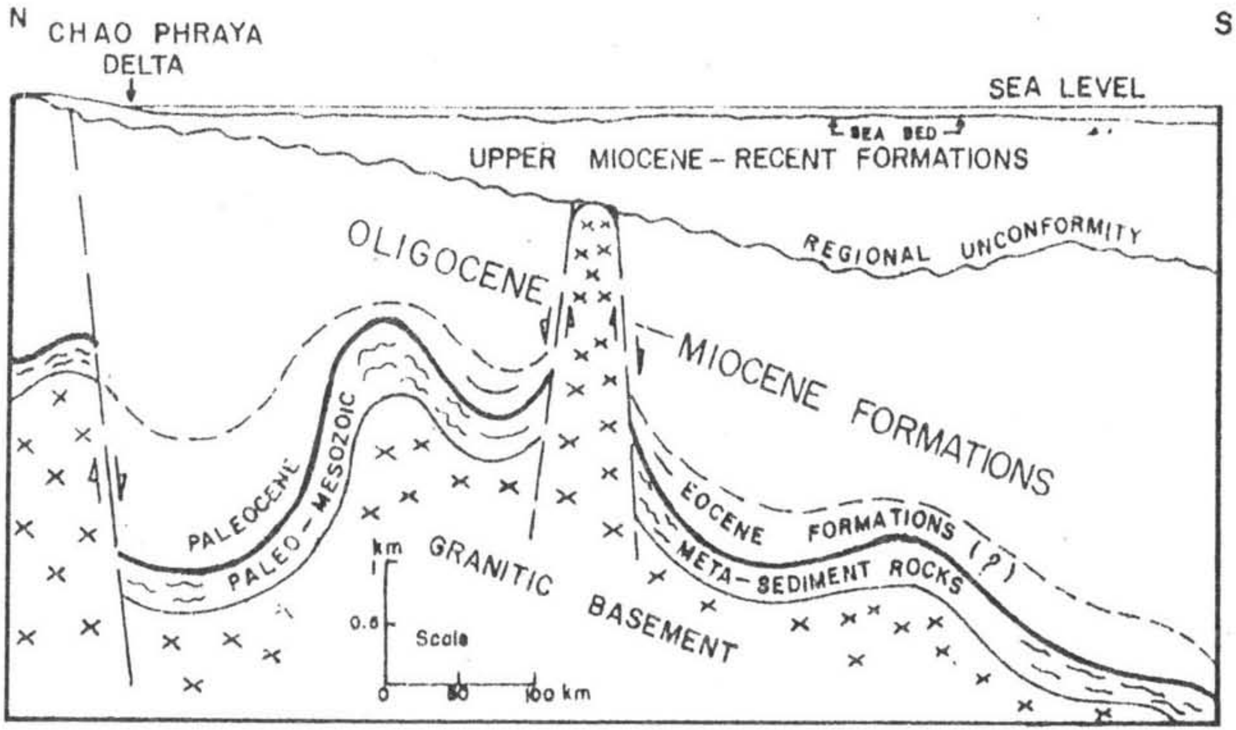
From the geological point of view, Achalabhuti (1974) concluded that the Gulf of Thailand is a tectonic basin and its northward extension is connected with the Chao Phraya depression. They occurred in Late Cretaceous-Early Tertiary orogeny and later modified by the movement of volcanic intrusions in Late Miocene time. From detailed geophysical surveys and the results of drilling wells, it revealed that the Gulf of Thailand is floored and underlain by clastic sediments and rocks of less than 800 to over 3,700 meters thick and ranging in age from Recent to Oligocene of Tertiary age by palynological dating. The acoustic basement varies from Upper Paleozoic-Mesozoic metamorphic rocks, Mesozoic granite, and Tertiary volcanic rocks as platforms or ridges which are interrupted by the basins or graben containing in excess of 1,000 meters of strata. A prominent regional unconformity is recognized in the seismic profile and was intersected in the wells at depth from about 300 to 1,400 meters. This unconformity is considered to be Late Miocene in age. Palynological data indicates that Tertiary strata was deposited under alternating sequences of depositional environment or system, namely, supralittoral, coastal swamp, lagoonal, littoral and inner sublittoral as classified by Hedgpeth (1957) or fluvial-deltaic, marsh-swamp, bay-estuary-lagoon, deltaic barrier-strandplain and offshore-shelf as defined by Fisher, Brown, and Scott (1972). These Tertiary depositional systems were active in filling the Gulf and Chao Phraya Basin and are interpreted to be similar to modern depositional systems that are active in forming the present Gulf and Chao Phraya deltaic plain. Natural gas and oil accumulations found in the Tertiary sandstone sequences of the Gulf of Thailand suggest that the occurrences of hydrocarbon is controlled primarily by depositional environments, particularly deltaic environments, in association with coincident structures. The generalized stratigraphic section and cross-section of the Gulf of Thailand are presented and illustrated in Table 4.3.5.1 and Figure 4.3.5.1 respectively.

Petroleum exploration in the Gulf of Thailand has been active since the Government granted the priviledge to explore and produce petroleum to the oil companies in early 1968. Drilling activities were started in year 1971 and up to mid 1973, 7 exploratory wells were drilled and the 2 of them discovered the hydrocarbon in Tertiary strata at depth less than 3,000 meters. Coming to the end of the year 1981, the total of 86 exploratory wells were drilled. It is apparent that 47 wells of natural gas and the condensate were found. The 2 wells of crude oil were discovered in the Block no. 6 and 15 with the rate of flow 789 and 1,133 barrels per day, respectively. Besides, 2 wells of the mixing of crude oil, natural gas and the condensate were reported. Recently, it can be estimated that the natural gas reserve within the Gulf of Thailand is approximately 16.5 trillion cf. The companies receiving exploration concessions, natural gas reserve and the petroleum exploration blocks including the significant structures in the Gulf of Thailand are summarized in Table 4.3.5.2 and Figure 4.3.5.2. In addition, natural gas from the Erawan field has been on stream, as scheduled, in mid-September 1981 at the rate of 200 MMcfd at the initial stage, and

Table 4.3.5.1 Generalized stratigraphic section of the Gulf of Thailand.

<table>
<tr><th>Major Lithologic Units</th><th colspan="2">Floral Zones</th><th colspan="3">Environmental Phases.</th><th colspan="2">Age</th></tr>
<tr><td>Lightgrey-grey brown clays, silty with lignite interbeds</td><td colspan="2">Podocarpus</td><td colspan="3">Inner sublittoral</td><td colspan="2">Quaternary</td></tr>
<tr><td>Lightgrey clays with sands and lignite interbeds</td><td colspan="2">Dacrydium</td><td>Coastal swamp</td><td>Littoral</td><td>Sublittoral</td><td>Pliocene</td><td rowspan="5">TERTIARY</td></tr>
<tr><td>Grey claystones and shales with sandstone and lignite/coal interbeds</td><td colspan="2">Florschuetzia meridionalis</td><td>Coastal swamp</td><td>Lagoonal</td><td>Coastal plain</td><td>Upper — Middle Miocene</td></tr>
<tr><td rowspan="2">Varigated shales with sandstone and coal interbeds</td><td rowspan="2">Florschuetzia levipoli</td><td></td><td>Flood plain</td><td>Coastal plain</td><td>Lagoonal</td><td>Middle Miocene</td></tr>
<tr><td>Alnipollenites verus</td><td>Coastal plain</td><td>Littoral</td><td>Inner-Sublittoral</td><td>Lower Miocene</td></tr>
<tr><td>Dark grey shale with sandstones interbeds</td><td colspan="2">Florschuetzia trilobata</td><td>Littoral</td><td colspan="2">Inner — Sublittoral</td><td>Oligocene</td></tr>
</table>

(After Achalabhuti, 1974)

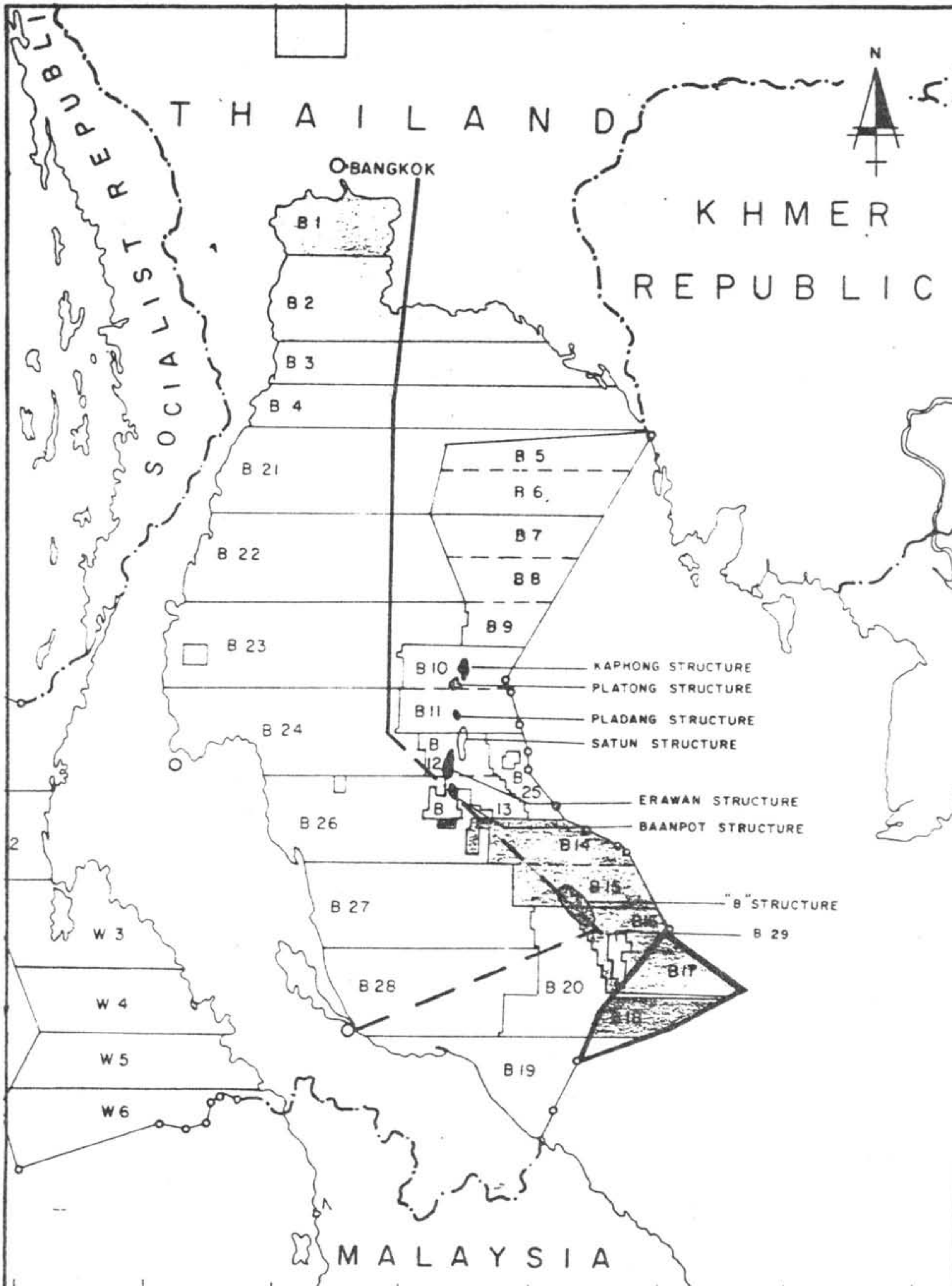


(After Achalabhuti , 1974)

GENERALIZED STRATIGRAPHIC CROSS - SECTION OF THE GULF OF THAILAND	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST , UPPER GULF OF THAILAND	
DEPARTMENT OF GEOLOGY , GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	SUNYA SARAPIROME	FIG. 4.3.5.1

Table 4.3.5.2 The companies receiving exploration concessions and natural gas reserves in the Gulf of Thailand

Company	Block No.	Approximate Area (Sq.km.)	Structure	Naturalgas Reserve MMCF.	Status (Remarks)
1) Amoco Thailand	5, 6	25,857	-	-	Drilling activity is not started
2) Pecten Thailand Co.	1, 2, 3	-	-	-	Finished in geophysical exploration Programme in year 1981, start drilling in 1982
3) Thailand Sun Oil Co.	7, 8, 9	35,909	-	-	Drilling activity is not started
4) Texas Pacific Thailand Inc.(group)	14, 15, 16, 17	-	"B"	5.8	During well-head price negotiation
5) Triton Oil Co. of Thailand	18	-	-	-	Drilling activity is not started
6) Union Oil Co. of Thailand (group)	10, 11, 12, 13, 23	-	Erawan	1.8	5 production platforms are completed
			Kaphong-Platong	1.3	During well-head price negotiation
			Baanpot	0.8	-
			Satun	3.2	-
			Pladang	0.6	-
			Chakkawan	1	-
			Pladang Nua	commercial value	-
					-
			Fu-nan	commercial value	-



PETROLEUM EXPLORATION BLOCKS AND STRUCTURES IN THE GULF OF THAILAND.	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND	
DEPARTMENT OF GEOLOGY, GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	SUNYA SARAPIROME	FIG. 4.3.5.2

will eventually be increased from other fields to over 500 MMSCFD by 1986.

4.4 Surficial Deposits

The characters of surficial deposits are among various factors that have directly influence on the soil characters and their formation. In general, those factors involve climate, plant and animal organisms, topography or relief, age of land, and finally, parent materials which closely related to surficial deposits. On the other hand, the surficial processes, landform and source rocks are considered to have influence on the characters of surficial materials. The surficial materials play the most important roles in providing sustenance for all lives on it. Their characters are the highly organised physical, chemical and biological complexes on which the lives are dependent.

Within the studied area, the surficial deposits can be divided into 3 categories, notably, coastal plain deposits, alluvial plain deposits and residual/landslide/talus deposits. The coastal plain comprises of beach/dune deposits, estuarine/tidal flat deposits, and old tidal flat/old marsh deposits, whereas alluvial plain deposits include floodplain/channel deposits and alluvial fan/terrace deposits (including valley fill deposits). Last, residual/landslide/talus deposits have various characters depending on different parent materials which are sediments/metasediments, quartz (mica) schist/quartzite, and granitic/gneissic rocks. The surficial deposits are compiled from the field investigation and aerial photograph interpretation including the information from Soil Survey Dirision, Department of Land Development. The map of surficial deposits is illustrated in Plate 4.4. Each type of deposit will be discussed in more detail as follows

4.4.1 Beach and Dune Deposits

Within the studied area, beach and dune deposits occur as strips along the coastline on either recent or former beach of the bays, namely, Ao Bang Saen, Ao Bang Lamung, Ao Naklua, Ao Laem Mai Ruak and Ao Bang Sare in Chon Buri Province. In Rayong Province they are found on Rayong bay from Ban Ao Prado eastwardly as well as the older and recent sand spits at Rayong estuary. The deposits are not followed any particular pattern of climatic condition. Therefore, their characteristics are significantly related to the nature of parent materials which are sediments generally derived from granitic rocks and quartzite or free-silica rich rock. The deposits occur on the nearly flat terrain with elevation ranging from 1 to 10 meters above the mean sea level and 1 to 2 per cent of slope. The profile of deposit is very deep to more than 20 meters in general. The texture of sediments is a coarse-texture with doninant sand that result in high permeability in the upper part whereas the permeability of the clayey lower part is comparatively lower. The runoff on the deposit is slow to moderate due to the slope and permeable character. The water table of the deposit is fluctuated but generally stay below 1 meter throughout the year. The consistency of sediment is non sticky and loose.

With regard to the properties of soil of the deposits, it is tabulated in Table 4.4.1. Naturally, they are not well suited for cultivation owing to their serious limitations to agricultural development, namely, acute nutrient dificiences, very poor water retention capacity, weak structure in the surface layers and weak to moderate compaction. However, where the rainfall is so frequent and abundant that the groundwater is relatively shallow, coconut and dry land crops have been successfully planted.

4.4.2 Estuarine and Tidal Flat Deposits

The deposits occur on the depression of the coastal plain of Bang Pakong estuary, adjacent to Chon Buri township. They covered comparatively small areal extent. Regarding to the low-energy of transportation of Bang Pakong River, the estuarine deposit, forming as tidal flats, is the result of limited sediment load. Undoubtedly, the transported sediments are dominantly fine texture of clay size. The relief of the area is flat with the elevation of 1 meters or less above the mean sealevel. The runoff is rapid. Permeability as well as the drained property are very poor but becoming moderate in the area where large number of root channels and crab holes are presented. The deposits are on the muddy, depression land facing the sea. Therefore, they are regularly flooded by sea water and the groundwater level remains at or near the surface throughout the year.

The soil properties of the deposit are summarized in Table 4.4.2. Considering those properties and physiography, it is interesting to note

Table 4.4.1 The soil properties of beach and dune deposits.

Properties	Surface Soil	Subsoil
Depth (cm)	5-20	deep
Colour	dark grey to dark greyish brown	yellowish brown to pinkish gray and dark brown in the depression
Texture	loamy sand to loamy coarse sand	medium to very coarse sand, sandy loam to loamy sand in the depression
Structure	medium subangular blocky to very weak granular, single grain	weak granular single grain and massive or weak blocky in the depression
Consistency	non-sticky, non-plastic,	loose, non-sticky, non-plastic
Pore character	fine to medium interstitial pores	fine to coarse interstitial
pH	4.5-6.5	5.0-6.5

Table 4.4.2 The soil properties of estuarine and tidal flat deposits

Properties	Surface soil	Subsoil
Depth (cm)	5-40	deep
Colour	brown to very dark grey	dark grey or greenish grey
Texture	Clay	clay and silty clay
Mottling	common in brown, yellowish red and grey	hard iron nodules
Structure	weak to moderake, medium subangular blocky structure	weak, coarse subangular blocky to massive
Consistency	plastic	sticky and plastic
Pore character	medium to fine tabular	very fine to fine tabular
Roots and crabholes	common	common crab holes
Organic matter	common	common
pH	6.0-8.0	6.0-8.0

that there are many serious limitations to agricultural development. These limitations include one or more of the following factors : nutrient deficiency, unfavourable soil texture and structure, susceptibility to flooding and severe salinity. However, mangroove forest can be applied to the area in producing woods for charcoal. Furthermore, the area can be used as salt evaporators, and fish/shrimp culture ponds.

4.4.3 Old Tidal Flat and Old Marsh Deposits

Within the studied area, these deposits occupy small areal extent. They are believed to be closely related with estuarine and brackish water deposits. They are found on the area of further landward and higher elevation as compared with the other two types of deposits earlier described. Seawardly, they are connected to beach and tidal flat deposits whereas landwardly, the brackish water deposit underlain the riverine alluvium are the distinct characters. Relief of the area is generally flat with elevation of 1 to 7 meters above the mean sea level and the slope is about 1 per cent or less. The dominant texture of lower elevation is clay while the deposit on higher level is clay to clay loam type. The drainage property is poor with low permeability and slow runoff. However, the permeability may be moderate in the sandy area. Groundwater level of the area falls below 1 to 1.5 meters from the soil surface during the peak of dry season. During rainy season, the area of elevation about 1 to 1.5 meters above the mean sea level is periodically inundated to the level of 0.5-1 meters by river/brackish water and/or impounded rain-water.

