CHAPTER 3
NECESSITY OF KOK-ING-NAN WATER DIVERSION PROJECT

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3.1 Potential Water Resources

(1) Limited Water Resources in Thailand and Chao Phraya Basin

(a) Water Resources in Thailand

In accordance with the data and information presented in the World Resources 1996-97, a joint publication by the World Resources Institute, the World Bank and the United Nations, Thailand has a large farmland of 21.6 million ha equivalent to 0.4 ha per capita under the 1995 population, and this scale of farmland will be enough to support sufficiently the national food security towards the 21 century. On the contrary, Thailand's annual renewable water resources are quite limited to 179,000 MCM/year which is equivalent to 350 mm in terms of the specific runoff yield or 3,000 cu.m per capita, having the lowest per capita value among the Southeastern Asian countries as shown in the following table.

Water and Land Resources in Southeastern Asian Countries

Country	Total Land (10^3sqkm)	1995 Population (million)	Water Resources			Land Resources		
			Amount (BCM)	Specific Runoff Yield (mm)	Per Capita Amount (cu.m)	Total Area million (ha)	Per Capita Area (ha)	Per ha Water (cum/ha)
Thailand	513.1	58.8	179*)	350	3,000	21.6	0.37	8,300
Lao PDR	230.8	4.9	270	1,170	55,100	1.6	0.33	168,800
Cambodia	176.5	10.3	498	2,820	48,400	4.3	0.42	115,800
Vietnam	325.5	74.5	376	1,160	5,000	6.9	0.09	54,500
Myanmar	657.6	46.5	1,082	1,650	23,300	10.1	0.22	107,100
Malaysia	328.6	20.1	456	1,390	22,700	4.9	0.24	93,100
Philippines	298.2	67.6	323	1,080	4,800	10.5	0.16	30,800
Indonesia	1,811.6	197.6	2,530	1,400	12,800	42.8	0.22	59,100
Japan	376.5	125.1	547	1,450	4,400	5.2	0.04	105,200

Note: *) Annual renewable water resources extracted from World Resources show relatively smaller value than that estimated by NESDB's 25 Basin Study.

The limited water resources will be the most significant constraints to Thailand's economic development towards the 21 century. Some visualized

information is given in the Database Map.

(b) Water Resources in Chao Phraya Basin

The distribution of water resources in various regions of Thailand calculated on the basis of the data from the Water Resources Development for 25 Basins and observed data of river runoff during the past 20 years, as follows;

Potential Water Resources in Various Regions of Thailand

	Total Land (10^3sqkm)	1993 Popula-tion (million)	Potential Water Resources			Potential Land Resources		
			Amount (BCM)	Specific Runoff Yield (mm)	Per Capita Amount (cu.m)	Total Area million (ha)	Per Capita Area (ha)	Per ha Water (cum/ha)
North East	168.9	20.5	47.3	280	2,300	9.2	0.45	5,100
Chao Phraya	157.9	21.7	32.9	210	1,500	5.9	0.27	5,600
East Coast	36.3	3.9	26.4	730	6,800	2.0	0.52	13,200
West Coast	43.2	3.5	13.7	320	3,900	1.4	0.40	9,800
South	72.1	7.6	73.8	1,020	9,710	2.8	0.36	26,700
Others	34.7	2.0	18.2	520	9,200	0.6	0.27	9,200
Total	513.1	59.2	212.3	410	3,600	21.9	0.37	9,700

Tha values of specific runoff yield in the North East and Chao Phraya basin, 280 mm and 210 mm, are considerably low compared to those in other basins. The amount of available water per capita in the Chao Phraya basin is estimated at only 1,500 cu.m, and this will not be sufficient to cover the demand for agriculture, domestic and industrial uses in the basin. Accordingly, the sustainable economic development in the Chao Phraya basin, especially in the delta area towards 21 century, may not be guaranteed due to shortage of water resources.

(c) Water Resources in Sub-Basins of Chao Phraya Basin

The water resources of sub-basins in the Chao Phraya basin are summarized as given below;

Water Resources in Sub-Basins of Chao Phraya Basin

Sub-Basin	Total Land (10^3sqkm)	1993 Popula-tion (million)	Water Resources			Land Resources		
			Amount (BCM)	Specific Runoff Yield (mm)	Per Capita Amount (cu.m)	Total Area million (ha)	Per Capita Area (ha)	Per ha Water (cum/ha)
Nan	34.3	2.3	9,160	270	4,000	1,080	0.47	8,500
Yom	23.6	1.8	2,960	130	1,600	760	0.42	3,900
Wang	10.8	0.7	1,100	100	1,600	150	0.21	7,300
Ping	33.9	2.6	7,970	240	3,000	650	0.25	12,300
Sakae Krung	5.2	0.5	1,300	190	2,700	260	0.52	5,000
Pasak	16.3	1.6	2,980	180	1,900	910	0.57	3,300
Delta	33.8	12.2	7,430	220	610	2,070	0.17	3,600
Total	157.9	21.7	32,900	180	1,500	5,880	0.27	5,600

The followings can be said from the above table;

- The Nan basin has the largest water resources in the Chao Phraya basin with the annual runoff of about 9,200 MCM and the specific runoff yield of 270 mm. The Nan basin also has a capability to supply water of 4,000 cu.m per capita and 8,500 cu.m per ha for cropland. Accordingly the Nan basin has a sufficient allowance to supply its surplus water to alleviate water shortage in the Chao Phraya delta area after meeting the demand of water within the basin.

- Being regulated by the Bhumibol dam, a comparatively large annual runoff of 8,000 MCM or 240 mm of the specific runoff yield is distributed in the Ping basin having the farmland area of 650,000 ha which is much smaller than 1.08 million ha in the Nan basin. Thus the Ping basin also has an allowance to supply its excess water to the delta area.

- In other sub-basins, available water resources are relatively small having annual runoff of less than 3,000 MCM and the specific runoff yield of less than 200 mm. Accordingly available water resources are to be limited for consumption within the basins, and there is no room to supply surplus water to the delta areas.

- Most of water required in the Chao Phraya delta area for agricultural and other uses is supplied from the Chainat barrage where runoffs from the upper Chao Phraya basins meet together. The runoffs from the Pasak and Tha Chin rivers are also utilized in the delta area. Although the farmland area of 2.1 million ha, largest in the Chao Phraya basin, is distributed in the delta, available annual runoff within the delta is 7,400 MCM only, which is far less than the requirement for agriculture in the area. The supplies from surplus water in the Nan and Ping basins are inevitably required for uses in the delta area.

(2) Characteristics of Water Resources in Chao Phraya Basin

It is rather difficult, unless regulated, to utilize effectively the available water resources in the Chao Phraya basin for agricultural, domestic, industrial and other purposes because of not only their limited amount but also wide fluctuation of runoff pattern in wet and dry season. In order to grasp such characteristics of seasonal pattern of river runoffs, the Sirikit damsite and the stream gauging stations N7 and N14 on the Nan river, station Y17 on the Yom river, Bhumibol damsite and station P7A on the Ping river, station C2 located on the Chao Phraya river just downstream of the confluence with the Ping river and the Chao Phraya diversion damsite (station C13) are selected as the representative control points, and seasonal runoffs observed at these stations are summarized as follows;

Seasonal Pattern of Runoff at Major Control Points

Basin and Station	Drainage Area (sqkm)	Normal Year			Wet Year			Dry Year		
		Season		Total	Season		Total	Season		Total
		Wet	Dry		Wet	Dry		Wet	Dry	
Along Nan										
Sirikit Inflow	13,130	4,420	700	5,120	7,650	920	8,570	2,560	560	3,120
Sirikit Outflow	13,130	2,130	2,720	4,850	3,520	3,700	7,220	578	1,840	2,410
Station N7	29,150	5,930	3,100	9,030	10,590	4,300	14,890	3,500	1,590	5,090
Station N14	33,200	6,750	2,700	9,450	12,560	4,120	16,680	3,320	1,290	4,610
Along Yom										
Station Y17	21,420	2,870	230	3,100	6,210	4,390	10,600	1,085	45	1,130
Along Ping										
Bhumibol Inflow	26,100	4,560	690	5,250	7,650	1,150	8,800	2,020	550	2,570
Bhumibol Outflow	26,100	1,920	3,020	4,940	3,710	3,910	7,620	1,800	990	2,790
Station P7A	42,700	3,890	3,020	6,910	7,370	4,140	11,510	2,640	870	3,510
Nakhon Sawan										
Station C2	110,570	14,700	6,700	21,400	28,630	9,440	38,070	6,900	2,890	9,790
Chao Phraya Dam										
C13 Inflow	119,000	16,030	6,380	22,410	29,760	9,010	38,770	6,260	2,330	8,590
C13 Diversion	119,000	7,430	4,190	11,620	9,100	5,480	14,580	4,440	1,500	5,940
C13 Outflow	119,000	8,600	2,200	10,800	25,980	5,080	26,060	1,820	830	2,650

Note: Runoff is given in MCM.

From the above table, the characteristics of the runoffs in the Chao Phraya basin are generalized as in the followings;

(a) Sirikit Damsite

The seasonal fluctuations both in wet and dry periods of a year and wet and dry years are remarkable for the inflows into the Sirikit reservoir. However the inflows are once stored in the reservoir and regulated so as to release 2,130 MCM of outflow in wet season and 2,720 MCM in dry season under the normal year condition.

(b) N7 and N14 Stations on the Nan River

The N7 station is installed at Amphoe Muang, Changwat Phitsanulok covering a large drainage area of 29,150 sq.km involving the major tributaries of the Nam Khwae Noi and Nam Wang Thong, while the N14 station is located just upstream of the confluence of the Nan river with the Yom river having a drainage area of 33,200

sq.km.

In the normal year, the runoffs at stations N7 and N14 increase considerably amounting to about three times of the outflow from the Sirikit reservoir in wet season, involving a large amount of side flow of 3,000 MCM to 3,500 MCM from tributaries of Khlong Tron, Nam Khwae Noi, Nam Wang Thong and others. In dry season in the normal year, runoff at the station N7 is about 3,100 MCM, which is only 300 MCM more than the outflow from the Sirikit reservoir. Accordingly, the side flow from tributaries in dry season is scarce and will be used for irrigation and other uses within the tributary basins. At the N14 station in dry season, runoffs observed are less than those at N7 station, because considerable amount of water is being diverted from the river between stations. In the dry year, the dry season runoff at N14 station decreases amounting to 1,290 MCM, which is equivalent to 70% of the Sirikit outflow. A considerable amount of the Sirikit outflow is being lost during the course of travelling, however the dry season runoffs of 2,700 MCM and 1,290 MCM respectively in the normal year and dry year at the station N7 will be the important source of water to be supplied to the delta areas.

(c) Y17 Station on the Yom River

The Y17 station is such a station where relatively longer period of observation is available in the downstream-most part of the Yom basin, having a drainage area of 21,415 sq.km occupying about 90% of the entire basin area of 23,600 sq.km, and will be the base for estimation of water resources in the Yom basin.

At the station Y17, the average annual runoff is evaluated at 3,100 MCM, showing a low specific runoff yield of 130 mm. In dry season, runoff is recorded at only 230 MCM, which will be used for agriculture and other uses within the basin, and no contribution of water supply for the delta area may be expected.

