Kingdom of Thailand
Royal Irrigation Department
Ministry of Agriculture and Cooperatives

FEASIBILITY STUDY

ON

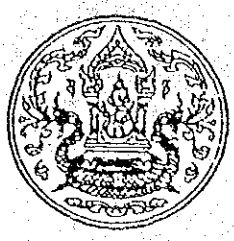
MAE CHANG IRRIGATION PROJECT

MAIN REPORT

JANUARY 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

No.



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PREFACE

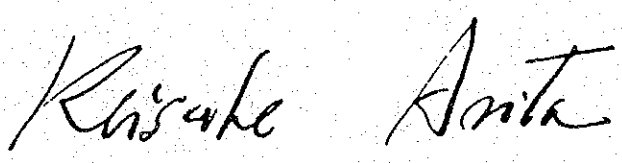
In response to the request of the Government of the Kingdom of Thailand the Japanese Government decided to conduct a feasibility study on the Mae Chang Irrigation Project and entrusted the study to the Japan International Cooperation Agency. The JICA sent to Thailand a preliminary survey team in October, 1982, the first survey team from January to March, 1983, and the second survey team from June to August 1983.

The teams exchanged views with the officials concerned of the Government of Thailand. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

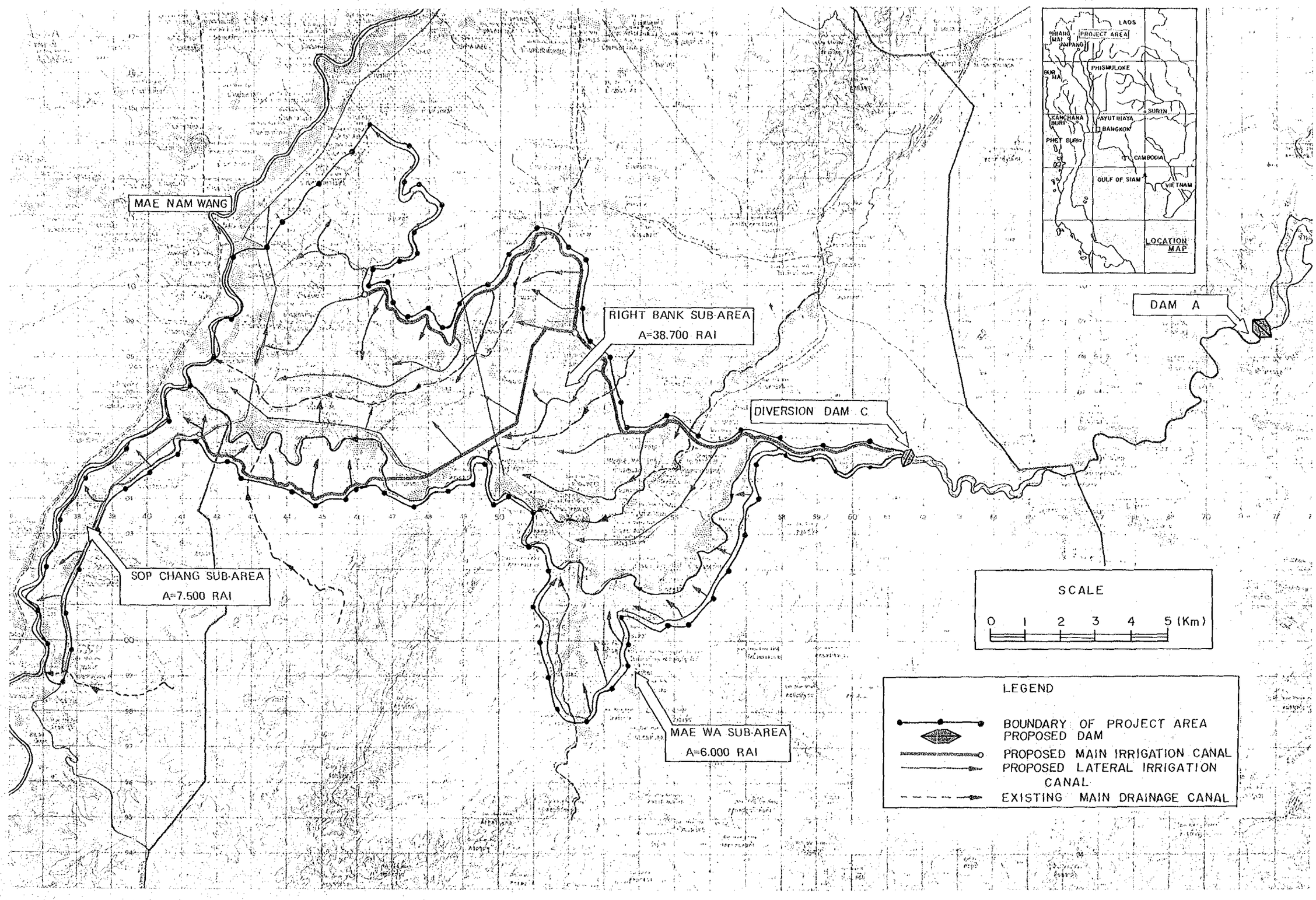
I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

