THE KINGDOM OF THAILAND

ROYAL IRRIGATION DEPARTMENT

FEASIBILITY REPORT
ON
KAENG KHOI — BAN MO
PUMPING IRRIGATION PROJECT

(MAIN REPORT)

JANUARY 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a survey on Kaeng Khoi - Ban Mo Pumping Irrigation Project and entrusted the survey to the Japan International Cooperation Agency (JICA). The JICA sent to Thailand a survey team headed by Mr. Satoshi Kadowaki from July to August, 1981.

The team exchanged views with the officials concerned of the Government of Thailand and conducted a field survey in Changwat Saraburi 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.

January, 1982

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency

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

Letter of Transmittal

Dear Sir:

We are very pleased to submit herewith the Final Report on the Feasibility Study on the Kaeng Khoi-Ban Mo Pumping Irrigation Project in the Kingdom of Thailand. The field survey and study had been conducted in two stages; the field survey, investigation and study were carried out for about two months from July 1 to August 31, 1981, and study and report compilation as home office works were made from September 5 to October 20, 1981, respectively. In the course of survey and study in Thailand, we held a series of discussion meetings with the Thai Governmental officials concerned and counterparts personnel for the Project formulation.

The Proposed Project Area of this feasibility study covers about 88,500 rai (14,160 ha) in net, being located at the lower most basin of the Pasak river, one of the major tributaries of the Greater Chao Phraya river, and the area is about 110 km north from Metropolitan Bangkok and administratively belongs to Changwat Saraburi.

The Project aims to stabilize the irrigation water supply and improve drainage conditions in the entire Project Area for increased agricultural production through establishment of the double cropping system and modernization of farm techniques.

The Feasibility Report consists of the following two volumes:

Volume I	Main Report
Volume II	Appendix

We are confident that the Project Area will sharply increase the farm production through supply of the stabilized irrigation water, and furthermore, we earnestly hope that implementation of the Project will greatly contribute to the socio-economic development of the region.

We wish to express our sincere gratitude to the Royal Irrigation Department, Department of Agriculture, Department of Land Development, Department of Agriculture Extension, Department of Technical Economic Cooperation, National Energy of Administration, and other organizations and agencies of the Government of Thailand, and Ministry of Foreign Affairs, the Japanese Embassy in Bangkok, Ministry of Agriculture, Forestry and Fisheries of the Government of Japan, and Japan International Cooperation Agency (JICA), the Supervisory Group for their closest cooperation and worthwhile advices given to us.

January 1982

Sincerely Yours,

S. Kadowaki

Satoshi Kadowaki
Team Leader of Feasibility Study
Team for the Kaeng Khoi-Ban
Mo Pumping Irrigation Project

GENERAL PLAN FOR KAENG KHOI - BAN MO PUMPING IRRIGATION PROJECT

KAENG KHOI PUMPING STATION

LEGEND

	Road
	Rail Way
	River or Stream
	Town or Village Area
	Project Boundary
IRRIGATION	
	Main Canal
	Lateral Canal
	Sub-Lateral Canal
(P)	Pumping Station
	Main Canal (Existing)
DRAINAGE	
	Main Canal
	Main Canal (Existing)
N	Drainage Sluice

Kaeng Khoi - Ban Mo Project
(14160 ha)

Demonstration Farm

RAMA VI BARRAGE

0 1 2 3 4 5km

BURMA
LAOS
Vientiane
Rangoon
THAILAND
PROJECT AREA
Bangkok
CAMBODIA
Phnom Penh
Gulf of Thai land
MALAYSIA

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ABBREVIATION AND GLOSSARY

Conversion factor

Japanese Yen	¥1.00 = US$0.004 (= ฿0.10)
US Dollar	US$1.00 = ฿23.00 (= ¥230.00)
Thai Baht (฿)	฿1.00 = ¥10.00 (US$0.043)
1 rai	Thai unit of area measurement, rai = 0.16 ha
1 ha	6.25 rai

Measures

mm	millimeter
cm	centimeter
m	meter
km	kilometer
km^2(sq.km)	square kilometer
ℓ	liter
cu.m(m^3)	cubic meter
MCM	Million Cubic Meter
c.m.s.(cu.m/sec)	cubic meter per second
ton(t)	metric ton
kw	kilowatt
KWH	Kilowatt Hour
°C	degree centigrade
HP	Horse Power

Abbreviation

BAAC	Bank for Agriculture and Agricultural Cooperatives
IBRD	International Bank of Reconstruction and Development
JICA	Japan International Cooperation Agency

LV	Local Variety
HYV	High Yielding Variety
FAO	Food and Agriculture Organization of the United Nation
MOAC	Ministry of Agriculture and Cooperatives
NEA	National Energy of Administration
NAEP	National Agricultural Extension Project
RID	Royal Irrigation Department
DAE	Department of Agriculture Extension
EL	Elevation
O.M.(O & M)	Operation and Maintenance
MSL	Mean Sea Level
ET	Evapotranspiration
IRR	Internal Rate of Return
CHO	Constant Head Orifice
CIF	Cost, Insurance & Freight
GDP	Gross Domestic Product

Glossary

Changwat	Province
Amphoe	District or title of district town
Tambon	Sub-district
Muban	Village
Muang	Capital of Changwat

SUMMARY, CONCLUSION AND RECOMMENDATIONS

SUMMARY, CONCLUSION AND RECOMMENDATIONS

A. SUMMARY

Location and Topography

A.1. The Project Area is located in the lower most basin of the Pasak river, one of the major tributaries of the Greater Chao Phraya river. The area is about 110 km north of Metropolitan Bangkok and administratively belongs to Changwat Saraburi. The Project Area covering about 88,500 rai (14,160 ha) in net is situated at the elevation ranging from 10 m to 20 m in strip which extends in flat lowland with the maximum width of seven kilometers, and surface and internal drainage of the lands is rather poor in the most part of the Project Area.

Climate

A.2. The climate of the Project Area is of the South-east Asian Monsoon type and can be specified into two seasons, the wet season from the end of May to October and the dry season from November to April. The annual mean temperature observed at the Lopburi station located about 70 km northwest of the Project Area is 28.3°C with the highest of 37°C in April and the lowest of 19°C in February.

The rainfall in and around the Project Area is observed at four stations of Muang Saraburi, Kaeng Khoi, Sao Hai and Rama VI Barrage. The averaged annual rainfall of said four stations is 1,416 mm per year, out of which 1,191 mm (84%) is concentrated in the wet season. The maximum monthly rainfall occurs in September at the amount of 305 mm.

Water Resources

A.3. The major water resources of the Project is the Pasak river, one of the major tributaries of the Chao Phraya river. The discharge observation record for 29 years at Kaeng Khoi gauging station (S2 station) is averaged at 1,894 MCM equivalent to 83 percent of the annual total of 2,288 MCM flowing in four months from August to November. Besides, the annual runoff discharges at the said gauging stations ranges from 607 MCM to 5,276 MCM with large fluctuation. On the other hand, the Chainat-Pasak Canal along the western boundary of the Project Area has supplied the irrigation water to the irrigable area of about 128,000 ha, and the surplus discharge from the Canal will be the supplementary water to the areas downstream of the Pasak river.

Geology and Soils

A.4. Geology of the Project Area is composed of hard bed rocks such as Permian Ratburi Group (mainly limestone) and Pre-Traiassic Khao Yai Volcanics (mainly Rhyolite), which are covered by such Quarternary Pleistocene-Holocene overburdens (mainly gravel and clay with weak consolidated or loose formation) as marl, terrace deposits, fan deposits and alluvium. However, bed rocks can be seen as monadnock only in some places, and most of the Project Area is covered by said overburdens.

The soils in the Project Area are mainly composed of clayey materials. The internal drainage is generally very poor and the soils are hard when dried.

In the wet season, soils are saturated by water and flooded by impounded rain water after heavy rain. The moisture conditions of soils are suitable for rice cultivation and the areas for upland crops are limited.

In the dry season, most of the area can be planted with HYV rice plants except some areas of poor fertility soils and also most of the area is moderately suitable for upland crops except the area of very hard soils, when sustained irrigation is available.

Transportation

A.5. The transportation networks in the Project Area are well arranged with the major facilities of the national roads and railway except eastern part. The national road No.1 passes through south-north direction in the middle of the Project Area. While, in the Project Area, road networks have been comparatively well provided and most of the transportation is being done by cars.

Present Land Use

A.6. The gross Project Area of 16,390 ha (102,400 rai) involves 14,600 ha (91,300 rai, 89%) of cultivable land, of which paddy field shares 14,110 ha (88,200 rai, 86%) and the rest 490 ha (3,100 rai, 3%) is the uplands. In the paddy fields farmers practise paddy mono-culture except Amphoe Sao Hai where pumping facilities have been provided by the agri-cooperatives. Most of the upland field are planted with maize, groundnut, mungbean and soybean in the wet season. The land holdings per farm household averages at about 4.0 ha (25 rai) for the total farm household of 3,660 in the Project Area.

Present Irrigation

A.7. A greater part of the paddy field in the Project Area is relying only on rainfall in the wet season. In the neighbour of the Project Area, there are three irrigation projects existing, namely Sao Hai Pumping Project (5,760 ha), Chainat-Pasak Project (128,000 ha, divided into four sub-projects Manorom, Chong Kae, Khok Kathiam and Roeng Rang) and Raphiphat Project (110,000 ha, with three sub-projects of Nakorn Luang, South Pasak and North Rangsit) which have been provided with a systematic canal networks by the RID.

However, in the proposed Project Area, the cultivated lands are situated higher than El.10 m, having been left intact as far as irrigation development is concerned mainly due to the averaged low water level of about MSL7.5 m at the Kaeng Khoi gauging stations. Such low water level makes gravity irrigation for the area impossible. In the Project Area, there are, several numbers of small streams flowing into, and these streams originate the northern mountains and join the Pasak river. Most of the surface water on the said streams is utilized for paddy cropping, resulting in a very little water available for the use in the Project Area.

Under such situation, the agricultural cooperative's pumping irrigation projects have been implemented with seven pumping stations and related canal systems in the Project Area since 1968, and three pumping projects have been planned by NEA and scheduled to be completed in April 1982 because inadequate irrigation facilities are provided in the Project Area. The commanding area of both projects are about 3,100 ha in total.

Present Drainage

A.8. The Pasak river has a drainage area of 14,522 km^2 at the S2 gauging station located near Kaeng Khoi. The recent maximum flood discharge occurred in 1978, amounting to about 2,000 c.m.s. with the highest water level of 21.1 m at the S2 station. The Rama VI Barrage controls the discharge not only for the Pasak river but also from the Chainat-Pasak canal for irrigation to the service area commanded by the Raphiphat canal, and there have been considerable flood damages on the lowland areas along the Nong Luang river which about seventy percent of the drainage area for said river is paddy field and there might be considerable water storage available in the paddy field during raining and the flow capacity of the main channels would be sufficient with some minor exceptions. Internal drainage conditions are very poor due to insufficient drainage facilities provided in the Project Area.

On-farm Facilities

A.9. In the rainfed paddy fields which occupy the most of the Project Area, there are none of irrigation and drainage facilities existing at on-farm level with some exceptions. Plot-to-plot irrigation at on-farm is generally practiced. The farm roads are provided very thinly except such local roads as can connect villages each other. These local roads are available for car traffic and farmers use them for transporting various inputs and outputs to and from the fields. To access to their own farm plots, however, farmers have to pass many plots between the local road and their own plots.

Present Agriculture

A.10. The wet season paddy is the main crop in the Area and transplanting and harvesting for both LV and HYV are practised in July to August for the former and November to December for the latter, respectively. For the dry season paddy, farming practice is quite similar to that of the wet season paddy. Cropping index in the Project Area showed 93.2 percent in the wet season, and is as low as only by 4.7 percent in the dry season.

Paddy production per hectare, as the major crop ranges from 2.4 ton to 2.6 ton in the wet season and 3.5 ton in the dry season for high yielding variety, and 1.8 ton in the wet season for local variety. Farm mechanization in the Project Area has a comparatively high rate with 37.3 percent of the total beneficial farmers.

Farm Economy

A.11. Changwat Saraburi within which the proposed Project Area is located, has the total population of 462,080 in 1979 with density of 138/km^2, and its gross provincial product is 10,248 million Baht in 1979 at constant 1972 prices.

On the basis of farm survey for 30 farms, number of full owners, part owners and full tenants are 22 farms, two farms and six farms, respectively. While only 10 farms are a full-time farmers, the rest are the part-time farmers. On an average, a farmer earns 30,588 Baht of which about 73 percent or 22,287 Baht was derived from on-farm and about 27 percent of 8,301 Baht from off-farm.

As for marketing of agricultural products, the similar procedure to that prevailing in the whole Kingdom can be seen in and around the Project Area. There are 22 rice mills with total capacity of 903 tons in paddy per day in and adjacent to the Project Area.

Purpose of the Project

A.12. The purpose of this project is to encourage the agriculture in the Project Area through stable irrigation water supply to the entire beneficial areas together with introduction of the dry season crops as much as possible. The following project components are planned to accomplish the above purposes. The project plans to provide integrated irrigation system and to introduce the better water management and operation method of the system, to improve the drainage system for introducing HYV paddy, to establish demonstration farm for education, training of farmers concerned and promotion of on-farm development in the Project Area, and to provide agricultural supporting services.

Proposed Land Use

A.13. The proposed land use in the Project Area is decided based on the study results on availability of water resources, optimum irrigation networks in taking into consideration the tendency of the current farming practices and land use. Finally, the following land use plan is concluded.

	Acreage	
1. Irrigable area		
Paddy field	13,680 ha	85,500 rai
Upland field	480	3,000
Sub-total	14,160	88,500
2. Non-irrigable area		
Forest	920	5,750
Residential area	660	4,125
Road and others	650	4,063
Sub-total	2,230	13,938
Total	16,390	102,438

Water Resources Availability

A.14. There are three existing irrigation projects and four NEA pumping irrigation projects which are now under construction, in and around Project Area. The irrigated areas and irrigable areas concerned are summarized as follows:

Project Name	Water Resources	Average ha	(rai)
1. Proposed project			
NEA area inside the project	Pasak river	1,489	(9,300)
proposed area	"	12,671	(79,200)
Sub-total		14,160	(88,500)
2. On-going project			
NEA area outside the project	"	1,743	(10,900)
Sub-total		1,743	(10,900)
3. Existing project			
Sao Hai	"	5,760	(36,000)
Chainat-Pasak	Chao Phraya river	127,840	(779,000)
Raphiphat	Both of Pasak and Chao Phraya	110,000	(687,500)
Sub-total		243,600	(1,522,500)
Total		259,503	(1,621,900)

As the results of study on availability of water resources for those areas concerned, water shortage in the month of July during the wet season when peak water requirements takes place, occurs by two years within 16 years examined from 1965 to 1980. It is judged that if Manorom intake discharge can be controlled in following water requirements, the said water resources are available for the proposed irrigation scheme. The dry season cropping intensity for those areas concerned were decided by 20 percent of cultivable land based on the same water balance computation as the wet season. Therefore, proposed irrigable areas in the Project were determined by 14,160 ha (88,500 rai) for the wet season and 2,800 ha (17,500 rai) for the dry season, respectively.

Furthermore, the Project Area will be favoured with more potentiality available by the comprehensive development scheme for the upper Pasak basin, under more intensive water management of the Chainat-Pasak canal systems and implementation of on-farm development.

Proposed Irrigation Facilities

A.15. The main, lateral and sub-lateral irrigation canals will be constructed with about 148 km length in total in the Project Area so as to supply the adequate irrigation water systematically to the entire farm lands. The canal systems consist of one main canal, twelve routes of lateral canal and nineteen routes of sub-lateral canal. The main pumping station will be provided with capacity of 1,000 mm x 560 kw (750 HP) x 7 units at the right bank of the Pasak river near the Kaeng Khoi town. The necessary facilities for the canals will also be installed in parallel with canal construction in order to conduct proper water management and water distribution.

Proposed Drainage Facilities

A.16. The main drainage canals for the Project are the Pak Bang and the Nong Luang rivers which are flow down through the center of the beneficial area to the Pasak river directly, and they have comparatively adequate canal capacity. The rivers and streams joining the said two main drains have inadequate capacity and unstable canal route at present. Therefore, seven routes of the rivers and streams will be improved for about 22 km length in total so as to reduce inundation damages.

Assessment of the Small Pumping Project

A.17. There are several existing or on-going small pumping irrigation projects in the proposed Project Area, such as three on-going projects controlled by the NEA and six existing and one on-going projects controlled by the agricultural cooperatives. Construction works of the former projects will be completed at the end of April 1982. Out of the latter seven projects, four project facilities will be upgraded under the said NEA project and remaining three projects will be controlled under the agri-cooperatives including on-going project. As the results of careful consideration on future planning of pumping facilities as well as related canal systems in the Area, it can be judged that the irrigation facilities concerned with the Area should be integrated into the proposed project facilities from the view points of technology and economy and proper water management in future.

Operation and Maintenance (O & M)

A.18. The operation and maintenance roads will be provided along the main and lateral canals with width ranging from three to six meters for the convenience of O & M of the irrigation and drainage facilities. The O & M organization will be established in both terms of staffing and facilities including adequate numbers of O & M equipments which will be procured by the foreign loans, and necessary education and training on the water management will given to the farmers concerned.

Establishment of Demonstration Farm

A.19. The on-farm developments aims at establishing highly modernized farm management, increasing agricultural production, utilizing water more effectively by rationalized management and upgrading the farming techniques. Establishment of a demonstration farm, therefore, would play a significant role to successfully execute the overall Project in encouraging the farmers through show-window of the irrigated agriculture, new crops and varieties, and better water management. The proposed site of the demonstration farm was selected near national road No.1 with net irrigable area of 260 ha (1,625 rai).

Proposed Cropping

A.20. At present, the main crops in the Project Area are paddy, both for the wet and the dry seasons, and maize on the upland fields. Taking several factors into consideration such as crop profitability to national economy, effect of irrigation, familiality of crop cultivation of farmers, it has been planned that the proposed cropping patterns do not drastically change the present ones. It is proposed that paddy (13,680 ha or 85,500 rai), maize (430 ha or 2,688 rai) and groundnuts (50 ha or 313 rai) would be grown in the wet season and only paddy (2,800 ha or 17,500 rai) in the dry season. Hence, the expected cropping intensity for both seasons with Project increases from 98 percent to 120 percent.

Target Yield

A.21. The target yields of the proposed crops can be determined based on the data and information collected, such as present yield records available in the related five Kaset Tambon offices, actual results of the existing irrigation project, prospective improvement in farming practices, effect of irrigation and agri-extension activities. The target yield of paddy as a main crop will be prospected to be at about 3.3 tons per hectare (528 kg per rai) of LV 4.0 tons per hectare (640 kg per rai) of HYV in the wet season and

4.2 tons per hectare (672 kg per rai) of HYV in the dry season, respectively.

Project Implementation

A.22. Since the project implementation takes about two years for preparatory works such as surveying and the canals designing including the main pumping station, the total project implementation period is scheduled to last seven years. The construction works are planned to take five years taking into consideration quick-yielding of the Project, staffing capability of RID, expected budgetary support and actual results of construction works undertaken by the capable contractors. The construction works are planned to be undertaken by the Contract basis following Government policy which will be applied in most cases for the Project.

Phasing Development Plan

A.23. The following phased development plan will be recommendable to the Project when the plan is needed from the view point of environmental impact. The first stage area should be involved mainly rainfed paddy field where no proper irrigation facilities exist for the total acreage of about 9,877 ha (61,700 rai), and the second stage area, as a remainder, is the paddy field with 4,283 ha (26,800 rai) in zone No.1 and No.3 along the right bank of the Pasak river where pumping facilities are being operated and or constructed in the area.

Project Cost

A.24. The total investment cost, including the cost for price escalation and excluding the interest during the construction period, was estimated at 936 million Baht (equivalent to US$40.7 million) including the foreign currency component of about 373 million Baht (equivalent to US$16.2 million) to cover the procurement of equipment, imported construction materials and consulting fee, sharing about 40 percent of the total amounts.

Project Benefit

A.25. Since the main objective of the Project is to make irrigation water available, the Project benefit is measured through an incremental net production value between two cases of "with project" and "without project". At the full development stage of the Project, incremental production of paddy, maize and groundnuts would be expected at 30,700 tons, 300 tons and 30 tons, respectively.