(d) Bhumibol Damsite

The inflow into the Bhumibol reservoir in wet season is as much as 4,560 MCM compared to the dry season inflow of 690 MCM. The wet season inflow is

regulated in the reservoir so as to release 1,920 MCM in wet season and 3,020 MCM in dry season, resulting considerable increases of the Ping river water downstream of the Bhumibol dam in dry season.

(e) P7A Station on the Ping River

The P7A station is installed on the Ping river at Muang Kamphaeng Phet and covers a drainage area of 42,700 sq.km. After released from the Bhumibol reservoir, the Ping river water joins waters from the Wang river and other tributaries before arriving at the P7A station. The average annual runoffs of the Ping river at P7A station are evaluated at 3,890 MCM in wet season, 3,020 MCM in dry season and 6,910 MCM as an annual total, which will produce a specific runoff yield of 160 mm under normal year condition. The sideflow of 1,070 MCM from tributaries between the Bhumibol dam and Kamphaeng Phet contributes towards the increase of the Ping river water in wet season, however, in dry season such sideflows are utilized within the tributary basins and the river flow does not increase compared to the outflow from the Bhumibol dam. In addition according to the information from RID, a large extent of agricultural area of more than 100,000 ha around Kamphaeng Phet is being suffered from serious water shortage problem in most years.

(f) Sideflow from the Lower Ping Basin

The Lower Ping basin, laying between Muang Kamphaeng Phet and Muang Nakhon Sawan having a drainage area of 20,600 sq.km, is formed mainly by the flat agricultural land except western high mountain areas of elevations 1,300 m to 2,000 m. The average annual runoff from the basin is about 1,870 MCM consisting of 1,130 MCM in wet season and 740 MCM in dry season. Because of the bulk water brought from the western mountain area, the basin produces the dry season sideflow of 740 MCM which becomes an important source of water used in the delta area.

(g) C2 Station on the Chao Phraya River

Four major tributaries, namely Nan, Ping, Wang and Yom rivers, meet together at Nakhon Sawan to become the Chao Phraya river. At the C2 station located in

Nakhon Sawan with a drainage area of 102,635 sq.km, the average annual runoff is about 21,400 MCM which can be separated into wet season runoff of 14,700 MCM and dry season runoff of 6,700 MCM. Although the runoff from upstream part of the Ping and Nan rivers are regulated by the Bhumibol and Sirikit reservoirs, the dry season runoff of the Chao Phraya river at C2 station is only 6,700 MCM or equivalent to 30% of the annual runoff. This is due to the fact that the runoffs from downstream parts of dams are relatively small in amount and most of them are utilized within their own tributary basins.

The summary of observed river runoffs at stations N7, N14, Y17, P7A and C2 is given in Table 3.1, while a schematic flow diagrams of the Chao Phraya river system under average year and dry year conditions are presented in Figures 3.1 and 3.2.

(h) Chainat Barrage Site

The Chainat barrage is located at Chainat, covering a drainage area of 119,000 sq.km after collecting runoff from the Sakae Krung river. The function of the dam is to provide waters to the agricultural area of 1.4 million ha including water for domestic purposes and to release water downstream river course for uses of water supply for Bangkok metropolitan area, navigation and salinity exclusion. In wet season inflow at the diversion dam increases from 14,700 MCM at C2 station to 16,000 MCM after collecting runoff from the Sakae Krung river, however, in dry season 6,400 MCM of inflow remains almost same order as compared with that of C2 station. This means that the Sakae Krung basin has no excess water in dry season.

3.2 Increasing Water Demand and Water Shortage

The water demand at present and in future for agricultural, domestic, municipal and industrial uses in the Chao Phraya basin is explained previously in paragraph 2.8 with the present and projected water demands as evaluated in Table 3.2. From the said table, the present water demand of 25,300 MCM per annum in total will increase to 33,300 MCM with an increase of 8,000 MCM. Under this situation, the status of increasing water demand and water shortage related to the proposed Kok-Ing-Nan water diversion project is summarized as given below;

Table 3.1 Summary of Runoff at Stations Y17, N7, N14, P7A and C2

Year	Yom River Basin			Nan River Basin						Ping River Basin			Chao Phraya River Basin		
	Station Y17 (21,415 sqkm)			Station N7 (29,153 sqkm)			Station N14 (33,197 sqkm)			Station P7A (42,700 sqkm)			Station C2 (110,569 sqkm)		
	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total
1974	3,006.2	518.0	3,524.2	5,517.2	2,973.7	8,490.8	5,066.0	1,993.0	7,059.0	6,259.7	3,665.2	9,924.9	15,189.0	6,835.0	22,024.0
1975	4,061.0	328.4	4,389.4	10,595.0	4,296.7	14,891.6	12,568.0	4,116.0	16,684.0	7,373.0	4,139.8	11,512.8	28,626.6	9,439.8	38,066.4
1976	2,633.9	268.8	2,902.7	8,817.1	4,270.9	13,088.1	10,145.0	4,209.0	14,354.0	6,188.4	4,155.9	10,344.3	22,318.8	8,980.5	31,299.3
1977	2,001.9	149.4	2,151.3	6,613.9	2,379.3	8,993.2	7,724.0	2,528.0	10,252.0	4,890.4	3,188.2	8,078.6	14,347.5	5,609.1	19,956.6
1978	4,035.6	154.7	4,190.3	9,028.5	4,343.2	13,371.7	11,029.0	3,134.0	14,163.0	4,992.7	3,814.5	8,807.1	24,284.5	8,144.4	32,428.9
1979	1,085.8	44.6	1,130.4	5,564.5	1,881.7	7,446.2	5,897.0	1,913.0	7,810.0	4,817.5	2,422.7	7,240.2	11,879.1	4,414.3	16,293.4
1980	4,923.0	269.0	5,192.0	8,867.2	3,842.6	12,709.7	12,442.0	3,382.0	15,824.0	3,124.6	2,896.6	6,021.1	24,057.6	7,239.4	31,297.0
1981	3,835.0	353.0	4,188.0	8,632.6	4,073.3	12,705.9	9,257.0	3,255.0	12,512.0	3,582.0	3,093.3	6,675.3	17,525.3	7,961.2	25,486.5
1982	2,298.0	153.0	2,451.0	5,527.9	3,879.6	9,407.5	4,951.0	2,352.0	7,303.0	3,707.3	3,797.8	7,505.1	12,498.9	7,558.3	20,057.2
1983	3,124.0	396.0	3,520.0	5,095.5	3,788.0	8,883.5	6,096.0	3,564.0	9,660.0	4,150.7	2,795.8	6,946.5	15,818.4	7,795.4	23,613.8
1984	3,857.0	269.0	4,126.0	6,232.1	3,773.9	10,006.0	6,969.0	3,294.0	10,263.0	2,331.3	2,601.9	4,933.2	11,627.0	7,214.2	18,841.2
1985	2,539.0	368.0	2,907.0	6,389.4	3,974.3	10,363.7	7,036.0	4,065.0	11,101.0	2,634.8	3,037.2	5,671.9	15,096.8	9,328.1	24,424.9
1986	2,017.0	141.0	2,158.0	4,990.1	2,630.1	7,620.2	5,201.0	2,786.0	7,987.0	4,019.8	3,431.9	7,451.7	11,874.8	6,900.0	18,774.8
1987	2,559.0	232.0	2,791.0	3,801.2	1,773.1	5,574.3	4,130.0	1,581.0	5,711.0	3,877.7	3,143.9	7,021.6	11,412.3	6,144.3	17,556.6
1988	3,766.0	246.0	4,012.0	2,819.6	2,395.8	5,215.4	2,185.0	1,337.0	3,522.0	3,464.0	3,986.2	7,450.2	12,229.0	6,663.0	18,892.0
1989	2,595.0	196.9	2,791.9	3,085.6	2,789.3	5,874.9	3,272.0	1,926.0	5,198.0	3,489.2	3,788.1	7,277.3	10,058.0	6,292.4	16,350.4
1990	2,295.0	192.9	2,487.9	5,455.8	2,018.5	7,474.3	4,287.0	1,873.0	6,160.0	3,177.7	2,238.1	5,415.8	10,756.2	5,148.4	15,904.6
1991	2,048.7	152.4	2,201.1	3,619.2	2,231.8	5,851.0	3,313.0	1,292.0	4,605.0	1,743.6	2,996.9	4,740.6	9,556.4	4,292.4	13,848.8
1992	2,012.4	185.9	2,198.4	2,383.7	1,943.4	4,327.0				2,292.9	2,786.2	5,079.1	7,500.0	4,833.0	12,333.0
1993	1,037.4	141.3	1,178.7	3,494.6	1,590.8	5,085.4				2,645.2	866.3	3,511.5	6,903.0	2,887.2	9,790.2
1994	5,404.4	97.9	5,502.3	7,955.6	4,157.3	12,112.9				3,406.2	3,151.9	6,558.1	18,941.7	6,478.1	25,419.8
1995										3,358.2	418.2	3,776.4	28,039.4	1,814.0	29,853.4
Mean	2,911.2	231.3	3,142.5	5,927.9	3,095.6	9,023.5	6,753.8	2,700.0	9,453.8	3,887.6	3,018.9	6,906.5	15,508.7	6,997.8	22,506.5

Note: Runoffs are given in MCM.

Figure 3.1 Flow Diagram of Water Resources in Chao Phraya Basin (Average)

