The average population density in the project area is 150 persons per km^2. Average size of farm household is 5.5 persons. Farm labor force is about 3 persons per household on an average.

4.9.2 Land tenure and land holding

The percentages of owner farmer, partial tenant and tenant (rented) are 77%, 7% and 16% of the total farm household, respectively. Average size of farm is 28.7 rai (4.6 ha). The land holding by farm size in the project area is as follows:

Land Holding Size (rai)	Number of Farm Household	% of Farm Household	Area of Holding (ha)	% of Area
Less than 2	40	0.4	-	-
3 to 10	1,028	10.1	608	1.3
11 to 20	1,586	15.6	2,521	5.4
21 to 30	1,932	19.0	5,371	11.5
31 to 50	2,766	27.2	12,282	26.3
51 to 80	1,475	14.5	9,901	21.2
More than 80	1,338	13.2	16,071	34.3
Total	10,165	100.0	46,700	100.0

Source: 1978 Agricultural Census

4.9.3 Present land use

The total area of the Mae Wong river basin is about 1.36 million rai (2,171 km^2), of which permanent agricultural land holdings account for 0.44 million rai (710 km^2) or about 33% of the total area. The rest of 0.92 million rai (1,461 km^2) comprises mountains, steep slopes, forest reserve, river and swamps, roads and public compounds. The present agricultural land use of the Mae Wong river basin is as follows:

(Unit: km^2)

Agricultural Land			Non-agricultural Land	Total
Paddy	Upland	Orchard & Others		
520 (24.0%)	170 (7.8%)	20 (0.9%)	1,461 (67.3%)	2,171 (100.0%)

Source: 1978 Agricultural Census

The prospective irrigation area envisaged under the project has been delineated within semi-recent alluvium and low terraces where major land use is paddy field. The gross delineated area is about 309,400 rai (49,500 ha). The present land use of the area is as follows:

(Unit: rai)

Paddy Field	Upland Field	Scrub & Forest	Villages & Others	Total
278,800 (44,600 ha)	13,100 (2,100 ha)	4,400 (700 ha)	13,100 (2,100 ha)	309,400 (49,500 ha)

Source: RID land use survey, 1985

The irrigation area will be selected within the above area, excluding scrub/forest and villages compounds. The maximum potential area for irrigation development will therefore be 291,900 rai (46,700 ha).

Irrigation facilities are well developed in this area. About 230,000 rai (36,800 ha) or 83% of the existing paddy fields, are more or less presently provided with irrigation facilities, while all of the upland crop fields are rainfed. Even though irrigation facilities are provided, all these paddy fields are not always actually irrigated due to limited availability of water.

Difficulties are involved in estimating the extent of well irrigated paddy field, because the area well-irrigated largely fluctuates year by year depending upon seasonal water availability. Water balance study on existing condition indicates that about 137,500 rai (22,000 ha) of the paddy fields are irrigated in the rainy season under normal condition with 80% probability rainfall. Field observations confirm that the study result reflects well the actual irrigated condition in the area; i.e. The potential irrigation area under the project is classified:

Land Use	Area		
	rai	ha	%
Paddy Field with Irrigation Facilities			
(1) Irrigated (partly double cropping)	137,500	22,000	47.1
(2) Semi-irrigated (mostly single cropping)	92,500	14,800	31.7
Sub-total	230,000	36,800	78.8
Rainfed Paddy Field	48,800	7,800	16.7
Rainfed Upland	13,100	2,100	4.5
Total	291,900	46,700	100.0

The present land use map is shown on Fig. 4.9.1.

4.9.4 Present cropping pattern

The irrigated paddy field where some double cropping is carried out, mainly extends along the upstream of the Mae Wong river. In these areas, paddy is planted from mid-June and harvested in November - December. Local varieties of paddy like Luang Pra Tarn and Kao Dawk Mali are planted on about 60% of the area; the rest is planted with high yieldig varieties (H.Y.V.) like RD 7 and RD 21. Dry season cropping usually starts immediately after harvesting of rainy season paddy. The extent of dry season cropping is around 20% of the area. Major crops in the dry season are mung beans (15%) and paddy (5%).

The mung beans are usually planted immediately after harvest of paddy. In most cases, mung beans are grown under rainfed condition due to lack of irrigation water.

The paddy field where irrigated single paddy cropping is almost practiced with partial supply of irrigation water, is observed on the downstream areas of each existing irrigation block. In these area, only rainy season paddy is cultivated on almost 100% of the paddy field. Planted area, however, largely fluctuates year by year. Local varieties are predominantly used for about 75% of the area. Paddy is usually planted from early July and harvested in December - January.

Upland crop area extends mainly on middle and high terraces. In the rainy season, maize is the major crop. About 40% of the upland crop fields are utilized for second cropping, depending on the rainfall in September/October. Major second crop is mung beans.

The present cropping pattern is shown on Fig. 4.9.2.

4.9.5 Present farming practices

The farming practices in the Mae Wong river basin are still conventional.

Land preparation: A combination of tractor power (8 ps class two wheel hand tractor) and animal draft is used. About 90% of paddy field are cultivated by hand tractors and 10% by buffaloes. Before land preparation, previous season's paddy stubble is burned in the dry months of March - April, and the field is ploughed using light showers of rain, or taking the irrigation water into the field where water is available, to moisten the soil, in May - June. A second harrowing is common.

Nursery/Transplanting: Nursery establishment is made in June - July and transplanting of 3 - 4 week old seedings is in July - August. In the Mae Wong river basin, the transplanted rice is predominant. Most of the rice grown in the area is non-glutionous. Transplanting is usually made by manual labour.

Crop management: Weed control is generally made by hand. Investment for weeding is however, generally low and present condition of weed control is unsatisfactory. Use of fertilizers is generally limited. The farmers use about 30 kg of fertilizer per hectare on an average. Types of fertilizer used are Ammonium Sulphate and Ammophos (16-20-0).

Chemical control of pest and diseases is not common. There is no farmer's institutions responsible for collective irrigation water distribution. Farmers take water at discretion from rivers/canals as they require if water is available.

Harvesting: The rainy season paddy is harvested in November/December. Harvesting is carried out manually with sickle knives. Threshing is usually made by tractor or under the feet of buffaloes. Winnowing is effected manually. The rice is thereafter bagged and transported, either for storage or for sale.

4.9.6 Crop yield and production

Crop production in the prospective irrigation area of 46,700 ha is roughly estimated, by multiplying the estimated crop areas and unit yield data given by the Agricultural Extension Office at Lat Yao, as follows:

Crops	Cultivated Area		Unit Yield		Production
	rai	ha	kg/rai	ton/ha	(ton)
Wet season paddy					
- Irrigated	137,500	22,000	450	2.8	61,600
- Semi-irrigated	92,500	14,800	250	1.6	23,100
- Rainfed	48,800	7,800	200	1.3	9,800
Dry season paddy	6,900	1,100	560	3.5	3,900
Mung beans (paddy)	20,600	3,300	100	0.6	2,000
Mung beans (upland)	5,000	800	80	0.5	400
Maize (upland)	13,100	2,100	350	2.2	4,600

4.9.7 Livestock

Various kinds of livestock; i.e., buffaloes, cattle, swine, goat, chicken and duck, are raised individually in the Mae Wong river basin. Buffaloes still play an important role in land preparation. Others are not economically significant in present farm economy.

4.9.8 Crop marketing and processing

(1) Agricultural marketing system

The marketing system is, in principle, of free trade. Agricultural institutional organization such as agricultural cooperative has not been well worked mainly due to shortage of their capital, facilities and staff. Private agents, therefore, have a very important role in the agricultural marketing system. The markets for agricultural produces may be divided into three types; local, provincial and terminal (Bangkok) markets. These are well networked. Details of the marketing system are described in ANNEX-VIII.

(2) Marketing situation in the project area

In the project area, most villages are accessible by road. Merchants can visit almost all villages by truck. The market is therefore quite competitive, with a smaller range of price variation. The pricing of agricultural produce is generally made based on its Bangkok price, deducting transportation costs and a profit margin.

According to the socio-economic survey conducted by the Economic Branch of RID in 1985, the percentages of crop production sold to local merchants (including rice millers) in the project area are estimated as follows:

	Percentage of Crop Production Sold	Average Price (Baht/kg)
Wet season		
Paddy	72.6	2.80
Maize	99.9	2.09
Mung beans	99.4	7.12
Dry season		
Mung beans	97.1	7.63

(3) Current price of major crops

Farm gate prices of major crops produced in the project area are as follows:

(Unit: Baht/ton)

	1982	1983
Rice (5% broken)	2,957	2,868
Mung beans (Ordinary grade)	6,950	7,310
Maize	2,120	2,660

Source: Office of Agricultural Economic, MOAC

Farm gate prices of rice and maize are recently rather stagnent with declining trend from the last peak in 1980. On the other hand, trend of mung bean price is gradually increasing with considerable fluctuation.

(4) Processing

The total number of rice mills in the project area amounts to about 130. The milling capacity is estimated at about 1,200 tons per day and this is considered to be sufficient for the present output and to have a plenty of reserve capacity for the incremental paddy in future.

4.9.9 Farmer's economy

In order to grasp economic activities of farmers in the project area, the socio-economic survey was conducted by RID for 180 farmers. Farmer's economy is studied preparing on the basis of the socio-economic survey. The study is made by the representative farm budgets for three farm size classes, small farm (S) less than 20 rai, medium farm (M) from 21 to 50 rai and large farm (L) more than 51 rai both in the irrigated area and non-irrigated area.

The results of analysis are summarized as follows:

(Unit: 10^3 Baht)

	Irrigated Area			Non-irrigated Area		
	S	M	L	S	M	L
Planted Area						
- Paddy (ha)	1.2	4.5	12.0	1.2	3.5	9.5
- Mung beans (ha)	-	0.4	1.0	-	-	-
- Maize (ha)	-	-	-	-	1.0	2.5
Cash Income (A)	20.2	40.0	95.4	12.1	29.2	63.3
Farm Income	12.4	32.4	86.8	7.0	24.2	56.4
- Paddy	10.0	30.0	79.8	6.9	18.4	44.9
- Others	2.3	2.4	7.0	0.1	5.8	11.5
Off-farm Income	7.8	7.6	6.6	5.1	5.0	6.9
Expenditure (B)	16.1	22.3	41.0	13.7	19.5	34.3
- Farm expenses*	2.7	7.8	41.0	13.7	19.5	34.3
- Living expenses	13.4	14.5	19.7	11.6	12.2	17.3
Balance (A - B)	4.1	17.7	54.4	-1.6	9.7	29.0

Note: *: Excluding farm family labour cost.

The above table indicates that:

(a) About 70% to 80% of net income is derived from farm operation and remaining 20% to 30% consists of off/non-farm income.

(b) Most of farm income are derived from paddy production in irrigated area, but in non-irrigated area, importance of upland crops production is high.

4.10 Agricultural Support System

4.10.1 Outline of governmental organization and activities

Agricultural and rural development services are mainly provided by Ministry of Agriculture and Agricultural cooperatives, Ministry of the Interior and Office of Prime Minister. The activities of these Ministries are described in ANNEX-VIII.

4.10.2 Agricultural extension

The Ministry of Agriculture and Cooperatives (MOAC) consists of nine major departments, one of which is the Department of Agricultural Extension (DAE). The DAE is primarily responsible for providing extension services for most agricultural crops to farmers.

The extension services of DAE are currently being expanded and strengthened through a country-wide program which has been made in two phases; National Agricultural Extension Projects I and II (NAEP I and II) with technical and financial assistance from IBRD. These projects have provided one extension agent for every 1,000 farmers at the sub-district level. Under the project program, the sub-district extension agents follow the training and visit system (T and V system), in which the agents visit each village in respective sub-district at least once every two weeks and attend bi-weekly training sessions given by the district agricultural officers and subject matter specialists (SMS) from the provincial office on a variety of topics relating to their services.

The Nakhon Sawan province has been covered in NEAP-I, and the number of agricultural extension staff has been increased remarkably, together with other improvement measures on the agricultural extension services, under the NEAP-I.

4.10.3 Agricultural research

Agricultural research is mostly carried out by the Department of Agriculture (DOA).

In general, rice research has been concentrated on breeding, agronomic practice, and foundation seed production. In the field crops research, improved agronomic practices and plant breeding are emphasized to increase the unit yields of economic field crops.

In the project area, there is no research station, but several stations are operated in Nakhon Sawan province and in Chainat province.

The Chainat Rice Experiment Station, which is one of the sub-branches of the Phitsanulok Rice Research Center under the Rice Research Institute of DOA, is a major experiment station for irrigated paddy.

Field Crop Experiment Stations under the Field Research Institute are situated in Nakhon Sawan province and Chainat province. The Nakhon Sawan Experiment Station is mainly conducting the research for maize and cotton under rainfed condition. The Chainat Experiment Station is also conducting the research for mung beans, soy beans, maize, cotton and sugarcane under irrigated condition.

4.10.4 Agricultural credit

Agricultural credit is available through credit institutions and from informal sources. Traditionally, about half of the farmers borrow from informal sources, such as relatives, friends, merchants and money-lenders at varying, but usually high, interest rates.

The major sources of institutional credit are BAAC and commercial banks. BAAC has expanded its program rapidly over the past ten years to cover virtually the entire country and now reaches approximately 30% of all farmers.

There are 123,600 farm households in Nakhon Sawan province at present, of which 55% of the farmer receive the agricultural credit through credit institutions. About 24% of the farmers, or 30,000 families receive loans directly from the BAAC, 15% from farmers associations, 10% from agricultural cooperatives and 6% from commercial banks. The loans of BAAC Nakhon Sawan Branch amounted to 425 million Baht in 1984.

4.10.5 Agricultural inputs

Seed

The Government has operated the Seed Exchange Program since 1981 to accelerate the distribution of high yielding seeds, by exchanging the present low yielding seeds with certified seeds of new improved varieties.

In Nakhon Sawan province, about 90% of paddy seeds are of local varieties produced by farmer themselves. In order to increase the yield of paddy, the seed exchange project has launched for 3 years plan period from 1982, with a total target area of 700,000 rai or 30% of the total paddy planted area in Nakhon Sawan province.

In addition to the above, the MOAC has now carried out the Thailand Seed Development Project with a financial assistant from USAID, EC and OECF. Under this project, Seed Center No. 4 was already established in Chainat province, and Seed Center No. 16 are now under construction in Nakhon Sawan province.

Fertilizer

There are two (2) institutional channels for fertilizer distribution; one is agricultural cooperative and the other is farmer's group under the control of DAE. In Nakhon Sawan province, agricultural cooperative dealt with 1,300 tons of fertilizers and farmer's group also did 1,000 tons in 1984. The fertilizers have been supplied to these institutional channels through MOF with a government subsidy. The prices of fertilizers are, therefore, cheaper than the merchant prices. Quantity of fertilizer distributed by MOF, however, has some limitations due to Government budgets' constraint.

4.10.6 Farmer's organization

(1) Agricultural cooperatives

The Department of Cooperative Promotion (DCP) is in charge of providing the support services for the establishment and operation of co-operatives throughout the country.

In Nakhon Sawan province, there are fifteen agricultural cooperatives (13,434 members) and one fishery cooperative (269 members). In the Mae Wong irrigation area, there are two agricultural cooperatives with total members of 1,544 families. The activities of these cooperatives are focused on the credit, sources of which mainly come from BAAC. Other activities are not remarkable.

(2) Farmer's group

Major functions of the farmer's group are to propagate the agricultural extension advices from DAE, to distribute farm inputs at fair price, and to arrange the credits from BAAC on a group basis.

There are 82 farmer's groups (18,835 members) at 10 farmer's groups (2,127 members) in Nakhon Sawan province and in the Mae Wong irrigation area, respectively. These farmer's groups have been involved in the above-mentioned activities.

CHAPTER V PROSPECTIVE DEVELOPMENT PLAN

5.1 Needs of the Project and Basic Development Concept

The Mae Wong Irrigation Scheme should be recognized as the first stage of irrigation development under the Sakae Krang Irrigation Project. The scheme will greatly contribute to the realization of the basic requirement for rural development in the Sakae Krang river basin, which basically aims at:

(1) improvement of present poor economic position of the area through full utilization of the endowed water resources for increase of paddy production, and

(2) uplifting of rural living standard and improvement of present income disparity in the area.

These basic principles are exactly conformed to the government policy given in the Fifth National Development Plan, and with this in view, the Government has accorded the high priority to the water resources development of the Sakae Krang river system in the said plan.

The Mae Wong Irrigation Scheme will have, following the basic concept of the Sakae Krang River Basin Irrigation Project which has been discussed in Chapter III, various aspects of development which include:

(1) exploitation of new water resources by construction of the Upper Mae Wong dam,

(2) up-grading of existing farmer's irrigation system

(3) expansion of irrigated paddy fields (irrigation to existing rainfed paddy fields)

(4) Other aspects of development including:

a. hydropower development at the Upper Mae Wong dam,

b. inland aquaculture development at the Upper Mae Wong reservoir

c. flood mitigation by dam construction

d. resettlement of the farmers who are living in the reservoir area

e. lumbering in the reservoir area

5.2 Water Resources Development Plan

5.2.1 Assessment of water resources

(1) Annual inflow

Potential watershed area for the storage reservoir in the Mae Wong river basin is limited topographically only along the western hilly region. The reservoir catchment area for the proposed Upper Mae Wong dam is counted at 612 km^2. Applying the results of streamflow simulation and observation records at CT-5A, the annual inflow to the reservoir was estimated for 30 years from 1954 to 1983. Average annual inflow was estimated at 220 MCM.

Inflow to the Reservoir

Item	Inflow (MCM/year)	Rainfall (mm/year)
1. Average year		
Dec. - July	41	644
Aug. - Nov.	179	694
Annual	220	1,338
2. Droughtyest year (1977)	55	967
3. 1/10 drought probability	122	1,111
4. 1/5 drought probability	148	1,176

There are two to three months discrepancy between the start of rainy month and start of river flow increase. The rainy season starts usually from May but river runoff increases from July or August. The significant annual fluctuation of the streamflow and long period of low flow for about successive 8 months from December to July give rise to the necessity of construction of dam and reservoir to control and regulate the streamflow for optimum utilization.

