2.2 Meteorology

2.2.1 General Meteorology

The climate in the Chao Phraya basin, and Kok and Ing basins are characterized by a distinct wet and dry seasons created by the air movement of the Northeast and Southwest Monsoon. The dry season lasts from November to May when the Northeast Monsoon brings dry stable airflow. March to April is the hottest period presenting a temperature of over 30°C. In June, the Southwest Monsoon is dominant with the prevailing winds bringing in unstable moist air streams, resulting in long period of rainfall. As the wet season progresses, rainfall becomes more intensive and prolonged till July, August and September, which are the months with highest rainfall. Table 2.2.1 shows the general meteorological conditions in the study area.

Table 2.2.1 General Meteorological Conditions in the Study Area

Basin	Temperature (°C)	Relative Humidity(%)	Wind Speed (Knot)	Cloudiness (Deca)	Dew Point (°C)	Pan Evaporation (mm)
Upper Nan	25.3	98.7	0.7	5.2	20.7	1,368
Lower Nan	27.5	71.7	2.0	5.5	21.3	1,746
Kok	24.8	73.9	1.8	5.2	19.2	1,481
Ing	25.4	72.7	1.5	5.2	19.1	1,530

2.2.2 Rainfall Analysis

(1) Gauging Station and Rainfall Data

Monthly rainfall data for the representative stations in the upper and lower Chao Phraya basins, and Kok and Ing basins were collected and compiled in the Supporting Report. Rainfall charts and isohyetal maps of the stations in the Kok, Ing and Nan basins were also prepared based on these data and shown in the Database Map. Annual rainfall and the total for the wet and dry seasons are summarized in the Table 2.2.2.

Table 2.2.2 Mean Annual Rainfall at the Representative Station

Unit: mm

Basin	Station	Mean 1974 - 1984			Mean 1985 - 1996			Ratio	Max	Min
		Wet ①	Dry	Total	Wet ②	Dry	Total	②/①		
Ping	Chiang Mai	886	239	1,125	888	262	1,150	1.00	1,874	795
	Tak	858	215	1,073	804	214	1,018	0.94	1,437	687
Wang	Lampang	779	261	1,040	828	242	1,070	1.06	1,536	651
Yom	Phrae	763	272	1,035	767	319	1,086	1.01	1,550	728
	Sukhothai	934	233	1,167	830	250	1,080	0.89	1,567	677
Nan	Tha Wang Pha	1,069	365	1,434	991	353	1,344	0.93	1,992	957
	Thung Chang	1,286	368	1,655	1,117	401	1,518	0.87	2,135	882
	Nan	952	337	1,289	812	324	1,136	0.85	1,617	705
	Uttaradit	1,106	329	1,435	1,035	367	1,402	0.94	2,106	1,077
	Phitsanulok	1,101	265	1,366	991	317	1,308	0.90	1,767	939
	Phichit	1,184	263	1,447	853	220	1,073	0.72	2,433	736
Sakae Krang	Pangma Kha	1,002	270	1,272	882	269	1,151	0.88	1,815	707
Pasak	Phetchabun	827	240	1,067	745	326	1,071	0.90	1,727	618
Chao Phraya	Nakhon Sawan	833	237	1,070	800	262	1,062	0.96	1,618	606
	Bangkok	1,142	324	1,466	1,209	352	1,561	1.06	2,112	905
Kok	Fang	1,046	267	1,313	1,029	316	1,345	0.98	2,086	831
	Chiang Rai	1429	346	1,775	1,306	324	1,630	0.91	2,320	1,234
	Mae Chan	1,404	395	1,799	1,161	313	1,474	0.83	3,318	943
	Chiang Saen	1,437	390	1,827	1,240	316	1,556	0.86	2,365	1,063
Ing	Phayao	668	251	919	718	247	965	1.07	1,480	566
	Thoeng	1,173	354	1,527	1,058	293	1,351	0.90	2,112	719
	Chiang Kham	1,030	316	1,346	1,006	347	1,353	0.98	1,929	792

(2) Rainfall Characteristics

Mean annual rainfall at the Ping, Wang, Yom, Sakae Krang and Pasak being located in the upper Chao Phraya is slightly small at 1,000 to 1,100 mm as compared with 1,300 to 1,500 mm in the Nan basin, 1,500 to 1,600 mm at Bangkok in the Delta and 1,500 to 1,800 mm in the Kok basin. The rainfall increases generally in the northern and southern region as compared with the central region.

Rainfall in all river basins has decreased slightly in the recent year (1985-96) from the past year (1974-84).

In the station of Wang Pha, Thung Chang, and Nan in the upper Nan basin, rainfall in the recent year decreases fairly to 85 to 90% of that in the past year. This is one of the reasons for the decrease in runoff in the upper Nan basin in the recent year.

As a general trend, rainfall in the mountain area is higher than that in the flat plain. It shows 1,300 to 1,500 mm in the upper Nan and 1,000 to 1,300 mm in the lower Nan.

The rainfall in the Kok and Ing basins shows the high value of 1,500 to 1,800 mm in the lower basin near the Mekong river, while a lower value of 1,000 to 1,300 mm in the upper basin.

About 70-80% of annual rainfall occurs in the wet season and the remaining scarce rainfall in the dry season.

In 1975 and 1995, the large rainfall with a return period of 1 to 20 years occurred and brought about large flood damages in the Chao Phraya and Kok-Ing basins, while the small rainfall with return period of 1 to 5 years happened in 1991 to 1993, and as a result, all river basins suffered from water shortage.

2.3 Hydrology

2.3.1 Gauging Stations and Data

Locations of runoff gauging stations and monthly runoff data in the upper Chao Phraya, Kok and Ing basins were collected and compiled in the Supporting Report. Only the important representative stations which are designated as the monitoring and control stations in future water management, are tabulated as follow:

River Basin	Representative/monitoring Stations
Ping	Bhumibol dam site, P7A (A Muang, Kamphaeng Phet)
Wang	W4A (San Ngao, Lampang)
Yom	Y14 (Si Satchanalai, Sukhothai)
Upper Nan	N51 (Tha Wang Pha, Nan), N17 (Thung Chang, Nan) N1 (A Muang Nan, Nan), Sirikit dam site
Lower Nan	Naresuan barrage site, N5A (A Muang, Phitsanulok) N7 (A Muang, Phichit), N14 (Chung Saen, Phichit)
Pasak	Pasak dam site
Chao Phraya	C3 (A Muang, Nakhon Sawan), Chai Nat barrage site,
Kok	GN3 (B Tha Don), G2A (Chiang Rai bridge), GN15 (Kok Lao), GN1 (B Tha Kok)
Ing	IN3 (Pra Mong), IN2 (Khao Ing Rod), IN1 (A Thoeng)

Summary of the main runoff features and basin characteristics of the above stations are tabulated in Table 2.3.1. Since the stations in the table have different record length and the mean values were taken over the different periods, the table can give only a general overview of the basins.

The locations of the main gauging stations in the Kok, Ing and Nan basins are shown in Figure 2.3.1(a) and (b). The hydrology of these three basins had been studied in detail by a parallel Thai side study. For consistency of analysis, the water (hydrological) year is taken as to be started from April and ending at the following March. The data for analysis in this study had been updated to include the hydrological year 1994-1996. Emphasis was given on seasonal and monthly distribution of river runoff to enable more detailed study on the diversion strategy.

2.3.2 Seasonal and Annual Runoff Variation

The runoff patterns of the rivers in the Study Area have similar characteristics and show similar patterns of wet and dry season runoff variations.

- Most of the rivers present rich runoff in the wet seasons (June-November) but scanty runoff in the dry seasons, corresponding to the rainfall patterns. Increase in runoff generally appears in June-July, when the dry sub-soils in the basin become saturated with rains falling in May-June. Runoff reaches its peak in August-September, bringing floods to the plains occasionally. Wet or dry year is determined primarily by the runoff from July-September. Runoff in these 3 months is about 60-70% of the annual runoff.
- Runoff in the recent years (1985-1996) shows a decreasing trend compared with that in the past year (1974-1984). This is probably due to a combined effect of decrease in annual rainfall and increase in water use by irrigation development in the upstream reaches of the basins.
- Runoff in the lower Nan and Ping basins is relatively large in dry season due to the water released from the Sirikit and Bhumibol dams.
- The Kok river has fairly rich dry season runoff. A large part of this runoff comes from the 3,000 km^2 of relatively undeveloped catchment in the Myanmar territory.

The characteristics of runoff variation at the key stations are summarized as follows:

Table 2.3.1 Hydrological Features of the Rivers in the Study Area

River and Station		Drainage area	Annual Average Runoff (MCM)			Runoff Yield	Annual Runoff		Discharge		Specific Yield
							Max	Min	Mean	Max	
		km^2	Wet	Dry	Total	(mm)	(MCM)	(MCM)	(m^3/sec)	(m^3/sec)	(m3/s/km)
1 Kok	GN3 Ban Tha Don	2,980	1,540	470	2,010	674	3,033	973	68	551	0.18
	G2A Kok Bridge	6,063	2,510	710	3,220	531	5,817	2,034	114	953	0.16
	GN1 Ban Tha Kok	10,300	3,870	940	4,810	467	6,268	3,836	165	874	0.08
	GN15 Kok-Lao	3,080	650	130	780	253	1,344	432	27	234	0.08
2 Ing	IN2 Khao Ing Rod	3,450	790	70	860	249	1,631	448	28	596	0.17
	IN1 A Thoeng	5,700	1,670	170	1,840	323	4,383	823	60	1,250	0.22
3 Yao	Ban Wang Hit (N51)	774	300	50	350	452	606	199	12	380	0.49
4 Nan	N17 Thung Chang	1,156	510	170	680	588	1,096	452	23	1,843	1.59
	N1 A Muang Nan	4,609	2,370	280	2,650	575	4,748	1,342	81	2,800	0.61
	Sirikit Inflow	13,100	4,090	660	4,750	363	8,574	3,119	163	3,378	0.26
	Sirikit Release	13,100	1,790	2,540	4,330	331	7,284	2,405	154	1,963	0.15
	N12A Uttaradit	15,718	2,891	2,466	5,357	341	10,270	2,486	171	3,300	0.21
	N5A Phitsanulok	25,286	3,860	2,340	6,200	245	12,131	3,199	286	1,896	0.07
	N7 Pichit	29,153	5,240	2,820	8,060	276	14,288	3,850	278	1,563	0.05
	N14 Chung Saeng	33,197	5,450	2,450	7,900	238	15,874	3,562	292	1,448	0.04
5 Yom	Y14 Sukhothai	12,131	2,080	200	2,280	188	5,092	840	81	-	
6 Wang	W4A Tak	10,507	790	100	890	85	2,104	408	100	445	0.04
7 Ping	Bhumibol Inflow	26,100	4,300	700	5,000	192	8,804	2,562	167	-	
	Bhumibol Release	26,100	1,400	3,040	4,440	170	7,620	2,790	157	-	
	P7A Kamphaeng Phet	42,700	3,060	3,060	6,120	143	12,221	4,184	35	2,452	0.06
8 Chao	C2 Nakhon Sawan	110,569	12,930	6,240	19,170	173	36,917	11,541	246	4,712	0.04
Phraya	C13 Chai Nat Inflow	119,000	14,160	5,840	20,000	168	38,771	8,587	711	4,360	0.04
	Chai Nat Release	119,000	7,700	1,850	9,550	80	26,055	2,650	343	-	
	Chai Nat Diversion	119,000	6,450	3,990	10,440	88	14,577	5,937	369	-	
9 Pasak	Dam Site	12,925	1,835	156	1,991	154	4,830	609	713	-	
	River mouth	16,290	2,350	190	2,540	156	5,855	738	77	-	
10 Sakae	Mae Wong	938	286	52	338	360	-	-	-	-	
11 Mekong	Chiang Saen (KHN2)	189,000	67,844	17,728	85,572	453	126,682	67,850	2,714	17,600	0.09
	Chiang Khong (KHN3)	204,000	75,993	19,508	95,501	468	129,696	75,328	3,029	18,000	0.09

Data Sources ; Hydrological Division of RID and DEDP, Basin 1 to 8 are of recent years (1985-1996)

Figure 2.3.1 (a) Location of Major Hydrological Observation Stations
– Kok, Ing and Upper Nan Basin

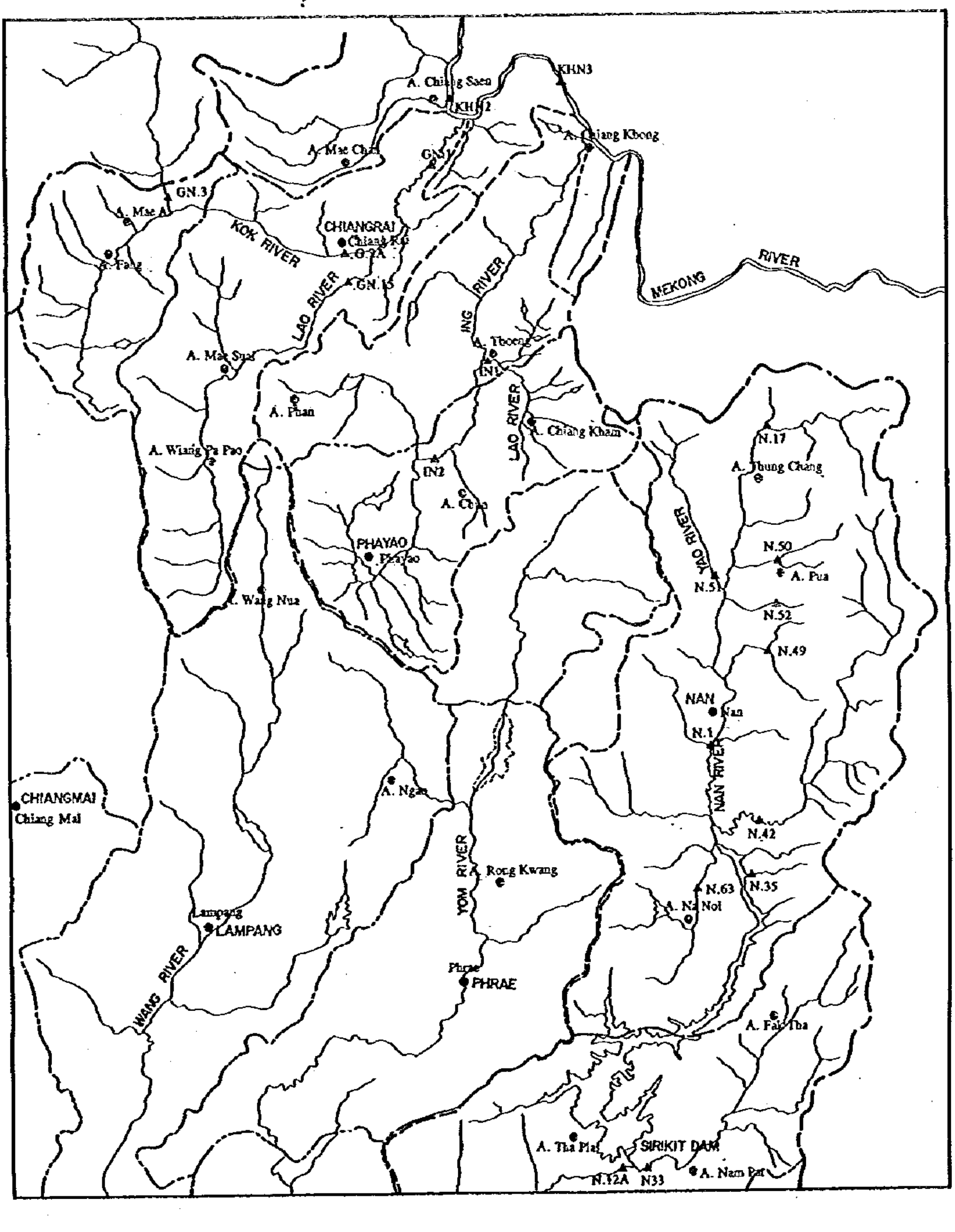
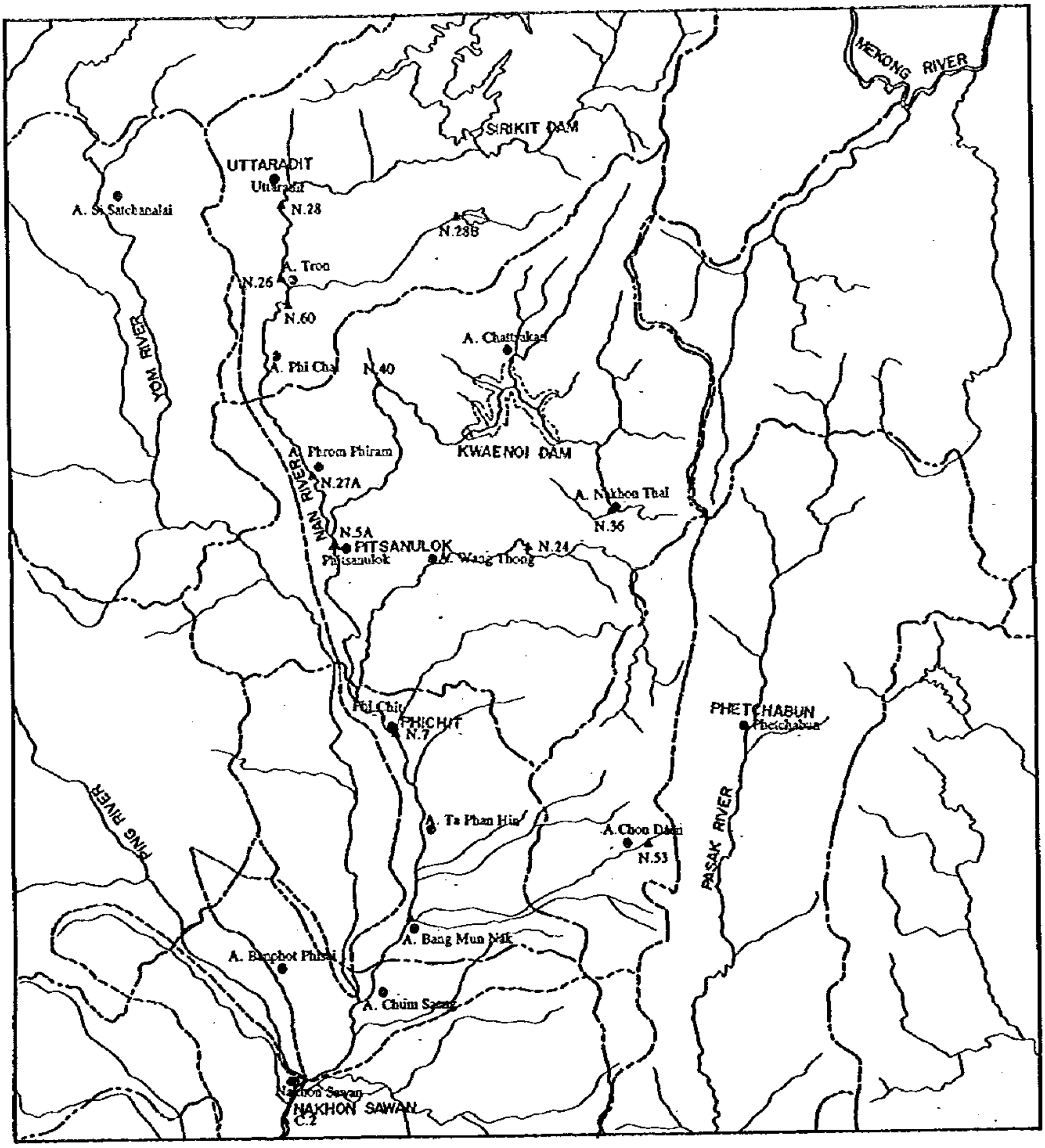


