CHAPTER II

ENVIRONMENTAL SETTING OF CHANGWAT BURIRAM

2.1 Socio-economic Background

2.1.1 Administration

The administration of Changwat Buriram is divided into 21 amphoes (districts), 2 king amphoes, 2 municipalities, 22 sanitaries, 189 tombons (sub-districts), 2,459 moobans (villages), and 295,737 dwellings. The amphoe and king amphoe administration areas of Changwat Buriram are shown in Figure 2.1. The area of amphoes and the distance from amphoe to changwat are shown in Table 2.1 (Buriram Provincial Statistical Office, 2000).

2.1.2 Population

The total population of Changwat Buriram was reported to be 1,520,419 persons in December 31, 1999 (Table 2.2). Among these, 759,480 persons were male and 760,939 persons were female. The rate of population change from previous year is 0.43. Historically, the highest population density area was in Amphoe Muang Buriram as shown in Figure 2.2. The population age structure of Changwat Buriram in 1999 is summarised and presented in Figure 2.3 (Buriram Provincial Statistical Office, 2000).

Age Groups - Out of the total population only 7 % are under 4 years old. About 12 % with ages between 5-14 years are in the compulsory schools. A junior age group of 15-24 years comprises 27 % of the population, while 33.5 % belongs to the senior working group with the age of 25-54 years. The rest 21.5 % belongs to the old age group. The relatively low annual birth rate of 1.7 % is noted (Figure 2.3).

Occupation and emigration - Majority of the working age group practice backward farming as the main occupation. Therefore most of the farm products have to depend upon existing and underdeveloped natural resources resulting in low yield in some years and damages to the natural environment e.g. excessive land erosion and deforestation. As a consequence, emigration of people to seek for additional income from other areas especially in big towns and cities through employment is at an alarming rate (Buriram Provincial Statistical Office, 2000).

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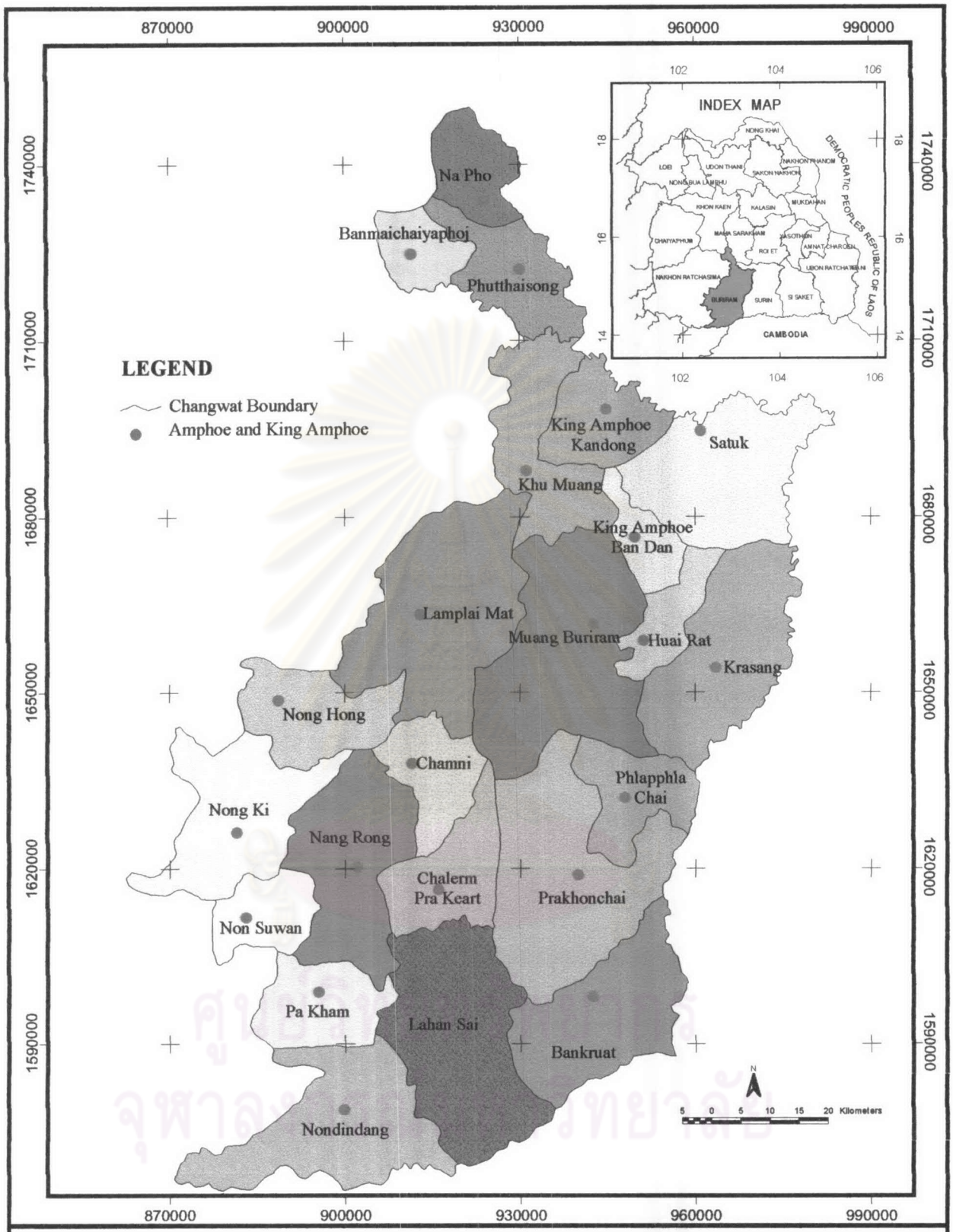

ENVIRONMENTAL GEOLOGY OF CHANGWAT BURIRAM

Figure 2.1 Amphoe and King Amphoe administration areas of Changwat Buriram
(Modified after: 1. Buriram Provincial Statistical Office, 2000
2. Royal Thai Survey Department, 1989)

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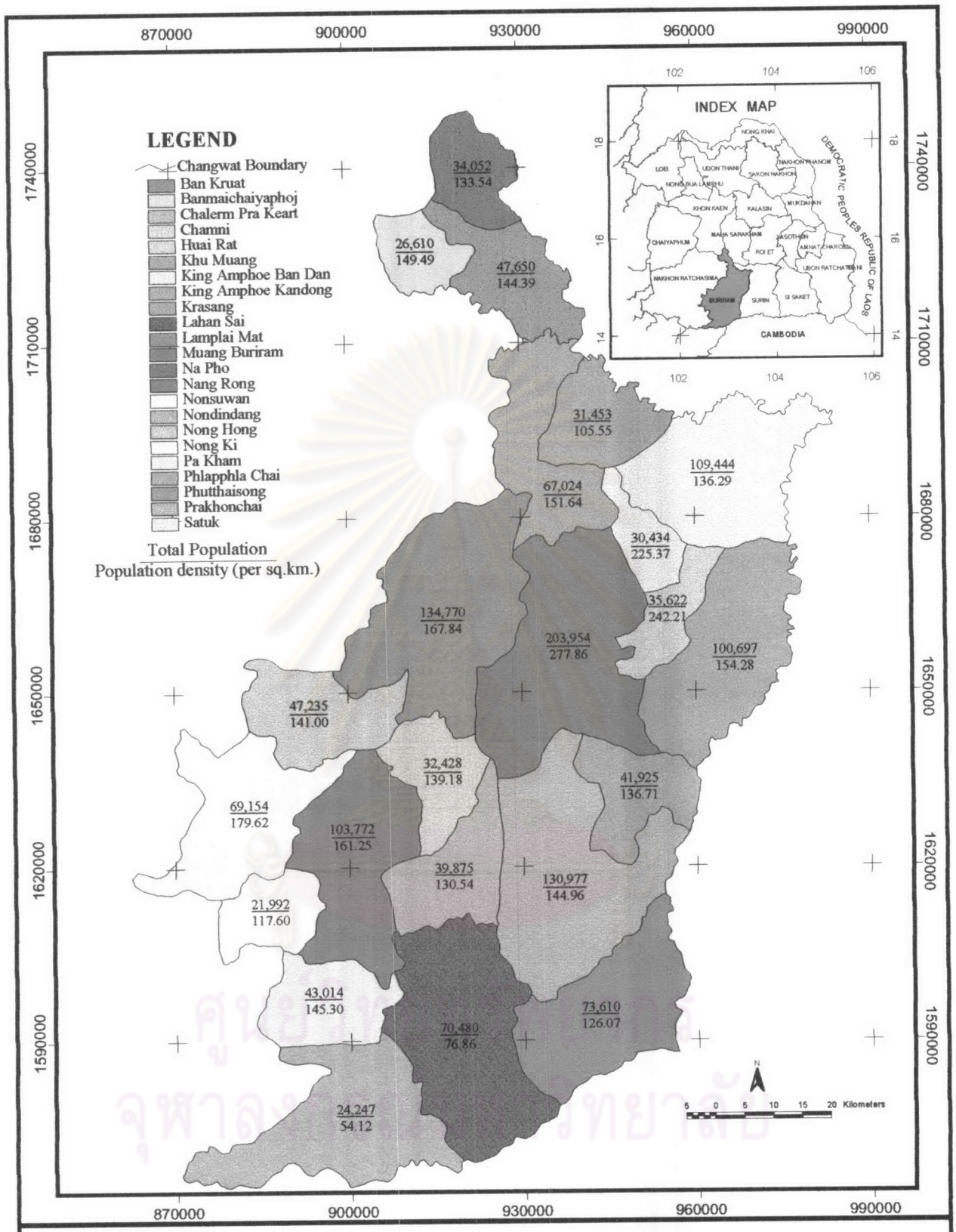

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Figure 2.2 Population density of Changwat Buriram
(Source: 1. Buriram Provincial Statistical Office, 2000
2. Royal Thai Survey Department, 1989)

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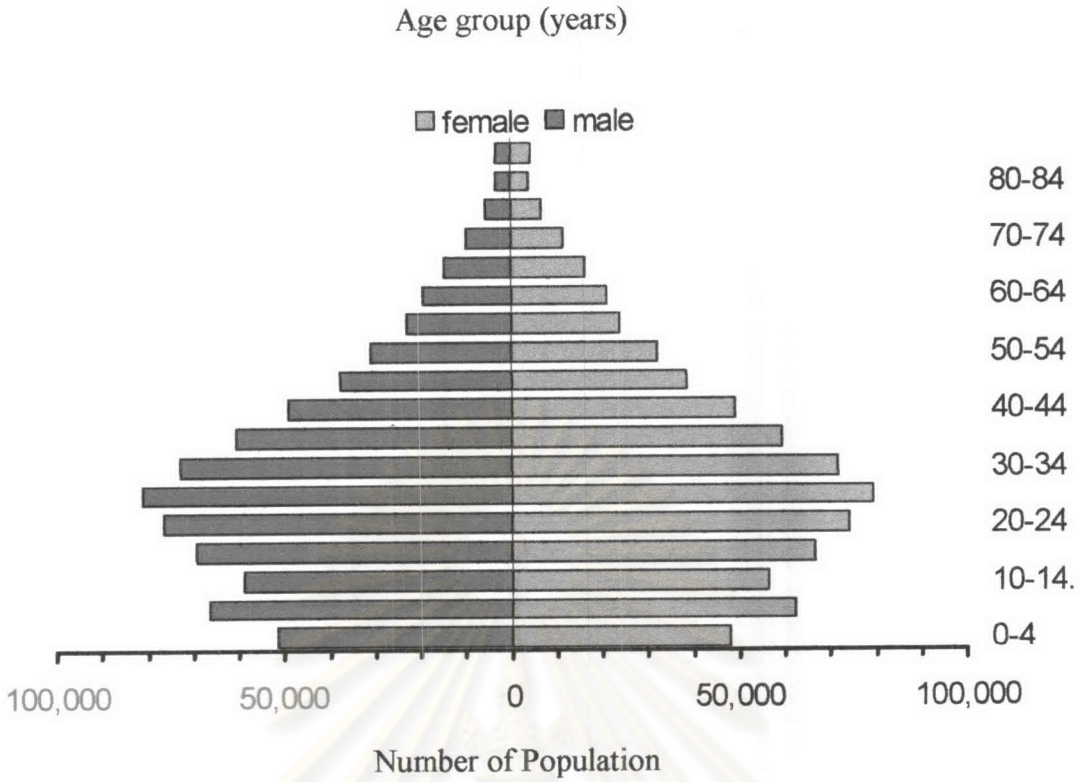

Figure 2.3 Population age structure of Changwat Buriram in 1999
(Source: Buriram Provincial Statistical Office, 2000, in Thai)

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Table 2.1 List of area, distance from amphoe to changwat, number of municipalities, sanitaries, tambons, villages, and dwellings (Buriram Provincial Statistical Office, 2000)

Amphoe/King Amphoe	Area (sq.km.)	Distance from Amphoe to Changwat (km.)	Number of Municipalities	Number of Sanitaries	Number of Tambons	Number of Villages	Number of Dwellings
Muang Buriram	734.020	-	1	-	19	307	44,291
-Municipal area	6.000	-	1	-	1	-	9,342
-Non-Municipal area	728.020	-	-	-	18	307	34,949
Nang Rong	643.530	54	1	-	15*	186	23,877
-Municipal area	20.768	-	1	-	2	-	6,700
-Non-Municipal area	622.762	-	-	-	15	186	17,177
Lam Plai Mat	802.950	32	-	2	16	212	25,575
Prakhonchai	903.537	44	-	1	16	178	26,784
Phutthaisong	330.000	64	-	1	7	94	10,462

* Tambon in Municipal Area of Tambon Nang Rong was overlapped with Non-Municipal Area 2 Tambons

Table 2.1. Continued.

Amphoe/King Amphoe	Area (sq.km.)	Distance from Amphoe to Changwat (km.)	Number of Municipalities	Number of Sanitaries	Number of Tambons	Number of Villages	Number of Dwellings
Satuk	803.000	40	-	1	12	176	21,564
Krasang	652.700	31	-	1	11	165	18,268
Khu Muang	442.000	33	-	2	7	100	13,579
Ban Kruat	583.869	66	-	2	9	108	14,552
Nong Ki	385.000	83	-	1	10	107	14,435
Lahan Sai	917.000	99	-	1	6	73	14,794
Pa Kham	296.029	78	-	1	5	65	10,395
Nong Hong	335.000	54	-	1	7	100	8,959
Na Pho	255.000	76	-	1	5	65	7,022

Table 2.1. Continued.

