CHAPTER 4
THE PROJECT WATER DIVERSION PLAN

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4.1 Concept of Kok-Ing-Nan Water Diversion Plan

The shortage of water for various sectoral uses including agriculture have been aggravated especially in the Chao Phraya river basin by the rapid economic development activities, as grasped in the previous chapter of this report. Strong environmental movement in the recent years to offer resistance against construction of any proposed large/medium scale storage dams has prompted RID to search a better alternative of transbasin diversion scheme.

(1) Concept of Kok-Ing-Nan Water Diversion Plan

The proposed Kok-Ing-Nan water diversion project is one of the optional plans which intend to divert surplus water in wet season transbasin from the river basin where water is abundant to the one where it is needed. The plan as envisaged would first divert the water from the Kok river possibly at the existing Chiang Rai weir constructed by DEDP near the city of Chiang Rai. The use of the existing weir would minimize the environmental impact to be induced by the proposed scheme in the upper Kok basin, since no further construction of storage type structure is required. The diverted water would then be transported under gravity to the head of the Nan river basin through a series of channel and tunnel systems to meet the requirement of water in the lower Nan basin as well as in the Chao Phraya delta area after once stored and regulated in the Sirikit reservoir. The diversion channel and tunnel will on the way intercept the runoff from the Ing river, and will supply water for irrigation and domestic uses in the Kok, Ing and upper Nan basins.

The conceptual planning study of this project has been made by the Thai Consultants JV under the contract with RID since March and just completed in October 1996. The scheme primarily comprises the following three components;

- Kok to Ing diversion scheme,
- Ing to Nan diversion scheme, and
- Associated development schemes in Kok, Ing and upper Nan basins

Kok-Ing Diversion Scheme

The water diverted form the Kok river will be conveyed to the proposed diversion damsite on the Ing river near Amphoe Thoeng through a 50 km long diversion channel, composed of open canal, siphon, culvert and tunnel sections as required by topographic, geographical and present land use conditions. About 1,100 MCM/year of water will be diverted from the Kok river and transported through the diversion channel during wet season from June to December. The diversion channel will carry dry season water from the Kok river for the purposes of agricultural and other regional development within the Kok and Ing river basins, however the proposed scheme does not intend to carry any portion of water into the head of the Nan basin. The capacity of the Kok-Ing diversion channel is preliminarily estimated at 125 cu.m/sec.

Ing-Nan Diversion Scheme

The above Kok-Ing diversion channel is linked with the Ing-Nan diversion channel at the proposed Ing diversion dam, where the water from the Kok river and the Ing runoff combine.The scheme will divert the Ing water with the first priority, in order to minimize the capacity of the Kok-Ing diversion channel. Since the alignment of the Ing-Nan diversion channel passes unavoidably a rugged mountainous region, the Ing-Nan diversion channel is composed mostly of tunnel sections. The total length of the tunnel is estimated preliminarily at some 50 km, with a discharge capacity of 175 cu.m/sec. The channel will carry about 2,000 MCM/year of water under gravity system, including 1,100 MCM from the Kok river and 900 MCM of the Ing runoff.

Associated Development Schemes in Kok, Ing and Upper Nan Basins

The proposed Kok-Ing-Nan water diversion project intends to first utilize the existing available runoffs of the Kok and Ing rivers for irrigated agriculture and other developments in the Kok, Ing and upper Nan basins. Remaining flows in the river systems after diverting waters for such developments are the potential sources of water for the proposed Kok-Ing-Nan water diversion project.

(2) Demand and Supply for Transbasin Water Diversion

As previously studied in Chapter 3, about 2,700 MCM/year of water resources is to be exploited in addition to the proposed developments within the basin in near future. As large empty space of storage as 2,700 MCM is left unused in the Sirikit reservoir under the normal year condition. The proposed scheme's priority concern is to fill this empty storage space with waters diverted transbasin from the catchment where waters are abundant.

The river basins where waters are abundant especially in wet season and from which transbasin water diversion is possible from technical and engineering points of view including topography, geography and geology without constructing a large scale storage dam/reservoir are the Kok and Ing river basins.

The proposed schemes assume the following uses of the Kok and Ing river waters;

Flow Condition of Kok and Ing River with/without Proposed Scheme

Water Allocation	Volume in MCM/year	
	Kok River	Ing River
Existing Runoff at Proposed Diversion Site	3,800	1,730
Primary Diversion for Development within Basin	1,200	680
Available Flow for Proposed Diversion Scheme	2,600	1,050
Flow to be Diverted by Proposed Diversion Scheme	1,100	900
Remaining Flow	1,500	150

4.2 Water Demand and Supply in Kok, Ing and Upper Nan Basins

(1) Water and Land Resources

Water and land resources in the Kok, Ing and upper Nan basins are summarized from the RID's Conceptual Planning Study (the Local Study) as follows;

Water and Land Resources in Kok, Ing and Upper Nan Basins

Water and Land Resources	River Basin		
	Kok	Ing	Upper Nan
Water Resources Drainage Area (sq.km) Annual Runoff (MCM)	 10,900 5,280	 7,100 2,335	 13,130 5,312
Land Resources (ha) Potential Irrigable Area Existing Irrigation Area Irrigation Area in Future	 132,200 (100%) 94,147 (71%) 127,015 (96%)	 105,515 (100%) 55,461 (53%) 73,541 (70%)	 N.A 21,269 (N.A) 47,265 (N.A)

In addition, in the Chao Phraya river basin downstream of Nakhon Sawan, there extends the potential irrigable areas of 1.4 million ha of which about 1.28 million ha has been under irrigation including 1.2 million ha covered by the Greater Chao Phraya irrigation project.

(2) Proposed Irrigation Development Projects

In the above table, the proposed irrigation development area amounts to 32,900 ha for the Kok river basin, 18,080 ha for the Ing basin and 26,000 ha for the upper Nan basin. Such proposed projects for irrigation development are listed in the following table.

Proposed Irrigation Projects and Proposed Irrigation Area

Kok Basin		Ing Basin		Upper Nan Basin	
Project	Irrigation Area (ha)	Project	Irrigation Area (rai)	Project	Irrigation Area (rai)
Upper Fang Res.	2,900	Upper Thoeng Weir	5,920	Tha Wang Pha	3,200
Mae Talop Res.	1,490	Lower Thoeng Weir	4,480	Ban Khong Nok	3,820
Huai Krai Res.	4,480	Pak Ing Regulator	7,680	Small Scale Projects	18,970
Mae Na Wang Res.	2,080				
Mae Jadee Res.	5,760				
Mae Pun Luang Res.	8,800				
Mae Yang Mint Res.	6,240				
Mae Suai Res.	1,120				
Total	32,870	Total	18,080	Total	25,990

From the existing and proposed projects distributed in river basins, short lists of the water resources development projects, involving improvement and rehabilitation of the existing projects, were prepared by the Thai-side Study as the candidates for the associated development projects to be further studied in the feasibility study, as shown in the Supporting Report.

(3) Existing and Future Water Demand

(a) Irrigation Water Demand

The irrigation water requirements were calculated by the FAO's Modified Penman Method, on the basis of meteorological data collected from Chiang Mai and Chiang Rai cities for the Kok basin, Phayao city for the Ing basin and Nan city and Tha Wang Pha for the upper Nan basin. In addition, the data from Uttaradit, Pitsanulok, Petchabun and Nakhon Sawan were used to estimate irrigation requirements for the lower Nan basin. The crop coefficients or Kc values were extracted from the existing reports for water resources development projects in the concerned basins in addition to the experiments of the pilot projects of RID. The requirements for land preparation and nursery was assumed to be 200 mm and 250 mm respectively for wet and dry season cropping while the rate of percolation was set at 1.5 mm/day. The effective rainfall was computed on weekly basis by means of balancing rain water supply, field water requirement, effective storage on paddy and deep percolation. The irrigation efficiencies were taken at 50% and 55% for wet and dry season rice cropping and 45% and 50% for wet and dry season upland crops. The existing and proposed cropping patterns and calendars are presented in the Database Map.

The results of such calculations are as in the following table;

There are significant differences in estimates of irrigation water requirement for dry season cropping compared to actual application of around 600 mm observed in the Phitsanulok and Greater Chao Phraya irrigation areas as previously studied in Chapter 3. This may be due to various hydrological factors and application of improved efficiencies for irrigation, however, it may be needed to undertake more careful studies on estimation of water demand for irrigation. For dry season cropping, estimates of irrigation water requirement are distributed within a acceptable range.

Irrigation Water Requirement (Unit: mm)

Crops	Kok Basin	Ing Basin	Upper Nan	Lower Nan	Chao Phraya
Wet Season					
Rice	324	318	505	421	560
Maize	45	65	156	102	-
Soybean	32	38	125	95	-
Mungbean	36	25	104	83	-
Dry Season					
Rice	1,153	1,133	1,186	1,192	1,430
Maize	-	-	-	-	287
Soybean	525	495	544	556	-
Cabbage	312	315	343	343	462
Perennial Crop					
Sugarcane	-	-	-	-	692
Mango	1,971	1,853	2,579	2,532	-
Pomelo	1,578	1,456	2,100	2,054	-
Fruit Trees	-	-	-	-	1,017

Regardless whether the implementation of all of the proposed projects in near future is possible or not, the waters required by those projects are to be secured within the basins. Accordingly, the water demands for irrigation are estimated corresponding to the existing and proposed irrigation areas as in the followings.

Water Demand for Irrigation

River Basin	Present Condition (1996)		Future Condition (2016)	
	Irrigation Area (ha)	Water Demand (MCM)	Irrigation Area (ha)	Water Demand (MCM)
Kok	94,147	562	127,014	754
Ing	55,460	334	73,540	438
Upper Nan	21,269	122	47,265	272
Chao Phraya Delta	1,200,000	6,971	1,269,000	10,927

(b) Water Demands for Sectors other than Agriculture

In the Thai-side Study, the water demand for domestic uses was estimated based on the projection of population increase by applying a constant rate of growth observed for the period from 1982 to 1994. The per capita consumption of water was taken at 140 liter/day/capita for the areas included in Muang and districts, and at

50 liter/day/capita for the area of villages and communities. For the Chao Phraya delta area, the projected values were extracted from the Feasibility Study of Raw Water, prepared by MWA in 1990. In general in Thailand, the per capita water consumptions for domestic uses are taken at 200 to 400 liter/day for Bangkok Metropolitan area, 100 to 180 liter/day for a large scale municipality, 80 to 100 liter/day for a medium scale municipality and 20 liter/day for rural areas.