Figure 2.3.1 (b) Location of Major Hydrological Observation Stations – Lower Nan Basin



(1) Inflow and Outflow of Bhumibol and Sirikit Dams

The Bhumibol and Sirikit dams are the largest and most important water sources in the Ping and Nan basins. The dams are playing the role of controlling wet season runoff including flood control, hydropower generation and water supply to the downstream area and the Chao Phraya Delta. Annual and seasonal variations of inflow and outflow of the reservoirs are summarized as follows. See Figure 2.3.2 (a) and (b) and Table 2.3.2.

Table 2.3.2 Inflow and Outflow of the Bhumibol and Sirikit Dam

Dam/Catchment Area, (km^2)	In/Out Flow	The Past Year (1974-1984) (MCM)			The Recent Year (1985-1996) (MCM)			Runoff Yield (mm) Total/catchment	
		Wet	Dry	Total	Wet	Dry	Total	Past	Recent
Bhumibol	Inflow	4,920	720	5,640	4,300	700	5,000	216	191
26,100	Outflow	2,390	3,140	5,530	1,400	3,040	4,440	212	170
Sirikit	Inflow	5,110	770	5,880	4,090	660	4,750	448	362
13,130	Outflow	2,640	3,070	5,710	1,790	2,540	4,330	435	329

(a) Inflow

- Despite the fact that catchment area of the Bhumibol dam (26,100km^2) is about twice larger than that of the Sirikit dam (13,130km^2), the inflows into the reservoirs are about the same. Low inflow into the Bhumibol is attributable to lesser rainfall (about 1,000mm) and higher farmland intensity. In the Sirikit catchment, rainfall is higher about 1,300 and farmland intensity is lower.
- Inflow in the recent year (1985-1996) has decreased in both of the basins, due to decreasing rainfall and increase in irrigation development in the upper reaches of the reservoirs. The annual inflow into the Sirikit has decreased from 5,880MCM to 4,750MCM. The rate of decrease for the Sirikit is rather high, about 20%, as compared with 11% for the Bhumibol. High decrease in rainfall (7-15%) is the main causal factor for the decrease in runoff in the catchment of the Sirikit. For the Bhumibol, the decrease in runoff is caused by increase in irrigation acreage since rainfall variation in the recent year is relatively small.
- Critical years occurred in 1991-1993. Both of the reservoirs received the lowest inflow in these years, about 65-70% of the normal year.

(b) Outflow

- The outflows from both of the dams are similar in the recent year, 4,440MCM and 4,330MCM, respectively. However, both have decreased from 5,530MCM and 5,710MCM of the past year (1974-1984).
- The dry season outflow in the recent year (1985-1996) has also decreased. About 3,040MCM is released from the Bhumibol and 2,540MCM from the Sirikit in the recent year. This figure is rather small when compared with the effective storage capacity of the reservoirs, 9,660MCM for the Bhumibol and 6,660MCM for the Sirikit. This implies that the reservoirs have been suffering from a chronic problem of inflow shortage in wet season. The dams have never been filled to the full water level in the past 22 years, except for 1975 and 1995.
- The ratio of dry season outflow to annual outflow is about 69% (3,040/4,440MCM) for the Bhumibol and 59% (2,540/4,330MCM) for the Sirikit. The reverse is true for the wet season outflow, indicating that more of the wet season inflow flows pass the Sirikit reservoir.

Figure 2.3.2(a) Annual Rainfall (Chiang Mai) and Inflow (Bhumibol Dam)

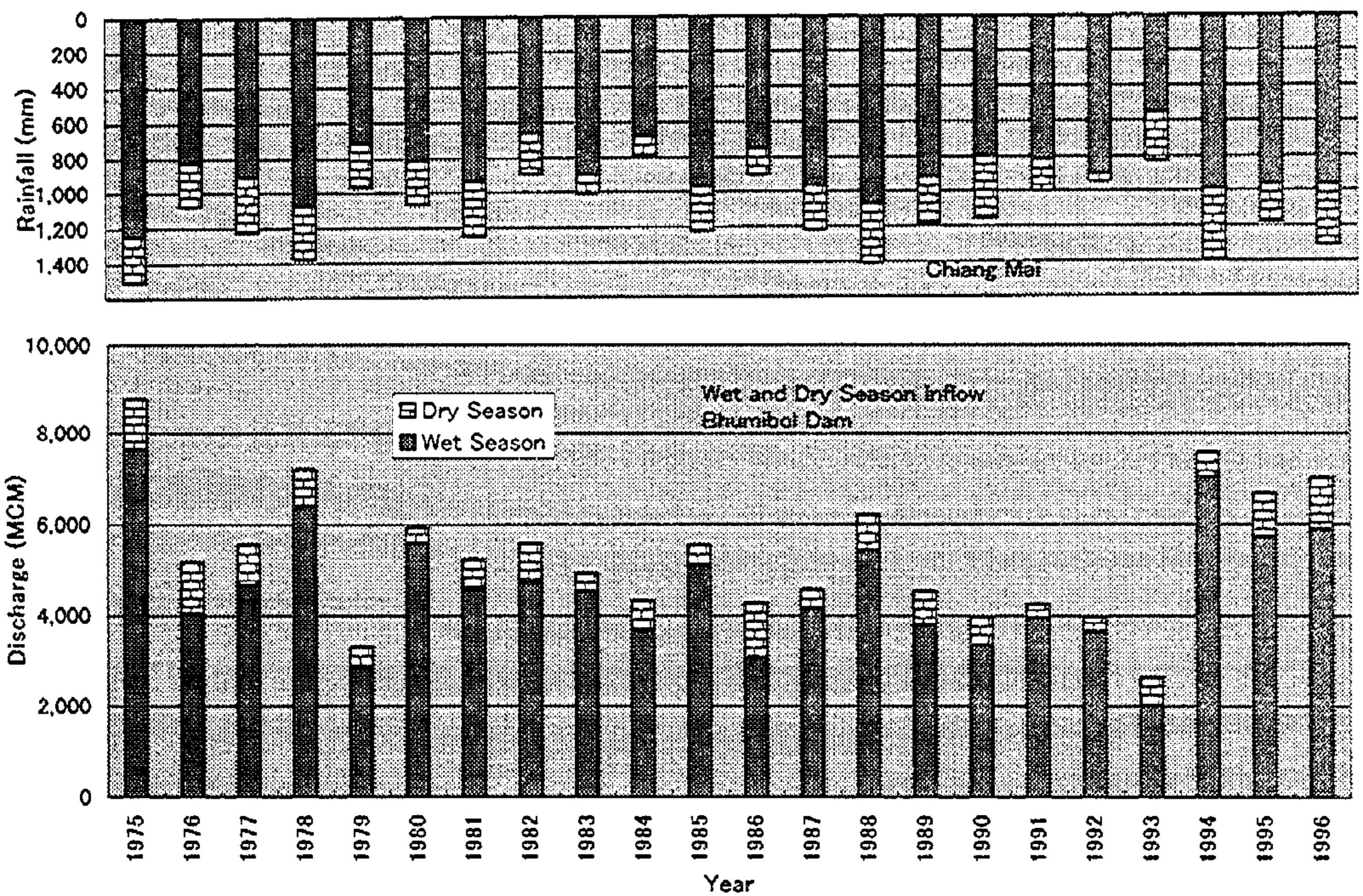


Figure 2.3.2(b) Annual Rainfall (Nan) and Inflow (Sirikit Dam)

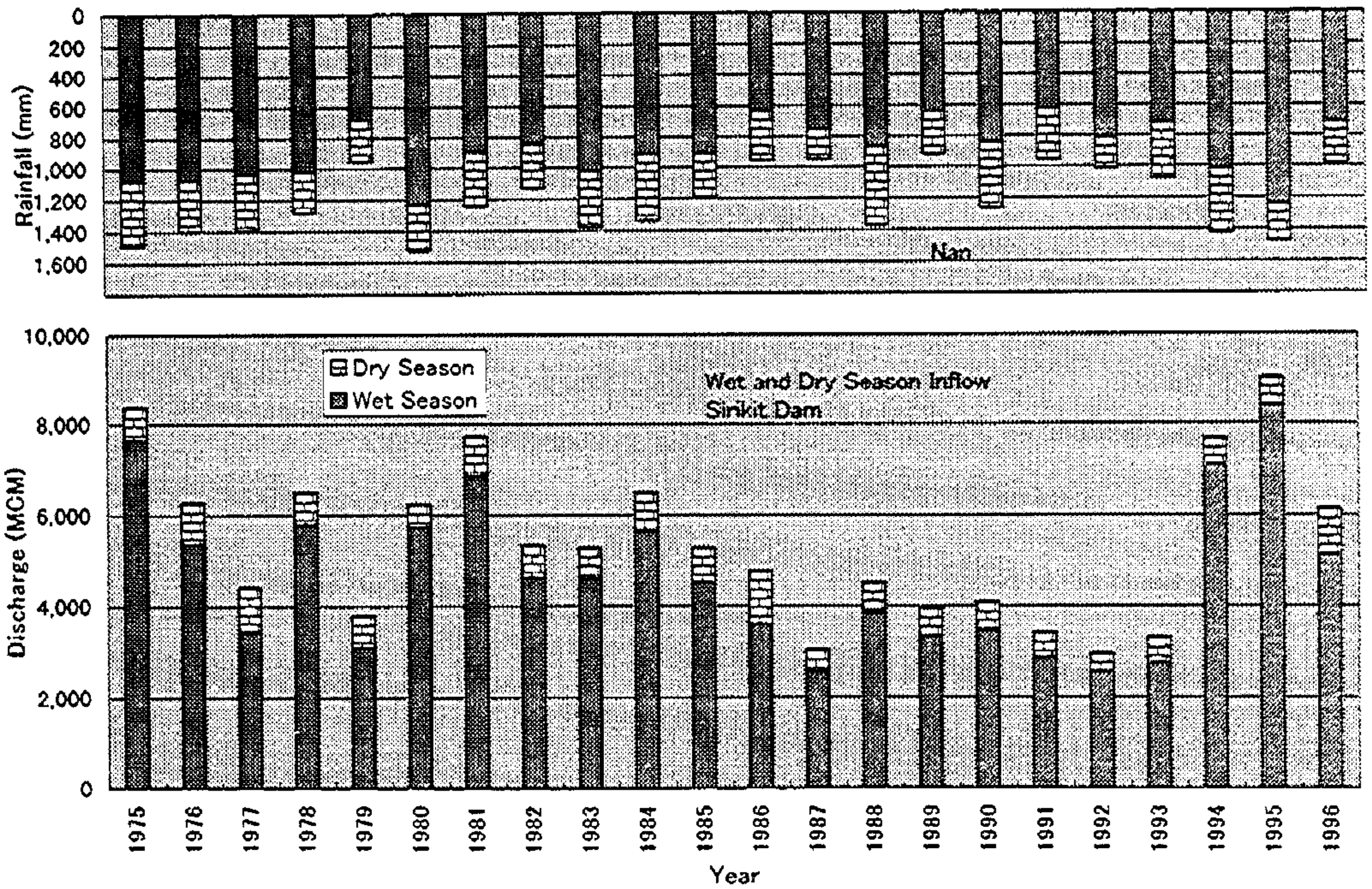


Table 2.3.3 (a) Runoff Variation in the Nan Basin

Station	Catchment Area (km^2) (1)	Past Year 1974-84 Runoff (MCM) Wet	Dry	Total (2)	Recent Year 1985-96 Runoff (MCM) Wet	Dry	Total (2)	Specific Yield for Total (mm) (2)/(1)*10^3 Past	Recent
1. Upper Nan									
(1) N 51 at Yao	774	370	60	430	300	50	350	556	452
(2) N 17 upstream Nan	1,156	620	160	780	510	170	680	675	588
(3) N 1 at Nan City	4,609	2,530	230	2,760	2,370	280	2,650	599	575
(4) Upper N1 Sideflow {(3)-(1)-(2)}	2,679	1,540	10	1,550	1,560	60	1,620	579	605
(5) Sirikit Inflow	13,130	5,110	770	5,880	4,090	670	4,760	448	363
(6) Upper Sirikit Sideflow {(5)-(3)}	8,521	2,580	540	3,120	1,720	390	2,110	366	248
(7) Sirikit Outflow	13,130	2,640	3,070	5,710	1,790	2,540	4,330	435	330
(8) Naresuan Inflow	19,500	-	-	-	2,570	2,390	4,960	-	254
(9) Upper Naresuan Sideflow {(8)-(7)}	6,370	-	-	-	780	-150	630	-	99
(10) Naresuan Outflow	19,500	-	-	-	2,040	2,040	4,080	-	209
(11) N 5A at Phitsanulok	25,286	5,750	3,270	9,020	3,860	2,340	6,200	357	245
(12) Upper N 5A Sideflow {(11)-(10)}	5,786	-	-	-	1,820	300	2,120	-	366
(13) N 7 at Phichit	29,153	7,230	3,610	10,840	5,240	2,820	8,060	372	276
(14) Upper N 7 Sideflow {(13)-(11)}	3,867	1,480	340	1,820	1,380	480	1,860	471	481
(15) N 14	33,197	8,290	3,100	11,390	5,450	2,450	7,900	343	238
(16) Upper N 14 Sideflow {(15)-(13)}	4,044	1,060	-510	550	210	-370	-160	136	-40
(17) N 14 Downstream Sideflow {(16)*27%}	1,092	286	-138	149	57	-100	-43	136	-40
(18) Total Nan Runoff {(15)+(17)}	34,289	8,576	2,962	11,539	5,507	2,350	7,857	337	229

Remark : 27% in (17) is the catchment ration of (17) for (16)

