5.2 Household Income

A Socio-Economic Survey for the whole Kingdom was conducted in 1981 by the National Statistical Office. According to the survey results shown in Table 6-19, the average annual household income was indicated at 40,536 baht for the whole Kingdom for the said year. Among households by region, those in the Bangkok Metropolitan Area had the highest average annual income of 71,664 baht per household, and was followed by the Central Region, the Southern Region and the Northern Region, which amounted to 43,980 baht, 39,072 baht and 34,632 baht, respectively. The lowest income was 30,144 baht in the Northeastern Region, which corresponded to 42% of that in the Bangkok Metropolitan Area.

The household income of Thailand in 1981 increased by 68.4% compared with that in 1975/1976. Among regions, households in the Northern Region showed the highest increase rate of income (87.9%) compared with the 1975/76 data, and was followed by the Southern Region (82.1%), the Bangkok Metropolitan Area (73.5%), the Northeastern Region (67.9%) and the Central Region (62.9%).

6. Infrastructures

6.1 Transportation

6.1.1 Highway

Inland transport in Thailand depends mainly on the highway transport. Share in the transport volume in 1985 accounted for approximately 85% on the highway, 13% on the railway, 1% on the waterway and 1% on the airway.

Highways and roads in Thailand are classified into seven (7) categories, namely, special highway, national highway, provincial highway, concessioned highway, rural road, municipal road and sanitary road. Highways of the first four types are administered by the Department of Highways.

Concerning the other categories, the respective changwat administrative organizations are administratively responsible.

Table 6-20 shows statistically the length of national highways (including special highways) and provincial highways. The total length increased from 14,175 km in 1981 to 15,132 km in 1985 for the national highways, and for the provincial highways from 15,841 km in 1981 to 21,017 km in 1985, at the increase rate of 1.6% and 7.3% per annum, respectively. Between them, it is noticed that the provincial highways grew remarkably in length during the said period. The highway network in the Study Area in 1985 amounted to about 20,000 km in the total length of national and provincial highways, which accounted for more than a half in length of the whole country's highway network.

The percentage of paved highways in 1985 achieved 99% on national highways and 76% on provincial highways. In general, the highway traffic in Thailand is in a favorable condition except traffic congestion in and around Bangkok City.

The number of vehicles registered at the Police Department in Thailand rose from 600 thousand vehicles in 1980 to 1.15 million vehicles in 1984 at the average growth rate of 17.7% per annum. Besides, there are buses registered at the Department of Land Transport which was estimated at 60 thousand vehicles in 1981 and 200 thousand vehicles in 1984. Accordingly, the number of vehicles registered in 1984 indicated 1.35 million (refer to Table 6-21).

In the Study Area, Bangkok City had about 640 thousand vehicles registered in 1984, excluding motorcycles and buses registered at the Department of Land Transport. This number corresponded to 55% of the total number of vehicles registered in the whole country. On the other hand, the number of vehicles registered in the Study Area, except the motorcycles and buses mentioned above, amounted to about 820 thousand in 1984 including those in Bangkok City. This figure

corresponded to about 70% of the total number of registered vehicles in the country.

6.1.2 Railway

Railways of Thailand was inaugurated in 1892 under the direct management of the Government. However, it afterward became an autonomous organization in accordance with the State Railway Act of 1951. For all the earlier lines, the railway tracks used the standard gauge system (1,435 mm). From the year 1900 onward, the Railway of Thailand has brought into use the meter gauge system (1,000 mm) and the conversion to meter gauge system was completed in April 1930.

The State Railway of Thailand extends from the Bangkok Station to Chiang Mai City in the Northern Region through major cities in the Study Area, to the Laos boundary through Nong Khai City in the Northeastern Region, to Ubon Ratchathani City in the East Region, to Kanchanaburi City in the Western Region, and the southern line connects with the Malaysian Railway at Padang Besar and Sungai Kolok in the Southern Region. The total length of lines is 3,735 km consisting of the single track of 3,645 km and the double track of 90 km.

The number of passengers transported by railway rose from 74.3 million people in 1980 to 81.5 million people in 1984 at the average growth rate of 9.7% per annum. However, the growth since 1982 has declined gradually, and the freight transport also showed a downward trend during the 1980-1984 period, i.e., 6.23 million tons in 1980 and 5.57 million tons in 1984 (refer to Table 6-22).

The operating revenue and expenditures of the State Railway of Thailand at the current price were 2,227 million baht and 2,585 million baht in 1984, respectively. The expenditures exceeded the revenue every year during the 1980-1984 period, and the number of staff was also declining.

6.1.3 Port

Thailand has the Bangkok Port and three other trading ports; Sattahip, Songkhla and Phuket, which are administered by the Port Authority of Thailand (PAT). Bangkok Port located on the downstream of the Chao Phraya River is the most important trading port and has accounted for over 90% of cargoes handled at all ports in Thailand. Water depth in the port is about 8.5 m under the mean sea level and it is possible to enter a vessel with 8.2 m draft, 12,000 DWT and 170 m long in the Port.

Table 6-23 shows the quantity of cargoes handled at the Bangkok Port, together with number of vessels entered. The quantity of goods loaded at the Bangkok Port reached 1,975 million tons in 1984, corresponding to about twice the 1,017 million tons in 1980. On the other hand, the quantity of goods unloaded was 4,151 million tons in 1984, or 1.15 times the 3,586 million tons in 1980. During the 1980-1984 period, the average annual growth rate of the quantity of cargoes handled showed 18.05% for the loaded goods and 3.73% for the unloaded goods. In recent years, the quantity of goods loaded rose remarkably, supported by the increase in the export of light industrial goods, etc. However, the unloaded goods still exceeded the loaded goods in quantity during the said period as shown in Table 6-23.

6.2 Telecommunications

The telecommunication business of Thailand is at present operated by two agencies; namely, the Telephone Organization of Thailand (TOT) and the Communications Authority of Thailand (CAT), under the control of the Posts and Telegraph Department (PTD). TOT provides all of the domestic telephone services and CAT conducts communication services such as telegram, telex, postal and international telephone services.

The number of telephone line capacity rose from 423,000 in 1980 to 571,000 in 1984 at an average rate of 7.8% per annum,

and the number of subscribers increased from 366,000 in 1980 to 519,000 in 1984 at a high average rate of 9.2% per annum. In 1984, about 70% of subscribers in the whole Kingdom was in the Bangkok Metropolitan Telecommunication Area (BMTA) at the ratio of one (1) set to 18 persons, and the remaining 30% was in other provinces at the ratio of one (1) set to 278 persons. Accordingly, the average ratio of subscribers in Thailand showed an extremely low figure, or one (1) set to 97 persons.

However, since 1980 the subscribers have made a remarkable increase as mentioned above, and especially the increase rate in provincial areas indicated 13.1% per annum on average during the said period (refer to Table 6-24). To meet the increased demand of people for telephone services, TOT formulated a large expansion project on the telephone line capacity in the Fifth Development Plan of TOT (1984-1991). According to this expansion project, it is expected that the subscriber ratio will come to one (1) set to 37 persons at the end of 1991 in the whole Kingdom.

6.3 Water Supply

The Government of Thailand has conducted waterworks dividing into municipal and rural areas. Waterworks in municipal areas are implemented by the Metropolitan Waterworks Authority (MWA), the Provincial Waterworks Authority (PWA) and the Department of Public Works (DPW). In rural areas, DPW executes waterworks in cooperation with other governmental agencies through underground water from wells.

MWA, which was established in 1967, has conducted the water supply activities in the four municipalities of Bangkok, Thonburi, Nonthaburi and Samut Prakan in the Bangkok Metropolitan Area. At present, the three treatment plants of Bangkhen, Samsen and Thonburi process surface water from the Chao Phraya River and its tributaries. Water supplied from these plants and some deepwells amounted to 820 million cubic meters (MCM) in 1986, or an increase of 200 MCM (or 32%) from

the 620 MCM in 1981. The quantity of underground water pumped out of the deep wells was only 70 MCM in 1986, decreasing year by year. Accompanied by an increase in water quantity produced, the served population increased from 3.52 million in 1981 to 4.71 million in 1986, spreading over the served area of 475 km2 (refer to Table 6-25). According to the future plan of MWA, in the year 2000 it is expected that water production will amount to about 1,400 MCM per annum for the served population of 7.8 million at the served ratio of more than 95%.

PWA, since its establishment in 1979, has carried out the waterworks in municipal areas (except areas served by MWA) having a population of 5,000 or more. At present, PWA has 183 waterworks under 10 regional offices. The quantity of water produced by PWA in 1985 amounted to 260 MCM for the served population of 2 million. In the Study Area except the Bangkok Metropolitan Area, the produced water quantity came to about 100 MCM for the served population of 0.8 million in the same year. According to the development plan of PWA, it is expected that water production will amount to about 300 MCM in 1991 for the served population of 2.2 million.

DPW has conducted water supply activities in cooperation with other governmental agencies for the small municipalities and the rural areas in the country. The waterworks of DPW are mainly to supply the underground water by using the small-scale facilities without the full-scale water supply system.

Despite the expansion in recent years of waterworks by MWA, PWA, DPW and other agencies concerned, the presently served population in the whole country is below 20 million, or the served ratio is less than 50%. Therefore, the spread of water supply system is a matter of vital importance for the Thai people, especially in the rural area.

6.4 Electric Power Supply

The electric power supply business in Thailand is mainly operated by three agencies, namely, the Electricity Generating Authority of Thailand (EGAT), the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA). EGAT, which was established in 1969, has conducted construction, operation and maintenance of the power plants and the transmission works from the plants to the first transformer stations to supply electricity to MEA, PEA and some large-scale factories. In 1985, share in the supply to these three sectors indicated 51%, 44% and 5%, respectively. Although MEA and PEA own some power plants, most of the electricity served by them for users are supplied from EGAT. The MEA service area is the Bangkok Metropolitan Administration (BMA) and the two provinces of Nonthaburi and Samut Prakan; other areas are served by PEA.

The total generation capacity in Thailand increased from 3,800 kW in 1980 to 6,200 kW in 1984 at an average growth rate of 13% per annum. Share of the capacity by generation origin in 1984 showed 27% for hydroelectric plants, 59% for steam plants, and 14% for other plants (refer to Table 6-26). The actual power generation made about 22,000 x 10^6 kWh in 1984 against about 15,000 kWh in 1980. During the 1980-1984 period, the growth rate of generation was 10% per annum on average.

Consumption of electric power in the whole country, except a distribution loss, amounted to 18,500 kWh in 1984 against 13,000 kWh in 1980 at an average growth rate of 9% per annum. Among the consumption sectors, consumption for commercial use showed the highest growth rate of about 30% per annum on average during the 1980-1984 period. Share in each consumption sector in 1984 indicated 26% for both residential and commercial uses, and 47% for industrial use. In the MEA area, the consumption increased from 8,000 x 10^6 kWh in 1980 to 10,000 x 10^6 kWh in 1984 at the average annual growth rate of 6% which was somewhat low compared with that in the whole country.

TABLES

Table 6-1. MACROECONOMIC TARGETS OF THE SIXTH PLAN COMPARED WITH RESULTS OF THE FOURTH AND FIFTH PLANS

Item	Fourth Plan (1977-1981) (Actual)	Fifth Plan (1982-1986) (Actual)	Sixth Plan (1987-1991) (Targets)
1. Real Economic Growth (%) (Average Rate Per Annum)			
1.1 GDP	7.1	4.4	5.0
1.2 Agriculture	3.5	2.1	2.9
1.3 Manufacturing	8.7	5.1	6.6
1.4 Mining	10.1	6.1	6.4
1.5 Electricity	11.7	8.0	6.1
1.6 Construction	9.5	3.6	5.1
1.7 Services	8.2	5.6	5.3
2. Real Expenditure Growth (%) (Average Rate Per Annum)			
2.1 Consumption			
- Private Sector	5.5	4.3	3.7
- Public Sector	10.2	3.3	5.3
2.2 Investment			
- Private Sector	8.6	-0.8	8.1
- Public Sector	12.9	1.8	1.0
3. Export & Import of Goods			
3.1 Real Growth Rate Per Annum (%)			
- Export	20.0	8.4	10.7
- Import	24.8	2.9	9.5
3.2 Average Value Per Annum (Current Prices)			
- Export (Million Baht)	-	177,500	290,700
- Import (Million Baht)	-	233,100	326,700
3.3 Trade Deficit (Million Baht)	45,000	55,600	36,000
4. Current Account Deficit (Average Value Per Annum)	37,400	36,000	11,800
5. Government Finance/GDP (%)			
5.1 Revenue	14.2	14.6	15.2
5.2 Expenditure	17.5	18.2	17.3
5.3 Financial Deficit	3.3	3.6	2.1
6. Population Growth Rate Per Annum (%)			
6.1 Whole Country	-	1.7 /1	1.3 /2
6.2 Bangkok Metropolitan Area	-	2.7 /1	2.5 /2
6.3 Other Areas	-	1.4 /1	0.8 /2
7. Consumer Price Escalation Per Annum (%)	10.6	2.9	2.3
8. Per Capita Income (Baht)	-	21,395 /1	27,783 /2

Note: /1 In 1986.
/2 In 1991.

Source: Summary of the Sixth National Economic and Social Development Plan (1981-1991), NESDB.

Table 6-2. ADMINISTRATIVE DIVISIONS IN THE STUDY AREA

Province	Area (km^2)	Number of Subdivisions			
		Amphoe/2	Tambon	Village	Municipality
Whole Kingdom	513,115	733	6,430	57,415	124
Study Area	194,479	270	2,461	19,552	48
Central Region	20,308	91	857	6,298	17
1. Bangkok	1,565	24	150	727	-
2. Chai Nat	2,470	6	49	417	2
3. Nonthaburi	622	6	50	394	2
4. Pathum Thani	1,526	7	58	512	1
5. Ayutthaya	2,557	16	208	1,457	3
6. Lop Buri	6,200	8	117	1,010	3
7. Saraburi	3,577	11	109	935	3
8. Sing Buri	823	6	43	349	1
9. Ang Thong	968	7	73	497	2
Eastern Region	1,004	5	44	467	2
10. Samut Prakan	1,004	5	44	467	2
Western Region	27,881	29	328	2,479	6
11. Kanchanaburi /1	19,483	10	85	632	1
12. Nakhon Pathom	2,168	6	100	802	1
13. Samut Sakhon	872	3	40	283	2
14. Suphan Buri	5,358	10	103	762	2
Northern Region	145,286	145	1,214	10,308	23
15. Kamphaeng Phet	8,608	7	61	642	1
16. Chiang Mai /1	20,107	20	184	1,491	1
17. Tak /1	16,407	8	52	418	2
18. Nakhon Sawan	9,598	12	117	1,075	3
19. Nan	11,472	11	86	681	1
20. Phayao /1	6,335	7	54	594	1
21. Phichit	4,531	8	82	629	3
22. Phitsanulok	10,816	9	84	785	1
23. Phetchabun	12,668	11	91	967	2
24. Phrae	6,539	7	64	445	1
25. Lampang	12,534	13	87	643	1
26. Lamphun	4,506	6	48	412	1
27. Sukhothai	6,596	9	80	612	2
28. Uttaradit	7,839	9	62	440	2
29. Uthai Thani /1	6,730	8	62	474	1

Note: /1 The watershed boundary line of Chao Phraya River passes through this province.
/2 Includes king amphoes.

Source: Statistical Yearbook 1985-1986, National Statistical Office

Table 6-3. GROSS DOMESTIC PRODUCT AND GROSS NATIONAL PRODUCT AT CURRENT MARKET PRICES (1981-1985)

Unit: Million Baht

Industrial Origin	1981	1982	1983	1984	1985
Agriculture	187,886	188,742	204,443	193,438	182,279
Mining and Quarrying	13,373	14,807	16,480	21,291	29,279
Manufacturing	158,272	164,659	176,200	196,793	207,691
Construction	42,008	43,040	47,129	52,772	53,758
Electricity and Water Supply	10,743	14,454	16,319	18,884	21,645
Transportation and Communications	57,281	63,133	73,708	83,588	96,254
Wholesale and Retail Trade	150,293	159,849	165,812	181,993	190,676
Banking, Insurance and Real Estate	52,025	61,021	71,722	80,577	89,751
Ownership of Dwellings	8,441	9,912	11,210	12,337	13,706
Public Administration and Defence	30,645	37,349	42,551	43,182	47,058
Services	75,229	89,170	98,680	106,704	115,467
Gross Domestic Product (GDP)	786,166	846,136	924,254	991,559	1,047,564
Net Factor Income	-21,787	-26,376	-25,370	-31,776	-37,081
Gross National Product (GNP)	764,379	819,760	898,884	959,783	1,010,483
Per Capita GNP (Baht)	16,096	16,906	18,174	19,044	19,697

Source: Statistical Yearbook 1985-1986, National Statistical Office

Table 6-4. CONTRIBUTION OF INDUSTRIAL SECTOR TO GDP (1981-1985)

Unit: Percent

Industrial Origin	1981	1982	1983	1984	1985
Agriculture	23.90	22.31	22.12	19.51	17.41
Mining & Quarring	1.70	1.75	1.78	2.15	2.80
Manufacturing	20.13	19.46	19.06	19.85	19.80
Construction	5.34	5.09	5.10	5.32	5.13
Electricity & Water Supply	1.37	1.71	1.77	1.90	2.07
Transportation & Communications	7.28	7.46	7.98	8.43	9.19
Wholesale & Retail Trade	19.12	18.89	17.94	18.35	18.21
Banking, Insurance & Real Estate	6.62	7.21	7.76	8.13	8.57
Ownership of Dwellings	1.07	1.17	1.21	1.24	1.31
Public Administration & Defence	3.90	4.41	4.60	4.36	4.49
Services	9.57	10.54	10.68	10.76	11.02
GDP	100.00	100.00	100.00	100.00	100.00

Source: Statistical Yearbook 1985-1986, National Statistical Office

Table 6-5. GDP, GNP AND PER CAPITA GNP AT THE 1972 CONSTANT PRICE (1981-1985)

Unit: Million Baht

Item	Year					Average Annual Growth Rate 1981-1985 (%)
	1981	1982	1983	1984	1985	
GDP	311,270	324,032	342,946	364,206	378,756	5.02
GNP	298,284	309,122	328,866	346,834	361,154	4.89
Per Capita GNP (Baht)	6,281	6,375	6,649	6,882	7,038	2.89

Source: Statistical Yearbook 1985-1986, National Statistical Office

Table 6-6. ANNUAL REAL GROWTH RATES OF GDP, GNP AND PER CAPITA GNP (1981-1985)

Unit: Percent

Item		1981	1982	1983	1984	Annual Average 1981-1985
GDP	-	4.10	5.84	6.20	3.99	5.02
GNP	-	3.63	6.39	5.46	4.10	4.89
Per Capita GNP	-	1.48	4.30	3.50	2.27	2.89

Source: Statistical Yearbook 1985-1986, National Statistical Office

Table 6-7. GROSS REGIONAL PRODUCT (GRP) AT CURRENT MARKET PRICES AND AVERAGE ANNUAL GROWTH RATE OF GRP BY REGION (1981-1985)

Region	Gross Regional Product (Million Baht)					Average Annual Growth Rate (%)	
	1981	1982	1983	1984	1985	Nominal	Real
Whole Kingdom	786,166	846,136	924,254	991,559	1,047,564	7.44	5.02
BMA /1	334,242	364,661	396,656	440,098	474,506	9.16	5.38
Central	33,706	35,316	37,053	41,158	43,464	6.56	4.23
Northern	105,980	110,491	122,255	128,189	135,898	6.41	4.87
Northeastern	110,341	122,799	141,136	141,919	146,435	7.33	5.64
Eastern	63,577	69,062	73,148	78,505	81,189	6.30	4.99
Western	57,070	60,997	58,743	63,112	63,711	2.80	4.05
Southern	81,250	82,810	95,263	98,578	102,089	5.87	3.76

Note: /1 BMA stands for Bangkok Metropolitan Area, which consists of Bangkok City and the five provinces of Samut Prakan, Samut Sakhon, Nakhon Pathom, Nonthaburi and Pathum Thani.

