ธรณีวิทยาสภาวะแวดล้อมของจังหวัดนครพนม ภาคตะวันออกเฉียงเหนือ ประเทศไทย

นายจิรศักดิ์ เจริญมิตร

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ENVIRONMENTAL GEOLOGY OF CHANGWAT NAKHON PHANOM IN NORTHEASTHERN THAILAND

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for the Degree of Master of Science in Geology

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จังหวัดนครพนมเป็นจังหวัดที่ตั้งอยู่ในภาคตะวันออกเฉียงเหนือของประเทศไทย ซึ่งเป็นจังหวัดที่อยู่ภายใต้ โครงการพัฒนาความร่วมมือทางเศรษฐกิจในอนุภูมิภาคลุ่มแม่น้ำโขง 6 ประเทศ (GMS) อันได้แก่ กัมพูชา-พม่า-สาธารณรัฐประชาธิปไตยประชาชนลาว-เวียตนาม-ไทย-ยูนนาน (จีนตอนใต้) ซึ่งโครงการนี้ต้องการข้อมูลพื้นฐานในด้านธรณีวิทยาสภาวะแวดล้อมของพื้นที่ ด้วยเหตุนี้ การศึกษาด้านธรณีวิทยาสภาวะแวดล้อมของจังหวัดนครพนมจึงมีความสำคัญในการวางแผนการพัฒนาในเขตอนุภูมิภาคลุ่มแม่น้ำโขงนี้

จุดมุ่งหมายของการศึกษาในครั้งนี้คือรวบรวมและวิเคราะห์ข้อมูลด้านต่างๆ ที่เกี่ยวข้องกับธรณีวิทยาสภาวะแวดล้อมภายในจังหวัดนครพนมภายใต้การจำแนกและวิเคราะห์ เพื่อการวางแผนการพัฒนาในอนาคต โดยไม่ส่งผลกระทบต่อสภาวะแวดล้อมโดยรวมของพื้นที่ จากผลการวิเคราะห์ได้เสนอไว้ว่าแผนการพัฒนาทางด้านการเกษตรควรจะเป็นแผนการพัฒนาหลัก โดยประเมินจากสภาวะแวดล้อมทางกายภาพ ลักษณะทางเศรษฐกิจ-สังคม รวมทั้งแผนพัฒนาต่างๆ ระบบ Weight-rating ได้ถูกนำมาใช้ในการวิเคราะห์เพื่อหาพื้นที่เหมาะสมในการเกษตรกรรมในรูปแบบต่างๆ ได้แก่ ข้าว พืชไร่ ไม้ผล ยางพารา มะพร้าว และการปศุสัตว์ โดยแบ่งระดับความเหมาะสมของพื้นที่เป็น 5 ระดับ คือ เหมาะสมสูงมาก เหมาะสมสูง เหมาะสมปานกลาง เหมาะสมต่ำ และเหมาะสมต่ำมาก

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

สาขาวิชา.....ธรณีวิทยา..... ลายมือชื่ออาจารย์ที่ปรึกษา.....

ปีการศึกษา.....2544..... ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....

4172253523 : MAJOR GEOLOGY
KEY WORD: CHANGWAT NAKHON PHANOM / ENVIRONMENTAL GEOLOGY
JIRASAK CHAROENMIT: ENVIRONMENTAL GEOLOGY OF CHANGWAT NAKHON PHANOM IN NORTHEASTHERN THAILAND, (ธรณีวิทยาสภาวะแวดล้อมของจังหวัดนครพนม ภาคตะวันออกเฉียงเหนือ ประเทศไทย) THESIS ADVISOR: ASSOC. PROF.CHAIYUDH KHANTAPRAB, Ph.D., 127 pp. ISBN 974-17-0625-1.

Changwat Nakhon Phanom is a province located in the northeastern part of Thailand and is currently identified under the economic cooperation development project of the Greater Mekong Subregion (GMS) of Burma, Cambodia, Lao PDR, Thailand, Vietnam, and Yunnan. This project needs the background information on environmental geology of the areas concerned. Thus, the study on environmental geology of Changwat Nakhon Phanom is the important fraction for Subregional development planning of the so-called “Greater Mekong Subregional, GMS”.

This study aims to acquire and analyse the data and information concerning the environmental geology of Changwat Nakhon Phanom in order to identify and evaluate the future development planning. As a result, agricultural development plan was presented as a major plan. The resolution was processed from considering the physical environment, socio-economic condition and existing plans. Finally, the weight-rating system was used to analyse the suitability of area for paddy field, non-flooded annual crops, fruit trees, para-rubber, coconut and permanent pasture or rangeland livestock farming. There are five suitability, namely, very high, high, moderate, low and very low suitability.

Department……..Geology……. Student’s signature……..
Field of study……Geology……. Advisor’s signature……...
Academic year……...2001……. Co-advisor’s signature…….

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CHAPTER I

INTRODUCTION

Nakhon Phanom is among one of the ancient human settlements in northeastern Thailand. Historically, the town was known as *Muang Srikhotraboon* of *Khotraboon* province in the *Suvannapum Empire* during the pre-Ayutthaya period (Nakhon Phanom office, 2529, in Thai). Otherwise, Nakhon Phanom is pointed as the high potential area for supporting the economic growth of the Greater Mekong Subregion, GMS (Japan International Cooperation Agency, 2001).

Originally, the former location of *Muang Srikhotraboon* was on the eastern bank of the Mekong river south of present Thakeak town of the Lao PDR. Later on in B.E. 2286 or 285 years ago, *Mung Srikhotraboon* was renamed as *Marukhanakorn* during the Ayutthaya period. During the Ruttanakosin period, *Marukhanakorn* was renamed as Nakhon Phanom in B.E. 2338 or 206 years ago, it had moved to the western bank of the Mekong river in lately period of King Rama I. The name Nakhon Phanom comes from two words “Nakhon” means city, and “Phanom” means mountain. It is all so important to note that there is the old and famous Chedi in this town so-called “Phrathat Phanom” with is among one of the most significant Buddhist Temples of Thailand and Lao PDR (Nakhon Phanom office, 2529, in Thai).

Nakhon Phanom has many important roles in the northeastern economic development such as agriculture, border area and transportation gateway between east and west in the Greater Mekong Subregional (GMS) project. From international trade value with Lao PDR, Changwat Nakhon Phanom is the third rank from nine Changwats, which is along the Mekong river and presented in Table 1.1.

Due to the strategic and important geographic location of Changwat Nakhon Phanom, it is therefore considered to be the gateway for Thailand to Lao PDR and Vietnam. Accordingly, the subregional development covering northeastern Thailand, Lao PDR,

Cambodia, Vietnam, northern Myanmar, and Yunnan province of PRC has been jointly proposed, under the name “Greater Mekong Subregional Development Project”.

The economic growth in this area is related to problem on the use of limited natural resources. Therefore, the area development plan is urgently necessary, which make a high profit and sustainability from using natural resources.

For Changwat Nakhon Phanom itself, the population increase coupled with the originally large area have brought the attention of the Royal Thai government to split the administration of the former Changwat Nakhon Phanom into present Changwat Nakhon Phanom and Changwat Mukdahan in B.E. 2525.

Table 1.1 Border trade of Changwat Nakhon Phanom-Lao PDR

(Million Baht)

Year	Export	Import	Total of border trade of Nakhon Phanom-Lao	Total of border trade of Thailand-Lao
1998	665.61	551.72	1,217.33	16,483.48
1999	813.49	927.15	1,740.64	18,750.65
2000	1,226.93	974.59	2,201.52	21,042.21
2001	1,215.52	1,069.97	2,285.49	22,076.17

(Source: Department of Foreign Trade, Ministry of Commerce, 2002, in Thai)

1.1 The study area

Changwat Nakhon Phanom is a province located in the northeastern part of Thailand on the northeastern border of the Khorat plateau. The city lies between the latitude 16° 41′ 54′ N to 18° 1′ 23′ N and the longitude 103° 59′ 10′ E to 104° 48′ 38′ E, covering an area of approximately 5,512 square kilometres. It extends approximately 135 kilometres in the north-south direction and up to 75 kilometres in width. It is borded on the north by Amphoe Seka and Amphoe Bung Khong Long of Changwat Nong Khai; on the south by

Amphoe Dong Luang, Amphoe Muang Mukdahan, and Amphoe Wan Yai of Changwat Mukdahan; on the west by Amphoe Kusuman, and Amphoe Akat Amnuai of Changwat Sakon Nakhon and face eastward the Mekong river. Physiographically, Changwat Nakhon Phanom is covered by mountainous area of approximately 10 percent whereas the rest is covered by flat and undulatory plain. The highest mountain is Phu Sua with maximum elevation of 641 metres MSL in the south of Changwat Nakhon Phanom. The average elevation of flat and undulatory plain is approximate 140 metres MSL. The shape of the city is elongated along the western bank of the Mekong river for approximately 153 kilometres long (Figures 1.1 and 1.2).

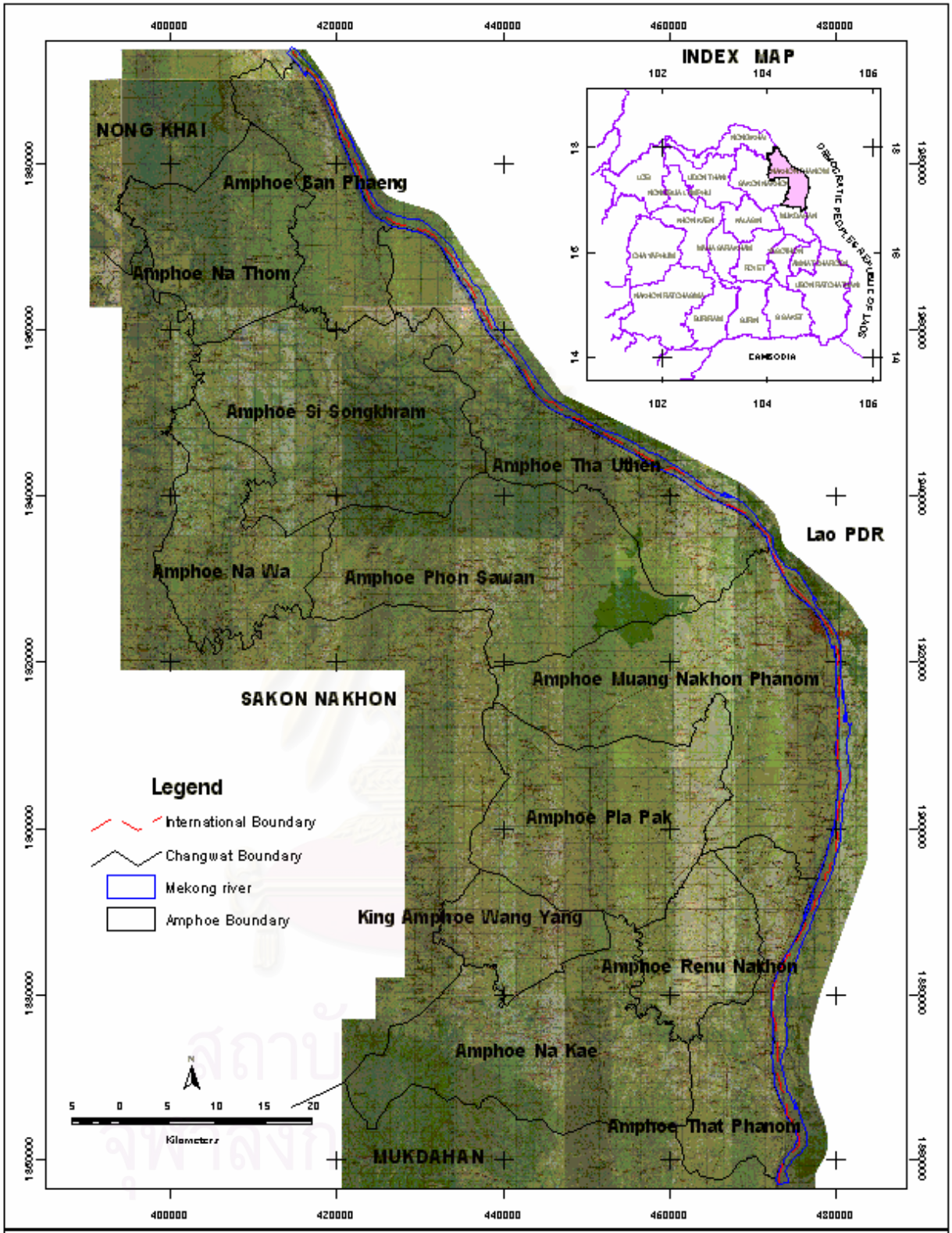
1.2 Objective

The objective of the present study is to acquire and analyse the data and information regarding the environmental geology of Changwat Nakhon Phanom in order to identify the potentials and limitations for the future development planning. It is anticipated that the future role of Changwat Nakhon Phanom is not only important for Thailand as a whole, but also for the Greater Mekong Subregion, GMS. Therefore, the environmental geology of the area will be served as an important foundation for the area development planning.

1.3 Scope of works and methodology

Under the present investigation, the first attempt has been made to review the existing and proposed development plans of Changwat Nakhon Phanom and nearby areas. Besides, the subregional development plans have also taken into consideration, particularly the Greater Mekong Subregional (GMS) Plan.

It is essentially important to acquire the most-updated background information regarding the physical environment of Changwat Nakhon Phanom for future planning purposes. This includes climate, topography and landform, land use and land cover, surface drainage system, soils, geology, groundwater, and geological hazards. These



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 1.1 Study area

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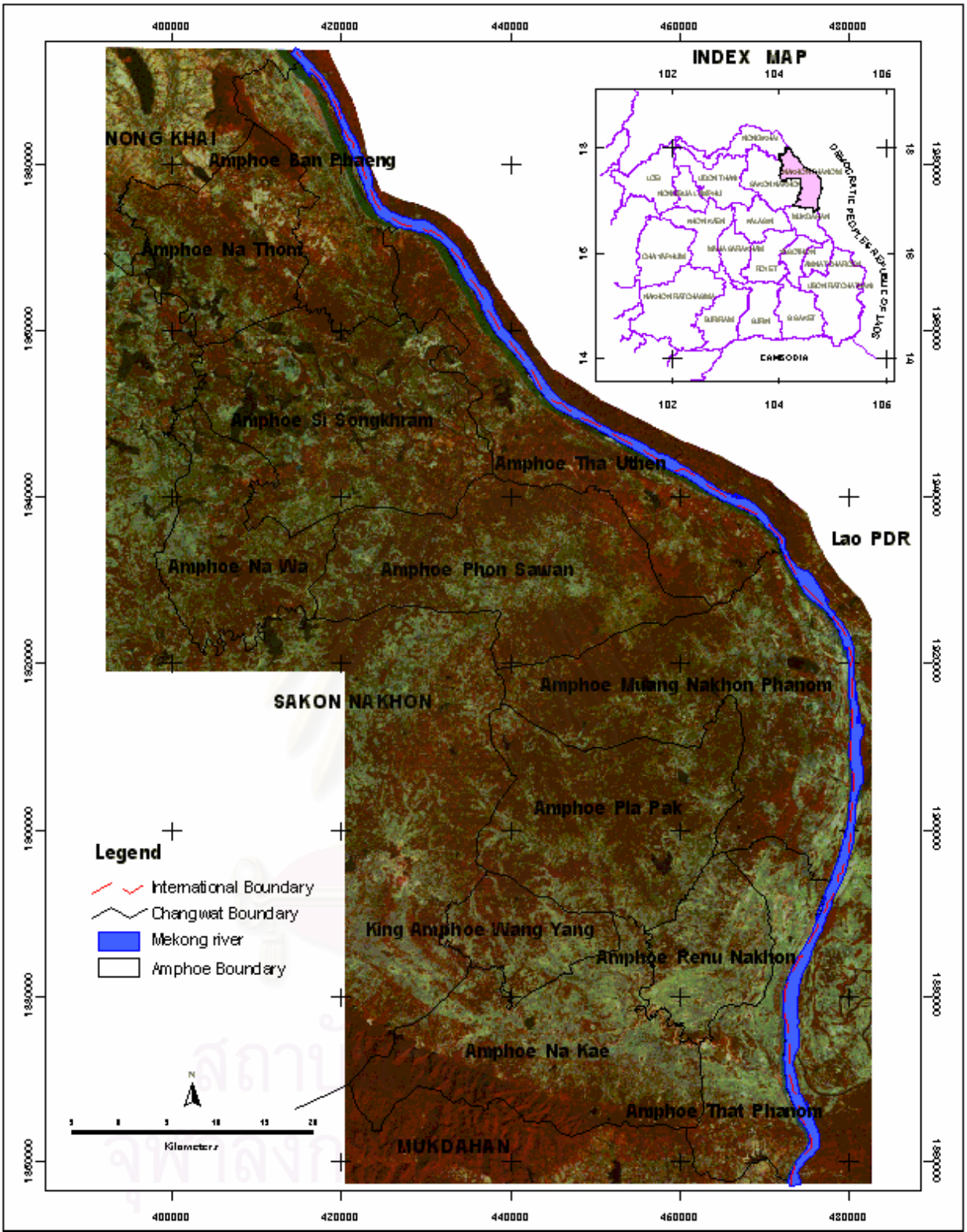

ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 1.2 Landsat TM5 image path/row 127/048, False color composite 2/B, 3/G, 4/R (1993)

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data and information are transferred into digital data, preferably in the form of a series of derivative or thematic maps.

In order to fulfill the purpose of complete understanding of Changwat Nakhon Phanom, additional attempt has been made to acquire the socio-economic conditions of the area. This includes administration, population and work force, education, economy and trades, occupation, communication and transportation, utility, health and medical services, tradition, culture and religion, and lifestyle. For more understanding, some data, namely, administration, population, transportation are transferred into the spatial form of a series of derivative maps.

The acquisition and evaluation of data and information including existing development plans will be carried out and presented using the methodology of geographic information system (GIS) on the personal computer (PC) and the software of Arc/View and Arc/Info.

Finally, the evaluation of the environmental potentials as well as limitations of the study area will be conducted on the basis of the environmental geology coupled with existing and proposed development plans using the GIS method. Consequently, appropriate recommendations and criteria will be made for sustainable development planning.

The scope of work and methodology of the present investigation is summarised and presented in Figure 1.3.

1.4 Previous works in Changwat Nakhon Phanom

In 1969, the Resources Atlas Project of Thailand., Atlas No. 1 Changwat Nakhon Phanom was undertaken by the Department of Army Engineer Agency for Resource Inventories (EARI), Washington, D.C. 20315 and Applied Scientific Research Corporation of Thailand (ASRCT), Bangkok, Thailand under the sponsor of Advanced

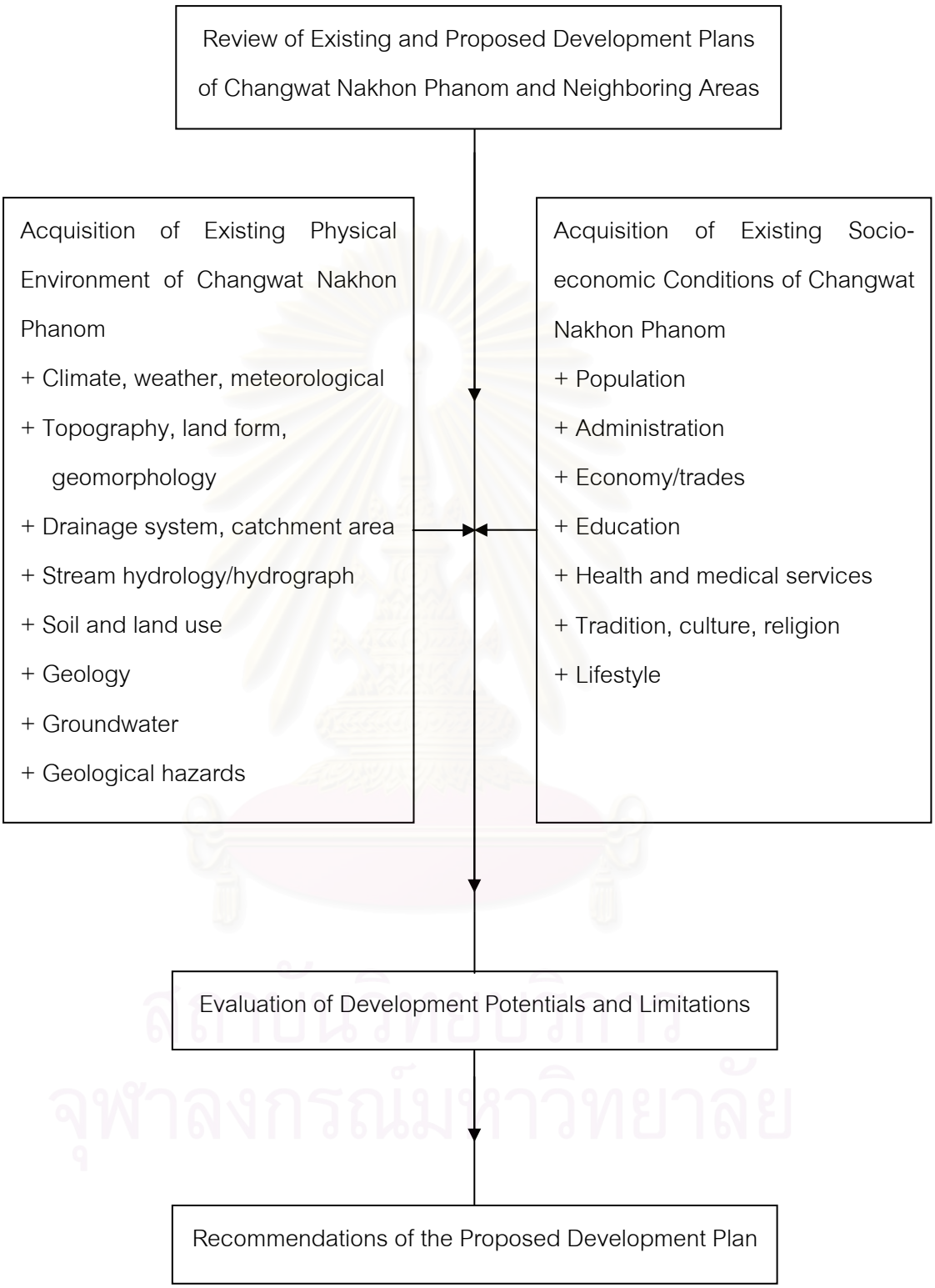


Figure 1.3 Diagram showing the scope of work and methodology of the present investigation.

Research Projects Agency Army Order No. 1035. The EARI and ASRCT have used the result of years of cumulative effort by many agencies in mapping, aerial photographic interpretation, research and other studies. They have analyzed and compiled the data, supplementing and up-dating them as necessary. Field checks of several topics have also been made. The contents of the Atlas cover physical resources, human resources, social and economic infrastructure for planning purposes.

Asian Institute of Technology (1994) proposed the study of potential development of water resources in the Mekong river basin, which is a broad scope covering four characteristics of the Mekong river basin, namely, climate, rainfall, streamflow, and hydrogeolgy. This study emphasizes on hydrology, water resources, and water use schemes. The result describes about the river basin development plan, including the short term and long term developments and the full potential development.

Phiromlert (in Thai, 2539) prepared the groundwater maps of Changwat Nakhon Phanom, showing the relation of expected well yield and groundwater quality, depth to water level of consolidated aquifer, isohyetal, chloride content, and hardness content.

Scientific Environmental Group Co., LTD., and Universal Engineering Consultants Co., LTD. (in Thai, 2541) determined the management and redesigned the existing waste disposal site of municipal area in Muang Nakhon Phanom. The study includes the data as follows: physical environment, natural resources, socio-economic and finances, population, land use, waste management, income and expenditure, waste quantity and waste quality.

Department of Mineral Resources (in Thai, 2541) studied the effect of rock salt strata in the reservoir of Kam river basin irrigation project, Changwat Nakhon Phanom. His Majesty the King initiated this project, which is for the folk's agriculture and consumption in Amphoe Renu Nakhon and That Phanom. The results indicate that there are no any effects to the reservoir and water resource quality in irrigation project.

National Economic and Social Development Board (in Thai, 2544) reported that the "Greater Mekong Subregional (GMS)" is six countries namely in the economic cooperation development project of Burma, Cambodia, Lao PDR, Thailand, Vietnam, and Yunnan. Changwat Nakhon Phanom is a province, which located in the northeastern part of Thailand and is currently under the economic cooperation development project. This project has identified and prioritised development plan into seven sectors, notably, transportation, energy, telecommunication, human resource development, tourism, environment and natural resource management, and trade and investment.

Japan International Cooperation Agency, JICA (2001) proposed the development vision and cooperation programs for the Cross Border Region (CBR), which is prepared to complement the Master Plans for Suvannakhet and Khammouan Region (SKR) in Lao PDR and for the Northeastern Border Region (NBR) in Thailand. This study is to facilitate region-to-region cooperation between SKR and NBR. Therefore, the basic requirements necessary to facilitate this cross-border cooperation are to know each other before starting to work together, to know surrounding conditions of SKR and NBR, and to have common baseline development visions for SKR and NBR.

JICA (2001) had also undertaken the study on the integrated regional development plan for the Northeastern Border Region in the Kingdom of Thailand. There are five development strategies, including 1) natural resource and land use management, 2) diversification of local economy, 3) promotion of new leading industries, 4) increase of technical and managerial workers in middle-class, and 5) urban centers and infrastructure development.

The Engineer Agency for Resources Inventories, Department of the Army, Washington, D. C., and the Applied Scientific Research Corporation of Thailand (1969) did research cover the topic physical resources, human resources, social and economic infrastructure for planning purposes in this area. However, Changwat Mukdahan was not separated yet from Changwat Nakhon Phanom at that time. Thus, Changwat Nakhon Phanom is the interesting province for the author to study more. This area used to be

studied by JICA to support the GMS project in providing the basic information for many other interesting plans. Land use management idea in development strategy of JICA 2001, which is the national level plan, was taken into this study and it was prepared to the regional level.

1.5 Previous works on Environmental Geology in Thailand

Sarapirome (1982) conducted “the environmental geology of an area along the eastern coast, upper gulf of Thailand”. The relevant parameters on environmental geological conditions include physiographical and geological setting, mineral resources, surficial deposits, water resources, marine geological conditions, tourist and recreational resources. In addition, the socio-economic background of Chon Buri and Rayong provinces are reviewed for understanding the basic social environment of the area. This study has integrated and synthesized data and information in terms of development potential for residential, heavy industrial and agricultural purposes by using weight-rating system.

Khantaprab, Pongsapich, and Phongprayoon (1985) had undertaken a “reconnaissance environmental geology of Thung Kula Ronghai”. This area has been identified as a relatively less developed and most depressed areas. The study contains data inventory of parameters on environmental geology that include six major factors, namely, climate, topography, hydrography, geology, mineral, and groundwater. In addition, sedimentary rocks of Mahasarakham Formation of the Khorat Group generally underlie this area. In the climatic condition, the potential for any agricultural development is marginal. With regards to the mineral potential, namely, petroleum, rock salt and potash, and phosphate deposits. The potential of groundwater for agriculture is in the vicinity of Amphoe Muang Yasothon, Amphoe At Samat, Amphoe Suwannaphum and Amphoe Phanom Phrai.

Khantaprab and Boonnop (1988) proposed a preliminary assessment of urban geology of Bangkok Metropolis using the relevant and existing geological data in forward planning and decision-making processes.

Sarapirome (1992) developed a useful terrain evaluation system for road corridor selection applicable to intermontane basin in northern Thailand. The study concerns with direct effects on construction costs from the terrain factors, namely, land cover, topography and landforms, surficial geology, soil strength, topsoil removal, difficulty of excavation, embankment height, construction material, and drainage characteristics. The findings are presented as map in digital form using the Geographic Resources Analysis Support System (GRASS).

Sompadung (1993) studied “environmental geology of Changwat Saraburi”. The parameters on environmental geological conditions include the physiographic setting, geological conditions, mineral and water resources, hazards, and recreation. Two land capabilities were presented in his thesis. There are land capabilities for industrial and sanitary landfill waste disposal site.

Chalermlap (1996) studied “systemization of geological information (GILM) for land management: a case study of Changwat Prachuap Khiri Khan”. They are demonstrated on 26 thematic maps, which are developed through the stages of Primary Geological Information (PGI), Intermediate Geological Information (IGI), and Ultimate Geological Information (UGI) based on TM images interpretation integrated with existing information.

Jearpattaranon (in Thai, 1996) had undertaken an “environmentally geological appraisal using GIS for land use planning in Changwat Saraburi, Thailand”. There are three main categories of land informations such as geography, natural resources, and geological hazards. This study has been used land information database for strategic planning in Changwat Saraburi and recommends 4 plans, including conservation plan, industrial plan based on the geological resource, urban plan concerned on the waste disposal

sites, and agricultural plan. This study brought environmental Acts and regulations to involve in land use planning.

Tantiwanit and Lietz (1998) proposed environmental geology for regional planning, which is to integrate environmental geological information and recommendations into land use planning and land development of fast growing areas in Thailand. The Chiang Mai-Lamphun Basin has been selected as a pilot area for the first project phase. Set of basic thematic data and derivative maps such as groundwater map, waste disposal map, soil map, economic geology map, and land use recommendation map.

Pokaew (1999) studied the environmental geology of Changwat Krabi for land use planning by use of GIS as a tool. The study covers topographic limitations, geological setting and geomorphological, geological resources, marine geological conditions, coastal erosion, including tourist and recreation resources. In addition, the social-economic background of Krabi is reviewed for understanding the basic social environment of the area. This study has described and presented in a series of GIS map layers. There are five main categories of preliminary planning, including conservation, carbonate rock for construction purposes, residential, agricultural and industrial development proposes.

All the previous researches in the study area were emphasised on the environmental geology that is very important for the land use planning. In this study, the author takes the weight-rating system to apply to the agricultural land use planning of the area. Because the method provides more elaborate results. This system brings 2 development plans to Nakhon Phanom province. One is for the conservation potential area and another is for the agricultural potential area.

1.6 Concepts of geographic information systems

Geographic Information Systems (GIS) is a computer-base tool to capture, manipulate, process, and display spatial or geo-referenced data (Environmental System Research

Institute, 1990). They contain both geometry data (coordinates and topographical information) and attribute data, which describe the properties of geographic elements such as points, lines, and polygons.

Burrough (1986) defined GIS as “A powerful set of tools for collection, storing, retrieving, transforming and displaying spatial data from the real world”.

Arnoff (1989) defined GIS as “Any manual or computer based set of procedure used to store and manipulate geographically referenced data”.

Not only does a GIS store amounts of data distributed over a geographic area, but it also has the ability to perform spatial operations on the data and link related data sets together. Both of these extra features are what distinguish as GIS form a simple Data Base Management System (DBMS). A GIS can display location using its digital mapping capabilities while its analytical functions can determine present conditions and general trends and pattern for a given area. Another important capability is the use of analytical programming to model future conditions given various input parameters.

A GIS consists of 2 types of data as “spatial data” describing location and shape and “descriptive data” (non-spatial data) relating features. There are some basic definitions associated with this system that will be used throughout this report. Spatial and descriptive data are combined in coverage. The spatial data display picture or coordinate of point, line or area that are components of map whereas the description data will show details related to that point, line, or area features (Antenucci, 1991). The GIS utilized in this project is the Arc/View and MapInfo programs. Specifically, a geographic feature in a map can be described as a point, line or polygon, as follows:

Point: A single x, y coordinate pair that defines the location of a map feature whose boundary of shape is too small to be displayed as an area or line, such as locations of cities on a small scale map, wells, meteorological stations, schools and mountain peaks.

Line: A set of ordered points which are connected and represent a map feature that is too narrow to be displayed as an area, or a map feature that has no width. Examples of line feature are roads, streams, contour lines and faults.