In the estimation of water uses for industries, a constant annual growth rate of 5% was adopted with a unit consumption of water at 10 cu.m/day/factory. For the estimation of water uses for industry as well as for tourism in Bangkok Metropolitan areas, an annual constant rate of increase of 2.9% was adopted.

The water demand for tourism was estimated on the basis of the data on the tourist expansion collected from the National Registration Office, with a projected growth of tourism at an annual rate of 6.3% under assumption that the local tourists stay overnight for 3 days while tourists from outside countries will stay overnight 6 days both with consumption of water of 615 liter/day/person.

As regards the river maintenance flow to be released downstream river course, the average flow in March, 22.8 cu.m/sec or 720.28 MCM/year, was taken for the Kok river at the proposed diversion damsite, 1.9 cu.m/sec or 58.97 MCM/year was applied for the Ing river, while 40 cu.m/sec or 1,261 MCM/year was considered as the minimum flow at the Chao Phraya diversion dam for navigation and salinity control purposes.

The water demands for sectors other than agriculture at present and in future are summarized as in the following table.

Water Demand for Sectors other than Agriculture

Sector and Demand	Kok Basin		Ing Basin		Upper Nan Basin		Chao Phraya	
	Present	Future	Present	Future	Present	Future	Present	Future
Domestic Uses								
Population (million)	0.89	1.32	0.77	1.09	0.40	0.55		
Water Demand (MCM)	21.84	33.08	22.15	31.51	9.96	13.63	1,769.0	3,226.0
Industrial Uses								
Number of Factory	985	2,613	513	1,376	585	1,551		
Water Demand (MCM)	2.80	7.41	1.89	5.02	2.13	5.66	600.0	1,100.0
Tourism Uses								
Number of Tourist (million)	0.81	2.75	0.38	0.69	0.27	0.49		
Water Demand (MCM)	2.54	8.68	1.18	2.18	0.85	1.56	-	-
River Maintenance Flow								
Water Demand (MCM)	720.28	720.28	58.97	58.97	-	-	1,261.0	1,261.0

(4) Water Balance Study

The water balance study was undertaken employing the HEC-3 model, developed by the Hydrologic Engineering Center of the US Army Corps of Engineers in 1981. The model simulation performs the river flow routings on a monthly basis, based on the historical record of river runoffs, requirements for water diversion for irrigation and other uses, and storage function of the existing and proposed reservoirs. The simulated results for the Kok, Ing, upper Nan and Chao Phraya basins for the present condition with the existing water uses and water resources development facilities are illustrated in the Database Map.

The future conditions, with full developments of the potential water resources for irrigation and other various activities in the year 2016, are also simulated with outputs given in the Database Map. In simulation of water balance for the future condition, the crop intensity for dry season irrigation was assumed at 30%.

4.3 Optimum Water Diversion Capacity

(1) Available River Runoff at the Proposed Diversion Site

(a) Kok Diversion Site

River discharges are primarily used to irrigate existing and potential agricultural areas, to supply domestic and other purposes and to maintain downstream river course. Residual river flow after such water diversion is the potential source of water for the proposed water diversion project. Since the proposed project also intends not to utilize the Lao (kok-Lao) runoff from engineering point of view, evaluation of the Lao runoff is therefore excluded from the water diversion planning study.

Monthly Runoff of Kok River at Proposed Diversion Site (Existing Condition)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Mean	86	130	207	404	728	733	516	356	241	179	118	97	3,796
Max.	149	295	357	805	1,49	1,07	798	664	431	287	190	160	5,920
Min.	16	24	87	121	258	415	324	141	86	56	34	17	2,031

(Unit=MCM)

Monthly Runoff of Kok River at Proposed Diversion Site (Available for Proposed Project)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Mean	20	65	76	301	529	588	458	295	149	76	35	13	2,606
Max.	63	151	169	565	853	845	640	519	346	149	73	36	3,776
Min.	0	4	0	135	320	344	269	158	52	15	0	0	1,564

(Unit=MCM)

(b) Ing Diversion Site

The Ing river runoffs, including those of the Lao river, the largest tributary of the Ing river are given as follows;

Monthly Runoff of Ing River at Proposed Diversion Site (Existing Condition)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Mean	11	34	63	164	398	479	319	166	52	29	12	8	1,733
Max.	39	196	179	569	796	1,14	632	543	190	74	27	24	3,046
Min.	2	2	2	11	104	200	99	37	18	8	4	3	823

Note: Record includes Lao river runoff. (Unit=MCM)

Monthly Runoff of Ing River at Proposed Diversion Site (Available for Proposed Project)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Mean	2	19	12	79	200	322	245	154	11	10	0	0	1052
Max.	14	105	89	331	443	709	487	415	76	77	0	0	1,848
Min.	0	2	0	3	52	132	121	19	0	0	0	0	500

(Unit=MCM)

(2) Existing and Projected Role of Sirikit Reservoir

(a) Existing Function of Sirikit Reservoir

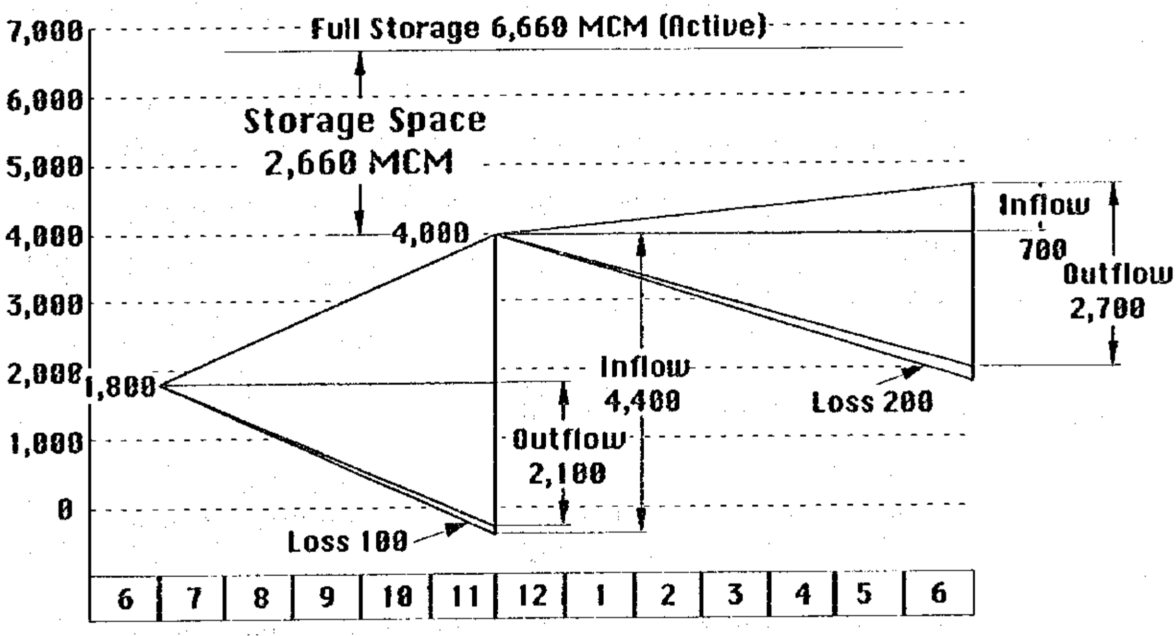
Of the annual total inflow of 5,100 MCM on the average in the past 21 years from 1974 to 1994, 4,400 MCM concentrate during wet season from June to November. In wet season, the reservoir releases 2,100 MCM of water for hydro-power generation, downstream water requirement and flood control, and remaining 2,300 MCM is used to restore storage for use in succeeding dry season. On the contrary in dry season from December to next May, the reservoir receives only 700 MCM of inflow from catchment and releases 2,700 MCM for downstream beneficiaries, thus consuming 2,000 MCM of storage.

Past Water Balance of Sirikit Reservoir (Unit=MCM)

	Inflow (1)	Outflow (2)	Balance (1)-(2)	Remarks
Wet Season	4,400	2,100	2,300	Used to restore storage
Dry Season	700	2,700	(-)2,000	Used to consume storage
Total	5,100	4,800	300	

As the result of above operation, the reservoir storage was 4,600 MCM in terms of total storage or 1,800 MCM in active storage at the end of June when storage is recommendable to be the lowest providing storage space for unforeseen flood during wet season, and 6,800 MCM or 4,000 MCM at the end of November when the highest storage is to be maintained to promote downstream releases in answer to the request from beneficiaries during dry season, meaning that the reservoir still keep 1,800 MCM of usable storage at the end of dry season and there remain 2,700 MCM of space to be filled with water at the end of wet season.

The existing problem of the reservoir operation evaluated above is mainly due to lack of inflow, and it is therefore impossible to be solved unless the water is imported by means of transbasin water diversion.



Existing Situation of Sirikit Operation

(b) Projected Role of Sirikit Reservoir

The proposed Kok-Ing-Nan Water Diversion Project aims at gaining as much increased storage in the Sirikit reservoir as possible at the end of wet season for promotion of downstream water release in the succeeding dry period and also providing as much increased storage space as possible at the end of dry season or beginning of wet season for unforeseen flood runoff from the catchment. These effects conflicting each other will be achieved only when the water diverted transbasin from Kok and Ing is introduced into the reservoir.

An ideal pattern of operation of the Sirikit reservoir is to restore its storage toward the full storage at the end of November using runoff during recovery period from July to November, and to utilize the storage during consumptive period from December to next May, in response to the request from downstream water users. In view of flood control, reservoir water level is also ideal to be the lowest at the end of June when flood runoff begins to flow into the reservoir. Such an improvement concept of Sirikit reservoir operation is visualized as shown in Figure 4.1.

(c) Water Demand to be Released from the Reservoir

In the proposed water diversion project the Sirikit reservoir performs an important part in receiving and storing the water diverted in wet season and releasing it during dry season for downstream utilization mainly in Uttaradit and Pitsanulok area in the lower Nan basin and the Chao Phraya delta area. The existing condition of water shortage in these areas has already been explained in the previous chapter.