Amphoe/King Amphoe	Area (sq.km.)	Distance from Amphoe to Changwat (km.)	Number of Municipalities	Number of Sanitaries	Number of Tambons	Number of Villages	Number of Dwellings
Phlappla Chai	306.670	40	-	1	5	66	8,183
Huai Rat	147.070	15	-	1	8	80	6,451
Nonsuwan	187.000	65	-	1	4	54	5,084
Chamni	233.000	70	-	-	6	63	5,990
Nondindang	448.000	92	-	1	3	32	5,630
Chalerm Pra Keart	305.470	76	-	1	5	63	8,086
Banmaichaiyapoj	178.000	85	-	1	5	54	5,733
King Amphoe Ban Dan	135.040	18	-	-	4	59	5,540
King Amphoe Khandong	298.000	60	-	1	4	53	6,525

Table 2.1. Continued.

Amphoe/King Amphoe	Area (sq.km.)	Distance from Amphoe to Changwat (km.)	Number of Municipalities	Number of Sanitaries	Number of Tambons	Number of Villages	Number of Dwellings
Total	10,321.885	-	2	22	189	2,459	311,779
-Municipal area	26.768	-	2	-	3	-	16,042
-Non-Municipal area	10,295.117	-	-	22	188	2,459	295,737

Table 2.2 Number of Population, Rate of Population Change, and Population Density in the year 1999
(Source : Buriram Provincial Statistical Office, 2000)

Amphoe/King Amphoe	Number of Population			Number of Births	Number of Deaths	Number of In-migrants	Number of Out-migrants	Rate of Population Change (from previous year)	Population Density (per sq.km.)
	Total	Male	Female						
Muang Buriram	203,954	101,956	101,998	4,982	503	9,858	8,649	0.44	277.86
-Municipal area	29,479	14,364	15,115	4,686	69	1,545	3,531	-0.51	4,913.17
-Non-Municipal area	174,475	87,592	86,883	296	434	8,313	5,118	0.60	239.66
Nang Rong	103,772	51,037	52,735	2,257	293	4,083	3,771	0.48	161.25
-Municipal area	20,489	9,985	10,504	2,216	64	973	2,032	-0.62	986.57
-Non-Municipal area	83,283	41,052	42,231	41	229	3,110	1,739	0.75	133.73
Lam Plai Mat	134,770	67,762	67,008	978	388	4,782	3,641	0.55	167.84
Prakhonchai	130,977	65,231	65,746	1,044	415	3,843	2,617	0.12	144.96
Phutthaisong	47,650	23,605	24,045	379	232	1,563	1,124	-0.35	144.39

Table 2.2. Continued.

Amphoe/King Amphoe	Number of Population			Number of Births	Number of Deaths	Number of In-migrants	Number of Out-migrants	Rate of Population Change (from previous year)	Population Density (per sq.km.)
	Total	Male	Female						
Satuk	109,444	54,416	55,028	902	331	4,043	2,291	0.89	136.29
Krasang	100,697	49,985	50,712	988	317	2,918	1,886	0.53	154.28
Khu Muang	67,024	33,687	33,337	588	190	2,690	1,822	0.78	151.64
Ban Kruat	73,610	36,914	36,696	642	209	2,582	1,979	-0.06	126.07
Nong Ki	69,154	34,918	34,236	454	198	2,288	1,694	-0.13	179.62
Lahan Sai	70,480	35,710	34,770	1,131	205	2,557	2,077	0.49	76.86
Pa Kham	43,014	21,551	21,463	415	136	1,816	1,239	0.33	145.30
Nong Hong	47,235	23,878	23,357	293	148	1,529	920	0.49	141.00
Na Pho	34,052	16,839	17,213	169	132	1,206	762	-0.05	133.54

Table 2.2. Continued.

Amphoe/King Amphoe	Number of Population			Number of Births	Number of Deaths	Number of In-migrants	Number of Out-migrants	Rate of Population Change (from previous year)	Population Density (per sq.km.)
	Total	Male	Female						
Phlapphla Chai	41,925	20,980	20,945	390	134	1,897	1,123	0.81	136.71
Huai Rat	35,622	17,702	17,920	252	116	1,512	928	0.45	242.21
Nonsuwan	21,992	11,084	10,908	58	53	1,035	641	0.91	117.60
Chamni	32,428	16,077	16,351	103	89	1,404	766	0.90	139.18
Nondindang	24,247	12,269	11,978	61	58	1,520	797	1.24	54.12
Chalerm Pra Keart	39,875	19,935	19,940	29	97	1,814	1,031	0.45	130.54
Banmaichaiyapoj	26,610	13,170	13,440	152	93	1,053	791	0.29	149.49
King Amphoe Ban Dan	30,434	15,017	15,417	35	101	1,502	837	0.61	225.37
King Amphoe Khandong	31,453	15,757	15,696	59	102	1,384	822	0.39	105.55

Table 2.2. Continued.

Amphoe/King Amphoe	Number of Population			Number of Births	Number of Deaths	Number of In-migrants	Number of Out-migrants	Rate of Population Change (from previous year)	Population Density (per sq.km.)
	Total	Male	Female						
Total	1,520,419	759,480	760,939	16,361	4,540	58,879	42,208	0.43	147.30
-Municipal area	49,968	24,349	25,619	6,902	133	2,518	5,563	-0.55	1,866.71
-Non-Municipal area	1,470,451	735,131	735,320	9,459	4,407	56,361	36,645	0.47	142.83

2.1.3 Education, Religion, and Health Services

2.1.3.1 Education

The education services of Changwat Buriram cover from kindergarten to tertiary level with totally 941 schools and institutions in 1999. The total number of teachers is 14,055 persons. Among these, 6,574 persons were male, 7,481 persons were female, whereas the total number of students is 296,816 persons. The ratio of teachers and students is 1: 21 (Buriram Provincial Statistical Office, 2000).

2.1.3.2 Religion

In 1999, Buddhism is the major religion in Changwat Buriram and being almost 100 per cent of the entire population. There are altogether 795 Buddhist monasteries, 557 Buddhist sanka abodes, and 10 Christian churches in Changwat Buriram (Buriram Provincial Statistical Office, 2000).

2.1.3.3 Health Services

Concerning the medical services in Changwat Buriram, there are 24 government hospitals, 2 private hospitals, 225 health centers, and 65 medical clinics. In 1999, there are totally 116 physicians, 33 dentists, 584 nurses, and 474 practical nurses (Buriram Provincial Statistical Office, 2000).

2.1.4 Transportation, Electricity, Water Utilization and Effective Irrigated Area

2.1.4.1 Transportation

Changwat Buriram is about 400 kilometers far away from Bangkok to the northeast. The main access road/highway starts from the Highway No.1, Pahonyotin Road, to Changwat Saraburi, connecting with the Highway No. 2 from Changwat Saraburi to Changwat Nakhon Ratchasima, and then to the Highway No. 224 from Changwat Nakhon Ratchasima to Amphoe Choke Chai, and the Highway No. 24 from Amphoe Choke Chai to Amphoe Nang Rong, and finally from the Highway No. 218 from Amphoe Nang Rong to Amphoe Muang Buriram. Apart from the highway, the other mean of transportation to Buriram are the domestic commercial airline and train. The road system of Changwat Buriram is shown in Figure 2.4 (Buriram Provincial Statistical Office, 2000).

2.1.4.2 Electricity

Regarding the electrification of Changwat Buriram, the numbers of consumers are 254,454. The total electricity consumption of Changwat Buriram in 1999 is 461,985,589.16 units, for residential is about 254,867,183.26 units, business and industry is 157,433,795.18 units, and the government office and public utility is 46,299,970.67 units (Buriram Provincial Statistical Office, 2000).

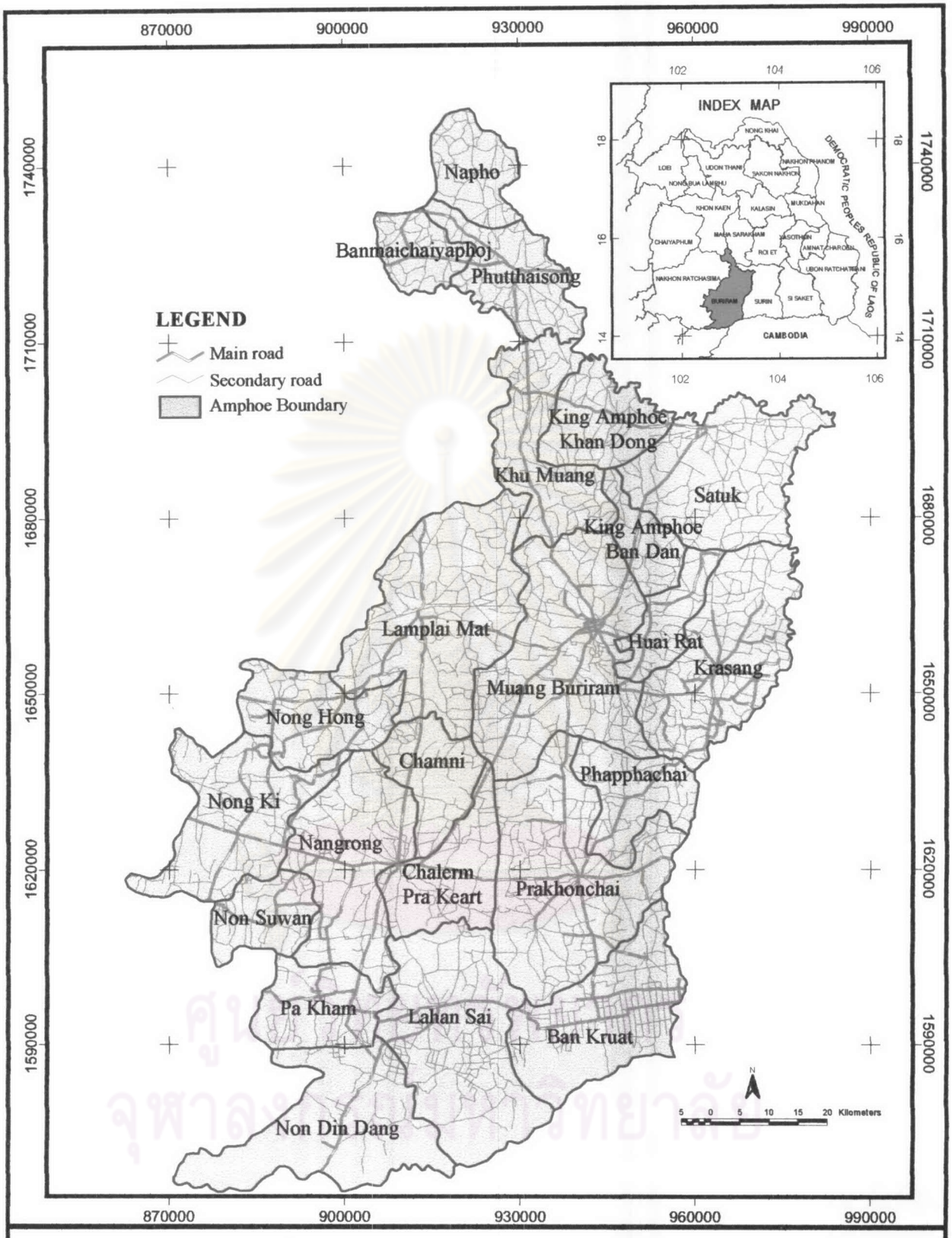

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Figure 2.4 Road system of Changwat Buriram
(Source: Royal Thai Survey Division, no date, in Thai)

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2.1.4.3 Water Utilization and Effective Irrigated Area

The reservoir in this study area is used for the four basic needs of the people living in the project area including:

1. supplemental to rainfall, irrigation water for rice field in rainy season and direct irrigation for upland crops and vegetables in dry season,
2. domestic use for household consumption and sanitation,
3. livestock, and
4. fisheries or aquaculture.

Due to high fluctuating amount of the water stored and due to the lack of proper operation rule of the tank, a large portion of tank water is used mostly in the rainy season primarily for irrigation. In addition, a substantial amount of water from the tank and canals for household consumption, sanitation and livestock is available to those living in the close vicinity of the canals and the tanks. Fishery in tank is practiced for household consumption only. The captive fishery is not large enough for marketing.

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There are fourteen water supply stations with total installed capacity of 13,651,200 cubic-meters and total production is 8,650,450 cubic-meters for consumer in 14 Amphoes in 1999. Another water resources of Changwat Buriram for water usage composed of 2 small reservoirs, 4 concrete wiers, 57 ponds, and 5 canals (Buriram Provincial Statistical Office, 2000).

2.1.5 Economy

The Gross Provincial Product, GPP, at current market prices of Changwat Buriram is 33,500,370 thousand Baht in 1997. The Per Capita Income is 22,805 Baht per annum, 1997 (the 67 per-capita priority by the country). The wholesale and retailing trades contribute approximately 24.01 per cent of the GPP, whereas the agriculture, services, manufacturing, mining and quarrying, and others are 23.73, 14.51, 9.84, 1.59, and 26.32 per cent respectively. The average economic growth of Changwat Buriram was 5.35 per cent (Buriram Provincial Statistical Office, 2000).

2.1.6 Culture, Tradition and Archaeological & Historical Heritage

According to the culture, tradition and the religion, Buriram people can be categorized into 4 ethnic backgrounds. Each ethnic has its own dialect, (1) Korat ethic in Amphoe Nang Rong, (2) Laos ethnic in Amphoe Phutthaisong, (3) Khamere ethic in Amphoe Prakhonchai, Amphoe Ban Kruat, and Amphoe Lahan Sai and (4) Suai ethnic in Amphoe Satuk. They all located in different parts of the province. However, they have related and communicated through ancient time till today. They all are attracted to tourists who want to have a look at their culture activities. The Tourist attraction is shown in Figure 2.5a and 2.5b (Buriram Provincial Statistical Office, 2000). The most recognizable culture and tradition for each ethnic are as the following;

Phanomrung Visit: In 1938, a monk called Opasthammayan whom resided in Wat Thaprasith Surin had visited and meditated at Phanomrung mountain and had

appreciated the beauty of the Phanomrung stone ruins. During that time, there was no road to the mountain. The local people had a tradition celebrated on the every first day of the fifth waning moon. This monk then help and encouraged people to pay a visit to the Buddha's footprint model located on top of the mountain and built a road up to the mountain. As a result, the celebration begun on the full moon day of the fifth in 1938 and had become the tradition since then (Buriram Provincial Statistical Office, 2000).

Water Pounding: Buriram previously had a name called 'The city of water pounding'. This reflected the hard time for local people during the dry season when there were not enough water supplied. People had to dig near a pond, where water was muddy and non-consumable. Water pounding was a family gathering activity, they dug a hole to contain 2-4 gallons and poured water into the hole then added some dirt and used a bamboo stick length 50-70 centimeters to pound. After 15-20 minutes, water in the hole changed then left till water became limpid. The water pounding tradition is unique and can be observed only in Buriram province (Buriram Provincial Statistical Office, 2000).

