การกัดเซาะชายฝั่งบริเวณพื้นที่ลุ่มแม่น้ำปากพนังจังหวัดนครศรีธรรมราช

นาย อภิชาติ ศุภเวชรักษากุล

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COASTAL EROSION AT THE PAK PHANANG RIVER BASIN, CHANGWAT NAKORN SI THAMMARAT

Mr. Apichart Suphawajruksakul

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Geology

Department of Geology
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การกัดเซาะชายฝั่งทะเล บริเวณพื้นที่ลุ่มแม่น้ำปากพนัง จังหวัด นครศรีธรรมราช เป็นปัญหาที่เกิดขึ้นมาอย่างยาวนานและต่อเนื่องตลอดระยะเวลา 30 ปีที่ผ่านมา อันเนื่องมาจากองค์ประกอบต่างมากมาย

วิทยานิพนธ์นี้มุ่งศึกษาถึงการประเมินลักษณะของคลื่นชายฝั่งทะเล กระแสน้ำ และลักษณะการเคลื่อนที่ของตะกอนชายฝั่งทะเล บริเวณชายฝั่งในอ่าวไทย รวมถึงการศึกษา ลักษณะการเปลี่ยนแปลงของชายฝั่งทะเลในบริเวณพื้นที่ลุ่มน้ำปากพนังตั้งแต่อดีตจนถึงปัจจุบัน โดยการเปรียบเทียบภาพถ่ายทางอากาศในปี 2518, 2535, และ 2545 จากการศึกษาพบลักษณะการกัดเซาะเด่นชัดในช่วงระหว่างปี 2535 ถึง 2545 โดยในช่วงปี 2518 ถึง 2535 พบบริเวณที่มีการกัดเซาะสูงสุดบริเวณบ้านปลายทรายมีอัตราการกัดเซาะเฉลี่ยประมาณ 6.84 เมตร/ปี และในช่วงปี 2535ถึง2545 พบบริเวณที่มีการกัดเซาะสูงสุดคือมีอัตราการกัดเซาะมากกว่า 10 เมตร/ปี ที่บ้านปลายทรายซึ่งมีอัตราการกัดเซาะประมาณ 11.3 เมตร/ปี และ บ้านนำทรัพย์ซึ่งมีอัตราการกัดเซาะประมาณ 10 เมตร/ปี และพื้นที่ที่มีอัตราการกัดเซาะประมาณ 6-8 เมตร/ปี ตั้งแต่บ้านเกาะฝ้ายจนถึงบ้านนำทรัพย์

การศึกษานี้ได้รวบรวมข้อมูลที่เกี่ยวข้องกับการประเมินหาพื้นที่ที่ประสบปัญหาวิกฤติเร่งด่วน เพื่อเป็นแนวทางในการเลือกพื้นที่ที่สำคัญในการป้องกันปัญหาการกัดเซาะชายฝั่ง โดยใช้ชั้นข้อมูลอัตราการกัดเซาะ ร่วมกับชั้นข้อมูลการใช้ที่ดิน ชั้นข้อมูลโครงสร้างการป้องกันชายฝั่ง ชั้นข้อมูลการสูญเสียมูลค่าทางเศรษฐกิจ และชั้นข้อมูลดัชนีชี้วัดทางเศรษฐกิจและสังคม พบพื้นที่ที่ควรเริ่มต้นทำการป้องกันปัญหาการกัดเซาะชายฝั่งบริเวณพื้นที่ลุ่มน้ำปากพนังในอันดับแรกสุด คือบริเวณ บ้านโก้งโค้ง

ภาควิชา..................ธรณีวิทยา......................ลายมือชื่อนิสิต........อภิชาติ ศุภเวชรักษากุล........
สาขาวิชา.................ธรณีวิทยา.................ลายมือชื่ออาจารย์ที่ปรึกษา..............................
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Coastal Erosion at Pak Phanang River Basin: Changwat Nakorn Si Thammarat has generally experienced the problem of shoreline erosion and it has been a continual occurrence for 30 years as the result of many elements.

This thesis aims to evaluate of the characteristics of waves, currents, and longshore transport in the nearshore zone of the Gulf of Thailand as well as the historical changes of the shoreline at the Pak Phanang areas. Shoreline comparison in the years 1975, 1995, and 2002, shoreline changes during each period. The study results revealed that there were changes of the Pak Phanang shoreline especially in the period of 1995-2002. In the period of 1975-1995 the highest erosion area was found at Ban Plai Sai which had an approximate erosion rate of 6.84 m/year. In the period of 1995-2003, the high rate of erosion (more than 10 m/year) from this study was found at Ban Plai Sai. It had an approximate erosion rate of 11.3m/year and Ban Nam Sup has an approximate erosion rate of about 10 m/year. The most severe erosion, about 6-8 m/year during 1995-2002, had occurred at the shoreline between Ban Ko Fai to Ban Nam Sap.

This study illustrates collected data relayed to estimate the critical urgent problem areas. The prioritization method of shoreline protection analyses outline the rate of erosion overlaid with layer of landuse, layer of economic-social index, layer of economic loss value and layer of existing shoreline protection measures. The area of ultimate urgency is in the Ban Kong Kong. This area has proved to be high priority due to evident erosion.

Department...............Geology.............Student's signature......อภิชาติ ศุภวัชรีรักษ์สกุล......

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CHAPTER I

INTRODUCTION

1.1 General

Thailand has approximately a total of 2,780 kilometers long shoreline covering 23 provinces. There are about 12 million people (0.23 meter per person) living near the shoreline (Kaiparnond, 2001). The shoreline has various physiographically complex features such as rocky outcrops, salt marshes, mangrove swamps and sandy beaches. Regularly, the shoreline is altered by many factors, both natural processes and human actives such as; waves, wind, tides, sediment supply, sediment transport and structural measure in the shoreline. The alterations can be divided in to 3 classifications: erosion coast, deposition coast and stable coast.

The problems of coastal erosion in Thailand can be found around the Gulf of Thailand and Andaman Sea, especially, the upper Gulf of Thailand in the Petchaburi, Chonburi and the eastern gulf in Rayong provinces (Kaiparnond, 2001).

For the Pak Phanang River Basin area, the sand bar on the beach extends from Talumpuk cape to Songkhla province. These include coastal area of 80 kilometers length, in Pak Phanang River Basin, which are facing a severe erosion rate of more than 5 meters per year (Sinsakul, 2002). This coastal erosion causes by both environmental factors and human activities, which have not only damaged agricultural areas but also people’s properties. Therefore, it is essential to study the causes of coastal erosion in more details in order to find methods of rectification to restore and protect the affected areas.

1.2 Objectives

1). To classify landforms in the Pak Phanang River Basin and to compile the coastal geomorphological map.

2). To study the details of coastal erosion in the Pak Phanang River Basin, Nakorn Si Thammarat province.

3). To propose the preliminary restoration and protection of the affected coastal areas in the Pak Phanang River Basin, Nakorn Si Thammarat province.

1.3 Method of study

This study used integral knowledge of geology, hydrology, oceanology, economy, coastal engineering, GIS, and remote sensing technique. The methodology of this study is divided into three steps. Firstly, the basic data acquisition of previous works and literature studies were collected. Then the field investigation was carried out during November 2004 to January 2005. The data analysis is composed of coastal geomorphology, hydro-meteorological data, oceanographic data and coastal erosion appraisal data. Afterward data were prepared and analyzed by the GIS technique (Figure 1.2). Secondary, the prioritizations of eroded areas were done and preventive measures in the eroded areas were proposed and then illustrated in maps. Finally includes integration of all the results to recommend for solve the eroded area of the study. The methods of study are shown on the schematic chart in Figure 1.1.

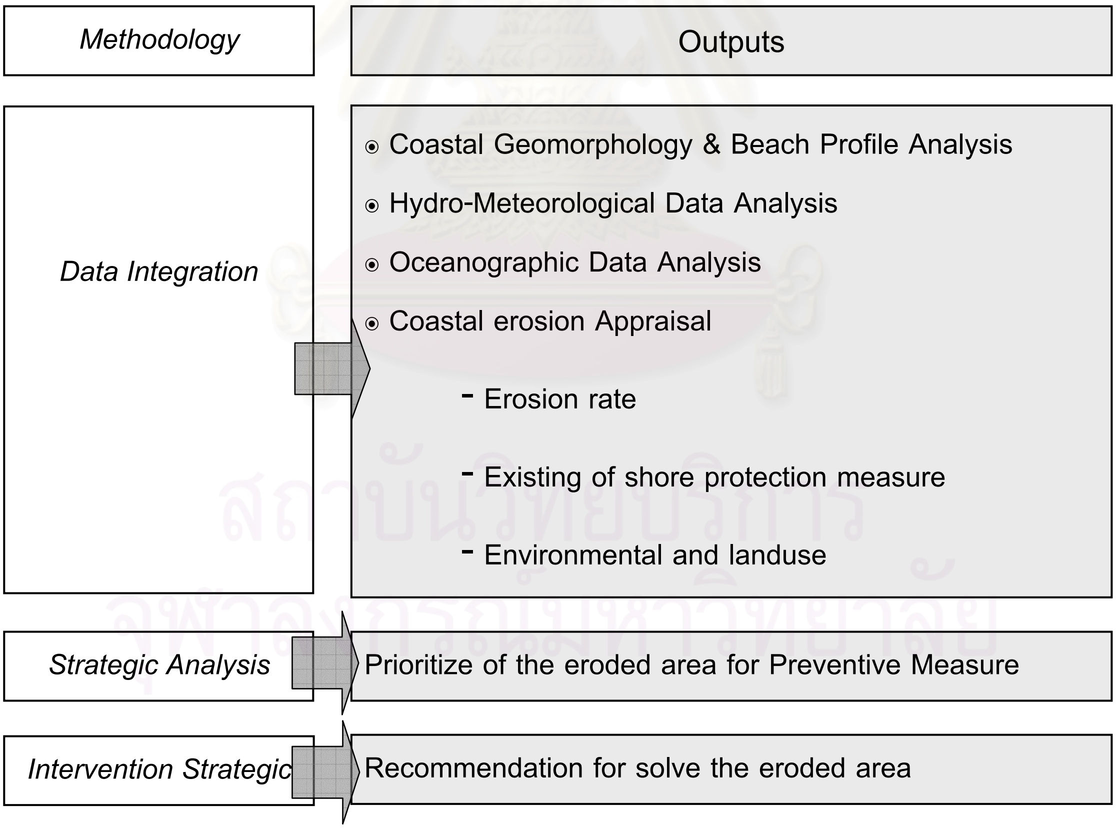


Figure 1.1 Illustrates the methodology used and outputs in this study

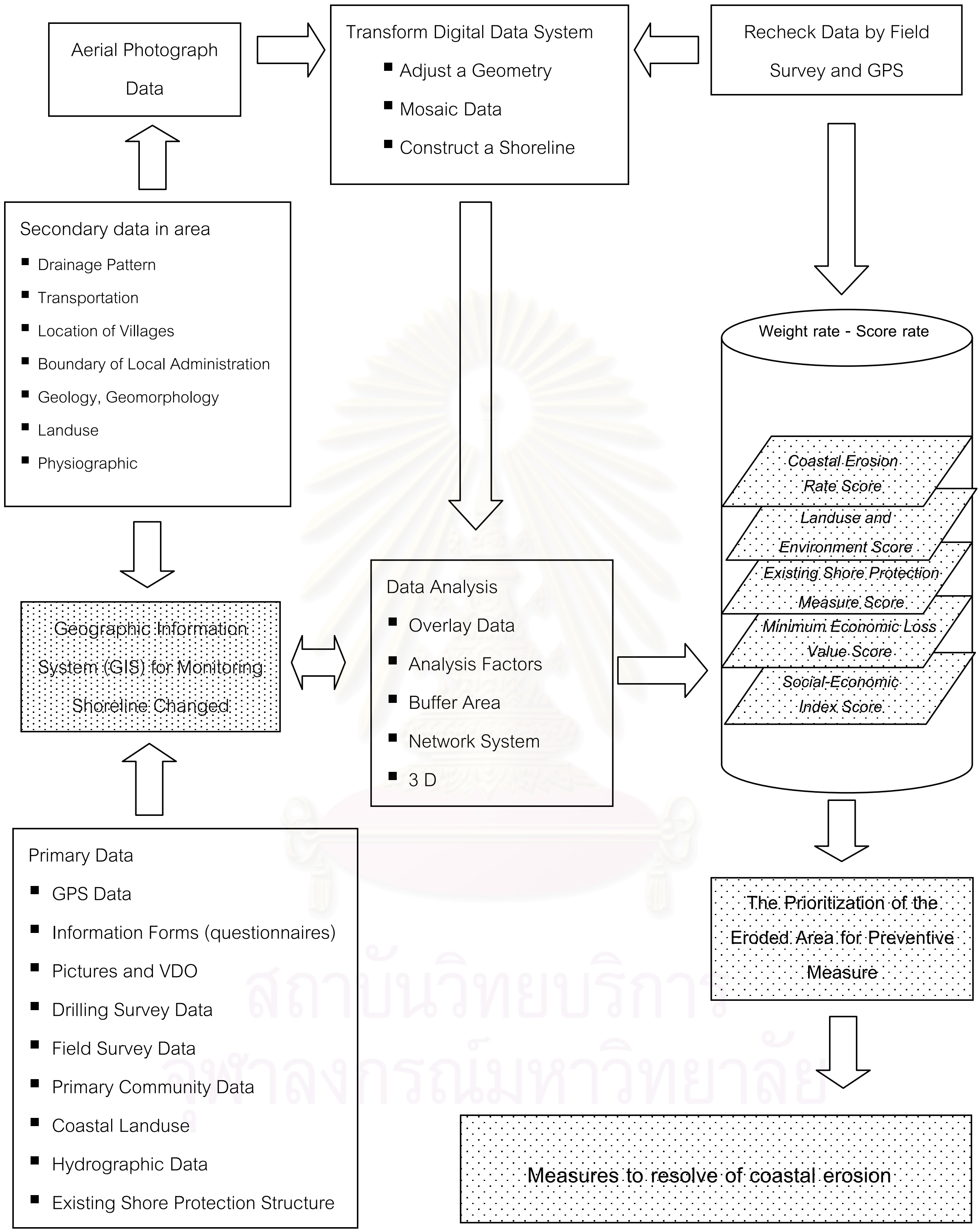


Figure 1.2 Flow chart illustrates the GIS process used in this study

1.4 Literature Review

Ritphring (2002) used aerial photography to study the shoreline changes in the Pak Phanang River Basin in 1966-1967, 1974-1975, 1995, and 1999. The results of his study showed shoreline erosion and silt depositions. The deposit was noted in 1995 - 1999 and the erosion was noted in 1975 – 1995. The most alarming area was in the Ban Kho Fai – Ban Nam Sup which had a maximum erosion rate of about 7.45 m/year. This loss occurred immediately after the construction of a jetty at the mouth of the Bo Khon Ti drainage canal in 1984

Royal Irrigation Department (1998) did field survey of the Pak Phanang River Basin and reported that the geological units were consisted of Paleozoic rocks, Mesozoic rocks, and Cenozoic rocks. In the Cenozoic era sediments and soil were unconformity beds in Quaternary period. The geomorphological units of the area were composed of colluvial deposits, alluvial deposits, river terrace, flood plain and beach sand. The topography in the eastern region was flat and it developed from emergent coast. Next, in the western region were ridges sand that had a depth of about 2- 10 meters and alternate depressions of clay with peat.

Harbour Department (1998) assessed the economics feasibility, engineering aspect and environment impact for the construction of the jetty at Ban Num Sup Nakorn Sri Thammarat province. The results of the study showed coastal changes were mainly caused by north-earth monsoon wind generates, which waves from east, north-east, and south-east directions longshore. The gross of sediment transport was 539,583 m^3 and the net sediment transport to the north was 205,244 m^3.

Nakapadungrat (1987) studied the geology in the Nakorn Si Thammarat Province from the geological map sheets 4925IV and 4925II. The area was 50 percent highland and 50 percent flat. The general geology in this area consisted of Pre Cambrian metamorphic rocks (?), Cambrian rock, Ordovician-Silurian-Devonian-Carboniferous rock, Quaternary sedimentary rocks and Granite

Pre Cambrian rocks are composed of orthogneiss at the bottom and schist and paragneiss at the top. The schistosity rocks trended to be located in the north-south and northeast-southwest directions.

Cambrian rocks consisted of metamorphosed sandstone, quartzite, quartz-schist and deformed conglomerate near the rim of granite rocks

Cambrian-Ordovician rocks consisted of shale, phyllitic shale interbedded with thin limestone and siltstone.

Ordovician rocks constituted of limestone and argillaceous limestone interbedded with thin shale bed and some fossils; cephalopods, crinoid stems, corals

Silurian - Devonian – Carboniferous (SDC) rock made up thick sandstone bed, sandstone interbedded with shale and shale.

Quaternary sedimentary rocks are composed of terrace and colluvium deposits, alluvial and coastal deposits.

And Granite was equigranular medium grained muscovite biotite granite, tourmaline muscovite granite, muscovite – biotite granite and leucocratic granite.

Land Development Department (2000) reported that flood occurred in the Pak Phanang area annually. The affected was area about 1,015,000 rai, which is approximately 60 percent of agricultural area. The causes of flood in the Pak Phanang area could be summarized as follows:

- heavy rain falls in November and December.
- the high tide in the sea prevented drainage of the Pak Phanang River.
- low surface gradient and low drainage rate of water. The gradient in the Pak Phanang area is about 22.36 meters/kilometer. It drains density about 0.64 kilometers/ square kilometers.
- the development of infrastructure in this area that blocks the drainage of water into the sea.

CHAPTER II

COASTAL GEOMORPHOLOGY

2.1 Physiographic Setting

The Pak Phanang River Basin is located in the southern part of Nakorn Sri Thammarat province in southeastern Thailand. The boundaries of this area is approximately located at latitude 7^0 55’ to 8^0 30’ north and longitude 99^0 45’ to 100^0 20’ east and it covers about 3,100 square kilometers or 1,940,000 rai (760,000 acres) spanning 10 districts; i.e. Amphoe Cha-uat, Amphoe Ron Phibun, Amphoe Hua Sai, Amphoe Chian Yai, Amphoe Pak Phanang, Amphoe Chulaporn Amphoe Lan Saka, Amphoe Phraphrom, Amphoe Thung Song and Amphoe Muang Nakorn Si Thammarat (Figure 2.1). The physiography of this river basin can be divided into three physiographic regions such as mountainous terrain in the west, hilly terrain and flat terrain in the middle and floodplain in the east. The western area covers with high mountains trending in N-S direction. The highest peak is about 1,365 meters above mean sea level at the Khao Luang Mountain. In the middle part, along both sides of the rail way are an undulating terrain interchange with flat terrain and swamp in the southern part. The remaining half of the study area is the flat terrain with slope angles of about 1 to 5 degrees. The lowest area is about 1 meter above mean sea level in the southeast end at Ban Kao Yao, Hua Sai district.

2.1.1 Drainage Basin

Pak Phanang River currently drains from into the basin in northeast direction. It has approximately 150 kilometers length and it drainage density is about 0.64 kilometers per square kilometer. The drainage pattern in the Pak Phanang area is dendritic pattern, which its shape is similar to the veins of tree. The drainage is meanderings and floods plain with its tributaries flowing from south-west to the north-east directions. It currently passes Cha-Uoad district, Chian Yai district, and Pak Phanang district. (Figure 2.2)

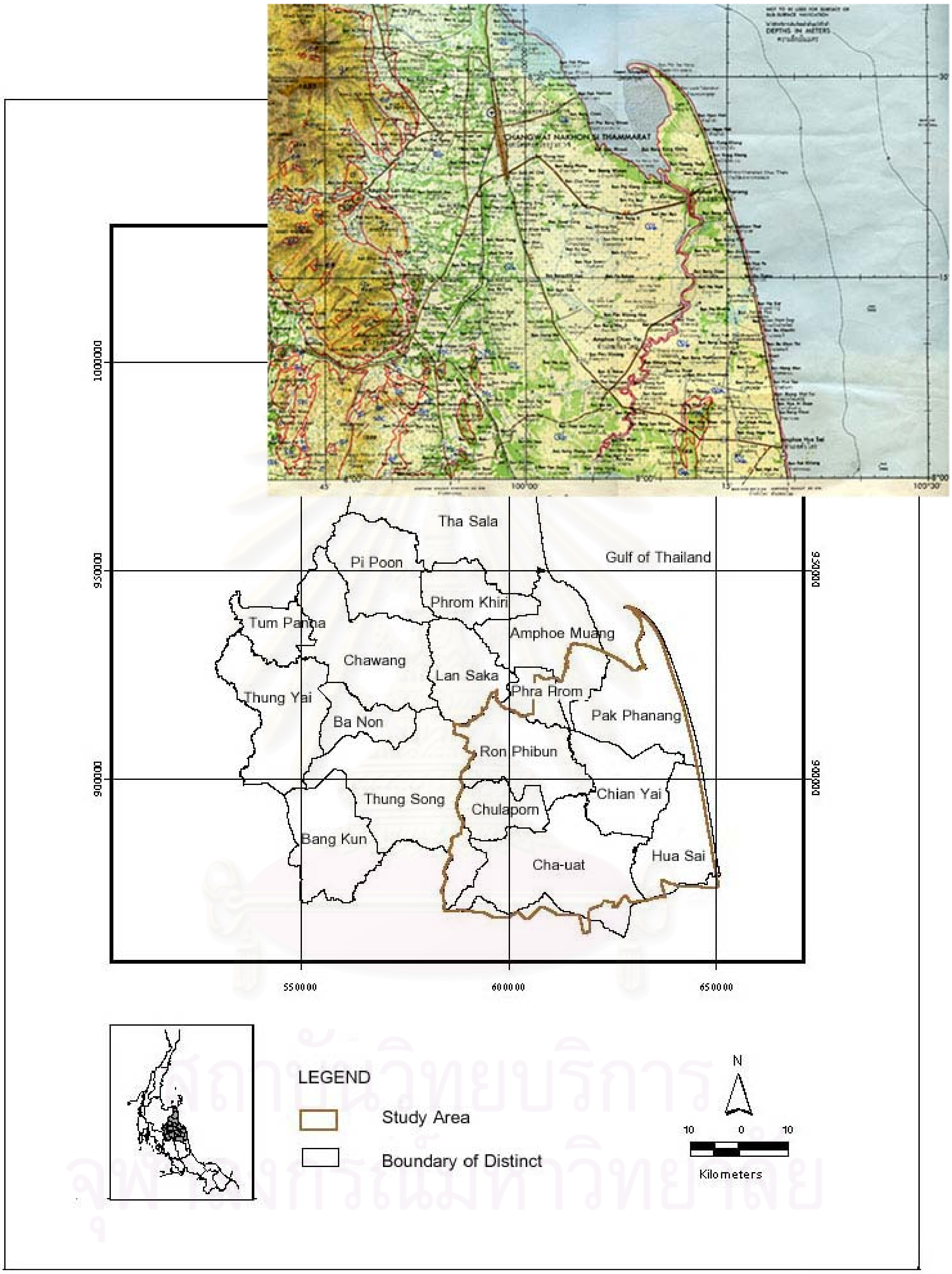


Figure 2.1 Boundary of the study area in the Nakorn Si Thammarat province

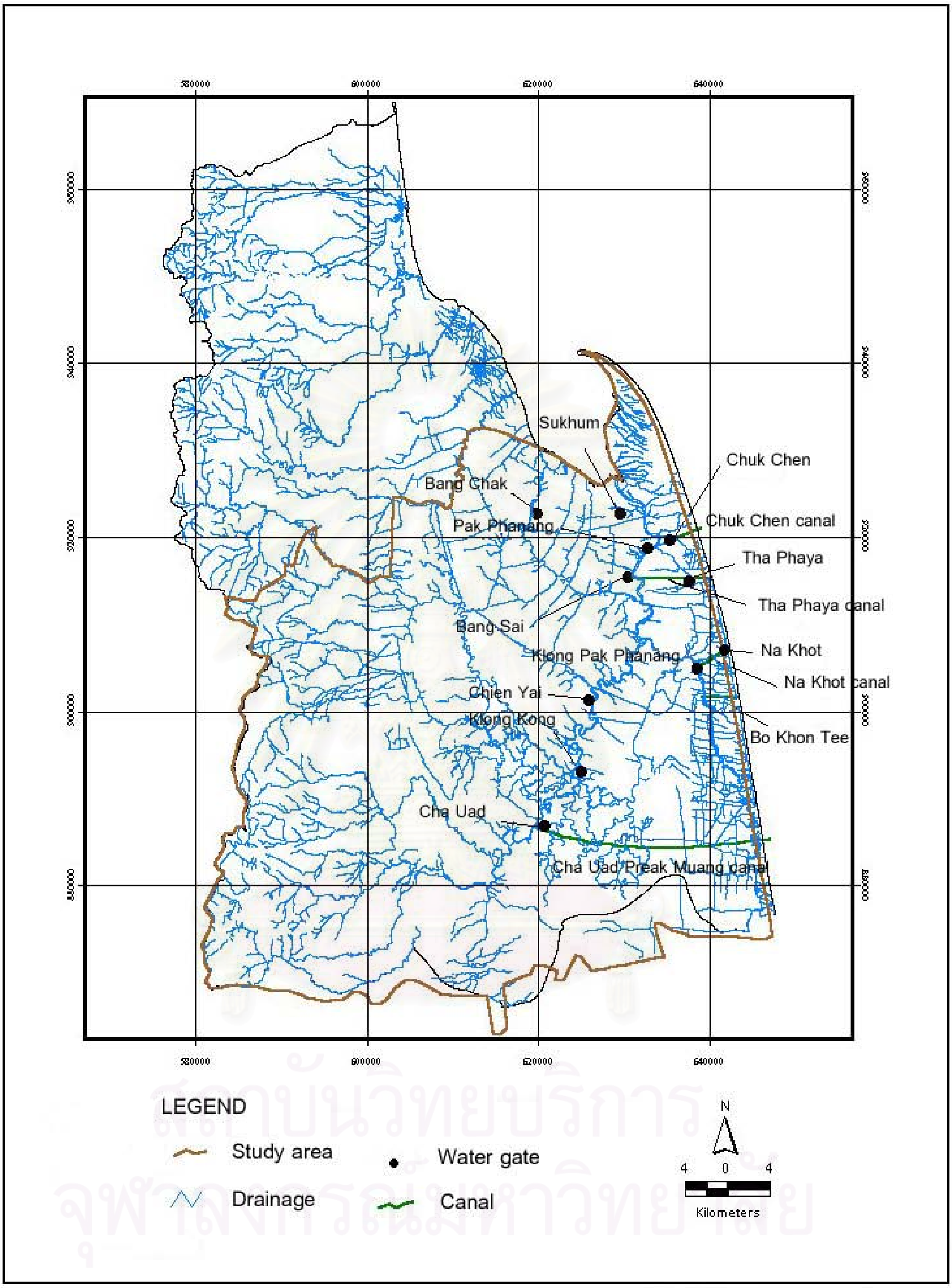


Figure 2.2 Drainage pattern in the study area

2.1.2 Soil

The characteristic of soil in Pak Phanang River Basin can be categorized into 5 geomorphic units based on The Land Development Department (2004). (25 formations in Table 2.1, and Figure 2.3)

- Soil in the sandy beach area: having many types of sand and humus layers. Soil in this area is unsuitable for agriculture.

- Soil in the intertidal flat area: having pH<7 in the low area.

- Soil in the old tidal flat area: the physical and chemical properties of this soil are suitable for rice fields.

- Soil in old lagoon area: the physical property of soil is suitable for rice fields but the chemical property is low quality so that technology and fertilizer are needed to use for this propose.

- Soil in the alluvial terrace area: In the high area, this soil is suitable for farming. It consists of clay and root soil.

Table 2.1 Formation and characteristics of soil in the Pak Phanang River Basin

Formation	Descriptions
Formation 2	Top clay: gray to black gray. Bottom clay: gray spotted brown, yellow, and red.
Formation 3	Top clay: dark gray and brownish gray, Bottom clay: gray, spotted brownish yellow and reddish brown.
Formation 5	Top clay: gray, brownish gray. Bottom clay: pale gray, spotted brownish and brownish yellow.
Formation 6	Top clay: dark gray. Bottom clay: brownish gray, spotted brown or red, and laterite.
Formation 7	Clay: brown or brownish gray, spotted brown, reddish yellow, and brownish yellow.
Formation 10	Top clay: black or dark gray. Bottom clay: gray, spotted brownish yellow, and red.
Formation 11	Top clay: black or dark gray. Bottom clay: gray, spotted brown, yellow, and red.

Formation 12	Clay or rooted clayish silt, and blackish: gray and spotted brown
Formation 14	Top clay: black or grayish black and high organic. Bottom clay: gray, spotted yellow and brown.
Formation 16	Rooted clayish silt: pale brown or brownish gray, spotted brown and yellow or red.
Formation 17	Top rooted clayish sand or rooted clay: black, pale brown, brownish gray, spotted brown, yellow and red. Bottom rooted clayish sand or rooted clay: pale brown, pale gray, grayish pink, and spotted brownish yellow.
Formation 22	Rooted clayish sand and sandy rooted clay: gray or brownish gray and spotted brownish yellow or yellowish brown.
Formation 26	Top rooted clay, rooted clayish clay or rooted clayish sand: brown, yellow, and red. Bottom clay: brown, yellow, and red.
Formation 32	Rooted clay, root clayish clay, root clayish silt and interbeded with sand: brown or yellowish brown.
Formation 34	Rooted clayish sand: brown and yellow or red.
Formation 39	Rooted clayish sand: brown and yellow or red.
Formation 42	Sandy clay: gray to white and high organic brown or red.
Formation 43	Sandy clay: gray, gray to white or brownish gray and some shell fragments.
Formation 45	Clay or rooted clay and gravel (rounded) or laterite: pale brown and yellow or red.
Formation 50	Top (50cm.) rooted clayish sand or rooted clayish clay and sand. Bottom (50-100cm.) clay and laterite: brown and yellow or red.
Formation 51	Rooted clay with rock fragments (sand and quartz): brown and yellow or red.
Formation 53	Top rooted clay or rooted clayish clay. Bottom (50-100cm.) laterite with rock fragments.
Formation 57	Organic clay (40-100cm.): black or brown and gray.
Formation 58	Organic clay (>100cm.) and small plant (found in marsh): black or brown and gray.
Formation 62	Top (have a slope>35%) rock fragment and loose blocks.

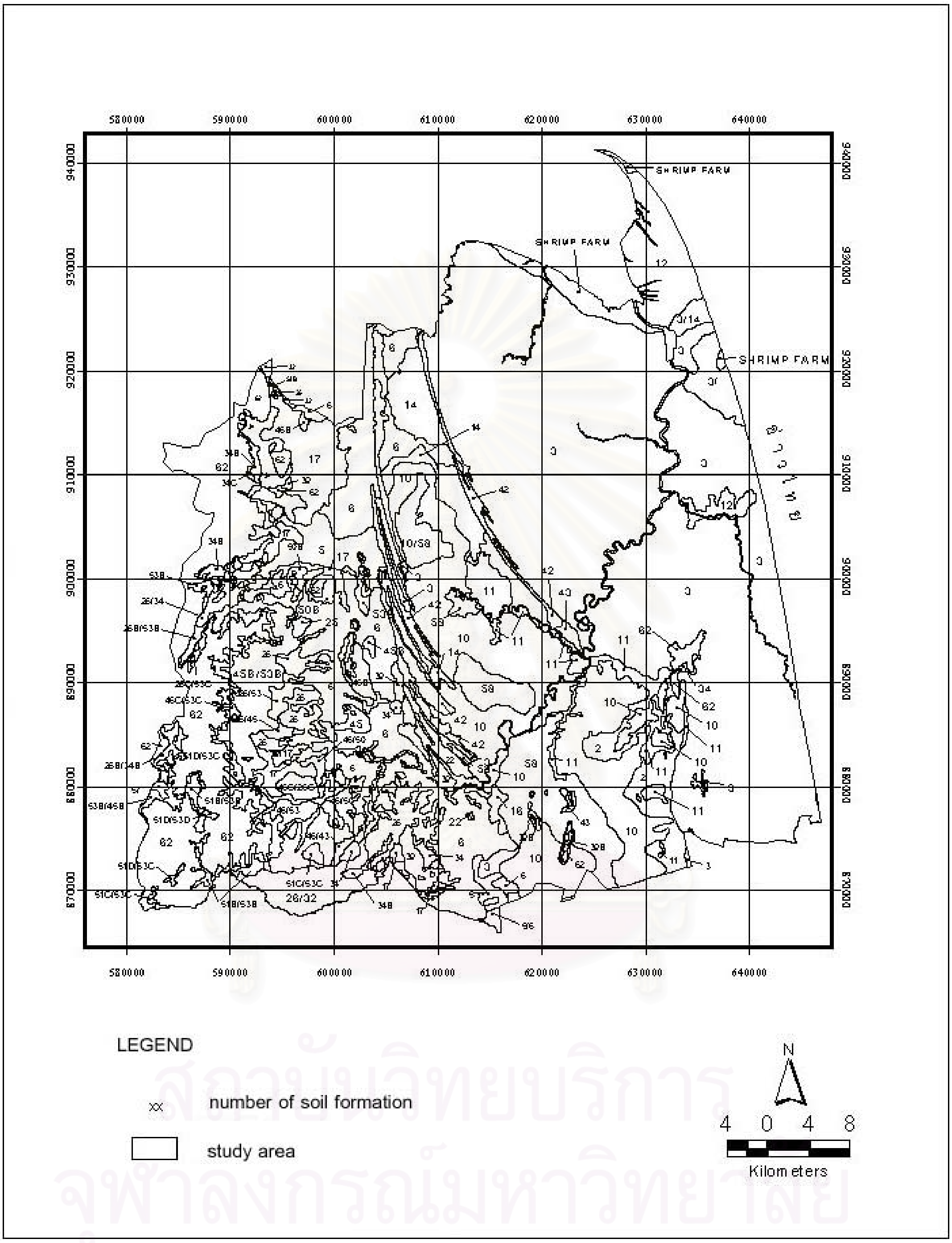


Figure 2.3 Number of soil formation in the Pak Phanang area (After Land Development Department, 2004)

2.1.3 Landuse

The study area can be divided into 2 types based on agricultural use and topography as low-lying area and high land area. Most of the low-lying area is in the east and mainly used for paddy field, but some parts are still covered by grasses, coconut, palm, para rubber (*Hevea braziliensis*), cajeput tree (*Euginia*), reed *(genus Cyperus)*, and mangroves are widely seem in this area. Most of high land area is in the west and used as para rubber, coconut, palm and orchard plantation (JICA, 2001).

Moreover, landuse in the lower lying area of the Pak Phanang River Basin is also for shrimp farming, which can be found in the east of the area. The consumptive landuse is shown in Figure 2.4. According to the information from the Land Development Department (2000), the landuse in the Pak Phanang area can be summarized as follows:

- Agriculture area, about 2,050 square kilometers or 1,283,600 rai (65.7% of the area), is composed of;
    - Paddy farm 663,473 Rai
    - Old paddy farm 68,935 Rai
    - Orchard farm 161,878 Rai
    - Coconut farm 32,493 Rai
    - Para rubber farm 356,821 Rai
- Aquatic animal farm area, which spans about 123 square kilometers or 76,816 rai (4% of the area), consists of;
    - Shrimp farm 38,634 Rai
    - Aquatic animal farm 38,182 Rai
- Forest area, about 610 square kilometers or 380,892 rai (19% of area), comprises
    - Virgin forest 79,591 Rai
    - Degenerate forest 33,175 Rai
    - Swamp forest 196,690 Rai
    - Mangrove forest 43,445 Rai
    - Beach forest 97 Rai
    - Forest garden 27,894 Rai

- Aquatic area spans about 18 square kilometers or 11,768 rai (0.6% of area)
- Village area is about 20 square kilometers or 12,770 rai (0.65% of area)
- Miscellaneous area, about 300 square kilometers or 188,032 rai (9.6% of area), is composed of:

-	Low-lying area	162,729	Rai
-	Grassland	5,089	Rai
-	Shrubbery	16,586	Rai
-	Old mining	2,584	Rai
-	Pond	1,044	Rai

In the past, Pak Phanang River Basin was used as paddy field and was a center of rice production in the southern Thailand. The land experienced widespread devastation after the population increased. Construction and development consumed the natural resources and altered the topography. Now, the Para rubber and shrimp farming are consuming this area because demands in the market are increasing.

2.2 Geological setting

Pak Phanang area is situated in Nakorn Sri Thammarat Province. The area has north-south trend and is encompassed by Khao Luang mountain range in the west and sea in the east. Floodplains and lower terraces are observed along both sides of the Pak Phanang River and also their tributaries.

The geological map of the area is shown in Figure 2.5 which is redrawn from the Map Sheet NC47-15 and NB47-3 at a scale of 1:250,000 (DMR, 1985). Main rock units of this region are composed of Paleozoic rocks, Mesozoic rocks, and Cenozoic rocks which are both sedimentary and igneous rocks. The oldest rocks are in Cambrian period. Dominant structure of the area is isolated by faults. The major set of fault directions lies northeast-southwest and also some minorities in the northeast-southwest. Most units, as mentioned above can be described from the oldest to the youngest in an ascending order as below (DMR, 2002). (Figure 2.5, Table 2.2)

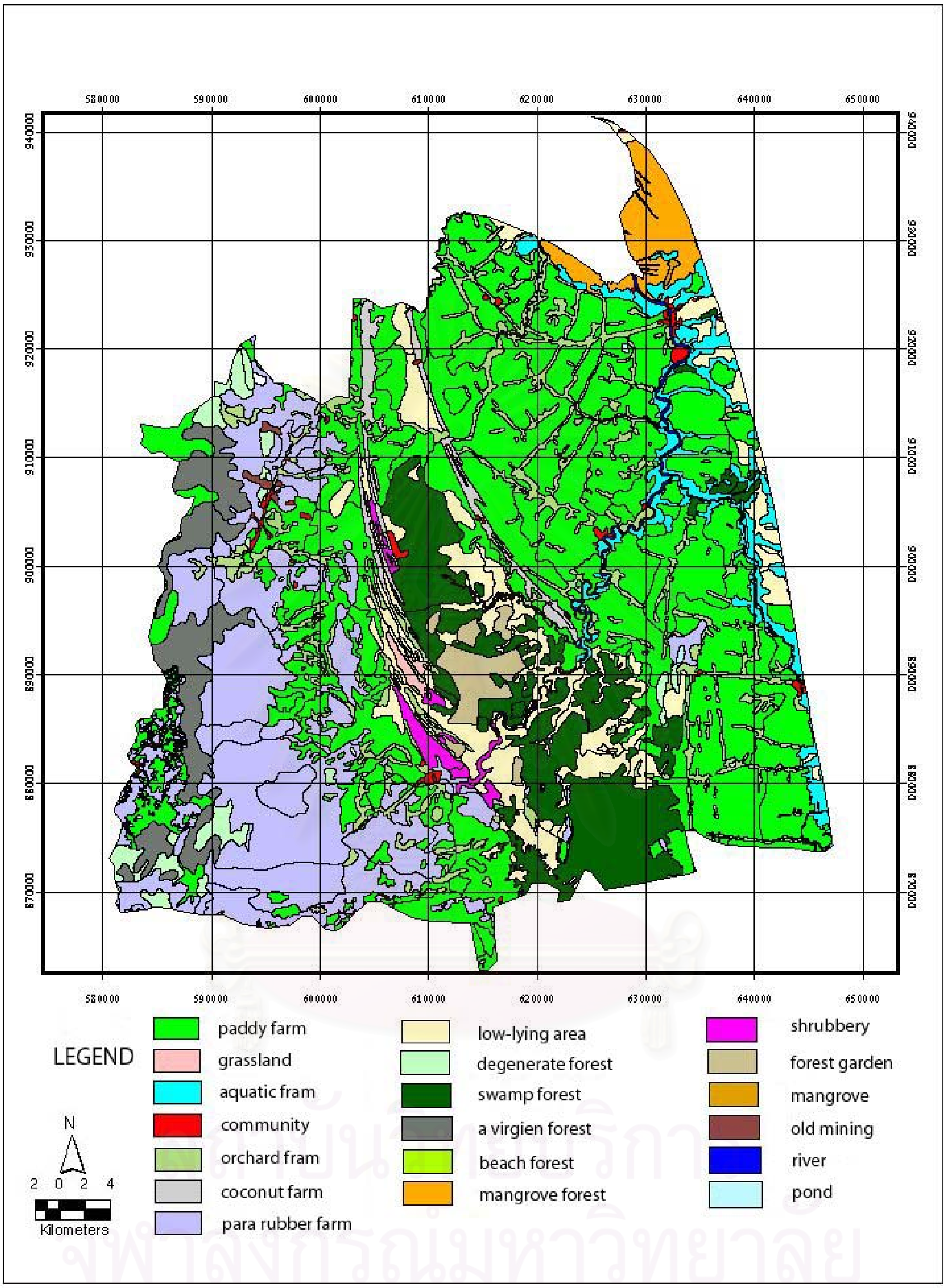


Figure 2.4 The landuse of the study area (after Land Development Department, 2000)

2.2.1 Paleozoic rocks

This rock unit can be found in the west of the study area which consists of;

Cambium to Ordovician Group (E)

This unit is metamorphosed sandstone, which is composed of quartzite, orthoquartzite, calcareous limestone and argillaceous limestone interbeded with bedded sandstone. It is found around the Wang Heab granite mountain. The inferred Cambrian to Ordovician rocks consist of coarse grained (deformed conglomerate) grayish white quartzite and orthoquartzite that have more than 40 centimeters of thick beds, and grayish green argillaceous limestones which have opened fold set under the Ordovician limestone.

