ธรณีวิทยาสิ่งแวดล้อมเพื่อการวางแผนการใช้ที่ดินของจังหวัดกระบี่ โดยใช้ระบบสารสนเทศภูมิศาสตร์

นาง สุรีย์ โพธิ์แก้ว

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ENVIRONMENTAL GEOLOGY OF CHANGWAT KRABI FOR LAND USE PLANNING BY USING GIS

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for the Degree of Master of Science in Geology
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สุรีย์ โพธิ์แก้ว: ธรณีวิทยาสิ่งแวดล้อมเพื่อการวางแผนการใช้ที่ดินของจังหวัดกระบี่โดยใช้ระบบสารสนเทศภูมิศาสตร์ (ENVIRONMENTAL GEOLOGY OF CHANGWAT KRABI FOR LAND USE PLANNING BY USING GIS) อาจารย์ ที่ปรึกษา ผศ. ดร. ธนวัตน์ จารุพงษ์กุล นายบรรเจิด อร่ามประยูร 138 หน้า ISBN 974-333-440-8

แนวชายฝั่งด้านทะเลอันดามันในพื้นที่ศึกษาตลอดความยาว 50 กิโลเมตรมีการเปลี่ยนแปลงอย่างรวดเร็ว ปัจจัยหลักมาจากอิทธิพลของธรรมชาติและการกระทำของมนุษย์ก่อให้เกิดการพังทะลายของชายฝั่งและการเติบโตของการเพาะเลี้ยงสัตว์ตลอดตามแนวชายฝั่งซึ่งแต่เดิมพื้นที่นี้เป็นแต่เพียงแหล่งอาหารทะเลจากการประมงและสถานที่พักผ่อนตามธรรมชาติ ในปัจจุบันแนวชายฝั่งทะเลมีการพัฒนาเป็นโรงงานอุตสาหกรรม ศูนย์กลางการค้าทางทะเล แหล่งท่องเที่ยว และการเพาะเลี้ยงสัตว์ทำให้พื้นที่ศึกษาเติบโตเป็นเมืองอุตสาหกรรมรวมทั้งจะมีโครงการพัฒนาพื้นที่ชายฝั่งทะเลภาคใต้ โครงการพัฒนาเมืองกระบี่ให้เป็นศูนย์กลางการท่องเที่ยว ปัญหาที่ตามมาคือการพัฒนาโครงสร้างพื้นฐานและสาธารณูประโภคไม่เพียงพอและเหมาะสม

ธรณีวิทยาสิ่งแวดล้อมเป็นปัจจัยหลักในการวางแผนการจัดการใช้ที่ดินนี้ ซึ่งประกอบด้วยปัจจัยหลักที่พิจารณา ได้แก่ ลักษณะภูมิประเทศ ธรณีวิทยา ธรณีสัณฐานวิทยา แหล่งทรัพยากรธรณี สภาพธรณีวิทยาทางทะเล การพังทะลายของชายฝั่ง แหล่งท่องเที่ยว แหล่งพักผ่อนหย่อนใจ และพิจารณาปัจจัยทางเศรษฐกิจและสังคมของจังหวัดกระบี่ประกอบกัน

การประมวลผลการวางแผนจัดการ การใช้ที่ดินเน้นหนักที่ปัจจัยของแหล่งทรัพยากรธรรมชาติและธรณีพิบัติภัย ผลการศึกษานำเสนอในรูปของแผนที่ โดยแบ่งออกเป็น 5 ประเภท คือ พื้นอนุรักษ์ พื้นที่ศักยภาพแหล่งหินคาร์บอเนตเพื่อการก่อสร้าง พื้นที่ศักยภาพแหล่งท่องเที่ยวและแหล่งพักผ่อน พื้นที่ศักยภาพเกษตรกรรม และพื้นที่ศักยภาพโรงงานอุตสาหกรรม

การจัดการพื้นที่ชายฝั่งทะเลที่เกี่ยวข้องกับการพังทะลายของชายฝั่งและกิจกรรมของมนุษย์ ประกอบด้วย การป้องกัน การอนุรักษ์ และการพัฒนาในทิศทางที่เหมาะสม ซึ่งปัญหาของสิ่งแวดล้อมตามพื้นที่ชายฝั่งเนื่องมาจากการแสวงหาผลประโยชน์จากทรัพยากรธรรมชาติและสิ่งแวดล้อมที่มากเกินไป ดังนั้นการวางแผนการจัดการที่เหมาะสมจะช่วยป้องกันและอนุรักษ์ทรัพยากรต่างๆและลดปัญหาสิ่งแวดล้อมได้ในระยะยาว

ภาควิชา.....ธรณีวิทยา..... ลายมือชื่อนิสิต.....

สาขาวิชา.....ธรณีวิทยา..... ลายมือชื่อ อาจารย์ที่ปรึกษา.....

ปีการศึกษา.....2542..... ลายมือชื่อ อาจารย์ที่ปรึกษาร่วม.....

SUREE POKAEW: ENVIRONMENTAL GEOLOGY OF CHANGWAT KRABI FOR LAND USE PLANNING BY USING GIS, THESIS ADVISOR : ASST. PROF. Dr.THANAWAT JARUPONGSAKUL, Mr. BUNJERD ARAMPRAYOON. 138 pp. ISBN 974-333-440-8

Coastline of the study area is approximately 50 kilometres long and rapidly change due to the combination of natural and human impacts.The Krabi coast become to industrial and commercial development related to tourism and also to aquaculture. It made the transition from less development province to industrialized province. The commonly problems related to these change are inadeguate infrastructure, insufficient recreation area, inadeguate water supply, mangrove deforestation and coastal erosion. Therefore, the present investigation aims to present the environmental geology database for planners and decision makers. Accordingly the efficient use of land and natural resources could be harmoneously achieved with minimum impact or sustainable development.

The environmental geological setting is among one of most significant determinants for land use planning which contained the topographic limitations, geological setting and geomorphological, geological resources, marine geological conditions, coastal erosion, including tourist and recreational resources. The addition, the socio-economic background of Krabi are reviewed for understanding the basic social environment of the area. Additional attempt has been made in this study to synthesize and integrate many aspect of environmental geology and relevant factors for the development potential of area such as, conservation, construction materials, and agricultural purposes.

The compilation of regoinal landuse planning is emphasized based on natural resources and geological hazard information, that have been described and presented in various geographic information maps. There are five main categories of preliminary planning, including conservation, carbonate rock for construction purposes, residential, agricultural, and industrial development proposes.

The coastal zone management as related to the coastal erosion problems and human activities in the coastal area must embrace the following activities: protection, preservation and conservation, and development.

Finally, the environmentsl problem are originated from the over exploitation of natural resources and environment. Appropriate strategic and management will aid sustainable use of limited resources, protection, conservation and development as long periods as possible and decrease the environmental problem.

ภาควิชา.....ธรณีวิทยา.....
สาขาวิชา.....ธรณีวิทยา.....
ปีการศึกษา.....2542.....

ลายมือชื่อนิสิต.....
ลายมือชื่อ อาจารย์ที่ปรึกษา.....
ลายมือชื่อ อาจารย์ที่ปรึกษาร่วม.....

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CHAPTER 1

INTRODUCTION

The coastline of Changwat Krabi is approximately 160 kilometers long, and has continuously developed rapidly in the last two decades. The environmental implications of coastal development on natural systems are alarming with the tendency to be intensified in the next few decades. As the country becomes more populous and technologies for destruction are more efficient, there are fewer and fewer places that remain untrammeled and unmolested especially the coastal zone. In the past, Changwat Krabi coastline provided food, recreation and security to the people in the area. Later on, the Changwat Krabi coastal zone becomes more industrialized and commercialized particularly relating to tourism and aquaculture industries.

At present, the coastal zones are of great importance to the country development. The coastal development planning and management must be undertaken in the context of environmental concernedness so that the benefits obtained from coastal resources are optimized forever.

In order to effectively plan for the future development, the present status regarding the environmental geology as well as the socio-economic background of the area must be carefully studied. According to this background data and information, the future development potentials will be identified the land use planning and management will be accordingly formulated on the basis of sustainable concept.

1.1 THE STUDY AREA

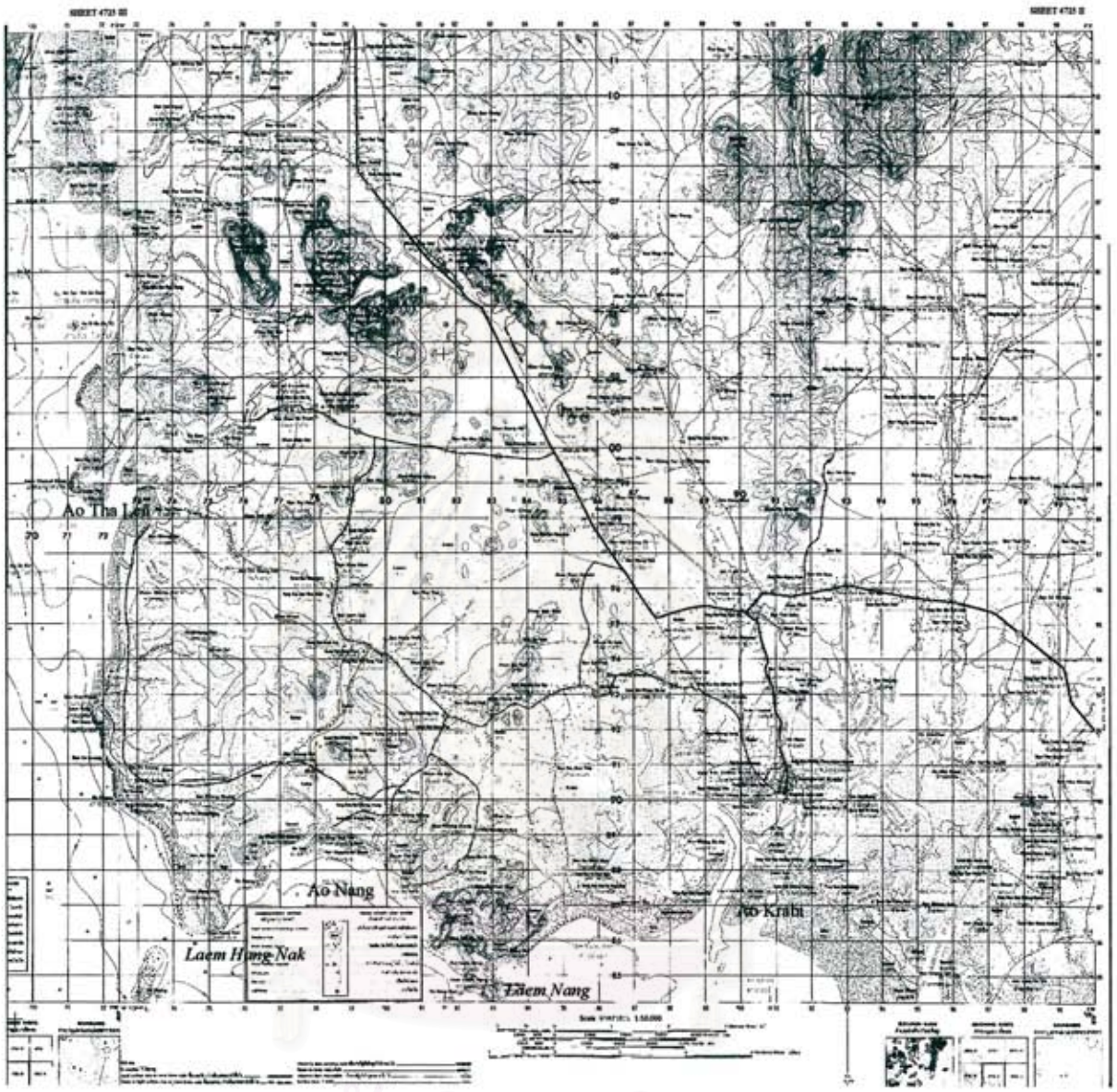
The study area is located in the southern region of Thailand with distance of 946 kilometers from Bangkok along the highway no. 4. The area includes the mainland, coastal zone, and islands of approximately 750 km^2 between longtitude 98° 43′ 00″ and 99° 00′ 00″. The area covering the topographic map sheet Changwat Krabi (4725 II) and eastern part of King Amphoe Ko Yao (4725 III) as shown in Figure 1.1.

The topographic of the area has two regions, upland and a coast. The upland area is categorized by mountains, undulating terrain and terraces. Mountains areas are characterized by north -south trending ranges, the elevation range from 600-700 meters above mean sea level, such as Khao Phanom Bencha. The mountains with elevation between 400-600 meters are located in the western part of the area. Scattered limestone monadnocks occur in the south. Undulating terrain comprise hill slopes, valley, and terraces. The elevation of this topography ranges from 10-70 meters above mean sea level. The flat area mainly flood plain deposits along usually narrow floodplain of Khlong Krabi Yai, Khlong Krabi Noi and Khlong Nam Mao have the elevation range between 5-10 meters above mean sea level. Khlong Krabi Yai and Khlong Krabi Noi are major streams running from north to south through this terrain into the Andaman Sea. Tidal flat, beach sand, and rocky coast dominate the coast of the study area. The elevation of coastal areas is less than 10 meters, being more or less 2-5 meters above mean sea level.

1.2 OBJECTIVE

The present study aims to acquire, to analyses and to evaluate the environmental geological data and relevant information as well as the socio-economic conditions and development policy in order to identify the potential development of the area for the future land-use planning. The geographic information system (GIS) provide a broad range of tools for determining areas of sustainable land use planning. The GIS database may also contain environmental geological, agricultural, infrastructure and socio-economic information. This can be used in conjunction with the development policy for the long-term land use management.

CHANGWAT KRABI



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2 0 2 4 6

Kilometers

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Figure 1.1 The study area outlines on portion of the 1:50,000 scaled of he Royal Thai Survey topographic map

1.3 GENERAL APPROACH

The coastal zones of Thailand of approximately 2800 kilometers have long been developed over the past two decades, particularly for industrial and commercial purposes. Besides expansion real estate developments have been extensively expanded along the coastlines, over the Gulf of Thailand and the Andaman Sea. This new industrialization zone has caused the rapid expansion of urban and simultaneously a rapid increase in land prices, resulting in economic growth and at the same time there is an urgent needs for land use management.

The center of attraction for the coastal development of the Thai peninsula is located in the western coast of Andaman sea, in the area around Ao Phangnga where Phuket, Phangnga and Krabi are located. The government has proposed the Southern Seaboard Development Project covering the area of Changwat Surat Thani, Changwat Nakon Sri Thamarat, Changwat Phuket, Changwat Phangnga and Changwat Krabi. Changwat Krabi is developing area for tourism, industry and commerce. Under this project, the new land bridge system comprising highway, deep-sea port, pipeline and industrial estate will link the deep-sea port between the eastern and western coast of the southern Thai Peninsula. For such a change in land use and development project, the factors of environmental geological becomes very importance to evaluate the land use categories and development strategy.

In the study area, there are a number of beautiful beaches and islands e.g., the Hat Nopparat Thara and Phi Phi Island National Park. This may explain why expensive resort developments have favored these places. Along the coastline, mangrove forest has been converted to shrimp farming communities. The population is a low-to-moderate income agricultural, farming and fishing communities. Under the Southern Seaboard Development Project, the proposed highway development between Krabi and Khanom is under construction. Thus, accelerated development seemed imminent, and the area presented a rope subject for the exercise described herein.

1.4 METHODOLOGY

The study involves four sequential steps, each of which will be described. The schematic diagram for methodology system is illustrated in Figure 1.2.

Data collection

The preparation involves the basic data acquisition, library search and literature study, to present these data on maps at a scale of 1:50,000, and to arrange data system.

Field work

The field investigation and data collection will be carried out on regional and detailed surveys. The fieldwork involves data gathering of geological features, geological resources, geomorphology, coastal characteristics, existing land use and coastal erosion. The local information obtained from provincial offices as well as the interviews of local people are undertaken. The collected data during this phase are used to determine boundaries, potential impacts, and data processing.

Development of database system and analysis

The data collected during the data collection step and field work were input into the GIS database formats on 1:50,000 scale. The results are presented in digital map showing land capability for development options. This step is very important task in providing the final recommendation (Table 1.1).

Reporting

After the data were collected, interpreted and evaluated, the results are finally presented in the forms of maps profiles and tables. The discussion and conclusion part cover decision on the coastal land planning.

Table 1.1 The outline of different types of data (modified after Jarupongsakul, 1995)

Secondary data	Primary data	Result
Topographic map	Geomorphology map	Conservation area map
Soil map	Slope map	Carbonate rocks potential map
Land use map	Shoreline erosion data	Agriculture potential area map
Forest map	Modified geologic map	Residential potential area map
Forest use map		Industrial potential area map
Watershed classification map		Shoreline erosion map
Geologic map		
Groundwater map		
Construction material map		
Geographical data		
Marine condition data		
Political, socio-economic data		

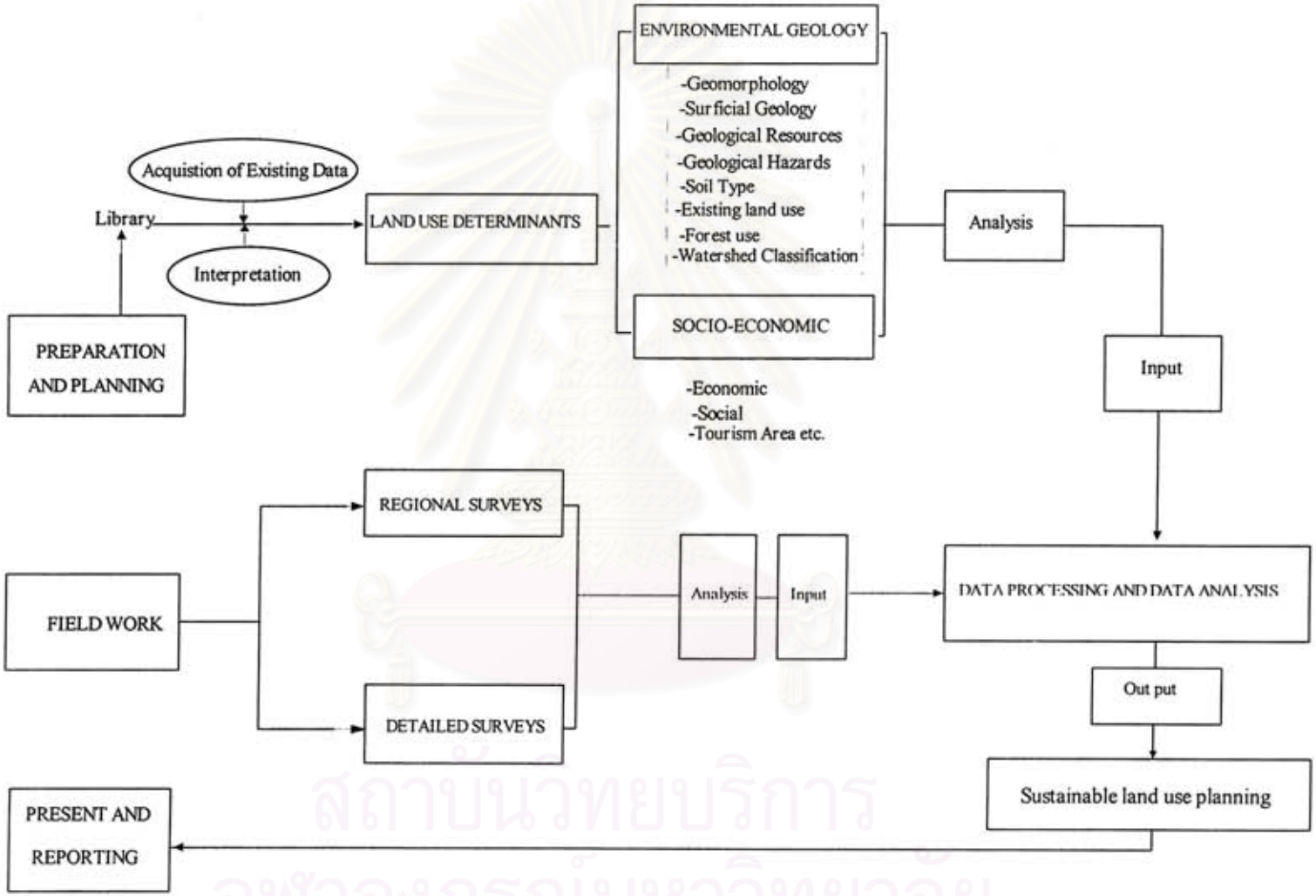

Figure 1.2 Flowchart of the Thesis methodology

1.5 PREVIOUS WORKS

The environmental geology and coastal zone development of Changwat Krabi, in terms of implication for coastal planning and management reported by Sinsakul (1996) reveals that Changwat Krabi has two regions, an upland and a coast, each has its own character but were linked together in the scope of environmental geology. The coastal zone development has been going on within Changwat Krabi under limited scientific knowledge and misconception concerning the nature of coastal zone

The decision on coastal resources management and development should be based on current scientific knowledge of the area. Emphasis should be based on coastal processes and their effects on coastal geomorphology. The environmental geological information should be applied to minimize features which have impacts on coastal change and sea level rise in the Krabi coastal zone.

In conclusion, the coastal zone management in Changwat Krabi should be undertaken under the concepts involving the following activities.

Conservation: should be carried out in sensitive areas, particularly Krabi's upper coast and the islands in the near shore area connected to the Phangnga bay. This area should be issued as a conservation zone for natural environment.

Protection: the magnitude hazardous problems are increasing in the Krabi coast due to rapid population growth, massive development, and natural changes, such as coastal erosion, deputed natural resources and aesthetic resources and etc. The basic policy and measures can be initiated for construction of engineering struction , beach nourishment, and shoreline restoration, with some concerns for coastal protection, in order to minimize the ever-increasing problem.

Development: based on coastal geological information, development activities should be encouraged mainly on recreation facilities for public use, particularly those areas of tourist attraction. Small- scale industrial estates should be developed further to the north or south of the Changwat Krabi coast.

The school of civil engineering, Asian Institute of Technology, had been requested by the Department of Mineral Resources, Ministry of Industry, to conduct a study on "Conservation of Fossil Beds at Ban Laem Pho, Krabi Province(AIT,1995). The fossil beds at Ban Laem Pho 1, Laem Pho 2 and Laem Pho 3 along 2-kilometer along the shoreline of Changwat Krabi. At present, the fossil beds are severely eroded. Therefore, it is essential to protect them from erosion. The study reveals that the major cause of erosion is the wave action and the minor cause is due to poor condition of geological structure and low resistance of the bed, which lead to rapid degradation. The recommended method of protection is to dissipate the wave action by constructing the rubber mound breakwater, which produces least environmental impact, easy to construct with low cost. The implications of rubber mound breakwater on the environment are the change of tidal current circulation and the change of coastal morphology. The current in Phangnga bay is weak, but still, is stronger than that of the Krabi bay. There is a limited amount of sand in the vicinity of the project site, therefore, it would not be any significant change of shoreline morphology. The construction of rubble mound breakwaters to protect the three fossil beds from wave attack was proposed by AIT (1995). However, the construction of the rubble mound breakwaters may have an impact on the surrounding environment particularly the visual pollution and, therefore a preliminary environmental impact study of the rubble mound construction should be carried out. The rubble mound must be higher than the mean high water spring so as to prevent the wave from crossing over the coast. However, the construction of the rubble mound breakwaters will have direct impact on the environment of fossil beds, that is, the benthos at the construction site will be destroyed approximately 25 rai of biomass and the morphology of the coast will be changed. The subordinate impact is the accumulation of sediments behind the breakwaters which may require dredging at interval.

According to Sinsakul (1996) the increasing deteriorating conditions in the coastal area of Thailand have raised the concerns among the government and non government organizations. The problems have greatly increased and accumulated to the level that threatens the human life and safety as well as to the economy of the country. Coastal areas of Thailand are changing in both shape and location due to a

complex natural and man-made causes. The impact of hazardous coastal processes is considerable, especially the coastal erosion which occurs continually and increasingly both number and intensity. Tropical cyclone is a serious coastal hazard which claims many lives and causes major property damage, usually along the Gulf of Thailand coast. The evidence of subsidence is also considerable in the coastal lowland which is directly related to over pumping of groundwater in many large scale of coastal city like Bangkok.

In Thailand the coastal hazard problem is solved by structural and non-structural structural measures, such as seawall, jetties, offshore break water, replanting of aquatic vegetation etc. A global sea-level rise of one meter would greatly modify coastal environment in Thailand, producing erosion and submergence, especially on low-lying areas of Changwat Krabi (Jarupongsakul, 1999).

CHAPTER 2

ENVIRONMENTAL GEOLOGICAL SETTING

The rapid development for tourism, industrial, commercial and urbanization, characterizing many large coastal city nowadays, calls for careful studies of environmental problem, land use planning, terrain configuration, and sub-soil conditions, particularly in new sub-urban zones. The contributions from the environmental geology to land use planning is essentially a multidisciplinary issue of physical characteristics and existing land use information with need to be combined with socio-economic and demographic data. It is therefore, essential to clearly indicate which factors of the different aspects of environments, terrain configuration, and the sub-soil conditions needs to be assessed, and the form in which they should be presented.

Application of environmental geology study to land use planning and management requires the ability of a scientist who is particularly well versed in geology, geomorphology, engineering geology, economic geology, and hydrogeology, and who also has an understanding and appreciation of the principles and administration of land use planning. And it must be able to make the results of environmental geological studies readily understandable to an usable by the non environmental geologically trained professional planners and citizens of the community to whom the decisions regarding land use development are entrusted.

Land use planning and management must be directed toward specific geological resources and environment that are likely to be of concern in planning the land. Features of the land about which environmental geologists are especially will qualify to supply knowledge and evaluations are: (1) economic mineral resources and potential; (2) natural hazard conditions that, if unrecognized, could become diasters to

property and health; (3) water supply potential; (4) geological significance of understanding scenic and educationally stimulating natural areas.

2.1 PHYSIOGRAPHIC SETTING

The topography of the study can be subdivided into two zones, namely the coastal zone and the mainland as show in Figure 2.1.

The coastal zone of the study area is characterizes by rough topography of hills and mountains. The coast of the study area is dominated by sandy plain, beach, and characterized by rocks, cliff and pocket beach. The sediments derived from Khlong Krabi Yai and Khlong Krabi Noi to Ao Krabi. These have been reworked into coastal barrier bar and mangrove swamps in thetidal coastal plain. Estuaries are present in the coastal area along Khlong Krabi Yai and Khlong Krabi Noi.

The mainland contain elongation of the hill and mountains are in the north-south trending ranges.The high mountain ranges of mainly limestone, sandstone and geranitic rocks of Khao Na Daeng, Khao Hang Nak and Khao Phanom Benjha. The highest peak is Khao Phanom Benjha with approximate elevation of 890 meters above the mean sea level. Most of mountain area with the elevation range of 400-600 meters above the mean sea level has been developed for agriculture and settlements. The forest area has been deforestation and, consequently, soil erosion is rapidly removed, especially during the rainy season. Most of the eroded material has been deposited in lowland area. The undulating area is located in valley with the elevation range of 10-70 meters above the mean sea level. The flat area of mainly floodplain deposits along the usually narrow floodplain of Khlong Krabi Yai, Khlong Krabi Noi and Khlong Nam Mao have the elevation range between 5-10 meters above the mean sea level.

The major drainage is Khlong Krabi Yai, Khlong Krabi Noi and Khlong Ao Nam Mao, which flow towards the southeast and south directions into the Andaman Sea.

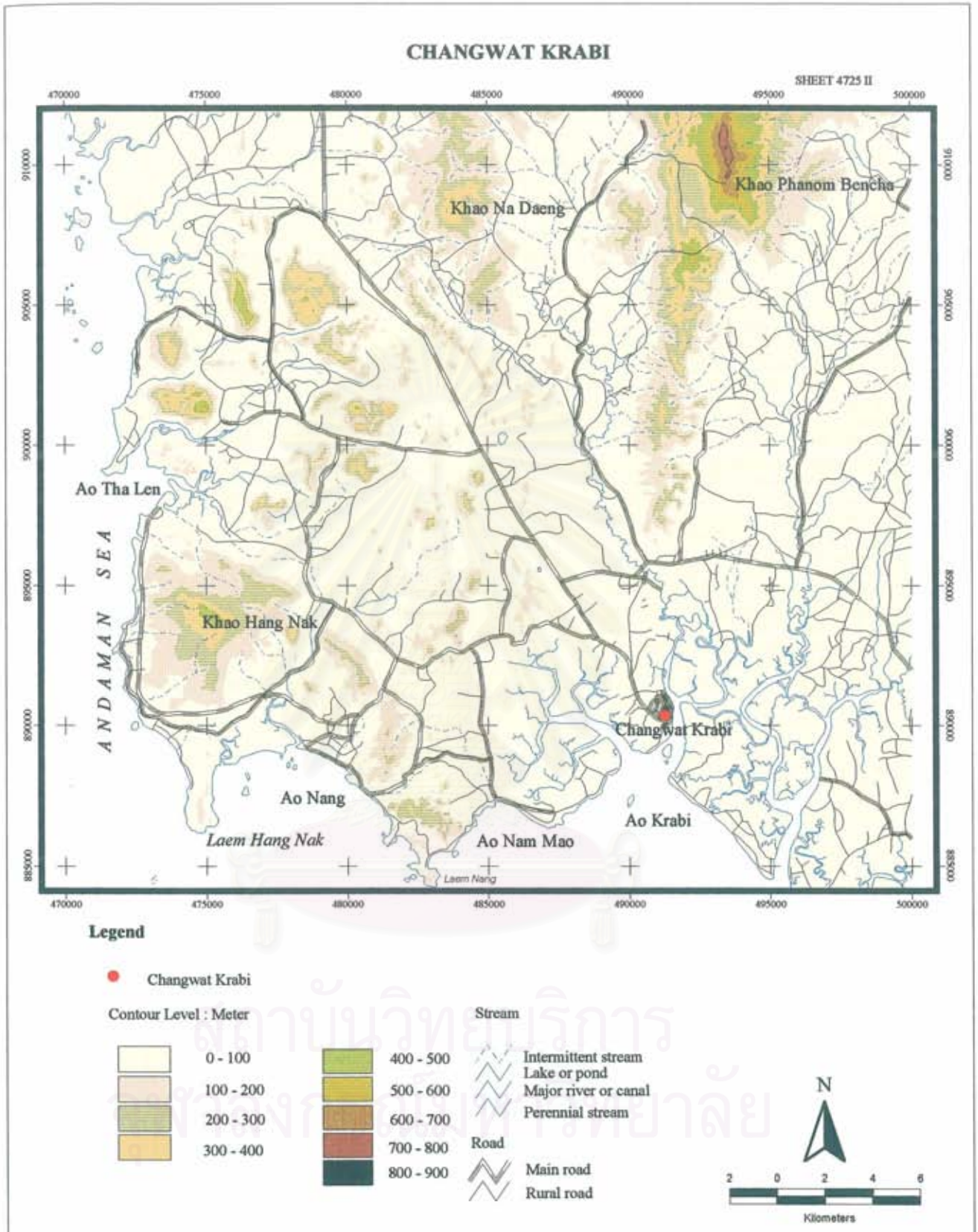

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Figure 2.1 Topographic map

The study area is situated under the influence of tropical monsoon climate (Arthur and Alan, 1979). The mean daily temperature varies between 19°C and 37°C, and the annual average precipitation is 1800 mm., and may be higher than 2,500 mm in some years . The information is taken from the Meteorological Department as presented in Tables 2.1 and 2.2.