All prices are based on the recent information available as of July, 1981, and several conversion factors are taken into consideration to obtain economic prices.

The economic project benefit is estimated a 145,160,000 Baht as an incremental net production value as shown below;

	Net Production Value (฿1,000)		
Crop	Without	With	Increment
Paddy	136,584	281,172	144,588
Maize	1,679	2,212	533
Groundnuts	131	170	39
Total	138,394	283,554	145,160

Economic Project Cost

A.26. The economic project cost is measured by deducting a price contingency and land acquisition cost from the financial project cost as well as by applying the conversion factors to the financial project cost as summarized below;

	Summary of Project Cost (฿1,000)	
	Financial	Economic
1. Initial Investment	935,800	548,264
2. Operation and maintenance	13,100	11,562
3. Replacement	23,100	23,100

Economic Internal Rate of Return

A.27. By discounting both stream of the economic cost and benefit with the several discount rates over 50 years of the evaluation period, 16.9 percent of economic internal rate of return has been worked out.

Sensitivity Analysis

A.28. The following is summary of the sensitivity analysis.

Item	E.I.R.R.(%)
1. Original	16.9
2. Initial Investment Cost	
10% increase	15.7
20% increase	14.7
3. Two years extension of construction period	15.6
4. 10% decrease in paddy yield	12.4
5. Project Benefit	
10% decrease	15.4
20% decrease	13.8
6. Including on-farm development	14.3

Repayment Capacity

A.29. Based on the farm budget analysis, farmers would obtain their repayment capacity which can bear the operation and maintenance cost of ฿925 per hectare or ฿3,579 per farm as well as about 20% of the total initial investment cost.

B. CONCLUSION

B.1. As mentioned above, the economic internal rate of return of 16.9 percent with the lowest E.I.R.R. of 12.4 percent in the sensitivity analysis, shows the proposed project economically feasible, and furthermore, the estimated repayment capacity of ฿12,912 per farm would make the proposed project financially viable.

B.2. The proposed project, when realized, directly or indirectly affect not only agricultural production but also other various fields. The benefit analysis is based on only the incremental benefit to be generated by agricultural production increase as the main objective. However, the following benefits would be generated from the Project; firstly, employment would be increased by implementing the project, secondly, the agri-business would be expanded by active marketing and processing of input and output materials which will be increasingly required and produced in the "with project" conditions, thirdly, the increase in farm income would result in an increase of disposal income, and fourthly, the security and stability in peoples' life would be assured from the result mentioned in the above first to third.

C. RECOMMENDATIONS

Arrangement of Water Resources

C.1. The irrigation water supply around Changwat Saraburi in the lower basin of the Pasak river has been carried out through the Rama VI Barrage, and the main irrigated areas are 110,000 ha (687,500 rai) commanded by the Raphiphat canal and 5,760 ha (36,000 rai) covered by the Sao Hai Pump Irrigation Project. In addition to the above, the irrigable areas of 14,160 ha (88,500 rai) proposed in this Project and about 1,740 ha (10,875 rai) under the NEA pump irrigation project will be added to result in the total irrigate or irrigable acreage in the area of about 131,660 ha (822,875 rai).

The Pasak river is deemed considerably unstable in its discharge because the annual discharge and the monthly discharge heavily fluctuate each year due to being seriously affected by its specific features of the basin, rainfall distribution, etc. In view of the irrigation water supply, the water shortage has taken place to a certain extent in the puddling stage for the wet season paddy cropping, while the Pasak river system will be quite unreliable as water sources for the dry season cropping areas. Under the circumstances, the irrigation projects to be formulated in the upper basin of the Pasak river in future should be carefully contemplated in due consideration of the situation encountered by the existing or on-going irrigation projects in the lower basin.

Intensive Operation and Maintenance (O & M)

C.2. The water source of the Project is the Pasak river, and the Sao Hai, Raphiphat Irrigation Project and the NEA's pumping irrigation projects have the vested water right on the Pasak river as well, whereas they are dependent upon the Chainat-Pasak canal for the most water sources of the dry season cropping. Consequently, a possibly proper control of diverting the water should be performed at the Manorom Regulator located at the diversion from the Chainat-Pasak canal as well as a adequate water distribution should be practised to those related areas. As an infrastructure of the existing RID water operation center, a consistent water control organization covering about 260,000 ha of the related areas should be established in the RID's Regional Irrigation Office VIII so as to secure an efficient water utilization and smooth operation and maintenance of the facilities.

Geological Investigation

C.3. The geological log (according to the well in the Project Area) suggests that the bottom of the structures of the proposed Kaeng Khoi Pumping Station would reach the bed rocks. Prior to the detailed design, however, three bore hole drillings, at least 25 m deep each, should be carried out in the site together with the standard

penetration test at every one meter intervals and other geological investigation for determining the most suitable foundation treatment method to the site. Furthermore, geological investigations should be carried out for the major canal structures when necessity requires.

Coordination with On-going Project

C.4. The implementation plan of the facilities construction for the Project should be formulated according to the prior consultative meetings with the agencies and organization concerned on the unification of the existing facilities to the proposed one or disuse of them in due consideration of the relationship among the Project, the NEA's projects and those under the control of the agri-cooperatives. According to the series of consultations, the powerful administration guidance should be given to avoid excessive investments to the projects in a gestation period before the relevant projects produce the yields.

Demonstration Farm

C.5. The proposed demonstration farm should be carefully designed based on thorough study of the site and full consent of the farmers concerned so as to function effectively in meeting its aim. For successful implementation of the plan, the alignment of the canal commanding the demonstration farm should be prudently determined and the necessary cadastral survey should be carried out to define the boundaries of the farm as well as to clarify the acreage to be used for the farm. The on-farm development of the demonstration farm should be determined at the level as model farm in view of the current status of the model farms and the future prospect of the agricultural development in Thailand.

Promotion of On-farm Development

C.6. As the second stage development scheme for the Project, the on-farm development plan, as a consolidation of terminal facilities, should be formulated in the entire Project Area so as to function effectively to the main irrigation and drainage facilities which have been planned to be provided in the Project. The investment cost and incremental benefit, which will be prospected by the Project after completion of the on-farm development works, are summarized as follows.

Implementation acreage: 14,160 ha
Investment cost : 1,352 million Baht
Incremental benefit : 161 million Baht
Economic internal rate of return: 14.3%

The on-farm development works should be commenced immediately after completion of the first stage programme taking into account the assessment of the demonstration scheme and local requirements.

Confirmation of Flood Damages

C.7. To have a sufficient knowledge of the inundation conditions in the areas along the two major drainage canals (the Pak Bang and the Nong Luang) joining the Pasak river, the water level observation should be carried out at the confluences of these rivers and several other points in the Project Area. On the other hand, the relationship between the gate operation at the Rama VI Barrage and the water levels observed should be thoroughly looked into for pursuing the cause of the inundation. Such knowledges on the cause of the inundation and the damages to the crops would enable to provide the detailed designs of the structures to be required for the flood protection.

Supporting Services

C.8. In coping with consolidation of the irrigation and drainage facilities in the Area, the local farmers should be organized to

carry out the successful operation and maintenance of the facilities and to be given the guidance on proper irrigation practices, advanced farming techniques, etc. The farmers in the Project Area, who have lacked experience in irrigation by modern facilities, should be trained well for possibly effective and efficient irrigation in terms of the pumping irrigation to be applied in the Project. For accomplishment of this purpose, the RID staff who would be a core of the O & M services should be assigned to the Project and serve for establishment of the effective guidance organization as well as take the necessary budgetary support in this respect.

I. INTRODUCTION

I. INTRODUCTION

In compliance with the request of the Government of Thailand, the Government of Japan dispatched a survey team through the Japan International Cooperation Agency (JICA), the executing agency of overseas technical cooperations under the Government of Japan, and let the team conduct the field survey, investigation and study for the Kaeng Khoi - Ban Mo Pumping Irrigation Project in the Kingdom of Thailand based upon the preliminary survey conducted in February 1981. The survey team has worked out a feasibility study for the Project through preparation of the integrated 'agricultural' development scheme in the total area of about 16,400 ha(102,500 rai).

The Project Area is located in Changwat Saraburi about 110 km north of Bangkok, Capital of the Kingdom of Thailand, and at the lowest basin of the Pasak river, one of the major tributaries of the Greater Chao Phraya river.

The survey team stayed in Thailand for about two months from July 1 to August 31, 1981, and conducted the survey, investigation and data collection, and held a series of discussions with the Thai Governmental officials concerned for formulating the Project. The survey team prepared a feasibility study report on the Project in Japan based on findings and basic concepts of development obtained in the above-mentioned field works.

The feasibility report consisting of the Main Report and Appendix, with the major drawings, has been compiled based on results of the surveys and study conducted in the field as well as on discussions made among the Thai Governmental officials, the Supervisory group members and the Team.

The name and designation of the above-mentioned personnel participated in the Project study are hereinafter listed.

A. Supervisory Commitee Members

	Name	Designation
1.	Mr. Yusuke Suematsu (Chairman)	Senior Technical Advisor, Design Division, Construction Department, Agricultural Structure Improvement Bureau, Ministry of Agriculture, Forestry and Fishery (MAFF)
2.	Mr. Hideyuki Kawanishi (Member)	Deputy Chief, Project Planning Division, Planning Department, Agricultural Structure Improvement Bureau, MAFF
3.	Mr. Hiromoto Aoki (Member)	Agricultural Policy Advisor, Regional Planning Division, Planning Department, Tohoku Regional Agricultural Administration Office, MAFF
4.	Mr. Akira Kazama (Member)	Technical Advisor, Design Division, Construction Department, Agricultural Structure Improvement Bureau, MAFF
5.	Mr. Yuji Sakamoto (Member)	Chief of Development Planning Division, Tohban Yosui Irrigation Improvement Project Office, Kinki Regional Agricultural Administration Office, MAFF

B. Survey Team Members

	Name	Period of Assignment
1.	Mr. Satoshi Kadowaki (Project Planning cum Team Leader)	June 29 to November 21, 1981
2.	Mr. Michio Goto (Hydrology)	June 15 to October 15, 1981
3.	Mr. Nobuo Ichiji (Irrigation and Drainage)	June 15 to October 20, 1981
4.	Mr. Makoto Yasuda (Geology)	July 15 to October 15, 1981
5.	Mr. Saburo Omata (Pump Design)	July 1 to October 20, 1981
6.	Mr. Kaoru Hoshii (Structure Design)	July 1 to October 20, 1981
7.	Dr. Susumu Nishigaki (Soil)	July 5 to October 15, 1981
8.	Mr. Kensuke Iriya (Agronomy)	June 15 to October 15, 1981
9.	Mr. Shizuo Sato (Construction Planning)	July 1, 1981 to January 14, 1982
10.	Mr. Yoshitomo Miyanishi (Agro-Economy)	July 1, 1981 to January 24, 1982

C. Thai Government Personnel to Whom the Team Contacted

	Name	Designation
1.	Mr. Sunthorn Ruanglek	Director General, Royal Irrigation Department (RID)
2.	Mr. Boonthai Otaganonta	Director, Design Division, RID
3.	Mr. Udom Rakchanya	Director, O & M Division, RID
4.	Dr. Boonyok Vadhanaphuti	Director, Project Planning Division, RID
5.	Mr. Suthep Tingsabhat	Director, Program Coordination and Budget Division, RID
6.	Mr. Phayool Chantasiro	Director, Topographical Survey Division, RID
7.	Mr. Damrong Jaraswthana	Director, Hydrology Division, RID
8.	Mr. Chamroon Chindasawguan	Director, Irrigation Regional Office No. 8, RID
9.	Mr. Charnchai Klinhom	Chief, Project Planning Division, RID
10.	Miss Supha Sing-intara	Chief, Project Planning Division, RID
11.	Mr. Taweechai Mackaman	Chief, Project Planning Division, RID

	Name	Designation
12.	Mr. Prabhansak Bhengbhon	Chief, Small Scale Project, Construction Division, RID
13.	Mr. Amphai Muthitacharoen	Chief, Soil and Geology Division, RID
14.	Mr. Danai Taiyadhen	Chief, Soil and Geology Division, RID
15.	Mr. Thonglaw Charoenrat	Office Engineer, Irrigation Regional Office No. 8
16.	Mr. Precha Prapasri	Project Manager, Khlong Phrieo Project
17.	Mr. Shoombhol Chaveesuk	Chief, Design Division, RID
18.	Mr. Penta Giathigong	Chief Engineer, O & M Division, RID
19.	Mr. Jumroen Paintying	Chief Engineer, Roadway Construction Division, RID
20.	Mr. Osot Charnvej	Chief Agronomist, O & M Division, RID
21.	Mr. Chumpol Chaweesuk	Chief, Design Division, RID
22.	Mr. Supot Rujiralul	Engineer, Project Planning Division, RID
23.	Mr. Mongkol Kalayaruen	Engineer, Project Planning Division, RID

Name	Designation
24. Mr. Lerdsak Maneepura	Engineer, Project Planning Division, RID
25. Mr. Pittaya Hiranburana	Economist, Project Planning Division, RID
26. Mr. Prasong Jitseri	Hydrologist, Irrigation Regional Office, No. 8, RID
27. Mr. Sarayuth Ratananakorn	Engineer, Irrigation Regional Office, No. 8, RID
28. Mr. Teerachai Chonhenchop	Engineer, Project Planning Division, RID

II. BACKGROUND OF THE PROJECT

II. BACKGROUND OF THE PROJECT

2.1. National Economy

2.1.1. General Description

The Kingdom of Thailand has total land of some 514,000 km^2, being located on the central part of the Indo-China peninsular, and borders on the west with Burma, on the north with Laos, on the east with Cambodia, and on the south with Malaysia and Gulf of Siam.

In 1979, the total population is estimated at about 46.1 million with population density of about 90/km^2. Although the annual growth rate of population is rather high, about three percent over the period from 1965 to 1979, it has recently decreased to about two percent per annum (See Table A.2.1-1 in Appendix II).

According to the results of labor force survey in 1978, percentage of persons in labor force against the total civilian non-institutional population ranges from 37.8 percent to 48.4 percent, showing seasonal fluctuation that more employment opportunity in farm labor is available in the farming season, July to September. (See Tables A.2.1-2 and A.2.1-3 in Appendix II).

2.1.2. Economic Performance

In 1980, the Gross Domestic Product (G.D.P.) is estimated at 673,732 million baht at current prices, of which leading sector is the agriculture, fishery and forestry, amounting to 176,303 million baht or 26.2 percent of G.D.P., followed by the manufacturing sector (18.7 percent) and the trade sector (18.6 percent). The contribution of the agricultural sector to the G.D.P. declined continuously from 31 percent in 1976 to 26.2 percent in 1980.

While the real G.D.P. growth is 7.4 percent per annum over the period from 1976 to 1980, the real growth of G.D.P. per capita is estimated at about 5 percent per annum over the same period, and the real growth of the agricultural sector remains only 2.9 percent per annum. (See Table A.2.2-1 and A.2.2-2 in Appendix II).

Since 1974, both index of wholesale price and consumer price had gradually increased until 1979 showing annual increase of 6.8 to 6.9 percent, but they jumped up sharply by 20 percent in 1980, reflecting rapid increase of prices of petroleum product. (See Table A.2.2-5 and A.2.2-6 in Appendix II).

While total amount of exports is estimated at 130,446 million baht in 1980, with annual increase of 21.3 percent over the period from 1976 to 1980, that of imports is 188,722 million baht with annual increase of 26.8 percent. As a result, the balance of trade has deteriorated from 12,080 million baht of deficit in 1976 to 55,025 million baht of deficit in 1980. (See Table A.2.2-7 in Appendix II).

In the balance of payment of Thailand, deficit in balance of trade has been offset by surplus of services, unrequited transfers, capital movements and allocation of SDRs, but since 1970, the balance of payment showed its deficit except years of 1972, 1973 and 1974, amounting to 13,298 million baht in 1978 and 7,925 million baht in 1979. (See Table A.2.2-9 in Appendix II).

2.1.3. National Development Plan

Since 1962, the Government of Thailand has implemented a series of her national economic and social development plan, and the Fifth Five-year Economic and Social Development Plan is now under preparation for the coming FY1982 to 1986.

For the past 20 years from the First Five-year Plan to the Fourth one, Thailand had attained remarkably her economic development by changing structures in production, foreign trade and income distribution. As a whole, her economy had grew at 7 percent of annual growth over the past 20 years, through expansion and diversification of production as well as export of agricultural and industrial products. However, the high economic growth had caused rapid deterioration of such resources as forest, land, water and fishery, and the benefit of economic growth might not be well distributed regionally. Further, recent deterioration in international affairs such as the rapid increase of oil prices, crisis in international financing, etc., caused increase of deficit in trade balance as well as current account in Thailand.

Under such circumstances, the Fifth Five-year Economic and Social Development Plan is now under preparation, of which main objectives are;

- To decrease absolute poverty and to promote development for under-developing region;
- To stabilize economic and financial situation,
- To reorganize agricultural and industrial sectors,
- To adjust social structures, and
- To adjust economic development and security of the country.

In order to realize the said objective, the following targets are given in the Fifth Five-year Plan during the plan period from 1982 to 1986;

	Amount (1986)	Growth Rate (% per year)
Population	52.1 million	1.9
Labor Force	-	3.1
GDP at Current Prices	฿ 1,819.4 million	16.5
GDP at Constant Prices	฿ 452.7 million	6.9
GDP per Capita at Constant prices	฿ 8,691	4.9

Details of the target are compiled in Tables A.2.2-10 to A.2.2-15 in Appendix II.

2.2. Regional Economy

The proposed project area is located on Changwat Saraburi of the Central Region. Changwat Saraburi has total area of about 3,353 km^2. (2,096 thousand rai) and borders upon Lopburi at north, Nakhon Nayok and Pathum Thani at south, Nakhon Nayok and Nakhon Ratchasima at east, and Lopburi and Phra Nakhon Si Ayuthaya at west.

According to the census in May 1979, total population of Changwat Saraburi is 462,080, of which 232,587 is male and 229,493 is female. While population density for the whole Changwat Saraburi is estimated at 138 persons/km^2, densely populated areas are in the municipal and sanitary limits with average density of 1,000 to 2,000 persons/km^2, except some sanitary limits.

Changwat Saraburi is administratively divided into 11 Amphoe including one King-Amphoe, and subdivided into 105 Tambon and further 909 Muban as shown in Table 2-1.

In 1979, it is estimated that the agricultural sector produced about 8.5 percent of the gross provincial product, or 868.2 million baht at constant 1972 prices, of which about 87 percent or 753.9 million baht was contributed by the crops cultivation while the real growth rate of gross provincial products from 1975 to 1979 is 6.2 percent per annum, that of the agricultural sector is far below this level, about 1.9 percent per annum. Table 2-2 shows detail of the gross provincial product at constant 1972 prices.

2.3. Project History

As the area extending between the right bank of Pasak River and the left bank of Chainat-Pasak Canal is situated at higher than its water supply level available and always suffers from shortage of water even in wet season, the farmers in the said locality frequently request the government agencies concerned for an emergency aid. It is the duty of RID to help them by sending various size of pumps to 14 different sites and providing them with the free of charge for the operation and maintenance services. It was in 1975 that the Governor of Changwat Saraburi requested to RID to continue permanently such aid throughout the entire season.

In this connections, the Project Planning Division of RID proposed in 1976 that the discharge to be diverted from Chainat-Pasak Canal should be 8.6 c.m.s. at two proposed pumping stations. Firstly at Ban Tao Poon, the pump capacity may require 6.6 c.m.s. to irrigate 7,360 ha (46,000 rai) of the upper stream area of Pak Bang river, secondly at Ban Thawud where the flow of 2.0 c.m.s. is required to serve an area of 2,240 ha (14,000 rai) between lower part of Pak Bang river and the paddy field along the Pasak river.

The Design Division in RID stated that the water taken from the upstream storage of Rama VI Barrage may adversely effect the dry season use of water for irrigation in the lower Chao Phraya project and it is better to pump water directly from Pasak river where no

negative effects would be considered.