Table 2.3.3 (b) Runoff Variation in the Rivers in the Upper Chao Phraya

Station	Catchment Area (km^2) (1)	Past Year 1974-84 Runoff (MCM)			Recent Year 1985-96 Runoff (MCM)			Specific Yield for Total (mm) (2)/(1)*10^3	
		Wet	Dry	Total (2)	Wet	Dry	Total (2)	Past	Recent
1. Upper Chao Phraya									
(1) Bhumibol Outflow	26,100	2,390	3,140	5,530	1,400	3,040	4,440	212	170
(2) Wang W 4A	10,507	1,020	120	1,140	790	100	890	108	85
(3) Ping P 7A	42,700	4,660	3,330	7,990	3,060	3,060	6,120	187	143
(4) Upper P 7A Sideflow {(3)-(1)-(2)}	6,093	1,250	70	1,320	870	-80	790	217	130
(5) Ping Downstream Sideflow {(4)*32%}	1,950	400	22	422	278	-26	253	217	130
(6) Ping & Wang Total {(3)+(5)}	44,650	5,060	3,352	8,412	3,338	3,034	6,373	188	143
(7) Yom Y 14	12,131	2,470	210	2,680	2,080	200	2,280	221	188
(8) Yom Y 17	21,415	3,170	260	3,430	2,870	200	3,070	160	143
(9) Upper Y 17 Sideflow {(8)-(7)}	9,284	700	50	750	790	0	790	81	85
(10) Y 17 Downstream Sideflow	2,185	170	10	180	180	0	180	82	82
(11) Yom Total {(8)+(10)}	23,600	3,340	270	3,610	3,050	200	3,250	153	138
(12) Pasak	16,290	-	-	-	2,350	190	2,540	-	156

Table 2.3.3 (c) Runoff Variation in the Chao Phraya Basin

Station	Catchment Area (km^2)	Past Year 1974-84			Recent Year 1985-96			Specific Yield for Total (mm)	
		Runoff (MCM)			Runoff (MCM)			$(2)/(1)*10^3$	
	(1)	Wet	Dry	Total (2)	Wet	Dry	Total (2)	Past	Recent
1. Chao Phraya Basin									
(1) Total of Nan, Ping & Yom	102,630	16,980	6,590	23,570	11,900	5,580	17,480	230	170
(2) C 2, Nakhon Sawan	110,569	18,020	7,380	25,400	12,930	6,240	19,170	230	173
(3) Upper C 2 Sideflow {(2)-(1)}	7,939	1,040	790	1,830	1,030	660	1,690	231	213
(4) Chainat Inflow	119,000	19,310	7,200	26,510	14,160	5,840	20,000	223	168
(5) Upper Chainat Sideflow {(4)-(2)}	8,431	1,290	-180	1,110	1,230	-400	830	132	98
(6) Chainat Outflow	119,000	11,060	2,620	13,680	7,700	1,850	9,550	115	80
(7) Chainat Diversion	119,000	8,260	4,580	12,840	6,450	3,990	10,440	108	88

Table 2.3.3 (d) Runoff Variation in the Kok and Ing Basin

Station	Catchment Area (km^2) (1)	Past Year 1974-84 Runoff (MCM)			Recent Year 1985-96 Runoff (MCM)			Specific Yield for Total (mm) (2)/(1)*10^3	
		Wet	Dry	Total (2)	Wet	Dry	Total (2)	Past	Recent
1. Kok Basin									
(1) GN 3 at Tha Don	2,980	1,550	470	2,020	1,540	470	2,010	678	674
(2) G 2A at Kok Bridge	6,053	2,830	780	3,610	2,510	710	3,220	596	532
(3) Upper G 2A Sideflow {(2)-(1)}	3,073	1,280	310	1,590	970	240	1,210	517	394
(4) GN 15, Kok-Lao	3,080	790	130	920	650	130	780	299	253
(5) GN 1 at Chan Chiang	10,300	4,320	980	5,300	3,870	940	4,810	515	467
(6) Upper GN 1 Sideflow {(5)-(2)-(4)}	1,167	700	70	770	710	100	810	660	694
(7) GN 1 Downstream {(6)*50%}	584	350	35	385	300	80	380	660	651
(8) Total Kok {(5)+(7)}	10,884	4,670	1,015	5,685	4,170	1,020	5,190	522	477
2. Ing Basin									
(1) IN 3 at Pra Mong	1,210	220	30	250	190	20	210	207	174
(2) IN 2 at Khao Ing Rod	3,450	900	50	950	790	70	860	275	249
(3) Upper IN 2 Sideflow {(2)-(1)}	2,240	680	20	700	600	50	650	313	290
(4) IN 1 at Thoeng	5,700	1,810	140	1,950	1,670	170	1,840	342	323
(5) Upper IN 1 Sideflow {(4)-(2)}	2,250	910	90	1,000	880	100	980	444	436
(6) Ing-Lao {(5)*65%}	1,463	592	59	650	572	65	637	444	436
(7) Ing Weir {(4)-(6)}	4,238	1,219	82	1,300	1,098	105	1,203	307	284
(8) Tak	340	100	10	110	100	10	110	324	324
(9) Lower Ing	1,080	420	40	460	410	50	460	426	426
(10) Total Ing {(4)+(8)+(9)}	7,120	2,330	190	2,520	2,180	230	2,410	354	338

(2) Runoff Variation in the Nan Basin

The Nan river has the largest runoff, about 7,850MCM in the recent year, comparing with the other rivers in the upper Chao Phraya basin.

The upper Nan basin (12,980km^2) has steep topography and the mountains covered with dense forest. High annual rainfall (1,300mm) on the area with such topographic condition has produce 4,750MCM (runoff yield 362mm) of runoff at the Sirikit dam in the recent year.

The catchment area of the lower Nan basin (21,350km^2) is about 1.6 times that of upper Nan basin. Rainfall in this sub-basin is moderate, 1,000mm. The annual runoff in the recent year, 3,530MCM (runoff yield 165mm), is rather low. The low runoff yield is probably caused by high water consumption in the numerous irrigation projects located along the Nan mainstream downstream of the Sirikit dam.

The runoff variation of the Nan basin, divided into the upper and lower Nan basins, is summarized in Table 2.3.3 (a). Brief description on the runoff characteristics is as follows:

(a) Upper Nan Basin

- The gauging stations - N17, N51 and N1, all located at or upstream of Amphoe Muang Nan, present high runoff yield, 450-600mm in the recent year. Large floods are often observed at these stations in August-September.
- The catchment between Amphoe Muang Nan and the Sirikit dam (N1-Sirikit) is about 8,520km^2. This stretch of catchment is also mountainous, but with large plateau and alluvial plain. Rainfall on the plateau and alluvial plain is lost through evaporation and/or retained in rainfed paddy farming, resulting in a low runoff yield of 250 mm in the recent year.
- The decrease in runoff yield at stations located in the upstream of N1 is less than that at the stations in the downstream. For the downstream reaches (N1-Sirikit), runoff has decreased from 3,120MCM to 2,110MCM in the recent year. This could be explained by the increase in water consumption by the irrigation and rainfed farming expanded in the large alluvial plain located downstream of Amphoe Muang Nan.
- Annual inflow into Sirikit reservoir in dry year can be as low as 3,100MCM (1992). In the wet year, this could spring to about 3 times higher, to about 9,400MCM (1996).

(b) Lower Nan Basin

- In the recent year, annual outflow of 4,330MCM from the Sirikit becomes 4,960MCM at the Naresuan barrage. The difference is the side flow coming from the interval basin (6,370km^2). Dry season runoff at the Naresuan barrage is 2,390MCM, about 150MCM less than the amount released at Sirikit dam (2,540MCM). This implies that some of the water (6%) released from the Sirikit never reaches the Naresuan barrage, leave alone the side flow from interval basin. Together with the dry season side flow, this amount of water is drafted by the numerous pumping irrigation projects developed by RID and DEDP along the Nan mainstream.
- Dry season discharge at the Naresuan barrage fluctuates greatly, from 3,280MCM (1995) and 4,250MCM (1996) to 1,460MCM (1993) and 910MCM (1994). Inflow at the Naresuan is primarily determined by the outflow from the Sirikit dam. But in the

recent year it has been affected by the pumping irrigation schemes in the upstream reaches.

- The catchment area between the Sirikit dam and N5A (Phitsanulok) is about 12,156km^2, inclusive of the catchment of Khwae Noi (5,775km^2). The average side flow from this reach of river is estimated at 4,200MCM, by multiplying the catchment area with runoff yield of 350mm. Runoff at N5A has decreased from 9,020MCM to 6,200MCM and the dry season runoff from 3,270MCM to 2,340MCM in the recent year. The large decrement of runoff is caused by many large irrigation projects such as the Phitsanulok and pumping projects.
- Mean runoff at N5A in the recent year is 6,200MCM, of which about 4,080MCM is the outflow from the Naresuan barrage. The remaining 2,120MCM come mainly from Khwae Noi basin. If the proposed Khwae Noi dam (730MCM, to irrigate 340,000 rai) will be implemented and supply irrigation water to its beneficial area, runoff at N5A will be remarkably reduced.
- Since there is not much irrigation area in the interval catchment (3,870km^2) along the reach of Nan river between N5A and N7 (Phichit), side flow is relatively abundant. Mean annual side flow is 1,860MCM (480mm) and for dry seasons it is 480MCM (125mm). The Wang Thong tributary (2,300km^2) has exceptionally high runoff, 800MCM (or runoff yield 350mm). Accordingly mean annual runoff at N7 increases to 8,060MCM, while that of dry season to 2,820MCM.
- The river reach between N7 (29,153km^2) and N14 (33,197km^2) should produce a side flow of 1,000MCM, when assuming a runoff yield of 250mm from catchment area of 4,000km^2. The observed side flow was -160MCM. This can be explained by assuming that part of the runoff at N7 and side flow was lost during its course down the permeable alluvial plain. At N14, the observed mean annual runoff in the recent year has decreased to 7,900MCM, and dry season runoff to 2,450MCM, which is similar in magnitude to the Sirikit outflow in dry season.
- Since much of the water is lost to rainfed farming, pumping irrigation projects and river maintenance, the potential surface runoff for the whole of Nan basin in the recent years is estimated at 7,900MCM, which could be used for water demand in the Delta. This value is the highest in the Upper Chao Phraya basin.

(3) Runoff Variation of Other Rivers in the Upper Chao Phraya Basin

Runoff variation in the Ping, Wang, Yom, Pasak and Sakae Krang are summarized in Table 2.3.3 (b).

(a) Ping and Wang Basin

- The Wang river (10,790km^2) is the largest tributary of the Ping river. The two rivers converge at the location immediately downstream of the Bhumibol dam. The catchment area of the Ping at Nakhon Sawan is 33,898km^2, inclusive of that of the Wang.
- Runoff in the Wang basin has been low due to scarce rainfall, less than 1,000mm. Dry season runoff is especially low in the recent year, 100MCM (or runoff yield 9mm), barely sufficient for river maintenance flow.

- Mean annual runoff at P7A (42,700km^2) has decreased from 7,980MCM to 6,120MCM and that of dry season from 3,320MCM to 3,060MCM. Decrease in annual rainfall and the resulting decrease in side flow in the recent year and increase in consumption in the large scale irrigation projects and pumping irrigation projects have all contributed to the decreasing trend.
- Mean annual runoff of the Ping river at Nakhon Sawan is 6,370MCM and dry season 3,030MCM. This is the potential of the Ping and Wang rivers combined and is available water to the Delta.
- Although the combined mean annual runoff of the Ping and Wang is 6,370MCM, slightly smaller than that of the Nan (7,900MCM), the dry season runoff of the Ping (3,030MCM) is larger than that of the Nan (2,350MCM).

(b) Yom, Pasak and Sakae Krang Basin

- The dry season runoff in the Yom, Pasak and Sakae Krang is very scarce when compared with the relatively rich wet season. Most of the dry season runoff is consumed within the basin for irrigation and domestic demand. In March-April, some of these rivers dry up, and when there is no rainfall, the runoff can become very scarce.
- Mean annual runoff of the Yom was 2,680MCM at Y14 (12,130km^2), 3,430MCM at Y17 (21,415km^2) in the past years (1974-1984). In the recent year this has decreased to 2,280MCM and 3,070MCM, due to decrease in the rainfall and increase in the rainfed farming and irrigation.
- Mean annual runoff for the recent year of the Yom (23,600km^2) is estimated at 3,250MCM. Since dry season runoff is exceptionally small, only 200MCM (6%), barely sufficient to supply in-basin consumption and river maintenance, the Yom has limited potential in supplying water to the Delta in the dry season.
- The situation of dry season runoff in the Pasak and Sakae Krang is similar to that of the Yom. Most of the dry season runoff, though only a small fraction of the wet season flow, is used for in-basin consumption, leaving little surplus to supply water demand in the Delta.

(4) Runoff Variation in Lower Chao Phraya Basin

The Ping (including the Wang), Yom and Nan converge at Nakhon Sawan to form the Chao Phraya river. Bung Boraphet, located in the east bank of Nakhon Sawan, is a huge natural depression. It functions as a natural regulating reservoir; imbibing some of the flood waters from the upper Chao Phraya basin in the wet season and releases them in the dry season. The side flow from the catchment area of Bung Boraphet also feeds into the Chao Phraya. The Chao Phraya flows down a very flat alluvial plain and finally empties into the Gulf of Thailand. Some of the water is lost to seepage through permeable banks and riverbed. Runoff variation at the key stations is summarized in Table 2.3.3 (c).

- Mean annual runoff at C2 (Nakhon Sawan, 110,569km^2) was 25,400MCM in the past year. But has deceased by 6,230MCM (25%) to about 19,170MCM in the recent year. Decrease in rainfall and increase in rainfed and irrigated farming in the recent year are the main causal factors. The dry season runoff has decreased from 7,380MCM to 6,240MCM, due primarily to the expansion of irrigation projects in the upstream in the recent year.

- The Chai Nat barrage was constructed in 1964 to control water supply to the Delta. At the Chai Nat, mean annual inflow has decreased from 26,510MCM to 20,000MCM, and dry season inflow from 7,200MCM to 5,840MCM.
- The interval catchment between Nakhon Sawan (C2) and the Chai Nat barrage is 8,431km^2. Side flow from this stretch of river has added to the inflow at the Chai Nat in wet season; in wet season inflow at the Chai Nat is larger than that at C2. In the dry season, inflow at the Chai Nat (5,840MCM) is smaller than that at C2 (6,240MCM), indicating that large river loses possibly occurs in this stretch of very flat and permeable alluvial plain.
- Mean wet and dry season inflows at the Chai Nat in the recent year are 14,160MCM and 5,840MCM, respectively. This value can be considered as the potential water resources for the Delta. As can be deciphered from this contrast, inflow in wet season is sufficient, but dry season inflow cannot meet the water demand of the Delta.

(5) Runoff Variation in Kok and Ing Basin

The Kok and Ing basins, blessed with higher rainfall, have the higher annual runoff as compared with the rivers in the upper Chao Phraya basin. Rainfall in both of the basins is higher in the downstream reaches; 1,300-1,500mm is observed in the upper basin as compared to 1,700-1,800mm in the lower basin. Accordingly, runoff yield in both rivers is greater in the downstream area. Runoff variation of both rivers is summarized in Table 2.3.3 (d).

(a) Kok Basin

- Mean annual runoff at Ban Tha Don (GN3, 2,980km^2) has decreased from about 2,140MCM to 2,010MCM in the recent year. Accordingly runoff yield has decreased from 718mm to 676mm. Despite the decrease, the runoff yield from the catchment in Myanmar territory is still the highest among the rivers in the Study Area. This is the result of higher rainfall, greater than 1,700mm, in the Myanmar territory falling on relatively less developed high ranges and deep valleys covered with dense forest.
- At GN3, the Kok river collects runoff from the Fang river flows down deep valley of the reserved forest and into the alluvial plain in Chiang Rai. Side flow from the reach of river between GN3 and G2A was about 1,400MCM (455mm) but has decreased to 1,250MCM (407mm) in the recent year.
- At G2A (Chiang Rai Bridge, 6,063km^2), about 3km upstream of the proposed Kok intake, mean annual runoff was 3,540MCM, but has decreased to 3,260MCM. This is the potential available water for diversion.
- The Kok-Lao originates in the upper highland to the south of Chiang Rai province, flows down the alluvial plain and merges with the Kok river at the location immediately downstream of the Chiang Rai DEDP weir. Runoff in the Kok-Lao is much smaller than that of the Kok mainstream because much of the rain water are retained by rainfed farming and runoff is used in large farmland area (420,000rai) in the middle of the basin. Annual runoff at GN15 (Ban Tha Sai, 3,080km^2) was about 925MCM (300mm), but has decreased to 780MCM (250mm). In the KIN project, the Kok-Lao water will be allowed

to flow freely down the Kok river.

- The catchment of the reach between Chiang Rai DEDP weir and the Kok river mouth is about 1,750km^2 of flat alluvial plain with swamps, grassland and densely forested plateau. Side flow from this reach is large, about 1,000MCM in wet season and 240MCM in dry season. The high runoff yield, about 650mm, is the result of high rainfall, 1,700-2,000mm and less farmland.
- Mean annual runoff at river mouth (10,875km^2) was about 5,740MCM, but has decreased to 5,190MCM in recent year. Dry season runoff has varied from 1,050 to 1,070MCM. Runoff variation in the Kok basin is small compared with those in the Upper Chao Phraya basin. This is the result of less variation in rainfall, scarce suitable farmland and gradual irrigation development.
- At present, the bulk of 5,190MCM (1985-1996), 4,120MCM in wet season and 1,070MCM in dry season, flows into the Mekong without use. A major part of this runoff could be diverted to more 'water-needy' areas with the implementation of the Project.