Source: Gross Regional and Provincial Product, 1985, National Statistical Office

Table 6-8. PER CAPITA GRP AT CURRENT MARKET PRICES AND AVERAGE ANNUAL GROWTH RATE OF PER CAPITA GRP BY REGION (1981-1985)

Region	Per Capita GRP (Million Baht)					Average Annual Growth Rate (%)	
	1981	1982	1983	1984	1985	Nominal	Real
Whole Kingdom	16,469	17,359	18,584	19,551	20,263	5.32	2.96
BMA /1	46,891	49,539	52,150	56,092	59,803	6.27	2.25
Central	13,327	13,903	14,570	16,146	16,749	5.88	3.56
Northern	11,064	11,355	12,375	12,781	13,353	4.81	3.30
Northeastern	6,581	7,185	8,107	8,009	8,124	5.41	3.74
Eastern	21,968	23,284	24,039	25,210	25,603	3.90	2.62
Western	20,230	21,157	20,055	21,228	21,047	0.99	2.24
Southern	13,496	13,419	15,058	15,200	15,358	3.28	1.22

Note: /1 BMA stands for Bangkok Metropolitan Area, which consists of Bangkok City and the five provinces of Samut Prakan, Samut Sakhon, Nakhon Pathom, Nonthaburi and Pathum Thani.

Source: Gross Regional and Provincial Product, 1985, National Statistical Office

Table 6-9. GROSS PROVINCIAL PRODUCT (GPP) AT CURRENT PRICES AND AVERAGE ANNUAL GROWTH RATE OF GRP BY PROVINCE IN THE STUDY AREA (1981-1985)

Province (Changwat)	Gross Provincial Product (Million Baht)					Average Annual Growth Rate (%)	
	1981	1982	1983	1984	1985	Nominal	Real
1. Bangkok /1	273,096	296,694	322,296	359,734	389,056	9.25	5.24
2. Nonthaburi /1	6,208	6,508	7,290	7,827	8,393	7.83	4.65
3. Pathum Thani /1	9,469	12,758	14,103	16,369	17,450	16.51	13.14
4. Ayutthaya	6,026	6,916	7,026	7,752	8,200	8.01	4.94
5. Ang Thong	3,272	3,247	3,566	3,819	3,933	4.71	3.65
6. Saraburi	8,916	9,246	10,017	11,668	12,876	9.62	4.83
7. Lop Buri	7,799	7,865	43,568	9,278	9,745	5.73	3.89
8. Sing Buri	2,772	3,228	3,139	3,425	3,506	6.05	5.53
9. Chai Nat	4,920	4,814	4,738	8,215	5,204	1.41	2.20
Sub-Total	322,478	351,276	380,743	425,087	458,363	9.19	5.41
10. Samut Prakan /1	28,938	31,117	34,707	37,008	39,896	8.36	4.67
11. Samut Sakhon /1	6,279	6,220	7,007	7,342	7,605	4.91	2.75
12. Nakhon Pathom	10,251	11,363	11,252	11,818	12,106	4.25	4.49
13. Suphan Buri	11,161	10,799	10,344	11,412	11,364	0.45	2.68
14. Kanchanaburi	16,611	17,642	14,730	16,102	15,930	-1.04	2.57
Sub-Total	44,302	46,024	43,333	46,674	47,005	1.49	3.12
15. Nakhon Sawan	11,025	11,583	12,352	12,985	13,367	4.93	4.34
16. Uthai Thani	3,351	3,486	3,923	4,148	4,159	5.55	6.52
17. Phetchabun	8,067	7,494	8,795	9,266	9,570	4.36	4.40
18. Kamphaeng Phet	6,605	7,358	8,816	10,627	12,008	16.12	9.02
19. Phichit	5,816	5,666	5,948	6,152	6,195	1.59	1.91
20. Phitsanulok	6,920	7,616	8,358	8,431	8,715	5.94	4.96
21. Sukhothai	5,764	6,232	7,033	7,472	7,721	7.58	7.89
22. Uttaradit	4,951	5,231	5,188	5,506	5,580	3.04	3.54
23. Tak	3,469	3,744	3,587	4,085	4,650	7.60	8.77
24. Lampang	8,650	8,160	8,874	9,727	11,607	7.63	2.75
25. Phrae	4,412	4,280	4,396	4,666	4,830	2.29	1.33
26. Nan	3,372	3,420	4,108	4,299	4,439	7.11	6.46
27. Phayao	3,739	3,813	4,009	4,132	4,215	3.04	3.54
28. Lamphun	3,565	3,834	4,371	4,123	4,408	5.45	2.13
29. Chiang Mai	16,160	17,657	19,810	19,927	21,224	7.05	4.69
Sub-Total	95,868	99,572	109,566	115,546	122,688	6.36	4.75
Study Area	491,583	527,989	568,349	624,315	667,952	7.97	5.05

Note: /1 Belongs to Bangkok Metropolitan Area.
Source: Gross Regional and Provincial Product, 1985, National Statistical Office

Table 6-10. PER CAPITA GPP AT CURRENT MARKET PRICES AND AVERAGE ANNUAL GROWTH RATE OF PER CAPITA GPP BY PROVINCES IN THE STUDY AREA (1981-1985)

Province (Changwat)	Per Capita GPP (Baht)					Average Annual Growth Rate (%)	
	1981	1982	1983	1984	1985	Nominal	Real
1. Bangkok /1	54,207	57,012	60,073	65,133	68,532	6.04	2.15
2. Nonthaburi /1	15,797	15,874	16,796	16,941	17,857	3.11	0.07
3. Pathum Thani /1	29,046	38,197	40,879	45,723	47,809	13.27	9.98
4. Ayutthaya	9,703	11,101	11,277	12,383	12,872	7.32	4.28
5. Ang Thong	12,883	12,732	13,821	14,576	14,731	3.41	2.37
6. Saraburi	19,051	19,588	21,087	24,826	26,881	8.99	4.23
7. Lop Buri	11,907	11,953	13,060	14,078	14,544	5.13	3.30
8. Sing Buri	13,724	15,900	15,389	16,706	16,773	5.14	4.63
9. Chai Nat	14,953	14,693	14,489	15,945	15,628	1.11	1.89
10. Samut Prakan /1	53,292	54,976	58,136	59,308	62,827	4.20	0.65
11. Samut Sakhon /1	23,603	22,896	24,672	24,887	25,351	1.80	-0.29
12. Nakhon Pathom	18,240	19,762	19,367	20,235	20,345	2.77	3.00
13. Suphan Buri	15,764	15,019	14,170	15,441	15,111	-1.05	1.14
14. Kanchanaburi	31,460	31,447	25,265	27,155	26,373	-4.31	-0.82
15. Nakhon Sawan	11,308	11,700	12,414	12,933	13,117	3.78	3.19
16. Uthai Thani	12,839	13,009	14,424	15,137	14,961	3.90	4.75
17. Phetchabun	10,263	9,355	10,457	10,589	10,777	1.23	1.27
18. Kamphaeng Phet	11,752	12,752	14,817	17,366	19,304	13.21	6.29
19. Phichit	10,952	10,689	11,160	11,330	11,243	0.66	0.97
20. Phitsanulok	9,802	10,726	11,755	11,858	12,087	5.38	4.41
21. Sukhothai	10,854	11,561	12,904	13,610	13,861	6.30	6.61
22. Uttaradit	11,461	11,970	12,036	12,893	12,887	2.98	3.47
23. Tak	12,431	13,091	12,116	13,437	15,095	4.97	6.13
24. Lampang	13,165	12,270	12,955	13,700	16,121	5.19	0.42
25. Phrae	9,913	9,467	9,620	10,120	10,320	1.01	0.07
26. Nan	8,897	8,860	10,534	10,828	11,015	5.48	4.83
27. Phayao	8,110	8,147	8,622	8,924	8,968	2.55	3.04
28. Lamphun	10,127	10,621	11,750	10,821	11,390	2.98	-0.26
29. Chiang Mai	13,871	14,875	16,386	16,293	17,088	5.35	3.03
Study Area	24,460	25,850	28,090	30,163	31,570	4.51	2.83

Note: /1 Belongs to Bangkok Metropolitan Area.
Source: Gross Regional and Provincial Product, 1985, National Statistical Office

Table 6-11. EXPORTS AND IMPORTS BY COMMODITY GROUP (1983-1985)

Unit: Million Baht

Commodity	Exports (1)			Imports (2)			Balance [(1)-(2)]		
	1983	1984	1985	1983	1984	1985	1983	1984	1985
1. Foods	73,755	86,482	86,582	6,501	7,511	9,441	67,254	78,971	77,141
2. Beverage & Tabacco	1,860	1,698	1,648	1,268	1,681	2,254	592	17	-606
3. Crude Materials	16,288	18,875	19,611	14,376	15,418	15,791	1,912	3,457	3,820
4. Mineral Fuel & Lubricant	30	411	2,448	57,065	57,353	56,718	-57,035	-56,942	-54,270
5. Animal & Vegetable Oils	270	432	583	781	1,130	493	-511	-698	90
6. Chemicals	1,673	2,187	2,440	31,805	31,681	35,167	-30,132	-29,494	-32,727
7. Manufactured Goods	26,002	29,187	35,860	39,034	38,913	42,835	-13,032	9,726	-6,975
8. Machinery	8,356	11,959	16,977	68,361	71,988	70,549	-60,005	-60,029	-53,572
9. Miscellaneous Manufactured Goods	14,756	19,558	24,030	14,039	15,525	14,043	717	4,033	9,987
10. Miscellaneous Transactions & Commodities	1,332	1,286	1,433	3,344	3,923	3,837	-2,012	-2,637	-2,404
11. Re-Exports	2,150	3,162	1,754	-	-	-	2,150	3,162	1,754
12. Gold	-	-	-	35	32	41	-35	-32	-41
Total	146,472	175,237	193,366	236,609	245,155	251,169	-90,137	-69,918	-57,803

Source: Statistical Handbook of Thailand 1985, National Statistical Office.

Table 6-12. QUANTITY AND AMOUNT OF EXPORTS OF PRINCIPAL COMMODITIES (1981-1984)

Commodity	Quantity (Thousand Tons)				Amount (Million Baht)							
	1981	1982	1983	1984	1981	(%)	1982	(%)	1983	(%)	1984	(%)
Rice	3,032	3,784	3,476	4,616	26,366	17.7	22,510	14.4	20,157	14.0	25,932	15.1
Rubber	427	544	555	592	10,841	7.3	9,490	6.1	11,787	8.2	13,004	7.6
Maize	2,547	2,801	2,630	3,116	8,236	5.5	8,231	5.3	8,387	5.8	10,050	5.8
Cassava	6,266	7,815	5,197	6,570	16,446	11.1	19,752	12.7	15,387	10.7	16,500	9.7
Sugar	1,119	2,206	1,537	1,242	9,572	6.4	12,932	8.3	6,338	4.4	5,221	3.0
Prawns	22	28	26	23	2,369	1.6	3,178	2.0	3,612	2.5	3,350	1.9
Tin	30	25	18	18	9,091	6.1	7,773	5.0	5,265	3.6	5,280	3.1
Others	-	-	-	-	65,041	44.3	72,173	46.2	73,389	50.8	92,638	53.8
Total /1	-	-	-	-	148,962	100.0	156,039	100.0	144,322	100.0	172,075	100.0

Note: /1 Excluding re-exports.
Source: Key Statistics of Thailand 1986, National Statistical Office

Table 6-13. BALANCE OF INTERNATIONAL PAYMENTS

Unit: Million Baht

Account	1982	1983	1984	1985	1986
Trade Balance	-36,137	-89,237	-68,796	-61,672	-16,526
Exports	157,203	145,076	173,520	191,703	229,324
Imports	-193,320	-234,278	-242,284	-253,334	-245,690
Non-Monetary Gold	-20	-35	-32	-41	-160
Service Account	8,795	16,575	15,200	15,253	16,604
Transfer Account	4,204	6,376	4,128	4,494	5,765
Current Account	-23,138	-66,286	-49,468	-41,925	5,843
Capital Account	38,345	34,681	58,365	51,433	10,772
Errors & Omissions	-11,893	13,527	1,691	2,956	16,964
Balance of Payments	3,314	-18,078	10,588	12,464	33,579

Source: Bank of Thailand

Table 6-14. REVENUE AND EXPENDITURES OF THE GOVERNMENT (1966-1985)

Unit: Million Baht

Fiscal Year	Actual Revenue (1)	Actual Expenditure (2)	Difference (1) - (2)
1966	12,711,589	14,598,923	-1,887,334
1967	14,874,145	18,460,070	-3,585,925
1968	16,649,572	20,388,541	-3,738,969
1969	18,581,160	22,904,343	-4,323,183
1970	19,102,069	26,454,150	-7,352,081
1971	19,552,664	27,710,140	-8,187,476
1972	21,296,469	28,114,558	-6,817,909
1973	25,646,335	31,316,757	-5,670,422
1974	38,207,455	37,995,772	211,683
1975	38,424,277	46,539,123	-8,114,846
1976	42,939,028	63,046,960	-20,107,932
1977	52,103,966	65,629,256	-13,525,290
1978	62,498,370	78,631,300	-16,132,930
1979	75,314,209	89,883,234	-14,569,025
1980	95,529,616	112,370,076	-19,840,460
1981	100,391,930	135,294,942	-24,903,012
1982	113,847,788	156,387,426	-42,539,638
1983	136,607,836	173,937,959	-37,330,123
1984	147,845,829	179,371,058	-31,525,229
1985	159,196,090	182,942,270	-23,746,180

Source: Statistical Yearbook of Thailand, 1985-1986, National Statistical Office.

Table 6-15. BREAKDOWN OF REVENUE AND EXPENDITURES OF THE GOVERNMENT (1981-1985)

Unit: Million Baht

Particulars	1981	1982	1983	1984	1985
Revenue	110,392	113,848	136,604	147,846	159,196
Taxes and Duties	95,496	100,261	118,613	130,015	138,525
Direct Taxes	21,580	24,436	26,705	31,454	34,157
General Sales Tax	21,661	22,697	25,429	30,434	30,711
Specific Sales Tax	26,508	30,343	32,434	34,557	40,161
Consumption Goods Tax	23,023	27,161	30,200	32,200	36,547
Natural Resource Tax	3,485	3,182	2,234	2,357	3,614
Import and Export Duties	24,964	21,545	27,805	32,819	31,826
Fees and Permits	782	1,239	6,175	750	1,669
Others	1	1	5	1	1
Sales of Goods and Services	2,920	3,496	4,066	4,222	4,602
State Enterprises	6,220	4,895	6,248	6,312	9,009
Miscellaneous	5,756	5,196	7,677	7,297	7,060
Expenditures	135,295	156,387	173,938	179,371	182,942
Economic Services	25,869	29,907	31,568	39,790	26,471
Education	28,228	33,525	36,244	37,559	35,926
Public Health and Utilities	20,040	15,744	18,194	20,228	21,089
Defence	27,319	30,955	34,246	35,297	31,166
Internal Security	7,293	8,172	9,130	9,735	9,704
General Administration	5,555	4,414	4,968	5,060	5,751
Debt Services Payment	16,858	20,469	27,088	33,385	44,394
Others	4,133	13,201	12,500	8,317	8,441

Source: Statistical Yearbook of Thailand, 1985-1986, National Statistical Office.

Table 6-16. POPULATION OF THAILAND BY REGION

Region	Population								Average Annual Growth Rate (%)		
	Census (Person)			Estimation (Thousand Persons)							
	1960	1970	1980	1981	1982	1983	1984	1985	1960-1970	1970-1980	1980-1985
Whole Kingdom	26,257,916	34,397,373	44,824,540	47,875	48,847	49,515	50,583	51,796	2.74	2.68	2.93
Bangkok	2,136,435	3,077,361	4,697,071	5,331	5,468	5,018	5,175	5,363	3.72	4.32	2.69
Central /1	2,101,492	2,465,932	3,089,408	3,293	3,337	3,393	3,431	3,553	1.61	2.28	2.84
Eastern	1,809,808	2,373,600	3,181,565	3,502	3,623	3,746	3,825	3,963	2.75	2.97	4.49
Western	2,223,567	2,694,984	3,475,299	3,706	3,818	3,866	3,933	4,023	1.94	2.57	2.97
Northeastern	8,991,543	12,025,140	15,698,878	16,393	16,720	17,219	17,638	18,061	2.95	2.70	2.84
Northern	5,723,106	7,488,683	9,074,103	9,714	9,834	10,106	10,281	10,391	2.73	1.94	2.75
Southern	3,271,965	4,271,674	5,628,216	5,935	6,046	6,166	6,300	6,441	2.70	2.80	2.74

Note: /1 Excluding Bangkok

Sources: . Statistical Yearbook, Thailand, 1985-1986, National Statistical Office.
. Statistical Handbook of Thailand 1985, National Statistical Office.
. 1980 Population and Housing Census, National Statistical Office.

Table 6-17. POPULATION AND HOUSEHOLDS BY PROVINCE IN THE STUDY AREA IN 1980 AND 1985

Province	1980			1985		Average Annual Growth Rate 1980-85 (%)
	Population	Number of Households	Person Per Household	Population	Population Density (persons/km^2)	
Whole Kingdom	44,824,540	8,419,238 /1	5.3	51,795,651	101	2.93
Study Area	18,254,195	3,643,563	5.0	21,158,260	109	3.00
1. Bangkok	4,697,071	906,591	5.2	5,363,378	3,427	2.69
2. Nonthaburi	369,777	67,455	5.5	504,424	811	6.41
3. Pathum Thani	319,674	60,011	5.3	384,713	252	3.77
4. Ayutthaya	602,021	120,570	5.0	652,977	255	1.64
5. Ang Thong	256,706	54,256	4.8	270,941	280	1.09
6. Saraburi	432,875	85,734	5.0	489,056	137	2.47
7. Lop Buri	571,713	117,819	4.8	695,992	112	4.01
8. Sing Buri	198,574	43,231	4.6	215,021	261	1.60
9. Chai Nat	318,068	66,717	4.8	339,478	137	1.31
Sub-Total	7,766,479	1,522,384	5.1	8,915,980	439	2.80
10. Samut Prakan	484,829	95,258	5.1	662,612	660	6.45
11. Samut Sakhon	247,168	43,592	5.7	315,373	362	4.99
12. Nakhon Pathom	525,906	94,229	5.6	609,316	281	2.99
13. Suphan Buri	709,432	140,284	5.1	779,703	146	1.91
14. Kanchanaburi	481,776	92,155	5.2	620,033	32	5.18
Sub-Total	1,964,282	370,260	5.3	2,324,425	83	3.42
15. Nakhon Sawan	942,068	190,081	5.0	1,042,936	109	2.06
16. Uthai Thani	225,632	47,093	4.8	283,074	42	4.64
17. Phetchabun	680,315	124,567	5.5	905,262	71	5.88
18. Kamphaeng Phet	507,532	99,284	5.1	621,243	72	4.13
19. Phichit	537,774	107,529	5.0	553,913	112	0.59
20. Phitsanulok	632,218	126,805	5.0	735,052	68	3.06
21. Sukhothai	500,140	102,628	4.9	566,915	86	2.54
22. Uttaradit	401,165	78,998	5.1	441,730	56	1.95
23. Tak	272,483	53,654	5.1	318,844	19	3.19
24. Lampang	649,006	137,802	4.7	737,145	59	2.58
25. Phrae	420,546	90,379	4.7	475,238	73	2.48
26. Nan	361,609	68,924	5.2	417,344	36	2.91
27. Phayao	418,228	86,524	4.8	480,420	76	2.81
28. Lamphun	335,039	75,713	4.4	398,292	88	3.52
29. Chiang Mai	1,154,850	265,680	4.3	1,277,835	64	2.04
Sub-Total	8,038,605	1,665,661	4.9	9,255,243	64	2.86

Note: /1 Excluding collective household.

Source: 1980 Population & Housing Census, National Statistical Office; and Statistical Yearbook 1985-1986, National Statistical Office.

Table 6-18. CONSUMER AND PRICE INDICES (1981-1985)

Region	1981	1982	1983	1984	1985	Average Annual Growth Rate 1980-1985 (%)
Consumer Price Index						
Whole Kingdom	172.1	181.1	187.9	189.5	194.1	3.05
Bangkok city	176.8	186.3	192.6	194.0	200.2	3.16
Central	167.2	175.2	181.6	183.0	186.2	2.73
Northeastern	169.1	178.2	188.2	188.4	189.9	2.94
Northern	162.8	171.5	181.0	181.8	184.1	3.12
Southern	164.4	173.0	178.4	182.9	185.3	3.04
Producer Price Index						
Whole Kingdom	169.5	171.0	174.5	169.1	169.0	-0.07
Central /1	161.6	148.8	152.9	151.6	148.3	-2.17
Northeastern	180.7	178.7	184.1	171.5	168.9	-1.70
Northern	174.0	159.9	168.7	164.3	154.5	-2.57
Southern	158.3	154.7	170.3	177.1	168.5	1.26

Note: /1 Including Bangkok City.
Source: Key Statistics of Thailand 1986, National Statistical Office.