Thung Song Group (O)

Thung Song Group or Thung Song limestone has an age in the Ordovician period. It consists of gray and pale pink massive limestone, argillaceous limestone, dolomitic limestone, calcareous sandy shale and schistose marble with interbedded shale. Fossils are abundant in this group such as coral, gastropod and bryozoa.

Thong Pha Phum Group (SDCtp)

This group is in the Devonian period and consists of grayish white physilitic shale, chert, siltstone, dark gray calcareous limestone, sandy marl, and thin-bedded nodular limestone. The Thong Pha Phum rockunit usually trends in the north-south and shows open fold dipping 40 to 60 degrees in the northeast. Fossils found in this unit are composing of graptolite, tentaculite, neautiloid, trilobite and many brachiopods.

Kaeng Kachan Group (CPk)

This rock unit crops out in the southwest parts of the study area. Kaeng Kachan Group consists of shale with intercalated sandstone and siltstone, shale with interbedded sandstone, mudstone, chert, tuffaceous sandstone, feldsparthic sandstone, quartzose sandstone, pebbly shale, and pebbly mudstone with dark gray, greenish gray and brown colors. The age of the Kaeng Karchan Group is referred to as late Carboniferous.

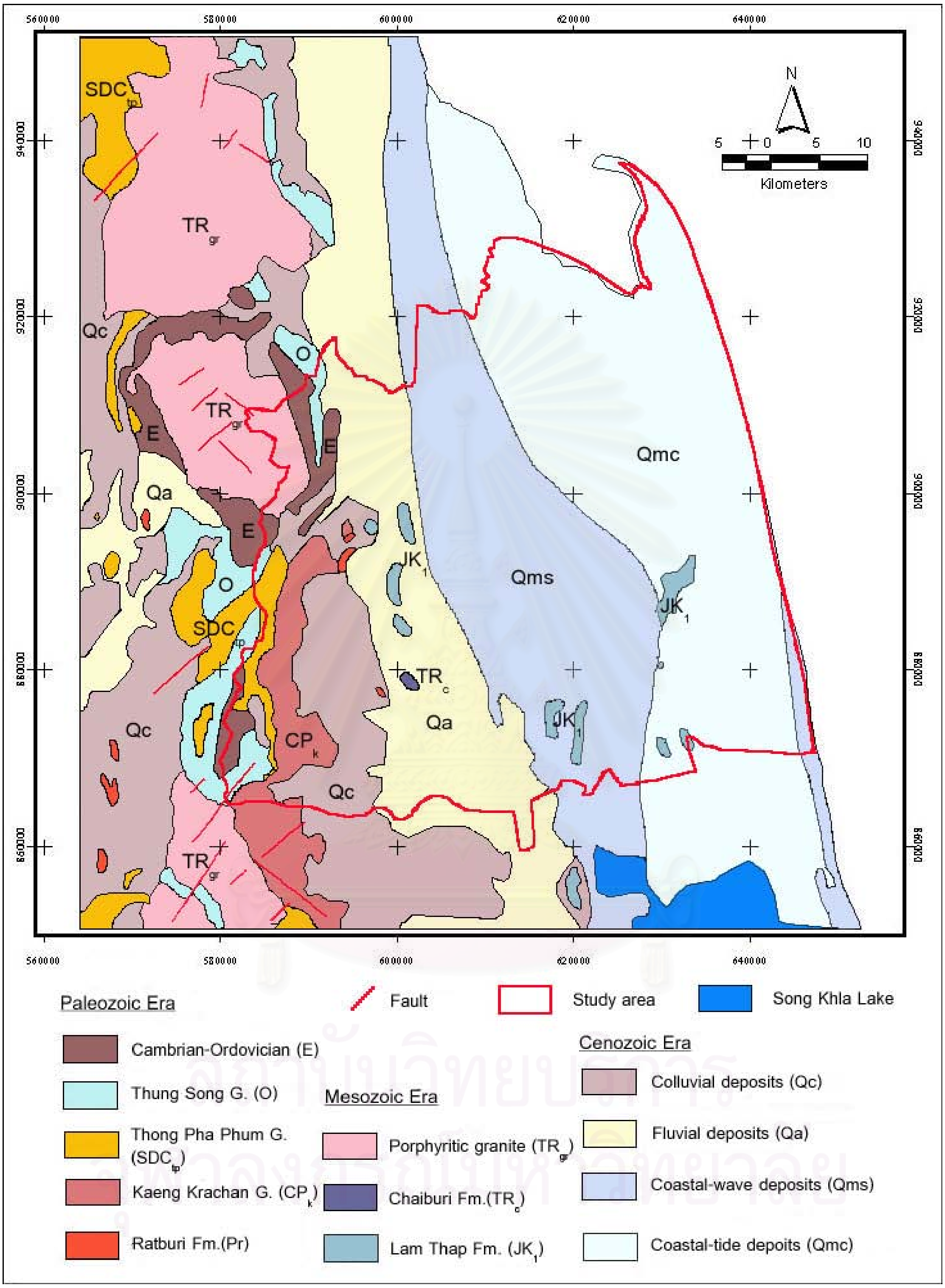


Figure 2.5 Geological map of the study area (after DMR, 2002)

Table 2.2 Geographic details in the Pak Phanang area

Era	Epoch	Group/Formation	Descriptions
Cenozoic	Quaternary	Conlluvial deposits	Residual sediments, laterite and rock fracements
		Fluvial deposits	Gravel, sand and clay of channel, river bank and flood basin.
		Coastal wave–dominated deposits	Sand, silica sand and beach ridge, barriers, dune, and lagoon
		Coastal tide-dominated deposits	Clay, silt, and fine sand of tidal flat, marsh, mangrove swamp and estuary
	Tertiary		
Mesozoic	Cretaceous		
	Jurassic		
	Triassic	Chai Buri	Limestone, dolomitic limestone, dolomite with intercalated chert nodules and layers, abundant conodont and radiolaria
	Triassic	Granit Gr.	Biotite granite, tourmaline granite, granodiolite, biotite-muscovite granite, muscovite-tourmarline granite, biotite-tourmaline granite
	Cretaceous–Triassic	Lam Tub	Sandstond, arkose and lithic; mudstone; siltstone, reddish brown; cross-bedded, conglomerate and sandstone in the upper part; fresh and brackish water bivalve in the lower part.
Paleozoic	Permian	Ratburi Gr.	Limestone, dolomitic limestone, with nodular and bedded chert; dolomite with abundant fossils
	Carboniferous	Kaeng Krachan Gr.	Shale with intercalated sandstone and siltstone; shale with interbedded sandstone, mudstone, chert, feldspathic sandstone, tuffaceous sandstone, quartzose sandstone, pebbly shale, and pebbly mudstone, dark gray, greenish gray and brown
	Devonian	Thong Pha Phum Gr.	Sandy marl, black shale, chert,siltstone, dark gray calcareous; limestone, thin-bedded and nodular; locally abundant fossils of graptolite, tentaculite,nautiloid,trilobite and brachiopod
	Silurian		
	Ordovician	Thung Song Gr.	Argillaceous limestone and limestone, gray and pink; dolomitic limestone and schistose marble; with interbedded shale, calcareous, and sandy shale; abundant fossils
		Cambium to Ordovician rock Gr.	Quartzite, orthoquartzite, and sandstone,bedded; and calcareous shale

Ratburi Group (Pr)

This group is the youngest rock unit in the Paleozoic Era. Its age is Carboniferous to Permian. Ratburi Group is composed of limestone, dolomitic limestone with nodular bedded chert and some fusulinids in limestone beds.

2.2.2 Mesozoic rock unit

This rock unit can be separated into two units based on the lithology, sedimentary rock unit and igneous rock unit (DMR, 2002)

Igneous rocks unit

The unit is exposed in the north west of the study area. It is mainly porphyritic granitic rocks, such as biotite granite, tourmaline granite, biotite-muscovite granite, muscovite-tourmarline granite, biotite-tourmaline granite and granodiorite. The age of this unit is referred to Triassic.

Sedimentary rock unit

Chaiburi Formation (TRc)

This formation consists of limestone, dolomitic limestone, dolomite with intercalated chert nodules and layers, with abundant conodont and radiolarian. The age of this formation is Triassic.

Lam Tup Formation (JKi)

The Lam Tup Formation is located in the central part of the study area, and consists of arkosic and lithic sandstone, mudstone and reddish brown siltstone. The upper part of the formation shows cross bedding of interbedded conglomerate and sandstone and the lower part of the formation contain some fresh and brackish water bivalves in the lower part. The age of this formation is Triassic.

2.2.3 Cenozoic rock unit

This rock unit has only Quaternary deposits which can be divided into 4 types as below:

Colluvial deposits (Qc): consisting of residual sediments, laterite and rock fragments.

Fluvial deposits (Qa): are gravels, channel sands and clays, river bank and flood basin.

Coastal wave–dominated deposits (Qms): are sand and silica sand beach ridge barriers, dune and lagoon.

Coastal tide-dominated deposits (Qmc): are clays, silts, and fine sands of tidal flat, marsh, mangrove swamp and estuary.

2.3 Coastal Geomorphology

2.3.1 Coastal Landform

The shoreline length from Laem Talumpuk district to Tha Sara district is 80 kilometers. In general, the coastal geomorphology is Tidal flat. Sediment, which developed by accretion from the Pak Phanang River Mouth called Pak Phanang Gulf. The tidal flat of the Pak Phanang Gulf is about 3 kilometers length in the west, about 6 kilometers length in the east, and about 1 to 2 meters depth.

Next, from Laem Talumpuk district to Hua Sai district there is a distance of about 80 kilometers lenght. The shoreline is strength and flat from the north to the south. In the northern part (from Laem Talumpuk district to Pak Phanang district), beach is clayish sandy, but it changes to sandy beach with approximately about 0.5 to 1 meter high above mean sea level. The road number 4013, which is behind the beach and parallel along the shoreline is about 2 meters above the mean sea level.

Coastal geomorphology of the study area can be divided into 10 types (Figure 2.16)

1. **Recent sandy beaches**

The characteristic of coastal geomorphic units of the study area is barrier beaches, in front of the sea, and sand spits in the north part of Talumpuk area. The recent sandy beaches are high approximately 60 kilometers length, 5 to 15 meters weight, and 0.5 to 1 meters height. Small runnels are coral and shell, are found between the beaches (Figure 2.6).

2. **Old sandy beaches**

Old sandy beach as have been affected by a maximum transgression process in last about 6,000 - 8,000 years ago (Thiramongkol, 1988). The regressive shoreline causes new sandy beaches to run parallel to the coast. Old sandy beaches trend in the north to the south in the center of the study area and it has lagoon between two old sandy beaches. The characteristic of these old sandy beach are 2 to 5 meters high, 1 to 5 kilometers wide and has a longest distance from shoreline about 40 kilometers at the Cha-Uoad district. These old sandy beach are village and living area (Figure 2.7).

3. Old tidal flat

Old tidal flat is flat area covering about 1,800 square kilometers, about one-third of the study area in the eastern part (Figure 2.8). It lies between an old sandy beach and a recent sandy beach with height topography of 0.5 to 2 meters. Sediment has been deposited from the maximum transgression to the regression of sea water about 5,000 years ago. It consists of greenish gray marine clay, which is used as rice field, shrimps farm and housing area.

4. Intertidal flat

Intertidal flat is a flat area that is affected by high tides and low tides. It is found from the north of Pak Nakorn river mouth in Pak Phanang River to Talum-Puk area, expanding totally 120 square kilometers. This area lies between old tidal flat and subtidal flat that is once a mangrove area (Figure 2.9).

5. Subtidal flat

Subtidal flat is the outside area that meets with shoreline and intertidal flat. It is a flat area that is under the lowest tide in the subtidal flat. It is found in the northern area in the Pak Phanang Gulf covering approximately 75-80 square kilometers. The characteristic of sedimentary deposition is clayey sand with plants cover (Figure 2.10).

6. Old lagoon

Old lagoon is a low-lying area which formed during maximum transgression, 6,000 years ago. After that, old river mouth in the southern of the study area was closed. It is between old sandy beaches from the north to the south in the middle part of the study area. Old lagoon in this area is narrow in the northern part and wide in the southern part. It is an extensive area about 400 square kilometers and comprises fine grained sand, silt interbedded with mud, clay and some organic matter. This area is suitable for paddy fields and rubber plantation (Figure 2.11).

Figure 2.6 Recent sandy beach at Lam Talum Puk UTM 628114E/940360N

Figure 2.7 Old sandy beaches near the train tracks (red line) UTM 603734E/920200N

Figure 2.8 Subtidal flat in the north of Lam Talum Puk

Figure 2.9 Intertidal flat in the study area UTM 622901E/941467N direction W

Figure 2.10 Old tidal flat in the study area UTM 602953E/920351N direction NE

7. Swamp

Swamp is a low-lying area that is always wet and soft or slightly covered with water. When the deposition of organic matter is high and tidal change is slow, swamp must subside. It has a thick stratigraphy that is composed of marine clay in the bottom, clay interbedded with organic matter and peat in the top. In some area, swamp produces H_2S and CH_4 gases. Swamp in Nakorn Sri Thammarat area is low-lying area that occurrs between old lagoon and old sandy beach. It can be found in low terrace in the center of the study area which has a width of more than 100 square kilometers such as Kum Pae swamp, Kaun Kheng swamp (Figure 2.12).

8. Old alluvial and alluvial deposits

Alluvial deposit is composed of gravel, loose block, sand and clay in the area that had been changed slope to flat area. Furthermore, the elevation of the alluvial deposit ranges from 4 meters to about 15-20 meters. In this area the alluvial deposit is situated in the west between colluvial and old sandy beaches. It is suitable for paddy fields and orchard farms (Figure 2.13).

9. Colluvial deposits

Colluvial deposit is composed of sediments and loose blocks that have been deposited near the foot of the hill. The colluvial deposit can be found in the west of the study area between mountains and flat plains. This area is used for agricultures such as para rubber, palm and areca palm (Figure 2.14).

10. Mountain and hills

The high area in the study area is in the west with smaller areas in the east and the center of the plain. The elevation of the mountain and hills are more than 20 meters above the mean sea level. They consist of limestone, granite, sedimentary and metamorphic rocks that are locally been mined for construction (Figure 2.15).

Figure 2.11 Old lagoons in the study area UTM 600110E/916308N direction NE.

Figure 2.12 Marsh forest (Kumpre) UTM 609798E/893368N direction N

Figure 2.13 Old alluvial and alluvial deposits in the study area

Figure 2.14 Colluvial and old alluvial fan in the study area UTM 593157E/908427N direction NE

Figure 2.15 Sandstone mountain (Khorat group) UTM 630956E/892181N direction N (upper picture) and granite mountain UTM 593154E/908415N (lower picture)

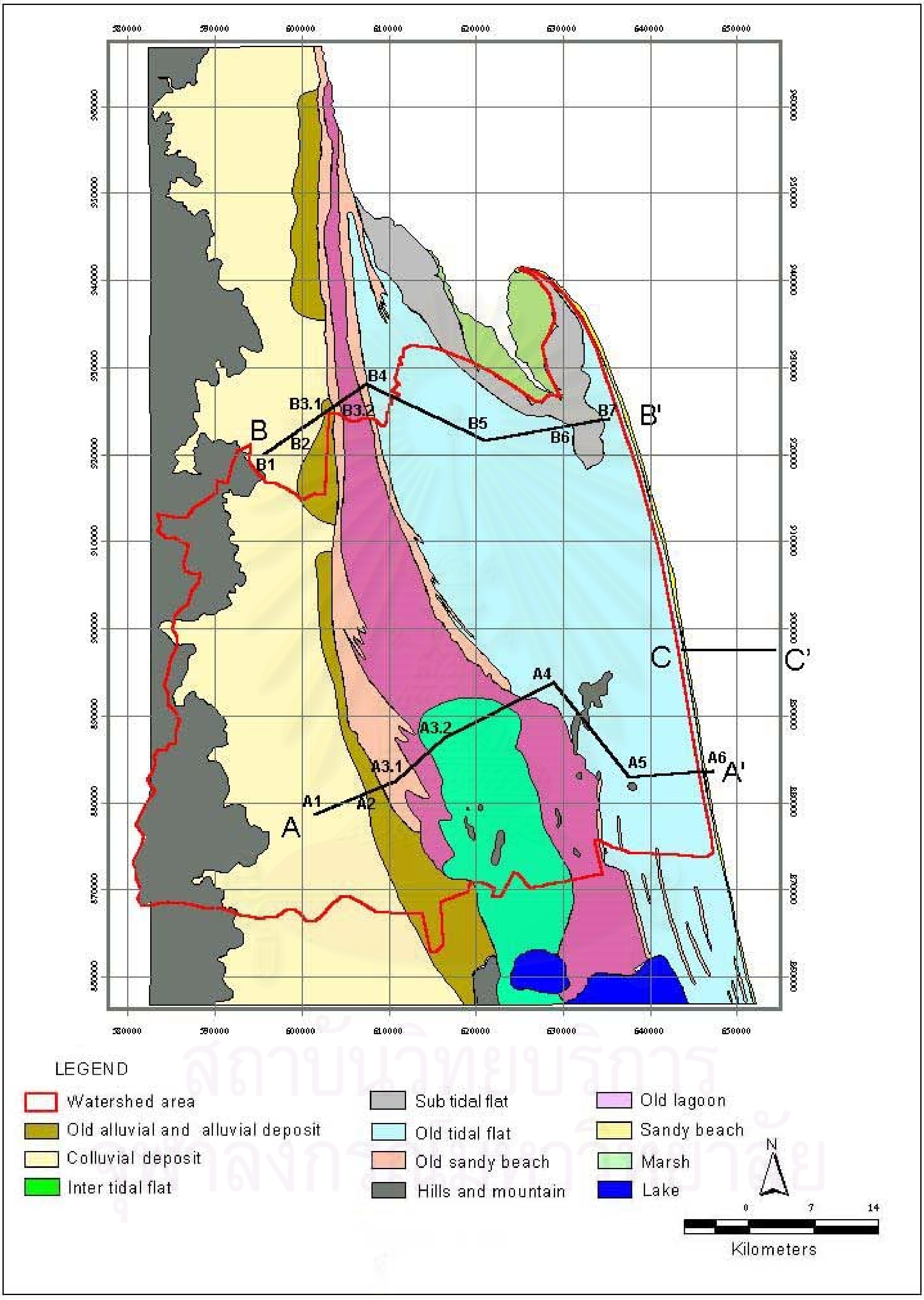


Figure 2.16 Geomorphological units and lines survey in the study area

2.3.2 Stratigraphy of Coastal Area

Stratigraphy of the coastal area has been studied from collected data in the field that utilized the hand auger drilling method (Figures 2.17-2.19). There are two cross lines in the area, one line (Line A) had six cores in the lower part of the area, and another line (Line B) had seven cores in the upper part of the area (Figure 2.16).

The east of the study area, in the top layer of the stratigraphy, had a deposition of clay, clayish sand that divided into the old tidal sediments with sand interbedded in the lens type. In the middle layer there was marine clay, well sorted very fine sand to mud, 2 to 4 meters thick. Also, there were hard clays, very coarse sand to coarse sand and poorly sorted (Pleistocene sediment) in the bottom layer of core.

In the west of the stratigraphy found fine to coarse sand and granule with hard clay mix sand in the top that interpreted to alluvial deposit. In the east of stratigraphy show the old lagoon deposits; poorly sorted clay and some thin bed coarse sand layer and rootlets. Also in the middle part of the cross section there was well sorted fine sand to interpreted old sand dune in this area.

There are small faults in the Pak Phanang River Basin in the northeast - southwest and northwest-southeast trend in the northeast. Also in the southwest of the area there appeared a small fault, which had a trend in the northeast direction.

The details of the core samples (see Appendix B) and the correlations of the stratigraphy of the study area are shown in the Figures 2.20 – 2.23 respectively.

2.3.3 Beach Profile

Beach profile in the study area

In 1998, the Harbour Department studied the beach profile in the Pak Phanang area in 3 lines which had a distance of about 40 kilometers. The average elevation of the beach is about 0.5 meters and average gradient is 1/200. Near the shoreline (distance of about 2 kilometers), there is an average gradient about 1/70. The gradient in the northern part is less than the gradient in the southern part.

Figure 2.17 Hand auger is the application tool used in the field

Figure 2.18 Samples from borehole were collected

Figure 2.19 Samples from borehole were described

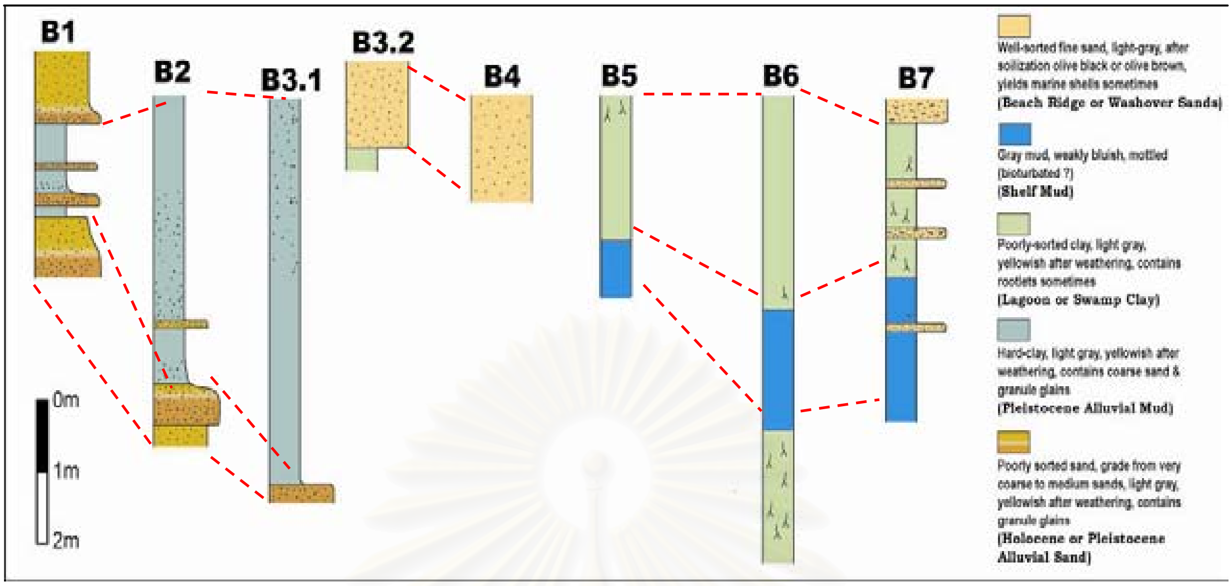


Figure 2.20 Stratigraphy of the line B-B' in the upper study area

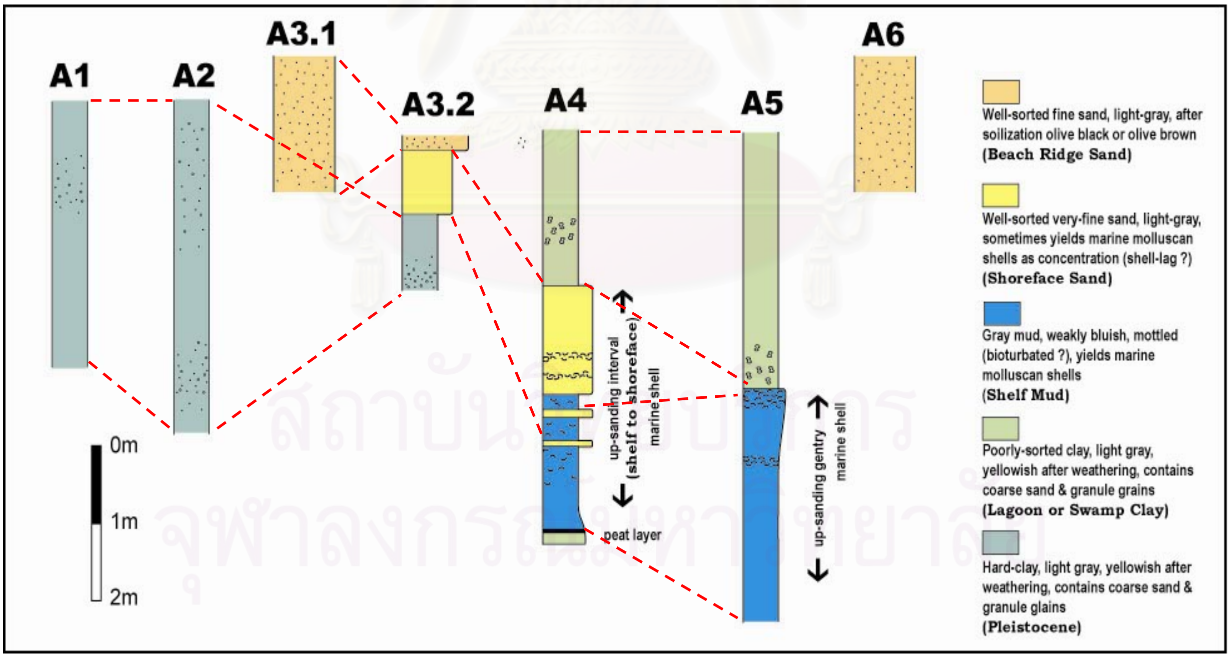


Figure 2.21 Stratigraphy of the line A-A' in the lower study area

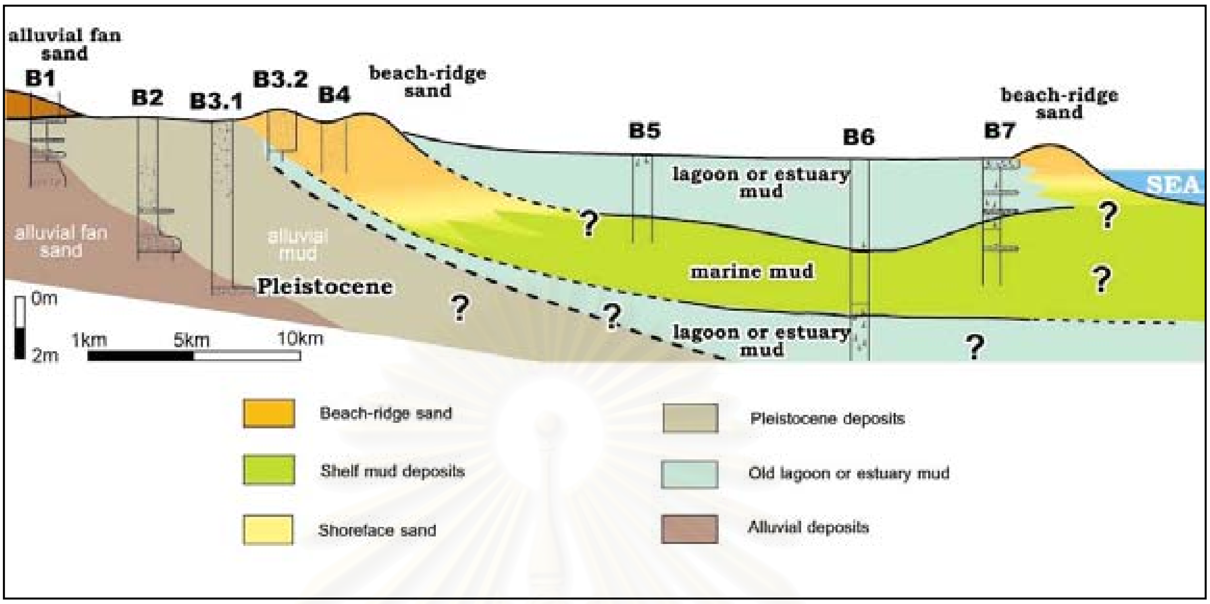


Figure 2.22 Cross-section of the line B-B' in the upper study area

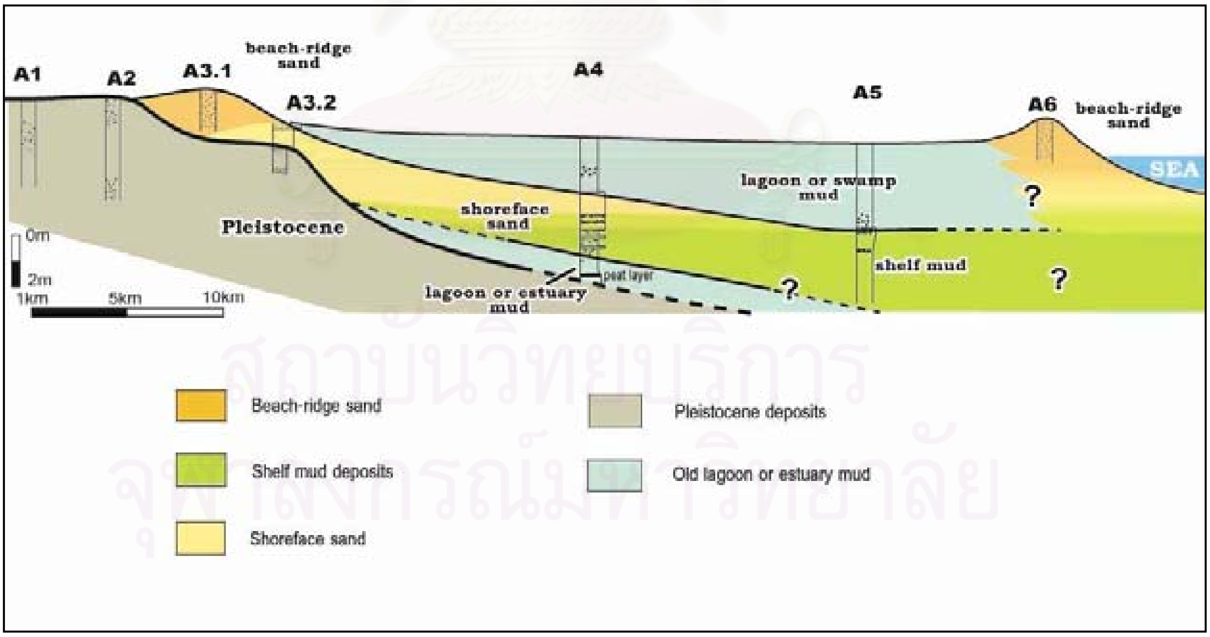


Figure 2.23 Cross-section of the line A-A' in the lower study area

Figure 2.24 The beach position for beach profile line study at Ban Na Sarn

Figure 2.25 Wave at beach profile study

Figure 2.26 Collected samples by the hand corer method

The results of field and laboratory study are shown in Table 2.3, the portion weight of mean grain size is shown in Tables 2.4, the water content is shown in Table 2.5, the suspended solid matter is shown in Table 2.6, and the cross-section of the beach profile is shown in Figure 2.27

Table 2.3 Illustrates beach profile in the Ban Na Sarn, Hua Sai district, Nakorn Si Thammarat province: (16 Nov, 2004)

Date	Time	x	y	Point	Position	Sea level (meter)	Distance from shoreline (meter)	Detail of sediment
16 Nov, 2004	8:53	647540	888463	NS1	Ban Na Sarn	6.2	2,080	silt and clay
16 Nov, 2004	9:15	646869	888945	NS2	Ban Na Sarn	4.3	1,520	-
16 Nov, 2004	9:18	646750	888666	NS3	Ban Na Sarn	3.5	1,320	-
16 Nov, 2004	9:21	646225	888690	NS4	Ban Na Sarn	3.2	830	-
16 Nov, 2004	9:23	646225	888668	NS5	Ban Na Sarn	4.1	820	silt and hard clay
16 Nov, 2004	9:32	646032	888515	NS6	Ban Na Sarn	4.2	590	-
16 Nov, 2004	9:33	645938	888503	NS7	Ban Na Sarn	2.3	490	-
16 Nov, 2004	9:34	645834	888469	NS8	Ban Na Sarn	2.2	380	-
16 Nov, 2004	9:35	645719	888418	NS9	Ban Na Sarn	2.3	260	-
16 Nov, 2004	9:36	645658	888463	NS10	Ban Na Sarn	3.0	220	coarse sand
16 Nov, 2004	10:40	645486	888364	NS0	Ban Na Sarn	0	0	coarse sand
16 Nov, 2004	10:40	645486	888364	NS0	Ban Na Sarn	0	0	-

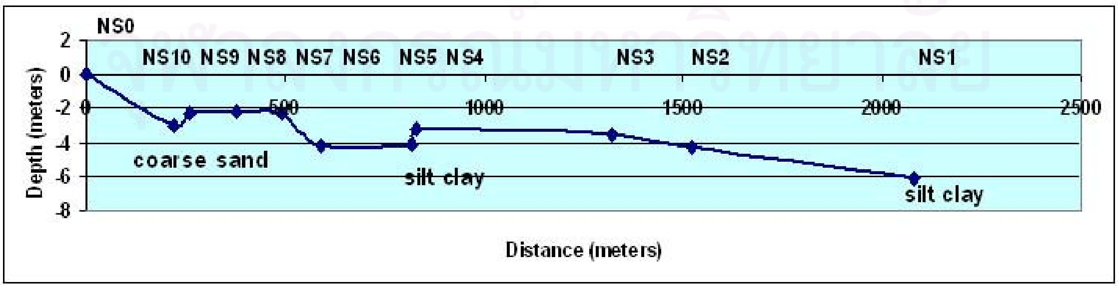


Figure 2.27 Cross-section of the beach profile, Ban Na Sarn, Hua Sai district, Nakorn Si Thammarat province

Table 2.4 Portion weight of mean grain size of sediments (MGS) in the Ban Na Sarn, Hua Sai district, Nakorn Si Thammarat province: (16 Nov, 2004)

Portion weight of MGS (Mean grain size)												Pre-total		
Point	Position	m.m.	1000u	600u	425u	300u	150u	106u	75u	63u	<63u	Weight (gm)	phe	MGS (mm)
		phe	0.00	0.74	1.23	1.74	2.74	3.24	3.74	3.99	<3.99	-	-	-
NS10	Ban Na Sarn	Sediment wt.	26.0	41.7	59.3	61.5	115.0	9.0	0.8	0.2	0.2	313.7	1.5752	2.98
NS10	Ban Na Sarn	cumulative	26.0	67.7	127.0	188.5	303.5	312.5	313.3	313.5	313.7	-	-	-
NS10	Ban Na Sarn	%Cumulative	8.3	21.6	40.5	60.1	96.7	99.6	99.9	99.9	100.0	-	-	-
NS0	Ban Na Sarn	Sediment wt.	32.0	45.5	67.0	75.0	82.0	12.0	9.0	6.0	0.2	328.7	1.8143	3.52
NS0	Ban Na Sarn	cumulative	32.0	77.5	144.5	219.5	301.5	313.5	322.5	328.5	328.7	-	-	-
NS0	Ban Na Sarn	%Cumulative	9.7	23.6	44.0	66.8	91.7	95.4	98.1	99.9	100.0	-	-	-

Table 2.5 Water content in the Ban Na Sarn, Hua Sai district, Nakorn Si Thammarat province: (16 Nov, 2004)

Date	x	y	Point	Position	Sea-level (meter)	Distance of shoreline (meter)	Detail	water_content (%)
16 Nov, 2004	647540	888463	NS1	Ban Na Sarn	6.2	2,080	silt and clay	42.7
16 Nov, 2004	646225	888668	NS5	Ban Na Sarn	4.1	820	silt and clay	27.2
16 Nov, 2004	645658	888463	NS10	Ban Na Sarn	3.0	220	coarse sand	11.2
16 Nov, 2004	645486	888364	NS0	Ban Na Sarn	0	0	coarse sand	11.0

Table 2.6 Suspended solid matter (milligram/liter), in the Ban Na Sarn, Hua Sai district, Nakorn Si Thammarat province: (16 Nov, 2004)

Date	x	y	Point	Position	Sea-level (meter)	Distance of shoreline (meter)	Suspended solid (milligram/liter)
16 Nov, 2005	647540	888463	NS1	Ban Na Sarn	6.2	2,080	20.4
16 Nov, 2005	646225	888668	NS5	Ban Na Sarn	4.1	820	30.3
16 Nov, 2005	645658	888463	NS10	Ban Na Sarn	3.0	220	20.6
16 Nov, 2005	645486	888364	NS0	Ban Na Sarn	0	0	70.2

From the data in the field and laboratory study, it can be concluded that

1. The first sand bar near shoreline is 260-500 meters from the present shoreline and the next sand bar is 830-1,320 meters from the present shoreline. The elevation is about 2 and 1 meter, respectively.

2. In the nearest sand bar exhibited coarse sand and the percentages of water content of about 11.2%. The mean grain size in the furthest sand bar was displayed silt and clay and the percentages of water content of about 27.2%.

3. The suspended solid in the study area is average about 35.37 milligram/liter.

2.4 Paleoshoreline in the Pak Phanang River Basin

Jarupongsakul (2005) explained the significant change in climate and sea-level that occurred to around 12 ka. There has been a continual warming and rise in sea-level of about 0.83 -1.25 mm per year. From 12 ka until about 6 ka, the shift of shoreline is dominated by the restoration of ocean level due to the melting of land ice caps. During this period, the shoreline of the coastal lowland moves inland at the rate of sea-level rise about 16-26 mm per year.

From the detailed study of Holocene marine sediment in Pak Phanang River Basin, it is clear that during the height of the Holocene transgression, during 6,000-8,000 years before present (Thiramongkol, 1988)., the sea covered most of the present area to as far east as Pak Phanang River Basin (Figure 2.28). The maximum transgression of the sea so far, is approximate 35 kilometers from the present shoreline. The old sandy beach was in the south-east trend. The direction of sedimentary transportation was generated in the north to south trend. The maximum depth of marine deposition from core sample of this study is not over 6 meters deep. The depth of the paleosea in the Pak Phanang River Basin had about 2-6 meters. Paleogeography of the study area had the paleocurrent in the north to south and had a paleo submarine barrier in the north-east of the Pak Phanang River Basin. The ancestral river was in the south of the study area which is in the Cha-uat district and had a direction to the north.