Table 2.1 Monthly rainfall of Changwat Krabi : 1980-1989 (Department of Meteorology, 1996)

Year	Annual rainfall	Jan.	Feb.	Mar.	May.	Apr.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1980	1921.1	0.0	8.4	82.8	83.1	138.4	230.2	367.2	377.7	258.3	164.0	152.4	58.6
1981	1517.7	0.0	0.0	27.8	263.2	285.3	152.9	169.3	61.3	198.4	144.9	150.2	64.4
1982	1672.5	0.0	0.0	19.9	25.2	450.4	51.5	484.0	224.7	128.2	137.9	126.2	24.5
1983	1507.5	1.3	0.0	11.1	0.0	214.3	167.8	225.1	256.2	424.1	140.1	45.6	24.9
1984	854.5	0.6	21.2	14.2	98.5	63.1	-	-	61.7	138.1	163.6	193.6	99.9
1985	2026.5	0.8	48.7	18.7	103.3	481.0	147.3	112.4	309.3	375.5	405.5	0.0	24.0
1986	2221.9	8.0	0.0	4.3	78.2	477.5	273.5	135.0	88.6	663.8	251.9	219.8	21.3
1987	2641.3	3.9	0.0	768	27.4	371.4	264.9	84.8	487.7	261.5	405.6	568.4	88.9
1988	1936.5	10.8	36.9	12.1	278.5	202.5	152.3	280.2	73.3	408.1	276.2	161.4	44.2
1989	2362.5	1.3	11.5	43.4	259.7	340.2	126.0	178.3	314.5	316.1	668.0	103.5	0.0
Average	1866.2	2.7	12.7	31.1	121.7	302.4	156.6	203.6	225.5	316.9	275.8	172.1	45.1

Table 2.2 Monthly rainfall and relative humidity : 1997(Department of Meteorological, cited in Statistical reports of Changwat Krabi , 1998)

Month	Rainfall (mm)	No. of rainy days	Temperature °(C)		Relative Humidity %	
			Minimum	Maximum	Minimum	Maximum
Jan.	4.2	2	18.20	35.20	47.39	88.65
Feb.	142.5	8	22.20	35.10	54.93	90.18
Mar.	14.9	3	20.50	37.10	47.65	89.19
Apr.	134.2	9	22.10	36.90	54.43	90.83
May	106.9	17	23.40	35.70	62.97	92.48
Jun.	232.2	17	22.40	34.50	64.50	93.83
Jul.	178.3	20	22.10	33.50	68.58	94.48
Aug.	585.2	16	21.80	34.30	67.23	93.42
Sep.	297.0	17	22.40	33.40	68.67	94.50
Oct.	372.7	23	22.40	34.00	64.48	95.68
Nov.	103.6	17	21.70	34.20	64.77	94.07
Dec.	91.2	11	21.30	34.30	61.32	93.13
Annual	2263.1	160	18.20	37.10	60.58	92.54

2.2. COASTAL PROCESS

Wind

The wind direction for all year round at Changwat Krabi is shown in Figure 2.2 (Wongvitavas, 1989) and the mean wind speed is uniform through the year between 30 to 40 kilometers/hour. The area effect by northeast monsoon wind pattern during December to March, and by the southwest monsoon during April to December. It was reported that the wave being associated, with the southwest monsoon wind are rarely predominance in the Andaman Sea (AIT, 1995).

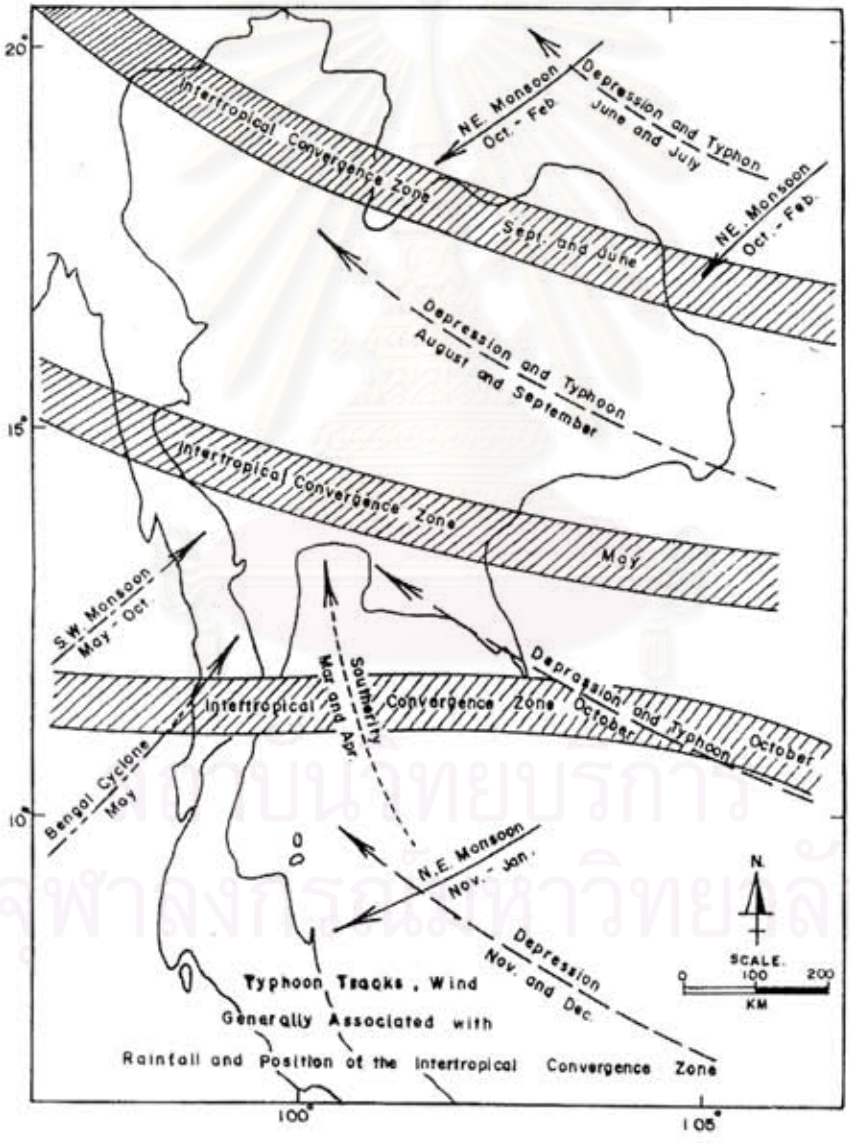

Figure 2.2 Monsoon and storm tracks in Thailand (after Wongvitavas, 1989)

Wave

The recorded wave data is not available in the study area for a long period. The nearest wave measurement station is at Changwat Phuket. The summary of statistics on wave data from offshore tin-mining project, at the west of Changwat Phuket is shown in Table 2.3.

Coastal zone waves are most active during the southwest monsoon, as shown in Figure2.3 (AIT,1995). The significant wave height is between 0.3 - 1.5 meters, and wave period varies between 4.5 - 7.0 seconds(Table 2.4).

Table 2.3 Maximum wave height recorded from shallow water of the western coast of Thailand(AIT, 1995)

Month	Maximum height (meter)		
	1980	1981	3-5 years record , 1974, 1977-1980
Jan.	0.8	-	-
Feb.	-	-	-
Mar.	0.5	-	-
Apr.	0.7	1.2	-
May	2.3	3.6	4.2 early May often fairly calm
Jun.	2.1	4.3	4.2 some years mostly less than 2.0
Jul.	2.0	-	-
Aug.	2.1	-	5.3 1980 calm year
Sep.	1.6	-	4.3 some year less than 2.0
Oct.	1.3	-	1.8, 3-years record; mostly less than 1.0

Table 2.4 Significant wave height data from the west coast of Thailand (AIT, 1995)

Month/Year	Significant wave height (meter)	Wave period (second)	Most commonly recorded wave	
			Height (meter)	Period (second)
Oct. 1979	0 – 2.0	4.5 – 14.5	1.5 – 2.0	5.5
Jan. 1980	0 – 0.5	2.5 – 4.5	0 – 0.5	3.5
Feb. 1980	-	-	-	-
Mar. 1980	0 – 0.5	4.5 – 14.5	0 – 0.5	8.5
Apr. 1980	0 – 0.5	4.5 – 14.5	0 – 0.5	6.5
Apr. 1981	-	-	-	5.5
May 1980	0 – 1.5	3.5 – 16.5	0 – 0.5	4.5
May 1981	0 – 0.25	3.5 – 16.5	0 – 0.5	5.5
Jun. 1980	0 – 1.5	3.5 – 12.5	0.5 – 1.0	6.5
Jun. 1981	0.5 – 3.0	3.5 – 9.5	2.0 – 2.5	6.5
Jul. 1980	0 – 1.5	5.3 – 13.5	0.5 – 1.0	6.5
Aug. 1980	0 – 1.5	5.5 – 17.5	0.5 – 1.0	6.5
Sep. 1980	0 – 1.0	3.5 –14.5	0.5 – 1.0	6.5
Oct. 1980	0 – 1.0	3.5 – 16.5	0 – 0.5	8.5

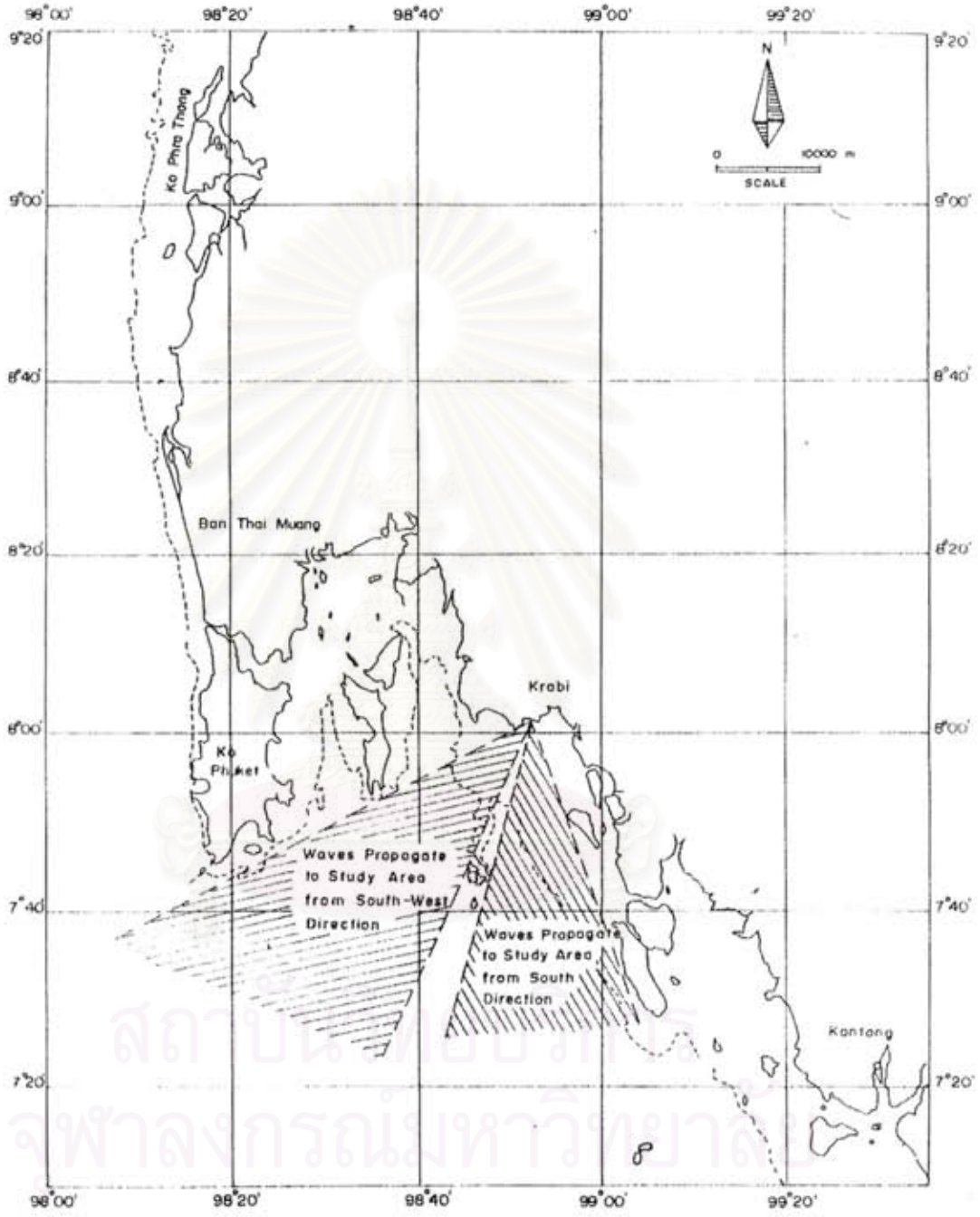

Figure 2.3 Directions of wave propagation of the study area (after AIT, 1995)

Tide

The tidal range of Changwat Krabi is quite high with maximum tidal range of 2.5 meters during spring tide and the velocity of ebb tide current is higher than the flood tide current. The recorded data of the Hydrographic Department, Royal Thai Navy during 1975 to 1993, at Taphao Noi island shows the following data (AIT, 1995):

Highest high water	1.72 meters
Mean high water spring	0.91 meters
Mean high water neap	0.14 meters
Mean sea level	0.00 meters
Mean low water spring	-0.70 meters
Mean low water neap	-1.53 meters
Lowest low water	-2.29 meters

Bathymetry

Krabi township is surrounded by relatively shallow water of Ao Krabi, Ao Nam Mao and Ao Nang. The depth of about 10 meters some 5 kilometers offshore. The depth of the seawater from Ban Khlong Sai northwardly extending about 3-4 kilometers from the coastline is approximately 10 meters. Coral reefs are common in water depth down to 2 meter around the headland and bay, such as, Laem Hang Nak, Laem Chamuk Khwai and Ao Nam Mao. The maximum depth of the sea water extending about 3 kilometers from the coastline between Khlong Mat Li and Laem Hang Nak is approximately 20 meters (The Hydrographic department , 1983)..

Water quality in the nearshore zone

The seawater quality of this area has directly effected by human activities on the coast, such as fishing, aquaculture, farming, recreation, etc. Generally, the salinity of the nearshore zones in the study area falls within the range of 10-30 part per

thousand. The pH average value falls within the normal range of 7.8-8.1 in dry season, and 7.6-8.0 in rainy season (Dept. Pollution control, 1998).

2.3 ENVIRONMENTAL GEOLOGY

2.3.1 GEOLOGY

The geology of the study area is largely dominated by rocks exposed in mountain areas, islands and erosion surfaces of hill slopes.The geological map of the study area is shown in Figure 2.4. The generalized stratigraphic succession of the study area consist of the Paleozoic, Mesozoic and Cenozoic sedimentary sequences, which broadly constitutes the following units;

Carboniferous - Permian rocks (Cp)

This unit comprises of sandstone, brown and grayish-green, medium to fine-grained; chert, white and pale brown, thin bedded and well bedded, fossilliferous; siltstone, brown, siliceous; mudstone, black and gray, thick bedded, siliceous, fossiliferous; and pebbly mudstone, gray and dark gray, massive, cobble as clast (Figure 2.5a,b). This unit is exposed on the northwestern side of Ban Laem Pho and northeastern part of Krabi province, such as, at Khao Klong Heang, Kuan Na Ban, Kuan Sang(Hua Lan) etc. The rocks are severely weathered, and brittle to friable. This unit is the oldest rock unit containing gastropods and corals.

Permian rocks (P)

This limestone unit is widely distributed in the study area, such as, Khao Laem Nag, Khao Nui, Khao Ao Nam Mao, Khao Chang Phi etc. This limestone unit is consisting of light gray, massive dolomitic limestone and pure limestone interbedded with shale (Figure 2.6a,b). The age of this unit is Middle Permian overlying the sandstone, chert and shale of Carboniferous age.

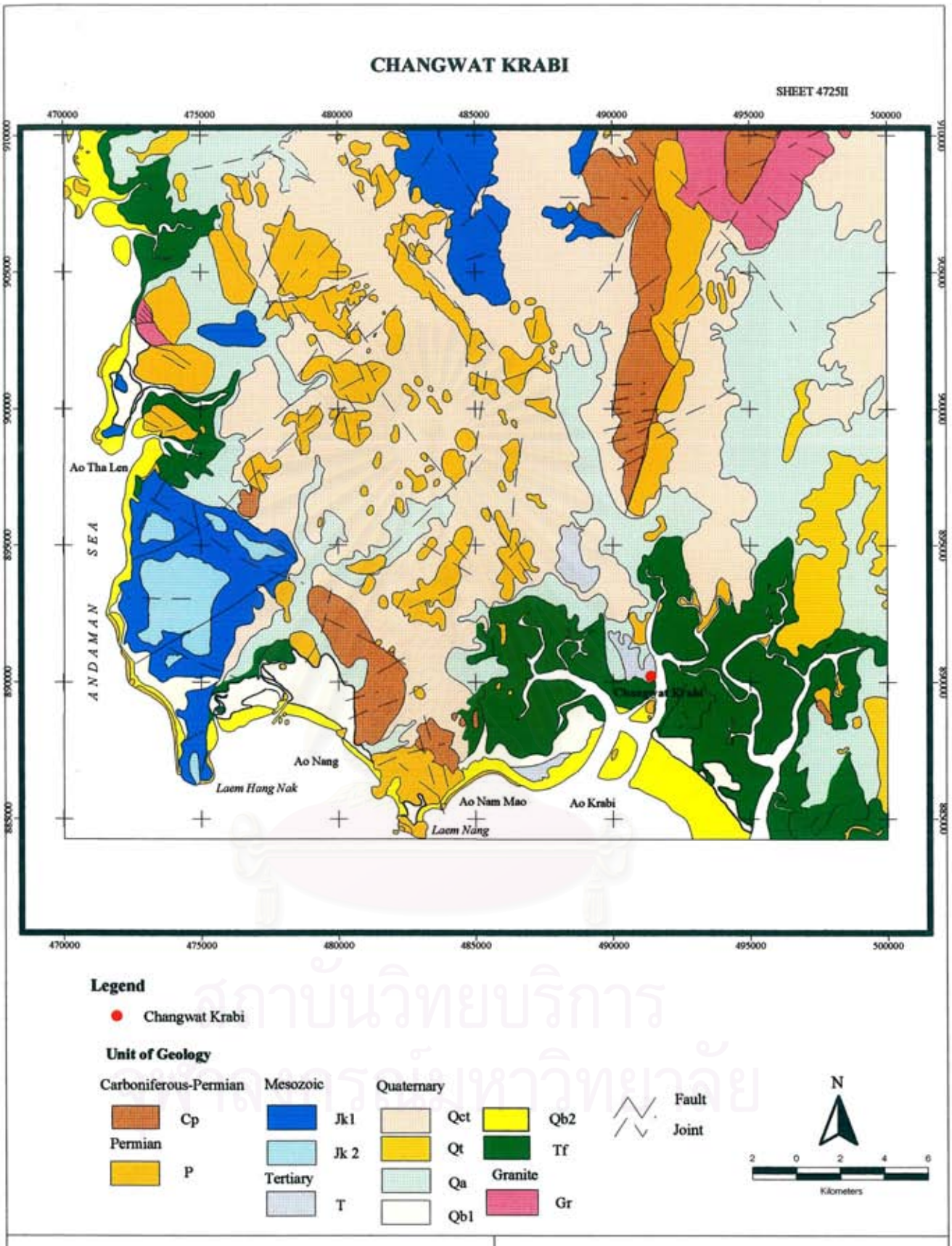

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Figure 2.4 Geological map

(a)

(b)

Figure 2.5 Carboniferous-Permian rock

(a) Thin-bedded sandstone, chert and siltstone at Khao Chong Pli

(b) Thick-bedded sandstone near Wat Tham Sua

(a)

(b)

Figure 2.6 Permian rock
(a) Thick-to very thick-bedded limestone at Laem Nang
(b) Thin-to thick-bedded limestone interbedded with shale at Laem Nang

Triassic - Cretaceous rocks (Tr - Jk)

The Mesozoic rocks unconformably overlie the Permian rocks. The unit consists of undifferentiated clastic rocks red to maroon siltstone, sandstone, conglomeratic sandstone, and conglomerate (Figure2.7a,b,c).

Tertiary rocks (T)

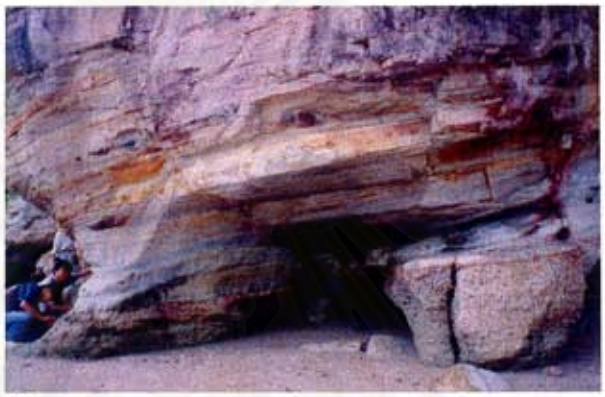
This rock unit is exposed in the south and northern parts of Ban Laem Pho including the areas where famous fossilized shell beds are exposed along the coastline. The rocks are moderately to completely weathered to clayey sand and sandy clay. This rock unit consists of intercalated sequence of mudstone, shale, sandstone, siltstone, conglomerate, fosilliferous limestone and lignite (Figure 2.8a,b,c). This rock unit unconformably overlies unconformable over the Paleozoic rocks and underlies the Quaternary sediments of alluvium, laterites, lagoon deposits, and marine terrace deposits.

Quaternary deposits (Q)

The sediments are characterized by gravel, sand, silt and clay. These unconsolidated sediments have been derived from erosional products of the underlying rock units and, further transported and deposited by river, stream, gravity, wind, and wave. The sediments are deposited in flood plains, terraces, sand beach, and mangrove areas. This unit can be devided into terrace and colluvium deposits, alluvium deposits, beach deposits and tidal flat deposits.

Terrace and colluvium deposits (Qt, Qct): The sediments are pebbly, gravel, sand, silt and clay and they were deposited as layers and lenses. A hardpan layer of laterite occurs in the upper sequence of terrace and erosion surfaces of bed rocks in upland areas(Figure 2.9a,b). All of these deposits indicate the former land surface deposition during the Pleistocene epoch.

(a)



(b)

(c)

Figure 2.7 Triassic-Cretaceous rocks

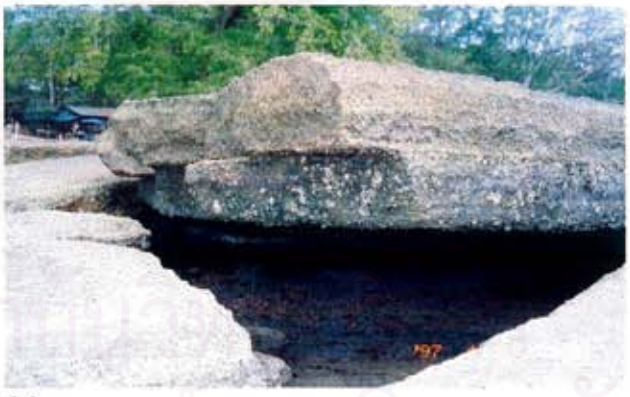
(a) Sandstone interbedded with shale at Khoa Nak Nui (Triassic)

(b) Conglomerate, siltstone and sandstone at Laem Chamuk Kwai (Jurassic-Cretaceous)

(c) Thick bedded sandstone at Ko Kwang (Jurassic-Cretaceous)

(a)

(b)



(c)

Figure 2.8 Tertiary rocks

(a) Semi-consolidated sandstone, siltstone and shale at Kuan Sabai

(b) Mudstone, siltstone, and sandstone at Laem Pho

(b) Fossiliferous limestone interbedded with mudstone and lignite at Laem Pho

(a)

(b)

Figure 2.9 Terrace deposit

(a) Pebbly, gravel, sand, silt, clay and laterite at Ban Sai Po Nua

(b) Hardpan layer of laterite on the erosional surface of bed rock at Ban Sai Po Tai

Alluvium deposits (Qa): The alluvium deposit is found along the usually narrow floodplain of Klong Krabi Yai floodplain, Klong Krabi Noi floodplain, and Klong Nam Mao. Floodplain. The thickness of the alluvium is between 1 to 3 meters which consists of brown to white clay, silty clay and silty sand (Figure 2.10).

Beach deposits (Qb1, Qb2): The beach deposit can be devided into two units: (1) Recent beach (Qb2); and (2) Old beach (Qb1). The beach deposit consists of medium to coarse to grained sand and some gravel, which is light brown to light grey in color. The thickness is more than 0.5 meters. The recent beach extends from the low water line to high water line. The old beach has been deposited by wave and has been located inland to where a change occures in landforms, sediment type, or vegetation along the coastal area (Figure 2.11a,b).

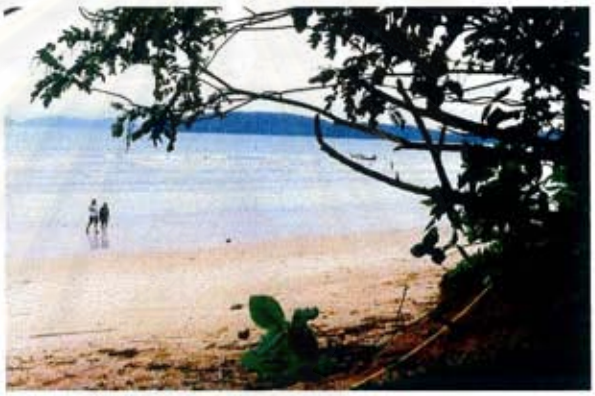
Tidal flat deposits (Tf): The mangrove swamp and river mouth are effected by the recent tidal current which consist of sediment mainly clay and sandy clay (Figure 2.12).

Granite

The granite belt of the western belt have been intensively studied by many gescienctists such as Arayakanon (1961), Garson et al., (1975), Pitragool and Panupaisal (1989), Puttaphiban (1984), Nakapadungrat et al.,(1985

The granite in Changwat Krabi consists of medium to coarse grained equigranular to porphyritic biotite-hornblende granites. The rocks somtimes contain pink feldspar phenocrysrs, complexly zoned plagioclase and sphene, allanite and magnetite as accessary phases consists mainly of very coarse grained porpholitic biotite±hornblende granites with big feldspar phenocrysts (up to 8 cm long). It's exposed at Khao Phanom Bencha and Khao Thong. These late Mesozoic granite intrude into the Carboniferous-Permian clastic strata of diamictie, mudstone and sandstone

Figure 2.10 Sand, silt and clay of alluvium deposit at Ban Krabi Noi



(a)

(b)

Figure 2.11 Beach deposit

(a) Recent sand beach

(b)Shell fragment deposit representing old beach

Figure 2.12 Mangrove swamp with clay and sandy clay accumulated at Ban Khlong Chi Lat

Geologic structure

The regional geological structure of Changwat Krabi, peninsular Thailand mainly orientates in the north-south direction for rocks ranging in age from Lower Paleozoic to Recent. The granites along the eastern part of the peninsular Thailand are mainly Triassic to Jurassic whereas those in the western part are Cretaceous to Tertiary (Charusiri, 1989) The major geological structure in the study area include fracture, and faults which mainly orientates in the north-south direction.

2.3.2 GEOMORPHOLOGY

The landform features of Changwat Krabi are in general the results of sub-aerial and fluvial weathering, and marine processes. The distribution of landforms in the study area can be divided into 4 units: (1) units of denudation origin; (2) units of alluvium-eluvium origin; (3) units of alluvial origin; and (4) units of coastal origin. The landform features are shown on the geomorphological map (Figure 2.13). The details of each landform types are described below:

(1) Units of denudation of origin

Mountain

These are a characterized by north - south trending ranges with elevations vary from 600 to 700 meters above the mean sea level. The mountains with elevations between 400 to 600 meters are located in the western part of the area. Scattered limestone monadnocks occur in the south. This unit is composed of sedimentary rocks of limestone, sandstone, chert, and granitic rock (Figure 2.14).

Hill

This unit is low lying elongate hills of north-south trending in the northern and western parts of the study area with an elevation of 60 - 200 meters above the mean sea level, such as Khao Laem Nang khao Nui, Khao Ao Nam Mao, Khao Chong Phi, etc. This unit is composed of sedimentary rocks of limestone, sandstone, chert and shale(Figure 2.15).

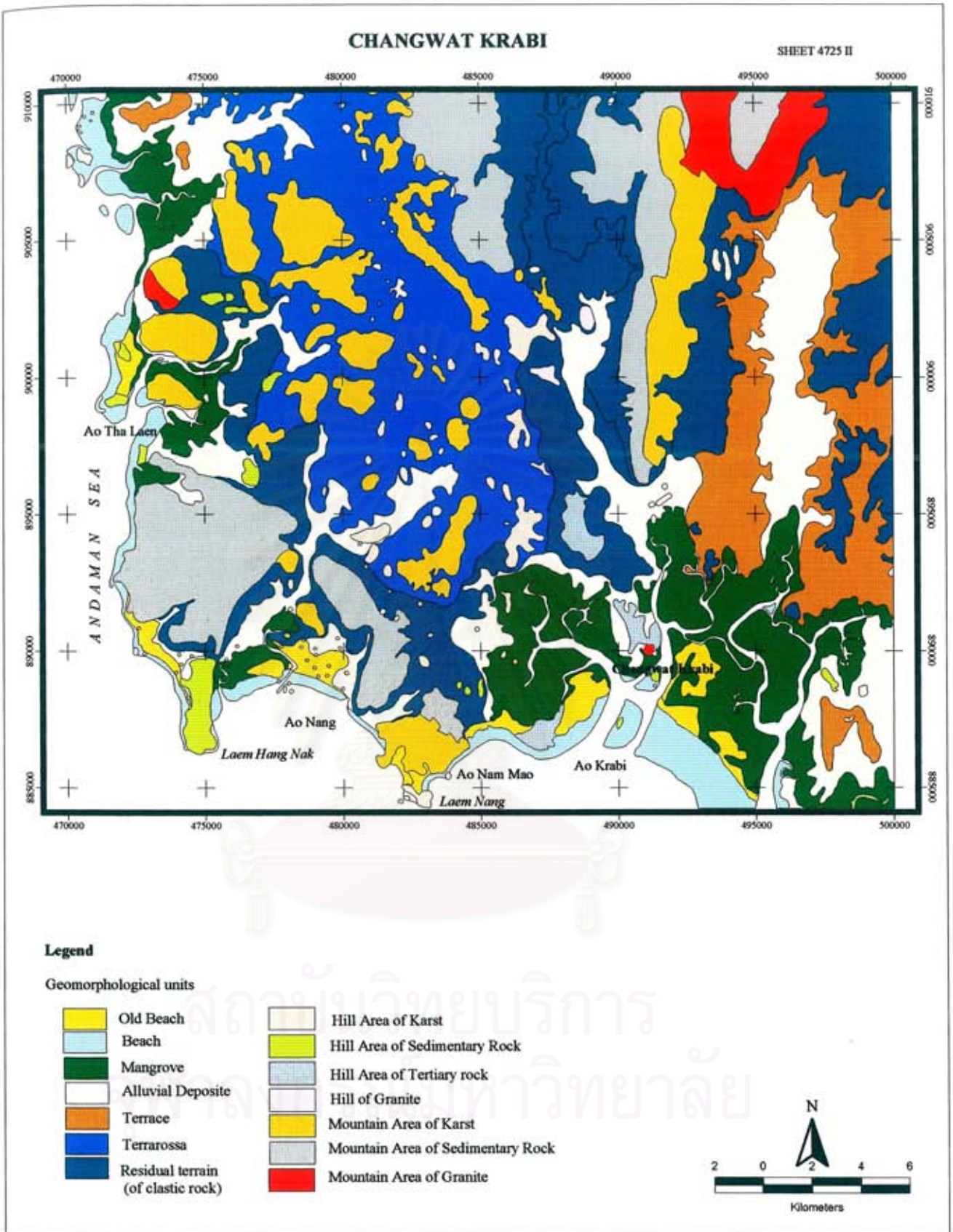


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Figure 2.13 Geomorphlogical map

Figure 2.14 Mountainous landform of limestone

Figure 2.15 Hilly landform of sandstone and alluvial plain

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(2) Units of residual-colluvium-eluvium origin

Residual hills

Upstanding on isolation in the flat lying lowlands of the study area are the predominance of residual hills (Figure 2.16). Many of the residual hills occur with rounded peak, which occasionally exceed the 20 to 60 meters above the mean sea level. The peaks are predominantly aligned towards the east of the area such as Ban Sai Po Nua, Ban Wat Klang.

Residual-colluvium-eluvium deposits

Residual and colluvium-elluvium deposits are erosional product and have been deposited in flat - lying lowland and foothills with an average elevation of 20 to 40 meters above the mean sea level. This unit can be divided into two sub-units as follows:

Residual and colluvium-eluvium deposits of limestone (Terra rossa) in the study area is cover a limited areas particularly in the vicinity of limestone (Figure 2.17). They are formed as the narrow strips on the foothills and erosional surface of hill slopes where the rocks are limestone. This unit is the weathered products of carbonate rocks characterized by red residual clayey soils and silty soils

Residual and colluvium-eluvium deposits of clastic rocks is mainly deposited in the vicinity of clastic rocks with an elevation ranging from 20 to 40 meter above the mean sea level (Figure 2.18). This terrain comprises erosional surface of hill slopes where the country rocks are sandstone, siltstone, claystone and conglomerate. It has an undulating topography with gentle slope. The unit is composed of weathered products of sedimentary rocks of sandstone, siltstone, clay stone and conglomerate.

Figure 2.16 Residual hill with round peak, exceed the 20-60 kilometers above the mean sea level

Figure 2.17 Hilly landform and residual deposit of limestone

Figure 2.18 Residual and colluvium-elluvium deposit of sandstone, siltstone

(3) Units of Alluvium origin

Terrace

The river terraces cover mainly the western and northeastern area with an elevation ranging from 10 to 70 meters above the mean sea level. It is the flat low-lying area which has some undulating topography. These terraces comprised fine to coarse grained clayey sand and gravel. Locally, there is a honeycomb of laterite and lateritic soil (Figure 2.19).