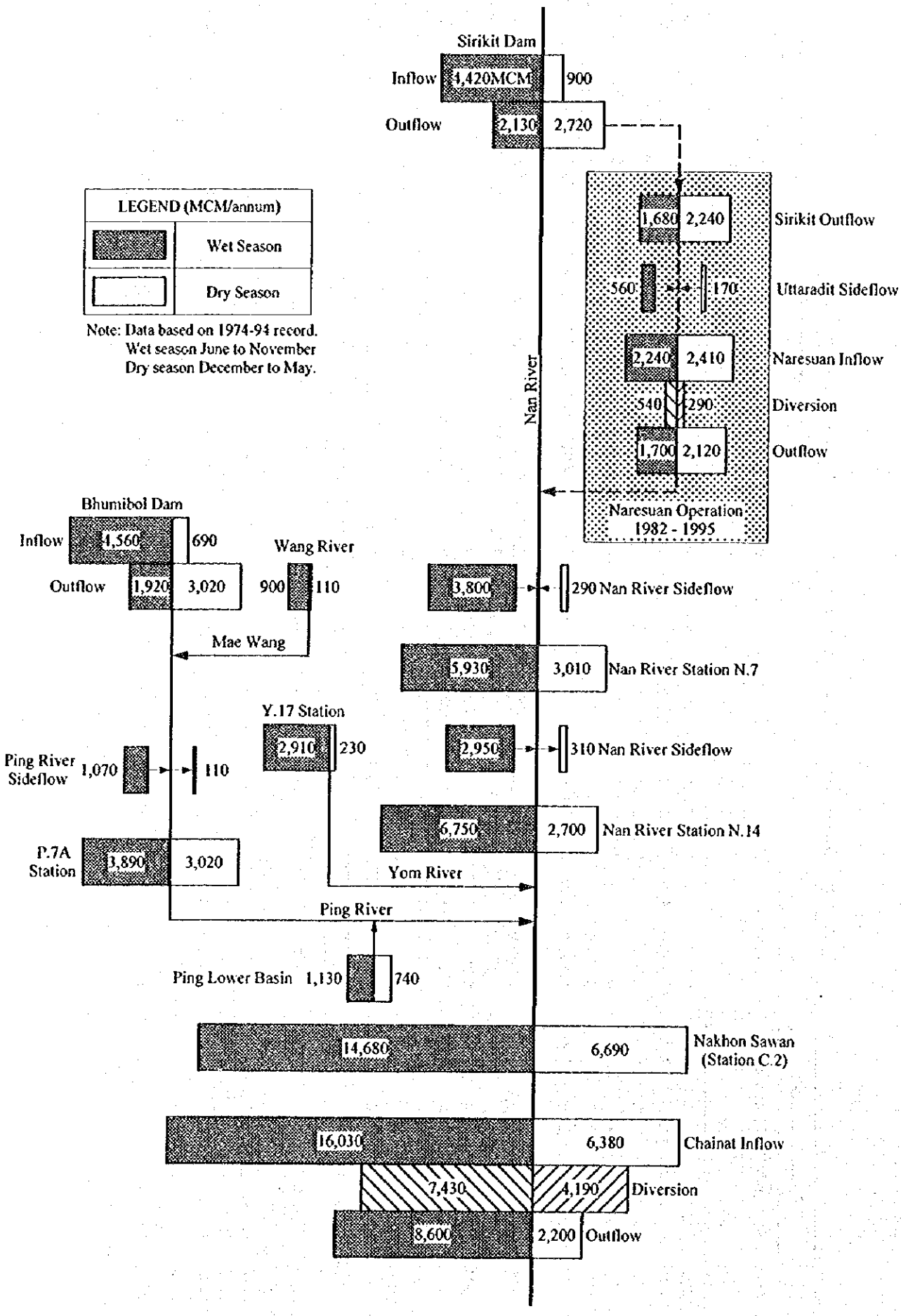


Figure 3.2 Flow Diagram of Water Resources in Chao Phraya Basin (Dry Years)

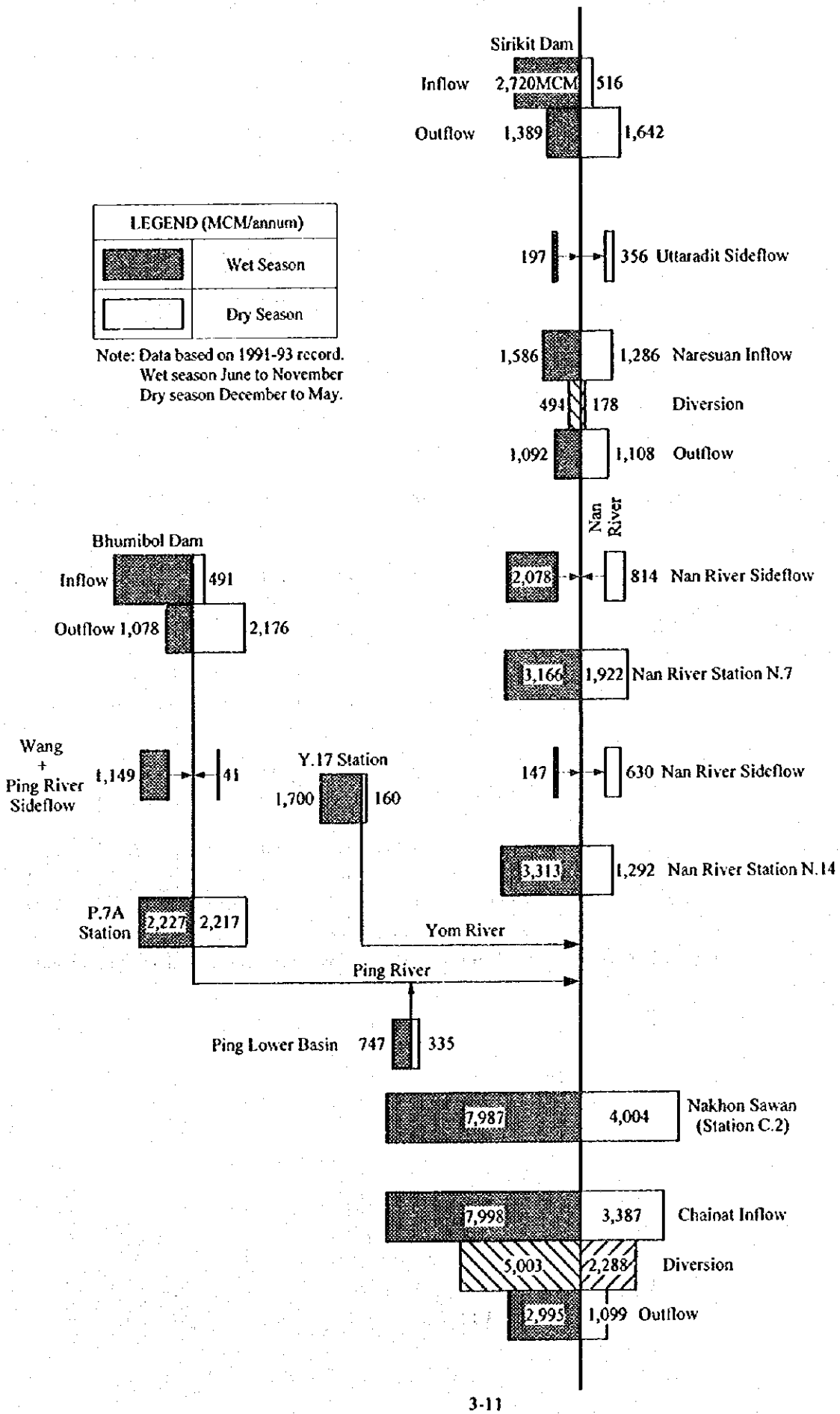


Table 3.2 Summary of Projected Water Demand at Present and in Future

Item	Unit	Nan	Yom	Wang	Ping	Sakae Krung	Pasak	Delta	Total
1. Basin Area									
Total Area	km^2	34,330	23,620	10,790	33,900	5,190	16,290	33,800	157,920
Farmland Area	10^3ha	1,080	760	150	650	260	910	2,070	5,880
2. Present Demand in 1993									
(1)Irrigation Area	10^3ha	278	132	68	260	88	121	1,281	2,232
(2)Population	10^3	2,310	1,960	670	2,430	430	1,670	13,150	22,620
(3)Water Demand									
Irrigation Water	MCM	2,871	859	487	2,428	1,161	835	11,620	20,261
Domestic Water	MCM	66	54	20	76	8	72	-	296
Municipal Water	MCM	37	15	-	53	-	-	1,200	1,305
Industry/Tourism	MCM	0	-	1	-	-	24	550	575
River Maintenance	MCM	-	-	-	-	-	-	2,860	2,860
Total	MCM	2,974	928	508	2,557	1,169	931	16,230	25,297
3. Future Demand in 2016									
(1)Irrigation Area	10^3ha	437	285	138	482	126	179	1,315	2,962
(2)Population	10^3	3,110	2,410	850	3,980	690	2,210	13,420	26,670
(3)Water Demand									
Irrigation Water	MCM	4,360	2,066	813	4,344	1,161	1,114	13,500	27,358
Domestic Water	MCM	76	64	23	94	16	114	-	387
Municipal Water	MCM	57	28	-	90	-	-	1,860	2,035
Industry/Tourism	MCM	6	1	3	6	-	34	1,100	1,150
River Maintenance	MCM	-	-	-	-	-	-	2,400	2,400
Total	MCM	4,499	2,159	839	4,534	1,177	1,262	18,860	33,300
4. Increment									
(1)Irrigation Area	10^3ha	159	153	70	222	34	58	34	730
(2)Population	10^3	800	450	180	1,550	260	540	270	4,050
(3)Water Demand									
Irrigation	MCM	1,489	1,027	326	1,916	0	279	1,880	6,917
Others	MCM	36	204	5	61	8	52	750	1,116
Total	MCM	1,525	1,231	331	1,977	8	331	2,630	8,033

Remark: The water demand of the delta area is estimated based on the amount of water diversion at the Chainat barrage collected from O/M Division of RID because of no available data for the delta area in 25 Basin Study.

(1) Increasing Water Demand in Future

(a) Irrigation Water Demand

- Irrigation water demand in the whole Chao Phraya basin is estimated at about 20,300 MCM at present (1993) and 27,400 MCM in future (2016) occupying the largest portion or 80% of all water demand including domestic, municipal and industrial supply. In the delta area, irrigation demand reaches especially large amount of 11,600 MCM at present and 13,500 MCM in future.
- In the Nan and Ping basins, important source of water for the delta area, the present irrigation water demand is estimated at 5,300 which will increase largely to 8,300 MCM in future. Accordingly, water use in the delta area in future will be influenced to a great extent by reduction of surplus water from both upstream basins.
- The unit water requirement for irrigation is evaluated as shown below;

Item	Nan	Yom	Wang	Ping	Sakae Krung	Pasak	Delta	Total
1. Present Irrigation (1993)								
(1) Area (1,000 ha)	278	132	68	260	92	121	1,281	2,232
(2) Total Irrigation Water (MCM)	2,871	859	487	2,428	1,161	835	11,620	20,261
(3) Unit Water Demand (cu.m/ha)	10,300	6,600	7,200	9,300	12,600	6,900	9,100	9,100
2. Future Irrigation (2016)								
(1) Area (1,000 ha)	437	285	138	482	126	179	1,315	2,962
(2) Total Irrigation Water (MCM)	4,360	2,066	813	4,344	1,161	1,114	13,500	27,358
(3) Unit Water Demand (cu.m/ha)	10,000	7,200	5,900	9,000	9,200	6,200	10,300	9,200

- In the Yom, Wang and Pasak basins, supplemental irrigation for wet season paddy is the main water use in water resources development plans due to insufficient river runoff in the basin. As a result, the cropping intensity for second crops without dry paddy is as small as 10% to 20%. In the basins, the unit irrigation requirement is assumed as;

Wet Season Paddy (6,500 cu.m/ha x 90%) + Dry Season Second Crops (6,000 cu.m/ha x 10 to 20%) = 6,500 to 7,100 cu.m/ha/year

- In the Nan, Ping and delta basins where there are relatively rich water at present, the cropping intensity of 100% for wet season paddy, 20 to 30% for dry season paddy and 15 to 20% for dry season upland crops are combined to assume the unit irrigation requirement as;

  Wet Season Paddy (6,500 cu.m/ha x 100%) + Dry Season Paddy (10,000 cu.m/ha x 20 to 30%) + Dry Season Upland Crops (7,000 cu.m/ha x 15 to 20%) = 9,600 to 10,900 cu.m/ha/year

(b) Other Water Demand

- Domestic water for towns and villages in rural area is supplied mainly from small tributaries in each basin.
- Municipal water for provincial capital cities such as Phitsanulok, Uttaradit and Phichit in the lower Nan basin and the Bangkok Metropolis and surrounding satellite cities in the Chao Phraya delta area is supplied from the mainstream of the Nan and Chao Phraya rivers. The population toward 21 century in the delta area is projected with a moderate growing rate, however, the per capita consumption of water will increase as the income of inhabitant increases and various activities in urban area expand. The municipal water demand in the delta area to be supplied from the Chao Phraya river is projected at 1,860 MCM in 2016 against the present demand of 1,200 MCM, according to the BMA's estimate.
- Water demand for industry and tourism in the delta area will also increase to 1,100 MCM in 2016 from the present demand of 550 MCM.