Table 6-19. AVERAGE ANNUAL HOUSEHOLD INCOME, 1975/76 AND 1981

Region	Average Annual Household Income				Increase Rate 1975/76-1981
	1975-76		1981		
	Baht	%	Baht	%	
Whole Kingdom	24,071 /1	-	40,536	-	68.4 /1
Bangkok Metropolitan Area /2	41,303	100	71,664	100	73.5
Central	27,000	65	43,980	61	62.9
Southern	21,456	52	39,072	54	82.1
Northern	18,432	45	34,632	48	87.9
Northeastern	17,952	43	30,144	42	67.9

Note: /1 Estimation based on the Average Annual Household Expenditure in 1975/76.

/2 Bangkok Metropolitan Area covers Bangkok City and three provinces of Samut Prakan, Nonthaburi and Pathum Thani.

Source: Report of the 1981 Socio-Economic Survey, Whole Kingdom, National Statistical Office.

Table 6-20. LENGTH OF HIGHWAY NETWORK IN THAILAND

Unit: km

Category	1981	1982	1983	1984	1985		
					Total	Paved	Unpaved
National Highways	14,175	14,349	5,072	15,160	15,218	15,132	86
Primary	6,797	6,806	7,225	7,252	7,305	7,255	50
Secondary	7,378	7,543	7,847	7,908	7,913	7,877	36
Provincial Highways	15,841	16,653	18,076	19,542	21,017	16,124	4,893
Total	30,016	31,002	33,148	34,702	36,235	31,256	4,979

Source: Statistical Yearbook 1985-1986, National Statistical Office.

Table 6-21. NUMBER OF MOTOR VEHICLES REGISTERED IN THAILAND

Kind	1980	1981	1982	1983	1984
Passenger Cars	409,855	450,465	512,337	558,775	687,697
Buses /1	703	471	319	305	301
Trucks & Vans	140,082	293,326	352,793	374,921	394,872
Motor Tricycles	9,114	8,715	8,928	11,269	10,967
Tractors	33,591	37,616	38,149	40,963	42,760
Others /2	5,912	6,533	10,976	11,722	12,449
Sub-Total	599,257	797,126	923,502	997,955	1,149,046
Motorcycles	919,928	1,168,824	1,422,971	1,737,210	1,893,140
Total	1,519,185	1,965,950	2,346,473	2,735,165	3,042,186

Note: /1 Excluding buses registered at the Land Transport Department.

/2 Including rollers, trailers, international cars, diplomatic cars, buses of special type, etc.

Source: Statistical Yearbook 1985-1986, National Statistical Office.

Table 6-22. OPERATION OF THE STATE RAILWAY OF THAILAND

Particulars	Fiscal Year				
	1980	1981	1982	1983	1984
1. Route Distance Operated (km)	3,735	3,735	3,735	3,735	3,735
Single Track	3,645	3,645	3,645	3,645	3,645
Double Track	90	90	90	90	90
2. Equipment (Number)					
Locomotives	326	354	349	341	343
Passenger Cars	1,075	1,106	1,110	1,119	1,123
Freight Cars	9,121	9,080	9,034	9,170	9,207
3. Train Kilometers (1,000 km)	30,105	30,680	30,400	30,242	30,498
4. Passenger Transport					
Persons (1,000 persons)	74,286	78,824	80,306	81,404	81,498
Person.km (million person.km)	8,861	9,483	9,231	9,699	9,643
5. Freight Transport					
Freight (1,000 tons)	6,230	6,041	5,614	5,259	5,573
Ton.km (million tons.km)	2,844	2,639	2,447	2,436	2,730
6. Revenue (Million Baht)	2,227	2,577	3,058	3,141	3,308
7. Expenditure (Million Baht)	2,510	3,980	3,344	3,471	3,585
8. Deficit (Million Baht)	283	403	286	330	277
9. Number of Staff (persons)	-	30,094	30,541	-	-

Sources: Statistical Yearbook 1985-1986, National Statistical Office; and Economy of Thailand (Japanese), 1984-1985, 1986-87, Japanese Chamber of Commerce, Bangkok.

Table 6-23. QUANTITY OF CARGOES HANDLED AT THE PORT OF BANGKOK

Unit: 1,000 metric tons

Category	1980	1981	1982	1983	1984	Average Annual Growth Rate 1980-1984 (%)
Goods Loaded	1,017	1,231	1,438	1,580	1,580	18.05
Goods Unloaded	3,586	3,734	3,378	4,363	4,151	3.73
Total	4,603	4,965	4,816	5,943	6,126	7.41
No. of Vessels	1,698	1,717	1,737	1,827	1,763	0.94

Source: Economy of Thailand (in Japanese), 1986-87, Japanese Chamber of Commerce, Bangkok

Table 6-24. TELEPHONE STATISTICS (1980-1984)

Item	1980	1981	1982	1983	1984	Average Annual Growth Rate (%)
No. of Telephone Exchanges						
Whole Kingdom	196	196	196	207	219	2.8
BMTA /1	42	42	42	46	46	2.3
Provinces	154	154	154	161	173	3.0
No. of Line Capacity						
Whole Kingdom	422,684	436,028	499,663	518,672	570,819	7.8
BMTA /1	314,684	317,028	370,628	381,438	383,438	5.1
Provinces	108,000	119,000	129,035	137,234	187,381	14.8
No. of Subscribers						
Whole Kingdom	365,894	389,238	425,679	463,231	519,491	9.2
BMTA /1	269,534	287,090	312,062	339,510	361,924	7.6
Provinces	96,360	102,148	113,617	123,721	157,567	13.1

Note: /1 BMTA stands for Bangkok Metropolitan Telecommunication Area which covers the four telephone areas of Bangkok Metropolis, Nonthaburi, Pathuru Thani and Samut Prakan.

Source: Statistical Yearbook 1985-1986, National Statistical Office

Table 6-25. STATISTICS OF WATER SUPPLY IN BANGKOK METROPOLITAN AREA (1981-1986)

Year	Service Area /1 (km^2)	Served Population (million)	Per Capita Water Consumption /2 (l/c/d)	Quantity of Water Produced (MCM)
1981	-	3,520	146	621
1982	-	3,735	149	640
1983	-	3,950	152	648
1984	-	4,164	155	726
1985	430	4,379	158	781
1986	475	4,714	161	826

Note: /1 Four municipalities of Bangkok, Thonburi, Nonthaburi and Samut Prakan.

/2 Residential use only.

Source: Annual Report, 1986, and other data of Metropolitan Waterworks Authority

Table 6-26. ELECTRIC POWER SUPPLY (1980-1984)

	1980	1981	1982	1983	1984	Share in 1984 (%)	Average Annual Growth Rate (%) 1980-1984
Capacity (10^3 kW)							
Hydropower	1,270	1,361	1,519	1,501	1,714	27	7.8
Steam	2,016	2,187	2,194	2,767	3,704	59	16.4
Gas Turbine & Others	563	910	1,164	1,280	844	14	1.8
Total	3,849	4,458	4,877	5,548	6,262	100	12.9
Generation (10^6 kWh)							
Hydropower	1,273	2,974	3,836	3,660	4,081	19	33.8
Steam Turbine & Others	13,309	12,574	12,569	12,806	15,504	70	3.9
Gas Turbine & Others	530	584	1,045	3,304	2,444	11	46.5
Total	15,112	16,132	17,450	19,770	22,029	100	9.9
Consumption (10^6 kWh)							
Whole Kingdom							
Residential	3,025	3,193	3,631	4,188	4,732	26	11.8
Commercial	1,666	1,564	1,693	4,455	4,192	26	31.0
Industrial	8,350	8,968	9,481	8,014	8,724	47	1.1
Others	95	95	213	244	169	1	15.5
Total (1)	13,136	13,820	15,018	16,901	18,537	100	9.0
MEAA /1							
Residential	1,565	1,521	1,682	1,874	2,059	20	7.1
Commercial	1,051	1,046	1,144	1,259	1,351	14	6.5
Industrial	5,373	5,543	5,712	5,987	6,524	64	5.0
Others	36	38	43	196	226	2	58.3
Total (2)	8,025	8,148	8,581	9,316	10,160	100	6.1
Share [(2)/(1) x 100%]	61	59	57	55	55		

Note: /1 Metropolitan Electricity Authority Area.

Source: Statistical Yearbook 1985-1986, National Statistical Office

FIGURES

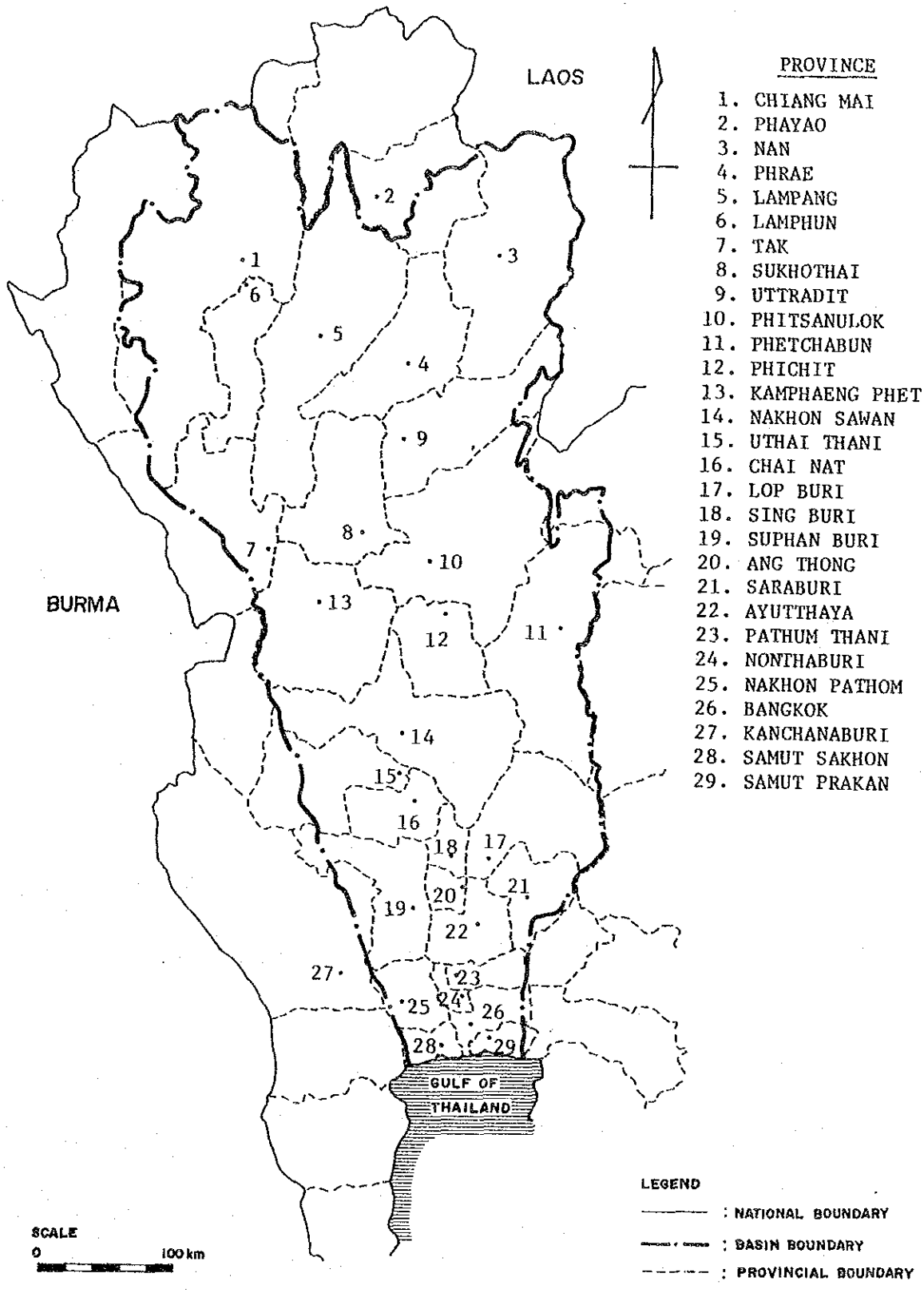

Fig. 6-1. ADMINISTRATIVE DIVISIONS

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

7. LAND USE

SUPPORTING REPORT
ON
LAND USE

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7. SUPPORTING REPORT ON LAND USE

The study on land use aims to figure out the land use features in the Chao Phraya River Basin and to obtain the basic data to be used for the flood damage analysis. The study was carried out for the whole river basin, especially the downstream area from Nakhon Sawan which suffers from more serious flood damage than the other areas.

1. Land Use in the Whole Basin

The cropping pattern in the Chao Phraya River Basin can be categorized into four (4) types, as shown in Fig. 7-1. Among these types, Type I is the most widely utilized, while the other three are found only in places where water supply in the dry season is sufficient or where water is available locally even in the dry season. Since flood damage to agriculture and to inhabitants occur mainly in the wet season, the following descriptions present mainly a general information on land use in the whole Chao Phraya River Basin in the wet season.

1.1 Present Land Use Pattern

The Chao Phraya River Basin has an area of 162,000 km^2 and the present land use therein can be roughly divided into five (5) categories, namely, built-up land, cultivated land, forest land, water area and other lands. These land use categories are composed mainly as follows:

Built-Up Land	:	city, town, village, commercial land, industrial land and roads
Cultivated Land	:	paddy, field and perennial crop lands, and nursery pond
Forest Land	:	dense and sparse forest lands
Water Area	:	river, lake and pond
Other Lands	:	rocky and waste land

Table 7-1 and Fig. 7-2 show the present land use in the Chao Phraya River Basin. Summarized hereunder are the areas of each land use category, together with their percentages in relation to the whole basin area.

Built-up Land	:	5,376.0 km^2 (3.3%)
Cultivated Land	:	70,037.7 km^2 (43.2%)
Forest Land	:	82,884.3 km^2 (51.2%)
Water Area	:	1,135.1 km^2 (0.7%)
Other Lands	:	2,566.9 km^2 (1.6%)

Among the above land use categories, the cultivated area existing mostly along river courses as presented in Fig. 7-2 can be divided further in each province, as shown in Table 7-1 and summarized below.

Paddy Field	:	44,454.7 km^2 (27.4%)
Field Crop Land	:	22,805.7 km^2 (14.1%)
Perennial Crop Land	:	2,149.4 km^2 (1.3%)
Nursery Pond	:	627.9 km^2 (0.4%)

1.2 Rice Varieties

Paddy fields occupy the largest portion of cultivated areas, and rice is the most essential agricultural product. According to the source of water supply, rice culture can be classified as either rainfed or irrigated.

Based on land and water management practices, the rice varieties can be classified into five (5), namely, low-yield variety, high-yield variety, traditional tall variety, deepwater rice and floating rice. Table 7-2 presents the rice varieties which are usually planted as follows:

Low-Yield Variety : planted in the wet season in the hilly area with no irrigation system

High-Yield Variety	:	planted in both wet and dry seasons in the area with irrigation and drainage systems
Traditional Tall Variety	:	planted in the wet season in the lowland area with or without irrigation system
Deepwater Rice	:	planted in the area with or without irrigation system that is submerged in the wet season
Floating Rice	:	planted in the area with or without irrigation system that is submerged in deep water in the wet season

Table 7-3 gives the rice planted area and the average yield in each province in the Chao Phraya River Basin. The table shows that only the high-yield variety, which is a flood-weak variety, is planted in the dry season to an area of 3,990 km^2 where irrigation and drainage systems are already completed, more particularly, the provinces of Chiang Mai, Lampang and Nonthaburi. However, all varieties are planted in the wet season including the high-yield variety, but as the special variety in the wet season deepwater/floating rice is planted in the lowland area of about 5,700 km^2 because this variety is more resistant to flood/inland water damage.

1.3 Irrigated Area

Water management in irrigated areas in the Chao Phraya River Basin can be categorized into two types in the wet season. One is the water supply system to paddy fields with no drainage system, and the other is a combination of both water supply and drainage systems.

In the area where only the water supply system is provided, traditional tall variety and deepwater/floating rice are planted in the wet season. In the area where water supply and

drainage systems are completed, high-yield variety is planted even in the wet season.

Since almost all of the irrigation systems are installed in paddy fields, about half of all paddy fields in the basin are already irrigated. The total irrigated area is 22,274.7 km^2, or around 30% of the cultivated land. The irrigated areas for large/medium scale projects, small scale projects and royal development projects in the basin are shown in Fig. 7-3 and summarized below.

Large/Medium Scale Projects	:	17,958.8 km^2
Small Scale Projects	:	4,273.8 km^2
Royal Development Projects	:	42.1 km^2

1.4 Future Land Use

The rate of expansion of the cultivated area which has been categorized into four, namely, paddy field, field crop land, perennial crop land and nursery pond, will not vary much in the future since forest conservation is being carried out as one of the national policies. For example, the trend of rice harvested area has remained constant as shown in Fig. 7-4. Minor changes may only occur due to such factors as forest conservation, land potential, irrigation plan and the trend of rice culture, the detailed schemes of which are not clear yet.

Forest Conservation

Expansion of the cultivated area will not be promoted as one of the national policies in the future. This is because cultivation of forest land will lead to the deterioration of forest resources, as well as the depletion of the water conservation capacity of the basin.

Land Potential

The land use map in Fig. 7-5, which was prepared from the geological point of view, and the present land use pattern in the Chao Phraya River Basin well coincide with each other.

Some minor differences are observed, called misused land, but the governmental offices concerned are taking efforts to convert such misused land into proper use.

Irrigation Plan

The expansion of ongoing irrigation projects in the near future will increase the irrigation area from the present 22,274.7 km^2 to 24,846.1 km^2. However, the future water development plan of large scale projects shown in Fig. 7-6 do not have any practical execution schedule of irrigation systems.

Tendency of Rice Culture

In the downstream area of the Chao Phraya River Basin, there is a yearly trend for the deepwater/floating rice area to switch into the traditional tall variety field or fish/shrimp pond because of their high productivity. Compared with the total deepwater/floating rice area, such an area is not so small but the switching trend does not have any official guideline.

The switched area in the past 10 years is estimated at 1,250 km^2, based on the comparison of the deepwater/floating rice area at present and in the past.

2. Land Use in the Downstream

In the downstream area of the Chao Phraya River Basin, specifically the downstream from Nakhon Sawan where the land is almost fully utilized for agricultural purposes, flood occurs more frequently and causes more serious flood damage than in the other areas. Therefore, the detailed study on present land use has been carried out in this area, as presented hereinafter.

2.1 Land Use Pattern

Fig. 7-7 shows the present land use pattern in the downstream from Nakhon Sawan which is composed of 15 provinces of 44,727 km^2, and Table 7-4 gives the classification of the areas in each province. As shown in Table 7-4, the paddy field is further divided into two (2) areas, lowland rice area and deepwater/floating rice area. The area of deepwater/floating rice is as shown in Fig. 7-8.

The areas and their corresponding percentages are summarized below:

Built-Up Land	:	3,312.5 km^2 (7.4%)
Cultivated Land	:	31,192.5 km^2 (69.7%)
Forest Land	:	8,797.9 km^2 (19.7%)
Water Area	:	302.8 km^2 (0.7%)
Other Land	:	1,101.3 km^3 (2.5%)

The cultivated area can be further divided as follows:

Lowland Rice Field	:	17,564.7 km^2 (39.3%)
Deepwater/Floating Rice Area	:	4,177.3 km^2 (9.3%)
Field Crop Land	:	7,995.1 km^2 (17.9%)
Perennial Crop Land	:	829.6 km^2 (1.9%)
Nursery Pond	:	625.5 km^2 (1.3%)

2.2 Irrigated Area

The irrigated area in the downstream from Nakhon Sawan is summarized by province in Table 7-5. As deduced from this table, 50% of the 31,192.5 km^2 of cultivated area which comprises 72% of the 21,742.3 km^2 of paddy field is already irrigated. However, except for some small areas, the irrigation system in this downstream area is only for water supply and it cannot drain out the flood water or inland water, since the water level of the water supply channel becomes high in the wet season.