Alluvium

The alluvium is generally limited to narrow strip bordering northwest trending streams in the eastern part of area, namely, Khlong Krabi Yai, Khlong Krabi Noi, Khlong Ao Nam Mao. The elevation of this unit ranges from 4 - 15 meters above the mean sea level.

(3) Units of coastal origin

The units of coastal origin are frequently presented in map form to illustrate the variability of processes or morphology (Dolan, 1975). The spatial variability of coastal characteristics results from interactions between the geophysical factors (winds, waves, tides and currents), and the geological factors (lithology, structure, topography). These characteristics may be recorded in term of a generalized classification of shoreline types representation of the actual processes and morphological features. The coastal characteristics of the study area can be classified as follow:

Figure 2.19 Terrace landform at Ban Sai Po Tai

Tidal flat, beach sand and mangrove swamp

This characteristics can be found in the western part at Ban Tao Tan area. The coastal morphology of this area is characterized by tidal flat and mangrove swamp. The topography is dominated by low relief associated with sand beach and mangrove swamp. This coastline has been developed for shrimp farming (Figure 2.20 a,b).

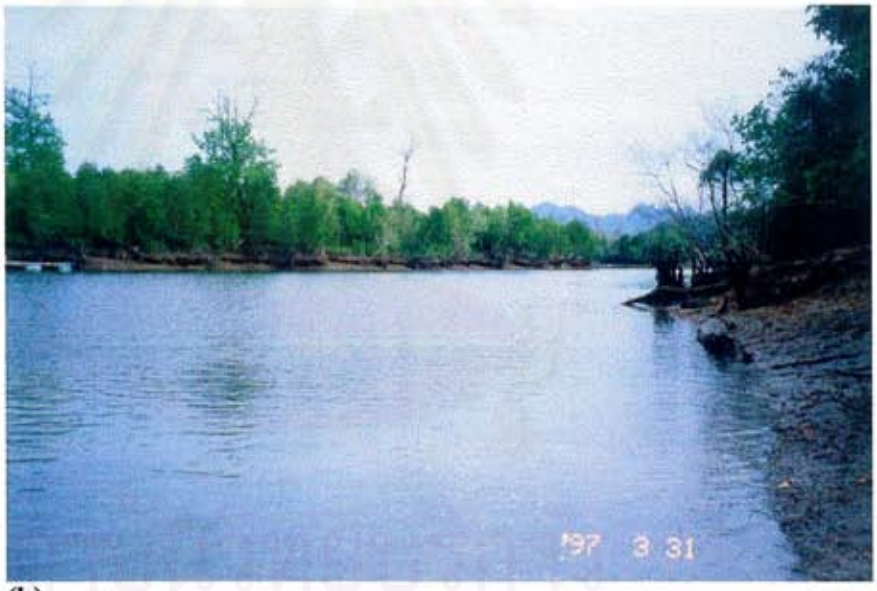
The topography around the coast of Ao Krabi, Ao Nang and Ao Nam Mao and Ao Tha Laen is characterized by low relief. The coastal morphology is dominated by tidal flat and old beach. These coastlines are made of sand beach, mangrove and estuaries. Some parts of the mangrove belt have been developed for shrimp farming, reclaimed, land and settlement areas. Ao Nang and Ao Krabi have been developed for tourism and recreation area (Figure 2.21 a,b).

Rocky coast

Coastal morphology of this study area is presented between Laem Chamuk Kwai to Laem Pho. The geology at Laem Chamuk Kwai and Laem Pho are underlain by clastic sedimentary rocks (Figure 2.22). The morphology consisting of sand beach and low to medium resistance headland.

The area between Ao Tha Laen to Laem Hang Nak is underlain by sedimentary rocks, such as, sandstone, conglomerate, siltstone, shale and mudstone. The coastline is characterized by narrow sand beach, rock headland and outcrops of sedimentary rocks (Figure 2.23). The coastline of Laem Nang is consisting of sand beach and limestone cliff headland (Figure 2.24).

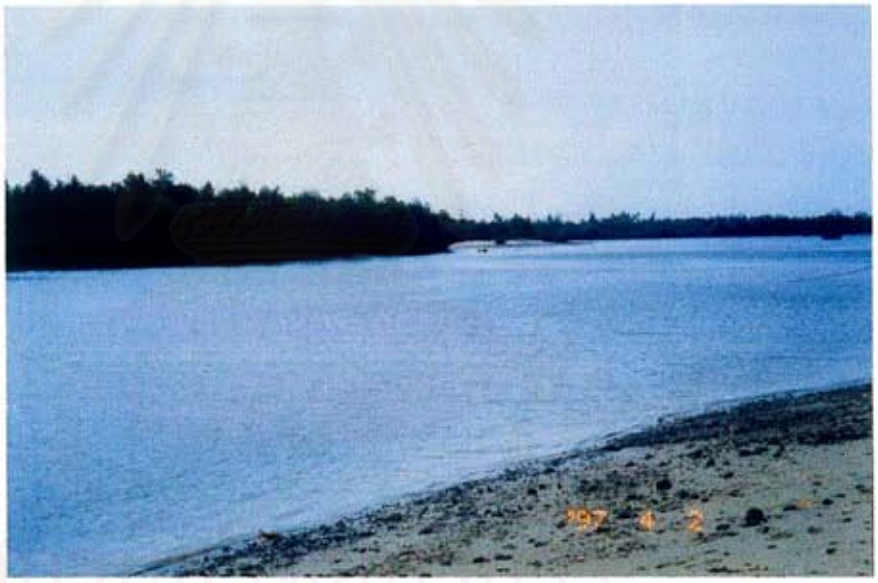
(a)



(b)

Figure 2.20 (a),(b) Mangrove swamp and mangrove wetlands along tidal creek

(a)



(b)

Figure 2.21 (a) Sand beach along Ao Nang coast
(b) Estuary and mangrove covering belt

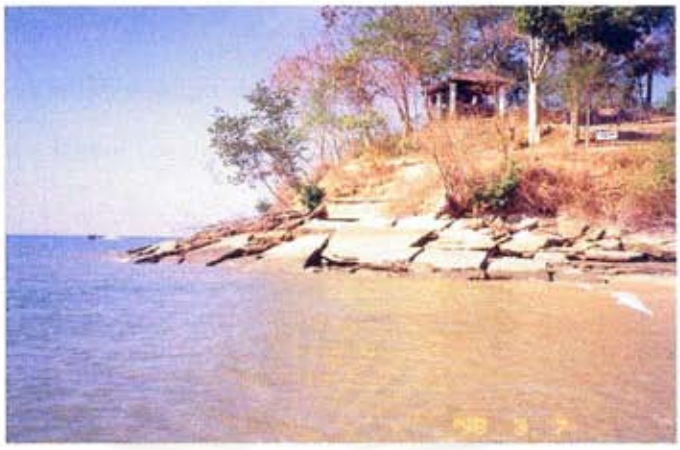


Figure 2.22 Rock headland characteristics at Laem Pho

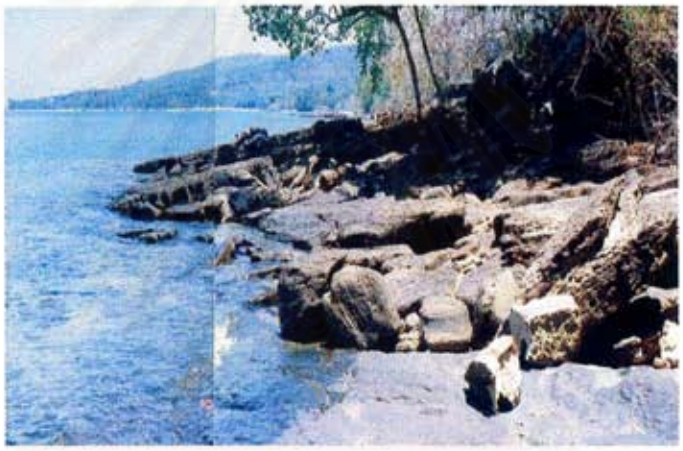


Figure 2.23 Rocky coast along Laem Chamuk Kwai to Laem Hang Nak

Figure 2.24 Limestone cliff headland at Laem Nang

2.3.3 GEOLOGICAL RESOURCES

(1) Mineral resources

Mineral resources in the study area are rarely as shown in Figure 2.25. Stibnite and galena at Ban Khao Thong, as well as cassiterite and fluorite were mined prior to 1990. Moreover, some limestone, sandstone, chert and laterite have been mined for building and civil engineering construction. Nevertheless, some rocks, such as limestone that is prominent in the landscape of Krabi province, can be reserved for environment conservation.

(2) Water resources

Surface water resources

The main surface water in Changwat Krabi are Khlong Krabi Yai and Klong Krabi Noi. These two streams originate from mountains areas and run to the Andaman Sea. Another source of water is collected in the collapsed sinkholes of fractures limestone terrain, such as, Nong Tha Lae and Sa Kaew (Figure 2.26).

Groundwater resources

The groundwater aquifer within the study area is generally based on the 1:100,000 groundwater map provided by Groundwater Division, Department of Mineral Resources (I.R.D.C and DMR., 1995) as shown in Figures 2.27 and 2.28. It can be classified into three groups following as:

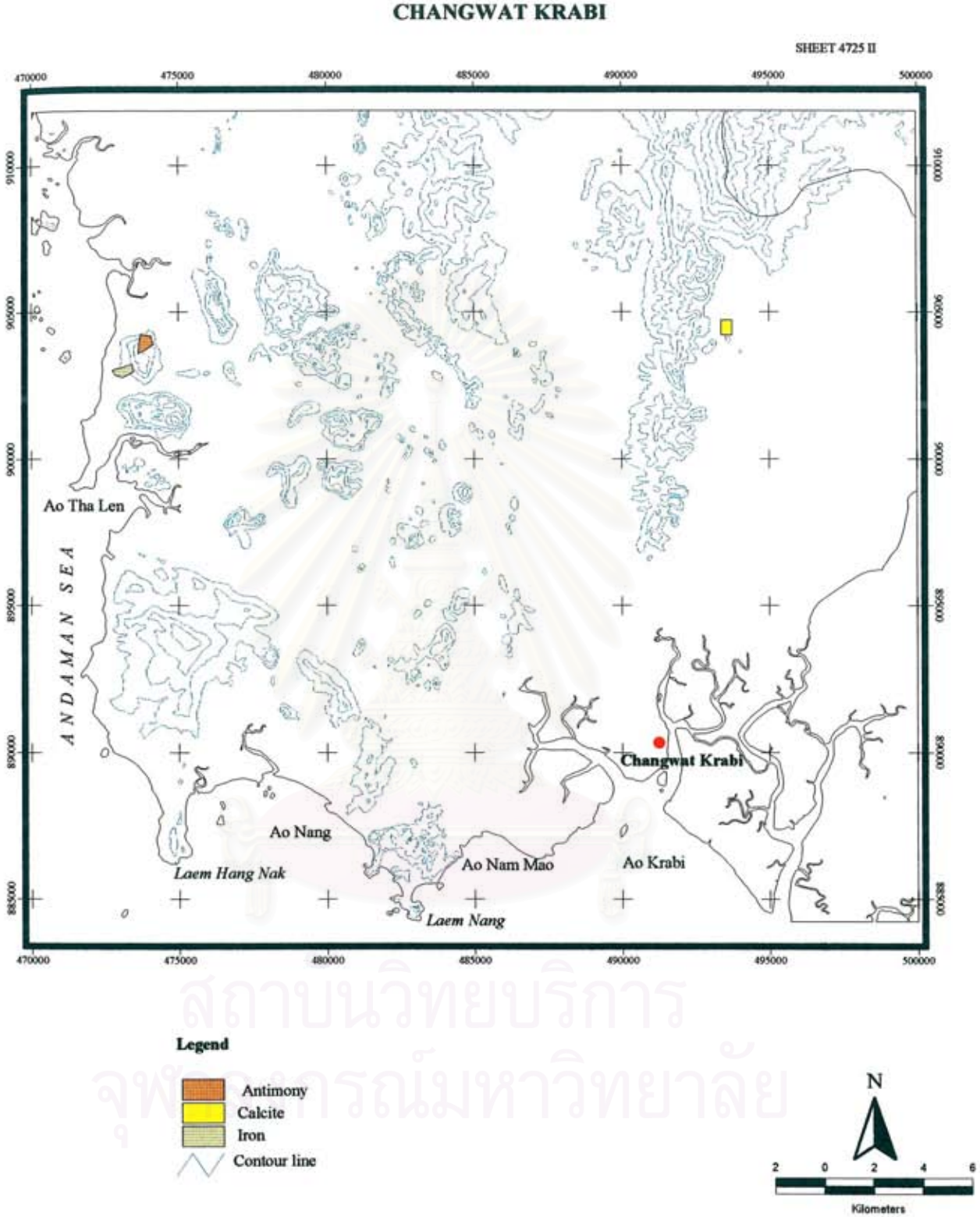


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Figure 2.25 Mineral resources map

Source: Dept. of Mineral Resources, 1992

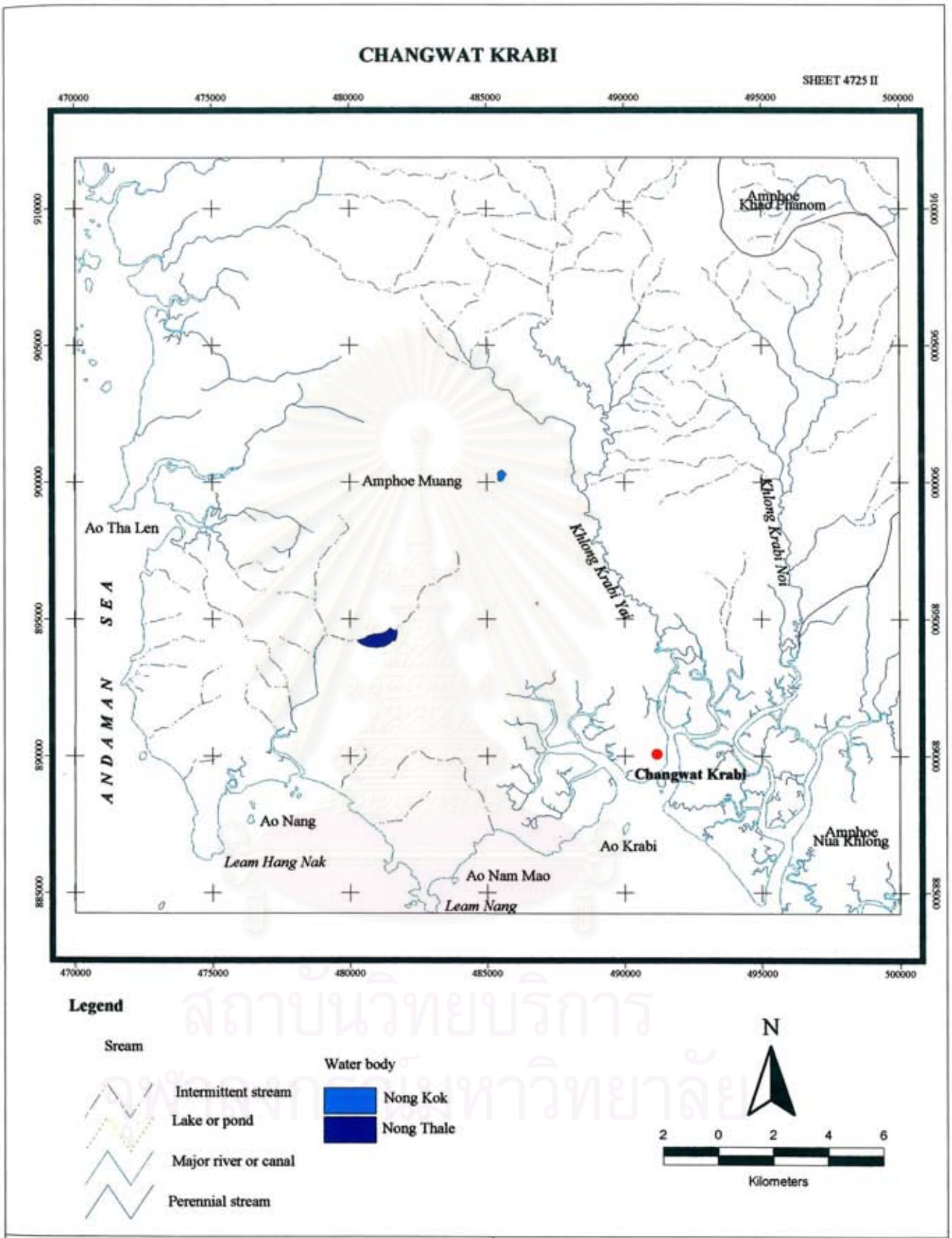

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Figure 2.26 Surface water resources map

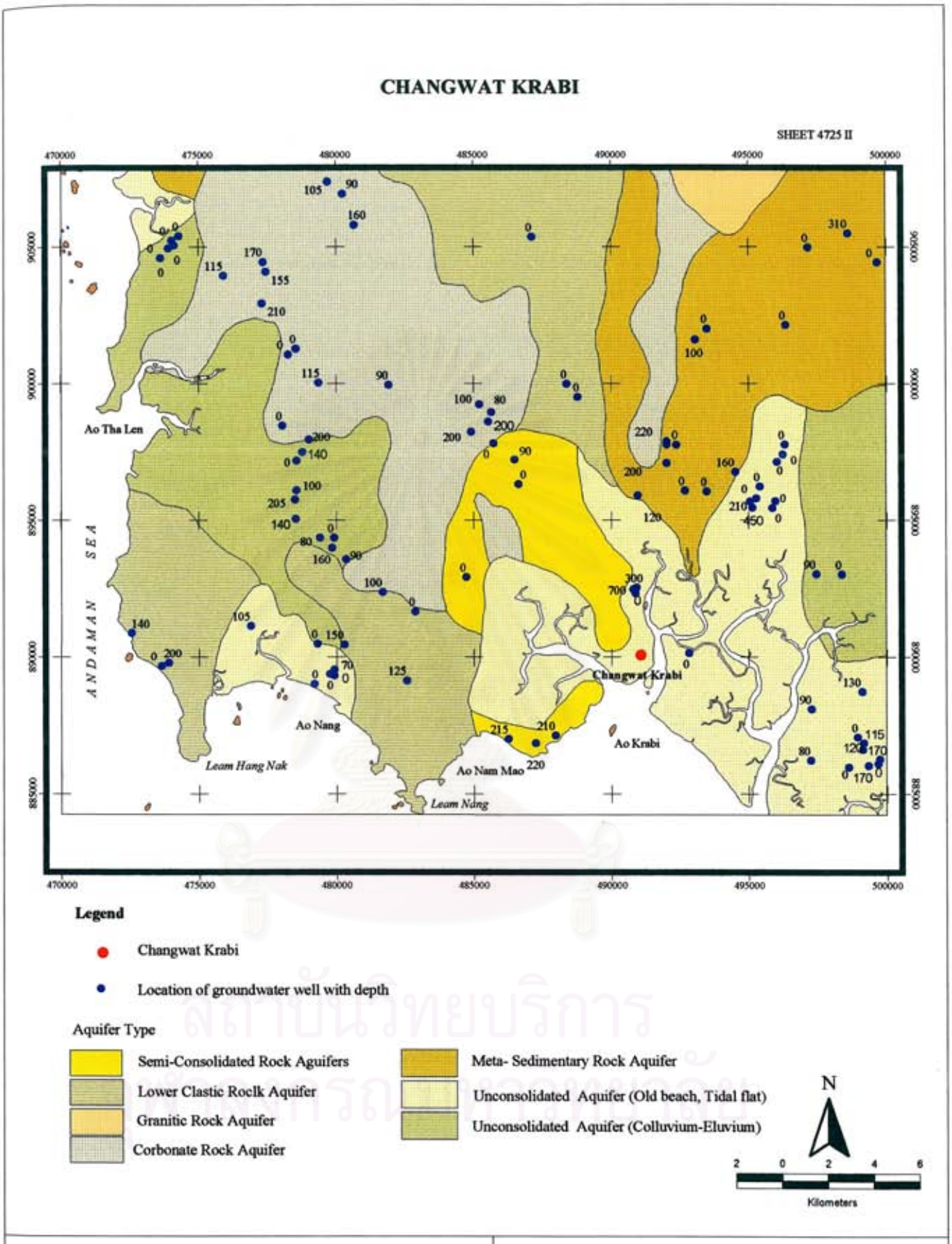

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Figure 2.27 Groundwater aquifer map

Source : I.R.D.C. and Dept. of Mineral Resources., 1995

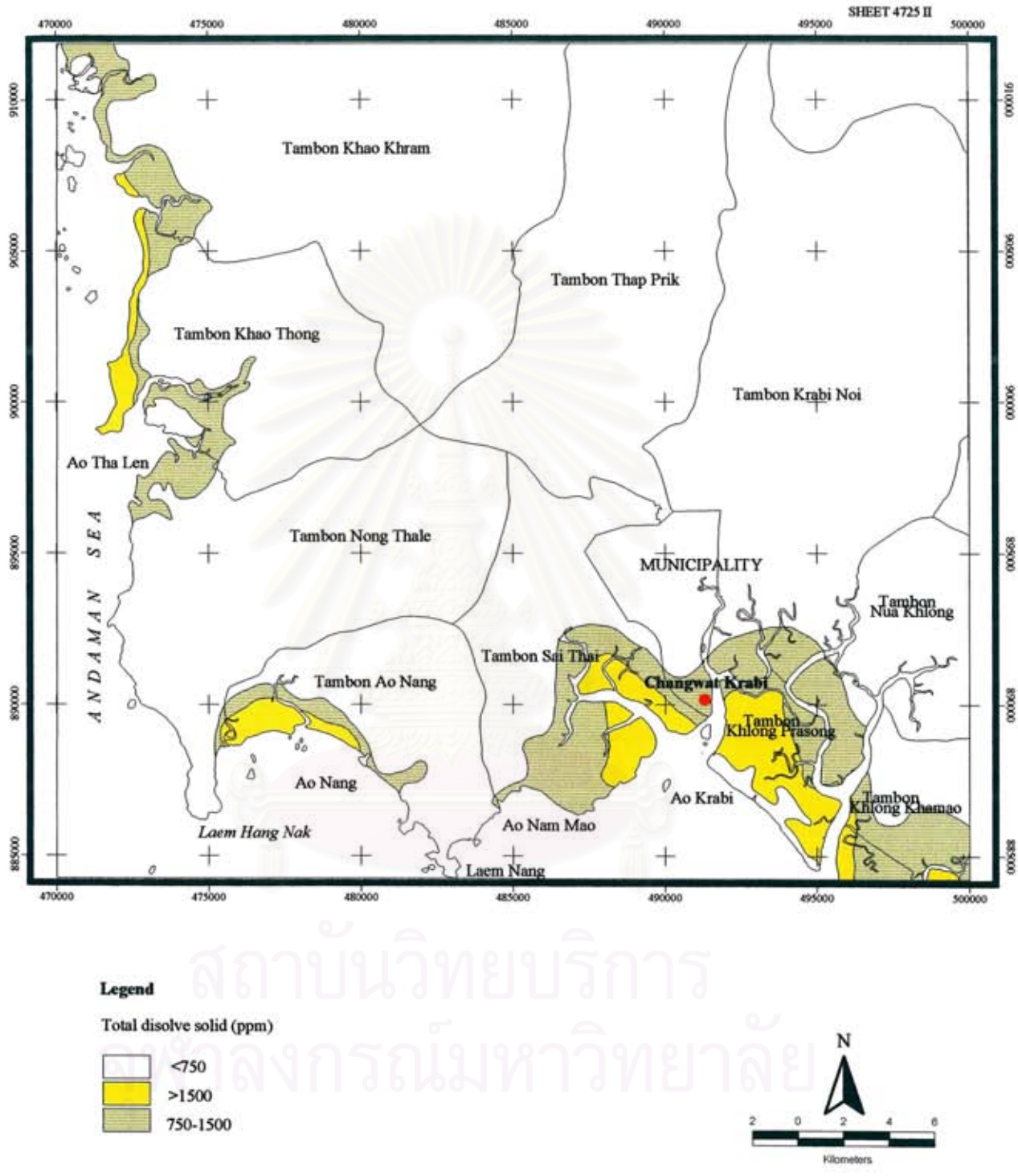

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Figure 2.28 Groundwater quality map

Source : I.R.D.C. and Dept. of Mineral Resources., 1995

Unconsolidated aquifer This is an aquifer where water has been trapped within pore spaces of unconsolidated sediments. The unconsolidated formation have been mapped as marine clay of mangrove areas and the old beaches. As being the area within tidal zone, the mangroves areas yield brackish water. Sand ridges with the depth of 2 to 4 meters have been located at Ban Khlong Prasong and Ban Ko Khlang where good quality water of approximately 5 to 10 m^3 /hr can be obtained from this aquifer.

Semi-consolidated rock aquifer The semi-consolidated aquifer of tertiary comprises shale, calcareous shale, sandstone, and siltstone with occasional intercalation of limestone, lignite, oil shale, and gypsum is located at Tambon Sai Thai and Tambon Khlong Prasong. The groundwater has been collected within fractures and bedding planes. With their specific yield of 10 to 15 m^3 /hr, it is good quality aquifer has been found at 60 to 65 meters depth. However, the higher specific yield of brackish water has been also found at Ban Laem Pho and Ban Ao Nam Mao.

Consolidated rock aquifer There are three groups of these consolidated rock aquifers. They are classified to be sedimentary rocks aquifer (clastic rock aquifer and carbonate rock aquifer), meta-sedimentary rock aquifer, and igneous rock aquifer.

The clastic rock unit covers the mountainous area of Tambon Tabprik and Tambon Nong Tha Lae. This unit is composed of sandstone, siltstone, shale, sandstone, conglomerate, and some intercalation of dolomitic limestone. The groundwater occurs within geological structures and weathered zones. Good quality aquifers of 1 to 5 m^3 /hr are found at the depth of 25 to 30 meters. An exceptionally specific yield of 20 m^3/hr has been located at Ban Huai To.

The carbonate rock aquifers comprising of limestone and dolomitic limestone have been found at Tambon Krabi Noi, Tambon Sai Thai, Tambon Nong Tha Lae, Tambon Ao Nang, Tambon Khao Khram, Tambon Khlong Prasong, and Tambon Tabprik. The groundwater has been occurred in geological structures especially caverns and cavities. Good quality of water of 5 - 10 m^3 /hr can be found at the depth

of 20 - 45 meters.Moreover, higher specific yield of this aquifer can be located at Ban Ao Nam Mao, Ban Nong Tha Lae, Ban khao Leam, Ban Nong Khon, Ban Thung, Ban Khlong Jik, and Ban Khao Maikaew.

The meta-sedimentary rocks, which are composed of mudstone, pebbly mudstone, siltstone, sandstone, orthoquartzite, and conglomerate, have been locally found. There are low productivity aquifers 1 - 5 m^3 /hr of good quality water from the depth between 20 - 25 meters. Groundwater has been found within certain geological setting, such as, fractures and weathered zones of hill and mountain ranges.

The granitic rock aquifer occur at Tambon Krabi Noi, at the depth of 20 - 50 meters. A good quality of water of 1 - 5 m^3 /hr has been recorded. It has been considered to be a low groundwater productivity because of its low porosity and low permeability characteristics. However, groundwater can be found in secondary porosity such as fracture zones (joints and faults) and some shallow weathered zones.

(3) Construction material

It is well known that Changwat Krabi has been prominent economic growth since the mid-1980s. Several infrastructure projects have been proposed and constructed in the area to support tourism and industrial development. It is suggested that the economic growth of the study area, general needs the supply of adequate quantity of construction materials. The preparation of infrastructures and construction of buildings, to support the people's living standard, all of which may demand for construction materials. The construction material in this area can be classified into rock materials and unconsolidated materials based on physical properties and engineering properties (Table 2.5).

Table 2.5 The two main groups of construction material based on physical and engineering properties (โชคเฉลิม, 2534)

Construction material group		
Rock materials		Unconsolidated materials
Carbonate rocks	Massive dolomitic limestone	Terra rossa
	High fracture dolomitic limestone	Residual deposit of clastic rocks
Clastic rocks	Sandstone, chert	Residual deposits of Tertiary rocks
	Sandstone, conglomerate	
Igneous rock	Granite	

Rock material

The rock material in the area can be classified into four groups as dolomitic-limestone, sandstone and conglomerate, sandstone and chert, and granitic rock, as shown in Figure 2.29. The physical properties and engineering properties are illustrated in Table 2.6.

Table 2.6 Engineering properties of rock material (โชคเฉลิม, 2534)

Engineering properties	Dolomitic limestone	Sandstone and Conglomerate	Granite
Unit weight (gm/cm)	2.57	2.40-2.62	2.73
Specific gravity	2.70	2.50-2.68	2.81
Porosity	2.67	36.73-55.48	16.30
Compressive strength	-	48.60-76.30	42.20-44.40
Point load test(Mpa)	14.60	9.50	8.60
Young modulus(kg/cm^2)	-	$1.24\text{-}1.68 \times 10^5$	$4.91\text{-}4.95 \times 10^5$
Percent of wear (%)	35.40	38.30	25.10

Note: The physical properties of sandstone and chert are highly weathered. The engineering term call this unit as soil, suitable for fill or sub grade material.

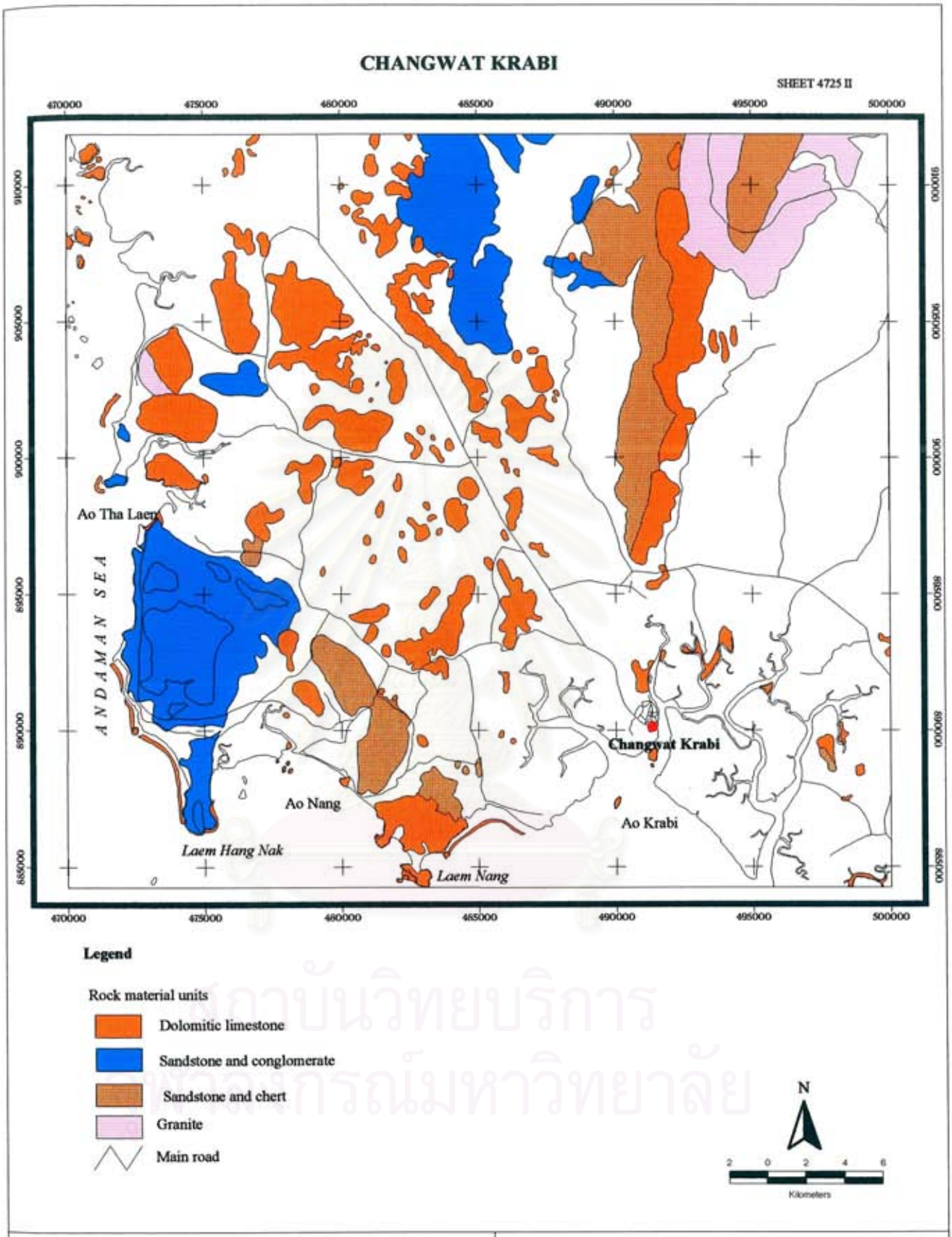

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Figure 2.29 Rock material map

Dolomitic limestone: Limestone in the study area is Permian limestone distributed in large area of Krabi. The rock is generally dark gray and massive, containing a small amount of shale interlaminea (Figure 2.30). Most of Permian limestone are dolomitic limestone. The samples from quarry and outcrop have $CaCO_3$ about 30 - 38 percent and MgO content in range of 10-21 percent (Table 2.7). The physical properties are characterized by slightly to moderately weathered, hard and dense. They have moderate to high strength and are suitable to be used, as rip-rap and rock fills.