(2) River water exploitation

Major hydrological dimensions, such as catchment area, annual inflow and effective storage volume are shown in Table 5.2.1 for 17 numbers of existing or under construction dams in Thailand, having more than 100 MCM effective storage. The average ratio of effective storage volume versus annual inflow to the reservoir for these dams gives 1.06. This indicates that the carry over operation of reservoir is generally accepted and the maximum exploitable amount of water resource will, in many dams, define the project scale. Average annual inflow to the reservoir for these dams in Table 5.2.1 is 0.358 MCM/km^2 while it is 0.360 MCM/km^2 in case of the Upper Mae Wong reservoir.

Assuming that hydrological characteristics of watershed of the Upper Mae Wong dam is similar to the average of above 17 dams, the exploitable water resources by reservoir construction will be given as follows:

Effective storage = 220 MCM x 1.06 = 230 MCM

As for the annual sediment inflow, it is assumed at 20 MCM or 300 $m^3/km^2/year$ evaluating from the bed load and suspended load analysis together with the geology and ground coverage of watershed. The exploitable total reservoir storage volume will be estimated from the point of water resources assessment to be about 250 MCM.

(3) Groundwater exploitation

As for the groundwater exploitation, the basin seems to have a limited potential productivity from the point of geological formation. The unconfined aquifer was formed within the area along the river course. In the downstream area of the Upper Mae Wong dam, topographical and geological formations are favorable to receive the groundwater flow from the watershed. However, the permeability of the aquifer is considered relatively low. Small scale groundwater development will be suitable within the Mae Wong river basin and will be accelerated under the technical assistance of RID and financial support of BAAC.

It is considered necessary to continue the observation and study on the groundwater balance and water quality to clarify the effects of reservoir construction at upstream and irrigation development at downstream of the basin.

5.2.2 Water balance study

The water balance study aims at clarifying the followings over the Mae Wong river basin:

- to clarify the present use of existing farmer's irrigation system in the basin and reveal the areas actually irrigated in the existing irrigation service areas under the water balance study of present condition, and
- to clarify the relationship among the proposed dam scale, irrigable area and cropping intensity for each alternative development plan under the water balance study of with-project condition and consequently get the useful results for determination of optimum development scale.

(1) Water balance study of present condition

A systematic layout of irrigation water supply system of present condition is shown in Fig. 5.2.1. In accordance with the above systematic layout of irrigation water supply, the water balance calculation was carried out during the period from 1954 to 1982 on 10-day basis by using runoff estimated in the hydrologic study and irrigation water requirements estimated on the present cropping patterns. In the calculation, the followings were taken into account.

- Return flow = 0.33 of diversion water requirement
- Excess water of rainfall = 0.20 x (Rainfall - Effective rainfall)

The followings were clarified through the water balance study of present condition:

- The present water use in the basin is shown in Fig. 5.2.2. As shown in the figure, the deficit of irrigation water in the downstream reach is severe than that in the upstream reach, and
- The areas actually irrigated are estimated based on the ratio of deficit amount versus irrigation water demand as shown in Table 5.2.2. About 60% of the existing irrigation areas are actually irrigated in the drought year with 5-year return period.

(2) Water balance study of with-project condition

Figure 5.2.3 shows the systematic layout of irrigation water supply system under the with-project condition. The water balance calculations of with-project condition are divided into the following two (2) steps.

Step 1 : The water balance of irrigation area is calculated in accordance with the same procedures as water balance calculation of the present condition. Through this calculation, required water amount for irrigation to be released from the proposed storage dam is estimated.

Step 2 : The reservoir operation is carried out to determine the possible irrigable areas and reservoir capacity of the proposed dams by trial and error method based on the released water amount for irrigation estimated through Step 1 and given reservoir capacity.

Water balance and reservoir operation calculations were carried out for 29 years from 1954 to 1982 on the 10-day basis. In the calculation, the followings were taken into consideration.

- Return flow = 0.27 of irrigation water requirement
- Excess water of rainfall = 0.20 x (Rainfall - Effective rainfall)
- Water use for the people living in the Lower Mae Wong area

Possible irrigation area was determined through the reservoir operation calculation in Step 2 on condition that reservoir is completely depleted five (5) times at least for the 29 years period, or in other word, drought damage recurs by 5-year return.

Through the water balance calculation, the relationship among the dam scale, irrigable area and cropping intensity for the alternative development plans was clarified as shown in Table 5.2.3 and Figures 5.2.4 to 5.2.5. The alternative plans are broadly divided into the following cases:

Case 101 to Case 104: In these plans, the upgrading works for the existing farmer's irrigation systems would not be carried out under the project. To secure the delivery of irrigation water to the paddy fields, the small size pumps would be provided at certain places in the area.

Case 201 to Case 302: In these plans, the upgrading works for the existing farmer's irrigation systems would be carried out to secure the delivery of irrigation water to the paddy fields by gravity.

As shown in Fig. 5.2.4, it was confirmed that the gross reservoir capacity of 250 MCM was the maximum capacity to be expected from the hydrologic viewpoint, because no more extension of irrigable area was expected even if the reservoir capacity increased more. Subsequently, the alternative plans of Case 104, Case 204 and Case 302 were deleted in the optimization study of development scale. The alternative plan of Case 203 was also deleted in the study, because the irrigable area of 301,900 rai (48,300 ha) exceeds the potential maximum development area of 291,900 rai (46,700 ha) in the Mae Wong river basin.

As stated hereafter, the alternative development plan of Case 301 was selected as the optimum scale of development. The results of water balance calculation for Case 301 are summarized in Table 5.2.4. The storage change of reservoir in Case 301 is shown in Fig. 5.2.6.

5.2.3 Optimum scale of development

(1) Alternative plan

From the results of water balance calculation, the following 11 cases of alternative plans were examined for the determination of optimum development scale.

Alternative Case	Irrigable Area (ha)	Gross Reservoir Capacity (MCM)	Cropping Intensity (%)
101	36,800	200	100
102	36,800	250	105
103	37,600	250	100
201	36,800	120	100
202	36,800	250	130
205	42,400	170	100
206	42,400	250	116
207	45,600	200	100
208	45,600	250	108
209	46,700	220	100
301	46,700	250	105

The upgrading works of existing farmer's irrigation system would not be done in the alternative plans of Case 101 to 103. Only two intake weirs would be provided to assure the stable intake of irrigation water at the diversion places to the Ban Tha Ta Yu and Khlong Saingu irrigation service areas.

(2) Preliminary estimate of cost and benefit

Preliminary project cost was estimated as shown in Table 5.2.5 (Details are reffered to ANNEX-III). Preliminary irrigation benefits were also estimated as shown in Table 5.2.6 (Details are referred to ANNEX-III).

(3) O & M cost and replacement cost

In case of the alternative plans of Case 101 to Case 103, the upgrading works of existing farmer's irrigation systems would not be executed under the project. Unless the irrigation water is assured at the diversion points by the release water from the Upper Mae reservoir, the gravity irrigation to all existing irrigation areas is not expected by the farmer's irrigation systems without the upgrading works. The irrigation by small pump is required for the areas where the gravity irrigation is difficult taking the above situation into consideration, the operation and maintenance cost of small pump was estimated in Case 101 to Case 103. The annual operation and maintenance cost and replacement cost for each alternative plan are shown in Table 5.2.7 (Details are referred to ANNEX-III).

(4) Evaluation

Using the costs and benefits, the economic internal rate of return (EIRR) are calculated as follows (for details, see Table 5.2.8):

Alternative Case	Reservoir Capacity (MCM)	Irrigation Area (ha)	Cropping Intensity (%)	EIRR (%)
101	200	36,800	100	11.6
102	250	36,800	105	11.6
103	250	37,600	100	11.5
201	120	36,800	100	11.5
202	250	36,800	130	12.1
205	170	42,400	100	12.0
206	250	42,400	116	12.5
207	200	45,600	100	12.6
208	250	45,600	108	12.9
209	220	46,700	100	12.8
301	250	46,700	105	13.0

(5) Selection of optimum development plan

Following the development concepts, the criteria for selection of optimum development plan are prepared as given below:

Criteria-1 : The alternative plans with higher economic internal rate of return should be first selected.

Criteria-2 : Higher priority should be given to the alternative plans with larger irrigation area because larger number of farmers could be benefited.

Criteria-3 : Dry season cropping should be considered as a secondary importance so as to expand the irrigation area in the wet season.

Criteria-4 : The alternative plan with the most sizeable reservoir should be selected within economically reasonable range, in view of maximum exploitation of the endowed water resources.

Criteria-5 : The laternative plan providing larger agricultural benefits should be selected in view of greater contribution to the regional economy.

The assessment of alternative plans is summarized as follows:

- All the alternative cases are economically feasible, with more than 11.5% of EIRR.

- The alternative plans from Case 101 to Case 103 show a bit lower economic viability. This means that upgrading of the existing farmer's irrigation systems will create greater benefit by saving enourmous operation and maintenance costs.

- The alternative plans with the reservoir capacity of 250 MCM show higher internal rates of return as compared with those of ones having other capacity of reservoirs. This indicates that the dam with a capacity of 250 MCM has the highest efficiency in irrigation area/effective storage and/or dam construction cost. The alternative plans with 250 MCM reservoir capacity should be put under further consideration and others be disregarded.

- Among four alternative plans, i.e., Cases 202, 206, 208 and 301 which have 250 MCM reservoir capacity, only the alternative Case 301 meets all the criteria given above.

Considering all these, it is recommended that the alternative Case 301 with the following features should be selected as the optimum development plan.

Reservoir Capacity	Irrigation Area	Cropping Intensity
250 MCM	291,900 rai (46,700 ha)	105%

5.3 Agricultural Development Plan

5.3.1 Assessment of land resources

For selection of the land for irrigation development, the first priority has been given to the existing irrigation area of 230,000 rai (36,800 ha). This will be the minimum area for irrigation development. If the available water will still remain after supplying sufficient water to the existing irrigation area, the rainfed paddy field that will be irrigable by gravity, will be developed to the maximum extent.

The maximum development area including the rainfed paddy fields has been delineated with special attention to topographic condition, present land use and land capability for irrigation, and its total area is estimated at 291,900 rai (46,700 ha), which comprises:

		(Unit: rai)
Existing Irrigation Area	Rainfed Area	Total
230,000 (36,800 ha)	61,900 (9,900 ha)	291,900 (46,700 ha)

The selected development areas are all irrigable by gravity and are endowed with productive soils suitable for irrigated paddy cultivation. Most of the lands outside the selected areas are generally not irrigable due to their undulating topography coupled with poor soil conditions.

5.3.2 Change in land use

The present land use in the potential maximum area will be changed as follows:

(Unit: ha)

Land Use Categories	Without Project	With Project
Paddy field		
- irrigated	22,000	46,700
- semi-irrigated	14,800	-
- rainfed	7,800	-
Sub-total	44,600	46,700
Upland (reinfed)	2,100	-
Total	46,700	93,400

Paddy cultivation is a mainstay in the area and its importance in rural economy will increase continuously. Drastic change in land use will not be occurred under such condition. All the paddy fields will be provided with the irrigation facilities through realization of the Project. The selected irrigation development area includes about 13,100 rai (2,100 ha) of upland where, if irrigation water is provided, paddy cultivation will become possible. These upland areas are to be reclaimed into new paddy fields.

5.3.3 Proposed cropping pattern

Paddy and mung beans are selected as main crops in future framework of cropping pattern. Paddy will be cultivated in the wet season and mung beans will be grown after harvest of wet season paddy in the dry season.

Paddy is Thailand's most important crop. It is the main staple for domestic consumption and is also the major source of foreign exchange earning. The country produces about 14 to 19 million tons of rice annually. About three-fourths of production is consumed domestically and the rest is exported.

In January 1985, the Government of Thailand announced that in anticipation of over-production problems for rice, the Government would change its policy for dry season paddy and seek the possibility of a reduction in local paddy production by encouraging rice farmer to grow other cash crops in the dry season yielding parallel income. The Government accorded its priority to sorghum and mung beans as substitute crops. For wet season paddy, in due consideration of its importance and present unstable production largely affected by the weather, the Government would make every possible efforts to stabilize the production.

Mung bean is one of the prospective crops since its demand in the world market is high. Thailand is one of the major producers and exporters of mung beans. The country produces about 10% of the world output and export a value of over one (1) billion Baht annually (about 133,000 tons). In the Mae Wong area, mung bean is main crop in the dry season, being planted with the area of 25,600 rai (4,100 ha) per annum. The farmers have long experience for mung bean cultivation and local marketing channels for this crop have already been well networked. Moreover, mung bean is one of the ideal crops in crop rotation and soil amendment due to leguminous crops.

The proposed cropping pattern is shown in Fig. 5.3.1. Two kinds of paddy varieties will be introduced; i.e., (1) high yielding RD varieties (H.Y.V.) and (2) improved local varieties. High yielding varieties will be cultivated mainly for export and improved local varieties will mainly be for home consumption.

5.3.4 Proposed farming practices

After the Mae Wong irrigation scheme is realized, the existing paddy fields will be fully irrigated and improved farming practice will be gradually introduced to the project area. The recommendable farming practices will be those developed by the Chainat Rice Experimental Station and the Field Crop Research Institute.

(1) Paddy cultivation

For the increase of paddy yield, use of high quality seeds is essential. The RD varieties such as RD-7, RD-21 and RD-23 are recommendable as the high yielding variety. Lueng Yai 148 and Khao Dawk Mali 105 which are non-glutinous improved local varieties, are also recommendable for local consumption.

The amount of seeds needed is about 5 - 6 kg per rai (35 kg/ha). The required amount of fertilizer for nursery (6% of main crop area) is 100 g of urea and 50 g of TSP respectively. Prior to the seeding, seeds should be selected by a solution of 1.13 specific gravity and further be treated with seed disinfectants like Benlate-T or Homai.

Land preparation will be started a half month before transplanting. For transplanting, the recommendable number of seedlings is 3 - 4 per hill and planting density of 20 hills per m^2 will be recommended.

Ammophos (16-20-0) of 19.2 kg/rai (120 kg/ha) will be applied as the basal fertilizer at the time of 5 days before transplanting. Top dressing will be carried out 2 - 3 times; about 15 days after transplanting, at the young panicle formation stage and at the full heading stage. The amount of fertilizer will be 8 kg/rai (50 kg/ha) of urea for each top dressing.

Insect and disease control for paddy cultivation should be carried out at the proper time without delay. Recommendable agro-chemicals are Sumithion, Diazinon, etc. for insect control, and Kasumin, Kitazin, etc. for disease control. Weed control will be carried out 2 - 3 times according to the condition of the weed growth. The weeding will be made by use of the rotary weeder.

Proper water management is very essential on paddy cultivation. There are critical periods in the life of the rice plant against the shortage of water, i.e. just after transplanting, panicle initiation stage, reduction division stage and flowering stage. Proper irrigation management should be introduced according to the growth stage.

At present, harvesting of paddy is being done manually using sickles, and threshing is also being done manually or using animal power. In future, however, the mechanical threshing by means of engine-driven harvester and treadle thresher will be introduced to the area.

(2) Mung beans cultivation

U-thong-1 is the recommendable variety. A new variety, VC1178, which is under multiplication, is also recommendable due to its characteristics of short growth period (60 - 65 days) and high yielding.

The seed requirement will be 6.4 kg/rai (40 kg/ha). The seed will be drilled at 50 cm interval. Fertilizers (ammophos) will be applied after germination at the rate of 9.6 kg/rai (60 kg/ha). Top dressing is also required. Ammophos of 6.4 kg/rai (40 kg/ha) will be applied at the intermediate stage of growth. Pest and diseases control will also be carried out by application of appropriate agro-chemicals. Harvesting will be made by hand.

5.3.5 Anticipated crop yield and production

The anticipated crop yields under future condition with the project are estimated, on the basis of data and information given by the Department of Agriculture, as follows:

Paddy	- H.Y.V.	720 kg/rai (4.5 tons/ha)
	- Local	640 kg/rai (4.0 tons/ha)
Mung beans		190 kg/rai (1.2 tons/ha)

Rice research and experiments have been carried out at Chainat Agricultural Centre. In 1969/70, nitrogen response to the variety C4-63 was examined, and more than 800 kg/rai of crop yield was obtained under standard cultivation technique with irrigation, as shown below:

N Level (kg N/ha)	Paddy Yield (kg/rai)	Paddy Yield (ton/ha)
50	846	5.29
75	822	5.14
100	928	5.80
150	845	5.58

RD varieties have been released since 1969, by the Rice Division, Department of Agriculture. RD varieties have a high productivity and a good response to fertilizer application under irrigated condition. In 1979, RD-7 and RD-11 were tested at Chainat. The result is as follows:

N Level (kg N/rai)	Paddy Yield (kg/rai) RD-7	Paddy Yield (kg/rai) RD-11
13	-	823
17	773	-
19	-	838
28	802	-

The experiments on the effect of different soil series on the N response of rice grown in the farmers fields were conducted in many locations in the Central Chao Phrayo Plain during the years from 1976 to 1983. Seven soil series were tested. Nakhon Pathom series which is one of the representative soil types in the prospective irrigation area, is included in the experiments. It has been observed that there is a clear relationship between N application level and paddy grain yield on the Nakhon Pathom series. Paddy yield is expressed as a result of the experiments, as follows:

<u>H.Y.V.</u> $Y = 609.6 + 22.8X - 0.41X^2$

<u>Local</u> $Y = 541.9 + 20.0X - 0.39X^2$

where, Y: Paddy grain yield (kg/rai)
X: N level (kg/rai)

The proposed amount of fertilizer under the Project is 100 kg/ha of urea and 120 kg/ha of Ammophos (16-20-0) which approximately corresponds to 65 kg N/ha (10.4 kg N/rai). If applied to the above equation, the expected paddy yield amounts to 802 kg/rai for RD varieties and 708 kg/rai for improved local varieties.

Judging from the above information, the anticipated paddy yield mentioned above would surely be attained.

The anticipated mung beans yield of 190 kg/rai is not high as compared with the experimental results obtained at Chainat which show about 350 kg/rai (2.17 tons/ha) under irrigated condition with proper farming practices. The anticipated mung beans yield is rather conservative.