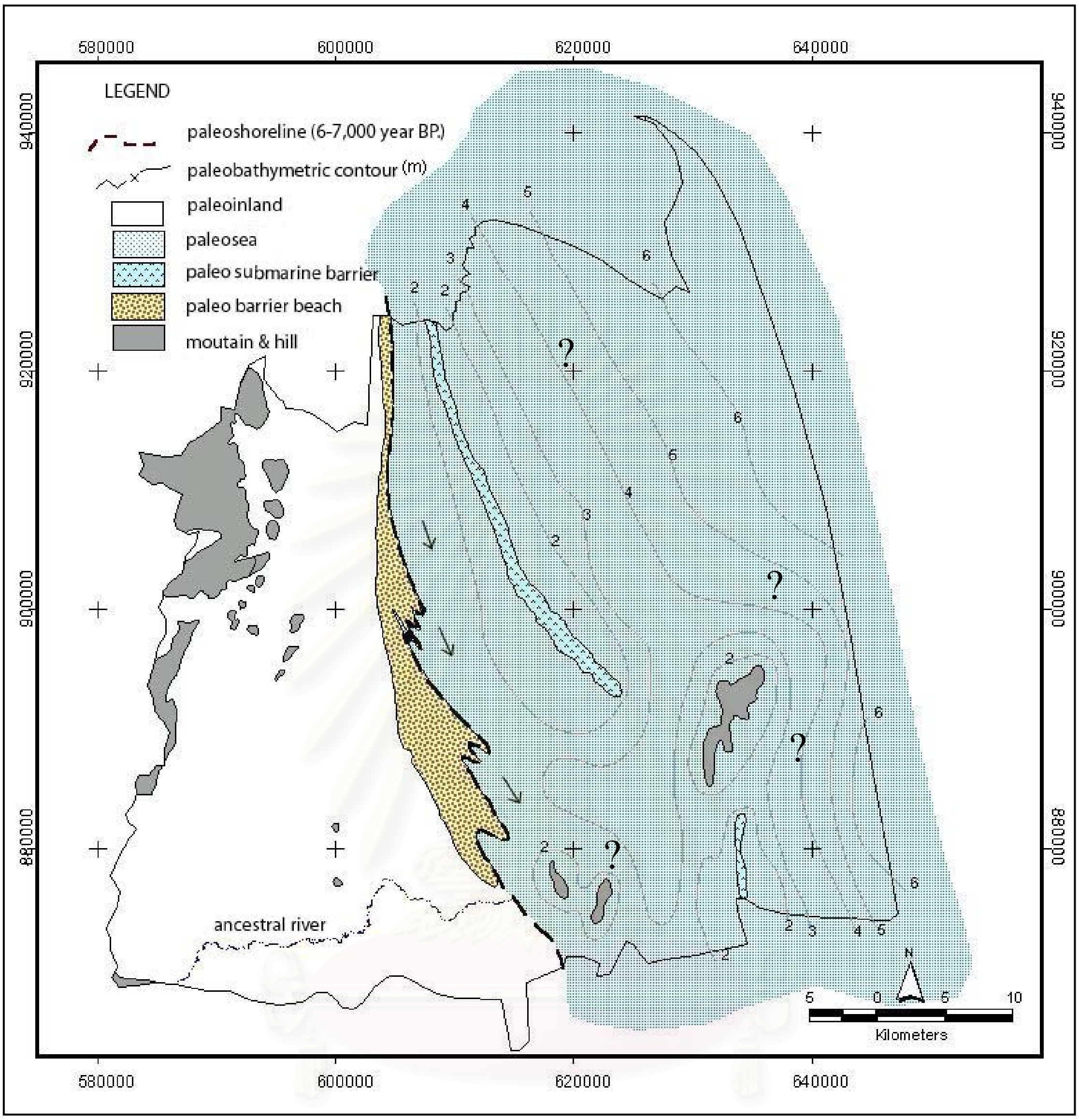


Figure 2.28 The paleogeologic map of the old coastal lowland during 6,000 – 7,000 year BP. in the Pak Phanang River Basin.

CHAPTER III
METEO-HYDROGRAPHY

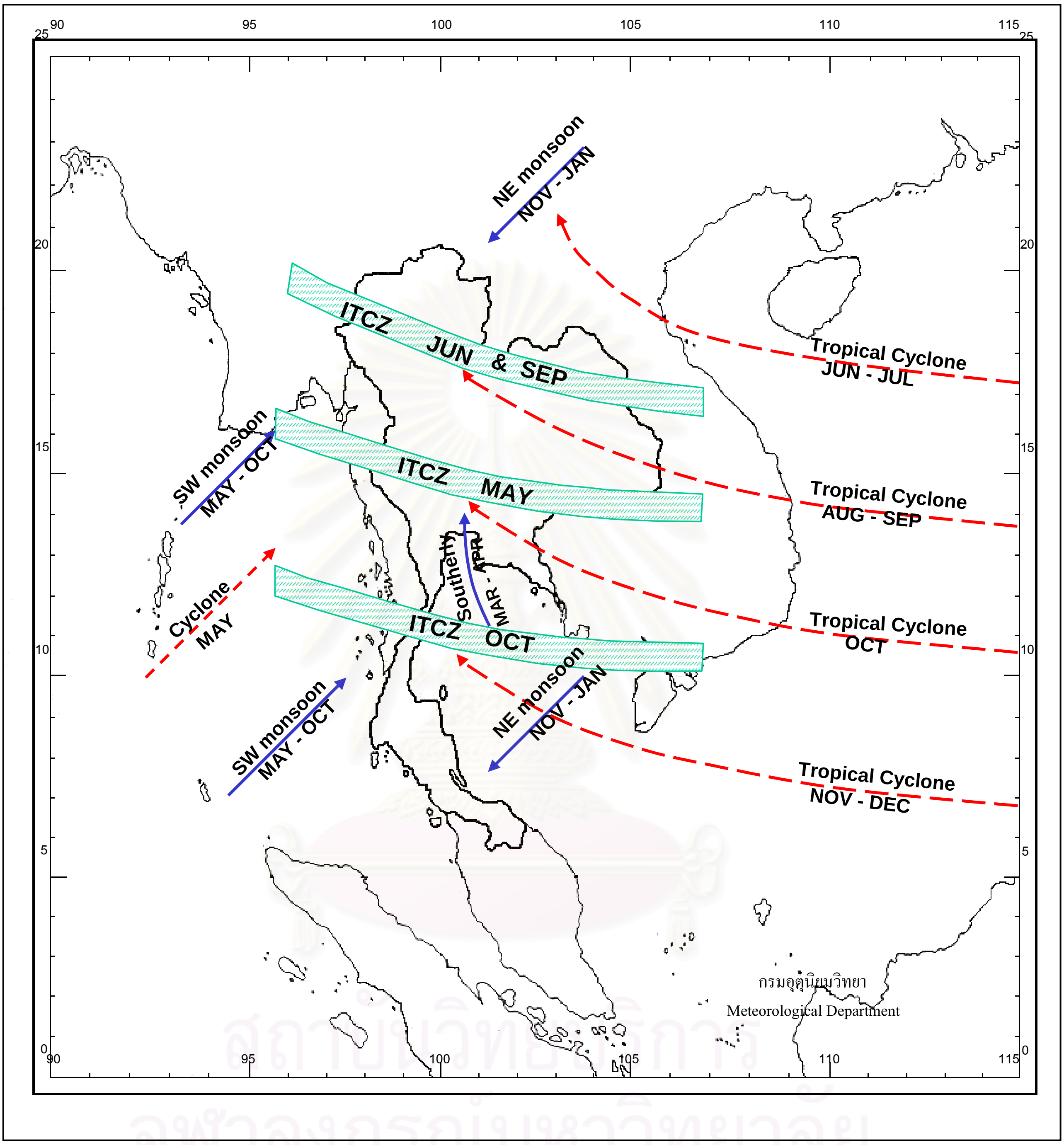
3.1 Wind and Storm

Wind

The weather in Thailand is affected by the northeast monsoon and southwest monsoon (Figure 3.1). The northeast monsoon has been associated with winter in the northern hemisphere which is in November to February. During this period, the weather in Thailand is dry and cold together with ocean swell in the gulf of Thailand except in the south of Thailand where it rains but the waves are still high. The southwest monsoon occurs in May to September which is rainy season, especially around the mountains and the sea.

In the period between the northeast monsoon and the southwest monsoon it is called “Inter-monsoon” when the direction of wind is unpredictable. The first inter-monsoon occurs in period of the northeast monsoon changing into the southwest monsoon betweens March to April. It can be rain during this time of the year. The next inter-monsoon occurs in October which causes reduced rain as a consequence expects in the east of southern Thailand. In addition to this month the influence of tropical cyclone from South China Sea makes a heavy rain in the southern Thailand.

The Meteorological data from Nakorn Si Thammarat station for 30 years (1971-2000) revealed that the average temperature was about 27 Celsius with the lowest temperature of about 17 Celsius in December and highest temperature of about 38 Celsius in April. This area has 81 percentages of humidity and 2,396.1 millimeter of rain annually. The north of Pak Phanang basin experiences more rainfall than that in southern basin. The rainfall is approximately 1,766.8 millimeter per year in the Pak Phanang district. The details are shown in the Table 3.1 and Figure 3.2



(ITCZ: Intertropical Convergence Zone)

Figure 3.1 The Monsoon period and cyclone paths in the Thailand (Metrological Department, 2005)

Table 3.1 Average amount of monthly rainfall (mm^3.) at Nakorn Si Thammarat Province

Station	Time	year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug	Sep	Oct	Nov	Dec	Total
Thung Song	1975-2000	26	42.4	22	49.8	125.5	195.1	144.9	204.8	200.6	249.9	232.5	297.2	152.5	1917.2
Chawang	1976-2000	25	16.6	13.6	43.1	109.7	201.1	163.7	215.2	227	286.6	262.6	204.3	108.6	1852.1
Hua Sai	1978-2000	23	49.9	27.5	53.5	85.2	133	113.2	94.9	82.1	119.4	230.5	565.4	276.2	1830.8
Pak Phanang	1975-2000	25	69.8	24.7	53.1	46.3	126.9	95.6	85.2	79.5	138.9	239	538	269.8	1766.8
Tha Sala	1975-2000	24	164.6	59.4	52.4	81.1	108	79.2	81.2	89.5	111.5	272.4	613	338	2050.3
Si Chon	1975-2000	26	89.3	49.6	37.1	35.3	100.3	74.4	77.7	97.2	116.8	217.6	393.1	198.3	1486.7
Ron Piboon	1975-2000	25	132.5	39.6	73.8	119.9	122.3	66.1	75.4	95.3	148.4	226.	497.8	275.5	1872.9
Thung Yai	1977-2000	23	15	17.2	50.7	88.2	178.5	130.5	184.5	190.6	211.2	225.3	211	81.7	1584.4
Khanom	1975-2000	26	116.7	54.4	36.4	52.5	149.3	113.1	99.4	103.5	148.1	277.3	563.3	221.6	1935.6
Cha Uoad	1975-2000	26	94	32.2	56.9	86.6	116.2	68.2	66.4	71.6	97.4	211	604.3	283.6	1688.3
Chein Yai	1975-2000	26	112.3	32.9	65.5	103.7	180.5	77.8	103.9	100.9	131	271.1	640.1	297.1	2116.8
Lan Saka	1976-2000	25	125	63.2	90.6	114.9	134.6	69.7	86.2	102.9	133.2	245	531.5	374.1	2070.9
Pi Poon	1989-2000	12	18.9	17.7	72.5	91.1	181.5	174.2	200.4	275.2	269.8	291.3	246.4	140.8	1979.8
Na Bon	1989-2000	12	24.4	29.8	56.2	113.5	182.2	178.8	211.8	235.5	267.5	277.6	255.1	175.2	2007.6
Chalerm Phakiet	1996-2000	5	157.7	252.9	8.2	37.9	144.1	86.9	159	90.3	253.7	324.8	486.7	433.7	2435.9
Walailak U.	1996-2000	5	177.8	122	138.5	140.4	151	73.8	75.4	110.	139.9	323.7	524.6	429.5	2406.9
Meung	1971-2000	30	146.9	59.9	59.7	106.5	172.2	99.1	113.4	115.7	160.1	322.1	624.7	415.8	2396.1
Khanom	1991-2000	10	117.6	125.3	114	83.8	135.2	162.6	146.6	124.5	162.8	322.9	559.9	297.9	2353.1
Kaset M.	1976-2000	25	97.1	65.2	72.2	111.8	176.2	94.1	126.3	124.6	177.6	289	580.9	364.3	2279.3
Average			93.1	58.4	62.3	91.3	152.0	108.7	126.7	132.5	174.9	266.4	465.1	270.2	2001.7

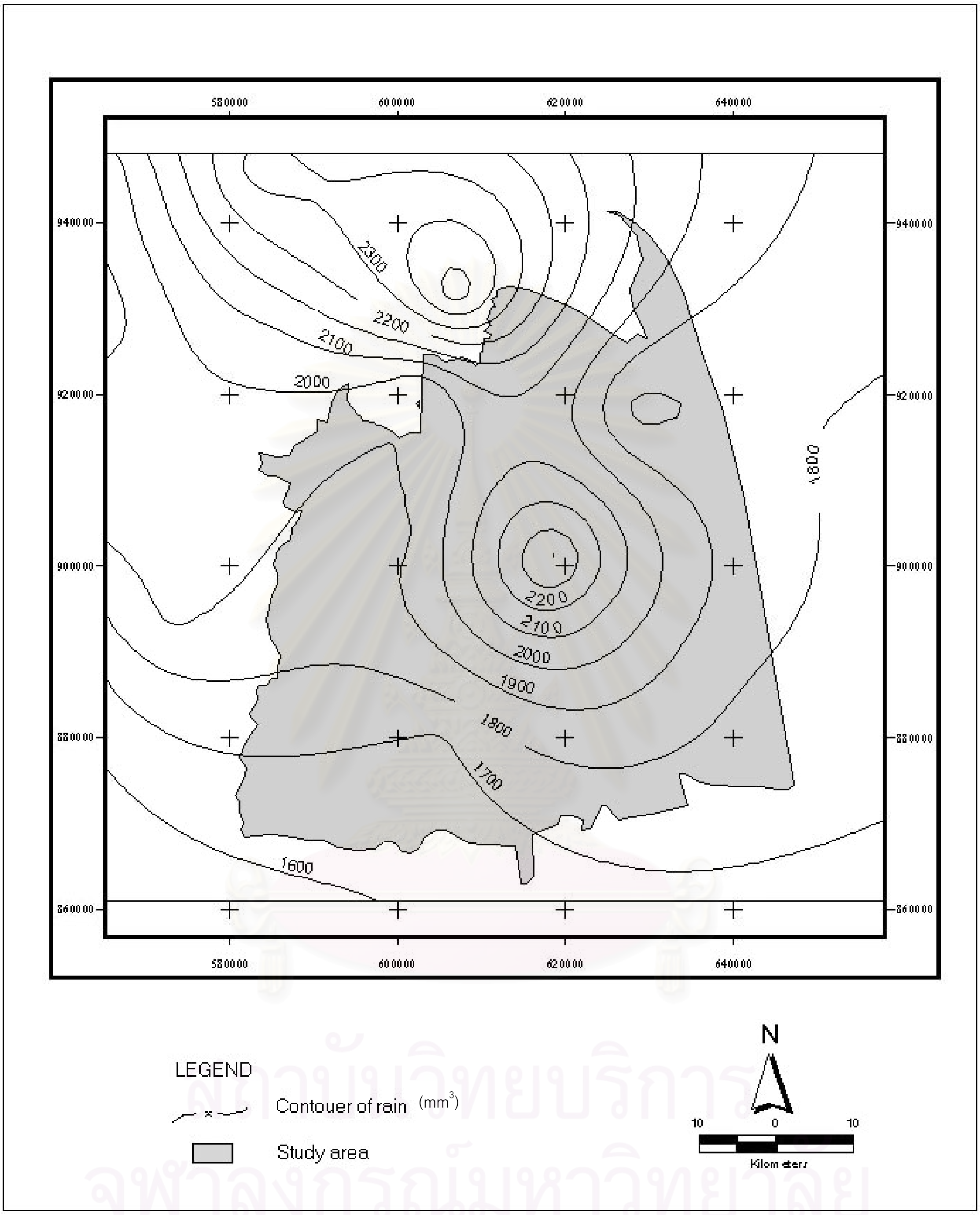


Figure 3.2 Annual rainfall charts (in years 1975-2000) at Pak Phanang area

Wind direction and speed are presented (Thana et al., 2005) in the Figure 3.3 and 3.4. The monthly wind direction in Nakorn Si Thammarat Province spanning 24 years (1981-2003) showed that prominent changes occurred in years 2001-2003. Especially, in January the wind direction changed from southeast (about 120 degree) to northeast-easterly direction of about 70 degrees. As well as the wind direction in April changed from southeast of about 160 degrees to an easterly direction of about 90 degrees while in June the direction changed from southwest of about 240 degrees to southerly of about 180 degrees. Finally, in September, the wind direction changed from southwest of about 240 degrees to south or southeast of about 170 degrees. Wind speed from 1999-2003 record showed that the wind speed during the north-east monsoon (November-February) increased from 7 to 10 knots and the south-west monsoon increased from 10 to 13 knots.

The result of the analysis of wind data in this area by Sojisuporn et al (2005) (Figure 3.5) indicated that

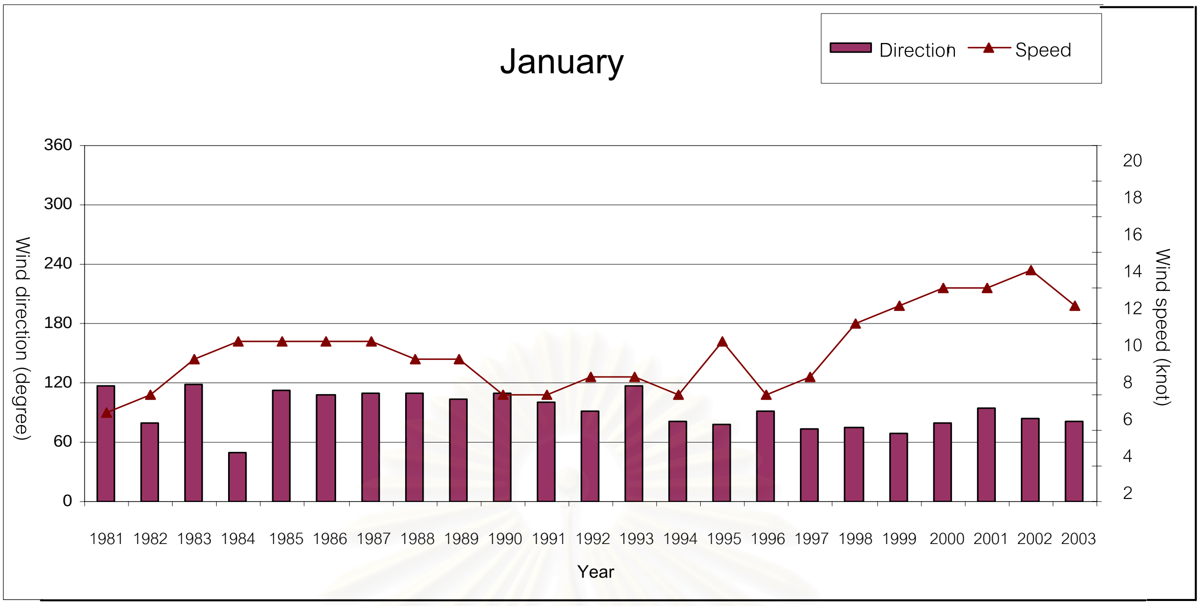
1.The northeast monsoon in November to February, wind direction mostly occurred from north and east. It had a wind speed of approximately10 to 15 knots.

2.The southwest monsoon in May to September, wind direction came from south west with an approximate wind speed of 5 to 10 knots.

3. The inter monsoon period in March to April and October, the direction of wind varied with an approximate wind speed of about 5 to 10 knots.

Storm

Thailand is in the path of tropical cyclones from both the Indian and the Pacific Oceans. The storms have affected people, property and also ocean swell, wind and shoreline changes. The number of tropical cyclones in Thailand in the last 50- years period has decreased from 4-5 times per year to 2-3 times per year. In southern Thailand, tropical cyclones which reached the depression level (34 knot or 63 km/hour) often occurred in October to December. The tropical cyclones have moved into the southern Thailand 5 times in last 50 years.



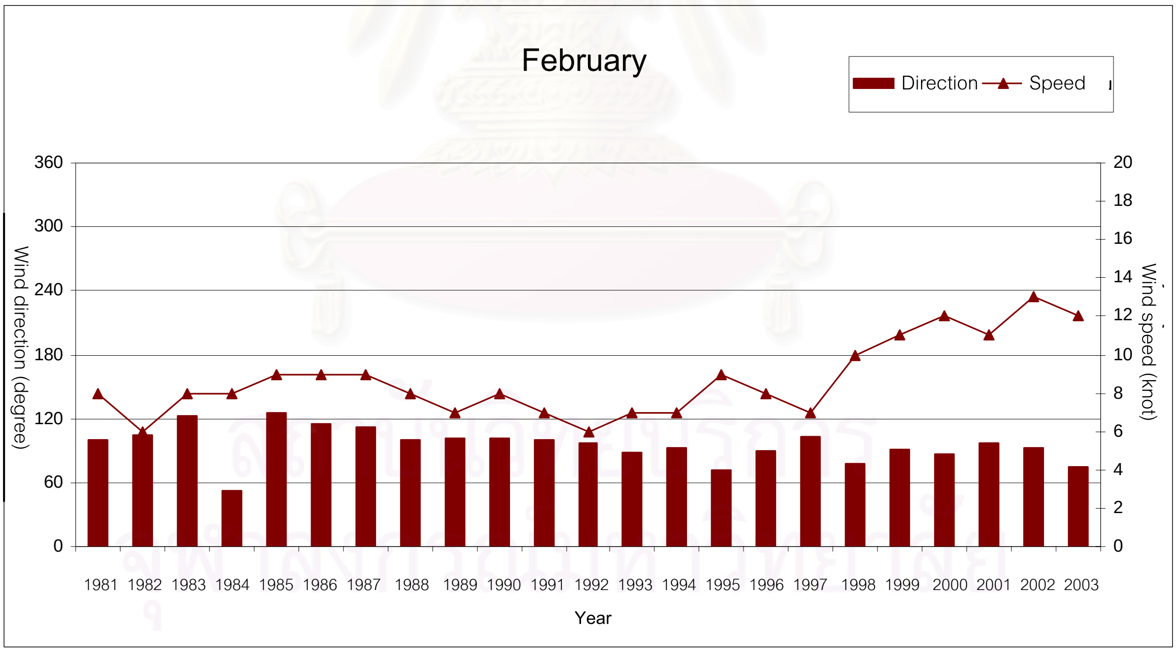
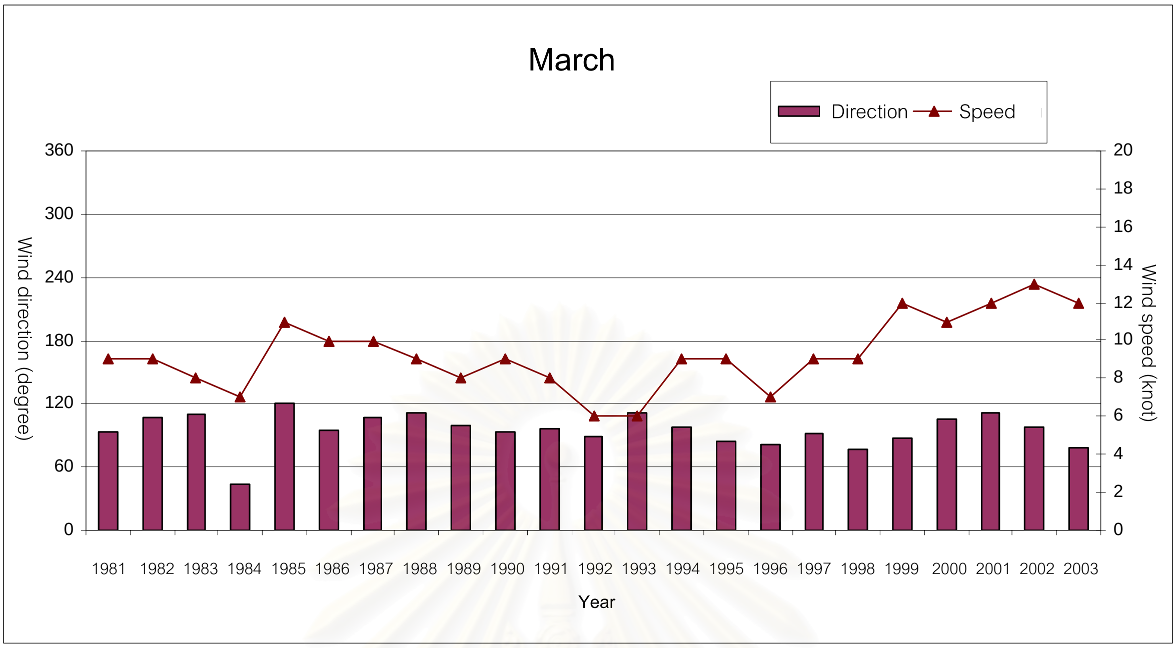


Figure 3.3 Monthly average wind speed and direction at Nakorn Si Thammarat, as recorded by Meteorological Station between years1981 -2003 (Thana et al., 2005)



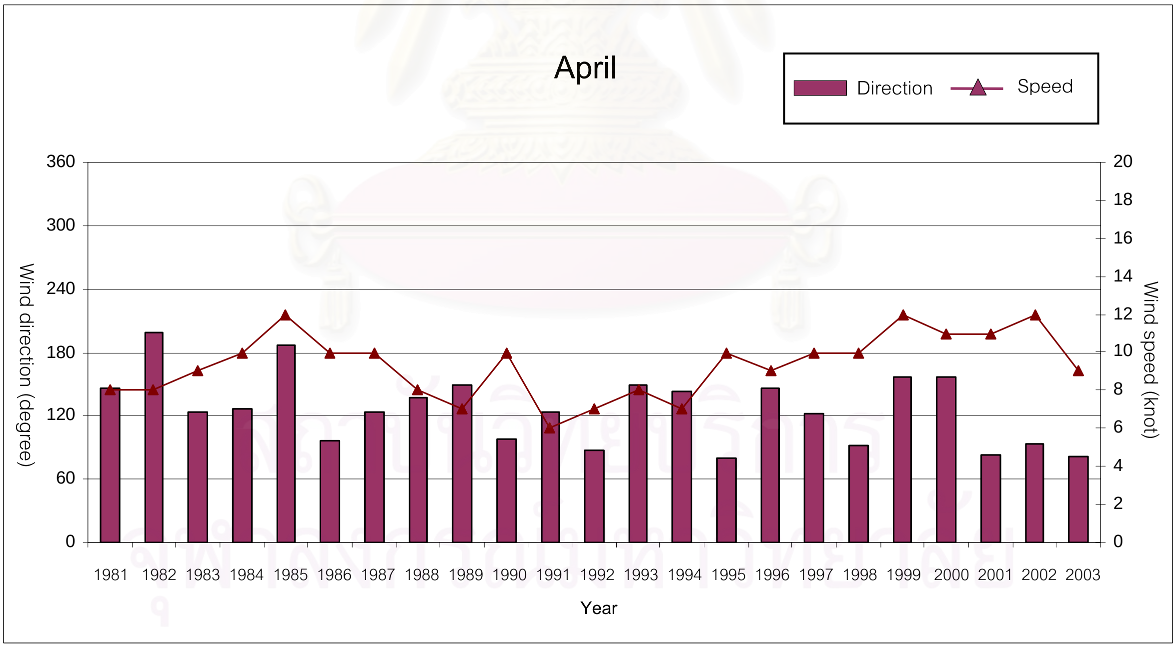
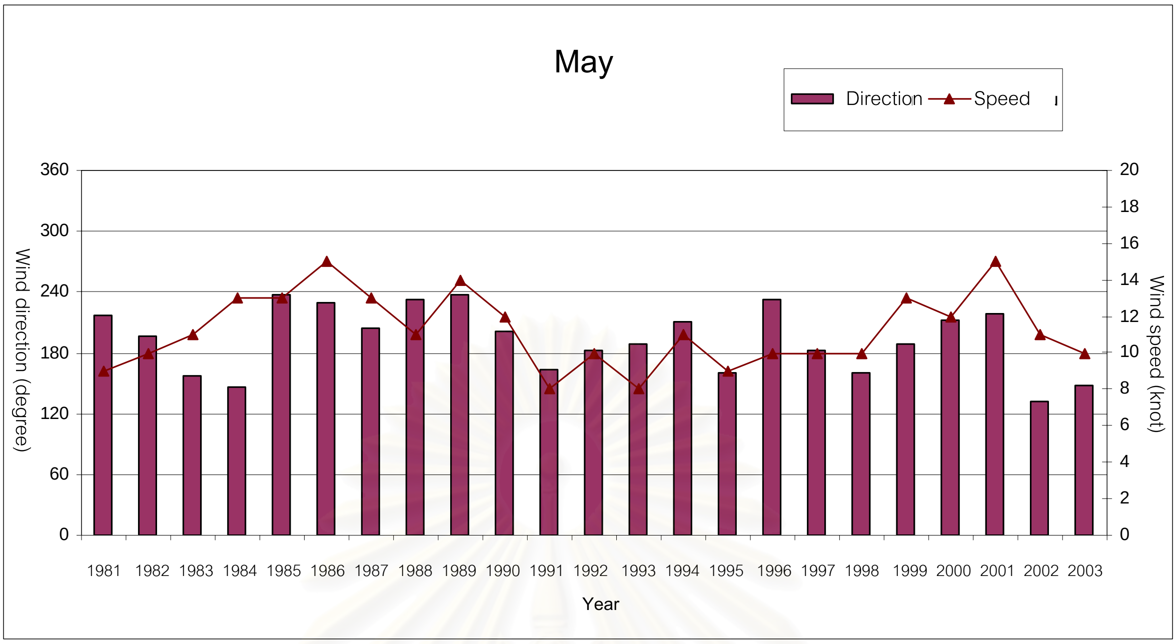
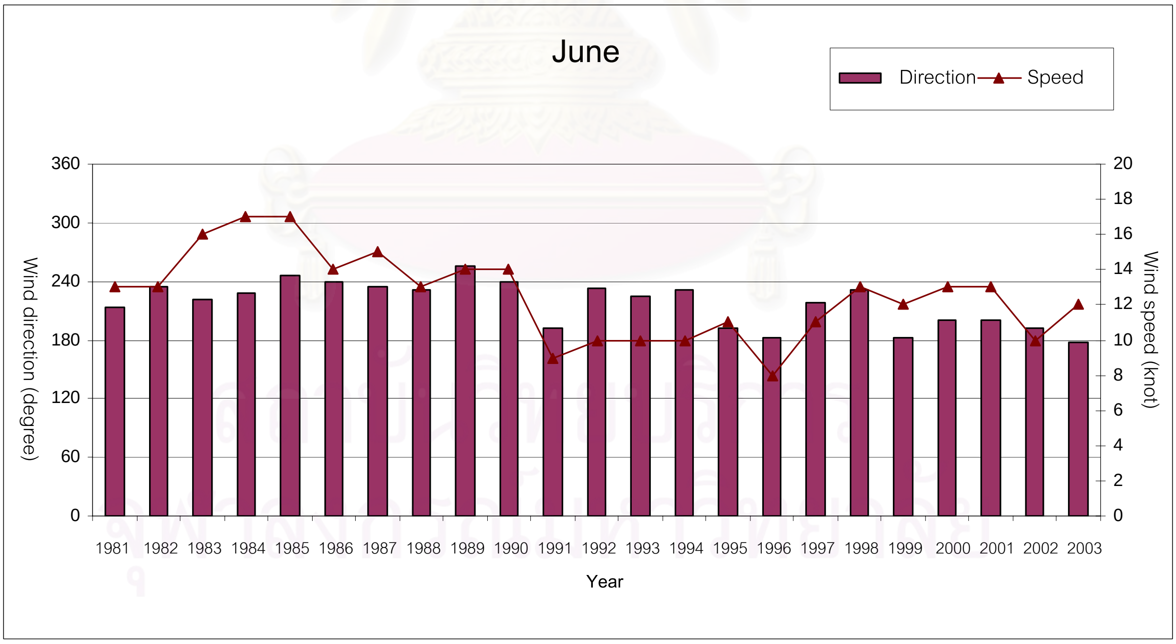


Figure 3.3 (Cont.)





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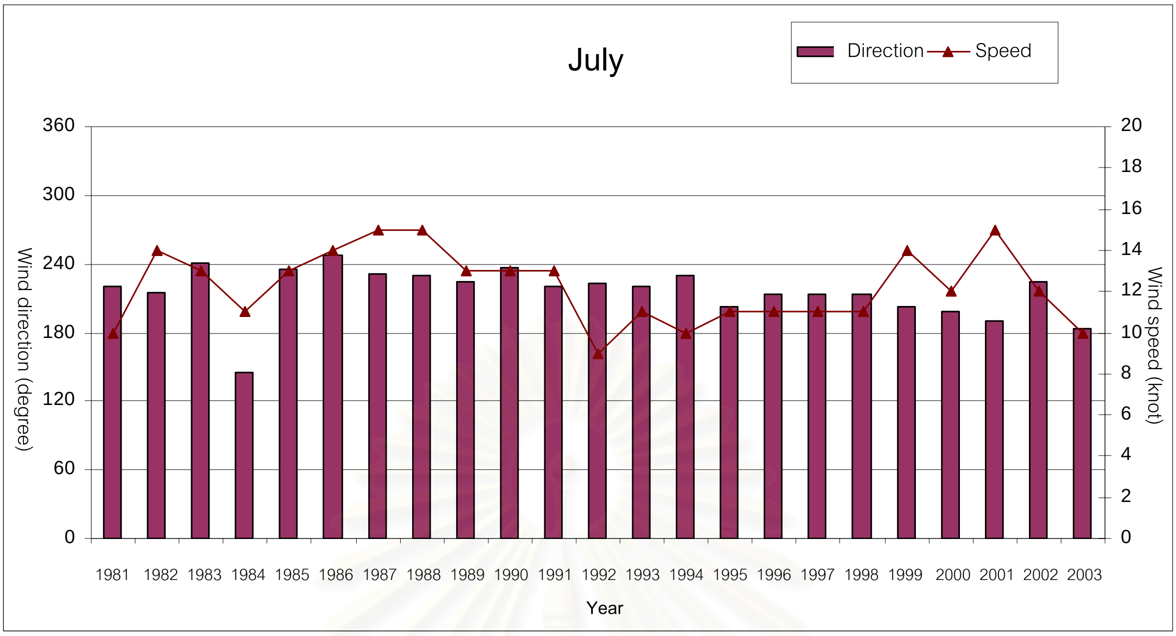

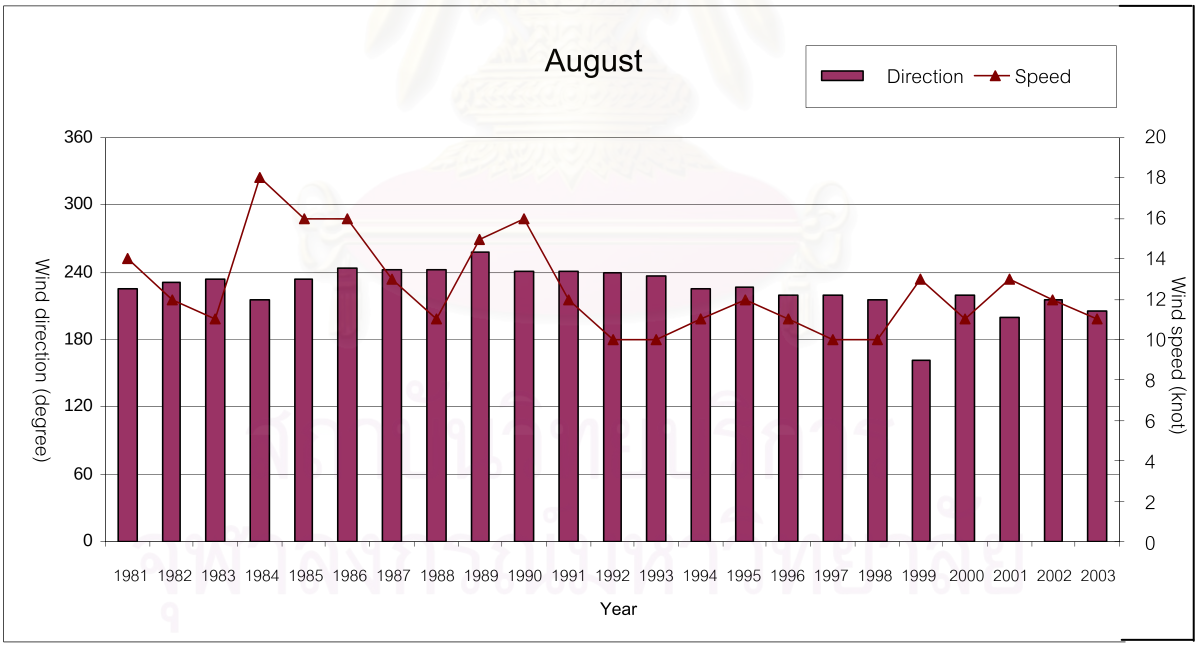

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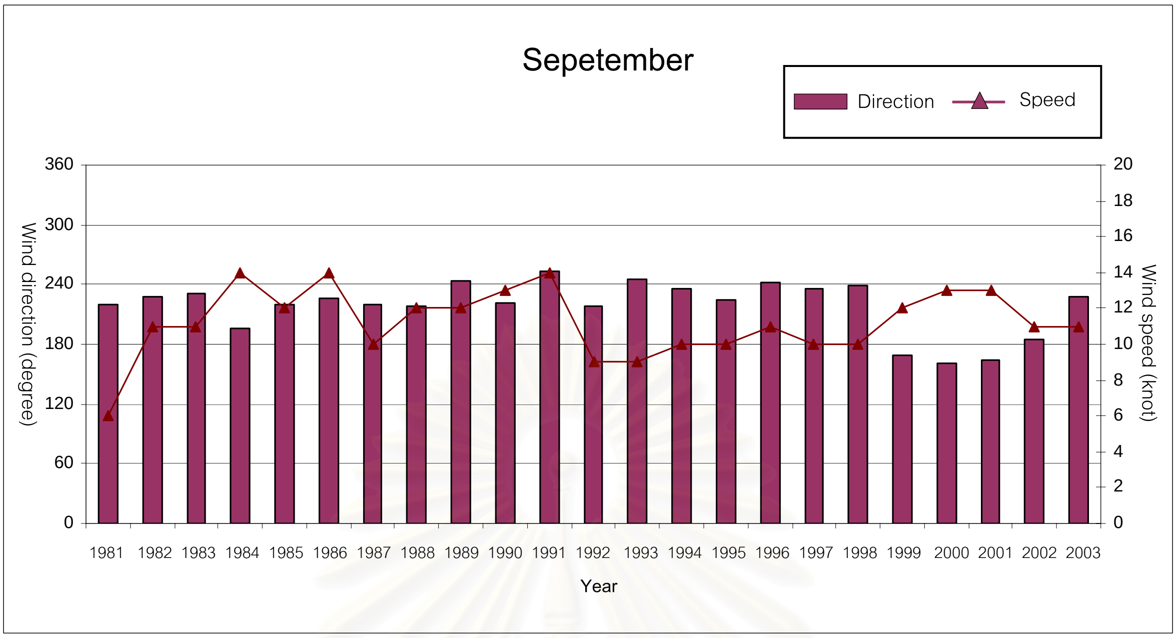


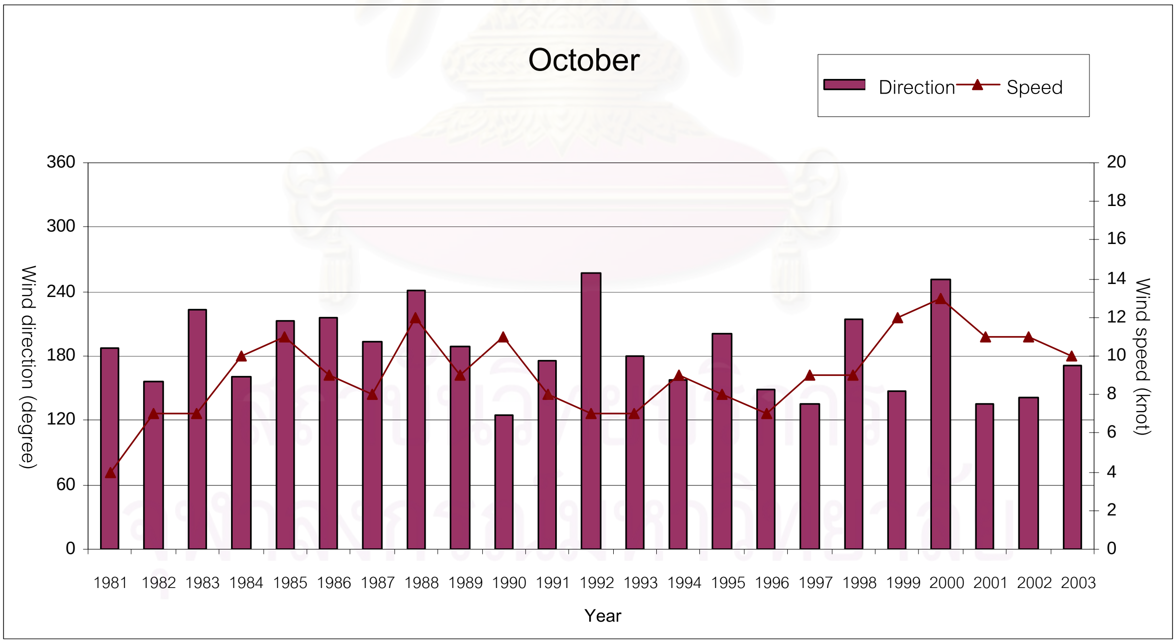
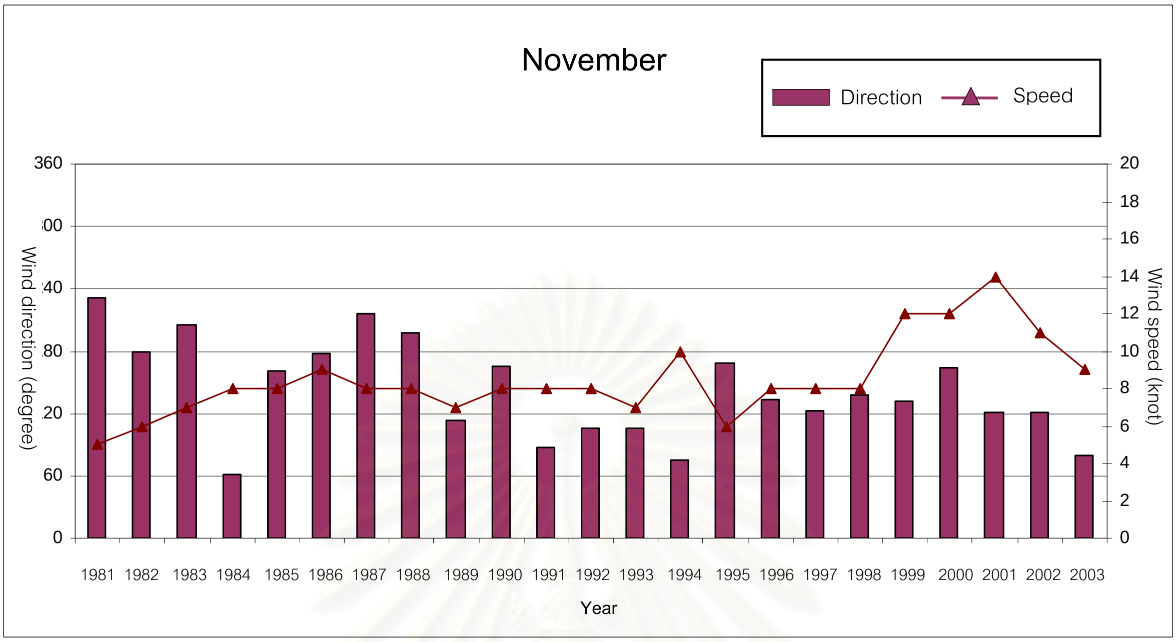


Figure 3.3 (Cont.)