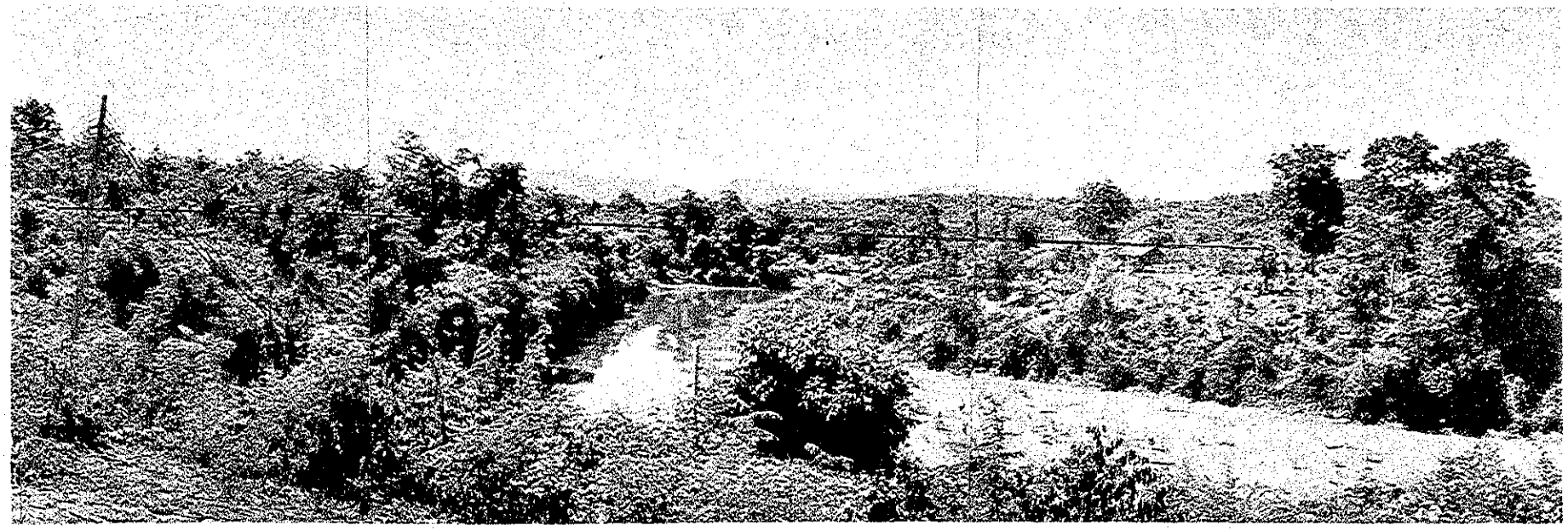
January, 1984



Keisuke Arita
President
Japan International Cooperation Agency

GENERAL PLAN OF MAE CHANG IRRIGATION PROJECT





Diversion Dam C View from Upstream

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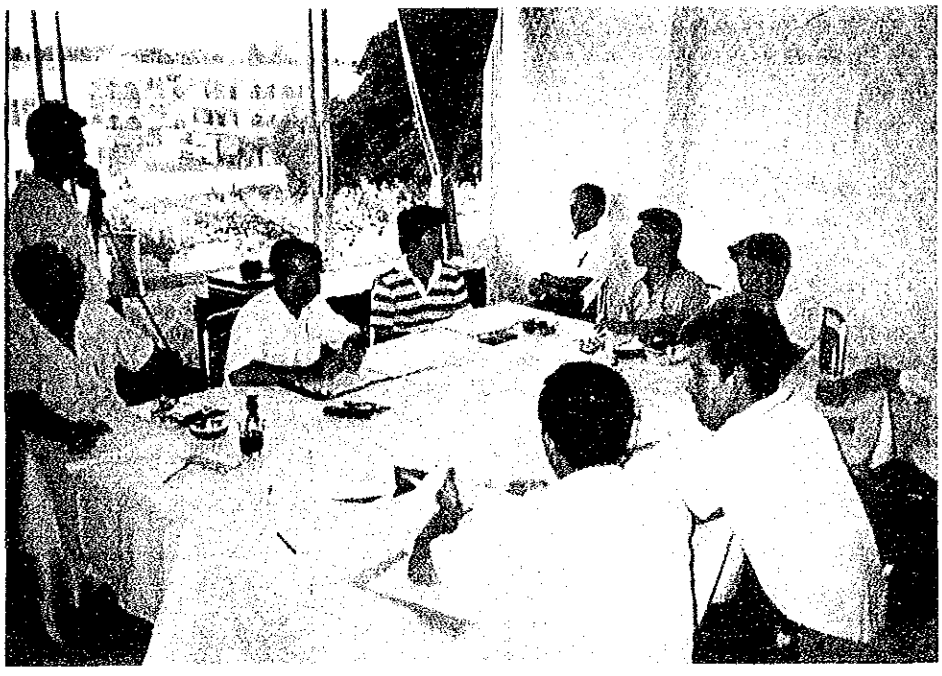

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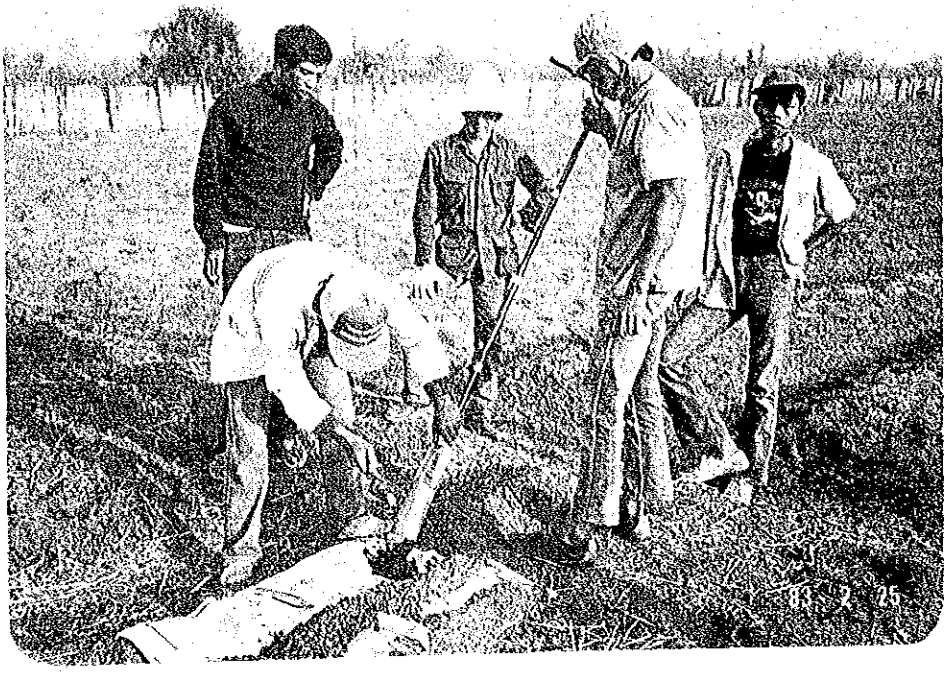

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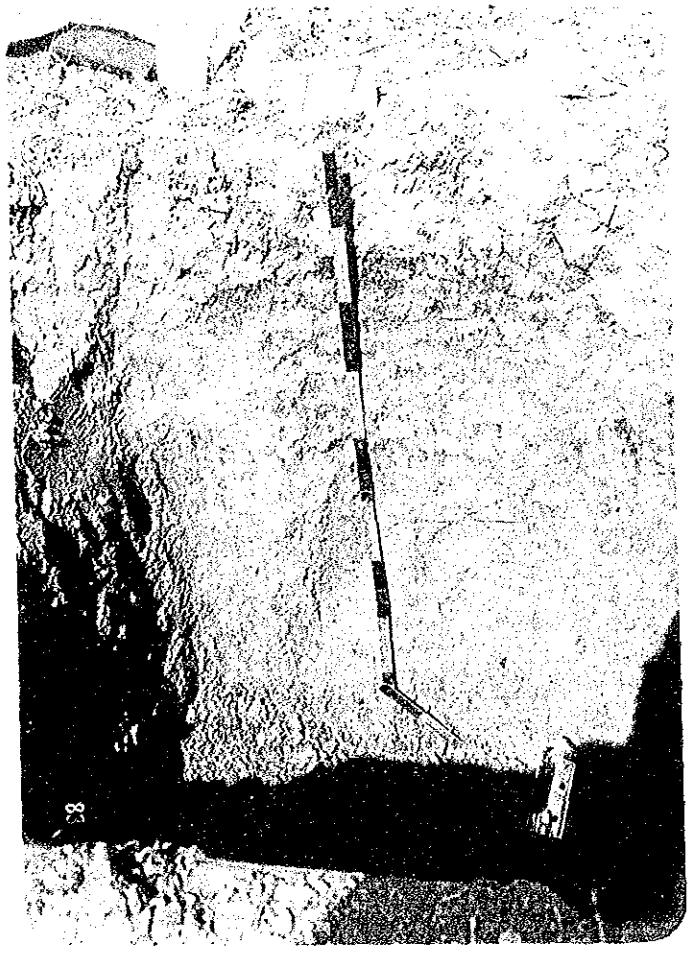

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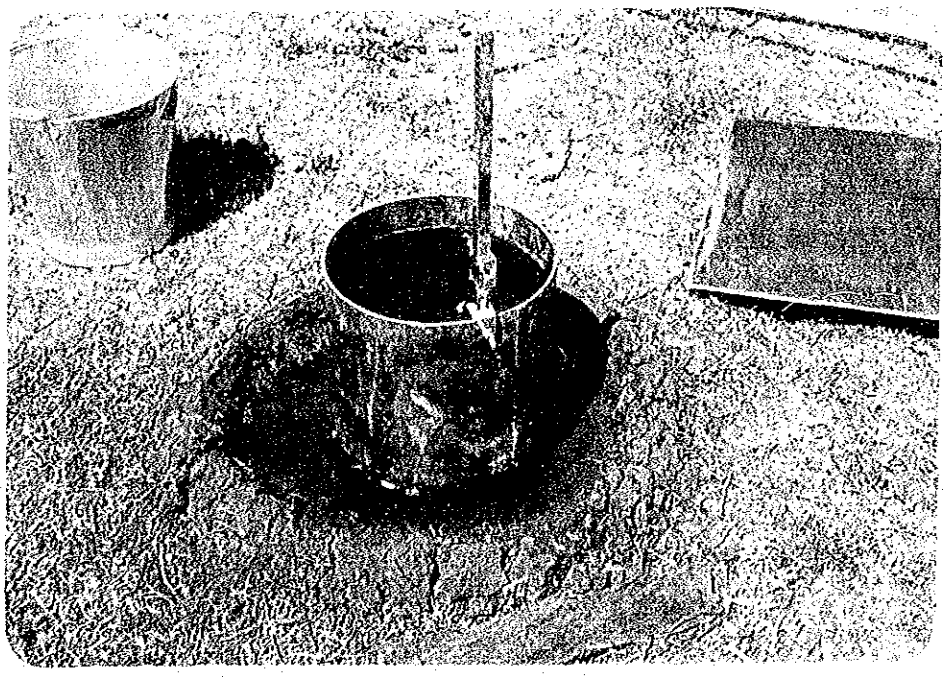