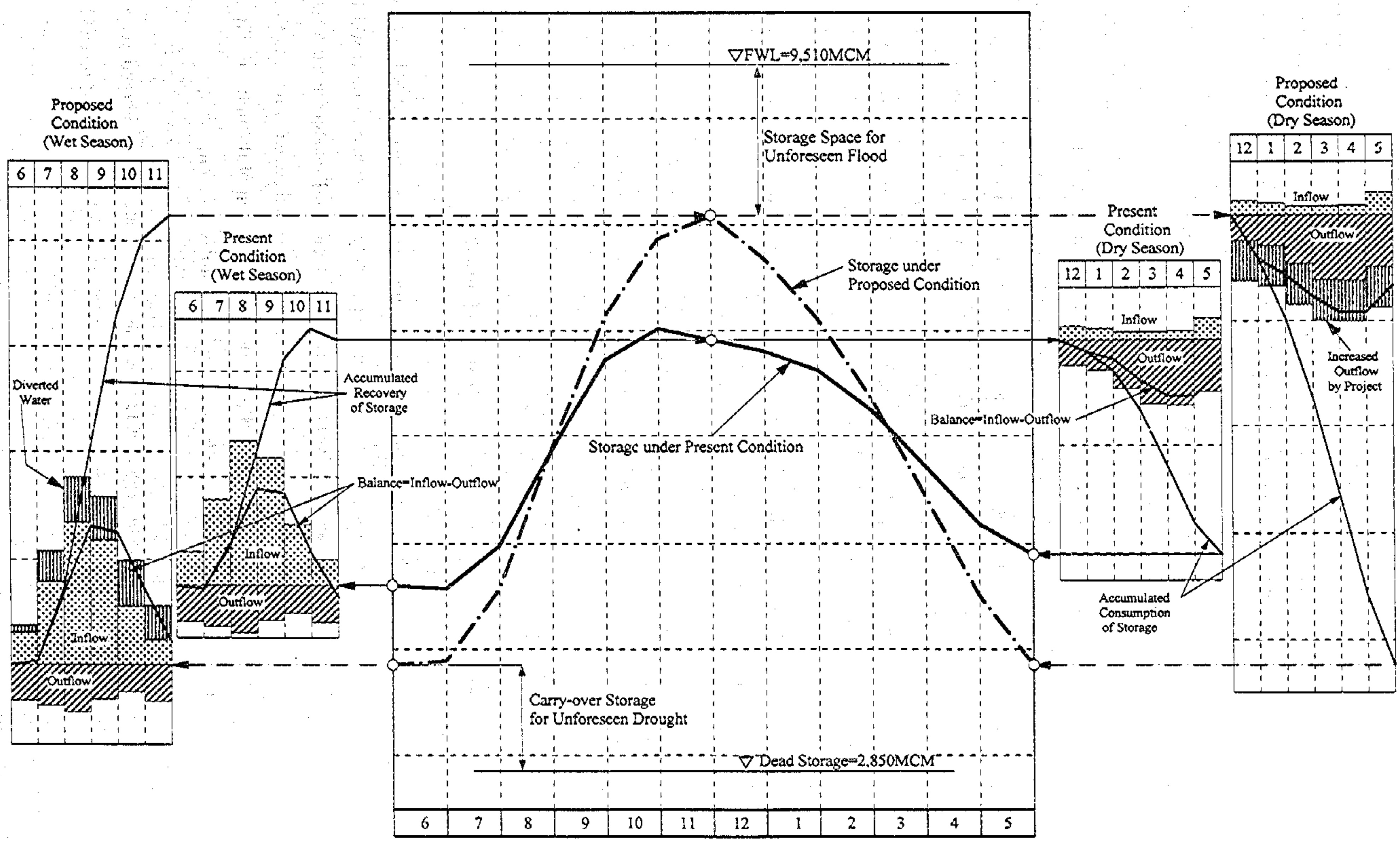
(3) Study on Optimum Diversion Capacity

(a) Potential Diversion and Preliminary Selection of Diversion Capacity

Possible amount of water diversion from the Kok and Ing basin to the Sirikit reservoir largely depends on the discharge capacity of diversion channel. A larger amount of water may be expected as the capacity enlarges, however the rate or incremental raise of amount may decrease when the capacity exceeds a certain limit. A greater construction cost will be required for a larger diversion channel and over-estimation may cause needless control of diversion when the reservoir is filled with runoff from its own catchment, and therefore be uneconomic. A preliminary study was undertaken to set up a range of diversion channel capacities for which further studies be made to select a suitable capacity linking the possible amount of diversion and the Sirikit reservoir operation.

Capacities of 100 to 200 cum/sec with an interval of 25 cum/sec were given to

Figure 4.1 Improvement Concept of Sirikit Reservoir Operation



the Ing-Nan diversion channel while 0 to 100% discharge capacities of corresponding Ing-Nan capacity were set for the Kok-Ing channel for evaluation of potential amount of diversion. As illustrated in Figure 4.2, the study reveals the followings;

- Potential amount of diversion from Ing basin is defined only by the capacity of Ing-Nan diversion channel.
- Potential total amount of diversion falls below 2,000 MCM when capacities of smaller than 150 cum/sec is given to Ing-Nan diversion channel.
- Potential total amount of diversion increases as the capacity of Kok-Ing channel enlarges, however a growth rate of increase turns to decrease if the capacity of Kok-Ing channel exceeds a certain turning point, and for every combination of diversion capacities, a growth rate of increase of potential diversion amount turns to rapid decrease when the capacity of Kok-Ing channel exceeds 80% of Ing-Nan capacity.

Accordingly the following combination of discharge capacity is selected for further selective study of suitable diversion capacity.

Ing-Nan Diversion Channel:	150,175 and 200 cu.m/sec
Kok-Ing Diversion Channel:	50% to 80% capacities of Ing-Nan channel

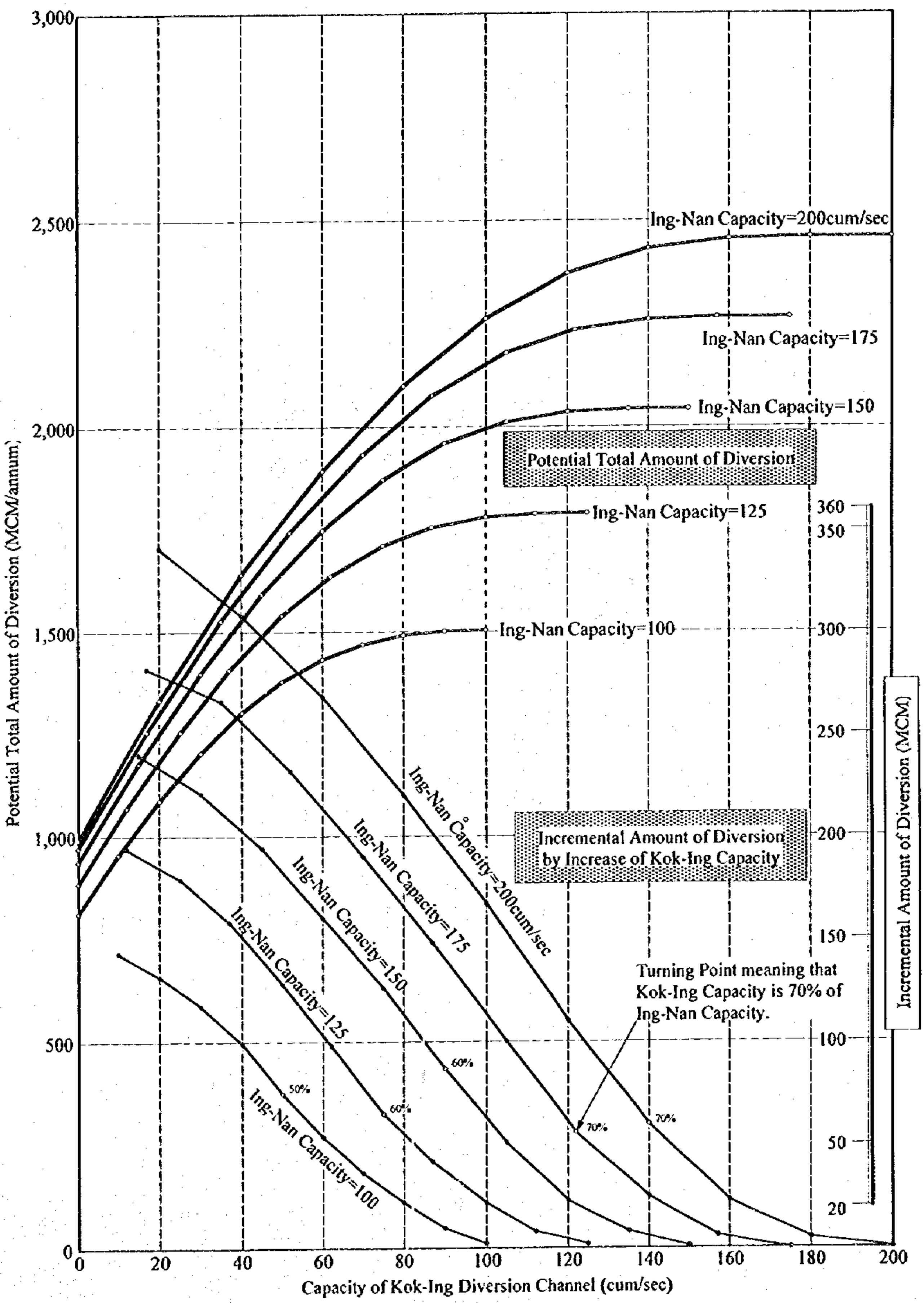
(b) Optimum Diversion Capacity

Criteria for Selection of Optimum Diversion Capacity

In consideration of the existing function and the projected role of Sirikit reservoir, the most important is to evaluate not only the amount of water which can be introduced through transbasin water diversion from the Kok and Ing basin but also the increase of usable storage in the reservoir from which water is released to meet downstream requirement. In this point of view, evaluation of the optimum diversion capacity should be linked with operation of the Sirikit reservoir.