Prior to this in 1965, by the decision of the Pasak River Development Committee, RID ever planned a storage dam on Pasak river at Kaeng Khoi, but during the past 15 years, the local informations and conditions have been changed, it is now recommended to initiate the entire basin study. The national policy for the Pasak River basin development as set up in 1979 consisted of five different projects and the Kaeng Khoi Pumping Project is one of the selected plans.

Table 2-1 Regional Administration

Name of Amphoe	Area (km^2)	No. of Tambon	No. of Muban
1. Muang Saraburi	231	15	120
2. Kaeng Khoi	882	15	105
3. Sao Hai	111	12	101
4. Ban Mo	160	9	71
5. Phra Phutthabat	224	9	88
Sub-total	1,608	58	485
6. Nong Khae	264	18	178
7. Nong Saen	81	9	68
8. Withan Daeng	169	4	48
9. Muak Lek	1,038	6	70
10. Nong Khon	125	4	32
11. Don Phut (King-Amphoe)	68	4	28
TOTAL	3,555	103	909

Table 2-2 Gross Provincial Product (at constant 1972 prices)

(Unit : million baht)

Industrial Origin	1975	1976	1977	1978	1979
Agriculture	804.2	750.6	775.0	825.4	868.2
Crops	682.1	648.2	637.0	716.0	753.9
Livestock	115.9	98.8	134.6	86.5	91.9
Fisheries	4.4	2.9	3.0	22.9	22.4
Forestry	1.8	0.7	0.4	-	-
Mining and quarrying	104.3	125.8	161.7	208.7	256.6
Manufacturing	1,240.1	1,336.4	1,464.7	1,598.3	1,695.2
Construction	54.6	85.0	122.8	85.9	122.1
Electricity and water supply	55.8	71.7	78.7	92.6	103.8
Transportation and communication	200.5	198.1	201.3	259.0	302.6
Wholesale and retail trade	838.4	830.8	882.5	900.6	933.4
Banking, insurance and real estate	52.3	59.0	70.3	84.7	93.9
Ownership of Dwellings	26.3	26.4	26.4	27.9	29.5
Public administration and defence	82.2	97.5	100.3	107.5	111.4
Services	125.6	140.0	178.0	187.7	223.0
GROSS PROVINCIAL PRODUCT, (GPP)	3,584.3	3,721.3	4,061.7	4,378.3	4,739.7
PER CAPITA GPP (BAHT)	8,046.0	8,363.0	8,979.0	9,559.0	10,248.0

III. GENERAL DESCRIPTION OF THE PROJECT AREA

III. GENERAL DESCRIPTION OF THE PROJECT AREA

3.1. Natural Conditions and General Features

3.1.1. Location and Topography

A. Location

The Project Area is located in the lower basin of the Pasak river, one of the major tributaries of the Greater Chao Phraya river, and is about 110 km north of Metropolitan Bangkok. Administratively the Project Area belongs to Changwat Saraburi.

The Project Area is bounded by the considerably meandering river of Pasak on the east and the south, and by Chainat-Pasak canal constructed by RID on the west. The northern Project boundary is the contour line of about 20 m in elevation.

The Project Area, as a whole, is a narrow and long land ranging from 10 m to 20 m in elevation which extends from east to west with width of two to seven kilometers covering about 16,400 ha (102,500 rai) in total.

Kaeng Khoi town is located adjacent to the southeastern portion of the Project Area where the Pasak river changes its direction from south to west. Saraburi city, Provincial Capital, and Amphoe Ban Mo also lie adjacent to the southern most of the central Project Area and its western edge, respectively.

B. Topography

In spite of a narrow and long area as mentioned above, the Project Area is, as a whole, a flat and low.

An alluvial plain below 10 m in elevation extends along Chainat-Pasak canal whereas a flat land is predominant in the area ranging from 10 to 15 m in elevation that has developed on the river terraces formed by the Pasak river. The boundary between the alluvial plain and the river terraces gradually fades out, and is not clearly observed.

The area of 15 to 20 m in elevation represents the edge of the fan created by eroded loads originating from the northern mountains, and has a gentle slope of only 1/100 to 1/200. This fan is a confluence fan composed of a number of small fans.

In and out of the western part of the Project Area are two plateaus having extremely complicated contour lines where no river terraces have developed. Complicated contour lines coincide with the distribution of marl as resulted from dissolved erosion of lime content. On these plateaus the river system is very poor.

Independent peaks of monadnock are locally seen here and there in the flat Project Area and in its surrounding areas, and the difference in elevation stands about 40 m at maximum, however, such high areas are negligibly small in acreage.

3.1.2. Meteorology and Hydrology

A. Meteorology

The Project Area has the savanna climate characterized by two separated seasons a year, that is, wet season and dry seasons, under the influence of Southeast Asian monsoon.

Wet seasons last from May to October whereas dry seasons from

November to April. November and April are apparently the transition months between the two seasons as suggested by a sharp yearly fluctuatin of monthly rainfalls.

Meteorological observation has been made at Lopburi station that is located about 70 km northwest of the Project Area. The meteorological features here can be briefed as follows. Table 3-1 shows the averaged climatological summary.

- Temperature: The mean annual temperature at Lopburi is 28.3° C with the mean maximum of 37.0°C in April and the mean minimum of 19.0°C in January.

- Humidity: The annual mean humidity is 70% with the highest of 94.4% in September and the lowest of 40.3% in January.

- Wind: From February to September winds blow from south to north with the averaged velocity of 5.7 knots whereas from October to January winds come from northeast and go to southwest with the averaged velocity of 5.6 knots.

- Evaporation: The observation record by Piche evaporation meter shows that the annual mean evaporation is 1,379.2 mm with the monthly maximum of 160.5 mm in January and the minimum of 60.4 mm in September.

B. Hydrology

B.1. Rainfall

Rainfalls in and around the Project Area have been observed at four stations of Muang Saraburi, Kaeng Khoi, Sao Hai and Rama VI barrage (Luang headworks). The location of the said four stations is illustrated in Figure 3-1. The averaged annual mean rainfall recorded at these four stations is 1,400 mm/year of which 1,241 mm (89 %) concentrate in wet seasons from May to October whereas only 159 mm (11 %) of the rainfall appear in dry seasons from November to April. The mean maximum monthly rainfall amounting to 305 mm occurs in September.

Rainfalls in the Project Area are of a shower type falling within a considerably small area, however, the monthly rainfalls observed at the said four stations show a correlation of more than 80 %.

The distribution of rainy days has a similar tendency to that of the mean monthly rainfalls at Saraburi station; it is most rainy from July to October - 16.4 rainy days in a month - whereas January has the fewest rainy days - only one day in the month. Table 3-2 shows the monthly rainfall data observed at Saraburi station.

B.2. River Discharge

The Pasak river discharge, one of the major water sources for the Project, has been observed at RID's gauging station No. S.2 from 1948 to 1976, and was observed at the gauging station No. S.9 since 1977.

The observation data indicate that the maximum runoff discharge usually appears September and October. The Pasak river has a narrow and long drainage area of about 14,500 sq.km at Kaeng Khoi gauging

station(S.2). The observation data at this station show that a discharge of 1,894 MCM (83%) out of the averaged annual runoff of 2,288 MCM appears within the four-month period from August to November whereas the averaged runoff discharge is only about 177 MCM (8%) in dry seasons from January to May, resulting in difficulties in irrigation water supply from this river.

The annual runoff discharge at the said station has a sharp fluctuation ranging from 607 MCM to 5,276 MCM. This big fluctuation could be attributed to the peculiar shape of the river basin causing an uneven rainfall distribution as well as a limited amount of so-called basin storage capacity of rainy water. Table 3-3 shows the monthly runoff discharges recorded at the gauging station S.2.

Another water source for the Project Area is Chainat-Pasak canal that runs along the western boundary of the Project Area. Through this canal the Chao Phraya water is diverted to service areas of 128,000 ha (800,000 rai) on the right bank of the canal. The terminal point of this canal is located about one kilometer upstream of Rama VI barrage where the canal empties itself into the Pasak river.

A surplus water of the canal is released to the Pasak river, and is diverted, together with the Pasak river discharge, to Raphiphat canal at the Phra Narai regulator in order to irrigate about 110,000 ha (687,500 rai) of farm lands. The surplus discharge of the Chainat-Pasak canal released to the Pasak river might be an important factor to determine an available quantity of water resource for the Project.

There are no clear patterns in water distribution from the said canal to service areas as shown by the actually measured record of discharges at the diversion point. Hence, it might be necessary to determine the water quantity available as well as the scale of development in the Project taking into consideration carefully the

surplus water in the canal.

Table 3-4 shows intake discharge records at Manorom regulator.

3.1.3. Geology and Soils

A. Geology

The Project Area is geologically underlain by hard bed rocks such as Permian Ratburi Group (mainly limestone) and Pre-Triassic Khao Yai Volcanics (mainly rhyolite), which are covered by such Quarternary pleistocene-holocene overburdens (mainly gravel and clay with weakly consolidated or loose formation) as marl, terrace deposits, fan deposits and alluvium.

However, bed rocks can be seen as monadnock only in some places, and most of the Project Area is covered by the said overburdens.

The general features of each rock unit found in the Project Area can be briefly described, referring mainly to the logs of wells (Drilled Logs of Wells", Vol. VII - xxii 1972 - 1981, Department of Mineral Resources (see Appendix III.3.2.)) since rock outcrops are poorly appear in the Project Area.

- Ratburi Group (Permian):- In the up north area being away from the Project Area, there are mountains as composed of this group, however, within the Project Area there is found none of this group except some independent peaks existing as monadnock. Limestone is the major component of the group although shale and quartzite are minorly inter-bedded in some places. Limestone is mined for manufacturing cement, and the parts already recrystallized are mined as marble.

- Khao Yai Volcanics (Pre-Triassic):- In the down south

area away from the Project Area, there exist mountains as consisting of this volcanics, however, in the Project Area there is none of volcanics outcropped except some independent peaks as monadnock. Only rhyolite has been confirmed as outcrop in the Area. As per the logs of wells, the volcanics might exist under the terrace deposits located at the eastern part of the Project Area. In some areas andesite can be found instead of rhyolite.

° Marl (Quarternary Pleistocene): Marl is extensively distributed mainly in two (2) plateaus in the western part in and around the Project Area which has topographically ups and downs showing rather complicated contour lines. These plateaus are formed by the secondary deposits of weathered limestone having no impurities. In the other words, the marl is composed of gravels of limestone (sub-angular - sub-rounded gravel) and limy clay as weakly consolidated in white color. This marl is mined for the use of kaoline material. In the area where this marl is distributed and the topography is rather complicated, limestone have been dissolved by rainfall erosion as same with the cases of Doline and Sinkhole.

° Terrace Deposits (Quarternary Pleistocene): Terrace deposits are found on the river terrace as formed by the Pasak River and this represents the most of the geology in the Project Area with the elevation of 10 - 15 m. The terrace deposits are loose including sub-angular - sub-rounded gravel (ϕ 2 - 8 mm), sand and sandy-silty clay. This layer has an averaged depth of about 10 m, and is considered to be 50 m depth at the deepest section.

- Fan Deposits (Quarternary Holocene): Fan deposits are distributed on the gently sloped mountain foot with the elevation of 15 - 20 m. Streams flowing down from the northern mountains carry those eroded loads as sub-angular - sub-rounded gravel (ϕ 1 - 8 mm), sand and sand-silty clay. The texture is loose with the depth of layer ranging from 5 m to 20 m.

- Alluvium (Quarternary Holocene): In the vicinity of the western boundary of the Project Area, alluvium is distributed on the area along the Chainat-Pasak canal with the elevation lower than El. 10 m. The texture is loose as composed of sub-angular - sub-rounded gravel (ϕ 1 - 5 mm) and sandy-silty clay. This layer is estimated to be ranging from 60 m to 130 m, in depth. As the boundary in between the alluvium and terrace deposits is faded out and not clearly observed, 10 m contour line has been employed as the boundary.

Generalized geologic table of the Project Area is as shown in Table 3-5. The geological map of the Area is shown in Fig. 3-2.

B. Soils

(1) Landform and Parent Materials in the Project Area

Generally, most parts of the Project Area are relatively flat, even surface with somewhat simple landform that is divided into three main physiographic units, namely, natural levee, semi-recent terrace and low terrace including very small extent of dissected erosion surface and of brackish environment deposits. The last two are sporadically confined to only four locations. Most parent materials are riverine alluviums which are subdivided into recent, semi-recent and old deposits based on deposition period and degree of weathering.

The remainders of very small extent are alluvial deposits, in brackish environment and colluvial-residual materials.

The correlation of landforms and type of parent materials in the Project is as below:

Natural levees:- Natural levees are slightly elevated and elongated, and occupy a small extent along the Pasak river course. Their parent materials are recently deposited;

Semi-recent terraces:- These physiographic units occupy lower-lying areas which are adjacent to the natural levees or the Pasak river including the upper western portion of the Project Area. They are regarded as the lowest belt which derived from semi-recent alluvium, and many parts are predominantly of the montmorillonitic clay type;

Low terraces:- Low terraces occupy the upper central portion of the Project Area which is slightly higher than other parts. The topography slopes southwardly to the Pasak river. The parent materials are of old riverine alluvium, which is somewhat highly weathered and whitish clay beds are exposed to the ground surface in many parts of the terraces;

Dissected erosion surface:- This unit occupies a very small extent only at the place adjacent to the northern boundary of the Project. The parent materials are composed of colluvial and residual deposits.

Brackish environment deposition:- Actually, no sizable former tidal falt is found within the Project Area, however, small extents of brackish environment deposition are confined in spots in the semi-recent terrace landform.

(2) Soil Classification

Soils in the Project Area are mainly composed of clayey materials and they have a large water holding capacity. However, the internal drainage is generally very poor.

The topograph in which soils are situated is flat, and the surface drainage is generally so poor that the soils occasionally suffer from deep standing water caused by impounded rainy water during the rainy season.

The data of the physical and chemical analysis (refer to Appendix III) shows that soil pH is high (over 6.5) in soils which received infurence from limestones and marls, and is slightly acid (5.0 to 6.5) in the area of semi-recent and recent alluvial deposits. In the area of semi-recent alluvial terraces, settling volume of subsoils is very high, and this fact shows up the high content of colloidal clay. The area would not support upland crops in rainy and dry seasons.

As to wet season crops, upland crops can be grown only in some limited areas because of a too long period of water saturation in soils. Rice plant culture is preferable in the most Project Area, however, HYV rice plants are suitable to cultivate only in about 45 percent of the Project Area at present status. When sufficient drainage facilities are installed, the area of HYV will be extended.

In the dry season all area can be planted with HYV rice plants for full yield except some area of poor fertility soils. Most of the area is suitable for upland crops in the dry season, except some areas of very hard soils when dried.

Soils in the Project Area are classified as follows, and shown in Figure 3-3, the Soil Map.

a) Natural Levee:-

Tha Muang Series (Tm), Chiangmai Series (Cm) (Alluvial Soils): It covers only a very small area.

Undifferentiated Alluvium (AU): This soil occupies the narrow belt along the Pasak river, forming low levees and lower river bed.

b) Semi-recent Terraces:-

Soils on the semi-recent terrace are derived from semi-recent alluvium, and they are much more profile developed than the soils confining to the natural levee. Textural profiles are generally also finer, and nine different soil series are encountered and mapped.

Nakhon Pathom Series (Np) (Hydromorphic Non-Calcic Brown Soils):-

They are deep, and somewhat poorly drained, comprising of clay loam in the upper horizon and clayey, underneath. Soil reaction is slightly acid to medium in the upper portion and neutral to moderately alkaline downward. It is commonly flooded by impounded rainy water for three to four months in rainy seasons.

Ban Mi Series (Bm) (Grumsols):-

The dark grayish clay texture is semi-recent alluvial deposits drived from Marl or limestone. Soil reaction is slightly acid at the surface and alkaline at deeper subsoil. The soil is poorly drained, and contains high content of organic matter that may cause root injury and lower the wet season rice yield. It is subjected to shallow floodings caused by impounded rain water for several months.

Ban Mi concretion variant (Bm-con) (Grumsols):-

Soil characteristics are similar to Bm except the existence of concretion layer in the deeper part of the solum. Generally, it occupies higher elevation than Ban Mi Series.

Chong Kae Series (Ck) (Grumsols):-

Textural profiles of the series are clayey and very hard when dry, and have poor drainage. Soil reaction is strong to medium acid. Shallow flood caused by impounded rain water for four to five months in rainy seasons is common.

Tha Rua Series (Tr) (Grumsols):-

Tha Rua soils have a clayey texture and are very hard when dry. Soil reaction is medium to slightly acid. In wet seasons it is subjected to deep floodings caused by impouned rain water.

Wathana Series (Wa) (Grumsols):-

Wathana soils have also a clayey texture, and are very hard when it is dried. Soil reaction is neutral to midly alkaline. Shallow flood by impound rain water is experienced for three to four months in rainy seasons.

Lopburi Series (Lb) (Grumsols):-

Lopburi soils are black clayey ones of montmorillonitic type which derived from Marl. Soil reaction is neutral to moderately alkaline. They occupy slight higher lying landscape and drainage is moderately well. This soil series is well suited to upland crops such as maize.

Saraburi Series (Sb) (Hydromorphic Alluvial Soils):-

Saraburi soils are of a deep, clayey texture, and are medium acid to mildly alkaline. They are confined to lowlying physiographic position that is subject to very deep flood by impounded rain water and by river overflow during wet seasons.

Manorom Series (Mn) (Low Humic Gley Soils):-

They are of a deep, clayey texture of Kaolinitic type and, are very strongly acid to strong acid. Natural drainage is poor and subjected to deep flood caused by impounded rain water.

c) Low Terraces

Soils of low terrace are generally old alluvium, and relatively highly leached. They have relatively low fertility. Soil profiles are much more developed. They are classified into two different soil series and one association of soil series.

Nakhon Phanom Series (Nn) (Low Humic Gley Soils):-

Textural profiles are silt loam to silty clay loam over silty clay loam to silty clay or clay. Soil reaction is medium to strongly acid over strongly to very strongly acid. Natural drainage is poor and subjected to deep floodings by impounded rain water and river overflow for three to five months.

Khao Yoi Series (Kyo) (Low Humic Gley Soils) / Hin Kong Series (HK)
(Low Humic Gley Soils) Association (Kyo/Hk):-

Khao Yoi soils are loam or sandy loam over sandy or silty clay loam or clay loam while Hin Kong series are silt loam over silty loam or silty clay. Both are deep, strongly to medium acid soils. They are

somewhat poorly drained and subjected to shallow floodings by impounded rain water for four months in wet seasons.

Deum Bang Series (Db) (Low Humic Gley Soils):-

Deum Bang soils are silty clay to clayey texture in whitish colour. They are deep, and are strongly to medium acid over neutral to middly alkaline. Organic content is low. Natural drainage is somewhat poorly drained and is flooded at a shallow depth in wet seasons. Rice yield is low due to injury of rice roots by low content of free iron under reduced conditions.

d) Dissected Erosion Surface and Hills

Takhli Series (Tk) (Rendzinas):

Takhli soils are formed on local colluvium and residium from limestone or marls. They occupy higher physiographic position and cover very small extent in the Project Area. Textural profiles are clay loam over clay. Soil reaction is alkaline in the surface, and moderately alkaline in the subsoil.

e) Brackish Environment Deposition

Ong Kharak Series (Ok) (Hydromorphic Alluvial Soils):

Ong Kharak soils cover a very small extent on the lowlying landscape of the Projct Area. They are all of clayey texture and poorly drained. The soils are characterized by yellow jarosite mottles which occur within 40 centimeter depth. Soil reaction is extremely acid so that soil amendment will be required for improvement. They are deeply flooded by impounded rain water and river overflow.