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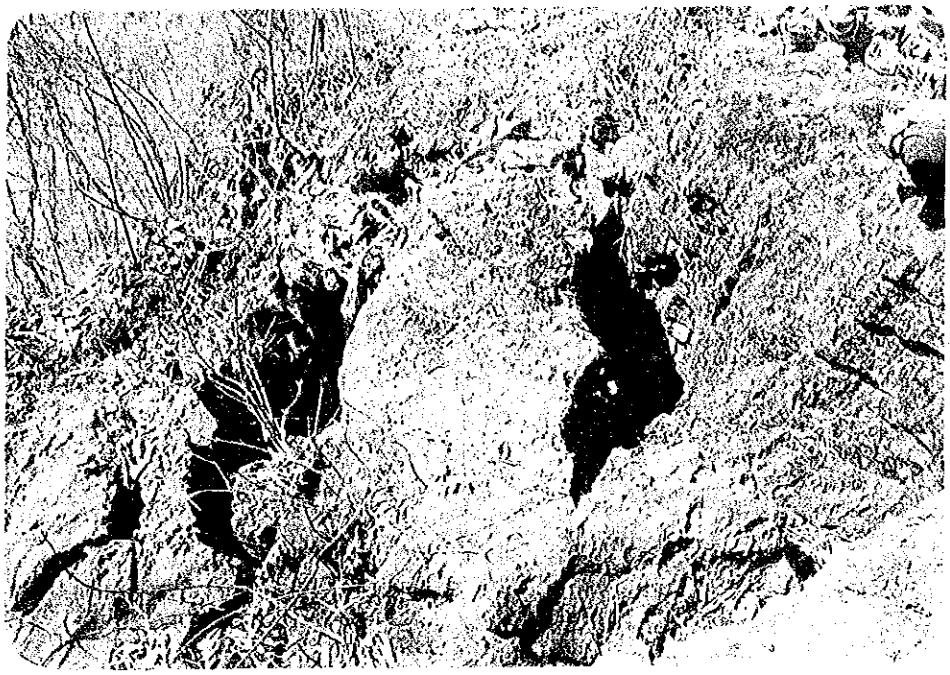

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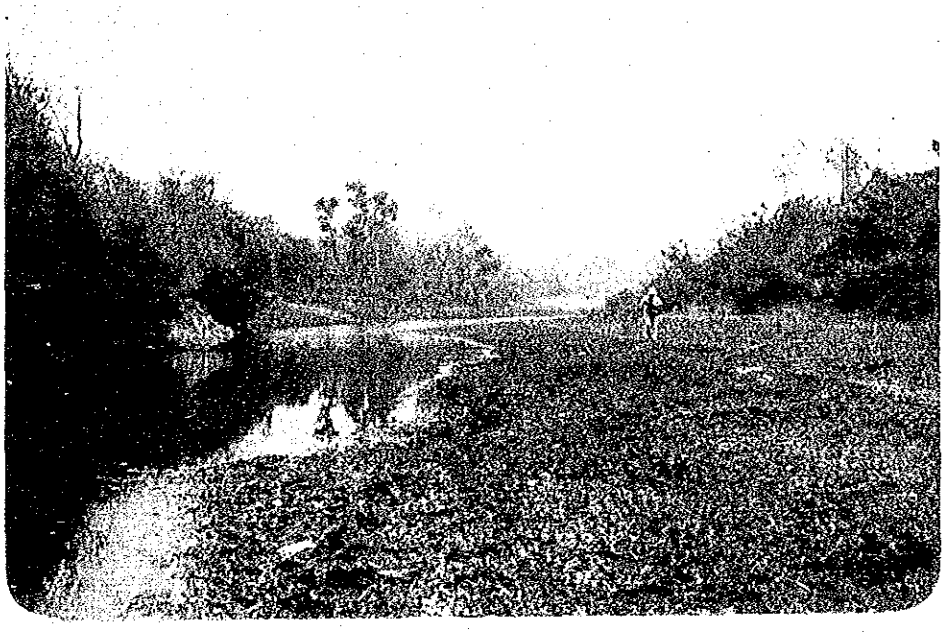

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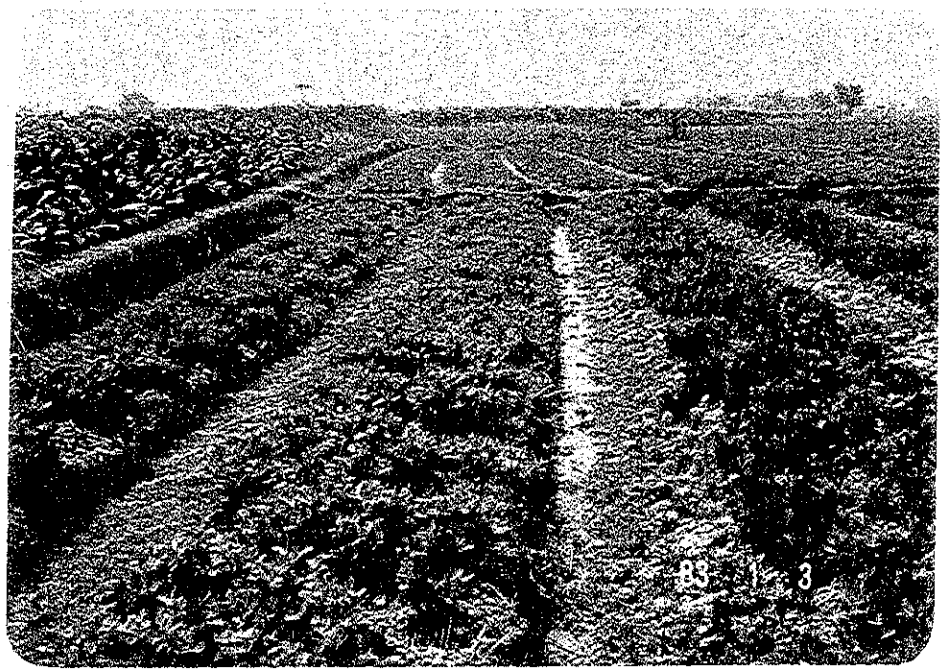
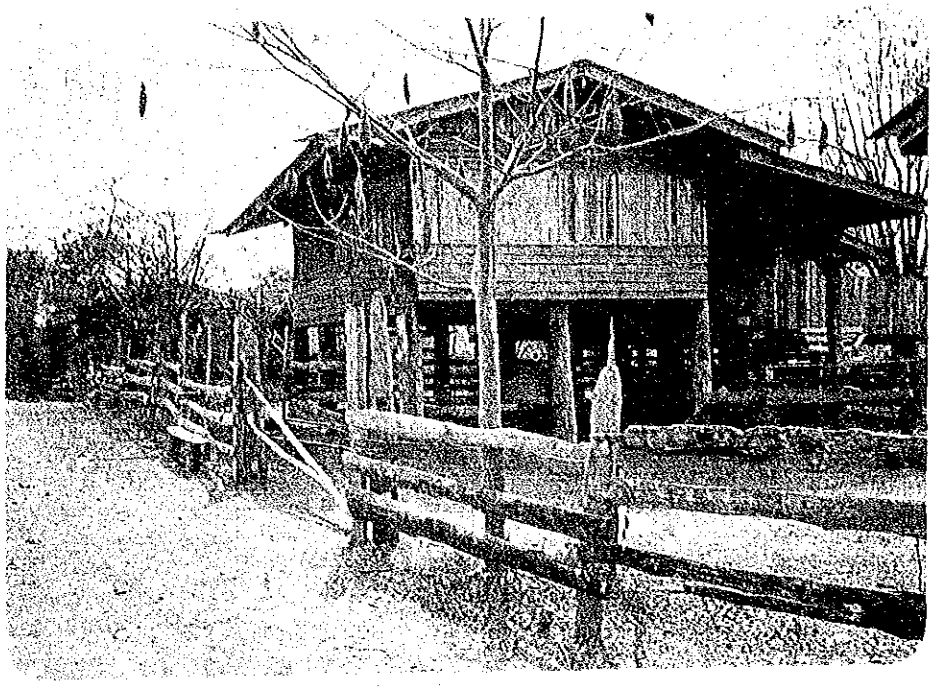


Above : Irrigation for Tobacco

Left Above : Irrigation for Groundnuts

Left Bottom: Garlic



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CONVERSION FACTOR AND GLOSSARY

Conversion Factor

1 rai	Thai unit of area measurement, rai = 0.16 ha
1 ha	6.25 rai
1 tang	volumetric crop measure equivalent to 20 liters
฿	Thai Baht
US$	Dollar, US$ = 23 Baht

Measures

mm	millimeter
cm	centimeter
m	meter
km	kilometer
km^2 (sq.km)	square kilometer
l	liter
cu.m (m^3)	cubic meter
MCM	million cubic meter
c.m.s. (cu.m/sec)	cubic meter per second
ton (t)	metric ton
kw	kilowatt
KWH	kilowatt hour
°C	degree centigrade
HP	horse power

Abbreviation

BAAC	Bank for Agriculture and Agricultural Cooperatives
CHO	Constant Head Orifice
CIF	Cost, Insurance & Freight
DAE	Department of Agriculture Extension
EL	Elevation

SUMMARY

Introduction

1. Most of the Project Area has never been under an irrigation system and is instead subject to a rainfed system so that farmers in this area have suffered from continuous droughts in the past, and these have resulted in frequent and great damage to the cultivated lands. For improvement of the situation in this area, RID and its regional office have made every endeavor to provide an irrigation system since the farmers in Amphoe Mae Tha, Changwat Lampang petitioned for the provision of an irrigation system in 1967. As a part of the activities, a development plan of the upper basin of the Mae Wang River was studied and implementation of five projects including Kew Lom Dam and Mae Chang Dam was recommended.

