FEASIBILITY REPORT

ON

THE MAE KUANG IRRIGATED AGRICULTURE DEVELOPMENT PROJECT

IN

THE KINGDOM OF THAILAND

(MAIN REPORT)

FEBRUARY 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

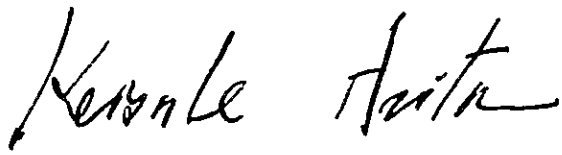
In response to the request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a survey on the Mae Kuang Irrigated Agriculture Development Project and entrusted it the Japan International Cooperation Agency (JICA). The JICA sent to Thailand a team headed by Mr. Shigekatsu Watanabe from February 15 to March 31, and July 1 to August 19, 1981.

The team exchanged views with the officials concerned of the Government of the Project Area. 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 Thailand for their close cooperation extended to the team.

February, 1982



Keisuke Arita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Keisuke Arita
President
Japan International Cooperation Agency (JICA)
Tokyo, Japan

Dear Sir,

We are very pleased to submit herewith the final report on the Feasibility Study for the Mae Kuang Irrigated Agriculture Development Project in the Kingdom of Thailand.

As for the Project Study, the field surveys had been carried out from February 15 to March 31 and July 1 to August 19, 1981, and during stay in the Project site, the survey team had frequently held many discussion meetings with the Thai authorities concerned in connection with the project planning and report has been compiled in Japan with the results of said procedures.

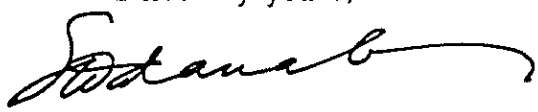
The objectives of the study are to establish a developed plan on the Mae Kuang Irrigated Agriculture Development Project (20,000 hectares) which has been promoted by the Government of Thailand.

We are convinced that the successful agricultural development in the area, when realized according to the direction indicated in this report, would greatly contribute to the socio-economic development of the country in the future.

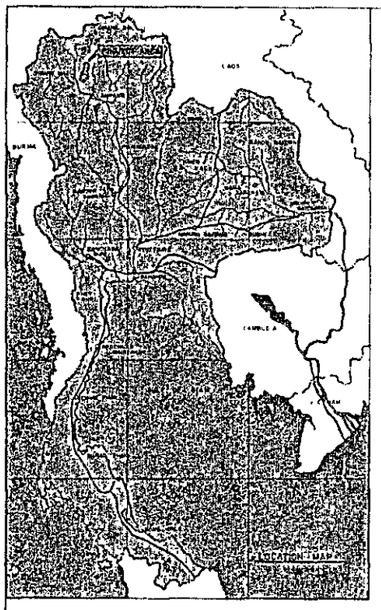
We wish to extend our deep gratitude to the Ministry of Agriculture and Cooperatives of the Government of Thailand, and the Ministry of Foreign Affairs, the Ministry of Agriculture, Forestry and Fisheries of the Government of Japan, and the Japan International Cooperation Agency (JICA), especially for the Japanese Embassy in Bangkok, Bangkok Office of JICA, and the advisory group which gave useful advices to the survey team from time to time so as to smoothen the study.

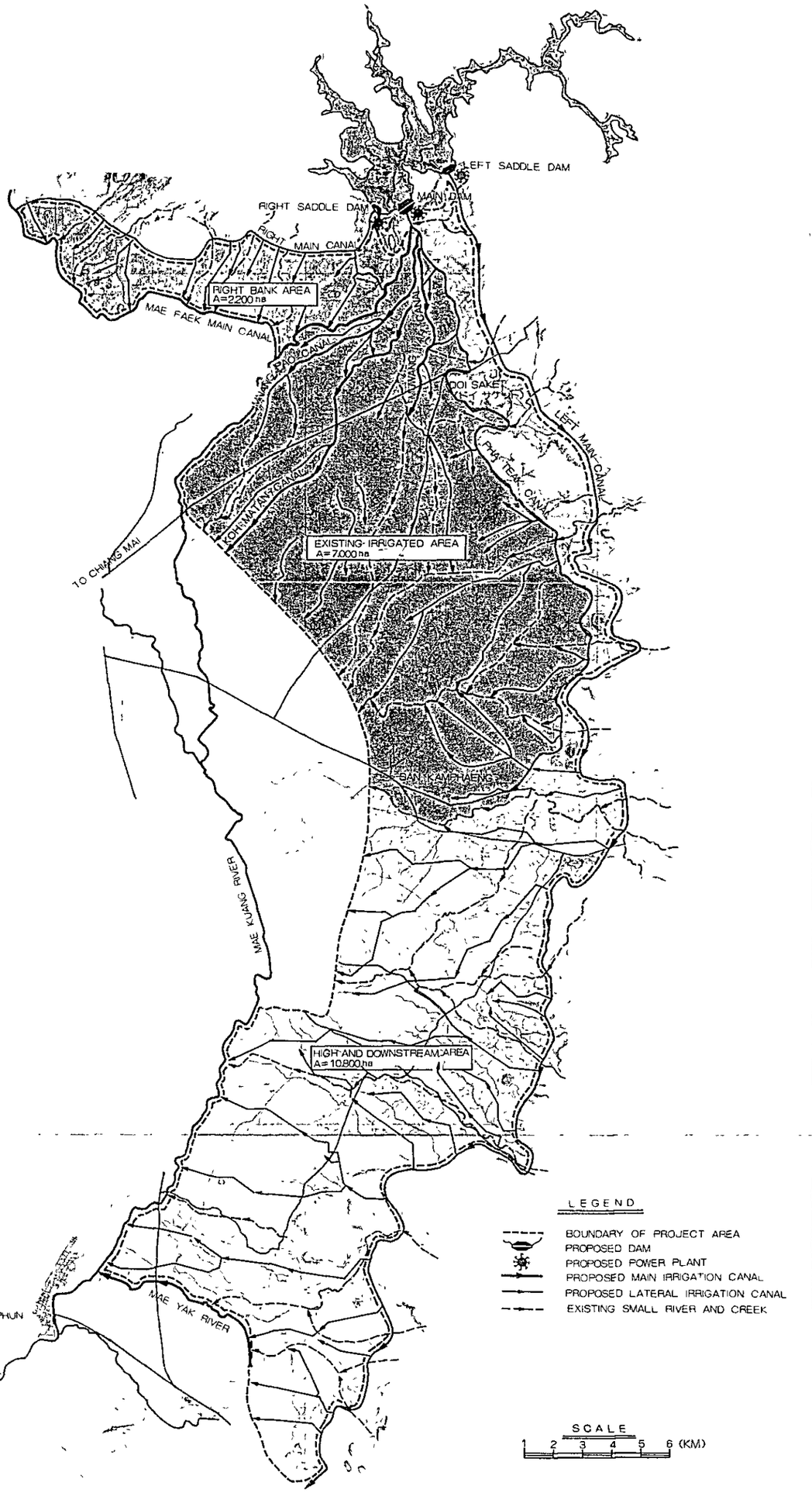
February, 1982

Sincerely yours,

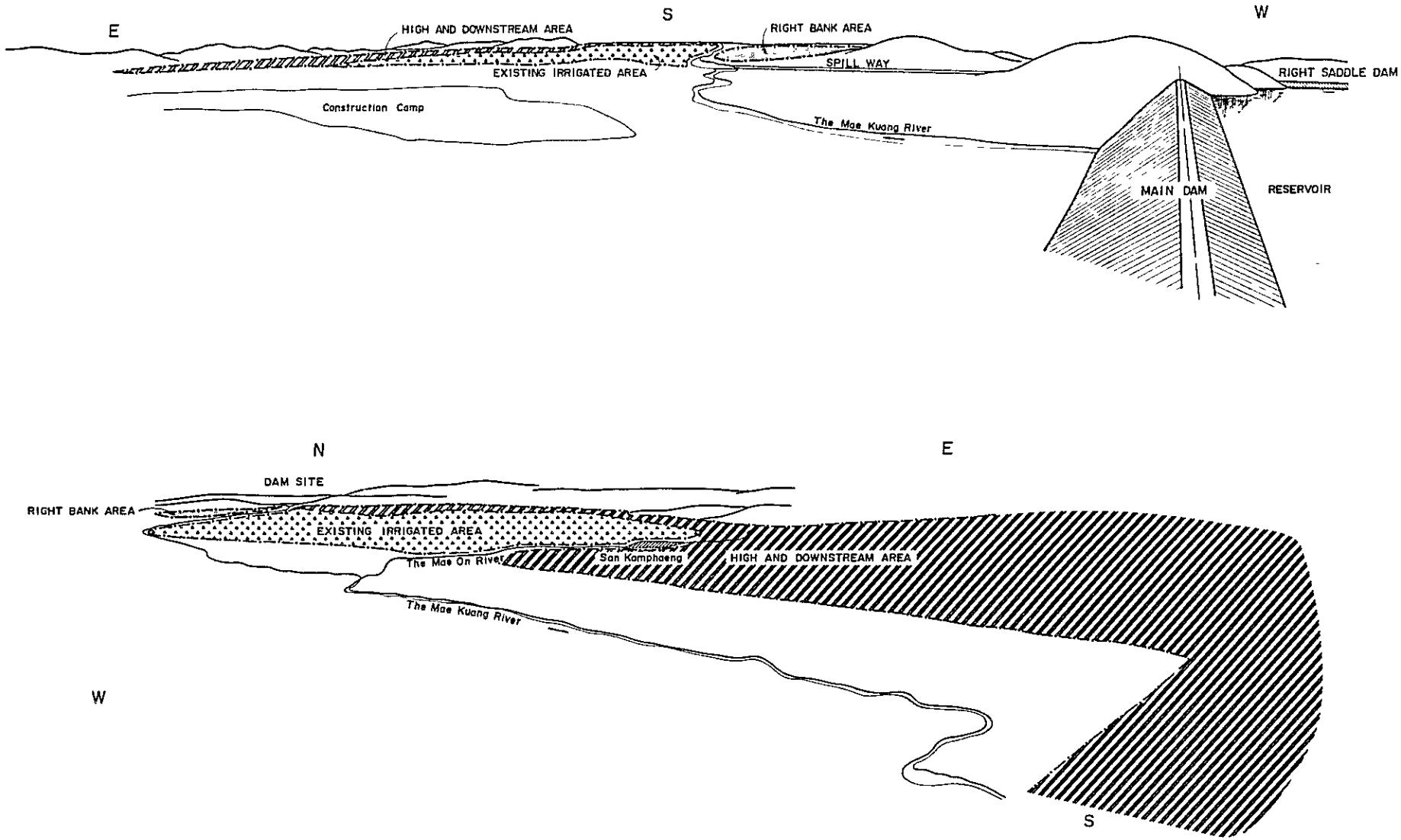


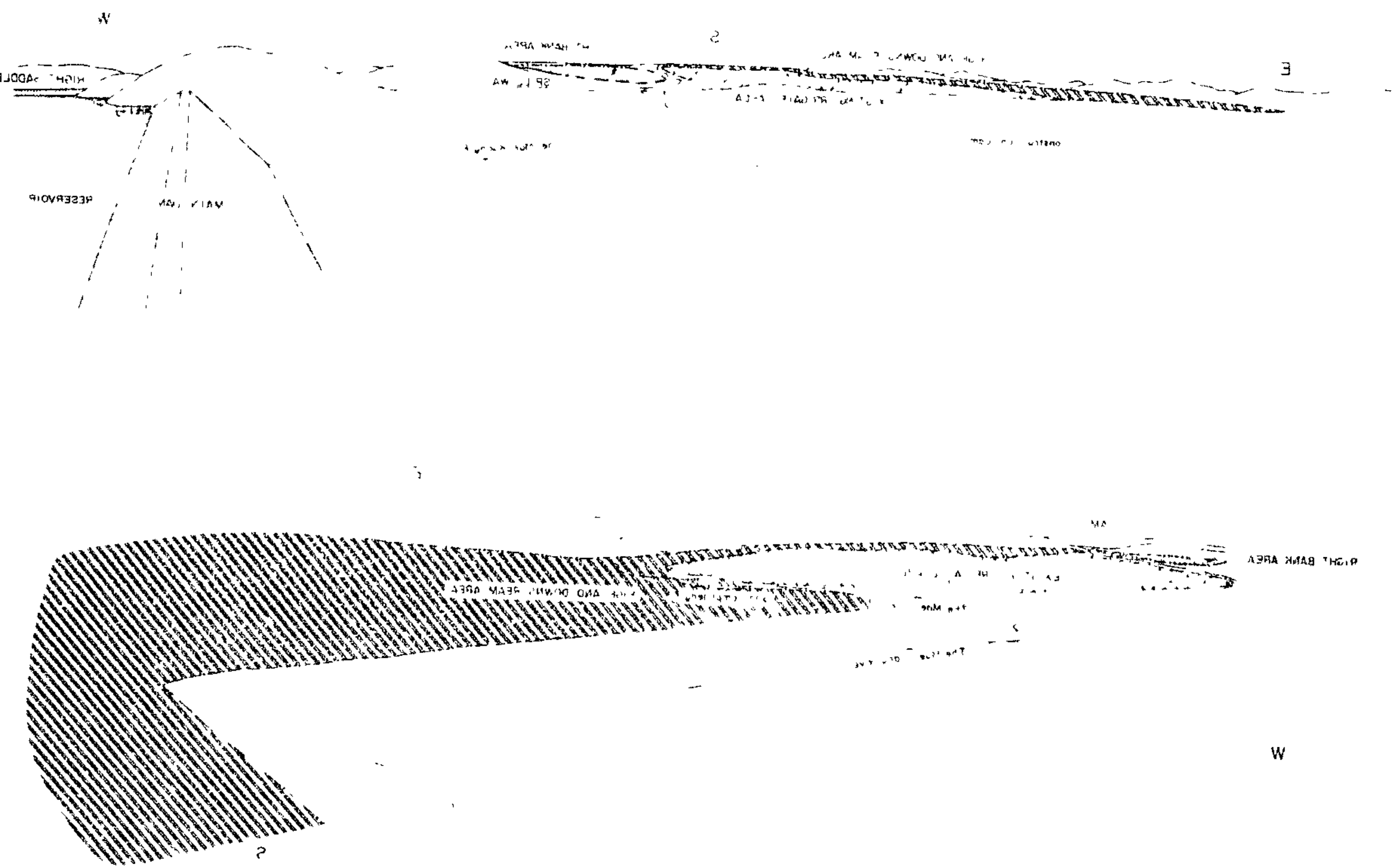
Shigekatsu Watanabe
Leader of the Feasibility Study
Team for the Mae Kuang Irrigated
Agriculture Development Project



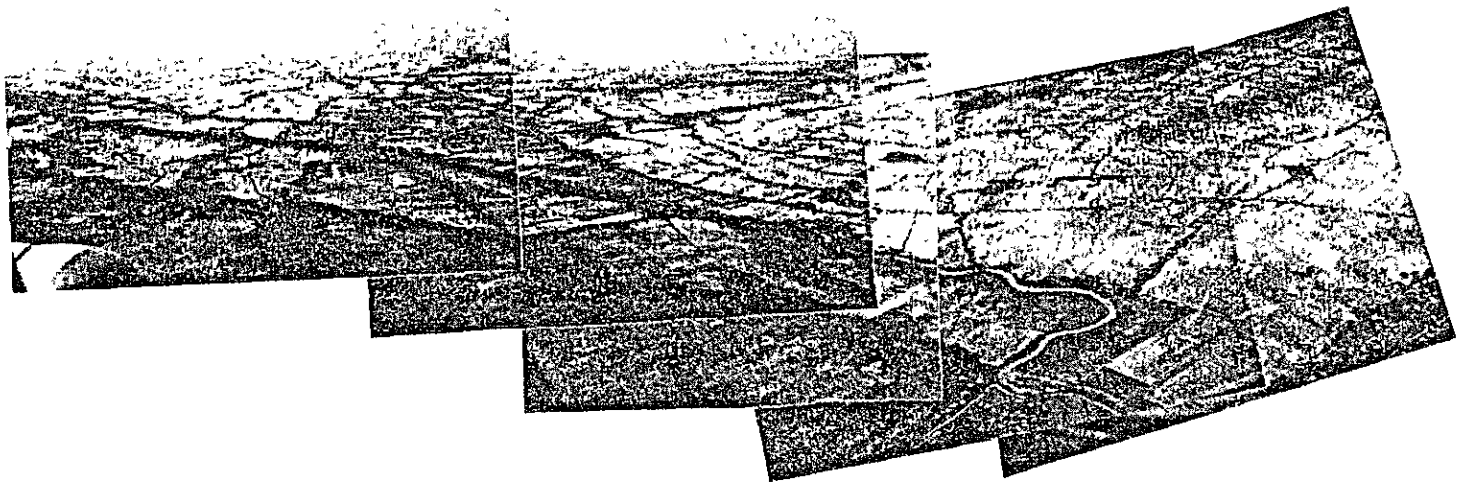


GENERAL PLAN FOR MAE KUANG IRRIGATED AGRICULTURE DEVELOPMENT PROJECT


E
S
W
HIGH AND DOWNSTREAM AREA
RIGHT BANK AREA
SPILL WAY
RIGHT SADDLE DAM
EXISTING IRRIGATED AREA
Construction Camp
The Mae Kuang River
MAIN DAM
RESERVOIR
N
E
DAM SITE
RIGHT BANK AREA
EXISTING IRRIGATED AREA
The Mae On River
San Kamphaeng
HIGH AND DOWNSTREAM AREA
The Mae Kuang River
W
S

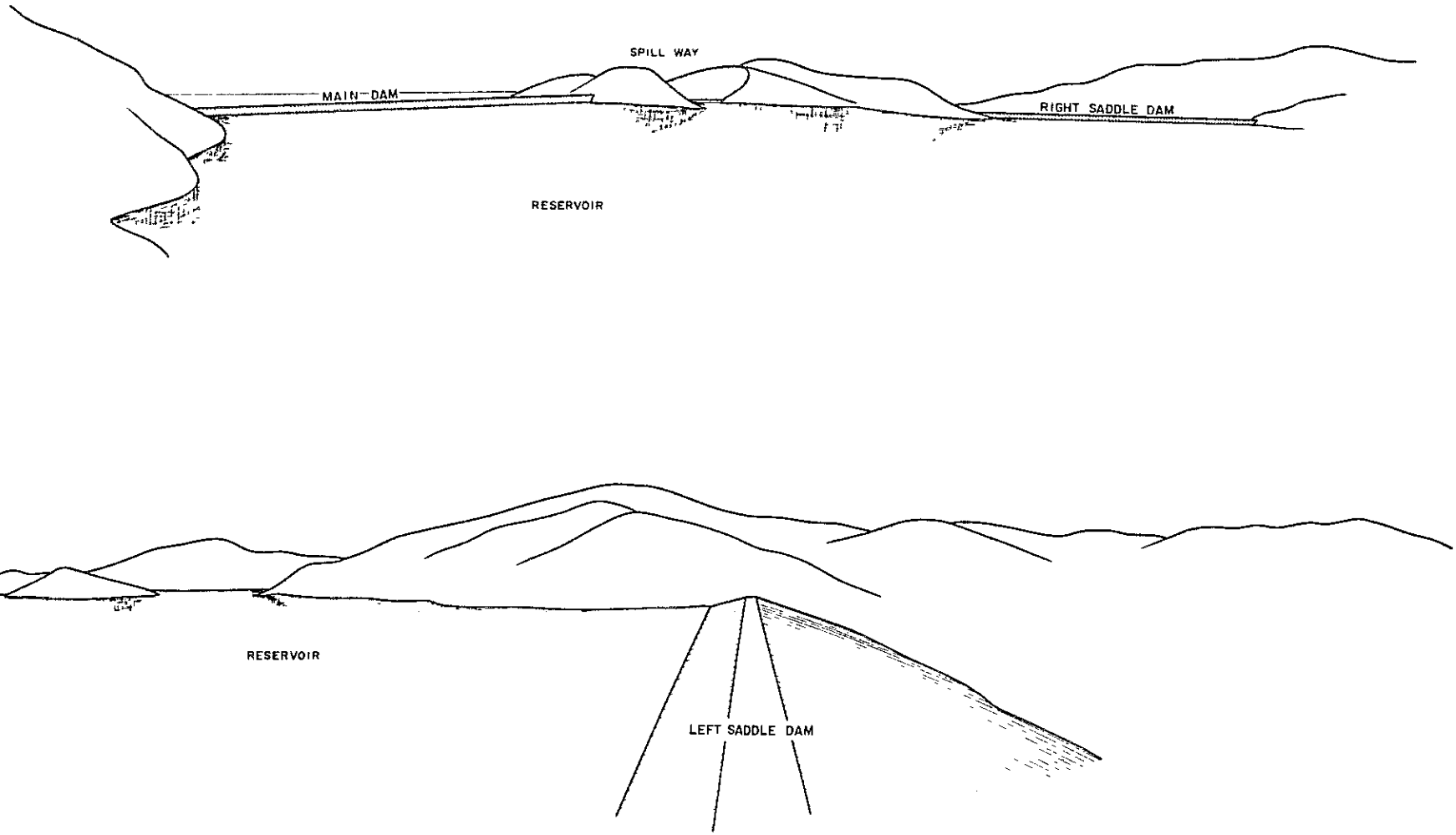

W
RIGHT SADDLE DAM
RESERVOIR
MAIN DAM
E
RIGHT BANK AREA
W

Upstream View of The Project Area
(July 1981)



Downstream View of The Project Area
(July 1981)

GENERAL VIEW OF THE PROJECT AREA


SPILL WAY
MAIN-DAM
RIGHT SADDLE DAM
RESERVOIR
RESERVOIR
LEFT SADDLE DAM

Main Dam and Right Saddle Dam
(View from the Reservoir Side)

Left Saddle Dam (under construction)
(View from the Right Bank)