Banjol Mamuad: It is a Khamere ceremony, which invites a high spiritual body and angels to cure. The medium has to be sinless and often making good deeds. This tradition can be seen in a festive season in Buriram.

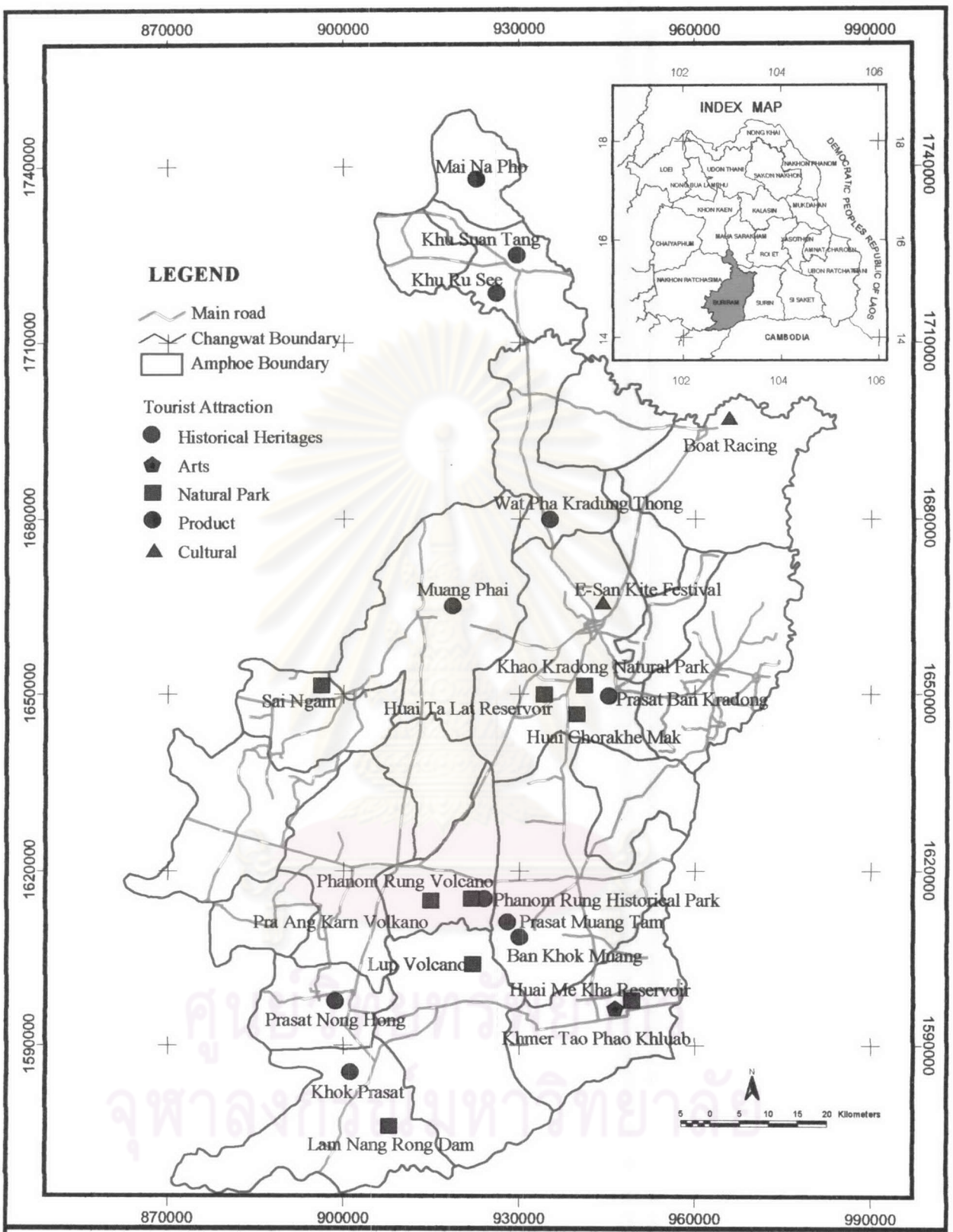

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Figure 2.5a Tourist attraction of Changwat Buriram
(Source: 1. Buriram Provincial Statistical Office, 2000
2. Royal Thai Survey Department, 1989)

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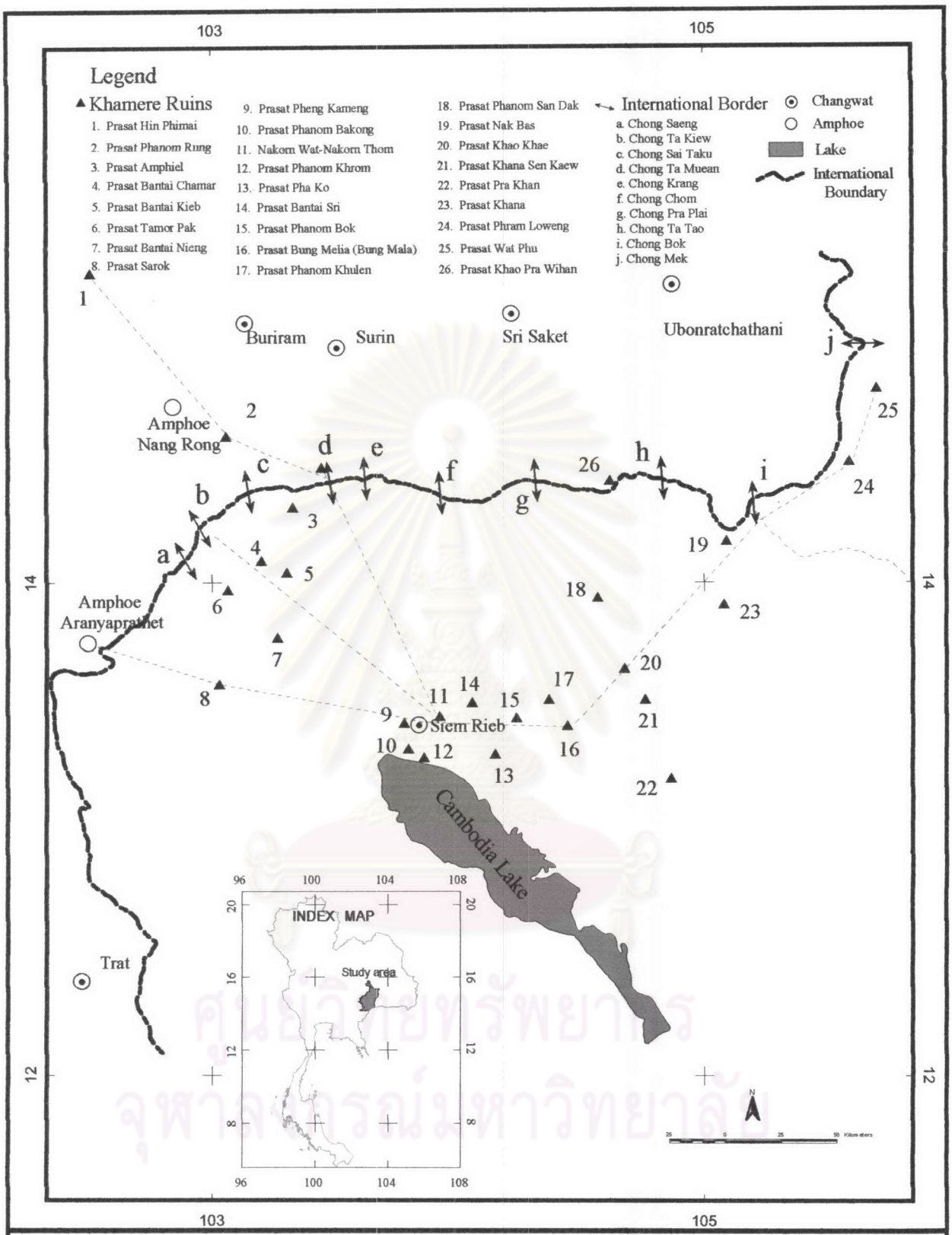

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Figure 2.5b Map showing the connection route among tourist attraction from Northeastern Thailand throughout Cambodia.
(Source: 1. Royal Thai Survey Department, 1989)
2. Buriram Governer's Office Plans,1994, in Thai)

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2.1.7 Recreation and Tourism Attraction

Changwat Buriram has many archeological and historical heritages, for example, the Khamere stone ruins Phanomrung, Muang Tam Stone ruins, Buddha Image at Wat Hongsa, Ancient bricklin. The provincial officers have promoted tourism in order to attract more tourists. There were many projects to restore ancient heritages and construct new facilities to accommodate a large number of tourists.

2.2 Physical Environment

2.2.1 Climate

The climate of the region is commonly monsoon season. The southwest monsoon, caused by low pressure over the Central Asia, brings heavy rainfall to the entire area of Thailand. Starting in May, precipitation increases steadily as the wet season progress until a maximum of 250 mm is reached in September. Accompanying this, there is a slight rise in humidity and a simultaneous decrease in temperature and radiation. The average wind velocity remains fairly steady at about 5 km/hr (Buriram Provincial Statistical Office, 2000).

Precipitation falls off rapidly in October and November in spite of occasional tropical storms that move inland from the South China Sea, bringing torrential rainfall near the coast but weakening rapidly as they penetrate inland.

2.2.1.1 The Total Annual Rainfall

The mean annual rainfall of the region is about 1,330 mm, with the range varying from 900 to 2,300 mm. Geographically, there is a preponderance of rainfall around the edges of the region and an especially high concentration in the extreme northeast. For Changwat Buriram, the mean annual rainfall is about 1,250 mm, with the range varying from 1,100 to 1,400 mm. In 1999, the annual rainfall of Changwat Buriram was 1,384.1 mm. and the annual days of rainfall is 142 days as shown in Table 2.3 (Buriram Provincial Statistical Office, 2000).

2.2.1.2 The Monthly Rainfall

The variations of mean monthly rainfall for the region indicate almost no rainfall in December. From then on, it increases slowly during the first three months of the year to about 2 mm/day at the end of March; thereafter the ascent is more rapid with the coming of the monsoon rains, with the maximum of 256 mm. occurring in September. In 1999, the maximum monthly rainfall is 243.9 mm in September (Table 2.3). From October to December the mean rainfall rapidly decreases (Buriram Provincial Statistical Office, 2000).

Because the rainfall is somewhat high during the wet season, more reservoirs to conserve the water are needed in the wet season for use during the following dry season.

Table 2.3 Monthly Rainfall, Temperature, and Relative Humidity

(Buriram Provincial Statistical Office, 2000)

Month	Total Rainfall (mm.)	Days of rain fall	Temperature (C)		Relative humidity (%)	
			Minimum	Maximum	Mean min.	Mean max.
January	2.5	2	13.1	32.6	18.4	30.3
February	0.0	-	14.5	37.8	19.6	33.1
March	146.0	6	19.7	39.7	23.2	36.2
April	115.8	15	22.5	36.3	24.2	33.5
May	217.0	23	23.0	34.2	24.1	32.8
June	234.5	16	22.5	34.6	24.1	32.9
July	165.2	18	22.7	34.6	24.2	33.0
August	79.6	15	15.0	34.8	24.2	32.7
September	243.9	18	22.1	34.0	23.9	32.4
October	87.1	14	20.7	33.5	23.3	31.0
November	90.4	13	17.0	33.8	21.3	29.5
December	2.1	2	8.5	30.5	15.8	26.4
Annual	1,384.1	142	8.5	39.7	15.8	36.2

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2.2.1.3 The Monthly Temperature

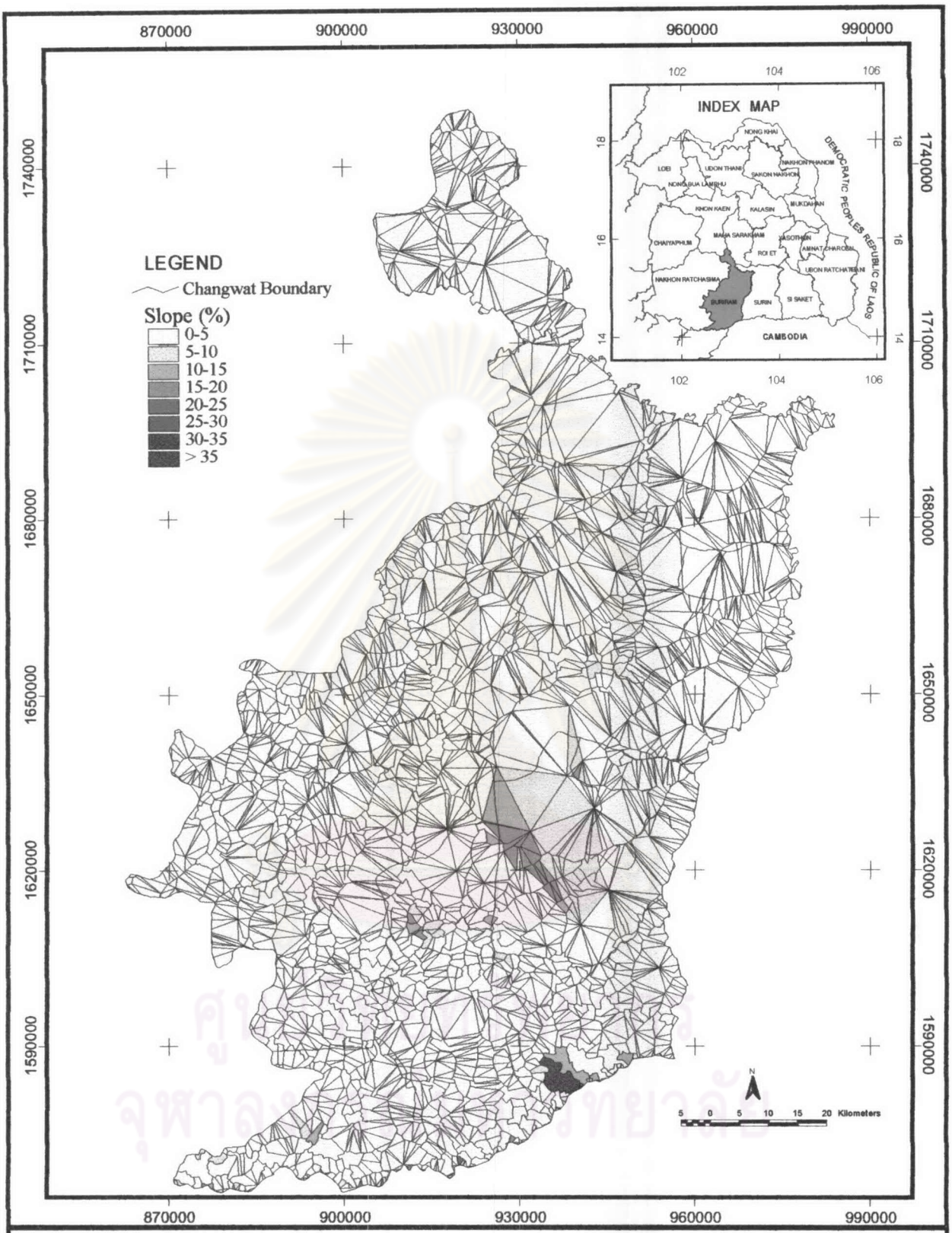
The mean monthly temperature of Changwat Buriram is lowest in December, 1999, at 8.5 °C, and the mean maximum temperature is reaching 39.7 °C in March. From then, the mean temperature gradually decreases to 17.0 °C in November (Buriram Provincial Statistical Office, 2000).