2. Since Kew Lom Dam and the irrigation system were completed in 1972 under the development plan of the Mae Wang River basin and agricultural productivity in the Mae Wang area was significantly improved and gave a great impact to the implementation of the Mae Chang Dam. As it is a large project requiring a large amount of fund to finance implementation, the Government of Thailand requested the Government of Japan to extend technical cooperation for the formulation of the development plan in this area.

3. In compliance with the scope of works for the feasibility study on the Mae Chang Irrigation Project agreed on between the Government of Thailand and the Government of Japan on November 4, 1982, the Japan International Cooperation Agency dispatched a feasibility study team for the first field work starting on January 30, 1983 and for the second field work starting on June 5, 1983 each for an approximately two month period.

(2) Alternative case studies

Based on the selected dam sites, the following alternative cases were studied:

Case-1:	Storage dam A at dam site A
Case-2:	Storage dam B at dam Site B
Case-3:	Storage dam C at dam site C
Case-4:	Storage dam D at dam site D
Case-5:	Combination of Storage dam A and Diversion dam C
Case-6:	Combination of Storage dam A and Diversion dam D
Case-6a:	Same as Case-6, covering the Area w/o Mae Wa
Case-6b:	Same as Case-6, covering the Area w/o Sop Chang
Case-6c:	Same as Case-6, covering the Mae Chang Right Bank only
Case-7:	Diversion dam C only
Case-8:	Diversion dam D only

Results of Alternative Case Studies

7. A study regarding the engineering, economic, social and environmental aspects was made for each reservoir area to be submerged by the dam construction and based upon cost estimates for the compensation of private properties and the resettlement cost for the inhabitants concerned.

Results of the alternative case studies are summarized as follows:

Case	Dam Capacity (MCM)	H.W.L.	Submerged Area		Project Cost (฿/rai)	EIRR (%)
			No. of Ban	Family		
Case-1	35	283.00	1	22	31,160	9.8
Case-2	58	268.00	7	1,024	51,900	7.3
Case-3	72	266.00	8	1,328	41,100	9.8
Case-4	87	263.00	9	819	32,900	11.2
Case-5	42	254.00	5	125	33,900	9.9
Case-6	37	250.00	2	22	28,300	11.7
Case-6a	37	250.00	2	22	28,600	11.6
Case-6b	37	250.00	2	22	28,900	11.3
Case-6c	37	250.00	2	22	32,200	10.3
Case-7	7	254.00	4	103	21,700	9.2
Case-8	2	250.00	1	0	16,200	4.9

* Note: 1) The above-mentioned alternative case studies were made based upon the roughly estimated construction cost as investment of the Project and also a conservative estimate of the benefits from the Project which does not including benefits from livestock and fisheries.

2) Therefore, a detailed case study should be made after selection of the optimum scale of development.

Selection of Optimum Scale of Development

8. Compensation and resettlement of the affected reservoir area of storage dam B, C and D are too large and not practical for implementation while that of storage dam A and diversion dams C and D have much less influence and are possible for implementation.

In conclusion, among the various alternative cases, Cases 5 and 6 involve construction of storage dam A with either diversion dam C or D required priority and so more detailed studies were conducted for these cases.

Proposed Development Plan

9. According to the results of the detailed case studies for cases 5 and 6, the economic internal rate of return (EIRR) for cases 5 and 6 are 13.6 percent and 13.5 percent, respectively, which are both higher than the opportunity cost of investment. Therefore, from the point of view of economics, both Case 5 and Case 6 can be said to be economically feasible.

However, since the Mae Chang Irrigation Project aims at the development of irrigated agriculture by the development of water resources, the amount of total storage capacity and usable water resources are much more important measures. The result of studies shows that the total storage capacity in Case 5 development is slightly larger than that in the Case 6.

In the case of a drought year, the difference in storage capacity will be very effective in stabilizing the agricultural production.

In this regard, it is recommended that the development of Case 5 should be given priority and second priority given to Case 6.

Summary of Detailed Case Studies

Description	Case-5	Case-6
Development Scheme ...	Storage Dam A with Diversion Dam C	Storage Dam A with Diversion Dam D
Effective Storage .... Capacity	42 MCM (35 + 7)	37 MCM (35 + 2)
Project Area	52,200 rai (8,346 ha)	47,400 rai (7,576 ha)

Description	Case-5	Case-6
Cropping Intensity		
- Wet season		
Paddy	80% (40,500 rai)	80% (36,400 rai)
Upland Crops	20% (10,100 rai)	20% (9,500 rai)
- Dry Season		
Upland Crops	30% (15,200 rai)	35% (16,050 rai)
Total	130% (65,800 rai)	135% (62,000 rai)

Meteorology and Hydrology

10. The climate of Thailand has generally tropical characteristics with the climatic seasons of the region influenced by two different monsoons. One is the north-east monsoon which begins in November and ends in the middle of March while the other is the south-west monsoon which lasts from the middle of May to September. Two seasons are defined by the annual distribution of rainfall, namely the wet season and the dry season.

(1) The annual rainfall ranges from 900 to 1,140 mm and is 1,090 mm on average.

(2) The annual average runoff observed between 1971 and 1980 at station W-15 is 203.6 MCM, corresponding to a comparable runoff of 0.188 cubic meter per square kilometer per year. On the basis of this runoff, the runoff for the four alternative dam sites was analyzed as follows:

Dam Site	Catchment Area (sq.km)	Annual Average Runoff (MCM)
A	403	76
B	575	108
C	657	124
D	696	131

(3) The design flood discharge was estimated based on the hydrograph which was prepared by applying Nakayasu's Synthetic Unit Hydrograph Method and the spilled discharge from the EGAT Mae Chang dam. The design flood at each alternative dam site is as follows:

Dam site	A	B	C	D
Design flood m^3/sec	1,660	1,776	1,803	1,809

(4) Specific sediment was analyzed at 0.24 mm/year based on the analysis of observed data.

Irrigation Plan

11. The irrigation water requirement, diversion water requirement and others are planned by the following manner:

(1) Reference crop evapotranspiration is estimated by the modified Penman method which offers the best results and the minimum possible errors under the climatic conditions. The irrigation water requirement for the proposed cropping pattern are computed on the basis of the consumptive use of crops which is predicted by applying the appropriate crop coefficient and the additional water supply for nursery beds, land preparation and paddy field percolation.

The irrigation water requirement is summarized as follows:

Paddy	Wet Season	813 mm
Groundnut	Wet Season	295 mm
Groundnut	Dry Season	425 mm
Soybeans	Wet Season	274 mm
Soybeans	Dry Season	368 mm
Tobacco	Dry Season	447 mm
Garlic	Dry Season	390 mm
Sugarcane	Year Round	1,302 mm

(2) Irrigation efficiency is applied at 54 percent for paddy fields and 46 percent for upland crops.

(3) As a result of the comparative study on effective rainfall, the RID method is applied for project planning.

(4) The diversion water requirement is calculated in considering effective rainfall and irrigation efficiency.

The design discharge of main and lateral canals is determined at 1.30 liter/sec/ha, taking into account the weighted average of maximum water requirement on paddy and upland crops and irrigation efficiency.

(5) The water rights for the Area in the upstream and downstream of the proposed storage dam and diversion dam was carefully studied and concluded that approximately 10 percent of released water from the storage dam A will be reserved for upstream area as the water right.