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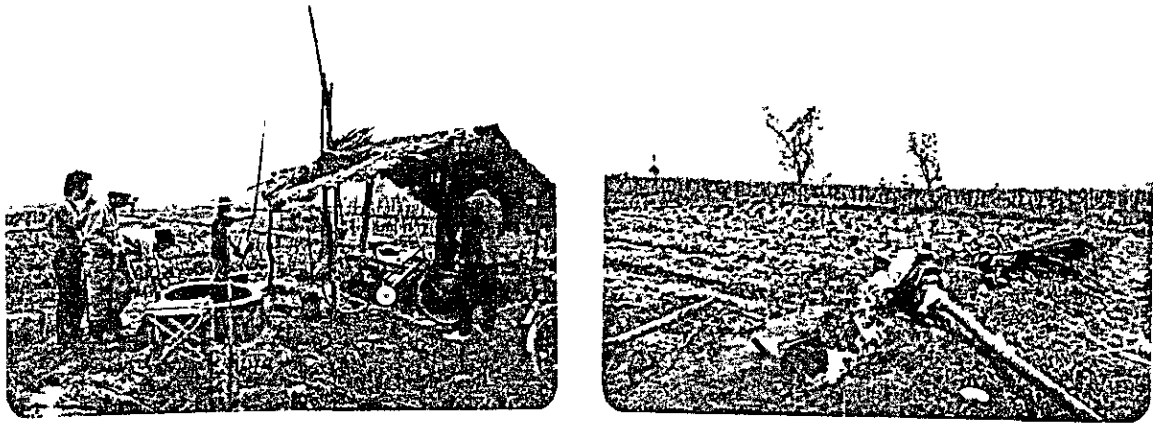


Irrigation by Well in Dry Season February 1981
(Left Highland Area)

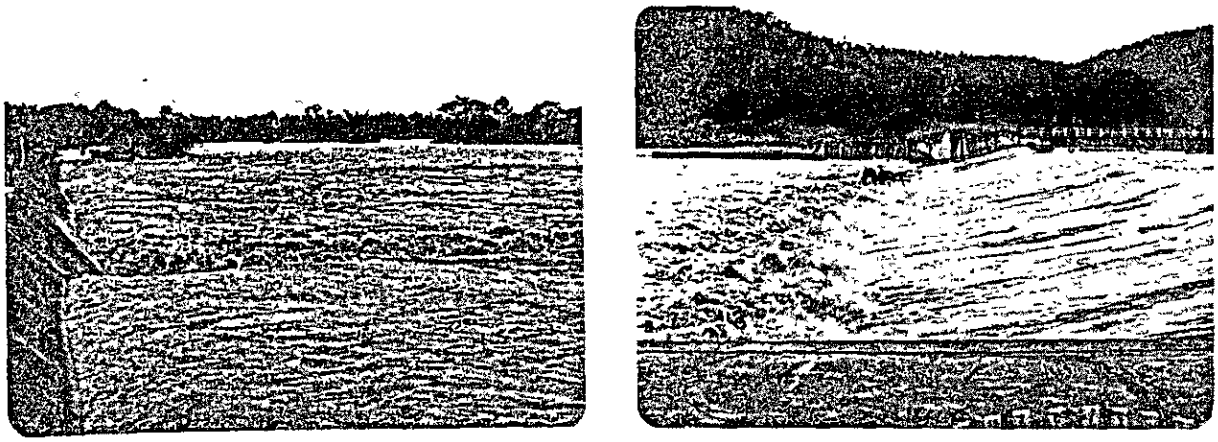
Paddy Field in Dry Season February 1981
(Downstream Area)

Nursery Bed June 1981 (Ban ko Salam, Downstream Area)

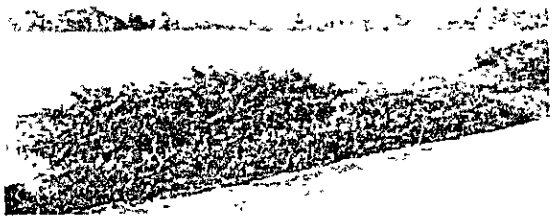
Ploughing the Paddy Field by Buffalo July 1981
(Doi Saket, Existing Irrigated Area)

Transplanting of Wet Season Paddy August 1981
(Doi Saket, Existing Irrigated Area)

PRESENT AGRICULTURE



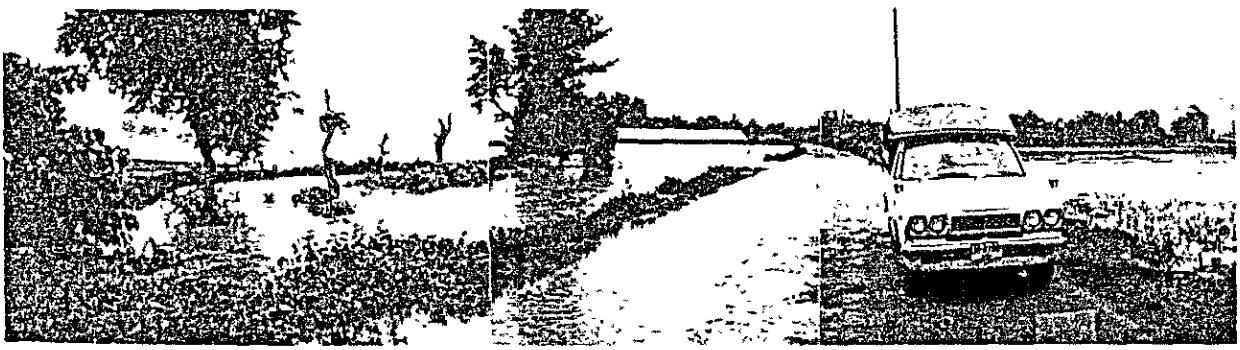
Flood Flow on the Mae Kuang Weir (1/9 cms)
(6th July 1981)



Inundation at the Downstream of the Provincial Road
(7th July 1981) (Chiang Mai Doi Saket)

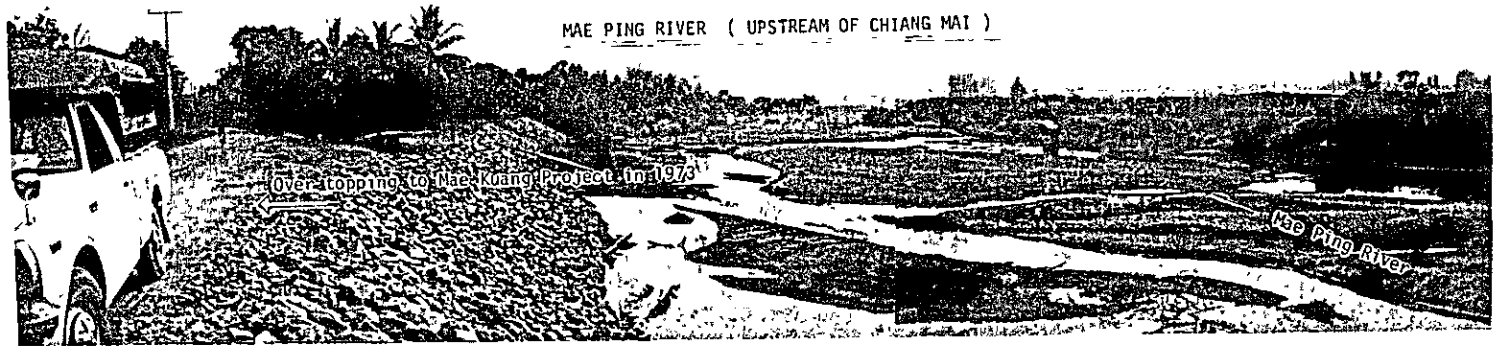
Over Flow on the Provincial Road (Chiang Mai Doi Saket)
(th July 1981)

FLOOD OF THE MAE KUANG RIVER
(6th – 7th July, 1981)

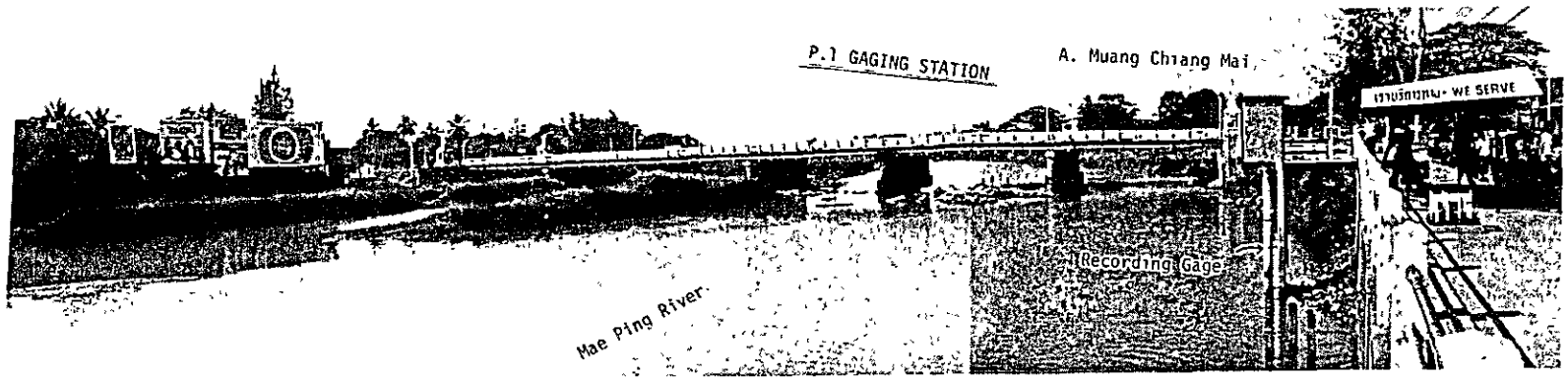


Inundation caused by Heavy Rainfall at the upper portion of the Existing Irrigated Area

INUNDATION IN THE PROJECT AREA
(20th July, 1981)

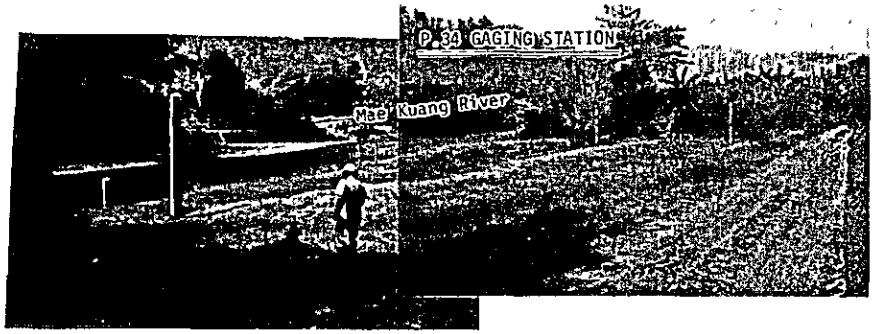


Upstream of Chiang Mai

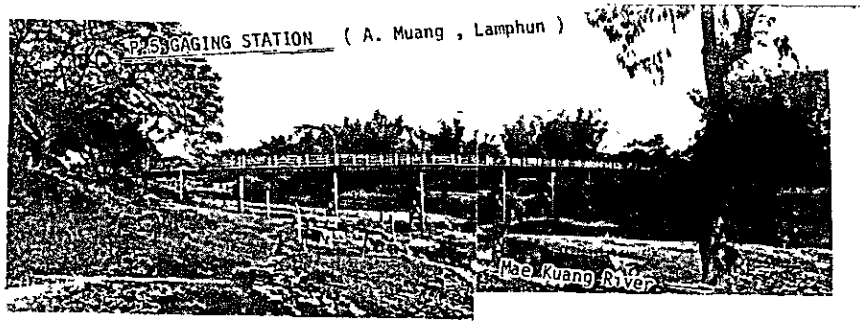


P-1 Gaging Station (Nawarat Bridge, Muang Chiang Mai)
(March 1981)

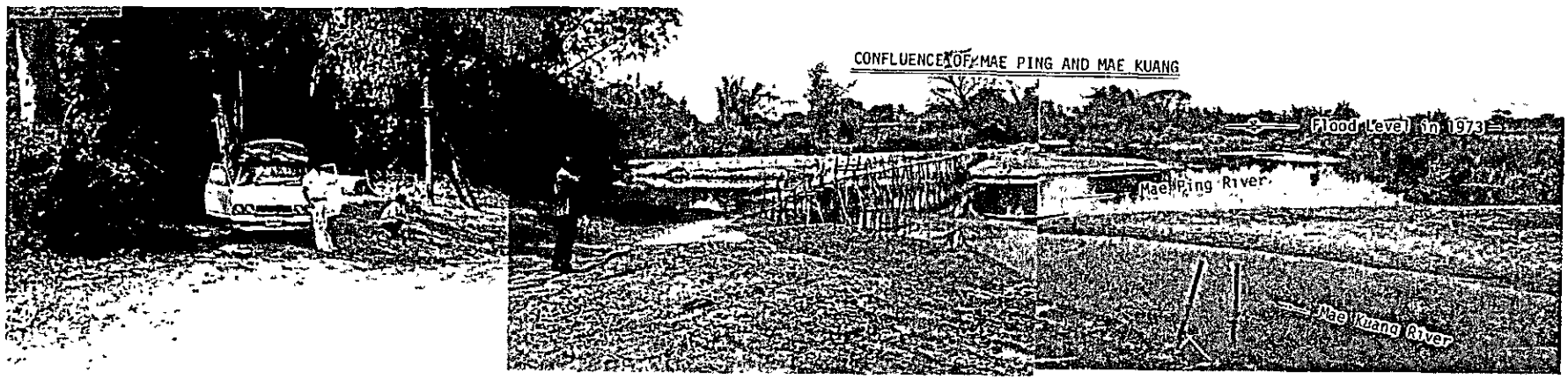
THE MAE PING RIVER



P-34 Gaging Station (Ban Pha Taek)

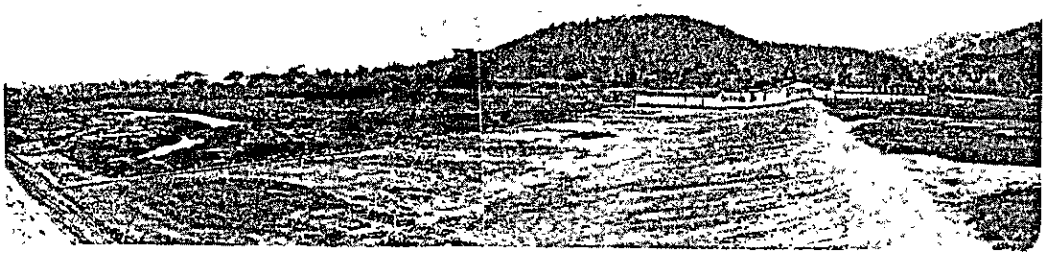


P-5 Gaging Station (Thasing Bridge, Muang Lamphun)



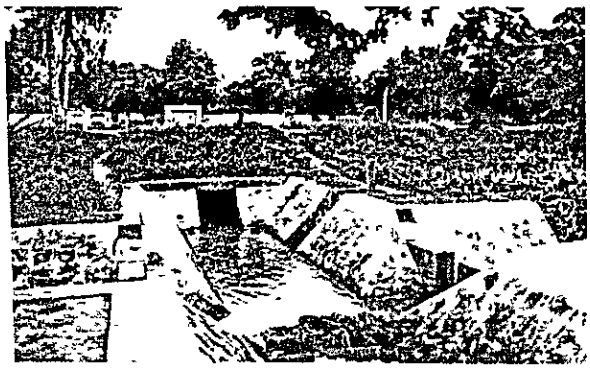
Junction of The Mae Kuang and The Mae Ping

THE MAE KUANG RIVER
March 1981



The Mae Kuang Weir (March 1981)

Existing Main Canals diverted from the Mae Kuang Weir, March 1981
(from left, Pha Taek Canal, Muang Wah Canal and Koh Matan Canal)



Diversion to Lateral Canal (Pha Taek Canal)
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Onfarm Irrigation (Dry Season)
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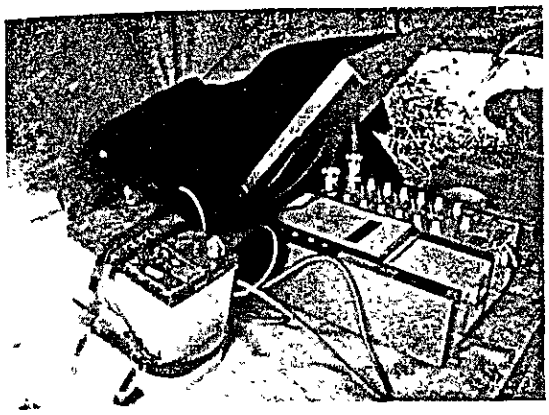
PRESENT IRRIGATION SYSTEM



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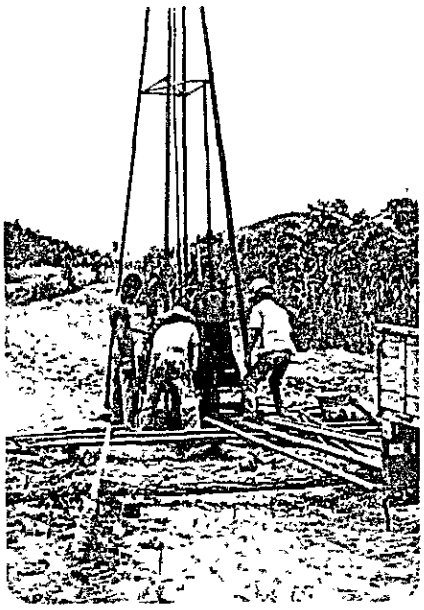
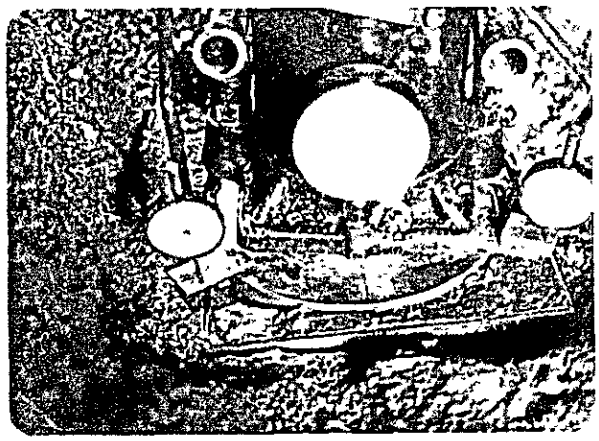
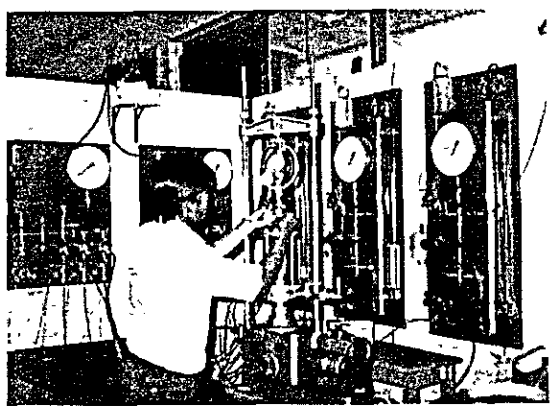


BORING TEST
(Right Saddle Dam Axis)



LOADING TEST
(Left Saddle Dam Axis)

Soil Sampling



Triaxtual Compression Test

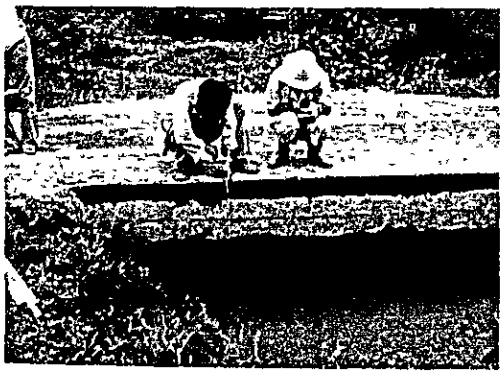
SOIL MECHANICAL TEST

San Sai Series: one of the Major Soil Series
(Doi Saket, Existing Irrigated Area)

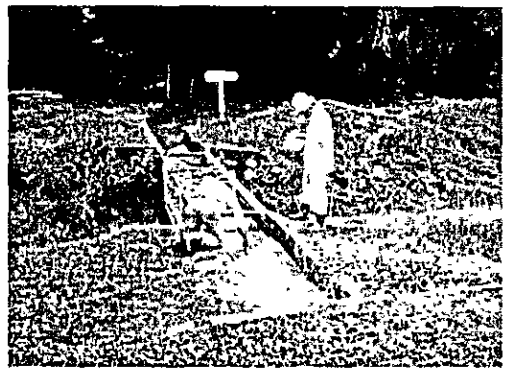
(Downstream Area)

SOIL SAMPLING
June 1981

FIELD OBSERVATION FOR INTAKE RATE
June, 1981



Flow Measurement for Outflow



Flow Measurement for Inflow

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ABBREVIATION AND GLOSSARY

Agencies

ADB	:	Asian Development Bank
BAAC	:	Bank for Agriculture and Agricultural Cooperatives
DLD	:	Department of Land Development
DAE	:	Department of Agricultural Extension
EGAT	:	Electricity Generating Authority of Thailand
FAO	:	Food and Agriculture Organization of United Nations
IBRD	:	International Bank for Reconstruction and Development
JICA	:	Japan International Cooperation Agency
MC	:	Ministry of Communication
MD	:	Meteorological Department
MOAC	:	Ministry of Agriculture and Cooperatives
NESDB	:	National Economic and Social Development Board
RID	:	Royal Irrigation Department
UNESCO	:	United Nations Educational, Scientific and Cultural Organization

Unit of Measurements

mm	:	millimeter
cm	:	centimeter
m	:	meter
km	:	kilometer
sen	:	Thai unit of length, 1 sen = 40 m
sq.cm, cm^2	:	square centimeter
sq.m, m^2	:	square meter
sq.km, km^2	:	square kilometer
MSM, $10^6 m^2$	:	million square meter
ℓ, lit	:	liter
cu.m, m^3	:	cubic meter
MCM, $10^6 m^3$	:	million cubic meter
lit/sec	:	liter per second
cu.m/sec	:	cubic meter per second
lit/sec/ha	:	liter per second per hectare
m/sec	:	meter per second
PPM	:	part per million
g	:	gram
kg	:	kilogram
ton, m.t	:	metric ton
EL	:	elevation above mean sea level
MSL	:	mean sea level
FWL	:	full water level
HWL	:	high water level
sec	:	second
minu	:	minute
hr	:	hour
min	:	minimum
max	:	maximum
%	:	percent
No.	:	number
°C	:	degree Celsius
°F	:	degree Fahrenheit
Cl	:	chlorine
HP	:	horse power
ET	:	evapotranspiration
N	:	nitrogen
P	:	phosphorus
K	:	potassium
HYV	:	high yield rice variety
O & M	:	operation and maintenance
EIRR	:	economic internal rate of return
B/C	:	benefit cost ratio
FY	:	fiscal year
KW	:	kilowatt
MW	:	megawatt

KWh	:	kilowatt hour
GWh	:	gigawatt hour
B.E	:	Buddhist Era 2524 B.E = 1981 A.D

Conversion Factors

rai	:	Thai unit of area measurement, rai = 0.16 ha
ha	:	6.25 rai
tang	:	volumetric crop measure equivalent to 20 liters
฿	:	Thai Baht, ฿ = 0.05 US$
US$	:	Dollar, US$ = 20 Baht

Glossary of Thai Terms

Changwat	:	Province
Amphoe	:	District or title of district town
Tambon	:	Sub-district
Muban	:	Village
Muang	:	Capital of Changwat
Khao	:	Mountain or hill
Mae Nam	:	River
Huai	:	Stream
Soi canal	:	Secondary distribution canal
Muang Yai	:	Main canal

SUMMARY, CONCLUSION AND RECOMMENDATION

SUMMARY AND CONCLUSIONS

(The Study and Report)

1. This Report summarizes the feasibility study thus far conducted on the Mae Kuang Irrigated Agriculture Development Project. In preparing this Report, all alternatives expected were studied and the one considered best available was selected.