The crop yield will gradually increase during the build-up period of 5 years after completion of the Project. The incremental crop production at the full development stage is estimated as follows:

Crops	Without Project			With Project			Incremental Production
	Planted Area (ha)	Unit Yield (ton/ha)	Production (ton)	Planted Area (ha)	Unit Yield (ton/ha)	Production (ton)	(ton)
(1) Wet Season Paddy							
- irrigated	22,000	2.8	61,600	46,700	4.4	205,500	107,100
- semi-irrigated	14,800	1.6	23,700	-	-	-	-
- rainfed	7,800	1.3	10,200	-	-	-	-
(2) Dry Season Paddy	1,100	3.5	3,900	-	-	-	-
(3) Mung Beans	4,100	0.6	2,400	2,300	1.2	2,800	400
(4) Maize	2,100	2.2	4,600	-	-	-	-

5.3.6 Farm inputs and labour requirement

(1) Farm inputs

After implementation of the Project, the use of farm inputs will increase substantially. The farm input requirements under future "with" and "without" project conditions are estimated as follows (see Tables 5.3.1 and 5.3.2):

	Seeds (ton)		Fertilizer (ton)		Agro-chemicals (k*l*)	
	H.Y.V	Local	Urea	Compound	Insecticides	Fungicides
(1) Without Project						
Paddy	940	2,690	1,020	2,430	6	-
Mung beans	-	160	-	-	-	-
Maize	-	80	-	60	-	-
(2) With Project						
Paddy	1,050	70	4,670	5,600	110	56
Mung beans	90	-	-	230	4	1
(3) Increment						
Paddy	110	-	3,650	3,170	104	56
Mung beans	90	-	-	230	4	1
Total	-	-	3,650	3,400	108	57

The farm inputs requirement under future "without Project" condition will be same as those under present condition. The farm inputs requirements under future "with Project" condition are estimated on the basis of the proposed farming practices.

(2) Labour requirement

Family labour will mainly be used for farming throughout the year. Some temporary labour will be employed during the periods of transplanting and harvesting. The proposed farming will be practiced basically by family labour with some agro-machinery such as hand tractor, sprayer, thresher and other farming equipment and tools.

The labour requirements under the future "with" and "without" project conditions are estimated as follow (Tables 5.3.1 and 5.3.2, to be referred):

Crops	Planted Area (ha)	Unit Labour Requirement (man-day/ha)	Total Labour Requirement (10^3 x man-day)
(1) Without Project			
Paddy	45,700	63.5	2,901
Mung beans	4,100	32.5	133
Maize	2,100	44.5	93
Total			3,127
(2) With Project			
Paddy	46,700	73.8	3,446
Mung beans	2,300	40.5	93
Total			3,539
(3) Increment	-	-	412

The family labour can cover the incremental labour requirement as shown in Table VIII-10 of ANNEX-VIII.

5.3.7 Marketing and price prospects

(1) Marketing prospects

Production surplus of rice in the year of 1995 is estimated as follows:

	Mae Wong Irrigation Area	Nakhon Sawan Province
Population in 1985	74,500	1,028,000
Population Growth Rate (%)	2.4	2.2
Population in 1995	94,440	1,277,900
Rice Consumption per Capita (kg)	300	300
Total Consumption in 1995 (ton)	28,330	383,370
Total Paddy Production in 1983	95,420	825,180
Total Paddy Production in 1995	205,480	935,240
Total Production of Milled Rice in 1995	133,560	607,906
Surplus	105,230	224,536

Anticipated surplus of rice in 1995 will be significant in and around the project area. The annual marketable surplus will be about 105,000 tons at the full development stage. The surplus in the project area will constitute about 3% of the total rice exports.

The incremental production of mung beans will be about 400 tons. This is a negligible fraction of the total domestic production of about 0.3 million tons.

(2) Price prospects

(a) Paddy

Economic prices of rice/paddy at farm gate are estimated on the basis of the projected international market prices forecasted by IBRD for the year of 1995 in 1983 constant US Dollars and further taking into account the costs for transportation, processing and others. The economic price of paddy at the farm gate is estimated at 4,230 Baht per ton, as shown in Table 5.3.3.

Financial prices of rice/paddy at farm gate are estimated based on available data on farm gate prices collected through farm economy survey and prevailing local market prices in Nakhon Sawan. The estimated financial price of paddy for the year of 1995 is 3,950 Baht per ton.

(b) Mung beans

Economic price of mung beans is estimated, on the basis of actual F.O.B. Bangkok export prices, at 6,920 Baht per ton as shown in Table 5.3.4. Financial price of mung beans at farm gate is estimated from the results of RID socio-economic survey. The financial price for the year of 1995 is 8,400 Baht per ton.

5.3.8 Farm budget

Farm budget analysis is made for both cases of "with" and "without" project conditions, using the crop yields, crop production costs and financial crop prices estimated above. Farm budget reflects the future condition in the target year of 1995. The analysis is made for different sizes of farmers, as shown below:

(1) Existing irrigation area

(Unit: 10^3 Baht)

	Small Farm (less than 20 rai)		Medium Farm (21 - 50 rai)		Large Farm (more than 51 rai)	
	With Project	Without Project	With Project	Without Project	With Project	Without Project
Planted area						
- Paddy	1.2 ha	1.2 ha	4.5 ha	4.5 ha	12.0 ha	12.0 ha
- Mung beans	0.1 ha	0.1 ha	0.2 ha	0.4 ha	0.6 ha	1.0 ha
Gross income (A)	39.6	29.2	96.6	59.7	237.5	237.5
- Farm income	34.5	14.1	82.3	45.4	221.0	221.0
- Others	15.1	15.1	14.3	14.3	16.5	16.5
Out-go (B)	33.0	29.4	63.8	51.5	139.9	139.9
- Farm expenses	11.0	7.4	40.0	27.7	107.2	107.2
- Living expenses	22.0	22.0	23.8	23.8	32.7	32.7
Balance (A - B)	6.6	-0.2	32.8	8.2	97.6	31.5

(2) Rainfed area

(Unit: 10^3 Baht)

	Small Farm (less than 20 rai)		Medium Farm (21 - 50 rai)		Large Farm (more than 51 rai)	
	With Project	Without Project	With Project	Without Project	With Project	Without Project
Planted area						
- Paddy	1.2 ha	1.2 ha	4.5 ha	3.5 ha	12.6 ha	9.5 ha
- Mung beans	0.1 ha	0.1 ha	-	0.1 ha	0.6 ha	0.2 ha
- Maize	-	-	-	1.0 ha	-	2.5 ha
Gross income (A)	39.6	15.8	96.6	34.5	237.5	77.2
- Farm income	34.5	6.0	82.3	25.3	221.0	64.0
- Others	15.1	9.5	14.3	9.6	16.5	13.2
Out-go (B)	33.0	25.6	63.8	37.8	139.9	82.6
- Farm expenses	11.0	5.6	40.0	20.2	107.2	53.8
- Living expenses	22.0	19.4	23.8	19.6	32.7	28.8
Balance (A - B)	6.6	-3.5	32.8	-4.9	97.6	-5.4

The implementation of the Project will significantly increase the farm incomes in every sizes of farm.

5.3.9 Net incremental benefits of the Project

The net incremental benefit of the Project is defined as the difference between the net production values under "with project" condition and "without project" condition. The net production value is further defined as the difference between the gross production value and the crop production costs in both "with project" and "without project" conditions.

The following shows the incremental benefit of the Project at the full development stage (for details, see Table 5.3.5).

(Unit: ฿/million)

	Without Project	With Project	Net Incremental
Wet season paddy			
- Irrigated	166.7	604.1	437.4
- Semi-irrigated	44.3	-	-44.3
- Rainfed	15.8	-	-15.8
Dry season paddy	10.9	-	-10.9
Mung beans (Paddy field)	6.3	10.7	4.4
Mung beans (Upland field)	1.0	-	-1.0
Maize	5.8	-	-5.8
Total	250.8	614.8	364.0

5.4 Irrigation and Drainage Development Plan

5.4.1 Irrigation water requirement

Irrigation water requirements under the following conditions are calculated:

- Irrigation water requirements under the present condition based on the present cropping pattern to grasp the areas actually irrigated through the present water balance calculation, and

- Irrigation water requirements under the with-project condition based on the proposed cropping pattern to determine the project scale through the optimization study.

Since no data on the field measurement of consumptive use of water by crop are available in the Mae Wong river basin, the consumptive use of water is estimated based on the potential evapotranspiration made by the modified Penman method. The net irrigation requirement is calculated on the above consumptive use of water taking percolation rate, water requirement for land preparation, effective rainfall into consideration.

The following overall irrigation efficiencies are assumed for calculation of diversion water requirement.

(Unit: %)

Crop	Present Condition	With-project Condition
Paddy	45	55
Upland crop	40	45

Thus, the following two (2) cases of irrigation water requirements for both "present" and "with-project" conditions are estimated.

<u>Present condition</u>

- irrigation water requirements in the irrigated field
- irrigation water requirements in the semi-irrigated field

<u>With-project condition</u>

- irrigation water requirements for with-upgrading of existing farmer's irrigation systems (overall irrigation efficiency of 55% for paddy and 45% for upland crop)

- irrigation water requirements for without-upgrading of existing farmer's irrigation systems (overall irrigation efficiency of 45% for paddy and 40% for upland crop)

The calculated irrigation water requirements are shown in Table 5.4.1 to Table 5.4.4.

The unit design water duty for canals and related structures is determined at 1.25 ℓ/sec/ha (0.20 ℓ/sec/rai).

5.4.2 Drainage modulus

The design discharge of drainage canal is estimated in accordance with the following criteria:

- Return period of design rainfall is 5 years,
- Design rainfall is of 3-day consecutive rainfall,
- Design rainfall shall be drained off for 3 days, and
- On-field storage of an average surcharge of 75 mm.

Design rainfall with return period of 5 years is determined at 170 mm based on the daily rainfall records at Lat Yao from 1983. Using this design rainfall, the drainage modulus of paddy fields is determined at 3.67 ℓ/sec/ha.

As for the drainage modulus of high terraces and hills, it is estimated at 4.84 ℓ/sec/ha based on the floods with return period of 5 years at the CT5A station.

The above drainage modulus is applied for the drainage area less than 3 km^2. The following runoff reduction ratio is applied for the drainage area larger than 3 km^2.

Drainage Area (km^2)	Reduction Ratio	Drainage Area (km^2)	Reduction Ratio
0-3	1.00	20-28	0.70
3-4	0.95	28-40	0.66
4-6	0.90	40-60	0.61
6-8	0.86	60-80	0.58
8-12	0.80	80-120	0.55
12-16	0.76	120-160	0.52
16-20	0.74		

5.4.3 Irrigation and drainage system

(1) Irrigation canal system

The preliminary layout planning of irrigation canal is made on the topographic maps on a scale of 1/10,000 prepared by RID. In the planning, the following matters are taken into consideration:

- Canal alignment should be straight and short as far as possible,
- Existing farmer's irrigation systems are to be incorporated into the project as far as possible, and
- Embankment portion should be minimized as far as possible.

For the upgrading plan of existing farmer's irrigation systems, the following concepts are considered:

- Existing intake weirs and regulator (gate) would be integrated under the project to simplify the water management on the Mae Wong river.

- Existing intake weirs and regulator other than the proposed or integrated ones under the project would be removed and all cutting of the Mae Wong river bank by farmers would be reclosed to assure the stable intake of irrigation water released from the Upper Mae Wong dam to each irrigation area,

- Existing farmer's irrigation systems with difficulty of gravity irrigation would be embanked to raise the water level in the canals for assured gravity irrigation,

- Related structures such as check, turnout, drop, syphon, spillway, cross drain, culvert, etc. would be provided to assure the distribution of irrigation water in a timely and efficient manner as to meet the crop water requirements,

- Measuring devices would at least be provided at the head of main canal for proper water management, and

- There exist no inspection roads along the existing canals. Inspection roads would be provided for proper operation and maintenance of irrigation facilities.

The layout of irrigation canal system is shown in Fig. 5.4.1.

(2) Drainage canal system

The preliminary layout planning of drainage canal is also made on the topographic maps on a scale of 1/10,000. In the layout, the existing natural streams in the areas are incorporated into the drainage canal system as many as possible. The layout of drainage canal system is shown in Fig. 5.4.1.

5.5 Other Considerations for Development

5.5.1 Hydropower development

Since the Upper Mae Wong dam is to built mainly for irrigation purpose, it has been planned that the Upper Mae Wong reservoir be operated according to an operation rule of the reservoir to supply the required amount of water for irrigation. The power generation plan is to fully utilize the irrigation water to be released from the Upper Mae Wong dam. Consequently, it has been planned that the power plant be of a type to utilize the head of the dam.

As a result of a series of the studies, the followings are details of the hydropower development with the optimum scale.

Maximum high water level	:	207.5 m
Normal high water level	:	204.5 m MSL
Rated water level (in case of maximum output)	:	197.0 m MSL
Minimum water level	:	180 m MSL
Tail water level	:	152.3 m MSL
Gross head	:	44.7 m
Rated effective head	:	42.5 m
Maximum discharge	:	18.5 m^3/sec
Maximum output	:	6,500 kW
Annual energy production	:	15,238 MWh

The construction cost would be 144 million Baht, or 9.45 Baht/kWh. Raising of dam height to obtain higher rated head is not recommendable, since it would require the incremental cost of 56.5 Baht/kWh.

5.5.2 Return flow to the other basins

According to the results of water balance study of with-project condition, the return flow to the other basins is estimated as follows:

	Wet Crop Season	Dry Crop Season
Drought year with 5-year return period (1982)	53,012 x 10^3 m^3	2,081 x 10^3 m^3

The above return flow can be used as irrigation water and/or domestic water for the people living in the other basins. The paddy fields of about 4,800 ha would be irrigated in the wet season by using the return flow. If the return flow of dry crop season would be used as domestic water, the people of about 230,000 would benefit for about three months from January to March.

5.5.3 Flood mitigation

The most important constraint to agricultural development in the Mae Wong river basin is the shortage of available water for irrigation. Among other major constraints in the basin, such as lack of proper irrigation facilities, yield limitation of local variety, etc., the flood damage is of minor importance when considered against almost regular crop damages caused by shortage in water supply. However, incidental but considerable reduction of flood scale and frequency will be attained from the implementation of dam and reservoir at upstream of the basin, even in case the purpose of operation of reservoir is single for irrigation.

Based on the results of flood routing analysis presented in ANNEX I, the reductions of flood peak and flood volume by the reservoir are calculated as follows:

Flood Probability (year)	Without Reservoir Peak (m^3/sec)	Without Reservoir Volume (MCM)	With Reservoir Peak (m^3/sec)	With Reservoir Volume (MCM)	Reduction Peak (%)	Reduction Volume (%)
10	860	91	650	70	24.4	23.1
50	1,200	127	990	103	17.5	18.9
100	1,340	141	1,130	116	15.7	17.7

Above calculation was conducted assuming the flood inflow against full reservoir storage. According to the reservoir operation study for 30 years, reduction of flood frequency is more remarkable because the reservoir water level is usually low at the beginning of rainy season. It is summarized in Table 5.5.1.

5.5.4 Water supplies

The water use for the people living in the Lower Mae Wong area is considered in the form of allowance in the water balance study. The water amount kept for the people is shown as follows:

- Released water from the Upper Mae Wong dam	$2,652 \times 10^3 m^3$/year
- Non-regulated water	$6,333 \times 10^3 m^3$/year
Total	$8,985 \times 10^3 m^3$/year

The above amount of water would be used as follows:

- Domestic water supply : 24,000 persons including water use of livestock
- Irrigated agriculture (Cropping intensity = 200%) : 625 rai (100 ha) along the Mae Wong river
- Irrigated agriculture (Cropping intensity = 100%) : 2,690 rai (440 ha) along the tributary of the Mae Wong river

The regulated water flow resulting from the construction of the Upper Mae Wong dam would improve the water supplies for domestic uses in the irrigation areas by utilizing the return flow of irrigation water. Upgrading of the existing farmer's irrigation systems would also improve the situation. New construction of irrigation canals in the rainfed area would provide the farmers with easy access to domestic water. Total return flow from the irrigation service areas is estimated at about $113 \times 10^6 m^3$/year.

5.5.5 Inland fishery

The current National Development states that "speed up the production of fresh-water fishes and release them to multiply in natural water reservoirs and various irrigation projects in order to provide a source of protain".

The project will provide a large possibility of inland fishery development in the area, by creating a reservoir and irrigation canals. In the reservoir, an annual fish production of about 170 tons is expected under natural condition without fish releasing and feeding. It is approximately valued at 8 million Baht. The possibility of aquaculture is also large in the reservoir. High production of high-valued fishes is expected; in the case of cage culture or heedless culture, an average of 1.6 tons per rai will possibly be realized under proper management.

There are many irrigation ponds in the Mae Wong area. The farmers collect the water during the wet season in the ponds and use it when they need mainly for irrigation. Actually, however, water is always scarce and the ponds do not function well. After completion of the Project, a part of irrigation water could be utilized to fill the ponds, and the fish culture in these ponds would become possible. The pond cultures of valuable prawn and fishes like Giant prawn, Snake head and Sand gobios are recommendable.

All these prospective activities on inland fishery development should be made in close cooperation with the Department of Fishery, MOAC.

5.5.6 Resettlement

The resettlement program is recognized as an important step to the project implementation with the intention of mitigating the impacts on the quality of life values. There is presumably little or no specific problem as to the relocation of inhabitants in the reservoir area, if they are provided appropriate compensation and resettlement site. The potential site for such resettlement is conceived in the forestry village project area which is managed by RFD and located close to Ban Wang San in Amphoe Lat Yao. There is, however, some uncertainty of the attitude of existing dwellers who had migrated there previously. Therefore, the inter-agencies cooperation should be required for partial cession of the lands in the forestry village.

Based on the experience obtained from the Thap Salao dam project, the total resettlement cost for about 100 households in the reservoir area is estimated at about 17.3 million Baht, including compensation cost of 4.7 million Baht.