(3) Land Classification

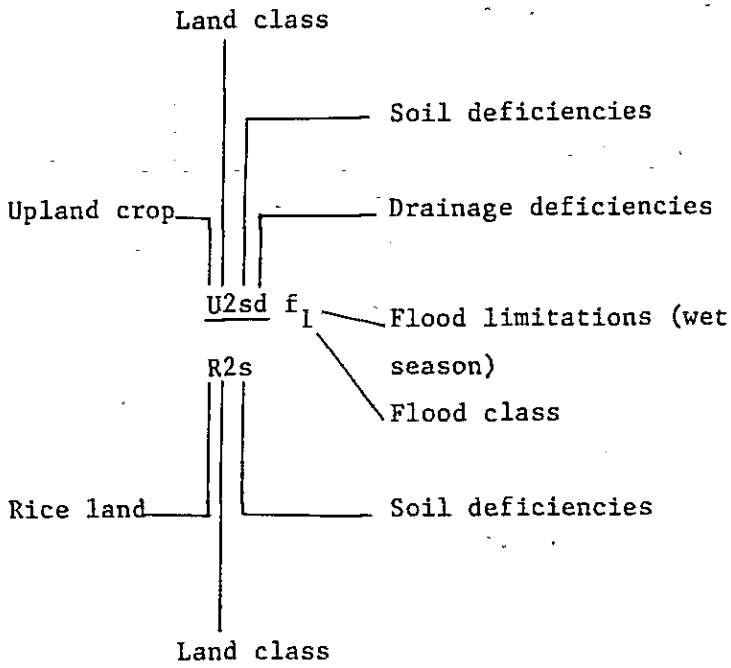
Land classification is a process of classifying lands according to their suitabilities for crop cultivation under sustained irrigation. Concept of classification is based on three main characteristics that effect the suitability of lands for irrigation.

- Soil characteristics which consist of soil texture, depth of soil, pH water holding capacity and others.

- Topographic characteristics relating to relief, slope, leveling requirement, gravel or rock removal.

- Drainage characteristics which constitute surface runoff, permeability, length; depth and frequency of flooding caused by impounded rainfall water or river overflow.

These characteristics are set into different class limits as per the specification criteria for classification (see Appendix III). Because the environment for growing rice is generally unfavorable for upland type crop which requires soil aeration. Two classification systems; one for rice and one for upland crops are developed for classifying lands for irrigation. To facilitate the mapping, various symbols are established, namely "U" for upland crops, "R" for rice, "s" for soil deficiencies, "t" for topographic deficiencies and "d" for drainage and "f" for flood limitations which pattern of symbolization is as follows:



As results of the classification, the different land classes and their extent in hectares within the Project Area are shown in Figure 3-4, Land Classification Map, and are summarized as follows:

a) Lands of better suitability for upland crops and marginal suitability for paddy. These lands are classified as U2t/R3st, U1/R3s, U2s/R3s and U2st/R3st with total extent of 379 hectares or 2.3%. They occupy relatively higher physiographic position and are naturally well drained. Textural profiles are commonly moderately coarse to moderate throughout or permeable clay appearing at depth. Due to high physiographic position and too coarse textured soil for paddy, they are better adapted to upland crops in both wet and dry seasons.

b) Lands of better suitability for upland crop and moderate suitability for rice. Lands of this type are classified as U1/R2s which covers area of 1,200 hectares or accounts 7.3%. Physiographic position is slightly lower than the land class group that previously mentioned and topography is generally favorable. Textural profiles

are commonly moderately fine (clay loam), no clayey horizon is encountered within 150 centimeter depth and moderately well drained. Due to moderately fine texture and high water table during wet seasons, these lands are deemed moderately suitable for paddy in wet seasons, however, are well adapted to upland crops in dry seasons if irrigation is provided.

c) Lands of moderate suitability for both upland crops and paddy. Lands of this unit are classified as U2s/R2s which accounts 2,042 hectares in extent or equivalent to 12.5%. Generally, topography of the lands is favorable and natural drainage is somewhat imperfect. Textural profiles commonly comprise of medium texture to moderately fine in the upper portion and clayey in the lower portion. Due to such textural profiles and relatively low fertility, they are graded as moderately suitable to both upland crops and paddy. These lands should be planted to upland crops in dry seasons and paddy in wet seasons.

d) Lands of best suitability for paddy and moderately suitability for upland crops. Lands of this unit are classified as U2s/R1 which covers the total extent of 6,101 hectares or 37.2%. Topography is generally flat which is suitable for paddy. Textural profiles comprise of less than 30 centimeter of moderately fine texture in the upper portion and permeable clay downward or permeable clay throughout. Drainage is somewhat poor to poor and their physiographic condition are relatively low that may be subjected to occasional flood in wet seasons. These lands are well adapted to paddy specifically during wet seaons, only some shallow rooted upland crops are recommended in dry seasons.

e) Lands of the best suitability for rice and marginal suitability for upland crops. Lands of this unit comprise of U3sd/R1 and U3std/R2 (locally unfavorable topography) which accounts 6,668 hectares in extent or 40.7%. These lands are generally confined to depressional areas or occupying the lowest physiographic position.

Textural profiles are very fine texture throughout or encountering at shallow depth. They are naturally poorly drained and subjected to annual flooding. The lands are best suited for paddy if flooding is prevented and sufficient drainage is provided. They are almost unsuitable for upland crops due to severe limitation of soil and drainage, however, very few annual cash crops may be grown.

f) The most important improvement to increase crop yield is the irrigation even in the rainy season, because the drought is the main limitation for the crop production every year.

g) The second limitation for the crop yield is the frequent flood caused by impounded rain water in the rainy seasons. In the area of said flood of under 25 cm (45%), high yielding rice varieties can perform their full yield. In the area of flood of 25 - 50 cm (f_1) (32%), local tall varieties can perform their full yield. In the area of flood of over 50 cm (f_2) (23%), even local varieties can have some limited yield.

The floods, caused by over flow or back flow of the river, are limited in small portion of the Project Area in the usual years, except the very rare case of big flood such as 1978 flood which deeply flooded most part of flat areas and rice plants were completely destroyed.

3.1.4. Transportation

Saraburi town, Capital City of Changwat Saraburi, is located only about 110 km distant from Metropolitan Bangkok. These two cities are connected each other by National Road No.1 and by a State Railway.

National Road No.1 runs towards the south-north through the middle portion of the Project Area. National Road No.2, which connects Bangkok and north-eastern regions of Thailand, diverges from

National Road No.1 at Saraburi town.

As regards the State Railway, there are Kaeng Khoi, Saraburi and Ban Mo railway stations. All of these stations are located outside the Project Area facing the Pasak river, however, near from the eastern, central and western portions of the Project Area, and the transportation by railway is convenient for people in the Project Area although the car transportation is predominant because of the short distance to Bangkok.

The Project Area itself is satisfactorily provided with road networks, and transportation within the Project Area is mostly made by car except the minor cases by ox-cart and farm tractor.

3.1.5. Population

There are no statistic data which directly indicate the population and number of households in the Project Area (16,390 ha). The Project Area consists of 18 Tambons (villages) which belong to five Amphoes (districts), namely, Amphoe Muang Saraburi, Sao Hai, Kaeng Khoi, Ban Mo and Phra Phutthabat.

Based on the demographic data related to the 18 Tambons that are collected from the respective Amphoe Agricultural Extension Offices concerned, the demography of the Project Area as of 1980 has been estimated as follows;

Population and Households

Item	18 Tambons		Project Area	
	Total	Agriculture	Total	Agriculture
Population				
Male	21,493	n.a.	13,218	n.a.
Female	22,067	n.a.	13,571	n.a.
Total	43,560	30,950	26,789	19,032
No. of Households	8,432	5,952	5,186	3,660
Averaged Family Size	5.17	5.20	5.17	5.20

3.2. Irrigation and Drainage Facilities

3.2.1. Irrigation Systems inclusive of Existing Pumping Stations

Most existing paddy fields in the Project Area (14,160 ha or 88,500 rai) are rainfed, and depend upon rainy water in wet seasons.

Near the Project Area, there is Sao Hai pumping irrigation project having a service area of 5,760 ha (36,000 rai) on the left bank of the Pasak river. The pumping station for this project was completed in 1978, and started irrigation water supply to the service area immediately after the systematic canal networks were constructed. Khlong Phrieo O & M Office, RID is responsible for O & M of the facilities.

Aparting from the above-mentioned project facilities, Chainat-Pasak canal runs in the west of the Project Area, and diverts the Chao Phraya water to a service area of about 128,000 ha (800,000 rai) in total inclusive of such sub-project areas as Manorom, Chong

Kae, Koke Kathiam and Roeng Rang that are located on the right bank of the Pasak river.

Another irrigation project area is located adjacent to the south-western corner of the Project Area. For this project area Rama VI barrage and Raphiphat main canal were constructed about 60 years ago to supply irrigation water to sub-irrigation areas of Nakorm Luang, South Pasak and North Rangsit covering the total area of about 110,000 ha (687,500 rai). The location map of the project and existing irrigation projects related are illustrated in Figure 3-5. As stated in the foregoing paragraph, irrigation facilities in neighboring areas of the Project Area are adequately provided, and are functioning well.

However, cultivated lands in the Project Area have an elevation more than 10 m whereas the available water head is low (the averaged low water level at Kaeng Khoi gauging station is about 7.5 m in elevation) which has made the gravity irrigation impossible. Under the situations, the cultivated lands in the Project Area have remained untouched so far as irrigation development is concerned.

Several small streams originating from the northern mountains flow through the Project Area. They join the Pak Bang river (of which upstream reaches are called "the Hae river") and the Nong Luang (of which upstream reaches are called "the San Chao river"). These small streams flow down through the central lowlying part of the Project Area. The Nong Luang river and the Pak Bang river empty themselves into the Pasak river.

Each of the small streams has a drainage area of 10 to 50 sq.km. However, most of their surface water in the upper reaches is utilized to irrigate paddy fields and upland fields along them, resulting in very limited water quantity available for the Project. Under the circumstances, no irrigation facilities are provided in the Project

Area at present.

The Hae river is the existing main drainage channel for the central lowlying area in the Project Area. This channel called the Pak Bang river at the downstream reaches has a drainage area of about 180 sq.km at the confluence of this river and the Pasak river.

Along this drainage channel of about 18 km long there are 12 check structures on its uppest reaches of six kilometers and two on the reaches between the crossing with National Road No. 1 and the downstream reaches constructed by farmers' cooperatives. These check structures are connected to earth canals of about 100 m long to supplement irrigation water to service areas. The service area of one check is about 50 ha in scale. Operation and maintenance of the facilities are made by benefited farmers.

Paddy fields along the Pasak river in the southern part of the Project Area are higher than the central lowlying area whereas available water is low since runoff discharges from the northern mountain areas are intercepted by the Pak Bang river and the Nong Luang river.

As described in the foregoing paragraphs, this part of the area is least favorable with irrigation water source among the others, and as many as 27 temporary pumps were installed by RID in the drought year 1978 to avail water of the Pasak river.

Under the circumstances, pumping irrigation projects have been implemented by agricultural cooperatives in the area, and seven pumping stations and related irrigation canal networks have been constructed up to date in order to supply irrigation water to about 3,400 ha (21,250 rai) of farm lands in total.

Table A.3.3-1 of Appendix III shows the main features of the said projects. Each of these stations can serve about 500 ha (3,125

rai) of farm lands on an average, and the main canals are either concrete lined or of cobble concrete. Laterals are provided with no lining, and direct diversion from laterals to fields is practised. Operation and maintenance of these facilities are carried out by agricultural cooperatives, and farmers share a cost of about Baht 100/rai/year for those O & M.

For the area located on the right bank of the Pasak river that is nearby the eastern boundary of the Project Area, the following pumping projects have been planned by NEA, and scheduled to be implemented by April 1982.

NEA Pumping Projects

Location	Irrigable Area
Ban Tao Pun	672 ha(4,200 rai)
Ban Song Khon	560 ha(3,500 rai)
Ban Ta Toom	1,280 ha(8,000 rai)
Total	2,512 ha(15,700 rai)

After construction of the facilities, operation and maintenance of them have been planned to be carried out by NEA. Table A.3.3-2 of Appendix III shows the main features of these projects. The location of the on-going NEA Project is illustrated in Figure 3-6.

Therefore, the provision of irrigation facilities which will afford to supply irrigation water regularly to a large acreage is most desired for this area.

3.2.2. Drainage System

The Pasak river has a drainage area of 14,522 sq.km at S.2 gauging station near Kaeng Khoi town. The recent maximum discharge of about 2,000 cu.m/sec occurred in 1978 with the highest water levels

of 21.1 m (MSL) at S.2 gauging station and of 11.9 m (MSL) at Rama VI barrage. In an average, however, the high water levels were 13.3 m (MSL) and 8.00 m (MSL) at the above-mentioned two observation points, and there still remains a sufficient head as compared with the averaged elevation of farm lands (EL.15 m) except some lowlying areas within the Project Area.

Rama VI barrage controls both the Pasak water and the discharge from Chainat-Pasak canal to irrigate the service areas of Raphiphat canal. Back water mainly due to the usual closure of sluice gates (7.90 m crest elevation) of Rama VI barrage has caused flood damages to a considerable extent on the lowlying areas along the Nong Luang river in the south-western part and also in areas on the lower stream of the Pak Bang river of the Project Area.

Figure 3-7 shows the location and scale of areas suffering flood damages.

The Pak Bang river and the Nong Luang river have drainage areas of 190 sq.km and 80 sq.km, respectively. Since 70 to 80 % of these drainage areas is considered to be paddy fields, the drainage areas have a considerable large storage in the fields during rainy periods. Runoff discharge appears in rather small amount, accordingly, and the flow capacity of these rivers might be sufficient, with some exceptions, to cope with a probable flood of a five-year return period.

Small streams flowing into the Pak Bang river and the Nong Luang river are stabilized at the northern part that is higher than 15 m in elevation. Their flow areas are sufficient in spite of their shallow water depth since these streams flow down through the alluvial fan having a comparatively steep slope. In the downstream area, however, the slope is gentle, and the streams are not stabilized, therefore, partial improvement of them will be required.

Areas along the San Chao river and the Nong Luang river at the western part of the Project Area also suffer from ill-drainage.

From the foregoing, it can be said that substantial drainage improvement have not yet been undertaken in the area up to date.

3.2.3. Road Networks

Road networks in the Project Area are comparatively favorable. For the north-south direction, National Road No.1 runs through the center of the Project Area, National Road No. 3022 extends along the western side of the Project Area, and provincial roads run in between. All of these roads have a double track or more, and are paved with asphalt or with concrete.

For the east-west direction, National Road No. 3048 goes across the above-mentioned north-south roads. Furthermore, some provincial roads with gravel pavement extend along the right bank of the Pasak river and also along the left bank of Chainat-Pasak canal. Both of them have a double track or more, and utilized as main roads in the Project Area.

Aparting from the above-mentioned roads, a considerable number of local roads connect villages and the said main roads in the Project Area. The majority of them is for car transportation although they are paved only by gravel and their maintenance is not so good. Some are not wide enough for car transportation.

It can be, as a rule, said that the present road networks in the Project Area are rather good in comparison with these in the other areas, and that the traffic condition could be further improved if a west-east main road is constructed in order to connect the northern part of the Project Area.

3.2.4. On-farm Facilities

A. Irrigation Facilities

In rainfed areas prevailing in the Project Area, irrigation facilities hardly exist, with some exceptions, whereas in irrigated area, that is, pumping irrigation areas, irrigation water is directly distributed from main canals, and so-called "plot-to-plot irrigation" is practised. This type of irrigation in on-farm level is observed in agri-cooperatives pumping project areas.

B. Drainage Facilities

The Project Area is hardly equipped with drainage facilities except the farm plots located along national roads where borrow pits for the road construction function as drains in on-farm level.

C. Farm Roads

Farm roads of the on-farm level are very poor in the Project Area excepting such local roads connecting villages which are available for car transportation. Farmers use the local roads for transportation of agricultural inputs and outputs to and from their farm lands. To access to farm plots, however, farmers have to pass a number of many farm plots owned by other farmers in many cases.

D. Size and Shape of Farm Plots

The size and shape of farm plots are rather uniform because of the flat topography in the Project Area. The size is about 0.15 ha and the shape is square.

3.3. Present Agriculture

3.3.1. Present Land Use

The proposed gross Project Area of 16,390 ha (102,400 rai) has been determined based on the case study made for the optimum size of development and irrigation system as described in later paragraph. The gross Project Area includes 14,600 ha (91,300 rai, 89 %) of cultivated lands, that is, 14,110 ha (88,200 rai) of paddy fields and 490 ha (3,100 rai) of upland fields.

As regards paddy fields, most farmers raise paddy only in wet seasons. In Amphoe Sao Hai where pumping facilities have been installed by the related agricultural cooperatives, double cropping of paddy has been practised. About 700 ha (4,400 rai) of paddy fields are cultivated with dry season paddy on an average, and the yield was higher than that of the other areas even in the serious drought year of 1979. The major varieties being planted are RD 7 and RD 9 in the above-mentioned irrigated area with pumping facilities whereas local varieties prevail in most rainfed paddy fields.

Broadcasting is practised in rather higher portion of about 940 ha (5,900 rai) mostly located between upland fields and lowlying paddy fields. Such paddy fields exist in the north-western portion of the Project Area.

Most upland fields are cultivated with upland crops such as maize, groundnuts, mungbean and soybean in wet seasons because of the constraints of complicated topography and difficulty in water supply.

The present land use by land categories is shown below;

Land Category	Acreage	Propotion
Paddy fields	14,110 ha (88,200 rai)	86%
Upland fields	490 " (3,100 ")	3%
Sub-taotal	14,600 ha (91,300 ")	89%
Residential area	660 ha (4,100 rai)	4%
Rivers, roads and others	1,130 " (7,100 ")	7%
Sub-total	1,790 ha (11,200 ")	11%
Total	16,390 ha(102,500 rai)	100%

The actual cropping area out of the cultivated lands within the Project Area consists of 13,610 ha (85,100 rai, 93.2%) of paddy and upland fields in wet seasons and 680 ha (4,250 rai, 4.7%) of paddy fields in dry seasons. The land use ratio throughout the year remains only 98% due to the poor irrigation facilities and unstabilized water supply for dry season crops. Present land use map is illustrated in Figure 3-8.

3.3.2. Farming Practices

Wet season paddy is the main crop in the Project Area. The present farm practices in the Project Area are outlined below;

- Nursery: Land preparation for nursery is made at the beginning of June after rains soften the soil texture. The growing period of seedlings of local varieties in the nursery is 30 to 35 days and that of HYV is 20 to 25 days. A nursery bed equivalent to 10% of the total paddy fields in acreage is prepared for local varieties whereas a nursery bed equal to about seven per cent of the paddy fields is for HYV. Seed 70 kg/ha

(11.2 kg/rai) of raised in the nursery bed for cultivation of local varieties whereas 60 kg/ha (9.6 kg/rai) for cultivation of HYV.

° Paddy field plowing: Plowing is usually made by two-wheel tractor of about 10 Hp about one month before transplanting. It is rather minor to use draft buffaloes in plowing. Harrowing is made about two weeks after plowing and basal fertilizer application follows under inundated conditions.

° Transplanting: Transplanting of local varieties is made in July and that of HYV is made from July to August, and is completed around August 20. The planting density of local varieties is 13 plant/sq.m (35 x 25 cm) whereas that of HYV is 16 plant/sq.m. (25 x 25 cm). In some areas tractor engines are operated to pump up stored water in depressions to irrigate paddy fields.

° Fertilizing/ controlling: About 147 kg/ha (23.5 kg/rai) of fertilizers are applied controlling: to local varieties whereas 180 kg/ha (28.8 kg/rai) to HYV. However, most of them are of basal fertilizers, and their use for top-dressing is scarce. Input of agricultural chemical for control is limitedly made; 0.06 kg/ha for local varieties and 2.56 kg/ha for HYV, respectively.

° Weeding: Weeding is made by man-power. Most farmers

use no herbicides since the cost is high and farmers are not so acquaintant with the application of herbicides. The labor requirement for weeding is estimated at 3.6 man-day/ha.

- harvesting: The growing period of local varieties from seedling to harvesting is 150 to 160 days whereas that of HYV is 120 to 130 days. In harvesting farmers cut paddy body around 50 cm from its top. After cutting, paddy is dried in the fields for four to five days, and then hauled to other places for threshing. Since no threshing machines are available, this works is made by man-power or animal-power.

Farm practices for dry season paddy are quite similar to those for wet season paddy. Land preparation ordinarily starts in January, transplanting follows in February, and harvesting in May.

Plowing for cultivation of maize, the main upland crop in the Project Area, is usually made at the beginning of May. Heavy tractors are operated for this work on rental basis. The rental fee is about Baht 300/hr.