Considering only the soil properties which are presented in Table 4.4.3 and the physiography, it can be suggested that the area are generally not suitable for cultivation. Fortunately, the rainfall of the area is so high and frequent that some parts can be used for broadcast and transplanted rice cultivation.

4.4.4 Floodplain and Channel Deposits

The area of floodplain and channel deposits mainly cover the Rayong and Bang Pakong floodplains, and scatteringly on the landward area between Chon Buri and Sattahip. A large proportion of the area is subject to seasonal flooding of varying depth and duration. Considering the parent materials in the short distance of upstream positions and poorly developing floodplain, it can be said that the sediments of the alluvial deposits essentially derived from granitic and gneissic rocks. Therefore, the distinct texture of the sediments is silt and fine sand of free silica despite the fact that silt and clay are mostly dominant for general floodplain deposit. The relief of the area is flat to nearly flat with the slope of approximately 2 per cent or less and the elevation is between 10 to 40 meters above the mean sea level. The drained property of the deposits is moderately well. Permeability is estimated to be moderate and runoff is comparatively slow owing to their medium texture and flat topography. Groundwater level of the area falls below 1.5 meters from the ground surface during the peak of dry season. The less elevated of the deposits are usually inundated by impounded rain water during the rainy season.

Table 4.4.3 The soil properties of old tidal flat and old marsh deposits.

Properties	Surface soil	subsoil
Depth (cm)	20-40	deep
Colour	dark grey, dark greenish brown to black	brown, light grey, greyish brown to dark grey, dark greenish grey
Texture	fine : sandy loam, clay loam, clay	sandy loam, sandy clay
Mottling	yellowish red to strong brown along root channels	brownish yellow and yellow
Structure	massive to weak coarse and medium blocky, moderate crumb in part	weak prismatic breaking to subangular blocky
Consistency	sticky and plastic, firm moist	sticky and plastic, firm moist
Pore character	fine to very fine tabular	very fine interstitial and very fine tabular with humous clay ceating
Root	very fine root	-
pH	4.0-8.0	4.0-8.0

Concerning the soil properties of the area, it is rather difficult to described more precisely due to the diversified environment of deposition. Mixed layers of sand rich material interbedded with the clay rich ones are usually found in the same horizon of the soil. Consequently, the soil characteristics vary within the same horizontal, for instance, the consistency of argillic horizon can be varied from very sticky and plastic to non sticky and non plastic. However, an attempt has been made to summarize these properties in Table 4.4.4.

During the rainy season, the low elevated areas are significantly used for transplanted rice cultivation while it reverts to be grass and secondary shrubs during the dry season. In the high elevated areas, they are proper for sugar cane, cassava, coconut, rubber and variety of fruits plantation.

4.4.5 Alluvial Fan/Terrace and Valley Fill Deposits

The alluvial plain deposits which cover comparatively large area are recognized to be of alluvial fan and terrace origins. They generally occupy the area paralleling to the coastline of the studied area and scattering as irregular areas of small and shallow valleys. Considering the parent materials, almost all of the sediments are derived from granitic and gneissic rocks in the adjacent area of the deposits. Relief of the area is nearly flat to undulating with 2 to 5 percent of average slope and the elevation is approximately 2 to 80 meters above the mean sealevel. The texture of the deposits vary from sand, loamy sand to sandy loam. The drained property is well to

Table 4.4.4 The soil properties of floodplain and channel deposits

Properties	Surface soil	Subsoil
Depth (cm.)	10-30	deep
Colour	light grey to dark grey, greyish brown or brown to dark greyish brown	light grey, light brownish grey, light reddish brown to yellowish brown
Texture	clay loam, sandy loam and loamy sand with more angular quartz sand	sandy clay and sandy clay loam
Mottling	yellowish brown to strong brown	dark brown, dark red
Structure	medium to coarse subangular blocky and single grain	medium to coarse blocky
Consistency	friable to slightly firm, non-sticky, non-plastic	friable, non-sticky, non-plastic
Pore character	interstitial pores, fine and medium tabular pores	fine and medium interstitial pores, few fine tabular pores
pH	4.5-8.0	5.0-8.0

excessive. The permeability is estimated to be moderate to rapid based on texture whereas the runoff is rapid based on the slope character. Groundwater table falls below 1.5 meters from the ground surface throughout the year and down deeper during the peak of dry season, particularly on the high-elevated area.

The soil properties are summarized in Table 4.4.5. Recently, most of the area are for cassava cultivation and partly for coconut and/or other upland crops and fruits.

4.4.6 Residual/Landslide and Talus Deposits (Sediments and Metasediments as Parent Materials)

The deposits occur on the small area relating to slope complex of sediments and metasediments which generally are fine-grained clastic rocks and their metamorphic equivalents. They form slump feature, dissected erosional surface, slope and foothill deposits on the elevation of approximately 20 to 60 meters above the mean sea level. Relief of the area is undulating to hilly with slope ranging from 2 to 10 per cent. The general texture of the deposits is medium with gravel such as gravelly loam and gravelly clay. The runoff is rapid while the permeability is moderate to high. The groundwater table usually falls 5 meters below the ground surface in the dry season. The deposits are obviously presented in the vicinity of Sattahip and the extreme east of the studied area.

Soil properties of the deposits are summarized in Table 4.4.6. Originally, the area was covered by mixed deciduous forest. Later, it

Table 4.4.5 The soil properties of alluvial fan/terrace and valley fill deposits

Properties	Surface Soil	Subsoil
Depth (cm.)	10-30	deep
Colour	greyish brown to brown	light brownish grey to pale brown
Texture	loamy sand	coarse sandy loam
Mottling	-	present in deeper part with iron nodules in part
Structure	weak blocky and single grain	very weak blocky and single grain
Consistency	friable, non-sticky non-plastic	friable, non-sticky
Pore Character	common fine and few medium tabular pores	fine interstitial pores and fine to medium tabular pores
pH	6.0-8.0	5.5-7.0

Table 4.4.6 The soil properties of residual/landslide and talus deposits which the parent materials are sediments and metasediments

Properties	Surface Soil	Subsoil
Depth	10-30	deep
Colour	dark brown, dark reddish brown or dark greyish brown	reddish brown or yellowish red to red
Texture	gravelly loam or gravelly clay loam	gravelly clay loam or gravelly clay
Mottling	-	iron nodules
Structure	fine to medium granular (uppermost) medium blocky (lower)	medium to cearse blocky with quartz gravel
Consistency	sticky, plastic, slightly firm friable (rich in coarse fractions)	sticky, plastic, slightly firm friable (rich in coarse fractions)
Pore Character	common fine and medium interstitial pores, few fine tabular pores	fine and medium interstitial pores, few fine tabular pores
pH	5.5-8.0	4.5-5.5

has been tranformed for upland crop cultivation. In the area of high rainfall at the extreme east of the studied area, it is most suitable for rubber plantation.

4.4.7 Residual/Landslide and Talus Deposits (Quartz (Mica) Schist and Quartzite as Parent Materials)

Within the studied area, the deposits cover only limited areas particularly in the vicinity of Si Racha. They are formed as the narrow strips on the foothills and erosional surface of hill slopes where the country rocks are quartz (mica) schist and quartzite. Relief of the area is rolling to hilly with the slope falls between 5 to 20 per cent. The elevation is extremely varied. The deposits show medium texture of sandy, silty and clayey loam with gravel in the deeper profile. The drained property is considered to be well whereas permeability is high and runoff is rapid. Groundwater table falls 2 meters below the ground surface throughout the year.

The soil properties are summarized in Table 4.4.7. Broadly, the area is used for fruits, upland crops and rubber plantation.

4.4.8 Residual/Landslide and Talus Deposits (Granitic and Gneissic Rocks as Parent Materials)

Within the studied area, it is apparent that these deposits occupy the largest areal extent particularly almost all of the central part. The northwest and southeast mountainous areas or the slope complexes of granitic and gneissic rocks are almost surrounded by this

Table 4.4.7 The soil properties of residual/landslide and talus deposits which quartz (mica) schist and quartzite are parent materials

Properties	Surface Soil	Subsoil
Depth (cm.)	10-30	deep
Colour	varying of reddish brown, dark grayish brown, and dark brown	red or dark, strong brown, yellowish to reddish brown
Texture	sandy, silty and clayey loam to loam	gravelly clay loam to gravelly clay
Structure	medium subangular blocky	fine to coarse subangular
Consistency	friable, slightly sticky, plastic	friable, sticky, plastic
Pore Character	fine interstitial pores	common thick contimeous clay coating on ped faces
pH	5.0-8.0	4.5-6.0

type of deposit. The deposits include residium, colluvium, eluvium, alluvial fan and eroded hill deposits. The area shows the relief of undulating, rolling and hilly with the slope of 2 to excess 15 per cent and the elevation of 20 to 120 meters above the mean sealevel. The drained property is considered to be well whereas permeability and runoff are estimated to be moderated in vegetated slope to rapid in vegetation-barren slope. The texture varies from loamy sand, sandy clay loam to gravelly sandy clay. The sediments are mainly consisting of angular/subangular quartz grains and feldspar including mica flakes in the deeper profile. It can be said that lateritic layers with gravelly sediments appear to be the dominant characteristics of the deposits. In the low-elevated area, groundwater level falls 1 meter below the ground surface throughout the year while it appears at greater depth in the high-elevated area. Considering the water conditions within the area, the deposits are influenced by seepage from the nearby high land and sometimes may be subject to flash floods for a brief periods during the heavy rains.

With respect to the soil properties of the deposit, it is recognized that they vary from place to place throughout the extensive area coverage. However, an attempt has been made to conclude the general properties of the deposits as presented in Table 4.4.8. In the steeper slope of the area, they remain as natural deciduous forest whereas the more flat land have been mostly transformed to fruit, rubber and upland crops of sugar cane, pine apples and particular on cassava plantation.

TTable 4.4.8 The soil properties of residual/landslide and talus deposits which granitic and gneissic rocks are parent materials.

Properties	Surface Soil	Subsoil
Depth (cm.)	10-15	deep
Colour	brown to dark brown and/or dark to very dark greyish brown	yellowish brown or strong brown to yellowish red or reddish yellow
Texture	sandy clay loam, loamy sand	coarse sandy clay loam grading to gravelly sandy clay (with discernable gravel and sand fraction)
Mottling	-	yellowish and reddish mottl mottler lateritic layer
Structure	fine crumb, fine blocky	fine to medium subangular blacky
Consistency	friable, slightly sticky non plastic	friable, slightly sticky and slightly plastic
Pore Character	fine interstitial and tabular pores	fine interstitial and fine tabular pores
pH	5.0-7.0	4.5-7.0

4.5 Water Resources

4.5.1 Surface Water

The studied area is characterized by the two major river basins, Chon Buri and Rayong Basins. The Chon Buri Basin is separated from Rayong Basin by the mountain range oriented in the north/south trend with distance of approximately 15-20 kilometers landward from the coastline. (Plate 4.5.1).

Chon Buri Basin occupies the narrow strip of the eastern coast of the Inner Gulf, having a total drainage area of about 1,126 million square meters. The average annual rainfall within the basin area is 1,379 millimeters and the average annual runoff is 448 million cubic meters. Chon Buri Basin comprises of several small streams which each of them is approximately 40-50 kilometer long, namely, Huai Krok luk, Khlong Yai, Huai Ta Khian, Klong Na Klua, Khlong Chak Nog, Huai Yai and others. Generally, these streams flow westward to the Inner Gulf. Due to the basin characteristics which are narrow, steep slope and comprising of comparatively short streams, the downstream area have been periodically damaged physically and economically from flooding to the level of 1.5-5.0 meters per second per million square meters after 1-8 hours of the rain-fall and the inflooding generally remains for 1-7 days.

The annual run-off within subdrainage basins are not directedly measured in the area. However, an attempt has been made to evaluate the runoff using the analogous comparison method with others with the same characteristics. The result of runoff is 6-12 litres per second per million square meters (or about 189,200-378,400 cubic meters per year per million square meters) for basin with area less than 40 million square meters and 12-18 litres per second per million square meters (or about 378,400-567,700 cubicmeters per year per million square meters) for basin with area between 40-150 million square meters. Bang Phra Basin, with drainage area of 130 million square meters, is the one that has been studied and the result is 58 million cubic meters of annual runoff.

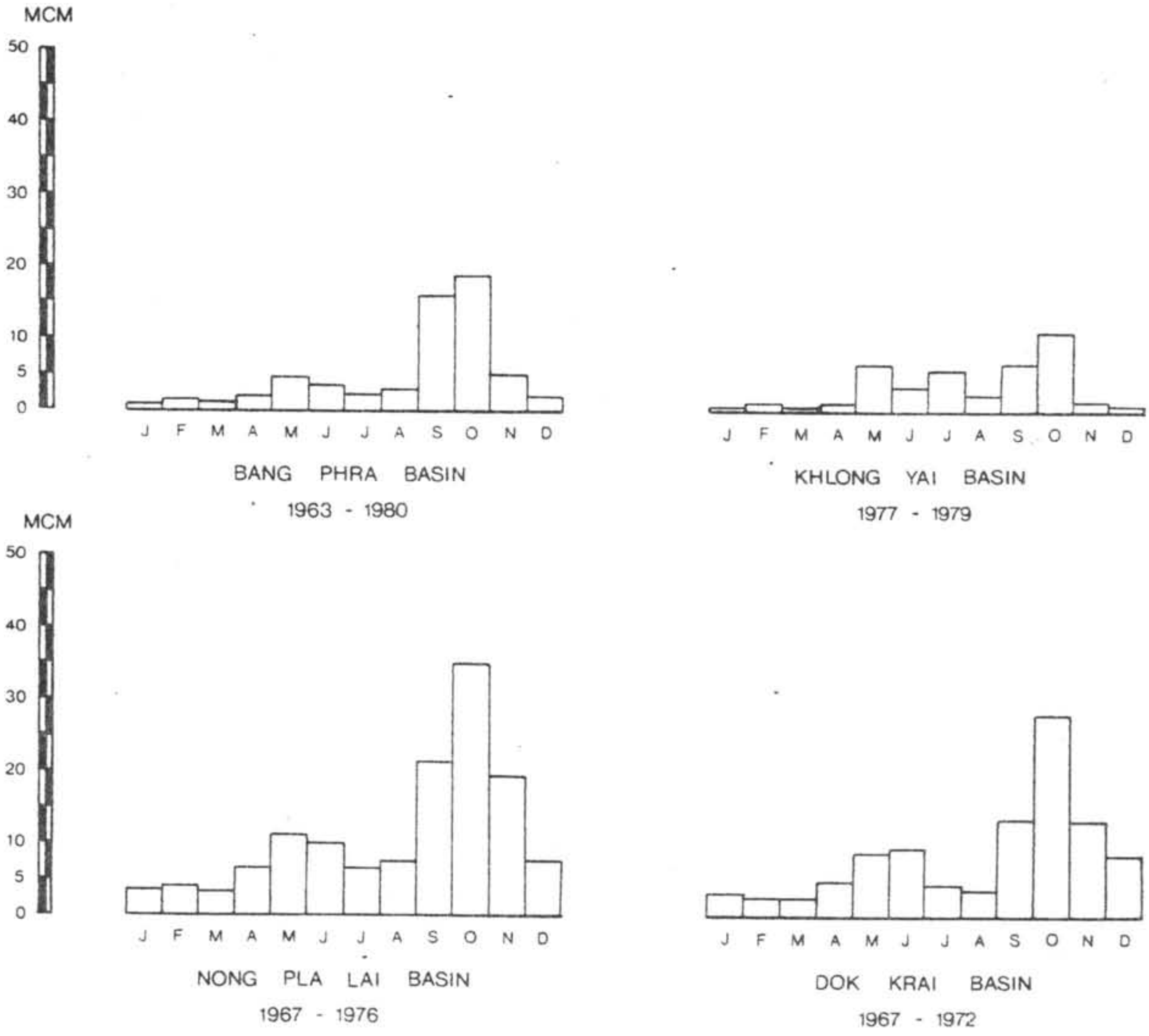
The Rayong Basin has a drainage area of about 5,620 million square meters with an average annual rainfall of 1,351 millimeters and an annual runoff of 2,044 million cubic meters. All rivers in this basin drain southwardly into the Gulf of Thailand through Rayong and Prasae. Rayong Basin occupies comparatively larger plain and the subdrainage basins also yield high quantity of surface runoff. The major subbasins of Rayong Basin are Khlong Yai, Nong Pla lai and Dok Krai including Khlong Thup Ma. The three former subbasins drain into Rayong River north of Amphoe Ban Khai before passing through Amphoe Muang Rayong to the sea at Ao Mae Ram Phung. The total length of Rayong River is approximately 80 kilometers. Dok Krai Basin occupies drainage area of 291 million square meters having an annual runoff 103 million cubic meters (1967-1976) while Nong Pla Lai, Khlong Thup Ma and Klong Yai Basins have drainage area and annual runoff of 414 million square meters, 137.84 million cubic meters (1967-1976); 157

million square meters, 60 million cubic meters; and 220 million square meters, 39.57 million cubic meters, respectively. The graphic presentation of average monthly runoff at Bang Phra, Khlong Yai, Nong Pla Lai and Dok Krai Basin is shown in Figure 4.5.1.

Considering the quality of surface water within the studied area, it is noted that the information concerned is very limited and only a few studies regarding this matter have been so far carried out. The available data on the quality of surface water in this area from various sources, notably, wells, rivers and streams, irrigation canals as well as reservoirs are compiled and presented in Table 4.5.1.

It is not possible, at the present state of knowledge, to generalize the overall picture of water quality. However, many lines of evidence indicate that in the vicinity of Pattaya City and Amphoe Naklua, where the water demand is apparently high, the surface water quality of both areas are extremely poor and unsuitable for water supply usage. This is deduced from the extraordinary low dissolved oxygen content and exceptionally high sulphur content. Besides, the surface water system is contaminated by wastes generated from the tapioca industry in the further inland section whereas in the coastal zone the salt water in flux has created a high chlorinity water in an extensive scale.

Numerous water wells in the coastal area exhibit the problem of salt-water encroachment due to excessive pumping particularly during the dry season.



AVERAGE MONTHLY RUNOFF AT BANG PHRA , KHLONG YAI , NONG PLALAI AND DOK KRAI BASINS	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST , UPPER GULF OF THAILAND

DEPARTMENT OF GEOLOGY , GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	SUNYA SARAPIROME	FIG. 4.5.1

Table 4.5.1 The quality of surface water within the studied area.