5.5.7 Forestry resource

Since the forests which are commercially valuable are found in some parts of the reservoir area, it is possible to gain the income by selling merchantable timber trees in advance of the inundation. Unit selling prices have a variation by various uses of different timbers, they are estimated in six types between 400 Baht/m^3 and 8,600 Baht/m^3. The most expensive timber tree is Teak and the least expensive one is firewood. Unit net profits in different types can be calculated by deducing the costs for logging and selling from the selling prices, to be between 70 Baht/m^3 and 5,100 Baht/m^3. The timber volumes of each type, which are estimated from result of field survey, vary from 500 m^3 to 114,600 m^3. Total net profit is calculated by multiplying the unit net profits and their corresponding timber volumes. The calculated total net profit is about 33.2 million Baht. It is highly recommended from this result that the forests in the reservoir should be cleared before impounding the water.

CHAPTER VI PROPOSED PROJECT WORKS

6.1 Dam and Reservoir

6.1.1 Damsite

(1) Location and accessibility

The proposed Upper Mae Wong damsite is on the Mae Wong river and on the boundary of Kamphaeng Phet and Nakhon Sawan provinces, approximately at Latitude 15°55'N and Longitude 99°19'50"E. The nearest village is Ban Taling Sung, about 13 km downstream.

The damsite is easily accessible during dry season by 4WD vehicle through cart road from the village but not always during wet season. This road is about 20 km in length and would be widened, straightened and surfaced for use as an access road during the period of construction.

(2) Topography

A topographic map of 1:1,000 scale with 1-meter contour intervals covering about 10 km^2, a distance of 1.5 km upstream and 1.5 km downstream from the damsite, was completed in June 1985 and used in the design of the dam. Another map of 1:10,000 scale with 5-meter contour intervals covering about 60 km^2 was also made at the same period of time and used in designing the area-storage capacity curves for the proposed reservoir. An aerial topographic map of 1:50,000 with 20-meter contour intervals was used for general purposes.

The first two basic maps were prepared by RID. The method used in the ground survey consists of the horizontal control referred to RID grid system and the vertical control referred to the mean sea level.

Topography of damsite is rather complicated. Valley shape is wide and river course is winding. Left side abutment is relatively thin and deep topographic depression is located at right side abutment. Saddle shape topography is located at about 1.5 km north of damsite, where the ground elevation is almost same as proposed dam crest elevation and deep valley develops at downstream of saddle shape.

(3) Geology and embankment material

A geological investigation of the damsite and the reservoir area was carried out to determine the soundness of the site and the watertight qualities of the reservoir. Twelve holes, including percolation tests and standard penetration tests, were drilled to a total depth of 297.95 m. Rock was drilled by diamond bits of Nwm and Bwm with double core tube.

Nineteen test pits of 2 x 2 m were excavated, for a total depth of 37.7 m in order to investigate the embankment materials and to obtain the samples for soil mechanical tests. Twenty nine auger-hold drillings were conducted around dam axis for total depth of 26.8 m. All these geological investigations and soil mechanical laboratory tests were conducted by RID.

From a detailed study on the geological data, it was concluded that the dam foundation consists of hard rocks of Quartzite, Calc-silicate and Schist and that there will be no leakage through the abutments or the foundation of dam. However, curtain grouting will be necessary to seal all fractures, joints and shear series near the rock surface. Consolidation grouting to supplement curtain grouting would be required.

Reservoir area is generally formed by granite rocks. Dissolvable limestone groups are not expected in the reservoir geology. A fault is in evidence crossing the reservoir from northeast to southwest at about 1.5 km upstream of dam. This fault is old and small in scale. There will be no problem of leakage and no treatment will be required to prevent such losses from the reservoir. Geological map is shown in Fig. 6.1.1.

Deep-weathered granite material is found at downstream of damsite and will be suitable for impervious material. However, such impervious materials as suitable for dam embankment will be limited in volume. Decomposed granite material having semi-pervious characteristics is deposited at about 2 km upstream of damsite within the reservoir area. Generally, the earth materials suitable for dam embankment are deposited thin and rock materials are dominant.

(4) Hydrology

The catchment area of proposed damsite is 612 km^2. The annual inflow to the reservoir varies from 55 MCM to 541 MCM with an average of 220 MCM. The effective storage capacity of 230 MCM is required to irrigate 46,700 ha. The reservoir capacity and the height of the dam was determined on the basis of optimization study presented in Chapter V. The area-capacity curve of the reservoir is shown in Fig. 6.1.2. The summary of reservoir hydrological data is as follows:

- Total storage capacity	250 MCM
- Effective storage capacity	230 MCM
- Dead storage capacity (100 year)	20 MCM
- Water level at total storage (FWL)	El. 204.5 m
- Water level at dead storage (DWL)	El. 180.0 m
- Flood water level (HWL)	El. 207.5 m
- Area at total storage	17.6 km^2
- Area at flood water level	19.8 km^2

6.1.2 Selection of dam type

During the initial phases of investigation of dam, concrete, rockfill and earthfill types were considered. However, as soil mechanical and geological investigations progressed, it became quite evident that a concrete dam and earthfill dam would not be economical.

Earthfill type dam was not selected with the following reasons.

(1) Sufficient volume of earth materials would not be obtainable in the vicinity of dam.

(2) Excavated materials from the appurtenant structures of dam, would not be balanced with the embankment, which would result high construction cost with plentiful disposals of excavated rocks.

Foundation rocks are quite hard and solid and the deformation of foundation will be negligible small even in case of concrete dam. The factors leading to the selection of a concrete dam are the savings assumed from river diversion and spillway over the dam body. The river diversion would be planned on the confinement of flows to one side of the channel during initial stage, followed by diversion through partially completed blocks during the second stage. The spillway would be designed on the dam body. These designs would result generally considerable savings over construction cost through diversion tunnel and side spillway as would be required on the abutments with a fill type dam.

However, the valley shape is so wide, 400 m at the base of dam and neary 800 m at the crest of dam, that total concrete volume of dam body will not be less than 700,000 m^3. It was confirmed from soil mechanical investigations that the excavated materials from service and emergency spillway, in case of rockfill dam, would be utilized as embankment materials. Estimated volumes of embankment and excavation are balanced with a rockfill dam of the height being considered. Borrow area for core zone is located only 2 km downstream. Total construction cost of rockfill dam will be less than half of concrete dam.

It was therefore concluded that rockfill type dam was suitable in all aspects such as material availability, suitability for high dam and economic construction.

6.1.3 Selection of dam axis

Detailed study on available topographic maps and geological conditions led to the comparison study on the alternative dam axes. The topographic conditions of damsite are relatively complicated; the directions of ridges on both abutments are in discord, the river course is crossing damsite in almost parallel with dam axis and a depression, small but deep and steep, is located at right abutment.

The surveyed dam axis, selected from the aerial topographic map of 1:50,000 scale, was considered unsuitable as it is located on the said depression and its crest length is considered too long. Three alternative dam axes were selected for comparison as shown in Fig. 6.1.3.

Preliminary designs and cost estimates were conducted on the alternative dam axes. The results are summarized below, and dam center line No. 2 was selected. In this comparison, the costs for intake and outlet facilities, foundation treatment, emergency spillway and temporary works are excluded since they are common for each dam axes and the cost of temporary works will be proportional to the direct cost.

Work Quantity

		Dam Center Line		
		No. 1	No. 2	No. 3
1. River diversion				
1-1 Diversion tunnel	(m)	370	230	390
1-2 Diversion canal	(m^3)	152,300	138,300	66,000
1-3 Diversion dam	(m3)	75,600	78,700	213,500
2. Dam				
2-1 Excavation	(m3)	126,000	108,000	99,000
2-2 Embankment	(m^3)	2,654,000	2,388,000	2,769,000
3. Service spillway				
3-1 Earth works	(m^3)	463,000	659,000	304,000
3-2 Concrete works	(m^3)	44,000	53,400	50,300

Construction Cost

(Unit: MCM ฿)

	Dam Center Line		
	No. 1	No. 2	No. 3
1. River diversion			
1-1 Diversion tunnel	74	46	78
1-2 Diversion canal	8	7	3
1-3 Diversion dam	3	4	9
Sub-total	85	57	90
2. Dam			
2-1 Excavation	24	21	19
2-2 Embankment	584	525	609
Sub-total	608	546	628
3. Service spillway			
3-1 Earth work	69	99	46
3-2 Concrete work	97	117	111
Sub-total	166	216	157
Total	859	819	875

6.1.4 Dam design

(1) Features governing design

- Sediment deposition, 100 years	20 MCM
- Spillway design flood	1,770 m^3/sec
- Intake discharge for irrigation	43 m^3/sec
- River diversion, 10-year probability	480 m^3/sec

(2) General description

The Upper Mae Wong dam is classified as a rockfill dam with an impervious center core. Major dimensions of dam and reservoir are summarized in Table 6.1.1. Site map, general plan and cross section of dam are shown in Fig. 6.1.4, Fig. 6.1.5 and Fig. 6.1.6 respectively.

The height of the dam will be 57 m above the dam foundation. The crest of the dam was designed at elevation 211.0 m with a minimum free-board of 3.5 m including crest road pavement thickness of 0.5 m and excluding camber allowance. The dam has 10 m top width. The length along the dam crest will be 794 m. The slope of the upstream and downstream faces of the dam was designed at 1:1.75 and 1:1.6, respectively. The total embankment volume of the dam will be about 2,500,000 m^3 and is divided into five zones, to permit optimum use of materials excavated from spillway and available in the vicinity of damsite.

The impervious core zone has maximum thickness of 22 m and volume estimated to be about 360,000 m^3. The source of materials to be used for core embankment will be deep-weathered granite and available from the borrow area located at about 2 km downstream, right side of the river. Stockpiling of core material will be required to accelerate weathering, to control moisture content and to obtain uniform quality.

Reservoir seepage through the embankment and underlying foundation will be controlled by 3.0 m wide filter zone along the downstream face of impervious core zone. The upstream filter zone was also designed to provide for relief of internal hydrostatic pressure and improved stability during rapid fluctuations in reservoir level.

The outer zones of the filter zone, both upstream and downstream, were designed to be semi-previous zone. Materials will be decomposed granite obtainable in the reservoir area less than two kilometers from the damsite. Excavated materials from diversion canal, service spillway and emergency spillway will also be utilized.

Rock zones will be divided into two zones, rock zone and transition zone, according to the rock size and gradation. Sources of rock materials are mainly excavations of service spillway, emergency spillway and dam cut-off trench. Expected rocks will be quartzite, calc-silicate and schist.

(3) Stability analysis

Stability of the dam against sliding was analyzed by means of sliced slip circle method for following cases.

Case A : End of construction with static condition

Case B : Rapid drawdown with static and seismic condition

Case C : Steady-state seepage condition with seismic force

Case D : Surface plate sliding

Results of analysis are summarized below and stability of dam was confirmed.

Case	Reservoir Water Level	Embankment Slope	Seismic Coefficient	Safety Factor	Min. Factor Required
A	Empty	Upstream	0	1.60	1.40
A	-	Downstream	0	1.44	1.40
B	El. 204.5 - El. 180	Upstream	0.03	1.42	1.10
C	El. 204.5	Upstream	0.06	1.35	1.30
C	El. 204.5	Downstream	0.06	1.39	1.30
D	El. 204.5	Upstream	0.06	1.33	1.20
D	-	Downstream	0.06	1.36	1.20

6.1.5 Foundation treatment

The dam foundation and abutments will be treated by curtain grout to seal all fractures, shears, joints and all cracks made during explosive excavation of cut-off tr nch. The maximum depth of curtain grout was designed at 20 m at abutments and under the cut-off trench.

In addition to the curtain grout, the consolidation grouts will be arranged into four rows. It was found that a small scale geological fault is crossing the emergency spillway site and the additional grouting treatment was included in the design.

6.1.6 Spillway

The Upper Mae Wong dam will have a service spillway of ungated side-channel type at rightside abutment and an emergency spillway of ungated chute type at about 1.5 km north of damsite. Design flood of 1,770 m^3/sec are allocated with 1,200 m^3/sec at 50-year return period for service spillway and with 570 m^3/sec for emergency spillway. Flood overflow depth was designed at 3.0 m at service spillway and 1.5 m at emergency spillway.

The reasons to layout the combined two spillways are topographic and geologic conditions and conveniences during construction. It is summarized as follows:

(1) Saddle shape topography is located at about 1.5 km north of damsite, where the ground elevation is about 210 m and lower than the dam crest elevation.

(2) A geological fault line is crossing this saddle portion and was confirmed by drilling hole No. 8. Some treatments will be necessary even without construction of emergency spillway.

(3) In the vicinity of the saddle portion, schist rocks are found and considered to be the quarry site nearest to the damsite.

(4) Delay or too much progress in the rock materials supply from the excavation of service spillway will not hinder the progress of dam embankment because of adjustment of material supply from the quarry site at emergency spillway.

6.1.7 River diversion

A diversion tunnel alignment was selected at left abutment from the topographic conditions. Diversion of the river will be accomplished through a concrete lined tunnel, 7.6 m in diameter and 230 m in length, which will pass the design flood of 480 m^3/sec with a water surface elevation of 173.0 m at upstream.

Geology along the tunnel alignment is expected to be hard rocks of schist, quartzite and calc-silicate. Since these rocks are hard, the tunnel will not require steel support except portal portions. Considering the subsequent increased costs for explosive excavation and concrete lining, the tunnel length was designed to be shortened as much as possible consistent with dam embankment safety by the use of approach channel and diversion channels excavation.

To avoid the possibility of over-topping during the early stage of construction, the crest of the upstream coffer dam was set at an elevation of 174.0 m. With this diversion tunnel, it has been estimated that the construction of dam will be protected from flood damage up to 10-year return period.

6.1.8 Intake and outlet works

For the purpose of furnishing irrigation water, the design discharge of 43 m^3/sec will be released with the minimum water surface elevation of 180 m in the reservoir. The intake structure was designed to be located at the inlet portion of diversion tunnel with a drop-inlet type. The outlet pipeline of 3.4 m in diameter will be located through diversion tunnel. The flow water through the pipe will be controlled by high pressure gate of 1.5 m in diameter.

Tunnel plugs will be provided at upstream portal of the diversion tunnel for closure and at the dam axis to resist reservoir pressure. The portal plug will contain temporary slide gate for closure.

6.1.9 Hydropower development works

The optimum hydropower development plan was examined changing the maximum discharge released from the Upper Mae Wong dam. Economic comparison was made based on the construction cost per kWh. Through the economic comparison, "Qmax. 18.5 m^3/sec" has been finally selected as the most economical maximum discharge in obtaining the annual energy production.

The followings are the salient features of the optimum hydropower development plan.

(1) Reservoir

Catchment area	612 km^2
Total storage volume	250 MCM
Effective storage volume	230 MCM
Dead storage volume	20 MCM
Water level	
Total storage level	El. 204.5 m
Flood surcharge level	El. 207.5 m
Dead storage level	El. 180.0 m
Reservoir area	
Total storage area	17.6 km^2

(2) Penstock

Type	Embedded
Inner diameter	3 m

(3) Powerhouse

Type	Semi-underground type
Dimensions (main building)	Width 19 m x length 19 m

(4) Power generation facilities

Unit capacity	6,500 kW
Number of unit	1
Type of turbine	Horizontal Francis type
Normal effective head	42.5 m
Discharge quantity	18.5 cm.m/sec
Rated capacity	6,500 kW
Revolving speed	300 RPM

(5) Transmission system — 30 km

6.2 Irrigation and Drainage Facilities

6.2.1 General

The major feature of the project is to properly supply the irrigation water to the paddy fields. The facilities required for the project include irrigation canals and their related structures, drainage canals and inspection road networks. The salient features of irrigation and drainage facilities are summarized in Table 6.2.1

6.2.2 Intake weirs

Two (2) intake weirs are proposed to divert the irrigation water to the Ban Tha Ta Yu irrigation area of 105,000 rai (16,800 ha) and the Khlong Saingu irrigation area of 51,000 rai (8,160 ha). For design of these weirs, RID prepared the topographic maps on a scale of 1/1,000 at the sites.

(1) Design flood discharge

According to the hydrologic study, the flood discharge with 50-year return period at the Upper Mae Wong dam site is estimated at 1,200 m^3/sec. The flow capacity of the Mae Wong river, however, is supposed to be less than 100 m^3/sec. The flood discharges of intake weirs for the existing small scale irrigation project is so designed as to be the same as the river flow capacity at the sites. Subsequently, the design flood discharges for the proposed intake weirs are estimated at 88 m^3/sec for the Ban Tha Yu and 63 m^3/sec for the Khlong Saingu based on the flow capacity calculated at the sites.

(2) Intake discharge

The unit peak irrigation water requirement with 5-year return period is estimated at 1.25 ℓ/sec/ha (0.20 ℓ/sec/rai) based on the results of irrigation water requirement estimation. Accordingly, the intake discharges to the irrigation service areas are calculated as follows:

Ban Tha Ta Yu area: 21 m^3/sec

Khlong Saingu area: 10.2 m^3/sec

(3) Design of intake weir

The intake weir of Ban Tha Ta Yu irrigation area would be 2.7 m high and 30 m long including the scouring sluice portion. In the left end of the weir, a scouring sluice with 2 sets of gate, 2.0 m wide and 1.5 m high, would be provided so that the deposited sand can be flashed down. The scouring sluice gate would be operated by man power. The intake gate would consist of 4 sets of slide gate, each 2.0 m wide and 2.5 m high, which would be operated by man power.

The intake weir of Khlong Saingu irrigation area would be 1.3 m high and 28 m long. Two (2) scouring sluice with stop-logs, 1.5 m wide and 0.8 m high would be provided on the intake weir body. The intake gate would not be necessary, because RID already constructed the Khlong Saingu regulator.

6.2.3 Irrigation canal system

Irrigation canal system to be provided under the project includes all the main canals and the lateral and sub-lateral canals. All the existing farmer's irrigation systems would be upgraded for incorporating into the project as many as possible.

(1) Canal

(a) Design discharge

The design discharge for the irrigation canals was calculated based on the unit irrigation water requirement of 1.25 ℓ/sec/ha (0.20 ℓ/sec/rai). Taking water management, soil textures, cropping patterns, adjustment of timing of irrigation water supply during the day, etc. into consideration, the following adjustment factor was adopted from USBR design standard.

Area (ha)	Adjustment Factor
20 - 50	3.0
50 - 150	1.75
150 - 250	1.20
250 - 500	1.15
500 - 1,500	1.10
1,500 - 2,500	1.05
2,500 and greater	1.00

The schematic irrigation diagrams are made by using above figures and adjustment factor (see DWG No. 16 to DWG No. 19).