Harvesting is made from the middle of August to the middle of September, and after harvesting of maize, mung bean and soybean are raised in some areas as second crops although their cropping area is limited. Upland fields are cultivated with no crops in dry seasons.

3.3.3. Present Cropping Pattern and Yield

A. Cropping Pattern and Cropped Area

Figure 3-9 shows the present cropping pattern in the Project Area. This figure has been prepared based on the cropping calendar furnished by the Provincial Agricultural Extension Office, Saraburi, and based on the data given by Kaset Tambon Agricultural Extension Offices in related Amphoe.

The cropped areas have been estimated based on the data prepared by the said agricultural extension office in each Amphoe. The cropping index of the Project Area is 93.2% in wet seasons. The index in dry seasons is so small as only 4.7%. The cropped area is further detailed in the following table.

Present Cropping Area

(Unit: ha)

Item	Cropped		Fallow		Total	
	Acreage	%	Acreage	%	Acreage	%
1. Wet Season						
Paddy Field	13,150	90.0	960	6.6	14,110	96.6
Upland Field	460	3.2	30	0.2	490	3.4
Total	13,610	93.2	990	6.8	14,600	100.0
2. Dry Season						
Paddy Field	680	4.6	13,430	92.0	14,110	96.6
Upland Field	-	-	490	3.4	490	3.4
Total	680	4.6	13,920	95.4	14,600	100.0

B. Production by Crops

The present production by crops has been determined depending upon the data on cropped areas and yield of crops in each Amphoe as well as on results of the farm management survey of 30 farms household conducted in the study. The estimated production of crops

are tabulated below;

Present Yield and Production of Crops

Item			Planted Area	Yield	Production	Remarks
			(ha)	(t/ha)	(ton)	
Paddy Field	Wet Season	LV (T.P.)	9,050	1.8	16,290	
		HYV (T.P.)	1,160	2.4	2,784	Rainfed
		HYV (T.P.)	2,000	2.6	5,200	Irrigated
		LV (B.C.)	940	1.6	1,504	
	Dry Season	HYV (T.P.)	680	3.2	2,176	
	Sub-total		13,830	-	27,954	
Upland Field	Wet Season	Maize	410	2.0	820	
		Groundnuts	50	1.8	90	
	Sub-total		460	-	910	
	Total		14,290	-	28,864	

Note: T.P.: Transplanting, B.C.: Broadcasting

3.3.4. Input Materials

As per the survey data on crop production cost, these prepared by the National Statistical Office and results of the interview with farmers in the Project Area are employed in this study, and input materials for each crop being consumed have been estimated below;

Crop	Input Materials		
	Seed	Fertilizer	Agri-chemical
	kg/ha	kg/ha	kg/ha
Paddy (LV)	70.0	146.9*	0.06
Paddy (HYV)	60.0	180.0	2.56
Maize	18.0	3.6**	6.10
Mung bean	12.5	1.3**	0.90
Soybean	31.6	0.9	0.90
Groundnuts	120.0	4.2	-

Note: * Compound, ** Manure

The consumption of fertilizers for paddy is rather smaller in amount than with the quantities recommended in the guidance of the

Department of Agriculture Extension (DAE) probably due to the recent sharp price escalation of fertilizers.

3.3.5. Farm Labor and Farm Mechanization

A. Labor Requirement

The following table shows the labor requirement by crops based upon the data on production economics prepared by the Office of Agricultural Economics, MOAC.

Present Labor Requirement by Crops

(Unit: per ha)

	Manning power (manday)							
	Hired		Owned		Total		Animal	Machinery
Name of Crop	No.	%	No.	%	No.	%	(days)	(hours)
Paddy (HYV)	35.25	42	49.13	58	84.38	100	4.69	43.31
Paddy (LV)	41.07	49	42.69	51	83.76	100	4.88	31.63
Mung bean	20.19	49	20.86	51	41.05	100	18.31	12.43
Groudnuts	64.82	47	72.37	53	137.19	100	14.60	2.19
Maize	45.76	74	15.94	26	61.70	100	7.45	5.76
Soybean	36.81	56	28.44	44	65.25	100	7.42	7.88

Supplemental labor force, that is, hired labor, is required for cultivation of all crops specially for land preparation and harvesting works. Hired labor at present covers a half of the total farm labor requirement. It is an increasing tendency that farm practices are mechanized due to the shortage of family labor sources and peculiar soil conditions of paddy fields. Heavy tractors are operated, on rental basis; in land preparation for upland crops.

B. Farm Mechanization

The survey on farm mechanization in the Project Area has

resulted as tabulated below;

Machine	Number	Proportion-owned*
Farm tractor (5 - 10 Hp)	1,336	
- " - (10 - 20 Hp)	5	37.3%
- " - (30 Hp over)	25	
Water pump	235	6.4%
Sprayer	136	3.7%
Thresher	2	-

Note: * Total number of farm household in the project area is estimated at 3,660.

Plowing and harrowing for paddy cultivation are mainly made by two-wheel tractor. In raising upland crops heavy tractors are extensively operated for plowing although such farmers' own tractors are not so many.

3.3.6. Farm Size

The cultivable area in the Project Area is estimated at 14,600 ha in total, that is, 14,110 ha of paddy fields and 490 ha of upland fields. The averaged farm size per farm household is computed at 4.0 ha (25 rai) approximately. This farm size is smaller than that of the averaged size of 5.2 ha (32.5 rai) in Changwat Saraburi.

3.4. Present Farm Economy and Marketing

3.4.1. Farm Economy

A. General

No statistic data on the present farm economy in the Project Area are available at present. Under the circumstances, this paragraph is described mainly based upon results of interviews with 30 farm households made in the field survey. It is noted that out of

the 30 farm households who live within the original Project boundary 21 farm households only will be directly benefited by the proposed Project newly delineated based on alternative study on the Project focussing on its boundary.

B. Farm Size and Tenancy

Out of the 30 farm households with whom interviews were made, 23 raise paddy only having the averaged farm size of 3.7 ha (23 rai); three raise upland crops only having the averaged farm size of 1.8 ha (11 rai); and four raise both having the averaged size of 4.2 ha (26.6 rai), as shown below;(Refer to Table A.3.6-1 in Appendix III)

	Paddy	Upland crops	Both crops	Total
No. of farms	23	3	4	30
Total farm size (rai)	529.0	33.0	106.0	668.0
Averaged farm size (rai)	23.0	11.0	26.5	22.3

The number of farms and averaged size by types of tenancy are indicated below;(Refer to Table A.3.6-1 in Appendix III)

	Full owner	Part owner	Full tenant	Total
No. of farms	22	2	6	30
Total farm size (rai)	480.0	62.0	126.0	668.0
Averaged farm size (rai)	21.8	31.0	21.0	22.3

C. Farm Family Income

The averaged income of the 30 farm households is Baht 30,588, of

which Baht 22,278 (73 %) fall in the category of agricultural income whereas the rest of Baht 8,301 (27 %) in non-agricultural income.

Out of the 30 farm households only 10 are full-time farmers and the rest are part-time farmers.(Refer to Table A.3.6-1 in Appendix III)

D. Cash Expenditure and Surplus

The cash expenditure of the farmers is required for agricultural production and for their living. The agricultural production cost amounts to Baht 7,727 whereas the living cost to Baht 12,723 on an average. In this cash expenditure, farmers' own consumption of agricultural products is not taken into account.(Refer to Table A.3.6-1 and Table A.3.6-2 in Appendix III)

By subtracting the cash expenditure from the above-described farm family income, a surplus of the 30 farm households in their family economy amounts to Baht 10,138 on an average.

E. Agricultural Credit

Out of the 30 farm households 17 have obtained agricultural credit amounting to Baht 228,000 in total, and five repaid the principal with the interest of Baht 9,860 as of the survey period of this study. The remainder of 12 paid the interest only amounting to Baht 19,430. The averaged interest rate is estimated at 12.8 per cent per annum, approximately, resulting in a slightly higher rate than that of the BAAC. It suggests that some have obtained their necessary credit from private sources.(Refer to Table A.3.6-1 in Appendix III)

3.4.2. Marketing Structure of Agricultural Products

A. General

As regards the marketing of agricultural products from producers to consumers in Thailand, there are three market steps, that is, local market, local central market and terminal market (Bangkok market) as shown below;

Local market	local central market	Terminal market
Famers	Farmers	Farmers
Local Middlemen	Middlemen	Wholesalers
Agents or brokers	Agents or brokers	Agents or brokers
Cooperatives	Cooperatives	Cooperatives
Local processing factory	Processing factory	Processing factory
Government organization	Retailers	Government organization
Retailers	Consumers	Exporters
Consumers		Retailers
		Consumers

B. Marketing in the Project Area

The cultivable area in the Project Area mostly consists of paddy fields, and marketing of upland crops is not so significant in comparison with that of paddy.

The field survey in the study has revealed that the present marketing of upland crops like maize and groundnuts, etc., is made as follows;

Farmers bring their agricultural products from fields to main roads such as national roads where middlemen negotiate the buying price of products with such farmers. After the transaction,

middlemen haul the products by their own transportation means.

As regards paddy, middlemen or rice mill owners directly visit farmers in fields or houses and buy it after simple quality test and grading. Sometimes, such buyers provide farmers with funds or give financial support to farmers for the coming cropping. Transportation cost of paddy from farmers to rice mills or to local central markets is borne by buyers.

After milling, some of milled rice flows back to local markets though the majority flows to Bangkok market.

C. Rice Mill

In the 18 Tambons related to the proposed Project, there are 22 rice mills of which total milling capacity is 903 ton/day as listed below;

Amphoe	No. of Tambons	Rice Mills	Capacity (ton/day)
Muang Saraburi	4	11	597
Sao Hai	8	7	270
Kaeng Khoi	3	3	24
Ban Mo	2	-	-
Phra Phutthabat	1	1	12
Total	18	22	903

These rice mills are mostly located along national roads.

3.5. Agricultural Institution

3.5.1. Agricultural Extension Services

The Project Area covers five Amphoes, and each of them has one

agricultural extension office. One agricultural extension office is lined up by about 10 extension staff on an average, and renders services to farmers under its jurisdiction. The number of farm households per one extension staff is estimated at 520.

Number of Extension Staff by Amphoes

Amphoe	Amphoe Acreage (rai)	No.of Farm Household	No. of Ext.Staff	Rai per one Ext. Staff	No.of Farm Household per one Ext. Staff
Ban Mo	76,590	2,973	7	10,941(1,750 ha)	425
Phra phu-tthabat	138,750	3,182	9	15,416(2,466 ha)	354
Muang	297,500	9,020	11	27,045(4,327 ha)	820
Kaeng Khoi	514,380	5,444	12	42,865(6,858 ha)	454
Sao Hai	74,356	4,232	9	8,251(1,321 ha)	470
Total or Average	1,101,576	24,851	48	22,950(3,672 ha)	518

Under the National Agricultural Extension Project (NAEP), which is under implementation by the Government since 1977, one extension staff is scheduled to take charge of the following;

One extension staff
10 villages
100 contact farmers
1,000 farm households

The above-mentioned standard suggests that the service coverage of one extension staff in the Project Area is comparatively smaller than that in the other areas although it differs by Amphoes.

The major objectives of the NAEP can be listed as follows;

- Extension of farming techniques and knowledge;
- Promotion of dry seasons' cropping;
- Introduction of improved varieties of paddy and new upland crops;
- Distribution of guaranteed seeds; and,
- Establishment of demonstration farms.

Among the above-listed, the number of demonstration farms, acreage to be cultivated with specified crops should conform to the frame work plan that will be prepared by the super organization, that is, the Provincial Agricultural Extension Office of Changwat Saraburi.

As regards the on-going extension works, farmers meetings are periodically held, demonstration farms are under establishment, and leaflets are distributed to farmers, however, it was observed during the field survey that instruments and vehicles for the services were not sufficiently provided, and also that the number of extension staff is not enough to meet the present requirement in extension services.

3.5.2. Agricultural Cooperatives

Table 3-6 shows the brief profile of agricultural cooperatives' activities in the related five Amphoes to the Project. The activities are mainly focussed upon agricultural crediting, marketing of agricultural products, banking and supply of agricultural input materials. Subscribers in the five Amphoes count 5,241 farmers.

As for marketing of agricultural products, only two Amphoes of Ban Mo and Phra Phutthabat purchased paddy from farmers in April 1, 1980 to March 31, 1981. The purchased quantity of rice amounted to 563 tons in total or to Baht 2,022,000.

3.5.3. Research and Experimental Station

There are nine rice experimental stations in the Central Plain of Thailand, however, none of them exists in the Project Area. Huntra rice experimental station is the nearest one to the Project Area. This station undertakes various experimentations in respect of floating rice.

At Suphanburi station, experimentations for fertilization effects and control for both local varieties and improved varieties are undertaken, and the experimental results have been compiled in "the Rice and Rice Cultivation".

As for upland crops, a field crop experimental station has been established in Phra Phutthabat that is located in the north of the Project Area. This station conducts experiments on improvement of varieties and fertilization for upland crops such as maize, mung bean, soybean, cotton and so forth.

Table 3-1 Lopburi Climatological Summaries (Period 1951 - 1975)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (c)													
Mean	26.4	28.5	30.2	31.1	30.1	29.1	28.4	28.3	27.9	27.7	26.8	25.8	28.3
Mean Max.	32.5	34.5	36.2	37.0	35.3	33.6	32.7	32.3	31.7	31.6	31.4	31.3	33.3
Mean Min.	19.0	21.9	23.8	24.9	24.8	24.3	24.0	24.1	24.0	23.5	21.4	19.2	22.8
Relative Humidity (%)													
Mean	58.0	61.0	62.0	64.0	72.0	75.0	77.0	79.0	81.0	77.0	69.0	60.0	70.0
Mean Max.	79.7	84.2	86.5	87.1	90.3	92.1	92.7	93.3	94.4	91.2	85.7	80.0	88.1
Mean Min.	40.3	40.7	40.7	43.0	52.9	58.2	61.1	63.6	67.5	63.0	54.1	44.6	52.5
Dew point (c)													
Mean	16.7	19.3	21.5	22.9	23.8	23.9	23.8	23.9	24.2	23.1	20.3	17.1	21.7
Evaporation (mm)													
Mean-Piche	160.5	144.7	157.8	146.6	111.5	91.1	79.1	70.9	60.4	83.5	117.5	155.6	1379.2
Cloudiness(0-8)													
Mean	3.8	4.2	4.4	5.0	6.0	6.6	6.7	6.9	6.5	5.5	4.3	3.6	5.3
Wind (Knots)													
Prevailing wind	NE	S	S	S	S	S	S	S	S	NE	NE	NE	-
Mean Wind Speed(knot)	5.4	6.0	7.0	6.6	5.6	5.9	5.3	5.2	4.3	4.8	5.7	6.4	-
Rainfall (mm)													
Mean	10.3	14.6	58.5	70.5	162.4	152.6	171.3	172.4	292.1	168.4	42.1	8.8	1324.0
Mean Rainy days	1.0	2.0	3.3	6.1	13.0	14.1	16.7	17.0	18.8	13.0	4.2	1.4	110.6

Data Source : Meteorological Department

Table 3-2 Monthly Rainfall, Amphoe Muang Saraburi (54012)

(Unit : mm)

YEAR	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	TOTAL
1952	47.6	70.6	144.3	278.9	249.2	129.9	269.4	25.1	0.0	0.0	0.0	4.6	1219.6
1953	19.8	132.3	200.6	139.1	239.0	250.4	154.9	22.1	0.0	0.0	17.9	30.5	1206.6
1954	41.1	114.4	189.5	84.7	322.0	402.1	62.2	0.0	12.1	0.0	5.4	51.3	1284.8
1955	130.6	204.1	249.3	132.7	250.9	222.9	85.8	73.9	0.0	0.0	3.8	59.0	1413.6
1956	71.0	337.5	409.7	236.2	252.3	293.0	150.2	40.5	0.0	0.0	1.8	52.0	1844.8
1957	142.7	75.1	234.3	217.7	258.6	578.7	373.3	135.5	0.0	0.0	0.0	0.0	2015.9
1958	0.0	232.0	232.0	284.8	368.6	458.5	47.0	0.0	0.0	0.0	16.7	90.9	1730.5
1959	105.7	139.7	36.7	326.1	201.6	552.6	199.9	15.1	0.0	0.0	0.0	0.0	1577.4
1960	18.5	123.1	296.1	319.4	165.1	288.3	223.6	111.5	0.0	3.2	35.0	60.7	1644.5
1961	148.8	179.5	170.4	187.5	284.5	241.1	176.4	20.2	8.7	0.0	2.8	0.0	1419.9
1962	210.9	114.9	182.7	300.3	180.2	560.8	141.6	0.0	0.0	0.0	0.0	8.5	1699.9
1963	24.5	7.1	281.5	159.8	290.1	268.5	187.4	131.1	0.0	0.0	39.9	8.5	1398.4
1964	24.1	281.6	97.9	164.0	191.1	239.5	107.0	0.0	10.2	0.0	39.5	17.8	1172.7
1965	23.8	285.8	194.0	132.3	332.7	296.6	74.9	58.6	0.0	0.0	27.8	46.8	1473.3
1966	52.6	445.0	245.7	329.0	397.7	223.9	296.0	42.0	36.4	0.0	0.0	0.0	2063.3
1967	58.0	129.1	105.4	183.6	185.2	335.4	106.3	0.0	0.0	0.0	84.6	0.0	1187.6
1968	77.3	135.7	225.0	175.3	226.7	174.1	21.2	48.3	0.0	114.9	0.0	0.0	1198.5
1969	11.8	125.5	305.4	288.6	199.9	330.1	83.0	26.6	0.0	0.0	50.3	0.0	1421.2
1970	58.0	206.0	383.8	312.1	217.5	410.8	65.1	6.8	83.7	0.0	47.5	17.5	1808.8
1971	89.7	64.3	154.1	189.6	477.4	198.1	158.5	0.0	1.9	0.0	6.8	49.5	1389.9
1972	92.6	42.8	230.2	161.6	184.8	527.7	68.1	259.5	49.3	0.0	2.4	51.7	1670.7
1973	0.0	189.0	197.0	268.8	234.7	298.0	114.8	35.2	0.0	0.5	3.8	63.1	1404.9
1974	80.1	134.5	92.7	259.1	184.0	188.7	215.3	75.0	4.2	92.4	3.8	68.0	1397.8
1975	72.4	144.6	276.4	209.8	174.0	165.2	106.1	45.0	36.5	0.0	0.0	0.0	1230.0
1976	0.0	82.3	176.8	284.1	299.1	167.0	204.1	11.7	0.0	9.2	12.7	94.7	1341.7
1977	45.1	138.3	113.3	190.2	111.6	236.4	103.1	4.1	1.5	4.6	146.4	0.0	1094.6
1978	28.2	225.3	131.6	302.9	136.5	434.1	92.2	0.8	0.0	12.9	0.8	0.0	1364.7
1979	31.8	130.8	118.9	143.6	139 7	411.5	21.8	0.0	0.0	0.0	14.4	82.0	1094.5
1980	35.1	84.8	221.2	208.4	268.7	214.8	175.0	0.0	0.0	0.0	0.0	0.0	1208.0
Mean	61.8	157.8	203.3	223.1	242.2	313.7	140.8	41.0	8.4	8.2	19.5	29.6	1449.4

Table 3-3 Discharge at S2 Station on Pasak River

(Unit : MCM, D.A. = 14,522 km^2)