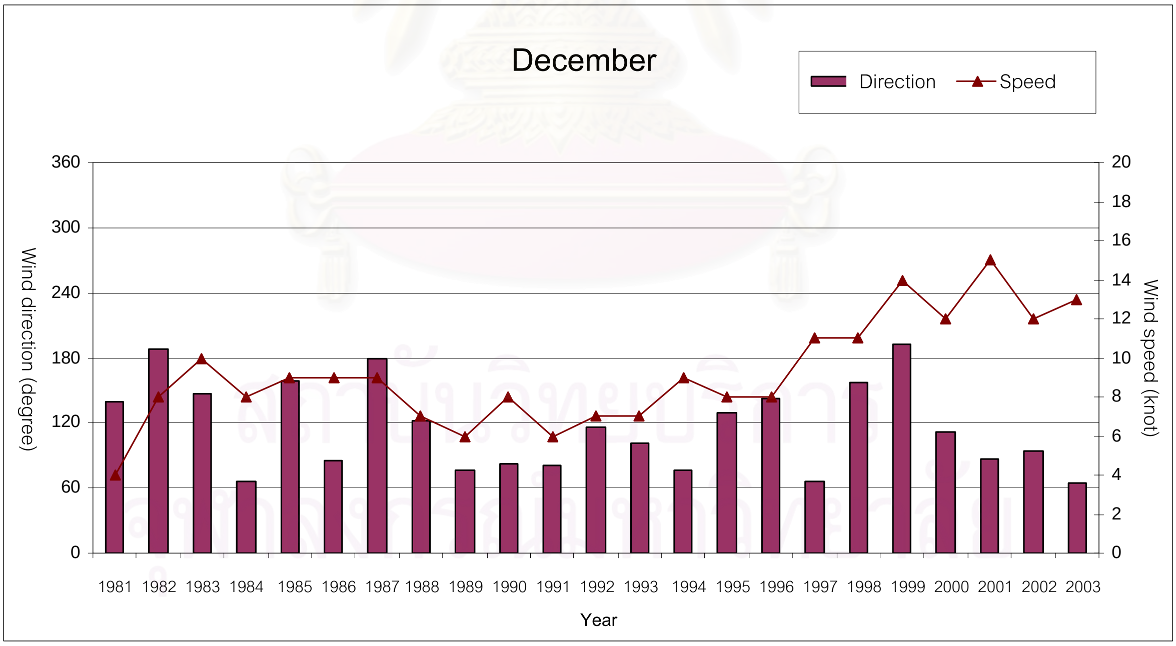


Figure 3.3 (Cont.)

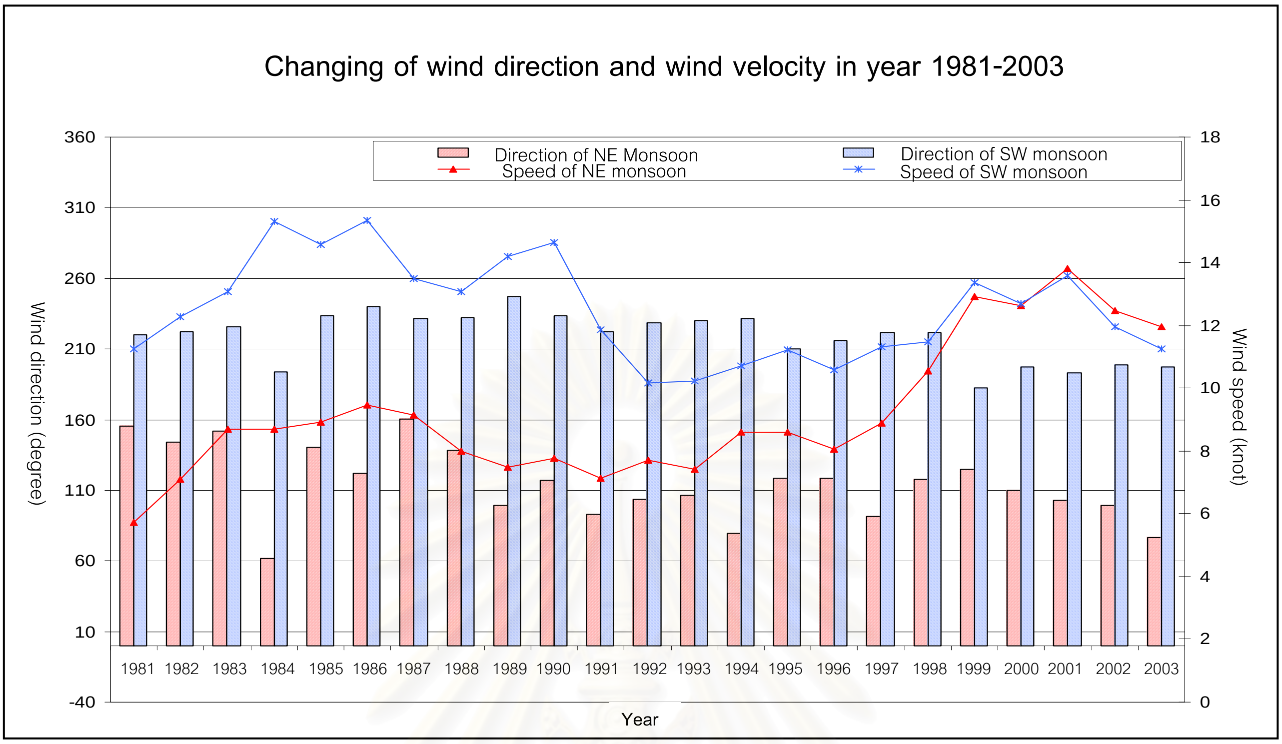


Figure 3.4 Graph illustrating change in direction and speed of wind in a 20 year period (1983-2003) during NE monsoon and SW monsoon period (Thana et al., 2005)

1. Tropical storm “Harriet” originated into the gulf of Thailand and reached the coast at Nakorn Si Thammarat Province on 25 October, 1962. Its speed was approximately 90 kilometers per hour (49 knots) and the highest rainfall was approximately 390.8 milliliters at Phang Nga Province.

2. Tropical storm “Root” originated in South China Sea and moved to Chumporn Province on 25 November, 1970. The wind speed reached 100 kilometers per hour (55 knots) and the highest rainfall was approximately 264 milliliters at Chumporn Province.

3. Typhoon “Gay” moved in the gulf of Thailand and reached the coast at Chumporn Province on 4 November, 1989. Its speed reached 222 kilometers per hour and the highest rainfall was approximately 120.9 milliliters at Prachuap Khirikhan Province.

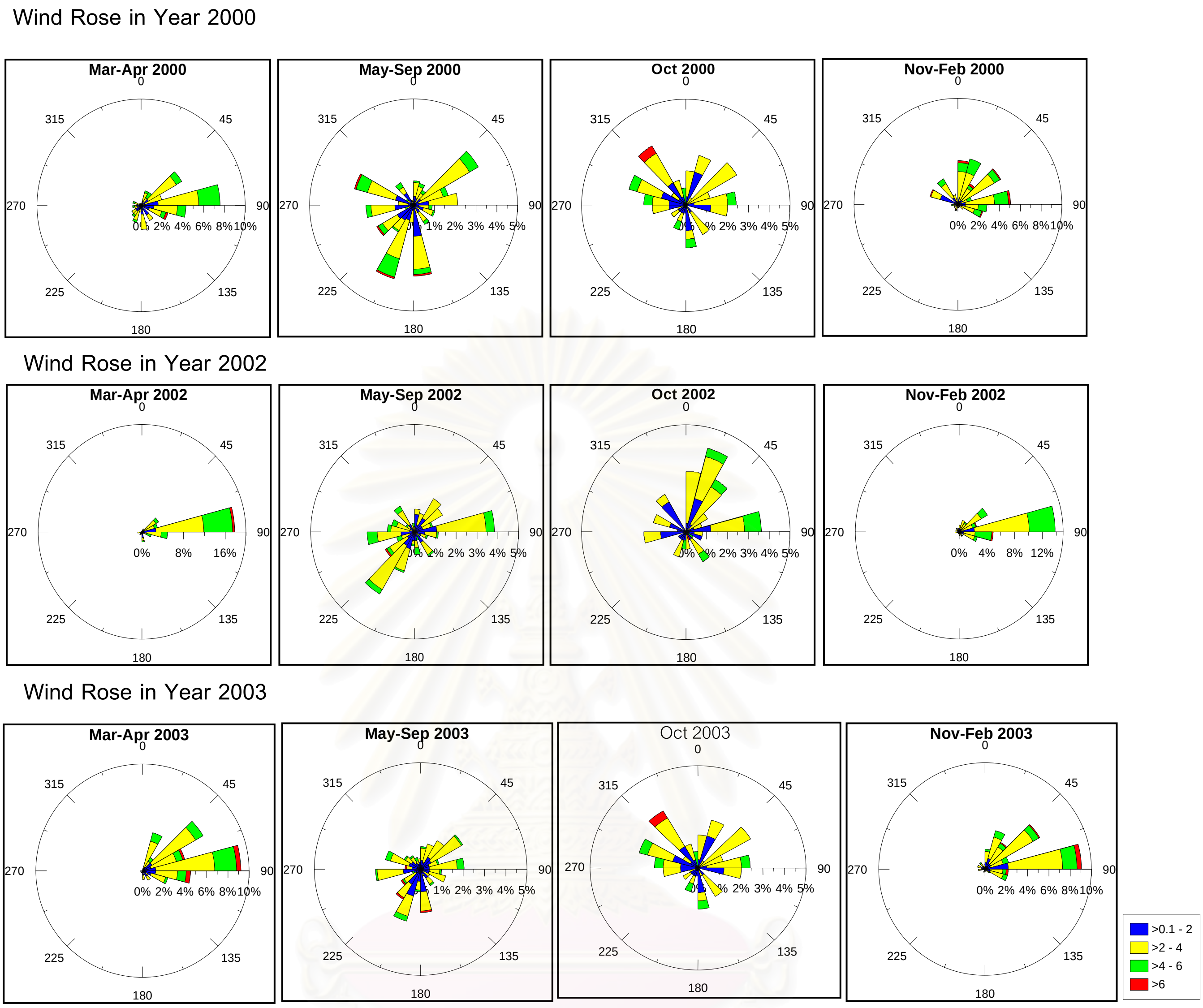


Figure 3.5 Wind rose diagrams in year 2000, 2002, and 2003 (Sojisuporn, 2005)

4. Typhoon "Forest" originated in the Pacific Ocean and move to Nakorn Si Thammarat Province on 15 November, 1992. The wind speed was about 232 kilometers per hour and the highest rainfall was approximately 166.3 milliliters at Nakorn Si Thammarat Province

5. Tropical storm "Linda" originated in the South China Sea and moved to Prachuap Khirikhan Province. The wind speed was about 118 kilometers per hour and the highest rainfall was approximately 304.9 milliliters at Ratchaburi province.

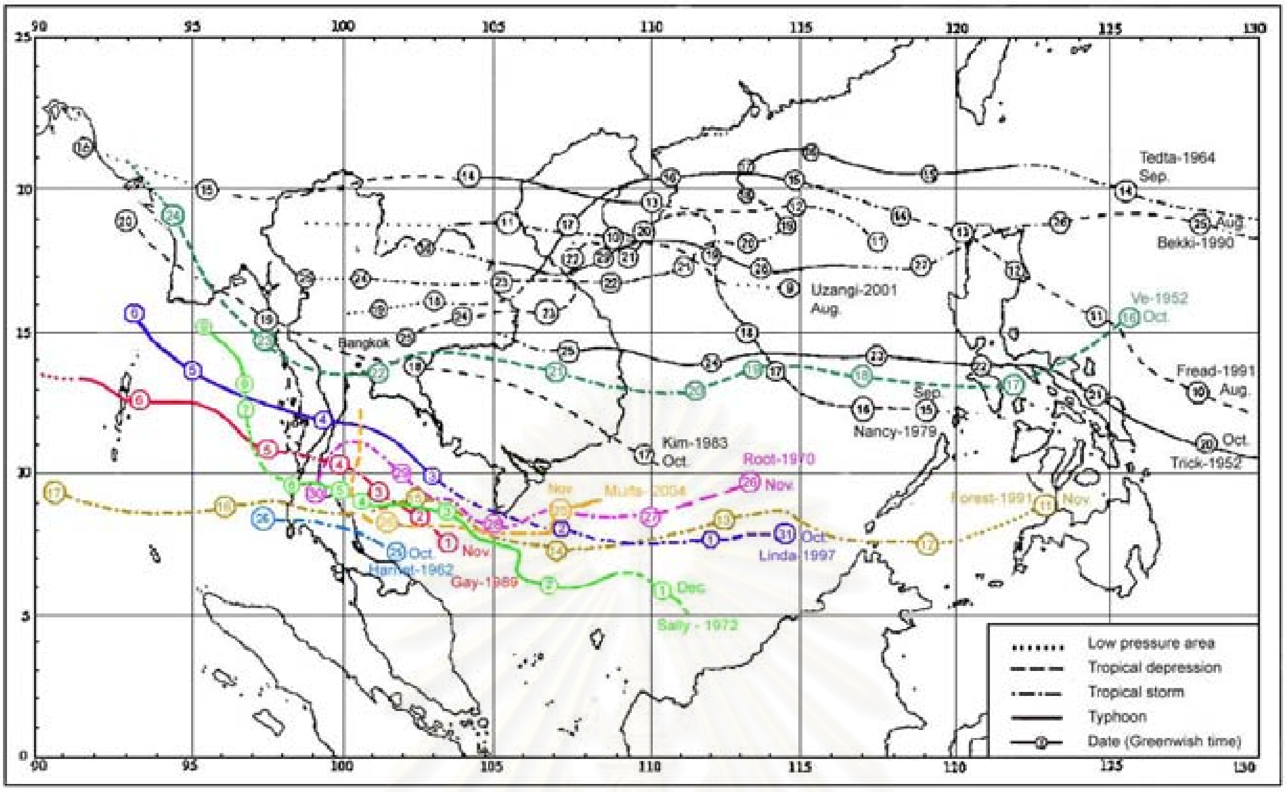


Figure 3.6 Route of Tropical cyclone in Thailand in year 1952-2001 (Thailand Integrated Water Resource Management 2005.)

3.2 Nearshore Swell

According to Nielsen and Adamantidis (2002a, 2002b), Significance waves high (H_s) and wave periods (T_p) were periods were computed as follow;

$$H_s = \frac{0.2433 \times U_A^2}{g} \qquad (1)$$

$$T_p = \frac{8.134 \times U_A}{g} \qquad (2)$$

where U_A = wind stress factor

$= 0.71 \times U_W^{1.23}$

g = 9.81 m/s (gravitational acceleration)

Wind data record was from 13.00 on 23 March, 2004 until 11.00 on 7 April, 2004. The maximum wind speeds from the meteorological stations and from satellite sensor were approximately 12 and 5 meters per second respectively. The significant wave height computed from the meteorological stations and satellite sensors were about

1.884 and 0.351 meter respectively. Also the computed wave periods were about 7.277 and 3.121 seconds, respectively.

From Figures 3.7 and 3.8 the significant wave heights and wave periods discontinued because the wind speed was equal to zero. Figure 3.8 shows the daily variation of wave period with wind speed as the wind speed was high during the day time and low during the night time.

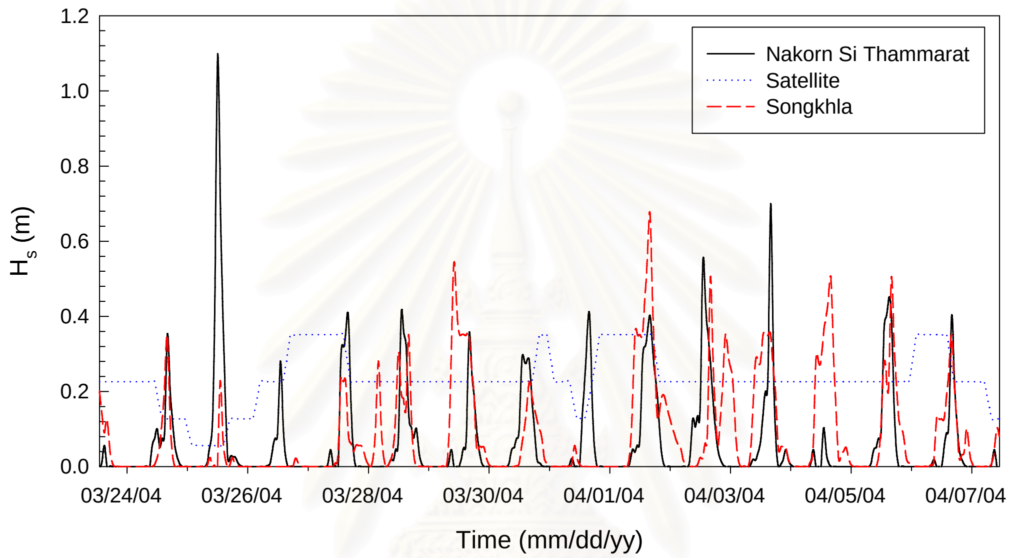


Figure 3.7 Significance wave heights at Nakorn Si Thammarat and SongKhla meteorological stations and from Satellite sensor (Sojisuporn et al., 2005)

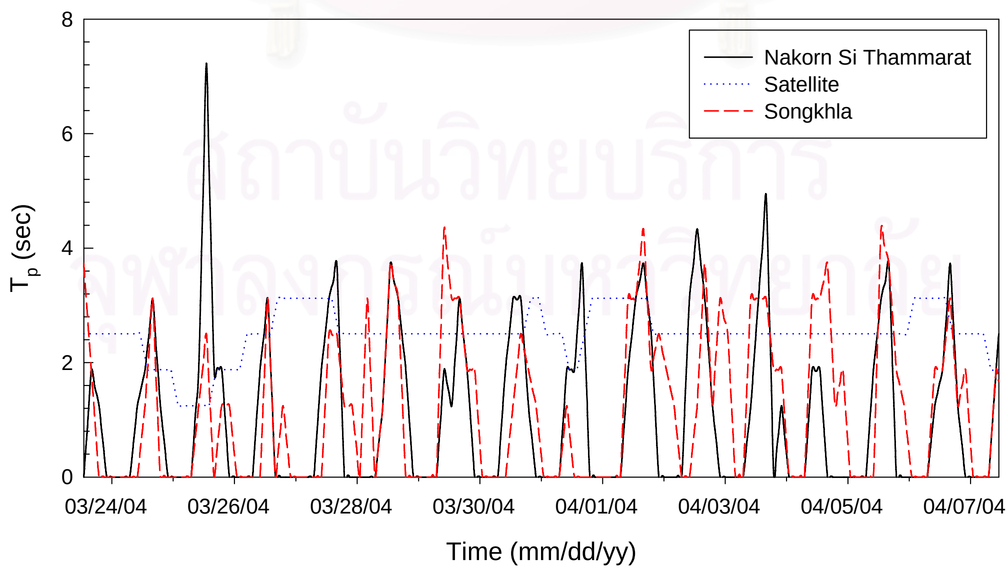


Figure 3.8 Wave periods from Nakorn Si Thammarat and SongKhla stations and from Satellite sensor (Sojisuporn et al., 2005)

Sojisuporn et al (2005) analyzed wind generated waves at Nakorn Si Thammarat station during year 2000, 2002, and 2003 respectively (Figure3.9). From the wave rose diagram, in 2000, the significance of wave high was about 0.5 meters. In 2002, the maximum significance wave height was about 3 meters. The waves in January were on average lower than 1 meter. In 2003, waves were low during the southwest monsoon and high during the northeast monsoon. Most of the wave periods were lower than 6 seconds.

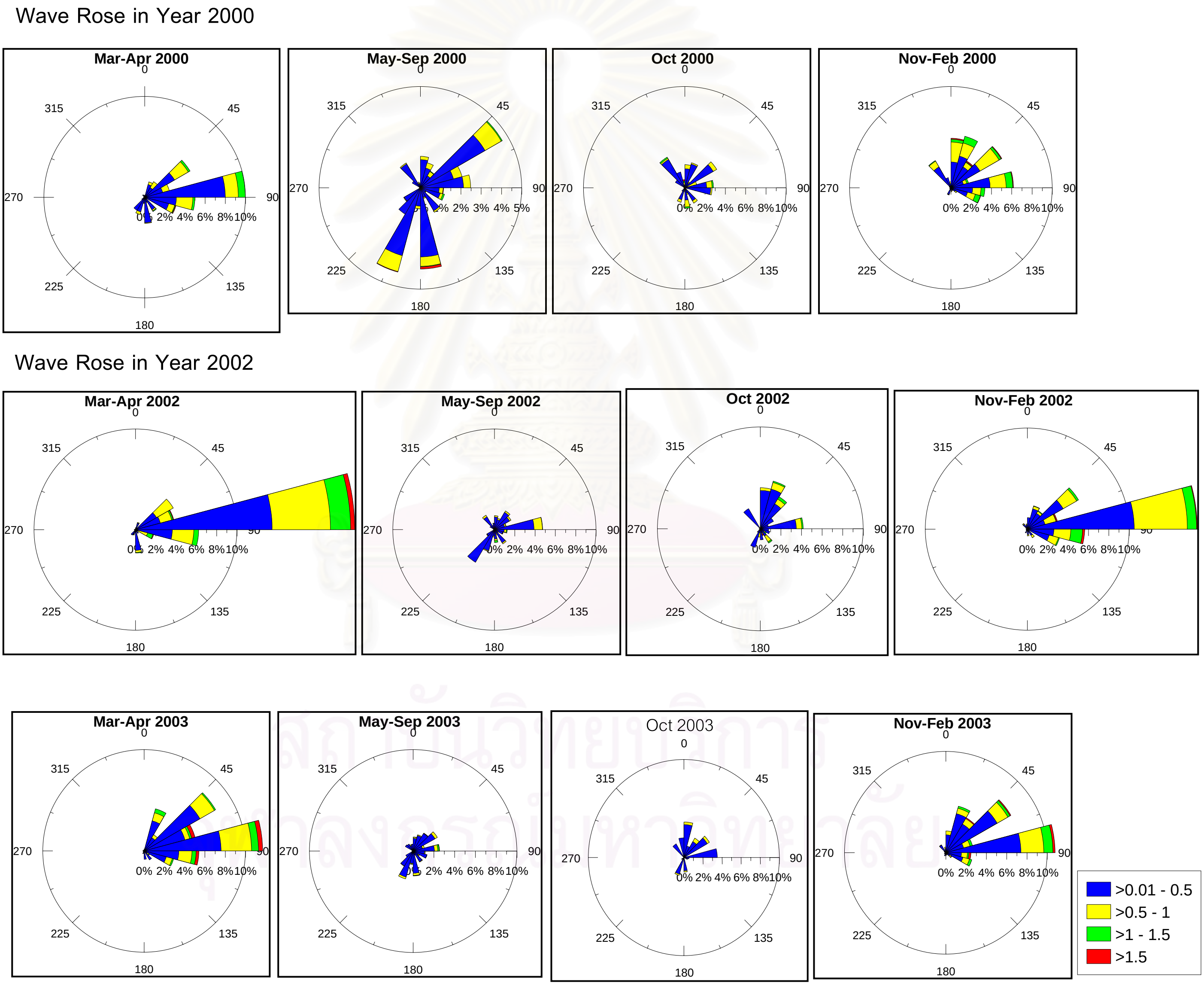
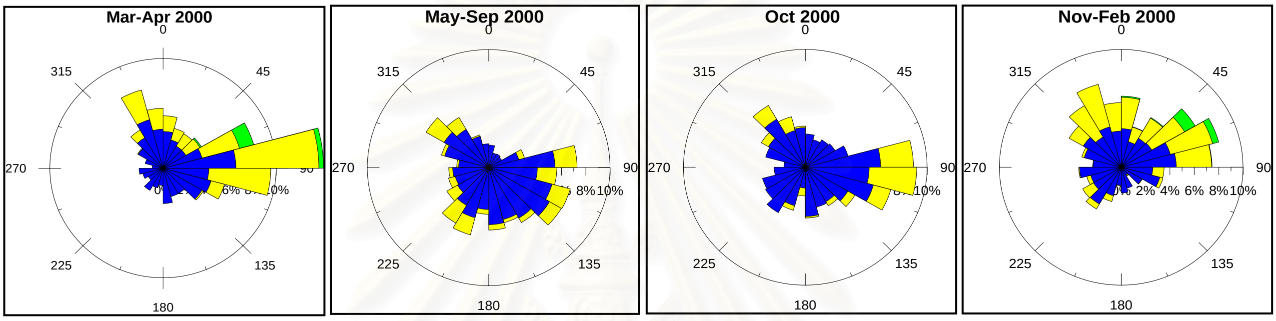


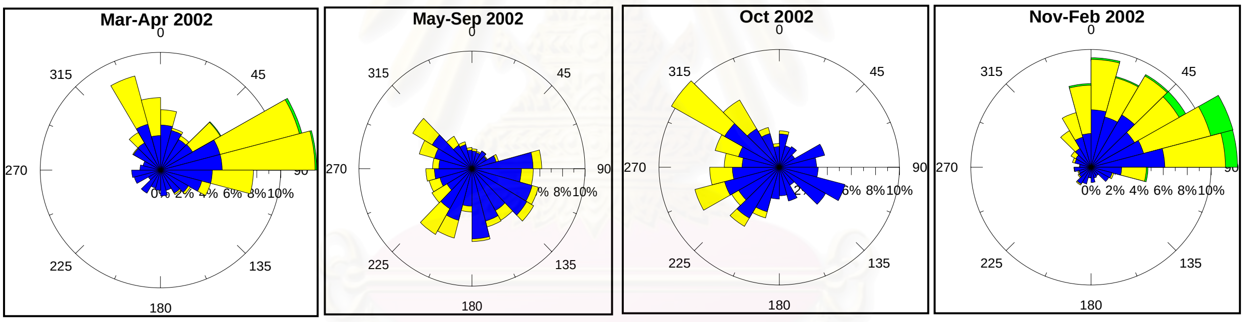
Figure 3.9 Wave rose diagrams in 2000, 2002, and 2003 (Sojisuporn et al., 2005)

Figure 3.10 displayed the velocity and direction of currents at the Nakorn Si Thammarat Province (Sojisuporn et al., 2005). Wind direction had an influence on the change of the speed and direction of the ocean currents. During the northeast monsoon the easterly and southerly winds caused the current to move to the east. The current speed was about 0.2-0.4 meters per second. The current in the southwest monsoon was slower and the current direction varied because of the wind's regimes.

Current Rose in Year 2000



Current Rose in Year 2002



Current Rose in Year 2003

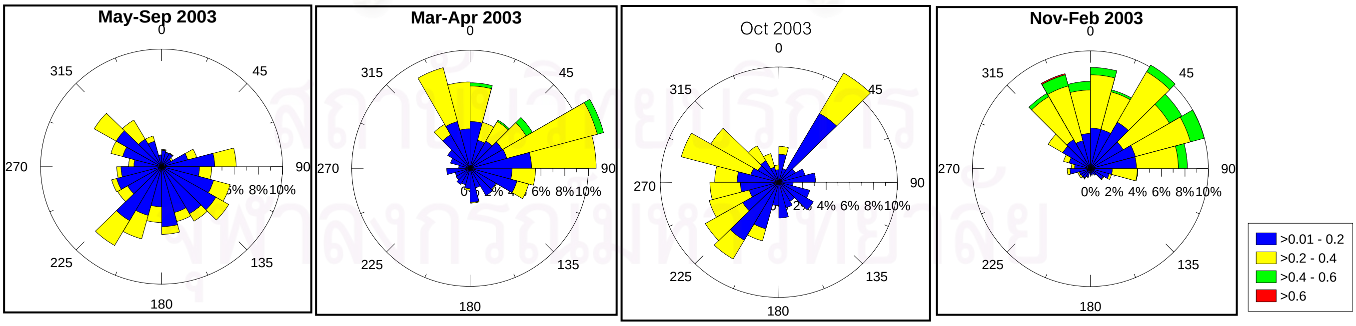


Figure 3.10 Current rose diagrams in 2000, 2002, and 2003 (Sojisuporn et al., 2005)

3.3 Tidal characteristics

Harbour Department (1998) reported the analysis tide data at Pak Nakorn and Pak Mae Num Tapee station. The value of Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) were +0.48 and – 0.42 meter from mean sea level respectively. The type of tide in this area was diurnal tidal. Non harmonic analysis on the tidal data at Pak Num Pak Phanang station (data set between 2529-2535 and 2540-2545) and Pak Num Pak Nakorn station (data set between 2529-2533) yielded the results as shown in Table 3.2

Table3.2 Non-harmonic data at Pak Num Pak Phanang and Pak Num Pak Nakorn station (Sojisuporn et al., 2005)

Tidal Data	Average (meter)			
	Pak Num Pak Phanang station (Lat100°12′8″E, Long 8°21′10″N)		Pak Num Pak Nakorn station (Lat100° 3′ 58″ E, Long8° 28′ 22″ N)	
	Station	M.S.L.	Station	M.S.L.
H'est H.W. (December 1999) [1] (December 1987) [2]	4.01	+1.51	3.95	+1.45
M.H.H.W.	2.75	+0.25	2.92	+0.42
M.L.H.W.	2.48	-0.02	2.52	+0.02
M.H.W.S.	2.76	+0.26	2.92	+0.42
M.H.W.	2.68	+0.18	2.79	+0.29
M.H.W.N.	2.67	+0.17	2.79	+0.29
M.T.L.	2.39	-0.11	2.48	-0.02
Loc.M.S.L.	2.37	-0.13	2.49	-0.01
M.L.W.N.	2.11	-0.39	2.16	-0.34
M.L.W.	2.11	-0.39	2.17	-0.33
M.L.W.S.	2.06	-0.44	2.15	-0.35
M.H.L.W.	2.22	-0.28	2.27	-0.23
M.L.L.W.	2.07	-0.43	2.12	-0.36
L'est L.W. (July 1987) [1] (January 1990) [2]	1.50	-1.00	1.44	-1.06
Mn	0.57	0.57	0.62	0.62

[1] For Pak Num Pak Phanang station [2] For Pak Num Pak Nakorn station

At the Pak Phanang station the Local Mean Sea Level (Loc.M.S.L.) is below the mean sea level by about 0.1 meters because of the influence of in the river flow. The tidal range (Mn) is about 0.6 meter and it indicated that the area experiences micro tide.

Method of analysis tide

In the study of tides, by Harmonic method, water level is the sum of all the tidal components;

$$\eta(t) = A_0 + \sum_{i=1}^{n} A_i \cdot F_i \cos(\omega_i \cdot t + (V_0 + u)_i - \kappa_i) \quad (1)$$

$\eta(t)$	is water level at time *t*
A_0	is mean water level at all times
n	is number of tide components
i	is the i *th* tidal components
A_i	is amplitude of the i *th* tidal components
F_i	is scale factor of the i *th* tidal components
ω_i	is angular of velocity of the the i *th* tidal components
$(V_0 + u)_i$	is astronomical argument of the i *th* tidal components
κ_i	is phase of the i *th* tidal components

Water level can be computed when $A_i + \kappa_i$ were known. The amplitudes of K_1, O_1, M_2 and S_2 can be used to calculate the wave number (F)

$$F = \frac{K_1 + O_1}{M_2 + S_2} \quad (2)$$

F = 0 - 0.25	tide is classified as semidiurnal tide
F = 0.25 - 1.50	tide is a mixed tide with strong semidiurnal components
F = 1.50 - 3.00	tide is a mixed tide with strong diurnal components
F = > 3.00	tide is diurnal tide

Sojisuporn et al., (2005) calculated the tidal component from the data in year 1987 at Pak Phanang and Pak Nakorn stations by using the harmonic method. The analysis was shown in Table 3.3. The main tidal component in the table is S_a which is a tide caused by monsoon effect. The low water level occurs in May to June where southwest monsoon pushes water out of the Gulf of Thailand. The high water level occurs during the northeast monsoon in October to November when the wind pushes water into the Gulf of Thailand. Both K_1 and O_1 factors are diurnal components and the semidiurnal components are M_2 and S_2.

K_1, O_1, M_2 and S_2 from Table 3.4 are used to calculate the form number F . F value computed from data from Pak Phanang and Pak Na Korn stations are approximately 2.046 and 1.796 respectively. The tides recorded by two these stations are known as mixed tides with strong the diurnal components.

Table 3.3 Tidal factor in year 1987 (Sojisuporn et al., 2005)

Factor	Pak Num Pak Phanang station (Lat100°12′8″E, Long 8°21′10″N)		Pak Num Pak Nakorn station (Lat100° 3′ 58″ E, Long8° 28′ 22″ N)	
	amplitude (centimeter)	phase (degree)	Amplitude (centimeter)	phase (degree)
S_a	28.0	276.8	29.1	275.0
MM	2.3	87.7	3.8	96.6
MF	1.4	97.2	1.3	129.1
Q_1	2.5	154.4	3.2	124.9
O_1	13.8	178.9	16.4	154.5
P_1	4.5	226.3	5.7	206.2
K_1	17.1	236.0	21.5	212.3
N_2	1.8	331.7	2.2	300.2
M_2	11.2	2.8	15.1	331.3
S_2	3.9	74.1	6.0	46.8
K_2	1.4	85.7	2.6	35.2

3.4 Longshore sediment transport

Longshore sediment transportwas the product of both the local storm waves and swell. The longshore transport in the Nakorn Si Thammarat Province is affected by waves and currents.

Sojisuporn et al., (2005) concluded that sediment transport occurred in the water column not over 4 meter deep

.

Table 3.4 shows the gross sediment transport and net sediment transport from 5 stations at Khanom, Si Chon, Tha Sala, Pak Phanang, Hua Sai during the years 2000, 2002 and 2003. Gross sediment transport was 40,000-110,000 cubic meters per year. Net of sediment transport was 6,000-38,000 cubic meters per year.

Table 3.4 Sediment transport at Hua Sai and Pak Phanang Station (in 2000, 2002, and 2003) (Sojisuporn et al., 2005)

Hua Sai	2000			2002			2003		
	gross	net	angle	gross	net	angle	gross	net	angle
NE Monsoon (Nov - Feb)	27677	15717	150	27677	15717	320	25575	18518	350
Inter Monsoon (Mar - Apr)	5571	3291	20	13404	4655	360	15676	7474	325
SW Monsoon (May – Sep)	7370	4954	350	4172	1894	350	7028	4825	350
Inter Monsoon (Oct)	1481	603	50	4976	4495	155	200	90	130

Pak Phanang	2000			2002			2003		
	gross	net	angle	gross	net	angle	gross	net	angle
NE Monsoon (Nov - Feb)	65652	46927	160	65658	36431	160	62500	35223	130
Inter Monsoon (Mar - Apr)	13764	2568	310	40135	7221	325	37955	9017	320
SW Monsoon (May – Sep)	17132	8248	320	10420	4522	330	15707	10505	335
Inter Monsoon (Oct)	2665	950	130	7305	5915	150	788	387	75

The gross sediment transport at each station was rather stable from year to year while net sediment at each station changed, due to direction of waves and currents. In the year 2000 the main wind direction was in the north therefore the direction of sediment transport was in the southeast direction. In the year 2002 and 2003 the wind direction was easterly and northeasterly; therefore the direction of sediment transport was to the north.

Figure 3.11 showed the net sediment transport and direction of sediment transport at Pak Phanang and Hua Sai station in the year 2000, 2002, and 2003. The net sediment transport and direction of sediment transport during each monsoon were different. During northeast monsoon (November-February) the direction of sediment transport at Pak Phanang station was from north to south with net sediment of about 35,000-47,000 cubic meters.