2.2.1.4 The Monthly Relative Humidity

The changes of humidity in the region follows the trend of the monsoons with the mean relative humidity reaching a minimum of 15.8 % in December and rising to a maximum of 36.2 % in March, 1999 (Buriram Provincial Statistical Office, 2000).

2.2.2 Topography and Landform

Topographically, Changwat Buriram is a part of Khorat Plateau. The southern edge of the plateau has several mountain ranges, which tilted gently towards the northern edge. The undulating terrains are recognised at the foot slopes that being the major sources for soil development in the area. These foothill slopes are not commonly cultivated. Slope map derived from topographic map (in this study, using contour interval 100 m.) by triangulated irregular network (TIN) method. Flood-risk area derived from geologic map and surface run off. Slope map and flood-risk area are shown in Figure 2.6 and 2.7. Some places are characterised by fertility clayey soils and badly-drained as compared with sandy soil.



ENVIRONMENTAL GEOLOGY OF CHANGWAT BURIRAM

Figure 2.6 Slope map of Changwat Buriram
(Source: 1. Geological Survey Division, Department of Mineral Resources, 1995)

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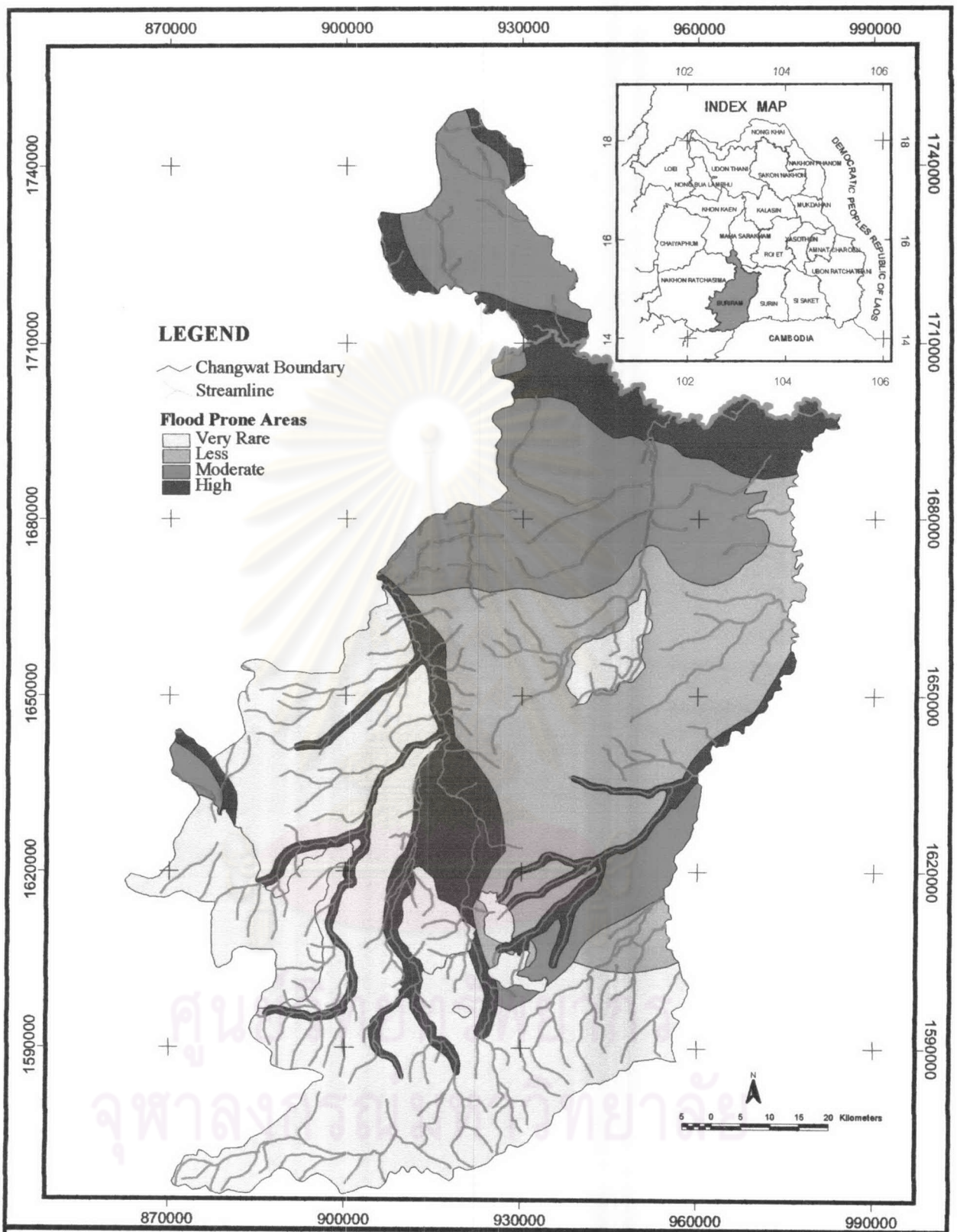

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Figure 2.7 Flood risk area of Changwat Buriram

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2.2.3 Geology

Changwat Buriram is located in Jurassic- Cretaceous Korat Group. The Khorat Rock units in Buriram include Phra Wihan Formation, Sao Khua Formation, Phu Phan Formation, Khok Kruat Formation, and Mahasarakham Formation. However, there are some volcanic basalts exposed in the province (Meesuk, et al., 2000, in Thai). Figure 2.8 shows the geology of the study area (Department of Mineral Resources, 1985).

Phra Wihan Formation in the province has the average thickness about 30 m. and sometimes upto 50 m. It lies conformably with Phu Kradung Formation and Sao Khua Formation. Phra Wihan contains yellowish white fine-coarse grained sandstone, well sorted and rounded. Siltstone, thin bedded mudstone and conglomerate and representing the Middle Jurassic-Early Cretaceous in age. This Formation was deposited by braided and occasional meandering streams in semi-tropical weather. In Buriram, Pra Wihan Formation is lying along East-West in the southern part of Amphoe Nondindang and Amphoe Lahan Sai (Meesuk, et al., 2000, in Thai).

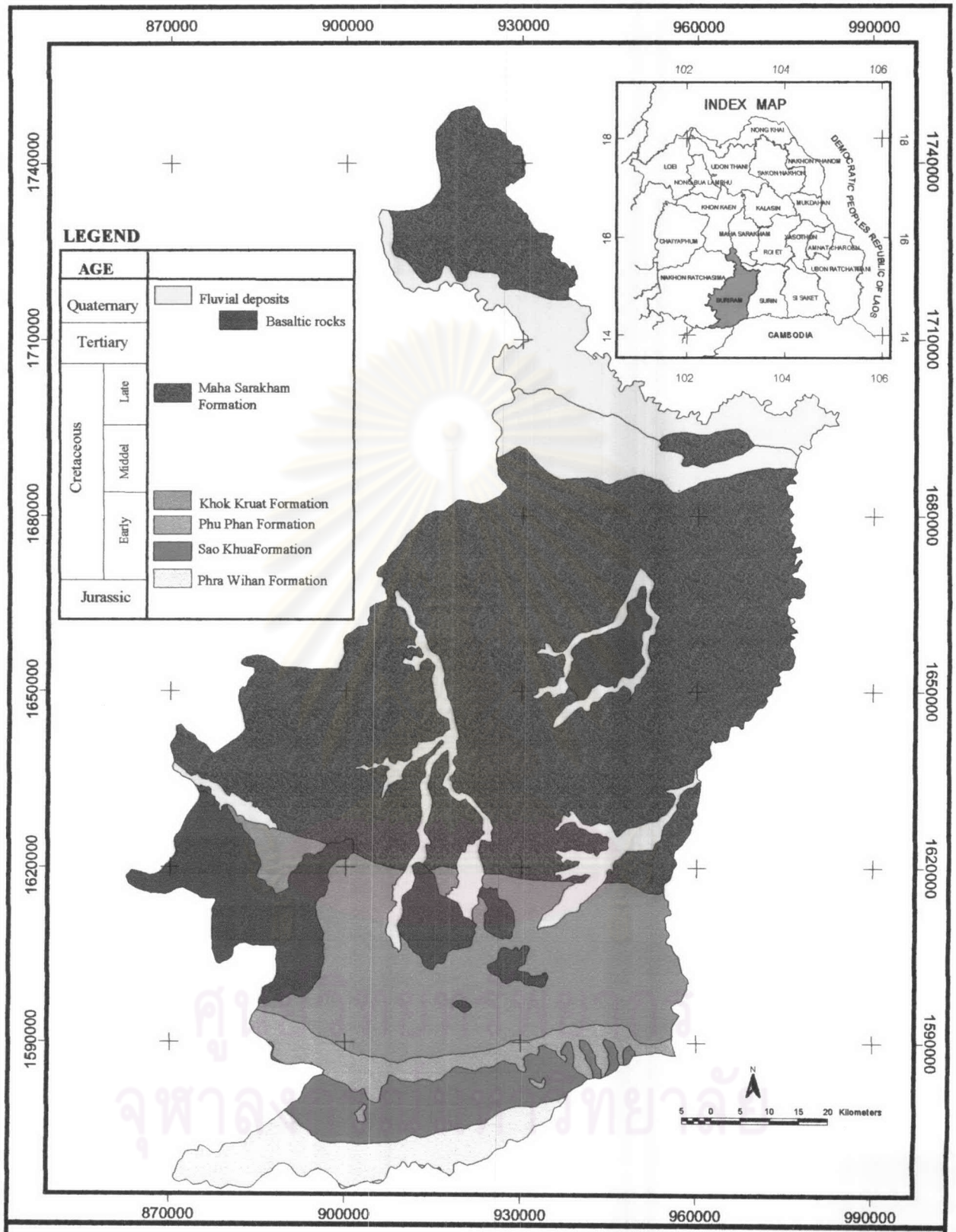
Sao Khua Formation has the average thickness of about 120 m. and ranging between 50-200 m. It lies conformably with Phu Phan Formation. This Formation includes cycles of reddish-brown silty mudstone, siltstone, fine-medium grained sandstone and conglomerate with caliches, calcrete nodules bed and thin bedded and nodular silcretes. Usually of Sao Khua Formation always has thicker calcretes and silcretes beds than Phu Kradung Formation and Khok Kruat Formation and it indicates the Early Cretaceous in age. This Formation is found in Amphoe

Nondindang, Amphoe Lahan Sai, and some parts of Amphoe Ban Kruat (Meesuk, et al., 2000, in Thai).

Phu Phan Formation lies conformably with Khok Kruat Formation with the average thickness of the formation about 80-140 m. This Formation includes pale gray sandstone, thick bedded of medium-coarse grained conglomeratic sandstone containing white quartz, volcanic rocks, gray, dark gray, reddish brown, black, pale gray, and green chert that are well rounded, but poor sorted. Phu Phan Formation represents the Early Cretaceous in age. It is found in Amphoe Nondindang, Amphoe Lahan Sai, Amphoe Ban Kruat, and Amphoe Pa Kham (Meesuk, et al., 2000, in Thai).

Khok Kruat Formation has about 430-700 m. of thickness. This Formation lies unconformably with Mahasarakham Formation. Rocks are reddish brown sandstone, siltstone, mudstone, and conglomerate. There are beds of calcrete nodules and caliche on the top of mudstone. The formation is in the Early Cretaceous. This Formation is recognised at Amphoe Nong Ki, Nonsuwan, Nang Rong, Chalerm Pra Keart, Lahan Sai, Ban Kruat, and Prakhonchai (Meesuk, et al., 2000, in Thai).

Mahasarakham Formation has 610-1000 m. of thickness, consisting of halite, carnallite, sylvite, anhydrite, and gypsum intercalated with deep reddish orange to purplish red sandstone, siltstone, and mudstone. This Formation lies conformably with Phu Tok Formation. Mahasarakham Formation covers most of the study area and is observed extensively in Amphoe Na Pho, Banmaichaiyapoj, Phutthaisong, Satuk, Khu Muang, Lamplai Mat, Muang Buriram, Huai Rat, Krasang, Nong Hong, Chamni,



ENVIRONMENTAL GEOLOGY OF CHANGWAT BURIRAM

Figure 2.8 Geological map of Changwat Buriram

(Source: 1. Geological Survey Division, Department of Mineral Resources, 1985)

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Nong Ki, Nang Rong, Chalerm Pra Keart, Prakhonchai, Phlapphla Chai, and King Amphoe Ban Dan (Meesuk, et al., 2000, in Thai).

Basalt represents only one extrusive rock in this area. It is located in small area southern part of Changwat Buriram, at Khao Kradong, Amphoe Muang, Khao Phanom Rung, Amphoe Chalerm Pra Keart, Khao Pra Ang Karn, Amphoe Nang Rong (Meesuk, et al., 2000, in Thai).

2.2.4 Water Resources

2.2.4.1 Surface Water

Runoff

Surface water in the study area is recognised and registered as stream flow or run off as the rainfall subtracted by infiltration and evaporation through the physical processes of the soil-vegetation. It can be noted that immediately after the rainy season in October there is no flow in the stream at all for a full period of 7 months. This is a consequence of severe restriction on developing surface water facilities, such as, weirs or reservoirs.