(b) Ing Basin

- The Ing river originates in the high plateau, flows into the Phayao lake, down the middle and lower reades of the basin and empties into the Mekong.
- Rainfall in the upper basin of the Ing river, including the Phayao lake and the surrounding areas, is about 1,000mm or less. Accordingly, runoff is about 850-950MCM at IN2 (Khao Ing Rod, 3,450km^2).
- Runoff at IN1 (A Thoeng, 5700km^2) is about 1,830MCM in wet season. Since runoff from the Ing-Lao (640MCM) is included in the observed data at IN1, the potential for diversion at the proposed Ing intake is about 1,200MCM. Like the Kok-Lao, water in the Ing-Lao will not be diverted and will be used to supply the water demand in the Lower Ing basin.
- The catchment area of the reach of the Ing river between IN1 and the confluence with the Mekong is about 1,400km^2, inclusive of 340km^2 of Tak river. Mean annual runoff from this catchment is estimated at 500-600MCM. Dry season runoff is about 50-60MCM.
- Mean annual runoff at the Ing river mouth is estimated at 2,400MCM and is the potential resources for the whole of the Ing basin.

2.3.3 Hydrological Conditions in the Project Area

The hydrological conditions at the proposed intake/weir site in the Kok and Ing rivers and at the Yao flood control dam in the Yao river are studied as follows based on the existing hydrological data.

(1) Available Runoff for Water Diversion at the Proposed Weir Site

The Ing intake/weir is proposed at about 3km upstream of the existing Thoeng bridge. At Thoeng bridge where the gauging station IN1 is installed, the Ing-Lao tributary joins the mainstream of the Ing river. Since the proposed intake/weir site is located at the mainstream of the Ing river, and thus cannot divert the runoff in the Ing-Lao river, the available runoff at the Ing intake/weir site is estimated by deducting the Ing-Lao runoff from the observed runoff at Thoeng station (IN1), as summarized in Table 2.3.4.

In Kok basin, the existing Chiang Rai DEDP weir constructed and operated by DEDP is proposed to be used for the Kok water diversion. The runoff data observed at G2A station are corresponding to the available runoff for the Kok intake site and summarized as shown in Table 2.3.4. In estimating the potential for diversion, the complemented set of data was used.

Table 2.3.4 Available Runoff for Water Diversion at Weir Site in Kok and Ing River

Unit: MCM

Item	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
1. Kok River													
(1) Monthly runoff													
Average (85-96)	67	120	190	346	649	632	442	300	192	153	101	79	3,271
Dry year (92-93)	51	43	66	249	369	405	331	242	193	120	71	52	2,192
(2) Discharge (m^3/s)													
Average (85-96)	25.9	44.8	73.3	129.2	242.3	243.8	165.0	115.7	71.7	57.1	41.7	29.5	103.7
Dry year (92-93)	19.7	16.1	25.5	93.0	137.8	156.3	123.6	93.4	72.0	44.8	29.4	19.4	69.5
2. Ing River													
(1) Monthly runoff													
Average(85-94)	8.0	30.4	40.7	89.5	297.6	351.0	194.0	106.3	34.7	12.8	4.8	6.1	1,176
Dry year (92-93)	1.0	0.7	0.9	5.7	64.9	151.4	148.3	92.2	49.2	50.8	4.8	8.1	578.0
(2) Discharge (m^3/s)													
Average (85-94)	3.1	11.4	15.7	33.4	111.1	135.4	72.4	41.0	13.0	4.8	2.0	2.3	37.3
Dry year (92-93)	0.4	0.3	0.3	22	24.2	58.4	55.4	35.6	18.4	19.0	2.0	3.0	18.3

Note: The complemented set of data, which is different from the above, was used in estimating diversion potential.

The discharge at the Ing intake/weir cannot meet the design diversion of 175m^3/s in all months except August and September in an average year. In contrast, the Kok intake site in the Kok river presents rich discharge of more than 90m^3/s from July to November, even in dry year, and could cover the deficit discharge for the design diversion water of 175m^3/s at the Ing intake/weir site.

At the Ing intake/weir site, discharge is scarce, about 2m^3/s in the dry season from January to May in an average year. The Kok intake site, holds rich discharge of more than 25m^3/s in an average year, and more than 16m^3/s in a dry year. The Kok discharge could be used to supplement dry season irrigation water to the farm areas in the Ing basin suffering from chronic water shortage.

(2) Flow Duration Analysis

The flow duration of the runoff at G2A station for the Kok intake and IN1 station for the Ing intake/weir was studied as shown in the Table 2.3.5.

Table 2.3.5 Flow Duration at G2A and IN1 Station

Unit: m^3/s

Station	Q_5	Q_{35}	Q_{50}	Q_{95}	Q_{185}	Q_{275}	Q_{300}	Q_{365}
	1.4%	9%	14%	26%	51%	75%	82%	100%
G2A (Kok)	484	267	230	160	74	42	37	20
IN1 (Ing)	317	196	147	70	15	6	4	1

At G2A, Q95 = 160m^3/s means that over a duration of 95 days or 26% of an average year the Kok river presents a discharge of more than 160m^3/s which is slightly higher than the designed diversion of 140m^3/s at the Kok intake site.

The duration when the river discharge is greater than the design diversion of 175m^3/s in the

Ing intake/weir site is about 40 days in an average year. The remaining duration of 145 days in the wet season will have to receive supplemental discharge from the Kok intake in order to meet the design diversion of 175m³/s at the Ing intake/weir site.

(3) Water Level Fluctuation Analysis

The rating curve at the Chiang Rai DEDP weir was studied for the hydraulics of the broad-crested weir as mentioned in (c) (Figure 2.3.3). In accordance with Figure 2.3.3 the water level at the Chiang Rai DEDP weir, when is fully open, for the available range of diversion discharge - 230 to 160m³/s - is 387.0 to 386.8m. The corresponding water level at Kok intake, assumed to be 1.0m higher than the flood water level at DEDP weir, is 388.0 to 387.8m. The assumption of 1.0m was well grounded on the operation record during the wet season of 1994 when the gates at DEDP weir were fully open. Naturally, the design diversion of 140m³/s will have to be diverted at these water levels if the Chiang Rai DEDP weir were to remain fully open.

At the Ing intake/weir site, the water level during the flood months of August to September is always above 362.5m. Since the flow in the upstream of Amphoe Thoeng is always affected by the narrow river section at the bridge, the Ing intake/weir will be submerged during the flood months due to the backwater effect.

(a) Water Level Duration Curve at the nearby Existing Stations

Water level duration curve at GN2/G2A (Chiang Rai bridge, Kok) and IN1 (A Thoeng, Ing) were studied to evaluate the design water level for diversion. Table 2.3.6 is a summary of the mean values.

Table 2.3.6 Water Level Duration Curve – GN2 (Kok) and IN1 (Ing)

Unit: m, MSL

Duration	GN2	IN1
WL_{1} = 0.3%	391.19	365.72
WL_{3} = 1%	390.82	365.41
WL_{35} = 9%	390.07	363.87
WL_{50} = 14%	389.91	363.28
WL_{95} = 26%	389.60	361.99
WL_{185} = 51%	389.20	360.70
WL_{275} = 75%	388.93	360.38
WL_{300} = 82%	388.87	360.31
WL_{329} = 90%	388.80	360.15
WL_{355} = 97%	388.72	360.06
WL_{365} = 100%	388.67	360.02

(b) Water Level Duration Curve at the Intake Locations

From past records, water level at the Kok intake is observed to be about 1m below that at GN2. Reading the water level duration curve for GN2 less 1m will give the duration curve at the Kok intake location. Table 2.3.7 shows that under natural flow conditions, the water level at the Kok intake location is above 388.0m for about 250 days in an average year.

Water level at the Ing intake is assumed to be about 0.5m higher than that at IN1. This could vary depending on inundation conditions. On the average, the water level at the intake stays above 362.0m for about 120 days. The weir built across the Ing mainstream is either deflated or fully open during the period of high flood stage. In 1/10 dry year, water level is below 362.0m level. Full operation of gates might be necessary in dry year.

Table 2.3.7 Water Level Duration at Kok and Ing Intake

Kok Intake (Value for reference station GN2 in parenthesis)

Water level (m MSL)	388.0 (389.0)	388.5 (389.5)	389.0 (390.0)
Duration (days)	250	120	40

Ing Intake (Value for reference station IN1 in parenthesis)

Water level (m MSL)	362.0 (361.5)	362.5 (362.0)	363.0 (362.5)	363.5 (363.0)
Duration (days)	120	95	75	60

(4) Flow Conditions of the Yao River

The Yao river will be used for the conveyance channel of the diversion water in the Project. The flood control dam and river training works will be proposed in the river in order to convey the diversion water smoothly along the river to the Nan river. The flow conditions of the Yao river were studied (Table 2.3.8) based on the data observed at station N51 located about halfway between the proposed dam site and confluence with Nan river. Since the Yao basin is elongated in shape, the hydrograph of the runoff from the basin upstream of the dam site can be assumed to be similar in shape to that of the basin as a whole.

Table 2.3.8 Monthly Flow Conditions at the Yao River

Unit: MCM, m^3/s

Item	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
1. Station N51													
(1) Average runoff	5.84	13.4	23.2	69.0	88.0	81.7	39.6	21.8	14.6	10.4	6.8	5.5	379.7
Average Discharge	2.1	4.5	7.4	23.5	33.4	29.6	13.7	8.4	5.4	4.0	2.9	2.1	11.4
2. Dam site													
Average runoff	2.8	6.4	11.1	33.2	42.3	39.3	19.0	10.5	7.0	5.0	3.3	2.6	182.5
Average discharge	1.0	2.2	3.6	11.4	16.1	14.3	6.6	4.1	2.6	1.9	1.4	1.0	5.5

Note: Based on complemented data (1970-1993). Runoff and discharge were calculated using area ratio (372/774km^2).

The Yao river also presents rich runoff in August and September, while the runoff in dry season is scarce. In accordance with past record, the high peak flood discharge such as in 1984 (Q=380m^3/s, 1/25 return period) had brought severe flood damage to the villages along the rivers. Observation at N51 was terminated in 1991.

(5) Design Peak Flood Discharge

(a) Peak Flood Discharge at the nearby Gauging Stations

Table 2.3.9 shows the frequency analysis of the observed momentary peak flood discharge at the nearby major gauging stations.

Table 2.3.9 Peak Flood Discharge by Frequency Analysis - Gauging Stations

Unit: m^3/s

Basin	Location		Return Period					
			1/2	1/5	1/10	1/25	1/50	1/100
Kok	G2A	6,030km²	633	772	852	943	1,004	1,062
	GN15	3,080km²	167	204	227	253	273	291
Ing	IN1	5,700km²	338	494	604	749	860	975
Yao	N51	774km²	202	282	332	394	438	482

The peak floods for the respective return periods are smaller than the Thai side study, probably due to the difference in the period of data record and analysis method used. They are, however, of similar order of magnitude. Multiplying these figures with a safety factor of 1.2 – 1.3 will give figures similar to those of Thai side study. Flood discharge of 25 years return period is normally adopted in designing the passing capacity of crossing structures.

(b) Design Flood Discharge at Intake Locations

Table 2.3.10 shows the design peak flood discharges at the intake locations in Kok and Ing and at Huai Nam Yao dam site. These values were obtained by multiplying specific flood discharge (frequency analysis) of the nearest existing station and catchment area at the location of interest. Rainfall and topography were taken into consideration in estimating peak flood at location without gauging station (Ing Lao) or when the index station is too far away (Yao Dam site). The result of interpolating flood discharge at Huai Nam Yao dam site using estimates of frequency analysis at N51 is smaller than the Thai side study. For comparison, flood discharge at Yao dam site was estimated with a different method (see (d)).

Table 2.3.10 Design Peak Flood Discharge – Intake Locations

Unit: m^3/s

Basin	Location	Return Period					
		1/2	1/5	1/10	1/25	1/100	1/200
Kok	Intake 6,220km²	650	792	874	967	1,090	1,146
Ing	Intake 4,400km²	261	382	466	578	753	860
Yao	Dam site 372km²	194	271	319	379	464	506

Note: The values above are slightly smaller than those of The Thai side study. Kok and Ing Intake by area ratio, Yao Dam site by area ratio multiplied by 2.0

(c) Rating Curve at DEDP Chiang Rai Weir

Since the DEDP Chiang Rai weir is the only structure near the Kok intake where the hydraulics of the river is fully studied, it provides a useful anchor point in estimating flood water level at the Kok intake. The rating curve at the Chiang Rai DEDP weir was studied for the hydraulics of the broad-crested weir as mentioned in Figure 2.3.3. Adding 1 to 2m to the flood level at the DEDP weir will give a rough estimate of flood level at the intake for the respective floods.

Figure 2.3.3 Hydraulic Calculation at Chiang Rai DEDP Weir

Q = C*B*H^(3/2)

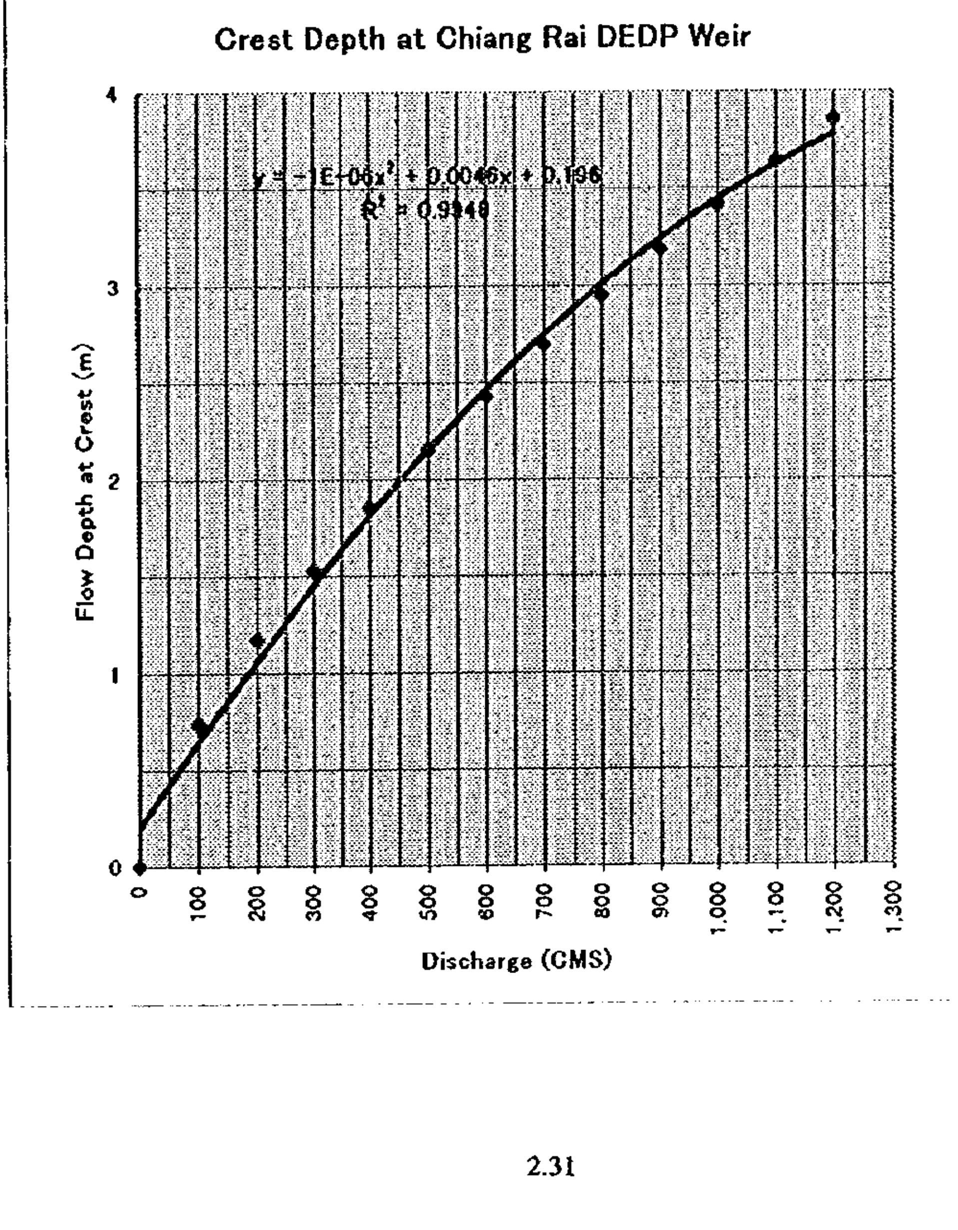
Broad Crest Weir
L>0.7H
L: Length of crest
H: Depth at crest

B (m) =	C=	B*C=
88	1.8	158.4

crest level = 385.75 m

Q (CMS)	H (m)	WL (m)	V(m/s)	H'=1.2H
1,200	3.86	389.61	3.54	4.63
1,100	3.64	389.39	3.43	4.37
1,000	3.42	389.17	3.33	4.10
900	3.18	388.93	3.21	3.82
800	2.94	388.69	3.09	3.53
700	2.69	388.44	2.95	3.23
600	2.43	388.18	2.81	2.92
500	2.15	387.90	2.64	2.58
400	1.85	387.60	2.45	2.23
300	1.53	387.28	2.23	1.84
200	1.17	386.92	1.95	1.40
100	0.74	386.49	1.54	0.88
0	0.00	385.75	0.01	0.00

Note: H' =1.2 H (20% on the steady flow side)



(d) Design Flood and Storm Runoff Distribution at Huai Nam Yao Dam Site

Design peak flood discharge at the Huai Nam Yao dam site was estimated for the 3-day rainfall used in the Thai side study. Flood concentration time was used to estimate the contribution of each of the daily rainfall to storm runoff. As shown in Figure 2.3.4 (a) and Table 2.3.11, multiplying the result with a factor of 1.2-1.3 gives values close to the Tha side estimates.