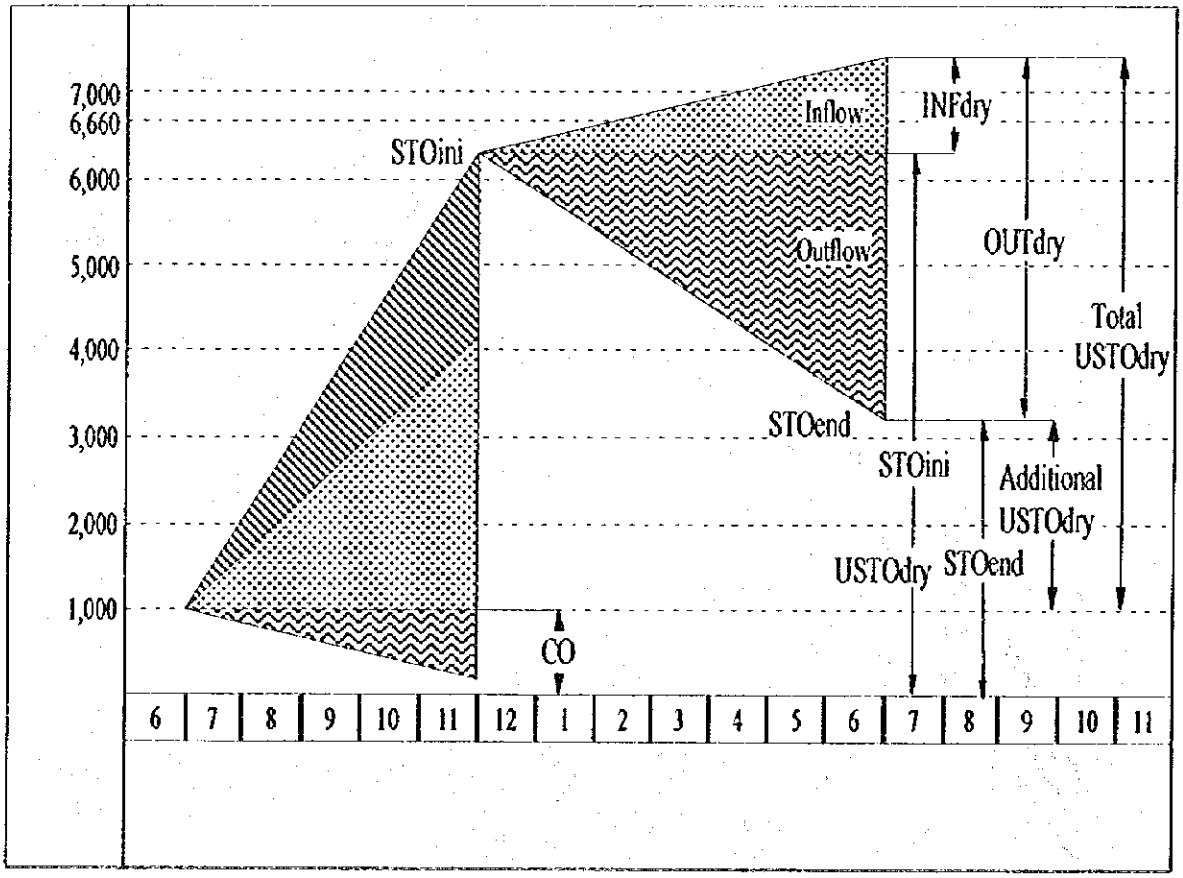
As is shown in Figure 4.1, under the present situation in normal years, the reservoir has been operated within a very narrow range of storage. This range of

Figure 4.2 Potential Total and Incremental Amount of Diversion from Kok and Ing Basin



storage operation can however be expanded by introducing water diverted into the reservoir.

In the study, 2,700 MCM of the average empty space of storage in the Sirikit reservoir was taken as the target for the additional usable storage (USTOdry in the following figure) to be provided by the project for normal years at the end of November for use in succeeding dry season.



Suitable Combination of Diversion Capacity

From the case studies of Sirikit reservoir operation in combination of various diversion capacities as shown in Table 4.1, the amounts of water to be effectively and safely diverted from the Kok and Ing rivers without wasted in the Sirikit reservoir through spillage (effective diversion), for the case with the Kok-Ing diversion channel capacity of 120 cu.m/sec, were compared with costs to be required for construction of various capacities of the Ing-Yot (Ing-Nan) tunnel in order to evaluate the best suitable capacity. The construction costs approximately estimated for this purpose are given in Chapter 5 of the Supporting Report.

Capacity of Ing-Yot Tunnel	Effective Amount of Diversion (MCM)	Construction Cost (million Baht)	Water Cost (Baht/cu.m)
150 cu.m/sec	1,869	19,933	10.67
175 cu.m/sec	**2,004**	**20,604**	**10.28**
200 cu.m/sec	2,012	21,306	10.59

As the result of study, the following combination of diversion capacities was selected preliminarily (refer also to Figure 4.2);

Diversion Channel	Capacity
Ing - Nan	175 cum/sec
Kok - Ing	125 cum/sec

More detailed studies on the capacity of diversion channel will be required during the feasibility study phase mainly for the range between 150 cu.m/sec and 175 cu.m/sec, in combination with the optimum rule of the Sirikit reservoir and in consideration of effect of the Mae Kok hydro-power dam to be constructed near the border of Thailand and Myanmar.

4.4 Proposed Water Diversion Plan

(1) Improved Operation Rule of Sirikit Reservoir

In consideration of seasonal pattern of rainfall in the irrigation service area as well as of available runoff flowing into the river from where water is diverted for irrigation and other purposes, the Sirikit water has a significant importance for dry season crops under vegetative and reproductive stages and under initial irrigation stage for wet season crops. In irrigated service area under such situations, it must be intolerable and irresistible that the water supply from the reservoir be interrupted. It is, therefore, inevitably necessary that the reservoir is so operated as to ensure its storage by this time. In planning a rational operation of the reservoir against more complicated requirement of water for irrigation and others, an objective standard must be necessarily required to be established.

During dry season, operation of reservoir is undertaken in a way that two purposes confronting each other can be adjusted. The first objective is to promote water release effectively in response to demand of the service area. However, as a result, promotion of water release accelerates consumption of available storage in the reservoir. Secondly, some countermeasures for unforeseen drought is needed. In preparation for present and future drought, water release is rather restricted intending preservation and restoration of storage.

During wet season when inflow into the reservoir largely exceeds water demand under the normal condition, the reservoir should be so operated that i) as much water release as possible be allotted for power generation, ii) as small amount of water as possible be wasted through spillage, and iii) reservoir be finally recovered to the full storage level as frequent as possible at the end of wet season. Accordingly even during wet season, a role of reservoir operation is constructed by means of establishing various modes of allowable release with respect to available storage, aiming at the most effective utilization of the limited water resources for multiple purposes of irrigation, hydro-electric power generation and other water supplies.

Apart from the above concept of reservoir operation, the following assumption is employed for evaluation of the proposed function of the Sirikit reservoir in this conceptual plan phase of study with no detailed information regarding water requirement, in order to simplify the problem.

- During the recovery period of reservoir storage, from July to November, the reservoir is so operated as to allot allowable release for power generation within the maximum limit of the power plant, following the existing operation rule curve (upper rule curve).

- During the consumptive period of storage from December to June, the reservoir is so operated as to release monthly amount of water corresponding to the past achievement, and additional usable storage is evaluated as the remaining storage at the end of consumptive period minus a certain volume of storage to be carried over for unforeseen drought.

- During the consumptive period, above additional usable storage is divided equally for the period for the purpose of evaluation of possible increase of energy output only.

(2) Contribution of the Project for Water Utilization

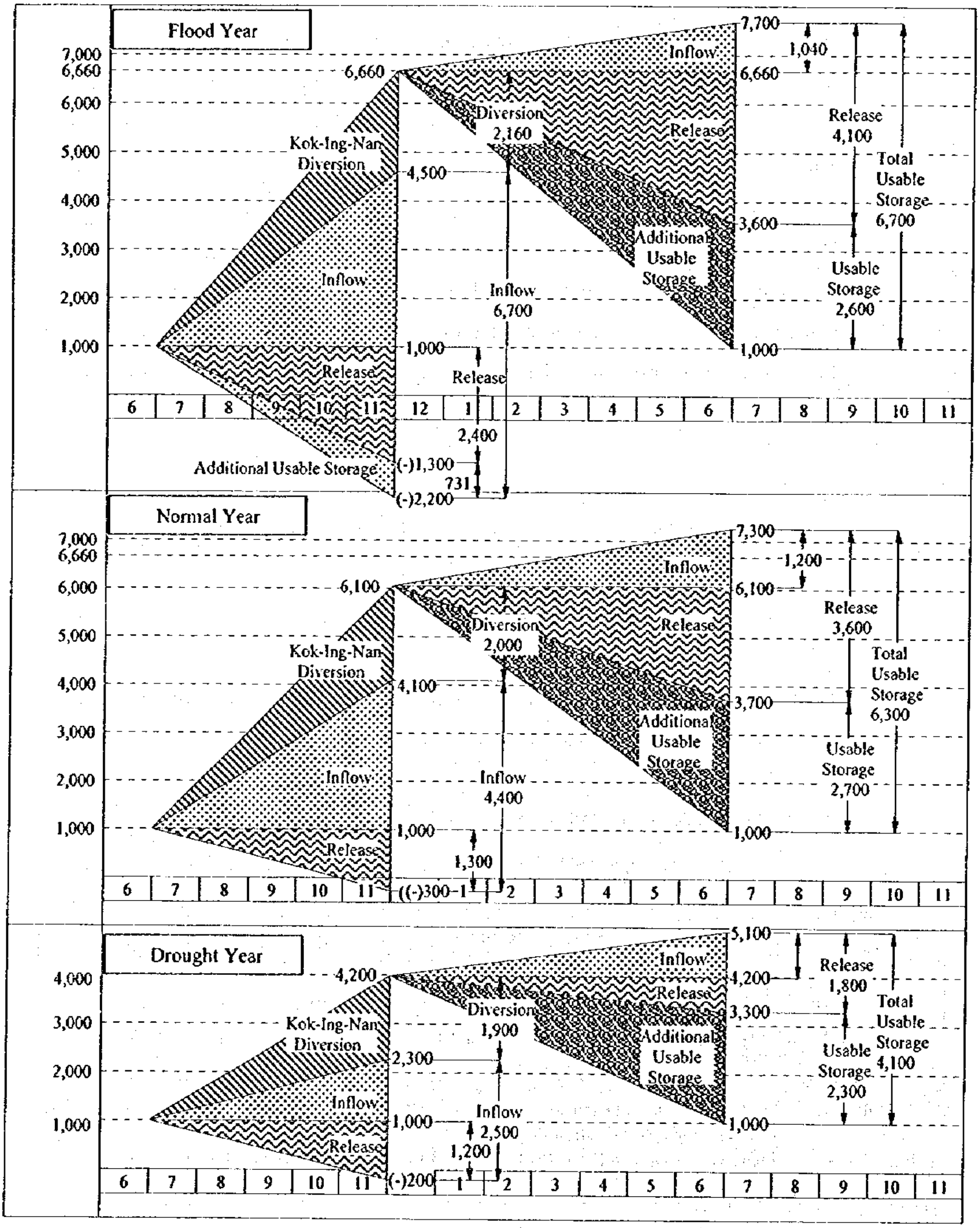
Contribution of the Project may be explained by the allocation of Sirikit storage in comparison with and without project (refer to Figure 4.3);

Storage Allocation of Sirikit Reservoir (With Project Condition)

Period	Recovery Period (July to November)			Consumptive Period (December to June)		
	Inflow	Release	Storage at End of November	Inflow	Release	Storage at End of June
Flood Year	8,060	2,400	6,660	1,040	4,100	3,600
Normal Year	6,400	1,300	6,100	1,200	3,600	3,700
Dry Year	4,400	1,200	4,200	900	1,800	3,300

Note:
- Unit is given in MCM and storage is shown in terms of active storage (full storage=6,660MCM).
- Inflow includes transbasin water diversion.
- Flood year comprises 1975, 1981, 1994 and 1995, while normal year contains 1982, 1983 and 1985, and dry year 1987, 1992 and 1993.