As a result, it was concluded that the proposed project was feasibile as it conformed with the nation's development policy, immediate priority, technical soundness and other project requirements.

(Economic Background)

2. Thailand has achieved a steady economic development since it started the First Economic and Social Development Plan in 1961 as expressed by per capita nominal gross domestic products of 3,900 Baht (US$199) in 1970 and that of 12,060 Baht (US$603) in 1979, tripled the former.

In the meantime, the gross domestic products in the agricultural sector is estimated to increase by 4.5 percent in 1981 because paddy output in the 1980-1981 crop year is forecasted at 17.5 million tons which are a large increase by about 11 percent from 15.8 million tons in the previous year.

(Regional Economy)

3. The Northern Region covers an area of 170,000 sq.km, about one-third of the total national land area encompassing sixteen provinces like Chiang Mai and Lamphun concerned with Mae Kuang Irrigated Agriculture Development Project.

In the Northern Region, the low annual growth rate over the past sixteen years can be largely attributed to the predominant role of agriculture. Even now it accounts for the major share of the income.

The Project Area extends widely in both Province (Changwat) Chiang Mai and Province Lamphun. Districts (Amphoes) concerned are San Sai, Doi Saket, and San Kamphaeng in Province Chiang Mai, and Muang Lamphun in Province Lamphun.

(The Project Area)

4. The Project Area is situated in the east side of the Province Chiang Mai with width of about 15 km from east to west, and about 40 km from north to south. The Mae Kuang river forms the western boundary of the Project Area flowing from north to south. Elevation in the Area is between EL 290.0 m and 350.0 m, and slope is as gentle as about 1/300 to 1/600 from north to southwest. The study was conducted over the farm land area of 20,000 ha (20,540 ha at present) out of total area of 37,270 ha.

The Project Area can be divided into three areas according to the land use as follows:

(1) Existing Irrigated Area	7,000 ha
(2) Right Bank Area	2,200 ha
(3) Left Bank Highland and Downstream Area	10,800 ha
Total	20,000 ha

(Project Components)

5. The Project aims primarily at the irrigated agriculture development of the proposed area. At the same time, the Project involves incidental components of flood control and hydro-power generation as below.

There are flood damages around the low-lying lands in the vicinity of the Mae Ping-Mae Kuang junction point in the Province Lamphun. The floods occur due to the overflow of the Mae Kuang and Mae Ping rivers or ill-drain river systems to the Mae Ping and the Mae Kuang rivers. The flood control effect by provision of the Mae Kuang reservoir has been studied, and it was concluded that an annual average flood damage would be reduced by 38 percent.

Basically, the hydro-power generation plan will be separately studied by EGAT. A very preliminary study clarified that an installation capacity would be 3,690 KW and an annual production 16.3 GWh.

(Agriculture)

6. It is envisaged in the field survey that more intensified cropping agriculture practices would become common among farmers in the Project Area. Intensive agricultural practices can be done only through agricultural package program. All kinds of agricultural inputs necessary for carrying out the said intensified agriculture should be provided to farmers backed up by institutional loan and at the same time effective agricultural extension services should be extended to farmers. Systematically constructed irrigation system is fundamental basis where intensified agricultural practices are to be performed.

The underwritten ten cropping patterns are to be proposed:

Rice-Rice, Rice-Groundnut, Rice-Soybean, Rice-Sweetcorn, Rice-Tobacco, Rice-Garlic, Rice-Vegetables, Soybean-Tobacco, Soybean-Groundnut and Longan.

(Agricultural Supporting Services)

7. It is entirely endorsed, in the survey conducted this time, that the existing multipurpose cooperative system should be more strengthened

because cooperative is conceivably believed to be the sole channel through which all kinds of agricultural inputs necessary for intensified agricultural practices are distributed to farmers in good cooperation with extension officers. The most serious problems which must be overcome are: i) shortage of fund to operate the proper activities, and ii) absence of marketing information about farm products to be provided appropriately to farmers, especially cash crops at the time of sales.

In order to accelerate the activities of cooperatives, a small rice milling plant attaching a small scale rice bran oil extraction device developed recently should be taken into consideration. Because rice milling is usually seasonal, however, new developed small scale bran oil extraction device can be utilized for soybean and groundnut as well. In anticipation of the increasing production of paddy, soybean and groundnut in the Project Area, such plant would run throughout the year and pay with fair profit.

(Pilot Farm)

8. In executing this Project, there will remain several problems to be solved pertaining to farming. Therefore, Pilot Farm must be founded prior to the general farming and meaning of irrigation must be understood by farmers. Two plots are chosen as proposed sites of Pilot Farm.

(Engineering Works)

9. The proposed Mae Kuang reservoir would have a total storage capacity of 325 million cubic meters for full exploitation of the Mae Kuang river water resources. The major engineering works consist of the three dams (Left Saddle Dam, Main Dam and Right Saddle Dam) with appurtenant facilities and two routes of new canal systems. Their major dimensions are as follows:

	Crest Elevation (m)	Embankment Volume (MCM)	Dam Height (m)	Dam Length (m)
Left Saddle Dam	395.0	2.26	52.0	650
Main Dam	395.0	5.58	77.0	645
Right Saddle Dam	395.0	1.44	41.0	655
Spillway	Q max = 1,452 cu.m/sec, Weir Length L = 150 m			
Main Irrigation Canal		87.4 km		
Lateral Irrigation Canal		146.6 km		
		25 m/ha		

A small scale hydropower generation plan is incidentally proposed to be irrigation water release in this Project. A very preliminary study was conducted and it clarified that an optimum installed capacity was 3.7 MW and an annual energy was 16.3 GWH. Further datails have been studied by EGAT upon the request of RID.

(Investment Cost)

10. The Project cost including price escalation has been estimated in two conditions of Project construction, on the force account basis and the contract basis, and their costs are summarized as follows;

	Without On-farm Facilities		With On-farm Facilities	
	Costs	(%)	Costs	(%)
Force Account Basis				
Foreign	฿1,556 million (US$ 77.8 million)	42	฿1,698 million (US$ 84.9 million)	42
Local	฿2,144 million (US$107.2 million)	58	฿2,386 million (US$119.3 million)	58
Total	฿3,700 million (US$185.0 million)	100	฿4,084 million (US$204.2 million)	100
Contract Basis				
Foreign	฿1,556 million (US$ 77.8 million	38	฿1,698 million (US$ 84.9 million)	38
Local	฿2,532 million (US$126.6 million)	62	฿2,774 million (US$138.7 million)	62
Total	฿4,088 million (US$204.4 million)	100	฿4,472 million (US$223.6 million)	100

The construction period is six years from 2526 (1983) to 2531 (1988).

(Executing Agency)

11. RID, which is responsible for the overall planning, programming and execution of all major flood control and irrigation projects in the country, would be the executing agency for the implementation of the project, with the assistance and cooperation of other Government agencies concerned.

The project office is already established beside the Mae Kuang dam construction site and is adequately staffed for efficient project implementation under the control of the Project Engineer.

(Project Benefit)

12. According to the economic justification of the Project, the investment is justifiable in terms of the net value added to the national and regional economy, the benefits to farm families and other socio-economic benefits.

The economic costs of the Project are estimated at ฿2,521 million at 1980 price which includes the total investment cost except for allowance for land acquisition, taxes and duties and price escalation. Operation and maintenance costs are also included.

The major direct benefits to evolve from the Project will be substantial increase in agricultural production and the resulting increase in income and employment opportunities for some 14,300 farm families. Apart from the agricultural benefits, benefits derived from flood control, power generation, etc. are considered as direct benefits.

The agricultural benefits are one of the major direct benefits derived from the Project. The Project, when fully developed, generate agricultural incremental net benefits of ฿610.5 million per year.

(EIRR and Financial Analysis)

13. On the basis of quantified economic benefits and economic costs, the economic internal rate of return (EIRR) of the Project is estimated at 17.7 percent. Also the results of sensitivity tests show that the Project is feasible.

The financial analysis of the Project is made from the farmers' viewpoint. A typical farm budget is studied, and as a result, the capacity to pay is worked out at ฿20,510 per farm family per year on an average when fully developed. From the capacity to pay, the farmer must pay the annual O & M cost, and repay the on-farm development costs. According to the calculation, the O & M cost and the repayment cost are worked out at ฿1,435 and ฿5,368 respectively. Therefore, each farmer could reserve about ฿13,700 of money as net profit even after payment O & M cost and development cost.

RECOMMENDATION

(Dam and Canal)

1. Prior to commencement of the final design, following investigations with sufficient detail and accuracy for the final design should be completed.

a) Topographical Survey (Canal, Main Dam, Right Saddle Dam and Spillway)

b) Geological Investigation (Canal, Main Dam, Right Saddle Dam and Spillway)

c) Material Investigation

Further detailed descriptions on the above items are given in Appendix C and Appendix H.

2. The Left Saddle Dam works, currently under construction, can proceed with the works taking into account the discussions made during the Survey and points mentioned in this Report in respect with dimensions and construction method.

3. The diameter of the conduit pipe is designed to be big enough anticipating the participation of hydropower generation. However, the size of outlet from the control house is not yet finalized because it will be subject to the hydropower generation plan. It is recommended to coordinate with the agencies concerned.

(Agriculture)

4. In anticipation of acceleration of intensified agricultural operation, some form of organization through which necessary agricultural inputs would be channeled to farmers level under agricultural package program in cooperation with extension offices. Cooperatives strengthened with more operational fund and reforms with better trained staffs are recommended as major channel for such purpose.

5. Farmers seek always accurate idea of marketing price of their own farm products. Market information services to farmers cannot be by-passed at any rate away from the activities of cooperatives. Recommendation is to be made for cooperative to take quick step in response with farmers' requirement.

6. Small scale rice milling plant attached with newly developed small scale bran oil extraction device which can be used as extractor for soybean and groundnut as well is also recommended in taking into consideration better activities of cooperatives.

(Overall Basin Development Plan)

7. The Project Area is located in the eastern edge of the Chiang Mai Plain and is proposed to be developed by the water resources of the Mae Kuang river. Meantime, the Mae Kuang river is a tributary of the Mae Ping river system. Therefore, it is recommended to review the overall Chiang Mai Plain development plan including the Mae Kuang Project from viewpoint of effective water use of the Mae Ping river. In particular, it is also recommended to clarify the relationship with the Kud Multipurpose Project and the Mae Kuang Project concerning the deducted area.

(On-farm Development)

8. For the quick yielding of the agricultural production in the Irrigated Agricultural Development Project, it is prerequisite to provide physical infrastructures, the so-called on-farm facilities such as farm roads, on-farm ditches for irrigation and drainage, etc., so that, it is recommended to construct such on-farm facilities soonest possible, together with the construction of major facilities of the project, although the study on on-farm development has not been involved in the scope of works for the project. As regarding on-farm development, only project costs in the manner of extensive development have been taken into accounts for the economic evaluation of the project in this study.

CHAPTER I INTRODUCTION

CHAPTER I INTRODUCTION

1.1 Background of the Survey

Agriculture holds the most important position in the economy of Thailand, accounting for 27 percent of the gross domestic product, 78 percent of employment population and 57 percent of export. Processing and marketing of the agricultural products play an important role in manufacture and commercial sectors. Hence, agricultural movement has large influence to the other industries.

In addition to such an vital role of agriculture in the national economy, an increase in agricultural production is required from the viewpoint of enhancement of living standard in the rural areas and correction of income disparity between the urban and the rural inhabitants. Since, however, an expansion of farm land comes to limit, it is said to be a pressing need to establish and implement irrigated agriculture plans which improve the land productivity.

Under these circumstances, the Mae Kuang Irrigated Agriculture Development Plan has been implemented on the force account basis of the Government of Thailand since 1976. Upon the request from the Government of Thailand for reviewing technical matters on dam construction and formulating an overall agricultural development plan, the Government of Japan responded by dispatching the survey team in July, 1980.

1.2. Objectives of the Survey

The objectives of the survey were as follows:

i) to formulate an irrigated agriculture development project and verify the feasibility of the Project, covering the gross area of 37,270 ha inclusive of the expected net irrigable area of 20,000 ha.

ii) to determine the optimum reservoir plan in view of multi-purpose uses of the water, and

iii) to undertake on-the-job training of the Government officials in the course of the survey.

1.3 History of the Survey

The history of the survey is as follows:

a) Preliminary Survey (3rd Dec. - 20th Dec. 1980)

Upon the request of the Government of Thailand, the Government of Japan dispatched a seven-member Preliminary Survey Team to Thailand for 18 days from 3rd December to 20th December 1980. The Survey Team discussed with the Thai Authorities concerned the basic guidelines for a future survey and conducted relevant data collection.

b) First Stage Survey (15th Feb. - 31st Mar. 1981)

The Government of Japan sent a nine-member First Survey Team to Thailand for 45 days, from 15th February to 31st March, 1981. The Survey Team concentrated its effort to study on the engineering aspects of the Project. The First Stage covered the dry season survey.

c) Second Stage Survey (1st June - 19th Aug. 1981)

A thirteen-member Second Stage Survey Team was sent to Thailand for 80 days from 1st June to 19th August 1981. The main tasks of the Second Stage Survey may be summarized as follows:

i) to make a supplementary data collection

ii) to conduct the site investigations

iii) to identify the irrigable area

iv) to formulate the development project, and

v) to prepare interim report

Tabulated hereinafter are the Supervisory Group, Team Members and Counterparts Personnel assigned to the Project.

Supervisory Group Assigned to the Project

1. Chief Advisor (Mr. Katsuhiro KAKIUCHI)	Director, Construction Department, Hokuriku Regional Administration Office, Ministry of Agriculture, Forestry & Fisheries (MAFF)
2. Advisor (Agronomy) (Mr. Kunikiho OHNO)	Director, Resources Division, Planning Department, Kanto Regional Administration Office, MAFF
3. Advisor (Agro-economy) (Mr. Jiro IWASA)	Deputy Director, Regional Planning Division, Planning Department, Kanto Regional Administration Office, MAFF
4. Advisor (Dam & Structure) (Mr. Hiroshi MIYAMOTO)	Deputy Director, Project Planning Division, Agricultural Structure Improvement Bureau, MAFF
5. Advisor (Irrigation & Drainage) (Mr. Masashi MORITA)	Senior Officer of Agricultural Civil Engineering, Design Division, Construction Department, Kinki Regional Administration Office, MAFF
6. Advisor (River Improvement) (Mr. Shoshi YOKOZUKA)	Director, Planning Division, Planning Department, Kanto Regional Administration Office, Ministry of Construction
7. Advisor (Economic Evaluation) (Mr. Toru SHIBUICHI)	Deputy Manager, 2nd Technical Appraisal Div. Economic Research and Technical Appraisal Department, The Overseas Economic Cooperation Fund (OECF)

Team Member Assigned to the Project

1. Team Leader (Mr. Shigekatsu WATANABE)	15 February - 28 February 19 March - 31 March 1 June - 15 June 5 August - 19 August

2. Water Resources & Flood Control (Mr. Koki MITSUNOBU)	15 February 1 June	- 31 March - 19 August
3. Irrigation & Drainage (Mr. Seiji TAKEUCHI)	15 February 1 June	- 31 March - 19 August
4. Hydrology & Meteorology (Mr. Yasuo MATSUBARA)	18 February 1 June	- 31 March - 25 July
5. Geology (A) (Mr. Ryoichi KAWASAKI)	18 February 1 June	- 31 March - 25 July
6. Geology (B) (Mr. Akira YAMAZAKI)	1 June	- 10 July
7. Soil Mechanics (Mr. Junichi IZUMI)	18 February 1 June	- 19 March - 25 July
8. Dam (Mr. Tadao INABA)	15 February 1 June	- 31 March - 19 August
9. Hydraulic Structure (A) (Mr. Kazuo KITANI)	18 February	- 31 March
10. Hydraulic Structure (B) (Mr. Akira TAKUBO)	14 June	- 9 August
11. Soil (Dr. Shigeru MISONO)	1 June	- 10 July
12. Agronomy (Mr. Katsura KARIYA)	1 June	- 9 August
13. Extension & Agri-institution (Mr. Yoshihiko HASEGAWA)	15 July	- 19 August
14. Agro-economy (Mr. Gakuji KIMURA)	25 June	- 19 August

Counterpart Personnel Assigned to the Project

1. Mr. Shaiyonta Maneekul	Project Engineer, Mae Kuang Dam Project, RID
2. Mr. Ruongrit Ammawat	Chief Engineer, Dam Branch Sub-Division, Design Division, RID
3. Miss Supha Sing-Intara	Chief, Economic Branch, Project Planning Division, RID
4. Mr. Osot Charnvej	Chief, Irrigated Agriculture Section, O & M Division, RID

5.	Mr. Teerapan Panumong	Irrigation Engineer, Mae Kuang Dam Project, RID
6.	Dr. Suphon Chirapuntu	Soil Engineer, Soil and Geology Division, RID
7.	Mr. Amnuey Somsin	Hydrologist, Hydrology Division, RID
8.	Mr. Wim Suwannawongse	Dam Engineer, Mae Kuang Dam Project, RID
9.	Mr. Preecha Burapakusolsri	Soil Engieer, Mae Kuang Project, RID
10.	Mr. Somchart Wonarawanant	Canal Engineer, Design Irrigation No.1, Design Division, RID
11.	Mr. Vikrom Pasit	Engineer, Mae Kuang Dam Project, RID
12.	Mr. Kanosak Thasma	Dam Design Engineer, Dam Design Section, Design Division, RID
13.	Mr. Supat Chaiwongrote	Geologist, Soil and Geology Division, RID

CHAPTER II ECONOMIC AND SECTORAL BACKGROUND

CHAPTER II ECONOMIC AND SECTORAL BACKGROUND

2.1 National Economy

Thailand has achieved a steady economic development since it started the First Economic and Social Development Plan in 1961, as expressed by nominal Gross Domestic Product (GDP) per capita of 3,900 Baht (US$199) in 1970 and that of 12,060 Baht (US$603) in 1979, that is, the triple of the former.

According to the latest information[1/], the growth of the gross domestic product in real terms is estimated to range from 7.1 percent to a little over eight percent. Nevertheless, in 1981, the country must encounter a number of economic problems, of which the most critical matters are a rapid rise of the living cost as estimated at 16 - 18 percent, and a trade deficit recorded by 60,000 - 70,000 million Baht (US$3,000 - 3,500 million). Although the estimated inflation rate is likely to be slightly lower in this year than 19.7 percent in the last year, in fiscal 1981 the current account deficit is estimated to be considerably larger than 58,590 million Baht (US$2,498 million) in 1980 as said above.

In the meantime, GDP in the agricultural sector is estimated in increase by 4.2 - 4.7 percent in 1981, compared with the growth rate estimated at about 3.5 percent by the NESDB last year. Fortunately, paddy output in the 1980/81 crop year is forecast at 17.5 million tons which are a large increase by about 11 percent over 15.8 million tons in the prior crop year. Other crops such as cassava roots, sugarcane and rubber were also lush because these had been planted a little before the heavy rain began. On the contrary, production of maize and kenaf dropped slightly due to a substantial decrease in planting areas.

1/ "1981 Mid Year Economic Review", Bangkok Post, 1981

2.2 Regional Economy

The Northern region covers an area of 170,000 sq.km or about one-third of the total national land area, encompassing sixteen provinces (Changwats) including Chiang Mai and Lamphun concerned with the Mae Kuang Irrigated Agricultural Development Project Area.

According to the report[1/], the annual Gross Regional Product (GRP) growth rate for the Northern region over the period of 1960 - 1978 was 5.7 percent while the GDP growth rate for the whole economy was 7.1 percent as shown in Table 2-1.

The per capita income greatly differs by regions in Thailand. Although for the Northern region it increased from approximately 1,500 Baht (US$75) in 1960 to 8,780 Baht (US$439) in 1979, this is equivalent to about 73 percent of the national average or to only 29 percent of the 30,160 Baht (US$1,508) in the metropolitan zone.

In the Northern region, the lower annual growth rate over the past 16 years can be largely attributed to the predominant role of agriculture. Even now it accounts for the major share of the income. As seen in Table 2-2, the shares of agriculture in GRP of the Northern region and in the GDP of the whole economy are 45.5 percent and 26.4 percent respectively, in 1976. On the other hand, the share of manufacturing in GRP of the Northern region is 50 percent less than that of the whole economy.

The Project Area extends widely in both Province Chiang Mai and Province Lamphun. Districts (Amphoes) concerned are San Sai, Doi Saket and San Kamphaeng in Province Chiang Mai, and Muang Lumpun in Province Lamphun. The Project Area consists in 33 sub-districts (Tambons), of which 28 belong to Province Chiang Mai and only five belong to Province Lamphun (see Figure K 2-1, Appendix K-2).

1/ "Basic Research for Formulating a Micropolitan Model"
- a Northern Study -
Prepared by Chiang Mai University, 1980

Province Chiang Mai and Province Lamphun are more agriculturally-based than the whole economy in structure. However, both provinces, especially Province Chiang Mai, are industrially-based to a great extent as compared with the average of the Northern region.

Detailed data relating to national economy and regional economy mentioned above are shown in Appendix K-1.