Drainage

Two main rivers, the Mun and the Chi Rivers, are the major rivers in Buriram. The Mun River originates near Nakhon Ratchasima and flows eastwards through the north

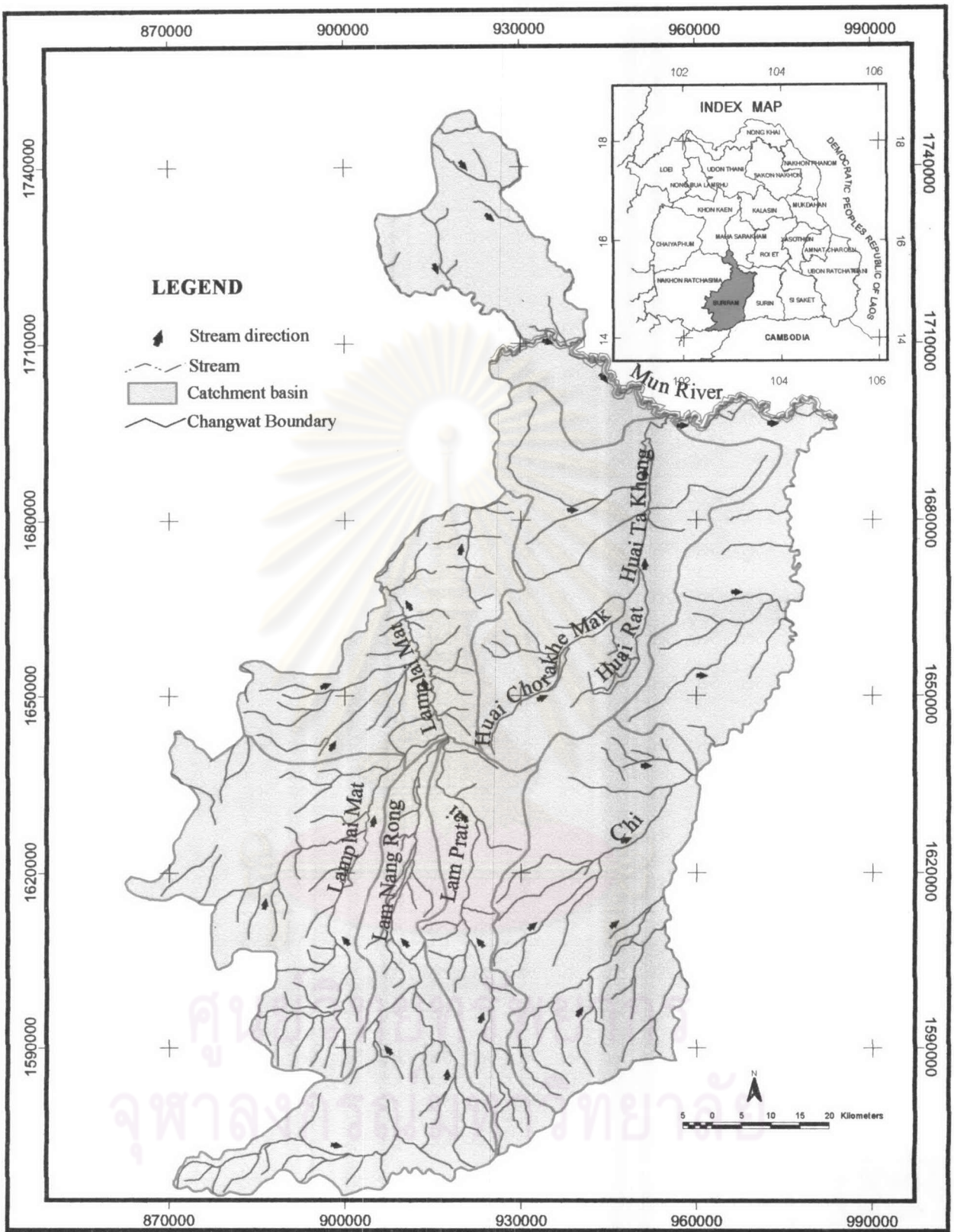

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Figure 2.9 Surface drainage of Changwat Buriram

(Modified after: 1. Geological Surverey Division, Department of Mineral Resources, 1985)

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of Changwat Buriram while the Lam Chi River flows between Buriram and Surin. The other streams are Lam Plai Mat, Lam Nang Rong, Lam Patai, Huai Chorakhe Mak, Huai Rat, and Huai Ta Khong, as shows in Figure 2.9 (Department of Mineral Resources, 1985).

2.2.4.2 Groundwater

2.2.4.2.1 Groundwater Rock Aquifer Types

Groundwater of Changwat Buriram can be divided into 2 groups of rock aquifer types as shown in Figure 2.10 (Wongsawat, et al., 1989).

A) Unconsolidated Sediment Aquifers

a) Alluvial Deposits are characterised by gravel, sand, silt, and clay. Groundwater is trapped in voids between gravel and sand grains of flood plain deposits and meandering belt deposits. The average depth is about 10-30 m.

b) Terrace Deposits are characterised by gravel, sand, silt, clay, local lateritic soil, and laterite. Groundwater stores in voids of gravel and sand of buried channels deposits. The average depths are 20-40 m. and 10-15 m. in some places.

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B) Consolidated Rock Aquifers

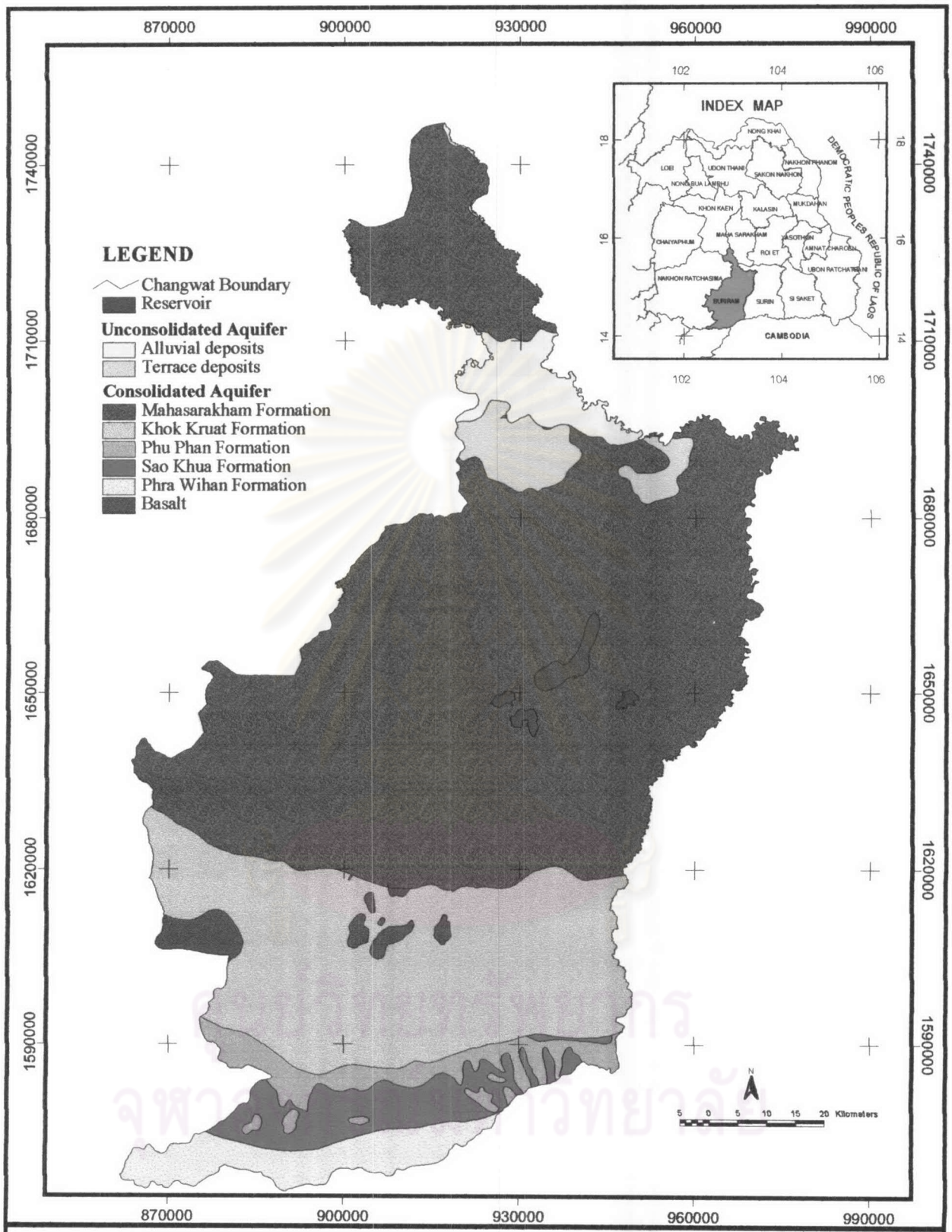
a) Mahasarakham Formation is characterised by orange, red to purplish red sandstone, siltstone, shale, and mudstone. Commonly found white bleadched along fracture and bedding plane with rocks salt and other evaporites in the lower part. Groundwater occurs in joints, fractures, and bedding planes. The average depths are about 20-40 m., and up to 70 m. in some areas.

b) Khok Kruat Formation is characterised by sandstone, siltstone, shale, and lime-nodule conglomerate with gypsum at the upper part. Groundwater occurs in joints, fractures, and bedding planes. The average depth is about 20-40 m.

c) Phu Phan Formation is characterised by sandstone, siltstone, shale, and lime-nodule conglomerate. Groundwater is trapped in fractures and joints. The average depths are 20-30 m. and 40-60 m.

d) Sao Khua Formation is characterised by sandstone, siltstone, shale, and lime-nodule conglomerate. There is mountain area along East-West. Groundwater is trapped in joints, fractures, cracks and bedding planes. This zone is low groundwater potential.

e) Phra Wihan Formation is characterised by white sandstone with pebbly sandstone at the upper part. Groundwater occurs in fractures, joints, and bedding planes. The average depths are about 30-40 m. and up to 70 m. in some areas.



ENVIRONMENTAL GEOLOGY OF CHANGWAT BURIRAM

Figure 2.10 Aquifer types of groundwater of Changwat Buriram

(Source: Groundwater Division, DMR., 1989)

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f) Basalt is gray to grayish black, vesicular locally. Groundwater is trapped in fractures, joints, connecting pores and weathered zone. The average depth is about 20-30 m.

2.2.4.2.2 Groundwater Yield and Quality

The yield and quality of groundwater of Changwat Buriram; Expected well yield, total dissolved solid (TDS), chloride content, hardness content, iron content, nitrogen, and the acidity (pH) are described as follows;

A) Expected Well Yield (m^3/hr)

Yield of groundwater can be divided into 4 groups as shown in Figure 2.11 (Wongsawat, et al., 1989) as follows;

(1) less than 2 m^3/hr

(2) 2-10 m^3/hr

(3) 10-20 m^3/hr

(4) more than 20 m^3/hr

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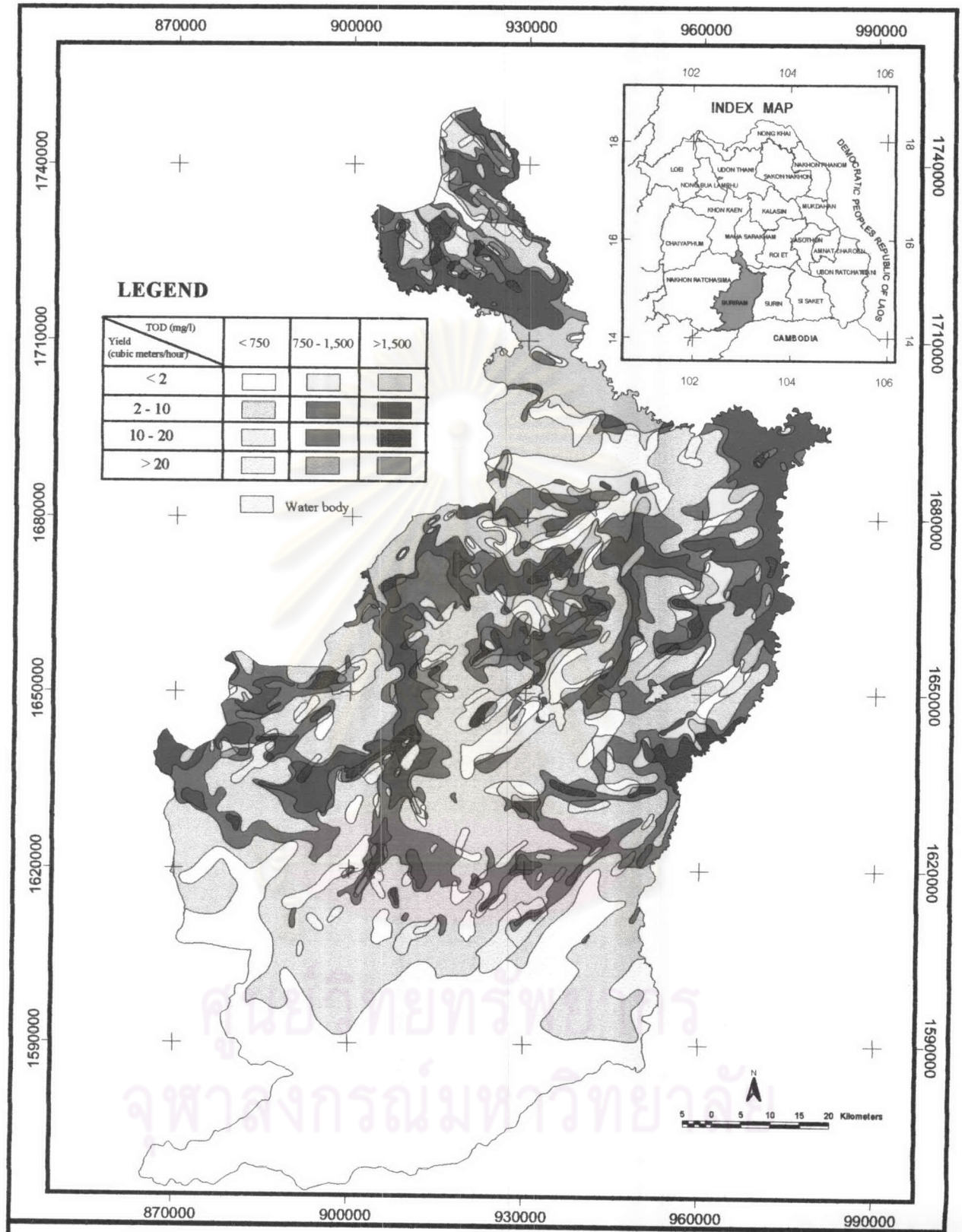
Moreover, Figure 2.11 is a combination map between yield and total dissolved solids (TDS) concentration, thus, 12 units of yield and TDS in groundwater will be shown.



ENVIRONMENTAL GEOLOGY OF CHANGWAT BURIRAM

Figure 2.11 Groundwater resources of Changwat Buriram

(Source: Groundwater Division, DMR., 1989)

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B) Total Dissolved Solid, TDS (mg/l)

Total dissolved solids (TDS), is defined as the concentration of all dissolved minerals in the water. TDS are a direct measurement of the interaction between groundwater and subsurface minerals. High TDS, greater than 1000 mg/L, is commonly offensive to taste. TDS levels over 2000 mg/L are generally considered undrinkable due to strongly offensive taste. A higher concentration of TDS usually serves as no health threat to humans until the values exceed 10,000 mg/L. At this level the water is considered saline water and defined as undrinkable. A high TDS (levels above 1,000 mg/L) may cause corrosion of pipes and plumbing systems.