Polygon: An area feature, a closed figure bounded by line features that enclose a homogeneous area, defined by the set of arcs which comprise its border, and a label point within the polygon which is used to assign a User-ID (Figure 1.4).

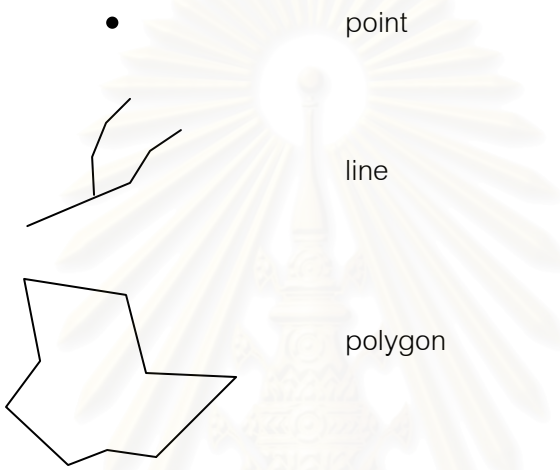


Figure 1.4 Graphic depiction of spatial data constructs (ESRI, 1992).

1.7 Basic concepts of environmental geology

In the 1970s and 1980s, the use of term “environmental geology” is widespread among geologists today that it seems hardly believable that the term is less than ten years old.

The first use is credited to Hackett, which he states: “The term environmental geology was initialed by me to identify a new orientation for the study and use of geology in a coordinated and integrated manner”. As a documented term, Hackett introduced it in a paper presented to a conference on “Water, Geology and the Future”, held at Indiana University in April 1964; the published proceedings appeared in 1967.

In1971, Fairbridge remarked “The concept of environment as commonly employed today is essential on aspect of the integrated biologic/geologic global system, the

physical ecologic habitat of *Man*. In this sense we exclude the social and cultural environment".

Looking somewhat further into concepts of "environment", Bates and Jackson (1980) observes that "Environmental geology is an application of geologic principles and knowledge to problems created by man's occupancy and exploitation of the physical environment. It involves study of hydrology, topography, engineering geology, geology and economic geology and concerned with Earth processes, Earth resources and engineering property of Earth materials. It involves problems concerned with construction of buildings and transportation facilities, safe disposal of solid and liquid wastes, management of water resources, evaluation and mapping of rock and mineral resources, and long-range physical planning and development of the most efficient and beneficial of the land".

i) Natural resource

There are many direction in the present development. Each direction use different type and size of the natural resources. There are two types of natural resources, which are renewable such as water resources, soil resources, and non-renewable for example, mineral resources, fuel resources. No matter what type of natural resource needed for the development, the benefit and the effect should be carefully concerned. One important way is using the knowledge of environmental geology to help creating the effective development plan. Environmental geology is the application of knowledge in geology to take a very good care of the environment. It is very useful for the natural management plan. The main objective of environmental geology is the long-range physical development planning of the most efficient and beneficial use of the natural resources.

ii) Environmental contamination

Most of the contaminations in the environment are caused by all kinds of developments, industrial, agricultural, and others. A contaminant may enter the natural environment from any of a vast number of sources. Once released, it will be influenced by a variety of factors, including its rate of decay or decomposition; the length of time it remains in a given reservoir; the mechanisms by which it is transported; and the way it interact with other contaminants. These contaminations lead to many types of damages in environment including water resources, soil resources, etc. Therefore, it is recommended that roles be set up to reduce and prevent the damages that might happen in the future.

iii) Geohazards

Many kinds of hazards are often come along with the development. The amount of these hazards is depend on the development or management plan. In present, a lot of damages happening from the unsuitable plans, for example the management and development plan for Bangkok area, to be the center of economics. This unsuitable plan bring about the big lost in managing with the flooding in ever year. The terms of natural hazard and geologic hazard denote a wide range of geologic circumstances, processes, and event. Geologic hazards include earthquakes, volcanic eruptions, floods, landslides, etc. Knowing ahead about the hazard the might occur is very important for the development plan. All these natural and geologic hazards should be considered in the future development planning to prevent and reduce the lost that might happen.

Planning objectives will vary, but in general will aimed at ensuring adequate supplies of materials and development to meet the needs of society at the best possible balance of social, economic and environmental costs. The nature of the balance will vary from country to country and is largely a matter for political decision. Planning strategies and policies will normally be stated in terms of factors such as those listed in Table 1.2.

In conclusion, an attempt to formulate a recommendation out of the existing knowledge to give our society the benefit of natural environmental utilization, experience and intellect have to be applied if mankind is to be capable of mastering the problems of the future.

Table 1.2 Illustrative list of some relationships between planning topics and earth science information (McCall and Marker, 1989)

Planning interests	*Earth science information*
Water supply and protection of water resources from derogation	Nature and extent of groundwater and surface water resources; quantities and flow patterns; vulnerability to pollution
Minerals supply and protection of mineral resources from sterilization by virtue of other forms of development	Types, extent, quality & uses of mineral resources; ease of extraction (e.g., depth, groundwater, excavation, problems)
Agriculture and forestry	Physical and chemical properties of soils; availability of water; soil erosion potential; chemical contamination
Fisheries	Surface water characteristics, composition and susceptibility to pollution
Housing, industry and infrastructure	Ground conditions including problems due to land instability and chemical reactivity with construction materials; rising or falling groundwater; chemical contamination; ease of excavation
Waste disposal	Suitability of ground for landfill and risks to ground and surface water
Reclamation, restoration and urban renewal	Ground conditions (physical and chemical); availability of materials suitable for infilling and landscaping; groundwater behavior
Conservation	Potential for ground and water pollution; potential effects of new development; land instability (e.g., damage to historic buildings; rising or falling groundwater)
Recreation and tourism	Potential effects of activities (e.g., erosion to footpaths); ground stability (e.g., open mine shafts, avalanches near ski resorts); coastal erosion and beach accretion

CHAPTER II

ENVIRONMENTAL SETTING OF CHANGWAT NAKHON PHANOM

Changwat Nakhon Phanom was originally a part of the landmass of the Khorat plateau. The area has been long known as one of the old human settlements for many hundred years. Changwat Nakhon Phanom is located on the western bank of the Mekong river and is connected with the Lao PDR. by ferry. Cottage industries are basically handicrafts carried on by family units specialising in one product. Some of these Amphoes are well-known for the quality of their products. For example, Amphoe Renu Nakhon is famous for cotton-wears. It is processing and manufacturing of commodities for domestic consumption. Cottage industries account for most of the employment and value of industrial processing.

2.1 Socio-economic conditions

2.1.1 Administration

The administration of Changwat Nakhon Phanom is subdivided into 11 Amphoes (district), 1 King Amphoe (an administrative office similar to an Amphoe), 99 Tambons (district), and 1,058 Mubans (village). For Amphoe Muang Nakhon Phanom, there are 15 Tambons and 155 Mubans; for Amphoe Tha Uthen, there are 9 Tambons and 107 Mubans; for Amphoe That Phanom, there are 12 Tambons and 133 Mubans; for Amphoe Na Kae, there are 12 Tambons and 132 Mubans; for Amphoe Na Wa, there are 6 Tambons and 57 Mubans; for Amphoe Ban Phaeng, there are 6 Tambons and 62 Mubans; for Amphoe Pla Pak, there are 8 Tambons and 85 Mubans; for Amphoe Phon Sawan, there are 7 Tambons and 77 Mubans; for Amphoe Renu Nakhon, there are 8 Tambons and 91 Mubans; for Amphoe Si Songkhram, there are 9 Tambons and 97 Mubans; for Amphoe Na Thom, there are 3 Tambons and 35 Mubans; and for King Amphoe Wang Yang, there are 4 Tambons and 27 Mubans (Nakhon Phanom Provincial Statistical Office [NPPSO], 2544, in Thai).

The areas under Amphoe-, King Amphoe- and Tambon- administration are shown in Figure 2.1 and are summarised in Table 2.1.

2.1.2 Population

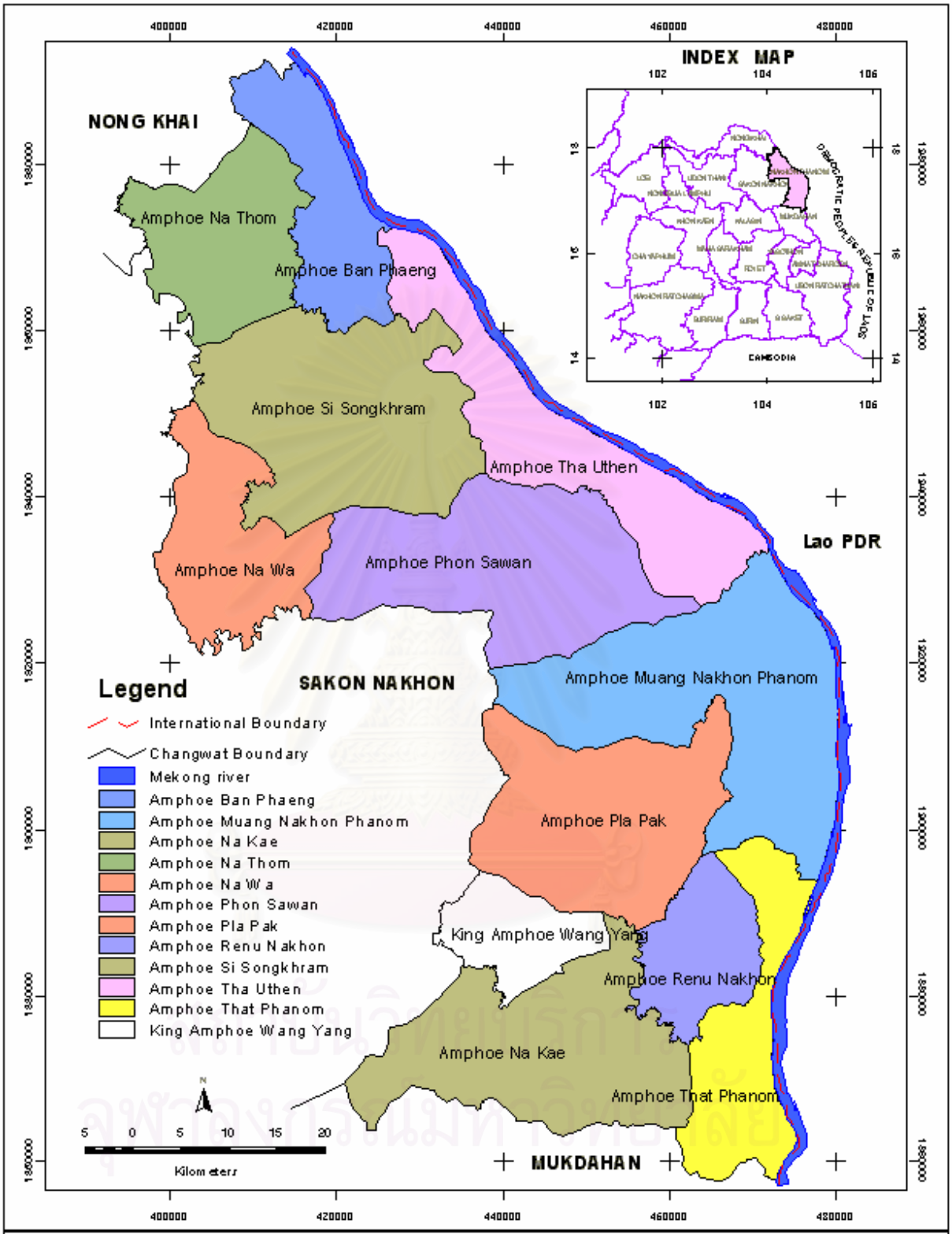
The total population of Changwat Nakhon Phanom was reported to be 716,914 persons in December 31, 2000 (NPPSO, 2544, in Thai). Among these, 358,211 persons were male (49.97 percent), 358,703 persons were female (50.03 percent). The average population density of Changwat Nakhon Phanom was approximately 130.1 persons per square kilometre in 2000. The highest population density was in Amphoe That Phanom, the second one was Amphoe Muang Nakhon Phanom, and Amphoe Na Thom was the least in 2000 with values of 230.3, 192.2, and 56.5 persons per square kilometre, respectively (Figure 2.2).

The population age structure of Changwat Nakhon Phanom in 2000 is summarised and presented in Figure 2.3.

2.1.3 Education, religion, and health services

The education services of Changwat Nakhon Phanom cover from kindergarten level to tertiary education with totally 532 schools and institutions in 2000. The total number of teacher is 6,761 persons. Among these, 3,232 persons were male (47.80 percent), 3,529 persons were female (52.20 percent), whereas the total number of student is 132,165 persons (NPPSO, 2543, in Thai).

In 1998, Buddhism is the prevailing religion in Changwat Nakhon Phanom and approximately 95.97 percent of the population 706,486 persons are Buddhists. There are also Christian and others of 4.02, and 0.01 percent, respectively. In 2000, there are altogether 664 Buddhist monasteries, 184 Buddhist sanka abodes, and 17 Christian churches in Changwat Nakhon Phanom (NPPSO, 2541, in Thai).



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 2.1 Amphoe and King Amphoe administration areas of Changwat Nakhon Phanom

(Source: 1.Nakhon Phanom Provincial Statistical Office, 2001, in Thai)
2. Royal Thai Survey Division, no date, in Thai

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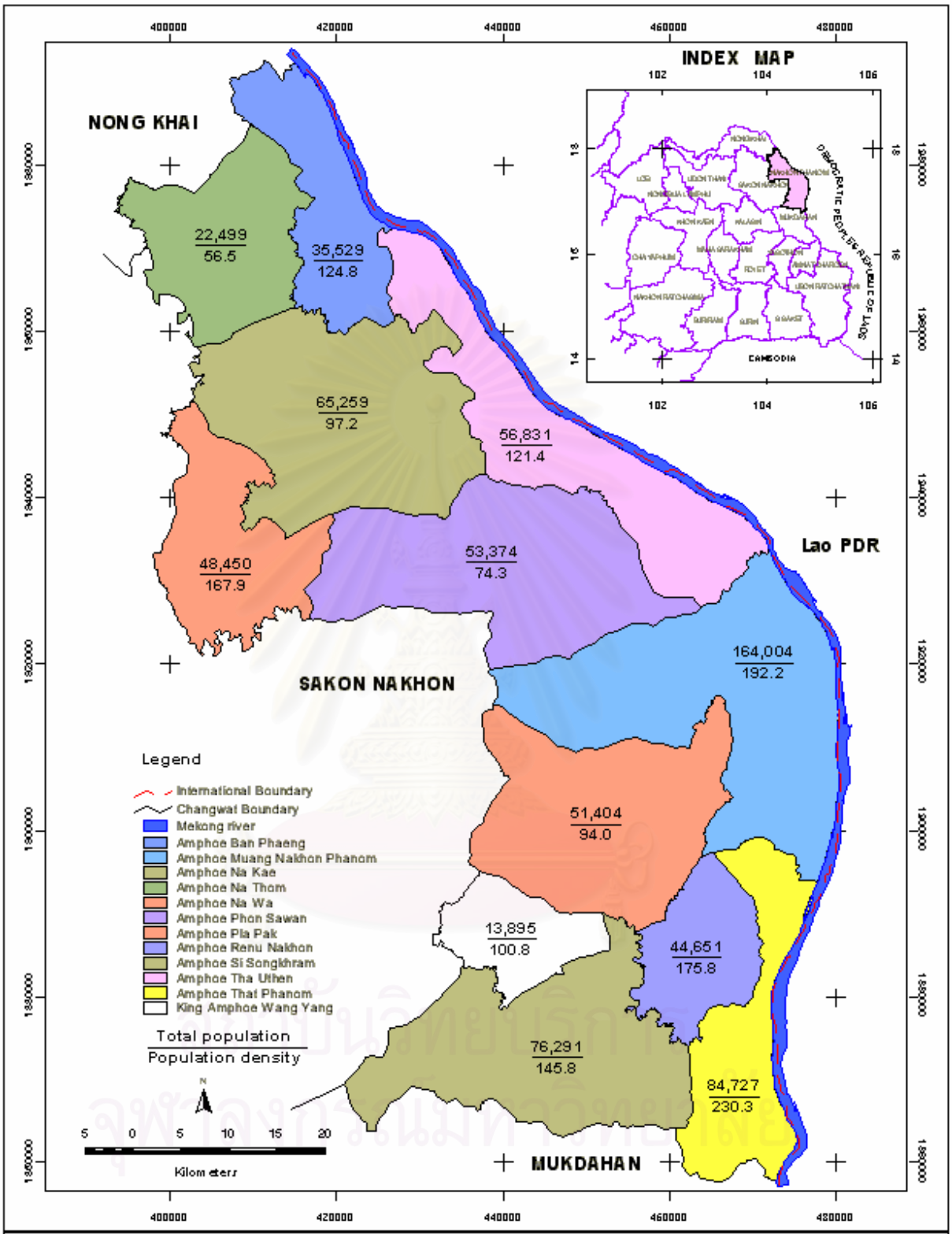
Table 2.1 The areas under Amphoe, King Amphoe and Tambon administration of Changwat Nakhon Phanom.

(Source: Nakhon Phanom Provincial Statistical Office, 2544, in Thai)

Amphoe/King Amphoe	Tambon	Area (Sq.km)	Distance from Amphoe to Changwat (km.)	Remarks
Muang Nakhon Phanom	15	853.2	-	Municipal Area
Tha Uthen	9	468.0	26	Municipal Area
That Phanom	12	367.9	52	Municipal Area
Na Kae	12	523.2	78	Municipal Area
Na Wa	6	288.5	95	Municipal Area
Ban Phaeng	6	284.7	93	Municipal Area
Pla Pak	8	547.1	44	Municipal Area
Phon Sawan	7	718.8	45	Municipal Area
Renu Nakhon	8	254.0	51	Municipal Area
Si SongKhram	9	671.3	67	Municipal Area
Na Thom	3	398.1	86	Non-municipal Area
King Amphoe Wang Yang	4	137.9	71	Non-municipal Area
Total	99	5,512.7	10 Municipal Areas and 2 Non-municipal Area	



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 2.2 Population Density of Changwat Nakhon Phanom

(Source: 1. Nakhon Phanom Provincial Statistical Office, 2001, in Thai)
2. Royal Thai Survey Division, no date, in Thai

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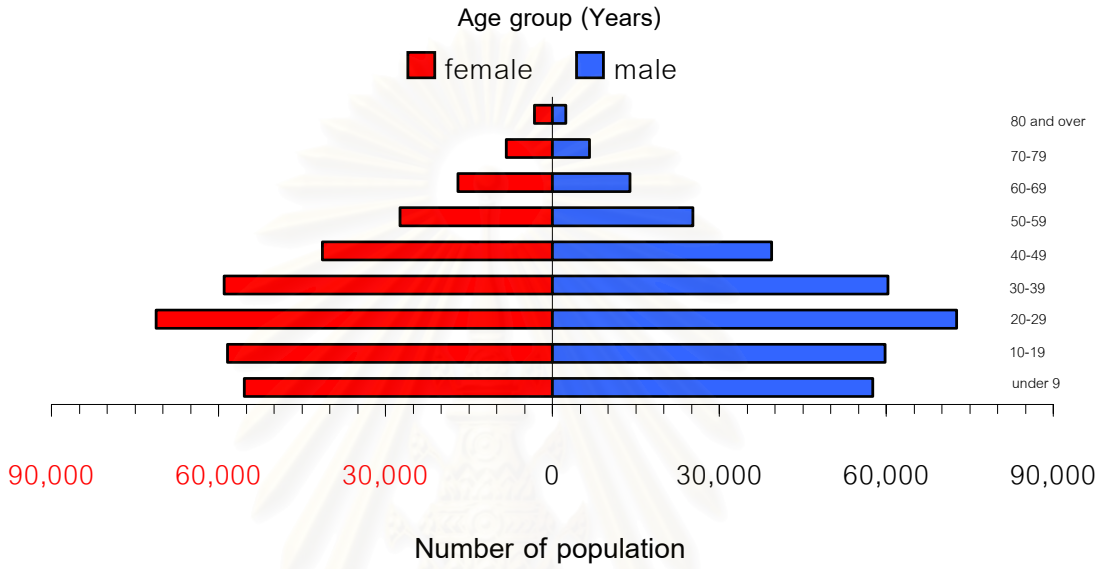


Figure 2.3 Population age structure of Changwat Nakhon Phanom (2001)

(Source: Nakhon Phanom Provincial Statistical Office, 2544, in Thai)

In 1998, Buddhism is the prevailing religion in Changwat Nakhon Phanom and approximately 95.97 percent of the population 706,486 persons are Buddhists (NPPSO, 2541, in Thai).

Concerning the medical services in Changwat Nakhon Phanom, there are 12 government hospitals, 149 health centers, and 96 medical clinics. In 2000, there are totally 53 physicians, 20 dentists, 689 nurses, and 5 practical nurses (NPPSO, 2543, in Thai).

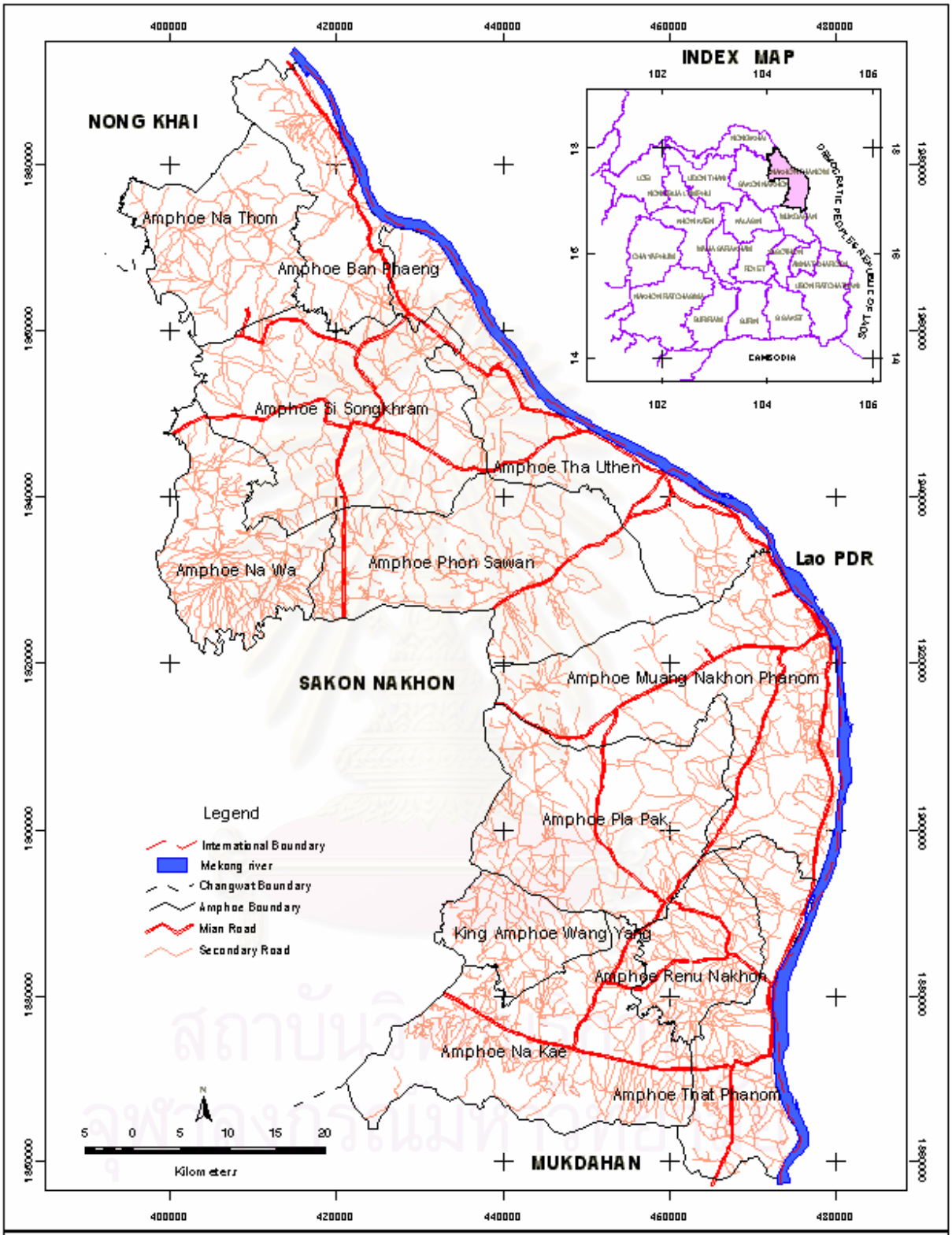
2.1.4 Transportation, electricity, and water supply

The road distance from Bangkok to Nakhon Phanom is 735 kilometres along Highway No. I, Pahonyothin Road, to Saraburi and Highway No. II to Ban Phai of Khon Kaen and Highway 23. via Mahasarakham, Karasin to Sakon Nakhon and then to Nakhon Phanom.

The transportation system of Changwat Nakhon Phanom can be categorised into three groups, namely, on-land road network, domestic commercial airport, and international riverport. The airport is located 15 kilometres west of the city centre, there is one direct flight a day to Nakhon Phanom. For river navigation, there are boat services and ferries from 8.30 to 18.00 along the Mekong river to Thakhek, Khommouane, Lao PDR. The road system of Changwat Nakhon Phanom is presented in Figure 2.4.

Regarding the electrification of Changwat Nakhon Phanom, the numbers of consumers are 130,588. The total electricity consumption of Changwat Nakhon Phanom in 2000 is 145,459,054.48 units which can divide into residential 58.462 per cent, business, and industry 25.721 per cent, government office and public utility 13.999 per cent, and other 1.818 per cent (NPPSO, 2543, in Thai).

There are eight water-supply stations with total installed capacity of 9,487,080 cubic-metres, whereas the actual water production capacity was 4,983,061 cubic-metres in 2000. They are, Provincial Waterworks Authority Regional Office 8, Muang Nakhon



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 2.4 Road system of Changwat Nakhon Phanom

(Source: Royal Thai Survey Division, no date, in Thai)

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Phanom Municipality Waterworks, Tha Uthen Municipality Waterworks, That Phanom Municipality Waterworks, Na Kae Municipality Waterworks, Na Wa Municipality Waterworks, Ban Phaeng Municipality Waterworks, Si Songkhram Municipality Waterworks, and Pla Pak Waterworks. The water resources of Changwat Nakhon Phanom can be classified by type of water resources as follows: 106 reservoirs, 49 concrete wire, 5 pond, 198, and 516 canal (NPPSO, 2543, in Thai).

2.1.5 Economy

The Gross Provincial Product, GPP, of Changwat Nakhon Phanom is 14,066.40 thousand baht in 2000 (NPPSO, 2543, in Thai). The Per Capita Income is 20,686 baht per annum in 2000. The agriculture contributes approximately 27.0 per cent of the GPP, whereas the wholesale and retail trade, services, and others contribute approximate 22.4, 15.4, and 35.2 per cent, respectively. The average economic growth of Changwat Nakhon Phanom in 2000 was 3.94 per cent.

2.1.6 Recreation and tourist attractions

For centuries, people from the Lao PDR and other ethnic groups migrated across the Mekong river and this is reflected in the local dialects, customs and cuisine of Nakhon Phanom. Many unique folk dances, such as, the Sri Kotrabun dance is regarded as the symbol of Nakhon Phanom's long history and the Fon Phu Thai, Sek-Ten-Sak and So Tung Bung are performed on special occasions. The custom of extending a generous welcome to guests can be experienced during a Bai-Sri-Su-Kwan ceremony when a potent brew of home-made liquor is usually served.

There are numerous places of attraction in Changwat Nakhon Phanom including festivals and events Prathat Phanom festival in February in Phra That Phanom Temple, Nakhon Phanom, which last for about one week, takes place during the period of the full moon in February or early March. It is one of the biggest and most important festival for the people of the northeast, both Thais and Laotians. Annual Illuminated Boat Festival in

October – November in the Mekong river, Nakhon Phanom. The most important festival for the people of Nakhon Phanom, takes place around October 31 - November 4, during the period of the full moon, and marks the end of the Buddhist Rains Retreat. This festival celebrates the time when the Lord Buddha returned to Earth, after spending the Buddhist Rains Retreat in Heaven. This day is called as "Wan Chao Lok" which means "The day the Buddha blessed the World". The people marked their showing of respect by illuminating their boats. This then became a local custom. During this week, there are Dragon Boat racing on the Mekong river, and the end of the festival is marked by Illuminated Boat Procession being paraded down river for all the people to see. These boats are made from bamboo and decorated with hundreds of lights. With respect to the natural beauty, they include Riverside Promenade and Terdprakiat Park and Strand, Dansaocoi (Na Kae), Tat Kham Waterfall, etc. Historical Sites, Prathat Renu, Prathat Phanom, Prathat Srikhun (Na Kae), Prathat Tha Uthen, Prathat Prasit is situated in Wat Prathat, Wat Okatsribuabun, Wat Srithep pradittharam, Pra Bang and Wat Triphum, Phrathat Mahachai, etc. In addition, there are facilities and infrastructures for tourism and for recreation, namely, hotel accommodation, restaurants, entertainment etc. The number of overseas visitors, tourists and excursionists as well as the Thai tourists coming to Changwat Nakhon Phanom from 1998 to 2000 are summarised and presented in Table 2.2.

Natural beauties and tourist attractions of Changwat Nakhon Phanom are presented in Figure 2.5.

2.2 Physical environment

2.2.1 Climate

Changwat Nakhon Phanom lies entirely within the tropical zone of the northern hemisphere, and is under the influence of seasonal monsoon wind. Seasonal influences of the Pacific Ocean trade winds and the Asiatic monsoons result in a climate showing two distinct seasons. The tropical cyclone or rainy season is mainly between May and

Table 2.2 Number of Hotels, Visitors, Tourists, and Travelers.