Table 2-1 Gross Regional and Gross Domestic Products: Northern Region, 1960 - 1978

(In 1962 constant prices)

(Unit: Billion Baht)

Year	GRP (M.฿)	GDP (M.฿)	Annual Percentage GRP (%)	Annual Percentage GDP (%)
1960	8.8	56.1	-	-
1961	9.1	59.0	2.8	5.3
1962	9.9	63.8	9.5	8.4
1963	10.6	69.1	6.6	8.4
1964	11.4	73.7	7.0	6.4
1965	11.9	79.5	4.6	7.9
1966	13.7	89.2	14.9	12.2
1967	14.8	94.1	8.0	15.5
1968	16.0	102.6	8.9	9.0
1969	16.9	112.4	5.8	9.6
1970	18.2	119.9	7.4	6.5
1971	18.6	129.6	2.5	8.1
1972	17.9	135.2	-4.1	4.3
1973	20.1	149.1	2.3	10.3
1974	21.3	156.0	6.0	4.6
1975	21.8	164.6	2.4	5.5
1976	23.1	174.9	5.8	6.3

Average growth rate (GRP) for the Northern region..5.7%

Average growth rate (GDP) for the whole economy ...7.1%

Source: NESDB

Table 2-2 Structure of the Whole Economy and the Northern Region Economy, 1976

(1962 constant prices)

(Unit: Billion Baht)

Sector	Whole Economy GDP	Whole Economy %	Northern Region GRP	Northern Region %
Agriculture	46.1	26.36	10.51	45.46
Mining and quarrying	1.8	1.03	0.28	1.22
Manufacturing	35.6	20.34	2.20	9.52
Construction	7.0	4.00	1.06	4.58
Electricity and water supply	5.7	3.26	1.03	4.46
Transportation and communication	11.8	6.75	1.41	6.10
Trade	28.8	16.47	3.39	14.67
Banking, insurance and real estate	8.9	5.08	0.37	1.61
Ownership of dwellings	2.9	1.66	0.21	0.10
Public administration and defence	7.5	4.27	0.95	4.11
Other Services	18.9	10.80	1.61	6.69
	174.9	100	23.12	100

Source: NESDB

CHAPTER III THE PROJECT AREA

CHAPTER III THE PROJECT AREA

3.1 Location and General Features

3.1.1 Geographic Location and Road System

The Mae Kuang Irrigated Agriculture Development Project Area extending about 15 km long from west to east and about 40 km long from north to south covers the easternmost of the Chiang Mai valley, North Thailand. The Project Area is located some 15 km east of Chiang Mai, the seat of the Chiang Mai Provincial Government Office. Administratively, the Project Area belongs to the two provinces (Changwat) of Chiang Mai and Lamphun.

Chiang Mai is accessible from Bangkok, the capital of Thailand, by land, by rail, and by air. From Chiang Mai to the Project Area a paved provincial road connecting Doi Saket and San Kamphaeng is available both in the wet and dry seasons. The existing road system in the Project Area is not sufficient in its density. Furthermore, transportation by vehicle suffers from inconvenience, specially during the wet season, resulting in difficulty in transporting agricultural inputs and outputs and in inter-village communication.

3.1.2 Population and Living Conditions

a) Population

Before 1972 the national population growth rate was greater than three percent per year. During the same period, the population in Provinces Chiang Mai and Lamphun grew slowly as compared with the national average. Recently, the population of these two provinces, however, is steadily increasing, and in the near future the population is expected to increase at a faster rate than in the past 15 years mainly due to the anticipated immigration from the adjacent rural areas.

Based on the data obtained from the field survey, the population in the Project Area is estimated at about 167,150. The population by districts is 29,978 for San Sai, 20,574 for Doi Saket, 63,414 for San Kamphaeng and 53,184 for Muang Lamphun. Population density in urban areas, especially San Kamphaeng and Muang Lamphun, is high comparatively with those in other areas.

b) Living Conditions

In general, a great part of farmers belongs to the lower income group, whereas traders and government employees belong to the higher income group. The average household income is estimated at about 12,000 Baht per annum. The income is divided into two components of farm income and non-farm income. In the urban area and its vicinity, the ratio of the non-farm income in total is more than 50 percent. Even in the rural area, the ratio is relatively high against expectation. This seems to be due mainly to the fact that most part of farm products are consumed by themselves and not encashed.

In general people in the Project Area lead a medium level life in the local conditions. The reason is probably that this area is located in the vicinity of Chiang Mai city and Muang Lamphun city which are part of the major administrative and commercial centers in the Northern region.

Detailed data relating to population and living conditions mentioned above are shown in Appendix K-2.

3.2 Physical Conditions

3.2.1 Topography and Rivers

a) Topography

The Project Area is located in the easternmost of the Chiang Mai valley as mentioned already. The Mae Kuang river flows across the eastern Chiang Mai valley from north to south along the western boundary of the Project Area, and separates the Project Area from

the other part of the Chiang Mai valley. Having an elevation of 290.0 m to 350.0 m, the Project Area is a flat land as a whole with a gentle slope of 1/300 to 1/600 from north-east to south-west.

In the aspects of topography and land use, the Project Area is sub-divided into i) an existing irrigated area, ii) a rainfed paddy area on the right bank, and iii) a highland and downstream rainfed paddy area on the left bank (see Figure 3-1).

b) Rivers

The Mae Kuang river is the main water resources in the Project Area. It is one of the main tributaries of the Mae Ping river flowing from the mountainous region where the border of Burma runs.

As shown in Figure 3-2, the Mae Kuang river originating in the mountainous side northeast of the Project Area enters into the flat area after passing the Mae Kuang diversion weir (Pha-Taek Weir) and flows along the western boundary of the Project Area. After running through the flat area, the river empties itself into the Mae Ping river at the downstream of Lamphun. The Mae Kuang river joins its tributaries such as Mae On, Mae Thi, Mae Yak, Mae San and Mae Tha rivers in order from the upstream before joining the Mae Ping river.

The Mae Kuang river has a drainage area of 1,871 sq.km excluding the area of the Mae Tha, at the junction.

3.2.2 Meteorology and Hydrology

a) Climate

The climate of Thailand is tropical, although cold air surges from the north occasionally during the winter. Temperatures remain above freezing point except those appearing on high peaks where frost may occur. Rainfall amounts vary greatly from place to place and from season to season. The Upper Ping River Basin is located in the area of less amount of rainfall.

FIGURE 3-1 TOPOGRAPHY OF THE PROJECT AREA

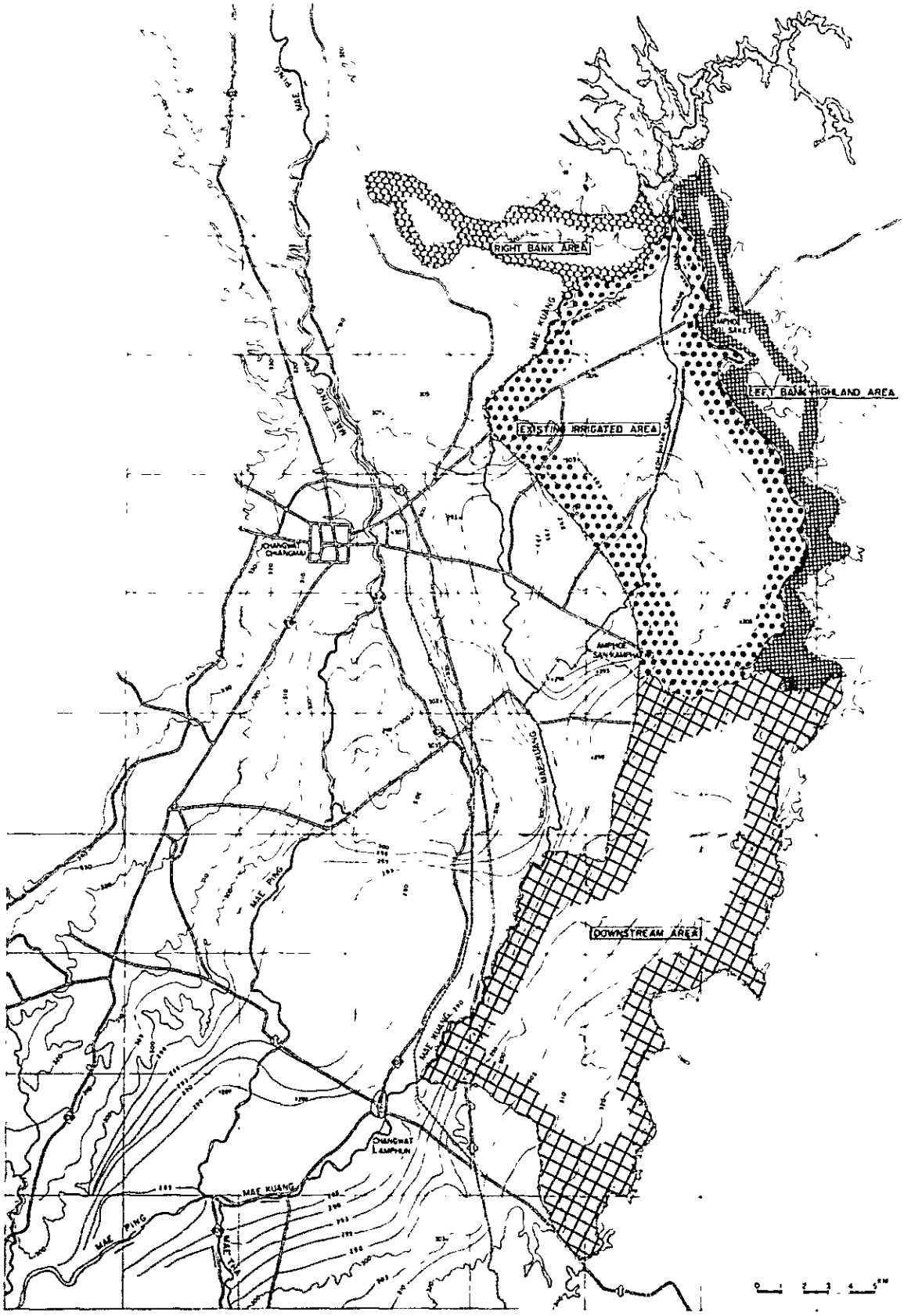
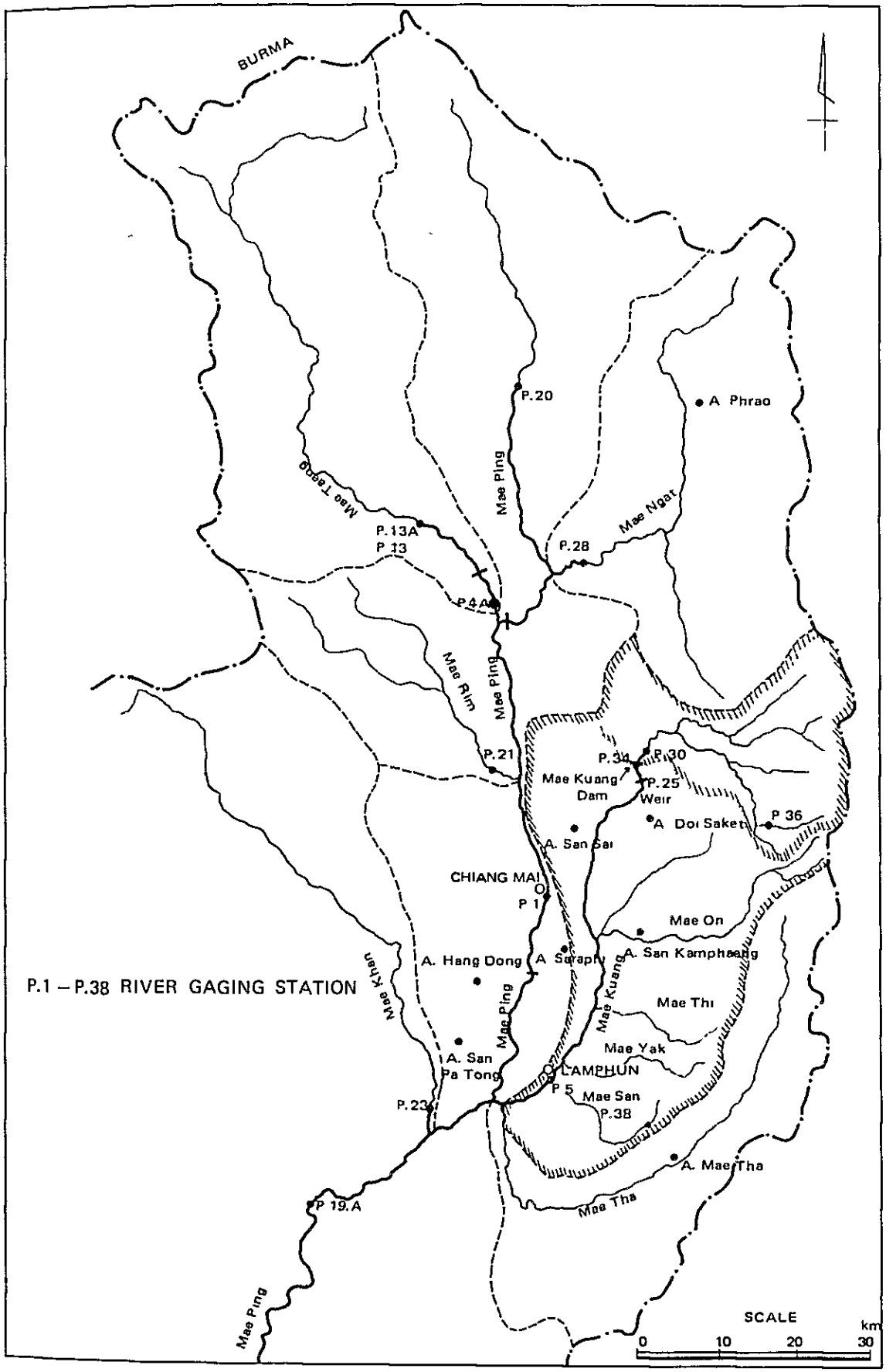


FIGURE 3-2 RIVER BASIN MAP



The climatic seasons are based on two major wind systems, the northeast and southwest monsoons. The northeast monsoon season extends from November to mid-March and the southwest monsoon season extends from mid-May to September. Between the major monsoons are transitional periods.

On the other hand, climate of Thailand is separated into two seasons, dry and wet seasons, by the characteristic of rainfall distribution. The dry season is generally defined from November to April, and the wet season is May to October. All most of the amount of rainfall is concentrated in the wet season.

Typhoons occasionally approach the Basin from the east, but before reaching the Basin they cross the mountains of Laos and Cambodia, where much of their energy is dissipated.

(1) Meteorological Observatories

Meteorological observatories in the region are operated mainly by Meteorological Department (MD) and Royal Irrigation Department (RID). Synoptic meteorological station is operated by MD only at Chiang Mai. At other stations, only rainfall or temperature, evaporation and wind are observed appropriately. Table 3-1 and Figure 3-3 show the meteorological observatories and their locations in the region. The longest-term observation record is available at Chiang Mai where the rainfall observation started in 1906. Table 3-2 shows the representative features of the climate in the vicinity of the Project.

(2) Evapotranspiration

Evapotranspiration was estimated theoretically with the obtained data shown in Table 3-2. Two kinds of evapotranspirations were estimated, one is reference crop potential evapotranspiration (ETPc) and the other is potential evapotranspiration (ETP). Reference crop potential evapotranspiration was estimated by Modified Penman Method, and it is used for estimating the consumptive use of crops. Potential

evapotranspiration was estimated by Original Penman Method, and it is about 80 percent of reference crop potential evapotranspiration as shown below. Potential evapotranspiration is adopted as lake evaporation.

Potential Evapotranspiration

(Unit: mm/month)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Total
ETPc	105	134	158	168	171	138	136	119	121	125	110	95	1,580
ETP	72	90	129	146	138	110	103	95	99	100	82	69	1,233

Note: ETPc: Reference Crop Potential Evapotranspiration
ETP: Potential Evapotranspiration

b) Hydrology

This section is dealing with rainfall and river discharge as the water resources and floods.

(1) Rainfall

The rainfalls around the Project Area are observed at 16 stations which are listed in Table 3-3. Field inspection has found out that the several stations are not well-maintained at present.

Annual Rainfall

The annual mean rainfall in the Mae Kuang River Basin varies from 1,000 mm at the center of the Project Area to 1,500 mm at the hilly region located in the northeast of the Project Area. For estimating the annual rainfall in the Project Area, following four stations are selected as the representative stations.

Representative Stations

Representative Station	Code	Average Rainfall (mm)	Area Weight
A. Doi Saket	07052	1,238	0.3250
A. San Kamphaeng	07032	976	0.4983
A. Muang Lamphun	17012	1,039	0.1667
A. Mae Tha	17042	1,163	0.0100
Weighted area rainfall		1,073 mm	

The annual rainfall in the Project Area is estimated at 1,073 mm in average by Thiessen Method.

Monthly Rainfall

Monthly distribution of the annual rainfall is as shown in the following table. Almost 90 percent of the annual rainfall is concentrated in the wet season from May to October.

Monthly Mean Rainfall in the Project Area

(Unit: mm)

Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.
42.5	126.5	124.4	140.1	235.6	227.0	107.3	28.3	12.8	8.9

Feb.	Mar.	Annual
6.0	13.8	1,073.2

Note: Average of 1952 - 1979

The estimated monthly rainfalls from 1952 to 1979 are listed in Table 3-4. The observed monthly rainfall records at various stations are shown in Appendix A.

Daily Rainfall

The annual maximum daily rainfall occurs generally in the period from July to October and frequently in August and September, but occasionally in May.

The probable annual maximum daily rainfalls at Chiang Mai, Doi Saket and San Kamphaeng were estimated as shown below:

Probable Annual Maximum Daily Rainfall

(Unit: mm)

Return Period	Chiang Mai			Doi Saket			San Kamphaeng		
	1-day	2-day	3-day	1-day	2-day	3-day	1-day	2-day	3-day
2-year	72	96	112	89	109	125	180	100	113
5-year	98	127	146	108	134	152	102	125	137
10-year	116	148	168	119	150	169	115	140	149
20-year	134	168	190	128	163	184	126	153	160
30-year	145	179	203	132	171	192	131	159	165
50-year	159	194	219	138	180	203	138	169	172
100-year	179	214	241	145	192	216	147	180	184

Note: Data period: 1952 - 1979

Record of annual maximum daily rainfall and its probability at various stations are described in Appendix A.

Hourly Rainfall

The data of hourly rainfall are available at only four stations which are Chiang Mai, RID Office, P.25 gaging station and P.36 gaging station.

The maximum hourly intensity is available only at Chiang Mai, and the hourly distribution of recorded maximum 24 hours rainfall is available at other three stations. Following table shows the rainfall intensities at said four stations.

Rainfall Intensities

(Unit: mm)

Station	Time Duration (hrs)						
	1/2	1	2	3	6	12	24
Chiang Mai	55.5	72.5	110.5	143.5	160.4	166.5	169.4 1/
RID Office	-	73.0	78.0	80.2	81.8	88.8	142.8 2/
P.25 Gaging Stat.	-	39.6	62.7	83.3	124.8	154.8	160.5 2/
P.36 Gaging Stat.	-	76.0	81.7	85.1	85.5	89.6	89.7 2/

Note: 1/ ECI Report 2/ Hydrology Division, RID

According to the above data, the following equation will be adopted for estimating hourly rainfall in the Project Area.

$$R_t = 0.4014\ t^{0.287}\ R_{24} \quad \ldots\ldots\ldots\ldots \quad (3.1)$$

R_t: t hours rainfall (mm)
R_{24}: 24 hours rainfall (mm)
t: time duration (hours)

(2) Stream Flows

The stream flows in the Basin were measured at the river gaging stations, of which locations are marked in Figure 3-3. The observed records are compiled on the water year basis from April to March in Thailand.

Annual Run-off

The average annual run-offs at various gaging stations are shown in Table 3-5. The average annual run-off from the Upper Ping River Basin for the period from 1952 to 1975 was estimated to be 6,403 MCM at P-12 and the specific yield to be 0.24 MCM/sq.km. Meantime, the average annual run-off from the Mae Kuang river was estimated to be 252 MCM at P-34 for the period from 1952 to 1979 and the specific yield to be 0.45 MCM/sq.km which almost double the value at P-12. The specific yield at P-5 in the Mae Kuang river is 0.48 MCM/sq.km, higher than the yield at P-34. The run-off at P-5 must be considered inclusive of the inflow due to over-topping from the Mae Ping river in the period of high flood.

Monthly Run-off

The monthly mean run-offs at key stations for the Project are shown in the below table. Monthly distribution of run-off is also presented in percentage.

It is clearly found that the monthly peak run-off is concentrated in the period from August to October. In the case of the Mae Kuang

river, almost 60 percent of the annual run-off is concentrated in this period and only 24 percent in the dry season.

Monthly Mean Run-off

(Unit: MCM)

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual Total
P-1	38.54	79.35	115.56	162.57	343.86	455.85	319.93	182.02	133.56	84.83	52.29	43.07	2,011.43
P-5	6.34	19.62	26.74	51.39	179.71	259.56	148.78	75.90	20.54	8.66	5.31	4.77	807.30
P-13	16.59	28.71	39.65	54.18	117.24	144.38	114.38	65.25	42.94	32.10	22.59	18.60	696.61
P-34	3.89	9.29	13.02	20.70	54.40	58.83	34.52	20.36	13.72	10.28	7.58	5.71	252.30

Monthly Percentage of Run-off

(Unit: %)

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
P-1	1.9	3.9	5.8	8.1	17.1	22.7	15.9	9.1	6.6	4.2	2.6	2.1
P-5	0.8	2.4	3.3	6.4	22.3	32.1	18.4	9.4	2.5	1.1	0.7	0.6
P-13	2.4	4.1	5.7	7.8	16.8	20.7	16.4	9.4	6.2	4.6	3.2	2.7
P-34	1.5	3.7	5.2	8.2	21.6	23.3	13.7	8.1	5.4	4.1	3.0	2.3

Appendix A shows the observed records, estimated run-off and estimation process at above stations.

(3) Reservoir Inflow

Annual inflow to the Mae Kuang dam was estimated at 254 MCM on an average as shown below;

Monthly Mean Inflow to the Mae Kuang Dam

(Unit: MCM)

Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual Total
3.91	9.34	13.09	20.80	54.69	59.14	34.70	20.47	13.79	10.33	7.62	5.74	253.62

The reservoir inflow was estimated based on P-34 run-off (Table A 6-5, Appendix A) with drainage area ratio on the monthly basis. The estimated reservoir inflow is given in Table 3-6.

(4) Floods

This section discusses the floods of the Mae Kuang river at proposed damsite. The floods in the basin are studied in paragraph 3.5. Moreover, the flood records and the flood situation around the Project Area during the flood at P-5 are presented in Appendix A.