LOCATION	BOD mg/1	DO mg/1	SS mg/1	Cl^- mg/1	Total N mg/1	Total P mg/1	Fe^{++} mg/1	pH	Acidity ($CaCO_3$) mg/1	Alkalinity ($CaCO_3$) mg/1	Hardness ($CaCO_3$) mg/1	MNP/100 ml.	Turbidity	Conductivity (uV/cm.)	Air Temp °C	Water Temp °C	Recommended uses	Remarks
BANG PHRA RESERVOIR	-	5.3	-	-	0.5	-	0.08	7.4 (7.53)	8.40	49.00	26.00	-	14.00	103	-	-		Data in year 1976
DOK KRAI RESERVOIR	-	5.5	40	-	-	-	-	7	-	-	-	-	-	-	-	-		Data in year 1979
PHLU TA LUANG RESERVOIR																		
BAN BUNG RESERVOIR																		
KHLONG BANG PHAI RESERVOIR																		
KHLONG PATTAYA	45	0	47	-	13.4	2.7	-	6.9	-	-	-	240×10^4	-	-	25.5	28.5	Irrigation only	Data in year 1980
KHLONG NA CHOM THIAN																		
River mouth	5	7.2	40	17,150	0.3	0	-	7.1	-	-	-	2,400	-	-	31.0	29	Aquaculture & fishevy	Data in year 1980
South of Sukhumvit Rd.	5	8.5	61	-	1.3	0	-	7.0	-	-	-	930	-	-	27.5	28.5		
KHLONG NA KLEAU																		
River mouth	5	3.2	106	18,500	0.6	0	-	6.3	-	-	-	1,400	-	-	26	28	Irrigation only	Data in year 1980
South of Sukhumvit Rd.	1,620	-	171	-	45.7	5.2	-	4.3	-	-	-	1,100	-	-	34.5	29.5		
KHLONG TAI (RAYONG)	0.5	5.45	37.5	9	1.72	0.05	-	6.8	-	-	-	-	-	-	-	-		Data in year 1980
HUAI MAPPRACHAN	-	-	-	-	-	-	0.07	6.4	6.0	8.0	27.0	-	16.0	-	-	-		Data in year 1976
Digging Well in old beach deposit at Orchid Lodge, Pattaya	-	-	-	-	-	-	0.1	7.33	25.2	410	366	-	0.87	-	-	-		Data in year 1976

In conclusion, it is believed that the surface-water quality within the studied area is satisfactory for general usages. However, it is strongly recommended that water treatment is essentially required for potable water.

4.5.2 Groundwater

Previously, there was no record of the groundwater usage within the studied area for any development programmes. Generally, the groundwater resources has been developed to supply only limited domestic consumption and the quantity evaluated would not be adequate for agricultural and industrial uses. Considering the geological characteristics of the area which is the most significant parameter in controlling the yield of groundwater, it is believed that the studied area has limited quantity of groundwater and the recovery is highly selective from place to place. Phiancharoen and Ramnarong (1976) conducted the groundwater study at Pattaya and adjacent area. The information regarding this matter is most useful for development planning in particular. Subsequently, Phiancharoen, Ramnarong and Isarankura (1976) prepared the hydrogeological map of Chon Buri and Rayong, and fortunately, it covers most of the studied area. Lithology, aquifer and the water-bearing properties including quality as well as recommendations based largely on these reports and a limited number of well logs recorded by the Provincial Water Supply Division, Public Work Department and Groundwater Division, DMR. The hydrogeological map of the area is illustrated in Plate 4.5.2.

Within the studied area, most of the basement rocks are granites and localized granite-gneisses and gneisses. They are exposed as a series of elongated ridges. The rocks crop out on the highland and beneath the unconsolidated sediments of the undulating terrains around the granite mountains and hills. The area extends from the western coast to the east and eventually terminated at Khao Khun In mountain range. The granites at the western coast are mostly concealed by other rock types or younger sediments at depth rarely exceeding 50 meters. Drilling along the seashores may encounter granite as shallow as 20 meters excluding the area where granites are well exposed. Bedrock of the plain,north of Khao Khieo, is expected to be found deeper than that of the coastal plain and the groundwater yield is relatively higher in quantity but the water quality is problematic due to the presence of brackish water. At the lower part of Rayong floodplain, the area shows the highest potential of groundwater excluding the undiscovered fracture zone. This is due to the fact that the thickness of unconsolidated sediments is greater and the vast recharged area including the advantage of landform characters. However, with respect to the granitic aquifer, the groundwater yield from decomposed or weathered zones is relatively low. The fracture systems which are prominent groundwater reservoir in this type of rocks are very limited. Higher yield, therefore, may be obtained from shallow channel-filled deposits or recharged areas but eventually the yield tends to decrease to about 2.5 cubic meters per hour or less. Within the fractured zone, the pumping rate of 3-5 cubic meters per hour can be expected, although the yield up to 10 cubic meters per hour has been obtained. Careful selection of proper drill-site with additional geophysical survey is recommended.

The carbonate rocks, which are usually attractive to be the potential of groundwater reservoirs, cover small area north of Sattahip and in the vicinity of Siracha along the western coast. They are generally exposed as the thin remnants on granitic rock without cavernous characteristic owing to the lithology which is mainly metamorphosed, laminated calcileutite and argillite with occasional thick bedded coupled with the less density of fractures. Therefore, the aquifer could not produce high groundwater yield and so far no drilling for water from this aquifer has been reported. Besides, the area along the western coastline of the Upper Gulf is underlain by interbedded sequence of medium - and fine - grained clastic sediments as well as their metamorphic equivalents including some carbonate rocks. They are complexly folded and subject to various degree of faulting or fracturing. In addition, remnant of granitic rock are exposed as range of hills along the western coast. The rocks are considered to be devoid of groundwater but may locally yield as high as 5 cubic meters per hour of potable water from the fractured zones. It is, therefore, concluded that an area along the western coastline of the Upper Gulf is not promissing for groundwater development.

With regard to the unconsolidated sediments within the studied area, at least 3 types of deposits, namely, terrace deposit, alluvium and beach deposit are recognized. The terrace deposit is located at higher elevation along the foot hills and is generally underlied the alluvium or beach sand. The terrace topography is the dissected surface terrain tilting towards the bays. Almost all of the deposits overlying exposed on granite. This type of deposit is essentially composed of granite wash, decomposed granite and valley-fill sediments. They are characterized by poor sorting of quartz sand and gravel, clay, feldspar and other rock fragments including some lateritic layers. The aquifer is less permeable with thickness of less than 30 meters. Generally, the depression area has more groundwater potential than the high altitude area. The wells penetrating the aquifer may produce the groundwater yield from a fraction of cubic meter per hour to about 2.5 cubic meters per hour.

The alluvial aquifer, overlying the terrace aquifer, is confined within the flood plains and stream channels. It is bounded by terrace and beach deposits. The most prominant area is Rayong flood plain with approximately 10 kilometers wide and 18 kilometers long, whereas on the western coast it is found as the small-scattered patches or strips on the area of stream adjoining. The aquifer is generally consisted of clay, fine to medium sand, gravel and minor rock fragments. The aquifer permeability is relatively low and its thickness is rarely exceeding 12 meters. The aquifer generally yield 2.5-7 cubic meters per hour.

The beach sand deposits within the area occur as a narrow sand ridges along the shoreline and usually separated from the nearby alluvium by back swamps, stream channels, or trace of old shoreline. The aquifer is consisting of well sorted fine-to medium grained sand with layers or lenses of gravels or shell fragments. The thickness is generally less than 8 meters. The groundwater yield from this type of aquifer is relatively low, and the pumping rate for almost all wells is at the rate of 2.5-3.5 cubic meters per hour. Since the aquifer is hydraulically connected with sea water, the fresh water within the aquifer is lying on the salt water at a certain depth. Over pumping of groundwater will withdraw the fresh water and consequently promotes the salt water intrusion. To restore such balance, the depth of penetration of groundwater well should be limited within 6 meters and the pumping rate of 2.5-3.0 cubic meters per hour is recommended.

According to the aforementioned reports, it apparent that the groundwater potential within the studied area is limited both in terms of quality and quantity. Considering the hardness of the groundwater, calcium, magnesium, carbonate and sulfate contents, generally, it is soft to moderately hard in the granitic and terrace aquifers while the alluvium and the beach sand aquifers produce moderately hard to very hard water.

The groundwater yield within studied area generally fall within the range of 1-5 cubic meters per hour for each aquifer. The groundwater potential is therefore most suitable only for domestic consumption in terms of the limited yield. However, considering the groundwater potential in terms of water quality in this study, an attempt will be made with respect to the domestic usage. Particular interest is given to the hardness, iron, chloride and fluoride contents of the water.

Hard water is objectionable for some uses and soft water may induce corrosion under certain conditions. General terms used in this report to describe hardness of water, with respect to $CaCO_3$ content, are as follows: soft, 0-60 mg/l (milligrams per liter); moderately hard, 61-120 mg/l; hard, 121-180 mg/l; and very hard, 181 mg/l or more. Along the western coast, within beach sand, alluvial and terrace aquifers including the alluvial and terrace aquifers in the vicinity of Ban Bung and Phanat Nikhom, the groundwater is considered to be hard to very hard, whereas in the terrace aquifer of Rayong and the other aquifers it is soft to moderately hard.

Generally, water containing more than 0.3 mg/l of iron content may cause staining of porcelains or enamel fixtures, clothing or fabrics. The groundwater along the western coast contains excessive iron content and the iron reduction is required before consumption. On the contrary, for Rayong plain including the area in the vicinity of Ban Bung and Phanat Nikhom, the iron content in groundwater is mostly under the permissible limit.

With regard to the fluoride content in driking water, this element is the essential constituent for the prevention of dental caries in children, but the excessive concentration may give dental fluorosis in some children. When the concentration is much higher, it may eventually cause endemic cumulative fluorosis with resulting skeletal damage in both children and adults. According to the International Standards for Drinking Water of the World Health Organization (WHO, 1971), it is suggested that where the annual average of maximum daily air temperature is between 33-38°C, temperatures of Chon Buri and Rayong also falls into this range, the lower control limit of fluoride content in the water should be 0.5 mg/l and 0.7 mg/l of the upper control limit. From this point of view, most of groundwaters in the western coast of the studied area show various fluoride contents which are out of the control limits both lower and over. Therefore, they should be adjusted to meet the standard of potable water. In the other part of the studied area, there is no record of this content in the water.

The chloride content also affects the suitability of water for many uses. Initially, if chloride is present in sufficient concentration, the water has an objectionable taste. Naturally, the upper part of the water-bearing formation near the shore contain fresh water while the lower part is saturated with salt water and the over-pumping will disturb this natural hydrodynamic balance which result in the contamination of salt water. Along the western coast of the studied area, the high amount of chloride content in groundwaters is obviously shown in the coastal aquifers due to the over-pumpings. The initial cause of the problem is the promotion of tourist resort activities along the western coast, especially at Pattaya, and the ever-increasing consumption of water to supply the expansion programmes for hotel business and the summer houses followed by the commercial activities. In the various aquifers of Rayong plain, the chloride content is believed to be relatively low. However, the water quality of the landward aquifers is locally found to be brackish or salty, for instance, in the vicinity of Ban Bung and Phanat Nikhom. The source of high chloride content may be connate water which is a salt water entrapped at the time of sedimentation. Intrusion of seawater into the streams at time of high stage of sea level, then recharged into the aquifer, might be another source.

4.5.3 Water Resources Development

It is rather apparent from the earlier discussion that water resource potential for any development programme within the studied area has to be rely on the surface water rather than the groundwater. This is basically due to the relatively limited quantity and quality of groundwater available. In this connection, the following discussion is focussed upon the assessment of surface water resource potential within this area.

The Royal Irrigation Department, Ministry of Agriculture and Cooperatives is the responsible agency of the Royal Thai Government for Water Resources Development in Thailand. The first water resources project in the Eastern Seaboard area was the Bang Phra reservoir of the Chon Buri Basin. This reservoir was completed in 1959 with the capacity of 22 million cubic meters and was enlarged in 1976 to increase its storage capacity to 110 million cubic meters. Also in Chon Buri Basin, six other small reservoirs have been completed, namely, Map Pra Chan (14.8 million cubic meters), Ban Bung (2 million cubic meters), Khlong Phai (12 million cubic meters), Phlu Ta Luang (2.8 million cubic meters), Chuk Samet (0.25 million cubic meters) and Nong Ta Khian (0.88 million cubic meters). A reservoir at Nong Kho is underconstruction and will be completed by 1983 with an additional storage of 22 million cubic meters. Besides, there are various potential drainage areas where reservoirs development could be undertaken such as Khlong Na Kleau (8.8 million cubic meters), Huai Bung (26 million cubic meters), Huai Takhian (11 million cubic meters), Huai Chak Nog (7.6 million cubic meters) and Huai Yai (17.28 million cubic meters).

In Rayong Basin, Dok Krai subbasin is the first for surface water development as reservoir. Its storage capacity is 58 million cubic meters, average annual collection and minimum annual collection are 119 and 81 million cubic meters respectively. The three other proposed reservoirs in Rayong Basin are currently planned for development in the near future. They are Nong Pla Lai (1982-1986), Klong Yai (1988) and Khlong Thup Ma.

In addition, there are two reservoirs within the Bang Pakong Basin, Chong Ma Fuang reservoir (4.6 million cubic meters) and Ban Bung reservoir. (2 million cubic meters)

However, Ban Bung reservoir will be enlarged in 1982, by JICA Company Limited, to increase its storage capacity to 10 million cubic meters for supplying domestic and industrial uses at Amphoe Ban Bung and 2,000 rai of irrigational area.

The characteristics of the aforementioned reservoirs are summarized and presented in Table 4.5.3.

Table 4.5.3 The characters of existing, planned and potential reservoirs within the studied area.

Basin/Reservoir	Catchment area mil. m^2	Design storage mil. m^3	Annual average collection mil. m^3	Annual minimum collection mil. m^3	Annual rainfall mm.	Annual run off mil. m^3	Irrigated area rai	Annual domestic and industrial supply mil. m^3 - Area	Area of flood controlled rai	Status
Chon Buri Basin										
Bang Phra	130	110	49	34	1,264 (1954-1979)	58	8,500	18.0 for Chon Buri township and the vicinity	-	Exist
Nong Kho	51	22	15	8	1,224	16.0	7,500	6.0 for Siracha and Chon Buri	-	1983
Map Prachan	37	14.8	-	-	1,272	14	500	supplying for Pattaya	-	Exist
Khlong Bang Phai	84	12	-	-	-	-	-	supplying for sugar industry	-	Exist
Phlu Ta Luang	-	2.8	-	-	-	-	-	supplying for millitary family at U-Taphao Airport (35,000 men)	-	Exist
Chuk Samet	-	0.25	-	-	-	-	-	supplying for millitary family at Ao Chuk Samet Naval base	-	Exist
Nong Takhian	-	0.88	-	-	-	-	-	supplying for Sattahip township	-	Exist
Khlong Na Klua	-	8.8	-	-	-	-	-		-	Potential
Huai Bung	66	26.0	-	-	-	-	-		-	Potential
Huai Takhian	-	11.0	-	-	-	-	-		-	Potential
Chak Nog	-	7.6	-	-	-	-	-		-	Potential
Huai Yai	-	17.28	-	-	-	-	-		-	Potential
Bang Pakong Basin										
Ban Bung	49	2(10)*	-	-	1,150	12.2	(2,000)*		-	Exist - *Expansion planning by JICA - 1982
Chong Ma Fuang	18	4.6	-	-	-	4.9	-		-	Exist
Rayong Basin										
Dok Krai	291	58	119	81	1,700	103.0	50,000		20,000	Exist
Nong Plalai	414	98	141	90	1,500	138.0	80,000		20,000	Plan (1986) by JICA (start-1982)
Khlong Yai	220	45	127	51	-	39.57	-		-	Plan (1988)
Khlong Thup Ma	157	35	-	-	1,500	60	40,000		-	Plan

4.6 Marine Geology

4.6.1 The Coastline of the Studied Area

4.6.1.1 The Morphology of the Coast

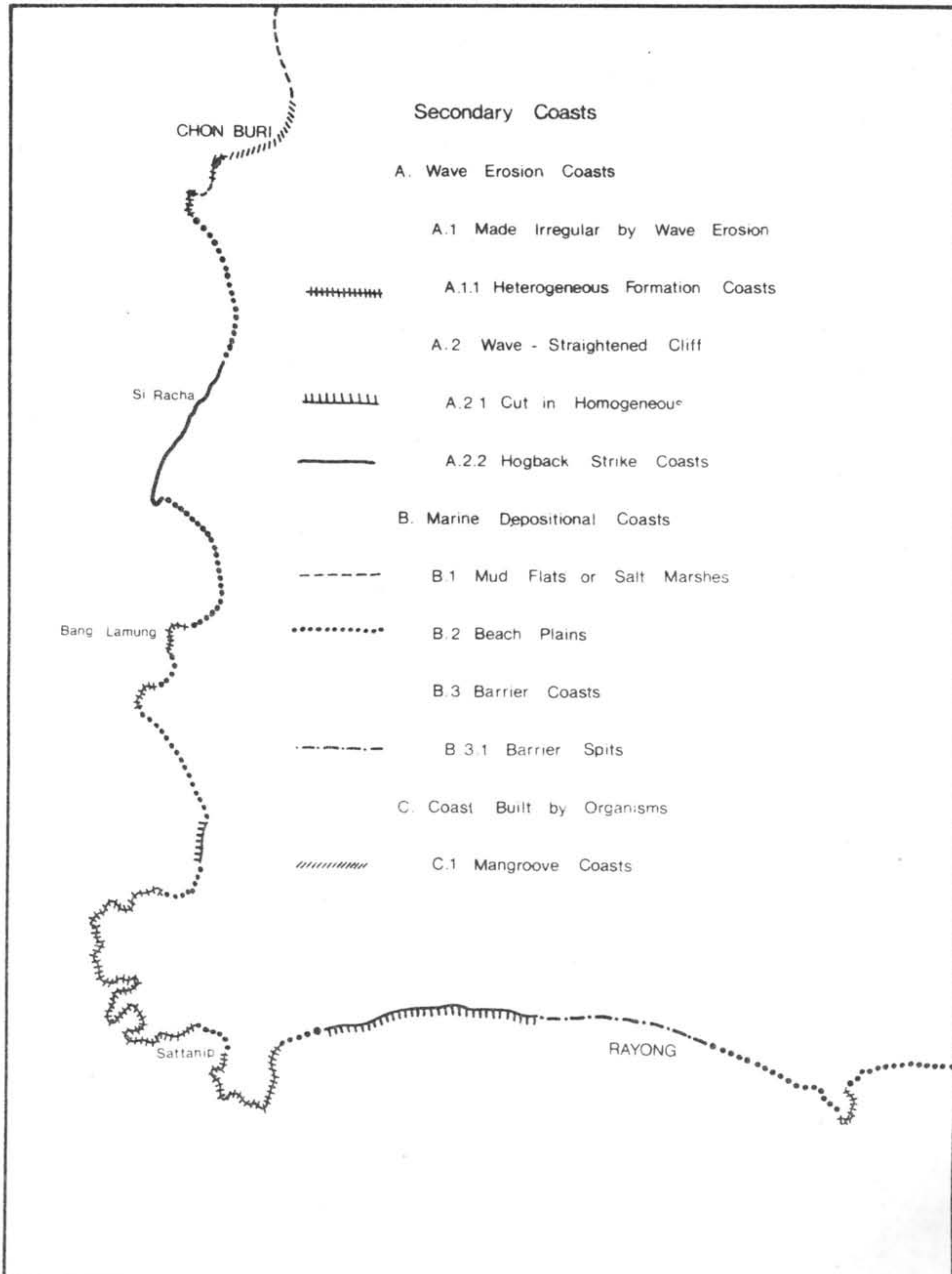
The coast of the studied area is partly of Eastern Coast, Upper Gulf of Thailand. It comprises of Chonburi coast and a half of Rayong coast with total length of approximately 222 kilometers. The extreme north of the coast, the estuary of Bang Pakong River, is the tidal flat with nipa and mangroove forests extending southwardly to Ban Ang Sila. Southerly, there are many headlands and bays alternating each other from Ban Angsila to Sattahip. This morphology is clearly the lithological control. From north to south, the series of bays and headlands are as follows : Ao Chonburi, Laem Sammuk, Ao Bangsaen, Laem Chabang, Ao BanLamung, Laem Pattaya, Ao Bang Sare and Laem Kham. The headlands coincide exactly with the occurrence of metasediments on the coast and the bays are located in an absence of these rocks. Ao Bangsaen near Siracha does not convex into the mainland very far; this is due to the presence of a range of hills of metasediments which extend from Laem Chabang over Khao Pho Bai, Khao Yai, Khao Chalak and KhaoPhu to Khao Choeng Thian. This range is oriented in the direction paralleling to the regional strike, north/northeast of the folded metasediments forming the rocky coastline from Laem Chabang to Siracha. More advanced erosion and deposition of the coast north of Ban Bang Phra have eventually given Ao Bang Saen the same shape as Ao Bang Lamung. The coastline in the southern part of Ao Bang Lamung is parrallel with the Laem Chabang-Khao

Choeng Thian range, so it can be assumed that starting from Laem Pattaya a similar range of metasediments protecting the underlying granite from erosion during the past geological time. Of this former range of Laem Pattaya is the only part that remains at the present. Ao Bang Lamung and Laem Pattaya represent a possible future configuration of Ao Bangsaen and Laem Chabang.