YEAR	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	TOTAL
1948	51.0	85.5	82.2	46.5	232.3	809.2	1069.6	130.0	43.5	36.5	30.8	30.3	2647.4
1949	28.6	37.9	25.6	42.9	304.6	710.0	1224.8	459.0	177.1	125.4	88.0	54.1	3278.0
1950	41.1	26.1	18.9	66.5	132.8	392.2	1465.6	471.2	86.4	78.0	41.7	17 9	2837.6
1951	16.1	15.6	34.2	207.4	256.9	476.7	678.2	236.6	117 9	77.2	42.4	92.9	2252.1
1952	32.7	17.1	25.9	47.0	159.9	534.2	578.8	231.1	70.4	56.8	46.6	51.3	1851.8
1953	29.9	60.4	68.1	223.8	209.7	413.9	402.6	129.9	75.5	56.0	36.1	45.2	1751.1
1954	29.9	25.3	82.5	36.3	62.2	403.1	1142.3	119.4	37.8	29.7	20.4	19.8	2008.7
1955	19.1	30.2	54.5	56.3	58.2	406.3	323.7	49.1	39.1	35.3	30.3	25.8	1127.9
1956	18.9	31.6	89.0	236.2	426.5	860.5	926.7	67.4	34.1	19.5	16.2	43.4	2770.0
1957	12.5	8.1	9.3	28.0	77.6	552.8	812.1	227.2	45.6	49.1	41.4	34.9	1898.6
1958	15.3	12.8	15.3	30.6	74.2	559.8	561.0	68.3	36.5	32.2	25.0	20.8	1451.8
1959	15.3	16.7	26.1	68.2	100.3	399.0	1075.2	58.3	52.2	20.8	8.7	11.3	1852.1
1960	5.3	7.1	31.0	19.9	50.3	164.2	525.0	110.4	23.0	29.9	18.5	7.6	992.2
1961	5.3	83.7	73.9	123.6	282.0	571.4	870.7	206.9	64.0	35.3	20.6	17.4	2354.8
1962	3.0	22.3	36.2	384.0	100.3	918.9	1848.3	183.8	71.5	65.9	47.6	38.0	3719.8
1963	15.2	6.5	6.1	31.9	472.4	1048.7	1832.6	368.2	93.0	86.7	109.8	89.9	4161.0
1964	67.4	145.0	120.3	101.6	132.9	571.7	2652.2	442.5	96.1	82.1	63.2	58.0	4533.0
1965	65.8	78.1	121.8	182.0	206.8	744.7	571.4	98.5	78.1	68.3	46.7	51.0	2313.8
1966	61.6	112.1	131.8	110.1	269.7	1228.6	516.9	192.3	83.1	32.1	29.8	28.8	2796.9
1967	24.1	25.9	23.5	24.7	58.8	313.7	736.5	49.5	22.9	13.6	15.1	10.7	1318.8
1968	8.3	34.4	64.1	66.5	165.4	112.7	51.4	29.0	16.7	7.9	6.4	4.1	606.9
1969	9.2	3.0	20.3	104.2	144.7	1144.4	830.7	105.0	33.4	30.8	29.1	28.1	2482.9
1970	32.8	29.5	58.2	164.8	292.8	769.9	445.4	93.0	38.4	28.5	25.7	28.7	2007.7
1971	28.5	36.6	25.3	36.7	177.1	464.1	334.3	26.8	15.8	22.4	28.2	35.0	1230.8
1972	38.1	32.2	21.4	25.4	36.2	587.1	629.1	170.6	44.0	37.0	28.1	30.6	1679 8
1973	21.1	40.4	36.9	38.8	58.8	374.4	509.1	40.4	36.6	31.3	****	35.9	****
1974	31.3	53.7	26.6	25.1	47.8	203.0	568.6	244.9	66.4	48.5	36.1	47.3	1399.3
1975	43.2	44.4	67.7	196.0	210.0	1099.4	1360.5	150.1	63.3	35.4	31.3	45.0	3346.3
1976	48.1	64.0	55.9	61.3	264.7	827.5	1132.0	416.8	75.2	51.4	23.5	38.4	3058.8
1977	19.7	55.0	37.1	16.3	55.1	667.4	449.8	34.3	23.2	18.0	9.6	7.9	1393.4
1978	18.2	39.0	48.6	435.1	814.2	981.8	2675.1	103.9	69.6	42.2	24.2	24.2	5276.1
1979	14.5	72.2	62.8	95.3	104.1	215.1	299.5	25.1	17.2	11.9	7.1	7.0	931.8
1980	13.6	18.1	84.8	218.6	296.1	700.4	1335.6	132.8	52.4	17.6	12.9	19.9	2902.8
Mean	26.8	41.5	51.1	107.6	192.0	612.9	923.5	165.8	57.6	42.8	32.6	33.3	2287.5x$10^6$$m^3$
	10.3	15.5	19.7	40.2	71.7	236.5	344.8	64.0	21.5	16.0	13.5	12.4	72.5m^3/sec

Notes : Discharge data from 1977 to 1980 indicate at S9 gauging station because S2 gauging station have been removed to S9 gauging station (D.A = 14,374km^2) since 1977.

Table 3-4 Intake Discahrge at Manorom Regulator

(Unit: MCM)

YEAR	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	TOTAL
1965	85	107	203	303	373	524	565	429	104	45	30	68	2,836
1966	46	39	157	333	442	351	478	449	126	109	60	73	2,663
1967	74	79	209	253	294	382	489	423	194	155	79	67	2,698
1968	72	132	265	411	434	457	291	169	123	82	79	45	2,560
1969	50	42	198	362	483	426	585	498	179	142	112	113	3,190
1970	104	156	303	402	410	600	626	426	325	221	195	154	3,916
1971	153	181	311	375	561	598	654	512	24	47	180	173	3,769
1972	194	196	281	325	442	233	358	384	191	133	114	157	3,008
1973	158	243	332	380	533	585	688	469	79	130	151	186	3,934
1974	285	289	289	323	539	594	473	354	183	126	152	240	3,847
1975	296	292	328	438	565	669	609	484	118	97	241	374	4,511
1976	398	297	489	512	471	495	648	495	166	411	248	363	4,993
1977	355	451	375	410	392	558	537	419	167	87	155	209	4,115
1978	225	134	152	206	379	454	129	533	213	211	323	364	3,232
1979	401	326	345	411	405	388	405	372	171	141	52	97	3,544
1980	90	236	384	445	484	354	370	487	139	160	198	254	3,601
Mean	187	200	289	370	450	479	494	431	156	144	142	184	3,526(MCM)
	72.1	74.7	111.5	138.1	168.0	184.8	184.4	166.3	58.2	53.8	58.7	68.7	111.8(m^3/sec)

Table 3-5. Generalized geologic table

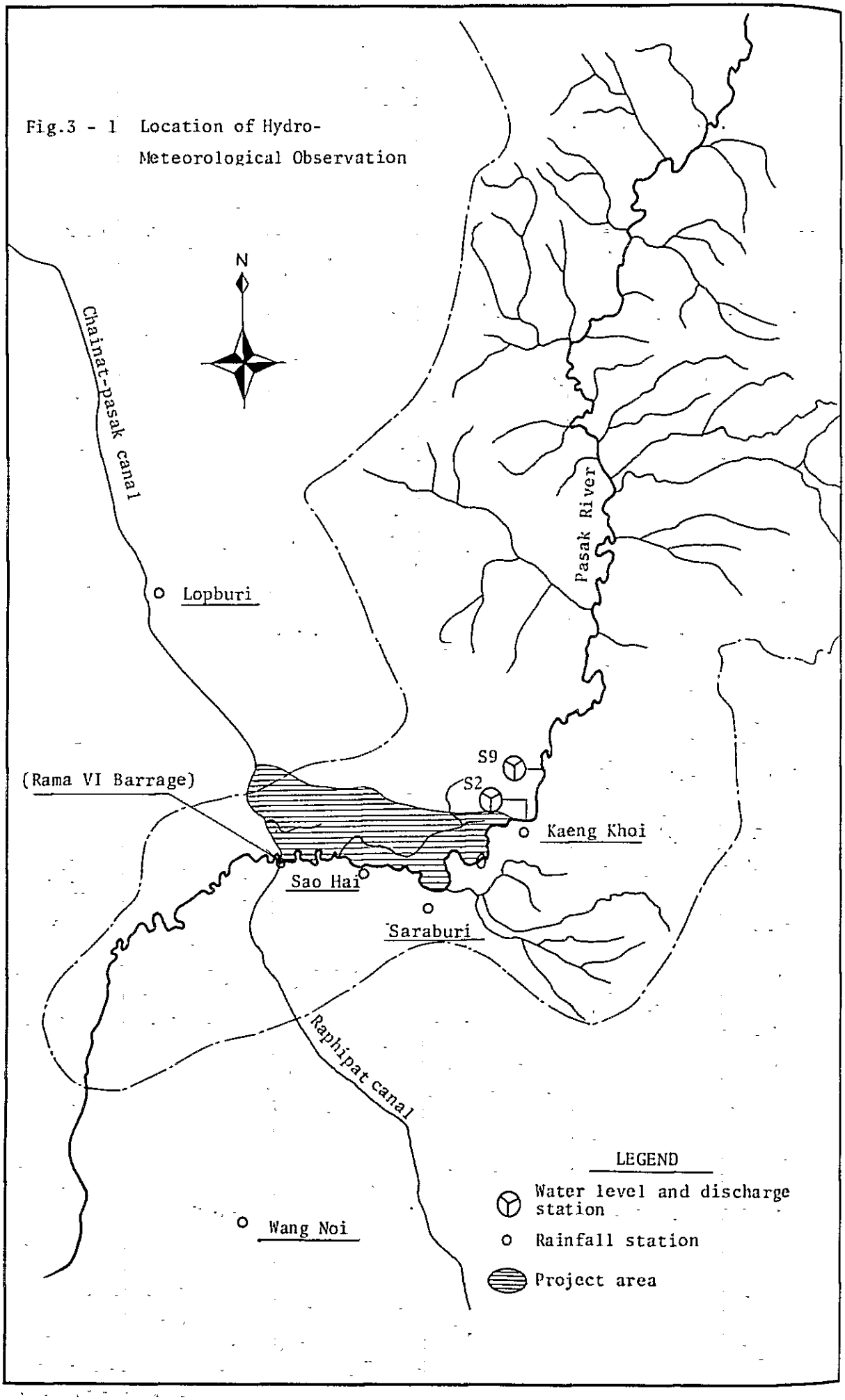
Era	Period	Rock Unit	Symbol	Lithologic description	
Quarternary	Holocene	Alluvium	al	Sub-rounded ∿ Sub-angular gravel sand. Sandy ∿ Silty Clay	Overburdens
		Fan Deposits	fd	Sub-rounded ∿ Sub-angular gravel sand. Sandy ∿ Silty Clay	
	Pleistocene	Terrace Deposits	tr	Sub-rounded ∿ Sub-angular gravel sand. Sandy ∿ Silty Clay	
		Marl	ml	Sub-rounded ∿ Sub-angular lime-stone gravel Limy Clay	
Pretri-assic		Khao Yai Volcanics	Rh	Rhyolite	Red rocks
Per-mian		Ratburi Group	Ls	Limestone	

Table 3-6. Profile of Agricultural Cooperatives

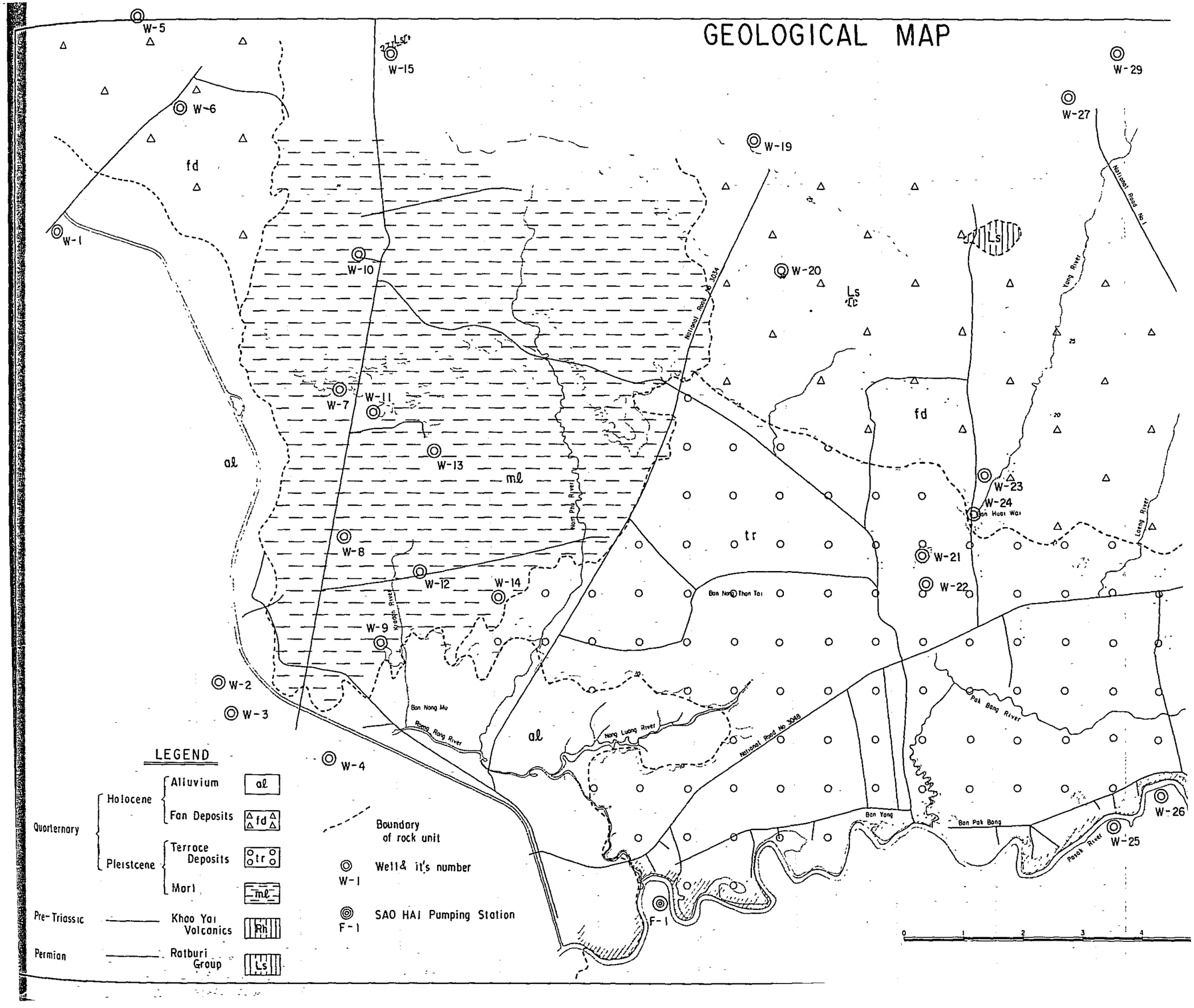
(1 Apr.'80 - 31 Mar.'81)

	Muang	Sao Hai	Khaeng Khoi	Ban Mo	Phra Phutthabat	Total
1. No. of Member	870	1,351	746	1,629	645	5,241
2. No. of Agr. Household	870	1,351	746	1,629	645	5,241
3. Agr. Credit						
Short-term						
- Number	120	87	418	1,060	321	2,006
- Amount(฿1,000)	1,476	1,186	1,572	12,345	4,123	20,702
Medium-term						
- Number	70	32	107	328	234	771
- Amoung(฿1,000)	975	716	932	4,360	3,047	10,050
4. Marketing Buying Paddy						
- Quantity(ton)	-	-	-	426.4	136.7	563.1
- Amount(฿1,000)	-	-	-	1,551	471	2,022
5. Storage Facility						
- Number	2	2	1	2	1	8
- Capacity(ton)	1,000	1,000	500	1,000	300	3,800
6. Money Deposit by Member						
Saving Deposit						
- Number	5	27	2	180	59	273
- Amount(฿)	71,248	224,500	1,087	222,327	15,488	534,650
Fixed Deposit						
- Number	3	-	-	5	115	123
- Amount(฿)	20,000	-	-	113,500	21,839	155,339
7. Selling of Agr. Input						
Fertilizer						
- Quantity(Bag)	2,893	5,720	200	15,820	287	24,920
- Amount(฿1,000)	757	1,507	59	4,151	113	6,589
Chemicals						
- Quantity(l)	5	-	-	-	5	10
- Amount(฿)	1,750	-	-	-	1,450	3,200

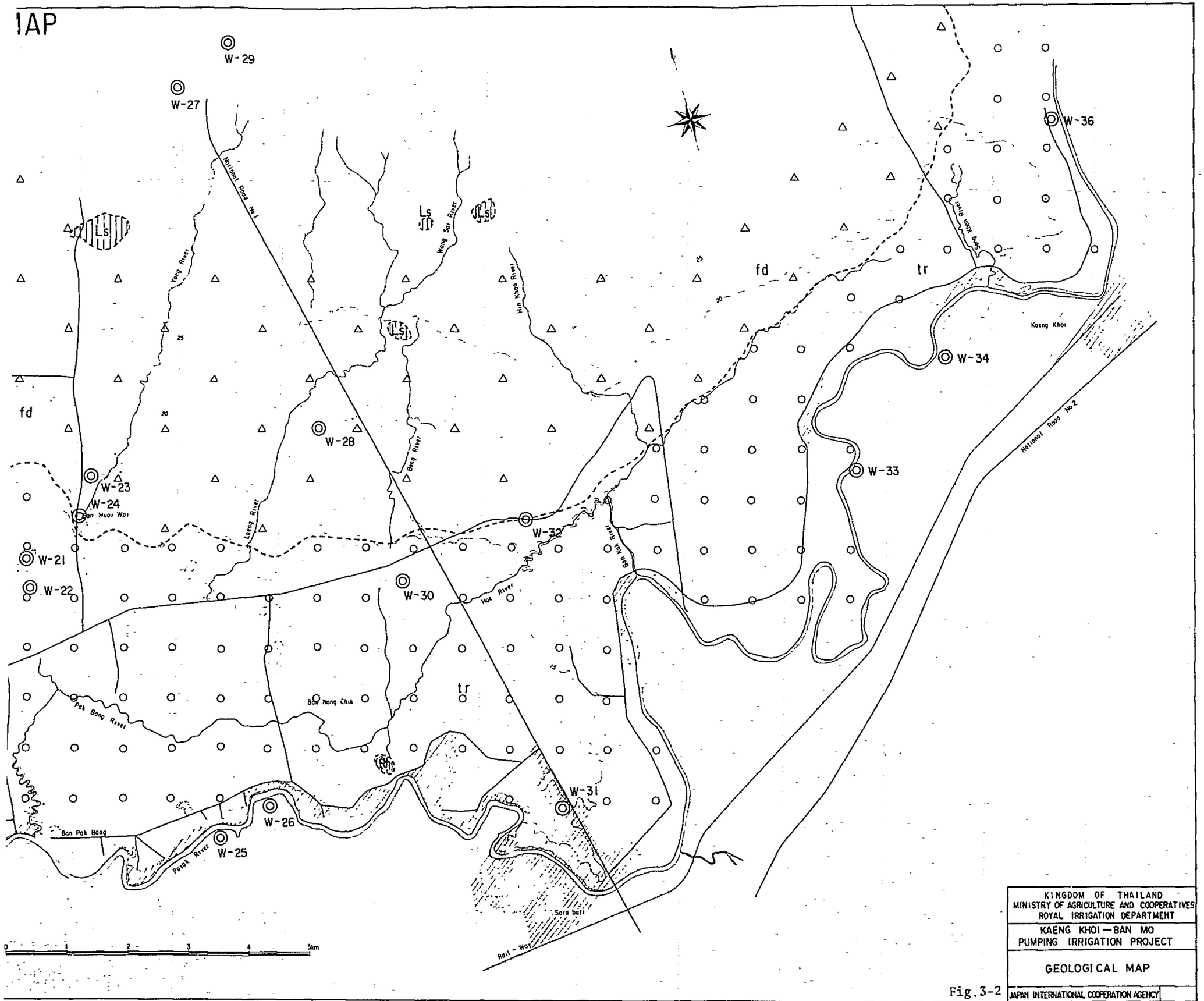
Fig.3 - 1 Location of Hydro-Meteorological Observation



GEOLOGICAL MAP



MAP



KINGDOM OF THAILAND MINISTRY OF AGRICULTURE AND COOPERATIVES ROYAL IRRIGATION DEPARTMENT
KAENG KHOI — BAN MO PUMPING IRRIGATION PROJECT
GEOLOGICAL MAP
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.3-2

SOIL MAP

0 1KM 2KM 3KM 4KM 5KM

Elevation in meter

Soil Series		Thai National
1. Tha Muang	(Tm)	Alluvial Soils
2 Chong Kae	(Ck)	Grumsols
3 Tha Rua	(Tr)	
4 Ban Mi	(Bm)	
5 Wathana	(Wa)	
6 Lop Buri	(Lb)	
7 Ongkharak	(Ok)	Hydromorphic Alluvial Soils
8. Saraburi	(Sb)	
9 Nakhon Pathom	(Np)	
10 Khao Yoi	(Kyo)	Low Humic Gley Soils
11 Deum Bang	(Db)	
12 Hin Kong	(Hk)	
13 Nakhon Phanom	(Nn)	
14 Manorm	(Mn)	
15. Takhli	(Tk)	Renzinos

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ROYAL IRRIGATION DEPARTMENT

KAENG KHOI - BAN MO
PUMPING IRRIGATION PROJECT

SOIL MAP

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.3-5

LAND CLASSIFICATION MAP

0 1KM 2KM 3KM 4KM 5KM

Elevation in meter

U2s / R3s , U2t / R3st , U2st / R3st	Lands of better suitability for upland crops and marginal suitability for paddy due to soil and/or topographic limitations. Upland crops in both wet and dry season.
U1 / Rs	Lands of best suitability for upland crops and moderate suitability for paddy.
U2s / R2s	Lands of moderate suitability for both upland crops and paddy. Paddy in wet season and upland crops in dry is recommended
U2s / R1	Lands of best suitable for paddy and moderate suitability for upland crops, mainly paddy, only some upland crops in dry season
U3sd / R1 , U3sdt / R2t	Lands of best suitability for paddy and marginal suitability for upland crops due to drainage and heavy textured soil limitation Paddy in both dry and wet season Topography is unfavorable only in very small extent.