Table 2.7 Chemical properties of carbonate rocks (after Raksaskulwong, 1990)

Sample No.	Grid ref.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5
K1	813119	0.03	0.06	0.34	33.04	19.97	0.02
K2	811110	<0.02	<0.02	5.3	33.37	18.92	0.01
K3	825118	0.15	0.18	2.38	32.75	18.86	0.01
K4	810097	0.11	0.08	0.32	36.00	16.19	0.05
K5	762085	0.16	0.19	0.77	31.49	19.55	0.03
K6	774078	0.10	0.15	0.19	39.29	13.40	0.07
K7	774066	<0.02	<0.02	0.82	31.72	19.85	0.01
K8	768039	6.6	0.51	1.83	38.12	10.15	0.04
K9	774036	1.04	0.81	0.45	32.47	18.91	0.02
K10	787010	0.21	0.22	0.85	31.75	19.52	0.03
K11	797997	<0.02	0.05	0.50	32.11	19.86	0.02
K12	793992	<0.02	<0.02	0.22	32.49	19.45	0.02
K13	970985	<0.02	0.06	0.62	30.87	20.39	0.02
K14	780979	<0.02	<0.02	0.79	30.73	20.30	0.03
K15	806003	0.27	0.22	1.47	35.17	16.04	0.03
K16	811999	<0.02	0.03	0.75	32.83	18.99	0.02
K17	869937	<0.02	<0.02	0.37	32.04	19.81	0.04
K18	864993	<0.02	0.04	0.77	31.66	19.75	0.03
K19	862932	0.17	0.19	0.68	31.17	20.30	0.02
K20	840928	0.06	0.10	0.54	30.98	20.72	0.03
K21	837926	<0.02	0.03	0.95	30.49	20.80	0.04
K22	815928	0.15	0.07	0.77	31.95	19.72	0.04
K23	810933	0.04	0.12	1.19	31.56	19.70	0.03
K24	783936	<0.02	0.07	0.13	34.94	16.48	0.03
K25	827000	0.06	0.17	0.32	35.29	16.84	0.02
K26	813049	3.04	0.10	0.09	32.75	9.17	0.02
K27	817063	<0.02	<0.02	0.80	30.40	10.24	0.02
K28	823044	0.21	0.23	0.27	30.63	20.58	0.02
K29	851017	<0.02	0.04	0.11	32.04	19.93	0.02
K30	849989	0.19	0.24	0.18	30.79	14.9	0.02
K31	922983	<0.02	<0.02	1.43	30.17	20.19	0.02
K32	918957	<0.02	0.03	0.54	30.29	21.30	0.03
K33	862975	<0.02	<0.02	0.96	31.19	20.34	0.03
K34	858960	0.51	0.16	0.61	30.98	20.06	0.03
K35	859947	<0.02	0.02	0.43	30.77	20.32	0.04
K36	847948	1.93	1.78	0.23	30.15	18.55	0.04

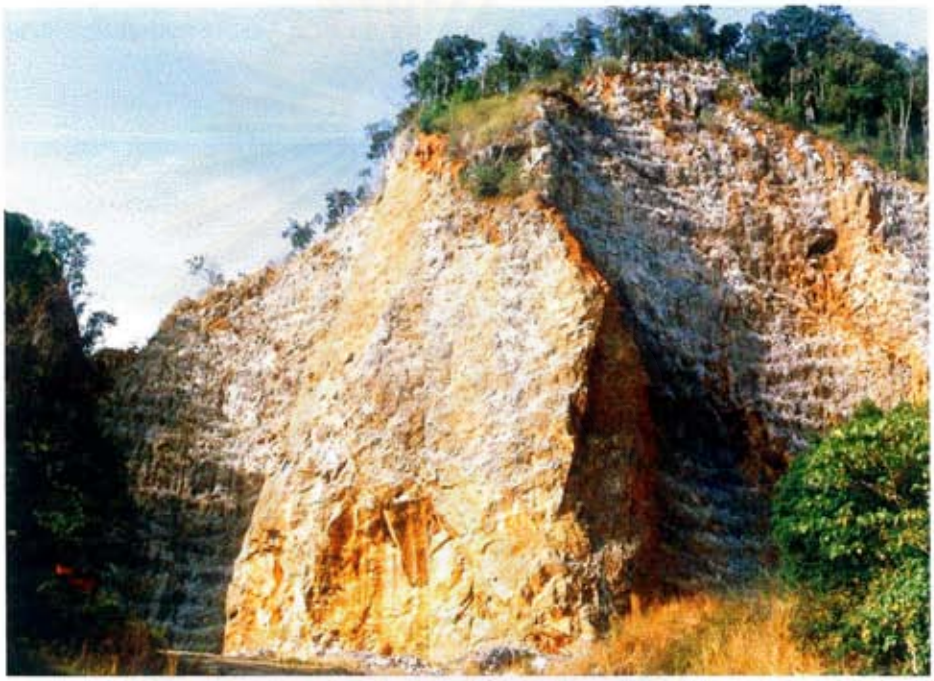

Figure 2.30 Quarry of dolomitic limestone near Wat Tham Sua

Sandstone and conglomerate: This unit is composed of sandstone, siltstone and conglomerate. The rocks is normally highly fractured, brittle and highly weathered. The utilization of this unit for rip-rap and fill materials.

Sandstone and chert: This unit comprises of thick-bedded sandstone, shale and chert interbedded which is highly fractured (Figure 2.31). The physical properties are brittle and moderate to highly weathered. According to these properties this unit of sandstone and chert is classified as material, which is suitable for embankment, and fill materials. It is composed of rock fragments, sand and clay.

Granitic rock: The granitic mountain range can be found at Khao Phanom Benja National Park. Hilly area of granite is located in the north, about 10 kilometer from Krabi township. The engineering and physical properties are indicated by high strength, hard and dense. This unit is suitable for dimension stone, rip-rap and construction materials.

Unconsolidated materials

The unconsolidated materials deposit is weather product and has been redeposit on the hill slope and low-lying areas of erosional surface of bed rocks (Figure 2.32). The sediments compose of pebbly, gravel, sand, silt, clay and laterite. This unit can be divided into four types as follows:

Figure 2.31 Quarry of sandstone and chert at Ban Ao Nam Mao

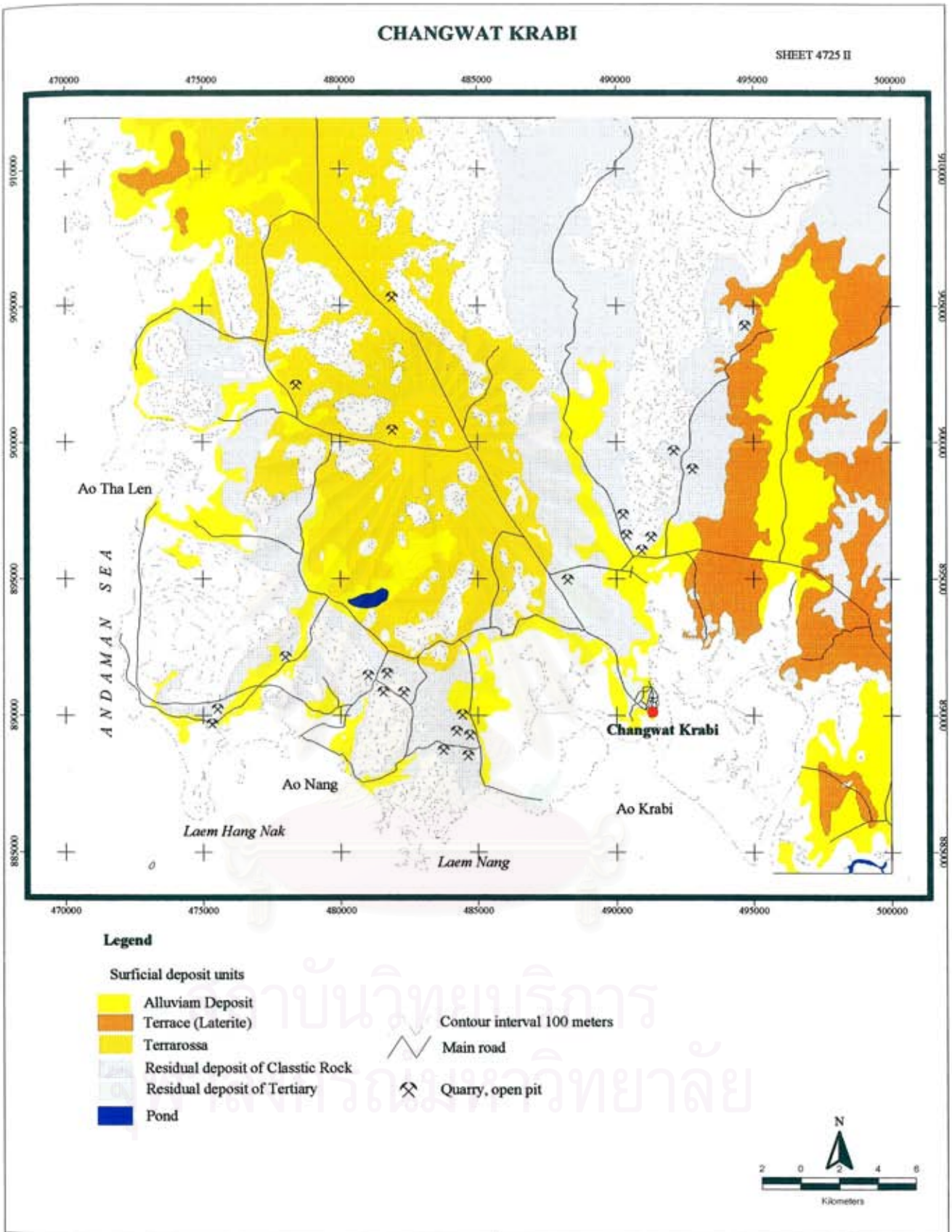

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Figure 2.32 Unconsolidated material map

Terra rossa: This unit composes of weathered sedimentary rock of limestone. The terra rossa deposits cover limited areas particularly in the vicinity of limestone (Figure 2.33). The engineering properties are suitable for fill and sub-grade materials (Table 2.8).

Table 2.8 Engineering properties of terra rossa (โชคเฉลิม, 2534).

Engineering properties	Terra rossa
Soil group	CL - CH
Specific gravity	2.72
Water content (%)	11.5 0- 22.30
Liquid limit (%)	19.80 - 37.00
Plastic limit (%)	12.00 - 21.20
Field density	-
Compaction	-
Depth to bed rock (m)	14.00 - 21.00
Suitable use	Fill and sub grade material

Residual deposit of clastic rocks: This unit is composed of weathered sedimentary rocks such as sandstone, siltstone, claystone and conglomerate. They are formed on hill slopes and erosional surface of the rocks (Figure 2.34). The sediments comprised of sand, silt, clay and gravel. The engineering characteristics are shown in Table 2.9.

Table 2.9 Engineering properties of residual deposit of clastic rocks (โชคเฉลิม, 2534).

Engineering properties	Residual deposit of clastic rocks
Soil group	CL - SM
Specific gravity	2.62
Water content (%)	7.00 - 16.90
Liquid limit (%)	31.00
Plastic limit (%)	17.30
Field density	17.50 - 19.20
Compaction	17.45 - 19.20
Depth to bed rock (m)	7.00 - 10.00
Suitable use	Fill and sub grade material

Figure 2.33 Open pit of terra rossa at Ban Thung

Figure 2.34 Open pit of residual deposit of clastic rocks

Residual deposit of semi-consolidated clastic rocks: This unit is composed of weathered rocks such as shale, calcareous shale, sandstone,and siltstone. The sediments comprise of silt, clay and gravel (Figure 2.35). This unit is exposed at Ban Kuan Sabai. The engineering properties is suitable for fair to good suitable for a construction material, fair for embankment and core material in rolled earth dam construction and fair for sub grade in road construction (Table 2.10).

Table 2.10 Engineering properties of residual deposits of Tertiary rocks

(โชคเฉลิม, 2534).

Engineering properties	Residual deposit of tertiary rocks
Soil group	SM - SC
Specific gravity	2.75
Water content (%)	-
Liquid limit (%)	0.14 - 0.025
Plastic limit (%)	15.80 - 55.00
Field density	15.00 - 15.90
Compaction	11.80 - 22.5
Depth to bed rock (m)	6.00 - 10.00
Suitable use	Fill, sub grade; and earth dam core and embankment

Laterite This laterite comprises of vermiform and gravelly laterite overlying the mottle clay at Ban Sai Po Tai (Figure 2.36). The physical and engineering properties are suitable for fill and sub-grade in road construction.

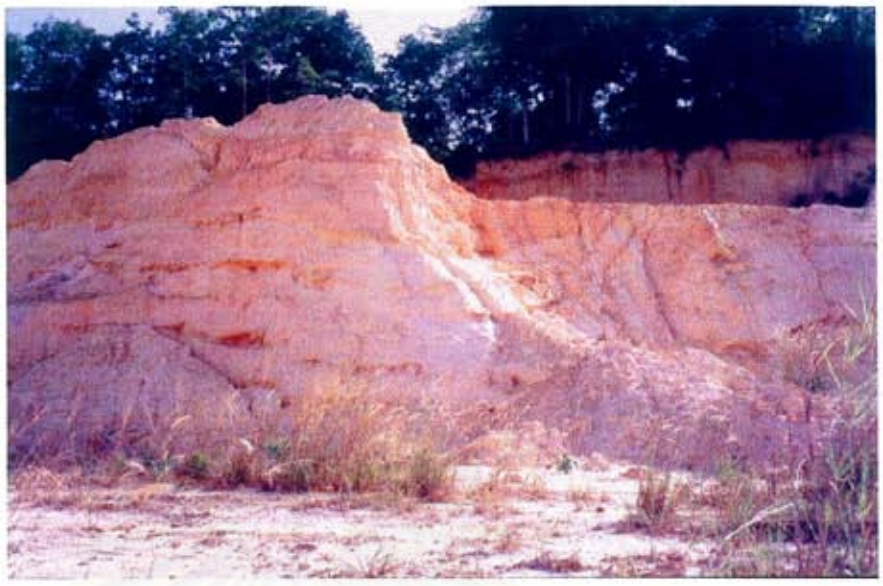

Figure 2.35 Quarry of residual deposits of Tertiary rocks

Figure 2.36 Quarry of lateritic soil at Ban Sai Po Tai

2.3.4 GEOLOGICAL HAZARDS

Coastal zone and shoreline erosion

The total economic value of coastal system is more than simply the financial value of coastal resources that they produce. It also includes their role in regulating the environment, their satisfaction of subsistence needs, and their satisfaction of human intellectual and emotional needs. Any coastal system can yield values related to the direct, indirect, and future use of the functions described above, as well as non-use, or intrinsic, values (Turner, 1988; Barbier, 1994). In most coastal provinces, a considerable part of gross provincial product (GPP) is derived from activities that are directly or indirectly connected with coastal zones. Therefore, maintaining the proper functioning of marine and coastal systems is of significant concern to a country's economy. In the shorter term, however, large financial benefits may be available at the expense of longer-term sustainability. Many coastal problems that are currently being encountered worldwide can be attributed to the unsustainable use and unrestricted development of coastal areas and resources. These problems include the accumulation of contaminants in coastal areas, erosion, and the rapid decline of habitats and natural resources. Great care must therefore be taken in planning to avoid over development and degrading or destroying the very environment that attracted coastal development in the first place.

One can state that sustainable development in coastal zones is realized only when it enables the coastal systems to self organize-that is, to perform all its potential functions with out adversely affecting other natural of human systems. Climate change could pose an additional threat to the full performance of these functions, compounding the pressures that present-day development activity already place on coastal zone capacities. Overexploitation of resources, pollution, sediment starvation, and urbanization may inhibit or destroy the working of functions that are essential to the provision of goods and services that are difficult to value in monetary terms, or in maintaining the resilience of coastal ecosystems to external stresses, such as climate changes. For instance, one important regulation function of natural systems in coastal zones is the provision of a buffering capacity, protecting the land against the dynamics

of the sea. As Climate changes and sea level rises, this function will become even more important than it is today, preventing coastal areas from being erodes and inundated as much as they would without this natural protection. Nevertheless, although present-day human activities often result in large financial payoffs in the short term, they may also lead to environmental degradation. Such degradation results in the loss of functions, may increase coastal vulnerability to climate change, and has adverse economic effects on tourism, fishing, and other aspects of the coastal economy.

Coastal erosion in the study area

Historical records of natural hazards with in Changwat Krabi coastal zone reveal no serious event. Coastal and shoreline erosion are mainly geo-hazard in this area. Areas with a high susceptibility of coastal and shoreline erosion are along west coastal area from the north to Ao Krabi (Figure 2.37). Some areas may be hazardous as a result of landslide, such as, mountainous area where forest were converted into oil-palm and rubber plantations and after heavy rainfall the deep weathered soil in steep slopes, are usually unstable.

Measuring coastal erosion in the study area can be determine shoreline locations from topographic maps, aerial photo, and beach profile and surveys as show in Figure 2.38a,b. For the case study, coastal change analyses involve plotting the shoreline at Ban Khlong Sai, Ban Ko Kwang, Ao Nang and Laem Pho, and comparing those positions overtime. The more shoreline positions eroded, the better for measuring beach changes and for distinguishing trends in shore movement. Statistical data or a combination of it is used to predict the extent of future land losses. It can be used to predict for the planning future use of the shoreline.

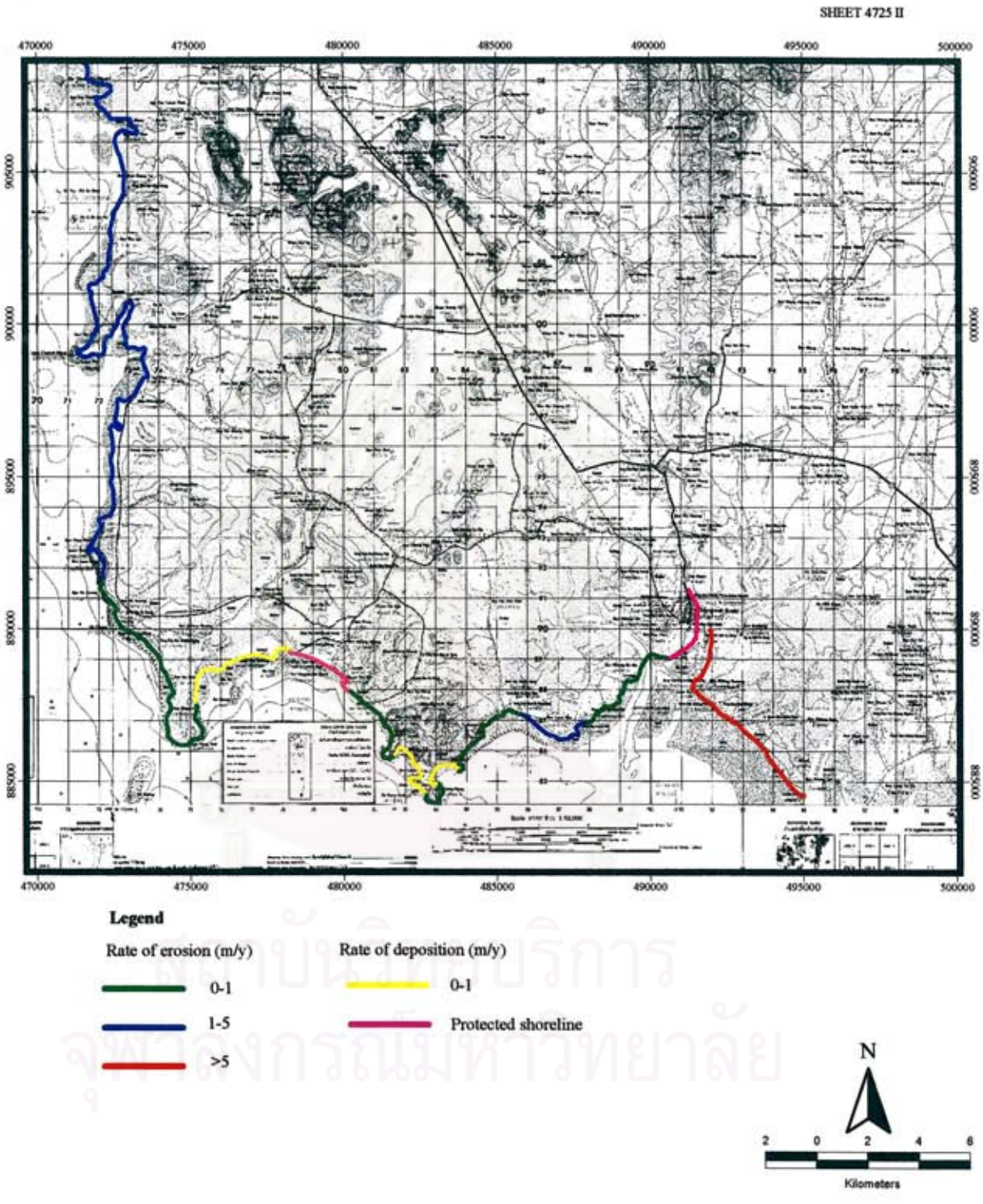

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Figure2.37 Shoreline erosion map

(a)

(b)

Figure 2.38 (a) Measuring of the shoreline change
(b) Measuring of the beach profile

Ban Khlong Sai coast, formed of pocket beach between rock headland. The coast displays rapid erosion variations along it length (Figure 2.39 a,b,c). The coastal profiles of Ban Khlong Sai are show in Figure 2.40. Along part of this coast fallen coconut palms, area of eroded mangrove trees and a wrecked landing stage indicate retreat of the coast. The coastal erosion by survey of Ban Khlong Sai coast is about 2 meters a year over the past three years (Figure 2.41a,b). Local fishermen confirmed that the erosion has proceeded at this pace for over 60 years, average 5 meters a year.

The beach at Ban Ko Kwang displays a single gentle gradient and contain is formed by slightly concave sand beach. The coastal profiles of Ban Ko Kwang are shown in Figure 2.42. The form of the beach and the well established trees that cover on the landward area, show that the coast in this area is slowly eroded (Figure 2.43).

Ao Nang beach, formed of an open, slightly concave bay is enclosed by the headland and gently shelving beach. The coast in this area was eroded by wave and human activities about 0.20 meters a years (Figure 2.44).The coastal profiles along Ao Nang Beach is show in Figure 2.45.

The Tertiary fossil beds at Ban Laem Pho which comprised limestone/mudstone and lignite bed, was eroded by wave cut at about 1.5 meters a year (AIT. 1995) (Figures 2.46a,b and 2.47).

(a)

(b)

(c)

Figure 2.39 (a) Ban Khlong Sai coast displaying rapid variation in erosion
(b),(c) Moderately erosion along Ban Khlong coast

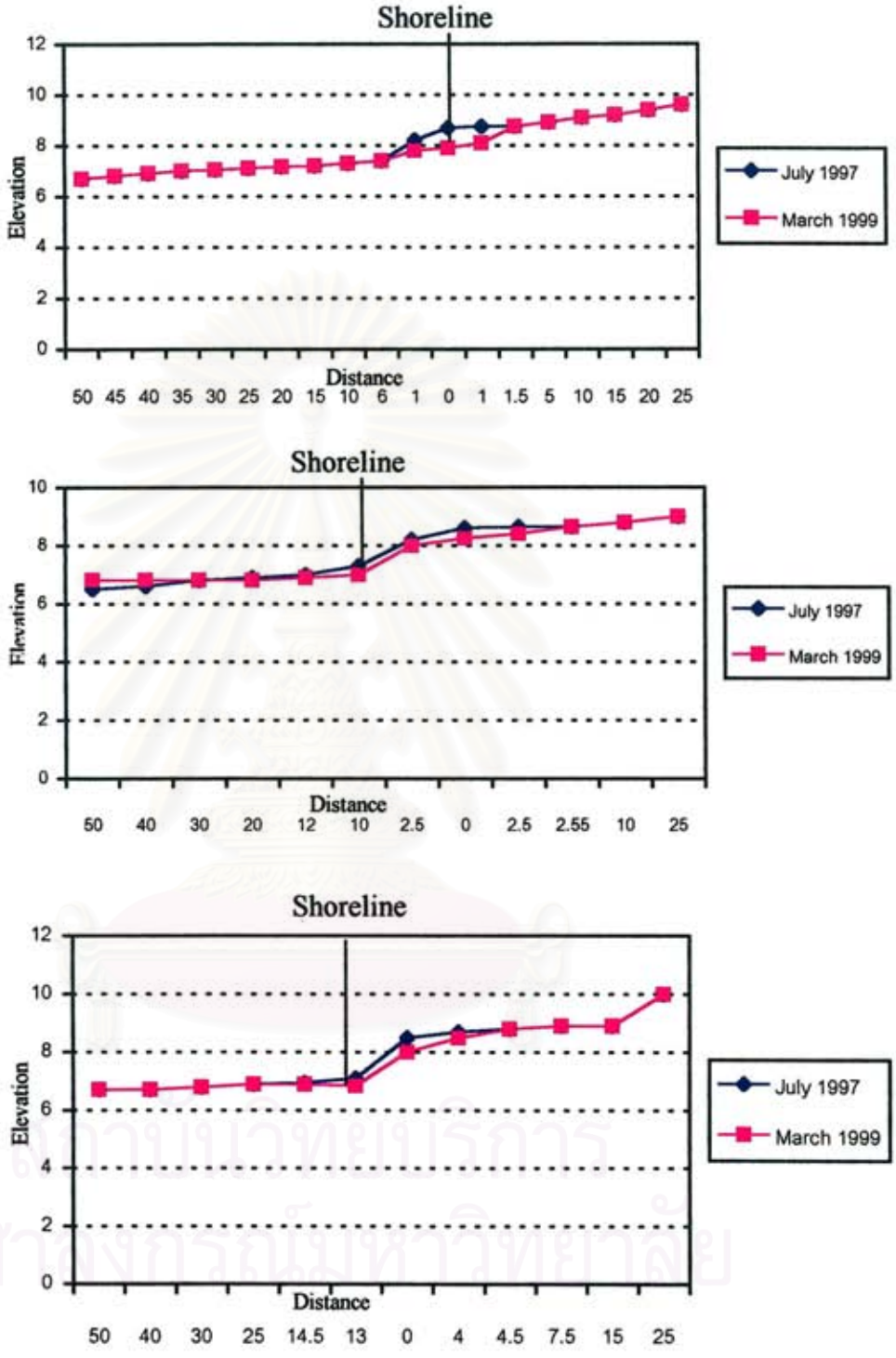

Figure 2.40 Beach profile change during southwest monsoon along Ban Khlong Sai coast

(a)

(b)

Figure 2.41 (a) Shoreline erosion of about 1.60 meters/year at Ban Khlong Sai Coast

(b) Map showing shoreline erosion along Laem Chamuk Kwai to Ban Khlong Sai

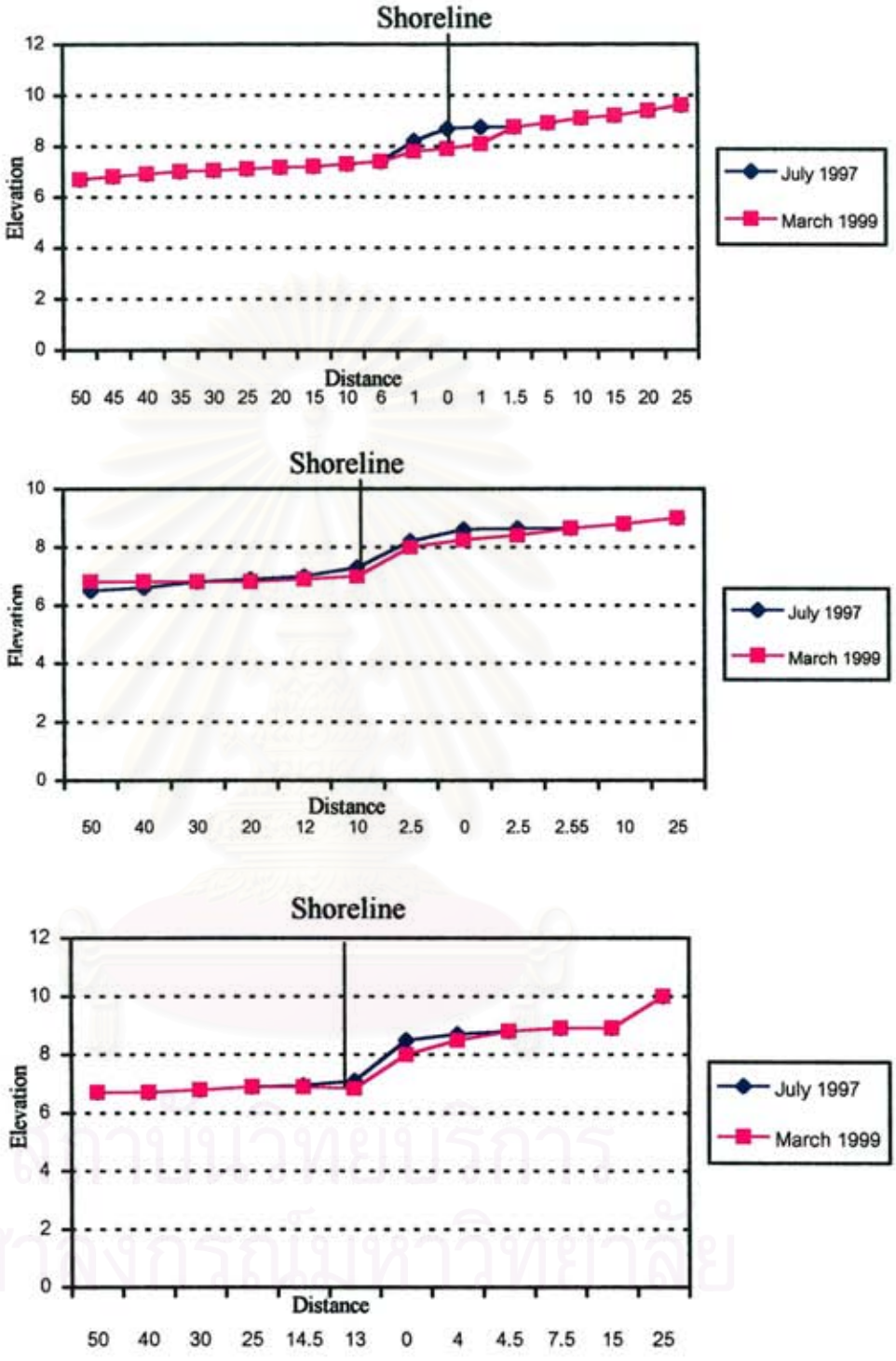

Figure 2.40 Beach profile change during southwest monsoon along Ban Khlong Sai coast

Figure 2.43 Shoreline erosion of about 0.80 meters along Ko Kwang beach

Figure 2.44 Shoreline erosion along Ao Nang coast

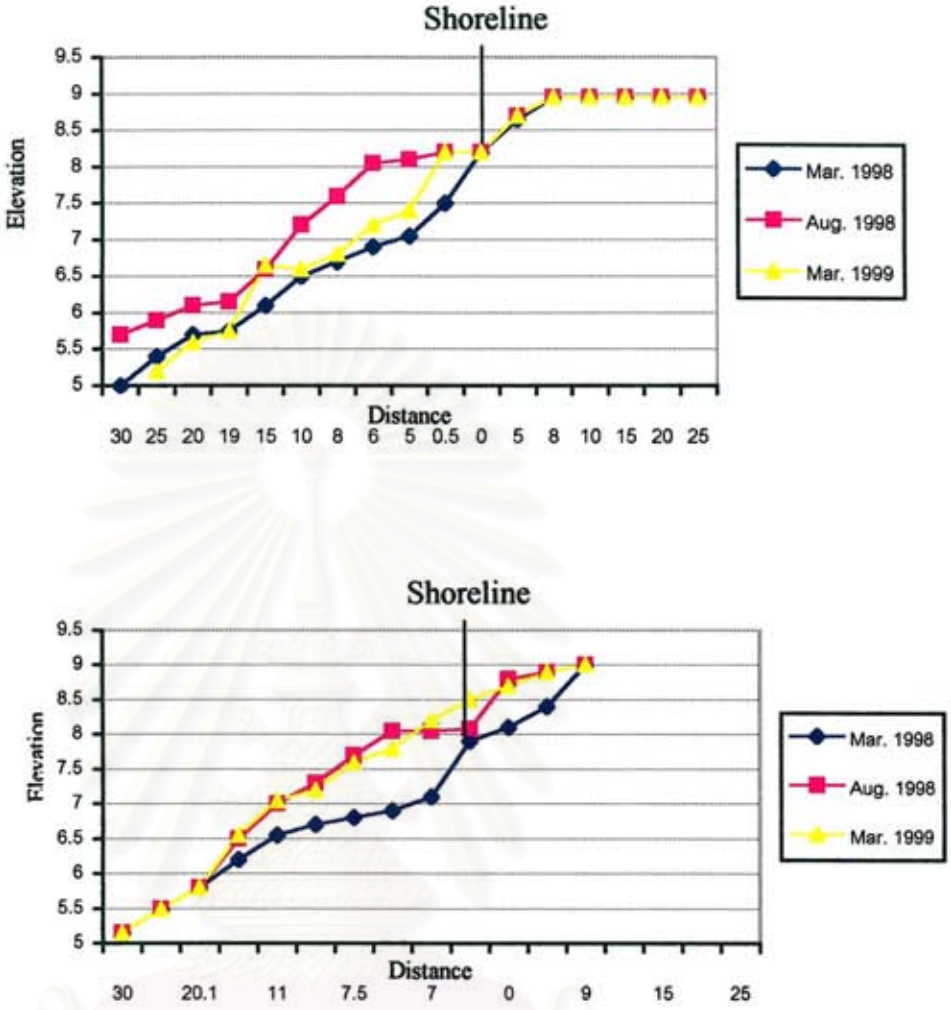

Figure 2.45 Beach profile change during southwest monsoon along Ao Nang coast

(a)

(b)

Figure 2.46 (a) Shoreline erosion at Laem Pho accelerated by wave action and human activities

(b) Erosion of soft bed underlying fossiliferous-limestone bed at Laem Pho

Figure 2.47 Map showing shoreline erosion from Ko Kwang to Laem Pho

2.4 EXISTING LAND USE

Land use in Changwat Krabi is properly planned. The land use map of Changwat Krabi is shown in Figure 2.48. It was based on present land use categories, geological information, and socio-economic. Six land use categories were classified and shown in Table 2.11.