Figure 4.3 Storage Allocation of Sirikit Reservoir (With Project)



Comparison on Usable Storage during Consumptive Period

Period	W/O Project	With Project			Increase (2)-(1)
		Release (1)	Usable Storage	Total Usable Storage (2)	
Flood Year	4,100	4,100	2,600	6,700	2,600
Normal	3,600	3,600	2,700	6,300	2,700
Dry Year	1,800	1,800	2,300	4,100	2,300

(Unit: MCM)

On an average for 20 years from 1974 to 1993, an increase of usable storage is evaluated at 2,420 MCM as presented in Table 4.1.

(3) Existing Operation Rule Curve and Increased Energy Output

Existing Operation Rule Curve

Possible amount of diversion water as evaluated in paragraph 4.3 is not always introduced into the reservoir since under existing situation the reservoir is controlled by the existing operation rule curve, especially by the upper rule curve during peak flood period. The study temporarily follows the existing rule curve for evaluation of suitable capacity of diversion channel. The operation rule curves of the Sirikit reservoir may be further studied and revised in the following detailed study phase.

To evaluate aforementioned diversion capacity in consideration of existing operation rule curve, a preliminary simulation study of the Sirikit reservoir operation was made employing the simple assumptions that, i) reservoir operation is simulated only during wet season because the amount and seasonal variation of the downstream water demand are still unknown and ii) release of water from the reservoir is initially fixed at a constant rate of 421.2 MCM/month or 650 cu.m/sec x 6 hours x 30 days, and iii) the release will be reduced to 75% of the initial rate when the July inflow lowered 1,000 MCM and reduced again to 56.25% when the total inflow during July and August falls lower than 1,800 MCM.

Various combinations of diversion capacity of Ing-Nan channel, such as 150, 175 and 200 cum/sec, with Kok-Ing capacity corresponding to 50 to 80% of Ing-Nan capacity were

Table 4.1 Case Study of Sirikit Reservoir Operation with Various Combination of Diversion Capacity

Ing-Nan Cap.	Kok-Ing Cap.	Carry-Over = 500MCM						Carry-Over = 1,000MCM						Carry-Over = 1,500MCM					
		Diversion		Usable Storage		Spill-age	Over URC	Diversion		Usable Storage		Spill-age	Over URC	Diversion		Usable Storage		Spill-age	Over URC
		Potent	Actual	Potent	Addit.			Potent	Actual	Potent	Addit.			Potent	Actual	Potent	Addit.		
150	75	1867	1803	5334	2238	0	0	1867	1741	5267	2171	26	1	1867	1631	5129	2033	459	2
	90	1956	1885	5414	2318	0	0	1956	1813	5336	2240	34	1	1956	1698	5193	2098	459	2
	105	2007	1930	5458	2362	0	0	2007	1852	5373	2278	37	1	2007	1735	5228	2132	459	2
	120	2030	1951	5477	2381	0	0	2030	1869	5389	2293	39	1	2030	1752	5243	2147	459	3
175	87	2071	1989	5520	2424	0	0	2071	1896	5416	2320	123	1	2071	1763	5258	2163	459	2
	105	2175	2077	5606	2510	0	0	2175	1970	5486	2391	133	1	2175	1838	5330	2235	459	3
	122	2230	2123	5649	2554	0	1	2230	2004	5517	2421	137	1	2230	1875	5365	2269	459	3
	140	2255	2142	5667	2572	0	1	2255	2018	5530	2434	140	1	2255	1889	5377	2281	459	3
200	100	2258	2137	5668	2573	0	0	2258	2026	5540	2444	210	1	2258	1880	5373	2277	459	4
	120	2367	2226	5753	2657	0	1	2367	2102	5610	2515	231	1	2367	1941	5430	2334	459	5
	140	2427	2271	5796	2700	0	1	2427	2148	5655	2559	237	2	2427	1974	5459	2364	459	5
	160	2450	2286	5810	2715	0	1	2450	2166	5671	2576	238	2	2450	2984	5468	2373	459	5

Note: (1) Carry-Over is the storage to be maintained at the end of dry season for unforeseen drought.
(2) Potential diversion is possible amount of diversion corresponding to capacity of diversion channel.
(3) Actual diversion is amount of water diverted after adjusted with the Sirikit storage.
(4) Potential usable storage is estimated at (November End Storage+Dry Season Inflow-Carryover).
(5) Additional usable storage is estimated at (Potential Usable Storage-Existing Water Use 3,095MCM).
(6) Spillage is the total amount of spillage during 20 years.
(7) Over URC means number of time when reservoir storage exceeds the upper rule curve.

put into the simulation. Table 4.1 summarizes all the simulated results, and Figure 4.4 presents variation of monthly storage in the reservoir simulated for the specified case with the diversion capacity of 175 and 125 cum/sec.

- No spillage and no exceeding of the upper rule curve would occur even in abnormal flood year of 1975 for every combination of diversion capacity, if the carry-over storage is taken at 500 MCM, however the storage exceeding the upper rule curve would occur when diversion capacity is taken larger than 175 x 125 cum/sec.
- Spillage of once in October 1975 would occur and, excluding 1975, the storage exceeding the upper curve would occur in September 1981 when carry-over storage is taken at 1,000 MCM.
- The storage exceeded the upper curve for two to five times within 20 years, when the carry-over was set at 1,500 MCM.

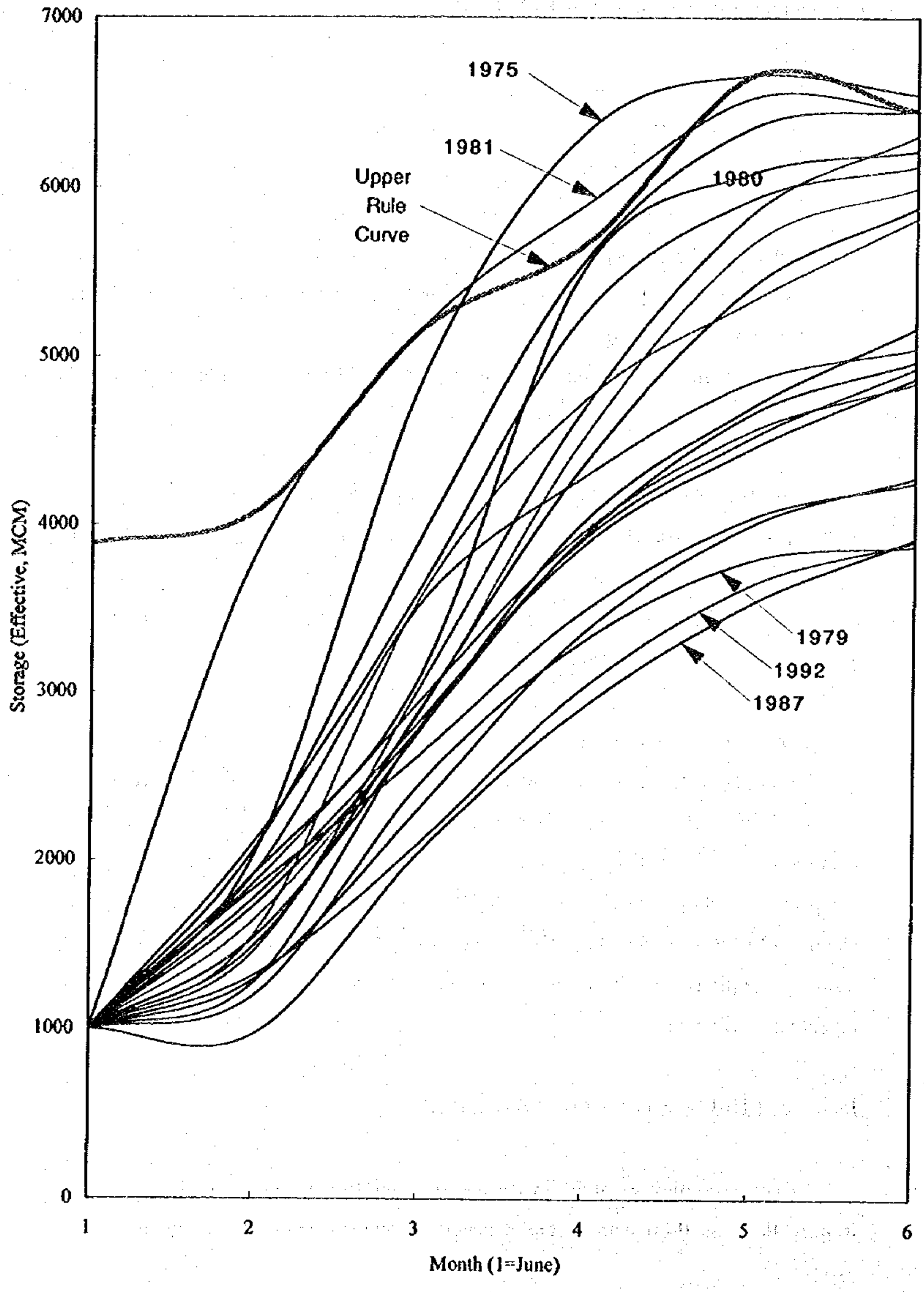
The 1981 flood was caused by the inflow of 4,370 MCM in July and August when the reservoir was so operated to release 1,070 MCM downstream in August, and the storage was controlled under the rule curve. This amount of release may cause downstream flood damage and therefore it may be judged unusual. For this reason the year 1981 can be eliminated from the evaluation study.

From the above point of view, the combination of diversion capacities, 175 cum/sec for the Ing-Nan diversion channel and 125 cum/sec for Kok-Ing channel, is evaluated reasonable when the carry-over storage is set around 1,000 MCM. With the 175 and 125 cum/sec capacities of diversion, as the long-term average for 20 years including dry years the project would produce about 5,520 MCM of usable storage as for dry season which is about 2,420 MCM greater than the existing usage together with a great increase of hydro-power generation since the reservoir storage or stage is maintained much higher than the present achievement.