(b) Canal lining

The proposed main canal route in the Khlong Saingu irrigation area runs along the Cenozoic Quaternary Pleistocen diluvial lower terrace on the upstream right bank of the Mae Wong river. The diluvial deposit is comparatively consolidated consisting gravels, sands, silts and laterite. The permeability is rather high. Consequently, the proposed main canal would be lined by concrete with 10 cm thick to protect seepage from the canal bank and bottom. No canal lining would be required for the proposed canals in the lowlying areas.

(c) Velocity

The maximum and minimum permissible velocities are as follows:

Canal	Maximum Velocity (m/sec)	Minimum Velocity (m/sec)
Concrete-lined canal	1.5	0.8
Unlined canal	0.7	0.5

(d) Roughness coefficient

The following Manning's roughness coefficient is used in the calculation of canal section:

Concrete-lined canal	0.015
Unlined canal	0.030

(e) Side slope

The side slope of canal is assumed at 1:1.5 referring the results of soil mechanical investigation in the irrigation area.

Considering the above design criteria, the preliminary designs of main canals and lateral canals were made as shown in DWG No. 23 to DWG No. 32.

(2) Related structures

Many different types of structures related to the irrigation canals are required in the irrigation canal system to effectively and efficiently convey and regulate the irrigation water. The following structures are proposed:

Function	Structures
1. Distribution of irrigation water	Turnouts
2. Regulation of irrigation water level	Checks, drops
3. Conveyance of irrigation water over or under road, river, streams, etc.	Syphon, culvert bridge
4. Protection of canal	Spillway, cross drain
5. Measuring of canal discharge	Parshall flume

The typical drawings of related structures are shown in DWG No. 33 to DWG No. 37.

6.2.4 Drainage canal system

The design discharge of respective drainage canals were calculated on the drainage modulus estimated in Section 5.4.3 (see DWG No. 20 to DWG No. 22). In design, the existing natural streams were incorporated into the proposed drainage canal network as far as possible. The designs were made with the same principles as those of irrigation canal system (see DWG No. 23).

6.2.5 Inspection road

For proper operation and maintenance of project facilities, well arranged inspection roads are of vital importance.

(1) Main inspection road

The main inspection road is required for inspection, operation and maintenance of the main canal. Considering the future increase of vehicles for the inspection and operation and heavy construction to be required for the canal maintenance and repair, all the main inspection roads are so designed as to have a width of 5 m and effective width of 4 m to be laterite-paved. These roads are also used for transportation of agricultural products, equipment and goods.

(2) Lateral inspection road

The lateral inspection road is mainly provided alongside the lateral canal. All these roads have a width of 4 m.

The typical cross section of inspection road is shown in DWG No. 23.

6.3 Construction Plan

6.3.1 Basic assumptions

(1) Workable days

25 days per month are applied to the workable days of normal works such as concrete works, foundation treatment works, construction works of irrigation facilities etc. On the other hand, as the impervious materials of dam embankment are affected by heavy rainfall, the workable days for these materials in a wet season are reduced from the 25 days of normal works, and total 286 days in a year are computed in accordance with the criteria.

(2) Definition of earth materials

The abbreviation of earth materials on the construction plan would be correlated with the geological definition as given in the table below:

Earth Materials of the Construction Plan	Abbreviation	Geological Definition
Sand, Filter, Drain	S	Sand, Gravel
Common Soil, Top Soil	C/S, T/S	Talus Deposit De-composed Granite
Gravel & Weathered Rock	G, W/R	Weathered Granite Group Weathered Green Rock
Excavated Rock	R	Green Rock*, Granite Group

Note: *: Quartzite, Calc-silicate, Schist

(3) Conversion rate of earth materials

The conversion rate of earth volume necessary for the estimation of earth work capacity by construction equipment is assumed as follows:

Earth Materials	Status of Material		
	In Place	Excavated	Compacted
S	1.00	1.20	0.95
C/S, T/S	1.00	1.25	0.90
G, W/R	1.00	1.20	1.00
R	1.00	1.60	1.30

(4) Basic method of earth works

Following equipments are basically introduced for earth works of the Project:

Earth Works	Earth Materials	Proposed Equipments
Excavation	Sand, Common Soil, Gravel	Bulldozer, Back-hoe Shovel
	Weathered Rock	Ripper Dozer, Back-hoe Shovel
	Rock	Blasting & Bulldozer
Loading	Any Kind of Excavated Materials	Tractor Shovel, Back-hoe Shovel
Hauling	Any Kind of Excavated Materials	Dump Truck
Spreading	Any Kind of Excavated Materials	Bulldozer
Compacting	Impervious Materials	Tamping Roller
	Coarse Materials	Vibration-Roller, Tire-Roller
	Common Soil	Compactor, Tamper

6.3.2 Dam construction

(1) Dam construction

(a) Earth moving plan

Taking into account the available earth materials, conversion rate of earth, most economical construction method, etc., the earth moving plan for the dam construction is confirmed as shown in Table 6.3.1.

(b) Construction procedure

After preparatory works, the dam construction works will be commenced from the beginning of dry season. The dam having enough length, the excavation works of the foundation can be progressed in parallel with river diversion canal and diversion tunnel works.

After completion of foundation excavation and foundation treatment, dam embankment will be commenced. Excavation of spillway will be executed in parallel to the dam embankment, because the useful excavated materials are planned to haul directly to the dam.

(c) Construction method

Diversion tunnel excavation will be executed by blasting and picking, and excavated muck is hauled to stock pile by dump truck. Concrete lining will be done by using steel form.

Excavation of dam foundation will be mainly made by heavy duty equipment such as bulldozer, ripper-dozer and back-hoe shovel. Rock excavation will be executed by blasting.

After excavation of the dam core trench, curtain-grouting will be executed by the combination of hydraulic boring machines and grouting pump.

According to the earth moving plan, embankment materials to be transported from the proposed areas will be spread by bulldozer at the specified thickness and compacting runs.

These specifications will be as follows:

Zone	Thickness of Spreading (cm)	Compaction (runs)	Compaction Machine
Core Zone	20	6	Tamping Roller
Filter & Drain	30	3	Vibration Roller
Semi-pervious Zone	25	6	Tire Roller
Transition Zone	50	4	Vibration Roller
Rock Zone	100	0	Bulldozer

Excavation of spillway will be executed following to the earth moving plan, and after completion of the excavation work, concrete works placed by concrete pump will be commenced.

The concrete works of intake structure will be also executed in parallel with the construction of spillway by the same method. Outlet steel pipe in diversion tunnel will be set up by using trolley and jack.

After completion of all facilities concerning to the dam construction, plug works in the diversion tunnel will be executed.

(2) Major temporary works

Taking account the proposed quantity and placement plan of concrete for the relevant structures, a concrete batching plant having 150 m^3/day of productive capacity and a aggregate production plant of 400 ton/day will be installed as a temporary construction equipments.

Furthermore, 500 kVA of power generator will be required for above equipment taking account a poor supply condition of electricity at the site.

Besides, construction of reservoir which can store the muddy water caused by the excavation works during the construction will be required.

6.3.3 Construction of irrigation and drainage facilities

(1) Canal construction

Excavation of main and laterals will be mainly made by heavy duty construction machineries such as bulldozer and back-hoe shovel, and man power will be contributed to the sub-lateral canals construction and the minor works.

A part of proposed main canals and laterals in the Khlong Saingu irrigation area will be lined with 10 cm thick of concrete. The concrete will be produced by portable concrete mixer and placed by man power with use simple sliding concrete form.

(2) Intake weir

The construction works of intake weir will be mainly executed during dry season in due consideration of magnitude of flooding in the river, and furthermore, the concrete placing of the weir will be executed by dividing into a scoring sluice portion and weir body portions taking account the diversion of river flow during constructions.

Concrete will be produced by several number of portable concrete mixers and placed using backet hanged by truck-crane.

6.3.4 Implementation schedule

The project implementation schedule is shown in Fig. 6.3.1. First two years will be necessary time for preparatory works including tendering, survey and mapping, detailed design works, construction of offices and quarters and so on. The actual construction works will be commenced from the third year.

Dam construction including relevant facilities will need five years in total.

After completion of the dam construction, plug works of diversion tunnel and minor works will be executed.

In parallel with the above dam construction schedule, hydro power facilities and irrigation facilities will also be executed and finished before completion of the dam construction, so as to enable to use stored water as early as possible.

6.4 Cost Estimate

6.4.1 Basic assumptions

The construction cost is estimated based on the following conditions:

(1) The unit prices are analyzed in constant mid-1985 current price basis prior to cost estimate.

(2) The exchange rate used in the estimate is shown as follows:

US$1.0 = ฿27 = ¥240

(3) The depreciation costs of machinery and equipment are considered in the estimate of the construction unit cost.

(4) Taxes on the construction materials, machinery and equipment to be imported from abroad are excluded in the cost estimate.

(5) The construction cost is divided into local and foreign currency portions. Local currency portion is estimated on the basis of current price in and around the project area. Foreign currency portion is estimated based on the CIF prices at Bangkok.

(6) The physical contingency, 10% of direct cost is included in the construction cost and price contingency is also taken into account at an annual escalation rate of 5% for foreign currency portion and 6% for local currency portion.

6.4.2 Financial construction cost

Financial construction cost comprises direct construction cost, land acquisition, resettlement, compensation, physical contingency, and price contingency. The total construction costs of the project are estimated at 2,895.1 million Baht, comprising 948.9 million Baht (32.8% equivalence of the total construction cost) of local currency portion and 1,946.2 million Baht (67.2% equivalence of the total construction cost) of foreign currency portion.

The summary of the construction cost is shown in Table 6.4.1.

6.4.3 Annual disbursement schedule

The annual disbursement schedule is worked out based on the construction implementation schedule. The details are stated in Table 6.4.2.

6.4.4 Annual operation and maintenance costs

The annual operation and maintenance costs including the salaries of project administration and water control staffs, the materials and labour costs for repair and maintenance of O & M equipment, and running cost of project facilities. The annual operation and maintenance costs are estimated at 32.0 million Baht. (Tables 6.4.3, 6.4.4)

6.4.5 Replacement cost

Some of the facilities, especially mechanical works have shorter useful life than the civil works and require replacement at a certain time within the project useful life. The Table 6.4.5 shows the useful life and replacement cost of the mechanical works.

CHAPTER VII ORGANIZATION AND MANAGEMENT

7.1 Organization for Project Execution

7.1.1 Royal Irrigation Department (RID)

The Royal Irrigation Department (RID) will be the main implementation body for the Mae Wong Irrigation Scheme (the Project). It will be resposible for the detailed design and construction of project works.

RID is in charge of planning, developing, operating and managing for most of all national and provincial level irrigation systems. RID has 35 Divisions and 12 Regional Offices under a Director General with assistance of three Deputy Director Generals and two Chief Engineers (see Fig. 7.1.1).

7.1.2 Electricity Generating Authority of Thailand (EGAT)

The main purpose of the Project is to irrigate the area of about 46,700 ha by constructing the Upper Maw Wong dam which has the gross storage capacity of 250 MCM. Incidentially, the Project has a possibility of hydropower generation of about 6,500 kW by using the dam head and the released water for irrigation. If the hydropower generation plan will be realized under the Project, the Electricity Generating Authority of Thailand (EGAT) will implement the design and construction of hydropower generation facilities.

7.1.3 Proposed Construction Office

For the execution of the Project, RID will appoint a Project Manager under the Deputy Director General. The Project Manager will be directly responsible for execution of the Project as a chief of the proposed Construction Office. The proposed organization structure of Construction Office is shown in Fig. 7.1.2.

Main functions of the Construction Office will be as follows:

- Financial arrangement needed for construction of dam and its related structures and irrigation, drainage and inspection road networks,
- Design and construction supervision of all the construction works including the assistance of tertiary development (on-farm development) to be done by farmers, and
- Accounting and management of construction works.

The Construction Office will consist of a main office and four branch offices taking the project scale into consideration. The main office will have four sections such as administrative, engineering, construction and tertiary development sections. The branch offices will take responsibilities for quality control of works, measuring of work quantities, records of work progress, etc. at each work site.

7.2 Organization for Operation and Maintenance

7.2.1 Proposed O/M Office

Generally, the followings should be taken into considerations for the proper water management:

- Planning of irrigation schedule,
- Control of irrigation water delivery,
- Hydrological measurement,
- Operation rule,
- Recording system (periodic data return),
- Maintenance and repair of project facilities, and
- Operation and maintenance equipment and facilities.

In light of the aboves to be considered, the Construction Office should be re-organized into the O & M Office after completion of construction works. A Project Engineer will be assigned as a chief of the O & M Office and responsible for operation and maintenance of the Project. The proposed organization structure is shown in Fig. 7.2.1. The Office will consist of a main office and four branch offices.

The main office will be responsible for all activities for operation and maintenance of the Project. The office will consist of two divisions, administrative division and technical division, and the technical division will have three sections, namely engineering, operation and maintenance and mechanical sections.

Four branch offices will be organized under the technical division of the main office. The main works of branch offices will be to carry out a daily work for operation and maintenance of the project facilities in their responsible areas in accordance with the irrigation schedule, maintenance program and instruction given by the main office. In addition, the periodic data collection will be also very important responsibility of the branch offices.

7.2.2 Water management

(1) Relationship of organization for the Project

The success of irrigation project depends fully upon the proper water management which assures the distribution of irrigation water in a timely and efficient manner as to meet the crop water requirements.

Nowadays, RID is facing with the following constraints and problems in water management for irrigation projects:

- Insufficient budget,
- Insufficient staff and qualified staff to operate the project,
- Insufficient equipment for water management, such as motorcycles, vehicles, construction machinery, etc.,

- Poor communication system, i.e. telephone, wireless set, walky-talky, etc., and

- Poor cooperation between farmers and RID staff.

For the proper water management, a suitable government organization and farmer's organization should be established to ensure that even distribution and optimum use of water available from the Project would be made for profitable irrigation farming through proper utilization of the project facilities.

In May 1985, the Cabinet approved a basic framework for post-construction operation/maintenance and management of irrigation project. This framework is to be applied to all ongoing and future projects, including the Project. In light of the basic framework, the relationship among O & M Office, governmental organizations and farmer's organization is presented in a diagram as shown in Fig. 7.2.2.

(2) Water management for the Project

The water management for the Project will broadly be divided into the water management for the Mae Wong river including the operation of the Upper Mae Wong dam and the water management for the irrigation service area.

In the full operation stage of the Project, the Mae Wong river will play an important role to feed the released water from the Upper Mae Wong dam to each irrigation service area. In order to assure the stable intake of irrigation water to the field at diversion points on the Mae Wong river, the river should properly be managed and maintained by RID (O & M Office). For this, the existing diversion structures on the river other than the proposed diversion structures under the Project should be removed and reclosed during the construction stage. Any violation action by farmers, such as bank cutting, blocking of the river course, stealing water by pump should be prohibited and protected.

Efficient operation of the irrigation systems in the irrigation area should ensure that the right amount of irrigation water is supplied to the crop at the right time. Accordingly, it is very important for the farmers to fulfill their planting time scheduled beforehand, because the delay of planting time gives a great influence on the water management. The water management of main systems such as intake facilities, main and lateral canals will be full responsibility of the O & M Office. The water management of on-farm facilities will be the responsibility of the farmers. For the proper water management at farm level, the establishment of Water User's Association by farmers themselves is indispensable.

(3) Water User's Association (WUA)

As already stated above, the operation and maintenance of the facilities in the tertiary block will be carried out by farmers themselves. Before completion of the construction works, the Water User's Association (WUA) should be established. There exist no WUAs in the project area. It is recommended to follow the following concepts for establishment of WUA:

- The member of WUA should be the owner farmers and/or tenant farmers whose cultivating lands will be served by irrigation water from a sole turnout,

- The benefited area of WUA is bounded by the tertiary block,

- WUA should be an antonomus organization and separated from the village administration,

- The member of WUA should pay the admission fee at the time of registration and annual fee thereafter, and

- WUA Federation should be established for systematic operation and maintenance works.

The proposed organization of WUA is shown in Fig. 7.2.3. WUA will have a committee which will consist of a chairman, deputies, treasurer and farmer's representatives. The chairman will be selected from and by the members and will manage the association. Irrigation supervisors who will be selected from the members of WUA, will carry out water management in the tertiary block, such as preparation of irrigation calender, handling the canal structures, diverting the schedule amount of water to the quarternary canals, supervision of maintenance works, etc. For the assistance of irrigation supervisor, the farmer's chief will be engaged in water management for the quarternary blocks. Each WUA shall have an advisory group which will consist of the head of village, agricultural extension worker and zoneman of the O & M Office (RID).

(4) Training of field staff and farmers

Proper operation and maintenance of the Project depends largely on the proper water management of farm level by the irrigation supervisors as well as the farmers and their cooperation with the staff of O & M Office. One of the main purposes of the O & M Office is to demonstrate the proper water management in the field and to train the irrigation supervisors and farmers in the practical irrigation farming. The training course of personnel related to the water management at farm level will consist of lecture and field practice. The training program shall be prepared by the O & M Office.

7.3 Future Improvement of Agricultural Support Systems

RID has been responsible for planning and construction of the irrigation works and for the operation and maintenance of the projects. It is not possible, however, for RID to provide all services which needed to maximize return from the project investment.

Under the Project, farmers will require the technical advices on farm management, farming practices and on-farm water management. Moreover, the supply of agricultural inputs necessary for irrigated farming is also needed. Agricultural credit is also essential for the purchase of agricultural inputs.

A part of these services has been rendered through private sector such as merchant, rice mill, etc. It is strongly expected that their activities will be enhanced for smooth supply of such services as more needs for such services will arise after implementation of the Project.

As regards the services provided through the Government agencies, it is recommended that these services should be provided through the existing channels (see Fig. 7.2.2). A new organization for providing agricultural supporting services will not be necessary.

However, it is desirable, in order to achieve successful implementation of the Project, that (i) the government agencies will provide the required services in close cooperation with others concerned, (ii) each agency will allocate their staff and/or budgets for the development of the project area as far as possible, within a framework of existing system in force. In addition to the above, the scope of the agricultural support services will have to be modified because the farmer's needs for supporting services may be changed to a certain extent after the completion of the Project. In order to cope with such changes, some institutional arrangement may be needed at national (Bangkok) and provincial levels.