Storm runoff from 1st day rainfall is about 41MCM for 1/25 return period (Figure 2.3.4 (b)). The first and/or second wave of runoff will need to be regulated by the Huai Nam Yao dam regulating reservoir.

(6) Design Flood Level at Intake Locations

(a) By Frequency Analysis

The design flood level at the intake locations was estimated from those of the nearby index station, taking into consideration the difference in water level between intake location and the index station. The design flood water levels are shown in Table 2.3.12.

Table 2.3.12 Design Peak Flood Level – Intake Locations

Unit: m, MSL

Basin	Location	Return Period					
		1/2	1/5	1/10	1/25	1/100	1/200
Kok	Intake 6,220km²	391.6	391.9	392.0	392.2	392.5	392.6
Ing	Intake 4,440km²	366.4	367.6	368.2	368.8	369.6	367.0

(b) By Hydraulic Estimation

The design water level for flood of 1/100 return period was also estimated for the intake locations in Kok and Ing river by the frequency analysis, non-uniform flow and rating curve method (Table 2.3.13). Rating curves of broad-crested weir was calculated for DEDP weir to check flood level in Kok river and the flow capacity of A. Thoeng bridge was calculated to check flow in Ing river. Flood water level estimated by non-uniform flow method is of sufficient accuracy for feasibility design and can be adopted for design of major structures. Howeiver, engineering judgement and adjustment are necessary when adopting these values for facility design.

Table 2.3.13 Design Flood Level of 1/100 Return Period - Kok and Ing Intake

Location	Discharge (m^3/s)	Design Flood Level of 1/100 Return Period (m, MSL)		
		Frequency Analysis	Non-uniform Flow	Rating Curve
Kok Intake	1,090	392.5	391.9	391.4 #1
Ing Intake	753	369.6	368.5	368.9 #2

Note: #1 2.0m was added to the flood level of 1/100 return period at DEDP weir (389.39m)

#2 0.5m was added to the flood level of 1/100 return period at A Thoeng bridge

Figure 2.3.4(a) Design Flood Discharge - Yao Dam Site

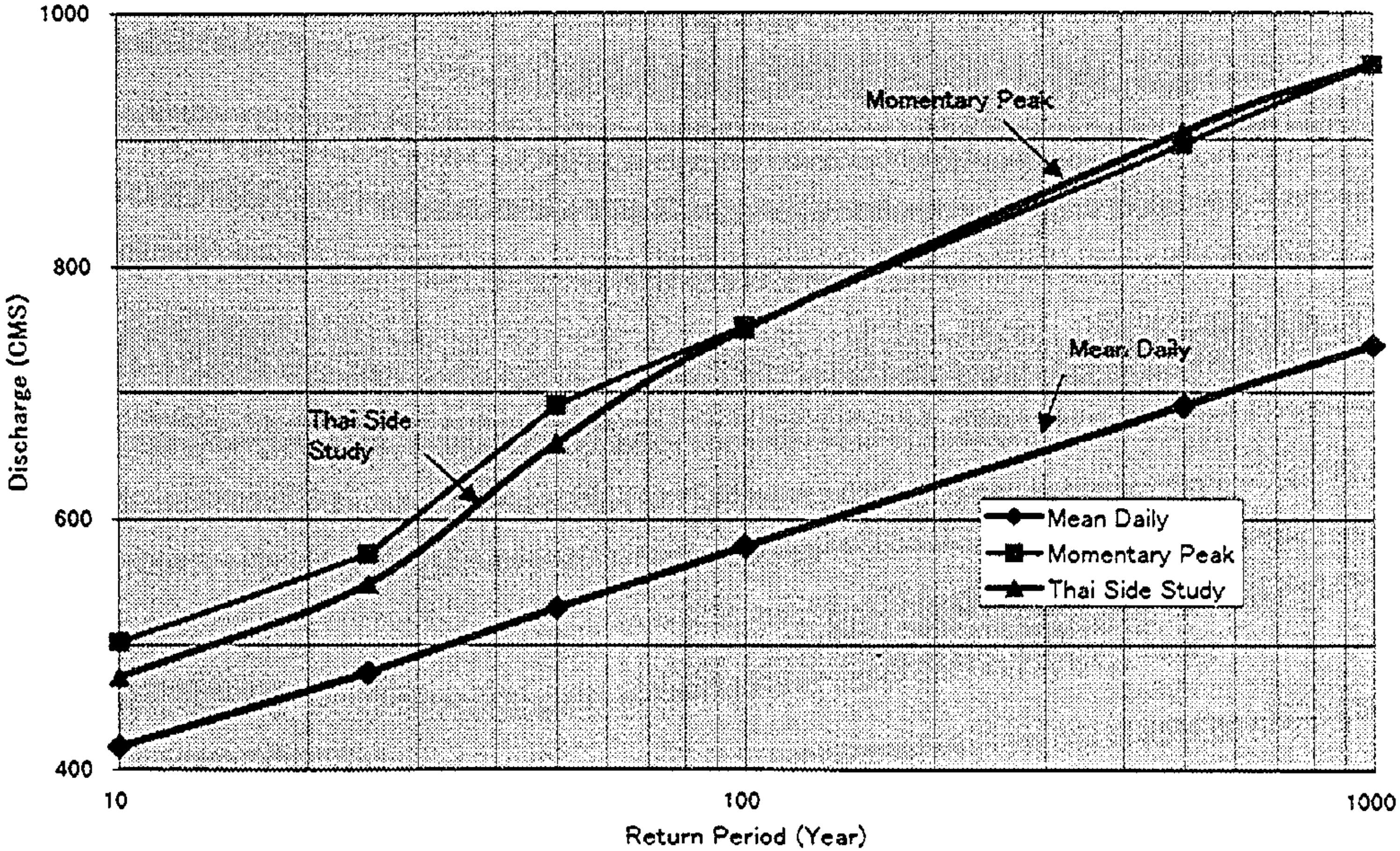


Figure 2.3.4 (b) Runoff Distribution - Yao Dam Site

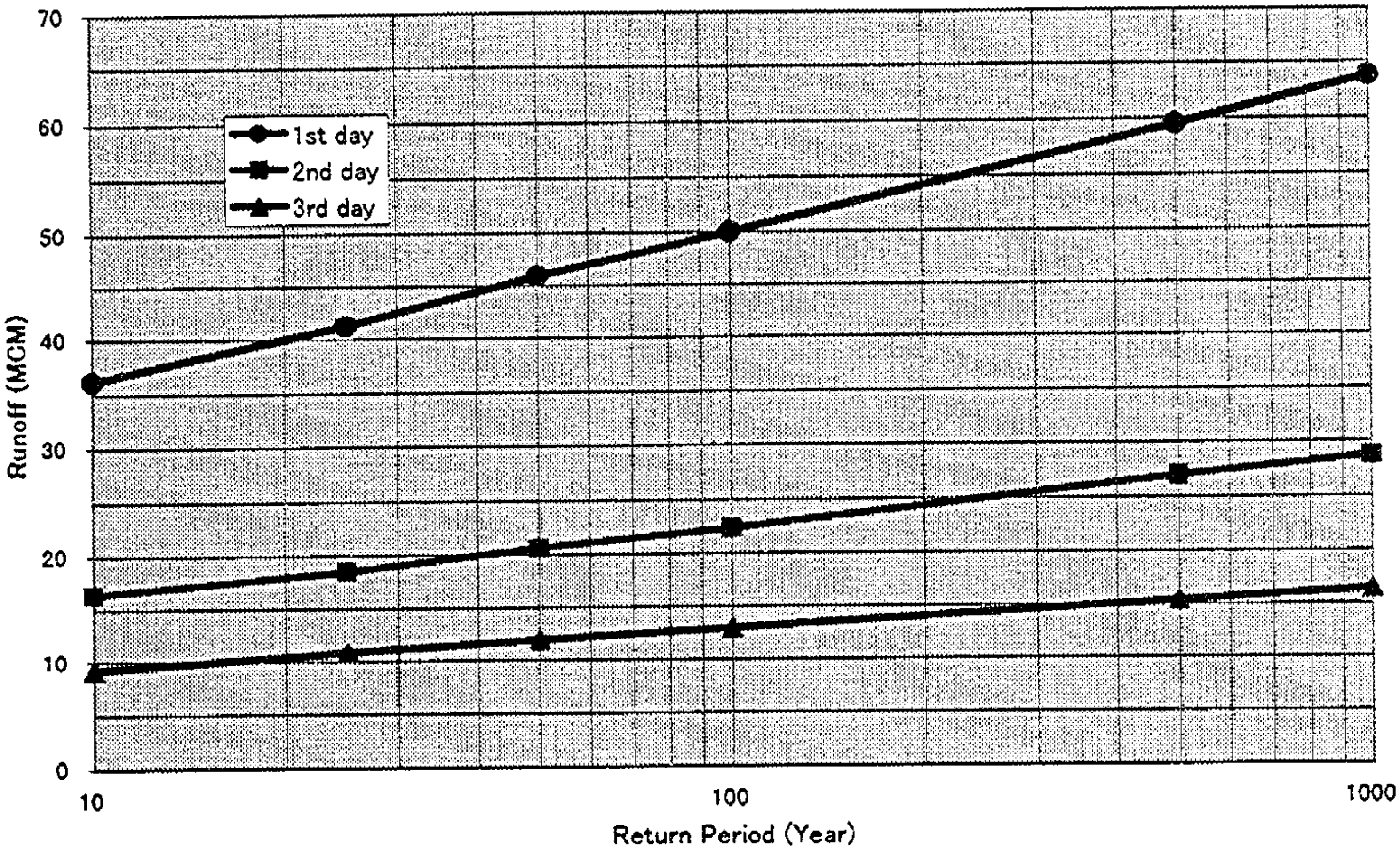


Table 2.3.11 Design Flood Discharge and Runoff Distribution - Yao Dam site

Design Discharge - Yao Dam Site

Return Period	Mean Runoff (CMS)	Momentary Peak (CMS) 1.2~1.3	RID Study (CMS)
10	418	502	473
25	477	572	549
50	530	689	660
100	579	753	750
500	689	896	905
1000	737	958	959

Runoff Distribution - Yao Dam Site

Return Period	Rainfall (mm)	Runoff Distribution						
		1st day (MCM)	2nd day (MCM)	3rd day (MCM)	4th day (MCM)	5th day (MCM)	6th day (MCM)	Total
10	229	36.1	16.3	9.2	1.8	0.4	0.1	63.9
25	262	41.2	18.5	10.8	2.1	0.4	0.1	73.1
50	291	45.9	20.6	11.9	2.3	0.5	0.1	81.3
100	317	50.0	22.4	12.9	2.5	0.5	0.1	88.4
500	378	59.5	26.9	15.3	3.0	0.6	0.1	105.4
1000	404	63.7	28.7	16.4	3.2	0.6	0.1	112.7

(7) Sediment at Intake Locations and Yao Dam Site

(a) Mean Monthly Suspended Sediment at Major Gauging Stations

Monthly suspended sediment data were collected from RID and DEDP, studied and complied. Table 2.3.14 gives the mean annual suspended sediment at major stations in the basins. At all stations sediment flow in the wet season is about 90% or more of the annual total. Total for July-September varies from 54-87%. In the more developed basin such as the Fang and Ing, the share of July-September is smaller, about 50-70%. The Upper Nan basin shows a different pattern: sediment flow in the wet season is about 96-97% and July-September is about 84-87%.

Table 2.3.14 Mean Monthly Suspended Sediment - Gauging Stations

Basin	Station	Catchment (km^2)	Annual (ton)	Wet (%)	Dry (%)	Jul-Sep (%)	Yield (t/km^2)	Remarks
Kok	GN3 Tha Don	2,980	406,654	90	10	67	137	1969-95
	GN4 Tha Mai Liam	1,800	96,034	87	13	54	53	1970-95
	GN2 Pong Na Kham	5,870	799,190	91	9	67	136	1967-95
Ing	IN2 Khao Ing Rod	3,450	80,985	93	7	62	24	1975-95
	IN1 A Thoeng	5,700	264,386	94	6	71	46	1968-95
Nan	Nam Kon Pha Daeng	176	17,263	96	4	84	98	1986-95
	Nam Pua B Na Fang	148	26,503	97	3	87	179	1977-95

(b) Sediment at Intake Location and Yao Dam Site

Correlation equations for mean annual suspended sediment and catchment area were obtained for the respective basins (Figure 2.3.5). The Nan basin has the highest specific sediment yield, followed by the Kok and Ing basin.

The linear equation for the respective basin was used to estimate the mean annual sediment volume at the intakes and the Huai Nam Yao dam site. In the Thai side study, the bed load was assumed to be 30% of the suspended sediment. This estimate is commonly used for riverbed gradient of about 1/5,000 – 1/8,000. The stretch of river upstream of the Kok intake is about 1/1,500, at Ing intake is 1/5,000 and at Huai Nam Yao is 1/300. Different bed load was assumed for the respective rivers. For the Kok river the bed load was assumed to be 50%, the Ing 30% and the Yao 200%, of the total suspended sediment (Table 2.3.15).

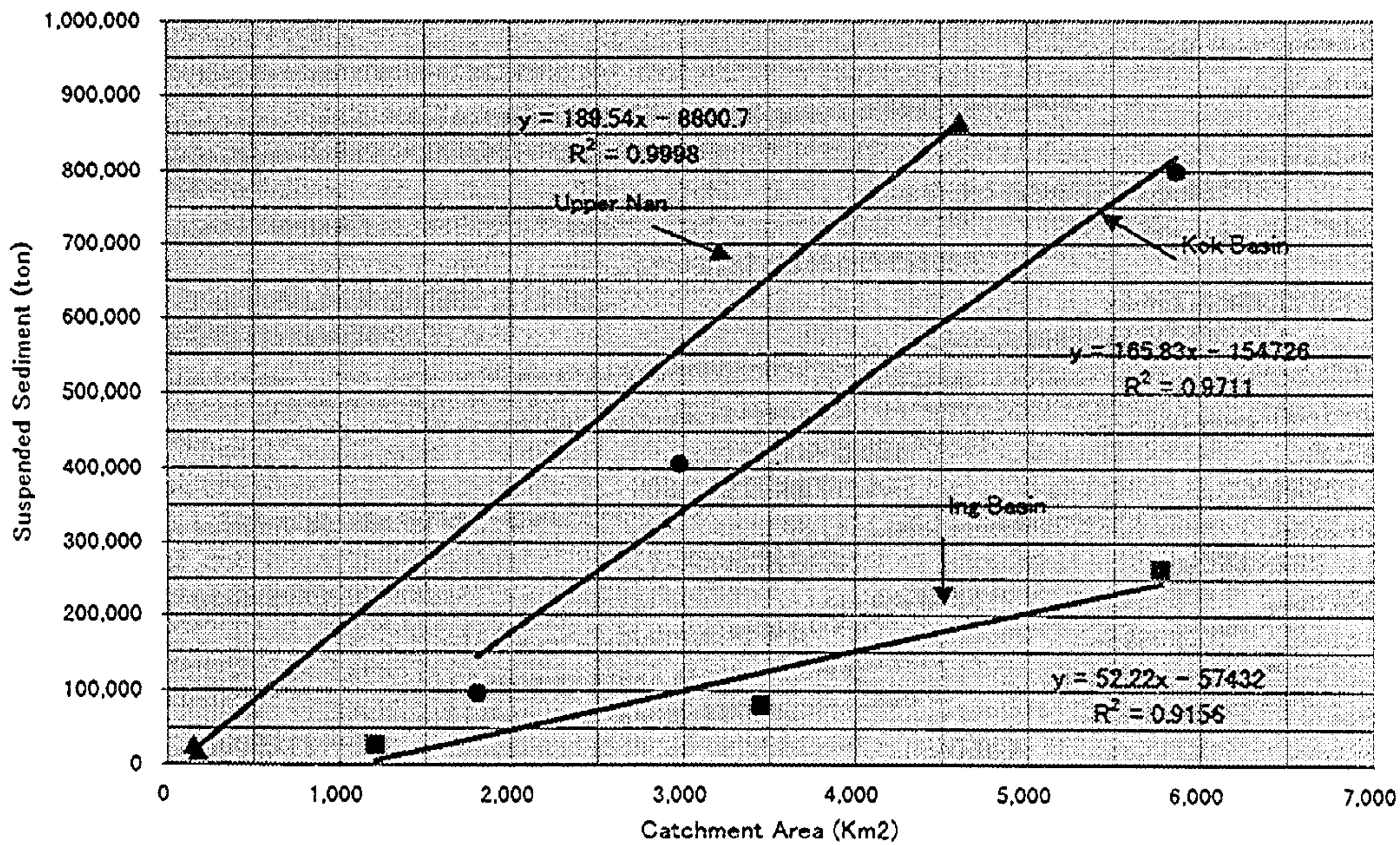
Table 2.3.15 Annual Sediment at Intake Locations

Unit: ton/year

Basin	Location	Catchment km^2	Suspended (t)	Total Sediment (t)	Yield ($m^3/year/km^2$)
Kok	Intake	6,220	876,800	1,315,200	140
Ing	Intake	4,400	172,400	224,100	35
Yao	Dam site	372	61,700	123,400	220

Note: The density of sediment was taken to be 1.5

Figure 2.3.5 Mean Annual Suspended Sediment



CHAPTER 3.