Table 2.11 Area, total area and present of area of existing land use

Existing land use	Area (km^2)	Total area (km^2)	Percent of area (%)
1. Forest land cover			
1.1 Tropical evergreen forest and forest plantation			
1.2 Mangrove forest area		266.50	33.93
1.3 National park			
2. Agriculture land use	6.84		
2.1 Paddy field, rained paddy field	5.48		
2.2 Abandoned paddy field	436.92		
2.3 Perennial crops, rubber	36.93	504.64	63.38
2.4 Oil palm, eucalyptus	15.94		
2.5 Swidden cultivation	1.20		
2.6 Shrimp farm	1.32		
3. Water resource area			
3.1 River			
3.2 Water body	0.73	0.73	0.09
4. Beach, sand bar and lagoon	1.56	1.56	0.20
5. Settlement area			
5.1 City, town and commercial land, institutional, transportation	15.42	18.43	2.32
5.2 Village	3.01		
6. Industrial land use	0.65	0.65	0.08

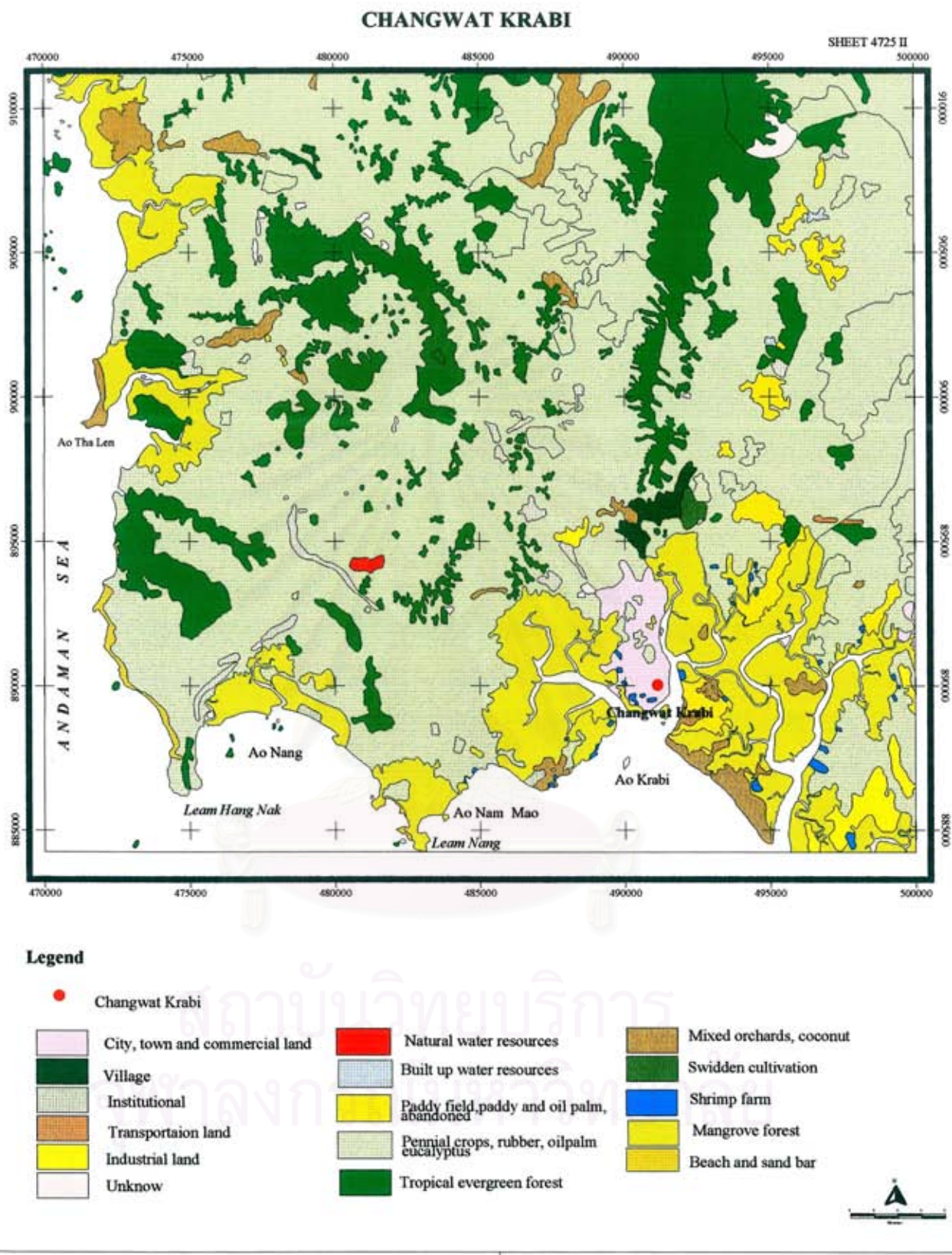

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Figure 2.48 1996 landuse map

Source : Land Development Dept., 1996

Forest land cover

The forest land cover in the study area can be classified into three types as follow:

A tropical evergreen forests and forests plantation, which occupies about 20% occur mainly in mountainous areas and undulating terrain. At present, most of the forest land cover in the undulating terrain has been exploited for agricultural purposes.

Mangrove forests occupy extensively on tidal flats, lagoons, and estuaries of Krabi's coastal area. The mangrove ecosystem provides basic human needs, such as food, wood, energy, environmental protection, etc. However, many mangrove areas have been destroyed for infrastructure development and some have been converted into shrimp farms.

The national park, there are two national parks in Changwat Krabi. One is, the marine national park of Noparathara beach and PHI PHI islands. This park covers an area of 389.96 square kilometers along the coastal zone plus an offshore area. The second is an a mountainous area of granitic rocks. This is Khao Phanom Benja national park and it covers an area of 50.12 square kilometers (Land Development Dept., 1986)

Agriculture land use

Rubber and oil palm are main plantations in the residual deposit of undulating terrain. Paddy fields are in lowland areas and floodplains of old stream channels.

Water resource areas

The main sources of water in Changwat Krabi are two major streams, Khlong Krabi Yai and Klong Krabi Noi. These two streams originate from mountains areas and run to the Andaman Sea. Another source of water is collected in the collapsed sinkholes of fractures limestone terrain.

Beach, sand bar and lagoon

Sand beach and lagoons are the aesthetic areas of Changwat Krabi. They are the places where people work and live. Moreover, they are also places for boat mooring, shipyards, and small scale fishery processing industries.

Settlement areas

The densely populated area of Changwat Krabi is located in the Krabi township, or Krabi municipality, on the river mouth of Khlong Krabi Yai. New settlement areas are expected to be in the undulating terrain or river terraces about 6 km. to the north of the present town.

New industrial areas

Industries in the area under the present study are small scale agro- industrial estates, such as, palm oil factories and rubber factories. Other industry are cement-block factories and rock quarries. Most of the industrial development of Changwat Krabi are located within 10 km. of the town. The new industrial development of Krabi is related to tourism. New industrial areas are expected to be located in the undulating terrain areas, particularly in the northeastern of Changwat Krabi.

2.5 RECREATION AND TOURIST ATTRACTION

There are several scenic places in Changwat Krabi (Figure 2.49). The center of attraction is in the coastal zone and islands, most of which are located in the marine national park. Other tourist attractions are located in upland areas. The environmental implications of land use development have destroyed the natural forest in steep slope area converse into oil palm plantations, conversion of mangrove forests into shrimp farms, and draining wastewater directly into stream. It will also have the repercussion on tourism. A suitable policy for land use planning and development is needed to sustain the development in Changwat Krabi, particularly for the coastal area, where tourism can be developed together with small scale industries.

(a)

(b)

(c)

(d)

(e)

(f)

Figure 2.49 Scenic views of Krabi province

(a) Sea notch at Hat Rai Lae (b) Khao Khanap Nam

(c, d) Natural bridge at Laem Chamuk Kwai

(e) Recreation area along Khlong Krabi Yai, Krabi township

(f) Chao Fa peir, Krabi township

Changwat Krabi is one of the most attractive tourist destinations in southern Thailand. To the west, it borders on the Andaman Sea where countless natural attractions abound, including white sandy beaches, fascinating coral reefs, numerous large and small islands, verdant forest and highly interesting archeological remains (Figure 2.50). The tourist attractions in the study area are as follow:

Khao Khanap Nam

Khao Khanap Nam, 100 meter-high hill rising from the water, is regarded as the symbol of Changwat Krabi. It is located in the north of Krabi township and can be visited by long tail boat from Chao Fa peir. Travel time is about 15 minutes. From the boat, one climbs a staircase to see caves with stalactites and stalagmites. Many human skeletons have been found in the area. It is theorized that they are the remains of migrants who became stranded and died after sudden flood.

Tham Sua or Tiger cave

Tham Sua is located about 3 kilometers north of Krabi township. Inside the cave, there are what appear to be tiger paw prints in the stone. The surrounding area is covered with large trees hundreds of years old, particularly in the Khiriwong valley. Mountains are on all sides and there are smaller caves in great number. Aside from being the site of meditation center, it is also a place of archeological and historical interests. Stone tools pottery remains, and the molds of Buddha footprints have been found in the excavations.

Tham Sadet

Tham Sadet is located at Ban Nong Kok, Tambon Saitai, 7 kilometers from the town on Highway No. 4034. It is a beautiful cave with stalactites and stalagmites. In 1909 the King Rama IV visited the cave here, earning it tittle "Sadet" indicating the presence of royalty.

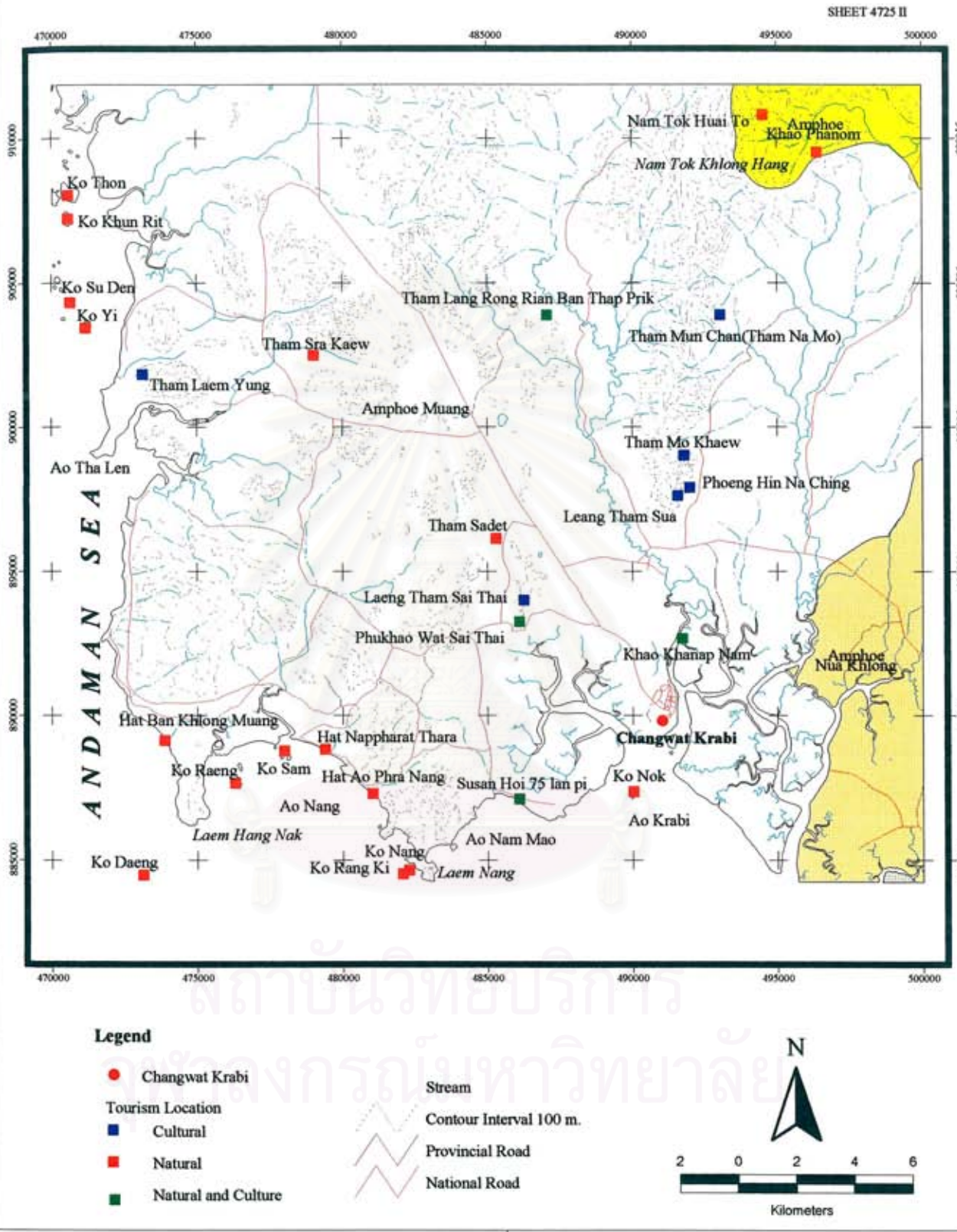

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Figure 2.50 Tourism Location map

Sa Kaew

Sa Kaew composed of eight small natural sinkholes in the vast valley of Tambon Khoa Thong. This forms part of a park which is being turned into the recreation area. Sa Kaew is accessible by the Krabi-Nai Sa route(Highway No. 4034), a distance of 28 kilometers

Hat Noppharat thara -Mu Ko Phi Phi National Park

This marine national park covers the coastal area and other offshore islands with in the district territory of Amphoe Muang. With white, clean stretches of beach and scenic coral reefs, it also offers numerous natural attractions such as the Hat Noppharat Thara beach, Hat Ao Nang, the Su San Hoi or Fossil shell beach, the Phi - Phi islands group and the Po Da islands.

Hat Noppharat Thara

Hat Noppharat Thara is a scenic beach lined with casuaring trees extending for several kilometers. A rocky island, about one kilometer from the mainland, can be reached by walk at low tide. Minibuses leave the town to the beach daily from 6.00 - 17.00 hrs. Accommodation at the beach is available. Reservations should be made in advance at the Forest Department.

Ao Nang

It is located approximately 6 kilometers south of Hat Noppharat Thara next to the road that runs parallel to the coastline. A scenic bay, its white sandy beach stretches to a foot of a conspicuously prominent limestone range. There are 83 small islands in the various size and shapes. Accommodation is available along the beachfront. Other facilities include diving shops, boat for rent and sight-seeing by canoe. From Ao Nang bay, tourists may hire boats to visit nearby attractions such as Hat Rai Le, Tham Phra Nang, Sa Phra Nang, located on the land to the east of Ao Nang, as well as other offshore islands of Poda, Tap and Mo.

Su San Hoi of Fossil Shell Beach

Su San Hoi is located at Ban Laem Pho, 17 kilometers from down town Krabi along the route to Hat Noppharat Thara. Long ago this was a freshwater marsh populated by brachiopods chiefly little two centimeters long "Hoi Khom" or pond snails, which grouped and multiplied in such numbers that dead formed a floor for the living. This process, repeated over eons led to the creation of layer of fossils.

Khao Phanom Bencha

Khao Phanom Bencha National Park covers an area of 50.12 square kilometers including some parts Amphoe Khao Phanom and Amphoe Muang. It lies 20 kilometers from town along the old market road to Ban Huai To. Its marvelous scenery is a waterfall and wild animals. The park's major attractions are Nam Tok Huai To, Tham Khao Phung, Na Nam Tok Khlong Haeng, Nam Tok Ton Han, etc.

2.6 SOIL MAP

According to the physical properties, such as, permeability, grained size and composition, soil classification in the study area can be defined into seven types and shown in Table 2.12. Figure 2.51 is the map of soil type prepared by the Department of Land Development.

Table 2-12 Soil descriptions (Dept. of Land Development, 1996)

Soil name	Soil type	Soil depth (m)	Drainage
Krabi	Loamy clay	Very deep, >1.50	Well
Lamphu La and Pak Chan undiffentiated	Loam silt	-	Medium
Khlong Chak	Loam	Deep, 1.00-1.50	Well
Na Thawi	Silt loam	Deep, 1.00-1.50	Well
Complex of poorly drained alluvial	Silty clay	Very deep, >1.50	Poorly
Bang Pakong	Clayey silt	Deep, 1.00-1.50	Poorly
Tha Sae	Sand	Very deep, >1.50	Rapid

Source : Dept. of Mineral Resources., 1995

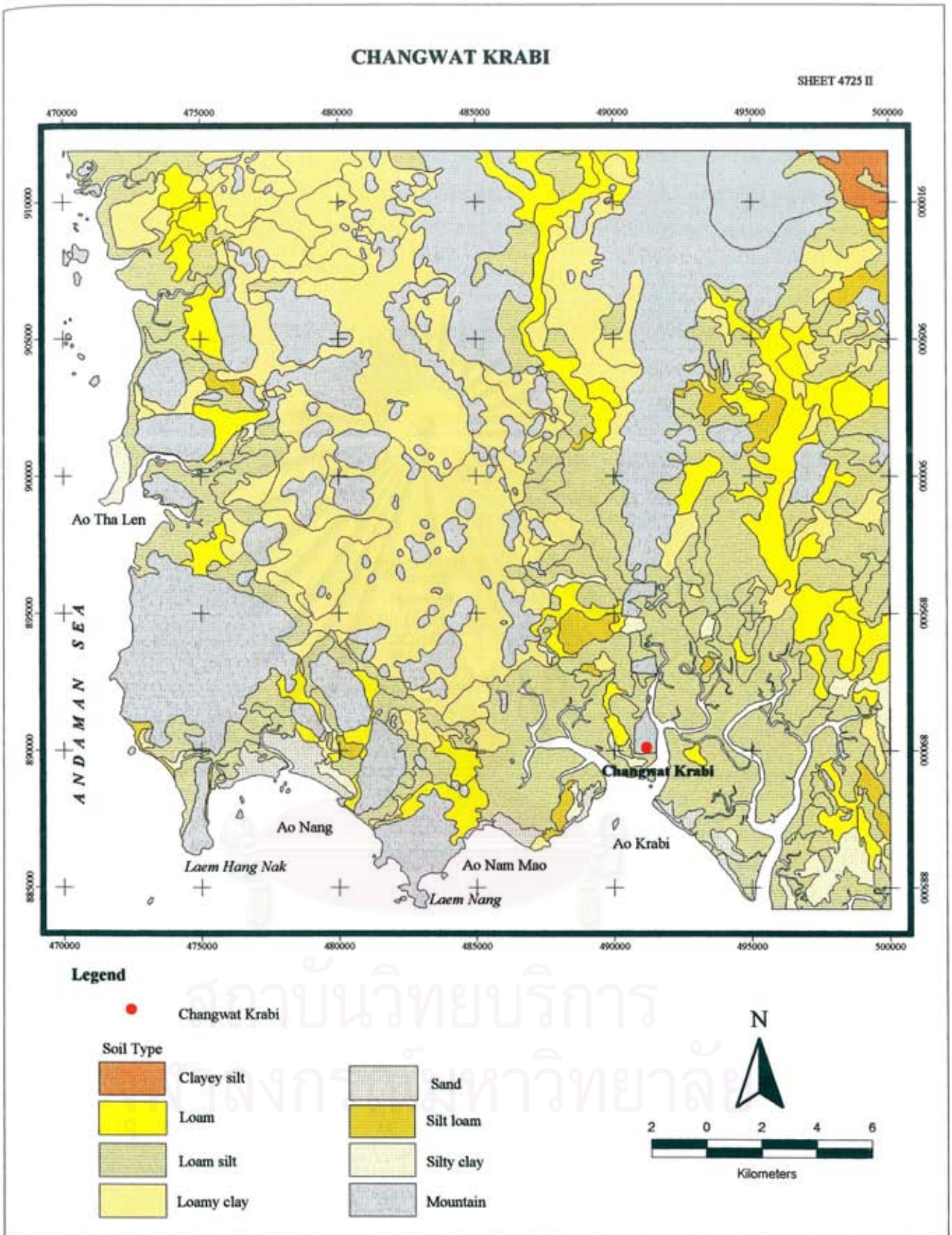

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Figure 2.51 Soil Map

Source :Land Development Dept., 1986

2.7 FOREST USE AND WATERSHEAD CLASSIFICATION

The information about the region of forestry and forest use were taken from the map "Forest map and Forest use map of Forestry Department,1993 (Figures 2.52 and 2.53). Forestry areas are generally situated on the hilly to mountainous area. The distribution of these forests is not uniform, but generally it covers upper parts of the mountains, rough morphology, including coastal area, and have a function for watershed divided. The watershed classification can be classified into five classes as show in Figure 2.54 and Table 2.13.

Types of the forest use are economic forest, national forest reserve, agriculture area, utilization area and non-forest (Table 2.14). These classification base on the condition of utilization of forest areas, that control by the law.

Table 2-13 Watershed classification

Watershed class	Area (km^2)	Percent of area (%)	Condition
1A	57.70	8.48	Conservation area
1AR	1.90	0.28	
1B	27.91	4.10	
1BR	8.52	1.25	
2	39.16	5.76	
3	61.41	9.03	
4	56.17	8.26	
5	426.55	62.72	

Table 2-14 Forest use

Type of forest use	Area (km^2)	Percent of area (%)	Condition
National forest reserve	162.42	23.47	Conservation
Agriculture area	14.23	2.06	
Economic forest	206.48	29.84	
Non-forest	15.59	2.25	
Non –RFD control	293.26	42.38	

Source : Dept. of Mineral Resources., 1995

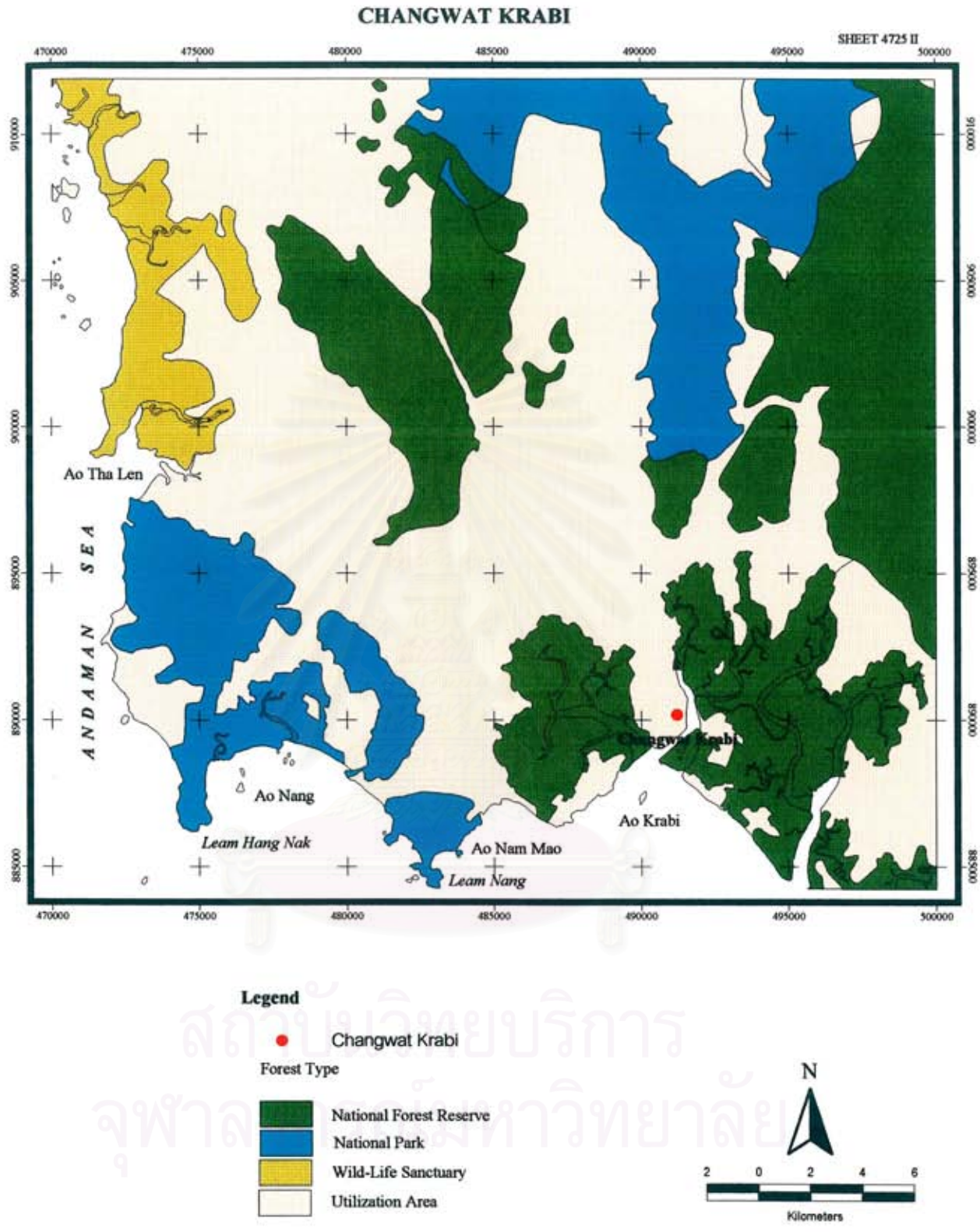

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Figure 2.52 Forest map

Source : Forestry Dept., 1993

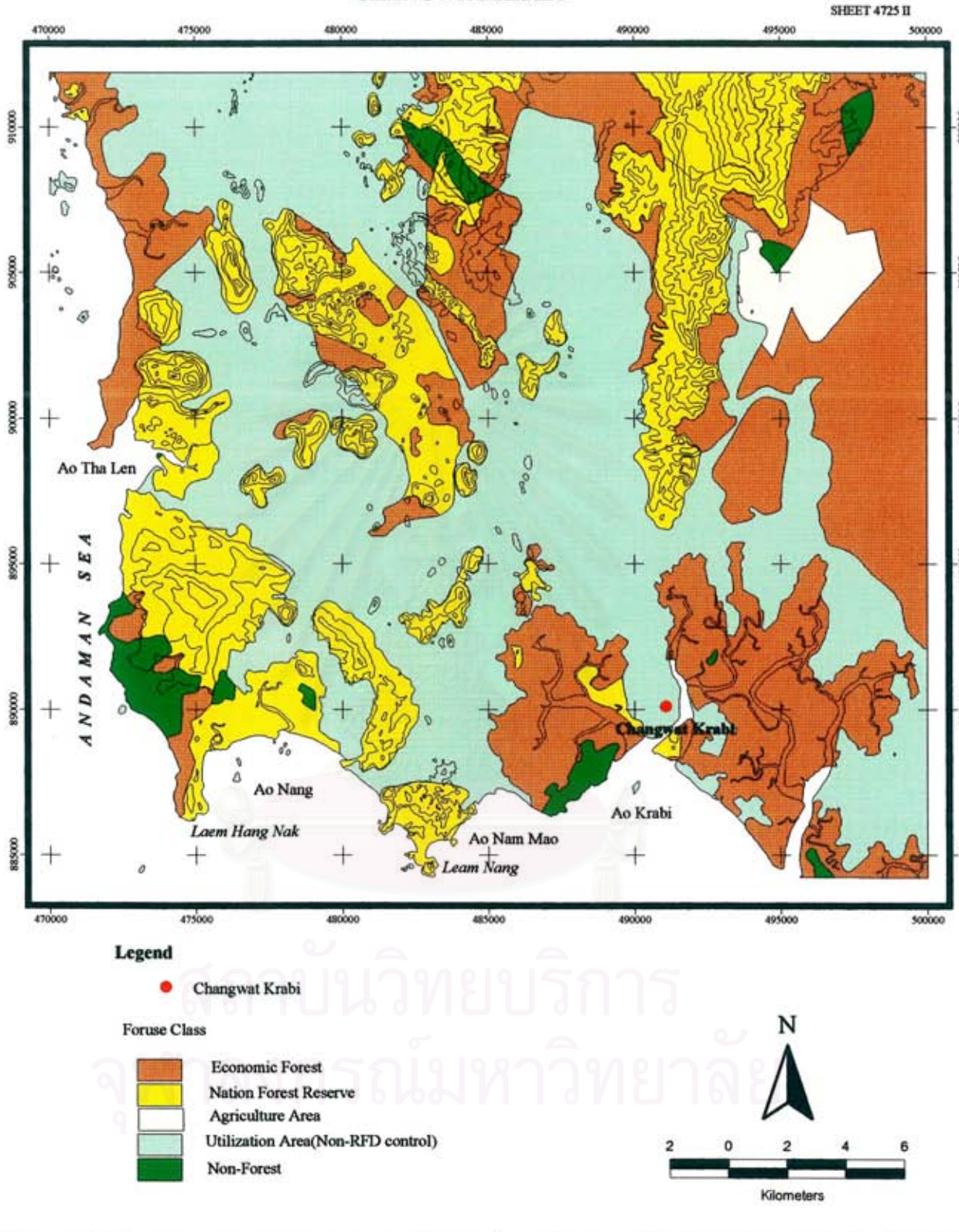

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Figure 2.53 Forestuse Map

Source : Forestry Dept., 1993

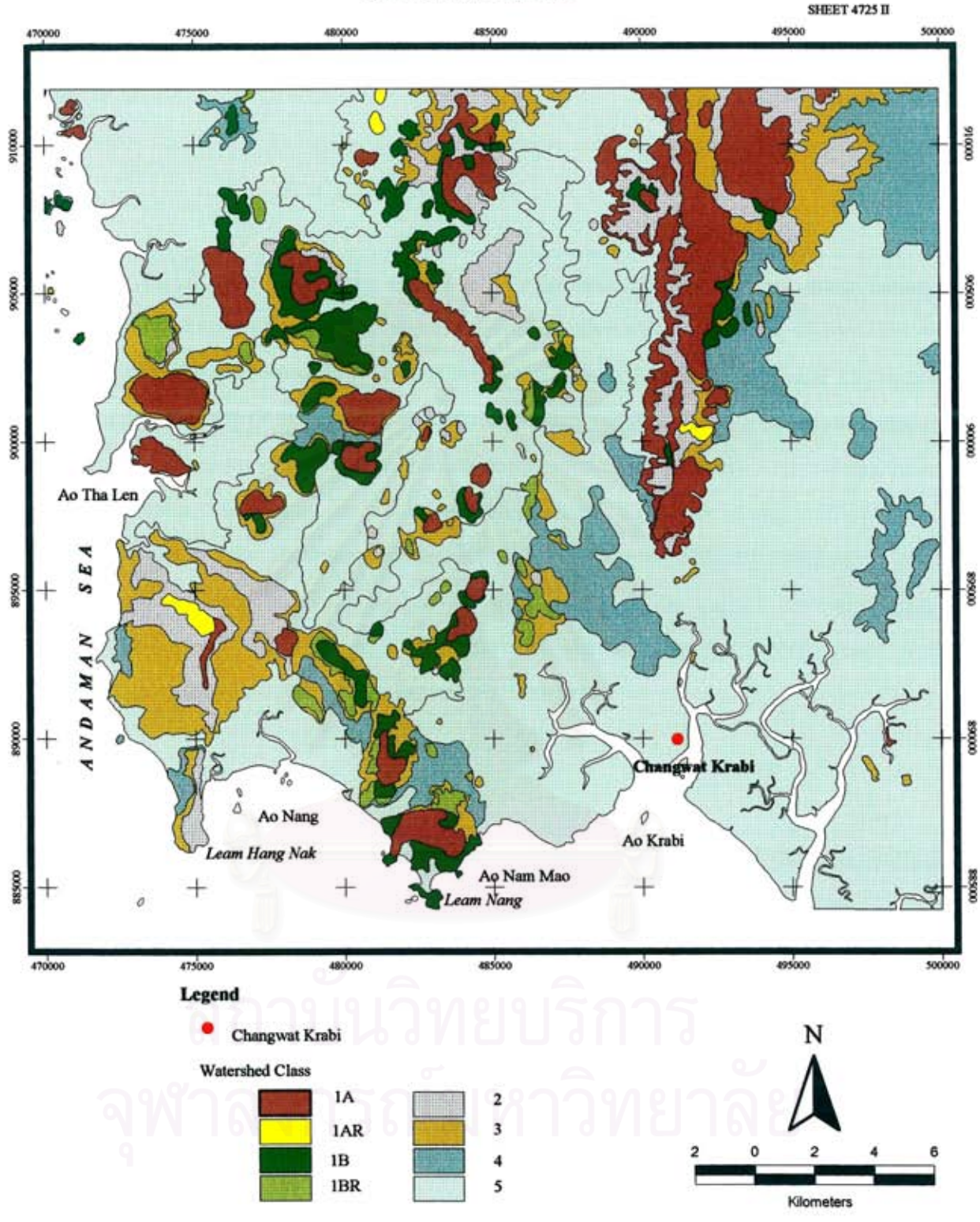

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Figure 2.54 Watershed Classification map

Source : Office of Environmental Policy and Planning

CHAPTER 3

SOCIO - ECONOMIC BACKGROUND

Social and economic trends of Krabi included increasing urbanization, expansion of tourism, agricultural and industrial activities at a fast rate, and growth of income in the survive industries. Although agriculture had been the most important economic activity of the country with most of the population livings in the rural areas, the area of land under cultivation was unlikely to increase. The major agriculture were rubber, palm oil, rice, maize and cassavana products, the major nonagricultural were agro-industrial, for instance industry of palm oil, rubber industry. Rather, it was projected that any increase in income would have to be gained through higher productivity of the labor and land now in use and by the development and diversification of tourism and industrial production.