It is therefore recommended that RID should study, in close coordination with other agencies concerned, the future institutional arrangement required for successful achievement of the development target, making reference to the experience obtained in other irrigation projects.

CHAPTER VIII PROJECT EVALUATION

8.1 General

The preliminary economic evaluations were carried out for eleven (11) alternative development options as part of the project optimization process discussed in Chapter V. The height of the Upper Mae Wong dam had been fixed at 57 m, corresponding to a reservoir storage capacity of 250 MCM, as the optimum size of the dam which also made optimum use of the available water resources.

The results from these initial evaluations, which revealed a number of economically feasible options, led to selection of the proposed development for an area of 291,900 rai (46,700 ha), enabling a cropping intensity of 105%. The development area comprises 230,000 rai (36,800 ha) of the existing irrigation areas and 61,900 rai (9,900 ha) of the extension area on the right bank of the Mae Wong river. In this Chapter, overall project evaluation is discussed in detail for this selected one particular case.

The project evaluation has been made through an assessment of project feasibility in view of economic, financial and socio-economic aspects. The economic feasibility is evaluated by calculating the internal rate of return (IRR) and the net present value (NPV) at the discount rate of 10%. Sensitivity analyses have also been made in order to elucidate the economic viability of the project against the changes in the benefits, build-up period, construction period and project costs.

Financial evaluation has been carried out by analysing the effect of the Project on a typical farm budget and by preparing the repayment schedule of the project capital cost.

The socio-economic impacts from the implementation of the Project have also been briefly studied.

8.2 Economic Evaluation

8.2.1 Basic assumptions

The economic evaluation has been made on the following basic assumptions:

(1) The construction period will be seven (7) years including two (2) years for detailed design and preparatory works.

(2) The economic useful life of the Project will be 50 years.

(3) All prices are expressed in constant mid-1985 prices.

(4) The exchange rate of US$1.00 = ฿27.0 = ¥240 as of mid-1985 is used throughout.

(5) Only irrigation benefit is counted in the evaluation, and any benefits to be derived from the fishery, hydropower generation, water release for downstream areas, etc., are not taken into account.

8.2.2 Evaluation of economic factors

For evaluation of economic prices and costs, the following criteria have been used:

(1) Standard convention factor (SCF)

In order to evaluate the project costs and benefits with respect to world market prices, a SCF of 0.92 has been applied to the price of non-traded goods and services. This figure has commonly been adopted in Thailand, as it has been recommended by IBRD in the Staff Working Paper No. 609, 1983.

(2) Transfer payment

From the viewpoint of the international economy, the transfer payments such as contract tax, duty, subsidy and interest are considered as a domestic monetary movement without direct productivity. These transfer payments are, therefore, excluded from the project cost as far as the economic analysis is concerned.

(3) Economic prices for agricultural outputs and inputs

The economic prices for farm products such as paddy and mung beans and farm inputs such as fertilizers and agro-chemicals have been estimated on the basis of the projected international market prices forecasetd for the year of 1995 by IBRD in the long-term range in 1983 constant US dollar. The IBRD forecasted prices are adjusted to 1985 constant price level using the factor of 0.977 based on manufacturing unit value (MUV) index computed by IBRD. The domestic components are adjusted by SCF of 0.92.

(4) Economic opportunity cost of farm labour

At present, a large part of the farm labour requirement are generally met by family labour. Seasonal labourers required for transplanting and harvesting are mainly hired from neighbours or small and/or tenant farmers in nearby area at the rate of ฿40/man-day. A general shortage of labour has been observed during the wet season. On the country, farm work is scarce during the dry season and the demand for farm labour decreases accordingly. Daily wages also fall by about 20 - 30% to an average ฿30/man-day during the dry season. With the implementation of the Project and a future situation with increased agricultural production, the average dry season wage rate would most likely increase to the level of the wet season wage rate. It is assumed that the present market wage rate is closed to the economic rate. The adjusted conversion factor for farm labour is therefore taken as 1.00 x 0.92 (SCF) being wage rate of ฿37/man-day both for the wet and dry seasons.

(5) Economic opportunity cost of unskilled construction labour

During the wet season, which is the season of peak demand for farm labour, the construction activities would slow down and labour would be less required. During the dry season, the Project would require more construction labour and such non-farm employment would be an attractive alternative for many of the local labour because of scarce farm work. In the case of short supply of unskilled construction labour, sufficient labour could be drawn from nearby areas. This suggests that the economic opportunity cost of unskilled labour corresponds to that of hired farm labour.

The fact observed in the Mae Wong area shows that, however, local labour require at least a 50% premium to be attracted to the construction work since it is harder work than in agriculture. This has been reflected in the financial wage rate that is an average ฿60/man-day, but should not in determination of the corresponding economic opportunity cost.

The economic opportunity cost of unskilled construction labour may be assumed to equal that of hired farm labour of ฿30/man-day during the dry season. Related to the average financial wage rate of ฿60/man-day, this would give a conversion factor of (฿30/฿60) x 0.92 = 0.46.

(6) Construction conversion factor (CCF)

The individual financial costs for major project components are split into four (4) categories of transfer payment, unskilled labour, non-traded costs and traded foreign costs, for each of which an economic/financial conversion factor is applied. The construction conversion factor (CCF) that is the weighted average of the above components, is calculated as 0.87 for the dam and 0.84 for the irrigation work, as shown in Table 8.2.1.

8.2.3 Economic benefits

The irrigation benefits are primarily derived from the increased crop production attributable to a stable irrigation water supply. These benefits are estimated as the difference of the annual net crop production values under future with and without project conditions.

The net production value is defined as the difference between the gross production value and the crop production cost. The net production values under future with and without project cnnditions are summarized as follows (for details, see Section 5.3):

(Unit: million ₿)

Description	Without Project	With Project	Increment
1. Gross production value			
(a) Paddy	420.0	869.3	449.3
(b) Mung beans	16.5	19.1	2.6
(c) Maize	11.4	-	-11.4
2. Total production cost			
(a) Paddy	182.3	265.2	82.9
(b) Mung beans	9.2	8.4	-0.8
(c) Maize	5.8	-	-5.8
3. Net production value			
(a) Paddy	237.7	604.1	366.4
(b) Mung beans	7.3	10.7	3.4
(c) Maize	5.8	-	-5.8
Total	250.8	614.8	364.0

It is assumed that the irrigation benefits will initially accrue from up-grading of the existing irrigation facilities in 6th year by 10% of full incremental benefits and 20% in 7th year, and after completion of dam construction, it will gradually increase during the build-up period of 5 years from 60% in 8th year to 100% in 12th year, as shown in Table 8.2.3.

8.2.4 Economic cost

(1) Capital cost

The project cost broadly comprises (1) cost for preparatory works, (2) construction cost for project facilities including contractor's overhead, profits and contract tax, (3) cost for land acquisition, (4) cost for compensation and resettlement, (5) administration expenses, (6) procurement cost of O/M equipment, (7) expenses for engineering services, (8) physical contingencies and (9) price contingencies. All these costs are estimated on a financial basis as given in Table 6.4.1.

The financial costs are convented into the economic costs by applying the CCF for each of major components (see Table 8.2.1):

Cost Component	Financial Cost (Million ₱)	CCF	Economic Cost (Million ₱)
(1) Dam & Reservoir	1,051.0	0.87	914.4
(2) Irrigation Works	638.8	0.84	536.6
(3) Office Quarters	24.2	0.77	18.6
(4) Land Acquisition, Resettlement & Compensation	28.0	0.92	25.8
(5) O/M Equipment	44.6	0.99	44.2
(6) Administration	42.9	0.92	39.5
(7) On-farm Development/1	-	-	11.4
(8) Physical Contingencies (10%)	183.0	-	159.1
(9) Engineering Services	235.3	0.89	209.4
(10) Price Contingencies	647.3	-	-
Total	2,895.1		1,959.0

Note: /1: The cost for on-farm development is not included in the financial cost estimate since the on-farm development is to be executed by the farmers themselves. It should be, however, included in the economic project cost (see Table 8.2.2).

(2) Annual operation and maintenance costs

The annual O & M cost estimated in Chapter VI includes the depreciation cost of O & M equipment and gates. In the economic evaluation, however, the depreciation is taken as the replacement cost, and accordingly it is excluded from the economic O & M cost. The O & M cost after exclusion of the said depreciation cost is then converted into the economic cost using respective CCF for each item:

Description	Financial Cost (Million ₱)	Conversion Factor/1	Economic Cost (Million ₱)
(1) Salaries & Wages	1.34	0.73	0.98
(2) Office Expenses	0.03	0.83	0.02
(3) O & M for Project Facilities			
(a) Dam	5.37	0.81	4.35
(b) Irrigation	15.97	0.80	12.78
Total	22.71		18.13

Note: /1: See Table 8.2.1

(3) Replacement cost

The replacement costs estimated in Chapter VI comprise (1) O & M equipment in every 10 years and (2) gates and their attachments in 25 years after project implementation. These costs are converted into the economic costs using a specific CCF of 0.99 for imported goods:

Description	Useful Life (year)	Financial Cost (Million ฿)	Con-version Factor	Economic Cost (Million ฿)
(1) O & M Equipment	10	44.6	0.99	44.2
(2) Facilities				
(a) Dam	25	27.6	0.99	27.3
(b) Irrigation Works	25	17.9	0.99	17.7

8.2.5 Internal rate of return (IRR)

The economic internal rate of return is calculated on the basis of the flows of economic benefits and costs mentioned above (see Table 8.2.3). The calculated result is:

IRR = 13.0%

8.2.6 Net present value (NPV)

The net present value at the discount rate of 10% is also calculated on the same assumptions mentioned above, and the calculated result is:

NPV = 475 million Baht

8.2.7 Sensitivity analysis

In order to evaluate the soundness of the Project against the possible changes in future economic conditions, sensitivity analyses are made for the following cases:

Case-1: 10% project cost increase due to unforeseen geological and topographical conditions and unexpected increases of material costs

Case-2: 10% project benefit decrease due to unexpected decrease in forecasted price of farm products and in crop yields

Case-3: Two years overrun of build-up period due to unexpected inefficiency in O & M management and agricultural extension services

Case-4: Two years overrun of construction period due to unexpected and unforeseen reasons

The effects of these changes on IRR and NPV (discounted at 10%) are summerized as shown below:

Case	IRR (%)	NPV (Million ฿) 10%
Case-1	11.9	331
Case-2	11.8	284
Case-3	12.5	406
Case-4	11.8	285

8.2.8 Results of economic evaluation

From the above results, the Project could be justified economically with IRR of 13.0% and NPV of 475 million Baht at the discount rate of 10%. The sensitivity analyses indicate that the economic feasibility of the Project is rather insensitive to the possible changes.

8.3 Financial Analysis

8.3.1 Financial cost

The financial cost estimated on the basis of the current prices as of mid 1985, is as follows:

(Unit: Million ฿)

Foreign Currency	Local Currency	Total
1,946.2	948.9	2,895.1

In this estimate, the price contingencies of 6% per annum for local currency portion and 5% per annum for foreign currency portion are included.

8.3.2 Farm budget analysis and payment capacity

In order to evaluate the Project from the financial aspect of the farmers, the farm budget analyses on different sizes of farmers are made under both future with and without project conditions as described in Section 5.3 of Chapter V.

The payment capacity is recognized as the ability of the project-benefited farmers to bear the expenses required for operation and maintenance of the project facilities as well as for repayment of capital cost. The payment capacity is measured by the difference of net disposable reserves under future with and without project conditions, which the farmers can actually earn from the Project after all the farm expenses and living costs are deducted from the gross farm income.

The payment capacity under the Project at the full development stage is estimated:

Payment Capacity

(Unit: ฿/farm/year)

Farm Size	Average Farm Size rai	Average Farm Size ha	Existing Irrigation Area (36,800 ha)	Rainfed Area (9,900 ha)	Weighted Average
(1) Small Size Farm (less than 20 rai)	7.5	1.2	6,800	10,100	7,500
(2) Medium Size Farm (21 - 50 rai)	28.1	4.5	24,600	37,700	27,400
(3) Large Size Farm (more than 51 rai)	75.0	12.0	66,100	103,000	73,900

The increased net disposable reserve would offer the incentives for farm reinvestment and further development to the farmers, and the substantial payment capacity would enable the farmers, if necessary, to make some payment for irrigation water.

8.3.3 Anticipated project revenue

In Thailand, the participating farmers are not imposed any water charges, but contribute indirectly to the government revenue and also by selling their rice surplus at low price which enable the exporters to contrive the export tax and premium.

Water charge will not be collected from the farmers. No direct project revenue is therefore anticipated. However, the Government will receive indirectly some revenue from the Project as rice export duties, rice expor premium and municipal tax. These indirect incremental revenue would amount to about 46.1 million Baht per annum in total under present regulations, as shown below:

Incremental Revenue	Amount (Million ฿)
Export Duties	16.8
Export Premium	19.4
Municipal Tax	9.9
Total	46.1

(1) Export duties

The export duties are imposed upon the export amount of rice at the rate of 2.5% against the basic price announced by the Ministry of Commerce. The exportable amount of rice to be produced in the Project area is about 105,000 tons (see Section 5.3). The basic prices for different quality of rice are averaged at ฿6,410 per ton. The anticipated export duties will therefore amount to about 16.8 million Baht.

(2) Export premium

A certain rate of export premium is imposed to the exporters upon the export amount of rice. The average rate of export premium for average quality of rice is about ฿185 per ton. It is expected that the Government will receive about 19.4 million Baht as export premium annually for the exportable surplus of 105,000 tons.

(3) Municipal tax

The municipal tax is paid by rice mills and exporters at the average rate of 2.2% for handling amount of rice valued at the current market price. The municipal tax will increase by about 9.9 million Baht for 105,000 tons of increased surplus at current market price of ฿4,300 per ton.

8.3.4 Repayment of project cost

It is assumed that the capital required for the project implementation will be arranged under the following conditions:

(1) For foreign currency portion, the capital is financed by bilateral or international organizations with an interest rate of 3.5% per annum for a repayment period of 30 years including 10 year grace period.

(2) For local currency portion, the capital is arranged by the government budget allocation with no repayment.

Based on the above conditions, the repayment schedule for the foreign currency portion is prepared as shown in Table 8.3.1.

8.3.5 Result of financial evaluation

The Project will bring about a great improvement in farm budget, and give an incentive for farm reinvestment to the farmers. The Project could be justified from the farmer's viewpoint.

Since no financial revenue is expected from the Project, difficulties are involved in justifying the financial feasibility of the Project. Following could, however, be said from financial viewpoint of the Project. During the repayment period of 30 years for foreign loan, the average amount of the government budget allocation required for covering the loan repayment, loan interest and O & M costs is about ฿125 million. The indirect financial revenue from the Project in terms of export duties, export premium, municipal tax and land tax is, on the other, estimated at about ฿46.1 million. Although it is not direct project return, it means that the Project will contribute such amount to the government budget. The farmers who will not pay any water charge and receive a large economic return, will spend their increased income for various purposes and the economic activities will thereby be enhanced. Increased tax revenue will also be expected from such future economic circumstances.

8.4 Socio-Economic Impacts

In addition to the direct project benefits counted in the economic evaluation, various secondary and intangible benefits and/or favourable socio-economic impacts are expected from the implementation of the Project. The major socio-economic impacts are described hereunder.

(1) Possibility of hydropower generation

The proposed Upper Mae Wong dam will provide a possibility of hydropower development. According to the preliminary study results, about 15,240 MWh of annual energy output will be produced with an installed capacity of 6,500 kW at the Upper Mae Wong dam. The construction cost will be about 167 million Baht or 11 Baht/kWh.

(2) Increase of potential fish production

After creation of the reservoir, the potential fish production will be increased to a great extent, and it would be made possible for the farmers to manage stable aqua-culture of valuable fishes. The estimated fish production in the reservoir is about 170 tons per annum which corresponds to a value of 8 million Baht per annum.

(3) Effective use of return flow

After implementation of the Project, about 53 MCM of return flow will drift down the Mae Wong river to other river basins in the wet season. About 4,800 ha of the paddy fields in the downstream basin could be irrigated with this return flow. The return flow in the dry season will be about 2 MCM. It could be utilized as a domestic water source in the downstream basis.

(4) Revenue from forestry resources

The forests with some economic value are observed in some parts of the reservoir area. The total net value is estimated at about 33 million Baht for a total merchandable timber volume of about 136,000 m^3, after deducting all the costs needed for logging and selling. These profits could be obtained by selling the timber trees in advance of the inundation.

(5) Foreign exchange earning

After completion of the projects, significant increase in crop production is expected. With the increased production, the marketable surplus of paddy and mung beans will also be increased. The estimated marketable surplus would be about 105,000 tons of rice and about 2,800 tons of mung beans.

These surplus would increase the annual amount of exports, resulting in the foreign exchange earning equivalent to around 945 million Baht per annum.

(6) Increase of employment opportunity

Employment opportunity to the local people will be increased by the project implementation, and a favourable impact will be given to the national economy. Furthermore, the employee will be able to gain more experience, technical know-how, skillfulness in the various working fields. These accumulations would be applied to the future development in the region.

(7) Improvement of local transportation

The local transportation will be much improved by the construction of the operation and maintenance road along the irrigation canals. The expanded road system will not only enhance the economic activity but also contribute to inter-regional accessibility and communication.

(8) Mitigation of flood damages

Flood control is not considered primary in the Project. However, incidental flood control could be realized to some extent by the operation of reservoir, especially in early part of the wet season.

CHAPTER IX ENVIRONMENTAL CONSIDERATIONS

9.1 Scope of Environmental Study

9.1.1 General

Dam and irrigation projects are generally considered influential in altering the environmental resources. The National Environmental Board (NEB) worked out "Guidelines for Preparation of Environmental Impact Evaluations" in 1979, with a view to conserve the environmental resources in Thailand. All the development agencies who propose to undertake construction of any new projects are requested by NEB to prepare an appropriate "Environmental Impact Statement (EIS)" in accordance with the said guidelines and to submit it to NEB for review and further actions.