SOCIO-ECONOMIC CONDITIONS

CHAPTER 3 SOCIO-ECONOMIC CONDITIONS

3.1 Existing Socio-economic Conditions

The series of financial instabilities rocking eastern Asia have dealt a heavy blow to Thailand, which experienced high economic growth over the last decade, following a shift to the floating of the Baht in July 1997. This impact has been stronger in rural areas which possess a generally weaker socio-economic base than urban areas. With the spreading effects of rapid increase in unemployment (from 1.5% in February 1997 to 5.3% in August 1998), depressed domestic consumption and investment, and accelerating inflation (from 5.8% in 1996 to 8.1% in 1998), real per capita income in rural areas has decreased by 19% (compared to February 1997), which is over twice the 8% decrease in urban areas. This has further threatened standards of living in rural society. Against this background, the Government has revised its Eighth Five-Year Plan (October 1996 ~ September 2001) in an effort to rebuild the economy.

Macro-economic and social indicators for Thailand are shown in Table 3.1-1 and Table 3.1-2. A detailed description of socio-economic conditions in the Study Area is presented thereafter.

Table 3.1-1 Macro-economic Indicators

Item	1995	1996[1)]	1997[1)]	1998[2)]	1999[3)]
Income and Growth					
(1) GDP (current price, Baht billion)	4,188.9	4,598.3	4,827.2	n.a.	n.a.
(2) Per Capita GDP (current price, US$)	2,833	3,027	2,543	n.a.	n.a.
(3) GDP Growth (constant 1988 prices, %)	8.8	5.5	-0.4	-8.0	-0.7
- Agriculture	2.5	3.8	1.2	n.a.	n.a.
- Industry	10.5	7.0	-0.1	n.a.	n.a.
- Services	9.0	4.6	-1.1	n.a.	n.a.
Inflation (annual change in %)					
- Consumer Prices	5.8	5.8	5.6	8.1	3.0
Government Finance (% of GDP)[3)]					
(1) Revenue	18.7	18.9	17.9	n.a.	n.a.
(2) Expenditure	15.8	16.7	18.9	n.a.	n.a.
(3) Overall Fiscal Surplus	2.9	2.2	-1.0	n.a.	n.a.
Balance of Payments					
(1) Trade Balance (% of GDP)	-8.7	-8.9	-3.0	n.a.	n.a.
(2) Current Account Balance (% of GDP)[4)]	-7.9	-7.9	-2.0	n.a.	n.a.
(3) Exports (growth rate, %)	24.8	-1.6	4.0	-6.9	4.1
(4) Imports (growth rate, %)	31.9	0.9	-13.4	-33.5	10.3

Note: 1) Preliminary estimates. 2) Forecast. 3) On a fiscal year basis.
4) Excluding official transfers.

Source: 1) "Country Assistance Plan, Thailand (1999 – 2001), Asian Development Bank, November 1998.
2) "Quarterly Bulletin", Bank of Thailand, June 1998.
3) "Forecast by Consensus Economics", IMF, February 1999.

Table 3.1-2 Social Indicators

Item	1985	1990	Latest Year
• Total Population (million)	51.6	55.8	60.6 (1997)
• Annual Population Growth Rate (%)	1.9	1.6	1.0 (1997)
• Total Fertility Rate (births per woman)	3.3 (1980-85)	2.6 (1985-90)	1.8 (1995)
• Maternal Mortality Rate (per 100,000 live births)	270 (1980-85)	180 (1988)	155 (1989-94)
• Infant Mortality Rate (per 100,000 live births)	38 (1988)	-	29 (1994)
• Life Expectancy at Birth (years)	64 (1987)	66	70 (1995)
- Female	66 (1987)	68	72 (1995)
• Adult Literacy Rate (%)	91	93	94 (1995)
- Female	88	90	92 (1995)
• Primary School Gross Enrollment Rate[1] (%)	96	99	98 (1989-94)
- Female	-	99	97 (1989-94)
• Secondary School Gross Enrollment Rate[2] (%)	30	30	37 (1989-94)
- Female	13.4	22.1	24.8
• Child Malnutrition (% of under age five)	23.6 (1987)	18.0	13.0 (1989-95)
• Population with Access to Safe Water (%)	64 (1985-87)	76 (1988-91)	89 (1990-96)
• Population with Access to Sanitation (%)	53 (1985-87)	74 (1988-91)	96 (1990-96)
• Government Expenditure on Education (% of GDP)	3.6 (1986)	2.8	4.3 (1997)
• Government Expenditure on Health (% of GDP)	0.9 (1986)	0.8	1.2 (1997)
• Human Development Index	-	0.715	0.833 (1994)
• Human Development Index (Rank)[3]	-	74	59 (1994)
• Per Capita Crop Land (ha)	0.38	0.40	0.34 (1995)
• Forest and Woodland (% of total land area)	29.2	27.6	26.4 (1994)
• Nationally Protected Areas (% of total area)	-	9.1	13.7 (1994)
• Per Capita Commercial Energy Use[4]	343	352	770 (1994)
• Per Capita Carbon Dioxide Emissions (metric tons)	0.86	-	1.7 (1992)

Note: 1) Percentage of the population in the age group 6-11years.

2) Percentage of the population in the age group 12-17 years.
3) For 1990 and 1994, a total of 173 and 175 countries, respectively were ranked from high to low human development, using the Human Development Index of UNDP as a basis.
4) In kilogram of oil equivalent.

Source: "Country Assistance Plan, Thailand (19999 – 2001)", Asian Development Bank, November 1998.

3.1.1 Demography

Provincial data for the period 1991 to 1995 were obtained from various line agencies and aggregated according to the proportions of the Study Area in the provinces occupying each basin. It should be noted that basin areas are approximate since conversion from provincial data to basins cannot be precise.

(1) Population

Total population in the Study Area in 1995 was 23.4 million, being 39.4% of the national total. Of the total, the Lower Chao Phraya Basin accounted for 12.5 million (53.4% of the total) due to inclusion of highly-populated urban areas of the Bangkok Metropolitan Region and its environs such as the Samut Prakan, Nonthaburi and Pathum Thani provinces in the Lower Chao Phraya Basin, the Upper Chao Phraya Basin for 9.5 million (40.6%), and the Kok and Ing Basins for 1.4 million (6.0%) as shown in Table 3.1-3.

Table 3.1-3 Basin-wise Population (1995)

Basin	Population (1,000)	Urban (%)	Rural (%)
1. Upper Chao Phraya Basin	9,463	8.2	91.8
1.1 Nan Basin	2,346	8.7	91.3
(1) Upper Nan Basin	578	5.9	94.1
(2) Lower Nan Basin	1,768	9.7	90.3
1.2 Yom Basin	1,989	6.3	93.7
1.3 Wang Basin	662	8.8	91.2
1.4 Ping Basin	2,372	8.1	91.9
1.5 Sakae Krang Basin	435	9.9	90.1
1.6 Pasak Basin	1,660	9.5	90.5
2. Lower Chao Phraya Basin	12,478	54.0	46.0
3. Kok and Ing Basins	1,455	4.5	95.5
3.1 Kok Basin	780	5.1	94.9
3.2 Ing Basin	675	3.9	96.1
Study Area	23,396	32.4	67.6
Whole Kingdom	59,460	18.3	81.7

Source: "Statistical Reports of Changwat", National Statistical Office, 1996.

The rural population as a proportion of the total population in the Study Area averages 67.6%, and all basins except for the Lower Chao Phraya Basin are rural.

The average annual rate of population growth for the period 1991 to 1995 in the Study Area was 1.02%, being highest at 4.42% for the Kok Basin due to large migration flows from outer provinces, and lowest at 0.51% for the Lower Chao Phraya Basin as shown in Table 3.1-4.

Table 3.1-4 Basin-wise Population Growth Rates (1991-95)

Basin	1991-95 Growth Rate (%)
1. Upper Chao Phraya Basin	1.37
1.1 Nan Basin	1.30
(1) Upper Nan Basin	0.93
(2) Lower Nan Basin	1.42
1.2 Yom Basin	0.75
1.3 Wang Basin	1.01
1.4 Ping Basin	2.36
1.5 Sakae Krang Basin	1.01
1.6 Pasak Basin	1.09
2. Lower Chao Phraya Basin	0.51
3. Kok and Ing Basins	3.61
3.1 Kok Basin	4.42
3.2 Ing Basin	2.72
Study Area	1.02
Whole Kingdom	1.08

As shown in Table 3.1-5, the working population in the Study Area averages 55.2% of the total population, being highest at 60% for the Lower Chao Phraya Basin, and lowest at 44.3% for the Pasak Basin. In terms of agriculture, the Nan Basin enjoys rich resources of agricultural working population at 53.6%, while the Lower Chao Phraya Basin suffers a scarcity of the same.

Table 3.1-5 Working Population (1995)

Basin	Total (1,000)	% of Total Population (%)	Agriculture (%)	Others (%)
1. Upper Chao Phraya Basin	4,738	50.1	47.0	53.0
1.1 Nan Basin	1,116	47.6	53.6	46.4
(1) Upper Nan Basin	283	49.0	52.7	47.3
(2) Lower Nan Basin	833	47.1	54.0	46.0
1.2 Yom Basin	1,034	52.0	46.8	53.2
1.3 Wang Basin	340	51.4	34.7	65.3
1.4 Ping Basin	1,281	54.0	44.9	55.1
1.5 Sakae Krang Basin	232	53.3	61.6	38.4
1.6 Pasak Basin	735	44.3	41.8	58.2
2. Lower Chao Phraya Basin	7,489	60.0	15.6*	84.4
3. Kok and Ing Basins	694	47.7	44.8	55.2
3.1 Kok Basin	372	47.7	44.4	55.6
3.2 Ing Basin	322	47.7	45.3	54.7
Study Area	12,921	55.2	28.7	71.3
Whole Kingdom	32,575	54.8	52.0	48.0

Note: * indicates exclusion of agricultural population in the Bangkok Metropolitan Region due to unavailability of such data.

Agricultural population during the Eighth Five Year Plan period (1996/97 – 2000/01) is expected to decrease for all basins except the Kok and Ing Basins with advancement of urbanization and industrialization.

As shown in Table 3.1-6, population density in 1995 averaged 136/km² (exceeding the national average of 115/km²), ranging from 44/km² for the Upper Nan Basin to 398/km² for the high-densely populated Lower Chao Phraya Basin.

Table 3.1-6 Population Density (1995)

Basin	Population Density (No./km²)
1. Upper Chao Phraya Basin	76
1.1 Nan Basin	68
(1) Upper Nan Basin	44
(2) Lower Nan Basin	83
1.2 Yom Basin	84
1.3 Wang Basin	61
1.4 Ping Basin	69
1.5 Sakae Krang Basin	83
1.6 Pasak Basin	102
2. Lower Chao Phraya Basin	398
3. Kok and Ing Basins	97
3.1 Kok Basin	99
3.2 Ing Basin	94
Study Area	136
Whole Kingdom	115

(2) Population Projection

Population projections for years 1996, 2006 and 2016 have been made based on the average annual rate of population growth for the period 1991 to 1995 as shown in 3.1-7.

Table 3.1-7 Population Projection

(Unit: 1,000)

Basin	1995	1996*	2006*	2016*	Annual Growth Rate (%)
1. Upper Chao Phraya Basin	9,463	9,590	11,040	12,720	1.37
1.1 Nan Basin	2,346	2,370	2,710	3,080	1.30
(1) Upper Nan Basin	578	580	640	700	0.93
(2) Lower Nan Basin	1,768	1,790	2,070	2,380	1.42
1.2 Yom Basin	1,989	2,000	2,160	2,330	0.75
1.3 Wang Basin	662	670	740	820	1.01
1.4 Ping Basin	2,372	2,430	3,070	3,870	2.36
1.5 Sakae Krang Basin	435	440	490	540	1.01
1.6 Pasak Basin	1,660	1,680	1,870	2,080	1.09
2. Lower Chao Phraya Basin	12,478	12,540	13,200	13,890	0.51
3. Kok and Ing Basins	1,455	1,500	2,170	3,120	3.61
3.1 Kok Basin	780	810	1,260	1,930	4.42
3.2 Ing Basin	675	690	910	1,190	2.72
Study Area	23,396	23,630	26,410	29,730	1.02
Whole Kingdom	59,460	60,522	67,653	75,623	1.08

Note: * indicates estimates.

Based on the above table, the characteristics of each basin are as follows.

1) Upper Chao Phraya Basin

The population of the Upper Chao Phraya Basin grows at an annual rate of 1.37%, and is forecast to increase by 32.6% from 9.6 million in 1996 to 12.7 million in 2016. Population increase rate in the Lower Nan Basin specifically is high, with population anticipated to grow from 1.8 million in 1996 to 2.4 million in 2016. Development of the agricultural sector will accordingly be essential, from the standpoint of future food supply and demand balance (assuming per capita annual rice consumption of 119 kg, new food demand of 372,500 tons will emerge by the year 2016, corresponding to 564,400 tons of paddy which is equivalent to 11.7% of the total production in the Upper Chao Phraya Basin in 1995/96) and creation of employment opportunities. The agricultural sector has the capacity to provide immediate locomotive effect on stimulating the regional economy, and a high capacity to absorb labour. The proportion of employed population within this basin accounted for by the agricultural sector is extremely high at 47.0% (compared to 15.6% for the Lower Chao Phraya Basin), and consequently the role of this sector as a base industry can be expected to increase in importance.

2) Lower Chao Phraya Basin

The population of the Lower Chao Phraya Basin grows at an annual rate of 0.51%, and is estimated to increase by only 1.1% from 12.5 million in 1996 to 13.9 million in 2016. On this basis, and in light of the deceleration of the earlier rapid pace of urbanization and industrialization in the area, it is forecast that no significant change will occur in terms of employment pattern and base-structure within the agricultural and industrial sectors. However, within the context of chronic irrigation water shortage in the dry season and the fact that development of new farmland has essentially reached a limit, it will be necessary to maximize efficiency of water use during the dry months, as well as to further promote crop diversification. It is essential that sufficient dry season irrigation water be secured and that the productivity and cropping intensity of existing farmland be increased to maintain and strengthen the role of this basin. Crop diversification and the effective combination of wet paddy and dry season farming is accordingly the recommended approach in avoiding over-vulnerability to price fluctuations and pest damage, as well as addressing the problems of saline contamination of soil and overcropping which tend to affect upland cultivation.

3) Kok and Ing Basins

The population in the Kok and Ing Basins is forecast to increase by around two-fold from 1.5 million in 1996 to 3.1 million in 2016 (annual growth rate of 3.6%). This is due to marked population inflow from neigbouring rural areas into urban areas particularly in the Kok Basin, including Chiang Rai which is the second largest city in the northern region after Chiang Mai and a popular resort area. In order to cope with this future population increase, it will be necessary to pursue development of irrigated agriculture (directed at the cultivation of high value crops which exploit in conformity with the regional climate) since there exists large potential for expansion of arable land and tourism in order to secure an adequate food supply and generate new employment opportunities.

(3) Households and Average Family Size

The number of households and average family size in the Study Area in 1995 are shown in Table 3.1-8 (see the Supporting Report for details).