(2) Water Shortage Condition

(a) Sirikit and Bhumibol Dams

As explained previously in the paragraph 2.9, the Sirikit and Bhumibol dams have large effective storage capacities of 6,660 MCM and 9,660 MCM. However, they have suffered from water shortage problems during these 20 years due to lack of inflow. As a consequence, reservoirs usually present large empty space of storage at

the end of wet season that in turn reduces volume of water to be released from reservoir in the successive dry season. Such dry season outflows from reservoirs are considerably small as compared with their storage capacities as explained below;

(Unit: MCM)

Item	Sirikit Reservoir		Bhumibol Reservoir	
	Normal Year	Dry Year	Normal Year	Dry Year
Reservoir Inflow	5,120	3,240	5,250	3,700
Empty Volume at End of November	2,700	5,000	4,300	7,100
Dry Season Outflow	2,720	1,640	3,020	2,180

Influenced by these small outflows from both reservoirs, the flow of Chao Phraya river at the Chainat barrage located at the entrance to the delta area is also as small as 6,000 MCM in normal years and 3,400 MCM in dry years which are equivalent respectively to 30% and 15% of the average annual runoff of 22,000 MCM at this point. In order to fill both reservoirs with water at the end of wet season and as a result to increase dry season outflow for downstream uses, the Thai Government has studied since 1980s a number of alternative water diversion plans to import excess water from river basins where water is abundant into both reservoirs.

(b) Water Shortage in Existing Phitsanulok Project Area

The Sirikit reservoir was so proposed originally as to cover not only the existing Phitsanulok irrigation project area lying on the right bank of the Nan river and the Chao Phraya delta area but also the Uttaradit irrigation area and the Phitsanulok left bank area. However, development of the Uttaradit and Phitsanulok left bank area has been suspended due mainly to lack of inflow into the Sirikit reservoir.

The existing Phitsanulok irrigation area has been receiving sufficient water in wet season from the Sirikit reservoir and wet season paddy is cultivated there showing the irrigation intensity of 90%. On the contrary in dry season, irrigation intensities are as low as 35% in normal years and 15% to 20% in dry years because of limited outflow from the Sirikit reservoir. As a result farmers in the area are placed under insecure farming conditions in dry season.

(c) Dry Season Water Shortage in Delta Area

The existing irrigation area in the Chao Phraya delta is about 1.2 million ha consisting of paddy area of 900,000 ha and other areas of 300,000 ha for upland crops, orchard, vegetable and fish ponds. As shown in Figure-6, irrigable area in the delta has been utilized for paddy cultivation with irrigation intensity of 90% to 95% in wet season receiving sufficient water from the Chao Phraya river at Chainat barrage, however in dry season irrigation intensities are as small as 35% in normal years and 20% in dry years due to lack of water.

The increase of various food demands in the Bangkok Metropolis, satellite cities, industrial estates and semi-urban areas in the delta has caused expansion of plantation for various upland crops, orchard and vegetables, and this tendency would continue from now on meaning that the dry season water will be required more and more in future.

(d) Shortage of Municipal and Industrial Water

Water demand for municipal and industrial uses in the Bangkok Metropolis and surrounding urban and industrial areas has increased year by year resulting the following problems caused by shortage of water;

- Ground subsidence in the Bangkok Metropolitan area caused by overpumping of groundwater
- Downstream release of Chao Phraya river water at the Chainat barrage, which is designed to be at least 100 cu.m/sec, has decreased to 70 to 90 cu.m/sec in dry months from January to April, as shown in Figure-7, due to shortage of dry season flow at the barrage. Saline problem caused by sea water intrusion during high tide period and water pollution due to sewage from cities and industrial zones have taken place in recent years.

(3) Water Balance in the Upper Basin

(a) Potential Water Resources in Upper Basin

Available water resources in the upper Chao Phraya basin are presented in Table 3.1. Water volumes in each river basin are such values that are estimated based on the observed river runoff data in the past 20 years. Accordingly they have already been reduced because of upstream water diversion for irrigation and other purposes. The potential water resources in the upper basins after consideration of upstream water use are assumed as follows;

(Unit: MCM)

	Nan	Yom	Wang	Ping	Sakae Krung	Total
River Runoff	9,160	2,960	1,100	7,970	1,300	22,490
Upstream Water Diversion	2,970	930	510	2,560	1,170	8,140
Total	12,130	3,890	1,610	10,530	2,470	30,630

- The potential water resources in the Nan and Ping rivers are evaluated at the large volume of 22,660 MCM or 74% of the total potential resources in the upper Chao Phraya basin, and could fulfill to respond the water demand in the Chao Phraya delta area.
- Provided from the upper basin, the potential water resources usable in the lower basin (the delta area) are 22,490 MCM at the Chainat barrage.

(b) Future Water Balance in Upper Basin

Water balance in the upper Chao Phraya basin in future will be as follows;

(Unit: MCM)

	Nan	Yom	Wang	Ping	Sakae Krung	Total
(1) Potential Water Resources	12,130	3,890	1,610	10,530	2,470	30,630
(2) Future Water Demand	4,499	2,159	839	4,534	1,177	13,208
(3) Surplus Water (1)-(2)	7,631	1,731	771	5,996	1,293	17,422
(4) Water Using Rate (2)/(1)	37	56	52	43	48	59

- The water using rate in the Yom, Wang and Sakae Krung basins reaches as high as 50%. It is rather difficult to achieve this order of water utilization without storage capacity of a large scale dam. Surplus water from these three basins in future will decrease to 3,800 MCM from the present surplus of 5,360 MCM if the projected water demands are used within basins.
- Although the water using rates in the Nan and Ping basins are relatively high showing around 40%, a large surplus water of 13,630 MCM will be still available in future for utilization in the delta area.
- The surplus water of 22,500 MCM is presently available at the Chainat barrage for water uses in the delta area. It will however decrease in future to 17,400 MCM due to water use in the upper basin.
- The result of water balance study is given in Figure 3.3.

(4) Water Balance in the Lower Basin

(a) Present Water Balance

The potential water resources available for use in the lower basin are the flow of Chao Phraya river at the Chainat barrage and runoff from the Pasak river. Additional runoff of some 7,400 MCM may exist in the basin caused by rainfall, however this runoff occurs mostly in wet season and is drained out through rivers and canals without utilized, and therefore this water is not counted as the available water resources.

The present balance of water in the lower basin can be evaluated as shown below;

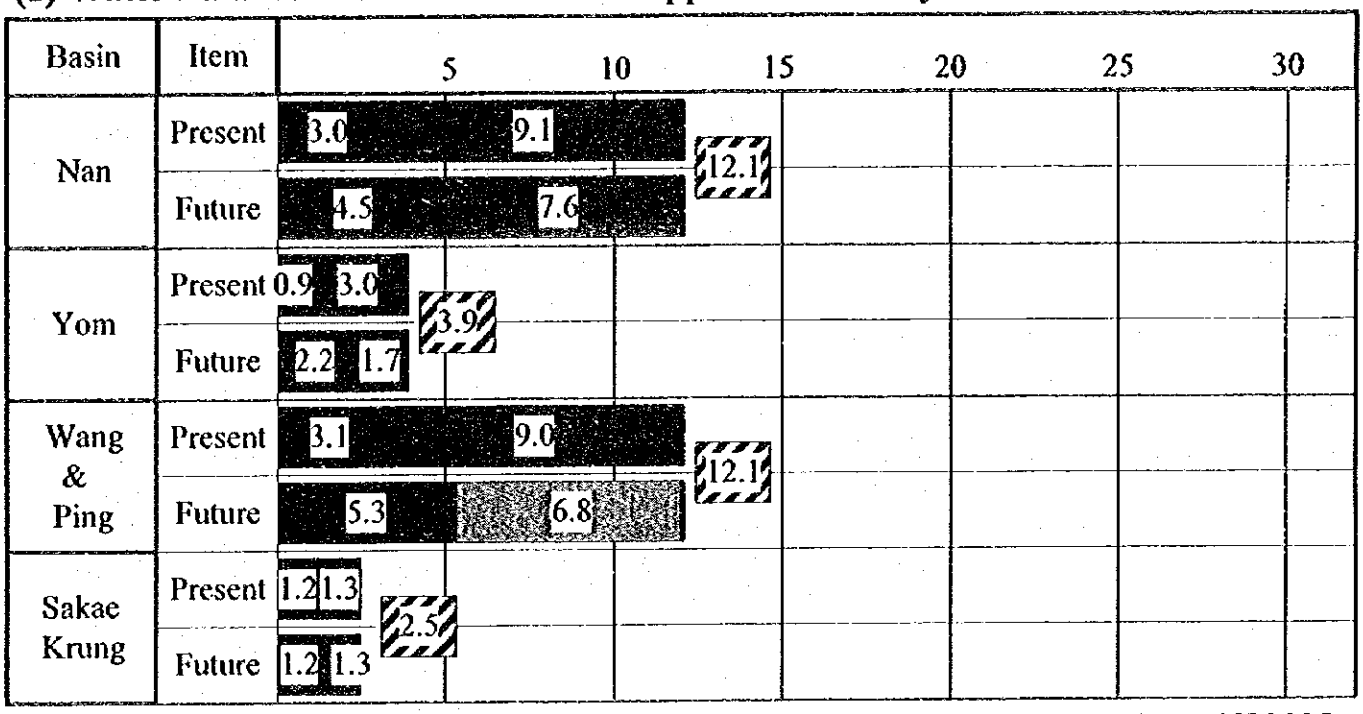
(Unit: MCM)

	Delta Area	Pasak Basin	Total
(1) Potential Water Resources	22,490	3,910	26,400
(2) Present Water Demand	16,230	930	17,160
(3) Surplus Water (1)-(2)	6,260	2,980	9,240

- In the lower basin it seems that currently available volume of water resources

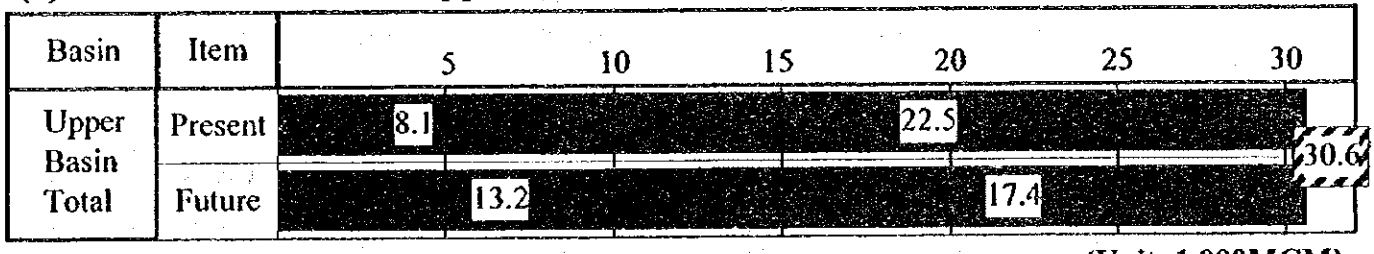
Figure 3.3 Water Balance of Upper and Lower Chao Phraya Basin