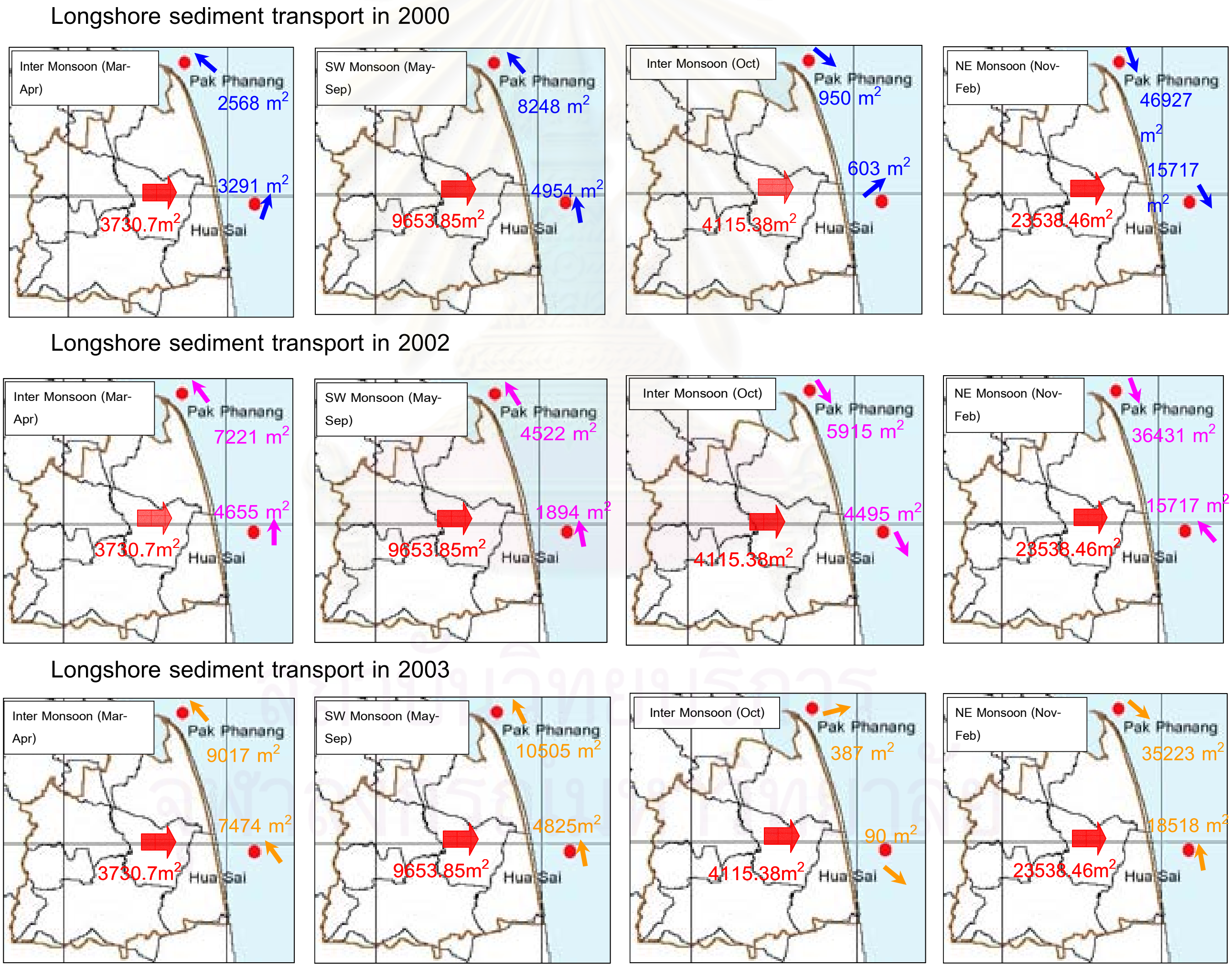


Figure 3.11 Longshore sediment transport at the Pak Phanang river basin in year 2000, 2002, and 2003 (Jarupongsakul, 2005)

At Hua Sai Station, the direction of sediment transport was from north to south with the net sediment transport of about 15,000-19,000 cubic meters. The net sediment transport during the northeast monsoon was about 58 percent of annual sediment transport. In the southwest monsoon (May – September), the direction of sediment transport at the Pak Phanang and Hua Sai area was from south to north with the net sediment transport of about 4,500-10,500 cubic meters at Pak Phanang station and 1,800-4,900 cubic meters at Hua Sai station which was equal to 20 percent of annual sediment transport.

During the intermonsoon period (March –April) direction of sediment transport at the Pak Phanang and Hua Sai area was from south to north with the net sediment transport of about 2,500-9,000 cubic meters at Pak Phanang station and 3,000-7,000 cubic meters at Hua Sai station which was equal to 19 percent of annual sediment transport.In the intermonsoon period (October), the direction of sediment transport at the Pak Phanang and Hua Sai area was from north to southeast with the net sediment transport of about 380-5,900 cubic meters at Pak Phanang station and 90-4,400 cubic meters at Hua Sai station which was equal to 3 percent of annual sediment transport.

CHAPTER IV
COASTAL EROSION

4.1 Identification of the shoreline changes

4.1.1 Data collection

The existing data related to the study was as follow:

1) Topographic maps, 1:50,000 scale in L7017 series; map sheet numbers 4924I, 4925I, 4925II, 4926II, 5025II, 5025III, 5025IV, and 5026III were prepared and published by the Royal Thai Survey Department in1975.
2) Aerial photographs produced in 1975, 1995, and 2002 by the Royal Thai Survey Department at the scale: 1:15,000, 1:50,000 and 1:25,000 respectively
3) The primary data including physical, economic and social data were presented in digital form at dBase file (*.dbf) for base data and linked maps.

   Physical data consists of:
   - Topography
   - Climate
   - Geology
   - Soil properties
   - Transportation
   - Stream and water body
   - Watershed classification

   Economic and social data consists of
   - Political boundaries
   - Human settlement
4) The software "PCI and ENVI 4.0" were used for processing and analyzing aerial photographs. Also, "Arc View GIS 3.2" was used for the utilization of GIS data and secondary data.

4.1.2 Remote sensing

<u>Image rectification</u>

Geometric correction could be defined as the process of projected data on horizontal plane and it was made to conform to a map projections system. For multi-temporal images, it was necessary to adjust the image coordinates to be in accordance to the map, in order to get accuracy of spatial references (Bunyachatphisuth, 1999). The geometric correction was done for setting aerial photographs based on topographic maps by GCPs (Ground control points) (Figure 4.1). Geometric position from the ground was made by the GPS (Global position system) to check for accuracy. After correcting geometric distortion, aerial photographs were mosaiced to form a complete image of the study area. (Figure 4.2)

Detection of shoreline change

In this study, shoreline changes were detected by using PCI software to delineate shoreline position. All shorelines of different years were digitized and stored in digital vector format. The land-water interface was identified as the shoreline. Tidal data at Pak Panang station was a predominantly mixed diurnal type. The mean tidal range, as calculated from data between 1986 to 1992 and 1997 to 2002 was just 0.57 meter (Marine Department, 2003). All photos taken during high tide and low tide showed non significant change of shoreline position. These images suggested that changes of shoreline position, according to the tidal effects were negligible.

Next, image reflection and detection of shoreline change, erosional and depositional area of the shoreline, were carried out twice. The processing step GIS data is shown in the Figure 4.3

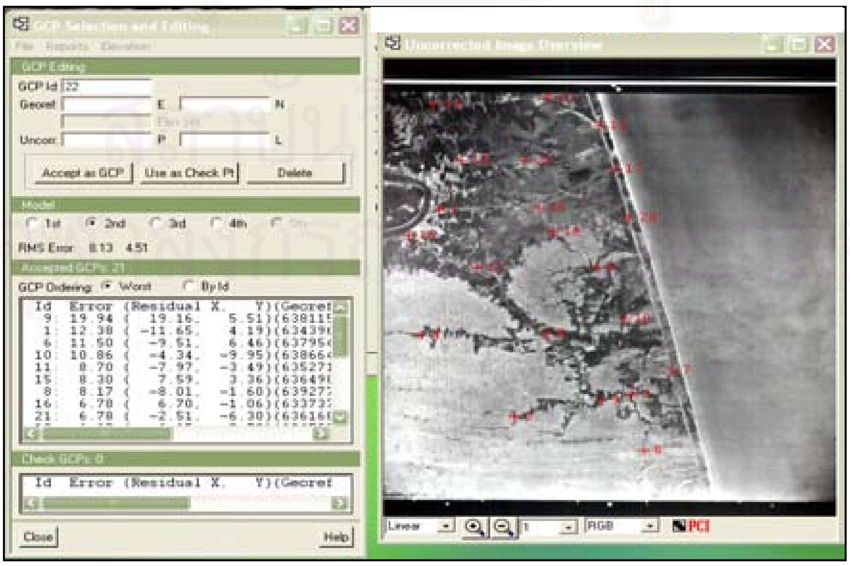


Figure 4.1 PCI program show in the ground control points (GCPs).

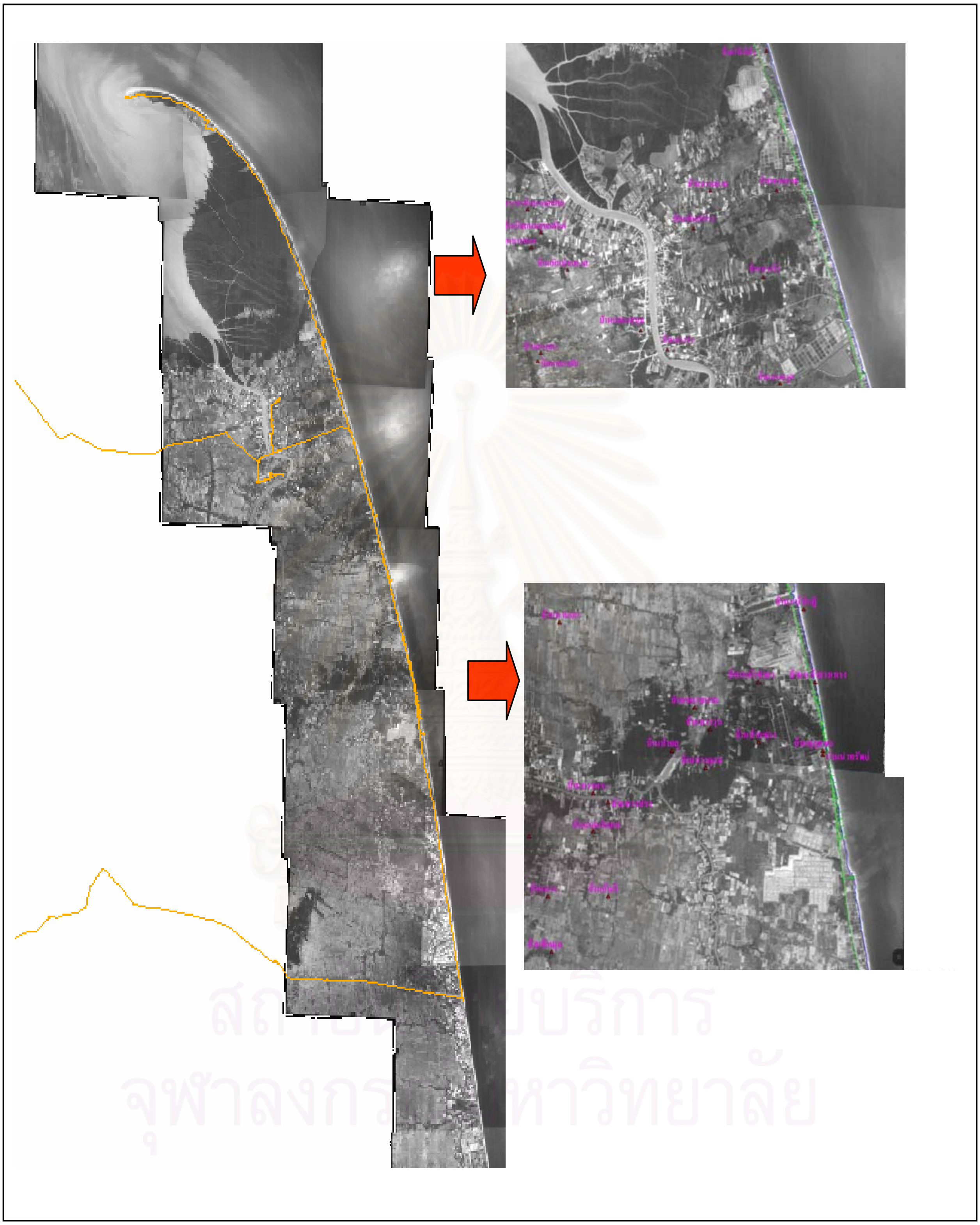


Figure 4.2 Mosaic arrangements of aerial photographs of the study area in 1995 combining with route images from GIS data in the field.

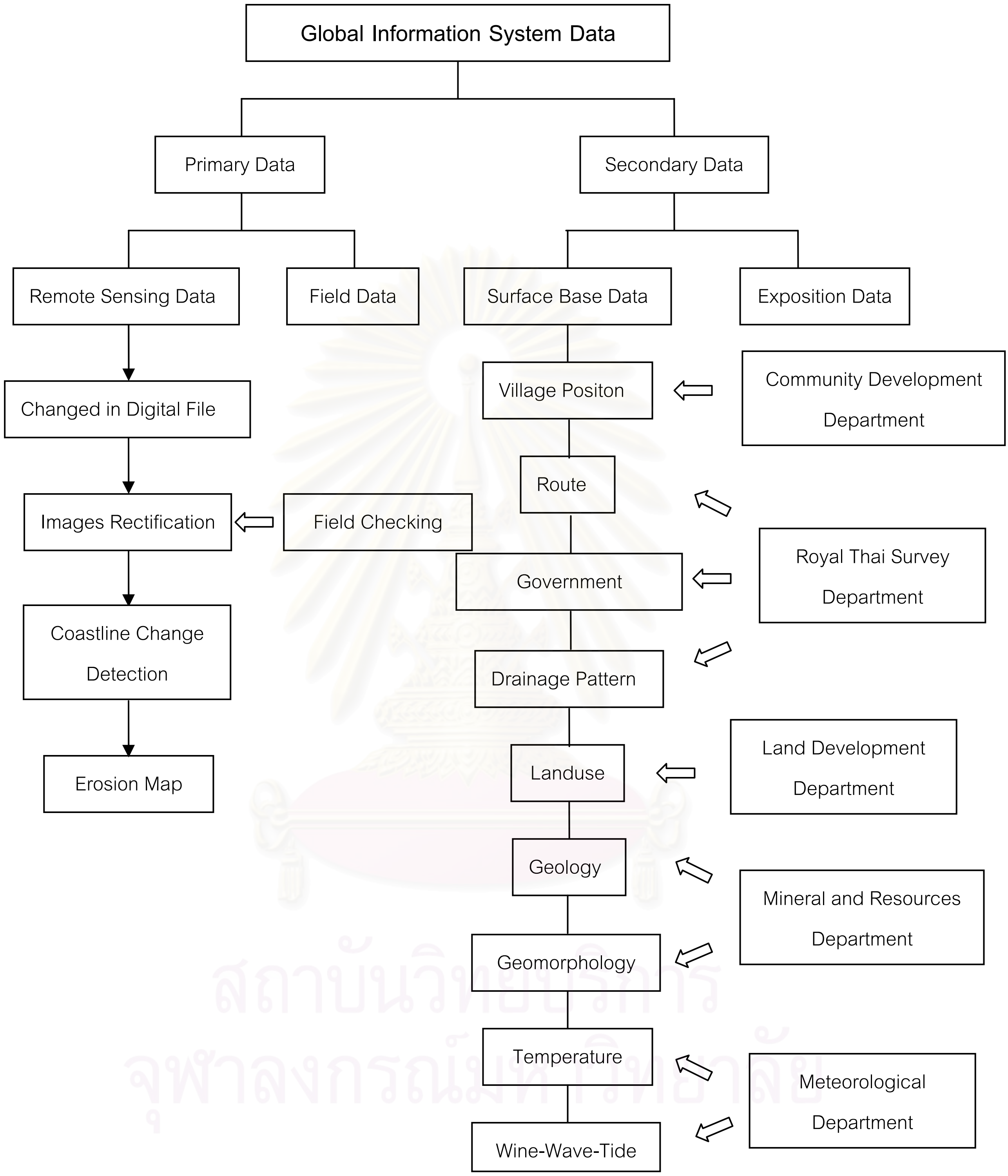


Figure 4.3 The steps taken in managing in the GIS system data.

4.2 Analysis results of the aerial photography

The coastal changes were detected by using three sets of aerial photograph in 1975, 1995 and 2002 (Table 4.1). In this study used the black-white aerial photograph scale 1:50,000 in 1975 and 1995. And colored aerial photograph scale 1:25,000 in 2002 to interpret the shoreline change

Table 4.1 Data types to interpreted the coastal changes

Type of data	Year	Scale
Topographic map	1975	1:50,000
Aerial photograph (black-white)	1975	1:50,000
Aerial photograph (black-white)	1995	1:50,000
Aerial photograph (RGB)	2002	1:25,000

To calculate the rate of erosion and deposition, the shoreline was divided into small blocks of about 200 meters long along the shoreline and 500 meters wide (in land). There were the totals of 345 blocks (PN1 to PN345). The rate of shoreline changes could be calculated from the change of area in each block between 2 successive photographs (see Figure 4.4).

4.2.1 Shoreline change between 1975-1995

When the Shoreline was compared between 1975 and 1995, it was noticed that there was a high rate of deposition, (more than 20 meters per year) in the upper part of the study area in the Lam TalumPuk cape. The highest rate of erosion in this study could be found at Ban Plai Sai, which had the erosion rate of 6.846 meters per year. Usually severe erosion was about 3-4 meters per year which occurred in the middle of shoreline study.

Details of areas that have a high shoreline change are shown below:

1. <u>The deposition area</u>

- Ban Plai Sai, Laem Talumpuk sub-district Block PN1-PN8 (km.0.2-1.6 from Talumpuk cape), has the deposition rate of about 22.97 meters per year.
- Ban Chim La, Na Saton sub-district Block PN307-PN314 (km.61.4-62.8 from Talumpuk cape) has the deposition rate of about 3.215 meters per year.

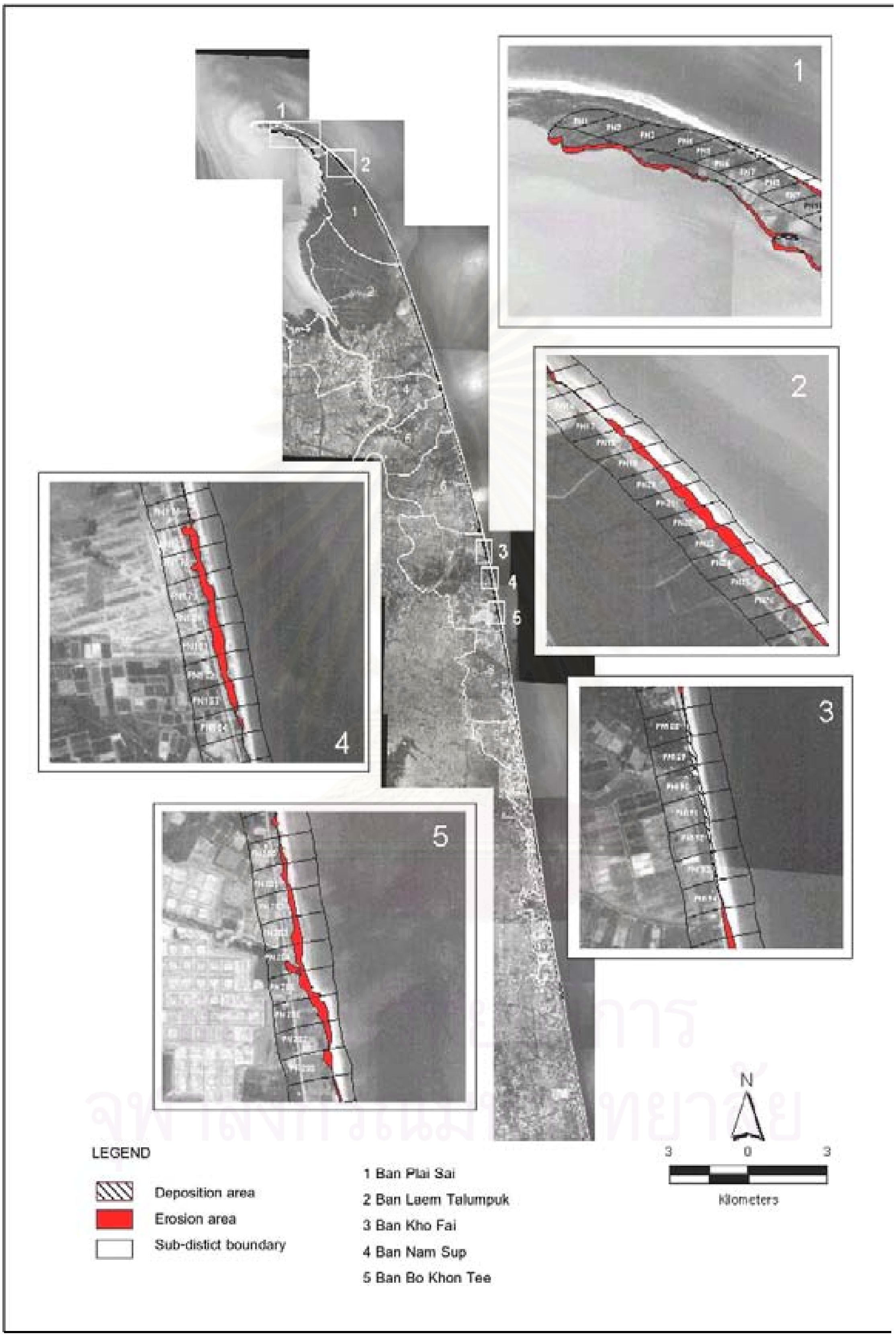


Figure 4.4 Coastline change as detected from aerial photographs in 1995 and 2002 showing the erosion and deposition areas.

2. The erosion area

- Ban Plai Sai, Laem Talumpuk sub-district Block PN15-PN24 (km.3-4.8 from Talumpuk cape) has the erosion rate of about 6.846 meters per year.

- Ban Noen Num Hak, Laem Talumpuk sub-district Block PN75-PN85 (km.15-17 from Talumpuk cape) has the erosion rate of about 3.8 meters per year.

- Ban Wat Sa, Tha Phaya sub-district Block PN152-PN159 (km.30.4-31.8 from Talumpuk cape) has the erosion rate of about 3.645 meters per year.

- Ban Ko Thang, Tha Phaya sub-district Block PN160-PN165 (km.32-33 from Talumpuk cape) has the erosion rate of about 4.244 meters per year.

- Ban Rim Khuen, Tha Phaya sub-district Block PN166-PN172 (km.33.2-34.4 from Talumpuk cape) has the erosion rate of about 4.34s meters per year.

- Ban Na Kote, Kha Nab Nak sub-district Block PN173-PN178 (km.34.6-35.6 from Talumpuk cape) has the erosion rate of about 4.44 meters per year

- Ban Kho Fai, Kha Nab Nak sub-district Block PN188-PN193 (km.37.6-38.6 from Talumpuk cape) has the erosion rate of about 4.025 meters per year.

- Ban Nam Sup, Kha Nab Nak sub-district Block PN194-PN205 (km.38.8-41 from Talumpuk cape) has the erosion rate of about 4.125 meters per year.

4.2.2 Shoreline change between in 1995-2002

From the comparison of aerial photographs between 1995 and 2002 the total change of shoreline was about 1,542,029.6 square meters, which can be defined into 3 types: deposition, erosion and stable areas. Deposition area was 222,379.5 square meters (14.42%). Erosion area was 1,319,150.1 square meters (85.54%) and stable area was 600 square meters (0.04%).

Details of areas that have a high change of coastline are following:

1. The deposition area

- Ban Plai Sai, Laem Talumpuk sub-district Block PN5-PN7 (km.1-1.4 from Talumpuk cape) has the deposition rate of about 3.2 meters per year.

- Ban Laem Talumpuk, Laem Talumpuk sub-district Block PN30 (km. 6 from Talumpuk cape) has the deposition rate of about 11 meters per year and rate of erosion about 6.8 meters per year.

- Ban Chaitalay, Ban Pleng sub-district Block PN137 (km.27.4 from Talumpuk cape) has the deposition rate ofabout 4 meters per year.

- Ban Kho Fai, Kha Nab Nak sub-district Block PN189-PN194 (km.37.8-38.8 from Talumpuk cape) has the deposition rate of about 3.4 meters per year.

2. The erosion area

- Ban Plai Sai, Laem Talumpuk sub-district Block PN9-PN11 (km.1.8-2.2 from Talumpuk cape) has the erosion rate of about 7.2 meters per year.

- Ban Plai Sai, Laem Talumpuk sub-district Block PN18-PN25 (km.3.6-5 from Talumpuk cape) has the erosion rate of about 11.3 meters per year.

- Ban Laem Talumpuk, Laem Talumpuk sub-district Block PN31-PN37 (km. 6.2-7.4 from Talumpuk cape) has the erosion rate of about 8.1 meters per year.

- Ban Noen Nam Huk, Laem Talumpuk sub-district Block PN73-PN74 (km. 14.6-14.8 from Talumpuk cape) has the erosion rate of about 6.75 meters per year.

- Ban Kong Kong and Ban Hua Tanon Chaitalay in East Pak Phanang sub-district Block PN85-PN90 (km. 17-18 from Talumpuk cape) have the erosion rate of about 6.2 meters per year.

- Ban Noen Takam, Bang Phra sub-district Block PN120-PN123 (km. 24-24.6 from Talumpuk cape) has the erosion rate of about 6.2 meters per year.

- Ban Na Kote and Ban Kho Fai, Kha Nab Nak sub-district Block PN177-PN183 (km. 35.4-36.6 from Talumpuk cape) have the erosion rate of about 8.1 meters per year.

- Ban Nam Sup, Kha Nab Nak sub-district Block PN204-PN206 (km. 40.8-41.2 from Talumpuk cape) has the erosion rate of about 10 meters per year. The erosion area during 1995-2002 is shown in the Figure 4.6

4.3 Verification by field surveys

4.3.1 Survey of existing structure and impacts on coastal erosion

The study area includes the coastal area of Pak Phanang River Basin comprising 10 sub-districts. The shoreline is about 72 kilometers long located in eight sub-districts of Pak Phanang districts: East Pak Phanang, Ban Poeng, Ban Phra, Ta Pya, Laem Talumpuk, Klong Noi, West Pak Phanang, and Khanab Nak sub-districts; and two sub-districts in Hua Sai district: Kohpetch and Na Saton Sub-districts. Man-made structures along the coastline in the study area (Figures 4.6-Figure4.14) can be divided into 4 types as follows:

1. Groin is a protective structure made of stone or concrete and extends from shore into the sea water to prevent the beach from longshore transport. These structures can be found on the shoreline of Ban Ko Fai, Ban Num Sup, Ban Bo Khon Tee in Kha Nab Nak sub-district and Pak Phanang district. The distance of revetment is about 200 meters with 23 groins. There are 19 T-shaped groins and four I-shaped groins to reduce the wave scouring action stop the sand movement. And there are other 7 groins in the Ban Na Sarn, Na Saton sub-district and Hua Sai district. Six of them have T-shape and only one has I-shape.

2. Jetty is a structure that projects into a body of sea water to influence the current or tide near a harbor. There are 5 jetties which one is 110 meters in length locating in the south-east in Ban Bo Khon Thi, Kha Nab Nak sub-distinct. These are 75 meters jetties in Ban Na Thuat, Na Saton sub-distinct. The Cha Uoad – Praek Muang old river mouth, jetty is about 50 meters length. The others stand at right angles with the shoreline in the Cha Uad – Praek Muang river mouth in Na Saton sub-district are 230 and 370 meters in lengths.

3. Pier is a platform extending from a shore over water and supported by piles or pillars. It is used for securing, protecting, and providing access to ships or boats and trapping sediments. Pier in this area is about 120 meters in length, 3 meters in width and is found in Ban Hua Tanon Chaitalay in East Pak Phanang sub-district and Ban Na

Sarn, Na Saton sub-district. And another is about 100 meters in length and 2 meters in width in Ban Chim la, Na Saton sub-district.

4. Rubble-mound revetment (Figure 4.14) is a stone structure of about 1 meter wide and 1-1.2 meters high and about 450 meters in length. It is constructed in Ban Kho Fai, Kha Nab Nak sub-district, Pak Phanang District.

4.3.2 Survey of physical damage and impact on coastal erosion

1. Coastal areas in Ban Plai Sai, Ban Laem Talumpuk, and Ban Noen Nam Huk in Laem Talumpuk sub-district, Pak Phanang district.

The coast at Ban laem Talumpuk in Laem Talumpuk sub-district is 15.40 km in length (distance from the cape end on the outside sea to the area of East Pak Phanang sub-district). It was found that the coast at the end of Talumpuk cape was eroded up to the pine-trees line. Sandy beach was swept away 25-30 m from its previous location along the coastline and some pine trees died. In some locations, the coastline was eroded until the mangrove clay was visibly observed on the beach. Some parts from lateritic road to the viewpoint on Talumpuk cape were clearly eroded approximately 150 m in length (Figure 4.15).

2. Coastal area in Ban Kong Kong and Ban Hua Tanon Chaitalay in East Pak Phanang sub-district, Pak Phanang district

The coast at Ban Kong Kong in East Pakphanang sub-district is 9.6 km in length. It extends from Ban Talumpuk coast. In this area, coastal erosion had been occurring in northeastern monsoon from October to February since 2002. The sandy beach was swept away and the clay was visible. More than 10 houses were damaged. Coconut trees died because of high wind and waves along the coastline. The steel-reinforced concrete road heading to community was eroded for more than 100 meters (Figure 4.16 and 4.17).

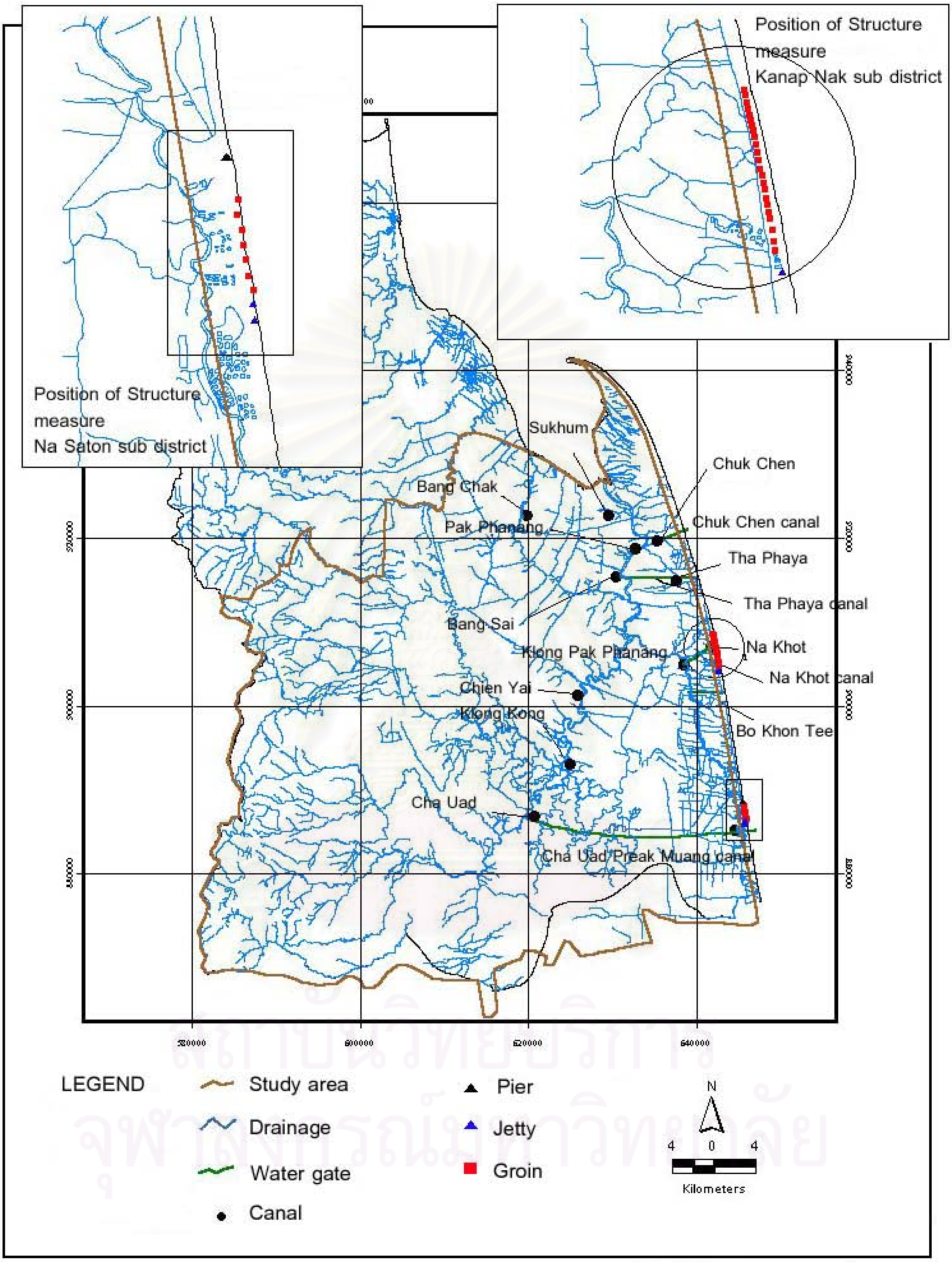


Figure 4.5 Position of the structure measured at Na Saton and Kanap Nak sub-district.

Figure 4.6 Groin T pattern at Ban Na Sarn, Na Saton sub-district, UTM 645698E/887542 N

Figure 4.7 Groin I pattern at Ban Na Sarn, Na Saton sub-district, UTM 645635E/887795N

Figure 4.8 Groin T pattern at Ban Kho Phi, Kha Nap Nak sub-district, UTM 642216E/906809N

Figure 4.9 Groin I pattern at Ban Kho Phi, Kha Nap Nak sub-district, UTM 641910E/908326N

Figure 4.10 Pier at Ban Hua Tanon Chai Talay, East Pak Phanang sub-district, UTM 637090E/924939N

Figure 4.11 Pier at Ban Chim La, Na Saton sub-district, UTM 646146E/884493N

Figure 4.12 Jetty at Pak Ra Wa canel, Ban Na Thod, Na Saton sub-district, UTM 647666E/876661N

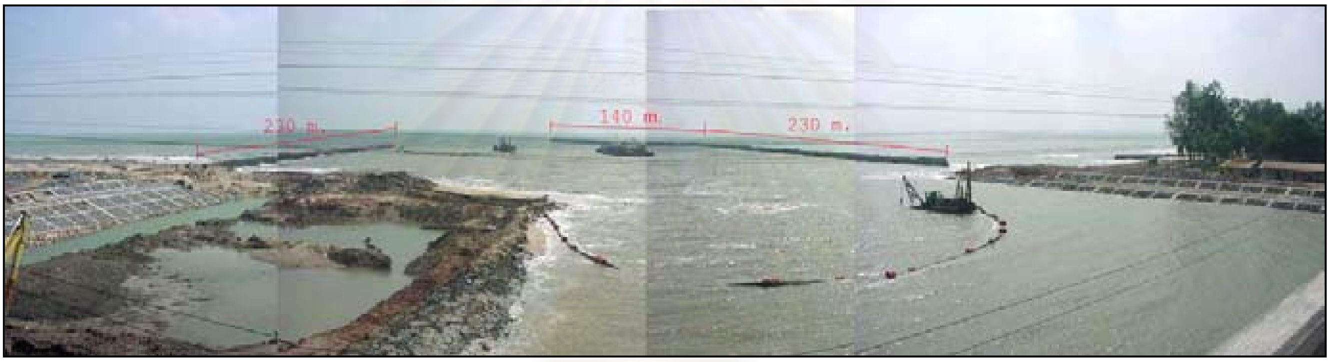


Figure 4.13 Jetty at Cha Uoad-Prak Mueng canal, Kha Nap Nak sub-district, UTM 645931E/886087N

Figure 4.14 Rubble-mound Revetment at Ban Kho Fai, Ka Nap Nak sub-district, UTM 642216E/906809N

3. Coastal area in Ban Kho Tang and Ban Ta Khen in Ta Pya sub-district, Pak Phanang district

The coast at Ban Kho Tang was eroded by about 32 m. in length. Two lines of coconut trees had died since 2002. There are shrimp farms in the area next to the beach (Figure 4.18).

4. Coastal area in Ban Kho Fai, Ban Nam Sup, and Ban Bo Khon Thi in Kha Nab Nak sub-district, Pak Phanang district

The heaviest coastal erosion was in the areas of Ban Kho Fai, Ban Nam Sup, and Ban Bo khon Thi in Kna Nab Nak sub-district. It was 3.4 km in length. From the survey, there were houses washed away from the beach area to the west side of the main road. There was damaged to shrimp farms, namely Nam Sup farm in Ban Nam Sup, and Hollywood farm in Ban Kho Fai.

At present, there are structures for coastal protection including revetments and 23 groins installed along the shoreline. In 1999, some part of the rubble-mound structure collapsed and the coast has been under no protection from erosion since them (Figures 4.19 - 4.21). From surveys and interviews, the shoreline was found to be strongly eroded. The heaviest erosion dominantly appeared 19 –20 km from the Pak Phanang-Hua Sai road where the beach was completely gone. Moreover, the erosion also extended to the edge of Pak Phanang-Songkhla highway.

5. Coastal area in Ban Na Sarn, Na Saton sub-district, Hua Sai district

The coastal area in Ban Na Sarn in Na Saton sub-district to Pak Klong Cha Uad – Praek Muang is protected by seven T-shaped groins in 2003. However, from surveys and interviews, the erosion before installation of the groins, was not severe when compared with that after the installation. Currently, the remaining beach is only 7 – 12 meters in width. In some area, there is no beach. Erosion also extended to the ridges of shrimp farms and caused the bank of Wipa Resort to collapse. Later, the bank was rebuilt. The foundation of the wayside shelter was also eroded (Figure 4.22).

Figure 4.15 Eroded area at Laem Talum Puk UTM 627426 E/ 940764 N shows road in the area had eroded

Figure 4.16 Eroded area at Ban Kong Kong, East, Pak Phanang sub-district UTM 636223E/ 927222 N shows coconut farm had destroyed

Figure 4.17 Eroded area at Ban Kong Kong, East, Pak Phanang sub-district UTM 636223E/927222N shows road, house and coconut tree had destroyed

Figure 4.18 Eroded area at Ban Kho Tang, East, The Phaya sub-district UTM 640676E/ 913251 N show the heavy mineral in the beach sand

Figure 4.19 Eroded area at Ban Kho Fai, Kha Nab Nak sub-district UTM 641956E/907902N

Figure 4.20 Eroded area at Ban Kho Fai, Kha Nab Nak sub-district UTM 641910E/908296N shows the shrimp farm had destroyed

Figure 4.21 Pak Phanang-Song Khra road Km. 19-20 in Ban Kho Fai, Kha Nab Nak sub-district UTM 641826 E/ 908579 N shows the violence of wave that insist to the road

Figure 4.22 Eroded area at Ban Na Sarn, Na Saton sub-district UTM 645748 E/ 886966N

4.4 The Prioritization of the coastal erosion in Pak Phanang River Basin

Coastal changes are physical alteration, along the coastal areas that are caused by natural or human activities. The coastal changes can be categorized into three types based Sinsakul (2002, 2003). They are

1. Stable coast, which is a dynamic coast that is always adjusted by natural processes. In this type, a rate of deposition is considered to be the same as a rate of erosion.
2. Depositional coast is a coast that has more than 1 meter per year of depositional rate. Generally, the rate of erosion is less than the rate of

deposition because of accumulated sediments, which are from the sea and the river and then accretes along the shoreline by wind, wave and tidal processes.

3. Erosional coast is a coast that has more than 1 meter per year of erosional rate. Certainly, the rate of erosion is more than the rate of deposition. Sediments on the coast are usually moved or washed from the beach by wind, wave or tidal processes. The rate of coastal erosion can be divided into two types: extreme erosion and moderate erosion. The rate of extreme erosion is more 5 meters per year and the moderate erosion is 1-5 meters per year.