Table 3.1-8 Number of Households and Average Household Size (1995)

Basin	Population (1,000)	No. of Households (1,000)	Average Family Size (No.)
1. Upper Chao Phraya Basin	9,463.5	2,477.7	3.8
1.1 Nan Basin	2,346.2	579.7	4.0
(1) Upper Nan Basin	578.3	141.9	4.1
(2) Lower Nan Basin	1,767.9	437.8	4.0
1.2 Yom Basin	1,988.7	514.4	3.9
1.3 Wang Basin	661.5	179.3	3.7
1.4 Ping Basin	2,372.3	676.7	3.5
1.5 Sakae Krang Basin	434.6	111.4	3.9
1.6 Pasak Basin	1,660.2	416.3	4.0
2. Lower Chao Phraya Basin	12,478.6	3,680.7	3.4
3. Kok and Ing Basins	1,454.8	411,4	3.5
3.1 Kok Basin	780.0	223.0	3.5
3.2 Ing Basin	674.8	188.4	3.6
Study Area	23,396.9	6,569.8	3.6
Whole Kingdom	59,460.4	14,697.1	4.0

Source: "Statistical Yearbook Thailand, 1996", National Statistical Office.

As indicated in the above table, the number of households in the Study Area in 1995 accounted for 44.7% of all households in the country. Of this, the Lower Chao Phraya Delta containing the Bangkok Metropolitan region accounts for 56.0% of the households and 53.3% of the population in the Study Area, respectively. Average household size in the Study Area is 3.6 persons, which is slightly smaller than the national average of 4.0 persons. In general, household size tends to be smaller in urban areas than in rural areas, and this trend is not anticipated to change in the future.

(4) Unemployment

As a result of the direct impacts on the Thai economy from the Asian crisis, the unemployment rate rose sharply from 1.5% in February 1997 to 5.3% in August 1998. The effects of this unemployment are particularly serious in rural areas. Table 3.1-9 (see the Supporting Report for details) indicates basin-wise unemployment rates for 1995.

Table 3.1-9 Unemployment Rate (1995)

Basin	Population (1,000)	Labour Force (1,000)	Employ-ment (%)	Unemploy-ment (%)	Seasonal Employment (%)
1.Upper Chao Phraya Basin	9,463.5	5,107.0	98.6	1.2	0.1
1.1 Nan Basin	2,346.2	1,204.3	97.9	2.0	0.1
(1) Upper Nan Basin	578.3	285.0	99.3	0.7	0
(2) Lower Nan Basin	1,767.9	919.3	97.5	2.4	0.1
1.2 Yom Basin	1,988.7	1,122.2	98.3	1.6	0.1
1.3 Wang Basin	661.5	365.9	99.4	0.5	0.1
1.4 Ping Basin	2,372.3	1,328.5	99.0	0.9	0.1
1.5 Sakae Krang Basin	434.6	246.2	99.3	0.6	0.1
1.6 Pasak Basin	1,660.2	839.9	99.1	0.7	0.2
2.Lower Chao Phraya Basin	12,478.6	7,511.7	98.9	1.0	0.1
3. Kok and Ing Basins	1,454.8	759.0	99.0	0.7	0.3
3.1 Kok Basin	780.0	401.0	99.1	0.7	0.2
3.2 Ing Basin	674.8	358.0	98.8	0.7	0.5
Study Area	23,396.9	13,377.7	98.8	1.1	0.1
Whole Kingdom	59,460.4	33,001.8	98.7	1.1	0.2

Source: "Statistical Yearbook Thailand, 1996", National Statistical Office.

As can be seen from the above table, the unemployment rate (number of unemployed per total labor population) for the Upper Chao Phraya Basin in 1995 was highest at 1.2% followed by that for the Lower Chao Phraya Basin at 1.0% and the Kok and Ing Basins at 0.7%. Within the Upper Chao Phraya Basin, the Lower Nan Basin exhibits an unemployment rate of 2.4%, which is significantly higher than that for the nation as a whole at 1.1%. Reasons for this include small farm scale and the fact that local agro-industries are very minor. It is, therefore, estimated that hidden full unemployment and under-employment are widespread. Although the unemployment rate in the Kok and Ing Basins is below the national average, temporary seasonal workers employed only during the peak agricultural months are numerous, at a rate exceeding that for the country as a whole by over two-fold. This situation has been further aggravated by the impacts of the economic crisis in recent years.

(5) Demography in Benefit Area

Demographic statistics for the benefit area are summarized in Table 3.1-10.

Table 3.1-10 Demography in Benefit Area

Benefit Area	Agricultural Population* (No.)	Farm Households* (No.)	Average Family Size* (No.)	Irrigable Area (1,000 rai)	Land Holding Size (rai)
1. Chao Phraya Delta	865,700	232,600	3.72	7,342.0	31.6
(1) Upper West	336,100	80,400	4.18	2,299.0	28.6
(2) Upper East	195,800	50,200	3.90	1,657.0	33.0
(3) Lower West	128,800	39,500	3.26	1,447.0	36.6
(4) Lower East	205,000	62,500	3.28	1,939.0	31.0
2. Lower Nan Basin	319,000	79,100	4.03	1,852.6	23.4
(1) Phitsanulok Irrigation Project (Stage 1)	83,600	20,900	4.00	667.0	31.9
(2) Phitsanulok Irrigation Project (Stage 2)	62,800	15,700	4.00	500.0	31.9
(3) DEDP Pumping Scheme (existing)	98,700	24,300	4.06	392.0	16.1
(4) DEDP Pumping Scheme (new)	73,900	18,200	4.06	293.6	16.1
3. Kok, Ing & Upper Nan Basin Associate Irrigation Projects	56,800	16,100	3.52	250.0	15.5
Benefit Area	1,241,500	327,800	3.79	9,444.6	28.8

Note: * indicates estimates.
Source: 1) Economic Study Group, PPD, RID.
2) "Agricultural Statistics of Thailand, Crop Year 1996/97", Office of Agricultural Economics, Ministry of Agriculture and Co-operatives.

Benefit population and households under the Project number 1,241,500 and 327,800, respectively. Average land holdings per household are 28.8 rai.

The importance of the agricultural and regional development discussed earlier is being re-examined as Thailand continues to remain heavily under the effects of the ongoing economic crisis in Asia. This type of development strengthens the localized socio-economic base, setting a firm foundation for future economic growth. Socio-economic impacts in this regard are myriad, and include (i) rectification of skewed levels of development by area and alleviation of poverty, (ii) self-sufficiency in meeting food demand which is increasing parallel to population growth and rising income levels, (iii) improved capacity of the agriculture and local industry sectors to absorb labor, (iv) foreign exchange earnings through the export of raw and processed agricultural products, (v) effective utilization of limited regional resources, etc.

3.1.2 Gross Basin Product (GBP)

Gross Basin Product (GBP) for the Study Area has been estimated on the basis of provincial data quoted from "Statistical Reports of Changwat" with the same methodology adopted for population projection in each basin.

(1) GBP

GBP (1988 constant prices) for the Study Area in 1994 was 1,768 million Baht, being 66% of the national total, of which the Lower Chao Phraya Basin at 1,505 million Baht was 85 % of the total GBP for the Study Area and 56% of the national GDP, as shown in Table 3.1-11.

Table 3.1-11 Basin-wise Gross Basin Product (1991 & 1994)

Basin	1991 GBP (million Baht)	1994 GBP (million Baht)	Changes (%)
1. Upper Chao Phraya Basin	196,654.5	237,479.7	20.8
1.1 Nan Basin	37,520.8	43,032.5	14.7
(1) Upper Nan Basin	8,099.7	9,137.4	12.8
(2) Lower Nan Basin	29,421.1	33,895.1	15.2
1.2 Yom Basin	31,419.8	36,574.3	16.4
1.3 Wang Basin	15,056.6	18,459.5	22.6
1.4 Ping Basin	59,920.4	70,220.6	17.2
1.5 Sakae Krang Basin	8,288.9	9,622.8	16.1
1.6 Pasak Basin	44,448.0	59,570.0	34.0
2. Lower Chao Phraya Basin	1,165,990.1	1,504,976.8	29.1
3. Kok and Ing Basins	21,292.3	25,324.1	18.9
3.1 Kok Basin	12,376.5	14,395.0	16.3
3.2 Ing Basin	8,915.8	10,929.1	22.6
Study Area	1,383,936.8	1,767,780.6	27.7
Whole Kingdom	2,110,022.0	2,685,977.0	27.3

Note : Based on 1998 constant prices.
Source: "Statistical Reports of Changwat", National Statistical Office, 1996.

(2) GBP Growth Rate

The national economy grew by 8.4% per year between 1991 and 1996, and GBP for the Study Area increased by 8.5% per year over the same period. On a basin-wise basis, as shown in Table 3.1-12, the Pasak Basin exhibits the highest growth rate at 10.3% due to the significant contribution of the manufacturing sector to its GBP, while the Upper Nan Basin shows the lowest at 4.1%, indicating that subsistence agriculture is predominant.

Table 3.1-12 Basin-wise GBP Growth Rates (1991-94)

Basin	1991-94 Growth Rate (%)
1. Upper Chao Phraya Basin	6.49
1.1 Nan Basin	4.68
(1) Upper Nan Basin	4.10
(2) Lower Nan Basin	4.83
1.2 Yom Basin	5.19
1.3 Wang Basin	7.03

1.4 Ping Basin	5.43
1.5 Sakae Krang Basin	5.10
1.6 Pasak Basin	10.25
2. Lower Chao Phraya Basin	8.88
3. Kok and Ing Basins	5.95
3.1 Kok Basin	5.17
3.2 Ing Basin	7.03
Study Area	8.50
Whole Kingdom	8.38

The Lower Chao Phraya Basin, which recorded the highest growth rate at 8.9% within the Study Area, and more precisely the highly industrialized Bangkok Metropolitan Region and its environs provide the engine for economic growth for the entire basin as well as the country as a whole under the Government's economic development strategy of a shift from import-substitute industrialization to export-promoting industrialization. It is, therefore, obvious that availability of employment and income generating opportunities and the practice of export-oriented crop cultivation are closely correlated with the extent of regional economic growth.

(3) Per Capita GBP

Basin-wise per capita GBP is shown in Table 3.1-13.

Table 3.1-13 Basin-wise Per Capita GBP (1991 and 1994)

Basin	1991 (1,000 Baht)	1994 (1,000 Baht)	Changes (%)
1. Upper Chao Phraya Basin	21.9	25.1	14.6
1.1 Nan Basin	16.8	18.4	9.5
(1) Upper Nan Basin	14.5	16.0	10.3
(2) Lower Nan Basin	17.6	19.1	8.5
1.2 Yom Basin	16.3	18.3	12.3
1.3 Wang Basin	23.7	27.9	17.7
1.4 Ping Basin	27.6	29.6	7.2
1.5 Sakae Krang Basin	19.8	22.1	11.6
1.6 Pasak Basin	27.9	35.8	28.3
2. Lower Chao Phraya Basin	95.3	122.1	28.1
3. Kok and Ing Basins	16.8	17.4	3.6
3.1 Kok Basin	18.7	18.4	-1.6
3.2 Ing Basin	14.6	16.2	11.0
Study Area	61.6	76.0	23.4
Whole Kingdom	37.0	45.5	23.0

As can be seen by the above table, significantly skewed levels of economic development are evident, with the 1994 average per capita GBP of other basins being roughly only one-sixth that of the Lower Chao Phraya Basin, and especially regional imbalance between the Lower Chao Phraya Basin and the Upper Nan and the Ing Basins accounts for a 7.6-fold differential. Within the Chao Phraya Basin itself, the sub-basins (excluding the Yom Basin) of Wang, Ping, Sakae Krang and Pasak exhibit an average GBP of around 30,000 Baht, which is approximately 90% higher than that of the Nan Basin. From this standpoint, the early implementation of agricultural development directed at the agriculturally-backward Nan Basin is recommended in order to rectify skewed economic levels as targeted under the Agricultural Land Reform Act.

(4) Sector-wise Contribution to GBP

Sector-wise contribution to GBP for the Study Area is summarized as shown in Table 3.1-14 (see the Supporting Report for details).

Table 3.1-14 Sector-wise Contribution to GBP (1994)

Basin	GBP (million Baht)	Agriculture (%)	Non-agriculture (%)
1. Upper Chao Phraya Basin	237,479.7	18.6	81.4
1.1 Nan Basin	43,032.5	26.2	73.8
(1) Upper Nan Basin	9,137.4	25.5	74.5
(2) Lower Nan Basin	33,895.1	26.3	73.7
1.2 Yom Basin	36,574.3	24.1	75.9
1.3 Wang Basin	18,459.5	10.1	89.9
1.4 Ping Basin	70,220.6	16.1	83.9
1.5 Sakae Krang Basin	9,622.8	26.0	74.0
1.6 Pasak Basin	59,570.0	14.0	86.0
2. Lower Chao Phraya Basin	1,504,976.8	3.2	96.8
3. Kok and Ing Basins	25,324.1	19.6	80.4
3.1 Kok Basin	14,395.0	17.4	82.6
3.2 Ing Basin	10,929.1	22.4	77.6
Study Area	1,767,780.6	5.5	94.5
Whole Kingdom	2,685,977.0	11.5	88.5

Note : Based on 1988 constant prices.
Source: "Statistical Reports of Changwat", National Statistical Office, 1996.

Sector-wise contributions to GBP for the Study Area in 1994 were at levels of 5.5% (half of the national figure) for agriculture, 35.2% for manufacturing, 16.7% for wholesale and retail trade, and 9.8% for banking, insurance and real estate. This small share of the agricultural sector is entirely influenced by the sectoral GBP contribution of the Lower Chao Phraya Basin where urbanization and industrialization are significantly acute. Agricultural contribution was highest at 26.2% for the Nan Basin, and lowest at 3.2% for the Lower Chao Phraya Basin.

Although the agricultural sector accounts for as low as 11.5% of GDP, the role of agriculture in the domestic economy is still important since the sector shares over 50% of total working population.

(5) GBP Projection

GBP projections for the years 1996, 2006 and 2016 have been made based on the past GDP achievements of the national economy as well as the target figures of the Eighth National Economic and Social Development Plan.

As shown in Table 3.1-15, GBP (1988 constant prices) for the Study Area is forecast to grow at an annual rate of 6.7% (6.5% for the national GDP growth) to 7,385,369 million Baht (10,823,888 million Baht for the national GDP) in 2016, being 68.2% of the national GDP. The Lower Chao Phraya Basin is expected to achieve a share of 88.4% of the total GBP in 2016, indicating a 4.3-fold increase over 1994.

As can be seen from the above, regional inequalities would be worsened without appropriate steps to be taken towards assurance of year-round irrigation water, and decentralization of economic development away from urban areas through relocation of industries in less-developed areas since a majority of the population live in rural areas where regional economies are agronomy based. This is evident from the fact that conditions in the north are reportedly the driest for at least ten years, and the drought is spreading into the Central Plain as dams and reservoirs in the northern watersheds reach critical levels. Under this Project, therefore, rectification of regionally skewed levels of economic development by making a shift from subsistence based farming to commercialized agriculture through promotion of crop diversification based on comparative area advantage is a major goal. It is essential for achievement of this goal to bring sustainability to dry season farming through the availability of adequate irrigation water.

3.1.3 Income and Expenditure

The northern part of the Study area is characterized by a predominantly mono-cultural agricultural economy and small land holdings, e.g. 16.1 rai for the DEDP pumping scheme in the Lower Nan Basin, with widespread poverty, while its southern part by a highly commercialized agricultural economy with crop diversification and large land holding, e.g. 31.6 rai for the Chao Phraya Delta. Under these circumstances, disparities in income and employment opportunities are wide and persistent due to land holding size and availability of irrigation water. Apart form the disadvantaged segment of the rural population, food security is guaranteed through higher income groups who are practicing a multiple cropping system in low-lying areas along rivers or in areas provided with irrigation canals with adequate water even during dry months, based on comparative area advantages. Smaller land holding households with poor access to irrigation water indicate increasing difficulties in supporting food requirements of their livelihood.

(1) Cash Income Sources

The main cash income sources of the farmers of different land holding size are summarized below.

1) Surplus Food Grains

The large farmers sell their surplus food grains to the local collectors/millers/central markets and earn cash income required for household necessities. Similarly, the medium farmers also sell a limited quantity of food grains during the harvesting period of crops to solve the household cash crisis and buy some needed items.