(1) Water Balance of Sub-Basins in the Upper Chao Phraya Basin



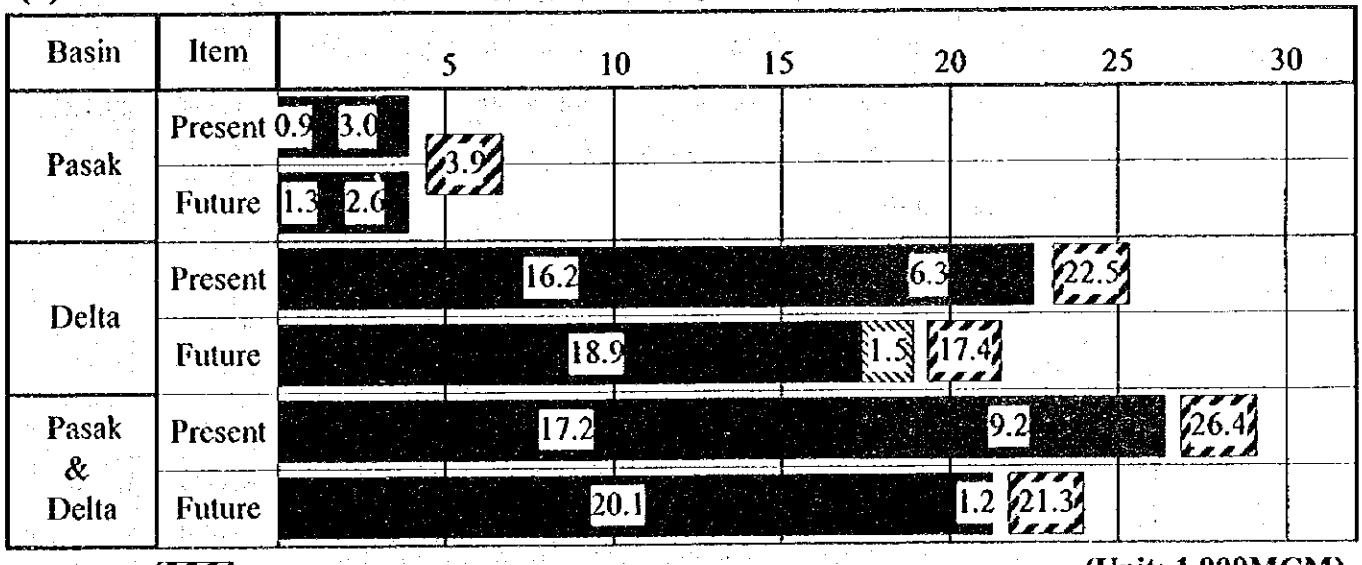
(Unit: 1,000MCM)

(2) Water Balance of the Upper Chao Phraya Basin



(Unit: 1,000MCM)

(3) Water Balance of the Lower Chao Phraya Basin



(Unit: 1,000MCM)

Average Annual Volume of Water Resources

Water Demand Surplus Water Water Deficit

of 26,400 MCM is sufficient to cover water demand within the basin when it is evaluated in terms of average annual volume of water resources.

- However, the dry season volume of water is limited to 6,400 MCM in the normal year and 3,400 MCM in dry years, which are not always sufficient to cover the water demand of about 7,000 MCM or 40% of the annual demand of 17,160 MCM in dry season.

(b) Water Balance in Future

The potential water resources for the lower basin in future will decrease because of increased water uses in the upper basin, while water demand in future will increase as shown in Table 3.2. The water balance will be as follows;

(Unit: MCM)

	Delta Area	Pasak Basin	Total
(1) Potential Water Resources	17,422	3,910	21,332
(2) Present Water Demand	18,860	1,262	20,122
(3) Surplus Water (1)-(2)	(-)1,438	2,648	1,210

- The future water demand will be almost same as the available water resources in the lower basin, meaning that many water shortage problems will occur even in wet season.
- In particular in dry season, available water resources of 6,400 MCM in normal years and 3,400 MCM in dry years are absolutely insufficient against the dry season demand of about 8,000 MCM or 40% of the annual demand of 20,122 MCM, meaning that severe and frequent water shortage problems will take place in the lower basin in future.

(5) Assumption of Additional Water Demand in Lower Nan Basin and Delta

In many basins, the future increasing water demand will take place in tributary sub-basin and it will be supplied from its own water resources within the basin. Accordingly only the areas requiring water from the mainstream of major river are the Phitsanulok irrigation project area and the Chao Phraya delta area.

In the NESDB's 25 River Basin Study, further development of the stage II and III of the Phitsanulok irrigation project is excluded from the proposed project in a long-term development plan, since the development of these areas would exert a bad influence on water utilization in the downstream delta area, unless the transbasin water diversion plan such as the proposed Kok-Ing-Nan project is accompanied.

Additional water demand in the possible irrigable areas of either existing or newly developed along the lower Nan river and in the delta area supplied by the proposed water diversion can be estimated approximately as in the followings;

(a) Irrigation Water Demand

The following additional water will be required for dry season irrigation in either existing or newly developed areas along the lower Nan river and in the Chao Phraya delta area taking into account the existing situation of irrigated agriculture being suffered from water shortages in dry season;

- For second crops in existing Uttaradit pump irrigation area
  7,000 cu.m/ha x 30,000 ha = 210 MCM
- For second crops in existing Phitsanulok project area
  7,000 cu.m/ha x 30,000 ha = 210 MCM
- For wet season paddy in newly developed Phitsanulok project area
  2,000 cu.m/ha x 120,000 ha = 240 MCM
- For second crops in newly developed Phitsanulok project area
  7,000 cu.m/ha x 50,000 ha = 350 MCM
- For second crops in delta area
  7,000 cu.m/ha x 250,000 ha = 1,750 MCM

Total 2,760 MCM

(b) Municipal and Industrial Water

Additional water demand for the municipal and industrial uses in future is presented in Table 3.2 or as summarized below;

-	For provincial capitals in the lower Nan basin	26 MCM
-	For Bangkok Municipal and others in delta area	1,210 MCM
	Total	1,236 MCM
	Additional water supply in dry season (50%)	618 MCM

(c) Total Additional Water : (2,760+618) MCM=3,378 MCM≈3,400 MCM

The total volume of water to be additionally supplied mainly in dry season for irrigation, municipal and industrial uses accounts for as large as 3,400 MCM, which is equivalent to more than 50% of presently available dry season runoff of 6,000 MCM in the Chao Phraya river at Chainat.

3.3 Limited Available Water by Water Resources Development in Basin

(1) Present Water Resources Development

Numbers of large, medium and small scale dams have been constructed and under operation in the Chao Phraya basin mainly for irrigation purpose as explained in the paragraph 2.6 (1). Among these dams, only Sirikit and Bhumibol dams are releasing water for irrigation and other uses in the areas along the lower Nan river and the Chao Phraya delta area.

Total effective storage capacity of such dams is estimated at 17,600 MCM, of which 93% is occupied by capacities of Bhumibol and Sirikit reservoirs. The reservoir inflow of both dams, however, is about 10,000 MCM, providing the major reason why 7,000 MCM of large empty space of storage exist in both reservoirs at the end of wet season. As a consequence, river runoffs regulated by these existing dams in the Chao Phraya basin accounts for 11,000 MCM or 50% of the total runoff in the basin.

All dams except Bhumibol and Sirikit have no function or contribution to supply excess water in response to the demand in the delta area, being utilized for irrigation and other purposes in tributary basins. The available waters to be supplied in dry season to the delta area are therefore limited to 6,000 MCM in normal years and 3,400 MCM in dry years, all of which are supplied only from Bhumibol and Sirikit dams.

(2) Future Water Resources Development

RID and other governmental agencies in Thailand have set up the future water resources development plan in the Chao Phraya basin since 1980 with the intention of storing more water in wet season and utilizing it during dry season as explained previously in the paragraph 2.6 (2). Implementation of such large/medium scale dams has, however, been delayed due to social and environmental constraints such as resettlement problem in the reservoir area.

The notable large dams nominated for implementation are the Kaen Sua Ten dam with the effective storage capacity of 1,200 MCM and the Pasak dam with 800 MCM capacity, both of which are relatively small scale when compared with the Bhumibol and Sirikit dams. The total effective storage capacity of all of proposed dams is more or less 4,000 MCM, which would be much smaller to regulate sufficiently wet season runoff in the Chao Phraya basin. Furthermore, the reservoir water will be used mostly for supplemental irrigation of wet season paddy, not allocated to second crops because of large existence of rainfed area for wet season paddy, insufficient inflow into reservoirs and others. Such waters stored in the proposed reservoirs will thus be supplied to irrigable areas in tributary basins, and no contribution to the Chao Phraya delta area will be expected.

3.4 Alternative Transbasin Water Diversion Plans Studied in the Past

Numbers of studies in various levels have been made. The most possible method is to divert the water transbasin to the Chao Phraya basin from the Salawin and its tributaries such as Moei and Pai rivers, and from the Mekong river and its tributaries such as Kok and Ing rivers. Since the both Salawin and Mekong are international rivers, the utilization of boundary waters requires the international water agreement among riparian countries.

Among the existing large scale dams constructed in the Chao Phraya basin, the Bhumibol and Sirikit dams are proud of their outstanding storage capacities. Their capacities are however not fully utilized due to lack of inflow into reservoirs. One of the best solution would be to fully utilize their empty capacities by means of introducing waters diverted transbasin from other basins where excess waters are wasted unutilized.

In total, 18 alternative transbasin water diversion plans have been formulated up to present with various phases of study by various agencies concerned such as RID, DEDP, EGAT, MRC and others, for solving the water shortage problems in the Chao Phraya basin. Such transbasin water diversion plans, whose projected features are summarized in Table 3.3 and locations are shown in Figure 3.3, are classified into the following two categories;

- Water diversion from the Salawin river and tributaries
- Water diversion from the Mekong river and tributaries

Each category comprises several alternatives for water resources development, as explained below.

(1) Water Diversion from the Salawin River and Tributaries

The Salawin river, originated deep in the Himalayas, flows down for a distance of 2,200 km mostly in the territory of China and Myanmar, and it forms a part of the border between Thailand and Myanmar. It finally empties into Andaman Sea at Martaban of Myanmar. The two countries have been deep and long concerned regarding the utilization of water resources of the Salawin river mainly for hydro-power generation and irrigation. In particular since the oil crisis of 1978, urgent necessity for developing the border rivers has become realized between two countries, and it has been seriously discussed with the objective of providing supply sources of water and electric power, demands of which are increasing with a high economic growth in Thailand.