4.4.1 Criteria for prioritization of erosion areas

Due to different degrees of erosion in Pak Phanang area, the prioritization of the study area is needed for immediate protection of the most critical areas from extreme erosion. GIS, remote sensing and the surveys in the field were used for prioritization of the coastal area. The standard criterion for choosing the critical area was modified by The Office of Natural Resources and Environment Policy and Planning (1997). Five sets of data: erosion rate, existing shore protection measure, land use and environment value, economic loss value, and economic and social index were combined into five layers by GIS. The layered data was different because of the characteristics of the area; it was composed of various degrees of erosion. In this analysis, we estimated the maximum erosion rate, based on the analyzed historical data in Thailand, was 20 m/year in 25 year. The maximum area that had affected from erosion was 500 m (25 year x 20 m). So that, the shoreline in this study area was separated into 345 blocks which were 500 meters wide (in land) and 200 meters long (along shoreline). The details of criteria used for selecting the critical erosion of the shoreline are below:

1) The layer of average erosion rate

Scores in this layer were graded depending on how high the erosion rate was. Thus, high erosion rates get high scores; low erosion rates get low scores. Fallow Sinsakul (2002) separated the erosion rate into three levels: extreme (>5m/year), moderate (1-5 m/year) and stable (<1m/year). But in this study, according to section

4.2.2, divided the rate of shoreline changes between in year 1995 and 2002 into five levels. The highest level was more than 10 meters per year of erosion rate, so was given a value of 5. The high level was 5-10 meters per year of erosion rate, so was given a value of 4. The midium level was 3-5 meters per year of erosion rate, so was given a value of 3. The low level was 1-3 meters per year of erosion rate, so was given a value of 2. The lowest level was less than 1 meter per year of erosion rate (stable area), so was given a value of 1. Remains are shown in table 4.2. The degree of erosion rate (meter/year) of 345 blocks in the Pak Phanang area is shown in Figure 4.23.

Table 4.2 Scores for erosion rate

Level of Erosion	Erosion rate (meter/year)	Erosion rate score
Highest level	>10	5
High level	5-10	4
Medium level	3-5	3
Low level	1-3	2
Lowest level	<1	1

2) The layer of existing shore protection measure

From the survey, the correct positions of shore-protection structures were measured by the GPS. The constructions for shore protection in the study area are sea wall, rubble mound revetments, jetties, groins, and piers. In this layer, scores were graded with two criteria in mind, which are the existing shore protection structures and their efficiency of protection. The highest score (five) was given to the area that didn't have shoreline protection measure. The area which had inefficient shore protection measures received a medium score (three). The stable areas that could be protected well by the shore protection were given a score of one. Table 4.3 shows the score of the layer of existing shore protection measures. Map of 345 blocks of existing shoreline protection measure in the study area is displayed in Figure 4.24.

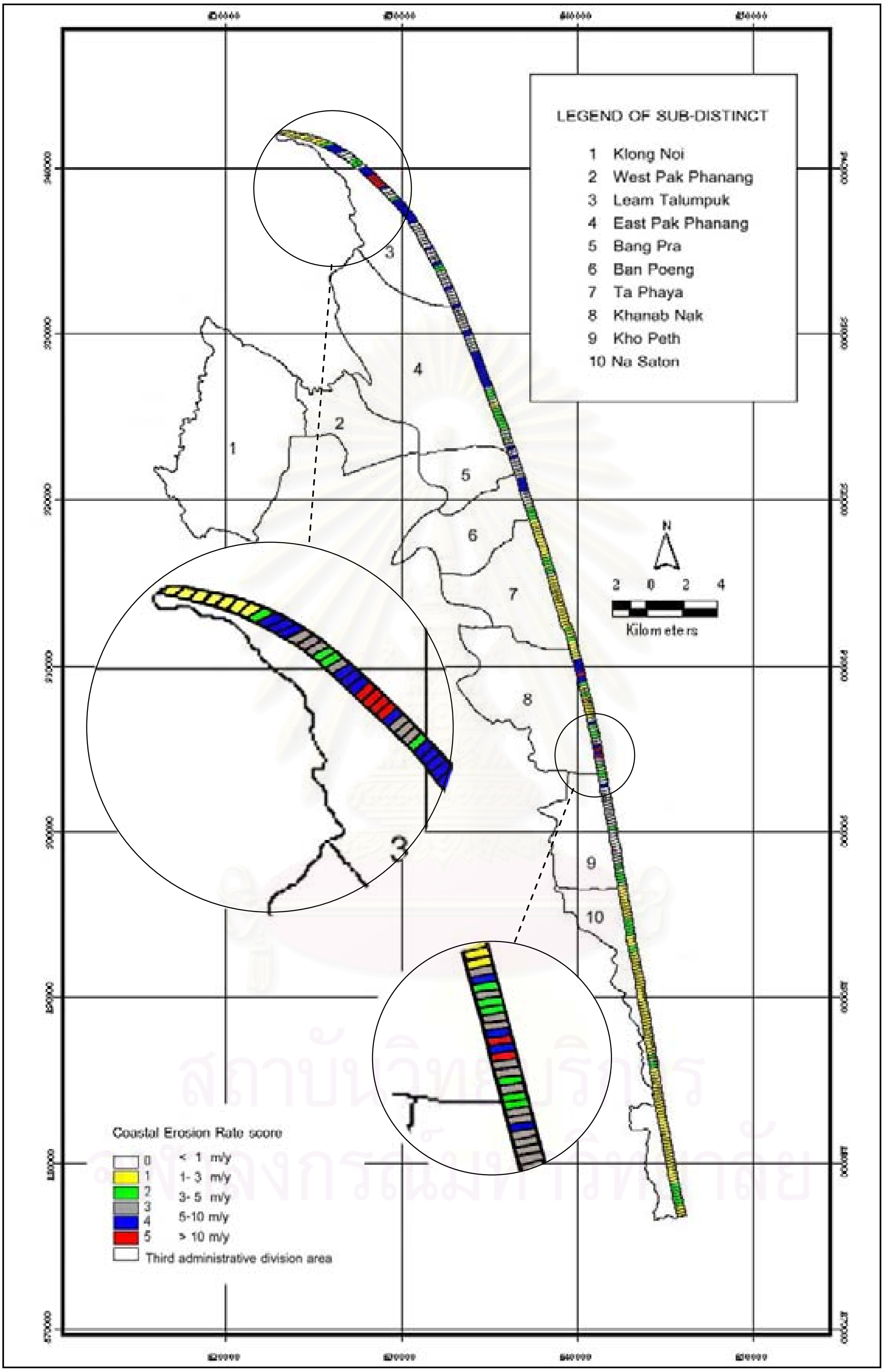


Figure 4.23 Degree of erosion rate (meter/year) of 345 blocks in the critical area of Pak Phanang

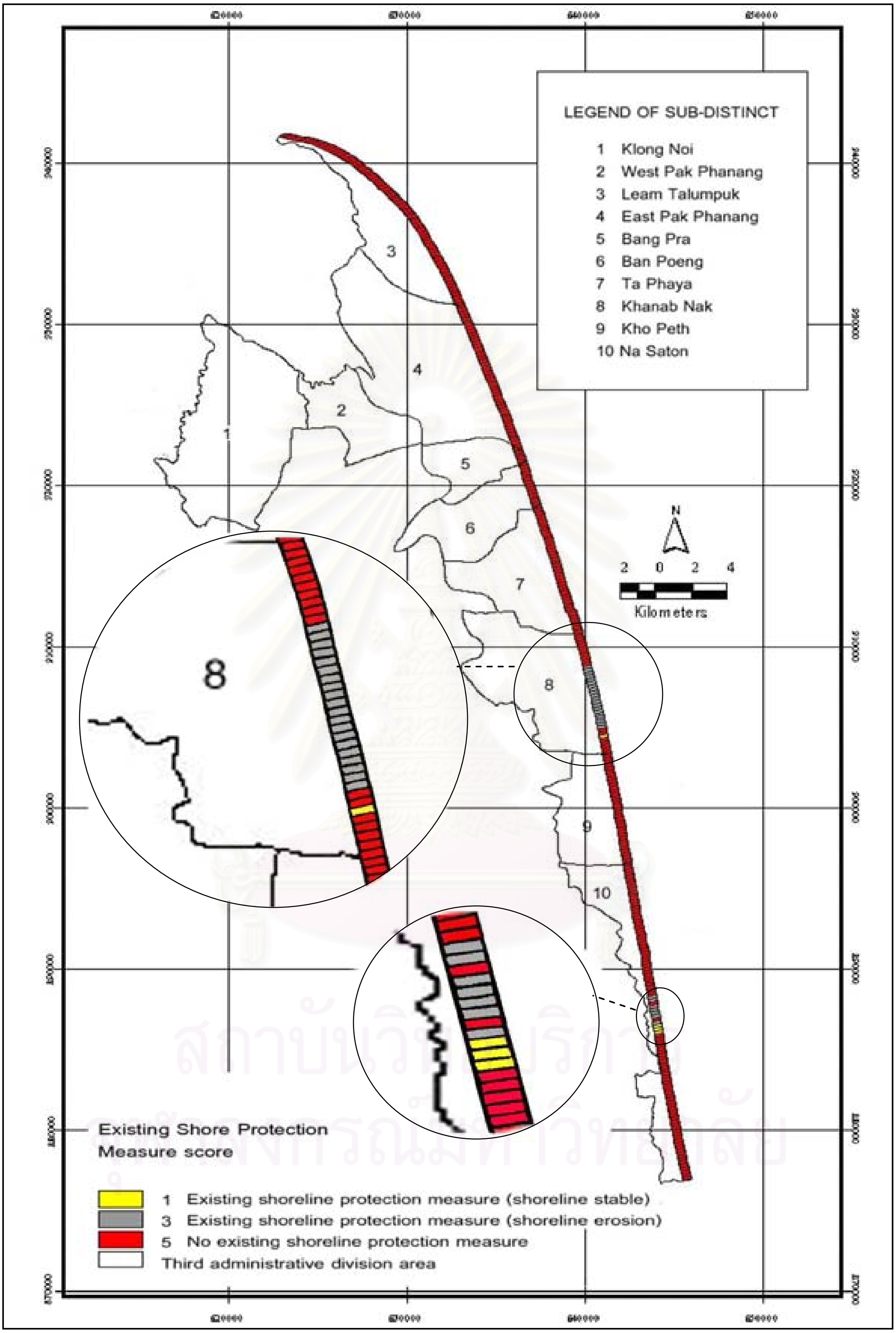


Figure 4.24 Degree of existing shore protection measure of 345 blocks in the critical area of Pak Phanang

Table 4.3 Score for existing shore protection measures

Existing shore protection measures	Score
No existing shoreline protection measure	5
Existing shoreline protection measure (shoreline erosion)	3
Existing shoreline protection measure (shoreline stable)	1

3) The layer of landuse and environment

This layer compares the consideration of landuse and environment of Pak Phanang area. The aerial photos in 2002 and surveys in the field force one to reconsider the rate of coastal erosion and the usefulness of the area. First, the royal palace, historical place, and community is very important for protection because those places have an effect on people and mind so are given a high score (5). Tourist attractions and government places are of secondary importance (4) because they can develop the economy in the country. Third, mangrove forests and pine trees are the next important places (3) because they are a source of marine animals and a stable ecology. The less important places are the areas of salt farms, aquatic farms; agriculture areas and open areas are given scores of 2 and 1 respectively. The type of important areas and scores are shown in Table 4.4 and the scores of 345 blocks in the study area are shown in Figure 4.25

Table 4.4 Landuse and environment scores

Landuse and Environment	score
A royal palace, historical site, temple, church, community, school	5
Tourist attraction, hotel, resort, governmental place	4
Mangrove forest, pine tree	3
Aquatic farm, salt farm, pier	2
Agriculture area, unused area	1

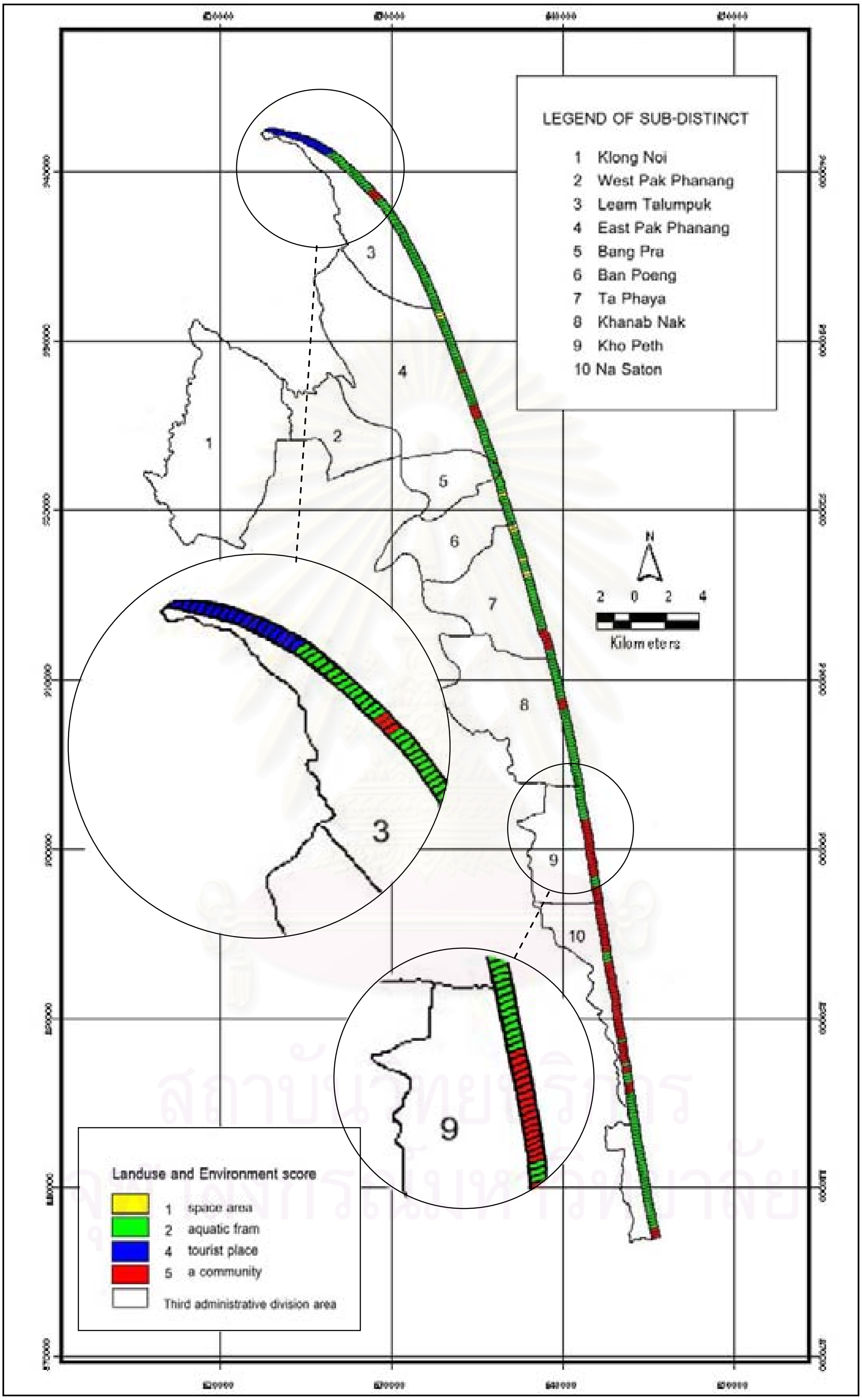


Figure 4.25 Landuse and environment of 345 blocks in the critical area of Pak Phanang

4) The layer of minimum economic loss value

This layer was calculated from the loss of area by coastal erosion in 1995 and 2002. It was duplicated with price of property in the Pakphanang and Hua Sai district. The minimum economic loss which averaged in one year was given a score of 1 to 5, sequentially in the Table 4.5. The minimum economic loss value of 345 blocks in this study was noted as being the minimum rate per year exhibits in Figure 4.26

Table 4.5 Minimum economic loss of value scores

Minimum economic loss of value (baht/year)	score
> 160,000	5
120,001-160,000	4
80,001-120,000	3
40,001-80,000	2
< 40,000	1

5) The layer of socio-economic index

The socio-economic index layer is a layer of estimation from economic and social situation. In the case of one area it had an expected high rate of erosion, about 20 meters per year in the following 25 years (500 meters). The socio-economic index, calculated from property value and public utilities (routes and electric poles), structures (houses and buildings), and loss of opportunity for landuse within 500 meters from shore.

To determine the socio-economic index, it was separated into 5 levels of scores. The highest score (score 5) was in the area that had the highest economic and social value per year. The lowest score (score 1) was controlled with a rate of economic and social value per years. Socio-economic index score are shown in Table 4.6. Map of Socio-economic index score of 345 blocks of the critical area are shown in Figure 4.27

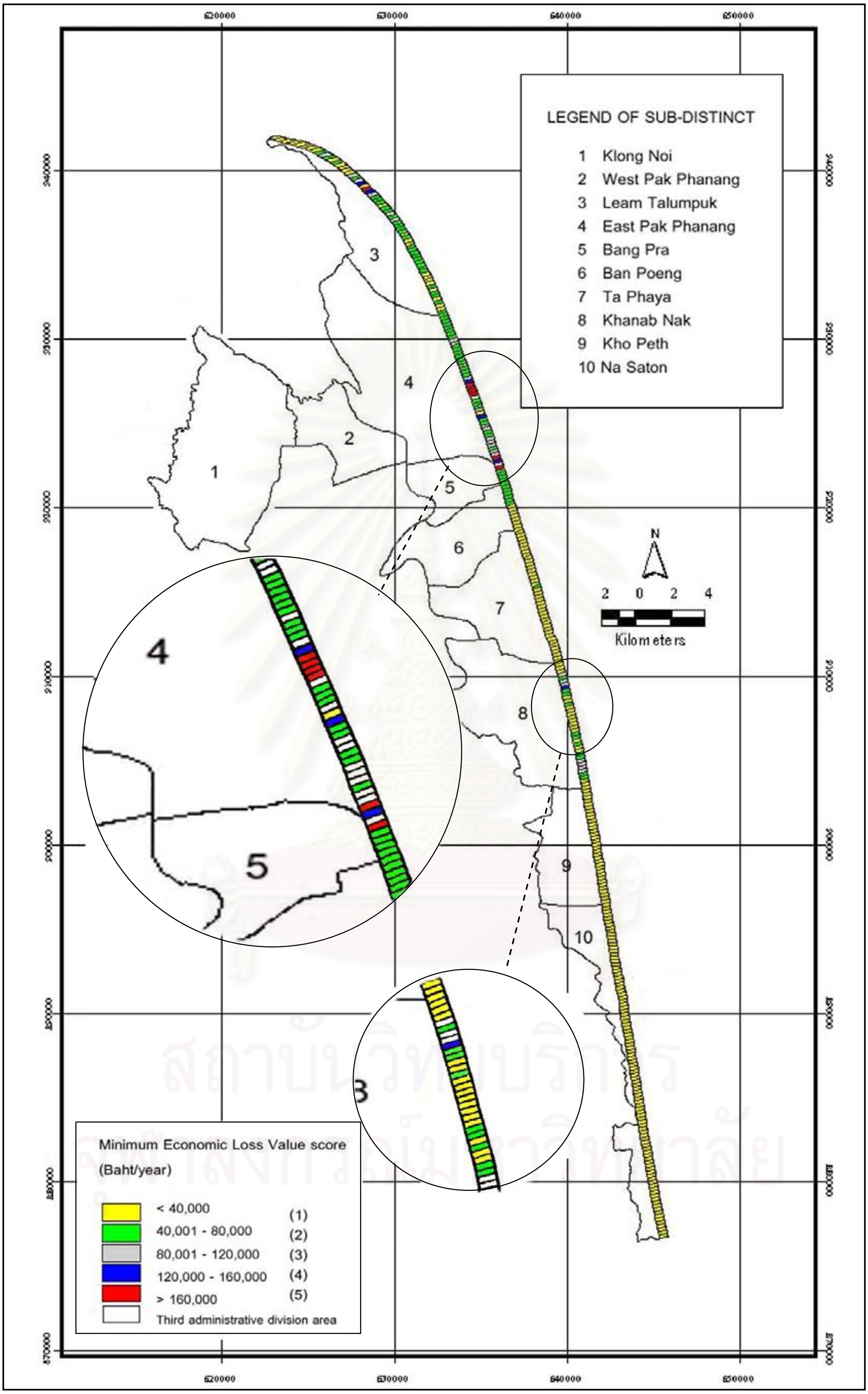


Figure 4.26 Minimum economic loss value (baht/year) of 345 blocks in the critical area of Pak Phanang

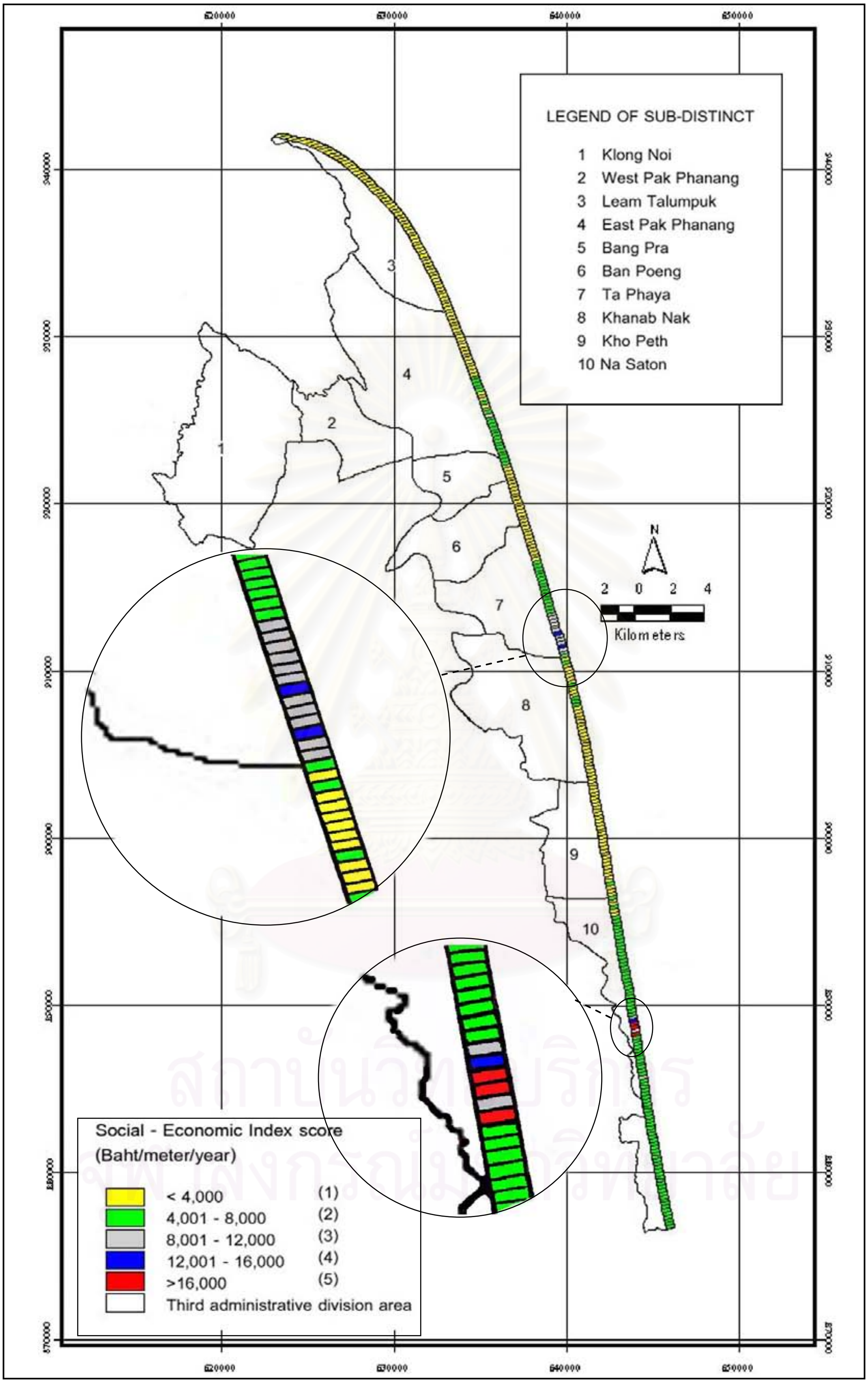


Figure 4.27 Socio-economic index score of 345 blocks in the critical area of Pak Phanang.

Table 4.6 Socio-economic index scores

Socio-economic index (baht/meter/year)	score
> 12,800	5
9,601 - 12,800	4
6,401 - 9,600	3
3,200 – 6,400	2
< 3,200	1

4.4.2 Evaluation of total economic loss from shoreline erosion

This section is assigned into 3 parts as;

4.4.2.1 Evaluation of economic loss from shoreline erosion in term of land loss.

From the data, land loss is the minimum economic loss value which does not include property, natural resources, or public utilities. Land loss evaluation used the estimated price of land from the Bank of Agriculture and Agricultural Cooperatives at Pak Phanang and Hua Sai branch in 2004 and within GIS method used to select the area. In this case, the land loss was near the shore, 500 meters, which estimated the all of land loss in 10 districts. This equaled 56,985.46 rai (91,176,736 square meters). All economic loss from shoreline erosion equaled 4,657,510,543 baht. In the Table 4.7 shows the estimated price of land in Pak Phanang and Hua Sai districts in 10 sub-districts (Figure 4.28-4.32).

4.4.2.2 Evaluation of economic loss from shoreline erosion in term of pubic utilities (roads)

In the study area, there was a route which had highway and paved road namely Pak Phanang-Song Kha (Figure 4.57 to Figure 4.61). The highway is 7 meters in width and side walk 1.5 meters in width and distance of 59.5 kilometers. An estimation of high way loss equals 299,500,000 baht. Paved road in this study is 6 meters width and 6.57 meters in length had an estimated loss of 19,710,000 baht. Totally evaluation of economic of route loss from shoreline erosion equals 319,210,000 baht (Table 4.8).

Table 4.7 Estimation of land loss (price of land) within a 500 meters buffer line

Sub-district	price of land (baht/rai)*	Area(rai)	Estimated price (bath)
Na Saton	1,000,000	133.55	133,550,000
	500,000	89.04	44,520,000
	400,000	1,854.08	741,632,000
	50,000	129.2	6,460,000
	30,000	6221.27	186,638,100
	Total	(8,427.14)	(1,112,800,100)
Ko Petch	200,000	700.04	140,008,000
	40,000	204	8,160,000
	20,000	2,208.64	44,172,800
	Total	(3,112.68)	(192,340,800)
Khanab Nak	200,000	1,529.56	305,912,000
	50,000	95.3	4,765,000
	30,000	2,442.52	73,275,600
	Total	(4,067.38)	(383,952,600)
Bang Phra	200,000	104.46	20,892,000
	50,000	42.4	2,120,000
	30,000	178.02	5,340,600
	Total	(324.88)	(28,352,600)
Bang Poeng	200,000	585.89	117,178,000
	50,000	68.1	3,405,000
	30,000	803.45	24,103,500
	Total	(1,457.44)	(144,686,500)
Ta Pya	200,000	936.41	187,282,000
	50,000	20.5	1,025,000
	30,000	2,512.66	75,379,800
	Total	(3,469.57)	(263,686,800)
Pak Phanangตะวันออก	400,000	1,556.19	622,476,000
	140,000	2,352.56	329,358,400
	120,000	820.23	98,427,600
	50,000	19	950,000
	30,000	314.4	9,432,000
	20,000	7,063.99	141,279,800
	Total	(12,126.37)	(1,201,923,800)

Laem Talum Puk	140,000	1,167.00	3,327,743,200
	60,000	4,543.70	272,626,309
	12,000	2,219,20	26,630,788
	Total	(7,929.9)	(462,641,694)
West Pak Phanang	30,000	1,720.25	51,607,605
Klong Noi	30,000	2,227.6	66,829,010
Total 10 districts		56,740.96	4,657,510,543

*Source: Bank of Agriculture and Agricultural Cooperatives at Pak Phanang and Hua Sai branch in year 2004

Table 4.8 Evaluation of economic loss from shoreline erosion due to pubic utilities (routes)

Sub-district	High way of Pak Phanang-Song Kha			Paved road			Total price
	Price of building* (Baht/km.)	Distrance (km.)	Estimate Price (baht)	Price of building* (Baht/km.)	Distrance (km.)	Estimate Price (baht)	
Na Saton	5,000,000	19.92	99,600,000	-	-	-	99,600,000
Ko Petch	5,000,000	6.89	34,450,000	3,000,000	3.05	9,150,000	43,600,000
Khanab Nak	5,000,000	7.63	38,150,000	-	-	-	38,150,000
Ta Pya	5,000,000	8.3	41,500,000	-	-	-	41,500,000
Bang Poeng	5,000,000	2.93	14,650,000	-	-	-	14,650,000
Bang Phra	5,000,000	0.88	4,400,000	-	-	-	4,400,000
East-PakPhanang	5,000,000	5.37	26,850,000	-	-	-	26,850,000
Laem Talum Puk	5,000,000	7.98	39,900,000	3,000,000	3.52	10,560,000	50,460,000
Total		59.9	299,500,000		6.57	19,710,000	319,210,000

*Source: Community Development Department

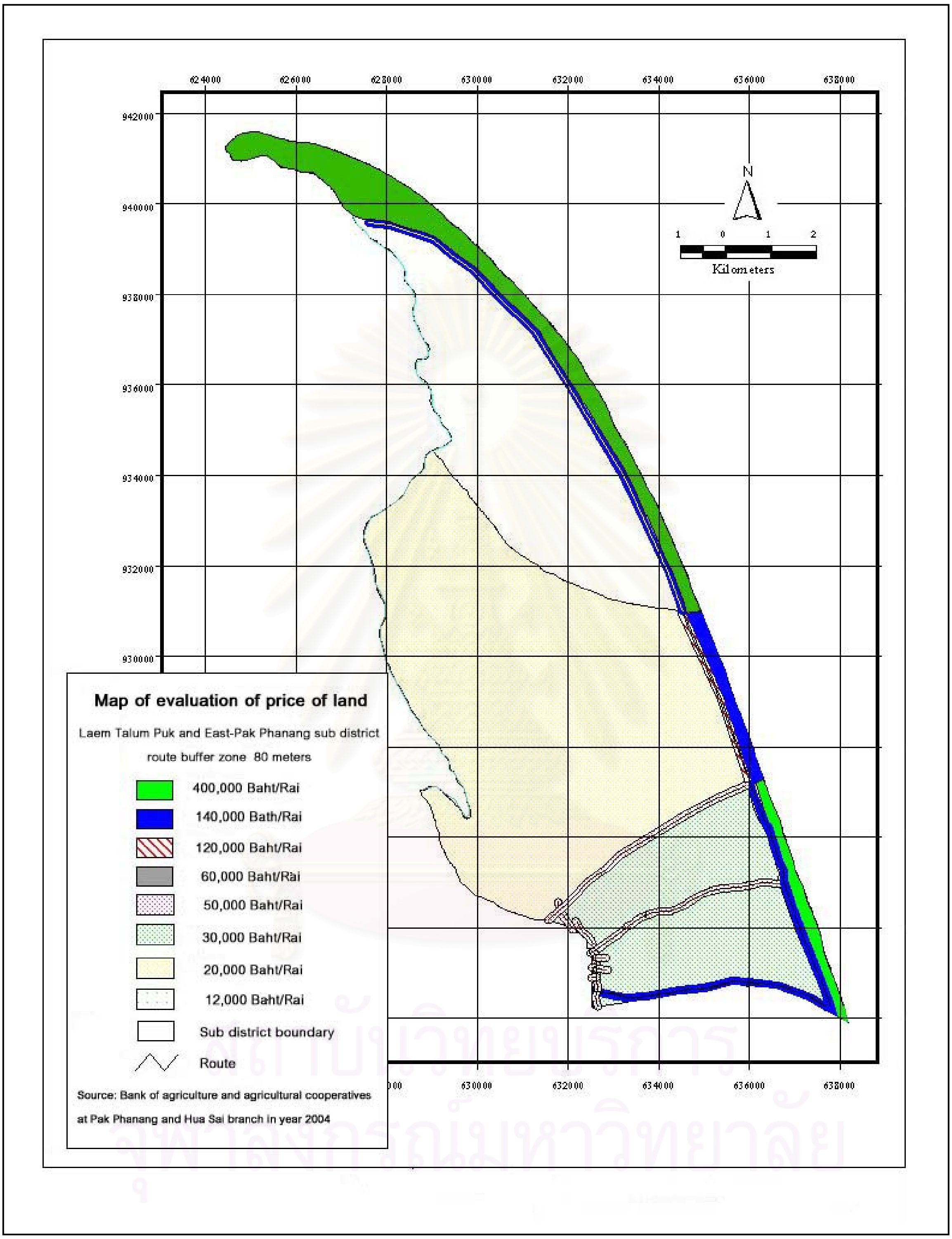


Figure 4.28 Map illustrating evaluated land price at Laem Talum Puk and East Pak Phanang sub-district, 2004

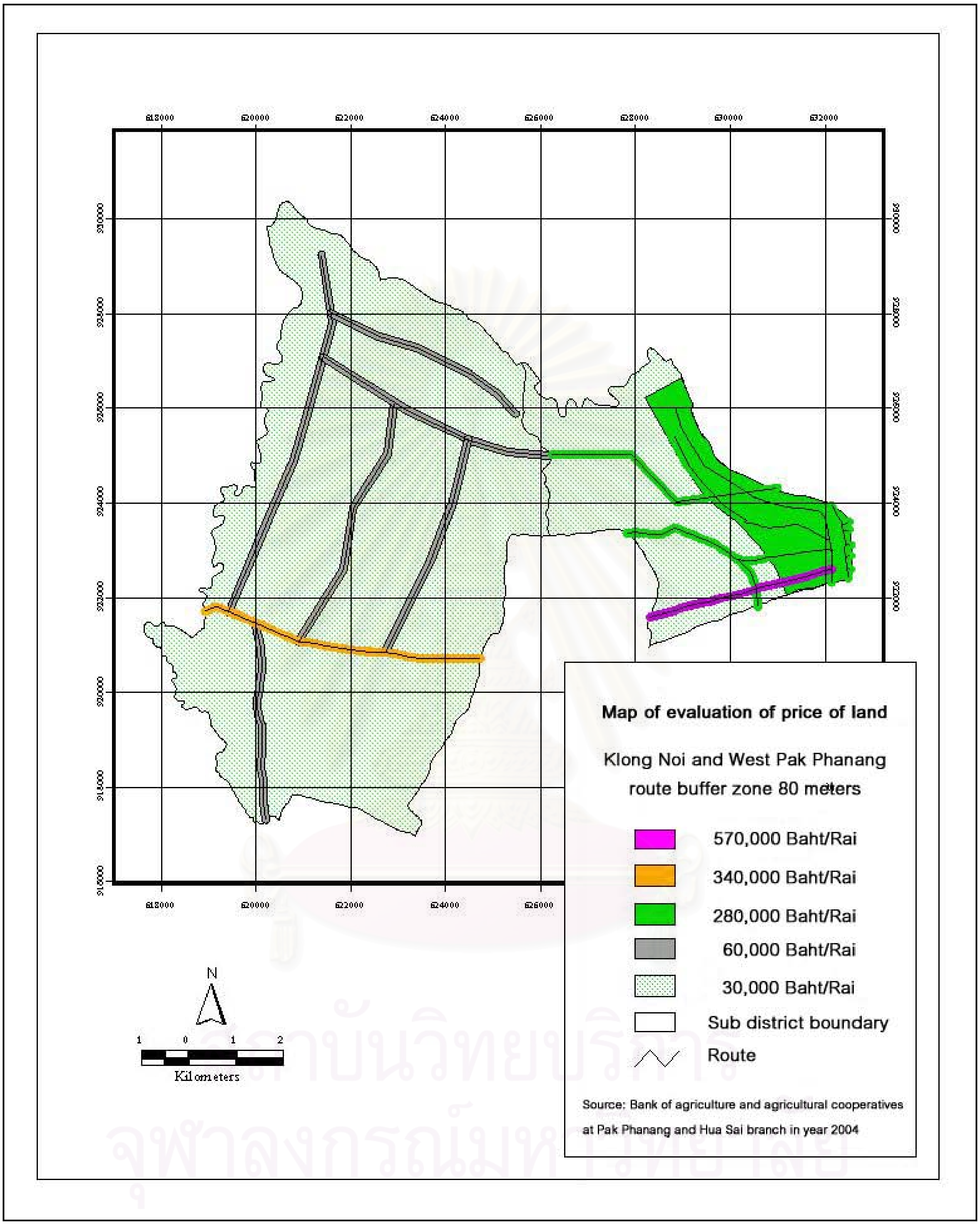


Figure 4.29 Map illustrating evaluated land price at Klong Noi and West Pak Phanang sub-district, 2004

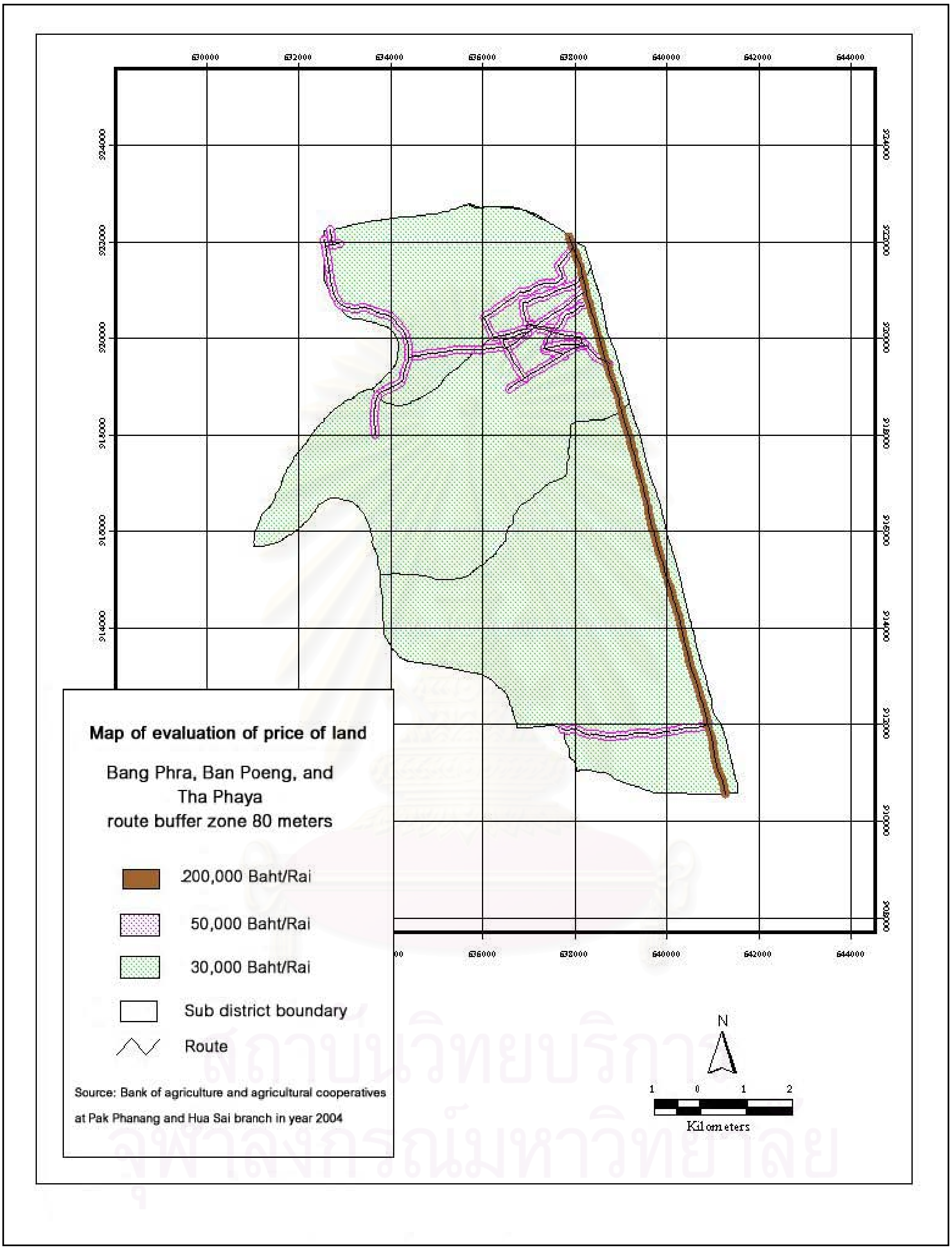


Figure 4.30 Map illustrating evaluated land price at Bang Phra, Bang Poeng, and Tha Phaya sub-district, 2004