Around Sattahip, the shoreline is rocky and formed by the resistance to erosion of metasediments underlying the area. Therefore, many headland and small bays are present in the vicinity including several near-shore islands. The granite batholith is locally present under these metasediments at small depth.

The coastline from Ban U-Tapao over the estuary of Rayong river to Laem Ket in the east is a small, wide, shallow and gentle-convex bay. The only ane island, Ko Saket, is present at a distance of 2.5-3.0 kilometers off-shore. The metasediments are completely absent. The coast from Ban U-Taphao to Ban Ta Kuan is believed to be formed by the reworking by wave and current. The consolidated granite-wash was eroded by waves producing low cliff and narrow beach. The beach width is dependent upon the distance between the low tide and high tide and in most cases lesser than 8 meters. Some of the cliff is as high as 4 meters.

In addition, an attempt has been made to classify the coasts within the studied area using the classification of Shepard (1973) and the result is shown in Figure 4.6.1.1 The classification is based



TYPES OF COASTS WITHIN THE STUDIED AREA	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND	
DEPARTMENT OF GEOLOGY, GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	SUNYA SARAPIROME	FIG. 4.6.1.1

on different geological processes that have been operated at the present times, or the young age. These processes are responsible for the erosion and deposition of the coasts.

4.6.1.2 Stability of the Coast

There are limited reports concerning the stability of the coast of the studied area. Bunopas (1973) stated that the coastal features of Rayong Bay are under the influence of eustatic change of the sealevel in Quaternary period. During this time, the sealevel in this region has retreated from the present shoreline for 5 times and one transgression. After five times of regression, the four marine terraces were accordingly formed and the sea transgressed from the lowest level in the preceeding phase to stand at about 8 meters above the present sealevel. Finally, the sealevel has fallen down to the present level and the raised beach is formed. Recently, USS Engineers and consultants, Inc.(UEC, 1980) studied the site selection for iron, steel and fertilizer complex at Laem Chabang, Sattahip and Rayong area. By soundings taken in 1919 and 1960, it is indicated that the average depth of Mapta Phud off-shore area, Rayong Bay, has decreased about 4 meters. This means that shoaling in this region is at the rate of about 10 centimeters per year. However this is limited to a distance of about 15 kilometers offshore and to the 20 meters depth line. At Laem Chabang, a study of the bathemetry was concluded in 1978 and found that over a 40 years period the sea bed in this region has been relatively stable. Just north of Laem Chabang, Woodward-Clyde and Associates (1969) studied a site of the proposed nuclear power plant at Ao Phai and reported that the area is considered to be tectonically quicent. The intense tectonic activity apparently ceased in the Jurrassic Period. Subsequently, the geological formation have been subjected only to broad and gentle warping (i.e. epeirogenic movement). Further more, the study of earthquake at Ao Phai also had also been carried out by employing criteria established by USNRC and the modified relationships between magnitude and epicentral distance developed by Seed et al (1968), a maximum horizontal ground acceleration of 0.20 g. has been selected for the Safe Shutdown Earthquake (SSE) at the site. However Nutalaya (1977) stated that at least three levels of marine terrace are present in the proposed nuclear power plant site, Ao Phai, the lowest level is 0.6 to 1 meter above the present beach. The tilting of this terrace seems to indicate tectonic uplift rather than eustatic change and the rate of uplifting of the coastal area can be determined by dating the shell fragments on that terrace.

4.6.2 Bathemetry

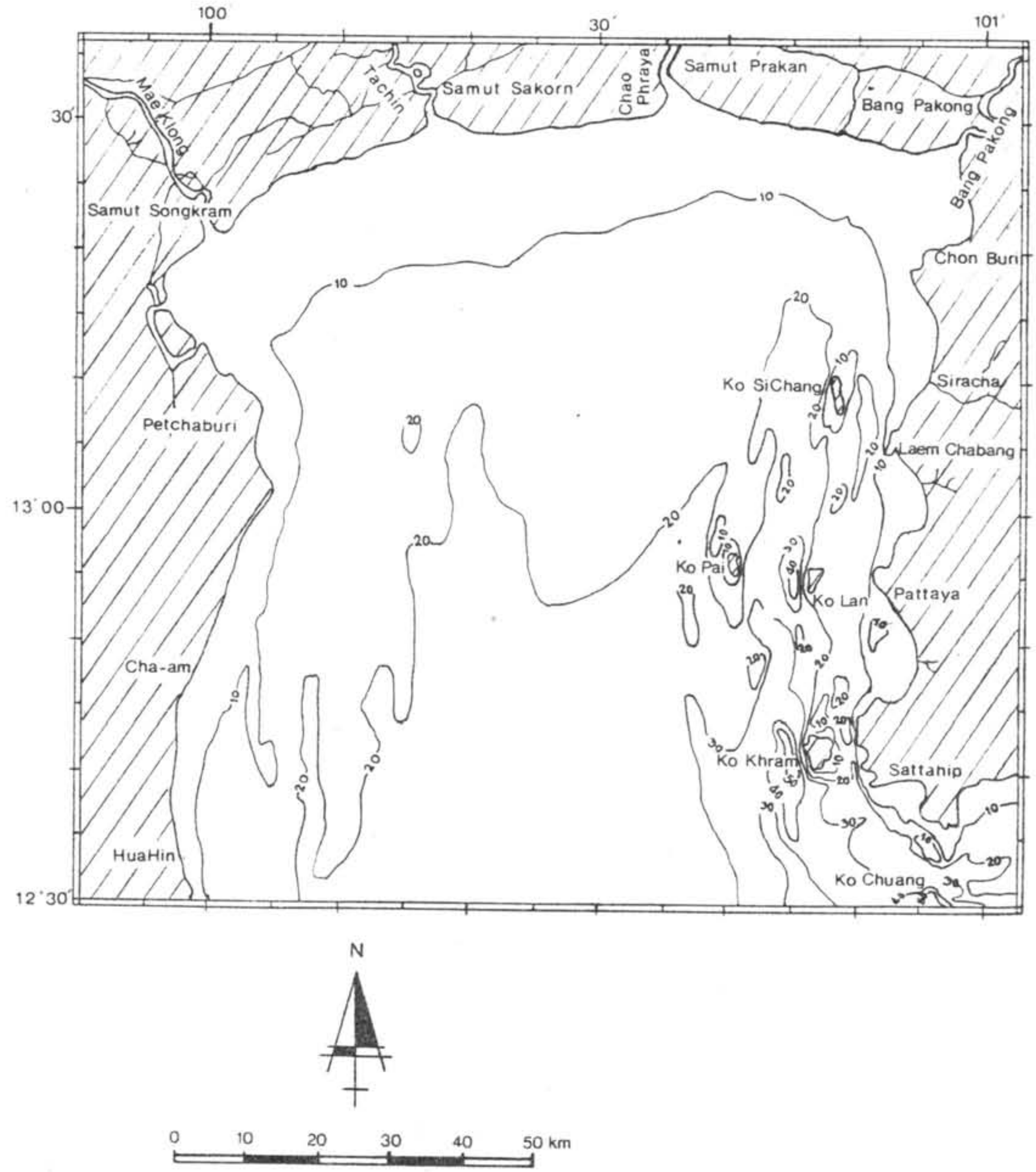
The Bay of Bangkok, being the upper part of the Gulf of Thailand, extends over a square of 100 x 100 square kilometers. The average depth of the bay is about 15 meters. From the shallow northern coast, the bottom slope gradually downward to a mean depth of 24 meters in it southern end between Sattahip and Hua Hin. The bottom slope of eastern coast, particular at Sattahip and adjacent area, is steeper than western coast.

Along the northern side of the Gulf, four rivers, namely, Me Klong, Tachin, Chao Phraya and Bang Pakong debouch into the bay.

They discharge fresh water with seasonal variation of silt content, c causing the fluctuation in density and silt transport in the northern part of the bay. The coastline on the western side shows a regular curved shape and depthcontourlines are more or less parallel to the coast. There is no island on this side of the coast. The eastern coast is more irregular with curved beaches and many islands. Depthcontourlines are more irregular and vary locally. The larger islands in the eastern coast are Ko Sichang, Ko Phai, Ko Lan, Ko Khram and Ko Samae San. Bathemetry of the Upper Gulf of Thailand is shown in Figure 4.6.2.1.

Naturally, the gradient of sea bottom within the studied area is higher where the coast is erosional, rocky and presently appeared as headland. The gradient gradually decreased toward the deeper part of the bays. NEDECO (1971), EGAT (1974) and UEC (1980) had studied parts of the coastal region emphasizing at Ao Phai, Laem Chabang, Sattahip and Rayong coasts. At Ao Phai, the beach profile has a slope of 1:160. The depth contours of 2, 6 and 10 meters are quite far from the beach at the distances of 250, 750 and 2,000 meters respectively.

Southerly, the sea bottom slope of Laem Chabang is steeper than of Ao Bang Lamung. The depth contour which characterized the bathemetry of Laem Chabang, in south direction, show depths of 10 meters and 14 meters off the headland at distances of about 150 meters and 250 meters respectively. The depth of 20 is approximately 1,000 meters away from the headland westwardly. The only one irregularity is a large 2 kilometer long shoal with its top at about 7 meters below mean sea level at about



THE HEAD OF THE GULF OF THAILAND	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST , UPPER GULF OF THAILAND	
DEPARTMENT OF GEOLOGY , GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	SUNYA SARAPIROME	FIG. 4.6.2.1

2 kilometers south of Laem Chabang. The channel between the shoal and the shore has a depth of about 15 meters below mean sea level at its entrance south of Laem Chabang; its minimum depth at its southern end is about 8 meters.

The coast of Sattahip area mainly comprises of steep rocky coasts alternating with small bays. The Sattahip coast is surrounded by reef-fringed islands, namely, Ko Khram, Ko Tao Mo, Ko Phra, Ko Mu, Ko Yo, Ko I Lao and Ko Chorake. The sea bottom of Laem Kham-Laem Pu Chao coast, including near-shore islands, is discernible steep slope. The bottom depth of 10 meters appears at the average distance of less than 1 kilometer from the shore whereas the 20-meter depthline is about 1-2 kilemeter offshore. The sea bottom of Sattahip bay is relatively shallow with 2-5 meters in depth. Besides, there are deeper channels exist between islands themselves and the shore.

The coast of Rayong within the studied area is an east-west oriented sand beach extending from the rocky headland of Sattahip towards the headland of Laem Ket. The beach is approximately 60 kilometers long and is composed of fine and medium sands. The depth of water in the nearshore area is relatively shallow and the bottom-depth of 10 meters appears at a distance of 3-4 kilometers away from the shore while the 20-meters depthline is about 15-18 kilometers offshore. The nearshore beach slope is generally uniform indicated by the nearly parallel contours. In the nearshore region about 25 kilometers east of Sattahip, the depthcontourlines of 6 meters are evenly spaced.

Further east, the area between Rayong estuary to Laem Ket, the depth-centourlines show closer spacing indicating a steeper slope and more active sand drift as well as on-shore and off-shore movement.

4.6.3 Temperature and Salinity

Generally speaking, the sea water mass in the Gulf of Thailand, particularly the Upper Gulf, is considered to be homogeneous due to the influence of astronomical tide (ebb and flood currents), the NE and SE monsoon including the shallow sea bottom. However, the upper most of the Inner Gulf of Thailand where the four rivers debouch have been seasonally affected by the running fresh water. The salinity will be decreased in October to December with respect to the runoff in the rainy season. This affect is not extensive from the river mouths. The characteristics of sea water in the region with regard to temperature and salinity are fluctuated resulting from the change of monsoon seasons. Inside the Inner Gulf of Thailand, the maximum temperature at the surface of seawater is 30.5°C in April and the minimum is 26.0°C in January. The average maximum salinity is 32.8 ppt. (parts per thousand) in Febuary and the minimum of 30.4 ppt. is in October.

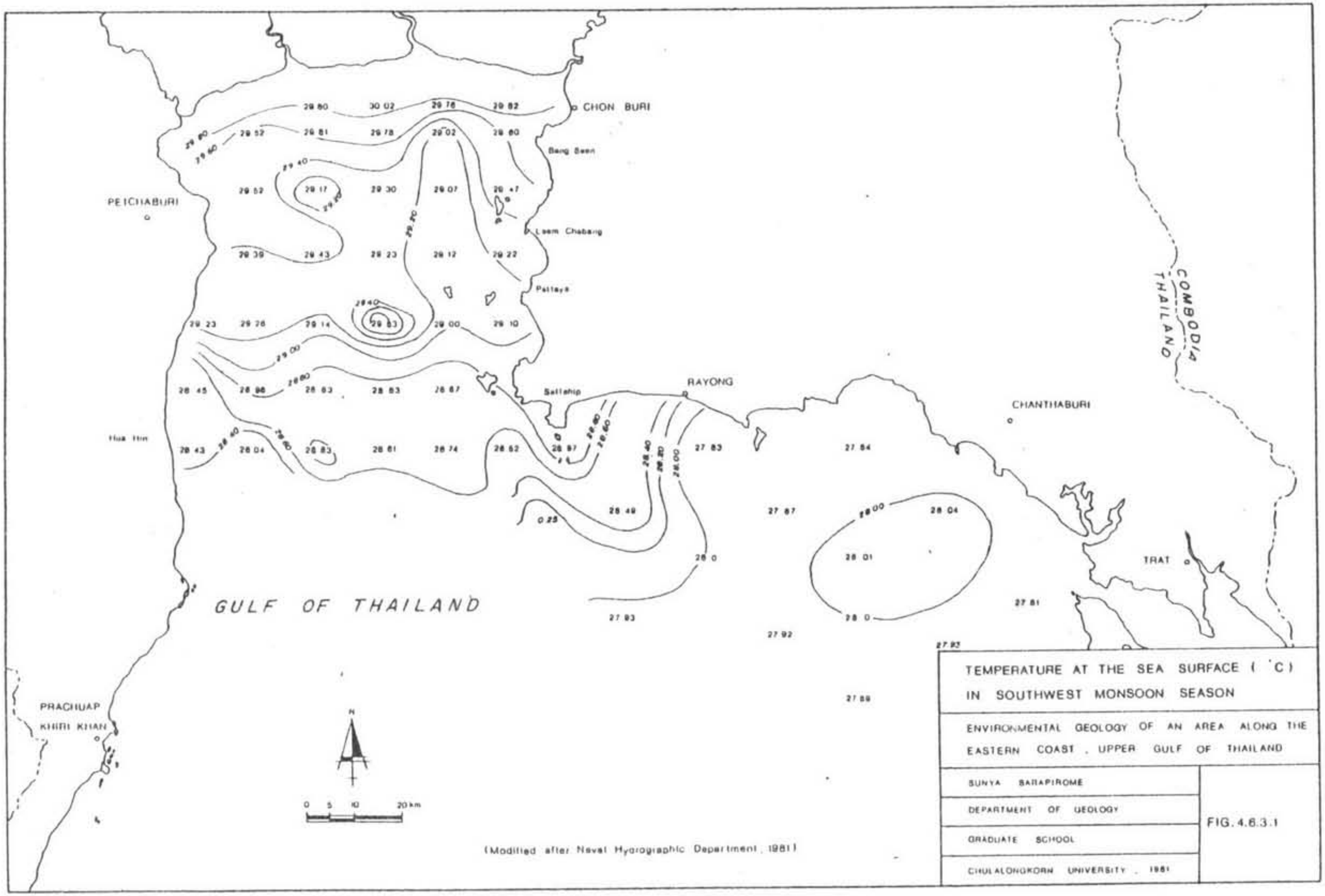
The sea water adjacent to Sattahip-Rayong shoreline is a part of open sea in the Gulf of Thailand, but its propertics are not different from the Inner Gulf. Therefore, it might be regarded they are homogenous. The temperature at the surface of sea water in this zone varies within the range of 29.8°-28.0°C, while the salinity is 32.2-33.0 ppt. The contour lines of temperature and salinity of the sea surface of the Upper Gulf of

Thailand are presented according to the monsoon season in Figure 4.6.3.1, 4.6.3.2, 4.6.3.3 and 4.6.3.4.