(Source: Nakhon Phanom Provincial Statistical Office, 2541-2543, in Thai)

Item	B.E. 2541	B.E. 2542	B.E. 2543
Number of Hotels	8	8	8
Number of rooms in hotel	595	595	595
Number of Visitors	476,472	231,933	248,329
Thai	448,126	218,322	233,758
Foreigner	28,346	13,611	14,571
Number of Tourists	228,082	115,055	133,220
Thai	225,141	113,466	130,854
Foreigner	2,941	1,589	2,366
Number of excursionists	248,330	116,878	115,109
Thai	222,925	104,856	102,904
Foreigner	25,405	12,022	12,205

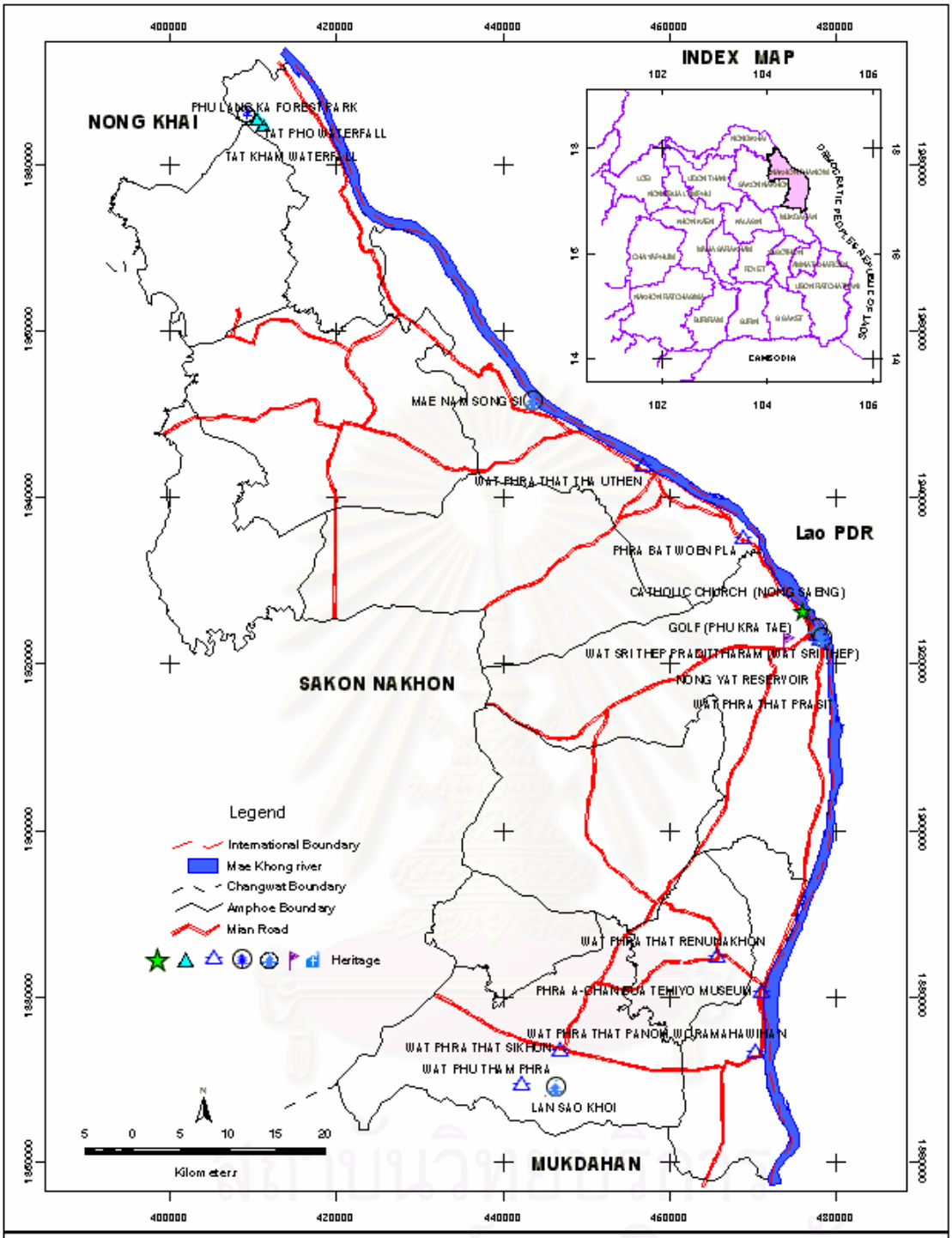

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Figure 2.5 Natural beauties and tourist attraction of Changwat Nakhon Phanom

(Source: 1. Royal Thai Survey Division, no data, in Thai)
2. Tourist Authority of Thailand, no date

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September. The northeast monsoon or dry season is mainly between October and March (Figure 2.6). Short transition periods separate these seasons. Climatic variations depend primarily upon fluctuations in rainfall and not upon temperatures. However, locally the higher relief features in this area will influence climatic conditions. The maximum precipitation in the Changwat, over 2,000 mm. annually, falls in the northern part. The minimum amount of precipitation, less than 1,200 mm. annually, falls in the southern part of Changwat Nakhon Phanom.

The tropical cyclone or rainy season begins in May and is well established by June. It is ushered in by the intertropical convergence zone (ITCZ) as it travels northward, and low cloudiness, heavy rain showers, and thunderstorms are prevalent. A nearly regular pattern is established by June, with almost daily local showers, occasionally torrential, occurring during the afternoon and early evening. These showers are caused mainly by convection. At times, the showers are followed by less intense but long lasting rains. During August and September developing tropical storms enter the area infrequently with longer lasting and heavy rainfall. Periods of fair weather with scattered clouds occasionally occur, but clear days are rare.

During the early part of the transition period in September, the weather is quite similar to the tropical cyclone. In places, there is some increase in cloudiness, rainfall, and local storms as the ITCZ moves over the area southward. However, cloudiness and precipitation decrease markedly. By October, the drier and cooler northeasterly flow dominates the area.

Commencing usually in October, the cooler and drier air from the northeast dominates the area within a month from its onset. Cloudiness is normally considerably less than during the tropical cyclone. Clear days are more frequent, but clouds build up in the afternoon. Early morning fog is common in deeper river valleys, but usually dissipates by noon. Nighttime temperatures are noticeably lower, but in the daytime, they are still relatively high. The air feels cooler in comparison to the sultriness experienced during

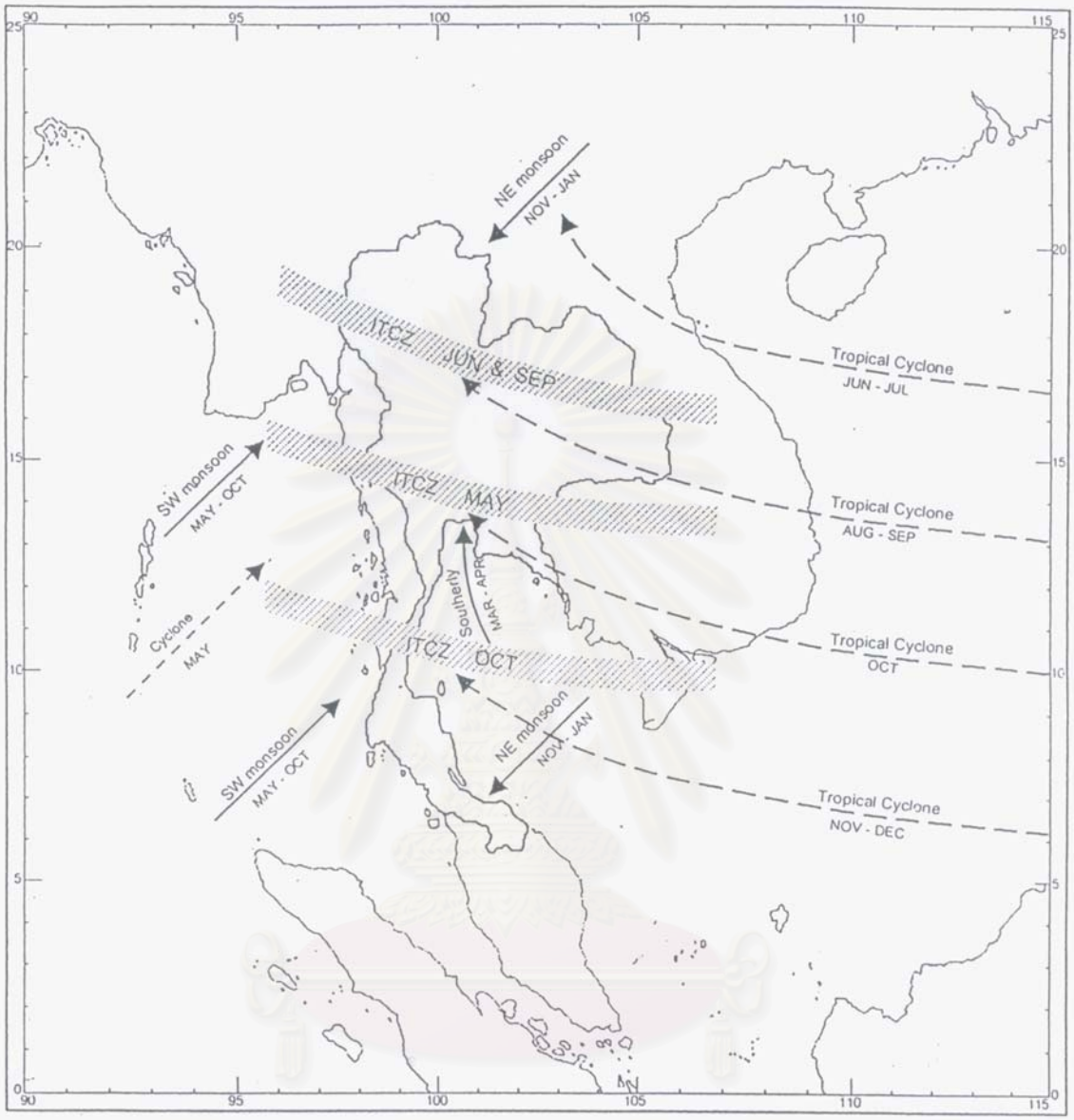


Figure 2.6 The historical record of Intertropical Convergence Zone (ITCZ) Monsoon and Tropical Cyclone

(Source: Meteorological Department, 1981-1990)

the tropical cyclone. Temperatures extreme minimum as low as 3.2 °C have been recorded at Nakhon Phanom (Meteorological Department, 1971-2000).

The northeasterly flow of air has dissipated by March and no longer dominates the area. This transition period, just before the tropic cyclone starts, temperatures reach their annual maximum. Humidity is still low as clouding amounts, and skies remain relatively clear. Rainfall, although still not heavy, is greater than during the tropical cyclone. By May, with the approach of the ITCZ and the onset of the tropical cyclone, relative humidity begin to increase and air becomes extremely oppressive.

Commencing usually in September, the wind moving over the area southwestward to westward. In addition, the average monthly wind speed and direction of Changwat Nakhon Phanom are summarised as the wind rose diagram in Figure 2.7.

In addition, the past 30 year (Meteorological Department, 1972-2001) mean annual temperature is 25.9 °C and the mean monthly temperature varies between 15.6 to 34.9 °C (Figure 2.8). The mean annual rainfall is 2,255.8 millimetres and the mean monthly annual rainfall between 3.5 to 578.8 millimetres (Figure 2.9). The pattern of relationship between average monthly temperature and average monthly rainfall are summarised as hythergraph in Figure 2.10. The mean annual humidity is 75 per cent and the mean monthly humidity is between 88 per cent in August and 65 per cent in March. The mean annual number of rainy days is 138.2 days and the mean monthly numbers of rainy days varies between 25.6 days in August and 0.8 days in December. The mean monthly relative humidity, rainfall, temperature and rainy day are summarised and presented in Figure 2.11. The climatological data of Changwat Nakhon Phanom for the period 1971-2000 is presented in Table 2.3. The distributions of annual rainfall in Changwat Nakhon Phanom and the adjacent areas are presented as the isohyetal map in Figure 2.12.

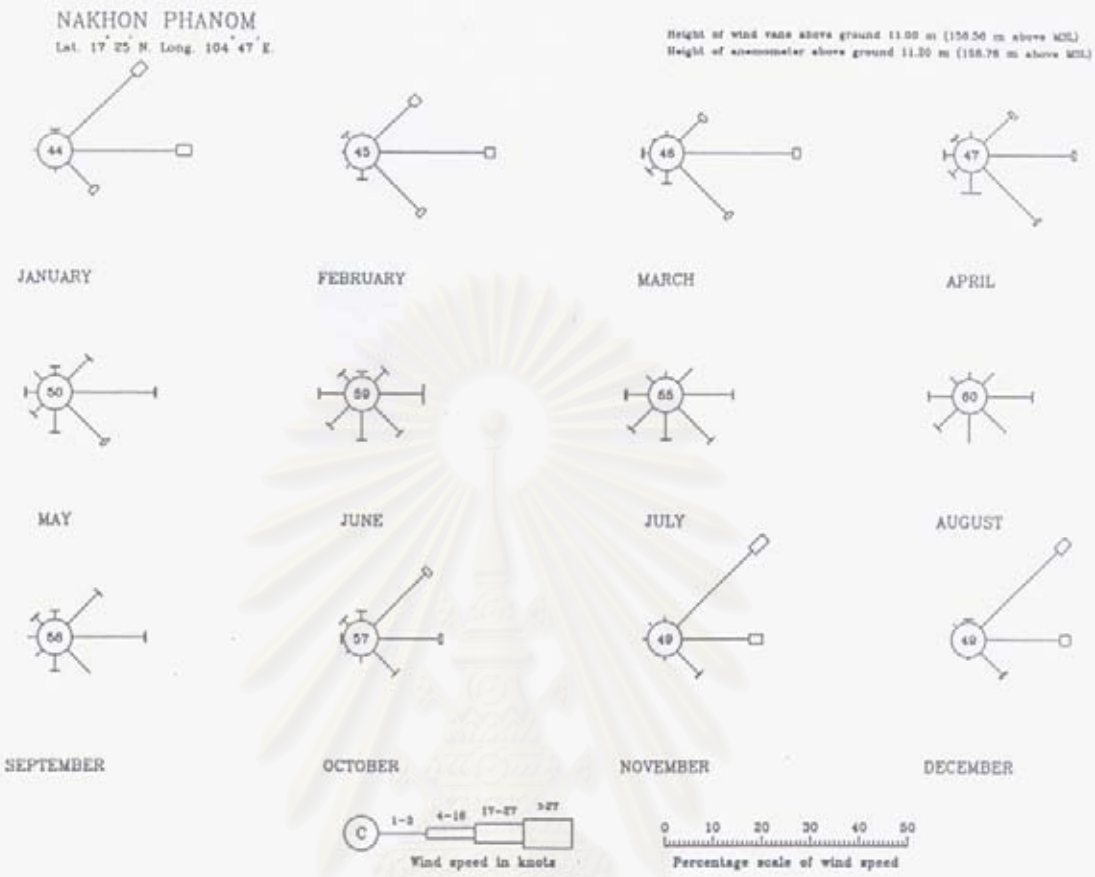


Figure 2.7 Wind rose diagram of Changwat Nakhon Phanom

(Source: Meteorological Department, 1981-1990)

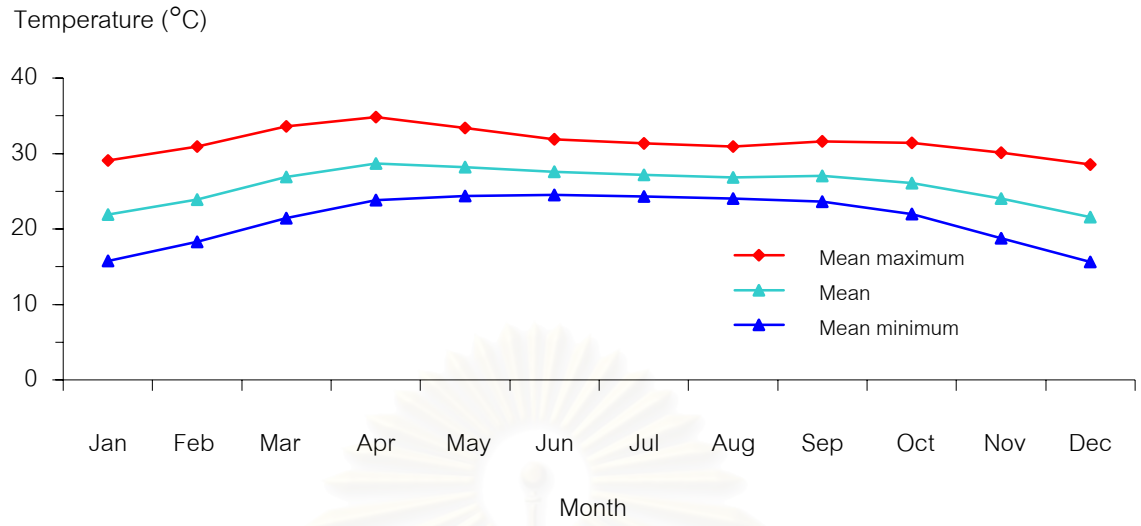


Figure 2.8 Mean monthly temperature of Changwat Nakhon Phanom (1971-2000)

(Source: Meteorological Department, 2001)

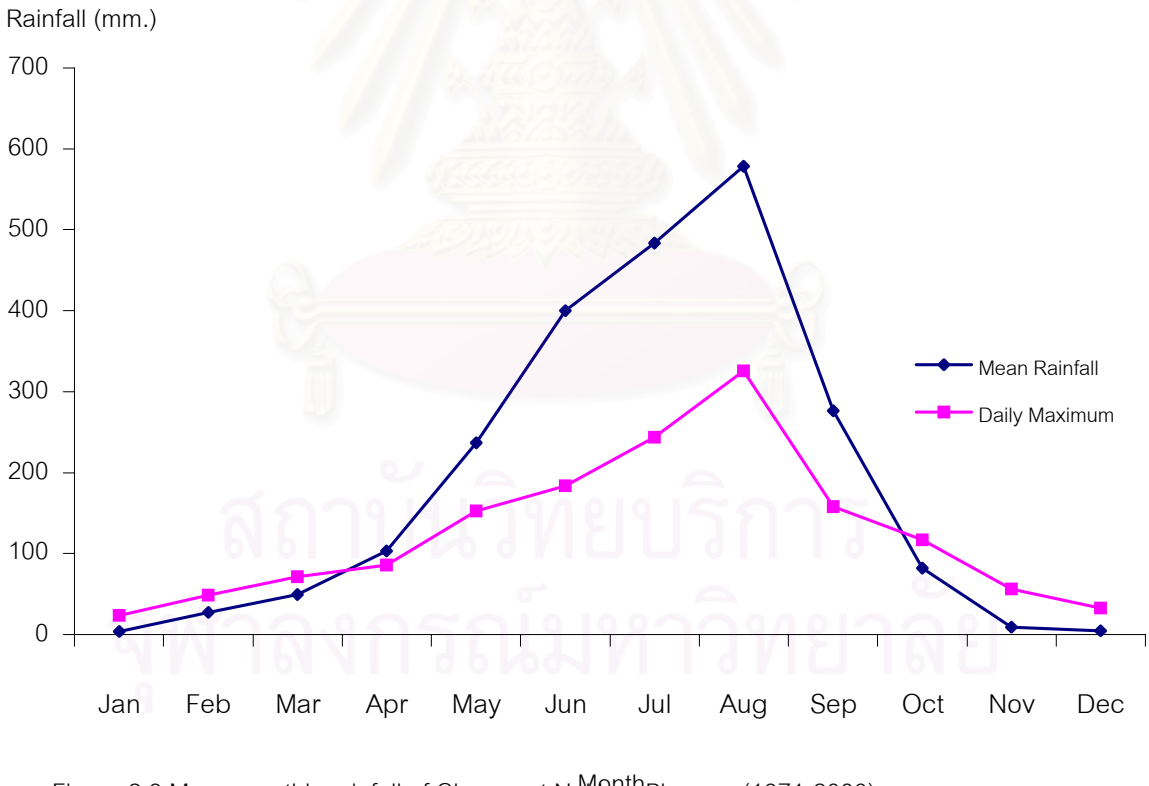


Figure 2.9 Mean monthly rainfall of Changwat Nakhon Phanom (1971-2000)

(Source: Meteorological Department, 2001)

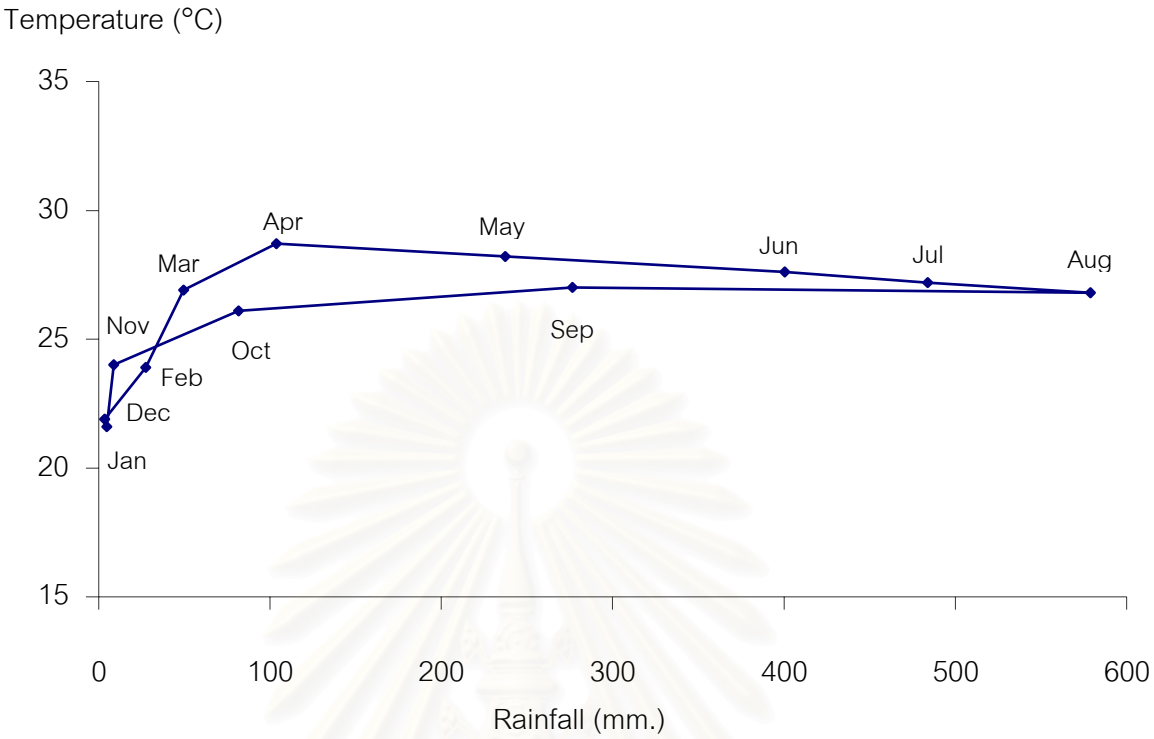


Figure 2.10 Hythergraph of Changwat Nakhon Phanom (1971-2000)

(Source: Meteorological Department, 2001)

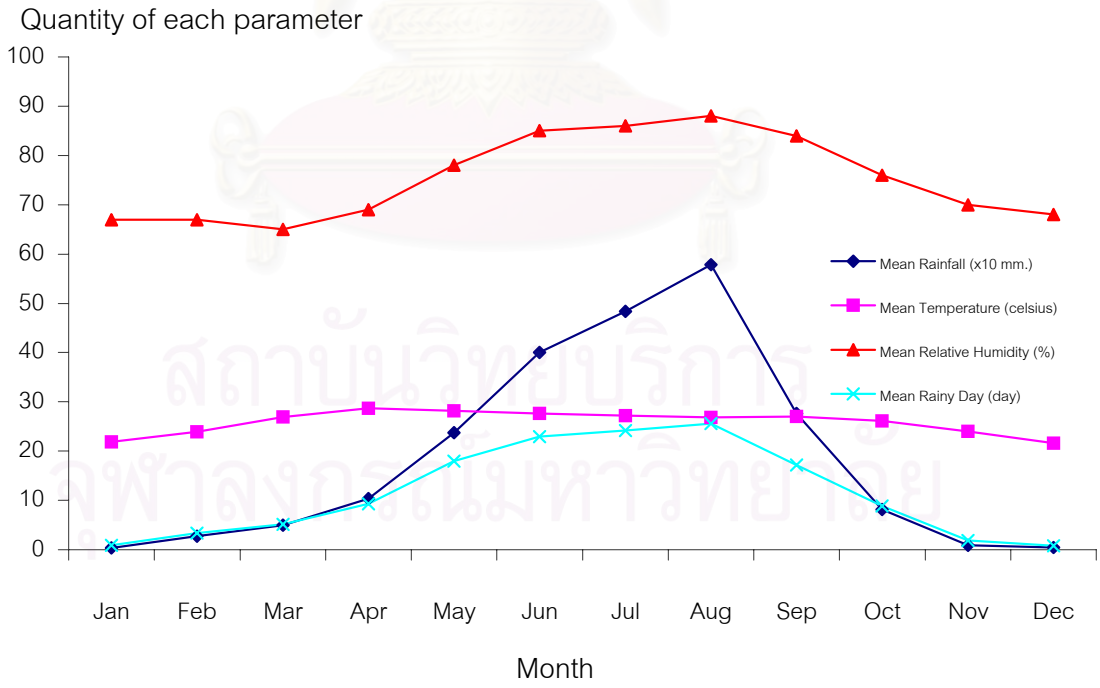


Figure 2.11 Mean month relative humidity, rainfall, temperature and rainy day of Changwat Nakhon Phanom (1971-2000)

(Source: Meteorological Department, 2001)

Table 2.3 Climatological data for the period 1971-2000 (Source: Meteorological Department, 2001)

Station NAKHON PHANOM	**Elevation of station above MSL**	140	Meters
Index station 48357	Height of barometer above MSL	148	Meters
Latitude 17 25 N	Height of thermometer above ground	1.20	Meters
Longitude 104 47 E	Height of wind vane above ground	11.00	Meters
	Height of raingauge	0.80	Meters

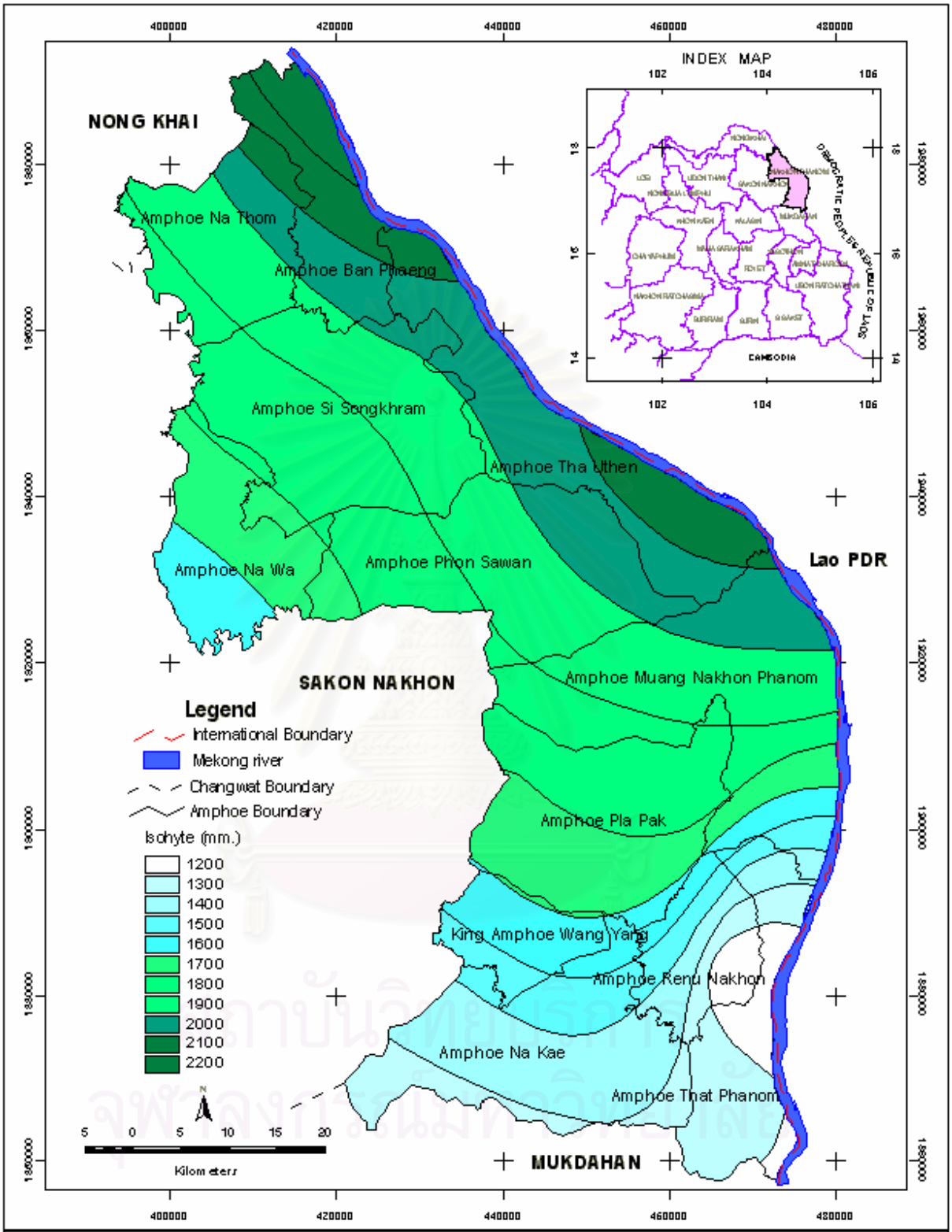
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Pressure (Hectopascal)													
Mean	1014.48	1012.37	1010.02	1008.05	1006.79	1005.17	1005.03	1005.12	1007.64	1010.64	1013.59	1015.61	1009.54
Ext. max.	1029.22	1025.28	1027.8	1021.06	1015.22	1011.86	1012.63	1013.76	1017.35	1021.28	1025.05	1026.48	1029.22
Ext. min.	1001.32	999.75	998.69	997.09	997.82	994.08	989.74	987.20	993.62	995.86	1001.38	1003.07	987.20
Mean daily range	5.15	5.58	5.94	5.74	5.04	4.17	3.99	4.21	4.63	4.56	4.38	4.62	4.83
Temperature (Celsius)													
Mean	21.9	23.9	26.9	28.7	28.2	27.6	27.2	26.8	27.0	26.1	24.0	21.6	25.8
Mean max.	29.1	30.9	33.6	34.8	33.4	31.9	31.3	30.9	31.6	31.4	30.1	28.5	31.5
Mean min.	15.8	18.3	21.4	23.8	24.4	24.5	24.3	24.0	23.6	22.0	18.8	15.6	21.4
Ext. max.	35.6	38.9	41.3	42.0	40.2	37.9	36.4	36.5	35.6	35.3	35.3	35.5	42.0
Ext. min.	3.2	8.0	8.2	15.9	18.8	20.3	21.4	21.5	20.2	14.7	8.8	4.1	3.2

Table 2.3 continued

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Relative Humidity (%)													
Mean	67	67	65	69	78	85	86	88	84	76	70	68	75
Mean max.	89	87	84	86	91	96	96	97	96	93	90	89	91
Mean min.	45	45	44	49	60	70	72	74	67	57	50	46	57
Ext. min.	13	14	14	17	30	40	47	49	36	28	25	16	13
Dew Point (Celsius)													
Mean	15.1	16.8	19.2	21.8	23.7	24.6	24.5	24.5	23.7	21.3	17.7	14.9	20.7
Evaporation (mm.)													
Mean-pan	114.9	116.5	147.4	152.9	135.6	102.1	101.2	96.1	104.4	116.8	113.8	109.3	1411.0
Cloudiness (0-10)													
Mean	2.5	3.1	3.6	5.0	7.1	8.3	8.3	8.7	7.1	5.4	3.6	2.6	5.4
Sunshine Duration (hr.)													
Mean	247.3	208	214.8	203.1	184.9	127.9	127.8	116.5	152.7	209.8	226.5	249.4	2268.7
Visibility (km.)													
0700 L.S.T.	5.4	4.7	4.5	5.6	8.5	8.7	8.6	8.1	8.1	7.4	6.4	5.4	6.8
Mean	8.3	6.5	5.5	6.8	10.1	10.3	10.2	10.0	10.0	9.6	9.2	8.4	8.7
Wind (Knots)													
Mean wind speed	2.3	2.2	2.1	1.8	1.5	1.2	1.2	1.1	1.1	1.5	2.3	2.3	-

Table 2.3 continued

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Prevailing wind	E	E	E	E	E	E	SE	SE	E	E	NE	E	-
Max. wind speed	22	49	35	36	40	25	30	35	25	25	23	27	49
Rainfall (mm.)													
Mean	3.5	27.3	49.4	103.6	237.2	400.3	483.9	578.8	276.5	81.7	8.8	4.8	2255.8
Mean rainy day	0.9	3.4	5.1	9.3	18	22.9	24.2	25.6	17.2	8.9	1.9	0.8	138.2
Daily maximum	23.9	48.7	71.2	85.8	152.9	184.1	243.7	325.7	157.6	117	56.3	32.4	325.7
Number of days with													
Haze	18.3	22.2	25.6	20.8	5.7	0.4	0.1	0.2	4.6	9.6	13.6	18.6	139.7
Fog	1	0.5	0.4	0.2	0.1	0	0	0.1	0.1	0.3	0.4	0.9	4
Hail	0	0.1	0	0	0.1	0	0	0	0	0	0	0	0.2
Thunderstorm	0.1	2.3	4.7	9.7	17.5	15.8	16.2	16.1	11.3	4.2	0.4	0	98.3
Squall	0	0	0.1	0	0	0	0	0	0	0	0	0	0.1