(6) The irrigation area for Case-5 and Case-6 respectively, are planned as follows:

	Case-5	Case-6
Gross Cultivation Land (Project Area)	52,200 rai (8,346 ha)	47,400 rai (7,576 ha)
Net Cultivation Land (Irrigable land with-Project)	50,600 rai (8,095 ha)	45,900 rai (7,349 ha)

Drainage Plan

12. The drainage plan was provided according to the present conditions of the existing facilities and the drainage modulus.

(1) The drainage modulus in the irrigated paddy field is computed at 4.88 liter/sec/ha taking into consideration probable rainfall with 5- and 10- year return period and that a little damage will not be given to paddy plants when aflood lasts for less than three days and remains less than 20 centimeter in depth on the average.

(2) Drainage from the hilly area is estimated at 24.3 liter/sec/ha by Rational method. However, this value will be modified depending upon the drainage area by using the reduction rate.

(3) For the drainage development, improvement or rehabilitation of the existing drainage facilities were considered depending upon the above-mentioned drainage modulus.

Proposed Agricultural Development

13. Agricultural development is proposed as follows:

(1) The total project area is surveyed at 71,940 rai (11,510 ha) and 66,200 rai (10,591 ha) for Case-5 and Case-6,

respectively according to the result of the field survey, out of which 52,200 rai (8,346 ha) for Case-5 and 47,400 rai (7,576 ha) for Case-6 are confirmed as cultivation land.

(2) Crop yield (kg/rai) are planned as follows:

Paddy Glutinous		580
Non-glutinous		660
Groundnut	(Wet)	250
	(Dry)	300
Soybeans	(Wet)	270
	(Dry)	300
Tobacco		2,600
Garlic		700
Sugarcane		8,000

(3) Planting ratio of glutinous and non-glutinous varieties of paddy is 40 to 60.

(4) Cropping pattern for Case-5 and Case-6 is proposed as follows:

Description	Case-5	Case-6
Wet Season		
- Paddy	40,500 rai(6,480 ha)	36,400 rai(5,819 ha)
- Soybeans ..	5,000 " (795 ")	4,600 " (740 ")
- Groundnuts.	3,300 " (530 ")	3,100 " (500 ")
- Sugarcane .	1,800 " (290 ")	1,800 " (290 ")
Sub-total	50,600 rai(8,095 ha)	45,900 " (7,349 ha)

Dry Season

- Soybeans ..	4,400 rai(700 ha)	4,800 rai(770 ha)
- Groundnuts.	6,500 " (1,050 ")	7,300 " (1,160 ")
- Garlic	3,000 " (480 ")	3,000 " (480 ")
- Tobacco ...	1,300 " (200 ")	1,000 " (160 ")
- Sugarcane .	(1,800 ")(290 ")	(1,800 ")(290 ")
Sub-total	15,200 rai(2,430 ha)	(16,050 rai(2,570 ha)
Total	65,800 rai(10,525 ha)	(62,000 rai(9,919 ha)
Cropping Intensity	130%	135%

14. General Geology

The general geology of the Project Area consists of sedimentary rocks as limestone, shales and sandstones from the Mesozoic age.

The terrace deposits in Quarternary widely distribute making a flat plane along the Mae Chang river at the irrigation area as well.

The limestone area forms hills or small mountains because of hard rock, while other rocks are not so hard, and covered with terrace deposits or form a flat plane.

Terrace deposits are observed in two or three planes and are mainly composed of silty soils, partly including sand and gravels.

The lower and middle terrace deposits are unconsolidated layers but usually stiff with semiconsolidated higher terrace deposits.

Except for the river deposits and new terrace deposits, the layers distributed at the Project Area are deemed satisfactory in terms of the bearability as a foundation for fill-type dam although a further thorough investigation is required about permeability.

15. Storage Dam A

(1) According to the results of geological boring and the field investigation, the bedrock of the dam site consists of mainly mudstone and interbedded sandstone and conglomerate with thin layers of mudstone. These bedrock are not so hard, boring core is easily broken by soft hammering and is partly non-core. However, the bearing capacity of the bedrock is not a problem for the foundation of a fill-type dam and the permeability of bedrock is generally small indicating under 20 lugeon in value.

(2) The dam axis of storage dam A was decided taking the following factors into consideration:

i) to select the dam site on a narrow valley,

ii) to select abutments having the greatest height in order to obtain the reservoir capacity as large as possible, and

iii) to select favorable topography for the situation of the spillway.

(3) A fill type dam is suitable for dam site A from the viewpoint of topography and geology. A homogeneous fill type dam is suitable because the borrow area is in vicinity of the dam site. However, it is more economical

to use the materials excavated at the spillway and core trench as part of the dam in order to reduce the construction cost. As a result, the fill dam will become a zone type earth fill dam similar to a homogeneous dam type because the majority of dambody is occupied by both of the above materials.

Reservoir

- Catchment Area ..... 403.00 sq.km
- High Water Level ..... EL 283.00 m
- Full Water Level ..... EL 280.20 m
- Intake Water Level ..... EL 272.20 m
- Usable Reservoir Capacity . 40.00 MCM
- Usable Water Depth ..... 8.0 m

Dam

- Dam Height ..... 35.00 m
- Dam Crest Elevation ..... EL 285.00 m
- Min. Trench Elevation ..... EL 250.00 m
- Crest Length ..... 470.00 m
- Dam Volume ..... 682,000 cu.m

(4) The type of spillway selected is a chute type without gate from the viewpoint of maintenance of the facilities and prevention of flood arising from inadequate gate operation. The crest length requires a 150 m overflow crest based on the design flood discharge (about 1,000 year return period) of 1,660 m^3/s, maximum spillway discharge of 1,464 m^3/s and overflow depth of 2.8 m.

(5) Outlet facilities are so designed as to satisfy the demand of irrigation water as well as the flood discharge during the the construction of the dam in the dry season and

the hydropower plant to be constructed in the future. A two- meter diameter steel liner conduit with a 1.3 meter jetflow gate and a slide gate 1.0 x 1.0 m as a guard gate are considered as regulating gates.

The top elevation of the drop inlet is designed at the elevation for 100 year sediments. However, the mouth of the drop inlet is opened up to the elevation equivalent to 20 year sediments for an effective utilization of storage water.

(6) Although replacement of unsuitable and poor quality riverbed materials and alluvium terrace deposits by excavation is deemed economical for the foundation treatment of the dam, the grouting method is recommended in view of the seepage control of the contact face of both abutments with the diluvium terrace deposits and bedrocks.

(7) General foundation treatment

The bedrock and foundation layer of the dam site have no particular problems for bearability except for river and lower terrace deposits. However, seepage control should be carried out with careful attention paid to the middle and higher terrace deposits in the contact face between the rocks and terrace, and the weathered rocks in the high permeability zone. Due consideration of the topographical and geological conditions shows that the open cut method is deemed most suitable as the foundation treatment for loose layer bearability and the grouting method for deeper layer seepage control.

(8) The river deposits shall be replaced with some suitable materials for the lower and middle terrace, and basalt and heavy weathered rocks in the high dam part. The grouting

method is suitable for seepage control for the higher terrace deposits and bed rock after considering ground water level and dam height.

In this area, the higher terrace deposits have various formation facies and which consequently will make it necessary to collect more geological information.

16. Diversion Dam C

(1) The bedrock of dam site C consists of very hard massive limestone which has no problem about bearing capacity for the dam structures.

At this dam site, the most important matter to be considered for the plan of the dam is how to control the water leakage through the bedrock and caused by the existence of sink holes and heavy open cracks. According to the previous investigation report prepared by the RID team, the bedrock shows usually high permeability ranging from 50 to 100 lugeon value in the weathered zone within five meters from the rock-surface, while the permeability shows a tendency to be smaller in range at the lower parts of fresh rock.

In the case of the diversion dam, the high water level is 255 m and the water depth is nine meters for most of the Area near the dam site. Rock surface covered with terrace deposits composed of lean clay three to five meters in thickness and at the riverbed, water depth will be about 20 m measured up to the trench. Since the bedrock is hard and solid, it is possible to control the leakage by high pressure grouting at the dam site.

(2) The dam site of diversion dam C was decided upon after taking the following items into consideration.

i) The scale of the spillway is quite large in comparison with the dam scale. In this connection, the proposed site is in a more favorable situation.

ii) The abutment of the dam axis is suitable to easily carry out foundation treatment.

iii) The topographical conditions ensure that the seepage paths of both abutments are long enough.