4.6.4 Tides and Currents

According to Phongphiphat (1978), Neelasri (1980) and Ad Hoc Working Committee on the Environment for Basic Industry in the Eastern Part of Thailand (1981),, it can be concluded that in the Upper Gulf of Thailand there is currents which proportionally depended on the influence of astronomical parameter and the monsoon. The flood current usually flows to the north direction while the ebb current is to the south. During the change from northeast monsoon to southwest monsoon, there is a prevailing wind moves northward to the land area. The prevailing wind causes the shallow zone of seawater moving to the eastern coast. Seawater in the deeper level moves southwardly to the Lower Gulf of Thailand. The constant current at different depth during March and April in year 1979 is shown in Figure 4.6.4.1.

During the time of southwest monsoon season, the surface seawater also moves to the eastern coast while during the northeast monsoon season, it moves to the western coast. Thus, the movement of seawater in the Inner Gulf of Thailand is considered to be the closed circuit circulation within the gulf. However, in the deeper level the sea water may flow out to the southern open sea between Hua Hin and Sattahip. By observing the movement of sediments, Allersma, Hockstra and Bijker (1961-1963) found that in the summer the sediments are transported from west to east and northeast directions whereas during the rainy season almost all of



TEMPERATURE AT THE SEA SURFACE (°C) IN SOUTHWEST MONSOON SEASON

ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND

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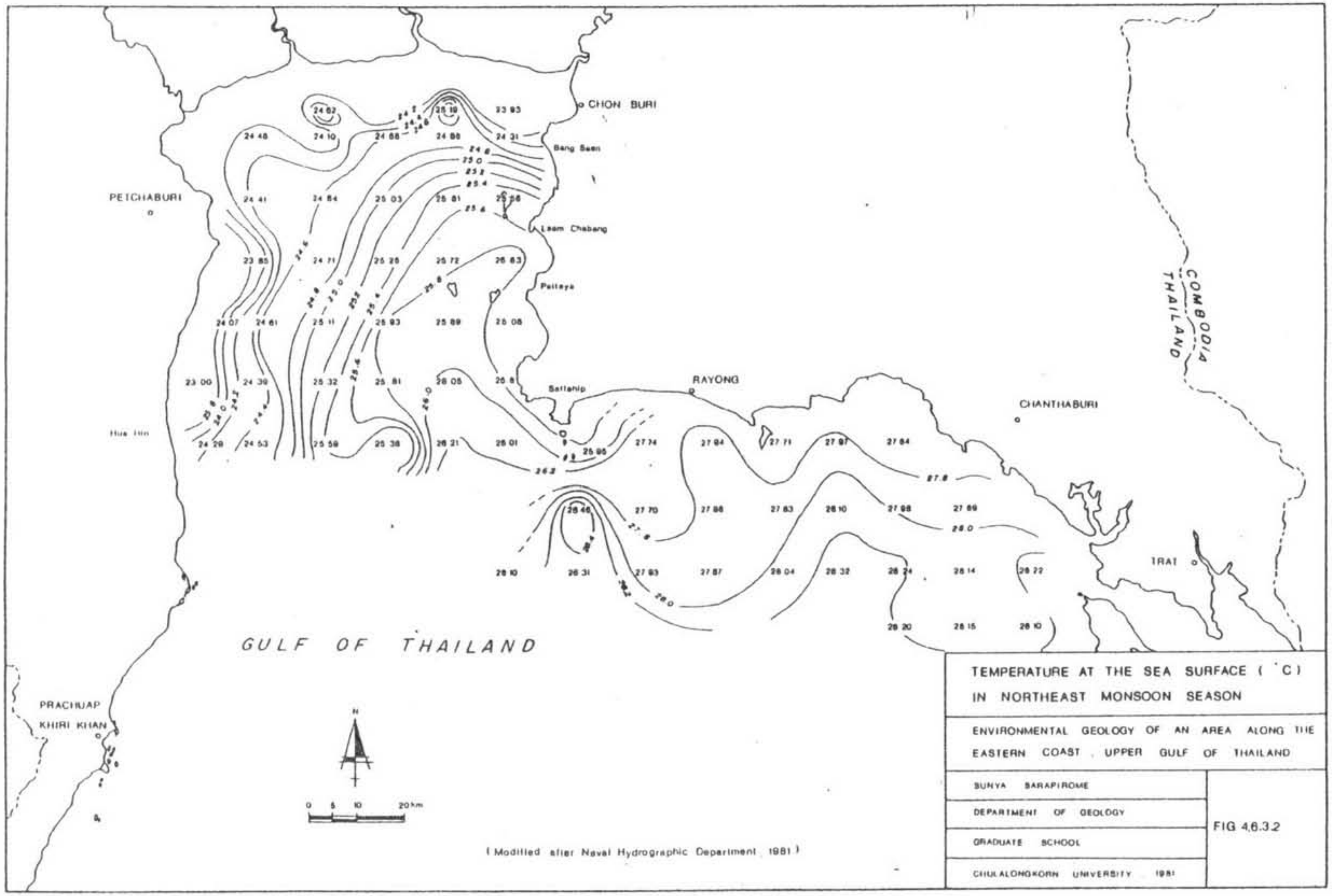
FIG. 4.6.3.1



TEMPERATURE AT THE SEA SURFACE (°C)
IN NORTHEAST MONSOON SEASON

ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST , UPPER GULF OF THAILAND

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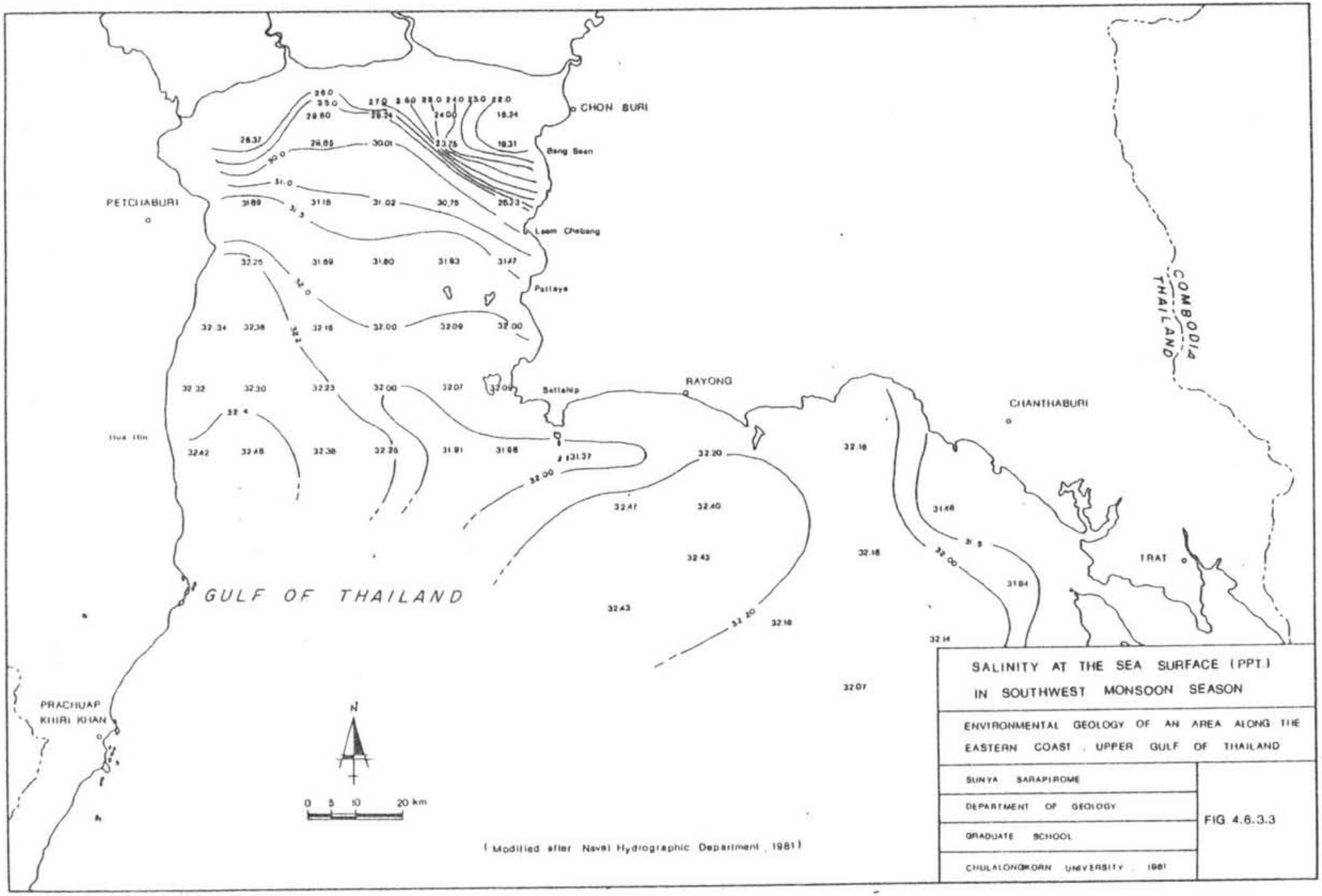
FIG 4.6.3.2



SALINITY AT THE SEA SURFACE (PPT.) IN SOUTHWEST MONSOON SEASON

ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND

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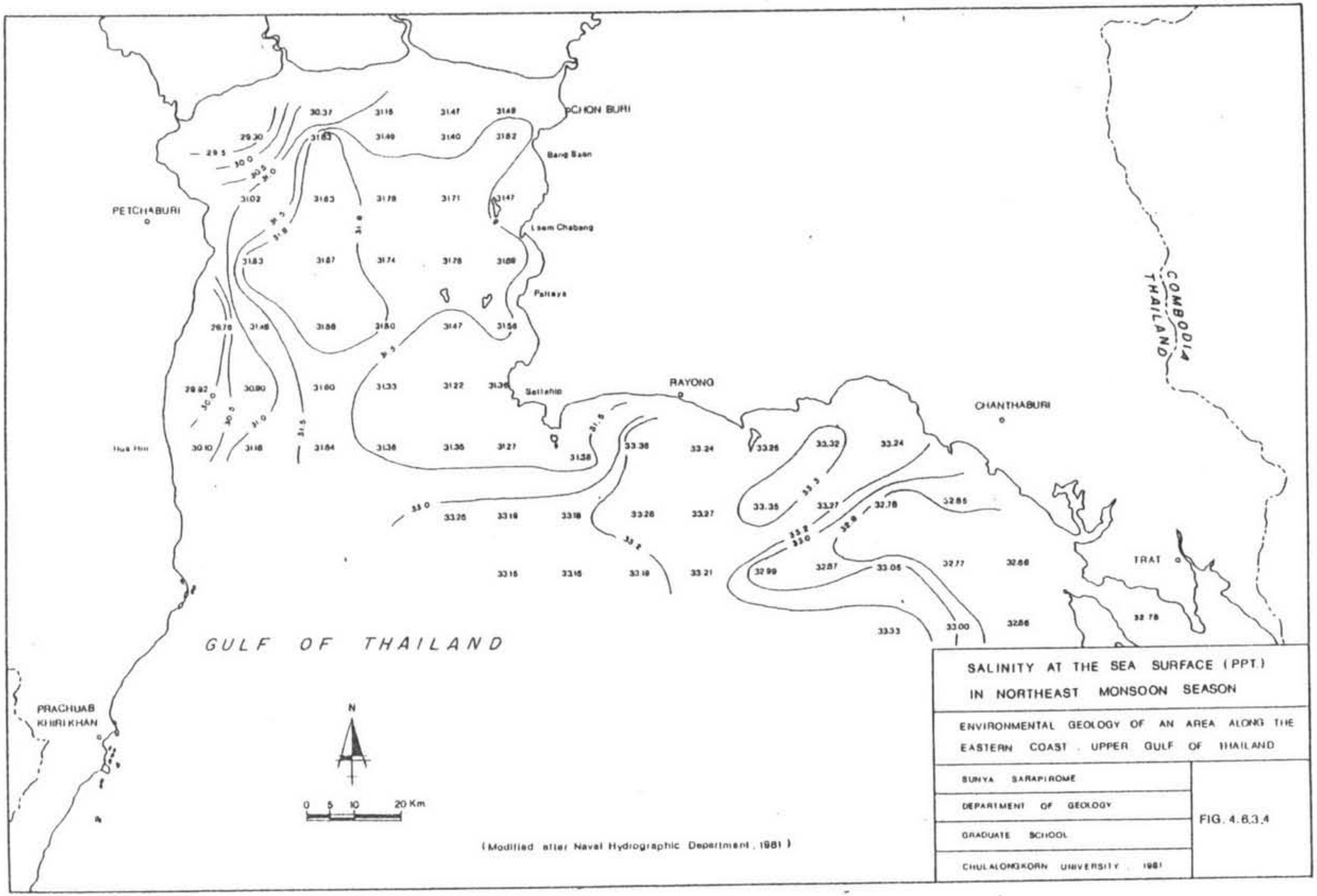
FIG. 4.6.3.3



SALINITY AT THE SEA SURFACE (PPT.) IN NORTHEAST MONSOON SEASON

ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND

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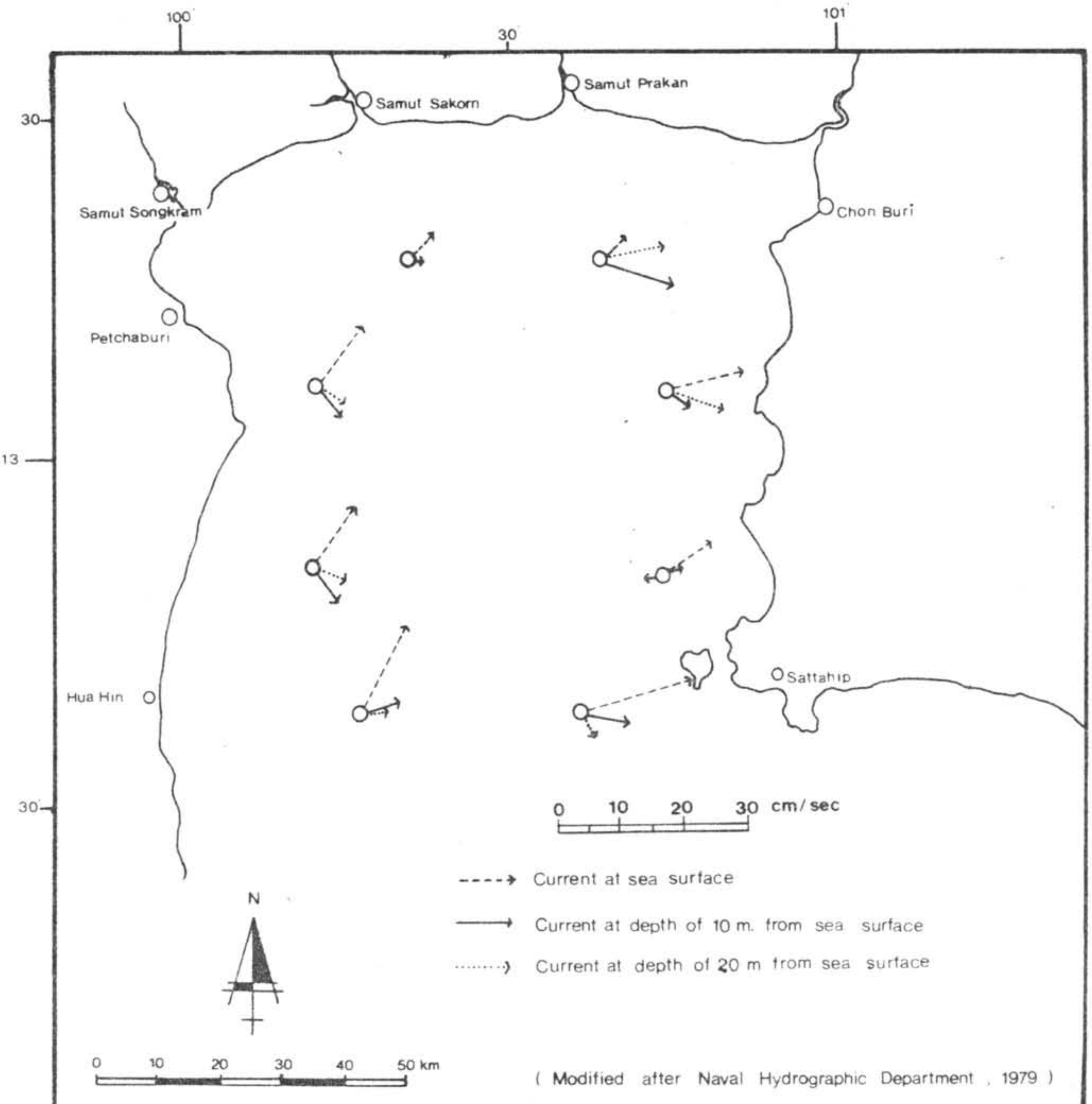
FIG. 4.6.3.4

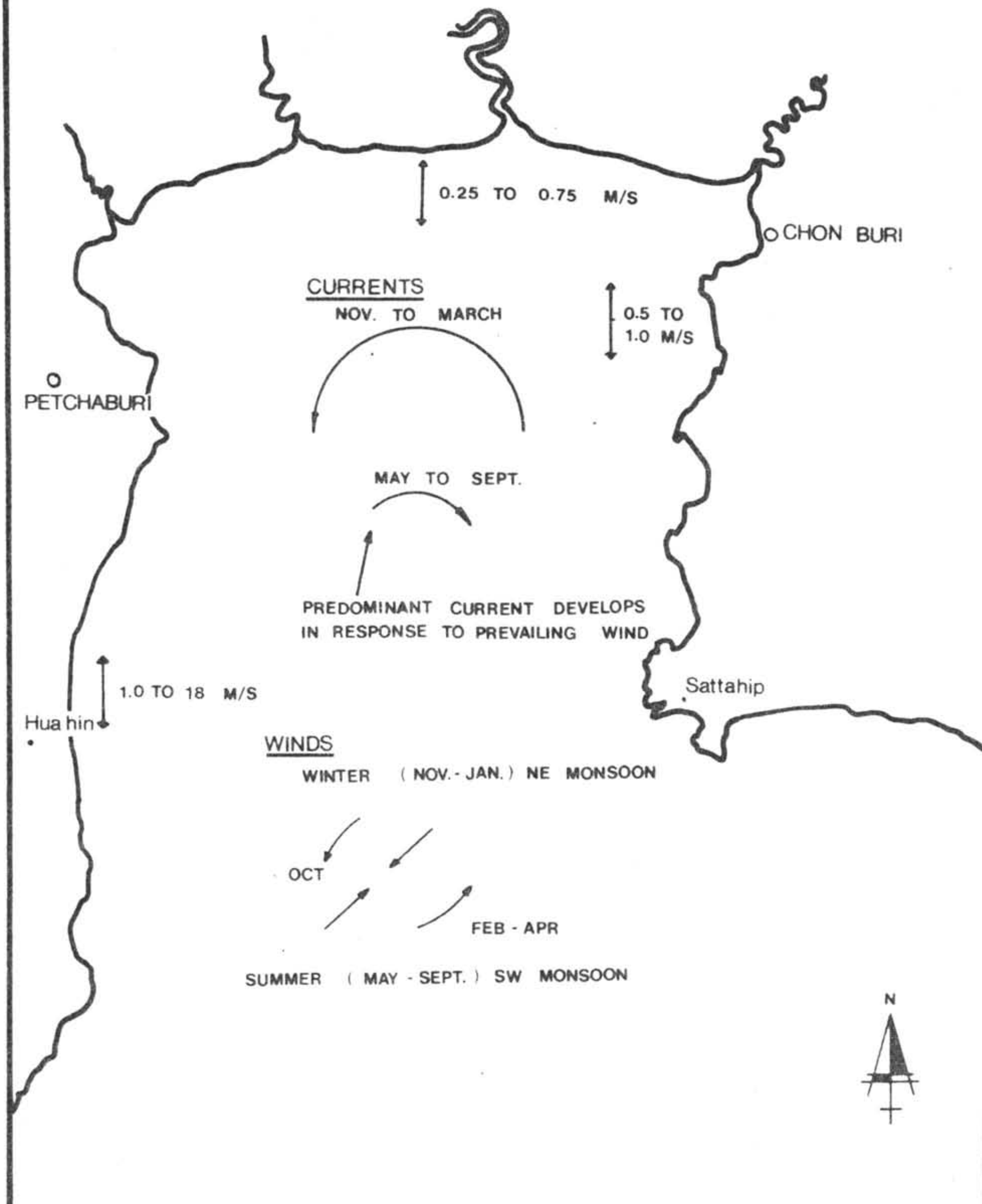


CURRENT AT VARIOUS DEPTHS DURING MARCH AND APRIL, 1979	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND	
DEPARTMENT OF GEOLOGY, GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	SUNYA SARAPIROME	FIG.4.6.4.1

sediments move from the river mouths in the north parallel to the eastern coast. This indicates that the circulation of current in the Inner Gulf is clockwise all the year. National Environment Board (1980) reported that the tidal current clockwisely circulate during the southwest monsoon season whilst during the northeast monsoon season it is counter-clockwise. The predominant current on the eastern coast is counter-clockwise and secondary current is clockwise. The move ment of currents and average wind in the Inner Gulf of Thailand is presented in Figure 4.6.4.2.