Flood Records

The annual maximum floods at P-30 and P-34 of the Mae Kuang river for 13 years from 1967 to 1979 are as follows;

Annual Maximum Floods

	P-30 (D.A. = 466 sq.km)				P-34 (D.A. = 566 sq.km)			
	Instantaneous		One Day		Instantaneous		One day	
Year	Discharge (cu.m/sec)	Date	Discharge (cu.m/sec)	Date	Discharge (cu.m/sec)	Date	Discharge (cu.m/sec)	Date
1968	55	15/Aug.	55	15/Aug.				
1969	88	22/Aug.	47	22/Aug.				
1970	212	24/Aug.	125	25/Aug.				
1971	149	14/Jul.	106	14/Jul.				
1972	188	25/Aug.	108	25/Aug.				
1973	425	24/Aug.	205	24/Aug.				
1974	(118)	12/Sep.	(75)	18/Aug.	229	12/Sep.	96	12/Sep.
1975	(216)	25/Aug.	(87)	25/Aug.	347	25/Aug.	214	22/Sep
1976	(48)	28/Sep.	(32)	28/Sep.	85	28/Sep.	49	28/Sep
1977	(69)	22/Sep.	(40)	22/Sep.	197	7/Sep.	100	22/Sep.
1978	-	-	-	-	347	3/Jul.	242	3/Jul.
1979	(52)	3/Oct.	(27)	5/Oct.	52	3/Oct.	43	3/Oct.

Note: ( ): Actual discharges are to be more than values quoted herein due to adoption of improper rating curve resulting from the river erosion during the flood in 1973.

The flood occurs frequently in the period from July to September and causes the damages to the area along the Mae Kuang river. The maximum flood was recorded on 25th August, 1973, and its Instantaneous peak discharge was 425 cu.m/sec at P-30.

Methods and Data for Flood Analysis

Floods have been analyzed by adopting the tank model and unit hydrograph methods, and following five floods have been selected in order from the maximum.

Selected Floods for Analysis

Flood Order	Date	Peak Discharge P.30 (cms)	Peak Discharge P.34 (cms)	Rainfall (07341 Mae Kuang) Hourly	Rainfall (07341 Mae Kuang) Daily	Time Lag (hours)	Observed Record & Hydrograph See Appendix A,
1st	24/Aug. 1973	425	(516)	o	o	7	Table A10-2, Fig.A9-2
2nd	25/Aug. 1975	216	347	x	o	x	Table A10-4, Fig.A9-4
3rd	3/Jul. 1978	208	347	Δ	o	x	Table A10-5, Fig.A9-5
4th	24/Aug. 1970	212	(258)	o	o	13	Table A10-1, Fig.A9-1
5th	12/Sep. 1974	118	229	x	0	x	Table A10-3, Fig.A9-3

Note: 1/ o: data are available
Δ: data are available partly
x: data are not available
2/( ). estimated by area ratio

$$\frac{AP.34}{AP.30} = \frac{566 \text{ sq.km}}{466 \text{ sq.km}} = 1.215$$

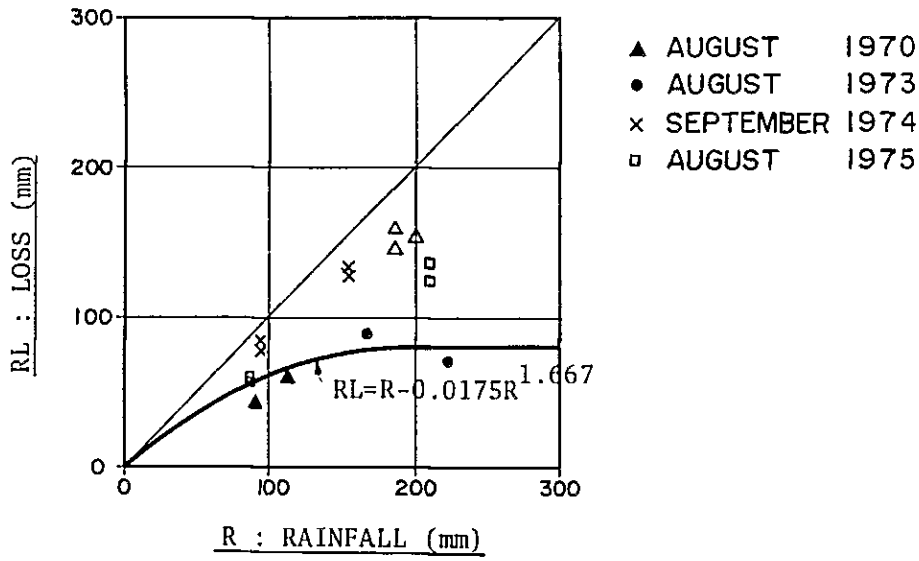
Only two floods in 1970 and 1973 present complete the data of discharge and rainfall records out of five floods. Finally, the flood in 1973 has been selected for analysis due to considerably low run-off coefficient at the flood in 1970. The other four floods than in 1973 have been used only for analysis of the run-off coefficient.

Unit time (t) of three hours has been adopted for this study considering a time lag of seven hours in the flood in 1973. The time lag of the flood is almost same at P-30 and P-34 as seen in hydrographs shown in Figure A9-1 - A9-5, Appendix A. Therefore, time lag at damsite will be seven hours same as time lag at P-30. Discharge at damsite is also estimated from the discharge at P-30 by area ratio. Flood hydrograph at damsite based on 1973 flood is shown in Figure A8, Appendix A.

Effective Rainfall

The effective rainfall was analyzed using the data of five floods. (see Table A9, Appendix A) The loss of rainfall are plotted in the figure below.

RAINFALL LOSS



The rainfall loss varies with the amount of rainfall. Therefore, the following equation shall be adopted for estimation of rainfall loss;

$$RL = R - 0.0175\,R^{1.667} \quad \text{---------- (3.2)}$$

RL: Loss of rainfall (RL ≦ 80 mm) (mm)

R: Cumulative rainfall (mm)

Rainfall for Flood Estimation

For estimation of flood, the rainfall at the Mae Faek Tail Regulator has been selected, where its probable value is maximum value among three stations at A. Doi Saket (07052), Mae Kuang Weir (07341) and the tail regulator of Mae Faek Project (07460). Probable maximum precipitation (PMP) refers to the value in the report of ECI.

Rainfalls for Flood Estimation

Return Period	1-day (mm)	2-day (mm)	3-day (mm)
1/2 years	83	115	135
1/5 years	121	155	181
1/10 years	149	179	207
1/20 years	179	201	231
1/50 years	221	227	259
1/100 years	255	267	280
PMP	350	426	481

Note: The hourly distribution and effective rainfall of the above data are shown in Table A11, Appendix A.

The following table shows the probable daily rainfalls exceeding the probability of once in 100 years at the tail regulator of Mae Faek Project based on the annual maximum daily rainfall records shown in Table A 5-11, Appendix A;

Probable Daily Rainfall exceeding 1/100 years

Return Period	1-Day Rainfall
1/200 yeras	291 mm/day
1/500 years	342 mm/day
1/600 years	354 mm/day
1/1,000 years	385 mm/day

The probable maximum precipitation of the daily rainfall of 350mm corresponds to the probability of once in 600 years as well as to the amount increased by 20 percent of the probable value of 291 mm of once in 200 years. The former, once in 600 years, corresponds to the probability of once in 500 years which was recommended in the Report[1/] of RID and the latter fact corresponds to the definition of the criteria for the fill dams in Japan.

Flood Estimation

The floods at damsite were estimated with following three methods,

Probability analysis (12 records at P-30 and P-34)

Tank Model (see Figure A 10, Appendix A)

Unit Hydrograph (see Figure A 11, Appendix A)

The following values are peak discharges which have been computed by the above three methods.

Estimated Peak Discharge at the Damsite

Return Period	Probability Analysis (cu.m/sec)	Tank Model (cu.m/sec)	Unit Hydrograph (cu.m/sec)
1/2 years	182	83	188
1/5 years	320	229	329
1/10 yeras	428	376	456
1/20 years	541	535	612
1/50 years	703	765	861
1/100 years	837	941	1,065
PMP	-	1,763	1,968

1/ Hydrological Characteristic and Water Uses, Mae Kuang Reservoir Project Hydrology Division, RID Nov. 1977
(in Thai, translated by the team)

The applicability of the values by probability analysis is considered to have some limitation due to small number of records. The tank model may have also limitation of applicability for the floods bigger than the recorded maximum. Therefore, it is recommended that the unit hydrograph shall be adopted for estimation of the floods.

The flood hydrographs computed by the unit hydrograph are shown in Figure 3-4, and hourly discharge is presented in Table A14, Appendix A.

(5) Floods in Dry Season

During the dry season, the following floods were recorded at P-30 and P-34. However, the magnitude of the floods is considerably smaller than that in the wet season.

Maximum One Day Discharges Recorded in Dry Season

(Unit: cu.m/sec)

Year	P-30		P-34	
	Nov. - Apr.	Dec. - Mar.	Nov. - Apr.	Dec. - Mar.
1967	8.22	4.42	10.0 *	5.4 *
1968	5.26	3.28	6.4 *	4.0 *
1969	8.95	3.75	10.9 *	4.6 *
1970	13.00	13.00	15.8 *	15.8 *
1971	10.00	6.24	12.2 *	7.6 *
1972	18.00	7.40	21.9 *	9.0 *
1973	10.00	7.50	12.2 *	9.1 *
1974	21.00	10.00	24.0	11.0
1975	5.10	5.10	20.0	16.0
1976	3.30	2.40	12.0	9.62
1977			8.9	8.0
1978			7.3	6.25

Note: * Estimated from the discharge at P-30 by area ratio of 1.215.

The following discharges will be expected as the probable maximum one day discharge at damsite during the dry season. The values were estimated by probability analysis using the data at P-34.

Probable Maximum One Day Discharge at the Damsite in Dry Season

Return Period	Nov. - Apr. (cu.m/sec)	Dec. - Mar. (cu.m/sec)
1/5 years	18	12
1/10 years	21	14
1/20 years	25	17

(6) Sedimentation

Suspended sediment materials in the Mae Kuang river were observed at P-34 Gaging Station from 1975 to 1978 (see Figure A 12, Appendix A). In Thailand, only the suspended sediment materials are generally observed, but not the bed load materials.

The observed data at P-34 are shown in the relation between the river discharge and the suspended sediment materials on the daily basis. Since the maximum river discharge was 70 cu.m/sec in this observation as shown in the figure, no data is available beyond this discharge. However, the suspended sediment materials can be estimated from the river discharge by the following regression equation.

$$Qs = 0.99\ Qw^{1.92} \quad - - - - - - - - - - - - \quad [3.3]$$

Qs: Daily suspended sediment yield (tons/day)
Qw: Mean daily discharge (cu.m/sec)

Annual suspended sediment yield at P-34 has been estimated at 54,000 tons according to the above equation. (see Table A 15, Appendix A) Therefore, an annual deposition in the reservoir by the suspended sediment materials can be estimated at 56,000 cu.m, based on the unit weight of suspended sediment of 0.96 ton/cu.m.

On the other hand, a total annual sediment in the reservoir by the suspended and the bed load materials had been estimated at 145,000 cu.m in the report of ECI. This estimation of 145,000 cu.m can be considered as an adequate volume of the annual sedimentation in the reservoir from the point of above investigation on the suspended sediment materials.

Table 3-1 Meteorological Observatories

Station	Observation Period: Temperature	Dew Point & Relative Humidity	Evaporation	Cloudiness	Wind	Rainfall	Sunshine Hours	Solar Radiation	Agent
A. Muang, Chiang Mai (07013)	1952-75	1951-75	1965-75	1951-75	1951-75	1906-79	1953-72*	1958-72*	MD
Mae Kuang (P-25) (07341)	1965-79		1964-73		1970-79	1964-79			RID
RID Office, A. Muang (07391)	1970-79		1970-79		1972-79	1971-79			RID
Huai Mae Lai (P-36) (07581)	1977-79		1977-79		1977-79	1977-79			RID
Mae Taeng Experimental Farm	1976-79		1975-79		1975-79			1979	RID

Note: 1. MD: Meteorological Department, RID: Royal Irrigation Department

2. *: Data Source; Summary of Monthly and Yearly Hydro-meteorological Data in the Thai Part of the Lower Mekong Basin.

Committee for Coordination of Investigations of the Lower Mekong Basin Oct. 1975.

Table 3-2 Major Element of Climate around the Project Area

Month	Max. Mean (°C)	Mean (°C)	Min. Mean (°C)	Mean Relative Humidity 2/ (%)	Mean Dew Point 3/ (°C)	Mean Evapora-tion 4/ (mm)	Mean Cloudiness 5/ (octas)	Mean Wind Speed 6/ (Km/hr)	Mean Sunshine Hours 7/ (hrs/day)	Mean Solar Radiation 7/ (cal/sq.cm/day)
Jan.	29.0	20.0	13.0	74.0	14.6	108.4	2.6	3.52	8.7	410
Feb.	32.1	22.2	13.8	65.0	14.1	137.0	2.0	4.44	9.3	501
Mar.	34.9	25.6	17.2	58.0	15.5	180.6	2.2	5.37	9.1	461
Apr.	36.2	28.3	21.1	60.0	19.1	197.2	3.3	6.66	8.9	478
May	34.1	28.0	23.2	72.0	22.0	176.2	5.6	6.48	7.7	519
Jun.	32.2	27.1	23.6	79.0	23.3	136.7	6.6	5.74	5.7	448
Jul.	31.4	26.7	23.3	80.0	22.8	128.5	6.9	5.00	4.7	440
Aug.	30.7	26.2	23.2	84.0	23.0	117.8	7.1	4.44	4.4	397
Sep.	31.0	26.2	22.8	84.0	22.8	126.4	6.4	4.44	5.9	419
Oct.	30.9	25.5	21.6	82.0	21.9	129.1	5.2	4.07	7.2	443
Nov.	29.8	23.4	18.6	80.0	19.3	104.4	3.9	3.33	8.2	436
Dec.	28.5	20.6	14.7	77.0	15.9	99.7	3.3	3.15	8.6	380
Ave.	31.8	25.0	19.7	75.0	19.5	1,642.0	4.6	4.72	7.4	444

Note: 1/: Observed at Chiang Mai (1952 - 1975)
2/: Observed at Chiang Mai (1951 - 1975)
3/: Observed at Chiang Mai (1951 - 1975)
4/: Observed at Chiang Mai (1965 - 1975) Class-A Pan
5/: Observed at Chiang Mai (1951 - 1975)
6/: Observed at Chiang Mai (1951 - 1975), at 15 m above ground.
7/: Summary of Monthly and Yearly Hydro-Meteorological Data in the Thai Part of the Lower Mekong Basin. (1958 - 1972)

Data Source) 1/ - 6/: Climatological Data for the Period 1951-1975, Meteorological Department.

Table 3-3. Rainfall Stations

Location	Station Code	Annual Mean (mm)	Annual Max. (mm)	Annual Max. Year	Annual Min. (mm)	Annual Min. Year	Record Period	Operation & Maintenance
A. Mung, Chiang Mai	07013	1,188	1,780	1953	587	1931	1906-79	good
A. Sarapi	07022	837	1,279	1975	319	1967	1952-79	poor
A. San Kamphaeng	07032	976	1,485	1961	560	1969	1952-79	good
A. San Sai	07042	1,190	1,559	1970	903	1976	1952-79	poor
A. Doi Saket	07052	1,238	1,677	1953	765	1968	1952-79	good
A. Hang Dong	07072	1,148	1,468	1961	773	1952	1952-79	poor
A. San Pa Tong	07082	942	1,339	1961	526	1968	1952-79	poor
A. Phrao	07122	1,230	2,364	1956	657	1979	1952-79	not inspected
Kaeng Kut, A. Mae Taeng (P.13)	07331	1,708	2,187	1971	1,341	1979	1952-79	not inspected
Mae Kuang, A. Doi Saket (P.25)	07341	1,248	1,769	1975	819	1979	1952-79	good
Mae Ngat, A. Mae Taeng (P.28)	07361	1,291	1,620	1975	1,035	1979	1968-79	not inspected
RID Office, A. Muang, Chiang Mai	07391	1,149	1,311	1978	1,019	1972	1971-79	good
Tail Regulator of Mae Faek Project	07460	1,165	2,001	1961	418	1965	1960-79	good
Huai Mae Lai, A. San Kamphaeng (P.36)	07581	1,527	*	*	*	*	1977-79	good
A. Muang, Lamphun	17012	1,039	1,586	1953	675	1955	1952-79	poor
A. Mae Tha	17042	1,163	2,180	1958	325	1959	1952-79	good

Note) *: not recorded

Table 3-4. Estimated Monthly Rainfall in Mae Kuang Project Area

(Unit: mm)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1952	2.5	80.4	224.5	204.1	269.4	217.6	84.4	21.0	0.0	22.6	37.6	0.0	1164.1
1953	96.6	71.8	230.4	157.6	177.3	364.7	148.4	66.3	6.4	0.1	4.7	58.6	1382.9
1954	43.7	232.2	91.8	52.8	309.5	199.3	165.2	4.3	1.8	0.2	5.0	21.5	1127.3
1955	29.3	103.8	120.6	119.6	299.8	180.2	90.2	21.8	0.0	0.0	5.5	0.0	970.8
1956	50.4	151.9	74.4	194.6	209.5	292.9	104.9	2.4	4.6	0.0	0.1	1.5	1087.2
1957	62.4	47.4	235.9	90.6	220.9	228.7	41.4	1.3	1.3	9.3	1.3	20.3	960.8
1958	87.1	61.4	147.1	123.0	202.1	192.6	162.9	5.2	1.3	10.3	1.3	13.0	1007.3
1959	30.5	116.0	56.9	179.6	237.4	261.2	72.9	1.4	1.3	22.3	1.3	4.6	985.4
1960	3.7	116.3	105.8	250.2	237.0	358.0	110.9	29.3	63.8	5.1	10.0	37.3	1327.4
1961	59.3	215.6	156.7	78.7	426.6	327.4	146.2	4.5	59.8	0.0	0.0	12.2	1487.0
1962	5.8	91.0	119.0	213.4	257.4	211.7	138.5	0.0	0.0	0.0	6.7	15.2	1058.7
1963	17.4	18.9	165.2	84.1	179.2	153.4	182.4	101.2	2.3	1.9	3.5	17.0	926.5
1964	66.1	185.1	88.9	228.9	149.2	278.3	164.4	38.2	0.7	0.0	9.3	6.2	1215.3
1965	0.0	68.9	93.7	61.4	206.1	186.6	157.7	77.1	7.1	7.9	5.6	0.3	872.4
1966	7.7	162.4	38.9	154.6	290.9	250.2	144.9	25.4	0.0	1.0	0.0	6.4	1082.4
1967	46.9	159.8	120.7	145.0	159.3	361.1	28.5	33.2	0.0	0.4	1.1	4.7	1060.7
1968	120.6	109.0	96.1	29.6	122.3	115.3	65.5	11.3	0.0	4.1	0.0	0.0	673.8
1969	13.9	172.5	62.0	105.3	179.3	99.7	43.0	43.9	3.3	0.0	0.0	30.6	753.5
1970	82.6	180.0	147.0	102.3	339.6	215.9	71.0	7.3	45.9	0.3	0.0	10.8	1202.7
1971	21.1	184.0	145.8	200.4	295.5	117.6	103.2	22.8	4.3	0.0	0.0	1.7	1096.4
1972	89.8	70.2	119.6	73.7	161.5	216.1	60.4	87.0	7.1	0.0	0.2	33.8	919.4
1973	5.1	102.7	107.8	153.1	339.0	251.7	49.6	28.4	4.4	4.4	4.4	21.2	1071.8
1974	63.8	107.9	100.7	86.5	144.5	222.8	122.6	64.7	9.1	82.7	5.6	5.0	1015.9
1975	16.3	100.2	218.3	203.5	365.5	172.4	175.8	56.4	41.1	4.4	10.5	13.0	1377.4
1976	18.6	86.5	116.0	102.7	217.1	171.1	142.1	16.5	5.8	37.8	4.9	28.1	947.2
1977	78.4	143.1	74.1	140.7	219.5	297.9	85.4	8.3	77.3	29.7	36.2	0.0	1190.6
1978	13.5	221.9	93.1	294.4	218.2	279.5	75.6	8.9	4.4	3.9	14.1	0.9	1228.4
1979	56.7	181.4	133.0	93.4	162.4	132.1	66.5	4.4	4.4	0.0	0.0	23.5	857.8
MEAN	42.5	126.5	124.4	140.1	235.6	227.0	107.3	28.3	12.8	8.9	6.0	13.8	1073.2

Note) Estimated by Thiessen Method with following weights of four stations.

