

CHAPTER 3

ENVIRONMENTAL SETTING

Changwat Chachoengsao is not far from Bangkok. Fortunately, the settlements on the basic of socio-economic conditions and geographical features are at the area of high advantage for economic development. Approximately half of the study area is fertile lowland that is good for rice-cultivation and orchard field. The southwestern part is contact with the Gulf of Thailand providing for fisheries development. Cassava, sugarcane, pineapple, and wood plants are well cultivated in the eastern part of highland within this study area.

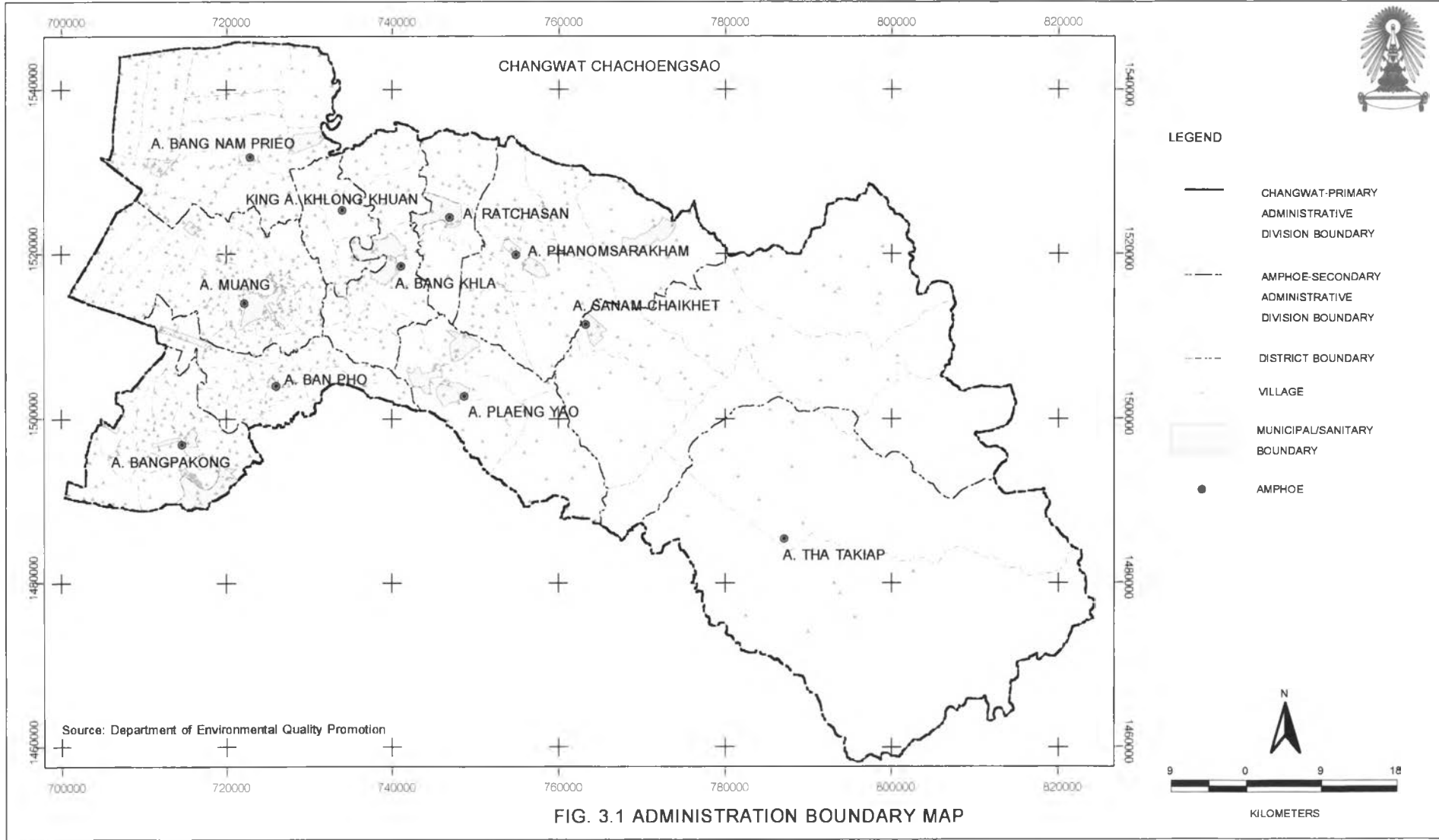
According to the National Economic and Social Development Plan, the area is planned as the area for agro-industry development. Agriculture is the most important in Changwat Chachoengsao. The major agriculture was rice and mangoes. Chicken and swine farms of Changwat Chachoengsao are first and second priority of economic activity in Thailand, respectively. Few years ago, fishermen adopt a new technique of marine shrimp-culture to culture the marine shrimp in fresh water. However, Changwat Chachoengsao is the potential area for investment of industrial activity, recently. There are two major industrial estates, Well Grow Industrial Estate and Gateway City Industrial Estates.

3.1 Socio-Economic

3.1.1 Social Conditions

3.1.1.1 Administration

According to Department of Environmental Quality Promotion (DEQP), the boundaries of Amphoe (1970; 1:50,000 RTSD Source), District (1985; 1:50000 RTSD Source), and Municipal and Sanitary (1989; 1:10000 Changwat Chachoengsao Office), the administration are divided into 10 Amphoe, 1 King Amphoe, 93 District, 817 Mooban, 23 Municipalities/Sanitarries. The administration boundaries are presented in Figure 3.1.



3.1.1.2 Population

Number of population of each municipal/sanitary in Changwat Chachoengsao during 1983-1993 is summarized in Table 3.1 (Team Consulting Engineer, 1995). For the present study, number of population of each municipal/sanitary is used for forecast number of population in next 20 years, because scope of study wanted a most potential area of Changwat Chachoengsao for solid wastes disposal (see forecast number of population in chapter 4.1.1).

3.1.1.3 Educational and Health Services

According to Chachoengsao Provincial Statistical Office (1999), the number of schools, classrooms, teachers and students by Jurisdiction are 386 locations, 4,674 classrooms, 6,192 persons, and 121,454 persons, respectively. Moreover, number of institutions, teaching staffs, and students/enrolled by jurisdiction are 12 locations, 596 persons and 15,228 persons, respectively (Chachoengsao Provincial Statistical Office, 1999). Figure 3.2 shows locations of school in Changwat Chachoengsao.

Government and private of hospitals in Changwat Chachoengsao have 13 locations, 94 persons of doctors, 20 persons of dentist, 460 persons of nurse, 24 persons of assist nurse, and 979 pieces of bed (Chachoengsao Provincial Statistical Office, 1999).

3.1.1.4 Religion

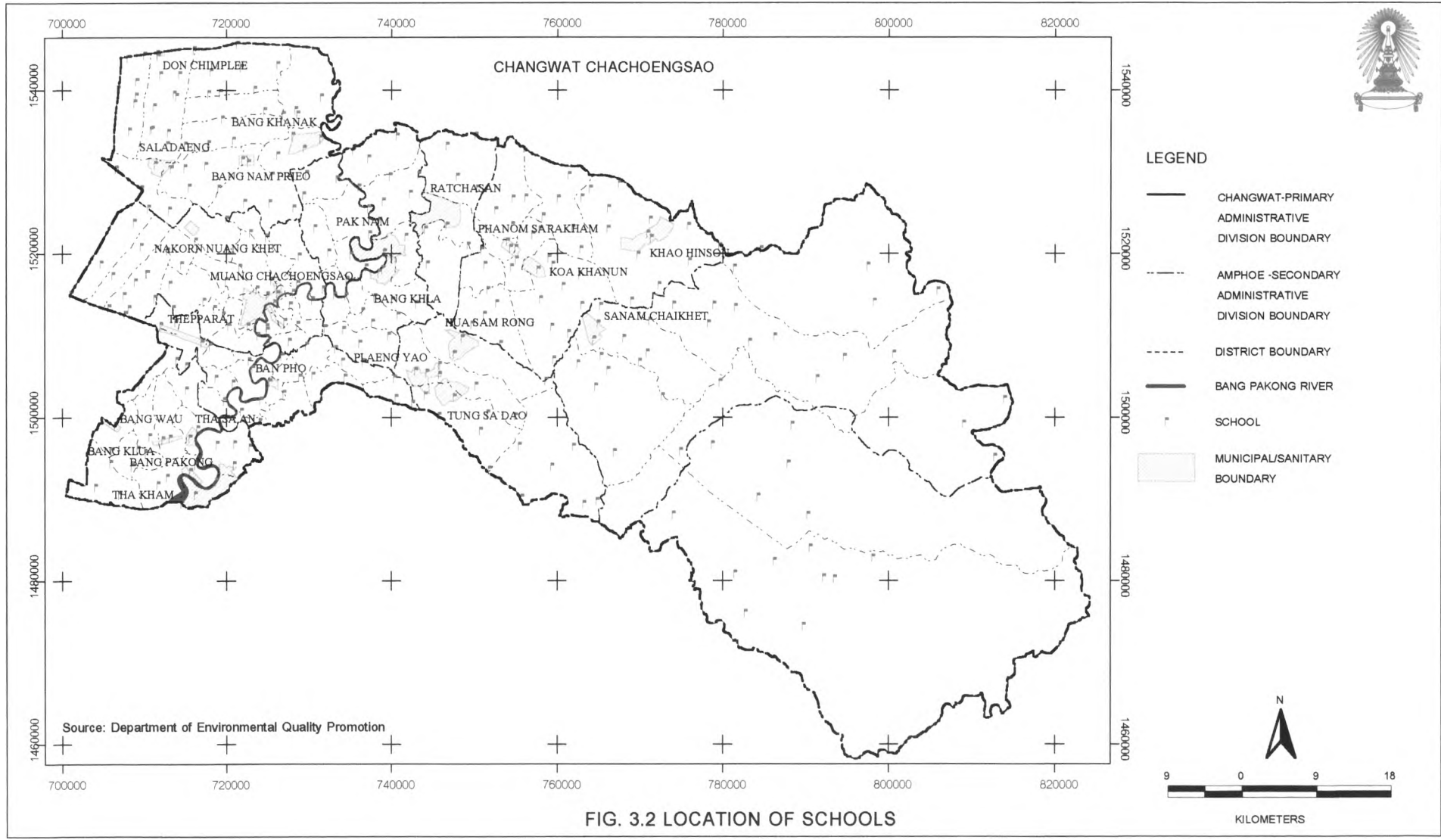
The main religion of population in Changwat Chachoengsao can be categorized into three groups, namely, 93.3 percent Buddhists, 6.1 percent Islamics, and 0.6 percent Christians (Munagkung, 1992).

Table 3.1 Number of Population by Municipalities and Sanitarries in Changwat Chachoengsao during 1983-1993

Year	Number of Population by Municipalities and Sanitarries during 1983-1993 (persons)										
	Muang Chachoengsao	Nakorn Nuang Khet	Bang Pakong	Bang Khlua	Bang Wau	Tha Sa An	Tha Kham	Bang Khla District	Pak Nam	Plaeng Yao	Hua Samrong
1983	38,588	1,161	8,565	2,266	6,138	4,990	-	6,187	3,520	8,377	-
1984	39,568	1,291	8,789	2,270	5,463	5,998	-	7,209	3,476	8,515	-
1985	41,359	1,471	8,880	2,273	6,220	5,005	-	7,732	3,625	8,598	-
1986	43,117	1,563	8,930	2,285	6,222	5,175	-	7,874	3,590	8,617	-
1987	43,165	1,731	8,943	2,277	6,244	4,995	-	7,888	3,609	8,623	-
1988	44,162	1,939	8,649	2,293	6,303	5,032	-	7,784	3,607	8,630	-
1989	43,406	1,731	8,918	2,302	6,470	5,865	-	8,044	3,568	8,635	-
1990	42,956	2,051	8,943	2,889	6,493	4,900	-	8,396	3,585	8,640	-
1991	42,233	2,314	8,981	2,306	6,518	5,210	-	8,009	3,561	8,645	-
1992	41,330	2,662	9,015	2,318	6,535	5,528	-	9,869	3,622	8,752	-
1993	42,649	2,272	9,077	2,357	6,640	5,576	7,885	9,193	3,630	8,757	5,411

Year	Number of Population by Municipalities and Sanitarries during 1983-1993 (persons)											
	Thung Sa Dao	Bang Nam Prieo	Bang Khanak	Don Chim Plee	Saladaeng	Ban Pho	Thepparat	Phanom Sarakham	Koa Khanoon	Khao Hinson	Sanam Chai Khet	Ratchasan
1983	-	2,928	2,877	2,265	-	1,286	6,703	8,891	5,401	-	5,847	-
1984	-	2,434	2,883	2,740	-	1,314	6,729	8,921	5,453	-	5,983	-
1985	-	2,925	2,890	2,754	-	1,417	6,726	8,975	5,403	-	6,002	-
1986	-	2,937	2,900	2,775	-	1,421	6,847	8,985	5,467	-	5,527	-
1987	-	2,948	2,915	2,853	-	1,406	6,769	9,881	5,521	-	6,031	-
1988	-	3,065	2,930	2,854	-	1,500	6,850	8,991	5,586	-	5,887	-
1989	-	3,192	2,944	2,882	-	1,500	6,671	8,002	5,656	-	5,745	-
1990	-	3,192	2,972	2,912	-	1,570	6,671	9,112	5,656	-	5,743	-
1991	-	2,263	2,994	3,100	-	1,570	6,710	9,132	5,810	-	5,598	-
1992	-	2,502	3,086	3,222	-	1,583	6,899	9,157	6,100	-	5,606	-
1993	1,928	2,787	3,133	3,321	1,965	1,864	6,918	9,455	6,344	4,287	6,676	6,102

Source: Changwat Chachoengsao, 1995



3.1.1.5 Water Supply and Electricity

There are four major water supply resources in Changwat Chachoengsao, including Amphoe Muang, Amphoe Bang Khla, Bang Pakong, and Amphoe Phanom Sarakham which water capacity and number of consumers of them are 10,950,000 cu.m., 14,543 persons, 3,066,000 cu.m., 3,161 persons, 4,504,578 cu.m., 2,160,000 persons, and 2,160,000 cu.m., 3,899 persons, respectively.

The demands of electricity are widely distributed to almost all of the rural area due to the increasing of numerous factories and domestic uses.

3.1.1.6 Transportation and Communication

From Bangkok to Changwat Chachoengsao, it can be traveled by vehicle and by train. Besides, travel of internal Changwat Chachoengsao is boat. Figure 3.3 shows the transportation system in Changwat Chachoengsao.

For the communication system, all of Amphoe in Changwat Chachoengsao have public post, 21-center telephone organization, and 29, 440 call numbers (Chachoengsao Provincial Statistical Office, 1998).

3.1.2 Important Economics

3.1.2.1 Agriculture

Approximately half of Changwat Chachoengsao is fertile lowland that is good for rice cultivation and orchard field. The southwestern part is contact with the Gulf of Thailand for fisheries development. Cassava, sugarcane, and wood plants are well cultivated in the eastern part of highland. Generally, the livestock farm area in Changwat Chachoengsao is cattle, buffaloes, duck, chicken, geese, and swine. Fishery of Changwat Chachoengsao includes marine and fresh water fisheries. However, marine fishery is more profitable than fresh water fishery due to the contact of the sea in southern of Amphoe Ban Pho and Amphoe Bangpakong. Figure 3.4a to 3.4e show agriculture in Changwat Chachoengsao.