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 2.12 Isohyetal map of Changwat Nakhon Phanom

(Source: Meteorological Department, 2001)

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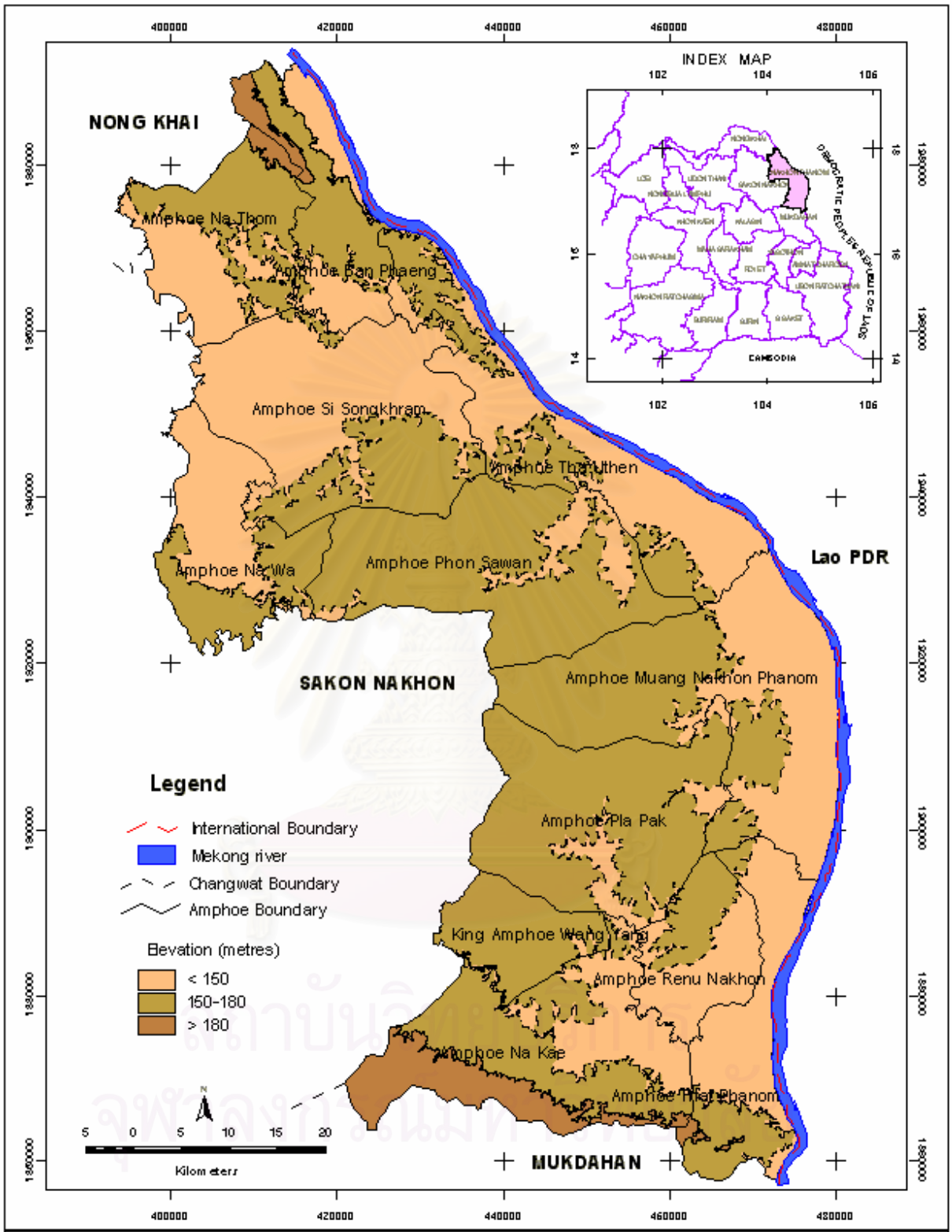
2.2.2 Topography and landform

Generally, the landform of Changwat Nakhon Phanom can be subdivided into 3 main types. These include an area of mountain and foothill slopes, undulating area, and flood plain. The mountain and foothill slopes in the northern and southern parts of the study area are composed of NW/SE to E/W trending mountain ranges with high relief and steep slopes. In the northern part, the altitude ranges from 180 to 563 metres above the mean sea level, whereas in the other side of area, the altitude ranges from 180 to 641 metres above the mean sea level. The terraces are present in the lower land in the central part of the study area. This unit has undulating terrain with moderate relief as elevation ranges from 150 to 180 metres above the mean sea level. Individual terrace units are scattered, cut apart by old river levee and flood plain. The old river levee and flood plain occupy the lowest position in the study area. They are the result of fluvial deposition by main streams of the area – the Mae Nam Songkhram, Huai Nam Yam, Huai Nam Kam, and Huai Nam Au, which cause the unit to be inundated during the wet season. The topography of Nakhon Phanom is summarised as hypsometry map in Figure 2.13, and slop map in Figure 2.14.

2.2.3 Geology of Changwat Nakhon Phanom

The general geology of the study area, which is a part of Khorat Group and Cenozoic sediments, which is presented in Figure 2.15. Changwat Nakhon Phanom has some formations of Khorat Group, consist of Phra Wihan, Sao Khua, Phu Phan, Khok Kruat, Mahasarakham, and Phu Tok Formations of Middle Jurassic to Early Cretaceous. The lithological descriptions are as follows from the bottom to the top formations;

i) Phra Wihan Formation in the southwest of Amphoe Na Kae is composed of mainly pink thick bedded, well sorted, medium-grained, cross-bedded, quartz-rich sandstone. In the upper part, with some interbedded thin laminated reddish brown to red siltstone, and pebbly sandstone. This formation is of Middle Jurassic age (Racey and others, 1994).



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 2.13 Hypsometry map of Changwat Nakhon Phanom

(Source: Royal Thai Survey Division, no date, in Thai)

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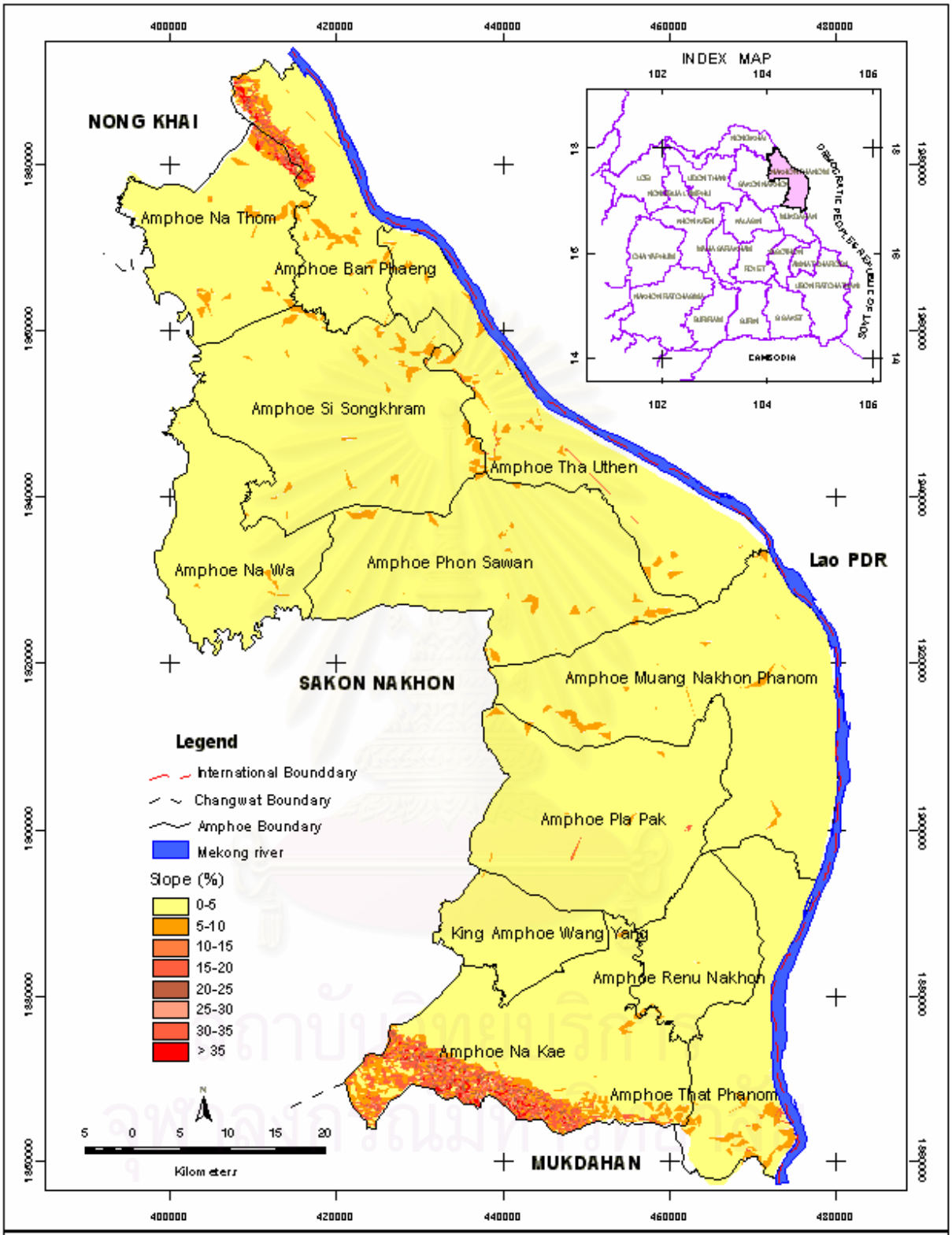

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Figure 2.14 Slope map of Changwat Nakhon Phanom

(Source: Department of Environmental Quality Promotion, 2000)

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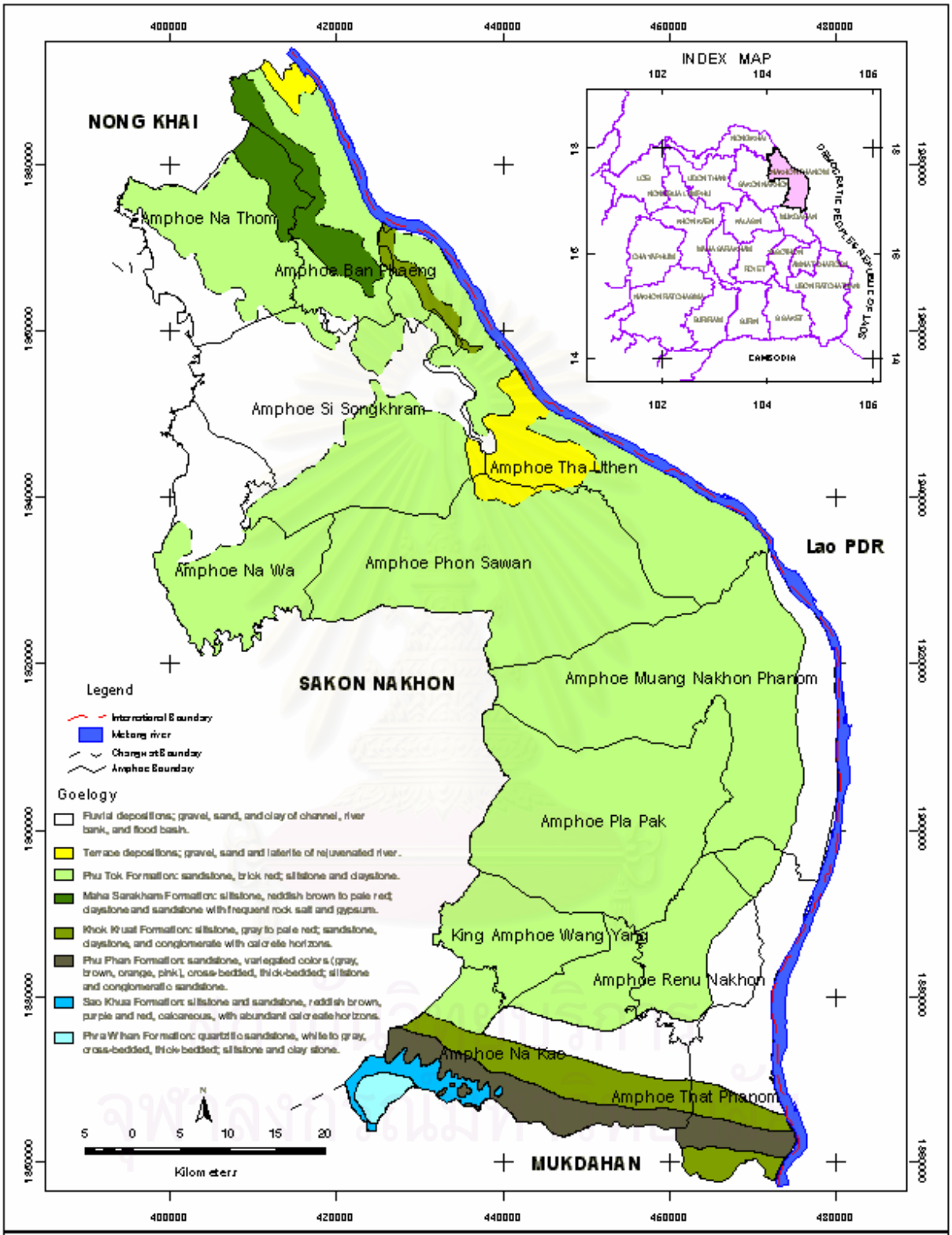

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Figure 2.15 Geological map of Changwat Nakhon Phanom

(Modified from Department of Mineral Resources, 1985)

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ii) Sao Khua Formation (Ward and Bunnag, 1964) consists of mainly red to purple shale associated with minor yellowish brown and pale red sandstone and pale red conglomerate. They are distributed along the southwest of Amphoe Na Kae. This formation is of Late Jurassic age (Racey and others, 1994).

iii) Phu Phan Formation designated by Nithipat and Bunnag (1954) and named for the widespread outcrops in the Phu Phan Range. This formation includes major sandstone, which are yellowish gray to pale orange, pinkish gray, and pale red, thick-bedded, cross-bedded, medium- and coarse- grained varying to fine-grained and typically conglomerate with rounded pebbles of quartz and light to dark gray chert and reddish brown or greenish gray siltstone. This formation distributed along the southern part of Amphoe Na Kae.

iv) Khok Kruat Formation consists predominantly of interbedded moderately consolidated red siltstone, and red to white quartz sandstones and fine conglomerate. This formation is poorly exposed because there is no the cap rock like the Sao Khua and Phu Kradung Formations. Gypsum occurs as thin-bedded and scattered crystals in some of the siltstone and sandstones. Khok Kruat Formation is distributed along the southern part of Amphoe Na Kae and Amphoe That Phanom.

v) Maha Sarakham Formation (Gardner and others, 1967) contains bed of rock salt (halite) with limited lateral extent. The attitude of this formation is nearly horizontal with very few and widely scattered outcrops. The salt – bearing rock indicates the continuing change towards evaporite depositions that was first evidenced by the presence of thin gypsum beds in the upper Khok Kruat Formation. Therefore, the boundary between the overlying Maha Sarakham Formation and the Khok Kruat Formation is the transitional change. In upper part of formation is composed of mudstone, shale, siltstone, and brownish red to red, fine-grained sandstone. Almost all of the study area is covered by this formation as follows: the northern of Amphoe Na Kae, the western of Amphoe Renu Nakhon, King Ampoe Wang Yang, Amphoe Pla Pak, Amphoe Muang Nakhon Phanom,

Amphoe Tha Uthen, northern of Amphoe Na Wa, Amphoe Si Songkhram, and Amphoe Ban Phaeng.

vi) Phu Tok Formation consists of two sandstone types, one with very large-scaled cross bedding and the other with small wavy structure; red coloured, fine-grained, well sorted and friable.

vii) Terrace deposits consist of gravel, sand and laterite of rejuvenated river.

viii) Fluvial deposits consist of gravel, sand, and clay of channel, river bank, and flood basin.

Structure geology: A major structural geology in the study area lies approximately in the WNW - ESE direction. This trend is a part of the regional trend of the Khorat rock sequences in the upper part of the northeastern Thailand. In fact, the mountain swings from east-west to roughly northwest-southeast, becoming part of the Phu Phan range. Fault systems in the area are the NW-SE fault, extending from Phu Kadan to Ta Khek Fault in Laos. There are also minor faults and fractures in the area trending approximately NW-SE and NE-SW directions. Foldings of the area are certainly represented the WNW-ESE major syncline. The syncline is about 120 km in length and 70 km in width. These folds are rather asymmetrical and their axis roughly parallel to the Maha Sarakham and Phu Tok Formations trends. The Phu Phan Range, where the southernmost part of the area, is the western edge of the major syncline which oriented approximately in the WNW-ESE direction. It is consisted of the Middle-Upper Khorat sequence such as Phu Kradung, Phra Wihan, Sao Khua, Phu Phan and Khok Kruat Formations with low dipping (5° to 10° to NNE). The other, Ta Uthen mountainous terrain locates at the northeastern part of the area. The NW-SE direction flank consists of Khok Khuat Formation in Thai side with gentle dipping (3° to 7° to SSW) and the older Khorat rock sequences with high dipping in Laos. The other range, Khao Phu Langka terrain, is a broad syncline with the axis of folding in the NW-SE direction. Both flanks of Phu Langka fold are easily revealed by the escarpment topography. The Phu Langka

syncline is asymmetrical style with about 20 km in length and 10 km in width. Dipping of the flank of the syncline is not more 5° to NE and SW. Generally, the Maha Sarakham and Phu Tok Formations are unconformably underlain by the older Khorat sequence and lie unconformably beneath the semi-consolidated Quaternary sediments.

2.2.4 Water resources

In terms of the water resources of Changwat Nakhon Phanom can be classified into two types as follows:

2.2.4.1 Surface water

All the main drainage in Changwat Nakhon Phanom flows from 4-tributary drainage basins into the Mekong river. The Mekong river is an international river that originates from an elevation of about 5,000 metres in the snow-covered mountain ranges of southwestern China and flows south and east across China, Myanmar, Lao PDR, Thailand, Cambodia, and Vietnam to discharge into the South China Sea. In the eastern part of Nakhon Phanom, the Mekong river is at the border between Thailand and Lao PDR. It is a meandering, braided river filled with sandbars, rock outcrops, and island. The riverbank are steep, 10 to 30 metres high, and bordered by natural levees.

Major tributaries of the Mekong river in Changwat Nakhon Phanom are the Mae Nam Songkhram, Huai Nam Yam, Huai Nam Kam, and Huai Nam Au.

Major Drainage Basins

The movement of water at surface drainage system is always flow eastwards and discharge into the Mekong river which can be classified into nine drainage basins as follows:

i) Huai Langka

The drainage basin area is 150 square kilometres. The stream, which is 17 kilometres in length, flows through hills in the northwestern part of the basin.

ii) Mea Nam Songkhram

In the study area, the drainage basin area is 2,078 square kilometres. The Mea Nam Songkhram originates from the western Phu Phan uplands and flows north and southeast 90 kilometres across the northern part of the Changwat. The flow of this meandering stream is sluggish. There are large areas subject to seasonal inundation and small areas of marsh along the Mae Nam Songkhram.

iii) Huai Khae Tai

This small stream, 10 kilometres in length, is roughly parallel the Mekong until it breaks through the natural levee to join the Mekong. The drainage basin has an area of 93 square kilometres.

iv) Huai Thuai

The Huai Thuai originates from Changwat Sakhon Nakhon, northeast of Nong Han, and flows northeastward about 40 kilometres to the Mekong. The stream is bounded by natural levee 140 to 153 kilometres in elevation. The drainage basin has an area of 514 square kilometres.

v) Huai Bo

This small basin of 147 square kilometres contains the 10 kilometres long Huai Bo.

vi) Huai Ho-Huai Bang Ko

This basin has an area of 528 square kilometres and a mean elevation of 150 kilometres. There are three reservoirs, Phu Kratae, Nong Yat, and Som Hong, in the drainage area.

vii) Huai Bang Huak

This drainage basin is 375 square kilometres in area. The Huai Bang Huak is comprised essentially of drainage behind the natural levee of the Mekong and is 15 kilometres in length.

viii) Huai Nam Kam

Slightly larger than half of this 1,950 square kilometres drainage basin is in the province. The Huai Nam Kam flows southeastward from Nong Han, the large lake in Changwat Sakon Nakhon. The Huai Nam Kam is extended over 60 kilometres in length in Changwat Nakhon Phanom. The Huai Nam Kam drains much of the area between the Nong Hun and the Changwat Capital. Huai Si Khun, and Kan Luang are reservoirs in this basin.

ix) Huai Ngaem-Huai Kut Don

Small streams, which have been unable to cross the natural levee to the Num Kam, have united to form the 17 kilometres long Huai Ngaem. The basin, which is hilly in its northern part, has an area of 185 square kilometres. The Huai Ngaem joins the Mekong 5 kilometres further downstream from Huai Ngaem.

In addition, there are many important streams and lakes in the northern and southern parts of area which can be developed for water resources, namely, Huai Nam Yam, Huai Bang Huak, Huai Thuai, Huai Nong Khao, Nong Yat, Nong Sai Wan, Nong Sarai, Huai

Seka Yai, Huai Nam Mao, Nam Bang, etc. The surface water resources of Changwat Nakhon Phanom are summarised and presented in Figure 2.16.

2.2.4.2 Groundwater

The standard of groundwater quality of Thailand was reviewed by the Ministry of Industry using the total dissolve solid (TDS) in consideration (in Thai, Aroonsong, 2539), which can be divided into 3 types as follows:

i) Suitable, TDS < 750 mg/l.

ii) Acceptable, TDS 750-1,500 mg/l

iii) Unsuitable, TDS > 1,500 mg/l

The quality groundwater is depend on concentration of dissolved matter in water. The total dissolved solids (TDS) in groundwater of Changwat Nakhon Phanom can be classified into 3 groups as follows:

i) less than 750 mg/l (unit 1, unit 2, unit 5, and unit 8). More than 95 per cent of the bore-hole provide a good quality of water.

ii) 750-1,500 mg/l (unit 3, unit 6, and unit 9). Approximately 80 per cent of the bore-holes yield fresh water.

iii) More than 1,500 mg/l (unit 4, unit 7, and unit 10). Over 90 per cent of the bore-holes are found brackish water.

The yield of the groundwater is divided into 4 groups as follows:

i) Yield < 2 cubic metres/hour Groundwater in unit 1 is in this group. It are distribute in the northeast of Amphoe Na Thom, the northwest of Amphoe Ban Phaeng, the east of Amphoe Muang Nakhon Phanom, the through out of Amphoe Na Kae and Amphoe That Phanom in the south trend.

ii) Yield 2-10 cubic metres/hour. Over 90 per cent of distribution in the area, consisting of unit 2, unit 3, and unit 4.

iii) Yield 10-20 cubic metres/hour. Groundwater in unit 5, unit 6, and unit 7 provide this rate of yield. They can be found in the east of Amphoe Muang Nakhon Phanom,

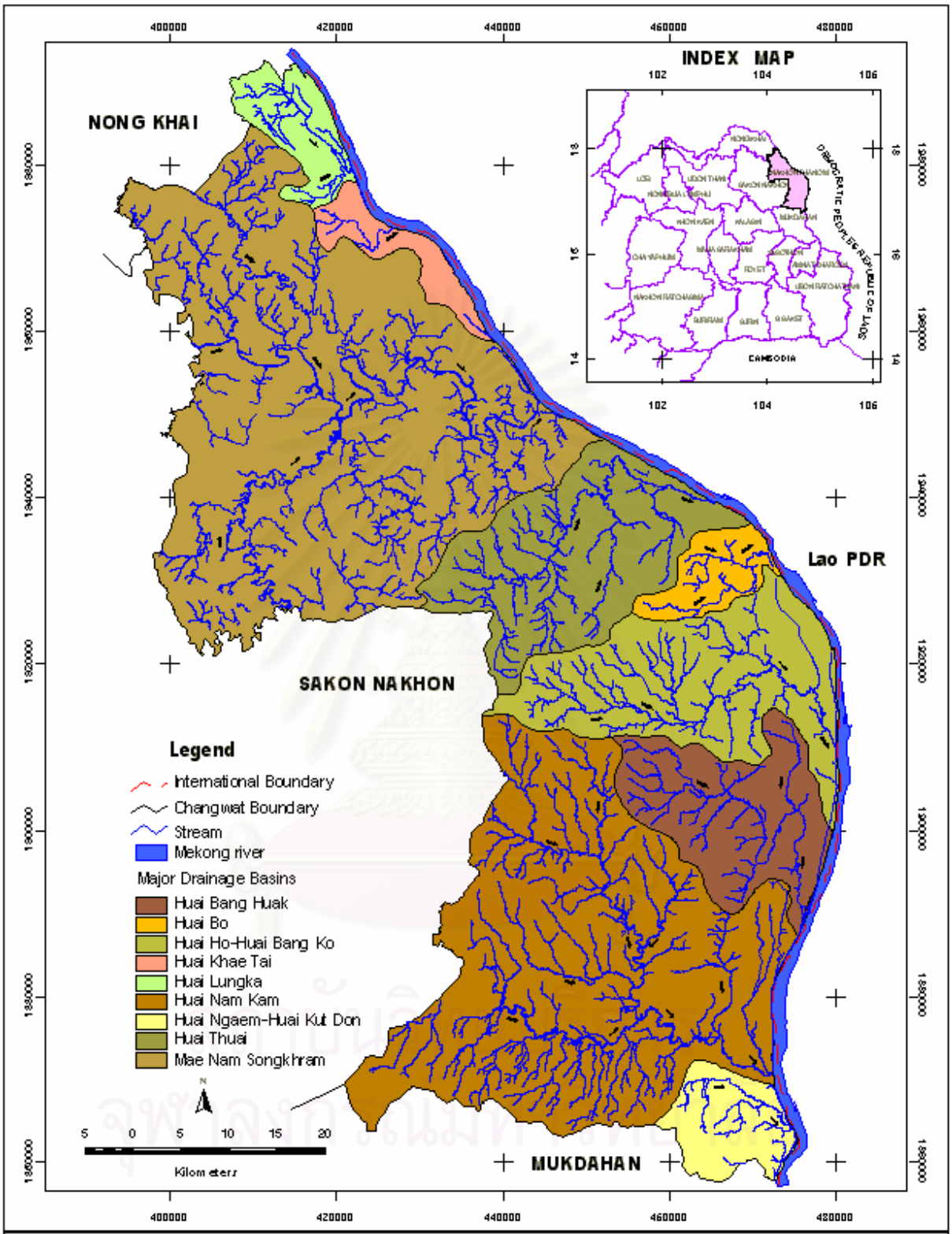

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Figure 2.16 Surface water resource of Changwat Nakhon Phanom

(Source: Royal Thai Survey Division, no dat, in Thai)

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Amphoe Renu Nakhon, Amphoe Na Wa, and Amphoe Pla Pak, the west of Amphoe Na Thom, Amphoe Tha Uthen and King Amphoe Wang Yang, the south of Amphoe Na Wa, Amphoe, the central of Amphoe Si Songkhram, Amphoe Na Wa, Amphoe Phon Sawan, and Amphoe Na Thom, the north of Amphoe Na Kae, Amphoe Renu Nakhon, Amphoe That Phanom, Amphoe Pla Pak, Amphoe Muang Nakhon Phanom, Amphoe Tha Uthen, and Amphoe Si Songkhram.

iv) Yield > 20 cubic metres/hour. Groundwater in this group are unit 8, unit 9, and unit 10. They are distribute in the north of Amphoe Na Kae, the south of Amphoe Renu Nakhon, the west of Amphoe Pla Pak, and the east of Amphoe Ban Phaeng.

The quality and yield of groundwater resources of Changwat Nakhon Phanom can be classified into 10 units, which is presented in Figure 2.17.

In addition, aquifer types (Figure 2.18) of the groundwater are divided into 2 main groups as follows:

1) Unconsolidated rock aquifer

The floodplain and terrace bold deposits: gravel, sand, silt, clay, and laterite of meandering belt is about 15-20 metres and up to 35 metres thick. Some places, the average depth of water table are 4-7 metres.

2) Consolidated rock aquifers

2.1) Phu Tok Formation: sandstone, brick red, fine- to medium-grained. This aquifer supplies groundwater mainly from joints and fractures

2.2) Mahasarakham Formation: shale, siltstone, mudstone, sandstone, with rock salt and other evaporites. The groundwater occurs in fractures, bedding planes and weathered zones. The average depth of water table is about 30-40 metres, in some places, there are up to 60-70 metres and low to 4-8 metres.