(3) From the viewpoint of topographical and geological conditions, the type of diversion dam C is considered to be a combination dam of the homogeneous type.

(4) Major dimension of diversion dam C are as follows:

Reservoir

Catchment Area	254.00	km^2
High Water Level	EL 255.00	m
Full Water Level	EL 254.00	m
Intake Water Level	EL 251.00	m
Usable Reservoir Capacity ..	7	MCM
Usable Water Depth	3	m

Gravity Concrete Dam

Dam Height	22.50	m
Dam Crest Elevation	EL 257.50	m
Min. Trench Elevation	EL 235.00	m
Crest Length	67.50	m
Dam Volume	11,700.00	cu.m

Fill Dam

Dam Height	10.50 m
Dam Crest Elevation	EL 257.50 m
Min. Trench Elevation	EL 247.00 m
Crest Length	242.50 m
Dam Volume	60,000.00 cu.m

Blanket

Height	10.50 m
Crest Elevation	EL 257.50 m
Min. Trench Elevation	EL 247.00 m
Length	250.00 m
Volume	6,500.00 cu.m

(5) A spillway with a gate was adopted to create an effective storage capacity as large as possible. However, taking into consideration safety of the operation of the gate, a 50 m longs fixed weir is designed in addition to the gated spillway which accommodateds for 105 m^3/sec of flood without gate operation. The design flood discharge is taken to be at 1,803 m^3/sec in case of a 1,000 year return period.

(6) An intake structure with three sets of 2.5 m x 2.5 m slide gates is planned to be located on the right bank of the diversion dam, because most of the irrigable area is on this of the Mae Chang River.

The bedrock is hard and solid massive limestone and usually shows a lugeon value not particularly great but showing a large permeability of more than 50 lugeon value at certain places and depths. In case of the diversion dam, it is not necessary to have deep seepage control, but the areas in which limestone is distributed need careful

foundation treatment as there are many unknown factors in the geology.

(7) On the dam axis, it is necessary to recognize the rock conditions for excavating the terrace and river deposits.

It is expected that there will be small sinkhole or a big open crack at this limestone area and so foundation treatment should be carried out according to the geological conditions.

The grouting zone is planed deep and wide in comparison with the dam height after taking into account the properties of the limestones and the over-estimate.

17. Diversion Dam D

(1) According to geological boring conducted by RID, the bedrock at dam site D consists of sandstone, shale, calcareous sandstone, limestone and conglomerate.

On the right bank, there is fine to medium sandstone, which is not particularly hard and distributed in alternate layers. At the riverbed and right riverside, there is distributed hard calciferous sandstone and partly banded limestone, while on the left riverside, there is distributed alluvium terrace deposits. On the left bank, there is massive limestone and sandstone and shale in alternate layers, and partly interbedded conglomerate.

Permeability of the bedrock ranges from zero to 44 lugeon value, but usually indicates a value of under 20 lugeon value for fresh rock.

(2) The dam axis of diversion dam D was restudied based on the topography map surveyed by RID and decided after considering the following factors:

i) to select the dam site on a narrow valley,

ii) to make the dam axis at right angles to the contour lines,

iii) to make the dam axis at right angles to the river in order to facilitate the intake of irrigation water and to wash out the sediment load effectively, and

iv) to select favorable topography for the siting of the spillway structure.

(3) According to the topographical conditions, diversion dam D is suitable to apply a combination dam with a homogeneous fill type.

(4) Major dam dimension are as follows:

Reservoir

Catchment Area	293	sq.km
High Water Level	EL 250.00	m
Full Water Level	EL 249.00	m
Intake Water Level	EL 248.99	m
Usable Reservoir Capacity ...	2.00	MCM
Usable Water Depth	1.00	m

Gravity Concrete Dam

Dam Height	21.50 m
Dam Crest Elevation	EL 252.50 m
Crest Length	70.00 m
Dam Volume	13,400.00 cu.m

Fill Dam

Dam Height	7.00 m
Dam Crest Elevation	EL 252.50 m
Crest Length	155.00 m
Dam Volume	12,000.00 cu.m

(5) The high water level and intake water level of diversion dam D are EL 250.00 and 248.00, respectively. A gated spillway combined with a 50 m fixed weir is proposed because of the small difference of both water levels. The gated spillway is located at the river course while a fixed weir is provided at the left bank in consideration of the location of the intake facilities located on the right bank and which is expected to wash out the sediments incurred in front of the intake structure.

(6) The alluvium terrace deposits consist of sandy silt which is required to be excavated down to the rock surface for a portion of the heavy structure, but this is not necessary for a portion of the small dam.

As for foundation treatment, the grouting method is suitable for seepage control due to the water pressure which is not particularly great.

(7) The bedrock is favourable in bearability and permeability at the river bed and the right bank. Only the curtain grouting will be satisfactory with foundation treatment.

Careful attention should be paid to the middle terrace deposit on the left bank. The terrace deposit seems low in permeability, but judging from unconsolidated layer the curtain grouting should be adopted to carried out at the rock surface level.

18. Irrigation Facilities

(1) In the wet season, the existing irrigation area is located in the left bank area (Mae Wa 400 ha) and in the right bank area (Mae Pung 2,500 ha).

(2) The irrigable area can be divided into right and left banks and in detail into five zones as follows:

Name of Zone	Name of Sub-area	Case-5	Case-6
1	Mae Chang	12,550 rai (2,008 ha)	11,600 rai (1,860 ha)
2	Mae Pung Left	8,450 " (1,352 ")	8,100 " (1,302 ")
3	Mae Pung Right	16,540 " (2,646 ")	14,400 " (2,300 ")
	Sub-total of Right Bank	37,540 rai (6,006 ha)	34,100 rai (5,462 ha)

Name of Zone	Name of Sub-area	Case-5	Case-6
4	Mae Wa	5,850 rai (935 ha)	4,800 rai (761 ha)
5	Sop Chang	7,210 (1,154 ")	7,000 " (1,126 ")
	Sub-total of Left Bank	13,060 rai (2,089 ha)	11,800 rai (1,887 ha)
	Total	50,600 rai (8,095 ha)	45,900 rai (7,349 ha)

(3) Five canals are named as the main irrigation canal to irrigate the Project Area. Out of the five, two canals take the routes of existing canals and will be improved as a new irrigation network. The other three will be newly constructed.

Case-5

Name	Service Area (ha)	Length (km)	Max. Discharge (m^3/sec)	Canal B. Width (m)
Mae Chang Main Canal	2,008	12.70	10.52	2.70
Mae Pung Left Canal	1,352	6.50	3.26	1.80
Mae Pung Right Canal	2,646	13.00	3.44	1.80
Mae Wa Canal	935	10.40	1.22	1.80
Sop Chang Canal	1,154	8.70	1.50	1.80
Total	8,095	51.30		

Case-6

Name	Service Area (ha)	Length (km)	Max. Discharge (m^3/sec)	Canal B. Width (m)
Mae Chang Main Canal	1,860	11.70	9.55	2.70
Mae Pung Left Canal	1,302	4.20	3.16	1.80
Mae Pung Right Canal	2,300	13.00	2.99	1.80
Mae Wa Canal	761	10.40	0.99	1.20
Sop Chang Canal	1,126	11.10	1.46	1.80
Total	7,349	50.40		

(4) Lateral canals and canal structures are as follows:

Case-5

Name of Canals	Lateral Canal Number	Lateral Canal Length (km)	No. of Diversion	No. of Siphon	No. of Turnout
Mae Chang M.C.	6	18.60	6	5	52
Mae Pung L.C.	7	11.60	7	3	34
Mae Pung R.C.	11	34.90	11	8	69
Mae Wa C	10	13.00	10	6	31
Sop Chang C	6	15.20	6	5	24
Total	40	93.30	40	27	210

Case-6

Name of Canals	Lateral Canal Number	Lateral Canal Length (km)	No. of Diversion	No. of Siphon	No. of Turnout
Mae Chang M.C.	4	15.50	4	4	66
Mae Pung L.C.	3	13.50	3	3	58
Mae Pung R.C.	9	30.60	9	9	33
Mae Wa C.	7	13.00	7	7	29
Sop Chang C.	6	14.70	6	6	19
Total	29	87.30	29	29	205

19. Drainage Facilities

(1) Major works for drainage facilities are proposed as the upgrading of trunk channels, their enlargement removal of existing weirs and enlargement of crossing structures.