<u>Increase of Hydropower Energy at Sirikit Dam</u>

Existing achievement of hydro-power generation is summarized in the Supporting Report. Based on these data, a rate of generated energy against storage volume was derived as;

Figure 4.4 Sirikit Operation (Kcapt=175, Kcapk=125)



Rate=2.8435E-03 x $Storage^{0.4708}$

The above equation was then put into the simulation study employing the following assumptions;

- Energy output was calculated in accordance with release of water for power generation together with averaged reservoir storage during the month, for recovery period from July to November, and

- For consumptive period from December to June, total volume of inflow was added to the simulated usable storage at the end of recovery period and then divided equally during the period to calculate energy output, because actual demand and its seasonal pattern are still unknown.

Comparison of Energy Output at Sirikit Dam (Unit: GWh)

	Present Condition			With Project Condition		
Month	Average	Maximum	Minimum	Average	Maximum	Minimum
April	98.50	165.28	17.77	127.6	163.1	83.7
May	76.18	152.81	13.15	119.8	151.3	79.7
June	54.06	142.64	3.99	113.3	140.7	77.2
July	62.54	117.13	1.98	49.6	67.6	43.7
August	75.57	202.96	3.44	48.4	79.1	34.8
September	58.86	150.34	8.14	53.9	84.5	38.3
October	47.86	137.51	5.92	57.5	88.7	40.7
November	63.32	123.73	10.37	59.1	89.1	42.3
December	42.40	103.61	7.00	154.5	202.5	98.0
January	53.62	102.18	22.78	148.5	193.7	95.1
February	81.80	127.95	24.09	141.6	184.4	91.5
March	106.13	176.45	36.39	134.1	174.3	87.6
Annual	820.85	1363.37	350.33	1,217.2	1,551.6	826.5

It should be noted here that the above calculation only presents possibility of increase of energy output at the Sirikit dam to about 1.5 times as much as the existing achievement, since computation is not based on practical release of water from the reservoir. Detailed study will be done during the feasibility study phase included in the study on optimum operation rule of the reservoir.

(4) Influence of Diversion on Flow Condition of Kok, Ing and Mekong River

(a) Influence on the Kok and Ing River

The proposed water diversion project with discharge capacity of 125 cum/sec and 175 cum/sec respectively for the Kok-Ing and Ing-Nan channel will divert 2,008 MCM of water from the Kok and Ing basins, of which 1,107 MCM (55%) are from the Kok river and 901 MCM (45%) from the Ing river inclusive of the Lao tributary. Flow condition of the Kok and Ing rivers before and after water diversion is tabulated in the Supporting Report.

Flow Condition before and after Water Diversion (Unit=MCM)

River	Existing Condition			Available for Diversion			Residual after Diversion		
	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total
Kok	2,944	851	3,795	2,248	358	2,606	1,211	288	1,499
Ing	1,588	145	1,733	1,011	41	1,052	116	36	152
Total	4,532	996	5,528	3,259	399	3,658	1,327	324	1,650

Note: Wet season from June to November and dry season from December to May.
Project diverts excess water in December.

Comparing with the existing flow condition, in wet season irrigation and other development within the basin will primarily utilize about 24% (696 MCM) of the Kok river water and some 35% (1,037 MCM) will be diverted transbasin to the Sirikit reservoir. On the contrary in dry season, irrigation and other development will use 58% (493 MCM) of Kok water and the proposed project will divert 8% (70 MCM) in December when the river still keep considerable amount of flow. During January to May, the project will not divert the Kok and Ing water at all.

As regards the Ing river including the Lao tributary, irrigation and other development within the basin will primarily utilize about 36% (577 MCM) of the Ing river water in wet season and by the proposed project 56% (895 MCM) will be diverted transbasin to the Sirikit reservoir. On the contrary in dry season, irrigation and other development will use 72% (104 MCM) of Ing water and the proposed project will divert 3% (6 MCM) in December.

(b) Influence on Mekong River

The proposed project intends to divert in total 2,008 MCM of water mainly from excess runoff of the Kok and Ing rivers in wet season from June to November, including 76 MCM of diversion in December when both rivers still maintain considerable amount of flow.

Influence of Water Diversion on Mekong River

Period of Year	Proposed Water Diversion (1)	Mekong River			
		At Chieng Saen		At Chiang Khan	
		Runoff (2)	Rate (1)/(2)	Runoff (3)	Rate (1)/(3)
June to November	1,932	62,850	3.1%	105,435	1.8%
December	76	4,023	1.9%	6,647	1.1%
January to May	0	13,880	-	17,288	-
Total	2,008	80,753	2.5%	129,370	1.6%

(Unit: MCM)

From the above table, the proposed amount of water diversion shares 3.1% of original flow of Mekong river at Chieng Saen during June to November, 1.9% in December and 2.5% as an annual total value. The proposed figures are also compared with Mekong's flow condition at Chiang Khan, showing 1.8% during June to November, 1.1% in December and 1.6% as an annual total. Since the Mekong river flows deep mountainous area in Laos and there are almost no existing or proposed water resources development in the area between Chieng Saen and Chiang Khan, it may be no objection to conclude that the proposed project would exert influence on the flow condition of Mekong river as small as less than 2%.

(5) Availability and Method of Water Diversion in Dry Season

(a) Available Diversion Water in Dry Season

Judging from the residual flows after projected water diversion as compiled in the Supporting Report, there are almost no excess water in the Ing river especially in dry season, however, the Kok river still keep some excess water throughout a year which can be additionally utilized for agricultural and other development within the basin.

Summary on Residual Flow in Kok and Ing River

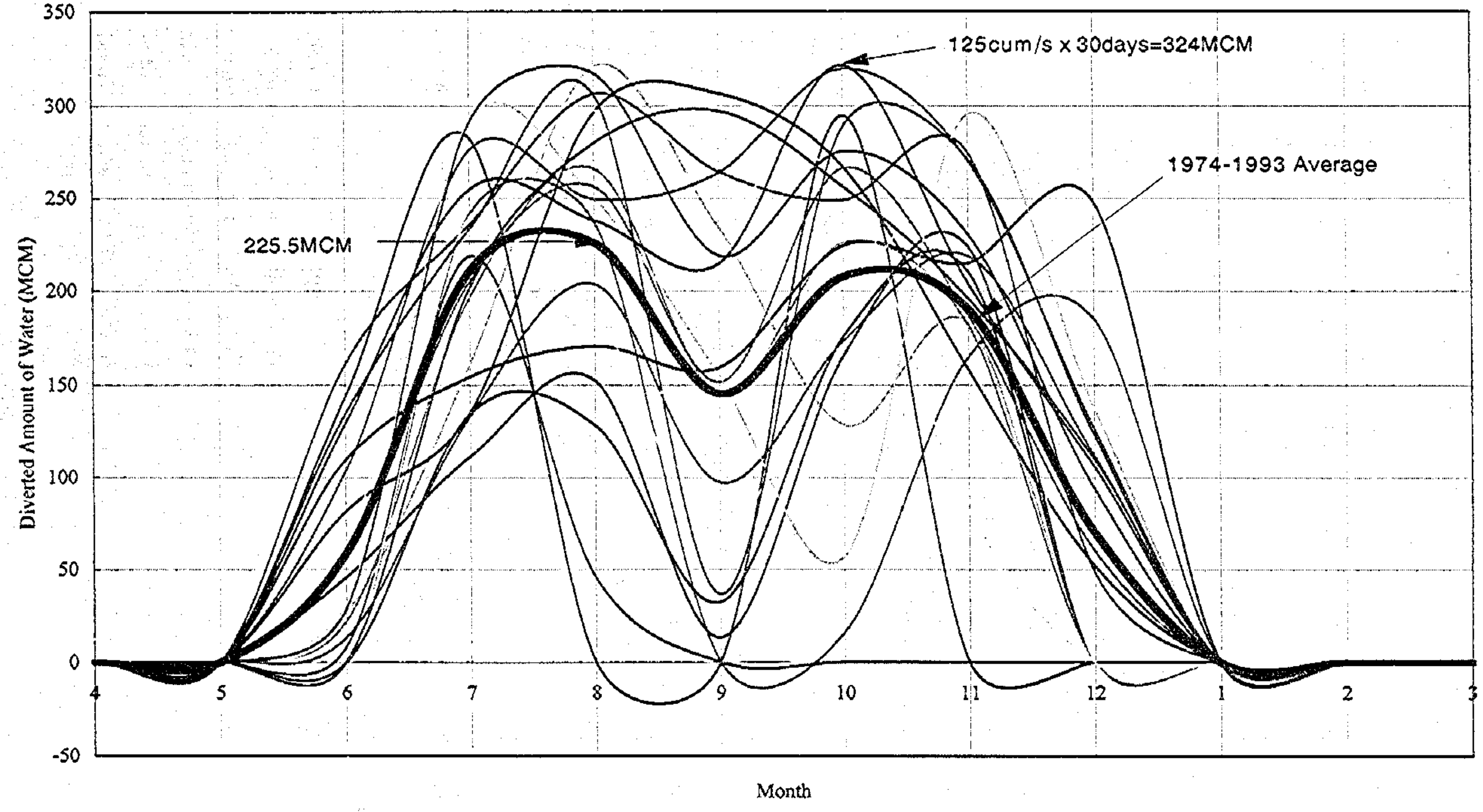
	Kok River	Ing River	Total
Wet Season	1,210	290	1,500
Dry Season	115	35	150
Total	1,325	325	1,650

(Unit: MCM)

(b) Method to Utilize Excess Flow in Dry Season

The above excess flow, however, fluctuates from time to time, and therefore can not be effectively used unless once stored and controlled. The method to utilize excess discharges in the river is to store them in the existing storage facilities such as small scale and medium scale reservoirs and/or swamps (i.e. Nong Luang Swamp) through the diversion channel and by distributing feeder canal to connect them. It is also possible to divert more excess water and distribute them into existing storage facilities through the Kok-Ing diversion channel in wet season, because the Kok-Ing diversion channel has a space to carry additional water for this purpose, except a quite limited period of peak flow as is seen in Figure 4.5.