3.1 POPULATION

Changwat Krabi an area of 4,409.31 km^2 has divided into 8 districts, with a combined population of 350,389(Statistical reports of Krabi Changwat Krabi, 1998). This total was divided about 181,185 males and 169,204 females. The population was approximately 86,497 in Amphoe Muang, 49,308 in Amphoe Nua Khlong, 24,257 in Amphoe Ko Lanta, 53,999 in Amphoe Khlong Tom, 16,436 in Amphoe Lam Tap, 47,760 in Amphoe Ao Luk, 31,119 in Amphoe Plai Phraya, 40,761 in Amphoe Khao Phanom. The annual growth rate in 1997 is 1.5 percent, decrease from 1.74 in 1987, 2.08 in 1988, 2.38 in 1989. The population mostly concentrated in the town and tourism region. Overall density 72.42 persons per square kilometer in 1997. The approximate population density was show in Tables3.1 and 3.2, and Figure 3.1.

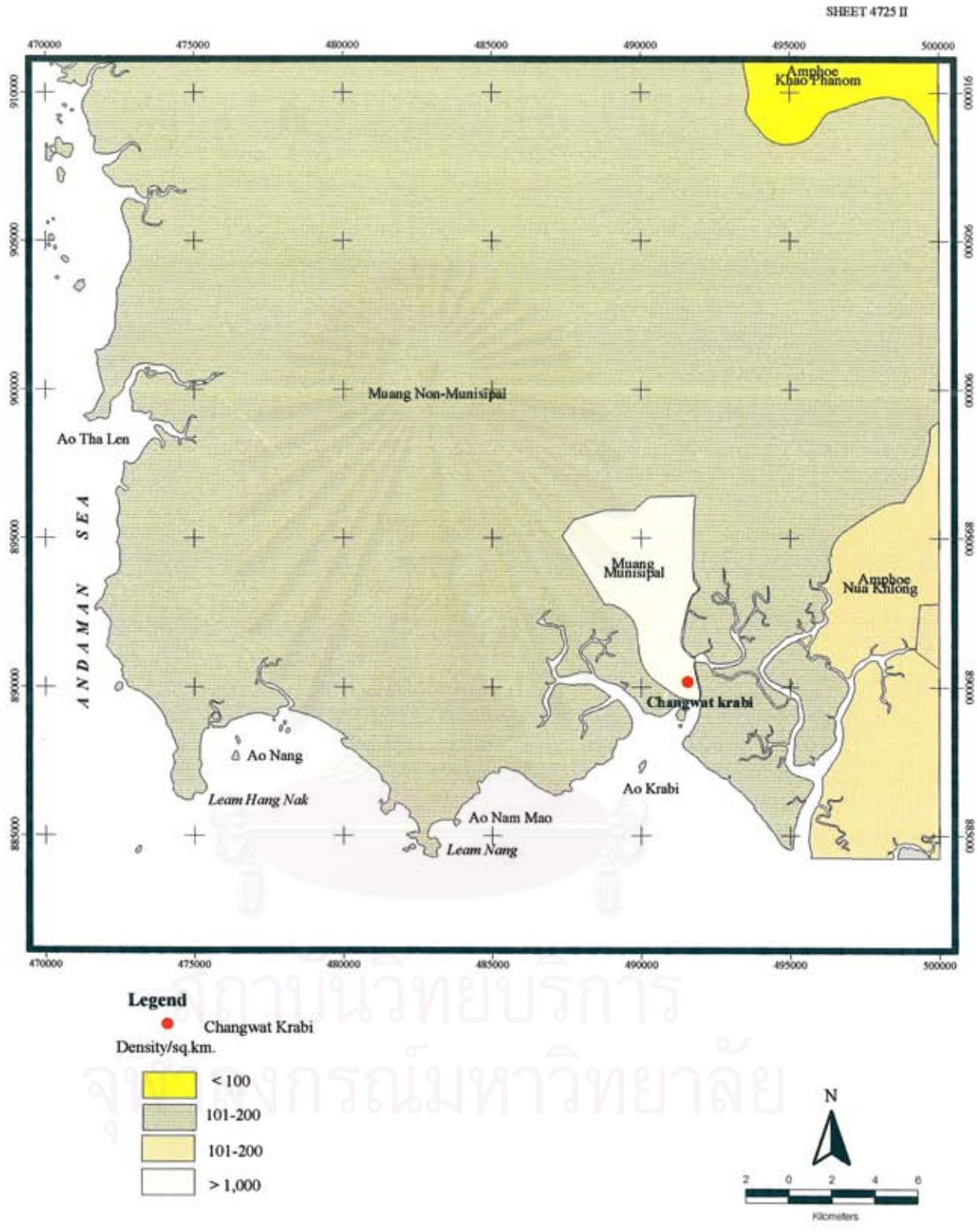

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Figure 3.1 Population Density map

Table 3.1 Number of Population, Birth Rate, death Rate and Percent of Growth Rate of Population in Krabi (Statistical reports of Changwat Krabi , 1998)

Year	Number of Population	Birth Rate	Death Rate	Rate of Population Growth
1987	272,365	2.05	0.003	1.74
1988	280,818	2.41	0.003	2.08
1989	290,300	2.70	0.003	2.38

Table 3.2 Number of Population, rate of Population Change and Population Density by Area and Amphoe: 1997(Statistical reports of Changwat Krabi , 1998)

Amphoe	Number of Population			Rate of Change	Population Density/Km^2	Growth rate
	Total	Male	Female			
Total	353,708	182,738	170,970	4.39	74.81	1.5
Municipal Area	22,231	11,296	10,935	3.23	1,170.05	
Non-Municipal	331,447	171,442	160,035	4.46	70.39	
Muang Krabi	87,339	44,583	42,756	10.97	130.83	
Municipal	22,231	11,296	10,935	3.23	1,170.05	
Non-Municipal	65,108	33,287	31,821	13.88	100.38	
Khlong Thom	54,360	27,404	26,956	4.85	52.14	
Khao Phanom	41,495	22,052	19,443	11.88	52.62	
Ao Luk	48,056	24,521	23,544	3.22	62.18	
Plai Praya	31,345	15,892	15,453	1.11	72.33	
Ko Lanta	24,645	13,613	11,032	6.21	72.52	
Lam Thap	16,513	8,514	7,999	3.53	51.49	
Nua Khlong	49,964	26,159	23,787	1.52	137.97	

3.2 EDUCATION AND RELIGION

The children between the ages of 7 and 12 attend primary school by government supports, and more than 85 percent of population literate. The government operate school in all parts of the country, the schools were organized into a six - three - three pattern that comprised six years of primary school, three years of secondary school, and three years of high school. The secondary education were

concentrated in major town and in the center. About 79.50 percent of the children in Krabi had finished in secondary education. The information regarding the government educational survice of Changwat Krabi at different level are summarized and presented in Table 3.3.

Table 3.3 Number of School and Institutes by Jurisdiction and Amphoe : Academic Year 1997(Statistical reports of Krabi province, 1998)

Amphoe	Total	Jurisdiction					
		Dept.Of General Education	Office Of National Primary Education Commission	Office of Private Education Commission	Office of Local Education	Vocational Education Dept.	The Physical Education Dept.
Muang Krabi	48	3	38	3	3	-	-
Khlong Thom	42	3	39	-	-	-	-
Khao Phanom	31	4	26	1	-	-	-
Ao Luk	39	2	36	1	-	-	-
Plai Praya	23	1	22	-	-	-	-
Ko Lanta	25	2	23	-	-	-	-
Lam Thap	15	1	12	2	-	-	-
Nua Khlong	44	1	41	2	-	-	-
Total	267	17	237	9	3	3	1

Religion plays a very important roll in Thai life. Considered and essential pillar of society, it is not only the major moral force of the Thai family and community but has also contributed to the molding of this freedom-loving, individualistic, and tolerant people for many centuries. That there is complete freedom of worship in Thailand. Out of the estimated 350,389 people in Krabi, about 64.7 percent are Buddhists, while about 34.5 percent are Muslims, 0.8 percent Christians and others.. The numerous of the temple was shown in Table 3.4.

Table 3.4 Number of Buddhist Monasteries, Buddhist Sanka Abodes, Churches, Mosques and Percent of Population in the Religion (Statistical reports of Changwat Krabi , 1998)

Religion	Percent of Population	Number of Temple
Buddhism	64.7	87
Muslim	34.5	148
Christ and Others	0.8	8

3.3 TRANSPORTATION AND COMMUNICATION

Thailand's transportation system of inland waterways, railroads, roads and air centered on Bangkok. From Bangkok to Changwat Krabi, it can be travelled by road, train and airplane. From Bangkok, highway No. 4 canbe used starting from Changwat Petchaburi to Changwat Prachuap Khiri Khan, Changwat Chumphon, Changwat Ranong, Changwat Phangnga and then Changwat Krabi, a total distance of 946 kilometers. From Changwat Chumphonhighway No. 41 can be an alternation route via Amphoe Lung Suan Amphoe Chaiya, Surat Thani, and Amphoe Wiang Sa before changing to Highway 4035 to Amphoe Ao Luk and once again turning to Highway No. 4 to Krabi, a total distance of 814 kilometers. By train, from Hualamphong Railway station(Bangkok), one can go as far as Trung station, or Thung Song station in Namhon Si Thammarat, then take a bus or taxi to Krabi. By airplane, from Bangkok's domestic airport, take a flight to Krabi or to Phuket, then take a bus to Krabi.

The existing system of main roads and provincial roads are radiation from city to all parts of province (Figure 3.2). These road had served to carry agricultural products from the other areas to the city for domestic processing and to transport foreign or locally made good back to rural areas In late 1980s, the main road was considered by foreign experts to be generally adequate for the country's overall transport requirement. Considerable upgrading of provincial road would be needed in the coming decade to handle growing traffic as commercialization spread through the rural areas. In particular, sustain development were required for subsidiary roads to provide villages and harmless access to the main transport arteries.

The port of Krabi had experienced continuous growth along coastline of the Andaman Sea. More than half were fishing ports and the remainder served multipurpose, including coastal services, tourism, export and import functions, and fisheries operations. Coastal operations were in generally small.

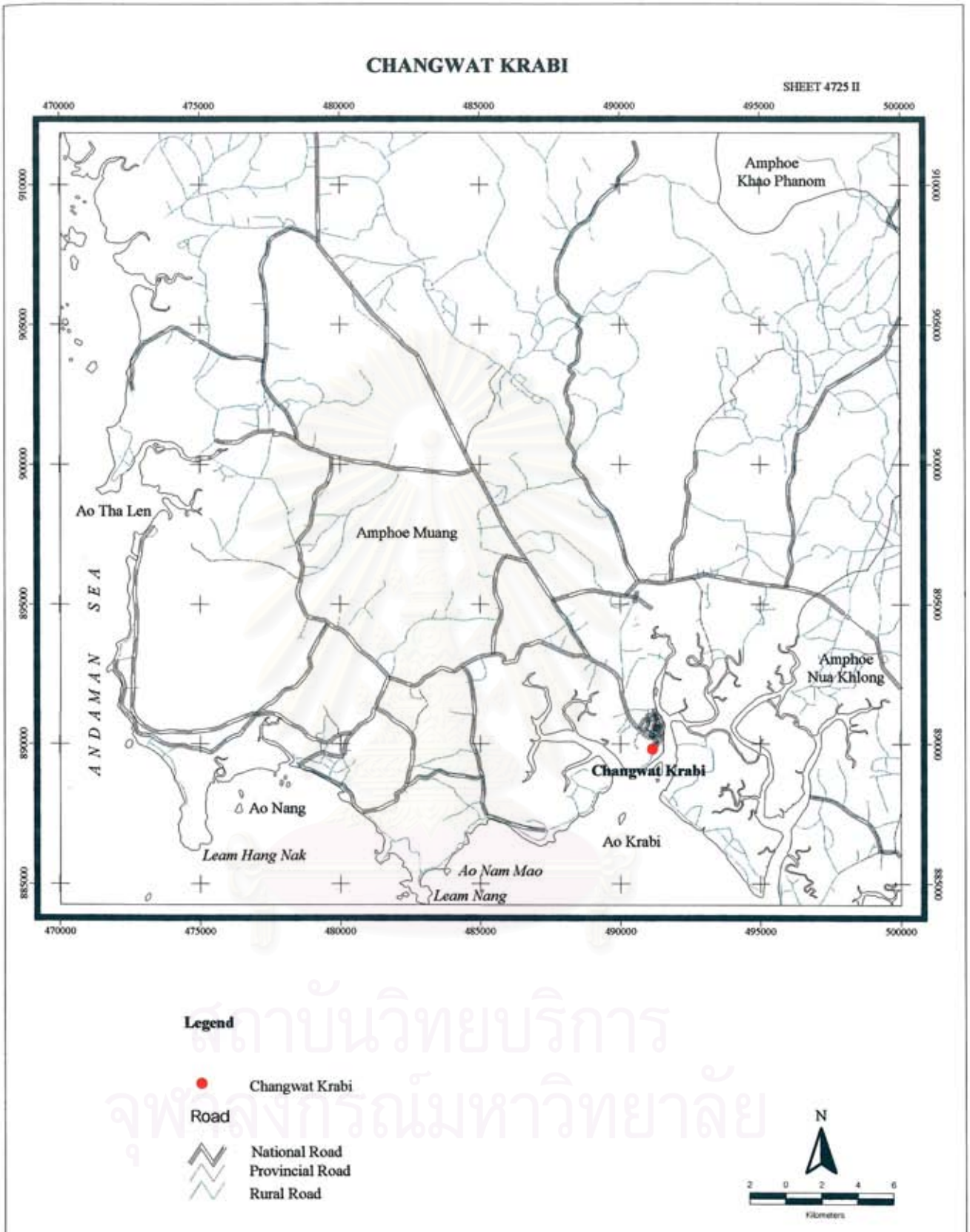

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Figure 3.2 Road map

The principle international airport in the southern Thailand was Phuket, Hat Yai and a new commercial airport at Krabi. The commercial airport of Krabi province is located at Ban Krabi Noi with 8 kilometers from Krabi township. Both Phuket and Hat Yai were far from Krabi 176 kilometers and 285 kilometers. International and National survice provided by Thai Airways, Thai's routes including flights to Asia, the middle East, Europe, North America, Australia and the provincial airport of Thailand.

Two major entities communication of Krabi province was responsible for the Thai communication and postal under the supervision of the Ministry of Communications. The provincial telephone organization of Krabi was responsible for the domestic telephone services, for international telephone services to several countries, such as Malaysia and Singapore, for leasing circuits for domestic point-to-point transmission of voices, telegraph, radio and television. All telegraph and telex survives international leasing circuits, domestic radiotelephone links to some isolated areas. Numerous government agencies and large private industrial and commercial entities operated their own radiotelephone network. By 1999, Krabi had average density of one telephone per hundred inhabitants. This density was better than the average of 0.7 for developing in East Asia region. Over all, only 25 percent of population had access to telephone services. There were about 125 local and long-distance pay (coin box) telephone in provincial town.

3.4 ELECTRIC POWER

The electricity of Krabi province covers approximately 85.80 percents of the total village. The lignite-fired plant at Krabi with installed capacity of sixty megwatts, and the peak demand of Krabi province is 26.34 MVA. The demand of electricity of Krabi are increasing 15.5 percents per year, according to widely distributed to almost all of the rural area due to the increasing of numerous factories and domestic use.

3.5 AGRICULTURE

Although Changwat Krabi comprise the rugged terrain about two-fifths of the area unsuitable for agriculture. But agriculture activities include crops, fisheries, livestock and forestry. It was estimated that some sixty to seventy percent of total population was dependent on the agriculture sector for its livelihood. The climate, however, favored the cultivation of rubber trees, and the majority of farms grew rubber as a case crop along with subsistence rice.

Crops

Climate and soil conditions permit the cultivation of a wide range of crops. The major emphasis in agriculture was on rubber, oil palm, coconut, coffee and cashew nut. Other crops regular grown included rice, peanut, bonavista bean, sweet corn, and various fruit, but all were supplementary and intended basically for domestic use. Many farmers continued to produce rice for subsistence purposed while expanding there activities to grow market - oriented upland crops. Planted area and production of major crops economic and field crops of the year 1996-1997 are shown in Tables 3.5.

Table 3.5 Planted area and Production Major Economic Crops: 1996 – 1997 (Statistical reports of Changwat Krabi , 1998)

Type of Crops	Planted area(Rai)		Harvested area(Rai)		Total Production(kgs)		Yield Per Rai (kgs)	
	1996	1997	1996	1997	1996	1997	1996	1997
Para rubber	770,947	730,464	664,740	656,477	190,063,329	171,103,629	286	260
Oil palme	537,637	554,840	466,866	467,353	956,234,435	1,121,635,350	2,048	2,399
Coconut	40,440	45,036	36,314	40,547	39,978,068	39,232,340	1,100	967
Coffee	25,147	25,112	24,377	24,592	5,655,941	4,917,280	232	199
Cashew nut	15,746	8,326	15,357	8,040	9,561,605	3,841,265	622	477

Fisheries

Fisheries of Krabi in the foregoing discussion include marine and inland fisheries (Tables 3.6 and 3.7). Of Krabi's 6,184 fishing vessels, nearly 3,000 were only marine capture fishery, many with outboard powered boat and some with modern communication and navigation equipment and refrigeration facilities (inboard powered boat). By about 1972 maximum exploitation of bottom - dwelling and open sea fish appeared to have been reached in the Andaman Sea. In early 1980s, production remained relatively static, and it was growing concern that these areas were being over fished. Government control of fishing was limited. The use of certain kinds of fishing gear within three kilometers of the coast was banned, but there appeared to be no restriction on trawl-net-mesh size, and undersized commercial food fish were being caught and dumped in with trash fish in the production of fishmeal. Moreover, Burma claimed territorial waters extending to 200 nautical miles from its coast. This reduced the area in the Andaman Sea to Krabi fishermen and increased the intensity of fishing off the coast.

Inland fisheries of Krabi, which included both fresh water and brackish water fish, annual catches of about 102.9 tons for fresh water fish and 12,910.75 tons for brackish water fish by the year 1996-1997 have been reported (Provincial office of fisheries, 1998). The actual catch principally freshwater from fresh water culture ponds. The most promising course for maintenance of fisheries production to increasing output, was the expansion of aquqcultue, including the culture of fish, shrimp, and various mollusks, such as mussels and oysters. According to the report of provincial office of fisheries about 9,134 rai that is including estuaries, mangrove, swamps and tidal flat also usable for aquaculture.

Table 3.6 Numbers of Fishery Households, Type of Fishery and total of Product and Annual income: 1996(Statistical reports of Changwat Krabi , 1998)

Type of Fishery	Number of Fishery Households	Total Products (Tons)	Annual Income (Million Baths)
Fresh Water Fishery	1,745	102.9	4.116
Coastal Aquaculture	1,424	12,910.75	1,580.04
Marine Capture Fishery	3,015	12,123.05	163.32

Table 3.7 Number of Shrimp Farms by Amphoe : 1996 – Early 1997(Statistical reports of Changwat Krabi, 1998)

Amphoe	Number of Shrimp Farms Household	Number of Shrimp Farms	Area(Rai)
Muang	198	453	1,420
Nua Khlong	220	501	1,510
Ko Lan Ta	157	190	510
Khlong Thom	480	980	3,136
Ao Luk	155	311	731
Total	1,210	2,435	7,307

Livestock

The unfavorable condition of livestock are the lacking of pasture, high initial investment coast, mechanical and electrical power are more favorable than animal power, domestic animal trades are of monopoly or oligopoly in character, the breeding problem and robbery.

Generally the animal farms in Krabi are of poultry, swine cattle and buffalo. Table 3.8 shows the statistics of livestock in the year 1997.

Table 3.8 Number of Livestock by Amphoe : 1997(Statistical reports of Changwat Krabi , 1998)

Amphoe	Type of Livestock					
	Cattle	Buffaloes	Duck	Chicken	Geese	Swine
Muang	3,067	442	808	70,953	-	3,177
Khlong Thom	4,145	193	10,058	55,601	168	3,444
Khao Phanom	2,134	-	682	83,671	-	11,090
Ao Luk	2,071	279	5,831	40,552	112	7,546
Plai Praya	1,417	275	3,824	43,199	-	2,735
Ko Lanta	1,257	1,028	8,731	36,489	-	-
Lam Thap	2,635	18	1,288	35,559	138	2,569
Nua Khlong	5,530	1,003	15,435	148,255	23	3,645
Total	20,999	2,210	37,926	477,790	441	34,026

3.6 INDUSTRY

The industrial sector in Krabi contributed considerably to economic growth during the late 1980s. Number of industrial establishments accounted for 335 in 1997.

The industries can be classified into three categories, namely, manufacturing, mining and tourism industry. A discussion of each follows:

Manufacturing

The manufacturing of Krabi was characterized by a high reliance on agricultural products, including palm-oil products, rubber products, wood products and furniture and food processing in small-scale industrial projects. The annual growth rate was 9 percent for the 1997, which was still very respectable by international standard (Table 3.9).

Table 3.9 Number of Industrial Establishments, Capital and Employees by Type of Industries: 1997 (Statistical reports of Changwat Krabi, 1998)

Type of Industries	Number of Industries Establishments	Capital (Million Baths)	Number of Employees
Rice Mills	118	8,371	195
Food and Breverages	15	454.217	1,172
Palm Oil Extraction	10	695.298	574
Drying and Grinding of Coffee	1	2.025	6
Crushing and Grinding	3	49.030	66
Manufacture of Wood Product and Furniture	36	138.403	593
Manufacture of Concrete Products	42	130.775	416
Rubber Smoked Sheets and Products	7	381.030	1,208
Manufacture of Metal Products	16	35.799	73
Printing	3	4.478	23
Motor Vehicle Reparing	14	7.518	80
Car and Motorcycles Reparing	25	58.427	146
Gas and Petroleum producing and containing	6	151.300	50
Brick and Ceramic Products	5	5.790	78
Other Manufacturing Industries	34	156.734	216
Total	335	1,279.195	4,896

The site of the Southern Seaboard Development Program will be a major center for industrial development that would extend from Panagnga bay to Krabi and Phuket. The goals were the development of a wide range of industries, including agro-industries, around Krabi and the development of tourism in and around Krabi coast, a popular beach resort area.

Mining

The active mines in the area have produced limestone for construction material. Abandoned mines in the area were tin and tungsten. The mineral productions in Krabi by the year 1993 to 1997 are summarized and presented in Table 3-10

Table 3.10 Quantity of Mineral Production by Kind of Mineral (Ton):

1993-1997 (Statistical reports of Changwat Krabi, 1998)

Kind of Minerals	1993	1994	1995	1996	1997
Lignite	216,800	266,488	144,233	0	0
Limestone	0	0	0	10,500	0
Total	216,800	266,488	144,233	10,500	0

Tourism industry

The coastal area in the vicinity of Changwat Krabi is spectacularly beautiful and suited for recreation uses. It has many beaches, islands, and dramatic karst formation. Tourists visit the town largely because it is a jumping of point for the Phi Phi Islands, Ko Lanta, Hat Noppharat Thara, Ao Nang and Rai Leh. Many people find the need to spend a night here, and the guesthouse and hotel, not to mention the multitude of tour agents and restaurants, have sprouted to serve this distinctly footloose community. Accommodation is poorest and Krabi township has little obvious to keep the visitor here for more than a single day. There is a general market on Srisawat and Sukhon rd., and a night market close to the Chao Fah pier. The Promenade, on the riverfront is a pleasant place to walk in the evenings. The statistics of tourist visiting Krabi and number of hotel are presented in Table 3.11.

Table 3.11 Number of Hotels and Visitors : 1995 – 1997

(Statistical reports of Changwat Krabi , 1998)

Item	1995	1996	1997
Number of Hotels	74	82	85
Number of Rooms in Hotel	3,687	3,519	3,619
Number of Visitors	685,213	651,978	701,443
- Thai	362,953	379,873	395,750
- Foreigner	322,260	272,105	305,693
Number of Tourists	640,281	606,355	655,524
- Thai	331,372	346,930	362,750
- Foreigner	308,909	259,425	292,774
Number of Excursionists	44,932	45,623	45,919
- Thai	31,581	32,943	33,000
- Foreigner	13,351	12,680	12,919

CHAPTER 4

APPLICATION OF GIS EVALUATION FOR LAND USE PLANNING

Geographic Information System (GIS) is a rapidly advancing computer based technology, where information is organized, analyzed and presented with reference to location (Aronoff, 1989). Frequently described as a spatial process because location exist within space, GIS has revolutionized the way geographical information such as maps, airphotograhps, satellite image and geographical statistics are use in evaluation and decision making. The GIS covers the integrated technology that links the field of computer to any fields of study that concern with spatial information. These fields are, for example geology, soil science, environment, urban and regional planning, etc;.

Land use planning or land use management is a general term, under this study the land use planning mean the processes of analysis and evaluation of land suitability for land use planning and policy formulation. The principal of the study concern with the environmental geology, in order to know how the environmental geology conditions respond to land use planning. GIS techniques allow the complication and organization of information and facilitated their integration with environmental geology conditions, such as geology, geomorphology, natural resources, soil and land use. Any spatial or geo-referenced information from this study can be input into computer systems by conversion conventional data in hard copy from digital form data and allows computer analysis and output. Thus the land use planning evaluation is an express in term of suitable potential area for several land uses planning. This knowledge can be use to plan future land use planning programs.

4.1 GIS COMPONENTS AND FUNCTIONS

GIS components

GIS is considered as a powerful tool used to handle the spatial information. Its main components involve hardware, software, data and people who also use it. These components can vary upon different applications and aims of organization. "Arc View" the GIS software is used in this study.

Hardware: Standard hardware use in GIS essentially includes computer for analysis, monitor and plotter for display, scanner, and magnetic storage such as floppy disk and compact disk.

Software: GIS should be basically composed of mapping software and database management system software. Mapping software has ability to organize geo-reference, geographic data while the database management system is use to organize their non-spatial attribute. This makes GIS to be different from other information system because it has an ability in spatial analysis with allow graphic an attribute data to be analyses simultaneously. It means that the output obtained from the analysis can answer quations, regarding resource management, in term of quality, quantity, and location of the resource and its potential uses.

Data: In GIS, the graphic data are composed of not only a set of geographic elements or entities i.e. point, line, and polygon but also the spatial relationships among these element which are technically called topology (Korte, 1992). The distribution of these elements on a map referenced by use of any designated coordinate systems such as latitude/longitude, UTM, user-defined systems, etc.

Topology is the mathematical method used to defined spatial relationships in GIS (Aronoff, 1989). The topological model is basically applied to vector data structure. The spatial relationships can be expressed as, for example, a certain line is noted that it consists of which nodes and a certain polygon is composed of which arcs.

Data structures of the graphic data are separated into two models i.e. vector and raster. A set of lines, which are defined by starting, and end points and some from connectivity represent an object in the vector structure. In the raster model, it is built up by a set of points on a grid. For the same object, each grid cell is assigned by the same which can be numerical value or a color or gray scale (Burrough, 1986) Definitely, the smaller ground size of a grid cell indicates higher degree of accuracy.

Compared to each other, these two structure posses advantage and disadvantage. For example, the raster model is efficient for manipulation and enhancement of digital images while the vector model shows less complex structure but obviously larger storage space is required. However, to save a storage space, a quadtree structure is designed to use as compressed raster format. Additionally, the efficiency of some functions such as ones for network analysis is dependent upon the characteristics of the data structures. The vector model data seems to be more proper for this activity.

Thematic and non-spatial attributes, for instance, types of soil, rock formation and land use can be encoded and linked to the graphic data. These data can be recorded as relational database in forms of tables, which share specific items or fields.

Liveware: There are groups of people dealing with GIS starting from programmers to computer system engineers, system manager, database and application developers, and technical users. However, organizations in Thailand who are using GIS, at present, are in the beginning stage that programmers and system engineers are not required routinely.

GIS functions

By its function capabilities, GIS becomes very useful in field of spatial data analysis. According to Parking (1991), there exist apparently twenty main functions in GIS technique. These main functions can be further divided into more than 120 functions. However, many GIS specialists, namely, Marble (1987) and Aronoff (1989), agree that all function can be groups to be four sets of capabilities to handle

geo-reference data. These capabilities include data input and edit, data storage and retrieval, data manipulation and analysis, and data display and query.

Data input and edit: Data input is how to encode data in various types into GIS. The input data types which cover graphic, attribute, and textual data can be in forms of hard copy (printed) and digital files. In case they are presented as printed format, the graphic data can be encoded to be digital using digitization or scanning to which attribute data are linked later.

Data storage and retrival: The GIS data should be able to manage efficiently. Not only high efficiently in data storage and retrival required in GIS but also data update and security should be provided. This depends on the facilities and capabilities of hardware and software. Redundancy of data should be avoided too because of great time consumption and the storage space wasting of the system.

Data manipulation and analysis: By nature, GIS data are generated as map layers. There fore, GIS analysis function is capable for new layer integration. This function can be used to replace conventional manual methods. Further, due to the automation capability used, GIS function can work for what never been done or never been able to do before by using manual methods. The GIS functions cover from simple analyses to the ones that use the facilities of mathematics and statistics.

Data display and query: Data display and query are functions used to show results to uses. The system should be able to produce the results in hard copy form through printing media. It would also allow querying, which is on-line questioning of the database such as attribute, statistics, measurements, etc.

4.2 GIS DATABASE DEVELOPMENT

GIS database development is considered to be the most tedious and time-consuming activity. But this leads to an achievement of a database, which is very useful. A database is invaluable and meaningful in itself and also for further

applications. Practically, the uses of a high quality database can results in fruitful outputs of GIS analysis.

The basic information for land use planning is the subject covering the environmental geology, socio-economic and lands information. For this study, all of information used in evaluation for land use planning is presented in map form (Figure 4.1 andTable 4.1). The subjects are recorded relating to position, being known as spatial data. These information are created in the processes of input data and the development data base system for land use planning using the Geographic Information System (GIS).