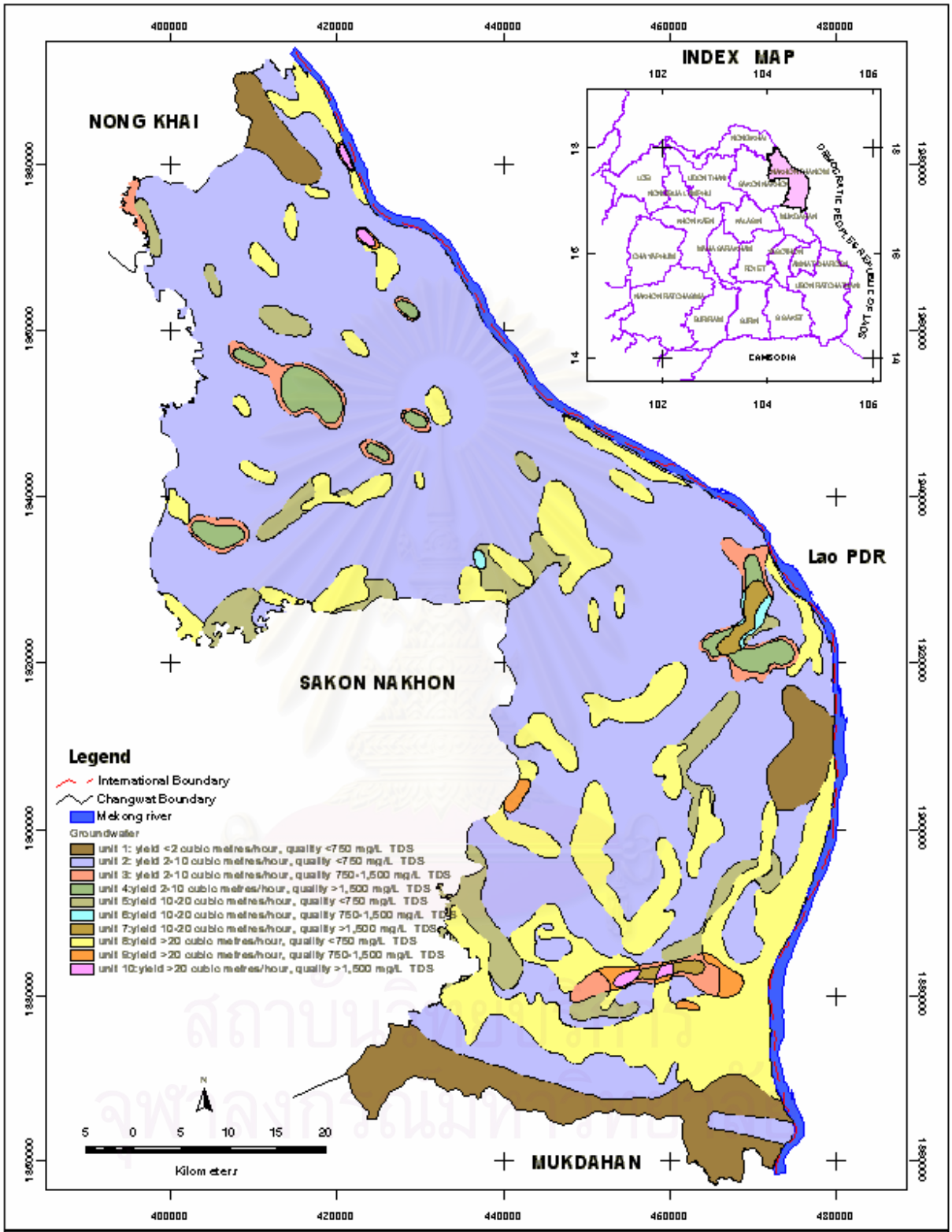

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Figure 2.17 Groundwater resource of Changwat Nakhon Phanom

(Source: Phiromlert and others, 1996)

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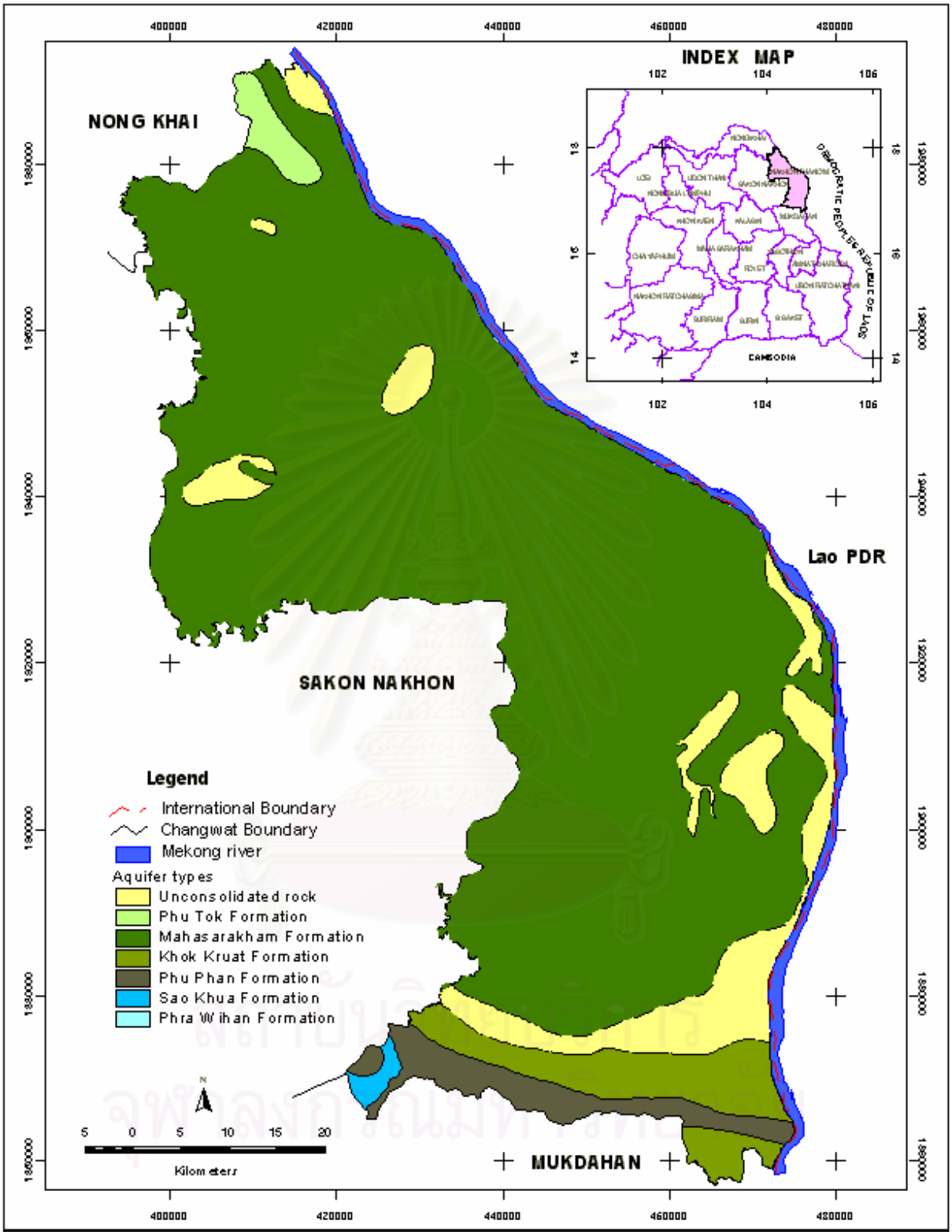

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Figure 2.18 Aquifer type of grourndwater of Changwat Nakhon Phanom

(Source: Phiromlert and others, 1996)

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2.3) Khok Kruat Formation: sandstone, siltstone, shale and lime-noduled conglomerate. The groundwater is stored in fractures, jonts and bedding planes, within the depth of water table about 30-40 metres. The piezometric level is about 5-8 metres in some places.

2.4) Phu Phan Formation: sandstone, pebbly sandstone and siltstone. The groundwater occurs in fractures, joints, bedding planes and weathered zones with average depth of water table about 20-50 metres. Some places, the depth of water table are 4-7 metres.

2.5) Sao Khua Formation: shale, siltstone, sandstone, and lime-noduled conglomerate. The groundwater is stored in fractures, joints, bedding planes and weathered zones.

2.6) Phra Wihan Formation: sandstone, siltstone, shale, and conglomerate. The groundwater is confined in fractures, joints, bedding planes.

2.2.5 Existing Land use

According to data and information obtained from the Department of Land Development (Singhawat, Putthitapnarin, and Mahareonchrong, 2531, in Thai), the land use pattern of Changwat Nakhon Phanom can be classified into four groups as follows:

i) Urban and built-up area:

Urban and rural settlements occupy a small part of the total land area of Changwat Nakhon Phanom, which are further subdivided into residential, commercial, industrial, transportation and communication, and institutional lands. This category of land use covers approximately 2.619 per cent of the total area.

ii) Agriculture area:

The largest group of land use is the agriculture area mainly covered by the paddy fields. The other agricultural areas are covered by field crops, orchards, horticulture, animal farm houses, and aqua-culture areas. This group of land use covers approximately 49.361 per cent of the total area.

iii) Forest area:

The forest areas of Changwat Nakhon Phanom, which are further subdivided into evergreen forest, deciduous forest and forest plantation. This category of land use covers approximately 40.465 per cent of the total area.

iv) Water area:

This water areas of Changwat Nakhon Phanom, which are also further subdivided into natural water resources, such as, Mae Nam Songkham, Nam Kam, Nam Yam, Nam Un, and built-up water resources, such as, Bung Mo, Chieng Yun, Phu Kratae, Nong Yat, Som Hong, Huai Bung, Kan Luang, Huai Si Khun, Rong Kra Bao. The total area of water bodies cover approximately 2.714 per cent of the total area.

v) Miscellaneous area:

The miscellaneous area, covers range land, wet land, rocky land, and laterite pit. This group of land use covers approximately 4.841 per cent of the total area.

The details of various types of land use are summarised in Table 2.4, and the land use map of Changwat Nakhon Phanom is presented in Figure 2.19.

Table 2.4 Existing land use of Changwat Nakhon Phanom (Singhawat, Putthitapnarin, and Mahareonchrong, 2531, in Thai)

Type of land use	Area	
	Rai	Per cent (%)
1. Urban and build-up land	**89,054**	**2.619**
City, town and commercial land	6,300	0.185
Village, institutional land, transportation land, industrial land	82,754	2.434
2. Agricultural land	**1,678,170**	**49.361**
Paddy field	1,391,658	40.933
Field crops	280,821	8.260
Orchards	5,038	0.149
Horticulture	526	0.015
Animal farm houses	52	0.002
Fishery	75	0.002
3. Forest land	**1,375,771**	**40.465**
Evergreen forest	103,075	3.032
Deciduous forest	1,272,412	37.425
Forest plantation	284	0.008
4. Water body	**92,274**	**2.714**
Natural water resources	80,391	2.365
Built-up water resources	11,883	0.349
5. Miscellaneous land	164,597	4.841
Range land	145,105	4.268
Wet land	13,806	0.406
Rocky land	5,233	0.154
Laterite pit	456	0.013
Total	**3,445414**	**100**

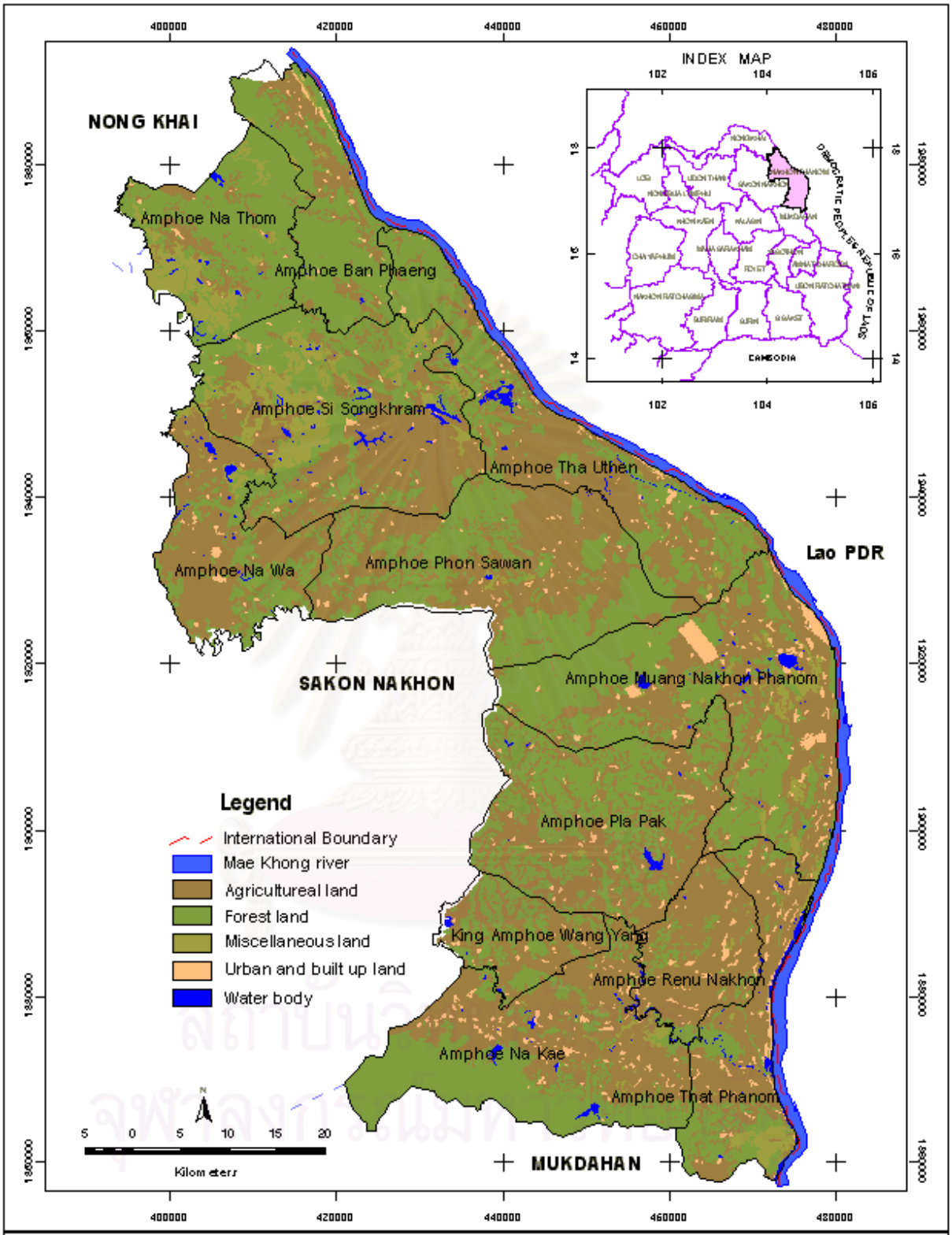

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Figure 2.19 Land use map (year B.E.2531) of Changwat Nakhon Phanom

(Source: Singhawat, Putthitapnarin, and Mahareonsong, 2531, in Thai)

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2.2.6 Soil Characteristics

From the Department of Land Development (in Thai, Survey Division and Classification Soil, 2530), the types of soil and landforms they occupy are usually well related. The various mapping units of soil are grouped according to general physiographic characteristics and their patterns as follows:

i) Bangnara Series (Ba)

Bangnara series is a member of clayey, kaolinitic family of Typic Paleaquults. They are formed from relatively old alluvium and occur in transitional areas between the low terrace and the alluvial plain proper and poorly drained soils. Mainly used for transplanted rice.

ii) Borabu Series (Bb)

Borabu series is a member of fine-loamy over skeletal, mixed family of Aquic Plinthustults. They are formed from old alluvium overlying a sandstone and occur on middle and high terraces and moderately well drained soils. Mainly covered by low poen dipterocarp forest.

iii) Chiang Rai Series (Cr)

Chiang Rai series is a member of clayey kaolinitic family of Phinthic Paleaquults. They are formed on semi-recent alluvium and occur on semi-recent terraces and poorly drained soils. The soils are mainly used for transplanted rice cultivation.

iv) Chumsaeng Series (Cs)

Chumsaeng Series is a member of fine, kaolinitic acid family o fAeric Plinthic Tropaquepts. They are formed from recent alluvium and occur in the valley bottom of

tributary streams and the higher parts of alluvial plains and poorly drained soils. Mainly used of transplanted rice clutivation.

v) Doembang Series (Db)

Doembang series is a member of fine, kaolinitic family of Aeric Plinthic Tropaqualfs. They are formed from old alluvium and occur on the low lying parts of local, coalescing alluvial fans and somewhat poorly drained soils. Mainly used for transplanted rice cultivation.

vi) Khok Khain Series (Ko)

Khok Khian series is a member of fine-loamy, mixed family of Typic Paleaqullts. They are formed from relatively old alluvium and occur on the lower part of low terraces. Poorly drained with show surface runoff. Mainly used for transplanted rice.

vii) Khorat Series (Kt)

Khorat series is a member of fine-loamy, siliceous family of Oxic Paleustults. They are formed old alluvium and occur on middle terraces. Moderately well drained soils, originally dry dipterocarp forest and mixed deciduous forest.

viii) Khao Yoi Series (Kyo)

Khao Yoi series is a member of fine-loamy, mixed family of aeric Tropaqualfs. They are formed from old alluvium and occur on low terraces. Somewhat poorly drained soils. Mainly used for transplanted rice cultivation.

ix) Manorom Series (Mn)

Manorom series is a member of clayed, kaolinitiic family of Aeric Paleaqullts. They are formed from semi-recent alluvium and occur on the lower parts of the semi-recent terraces and somewhat poorly drained soils. Mainly used for transplanted rice culltivation.

x) Nakhon Phanom Series (Nn)

Nakhon Phanom series is a member of clayed, mixed family of Aeric Plinthic Paleaquults. They are formed from relatively old alluvium and occur on the lower parts of the semi-recent terrances and the low terraces. Poorly drained soils. Mainly used for transplanted rice.

xi) Nakhon Pathom Series (Np)

Nakhon Pathom series is a member of fine, mixed family of Aeric Tropaqualfs. They are formed from semi-recent alluvium and occur on low terraces and somewhat poorly drained soils. Mainly used for transplanted rice cultivation.

xii) On Series (On)

On series is a member of clayed-skeletal, kaolinitic family of Oxic Plinthaquults. They are formed from old alluvium and occur on the low terraces and poorly drained soils. Used for transplanted rice.

xiii) Phak Kat Series (Pat)

Phak Kat series is a member of fine, mixed family of Aeric Tropaqualfs. They are formed from relatively old alluvium and occur on alluvial fan (coalescing fans) and valley filled and somewhat poorly draine soils. Mainly used for transplanted rice.

xiv) Phan Series (Ph)

Phan series is a member of fine, kaolinitic family of Plinthic Tropaqualfs. They are formed from alluvium and occur on semi-recent terraces and poorly drained soils. Mainly used for transplanted rice cultivation.

xv) Phimai Series (Pm)

Phimai series is a member of very-fine, mixed nonacid family of Vertic Tropaquepts. They are formed from alluvium (recent or semi-recent) and occur on river basin and backswamp areas of flood plains and poorly drained soils. Mainly used for transplanted and broadcast rices and some are covered by grasses and shrubs.

xvi) Phen Series (Pn)

Phen series is a member of clayey-skeletal, family of Typic Plinthaquults. They are formed from old alluvium and occur in the shallow depressions of the middle terraces and poorly drained soils. Mainly used for transplanted rice with some scattered dipterocarp spp.

xvii) Phon Phisai Series (Pp)

Phon Phisai series is a member of clayey-skeletal, mixed family of Typic Plinthustults. They are formed from old alluvium and occur an middle terraces. Moderately well drained. Mainly in low open disterocerp forest with some shrubs.

xviii) Ratachaburi Series (Rb)

Ratachaburi series is a member of fine, mixed, nonacid family of Aeric Tropaquepts. They are formed from recent alluvium and occur on the transition between levees and river basins. Somewhat poorly drained. Mainly used for broadcast rice cultivation.

xix) Roi Et Series (Re)

Roi Et series is a member of fine-loamy, mixed family of Aeric Paleaquults. They are formed from old alluvium and occur on the low terraces. Poorly drained soils. Used for transplanted rice in the wet season.

xx) Renu Series (Rn)

Renu series is a member of fine-loamy of Aeric Plinthic Paleaquults. They are formed from old alluvium and occur on the low terraces. Somewhat poorly drained soils. Mainly used for transplanted rice in the wet season.

xxi) Sakon Series (Sk)

Sakon series is a member of loamy-skeletal, mixed family of Petroferric Haplustults. They are formed from old alluvium over sheet of laterite and occur on low and middle terraces. Somewhat poorly drained soils. Mainly low open disterocarp forest and used for constructing material.

xxii) San Pa Tong Series (Sp)

San Pa Tong series is a member of coarse-loamy, mixed family of Oxic Paleustults. They are formed from old alluvium on the older terraces and fans. Well drained. Originally under mixed deciduous forest; but large areas have been cleared for shifting cultivation of various upland crops such as ground-nuts, soybeans, upland rice and corn.

xxiii) Si Songkhram Series (Ss)

Si Songkhram series is a member of fine, mixed, acid family of Vertic Tropaquepts. They are formed from alluvium (recent) and occur an river basin and poorly drained soils. Natural grass land and some scottered shrub and bamboo.

xxiv) Si Thon Series (St)

Si Thon series is a member of fine-loamy mixed, nonfamily of Aeric Tropaquepts. They are formed from alluvium and occur on valley flats of streams. Poorly drained soils. Used for transplanted rice in the wet season.

xxv) Satuk Series (Suk)

Satuk series is a member of fine-loamy, siliceous family of Oxic Paleustults. They are formed from old alluvium and occur on the middle and high terraces. Well drained soils. Mainly dipterocarp and mixed deicuduous forest with parts cleared for the cultivation of upland crops such as kenaf, water melon, beans, corns, etc.

xxvi) Tha Uthen Series (Tu)

Tha Uthen series is a member of coarse-loamy over clayey, silicous family of Entic Tropaquods. They are formed from old sandy alluvium overlying ironstone layer and clayey alluvium and occur on the low and middle terraces and moderately well drained soils. Mainly under mixed deciduous forest with some shifting cultivation.

xxvii) Warin Series (Wn)

Warin series is a member of fine-loamy, siliceous family of Oxic Paleustults. They are formed from old alluvium and occur on the middle and high terraces. Well drained soils.

Originally mixed deciduous forest and dipteracarp forest. Parts are cleared for upland crops such as corn, cotton, sugar cane, kenaf, water melon, and some fruit crops such as pineapple, custard apple etc.

The map showing soil characteristic of soils (in Thai, Survey Division and Classification Soil, 2530) in Changwat Nakhon Phanom is presented in Figure 2.20.

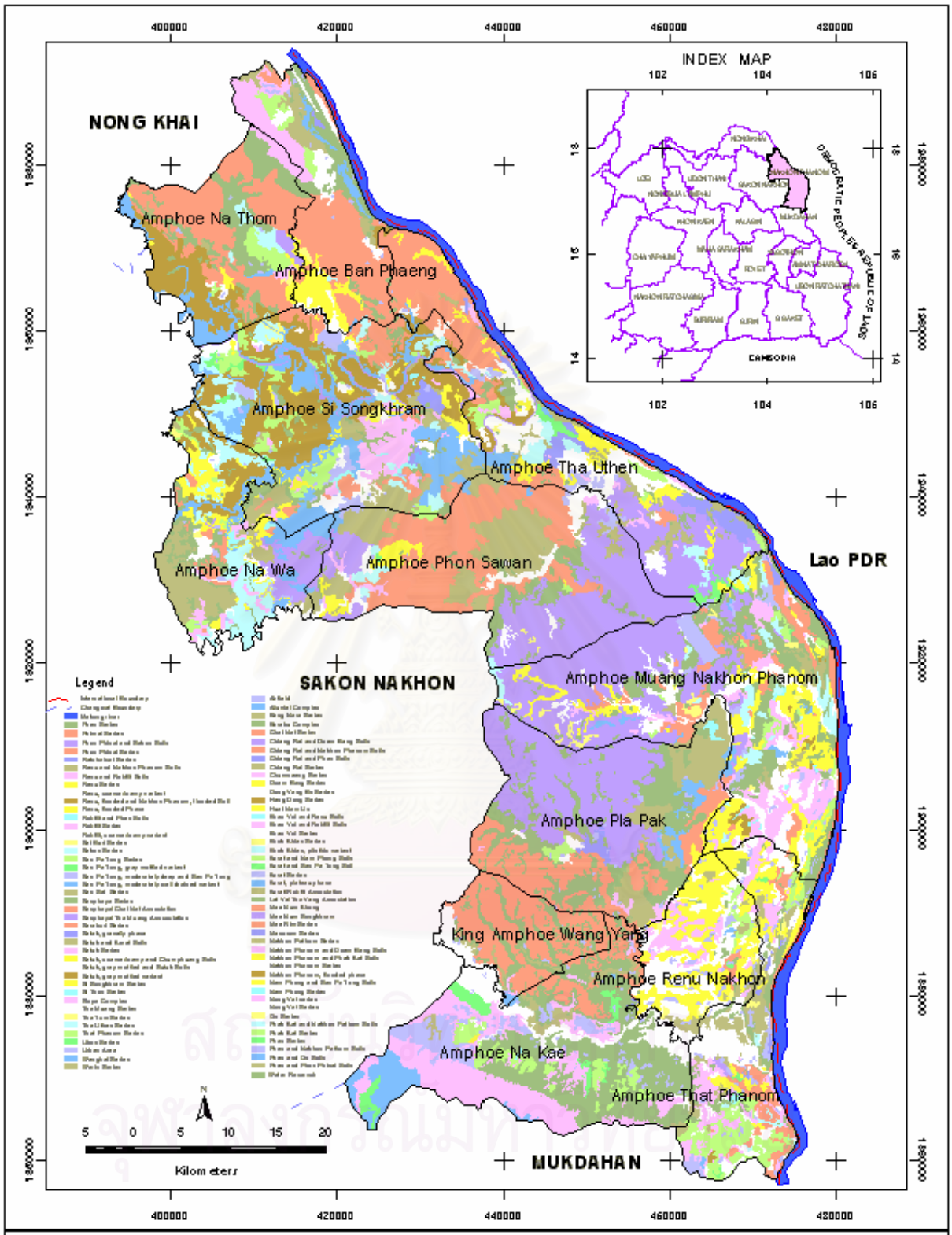
2.3 Geological hazards

2.3.1 Flood prone area

From the beginning of civilization, people have tended to live by the water's edge-beside streams, rivers, or lakes. Land adjacent to water has traditionally offered many advantages to settlers. An advantages at first were necessary for survival and later were conducive to development. Those advantages include fertile soil; access water, flood, energy, and other resources; and transportation routes. River valleys, in particular, are the favorite localities for human settlement because valley floors are flat and easy to build on and the soils typically are deep and arable. But living by the water's edges has some disadvantages. The most obvious disadvantage is the repeated threat of flooding.

A flood occurs when the level of water rises until it overflows its natural or artificial confines and submerges land in the surrounding area. Because the human tend to develop and inhabit in such land, floods can take a big loss of life and damage of structures. This is especially true in less developed countries where factors such as population density; absence of strict zoning regulations; and lack of effective response, control, and early warning systems combine to increase the risks associated with flooding.

Flooding in the study area has occurred in every year and it would be harmful in every decade. Form the past records which was recorded by Department Local Administration. The flood occurred where elevation is lower than 150 meters above MSL



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 2.20 Soil map of Changwat Nakhon Phanom

(Source: Survey Division and Classification Soil, 2530, in Thai)

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and in low permeability soil. Areas with a vulnerability of flood are at Mae Nam Songkhram basin in the northern part and Huai Nam Kam basin in the southeastern part along the Mekong river. As a result of flooding occurring in every year, a map of flood prone area was made in this study from analysing of the geomorphologic map, and the soil map as shown in Figure 2.21.

2.3.2 River bank erosion in the study area

The riverbank erosion is the geologic process that cause the meandering of the river. This process is often occur at the outer bank or erosional bank of the river. The erosional sediments will deposit at the inner bank as shown in Figure 2.22.

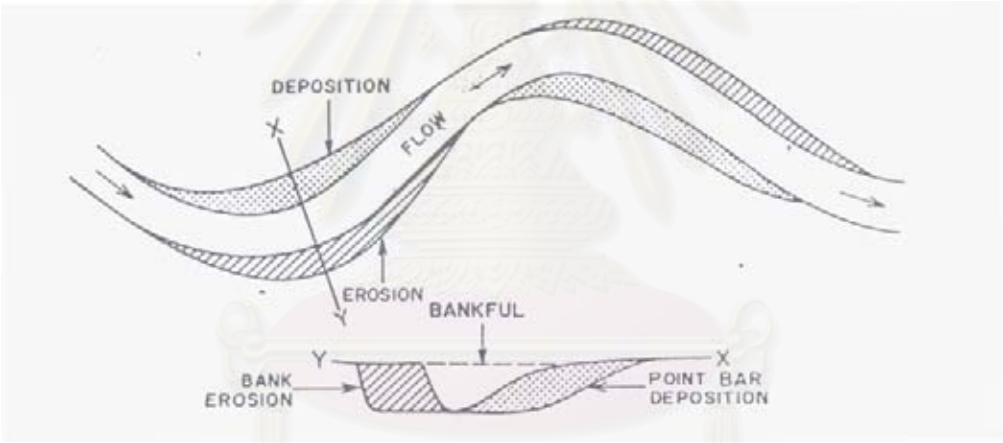
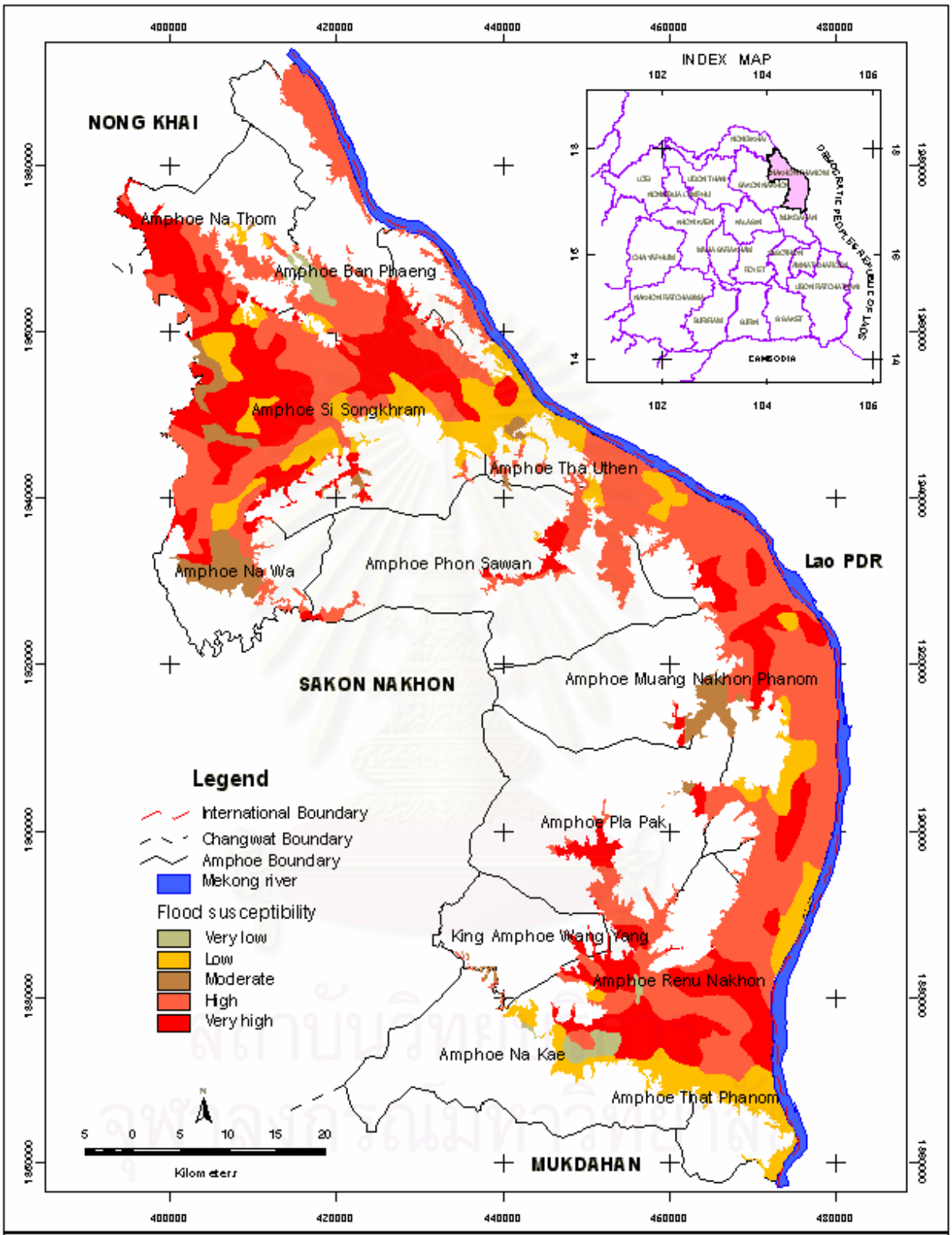


Figure 2.22 Sketch illustrating erosion and deposition on a section of a meandering stream. Such a process of channel erosion and deposition keeps the channel at a constant width (Neill and Galay, 1967)

Because Changwat Nakhon Phanom is situated in the Mekong river bank, there is an erosion problem along the river banks. Areas with a susceptibility of riverbank erosion are at Amphoe Ban Pang, Amphoe That Phanom, and Amphoe Muang Nakhon Phanom which is the very important area for commercial and economic activities. The



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 2.21 Flood prone area of Changwat Nakhon Phanom

(Source: 1. Royal Thai Survey Division, no date, in Thai)

2. Survey Division and Classification Soil, 2530, in Thai

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igh erosion zones and some important areas. A map of riverbank erosion was prepared base on topographic maps at the scale of 1:50,000 and presented in Figure 2.23.