3. Land Use in the Flood Damaged Area

As mentioned in Section 2, land in the downstream is almost fully utilized for agriculture, and flood occurs more frequently with more serious damage than in other areas. The land use in the flood inundation area has been studied as described hereinbelow.

3.1 Land Use Pattern

According to the records, flood inundation had occurred four times in recent years in the downstream of the Chao Phraya River Basin. The inundation area of each flood and the land use categories have been estimated, as shown in Table 7-6.

The flood damaged area in the downstream from Nakhon Sawan has accumulated to about 3,413.1 km^2, based on the past flood records. The land use pattern in the flood damaged area, as shown in Fig. 7-9, was obtained by superimposing the flood damage area with the land use pattern in the downstream from Nakhon Sawan.

The areas and their corresponding percentages are summarized below:

Built-Up Land	:	147.4 km^2
Cultivated Land	:	3,267.7 km^2

The cultivated area can be further divided as follows:

Lowland Rice Field	:	2,540.0 km^2
Deepwater/Floating Rice Area	:	691.4 km^2
Field Crop Land	:	3.6 km^2
Perennial Crop Land	:	27.1 km^2
Nursery Pond	:	3.6 km^2

3.2 Flood Damage

The flood damaged area of 3,413.1 km^2 in the downstream from Nakhon Sawan mentioned in 3.1 above may be classified into two, i.e., 1,652 km^2 of seriously damaged area and 1,761.1 km^2 of not so seriously damaged area. Based on this classification, the flood damaged area was further divided, as presented in Table 7-7.

Table 7-7 indicates that flood damage affects a large portion of the built-up land including Metropolitan Bangkok and the deepwater/floating rice area, although this variety is relatively strong against flood.

TABLES

Table 7-1 (1/2). LAND USE IN PROVINCES IN THE CHAO PHRAYA RIVER BASIN

(Unit: km^2)

	Province	Provincial Area	Build-Up Land /2	Cultivated Area					Forest /7	Water Area /8	Other Areas /9
				Paddy /3	Field Crop /4	Perennial Crop /5	Nursery Pond /6	Total			
1	Bangkok Metropolis	1,565	605.3	678.6	79.5	99.8	75.3	933.2	-	8.4	18.1
2	Chai Nat	2,470	122.4	1,734.4	149.7	0.5	-	1,184.6	428.5	16.2	18.3
3	Nontha Buri	622	119.1	409.6	16.8	70.5	0.4	497.3	-	5.6	-
4	Pathum Thani	1,526	64.1	1,282.5	7.3	124.0	1.3	1,415.1	6.0	9.2	31.7
5	Ayutthaya	2,557	254.9	2,300.6	-	-	-	2,300.6	1.5	-	-
6	Lop Buri	6,200	162.1	1,694.5	3,012.5	83.2	-	4,790.2	895.7	26.1	325.9
7	Sara Buri	3,577	305.9	1,210.9	1,104.0	44.8	-	2,359.7	849.7	9.6	52.1
8	Sing Buri	822	497.7	323.1	-	-	0.4	323.5	-	0.7	0.1
9	Ang Thong	968	138.3	808.5	13.8	3.3	-	825.6	0.4	3.2	0.5
10	Samut Prakarn	1,004	159.2	396.1	0.5	51.5	349.4	797.5	29.1	16.2	2.1
11	Kanchanaburi /1	3,000	53.1	132.8	650.0	40.0	-	822.8	1,890.5	138.8	179.9
12	Nakhorn Pathom	2,168	161.0	1,703.1	220.2	83.7	-	2,007.0	-	-	-
13	Samut Sakhorn	872	70.6	222.4	0.2	211.2	198.7	632.5	112.3	9.1	47.5
14	Suphan Buri	5,358	336.6	2,839.4	1,260.8	1.5	0.1	4,101.7	822.7	77.2	19.8
15	Kamphaeng Phet	8,608	123.7	1,981.7	1,059.8	252.0	-	3,293.5	5,096.0	-	94.8
16	Chiang Mai /1	17,584	268.7	1,347.4	110.9	372.5	-	1,830.8	15,185.8	70.5	228.2
17	Tak /1	7,400	58.7	370.5	537.8	3.6	-	911.9	6,260.1	109.0	60.3
18	Nakhon Sawan	9,598	281.1	4,985.1	1,818.1	52.3	-	6,855.5	1,844.5	64.7	552.1
19	Nan	11,472	106.1	687.1	102.3	43.8	-	833.2	10,399.2	56.9	76.6
20	Phayao /1	3,200	83.7	829.9	46.6	0.4	-	876.9	2,095.1	15.4	128.9
21	Phichit	4,531	224.1	3,708.2	486.0	43.0	-	4,237.2	24.8	34.3	10.6
22	Phitsanulok	10,816	271.9	2,924.1	3,117.1	449.6	-	6,490.8	3,903.8	63.4	86.1
23	Phetchabun	12,668	239.5	1,999.0	5,489.8	29.9	-	7,518.7	4,735.8	6.5	167.5
24	Phrae	6,539	98.2	5,474.0	430.6	1.8	-	5,906.4	524.6	-	9.8
25	Lampang	12,534	189.4	1,259.1	320.1	26.1	-	1,605.3	10,718.2	18.9	2.2
26	Lamphun	4,506	117.0	642.1	79.2	65.8	0.3	787.4	3,462.8	4.3	134.5

Table 7-1 (2/2). LAND USE IN PROVINCES IN THE CHAO PHRAYA RIVER BASIN

(Unit: km^2)

Province	Provincial Area	Build-Up Land /2	Cultivated Area					Forest /7	Water Area /8	Other Areas /9
			Paddy /3	Field Crop /4	Perennial Crop /5	Nursery Pond /6	Total			
27 Sukhothai	6,596	113.3	394.1	1,736.0	0.2	2.1	2,132.4	4,281.8	7.8	60.9
28 Uttaradit	7,837	116.1	962.4	687.2	2.8	-	1,652.4	5,535.8	306.5	225.3
29 Uthai Thani /1	5,400	34.2	1,153.5	311.7	3.3	-	1,468.5	3,807.5	56.6	33.2
Total (Chao Phraya Basin)	162,000	5,376.0	44,454.7	22,805.7	2,149.4	627.9	70,037.7	82,884.3	1,135.1	2,566.9
Percentage (%) /10	100	3.3	(63.5)	(32.5)	(3.1)	(1.0)	43.2 (100.0)	51.2	0.7	1.6

Note: The whole area of the Kingdom of Thailand is 513,115 km^2.

Data on provinces and their area were taken from the Statistical Yearbook for 1985-1986 published by the National Statistical Office.

The estimation of area of each land category is based on the interview survey with the Land Development Department of the Ministry of Agriculture and Cooperatives.

/1 The watershed boundary line of the Chao Phraya River Basin passes through the province.
/2 Cities, towns, villages, commercial land, industrial land and roads.
/3 Low-yield and high-yield varieties, traditional variety and deepwater/floating rice variety.
/4 Corn, sugarcane, beans, etc.
/5 Coconut, mango, orange, etc.
/6 Fish and shrimp ponds, saltbeds.
/7 Dense and sparse forest lands.
/8 Rivers, lakes and ponds.
/9 Rocky and wasteland.
/10 Percentages in parenthesis refer to the categories of Cultivated Land only.

Table 7-2. RICE VARIETIES

Category	Variety	Height/Water Condition	Yield
Upland Rice	Low-Yield Variety	130-150 cm tall, with no standing water	1.5-2.0 t/ha
Lowland Rice	High-Yield Variety	Less than 100 cm tall, with occasional water supply	3.5-4.0 t/ha
	Traditional Tall Variety	100-200 cm tall, with 5-50 cm of standing water	2.0-2.5 t/ha
Deepwater Rice	Deepwater Rice	120-150 cm tall, without standing water; 200-300 cm tall, with rising water	2.0-2.5 t/ha
	Floating Rice	more than 150 cm tall, without standing water; 500-600 cm tall, with rising floodwater	1.5-2.0 t/ha

Table 7-3. AREA PLANTED TO RICE AND AVERAGE YIELD IN THE CHAO PHRAYA RIVER BASIN PROVINCES

Province		Provincial Area (km^2)	Dry Season		Wet Season	
			Planted Area (km^2) /2	Yield Per Ha (kg)	Planted Area (km^2) /2	Yield Per Ha (kg)
1	Bangkok Metropolis	1,565	116.7	2,781	678.6	2,300
2	Chai Nat	2,470	437.3	3,788	1,734.4	2,356
3	Nontha Buri	622	307.9	4,038	409.6	3,478
4	Pathum Thani	1,526	479.8	4,031	1,282.5	2,481
5	Ayutthaya	2,557	373.6	3,969	2,300.6	2,181
6	Lop Buri	6,200	122.6	3,800	1,694.5	2,338
7	Sara Buri	3,577	69.6	3,606	1,210.9	2,269
8	Sing Buri	822	144.0	4,500	323.1	2,863
9	Ang Thong	968	222.8	4,031	808.5	2,275
10	Samut Prakan	1,004	149.9	3,031	396.1	3,269
11	Kanchanaburi /1	3,000	4.6	3,294	132.8	1,563
12	Nakhorn Pathom	2,168	646.6	4,175	1,703.1	2,969
13	Samut Sakhorn	872	73.5	3,344	222.4	2,781
14	Suphan Buri	5,358	222.8	4,144	2,839.4	2,575
15	Kamphaeng Phet	8,608	73.4	3,281	1,981.7	2,131
16	Chiang Mai /1	17,584	57.6	3,450	1,347.4	3,306
17	Tak /1	7,400	7.7	3,188	370.5	2,338
18	Nakhon Sawan	9,598	134.3	3,813	4,985.1	2,069
19	Nan	11,472	0.3	3,106	387.1	2,363
20	Phayao /1	3,200	2.8	3,194	829.9	2,881
21	Phichit	4,531	88.2	3,631	3,708.2	2,269
22	Phitsanulok	10,816	142.0	4,075	2,924.1	2,425
23	Phetchabun	12,668	0.6	3,488	1,999.0	2,838
24	Phrae	6,539	0.3	2,575	5,474.0	2,975
25	Lampang	12,534	14.2	3,475	1,259.1	2,319
26	Lamphun	4,506	6.8	3,688	642.1	3,281
27	Sukhothai	6,596	37.7	3,138	394.1	1,906
28	Uttaradit	7,837	41.9	3,076	962.4	2,900
29	Uthai Thani /1	5,400	11.3	3,156	1,153.5	1,925
Total (Chao Phraya Basin)		162,000	3,990.8	3,880.7	44,454.7	2,502.9

Note: The whole area of the Kingdom of Thailand is 513,115 km^2.
/1 The watershed boundary line of the Chao Phraya River Basin passes through the province.
/2 1 km^2 = 100 ha
Source: Agricultural Statistics of Thailand, Crop Year 1985/86, Land Development Department, Royal Irrigation Department.

Table 7-4. PRESENT LAND USE IN THE DOWNSTREAM OF NAKHON SAWAN

(Unit: km^2)

	Province	Provincial Area	Build-Up Land /2	Cultivated Area						Forest /6	Water Area /7	Other Areas /8
				Paddy Field								
				Lowland Rice	Deep-water/ Floating Rice	Field Crop /3	Perennial Crop /4	Nursery Pond /5	Total			
1	Nakhon Sawan	9,598	281.1	4,449.8	535.3	1,818.1	52.3	-	6,255.5	1,844.5	64.7	552.1
2	Uthai Thani /1	5,400	34.2	1,153.5	-	311.7	3.3	-	1,488.5	3,807.5	56.6	33.2
3	Chai Nat	2,470	122.4	1,584.7	149.6	149.7	0.5	-	1,884.6	428.5	16.2	18.3
4	Lop Buri	6,200	162.1	2,461.5	551.0	3,012.5	83.2	-	4,790.2	895.7	26.1	325.9
5	Sing Buri	822	497.7	131.1	192.0	-	-	0.4	323.5	-	0.7	0.1
6	Ang Thong	968	138.3	402.3	406.2	13.8	3.3	-	825.6	0.4	3.2	0.5
7	Sara Buri	3,577	305.9	1,185.9	25.0	1,104.0	44.8	-	2,359.7	849.7	9.6	52.1
8	Ayutthaya	2,557	254.9	921.6	1,379.0	-	-	-	2,300.6	1.5	-	-
9	Suphan Buri	5,358	336.6	2,066.9	772.5	1,260.8	1.5	0.1	4,101.7	822.7	77.2	19.8
10	Pathum Thani	1,526	64.1	1,267.8	14.7	7.3	124.0	1.3	1,415.1	6.0	9.2	31.7
11	Nakhorn Pathom	2,168	161.0	1,565.5	137.6	220.2	83.7	-	2,007.0	-	-	-
12	Bangkok Metropolis	1,565	605.3	678.6	-	79.5	99.8	75.3	933.2	-	8.4	18.1
13	Nontha Buri	622	119.1	395.2	14.4	16.8	70.5	0.4	497.3	-	5.6	-
14	Samut Prakarn	1,004	159.2	396.1	-	0.5	51.5	349.4	797.5	29.1	16.2	2.1
15	Samut Sakhorn	872	70.6	222.4	-	0.2	211.2	198.7	632.5	112.3	9.1	47.5
	Total	44,727	3,312.5	17,564.7	4,177.3	7,995.1	829.6	625.5	31,192.5	8,797.9	302.8	1,101.3

Note: The whole area of the Chao Phraya River Basin is 162,000 km^2.
/1 The watershed boundary line of the Chao Phraya River Basin passes through the province.
/2 Cities, towns, villages, commercial land, industrial land and roads.
/3 Corn, sugarcane, beans, etc.
/4 Coconut, mango, orange, etc.
/5 Fish and shrimp ponds, saltbeds
/6 Dense and sparse forest lands.
/7 Rivers, lakes and ponds.
/8 Rocky and wasteland.

Table 7-5. IRRIGABLE AND IRRIGATED AREAS DOWNSTREAM OF NAKHON SAWAN

(Unit: km^2)

	Province	Provincial Area	Irrigable Area				Irrigated Area			
			Large/ Medium Scale Project	Small Scale Project	Royal Development Project	Total	Large/ Medium Scale Project	Small Scale Project	Royal Development Project	Total
1	Nakhon Sawan	9,598	740.6	674.7	-	1,415.4	716.6	674.7	-	1,391.3
2	Uthai Thani*	5,400	227.2	357.3	-	584.5	131.6	282.7	-	414.3
3	Chai Nat	2,470	1,070.7	287.6	-	1,358.2	954.4	277.8	-	1,232.2
4	Lop Buri	6,200	729.8	148.0	1.4	879.3	715.0	148.0	1.4	864.4
5	Sing Buri	822	678.4	-	-	678.4	678.4	-	-	678.4
6	Ang Thong	968	811.8	-	-	811.8	811.8	-	-	811.8
7	Sara Buri	3,577	516.7	41.9	1.6	560.2	516.7	41.9	1.6	560.2
8	Ayutthaya	2,557	1,975.7	-	2.4	1,978.1	1,975.7	-	2.4	1,978.1
9	Suphan Buri	5,358	2,735.0	16.9	-	2,751.8	2,182.4	968.0	-	3,150.4
10	Pathum Thani	1,526	1,241.1	-	-	1,241.1	1,241.1	-	-	1,241.1
11	Nakhorn Pathom	2,168	1,782.9	-	-	1,782.9	1,289.7	-	-	1,289.7
12	Bangkok Metropolis	1,565	604.8	-	-	604.8	604.8	-	-	604.8
13	Nontha Buri	622	367.8	-	-	367.8	367.7	-	-	367.7
14	Samut Prakarn	1,004	605.3	-	-	605.3	605.3	-	-	605.3
15	Samut Sakhorn	872	514.6	-	-	514.6	514.6	-	-	514.6
	Total	44,727	14,602.4	1,526.4	5.4	16,134.2	13,305.8	2,393.1	5.4	15,704.3

Note: *: The Chao Phraya River Basin boundary line passes through the province.

Whole Kingdom Area = 513,115 km^2

Table 7-6. FLOOD INUNDATION AREA OF BUILT-UP LAND AND CULTIVATED LAND

(Unit: km^2)

Flood Year	Flood Inundation Area	Build-Up Land		Cultivated Land	
		Serious	Not Serious	Serious	Not Serious
1975	32.3	-	-	32.3	-
1978	2,276.3	43.0	32.7	1,320.4	880.2
1980	870.1	11.4	28.5	453.5	376.7
1983	1,328.7	20.3	30.4	611.0	667.0
Accumulated Inundation Area	3,413.1	88.6	58.8	1,542.5	1,723.2

Table 7-7. LAND USE IN THE ACCUMULATED FLOOD DAMAGED AREA

(Unit: km^2)

Category	Seriously Damaged Area	Not So Seriously Damaged Area	Total
Build-Up Land	88.6	58.8	147.4
Cultivated Land:			
1. Paddy Field			
- Lowland Rice Field	1,012.1	1,127.9	2,140.0
- Deepwater/Floating Rice Field	513.9	560.2	1,091.4
2. Field Crop Land	-	3.6	3.6
3. Perennial Crop Land	12.9	14.2	27.1
4. Nursery Pond	3.6	-	3.6
Total	1,631.1	1,782.0	3,413.1