Land class

Upland crop — U2sd / R2s f_1 — Soil deficiencies; Drainage deficiencies; Flood limitations (wet season); Flood class

Rice land — Soil deficiencies

Land class

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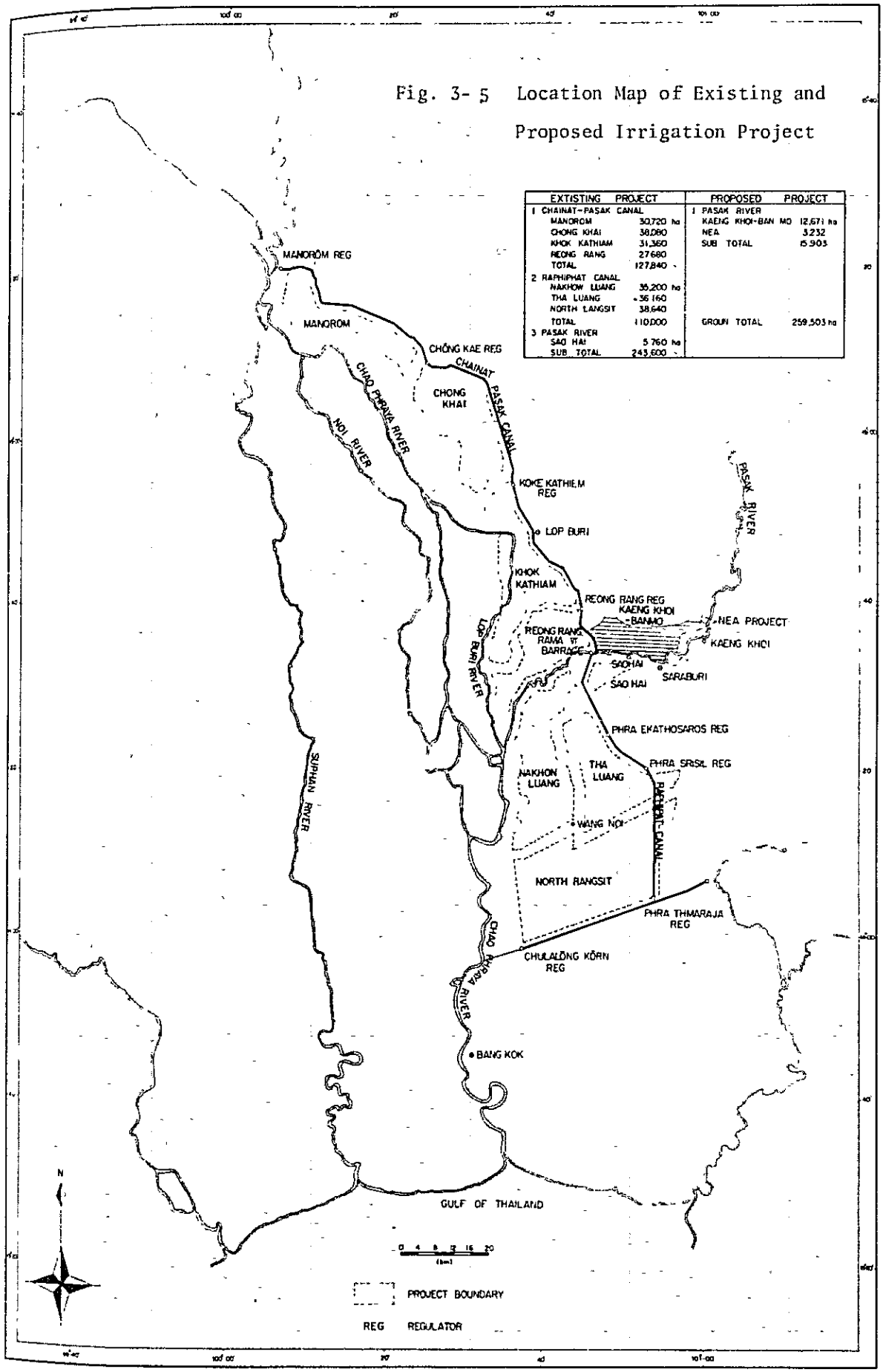
KAENG KHOI–BAN MO
PUMPING IRRIGATION PROJECT

LAND CLASSIFICATION MAP

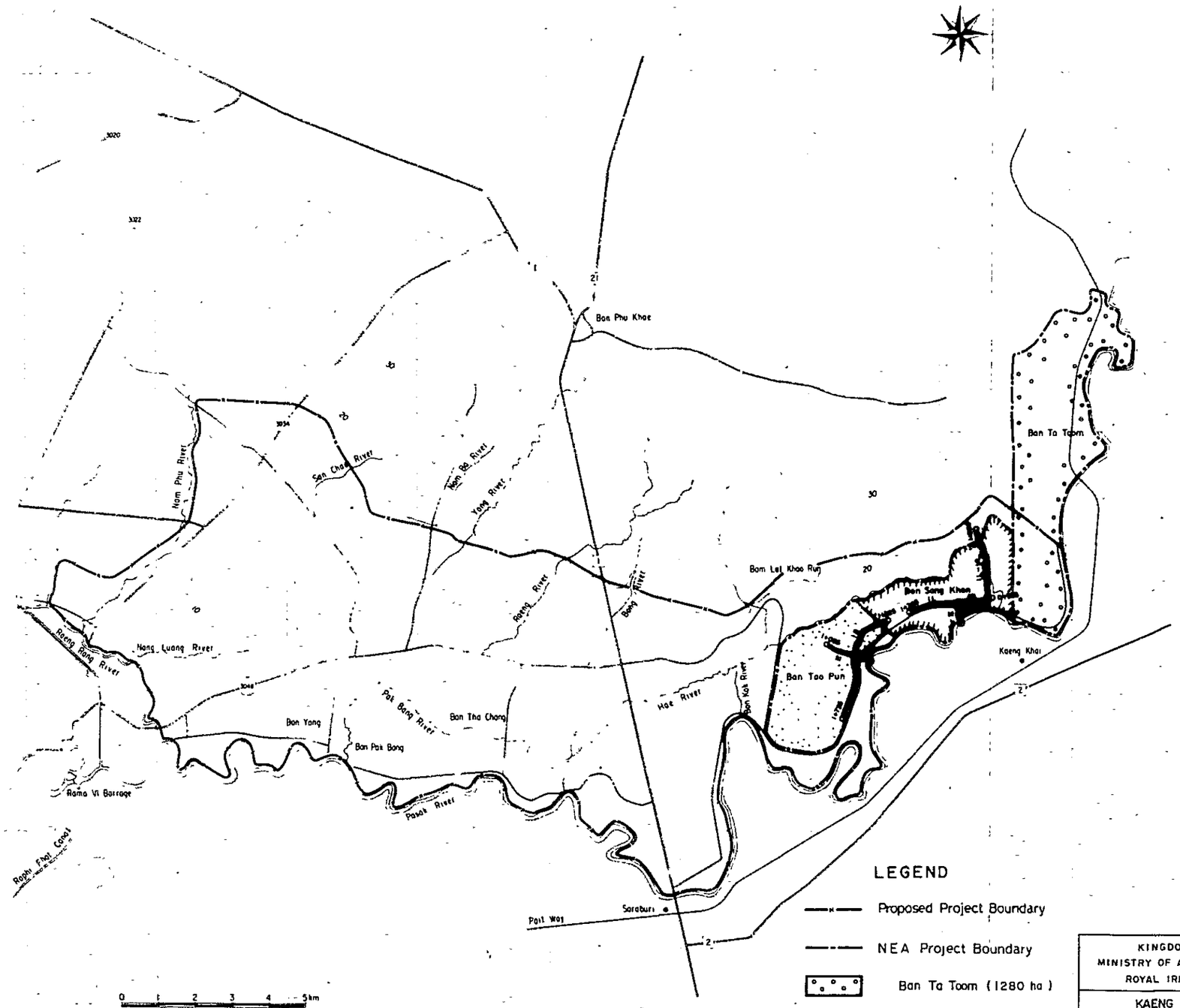
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig 7.1

Fig. 3- 5 Location Map of Existing and Proposed Irrigation Project



EXISTING NEA PUMPING IRRIGATION PROJECT



KINGDOM OF THAILAND MINISTRY OF AGRICULTURE AND COOPERATIVES ROYAL IRRIGATION DEPARTMENT
KAENG KHOI — BAN MO PUMPING IRRIGATION PROJECT
EXISTING NEA PUMPING IRRIGATION PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig 3-6

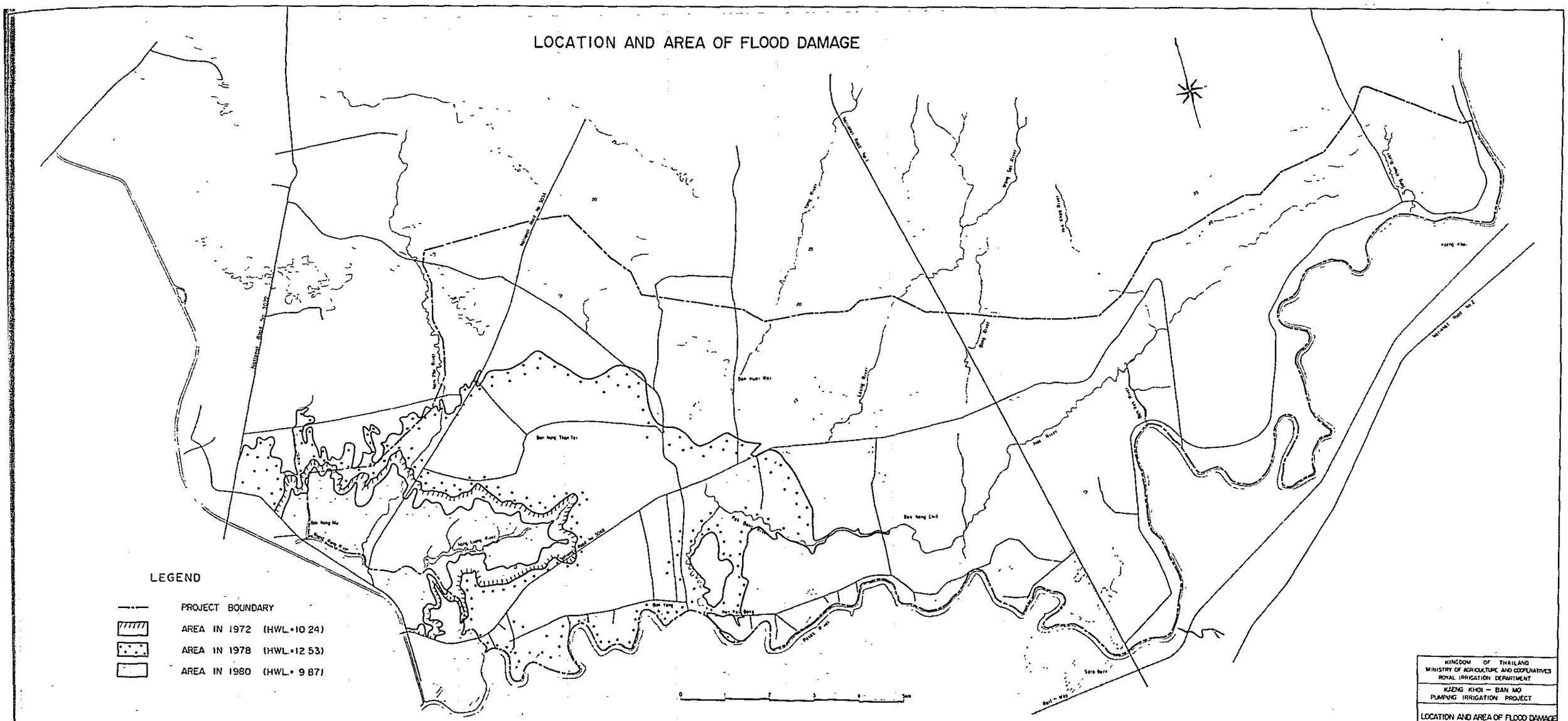

LOCATION AND AREA OF FLOOD DAMAGE
LEGEND
PROJECT BOUNDARY
AREA IN 1972 (HWL.=10.24)
AREA IN 1978 (HWL.=12.53)
AREA IN 1980 (HWL.= 9.87)
KINGDOM OF THAILAND
MINISTRY OF AGRICULTURE AND COOPERATIVES
ROYAL IRRIGATION DEPARTMENT
KAENG KHOI - BAN MO
PUMPING IRRIGATION PROJECT
LOCATION AND AREA OF FLOOD DAMAGE
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig 3-7

PRESENT LAND USE

0 1KM 2KM 3KM 4KM 5KM

Elevation in meter

LEGEND

R	Paddy	
R-Tm	Paddy with termite mounds	
F	Diversified crops	(Maize etc.)
T	Fruit trees	(Tamarin, banana etc.)
Tr	Trees	
Sh	Shrubs	
▨	Residential area	

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ROYAL IRRIGATION DEPARTMENT

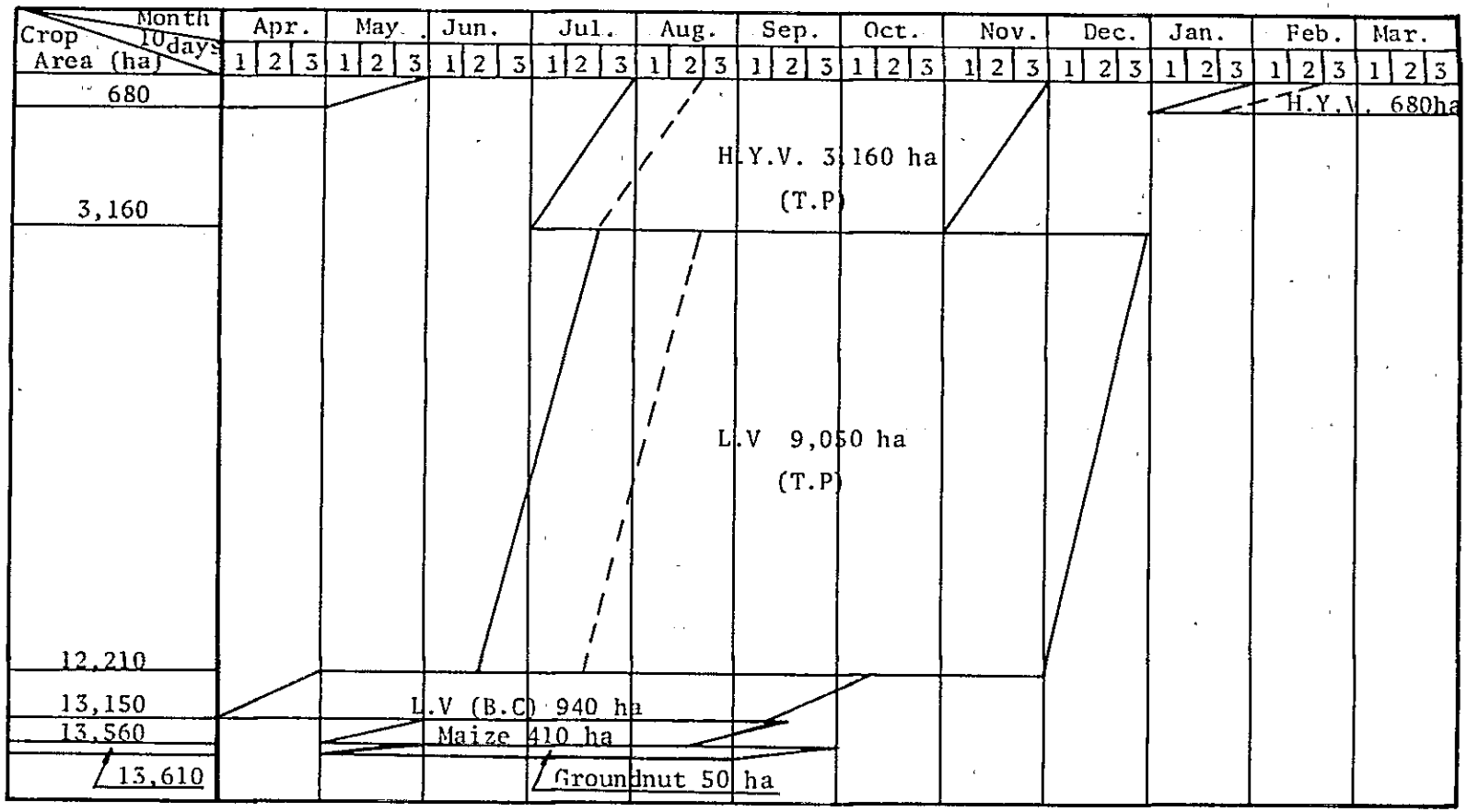
KAENG KHOI - BAN MO
PUMPING IRRIGATION PROJECT

PRESENT LAND USE

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3-8

Fig. 3-9 Present Cropping Pattern



* H.Y.V. : High yielding variety
L.V : Local variety
B.C. : Broadcasting method
T.P. : Transplanting method

IV. THE PROJECT.

IV. THE PROJECT

4.1. Objectives and Components of the Project

4.1.1. Objectives

The Project aims to stabilize the irrigation water supply and improve drainage conditions in the entire Project Area for increasing agricultural production through establishment of the double cropping system and modernization of farming techniques.

The Project has been planned (i) to provide in its service areas with a large-scaled, irrigation system and to introduce the proper water management in order to secure the stabilized irrigation water supply in the wet season and increase the cropping intensity in the dry season, (ii) to improve the drainage systems so as to introduce high yield varieties of paddy in the wet season and to prevent inundation damages in some lowlying paddy field caused by floods of the Pasak river, and (iii) to educate and train the beneficiary farmers in proper water management and operation and maintenance of the facilities and in improved farming practices.

4.1.2. Projects Components

In order to accomplish the above-mentioned purposes, the Project plan has been formulated for the following Project works;

i) Construction or improvement of the main pumping station, main, lateral and sub-lateral irrigation canals with appurtenant structures for stabilized water supply to the service areas, and provision of water control facilities such as check structures, distributors and waste ways, etc., for proper water distribution by advanced water management techniques.

ii) Construction or improvement of the main drainage canals as well as main drainage sluices in order to introduce high yield varieties of paddy and to prevent inundation damages;

iii) In addition, construction of demonstration plots in the eastern part of the Project Area for on-farm development, which are provided with irrigation ditches, drains and farm roads but without land leveling works so as to educate and train the related farmers to the Project in water management and in farm practices, and promotion on the consolidation of on-farm level facilities;

iv) Construction of O & M roads along the main and lateral canals for effective operation and maintenance services, which will be made in parallel with that for irrigation and drainage facilities. The O & M Office will be, after the completion of construction works, strengthened in staffing and in necessary equipment for maintenance services;

v) Strengthening of agricultural supporting services to improve the agricultural infrastructure in close coordination among various Governmental agencies concerned and agricultural research institutes in and around the Project Area for upgrading the agricultural production and living standard of the related farmers for which an execution program will be proposed taking into consideration the works to be required in the Project implementation and in past projects, if necessary.

vi) Establishment of a socio-economic monitoring and evaluating system for the expected Project impacts on the socio-environment in order to make a basic guidance on the agricultural supporting services.