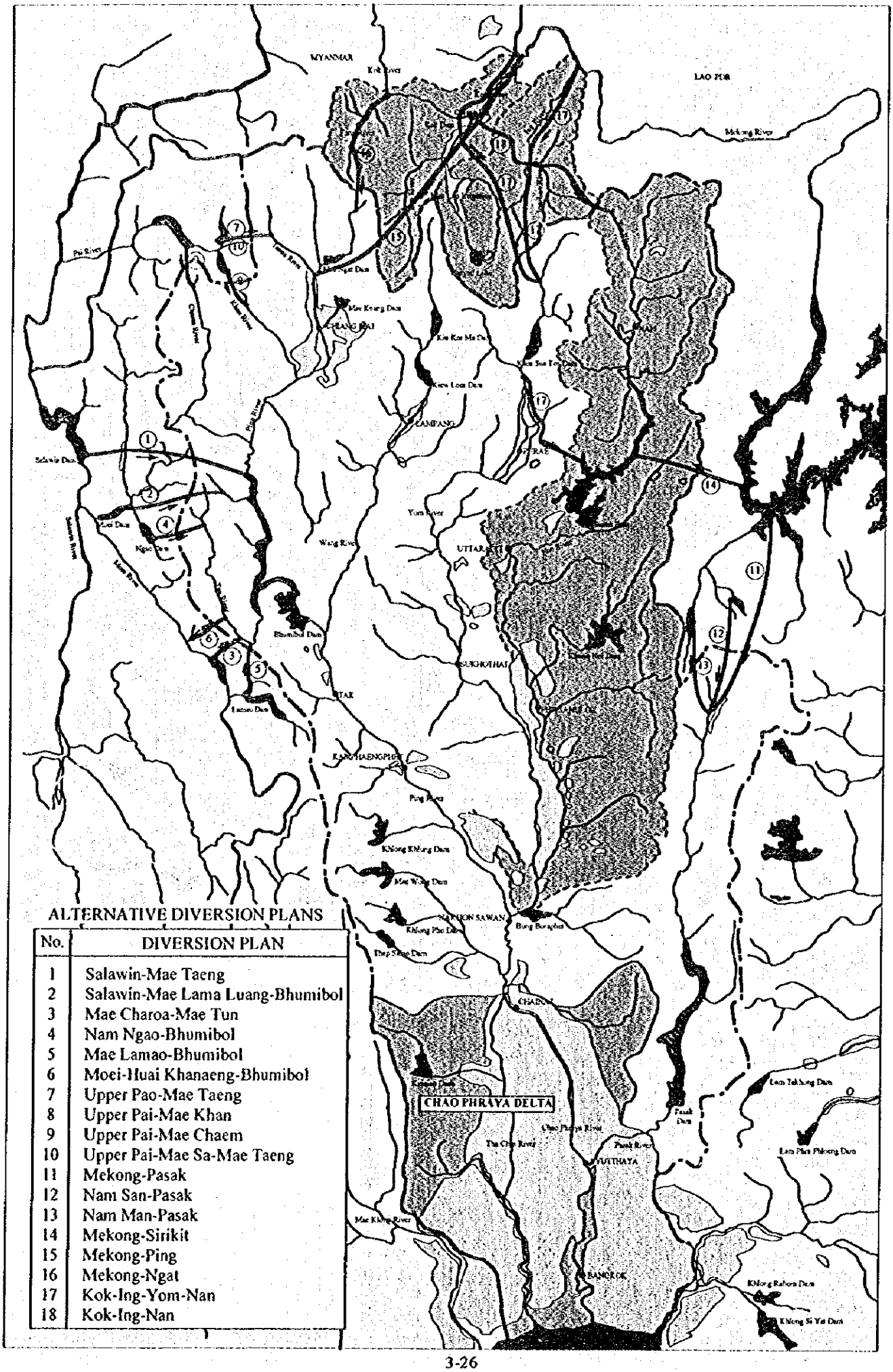
- Salawin-Bhumibol Diversion Plan

The so-called Salawin Project studied by DEDP and EGAT individually consists of a single dam at about 10 km upstream of the confluence of the Salawin and Moei rivers (DEDP), or two dams, an upper dam planned about 76 km upstream and a lower dam at 1 km upstream of the confluence (EGAT). The projected outline of these dams are as follows.

Table 3.3 Alternative Transbasin Water Diversion Plans

No	Alternative Diversion Project/Plan	Phase of Study	Agency	Dam/Reservoir			Pump Head m	Canal/Tunnel		Annual Diversion m	Irrigation Area (ha)	Remark
				NHWL m,MSL	Height m	Storage MCM		Size m	Length km			
1	Salaween-Bhumipol	Desk Study	EGAT	400	-	-			32/88	10,000	1,600,000	# International river, long tunnel
2	Salaween-Mae Lama Luang-Bhumibol	Pre-F/S	DEDP	155	100	344.0	329	Ø7.5	82	2,450	-	# National reserved forest
3	Mae Charoa-Mae Tun	Preliminary	DEDP	-	-	-	85	4.5	13	500	-	# National reserved forest # Watershed class 1A, 1B # Less irrigable area # Hard accessibility
4	Nam Ngao-Bhumibol	F/S	EGAT	270	80	-	235	Ø3.7	35.4	500	-	
5	Mae Lamao-Bhumibol	F/S	EGAT	255	60	94.3	48	Ø4.2	23.5	360	2,900	
6	Moei-Huai Khanaeng-Bhumibol	Pre-F/S F/S	DEDP EGAT	189	41	10.8	188	Ø7.5	18.5	1,100	-	# National reserved forest
7	Upper Pai-Mae Taeng	Preliminary Preliminary	EGAT DEDP	480	40 80	136	65 32.3	Ø4.4 3.3	27.3 27.2	500 368	- -	# National reserved forest # Watershed class 1A, 1B # Less irrigable area # Hard accessibility
8	Upper Pai-Mae Khan	Preliminary	EGAT	480	40	-	380	Ø4.4	15	300-500	-	
9	Lower Pai-Mae Chaem	Master Plan	DEDP	400			500	Ø3.5	15.5	500	-	
10	Upper Pai-Mae Sa-Mae Taeng	Preliminary	DEDP	475	40		non	3.8	42.8	416	-	
11	Mekong-Pasak	Preliminary	MRC		-	-	35		110	50cms	26,000	# Diversion from Laos # Low benefit
14	Mekong-Sirikit	Preliminary	MRC		-	-	-		60.5	50cms	26,000	
12	Nam San-Pasak	F/S	EGAT	686	-	235.0	non	2.5	3.6	88.5	4,040	# Resettlement problem
13	Nam Man-Pasak	F/S	EGAT	600	-	100.7	non	4.0	13.5	127.5	5,990	
15	Mekong-Ping	Desk Plan							185			# Ideal desk plan only
16	Mekong-Ngat	Desk Plan							127			
17	Kok-Ing-Yom-Nan	F/S	EGAT	284	96	4,450	85	17.8		3,237	34,280	# Resettlement problem
18	Kok-Ing-Nan	Conceptual	RID	-	-	-	non		110	2,000	200,000	

Figure 3.4 Location of Alternative Water Diversion Plan



ALTERNATIVE DIVERSION PLANS

No.	DIVERSION PLAN
1	Salawin-Mae Taeng
2	Salawin-Mae Lama Luang-Bhumibol
3	Mae Charoa-Mae Tun
4	Nam Ngao-Bhumibol
5	Mae Lamao-Bhumibol
6	Moei-Huai Khanaeng-Bhumibol
7	Upper Pao-Mae Taeng
8	Upper Pai-Mae Khan
9	Upper Pai-Mae Chaem
10	Upper Pai-Mae Sa-Mae Taeng
11	Mekong-Pasak
12	Nam San-Pasak
13	Nam Man-Pasak
14	Mekong-Sirikit
15	Mekong-Ping
16	Mekong-Ngat
17	Kok-Ing-Yom-Nan
18	Kok-Ing-Nan

Feature of Salawin Project

Feature	DEDP Dam	EGAT Upper Dam	EGAT Lower Dam
Drainage Area (km^2)	295,000	293,100	295,000
Runoff (MCM/yr)	119,200	118,600	119,200
Dam Height (m)	209	170	43
High Water Level (m)	200	220	86
Gross Storage (MCM)		21,000	740

The major purpose of the dams is hydroelectric power generation. It is however expected as the associated scheme to also serve for the purposes of flood control and irrigation in the downstream area. According to the paper prepared by DEDP; Development of Hydropower on Rivers Bordering Thailand-Burma in 1988, irrigable areas are estimated as below;

Irrigable Area by the Salawin Project

	Thailand	Myanmar	Total
Irrigable Area in ha	0	1,600,000	1,600,000

Apart from original development plans prepared by either DEDP or EGAT and although study is not made in any phase, it may not be impossible to divert the Salawin water into the Bhumiphol reservoir by means of constructing diversion canals and tunnels. Based on a desk study, the length of diversion canal/tunnel is estimated at some 90 km, and this idea will have advantages and disadvantages as summarized below;

Advantages

- The diversion route will be shorter than those for the Mekong Diversion Projects, as mentioned later, and monitoring control of diversion water by riparian rights will be easy because that the diversion route will be mostly consist of tunnel works.
- Myanmar is the only riparian country concerned
- Irrigation areas will be provided in two countries, Thailand and Myanmar
- Both banks of Salawin river locate in high mountainous areas, causing no serious problem due to flood from reservoir impoundment

Disadvantages

- According to the original development plan by DEDP, irrigation areas are

extended only within Myanmar territory where water use is advantageous from topographical point of view, while Thailand will obtain only benefit from power generation.

- The riparian countries who mutually use the boundary water shall have to make agreement in advance of commencement of the project, but Myanmar still not join declaration as specified by the Helsinki Rules.
- Pump lifting of diversion water with a head of about 90 m will be required to divert Salawin water to Chao Phraya basin through the Bhumiphol reservoir.
- There are minority groups in the project areas which may cause inconvenient field works and other activities.
- Diversion plan itself is only of desk study level.

- **Moei-Huai Khanaeng Dam-Bhumibol Diversion Plan**
- **Salawin-Mae Lama Luang Dam-Bhumibol Diversion Plan**

The Moei river, which flows towards the northwest through Thailand territory, passes Mae Sot, Mae Ramat and Tha Song Yang, and joins the Salawin river at Ban Kho Puai after adding the Yuam river, is also the bordering river between Thailand and Myanmar. The feasibility study was conducted in 1995 to formulate so-called Moei-Salawin Diversion Project. The project aims to divert the Moei river water to Chao Phraya basin through the Bhumiphol dam. In total five alternative plans were studied under prefeasibility study level by DEDP, and two possible alternative plans, the second route through Huai Khanaeng dam and third diversion route through Mae Lama Luang dam, were extracted from the study for comparison.

Some Comparison on Alternative Route 2 and 3

	Alternative Route 2	Alternative Route 3
Diversion Route	Moei - Huai Kanang Dam - Bhumiphol Dam	Salawin - Mae Lamalung Dam - Bhumiphol Dam
Possible Diversion Water	2,450 MCM/annum	1,090 MCM/annum
Diversion Tunnel	7.5 m(D)x81.9 km	7.5 m(D)x15.9 km
Total Lifting Head Required	329 m	188 m
Internal Rate of Return	11.9%	15.4%
Water Cost in Bahts	1.86	1.38

From the comparative table, the alternative route 3 will be the most feasible from

both engineering and economic points of view. However, the possible amount of diversion water of 1,090 MCM as an annual average, determined in consideration of practical water right for wet and dry season irrigation, will be insufficient to meet water shortage in the Chao Phraya basin. Moreover, dam and reservoir areas and other structure sites are located mostly in the Mae Lamao national reserved forest area. In addition, major structure sites for the alternative plan 2 also locate in the Ta Song Yang national reserved forest area.