FIGURES

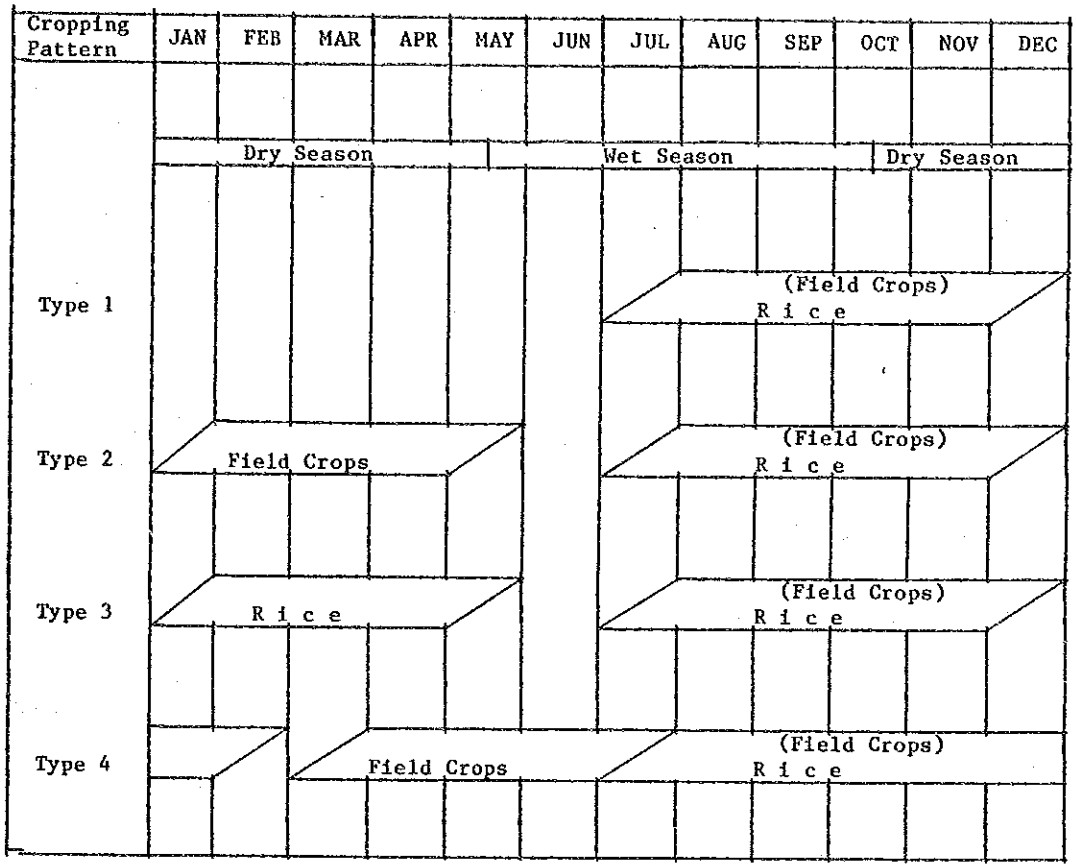


Fig. 7-1. TYPICAL CROPPING PATTERN IN THE CHAO PHRAYA RIVER BASIN

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

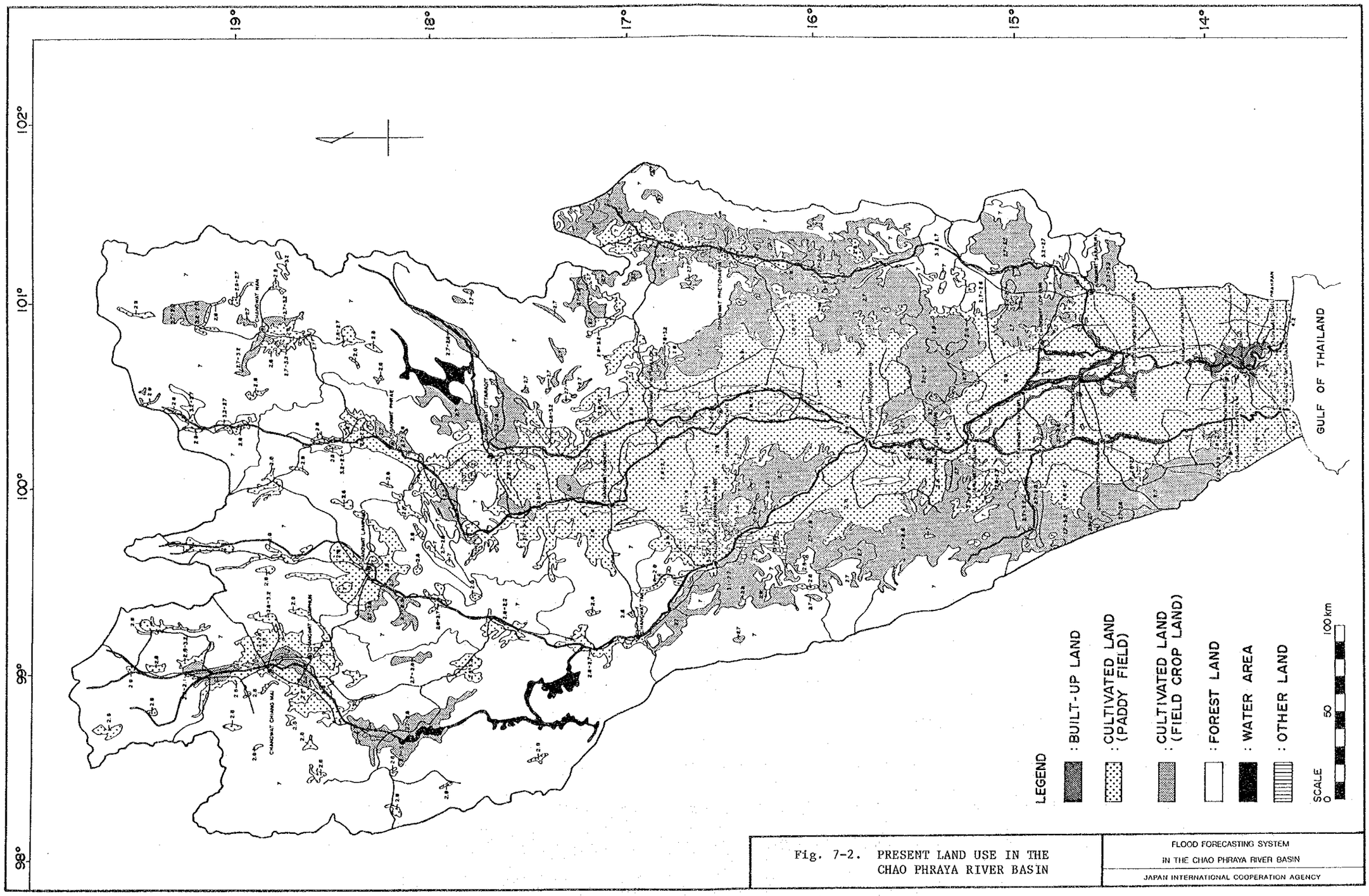


Fig. 7-2. PRESENT LAND USE IN THE CHAO PHRAYA RIVER BASIN

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

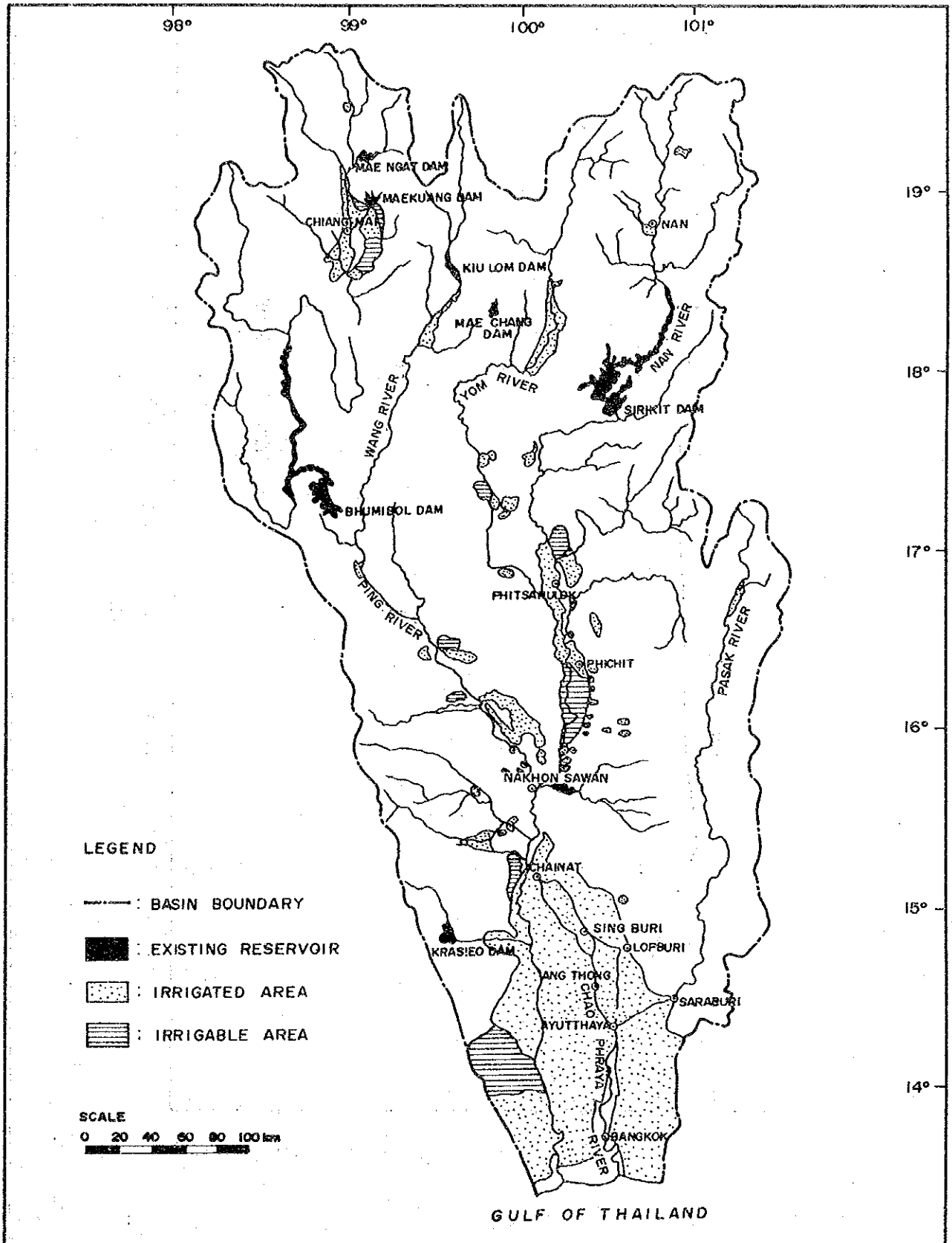


Fig. 7-3. IRRIGATION AREA IN THE CHAO PHRAYA RIVER BASIN

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

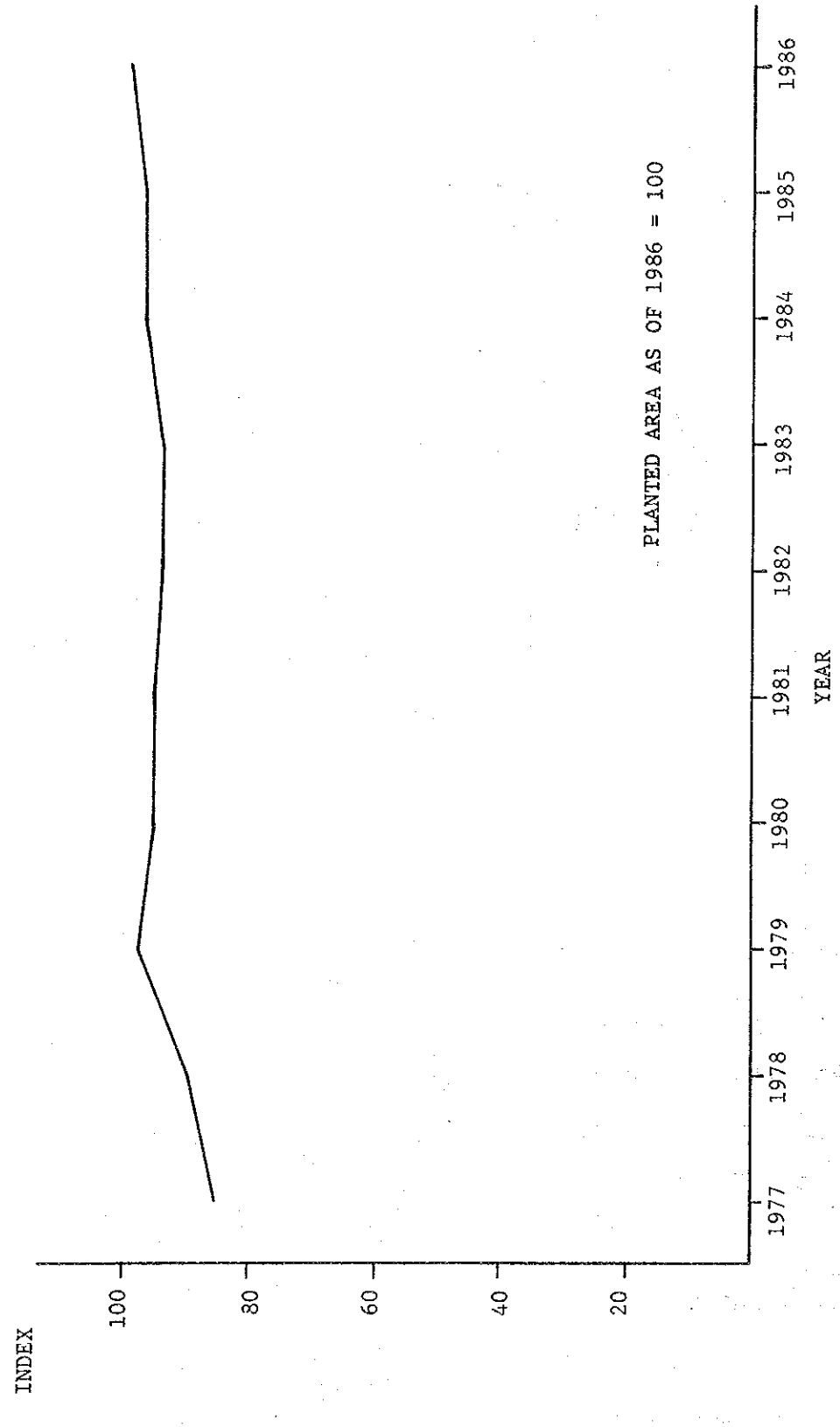


Fig. 7-4. TREND OF RICE HARVESTED AREA

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

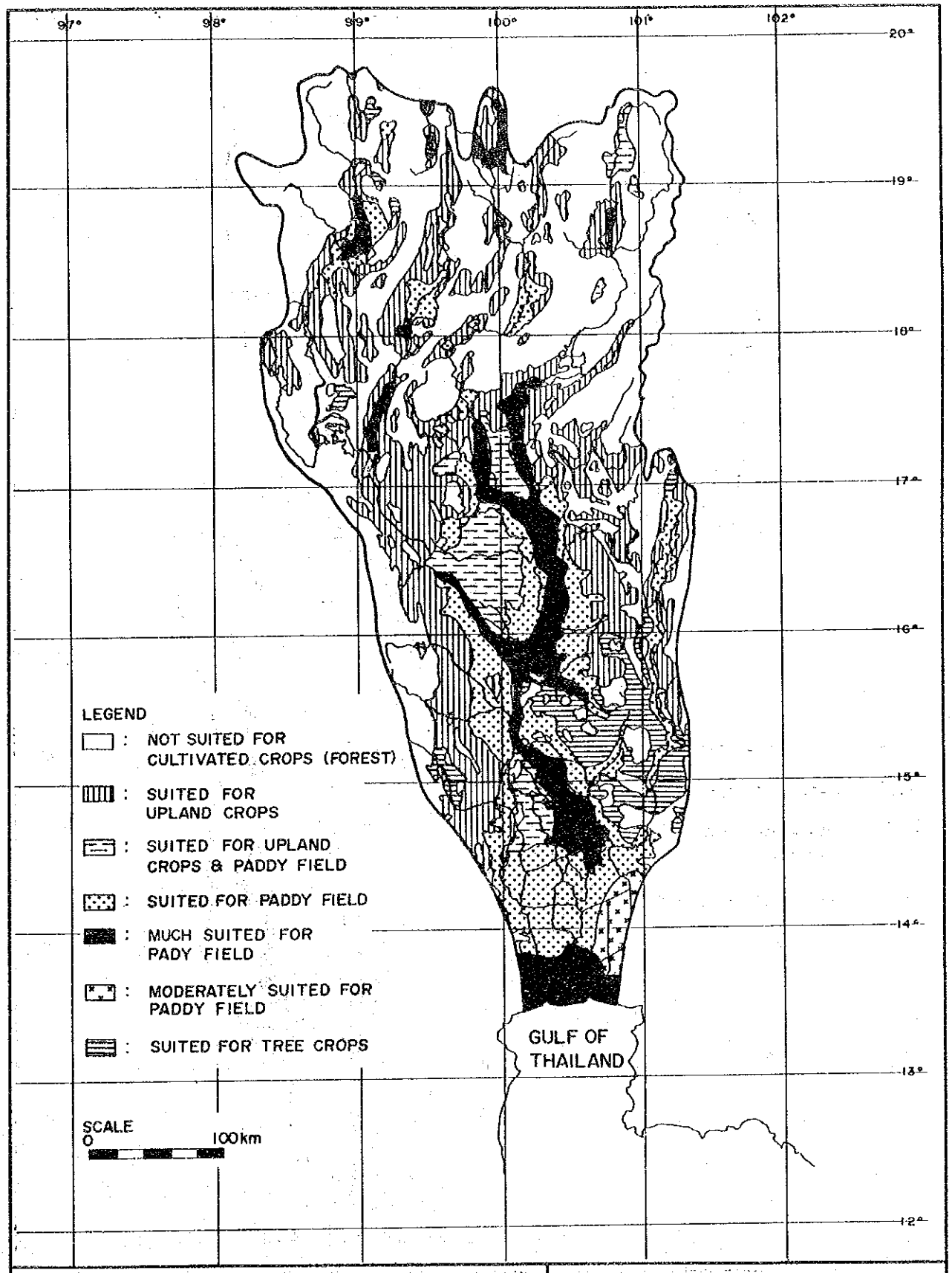


Fig. 7-5. LAND POTENTIAL MAP OF THE CHAO PHRAYA RIVER BASIN

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

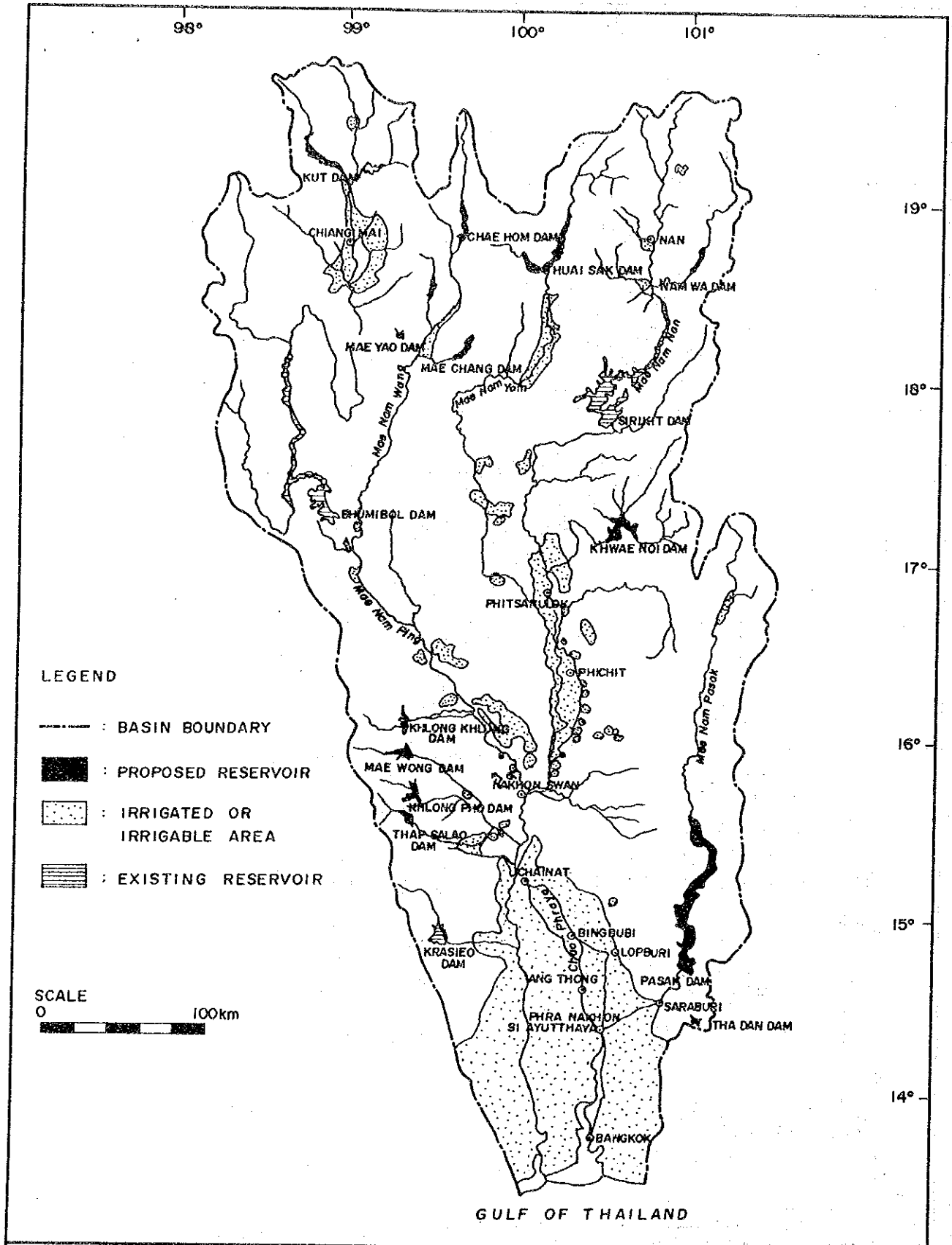


Fig. 7-6. PROPOSED RESERVOIRS IN THE CHAO PHRAYA RIVER BASIN

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

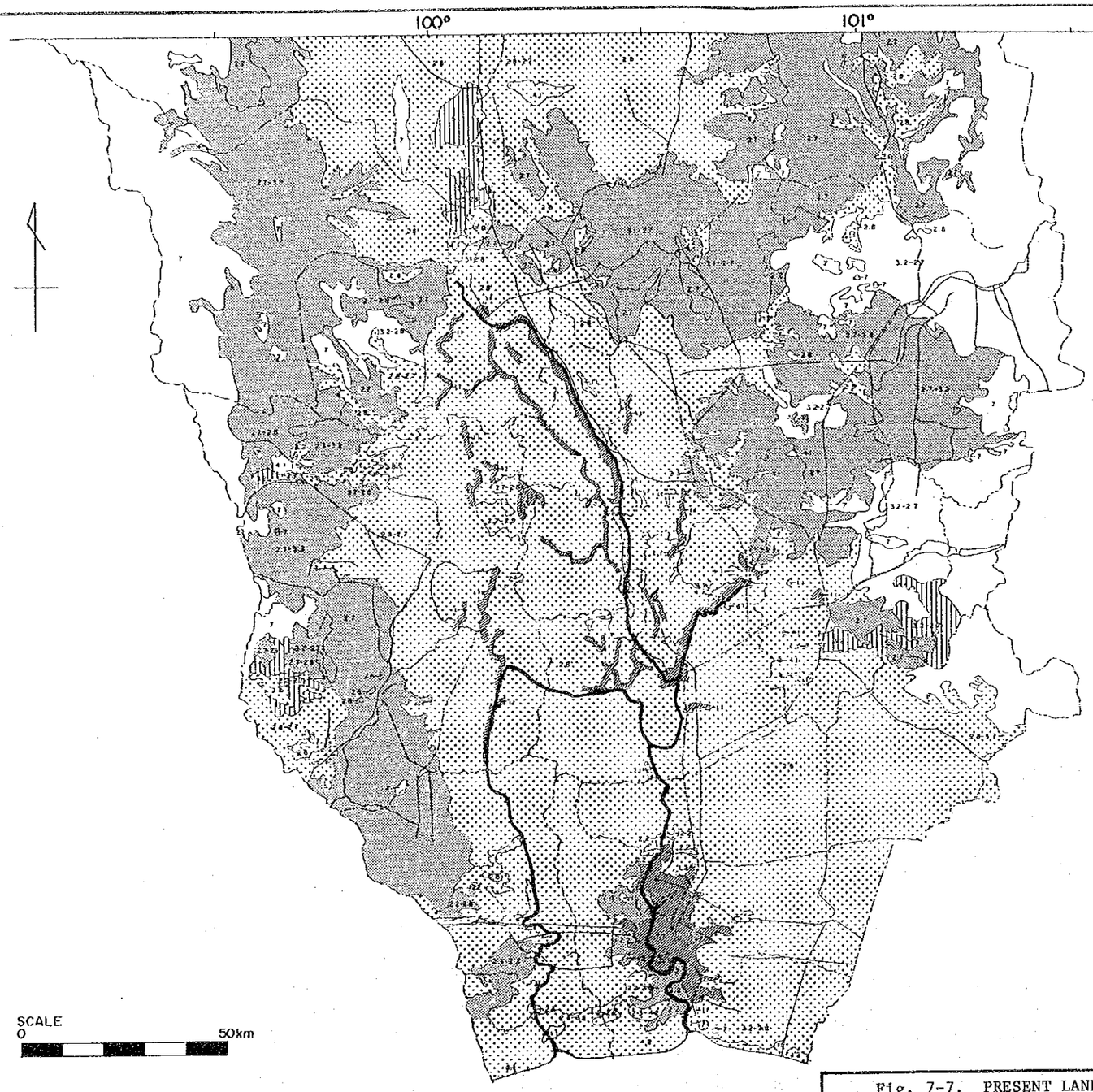


Fig. 7-7. PRESENT LAND USE IN THE DOWNSTREAM FROM THE NAKON SAWAN

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

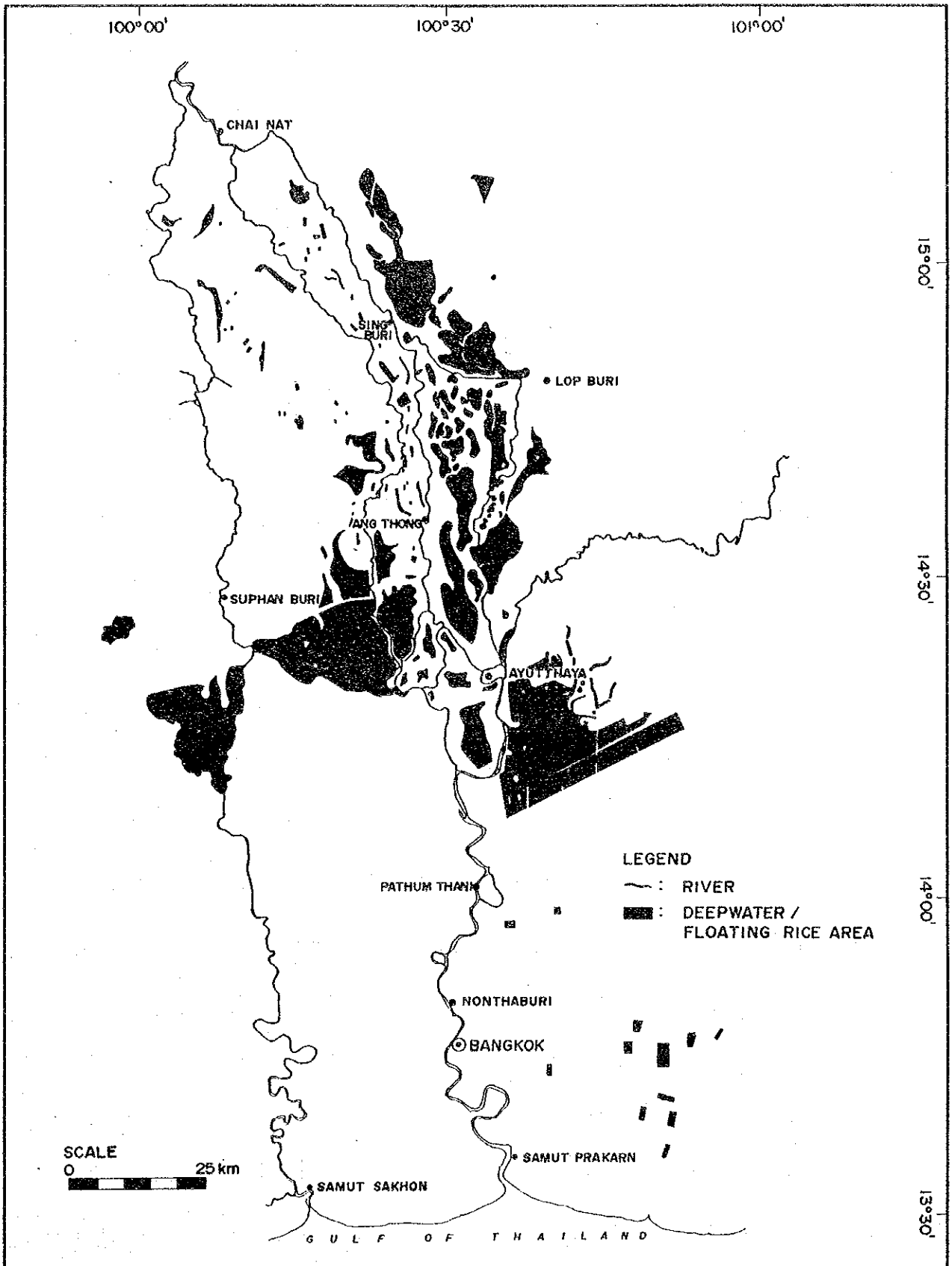
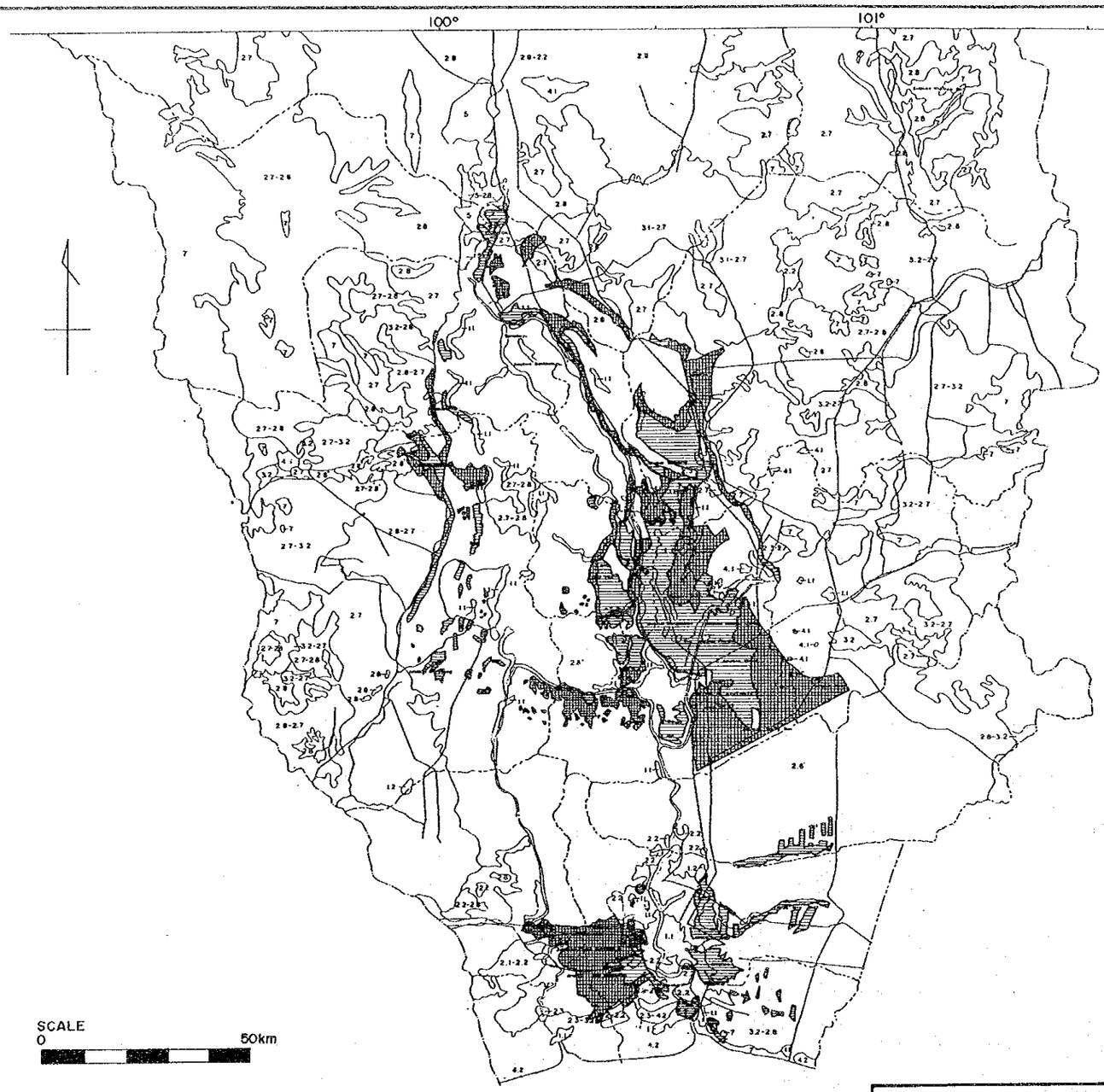


Fig. 7-8. DEEPWATER/FLOATING RICE AREA

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY



REMARKS

1: URBAN LAND
 1.1: RESIDENTIAL
 1.2: AIR FIELD
 1.3: INDUSTRIAL
 1.4: INDUSTRIAL, MINE
2: AGRICULTURAL LAND
 2.1: HORTICULTURAL
 2.2: ORCHARD AND PERENNIAL TREE
 2.3: COCONUT
 2.4: RUBBER
 2.5: OIL PALM
 2.6: SUGAR CANE
 2.7: FIELD CROP
 2.8: IRRIGATED PADDY
 2.9: LOTUS
3: PASTURE AND RANCH LAND
 3.1: PASTURE
 3.2: IDLE LAND
4: WATER
 4.1: RESERVOIR
 4.2: FISH AND SHRIMP POND
5: MISCELLANEOUS LAND
6: BARREN LAND
 ROCKY LAND
7: OTHERS

: SERIOUSLY DAMAGED AREA
: NOT SO SERIOUSLY DAMAGED AREA

NOTE :
* TWO UNITS IN PROPORTION : 70-30%
* THREE UNITS IN PROPORTION : 50-30-20%

Fig. 7-9. FLOOD DAMAGED AREA AND LAND USE PATTERN

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

8. RIVER STRUCTURES

SUPPORTING REPORT
ON
RIVER STRUCTURES

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8. SUPPORTING REPORT ON RIVER STRUCTURES

1. General

In the Chao Phraya River Basin, the existing river structures are being operated for the purpose of irrigation, hydropower generation, municipal water supply, navigation, flood control, salinity control, and so on. Among these purposes, irrigation and hydropower generation are given priority importance.

River structures related to flood control can be classified into the following four groups, in consideration of their functions, structural features, scale and importance.

(1) Dams and reservoirs on main tributaries in the upper basin.

(2) Diversion weirs/barrages across the main rivers.

(3) Regulators/gates installed on the main canals.

(4) Flood protection dikes along the main rivers.

These existing river structures are schematized in Fig. 8-1. Their outline, management and operation are described hereinafter, including some comments on their flood control effects.

2. Function and Structural Features of Existing River Structures

2.1 Dams/Reservoirs

There are six (6) major multi-functional dams in the basin, one of which is under construction. The location of these dams are shown in Fig. 8-2. Among these dams, Bhumibol and Sirikit dam are much larger in scale, serve more purposes, and affects the Chao Phraya River Basin to a great deal.

Bhumibol Dam

The Bhumibol Dam was completed in 1964 at Amphoe Sam Ngao, Changwat Tak, on the Ping River. It has a catchment area of 26,386 km^2, a gross storage capacity of 13,462 MCM, and it regulates the flow of the Ping River.

The general structural features of the dam are presented in Table 8-1. The dam is a concrete arch-gravity type structure, with the crest length of 486 meters and the maximum height of 154 meters. The design maximum flood is 6,000 m^3/s, and the dam performs a variety of functions, including the following:

(1) Electricity generation to keep up with the growing power load in Thailand (Installed Capacity: 535 MW);

(2) Irrigation of the plantation area along the Ping River and supply of water for the irrigation area in the lower reaches from Nakhon Sawan; and

(3) Mitigation of flood hazard in Changwat Tak, Changwat Kamphaeng and the lower reaches from Nakhon Sawan in the rainy season.

Aside from the above, freshwater supply to the downstream area, navigation and salinity control are added, but with less priority. From the viewpoint of flood control, the dam is supposed to have a large flood control effect to the lower reaches from Nakhon Sawan because the released water from the dam greatly affects the discharge at Nakhon Sawan.

Sirikit Dam

The Sirikit Dam at Amphoe Ta Pla, Changwat Uttaradit, with a catchment area of 13,130 km^2 and a gross storage capacity of 10,500 MCM, regulates the flow of the Nan River. The dam is an earthfill type structure with a height of 113.5 m, a length of 800 m at the crest, and the design peak discharge of 8,000 m^3/s.

The outline of the dam and reservoir are presented in Table 8-2. This dam was built in 1971 aiming primarily for the following:

(1) Hydroelectric power generation, (installed capacity: 375 MW);

(2) Regulated flow for irrigation in Uttaradit and Phitsanulok project areas, and the lower reaches from Nakhon Sawan; and

(3) Flood control in the area along the Nan River and in the lower reaches from Nakhon Sawan in the rainy season.

In addition, the dam contributes to navigation, municipal water supply and salinity control in the lower reaches from Nakhon Sawan. As for flood control, the dam has a large potential for the same reason as the Bhumibol Dam.

Others

Aside from the Bhumibol and Sirikit dams, there are three major existing dams and one under construction. They are the Mae Ngat and Mae Kuang dams in the Ping River Basin, the Kiu Lom Dam on the Wang River, and the Krasieo Dam on the Krasieo River.