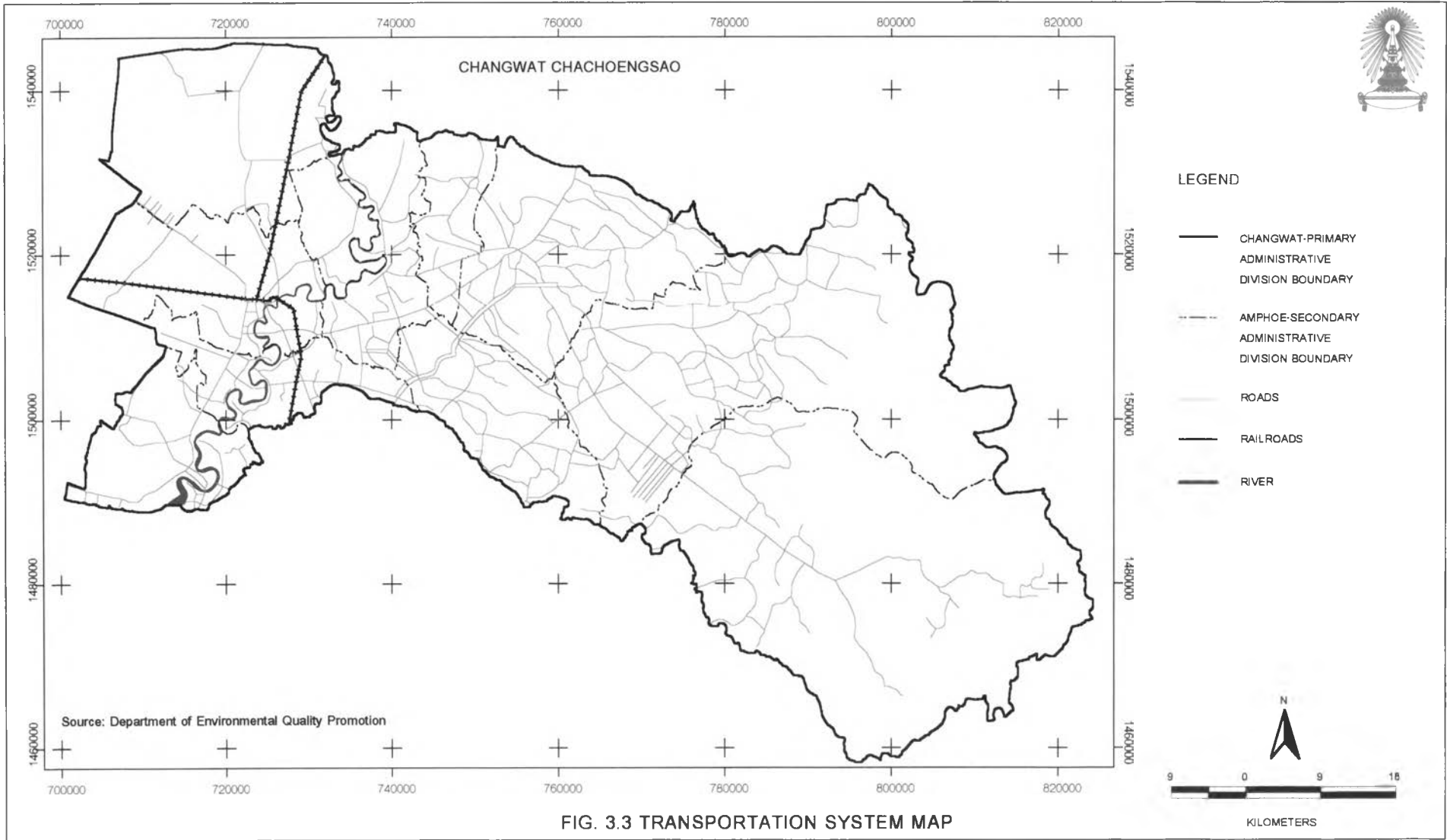
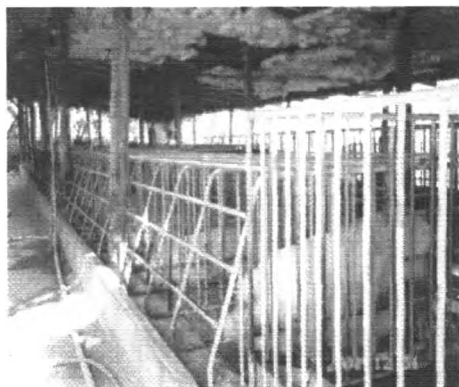


FIG. 3.3 TRANSPORTATION SYSTEM MAP



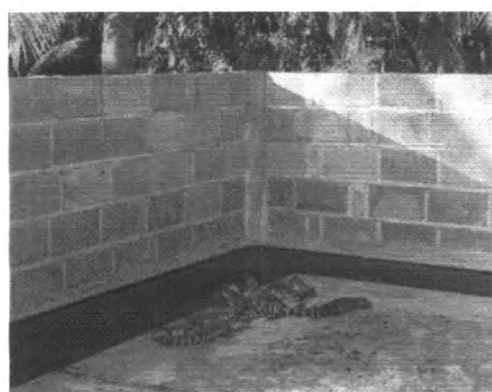
(a) Swine Farm



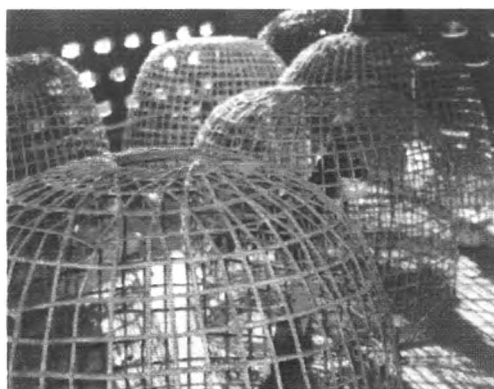
(b) Shrimp Farm



(c) Fish Farm



(d) Crocodile Culture



(e) Cock Farm

FIG. 3.4 AGRICULTURE IN CHANGWAT CHACHOENGSAO.

3.1.2.2 Industry

Generally, industries have been ranked in second in terms of the economic structure. Table 3.2 presents number of industrial establishments, capital, and employees by type of industries in 1998.

Table 3.2 Number of Industrial Establishments, Capital, and Employees
by Type of Industries : 1998

Type of Industries	No. of Industrial Establishments	Capita (Million Baht)	No. of Employees
Total	50	2,662.2	1,785
Agriculture	6	141.8	129
Construction	3	37.0	70
Food and Beverages	6	282.9	116
Wood Products	5	29.6	619
Textiles, and Wearing Apparel	-	-	-
Chemical and Plastic	4	887.3	256
Metal and Non-metallic	8	279.9	169
Service	10	256.2	185
Others	8	747.5	241

Source: Chachoengsao Provincial Industrial Office, 1999.

3.1.2.3 Provincial Product

The Gross Domestic Product (GDP) and Gross Provincial Product (GPP), at current market price, were indicated to extension growth of country and province, respectively. Table 3.3 shows The Gross Domestic Product and Gross Provincial Product at current market price during 1975-1998. Table 3.4 shows Gross Provincial Product at current market prices by industrial origin during 1992-1996. Loawatcharin (in thai, 1988) who referred to JICA (1982) studied the relationship

between the GDP of province and municipal solid wastes generated rate in Bangkok Metropolis. As a result, if the GDP is increased 10%, the increasing waste generated rate is computed as 3.3%. Consequently, the GPP of Changwat Chachoengsao is considered with other parameters for solid wastes generated quantities calculation (see Chapter 4.1.1).

3.1.2.4 Recreation and Tourism Attractions

In Changwat Chachoengsao, there are numerous places of attraction. Wat Sothorn Wararam is one of the popular places where Luang Por Sothon is position. In addition, other important places are shown in Figure 3.5.

Table 3.3 The Gross Domestic Product and Gross Provincial Product
at Current Market Price During 1975-1998

Year	GDP (million bath)	GPP (million bath)
1975	307,366	3,079
1976	349,927	3,516
1977	406,659	4,322
1978	490,983	5,293
1979	562,580	5,214
1980	662,482	7,301
1981	760,356	7,528
1982	841,569	8,328
1983	920,989	8,848
1984	988,070	9,578
1985	1,056,496	11,240
1986	1,133,397	11,934
1987	1,299,913	14,426
1988	1,559,804	19,287
1989	1,856,992	24,875
1990	2,183,545	25,243
1991	2,506,634	31,624
1992	2,830,914	34,887
1993	3,170,259	37,352
1994	3,634,497	42,667
1995	4,192,696	50,006
1996	4,622,831	53,098
1997	4,740,249	35,129
1998	4,628,430	53,320

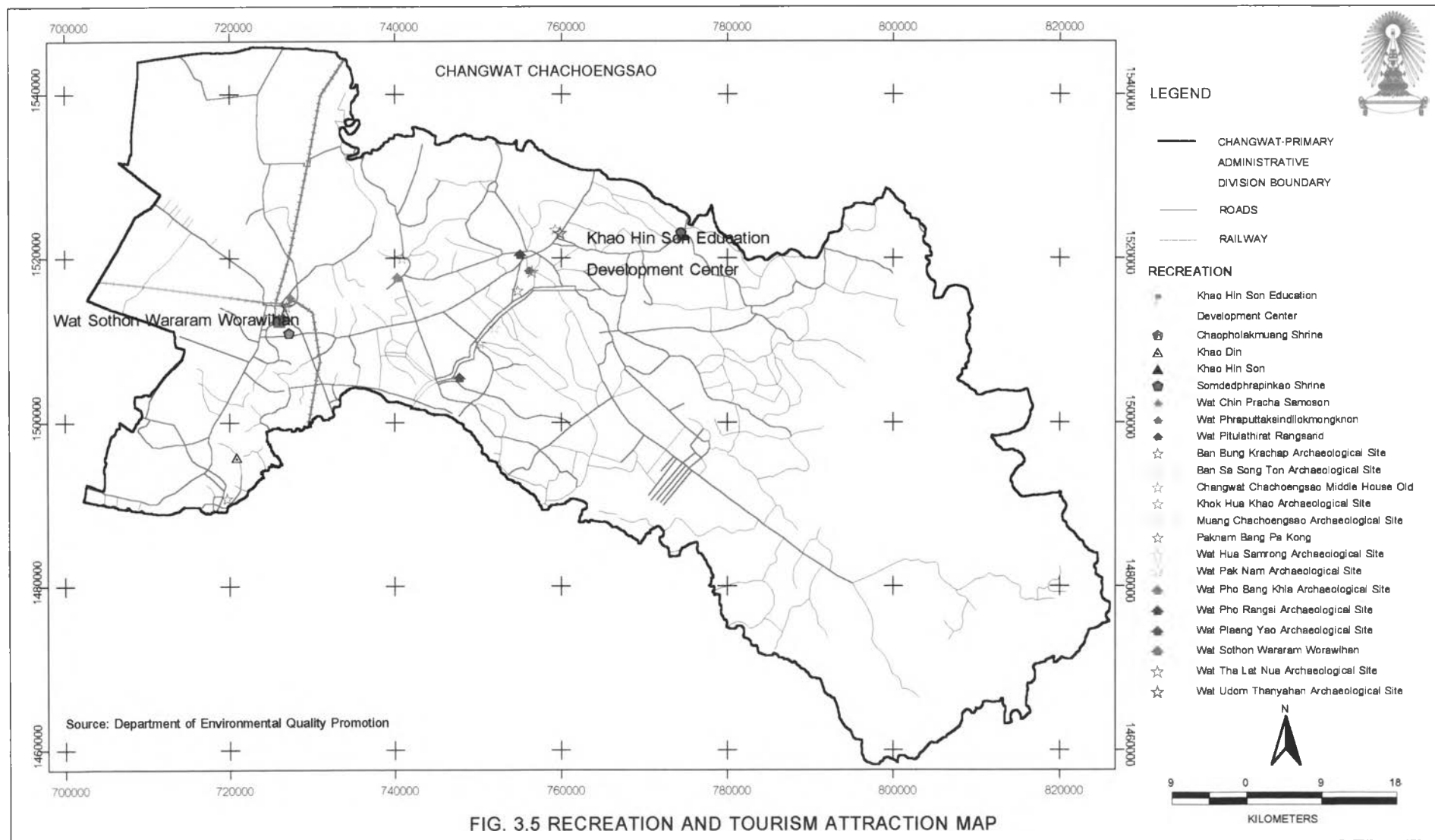
Source : National Statistical Office, 2001.

Table 3.4 Gross Provincial Product at Current Market Prices by Industrial Origin : 1992-1996

Industrial Origin	1992	1993	1994	1995	1996p
Agriculture	5,800,693	5,193,195	6,165,805	7,758,917	7,661,277
Crops	3,399,231	2,520,998	3,164,588	3,725,769	3,934,620
Livestock	1,363,151	1,416,212	1,652,785	2,492,854	1,993,488
Fisheries	514,749	750,973	809,167	954,628	1,079,158
Forestry	3	0	63	0	555
Agricultural services	242,675	226,144	242,555	246,472	257,485
Simple agri. Processing products	280,884	278,868	296,647	339,194	395,971
Mining and quarrying	4,595	5,104	23,740	23,211	27,780
Manufacturing	16,847,644	18,333,918	21,313,675	24,547,548	25,701,194
Construction	771,759	629,475	1,149,975	1,519,972	2,538,986
Electricity and water supply	1,836,505	2,411,840	2,300,731	2,841,831	2,939,714
Transportation and communication	1,121,930	1,633,357	2,024,504	2,646,750	3,263,472
Wholesale and retail trade	3,379,317	3,500,851	3,885,925	4,312,802	4,823,830
Banking, insurance and real estate	1,077,048	1,438,221	1,607,132	2,060,866	2,802,003
Ownership of dwellings	868,020	913,854	969,973	1,045,006	1,131,075
Public administration and defence	769,002	860,426	906,213	1,131,610	1,210,886
Service	2,483,082	2,485,329	2,470,777	2,706,684	3,174,465
Gross Provincial Product (GPP)	34,959,595	37,405,570	42,818,450	50,595,197	55,274,682
Percapita GPP (baht)	60,905	64,381	72,697	84,749	91,363
Population (1,000 persons)	574	581	586	597	605

1996 p : Preliminary Data

Source : Office of the National Economic and Social Development Board.



3.2 Physical Environment

3.2.1 Topography

Topographically, the study area consists of vast flat-lowland area in the west. The elevation increases westward within the area. Southwestern part, from the shoreline, is tidal flat area with less than 2 percents of inclination. The ground elevation is about 0 to 2 meters above the mean sea level (MSL). The extensive flat-lowland area is situated in the west and southwest sectors. Slopes are not greater than 2 percent in this area and elevation is approximately 2 to 3 meters above MSL. The Bangpakong River is flowing through Amphoe Bang Namprieo, Amphoe Bang Khla, Amphoe Muang, Amphoe Ban Pho, and into The Gulf of Thailand at Amphoe Bang Pakong. Characteristic of terrain is flat to highland from west to east. Some of them are floodplains of Khlong Rabom, Khlong Siyat, and Khlong Tha Lat. Figure 3.6 shows general characteristic of terrain in Changwat Chachoengsao.

According to DEQP that modified contour map (RTSD, 1970) in digital format, it can be classified slope of Changwat Chachoengsao into eight classes, including 0-5% of Class 1, 5-10% of Class 2, 10-15% of Class 3, 15-20% of class 4, 20-25% of class 5, 25-30% of class 6, 30-35% of class 7, and more than 35% of class 8, as shown in Figure 3.7.

3.2.2 Climate

The climate of Changwat Chachoengsao is classified as "Tropical Monsoon Climate" according to the Koppen Classification (Thassanapak, 2001). The study area is under the influence of the Southwest Monsoon between May to September. This monsoon brings the rain from the India Ocean. During October to April, the area is under the influence of the Northeast Monsoon, which brings the cold climate from China. According to Meteorological Department, the annual mean temperature of Changwat Chachoengsao using observed data from Station 459201 Chonburi, Changwat Chonburi that was 28.6°C, as summarized in Table 3.5. The mean annual rainfall and the mean monthly rainfall of each station are summarized in Table 3.6 and presented in Figure 3.8.