Table 4.1 The Geographic Information System database of environmental geology

Theme	Spatial and attribute database
1	Land tenure - administrative of Amphoe, Tambon, Municipal and sanitary districts
2	Topography - elevation, slope classification and aspect
3	Water resource- water basin, watershed class, stream, water bodies, aquifer and groundwater quality
4	Mineral resource - mineral resources location, mining
5	Geology - geological boundary, units and landforms, fault and joint
6	Geomorphology - geomorphological boundary, units and landforms
7	Construction material - surficial and rock material
8	Soil type - soil boundary, soil type, soil characteristic
9	Forest - forest land, forest use
10	Land use - land use type
11	Tourism - cultural and amenity tourism location
12	Infrastructure – factories, place and public facilities, transportation

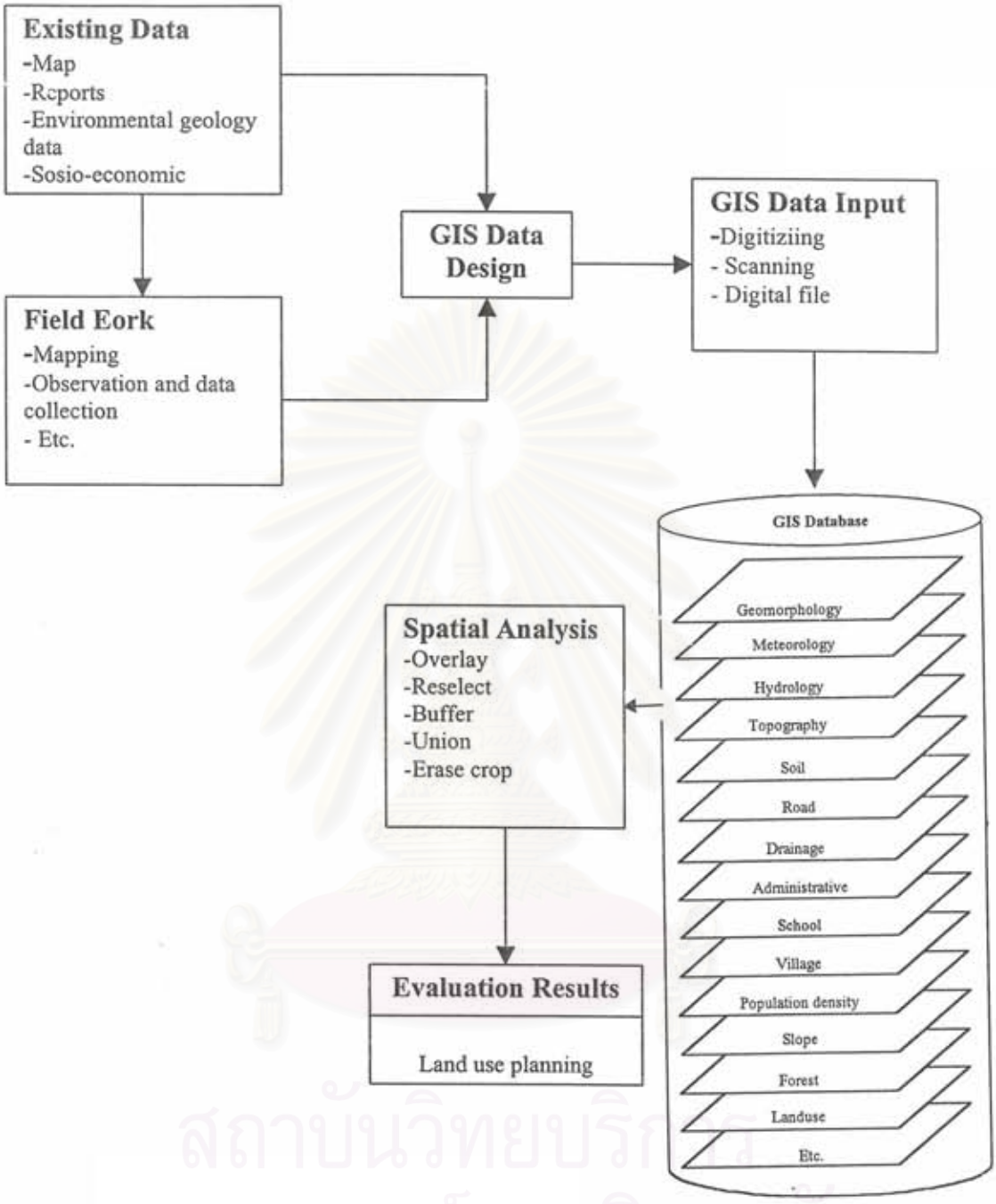


Figure 4.1 Flowchart of the GIS database development

4.3 LAND USE PLANNING

In the study area, the common problems are the implication of human activities on the natural environment, such as mangrove cultivation for shrimp farming, reclamation in the coastal zone, and natural impact mainly coastal erosion. The other problems are insufficient recreation areas, inadequate water supply and lack of utilities. The role of geosciences in land use planning is directly related to these various problems to be performed by planning. The backgrounds of study area and the basic groups of factors affecting land use are reviewed in chapters 1, 2 and 3.

This study is attempted to recommend the regional land use planning for five different development planning propose, notably conservation, carbonate rock, residential, agricultural and industrial potential areas. In order to evaluate the land use potential, the limitation for land use capability is employed. The limitation of land use for each parameter of environmental geology for different development purposes, namely, conservation, carbonate rock, residential, agricultural and industrial potential areas are assigned according to the degree of importance and relevancy. The concern parameter and limitation of environmental geology are decided in Table 4.2. Finally, for each land use of development potential are defined into the suitability potential areas. The discussions show how some environmental geology have been deal within land use planning.

Table 4.2 Limitation of environmental geology factor for evaluated Land use planning (สำนักผังเมือง, ม.ป.ท., ม.ป.ป.).

Environmental geology factor	Subclass	Land use option
1. Topography		
1.1 Slope	0%	Water drainage problem
	0.5%	Large-scale industries
	0.5-6%	Urban area
	>6%	Luxurious development area, luxury housing (expensive coast for development)
1.2 Drainage	Sheet flow	Expensive cost for utilities and infrastructure development
	Stream flow	Conservation, catchment area
	Water flow	Transportation
	Reservoir and pond	Green route, open space
1.3 Flood area	Elevation	Unsuitable for development (Urban, Industrial, etc.)
	Swamp	Unsuitable for development (Urban, Industrial, etc.)
	Flood zone	Unsuitable for development (Urban, Industrial, etc.)
2. Forest land	National forest reserved	Conservation area
	National park	Conservation area
	Wildlife suantary	Conservation area
3. Agricultural land	Mixed orchard	Garden housing area
	Swidden cultivation	Residential area with population density 1.5 person/rai
	Paddy field	Presant area
	Irrigation area	Open space and recreation area
	Range land	Agro-industrial
4. Mineral resources	Mineral resources	Open space for managed product of resources
5. Historical preservation	Ancient remains	Low density residential area related of school, official center, building control of height
	Heritage cultural	Tourism area
6. Natural view	Scenic place	Conservation for tourism area
7. Critical impact	Airport	Limitation of noise contour (buffer zone)
	Heavy industry	Pollution control (buffer zone)
	Highway	Control frontage road, control noise and air pollution (strip zoning),
	River	Green belt in minimum 15 meters strip zoning of pollution control
	Mining	Pollution control (buffer zone)
	Electric station	Limitation height of power line
	Waste disposal site	Buffer zone

4.3.1 CONSERVATION POTENTIAL AREA

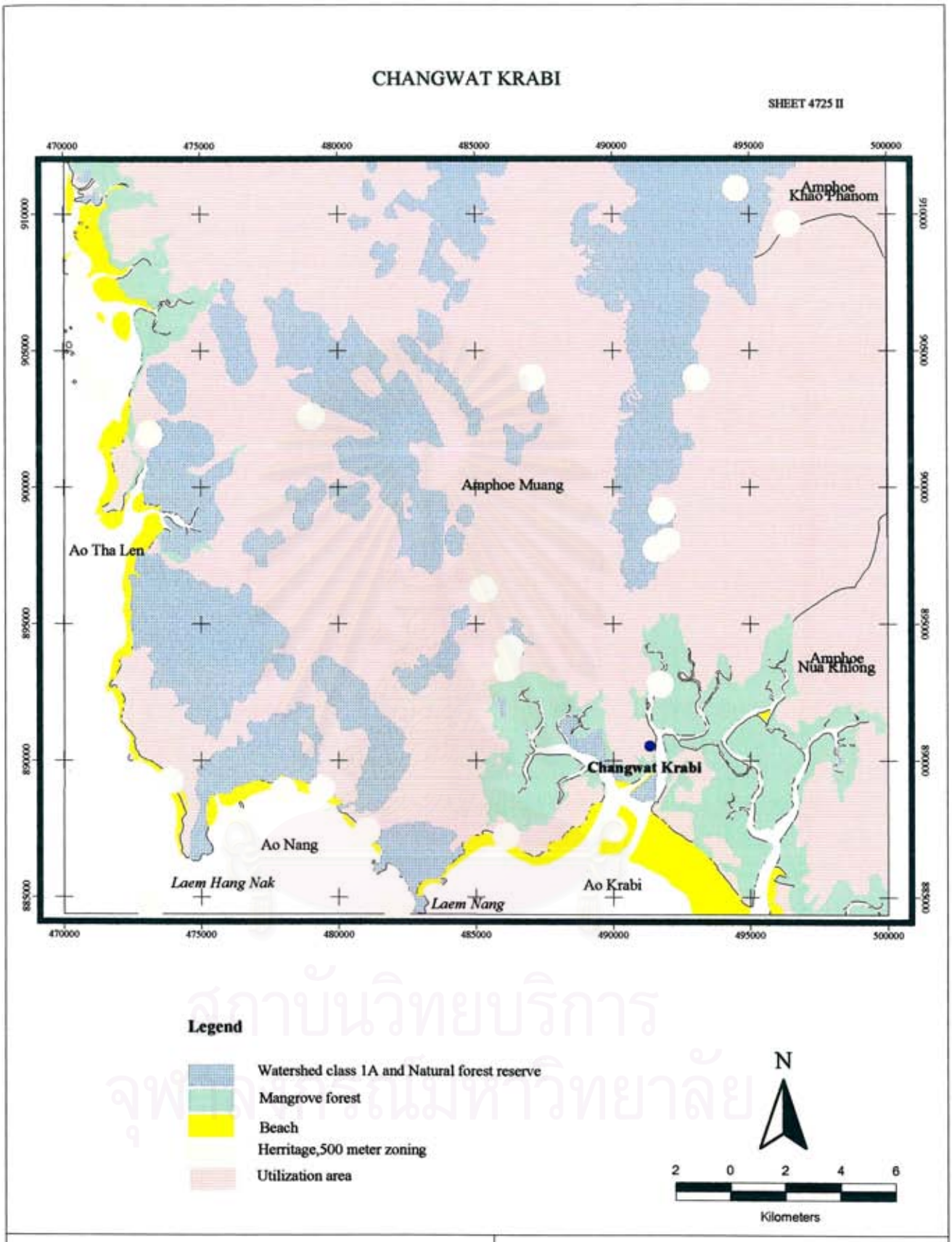
The conservation area must be including in considerable of resources plans. For the conservation potential area, the environmental geology and related parameter concerned are including forest, wildlife, heritage, river and reservoir and natural resources. The portion of the conservation element containing of environmental geology shall be conserved or developed for any propose in the planning.

The conservation areas in a general plan of the study area are address in type of the open space as described in Table 4.3 and Figure 4.2.

The processes of evaluation for conservation area using GIS are presented in Figure 4.3.

Table 4.3 Limitation of environmental factor for evaluated conservation potential area (after Office of Environmental Policy and Planning, 1992).

Environmental geology factor	Subclass	Limitation
1. Forest land	National forest reserves	Buffer zone
	National park	Buffer zone
	Wildlife sanctuary	Buffer zone
2. Watershed classification	Watershed class 1A	Buffer zone
3. Water supply	Stream	Green belt (strip zoning)
	Reservoir	Buffer zone
4. Infrastructure	Highway, road	Strip zoning (control pollution)
5. Historical preservation	Ancient remains	Buffer zone
	Heritage cultural	Buffer zone
6. Natural view	Scenic place	Buffer zone
	Recreation area	Buffer zone



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Department of Geology, Chulalongkorn University

Figure 4.2 Conservation potential area map

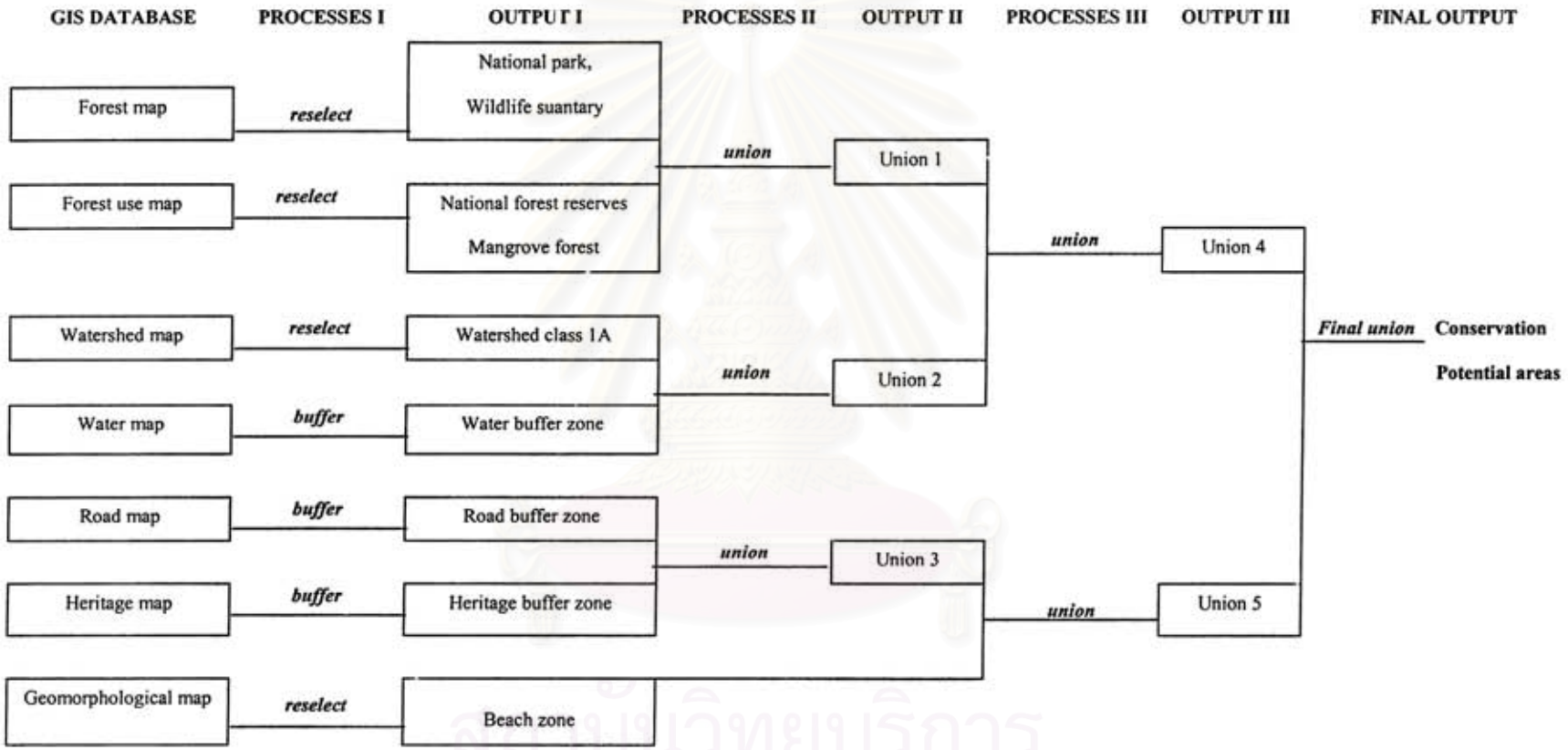

Figure 4.3 The processes and evaluated conservation potential areas using GIS

4.3.2 CARBONATE ROCK POTENTIAL AREA

For the carbonate rock potential area (Figure 4.4), the environmental geology parameters concerned are rock material with physical and chemical properties. The locations of mining facilities are subject to geological prospectively and site specific factors such as nature of land: location of river; transportation and infrastructures; rivers, roads; population: dense settlement, urban; land use: water protection area, national forest reserve, watershed, wildlife sanctuaries and national park. These site-specific factors are the most important environmental law for the mining industry by the enhancement and conservation of National Environmental Quality Activities in 1992. The office of Environmental Policy and Planning administers it (Table 4.4).

In the further planning, this study proposed the carbonate rocks as a potential area which including location, area, volume and reserve of the carbonate rocks (Table 4.5)

The technical and processes in evaluated carbonate rock potential area are present conclusively in the flow chart procedure (Figure 4.5).

Table 4.4 Limitation of environmental geology factor for evaluated carbonate rock potential area (after Office of Environmental Policy and Planning, 1992)

Environmental geology factor	Subclass	Limitation
1. Forest land	National forest reserve	Buffer zone for conservation
	National park	Buffer zone for conservation
	Mangrove forest	Buffer zone for conservation
	Wildlife sanctuary	Buffer zone for conservation
2. Watershed classification	Watershed class 1A	Buffer zone for conservation
3. Urban Land	High density urban	Buffer zoning 500 meters for control pollution
4. Infrastructure	Highway, road	Buffer zoning 500 meters for control pollution
5. Historical presentation	Ancient remains	Buffer zoning 500 meters for control pollution
	Heritage cultural	Buffer zoning 500 meters for control pollution
6. Natural view	Scenic place and recreation area	Buffer zoning 500 meters for control pollution

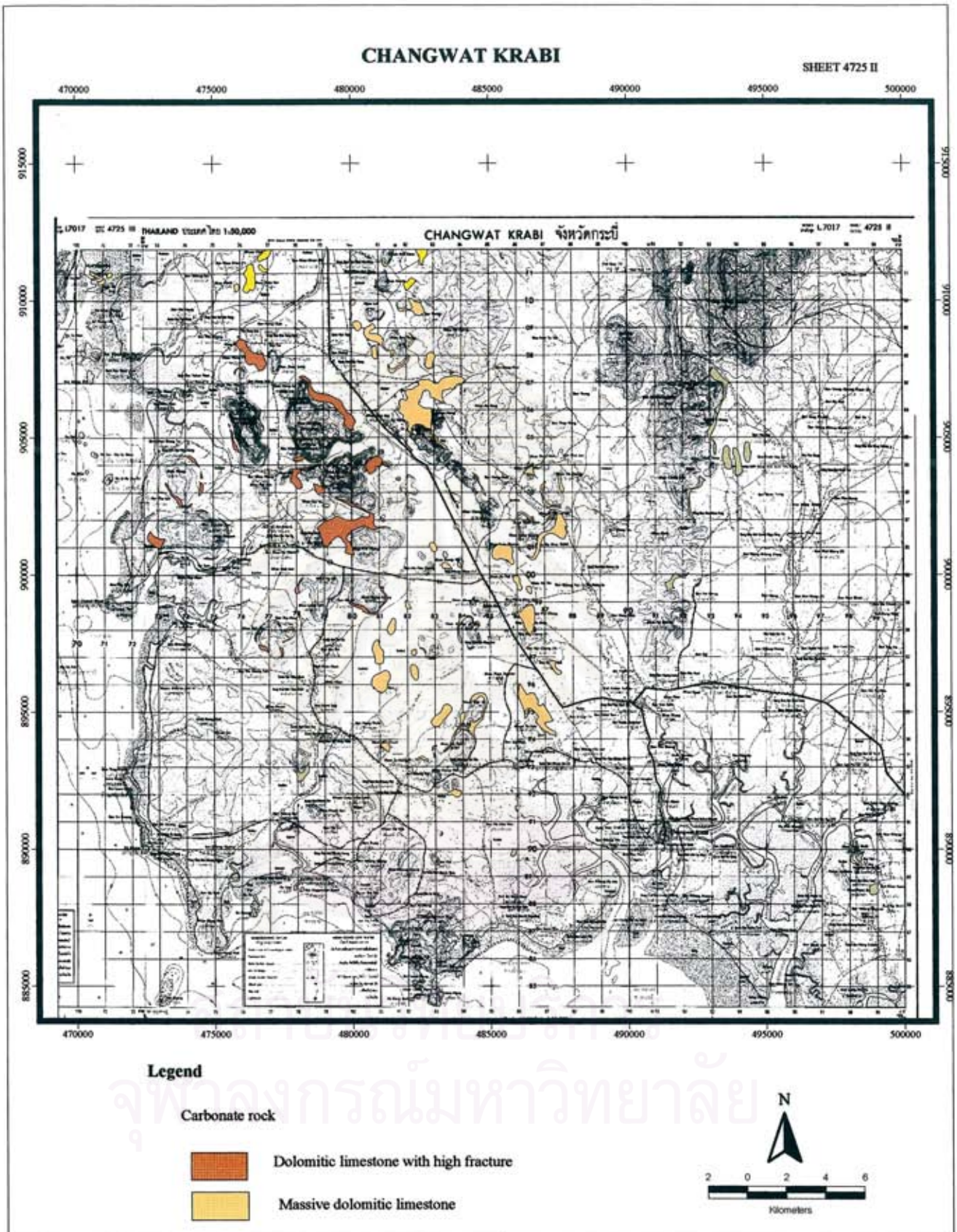

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Figure 4.4Potential of carbonate rocks

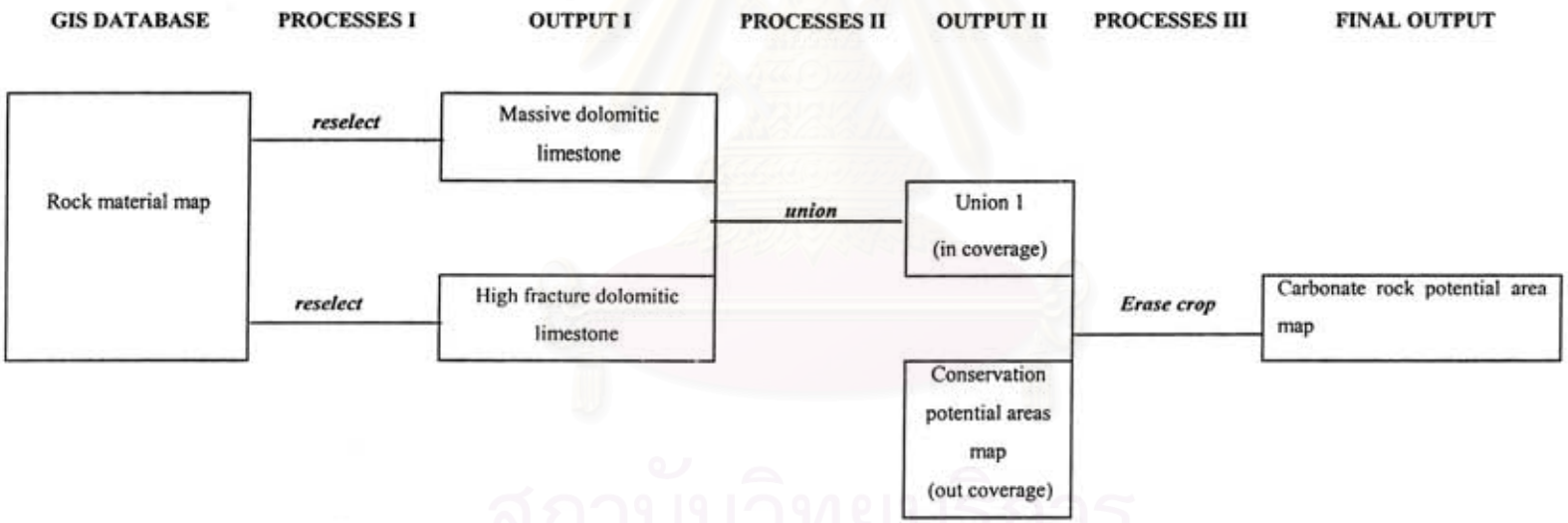

Figure 4.5 The processes and evaluated carbonate rock potential areas using GIS

Table 4.5 Area, volume and reserve of Carbonate rocks potential from the GIS analysis of this study

ID	AREA(m^2)	VOLUME(m^3)	RESERVE(Tons)	HEIGHT(m)	LOCATION
0	117148.31	7	6	80	Khuan Chong
1	40224.93	40225	3048316	50	Khao Mai Kaew
2	130642.13	130642	3048316	70	Khao Huai Na
3	4589.79	22949	57372	15	Khao Nap Nam
5	22857.74	76192	190481	10	Khao Nap Nam
8	2763.82	9213	23032	10	Khao Nap Nam
9	334591.21	17844865	44612161	160	Khao Tham Bot
10	46511.98	155040	387600	10	
11	24199.59	24200	161331	20	Khao Khram
12	8417.29	8417	70144	10	Khao Khram
13	28607.40	572148	1430370	60	Khao Nap Nam
14	1310.17	4367	10918	10	Khao Ban Thung
15	102877.95	34289265	857316	100	
17	38077.42	1013531	2533828	80	Khao To
18	7654.48	9531955	23829888	120	Khao To
19	43035.32	573804	1434511	40	Khao Khom
20	238298.88	9743296	19858240	100	Khao Ban Thung
21	34506.11	690122	1725035	60	
22	424989.55	4249896	10624739	30	Khao Huai Raing
23	153248.85	102066	2554148	20	Khao Chong Lom
24	140925.65	939504	2348761	20	Khao Na Dang
25	20330.06	135534	338834	20	Khao Luk
26	83471.07	1669424	4173554	60	Khao Khram
27	91056.25	1821152	4552813	60	Khao Ban Thung
28	22217.57	370293	925732	50	Khao Ban Thung
29	276206.73	55241135	13810337	60	Khao Khram
30	10722.42	35741	89354	10	Khao Ban Thung
32	32811.37	437485	1093712	40	Khao Ban Thung
33	511242.80	35786997	89467492	210	Khao Wat
34	80234.14	1604683	4011707	60	Khao Ban Thung
36	158261.87	8440633	21101583	160	Khao Na Dang
39	22307.57	126410	316024	17	Khao Nong
40	62096.46	413976	1034941	20	Khao Nong
41	871.16	2904	7260	10	Khao Nong Khain
46	10957.71	18263	45657	5	Khao Nong Khain
49	672371.25	17929900	44824750	80	Khao Na Said
50	62660.81	3759649	9399122	60	Khao Chong Pli
52	2021745.57	88956805	222392013	132	Khao Khuan Klang
54	11319.94	18867	47166	5	Khao Chong Mai
55	37519.98	125067	312667	10	Khao Chong Mai
62	145385.69	2907714	7269285	60	
63	48452.02	807534	2018834	50	Khao Kwang
64	10735.21	7157	17892	2	Khao Kwang
65	97649.98	1302000	3254999	40	Khao Kwang
66	47462.64	237313	593283	15	Khao Kwang

Table 4.5 (cont.) Area, volume and reserve of Carbonate rocks potential from the GIS analysis of this study

ID	AREA(m^2)	VOLUME(m^3)	RESERVE(Tons)	HEIGHT (m)	LOCATION
67	1618.95	8095	20237	5	Khao Sak Nok
68	239184.34	11161936	27904840	140	Khao Sak Nok
70	1398471.38	65261998	1631549894	140	K.Nong Chang Tai
72	95397.93	1271284	3179931	40	Khao Sak Nok
73	208045.74	6934858	17337145	100	Khao Sak Nok
74	2297.25	3829	9573	5	Khao Khain
75	208306.73	8332269	20830673	120	Khao Chong Lom
76	205989.09	5493042	1373261	80	Khao Chong Lom
77	19818.94	397284	743210	45	Khao Sak Nok
78	543738.34	2899938	7249844	160	Khao Na Wua
80	96067.77	640452	16001130	20	Khao Tham Nam
81	64566.75	430455	1076113	20	Khao Na Dang
82	74264.77	2475492	6188731	100	Khao Nong Put
83	95862.47	639083	1597708	20	Khao Na Dang
85	2372.97	79099	19775	10	Khao Kayum
86	15711.98	78560	196400	15	Khao Kayum
87	25035.83	166906	417264	20	Khao Kayum
88	17009.18	113395	283486	20	Khao Kayum
89	197605.01	3952100	9880250	60	Khao Kayum
90	399855.73	21325639	53314097	160	K.Suan Thurian
91	67695.19	1353904	3384760	60	Khao Rang Hat
92	6556.12	43707	109269	20	Khao Rang Hat
93	26760.89	535218	1338045	60	Khao Rang Hat
94	26266.59	525332	1313330	60	Khao Rang Hat
95	57742.12	1924737	4811843	100	Khao Rang Hat
97	43195.03	331162	827905	23	Khao Na Mi
100	143612.27	2872245	7180614	60	K. Khlong Khang
101	91094.37	2429183	6072958	80	K.Ruan Pak Mak
102	40175.90	803518	2008795	60	Khao Na Din
105	1333.87	889	2223	2	Khao Nong Tao
106	8381.87	13970	34924	5	Khao Nong Tao
107	5174.62	17249	43122	10	Khao Nong Tao
108	410261.02	1641044	4102610	120	Khao Nai Chong
109	6697.81	17861	44652	8	
110	113795.28	758634	1896586	20	Khao Chong Ai Mi
111	18279.76	121865	30467	20	Khao Chong Ai Mi
113	29418.19	196121	490303	20	Khao Nak Nui
115	2630.10	1753	4384	2	Khao Nak Nui
117	20250.24	135002	337504	20	Khao Nak Nui
119	7415.73	49438	123596	20	Khao Nak Nui
120	50216.29	669551	1673876	40	Khao Nak Nui
121	5807.85	38719	96798	20	
123	10499.10	34997	87493	10	
124	250979.92	8365864	20914660	100	
125	31252.18	416696	1041739	40	

Table 4.5 (cont.) Area, volume and reserve of Carbonate rocks potential from the GIS analysis of this study

ID	AREA (m^2)	VOLUME (m^3)	RESERVE (Ton)	HEIGHT (m)	LOCATION
126	93141.50	1862830	4657075	60	Khao Nong Kok
127	131115.78	3496421	8741052	80	
128	380540.91	177585785	44396438	140	Ban Thai Thai
129	14620.40	24367	60918	5	Kuan Ta Lam
130	5776.20	38508	96270	20	Kuan Ta Lam
131	811033.69	21627565	54068912	80	Kuan Ta Lam
133	91546.38	1373196	3432989	45	Khao Chong Pli
134	287284.28	4309260	10773150	45	Khao Sai Thai
135	112114.77	747432	1868580	20	Khao Sai Thai
136	35367.09	7073432	1768355	60	Khao Chong Pli
137	3334.73	22232	55579	20	Khao Chong Pli
138	38001.40	253343	633357	20	Khao Chong Pli
139	3840.28	25602	64005	20	Khao Chong Pli
140	4418.52	14728	36821	10	Khao Chong Pli
141	289748.44	11589928	28974820	120	Khao Tha Lae
142	70112.01	8413441	21033603	160	Khao Yan Chuak
144	135477.09	180636	4515903	40	
146	3463.31	22909	57272	20	
148	3377.72	16886	42216	15	
149	5763.53	19212	48029	10	
151	44973.55	374780	936949	25	Khao Tha Lae
152	37575.78	375758	939395	30	Khao Tha Lae
153	16335.94	108906	272266	20	Khao Nui
154	3053.85	20359	50898	20	
155	108493.38	3616446	9041115	100	Khao Kaew Bok
156	46553.15	232766	581914	15	Khao Ao Nam Mao
157	4264.81	14216	35540	10	Khao Ao Nam Mao
158	10875.13	36250	90626	10	
148	3377.72	16886	42216	15	
149	5763.53	19212	48029	10	
151	44973.55	374780	936949	25	Khao Tha Lae
152	37575.78	375758	939395	30	Khao Tha Lae
153	16335.94	108906	272266	20	Khao Nui
154	3053.85	20359	50898	20	
155	108493.38	3616446	9041115	100	Khao Kaew Bok
156	46553.15	232766	581914	15	Khao Ao Nam Mao
157	4264.81	14216	35540	10	Khao Ao Nam Mao
158	10875.13	36250	90626	10	

Area = m^2 Height of area = m

Volume = m^3 = 1/3 x area x height of area

Reserve = Metric ton = 2.5 (Specific gravity of carbonate rocks x volume)

4.3.3 RESIDENTIAL POTENTIAL AREA

The present residential planning in the study area discusses within the framework of local residential land use planning and emphasizes the role of environmental geology. In the application for residential potential area, the environmental geology parameters concerned are geology, topography and landform, slope, water supply, infrastructure, existing land use and land cover, construction material and natural hazard. The limitation of these parameters for residential land use planning is further limited of different capability values. Finally, the residential potential areas are evaluated on the base of environmental factors summarized and presented in Table 4.6. In the further planning, this study proposed the residential potential area as a suitable potential area as show in Figure 4.6.

The technically and processes in evaluated the residential potential area are presented conclusively in the flow chart procedure (Figure 4.7).