For the most of year, the rate of tidal current along the northeast shore generally varies from 1.0 to 2.0 knots or less and occasionally 5.0 knots. Along the southwest shore, the rate varies from 2.0-3.5 knots and may reach a value of about 4.0 knots depending upon the influence of the monsoon. At the extremity of the Upper Gulf, the periodic tidal currents usually range from 0.5-1.5 knots. Regarding the tide, Siripong (1976) stated that there are three types of tides in the Gulf of Thailand, semidiurnal, diurnal and mixed tides. The tide in the Inner Gulf is a mixed type while at the Sattahip-Rayong Coast it is a diurnal tide. Figure 4.6.4 3 shows the areas of which kinds of tides have been occured.

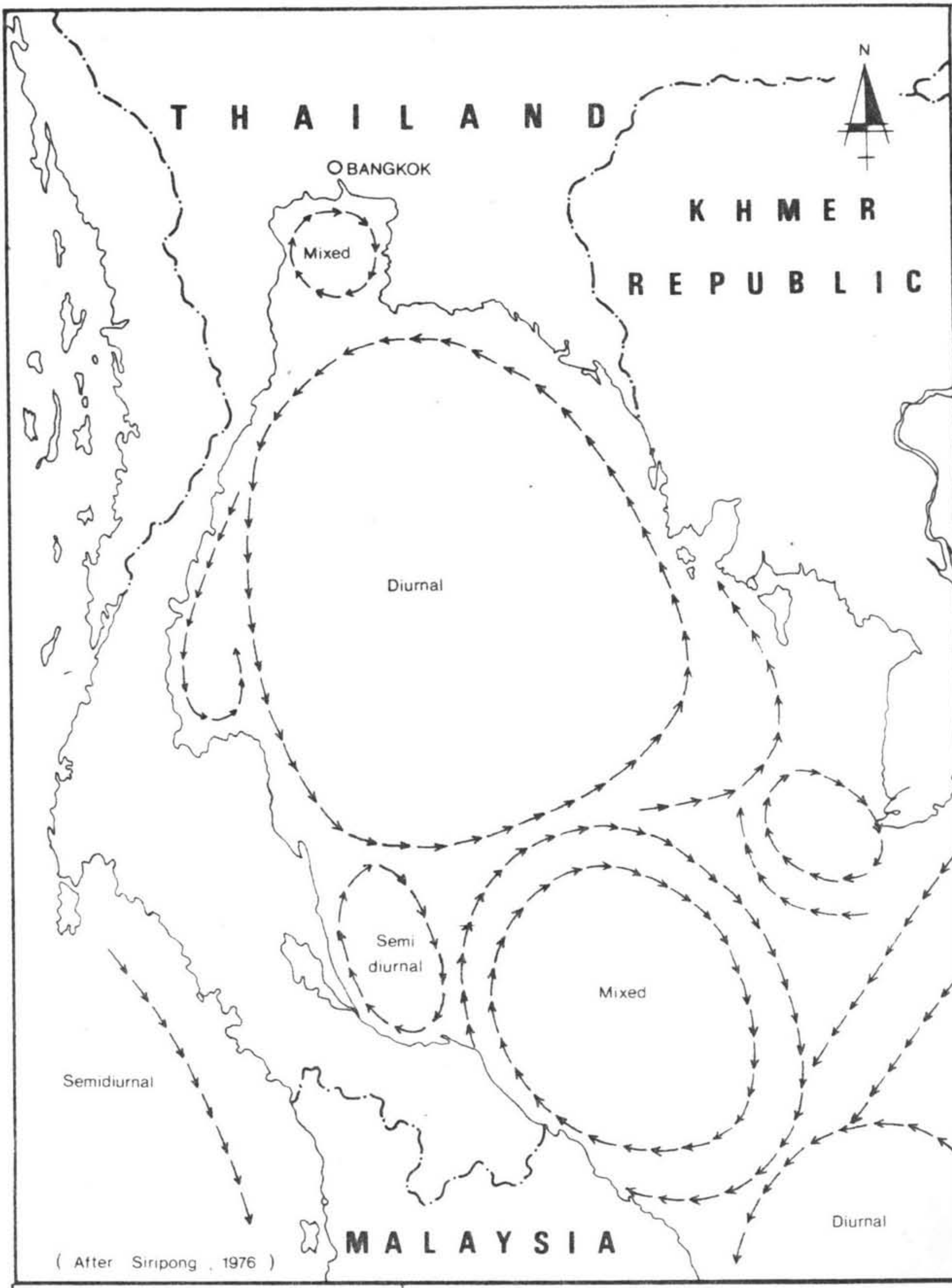
In the Gulf of Thailand, there is a difference in the characteristics of tide at each locality depending on the influence of the moon and the topographical feature of the coast. The local tides and tidal currents of the eastern coast have been studied at Ao Phai, Ko Si Chang, Laem Chabang, Sattahip and Map Ta Phud.



(Modified after National Environmental Board, 1980)

MOVEMENT OF CURRENTS AND AVERAGE WIND IN THE INNER GULF OF THAILAND	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND

DEPARTMENT OF GEOLOGY, GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	SUNYA SARAPIROME	FIG. 4.6.4.2



DIFFERENT KINDS OF TIDES OCCURING IN THE GULF OF THAILAND	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND

DEPARTMENT OF GEOLOGY, GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	SUNYA SARAPIROME	FIG. 4.6.4.3

The tide at Ao Phai is indicated as a mixed type and its characteristics are as follow :

Table 4.6.4.1 Detailed information of tides at Ao Phai. (after EGAT, 1974)

Characteristics.	Magnitude
Lowest low water	- 2.48 meters (M.S.L.)
Spring tide	3.36 meters (L.L.W.)
Velocity of flood tide move northward	0.35 knots (within 1 km)
Velocity of ebb tide move southward	0.25 knots (within 1 km)
Tidal range	1-2 meters

The tide at Laem Chabang is characterized by that in the Upper Gulf of Thailand. It possesses a mixed type of tide having both semi-diurnal and diurnal components with inequalities. The characteristics of the tide at Ko Si Chang near Laem Chabang are as follows :

Table 4.6.4.2 The characteristics of tides at Ko Sichang. (after NEDECO, 19[illegible])

Tide Level	Elevation From MSL in Decimeters
Highest high water	+ 17.10
Mean higher high water	+ 9.40
Mean high water	+ 7.42
Mean sea level	0
Mean low water	- 8.12
Mean lower low water	- 13.38
Lowest low water	- 14.80

Tidal current direction in the vicinity of Laem Chabang (after NEDECO, 1971) is mostly parallel with the shoreline. It has a magnitude of about 0.7-0.8 knots during quater tide and half tide of the flood and ebb current, respectively. During the slack tide, in both ebb and flood, the weakening current is about 0.05 to 0.2 knots with a direction about 45° to the shore.

The vertical displacement of water level in Sattahip and Map Ta Phud, Rayong shows a mixed type with semidiurnal and diurnal features having a range of about 1.5 meters to 2.5 meters. The characteristic of the tide at both areas are as follows :

Table 4.6.4.3 The characteristics of tides at Sattahip and Map Ta Phut.

Tide Level	Elevation From MSL in Decimeters
Highest high water	+ 14.9
Mean higher high water	+ 5.9
Mean high water	+ 4.2
Mean sea level	0.0
Mean low water	- 8.1
Mean lower low water	- 10.4
Lowest low water	- 21.9

(after UEC, 1980)

The tidal current at Sattahip shows a predominantly northwest-southeast direction as influenced by the islands near shore. The current has a magnitude of 1 to 1.5 knots for both flood and ebb currents. Eddies are created in the channel between the islands and the mainland.

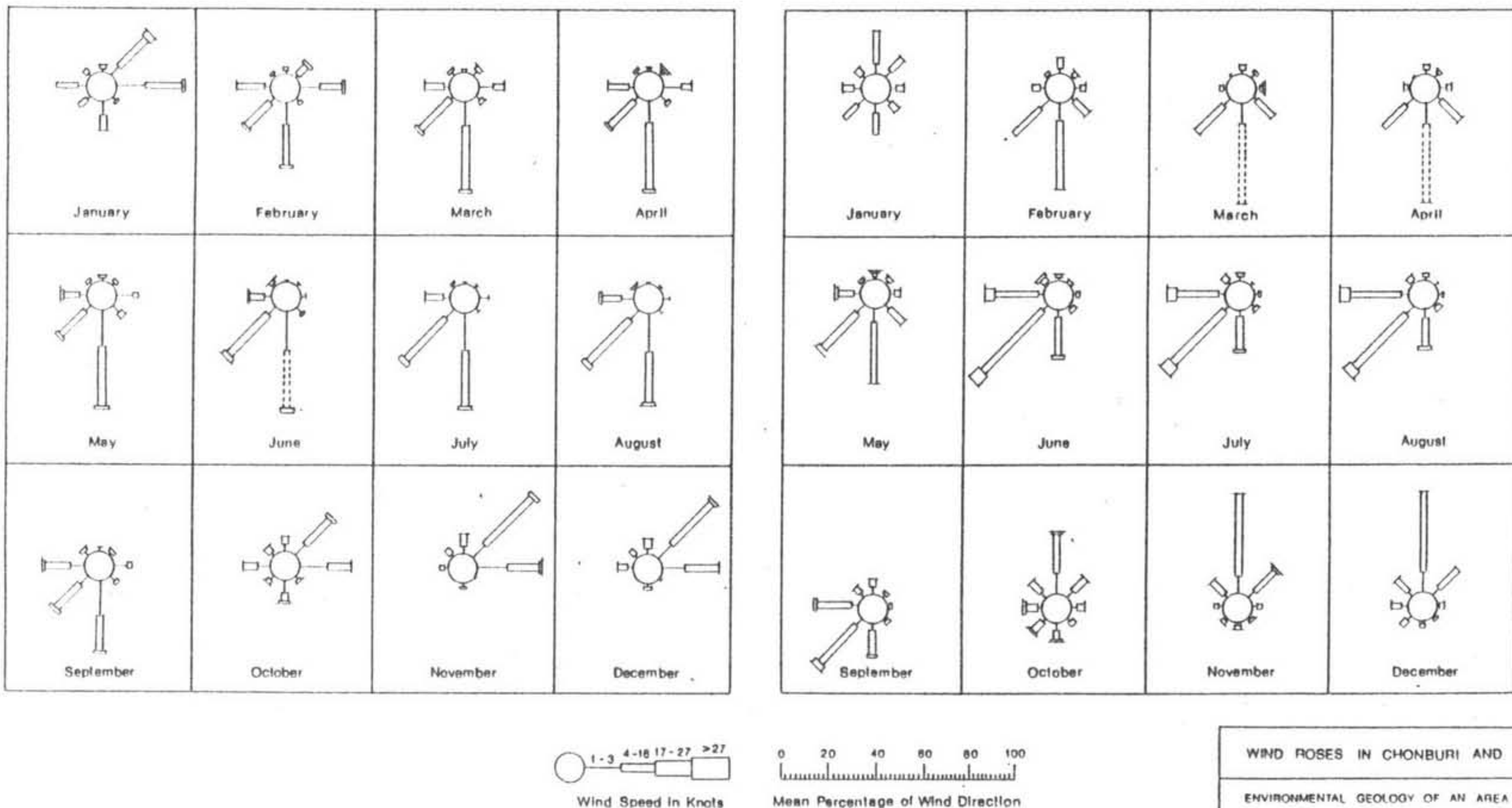
The tidal current at Rayong shows a predominantly north-south direction which is almost normal to the coastline. It has a small magnitude of about 0.2 to 0.5 knots for both flood and ebb currents. There is a pronounced current of 1-1.5 knots in the east-west direction in the vicinity of Ko Raet.

4.6.5 Winds and Waves

The information about wind speed and direction as shown in Figure 4.6.5.1, obtained from the meteorological stations at Chon Buri and Sattahip, show that they vary with the monsoon season. Two prevailing winds : southwesterly and northeasterly with speeds of 4-16 knots are normal. Wind in the other directions; north and south are less frequent. The monthly wind roses at Chonburi and Sattahip show that the frequencies of occurrence of the 4-16 knots winds are : 34.3 % S, 27.4 % SW, 14.0 % NE, 12.2 % E and 11.8 % W for Chon Buri whereas at Sattahip the directional frequencies of the 4-16 knots winds are 33.6 % SW, 31.8 % S, 14.3 % W, 15.2 % N and 4.9 % NE. Stronger winds of 17-27 knots are noted with very short gusts in excess of 27 knots lasting than 5 % in all directions (UEC, 1980).

CHONBURI index 48459
Lat 13° 22' N Long 100° 59' E Height of Windvane 10.9 m (15.9 m above MSL.)

SATTAHIP Index 48477
Lat 12° 41' N Long 100° 59' E Height of Windvane 12.0 m (30.0 m above MSL)



WIND ROSES IN CHONBURI AND SATTAHIP

ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST, UPPER GULF OF THAILAND

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CHULALONGKORN UNIVERSITY, 1981

Fig 4.6.5.1

It is found that the characteristics of wave, so-called wind wave, in the Upper Gulf of Thailand, is proportionally depending on the occurence of winds particularly the northeast and southwest monsoon. The tropical cyclone or the depression, with wind speed over 35 kilometers per hour, usually occurs in the South China Sea and occasionally moves into the Gulf of Thailand during September and November. The swell will be generated as a result of those violent winds and its destructive power is comparatively high. However, its power is limited by the decreasing of fetch distance and the shallow sea bottom which are the general characteristics of the Gulf of Thailand. From that angle, the wave height of the swell ever occurred in the Upper Gulf of Thailand is less than 2.5 meters.

In addition, the wind in the Upper Gulf of Thailand can be identifeed after Beaufort Wind Scale as light breeze to moderate breeze that generating the state of sea surface to be small wavelets (crests have glassy appearance but do not break) to small waves (becoming longer, fairly frequent white horses). Occasionally, the swell of wave hight of about 1.25-2.5 meters is generated few times a year due to the occuring of the tropical cyclone or the depression within the South China Sea.

During year 1973-1977, EGAT conducted intensive wind measurement at Ao Phai, the proposed site for a nuclear power plant, and found a similar pattern. It revealed that winds of 4-16 knots occur about 60 to 80 per cent of the time with the southwest and west winds occuring about 15-20 per cent of the time. With regrard to waves, it shows that during the northeast monsoon, from Febuary to April, there is high wave whereas during the southwest monsoon, from May to September, the wave height is low. From the ever been-recorded data, the wave height did not exceed 0.6 meter and most of them was under 30 centimeters. The maximum significant wave, observed during the period of July 1973 to March 1974, is 0.45 meters in height and 1.5 second in period. At Laem Chabang, just south of Ao Phai, NEDECO (1971) analyzed the wave conditions and revealed that the significant wave height in this region is about 0.3 to 0.5 meters with a period of 2 to 3 seconds and a frequency of occurence of 30 per cent. The maximum wave height is about 1 to 1.5 meters and occur only 0.1 % of the time which is about one day per year. Sieches could occasionally be observed and their resonant periods of 6, 10, 18, 25 and 48 minutes have been recorded. The origin of these variations could not be traced with certainty. No enclosed basin with the appropriate dimensions exists in the vicinity. The causes may be variations in the force of the wind or in the atmospheric pressure and the generation of eddies by the tidal currents around Laem Chabang. The amplitude of the oscillations with periods of 6 and 10 minutes never exceed a few centimeters. The most frequent period was 48 minutes with the wave height of 5 to 10 cm. and the maximum observation of 20 cm. Period of 18 and 25 minutes were less frequent and the height was less.

At Sattahip, the southwesterly wind of 6-14 knots is predominant from May through September while the northerly wind of the same magnitude plays an important role from October through January. During the summer, southerly winds of 6-14 knot prevail. The wave height of 0.6 meters from the south and southwest are predominant with about 30 per cent frequency of occurence. The wave of 1.2 to 2.5 meters in height are occasionally generated within a duration of less than 1 per cent.

Winds and waves in the Rayong coastal region are considered to be the same characteristics as in Sattahip.