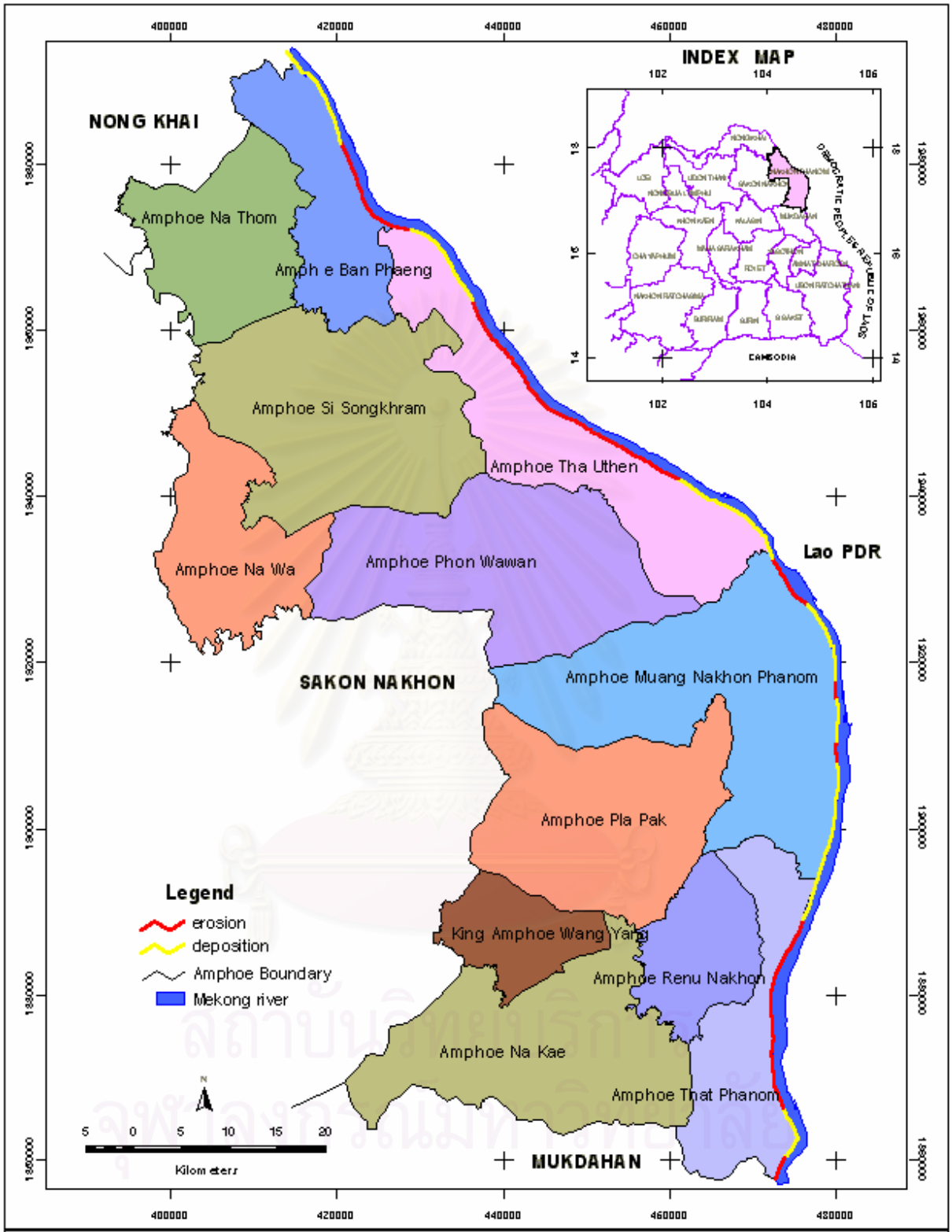
2.4 Environmental geologic data of Changwat Nakhon Phanom

The fundamental in formation of environmental geology of Changwat Nakhon Phanom is digitally provided in maps scales 1:50,000, 1:100,000 and 1:250,000 by the government sectors. All map project is in the Universal Transverse Mercator (UTM). The results of this study are shown in regional scale (Table 2.5) which is suitable for the presentation. Environmental geology data (Table 2.6) used is divided into 3 main groups as follows: 1) Socio-economic condition which is consist of administration map, population, education, religion, health services, transportation, electricity, water supply, and economy 2) Physical environment which is compose of climate, topography and landform map, geological map, surface water map, groundwater map, land use map, and soil map. 3) Geological hazards are comprise flood prone area map, and river bank erosion map.

Table 2.5 Some example of scales of presentation of environmental geologic maps (Marker and McCall, 1989)

Level of treatment	Example scales
National	1:1,000,000-1:625,000
Regional	1:625,000-1:100,000
Area	1:100,000-1:10,000
Site*	1:2,500-1:1,250

* Outside the field of environmental geology



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 2.23 Riverbank erosion of Changwat Nakhon Phanom

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Table 2.6 Thematic data and their sources of Changwat Nakhon Phanom

Thematic map	Data source	Digital Sources	Scale	Spatial element
Amphoe and King Amphoe administration areas map of Changwat Nakhon Phanom (Figure 2.1)	Royal Thai Survey Division (in Thai, no date) Nakhon Phanom Province Statistical Office (in Thai, 2544)	Department of Environmental Quality Promotion (2000)	1:50,000	polygon
Population density of Changwat Nakhon Phanom (Figure 2.2)	Royal Thai Survey Division (in Thai, no date)	not available	1:50,000	polygon
	Nakhon Phanom Province Statistical Office (in Thai, 2544)	not available		
Road system of Changwat Nakhon Phanom (Figure 2.4)	Royal Thai Survey Division (in Thai, no date)	Department of Environmental Quality Promotion (2000)	1:50,000	line
Natural beauties and tourist attraction of Changwat Nakhon Phanom (Figure 2.5)	Royal Thai Survey Division (in Thai, no date), Tourist Authority of		1:50,000	point
	Thailand , Nakhon Phanom province statistical office (in Thai, 2544)	Department of Environmental Quality Promotion (2000)		
Isohyetal map of Changwat Nakhon Phanom (Figure 2.12)	Meteorological Department (2001)	not available	1:250,000	polygon
Hypsometry map of Changwat Nakhon Phanom (Figure 2.13)	Royal Thai Survey Division (in Thai, no date)	not available	1:50,000	polygon
Slope map of Changwat Nakhon Phanom (Figure 2.14)	Department of Environmental Quality Promotion (2000)	Department of Environmental Quality Promotion (2000)	1:50,000	polygon
Geological map of Changwat Nakhon Phanom (Figure 2.15)	Modified from Department of Mineral Resources (1985)	Department of Environmental Quality Promotion (2000)	1:250,000	polygon
Surface water resource of Changwat Nakhon Phanom (Figure 2.16)	Royal Thai Survey Division (in Thai, no date)	Department of Environmental Quality Promotion (2000)	1:50,000	line/ polygon
Groundwater resource of Changwat Nakhon Phanom (Figure 2.17)	Department of Mineral Resources	Phiromlert and others (1996)	1:100,000	polygon
Aquifer type of groundwater of Changwat Nakhon Phanom (Figure 2.18)	Department of Mineral Resources	Phiromlert and others (1996)	1:100,000	polygon
Land use map of Changwat Nakhon Phanom (Figure 2.19)	Land Development Department	Department of Environmental Quality Promotion (2000)	1:100,000	polygon
Soil map of Changwat Nakhon Phanom (Figure 2.20)	Land Development Department	Department of Environmental Quality Promotion (2000)	1:100,000	polygon
Flood prone area map of Changwat Nakhon Phanom (Figure 2.21)	Royal Thai Survey Division (in Thai, no date)	Department of Environmental Quality Promotion (2000)	1:50,000	polygon
	Land Development Department	Department of Environmental Quality Promotion (2000)	1:100,000	polygon
Riverbank erosion of Changwat Nakhon Phanom (Figure 2.23)	not available.	not available	1:100,000	line

CHAPTER III

EXISTING DEVELOPMENT PLANS OF CHANGWAT NAKHON PHANOM

At present, there are many plans and projects related to the development of Changwat Nakhon Phanom in many aspects. Three important interested plans are reviewed and presented shown as follows:

3.1 The Nakhon Phanom governor's office plans

In 2002, the governor's office has formulated the 5-year (2002-2006) a strategic plan for Changwat Nakhon Phanom. Under the plan, three development strategies have been outlined as follows:

a). Economic and infrastructure aspect

- To be the center of economic, trade, and investment.
- To be the center of tourism in the subregion. Changwat Nakhon Phanom is relatively rich in natural, cultural, and historical resources that provide enormous potential for tourism development.
- To improve the transportation network in the subregion.
- To promote SMEs and household industries in order to reduce unemployment problem and increase the community strength.
- To develop infrastructure in order to support sustainable economic development.

b). Social and life quality

- To promote Changwat Nakhon Phanom to be the center of education and human resource development.
- To improve safety, security, and life quality standards.

c). Environment and natural resources management

● To develop Changwat Nakhon Phanom be an attractive place of fascinate geography, pollution free and Thailand's conservative eco-tourism area.

● To construct the irrigation system for sustainable agriculture development.

3.2 The ninth national social and economic development plan (2002-2006)

The Office of the NESDB's main function is to formulate the National Economic and Social Development Plan to be the guideline for National Development. The Ninth Plan formulation process was initiated at the end of 1999. This plan will be in a continuation with the Eighth Plan and the 1997 constitution which is focusing on the public participation in every sector of society has been taken into consideration for national development planning. The ninth plan development vision framework (2002-2006) was approved by the cabinet on August 1, 2000, which can be summarised as follows :

Vision

The vision of future Thai society should be based on Thai culture and conservation of Thai identity to promote change and desirable values of the Thai society in three areas; namely;

a). "Quality society": based on balance and self-sufficiency concepts. The people should be good citizen and efficient with self-reliance and high moral standard.

b). "Wisdom society": The people should have life-long commitment to the learning processes and be ready for changes.

c). "Harmoneious society" will be created through the promotion of national culture identity, generosity and helpfulness, especially to underprivileged group of the society and strengthening self-reliance community for well-being of the Thai society.

Development strategies

The development strategies are divided into three inter-related approaches. Firstly, the enhancement of the capability for the grass-root level should be strengthened and be

ready to face the globalised world. This approach will focus on human, community and societal development. Secondly, the economy should be readjusted to suit the current world situation and the new economy. Thirdly, the governance for management system should be improved in every part of the society through prioritising the strategies and development guidelines associated with poverty alleviation and enhancing more efficiency of management system gained from brainstorming of every group of the society. In so doing, the existing capital will be fully utilized in line with the limited resources. The development strategies may be summarised as follows.

Strategy 1 : Human resource development and social protection

This strategy aims at developing the life-long learning process through educational reform and skill development.

Strategy 2 : Restructured rural development and sustainable urbanisation

The area management should be focusing on the connection between rural and urban development so as to reduce gaps between rural and urban areas.

Strategy 3 : Management of natural resources and environment

This strategy aims at managing environment and natural resources rehabilitation. This will be emphasis on enhancing the efficient management and public participation along with sharing costs and building appropriate rules and regulations which facilitate the balanced ecology system and the whole society.

Strategy 4 : Macro-economic management

This approach focuses on macro-economic management in terms of monetary policy, capital market and public finance policy. This guideline will create the stability and security for economic system under the liberalised trade, finance and investment.

Strategy 5 : International competitiveness

The production structure should be made to increase the competitiveness of the country through utilising modern knowledge and technology to increase productivity, improving

labor skills and creating links among the activities in agriculture, industry and service sector.

Strategy 6 : Strengthening science and technological base

Science and technology should be strengthened and modernised. Degree of dependence should be reduced. Access to appropriate technology should be more equitable. This will enhance the competitiveness in future through developing body of knowledge in association with local wisdom in the context of Thai culture and folkways. Moreover, the basic concept of science, investment, human resource development, innovation, as well as policy design and research management should be given more priority.

Strategy 7 : Development management for good governance

This is a key strategy with particular emphasis on transparency and public participation. This approach will help to prevent the corruption and determine the direction of development for the poor and the underprivileged. However, the good governance approach and the public participation will streamline collaborative efforts for changes.

3.3 Greater Mekong Subregion (GMS)

The Greater Mekong Subregion (GMS) comprises Cambodia, Lao People's Democratic Republic, Myanmar, Thailand, Vietnam, and Yunnan Province of the People's Republic of China. The program has contributed to the development of infrastructure to enable the development and sharing of the resource base, and promote the free flow of goods and people in the subregion. It has also led to the international recognition of the subregion as a growth area. This GMS program is a major existing international movement that promotes integration of the Indochina into one regional economy.

In Thailand, it comprises 19 Changwats, within 3 regions: 9 Changwats of the northern region: Chiang Mai, Chiang Rai, Phayao, Mae Hong Son, Lampang, Lamphun, Phrae, Nan, and Tak; 8 Changwats of the northeastern region: Nakhon Phanom, Loei, Sakon

Nakhon, Nong Khai, Udon Thani, Amnat Charoen, Ubon Ratchathani, and Mukdahan; and 2 Changwats of the eastern region: Prachinburi, and Sa Kaeo.

The GMS countries have identified and prioritised almost 100 projects in these eight sectors, notably,

- **Energy:** An integrated power development approach brings about environmental benefits through reduced emissions from hydrocarbon fuels with the substitution of oil-fired plants by hydropower. The integrated approach will also allow for more optimal utilisation of indigenous resources. It will also better equip the GMS countries in addressing environmental and socioeconomic concerns arising from cumulative impacts of hydropower development. Cooperation in the energy sector under the GMS Program thus focuses on the optimal utilisation and development of the region's energy potential and provision of cross-border power transmission links to allow efficient electricity trade. Support initiatives include the establishment of institutional mechanisms within the subregion to support the momentum toward increased cooperation in the field of electric power and natural gas (Figure 3.1).

- **Environment and natural resources management:** The logical basis for subregional cooperation in the environment and natural resources management sector stems from the shared issues and problems faced by the subregion's countries; initiatives taken by one country usually will affect its neighbours. The ecology, geology, and climate are very similar across the subregion, and major features such as the largest rivers and the coastal zone are shared among at least several of the countries. The countries face common socioeconomic issues, such as population control and development without destruction of their natural resource base. Environmental degradation due to deforestation and widespread pollution are common to all. Addressing environmental sustainability includes putting environmental considerations in the forefront of all development decision-making. Subregional cooperation could provide a mechanism for supplementing national efforts at curbing or reversing environmental degradation. While the primary responsibility for environmental protection rests with the national and local

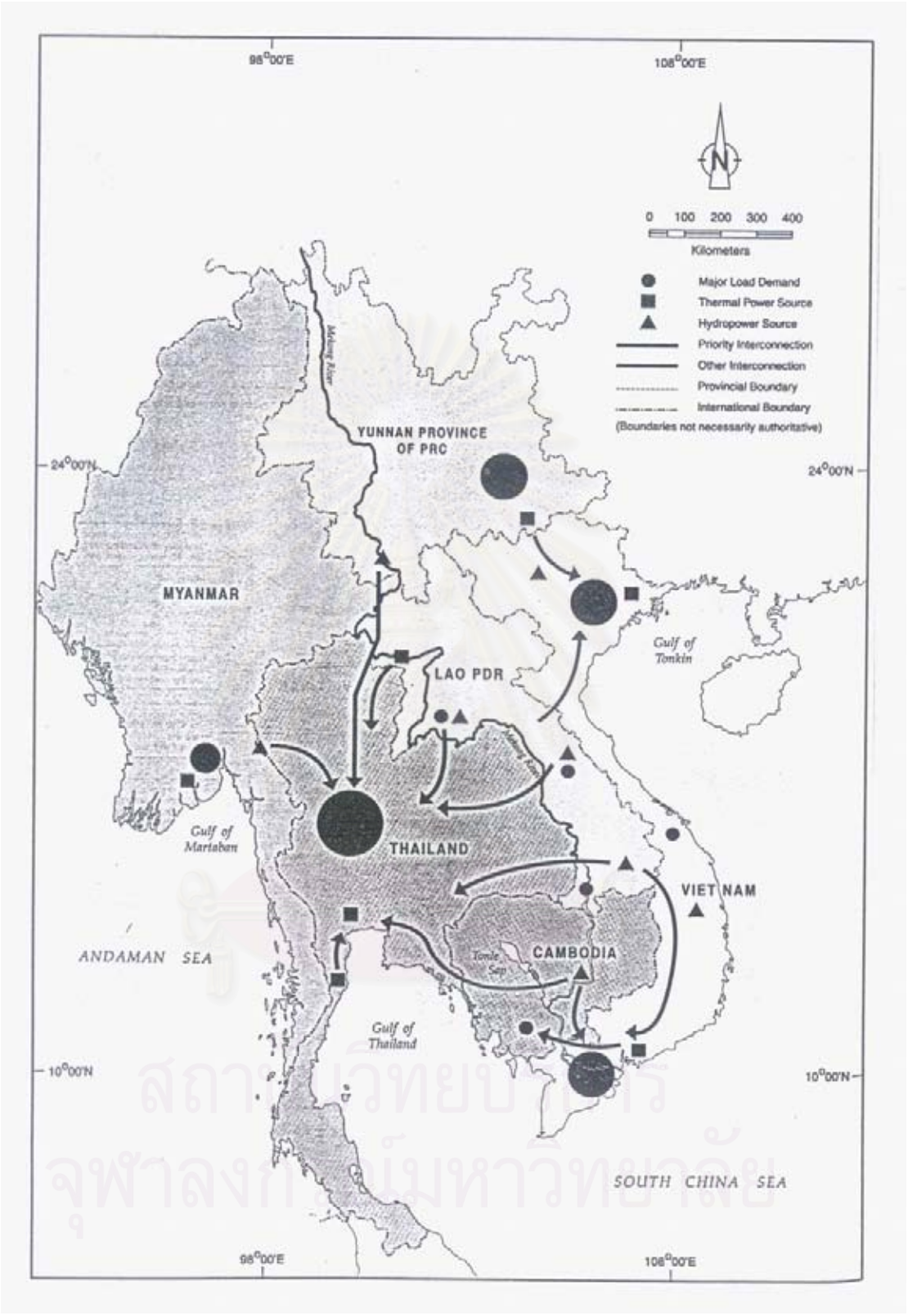


Figure 3.1 Mekong subregional power interchange (NESDB, 2544, in Thai)

governments, cooperation among neighboring countries is critical to resolving negative externalities and protecting shared natural resources.

- **Human resource development (HRD):** There is a need to build up the systems for harmonising the training standards, skills certification, and accreditation of training institutions. Another area in HRD requiring a subregional approach concern health and other social problems associated with mobile population and migration, such as the spread of communicable diseases (e.g., HIV/AIDS), the rights of migrants and guest workers, and the trafficking of women and children.

- **Investment: Foreign direct investment (FDI)** is playing an increasingly important role in the development of the GMS countries as economic reforms move towards greater trade liberalisation and privatisation. An enabling environment conducive to FDI flows combines the friendliness of the policy framework, the economic opportunities available, and the ease of doing business in the country.

- **Telecommunications:** As the economies of the GMS countries grow and develop, there will be increasing demand for expanded telecommunications capacity and capability, including the Internet. This will require that their domestic telecommunications networks have greater complexity and sophistication. Subregional cooperation in the telecommunications sector will give the GMS countries the opportunity to maximise the benefits to be derived from telecommunications technology (Figure 3.2).

- **Tourism:** The GMS is rich in natural, cultural, and historical resources that provide enormous potential for tourism development. The subregion's cultural heritage and varied natural geography make it a desirable single tourism destination (Figure 3.3).

- **Trade:** Trade facilitation initiatives under the GMS Program have taken into account the important role played by ASEAN, especially in the light of expanded membership to include five of the GMS countries (Thailand as a founding member plus Cambodia, Lao PDR, Myanmar and Vietnam). The ASEAN Free Trade Agreement (AFTA) sets a

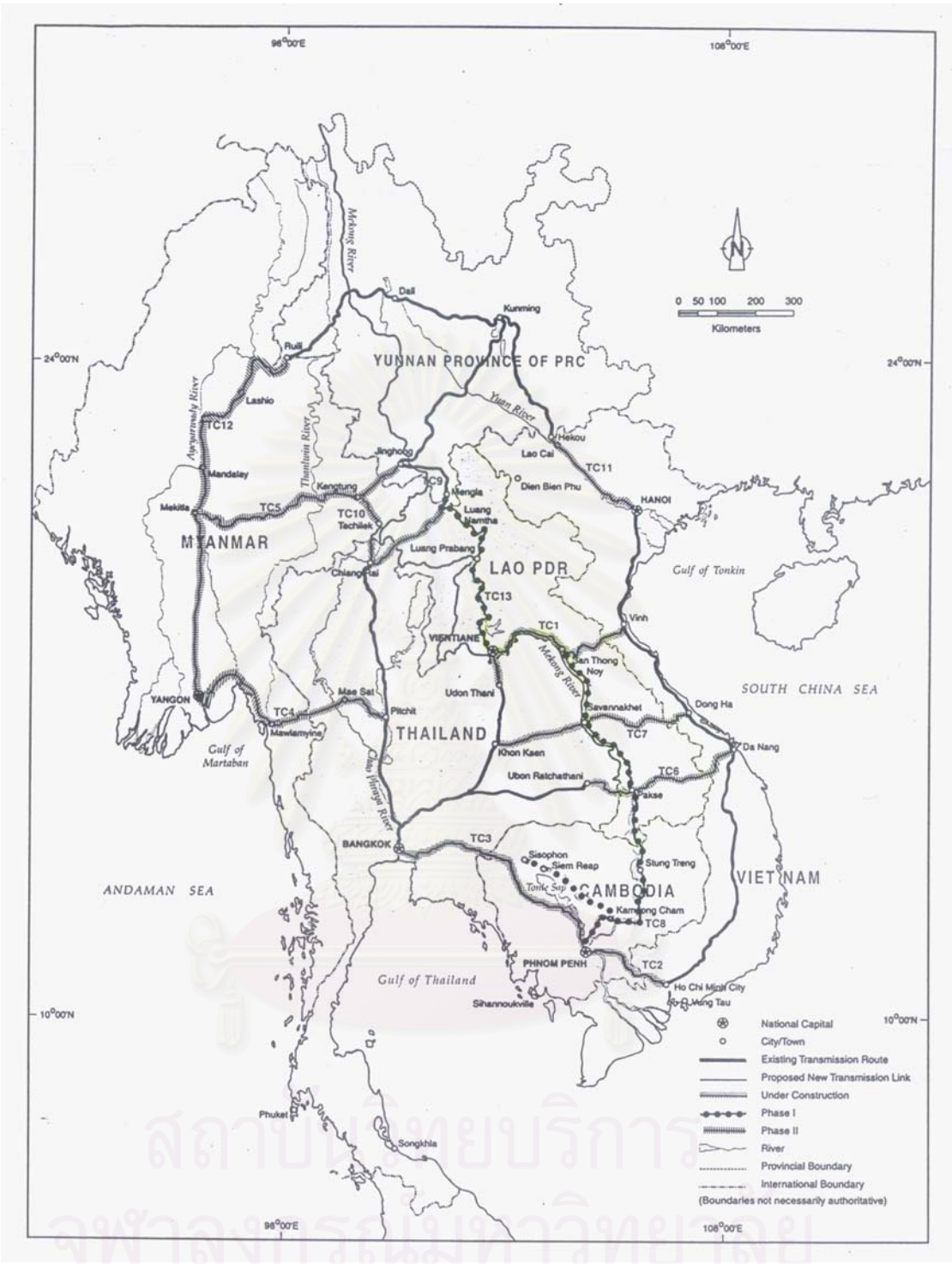


Figure 3.2 Proposed subregional telecommunications network (NESDB, 2544, in Thai)

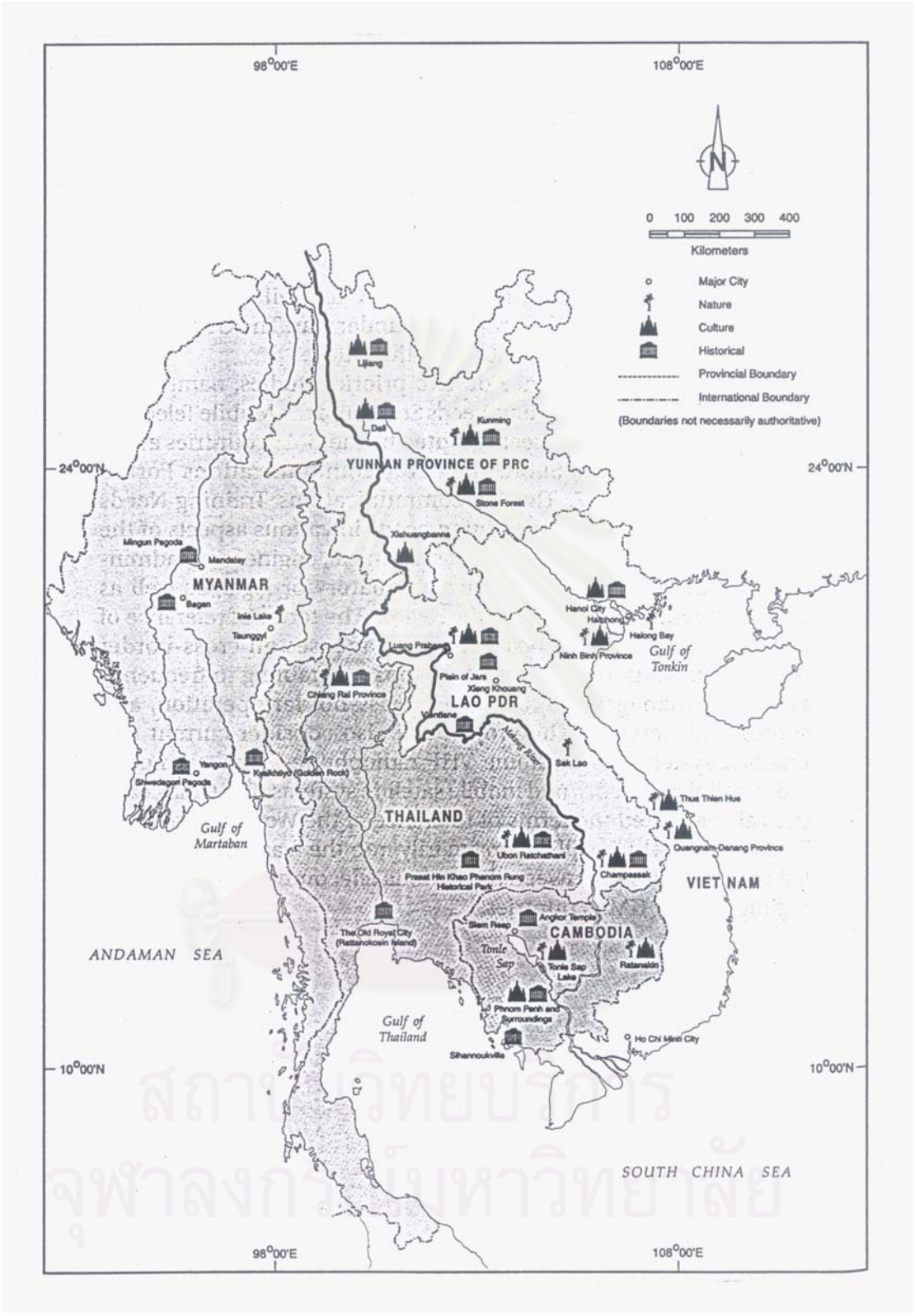


Figure 3.3 Subregional tourism (NESDB, 2544, in Thai)

schedule of tariff reductions that will result in widespread free trade among members by 2010. Other initiatives of ASEAN also bear importantly upon trade liberalisation, including customs harmonisation and the ASEAN Investment Area (AIA).

- **Transport:** Improved transportation linkages within the GMS are central to facilitating increased trade and other forms of economic cooperation. Subregional cooperation in the transport sector supports the national development goals of the GMS countries through the establishment of physical infrastructure linkages and cross-border facilitation measures that would promote trade and investment, enhance labour and social mobility, and increase access to markets and other economic opportunities. Further more, the implementation of priority infrastructure projects is expected to stimulate demand, create jobs, and enhance the competitiveness of the GMS countries, thereby contributing further to promoting pro-poor economic growth.

In addition, the statuses of subregional projects are presented in Figure 3.4, 3.5, 3.6 and 3.7.

The reviews of these development plans lead to the interest in the GMS plan. However, the agricultural development was promoted as an important (NESDB, 2544, in Thai). Because of in the northeastern region on Thailand, the agriculture is a major income of people. Thus, Thai government has tried to promote the agricultural development plan in GMS project.