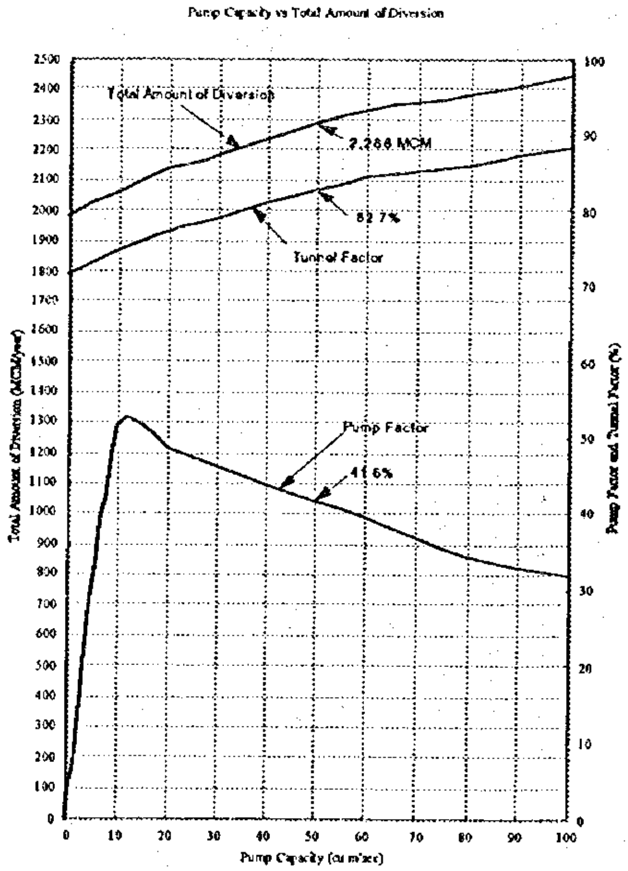
Figure 4.5 Projected Water Diversion from Kok River



4.5 Possibility of Pumping Water Diversion from Lower Ing River

According to the analyses made for selection of a suitable capacity of the diversion channel, the average annual volume of water to be diverted from the Kok and Ing rivers and to be conveyed through the channel is estimated at 2,010 MCM, showing a much smaller value when compared with its full capacity of 2,770 MCM (175 cu.m/sec x 183 days in wet season). This is due to the fact that the flows in the river system in June, July and November varying from 40 cu.m/sec to 110 cu.m/sec are more or less smaller than the channel capacity, resulting that there are considerable empty spaces in the diversion channel.

Along the Ing river downstream of the proposed Ing diversion damsite, there are numbers of large and small tributaries, represented by the Nam Hong Khua and Nam Mae Tak, flowing into the Ing river supplying a plenty of excess flow especially during wet season. In addition, the river water level is used to reach 345 m to 350 m, MSL around the Ing river mouth affected by water level in the Mekong river. Such hydrological and hydraulic condition allows the Ing river water level to reach 360 m, MSL at the Ban Nam Ing, located at the confluence of the Nam Mae Tak with the Ing river about 20 km downstream of the Ing diversion dam. It is considered to be possible and easy to divert excess flows from the lower Ing river into the proposed diversion channel in order to fill the empty capacity and to increase the total volume of diversion, if a rubber dam is constructed and a pumping station is installed at this point.



A preliminary study was undertaken to set up a suitable pumping capacity as shown in the figure. The study showed that the pumping capacity of 50 cum.m/sec would be suitable, indicating a pumping factor of 41.6%, tunnel factor of 82.7% and the total amount of diversion into the Sirikit reservoir would be about 2,300 MCM/year meaning that about 320 MCM of water could be diverted from the lower Ing basin.

In the above explanation, the pumping factor is defined in terms of a rate of the total volume of water to be pumped up against the full capacity of pumping for 24 hours during the concerning period from June to November, a tunnel factor is a rate of volume of water to be conducted through the diversion tunnel against the full capacity of 2,770 MCM, and the total amount of diversion is defined as the total volume of water come from the Kok and Ing rivers supplemented with water pumped up from the lower Ing river.

Furthermore, the additional water of some 200 MCM might be available for this pumping operation since there are sufficient volume of water available in the lower Ing river basin.

The construction cost of the said pumping station and rubber dam would be some 1,200 million Bahts, producing a water cost of 2.4 Bahts per cubic meter (1,200 million Bahts divided by 500 MCM), which would be considered to be feasible. More details are given in the following table;

Pumping Capacity, Pump Factor, Tunnel Factor and Total Diversion

Pumping Capacity (cu.m/sec)	Pump Factor (%)	Tunnel Factor (%)	Total Amount of Diversion (MCM/year)	Diversion by Pump (MCM/year)
0	0.0	71.6	1,980	0
10	51.3	74.5	2,062	80
20	48.8	77.2	2,135	152
30	46.3	78.7	2,178	216
40	43.9	80.8	2,236	273
50	41.6	82.7	2,288	323
60	39.6	84.4	2,334	370
70	36.9	85.3	2,360	402
80	34.4	86.0	2,379	428
90	33.0	87.2	2,412	462
100	31.6	88.3	2,443	491

Note: Water diversion in December is excluded from computation.

Some additional studies were further progressed on the operation of the Sirikit reservoir, on the premise of the above pumping diversion plan. In the actual practice of irrigation in the Phitsanulok and Chao Phraya delta areas in dry season, cropping area is restricted in accordance with the available storage in the Bhumibol and Sirikit reservoirs. In the simulation of the Sirikit reservoir operation, assumptions were made as follows;

Storage of Sirikit Reservoir at Wet Season End and Delta Planted Area

Storage of Sirikit Reservoir at End of November (Active Storage in MCM)	Release of Reservoir Storage for the Successive Dry Season (MCM)
Less than 3,000 MCM	3,000 (50% of potential)
3,000 to 4,000 MCM	3,600 (60% of potential)
4,000 to 5,000 MCM	4,200 (70% of potential)
5,000 to 6,000 MCM	5,100 (85% of potential)
More than 6,000 MCM	6,300 (105% of potential)

The study shows that about 5,370 MCM of water, about twice as large compared to the existing outflow of 2,700 MCM, can be expected in dry season released from the Sirikit reservoir if a pumping station is installed at the lower reach of the Ing river with a capacity of 50 cum/sec. The results of simulation study are summarized as follows, with more details given in the Supporting Report.

Operation of Sirikit Reservoir with and without Pumping Diversion
(Diversion Channel Capacity = 125 cu.m/sec x 175 cu.m/sec)

Pump Capacity (cu.m/sec)	Amount of Diversion (MCM)			Reservoir Outflow (MCM)		
	From Kok and Ing	From Pump	Total	Wet Season	Dry Season	Total
None	2,076	0	2,076	1,895	5,010	6,905
50.0	2,076	329	2,405	1,895	5,370	7,265
100.0	2,076	499	2,575	1,895	5,505	7,400

4.6 Possibility for Water Diversion Plan by Kok Hydropower Dam

(1) Background

Italian Thai Development Public company Limited (ITD) is going to construct the Kok hydropower dam at the upstream of the Kok river in Myanmar territory by BOT manner (Built, Operation and Transfer). In accordance with the information given by ITD, he has negotiated with the Ministry of Energy in Myanmar to construct the hydropower dam and obtained a tentative approval by the Myanmar Government. ITD also has negotiated with PEA and EGAT of the Thai Government to use the power energy generated by the Kok dam for electrical consumption in Thailand, while he is asking the RID what will be the influence of the Kok dam on the downstream agricultural area.

This hydropower dam plan was originally formulated by the Electric Power Development Company (E.P.D.C), Japan under the technical assistance to EGAT in 1992 and has a high possibility for implementation from technical and economic aspect, so that the JICA Team has collected relevant data and carried out the following preliminary study.

(2) Outline of Project

- Damsite Location, Kok upstream in Myanmar territory 3 km far from the border of Thailand
- Reservoir Dimension

Drainage Area at Damsite	2,980 km^2
Annual Inflow	2,230 MCM
Full Water Level	570 m, MSL
Low Water Level	550 m, MSL
Gross Storage Capacity	4,650 MCM
Effective Storage Capacity	1,650 MCM

- Dam Dimension

Type	Concrete Dam
Crest Elevation	575 m
River Bed Elevation	450 m

	Dam Height	125 m
-	Hydropower Outline	
	Maximum Outflow	300 m³/sec
	Effective Power Head	112 m
	Installed Power Capacity	290 MW
	Annual Energy Production	637 GWh

The annual average runoff of 2,200 MCM consisting of 200 to 400 MCM/month in wet season and 50 to 100 MCM/month in dry season will be completely controlled with the Kok reservoir with the large effective capacity of 1,650 MCM. The reservoir operation will be set up as follows ;

- Out of average annual runoff of 2,200 MCM, the wet and dry season runoffs are 1,700 MCM and 500 MCM respectively.
- Out of 1,700 MCM in wet season runoff, 900 MCM will be used for the hydropower in wet season without storage and the remained 800 MCM will be stored in the reservoir and be used for the dry season.
- Accordingly, the dry season outflow at the dam will reach as much as 1,300 MCM combining the dry season natural runoff of 500 MCM and the retained water of 800 MCM.
- Annual runoff has generally a large annual fluctuation as showing 3,000 MCM in wet year and 1,300 MCM in dry year. Therefore, the carry-over capacity of 600 to 700 MCM will be required at the reservoir to cover the less reservoir inflow in dry year. Namely, the capacity of 1,000 MCM out of the effective capacity of 1,650 MCM would be used for actual reservoir operation in the normal year.

(3) Utilization of Controlled Outflow in the Kok Dam

Runoff at the Kok diversion damsite will be changed as follows by the controlled outflow from the Kok dam, as a result, the water to be diverted at the Kok diversion dam will be considerably increased.

Items	Total	Wet Season			Dry Season		
		6-7	8-9	10-11	12-1	2-3	4-5
Present Runoff at Diversion Dam	3,800	610	1,450	880	420	220	220
Side Flow excluding Kok Water	1,600	260	600	370	180	90	100
Outflow from Kok Dam	2,200	300	300	300	430	440	430
Changed Runoff at Diversion Dam	3,800	560	900	670	610	530	530
Discharge for Total Runoff (m^3/sec)	120	106	170	127	114	104	101
Discharge for Kok Outflow (m^3/sec)	70	57	57	57	82	86	82

As is clear in the above table, the runoff at the Kok diversion dam after the construction of Kok dam is mostly controlled and the average discharge is 100 to 120 m^3/sec through the year except the discharge of 170 cum./sec in August and September which is the flood months.

Accordingly the diversion water could be easily taken at the diversion damsite as increased as follows;

June to July	120 m3/sec x 86,400 sec x 61 days x 70% =	440	MCM
August to September	125 m3/sec x 86,400 sec x 61 days x 90% =	590	MCM
October to November	125 m3/sec x 86,400 sec x 61 days x 70% =	460	MCM
Wet Season Subtotal		1,490	MCM
December to January	110 m3/sec x 86,400 x 61 days x 70% =	410	MCM
February to March	100 m3/sec x 86,400 x 59 days x 70% =	360	MCM
April to May	100 m3/sec x 86,400 x 61 days x 70% =	370	MCM
Dry Season Subtotal		1,140	MCM
Annual Total		2,630	MCM

The diversion water at the Kok diversion damsite will reach at about 1,500 MCM in wet season which increases about 400 MCM as compared with the case of 1,100 MCM without Kok hydropower dam, while the 1,140 MCM could be additionally diverted in dry season to Sirikit dam. The above increased additional water will be used as follows ;

- 400 MCM in wet season will be controlled at Sirikit dam and used for dry season irrigation in the Chao Phraya basin.
- Out of 1,100 MCM in dry season, 300 MCM will be used for irrigation in the Kok and Ing basin and the remained 800 MCM for irrigation in the Chao Phraya basin through Sirikit dam.
- As a result, available dry season water in total in the Chao Phraya basin reaches at

3,200 MCM.