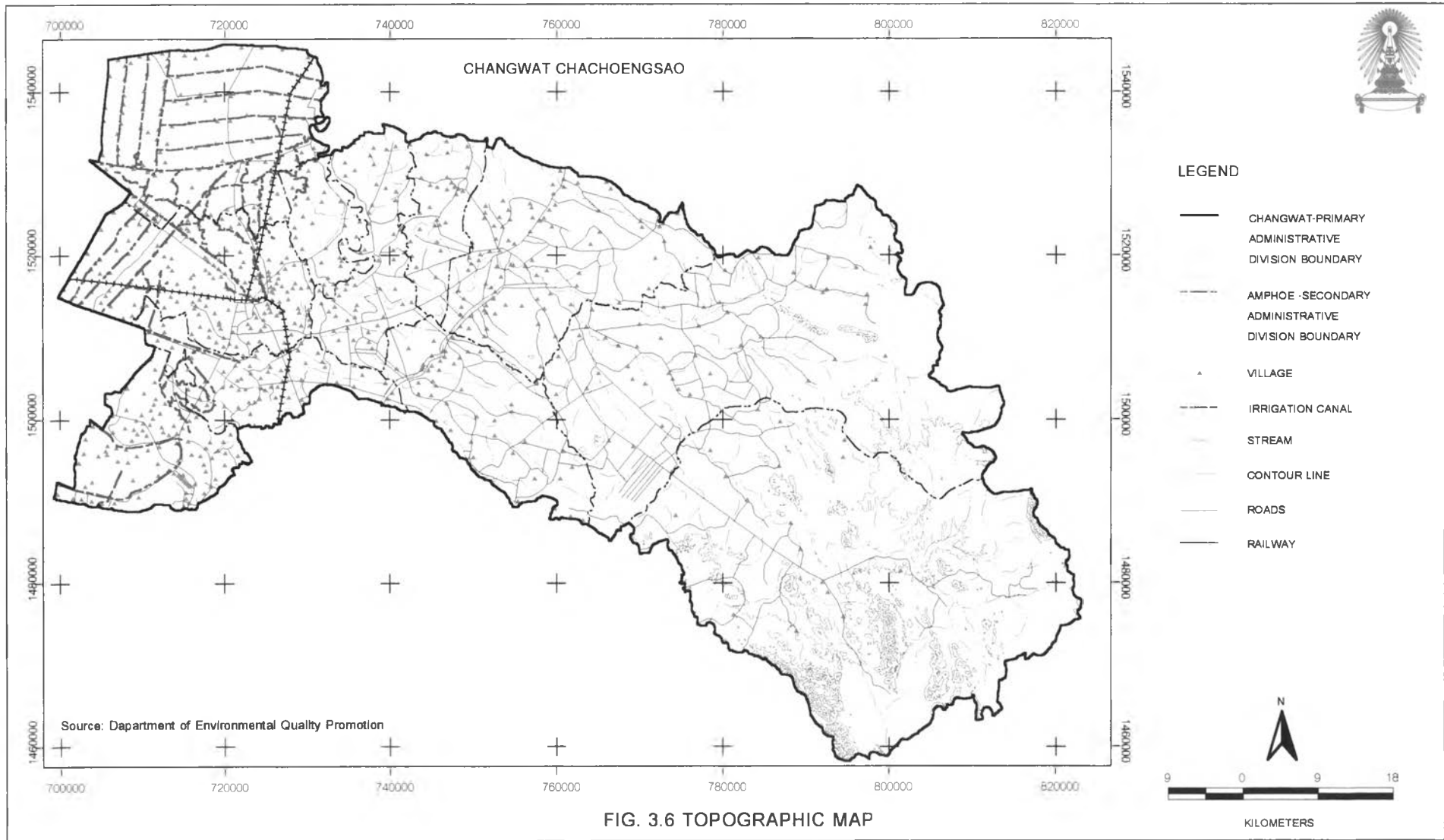


FIG. 3.6 TOPOGRAPHIC MAP

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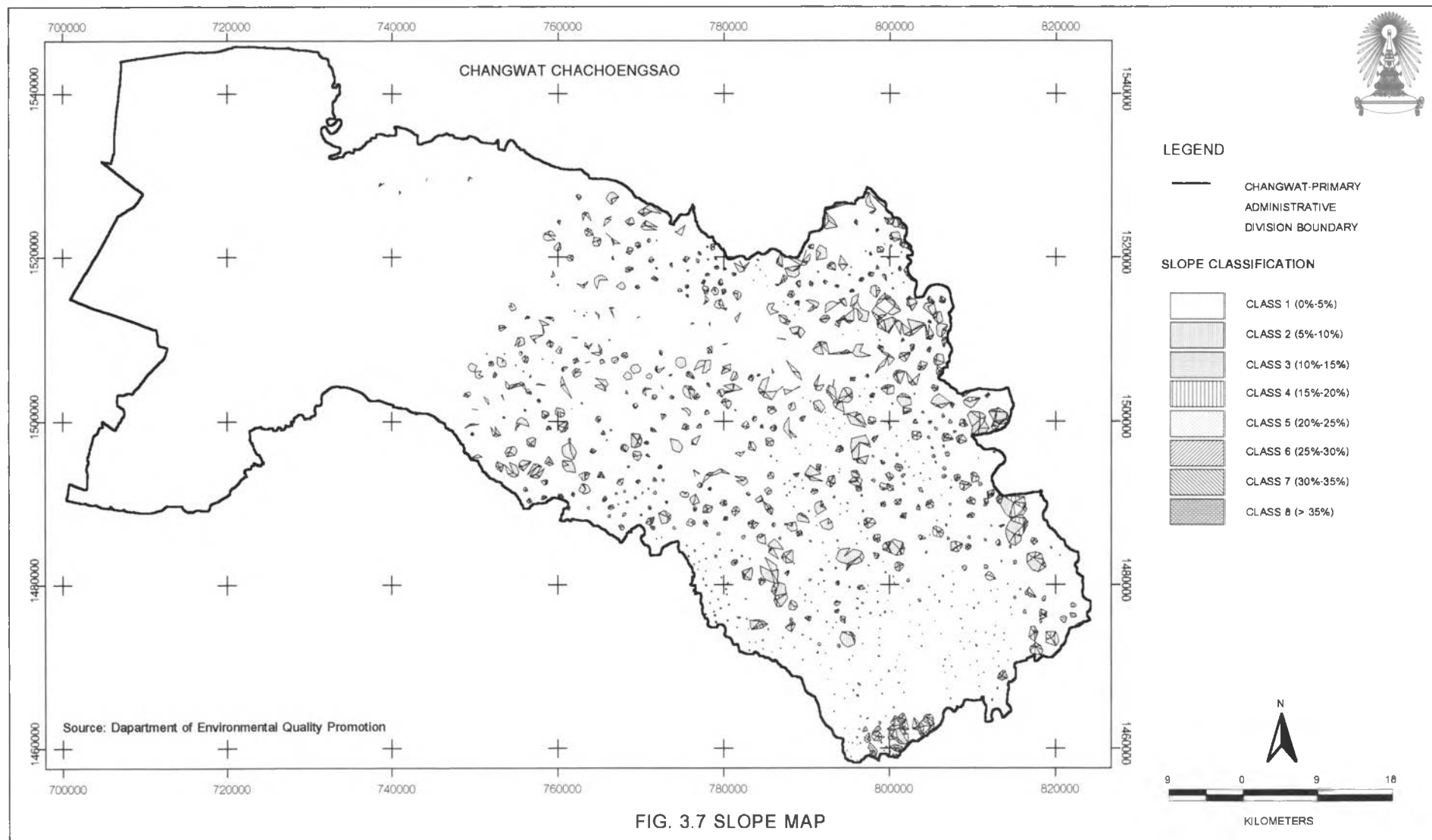


FIG. 3.7 SLOPE MAP

In the present study, a maximum of mean monthly rainfall and average rain-day of Changwat Chachoengsao during 1967-1999 were measured at Station No. 423009 (Phanom Sarakham Animal Breeding) that were 288.8 mm. of mean rainfall and 19.2 days of rain-day in September. In addition, the wind direction for all year round at Changwat Chachoengsao is shown in Figure 3.9 (Pokaew, 1999).

Table 3.5 The Daily Mean Dry Temperature of Changwat Chachoengsao in 1995

Station	Month	Daily Mean Temperature (°C)
459201 Chonburi*	Jan	26.9
	Feb	27.4
	Mar	29.6
	Apr	30.9
	May	29.9
	Jun	30.5
	Jul	29.3
	Aug	28.7
	Sep	27.9
	Oct	28.1
	Nov	27.8
	Dec	26.0
	Annual mean	28.6

Source: Meteorological Department

Remark * = No observed data from Station in Changwat Chachoengsao

Table 3.6 The Mean Annual Rainfall and the Mean Montly Rainfall of Each Station in Changwat Chachoengsao During 1967-1999

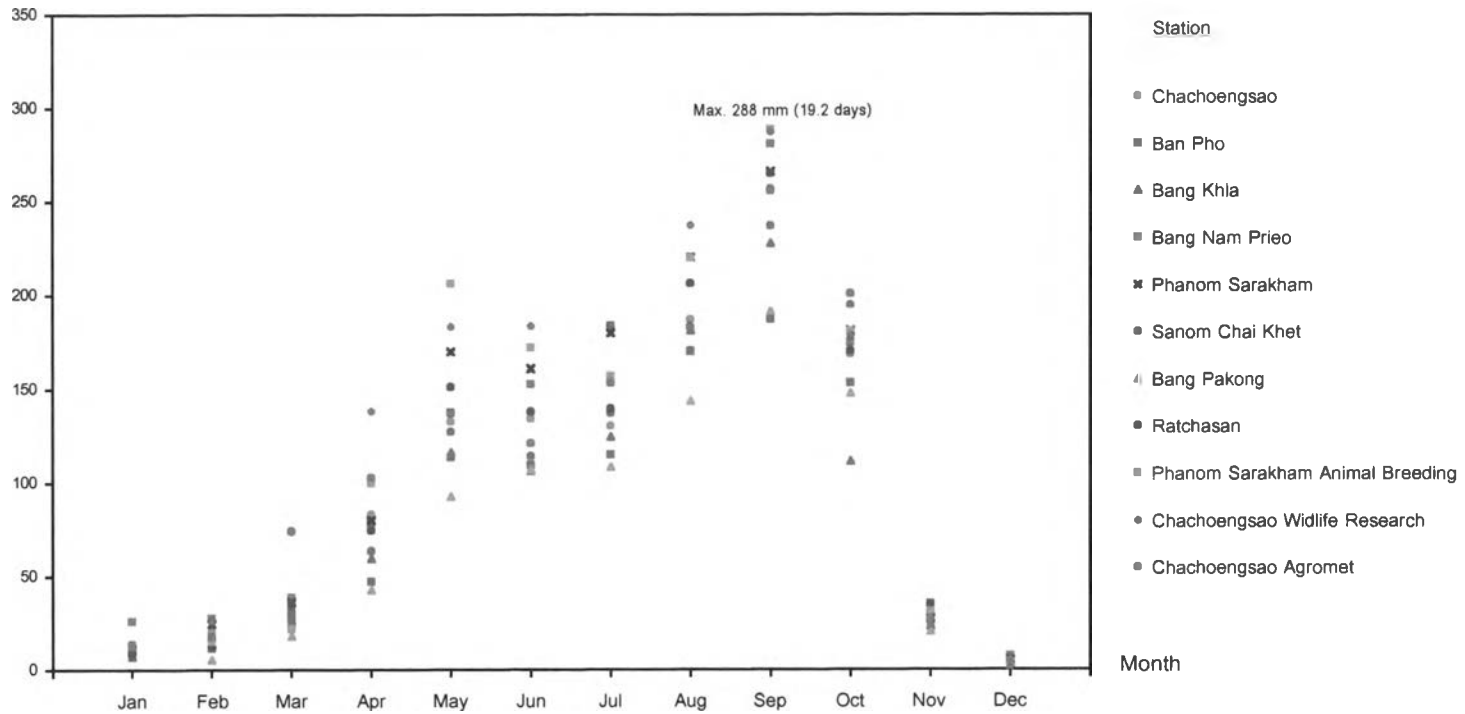
Station Month	423001 Chachoengsao (1967-1999)		423002 Ban Pho (1975-1999)		423003 Bang Khla (1977-1999)		423004 Bang Nam Prieo (1976-1999)		423005 Phanom Sarakham (1975-1999)		423006 Sanom Chal Khet (1975-1999)	
	Av.Rainfall	Av.Rain-day	Av.Rainfall	Av.Rain-day	Av.Rainfall	Av.Rain-day	Av.Rainfall	Av.Rain-day	Av.Rainfall	Av.Rain-day	Av.Rainfall	Av.Rain-day
	(mm)	(day)	(mm)	(day)	(mm)	(day)	(mm)	(day)	(mm)	(day)	(mm)	(day)
Jan	9.5	0.7	11.8	0.5	7.1	0.3	25.9	1.3	10.8	0.7	10.0	0.5
Feb	20.2	1.2	11.5	0.5	13.6	0.7	27.9	0.9	24.7	2.0	16.8	1.2
Mar	32.2	1.8	27.4	1.2	25.9	1.8	38.7	2.1	36.3	2.9	30.3	2.3
Apr	83.3	4.0	47.2	3.0	59.7	4.5	78.0	3.3	80.2	4.9	63.7	4.2
May	132.9	8.5	113.7	7.6	116.5	9.0	137.8	7.3	169.7	11.5	127.5	8.9
Jun	134.3	10.5	109.5	6.8	106.4	8.1	152.9	7.9	160.9	11.6	114.4	8.9
Jul	130.5	10.3	115.1	7.6	124.6	9.9	183.7	9.2	179.8	12.8	137.2	9.2
Aug	186.9	12.7	169.8	10.1	181.3	12.8	220.1	10.7	220.1	13.3	170.2	11.3
Sep	256.7	13.7	187.1	11.0	227.7	13.3	280.7	10.8	266.2	15.6	236.9	13.2
Oct	168.6	9.9	153.4	8.5	111.7	8.6	174.8	7.4	181.1	11.2	194.6	9.6
Nov	32.0	2.5	29.2	2.0	23.4	1.8	35.3	1.9	27.5	2.9	33.0	2.6
Dec	5.0	0.3	2.6	0.2	3.4	0.3	7.1	0.3	5.1	0.6	1.3	0.2
Annual	1192.1	76.1	978.3	69.0	1001.3	71.1	1362.9	63.1	1362.4	90.0	1135.9	72.1

Table 3.6 (continued)

Station Month	423007 Bang Pakong (1975-1999)		423008 Ratchasan (1978-1999)		423009 Phanom Sarakham Animal Breeding (1975-1997)		423010 Chacheongsao Wildlife Research Station (1991-1999)		423301 Chacherngsao Agromet (1989-1999)	
	Av.Rainfall	Av.Rain-day	Av.Rainfall	Av.Rain-day	Av.Rainfall	Av.Rain-day	Av.Rainfall	Av.Rain-day	Av.Rainfall	Av.Rain-day
	(mm)	(day)	(mm)	(day)	(mm)	(day)	(mm)	(day)	(mm)	(day)
Jan	13.0	0.7	8.7	0.4	13.5	1.0	12.0	1.6	13.6	1.1
Feb	5.5	0.3	13.5	0.8	14.9	1.6	25.9	2.2	17.3	2.1
Mar	18.1	0.8	34.8	2.5	22.0	1.7	74.1	5.8	74.4	6.7
Apr	42.7	1.8	74.6	4.7	100.1	5.9	138.4	8.2	102.9	7.1
May	92.8	5.2	151.2	10.3	206.0	13.3	183.1	12.7	137.5	14.1
Jun	107.3	5.2	138.0	8.8	171.8	11.4	183.7	13.3	121.3	14.2
Jul	108.7	6.0	139.7	9.5	157.3	14.8	183.4	15.0	153.4	15.2
Aug	143.8	8.1	206.2	12.5	219.8	17.2	237.4	17.0	182.9	17.5
Sep	191.5	9.5	265.2	13.2	288.8	19.2	287.4	18.6	255.7	18.9
Oct	148.1	6.8	170.1	8.7	180.7	14.4	178.3	13.2	200.7	13.9
Nov	20.4	1.5	34.5	2.5	31.1	3.5	24.1	3.3	27.1	4.1
Dec	3.5	0.1	3.8	0.3	4.0	0.8	5.9	1.3	4.9	1.4
Annual	896.4	46.0	1240.3	74.2	1410.0	104.8	1533.7	112.2	1291.7	116.3

Source: Meteorological Department

Rainfall (mm)