4.6.6 Bottom Sediments and Sediment transportation

According to Emery (1961), the classitication of all possible types of sediments on the continental shelves includes detrital, biogenic, residual, authigenic, volcanic and relict. The term "relict" means the land-laid or shallow-marine sediments which occur in deep water, such as those near the seaward edge of the continental shelf. Formerly, those sediments were deposited on the continental shelves during and immediately after the latest glacial stage of the Pleistocene Epoch and unrelated to their present environments. The rise of sea level during the past 19,000 years has caused previous subaerial deposits of lacustrine, and paludal sediments to submerge in shallow marines waters and later on becoming deeply submerged. (Emery, 1968). In the Gulf of Thailand and adjacent continental shelf, Emery and Niino (1963) revealed that the sediment is dominantly detrital in origin but of two different general dates of deposition, namely, modern and relict (Figure 4.6.6.1). The modern detrital sediments are distributed in the Gulf and on the inner third of the shelf, as indicated by its fresh appearance and seaward gradation in median diameter. The source of these sediments. must be the rivers which drain the adjacent land areas. The coarse-grained sediments line the sides of the Gulf and only fine-grained ones occur immediately off the mouth of the Chao Phraya River at the head of the Gulf (Figure 4.6.6.2). Thus filling of the Gulf is proceeding from

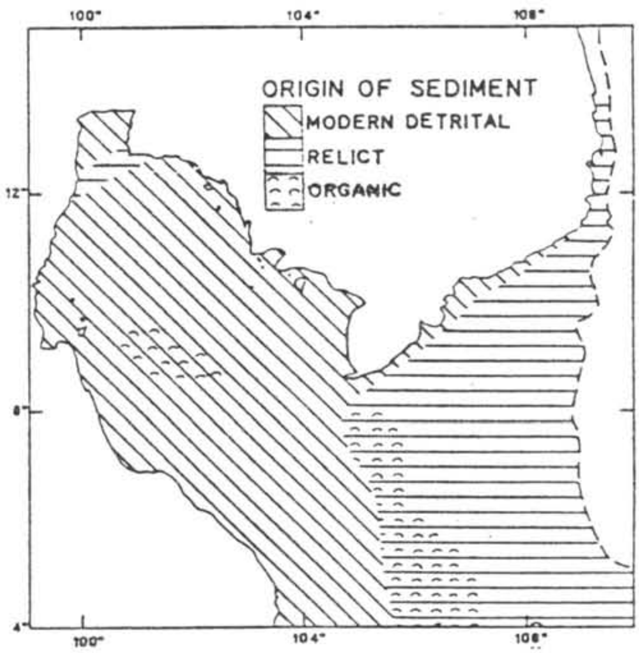


Fig. 4.6.6.1 Origin of sediments in the Gulf of Thailand and adjacent continental shelf. (After Emery & Niino, 1963)

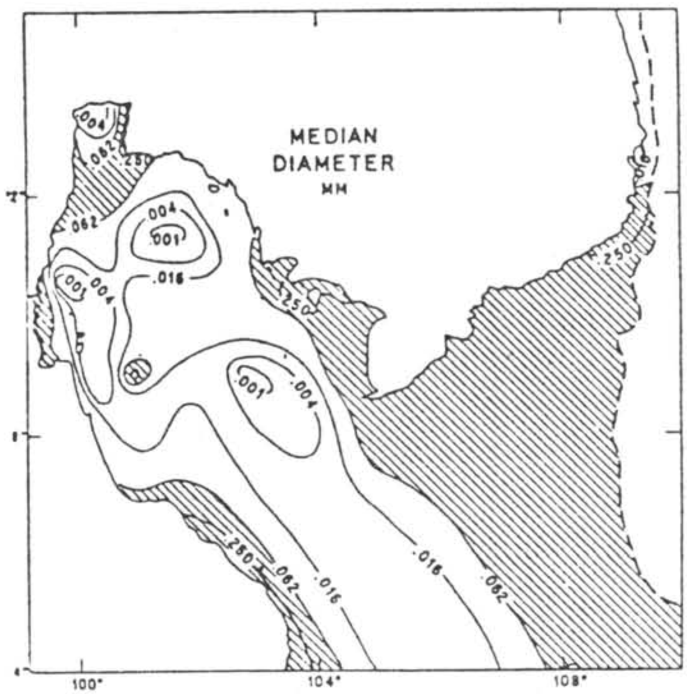


Fig. 4.6.6.2 Median diameter of the sediments in the Gulf of Thailand. (After Emery & Niino, 1963)

the sides as well as from the head of the elongate water body. The relict cover on the outer half of the shelf including a band connecting of Sattahip and Hua Hin. The relict sediment is coarse, slightly iron stained and rounded; it is probably relict beach sand left from a Pleistocene time of glacially lowered sea level. The organic matter deposits are found distributedly as the north/south trend in the continental shelf, near the mouth of the Gulf and in the off-shore area of Nakhon Sithammarat. Besides, the authigenic, residual and volcanic sediments are found in trace amount (0.3-0.4 %). The general sediment chart of the Gulf of Thailand and adjacent continental shelf is shown in Figure 4.6.6.3. From the chart, there are two provinces of different bottom sediments : the Gulf-dominated by muds, and the shelf-dominated by sands . Within the Gulf irregular patches of sand-and-mud, sand, gravel, and even rock occur near the margins, particularly on slight topographic highs and off irregular rocky shores. The patterns of grain size (Figure 4.6.6.2) and of organic matter also suggest that a current flows into the Gulf at the north side of its mouth and that another flows out at the south side as shown in Figure 4.6.6.4. The distribution pattern of organic matter caused by seasonal winds indicates the upwelling probably along both sides of the Gulf.

Regarding the bottom sediments and sediment transportation, local observations have been made at Ao Phai, Laem Chabang, Ao Bang Lamung Sattahip Bay and Rayong Bay by NEDECO (1971), EGAT (1974) Vongvisessomjai and Thinaphong (1976), Sapsomwong (1977) and UEC (1980). The results are as follows.

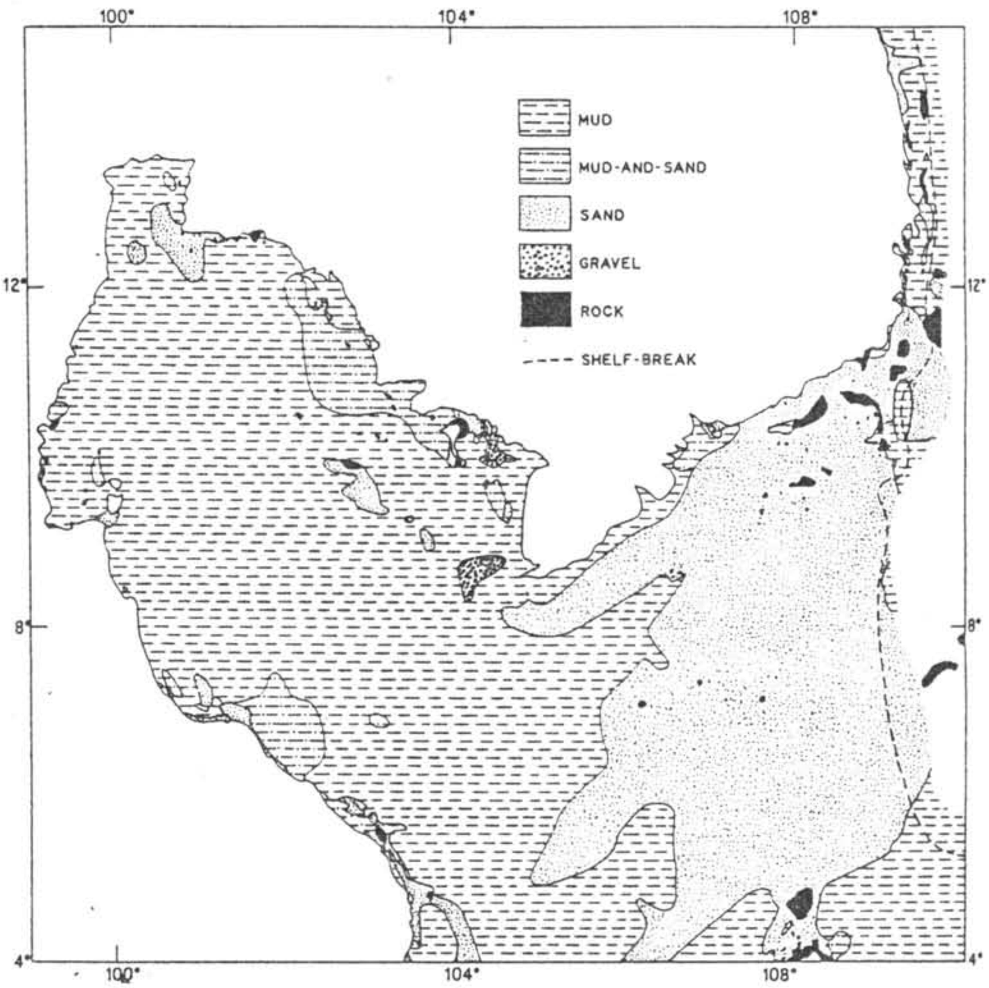


Fig. 4.6.6.3 General sediment chart of Gulf of Thailand and adjacent continental shelf. (After Emery & Niino, 1963)

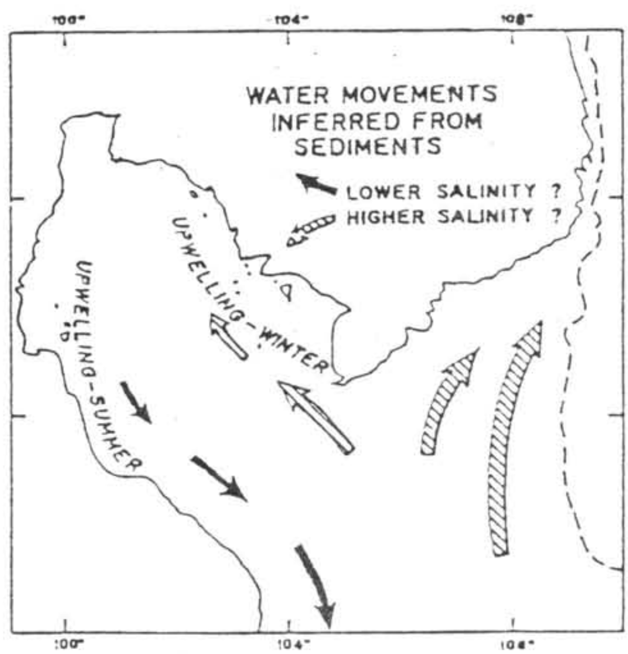


Fig. 4.6.6.4 Water movement inferred from sediments.
(After Emery & Niino, 1963)

At Ao Phai, the sediments in the bay are predominantly very fine sand and at greater depths the sand is mixed with silt in a soft state. The mean grain sizes show trend of decreasing grain size in the offshore directions. There are both of deposition and erosion as deduced from the sand movement at the bottom. From observation during October 1973 - Febuary 1974, it is found that during the period of October to December the beach was being built up by process of deposition and from December to January the beach process change to eroding and repeat back from eroding to deposition from January to Febuary. Hence, the corresponding beach processes are also, more or less, repetitive in nature but the circle of beach profile can not be obtained because the period of investigation was not completed in one year. Based on available data, however, deposition and erosion of sea bottom in the vicinity of the Ao Phai vary within the magnitude of 1 meter vertically. The transportation should be affected by the littoral current with a magnitude of 0.1 to 0.5 meter per second moves in northerly and southerly directions along the beach. The predominant littoral current develops in response to the prevailing southwest and south winds which in turn have caused the current to move northward in the counter clockwise direction over a normal climate circle.

At Laem Chabang, it may be concluded that the supply of sediments from elsewhere is small and that the movement of sediments are local and determined by currents, waves, and the nature of the sediments. The upper layer of the bottom sediments in the northern half of the Bang

Lamung Bay, south of Laem Chabang are mainly comprise of coarse sand, fine sand, fine sand with silt and pure silt. The coarse sand deposits occur on the top and along the western flank of the shoal with the depth range of 4.5 to 6.0 meters below the mean sea level off the coast. The very fine silt has been found in the lower part where the depth is greater than 7.0 meters. Fine sand and mixtures of fine sand and silt occur in the transition zone between these extremes and in a narrow strip below the low water contour along the shore.

The crenulated bay at Ao Bang Lamung indicates a stable condition and that the overall sediment transport is in equilibrium. The reason for this stability is that the predominant direction of incoming waves vary from west to southwest approximately normal to the beach with some concentrations at the northern headland. The small waves of 0.50 meter waveheight break when the wavelength is about 3.52 meters and at a water depth of about 1.52 meters. This occurs about 150 meters from the shore. This limits the littoral transport to within about 150 meters from the shore. The littoral current is very weak having an average magnitude of about 0.2-0.3 meters per second.

At Ao Sattahip, the bottom sediments is mainly fine to medium sand. The grain size decreases seawardly. There are both deposition and erosion depending on the season and morphotogy of the shore. However, the deposition is a predominant character. The sediment transport direction is toward the east and it is reported that within one-year period a volume of sediments of 2,186 cubic meters have been deposited in the pier area of the Operation Fleet, Sattahip (Sapsomwong, 1977). This phenomena will jeopadize the maximum utilization of the pier in a very near future.

At Rayong Bay, estimation of sand transport within the breaker zone of the beach is made assuming that the predominant wave is 0.6 meters with a 5 second period and strikes the beach from the deep water region at 60°. It has been found that the rate of transport of sand in the east-west direction is about 1.85 million cubic meters per year. The most active region is in the breaker zone which is at about the 5 to 6 meters depth line for a significant wave height of 0.6 meter. For waves of 0.6 meter high, the effective depth that will cause bottom disturbance is 12 meters. In case of the rare larger waves of up to 2 meters the influence of the waves could reach a depth of 25 meters.

4.6.7 Marine Geochemistry and Pollution Problems

4.6.7.1 Sources of Water Pollution in the Near-Shore Zone of the Inner Gulf of Thailand and Rayong Coastal Zone

The pollution of the near shore zone in the Inner Gulf of Thailand is mainly contributed by 4 big rivers, namely, Chao Phraya, Bang Pakong, Tha Chin and Mae Klong. Other wastewater is also directly discharged from the area along the coastal region of Chon Buri and Rayong. Therefore, the nearshore zone of the Inner Gulf is the center of water pollution from the surrounding land area.

There are 3 major sources of pollution which will be discussed as follows :

- Sanitary wastewater includes untreated domestic wastewater and septic tank effluent.

- Garbage and solid organic wastes that are disposed into the rivers and sea.

- Industrial wastewater.

These pollution sources within the Inner Gulf and Rayong coastal zone have never been completely evaluated, but in year 1979 they have been roughly estimated under the reliable assumptions by the Petroleum Authority of Thailand. In this context, the biochemical oxygen demand (BOD) amount will be used as a comparative indicator for water pollution. The result of estimation is summarized and presented in Table 4.6.7.1. It reveals that the total BOD amount drained into the Inner Gulf and Rayong coastal zone is approximately 411 tons per day; comprising of 158.8 tons per day of sanitary wastewater and garbage, and 252.3 tons per day of industrial waste water. Out of this, 154.3 tons of BOD from sanitary wastewater and garbage including 179.3 tons of BOD from industrial wastewater drained into the Inner Gulf and 4.5 tons of BOD from sanitary wastewater and garbage including 73 tons of BOD from industrial waste water drained into Rayong coastal zone. Within the coastline of the Inner

Table 4.6.7.1 The BOD amount from different sources drained into the Inner Gulf of Thailand and Rayong coastal zone. (After Petroleum Authority of Thailand, 1979).

Locality	Ton of BOD/day		
	sanitary waste water and garbage	Industrial waste water	Total
1. Inner Gulf of Thailand	154.3	179.3	333.6
1.1 Lower part of Chao Phraya River	107.5	37.6	145.1
1.2 Lower part of Bang Pakong River	3.1	0.4	3.5
1.3 Lower part of Tha Chin River	4.5	2.8	7.3
1.4 Mae Klong River	4.9	27.5	32.4
1.5 The coastline of the Inner Gulf	34.3	111.0	145.3
2. Rayong coastal zone	4.5	73.0	77.5
Total. (1 + 2)	158.8	252.3	411.1

Gulf, it includes the coastline of various provinces, namely, Chon Buri, Samud Prakarn, Samud Sarkorn, Samud Song Khram and Petchaburi. The Chon Buri coastline is the most significant sources of water pollution. It drains 12.8 tons of BOD per day from sanitary waste water and garbage. Among those provinces, the BOD amount from the industrial waste water from tapioca factories of Chon Buri is the largest one. Similar situation to that of Chon Buri is also found in Rayong.

4.6.7.2 Marine Geochemistry in the Off-shore and Near-shore zone

Within the studied area of the eastern coast, Upper Gulf of Thailand, the general seawater quality in terms of physico-chemical characteristics, is separately discussed for the off-shore and near-shore zones. The off-shore zone covers the locality at Laem Chabang and Ko Sichang, Sattahip, and Rayong where the physico-chemical characteristics of the seawater at surface and bottom including bottom sediments are summarized and presented in Table 4.6.7.2.a. The near-shore zone is the area within the proximity of 200-300 meters from the coastline. The seawater quality of this area has a direct effect to human activities on the coastal zone, such as, fishing, marine animal farming and recreation, etc. The present investigation of seawater quality is concentrated within the areas of Bang Pakong estuary, Amphoe Muang Chon Buri, Ao Angsila, Bang Saen, Siracha, Ao Phai, Laem Chabang, Bang Lamung, Pattaya, Ko Lan, Sattahip, Ko Samaesan, Map Ta Phud, and Ban Phe. The physico-chemical

Table 4.6.7.2-a The physio-chemical characteristics of the seawater in the off-shore zone within Laem Chabang, Ko Sichang, Sattahip and Rayong; during 1977-1980.

Characteristics \ Locality	Laem Chabang and Ko Si Chang			Sattahip			Rayong (Mapta Phud)			Remarks		
	seawater at the surface	seawater near the bottom	bottom sediment	seawater at the surface	seawater near the bottom	bottom sediments	seawater at the surface	seawater near the bottom	bottom sediments	seawater	bottom sediment	Reference agency
Salinity, ppt.	29.04-32.66	31.69-32.91	-	31.20-32.77	32.0-32.92	-	32.20-32.69	32.75-32.87	-			
Temperature, °C	25.03-29.47	<30.4*	-	<25.80-29.75	29.0*	-	27.74-27.83	29.9**	-			
Transparency, m.	6-10*	-	-	7-10*	-	-	-	-	-			
pH	7.2-8.5	8.0-8.2	-	8.0-8.5	8.0-8.2	-	-	-	-	6.5-8.5		U.S. EPA
Dissolved Oxygen, mg/l	4.08-4.25	3.85-4.34	-	4.26-4.35	4.25-4.34	-	4.21-4.26	4.27-4.34	-	≥3.0		(normal value)
Coliform bacteria (cell/100 ml.)	150-200	100+	-	150-200	20-50+	-	200-250	20-50+	-	≤70		Hawaii State standard,
Phosphate (µg-at/l)	0.15-0.23	0.08-0.17	-	0.08-0.09	0.08-0.10	-	0.09-0.13	0.08-0.10	-			
Total phosphorus (µg-at/l)	0.01-0.62	0.51-0.64	-	0.49-1.43	0.44-1.11	-	0.49-1.43	0.57-1.11	-	0.65 max		Hawaii
Nitrate (µg-at/l)	0.84-1.24	0.75-1.14	-	0.60-1.10	0.64-0.81	-	0.85-1.10	0.81-1.18	-	0-1.0		(normal value)
Nitrite (µg-at/l)	0.12-0.29	0.15-0.18	-	0.15-0.17	0.13-0.16	-	0.15	0.16-0.32	-	<6428.50	<357.14	U.S. EPA for warm water fishes
Sulfite (ppm.)	1.3	1.2-1.4	-	1.3	1.4-1.5	-	1.3	1.5	-	—		
Heavy metals	(µg/1)*		(µg/g)*	(µg/g)*		(µg/g)*	(µg/1)x		(µg/g)x	(µg/1)	(µg/g)	
Cadmium (Cd)	0.03		0.04	0.03		0.04	0.03		1.50	0.10 5.0	0.40	(normal value) U.S. EPA
Cobalt (Co)	0.50		0.25	0.25		0.35	0.63		0.10	0.05	74.00	(normal value)
Copper (Cu)	0.25		0.40	1.25		0.14	16.50		17.10	0.50	250.00	(normal value)
Mercury (Hg)	0.01		0.07	0.02		0.11	0.50		49.30	0.03 0.1	0.1-0.9	(normal value) U.S. EPA
Lead (Pb)	4.00		0.16	2.00		1.04	7.00		nil	0.03	80.00	(normal value)
Zinc (Zn)	8.18		2.10	8.41		0.27	2.50		0.40	4.90	195.00	(normal value)

x 1973

* 1974

** 1975

\+ 1976

characteristics of the seawaters are compared to the normal values (Brewer, 1975; Berton and Liss, 1976) and various other standards.