Groundwater quality is dependent upon the total dissolved solid, TDS (Figure 2.11) that can be divided into 3 groups (Wongsawat, et al., 1989) as follows;

(1) Suitable : less than 750 mg/l TDS

(2) Acceptable : 750-1500 mg/l TDS

(3) Unsuitable : more than 1500 mg/l TDS

C) Chloride Content, Cl (mg/l)

Chloride occurs as the predominant negatively ion in seawater. Major source of chloride is sedimentary rock (evaporites); minor sources are igneous rocks. The chloride content of the groundwater found elsewhere averages close to 6 mg/l unless the aquifers have been contaminated with saline water. Where wells near the heavily pumped, some saline water may move into the fresh water aquifer. A running record

of the chloride content of water samples from observation wells provides information as to whether contamination of the aquifer may be occurring.

Chloride content (Figure 2.12) of groundwater can be divided into 4 levels (Wongsawat, et al., 1989) as follows;

(1) Suitable : less than 200 mg/l

(2) Acceptable : 200-600 mg/l

(3) Unsuitable : 600-1,000 mg/l

(4) Unacceptable : more than 1,000 mg/l

D) Hardness Content (mg/l)

Hardness is defined as water that is rich in calcium (Ca^{2+}) and/or magnesium (Mg^{2+}). Hard water generally causes the formation of soap curd in pipes, sinks, and bathtubs. Calcium may precipitate as calcium carbonate within the plumbing and clog pipes. Calcium and Magnesium are primarily found in ground water due to the dissolving of limestone (primarily composed of calcium carbonates). The dissolving of limestone occurs when the limestone reacts with rainwater, which has become slightly acidic through a reaction with carbon dioxide. Calcium and Magnesium ions are also released when the water reacts with naturally occurring gypsum.

Hardness content (Figure 2.13) can be divided into 3 levels (Wongsawat, et al., 1989) as follows;

(1) Suitable : less than 300 mg/l

(2) Acceptable : 300-500 mg/l

(3) Unsuitable : more than 500 mg/l

E) Iron Content (mg/l)

Iron (Fe^{2+}, Fe^{3+}) in groundwater provides the typical well water "rust" taste. Not only is the taste unpleasant, iron can also stain plumbing fixtures, clothes, and dishes. Most groundwater has at least trace amounts of iron because its presence in nature is so common. Iron concentrations exceeding this level may cause the characteristic reddish staining. Iron is generally derived from minerals contained within the underlying bedrock. Limestone, shale, and coal, which often contain the iron-rich mineral pyrite, are large contributors of iron. Like calcium and magnesium; carbonate rocks, acidic rainwater releases iron ions into solution. Furthermore, teeth may be brittle because fluoride affects tooth density.

Iron content (Figure 2.14) can be divided into 3 levels (Wongsawat, et al., 1989) as follows;

(1) Suitable : less than 0.5 mg/l

(2) Acceptable : 0.5-1.0 mg/l

(3) Unsuitable : more than 1.0 mg/l

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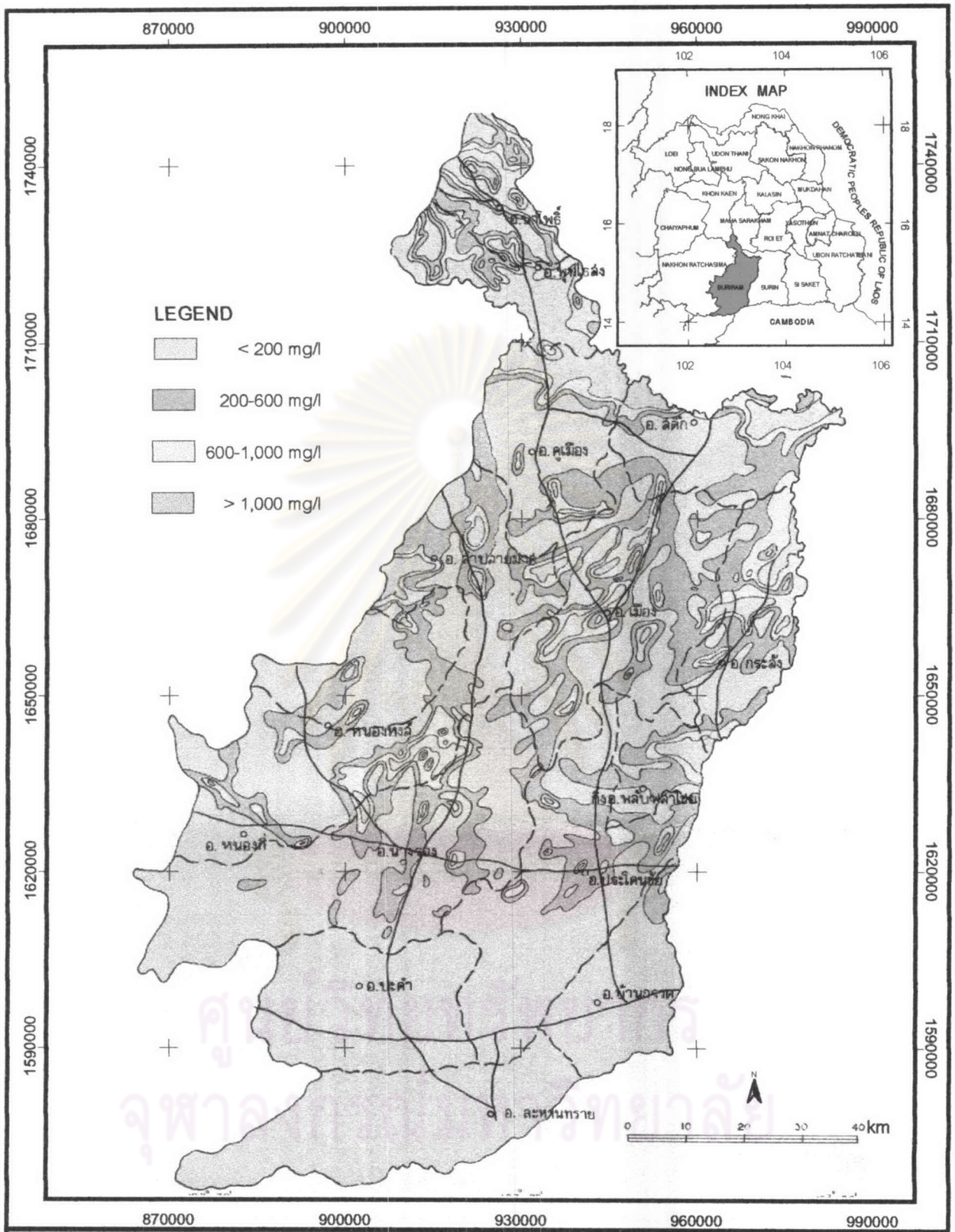

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Figure 2.12 Chloride content in groundwater of Changwat Buriram
(Source: 1. Groundwater Division, DMR, 1989 in Thai)

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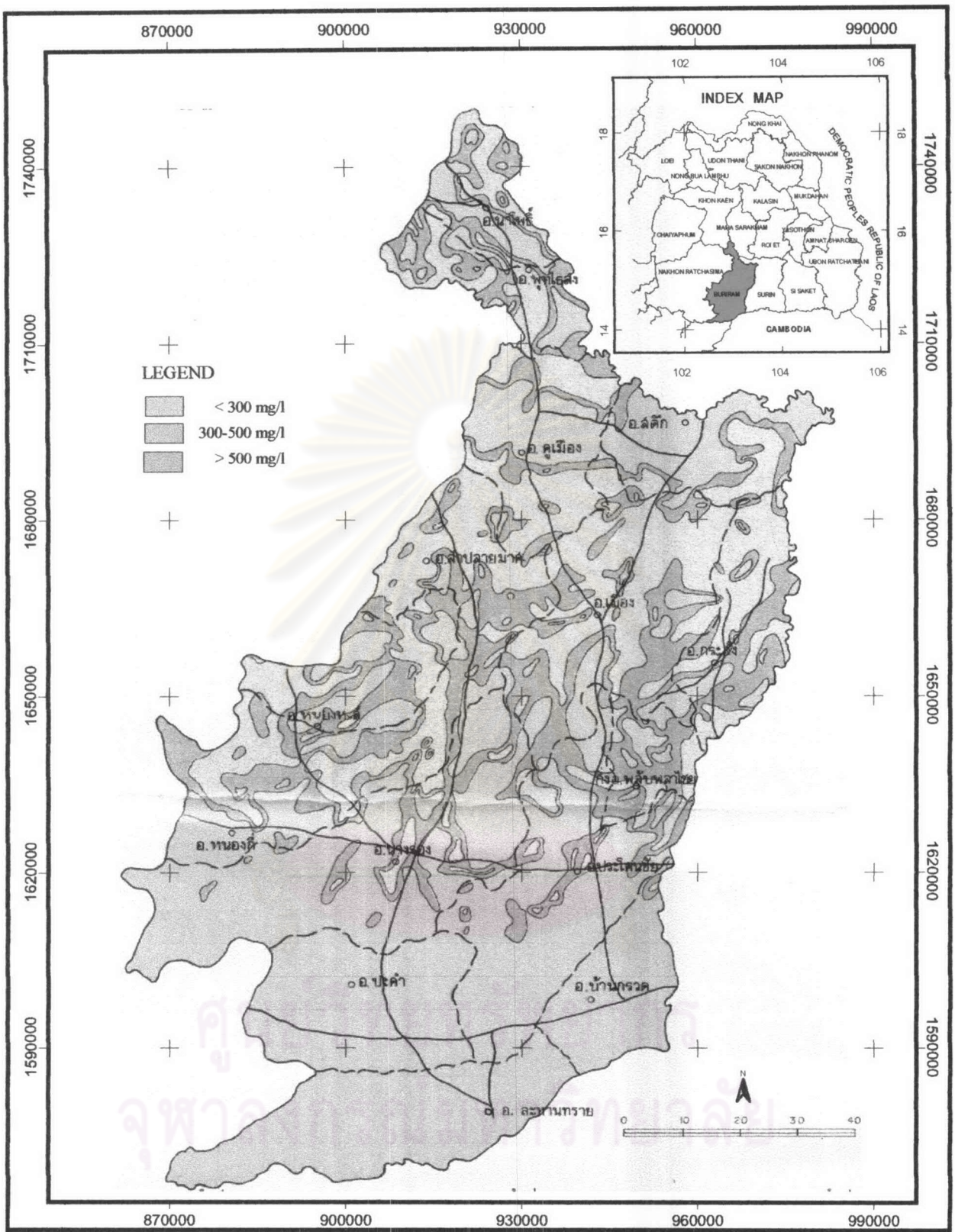

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Figure 2.13 Hardness content in groundwater of Changwat Buriram.
(Source: 1. Groundwater Division, DMR, 1989, in Thai)

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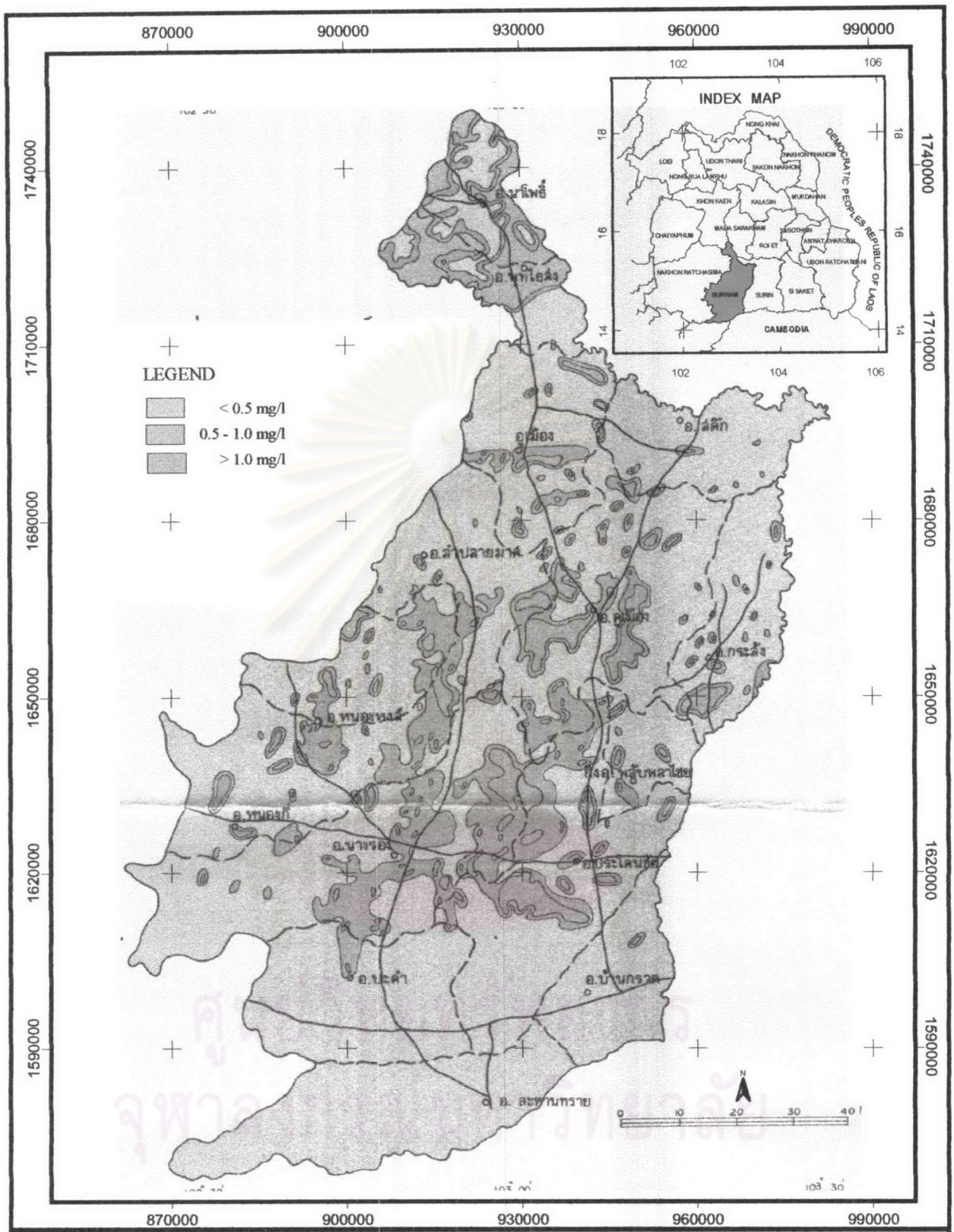

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Figure 2.14 Iron content in groundwater of Changwat Buriram.
(Source: 1. Groundwater Division, DMR 1989, in Thai)

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F) Nitrogen

Nitrogen is typically present in ground water in three forms: ammonia (NH_3), nitrate (NO^{3-}), and nitrite (NO_2^{2-}). Of the three, nitrite is the most toxic. Most nitrogen compounds found in the ground water are partially derived from the atmosphere, fertilizers, manure and urine from feedlots and pastures, sewage, and landfills. Nitrates are especially toxic to children less than six months of age known as "blue-baby syndrome". High nitrate concentrations in well water are cause for concern, which there originate from either direct discharge of contaminated surface water into a well or natural infiltration by contaminated surface water.