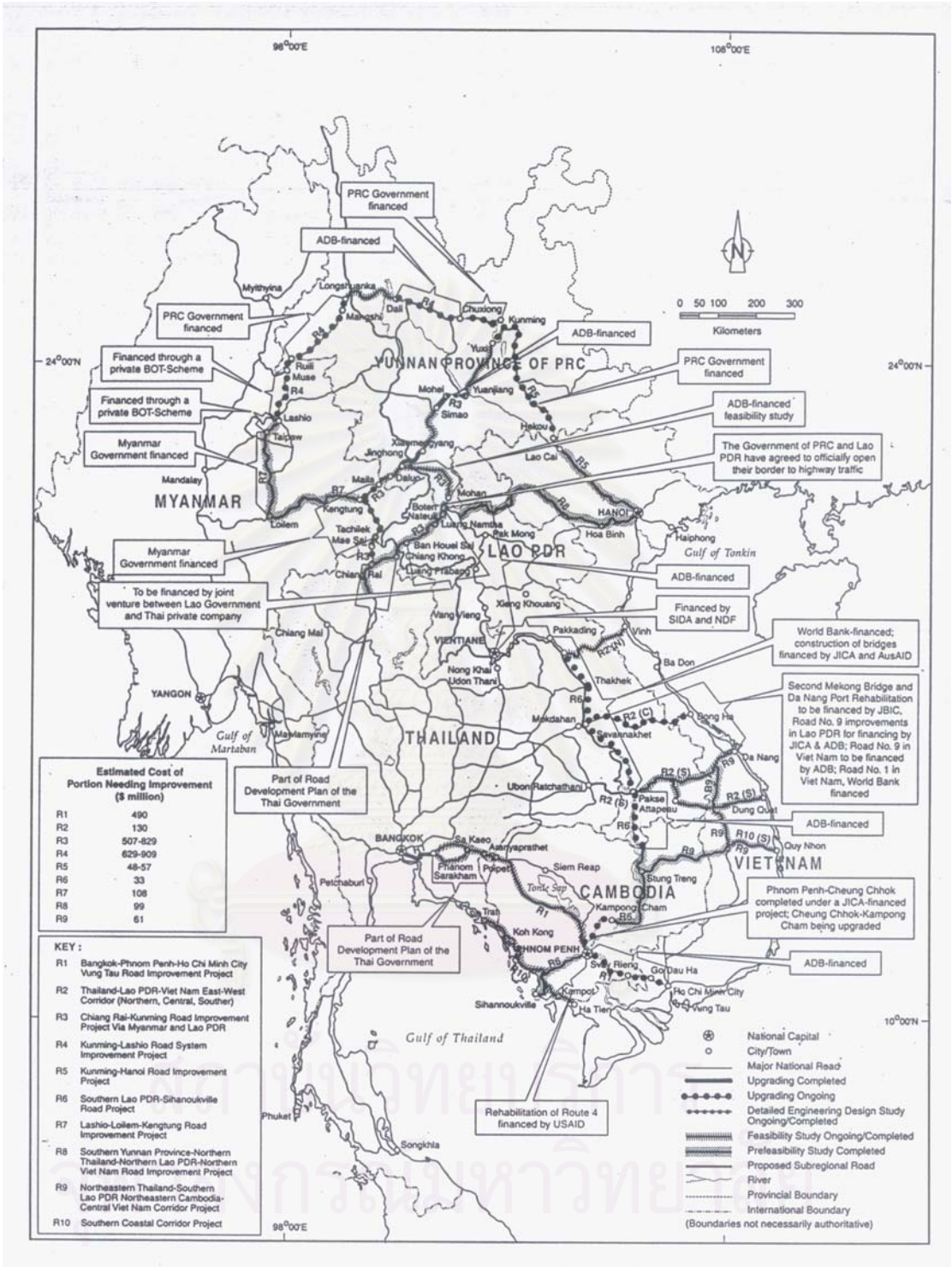


Figure 3.4 Status subregional road projects (NESDB, 2544, in Thai)

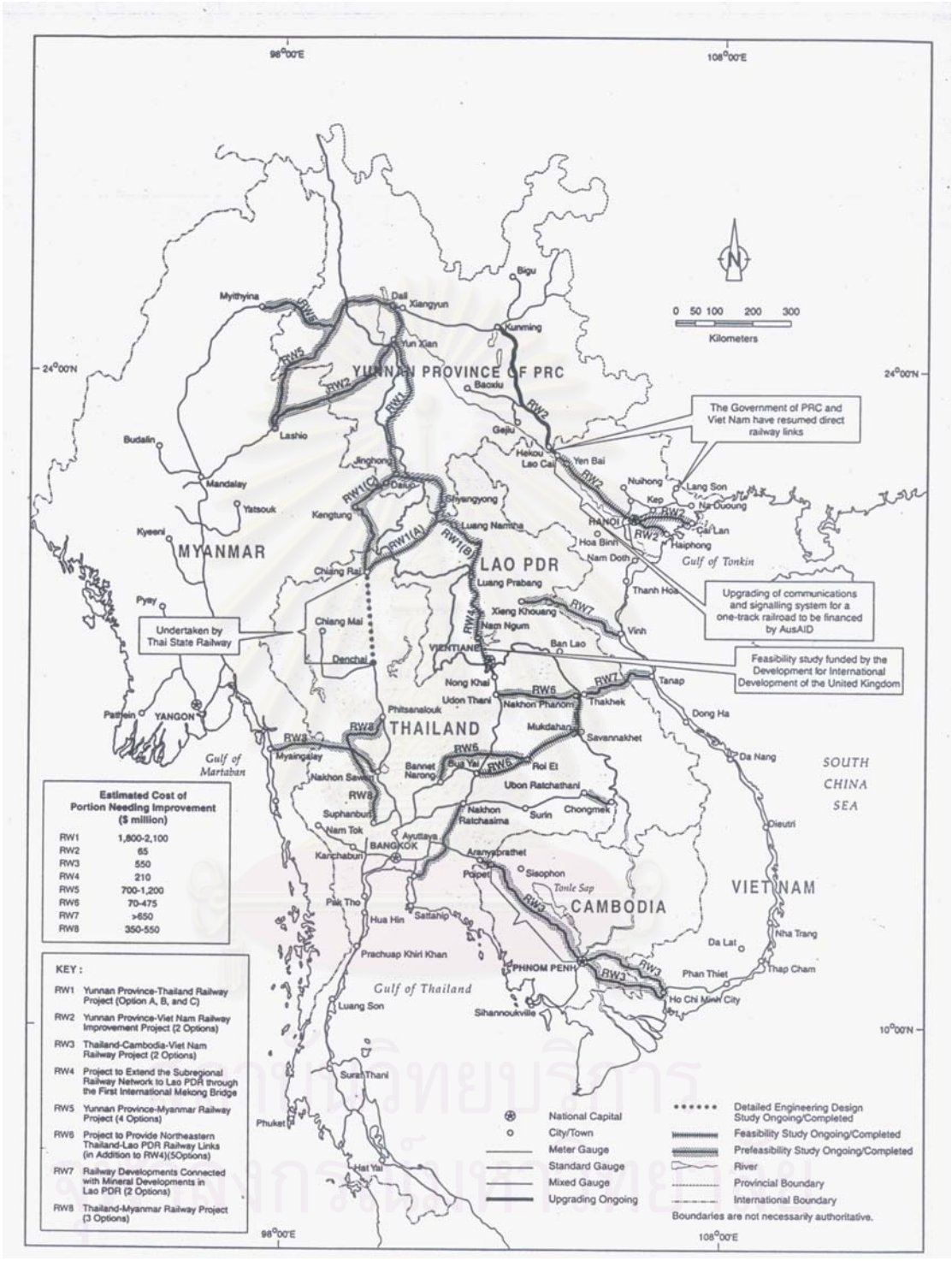


Figure 3.5 Status of subregional railway projects (NESDB, 2544, in Thai)

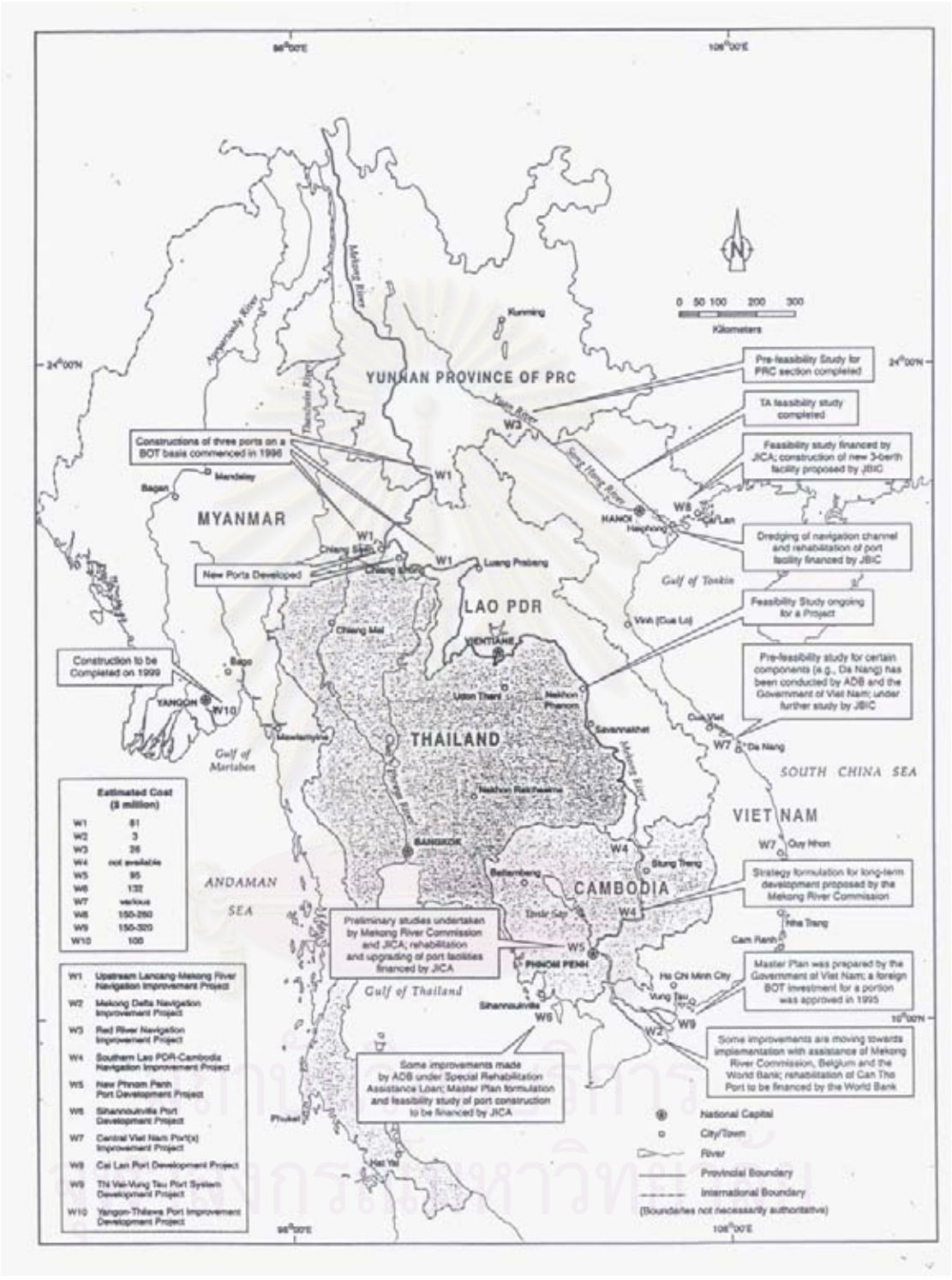


Figure 3.6 Status of subregional water transportation projects (NESDB, 2544, in Thai)

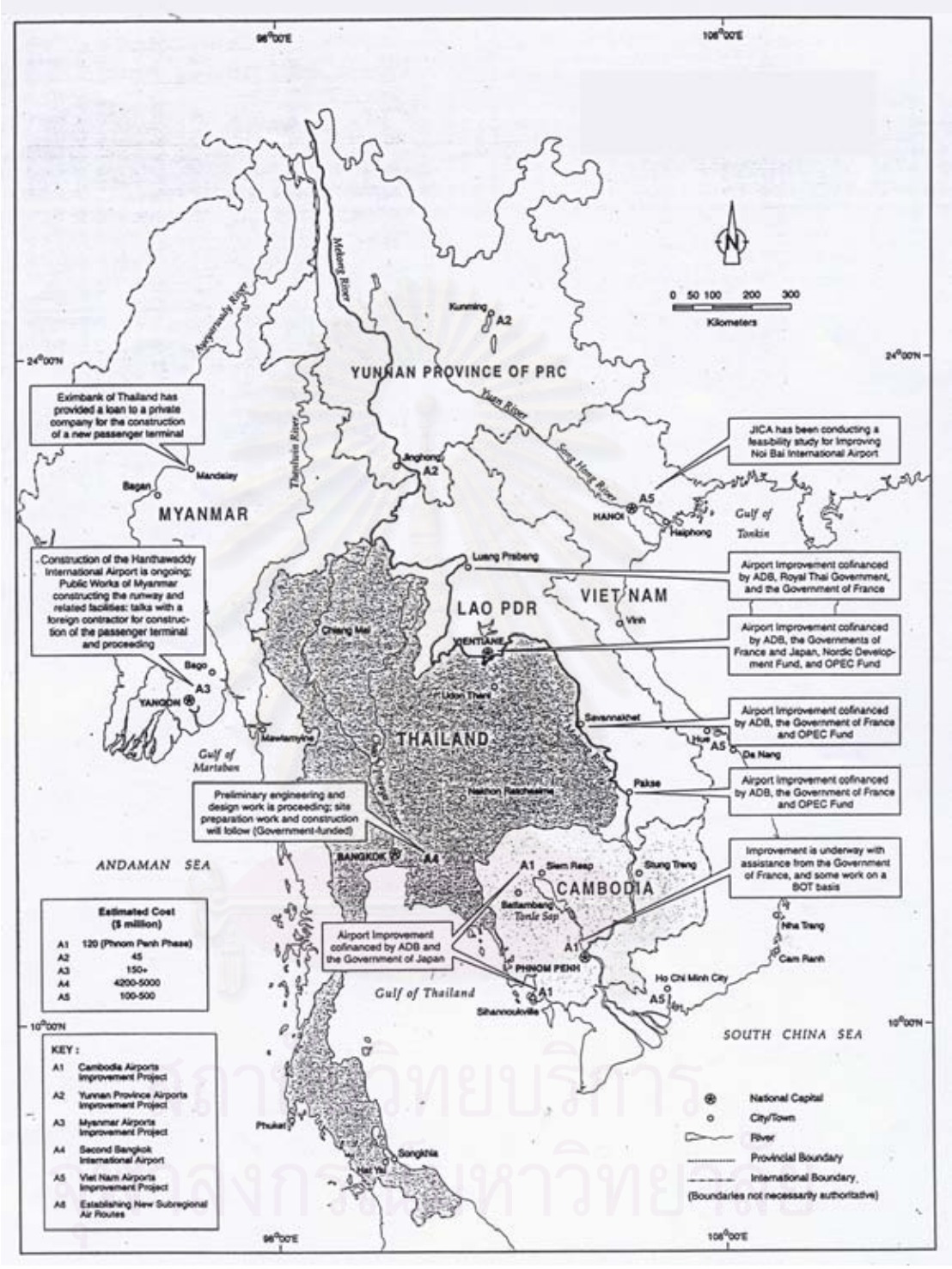


Figure 3.7 Status of subregional air transportation projects (NESDB, 2544, in Thai)

CHAPTER IV

EVALUATION AND DEVELOPMENT POTENTIAL FOR LAND USE PLANNING

This study attempts to analyse and evaluate of land suitability for agricultural land use planning that leads to policy formulation. The principles of the study concerns with the environmental geology, in order to know how the environmental geology conditions influent and assist to land use planning. GIS techniques allow the integration and organisation of information and facilitate their evaluation with environmental geology conditions, such as geology, natural resources, soil and existing land use. Any spatial or geo-referenced information from this study can be input into computer system by conversion conventional data in hard copy to digital form data and allows computer analysis and output. Thus the land use planning evaluation can be expressed in terms of potential suitable area for several land uses planning. This knowledge can be used to plan for the future land use planning programmes.

4.1 Development potentials

The importance for making decision about selected potential plan must consider many factors, namely, locality, existing plans, physical environment, socio-economic conditions, and social problems. Because Changwat Nakhon Phanom locates so far from economic center of the GMS and lack of Governor's promotion plans. Thus the industrial potential in the study area is not a major development plan.

In the assessment on environmental geology of study area, which are summarised into development potentials, constraints, prospects and negative concern that are related and influential to development of Nakhon Phanom. Analyses of existing natural resources and socio-economic environment of Nakhon Phanom, four development potentials have been identified as follows:

4.1.1 Agriculture

The agriculture is a major source of income of Changwat Nakhon Phanom. It contributes approximately one fourth of the Gross Provincial Product (GPP) and the agricultural land occupies approximately 48 percent of the total area of Changwat Nakhon Phanom.

4.1.2 Tourism in Nakhon Phanom

Tourism development can be advantageous for Changwat Nakhon Phanom. Tourists can be attracted by promoting traditional festivals/events, temples, Mekong River and natural beauty along the riverbank of both Thailand and Lao PDR.

Phra That Phanom temple, located 50 kilometres south of provincial capital, attracts thousands of domestic tourists from all over Thailand as well as tourists from neighbouring countries. A lot of devotees participate in homage paying fair held during 14^{th} – 20^{th} January, every year. The 50-metre high pagoda is the most revered shrine in the northeastern region and regularly attracts pilgrims. Several temples are also scattered in the periphery of the province, namely, Wat Okatsribuaban, Wat Srithep Praditthaaram, Wat Phra That Renu, Phra That Tha Uthen.

The Illuminated Boat Procession Festival, held annually marking the end of the Ok Phansa (Buddhist Lent) calls thousands of domestic as well as overseas tourists. Colourful street procession and cultural performances are performed during the festival.

Renu Nakhon is located 52 kilometres south of the provincial capital and famous of Phu Thai ethnic minority group who still retain their ancient culture, namely, form of dances and custom of the Bai Sri-Su-Kwan welcoming ceremony. Local products including woven hand-cotton are the attractive souvenirs.

Mekong river promenade is also the scenic point during sunrise and water front view. Renovation of promenades and development of a festival park are being conducted by the provincial authority.

Phu Lungka Nation Park, located 92 kilometres northwest of the provincial capital near the border of Changwat Nong Khai, attracts Thai natural lovers by numerous wild flowers, orchids, tree, and Tad Kham waterfalls.

Dinosaur Footprints, one of the interested geological information that was found at the active quarry mine near the Km 257.3, highway No. 212, Amphoe Tha Uthen on September, 2001 by geologists from Department of Mineral Resource. The dinosaur footprints comprise many casts and molds of theropod which preserved on surface of thin bedded dark gray mudstone of the Khok Kruat Formation. Sedimentary structures such as mudcracks and ripple structures on surface of mudstone bed are also preserved. At least numerous dinosaur footprints, show three long slender and pointed toes and have size vary from 10-20 cm. The direction of them are conclusive because their preserved rock was floated. The geologic information is very useful for tourism because the dinosaur remain is very well known in Thai people. Moreover, The research of geological history and paleoenvironment of dinosaur life can be studied by the evidence of geology in field. However, recently, this site and dinosaur traces are damaged by activities of mine. They are continuously destroyed for construction in Changwat Nakhon Phanom and Nong Khai. The area are still not protected by local or any government services.

4.1.3 Fisheries in Nakhon Phanom

1) Capture fisheries

Although there are huge water bodies for fishing in the study area that provide spawning, nursery, and growing grounds for fresh-water fishes, the production can not be expanded because the favorable environment for fish is threatened by agricultural

and industrial pollution. Death of natural fishes in the river has been frequently reported in the media.

Accordingly, efforts to maintain and increase the production of natural stocks are very important. Large number of people, particularly the poorer segments of the population, take refuge on inland catch for both cash income and nutrition. To increase production in natural waters, captive fisheries must be inevitably encouraged.

2) Culture fisheries

Fragmented data available from Nakhon Phanom suggested that the number of freshwater culture household, number of ponds, area, and inland captive fishery quantity have consistently increased during the last five years, as shown in Table 4.1.

Table 4.1 Number of freshwater culture household, number of ponds, area and inland captive fishery in quantity
(Source: Nakhon Phanom Provincial Statistical Office, 2539-2543, in Thai)

Culture fisheries / Year (B.E.)	Freshwater culture			Inland captive fishery in quantity (kg)
	Number of households	Number of ponds	Area (rai)	
2539	9,582	12,072	10,448.00	2,429,000
2540	16,221	16,966	19,437.75	4,765,382
2541	19,293	20,152	23,146.77	3,884,542
2542	20,163	21,743	25,618.58	4,001,732
2043	20,619	22,499	26,853.15	3,955,803

4.1.4 Experience on border trades practice

The border trades activities have already developed in the study area along/across the Mekong river. The border trading locations between Nakhon Phanom and Lao PDR are

limited to 3 points along the Mekong river, namely, Tha Uthen, Muang Nakhon Phanom, and That Phanom. The volume of border trades at Nakhon Phanom is the third largest one among all border-trading locations along the Mekong river in Thailand. The volumes of Tha Uthen and That Phanom are negligent. Growth of the trading at Nakhon Phanom has been remarkable, achieving a 35 % annual increase in the last 5 years in terms of Baht.

4.2 Limitations

Nakhon Phanom is recognised as the border area that may have some security problems from many factors such as foreign labours, illegal goods and drugs, etc. The study area is geographically regarded as one of the most remote from both sea-ports and major economic center along the coastal areas of the GMS, namely, Bangkok, Hanoi, and Ho Chi Minh City, therefore the cost and price of good and products are relatively high. There are some limitations for freight and trade activities.

Nakhon Phanom's economy has remained stagnant relatively backward from the standpoint of national economic development.

The area does not have adequate urban agglomeration, which has resulted in weak urban economy. This weak urban economy limits employment opportunities and value added products in Nakhon Phanom.

4.3 Prospects

The maximum precipitation is over 2,000 millimetres per annum, in the northern part and the minimum is less than 1,200 millimetres per annum, in the southern part. It is sufficient for agriculture and irrigation.

Changwat Nakhon Phanom has an advantage of water resource because of high potential of groundwater. The amounts of water yields are about 8 m^3/hr and some places can be developed to produce groundwater up to 50 m^3/hr.

The GMS Programme is a major existing international movement that promotes the integration of Indochina into regional economy.

Advantage on International Tourism Development of this area is linked towards Takek of Lao PDR across the Mekong River. The Lao PDR is relatively rich in natural resources.

4.4 Negative concerns

In 2001, the per Capita GPP ranking of Nakhon Phanom were at the level of only14 and 71, of the Region, and of the Country, respectively. The rural household income has remained at a lower level. This problem is attributed to the following root causes:

- Unstable and lower prices of agricultural products.
- Lower bargaining power of farmers.
- Marginal agricultural production.
- Less income opportunities in the non-agricultural sector.

4.5 Land use planning

The geography of most part of the study area is the floodplain. Majority of the land use in this area is for agriculture. Using the land without any caution might cause problems. The common land use problems are implications of human activities on the natural environment. The river bank zone is the major problem area from erosion. Other problems are inadequate water supply and the lack of utilities. Geoscientist can take important roles in preventing and reducing these problems directly related to the land use by applying geological knowledge on effective planning.

The backgrounds of study area and the basic groups of factors affecting land use are reviewed in Chapters I, II and III. This study attempts to recommend the regional land use planing for two different development planning propose, notably, conservation, and agricultural potential areas. In order to evaluate the land use potential, the limitation for land use capability is employed. The limitation of land use for each factor of environmental geology for different development purposes, namely, conservation, and agricultural potential areas are assigned according to the degree of importance and relevancy. The concerned factors and suggestion of environmental geology are presented in Table 4.2. Finally, development potential for each land use is defined into the suitability potential areas. The discussions show how some environmental geologic factors have been dealt within land use planning.

Table 4.2 Suggestions of environmental geologic factors for evaluating in Land use planning (Department of Town and Country Planning, no date, in Thai)

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

4.5.1 Potential conservation area

Conservation area is the area that should follow the ruler strictly in order not to make any negative effect on its environment in using the area. It is the area that has the natural dianostic features. The conservation area could also be the area that can not do any actively on it. Like the military area, airport area, ancient remaining area, etc.

The conservation area must be included in the resources plans. For the potential conservation area, factors concerned include forest, wildlife, heritage, river and reservoir and natural resources. The portion of the conservation element containing of environmental geology will be conserved or developed for any propose in the planning.

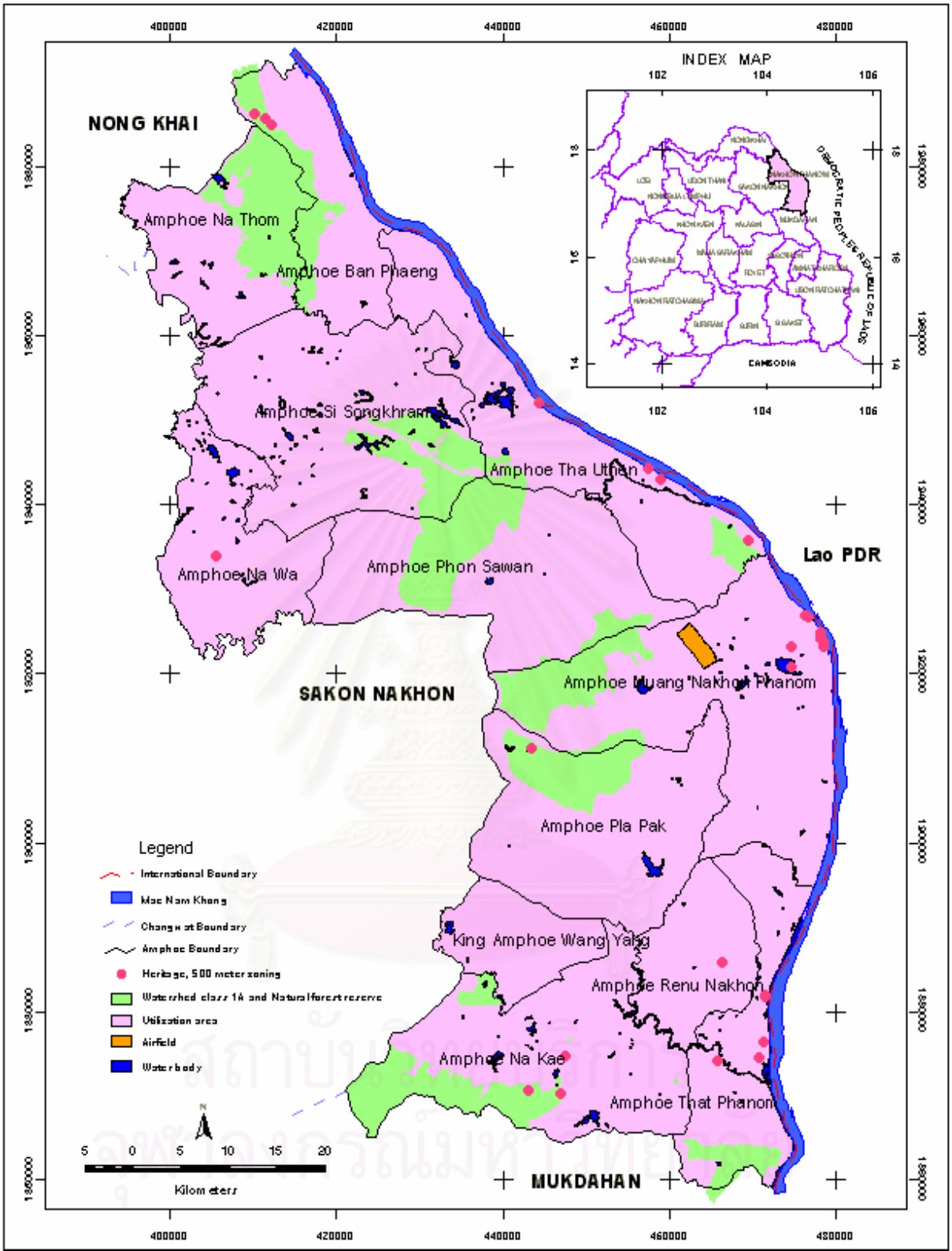
The conservation areas in a general plan of the study area are addressed in types of the open space as described in Table 4.3 and Figure 4.1. The processes of evaluation for conservation area using GIS are presented in Figure 4.2. The environmental geology, in Chapter II, indicates that the conservation area can be divided into 3 categories (Table 4.3) as listed follows;

i) Preservation area – the area that should be presented for environment, such as, natural park, nation forest reserve, watershed class 1A and 1B, etc.

ii) Utilization area – the area that suitable for the economic activity: for examples, airport, etc.

iii) Historical preservation and Natural view – the ancient remaining and natural areas like heritage culture, scenic place, recreation area.

The evaluated factors in conservation areas comprise of forest map, watershed map, water map, transportation map, and heritage map. GIS processes were used in evaluation of this conservation area as presented in Figure 4.2.



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 4.1 Potential conservation area map of Changwat Nakhon Phanom

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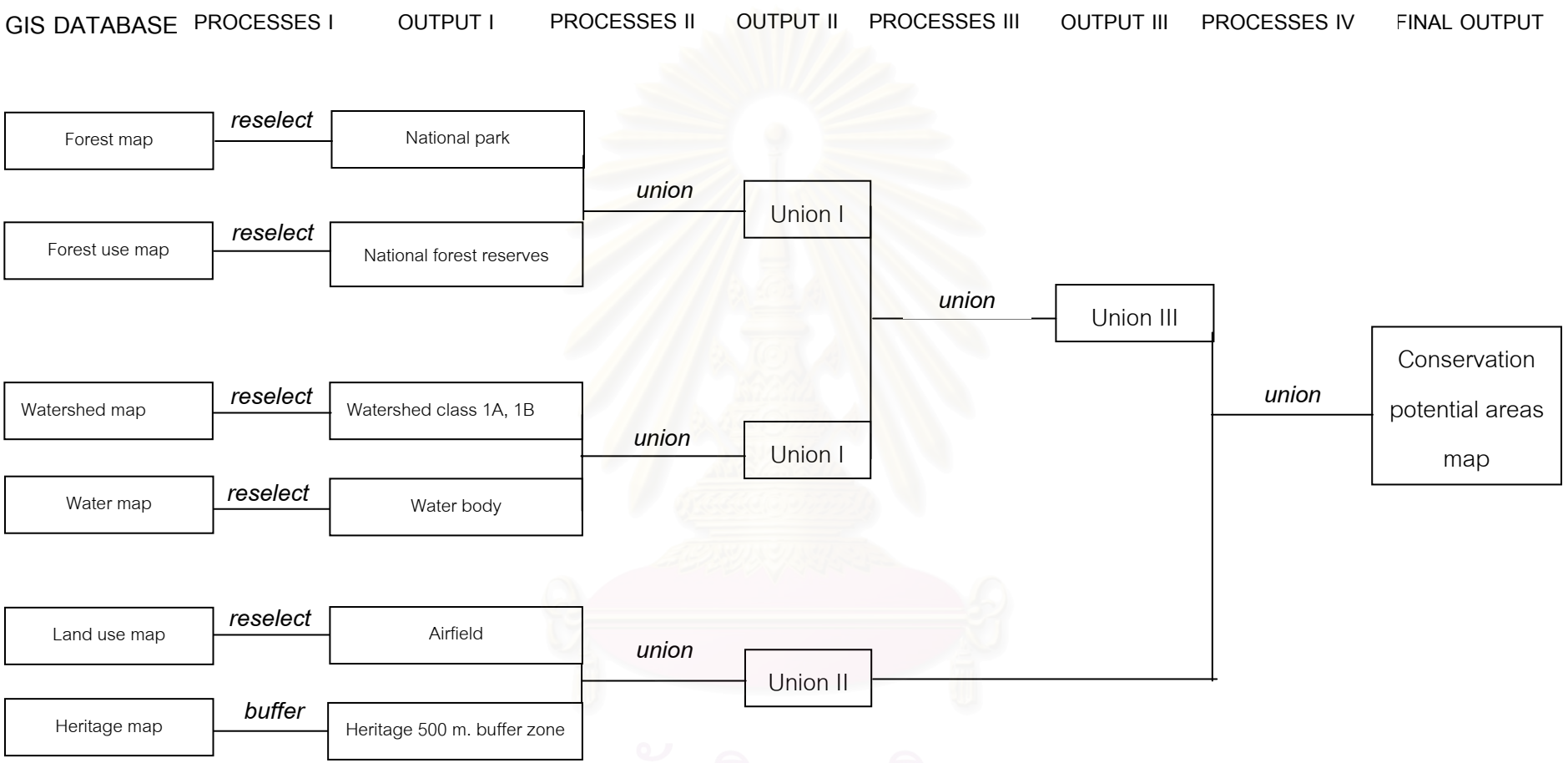


Figure 4.2 The processes and evaluated conservation potential areas using GIS

Table 4.3 Environmental factor for evaluated conservation potential areas of Changwat Nakhon Phanom.
(after: Department of Town and Country Planning, no date, in Thai and Forestry Department, 2535, in Thai).

Environmental geology factor	Subclass	Processes
1. Forest land	National forest reserves	reselect
	National park	reselect
	Wildlife sanctuary	reselect
2. Watershed classification	Watershed class 1A, 1B	reselect
3. Water supply	Reservoir	reselect
4. Infrastructure	Airport	reselect
5. Historical preservation	Ancient remains	buffer zone 500 metres
	Heritage cultural	buffer zone 500 metres
6. Natural view	Scenic place	buffer zone 500 metres
	Recreation area	buffer zone 500 metres

4.5.2 Potential agricultural area

A numerical rating system or a weight-rating system is based on the theory of logical combination. A weighting or a measure of relative importance, must be assigned each influencing factor. Each of the influencing factors was subdivided into subclasses and given index numbers called 'a rating'. Although the index numbers are for identification only, the subclasses should be arranged in a logical sequence. The sum of the product of these to factor weights was the potential of the area indicated susceptibility to potential agricultural area.

For the proposed of this study, a simplified formula (Roger, Golden and Halpern. 1985) has been developed to assume the potential of an area. This result in the formula:

$$S = W_1R_1 + W_2R_2 + \ldots + W_nR_n$$

Where S = total scores in each area

$W_1, W_2, \ldots, W_n$ = value of the importance factor

$R_1, R_2, \ldots, R_n$ = value of subclasses of the importance factor

Agricultural developments in the study area are subject to the existing land use prospectively and existing plans. Recommendation of the potential development for agricultural purpose is based on soil suitability, existing land use and land cover, slope, topography and landform, and transportation. Each of environmental factors is further limited into different capability values according to the suitability. Finally, the potential agricultural areas are evaluated on the area based on environmental factors summarised and presented in Table 4.4. For further planning, the area of low land, such as residual deposit, terrace and alluvial deposit is occupied by paddy, fruit trees, and para-rubber. They are focused here because the status of local government supported this activity. The area of agriculture occupies the foot-slope of hills consisting of para-rubber. The assigned weight system to factors influencing the potential agricultural area in Changwat Nakhon Phanom are summarised and presented in Table 4.5 for paddy, Table 4.6 for non-flooded annual crops, Table 4.7 for fruit trees, Table 4.8 for para-rubber, Table 4.9 for coconut and Table 4.10 for permanent pasture or rangeland livestock farming. The total scores of weight-rating system for the agricultural potential areas of Changwat Nakhon Phanom are vary between 18-115. Addition attempt has been made to classify the agricultural potential area, on the basis of total scores, into 5 suitability, namely, very high, high, moderate, low and very low suitability. The agricultural potential area and the range of total scores are summarised and presented in Table 4.11.