Considering the information of the seawater quality within the off-shore zone, it is observed that the seawater quality in terms of salinity, temperature, transparency and pH including the concentrations of dissolved oxygen (DO), phosphate, sulfite and some heavy metals are comparatively under the norm composition of seawater. Other parameters, namely, the concentrations of coliform bacteria, total phosphorus, nitrate and nitrite, cobalt, copper, mercury, lead and zinc are higher than the normal values and each of them are discussed as follows :

The average concentration of the coliform bacteria at the surface of each locality is 200 cells per 100 milliliters and higher than 70 cells per 100 milliliters of standard value of the Hawaii State, U.S.A. At the bottom, the seawaters of only Laem Chabang and Ko SiChang, have coliform bacterial higher than the standard value. It may depend largely on the sanitary and domestic wastes.

The maximum value of the total phosphorcus at Laem Chabang and Ko Si Chang is about 0.65 microgram-atom per liter that equal to the maximum limit of the standard value at Hawaii. In Sattahip and Rayong, the maximum value at the surface and bottom are 1.43 and 1.11 microgram-atom per liter respectively. It is indicated that the seawater will be polluted if the less circulation exists.

With regard to the concentration of nitrate and nitrite, they fall within the range of 0.12-1.24 microgram-atom per liter for both surface and near bottom. This value is rather high compared to the normal value of 0-1.0 microgram-atom per litre. However, they are still under the suggestion of U.S. EPA for warm water fishes.

The concentration of cobalt in seawater at Laem Chabang and Ko Si Chang, Rayong and Sattahip are 0.50, 0.25 and 0.63 microgram per liter respectively. Each of them is higher than 0.5 microgram per liter for the normal value of cobalt in seawater.

In bottom sediments, the concentration of cobalt at each locality falls within the range of 0.10-0.35 microgram per gram. It is relatively low compared to the normal value of 74 microgram per gram.

The concentration of copper in the sea water at Laem Chabang and Ko Sichang is comparatively low whereas at Sattahip and Rayong they are 1.25 and 16.50 microgram per litre, respectively. This is considered to be very high compered to 0.5 microgram per liter of the normal value. The concentrations of copper in the bottom sediments at Laem Chang, Ko Si Chang and Sattahip are lower than that of Rayong but most of them are still under 250 micrograms per gram of normal value.

The normal value of the mercury concentration is 0.03 microgram per liter and the U.S. EPA standard is 0.1 microgram per liter. It is found that the mercury concentrations in the seawater at Laem Chabang, Ko Si Chang and Sattahip are within the range of 0.01-0.02 microgram per liter which is under the normal value. At Rayong, it is 0.50 microgram per liter, this is higher than the normal value and U.S. EPA standard. In the bottom sediments of Laem Chabang and Ko Si Chang, the mercury concentrations are about 0.07 microgram per gram while the normal value falls within the range of 0.1-0.9 microgram per gram. At Sattahip and Rayong, they are 0.11 and 49.3 microgram per gram, respectively. From this point of view, it is interesting to note that care must be taken on the environmental aspect at Rayong coastal zone area.

For lead in seawater of each aforementioned locality, they are higher than 0.03 microgram per liter of the normal value. However, they are all under the U.S. EPA standard. In contrast, the lead concentration in bottom sediments of each locality is under the 80 micrograms per gram of normal value.

The concentration of zinc in seawater of each locality is under the U.S. EPA standard (10-100 micrograms per liter). But comparing to the 4.9 micrograms per liter of the normal value, the zinc concentration of only Rayong, 2.50 micrograms per liter is lower than the norm. The rest, 8.18, 8.18, and 8.41 micrograms per liter of Laem Chabang, Ko Si Chang, and Sattahip, respectively are higher. Considering the zinc concentration in bottom sediments of each locality, it is very low as compared with 190 micrograms per gram of the normal value.

The seawater quality of the near-shore zone within the studied area in terms of the physico-chemical characteristics is summarized and presented in Table 4.6.7.2.b. Details are as follows :

Generally, the salinity of the near-shore zone within the studied area falls within the range of 10-30 part per thousand (ppt.). The different salinity characteristics has a direct impact on the early stage of different marine lives, namely, shrimps, fishes and crabs.

The temperature falls within the normal range of 26°-32°C for each season.

The pH average value falls within the normal range of 6.5-8.5 and is considered within the range of 6.5-8.3 for the U.S.EPA standard.

The data on turbidity are only available from Bang Saen and Ao Phai of 100 and 10 (FTU), respectively. Due to the fact that there is is no standard for marine turbidity, the impact of high turbidity is limited to recreation and the ecology of marine lives.

For oil and grease, at Sattahip, Ao Phai and Ban Phe are 2.2-38.7, 4.8-8.8 and nil.-6.8 ppm. respectively and higher than the limiting treshold of the recreational standard of California State, U.S.A. Considering from the aspect of water contact activities, namely, boating and aestheitcs, it is suggested that the value should be between 5-10 ppm. The near-shore zone around Sattahip is considered to be the potential area of oil and grease pollution. Other localities are less important point source for this problem.

able 4.6.7.2-b Physico-chemical characteristics of the water in the near shore zone within the eastern coast, Upper Gulf of Thailand, during 1977-1980

Characteristics \ Locality	Bang Pakong estuary	A.Muang Chonburi	Ao Angsila	Bang Saen	Sirachs	Ao Phai	Laem Chabang	Bang Lamung	Pattaya	Ko Lan	Sattahip	Ko Samaesan	Map Ta Phud	Ban Phe.	Normal value	Other Standard
Salinity (ppt)	8.51-29.54	23.25	20.16-31.91	24.8	26.9	27.2-32.5	27.4	27.4	27.2-27.5	-	-	-	-	-		
Temperature (°C)	26.1-32.3	28.92	26.5-32.2	20.91	30.22	25.9-30.6*	30.57	30.75	26.0-32.0	29	-	-	-	-		
pH	7.1-8.85	6.4-7.6	7.20-8.75	7.57-8.0	6.4-7.68	6.4	7.7	7.76	7.1-8.6	8.3-8.5	5.1-8.0	7.3-8.2	7.0-8.0	7.2-9.0	7.2-9.0	6.5-8.3 (U.S. EPA)
Turbidity (JTU)	-	-	-	100**	-	10*	-	-	-	-	-	-	-	-		
Oil and grease (ppm.)	1.1	nil	-	5.4	3.3	4.8-8.8	-	-	1.1	-	2.2-38.7	1.0-4.9	nil-15.6	nil-6.8	-	5-10 (California, U.S.A.)
Dissolved oxygen (gm/l)	3.60-7.5	4.39-6.8	2.23-5.25	6.09-9.8	5.8	6.5	6.94	6.01	0-9.4	5.1-8.2	6.0-8.3	6.4-6.7	6.0-7.1	4.5-8.4	2-3 min.	
BOD (mg/l)	0.4-4.0	1-3.2	0.2-3.5	1-3.23	1-2.33	2.0	1.65	1.24	0-90	0.62-2.25	1.0-2.0	1.0	1.0	1.0-4.0	-	2 (Washington, U.S.A.)
Coliform bacteria(cell/100 ml.)	-	6,664.3	-	2,450	2,522.5	>1,000	192.5	1,947.7	201-5,302	20-490	-	-	-	-	-	230 (Hawaii, U.S.A. 1,000, WHO 1,000 MPN/100 ml, Japan)
Phosphate (ug-at/l)	0.65-22.58	3.35	0,32-30.65	0.45	1.67	0.32-4.84*	0.36	0.43	0.27-1.37	-	-	-	-	-	-	10
Total phosphorus (ug-at/l)	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Nitrate-Nitrogen (ug-at/l)	17.86-215.71	-	21.43-194.29	-	-	82.86-125.70	-	-	0-0.004	-	-	-	-	-	0.10	6428.5 (U.S. EPA for warm water fishes)
Nitrite-Nitrogen (ug-at/l)	0.07-10.36	1.25	0.14-26.14	0.14	0.32	-	0.14	0.13	0.14-0.16	-	-	-	-	-		
Sulfite (mg/l)	1.04	-	1.04	-	-	-	-	-	-	-	-	-	-	-		
Heavy metals (ug/l)																
Mercury (Hg)	4.6	0.1-0.2	0.3	0.2-7.8	0.3-0.7	0.1-0.7	-	nil	nil	nil-0.5	0.1-0.5	0.1-0.35	0.1-1.1	0.1-2.0	-	
Lead (Pb)	28.0	2-3	12.0	5-11	7.2-9.0	4.0-25.2	-	6.0	1.3-6.0	4.2-29.0	nil-19.5	nil-1.5	nil-19.0	nil-13.3	-	

* 1973-1974

** 1972-1973

Almost all of the localities, the dissolved oxygen is reported to be in good condition. However, at Bang Pakong estuary, Ao Angsila and Pattaya the dissolved oxygen is sometimes under 2-3 milligrams per liter of the normal value. That event depends mainly on the waste water periodically discharged from industries, hotels and restuarants.

The average BOD value of the near-shore zone within the studied area is 1-5 milligrams per litre. It is higher than the standard value of Washington State, U.S.A. (2 milligrams per liter). At Pattaya, in the year 1977, the BOD had been exceptionally increased to 90 milligrams per liter. It is believed that wastewaters discharging from industries, hotels and restuarants within the vicinity of Pattaya are responsible for this problem.

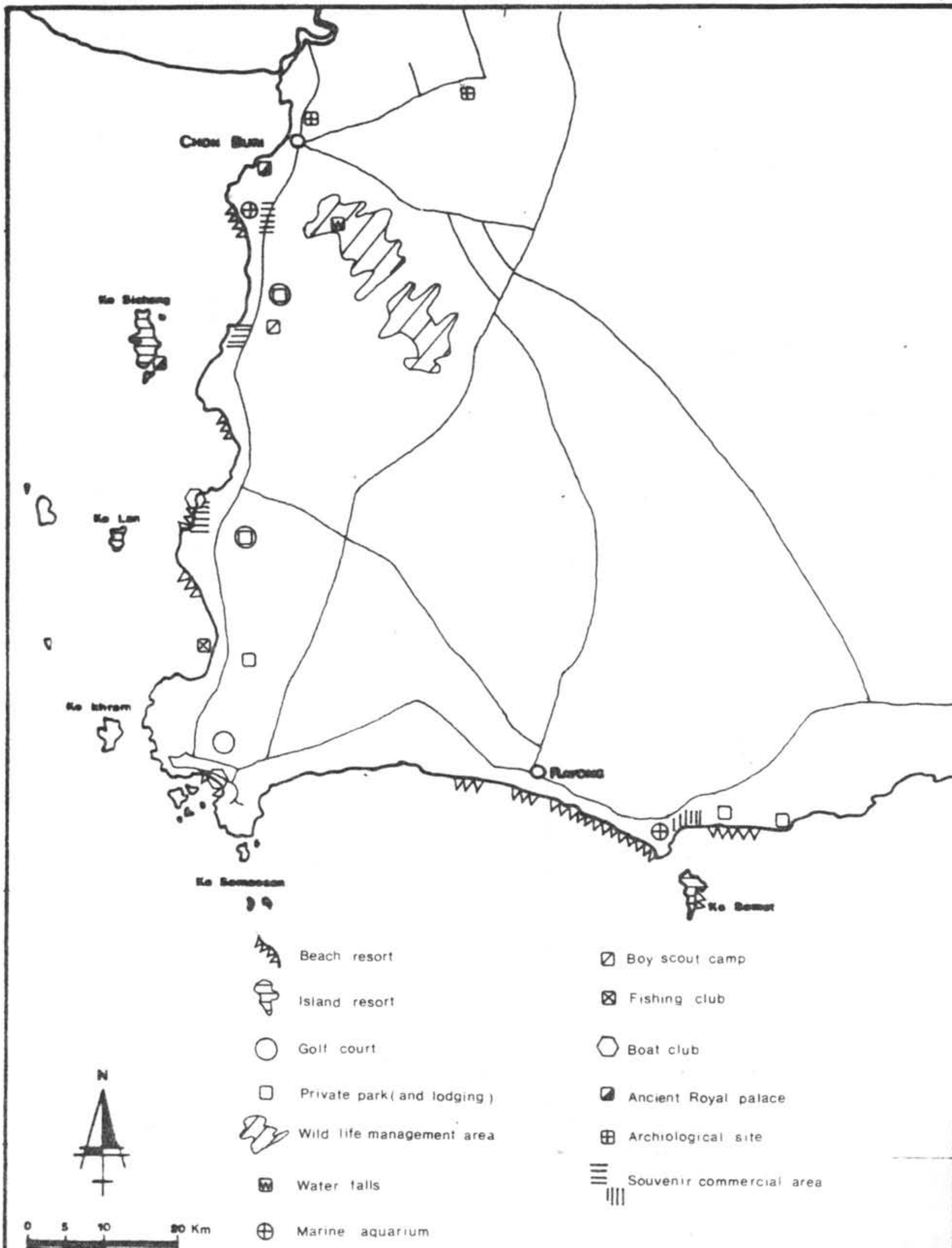
Considering the concentration of coliform bacteria in near-shore seawater of Amphoe Muang Chon Buri, Bang Saen, Siracha, Ao Phai, Bang Lamung and Pattaya, it is observed that the concentration is very high as compared with various standards, namely, 1,000 MPN per 100 milliliters of Japan, 230 cells per 100 milliliters of Hawaii state, U.S.A. and 1,000 cells per 100 milliliters of WHO. The breeding of marine animals, according to the standard of California State, U.S.A., it is suggested to be 70 cells per 100 milliliters of coliform bacteria.

With regard to the concentration of phosphate in the near-shore seawater of Bang Pakong estuary and Ao Angsila, the value is generally high within the range of 22 and 30 microgram - atom per liter. At other localities, namely, Amphoe Muang Chon Buri, Bang Saen, Siracha, Ao Phai, Laem Chabang, Bang Lamung and Pattaya, the concentrations of phosphate are between 0.3-4.8 microgram-atom per liter. The FAO (1971) reported that if the concentration of phosphate in the near-shore seawater increased to 10 microgram-atom per liter, the algal bloom or eutrophication will take place. This condition is dangerons to marine lives. Therefore, it is interesting to note that the environmental problem within the near-shore area of Bang Pakong estuary and Ao Angsila is anticipated unless the remedial measure is introduced.

With respect to the concentration of nitrate and nitrite, they are comparatively high at Bang Pakong estuary, Ao Angsila and Ao Phai. The concentration of nitrate and nitrite are reported to be 20-200 and 10-26 microgram-atom per liter respectively. The values are higher than the normal value reported by FAO but lower than the U.S. EPA standard for warm water fish.

4.7 Recreations

According to the afore-mentioned chapter (Chapter II) with regard to the tourist industry, it is interesting to note that the existing recreational facilities within the studied area is considered to be the one item of the essential physical determinants in planning. Recreations within the studied area include asthetic and visual aspects, and recreation-oriented activities. The type and locations of recreation facilities within the studied area are illustrated in Figure 4.7.1.



RECREATIONAL FACILITIES	ENVIRONMENTAL GEOLOGY OF AN AREA ALONG THE EASTERN COAST , UPPER GULF OF THAILAND

DEPARTMENT OF GEOLOGY , GRADUATE SCHOOL CHULALONGKORN UNIVERSITY	SUNYA SARAPIROME	FIG. 4.7.1

Recreational facilities within the studied area is believed to be well developed comparing with other region of Thailand. These can serve a big number of tourists with almost of recreational facilities for all seasons of the year. Various kinds of recreational facilities within this area are, namely, beach resorts, island resorts, archiological sites, ancient Royal palace, private parks (and lodging), golf course, wild-life management area, waterfalls, boy-scout camp, water-related sport clubs, marine aquariums and souvenir commercial area including various levels of restuarants and hotels with complete facilities.

Beach resorts within the studied area have been famous and attractive places for a long time. They are located at Bang Saen, Laem Chabang, Pattaya, Haad Chom Thian, Haad Dong Tan (Sattahip), Haad Sai Thong, Rayong estuary beach, Rayong-Kon Ao beach, and Haad Suan Son. Island resorts are well known at Ko Si Chang, Ko Lan and Ko Samet with beautiful Haad Sai Kaew. Archeological sites are Muang Sri Pha Lo and Muang Phra Rot located at Nong Mai Daeng, Amphoe Muang and Amphoe Phanat Nikhom, Chon Buri respectively. There are two ancient Royal palaces located at Ko SiChang and Ban Angsila. Three golf courses are located at Bang Phra, Siam Country Club in the vicinty of Pattaya and Phlu Ta Luang in the vicinity of Sattahip. The only one waterfalls, so called Chan Ta Then Water Falls, is found in the studied area at Khao Khieo. Vachirawudth boy-scout camp is located in the vicinity of Siracha. The open zoo is at Khao Khieo which is the wild-life management area (including Khao Chomphu). Private parks and lodgings are at Siam Country club, Suan Nong Nuch, Suan Son and Wang Kaew. Two marine aquariums are open to public at Sri Nakarin Wirot University (Bang Saen) and Ban Phe fisheries station. Souvenir commercial area is generally situated in many urban areas particularly at Nong Mon, Siracha, Pattaya and Ban Phe. Besides, water-related sport includs fishing, boating, surfing and skiing are also available. Boat clubs are localized at Pattaya and Sattahip while fishing club is at Bang Sa-re. In addition, many other places of high-value in terms of scenic and landscaping are common place in the studied area along the coastline in particular.