Effect of Mae Kok Hydro-Power Dam

	Volume of Water Diversion (MCM)
Original plan without Kok dam Increased Water through storage Increased Water without storage	2,000 400 800
Total	3,200

4.7 Water Use Plan

The beneficial areas of about 2,400 MCM of additional usable dry season water from the proposed Kok-Ing-Nan water diversion project are irrigable areas of either existing or newly developed located in the lower Nan basin downstream of the Sirikit reservoir and/or the Chao Phraya delta area. Provision of water to irrigable areas in other river basins or tributary sub-basins under gravity is not possible, and therefore the following dry season water allocation plans are proposed.

(1) Municipal and Industrial Water Supply

The annual demand increments of municipal and industrial water supply to the Bangkok Metropolitan area, satellite cities, industrial zones, provincial capitals along the Nan river such as Phitsanulok, Uttaradit and Phichit are estimated at 1,240 MCM, of which 50% or 600 MCM accounts for water demand in dry season.

Out of 1,700 MCM of outflow from the Sirikit reservoir during wet season, 600 MCM is allocated to municipal and industrial purposes after utilized for power generation. The remaining 1,100 MCM together with about 4,600 MCM of side flow from the catchment is used for supplemental irrigation as well as domestic purpose in the areas downstream of the reservoir. In this connection, it is preferable to control the Sirikit outflow in wet season by allocating more water in the early and late period while less water during August and September when side flows are abundant. The priority is to be given in dry season to allocate 600 MCM of water for water supply from additionally available water of 2,400 MCM taking into account the critical situation of supply and demand of water as well as the special importance of urban and industrial development in the delta area. More detailed study will be done regarding allocation of water in the course of the feasibility study.

(2) Irrigation Water Supply

The remaining water of 1,780 MCM per annum (2,400 MCM minus 620 MCM) is usable to upgrade irrigation conditions in the lower Nan and Chao Phraya delta basins. The preliminary water allocation plans to these irrigable areas are proposed as in the following, however, this tentative plans would require more detailed study during the course of the feasibility study.

(a) Water Use Plans A and B

For effective utilization of land resources and due to restriction from limited water resources, the existing agricultural policy in Thailand intends to shift the dry season crops from paddy which consumes much water to upland crops including orchard and vegetables. Actually in the field, production of these crops other than rice, livestock and inland fishery has been increasing supported by the change or diversification of diet and promotion of export of agricultural product.

In the existing Phitsanulok project area of 108,000 ha and Chao Phraya delta area of 1,190,000 ha, the cropping intensity in dry season is limited to less than 30% due to shortage of irrigation water. In order to improve the current situation in these irrigation areas, the proposed project aims at increasing dry season irrigation for upland crops other than paddy, such as maize, soybean, sugarcane, fruit trees and vegetables together with the promotion of fishery.

In both irrigation areas, there is no need for additional investment of irrigation system development since the irrigation facilities have already been completed, irrigation technology of beneficial farmers is quite high, water users' association and agricultural cooperatives have already established, and therefore high productivity can be expected by use of additional water provided by the proposed project.

The water use plan A to irrigate dry season crops entirely excluding paddy and plan B to irrigate dry season crops including paddy are proposed in these irrigation areas. As shown in Tables 4.2 and 4.3, in total 270,000 ha with a dry season cropping intensity of 27% under the plan A and 224,000 ha with a dry season intensity of 17% under the plan B can be irrigated by the water of about 1,800 MCM introduced by the proposed project.

Table 4.2 Water Use Plan A
(For Existing Irrigation Area without Dry Season Paddy)

Crops	Unit Irrigation Demand (m^3/ha)	Phitsanulok Area		Delta Area		Total	
		Area (ha)	Water Demand (MCM)	Area (ha)	Water Demand (MCM)	Area (ha)	Water Demand (MCM)
Dry Maize	4,000	6,000	24.0	64,000	256.0	70,000	280.0
Dry Soybean	5,000	5,100	25.5	54,900	274.5	60,000	300.0
Dry Peanut	4,000	1,700	6.8	18,300	73.2	20,000	80.0
Sugarcane	7,000	3,400	23.8	36,600	256.2	40,000	280.0
Orchard	11,000	3,400	37.4	36,600	402.6	40,000	440.0
Vegetable	6,000	900	5.4	9,100	54.6	10,000	60.0
Fishery	12,000	2,600	31.2	27,400	328.8	30,000	360.0
Total		23,100	154.1	246,900	1,645.9	270,000	1,800.0

Table 4.3 Water Use Plan B
(For Existing Irrigation Area with Dry Season Paddy)

Crops	Unit Irrigation Demand (m^3/ha)	Phitsanulok Area		Delta Area		Total	
		Area (ha)	Water Demand (MCM)	Area (ha)	Water Demand (MCM)	Area (ha)	Water Demand (MCM)
Dry Paddy	10,000	6,000	60.0	85,000	850.0	91,000	910.0
Dry Maize	4,000	3,000	12.0	32,000	128.0	35,000	140.0
Dry Soybean	5,000	3,000	15.0	27,000	135.0	30,000	150.0
Dry Peanut	4,000	-	-	9,000	36.0	9,000	36.0
Sugarcane	7,000	2,000	14.0	18,000	126.0	20,000	140.0
Orchard	11,000	2,000	22.0	18,000	198.0	20,000	220.0
Vegetable	6,000	-	-	4,000	24.0	4,000	24.0
Fishery	12,000	1,000	12.0	14,000	168.0	15,000	180.0
Total		17,000	135.0	207,000	1,665.0	224,000	1,800.0

Note: Irrigable areas in Phitsanulok and delta areas are 108,000 ha and 1,190,000 ha respectively. Accordingly the increasing cropping intensity in dry season is 22% under the plan A and 17% under the plan B because of higher water consumption of dry season paddy.

(b) Water Use Plan C

The irrigated agricultural development of the Phitsanulok Stage II area extending over the left bank of the Nan river with the potential area of 120,000 ha has been suspended due to lack of the Nan river water as well as lack of the Sirikit outflow during dry season. An alternative plan C of water allocation to this area is also proposed in order to expect promotion of agricultural productivity in the area which would in turn redress deteriorating balance of income between both banks of the Nan river. By constructing the irrigation canal system in the service area to link with the existing Naresuan barrage, irrigation waters can be distributed easily with smaller investment and the beneficial land is converted from rainfed situation to irrigable farmland. The supplemental water for wet season paddy can also be distributed providing large benefits. Surplus water after irrigating the newly developed area is used in the existing irrigation areas, providing waters to 335,000 ha of irrigable area as shown in Table 4.4.

Table 4.4 Water Use Plan C
(For Existing and New Irrigation Area with Dry and Wet Season Paddy)

Crops	Unit Irrigation Demand (m^3/ha)	Phitsanulok Existing Area		Pitsanulok Newly Developed		Chao Phraya Delta Existing Area		Total	
		Area (ha)	Water Demand (MCM)	Area (ha)	Water Demand (MCM)	Area (ha)	Water Demand (MCM)	Area (ha)	Water Demand (MCM)
Wet Paddy	2,000	-	-	120,000	240	-	-	120,000	240
Dry Paddy	10,000	-	-	12,000	120	25,000	250	37,000	370
Dry Maize	4,000	3,000	12	4,000	16	39,000	156	46,000	184
Dry Soybean	5,000	3,000	15	3,000	15	33,000	165	39,000	195
Dry Peanut	4,000	1,000	4	1,000	4	11,000	44	13,000	52
Sugarcane	7,000	2,000	14	2,000	14	22,000	154	26,000	182
Orchard	11,000	2,000	22	2,000	22	22,000	242	26,000	286
Vegetable	6,000	1,000	6	1,000	6	6,000	36	8,000	48
Fishery	12,000	1,000	12	2,000	24	17,000	204	20,000	240
Total		13,000	85	147,000	461	175,000	1,251	335,000	1,797

(3) Water Use Plan for Hydro-Power Generation

As the byproduct of water release from the Sirikit reservoir for irrigation and other uses in the lower Nan basin and Chao Phraya delta area, present achievement of energy production of 820 GWh at the Sirikit plant will increase to about 1,200 GWh after implementation of the proposed Kok-Ing-Nan water diversion project.

(4) Water Allocation Plan in the Kok and Ing Basin

There is considerable amount of flow in the Kok river even in dry season although no or less flow in Ing river.

Flow Condition of Kok River in Dry Season

	December	January	February	March	April	May	Total
Ordinary Flow in MCM	241	179	118	97	86	130	851
Ordinary Flow in cu.m/s	90	67	49	36	36	49	54
Drought Flow in MCM	90	60	35	20	20	25	255
Drought Flow in cu.m/s	34	22	14	7	8	9	16

There are about 100,000 ha of bulk and fertile farmland in the Ing basin and are utilized for paddy cultivation in wet season under rainfed condition. In the basin in dry season, however, rainfall and runoff of the Ing river is small making the area quite dry. The strong desire of the resident peoples to the proposed Kok-Ing-Nan water diversion project is to stabilize the irrigated agriculture and inland fishery in the area by means of diverting and introducing the Kok river water especially in dry season. It can be evaluated from the above Kok river flow that about 30,000 to 50,000 ha in ordinary years and 10,000 to 15,000 ha in dry years can be irrigated by the Kok water in dry season. It is also judged that at least 30,000 ha of dry season irrigation is possible by the Kok water when the existing and proposed reservoirs in the Ing basin are combined with water to be diverted from the Kok river. The study tentatively proposes the following cropping plan in the Ing basin;

Proposed Cropping Plan in the Ing Basin by Use of Kok Water

Crops	Area (ha)	Unit Water Requirement (m^3/ha)	Total Water Demand (MCM)
Maize	10,000	4,000	40
Soybean	6,000	5,000	30
Peanut	6,000	4,000	24
Orchard	6,000	11,000	66
Vegetable	2,000	6,000	12
Fishery	2,000	12,000	24
Total	32,000	-	196