4.2. Availability of Water Resources

4.2.1. Irrigation Water Requirement

A. General

The irrigation water requirements have been estimated based on the proposed irrigable area and the consumptive use of water by crops with several losses. Basic factors of the water requirements are the evapotranspiration of crops and the percolation in paddy fields. The consumptive use (evapotranspiration) was estimated based on many climatological factors and data of similar natured irrigation projects nearby due to the lack of measured data available for the Project. To determine the irrigation water requirements under the Project, the following definitions have been applied;

° Net water requirement (NWR)	Consumptive use of crops + percolation + Puddling water (for land preparation)
° Field water requirement (FWR)	NWR - Effective rainfall + Field losses
° Diversion water requirement (DWR)	FWR + Conveyance and operation losses

B. Consumptive Use of Crops

i) Evapotranspiration (ET)

The monthly evapotranspiration was estimated by applying the modified Penman Method. The climatological data on temperature, wind velocity and so on, recorded at Lopburi station, were utilized. As results of the estimates, the maximum value occurs in April by 6.7 mm/day with the minimum by 3.8 mm/day in September. The procedures and results of the computation in details are described in Appendix IV.

ii) Crop factors

The crop factors of the respective crops in their growing stages were taken from the projects in similar conditions in Thailand. The related crop factors are shown in Appendix IV.

iii) Consumptive Use

The consumptive use of crops can be estimated by multiplying the estimated evapotranspiration values by crop factors. The consumptive use of the respective crops was obtained as shown below;

(Unit: mm/day)

	Wet Season				Dry Season
	Paddy		Maize	Groundnut	Paddy
Month	L.V.	H.Y.V			H.Y.V.
Feb.	-	-	-	-	6.0
Mar.	-	-	-	-	7.9
Apr.	-	-	-	-	7.7
May	-	-	2.1	1.6	6.1
Jun.	-	-	1.9	2.4	-
Jul.	4.2	-	3.4	4.4	-
Aug.	4.0	4.0	3.2	4.2	-
Sept.	4.1	4.4	-	-	-
Oct.	4.8	4.8	-	-	-
Nov.	5.6	5.6	-	-	-

C. Percolation

The field percolations in the horizontal and the vertical directions was decided at 1.0 mm/day on an average taking into account the soil textures in paddy fields. Although there are no measured data in the Project Area, soils of the Project Area are generally rich in clayey properties, which seems to be comparatively small in percolation.

D. Water for Land Preparation

The water for puddling of paddy fields is required in addition to the consumptive use of crops. Taking into account the proposed cropping pattern and the present farm practices, land preparation water of paddy field was estimated at 200 mm both for wet and dry season croppings, and the required period for this work is fixed at 30 days. Detailed discussions are described in Appendix IV.

E. Effective Rainfall

The effective rainfall for the growth of wet season paddy is, in general, taken into their water requirements. There are four rainfall observation stations around the Project Area, that is, at Kaeng Khoi, Saraburi, Sao Hai and Rama VI barrage. Rainfall data at Muang Saraburi station was selected as a representative station based on the following;

i) It is located in the central part of the Project Area which extends in strip from east to west.

ii) The averaged annual rainfall in Muang Saraburi indicates very similar value to the averaged value of the four stations.

The effective rainfall was estimated by the following criteria in using the data obtained at Muang Saraburi.

Effective Rainfall (mm)

Crops	Effective Rainfall	Upper Limit of Effective Rainfall	
		One-month	10-days
Paddy	0.75 R*	200	70
Upland crops	0.75R	120	40

* R : Daily rainfall

In particular, the expected effective rainfall in the month of July, when the peak water requirement occurs during the land preparation period in the Project Area, is vitally important for irrigation planning and study on availability of water resources.

Results of the computation on the probability of effective rainfall during the said period, are summarized in the following table;

Probability of Effective Rainfall

(Unit: mm)

Return Period	Total Year	Wet Season (Jul-Nov)	July	July-1	July-2	July-3
1/2	890.2	564.4	133.3	41.4	51.2	33.4
1/3	848.8	533.5	120.1	32.6	32.2	23.9
1/5	812.1	505.5	108.8	25.9	20.7	17.3
1/10	775.7	477.2	97.9	20.2	12.9	12.3

F. Irrigation Efficiency

The irrigation efficiency is specified into the field efficiency, conveyance efficiency and operational efficiency. Based on this concept, the integrated efficiency was estimated by applying the data obtained from some experiences and researches under the conditions of concrete lined canals up to the sub-lateral canal system.

Irrigation Efficiency

Crop	Field Efficiency	Conveyance Efficiency	Operational Efficiency	Total
Paddy	0.70	0.90	0.95	0.60
Upland	0.60	0.90	0.95	0.51

G. Unit Diversion Water Requirement (Peak Period)

Taking into consideration the various factors above mentioned,

the unit diversion water requirements for the Project were estimated as tabulated below;

Table 4-1 Unit Diversion Water Requirement

Crop	Month	Return Period	DC (mm/day)	Re (mm/day)	We (mm/day)	Q1 (l/s/ha)	Q2 (l/s/ha)
Wet paddy	Jul.	1/2	6.5	3.3	5.4	0.63	1.26
Wet paddy	Jul.	1/3	6.5	3.2	5.5	0.64	1.26
Wet paddy	Jul.	1/5	6.5	2.1	7.4	0.86	1.26
Dry paddy	Mar.	-	8.9	-	14.8	1.72	1.72
Maize	Jul.	-	3.4	3.2	0.3	0.05	0.77
Groundnuts	Jul.	-	4.4	3.2	2.4	0.82	1.00

Note: Dc: Paddy crop: Land preparation + Percolation + Consumptive use
Upland crop: Consumptive use
Re: Effective rainfall
If: Integrated irrigation efficiency
We: (Dc - Re)/If
Q1: We/8.64
Q2: Dc/8.64 x If
Dc values of wet season paddy in the above table indicates the averaged water requirement both for the local varieties and the high yield varieties.

4.2.2. Existing and Proposed Irrigation Projects related to the Project

There are three existing irrigation projects and three NEA pumping irrigation projects being under construction that are closely related to the Project. The water resources for these areas are mainly the Pasak river and the Chainat-Pasak irrigation canal which diverts from the Chao Phraya river at Manorom head regulator.

The irrigated area and irrigable area are summarized as shown in the following table. (Refer to Appendix IV in details)

Table 4-2 Irrigated Areas and Irrigable Areas

(Unit: ha)

Name of Projects	Water Resources	Irrigation Acreage	Irrigable Acreage	Total
1. Kaeng Khoi - Ban Mo	Pasak			
1.1. Proposed NEA		-	1,489	1,489
1.2. Newly proposed		-	12,671	12,671
Sub-total			14,160	14,160
2. Sao Hai	Pasak	5,760	-	5,760
3. NEA projects	Pasak	-	1,743	1,743
Total (1 - 3)		5,760	15,903	21,663
4. Chainat-Pasak	Chao Phraya	127,840	-	127,840
5. Raphiphat	Chao Phraya and Pasak	110,000	-	110,000
Total (4 - 5)		237,840	-	237,840
Grand Total		243,600	15,903	259,505

4.2.3. Water Resources of the Project

The current runoff of the Pasak river and water utilization of Chainat-Pasak canal are briefly described as follows;

A. Runoff of the Pasak River

The Pasak river has a drainage area of about 14,500 sq.km. in strip extending in the north-south direction, and a heavy discharge fluctuation would be caused from uneven rainfall distribution in the basin and the smallness in the so-called basin storage capacity.

According to the records at Kaeng Khoi gauging station (S2) for 33 years from 1948 to 1980, an annual runoff is revealed at 2,288 MCM of which 2,053 MCM or 90 per cent of the total is discharged during the wet season covering six months from June to November. As is the case, it is considered that the runoff of the Pasak river during the wet season is abundant except July when the peak water requirement takes place, and there would be no negative effect on the irrigation water demand in the lower stream basin.

In the dry season from January to May, the discharge is only 177 MCM, eight per cent of the annual total, which makes it quite difficult to supply irrigation water for the Area.

The discharge for navigation in the downstream reach is released from the Barrage on request as well.

Ten day probable discharge of Pasak river at S2 station is illustrated in Figure 4-1.

B. Chainat-Pasak Irrigation Canal

Along the western boundary of the project area, the Chainat-Pasak canal is provided for diverting the water from the Chao Phraya river to the 128,000 ha service area, including Manorom, Chong Khae, Koke Katiem and Roeng Rang on the right bank of the canal. The Chainat-Pasak canal empties itself into the Pasak river at about one kilometer upstream of the Rama VI Barrage. There are four (4) regulators and 67 diversion structures provided along the Chainat-Pasak canal. Absence of a regular pattern in water distribution and lack measured data available on its discharge at diversion point, however, have not allowed to confirm the actual discharges of the canal during the term of this survey. Under the circumstances, actual irrigation water demands in each sub-project have also not been confirmed accurately.

The surplus discharge emptied into the Pasak river from the Chainat-Pasak canal together with the discharge of the Pasak river itself are diverted to Raphiphat canal through the Phra Narai regulator at the Rama VI Barrage to irrigate about 110,000 ha area.

As stated previously, the surplus discharge from Chainat-Pasak canal to the Pasak river is closely related to the water resources availability for the Project. Hence, it may be necessary to fix the water availability and acreage to be developed under the Project through carrying out a water balance study on various water sources and related service areas of about 260,000 ha as stated before. For the left bank areas of the Chainat-Pasak canal, no water is supplied in principle from the Canal because of the water management policy of the Government Agencies concerned and the limited water resources available in the Chao Phraya basin.

4.2.4. Study on Availability of Water Resources

A. Present Water Use by Related Projects

Table 4-3 shows the actual record on irrigation water supply in the related service areas for the period of four (4) years from 1978 to 1981. According to the table, the whole area can be irrigated in the wet season but it can cover only about 10 percent of the area in the dry season. As seen from the above, the cropping acreage in the dry season largely depends on the discharge of the Chao Phraya river, rainfall and the amount of water stored in the previous year in the reservoirs which have been constructed on the Chao Phraya river basin. As the discharge of the Pasak river, water source for the Project, is rather limited in the dry season, it will be necessary to look into a potential irrigation area under the Project through taking into account such the existing irrigation areas as commanded by the Cahinat-Pasak canal, Pasak river and Raphiphat canal. The location map of the related projects to presented in Figure 3-5.

B. Conditions for Water Balance Study

Conditions employed for the water balance study are described as follows:

i) Diversion water of Chainat-Pasak canal shall be represented by the inflow measured at the Manorom regulator and discharges from the tributaries existing in the left bank of the said canal to the Chainat-Pasak canal was accounted by using specific discharge of the Pasak river.

ii) The whole area concerned was roughly divided into three parts and the representative rainfall stations

were selected at Lopburi for Chainat-Pasak canal area, Muang Saraburi for the Project, Sao Hai and NEA Project and Wang Noi for Raphiphat canal area, respectively.

iii) The water requirements of respective areas were estimated based on the unit water requirement as discussed previously and the representative rainfall for each project area.

C. Water Balance Computation

Water balances during the period of 16 years from 1965 to 1980 have been computed for two cases, one for the whole related areas (hereinafter called case-1) and the other for the areas obtaining the irrigation water only from the Pasak river (hereinafter called Case-2). Cropping intensity in the dry season is taken by three cases 15, 20 and 30 percent of the cultivable land for the respective divided areas. The results of water balance computation are illustrated in Figure A.4.1-6 to A.4.1-10, Appendix IV.

C.1. Wet season

As the results of this calculation, the frequency in shortage in the month of July, when the peak water requirement occurs, has taken place in two years for both cases within 16 years period examined. If the month of July is divided into each 10-day period as the first, second and third decade, the frequency in shortage in the second decade occurred seven years for case-1 and three years for case-2, respectively.

The specified drought years are included in 16 years examined, as 1972 and 1977. Besides, intake discharges at Manorom regulator at

present has not been properly controlled for with actual water requirements with considering effective rainfall for the objective area.

In this connection, if the intake discharge from the Manorom regulator can be properly adjusted or controlled, it is considered possible to secure the required irrigation water for the Project Area with about 1/3 probability runoff from the Pasak river and effective rainfall for the respective divided areas.

C.2. Dry season

The summary of the computation results for each cropping intensity are as follows:

The consideration made in this study was based on the period for the last 10 years from 1971 to 1980 taking into account the tendency of dry season paddy plantation in the existing irrigation Project area.

i) 15% cropping intensity

Frequency in shortage has occurred for three years in the month of January and one year in the month of March, respectively (Refer to Figure A.4.1.-14, in Appendix IV). As mentioned previously, cropping intensity in the dry season has a great fluctuation depending upon the rainfall and the amount of water stored in the reservoirs in the previous year. Besides, it can be judged that there are some discrepancies between actual practices and this assumption on the crop calendar and cropping acreage during the examined years.

ii) 20% cropping intensity

Frequency in shortage has increased by three or four years compared with the case of 15% intensity in the month of January and March. However, if intake discharge at Manorom regulator can be well controlled to meet the water requirements for the respective growing stages, this intensity will be able to be adopted without any negative affects except the specified drought years like 1980 (Refer to Figure A.4.1.-15, in Appendix IV).

iii) 30% cropping intensity

The shortage has occurred almost every year in the month of January and March. Some shortage will occur, even with intake operation made at Manorom regulator could so as to meet the scheduled water requirements (Refer to Figure A.4.1.-16, in Appendix IV).

C.3. Conclusion

Based on the study results discussed in the foregoing paragraphs, it is recommended that the irrigation development under the present study shall conform with the standard of effective rainfall with about 1/3 probability together with the level of available runoff in the Pasak river, with which the potential service area could be expanded as large as possible.

On the other hand, a comprehensive study on water resources development in the Pasak river basin is to be commenced soon and more stabilized water discharge in the Pasak river is expected in the near future when a series of dams in the upstream basin is completed. Furthermore, under the Project, a rotational irrigation should also be introduced for land preparation period as coupled with proper guidances on water management for related farmers, so that the expected Project benefit can surely be generated as envisaged.

Finally, the cropping intensity both for the wet and dry seasons can be adopted 100 percent and 20 percent respectively for the proposed Project Area as well as the related projects on an average level. Therefore, the proposed irrigable areas of the Project are decided 14,160 ha (88,500 rai) for the wet season crops and about 2,800 ha (17,500 rai) for the dry season crops, respectively.

4.3. Irrigation Scheme

4.3.1. Study on Optimum Irrigation System

A. Basic Concept in Alternative Study

In comparative study on irrigation development plans, taking into consideration the prevailing hydrological conditions, topographic conditions and the other factors such as the Governmental policy for better control and distribution of the Chao Phraya water, etc., it has been primarily assumed that the water source available for the Project is the runoff discharge of the Pasak river only.

In view of the available water resources for the Project as discussed in the foregoing paragraph, the net irrigable area under the Project has been fixed approximately at 14,000 ha, and the Project boundary has been delineated taking into account such economic and technical factors as future national operation and maintenance of the Project facilities.

Based on the above-mentioned conditions, a case study has been made on the following basic considerations;

A.1. Delineation of the Project Boundary

For the most effective utilization of the limited water resources of the Pasak river, the following two cases could be considered in determining a potential irrigable area;

- The case to place emphasis on the central part of the Project Area which covers the largest area. In this case, irrigation water will be conveyed with a high water head, therefore, the irrigation area can be expanded to the maximum extent from Amphoe Kaeng Khoi, which is located at the eastern end of the Project Area, to the vicinity of the National Road No.3022 at the western most of the Project Area which has a highest elevation of 22 m.

- The other case that is originally planned by RID. In this case, the Project Area extends from Kaeng Khoi to the area located along the Chainat-Pasak canal at the western most of the Project Area.

A.2. Study on Pumping Scheme

Project Area is a narrow and long area extending from east to west along the Pasak river. The averaged head between the low water level in the Pasak river and the highest irrigation area is about 10 m (16 m at the maximum). From this topographic condition, the following two cases have been studied in determining the pump station sites and the layout of irrigation network.

The Case of One Pumping Station:

For this case, two pumping sites were selected, one about three kilometers upstream of Kaeng Khoi town and the other at Ban Huai Noi

about six kilometers upstream of Saraburi city is view of effective and economicaly water distribution to the whole Project Area. From Kaeng Khoi station water can be distributed to the whole area by a single gravity system. From Ban Huai Noi station water is divided to two irrigation systems, one for the high areas ranging from El 14 to 22 m and the other for the low areas of which elevation is below 14 m. The latter pumping station requires different pumping facilities, accordingly.

The Case of Two Pumping Stations:

In addition to the two pumping stations as stated above, Ban Nong Bo Phrong station is considered. In this case, the Nom Phu river, which joins the Roeng Rang river at the western end of the Project Area, shall be enlarged so as to utilize the back water dammed up by Rama VI barrage for irrigating the western part of the Project Area as well as the areas located along the Chainat-Pasak canal.

By the combination of the above-mentioned cases, alternative study has been conducted, and its alternative are summarized in Table 4-4. In consideration of the required suction head and fluctuation of the Pasak river water level, a vertical type mixed -flow pump has been proposed for each case.

B. Preliminary Cost Estimate for Construction Works and Operation and Maintenance

The construction cost consists of these for pumping stations with pump house and delivery pipes, main and lateral canal networks inclusive of appurtenant structures and land acquisition. The delineation of each alternative plan and the breakdown of cost are made in Figures A.4.2-1 to A.4.2-5 and Tables A.4.2-1 to A.4.2-6, respectively.

The summary of this comparison with O & M cost is shown in Table 4-5.

In order to conduct an economic comparison of the proposed five alternative plans, the present worth value of each alternative plan has been worked out by discounting the respective cost stream with the discount rate of 10 per cent for 22 years, assuming that the pumping equipment have a durable life of 20 years.

Table 4-5 shows the cost stream of each alternative plan consisting of the initial investment cost and operation and maintenance cost. As is clear in this table, the alternative plan 1-1 is the most advantageous in the aspect of required cost among the five.

C. Assessment of the Comparison and Conclusion

The comprehensive assessment is summarized as follows;

Alternative	Advantage	Disadvantage
1-1.	1. Operation and water control for pumping plant are easier than these in the cases of two stations	1. Operation and maintenance of main and laterals is rather difficult because the canal length of some routes is quite long.
	2. Foundation treatment of the station seems to have no problems.	2. Pump operation cost for lowlying area is comparatively high.

		3. Construction cost for both pump stations and canal networks is more economical than the other cases. Besides, O & M cost is not so much different from that of Cases 3-1 and 3-2.	
		4. There is no difficulty in diverting irrigation water from available water sources.	
1-2.	1. Even when an accident happens, water supply is easier than in the case of one station		1. Long delivery pipe-lines are required (Ban Nong Bo station)
	2. O & M cost for lowlying area can be saved to an extent since high and low lifting heads of pumps are operated		2. Diverting water from natural stream is difficult to some extent (Ban Nong Bo station)
			3. Construction cost is rather high due to the considerably long pipeline of about 6.3 km (dia 1,350 mm steel pipe)

2.	1. Construction cost of main canal facilities can be saved by providing the main pump system in the central part of the Project Area 2. The same as mentioned in Items 1 and 2 of the alternative 1-2 is noted.	1. The same reasons as said in Items 1 and 3 of the above 1-2 (dia 1,350 mm x 3.3 km x 3 rows)
3-1.	1. The same advantages as the alternative 1-1	1. Very similar short points to these of the alternative 1-1
	2. O & M cost is low in comparison with these for the other cases.	2. Future O & M will be difficulty to some extent due to the long main canal system of 48 km in total.
3-2.	1. Very similar to these of the alternatives 1-2	1. Similar disadvantage to these of the alternatives 1-2 and 2.

As discussed above, the alternative 1-1 can be finally adopted with the first priority from both technical and economic points of view, and the alternative 3-1 (original plan of RID) with the second priority.

Based upon the above-mentioned conclusion, the Project Area and boundary should be determined further taking into consideration the technical, economic and social aspects.