The outline of the dams are presented in Table 8-3. Being multipurpose dams, first priority is placed on water supply for irrigation, followed by power generation and flood control. With respect to flood control, each dam covers only a limited part of the basin as the target areas for flood control. Besides, the storage capacity of each dam is far smaller compared to that of Bhumibol and Sirikit dams. Therefore, flood control effect to the lower reaches from Nakhon Sawan cannot be greatly expected.

2.2 Diversion Weirs/Barrages

There are five (5) major diversion weirs/barrages in the Basin (refer to Fig. 8-2), which are operated primarily for irrigation. The structural features of these structures are shown in Tables 8-4 and 8-5.

Chao Phraya Dam/Barrage

Being situated in the upmost part of the vast plain of the Chao Phraya River, this barrage has multipurpose functions such as distribution of water for irrigation, navigation, municipal water supply, salinity control and flood control in the lower reaches. With respect to flood control, when peak discharge flows from Nakhon Sawan into the Chao Phraya Dam, the dam helps in distributing part of the floodwater into the main watercourses such as the Chai Nat-Pasak Canal, the Chai Nat-Ayutthaya Canal, the Makhanthao-Uthong Canal, the Suphan River and the Noi River through the coordinated operation of each head regulator as mentioned later.

The dam is composed of 16 units of 12.5-m wide radial gates and a 14-m wide lock with a miter gate to pass the design discharge of 3,300 m^3/s. An emergency spillway of about 1,000 m long and crest elevation of +17.00 m (MSL) exists on the left bank behind the dam.

Rama VI Dam

This diversion dam/barrage located in the Pasak River, a tributary of the Chao Phraya River, regulates the flow of the Pasak River. Joining the water flow from the Chainat-Pasak Canal, it also controls the amount of water released into the irrigation area of the East Bank Project. Having 6 units of 12.5 m wide by 7.5 m high slide gates, this barrage was completed in 1924. In time of flood of the Pasak River, gates of the barrage are fully opened to pass the flood flow into the downstream reaches.

Phitsanulok Weir (Naresuan Dam)

This weir was built in 1981 on the Nan River about 30 km north of Phitsanulok to supply irrigation water for the Phitsanulok irrigation project area of about 110,000 ha. It is a movable diversion weir with 5 units of radial gates, each having the width of 12.5 m.

The diversion weir was designed to pass a maximum discharge of 1,600 m^3/s into the downstream with the gates fully opened. The discharge at the dam is greatly affected by the water released from the Sirikit Dam.

Others

Aside from the aforementioned diversion weirs/barrages, Mae Yom Weir on the Yom River and Thap Salao Weir in the Sakae Krang River Basin are comparatively big in scale and important in each basin. The outline of the structures is given in Table 8-5.

Mae Yom Weir is located on the upper part of the Yom River, about 43 km north of Phrae. It is a fixed weir with a rubber dam installed at the crest of the existing weir, and has the head of 6.0 m and a width of 350 m. Thap Salao Weir is also a fixed type weir built on Thap Salao River about 35 km from Uthai Thani. It has the head of 3.0 m and a width of 74 m.

2.3 Main Watercources and Regulators/Gates

Flow Pattern in the Lower Reaches from Nakhon Sawan

In the downstream of Nakhon Sawan at Chai Nat, the Chao Phraya River branches out into main watercourses such as the Chai Nat-Pasak Canal, the Suphan River, the Noi River, the Makhamthao-Uthong Canal and the Chai Nat-Ayutthaya Canal. These main watercourses further branch out into main canals, laterals and sub-laterals, forming a complex canal network.

The Chao Phraya river flow is diverted by means of the Chao Phraya Diversion Dam at Chai Nat to the above-said main

watercourses. Depending on the flow capacity, the flow released into each main watercourse is regulated by a head regulator installed at the upmost part of the watercourse.

The flow pattern and the major regulators in the lower reaches from Nakhon Sawan are shown in Fig. 8-3. The flow capacities of the main watercourses were designed without taking into account the flood control effect to the Chao Phraya River, but determined basically from the required irrigation water in each irrigation area in the rainy season.

Regulators/Gates

The location of major regulators in the lower basin from Nakhon Sawan is shown in Fig. 8-4 and the structural features are given in Table 8-4. Regulators on the main watercourses are meant to control the discharge through the gate and adjust the water level, so that the distribution of water into the main canals can be done smoothly. Some of the characteristics of the main regulators are as follows:

(1) All main regulators have satisfactory capacity to pass the design flow of the channel.

(2) In places where the regulators are installed, the river width is narrowed.

(3) Critical flow occurs at most regulators, because changing points of bed slope or head of riverbed are placed at the regulators.

(4) All gates are hand-operated.

2.4 Flood Protection Dikes

Up to the present, flood protection dikes are constructed mainly along the Chao Phraya River. Flood protection dikes are also found in some portions of the Pasak, the Lop Buri, the Suphan, the Noi and the Yom rivers.

(1) Flood Protection Dikes in the Lower Reaches from Nakhon Sawan

The vast plain of the Chao Phraya River can be divided into two parts. One is the upper area with a gentle slope of ground surface going from north to south direction in the north of Ayutthaya. The other is the flat low-lying area in the south of Ayutthaya.