- **Nam Ngao-Bhumibol Diversion Plan**

This plan aims at developing downstream areas of the Ngao basin and alleviating the water shortage problem in the Chao Phraya basin by means of diverting surplus water of about 500 MCM/annum through the Ngao dam and Mae Tun river finally into the Bhumibol reservoir. This plan requires 235 m of pump lifting, only 65% of which can be recovered at the Bhumibol power plant. Moreover 500 MCM/year of water is not sufficient to restore the empty capacity of the Bhumibol reservoir.

- **Mae Lamao-Bhumibol Diversion Plan**

This plan aims at developing downstream areas of the Mae Lamao basin and alleviating the water shortage problem in the Chao Phraya basin by means of diverting surplus water of about 360 MCM/annum through the Mae Lamao dam and Mae Tun river finally into the Bhumibol reservoir. This plan requires 48 m of pump lifting and most part of underground tunnel (15 km of 23.5 km) passes through the watershed classified into 1A. Moreover 380 MCM/year of water is not sufficient to restore the empty capacity of the Bhumibol reservoir.

- **Mae Charao-Mae Tun Diversion Plan**

This plan is to supplement water from Moei river at Mae Charao pumping station and to divert about 500 MCM/year of water into Mae Lamao dam which will flow through Mae Tun into Bhumibol reservoir. The plan requires in total 85 m of pump lifting.

- **Upper Pai-Mae Taeng Diversion Plan**
- **Upper Pai-Mae Khan Diversion Plan**

- **Upper Pai-Mae Sa-Mae Taeng Diversion Plan**
- **Lower Pai-Mae Chaem Diversion Plan**

The Upper Pai-Mae Taeng plan intends to divert about 500 MCM of annual water from the proposed Upper Pai dam with pump lifting of 65 m. The diverted water flows into Mae Taeng, a tributary of the Ping river, through a diversion tunnel of 3.3 m diameter and 27 km long. The Upper Pai-Mae Khan plan consists of two dams of 40 m high, whose reservoirs are connected by feeder canal. Some 300 to 500 MCM per annum of water are pumped up from the middle dam at an elevation 480 m, MSL to the regulating reservoir at the elevation of 860 m, MSL, thus requiring a pumping head of 380 m and consuming 132 MW of energy. The Upper Pai-Mae Sa-Mae Taeng diversion plan also consists of two dams of 40 m and 35 m high. A diversion tunnel of 3.8 m diameter and 43 km long will conducts 420 MCM of water annually under gravity. The lower Pai-Mae Chaem diversion plan will divert some 500 MCM of excess water from downstream area of the Lower Pai dam to Mae Chaem which flows into the Bhumibol reservoir. A pumping lift of 500 m is required consuming 512 MW of energy, not more than 20% of which can be recovered at the Bhumibol power plant.

Most of above plans can divert some 500 MCM or less water annually and consume huge energy of out of sense. Moreover, some parts of the project sites locate in the national reserved forest area and watershed areas of class 1A and 1B.

(2) Water Diversion from the Mekong River and Tributaries

Being the largest in Southeast Asia, the Mekong river is another source whose runoff is not utilized since long ago. There are some preliminary studies to make use of the Mekong runoff such as the Pamong project, in the light of the present political situation, however, it can not be imagined how far the plan would be implemented. The Mekong river has the average annual runoff of about 101 billion cu.m and in March the minimum average monthly runoff of 2,090 MCM at the confluence with the Ing river.

In the preliminary study report on the Analysis of Mekong Water Diversion Schemes for Thailand prepared by MRC in 1979, various diversion projects from the mainstream of the Mekong river were taken into consideration. Among those, projects directly related to

Mekong - Chao Phraya diversion are extracted as below;

- Mekong - Pasak Diversion Project
- Mekong - Sirikit Diversion Project

Besides, DEDP has a plan to study on the Diversion Plan from the Mekong River to Sirikit Reservoir, while EGAT summarized the possibilities of diversion projects for the followings;

- Mekong-Mae Ping diversion plan
- Mekong-Mae Ngat diversion plan
- Nam Man diversion plan
- Nam San diversion plan
- Kok-Ing-Yom-Nan diversion plan

- **Mekong-Pasak Diversion Plan**

The Mekong-Pasak diversion project is a pumping project in which waters are taken from the mainstream of the Mekong river at Ban Tha Dae Mae, Changwat Nong Khai, lifted about 35 m by pumps and then conducted through diversion canal of 11 km long and tunnel of 99 km long into the Pasak river near Amphoe Lom Sak.

- **Mekong-Sirikit Diversion Plan**

The Mekong-Sirikit project is a diversion project in which waters are taken from the mainstream of the Mekong river at Ban Pak Man in Laos by a gravity tunnel system of 60.5 km long into the Sirikit reservoir near Amphoe Na Noi.

For either of above projects, pumping and canal capacity was taken at 50 m^3/sec to irrigate 162,500 rai (26,000 ha) of farmland. The Committee concluded that the both projects were less feasible because of their low benefits.

Comparison of Mekong-Pasak and Mekong-Sirikit Diversion Plans

	Mekong-Pasak Project	Mekong-Sirikit Project
B/C Ratio	0.18	0.6
Internal Rate of Return (%)	0.5	4.7
Water Cost (Bahts/m^3)	2.09	1.09

- **Mekong-Sirikit Diversion Plan (DEDP)**

The DEDP proposed a study for external finance entitled the Diversion Plan from Mekong River to Sirikit Reservoir. The concept of the project is to divert part of the excess Mekong river water during wet season, mainly flood flow, to the Sirikit multipurpose reservoir by gravity to improve the stored water availability for use for irrigation and urban water supply in the Chao Phraya basin in the dry season and for power generation without any additional cost for storage and distribution of water. The division of Mekong river water during flood flow will contribute to reduce the magnitude of flood in the downstream area. A conceptual study called "Report of Diversion from Mekong and Mae Pai to Upper Chao Phraya River Basin" was prepared in March 1993. The intake area of the proposed diversion is assumed on the right bank of the Mekong river upstream of Chiang Khan in Lao PDR. The diverted water will flow under gravity in open channel and mainly in large tunnel across the mountains to the Sirikit reservoir. About 40% of the diversion route will be located in Lao PDR and 60% in Thailand. The administrative and legal aspects of cooperation between the two countries Thailand and Lao PDR is inevitably needed.

- **Mekong-Mae Ping Diversion Plan**

The Mekong-Mae Ping diversion plan is such a plan in which waters are taken from the mainstream of the Mekong river at the Kok river mouth and conveyed by gravity through a diversion tunnel of 185 km long into the Ping river near Changwat Chiangmai.

- **Mekong-Mae Ngat Diversion Plan**

The Mekong-Mae Ngat diversion plan is a pumping project in which waters are taken from the mainstream of the Mekong river at the Kok river mouth and conveyed through a

diversion canal of 120 km long with a series of pumping lifts and a tunnel of 7 km long into the Mae Ngat reservoir at an elevation of 360 m.

- **Nam Man Diversion Plan**

The Nam Man dam, with a storage capacity of 235 MCM, is proposed to be constructed on the Nam Man, which is a tributary of Nam Heung flowing into Mekong river. This dam will irrigate 120,000 rai of cropland and generate an annual energy of 67 GWh. An excess water of 88 MCM per annum is diverted transbasin into the head of the Pasak river by gravity. Some 560 households are however requested to be resettled.

- **Nam San Diversion Plan**

The Nam San dam with a storage capacity of 101 MCM is proposed to be constructed on the Nam San, which is a tributary of Nam Heung flowing into Mekong river. This dam will irrigate 37,500 rai of cropland and generate an annual energy of 62 GWh. An excess water of 128 MCM per annum is diverted transbasin into the head of the Pasak river by gravity. Some 280 households are however requested to be resettled.

- **Kok-Ing-Yom-Nan Diversion Project**

Originated in the mountainous terrain in Myanmar at an elevation of 1,600 m, the Kok river flows southward through Thai/Myanmar border to its confluence with the Mekong river near Chiang Saen. Its drainage area is about 10,800 km^2 of which 2,980 km^2 is in Myanmar territory. The average annual runoff flowing into the Mekong river is about 5,280 MCM.

The Ing river starts from Kwan Phayao, the common pond for several small streams originating from mountain ridges, and flows in the northeastern direction to merge with the Mekong river ar Ban Sop Ing in Amphoe Chiang Khong. The average annual runoff flowing into the Mekong river is estimated at 1,940 MCM. Being located in the northern-most region of the country, the Ing basin shares the common drainage boundary with Chao Phraya basin. The Ing river basin is the one whose runoff is left unutilized at present.

Considerations were given firstly to storage possibilities in the Yom basin which is unregulated at present. A prefeasibility study was undertaken in 1980 by EGAT to evaluate alternative damsites at Kaeng Sua Ten or Huai Sak. Soon after, investigations were carried out to examine alternatives for diverting water by pumping from the Ing and ultimately from the Mekong into the head of the Yom catchment, which forms a part of the Chao Phraya river system. A prefeasibility study of the Ing-Yom-Nan Diversion Project was undertaken in 1981 by EGAT.

The results from the study on economic terms showed that the optimum diversion capacity from the Ing and Mekong was in excess of 500 m^3/sec. The Huai Sak dam was shown to be more economical than Kaeng Sua Ten for storage less than 2,750 MCM, the optimum diversion capacity to the Nan would be 400 m^3/sec and the best intermediate stage development of the Ing diversion would be 220 m^3/sec.

During the reconnaissance for this study, it was recognized that a possible additional source or alternative to the Ing-Yom diversion might be to divert water from the Kok river. Flows in the Kok tributaries could also be intercepted and diverted. A prefeasibility study to examine diversion from the Kok was undertaken by EGAT in 1982. The main elements of the scheme are to construct a dam on the Kok river some 10 km west of Chiangrai, to generate hydro-power and to divert water into an earth canal of 105 km by gravity which would reach the Ing-Yom canal alignment at an elevation of 400 m. No pumping would be required in this scheme. During the course of the study, a decision to divert the Kok water would bring a canal geographically closer to the Mekong than in the Ing-Yom scheme. Consideration at reconnaissance level was therefore given to the possibility of diversion of Mekong water from Ban Sop Kok.

The Kok-Ing-Yom-Nan diversion project is thus a pumping project in which waters are taken from (1) the Ing river with a pumping lift of 43 m, (2) the Kok river by gravity, and (3) mainstream of the Mekong river at Sop Kok (Kok river mouth) with a pumping lift of 42 m, and then conveyed into the Yom basin where three dams, namely Pong No.1, 2 and 3 dam, are constructed to regulate flow, and finally waters are diverted into the Kaeng Sua Ten dam to be constructed with a storage capacity of 4,550 MCM. From the Kaeng Sua Ten dam water can be diverted to the Sirikit dam. According to the EGAT study, the total length of the diversion canal is 260 km and the tunnel is 32 km long. The project

components therefore comprise the following five sub-projects;

- Mekong Diversion Sub-Project
- Ing-Yom Diversion Sub-Project
- Kok-Yom Diversion Sub-project
- Kaeng Sua Ten Multipurpose Dam Sub-Project
- Yom-Nan Diversion Sub-Project

The feasibility studies were undertaken for Ing-Yom diversion sub-project as well as for Kaeng Sua Ten multipurpose dam sub-project both by EGAT, and reports were issued in early 1984.