Table 3.1-15 GBP Projection

Basin	Population				GBP				Per Capita GBP			
	1994 (1,000)	1996* (1,000)	2006* (1,000)	2016* (1,000)	1994 (10^6 Baht)	1996* (10^6 Baht)	2006* (10^6 Baht)	2016* (10^6 Baht)	1994 (10^3 Bhat)	1996* (10^3 Bhat)	2006* (10^3 Bhat)	2016* (10^3 Bhat)
1. Upper Chao Phraya Basin	9,476	9,590	11,040	12,720	237,479.7	263,714.0	448,248.8	770,542.0	25.1	27.5	40.6	60.6
1.1 Nan Basin	2,344	2,370	2,710	3,080	43,032.5	46,992.6	72,978.0	113,332.6	18.4	19.8	26.9	36.8
(1) Upper Nan Basin	571	580	640	700	9,137.4	9,978.3	15,495.9	24,064.7	16.0	17.2	24.2	34.4
(2) Lower Nan Basin	1,773	1,790	2,070	2,380	33,895.1	37,014.3	57,482.1	89,267.9	19.1	20.7	27.8	37.5
1.2 Yom Basin	1,995	2,000	2,160	2,330	36,574.3	39,940.0	62,025.7	96,324.0	18.3	20.0	28.7	41.3
1.3 Wang Basin	661	670	740	820	18,459.5	20,561.5	35,255.3	60,449.9	27.9	30.7	47.6	73.7
1.4 Ping Basin	2,376	2,430	3,070	3,870	70,220.6	80,245.4	156,385.7	304,771.3	29.6	33.0	50.9	78.8
1.5 Sakae Krang Basin	435	440	490	540	9,622.8	10,922.6	20,580.4	38,777.6	22.1	24.8	42.0	71.8
1.6 Pasak Basin	1,665	1,680	1,870	2,080	59,570.0	65,051.9	101,023.7	156,886.6	35.8	38.7	54.0	75.4
2. Lower Chao Phraya Basin	12,328	12,540	13,200	13,890	1,504,976.8	1,719,828.8	3,351,677.8	6,531,896.9	122.1	137.1	253.9	470.3
3. Kok and Ing Basins	1,454	1,500	2,170	3,120	25,324.1	28,207.7	48,365.9	82,929.7	17.4	18.8	22.3	26.6
3.1 Kok Basin	781	810	1,260	1,930	14,395.0	16,034.1	27,492.7	47,139.8	18.4	19.8	21.8	24.4
3.2 Ing Basin	673	690	910	1,190	10,929.1	12,173.6	20,873.2	35,789.9	16.2	17.6	22.9	30.1
Study Area	23,258	23,630	26,410	29,730	1,767,780.6	2,011,750.5	3,848,292.5	7,385,368.6	76.0	85.1	145.7	248.4
Whole Kingdom	59,095	60,522	67,653	75,623	2,685,977.0	3,075,175.0	6,337,347.0	10,823,888.0	45.5	50.8	93.7	143.1

Note: * indicates estimates.

However, there are many cases in which farmers sell all harvested food grains and procure food requirements of their livelihood from the local markets, especially in the Phitsanulok irrigation area as well as the Upper Chao Phraya Delta.

2) Livestock and Fish Farming

Livestock and fish raising is an important source of household income. Farmers domesticate cattle, buffaloes, chicken, duck, and freshwater fish. Large farmers earn more income from raising livestock and poultry than smaller farmers, while farmers specialized by aquaculture earn more income than those only by crop cultivation irrespective of land holding size.

3) Horticulture

Fruit and vegetable growing is also an important source of household income. Commercial fruit production is significant in the Central Plain due to well-organized marketing network and processing facilities. A great majority of the households traditionally own a few fruit trees, which are at no additional and visible cost to them, and whose produce is entirely used for home consumption. The most common fruits are mango, banana, guyava, citrus, etc. Vegetable cropping can in recent years be found all over the Chao Phraya Basin.

4) Side Business

Side business such as weaving, bamboo crafts making, etc. is run mostly by women's groups to supplement the agricultural income of their households.

5) Service

The service sector is the next most important sector after agriculture, both in terms of income and employment. The nearer the district capitals, there will be more job opportunities. This indicates that the annual income derived from this sector occupies a large proportion of the total farm income, irrespective of land holding size.

6) Labour

Since the majority of small farmers suffer difficulties in maintaining their livelihood, they have to work as agricultural labourers during the peak agricultural season at the average daily wage rate of 110 Baht. Thus, agricultural labour is particularly important for the small households, who are able to earn a higher income from provision of their agricultural labour force than from crop production.

(2) Farm Household Economy

Farm household income in each basin/area is summarized as shown in Table 3.1-16 (see the Supporting Report for details).

Table 3.1-16 Basin-wise Farm Income (1996/97)

Basin/Area	Average Land Holding (rai)	Total Income (1,000 Baht)	Agriculture (%)	Non-agriculture (%)	Land Productivity (Baht/rai)
1. Kok-Ing Canal Alignment	15.4	143.3	77.3	22.7	7,200
2. Ing-Nan Canal Alignment	13.7	98.4	59.7	40.3	4,300
3. Ing Basin	6.1	64.1	49.3	50.7	5,200
4. Upper Nan Basin	24.5	53.9	52.8	47.2	1,200
5. Lower Nan Basin	28.2	90.2	56.1	43.9	1,800
6. Upper Chao Phraya Delta	32.7	229.8	83.2	16.8	5,800
Study Area	27.0	136.2	71.6	28.4	3,600

Source: Farm household survey.

Results of analysis by different basins for the Study Area are as follows:

1) Average annual income for the Upper Chao Phraya Delta is about 4 times that of the Ing Basin and the Upper Nan Basin due to progress in crop diversification and cultivation of high value crops.

2) Main source of income for the Ing Basin and the Upper and Lower Nan Basins is non-agricultural activities, accounting for 44～51% of total income due to subsistence agriculture.

3) Land productivity for the Upper Chao Phraya Delta at 5,800 Baht/rai is the highest for all basins and, on the other hand, those for the Upper and Lower Nan Basins amount to about one-fourth that of the Upper Chao Phraya Delta, indicating that the average land holding of 26 rai for these basins cannot produce sufficient food to support the average number of household members of 4.5.

Based on the above analysis, the following development strategy is considered, reflecting regional characteristics:

1) Within the Donor Basin, farm income is particularly high along the Kok-Ing canal alignment due to suburban-type agriculture comprising cultivation of high value fruit trees and vegetable crops, and fish farming. In contrast, farm income in the Ing Basin and the Upper Nan Basin is much lower (38～45% of that along the Kok-Ing canal alignment), and households must rely on off-farm sources for approximately half of their income. Limited crop production depends primarily on rainfed agriculture, making it difficult for farm households to achieve even self-sufficiency in food production. In conjunction with the implementation of the project, it will accordingly be necessary to formulate an agricultural development plan as one part of the poverty alleviation strategy aimed at the Donor Basin, in order to bottom-up living standards in impoverished areas.

2) The Lower Nan Basin as well, despite the presence of the urban centers of Phitsanulok and Nakhon Sawan within the benefit area, exhibits low farm income at roughly one-fourth that of the Upper Chao Phraya Delta. This is due to limited irrigation water during the dry season, making productive cropping of paddy as well as varieties such as mungbeans and soybeans difficult. Measures to secure sufficient irrigation water during the dry season are accordingly urgently necessary. In this light, it is concluded that the promotion of sustainable irrigated agriculture (during the dry season as well) with its anticipated ripple-effect on agro-industry will provide the catalyst for invigorating the regional economy under the Project. No problems with regard to marketing of agricultural products are seen due to robust private sector participation, and the presence throughout the area of government-established central markets for the collection and shipping of agricultural produce.

(3) Expenditure

Household expenditure in each basin/area is summarized as shown in Table 3.1-17 (see the Supporting Report for details).

Table 3.1-17 Basin-wise Household Expenditure (1996/97)

Basin/Area	Average Land Holding (rai)	Total Expenditure (1,000 Baht)	Agriculture (%)	Others (%)	Agricultural Investment (Baht/rai)
1. Kok-Ing Canal Alignment	15.4	105.2	21.1	78.9	1,400
2. Ing-Nan Canal Alignment	13.7	70.3	18.5	81.5	1,000
3. Ing Basin	6.1	48.2	17.1	82.9	1,300
4. Upper Nan Basin	24.5	41.0	23.3	76.7	400
5. Lower Nan Basin	28.2	78.0	25.7	74.3	700
6. Upper Chao Phraya Delta	32.7	160.1	55.3	44.7	2,700
Study Area	27.0	104.6	38.6	61.4	1,500

Source: Farm household survey.

Results of analysis by different basins for the Study Area are as follows:

1) Average annual expenditure for the Ing Basin and the Upper Nan Basin accounts for 28% of that for the Upper Chao Phraya Delta due to smaller land holding size.

2) The share of agricultural expenses to the total family expenses is highest at 55% for the Upper Chao Phraya Delta, and lowest at 18% for the Ing-Nan route and the Ing Basin.

3) Annual agricultural investment for the Upper Chao Phraya Delta is about 7 times that of the Upper Nan Basin, indicating that although commercialized agriculture is more costly than mono-cultural agriculture, it is also much more profitable.

As the agricultural sector continues to be a major source of employment and income, and is overwhelmingly dominant in terms of labour force absorption, introduction of market-oriented multiple cropping to the benefit area constitutes a major potential for generating substantial employment and income opportunities especially for subsistence farmers in the Donor Basin.

3.1.4 Poverty

As a result of earlier sustained economic growth over an approximate 20 year period, the poverty rate in Thailand dropped from 32.6% in 1988 to 11.4% in 1996. The economic crisis which kicked off with the floating of the Baht in July 1997, however, has resulted in slumping production, investment and demand, the burdening of the financial system with a large volume of irrecoverable loans, an increase in unemployment and a drop in real income, which in turn have put a break on further lowering of the incidence of poverty. The Government's Eighth Five-Year Plan calls for a reduction of the poverty rate below 10% by 2001; however, this is considered extremely difficult given the serious state of the economy. At this point in time one year after the onslaught of the economic crisis, some initial signs of economic recovery have begun to emerge, and the challenge for the Government will be to induce domestic and foreign investment through economic restructuring to ensure a return to sustainable economic growth.

(1) Incidence of Region-wise Poverty

Reflecting regionally skewed levels of income, the incidence of poverty varies significantly from area to area. As shown in Table 3.1-18, the poverty rate in northeast Thailand at 19.4% in 1996 was significantly above the national average of 11.4%. In contrast, the poverty rate for the Bangkok Metropolitan Region and environs is a low 0.6%. The poverty rates for northern Thailand and central Thailand comprising the benefit area under the Project are 11.2% and 6.2%, respectively. These are below the national average, and attest to the fact that poverty in these regions is not as serious an issue overall as it is in the northeast of the country. Nevertheless, poverty remains a problem in certain specific rural locales within the Project area.

Table 3.1-18 Region-wise Poverty Incidences

Region	1988	1990	1992	1994	1996
Central	32.9	20.7	15.4	7.2	6.2
Eastern	15.5	19.4	11.9	7.5	3.8
Western	32.0	26.4	13.1	12.5	9.3
Northern	32.0	23.2	22.6	13.2	11.2
Northeastern	48.4	43.1	39.9	28.6	19.4
Southern	32.5	27.6	19.7	17.3	11.5
Bangkok & Vicinity	6.1	3.5	1.9	0.9	0.6
Whole Kingdom	32.6	27.2	23.2	16.3	11.4

Note: The poverty incidence has been estimated by the Development Evaluation Division of NESDB, adopting a new approach for estimation of poverty line.
Source: "Indicators of Well-being and Policy Analysis", Vol.2, No.3, NESDB, May 1998.

A 48.3% alleviation of poverty was achieved in northern Thailand over the six year period from 1990 to 1996, topping that for the poorest region, northeastern Thailand at

45.0% (the national average for the same period is 41.9%) and that for central Thailand at 30.0%. The reason for this high alleviation rate in northern Thailand is attributed to the rapid economic development occurring in the urban centers of Chang Mai and Chang Rai, with ripple effect into suburban-rural and other areas of the region. This has had a bottoming-up impact on the overall economy in northern Thailand. Nevertheless, despite this economic growth in the cities and towns of the region, certain backward rural districts (for example villages along the tunnel route as well as in the Nan Basin) continue to suffer marked poverty and a widening gap in income level compared to urban areas.

According to recent data, the impacts of the economic crisis on poverty have been serious, with the nation-wide poverty rate worsening from 11.4% in 1996 to 12.7% in 1998 and reportedly pushing an additional approximately one million persons below the poverty line. This is cited as inducing more significant poverty in already backward rural districts as a result of dwindling jobs for migrant laborers from these areas, and a corresponding drop in the remittance of pay back to their home villages.

(2) Poverty Incidence by Land Holding Size and Land Tenure

Based on NESDB data, poverty incidence by land holding size and land tenure pattern for the nation as a whole in 1996 is as shown in Table 3.1-19. The poverty rate for owner cultivators with holdings under 20 rai was 67.1% while that for tenant cultivators was slightly higher at 70.3% suggesting the continuing seriousness of poverty in rural areas compared to urban centers. In contrast to large and medium farmers whose primary source of income is agriculture, small and marginal farmers tend to rely heavily on off-farm earnings.

Table 3.1-19 Poverty Incidence by Land Holding Size and Land Tenure

Land Holding	1988	1990	1992	1994	1996
1. Owner Cultivator	47.5	40.7	39.2	29.2	22.5
< 5 rai	67.7	52.9	41.2	28.9	37.2
5 – 19 rai	56.2	52.1	46.3	36.0	29.9
≧ 20 rai	32.9	26.9	31.2	21.0	12.1
2. Tenant Cultivator	47.8	43.9	30.7	26.6	23.2
< 5 rai	67.4	60.0	30.3	21.0	35.1
5 – 19 rai	58.1	56.5	40.3	40.1	35.2
≧ 20 rai	35.0	28.3	19.6	15.4	13.8

Note: Same as in the table 3.1-18.
Source: Same as in the table 3.1-18.

Within the benefit area of the Project as well, average land holdings per household are extremely small at 16.1 rai particularly in the DEDP Pumping Scheme compared to that in the Chao Phraya Delta at 31.6 rai, and this combined with the inability of the local minor industries to provide sufficient off-farm employment establishes a scenario for most farm households subsisting below the poverty line.

(3) Income Inequality by Region and Income Group

The Gini Coefficient indicating earning disparity among income groups is shown in Table 3.1-20 on a region-wise basis.

Table 3.1-20 Region-wise Gini Coefficient

Region	1990	1996	1998*
Central	0.395	0.346	0.368
Northern	0.401	0.386	0.377
Northeastern	0.337	0.391	0.372
Southern	0.371	0.367	0.430
Bangkok & Vicinity	0.356	0.383	0.373
Whole Kingdom	0.429	0.429	0.430

Note: * indicates estimates.
Source: "Household Socio-economic Survey, Economic Statistical Division, National Statistical Office.

Although the Gini Coefficient has risen slightly from 0.429 in 1990 to 0.430 in 1998, there is still indication that income distribution remains essentially equal on an overall region-wise basis. Within specific regions, however, income inequality among income groups has worsened in areas other than northern and central Thailand. This trend is particularly marked in southern Thailand.

Income disparity among regions is widening, due to a concentration of industrial and commercial activity primarily within the Bangkok Metropolitan Region. This is a factor in the influx of population from rural to urban area, and the serious social problem of people abandoning their traditional farms and villages. Basin-wise income inequality is as shown in Table 3.1-21. The impoverished group with annual income under 10,000 Baht is concentrated in the Upper Nan Basin (accounting for 60.5% of total households) and in the Kok and Ing Basins (accounting for 51.5% of total households). In contrast, the high income group with annual income over 30,000 Baht is largely found in the Lower Chao Phraya Basin (accounting for 33.9% of total households) where irrigation infrastructure is well in place and good progress in crop diversification has been achieved. In order to rectify these skewed levels in income, it is necessary to pursue crop diversification in northern Thailand with specific focus on a shift from rainfed to irrigated agriculture, a transition from traditional cropping patterns to the introduction of high value crops (from food crops only to diversified agricultural activities including horticultural cropping, animal husbandry and fish farming), expansion of production in the agricultural product processing sector, as well as an increase in non-agricultural production activities based in rural areas (the nurturing of regional industries), etc.

Table 3.1-21 Basin-wise Income Inequality (1995)

Basin	Households (1,000)	<10,000 (%)	10,000 - 29,999 (%)	≧30,000 (%)	Unknown (%)
1. Upper Chao Phraya Basin	1,657.9	40.9	32.3	15.0	11.8
1.1 Nan Basin	407.6	44.7	32.9	15.3	7.1
(1) Upper Nan Basin	117.6	60.5	24.0	9.0	6.5
(2) Lower Nan Basin	290.0	38.3	36.5	17.9	7.3
1.2 Yom Basin	383.5	41.9	33.1	14.4	10.6
1.3 Wang Basin	132.8	50.2	24.5	7.7	17.6
1.4 Ping Basin	463.1	40.1	30.2	12.8	16.9
1.5 Sakae Krang Basin	69.2	31.9	40.8	22.4	4.9
1.6 Pasak Basin	201.7	30.0	36.7	23.2	10.1
2. Lower Chao Phraya Basin	814.4	22.1	34.7	33.9	9.3
3. Kok and Ing Basins	281.9	51.5	30.8	10.7	7.0
3.1 Kok Basin	148.0	50.2	30.3	11.2	8.3
3.2 Ing Basin	133.9	52.9	31.3	10.2	5.6
Study Area	2,754.2	36.4	32.9	20.2	10.5

Note: The above table shows income differentials in the non-municipal area.
Source: "Statistical Reports of Changwat", National Statistical Office, 1996.

In order to correct inequalities in income by region and promote population retention in rural areas, the Government has emphasized the need for establishing agricultural infrastructure, greater social welfare, and improved education and training of agricultural labor. These are seen as the catalyst for upgrading agriculture production, developing a solid industrial base, and promoting a diversified agro-economy in the subject regions.