(2) Upgrading and enlargement of trunk channels, removal of existing weirs and enlargement of existing cross structures are listed as follows:

Name of Channels	Length of Upgrading (km)	Length of Enlargement (km)	Removal of Exist.Weir (Places)	Enlargement of Exist.Structures (Places)
Huai Mae Tha	0.7	1.3	5	2
Huai Mae Thaet	-	1.2	2	1
Huai Mae Pung	0.8	3.0	5	2
Nam Mae Wa	-	-	-	-
Others	-	-	-	-
Total	1.5	5.5	12	5

20. On-farm Development

(1) The provision of on-farm facilities is essential work for irrigated agriculture with farm mechanization and the farmers' eagerness for agriculture will act as the prime mover. To carry out the proper water management, careful control and measurement of water are required.

(2) It is recommended to implement the on-farm development by by the RID quickly to realize the purpose of the agricultural development. However, taking the recent Thai Government policy on the agricultural development into consideration, implementation of on-farm development should be carried out by farmers themselves under assistance of the Project office and Regional office of RID after completion of construction of main and lateral canals.

(3) The on-farm facilities are projected to be so that an irrigation block (chak) covers 250 rai (40 ha) of cultivated land. Main farm ditches, supplementary farm ditches, field ditches, division boxes and end checks are major structures.

(4) Construction cost of the on-farm facilities was estimated at 800 Baht per rai in total, and 200 Baht per rai and 600 Baht per rai were, respectively projected for foreign currency and local currency.

21. Hydropower Development

(1) The purpose of the hydropower development plan is to generate electric power by of a hydropower plant proposed for immediately downstream of the planned storage dam A.

(2) The designed installed capacity is 164 KW (two units of 82 KW) and will generate about 1.18 GWH of energy.

(3) The proposed storage dam A, which will be operated to meet the irrigation requirements and can serve for power generation by its discharge and water head available.

(4) The power plant was so designed that a firm peak can be secured to obtain a maximum output of 338 KW (two units of 119 KW) for the net head of 17 meter and a discharge of 1.65 cubic meter per second. For this plant, horizontal shaft, twin Francis turbine-generator unit was proposed.

(5) Taking into consideration the objectives of the Mae Chang Irrigation Project, the hydropower generation will be developed in the near future as Phase II development after the completion of the irrigation project.

(6) For reference to the future development, the construction cost of the hydropower plant was estimated as follows:

Description	Cost (฿'000)
Civil Works	2,000
Hydropower Facilities	35,000
Communication and Others	5,000
Engineering and Administration	13,000
Total	55,000

22. Compensation and Resettlement of the Affected Reservoir Area

For Case-5 and Case-6, the following compensation and resettlement shall be countermeasured:

(1) Farm Land Area to be compensated

(Unit: rai)

Villages	Storage Dam A			Diversion Dam C			Diversion Dam C		
	Paddy	Upland	Other	Paddy	Upland	Other	Paddy	Upland	Other
Ban Mae Lu	200	200	10	-	-	-	-	-	-
Ban Kon	-	-	-	25	17	1	-	-	-
Ban Mai	-	-	-	98	53	-	-	-	-
Ban Pong Pa Pao	-	-	-	251	31	5	-	-	-
Ban Thung Ton	-	-	-	267	137	9	-	-	-
Ban Sop Po	-	-	-	-	-	-	150	100	4
Total	200	200	10	641	238	15	150	100	4

(2) Number of family to be compensated and resettled

	Compensated			Resettled		
	Storage A	Diversion C	Diversion D	Storage A	DD-C	DD-C
Ban Mae Lu	22	-	-	22	-	-
Ban Kom	-	10	-	-	-	-
Ban Mai	-	140	-	-	56	-
Ban Pong Pa Pao	-	26	-	-	26	-
Ban Thung Ton	-	21	-	-	21	-
Ban Sop Po	-	-	-	-	-	-
Total	22	197	0	22	103	0

23. Project Cost

(1) Construction method was considered on the contract basis through international competitive bidding.

(2) The cost of construction work is estimated on the basis of the prevailing unit costs used in Mae Kuang Dam Project and Mae Wang Project as of March 1983.

(3) The cost of construction works is divided into two portions of foreign and local components, which were estimated by using the following rate:

	Rate Foreign Currency	Rate of Local Currency
Cement	60%	40%
Steel Bar	70	30
Lumber	20	80
Fuel & Oil	80	20
Labour	-	100
Explosive	80	20
Construction Equipment		
Depreciation Cost	100	-
Repair Cost including Spare Parts	80	20
Administration Cost	-	100

(4) Land acquisition and compensation costs are estimated on the basis of the following three items:

Reservoir area: Compensation for private properties, houses and public properties in the reservoir area

Resettlement: Construction cost of resettlement

Project area: Land acquisition of project facilities, and compensation for borrow site and quarry sites

(5) Cost of construction equipment is that for procurement of vehicles for construction management and operation and for maintenance of the irrigation system.

(6) The cost of project facilities is that for the construction of offices and facilities for implementation of the Project, while the project administration cost is estimated as the administrative charges of government staff to be engaged in the newly organized Project office.

(7) Consulting services cost is the engineering cost for consultants of foreign and local experts for the implementation of detailed design and supervision of the Project implementation.

(8) Contingencies are estimated at the rate of 10 percent of the project cost, while price escalation rates are applied with the following annual rate being used by the IBRD and ADB.

Year	Escalation Rate (%)	
	Foreign Currency	Local Currency
1984	7.5	8.0
1985	7.0	8.0
1986 to 1987	6.0	7.0
1988 to 1990	6.0	6.0

(9) The investment cost of the Project for Case-5 and Case-6 was estimated as shown in the following table.

24. Project Evaluation

(1) The economic evaluation presented here compares the economic returns of the proposed project to the whole economy of Thailand by calculating the economic internal rate of return (EIRR). In order to determine the EIRR the present worths of both cost and benefit streams are discounted over the entire project life (50 years). The discount rate which makes the present worths of the cost and benefit streams equal is the EIRR.

(2) Economic prices were calculated from financial prices by applying the following conversion factors from a World Bank publication which also includes an economic appraisal study on an irrigation project in Thailand.

Standard conversion factor	0.80
Conversion factor for construction	0.74
Conversion factor for transpotation	0.76
Conversion factor for government services	0.65

(3) On the basis of the estimated economic costs and benefits the economic internal rate of return (EIRR) was calculated at 13.6 percent for Case 5 and at 13.5 percent for Case 6.

(4) A sensitivity test is an effective way to check what happens to the earning capacity of a project if something does not go according to plan. For this project an analysis has been made on the following items for Case 5:

		Result (EIRR)
1)	Project cost overrun of 20 percent	11.9%
2)	Extension of the construction period	
	One year	12.7%
	Two years	11.8%
3)	Decrease in crop target unit yields by 10%	11.8%
4)	Delay in reaching the target year by five years	11.4%
5)	Applying conversion factors from Table-3, Summary of Country Parameter for Thailand (1980) in the Draft Report, Shadow Price for Economic Appraisal in Thailand (IBRD March 1982)	12.9%

(5) Various socio-economic effects are expected to occur along with the direct benefits of the Project. The main socio-economic impacts are considered to be an increase of employment opportunities, high income for keeping a much higher standard of living than at present and political stability.

(6) Typical farm budgets have been estimated for "without" Project average farm size of eight rai and "with" Project representative farm sizes of five, eight and twelve rai.

By comparing the "without" Project average farm of eight rai to the "with" Project medium scale farm of eight rai, the results show that the surplus income (฿7,501) would nearly triple in the "with" Project Case even without taking off-farm income into consideration.

(7) Presuming that farmers are willing to re-invest at least two-thirds of their surplus income toward repayment of the construction costs a total of ฿28,570,000 per annum would be realized at full development of the Project.

25. Implementation Schedule

The implementation schedule is carefully programmed taking into account the work volume and the Project Cost. As a result, it is scheduled that detailed design and preparation of tendering and procedures for implementation will be taken about one year period each after the completion of the feasibility study and budgetary arrangement in September 1984 and then construction of the diversion dam and main canals will be begun taking a period of three years from November 1986 followed by the construction of the storage dam and lateral canals also taking a period of three years from November 1987.

26. Consulting Services

The consulting services for the implementation of the Project include those for the detailed design and supervision of the Project.

The consulting services are divided into the following two stages:

(1) The detailed design of the Project as well as the preparation of tender documents. It will cover a 186 man-month period, with 87 man-months for foreign consultants and 99 man-months for local consultants, starting from September 1984.