Table 4.6 Limitation of environmental geology factor for evaluated residential potential area (สำนักผังเมือง, ม.ป.ท., ม.ป.ป.).

Environmental geology factor	Subclass	Limitation
1. Topography		
1.1 Slope	0.5-6%	Residential area
1.2 Flood area	Elevation	0-10 meters above mean sea level (buffer zoning)
	Swamp	Buffer zone
	Flood plain	Buffer zoning
1.3 Drainage	Stream	0.15-5 kilometers
	Reservoir and pound	Within 5 kilometers (buffer zone for green route and open space)
2. Infrastructure	Access road and highway	0.15-20 kilometer
3. Forest land	National forest reserve	Buffer zone
	National park	Buffer zone
	Wildlife sanctuary	Buffer zone
	Mangrove forest	Buffer zone
4. Watershed classification	Watershed class 1A	Buffer zone
5. Existing land use and land cover		
5.1 Urban land	Urban land	Urban area
5.2 Agriculture land	Mixed orchard	Residential area (rural housing)
	Swidden cultivation	Residential area (Population density 1.5 person/rai)
	Paddy field	Peasant area
6. Mineral resources	Mineral resources	Open space for the manage product of resources
7. Historical preservation	Ancient remains	Open space for conservation, tourism
	Heritage cultural	Open space for conservation, tourism
8. Natural view	Scenic place	Open space for tourism and recreation
9. Construction material	Rock material	Within 50 kilometers

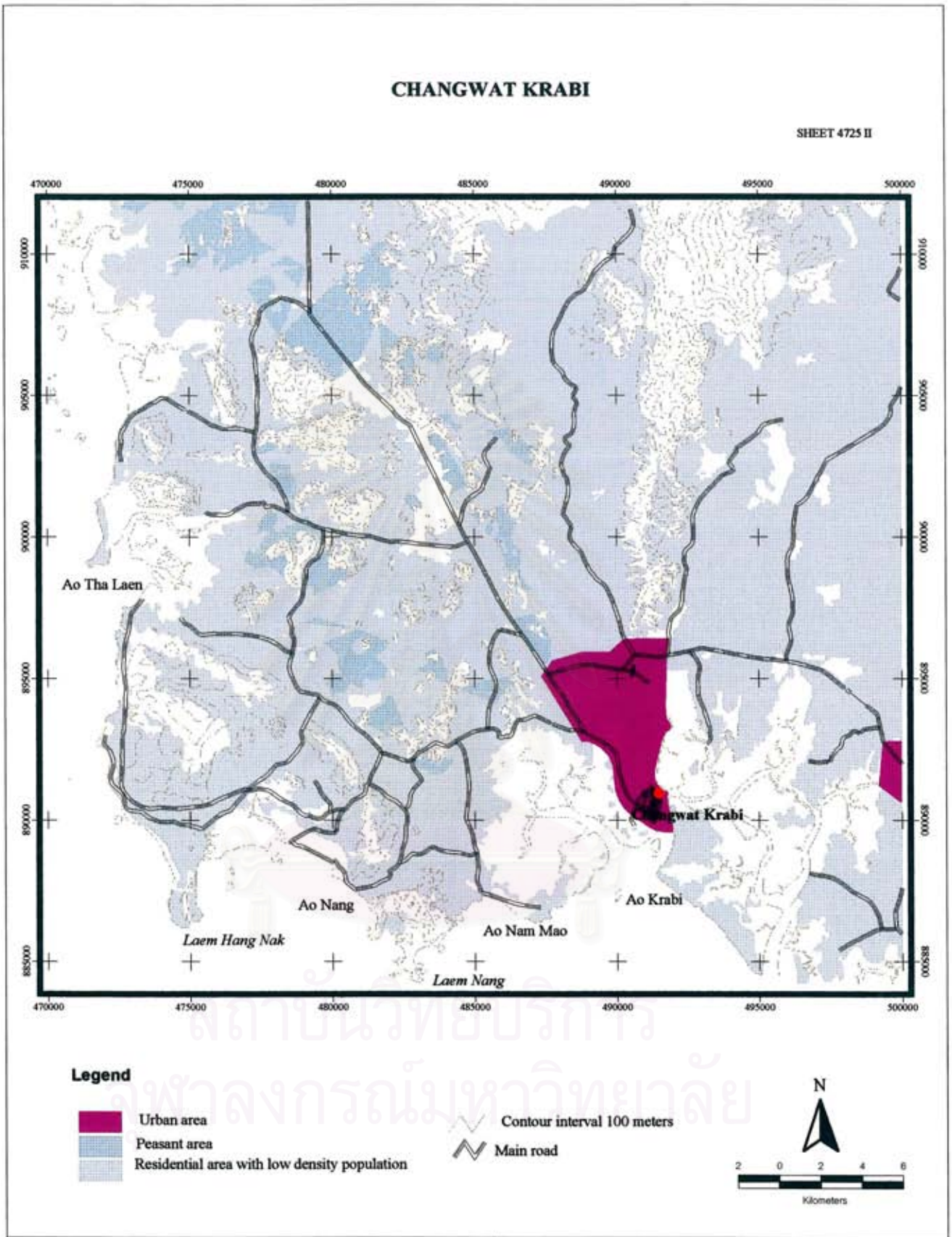

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Figure 4.6 Residential potential areas map

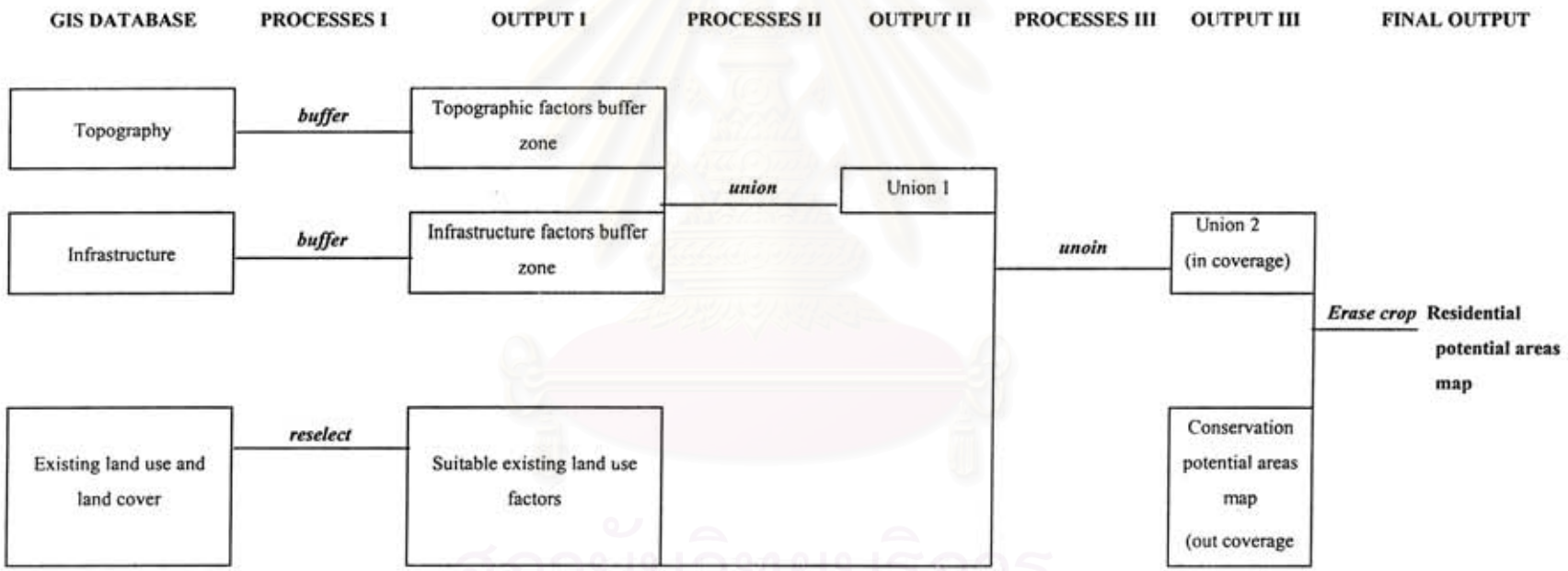

Figure 4.7 The processes and evaluated residential potential areas using GIS

4.3.4 AGRICULTURAL POTENTIAL AREA

Agricultural land use development in the study area is subject the existing land use prospectively and information of the aerial photography interpretation. The recommendation of the development potential for agricultural purpose is base on soil permeability, existing land use and land cover, slope, surficial deposit, topography and landform, and transportation. Each of environmental factors is further limited into different capability values according to the suitability. Finally, the agricultural potential areas are evaluated on the area base on environment factors summarized and presented in Table 4.7. In the further planning, the area of agriculture generally occupies the foot-slope of hill and mountains consist of rubber, perennial crops and oil palm. The area of low land, such as residual deposit, terrace and alluvium deposit are consist of paddy field, mixed garden, vegetable and other agriculture. Especially the area of rubber, perennial crops and oil palms were focused here because the status of local government supported this activity. The map recommended land use for agricultural potential area as a suitable potential as show in Figure 4.8.

The technical and processes in evaluated the residential potential areas are presented conclusively in the flowchart procedure (Figure 4.9).

Table 4.7 Limitation of environmental geology factor for evaluated agricultural potential area (สำนักผังเมือง, ม.ป.ท., ม.ป.ป.).

Environmental geology factor	Subclass	Limitation
1. Topography		
1.1 Slope	Within 5%	Green belt (buffer zone)
	5-20%	Agricultural area
1.2 Drainage	Stream	0.10-5 kilometers
	Reservoir, pond	0.10-5 kilometers
1.3 Flood area	Elevation	10 meters above mean sea level (buffer zone)
	Swamp	Buffer zone
	Floodplain	Paddy field
2. Forest land	National forest reserve	Buffer zone
	National park	Buffer zone
	Wildlife sanctuary	Buffer zone
	Mangrove forest	Buffer zone
3. Watershed classification	Watershed class 1A	Buffer zone
4. Existing land use	Agricultural land	Agricultural area
	Urban land	1-5 kilometers (buffer zone)
	Heavy industrial	1-5 kilometers (buffer zone)
5. Infrastructure	Highway	0.10-20 kilometers
6. Historical preservation	Ancient remains	Buffer zone
	Heritage cultural	Buffer zone
7. Natural view	View place	Buffer zone

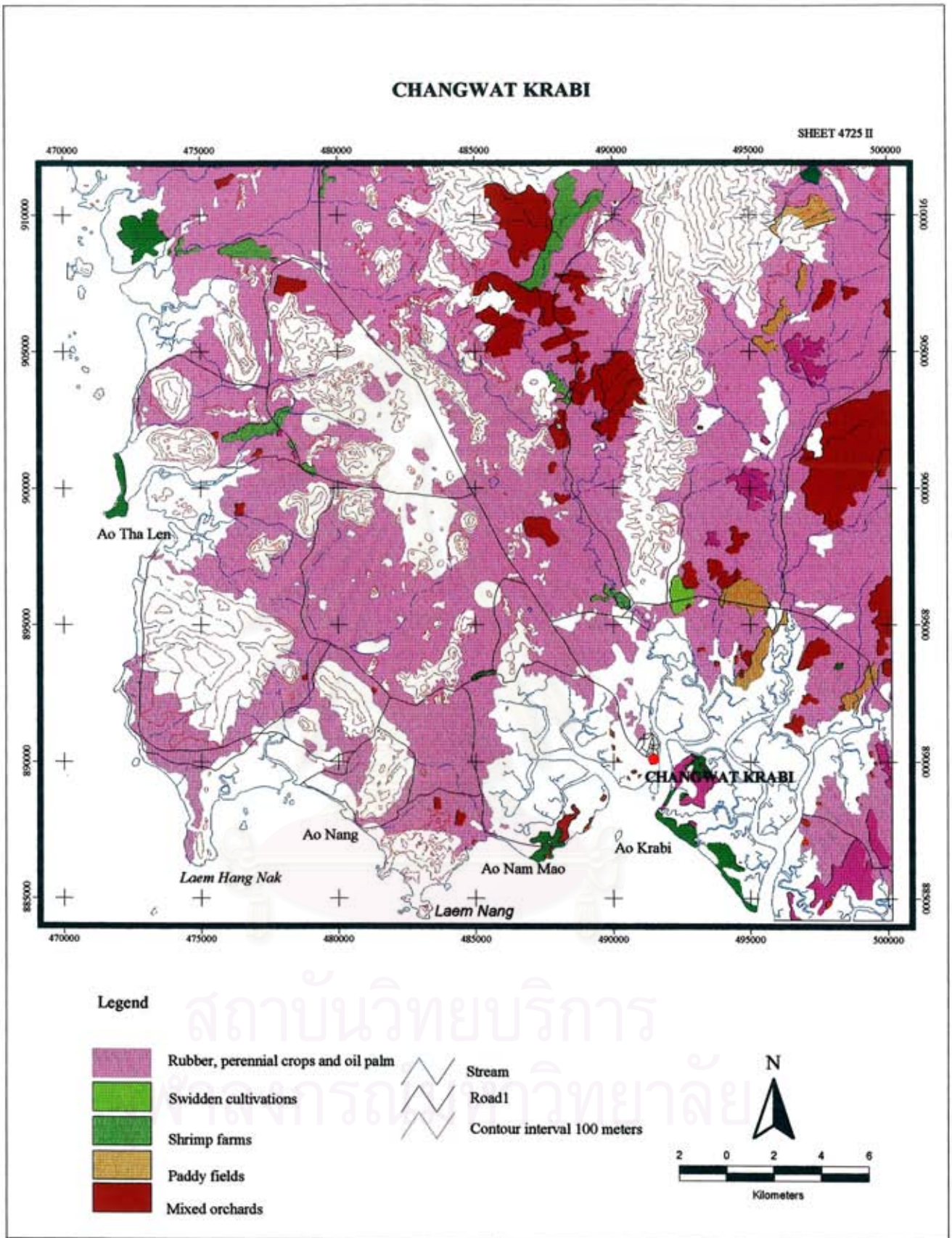

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Figure 4.8 Agricultural potential areas map

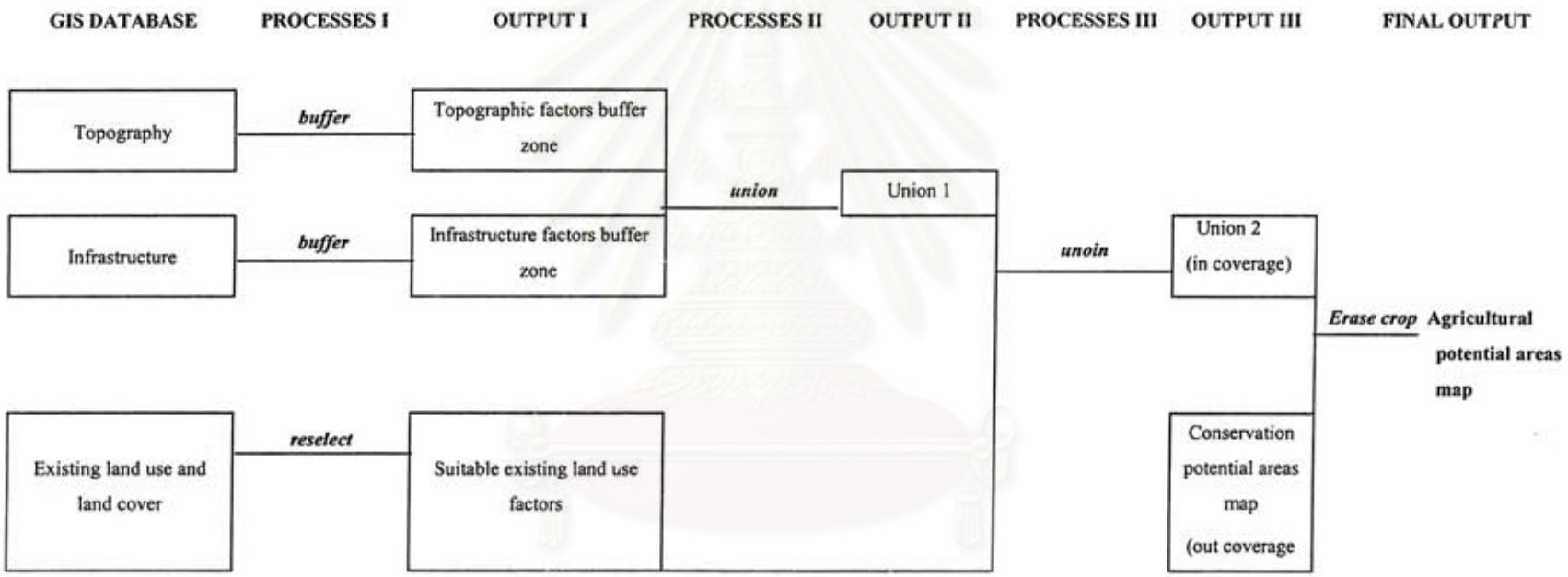

Figure 4.9 The processes and evaluated agricultural potential areas using GIS

4.3.5 INDUSTRIAL POTENTIAL AREA

The location of industrial facility is subject to geological prospectively and independent on the choice or proximity of markets. Accordingly, large-scale industries are designed for specific sites and the environment effects. The site-specific factors of industrial development on environment geology are topography and landform, transportation and infrastructure, existing land use, slope, foundation, construction material and others (marine geological condition and hazard). The limitation of these parameters for industrial development is further limited of different capability values (Table 4.8). Finally, the industrial potential areas are evaluated on the base of environmental factors as presented in Figure 4.10.

The technically and processes in evaluated the residential potential area are presented in the flow chart procedure (Figure 4.11).

Table 4.8 Limitation of environmental geology factor for evaluated industrial potential area (สำนักผังเมือง, ม.ป.ท., ม.ป.ป.).

Environmental geology factor	Subclass	Limitation
1. Topography		
1.1 Slope	Within 5%	Heavy industrial area
	15-30%	Light industrial
1.2 Drainage	Stream	0.10-50 kilometers
	Reservoir	0.10-50 kilometers
1.3 Flood area	Swamp	Buffer zoning
	Flood plain	Buffer zoning
2. Forest land	National forest reserve	Buffer zoning
	National park	Buffer zoning
	Wildlife sanctuary	Buffer zoning
	Mangrove forest	Buffer zoning
3. Existing land use	Agricultural land	Agro-industrial area
	Barren land	General industrial area
	Urban and residential land	General industrial area
4. Infrastructure	Highway and road	0.015-20 kilometers
	Port and harbor	0.015-50 kilometers
6. Historical preservation	Ancient remains	Buffer zone
	Heritage cultural	Buffer zone
7. Natural view	View place	Buffer zone

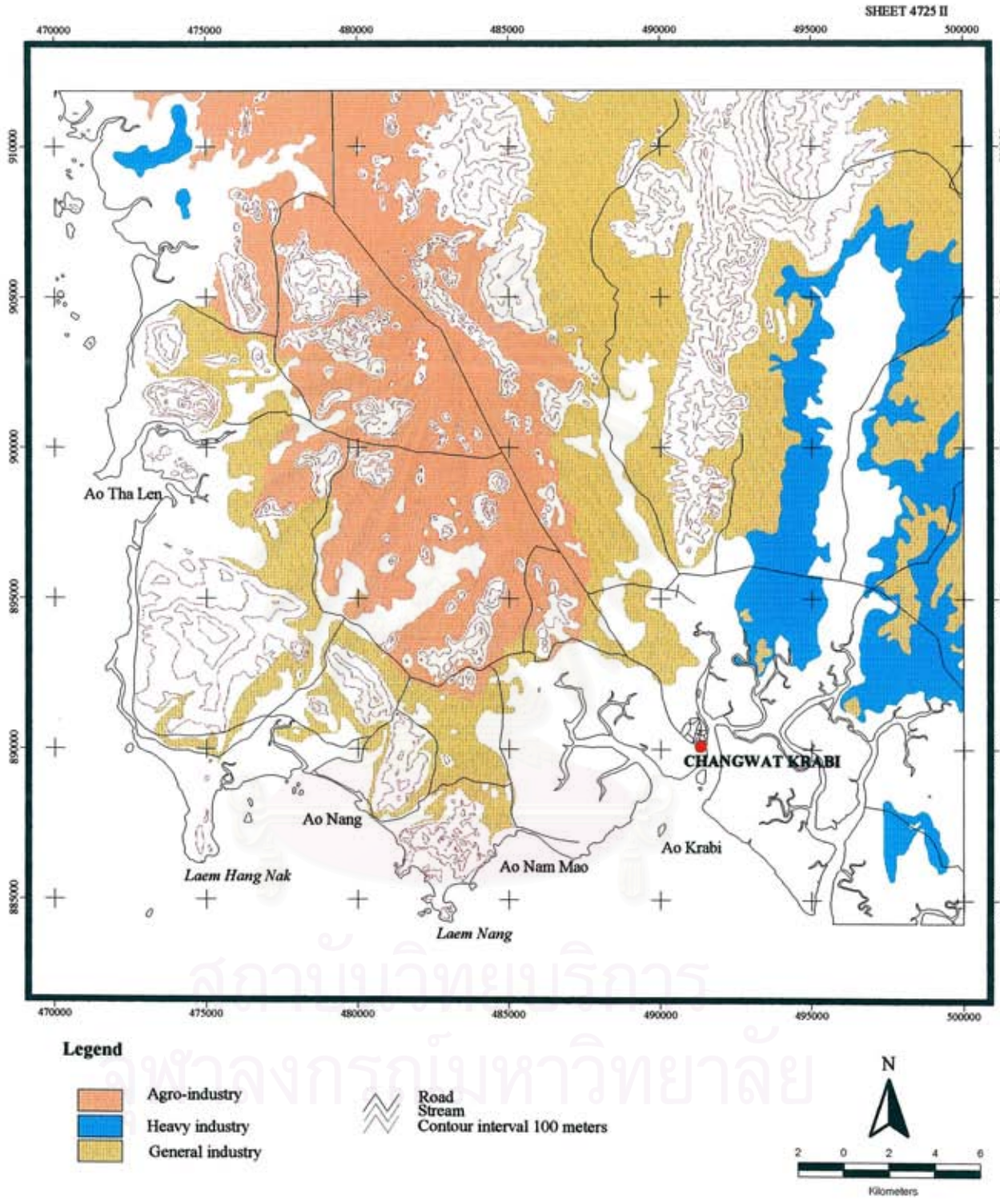

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Figure 4.10 Industrial potential areas map

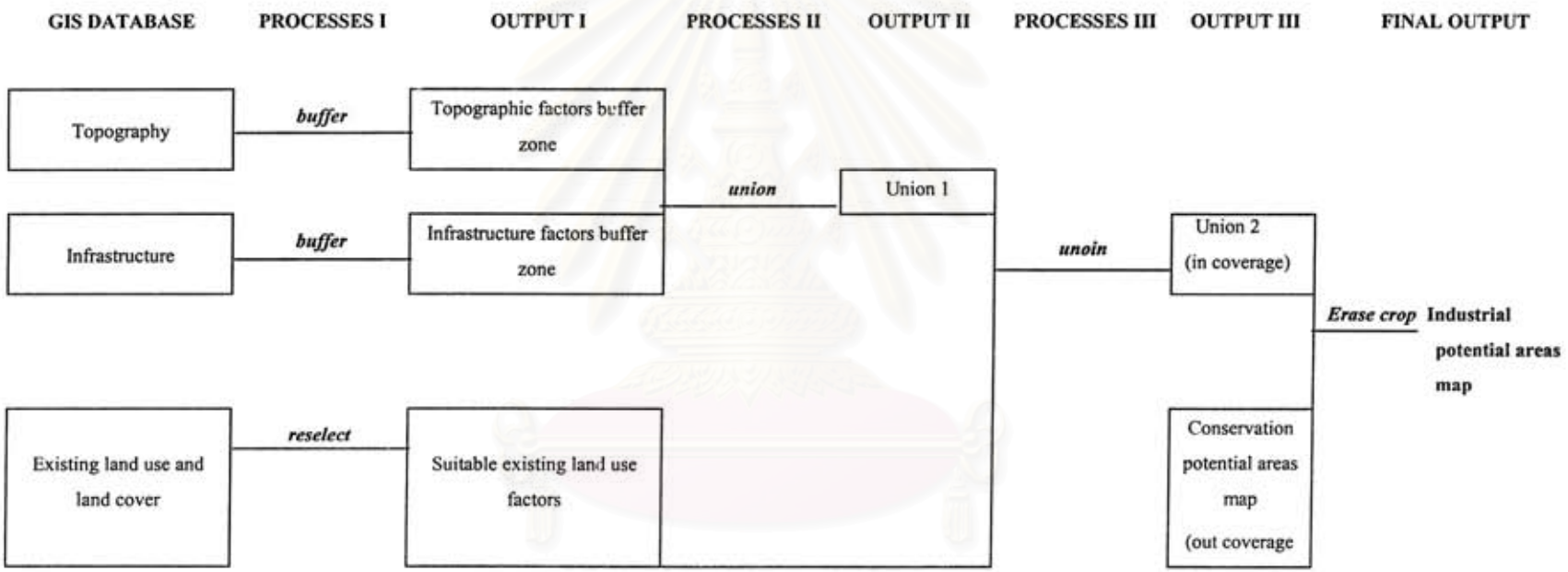

Figure 4.11 The processes and evaluated industrial potential areas using GIS

4.4. RECOMMENDATION

The environmentally sensitive resources and other restriction to general development planning, namely forest land, river and reservoir, harbors, wildlife, heritage, recreational area, and natural resources have been address type of conservation area. The conservation potential areas are limited factors of environmental parameter, which must be given to the negative parameters of every development planning on these value and resources.

Note that, the emphasis of the present investigation has been laid upon developing the appropriate methodology to transfer the portray geological data and related information for the planner particulary decision maker. The usage of limitation of environmental parameters in evaluating the land capability for five different purposes is administrated by the office of Environmental Policy and Planning and the office of Town and Urban Planning, and arbitrary. The adoption of various limitations values for each environmental geological factor primarily aims at demonstrating the evaluation processes in more quantitative terms. It is also realized that the most efficient value judgement system must be based upon wisdom of numerous expertises in specific field concerned.

Finally, the development potential for conservation, carbonate rock, residential, agricultural and industrial purposed of the studied area including environmentally sensitive area have been evaluated and presented in form of maps, shown in this chapter. These maps would allow that preliminary assessment on development planning particularly regarding conservation, carbonate rock, residential, agricultural and industrial purpose to be carried out easily.

In order to make the finding of present investigation most effective and practical for actual planning and decision making purposes, it is recommended that additional study to verify the limitation value or the weight-rating system and to incorporate other relevant factors into consideration are essentially required. Furthermore, detailed site selection analysis, environmental impact assessment, as well as the public hearing activities should be carried out.

CHAPTER 5

DISCUSSION AND CONCLUSION

According to the study of "Environmental geology of the coastal land of Changwat Krabi for land use planning using GIS", the study area has continuously developed rapidly in many sectors, such as tourism, aquaculture, commercial and industrial development. The effect of human activity is most extremely sensitive to disturbance. In view of the predicted increase of pressure in the coming decades, not only by natural impacts but possibly even more by human action. It is necessary to development action plans, for the developments of these areas in harmony with nature. The coastal and land use development planning and management must be undertaken in the context of environmental conservation, protection and development, so that the benefits obtained from natural resources are optimized forever. The study can be summarized and discussed as follow.

5.1 The objective of study, aims at the acquisition, analysis and evaluation of environmental geological data and information as well as the socio-economic and cultural conditions, including development policy in order to identify the development potentials of the area for further land use planning. The Geographic Information System, GIS has been employed to assist the study as much as possible.

This study has focussed on environmental geology and coastal environmental problems, especially in the application of environmental data in coastal zone management and land use planning. The application on environmental geology to sustain development has carried out.

5.2 Database development and information, framework concepts in constructing of data base and information system are formed according to the result of the field investigation and previous work. They are as the following.

All map topics and information in environmental geology, and socio-economic must be collected and demonstrated.

Information collected is categorized to construct a GIS database in form of thematic map and statistical data.

GIS database system prepared for land capability development options must be easily updated and evaluated whenever necessary.

The result of analysis and evaluation are presented in map form and statistical data, showing land capability for development options.

5.3 For the implementation of coastal and land use planning, it will be desirable to use a Geographical Information System (GIS). It is expected that must be spatial arrangement of data, needed for planning, will be provided by map. The use of GIS will enable to handle and process data in a systematic way. In this way, a database on coastal and land use planning can be construct systematically and can be analyzed. The output of database and the result of study will be present in the form of thematic maps and statistical data.

5.4 The natural hazard problem along the coast of study area is mainly coastal erosion. This erosion is due to sea level change, southwest monsoon, and human activities. The measuring of shoreline change in the study area can be determine shoreline position from topographic map, aerial photography and field survey. According to this study, coastal erosion at each site is difference in the rate of change per year. For example, the coastal recession at Ban Khlong Sai is about 1-5 meters/year, Ban Ko Kwang and Ao Nang Beach about 0-1 meter/year, Fossils shell Bed at Ban Laem Pho about 1-5 meters/year and Ban Khlong Prasong more than 5 meters/year.

The classification of erosion including the severely eroding coast is a major impact with the recession rate more than 5 meters/year, the moderate erosion with the rate between 1-5 meters/year and the stable coast with the rate of recession and accretion between 0-1 meter/year.

5.5 In the study area, the common problems are the implication of human activities on natural environment, such as mangrove deforestation for shrimp farming, reclamation in the coastal zone and natural impact mainly coastal erosion. The other problems related to tourism, commercial and industrial development are insufficient recreation area, inadequate water supply and lack of utilities. Planning directly related these various problems to perform the role of geoscience in land use planning.

5.6 Coastal zone management, as related to the coastal erosion problems and human activity in the coastal area must embrace the following activities:

Protection, control and correction: In order to solve coastal erosion problems, a basic policy should be initiates for construction of engineering structure to stabilized beach and shore, such as sea wall, revetment and off shore break water; beach nourishment, and shore restoration, with some concerned for coastal protection measure. Most of coastal parts in the study area are unprotected from coastal erosion. There are about 5 percent of the coastal area to protect with engineering structure such as sea wall along Kabi Yai River mouth, and sea wall and revetment along Hat Noppharat Thara coastline.

Preservation and conservation of natural resources: These areas are bays, estuaries, coastal beaches, wetland and mangrove swamps.

Development of the outdoor recreation and tourism area: Include the areas of outstanding scenic and cultural value. The areas particularly suited for park and recreation purposes are marine national parks and other natural scenic view, such as Hat Noppharat Thara, Ao Nang and Fossil shell bed at Laem Pho; Sea notch, Sea cave and Natural bridge.

5.7 This study is attempted to recommend five categories of land use planning purpose i.e. conservation, carbonate rock, residential, agricultural and industrial potential areas. In order to evaluate these land uses potential on the basis of efficient use of land resources as well as taking the environmental values into consideration, the limitation for land use capability is employed. In chapters 2 and 3, all of environmental geology and socio-economic information have been described and presented aspect by aspect so far as the scope of the present investigation concerned. The concerned parameter and limitation of environmental geology for each land use potential areas are presented in chapter 4.

All of information used in evaluation and results for this land uses planning is created in the processes of the development database system, analysis and evaluation for land use planning using the Geographic Information System (GIS). The final of evaluation of each potential area is expressed in terms of suitability of parameters of environmental geology.

The compilation of regional land use planning was emphasized base on natural resources and geological hazard information, that have been previously described and presented in various geographic information maps. There are five main categories of preliminary planning, including conservation, carbonate rock, residential, agricultural and industrial development purpose.

The conservation potential areas comprise of nine types as follow:

1) National forest reserve
2) Nation park
3) Wildlife sanctuary
4) Mangrove forest
5) Watershed class 1A
6) Beach
7) River and reservoir
8) Mineral resource
9) Tourism and recreation area

The carbonate rock potential area comprise of four factors as follow:

1) Location of carbonate rock potential
2) Area and total area of carbonate rock potential
3) Volume of carbonate rock potential
4) Reserve of carbonate rock potential

The residential potential area comprise of three types as follow:

1) Urban area
2) Peasant area
3) Residential area with low density population

The agricultural potential area comprise of five types as follow:

1) Rubber, perennial crops and oil palm
2) Mixed orchards
3) Swidden cultivation
4) Paddy field
5) Shrimp pond

The industrial potential area comprise of three types as follow:

1) Agro-industrial
2) General industrial
3) Heavy industrial

All of the recommendations are changeable due to appropriate condition of areas. Most of land use patterns will be covered and distributed by exploitation as well as natural resources. More and more used of the glorious resources are directly related to various developments. The suitable one might be undeveloped due to over exploitation of the caused of deterioration of resources. Finally, the environmental problems are originated from over exploitation of natural environment and resources. Appropriate planning and management will aid sustainable use of limited resources, protection, conservation and development as long periods as possible and decrease the environmental problems.

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