Doi Saket: 0.325, San Kamphaeng: 0.4983
Lamphun : 0.1667, Mae Tha : 0.01

Table 3-5 Annual Run-off

Gage	River	Station	Water Year (Apr.-Mar.)	Drainage Area (sq.km)	Average Annual Runoff (MCM)	Specific Yield MCM/km²	Specific Yield l/s/km²	Adjusted Years
	1. Original Data							
P-1	Mae Ping	Nawarat Bridge	1921-79	6,356	2,011	0.32	10.0	-
P-12	Mae Ping	Wang Kra Chao	1937-62	26,386	8,725	0.33	10.5	-
P-20	Mae Ping	Chiang Dao	Only stage records available					
P-28	Mae Ngat	Ban Mai	1966-75	1,261	420	0.33	10.6	
P-30	Mae Kuang	Ban Kiang Kha Mai	1967-73	466	237	0.51	16.1	1974-79: Omitted considering low reliability
P-34	Mae Kuang	Ban Pha Taek	1974-79	566	243	0.43	13.6	-
P-25	Mae Kuang	Pha-Taek Weir	1964-79	572	220	0.38	12.1	Data missing in 1973
P-36	Nam Mae Lai	Ban Huai kaeo	1977-79	35	25.4	0.73	23.0	-
P-38	Nam Mae San	Ban Cham Khi Mot	1979-80	34	-	-	-	-
P-5	Mae Kuang	Thasing Bridge	1952-79	1,665*1/	807	0.48	15.4	-
P-29	Mae Li	Ban Hong, Lam Phun Highway Bridge	1960-75	1,970	228	0.12	3.7	-
P-24A	Mae Klang	Pracha U-Thit Bridge	1975-75	467	215	0.46	14.6	-
P-24	Mae Klang	Mae Klang Bridge	1956-72	616	270	0.44	13.9	-
P-25	Mae Khan	Mae Khan Bridge	1955-75	1,777	388	0.22	6.9	-
	2. Adjusted Runoff							
P-13	Mae Taeng	Kang Kud	1952-79	1,765	697	0.39	12.5	1969, 70
P-4A	Mae Taeng	Mae Taeng Bridge	1955-75	1,902	689	0.36	11.5	1969
P-19A	Mae Ping	Tha Sala	1958-79	14,023	3,424	0.24	7.7	1970
P-12	Mae Ping	inflow to Bhumiphol	1937-76	26,386	7,897	0.30	9.5	1963-76
P-12	Mae Ping	inflow to Bhumiphol	1952-75	26,386	6,403	0.24	7.7	1963-75
P-28	Mae Ngat	Ban Mai	1952-75	1,261	395	0.31	9.9	1952-65
P-34	Mae Kuang	Ban Pha Taek	1952-79	566	252	0.45	14.2	1952-73
P-14	Mae Chaem	Kang Ob Luang	1953-75	3,853	1,201	0.31	9.9	1969, 70
P-21	Mae Rim	Mae Rim Bridge	1954-75	515	165	0.32	10.2	1969

Note) This table is derived from EC1 report adding the data in this study

*1/ Drainage area of Mae Kuang river has been changed to be 1,665 sq km from 1,569 sq km at P-5 with careful field investigation and discussion with the staffs of RID Region 1 Office

Table 3-6 Estimated Inflow to Reservoir

(D.A. = 569 sq.km)

ROYAL IRRIGATION DEPARTMENT, THAILAND
RESERVOIR OPERATION FOR MAE KUANG IRRIGATION PROJECT (CASE 2-4)

COMPUTER CENTER
SIMULATION - 2

INFLOW IN MILLION CUBIC METERS

WATER YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
1952	3.68	9.26	10.93	18.24	59.61	112.78	37.25	23.72	21.85	16.57	9.59	10.57	334.05
1953	5.73	11.07	24.63	24.96	58.06	64.49	41.41	31.04	21.26	14.74	8.99	13.31	319.69
1954	4.78	15.07	15.75	14.24	38.07	47.66	33.52	14.41	11.14	9.14	7.14	5.12	216.04
1955	4.49	10.08	24.56	21.97	56.49	55.71	32.21	21.84	14.92	11.19	8.31	7.11	268.88
1956	4.96	14.42	13.80	28.77	67.44	66.32	28.28	22.50	15.98	11.55	8.03	6.78	288.83
1957	2.74	6.59	15.16	15.62	40.29	61.56	30.26	12.47	8.66	8.59	7.16	3.98	213.08
1958	3.03	7.20	9.87	15.16	42.74	42.21	21.62	9.03	7.24	7.55	6.62	2.95	175.22
1959	2.67	7.69	9.18	17.04	43.73	76.93	39.44	22.26	11.18	9.38	7.45	5.50	252.45
1960	3.05	7.84	7.96	9.09	40.20	45.83	25.15	10.77	13.26	6.75	5.96	0.53	176.39
1961	3.01	9.34	14.53	17.91	57.43	80.96	44.49	26.04	17.04	10.23	7.64	5.59	294.21
1962	3.55	8.48	6.88	21.37	45.08	29.63	34.83	11.53	7.67	7.15	6.36	3.47	186.00
1963	2.86	5.76	7.37	13.41	50.55	40.82	45.79	52.67	21.65	11.80	7.96	6.58	267.22
1964	3.14	14.53	13.14	28.82	43.02	57.17	43.60	19.61	13.97	9.66	7.52	5.12	259.30
1965	3.35	7.75	13.70	8.81	40.54	43.64	41.85	32.05	18.39	10.58	7.41	5.12	233.19
1966	3.37	8.36	7.11	8.65	45.52	50.95	21.87	9.48	7.00	6.75	6.45	3.37	178.88
1967	3.05	7.90	6.68	10.84	38.48	83.15	31.99	16.93	12.03	8.56	5.81	4.98	230.40
1968	6.29	12.49	10.41	10.61	31.94	30.38	31.89	12.95	9.27	5.86	2.70	2.35	167.14
1969	0.72	11.88	10.06	15.81	41.24	27.37	27.89	16.86	9.93	6.14	3.85	3.31	175.06
1970	3.90	11.30	33.45	22.18	109.35	60.37	28.59	17.48	19.01	10.04	6.48	5.45	327.60
1971	4.49	9.64	20.53	64.08	84.36	71.02	45.21	24.00	17.33	11.69	6.82	5.29	364.46
1972	6.71	4.94	11.72	6.84	54.59	42.66	35.90	24.37	17.89	11.36	6.67	6.06	229.71
1973	4.32	8.33	12.75	28.37	148.29	132.13	48.54	29.25	23.16	19.19	10.98	10.51	475.82
1974	5.37	7.86	7.84	11.97	35.21	45.28	19.52	20.60	7.17	9.55	4.15	2.93	177.45
1975	1.85	4.15	23.29	65.86	128.12	103.36	59.24	32.79	23.74	17.13	13.36	12.69	485.58
1976	5.69	7.21	7.48	6.85	20.75	45.15	30.78	19.30	10.02	7.56	4.83	4.10	169.72
1977	4.69	9.27	4.13	13.75	27.34	49.21	22.61	16.51	12.40	11.82	11.11	9.57	192.41
1978	4.25	9.05	7.12	50.43	58.91	65.07	39.54	14.99	8.44	12.79	10.82	7.20	288.61
1979	3.77	14.07	16.59	10.86	23.93	24.13	28.35	7.63	4.50	5.92	13.27	1.08	154.10
AVERAGE	3.91	9.34	13.09	20.80	54.69	59.14	34.70	20.47	13.79	10.33	7.62	5.74	253.62

Note; Estimated from P-34 run-off by following equation

Inflow = 1.0053 P.34 run-off (1.0053 = 569 sq.km/566 sq.km)

FIGURE 3-3 RIVER BASIN AND HYDRO-OBSERVATORY MAP

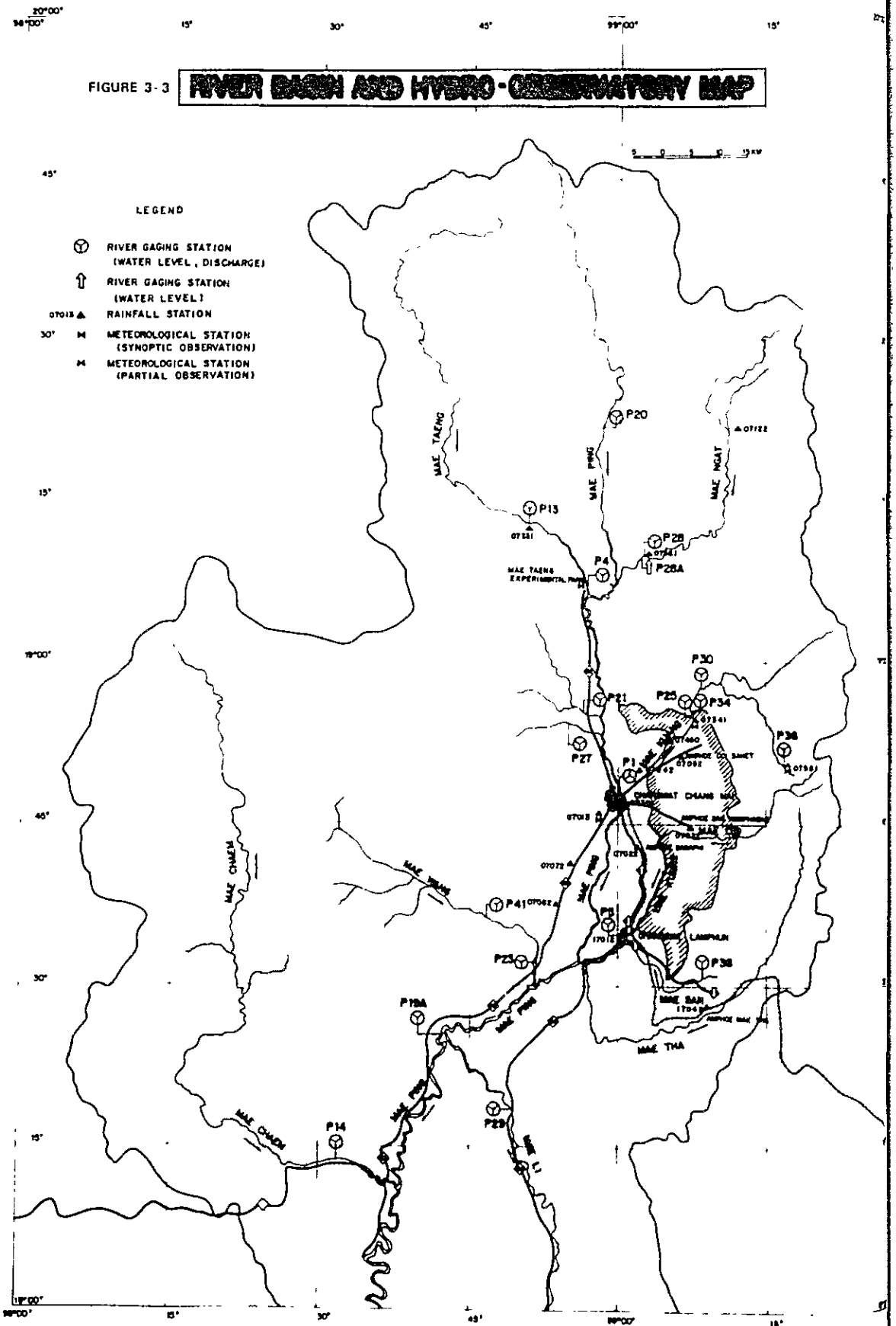
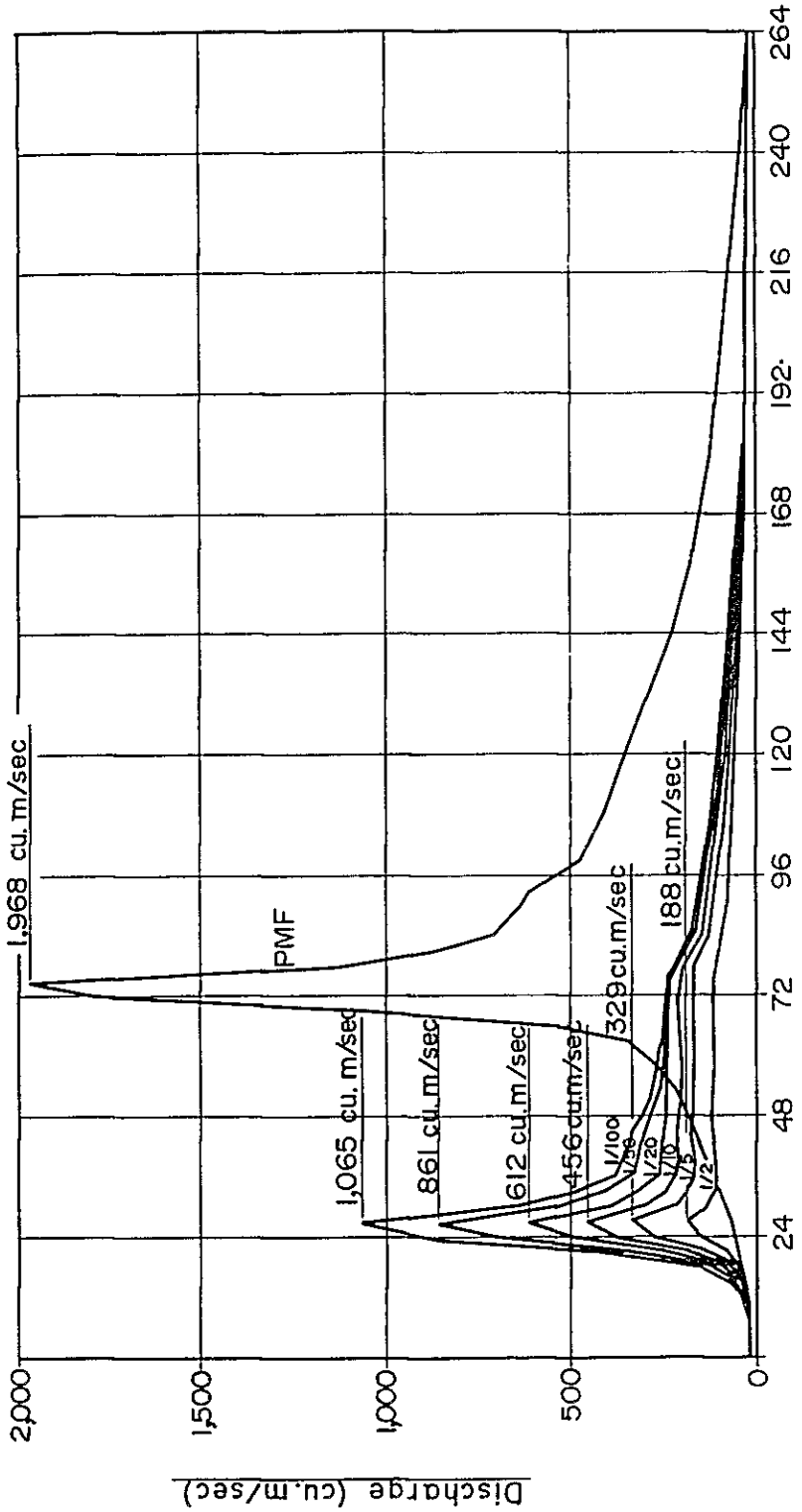


FIGURE 3-4 PROBABLE FLOOD HYDROGRAPHS AT DAMSITE



3.2.3 General Geology

Northwestern Thailand including the Project Area is situated in a part of so-called Burmese-Malayan folded mountain (see Figure 3-5).

Geology of the area is composed of bed rock which is regarded as Paleozoic in age and overlying unconsolidated sediments of Quaternary in age.

The bed rock consists of the Khaeng Krachan formation which is assigned to Carboniferous and Ratburi Limestone of Permian age, and the former consists of sandstone, shale, slate and their alternations and the latter is composed of massive limestone. The Khaeng Krachan formation is widely distributed in this region forming a mountain range, but the distribution of the Ratburi Limestone is restricted in a part along a syncline existing at eastern part of the region, trending NW-SE direction.

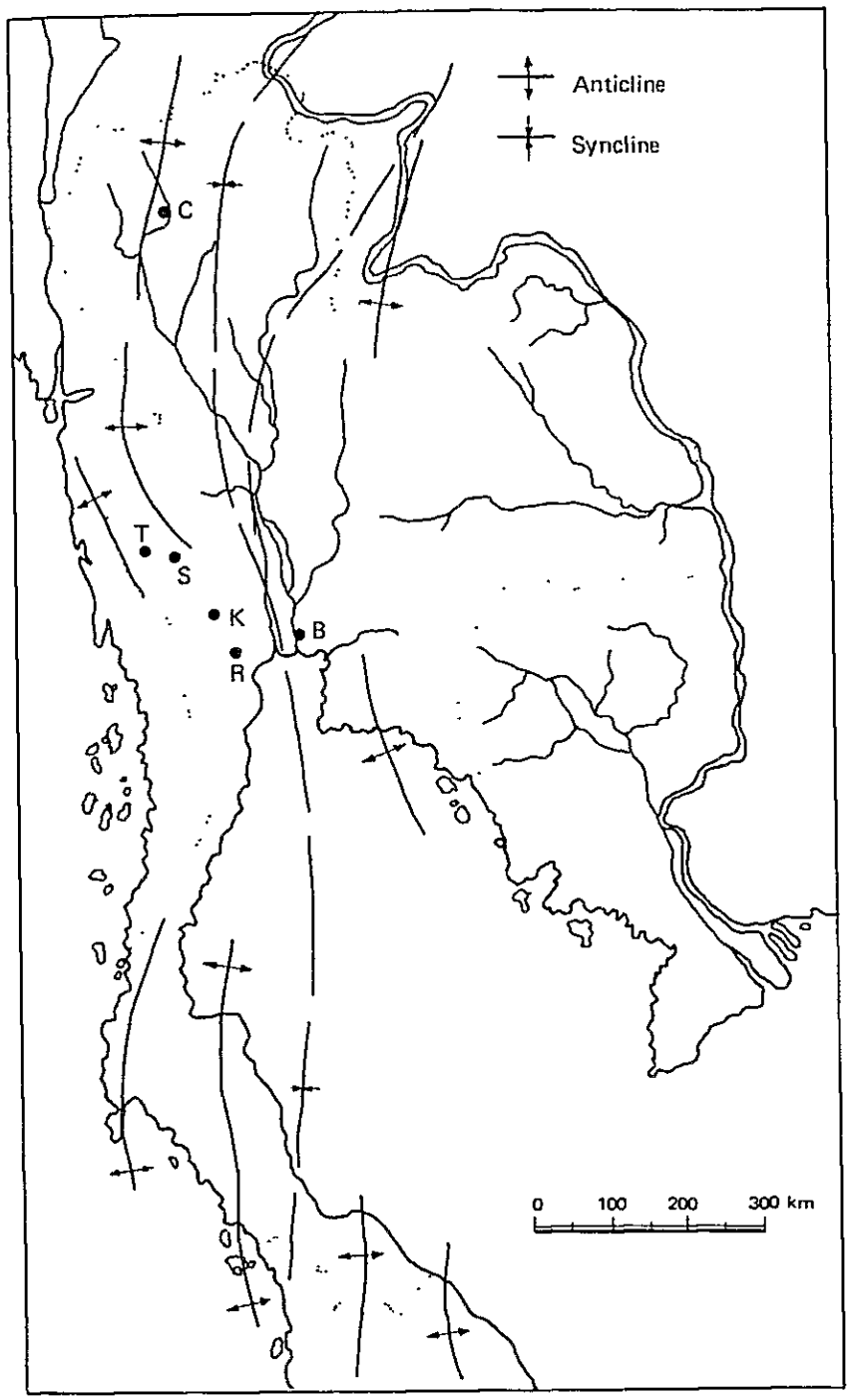
The Quaternary deposits are composed of diluvium and alluvium. The diluvium is distributed around the mountain range which consists of the bed rocks forming a foothill or a fan. The alluvium is widely distributed as a flood plain deposits by the Mae Ping, the Mae Kuang, and other rivers and also as a talus in foot of the mountains. At the surface of these Quaternary deposits, the laterite which is peculiar in humid tropical region is formed extensively.

3.2.4 Soil

a) Outline of the Survey Area

(1) Location

The survey area is located in the eastern part of the Chiang Mai Plain from Lat. 18°30'55" N to Lat. 18°56'23" N and from Long. 99°00' E to Long. 99°12', and comprises a total area of 37,270 ha within the radius of EW 10 - 15 km and NS 40 km. Approximately 20,540 ha is under cultivation at present.



T : Tong Pha Phum
S : Si Sawat
K : Kanchanaburi
R : Ratcha Buri
B : Bang Kok
C : Chiang Mai

Source: The Reservoir Photogeological Survey
Quae Yai No 1 Project

FIGURE 3-5 BRIEF GEOTECTONIC MAP OF THAILAND

(2) Geology

The area consists of the deposits dating back to the Pleistocene epoch as well as Holocene epoch of the Quaternary period of the Cenozoic Era. The hilly areas in the north and the east of the survey area are made up of the sedimentary and metamorphic rocks belonging to the Palaeozoic Era.

(3) Topography

The survey area gently slopes (less than 2%) from north to south as well as from east to west, and the slope class may correspond to that specified by FAO-UNESCO (1974) as "level to undulating.[1/] The elevation ranges between 290 m and 350 m. From the topographic viewpoint, the survey area will be classified into three terraces of (i) semi-recent terrace, (ii) low terrace, and (iii) high terrace, and also into five divisions of (i) flood plain, (ii) semi-recent terrace, (iii) low terrace lower part, (iv) low terrace upper part, and (v) high terrace in part.[2/]

(4) Parent Materials

Parent materials and the era of their formation may be described as follows:

Parent Materials	Era
Fresh water alluvial deposits	Holocene
Recent alluvial deposits	Holocene
Semi-recent alluvial deposits	Holocene or Uppermost Pleistocene
Old alluvial deposits	Upper to Middle Pleistocene
Residuum (in part)	Palaeozoic

1/ FAO-UNESCO (1974): The Soil Map of the World 1:5,000,000 Volume 1, Legend

2/ Kawaguchi K. and K. Kyuma (1969); Lowland rice soil in Thailand, Report on Research in Southeast Asia Natural Science Series N-1, The Center for Southeast Asian Studies, Kyoto University.

As for their distribution, the semi-recent alluvial deposits and the old alluvial deposits widely spread, while the fresh water alluvial deposits, the recent alluvial deposits and the residuum are found sporadically only.

(5) Land Utilization

The cultivated areas occupy 55.1 percent of the survey area. The paddy fields are dominant mainly in the lower part of the low terrace and the semi-recent terrace. The upland fields and orchards, whose combined area occupy only a small portion in the total farm land, spread in the upper part of the low terrace and the high terrace. Even in the lower part of the low terrace and the semi-recent terrace which are mainly used for paddy cultivation, some orchards and upland fields are maintained around the farmers' homestead.

(6) Survey Period

The survey has been carried out for a period of 40 days, from June 1 to July 10, 1981, which fell on the beginning of wet season (May - October).

b) Objective and Method of Survey

(1) Aim of the Survey

The survey had been originally designed to identify the soil characteristics for obtaining the basic data of land use and irrigation planning in the Project Area. The Area, however, had already been surveyed in details in the reconnaissance by the Soil Survey Division (SSD) of the Department of Land Development (DLD) and the results have been laid down in the soil maps (1976).[3/4/] Therefore, the current survey has been mainly confined to the confirmatioin of the spot of the existing survey results.

3/ Soil Survey Division (1976); Kingdom of Thailand, Detailed Reconnaissance Soil Map of Chiang Mai Province, 1:100,000.

4/ Soil Survey Division (1976); Kingdom of Thailand, Detailed Reconnaissance Soil Map of Lamphun Province, 1:100,000.

(2) Survey Method

In addition to the review of the existing data and information available from the relevant literature, the soil profile survey by pits and soil auger has been carried out, the former of the dimension by 1m x 1m x 1m and the latter by 10 cm in diameter and one meter in depth. The survey-items include location, land use, topography, geology, parent materials, great soil-group, and soil series. The soil profile survey has also been conducted to identify the texture, gravel content, humus percentage, colour, structure, porosity, mottles, permeability, compactness, stickness, plasticity, and rooting of each horizon of the soil profile. The classification standards for each survey item given in the above are shown in Appendix B-1[5/]. Electric conductivity of each horizon of the soil profile obtainable in every pit has also been measured by portable EC meter. The sheet for soil profile survey are shown in Table B 1-1, Appendix B-1.