The detailed EIS is required if the main features of the proposed project exceed the following guideline:

(1) Effective storage: 100 MCM

(2) Reservoir area : 15 km^2

(3) Irrigation area : 80,000 rai

The proposed Mae Wong Irrigation Scheme is larger than the above guideline in scale and therefore the detailed EIS will be required.

The environmental study required by NEB comprises manifold items of environmental impact evaluations. They are classified into four (4) categories (Table 9.1.1, to be referred) as follows:

(1) Physical resources

(a) Surface water hydrology

(b) Surface water quality

(c) Groundwater hydrology

(d) Groundwater quality

(e) Soils

(f) Geology/Seismology

(g) Erosion/Sedimentation

(h) Climate

(2) Ecological resources

(a) Fisheries

(b) Aquatic biology

(c) Wildlife

(d) Forests

(3) Human use values

- (a) Agriculture/Irrigation
- (b) Aquaculture
- (c) Water supplies
- (d) Navigation
- (e) Recreation
- (f) Power
- (g) Flood control
- (h) Dedicated area uses
- (i) Industry
- (j) Agro-industry
- (k) Mineral development
- (l) Highway/Railway
- (m) Land use

(4) Quality of life values

- (a) Socio-economic
- (b) Resettlement
- (c) Cultural/Historical
- (d) Aesthetic
- (e) Archaeological
- (f) Public health
- (g) Nutrition

In case of large scale dam/irrigation development like the Mae Wong Irrigation Scheme, a full-scale environmental study is required for preparation of the detailed EIS which will cover all the above items with appropriate analysis and recommendations in sufficient detail. However, such full-scale environmental study has not been included in the "Scope of Work for Feasibility Study on Sakae Krang River Basin Irrigation Project" for the reasons that (1) such environmental study will be made more efficiently after the project feasibility is surely verified and (2) NEB requirement for environmental impact evaluations has not been clearly specified yet and no detailed specifications for the required study and/or environmental standards have not been made available yet, therefore difficulties are involved in making such full-scale environmental study in sufficient detail within the limited time of study period under the present frame-work of the feasibility study.

Such being the case, only preliminary study is possibly carried out at the present stage of the study for the purpose to point out the present environmental problems and the anticipated alteration in environmental resources which may be caused by the project construction.

9.1.2 Scope of environmental study

The following method of environmental study was mutually agreed between RID and the JICA study team in the meeting held on March 14, 1985.

(1) Study area

The study area covers the Mae Wong river basin of 2,170 km^2 which may receive more or less environmental impacts by the development of dam and irrigation under the Mae Wong Irrigation Scheme.

(2) Study items

The environmental study required by NEB comprises manifold items of environmental impacts evaluations. In order to cover all the items, enormous efforts will be required for collection of data and information. All these items are, therefore, classified as listed in Table 9.1.2.

(a) For the items already included in the original scope of the feasibility study, additional data collection is made by the JICA study team in close cooperation with RID and the study results in those fields obtained through the feasibility study are fully utilized in the environmental impacts evaluations.

(b) For the remaining items which are not included in the original scope of the feasibility study, additional survey and data collection are required. RID is requested to make such survey and data collection to the extent that RID considers necessary. These study items are divided into two (2) groups: 1) the items which the JICA study team would assist RID to make the additional survey and data collection, and 2) the items that RID would be solely responsible for the additional survey and data collection.

The JICA study team makes the required study on the basis of the data and information to be collected in the above manner, and prepares a report on the environmental impacts evaluations as part of the feasibility study (not official EIS).

The major items that the JICA study team has carried out the additional survey and data collection are as follows:

(1) Ecological resources : Fisheries
Aquatic biology
Terrestrial wildlife
Forest

(2) Human use values : Aquaculture

(3) Quality of life values: Resettlement

9.2 Preliminary Assessment on Environmental Impacts

The anticipated environmental impacts affected by the Project are divided into two groups; i.e., (1) those by construction of dam and reservoir, and (2) those by development of irrigation system. The following items are conceivable as environmental impacts due to dam construction:

Physical resources

(1) Change of the river flow pattern, sediment transportation mechanism and water quality in the river system

(2) Increase of groundwater potential in the basin, particularly in Lower Mae Wong area

Ecological resources

(3) Impacts on aquatic fauna and flora

(4) Increase of productivity of aquatic life, especially fish population

(5) Impacts on terrestrial wildlife

(6) Loss of forest resources in the reservoir area

Human use values

(7) Mitigation of flood damages

(8) Development potential of hydropower

Quality of life values

(9) Inundation of farm lands and house in the reservoir area

(10) Development potential of recreation area in the vicinity of the reservoir

The following items are conceivable as environmental impacts due to development of irrigated agriculture:

Physical resource

(1) Change of soil fertility condition under the irrigation

(2) Change of water quality

Ecological resource

(3) Increase of productivity of fish production and possibility aquaculture in the irrigation area

Human use value

(4) Increase of crop production

(5) Acceleration of development for agro-industries and marketing activities in the irrigation area

(6) Provision of easy access to domestic water for farmers

Quality of life value

(7) Improvement of local transportation

(8) Increase of employment opportunity

9.2.1 Dam Construction

(1) Physical resource

(a) By the operation of the proposed dam, the pattern of river flow will be remarkably changed in the downstream of the damsite. However, the irrigation water from the dam is once released to the river channel and taken at the downstream diversion weirs to the irrigation areas. Thus, it is expected that the future river flow will become more steady than the present natural river flow and contribute to maintenance of river channel fisheries, local navigation, domestic water use, etc. The situation of the present river water quality will not turn worse.

(b) Exploitation of water resources by a storage dam and irrigation development will increase the potential of groundwater in the whole basin, particularly in the downstream area of the Mae Wong river. The present observation of groundwater in the area should be continued for future development.

(c) A storage dam on a river will change the transportation mechanism of sediment in the river system. In the upstream of the dam, sediment will be trapped in the reservoir and the channel bed of rivers flowing into the reservoir will be elevated because of back sand at the edge of the reservoir. The elevation of riverbed will cause flooding in the riparian area at the reservoir edge. The compensation of the land to be damaged will be a possible solution. In the dam design, it is planned that the lands of reservoir rim up to the flood water level of 207.5 m are to be compensated, and the cost has been counted in the project cost.

On the contrary, in the downstream of the damsite, reduction in sediment supply will cause degradation of the riverbed. Careful consideration will be taken in the design of such structures as diversion weir and bridge on the downstream river channel of damsite.

(2) Ecological resources

(a) Fisheries

The dam construction will create a new opportunity for fish production in the reservoir. The anticipated fish production is about 170 tons per annum which corresponds to the value of 3 - 8 million Baht. If aquatic culture is made in the reservoir, more fish production is expected.

(b) Terrestrial wildlife

The impact on wildlife will be derived from the loss of their habitats in the reservoir area. It is considered, however, from the following facts that the impact on wildlife is relatively small:

1) Forests in the reservoir area have already received the human pressure, and fauna is decreasing in number recently.

2) The area to be inundated in about 12,400 rai (19.8 km^2) or only about 3% of the whole watershed.

3) Most of wildlife in the reservoir area will be able to move toward surrounding area.

(c) Forests

Forests of 9,400 rai (15 km^2) which occupy about 2.5% of the whole watershed, will be inundated by dam construction. The endowed forest resources are evaluated as follows:

1) Two types of forest are observed in the reservoir area; Mixed Deciduous Forest and Dry Dipterocarp Forest. Most of them are second-growth forests with an average DBH (Diameter at Breast Height) of 14.3 cm.

2) Volumes of all merchantable trees in the reservoir are estimated to be 136,000 m^3 (488,000 trees). Only about 16% (21,000 m^3) of them are considered valuable as timber and others (115,000 m^3) are only usable for firewood.

Loss of Timber volumes will be relatively large but natural and commercial value of the forests is low.

(3) Human use values

(a) Although the proposed plan does not include flood control in its purpose, operation of reservoir will have incidental effects on flood control through reduction in flood frequency and peak discharge.

(b) The proposed dam will create the possibility of hydropower development. The estimated annual energy outputs are about 15.2 GWH. The hydropower generation will contribute to rural electrification.

(c) The regulated water flow resulting from the dam construction will improve the water supplies for domestic uses.

(4) Quality of life values

(a) Resettlement problems are most important as the reservoir area is partly occupied by about 100 households. Most of those villagers are illegal encroachers to the forest reserves in the reservoir area. However, their movable properties are subject to compensation and resettlement area for them will have to be prepared. Moreover this, the resettlement area is not easily found in the vicinity of porposed reservoir unless the reserved forest area is to be sacrificed. (Table 9.2.1 and Fig. 9.2.1)

9.2.2 Irrigation development

(1) Physical resources

The proposed irrigation scheme has been formulated and designed on the basis of technical assessment on present condition of fertility and water quality in order to minimize the environmental impacts in future. Serious impacts are not therefore anticipated.

(2) Ecological resources

The irrigation development will provide the farmers with more steady supply of irrigation water and thereby fish production will be remarkably increased in the prospective irrigation area. An aquaculture will also become possible if the farmers use the ponds for this purpose with steady supply of water.

(3) Human use values

(a) Irrigation will improve the present low land productivity and increase crop production in the Mae Wong river basin. The increased crop production may accelerate the further development of agro-industries and marketing activities in the area. It will also increase the employment opportunity.

(b) Upgrading of the existing canal system will also improve the situation of water shortage. New construction of irrigation canals in the rainfed area will provide the farmers with easy access to domestic water.

(4) Quality of life values

The inspection roads which will be constructed along the irrigation canals, will enhance the economic activities in the area. The improvement of road network will give favourable impacts to socio-economic aspects of the area.

9.3 Proposed Measures for Unfavourable Environmental Impacts

The environmental impacts will give more or less some influence to the Mae Wong river basin area. Most of the anticipated impacts are not serious. Further, unfavourable impacts will be minimized by taking the following consideration and measures:

(1) Dam construction

From the environmental points of view, dam designs should follow the following requirements:

(a) keeping natural beauty of the surrounding area intact,

(b) creating esthetically satisfying structures and land scapes, and

(c) causing minimal disturbance to the areal ecology.

Keeping the above in mind, the following measures should be considered in design and construction stages. The borrow areas should have their final slopes flattened to conform with the surrounding area and yet be flat enough for easy reseedings. Scenic overlooks should be provided for viewing the dam and reservoir. The river diversion works should be such that excessive siltation created during construction will not find its way into the downstream water. Unusable materials from excavation should be spoiled in the reservoir area. As much natural vegetation as possible should be left in place. Borrow area should be vegetated with grasses, trees, and shrubs, soon after the job is completed. All slopes cut adjacent to the reservoir area should be reseeded and mulched. Erosion control should be stated at the beginning of the job. Roads, cutslopes, and borrow areas should be provided with terrace, berms, or other check structures if required.

(2) Forests in the reservoir

In order to sustain the water quality in the reservoir, the forests should be lumbered before inundation. Since the forests that are economically valuable are found in some parts of the reservoir area, it is possible to gain the some profits by selling the merchandable timber trees. Clearing of the forests in the reservoir area should therefore be considered.

(3) Ecological resources

Quality, temperature, and flow change of river water are important to the survivals of fish and wildlife. The quantity of pollutants which will enter the stream during construction period should be kept to the minimum. For the future fishery development, care should be taken to avoid the entire destruction of vegetation in the reservoir areas. The forests along the anticipated waterfront of the reservoir should partially be maintained. Standing trees debris left in the reservoir area may provide habitats for several species of fish. Certain aquatic plants may be desirable for water birds feedings. Prior to the inundation, forest clearing of the reservoir area should be started from damsite toward the upperstream, in order to evacuate wildlife from inundation.

After completion of the Project, the accesibility to the upstream forest areas will much improved and further illegal logging and burning are anticipated. In order to prevent such future destruction of forests in the upstream areas, a strong government control will be required under present regulations.

(4) Resettlement

The impacts on living and working conditions of evacuees will be mitigated through resettlement program. Recommendable site for such resettlement is conceived in the forestry village area located in Amphoe Lat Yao. Practically it may not be easy to meet all the requirements of the resettlers who are the farmers in the forest. The important measures for such impacts will be provision of the agricultural support services during the initial stage of the resettlement. These will include followings:

(a) supplies of agricultural inputs, together with agricultural extension services for training the resettlers at site,

(b) establishment of the cooperatives for crop production as well as community development, and

(c) provision of credit for the resettlers during the pertinent term.

(5) Recreation

The rapid increase of rural population around the Nakhon Sawan municipality will cause a significant increase in the use of reservoir for recreational activities. In fact, in the existing Bhumiphol reservoir, fishing and boating have been enjoyed by local people. Provision, therefore, should be made to obtain the maximum recreational benefits from the completed reservoirs.

(6) Irrigation development

In order to minimize environmental problem on irrigation development, the following considerations and measures are recommendable:

(a) To avoid inflow of pollutants caused by construction works,

(b) To guide farmers for proper use of fertilizer and chemicals under irrigated agriculture,

(c) To practice appropriate farming such as fertilization, deep tillage and liming for keeping soil fertility, and

(d) To make a long term improvement in hygiene and sanitation.

CHAPTER X RECOMMENDATION

10.1 Early Implementation of the Project

Agriculture in Thailand accounts for about 24% of GDP, 74% of national labour force and 65% of total export. It has been and will continue to be the most important key determinant in national economy of Thailand.

During the last decade, the agricultural production has expanded at annual rate of 5% mainly owing to expansion of farmland. It is recognized however among the government officials concerned that further expansion of farmland has become difficult due to the limited land resources. Under such situations, more emphasis will have to be paid to the improvement of agricultural productivity, in order to uplift the living standard of the farmers who occupy the majority of the nation and also to improve the agricultural structure which basically constitutes the framework of the national economy.

For improvement of agricultural productivity, irrigation development coupled with exploitation of new water resources, is the most important and will have to be realized under the long term government program, irrespective of present difficulties in social-economic-financial aspects.

Rice is by far important crop in Thailand, accounting for 60% of the total farmland, 36% of the total crop production value and 21% of the agricultural export. Paddy yield is however still at low level, ranging from 255 kg/rai (1.6 tons/ha) to 326 kg/rai (2.0 tons/ha) in the last decade. If the present low yield is continued, the present level of rice export (3 - 4 million tons/year) will not be maintained because of increasing domestic demand for rice. The World Bank forecasts that in order to meet the domestic demand and maintain the present level of rice export, the irrigated paddy fields will have to be expanded at an average rate of 4% per annum.

Rice is produced throughout the country. Rice surplus for export is however mainly supplied from the Central Chao Phraya Plain. Other rice producing areas may not afford to produce the surplus. This situation will not change even in future. Agricultural development in rice-deficit areas is, needless to say, necessary for improvement of poor economic situations in these areas; however, it will limitedly contribute to the national agricultural production as a whole, because of the limited availability of land and water resources. The Chao Phraya river basin is endowed with large land and water resources and still have a potential for further irrigation development which requires less investment and sustains high economic returns. It is therefore considered that the irrigation development in the said area will largely contribute to the effective utilization of domestic natural and financial resources.

The Sakae Krang river basin which extends over the northeastern part of the Central Chao Phraya Plain, is endowed with the vast land resources suitable for rice production. Water resources, however, have not been fully exploited for agricultural development. About 0.32 million people in the

Sakae Krang river basin primarily rely on rice cultivation. The area is surely suitable for rice cultivation in economic-social-historical-cultural-physical context. The farmers are accustomed to rice cultivation and heavily rely on this crop economically. It however gives them only instable and poor result of yield due to irregular supply of water.

Two provinces of Nakhon Sawan and Uthai Thani where most of the Sakae Krang river basin are included, have about 2.6% of the Kingdom's population. The share of the provinces in GDP is however only less than 1.3%. The relatively poor position of the area is also indicated by its lag in per capita income; the average in the past five years amounts to about 3,670 Baht, corresponding to roughly two-thirds of national average (5,610 Baht). The area suffers also from the instability in annual income which fluctuates largely year by year. Such poor economic situation of the area is mainly derived from low productivity of agriculture.

The farmers in the Sakae Krang river basin have concentrated their efforts to improve the agricultural productivity by constructing the irrigation facilities by themselves. Due to unstable river flow, however, these facilities are not fully utilized. This means that if new water resources are exploited, the existing farmers irrigation systems will effectively be utilized at less additional investment cost and agricultural production will drastically increase.

Agricultural development in the Sakae Krang river basin should thus be primarily geared to the irrigation development inclusive of new water resources exploitation. The feasibility study on the Sakae Krang River Basin Irrigation Project identified, with this in view, the following irrigation development projects:

(1) irrigation of 291,900 rai (46,700 ha) by Upper Mae Wong dam (Mae Wong Irrigation Scheme),

(2) irrigation of 111,900 rai (17,900 ha) by Khlong Pho dam,

(3) irrigation of 81,300 rai (13,000 ha) by Upper Khun Kaew dam, and

(4) groundwater irrigation development of 218,800 rai (35,000 ha) in the downstream areas.

It is recommended that these projects be realized gradually in several stages. As discussed in previous Chapters, the first stage of the irrigation development in the Sakae Krang river basin should be the Mae Wong Irrigation Scheme which will cover the largest irrigation area and give the largest economic impacts to the area.

The Mae Wong Irrigation Scheme (the Project) is technically sound and economically feasible. About 74,500 people in the project-benefited area have long desired its early implementation. Irrigation development in the Sakae Krang river basin was started in the Thap Salao area in the Uthai Thani province and the Mae Wong area which belong to the Nakhon Sawan province, has been left behind. This situation causes some social tensions.

If project implementation is delayed, the watershed area will be encroached by illegal immigrants and the forests will be cleared for farming. These will result in more serious problems of water shortage and floods in the downstream area. The implementation of the Project will also become difficult, if construction is delayed, because of the increasing number of illegal immigrants in the reservoir area.

With such background, it is highly recommended that the Project be implemented as early as possible.

10.2 Further Survey and Investigation for Project Implementation

(1) Photogrammetric mapping

In the feasibility study, the topographic maps on a scale of 1/10,000 made by RID were mainly used for the preliminary design works of dam and reservoir, and irrigation facilities. More accurate topographic maps, however, are required for the detailed design works of the Project. Before commencement of the detailed design works, the following topographic maps should be prepared by means of photogrammetric mapping to smoothly implement the Project.