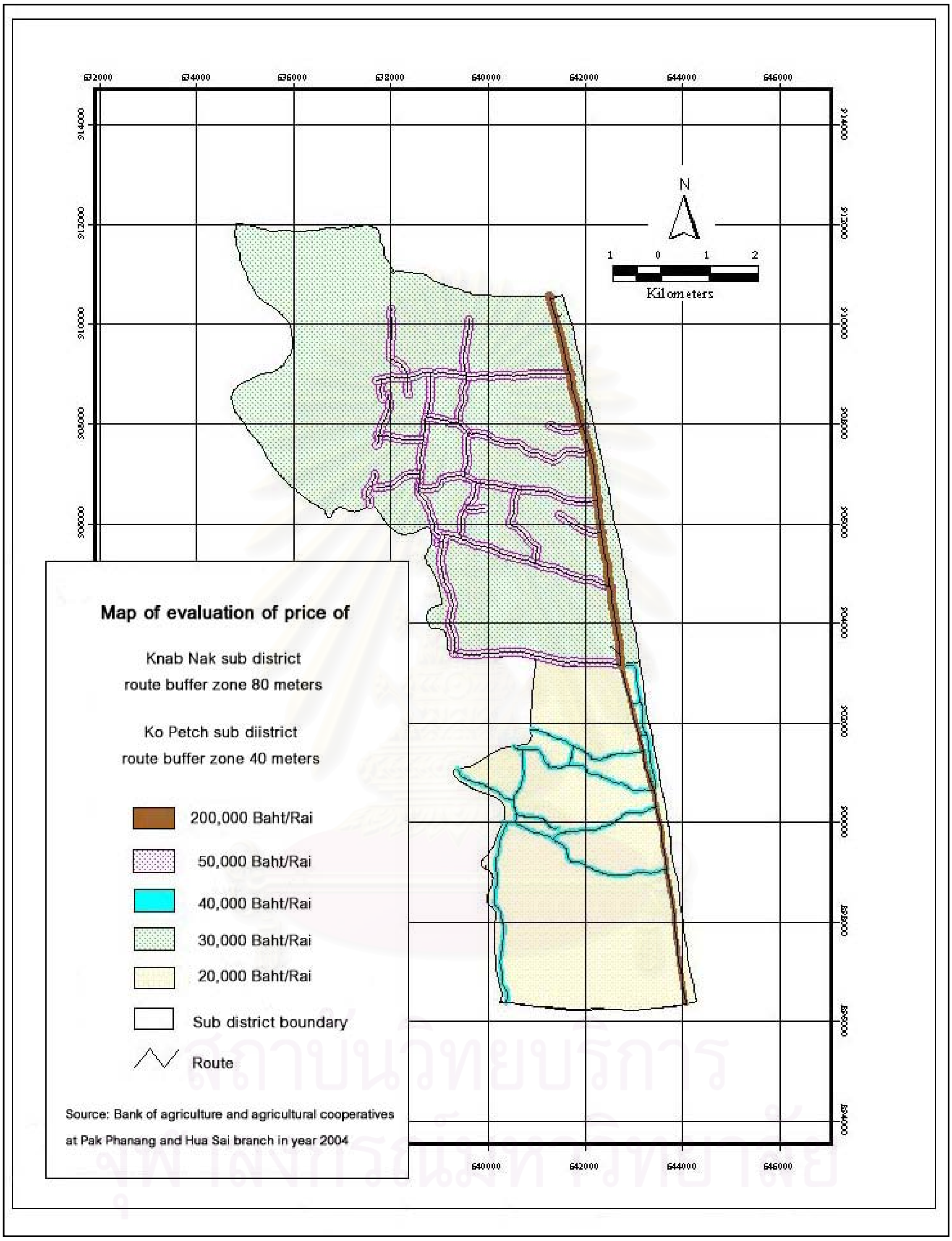


Figure 4.31 Map illustrating evaluated land price at Khanap Nak and Ko Petch sub-district, 2004

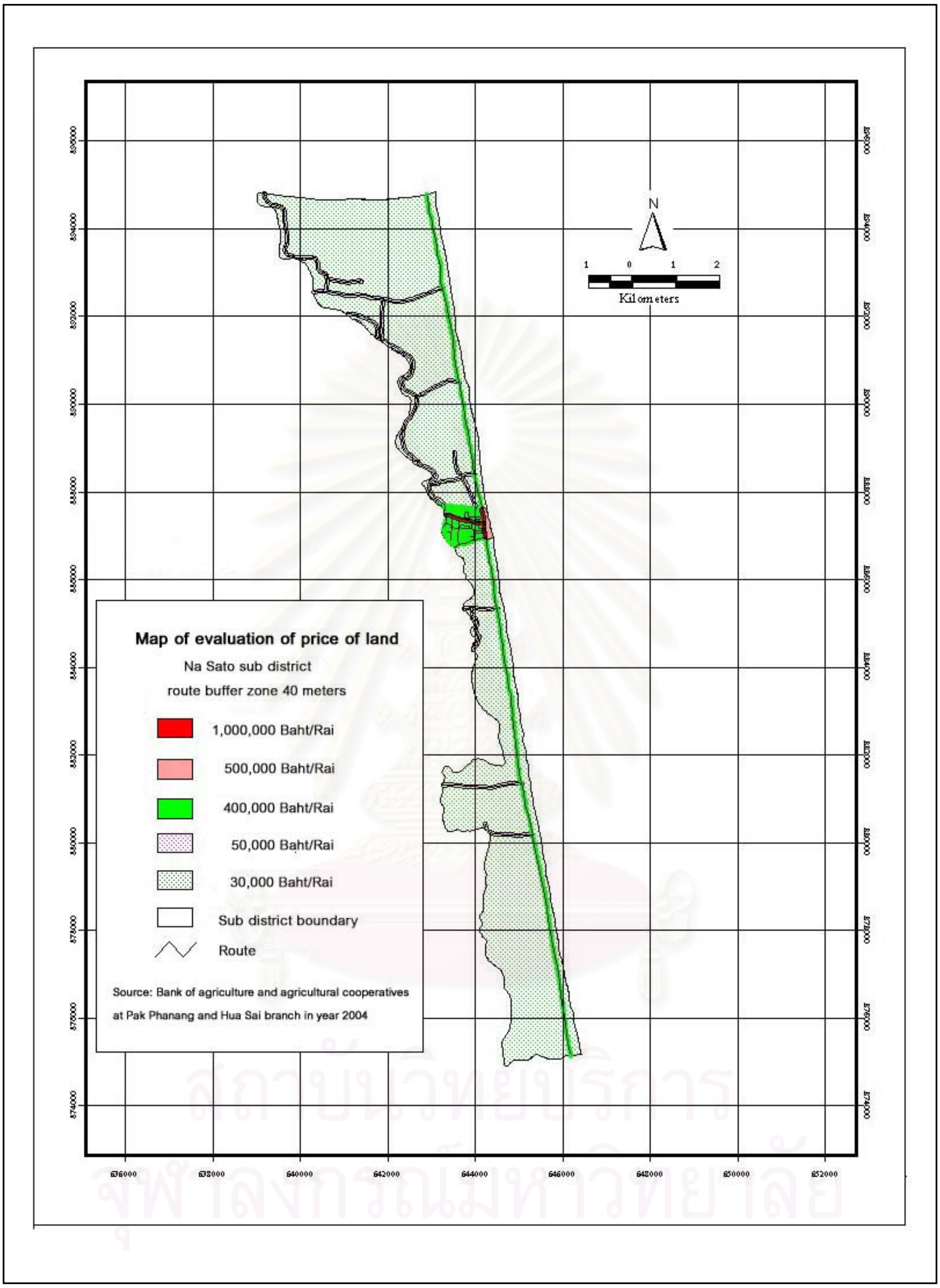


Figure 4.32 Map illustrating evaluated land price at Na Saton sub-district, 2004

4.4.2.3 Evaluation of economic loss from shoreline erosion in term of pubic utilities (power poles and construction).

In this evaluation, we used the GIS method and remote sensing to study the distance between electric poles and positions of houses in the buffer block. The value of electric poles in 1 kilometer equals 1,500,000 baht. The route was 59.9 kilometers long, so the price of electric poles and buildings equals 89,850,000 baht.

The estimation of house loss: houses could be divided into 3 types: The two storey houses that were about 500,000 baht each. Single storey houses were about 300,000 baht each. Timber houses that were about 50,000 baht each. The houses in the study area were counted by GIS method. The two storey houses totaled 16, Single storey houses totaled 2,159 and wooden houses totaled 212. So the evaluation of electric poles and buildings loss totaled 756,150,000 baht (Table 4.9)

4.4.2.4 Evaluation of economic loss from shoreline erosion in term of income loss.

Incomes of 10 sub-districts affected by coastal erosion were calculated from data by the Community Development Department, (2003). It was estimated with the loss income in mind from activities along the shoreline.

Table 4.9 Evaluation of economic loss from shoreline erosion due to pubic utilities (power poles and construction)

district	electric pole (33 KV) at Pak Phanang - Song Khra route			House of 2 floor		House of1 floor		Wood house		Total
	Price of building* (baht/km)	Distrance (km.)	Estimate Price (baht)	Price of building 500,000 (baht/house)	Estimate Price (baht)	Price of building 300,000 (baht/house)	Estimate Price (baht)	Price of building 50,000 (baht/house)	Estimate Price (baht)	
Na Saton	1,500,000	19.92	29,880,000	10	5,000,000	1,062	318,600,000	26	1,300,000	354,780,000
Ko Petch	1,500,000	6.89	10,335,000	4	2,000,000	366	109,800,000	13	650,000	122,785,000
Khanab Nak	1,500,000	7.63	11,445,000	2	1,000,000	144	43,200,000	5	250,000	55,895,000

Tha Phaya	1,500,000	8.3	12,450,000	-	-	178	53,400,000	19	950,000	66,800,000
Bang Poeng	1,500,000	2.93	4,395,000	-	-	14	4,200,000	-	-	8,595,000
Bang Phra	1,500,000	0.88	1,320,000	-	-	34	10,200,000	13	650,000	12,170,000
E. Pak Phanang	1,500,000	5.37	8,055,000	-	-	259	77,700,000	-	-	85,755,000
W. Pak Phanang	1,500,000	-	-	-	-	-	-	-	-	-
Laem Talum Puk	1,500,000	7.98	11,970,000	-	-	102	30,600,000	136	6,800,000	49,370,000
Klong Noi	1,500,000	-	-	-	-	-	-	-	-	-
Total		**59.9**	**89,850,000**	**16**	**8,000,000**	**2,159**	**647,700,000**	**212**	**10,600,000**	**756,150,000**

*Source: The Provincial Electricity Authority

Table 4.10 Income of 10 districts along the eroded shorelines*

Economic activity in 10 districts in shoreline erosion										
Pak Phanang District									Hua Sai District	
Sub-district	Khanap Nak	Ta Pya	Ban Poeng	Bang Phra	East Pak Phanang	Talum Puk	Klong Noi	West Pak Phanang	Na Saton	Ko Petch
Income (Million baht)										
Small fishery	0.63	0	0.15	0	8.6	12.44	4.26	10.7	27.5	2.78
Medium-big fishery	0	0	0	0	0	0	0.35	0.14	5.13	0
Inland fisheries	0	0	0.1	0.76	0.16	0	0.24	0	0	0.28
Aquatic marine (brackish water)	102.39	64.3	1.86	25.8	20.59	4.15	10.27	14.97	129.86	59.42
Aquatic marine (fresh water)	10.67	0	0	0	0.14	0	0.23	0	0	0
Agriculture (dry season)	11.97	0	0.17	0	0	0	0	0.99	0	3.6
Paddy field	0.65	11.52	9.53	0	0.45	0	13.33	14.24	0	0
Perennial plant	0.03	0	0	0	0.06	0	5.07	0.11	0	0.6
Orchard	0	0	0.17	0	0	0	19.41	0	0	0

Vegetable garden	0.01	0	0.02	0	0.05	0	12.04	0.53	0	0
Domestic cow	6.46	0.36	0.5	0.11	0.65	0	3.54	0.75	0.22	0.44
Domestic pig	0	0	0.18	0.1	0.1	0	0.56	0.18	0	0.04
Domestic poultry	0	0	0.21	0.01	0.3	0	0.42	0	1.38	0.26
Domestic animals	0	0	0	0	8	0	0.56	8	0	0.02
Total	**132.8**	**78.18**	**12.89**	**26.78**	**39.89**	**16.59**	**69.76**	**50.61**	**164.08**	**66.91**

*Source: Community Development Department

Total income from economic activity in 10 sub-district equal 658.49 million baht

Evaluation of total economic loss from shoreline erosion

Evaluations of economic loss from shoreline erosion means lost opportunity to earn maximum income from economic activity (Nitungkorn, et al., 2005) at the shoreline area (in 10 sub-districts).

A. Estimation of land loss in 10 districts had a total value of **4,657.51** million baht

B. Estimation of route loss in 10 districts had a total value equal to **319.21** million baht

C. Estimation of electric pole and building loss in 10 districts that had total value of **756.15** million baht

D. Economic loss of 10 districts had a total value equal to **658.49** million baht /year

In this analysis, we estimated the maximum erosion rate was 20 m/year in 25 year.

From table 4.10 total economic loss spanning 25 years equaled **8,555.36** million baht*

Total economic loss equaled 14,288.23 million baht

* Economic loss in the first year plus economic loss in the following years, spanning 25 years. The economic loss in the next year is out of the calculation.

Economic loss in the following years = economic loss in the first year x (25 – i)/25

by i equal 1 to 25

4.4.3 The multi criteria analysis (MCA) of difference factors of coastal erosion

Weight of factor in multi criteria in prioritization of erosional area followed The Office of Natural Resources and Environment Policy and Planning (1997) by using multi criteria analysis (MCA) method. The priorities of erosional area have to avoid the resolved resemble layer in 5 layers. The principle of multi criteria analysis has three main steps to decide the critical urgent problem areas as follows:

Primary procedure for MCA method to assign and consider the interesting factors in 5 layers as follows:

(1) The layer of erosion rate score

(2) The layer of existing shore protection measure

(3) The layer of land use and environment

(4) The layer of minimum economic loss value

(5) The layer of socio-economic index

Secondary procedure for MCA method to prioritize the important factors by comparing all 5 factors (Table 4.11).

- If factor in column (C_j) is less important than factor in row (R_i), it gets 3 marks.
- If factor in column (C_j) is as important as factor in row (R_i) it gets 2 marks.
- If factor in column (C_j) is more important than factor in row (R_i) it gets 1 mark
- If factor in column (C_j) is the same as factor in row (R_i) it gets 0 marks

Table 4.11 Comparisons of 5 important factors by MCA method

	Erosion rate(C1)	Existing shore protection measure (C2)	Landuse & Environment (C3)	Min. economic loss value (C4)	Socio-economic index (C5)	Total score	Weight
Erosion rate (R1)	0						
Existing shore protection measure (R2)		0					
Landuse & Environment (R3)			0				
Min economic loss value (R4)				0			
Socio-economicl index (C5)					0		
					Total		1.0

Principle:

Ri	Important more	Cj	weight score	3
Ri	Important equal	Cj	weight score	2
Ri	Important less	Cj	weight score	1
Ri	Same	Cj	weight score	0

Remark: i and j is 1 to 5

In this method, we assigned the factors of landuse and environment and minimum economic loss value were in the first important. Because the first important was most effected to the human life. The secondary of the important factors were erosion rate and socio-economic index. The existing shore protection measure was the less important. The result of comparisons is in Table 4.12.

Table 4.12 Score of comparisons of 5 important factors by MCA method

	Erosion rate(C1)	Existing shore protection measure (C2)	Landuse & Environment (C3)	Minimum economic loss value (C4)	Socio-economic index (C5)	Total score	Weight
Erosion rate (R1)	0	3	1	1	2	7	0.17
Existing shore protection measure (R2)	1	0	1	1	1	4	0.10
Landuse & Environment (R3)	3	3	0	2	2	10	0.25
Minimum economic loss value (R4)	3	3	2	0	2	10	0.25
Socio–economicl index (C5)	2	3	2	2	0	9	0.23
					Total	40	1.0

Result of comparison is to obtain priorities of important factors and weight of factors as.

First order is factor of landuse and environmental and minimum economic loss value which has a weight equal to 0.25

Secondary order is factor of socio-economic index which has a weight equal to 0.23

Third order is factor of erosion rate which has a weight equal to 0.17

Forth order is factor of existing shore protection measures equal 0.10

Final procedure for MCA method to prioritize the important factor is to give scores to each factor (data layer) in the erosion area of 345 blocks and multiplies with weight of factors. Highest score of the erosion area means critical urgency.

4.5 Prioritization of importance and severity of areas affected by coastal erosion

The areas in Pak Phanang River Basin affected by coastal erosion are categorized by level of urgency and importance. Monitoring problems of coastal erosion, the area from the end of Talumpuk cape to Pak Klong Rava, Na Saton sub-district, is divided into of 345 small areas, the size of 200x500 square meters. Individual areas are coded PN001 to PN345. Information of every factor used for determining urgency and importance are weighed and distributed into all 345 sections using geographical information system (GIS) to create a map showing the level of importance in the area that affected by coastal erosion. Factors used to determine importance of the affected areas include five levels of information: (1) erosion rate, (2) existing shore protection measures, (3) landuse and environment, (4) low loss of value, and (5) socio-economic index.

Prioritizations of 345 monitored areas affected by coastal erosion revealed that, there are twenty five significant areas in the first. The priority area number PN85 was the highest significance ranked with a score of 3.41 while there were six areas ranked second with a score of 3.35 including the area coded PN87,PN88, PN89, PN90, PN110, and PN113.

In the study area, in order to determine urgency of problem resolution, the level of coastal erosion severity can be classified as below; (Figure 4.33)

4.1 The areas with critical and urgent problems

4.2 The areas with critical problems

4.3 The areas being monitored for coastal erosion at level 1

4.4 The areas being monitored for coastal erosion at level 2

4.5 The areas with normal coastal change

4.6 The result of prioritization of importance and severity of coastal erosion problems

The results of prioritization of importance and severity of the 345 monitored areas affected by coastal erosion and the information were obtained from field surveys, and revealed that there were 3-4 areas suffering from extreme coastal erosion. These areas were in Ban Pai Sai (PN21-PN24), Ban Kong Kong to Ban Hua Tanon Chai Talay (PN85-PN90 and PN97-PN99), Ban Na Kot to Ban Kho Fai (PN181-PN186), and Ban Na Sarn (PN283-PN285). In order to set priority for urgent problem resolution, the affected areas were categorized into four groups as follows.

4.6.1 The area with critical and urgent problems

The areas with critical and urgent problems were areas that needed immediate measure for problematic resolution. These areas had a total score multiply by weight factor of more than 3 and also had contact of blocks area of more than 3 blocks, such as in Ban Plai Sai (PN21-PN24), Ban Kong Kong to Ban Hua Tanon Chai Talay (PN85-PN90 and PN97-PN99), Ban Na Sarn (PN283-PN285), and Ban Nam Sup to Ban Kho Fai (PN181 and PN186). The percentage areas with critical and urgent problems were 7.25.

4.6.2 The area with critical problems

Areas with critical problems are areas that need consideration for problem resolution in the next step area. These areas had a total score multiply by weight between 2.61 - 3.0 and had a contact block area of more than 3, such as Ban Kho Petch (PN222-PN231), Ban Hua Rong (PN232-PN238), Ban Hua Ai Tao to Ban Na Saton (PN252-PN260), and Ban Saton to Ban Kho Yao and Ban Na Sarn (PN264-PN282). The percentage areas with critical problems were 23.48.

4.6.3 The areas under monitoring level 1

Areas that had erosion problem are in the medium level but had low effects to community or economic value. Some areas were monitored and it used shoreline prevention measures in the long term. These areas had a total score multiply by weight between 2.21-2.6 and had contact block areas of more than 3, such as in Ban Laem Talum Puk (PN43-PN51) and Ban Noen Ta Kum (PN114-122). The areas under monitoring level 1 can be calculated into 25.51 percentages

4.6.4 The areas under monitoring level 2

Areas under monitoring level 2 had erosion problem are in the medium to low level and it had low effect to community or economic value. These areas do not need any measures for resolution of coastal erosion problems in short and long term but it should keep watch and be concerned with the areas. These areas had a total score multiply by weight between 1.81-2.2 and also had a contact blocks area of more than 3, such as in Ban Plai Sai (PN1-PN7) and Ban Bo Kon Ti to Ban Ko Petch (PN114-122), (PN209-PN221) and Ban Na Tod (PN313-PN342). The areas under monitoring level 2 can be calculated into 35.36 percentages

4.6.5 The areas with normal coastal changes

Areas with normal coastal changes are areas that have fewer problems caused by coastal erosion. These areas had a total score multiply by weight less 1.8, such as in Ban Chay Tha Lay to Ban Tha Khen (PN133-PN143) and Ban Ko Phai to Ban Num Sup (PN189-PN194) etc. The percentage areas with normal coastal changes were 8.4.

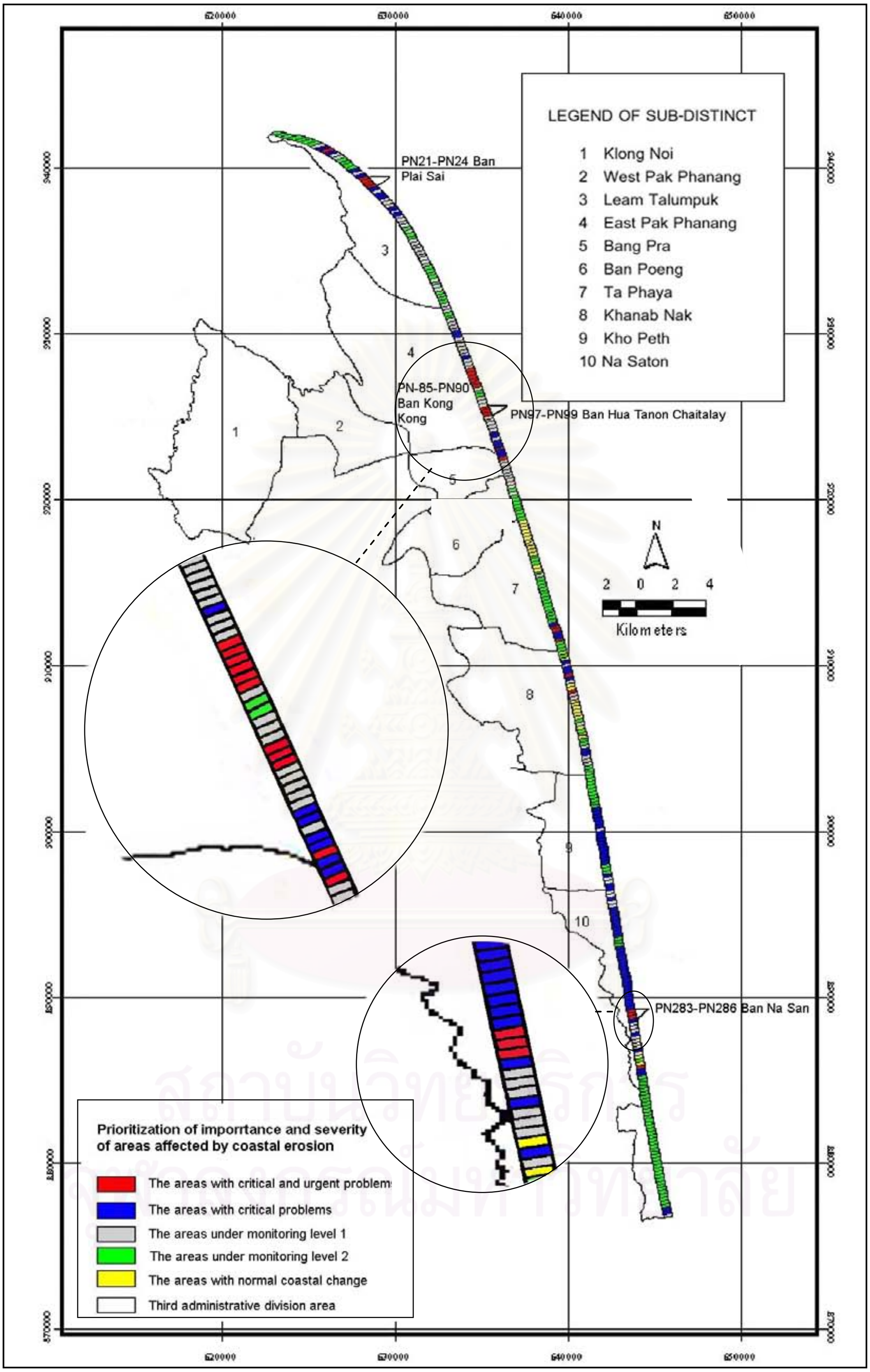


Figure 4.33 A map representing order of coastal erosion importance problems in 345 blocks being monitored in Pak Phanang River Basin.

CHAPTER V
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study assumed to classify landform and to exploring causes of coastal change and rate of erosion in the Pak Phannang River Basin between 30period from 1975-2002.

In this study, used the knowledge integration of various sciences relevant to finding and prioritize the areas that had affected from the coastal erosion problem.

In the first step of this study, was managed the raw data, such as; drainage pattern, route, soil, landuse, and previous work and data from the fields survey. The scope of this part would like to study coastal geomorphology and survey geographical condition of the area. The result of this study can be classified the coastal geomorphology in this area into 10 types; 1) resent sandy beaches, 2) old sandy beach, 3) old tidal flat, 4) intertidal flat, 5) subtidal flat, 6) old lagoon, 7) swamp, 8) old alluvial and alluvial deposit, 9) colluvial and 10) mountain and hill. The profile of shoreline showed the submarine bar at the 260-500 m. and 830-1320 m. from the shorelines, which showed the coarse sand and silty clay representative. The slopes of the seashore were approximately from the near submarine bar 1 degree and from the far submarine sand bar 0.25 degree. The pattern of paleoshoreline in the Pak Phanang area exhibited the paleo current pattern in the north to south trend.

The secondary of this study, was identified the metro-hydrographic factors in the Pak Phanang area. From the studied data, the rain fall of the area was approximately 1,800 millimeter per year. The main affected of coastal erosion was happened in the north-east monsoon, which had wind direction from northeast-easterly and wind speed of approximate 10 to 15 knots. The significant of wave high were about 0.5-1 m. The tidal mean sea level in Pak Phanang area has diurnal components which showed the subsidence or sea level rise in this area. The sediment transport in the Pak Phanang area in 2000-2003 was in the north to south trend which same as the paleo current pattern. These criteria can be predicted the cycle of shoreline change into the future.

The trend of sediment transport will be change from south to north to north to south in the future.

Final measure was analyses, by the GIS method, the coastal erosion rate, economic and social condition landuse and environment, and structure to provide the areas that had affected from the coastal erosion problem. From resolve, can be prioritized the areas the had affected the shoreline erosion into 5 orders; 1) The areas with critical and urgent problems, 2) the areas with critical problems, 3) The areas being monitored for coastal erosion at level 1, 4) The areas being monitored for coastal erosion at level 2 and 5) The areas with normal coastal change. The areas that had confronted the critical and urgent problems were Ban Plai Sai, Ban Kong Kong, Ban Hua Tanon Chai Talay and Ban Na Sarn. These areas need immediate procedure for problem resolution.

From convolved the data of this study, can be concluded the main causes of coastal erosion in these study areas, especially in the short term, was the structure of existing shore protection and in the long term was the natural changes of sediment transport, wind, wave and sea level rise.

5.2 Recommendations for the problems of coastal erosion

The result of prioritization of importance and severity of 345 monitored areas affected by coastal erosion and the information for geological surveys and foundation engineering, it was found that the area of 100 –150 meter from coastal beaches comprised a sand layer that was 1-3 meters thick, and a soft soil layer beneath, that had a low bearing capacity. As such, it is essential to consider geological conditions for foundations of the structures that are used for coastal protection. In order to set priorities for urgent problem resolutions, the affected areas were categorized into four groups as follows:

5.2.1 The areas with critically urgent problems

This area that needed immediate protection, especially a short-term resolution (1-3 years), which was an urgent process, for the affected area coastal stability was needed. The coastal engineered structures were appropriate solutions for protection and resolution of coastal erosion in the severely affected areas. There were two recommended methods.

Method 1, Sea Wall: This type of protection was appropriate for the affected areas that were used by the public, such as roads. For the severely affected areas that were quite short in distance, aggregate soil could be replaced and then the sea wall could be built.

Method 2, Detached Breakwater: This type of protection was appropriate for the affected areas that were quite long in distance. The detached breakwaters were built parallel to the coastline. Gaps between breakwaters were between 300-1000 meters. Appropriate gaps can not only reduce forces of the waves but also adjust the coast conditions for new and more balanced beaches, before and after the breakwaters. As such, there would be two types of coastal beaches, Silent or Tompolo shapes. The gap distance should not be less than twice the wavelength and not more than five times the wavelength. The structure of these detached breakwaters can be designed variably depending on purposes of use, geological conditions, and construction materials, amount of work, as well as methods and cost of construction.

From the field surveys in the project area reveal that there were 23 groins built in the area of Ban Na Kot to Ban Kho Fai (PN181–PN186) in Khanak Nab sub-district, Pak Phanang district. Some parts of these groins could effectively stop the sand but some parts could not, resulting in severe coastal erosion. These coasts are at very low level so that the tidal waves can sweep across to erode the coast as well as to sweep away sand on the beaches. As such, the current measures of coastal protection and problem resolution can be improved by adding barriers between existing groins and increase the height of the coast in order to prevent waves sweeping across the coastline.

For the long-term, this should be carried out afterwards or in parallel with the short-term measures to combine soft solution and hard solution in order to effectively solve problems in most suitable way for each location with different geographies. There are concepts and ideas to solve such problems. Building coastal stability by coastal engineered structures is a short-term measure with the hard solution. Then, a long-term measure with the soft solution is to carry out beach nourishment and inspect mangrove plantations in sediment accumulation areas in order to create new mangrove areas and new beaches. However, protection measures, which prevent losses and reduce severity, should be specified in the master plan for the resolution of coastal erosion in these affected areas. In addition, the Coastal Development Setback Distance, which can prohibit construction of buildings on beaches, should be consistently implemented in order to avoid trouble and minimize property loss.

5.2.2 The areas with critical problems

The areas with critical problems are areas that need resolution measures but are not very urgent. They should be treated with a long-term protection measure (3-5years). The soft solution was considered the most appropriate measure for current problems caused by coastal erosion, for example; building up the beach stability with sand (beach nourishment) and also have mangrove plantation in sediment accumulation areas. There should be a study of the master plan for resolution of coastal erosion problems in these affected areas. Sand excavation or sand removal must be strictly prohibited.

5.2.3 The areas under close monitored

The areas under monitoring are areas that do not need any measures for resolution of coastal erosion problems at present. However, there should be periodical evaluation and monitoring of coastal erosion. A long-term protection measure can be implemented in some areas that suffer from large scale erosion.

5.2.4 The areas with normal coastal change

The areas with normal coastal change are areas that have fewer problems caused by coastal erosion. The erosion rate is normal. The coast may be accreting further into the sea.

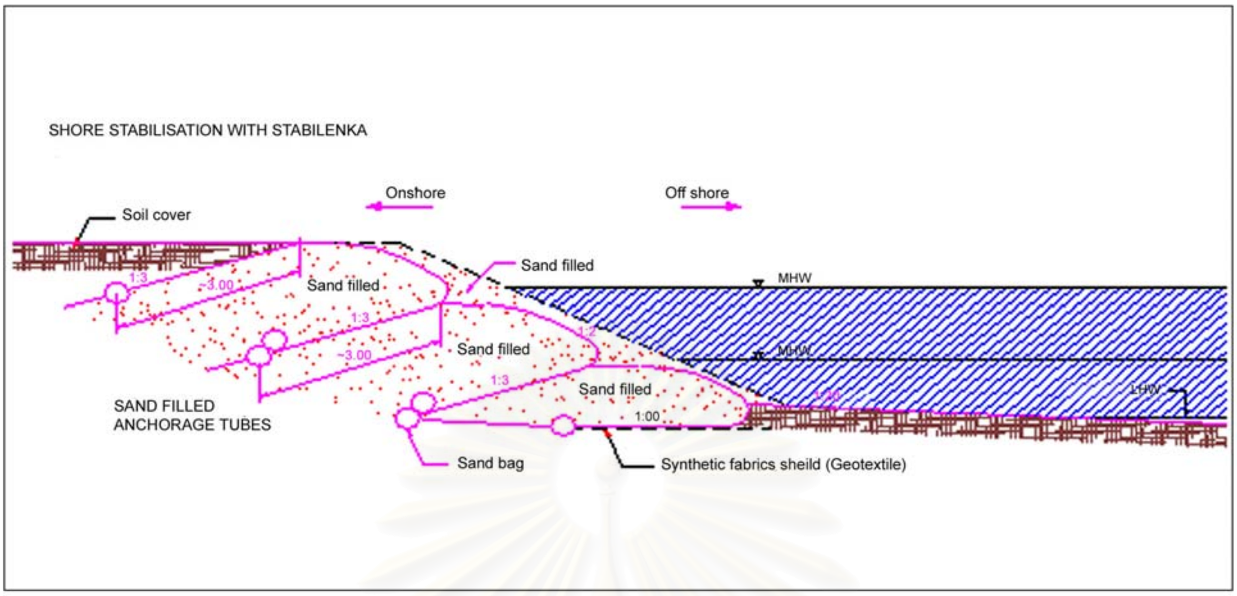


Figure 5.1 The measure of shore protection in a non structural measure pattern.

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APPENDICES

APPENDIX A

A. The survey and analysis of the beach profile

The criteria of the survey and analysis of the beach profile in this area is

- For primary survey of the beach profile in the Pak Phanang shoreline
- To analyze particle size of the sediment (mean grain size), water content and suspended solid

The survey line in Ban Na Sarn, Hua Sai district was a long line, about 2 kilometers. And the sediment and water were collected by hand corer every 250 meters from the beach and the depth was measured every 100 meters. The position of the line survey is shown in the Figure 2.16

In the laboratory, the sediment sample has been separated into 3 steps

Step1. Analysis of mean grain size

1) Sieve shaking method used for sediment that has a grain size more than 63 micron.
2) Pipette method used for silt size to silty clay size

Step2. Analysis of water content is used as a parameter to see hard and soft of the sediment in the beach profile.

1) Weight the sample before warm
2) Take a sediment sample 5 gram and warm at the 105 centigrade, 24 hour after that weight the sample and calculate in the percentage.

$$\text{Water Content} = \frac{(\text{weight of sample before warm} - \text{weight of sample after warm}) \times 100}{\text{Weight of sample before warm}}$$

Step3. Analysis of suspended solid is used as parameter to see suspension of water.

1) Take a water sample 1,000 milliliters to strain by the 0.45 micron filter paper (GF/C)
2) Take it to warm at the 105 centigrade, 24 hour after that weight the sample and calculate in the milligram/liter

Suspended solid = (weight of filter and sample – weight of filter) / water capacity

B. Concepts and principles of shoreline erosion resolution

Measure to resolve shoreline erosion problem can be divided into 3 patterns

1). Non structural measures

2). Structural measures

And 3). No action measures

1. Non structural measures

Measures to resolve shoreline in non structural pattern are soft solution measures that are suitable for none violently eroded areas, low community and tourist places. The method used to resolve the problem was replacing the sand on the beach (beach nourishment) and growing grass or tree that had long roots. Also, using a synthetic sheet to protect the beach nourishment that was carried out.

For advantages and disadvantages of non structural measures as follows

Advantage

- The beach looked natural
- Was suitable for tourists
- Landscape was beautiful

Disadvantage

- There was a high maintenance cost involved
- Non suitable for high erosion areas

2 Structural measures

Measures to resolve shoreline problems in structural pattern are hard solutions to reduce wave energy and trap the sediment around the beach, which is suitable for a high rate of erosion. This resolution used the engineered structures to protect the eroded shoreline and the beach.

After the study and wave characteristic analysis, direction of waves, morphology in the beach profiled, type of beach use and sediment transport observed as was mentioned, a pattern of structure protection was chosen. The principle and condition of shore protection measures were as follows;

1) The material used for shore protection had to be strong and suitable for use in salt water. It could be found near the shoreline to reduce the cost of building.
2) The pattern of shore protection had to have no effect on communities and the environment.
3) The pattern of shore protection had to be cheap, easy to build and had to provide protection against erosion.
4) Position was to cause no effect on communities and the environment.
5) The pattern of shore protection had to be easily maintained.

Patterns of extensive shore protection:

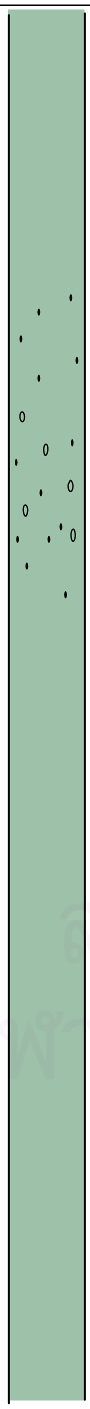
1) Head lands
2) Detached breakwaters
3) Groins
4) Jetties
5) Seawalls

3. No action measure

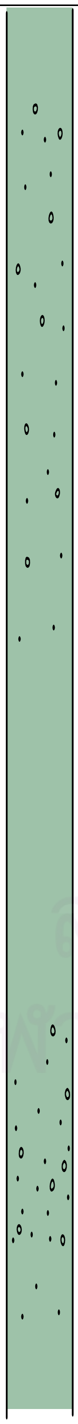
No action measure was the all thought about choice used to protect the eroded areas. Most no action measures were under the control of economic circumstance. It is low and not enough to cover the cost of buildings. In theory, this alternative was suitable for areas that had a buffer zone and had enough area for erosion in a long time period. This case could be slowed for testing until a buffer zone was established.

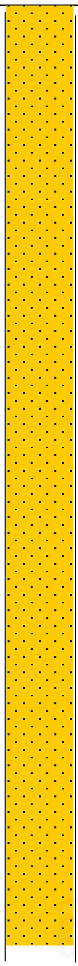
APPENDIX B

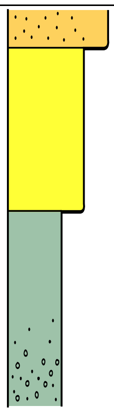
The geological drilling chart in the study area

Geological Drill Chart				
Hole No: A1		Depth (meters): 3.4		
Location:				
Date of Drilling: 15/11/2004				
Map Sheet:		Grid Reference: 603189E 0878925N		
Sample	Type	Depth (m)	Description	Remark
0m 1m 2m 3m 4m 		0.0 – 0.7 0.7 – 2.8 2.8 - 3.8	Clay: olive brown 4/3. Clay: pale-yellow 8/3 with very coarse sand to coarse grain. Clay: light gray 8/1 mottled with orange 6/6.	Gradual contact Gradual contact

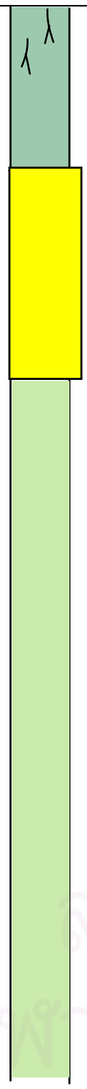
Geological Drill Chart	
Hole No: A2	Depth (meters): 4.5
Location:	
Date of Drilling: 15/11/2004	
Map Sheet:	Grid Reference: 607664E 0879986N

Sample	Type	Depth (m)	Description	Remark
0m 1m 2m 3m 4m 		0.0 - 0.1	Clay: light brown with gray humid and root.	
		0.1 - 0.35	Clay: light gray yellowish brown, and Fe oxide.	
		0.35 - 0.55	Clay: yellowish brown orange and light gray with Fe oxide.	
		0.55 - 1.0	Clay: yellowish brown orange and light gray with Fe oxide interbeded coarse to medium sand sub angular to sub round.	
		1.0 - 1.3	Clay: yellowish brown orange with Fe oxide, coarse to fine sand and peat.	
		1.3 - 3.0	Clay: reddish brown and light gray, muddy sand and Fe oxide.	
		3.0 - 3.5	Clay: grayish red.	
		3.5 – 4.5	Clay: yellowish gray interbeded coarse to fine sand, sub round.	