The EGAT concluded in the Summary Report of Kok-Ing-Yom-Nan Diversion Project issued in 1984 that the project which would be economically and socially feasible and could be developed to be a large scale, after comparison of all possible diversion projects, was the Kok-Ing-Yom-Nan diversion project.

(3) Progress of Kok-Ing-Yom-Nan Diversion Project

In consideration of existing political situation of utilizing the Mekong mainstream water, EGAT decided to exclude as the first stage Mekong diversion and Yom-Nan diversion sub-projects from their original plan, as stated in the Memorandum dated 7 June 1984 subjected on Summary of the Result Study on Kok-Ing-Yom-Nan Diversion Project, submitted to the Minister of Agriculture and Cooperatives and Secretary of NESDB.

(a) Kaeng Sua Ten Dam Project (Multi-purpose)

The first main objective of the feasibility study for the proposed Kaeng Sua Ten multi-purpose dam was to determine the size and type of dam required at Kaeng Sua Ten in the upper Yom basin in order to store water from the catchment itself as a first stage followed by the size of the dam required for the diversion of flows from rivers in northern catchments for later stages. Studies were undertaken for the following staged project as below;

- Stage 1 (Yom only catchment with no diversion)

To Construct Kaeng Sua Ten dam of 82 m high with normal high water level of 270 m, capacity of 2,250 MCM and powerhouse of 65 MW

- Stage 2 (Yom with Ing diversion from Thoeng)

To construct Ing-Yom diversion channel of 120 m3/sec capacity, two pumping stations with capacity 69 MW and Nam Phae and Rieng dams with powerhouse of 102 MW, to raise the Kaeng Sua Ten dam for 14 m with normal high level of 284 m and capacity of 4,550 MCM, to add install capacity of powerhouse with 65 MW, and to construct Yom/Phae and Yom/Sukothai irrigation system.

- Stage 3 (Yom with Kok and Ing diversion)

To construct Kok dam at 50 m high, normal water level 445 m, capacity 570 MCM, 48 MW powerhouse and Kok-Yom diversion channel of 150 m3/sec capacity, to add installed capacity of 100 MW at Kaeng Sua Ten and 30 MW at Rieng.

- Stage 4 (Final)

To construct Mae Kok/Mae Lao irrigation system and to construct Pong No.2 dam and powerhouse with capacity of 96 MW

(b) Kaeng Sua Ten Dam Project (Agricultural Dam)

The above study also revealed that although Stage 1 of the project was shown to be economically attractive as a multi-purpose project, power alone was only marginally economic. From EGAT's point of view, there are other hydro-power projects which might be considered more favorable. It is only in Stage 2 when diversion from northern catchment rivers are brought in, that hydro-power becomes much more attractive. Another major disadvantage of the Stage 1 project as originally conceived was the need for resettlement of some 3,390 families within the reservoir area, especially the town of Chiang Muan.

To overcome these two major constraints of large resettlement and marginally economic power, it became necessary to reconsider the concept of the Kaeng Sua

Ten dam as a single purpose dam to satisfy the demand of water for agriculture only, as opposed to the multi-purpose concept set out for the feasibility study. By removing operating level constraints for hydro-power generation, reservoir levels could be drawn down much lower, thereby making more efficient use of storage. Consequently, a smaller dam could create the same agricultural benefits as a larger dam under hydro-power operating rules. The Kaeng Sua Ten dam feasibility study-Alternative Stage 1-Agricultural Dam was conducted under the revised concept by EGAT in 1985.

Major Features of Kaeng Sua Ten Agricultural Dam

Feature	Dimension
Catchment Area	3,583 km2
Average Annual Runoff	933 MCM
Dam	Rockfill of 72 m high, 695 m long
Water Retention Level	258 m
Capacity at Retention Level	1,175 MCM
Projected Irrigation Area	48,800 ha
Resettlement Families	620 families

Responsible agency for overall activities of study and project implementation of the Kaeng Sua Ten dam was transferred from EGAT to RID since December 1985.

(c) Mae Kok Multipurpose Project

In 1986, EGAT undertook a prefeasibility study of the Mae Kok multipurpose project. The study analyzed the possibility to divert water from the proposed Kok dam into the Yom catchment by gravity, either instead of or in addition to the Ing to Yom diversion where pumping of all water is required. However, the feasibility study on the Kok Diversion Project, which would complete a series of diversion studies and would be the basis for formulating the overall Kok-Ing-Yom-Nan Diversion Scheme, has been delayed since 1986.

In 1989, a joint proposal by EGAT and RID to upgrade the diversion project to the feasibility study level was submitted to be financed by EEC. The study was never carried out due to different views of both agencies on the consultant selection process, and it has been delayed since then.

Water shortages in the Chao Phraya basin have steadily been aggravated by rapid economic development activities. Strong environmental movements to protect the Kok and Yom rivers from construction of any major storage dams have prompted RID to search for better alternatives of diversion scheme.

(4) Kok-Ing-Nan Diversion Project

The Kok-Ing-Nan development scheme is proposed as one of the possible option to divert surplus water in wet season trans-basin from the river basins where runoff is abundant to the one where water is needed. The scheme as envisaged would first divert the water from the Kok river possibly at the existing barrage already constructed by DEDP near the city of Chiangrai. This would minimize environmental impact to the upper Kok basin since no large storage dam and reservoir is required. The diverted water would then be transported by gravity to the Ing and Nan catchments through a series of canal and tunnel systems to meet the requirement of water in the Ing and Nan valleys as well as in the Chao Phraya basin after once stored in the Sirikit reservoir.

The conceptual plan study of this project has just started in March 1996 by RID. The project will primarily be composed of two major project components, namely Kok-Ing diversion scheme and Ing-Nan diversion scheme.

Since the latter half of 1980s, social and environmental problems for construction of large and medium dam/reservoirs have become serious. Even construction of the Kaeng Sua Ten agricultural dam with the cabinet's approval has been suspended because of strong resistance of local inhabitants and activists against ecological changes and resettlement problem. It will not be realistic to expect implementation of the further stages of the Kok-Ing-Yom-Nan diversion project if a great number of inundated families within the reservoir area is taken into consideration. Moreover, it will not meet the water requirement in the Chao Phraya basin if implementation of the stage-1 alone of the Kok-Ing-Yom-Nan diversion project has been achieved.

Meanwhile, the Kok-Ing-Nan diversion project is not a reservoir type project as a result bringing no or less problems concerning encroachment of watershed and forestry resources, people resettlement, land expropriation and others. The project in principle

requires no pumping. Diverted water of some 2,000 MCM per annum will meet the existing space for additional storage in the Sirikit reservoir, and will fulfill the requirement in the Nan and Chao Phraya basin when a proper rule of the Sirikit reservoir operation is accompanied. Although the Kok and Ing rivers are the tributaries of the Mekong river, agreements for exploiting the water diversion within local rivers have already been achieved among riparian countries in 1995.

From every aspects as considered above, the Kok-Ing-Nan diversion project will be the one which can meet the water requirement and can be implemented in near future.

3.5 Water Agreement and Other Related Topics

(1) Water Agreement

The Governments of the Kingdom of Cambodia, the Lao People's Democratic Republic, the Kingdom of Thailand and the Socialist Republic of Vietnam, being equally desirous of continuing to cooperate in a constructive and mutually beneficial mannar for sustainable development, utilization, conservation and management of the Mekong river basin water and related sources, have resolved to conclude an agreement on The Cooperation For The Sustainable Development Of The Mekong River Basin at the Fifth and Final Meeting of The Mekong' Working Group held on November 28-29 1994 in Hanoi, Vietnam. More details are given in the Supporting Report.

(2) Notification of Two Tributaries Projects in Thailand

At the Joint Committee held on November 20-21 1995 in Ho Chi Minh city of Vietnam, Dr. Prathes Sutabutr, Head of the Thai Delegation, on the basis of Article 5 of the Agreement and in a spirit of goodwill and cooperation, notified the Joint Committee on two tributary projects being implemented by Thailand, namely, the Kok-Ing-Nan and Lamtakhong. The former is a feasibility study project involving a diversion plan of water to the Chao Phraya river basin. The latter is a hydropower project on the Lamtakhong river, a tributary of the Mun river, involving the use of water from the existing Lamtakhong reservoir for generating electricity by means of pump-storage. The Joint Committee acknowledged the notification by Thailand with great appreciation.

The minutes of the special session of the said Joint Committee is also compiled in the Supporting Report.

(3) Position in the National Economic and Social Development Plan

RID finally concluded in 1996 a master plan for the medium and large scale construction projects to be listed up in the 8th National Economic and Social Development Plan (1997-2001). According to the master plan, the proposed Kok-Ing-Nan water diversion plan is nominated as the large scale irrigation project of which detailed design works has been scheduled for the year 2000. More details of this master plan is compiled in the Supporting Report.

3.6 Necessity of Kok-Ing-Nan Water Diversion Project

The necessity of the proposed Kok-Ing-Nan water diversion project is summarized as in the followings;

- The agricultural and socio-economic development in 21 century in the Chao Phraya basin, especially in the delta area holding a large irrigated farmland of 1.2 million ha, expanded urban area involving the Bangkok Metropolis with dense population of exceeding 1.0 million and developed industrial zone achieving successful growth will be stagnant because the area will face the critical water shortage problem due to limited water resources and increased water demand in dry season. It is inevitably necessary to introduce additional water to the Chao Phraya basin to solve water shortage problem and to achieve sustainable development of the area in 21 century.

- The Thai Government has studied numbers of water resources development projects in the Chao Phraya river basin since the early 1980s intending to implement feasible projects toward 21 century. The total volume of water resources to be developed in future by large and medium scale storage dam projects are however limited to less than 4,000 MCM in the whole Chao Phraya basin, and they will be consumed mostly for supplemental irrigation of wet season paddy in the tributary sub-basins where dams/reservoirs are constructed, meaning that there is no allowance at all to supply excess water in dry season to the Chao Phraya delta area.

- The Thai Government has studied as well a number of alternative plans of transbasin water diversion from the Salawin and Mekong rivers to the Chao Phraya basin since the 1980s. All of such plans except the Kok-Ing-Nan water diversion project have, however, been judged to be no or less viable for project implementation due to difficulty of diverting water from international rivers which needs water agreement among riparian countries, long distance tunnel and high pumping head which require high construction and operation costs, no availability of suitable construction site of large scale dam/reservoir to regulate the bulk amount of wet season runoff as well as large environmental impact such as peoples resettlement to be induced by dam construction, etc.

- Only the Kok-Ing-Nan water diversion project among many alternative plans is advantageous and viable for project implementation since the project is technically and economically viable and would bring less environmental impact as compared to the other transbasin water diversion projects ever studied.