G) The Power of Hydrogen Ion (pH)

Water is said to be either acidic or alkaline, depending on the relative concentration of hydrogen ions. Hydrogen ion in water causes it to act as acid whereas the capability of water to neutralize acid, that is, reduces the number of hydrogen ion in solution, is called alkalinity. The pH range is from 0 to 14; with a pH value of 7 at 25 °C indication a neutral solution in which H^+ and OH^- ions have the same concentration. A pH less than 7 indicates an acid solution, while a pH greater than 7 indicates an alkaline solution. Temperature plays a roll in determining the pH at which neutrality occurs. The variation of pH can be identified as follow: very high pH values, that is above 8.5, are usually associated with sodium-carbonate-bicarbonate waters, moderately high pH values are commonly associated with water high in bicarbonate, very low pH values, that is below 4.0, are associated with water containing free acid derived from oxidizing sulfide minerals, usually pyrite, or from

waters in contact with volcanic gases containing hydrogen sulfide, hydrochloric acid, and other volatiles and moderately low pH values may be associated with small amounts of mineral acids from sulfide sources or with organic acid from decaying vegetation (Davis and Dewiest, 1966).

2.2.5 Existing Land use

Land use is a function of culture and settlement pattern as well as environmental characteristics. The interactions of social, economic, and ecological factors are described in a large, diverse literature. Measures of social and economic conditions that have been shown to influence or be correlated to land use patterns include historical land use, rural population density, economic land value, tax status, access, type of owner, and residency of owner.

Table 2.4 and Figure 2.15 show the land use pattern of Changwat Buriram that can be classified into five groups according to data and information which obtained from the Department of Land Development as follow:

1. Urban and Built-up Area Urban and rural settlements occupy a small part of the total land area of Changwat Buriram, which are further subdivide into residential, commercial, industrial, transportation and communication, and institutional lands.

2. Agriculture Area The largest group of land use is the agriculture area is mainly covered by the paddy fields. The other agricultural areas are covered by field crops, orchard, horticulture, animal farm houses.

The agriculture area in the entire area of Changwat Buriram can be classified as follows.

1) About 50 % of rice area is suitable for farm.

2) About 30 % of high land rice fields is sufficient to grow farm crops and fast growth plants.

3) There are suitable areas for fruit plantation i.e. Sweet tamarind, guava, and cabbages etc.

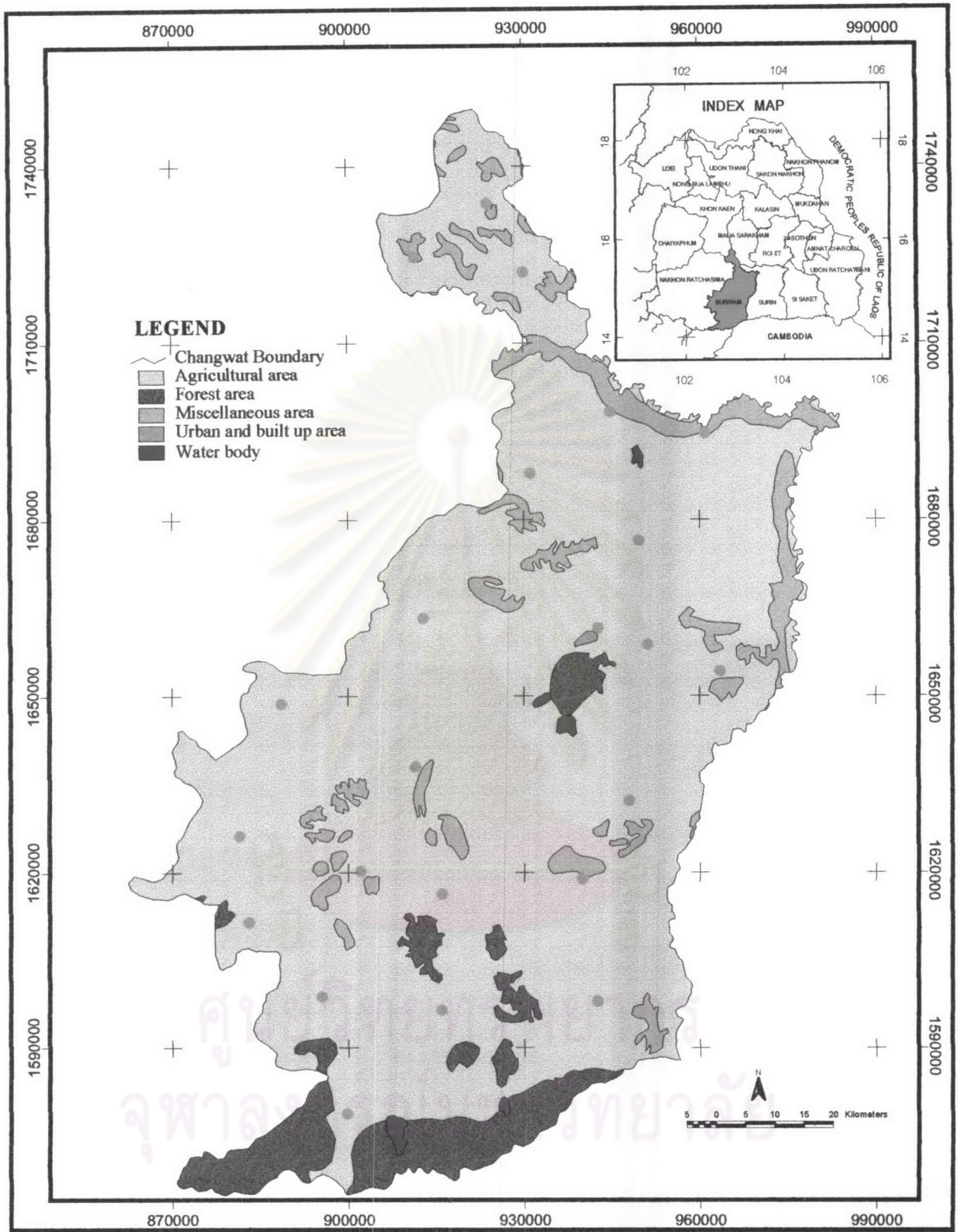
4) The area is suitable for jasmine rice.

5) About 50% of the whole province is suitable for livestock pastures.

3. Forest Area The forest areas of Changwat Buriram, which are further, subdivided into evergreen forest, deciduous forest and forest plantation.

4. Water Area These water areas of Changwat Buriram, which are also further, subdivided into natural water resources and build-up water resources.

5. Miscellaneous Area The miscellaneous area covers range land, wet land, rocky land, etc.



ENVIRONMENTAL GEOLOGY OF CHANGWAT BURIRAM

Figure 2.15 Land use map of Changwat Buriram, 1987.
(Modified after 1. Land Development Department , 1988, in Thai
2. Royal Thai Survey Department, 1989)

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Table 2.4 Land Utilization of Changwat Buriram, 1986-1995 (Source: Buriram Provincial Statistical Office, 2000)

Year	Total Area	Forest Area	Dwelling Area	Agriculture Area (rai)							Miscellaneous Area
				Paddy Field	Crop Field	Fruit Trees and Tree Crops	Vegetables	Livestock Area	Other Trees	Total	
1986	6,451,178	377,810	65,174	3,142,605	512,715	47,168	3,674	2,748	149,023	3,923,107	2,150,261
1987	6,451,178	375,633	71,512	3,246,788	501,234	67,578	3,000	1,714	82,132	3,973,958	2,101,587
1988	6,451,178	373,468	77,865	3,248,719	498,407	82,782	5,041	9,202	80,078	4,002,094	2,075,616
1989	6,451,178	372,500	79,313	3,184,548	524,091	96,704	8,542	12,138	68,537	3,973,873	2,104,805
1990	6,451,178	353,253	80,761	3,144,835	548,798	110,074	11,738	15,747	101,928	4,013,881	2,084,044
1991	6,451,178	335,000	81,621	3,188,726	526,790	122,082	4,912	4,523	98,858	4,027,512	2,088,666
1992	6,451,178	332,766	71,894	3,180,920	519,864	94,054	8,003	1,221	74,051	3,950,007	2,168,405
1993	6,451,178	330,938	74,336	3,134,152	474,992	92,927	7,265	1,221	65,910	3,850,803	2,269,437
1994	6,451,178	330,234	75,200	3,152,956	465,774	90,556	8,383	2,696	63,901	3,859,466	2,261,478
1995	6,451,178	329,532	76,440	3,173,450	456,256	89,171	9,624	4,193	64,244	3,873,378	2,248,268

Table 2.5 Thematic data and sources of Changwat Buriram

Thematic map	Data sources	Digital sources	Scale	Spatial element
Amphoe and King Amphoe administration areas of Changwat Buriram (figure 2.1)	Buriram Provincial Statistical Office (2000, in Thai) Royal Thai Survey Division (no date, in Thai)	Geological Survey Division, DMR (2001)	1:250,000	polygon
Population Density of Changwat Buriram (Figure 2.2)	Buriram Provincial Statistical Office (2000, in Thai) Royal Thai Survey Division (no date, in Thai)	Not available	1:250,000	polygon
Road System of Changwat Buriram (Figure 2.4)	Royal Thai Survey Division (no date, in Thai)	Geological Survey Division, DMR (2001)	1:250,000	Line
Tourist Attraction of Changwat Buriram (Figure 2.5a)	Buriram Provincial Statistical Office (2000, in Thai)	Not available	1:250,000	point
Map showing the connection route among tourist attraction from Northeastern Thailand throughout Cambodia (Figure 2.5b)	Royal Thai Survey Division (no date, in Thai) Buriram Governor's Office Plans (1994-2004, in Thai)	Not available	1:250,000	point
Slope Map of Changwat Buriram (Figure 2.6)	Geological Survey Division, DMR (1989)	Geological Survey Division, DMR (2001)	1:250,000	polygon
Flood-Risk Area of Changwat Buriram (Figure 2.7)	Geological Survey Division, DMR (1989)	Not available	1:250,000	Polygon
Geological Map of Changwat Buriram (Figure 2.8)	Geological Survey Division, DMR (1989)	Geological Survey Division, DMR (2001)	1:250,000	polygon
Surface Drainage of Changwat Buriram (Figure 2.9)	Geological Survey Division, DMR (1989)	Geological Survey Division, DMR (2001)	1:250,000	polygon
Aquifer Types of Groundwater of Changwat Buriram (Figure 2.10)	Division of Groundwater, DMR (1989)	Division of Groundwater, DMR (2001)	1:100,000	polygon
Groundwater Resources of Changwat Buriram (Figure 2.11)	Division of Groundwater, DMR (1989)	Division of Groundwater, DMR (2001)	1:100,000	polygon

2.2.6 Waste Generation in Changwat Buriram

Waste in the study area can be divided into 3 types as follows.

a) Human Waste

A major difficulty encountered in this area is the shortage of water for flushing latrine. Promotion for use of latrine can be effective only when water supply is made available. The installation of latrines within the five-year periods should be done properly. This should also be promoted by encouraging the people to build and pay for it prior to providing the water supply.

b) Domestic Waste

Seriously, to get rid of domestic waste, no littered food residuals and others will be allowed anywhere. Village dumping pits should be constructed and the disposed waste should be burned occasionally. Garbage containers for every house and public places should be provided and a campaign through competition of cleanliness among the houses and villages should be readily carried out. The use of food residuals for livestock, e.g. scavenging pigs, should be encouraged.

c) Agricultural Waste

This type of waste comes from both plants (e.g. rice and cassavana) and livestock. Cassavana stem can be used for firewood while rice straw should be used

for growing mushrooms or making ropes, etc. Livestock waste should be collected and used for fertilizers.

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2.2.7 Soils Characteristics

Pendleton (1953) classified the soil in Northeast Thailand, which covered Burirum, into four main types:

1. Khorat find sandy loams, and often with laterite, were found in the foothill slopes. They are not commonly cultivated.
2. Roi Et fine sandy loams occur below the type 1 layer. They are dyked and can be used for rice growing.
3. Gula Ronghai silt loams were found in the lower depressions of the plain along the banks of Mun, Chi and Songkhram Rivers and covered with spare grass.
4. Sandy soils derived from quartzite and silicacious sandstone hills, found in the Phu Phan Range south of Sakhon Nakhon and in the Petchabun hills to the west.

Soils Characteristics of Changwat Buriram

Soil characteristics of Changwat Buriram (Chotimon, 1978, in Thai) were classified into 41 groups that are described as below;

1. Alluvial Soil

This soil series groups in Alluvial Soil (National). It occurs in river natural levee and flood plain with slope less than 3% and shows poorly to moderate well

drained, low to rapid of permeability and slow to moderate of run off. Texture of upper and lower soil is sand to clay, acid to neutral of soil reaction.

2. Chiang Mai Series: (Cm)

It occurs in recent alluvium. Relief is undulating micro and slope less than 2%, deep soil, moderately well drained, moderate permeability and run off. Ground water level falls below 3 m during dry season. Brown to grayish brown silty loam, silt, and sandy loam, very strongly acid to neutral (pH 5.0-7.0) is found in upper soil (< 30 centimeter). Brown to yellowish brown silty loam, and sandy loam, very strongly to slightly acid (pH 5.0-6.5) is found in lower soil.

3. Ratchaburi Series: (Rb)

It occurs in recent alluvium. Physiography is levees and river basin, slope less than 1%, deep soil, somewhat poorly drained, slow of permeability and run off. Ground water level falls below 1.5 m during dry season. Dark grayish brown clay and silty clay, dark brown and yellowish brown mottles, strongly to slightly acid (pH 5.5-6.5) is found in upper soil (< 30 centimeter). Dark grayish brown to dark brown clay or silty clay, dark yellowish brown mottles, medium acid to neutral (pH 5.5-6.5) is found in lower soil.

4. Phimai Series: (Pm)

It occurs in recent or semi-recent alluvium. Physiography is river basin and backswamp areas of flood plains, slope less than 1%, deep soil, poorly drained, slow of permeability and run off. Ground water level falls below 1.5 m during dry season. Dark gray to brownish gray clay and silty clay, yellowish red mottles, strongly acid neutral (pH 5.5-7.0) is found at upper soil (< 50 centimeter). Dark gray to gray clay, dark gray to yellowish brown mottles, slightly acid to moderately alkaline (pH 6.5-8.0) is found in lower soil.