Seventeen samples collected from the six soil series were sent to Chiang Mai University for analysis covering the measurement of pH (H_2O), pH (Kcl), T-N, T-C, available P_2O_5' CEC, Ex.Ca^{+2}, Ex.Mg^{+2}, Ex.K^{+}, Ex.Na^{+}, base saturation, and mechanical analysis.

c) Survey Results

(1) Soil Characteristics

According to the above-referred Soil Maps (3/ , 4/, the soil series found in the survey area count 15. As a result of the textural classification[1/], the surface soil to the depth of 30 cm of these soil series can be grouped as follows:

Coarse Textured Soil

Tha Ynag (Ty) Series, Mae Rim (Mr) Series, Hang Chat (Hc) Series, Nam Pong (Ng) Series, Ubon (Ub) Series, and San Sai (Sai) Series

5/ Methods of Profile Description, cited from Motomura S. (1979); Field Observations and Laboratory Analyses of Paddy Soils in Thailand, Nekken Shiryo No.45.

Medium Textured Soil

Lampang (Lp) Series, Phan (Ph) Series, Mae Sai (Ms) Series, Hang Dong (Hd-M) Series, Kampaheng Saen (Ks) Series, Pak Chong (Pc) Series, Sanphaya (Sa) Series, and Tha Muang (Tm) Series

Fine Textured Soil

Hang Dong (Hd-F) Series and Ratchaburi (Rb) Series

The Hang Dong Series spreads over the Medium as well as the Fine Textured Classes. The areal distribution areas and the ratio of these texture classes are shown in Table 3-7. The said Soil Maps (3/, 4/) have been used for measuring the total area, and the area under cultivation was estimated therefrom. The entire Project Area is divided into (i) Right Bank area, (ii) Existing Irrigated Area, (iii) Left Bank Highland Area, and (iv) Downstream Area. And the textural classes are presented in Table 3-7 according to this areal division.

The Right Bank Area is made up, by 90 percent, of the coarse textured soils. The Left Bank Highland Area follows this tendency. Existing Irrigated Area consists of medium textured soils by 48 percent and of coarse textured soils by 34 percent. The Downstream Area consists of medium textured soils by 67 percent and of coarse textured soils by 29 percent. The main characteristics of the Project Area as observed from the viewpoint of the textural classification can be summarized that almost 90 percent of the total area is made up of the coarse and the medium textured soils, while the fine textured soils occupy only a very small part.

Table 3-8 shows the major characteristics6/ of the seven soil series out of 15, which occupy more than 1,000 ha each. The slope of the relevant areas is invariably less than eight percent,

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6/ Soil Survey Division (1976); Major Soil Characteristics, Chiang Mai Province

classifiable to "a" of FAO-UNESCO Soil Map Legend[1/]. They have a considerable depth of effective soil and their profiles show YR/YR colour sequence. Other soils than Nam Pong Series have subangular blocky structure although vary in structural formative grades. The humus content, however, is poor and CEC is also small except those belonging to Ratchaburi Series. The CEC of the coarse-textured soils which belong to the Nam Pong Series and the San Sai Series is extremely small. The subsoils of the Lampang Series show a strong acid reaction but others show no critical reactions in any layers. The EC remains below 280 μ mho/cm.25°C in any layers of all the soils.

(2) Profile Description

Each soil series contained in Table 3-8 is described of its profile as follows. All of the surveyed profiles (22 profiles) are described in Appendix B-2.

Figure 3-6 shows the soil map in the Project Area.

1. Profile No.5

Date of survey	:	12 June 1981
Location	:	Ban Doi Kamphra, Changwat Chiang Mai
Physiographic position	:	Higher part of low terrace
Surrounding land form	:	Gently undulating
Land use	:	Upland field
Parent materials	:	Old alluvial deposits
Great soil group	:	Regosols
Soil series	:	Nam Pong Series (Ng)

Profile Description:

A A0 - 20 cm, Dull orange (5YR7/4) fine sand (S), single grain, many fine pores, compact (21 mm), EC 240 μ mho/cm.25°C, common roots. Gradual smooth boundary

C1 20 - 80 cm, Dull orange (5YR7/3) fine sand (S), single grain, many fine pores, compact (23 mm), EC 240 μ mho.cm 25°C, few roots. Gradual smooth boundary

IIC2 80 - 100 cm, Dull orange (5YR7/3) fine sand (S), common medium angular gravels (10%), single grain, many fine pores, compact (23 mm), EC 240 μ mho/cm.25°C.

2. Profile No.1

Date of survey	:	11 June 1981
Location	:	Doi Saket, Changwat Chiang Mai
Physiographic position	:	Lower part of low terrace
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent materials	:	Old alluvial deposits
Great soil group	:	Low Humic Gley Soils
Soil series	:	San Sai Series (Sai)

Profile description;

Apg 0 - 20 cm, Brownish gray (7.5YR5/1) sandy loam (SL) with some humus, common distinct fine tubular and filmy orange (7.5YR6/6) mottles, weak medium subangular blocky structure, common fine pores, slightly compact (12 mm), slightly plastic, slightly sticky, EC 202 μ mho/cm.25°C, common roots. Clear smooth boundary

B1g 20 - 35 cm, Dull orange (7.5YR7/3) sandy loam (SL), common distinct fine tubular and filmy brown (7.5YR4/4) mottles, weak medium subangular blocky structure, common fine pores, slightly compact (17 mm), very slightly plastic, slightly sticky, EC 258 μ mho/cm.25°C, few roots. Gradual smooth boundary

B2g 35 - 70 cm, Light brownish gray (5YR7/2) loamy sand (LS), common distinct cloudy orange (7.5YR6/6) mottles, single grain, common fine pores, slightly compact (18 mm), non plastic, non sticky, EC 240 μ mho/cm.25°C. Gradual smooth boundary

Cg 70 - 100 cm, Light gray (5YR8/2) loamy sand (LS), few distinct cloudy orange (7.5YR6/6) mottles, single grain, common fine pores, compact (22 mm), non plastic, non sticky, EC 240 μ mho/cm.25°C

* Ground water level: 70 cm

3. Profile No.10

Date of survey	:	15 June 1981
Location	:	Ban Ko Saliam, Changwat Chiang Mai
Physiographic position	:	Lower part of low terrace
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent materials	:	Old alluvial deposits
Great soil group	:	Low Humic Gley Soils
Soil series	:	Lampang Series (Lp)

Profile description;

Apg 0 - 14 cm, Grayish yellow brown (10YR6/2) loam (L), common distinct diffuse tubular brown (7.5YR4/6) mottles, weak medium subangular blocky structure, common fine pores, slightly compact (16 mm), slightly plastic, slightly sticky, EC 200 μ mho/cm. 25°C, common roots. Gradual smooth boundary

B2g 14 - 30 cm, Brownish gray (5Y6/1) silty clay loam (SiCL), common round fine gravels (10%), common distinct cloudy brown (7.5YR4/4) mottles, few manganese concretions, weak medium subangular blocky structure, common fine pores, compact (21 mm), plastic, sticky, EC 218 μ mho/cm.25°C, few roots. Gradual smooth boundary

C1g 30 - 50 cm, Brownish gray (5Y6/1) silty clay loam (SiCL) many round fine gravels (20%), common distinct cloudy brown (7.5YR4/6) mottles, massive, few fine pores, very compact (26 mm), plastic, sticky, EC 118 μ mho/cm.25°C. Clear smooth boundary

IIC2g 50 - 100 cm, Light gray (5Y7/1) silty clay loam (SiCL), many round and angular fine gravels (25%), many distinct filmy brown (7.5Y4/6) mottles, massive, few fine pores, very compact (28 mm), plastic, sticky, EC 110 μ mho/cm.25°C

4. Profile No.11

Date of survey	:	18 June 1981
Location	:	Ban Muang Kwak, Changwat Lamphun
Physiographic position	:	Semi-recent terrace
Surrounding land form	:	Flat to gently undulating

Land use	:	Paddy field
Parent materials	:	Semi-recent alluvial deposits
Great soil group	:	Hydromorphic Non-Calcic Brown Soils
Soil series	:	Mae Sai Series (Ms)

Profile description;

Apg 0 - 15 cm, Light brownish gray (7.5YR7/2) silty clay loam (SiCL) with some humus, common distinct fine tubular brown (7.5YR4/6) mottles, weak medium subangular blocky structure, common fine pores, compact (20 mm), slightly plastic, slightly sticky, EC 162 μ mho/cm.25°C, many roots. Gradual smooth boundary

A2g 15 - 25 cm, Grayish brown (7.5YR6/2) clay loam (CL) with some humus, common distinct cloudy bright brown (7.5YR5/6) and dark brown (7.5YR3/4) mottles, weak medium subangular blocky structure, common fine pores, very compact (25 mm), slightly plastic, slightly sticky, EC 243 μ mho/cm.25°C, common roots. Clear smooth boundary

B2g 25 - 55 cm, Grayish yellow brown (10YR6/2) sandy clay loam (SCL), common distinct cloudy orange (7.5YR6/6) mottles, weak coarse subangular blocky structure, common fine pores, very compact (24 mm), slightly plastic, slightly sticky, EC 252 μ mho/cm.25°C, few roots. Gradual smooth boundary

Cg 55 - 100 cm, Dull yellow orange (10YR6/3) sandy clay loam (SCL), common distinct cloudy dark brown (7.5YR3/4) mottles, weak coarse subangular blocky structure, common fine pores, very compact (26 mm), slightly plastic, slightly sticky, EC 243 μ mho/cm.25°C

5. Profile No.19

Date of survey	:	18 June 1981
Location	:	Ban Phayak Luang, Changwat Chiang Mai
Physiographic position	:	Semi-recent terrace
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field

Parent materials : Semi-recent alluvial deposits
Great soil group : Low Humic Gley Soils
Soil series : Hang Dong Series (Hd)

Profile description;

Apg 0 - 15cm, brownish gray (10YR5/1) sandy clay loam (SCL) with some humus, common distinct fine tubular brown (7.5YR4/6) mottles, moderate medium subangular blocky structure, common fine pores, compact (21 mm), non plastic, slightly sticky, EC 123 μ mho/cm.25°C, many roots. Clear smooth boundary

A2g 15 - 35 cm, Brownish black (10YR3/1) clay loam (CL) with some humus, common distinct cloudy dark brown (7.5YR3/4) mottles, moderate medium subangular blocky structure, common fine pores, slightly compact (17 mm), slightly plastic, slightly sticky, EC 238 μ mho/cm.25°C, few roots. Clear smooth boundary

B1g 35 - 55 cm, Brownish gray (10YR4/1) sandy clay loam (SCL), common distinct cloudy dark brown (7.5YR3/4) mottles, weak to moderate coarse subangular blocky structure, common fine pores, compact (22 mm), slightly plastic, slightly sticky, EC 255 μ mho/cm.25°C. Clear smooth boundary

B2g 55 - 80 cm, Grayish yellow brown (10YR6/2) sandy clay loam (SCL), common distinct cloudy brown (7.5YR4/4) mottles, weak fine subangular blocky structure, common fine pores, slightly compact (18 mm), slightly plastic, slightly sticky, EC 280 μ mho/cm.25°C. Clear smooth boundary

Cg 80 - 100 cm, Light gray (10YR7/1) light clay (LiC), few fine round gravels, common distinct cloudy brown (7.5YR4/4) mottles, massive, few fine pores, compact (22 mm), plastic, sticky

* Ground water level: 75 cm

6. Profile No.12

Date of survey : 15 June 1981
Location : Ban Phap, Changwat Lamphun

Physiographic position	:	Semi-recent terrace
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent materials	:	Semi-recent alluvial deposits
Great soil group	:	Non-calcic Brown Soils
Soil series	:	Kamphaeng Saen Series (Ks)

Profile description;

Apg 0 - 15 cm, Grayish olive (5Y5/2) light clay (LiC) with some humus, common distinct fine tubular brown (7.5YR4/6) mottles, moderate medium subangular blocky structure, common fine pore, slightly compact (17 mm), plastic, sticky, common roots. Clear smooth boundary

A2g 15 - 35 cm, Olive black (5Y3/2) light clay (LiC) with some humus, common distinct cloudy brown (7.5YR4/4) mottles, moderate medium subangular blocky structure, common fine pores, compact (21 mm), very plastic, very sticky, few roots. Clear smooth boundary

B2g 35 - 70 cm, Grayish brown (7.5YR4/2) heavy clay (HC), common distinct cloudy brown (7.5YR4/6) mottles, weak coarse subangular blocky structure, common fine pores, compact (22 mm), very plastic, very sticky. Gradual smooth boundary

Cg 70 - 100 cm, Grayish brown (7.5YR5/2) heavy clay (HC), common distinct cloudy bright brown (7.5YR5/6) mottles, weak coarse subangular blocky structure, common fine pores, compact (22 mm), very plastic, very sticky

7. Profile No.4

Date of survey	:	11 June 1981
Location	:	Ban Mae Pong near Huai Bon, Changwat Chiang Mai
Physiographic position	:	Alluvial plain
Surrounding land form	:	Flat
Land use	:	Paddy field
Parent materials	:	Fresh water alluvial deposits

Great soil group : Fresh water alluvial soils

Soil series : Ratchaburi Series (Rb)

Profile description;

Apg 0 - 15 cm, Brownish black (10YR3/2) light clay (LiC) with some humus, common distinct fine tubular reddish brown (5YR4/6) mottles, weak medium subangular blocky structure, common fine pores, slightly compact (15 mm), plastic, sticky, EC 240 μ mho/cm.25°C, common roots. Clear smooth boundary

B1g 15 - 35 cm, Brownish gray (10YR4/1) light clay (LiC) with some humus, common distinct fine tubular reddish brown (5YR4/8) mottles, weak medium subangular blocky structure, common fine pores, slightly compact (14 mm), plastic, sticky, EC 254 μ mho/cm.25°C, common roots. Gradual smooth boundary

B2g 35 - 70 cm, Brownish gray (10YR5/1) light clay (LiC) with some humus, common distinct spotty bright brown (7.5YR5/6) mottles, weak coarse subangular blocky structure, few fine pores, slightly compact (18 mm), plastic, sticky, EC 296 μ mho/cm.25°C, few roots. Clear smooth boundary

IICg 70 - 100 cm, Grayish yellow brown (10YR5/2) heavy clay (HC), common distinct spotty bright brown (7.5YR5/6) mottles, weak coarse subangular blocky structure, few fine pores, compact (21 mm) plastic, sticky, EC 260 μ mho/cm.25°C

* Water in irrigation canal, EC 190 μ mho/cm.25°C

(3) Soil Analysis

Soils in the Project Area were sampled at 17 sites by using an auger during the survey period and analysed by Chiang Mai University. Table B2-2, Appendix B-2 indicates the results of analysed soil.

(4) Soil Distribution Map

Soil distribution map in the Project Area as shown in Figure 3-6 was prepared based on the collected data and soil survey conducted.

(5) Problem and Solution on Soil Management

Existing Irrigation Areas and Downstream Areas

The subject areas (31,300 ha) occupy 84 percent of the entire Project Area (37,270 ha) in alternate distribution, although the paddy fields are dominant.

In spite of flat to gently undulating topography and a long history of being used for paddy cultivation, the medium and coarse textured soils comprise 89.6 percent (28,030 ha) with small proportion of the fine textured soil.

Although the soil texture in the areas might provide favourable condition for mechanized farming in the future, the combination of the poor humus content and the low CEC in general would help to keep the soil fertility at a rather low level. Hence, it is necessary to increase the organic matters, encourage input of clayey soil and make soil management for augmenting the CEC to attain the high agricultural productivity. These are the important recommendations as the Project should expand the productive use of the lands in these areas through an increasing supply of irrigation water.

In areas where coarse textured soils are dominant, it is suggested that the following soil management method will be applied as required;

i) Ploughing back of crop residues, and
ii) Cultivation of green manure crops

Right Bank and Left Bank Highland Areas

These areas is occupy in total about 16 percent (5,970 ha) of the Project Area (37,270 ha) and the topography is gently undulating (slope less than 8%).

Coarse textured soils which occupy 83.6 percent (4,990 ha) of these areas are characterized by poor humus content and extremely

low CEC. Their soil structure, being made up of single grains, is particularly under-developed. With high permeability of the soils which would imply relatively high erodability, the topographic condition ruling there also expedites soil erosion.

Under these circumstances, the areas would be utilized better as orchards, pasture lands, and ordinary upland fields. It is essential to adopt the land management policy for soil conservation, to increase the organic matters, and to give the input of clayey soil for increasing the CEC.

3.2.5 Seismology

a) Earthquakes in Thailand

Thailand has not suffered from serious earthquakes in its history. And also, people near the damsite reported that they had no experiences of big earthquakes. Nevertheless, the Meteorological Department (MD) under the Ministry of Communication (MC), has operated the following Seismological Stations since 1975.

- Chiang Mai
- Bhumipol Dam
- Pak Chonk
- Songkhla

A newly-installed station at the Srinagarindra Dam is also expected to join the system mentioned above.

The observation records of the stations reveal that many earthquakes occur at the following places;

- Andaman Sea
- The Belt Zone (A) through Burma from the south to the north
- Another Belt Zone (B) along the border between Burma and Thailand, Laos and China

Table 3-7 Soil Classification (textural classes), Mae Kuang Project Area

Textures Class	Area	Right Bank Area		Existing Irrigated Area		Left Bank High Land Area		Downstream Area		Total Area	
		Whole land	Arable land	Whole land	Arable land	Whole land	Arable land	Whole land	Arable land	Whole land	Arable land
Coarse	Area (ha)	2,770	2,080	5,050	2,390	2,220	930	4,800	2,820	14,820	8,220
	Ratio (%)	90.2	90.8	33.7	33.4	76.6	64.1	29.3	29.2	39.8	40.0
Medium	Area (ha)	200	140	7,200	3,400	460	340	11,000	6,490	18,860	10,370
	Ratio (%)	6.5	6.1	48.2	47.6	15.9	23.4	67.2	67.3	50.6	50.5
Fine	Area (ha)	100	70	2,700	1,360	220	180	570	340	3,590	1,950
	Ratio (%)	3.3	3.1	18.1	19.0	7.6	12.4	3.5	3.5	9.6	9.5
Sub-Total	Area (ha)	3,070	2,290	14,930	7,150	2,900	1,450	16,370	9,650	37,270	20,540
	Ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Ratio (%)	8.2		40.1		7.8		43.9		100.0	
	Ratio (%)		11.1		34.8		7.1		17.0		100.0

Table 3-8 Major Soil Characteristics, Mae Kuang Project Area

Soil Series Great Soil Group	Range of Slope (%)	Effective Soil Depth (cm)	Textural Profile 0-30cm / 30cm<	Textural Class	Color Profile 0-30cm / 30cm<	Structure 0-30cm / 30cm<	Permeability Order of k(cm/sec)	Period of Water Saturation (month)	Parent Material	Physiographic Position	Humus (%) 0-30cm / 30cm<	Base Saturation (%) 0-30cm / 30cm<	CEC (me/100gs) 0-30cm / 30cm<	Available P, (ppm) 0-30cm / 30cm<	Available K, (ppm) 0-30cm / 30cm<	pH (H_2O) 0-30cm / 30cm<	EC (μ mho/cm) 25°C 0-30cm / 30cm<	Compactness (mm) 0-30cm / 30cm<
Nam Pong (Ng) Regosols	2-8	100<	LS,S / LS,S	C	YR / YR	Single gr. / Single gr.	Rapid 10^{-1}	0 0	Old alluvial deposits	lower terrace, higher part	0.5 0.5	35-75 >75	3> 3>	3-6 3>	30> 30>	5.5-7.0 5.5-6.5	240-260 240-260	21-22 21-23
San Sai (Sa) Low Humic Gley Soils	0-3	100<	SL / SL,LS	C	YR / YR	Subang.b. / Subang b.	Moderate 10^{-4}	4-5 5-6	Old alluvial deposits	low terrace, lower part	0.5 - 1.0 0.5>	35-75 >75	3> 3-5	3-6 3	30-60 30-60	6.0-7.0 6.0-7.0	180-250 200-240	12-21 12-22
Lampang (Lp) Low Humic Gley Soils	0-2	100<	SiCL,L / SiCL	M	YR / Y(YR)	Subang.b. / Subang.b.	Slow 10^{-4} - 10^{-5}	4-5 5-6	Old alluvial deposits	low terrace, lower part	0.5 - 1.0 0.5>	35-75 35-75	3-5 3-5	6-10 6-10	30-60 30-60	5.5-6.5 4.5-5.5	200-220 100-120	16-21 26-28
Mae Sai (Ms) Hydromorphic Non Calcic Brown soils	0-2	100<	SiCL,CL / CL,SCL	M	YR / YR	Subang.b. / Subang.b.	Slow 10^{-4} - 10^{-5}	3-4 4-5	Semi-recent alluvial deposits	Semi-recent terrace	1.0 - 1.5 2>	35-75 35-75	10-15 15-20	3-6 3-6	30-60 90-120	5.5-6.5 6.5-8.0	160-240 240-260	20-25 24-26
Hang Dong (Hd) Low Humic Gley soils	0-2	100<	SiCL,CL / LiC,CL	M	YR / YR	Subang.b. / Subang.b	Slow 10^{-4} - 10^{-5}	4-5 5-6	Semi recent alluvial deposits	Semi-recent terrace	1.5 - 2.5 2>	35-75 35-75	10-15 10-15	3-6 6-10	90-120 60-90	5.5-6.5 6.0-7.0	180-260 250-280	13-20 16-21
Kanphaeng Saen (Ks) Non Calcic Brown Soil	0-2	100<	CL,L / CL	M	Y(YR) / YR	Subang.b. / Subang b	Slow 10^{-4} - 10^{-5}	0 0	Semi-recent alluvial deposits	Semi-recent terrace	2.5 - 4.5 2>	35-75 35-75	10-15 20-30	10-15 3-6	90-120 30-60	6.0-7.0 6.0-7.0	160-200 170-200	12-20 20-22
Ratchaburi (Rb) Hydromorphic Alluvial Soils	0-1	100<	SiC,LiC / LiC	I	YR / YR	Subang b. / Subang b.	Slow 10^{-5}	3-4 4-5	Recent alluvial deposits	Flood (alluvial) plain	2.5 - 4.5 2-3	35-75 >75	20-30 >30	3-6 3-6	60-90 60-90	5.5-6.5 6.0-7.0	200-260 250-280	14-16 18-21