(2) The second stage is for tendering and construction supervision in all aspects of the Project activities. The service period will cover 210 man-month, with 132 man-months for foreign consultants and 88 man-months for local consultants, from November 1985 to June 1990.

B. CONCLUSIONS

1. The results of economic evaluation for both Case-5 and Case-6 show the economic internal rate of return (EIRR) of 13.6 percent and 13.5 percent, respectively, which exceeds the opportunity cost of capital in this country. Therefore, it can be said that both cases are feasible from the viewpoint of the national economy.

2. According to the farm income analysis of the representative farmer in the Area, the farm income is only ฿2,784 and therefore the farmer cannot live in ease unless he can acquire an off-farm income of more than ฿2,200. After completion of the Project, however, the farm income of the representative farmer will become ฿7,501 without taking off-farm income into consideration. This means that farmer can save some surplus of his farm income without any off-farm income.

   Through the above farm budget analysis, it is quite clear that the proposed irrigation project is feasible from the viewpoint of the individual farmer's economy.

3. Although both Case-5 and Case-6 of the development plan are technically sound and economically feasible, and taking into consideration the difference of proposed project area and the total cropping area between Case-5 and 6 since the Mae Chang Irrigation Project aims at the development of irrigated agriculture by the development of water resources, it is recommended that the development of Case-5 be given priority.

4. The proposed scope of the Mae Chang Irrigation Project is, delineated as follows as a condition of the feasibility study:

Storage Dam A

Reservoir

Catchment Area	403.00	sq.km
High Water Level	EL 283.00	m
Full Water Level	EL 280.20	m
Intake Water level	EL 272.20	m
Usable Reservoir Capacity	40.00	MCM
Usable Water Depth	8.0	m

Dam

Dam Height	35.00	m
Dam Crest Elevation	EL 285.00	m
Min. Trench Elevation	EL 250.00	m
Crest Length	470.00	m
Dam Volume	682,000	cu.m

Diversion Dam C

Reservoir

Catchment Area	254.00	km^2
High Water Level	EL 255.00	m
Full Water Level	EL 254.00	m
Intake Water Level	EL 251.00	m
Usable Reservoir Capacity	7	MCM
Usable Water Depth	3	m

Gravity Concrete Dam

Dam Height	22.50	m
Dam Crest Elevation	EL 257.50	m
Min. Trench Elevation	EL 235.00	m
Crest Length	67.50	m
Dam Volume	11,700.00	cu.m

Fill Dam

Dam height	10.50	m
Dam Crest Elevation	EL 257.50	m
Min. Trench Elevation	EL 247.00	m
Crest Length	242.50	m
Dam Volume	60,000.00	cu.m

Blanket

Height	10.50	m
Crest Elevation	EL 257.50	m
Min. Trench Elevation	EL 247.00	m
Length	250.00	m
Volume	6,500	cu.m

Irrigation Canals

Main Canal

Name of Canals	Service Area (ha)	Length (km)	Max. Discharge (m^3/sec)	Canal B.Width (m)
Mae Chang Main Canal	2,008	12.70	10.52	2.70
Mae Pung Left Canal	1,352	6.50	4.26	1.80
Mae Pung Right Canal	2,646	13.00	3.44	1.80
Mae Wa Canal	935	90.40	1.22	1.80
Sop Chang Canal	1,154	8.70	1.50	1.80
Total	8,095	51.30		

Lateral Canals and Canal Structures

Name of Canals	Lateral Canal Number	Lateral Canal Length (km)	No. of Diversion	No. of Siphon	No. of Turnout
Mae Chang M.C.	6	18.60	6	5	52
Mae Pung L.C.	7	11.60	7	3	34
Mae Pung R.C.	11	34.90	11	8	69
Mae Wa C.	10	13.00	10	6	31
Sop Chang C.	6	15.20	6	5	24
Total	40	93.30	40	27	210

Drainage Facilities

Name of Channels	Length of Upgrading (km)	Length of Enlargement (km)	Removal of Exist.Weir (places)	Enlargement of Exist.Structures (places)
Huai Mae Tha	0.7	1.3	5	2
Huai Mae Thaet	-	1.2	2	1
Huai Mae Pung	0.8	3.0	5	2
Nam Mae WA	-	-	-	-
Others	-	-	-	-
Total	1.5	5.5	12	5

C. RECOMMENDATIONS

1. The following test pit and laboratory test with sufficient detail and accuracy in borrow area of storage dam A for the final design should be completed prior to the commencement of the final design.

(1) Location of Borrow Area : Approximately 1.5 km North-west of Ban Hua Sua

(2) Interval of Test Pit : 100 m interval
64 places test pit
3.0 m depth each

(3) Laboratory Test

Five (5) representative samples among the above mentioned samples should be taken and the following impervious material test shall be conducted:

a) Physical Test

Chloride Content of Soils	JSF T11-1968
Content of Water-soluble Component of Soils	JSF T12-1968
Water content	ASTM D2216-71
Specific gravity	ASTM D854-58
Grain size analysis	ASTM D422-63
Liquid limit	ASTM D423-66
Plastic limit	ASTM D424-59
Shrinkage limit	ASTM D427-61

b) Mechanical Property Test

Compaction	ASTM D698-78
Permeability (Falling head)	ASTM D2434-68
Triaxial test	(C-U)

(4) Note: Two test points should be used i.e. a maximum dry density and a 95 percent of maximum dry density both under the optimum water content.

2. The following rock material test should be conducted:

(1) Location of Quarry Site: Surrounding Doi Wiang Ho Approximately 6 km East of Ban Mae Tha

(2) Rock Material Test

Three (3) representative samples from outcrop at the quarry site should be taken and the following rock material tests conducted:

Absorption	ASTM C97-47
Specific Gravity	ASTM C97-47
Sodium Sulfate Soundness	ASTM C88-76
Compressive Strength	ASTM D2938-79

(Geological Survey at Storage Dam A)

3. Drilling of borehole at Storage dam A should be carried out at the following location and depth:

(i) Dam axis : 3 boreholes (two 30 m each and 25 m)
(ii) Right Abutment : 5 boreholes (35 m each)

(iii) Left Abutment : 2 boreholes (35 m each)

(iv) Spillway Center line : 3 boreholes (20 m each)

Total 13 boreholes and 370 m in depth

Standard penetration test should be carried out at every 1.5 meters of depth until the bedrock and excepting difficult layers, such as gravel, hard clay, etc. And permeability test should also be conducted at every 2.0 m of depth from the rocksurface at maximum water pressure of 10 kg/cm^2 in hard rock and 3 to 5 kg/cm^2 in soft rock.

(Geological Survey at Diversion Dam C)

4. Drilling of two observation wells (25 m of depth each) should be carried out at the location of approximately 60 m upstream dam axis on the terrace of approximately 251 meters above mean sea level at the both river side.

The boring depth will be required to be 5 meters below the riverbed. After completing the borehole, a strainer pipe should be inserted into the finished borehole and fixed with groundsurface by mortar cement.

Water table measuring at the boring point should be carried out 2 to 4 times a month at least for a period of one year.

(Survey of Submerged Area)

5. Submerged area by construction of dams should be surveyed on topography and private and public properties for negotiation of countermeasures on this matter as soon as possible.

(Investigation of Sinkholes)

6. There are some sinkholes confirmed on the left and the right bank upstream from the dam site C. Among them, those on the left bank have some fear for leakage out of the reservoir area. For these sinkholes, groundwater trace was carried out in salt water (NaCl) but could not detect any new spring water in and out the reservoir area. Also, the Mae Chang river water contains chloride radical and therefore, the experiment of the groundwater trace could not find out ways of water flow from the sinkholes. Such being the case, it is difficult to confirm the groundwater way even if using other chemicals.

The purpose of this trial is to find out the groundwater way and to check the permeability of the rocks and consequently, it is considered better to measure the groundwater table at the boring points for the purpose.

In the reservoir area near the dam site, it is necessary to set up a grid on a map for selecting boring points at least with 100 meters intervals. Groundwater table measuring and permeability test are necessary to the borehole drilling.

It is necessary to observe the changing groundwater table at the boring points and new spring water points near boring sites by using a large about of Fluoresser solved water.

(Survey on Quality of Mae Chang)

7. Sampling of water of the Mae Chang and quality analysis of the sample shall be carried out during the detailed design in order to confirm a suitability of water for irrigation purpose.