The map recommended land use for potential agricultural areas are divided in 6 major economic crops, namely, paddy (Figure 4.3), non-flooded annual crops (Figure 4.4), fruit trees (Figure 4.5), para-rubber (Figure 4.6), coconut (Figure 4.7), permanent pasture or rangeland livestock farming (Figure 4.8).

However, soil salinity problem is also well-known in this area Therefore, the area high salinity that can affect to the agricultural development will be masked out as negative area.

Table 4.4 Suitability of environmental geologic factor for evaluated agricultural potential area. (Department of Town and Country Planning, no date, in Thai)

Environmental geologic factor	Subclass	Suitability for agriculture
1. Topography		
1.1 Slope	0-20%	Moderate to high
	Over 20%	Low
1.2 Drainage		
Stream, reservoir and	0.10-4 kilometres	Moderate to high
pond	Over 4 kilometres	Low
2. Forest land		
National forest reserve		None
National park		None
Wildlife sanctuary		None
Watershed class 1A, 1B		None
3. Existing land use		
Urban land		Low to high
4. Infrastructure		
road	0.1-5 kilometres	Moderate to high
	Over 5 kilometres	Low
5. Historical preservation		
Ancient remains		None (buffer zone 500 metres)
Heritage cultural		None (buffer zone 500 metres)
6. Natural view		
View place		None (buffer zone 500 metre)

Table 4.5 The numerical weight-rating system to factors influencing the potential agricultural area for paddy field in Changwat Nakhon Phanom.

Factors	Weight value	Rating value	Weighted rating value
1. Water supply (main stream, reservoir, irrigation area and potential reservoir)	5		
● within 1 kilometres		5	25
● between 1-2 kilometres		4	20
● between 2-3 kilometres		3	15
● between 3-4 kilometres		2	10
● over 4 kilometres		1	5
2. slope	3		
● between 0-5 %		5	15
● between 5-10 %		4	12
● between 10-15 %		3	9
● between 15-20 %		2	6
● over 20 %		1	3
3. Existing land use and land cover	3		
● Agricultural land		5	15
● Disturbed forest		3	9
● Miscellaneous land		2	6
● Urban and built up land		1	3
● Forest land		0	0
4. Soil permeability	4		
● very poorly		5	20
● poorly		4	16
● moderately		3	12
● well		2	8
● very well		1	4
5. road and highway	3		
● within 1 kilometres		5	15
● between 1-2 kilometres		4	12
● between 2-5 kilometres		3	9
● between 5-10 kilometres		2	6
● over 10 kilometres		1	3
6. Topography	2		
● < 150 metres above MSL		5	10
● 150-180 metres above MSL		3	6
● > 180 metres above MSL		1	2

Table 4.6 The numerical weight-rating system to factors influencing the potential agricultural area for non-flooded annual crops in Changwat Nakhon Phanom.

Factors	Weight value	Rating value	Weighted rating value
1. Water supply (main stream, reservoir, irrigation area and potential reservoir)	5		
● within 1 kilometres		5	25
● between 1-2 kilometres		4	20
● between 2-3 kilometres		3	15
● between 3-4 kilometres		2	10
● over 4 kilometres		1	5
2. slope	3		
● between 0-5 %		5	15
● between 5-10 %		4	12
● between 10-15 %		3	9
● between 15-20%		2	6
● over 20 %		1	3
3. Existing land use and land cover	3		
● Agricultural land		5	15
● Disturbed forest		3	9
● Miscellaneous land		2	6
● Urban and built up land		2	6
● Forest land		0	0
4. Soil permeability	4		
● very well		5	20
● well		4	16
● moderately		3	12
● poorly		2	8
● very poorly		1	4
5. road and highway	3		
● within 1 kilometres		5	15
● between 1-2 kilometres		4	12
● between 2-5 kilometres		3	9
● between 5-10 kilometres		2	6
● over 10 kilometres		1	3
6. Topography	2		
● 150-180 metres above MSL		3	6
● > 180 metres above MSL		2	4
● < 150 metres above MSL		1	2

Table 4.7 The numerical weight-rating system to factors influencing the potential agricultural area for fruit trees in Changwat Nakhon Phanom.

Factors	Weight value	Rating value	Weighted rating value
1. Water supply (main stream, reservoir, irrigation area and potential reservoir)	5		
● within 1 kilometres		5	25
● between 1-2 kilometres		4	20
● between 2-3 kilometres		3	15
● between 3-4 kilometres		2	10
● over 4 kilometres		1	5
2. slope	3		
● between 0-5 %		5	15
● between 5-10 %		4	12
● between 10-15 %		3	9
● between 15-20%		2	6
● over 20 %		1	3
3. Existing land use and land cover	3		
● Agricultural land		5	15
● Disturbed forest		3	9
● Miscellaneous land		2	6
● Urban and built up land		2	6
● Forest land		0	0
4. Soil permeability	4		
● very well		5	20
● well		4	16
● moderately		3	12
● poorly		2	8
● very poorly		1	4
5. road and highway	3		
● within 1 kilometres		5	15
● between 1-2 kilometres		4	12
● between 2-5 kilometres		3	9
● between 5-10 kilometres		2	6
● over 10 kilometres		1	3
6. Topography	2		
● 150-180 metres above MSL		3	6
● > 180 metres above MSL		2	4
● < 150 metres above MSL		1	2

Table 4.8 The numerical weight-rating system to factors influencing the potential agricultural area for para-rubber in Changwat Nakhon Phanom.

Factors	Weight value	Rating value	Weighted rating value
1. Water supply (main stream, reservoir, irrigation area and potential reservoir)	5		
● within 1 kilometres		5	25
● between 1-2 kilometres		4	20
● between 2-3 kilometres		3	15
● between 3-4 kilometres		2	10
● over 4 kilometres		1	5
2. slope	3		
● between 0-5 %		5	15
● between 5-10 %		4	12
● between 10-15 %		3	9
● between 15-20%		2	6
● over 20 %		1	3
3. Existing land use and land cover	3		
● Agricultural land		5	15
● Disturbed forest		3	9
● Miscellaneous land		2	6
● Urban and built up land		1	3
● Forest land		0	0
4. Soil permeability	4		
● very well		5	20
● well		4	16
● moderately		3	12
● poorly		2	8
● very poorly		1	4
5. road and highway	3		
● within 1 kilometres		5	15
● between 1-2 kilometres		4	12
● between 2-5 kilometres		3	9
● between 5-10 kilometres		2	6
● over 10 kilometres		1	3
6. Topography	2		
● 150-180 metres above MSL		3	6
● > 180 metres above MSL		2	4
● < 150 metres above MSL		1	2

Table 4.9 The numerical weight-rating system to factors influencing the potential agricultural area for coconut in Changwat Nakhon Phanom.

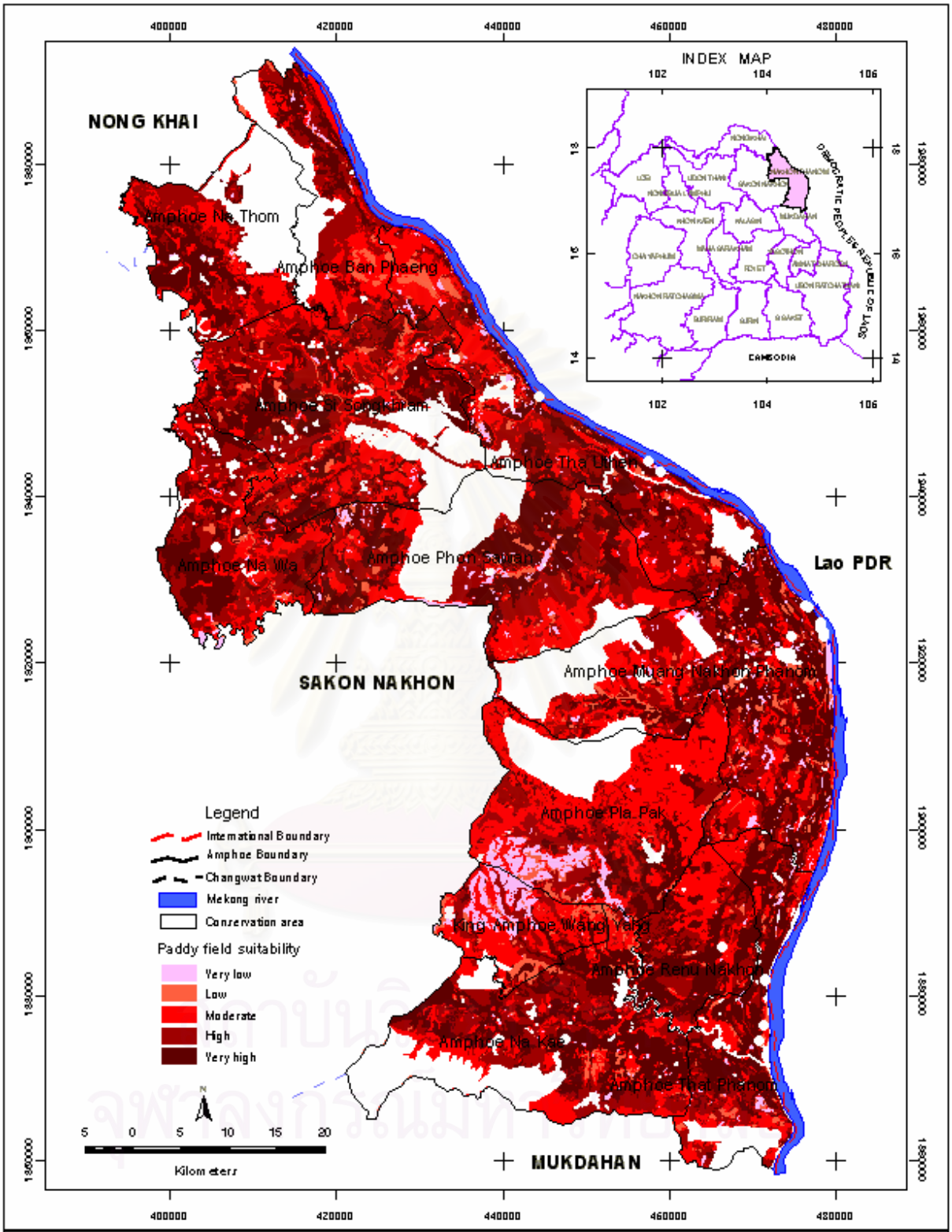
Factors	Weight value	Rating value	Weighted rating value
1. Water supply (main stream, reservoir, irrigation area and potential reservoir)	5		
● within 1 kilometres		5	25
● between 1-2 kilometres		4	20
● between 2-3 kilometres		3	15
● between 3-4 kilometres		2	10
● over 4 kilometres		1	5
2. slope	3		
● between 0-5 %		5	15
● between 5-10 %		4	12
● between 10-15 %		3	9
● between 15-20%		2	6
● over 20 %		1	3
3. Existing land use and land cover	3		
● Agricultural land		5	15
● Disturbed forest		3	9
● Miscellaneous land		2	6
● Urban and built up land		2	6
● Forest land		0	0
4. Soil permeability	4		
● very well		5	20
● well		4	16
● moderately		3	12
● poorly		2	8
● very poorly		1	4
5. road and highway	3		
● within 1 kilometres		5	15
● between 1-2 kilometres		4	12
● between 2-5 kilometres		3	9
● between 5-10 kilometres		2	6
● over 10 kilometres		1	3
6. Topography	2		
● < 150 metres above MSL		3	6
● 150-180 metres above MSL		2	4
● > 180 metres above MSL		1	2

Table 4.10 The numerical weight-rating system to factors influencing the potential agricultural area for permanent pasture or rangeland livestock farming in Changwat Nakhon Phanom.

Factors	Weight value	Rating value	Weighted rating value
1. Water supply (main stream, reservoir, irrigation area and potential reservoir)	5		
● within 1 kilometres		5	25
● between 1-2 kilometres		4	20
● between 2-3 kilometres		3	15
● between 3-4 kilometres		2	10
● over 4 kilometres		1	5
2. slope	3		
● between 0-5 %		5	15
● between 5-10 %		4	12
● between 10-15 %		3	9
● between 15-20%		2	6
● over 20 %		1	3
3. Existing land use and land cover	3		
● Agricultural land		5	15
● Disturbed forest		3	9
● Miscellaneous land		3	9
● Urban and built up land		2	6
● Forest land		0	0
4. Soil permeability	4		
● very well		5	20
● well		4	16
● moderately		3	12
● poorly		2	8
● very poorly		1	4
5. road and highway	3		
● within 1 kilometres		5	15
● between 1-2 kilometres		4	12
● between 2-5 kilometres		3	9
● between 5-10 kilometres		2	6
● over 10 kilometres		1	3
6. Topography	2		
● < 150 metres above MSL		5	10
● 150-180 metres above MSL		3	6
● > 180 metres above MSL		1	2

Table 4.11 The agricultural potential and rang of total scores.

Suitability classes	Range of scores
Very low suitability	18-37
Low suitability	38-56
Moderate suitability	57-75
High suitability	76-94
Very high suitability	95-115



ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 4.3 Paddy field suitability map of Changwat Nakhon Phanom

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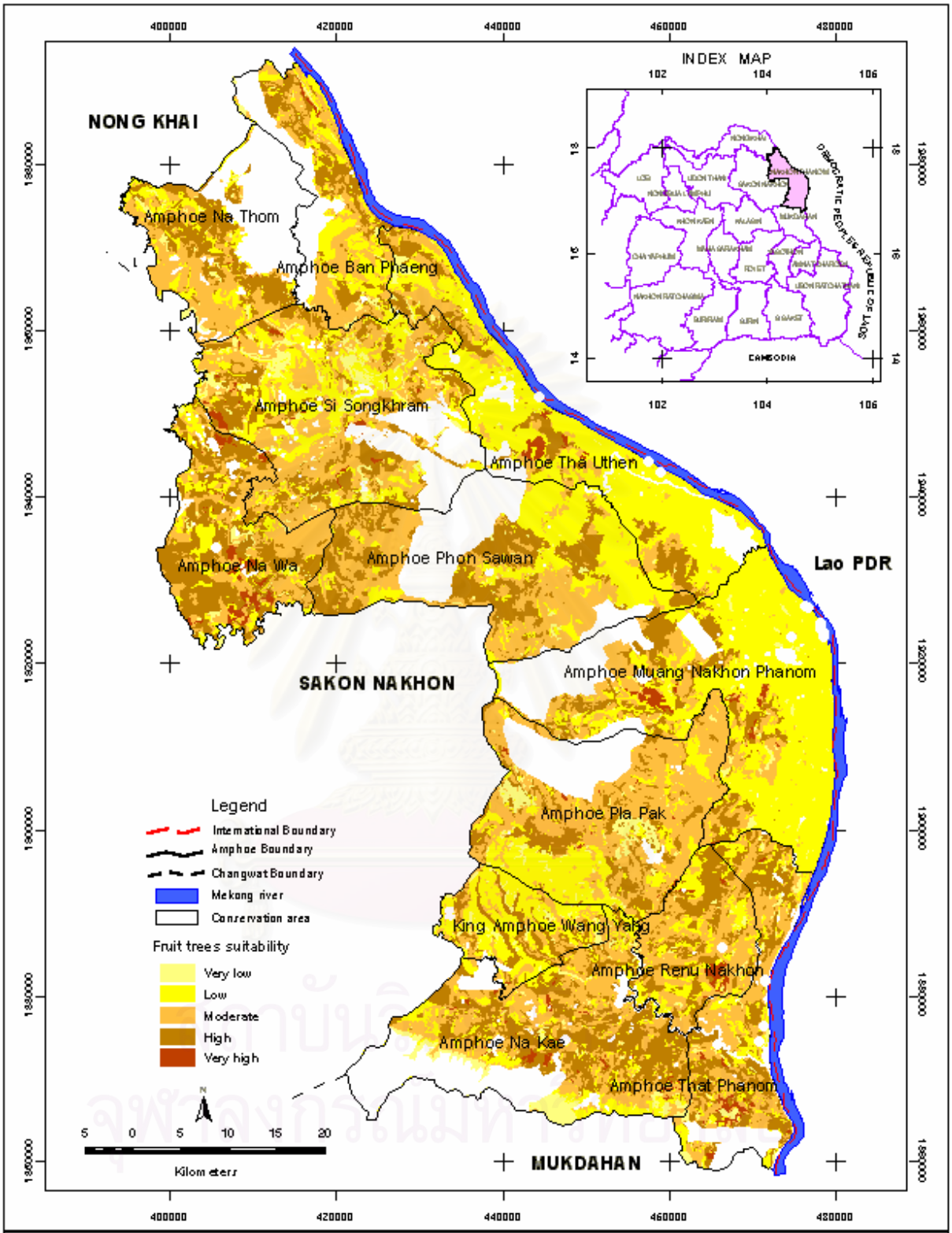

ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 4.5 Fruit trees suitability map of Changwat Nakhon Phanom

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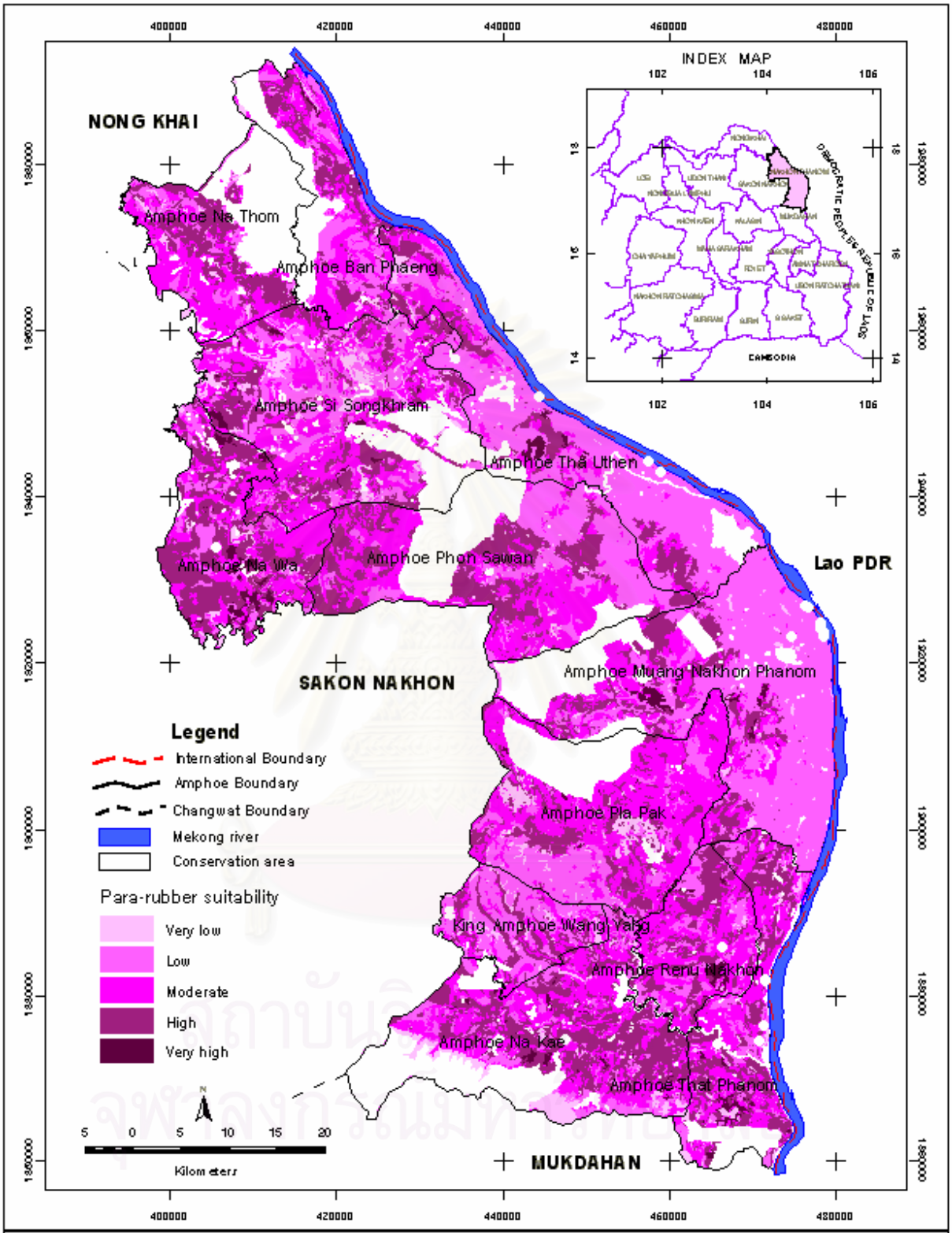

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Figure 4.6 Para-rubber suitability map of Changwat Nakhon Phanom

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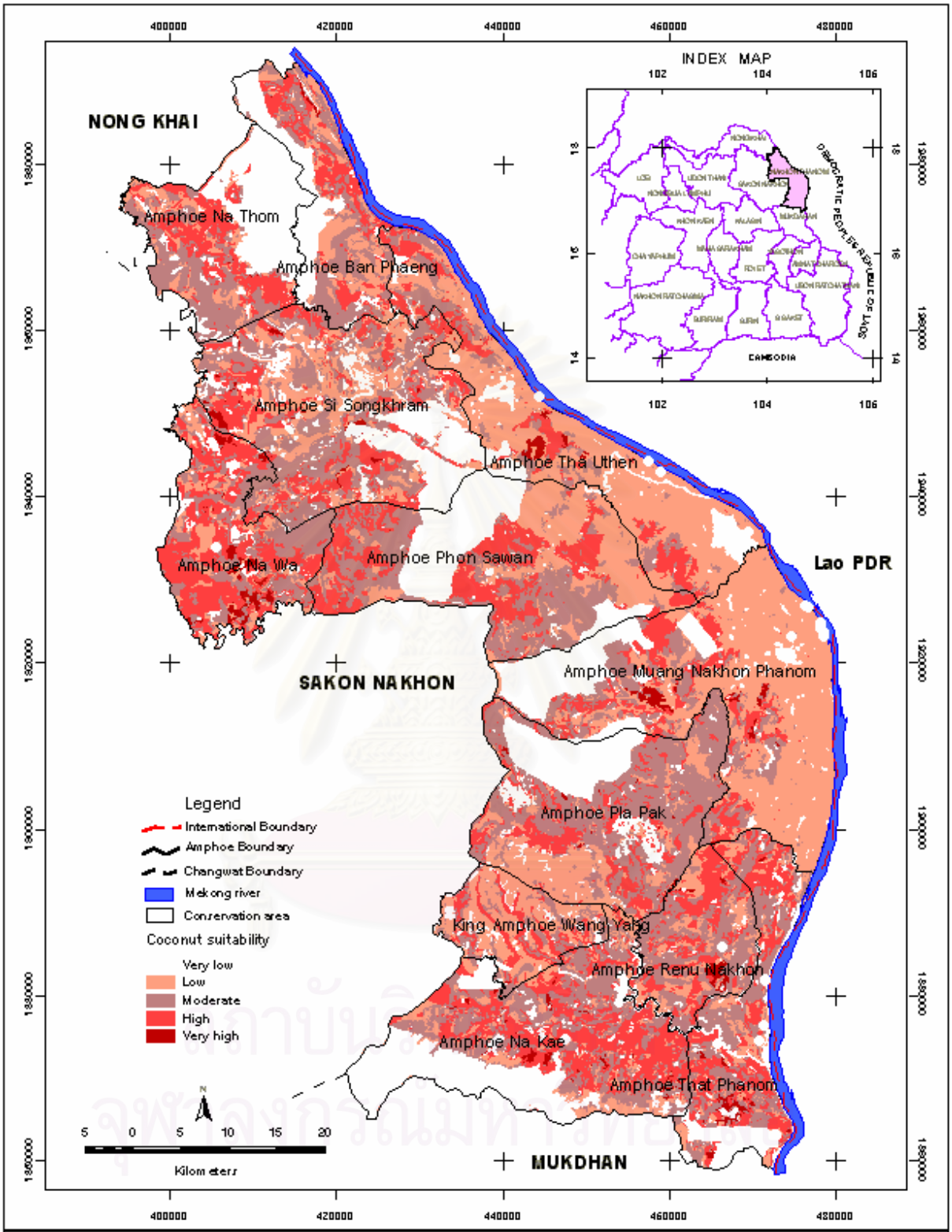

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Figure 4.7 Coconut suitability map of Changwat Nakhon Phanom

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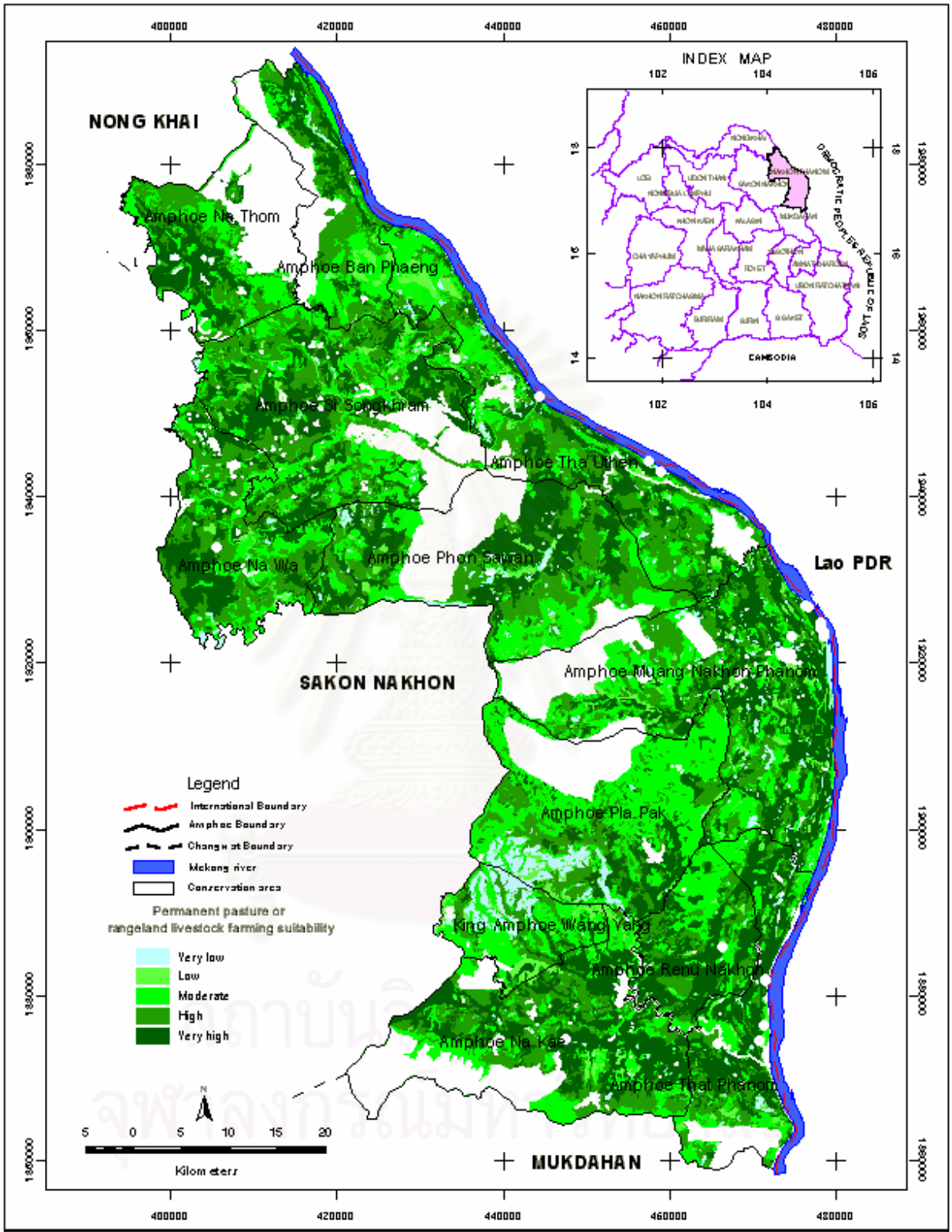

ENVIRONMENTAL GEOLOGY OF NAKHON PHANOM

Figure 4.8 Permanent pasture or rangeland livestock farming suitability map of Changwat Nakhon Phanom

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CHAPTER V

CONCLUSION AND DISCUSSION

Conclusion

According to the study of “Environmental Geology of Changwat Nakhon Phanom in Northeastern Thailand”, the study area has continuously been developed in many sectors, such as the development of agriculture, tourism, fishery and foreign trade. The effects of human activity are most extremely sensitive to disturbance. It is necessary to develop action plans for the development of this area in harmony with nature. The land use development planning and management must be undertaken in the context of environmental conservation, protection and development, so that the benefits obtained from natural resources are optimized forever. However, the foreign trade and relationship development planning should be done at the same time with the physical development planning for support each other. The study can be summarizes and discussed as follow.

5.1 The objective of study aims at the acquisition and analysis of environmental geologic data and information in order to identify the potentials and limitation for the future development planning using GIS techniques.

This study collected and prepared environmental geologic data, namely, climate, topography and land form, water resources, existing land use, and geological hazards as in Chapter II. The application on environmental geology to sustain development has been carried out.

Weight-rating method was used for analyse some of those data which to propose agricultural potential area, results as a series of map in Chapter IV.

5.2 Data and information development: the data and information in many sources must be desired to be uniform for easily evaluation. In spatial data, all of maps, in many scale, were rebound by the main boundary which the most exactly as topographic map (scale 1:50,000) and present in 1: 600,000 map scale. In other hand, non-spatial data and information were collected in form of table, graph, and picture.

5.3 Implementation of land use planning: On the basis of evaluating land use development in this study is used in GIS technique in many reasons , such as, GIS is easy to develop of data and information, easy to analyzed, easy to presentation. The result of data and information from GIS analysis are exalter than other objects. It also present in field of map, table, graph, and picture.

5.4 From the review of all development plans, it reveals that the agricultural land use planning of the area could be basic required and firstly necessary before any other development should be considered. Therefore, this study is attempted to recommend two categories of land use planning purpose i.e. conservation and agricultural. In order to evaluate these land use potentials on the basis of efficient use of land resources as well as taking the environmental values into consideration, the limitation for land use capability is employed. In chapter II and III, environmental geology and development planning for Changwat Nakhon Phanom have been described and presented aspect by aspect so far as the scope of the present investigation concerned. The concerned parameter and limitation of environmental geology for each land use potential areas are presented in chapter IV.

All data used in evaluation and a result for this land use planning are created to be digital data layers for easy, analysis and evaluation using the GIS. The final of evaluation of each potential area is expressed in terms of suitability of parameters of environmental geology.

The compilation of regional land use planning was emphasized base on natural resources and geological hazard information, that have been previously described and

presented in various geographic information maps. There are two main categories of potential area as follows:

The conservation potential areas comprise of six types as follow:

1) National forest reserve

2) Nation park

3) Wildlife sanctuary

4) Watershed class 1A and 1B

5) River and reservoir

6) Tourism and recreation area

The agricultural potential area comprise of six types as follow:

1) Paddy field

2) Non-flooded annual crops

3) Fruit trees

4) Para-rubber

5) Coconut

6) Permanent pasture or rangeland livestock farming

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

Discussion

Awareness for anyone who will be considered this study result as an information for further application or study includes,

+ available source maps came from different scale

+ this study deals with too many factors, therefore all data layers can not be updated thoroughly

+ weight – rating method is assigned according to arbitrary consideration which basically relied on scientific and logic thoughts. Opinions from group of expertise on these subjects can give better result of the study.

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