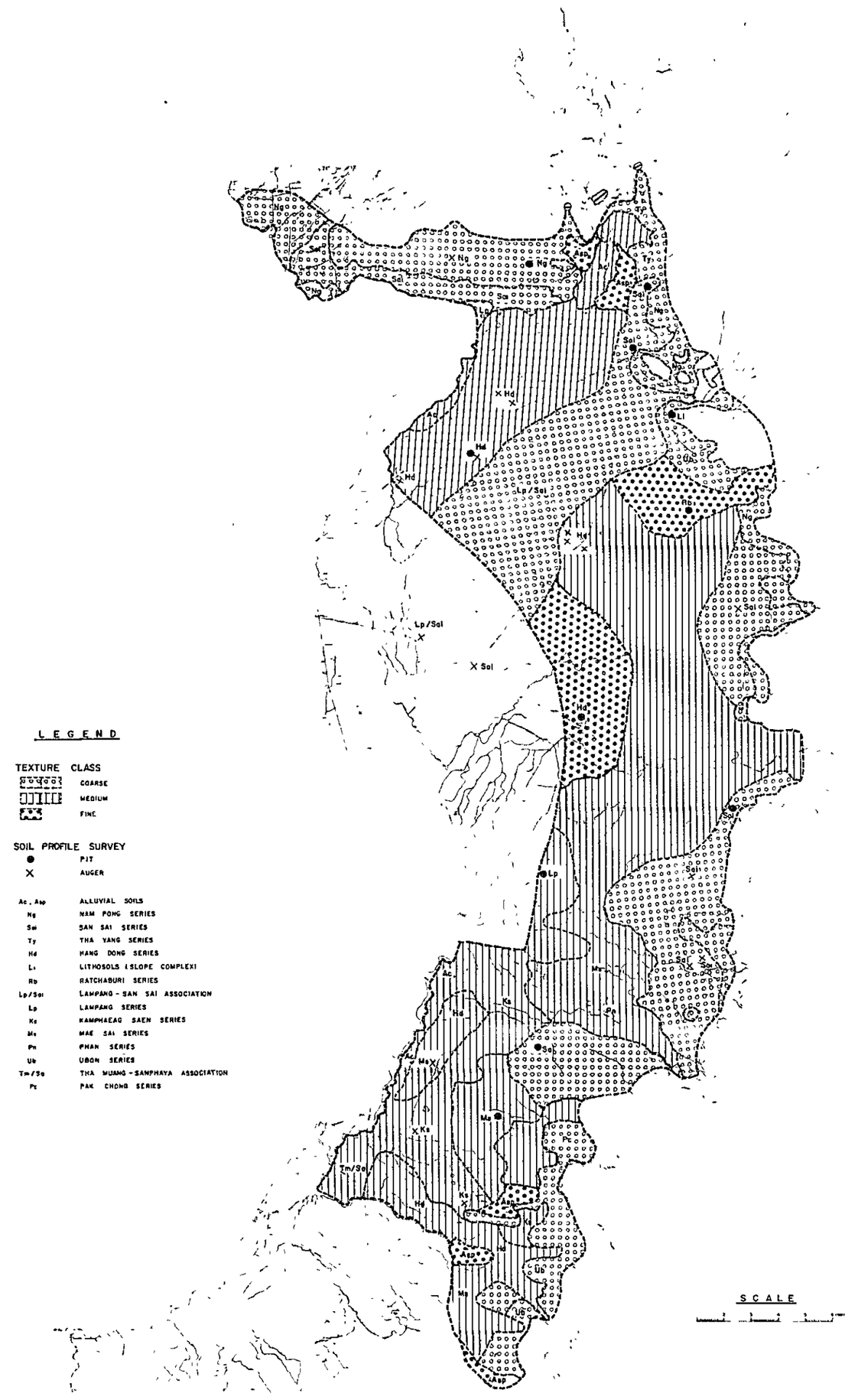


FIGURE 3-6 SOIL MAP IN THE PROJECT AREA

The Mae Kuang dam is situated at the Belt Zone (ß) where the inhabitants of the area reported to have rare occurrence of earthquakes, because the earthquake magnitude is so small.

b) Seismological Accelerations at the Damsite

From the whole observation records of the Meteorological Department during 1975 to July, 1981, the significant data of the earthquakes with the epicenters within 500 km from the damsite are listed in Table 3-9.

By means of OKAMOTO's Formula, the seismological acceleration of the listed earthquakes at the damsite were estimated and noted in the same table.

In Table 3-9, the maximum acceleration is about 30 Gal. which means that the ratio K of seismological acceleration to gravity acceleration is 0.03 at maximum. Therefore, the value of K of 0.1 on the safety analysis of the dam should be reasonable enough.

3.3 Present Land Use

3 3.1 Prevailing Conditions

Generally speaking, the Northern Region in Thailand has achieved a considerable development in agriculture, particularly in paddy and upland crop production.

The ratio of paddy field in the total land under cultivation is especially high in the two Provinces of Chiang Mai and Lamphun. In the four districts of the aforesaid two Provinces which are proposed to involve in the Project, namely, San Sai, Doi Saket, San Kamphaeng and Muang Lamphun; the paddy field ratio in the total cultivation area is as high as 86 percent and the area used for orchards and upland fields occupies only 12 percent, according to the Agricultural Statistics, 1978 - 1979 and 1978 Agricultural Census in Chiang Mai and Lamphun.

Table 3-9 Seismographical Record Near Mae Kuang Damsite

1975 - 1981 (July), Distance ≤ 500 km

No.	Date	Direction[1] from the Dam	Distance from the Dam (km)	Depth (km)	Actual Distance (km)	Magnitude	Estimated Acc.[2] at the Dam (gal.)
1	Feb. 10, 1980	N 20° E	40	8	40	4.9	31
2	May 25, 1978	N 20° E	40	8	40	4.8	27
3	Apr. 9, 1980	N 10° W	30	-	30	3.0	2.8
4	Feb. 17, 1975	S 42° W	190	6	190	5.6	1.1
5	Sep. 18, 1975	N 26° W	140	33	145	5.1	1.0
6	Sep. 29, 1975	S 74° W	300	64	310	6.1	3.2×10^{-1}
7	Apr. 5, 1980	N 40° E	95	-	95	5.6	1.3×10^{-1}
8	(Dec. 19, 1980-Jan. 1981	S 52° E	145	-	145	2.1-4.2	5.7×10^{-2}
9	Aug. 2, 1978	N 40° E	250	33	250	5.2	4.2×10^{-2}
10	Sep. 1, 1978	N 41° E	245	48	250	4.9	1.1×10^{-2}
11	Dec. 13, 1978	N 42° E	230	43	235	4.6	4.7×10^{-3}
12	Jan. 22, 1979	N 46° E	240	33	240	4.5	2.3×10^{-3}
13	Jul. 23, 1978	S 6° E	200	-	200	4.0	1.3×10^{-3}
14	Oct. 3, 1979	S 79° W	480	56	480	5.6	3.7×10^{-4}
15	Jan. 9, 1979	N 50° E	360	33	360	4.8	8.8×10^{-5}
16	Jan. 5, 1979	N 52° E	390	33	390	4.9	5.5×10^{-5}
17	Mar. 18, 1979	N 53° E	370	33	370	4.6	1.4×10^{-5}
18	Jan. 22, 1976	N 39° E	440	-	440	4.6	7.1×10^{-7}

1/: Directions and distances were roughly measured on Seismographical Map of Thailand

2/: Acc. (Acceleration) was estimated based on OKAMOTO'S Formula:

$$\log \frac{\text{Acc.}}{640} = \frac{(D + 40)}{100} \cdot (-7.604 + 1.7244\ Mg - 0.1036\ Mg^2);$$

D; Distance between Epicentre and damsite.

The present land use pattern in the Project Area, which is shown in the following table, tells even higher paddy field percentage of 88 percent. Irrigable area under present irrigation system is almost confined to the Existing Irrigated Area whose current cropping intensity remains at a relatively low level of 113 percent. The cropping intensity in the other area outside the Existing Irrigated Area is 100 percent only. The low cropping intensity even in the Existing Irrigated Area can be explained on the ground that the majority of the land is planted with rice once a year only during the wet season.

Land Use Pattern in the Project Area

(Unit: ha)

	Right Bank Area	Existing Irrigated Area	Left Bank Highland Area	Down-stream Area	Total
1. Cultivated Land					
a) Paddy field					
- Irrigated	-	6,670	-	-	6,670
- Rainfed	1,830	-	1,250	8,320	11,400
Sub-total	1,830	6,670	1,250	8,320	18,070
b) Other land	460	480	200	1,330	2,470
Total	2,290	7,150	1,450	9,650	20,540
2 Non-Cultivated Land	780	7,780	1,450	6,720	16,730
Grand Total	3,070	14,930	2,900	16,370	37,270

3.3.2 Existing Problems and Development Potentials

As briefed in the preceding paragraph, the land use pattern in the Project Area is characterized by a single paddy mono-culture. An average holding per family is assumed to be about nine rai (1.4 ha) in keeping balance with that prevailing in the neighbouring districts, although the sampling survey conducted in the Project Area suggests a little higher holding of 11 rai (1.76 ha).

The smallness of the average holding is a common phenomenon in this region which is the main reason why comparatively more intensive

farming has been practiced in the past. The development of this area will, therefore, be very much accelerated by raising productivity significantly through infrastructural improvement aimed at an increase in the cropping intensity by means of year-round cultivation without being menaced by flood and drought.

3.4 Irrigation and Drainage Conditions

3.4.1 Irrigation Conditions

a) Project Area

From the viewpoint of topography and land use, the Project Area of 20,540 ha in total is sub-divided into the following areas.

i) Right Bank Area:	2,290 ha
ii) Existing Irrigated Area:	7,150 ha
iii) Left Bank High Land Area:	1,450 ha
iv) Downstream Area:	9,650 ha
Total	20,540 ha

Right Bank Area

The Right Bank Area is the rainfed area and the area is 2,290 ha. Topographically, the area is full of ups and downs, and some of the area have been newly reclaimed. At present, a new farm land of 560 ha is under construction on the force account basis of RID for farmers whose farm lands will be submerged by the Mae Kuang storage dam construction to be settled in the new farms. To supply irrigation water and drinking water to the new farms, two small earth dams as water sources have been constructed.

Existing Irrigated Area

The Existing Irrigated Area of 7,150 ha, which is a part of the Mae Kuang irrigation area of 9,600 ha[1/] extends on the left bank of

1/ Existing Mae Kuang Irrigation area is 9,600 ha in total, but this area will be divided into two areas by the Project, that is 7,150 ha by the Mae Kuang Project and 2,450 ha by the Kud Multi-purposed Project which is studied under the ADB.

the Mae Kuang river. The irrigation water is now supplied to the area through Mae Kuang weir and three irrigation canals. Agriculture focusing upon paddy culture is dominant in the wet season. In the dry season the second crops such as peanut, soybeans, tobacco, vegetables, etc., are raised. Agricultural production in the area is much stabilized in comparison with that in the other three areas since sufficient irrigation water is available for the wet season paddy culture.

Left Bank Highland Area

The Left Bank Highland Area of 1,450 ha is also the rainfed area in a strip with the elevation of 320 m to 350 m. It has a steeper slope than the Existing Irrigation Area. The wet season rainfed paddy is the major crop in this area. A stream flows from eastern hill-side are diverted to some paddy fields for irrigation; however, such water is not stable as a water source, causing floods in the wet years and the water shortage in the dry years. Furthermore, small-scaled diversion weirs and canals have been provided by farmers, resulting in a great burden for farmers to repair them.

Downstream Area

The Downstream Area is a flat land of 9,650 ha and also rainfed, being located in the south of the Existing Irrigated Area mentioned above. The wet season paddy is also the major crop in this area. Groundwater is used for irrigation in the limited portion of the area, however, the availability is too limited in quantity to introduce a systematized irrigation system using groundwater into the area. Under these situations, the groundwater irrigation is employed by individual farmers in a small scale during dry seasons. Paddy raised in the western and southern portions of the area suffers from floods of the Mae Kuang river and the Mae Ping river in wet years.

b) Present Irrigation Systems and Facilities

Irrigation System

Out of the Project Area of 20,540 ha, the Existing Irrigated

Area of 7,150 ha is equipped with irrigation facilities as shown in Figure 3-1. As seen in this figure, the Pha Teak, Muang Wah and Koh Matan canals supply irrigation water to the area. To divert irrigation water to these canals, the Mae Kuang diversion weir and intake gates have been constructed. The major dimensions of these facilities are mentioned in subsequent section. RID constructed the Pha Teak canal in 1954, whiles farmers themselves constructed the Muang Wah and Koh Matan canals. In other words, the latter two canals are the "People's Irrigation System". The canals have the following services areas:

	Service Area (ha)		
	Present Area	Outside of Project Area	Total
Pha Teak Canal	3,680	-	3,680
Muang Wah Canal	480	-	480
Koh Matan Canal	2,990	2,450	5,440
Total	7,150	2,450	9,600

Figure 3-7 indicates the observation data on discharges diverted to the Existing Mae Kuang Irrigation area of 9,600 ha for six years from 1975 to 1980. The data show that 49 percent of the Mae Kuang discharge is diverted for irrigation in the dry season, whereas 31 percent in the wet season and 35 percent per annum. The water resources development by means of constructing dams, etc., might be worthy studying since the annual rainfall in the Project Area is so small, ranging from 1,000 mm to 1,500 mm.

In addition to the existing irrigation system mentioned above, the following four intake weirs have been constructed on the Mae Kuang river from downstream of the Mae Kuang Weir to the southern edge of the Project Area and the Mae Kuang river discharges are diverted to the fields during the wet season.

Existing Water Right on the Mae Kuang River

Name of Weir	Area (ha)	Maximum Intake Discharge (cu.m/sec)	Constructed	Remarks
1. Nong Ung	128	ϕ 800mm	People's Irrigation	to irrigate Existing Irrigated Area
2. Pa Kuai 3. Khok Mupa	440	1.0 - 2.0	People's Irrigation	to irrigate Existing Irrigated Area
4. Ban Tha	480	1.0	People's Irrigation	to irrigate Downstream Area

Major Dimensions of the Main Irrigation Facilities

The present main irrigation facilities consist of the Mae Kuang diversion weir, intake gates, canals, and dams. The major dimensions of them are shown below:

Mae Kuang Diversion Weir

Weir Length:	120 m
Type:	Floating type
Crest Elevation:	EL 337.0 m

Intake Gates

Pha Teak gate:	3.00m wide x 1.40m height
Muang Wah gate:	0.60m wide x 0.80m height
Koh Matan gate:	3.00m wide x 1.40m height
Sill elevation:	EL 335.65m

Canals

Item	Pha Teak Canal	Muang Wah Canal	Koh Matan Canal
Irrigated Area (ha)	3,680	480	2,990
Designed Maximum Intake Discharge (cu.m/sec)	4.00	0.60	5.00
Canal Length (km)	27.75	4.00	28.80

Item	Huai Hug Dam	Huai Kiang Dam
Catchment Area (sq.km)	1.5	1.2
Gross Storage Capacity (MCM)	0.60	0.40
Effective Storage Capacity (MCM)	0.38	0.39
Designed High Water Level	371.10	386.70
Designed Low Water Level	363.00	372.00
Dam Crest Elevation (m)	374.50	389.00
Dam Height (m)	15.00	17.00
Dam Volume (10^3 cu.m)	150.0	160.0
Constructed Year	1979	1978

c) Water Management Problems in the Irrigated Area

Irrigation Canals

As stated previously, the major facilities in the irrigated area are the Mae Kuang diversion weir and three main irrigation canals. The design intake discharge from the Mae Kuang diversion weir is 9.6 cu.m/sec in total and the diverted water is conveyed to the service area through the following three main canals.

Description of Irrigation Canals

Canals	Area (ha)	Intake Discharge (cu.m/sec)	Length of Main Canal (km)	Secondary Canal: Number of Canal	Secondary Canal: Total Length (km)
Pha Teak	3,680	4.0	27.75	26	67.0
Muang Wah	480	0.6	4.00	7	12.0
Koh Matan	2,350	5.0	18.00	50	105.5
(Muang Poa)1/	640	(0.8)	10.80	30	25.1
Total	7,150	9.6	60.55 (6.3 m/ha)	113	209.6 (21.8 m/ha)

The Pha Teak canal was constructed by RID in 1954 and other two canals were constructed by farmers utilizing natural small rivers.

1/ Muang Poa is branch canal of Koh Matan canal

Therefore, operation and maintenance of the Pha Teak canal are relatively well performed, whereas those of other two canals are not considered so well under farmer's maintenance. All of these canals are earth canal except at the surroundings structures such as bridge and at bending portions

Diversion Facilities

The water in main canals is diverted to secondary canals through diversion facilities, but no provision of measuring devices for diversion causes unfavorable intake particularly in the upstream Hence, the downstream farmers can hardly intake irrigation water during the dry season. Furthermore, the Pha Teak canal has no provision of check facilities to raise water level in canals, so that small pumps are used to lift irrigation water from main canal to fields at the middle course of canal in the dry season. Under these conditions, strict water management systems should be introduced in the area after completion of the Project.

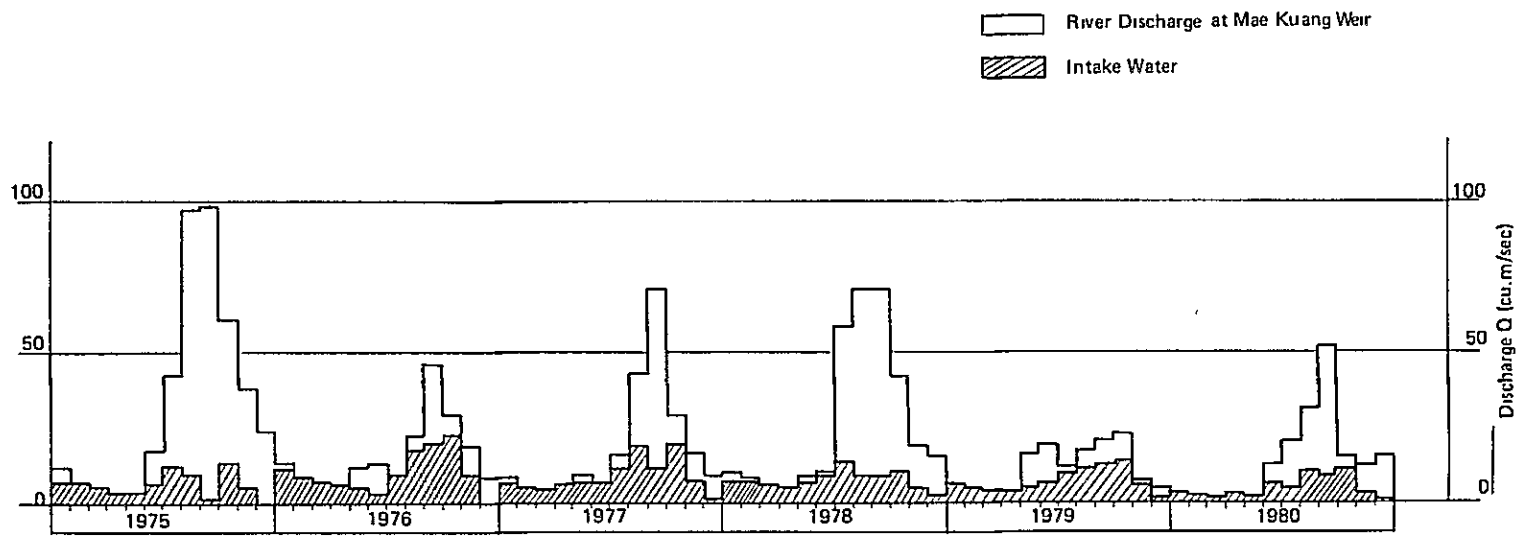
3.4.2 Drainage Conditions

a) Drainage Systems

The Project Area except the Right Bank Area is situated on flat land with the gentle slope of 1/300 to 1/600. In the Area, the existing small rivers and creeks such as Mae On, Mae Thi and Mae Yak are used for drainage purposes. Such rivers and creeks are connected to the Mae Kuang river. On the other hand, the Right Bank Area has a slightly steep slope of 1/60 to 1/100 and the small streams used for drainage are connected to the Mae Faek Main irrigation canal at their downstream.

The surplus waters from fields caused by the heavy rainfall, are directly drained to the rivers and creeks through plot to plot in the fields. In the both areas mentioned above, there exist no drainage canals at on-farm level.

FIGURE 3-7 MONTHLY MAE KUANG RIVER DISCHARGE AND INTAKE WATER (1975-1980)



Year	River Dis. (MCM)	Intake Water (MCM)
1975	407	71
1976	193	120
1977	224	103
1978	324	90
1979	136	84
1980	171	56
Average	243	86 (35%)

Note: Detailed figures are given in Table D 1-1, in Appendix D-1.

b) Drainage Conditions

There are no severe damages by ill-drainage, due to favorable slope mentioned above. However, in the southern parts of the Project Area near Lamphun, flooding is observed in the wet years. Inundation of flooding water of which flooding period was one to two days and an average flooding depth was 0.5 m on fields, was recorded in 1973.

The principal causes of the problems are i) the overflow from the Mae Ping and Mae Kuang rivers, and ii) no adequate drainage ways to collect and convey the discharge across the land to the outlet, and iii) also no adequate terminal drainage systems.

Under these situations, it is considered that adequate counter-measures to prevent from flooding in the area and to improve the drainage conditions should be taken in the Project.

3.5 Flood Conditions

a) Outline of River Basin

The Project aims at developing the farm lands of 20,000 ha out of the total gross area of 37,270 ha which extends in the left bank side of the middle reach of the Mae Kuang river, a tributary of the Mae Ping river. The Mae Ping river originating in a mountain about 100 km north of the Changwat Chiang Mai, a central city in the basin, flows straightly southward and joins the Mae Ngat river and the Mae Taeng river to reach the northern edge of the Chiang Mai-Lamphun valley.

Furthermore, the Mae Ping river flows down southward passing an eastern part of the Changwat Chiang Mai and joins the Mae Kuang river at the point of 30 km south of the Changwat Chiang Mai. Another central city, the Changwat Lamphun, is located at about 10 km north-east of the junction. The Changwat Lamphun and its vicinity is the lowest part in the basin and frequently damaged by flood.