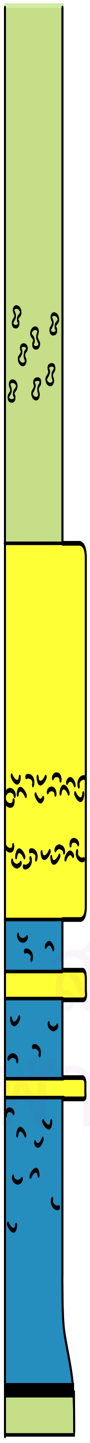
Geological Drill Chart				
Hole No: A3.1		Depth (meters): 1.8		
Location:				
Date of Drilling: 15/11/2004				
Map Sheet:		Grid Reference: 610376E 0882434N		
Sample	Type	Depth (m)	Description	Remark
0m  0.5m 1m 1.5m		0.0 – 0.2	Fine sand: well sorted, olive black3/1.	
		0.2 – 0.6	Fine sand: well sorted, light gray 7/1.	
		0.6 – 1.2	Fine sand: well sorted, olive brown 4/3.	
		1.2 – 1.8	Fine sand: well sorted, olive brown 4/4.	water rich layer

Geological Drill Chart				
Hole No: A3.2		Depth (meters): 2.3		
Location: Km.14 Rd.4151 Moo 3 Ban Khokyor Tambon Ban Toom Amphoe Chaaoe				
Date of Drilling: 20/12/2004				
Map Sheet:		Grid Reference: 614200E 0885700E		
Sample	**Type**	**Depth (m)**	**Description**	**Remark**
0m		0.0 – 0.5	Sandy clay: black to grayish black.	Peat swamp
		0.5 – 1.0	Sandy clay: light gray.	
1m		1.0 - 2.2	Clay: light gray with yellow and sandy clay to coarse grain.	
2.3m				

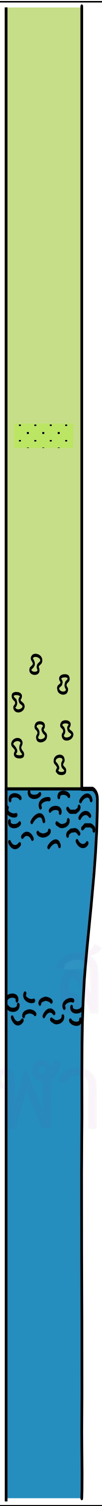
Geological Drill Chart	
Hole No: A3.3	**Depth (meters):** 4
Location: Km.8 Rd.4151 Ban Nong Hin Luk Tombon Suan Luang Amphoe Chalurm Pra Kiet	
Date of Drilling: 20/12/2004	
Map Sheet:	**Grid Reference:** 616800E 0889800N

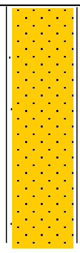
Sample	Type	Depth (m)	Description	Remark
0m		0.0 – 0.1	Clay: yellowish brown.	(Top soil)
		0.1 – 0.75	Silt and clay: yellowish gray, jarosite and root.	(fresh water)
			Clay: purple gray.	(swamp)
		0.75 – 2.0	Clay: grayish black.	
		2.0 – 3.0	Clay: blackish gray.	
		3.0 – 4.0		
2m				
4m				

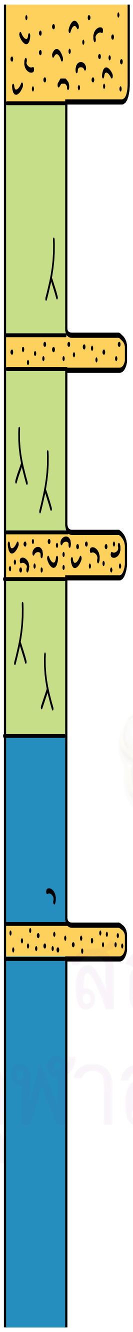
Geological Drill Chart				
Hole No: A4		Depth (meters): 5.2		
Location:				
Date of Drilling: 15/11/2004				
Map Sheet:		Grid Reference: 628544E 0893471N		

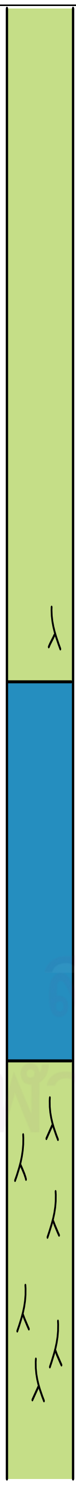
Sample	Type	Depth (m)	Description	Remark
0m 1m 2m 3m 4m 5m 		0.0 – 0.2	Clay: grayish yellow 6/2.	(Top soil)
		0.2 – 0.6	Clay: dull yellow 6/3.	
		0.6 – 2.0	Clay: light yellow 7/3, olive brown patch.	
		2.0 – 3.4	Very fine sand: light gray 7/1, well sorted and clean.	
		3.4 – 3.6	Clay: gray 6/1.	
		3.6 – 3.7	Very fine sand: light gray 7/1.	
		3.7 – 4.0	Clay: gray 6/1.	
		4.0 – 4.1	Very fine sand: light gray 7/1.	
		4.1 – 4.5	Clay: gray 6/1.	
		4.5 – 5.1	Sandy silt (very fine sand): gray 6/1.	
		5.1 – 5.2	Peat: dark reddish brown 3/3.	

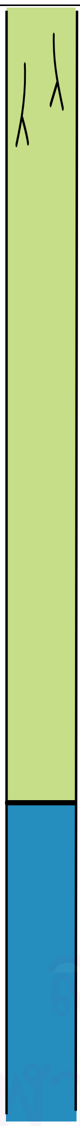
Geological Drill Chart	
Hole No: A5	Depth (meters): 6.0
Location:	
Date of Drilling: 15/11/2004	
Map Sheet:	Grid Reference: 637658E 0882878N

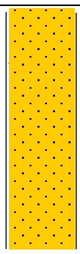
Sample	Type	Depth (m)	Description	Remark
0m 1m 2m 3m 4m 5m 6m 		0.0 – 0.4	Soil clay: grayish olive 5/3.	
		0.4 – 2.4	Clay: light gray 8/2 Interbedded with very fine sand and granule layer.	
		2.4 – 3.0	Clay: dark reddish brown 3/3, patches 2-3 mm.	
		3.0 – 3.8	Sandy clay (very fine sand): light gray 7/1 with shall and fragment.	
		3.8 – 6.0	Clay: light gray 7/1 and shell.	

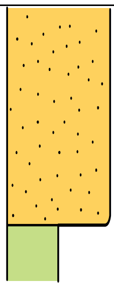
Geological Drill Chart				
Hole No: A6		Depth (meters): 1.5		
Location:				
Date of Drilling: 15/11/2004				
Map Sheet:		Grid Reference: 646353E 0883265N		
Sample	Type	Depth (m)	Description	Remark
0m		0 – 0.3	Fine sand: pale yellow 8/4, well sorted and clean.	
1.5m		0.3 – 1.5	Fine sand: yellow 8/6, well sorted and clean.	

Geological Drill Chart				
Hole No: B7		Depth (meters): 4.5		
Location:				
Date of Drilling: 14/11/2005				
Map Sheet:		Grid Reference: 637806E 0922655N		
Sample	Type	Depth (m)	Description	Remark
		0.0 -0.2	Muddy sand: with fine to medium sand and shelly fragment.	
		0.2 -1.2	Sandy mud with very fine sand: gray 5/1 and roots.	
		1.2 – 1.8	Sand: fine to medium, sandy mud with very fine sand, gray 5/1 and roots.	
		1.8 - 3.1	Shelly fragments: sandy mud with very fine sand, gray 5/1 and roots.	
		3.1 - 4.5	Very fine to fine sand: sandy mud gray 5/1 and roots.	

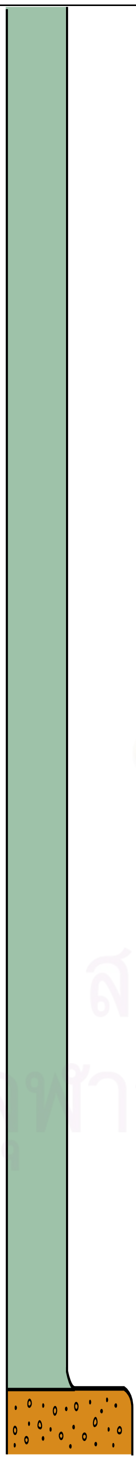
Geological Drill Chart				
Hole No: B6		Depth (meters): 6.5		
Location:				
Date of Drilling: 14/11/2004				
Map Sheet:		Grid Reference: 631260E 0922901N		
Sample	Type	Depth (m)	Description	Remark
0m 1m 1.5m 4m 4.5m 5m 5.5m 6m 6.5m 		0.0 – 0.2 0.2 – 4.0 4.0 – 6.5	Clay: bright yellowish brown 6/6. Clay: light gray 7/1. Clay: light gray 7/1 interbedded with root.	

Geological Drill Chart				
Hole No: B5			Depth (meters): 2.5	
Location:				
Date of Drilling: 14/11/2004				
Map Sheet:		Grid Reference: 620912E 0921526N		
Sample	Type	Depth (m)	Description	Remark
		0.0 – 0.2	Clay: blackish gray with root.	
		0.2 – 0.5	Clay: black with some gravel and iron oxide.	
		0.5 – 2.0	Clay: yellowish brown with pisolitic, some gravel and thin peat layer.	
		2.0 – 2.5	Clay: greenish gray and blackish.	

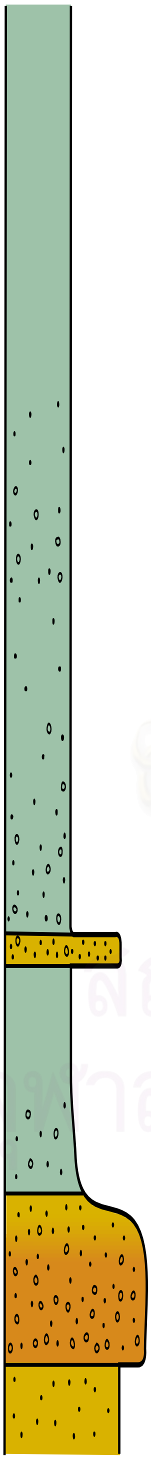
Geological Drill Chart				
Hole No: B4		Depth (meters): 1.5		
Location:				
Date of Drilling: 14/11/2004				
Map Sheet:		Grid Reference: 606837E 0927922N		
Sample	**Type**	**Depth (m)**	**Description**	**Remark**
0m 1.5m		0.0 – 1.5	Sand: yellowish light gray coarse to medium sand.	

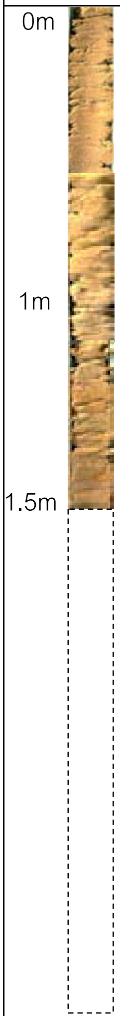
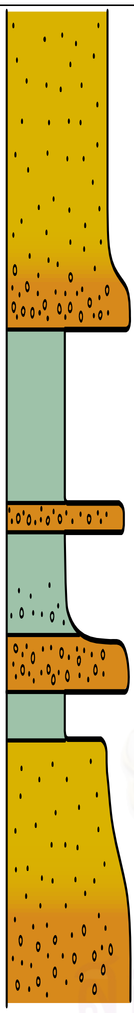
Geological Drill Chart				
Hole No: B3.2		Depth (meters): 1.5		
Location:				
Date of Drilling: 14/11/2004				
Map Sheet:		Grid Reference: 604280E 0925001N		
Sample	Type	Depth (m)	Description	Remark
0m 1.5m		0.0 – 0.3 0.3 – 1.2 1.2 – 1.5	Clay: brownish gray with jarosite and root. Clay: light grayish yellow and fine to coarse sand sub angular to round. Clay: light gray with peat and medium sand.	

Geological Drill Chart	
Hole No: B3.1	Depth (meters): 5.5
Location:	
Date of Drilling: 14/11/2004	
Map Sheet:	Grid Reference: 603817E 0924419E

Sample	Type	Depth (m)	Description	Remark
		0.0 – 0.2	Clay: grayish brown with coarse sand and root.	
		0.2 – 2.0	Clay: light gray and yellow with pisolitic and coarse to medium sand.	
		2.0 – 2.8	Clay: light grayish purple and mud, red lateritic.	
		2.8 – 4.5	Clay: light gray with yellow.	
		4.5 – 5.5	Clay: light gray with orange.	
			Clay: yellowish gray, and medium to fine sand.	

Geological Drill Chart	
Hole No: B2	Depth (meters): 5
Location:	
Date of Drilling: 14/11/2004	
Map Sheet:	Grid Reference: 602308E 0923163N

Sample	Type	Depth (m)	Description	Remark
0m 1m 2m 3m 4m 5m 		0.0 – 2.5	Clay: light yellow 7/4 with very coarse sand grain.	
		2.5 – 2.6	Very fine sand with very coarse sand and bright yellowish brown 7/8.	
		2.6 – 3.6	Clay: light gray 7/1 mottled with bright yellowish brown 7/8 and some plant fragment.	
		3.6 – 4.1	Medium to very coarse sand with granule, light gray8/1 mottled with orange 6/8.	
		4.1 – 5.0	Fine sand: light gray 8/1 well sorted	

Geological Drill Chart				
Hole No: B1		Depth (meters): 3		
Location:				
Date of Drilling: 14/11/2004				
Map Sheet:		Grid Reference: 597860E 0920980N		
Sample	Type	Depth (m)	Description	Remark
		0.0 – 0.2	Fine sand: olive 5/4 well sorted.	
		0.2 – 1.0	Fine sand: bright yellowish brown 7/6 well sorted.	
		1.0 – 1.1	Medium sand: with very coarse sand, bright yellowish brown 7/6.	
		1.1 – 1.7	Sandy clay: light gray 8/1 and thin medium sand layer.	
		1.7 – 2.0	Clay: light gray 8/1.	
		2.0 – 2.2	Medium to coarse sand: light gray 8/1 with very coarse sand grain.	
		2.2 – 2.4	Medium sand: light gray 8/1 well sorted.	
		2.4 – 2.9	No sample: but probably clean sand and water rich.	
		2.9 – 3.0	Medium to coarse sand with very coarse sand.	

Prioritized weight scores of 345 blocks study area

NAME_VILL	CODE	ECO_S	ERO_S	INFA_S	LAN_S	LOSE_S	W_ECO	W_ERO	W_INFA	W_LAN	W_LOSE	MCA_S	FINAL_S
Ban Plai Sai	PN1	1	1	5	4	1	0.23	0.17	0.50	1.00	0.25	2.15	2
Ban Plai Sai	PN2	1	1	5	4	1	0.23	0.17	0.50	1.00	0.25	2.15	2
Ban Plai Sai	PN3	1	1	5	4	1	0.23	0.17	0.50	1.00	0.25	2.15	2
Ban Plai Sai	PN4	1	1	5	4	1	0.23	0.17	0.50	1.00	0.25	2.15	2
Ban Plai Sai	PN5	1	1	5	4	1	0.23	0.17	0.50	1.00	0.25	2.15	2
Ban Plai Sai	PN6	1	1	5	4	1	0.23	0.17	0.50	1.00	0.25	2.15	2
Ban Plai Sai	PN7	1	1	5	4	1	0.23	0.17	0.50	1.00	0.25	2.15	2
Ban Plai Sai	PN8	1	2	5	4	1	0.23	0.34	0.50	1.00	0.25	2.32	3
Ban Plai Sai	PN9	1	4	5	4	2	0.23	0.68	0.50	1.00	0.50	2.91	4
Ban Plai Sai	PN10	1	4	5	4	3	0.23	0.68	0.50	1.00	0.75	3.16	5
Ban Plai Sai	PN11	1	4	5	4	2	0.23	0.68	0.50	1.00	0.50	2.91	4
Ban Plai Sai	PN12	1	3	5	4	1	0.23	0.51	0.50	1.00	0.25	2.49	3
Ban Plai Sai	PN13	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Plai Sai	PN14	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Plai Sai	PN15	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Plai Sai	PN16	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Plai Sai	PN17	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Plai Sai	PN18	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Plai Sai	PN19	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3

Prioritized weight scores of 345 blocks study area

Ban Plai Sai	PN20	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Plai Sai	PN21	1	5	5	2	4	0.23	0.85	0.50	0.50	1.00	3.08	5
Ban Plai Sai	PN22	1	5	5	2	5	0.23	0.85	0.50	0.50	1.25	3.33	5
Ban Plai Sai	PN23	1	5	5	2	5	0.23	0.85	0.50	0.50	1.25	3.33	5
Ban Plai Sai	PN24	1	5	5	2	4	0.23	0.85	0.50	0.50	1.00	3.08	5
Ban Plai Sai	PN25	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Plai Sai	PN26	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Plai Sai	PN27	1	3	5	5	2	0.23	0.51	0.50	1.25	0.50	2.99	4
Ban Laem Talumpuk	PN28	1	3	5	5	2	0.23	0.51	0.50	1.25	0.50	2.99	4
Ban Laem Talumpuk	PN29	1	2	5	5	1	0.23	0.34	0.50	1.25	0.25	2.57	3
Ban Laem Talumpuk	PN30	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Laem Talumpuk	PN31	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Laem Talumpuk	PN32	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Laem Talumpuk	PN33	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Laem Talumpuk	PN34	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Laem Talumpuk	PN35	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Laem Talumpuk	PN36	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Laem Talumpuk	PN37	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Laem Talumpuk	PN38	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Laem Talumpuk	PN39	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2

Prioritized weight scores of 345 blocks study area

Ban Laem Talumpuk	PN40	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Laem Talumpuk	PN41	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Laem Talumpuk	PN42	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Laem Talumpuk	PN43	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Laem Talumpuk	PN44	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Laem Talumpuk	PN45	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Laem Talumpuk	PN46	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Laem Talumpuk	PN47	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Laem Talumpuk	PN48	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Laem Talumpuk	PN49	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Laem Talumpuk	PN50	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Laem Talumpuk	PN51	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Laem Talumpuk	PN52	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Laem Talumpuk	PN53	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Laem Talumpuk	PN54	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Noen Num Hak	PN55	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Noen Num Hak	PN56	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN57	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Noen Num Hak	PN58	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN59	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3

Prioritized weight scores of 345 blocks study area

Ban Noen Num Hak	PN60	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Noen Num Hak	PN61	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN62	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Noen Num Hak	PN63	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Noen Num Hak	PN64	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN65	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Noen Num Hak	PN66	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN67	1	3	5	1	2	0.23	0.51	0.50	0.25	0.50	1.99	2
Ban Noen Num Hak	PN68	1	3	5	1	2	0.23	0.51	0.50	0.25	0.50	1.99	2
Ban Noen Num Hak	PN69	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN70	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN71	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN72	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN73	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Noen Num Hak	PN74	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Noen Num Hak	PN75	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN76	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN77	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN78	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Num Hak	PN79	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3

Prioritized weight scores of 345 blocks study area

Ban Noen Num Hak	PN80	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Noen Num Hak	PN81	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Noen Num Hak	PN82	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Noen Num Hak	PN83	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Noen Num Hak	PN84	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Kong Kong	PN85	1	4	5	5	3	0.23	0.68	0.50	1.25	0.75	3.41	5
Ban Kong Kong	PN86	2	4	5	2	4	0.46	0.68	0.50	0.50	1.00	3.14	5
Ban Kong Kong	PN87	2	4	5	2	5	0.46	0.68	0.50	0.50	1.25	3.39	5
Ban Kong Kong	PN88	2	4	5	2	5	0.46	0.68	0.50	0.50	1.25	3.39	5
Ban Kong Kong	PN89	2	4	5	2	5	0.46	0.68	0.50	0.50	1.25	3.39	5
Ban Hua Tanon Chaytalay	PN90	2	4	5	2	5	0.46	0.68	0.50	0.50	1.25	3.39	5
Ban Hua Tanon Chaytalay	PN91	1	3	5	2	3	0.23	0.51	0.50	0.50	0.75	2.49	3
Ban Hua Tanon Chaytalay	PN92	1	2	5	2	2	0.23	0.34	0.50	0.50	0.50	2.07	2
Ban Hua Tanon Chaytalay	PN93	1	2	5	2	2	0.23	0.34	0.50	0.50	0.50	2.07	2
Ban Hua Tanon Chaytalay	PN94	2	2	5	2	2	0.46	0.34	0.50	0.50	0.50	2.30	3
Ban Hua Tanon Chaytalay	PN95	1	3	5	2	3	0.23	0.51	0.50	0.50	0.75	2.49	3
Ban Hua Tanon Chaytalay	PN96	1	1	5	5	1	0.23	0.17	0.50	1.25	0.25	2.40	3
Ban Hua Tanon Chaytalay	PN97	2	1	5	5	4	0.46	0.17	0.50	1.25	1.00	3.38	5
Ban Hua Tanon Chaytalay	PN98	3	2	5	5	2	0.69	0.34	0.50	1.25	0.50	3.28	5
Ban Hua Tanon Chaytalay	PN99	2	2	5	5	2	0.46	0.34	0.50	1.25	0.50	3.05	5

Prioritized weight scores of 345 blocks study area

Ban Hua Tanon Chaytalay	PN100	2	2	5	2	3	0.46	0.34	0.50	0.50	0.75	2.55	3
Ban Hua Tanon Chaytalay	PN101	2	2	5	2	3	0.46	0.34	0.50	0.50	0.75	2.55	3
Ban Hua Tanon Chaytalay	PN102	2	2	5	2	2	0.46	0.34	0.50	0.50	0.50	2.30	3
Ban Hua Tanon Chaytalay	PN103	2	2	5	2	2	0.46	0.34	0.50	0.50	0.50	2.30	3
Ban Hua Tanon Chaytalay	PN104	2	2	5	2	3	0.46	0.34	0.50	0.50	0.75	2.55	3
Ban Hua Tanon Chaytalay	PN105	2	3	5	2	3	0.46	0.51	0.50	0.50	0.75	2.72	4
Ban Bang Wa	PN106	2	3	5	2	3	0.46	0.51	0.50	0.50	0.75	2.72	4
Ban Bang Wa	PN107	2	2	5	2	2	0.46	0.34	0.50	0.50	0.50	2.30	3
Ban Bang Wa	PN108	2	3	5	2	3	0.46	0.51	0.50	0.50	0.75	2.72	4
Ban Bang Wa	PN109	2	3	5	2	3	0.46	0.51	0.50	0.50	0.75	2.72	4
Ban Noen Ta Kum	PN110	2	4	5	2	5	0.46	0.68	0.50	0.50	1.25	3.39	5
Ban Noen Ta Kum	PN111	2	3	5	2	4	0.46	0.51	0.50	0.50	1.00	2.97	4
Ban Noen Ta Kum	PN112	2	3	5	2	3	0.46	0.51	0.50	0.50	0.75	2.72	4
Ban Noen Ta Kum	PN113	2	4	5	2	5	0.46	0.68	0.50	0.50	1.25	3.39	5
Ban Noen Ta Kum	PN114	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Ta Kum	PN115	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Ta Kum	PN116	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Ta Kum	PN117	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Ta Kum	PN118	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Noen Ta Kum	PN119	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3

Prioritized weight scores of 345 blocks study area

Ban Noen Ta Kum	PN120	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Noen Ta Kum	PN121	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Noen Ta Kum	PN122	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Noen Ta Kum	PN123	1	4	5	1	2	0.23	0.68	0.50	0.25	0.50	2.16	2
Ban Noen Ta Kum	PN124	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Makamted	PN125	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Makamted	PN126	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Makamted	PN127	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Makamted	PN128	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Makamted	PN129	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Makamted	PN130	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Makamted	PN131	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Chaitalay	PN132	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Chaitalay	PN133	1	1	5	1	1	0.23	0.17	0.50	0.25	0.25	1.40	1
Ban Chaitalay	PN134	1	1	5	1	1	0.23	0.17	0.50	0.25	0.25	1.40	1
Ban Chaitalay	PN135	1	1	5	2	1	0.23	0.17	0.50	0.50	0.25	1.65	1
Ban Chaitalay	PN136	1	1	5	2	1	0.23	0.17	0.50	0.50	0.25	1.65	1
Ban Chaitalay	PN137	1	1	5	2	1	0.23	0.17	0.50	0.50	0.25	1.65	1
Ban Tha Khen	PN138	1	1	5	2	1	0.23	0.17	0.50	0.50	0.25	1.65	1
Ban Tha Khen	PN139	1	1	5	2	1	0.23	0.17	0.50	0.50	0.25	1.65	1

Prioritized weight scores of 345 blocks study area

Ban Tha Khen	PN140	1	1	5	2	1	0.23	0.17	0.50	0.50	0.25	1.65	1
Ban Tha Khen	PN141	1	1	5	2	1	0.23	0.17	0.50	0.50	0.25	1.65	1
Ban Tha Khen	PN142	1	1	5	2	1	0.23	0.17	0.50	0.50	0.25	1.65	1
Ban Tha Khen	PN143	1	1	5	1	1	0.23	0.17	0.50	0.25	0.25	1.40	1
Ban Chonlapatan Ta Ook	PN144	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Chonlapatan Ta Ook	PN145	2	2	5	2	1	0.46	0.34	0.50	0.50	0.25	2.05	2
Ban Chonlapatan Ta Ook	PN146	2	2	5	2	1	0.46	0.34	0.50	0.50	0.25	2.05	2
Ban Chonlapatan Ta Ook	PN147	2	1	5	1	1	0.46	0.17	0.50	0.25	0.25	1.63	1
Ban Chonlapatan Ta Ook	PN148	2	2	5	1	1	0.46	0.34	0.50	0.25	0.25	1.80	1
Ban Chonlapatan Ta Ook	PN149	2	2	5	2	1	0.46	0.34	0.50	0.50	0.25	2.05	2
Ban Chonlapatan Ta Ook	PN150	2	3	5	2	2	0.46	0.51	0.50	0.50	0.50	2.47	3
Ban Chonlapatan Ta Ook	PN151	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Wat Sa	PN152	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Wat Sa	PN153	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Wat Sa	PN154	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Wat Sa	PN155	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Wat Sa	PN156	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Wat Sa	PN157	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Wat Sa	PN158	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Wat Sa	PN159	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2

Prioritized weight scores of 345 blocks study area

Ban Ko Thang	PN160	3	1	5	2	1	0.69	0.17	0.50	0.50	0.25	2.11	2
Ban Ko Thang	PN161	3	1	5	2	1	0.69	0.17	0.50	0.50	0.25	2.11	2
Ban Ko Thang	PN162	3	1	5	2	1	0.69	0.17	0.50	0.50	0.25	2.11	2
Ban Ko Thang	PN163	3	1	5	2	1	0.69	0.17	0.50	0.50	0.25	2.11	2
Ban Ko Thang	PN164	3	1	5	2	1	0.69	0.17	0.50	0.50	0.25	2.11	2
Ban Ko Thang	PN165	3	1	5	5	1	0.69	0.17	0.50	1.25	0.25	2.86	4
Ban Rim Khuen	PN166	4	1	5	5	1	0.92	0.17	0.50	1.25	0.25	3.09	5
Ban Rim Khuen	PN167	3	2	5	5	1	0.69	0.34	0.50	1.25	0.25	3.03	5
Ban Rim Khuen	PN168	3	1	5	5	1	0.69	0.17	0.50	1.25	0.25	2.86	4
Ban Rim Khuen	PN169	3	1	5	5	1	0.69	0.17	0.50	1.25	0.25	2.86	4
Ban Rim Khuen	PN170	4	2	5	5	1	0.92	0.34	0.50	1.25	0.25	3.26	5
Ban Rim Khuen	PN171	3	1	5	2	1	0.69	0.17	0.50	0.50	0.25	2.11	2
Ban Rim Khuen	PN172	3	1	5	2	1	0.69	0.17	0.50	0.50	0.25	2.11	2
Ban Na Kote	PN173	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Kote	PN174	1	1	5	2	1	0.23	0.17	0.50	0.50	0.25	1.65	1
Ban Na Kote	PN175	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Kote	PN176	1	1	5	2	1	0.23	0.17	0.50	0.50	0.25	1.65	1
Ban Na Kote	PN177	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Na Kote	PN178	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Na Kote	PN179	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4

Prioritized weight scores of 345 blocks study area

Ban Na Kote	PN180	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Na Kote	PN181	1	5	5	2	4	0.23	0.85	0.50	0.50	1.00	3.08	5
Ban Kho Fai	PN182	2	4	5	2	2	0.46	0.68	0.50	0.50	0.50	2.64	4
Ban Kho Fai	PN183	1	4	5	2	2	0.23	0.68	0.50	0.50	0.50	2.41	3
Ban Kho Fai	PN184	1	2	3	2	1	0.23	0.34	0.30	0.50	0.25	1.62	1
Ban Kho Fai	PN185	1	1	3	2	1	0.23	0.17	0.30	0.50	0.25	1.45	1
Ban Kho Fai	PN186	2	3	3	5	2	0.46	0.51	0.30	1.25	0.50	3.02	5
Ban Kho Fai	PN187	2	2	3	5	1	0.46	0.34	0.30	1.25	0.25	2.60	3
Ban Kho Fai	PN188	2	1	3	5	1	0.46	0.17	0.30	1.25	0.25	2.43	3
Ban Kho Fai	PN189	1	1	3	2	1	0.23	0.17	0.30	0.50	0.25	1.45	1
Ban Kho Fai	PN190	1	1	3	2	1	0.23	0.17	0.30	0.50	0.25	1.45	1
Ban Kho Fai	PN191	1	1	3	2	1	0.23	0.17	0.30	0.50	0.25	1.45	1
Ban Kho Fai	PN192	1	1	3	2	1	0.23	0.17	0.30	0.50	0.25	1.45	1
Ban Kho Fai	PN193	1	1	3	2	1	0.23	0.17	0.30	0.50	0.25	1.45	1
Ban Nam Sup	PN194	1	1	3	2	1	0.23	0.17	0.30	0.50	0.25	1.45	1
Ban Nam Sup	PN195	1	3	3	2	2	0.23	0.51	0.30	0.50	0.50	2.04	2
Ban Nam Sup	PN196	1	4	3	2	2	0.23	0.68	0.30	0.50	0.50	2.21	3
Ban Nam Sup	PN197	1	2	3	2	1	0.23	0.34	0.30	0.50	0.25	1.62	1
Ban Nam Sup	PN198	1	3	3	2	2	0.23	0.51	0.30	0.50	0.50	2.04	2
Ban Nam Sup	PN199	1	2	3	2	1	0.23	0.34	0.30	0.50	0.25	1.62	1

Prioritized weight scores of 345 blocks study area

Ban Nam Sup	PN200	1	2	3	2	1	0.23	0.34	0.30	0.50	0.25	1.62	1
Ban Nam Sup	PN201	1	3	3	2	2	0.23	0.51	0.30	0.50	0.50	2.04	2
Ban Nam Sup	PN202	1	3	3	2	2	0.23	0.51	0.30	0.50	0.50	2.04	2
Ban Nam Sup	PN203	1	4	3	2	3	0.23	0.68	0.30	0.50	0.75	2.46	3
Ban Nam Sup	PN204	1	5	5	2	3	0.23	0.85	0.50	0.50	0.75	2.83	4
Ban Nam Sup	PN205	1	4	5	2	3	0.23	0.68	0.50	0.50	0.75	2.66	4
Ban Bo Kon Ti	PN206	1	5	h	2	3	0.23	0.85	0.10	0.50	0.75	2.43	3
Ban Bo Kon Ti	PN207	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Bo Kon Ti	PN208	1	3	5	2	2	0.23	0.51	0.50	0.50	0.50	2.24	3
Ban Bo Kon Ti	PN209	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Bo Kon Ti	PN210	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Bo Kon Ti	PN211	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Ko Petch	PN212	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Ko Petch	PN213	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Ko Petch	PN214	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Ko Petch	PN215	1	4	5	2	1	0.23	0.68	0.50	0.50	0.25	2.16	2
Ban Ko Petch	PN216	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Ko Petch	PN217	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Ko Petch	PN218	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Ko Petch	PN219	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2

Prioritized weight scores of 345 blocks study area

Ban Ko Petch	PN220	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Ko Petch	PN221	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Ko Petch	PN222	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Ko Petch	PN223	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Ko Petch	PN224	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Ko Petch	PN225	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Ko Petch	PN226	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Ko Petch	PN227	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Ko Petch	PN228	1	2	5	5	1	0.23	0.34	0.50	1.25	0.25	2.57	3
Ban Ko Petch	PN229	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Ko Petch	PN230	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Ko Petch	PN231	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Hua Rong	PN232	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Hua Rong	PN233	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Hua Rong	PN234	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Hua Rong	PN235	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Hua Rong	PN236	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Hua Rong	PN237	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Hua Rong	PN238	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Hua Rong	PN239	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2

Prioritized weight scores of 345 blocks study area

Ban Hua Rong	PN240	1	2	5	2	1	0.23	0.34	0.50	0.50	0.25	1.82	2
Ban Hua Rong	PN241	1	3	5	2	1	0.23	0.51	0.50	0.50	0.25	1.99	2
Ban Hua Rong	PN242	2	2	5	5	1	0.46	0.34	0.50	1.25	0.25	2.80	4
Ban Hua Rong	PN243	1	2	5	5	1	0.23	0.34	0.50	1.25	0.25	2.57	3
Ban Hua Ai Tao	PN244	1	2	5	5	1	0.23	0.34	0.50	1.25	0.25	2.57	3
Ban Hua Ai Tao	PN245	1	3	5	5	1	0.23	0.51	0.50	1.25	0.25	2.74	4
Ban Hua Ai Tao	PN246	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Hua Ai Tao	PN247	1	1	5	5	1	0.23	0.17	0.50	1.25	0.25	2.40	3
Ban Hua Ai Tao	PN248	1	1	5	5	1	0.23	0.17	0.50	1.25	0.25	2.40	3
Ban Hua Ai Tao	PN249	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Hua Ai Tao	PN250	1	1	5	5	1	0.23	0.17	0.50	1.25	0.25	2.40	3
Ban Hua Ai Tao	PN251	1	1	5	5	1	0.23	0.17	0.50	1.25	0.25	2.40	3
Ban Hua Ai Tao	PN252	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Na Saton	PN253	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Na Saton	PN254	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Na Saton	PN255	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Na Saton	PN256	2	2	5	5	1	0.46	0.34	0.50	1.25	0.25	2.80	4
Ban Na Saton	PN257	2	2	5	5	1	0.46	0.34	0.50	1.25	0.25	2.80	4
Ban Na Saton	PN258	2	2	5	5	1	0.46	0.34	0.50	1.25	0.25	2.80	4
Ban Na Saton	PN259	2	2	5	5	1	0.46	0.34	0.50	1.25	0.25	2.80	4

Prioritized weight scores of 345 blocks study area

Ban Na Saton	PN260	2	2	5	5	1	0.46	0.34	0.50	1.25	0.25	2.80	4
Ban Na Saton	PN261	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Saton	PN262	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Saton	PN263	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Saton	PN264	2	2	5	5	1	0.46	0.34	0.50	1.25	0.25	2.80	4
Ban Na Saton	PN265	2	2	5	5	1	0.46	0.34	0.50	1.25	0.25	2.80	4
Ban Na Saton	PN266	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Na Saton	PN267	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN268	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN269	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN270	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN271	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN272	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN273	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN274	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN275	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN276	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN277	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Ko Yao	PN278	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Na San	PN279	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4

<u>Prioritized weight scores of 345 blocks study area</u>

Ban Na San	PN280	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Na San	PN281	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Na San	PN282	3	1	5	5	1	0.69	0.17	0.50	1.25	0.25	2.86	4
Ban Na San	PN283	4	1	5	5	1	0.92	0.17	0.50	1.25	0.25	3.09	5
Ban Na San	PN284	5	1	5	5	1	1.15	0.17	0.50	1.25	0.25	3.32	5
Ban Na San	PN285	5	1	5	5	1	1.15	0.17	0.50	1.25	0.25	3.32	5
Ban Na San	PN286	3	1	5	5	1	0.69	0.17	0.50	1.25	0.25	2.86	4
Ban Hua Ta Ken	PN287	5	1	5	2	1	1.15	0.17	0.50	0.50	0.25	2.57	3
Ban Hua Ta Ken	PN288	2	1	3	5	1	0.46	0.17	0.30	1.25	0.25	2.43	3
Ban Hua Ta Ken	PN289	2	1	3	5	1	0.46	0.17	0.30	1.25	0.25	2.43	3
Ban Hua Ta Ken	PN290	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Hua Ta Ken	PN291	2	1	3	5	1	0.46	0.17	0.30	1.25	0.25	2.43	3
Ban Hua Ta Ken	PN292	2	1	3	5	1	0.46	0.17	0.30	1.25	0.25	2.43	3
Ban Hua Ta Ken	PN293	2	1	3	5	1	0.46	0.17	0.30	1.25	0.25	2.43	3
Ban Hua Ta Ken	PN294	2	1	3	2	1	0.46	0.17	0.30	0.50	0.25	1.68	1
Ban Hua Ta Ken	PN295	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Hua Ta Ken	PN296	2	1	3	5	1	0.46	0.17	0.30	1.25	0.25	2.43	3
Ban Hua Ta Ken	PN297	2	2	1	2	1	0.46	0.34	0.10	0.50	0.25	1.65	1
Ban Hua Ta Ken	PN298	2	3	1	2	1	0.46	0.51	0.10	0.50	0.25	1.82	2
Ban Hua Ta Ken	PN299	2	2	1	2	1	0.46	0.34	0.10	0.50	0.25	1.65	1

Prioritized weight scores of 345 blocks study area

Ban Prak Meung	PN300	3	2	5	5	1	0.69	0.34	0.50	1.25	0.25	3.03	5
Ban Prak Meung	PN301	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Prak Meung	PN302	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Prak Meung	PN303	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Prak Meung	PN304	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Prak Meung	PN305	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Prak Meung	PN306	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Chim La	PN307	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Chim La	PN308	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Chim La	PN309	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Chim La	PN310	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Chim La	PN311	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Chim La	PN312	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN313	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN314	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN315	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN316	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN317	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN318	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN319	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2

<u>Prioritized weight scores of 345 blocks study area</u>

Ban Na Tod	PN320	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN321	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN322	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN323	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN324	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN325	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN326	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN327	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN328	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN329	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN330	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN331	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN332	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN333	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN334	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN335	2	1	5	2	1	0.46	0.17	0.50	0.50	0.25	1.88	2
Ban Na Tod	PN336	2	2	5	2	1	0.46	0.34	0.50	0.50	0.25	2.05	2
Ban Na Tod	PN337	2	2	5	2	1	0.46	0.34	0.50	0.50	0.25	2.05	2
Ban Na Tod	PN338	2	2	5	2	1	0.46	0.34	0.50	0.50	0.25	2.05	2
Ban Na Tod	PN339	2	2	5	2	1	0.46	0.34	0.50	0.50	0.25	2.05	2

Prioritized weight scores of 345 blocks study area

Ban Na Tod	PN340	2	2	5	2	1	0.46	0.34	0.50	0.50	0.25	2.05	2
Ban Na Tod	PN341	2	2	5	2	1	0.46	0.34	0.50	0.50	0.25	2.05	2
Ban Na Tod	PN342	2	2	5	2	1	0.46	0.34	0.50	0.50	0.25	2.05	2
Ban Na Tod	PN343	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Na Tod	PN344	2	1	5	5	1	0.46	0.17	0.50	1.25	0.25	2.63	4
Ban Na Tod	PN345	2	1	5	5	1	0.46	0.00	0.50	1.25	0.25	2.46	3

BIOGRAPHY

Mr. Apichart Suphawajruksakul was born on March 4, 1980 in Ratchburi. He completed high school at Ratchawinit Bang Keaw School and graduated with a Bachelor degree in Geology, Department of Geology, Faculty of Science, at Chulalongkorn University in 2002. Presently, he is completing a Master’s course in geology at the Department of geology, Faculty of science, Chulalongkorn University.