5. Kula Ronghai Series: (Kr)

It occurs in old alluvium. Physiography is low terrace, deep soil, poorly drained, moderately to slow of permeability and run off. Ground water level falls below 1.5 m during dry season. Lightly brown to brown loam or sandy loam, very strongly to slightly acid (pH 5.0-6.5) is found at upper soil (< 20 centimeter). Light gray to grayish brown clayey loam, clay or sandy clay, neutral to moderately alkaline (pH 7.0-8.0) is found in lower soil.

6. Nakorn Phanom Series: (Nn)

It occurs also in old alluvium. Physiography is semi-recent terrace and low terrace, slope less than 1%, deep soil, poorly drained, slow of permeability and run off. Ground water level falls below 3.0 m. Yellowish brown to pale brown silty clay loam to clay loam, dark brown to yellowish brown mottles, strongly to slightly acid of

soil reaction (pH 5.5-6.5) is found at upper soil (< 20 centimeter). Light grey to pale brown silty clay and clay, red mottles, extremely to strongly acid (pH 4.5-5.5) in lower soil.

7. Roi Et Series: (Re)

It occurs in old alluvium. Physiography is low terrace, 0-3% of slope, deep soil, poorly drained, rapid of permeability for upper soil and moderate for lower soil, slow of run off. Ground water level falls below 3.0 m during dry season. Grayish brown or light brown sandy loam , loam or loamy sand, yellowish brown to dark brown mottles, very strongly to slightly acid (pH 5.0-6.5) for upper soil (< 30 centimeter). Light grey clay loam, yellowish brown and dark brown mottles, extremely to strongly acid (pH 4.5-5.5) for lower soil.

8. Roi Et, loamy variant Series: (Re-l)

It occurs in old alluvium. Physiography is lower parts of low terrace, 1% of slope, deep soil, poorly drained, slow to moderate of permeability, slow of run off. Ground water level falls below 1.5 m during dry season. Grayish brown or light brown loam or sandy clay loam, dark brown or yellowish brown mottles, very strongly to slightly acid (pH 5.0-6.5) is found at upper soil (< 30 centimeter). Light brown or pinkish gray sandy clay loam, sandy clay or clay loam, dark brown or yellowish brown mottles, extremely to medium acid (pH 4.5-6.0) is found in lower soil.

9. Roi Et, clayey variant Series: (Re-c)

It occurs in old alluvium. Physiography is lower parts of low terrace, 1% of slope, deep soil, poorly drained, slow to moderate of permeability, slow of run off. Ground water level falls below 1.5 m during dry season. Light brown loam sand, sand loam or sandy clay loam, dark brown or yellowish brown mottles, very strongly to slightly acid (pH 5.0-6.5) is found at upper soil (< 30 centimeter). Pinkish gray or light brown clay loam or sandy clay loam, dark brown or yellowish brown mottles, extremely to medium acid (pH 4.5-6.0) is found in lower soil.

10. Roi Et, calcareous variant Series: (Re-ca)

It occurs in old alluvium. Physiography is low terrace, 1-2% of slope, deep soil, poorly drained, slow and moderate of permeability for upper and lower soil respectively. Ground water level falls below 1.5 m during dry season. Grayish brown or light brown sandy loam, loam sand, or loam, dark brown or yellowish brown mottles, strongly to slightly acid is found at upper soil (< 30 centimeter). Light brown or pinkish gray sandy clay loam, clay loam, or sandy clay, dark brown or yellowish brown mottles, secondary lime and iron-manganese concretions less than 15%, mildly to moderately alkaline (pH 7.5-8.0) is found in lower soil.

11. Roi Et, clayey variant and high phose Series: (Re-h)

It occurs in old alluvium. Physiography is low terrace, 1-2% of slope, deep soil, poorly drained, slow to moderate of permeability, moderate of run off. Ground water level falls below 1.5 m during dry season. Grayish brown or pale brown loam and sandy loam, dark brown or yellowish brown mottles, very strongly to slightly acid (pH 5.0-6.5) is found at upper soil (< 20 centimeter). Light brownish gray clay loam and clay, dark brown and yellowish red mottles, extremely to strongly acid (pH 4.5-5.5) is found in lower soil.

12. Tha Tum Series: (Tt)

It occurs in old alluvium. Physiography is low terrace, 0-1% of slope, deep soil, poorly drained, slow and moderate of permeability for upper and lower soil respectively, slow of run off. Ground water level falls below 1.5 m during dry season. Brown, light brown or grayish brown sandy loam, loam or silty loam, yellowish red and dark brown mottles, very strongly to slightly acid (pH 5.0-6.5) is found at upper soil (< 20 centimeter). Pinkish gray or gray clay or sandy clay, red and brownish yellow mottles, extremely to strongly acid (pH 4.5-5.5) is found in lower soil.

13. Si Thon Series: (St)

It occurs in old alluvium. Physiography is valley flats, 0-1% of slope, deep soil, poorly drained, somewhat well of permeability, slow of run off. Ground water level falls below 2.0 m. Dark brown to light brown sandy loam or loam sand,

yellowish red and reddish yellow mottles, very strongly to medium acid (pH 5.0-6.0) is found at upper soil (< 30 centimeter). Pinkish gray or grayish brown sandy clay loam and loamy sand, dark brown or deep reddish brown mottles, very strongly acid to neutral (pH 5.0-7.0) is found in lower soil.

14. That Phanom Series: (Tp)

It occurs as alluvium. Physiography is semi-recent terraces and old levees, 1-4% of slope, deep soil, somewhat well drained, somewhat well of permeability, moderate of run off. Ground water level falls below 3.0 m during dry season. Dark brown to dark grayish brown silty loam, loam, sandy loam, extremely acid (pH 4.5) is found at upper soil (< 30 centimeter). Yellowish red or red silty clay loam, clay loam, silty clay or clay, Pinkish gray, reddish brown or yellowish brown mottles, very strongly to slightly acid (pH 5.0-6.5) is found in lower soil.

15. Ubon Series: (Ub)

It occurs as alluvium. Physiography is higher parts of low terrace, 0-3% of slope, deep soil, somewhat excessively drained, rapid of permeability, slow of run off. Ground water level falls below 4.0 m during dry season. Light brown or brown loam sand or sand, deep yellowish brown mottles, very strongly to slightly acid (pH 5.0-6.5) is found at upper soil (< 20 centimeter). Light brown to reddish brown loam sand to clay, dark brown, reddish yellow or yellowish brown mottles, strongly to slightly acid (pH 5.5-6.5) is found in lower soil.

16. Phen Series: (Pn)

It occurs in old alluvium. Physiography is the shallow depressions of the middle terrace, 1-2% of slope, shallow soil, poorly drained, moderate of permeability for upper soil and slow for lower soil, slow of run off. Ground water level falls below 3.0 m during dry season. Grayish brown or brown loam or sandy and gravelly loam, dark brown, yellowish brown or yellowish red mottles, strongly to slightly acid (pH 5.5-6.5) is found at upper soil (< 20 centimeter). Light brown or pinkish gray gravelly clay loam or sandy and gravelly clay loam, reddish yellow or red mottles, extremely to strongly acid (pH 4.5-5.5) is found lower soil.

17. Roi Et/On association Series: (Re/On)

On series associated occurs at low terrace with Roi Et series

18. Roi Et/ Phen association Series: (Re/Pn)

Phen series associated occurs at low terrace with Roi Et series

19. Kula Ronghai/ Tha Tum association Series: (Ki/Tt)

Kula Ronghai series associated occurs at low terrace with Tha Tum Et series

20. Renu Series: (Rn)

It occurs in old alluvium. Physiography is lower parts of middle terraces and the alluvial fan, 1-4% of slope, deep soil, somewhat poorly drained, moderate of permeability and run off. Ground water level falls below 1.0 m during dry season. Brown, grayish brown or dark sandy loam or loam sand, dark brown or yellowish brown mottles, very strongly to medium acid (pH 5.0-6.0) for upper soil (< 40 centimeter). Gray clay loam or clay, yellowish red or red mottles, extremely to strongly acid (pH 4.5-5.5) for lower soil.

21. Korat Series: (Kt)

It occurs in old alluvium. Physiography is middle terrace, 0-3% of slope, deep soil, somewhat well drained, moderate to rapid of permeability and run off. Ground water level falls below 2.0 m during dry season. Grayish brown or dark grayish brown sand loam or loam sand, strongly to slightly acid (pH 5.5-6.5) for upper soil (< 30 centimeter). Brown or light brown sandy clay loam, dark brown or reddish yellow mottles, extremely to strongly acid (pH 4.5-5.5) for lower soil.

22. Phon Phisai Series: (Pp)

It occurs in old alluvium. Physiography is middle terrace, 2-6% of slope, shallow soil, somewhat well drained, moderate of permeability for upper soil and slow for lower soil, moderate to rapid of run off. Ground water level falls below 3.0 m during dry season. Dark grayish brown, yellowish red or dark brown sandy loam,

loam, gravelly loam sand to gravelly clay loam or gravelly clay, extremely to slightly acid (pH 4.5-6.5) for upper soil. Lower soil is dark gray clay, dark brown mottles, extremely to strongly acid (pH 4.5-5.5).

23. Nam Phong Series: (Ng)

It occurs in old alluvium and locally colluvium. Physiography is middle terrace and foot slopes, 3-10% of slope, deep soil, somewhat excessively drained, rapid permeability and run off. Ground water level falls below 3.0 m during dry season. Dark grayish brown and light brown to pink or yellowish brown, reddish yellow loam sand, sand or sandy loam, extremely to slightly acid (pH 4.5-6.5) for upper soil. For lower soil, pale color sandy clay loam or sandy clay, dark brown or reddish yellow mottles, extremely to strongly acid (pH 4.5-5.5).

24. Korat/Phon Phisai association Series: (Ki/Tt)

Korat series associated occurs at middle terrace with Phon Phisai series

25. Korat /Nam Phong association Series: (Kt/Ng)

Korat series associated occurs at middle terrace with Nam Phong series

26. Korat /Nam Phong /Renu association Series: (Kt/Ng/Rn)

Korat series associated occurs at middle terrace with Nam Phong and Renu series.

27. Tha Uthen Series: (Tu)

It occurs in old sandy alluvium. Physiography is low and middle terrace, 1-4% of slope, moderate deep soil, somewhat well drained, moderate permeability in upper soil and slow permeability in lower soil, moderate to rapid run off. Ground water level falls below 2.0 m during dry season. Gray, grayish brown and brown or dark brown loam sand to sandy loam and sandy clay, extremely to medium acid (pH 4.5-6.0) found in upper soil. White, light gray or pale brown clay, very strongly to medium acid (pH 5.0.-6.0) found in lower soil.

28. Roi Et/ Korat association Series: (Re/Kt)

Roi Et series which occurs at low terrace associated occurs with Korat series which occurs at middle terrace.

29. Roi Et/ Renu association Series: (Re/Rn)

Roi Et series which occurs at low terrace associated occurs with Renu series which occurs at middle terrace.

30. Tha Uthen/ Korat association Series: (Tu/Kt)

Tha Uthen series which occurs at low terrace associated occurs with Korat series which occurs at middle terrace.

31. Satuk Series: (Suk)

It occurs in old alluvium. Physiography is middle and high terrace, 2-8% of slope, deep soil, well drained, moderate permeability, rapid run off. Ground water level falls below 4.0 m during dry season. Dark grayish brown to dark brown sandy loam, loam sand or sandy clay loam, strongly to slightly acid (pH 5.5-6.5) is found in upper soil (< 40 centimeter). Brown, yellowish brown or reddish brown sandy clay loam, clay loam or sandy clay, extremely to strongly acid (pH 4.5.-5.5) is found in lower soil.

32. Warin Series: (Wn)

It occurs in old alluvium. Physiography is middle and high terrace, 2-5% of slope, deep soil, well drained, moderate permeability, moderate to rapid run off. Ground water level falls below 5.0 m during dry season. Dark brown, brown or dark grayish brown sandy loam or loam sand, very strongly to slightly acid (pH 5.0-6.5) is found in upper soil. Yellowish red or reddish yellow sandy loam, extremely to strongly acid (pH 4.5.-5.5) is found in lower soil.

33. Yasothon Series: (Yt)

It occurs in old alluvium. Physiography is high terrace, 2-5% of slope, deep soil, well drained, rapid permeability and run off. Ground water level falls below 5.0 m during dry season. Dark brown, deep reddish brown, yellowish red to red sandy loam, loam sand, sandy clay loam, strongly acid to neutral (pH 5.5-7.0) is found in

upper soil. Red to deep red sandy clay loam or sandy clay, extremely to strongly acid (pH 4.5.-5.5) is found in lower soil.

34. Roi Et/ Satuk association Series: (Re/Suk)

Roi Et series which occurs at low terrace associated occurs with Satuk series which occurs at high terrace.

35. Roi Et, clayey variant and high phase/ Satuk association Series: (Re-c-h/Suk)

Roi Et, clayey variant and high phase series which occurs at low terrace associated occurs with Satuk series which occurs at high terrace.

36. Korat/ Satuk association Series: (Kt/Suk)

Korat series which occurs at middle terrace associated occurs with Satuk series which occurs at high terrace.

37. Buri Ram Series: (Br)

It occurs from basalt rock. Physiography is lower parts of lava flow, 1-2% of slope, deep soil, somewhat well drained, very slow permeability and run off. Ground water level falls below 1.0 m during dry season. Black or dark gray clay, medium acid to neutral (pH 6.0-7.0) is found in upper soil. Dark gray or dark grayish brown clay,

neutral to moderately alkaline (pH 7.0-8.0) is found in lower soil. In dry season, slickensides and pressure face are found on surface and in lower soil, respectively.

38. Surin Series: (Su)

It occurs from residium and local colluvium from basalt. Physiography is dissected lava flow or erosion surface, 2-8% of slope, moderate deep soil, well drained, moderate permeability, moderate to rapid run off. Ground water level falls below 3.0 m during dry season. Dark brown or deep reddish and yellowish brown loam, clayey and basalt to coat with pseudo laterite gravelly loam or basalt to coat with pseudo laterite gravelly clay, very strongly acid to neutral (pH 5.0-7.0) is found in upper soil. Lower soil is decomposed rock, at 60 to 100 centimeters may be found bedrock.

39. Chok Chai Series: (Ci)

It occurs from basalt. Physiography is dissected lava flow, 2-5% of slope, deep soil, well drained, moderate permeability, moderate to rapid run off. Ground water level falls below 5.0 m during dry season. Red silty clay or clay, medium acid to neutral (pH 6.0-7.0) is found in upper soil. Red clay, extremely to strongly (pH 4.5-5.5) is found in lower soil. Bed rock can be found below 2.0 m from ground surface.

40. Slope Complex: (SC)

This soil series is found in area that slope is more than 35%. Physiography is mountains that composed of sandstone, siltstone, shale, micaceous shale, micaceous siltstone, basalt and its equivalent.

41. Stony land, basalt outcrops: (S-ba)

Physiography is stone land and basalt outcrops.

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