Flood protection dikes in each area have slightly different characteristics in shape, function and design condition. Fig. 8-5 gives the existing dike alignment.

Upper Reaches from Ayutthaya

Flood protection dikes in this section were constructed on the basis of the development of irrigation system. In general, dikes of irrigation canals running in parallel with the Chao Phraya River are used as the river dikes which are to prevent flood damage in the cultivated area. More specifically, they are the right side dike of Chai Nat-Ayutthaya Canal and the left side dike of Il-Borommathat Canal. Besides, some portions of roads also serve as flood protection dikes.

(a) Dike Elevation

Flood protection dike in this section was designed based on a 25-year return period flood considering the freeboard of about 0.5 m. However, in 1983 the lower portion was seriously damaged by the high flood water level of the river. After this flooding, the dike elevation was raised higher than the flood water level of the 1983 flood with a freeboard ranging from 0.5 m to 1.0 m.

Fig. 8-6 presents the longitudinal profile of the dike. Raising work on dikes is still underway.

(b) Dimension of Dike

Typical cross sections of the dike are described in Fig. 8-7. Dikes along the river have a minimum crest width of 3.0 m. When used as both canal dike and road, the crest width of 6.0 m or wider is adopted.

The height of the dike ranges from 1.0 m to 3.0 m, and the average slope takes 1:2. Concerning dike materials, sandy loam and sandy clay loam which are available at the job site are primarily utilized. Lateritic soil is also used mainly for the upper portion of the dike.

Lower Reaches of Ayutthaya

Dikes in the area south of Ayutthaya were constructed to prevent not only the overflow from the Chao Phraya River but also the inflow from the north and east areas of the Bangkok metropolis.

(a) Ayutthaya to Bangsai

Dikes of both drainage channel and feeder road running in parallel with the Chao Phraya River function as the flood protection dike of the river. Raising works on the dikes have been implemented by the Royal Irrigation Department (RID) after the 1983 flood.

(b) Bangkok and Its Vicinity

A polder system was proposed for flood protection and drainage in 1968. On the occasion of the 1980 and 1983 floods, construction of a permanent flood protection barrier consisting of dikes of khlongs, road and gates was executed. The average elevation of the dike was set at about 3.0 m MSL.

(c) West Bank Area

Most of the west bank area especially the northern part is characterized as a conservation area. Dikes aiming for flood protection against flooding from the Chao Phraya River have not been constructed. Instead, only the embankments for road and railway built in the urban area play the role of flood protection dikes, but they are not sufficient for the purpose. At present, a polder system in the urban area is under feasibility study and detail design.

(2) Yom River Flood Protection Dike

The Yom River Flood Protection Dike was constructed from 1982 to 1983 to protect the Phitsanulok Irrigation Project from flooding of the Yom River. This dike is approximately 164 km long, and its alignment is along the left bank of the Yom River from the Phitsanulok-Bang Rakam Highway to the Yom-Nan confluence. The location and the typical cross section of the dike are presented in Fig. 8-8.

(a) Condition of the River

A 20-year return period flood with 890 m^3/s peak discharge on the Yom River was adopted.

(b) Dimension of the Dike

The dike was designed to serve as a farm road with a top with of 6 m and a side slope of 1:2. It has an average height of 2.3 m.

3. Management and Operation of River Structures

3.1 Operation of Bhumibol and Sirikit Dams

Management and Operating Principles

The Bhumibol and the Sirikit dams/reservoirs are managed by EGAT and RID, in coordination with each other, to satisfy the requirements of power and downstream water demands. RID is primarily responsible for irrigation and released water activities, and EGAT is primarily responsible for power generation.

In principle, the actual gate operation of both dams is made by EGAT. EGAT controls the water releases from the reservoirs to meet hydroelectric generation needs, taking into account the required water releases for irrigation requested by RID.

Fig. 8-9 shows the irrigation demand requested by RID, together with the actual releases made by EGAT.

Operation Rule

The storage level and reservoir release from each dam are managed through the upper and lower operation rule curves established for each reservoir by EGAT. The present operation rules are summarized as follows:

(1) When reservoir levels are above the Upper Rule Curve, extra energy is generated to avoid unproductive spill.

(2) When reservoir levels are between the upper and the lower rule curves, EGAT releases water primarily to satisfy downstream demands requested by RID.

(3) When reservoir levels are below the Lower Rule Curve, releases are reduced or restricted. In this case, releases are made to meet the minimized request for downstream water demand.

With reference to flood control function, both dams control flooding water by using the capacity between the Normal High

Water Level and the Upper Operation Rule Curve Level. The operation rule curves for both dams, together with the recent storage level records, are presented in Fig. 8-10.

Operating Practice

The recent operating practice on the dams was investigated from the aspect of hydropower generation demand and irrigation water demand. The recent operating practice/policy is to increase storage as much as possible during the rainy season by minimizing releases for hydropower so as to assure water for irrigation in the dry season. This operating policy contributes directly to the promotion of flood control by the dams. The present situation of hydroelectric generation and irrigation water supply and demand are described hereinafter.

(1) Hydropower Generation

The installed capacity of electrical systems in Thailand and the peak load of generation are shown in Fig. 8-11. As of June 1987, the maximum daily peak load reaches about 5,000 MW. On the other hand, the total installed capacity is 6,640 MW as of November 1986. This means that the present supply of electricity satisfactorily meets the demand.

Of all power generation, hydropower occupies about 30% at present. With respect to the dependence on both the Bhumibol and Sirikit dams, as shown in Table 8-6, the rate is decreasing and it marks 13.8% as of November 1986. This is due to the notable increase of newly developed hydropower generation plants. Though dependence on the hydropower plants became low, they still contribute to system capacity and energy requirement, just in case "forced outages" of major thermal plants happen.

(2) Irrigation

The irrigation areas supplied with water from both reservoirs are as follows:

Dam	Irrigation Area	Area (ha)	
		Dry Season	Rainy Season
Bhumibol Dam	Ping River Basin	64,000	240,000
	Central Chao Phraya Plain	400,000	-
Sirikit Dam	Nan River Basin	110,000	
	Central Chao Phraya Plain	636,000	-

As can be seen in Fig. 8-9, irrigation demands on reservoirs rise in the dry season from the months of February to April, and fall in the rainy season from September to November. The actual releases by EGAT are nearly suited to the amount requested by RID in the dry season. On the other hand, even if irrigation demand is extremely low or zero in the rainy season, releases of about 100 m^3/s to 200 m^3/s are made. This is because EGAT requires a minimum reservoir release to maintain the contribution of the hydropower plants to the overall system.

(3) Others

Salinity control in the southern portion of the Central Plain, navigation, and municipal and industrial water supply are also dependent on reservoir releases from the dams. In practice, a minimum discharge of 75 m^3/s is needed for navigation, salinity control, and municipal and industrial water supply.

Operation Records

The reservoir records of recent flood years on storage level and the relationship between inflow and outflow are shown in Figs. 8-12 to 8-13. From the figures, the following are recognized:

(1) During flood season, recent releases from each reservoir tend to be reduced to less than 100 m^3/s.

(2) Flood control effect of these two reservoirs shows inflow reduction of 1,000 to 1,500 m^3/s.

(3) The storage levels of both reservoirs exceeded the Normal High Water Level only in 1975.

(4) Since the 1975 flood, the storage levels tended to recede, and consequently, fell below the Lower Operation Rule Curve, especially from the late dry season to the early wet season in most recent years.

(5) Ripples of the outflow waves are attributed to the difference of demands of electricity between Sundays and other days.

3.2 Operation of Barrages and Regulators

Management and Operation Principles of Barrages and Regulators

River structures related to water control are managed by RID through the coordination of its head office (O&M Division) in Bangkok, its regional offices and project offices. The executing body for management and maintenance varies depending on purpose, scale and importance of structures. Hence, major river structures are managed and maintained by each regional office, and other small-scale ones by each project office having jurisdiction over them.

The basic operating principle for structures was established based on the irrigation system. The head office (O&M

Division) periodically obtains hydrological data, crop data, water demands, etc., (flooding data in times of flood) of each project through communication with each regional and project office. Water allocation is determined on the basis of these data and the simulated output. Depending on the water allocation determined, each river structure is operated; major ones by regional offices, small-scale ones by project offices.

Operation of the Chao Phraya Dam and Head Regualtors

(1) Distribution of Flood Flow at the Chao Phraya Dam

The basic operation rule is that the design flow is diverted into each main watercourse by means of gate operation of the Chao Phraya Diversion Dam and other head regulators, and any surplus water will be released down the Chao Phraya River. At the time of an extraordinary flood, surplus water far beyond the allowable flow capacity is supposed to be released through the emergency spillway behind the dam to the retarding basin. Recently, however, use of the spillway has been avoided owing to the social problems.

(2) Present Operation Rule of the Chao Phraya Dam

The Chao Phraya Dam is normally operated by RID through the coordination between its head office and its Regional Office No. 7. The procedure of operation is that the head office determines the required releases from the dam and conveys them to Regional Office No. 7, and this office commences the gate operation according to the request.

Although no specific operation rule for the dam has been established, practically, the following operations are taken:

(a) The water level behind the dam is managed to remain at EL +16.50 m MSL to assure the diversions into each main watercourse for irrigation.

(b) The water head between the upstream and downstream is controlled at less than 9.5 m to assure structural stability.

(c) A minimum discharge of 75 m^3/s is needed for navigation, salinity control and municipal water supply.

(3) Operation Records

Records on gate operation including discharge and water level at the major floods in 1975, 1978, 1980 and 1983 are presented in Fig. 8-14. Details of operation records in each peak discharge are as shown in the following table.

Year	Peak Discharge (m^3/s)	Water Level (m MSL)		Gate Opening	Rate of Opening (%)
		Upstream	Downstream		
1975	3,980	+16.38	+16.37	6.7m x 15 5.7m x 1	91
1978	3,769	+16.52	+16.22	3.9m x 4 6.1m x 12	76
1980	3,825	+16.88	+16.67	7.2m x 12 (unknown)	Over 90
1983	3,370	+16.75	+16.52	6.6m x 16	90

Through investigation of the records, the following are pointed out:

(a) Compared to the design discharge of 3,300 m^3/s, peak discharges of each flood exceeded highly and stayed at longer periods of 5 to 22 days.

(b) Upstream water levels are kept nearly at EL +16.50 m MSL, which is the operating water level. (Incidentally, the crest elevation of the emergency spillway was set at EL +17.00 m MSL.)

(c) A turning pin of the radial gate was completely submerged during each flooding period, because the downstream water levels rose close to the upstream water level.

(d) The gates were opened at the opening rate of over 90%, except one in 1978. In 1980, the width of gate opening reached 7.2 m, which compares with the maximum estimated width of 7.3 m.

Based on the records obtained, the maximum flow capacity of the Chao Phraya Dam can be estimated. Assuming that the upstream water level is at EL +16.50 m MSL, the maximum flow capacity/discharge would be around 4,000 m^3/s with a gate opening rate of 100%. (Refer to Fig. 8-15.)

Operation of Major Regulators/Gates

(1) Operating Procedure

The head office of RID determines the water allocation for each main watercourse, taking crop data, irrigation demand, hydrological data and simulated output into consideration. Based on its instructions, regional offices perform gate operation of the head regulators. Other main regulators, in general, are operated by regional offices in accordance with water operation rule curves established for each regulator. In this case, water level-discharge conversion tables are used to estimate the appropriate amounts of release.

In time of flood, in addition to the operation rule curve, flooding condition and growing condition of rice in each project area are considered. Gate operation is made through the coordination among the head office and each regional and project offices.

(2) Records of Discharge from the Major Regulator

In connection with gate operation, the records of maximum discharge from the head regulators, together with the discharge from the Chao Phraya Dam, are given in Table 8-7 and the records of discharge through the major regulators on each watercourse are shown in Figs. 8-16 to 8-18. From these data, the following comments can be made.

(a) When peak flood flows occur in the Chao Phraya River, releases from each head regulator are nearly commensurate with the design flow, although some excess flows were observed at the Manorom Regulator.

(b) In the Suphan River, judging from the recent discharge records (refer to Fig. 8-16), gate operation during flood time seems to have been performed, so that inflow of flood is released directly downstream.

(c) In the Noi River, flood flows released through the Borommathat Regulator are reduced when they rejoin the Chao Phraya River, because the flood flows as they go downstream are distributed into the irrigation canals in each project by the gate operation of the main regulators. (Refer to Fig. 8-17.)

(d) In the Chai Nat-Pasak Canal, compared to the design flow, the excess flows were observed at the Manorom and Reong Rang regulators. In addition, the

releases of about 100 to 150 m^3/s are distributed into the East Bank Irrigation Area even in flood time. (Refer to Fig. 8-18.)

Operation for Other Major Barrages

(1) Rama VI Dam/Barrage

Records of the gate operation in major flood years are presented in Fig. 8-19. The gate operation is primarily made to control the water level behind the barrage at about EL +7.50 m MSL to assure the water supply for the East Bank Irrigation Area. The Phranarai Regulator installed next to this barrage controls the water release ranging from about 50 to 150 m^3/s. At the time of Pasak river flood, the gate is opened to pass the flood flow safely.

(2) Phitsanulok Diversion Weir

To enable the stable intake, the water level is adjusted to around EL +47.50 m MSL throughout the year. Dealing with the Nan river flood, the gate is fully opened, and inflow-outflow relationship is mostly kept (refer to Fig. 8-20). Besides, the discharge at the weir is dependent on the release from the Sirikit Dam.

4. Flood Control Effect of Existing River Structures

The existing river structures are now operated principally for water use such as irrigation, hydropower generation, and municipal water supply. As for the purpose of flood control, the existing structures have a minor priority, and the integrated operation of the structures are not carried out to protect certain areas from flood damage. Since large potentials of flood control function are expected from some existing river structures such as Bhumibol and Sirikit dams, effectiveness of these structures from the flood control aspect is examined in this section.

Among the existing river structures in the basin, the Chao Phraya Dam and main regulators, the Bhumibol Dam, the Sirikit Dam, and the Kiu Lom Dam are expected to have flood control effect to the target area selected in this study. The effectiveness of these structures are specified as follows:

(1) Chao Phraya Dam and Main Regulators

Chao Phraya Dam and main regulators contribute to mitigation of flood discharge flowing down to lower reaches through the distribution of flood water to the four (4) main watercourses of Chai Nat-Pasak Canal, Chai Nat-Ayutthaya Canal, Noi River and Suphan River.

As for the flood discharge from the upper basin of Nakhon Sawan and from Sakae Krang River Basin, approximately 850 m^3/s of flood discharge at maximum can be diverted to these four main watercourses from the main river through the operation of Chao Phraya Dam and the four main regulators. According to the previous operation records of the dam and the four main regulators, RID pays full attention to the appropriate operation of these structures during a flood and executes the operation to mitigate flood damage in the lower reaches by bringing the flood control effect of the structures to the maximum extent. In this connection, it may be hard to find out more room for the alternative operation of these structures within the present operation rule.

(2) Bhumibol, Sirikit and Kiu Lom Dams

Present Regulation Rule

As aforementioned, these three dams are managed through the upper and lower operation rule curves summarized as follows:

(a) When reservoir levels are above the Upper Rule Curve, extra energy is generated to avoid unproductive spill.

(b) When reservoir levels are between the upper and the lower rule curves, EGAT releases water primarily to satisfy downstream demands requested by RID.

(c) When reservoir levels are below the Lower Rule Curve, water releases are reduced. In this case, releases are made to meet the minimized request for downstream water demand.

Previous Operations for 1978, 1980 and 1983 Floods

According to the previous operation records of the 1978, 1980 and 1983 floods, the three dams released the discharge during flood time for the purpose of hydropower, though the amount of the released discharge is remarkably reduced compared with that of inflow discharge to the reservoir. Since the water stage of the reservoir of these dams are below the upper rule curve, further flood control effect can be expected through the retention of water released for hydropower within the present operation rule (refer to Fig. 8-10).

To know the further effectiveness on flood control, runoff calculation was made by using the flood prediction model developed in this study assuming that the released discharge from these dams is zero. The calculation results are shown in Table 8-8.

Judging from this table, further effectiveness on flood control is expected between 100 m^3/s and 250 m^3/s at Nakkon Sawan within the present operation rule when the released discharge for hydropower is retained in the reservoir for several days while the water stage in the reservoir is still below the upper rule curve.

Operation for 1975 Flood

In this flood, the maximum water level of the reservoir was over the upper rule curve and reached the normal high water level. Therefore, there may be less possibility for further effectiveness through the retention of flood water in the reservoir. However, as far as the operation of Sirikit Dam is concerned, the following matters may be pointed out:

(a) The water level of the reservoir had been over the upper rule curve from August until the middle of October. Consequently, there was little room for flood control operation when the flooding condition in the lower reaches was the most serious in October. As noted, the peak discharge of 4,300 m^3/s at Nakhon Sawan emerged in the middle of October.

(b) It may have been possible to lower the water level of the reservoir until the end of August by increment of released discharge, so that the released discharge might be within the flow capacity of the lower reaches. The flood discharge at Nakhon Sawan at that time had been in the range between 1,000 m^3/s and 1,600 m^3/s.

(c) By using the remaining storage capacity of about 1.5×10^9 m^3 between the upper rule curve as of August and the normal high water level, it may have been possible to execute dam operation for further flood discharge mitigation.

(d) In case the said capacity is effectively used for flood control, the flood discharge at Nakhon Sawan may have been reduced by approx. 300 m^3/s judging from the released discharge record between 300 m^3/s and 400 m^3/s during the flooding time in October.

(e) Since these structures are mainly operated for water use as aforementioned, flood control effect is not expected so much compared with the potential of flood function of these structures, which may be found out from the operation records of the 1975 flood. In this connection, review of the operation rule putting emphasis on the operation for flood control is considered.