Source: Meteorological Department

FIGURE 3.8 THE MEAN MONTHLY RAINFALL OF EACH STATION IN CHANGWAT

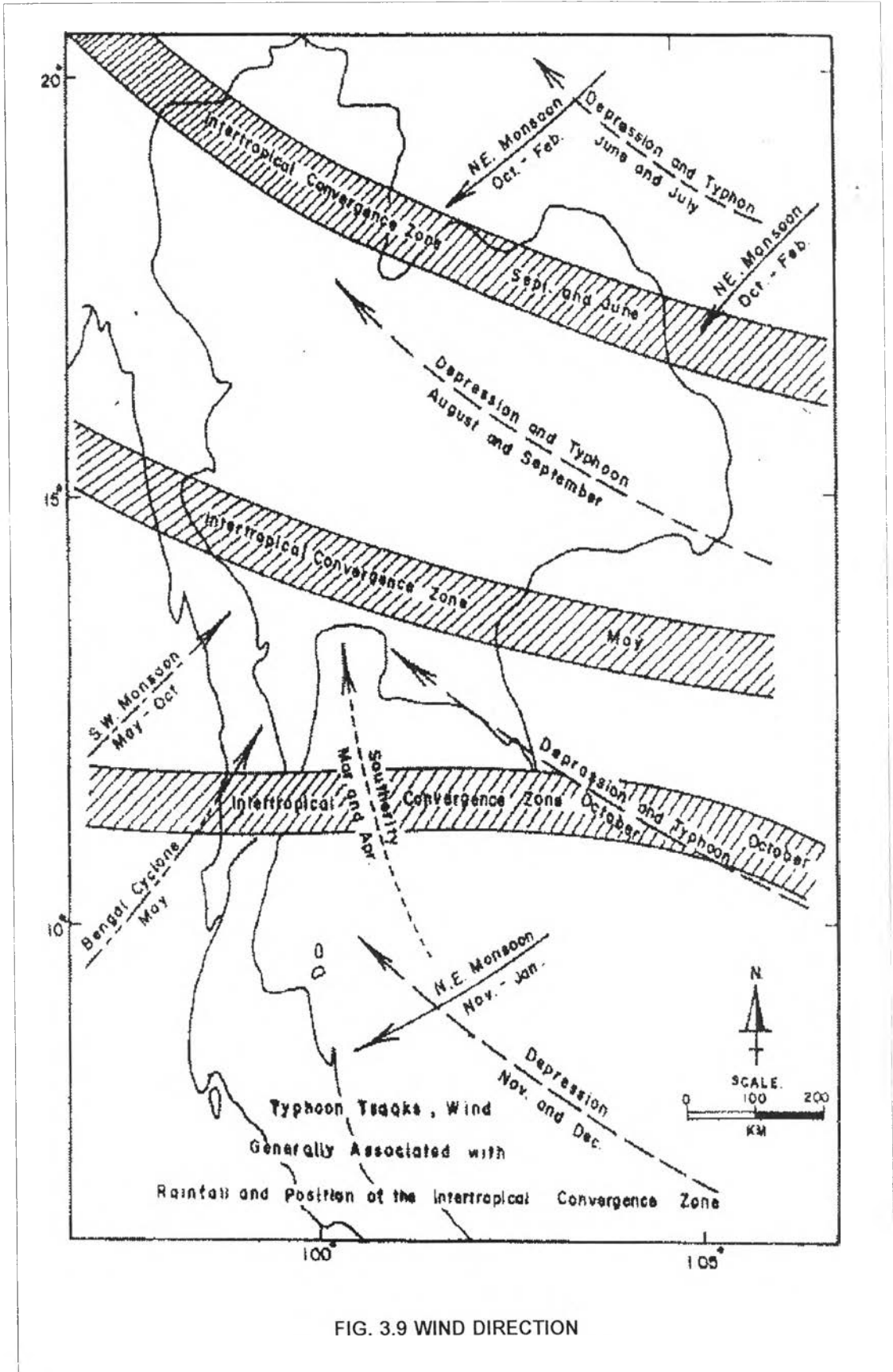


FIG. 3.9 WIND DIRECTION

Source: Diagram cited in Pokaew, 1999

3.2.3 Geology

According to the geological map (Sheet ND47-12 in 1:250,000 scale, namely, Bangkok Metropolis) of Geological Survey Division, DMR (1976), in Figure 3.10, the generalized stratigraphic succession of the study area has been described in ascending order as follows:

3.2.3.1 Sedimentary and Metamorphic Rocks

Precambrian (PE_{sch}) *sequence* exposes in the NW-SE from Changwat Chachoengsao consists of high grade metamorphic, quartz, mica schist and quartz kyanite schist. The rock is silver gray to grayish-brown, high weathered with some iron bonds of hematite and magnetite, consists of quartz, muscovite, sericite, kyanite, orthoclase. It shows the oldest rocks in the study area, which are exclusively metamorphic rocks. They consist essentially of quartz-mica schist and quartz-kyanite schist. They are dominantly exposed as hills and small mountains that are oriented approximately north/southeast trendings. Especially, Khao Nam Yot and Khao Din in the area of Gate Way Industrial Estates in Amphoe Plaeng Yao and Amphoe Panom Sarakham (Mungkung, 1992).

Silurian-Devonian (Kanchanaburi Formation) (SD) consists of low grade metamorphic rock, quartz mica schist, quartzite, sandstone, yellowish- brown, medium grained interbedded with tuffaceous sandstone and chert bed with fossil of nautiloid. According to the geological map of Thailand at scale 1:1,000,000 of DMR (1999), its age change to *Devonian-Carboniferous* age (DC).

Carboniferous (Kaeng Krachan Formation) consists of two rock units which are described as a below:

1. *Lower Carboniferous* (Ck_1) with the succession of the sequence from the younger to the older that they are conglomerate quartzite and sandstone with chert interbedded, micaceous siltstone with interbedded limestone, and black slate, respectively. Fossil of bryozoa have found in micaceous siltstone at the

northern part of Khao Yai. They are Penniretepora sp., Fenestella cf.F. triserialis, Fenestella sp. and Polypora sp. that indicate Lower Carboniferous age. According to the geological map of Thailand at scale 1:1,000,000 of DMR (1999), its age change to *Triassic age (Noen Phuyai Yua Formation) (TRn)*.

2. *Middle Carboniferous (Ck₂)* consists mainly of tuffaceous sandstone, greywacke, shale and slaty shale. According to the geological map of Thailand at scale 1:1,000,000 of DMR (1999), its age change to *Triassic age (Pong Nam Ron Formation) (TRpn)*.

Permo-Carboniferous (Ratburi Group) (CP) expose mainly at the southeastern part, consists of clastic sediment with the succession sequence from younger to older as following

- Sandstone, Mudstone, Pebbly Sandstone
- Tuffaceous Shale, Chert
- Conglomerate

Fossil of bryozoa was found in limestone at Khao Som Pung, and identified to be Rhadomeson mammillatum (?) (Lower Permian). Fossil of fusulinid at Khao Rewadee was identified as Pseudofusulina cf regularis that indicate Upper Carboniferous – Lower Permian age. According to the geological map of Thailand at scale 1:1,000,000 of DMR (1999), its age change to *Jurassic age (JK)*.

Permian (Ratburi Group)(P) consists dominantly of limestone, gray to light gray, bedded to massive with argillaceous seam along bedding or fracture plane, partly metamorphosed and recrystallized.

The Quaternary deposits (Qa and Qt) in this region comprises mainly of unconsolidated clastic sediments. They are alluvium sediments and marine sediments. Low and high deposits characterize the lower sequence. They composed mainly of laterite, gravel, sand, silt, and clay of fluvial and marine origins. The upper part of the sequence is shown by alluvium and beach sand, which are practically found on the active plains of large rivers, and on the recent beaches, respectively. According to

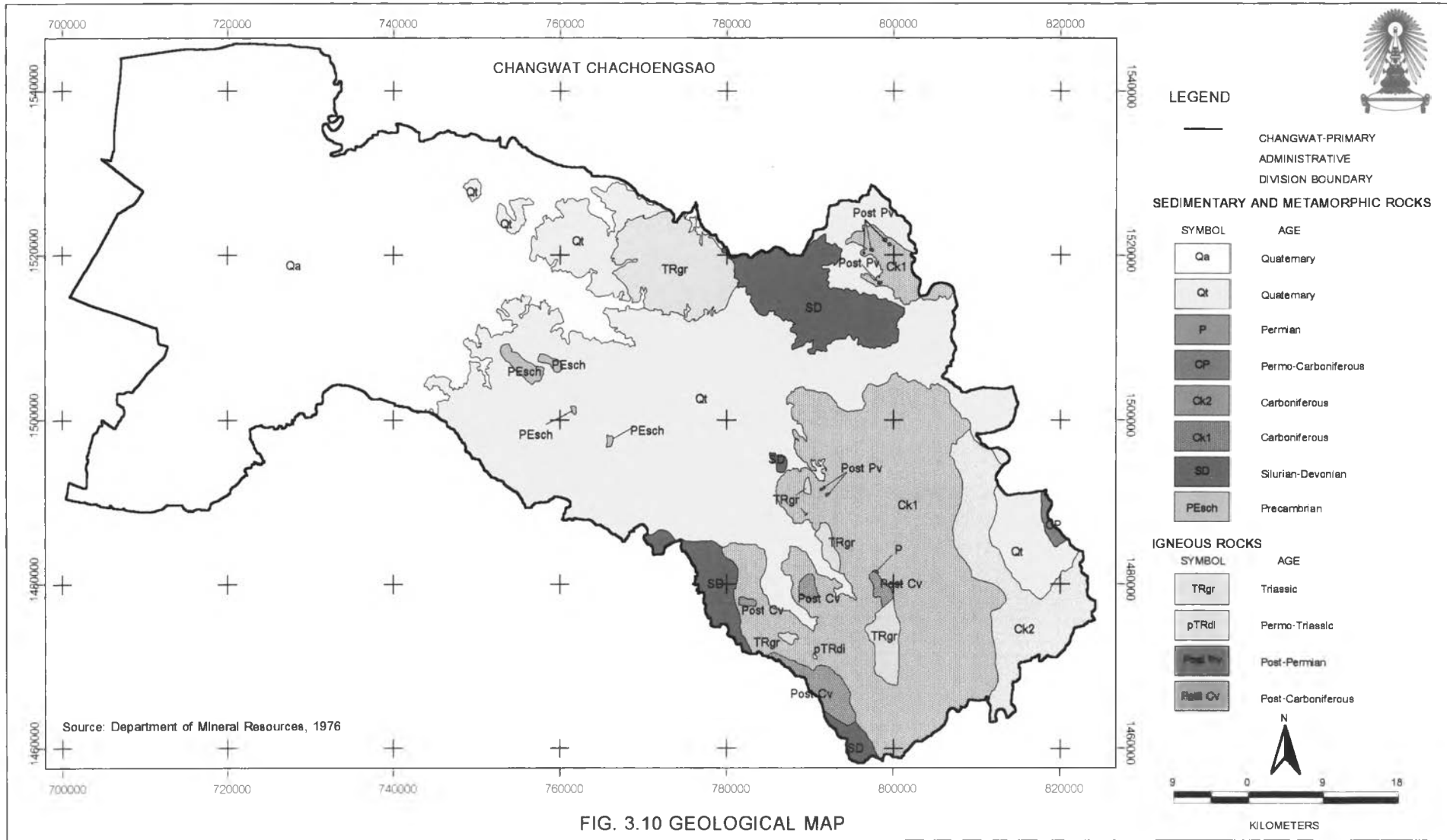


FIG. 3.10 GEOLOGICAL MAP

the geological map of Thailand at scale 1:1,000,000 of DMR (1999), the Quaternary deposits (Qa and Qt) consist of coastal tide-dominated deposits (Qm); clay, silt and fine sand of tidal flat, marsh, mangrove swamp and estuary, fluvial deposits (Qa); gravel, sand, and clay of channel, river bank, and flood basin, terrace deposits (Qt); gravel, sand, and laterite of rejuvenated river, and colluvial deposits; residual sediments, laterite and rock fragments.

3.2.3.2 Igneous Rocks

Post Carboniferous (PostC_v) consists of massive greenish-gray to grayish-purple rhyolite tuff, quartz and felspar as phenocryst, felsite, sericite and muscovite as ground mass.

In the southern part of Amphoe Tha Takiap, volcanic rocks (*Post Permian age*; PostP_v) have reported by Nakinbodee et.al (1976), which consists of Andesite; dark greenish gray to purple, fine grained, consists mainly of pyroxene.

Diorite (*Permo-Triassic*; PTR_{qv}) is intruded stockily, greenish gray, very coarse, coarse and medium grained, consists predominantly of pyroxene and hornblende intrusive.

Triassic (TR_{gr}) consists of Khao Hin Son Hornblende Biotite Granite, medium to coarse grained, the smaller isolate batholith are exposed in the eastern margin of the area. According to the geological map of Thailand at scale 1:1,000,000 of DMR (1999), its age no change that is *Triassic* age (TR_{gr}).

In the present study, rock units from the geological map of Geological Survey Division, DMR (1976) were used for geological evaluation (see in Appendix B-Table B.2-B.3). However, it is worth mentioning that even though there are different detailed scale geological maps and the revised 1:1,000,000 scale geological map of DMR, but they were not utilize for such evaluation. All rock units and geological ages, which are presented in this study, may not be coincided with the up-dated detailed and revised DMR geological maps.

3.2.4 Geomorphological Setting

According to Mungkung (1992) classified landforms of Changwat Chachoengsao into six types, namely, tidal zone, brackish swamps, delta plain of marine and brackish clays, floodplains, terrace, and mountains and hills. The Geomorphology of Changwat Chachoengsao was modified and presented in Figure 3.11. They are described as below:

3.2.4.1 Tidal Zone

The zone lies along the shoreline of the Gulf of Thailand. At two sides of Bang Pakong estuary, the zone is closely related to the marine activities. The elevation of this area is usually 0 to 1 meter above MSL. Slope is not over 2 percents. The mangrove, Nipa swamps, and tidal flats mainly occupy the tidal zone.

3.2.4.2 Brackish Swamps

The area occupies south of the western sector or in Amphoe Bang Pakong. Marine water could be intruded into the area and effected fresh water in dry summer. Swamp areas are effected by sea water intrusion and caused them to brackish swamps. The elevation of this area is nearly 2 meters above MSL. Aquatic plants such as reeds, nipa palms, and etc, all of which indicate brackish environment.

3.2.4.3 Delta Plain

The Delta Plain refers to a flat and low-lying plain which forms a triangular shape in plain. The elevation of the delta plain ranges from 5 meters to about less than 2 meters above the mean sea level with average elevation of 2 meters. The deposits of delta plain comprise brackish and marine deposits. The brackish deposits are characterized by medium black clay interbedded with thin layer of sandy clay containing abundant wood fragment, jarosite, and gypsum crystal. The marine clay deposits are characterized by light yellowish gray clay interbedded with thin layers of sand containing pisolitic fe-oxide concentration and shell fragments. Most of the areas

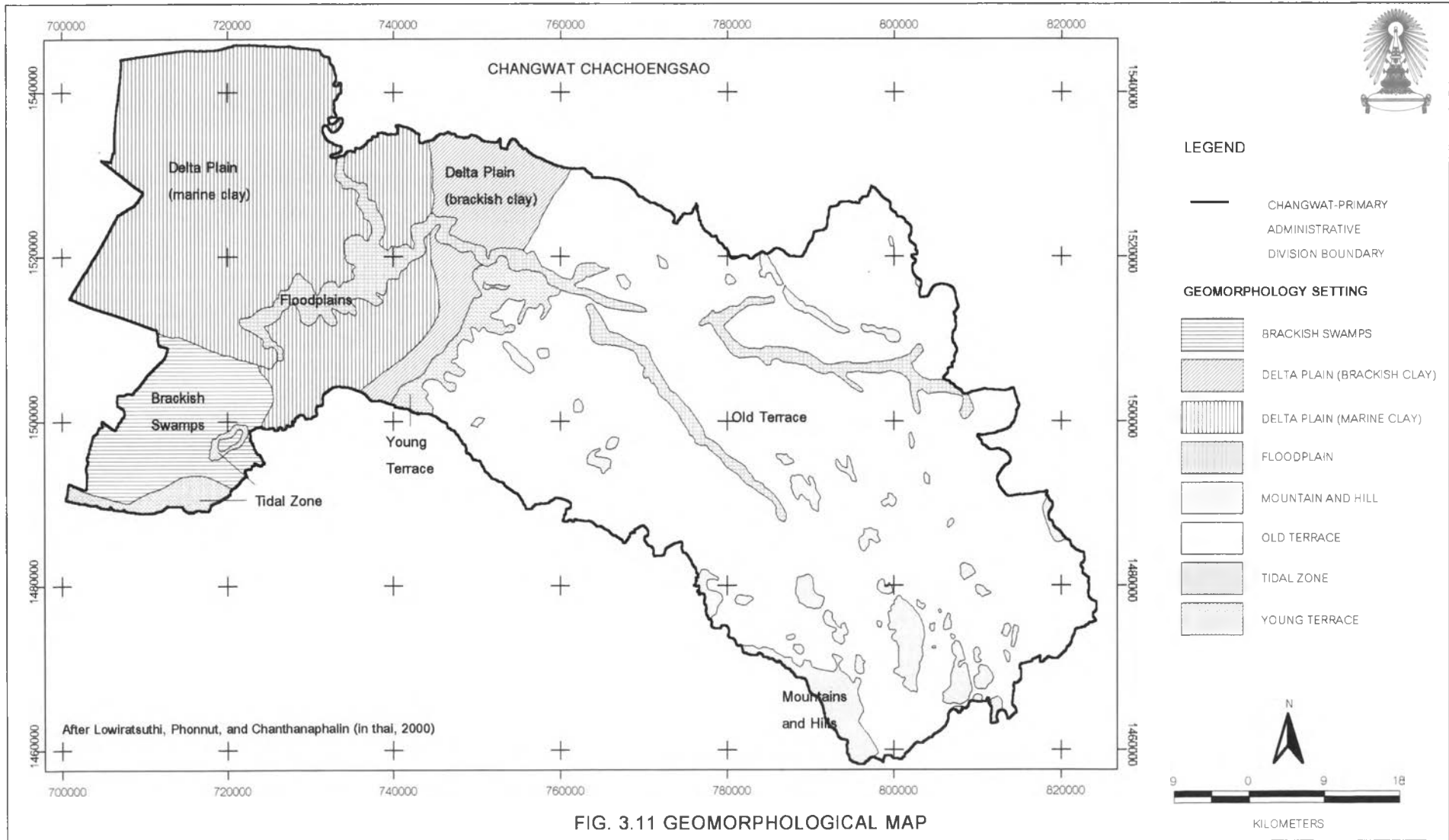
of delta plain are used as paddy field, but some area is still covered by grass, bamboo, and trees (Jarupongsakul, 1990).

Marine Clay area covers Amphoe Bang Nam Prieo, Amphoe Bang Khla, Amphoe Ban Pho, Amphoe Ratchasan, and Amohoe Muang. This flat lowland was flooded by marine in the past times. Average elevation is about 3 meters above MSL and almost flat. According to Thiramongkol (1983), the marine delta plain is predominantly composed of dark to black coloured clays and brown to bluish silty clays with mottles of iron oxide and soft manganese concretion.

Brackish Clay occupies some parts of Amphoe Ratchasan, Amphoe Plaeng Yao, and Amphoe Ban Pho. The brackish clay shows a narrow zone of north-south trending. The elevation is about 2-3 meters above MSL and almost flat. Thiramongkol (1983) who referred Takaya (1971), Hattori (1972a) reported that the delta consists of dark and black clay with weathering features (yellow-brown mottles), and manganese and iron pisolitic concretions. Stiffness is a further distinct characteristic of the clay bed. This clay bed is characterized by basic ferric sulphate (jarosite), which gives characteristic yellow colored spots and gypsum needles. The basic ferric sulphate and gypsum needles are formed in a brackish water environment rich in sulphate iron.

3.2.4.4 Floodplains

Floodplains are form narrow zones along Mae Nam Bang Pakong, Khlong Ta Lat, Khlong Si Yat, and Khlong Rabom. They consist of natural levees and brackish swamps. Natural levees form narrow strips along the river and composed of silty to sandy layers. They are commonly 2 to 3 meters higher than the brackswamps. The brackswamps comprise silty sediments about 1 meter thick (Thiramongkol, 1984). Most of the backswamp are used as paddy fields. The levees portion has Makhaam Theet, Phuthsaa, other garden trees such as mango, jackfruit, Majaam, and etc. Within the study area, small floodplains are located along the small rivers/khlongs. Bang Pakong floodplain is biggest and situated along the trend of NNE/SSW.



3.2.4.5 Terraces

Terraces or old floodplains cover more than a half of the study area. They occur as an extensive undulating terrain bordering the eastern part of the area. The elevation is between 3 to less than 100 meters above MSL. Within the study area, they can be divided into two types as follows:

3.2.4.5.1 *Young Terrace*

The terrace covers some parts of Amphoe Ban Pho and Amphoe Plaeng Yao. It mainly consists of pale to light brown colored silty clay to clay. The iron and manganese concretion have found in the area. They were occurred by the fluctuation of groundwater in different seasons. Young terrace can be separated from old terrace by less laterite formations and all of young terraces are soft sediments.

3.2.4.5.2 *Old Terrace*

The old terrace comprises high terrace and middle terrace. According to Thiramongkol (1984), the eastern margin of the Chao Phraya plain, from Chon Buri to Si Maha Phot, is a strongly undulating surface with scattered hill, interfluvial crests and slopes, and with unchannelled drainage floors. This surface lies between 10 and 100 meters above MSL with a local relief of 30 meters. Near the surface of the plain thick laterite, saporite, and footslope deposits occur. Thick laterites are widely distributed in this area. The thickness of the lateritic layer is generally 3-4 meters. The terrace consists of honeycomb structure. The gravel beds are found overlying the lateritic bed. However, from existing investigation, terrace consists of clayey, silty and sandy layers. The thin lateritic bed can be investigated in the area and most of them seem to be softer than that mentioned previously.

3.2.4.6 Mountains and Hills

The mountains and hills obviously exist in east of the study area. In the northeast, pluton of granitic rocks intruded and formed the dome-shaped with the peak at Khao Hin Son. The mountain of Paleozoic rocks are restricted at the lower part of east section. They formed small and isolated hills and mountains. The peak of the study area is about 777 meters above MSL. It is situated at the crest of Khao Yai near the boundaries of Changwat Chachoengsao and Changwat Chonburi. A structural terrace is in marl and calcareous material. The elevation is between 30 and 120 m above MSL with a relief of up to 30 m. Scattered limestone monadnocks emerge from the undulating surface of the terrace.

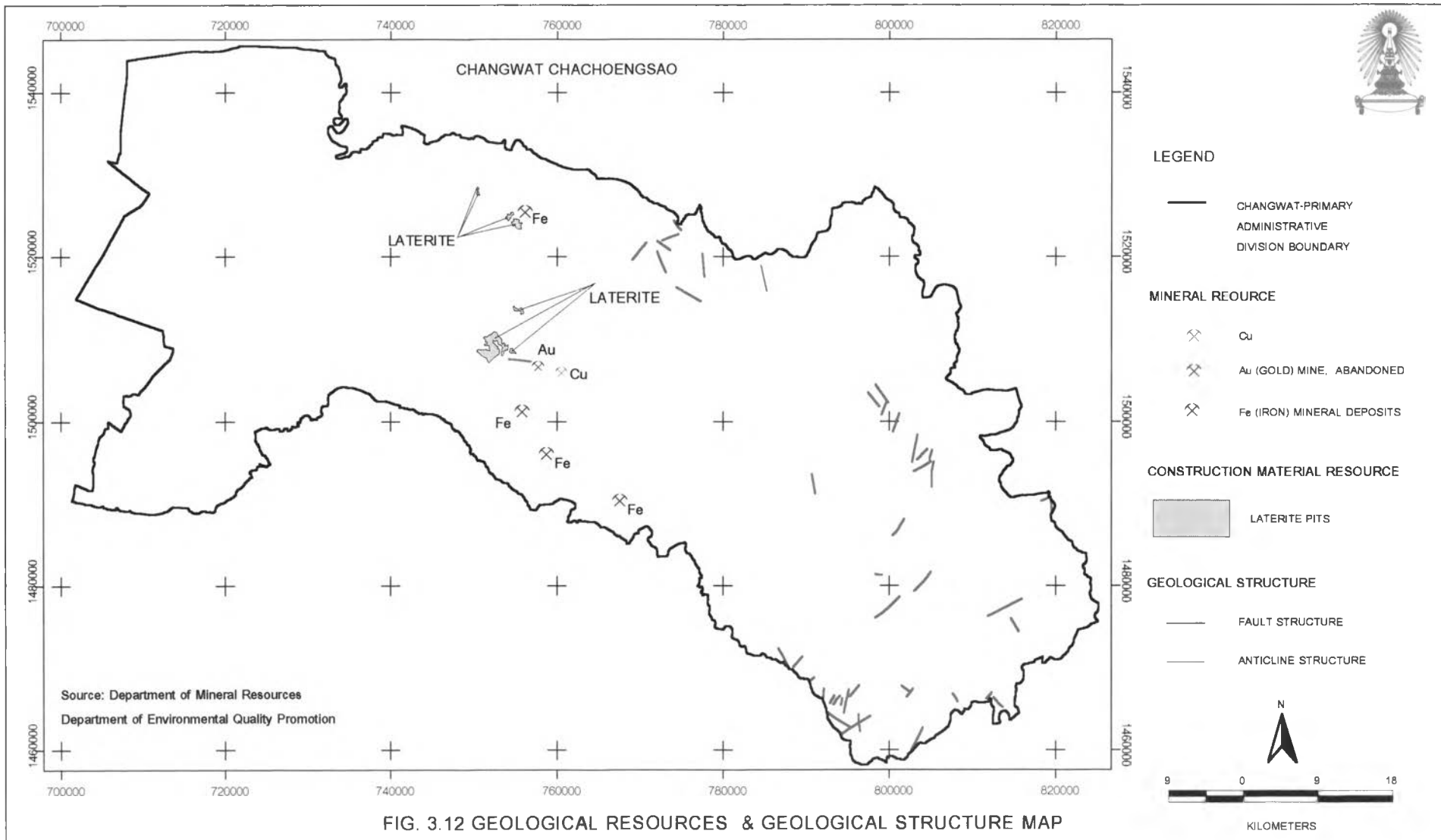
3.2.5 **Geological Resources and Geological Structure**

3.2.5.1 Mineral Resource

According to the geological map (Sheet ND47-12 in 1:250,000 scale, namely, Bangkok Metropolis) of Geological Survey Division, DMR (1976) copper (Cu), iron (Fe) of mineral resources are digitized into digital form as shown in Figure 3.12. Moreover, DEQP digitized iron (Fe) and Gold (Au, abandoned) of mineral resources from the geological map (Sheet ND47-12 in 1:250,000 scale, namely, Bangkok Metropolis) of Geological Survey Division, DMR, 1980) into digital form as shown in Figure 3.12.

3.2.5.2 Construction Material Resource

According to DEQP, Construction materials in this study area are laterite pits as illustrated in Figure 3.12.



3.2.5.3 Geological Structure

According to the groundwater map at scale 1:100,000 (1996) and the geological map at scale 1:100,000 (1976), Fault and Anticline structures are digitized into digital form as shown in Figure 3.12.

3.2.6 Water Resources and Flood Hazard

3.2.6.1 Surface Water Resource

The main surface water in Changwat Chachoengsao is Bang Pakong river which run to the Andaman sea at Amphoe Bang Pakong. Figure 3.13a and 3.13b show characteristic of Bang Pakong river and settlement near river. Surface water resources are presented in Figure 3.14.

3.2.6.2 Groundwater Resource

Geological Survey Division (1996) divided aquifer type in Changwat Chachoengsao into six units, namely, alluvial deposit and flood plain, terrace deposit, sedimentary rocks, metamorphic rocks, volcanic rocks, and granite rocks as described below:

1) *Alluvial deposit and flood plain* (Sa) – consist of gravel, sand, silt, and clay; multiple aquifer from the depth of 20-140 meters; expected well yield mainly ranges from 2 to 10 m³/hr.

2) *Terrace deposit* (St)– consists of gravel, sand, silt, clay, lateritic and decomposed rocks; average depth 10-40 meters; expected well yield mainly ranges from 2 to 10 2 m³/hr.

3) *Sedimentary rocks* (Rss) – consist of sandstone and siltstone; groundwater mainly in bedding plane, fracture and joint with average depth 15-30 meters; expected well yield mainly less than 2 m³/hr.

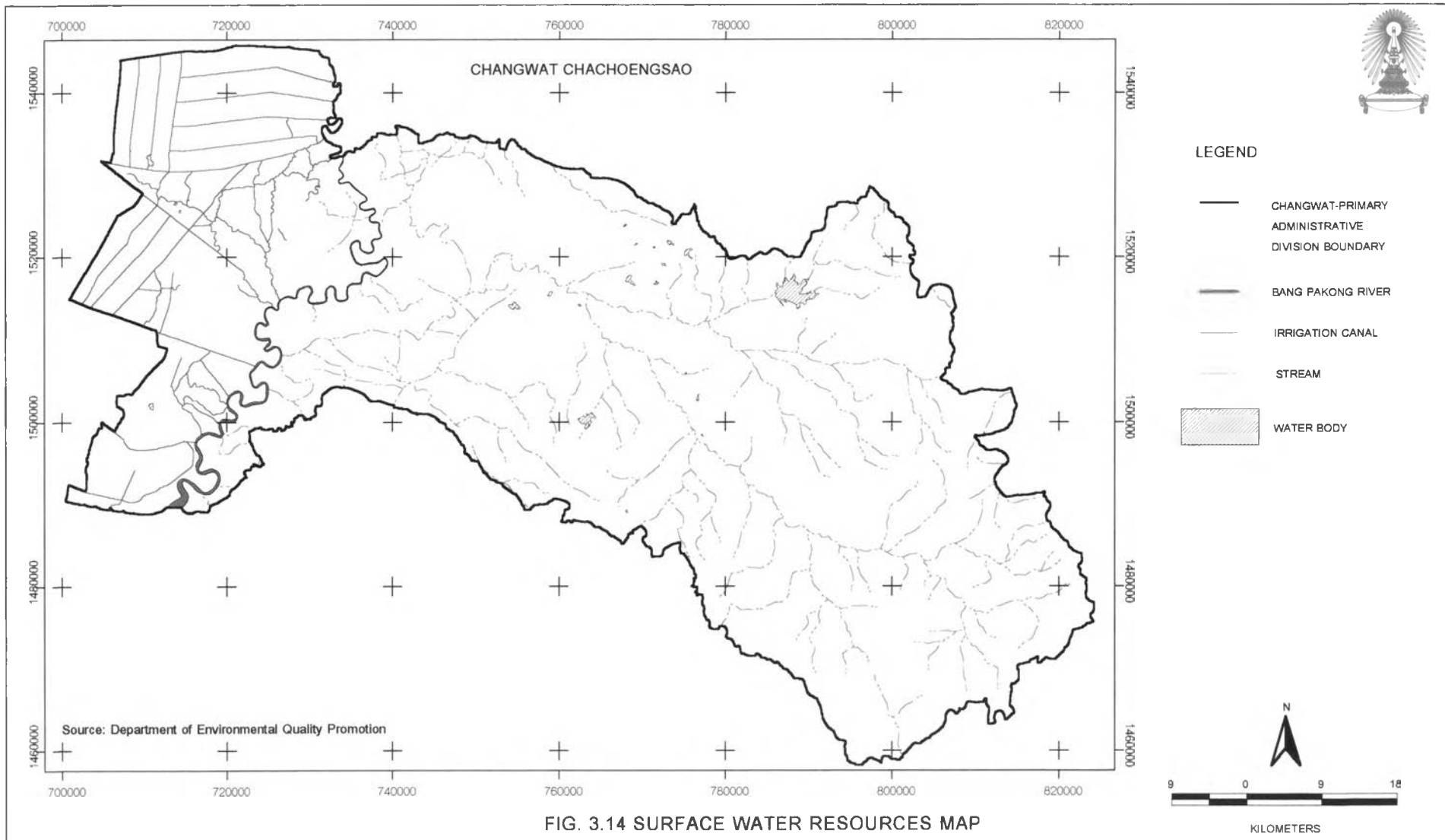


(a)



(b)

FIG. 3.13 CHARACTERISTIC OF BANG PAKONG RIVER



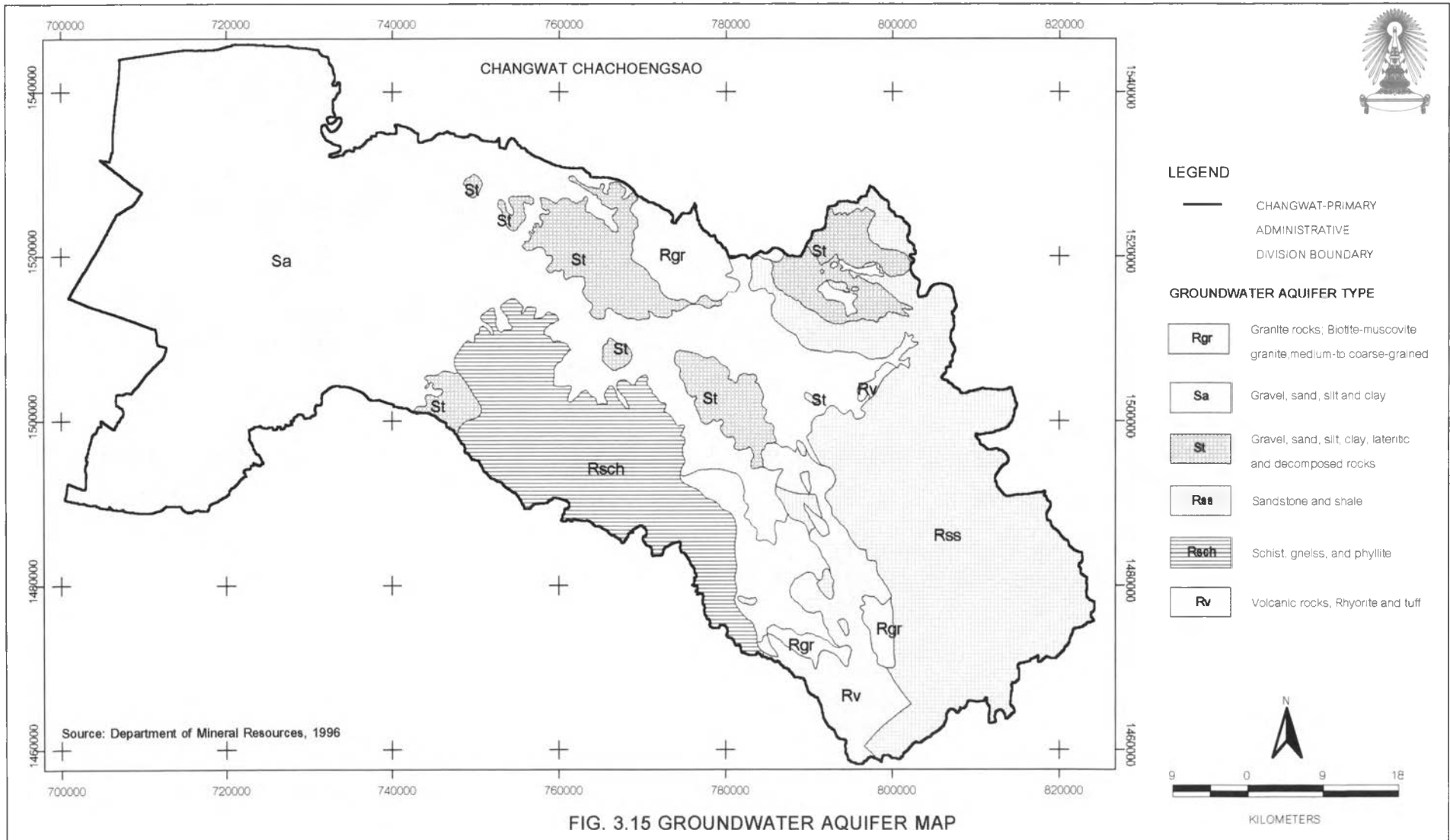
4) *Metamorphic rocks* (Rsch) – consist of schist, gneiss, and phyllite; groundwater occurs mainly in fracture and joint with average depth 15-35 meters; expected well yield mainly less than 2 m³/hr.

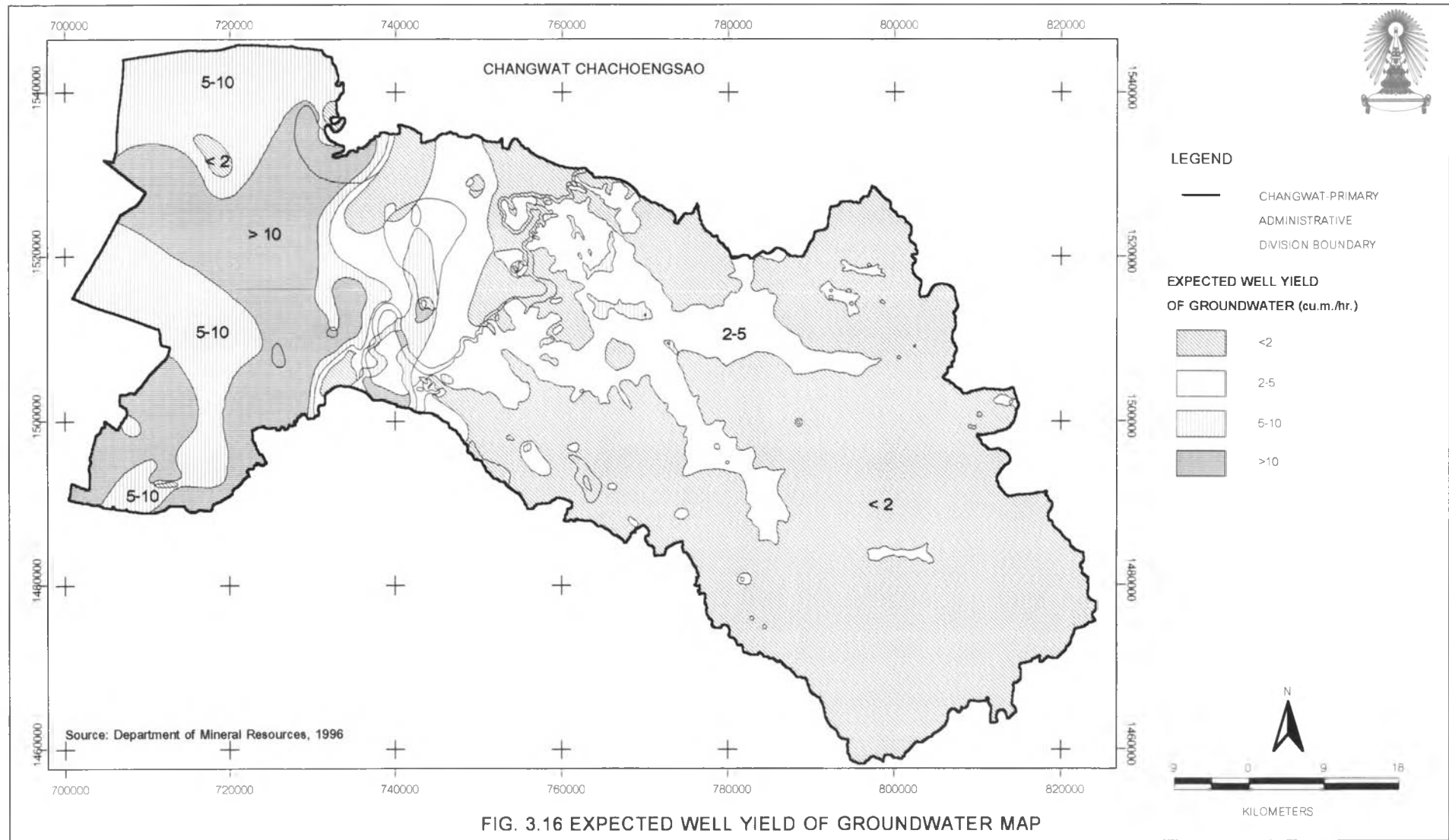
5) *Volcanic rocks* (Rv) – consist of rhyolite and tuff; groundwater occurs mainly in fracture and joint with average depth 15-30 meters; expected well yield mainly less than 2 m³/hr.

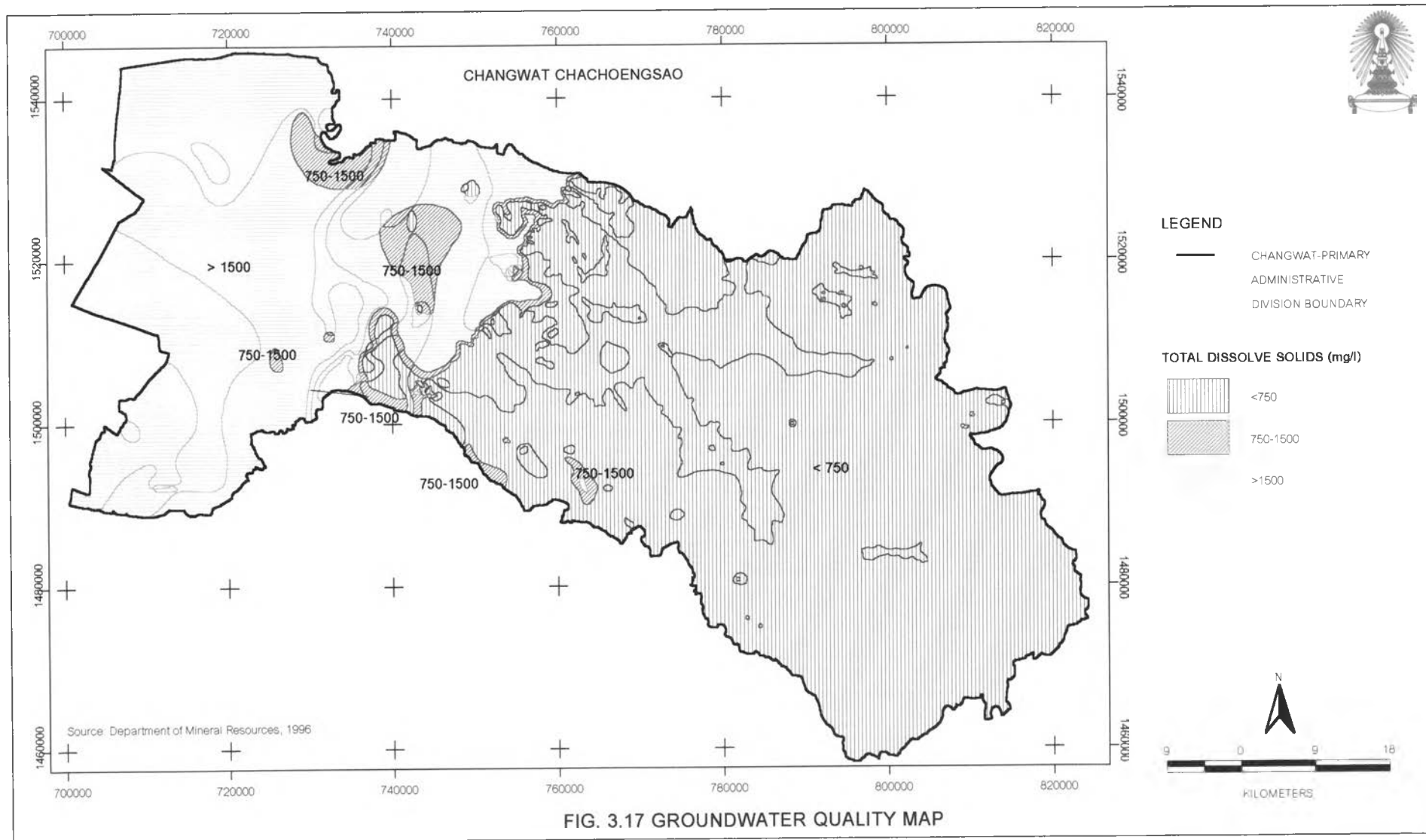
6) *Granite rocks* (Rgr) – consist of biotite-muscovite granite, medium-to coarse-grained, porphyritic granite with pegmatite and quartz veins; groundwater occurs mainly in fracture and joint with average depth 15-40 meters; expected well yield mainly less than 2 m³/hr.

In the present study, (Sa), (St), (Rss), (Rsch), (Rv), (Rgr) are abbreviations of those aquifer types that will be used in section 4.2.2.1.

Figure 3.15, 3.16, and 3.17 show Groundwater Aquifer map, Expected well yield of Groundwater map, and Groundwater quality map respectively. Besides, Groundwater contour map is created, which used as the basic information including record of wells (Department of Mineral Resource and The Public Work Department) as shown in Figure 3.18.





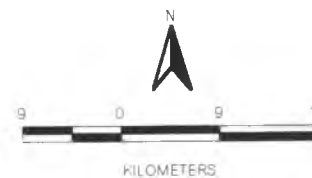


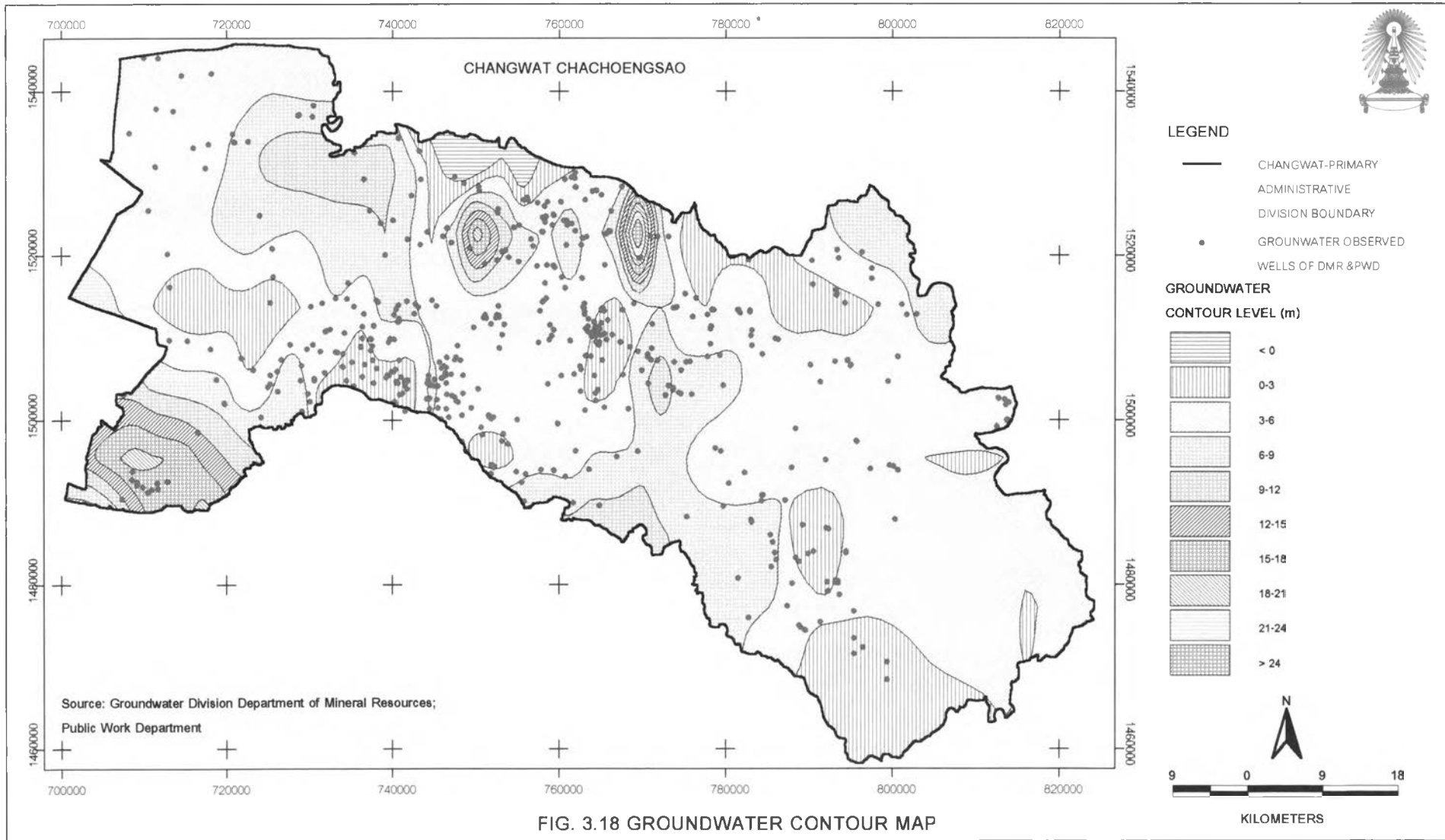
LEGEND

— CHANGWAT-PRIMARY ADMINISTRATIVE DIVISION BOUNDARY

TOTAL DISSOLVE SOLIDS (mg/l)

- <750
- 750-1500
- >1500





3.2.6.3 Flood Hazard

From the geomorphological conditions (Lowiratsuthi, Phonnut, and Chanthanaphalin, 2000), slope characteristics, and mainstream patterns, the landform is constructed that it can be divided into six landforms, namely, Tidal Zone, River Banks and Floodplains, Floodplains and Nearly Flat-Lowlands, Terraces, Undulating Terrains and Highlands, and Mountains and Hills. Then, the possibility of flood-prone area are defined from landforms including Very High, High, Moderate, Less, and Very rare. Landform and The Possibility of Flood-Prone Area Classification are presented in Table 3.7, Figure 3.19, and Figure 3.20.

Table 3.7 Landform and the Possibility of Flood-Prone Area Classification

No.	Landform	Possibility of Flood Prone Area
1	Tidal Zone	Very High
2	River Banks and Floodplains	Very High
3	Floodplains and Nearly Flat-Lowlands	High
4	Terraces	Moderate
5	Undulating Terrains and Highlands	Less
6	Mountains and Hills	Very rare

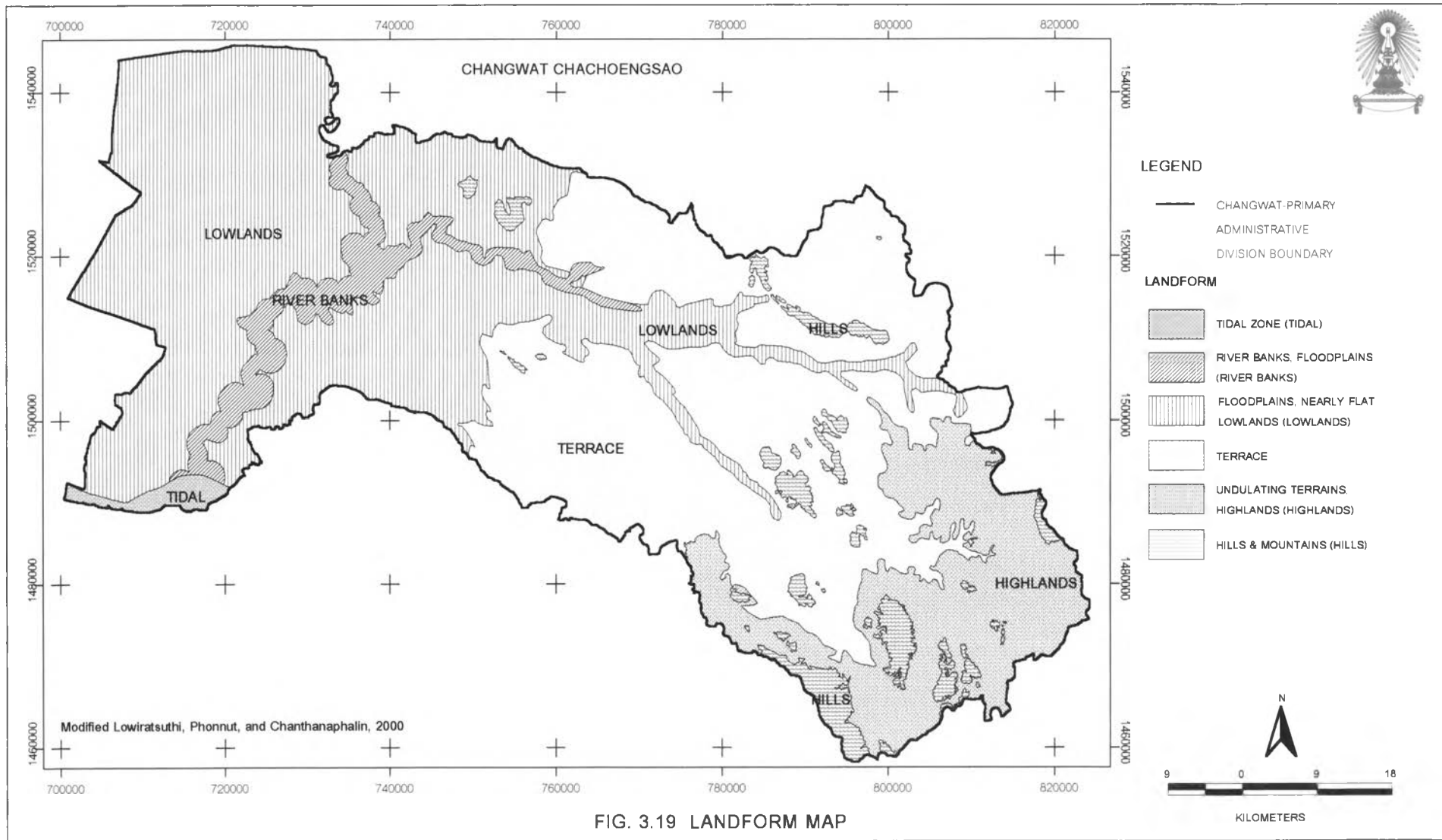
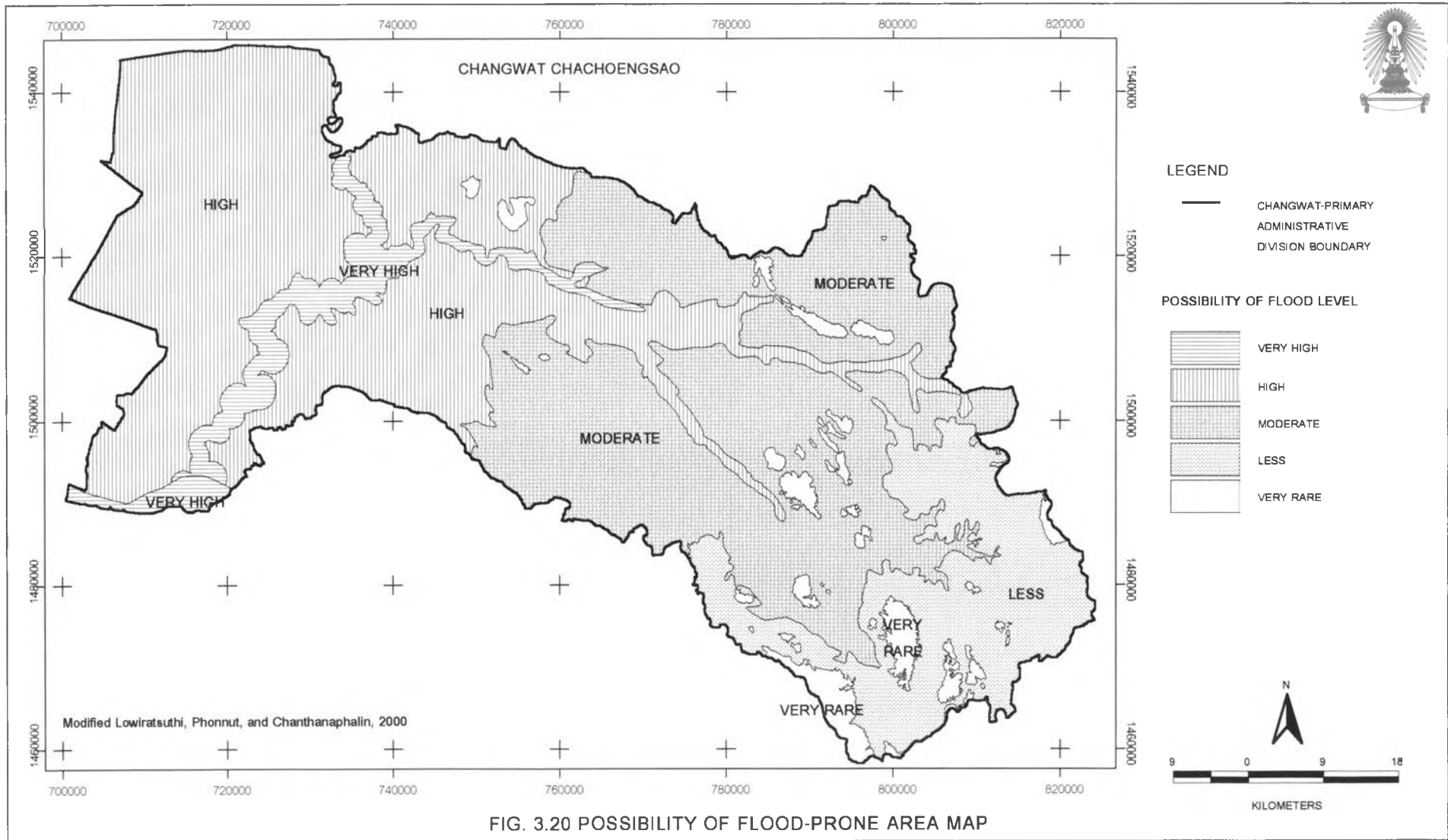


FIG. 3.19 LANDFORM MAP



3.2.7 Forest Use and Watershed Classification

According to Royal Forest Department; RFD (1992), forest use can be categorized into four types, namely, agriculture area, conservation forest, economic forest, and Non-Royal Forest Department Control (Non-RFD control) as shown in Table 3.8 and Figure 3.21. According to DMR (1975), watershed in Changwat Chachoengsao can be classified into five classes include 1A, 2, 3, 4, and 5 as presented in Table 3.9 and Figure 3.22.

Table 3.8 Forest Use

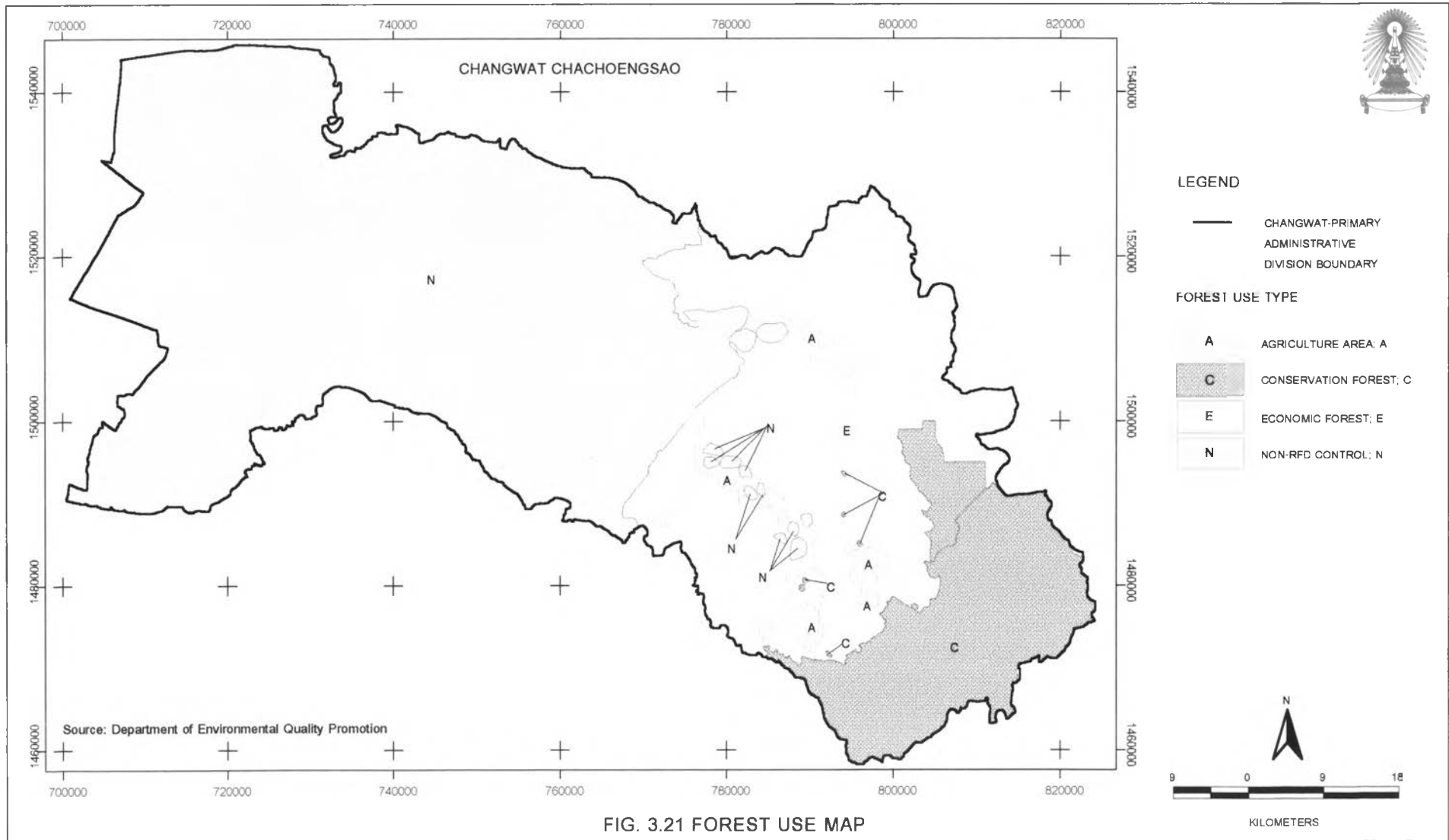
Type of forest use	Area (km ²)	Percent of area (%)	Condition
Conservation forest	138.80	2.57	Conservation area
Agriculture area	687.78	1.73	
Economic forest	1,573.94	29.13	
Non-RFD control	3,002.98	55.57	

Source: RFD, 1992

Table 3.9 Watershed Classification

Watershed Class	Area (km ²)	Percent of area (%)	Condition
1A	48.72	0.94	Conservation area
2	78.15	1.51	
3	163.78	3.16	
4	970.34	18.73	
5	3,918.36	75.65	

Source: DMR, 1975



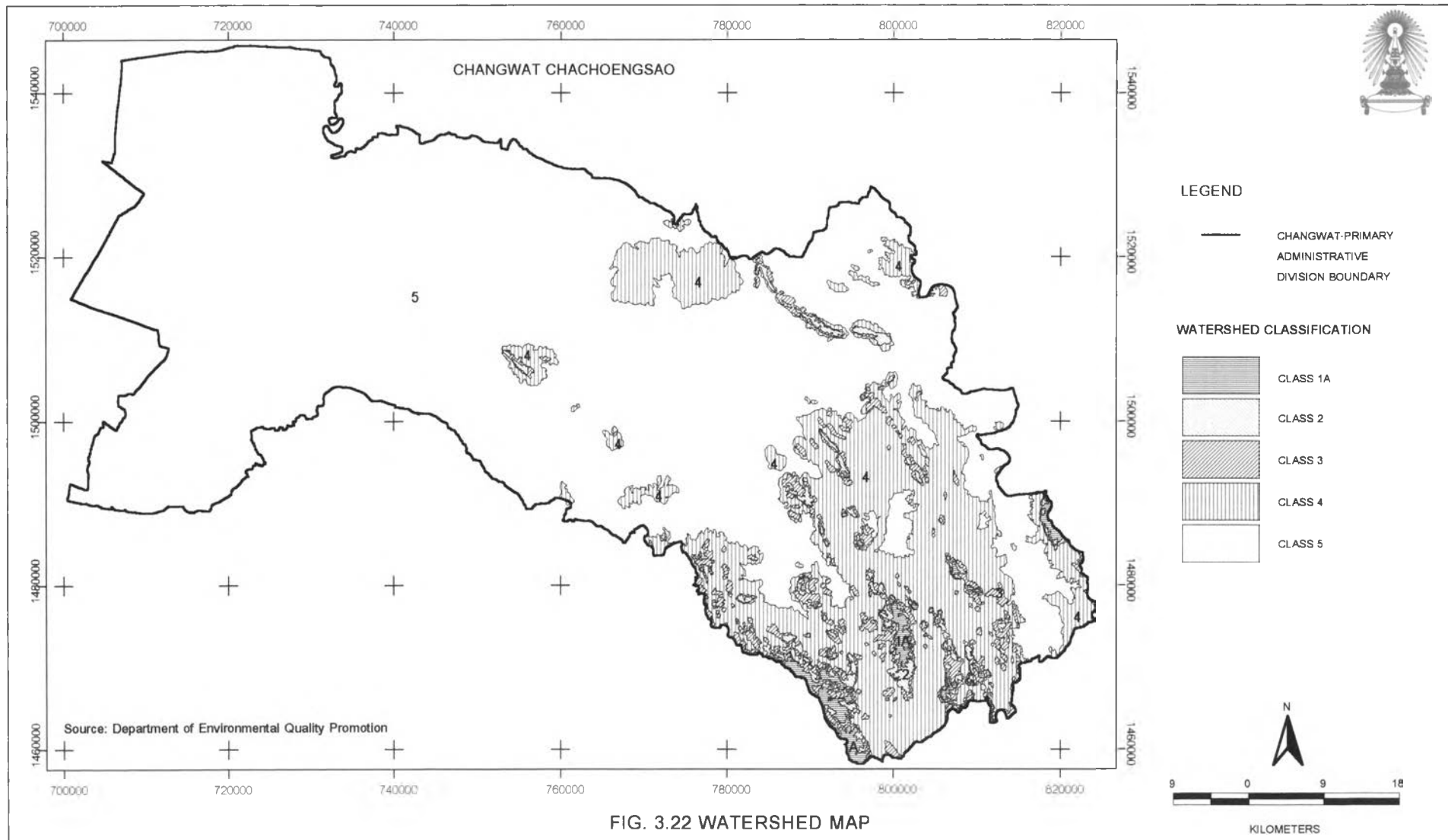


FIG. 3.22 WATERSHED MAP

3.2.8 Soil Characteristic

According to the Department of Land Development (1985), soil units in the present study can be classified into sixty groups that are summarized in Table 3.10 and presented in Figure 3.23. Each soil unit was evaluated for suitable areas selection for solid wastes disposal, see in Chapter 4.2.1 and Appendix B-Table B.1

3.2.9 Existing Land Use

Image of Changwat Chachoengsao was classified landuse into six categories which include 16.01% of forest land cover, 72.95% of agriculture landuse, 0.73% of water resources area, 5.77% of settlement area, 0.74% of industrial landuse, 3.8% of miscellaneous areas by DEQP. Forest land cover includes Tropical evergreen forest and Forest plantation, and Mangrove forest area. Agriculture landuse includes paddy field, rained paddy field, mixed field crop, sugar cane, para rubber, eucalyptus, pine plantation, bamboo, mixed orchards, mango, swine, poultry farm, and shrimp and fish pits. Water resources area includes natural water resources and man-made water resources. Settlement area includes city, town and commercial land, institutional, village, and recreation land, cemetery. Table 3.11 and Figure 3.24 present details of existing land use.

Table 3.10 Characteristic of Soil Units in Changwat Chachoengsao

No.	Soil_Unit	(1) Depth (m)	(2) Slope (%)	(3) Soil_Type		(4) Drainage	(5) Permeability (Relative)	(6) Time of Flood Hazard (month)	(7) Water Table (m.)	(8) Location
				(3.1) Upper	(3.2) Lower					
1	2	Deep	< 2	C	C	Low	Low	3-5	-	Central Plain
2	3	Deep	< 2	C	C	Low	Low	4-5	-	Penepplain
3	8	Deep	< 2	C	C	Low	Low	-	-	Tidal flat deposit
4	10	Deep	< 2	C	C	Low	Low	6-7	-	Tidal flat deposit
5	11	Deep	< 2	C	C	Low	Low	6-7	-	Tidal flat, alluvium deposit
6	12	Too Deep	< 2	C, SiCL	C, SiCL	Low	Low	-	-	Tidal flat and estuary deposit
7	13	Deep	< 2	C, SiCL	C, SiCL	Low	Low	-	-	Tidal flat deposit
8	16	Deep	< 2	SiL	SiL	Low	Low	4-5	-	Penepplain & lower terrace
9	17	Too Deep	< 2	SL	SCL, CL	Low to Moderate	Low to Moderate	2-4	-	Penepplain & lower terrace
10	18	Too Deep	< 2	SL	SCL	Moderate	Moderate	4	-	Penepplain & lower terrace
11	24	Too Deep	< 2	S	S	High	High	-	-	Penepplain
12	25	Deep	< 2	SL	C, GCL	Moderate	Moderate to High	3-4	-	Penepplain/Lower to middle terrace
13	35	Deep	< 2	SL	SCL	Moderate	Low	-	>1.5	Penepplain & lower terrace
14	40	Deep	< 2	SL	SL	Moderate	Moderate	-	> 1.0	Penepplain to undulating
15	43	Deep	< 2	S	S	High	High	-	>1.5	Penepplain to undulating/beach deposit
16	46	Shallow	< 2	GC	GC	Moderate	Moderate	-	> 5.0	Penepplain to undulating
17	48	Shallow	< 2	SL	GCL	Moderate to High	Moderate to High	2	-	Undulating to hill
18	55	Shallow	< 2	C	Weathered Rock	Low	High	-	-	Undulating to hill
19	56	Shallow	< 2	L, SL	GC	Moderate to High	Moderate	-	> 2.0	Undulating to hill
20	59	Shallow	< 2	Mix Soil	Mix Soil	Moderate to High	Moderate to High	-	-	Alluvium deposit/Intermontane basin
21	60	Deep	< 2	Mix Soil	Mix Soil	Moderate to High	Moderate to High	Rain Season	-	Levee deposit
22	62	Shallow	> 35	GCL	Rock	Moderate	-	-	-	Intermontane basin
23	16/6	Deep	< 2	SiL, C	SiL, C	Low	Low	3-5	-	Tidal flat deposit to lower terrace
24	17/6	Too Deep	< 2	SL, C	SCL, CL, C	Low to Moderate	Low to Moderate	3-5	-	Penepplain & lower terrace
25	17B	Too Deep	2-5	SL	SCL, CL	Low to Moderate	Low to Moderate	2-4	-	Penepplain & lower terrace
26	2/11	Deep	< 2	C	C	Low	Low	6-7	-	Tidal flat deposit & Central Plain
27	2/3	Shallow	< 2	C	C	Low	Low	4-5	-	Central Plain
28	25/49	Deep	< 2	SL	C, GCL	Moderate	Moderate to High	3-4	-	Penepplain/Lower to middle terrace
29	25B/17B	Deep	2-5	SL	C, GCL, SCL, CL	Moderate	Low to Moderate	3-4	-	Penepplain/Lower to middle terrace
30	35/17	Deep	0-2 /3-35	SL	SCL, CL	Moderate	Moderate	-	>1.5	Penepplain & lower terrace
31	35B	Deep	2-5	SL	SCL	Moderate	Moderate	-	>1.5	Penepplain & lower terrace

Table 3.10 Characteristic of Soil Units in Changwat Chachoengsao (continued)

No.	Soil_Unit	(1) Depth (m)	(2) Slope (%)	(3) Soil_Type		(4) Drainage	(5) Permeability (Relative)	(6) Time of Flood Hazard (month)	(7) Water Table (m.)	(8) Location
				(3.1) Upper	(3.2) Lower					
32	35B/43B	Deep	2-5	SL, S	SCL, S	Moderate to High	Moderate to High	-	>1.5	Peneplain & lower terrace
33	35C	Deep	5-12	SL	SCL	Moderate	Moderate	-	>1.5	Peneplain to undulating
34	40B	Deep	2-5	SL	SL	Moderate	Moderate	-	> 1.0	Peneplain to undulating
35	40B/46B	Shallow	2-5	SL, GC	SL, GC	Moderate	Moderate	-	> 1	Peneplain to undulating
36	40C	Deep	5-12	SL	SL	Moderate	Moderate	-	>1	Peneplain to undulating
37	41B	Deep	2-5	S, LS	SCL, L	High	Moderate	-	> 3	Peneplain to undulating and medium terrace
38	43/24	Deep	< 2	S	S	High	High	-	-	Peneplain to undulating/beach deposit
39	43B	Deep	2-5	S	S	High	High	-	>1.5	Peneplain to undulating
40	46/25	Shallow	< 2	GC, SL	GC, C, GCL	Moderate	Low to Moderate	-	-	Peneplain
41	46/48	Shallow	< 2	GC, SL	GC, GCL	Moderate	Moderate to High	-	> 5.0	Undulating to hill
42	46/56	Shallow	< 2	GC, L, SL	GC	Moderate	Moderate to High	-	> 2.0	Undulating to hill
43	46B	Shallow	5-12	GC	GC	Moderate	Moderate to High	-	> 5.0	Undulating to hill
44	46C	Shallow	5-12	GC	GC	Moderate	Moderate to High	-	> 5.0	Undulating to hill
45	47B	Shallow	2-5	CG, G	Weathered Rock	High	High	-	> 3.0	Undulating to hill
46	47B/55	Shallow	2-5	CG, G, C	Weathered Rock	High	High	-	> 3.0	Undulating to hill
47	47B/55B	Shallow	2-5	CG, G, C	Weathered Rock	High	High	-	> 3.0	Undulating to hill
48	47C	Shallow	5-12	CG, G	Weathered Rock	High	High	-	> 3.0	Undulating to hill
49	47C/55C	Shallow	5-12	CG, G, C	Weathered Rock	High	High	-	> 3.0	Undulating to hill
50	48B	Shallow	2-5	SL	GCL	Moderate to High	Moderate to High	-	-	Undulating to hill
51	48C	Shallow	5-12	SL	GCL	Moderate to High	Moderate to High	-	-	Undulating to hill
52	48D	Shallow	12-20	SL	GCL	Moderate to High	Moderate to High	-	-	Undulating to hill
53	48E	Shallow	20-35	SL	GCL	Moderate to High	Moderate to High	-	-	Undulating to hill
54	51B/53B	Shallow	2-5	SL	GCL	Moderate to High	Moderate to High	-	-	Undulating to hill
55	51C/53C	Shallow	5-12	SL	GCL	Moderate to High	Moderate to High	-	-	Undulating to hill
56	56B	Shallow	2-5	L, SL	GC	Moderate to High	Moderate	-	-	Undulating to hill
57	56B/48B	Shallow	2-5	L, SL	GC, GCL	Moderate to High	Moderate	-	-	Undulating to hill
58	56C/48C	Shallow	5-12	L, SL	GC, GCL	Moderate to High	Moderate	-	-	Undulating to hill
59	62/47E	Shallow	> 20	GCL, CG, G	Weathered Rock	High	High	-	-	Undulating to hill
60	62/48C	Shallow	> 5	GCL, SL	Weathered Rock	Moderate to High	High	-	-	Undulating to hill

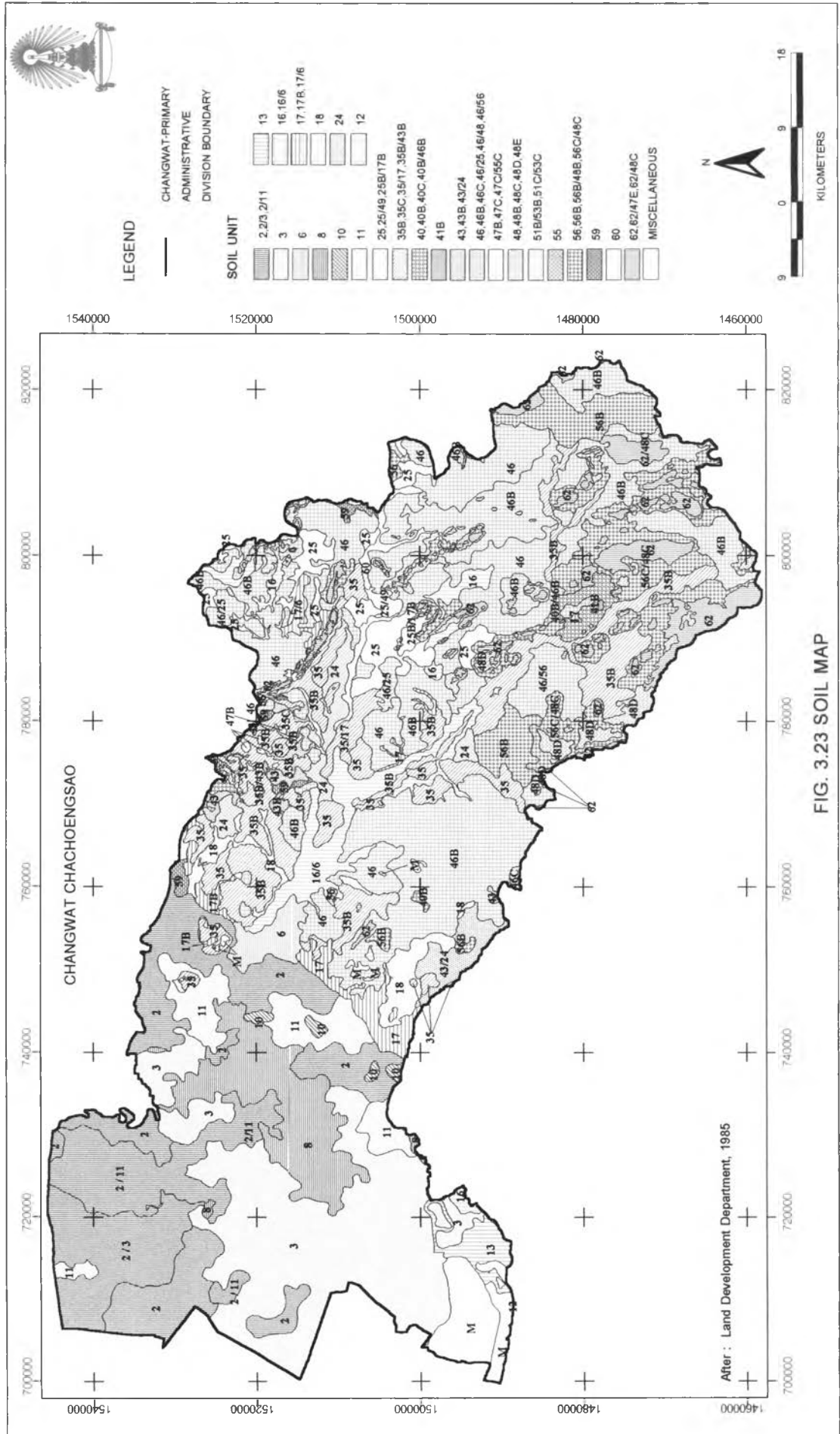


FIG. 3.23 SOIL MAP

Table 3.11 Existing Land Use

Existing land use	Area (km ²)	Total area (km ²)	Percent of area (%)
1. Forest land cover			
1.1 Tropical evergreen forest and Forest plantation	814.60	829.60	16.01
1.2 Mangrove forest area	14.46		
2. Agriculture land use			
2.1 Paddy field, rained paddy field	1788.68		
2.2 Mixed field crop, Sugar cane	1447.71		
2.3 Para rubber, Eucalyptus	232.73	3776.76	72.95
2.4 Pine plantation, Bamboo	2.62		
2.5 Mixed orchards, Mango	31.84		
2.6 Swine, Poultry farm	20.45		
2.7 Shrimp and fish pits	252.73		
3. Water resources area			
3.1 Natural water resources	23.49	37.83	0.73
3.2 Man made water resources	14.34		
4. Settlement area			
4.1 City, town and commercial land, Institutional, Village	290.58	298.76	5.77
4.2 Recreation land, Cemetery	8.18		
5. Industrial land use	38.13	38.13	0.74
6. Miscellaneous	196.61	196.61	3.80

Source: DEQP, 1993