- Topographic maps on a scale of 1/5,000 with 0.5 m contour intervals covering the entire irrigation service area, and

- Topographic maps on a scale of 1/5,000 with 1.0 m contour intervals covering the proposed reservoir area.

(2) Geological investigation

The seismic exploration was recommended for the geological investigation of proposed damsite during the course of the pre-feasibility study. However, the exploration could not be executed due to difficulty of preparatory works. It is recommended that the geological investigation by means of seismic exploration and core boring at the proposed dam axis and both service and emergency spillway sites should be executed and completed before commencement of the detailed design works.

(3) Survey for establishment of resettlement program

The resettlement program is an important step to the project implementation. In the feasibility study, the preliminary resettlement plan was formulated based on the data from RID. Many governmental agencies will be associated for establishment of the resettlement program. More detailed field survey in the reservoir area should be carried out to smoothly establish the resettlement program. Such aspects as land use, house, population, public facilities, etc. should be clarified through the field survey. The topographic survey for the potential site proposed in the feasibility study should also be carried out in collaboration with the other governmental agencies concerned.

10.3 Ancillary Works related to the Project

To successfully implement the Project and maximize the impacts from the Project, the following matters should be considered in collaboration with the other governmental agencies concerned:

(1) Hydropower development

In the feasibility study, it was found that the substantial hydropower development would become possible if the Project would be realized. It would greatly contribute to the effective utilization of the endowed water resources and also to the increasing power demand in the project area. It is recommended that further detailed study of the hydropower development should be carried out in collaboration with EGAT.

(2) Inland fishery

The possibility of aquaculture in the reservoir area was identified through the preliminary study. The estimated fish production is about 170 tons per annum which corresponds to a value of 8 million Baht per annum. Although production of aquaculture is not so large, its activity will play an important role for providing the rich protain food to people, especially those living in the depressed rural areas. Further detailed study of aquaculture should be made to increase the impact from the Project.

(3) Strengthening of agricultural support system

In order to ensure the proposed agricultural development plan and to reap the fruitful project returns, the current agricultural support system should be strengthened through increase of staff and budget allocation. In particular, cooperative movement should be enhanced through effective extension services.

(4) Establishment of Water User's Association

The water management at farm level is very important to ensure the right amount of irrigation water to the paddy fields. The water management of on-farm facilities will be the responsibility of farmers. For the proper water management at farm level, the establishment of Water User's Association (WUA) by farmers themselves is indispensable. Since there exist no WUAs in the project area, WUA should be established before completion of the construction works.

10.4 Further Studies for Possible Irrigation Development Projects

Following the implementation of the Upper Mae Wong Irrigation Scheme, the remaining possible irrigation development projects would be implemented gradually in several stages as recommended above. According to the overall implementation schedule of possible irrigation development projects prepared in the pre-feasibility study, the further studies for these remaining possible projects should be carried out in due order.

TABLE

Table 4.3.1 METEOROLOGICAL DATA FOR THE PERIOD 1951-1980 AT NAKHON SAWAN

Lat 15-48 N
Long 100-10 E

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (°C)													
Mean	25.6	28.3	30.7	31.9	30.6	29.6	29.0	28.5	28.0	27.9	26.7	25.2	28.5
Mean Max	32.2	34.5	36.7	37.9	36.1	34.5	33.8	33.1	32.2	32.0	31.5	31.1	33.8
Mean Min	17.7	21.0	23.7	25.3	25.1	24.7	24.3	24.1	23.9	23.5	21.0	18.2	22.7
Ext Max	37.0	39.8	41.2	42.5	42.7	41.0	38.9	37.8	36.3	35.9	35.7	35.8	42.7
Ext Min	6.1	12.0	14.2	17.0	20.3	21.4	20.9	20.9	20.4	18.4	11.9	8.2	6.1
Relative Humidity (%)													
Mean	63.0	62.0	61.0	61.0	70.0	74.0	75.0	78.0	82.0	80.0	73.0	67.0	70.0
Mean Max	87.3	86.9	87.3	86.5	89.1	90.5	91.5	92.9	95.5	94.7	92.4	89.9	90.4
Mean Min	41.3	40.3	39.1	40.8	51.2	56.6	58.4	62.0	66.4	63.3	53.9	45.9	51.6
Dew-Point (°C)													
Mean	17.1	19.3	21.2	22.7	23.8	23.9	23.8	24.0	24.4	23.7	20.8	17.9	21.9
Evaporation (mm)													
Mean - Pan	150.6	174.9	232.8	260.3	218.9	184.1	174.3	153.2	127.7	138.8	132.8	140.5	2088.9
Wind (knots)													
Previaling wind	E	S	S	S	S	S	S	S	S	S	E	N	--
Mean wind speed	3.7	4.8	6.3	6.4	5.4	5.5	5.0	4.4	3.2	3.0	3.4	3.5	-
Max wind speed	33NE	58S	62N	60N	70S	50S	52S	45SSW	65N	54NE	27NW	27E	70S
Sunshine Duration (hr)													
Mean	264.1	242.9	249.0	259.2	243.0	186.2	174.2	169.0	158.7	228.6	256.8	275.5	2707.2
Cloundiness (0-8)													
Mean	3.0	3.3	3.3	4.0	5.6	6.4	6.7	6.9	6.6	5.4	4.2	3.4	4.9

Table 4.4.1 MONTHLY RIVER RUNOFF SIMULATED BY TANK MODEL (1,000 cum/sq. km)
THE MAE WONG RIVER AT GAGING STATION : CT-5A

Water Year	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1954	0.9	1.6	8.9	18.2	40.3	83.1	128.8	9.0	3.8	2.9	1.7	1.0	300
1955	0.9	6.2	21.0	27.1	51.7	96.0	67.0	11.6	4.6	3.6	3.0	2.5	295
1956	1.9	5.5	17.9	13.2	62.8	108.1	82.6	15.5	5.6	4.7	3.7	3.0	324
1957	2.6	1.9	12.5	48.5	74.8	106.0	172.2	14.0	5.8	4.9	4.0	3.3	451
1958	2.3	1.6	14.5	39.1	39.5	104.9	135.3	11.7	5.1	4.1	3.0	2.1	363
1959	1.6	1.5	7.8	20.3	77.9	107.4	132.8	16.1	5.1	4.1	3.0	1.7	380
1960	0.4	0.5	8.7	15.8	36.6	62.2	109.7	27.5	4.1	3.2	2.2	1.3	272
1961	0.5	5.8	27.6	20.3	79.9	103.9	111.3	20.2	4.7	4.0	2.9	1.7	383
1962	1.2	1.4	5.5	21.9	57.3	116.0	128.7	12.3	4.8	3.8	2.8	1.8	358
1963	0.9	0.8	2.7	12.8	43.4	87.5	158.0	54.7	4.9	4.0	2.9	1.7	374
1964	0.9	3.9	32.9	41.5	54.9	122.2	175.9	55.8	6.0	5.0	4.1	3.4	506
1965	2.2	2.2	16.9	14.7	37.6	97.4	102.2	24.6	5.7	5.6	4.7	3.9	318
1966	3.1	3.4	12.4	14.5	46.4	85.6	70.7	39.5	6.6	6.1	5.0	3.6	297
1967	2.9	4.2	17.7	11.6	12.0	48.1	66.8	15.1	5.8	4.8	3.8	2.8	196
1968	2.7	10.1	18.7	37.0	69.7	34.3	31.8	10.9	5.2	4.7	3.7	2.6	231
1969	1.4	1.9	4.2	5.6	22.7	70.2	54.6	61.9	10.8	4.3	1.8	1.4	241
1970	1.6	14.6	26.3	11.5	46.1	53.1	134.4	61.6	56.2	12.7	5.7	3.7	427
1971	3.1	9.1	13.7	19.2	32.6	68.9	109.1	50.5	11.7	6.5	3.2	2.4	330
1972	1.2	0.8	0.8	4.2	5.8	72.1	155.4	87.0	47.0	15.3	6.9	5.9	402
1973	3.2	8.6	33.6	20.2	18.8	80.1	128.3	42.6	19.8	11.1	6.4	5.7	379
1974	11.2	13.3	9.3	8.9	31.9	172.0	222.1	99.8	20.0	17.5	8.3	5.4	620
1975	4.1	15.8	23.4	14.0	15.2	79.8	133.0	59.4	20.5	11.2	5.7	3.9	386
1976	3.0	16.4	4.7	5.2	23.0	88.2	95.8	107.8	11.1	5.6	2.2	1.4	364
1977	2.4	4.5	2.0	3.5	5.8	27.9	26.5	9.4	3.5	2.0	1.4	1.5	90
1978	1.4	8.8	6.3	35.9	26.6	89.9	159.7	20.9	9.1	4.4	1.9	1.3	366
1979	1.5	5.1	28.7	7.2	7.9	103.4	55.6	8.6	3.9	2.3	1.3	0.7	226
1980	1.3	76.7	31.1	23.3	26.8	87.2	220.3	30.4	9.4	5.5	4.0	3.4	520
1981	4.9	15.8	23.9	18.8	27.8	59.0	96.4	59.4	24.6	6.4	3.0	2.2	342
1982	2.3	9.6	16.5	13.7	18.4	27.0	61.8	14.7	7.9	5.5	3.8	3.6	185
1983	0.6	3.7	12.3	9.6	33.5	112.7	422.6	235.3	25.7	13.6	9.2	5.3	884
Mean	2.3	8.5	15.4	18.6	37.6	85.1	125.0	45.0	12.0	6.3	3.8	2.8	360

Note ; 1954 - 1968 ; generate by tank model
1969 - 1983 ; observed at CT-5A

Table 4.5.1 CHRONOLOGY

Symbol	Era	Period	Epoch/Series	Name	Remarks
Q	Cenozeic	Quaternary	Recent	Alluvial	flood plain alluvials, sand, silts develops at along rivers and back swamp
Q1			Pleistocen	Diluvial	old flood deposits of gravel, sand, silt and laterite
	(Unconformity)				
Gr				Igneous Rocks	granite, grano-diorite, diorite & quartz
rh	Mesozoic				rhyolite, andesite
Mz		Jurassic	Khao Chonkan Formation		mainly red sand stone, shales, minor conglomerates and volcanic conglome
	(Unconformity)				
P		Permian	Ratbri Group		massive, grey limestones with fusulinids, minor shale, chert and conglomerate
C	Paleozoic	Caboniferous	Takli Sand Stones		intercalation of red shale sandstone, quartz sand stone; intersified conglomerates and reddish grey shale and sandstone
			(Unconformity)		
SDc		Devorian	Kao Gob Cherts		mainly chertbeds and thinly interbedded tuff and shale
SDm		Silurian	Kao Mano Marble		mainly grey to white, massive to poorly beeded marble
SDt			Kao Luang Tuff		mainly quartz, fields pathic tuff, green schist and greywake
SD					undifferentiated sequences of quartzite, phyllite; greywake chert bed and local conglomerates
			(Unconformity)		
O		Ordovician	Thung Song Group		
Eo		Canbro-Ordovician	Phubon Marble		micaschist, contorted marble and minor calc-silicate rock
E		Cambrian	Huai Wai Quartz		quartzite, phyllite and quartz biotite schist
			(Unconformity)		
Pe		Proterzoic	Precambrian	Uthai Thani Complexes.	

Table 5.2.1 EFFECTIVE STORAGE/ANNUAL INFLOW

Dam	River	Purpose	Catchment Area (km^2)	Annual Inflow A(MCM)	Effective Storage E(MCM)	E/A
1. Bhumibol	Ping	I,P,F	26,386	8,600	8,600	1.0
2. Sirikit	Nan	I,P,F	13,130	7,006	8,800	1.26
3. Chulabhorn	Phrom	P	545	170	165	0.97
4. Kang Krachan	Petchburi	I,P,F	2,200	880	640	0.73
5. Lam Phra Phloeng	Lam Phra Phloeng	I,F	807	116	145	1.25
6. Pranburi	Pranburi	I,F	2,029	320	375	1.17
7. Sirindhorn	Lam Dom Noi	I,F,P	2,097	1,313	900	0.69
8. Lam Takhong	Lam Takhong	I,F	1,430	212	290	1.37
9. Nam Pung	Nam Pung	I,P	297	106	122	1.15
10. Lam Pao	Huai Yang	I,F	5,960	1,363	1,260	0.92
11. Ubon Ratana	Nam Pong	I,P,F	11,980	1,750	1,920	1.10
12. Nam Un	Nam Un	I,F	1,100	365	475	1.30
13. Pattani	Pattani	I,F,P	2,080	1,460	1,100	0.75
14. Krasieo	Krasieo	I,F	1,200	165	200	1.21
15. Khao Laem	Quae Noi	P,T,F	10,640	5,500	7,450	1.35
16. Mae Ngot	Mae Ngot	I,F,P	1,281	406	265	0.65
17. Mae Kuang	Mae Kuang	I.F,P	569	254	311	1.22
Average			4,925	1,764		1.06

I : Irrigation
P : Hydropower
F : Flood Control

Table 5.2.2 ACTUALLY IRRIGATED AREA

(Unit : rai)

Irrigation Block	Irrigation Service Area	Actually Irrigated Area: Average Year (1954 to 1982)	80% Dependable Year (1982)	Dryest Year (1977)
MW1	105,000	85,000	81,900	48,300
MW2	10,000	6,600	4,900	1,600
MW3	3,000	2,800	2,900	2,100
MW4	3,000	1,800	1,200	300
MW5	73,000	44,500	30,000	11,000
MW6	10,000	9,200	9,700	7,000
MW7	26,000	13,500	6,800	2,300
Total	230,000	163,400	137,400	72,600
		(71%)	(60%)	(32%)

Note ; BW1 : Ban Tha Ta Yu
BW2 : Khlong Saingu
BW3 : Huai Hin Lab
BW4 : Ban Wang Nam Khao
BW5 : Khun Lard Boriban
BW6 : Khlong Nam Hom
BW7 : Wang Ma

Table 5.2.3 RESULTS OF WATER BALANCE CALCULATION UNDER WITH-PROJECT CONDITION

Alternative Case	Irrigable Area (ha)	Gross Reservoir Capacity (MCM)	Cropping Intensity (%)
101	36,800	200	100
102	36,800	250	105
103	37,600	250	100
104	37,600	290	100
201	36,800	120	100
202	36,800	250	130
203	48,300	250	100
204	48,300	290	100
205	42,400	170	100
206	42,400	250	116
207	45,600	200	100
208	45,600	250	108
209	46,700	220	100
301	46,700	250	105
302	46,700	290	105

Note : Existing Irrigation Area = 36,800 ha
Potential Maximum Development Area = 46,700 ha

Table 5.2.4 RESULTS OF WATER BALANCE CALCULATION (CASE 301)

(Unit : 10^3 m^3)

Year	Inflow	Release for Irrigation /1	Evaporation	Spillout	Deficit
1954	186,570	158,271	15,771	75,389	0
1955	180,776	193,279	14,075	2,072	0
1956	196,781	144,626	15,164	0	0
1957	275,353	96,354	16,122	151,228	0
1958	221,851	170,294	15,630	50,161	0
1959	230,936	120,083	15,744	96,106	0
1960	169,826	174,190	14,409	0	0
1961	232,091	120,114	15,761	68,411	0
1962	218,252	138,071	15,569	76,718	0
1963	230,919	115,113	16,435	56,839	0
1964	309,768	60,024	17,271	231,020	0
1965	195,743	152,539	16,401	44,942	0
1966	182,081	163,908	16,122	0	0
1967	123,339	301,460	6,459	0	0
1968	135,804	298,943	2,784	0	154,407
1969	155,223	201,911	5,009	0	87,876
1970	259,108	198,794	10,619	0	48,698
1971	195,740	188,611	12,644	0	0
1972	252,293	183,007	13,832	0	0
1973	239,414	213,530	15,730	0	0
1974	376,448	92,700	17,360	242,150	0
1975	236,002	137,644	17,379	80,978	0
1976	215,393	200,379	16,886	13,099	0
1977	57,336	361,315	4,065	0	98,042
1978	221,867	150,871	9,304	0	0
1979	182,122	316,153	2,855	0	93,852
1980	282,828	134,009	13,531	0	0
1981	204,075	165,131	16,019	0	0
1982	108,338	279,883	8,021	0	0
Mean	209,527	180,386	12,999	41,004	16,651

/1 : Including the release water of 2,652 x 10^3 m^3 for the people living in the Lower Mae Wong area.

Table 5.2.5 CONSTRUCTION COST OF ALTERNATIVE PLAN

(Unit: 10^6 ฿)

Work Item	Alternative Plan										
	101	102	103	201	202	205	206	207	208	209	301
1. Construction Cost (including overhead, profit, tax)											
1.1 Dam Construction	1,006.6	1,051.0	1,051.0	824.6	1,051.0	955.4	1,051.0	1,006.6	1,051.0	1,042.5	1,051.0
1.2 Irrigation Facilities	10.6	10.6	23.7	449.3	449.3	590.0	590.0	626.3	626.3	626.3	638.8
1.3 Office & Quarters	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2
Sub-total	1,041.4	1,085.8	1,098.9	1,298.1	1,524.5	1,569.6	1,665.2	1,657.1	1,701.5	1,705.5	1,714.0
2. Land Acquisition, Resettlement & Compensation	17.3	17.3	17.3	25.7	25.7	27.0	27.0	27.7	27.7	28.0	28.0
3. O & M Equipment	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6
4. Pump	47.7	47.7	47.7	-	-	-	-	-	-	-	-
5. Administration	26.0	27.1	27.5	32.5	38.1	39.2	41.6	41.4	42.5	42.6	42.9
6. Physical Contingency	117.7	122.3	123.6	140.1	163.3	168.0	177.8	177.1	181.6	182.1	183.0
7. Engineering Services	117.7	117.7	119.7	210.4	210.4	224.5	224.5	235.3	230.4	230.4	235.3
Sub-total	371.0	376.7	380.4	453.3	482.1	503.3	515.5	526.1	526.8	527.7	533.8
Total	1,412.4	1,462.5	1,479.3	1,751.4	2,006.6	2,072.9	2,180.7	2,183.2	2,228.3	2,233.2	2,247.8

Note: Price contingency is excluded.