TABLES

Table 8-1. PRINCIPAL FEATURES OF BHUMIBOL DAM

Particulars		Features
General Data	° River System and River Name	Chao Phraya Basin; Ping River
	° Year of Completion	1964
	° Purpose	I; P; F /1
	° Catchment Area	26,386 km^2
Dam	° Type	Concrete Arch Gravity Type
	° Height	154.0 m
	° Crest Elevation	261.0 m (MSL)
	° Crest Length	486.0 m
Reservoir	° Maximum High Water Level (HWL)	262.2 m (MSL)
	° Normal HWL	260.0 m (MSL)
	° Minimum HWL	213.0 m (MSL)
	° Available Drawdown	47.0 m
	° Storage at Normal HWL	13,462 x 10^6 m^3
	° Storage at Minimum HWL	3,800 x 10^6 m^3
	° Effective Storage	8,600 x 10^6 m^3
	° Minimum Water Level for Power Operation	213.0 m (MSL)
	° Minimum Water Level for Irrigation	202.5 m (MSL)
Spillway	° Type	Tunnel Type
	° Crest Elevation	242.9 m (MSL)
	° Control Gate	Radial Gate (11.0m wide x 17.4 m high x 4)
Intake Structure	° Intake Gate	7 Fixed Wheel Gates
	° Gate Size	4.2m x 6.7m
	° Base Elevation of Inlet	201.0 m (MSL)
Discharge	° Design Flood Discharge	6,000 m^3/s
	° Maximum Flood Recorded	4,500 m^3/s (1975)
	° Discharge Capacity of Spillway	6,000 m^3/s
	° Discharge Capacity of River Outlet	200 m^3/s (Use No. 8 Penstock)
	° Discharge for Maximum Power Output Per Unit (No. of Turbines: 7 units)	
	- At Max. Head (123.2m)	75.8 m^3/s
	- At Nor. Head (100.0m)	79.5 m^3/s
	- At Min. Head (71.8m)	61.0 m^3/s

Note: /1 I = Irrigation; P = Power Generation; F = Flood Control

Table 8-2. PRINCIPAL FEATURES OF SIRIKIT DAM

Particulars		Features
General Data	° River System and River Name	Chao Phraya Basin; Mae Nan River
	° Year of Completion	1972
	° Purpose	I; P; F /1
	° Catchment Area	13,130 km^2
Dam	° Type	Earthfill Dam
	° Height	113.6 m
	° Crest Elevation	169.0 m (MSL)
	° Crest Length	800.0 m
Reservoir	° Maximum High Water Level (HWL)	166.0 m (MSL)
	° Normal HWL	162.0 m (MSL)
	° Minimum HWL	128.0 m (MSL)
	° Available Drawdown	34.0 m
	° Storage at Normal HWL	9,510 x 10^6 m^3
	° Storage at Minimum HWL	2,850 x 10^6 m^3
	° Effective Storage	8,800 x 10^6 m^3
	° Minimum Water Level for Power Operation	128.0 m (MSL)
	° Minimum Water Level for Irrigation	105.75m (MSL)
Spillway	° Type	2 Tunnels, horse shoe section
	° Crest Elevation	150.5 m (MSL)
	° Control Gate	Radial Gate (11.85m wide x 15.00 m high x 2)
Intake Structure	° Intake Gate	1 Fixed Wheel Gate
	° Gate Size	6.0m wide x 8.5m high
	° Base Elevation of Inlet	105.75m (MSL)
Discharge	° Design Flood Discharge	8,000 m^3/s
	° Maximum Flood Recorded	/2 m^3/s (1975)
	° Discharge Capacity of Spillway	3,250 m^3/s
	° Discharge Capacity of River Outlet	400 m^3/s
	° Discharge for Maximum Power Output Per Unit (No. of Turbines: 3 units)	
	- At Max. Head (84.3m)	194.3 m^3/s
	- At Nor. Head (75.4m)	183.0 m^3/s
	- At Min. Head	/2 m^3/s

Note: /1 I = Irrigation; P = Power Generation; F = Flood Control
/2 = Data not available

Table 8-3. FEATURES OF MAJOR DAMS IN CHAO PHRAYA RIVER BASIN

Features	Unit	Mae Kuang Dam	Mae Ngat Dam	Kiu Lom Dam	Krasieo Dam
Location		Lat. 18°55'32"N Long. 99°7'41"E	Lat. 19°9'29"N Long. 90°2'23"E	Lat. 18°31'19"N Long. 99°37'34"E	Lat. 14°49'57"N Long. 99°39'41"E
River System		Ping River	Ping River	Wang River	Krasieo River
Purpose		I, H, F	I, H, F	I, H, F	I, F
Year of Completion		1990 (Expected)	1985	1981	1981
Catchment Area	km^2	565	1,281	2,700	1,220
Annual Mean Runoff	m^3	249.76 x 10^6	406 x 10^6	574 x 10^6	165 x 10^6
Design Flood Discharge	m^3/s	1,470	1,570	2,900 (Emergency Spillway)	260
Dam: Type		Zoned Earthfill	Zoned Earthfill	Concrete Gravity	Earthfill
Height	m	61.00	59.00	26.50	32.50
Crest Elevation	m (MSL)	+400.00	+404.00	+286.50	+92.50
Crest Length	m	700.0 (Main Dam)	1,950.0	142	4,250
Emergency Spillway:					
Type		/1	Chute	Ogee; Gated	Overflow; Ungated with crest length of 20m
Max. Discharge	m^3/s	/1	1,035	/1	260
Control Gate		/1	Radial (3x12.50mWide x6.0mHigh)	Radial (5x13mWide x8mHigh)	/1
Crest Elevation	m (MSL)	/1	+394.00	/1	+87.00
Reservoir:					
Gross Capacity	m^3	400 x 10^6	325 x 10^6	112 x 10^6	390 x 10^6
Effective Capacity	m^3	390 x 10^6	265 x 10^6	106 x 10^6	200 x 10^6
Area	km^2	15	16	16	48
Drawdown	m	/1	35.5	13	9
Max. Water Level	m (MSL)	+398.00	+400.00	+285.00	+90.64 (HWL)
River Outlet:					
Type		Steel-lined Concrete Conduit	Concrete Conduit with Steel Liner	Steel Conduit	Steel-lined Concrete Conduit
Diameter	m	3.0	2.50	1.2	2.50
Max. Discharge	m^3/s	40.0	47.0	21.0 - 35.6	18.0
Discharge for Maximum Power Output	m^3/s	/1	15.0	/1	/1
Irrigation Area	ha	28,000	30,080	21,280	20,800

Note: /1 Data not available; I = Irrigation; H = Hydropower Generation; F = Flood Control

Table 8-4. MAJOR RIVER STRUCTURES IN CHAO PHRAYA RIVER BASIN (LOWER BASIN FROM NAKHON SAWAN)

Water Course	Name of Structure	Location (Province)	Structural Features				Full Supply Level (m MSL)		Flood Level (m MSL)		Design Flow (m^3/s)
			Gate			Sill Elevation (m MSL)	Upper	Lower	Upper	Lower	
			Type	Number	Width (m)						
Chao Phraya River	Chao Phraya Dam (Barrage)	Chai Nat	* Radial Gate	16	12.50	+9.00	+16.50	+7.50	+18.00	+16.00	3,300.0
			* Miter Gate	1	14.00	+9.00					
Suphan River	* Phonlatep Head Regulator	Chai Nat	Slide Gate	4	6.50	+7.50	+16.50	+13.90	+19.40	+15.86	320.0
	* Ban Thabot Regulator	Chai Nat	Radial Gate	4	6.00	+8.75	+13.50	+9.80	+13.73	+13.68	318.0
	* Sam Chook Regulator	Suphan Buri	Slide Gate	2	12.50	+2.50	+9.15	+6.30	+9.52	+9.31	318.0
	* Pho Phraya Regulator	Suphan Buri	Slide Gate	2	12.50	+0.20	+6.00	+0.75	+5.91	+5.82	318.0
Noi River	* Boromma-that Head Regulator	Chai Nat	Radial Gate	4	6.00	+9.60	+16.00	+15.10	+18.24	+16.20	260.0
	* Chanasut Regulator	Sing Buri	Radial Gate	4	6.00	+5.72	+11.60	+9.73	+11.84	+11.40	260.0
	* Yang Hani Regulator	Sing Buri	Radial Gate	4	6.00	+2.32	+7.74	+6.16	+7.74	+7.30	260.0
	* Phak Hai Regulator	Ayutthaya	Radial Gate	3	6.00	-2.00	+3.50	+3.30	+3.50	+3.30	150.0
Chai Nat-Pasak Canal	* Manorom Head Regulator	Chai Nat	Radial Gate	6	6.00	+12.80	+16.472	+16.142	+20.00	+16.142	210.0
	* Chongkae Regulator	Chai Nat	Radial Gate	6	6.00	+9.50	+13.390	+13.150	-	-	207.0
	* Koke Kathiem Regulator	Lop Buri	Radial Gate	4	6.00	+6.29	+10.79	+10.59	-	-	174.1
	* Reong Rang Regulator	Saraburi	Radial Gate	3	6.00	+3.97	+8.53	+8.27	+9.810	+9.810	131.0
Chai Nat-Ayutthaya Canal	Maharaj Head Regulator	Chai Nat	Radial Gate	3	4.00	+11.60	+16.00	+15.50	+18.00	-	75.0
Maksathao-Uthong Canal	Maksathao-Uthong Head Regulator	Chai Nat	Slide Gate	6	1.75	+13.75	+16.10	+15.95	-	-	35.0
Pasak River	Rama VI Barrage	Saraburi	Slide Gate	6	12.50	+0.10	+7.50	-	+9.81	-	Unknown

Table 8-5. MAJOR RIVER STRUCTURES IN CHAO PHRAYA RIVER BASIN
(UPPER BASIN FROM NAKHON SAWAN)

Water Course	Name of Structure	Location (Province)	Structural Features					Retention Level (m MSL)	Flood Level (m MSL)		Design Flow (m^3/s)
			Type	Number	Width (m)	Height (m)	Sill Elevation (m MSL)		Upper	Lower	
Yom River	Mae Yom Weir	Phrae	Fixed Weir & Rubber Dam	5	68.80	3.50	+178.00	+181.50	+183.75	+183.00	3,000
Nan River	Phitsanulok Diversion Weir (Naresuan Dam)	Phitsa-nulok	Movable Radial Gate	5	12.50	7.60	+40.20	+47.80	+50.35	+49.75	1,600
Thap Salao River	Thap Salao Diversion Weir	Uthai Thani	Fixed Weir	6 2 2	8.0 9.9 3.0	3.00	+71.00	+74.00	+77.25	+76.40	700
Yom to Nan River (Curtain Canal)	Control Regulator	Phitsa-nulok	Radial Gate	2	6.0	4.00	+33.975	/1	+37.675	+36.750	85
Yom to Nan River (DR 15.8 Canal)	Control Regulator No. 1	Phitsa-nulok	/1	/1	/1	/1	/1	/1	/1	/1	60
	Control Regulator No. 2	Phitsa-nulok	/1	/1	/1	/1	/1	/1	/1	/1	60

Note: /1 Data not available yet.

Table 8-6. ENERGY GENERATION IN THAILAND IN 1977, 1983 AND 1986

Plant	1977 Installed Capacity (MW)	1977 (% of Total)	1983 Installed Capacity (MW)	1983 (% of Total)	1986 Installed Capacity (MW)	1986 (% of Total)
Hydroelectric						
Bhumibol	420.0	17.2	535.0	10.7	535.0	8.1
Sirikit	375.0	15.4	375.0	7.5	375.0	5.7
Others	114.0	4.7	587.1	11.8	1,104.5	16.6
Sub-Total	909.0	37.3	1,497.1	30.0	2,014.5	30.4
Thermal						
North Bangkok	238.0	9.7	237.5	4.8	237.5	3.5
South Bangkok	1,000.0	41.0	1,300.0	26.0	1,300.0	19.6
Others	96.0	3.9	1,180.0	23.6	2,070.0	31.2
Sub-Total	1,334.0	54.6	2,717.5	54.4	3,607.5	54.3
Diesel	30.0	1.2	33.6	0.7	31.6	0.5
Gas Turbine	169.0	6.9	745.0	14.9	745.0	11.2
Combined Cycle	-	-	-	-	240.0	3.6
Total	2,442.0	100.0	4,993.2	100.0	6,638.6	100.0

Note: Figures indicate contributions to the system peak in June 1977, 1983, and November 1986.

Source: EGAT

Table 8-7. MAXIMUM RELEASED WATER FROM MAJOR DIVERSION STRUCTURES

(Unit: m^3/s)

Water Course and River Structure	Design Flow	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Chao Phraya River		1975	219	106	81	91	137	285	271	371	2,037	3,572	1,414	615
		1978	127	101	77	75	97	102	1,069	1,066	1,062	2,983	546	188
° Chao Phraya Dam	3,300	1980	74	58	66	70	161	472	392	677	1,320	3,270	943	258
		1983	97	97	103	101	95	119	81	356	614	2,071	2,174	626
Chainat-Pasak Canal		1975	47	63	90	114	109	127	164	211	258	227	187	44
		1978	32	64	78	87	50	58	77	141	175	48	206	80
° Manorom Regulator	210	1980	52	21	36	35	88	148	166	181	136	144	188	52
		1983	100	134	128	143	128	107	81	152	138	68	158	75
Noi River		1975	32	48	72	74	64	53	91	188	140	198	224	59
		1978	31	43	59	65	56	58	43	122	192	129	211	98
° Borommathat	260	1980	142	114	72	48	54	50	109	186	246	230	118	60
Regulator		1983	38	82	124	124	102	62	51	69	247	164	54	39
Suphan River		1975	11	60	108	113	86	46	63	102	39	208	220	23
		1978	50	39	75	96	78	93	21	81	177	239	156	75
° Phonlatep Regulator	320	1980	30	26	48	51	65	74	95	102	96	210	25	11
		1983	50	106	127	142	123	61	61	42	124	89	6	5
Chainat-Ayutthaya Canal		1975	-	-	-	-	-	-	-	-	-	-	-	-
		1978	-	-	-	-	-	-	-	-	-	-	-	-
° Maharaja Regulator	75	1980	9	18	17	15	14	11	42	63	67	55	48	5
		1983	0	12	23	20	23	5	30	51	63	69	64	3

TABLE 8-8. RUNOFF CALCULATION RESULTS

(Unit: m^3/s)

Year	Peak Discharge At Nkhon Sawan By Present Operation (1)	Case-1		Case-2		Case-3		Case-4	
		Peak Discharge at Nakhon Sawan (2)	Reduced Amount (1)-(2)	Peak Discharge at Nakhon Sawan (3)	Reduced Amount (1)-(3)	Peak Discharge at Nakhon Sawan (4)	Reduced Amount (1)-(4)	Peak Discharge at Nakhon Sawan (5)	Reduced Amount (1)-(5)
1978	3,573	3,472	101	3,455	118	3,530	43	3,316	257
1980	4,377	4,362	15	4,162	215	4,365	12	4,136	241
1983	2,330	2,321	9	2,269	61	2,318	12	2,247	83

FIGURES

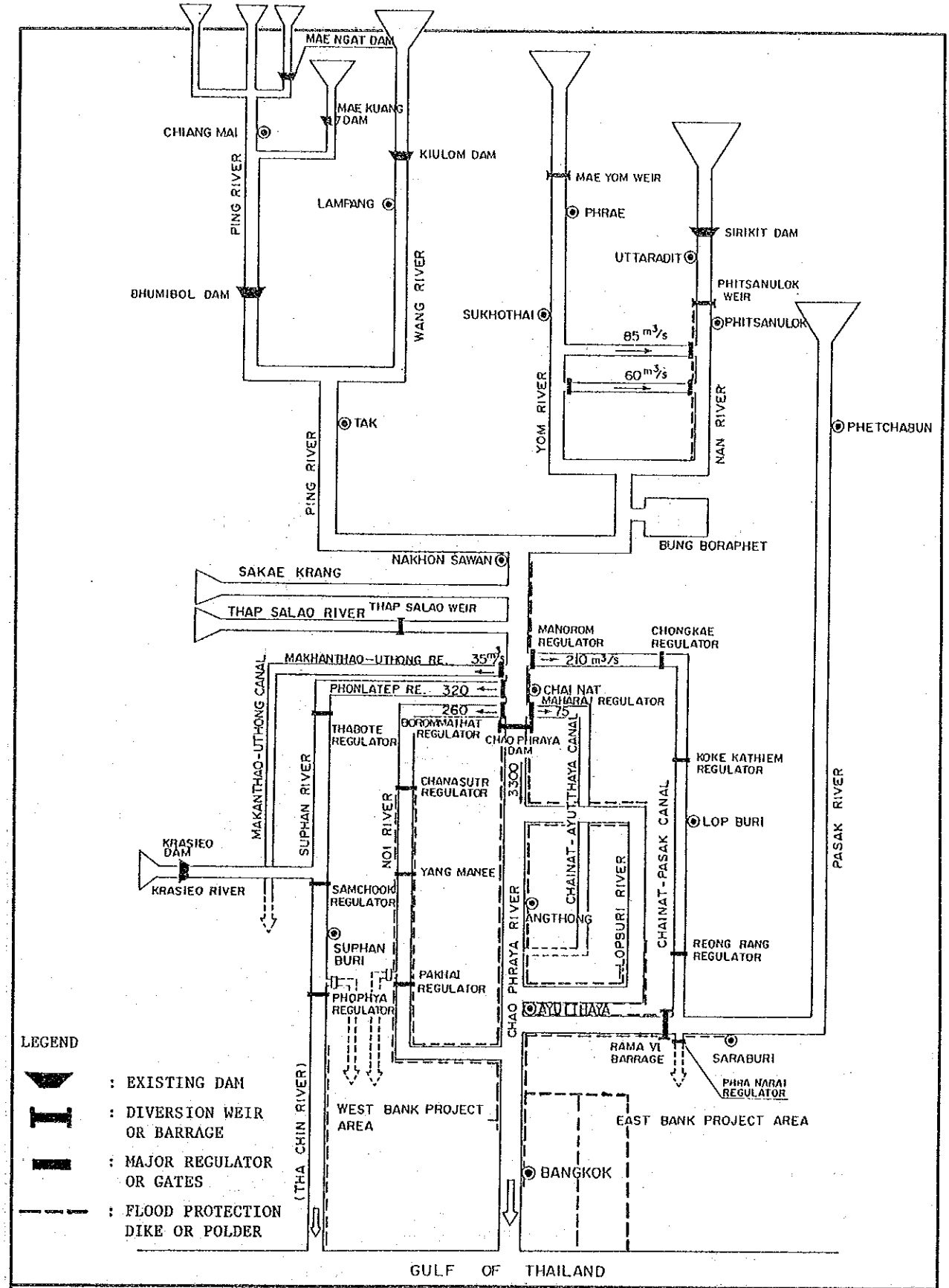

Fig. 8-1. MAJOR RIVER STRUCTURES IN CHAO PHRAYA RIVER BASIN

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

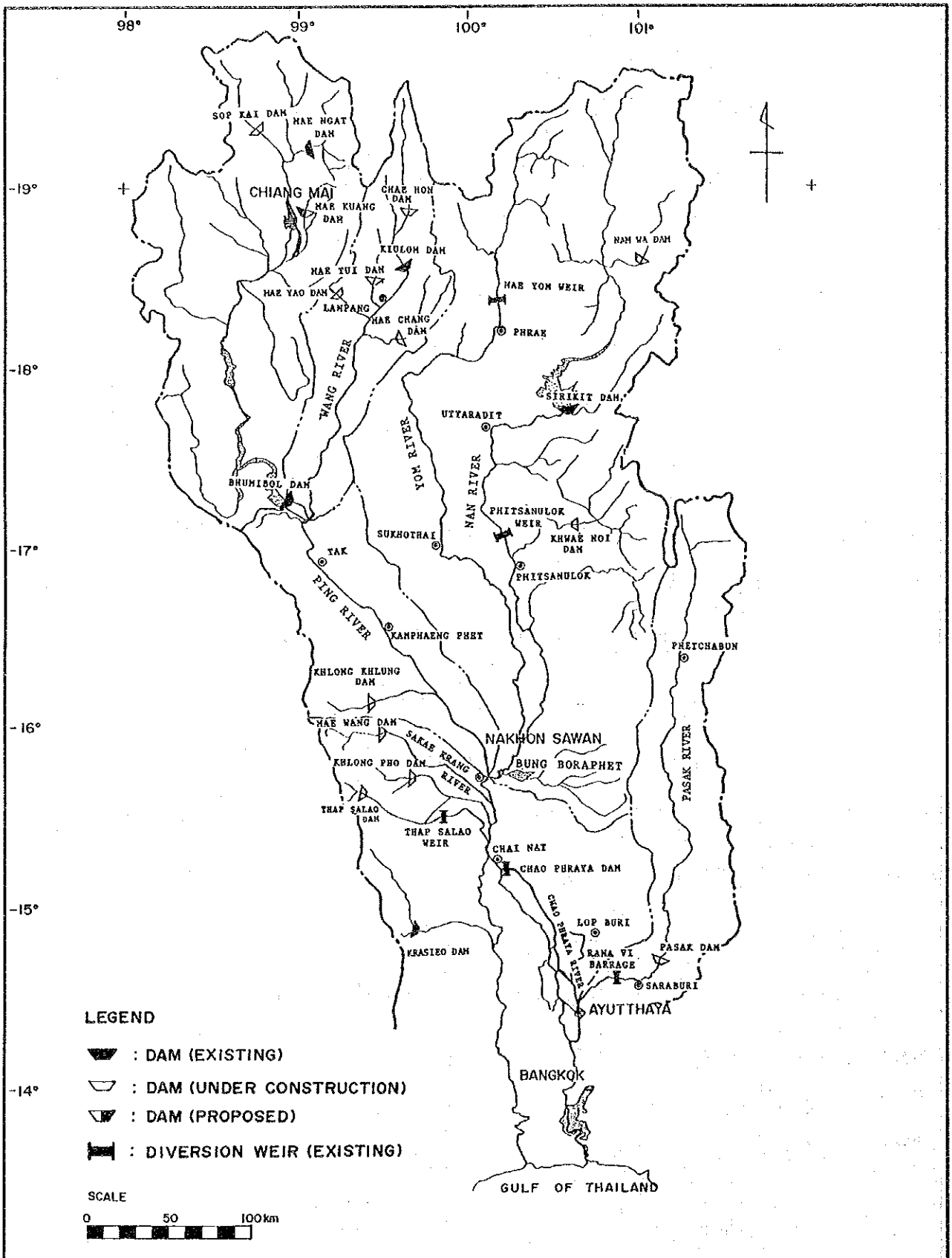

Fig. 8-2. LOCATION OF DAMS AND DIVERSION WEIRS/BARRAGES

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY