THE KINGDOM OF THAILAND

FEASIBILITY REPORT
ON
IRRIGATED AGRICULTURAL DEVELOPMENT PROJECT
IN
THE WEST BANK TRACT OF THE GREATER CHAO PHYA

(MAIN REPORT)

MAY 1977

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

The Japan International Cooperation Agency has performed the feasibility study on the Irrigated Agricultural Development Project in the West Bank Tract of the Greater Chao Phya in the Kingdom of Thailand for a period of five months since October 18, 1976 as part of technical cooperation service to the Kingdom of Thailand

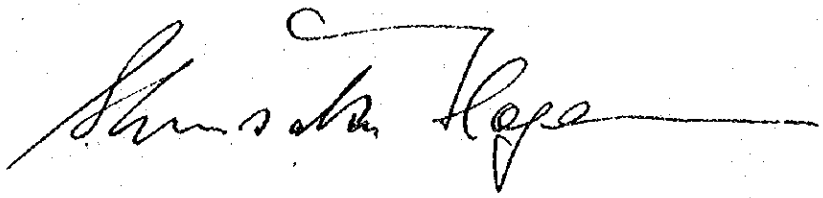
During this period, the survey team consisting of total ten experts, headed by Mr. Shigekatsu Watanabe, Adviser of Sanyu Consultants Inc., carried out field investigation and subsequent study in Japan

Hereby presented in the final feasibility report of the above proposed project based on the findings the team has attained.

I firmly believe that this report is worthwhile contribution to the social and economic development in the areas involved as well as promotion of friendship between our two countries.

I take this opportunity to express my hearty gratitude to the Government agencies concerned of the Kingdom of Thailand for their kind cooperation and assistance extended to the team, without which the survey work could not be completed so successfully.

May 1977



Shinsaku Hogen
President
Japan International Cooperation Agency

Letter of Transmittal

Mr. Shinsaku Hogen
President
Japan International Cooperation Agency

Dear Sir,

I have the honor to submit herewith our report on the feasibility study for the Irrigated Agricultural Development Project in the West Bank Tract of Greater Chao Phya, Kingdom of Thailand, of which the field survey was conducted for a period of two months from October 21 to December 23, 1976. The report was also made on the bases of various discussions held between the Thai government agencies concerned and the Mission.

The Mission has completed the feasibility study on farm level for the Irrigated Agricultural Development with land consolidation, covering about 12,300 hectares, out of 223,000 hectares of the whole project area located in the West Bank Tract of Greater Chao Phya about 30 km south-west of Ayutthaya City in the central part of Thailand, province of Ayutthaya.

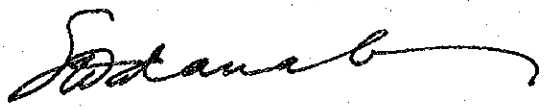
There are two remarkable characteristics of the Project. One is that the agricultural development with land consolidation is to be conducted in parallel with the agricultural land reform in accordance with the new policy of the Thai Government, thereby, the Government intends to distribute the farmers the reformed land, of which the productivity will be increased by the land consolidation and other supporting services.

The other one is that the polder dike system is going to be introduced for the first time in this country as a method of agricultural development. It might remain some technical and economic problems which require further studies, however, this system must be one of the best solutions to increase the agricultural production in such low-lying area.

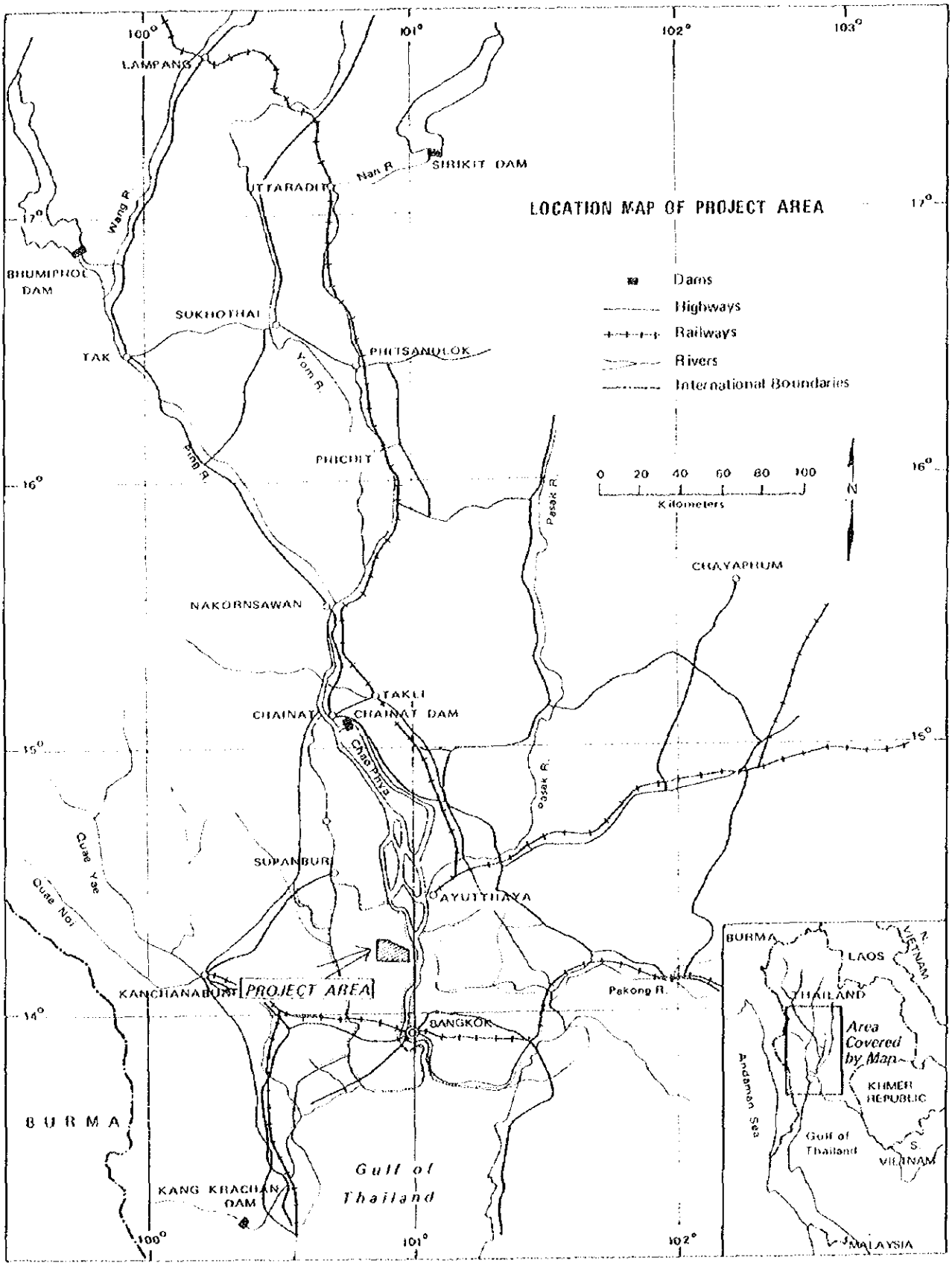
I sincerely wish that the successful realization of new method of agricultural development will never fail to give a greater effect to the future socio-economic development of this country and may be a good example to draw the attention of other neighboring countries.

Finally, I take this opportunity to express my deep gratitude to the Agricultural Land Reform Office, Royal Irrigation Department, Central Office for Land Consolidation, Ministry of Agriculture and Cooperatives, Department of Technical and Economic Cooperation, Ministry of Foreign Affairs (Japan), Embassy of Japan in Bangkok, Ministry of Agriculture and Forestry, Japan International Cooperation Agency, Advisory Group of the Project for their valuable assistance and cooperation extended us throughout the survey period and in the compilation of this report.

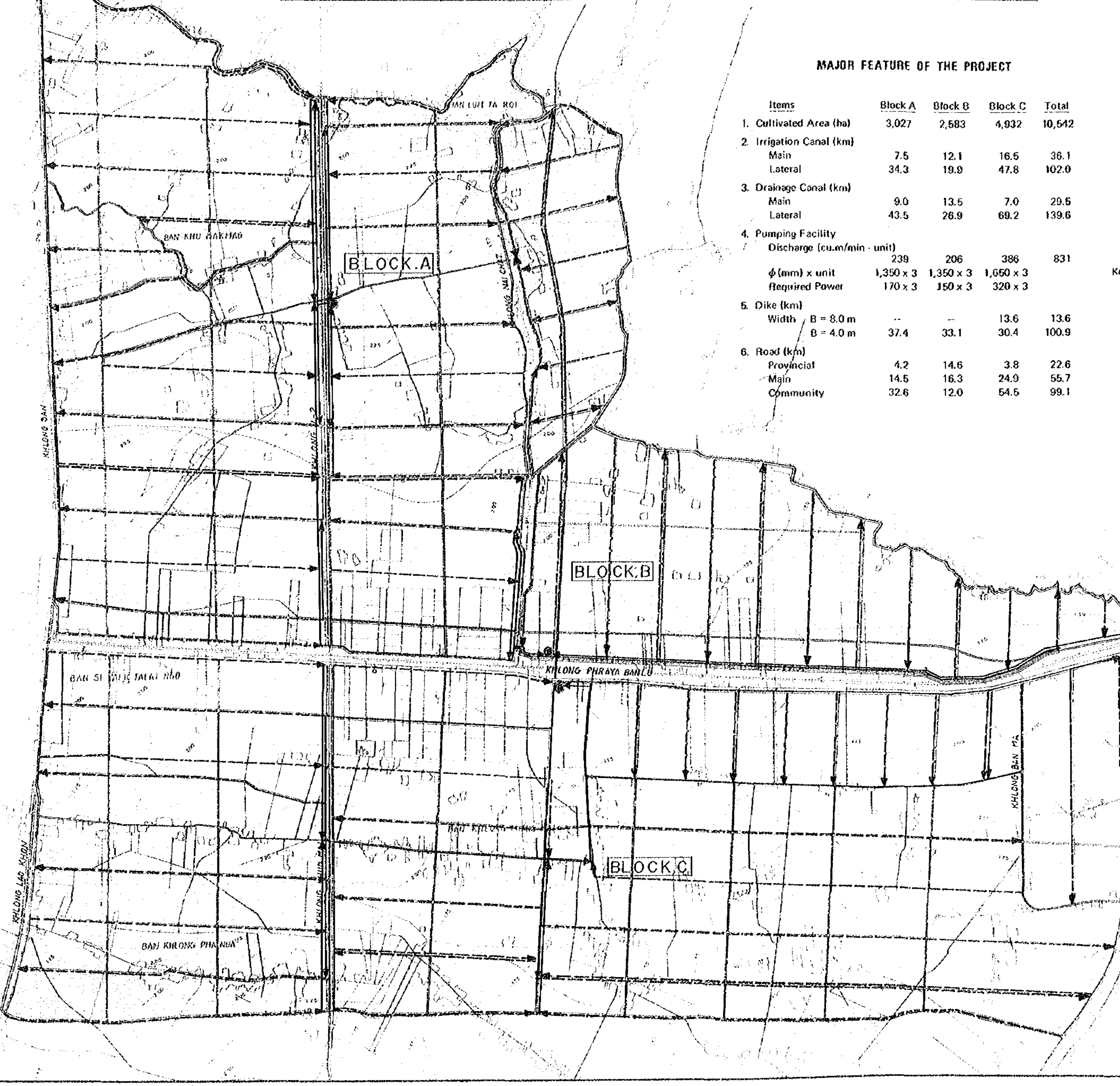
May 1977



Shigekatsu Watanabe
Team Leader
for Feasibility Study Project
on the IADP in the West Bank Tract
of the Greater Lower Chao Phya


LOCATION MAP OF PROJECT AREA
Dams
Highways
Railways
Rivers
International Boundaries
0 20 40 60 80 100
Kilometers
N
100°
101°
102°
103°
17°
16°
15°
14°
LAMPANG
UTTARADIT
Nan R.
SIRIKIT DAM
Wang R.
BHUMIPHOL DAM
SUKHOTHAI
TAK
PHITSANULOK
Yom R.
Ping R.
PHICHIT
Pasak R.
CHAYAPHUM
NAKORNSAWAN
TAKLI
CHAINAT
CHAINAT DAM
Chao Phraya
Osak R.
Qua Yae
Qua Noi
SUPANBURI
AYUTTHAYA
KANCHANABURI
PROJECT AREA
Pakong R.
BANGKOK
BURMA
Gulf of Thailand
KANG KRACHAN DAM
BURMA
LAOS
VIETNAM
THAILAND
Area Covered by Map
KHMER REPUBLIC
Andaman Sea
Gulf of Thailand
S. VIETNAM
MALAYSIA

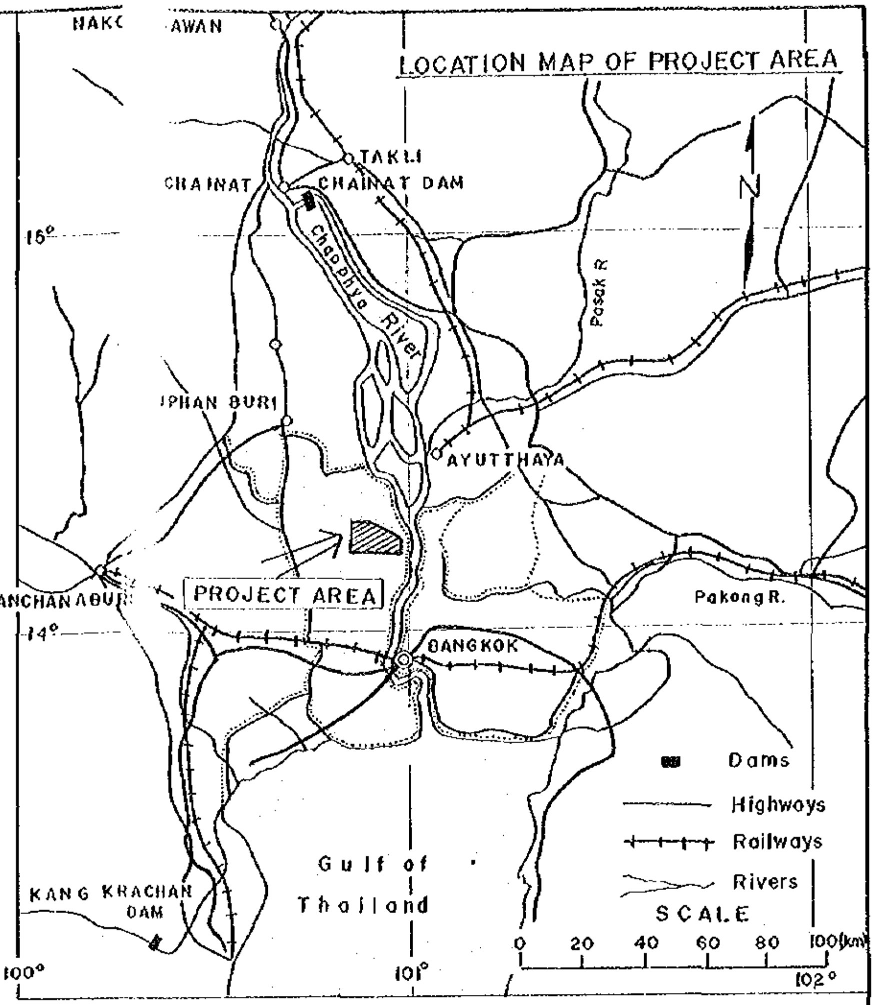
PROJECT MAP OF IRRIGATED AGRICULTURAL DEVELOPMENT



MAJOR FEATURE OF THE PROJECT

Items	Block A	Block B	Block C	Total
1. Cultivated Area (ha)	3,027	2,583	4,932	10,542
2. Irrigation Canal (km)				
Main	7.5	12.1	16.5	36.1
Lateral	34.3	19.9	47.8	102.0
3. Drainage Canal (km)				
Main	9.0	13.5	7.0	29.5
Lateral	43.5	26.9	69.2	139.6
4. Pumping Facility				
Discharge (cu.m/min · unit)	239	206	386	831
ϕ (mm) x unit	1,350 x 3	1,350 x 3	1,650 x 3	
Required Power	170 x 3	150 x 3	320 x 3	
5. Dike (km)				
Width B = 8.0 m	--	--	13.6	13.6
B = 4.0 m	37.4	33.1	30.4	100.9
6. Road (km)				
Provincial	4.2	14.6	3.8	22.6
Main	14.5	16.3	24.9	55.7
Community	32.6	12.0	54.5	99.1

LOCATION MAP OF PROJECT AREA



SCALE
0 10 20(km)

LEGEND

- Boundary of Project Area
- Existing Canal and River
- Proposed Pumping Station
- Main Irrigation Canal and Road
- Lateral Irrigation Canal and Road
- Main Drainage Canal
- Lateral Drainage Canal

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ABBREVIATIONS AND GLOSSARY

mm	:	millimeter
cm	:	centimeter
m	:	meter
km	:	kilometer
sen	:	Thai unit of length, 1 sen = 40 m
sq.cm, cm^2	:	square centimeter
sq.m, m^2	:	square meter
sq.km, km^2	:	square kilometer
MSM, $10^6 m^2$	:	million square meter
rai	:	Thai unit of area, 1 rai = 0.16 ha
ℓ, lit	:	liter
cu.m, m^3	:	cubic meter
MCM, $10^6 m^3$	:	million cubic meter
lit/sec	:	liter per second
cu.m/sec	:	cubic meter per second
lit/sec/ha	:	liter per second per hectare
m/s	:	meter per second
PPM	:	part per million
g	:	gram
kg	:	kilogram
ton,m.t	:	metric ton
EL	:	elevation above mean sea level
MSL	:	mean sea level
FWL	:	full water level
HWL	:	high water level
sec.	:	second
minu.	:	Minute
hr.	:	hour
min.	:	minimum
max.	:	maximum
%	:	per cent
No.	:	number
°C	:	degree centigrade
°F	:	degree fahrenheit
Cl	:	chlorine
HP	:	horse power
ET	:	evapotranspiration
N	:	nitrogen
P	:	phosphorus
K	:	Potassium
HYV	:	high yield rice variety
O & M	:	operation and maintenance
IRR	:	internal rate of return
B/C	:	benefit cost ratio
FY	:	fiscal year

MOAC	:	Ministry of Agriculture and Cooperatives
ALRO	:	Agricultural Land Reform Office
RID	:	Royal Irrigation Department
CLCO	:	Central Land Consolidation Office
BAAC	:	Bank for Agriculture and Agricultural Cooperatives
PEA	:	Provincial Electricity Authority

Cahangwat	:	province
Amphoe	:	district
Tambon	:	sub-district
Muban	:	village
Mae Nam	:	large river
Nam	:	river
Khlong	:	canal
Lam	:	small river
Kwae	:	tributary
Huai	:	creek

฿	:	Baht, ฿1 = approx. $0.05
$	:	Dollar, US$ = approx. ฿20

SUMMARY, CONCLUSION AND RECOMMENDATIONS

A. SUMMARY

1. The Project Area about 70 km north from Bangkok is located in the Amphoe Lad Bao Laung in Changwat Ayutthaya, included in the West Bank Tract which lies on the right side of the Chao Phya river, and its area is about 12,300 ha.

The topography of the Project Area is very flat with an average slope of about 1/20,000 from the north-west to the south-east. The elevation ranges from 1.75 m to 2.25 m above mean sea level.

2. The major rivers in the vicinicy of the Project Area are the Chao Phya river and the Suphan river which is the tributary of the Chao Phya river. These rivers run through the Central Plain of Thailand forming very gentle slope and empty themselves into the Gulf of Thailand. The maximum run-off discharge of the Chao Phya river is recorded at 6,500 cu.m/sec in 1942 at the immediate downstream of the Chao Phya dam, and an annual mean run-off discharge is 22.6 x 10^3 MCM, 16.6 x 10^3 MCM in the wet season and 6.0 x 10^3 MCM in the dry season respectively.

3. The climate around the Project Area is of tropical savanna type and is characterized by two seasons, the wet season from May to October and dry season from November to April. The average temperature throughout the year is 28.2°C. There is almost no seasonal difference in temperature. The relative humidity and sunshine hours are 73 per cent and 7.3 hours per day at annual mean. The average annual rainfalls in the area are about 1,300 mm, of which 88 per cent (1,150 mm) falls in the wet season, but these annual rainfalls vary significantly by year, for instance, 1,020 mm to 1,940 mm at Sing Ha Nat station.

4. The distinctive hydrological characteristics in the West Bank Tract allow the farmers in the Project Area to carry out the flooding irrigation and to cut off and store the peak flood discharges by conservation

areas for the whole lower basin of the Chao Phya river. No irrigation system exist in the Project Area except the main irrigation canals, so flooding irrigation has been practiced for the wet season paddy cultivation. These facts lead to keep water in the field deep for about three months from mid-September to mid-December, and an average water level during this period is 2.60 m above mean sea sevel, while the maximum water level is 3.01 m in 1975.

5. Fairly high standard provincial road leading to Ayutthaya via Sena passes outside of the Project Area, and no means of transportation to approach the Project Area from Sena is available in the wet season although one provincial road six to eight meters wide has been constructed by the local government.

No systematic farm road networks are seen in the whole Project Area. This hamper not only the transportation of living materials, agricultural inputs and farm products but also restricts communication between villages. All of the transportations have been made by water.

6. The population density of the Changwat Ayutthaya is 216 per sq.km and that of the Amphoe Lad Bao Laung is 120 per sq.km in 1972. The Project Area and its neighborhood have been left behind the progress up to now; consequently, the population density of 96 per sq.km in 1976 is considerably lower than the average one described above as a whole. The major constraints for development of thinly populated regions in the Changwat are the lack of infrastructures such as road networks and irrigation and drainage facilities on the on-farm level due to low-lying area.

7. The inhabitants in the Project Area get the domestic water from rivers and rainfall. In the dry season, however, they have suffered from extreme water shortage and poor water quality, and also have suffered from various epidemics. The Department of Health recently had a plan to provide the water supply facilities consisting of pumps and water tank in the country, but the plan does not include installation of relevant facilities in the Project Area.

8. The irrigation and drainage systems in the on-farm level have not been established yet in the Project Area, except the main irrigation canals and waterways, Khlong San, Khlong Khud Mai, Khlong Nai Chat and Khlong Phraya Banlu, which had been constructed by the RID. These main canals and waterways are used for irrigation, drainage, navigation, water source for living water, and so forth.

The most serious constraint to agriculture in the Project Area is the absence of on-farm facilities and shortage of water in the dry season. Although, in the wet season, flooding irrigaton has been traditionally carried out in keeping the water level high with regulators, floods at the upper reaches of the Chao Phya river have given serious difficulties and damages to standing crops and infrastructural facilities such as provincial roads, due to insufficient cross-section of the river, no effective protection dike nor adequate drainage systems in the low-lying area. It is reported that the maximum flood damages was estimated at $1.2 million in 1975 in the both Chao-chet Bangyeehon and Phraya Banlu Irrigation Projects, in which the Project Area is located.

On the other hand, in the dry season, irrigation is available only in the limited areas along the main irrigation canals and some waterways due to the absence of on-farm irrigation facilities and about one meter lower water level of the canals than the ground surface. For irrigation, the farmers are using wooden water lifting device made by themselves.

9. According to the topographic conditions of the area, the cultivated area of about 10,070 ha out of the total Project Area of about 12,300 ha can be classified into three types of land categories: paddy fields 8,950 ha, upland fields 350 ha and fallow lands 770 ha. Paddy fields are divided further into the following three areas.

- Wet season broadcasting paddy area

Wet season broadcasting paddy has been grown in the relatively high area located far from the canals and the cultivation method is characterized by the broadcasting and extensive flooding irrigation prevailing in the whole Chao Phya river basin. This kind of paddy is grown in 31 per cent of the total paddy fields.

- Wet season transplanting paddy area

Wet season transplanting paddy has been recently introduced in parallel with the construction of main irrigation canals and waterways. Due to the absence of on-farm irrigation and drainage facilities, its cultivation area is, however, limited to the area along canals where the pumping irrigation is easily made. This kind of paddy is grown in 28 per cent of the total paddy fields.

- Dry season transplanting paddy area

Dry season transplanting paddy is grown in the limited to the low-lying areas where individual farm household can supply waters of existing main canals or waterways to their paddy fields with low-head pumps. This kind of paddy is grown in 41 per cent of the total paddy fields.

10. The Project Area is covered with brackish alluvial soil, and there exist three soil series, Bang-Khen, Ayutthaya and Sena soil series. These soils are suitable for rice cultivation, but for upland cultivation, some drainage improvement and soil amendment by application of lime and organic matters should be made. Water percolation rate is very low at less than one millimeter per day.

The most extensive cropping pattern has been practiced in the paddy fields without double cropping of paddy in the Project Area at present, but in a part of the area, the intensive cultivation of citrus, mainly sweet oranges and vegetable is partially performed. The average yield of wet season broadcasting paddy is low, 1.6 tons per hectare in

dry grain paddy, because of traditional farming practices such as flooding irrigation and lack of farm input and agricultural supporting services. The average yield of transplanting paddy is relatively high, especially the dry season transplanting paddy. The average yield of which is 3.0 tons per hectare with effective fertilizer application, whereas that of the wet season transplanting paddy is 2.2 tons per hectare.

11. The average farm size in the Project Area is estimated at about 3.8 hectares per household, but their farming areas range from one to twenty hectares and this figure is rather high, as compared with that in the Changwat Ayutthaya.

Regarding the land tenure in the Project Area, farmers engaged in farming by themselves in the area less than eight hectares (50 rai), which are deemed to be area out of application of the land reform occupy 89 per cent of the total farmers, and their areas are of 59 per cent in proportion. The areas to be released by the land reform are estimated to be about one fifth of the Project Area.

12. The networks of agricultural extension services in the Project Area have already been set up by the responsibility of the Department of Agricultural Extension, but the number of field extension workers and necessary facilities are insufficient. Cooperative activities in the area are inactive yet, although the Ministry of Agriculture and Cooperatives intends to strengthen new agricultural cooperatives to serve in input supplies, credit and marketing in the Amphoe level. But at present most of the farmers in the Project Area are not yet eligible to this advantageous program, and all of the supplies of input materials, such as seeds, fertilizers and agricultural chemicals are handled by dealers and agents at Sena and Ayutthaya or some land-owners. Under the conditions, the Amphoe Lad Bao Laung Agricultural Cooperative takes responsibility only in credit.

13. The Project aims to increase agricultural production, create the employment opportunities and improve environment. In order to achieve these objectives and to yield benefit quickly in the whole Project Area, following components should be envisaged by phasing manner together with land reform.

Civil Works

i) On-farm development:
the construction of on-farm roads, irrigation and drainage ditches.

ii) Irrigation and drainage:
the construction of irrigation and drainage facilities such as canals and pump stations.

iii) Flood protection:
the construction of flood protection dikes.

iv) Roads: the construction of road networks including rehabilitation of the existing provincial roads, etc.

v) Drinking water:
the establishment of water supply facilities for inhabitants.

Agricultural Development

vi) Pilot farm:
the establishment of one pilot farm of about 500 ha for intensive guidance of irrigated agriculture.

vii) Irrigated agriculture:
the introduction of new agricultural techniques with double-cropping of transplanting paddy of high yield varieties under well-controlled water management.

viii) Supporting services:
the provision of necessary extension and training services - strengthening of input supply, credit, marketing and agricultural processing.

ix) Institutional arrangement:

the establishment of farmers' organizations including those for operation and maintenance and the agricultural cooperatives.

x) Rural community development:

the execution of rural community development including environmental improvement such as village roads, drinking water supply and so forth.

14. Seven (7) alternative studies consisting of with and without dike plans have been made to decide the optimum scale of sub-project area as well as adequate irrigation and drainage systems in the Project prior to the Project formulation, and after due consideration to the economical and technical viewpoints, the plan with protection dike was proposed as the most suitable plan of the seven. According to the plan, the Project Area will be divided into three blocks based on the topographic conditions, the existing main canals and administrative boundaries, and the water managements for irrigation and drainage in each block will be made sufficiently by pumps to be installed.

15. Land consolidation works to provide infrastructural facilities such as roads, irrigation and drainage canals including on-farm level will be prerequisite for the Project to achieve the increase in agricultural production. In the Project, the land consolidation works are planned to be carried out in parallel with land reform, the Government policy, to meet the irrigated agricultural farming with new paddy varieties and mechanizations introduced.

In order to materialize the plan described above, careful attention have been paid to the decision of the land reparcelling and the size of plot.

As the result of case studies in the aspects of earth moving works, construction cost and reduction ratio of land, one rotation block is decided at 38.4 ha (600m x 320m x 2), which will be divided

into 48 plots. The one plot should cover 0.8 ha, length of run of plot 160 m and width of plot 50 m. Irrigation water supply during the puddling period is to be made in the rotation of one plot per day in each rotation block of 38.4 ha.

16. The eight meters width existing provincial roads, which require some rehabilitation, will be used for the chief means of transporation of construction materials and smooth execution of progressive farming works after completion of the Project. Besides these roads, main roads, community roads and on-farm roads will be provided as a mean of facilitating operation and maintenance of the irrigation and drainage facilities and transportation of agricultural inputs and products.

17. Major facilities to be provided in the cultivation area of about 10,540 ha are irrigation and drainage canals including on-farm ditch, pumping station, dikes and roads. The density of these facilities is as follows: irrigation canals, 44.4 m/ha; drainage canals, 49.7 m/ha; three pumping stations, dike, 10.9 m/ha; and roads, 55.2 m/ha. The reduction ratio of land is computed at 6.6 per cent with these facilities, excluding the area for provincial roads, dikes and borrow pits.

18. The inhabitants have been suffering from insufficient drinking water especially in the dry season, so water supply facilities consisting of deep well, pumps, storage room, clean well, storage tank, etc., are to be constructed in each production unit, totalling four units. The total daily demand for the domestic water is estimated at 800 cu.m/day on the assumption that daily consumption of water is 50 lit/day per capita.

19. A pilot farm covering about 500 ha equipped with all the necessary infranstructural facilities is planned in the Project Area at the central part of area along Phraya Banlu canal for demonstrating the Project itself to the farmers and staffs concerned, prior to the commencement of the implementation of the project.

20. After the implementation of the Project, the area of about 10,540 ha, which is equivalent to 86 per cent of the total gross area of about 12,300 ha will be developed to the cultivated area, 9,540 ha of paddy fields with double cropping for the both seasons and 1,000 ha of upland fields. In the paddy fields, high yield varieties such as RD series with short growing period and high sensitivity to fertilizers will be grown in whole paddy fields, and in the upland crops such as vegetables and fruits, mainly citrus, are to be introduced.

Total productions of the paddy rice are estimated at about 84,920 tons per annum, which are created by the yield of 4.2 tons/ha in the wet season and 4.7 tons/ha in the dry season (average 4.5 tons/ha), and about 70,300 tons of paddy are to be increased after the Project. On the other hand, 19,350 tons of upland crops and 15,000 tons of fruits will be created. With these land use and cropping pattern, cropping intensity amounts to 200 per cent, whereas the existing one is 67 per cent as a whole.

Besides these increased benefit by crops, land consolidation with flood protection dikes will enable farmers to introduce the animal husbandry and fresh-water fish culture in the area.

21. On-farm development in the Project makes it possible to have sufficient farm management of crop cultivation by the introduction of farm mechanization. For the time being, simple farm mechanization based on the combination of heavy and hand tractors will be introduced throughout the Project Area, although the integrated mechanization system will be introduced in far future. As a result, the farm management in the scale of four hectares of the cultivated area per farm household on an average will be performed by available labor force in the Project Area plus some amount of temporary hired-labors outside the Project Area at the peak labor requirements in the periods of the land preparation, transplanting and harvesting. During such periods, 1.3 times of the present available labor force in the Project Area are required.

22. In the agri-institutional aspect, it is considered highly recommendable to organize the farmers' organization, such as farming group, management group and production unit under the Agricultural Land Reform Cooperatives (ALRC) to be newly organized. Farming group consisting of about 20 farm households are for water users' unit in the area of two rotation blocks, 76.8 ha (38.4ha x 2), and about four farming groups are integrated as one management group, which covers the area of about 300 ha and consists of about 80 farm households, equivalent to about one Muban. Furthermore, Production unit will be organized as the branch office of ALRC as well as one unit of production.

The farmers' organization is to function for water management, operation and maintenance of facilities, farm management and supporting services such as input supply of necessary materials, credit & marketing and processing. At the same time, agricultural extension services are to be strengthened by newly establishing ALRC. The ALRC will be fully responsible for the execution of the above mentioned, and will also function as their extension services through the aforesaid farmers' organization.

All of the above-stated activities are to be well integrated, otherwise the production increase which is the ultimate target of the project would not be attained. For the realization of the aforesaid integration, it is considered to be essential to organize the Joint Coordination Committee at the national level to secure smooth communication and execution of all matters concerned.

23. The construction works of the Project will be commenced in Fy 1979 after completing the final design in Fy 1978. Total construction periods for the Project are six years from Fy 1978 to Fy 1983, including final design.

24. The Agricultural Land Reform Office (ALRO) will be the executing agency of the project. And, it will be responsible for the design, supervision and construction of the project works, and will coordinate the activities of all the relevant government agencies and the regional

administration in connection with the implementation of the Project.

Changwat Ayutthaya Agricultural Land Reform Office will be strengthened as a government's force for construction and on-site coordination of the Project. The office will be headed by a Project Manager appointed by the ALRO. After the project is completed, the entire project works will be turned over to the Changwat Ayutthaya Land Reform Office. And the responsibility of operation and maintenance of all irrigation and drainage systems will fall on the ALRO to be newly organized.

25. Total initial investment costs of the Project amount to US$ 36,200,000, of which US$18,560,000 will be a foreign currency component and US$17,640,000 will be an equivalent local currency component.

The economic benefits of the Project will occur from increase in yields of both paddy and upland crops as well as the increase of cropping intensity. Total net agricultural benefits have been estimated at about US$10.0 million annually at full development stage. The economic investment costs of the Project have been estimated at about US$25.2 million. The internal rate of return of the Project has been calculated at 16.0 per cent. Besides the direct benefit obtained from the Project as mentioned above, the following indirect benefit would also be created from the Project, that is, saving of US$14.1 million of foreign currency due to 45,940 tons of rice exported and creation of 1.6 million man-days of employment opportunities of labor per annum.

26. After completion of the Project, the net income of average farmers having the paddy fields of four hectares will be increased to about 50,790 Baht per year while their present income amounts to 7,810 Baht.

B. CONCLUSION

High priority is given to this Project in the Fourth Five-Year Plan of the National Economic and Social Development in Thailand. The Project with distinguished characters aim to develop the irrigated agriculture in the area of about 12,300 ha for quick yielding of the benefits, to level up the living standard of people, and to further the regional development.

It is concluded that the Project is found to be technically feasible and economically viable.

C. RECOMMENDATIONS

For the subsequent study and final design of the project, the following items are recommended:

(1) The feasibility study was conducted only for the area of about 12,300 ha out of the vast West Bank Tract of the Chao Phya river covering an area of about 223,000 ha. Various problems were encountered during the course of the study, and it was very difficult to form conclusions in each field of meteorology, hydrology, irrigation, drainage, flood protection, farm management, transportation and living environmental improvement, etc. based on the limited investigation and study.

However, we are confident to say that we have drawn up one of the best plans practicable in this stage, and that the plan formulated will be valuable to the future development in the whole West Bank Tract, if the plan is materialized as a pioneer project.

It was pointed out at the meeting held between the Government officials and the Mission that the proposed plan to construct dikes in order to realize high yield paddy cultivation in both the dry and wet seasons may cause an ill-effect to the lower basin to an extent. We gave it a satisfactory explanation that, so far as this plan is

concerned, the ill-effect to the lower basin is negligible, if any. However, if the agricultural development with dike is carried out one by one in the West Bank Tract, it will cause some effects on the lower basin inclusive of Bangkok.

Under the circumstances, it would be prerequisite to formulate a master plan at the earliest possible time for the further development of the West Bank Tract based on sufficient studies in respect of water utilization including the construction of dams on the upper reaches of the Chao Phya river for irrigation, municipal and industrial water supply, especially for flood control in the wet season as well as in respect of the social development such as river improvement and road and navigation systems improvement, in addition to the studies for the development in agricultural sector so that the priorities in development will be made clear.

(2) For carrying out the final design of the project, following surveys and investigations would be necessary.

- Topographical survey of the whole Project Area and drawing up the map of 25 cm contour interval (1/4,000 or 1/5,000)

- Cadastral survey for the Project Area

- Longitudinal and cross-sectional surveys of the existing main canals in the Project Area

- Core boring at the proposed site of main facilities

(3) In addition, soil survey and chemical analysis shall be made at sample spots in the whole Project Area which is selected at every 30 - 50 ha and land classification map indicating land capability and soil suitability for crops to be introduced shall be prepared based on the result of survey.

(4) The Irrigated Agriculture Development Project under the MOAC should be organized by experienced engineers for the execution of the Project.

(5) It is strongly recommended to establish the Agricultural Land Reform Cooperatives under the Project for promoting water management and operation, extension services, farm mechanization and so forth.

(6) For quick yielding the agricultural production in the on-farm development project, it is important to provide soonest possible physical infrastructures such as farm roads, on-farm ditches for irrigation and drainage, etc. But it is much more important to make various legal prearrangements before implementation of the construction works, such as establishment of the practical organization involving farmers through cooperatives, associations and other groups. And also the organization should be established firmly for smooth execution of local financing aid and coordination for the Project.

(7) The Coordinating Committee for Irrigated Agricultural Development Project should be established for the implementation and cooperation of the Project.

(8) Decision of location of pumping facilities for village water supply should be made based on the result of investigation for both water quality and quantity to expect the effective use of facilities.

CHAPTER I. INTRODUCTION

The Government of Thailand has made a request to the Government of Japan for cooperation to accelerate the implementaton of related projects. Since then, the Government of Japan has dispatched several missions to make survey of the projects as well as to have deliberate discussion in positive manners. Finally, the Mission, headed by Mr. Shigekatsu Watanabe, has come to conduct the Feasibility Study on the Irrigated Agricultural Development in the West Bank Tract of the Greater Chao Phya Project, Ayutthaya, which was selected as the first promissing project in compliance with the Agricultural Land Reform Act.

This Final Report has been prepared by the Mission in accordance with the scope of work for the Feasibility Study, of which outline is summarized as shown below;

i) to examine and evaluate all the data and information available on the Project Area including its vicinities, to carry out necessary supplementary studies, and to assess the overall development potentials of the proposed area;

ii) to draw up an irrigated agricultural development plan for the Project Area which includes provision and improvement of necessary rural and agricultural infrastructures and supporting services;

iii) to suggest an implementation program including the proposed modes of implementation, organization, institutional arrangements, phasing, and a time schedule;

iv) to examine the need of consulting services for implementation of the Project, and propose the framework of such services with expertise, assignment schedule, outlines of terms of reference, etc. The proposal should include approximate costs of consulting services required;

v) to work out the project investment costs required, inclusive of a breakdown into foreign and local currency components, taking into account the alternative modes and schedule of execution for project works and other related activities.

vi) to complete the economic analysis of the development project in accordance with standard procedures internationally accepted, and to submit the final feasibility reports including a definite project proposal in an appropriate form for immediate appraisal and implementation;

vii) to make recommendations, in its final report, on preparatory works for implementation of the project and other necessary measures to be taken by authorities concerned for smooth implementation and quick accrual of the project benefits;

viii) to assess the need of a pilot farm scheme in the project area, and to locate possible site for it;

In compliance therewith the mission has completed the feasibility study in the preliminary level for the Irrigated Agricultural Development with land consolidation, the main component of the Project, in about 12,300 ha in the West Bank Tract about 30 km southwest from Ayutthaya city at the central part of Thailand.

The report covers the results of field studies carried out by the Mission from October 21 to December 23, 1976, and also incorporates all the revisions in respect of the results of discussion meeting held between the Government of Thailand and the Mission on November 19 and December 1, 1976, and also of the Government's comments on the study.

The following tabulates the Advisory Group, Mission Members and Counterpart personnel assigned to the Project.

Advisory Group Assigned to the Project

1. Chief Adviser Mr. Tatsuo Asahara	Director of Design Div., Construction Dept., Agricultural Structural Improvement Bureau, Ministry of Agriculture and Forestry (M.A.F.)
2. Adviser (Land Consolidation) Mr. Susumu Ando	Senior Technical Adviser, Land Improvement and Consolidation Div., Construction Dept., Agricultural Structure Improvement Bureau, M.A.F.
3. Adviser (Agronomy) Mr. Toshio Yamamoto	Deputy Director of Resources Div., Planning Dept., Agricultural Structural Improvement Bureau, M.A.F.
4. Adviser (Agricultural Economy) Mr. Saburo Fukuoka	Deputy Director of Planning Div., Planning Dept., Agricultural Structural Improvement Bureau, M.A.F.
5. Adviser (Economy) Mr. Tai Yamamoto	Deputy Manager 2nd Div., Economic Research and Technical Appraisal Dept., The Overseas Economic Cooperation Fund.

Mission Members Assigned to the Project

1. Team Leader Mr. Shigekatsu Watanabe	18 Oct. - 25 Dec., 1976
2. General Coordination Mr. Toshitake Nakayama	18 Oct. - 4 Nov., 1976
3. Irrigation and Drainage Mr. Seiji Takeuchi	20 Oct. - 25 Dec., 1976
4. Meteorology and Hydrology Mr. Yasuo Matsubara	20 Oct. - 20 Dec., 1976
5. Land Consolidation Mr. Hideo Hiratsuka	20 Oct. - 25 Dec., 1976
6. Design of Facilities Mr. Masayasu Sato	20 Oct. - 20 Dec., 1976

7.	Construction Program Mr. Yoshiteru Tsunoda	20 Oct. - 25 Dec., 1976
8.	Rural Development Mr. Tatsuo Hamajima	1 Nov. - 20 Dec., 1976
9.	Agronomy Mr. Yasunori Hasegawa	20 Oct. - 25 Dec., 1976
10.	Agro-Economy Mr. Koki Nakamura	20 Oct. - 25 Dec., 1976

Counterpart Personnel Assigned to the Project

1. Coordination & Administration
   - Mr. Charin Atthayodhin
   - Mr. John Boonlu
   - Mr. Kangwang Dhephasadin Na Ayutthaya

2. Planning and Design
   - Mr. Suraphol Phetlom

3. General Affairs
   - Mr. Pitipong Pungbun Na Ayutthaya
   - Mr. Chalermthep Ratanaprayooh

4. Hydrology
   - Mr. Damrong Jaratwat
   - Mr. Ammuey Somsin

5. Geology and Soil
   - Mr. Danai Triyadhen

6. Irrigation and Drainage
   - Mr. Maitri Poolsup

7. Land Consolidation
   - Mr. Prateep Soampong
   - Miss Somsri Isarasakdi

8. Design Engineering and Civil Engineering
   - Mr. Maitri Poolsup
   - Mr. Surathep Kowangoon
   - Mr. Kamol Toleb

9. Agronomy
   Mr. Danai Triyadhen
   Mr. Krairirik Chaliengratchai
   Mr. Songpol Suvannadabbe
   Mr. Pradit Ritrungdej

10. Agro-economy
   Mr. Tasanapong Ettakkapark

11. Rural Development
   Mr. Damrongsak Tasanasanta
   Mr. Wittya Tirananon

The data which have been used for the Feasibility Study are listed in Appendix 1-2.

CHAPTER II. ECONOMIC AND SECTORAL BACKGROUND

A. National Level

The Kingdom of Thailand, having a territory of about 51,400,000 ha, is situated in the central part of the Indo-China peninsular. More than a half of the country is covered by forests, and about 18,000,000 ha, equivalent to 35 per cent of the entire national land, are used for agricultural purpose. The agriculture in Thailand is much blessed with natural conditions as well as natural resources.

With vast land and abundant water resources and in the climate of tropical monsoon type, Thailand has been predominantly an agricultural country. To say the least, before the end of World War II, the national economy of this country was of the monocultural agricultural country. However, the movement for independence and self-supporting national economy in neighbouring countries exerted a great influence on the economy of Thailand whose structure was quite similar to that of colonized countries though Thailand has never been a dependency.

The trend toward the industrialization became active at the beginning of the 1960s due to the crisis of the monocultural economic structures and rapid increase of population, both of which had been steadily accelerated since the 1930s, in addition to the new trends in neighbouring countries mentioned above. Under the circumstances, an average cultivated land per farm house-hold decreased to a considerable extent, and especially it was noteworthy that the commercialism penetrated with breathless speed into rural areas, and people who had hardly concerned with currency system were involved in the commercial transactions. The penetration of commercialism carried into the rural areas modernized consumable and durable goods and incorporated people into new life with these goods as their daily necessities. However, it was the existing conditions that most house-holds suffered from this new situation. Some found it hard to pay back even their basic living necessities they purchased. Even farm machinery, fertilizers and agricultural chemicals could not be the exception. Such economic situations

have caused the cityward migration of farmers. And there appeared the new social conflicts of "the municipal and rural" and well as "the agriculture and the others including industrial and service sector" in Thailand.

The oil crisis in 1972 formed a big turning point in the industry and economy of Thailand as in the other countries in the world, and the attempt for industrialization aiming at the self-supporting economy was temporarity held up. On the other hand, the social conditions of Thailand at that time made it necessary to take some urgent measures for rehabilitation of rural economy. Thus, the agriculture was focused as one of the most important sectors for the rehabilitation of the national economy of Thailand.

The national income of Thailand has been mostly supported by its agricultural production. About one-third of the foreign exchange earnings depends on the export of agricultural products even now. In spite of the importance of the agriculture in the national economy, the rate of agricultural production in the gross national production has recently decreased to a considerable extent as indicated by the records of 34 per cent in 1966 and 28 per cent in 1974. This decrease means a remarkable growth of non-agricultural sectors especially in the industrial and service sectors as the result of the past 15 years' nation-wide effort for the development in the above-mentioned sectors. It is noted that, in spite of the decrease of the rate, the agriculture is still the source for supporting the 42 million, about 80 per cent of a total population in Thailand. In this respect, it is anticipated with fear as a result of a simple calculation in respect of the population growth that Thailand, an exporter of paddy rice of about 1.5 million ton per annum at present, has a possibility to be degraded to an importer of the same within a decade due to the continuous population growth with an increasing rate of about 3 per cent in spite of the effort in population planning.

The expansion of industrial production, which is now sluggish by conquering every problem to be faced to, will be one of the key moves

for future development of this country. However, the national consensus arrived at a conclusion that the rehabilitation and strengthening of the agricultural sector should be given the first priority especially in the social and economic aspects of this country.

The increase of agricultural production has been attained mainly by expansion of arable lands in the past, but this way of agricultural development has been no more practicable due to the fact that most of the land available for crop cultivation has been already developed and there is no land suitable to be reclaimed. Under the circumstances, the introduction of modernized and intensified farming has been performed recently under the new policy for increasing agricultural products.

Along with the policy, the Land Consolidation Act was enacted in 1973, and furthermore, the Agricultural Land Reform Act and the other related laws and regulations were enforced to be the first step in solving the social and economic problems and rebuilding the rural societies.

The Governmental policy for the agricultural land reform supported by the series of laws and regulations mentioned above does not simply aim at the rationalization of landholding, but also aim at purchasing land lords' land one by one where possible, at carrying out the land consolidation works and the construction of necessary agricultural facilities and at distributing them at a reasonable price to farmers who actually cultivated land so that farmers who acquired farm land equipped with modernized facilities will enjoy their new life in rural areas, and never try to move to urban areas. These are both time and money-consuming works, but this way of land reform is of the epock-making in whole the rice growing countries. Under the circumstances, the Project has a special characteristics as the pioneer works to be undertaken along with the new Governmental policy in Thailand.

B. Regional/Provincial Level

Ayutthaya province is situated in the right bank tract of the Chao Phya river which runs down across the heart of the Central Plain of Thailand. The capital city of this province, Ayutthaya, is located at about 70 km north of Bangkok, the metropolis of Thailand. The total acreage of this province is about 248,000 ha. The elevation is in a range of 1.5 to 4.0 m above mean sea level. The soil texture is heavy clay which is generally seen in the deltaic zones. Most part of Ayutthaya province is topographically flat; the undulation of land surface is hardly seen in the province. The annual mean temperature is 28°C.

Traditionally the floating rice has been grown in the wet season. However, in parallel with the extension of irrigation facilities, mainly main irrigation canals which play a role to distribute irrigation water to vast areas, high yield varieties of paddy have been introduced to the province. These varieties are grown in limited areas along canals where water is available by simple irrigation methods such as using a low head pump etc. Both the high yielding varieties of the dry and wet season are grown in the province. But the double cropping of paddy has not been performed. In addition to paddy, vegetables and fruits have been grown, and the livestock breeding has also been performed, but their productions are very small.

The Project Area covers three Tambon (sub-district) of Khusalod, Phraya Banlu and Sing Ha Nat out of six Tambon in Amphoe (district) Lad Bao Laung. The service area is about 12,300 ha, which is roughly classified into 8,947 ha of paddy fields, 240 ha of orchards, 106 ha of upland fields and 3,001 ha of the others. A total number of households was about 1,863 as of 1976, and its 83 per cent was occupied by farm households.

The natural population increase rate is 2.16 per cent in the Project Area, but the social population increase rate arrives at minus 0.26 per cent. The net increase rate of population in the Project

Area is, therefore, 1.9 per cent. The floating rice varieties have been grown in about 31 per cent of a total paddy field in the Project Area. Except busy periods for planting and harvesting works, of these farmers, many farmers leave the Project Area to work in Northern Thailand or in Bangkok. This dynamic population trend is a special feature seen in the single cropping area with flooding irrigation. This phenomenon of population suggests that the problem of the tenancy system has had a deep root in the Project Area. In view of these facts, it might be easily understood why the Project Area was given the first priority by the imperial ordinance in carrying out the land reform and by what background and target the Project has been rendered.

The major transportation system in the Project Area and its vicinity is traditionally navigation on rivers and canals. The freight rate of 35/ton by boat from the Project Area to Bangkok is a half of that by truck. It is anticipated from the above-mentioned that the navigation will remain for a rather longer period in the position of major transportation system even after the completion of the Project.

There is a plan to lay the electric lines to the Project Area in 1979. At present, telephone communication is hardly available in the Project Area.

CHAPTER III. PROJECT AREA

A. Location and General Features

1. Geographical Location and Road Systems

The Project Area covering an acreage of about 12,300 ha is located on the Amphoe Lad Bao Laung in Changwat Ayutthaya, about 70 km north of Bangkok, and largely divided into two sub-areas by the Phraya Banlu canal running through the Project Area from the west to east.

The Project Area occupies a part of the West Bank Tract of the Chao Phya river, and its elevation is mostly less than 2.25 m above mean sea level. In the wet season the flooding irrigation has been traditionally made, but in the dry season no irrigation water supply could be made without pumping facilities, as water level in canals lowers to about one meter below the ground surface. Some farmers have used a wooden water lifting device provided by themselves for the irrigation.

No road system exists in the Project Area and its vicinity except two provincial roads of six to eight meters wide which are under construction by the local government. No systematic farm road networks are also seen in the whole Project Area. Consequently the transportation of living materials, agricultural inputs and outputs as well as the communication between villages have been made by water.

2. Population and Living Conditions

(a) Population

Population density

From the 1970 Census in Thailand, the population density in each region is summarized below. According to the Census the Central Plain has the highest population density in Thailand because of flat geographical features, a higher agricultural productivity of land, and

the existence of Bangkok-Thonburi having the population of 8.5 per cent of the whole country.

Regional Population Density

Region	Area (sq.km)	Population ('000)	Percentage (%)	Density (per sq.km)
Central Plain	103,579	10,392	30.4	100.3
North Region	170,006	7,468	21.9	43.9
Northeast Region	170,226	12,023	35.2	70.6
South Region	70,189	4,269	12.5	60.8
Thailand	514,000	34,152	100.0	66.4

Source: The 1970 Census, Thailand Year Book 1975-76.

Furthermore, following table shows the comparison of the population density in administrative districts, such as Changwat Ayutthaya, Amphoe Lad Bao Laung, and the Project Area, excluding the municipal areas[1/] established by the Royal Decree of the 1953 Municipality Act.

Comparison on Population Density in Non-municipal Areas

Areas	Area (sq.km)	Population	Population Density (per sq.km)	Source
Changwat Ayutthaya	2,457	530,491	216	As of 1972, Data of National Statistical Office, Office of The Prime Minister
Amphoe Lad Bao Laung	216	25,933	120	As of 1972, - ditto -
Project Area	123	12,280	96	As of 1976, - ditto -

Note 1/: Municipal areas are divided into three categories according to the classification of Thailand's Population Statistics, as follows;

- A municipal area in Tambon; an area being appropriate as a municipal area.
- A municipal area in Muban; an area having the population density of more than 3,000 persons per sq.km and population of more than 10,000.

- A municipal area in Nakohn; an area having the population density of more than 3,000 persons per sq.km and the population of more 50,000 persons.

These municipal areas do not exist in Amphoe Lad Bao Laung.

The above two tables denote that the population density in Changwat Ayutthaya is more than two times of the average density in the Central Plain and the population in Amphoe Lad Bao Laung is more than the average in the Central Plain. On the other hand, the population density in the Project Area is 96 persons per sq.km and less than that in the Central Plain.

Growth Rate of Population

The trend of population in Thailand for last decade is tabulated as shown below;

Trend of Population

Year	Whole country		Changwat Ayutthaya		Amphoe Lad Bao Laung		Project Area	
	Population	Yearly Growth Rate (%)	Population	Yearly Growth Rate (%)	Population	Yearly Growth Rate (%)	Population	Yearly Growth Rate (%)
1947	17,442,689	3.2						
1960	26,257,916		478,738	0.45	18,453	1.67		
	(26,634,000)	2.7						
1970	34,397,374	(3.1)	501,737		21,772			
	(36,215,000)			1.66				
1971			584,795		25,663			
1972			588,701		25,933			
1973			595,400	1.0	26,373	1.9	11,408	
1974			601,586		27,058		11,288	-1.1
1975			608,486		27,625		12,254	+8.6
1976							11,805	-3.7

Source: 1947: Population Census: as of 23rd May 1947
1960: -do- as of 25th April 1968
1970: -do- as of 1st April 1970
1971-1976: Data of National Statistical Office

Note: According to the two censuses in 1960 and in 1970, the population of whole country was 26,257,916 persons in 1960 and 34,397,347 persons in 1970, respectively. Figures in parentheses show the modified estimates by the National Statistical Office, the Office of The Prime Minister, Thailand, in cooperation with the National Economic and Social Development Board and this Institute of Population Research of Chulalongkorn University, because the average yearly growth rate of 2.7 per cent between 1960 to 1970 was too low in comparison with the rate of 3.2 per cent between 1947 to 1960.

It is obvious that the growth rate of population in Changwat Ayutthaya is lower than that in the whole country and the growth rate in Amphoe Lad Bao Laung are lower than that in Changwat Ayutthaya.

The growth rate of population in the Project Area is regarded as same figure of 1.9 per cent in the Amphoe. Also, according to the data of National Statistical Office and Office of The Prime Minister, the natural growth rate in Amphoe Lad Bao Laung is 2.16 per cent (birth rate of 2.60 per cent and death rate of 0.44 per cent), therefore, the estimated growth rate of 1.9 per cent in the Project Area will be adequate in consideration of a social decrease.

(b) Living Conditions

Transportation

Only one road is available to and from other areas by means of the provincial road, which extends to Tambon Khusalod from Amphoe Sena, northern part of the Project Area. A new road between Amphoe Phatomtani, east of the Project Area, and southern part of the Project Area will be completed in 1977. The traffic distance to Bangkok will be shortened by the completion of the new road. However, transportation of agricultural materials and products will be conducted by means of navigation, until the whole road net works in the West Bank Tract will be completed.

Wooden bridges are provided at the sites where relatively utilizable roads are crossing waterways, and the top elevation of bridge is, in general, higher than the road surface in order to give overhead clearance for navigation. The structures of such bridges are not strong to bear traffic loads such as automobiles and waterbuffalos.

According to the enumeration with regard to 227 households in three Muban in Tambon Phraya Banlu, number of boats, bicycle, vehicles etc. owned by households in three Muban are as follows:

Boat	315
Bicycle	5
Sedan	0
Truck	0

It was observed through the field survey conducted in the dry season, February 1977 that navigation by small boats were obstructed due to low water level in canals.

Villages

Residences in the Muban areas are built in a line along waterways, and shows a long-strip shape. Pedlars on boats loading commodities are often seen on canals in Muban areas.

Drinking water

Rainwater stored in earthen pots is used as drinking water in the period of the wet season, but canal water is also used as drinking water in the dry season. There are four wells in the Project Area, and some of the families obtain their drinking water from those wells situated about one kilometer from their residence due to the shortage of canal water in the dry season.

Education

There are 17 primary schools in the Project Area and the number of pupils (6 to 15 years old) per school is 197 on average and a school covers the area of 7.2 sq.km.

Sanitation

No hospital (First-class Health Center) exists in the Project Area, however, four clinics (Second-class Health Center) are scattered over the area, and one clinic covers 31.6 sq.km, or 466 households.

Electric power facilities and Communication

Electric power services as the public utilities are not introduced into the Project Area. However, some rich farmers who culture citrus trees have their private power-generating plants. Some farmers among 227 households near the proposed Pilot farm site have 14 television sets and 160 portable radio sets. This Proposed site is located along the Khlong Phraya Banlu, and many merchants and citrus-farmers live there. But in the other areas it seems that a few farmers possess television and radio.

Number of Farm households

Number of farm households in the Project Area is 1,610, which is equivalent to 83% of the total number of households of 1,940 as of 1976.

B. Natural Conditions

1. Topography and River Conditions

(a) Topography

Most of the areas in and around the Project Area is topographically very flat. Its average slope is about 1/20,000 from the north-west to south-east, and its elevation ranges in 1.75 to 2.25 m above mean sea level. But some depressed grounds are seen in the existing paddy fields.

(b) River Conditions

The major rivers in the vicinity of the Project Area are the Chao Phya river running along the left side of the West Bank Tract and the

Suphan river along the right side of the Tract. The Suphan river is a tributary of the Chao Phya river, which branches off at the upstream reach of the Chao Phya dam, about 150 km upstream from the Project Area. Both rivers run through the Central Plain of Thailand forming very gentle slope and empty themselves into the Gulf of Thailand. The course and location of these rivers, inclusive of their tributaries and major existing canals in the West Bank Tract, are illustrated in Figure 3-1.

The Chao Phya river has a catchment area of about 162,000 sq.km, which covers one-third of the entire area of Thailand extending from the southern bank of the Mekong to the Gulf of Thailand.

Waters in the Chao Phya river are diverted into the Suphan and Noi rivers, and also into major irrigation canals. Thus, this river is the major water resources not only for the Project Area and its vicinity but also for the whole Central Plain of Thailand. An annual mean discharge and specific runoff of the river observed at Nakorn Sawan, a catchment area of 110,569 sq.km, are 22.6 billion cubic meters and 204.6 millimeters respectively, as shown below.

Monthly Mean Specific Run-off of Chao Phya River at Nakorn Sawan

(unit: millimeter)

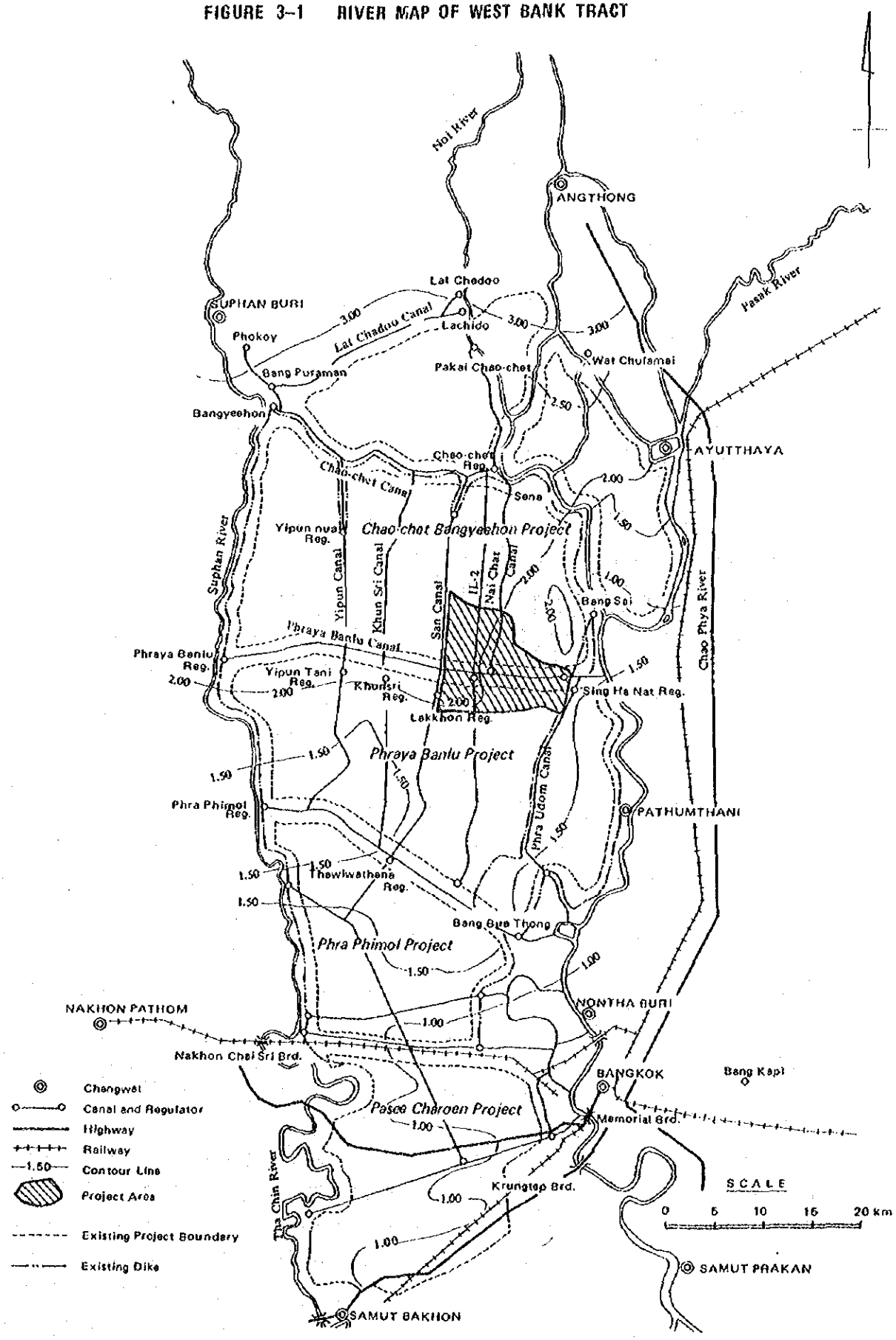
Month / Period	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1957-'75	5.0	4.1	4.6	4.4	5.8	9.4	12.8	23.8	43.3	55.7	25.8	9.9	204.6
1957-'63	3.2	1.8	1.4	1.1	2.1	5.9	9.6	24.4	46.9	66.0	27.4	8.0	197.8
1964-'75	5.9	5.2	6.2	6.4	7.9	11.4	14.8	23.4	41.2	49.7	24.9	11.0	208.0

Note: Detail figures are given in Table A.3-30 (Appendix 3-8)

Discharge in the Chao Phya river during the dry season since 1964 have been increased and stabilized by operation of the Bhumiphol dam, constructed in 1964. The multipurpose Bhumiphol dam plays both roles to secure the irrigation water in the dry season and to control floods

LOP BURI

FIGURE 3-1 RIVER MAP OF WEST BANK TRACT



in the wet season, as well as the Sirikit dam which has started its operation since 1973.

2. Climate and Hydrology

(a) Climate

Thailand is divided into two climate zones: the tropical savanna climate zone and the tropical rainy climate zone. The former extends from the coastal area to the northern Thailand while the latter covers the whole southern Thailand.

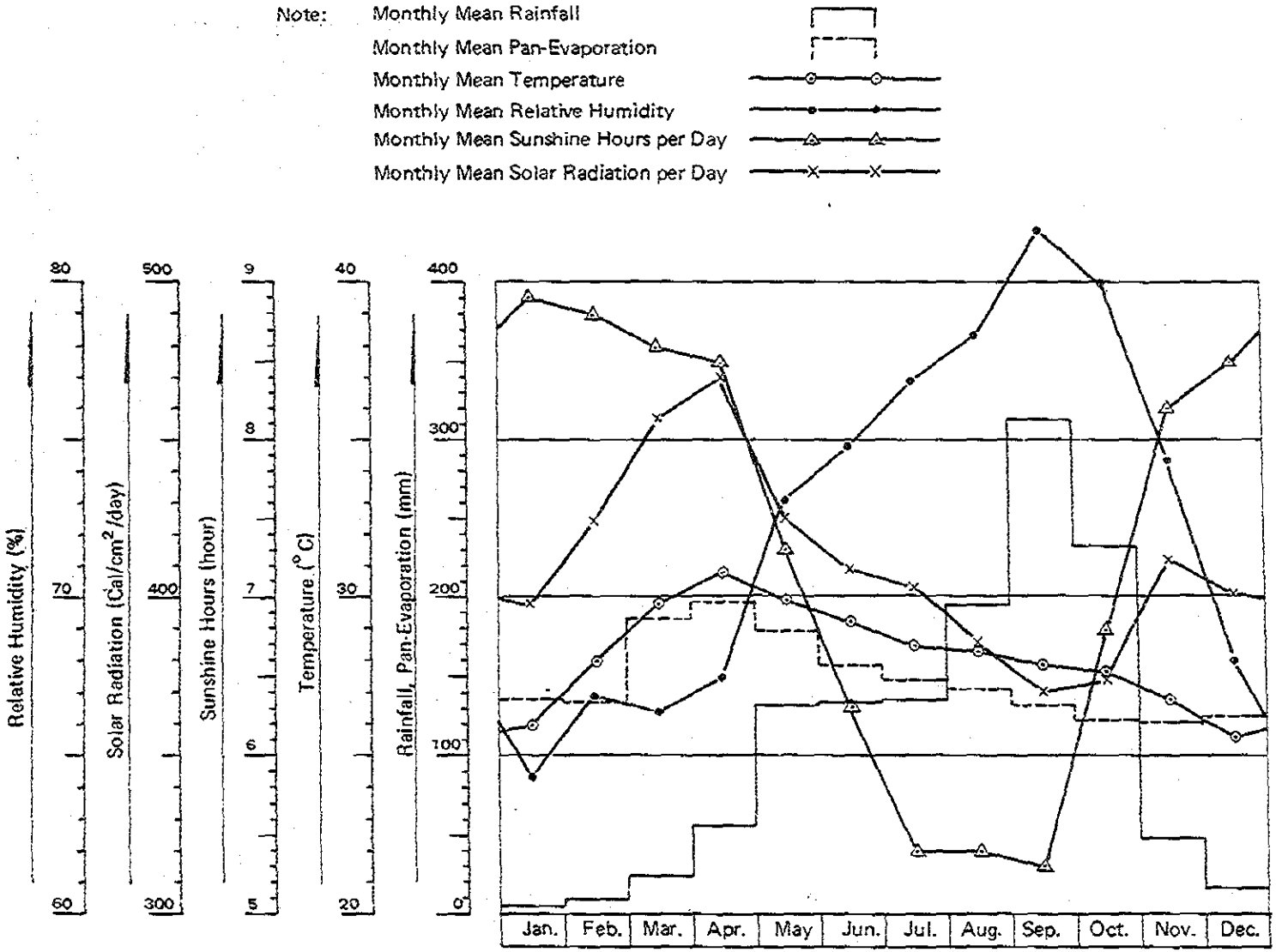
Located in the tropical savanna climate zone, the Project Area has two seasons, the dry and the wet in a year. The wet season lasts six months from May to October while the dry season from December to April. April seems to be the transition period of the two seasons, from the viewpoint of yearly variation of monthly rainfall.

As neither climatological data in the Project Area nor in the West Bank Tract are available except some on the precipitation, the climate in the Project Area has been studied based on the data collected at four observation stations, Lop Buri, Suphan Buri, Bangkok and Kanchana Buri. The data recorded at Kanchana Buri are, however, much different from those at the other three stations. Especially, data in respect of annual rainfall, minimum temperatures and most frequent monthly wind directions prove that the climate at Kanchana Buri is quite peculiar.

This country has a general tendency of the rainfall that eastern part has more rainfall than the western part. For instance, an annual rainfall at Bangkok is 1,470 mm on an average while that in Kanchana Buri 1,120 mm. It is specific that rainfalls in the Project Area and its vicinicy are clearly classified into the Bangkok type and Kanchana Buri type by the factor analysis as undermentioned.

The major features of the climate in the Project Area are illustrated on the monthly basis in Figure 3-2.

FIGURE 3–2 PRINCIPAL ELEMENTS OF CLIMATE



(1) Temperature

The Project Area is located about 80 km north of the seashore facing the Gulf of Thailand, and the temperature being under the oceanic influence, the fluctuation of monthly mean temperatures is extremely small throughout the year, ranging of ±2.6°C from the mean annual temperature of 28.2°C. Monthly mean temperatures observed at Lop Buri, Suphan Buri and Bangkok stations are tabulated below:

Monthly Mean Temperature (°C)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Mean
26.0	28.0	29.8	30.8	29.9	29.2	28.5	28.3	27.9	27.7	26.8	25.6	28.2

25 years (1951 - 1975)

Monthly Extreme Minimum Temperature (°C)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Low
9.2	13.5	15.8	18.9	20.7	20.8	21.3	21.0	20.9	18.6	13.1	10.4	9.2

25 years (1951 - 1975)

Monthly Mean Minimum Temperature (°C)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Mean
19.4	21.9	23.8	25.1	25.1	24.7	24.4	24.4	24.3	24.0	22.0	19.7	23.2

25 years (1951 - 1975)

Monthly Extreme Maximum Temperature (°C)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	High
37.0	38.3	40.5	41.0	41.2	38.4	37.0	36.1	35.5	34.5	34.9	34.9	41.2

25 years (1951 - 1975)

Monthly Mean Maximum Temperature (°C)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Mean
32.1	33.8	35.4	36.4	35.0	33.6	32.8	32.4	31.7	31.4	31.0	31.0	33.0

23 years (1951 - 1973)

(2) Humidity Pan-evaporation, Sunshine Hours, Solar Radiation and Wind

The variation of humidities follows almost the same curve as that of distribution of rainfalls through the year as shown in Figure 3-2. The maximum humidity is 81.6 per cent in September while the minimum humidity is 64.3 per cent in January.

On the other hand, pan-evaporation, sunshine hours and solar radiation describe the adverse curves to the above-mentioned one. The data observed with pan-evaporation show that the maximum is about 197.5 mm in April while the minimum about 121.1 mm in November. The annual mean sunshine hours is 7.3 hour/day. The mean sunshine hour in the wet season is 6.1 hour/day while that in the dry season is 8.6 hour/day, so the difference is more than 2 hours. It is noticeable that sunshine hour decreases to 5.4 hour/day during July to September.

The solar radiation shows almost the same pattern as that of sunshine hour except in December and January. During these two months the solar radiation decreases to a considerable extent due to the incidence angle of solar light. The maximum solar radiation is 470 cal/sq.cm/day in April when the temperature goes up to its peak while the minimum is 370 cal/sq.cm/day in September when the maximum rainfall is expected.

The wind velocity is almost constant throughout the year. The annual mean wind velocity is 6.05 knots. The maximum wind velocity occurs in March and April when the temperature arrives at its peak. However, the winds take completely adverse direction in the dry season and wet season. During eight months from February to September winds take the course from south, but during four months from October to January take the course from northeast, so-called monsoon winds. The coming of monsoon winds suggests that the dry season has already started, and the rainfall excessively decreases from October to November. The winds again change their course from south in February, but do not bring rains to the West Bank Tract immediately. Rainfalls gradually increase from February to April.

(3) Rainfalls

Rainfalls in the Project Area and its vicinity are also of the tropical savanna type. It rains concentratedly at a spot of area in a short time as if it is a shower. During the wet season, rain-bearing south winds blow mainly in the afternoon, and bring rains to the tropical savanna zone. The duration of a rain at a spot is in the order of few hours even if rainfall having long consecutives time.

Rainfalls have a big seasonal fluctuation as shown in Figure 3-2. The annual mean rainfall is about 1,300 mm of which 88 per cent (1,150 mm) falls in the wet season and the remaining 12 per cent (150 mm) in the dry season. Especially during December to February it hardly rains, and the mean monthly rainfall during those months is very small as 9.9 mm.

Monthly Mean Rainfall (mm)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
4.7	8.9	24.3	54.8	132.6	134.1	135.2	195.0	313.0	232.2	47.6	16.0	1,298.4

Note: Average of following three stations

Sing Ha Nat	14 years (1962 - 1975)
Lakkhon	13 years (1963 - 1975)
Phraya Banlu	11 years (1965 - 1975)

Annual Rainfall

As mentioned above, the eastern part of the country has more rainfall than in the western part. As shown in the following table, Bangkok has an annual rainfall of 1,488 mm while Kanchana Buri 1,122 mm with the difference of about 370 mm. The similarity and peculiarity in the yearly fluctuations of annual rainfall have been studied by applying Direct Varimax method, based on the observed data at seven stations. As a result, it has been found that rainfalls in the Project Area are classified into the Bangkok type and the Kanchana Buri type. Figure A.3-1 (Appendix 3-2) shows the transition of annual rainfall at each station.

Annual Rainfall in the Vicinity of Project Area

Station	Annual Mean Rainfall (mm)	Standard Deviation (mm)	Extreme Annual Rainfall Records (mm) Maximum	Minimum
(1) Sing Ha Nat	1,428	294	1,941.5 (1962)	1,019.7 (1973)
(2) Lakkhon	1,198	273	1,577.7 (1970)	659.4 (1967)
(3) Phraya Banlu	1,257	250	1,714.1 (1972)	926.4 (1967)
(4) Lop Buri	1,286	221	1,639.6 (1957)	855.0 (1973)
(5) Suphan Buri	1,248	206	1,584.9 (1957)	800.2 (1968)
(6) Bangkok	1,488	257	1,946.1 (1957)	865.6 (1967)
(7) Kanchana Buri	1,122	232	1,581.7 (1974)	780.2 (1968)
mean (1)	1,294	272	1,744	869
mean (2)	1,290	248	1,714	844

Note: mean (1): Average of three stations (1 - 3)
mean (2): Average of seven stations (1 - 7)

Structure Vectors of Annual Rainfall by Direct Varimax Method

Pattern	Sing Ha Nat	Lakkhon	Phraya Banlu	Lop Buri	Suphan Buri	Bangkok	Kanchana Buri
Pattern-1	0.332	0.184	[0.961]	0.402	[0.938]	0.321	[0.678]
Pattern-2	[0.810]	0.456	0.243	[0.868]	0.236	[0.797]	0.276
Pattern-3	0.316	[0.870]	0.153	-0.09	0.003	0.184	0.328

Note: Analized for 11 years (1965 - 1975)

The Pattern-1 in the above table has a similar fluctuation to that of Kanchana Buri, and is considered as the Kanchana Buri type. On the other hand, the Pattern-2 resembles the rainfall pattern at Bangkok, which is so called the Bangkok type. The Bangkok type covers the three stations of Bangkok, Sing Ha Nat and Lop Buri located at the east of the Project Area. This type is characterized by an abundant rains in the wet season. The Pattern-3 is seen only at Lakkhon, and has almost no similarity to the others.

Rainfalls can be classified into two types, the Bangkok type prevailing at the eastern part of the Project Area and the Kanchana Buri type covering the western part of the Project Area. Observation station in both parts are located in the direction of the south to north, and south winds during the wet season may have close relation to the distribution of the rainfall patterns. Sing Ha Nat and Lop Buri are

affected by rainfalls passing through Bangkok, but Kanchana Buri is not. In the same way the eastern part of the Project Area is hardly affected by rainfalls passing through Kanchana Buri.

It seems that constant monsoon rainfall and simple topographic conditions of the Central Plain cause the phenomenon described above. Therefore, an annual rainfall in the whole Central Plain could be estimated based on limited data available at a few observation stations. However, the estimation of rainfall at the mountainous and hilly zones such as the upper basin of the Chao Phya should be performed taking into due consideration the topographic and other conditions in the zones.

Return Period	Probable Annual Rainfall (mm) Maximum	Minimum
2 years	1,264	1,259
5 years	1,535	1,042
10 years	1,698	946
15 years	1,786	902
20 years	1,846	875
25 years	1,892	855
30 years	1,929	841
40 years	1,986	819
50 years	2,029	803

Note: Average of following three stations

Sing Ha Nat	14 years (1962 - 1975)
Lakkhon	13 years (1963 - 1975)
Phraya Banlu	11 years (1965 - 1975)

Rainfall in the Wet Season

The total rainfall in the wet season is equivalent to 88 per cent (1,150 mm) of the annual rainfall as mentioned above. The maximum monthly rainfall is recorded in September.

Station	Reinfall in Wet Season (mm) Mean Rainfall	Standard Deviation	Extreme Rainfall Records Maximum	Minimum
Sing Ha Nat	1,273.7	292.2	1,865.2 (1963)	867.8 (1973)
Lakkhon	1,082.3	276.3	1,552.2 (1963)	650.6 (1965)
Phraya Banlu	1,092.9	191.1	1,378.7 (1972)	814.1 (1971)

Following table shows the Probable rainfall in the wet season.

Return Period	Probable Rainfall in Wet Season (mm)	
	Maximum	Minimum
2 years	1,116	1,105
5 years	1,365	913
10 years	1,521	833
15 years	1,606	797
20 years	1,664	775
25 years	1,709	734
30 years	1,745	718
40 years	1,802	695
50 years	1,845	678

Note: Average of following three stations

Sing Ha Nat	15 years (1962 - 1976)
Lakkhon	15 years (1962 - 1976)
Phraya Banlu	12 years (1965 - 1976)

Rainfall in the Dry season

It occasionaly rains in the dry season, and its amount is estimated at 150 mm, which is about 12 per cent of the annual rainfall. Especially during December to February it hardly rains, and the rainfall during those months is about 30 mm in total, equivalent to 20 per cent of the total dry season rainfall.

Monthly mean rainfalls in the dry season are tabulated below. It is noted that the records at three stations near the Project Area, Sing Ha Nat, Lakkhon and Phraya Banlu, are relatively small in comparison with those at the other four stations.

Rainfall in Dry Season (mm)

Station	Nov. - Mar. Mean	S.D.	Extreme Max.	Min.	Nov. - Apr. Mean	S.D.	Extreme Max.	Min.	Data Period
1. Sing Ha Nat	91.7	57.0	157.2	0.0	152.2	71.7	279.4	14.3	25 years (1952-1975)
2. Lakkhon	82.2	62.0	197.0	7.4	125.1	49.6	197.4	8.4	14 years (1962-1975)
3. Phraya Banlu	117.9	82.9	307.4	2.3	172.0	61.2	307.4	52.3	12 years (1964-1975)
4. Lop Buri	120.1	83.3	382.4	4.1	195.4	98.0	473.8	63.2	20 years (1955-1974)
5. Suphan Buri	89.8	51.2	195.9	9.9	172.9	84.8	352.5	32.7	-do-
6. Bangkok	125.4	37.7	245.7	42.3	192.5	84.9	378.1	57.1	-do-
7. Kanchana Buri	123.9	86.9	321.7	2.3	203.2	101.3	468.1	9.4	-do-
Mean (1)	97.3	67.3	220.5	3.2	150.8	60.8	261.4	25.0	
Mean (2)	107.3	65.9	258.2	9.8	173.8	78.8	351.0	33.9	

Note: Mean (1): Average of three stations (1 - 3)
Mean (2): Average of seven stations (1 - 7)
S.D.: Standard Deviation

The estimation of probable rainfalls in the dry season is one of the key factors for the irrigation plan. Following table indicates the average probable rainfall analyzed based on the three rainfall data above-mentioned.

Probable Rainfall in Dry Season (mm)

	Probable Maximum Nov. - Mar.	Nov. - Apr.	Probable Minimum Nov. - Mar.	Nov. - Apr.
2 years	83	152	73.9	140.4
5 years	143	227	30.6	86.7
10 years	182	278	16.8	64.2
15 years	205	307	11.6	54.1
20 years	220	328	8.4	47.9
25 years	232	344	6.4	43.3
30 years	242	357	4.9	39.9
40 years	258	377	2.8	34.9
50 years	269	393	1.8	31.3

Note: Probable rainfall of seven stations are indicated in Appendix 3-4.

Hourly and Daily Rainfall

The short term rainfalls such as hourly and daily rainfalls are very important for planning drainage systems. The hourly and one to three day consecutive rainfalls are herein dealt with.

Hourly rainfalls are observed at Bangkok and Suphan Buri, but the observation data are not kept well, and some are lost and some are unreadable. Hourly distribution of rainfalls including the maximum hourly rainfalls throughout the year is shown in Figure A.3-2 (Appendix 3-5). This figure suggests that the West Bank Tract rarely has heavy rains from morning to noon. Data collected at Suphan Buri station are insufficient to study the probability analysis, because many years' data are lacking. However, the data on the maximum hourly rainfalls in seven years are collected at Bangkok station as shown below:

Year	Hourly Rainfall (mm)
1974	73.0
1966	72.0
1957	64.0
1952	61.1
1959	49.5
1975	47.0
1973	46.0

Source: Meteorological Department

The probability analysis has been performed and the results are shown below on the assumption that the data mentioned above were extracted at random;

Return Period	Rainfall (mm)
2 years	58.0
5 years	68.5
10 years	74.7
15 years	78.0
20 years	80.2

The maximum daily and consecutive rainfalls observed at the seven stations are shown below:

Station	Observed Maximum Consecutive Rainfall (mm)		
	1-Day Rainfall	2-Day Rainfall	3-Day Rainfall
Sing Ha Nat	158.5 (1972)	203.3 (1963)	204.0 (1972)
Lakkhon	128.2 (1972)	184.3 (1962)	257.5 (1962)
Phraya Banlu	194.0 (1972)	278.0 (1972)	317.0 (1972)
Lop Buri	165.0 (1957)	192.6 (1957)	213.6 (1957)
Suphan Buri	132.4 (1954)	162.0 (1972)	236.0 (1972)
Bangkok	153.7 (1968)	224.6 (1972)	290.2 (1972)
Kanchana Buri	165.5 (1972)	215.3 (1972)	241.4 (1959)

Source: Meteorological Department and RID
Sing Ha Nat 15 years (1962 - 1976)
Lakkhon 15 years (1962 - 1976)
Phraya Banlu 14 years (1962 - 1976 except 1963)
Lop Buri, Suphan Buri, Bangkok and Kanchana Buri
24 years (1952 - 1976)

The probable maximum consecutive rainfalls at each station are shown in Table A.3-19 (See Appendix 3-5).

Rainy Days and Consecutive Drought Days

If it rained more than 0.1 mm in a day, the day is considered as the rainy day. Averaged rainy days in each month are indicated in Table A.3-20 (See Appendix 3-6). It is noted that the distribution of the averaged rainy days by month is quite similar to that of the monthly mean rainfall as shown in Figure 3-2.

The averaged rainy days based on the data observed at Sing Ha Nat, Lakkhon and Phraya Banlu are considered smaller than those based on the data recorded at the other four stations.

The maximum monthly mean rainy days at three stations are 15 days in September, just a half of the month, while the minimum is 0.5 days in January. The maximum and minimum monthly rainfalls also are observed in September and January respectively. Annual rainy days are 75 days, that is, 20 per cent of a year.

The consecutive drought days in the wet season are more important than those in the dry season because it hardly rains in the dry season. Therefore, in order to grasp a water quantity for supplemental irrigation in the wet season, careful attention should be paid to the consecutive drought in the wet season. The maximum annual drought days in the wet season are shown in Table A.3-27 (Appendix 3-6).

The maximum consecutive drought days mostly occur in May, during which 50 per cent of the maximum drought days records occur.

Station	Extreme Maximum Drought in Wet Season (Unit: days)
Sing Ha Nat	22 days (11 May - 1 Jun. 1968, 21 Jun. - 13 Aug. 1972, 10 Oct. - 31 Oct. 1973)
Lakkhon	34 days (25 Jun. - 25 Jul. 1965)
Phraya Banlu	22 days (29 May - 19 Jun. 1967)

Note: Sing Ha Nat, Lakkhon 15 years (1962 - 1976)
Phraya Banlu 12 years (1965 - 1976)

The peak of monthly rainfall appears in September and the consecutive drought days are rare, if any, in this month. It is concluded, therefore, that the rainfalls in September are much stabilized, but those in May widely varies year by year.

The probable maximum drought in the wet season is shown below;

Return Period	Probable Maximum Drought in Wet Season (days)			
	Sing Ha Nat	Lakkhon	Phraya Banlu	Mean
2 years	12.9	15.8	15.2	14.6
5 years	17.7	21.6	19.0	19.4
10 years	20.9	26.3	21.3	22.8
15 years	22.7	29.2	22.6	24.8
20 years	24.0	31.4	23.4	26.3
25 years	24.9	33.2	24.0	27.4
30 years	25.7	34.6	24.6	28.3
40 years	27.0	37.0	25.3	29.8
50 years	27.9	39.0	26.0	31.0

(b) Hydrology

(1) Discharge of the Chao Phya River

The existing hydrologic observation networks in the Chao Phya river basin is as illustrated in Figure A.3-3 (See Appendix 3-2). Out of these observation stations, data at the ten stations listed below are used for the potamologic analyses of the Chao Phya river.

Observation Station		Observed Items		Data Period	
		Water	Dis-		
Name	Cord	Level	charge	Observation	Collected Data
Nakorn Sawan	C.2	o	o	W.L. 1914-	1957 - 1975
				D. 1956-	
Chainat(Chao Phya D.)	C.13	o	o	1947-	-do-
In Buri	C.14	o	o	W.L. 1950-	1957 - 1968
				D. 1955-	
Ang Thong	C.7	o	o	W.L. 1930-	1957 - 1966
				D. 1955-	
Wat Chula Mani	C.15	o	o	W.L. 1950-	1957 - 1975
				D. 1955-	
Ayutthaya	S.5	o	-	1950-	1950 - 1975
Pak Kret	C.22	o	-	1953-	1953 - 1975
Rama VI Bridge	C.23	o	-	1959-	1959 - 1966
RID, Bangkok	C.12	o	-	1942-	1942 - 1975
Memorial Bridge	C.4	o	-	1938-	1938 - 1975
Sing Ha Nat Regulator		o	-	1967-	1967 - 1976
Phraya Banlu Regulator		o	o	1966-	1966 - 1976
Lakkhon Regulator		o	o	1971-	1971 - 1976

Note: W.L.: Water Level
D.: Discharge
C.: Chao Phya River
S.: Pasak River

The potamologic analyses of the Chao Phya river along the West Bank Tract have been made by using the discharges observed at Nakorn Sawan station and at the immediate downstream of the Chao Phya Dam. Nakorn Sawan station has the records of both the discharges and water levels at the downstream reaches of the confluence of the Ping, Yom and Nan rivers, the major three tributaries of the Chao Phya river. Discharges of the Chao Phya river in its downstream reaches from Ayutthaya have not been observed though its water levels have been recorded at some places along its downstream reaches. The major reason why the observation of discharges has not been conducted is that the

H-Q curve cannot be applied to the potamologic study on the lower reaches of the river due to the over-bank flows in the wet season and the tidal influence on water levels in the dry season.

The monthly mean discharges of the Chao Phya river at Nakorn Sawan and at Chao Phya dam site during 1957 to 1975 are as shown below. The maximum monthly discharges occur in October almost every year, and reach 2,300 cu.m/sec on an average at the Nakorn Sawan while the minimum monthly discharges appear from February to April, and arrive at about 190 cu.m/sec, which is less than one-tenth of the maximum monthly mean discharges of the river.

Monthly Mean Discharge of Chao Phya River (unit: cu.m/s)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual mean
Nakorn Sawan	209	185	189	189	238	400	530	982	1,851	2,300	1,101	411	715
Chao Phya Dam	128	81	71	70	106	202	217	435	1,189	1,911	731	310	454

Note: Data Period: 19 years (1957 - 1975)
Detail data are given in Appendix 3-8

The Chao Phya dam has played a role to divert river waters to the Central Plain for irrigation and also to control peak floods. Therefore, discharges observed at immediate downstream of the dam are always smaller than those recorded at Nakorn Sawan.

The maximum discharge of the Chao Phya river observed at immediate downstream of Chao Phya dam was 6,500 cu.m/sec in 1942. This discharge is of the about 100-year return period. According to the records of maximum flood discharges during 1957 to 1975 (See Appendix 3-9), the maximum flood discharge after the construction of Bhumiphol dam, constructed in 1964, was 4,049 cu.m/sec at Chai Nat dam site in 1970. The second was 3,977 cu.m/sec at Chai Nat dam site in 1975. These flood discharges correspond to the return period of about 15-year.

Probable Discharge of Chao Phya River

(unit: cu.m/s)

Return Period	Maximum Discharge	
	Nakorn Sawan	Chao Phya Dam
2 years	2,515	2,145
5 years	3,550	3,134
10 years	4,218	3,771
15 years	4,590	4,145
20 years	4,849	4,409
25 years	5,048	4,614
30 years	5,209	4,781

Note: Data period: 1964 - 1975
Reference will be made to Appendix 3-10

The river slope of the Chao Phya along the West Bank Tract is almost horizontal (See Figure A.3-6), so river waters are under the influence of the tidal water until pretty upper reaches. The intrusion of saline water from the estuary is a big problem especially in the dry season. In this regard, RID has tried to keep low the salinity density of the river water by operating Bhumiphol dam. The target is to keep it less than 2 g/lit (2,000 ppm) at the Memorial bridge site in Bangkok. It is reported that a discharge of 70 cu.m/sec is at least required for this purpose. However, an average discharge during March to May in 1969 was 55 cu.m/sec as shown in Figure A.3-7 (Appendix 3-14), which is, of course, far below 70 cu.m/sec. Therefore, the salinity density went up to 6 g/lit (6,000 ppm) during these three months.

(2) Water Level in and around the Project Area

The hydrological phenomena in the West Bank Tract including the Project Area are much more complicated than those in the Northern Chao Phya, the upper basin of the Chao Phya river. Namely, the whole West Bank Tract is directly affected by floods from the Chao Phya river in the wet season. When the water level of the Chao Phya river rises more than W.L. 2.60 m at Sing Ha Nat, the phenomenon of the over-bank flows from the Noi river and runoff from Northern Chao Phya region will bring about the complicated hydrologic regime in the West Bank Tract.

The water level at Sing Ha Nat during January to June is around W.L. 1.00 m, but it gradually rises during July to October, and finally arrives at W.L. 2.6 m at the maximum in the late November. After that, it rapidly lowers to around W.L. 1.00 m with opening the regulators during December. The regulators are always closed to control the inner water level in the West Bank Tract except one month period when the inner water is discharged to the rivers for the harvesting of wet season paddy.

Inner water levels show a similar variation to the water levels in the Chao Phya river, always being kept with a difference of about one meter higher than that in the Chao Phya river.

The discharge of inner water to the main rivers, the Chao Phya and the Suphan, causes a rise of the hydraulic gradient, resulting in the rise of water level in the main river. The fluctuation of yearly mean inner water levels is shown by applying the standard deviation in Figure A.3-9 (Appendix 3-16). From the Figure the fluctuation of inner water levels is within ± 0.20 m. This fact shows that water levels are much stabilized through the year in comparison with the water levels of the Chao Phya river except in December when the inner water level widely varies due to the yearly time lag to start discharging inner waters. The big fluctuation of water level in the Chao Phya river appears twice a year, that is, from February to March in the dry season and from September to November in the wet season. Furthermore, it is found by the fact mentioned above that the droughty and flooding water levels show a big fluctuation by year.

Figure A.3-10 (Appendix 3-17) shows the relation between the annual maximum inner and outer water levels. The inner water level rises up to EL. 2.60 m at Sing Ha Nat and up to EL. 2.90 m at Phraya Banlu every year, having no relation with the fluctuation of outer water level. The above-mentioned inner water levels at the two stations seem to be the height enough to irrigate higher paddy fields in their vicinities, to make it easy to perform the flooding irrigation in the wet season,

and also to release irrigation water conveyed from Northern Chao Phya area to the lower reaches of the West Bank Tract. When the outer water level exceeds the W.L. 2.60 m and W.L. 2.90 m, the inner water level rises to the same height of the outer water level. This suggests that over bank flow from the river side to the inside has occurred due to the lowering of dikes.

The following table shows the probable water levels analyzed based on the data of water levels recorded in the West Bank Tract.

Probable Inner Water Levels in the Vicinity of Project Area

(Unit: m)

Return Period	Max. Water Level		Min. Water Level	
	Phraya Banlu	Sing Ha Nat	Phraya Banlu	Sing Ha Nat
2 years	2.96	2.58	0.96	0.65
5 years	3.09	2.77	0.80	0.55
10 years	3.18	2.91	0.74	0.49
15 years	3.23	2.99	0.71	0.47
20 years	3.26	3.06	0.70	0.45

Note: Reference will be made Appendix 3-18.

The water levels of the Suphan river observed at Phraya Banlu are considerably higher than those of the Chao Phya river observed at Sing Ha Nat station. According to the four years' data from 1973 to 1976, the hydraulic gradient of the Phraya Banlu canal is about 1/80,000 in the wet season and 1/170,000 in the dry season on an average. Furthermore, the minimum water levels observed at Phraya Banlu from 1966 to 1976 are also higher than those observed at Sing Ha Nat (See Appendix 3-18).

(3) Fluctuation of Free Surface Groundwater Table in the West Bank Tract

The data recorded in the vicinity of Sena, which is located in the upper West Bank Tract, are available only for studying the fluctuation of the free surface groundwater tables. In accordance with the data, the seasonal fluctuation has been illustrated in Appendix 3-19. This

figure shows that the free surface groundwater table reaches about 0.70 m below ground surface in April without irrigation water supply at present. If irrigation water supply is performed throughout year after the project, the free surface groundwater table will be kept around the ground surface owing to the soil texture with extremely small permeability coefficient.

(4) Water Quality

Judging from the existing data, waters in the Chao Phya river and main canals in the West Bank Tract present no problems as irrigation water. Potential of Hydrogen (pH) of waters in the West Bank Tract is almost neutral, while pH of waters in the Chao Phya river become neutral during the flooding season but show weak alkalinity except in the flooding season.

The electric conductivity of waters in the Chao Phya river ranges in 120 - 150 EC x 10^6 (25°C) at the flooding time in 1961, and 250 - 330 EC x 10^6 (25°C) at Sena. The total dissolved solid in water of the Chao Phya river is constant at about 120 ppm, while the suspended solid is 480 ppm before the flooding time and it lowers to 70 ppm at the peak flood period. (See Appendix 3-20)

3. Geology and Soils

(a) Geology

Geological Conditions

The Central Plain is a large depression extending from the Gulf of Thailand to about 450 km north, which was formed as a result of the upheaval of Korat plateau situated in the north-east of this plain during the tertiary period. Many faultings accompanied by the diffusion of basalts, andesites and lavas are observed anywhere in the eastern edge of the Central Plain. The depression was covered with a thick layer of the quarternary alluvial deposits. The thickness of this layer reaches about 300 m in Bangkok and its vicinity. (See Appendix 3-21)

One boring test of 30 m deep was conducted at the central part of the Project Area in order to study the geological conditions. This test revealed that a very soft and dark grey clayey layers having a N-value ranging in zero to three in the standard penetration test, is distributed to the depth of about 10 m from the ground surface. This clayey layer has a thickness of about 30 to 40 m at Bangkok and its vicinity which are located in the lower basin, while it has a thickness of about 10 m at Ayutthaya and its neighborhood which are situated in the upper basin. It seems that the upper the location, the thinner the layer. Layers distributing more deeply than the above-mentioned layer are very stiff alternation of silty clay and sand with a N-value ranging to 20 to 30 or in the order of 40 in some parts. Especially, these layers in the depth of 20 to 30 m are medium or coarse sandy layers. (See Appendix 3-22). So it is expected that the groundwater in this aquifer will be available for drinking water supply and other purposes in future.

When heavy structures such a pumping station are constructed on the foundation under such geological conditions as mentioned above, the surface soils to a considerable depth should be replaced with sandy materials, because the surface clayey layer does not have a sufficient bearing capacity to cope with the load.

Soil Mechanic Conditions

The sampling to a depth of 0.5 to 1.0 m from the ground surface was conducted at five points in the Project Area in order to execute a simple soil mechanical test. As a result, it was found that the surface soil, containing clay and silt in the order of 90 to 100 per cent, is classified as CH in accordance with the USCS-classification, or silty clay in accordance with the USDA-classification. (See Appendix 3-22)

This clayey soil, having a considerably high liquid limit ranging in 70 to 90 per cent, shows a high compressibility, and shows a low

trafficability when it is wet, but it becomes very hard and has many cracks in it when it is dry. Having a high impermeability and good resistance against piping, this clayey soil consisting of fine particles will be available for embankment of small dikes as being planned in this Project. However, in case that this soil is used for roads, the road surface will become muddy and slippery in rainy days, so the pavement with the other materials containing gravel should be provided.

(b) Soils

The Project Area is covered by the brackish alluvial soils which are defined as "the soils on former tidal flats with older brackish water deposits"[1/]. The surface soil layer in the Project Area is relatively thick, and consists of clay and silty clay. Its colour is dark grey. Being acid sulfate soils originated in the brackish water deposits, the surface soil layer is acid.

The soil map prepared by the Land Development Department under the Ministry of Agriculture and Cooperatives indicates that there exist three soil series in the Project Area, namely, Bang Khen, Ayutthaya and Sena soil series. The distribution and characteristics of these soil series are shown in Appendix 3-23. All these soil series have almost similar characteristics as follows:

i) their effective soil layer is thick
ii) their soil texture is clay to silty clay according to the USDA classification; and
iii) a percentage of clay in the soils is as high as about 60 per cent.

The following are pointed out in respect of the soils in the Project Area:

1/ W. Van Der Keive and Banchong Yenmanas, "Detailed Reconnaissance Soil Survey of Southern Central Plain Area"

i) the soils become extremely soft when they are wet, while too hard to be plowed when dry. To materialize a fruitful result of crop cultivation, some appropriate measures for soil management as well as farm practices will be required;

ii) the soils are much acidified when they are dry due to the characteristics of the acid sulphate with a relatively low pH ranging in 4.5 to 5.5;

iii) the soils contain a little effective phosphoric acid as well as nitrogen. Therefore, the application of these soils will be required for a favourable yield of crops.

According to "the suitability of soil for paddy" of the above-mentioned map, all the three soil series are blessed with the potentiality of high yield of paddy. The betterment of paddy cultivation practices accompanied by lime application for soil amendment and the improvement of on-farm irrigation and drainage facilities etc. will work out the potentiality.

On the other hand, all the soil series stand in the rank of "poor" in the aspect of "the land capability classification for upland crops." One of the major restrictive factors in cultivating the soils with upland crops might be the flooding water during the wet season. However, the construction of dikes and pumps for flood control and improvement of irrigation and drainage facilities including these in the on-farm level will make it possible to grow upland crops in the Project Area though the application of lime[1/] and organic matters is required for soil amendment, and furthermore, careful attentions should be paid in selecting crops themselves to be cultivated.

1/ The amount of lime required to bring up pH of the soils from 4.5 to 6.5 is estimated at six ton per hectare in the Project Area.

C. Existing Irrigation and Drainage Systems and On-farm Conditions

1. Irrigation Conditions

(a) Irrigation System

The West Bank Tract of the Chao Phya river covering about 222,000 ha is divided into four irrigation project areas, that is, Chao-Chet Bangyeehon, Phraya Banlu, Phra Phimol and Pasee Charoen. The Project Area is located between the two project areas, Chao-Chet Bangyeehon and Phraya Banlu Irrigation Project. RID has already equipped this vast tract with the main irrigation systems, and installed intake regulators at Phokoy, Pakhai Chao-Chet and Lat Chadoo etc. on the upper reaches of the Noi and Suphan river in order to release necessary waters to the main canals. (See Figure 3-1)

In the Project Area and its neighborhood, four main canals, Khlong San, Khlong Khud Mai, Khlong Nai Chat and Khlong Phraya Banlu run at present. (See Appendix 3-24) These canals are used in various ways such as irrigation and drainage, navigation and the source for living water etc., because of the absence of any other infrastructural facilities.

Besides these main canals, RID has a plan to construct a new canal, IL-2, between Khlong San and Khlong Nai Chat in 1977 to execute more effective irrigation. The systematic terminal irrigation canals consisting of laterals and tertiary branching off from the main canals are not prepared at present.

(b) Available Irrigation Water

The major water source for irrigation in the West Bank Tract in which the Project Area is located is river waters in the upstream reaches of the Noi and Suphan rivers. To analyze an available irrigation water for the Project Area, the data of daily discharges during the three years from 1973 to 1975 have been collected at six stations at Phokoy, Pakhai Chao-Chet, Lad Chadoo, Lad Chid, Bang Prama and

Bangyeehon. Figure 3-3 indicates the fluctuation of water quantity available for irrigation in the whole West Bank Tract on the half monthly basis. The maximum discharge in the wet season amounts to 134 cu.m/sec, while that in the dry season is limited to only 67 cu.m/sec in the maximum inclusive of 10 cu.m/sec of the lifted water by pump operation. Regarding the water lifted by pump, descriptions are to be made in subsequent paragraph.

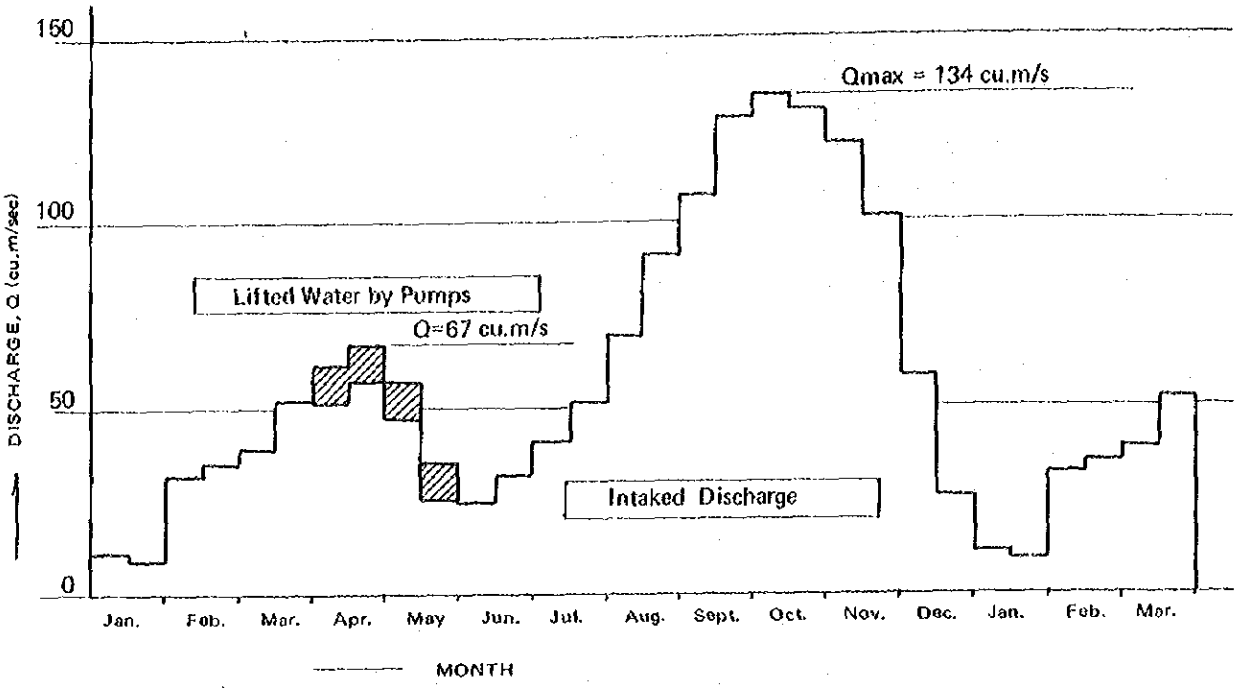
(c) Irrigation Conditions

The Project Area is equipped with no systematic irrigation system except the main canals to convey waters to the whole West Bank Tract, therefore, so called the flooding irrigation has been practiced for the wet season paddy cultivation. In this method relatively high paddy fields in elevation are cultivated with the transplanting paddy with a short growing period in the early half of the wet season, and the broadcasting paddy with a long growing period during the wet season. On the contrary, low-lying paddy fields which are covered by deep water during the flood season are cultivated with the transplanting paddy during the dry season using the water lifted by tools.

The water supply conducted at present is aiming to stabilize the yield of the transplanting paddy during the early wet season and also to expand irrigable areas in the dry season as much as possible. In addition to waters released from the regulators on the upper reaches of the Noi and Suphan rivers, about 10 cu.m/sec of water is pumped up from time to time by movable pump from the Chao Phya and Suphan rivers. According to the RID's information, about 13 units of pump with a bore ranging in 300 to 600 mm are usually operated during the two months, April and May, to cover the shortage of water demand. The operation hours are mostly 22 hr/day.

Under the circumstances, the provision of systematic irrigation systems inclusive of those on the on-farm level with pumping facilities is prerequisite to materialize the double cropping by new paddy variety in the Project.

FIGURE 3-3 AVAILABLE IRRIGATION WATER FOR WHOLE WEST BANK TRACT



Note: three years average from 1973 to 1975
Total project area: 221,900 ha
Total irrigable area: 221,000 ha
Total dry season rice: 131,300 ha
Total dry season crops: 4,100 ha

(Unit: m^3/s)

Month		Intaked Discharge 1973	1974	1975	Average	Lifted Water by pump
Jan.	I	19.3	3.4	11.4	11.4	
	II	13.6	15.3	0	9.6	
Feb.	I	34.5	29.0	32.8	32.1	
	II	45.0	26.4	33.5	35.0	
Mar.	I	46.4	33.3	38.2	39.3	
	II	49.0	48.5	59.2	52.2	
Apr.	I	52.1	44.4	58.9	51.8	10.0 1/
	II	51.7	49.4	68.7	56.6	10.0
May	I	41.2	58.3	41.9	47.1	10.0
	II	22.9	31.4	21.6	25.3	10.0
Jun.	I	26.9	31.9	13.9	24.2	
	II	22.4	33.8	41.1	32.4	
Jul.	I	29.7	40.7	53.9	41.4	
	II	46.6	51.3	57.1	51.7	
Aug.	I	60.6	65.9	80.3	68.9	
	II	88.9	73.6	110.5	91.0	
Sep.	I	86.7	116.6	118.5	106.9	
	II	101.3	120.5	161.7	127.8	
Oct.	I	118.9	131.2	151.9	134.0	
	II	116.5	130.5	143.1	129.7	
Nov.	I	114.2	85.2	163.1	120.8	
	II	96.1	79.9	128.1	101.4	
Dec.	I	71.4	17.9	86.3	58.5	
	II	22.2	14.8	40.8	25.9	
Average Jun. – Dec.		83.5	82.7	112.5	92.9	
Jan. – May		32.1	28.2	30.5	30.3	

Source: Royal Irrigation Department in Bangkok

1/ : Shows an approximate discharge lifted by pumps, of which dimensions are 300 mm to 600 mm with operation hours of 22 hours/day

(d) Irrigation Facilities

The major existing irrigation facilities in the Project Area are as follows:

Main Irrigation Canals

The main irrigation canals are used for irrigation to distribute irrigation water to the whole West Bank Tract, drainage and navigation. The main features of the canals are as shown below:

Main canals	Width (m)
- Khlong Phraya Banlu	30 to 60
- Khlong Nai Chat	25
- Khlong Khud Mai	20 to 30
- Khlong San	20 to 30
- Khlong Lao Khon	20 to 30

Note: An averaged water depth ranges from 2.5 to 4.0m

Waterways

The waterways branched off from the main irrigation canals are listed below:

Waterways	Width (m)
Khlong U Tapho	10
Khlong Uum Tuam	8
Khlong Cha Ra Khe Kod	6 - 7
Lam Rang Wua Non	5 - 6
Lam Rang Ban Ha	4 - 5
Lam Rang Khu Mak Mao	10
Lam Rang Kala	5
Lam Rang Lam Pong	7 - 8
Lam Rang Kang Mao	7 - 10
Khlong Phi Son	10
Khlong Lum Thong Lang	15
Khlong Ban Ma	15 - 20
Khlong Kayad	10
Lam Rang Nong Sa Non	7 - 10
Lam Rang Rad Phum Ya Rum	5 - 6
Lam Rang Kha Phling	4

Note: An averaged water depth ranges from 1.5 to 2.0m

Regulators

The main features of the regulators to keep the water level high for irrigation purpose are summarized as follows:

Gates	Dimension width x height (m)	Remarks
Lock Sing Ha Nat	6.0 x 6.0 x 2 units	iron sluice gate
Lock Phraya Banlu	6.0 x 6.0 x 2 units	ditto
U Ta Phao	2.0 x 2 units	wooden gate
Khu Mak Mao	2.0 x 1 unit	ditto
Num Tuam	2.0 x 1 unit	ditto
Lam Kala	2.0 x 1 unit	ditto
Khu Salod	2.0 x 1 unit	ditto
Mai Chat	4.0 x 1 unit	iron gate
Phi Son	3.0 x 1 unit	wooden gate
Thong Lang	3.0 x 1 unit	ditto
Khut Mai	4.0 x 1 unit	iron gate
Ban Ma	4.0 x 1 unit	ditto

Intake Facilities from Main Canals

Several concrete pipes with a diameter of about 0.5 m have been installed along Khlong San in order to intake water in the dry season.

2. Drainage Conditions

(a) Drainage Systems

The low-lying areas with the elevation less than 2.5 m prevailing in the central part of the West Bank Tract of the Lower Chao Phya are provided with waterways to drain excess waters, which run to the main canals. The main canals are mostly connected to the major rivers, the Chao Phya and Suphan rivers.

(b) Drainage Conditions and Resulting Damages

Most of the low-lying areas are habitually covered by the flooding water during three months from the mid-September to mid-December. The major cause of this phenomenon are as follows:

- flooding irrigation;
- absence of adequate drainage facilities to collect and convey run-off to outlets, and
- absence of terminal drainage system

To make the matter worse, the low-lying areas play a role of conservation area as flood regulating pond when a big flood occurs in the upper basin. According to the data furnished by Chao-Chet Bangyeehon and Phraya Banlu Irrigation Offices, a total damages caused by the recent flood in 1975, which marked the maximum water level of 3.01 m above mean sea level at Sing Ha Nat regulator (equivalent to the probable water level of about 15-years), is estimated at about $1.2 million in the both irrigation project areas as shown in the following:

Flood Damage in 1975

Project	Project Area (ha)	Damaged Area (ha)	Loss ('000 US$)
Chao-Chet Bangyeehon Project	70,050		
Paddy rice		870	196
Upland crops		40	35
Phraya Banlu Project	78,100		
Paddy rice		580	175
Upland crops		240	185
Total	148,150	1,730	1,221

The flood damages are relatively small in comparison with the scale of flood. The major reason is that the floating rice was mainly planted in the low-lying areas to cope with such deep inundation. However, in order to introduce the double cropping of high yield paddy to increase production in such areas, the improvement of drainage system and flood protection are the essential. The drainage and flood protection would also contribute to the stabilization of living environment in the socio-economic aspects.

3. Land Consolidation (on-farm conditions)

(a) Present Land Consolidation Project in Thailand

Major Land Consolidation Projects

The major land consolidation projects under planning or construction at present are the three at Suppaya, Channasutra and Nong Wai. A total service areas of these three projects amount to 85,500 ha.

(See Appendix 3-27) The construction works for land consolidation have been already completed in 8,420 ha as of 1976, which is equivalent to 9.8 per cent of the total service area. The experience of large scaled land consolidation projects in Thailand is just a six-year period from 1971. Taking into consideration the vast cultivated area in this country, it is well anticipated that the land consolidation projects will be carried out in more ample scale in future. The best record in respect of the yearly progress of land consolidation works is about 2,370 ha in the Channasutra project.

Main Features of Land Consolidation Projects

Land consolidation projects in Thailand are roughly classified into the Suppaya project type and the Channasutra project type. Difference of these two projects are summarized as follows:

Description	Suppaya type	Channasutra type
Size of one plot	o,15 to 1.0 ha	0.15 to 6.0 ha
Allocation of canal	At the interval of 100 to 130 m	At the long interval of 150 to 350 m
Allocation of road	Mostly at the same interval, Every plot is surrounded by roads	At various intervals, Roads and canals end at terminal plots
Construction cost1/	720 $/ha	470 $/ha

Note: Details are given in Appendix 3-27
1/ No inclusive of depreciation cost of construction machinery

(b) Present Farm Fields in the Project Area

Farm Roads and Irrigation and Drainage Facilities

Farm fields in the Project Area have been hardly equipped with the terminal farm roads, and irrigation and drainage facilities because floating rice has been traditionally grown with flooding irrigation. In the wet season farm practices and transportation of agricultural input and output are mostly made by small boats while in the dry season tractors or oxcarts are used. For daily farm practices farmers

mutually enter into the other farmers' farm fields on foot.

Farmers are very eager to introduce the dry season RD varieties (Rice Department varieties), but the shortage of the terminal irrigation and drainage canals and farm roads has prevented them from doing it in full scale.

Size and Shape of Farm Fields

A width of farm fields is mostly in a range of 30 to 40 m in the Project Area. A size of farm plots ranges in 1,600 sq.m to 3,000 sq.m. It seems that such size is adequate for manual broadcasting and harvesting of the floating rice. (See Appendix 3-28)

D. Present Agriculture

1. Land Use and Productivity

(a) Land Use

The total acreage of the Project is 12,294 ha of which 10,067 ha (82%) are utilized as the cultivated area, and the remaining 2,227 ha (18%) are occupied by homesteads and canals, etc. The cultivated area is further divided into 8,947 ha of paddy fields, 106 ha of upland fields, 240 ha of orchards and 774 ha of fallow lands (See Table 3-1 and Appendix 3-29, Figure A.3-25-1). Out of the cultivated area of paddy fields described above, an actual cropping area was estimated at 6,353 ha from the results of survey as shown in Figure 3-4.

(1) Paddy Fields

In accordance with the topographic conditions, especially in relation to the availability of irrigation water, the paddy field in the Project Area comprises three areas and each area has one type of paddy cultivation as shown below. The double cropping of paddy is scarcely performed in the Project Area.

Table 3-1 Present Land Use

Unit: ha

Tambon	Gross Area	Cultivated Area							Others[3]		
		Paddy Fields									
		Wet Season T.P.	Wet Season B.C.	Dry Season T.P.	Fallow Land	Upland Fields	Orchard	Total	Homestead	Roads & Dike	Canal & Others
Khusalod	3,532	930	854	801	225	39	-	2,849	256	23	404
Phraya Banlu	3,055	741	1,004	436	199	20	60	2,460	164	34	397
Sing Ha Nat	5,213	760	769	2,292	319	47	180	4,367	392	10	444
Sub-Total	11,800	2,431	2,627	3,529	743	106	240	9,676	812	67	1,245
	(73,750)[1]	(15,194)	(16,419)	(22,056)	(4,644)	(662)	(1,500)	(60,475)[2]	(5,075)	(419)	(7,781)
Other Tambon[4]	494	102	110	148	31	-	-	391	34	23	46
Total	12,294	2,533	2,737	3,677	774	106	240	10,067	846	90	1,291
	(76,838)	(15,830)	(17,106)	(22,981)	(4,838)	(662)	(1,500)	(62,919)	(5,287)	(563)	(8,069)

Note: Wet Season T.P.: Wet season transplanting paddy area
Wet Season B.C.: Wet season broad-casting paddy area
Dry Season T.P.: Dry season transplanting paddy area

[1]: Referred to the cadastal area obtained from Land Reform Office
[2]: Total cultivated area of 9,676 ha is derived from the Land Department, but each land category in the cultivated area is estimated, based on the land use map obtained from Chao-Ched Bangyeehon and Phyray Banlu Irrigation Offices
[3]: Estimated based on the 1/10,000 map of at each Muban
[4]: Inclusive of a part of Amphoe Bangtri

( ) : Shows the area in Rai

Wet Season Broadcasting Paddy Area

The wet season broadcasting paddy is grown in 31 per cent of the total paddy field area. This kind of paddy has been grown in relatively high-lying areas located far from canals, where the paddy cannot grow without flooding water. The cultivation method for this paddy is characterized by applying the direct seeding (broadcasting) and extensive flooding irrigation, which had prevailed in the whole lower Chao Phya river basin about a decade before, and still this type of cultivation is performed in a large scale in the river basin.

Wet Season Transplanting Paddy Area

About 28 per cent of the total paddy field area is cultivated with the wet season transplanting paddy of high yield varieties which has been recently introduced in parallel with the construction of main irrigation canals. Due to the absence of on-farm irrigation and drainage facilities, its cultivation is, however, limited to the areas along canals where the pumping irrigation is easily made.

Dry Season Transplanting Paddy Area

About 41 per cent of the total paddy field area is cultivated with the dry season transplanting paddy of high yield varieties. During the dry season, in addition to scarce effective rainfall and also low water level in the canals, its cultivation is limited to the low-lying areas where individual farmer can supply water in the existing canals to their paddy fields with a low-head pumps or to the other relatively high-land area where the irrigation is possible by raising the water level in canals to a considerable high level with check gate. Paddy fields with favorable topographic conditions for irrigation are quite limited in the Project Area as the canal density is extremely low. And furthermore, insect and bird damages on yield cannot be negligible in this case. However, farmers have introduced this paddy to a possible extent by their efforts to prepare farm ditches from the existing main canals and operate their own pump. The dry season transplanting paddy cultivation is blessed with favorable drainage condition

due to the lower groundwater tables during this season and sufficient sunshine hours. In a part of Tambon Khusalod and most part of Tambon Sing Ha Nat, the dry season transplanting paddy has been introduced since six to seven years ago. It should be noted that, in spite of the introduction of high yield varieties and labor-consuming works for transplanting as well as a considerable amount of fertilizer application, a yield of this paddy is not always satisfactory because of the difficulty in irrigation water supply due to the absence of on-farm irrigation and drainage facilities.

Most farmers do not like to grow the wet season paddy following the dry season paddy, and after harvesting the dry season paddy, they remain their farm fields as it is covered by flooding water during the long wet season period though the native floating rice (broadcasting paddy) can grow under the eixsting conditions. The reason why they hesitate to grow the floating rice is that the six-month's period is too short for this paddy to mature so long as transplanting cultivation is not performed in place of broadcasting cultivation. So farmers who grow the high yield dry season transplanting paddy are compelled to keep their farm field as fallow land during the wet season. Farmers say that a satisfactory yield of the native paddy is not expected and that they have no sufficient labor force needed to the transplanting works.

(2) Upland Fields, Orchards and Others

Upland fields dotted around villages in the Project Area are mainly cultivated with bananas, coconuts, vegetables and grains. Most of such products are for self-consumption though some vegetables are brought into the market. Orchards in the Project Area are mostly cultivated with citrus, and the citrus fruits are put into the market mainly in Bangkok. As is popular in the suburbs of Bangkok, each of the upland fields and orchards for cash crops is equipped with a surrounding dike, high ridges and large and deep ditches between ridges to cope with flood in the wet season and to secure irrigation water in

the dry season. Such upland fields and orchards are seen along large canals which are used for irrigation and drainage as well as transportation of the products.

(b) Productivity

(1) Cropping Pattern

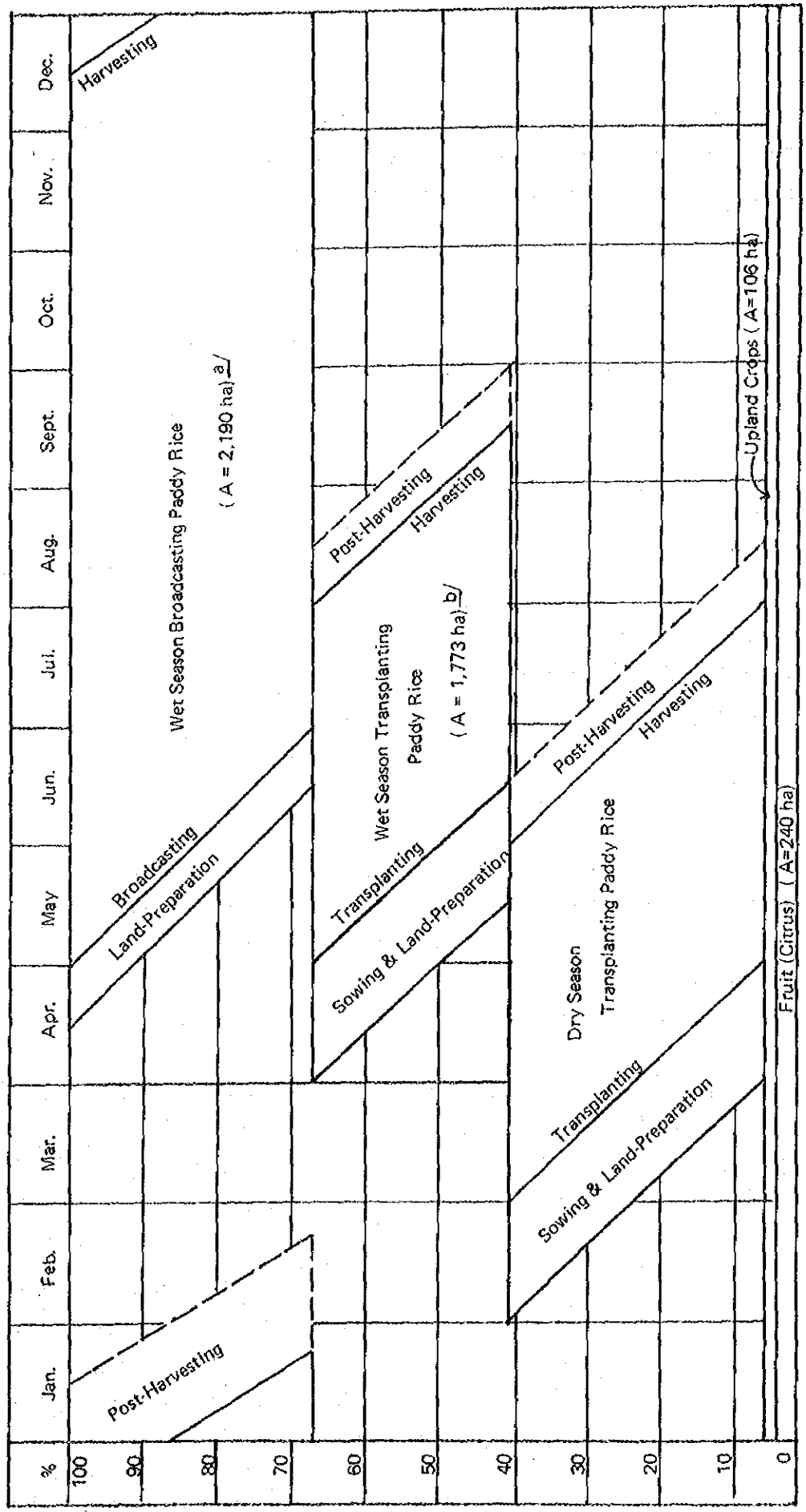
The cropping pattern prevailing in the Project Area is shown in Figure 3-4. The wet season broadcasting paddy is the native floating rice having a photoperiodic sensitivity and a long growing period, which is suitable to the flooding irrigation. This paddy is broadcasted to dry paddy fields in May and June. The flooding to irrigate the paddy fields starts in September, and the harvesting is carried out in late-December to January when the flood season is over. In general, each variety of the floating rice has its own maturing date. Several varieties having the maturing dates suitable to be harvested in late-December to January have been grown in the Project Area.

Almost no farm management for farm practices except the land preparation, broadcasting and harvesting is performed for growing this paddy. As a matter of course, no fertilizer is applied. A yield of this paddy per hectare is accordingly low, 1.6-ton per hectare on average (see Appendix 3-29). So farm house-holds in the Project Area are eager to switch it over to the high yield transplanting paddy cultivation.

Both the wet season and dry season transplanting paddy cannot be grown during September to December when the flooding water covers the whole Project Area. So the former is planted in the early half of the wet season and the latter in the dry season.

The wet season transplanting paddy, average yield 2.2 tons per hectare, is sown in April to May and transplanted in May to June so that it can be harvested before the beginning of flooding. The sowing, transplanting and harvesting of the dry season transplanting paddy,

FIGURE 3 - 4 PRESENT CROPPING PATTERN



Note: a/ 2,737 ha x 0.80, b/ 2,533 ha x 0.70, c/ 3,677 ha x 0.65

average yield 3.0 tons per hectare, are carried out in February to March, March to April and June to July, respectively. The land preparation for transplanting is made in the dry season. The same improved varieties are used for both cultivations of the wet and dry season transplanting paddy. The cultivation of these varieties is much intensive with effective fertilizer application. The high yield varieties of RD and C4-63, etc. have been grown in the Project Area, especially C4-63 is the most popular in the Project Area.

Nitrogen of about 30 kg/ha and phosphoric acid of about 38 kg/ha on average are consumed for both transplanting paddies, but fertilizers are not sufficiently used. The artificial control of irrigation and drainage waters in each farm plot is the prerequisite for growing high yield varieties with a short stalk. At present, even if sufficient labor force is supplied, high yield varieties cannot be planted in the whole Project Area except some limited areas due to the absence of systematic infrastructural facilities in the on-farm level.

The intensive cultivation of citrus, mainly sweet oranges, and vegetables such as water melons and so forth for marketing is partially performed in the Project Area. However, a number of house-holds engaged themselves in such cultivation is quite limited because a big fund is needed to prepare the special farm field and furthermore, a considerable amount of fertilizers, chemicals and herbicides as well as farming techniques which only the devoted farmers may have are required.

The present cropping intensity in the Project Area is about 67 per cent.

(2) Agricultural Production

The present agricultural productions by each crop in the Project Area are estimated as shown below:

Agricultural Production

Crops	Cropping Area (ha)	Yield (ton/ha)[a/]	Production (ton)
Paddy Rices			
Wet season broadcasting	2,190	1.6[b/]	3,504
Wet season transplanting	1,773	2.2	3,900
Dry season transplanting	2,390	3.0	7,170
Sub-total	6,353	2.3	14,574
Upland Crops	106	5.0	530
Fruits	240	15.0	3,600
Total	6,699		18,704

a/ See Appendix 3-29
b/ Unhulled rice

Besides crop production, small-scaled domestic animal breeding and natural fresh-water fish catch are performed in the Project Area. Domestic animals have to be grown in high-floored barns during the flooding season from September to December, which hinders livestock raisers from expansion of the farming scale. Major domestic animals bred at present are as follows (See Appendix 3-30).

Water buffalo	307 heads
Cattle (Zebu)	516
Pig	561

Water buffalos and cattle are bred as draft animal. They have decreased recently as farmers are switching over their farming by draft animal to the mechanized farming. Poultry such as hens and domestic ducks have been also bred in the Project Area. Hens are left free in farmers' house yards for farmers' consumption. Domestic duck breeding is made in a relatively large scale. Fresh-water fish in canals and ditches is the major source of protein. An annual catch of them is estimated at 156 tons, but the catch has remained in the same level these years.

2. Farming Status

(a) Farm Size

Data on the number of households and cultivated area classified by farm size are not available for the whole Project Area covering the 29 Muban, however, the data on the above in the 17 Muban are available at present, of which survey has been carried out by the Changwat Agricultural Land Reform Office to enforce the agricultural land reform. Following table indicates the result of the survey.

Number of Households and Area by Farm Size

Size of Farm Land (rai)	No. of House-holds	Farm Land (rai)	Percentage(%) House-holds	Percentage(%) Farm Land	Average Area per Household (rai)	Average Area per Household (ha)
less 10	287	1,956	28.9	8.3	6.8	1.1
10 - 30	488	9,091	49.1	38.6	18.6	3.0
30 - 50	126	5,127	12.7	21.8	40.7	6.5
50 - 70	45	2,591	4.5	11.0	57.6	9.2
70 - 100	37	3,170	3.7	13.5	85.7	13.7
100 - 120	7	742	0.7	3.2	106.0	17.0
over 120	4	860	0.4	3.7	215.0	34.4
Total	994	23,537	100.0	100.0	23.7	3.8

It is found out that the farm households having farm lands less than 4.8 ha (30 rai) occupy 78 per cent of the total households and those having areas of 1.6 ha to 4.8 ha (10 rai to 30 rai) are of the most prominent occupying the 49.1 per cent of the total households. Furthermore, about five per cent of farmers cultivate the area of more than 11.2 ha (70 rai). Although an average cultivation area per household was estimated at 3.8 ha (23.7 rai), it could be considered that those in the whole Project Area would be more than 3.8 ha, because the 17 Muban described above are located on the north side of the Khlong Phraya Banlu with dense population.

(b) Farm Labor

With regard to the existing farm labor force, it is noted that the demand and supply are balanced only in June when the maximum labor

is required due to the lap of harvesting for the dry season transplanting paddy and transplanting for the wet season paddy. (see Appendix 3-31). Except in June, the demand is much less than the existing labor force. Especially from September to December when the flood covers the whole Project Area, the farm labor is hardly required. It seems that the idle production labor retained to meet the peak demand in the short period has caused the latent unemployment in the Project Area and its neighborhood.

Farmers are compelled to consume big labor force irrationally for growing the transplanting paddy varieties which have been recently introduced to the Project Area, due to the absence of on-farm facilities such as on-farm canals and farm roads. And furthermore, the existing cropping pattern cannot be widely altered due to the flood, and the cropping area cannot be expanded because of a limited labor force at the peak demand period so far as the existing conditions continue in future. In fact, many farm house-holds suffer from labor shortage at the peak time due to the absence of well-organized labor market.

Under the conditions, some measures to acquire the balance of the demand and supply of labor and solve for the latent unemployment problem are required.

The paddy cultivation has been mechanized to a considerable extent. About 90 per cent of the land preparation including plowing and puddling is mechanically performed in the Project Area. The machines are also used for transportation and threshing. Thus, the animal power is scarcely used for farming practices though water buffalos are supplementally used in limited areas where mechanized works are difficult. However, the operation of farm machineries has not produced the desirable result in comparison with their capacities under the present status such as the absence of on-farm facilities, poor drainage and small-size plot.

The transportation is done by boat. The transportation of input materials and yields on farmers' level is made by the machines during the dry season, but boats have to be used during the wet season.

As described above, the farm practices have been mechanized to a considerable extent. However, all the works except plowing, puddling, transportation and threshing are performed by man-power, especially transplanting and harvesting require a great deal of labor force. As a result, the agriculture in the Project Area is still quite extensive.

(c) Land Tenure

The number of owners and the areas by size of owned land are given in the following table:

Number of Owners and Area by Size of Owned Land

Size of Owned Land	No. of Owners	Farm Land (rai)	Percentage (%)	
			Owner	Farm Land
less 20 Rai	1,230	13,690	56.7	22.6
20 - 50 Rai	693	21,902	32.0	36.2
50 - 100 Rai	184	12,828	8.5	21.2
100 - 500 Rai	58	8,842	2.7	14.6
500 - 1,000 Rai	4	3,215	0.2	5.3
Over 1,000 Rai	0	0	0	0
Total	2,169	60,477	100.0	100.0

The table shows that the number of land owners who own the land less than eight ha (50 Rai) is 1,923, about 89 per cent of total owners; and 5,695 ha (35,592 Rai) is owned by this group, which is equivalent to about 59 per cent of the total area. When these lands would be cultivated by the owners themselves, the lands would not be purchased by government in accordance with the provisions of Paragraph 1, Subsection 1 of Section 29 of Agricultural Land Reform Act.

The 3,981.6 ha (24,885 Rai) is owned by the land owners who own eight ha or more. When all the owners of this group would cultivate

eight ha, the land purchased by government according to the provisions mentioned above would be 2,014 ha (12,585 Rai), equivalent to 21 per cent of the project area or 57 per cent of rented land of 3,548 ha (22,173 Rai).

According to the survey on the land rent conducted by Changwat Agricultural Land Reform Office in 1974, the 37 farmers out of 38 farmers paid in cash as land rent and only one farmer paid in kind in the Amphoe Lad Bau Lang. The land rent is usually 50 to 100 Bahts per rai as shown in the following table:

Farm Rent (฿/rai)	No. of Samples
1 - 50	1
50 - 100	32
100 - 150	4

(d) Taxation

Land owners have been levied land taxes on the basis of the assessed values of lands. The assessed values of farm land in the Project Area and the tax rates are shown as follows:

Average Price of Land and Tax Rates

Tambon	Average Price of Land (Baht/rai)	Tax Rate			
		Operated by Owner		Rental	
		(Baht/rai)	(Baht/ha)	(Baht/rai)	(Baht/ha)
Khusalod	2,000 - 2,200	5.5	34.4	11.0	68.8
Phraya Banlu	2,400 - 2,600	6.5	40.6	13.0	81.3
Sing Ha Nat	2,400 - 2,600	6.5	40.6	13.0	81.3

The income derived from the sale of rice cultivated by the farmer himself and his family is exempted from taxation, regardless of the amount of income involved.

(e) Farm Income

Socio-economic survey was conducted by the Agricultural Land Reform Office, in Amphoe Lad Bao Laung in 1975. The results of the

survey give a sketchy picture of the present agricultural situation in the area, as follows:

General Information on Sample Farms

Item	Category A	Category B
No. of sample farms	22	24
Cropped Area (ha)	9.5	8.3
Rice		
Wet Season	4.8	2.1
Dry Season	4.2	3.0
Citrus	0	3.1
Water Melon	0.5	0.1

Gross and Net Income

Item	Category A (Baht)	Category B (Baht)
Gross Crop Income		
Rice	29,150	20,000
Citrus	0	87,080
Others	1,670	510
Sub-total	30,820	107,590
Net Crop Income		
Rice	13,250	10,020
Citrus	0	54,590
Others	620	390
Sub-total	13,870	65,000
Net Income from Livestock	580	-1,250
Total Net Agricultural Income	14,450	63,750
Off-Farm Income	2,070	5,170
Total Farm Income	16,520	68,920

Following points were found out in the survey:

i) Category A consists of full owner farmers and part-owner farmers. The average size of this category (9.5 hectares) is considerably bigger than that of the Project Area. It can be said that farmers who grow rice on four hectares have an income of only about 6,160 Baht from rice cropping as compared to 13,250 Baht in Category A.

ii) Category B consists of tenant farmers. Farmers who grow citrus enjoy a favorable income. The average net crop income of 65,000 Baht seems to be much higher than that of the Project Area.

iii) 96 per cent of net agricultural benefit in Category A and 100 per cent in Category B are accrued from crop farming. That is, animal husbandry and horticulture are minor sectors in the area.

iv) Off-farm income is about 13 per cent of total farm income in Category A and about 8 per cent in Category B.

3. Research and Extension

In executing the agricultural extension services, the most important is to introduce systematically and smoothly the techniques and knowledge for modernized farm management and practices to farmers. The Departments of Agriculture and of Agricultural Extension, which are under the Ministry of Agriculture and Cooperatives, are responsible for agricultural research and extension services in Thailand whereas the Departments of Livestock and of Fisheries are in charge of extension services in each of their specialized fields (Appendix 3-32). For the extension services in Amphoe level, only two extension workers are assigned to render the supporting services directly to farmers in an area of about 20,000 ha. It is informed that the extension workers must spare about a half of their working hours for recording and general reporting and about 25 per cent for communication with the other offices, therefore, the time they can actually spare for the essential works is just 25 per cent of their working hours. Most extension workers, having no research institute training, are given few opportunities to make contact with staff of the agricultural research institutes, which hinder the timely transfer of research and experimental results from the institutes to farmers. Furthermore, it is a tendency of the extension workers in Thailand that they hesitate to intervene in farm management, which might also counteract the effect of their effort.

4. Input Supply and Credit

The major agricultural input in the Project Area consists of seeds, fertilizers, agricultural chemicals, agricultural machineries and fuels, etc. At present, dealers, landowners and so forth deal with these agricultural input materials. Farmers in the Project Area have to spare their limited funds for seeds, fertilizers, chemicals and farm machineries anticipating with fear the bad climate, rainy and flood conditions in the coming year. The existing condition of supply of these agricultural input materials is described below.

Seed Supply

Farmers have traditionally used a part of their previous yield for sowing. In the Project Area, 187 tons of RD varieties (4,163 ha x 45 kg/ha) and 284 tons of native varieties (2,190 ha x 130 kg/ha) are required for sowing. In case of RD varieties, at least one-fourth of the required tonnage, that is, 47 tons should be supplied every year so that every farmer who grow the high yield paddy can be given new seeds once every four croppings. For this purpose, the seed breeding field of more than 20 ha should be prepared. However, it seems that neither such seed breeding field nor seed distribution system is provided in the Project Area.

Fertilizers and Agricultural Chemicals

A considerable amount of fertilizers and chemicals have been consumed for transplanting paddy varieties as shown in the following table, however, no fertilizer has been used for broadcasting paddy though some agricultural chemicals have been applied.

All the fertilizers and chemicals listed in the table are handled by dealers and agents at Sena and Ayutthaya or landowners, etc., and the agricultural cooperatives in the Project Area do not participate in marketing of these agricultural input.

Fertilizers and Agricultural Chemicals

Crops	Cropping Area (ha)	Application (kg/ha)	Application (ton)	Cost (฿/ha)	Cost (฿'000)
1. Fertilizer					
Paddy fields:					
Wet season broadcasting	2,190	-	-	-	-
Wet season transplanting	1,773	188	334	771	1,367
Dry season transplanting	2,390	188	449	771	1,843
Fruits	240	1,372	329	5,684	1,363
Vegetables etc.	106	-	-	-	-
Sub-total	6,699		1,112		4,573
2. Agricultural chemical					
Paddy fields:					
Wet season broadcasting	2,190	8	18	385	843
Wet season transplanting	1,773	38.6	68	581	1,030
Dry season transplanting	2,390	38.6	92	581	1,389
Fruits	240	900	216	10,364	2,487
Vegetables	106	-	-	-	-
Sub-total	6,699		394		5,749

Agricultural Machinery and Others

An average number of agricultural machinery per farm household as well as fuels and other materials consumed in the Project Area are as tabulated in Appendix 3-33.

Farmers purchase the agricultural machinery and consumable materials through the dealers and agents mainly at Sena and Ayutthaya. Especially the number of hand tractors has been rapidly increasing recently in the Project Area. For example, 541 units were introduced in 1974, and at present, the number of this farm machines is numerated at about 640 against the decrease of water buffalos.

Credit

Most farm house-holds are compelled to go into debt in order to obtain their agricultural input, and pay it back after harvesting. In case of a crop failure, many farm house-holds cannot repay it. It was informed at Amphoe Agricultural Cooperatives that most farm house-holds have a debt of about 2,000 Baht on an average.

Reportedly, they borrow 50 per cent of their necessary amount of money from their relatives, acquaintance and banks, 40 per cent from landowners, dealers and rice-mill owners and 10 per cent from agricultural cooperatives.

The agricultural cooperatives lend money to farmers with an interest rate of 15 per cent per annum in case of a short-term loan. However, it is said that an average interest rate per annum exceeds 20 per cent because farmers pay in kind, paddy rice in most cases. Agricultural cooperatives in the Project Area are now dealing with the agricultural loans, both the short-term (one year) and middle term (five-year) loans. The rate of interest are different according to the terms of loan, but an average rate is about 12 per cent. Some farm house-holds obtain individual loans from the BAAC, but it is the Governmental policy to intensify and replenish the agricultural cooperatives activities for loan so that agricultural loan will be dealt with by the cooperatives only in future. The short-term loan is used for purchasing fertilizers and agricultural chemicals while the middle-term loan for obtaining agricultural machineries, livestocks and farm land as well as for land improvement and fish pond construction, etc. The maximum amounts of loans are determined as follows:

Amount less than ฿3,000:	by mutual guarantee of subscribers of the cooperatives
Amount ranging from ฿3,000 to ฿7,000:	on the security of farm land, etc.

Under the circumstances, the unrepaid amount has been increasing year by year. Farmers desire that working funds of the cooperative will be expanded to meet the demand of subscribers.

5. Processing and Marketing

The major farm products in the Project Area are rice, fruits and vegetables. The yield and production for each were previously described.

The agricultural cooperatives in the Project Area serve neither for cooperative shipping and selling of agricultural products nor group utilization of processing facilities. Many farm house-holds who engaged themselves in paddy cultivation do not have their own rice storage facilities. So they are compelled to sell all their yield including a part for their self-consumption to dealers or the others, and purchase rice they need at the price of 7 Baht/kg. Some farm house-holds who engaged in fruits and vegetables cultivation have industrialized their farming, and shipped their products to the market in Bangkok by their own boats or sold them directly to dealers in the Project Area.

As for processing facilities, there are six rice mills mostly operated by dealers. Their capacity is in the range of 10 to 20 ton/day. The annual milling capacity is estimated at 4,930 tons in total.

6. Farmers' Organizations

Three kinds of farmers' organizations have been established in Thailand, as follows:

i) Agricultural Cooperatives

About a half century ago, the Government of Thailand encouraged farmers to establish agricultural cooperatives in Muban basis, and made the cooperatives be responsible for irrigation, credit and others. But some of them got bankrupt. Even the remaining ones have suffered from difficulty in management. In 1972, the Agricultural Cooperative Act came into force, and by integrating small cooperatives many new agricultural cooperatives on Amphoe level have grown up under the competent guidance and assistance of the Government.

As a result, there exist some old cooperatives in Thailand which carry on their customary activities independently, and there are also new cooperatives established under the above-mentioned Act. However, there is no old cooperative in the Project Area.

The Amphoe Lad Bao Laung Agricultural Cooperatives which takes responsibility only in credit has subscribers of 1,190 farm households out of 2,684 in six Tambon, that is, the rate of subscribers is 44 per cent, while in the three Tambon in the Project Area, the subscribers are 867 house-holds out of 1,548, that is, the rate is 56 per cent. Recently, subscribers of agricultural cooperatives are decreasing year by year due to the decrease of merit such as lowering of the loan limit, etc.

ii) Farmers' Groups

The farmers' group on Muban basis consisting of about 20 members has been established to promote the extension works under the instruction of the extension workers. A foreman is elected among the group members, and takes the leadership among the group members in introducing new agricultural techniques and knowledge. In this Project Area, the farmers' foreman systems have been established. In addition to the group above mentioned, there are wives' group for promotion of the living environmental improvement and 4-H Club consisting of young people. But their activities are limited.

iii) Irrigation Users' Association

A zoneman is assigned to each irrigation users' association, sub-organization of the RID Project Office, having a service area of about 20,000 rai (Tambon basis). Under the guidance of the zoneman, common irrigators are elected among farmers engaged in the water management from turn-outs on Muban basis. There are more than 60 farmers groups, and about 1,400 subscribers in the Project Area. Most of these groups were organized for irrigation purpose.

CHAPTER IV. THE PROJECT

A. Objectives and Components of the Project

1. Objectives and Scope

The Project Area and its neighborhood have been left behind the progress up to now; consequently, the population density is considerably lower than the averaged one in Changwat Ayutthaya as a whole. There might be many reason, but one of the major reason is the absence of agricultural infrastructural facilities such as irrigation and drainage canals and farm road networks in on-farm level, which results in poor production. Since the natural conditions such as soils, climate and topography are well suited for paddy cultivation if adequate facilities are provided, it will be possible to exploit the potentiality of the Project Area for agricultural development.

The Project aims to increase agricultural production, create the employment opportunities through the year, and improve the living environment through the provision of assured irrigation water with improved agricultural supporting services, drainage facilities, road system and drinking water supply. In order to achieve the above-mentioned objectives and to get quick benefit in the whole Project Area, the following should be envisaged, by phasing manner together with land reform, in accordance with the proposed work schedule.

(i) land consolidation for irrigated agriculture as well as for modernized agricultural practices;

(ii) institutional arrangements and strengthening of agricultural supporting services for full development of the Project Area;

(iii) construction of systematic road networks for transportation;

(iv) construction of irrigation and drainage facilities with pump for double cropping of high yield paddy varieties and the other profitable crops;

(v) construction of flood protection dikes for increase of agricultural production in the wet season and for stabilization of living environment; and

(vi) rural community development after the implementation of land consolidation

2. Components

The Project includes the following components;

Civil Works:

(i) On-farm development:	the construction of on-farm roads, irrigation and drainage ditches
(ii) Irrigation and Drainage:	the construction of irrigation and drainage facilities such as canals and pump stations
(iii) Flood protection:	the construction of flood protection dikes
(iv) Roads:	the construction of road networks including rehabilitation of the existing provincial roads etc.
(v) Drinking water:	the establishment of water supply facilities for inhabitants

Agricultural Development:

(vi) Pilot farm:	the establishment of one pilot farm of about 500 ha for intensive guidance of the irrigated agriculture
(vii) Irrigated Agriculture:	the introduction of new agricultural techniques with double-cropping of transplanting paddy of high yield varieties under well-controlled water management
(viii) Supporting services:	the provision of necessary extension and training services - strengthening of input supply, credit, marketing and agricultural processing
(ix) Institutional arrangement:	the establishment of farmers' organization including those for operation and maintenance and the agricultural cooperatives

(x) Rural Community development: the execution of rural community development including environmental improvement such as village roads, drinking water supply and so forth

For the implementation of the above-mentioned Project components, sufficient construction equipment would be procured and necessary consulting engineers and experts would be recruited.

B. Project Formulation

1. Alternatives on Optimum Scale of Sub-Project Areas

Alternative studies on the optimum scale of sub-project areas as well as adequate irrigation and drainage systems for the Project Area have been made considering the existing conditions on topography, irrigation and drainage and local water management etc. in the Project Area and its vicinity.

Three case studies as alternatives were considered in the first stage of the studies; the first is "without dike" plan, the second is "with dike" plan and the third is the compromise of the above-mentioned two plans, that is, "with and without dike" plan. In the second stage, these case studies were sub-divided into several alternatives by dividing the Project Area into small sub-project areas. As a result, the following seven alternative studies have been conducted in the Project. (See Figure 4-1).

Case I. Without dike plan

Plan I-1: to divide the Project Area into two irrigation areas setting up the borderline along Phraya Banlu canal

Plan I-2: to divide the Project Area into five small irrigation areas setting up the borderlines along Phraya Banlu and the other existing canals

Plan I-3: to divide the Project Area into three irrigation areas setting up the almost same borderlines on the existing boundaries of Tambon(s)

Case II. With dike plan

Plan II-1: to divide the Project Area into two blocks setting up the borderline along the proposed dikes. Irrigation systems are the same as those for Plan I-1

Plan II-2: to divide the Project Area into five blocks setting up the borderlines along the proposed dikes. Irrigation systems are the same as those for Plan I-2

Plan II-3: to divide the Project Area into three blocks setting up the borderlines along the proposed dikes. Irrigation systems are the same as those for Plan I-3.

Case III. With and Without dike plan

Plan III-1: to divide the Project Area as mentioned in Plan II-3, but Block A in the upper area with relatively high area equips with no dike.

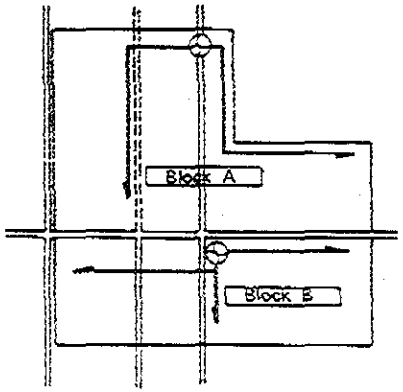
Out of the above-mentioned alternatives, the Plan I will make it inevitable to inundate the Project Area during the wet season even after the completion of the on-farm facilities in the Project, because this Plan aims at not only an increased production of paddy rice by expanding the cropping area of new high yield varieties in the dry season, but also by way of transplanting the floating rice in the wet season, though the pumping irrigation is to be carried out for new paddy varieties grown in the dry season as in case of the other plans. On the other hand, in case of "with dike" Plan, the service areas of the Project will be surrounded by dikes, and the irrigation and drainage with pump operation will be sufficiently practiced for cultivation of both the dry and wet seasons transplanting paddy of high yield varieties.

The Plan III-1 is the compromise of "with dike" and "without dike" plans. In this Plan, Block A located on the upper basin and having a relatively high elevation of more than two meters above mean sea level will not be equipped with dikes though the same irrigation and drainage systems as in the "with dike" plans mentioned above are to be provided. In this Plan, Block B and Block C whose elevations are less than two meters above mean sea level will be equipped with the dikes for flood

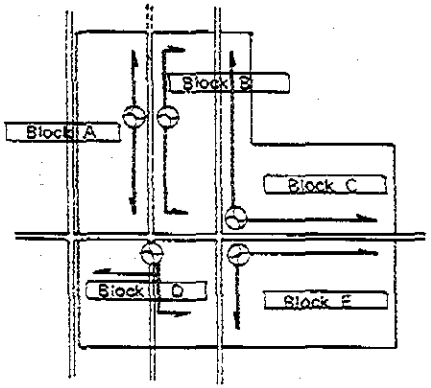
FIGURE 4–1 ALTERNATIVE PLAN OF IRRIGATION AND DRAINAGE SYSTEMS

I. WITHOUT DIKE PLAN

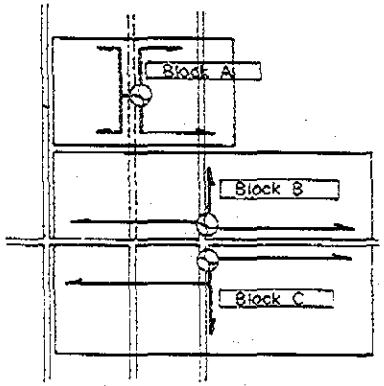
PLAN I - 1



PLAN I - 2

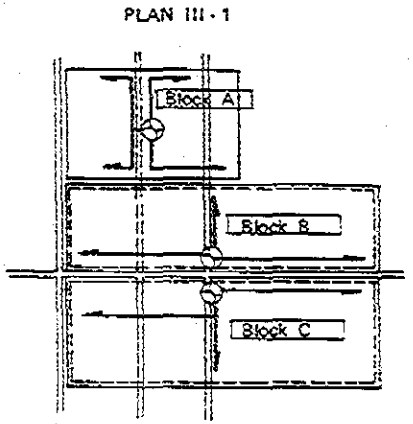


PLAN I - 3



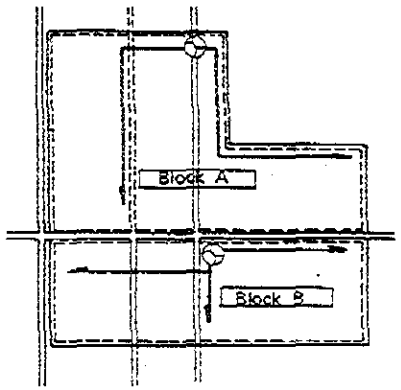
III. WITH AND WITHOUT DIKE PLAN

PLAN III - 1

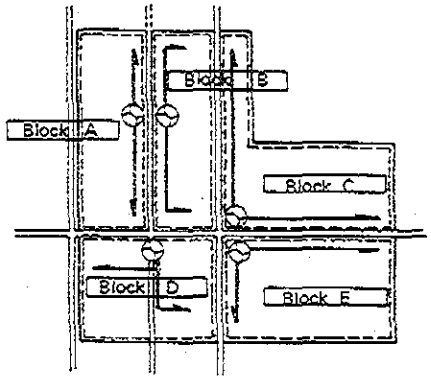


II. WITH DIKE PLAN

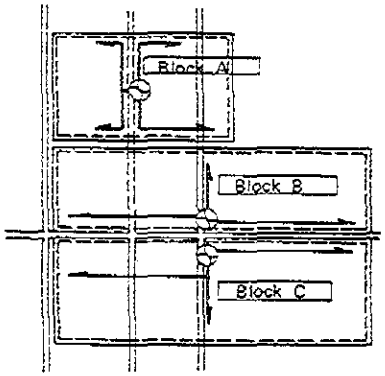
PLAN II - 1



PLAN II - 2



PLAN II - 3



LEGEND

- Existing Main Irrigation Canal
- Pumping Station
- Dike
- Canal

protection in the wet season, and the double cropping of paddy will be introduced.

The reference to the major features of each plan will be made in Appendix 4-2. The preliminary studies for selecting the most suitable and adequate plan for irrigation and drainage in the Project Area were carried out both in the technical and economical aspects based on the following criteria:

- Paddy should be, in general, grown both in the wet and dry seasons.
- The incremental benefits equal the benefit in case of "with project" minus the benefits in case of "without project". These benefits are mostly converted into and shown as a yield of paddy rice so far as the cultivated areas are concerned. And the benefits from animal husbandry and inland fishery are evaluated exceptionally in case of the "with dike" plan. Cropping area and yield in each alternative plan are as follows:

Description	Plan I	Plan II	Plan III
Cropping Area (%)			
Wet season	30[a/]	100	30 (Block A) 100 (Block B & C)
Dry season	100	100	100
Yield (ton/ha)			
Wet season	2.0	4.2	2.0 (Block A) 4.2 (Block B & C)
Dry season	4.2[b/]	4.7	4.2 (Block A) 4.7 (Block B & C)

Note: a/ In the without dike plan (Plan I), cropping area in the wet season is restricted by the balance of labour force for the transplanting of floating rice and by the raise of water level in the field due to flooding irrigation

b/ Yield of transplanting dry season paddy in case of plan I is decided at 4.2 ton/ha, equivalent to 90% of that of Plan II, taking into consideration the water conditions of drainage at the low land in the Project Area, which will be caused by flooding irrigation around the Project Area.

- The land consolidation works should be carried out in the whole Project Area in both cases of "with dike" and "without dike" plans.

- One unit of pumping facilities should be installed at each block for both irrigation and drainage.

- If a plan to construct flood protection dikes is adopted, the dikes with the top widths of eight or four meters and height of 3.5 m above means sea level should be constructed as a result of probability analysis of maximum water levels.

- The cost should be estimated based on the layout of facilities which is made on the map of 1:50,000 in scale, and based on rough unit costs.

- Economic evaluation should be tentatively made by using internal rate of return (IRR).

The study results are as summarized in Table 4-1. This table proves that the most feasible plan out of the alternatives is the Plan II-1 which shows the highest IRR of 16.1 per cent, while the Plan I-2 having the IRR of 12.0 per cent is of the lowest priority among these alternatives. The order of economic priority among the alternatives is as follows:

The first:	With dike plan (Plan I)
The second:	With and without dike plan (Plan II)
The last:	Without dike plan (Plan)

The net incremental benefit created by Plan II amounts to about 2.4 times of that in Plan I. In the Plan II, however, Plan II-1 to divide vastly the Project Area into two sub-areas with the highest IRR of 16.1 per cent points out a problem in determining pumping station site suitable both to the irrigation and drainage from technical view point. When the pump is installed at a relatively high place in a sub-area for materializing gravity irrigation in the vast area, the water

Table 4-1. Alternative Study on Optimum Scale of Sub-Project Area

Descriptions	Without Dike Plan			With Dike Plan			With and Without Dike Plan
	Plan I-1	Plan I-2	Plan I-3	Plan II-1	Plan II-2	Plan II-3	Plan III-1
1. Cultivated Area (ha)							
Without Project	10,067	10,067	10,067	10,067	10,067	10,067	10,067
With Project	10,988	10,988	10,988	10,542	10,542	10,542	10,542
2. Cropping Area (ha)							
Without Project							
Wet season	3,963	3,963	3,963	3,963	3,963	3,963	3,963
Dry season	2,736	2,736	2,736	2,736	2,736	2,736	2,736
Sub-total	6,699	6,699	6,699	6,699	6,699	6,699	6,699
With Project							
Wet season	3,297	3,297	3,297	10,542	10,542	10,542	8,423
Dry season	10,988	10,988	10,988	10,542	10,542	10,542	10,542
Sub-total	14,285	14,285	14,285	21,084	21,084	21,084	18,965
3. Cropping Intensity (%)							
Without Project	67	67	67	67	67	67	67
With Project	130	130	130	200	200	200	180
4. Construction Cost	18,060	19,560	18,590	26,250	27,570	26,920	24,260
(US$'000)	(100)	(108)	(103)	(145)	(153)	(148)	(134)
5. Net incremental benefit	2,500	2,500	2,500	5,990	5,990	5,990	4,950
(US$'000)	(100)	(100)	(100)	(240)	(240)	(240)	(198)
6. Internal Rate of Return (IRR)[a/]							
(%)	12.6	12.0	12.4	16.1	15.6	15.9	14.9

Note: a/ Detailed estimate is given in Appendix 4-3.

level in the drainage canal adjoining to the pumping station has to be kept considerably lower than the ground surface while the pumping drainage is performed in order to drain the excess water in the paddy fields located at the furthest from the pumping station. So, the drainage canal will be necessarily deep and large especially in its lower reaches, which results in vast construction costs.

Therefore, the Plan II-3 appears the most recommendable for this Project from the economic and technical view points. Furthermore, this plan has such merits that water distribution by pump operation after the implementation of the Project will be carried out within almost the same administrative districts of the existing Tambon, and also that the pilot farm to be constructed in advance of the Project falls in one Block, Block B.

The Plan II-3 is finally selected among the alternatives as the most suitable and optimum plan for the Project. Therefore, the irrigation and drainage schemes which will be discussed hereinafter have been formulated based on the Plan II-3.

2. Irrigation Plan

(a) Irrigation Water Requirement

Potential Evapotranspiration

Potential evapotranspiration (ETp), generally recognized as fairly reliable index in calculating consumptive use, can be determined by a number of methods, such as the evaporation measurement from evaporation pans and the application of empirical formula based on the climatological data. In the Project, the evapotranspiration of each proposed crop is estimated by applying the Penman method[1/], by using an average climatological data observed at Suphan Buri, Lop Buri and Bangkok, of which averaged figures are given in Appendix 3-1.

1/ Penman Method - this is the most complete theoretical formula applicable better for the rather humid area not far from ocean and essentially covered with growing vegetation.

The following table indicates the comparison of the estimated potential evapotranspiration (ETp) with the converted ETp based on the evaporation.

Estimated Potential Evapotranspiration (ETp)

(Unit: mm)

Month	Penman Method ETp	Penman Method ETp/E	Observed Evaporation	Converted ETp
Jan.	3.90	0.65[a/]	4.33[b/]	2.80[c/]
Feb.	4.65	0.77	4.80	3.70
Mar.	5.22	0.73	5.98	4.37
Apr.	5.71	0.78	6.58	5.13
May	5.02	0.89	5.75	5.12
Jun.	4.56	0.86	5.23	4.50
Jul.	4.15	0.86	4.79	4.11
Aug.	4.01	1.01	4.57	4.62
Sep.	3.78	1.18	4.43	5.22
Oct.	3.91	1.11	3.93	4.36
Nov.	4.04	0.86	4.04	3.47
Dec.	3.87	0.71	3.91	2.78
Average	4.40	0.84	4.86	4.18

Note: a/: Ratio of evapotranspiration to evaporation calculated by Penman method

b/ Monthly average evaporation observed at Suphan Buri and Phra Nakhon (Bangkok) during the periods of 10 years from 1961 to 1970.

c/ a/ × b/

It appears in the above table that the estimated ETp values are relatively similar to the converted ETp except those in a few months. So, the ETp values estimated by the Penman method are used for the estimation of the consumptive use in the Project.

Consumptive Use

The consumptive use (actual evapotranspiration, ETa) is estimated by multiplying the estimated ETp values by crop coefficients (K) shown in the following table. These coefficients express the relationship between potential and actual evapotranspirations during distinct vegetative growth stages of the crops.

Crop Coefficient (k)

Crops	Percentage of Growing Season										
	0	10	20	30	40	50	60	70	80	90	100
Rice[a/]	0.85	0.87	0.95	1.06	1.10	1.20	1.19	1.15	1.10	1.03	0.90
Upland Crop	0.20	0.24	0.40	0.66	0.96	1.02	1.00	0.90	0.75	0.60	0.20
Vegetables & Orchard	0.80 throughout growing season										

a/ derived from Northeast Thailand Irrigation Improvement Project Report.

Table A.4-11 (Appendix 4-4) gives the consumptive use of crops estimated on the half-month basis with due consideration of the gradual sliding of seeding, land preparation and transplanting within about one and a half months, and the estimated values were confirmed by the comparison with used values in the reports having already been prepared in Thailand.(See Appeneix 4-5).

Field Water Requirement

Field water requirement is estimated based on the proposed cropping pattern on the half-month basis. In this estimation, the following assumptions are made:

- percolation rate in fields is one millimeter per day throughout the growing period of paddy
- additional water supply for nursery bed and land preparation is decided at 190 mm for both of the wet and dry seasons paddy varieties as shown below:

Nursery bed:

Area: One-twentieth of paddy cropping area

Water requirement: 300 mm

Water requirement per the whole paddy cropping area: 15 mm

Land preparation:

Pre-irrigation: 15 mm (plowing depth: 150 mm, increasing soil moisture from 10% to 20%)

Land preparation: Saturation of surface soil layer: 60 mm
Standing water on soil surface: 100 mm

The total additional water requirement for nursery bed and land preparation is estimated at 190 mm. For the dry season paddy, water of 30 mm deep should be supplied in the early stage of land preparation for easy plowing as pre-irrigation, and water of 160 mm deep in a few days before plowing. But for the wet season paddy, pre-irrigation will not be needed due to the fact that the Project Area has effective rainfall in this season.

The estimated field water requirement is shown in Table A.4-13. (Appendix 4-6) The maximum field water requirement of paddy is estimated at 9.6 mm/day in the first half-month in March for the dry season paddy cultivation which coincides with the water requirement in the last day of land preparation in case of 48-day rotation of water supply. On the other hand, the maximum field water requirement for vegetables and fruits trees is 4.6 mm/day in April.

Irrigation Water Requirement

Irrigation water requirement should be calculated by taking into account the effective rainfalls and water losses in adding to the average field water requirement weighted by the planted area. The criteria of the effective rainfalls and water losses used for the Project are summarized as follows, of which details are explained in Appendix 4-7.

Effective rainfalls:

Paddy field:	December to March:	90% of monthly rainfall
	April to September:	75% of monthly rainfall
	October:	65% of monthly rainfall
	November:	80% of monthly rainfall
Upland field:	See Figure A.4-4 (Appendix 4-7)	

Water Losses:

Paddy field:	Application losses:	20%
	Conveyance losses:	17.5%
		(main 7.5% and lateral: 10%)
Upland field:	Irrigation efficiency:	65%

The irrigation water requirement in the whole Project Area in case of normal year and the design year has been estimated and shown in Appendix 4-8. These figures show that the maximum water requirement in normal years is 744 mm while the same requirement in the design year is 1,010 mm as summarized below:

Total Water Requirement

Description	Normal year (2-year)	Design year (10-year)
1. Cropping area (ha)		
Paddy field	9,542	9,542
Upland field and orchard	1,000	1,000
Total	10,542	10,542
2. Water requirement (mm)		
Water demand	1,671	1,671
Effective rainfall	927	661
Water requirement	744	1,010

The diagram of the irrigation system for each block is shown in Appendix 4-46 together with required capacity of each canal for the system.

(b) Pumping Discharge and Operation Hours

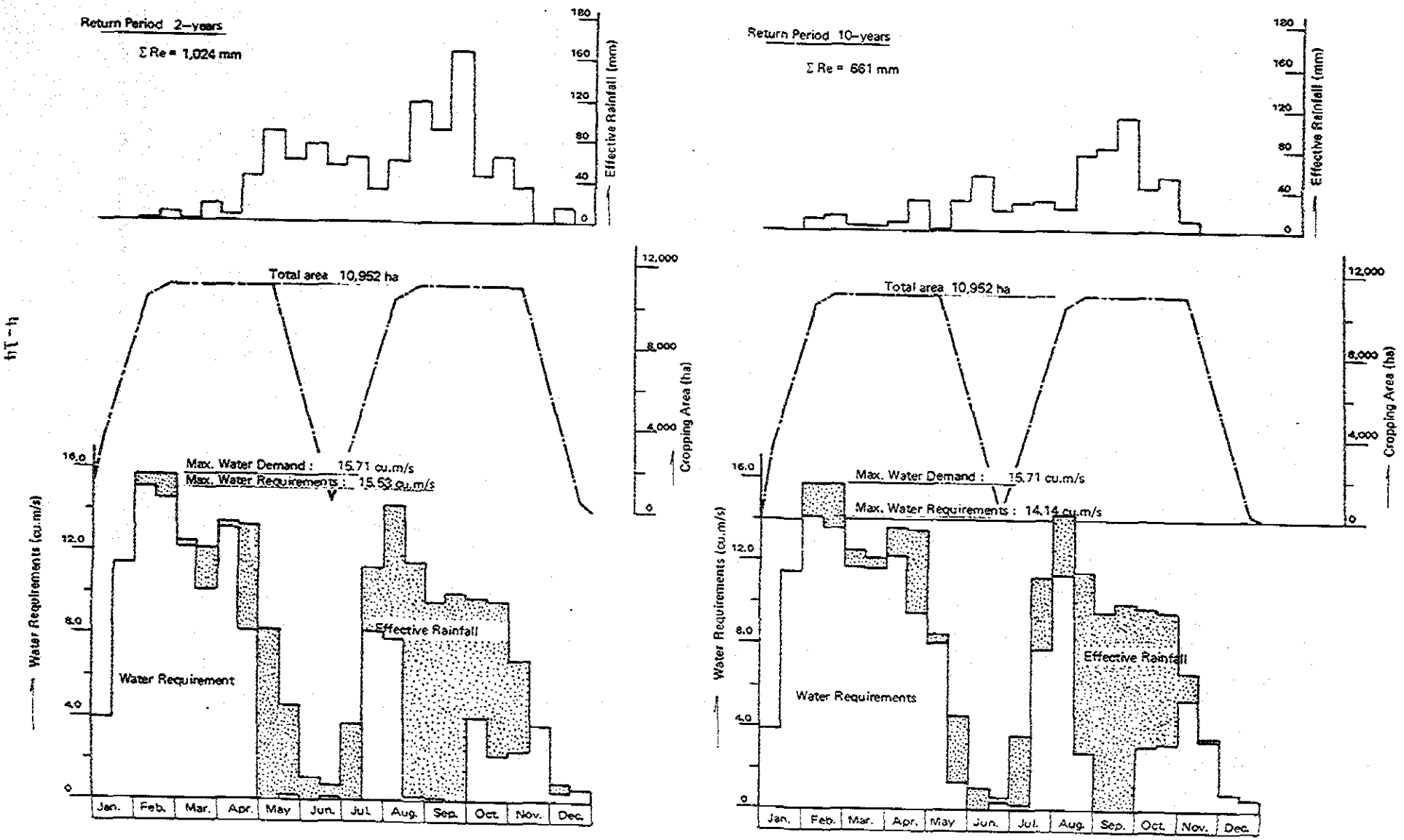
A required pumping discharge and operation hours for irrigation in the whole Project Area have been studied for the both years based on the proposed facilities of pump, of which detailed descriptions are given in Paragraph D, Proposed Facilities. The following shows the summary of the study:

Operation Hours of Pump for Irrigation

Description	Normal year (2-year)	Design year (10-year)
Operation period 1/	8 months	9.5 months
Operation hours (hrs)		
Total hours 2/	13,457	15,523
Hour/unit-day 3/	9.3	9.1

Note: 1/: See Figure A.4-5 2/: See Figure A.4-5
3/: 12,818 ÷ 8 months x 30 dayx x 3 stations x 2 units (assumption)

FIGURE 4-2 CROPPING AREA – EFFECTIVE RAINFALL – WATER REQUIREMENTS



Yearly pump operation hours in the normal year are estimated at about 13,500 hours, while about 15,500 hours in the design year, that is, the pump operation hours in the normal year are 14 per cent shorter than that in the design year. But an average daily operation hours per unit are estimated at about nine hours in the both cases.

3. Drainage Plan

(a) Drainage Modulus for Designing Drainage Canals

Drainage in Irrigated Area

In general, excess water in paddy fields shows the following phenomena:

- The excess water during and after heavy rains overflows from a higher paddy field to the neighboring lower paddy field.

- In sloping area, the overflow mentioned above in hydraulically the same phenomenon as seen at a broad-crested weir of free overflow type. In this case, a quantity of overflow discharge is decided by a difference of the water levels in the upper and lower paddy fields. On the other hand, in an area having no so much difference of the water levels in two adjoining paddy fields, the quantity of overflow discharge is decided mainly by the water level in the lower paddy field as is seen at a submerged broad crested weir.

- Both in sloping and slightly sloping areas, the paddy field from which excess water is naturally discharged to the lower paddy fields has no drainage problem, and even if a paddy field is covered by excess water, paddy does not suffer from it in case the water depth and duration are within an allowable extent.

- However, the paddy field located at the lowest end has not place to discharge excess water, if no measures are taken. It is generally said that the natural drainage, drainage by gravity, is effective in the areas having a slope of more than 15 cm/km. In the other areas especially flat or very slightly sloping area,

the drainage problem is caused, and some facilities including pump are required.

Method for Estimation of Drainage Modulus

Studies have been made to clarify the relationship between the possible deduction of paddy rice yield and excess water discharge. In general, water of more than 10 cm depth causes a damage in yield of paddy rice according to the inundation period and an average depth in this duration. Therefore, an actual maximum depth in the lower paddy fields is not so important in this study. So, the study has been made based on the following simplified principles and assumptions:

- The excess water in higher paddy fields is discharged immediately to lower paddy fields.

- All rainfall in an sub-area in the Project Area flows into depressed areas such as lower paddy fields, which occupied (1/A) of the total sub-area.

- The irrigation water supply is stopped during the heavy rainfall period.

- The depth of standing water after n days from the starting date of rain is as follows:

$$D = A[R(n, max.)_T - n(DC + CU)]$$

where, D: depth of standing water after n days in mm

R(n, max.) T:
Maximum rainfall during n days in mm, which is equal or exceeds the rainfall of once every T years

DC: drainage capacity in mm/day

CU: consumptive use of paddy rice in mm/day:
CU = 4 mm/day

- It is assumed from topographic map that the depression area occupies about 30 per cent of the total sub-area. This means that the value of A is 3.3.

- If a smaller percentage than 30 per cent is chosen, the damage itself becomes severe because the concentration of a certain water quantity in a smaller area causes a deeper standing water during a longer time. On the contrary, if a larger percentage is chosen, the damage is not so severe in comparison with the above case because both the depth and duration of standing water become small. In the former, the damage is severe but damaged area is limited while in the latter the damage is not so severe but large area suffers from standing water. Under the situations, a total yield reduction will not be much affected by the difference of A value.

- The other factor to estimate the depth of standing water in lower paddy fields is the design return period of (T). If a small return period such as two or five years is adopted just from the economic point of view, the Project Area will be frequently suffered from the standing water. On the contrary, if a larger return period is chosen for drainage, it will result in increase of costs. The decision of the return period should be made only after having compared the benefits with costs in a number of alternatives. For the moment, the value of T is decided at ten years in this study from the aspect of agricultural development.

- It is considered that the combination of A = 3.3 and damage amounting to 10 per cent of the yearly yield of paddy will lead to a reasonable relation between the value of increased yield of paddy rice and the cost for drainage facilities.

- In general, even if a paddy field is covered by excess water of more than 10 cm depth, paddy grown in the field does not suffer from it in case that its duration is less than three days and an average standing water depth in the duration is less than 25 cm.

In applying the above-mentioned calculation method, it appears that one or two days rainfall has to be drained so that the depth of excess water in paddy fields is kept less than 250 mm.

$$D_1 = A[R(1,max.)_T - DC - CU]$$

$$D_2 = A[R(2,max.)_T - 2DC - 2CU]$$

$$\frac{D_1 + D_2}{2} = \frac{1}{2}[R(1,max.)_T - R(2,max.)_T - 3DC - 3CU] < 250$$

and the following formula is derived from the above equation,

$$DC > \frac{1}{3} R(1,max.)_T + \frac{1}{3} R(2,max.)_T - \frac{500}{3A} - CU$$

Estimation of Drainage Modulus

On the basis of the above-mentioned assumptions and principes, the drainaged modulus of 6.34 lit/sec/ha (1.01 lit/sec/rai) is computed, which is equivalent to the drainage capacity of 54.8 mm/24 hr. In this estimation, the following average probable rainfalls observed at three stations at Sing Ha Nat, Phraya Banlu and Lakkhon regulators are used. (See Table A.3-19, Appendix 3-5)

Maximum Probable Rainfall (Unit: mm)

Return period	R(1, max.)	R(2, max.)
5-year	118	162
10-year	139	189

The modulus of 6.34 lit/sec/ha could be applied to a flat area small than 320 ha, but a smaller modulus should be applied to a larger area than the above-mentioned because the rainfall intensity becomes low in a large areathan 320 ha. Figure 4-6 (Appendix 4-9) shows an approximate linear double logarithmic relation between a reduction factor and an area.

When such reduction factor (F) is applied to the areas larger than 320 ha, the discharge criteria are obtained. The discharge criteria for drainage are tabulated below:

Discharge Criteria for Drainage

Area (ha)	Drainage Modulus (ℓ/sec/ha)
0 - 320	6.34
320 - 1,000	6.15
1,000 - 3,000	5.95
3,000 - 5,000	5.83
5,000 - 10,000	5.71

(b) Optimum Drainage Rates of Pumps

Run-off Analysis

Run-off analysis on the discharges from paddy fields has been made for determination of a optimum rate of the pumping facilities to be provided in the Project. Due to the absence of unit hydrograph based on the observed records, the run-off from the paddy fields has been estimated based on the unit hydrograph derived from Dr.Mononobe's graphic analysis, which was developed out of Ekadahl's analysis. This is a method to estimate the water balance between inner and outer water levels, and the basic equation is shown in Appendix 4-10.

The run-off analysis in the three blocks have been made on the assumption that the land consolidation works have been completed (one plot: 0.8 ha, 160m x 50m), and the results have been indicated in Figure A.4-11 to A.4-13. (See Appendix 4-10). In the above estimation, the following three-day consecutive rainfalls with the return period of 10-year were used.

Design Rainfall for Run-off Analysis

(unit: mm)

Date	Design 1/ Rainfall	Hourly Distribution 2/			
		1st hr	2nd hr	3rd hr	4th hr
1st day	139	34.7	76.4 3/	20.9	7.0
2nd day	50	12.5	27.5	7.5	2.5
3rd day	32	8.0	17.6	4.3	1.6
Total	221				

Note: 1/ Average probable rainfall at three stations, Sing Ha Nat, Phraya Banlu and Nakkhon. Daily distribution of rainfall is assumed as follows, taking into consideration of rainfall characteristics:

1st day: on day probable rainfall
2nd day: two days consecutive probable rainfall minus one day probable rainfall
3rd day: three days probable rainfall minus two days consecutive rainfall.

2/ Hourly distribution of design daily rainfall is assumed as follows, that is, daily rainfall will concentrate during the short times of four hours, and their distribution ratio is 25 per cent in 1st hour, 55 per cent in

2nd hour, 15 per cent in 3rd hour and 5 per cent in 4th hour.

3/ Max. hourly probable rainfall at 10-year return period: 74.7 mm/hr.

In the estimation of run-off discharges, the above-mentioned rainfall is reduced by applying the reduction factor (F) taking into account the rainfall intensity of the areas.

Optimum Drainage Rates of Pump

To select an optimum drainage rates of pumps to be installed in the three blocks, several case studies have been made by applying the drainage pumping rates ranging in 1.20 mm/hr to 1.50 mm/hr as well as the widths of notch in the range of 0.20 to 0.30 m based on the obtained hydrograph and also topographic conditions (stage-area and storage curve). The results of the studies are shown in Tables A.4-26. (Appendix 4-10) It is found out in this table that the maximum water level does not fluctuate in proportion to the change of the drainage rate of pump.

As a result of the careful studies, the rate is decided at 1.25 mm/hr with the notch width of 0.30m, taking into account the fact that no damage on yield of paddy rice will take place if the duration of inundation higher than the allowable water level is within four days because the paddy will grow up to the hight more than 0.45 m by Octover[1/], one month later than the transplanting works for the latest planted paddy.

The following table indicates the run-off discharge and the drainage conditions in each block on the assumption that the proposed pumping facilities with a capacity of 1.25 mm/hr is operated.

1/ According to the discharge data of the Chao Phya river, the maximum discharge almost occurs in the middle of October.

Drainage Conditions with Optimum Pump Rates

Descriptions	Block A	Block B	Block C
1. Drainage Area (ha)	3,449	2,970	5,569
2. Run-off Discharge			
Design rainfall (mm)	205.5	207.7	203.3
Reduction factor	0.93	0.94	0.92
Max. run-off discharge(cu.m/s)	80.31	69.69	127.69
3. Proposed Drainage Pump Rate			
mm/hr	1.25	1.25	1.25
cu.m/s	11.98	10.31	19.33
4. Drainage Conditions			
Max. water level (m)1/	2.25	2.01	1.85
Max. water depth (m)2/	0.35	0.31	0.35
Inundation periods (day)3/	4.5	3.2	4.1
Inundation area (ha)4/	2,387	1,683	3,139
Water depth of each field (m)	0.20	0.21	0.21

Note: 1/ water level above the lowest elevation of paddy fields
2/ water depth above basic elevation of paddy fields
3/ inundation period above allowable water level
4/ inundated area at the maximum water level
5/ water depth of each paddy field controlled by notch and drainage ditch
* The terminology used in the above descriptions is explained in Figure A.4-10. (Appendix 4-10).

(c) Pumping Discharge and Operation Hours of Pump for Drainage

The pumping discharge and pump operation hours for drainage in the whole Project Area have been studied in the both cases of the normal year with the return period of 2-year and the design year with the return period of 10-year, based on the proposed facilities of pump, of which detail descriptions will be made in Paragraph D, Proposed Facilities. The following shows the results of the study.

Operation Hours of Pumps for Drainage

Description	Normal year (2-year)	Design year (10-year)
Operation period1/	4 months	4 months
Operation hours (hr)		
Total hours2/	2,926	5,229
Hour/unit-day	4.03/	4.84/

Note: 1/ See Figure A.4-5 and Figure A.4-13
2/ See Figure A.4-5 and Figure A.4-13
3/ 2,926/4 x 30 x 3 stations x 2 units (assumed)
4/ 5,229/4 x 30 x 3 stations x 3 units

Yearly pump operation hours in the normal year are estimated at about 2,930 hours, while about 5,230 hours in the design year, and an average daily operation hours per unit are estimated at 4.0 hours in the normal year and 4.8 hours in the design year respectively.

4. Flood Protection Plan

Flood protection dikes are essential facilities in the Project to protect the Project Area from high water during September to December. The area along the lower reaches of the Chao Phya river including the Project Area has functioned as the conservation area for the Chao Phya river basin in the wet season. Furthermore, the area is submerged to an averaged depth of 0.65 m until the mid December for the plactice of flooding irrigation as seen in the whole West Bank Tract.

Even after the completion of the Project, the flooding irrigation will be carried out in most part of the West Bank Tract for the time being. Therefore, the flood protection dikes are indispensable for high yield paddy cultivation in the wet season being planned in the Project.

Careful attentions have been paid in determining the scale of the protection dikes because the dikes closely relate to not only the security of people and farm fields but also the project benefits and costs. The elevation of the proposed dikes is decided at 3.5 m above mean sea level inclusive of 0.5 m of the free broad, which corresponds to the inner water level at Sing Ha Nat Regulator having the return period of 15-year, as shown below:

Probable Water Level

(Unit: m + MSL)

Return Period	Inside Water Level		Outside Water Level
	Sing Ha Nat	Phraya Banlu	Sing Ha Nat
1/5	2.77	3.09	2.59
1/10	2.91	3.18	2.91
1/15	2.99	3.23	3.03
1/20	3.06	3.26	3.20

5. Road Plan

Four types of roads are planned in the Project as follows:

Provincial Roads

Two provincial roads constructed by the local government come across at the central part of the Project Area. These roads are, however, not well maintained. So, the expansion and improvement of them are planned in the Project so that these roads will function as the trunk roads of the Project Area. The proposed roads will have the width of eight meters paved by laterite materials.

Main Roads

The main road is major roads for transportation within each block. In principle, at least two or three main roads to cross each other at right angle will be provided in each block. The proposed roads have six meters in width and will be paved by laterite materials.

Community Roads

The community roads having the width of four meters are planned to be constructed at the interval of about 1,200 m in the direction of the length of run of farm plot. The major community roads will function as the main roads. No pavement is planned for these roads.

On-farm Roads

On-farm roads, which are the terminal roads in the Project Area, are planned to be located at the interval of 320 m along the width of plot, and these will not be paved.

6. Farm Land Development Plan (On-farm Level)

(a) Land Consolidation and Land Reform

The Government of Thailand has been proceeding land consolidation project in parallel with the land reform. This might be the best way for both works because their effects are multiplied each other. The

rationalization of landownership, which is undertaken in the land reform to abolish the tenant farming system one by one, will be a strong incentive to benefited farmers to replenish their agriculture. Farmers' eagerness for agriculture will act as the prime mover for land consolidation works. With their support, the rationalized land readjustment and land allocation will be materialized, which are the prerequisite for upgrading the agriculture. Thus, modernized irrigation and drainage systems as well as new organizations for farm management will be established in early time.

(b) Principles in Land Consolidation Works

The principles in land consolidation works might be as follows:

(i) Farm managements

An average cultivation area per farm house-hold to be allocated in the Project is 4.0 ha. For common use of farm roads and irrigation and drainage canals and especially for rotational irrigation based on an rationalized irrigation schedule, management groups will be organized by farm house-hold having a total cultivated area of about 300 ha.

(ii) Crops

Paddy of high yield varieties as the major crop will be grown both in the dry and wet seasons after the implementation of the Project. This Project will increase the cropping rate up to 200 per cent and the yield of paddy rice per unit area up to 390 per cent of the existing one.

(iii) Farm Practices

For the farm practices to grow paddy, an integrated farm mechanization system will be established though tractors with a capacity of 8 to 60 HP which will be introduced for land preparation works and the other works are mostly to be made by man-power for the time being.

(c) Land Reparcelling

(1) Principles for Land Reparcelling

In order to materialize the farm land reparcelling covering all the requirements mentioned in (b) above, due attentions should be paid to the following:

(i) to plan it in close relation with the farm management plan

(ii) to plan it for materializing rationalized irrigation and drainage water control

(iii) to plan it for rationalized farm management for paddy cultivation

Further detail on the above-mentioned are as follows:

(i) to determine the location of main and community roads, the skeleton for land reparcelling plan, taking into account all the farm management, rural community development and public facilities construction plans.

(ii) to determine the location of irrigation and drainage canals taking into consideration the separation of irrigation and drainage canals, lengths of terminal canals and rotational irrigation. The separation of irrigation and drainage canals is a principle in land consolidation works. By this way, farm management and irrigation water control are simplified and rationalized. Irrigation canals will be located along roads for their easy maintenance. (See Appendix 4-12 in respect of further detail on the necessity of separation of irrigation and drainage canals). In order to systematize drainage and simplify supplemental irrigation, a commanding area of one turn-out is planned to correspond to one rotation block.

(iii) to provide all the farm plots with the same width of plot for simplifying the extension of new technical system for paddy

cultivation to farmers. If all the farm plots are in the same size, a certain quantity of agricultural chemicals can be sprayed to each farm plot for control of disease and insect damages. The same can be said in fertilizer application. Furthermore, planning and execution of both the puddling works by tractors and management of irrigation water for puddling become simple and easy for the same reason mentioned above.

(2) Size of Plot and Land Reparcelling Plan

A size of plots should be determined in close relation with technical systems to be introduced for crop cultivation, crops to be grown, farm machinery to be operated as well as the scale of cultivated area per farm house-hold. The width of plot and length of run of a farm plot should be determined in consideration of the following:

Length of run

- The longer is the length of run, the more advantageous is the operation of tractors for land preparation.

- The longer is the length of run, the smaller are the deduction ratio of land and the construction cost.

- In Sappaya project, one of the major land consolidation projects in Thailand, the length of run was first determined at 100 m, but now farm plots with the length of run of 200 m long are constructed. On the contrary, in Channasutra project, the length of run was first designed at 300 m but now 200 m is adopted. These facts show that the length of run in land consolidation projects in this country have been approaching to a certain length as a result in try and error. In Nong Wai project, which is under construction, the length of run of 150 m is adopted.

- If the length of run is too long, mechanized farm practices, except the land preparation, such as chemical spray ect. and weeding by manpower become difficult or uneffective.

- If the length of run is too long, the irrigation water control become difficult because the irrigation water takes a long time to cover a whole farm plot. Furthermore, land leveling works in one plot are also quite difficult in this case.

- As a matter of course, a size of plots has a close relation with farm practices by farmers themselves. For easy farm practices by farmers, a length of run and size of plots should be determined at a multiple of the units of length and acreage currently used in Thailand. Therefore, "sen" is used to express a length and "rai" to express an acreage. (One sen is equivalent to 40 m, and one rai to 40 x 40 sq.m).

The lengths of run of 100 m, 130 m, 150 m and 160 m were considered as alternatives. The deduction ratio of land by each length of run and construction cost on the assumption that the width of plot is fixed at 50 m is tabulated below:

Alternatives on Length of Run of Plot

Alternatives	Size of Plot	Construction Cost ($/ha)	Deduction Rate of Land (%)
Case (1)	100m x 50m	642 (106)	8.0
Case (2)	130 x 50	615 (102)	7.3
Case (3)	150 x 50	607 (101)	6.7
Case (4)	160 x 50	603 (100)	6.6

Note: The parenthesized figures show percentage of the construction costs in case that the cost in Case (4) is 100%. (See Appendix 4-13).

The above table shows that the longer is the length of run, the smaller are the construction cost and deduction ratio of land. Consequently, the length of run is determined at 160 m, considering the mentioned above.

On the other hand, the width of plot should be determined on the basis of the following conditions;

Width of Plot

- In general, a width of plot ranging in 1/3 to 1/5 of the length of run is the most effective for tractor operation.

- The wider is the width of plot, the more convenient are diversification of crops and intensive land use, while the more narrow is it, the more suitable for intensive cultivation of paddy, if only paddy is grown in the farm plots.

- If the width of plot is determined at 40 m to use the practical unit of length "sen", four rai is a multiplied acreage of "rai". If focus is placed on the acreage of five rai, the width of plot is determined at 50 m.

- It is a basic policy in the land reform in Thailand to allocate the cultivated area of 4.0 ha (25 rai) to each farm house-hold. Therefore, the size of plots should be determined at 5 rai.
  (5 rai x 5 plots = 25 rai)

The following four cases are considered suitable in respect of the width of plot in the aspects of the width of plot itself and size of rotation block, if the length of run is determined at 160 m as mentioned above. Farm plots in the four cases are illustrated in Appendix 4-14.

Case A: the width of plot of 40 m long (the plot of 4 rai), commanding area per turnout of 32.0 ha, farm ditch of 1,000 m long

Case B: the width of plot of 40 m (size of plot of 4 rai), commanding area per turnout of 30.72 ha, farm ditch of 480 m long

Case C: the width of plot of 50 m (size of plot of 5 rai), commanding area per turnout of 40 ha, farm ditch of 1,250 m long

Case D: the width of plot of 50 m (size of plot of 5 rai), commanding area per turnout of 38.4 ha, farm ditch of 600 m long

Out of the above-mentioned four cases, Case A and Case C are unfavourable because of difficulties in distribution of irrigation water as well as in construction of the longitudinal sections of terminal irrigation canals as very long terminal irrigation canals are required. So the comparative studies in respects of the construction costs and reduction rates of land in Case B and Case D have been made, and the results have been tabulated below:

Alternatives on Width of Plot

Alternative	Size of Plot	Size of Rotation Block	Construction Cost	Deduction Rate of Land (%)
Case B	160m x 40m	480m x 320m	623 (103)[a/]	7.1
Case D	160 x 50	600 x 320	603 (100)	6.6

Note: a/ The parenthesized figures show percentages of the construction costs in case that the cost in Case D is 100% (See Appendix 4-15 on the detail of calculation)

Case B is more advantageous than Case D in irrigation water control and farm management for paddy cultivation, but Case D is better than Case B in respect of the construction costs and the deduction rate of land. Comparative studies in respect of the earth work volumes and costs for land levelling and land adjustment in elevation in Case B and Case D have been made, and the results are tabulated below:

Comparison of Earth Works

Alternative	Leveling Works: Cutting Works (cu.m/ha)	Leveling Works: Land Adjustment Volume (cu.m/ha)	Average Hauling Distance: Cutting Works (m)	Average Hauling Distance: Land Adjustment Works (m)	Earth Moving Works ($10^3 m^4$)
Case B	506 1/	285	67	190	15,779 (108)
Case D	520 2/	242	65	197	14,665 (100)

Note: 1/ Averaged value for the total area of 179.2 ha
2/ Averaged value for the total area of 180.0 ha

Parenthesized values show the percentage of earth moving works in case that the works in Case D is 100%. Detailed estimation on the abovementioned is shown in Appendix 4-18 (Table A.4-36). In Table A.4-36, Case B corresponds to Case H and Case D corresponds to Case I.

The cut volume in Case B, in the above table, is 3 per cent smaller than that in Case D. However, the total earth moving works in Case D including land adjustment in level is 8 per cent smaller than that in Case B. So, Case D is more economical than Case B from a view point of the construction costs.

As a result of the comparative studies in the aspects of earth moving works, construction costs and reductive rates of land, the farm plot with the length of run of 160 m and the width of plot of 50 m and the rotation block of 38.4 ha (600 m x 320 m x 2) seem the most suitable to the Project Area. This farm size also seems to satisfy all the requirements mentioned above. As a conclusion, the size of spot is determined at 160 m x 50 m. The typical layout of plots and the relating land reparcelling are shown in Appendix 4-16.

(d) Terminal Water Management System

Irrigation System

Turnouts will be constructed on the lateral irrigation canals so that two farm ditches stretch out to opposite direction each other from each turnout. A total length of farm ditches, which will be located along on-farm roads, will be 600 m (500m x 12 plots), and these farm

ditches command an area of 19.2 ha (600m x 320m). In this case, a commanding area per turnout is 38.4 ha (one rotation). In order to divert irrigation water from an on-farm ditch to farm plots, one inlet will be installed for two plots.

Irrigation water supply during the puddling period is made in the rotation of one plot per day in each rotation block of 38.4 ha (160m x 50m x 48 plots). In this case, the designed capacity of a farm ditch is 1.39 lit/sec/ha. Outline of the terminal irrigation facilities are described below:

Turnout: the facility to divert water from a laterial irrigation canal to farm ditches.

Farm ditch: the terminal irrigation canals made of earth to convey irrigation water to farm plots. The design capacity is 1.39 lit/sec/ha.

On-farm road: the terminal road prepared for farmers to go into or out from farm plots, and farm ditch is located along its one side.

Inlet: the facility to divert irrigation water from a farm ditch to farm plots. One inlet is installed for two farm plots. A pipe with the diameter of 200 m and the length of 4.0 m will be installed to divert and supply irrigation water to a farm plot which does not face to the farm ditches.

Check: the facility to raise water level in the lower reaches of farm ditch for water management.

Culvert (1): the facility installed under a farm inlet so that water in a farm ditch can flow through it without being intercepted by the farm inlet. A pipe with the diameter of 300 m and the length of 4.0 m will be used for this purpose.

Culvert (2): the facility installed across a community road so that water in a farm ditch can flow through it without being intercepted by the community road. A pipe with the diameter of 500 m and the length of 6.0 m will be used for this purpose.

Culvert (3): the facility installed across an on-farm road at the lower reaches of farm ditch so that water in a farm ditch can flow across the on-farm road without being intercepted by the on-farm road. A pipe with the diameter of 300 mm and the length of 4.5 m will be used for this purpose.

Drainage System

Excess water in each farm plot is drained through a notch with the width of 30 cm to a drainage ditch. The terminal drainage ditch is located in parallel with the width of plot at the middle of two farm ditches, and a typical length of it is 600 m. Therefore, it commands typically an area of 19.2 ha. The drainage ditches made of earth are linked to a leading ditch at their lowest reaches. The capacity of the drainage ditches is 6.34 lit/sec/ha.

Outline of the terminal drainage facilities are as mentioned below:

Drainage ditch: the terminal drainage canal made of earth to be constructed in each farm plot. Its design capacity is 6.34 lit/sec/ha.

Culvert (4): the facility to be installed across an on-farm road at the lower reaches of drainage ditch so that drainage water can flow across the road without being intercepted by the road. Pipes with the diameter of 800 mm and the length of 6.0 m will be used for this purpose.

The typical layout of terminal irrigation and drainage water management systems is shown in Drawing No.1 and No.2 at the end of this report.

(e) Land Leveling

The land leveling in land consolidation works is important both for paddy growth and farm management. In order to simplify the irrigation and drainage and attain a fruitful result, the land adjustment in elevation will be carried out where an farm plot elevation on the upstream reaches of ditches is lower than the elevation of the neighboring one located on the lower reaches.

Land Leveling

The land leveling in a farm plot (160m x 50m) will be carried out so that a difference of elevation in a farm plot is kept within 10 cm. For smooth irrigation and drainage within a farm plot, the depression like a ditch will be prepared along the ridge of the farm plot in the direction of the length of run. The mesh method has been applied in calculation for the land leveling works. (See Appendix 4-17).

Land Readjustment in Elevation

Field surfaces should be lowered one by one from the upstream reaches of a ditch for simplifying the canal system as well as water management. However, the existing topographic conditions do not cover this requirement at some places, if no treatment is provided. So, the land readjustment in elevation will be executed at such places. However, even if the field surface on the upper reaches is lower than the adjacent paddy field surface on the lower reaches, they will be remained as they are in case the difference of elevations after land leveling is within 10 cm.

In determining the allowable difference in field elevations for land adjustement in the Project, the following three case studies in respect of the each moving works (earth moving volume x average

hauling distance) have been conducted at the two sample areas of land consolidation. As a result, the allowable difference in field elevations is decided at 10 cm.

Alternatives on Land Adjustment in Elevation

Alternatives	Allowable difference in field elevations	Size of plot	Earth moving work D(m) x V(m^3)
Case (E)	no land adjustment	160m x 50m	-
Case (F)	10 cm	160 x 50	8,610 x $10^3 m^4$ (100)
Case (G)	5 cm	160 x 50	13,790 x $10^3 m^4$ (161)

Note: the detail estimation is given in Appendix 4-18.

(f) Model Design for Sample Areas

In order to give shape to the concept of the proposed terminal facilities, the model design of roads and irrigation and drainage canals as well as land parcelling have been actually carried out at the two sample areas. Furthermore, the required land leveling works and hauling distance etc. were estimated and their results were applied for the design of land consolidation works in the whole Project Area.

Determination of Sample Area

The sample areas are located at the central part of the Project Area which has natural conditions including topography that prevails in the Project Area. One sample area is located along Phraya Banlu canal near from the crossing of this canal and Nai Chat canal. It is anticipated that this sample area will be covered by the Pilot farm proposed in the Project. The other sample area is located along the same canal near the eastern boundary of the Project Area. An acreage of each sample area is about 100 ha.

Land Reparcelling and Typical Design

The land reparcelling in the sample areas has been executed based on the typical design of farm plot (160m x 50m). Estimation of earth moving volume and design of facilities have been also made in accordance

with the criteria. The result of calculation is shown below. Typical layout for the sample areas is shown in Drawing No.1 and No.2 at the end of this report.

Result of Typical Design in Sample Areas

Description	Site I	Site II	Average Total	Average per ha 5/
1. Area (ha)	84.0	96.0	180	
2. Clearing (ha)	1.0	1.0	2.0	0.011
3. Land leveling (m^3)	29,731 1/ (ℓ=63) 2/	63,930 (ℓ=66)	93,661	520 (ℓ=65)
4. Land adjustment in elevation (m)	9,315 3/ (ℓ=140) 4/	34,303 (ℓ=213)	43,618	242 (ℓ=197)
5. Farm road with farm ditch (m)	2,100	2,400	4,500	25
6. Drainage ditch (m)	2,100	2,400	4,500	25
7. On-farm facilities (place)				
Turn-out	2	2	4	0.022
Check	4	4	8	0.044
Culvert (1)	24	28	52	0.290
Culvert (2)	2	2	4	0.022
Culvert (3)	4	4	8	0.044
Culvert (4)	4	4	8	0.044
Inlet	22	24	48	0.270

Note: 1/ see Table A.4-36 (Appendix 4-18)
2/ hauling distance of land leveling
3/ see Table A.4-36 (Appendix 4-18)
4/ hauling distance of land adjustment in elevation
5/ weighted average of Site I and Site II
culvert (1): ϕ300, ℓ=4.0 m (crossing farm inlet)
culvert (2): ϕ500, ℓ=6.0 m (crossing community road)
culvert (3): ϕ300, ℓ=4.5 m (crossing on-farm road ..... end of farm ditch)
culvert (4): ϕ800, ℓ=6.0 m (crossing on-farm road ..... end of drainage ditch)
Inlet: ϕ200, ℓ=4.0 m (crossing on-farm road)

7. Village Water Supply

Inhabitants in the Project Area have been suffering from the shortage of domestic water, especially of drinking water in the dry season, as is symbolized by rain-water storage tanks being placed below the roof of houses to secure drinking water. Therefore, water supply facilities equipped with pump will be constructed in the Project for each production unit to be organized under the ALRC, branch office on Tambon basis for smooth execution of supporting services. The total daily demand for domestic water is estimated at 800 cu.m/day as shown below:

Production Unit	Population		Water Demand (cu.m)	Production Unit	Pumps	
	Present	After Decade			Q (lit/min.)	Specification
Khusalod	3,237	4,640[1/]	232[2/]	1	420[3/]	30mx80mmx7.5kw
Phraya Banlu	3,303	4,480	224	1	420	30 x80 x7.5
Sing Ha Nat	5,265	6,880	334	2	840	30 x80 x7.5
Total	11,805	16,000	800	4	1,680	

Note: 1/ estimation based on the population growth of 3.0%
2/ estimation based on the daily consumption of domestic water (50 lit/day per capita)
3/ supply hours are assumed at 10 hr/day

As a result of geological investigation including the trial boring test to the depth of 30 m, which was conducted at the proposed pumping station site in Block B, it was found out that the groundwater is available for this purpose. According to the geological columnar section (See Appendix 3-22), sandy layer exists in the range of 15 to 30m below the ground surface. This sandy layer extends from the northern part of Bangkok to Ayutthaya inclusive of the Project Area, and is similar in nature to the aquifer existing around the industrial zone in the northern part of Bangkok. Thus, it appears that the water of about 600 to 1,000 cu.m/day could be lifted by pump in deep wells to be constructed. However, further investigation for the water quality and quantity of the groundwater should be carried out in the future.

Figure A.4-22 (Appendix 4-19) shows the typical layout of village water supply plant.

C. Proposed Agricultural Development

1. Proposed Land Use

After the implementation of the Project, the proposed cultivated area of 10,542 ha will be divided into 9,542 ha of paddy fields, 500 ha of upland fields and 500 ha of orchards (See Table 4-2). The polder dike construction, irrigation and drainage improvement and land consolidation works to be carried out in the Project will make it possible to introduce the double cropping of high yield paddy varieties in the paddy fields, which occupy 90 per cent of the total cultivated area, and to grow upland crops such as vegetables in upland fields (5%), and fruits, mainly citrus, in orchard (5%). At present, about 240 ha of the cultivated area is used for citrus cultivation. After studying the farmers' intention to increase it to the double of the existing one, an area of 500 ha is allocated for this purpose in the proposed land use plan. In formulating the future land use plan, attentions have been paid to the following:

(a) Most of the cultivated area consists of paddy fields at present, and the Project Area is much blessed with favorable soil and natural conditions for paddy cultivation. So the major emphasis has been placed on paddy fields in this Project.

(b) Being located near Bangkok, the Project Area is favorable for cash crops cultivation such as vegetables and fruits to be shipped to Bangkok. The land consolidation planned in the Project to materialize the double cropping of paddy will make it possible to grow the other crops than paddy in farm fields of relatively high elevation. Simultaneously, the land consolidation together with flood protection facilities will enable farmers to introduce the animal husbandry and fresh-water fish culture to a degree.

Table 4-2 Proposed Land use

(Unit: ha)

Sub-irrigation Area	Gross Area	Cultivated Area				Others				
		Paddy Field	Vegetable	Orchard	Sub-total	Area of Existing Canal	Area of Project Facilities	Area of Public Facilities	Riverside Land	Sub-total
Block A	3,493	2,885	142	-	3,027	26[1]	301[2]	121[3]	18[4]	446
Block B	3,057	2,334	124	125	2,583	12	262	125	75	474
Block C	5,744	4,323	234	375	4,932	93	439	198	82	812
Total	12,294	9,542	500	500	10,542	131	1,002	444	175	1,752
	(76,838)[5]	(59,638)	(3,125)	(3,125)	(65,894)	(819)	(6,263)	(2,775)	(1,093)	(10,950)

Note: [1]: Consists of the existing main irrigation canals of Khlong Phraya Banlu, Khud Mai and Nai Chat

[2]: Consists of the proposed dikes, borrow pits, canals, roads, pumping stations

[3]: Consists of homestead, school, supporting services, fish pond, and animal husbandry

[4]: Areas between dikes to be provided along the Khlong Phraya Banlu, Khud Mai, and Nai Chat

[5]: Indicates the area in Rai

The diversification of farming will, no doubt, increase and stabilize farmer's income in comparison with the existing income based on the monoculture of paddy.

(c) The land for common facilities such as canals, roads, dikes and offices for supporting services will be acquired in the way that every benefitted farm house-hold offers a certain acreage of their own land.

2. Proposed Cropping Pattern

In selecting crops for future cropping pattern, the double cropping of paddy, cash crop cultivation of mainly vegetables and increased production of citrus as well as introduction of new fruits such as mangoes and grapes have been taken into consideration for the following reasons:

(a) Soils in the Project Area are much suitable to the paddy growth as is proved by the fact that paddy has been traditionally the major crop here. Furthermore, relatively modernized farm practices have been introduced in the Project Area.

(b) Upland crop cultivation focusing on vegetables for shipping will promise an increased farmer's income. Furthermore, it will much contribute to the maintenance of soil fertility, if the rotation of paddy - upland crops is adopted.

(c) As mentioned in CHAPTER III, the soil amendment, drainage improvement and upland irrigation in the dry season will be required for introduction of upland crops to the Project Area. Therefore, it may be difficult to expand the upland field area in a short time because it requires much labor force and materials, and furthermore, the marketability will be one of the major restrictive factors for vegetables and fruits cultivation.

The proposed cropping pattern is as shown in Figure 4-3. The cropping area of paddy will be about 90 per cent of the total cropping area due to the fact that the double cropping will be introduced. High yield varieties such as RD series with a short growing period and high sensitivity to fertilizers will be grown in the whole paddy fields after the implementation of the Project. Five varieties of the RD series, non-glutinous rice, have been already registered and grown in this country and a new variety of the same series will be released to farmers in near future. These varieties, being suitable to grow in the natural conditions of Thailand, promise a high yield. And furthermore, the quality of rice is by no means inferior to the native one. So C 4-63 has been gradually switched over to the RD varieties in the dry season cultivation in the Project Area.

The growth period of these high yield varieties from sowing to harvesting is about 125 days in the wet season cultivation while about 130 days in the dry season cultivation. Therefore, the cropping calendar will be as follows:

- The first cropping (the wet season cultivation)

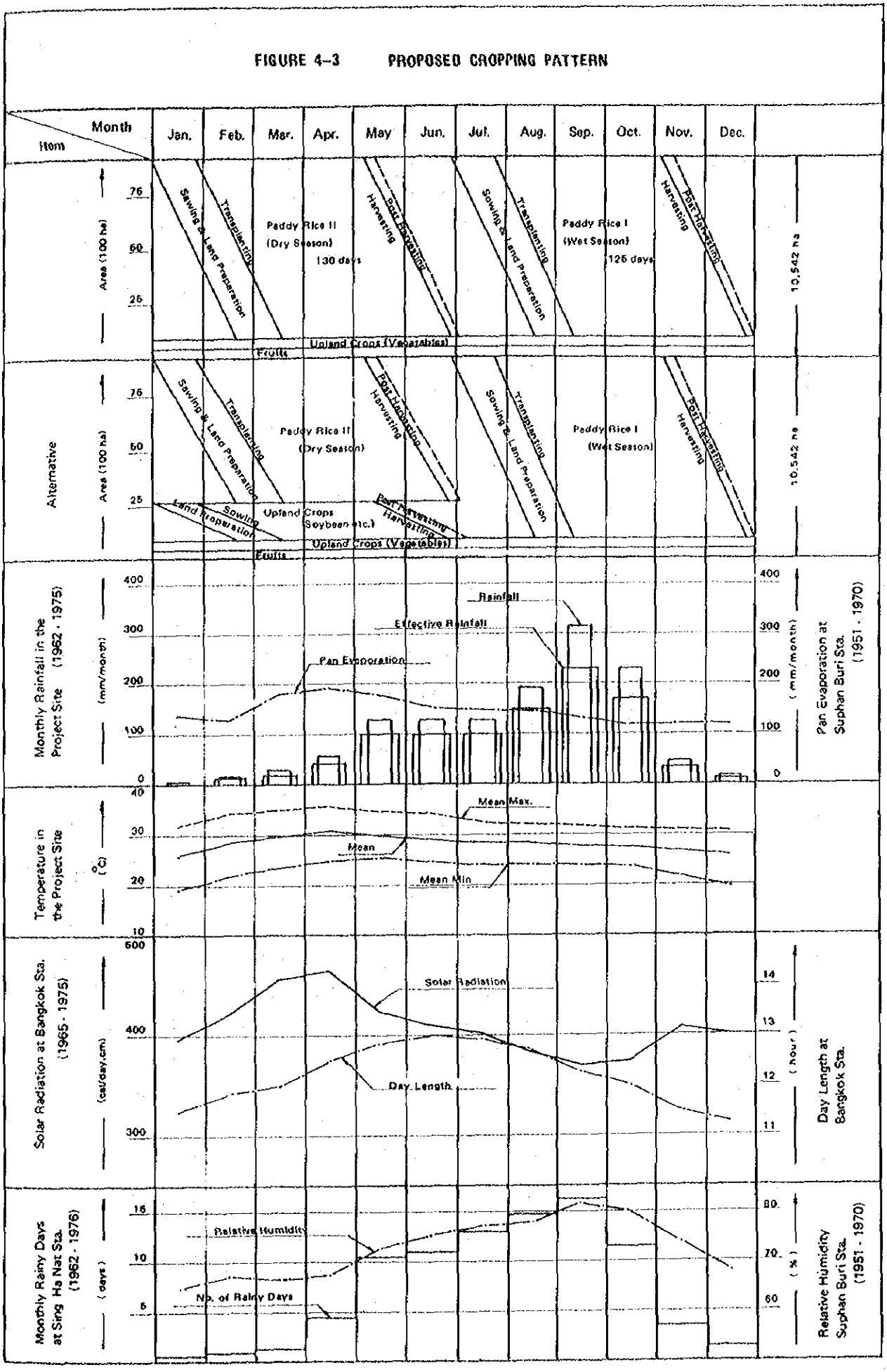
Sowing	July
Transplanting	August
Harvesting	November to December

- The second cropping (the dry season cultivation)

Sowing	January
Transplanting	February
Harvesting	May to June

The land preparation, transplanting and harvesting require a great deal of labor force in a short time. Taking into consideration the required labor force and work volume, the 48-day duration is given to each operation in this cropping calendar. Furthermore, it is planned that the harvesting can be completed during the best suited season for these works and that the transplanting for the wet season

FIGURE 4-3 PROPOSED CROPPING PATTERN



paddy can be finished prior to the beginning of flood in mid-September. Furthermore, taking into account the soil conditions, it is planned to complete the plowing while soils are kept dry. And about one week period between the first and second cultivations would be kept for the purpose of checking and maintenance of canals.

The upland crops, mainly vegetables, can be planted three times a year, and annual harvesting of fruits especially citrus will be made. The kinds of vegetables to be introduced should be chosen by considering soil suitability, marketability, possibility of extension of farming techniques and so forth. And the vegetables should be limited to a minimum number in order to obtain massive marketing. Based on the proposed cropping pattern, the cropping intensity of the whole crops in the Project Area is 200 per cent of the total cultivated area.

The cropping pattern of "paddy-upland crops" is also possible in place of "paddy-paddy" in the paddy fields after the implementation of the land consolidation works. According to an experimental result at Suppan Buri Experimental Station located near the Project Area whose soil conditions are much similar to those in the Project Area, cultivation of soybean, mungo bean, peanuts and corn with furrow irrigation in the dry season showed a favorable result among other upland crops. Taking account of such result, it can be considered that another cropping pattern inclusive of paddy-upland crops in paddy field may be introduced instead of above-mentioned proposed pattern in this Project Area, as shown in Figure 4-3. However, clayey soils in the Project Area show a relatively high acidity, and furthermore, paddy rice is more profitable than upland crops. So, it seems that the introduction of upland crops in the pattern of paddy-upland crops in a large area is difficult.

3. Agricultural Production

After the implementation of land consolidation works, irrigation and drainage waters will be rationally controlled in each farm plot for double cropping of high yield paddy varieties. The use of

necessary but minimum fertilizers and agricultural chemicals as shown in Appendix 4-20 and the improvement of farm operation techniques including the rational water control for each plot in each growth stage, will promise the target yields, as follows:

The first cropping (the wet season cultivation): 4.2 ton/ha (67 tang/rai)

The second cropping(the dry season cultivation): 4.7 ton/ha (75 tang/rai)

According to an experimental result at National Rice Experiment Station located in the vicinity of the Project Area, a yield of unhulled rice ranging from 4.7 to 5.5 tons/ha in the wet season cultivation, and 6.3 to 6.8 tons/ha in the dry season cultivation was recorded in case that nitrogen of 75 kg/ha is applied (see Appendix 4-21). Also, the result indicates that nitrogen application up to 50 to 60 kg/ha is quite effective for paddy yield.

The land consolidation works have been already completed in Sappaya and Channasutra districts located in the upper Chao Phya region. An average yield of paddy in the dry season cultivation in 1976 was, for instance, 4.7 tons/ha in Suppaya and 3.2 tons/ha in Channasutra. After the implementation of land consolidation, terminal irrigation and drainage water control condition in the Project Area will be in no way inferior to that one in Sappaya. So, with the various supporting services mentioned below, the target yield will be attained in the year of full development.

On the assumption that the improvement of irrigation and drainage as well as the supporting services especially in respect of credit and extension services for farming techniques are made to a full extent, yields of upland crops, mainly vegetables and fruits are estimated at 12.9 tons/ha/crop and 30.0 tons/ha crop, respectively.

Crop Production With Project

Crop	Cropping Area (ha)	Yield (ton/ha)	Production (ton)
a) Paddy rice			
First cropping (wet season)	9,542	4.2	40,076
Second cropping(dry season)	9,542	4.7	44,847
Sub-total	(19,084)	(4.5)	(84,923)
b) Upland crops (vegetables)	500 x 3	12.9	19,350
c) Fruits (citrus)	500	30.0	15,000
Total	21,084		119,273

Accordingly, it is planned to attain the target crop productions shown in the table above in the fifth year after the implementation of land consolidation. An increase yield of Paddy rice with project is about 70,300 tons, while its production with Project is equivalent to about six times of the present one. An increase of upland crops and fruits production with project is estimated at about 18,800 tons and 11,400 tons, respectively.

4. Farm Mechanization

As average holding of cultivated area per farm house-hold will be about four hectares. It shows that the farming scale is relatively big. As shown in the proposed cropping pattern, the double cropping of paddy will be introduced in place of the existing single cropping after the implementation of the Project. So, more intensive farm practices and managements will be required. Furthermore, the present monocultural cultivation of paddy once a year will be switched over to a diversified farming including cash crop cultivation such as vegetables and fruits, animal husbandry and fresh-water fish culture for increased and stabilized farm income.

The farm mechanization for paddy cultivation as shown in farm mechanization system "Type I" (Figure A.4-23, Appendix 4-22) will be at least required. The combination of heavy and hand tractors will

be the primary machines for mechanization in the Project Area. The land preparation, which requires a great deal of labor force, if made by manpower, will be effectively carried out by these tractor operations in a short period. In addition to this, threshers to utilize the power of hand tractor will be also used. Regarding the driers for unhulled rice, it is anticipated that farmers cannot dry their rice to a sufficient degree especially in the case of the dry season cultivation of paddy because the harvesting period of this cultivation falls in the beginning of the wet season in the proposed cropping calendar. Therefore, some driers as are actually used at rice mills in the Project Area at present should be installed at the rice mills.

The vegetables and fruits cultivation will be mainly made by manpower as shown in the above figure. From the economic point of view, a minimum number or farm machineries should be systematically operated to attain the biggest effect possible. In this respect, heavy tractors and threshers are needed only in a short period every year. Therefore, the joint use of farm machineries by the agricultural cooperatives and farmers' groups will be required. Under the circumstances, the system for group operation of farm machineries should be established for effective utilization of them as well as for saving of initial costs and operation/maintenance costs. The capacity of each farm machinery and the cost of them per hectare in the case of farm mechanization system "Type I" are shown in Table A.4-39 and Table A.4-4- (Appendix 4-22) respectively.

Most of these farm machineries mentioned above has not only been manufactured in Thailand but also actually used in the Project Area. Heavy tractors have been also manufactured in the knock down system, and various attachments have been also produced in Thailand. Most farm machineries whose introduction is planned in this Project can be domestically purchased.

In this farm mechanization program, much farm practices still have to depend on man-power. Especially for transplanting and reaping

of paddy, a great deal of manpower will be required. Farm house-holds have to employ many laborers in the busy seasons as the scale of farm management per farm house-hold is relatively big. However, it is well anticipated that these works will be mechanized in near future because rice transplanters for transplanting and binders or combines for harvesting will be home-made, and farmers will be able to purchase them from their increased incomes resulted from the implementation of the Project.

The farm mechanization system for paddy cultivation in this case is shown as "Type II" in Figure A.4-23. (Appendix 4-22) As a result of the computation of labor balance based on the farm mechanization system, it is concluded that farmers can spare some of their labor force for the other farm managements than paddy cultivation, even if they consume their labor force for double cropping of paddy in an area of four hectares per farm house-hold.

5. Labor and Material Requirements

(a) Labor Requirements

Based on the proposed farm mechanization mentioned above, labor requirements per hectare per crop in case of with project are estimated as follows:

Paddy rice:	99.1 man-day/ha/crop[1/]
Vegetables and fruits:	360.0 man-day/ha/crop

According to the computation on farm labor balance, the peak demand of farm labor occurs in the transplanting and harvesting seasons. Labor requirement for each of the above listed crops as well as animal husbandry and fresh-water fish culture in the whole Project is estimated in Table A.4-42. (Appendix 4-23)

1/ In the case of farm mechanization system "Type I", refer to Table A.4-41. (See Appendix 4-23, Table A.4-41)

The labor force shortages appear for 6 months every year, so farmers have to employ seasonal labors in such months. According to the existing cropping pattern in neighboring area, it seems that additional labor force at the peak demand periods can be covered by labor force mobilized from neighboring areas for the time being. But in future, it is expected that the double cropping will be gradually introduced to neighboring areas, and mobilization of idle labor force will become impossible. However, such integrated farm mechanization system of "Type II" as shown in Figure A.4-23, will be materialized in the Project before such time comes.

(b) Required Agricultural Input Materials

Smooth and effective supply of agricultural input materials such as new seeds, fertilizers and chemicals will be required after the implementation of the Project to attain an increased and stabilized agricultural production with the modernized agricultural infrastructural facilities to be equipped in the Project.

A required amount of the agricultural input materials per hectare for paddy cultivation "with project" is compiled in Appendix 4-20, Table A.4-38. As for paddy seeds of high yield varieties, a quantity to renew farmers' seeds at least once every croppings and to switch over the existing native rice varieties to high yield ones will be required after the implementation of the Project. As for fertilizers, nitrogen of 50 kg/ha for the first cropping of paddy (wet season cultivation) and 60 kg/ha for the second cropping (dry season cultivation) will be required to attain the target yield in addition to phosphoric acid. Some lime application is also recommendable to cope with the prevailing acid soil condition. The Land Development Department has given facilities in collecting and supplying marl to farmers, who are ready to pay the necessary transportation fee, so that marl obtainable near the Project Area is applied to improve the soil acidity.

The present way of harvesting to cut and gather in only a high portion of paddy stalk results to an increase of organic matters in soils as a considerable quantity of paddy straw remains in paddy fields. After the implementation of the Project, there will be the necessity for spraying chopped-paddy straw or animal manures with straw. This method of application is based on the result obtained in the experimentation at Bangkhin national experiment station.

Vegetables and fruit trees require more fertilizers and chemicals per unit area than paddy. Appendix 4-27 and Appendix 4-29 indicate the major agricultural input materials required in the whole Project Area "with project," including those materials for upland crops and fruits cultivation.

In comparison with the present situation, an increment of paddy seeds of high yield varieties by year has been estimated at 577 tons (Demand of seeds after Project is about four times of present amount), that of fertilizers 3,816 tons (about three times) and that of chemicals 226 tons (about two times).

The various supporting services stated below would be needed to carry out smoothly and effectively these input material supply to farmers. Moreover, special attentions should be paid to selection of agricultural chemicals so that low toxicity and low cost chemicals should be used for pesticides and herbicides. People always catch and eat fresh-water fish, therefore, careful attentions should be placed on the toxicity of agricultural chemicals.

6. Animal Husbandry and Inland Fishery

(a) Animal Husbandry

The Project will solve the problem of inundation over the Project Area during the wet season, so the existing small-scaled animal husbandry for small and medium animals such as poultry, domestic duck and hog will be able to develop into a big scale. The diversification

of farming by introducing an appropriate scale of animal husbandry will much contribute to stabilized farm income. By-products such as broken rice and rice bran in paddy rice processing, which will increase to a great extent, will be applicable for animal breeding. Furthermore, animal husbandry for the time being after the implementation of the Project is planned as shown in Table A.4-43 (Appendix 4-24) after studying the demand and supply of farm labor "with project." Animal sheds should be located in areas with a relatively high elevation near villages where the animal discharges are conveniently fed to fishponds. From the sanitary point of view, it is desirable to form collective animal shed zone, and carry out the group breeding of domestic animals to save O & M costs for shed facilities.

(b) Fresh-water Fish Culture

Recently, the fresh-water fish culture has become prosperous in Ayutthaya province. A considerable number of farm house-holds have introduced the fresh-water fish culture to their farming to diversify their farm production. The demand for fresh-water fish is quite high in Bangkok and the other big cities in Thailand.

After the implementation of the Project, the fresh-water fish culture will be introduced, and it will contribute to the diversification of farm productions. According to the experiment data prepared by National Inland Fisheries Institute, Department of Fishery, the introduction of carp (Puntius Goinotus), ciclid (Tilapia Nilotica) and catfish (Pangasius Pongasius) are promising. Discharges of domestic animal and rice bran, a by-product in processing paddy rice, will be utilized for breeding carp and ciclid. Rice bran and broken rice are utilized for breeding catfish as a supplemental feedstuff to trash fish.

The proposed fresh-water fish culture is shown in Table A.4-44. (Appendix 4-24). Fishponds should be prepared at the sites favorable for water supply through the year, and free from drainage water contaminated with agricultural chemicals as well as from floods. Attentions should be paid to the fact that re-use of discharge from fish-ponds

for irrigation cause a damage in paddy growth due to high nitrogen content in the water, if animal manures are used to breed fish.

7. Pilot Scheme

The pilot farm of about 500 ha equipped with all the necessary infrastructural facilities including irrigation and drainage canals, roads and so forth is proposed for demonstrating the Project itself to the farmers and staff concerned. This scheme should be implemented at the earliest time possible, prior to the commencement of the major construction works for the Project at the latest, so that models of farmers' organizations for water management and farm operation to increase agricultural productions, for credit and input supply and for processing, storage and marketing, etc., which are to be carried out under the integrated services rendered by the agricultural cooperative and extension office will be established.

The location of the pilot farm is determined at the central part of the Project Area along Phraya Banlu canal, which will be a part of Block B in the Project, after studying the topography, navigation, present conditions of the rural community at the site among the other communities, administrative boundary and availability of irrigation water, etc.

To supply irrigation water to the pilot farm, pumping facilities will be temporarily installed to lift water in the Nai Chat canal before the proposed irrigation system in the Project starts to be operated.

8. Supporting Services

(a) Objectives

The supporting services to be rendered under the Project aim to assist farmers in accepting systematically and smoothly the irrigated agriculture with modernized infrastructural facilities so that farmers will attain the maximum result of the land reform and land consolidation.

Therefore, the following major activities of the supporting services should be carried out systematically.

1) to promote the land consolidation in parallel with the land reform;

2) to strengthen the extension services and training of farmers;

3) to organize the farmers' groups for rationalized water and farm management;

4) to supply smoothly the agricultural input materials to cope with the modernized agriculture with high productivity (irrigated agriculture), and to rationalize cargo booking, storage, processing and marketing;

5) to promote the farm mechanization;

6) to improve the rural living environment;

7) to establish an agricultural financing system, and to promote farmers saving for their own capital reserves;

b) Executing Body for the Supporting Services

Agricultural Land Reform Cooperatives multi-purpose agricultural cooperatives to be established (hereinafter called the ALRC) would be the executing body of all supporting services in farmers' level. In general, no agricultural cooperatives can make farmers to participate in it by force. Therefore, the farmers' group consciousness to grow up ALRC would be essential because ALRC has to take charge of promoting the water management and the related group farming after the implementation of the Project. Some legal measures to give ALRC a compelling force might be required in some cases so that ALRC can make all farm house-holds under its jurisdiction participate in as a subscriber.

The farming groups, management groups and production units, sub-organizations of ALRC, should be first organized prior to the establishment of ALRC. The organization chart is shown in Figure 4-4.

(1) Farming Group

A farming group will be organized by the farm house-holds whose farm fields are located in two adjoining rotation blocks with an acreage of 76.8 ha. In this case, members of a farming group is about 20 farm house-holds. (See Appendix 4-25).

The farming group is a farmers' organization which is responsible to promote directly such works as water management, planning of farm practices, operation and maintenance of farm machinery, management of group farm practices, group marketing, etc.

(2) Management Group

A management group will be organized by four farming groups. A total acreage of farm field in the one management group is 307.2 ha, that is, 1,920 rai, which corresponds to above one Muban. This organization will be responsible to adjust and guide the farm practices, water management and operation and maintenance of farm machinery by each farming groups under the management group, and furthermore, to make accounting for itself under the guidance of ALRC staff.

(3) Production Unit

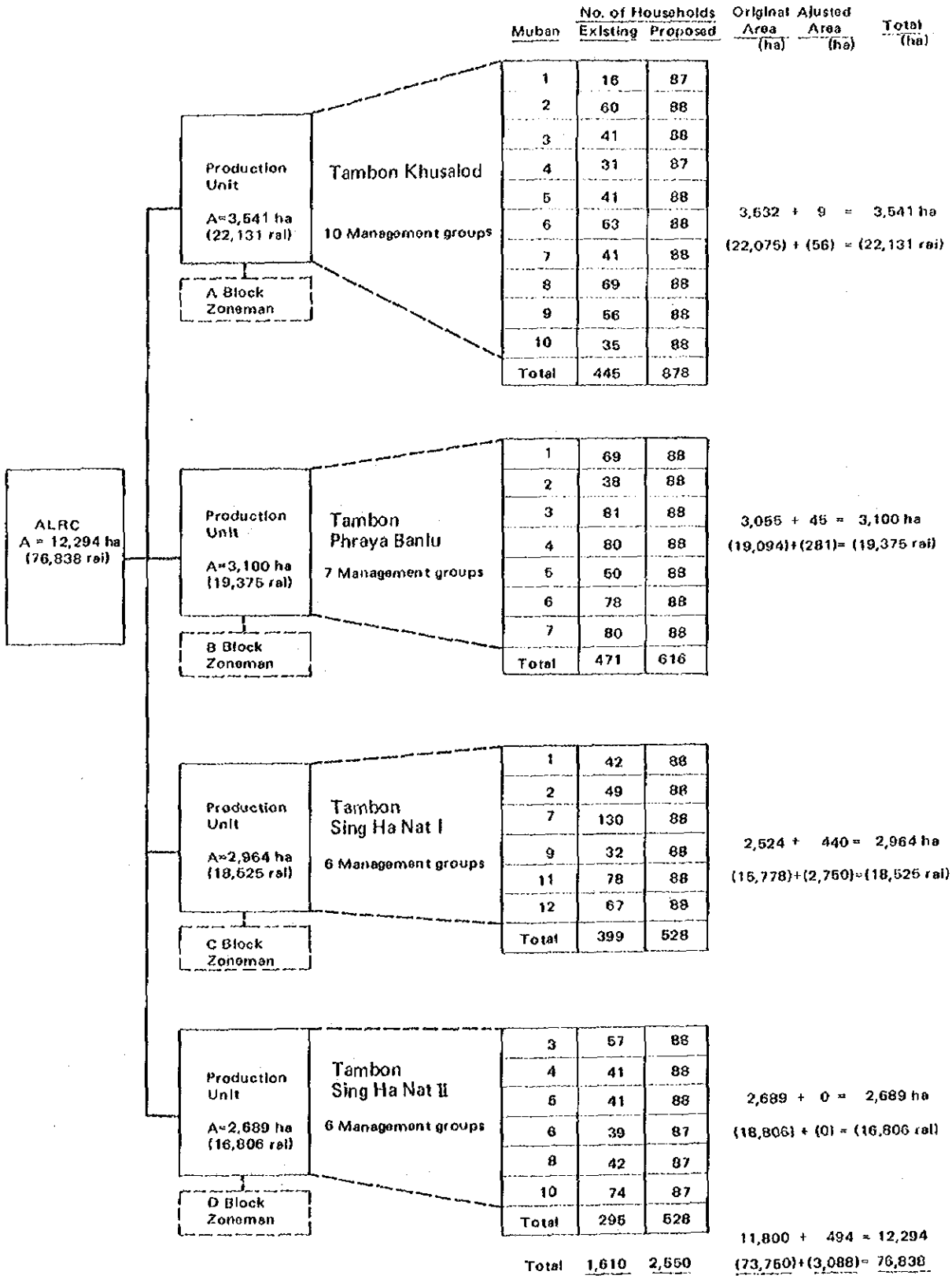
The production unit will be organized in each Tambon, and responsible for various works in connection with agricultural production on Tambon basis including production planning. Therefore, this organization will serve keeping close contact with the administrative organization of Tambon.

(4) ALRC

In order to establish ALRC, a preparatory committee should be organized by some members of the present Changwat Land Reform Committee and persons nominated by the said land reform committee. One of the officials of Ayutthaya Land Reform Office should position as Chairman of the preparatory committee, and some measures should be taken to let all the leading figures on Amphoe level, including three Tambon,

FIGURE 4 -- 4.

ORGANIZATION OF ALRC, PRODUCTION UNIT AND MANAGEMENT GROUP



Muban	No. of Households Existing	No. of Households Proposed	Original Area (ha)	Ajusted Area (ha)	Total (ha)
1	16	87			
2	60	88			
3	41	88			
4	31	87			
5	41	88			
6	63	88	3,532	9	3,541 ha
7	41	88	(22,075)	(56)	(22,131 rai)
8	69	88			
9	56	88			
10	35	88			
Total	445	878			
1	69	88			
2	38	88			
3	81	88			
4	80	88	3,055	45	3,100 ha
5	50	88	(19,094)	(281)	(19,375 rai)
6	78	88			
7	80	88			
Total	471	616			
1	42	88			
2	49	88			
7	130	88			
9	32	88	2,524	440	2,964 ha
11	78	88	(15,778)	(2,750)	(18,525 rai)
12	67	88			
Total	399	528			
3	57	88			
4	41	88			
5	41	88	2,689	0	2,689 ha
6	39	87	(16,806)	(0)	(16,806 rai)
8	42	87			
10	74	87			
Total	295	526			
Total	1,610	2,550	11,800	494	12,294
			(73,760)	(3,088)	76,838

participate in the preparatory committee. The preparatory committee will be responsible for planning of disposition for substitute plots in accordance with the final design prepared in each year for land consolidation. Based on the plan, the proposed substitute plots will be distributed to concerned farmers immediately after the completion of land consolidation works. Accordingly, the planning and the disposition for substitute plots should be carried out successfully, considering the smooth settlement of farmers living now outside the Project Area, the possible extension of new farming practices in the substitute plots and also the social structure in the villages, for instance the difference in religion, etc. Furthermore, the preparatory committee will assist farmers, who are involved in the disposition, in organizing the farming groups and management groups based on the proposed organizations shown in Figure 4-4, conduct the training of farmers for water and farm management to cope with the new irrigated agriculture, and organize the production unit as soon as a number of the management groups increases to do it. In this case, the preparatory committee should give guidance to Muban(s) and Tambon(s) in making close contact with each other.

(5) Functions of the Farming Group and Management Group

Farming Group

i) to prepare the cropping schedule in its farm block in charge under the assistance of extension workers of ALRC Extension Service Division;

ii) to decide the annual water requirement for the farm block in charge based on the above-mentioned schedule under the assistance of extension workers of ALRC Extension Service Division;

iii) to decide the order to carry out the transplanting works among farm plots;

iv) to plan and execute the group farming such as for preparation for nursery, land preparation, pest control and O/M of farm machinery;

v) to execute the group cargo booking and marketing, and to give advices to farmers in agricultural financing;

vi) to execute the irrigation, water distribution and drainage according to the instructions issued by common irrigators.

Management Group

i) to promote the land consolidation and land reform;

ii) to execute the water management giving instructions to common irrigators and keeping close contact with zonemen of RID; (especially, to request RID through ALRC to distribute the necessary water quantity based on the groups' request.)

iii) to adjust and give guidance in group farm practices and cooperative works carried out by farmers groups;

iv) to serve for the members in agricultural financing including the preparation of necessary documents;

v) to promote the education and training for farmers.

After the production units of two or more have been organized, ALRC preparatory committee will start to establish ALRC. On this stage, some measures should be taken to let all the farm house-holds whose farm fields are involved in the disposition for substitute plots participate in ALRC as subscribers, make them receive ALRC training and let them enter into the contract with ALRC so that they must fulfill all duties in relation with ALRC's activities, and if they fail to do it, they have to pay some penalty.

(c) Strengthening of Extension Services and Training of Farmers

To attain the aim of this Project, it will be one of the most important items to transfer surely and at the soonest possible, the new techniques and knowledge on the irrigated agriculture and farm management to farmers. For this purpose, a number of extension workers

should be increased to an extent, and furthermore, they should receive the training on the irrigated agriculture and farm management so that they will be able to give substantial guidance to farmers. It is the policy of the Ministry of Agriculture and Cooperatives to assign six extension workers to the Amphoe belonging to the Project Area to cope with the Project in near future so that one extension worker will serve for 3,000 ha, that is, one production unit. However, the acreage of 3,000 ha is still too big for an extension worker to carry out his services sufficiently. To cope with it, the Extension Services Division should be established in ALRC so that it will be responsible for operation of the seed center, training center and motor pool, etc., keeping close contact with the extension workers. The training of farmers will be one of the major works of the Extension Service Division. (Detailed plan for training of farmers is shown hereinafter.) The training aims to grow up leaders for the farming and management groups. Therefore, the field training, that is, the training in parallel with the execution of actual works for the groups should be emphasized for them.

(d) Execution Supporting Services

(1) Cargo Booking, Storage, Processing, Marketing and Transportation of Agricultural Products

Paddy Products

On the assumption that an amount of paddy rice equivalent to the existing yield is dealt with as it is made now, the extension services in respect of the cargo booking, storage, processing, marketing and transportation of agricultural products have been planned for an increased production of paddy by the Project. The Sales Division to be established in ALRC will be responsible for the above-mentioned services. A paddy quantity delt with by ALRC, and the capacities and construction costs of warehouses and rice mills required for the increased paddy production have been estimated and shown in Appendix 4-26.

The increase of paddy production per annum will be 70,349 tons. In order to store about 77 per cent of the increased paddy in the dry season cultivation, 40 warehouses with the storage capacity of 300 cu.m for the ALRC and 600 warehouses with the capacity of 10 cu.m for farm house-holds will be required. The construction cost of them is estimated at ฿23,630. On the assumption that a half of the stored paddy is shipped to the market as unhulled rice, a total capacity of rice mills should cope with the remaining half of the stored paddy plus paddy for local consumption so a capacity of not less than 15,000 tons will be required for the dry cultivation. Therefore, three units of mill with the capacity of 6,000 tons per annum each and three with the capacity of 4,000 tons each had been planned to be newly installed. The construction cost of them is estimated at ฿10,500,000.

Other Agricultural Products

The other major agricultural products than paddy in the Project Area are orange and vegetables. The farm house-holds who are engaged themselves in orange cultivation have already introduced the industrialized system in their farming. Therefore, they will be able to deal with their products by themselves even if they expand their farming after the implementation of the Project, by establishing their group, if necessary. As for vegetable cultivating farm house-holds, the same farmers groups as mentioned in respect of paddy cultivating farm house-holds should be organized for cargo booking, assorting their products and marketing, etc. so that the market-value of their products will be kept high through the complete quality control of products. For transportation of these, the transportation by boats to Bangkok and that by trucks to Sena and Ayutthaya have been planned. Transportation cost by boat (฿35/ton) is a half of that by truck (฿70/t).

(2) Supply of Input Materials

Seeds

The seed supply is the first step for fruitful production based on

the proposed cropping schedule. The seed center to be established under ALRC will be responsible for timely supply of seeds to farm house-holds with close cooperation of the ALRC Extension Service Division. Paddy seeds of 382 tons will be required for each of the dry and wet season cultivations. (See Appendix 4-27). In order to renew farmers' seeds once every four croppings, at least, paddy of 96 tons should be supplied by the ALRC Seed Center every season. For this purpose, a seed breeding farm of about 35 ha will be necessary. It is planned that ALRC will entrust the management of the seed breeding farm to some farm house-holds under the necessary guidance to be given to the farmers by staff of the ALRC Seed Center. As for seeds of vegetables, a required quantity is limited, but very expensive. Therefore, ALRC Seed Center will directly deal with those. Saplings will be densely planted in the newly prepared orchards of about 260 ha, and a half of them will be thinned out within a few years. The saplings thinned out will be sold to the farmers who want to replant their fruit trees in their orchards. Young hog and poultry will be also sold at the ALRC Seed Center.

In order to carry out the guidance and administrative works for the above-mentioned, four specialists will be assigned to the ALRC Seed Center, and given the roles to carry out the following works, keeping close contact with the extension workers:

i) to prepare necessary amount of seeds based on the cropping schedule to be submitted by each farming group;

ii) to give guidance and engage in the field works for the seed breeding entrusted by ALRC to farm house-holds;

iii) to distribute seeds to farming groups according to their cropping schedules;

iv) to manage the ALRC Seed Center;

v) to establish the overall cropping schedule of ALRC, to assist production units in attaining target yields based on their cropping schedule, and check the actual results of yielding.

The construction cost for the ALRC Seed Center is estimated as follows:

A complete set of seed breeding plant:	฿1,000,000
Buildings and so forth:	฿1,000,000
Total:	฿2,000,000

The layout of the ALRC Seed Center is shown in Appendix 4-28.

Fertilizers and Chemicals, etc.

The amount of fertilizers required inclusive of those for vegetables and fruit as well as lime is 41,159 tons, and its costs ฿30,759,000. An amount of chemicals is 1,605 tons, and its costs ฿31,944,000. (See Appendix 4-29). The consumption of fertilizers exept for lime and chemicals will be 5.9 times and 4.1 times of the amounts now being consumed, respectively. An average expenditure per farm house-hold will arrive at ฿12,062 for fertilizers inclusive of lime and ฿12,527 for chemicals. Most farm house-holds could not bear such a big amount of expenditure at the initial stage. Therefore, ALRC should take some measures for agricultural financing and credits in order to decrease farmers' expenditure at the initial stage. It will contribute to an extent, to the decrease of initial expenditure if ALRC facilitates farmers and manufacturers to enter into a special contract to materialize the deferred payment of interests. Moreover, the Government or financing organizations should help farmers financially by giving special funds to manufacturers. It is also necessary to make a nationwide storage plan of chemicals under the cooperation of the Government and chemical manufacturer to meet urgent necessities at the time of outbreak of diseases and injurious insects, etc.

(3) Farm Machinery

Farm mechanization is planned for each farming group. Tractors are the major farm machine in the farm mechanization plan. Heavy or standard tractors will be introduced in accordance with the scale of each farming group. ALRC will be responsible for guidance of a leader or a person in charge of farm machines so that they can fully operate and maintain machines. Units of farm machinery required by each farming group for paddy cultivation and those required for vegetables and fruits cultivation are shown in Appendix 4-30.

Introduction of Operation of Farm Machinery

The hand-over of farm machinery from ALRC to each farming group will be made in the form that ALRC leases them to a person in charge of O/M of farm machinery or to the leader of a farming group under the condition that O & M and payment of rental charge should be duly made by them. But actually such person mentioned above or the farming group will purchase the farm machinery from ALRC by installment, etc. in future following the regular procedure set out by ALRC. In this case, tractor operation on contract basis will be introduced, so ALRC should have the right to decide operation charge to prevent the undue profit of owners of farm machinery and to promote group farming and water management effectively and smoothly.

Costs for Farm Machinery

ALRC will purchase the farm machinery on a blanket contract. A total expenditure for farm machinery is ฿59,418,000 in Case I and ฿55,613,000 in Case II, as shown Appendix 4-31.

Repair and Training of Farmers for Farm Machinery

The ALRC will open a motor pool for repair of farm machinery and farmers' training on mechanized farming. Some spare machines will be prepared at the motor pool for stand-by. Farmers should master how to repair farm machineries at a simple trouble during operation in field though a shop truck will be prepared to serve to repair farm machinery at a trouble beyond farmer's hand.

The scale of the motor pool is as follows:

Description	Specification	Cost (฿'000)
Repair shop with a set of necessary equipment and tool	600 sq.m	1,000
Hangar	300 sq.m	225
75 HP tractor	2 units @270	540
24 HP tractor	5 units @ 98	490
Thresher	3 units @ 12	36
Power tiller	5 units @ 25	125
Shop truck	1 unit @270	270
Total		2,686

Costs for fuel and other materials (@฿350 x 10,542ha) 3,690.

The layout of the motor pool is shown in Appendix 4-32.

(4) Training of Farmers

For the irrigated agriculture with modernized agricultural infrastructural facilities, the training is required not only for farmers but also leaders of the farming groups as well as ALRC staff. A training center will be established in ALRC for training of farmers. The training of leaders of farming groups and ALRC staff will be mainly conducted at the Suphan Buri Training Center which is operated by the Government.

The subjects of the training will be as follows:

- On water management of on-farm level:	Once in each wet and dry season cultivation
- On preparatory works for establishing ALRC:	Once in 1978, 1979 and 1980
- On operation and management of farming groups:	Twice in each wet and dry seasons
- On seed breeding farm:	Once in dry season
- On farm mechanization:	Once in each wet and dry seasons

The schedule for training is incorporated in Appendix 4-33. The facilities required for the training will be as follows:

Description	Cost (฿ '000)
- Teaching room (for 100 persons) and accommodation (for 20 persons):	1,000
- Training facilities:	1,000
Total	2,000

(5) Execution of Supporting Services

ALRC to be established in the Amphoe level will be responsible for execution of supporting services under the assistance of RID, Extension Service Offices, Changwat Agricultural Cooperative and Amphoe Office, etc. Organization chart is shown in Figure 5-3. The zonemen in charge of operation and maintenance of irrigation and drainage facilities will belong to RID, but the common irrigators to ALRC. ALRC staff will be responsible for operation and maintenance of pumping stations. RID will dispatch some experts to ALRC from time to time so that the water management in the Project Area will be carried out along with the irrigation water distribution plans prepared by Chao-Chet Bangyeehon Project Office and Phraya Banlu Project Office under RID. Zonemen of production units, staff of the ALRC Irrigation Water Management and Extension Service Divisions and extension workers will participate in the formulation of overall water management plan in the Project Area every year based on water distribution plans prepared by management groups. Leaders of the management groups will be fully responsible to request the change of water distribution, if the necessity arises due to the unfavorable climate, change of discharge from dams or obstacles in farm management. The number of extension workers is in shortage, therefore, it is recommendable to assign one extension worker who can give guidance in the fields of paddy, vegetables and fruits cultivation to each production unit.

The details of the organization and its operation costs are shown in Appendix 4-34.

(6) Summary of Annual Costs for Supporting Services

According to the construction sheedule of the Project, the land consolidation in Block A will be started in the dry season in 1980. As a result, paddy fields of about 2,600 ha in Block A will be cultivated for the wet season paddy in 1980. Therefore, the preparatory works should be carried out to start the supporting services in each block in 1980.

Implementation Plan for Land Consolidation

(Unit: ha)

Block	1979 D	1979 W	1980 D	1980 W	1981 D	1981 W	1982 D	1982 W	1983 D	1983 W	Total
A Block	X	X	2,600	X	430	Y	Y	Y	Y	Y	3,030
B Block	-	-	X	X	2,580	Y	Y	Y	Y	Y	2,580
C Block	-	-	-	-	X	X	2,450	Y	2,482	Y	4,932
Total	-	-	2,600	-	3,010	-	2,450	-	2,482	-	10,542

Note: X indicates the final design for land consolidation. Y indicates the practicability of cultivation. Figures represent the acreage of farm fields where land consolidation will be implemented.

ALRC will control paddy cultivation in accordance with implementation plan of land consolidation so that no deduction of yield occurs due to the land consolidation works.

Detailed cropping schedule, expected yields of crops, input materials required and annual expenditures for supporting services before and after the land consolidation are shown in Appendix 4-35, and Table A.4-56 Appendix 4-36. Additionally, the total expenditure for supporting service facilities and annual cost for them are tabulated in Table A.4-57 (Appendix 4-36).

(7) Budgetary Plan for Supporting Services

The total expenditure for supporting services consists of the following:

Description	Cost (฿ '000)
i) Facilities for supporting services during 7 years	14,862
ii) Facilities to upgrade the market price of products such as warehouses and mills	34,130
iii) Farm machinery and its hangars whose costs included in the production cost	57,731
iv) Fertilizers and chemicals, etc., which are directly needed for production (max/season)	25,000
v) Establishment and operation of ALRC including the training (max/year)	7,230

All the above-listed items are indispensable for execution of supporting services.

The item i) mainly consists of general public facilities, therefore, ALRC should prepare these facilities under the financial assistance from the Government. Charges and fees of the motor pool, trucks and boats will be accumulated to replace them in future. As for the item ii), charges and fees of these facilities should be decided at reasonable prices so that ALRC will be able to pay back the subsidy for those to the Government under the terms of redemption, and furthermore to accumulate necessary funds to replace them before their deterioration. The farm machinery and hangars under the item iii) will be purchased by the financial aid from a foreign country with a long redemption period. Therefore, it will be easy to decide their charges and fees to cover both the amount required to pay back the aid and the amount to replace them. In respect of the item iv), most farm households in the Project Area will not be able to pay for fertilizers, chemicals and the other input materials for the time being. Therefore, ALRC should take some measures as mentioned above. In respect of the item v), the expenditure for establishing and managing ALRC and the other costs required for the Governmental services including the training of farmers should be borne by the Government taking into consideration the objectives of the expenditures. However, most expenses could be covered by the profit obtained from the economic activities of ALRC. In General, the profits of an agricultural cooperative

from marketing are about 20 per cent of the purchasing prices and 15 to 16 per cent of the selling prices.

If the above-mentioned rates are applied, ALRC will realize a yearly profit of about ₿10,000,000 on fertilizers, chemicals and other input materials, which will be more than enough to cover all the personnel and operation costs of ALRC. However, such profits cannot be expected for a few years after the implementation of the Project. Therefore, the Government has to take some measures to secure the initial cost for ALRC, for instance, by providing the financial aid or guarantee for bank loans. Utilization of foreign funds through BAAC should be taken into consideration for budgetary planning.

(e) Promotion of Saving

The success of the Project will be recorded in farmers' savings passbooks. ALRC should make every possible effort to increase farmers' and ALRC's savings by repeating sound investment. The following measures will be needed for it.

1) to introduce as much as possible the chit system into the settlement of account for marketing of input materials and products in order to increase the cash reserve of ALRC, and to allow farm households to draw money of more than their savings under some conditions.

2) to make payment for selling and buying of lands and for construction works through ALRC Credit Division in order to earn interest.

3) to keep the interest rates higher than those of the other financing organizations, and to introduce the incentive system for depositors.

4) to encourage farmers to make daily and fixed deposits by combining them to agricultural disaster insurance, etc. and make ALRC staff visit periodically farm house-holds to gather their idle money.

9. Community Development (Living Environmental Improvement)

(a) Necessity and Objective

The necessity and objective of the living environmental improvement are as follows:

1) People in the Project Area have made a living on the water for four to five months every year. The proposed dikes and pumping will enable them to live on the land through the year. However, a sudden change of living environmental is not desirable from the viewpoints of their economy, stability of living and health. For instance, it might be difficult to switch over the existing transportation by boat to that by truck in a short time. The living environmental improvement plan should be carried out considering the above.

2) Farm management after the implementation of the Project will be conducted by farming groups as mentioned above. It is desirable that the members of one farming group form one living group in order to establish a favorable community with a strong feeling of solidarity as shown in Appendix 4-37.

3) No immigration to the Project Area is planned for the living environmental improvement. Taking account of the possibility of immigrant of relatives of farmers and absentee landlords, etc., housing lots for 2,550 farm house-holds have been secured in the plan.

4) Housing sites will be prepared for the house-holds whose houses should be moved in accordance with the construction of dikes, roads and land consolidation.

5) The existing navigation system will be broken by the Project, and a new navigation system will be planned based on the proposed road system, etc.

6) In the Project, the separation of living and production areas will be, in general, performed. A community will be formed by four sub-communities consisting of about 20 house-holds. Each house-hold will be provided with a housing lot of 1,000 sq.m (0.625 rai). Such communities will be mostly located outside the dikes for main irrigation canals. For the communities surrounded by the farm fields, roads will be constructed to connect to a landing place for navigation. Based on the above-mentioned housing area per farm household, acreage of community area is estimated as follows.

Block	No. of Muban	No. of farm household	Housing Area (ha)	Public Land (ha)	Temple & School (ha)	1/ (ha)	2/ (ha)	Community Area(Total) (ha)
A	10	725	73	20	25	18	32	168
B	7	632	64	50	20	14	28	176
C	12	1,193	119	30	40	28	58	275
Total	29	2,550	256	100	85	60	118	619
Percentage in gross area (%)			2.1	0.8	0.7	0.5	0.9	5.0

Note: 1/ area for fish pond and collective animal breeding
2/ area of canals, roads and housing area for non-farm households, etc.

7) Funds required for living environmental improvement will be prepared by ALRO as a part of funds of land reform project. And the funds will be paid back in a long term after the construction for the living environmental improvement.
The construction cost for living environmental improvement have not been counted in economic evaluation of the project.

(b) Plan of Living environmental Improvement

Each item of the works to be carried out for living environmental improvement should be carefully checked from the viewpoints of economy, safety, sanitation, convenience and comfortability of inhabitants. The costs estimation and description on the facilities which are easily

installed in connection with the infrastructural improvement and supporting services in the Project, the facilities which play a big role for living environmental improvement if attention is paid, and the facilities which are the pre-requisite for people's life after the implementation of the Project are made hereinafter.

1) Roads

Although the road improvement inside villages is exclusive of the project plan, the newly established road networks outside villages should be linked with them for more convenient transportation in the Project Area, as shown in Appendix 4-38.

2) Navigation

The navigation system after the implementation of the Project is proposed in Appendix 4-39. ALRC will be responsible for transportation by the owned large-size boat. The navigation center, rice mills, warehouses, truck terminal will be functionally located for effective transportation of agricultural inputs and outputs. For the convenience in navigation, communities will be mostly located along canals. Some modernized navigation facilities should be provided for transportation within a community.

3) Prevention of Water Pollution

The prevention of water pollution based on some water quality standards will be required to cope with the intensive use of water after the implementation of the Project. Canal water is used for various purposes such as irrigation, fresh-water fish cultural, domestic water supply, etc., therefore, exhausted water from industrial, mine, animal breeding facilities and so forth in the upper basin should be carefully checked in future though there is no source to pollute water at present. Water pollution directly cause the contamination of soils, so natural purification of exhausted domestic water and domestic animal breeding water or installation of common treatment facilities of such water should be taken into consideration, if the necessity arises in future.

4) Control of Mosquitoes, Flies and Rats

The control and extermination of mosquitoes, flies and rats should be completely carried out in parallel with the prevention of water pollution. The river water streaming now is kept clean. Many fish lives and eat filty things and mosquitoes' larvae at present. However, a big outbreak of mosquitoes and flies after the implementation of the Project is anticipated, due to the stagnation of water, which causes a decrease of fish. Simultaneously, careful attention should be paid to rats. Rats inflict serious damage on crops, and spread infectious disease. Therefore, participation of an expert in the field of rat control and extermination in the Project on the final design stage would be necessary.

5) Electric Supply and Telephone

PEA (Provincial Electricity Authority) has a plan to lay an electric line along the southern provincial road in order to supply the power of 500 KW to the Project Area by 1979. However, the proposed pumping Stations require power supply of about 2,000 KW, therefore, the PEA plan has to be altered.

The telephone communication will be needed on the stage for Project implementation, so it is expected that telephone facilities will be installed in parallel with the construction for power supply.

6) Hospital

The Project Area is equipped with four clinics at present. But the capacity of these clinics is too small to cope with the population in the Project Area. ALRC should establish and run a hospital equipped with some travelling clinic facilities.

7) Establishment of Agricultural High School

There exist 17 primary high schools and one junior high school. It is desirable that an agricultural high school in the Project Area will be established for education of successors of farm house-holds

and ALRC staff, apart from the ALRC training center for farmers mentioned above.

8) Construction of Fish Ponds and Collective Domestic Animal Breeding Area

The borrow pits of embankment materials for foundations of collective domestic animal breeding areas and the other public facility areas will be utilized to prepare fish ponds. The existing fishery to catch natural fish should be switched over to the fishery to grow fish in fish ponds artificially. The shrimp breeding is a long-pending items of the inland fishery in the Project Area and its vicinity.

9) In planning the living environmental improvement, careful attentions should be paid to the destruction of natural conditions so that the attempt to improve the living conditions never be against nature. Especially, the landscape of riverside villages will have a scarcity value as a tourist potential in future.

(c) Re-arrangement of Villages

The re-arrangement of villages in the Project aims to establish the rural communities best suited for the irrigated agriculture with infrastructural facilities as well as for daily life of farmers as mentioned above. For this purpose, each community will be organized by one management group consisting of about 80 house-hold, that is, by four sub-communities, farming groups, consisting of about 20 house-holds each, and each community will be equipped with common facilities necessary for agricultural production and daily life so that such community will function as the base for further development in future. Farmers in the Project Area hardly have the common facilities for agricultural production and their daily life. Under the circumstances, the land reform to be carried out in parallel with the land consolidation would be a good chance to reorganize villages and equip these with common facilities so that the most effective utilization of the facilities will be realized. In acquiring house lots for the

reorganization of villages, participation of farm house-holds to villages who live apart form villages in the Project, farm house-holds who will be compelled to move their houses due to the construction works in the Project, possibility of establishing branch families and homecoming of absentee landowners, etc. are taken into consideration.

The typical layout of farm villages for management group and production unit as well as for the ALRC central area are shown in Appendix 4-41. The total construction cost required for re-arrangement of villages is estimated at ฿42,655,000 as worked out in Appendix 4-42.

D. Proposed Facilities

1. Irrigation Canals

In principle, the earth canal is proposed for all the irrigation networks in the Project Area from the economic viewpoint.

(a) Classification of Irrigation Canals

The proposed irrigation canals are classified into main canals, lateral canals and farm ditches. This classification is not made from a view point of discharges in canals but function of each canal. (See Appendix 4-43)

Main Irrigation Canals

Main irrigation canals are planned to be constructed along the dikes so as to keep their effective head possibly high, because the topographical platness of the Project Area makes it difficult to give a sufficient hydraulic gradient to the canals. The dikes along the main canals are designed to serve dual purposes of dikes and canals to be provided on inside slope of the dikes so that the construction costs and canal lots may be saved.

Lateral Irrigation Canals

The lateral irrigation canal receives water from the main irrigation canal through a diversion box, and conveys it to a turn-out, which diverts the water to farm ditches.

Farm Ditches

The farm ditch receives water from a lateral irrigation canal to irrigate farm field directly.

All the irrigation canals mentioned above are planned to be located along the road or the dike for their easy operation and maintenance.

(b) Principles in Hydraulic Design

The canals are designed to cope with the maximum designed duty of water under the conditions described blow.

Permissible Velocity of Water

A water velocity in an irrigation canal should be ranged within the maximum water velocity that does not cause the erosion in the canal and the minimum water velocity that can prevent both the accumulation of silt and growth of water grasses in the canal. The permissible maximum water velocity in unlined canals by each materials is generally as follows:

Permissible Max. Velocity

Materials of Canal Surface	Permissible Maximum Water Velocity (m/s)
Sandy soil	0.45
Sandy loam	0.60
Loam	0.70
Clayey loam	0.90
Clay	1.00
Sand mixed clay	1.20

The soil texture in the Project Area is silty clay to clay. The standard permissible maximum water velocity of the irrigation canals will be set up at 0.90 m/sec accordingly. The Kenedy's formula, which is generally applied to calculate a mean water velocity that cause neither erosion of canal bed and slope, nor accumulation of silt in a unlined canal, is used in this study. The formula is as follows:

$$V_S = C.D^{0.64} \text{ (in case of muddy water)}$$

where, Vs: mean water velocity which cause neither erosion nor accumulation of silt (m/sec)
D: water depth (m)
C: Coefficient by material 0.5 - 0.6

A mean water velocity by water depth calculated by the above formula is tabulated as follows:

Water depth (m)	Vs (m/s)	Water depth (m)	Vs (m/s)
0.25	0.23	1.00	0.55
0.50	0.35	1.25	0.63
0.75	0.46	1.50	0.71

Design Discharge

The designed discharge of canals is determined as follows:

$$Q = A.V$$

where, Q: Quantity of discharge (cu.m/sec)
A: Cross-sectional area of flow (sq.m)
V: Mean water velocity (m/sec)

The Manning's formula, which is generally applied to calculate a mean water velocity, is used in this study as follow:

$$V = \frac{1}{N} R^{2/3} I^{1/2}$$

where, V: mean water velocity (m/sec)
N: roughness coefficient
I: hydraulic gradient
R: hydraulic radius (m) R = A/P
P: wetted perimeter (m)

Roughness Coefficient

The roughness coefficient, which shows an overall roughness of the cross-section of a canal, is an important factor in applying the Manning's formula. A straight canal with an uniform cross-section will be constructed because its construction is to be performed as a part of the land consolidation works. However, the mean water velocity mentioned above can not be expected due to the topographic conditions of the Project Area. The roughness coefficient of the irrigation canals is determined at 0.035. If the sufficient operation and maintenance of a canal is not provided, a roughness coefficient of the canal will go up to a greate. But in case of irrigation canal, the operation and maintenance can be periodically performed. So, the above-mentioned roughness coefficient is appropriate for the calculation (See Appendix 4-44).

(c) Typical Cross-section

Freeboard

A freeboard is determined as follows:

$$Fb = 0.05D + hv + (0.05 \sim 0.15)$$

where, Fb: freeboard (m)
hv: velocity head (m)
D: depth at designed maximum discharge (m)

The water velocity in the proposed canals is so low that the velocity head is negligible. The standard freeboard at the designed maximum discharge by scale of canals is decided as follows:

Main irrigation canal	0.20 m
Lateral irrigation canal	0.10 m
Farm ditch	0.05 m

Side Slope

A canal side slope less than 1:1.0 is considered to be applicable from the soil mechanical point of view. However, the following are adopted as criteria.

Main irrigation canal	1 : 1.5
Lateral irrigation canal	1 : 1.0
Farm ditch	1 : 1.0

The relationship between the cross-section of canal based on the above-mentioned criteria and the designed discharges is shown in Appendix 4-45. Typical design of the canals is given in Drawing No.3.

(d) Designed discharge in Each Irrigation Canal

The following formula is applied to determine the design discharge

$$Q = q \times A$$

where, A: designed discharge (cu.m/sec)
q: unit water requirement (cu.m/s/ha)
A: net irrigation area (ha)

$$q = \frac{d\ \text{mm/day} \times 1/1{,}000\ \text{m/mm} \times 10{,}000\ \text{sq.m/ha}}{86{,}400\ \text{sec/day} \times a \times (1-b)(1-c)}$$

where, d: maximum field water requirement (mm/day)
a: application loss
b & c: conveyance loss

- In case of paddy field

d = 9.6 mm/day a = 0.80
b = Main canal 0.075 c = Lateral canal: 0.10

Name of Canal	d	(a)	(1-b)	(1-c)	q(cu.m/sec/ha)
Main irrigation canal	9.6	0.80	0.925	0.90	0.00167
Lateral irrigation canal	9.6	0.80		0.90	0.00154
Farm ditch	9.6	0.80			0.00139

- In case of upland field

d = 4.6 mm/day a = 0.65

Name of Canal	d	(a)	(1-b)	(1-c)	q(cu.m/sec/ha)
Main irrigation canal	4.6	0.65	0.925	0.90	0.00098
Lateral irrigation canal	4.6	0.65		0.90	0.00091
Farm ditch	4.6	0.65			0.00082

Design discharge for planning the irrigation system in each block is shown in Figure A.4-35 to A.4-37. (See Appendix 4-47)

(e) Related Facilities

Diversion box: Diversion boxes are planned to be installed to divert water to the lateral irrigation canal. Diversion boxes of the double gate type with a constant head are proposed. (See Appendix 4-48)

Turn-out: Turn-outs with stop log are proposed for diversion of water in a lateral irrigation canal to farm ditches.

Inlet: Inlet pipe with a simple gate will be used to divert water in a farm ditches to each farm plot.

Check: A check will be used for raising water level in irrigation canals. The location of checks is determined based on canal slopes, but criteria are as follows:

Main irrigation canal	2.4 km
Lateral irrigation canal	1.3 km
Farm ditch	0.6 km

(only at the terminal of ditches)

Culvert: The culvert will be used to convey irrigation water across roads and the Phraya Banlu, IL-2, Khud Mai and Nai Chat canals. (See Appendix 4-49)

Typical design of the related facilities is given in Drawing No.6, No.7 and No.8.

2. Drainage Canals

The earth canal is proposed for drainage in the Project Area. Excavation and dredging will be, therefore, the major construction works for the drainage system.

(a) Classification of Drainage Canals

The proposed drainage canals are classified into the main drainage canals, leading drainage canals and drainage ditches. This classification does not depend on canal discharges but on their functions. (See Appendix 4-43)

Main Drainage Canal

In order to minimize the canal lot and the construction cost, the borrow pit will be used as main drainage canal, that is, the main drainage canals are planned to be constructed along the dikes so that soils excavated for canal construction are directly utilized for the embankment of dikes.

Leading Drainage Canal

The leading drainage canals are given a role to lead drainage water of drainage ditches to a main drainage canal. The leading drainage canals provide the on-farm roads at both sides. The interval of leading drainage canals is planned at 1,200m as a rule.

Drainage Ditches

The drainage ditches to which the drainage water in each plot is directly released are the so called terminal drainage canals. The drainage ditches are planned to be located at an interval of 320 m.

(b) Principles in Hydraulic Design

The hydraulic design principles described previously in respect of the irrigation canals are applied to the drainage canals. Width of drainage canals, especially that of the main drainage canals will be larger than the actually required because a big amount of embankment materials for dikes is excavated from the site of canal lot. Therefore, water velocity in the drainage canals will be far less than that in the irrigation canals.

Roughness Coefficient

The roughness coefficient of drainage canals should be, in general, designed larger than that of irrigation canals because of the difficulties for the operation and maintenance.

The roughness coefficient of the draiange canals is determined at 0.040, the maximum roughness coefficient of an earth canal covered thickly by weeds and water-grasses with various cross section.

Canal Conditions	Min.	Standard	Max.
An earth canal with non-uniform cross sections thickly covered by weeds and water grasses	0.030	0.035	0.040

(c) Typical Cross Section

Freeboard

When designing the drainage canals, no consideration is required on freeboard because they will be given a role to drain the surface water at the water level of paddy field.

Side Slope

The side slope of drainage canals is also determined as follows:

Main drainage canal	1 : 1.5
Leading drainage canal	1 : 1.0
Drainage ditch	1 : 1.0

The relationship between the cross-section of canal based on the above-mentioned criteria and the design discharge is shown in Appendix 4-50. Typical design of the canals is given in Drawing No.3.

(d) Design Drainage Discharge

The designed drainage discharge of canals is determined by their drainage area as follows:

$$Q = q \times A$$

$$q = \frac{d \text{ mm/hr} \times 1/1,000 \text{ m/mm} \times 10,000 \text{ sq.m/ha}}{3,600 \text{ sec/ha}}$$

where, Q: designed drainage discharge (cu.m/sec)
q: unit drainage discharge (cu.m/sec/ha)
A: drainage area (ha)
d: drainage modulus (mm/hr)

A (ha)	d (mm/hr)	q ($m^3/s/ha$)
0 - 320	2.3	0.00634
320 - 1,000	2.2	0.00615
1,000 - 3,000	2.1	0.00595
3,000 - 5,000	2.1	0.00583
5,000 - 10,000	2.0	0.00571

Drainage discharges for the drainage system to be constructed for each block are shown in Figure A.4-38 to A.4-40. (See Appendix 4-51)

(e) Related Facilities

The culverts will be provided to convey drainage waters across the roads and the existing canals, and pipe culverts are planned to convery drainage water across roads. But the concrete box type culverts are planned to cross the existing main canal due to much discharge (See Appendix 4-52). Typical design of the related facilities is given in Drawing No.9 and No.10.

3. Pumping Facilities

The pumping facilities will be required both for irrigation in the dry season and drainage in the wet season. The Project Area hardly has the effective rainfall for about eight months, October to May, and water levels in canals, the major water source for irrigation in the Project Area, lower to less than WL 2.00 m. Contrarily the Project Area will suffer from excess water during the wet season, June to September, even after the construction of the polder dikes. Since the drainage pumping unit requires a bigger capacity than the irrigation, the installation of dual purpose pump units for irrigation and drainage is planned for the Project.

(a) Determination of Pumping Station Site

Such dual purpose pumping stations are planned for each Block A, B and C under the Project. All these pumping stations are installed along the existing canals.

The hydraulic conditions for designing the pumps do not vary at any spot in the Block. But the pumping station, major facilities for supply and drain water, should be located at the central part of the block to a possible extent in such a flat area, because a certain water quantity should be supplied and drained by the irrigation and drainage canals with minimum cross-sectional area under the rationalized water distribution system. In addition to the above-mentioned, in determining the suitable pumping site, trafic conditions should be considered for easy operation and maintenance of facilities.

Taking into account the above-mentioned matters, the pumping station sites for respective Blocks A, B and C are selected as follows:

Block A. The existing canals of IL-2 and Nai Chat run across the Block A. The IL-2 canal is located closely to the central part of the block. Furthermore, this canal has a larger area in its eastern side than the western side. So, the pumping station site for this block is planned on the eastern bank of IL-2 canal.

Block B. Nai Chat and Phraya Banlu canals have the junctions in the central part of this block. Taking into the stability of water supply, Phraya Banlu canal, which is bigger than Nai Chat canal, is preferable for the pumping station site. For easy operation and maintenance, it is recommended to construct the pumping station along Phraya Banlu canal near the Provincial road.

Block C. In the case as Block B, the pumping station site should be

determined to be located along the Phraya Banlu and near the new Provincial road, and the eastern side of the provincial road is preferable.

(b) Types of Pump

A total pump head required for both irrigation and drainage in each block is lower than 4.00 m. The following two pump types are available in case of a low total pump head required in the Project Area.

- Axial flow pump
- Mixed flow pump

Both of them have merits and demerits due to their own mechanical properties. In general, the merits and demerits are tabulated as follows.

Comparison of Mixed and Axial Flow Pumps

Items	Mixed flow pump	Axial flow pump
Weight	Heavy (1.1 to 1.2 times of Axial flow pump)	Light
Pump efficiency	High	A little low
Shaft horse power	Constant in wide head variation	A shaft horse power in shut-off operation is twice of that in normal operation
Suction performance	Superior	Inferior
Unit cost	A little expensive	Not expensive
Operation range of head	All variation of head	Within about 135% to 70% of designed head
Usability as a drainage pump	Superior	Inferior

Both types of the pumps are further classified into two types, vertical type and horizontal type, and these pumps have also some merits and demerits.

In general, the former is superior to the latter in performance but the latter is 80 per cent cheaper than the former. The pumping units to be installed have the dual purposes of irrigation and drainage, so their suction performance should cope with wide head variations.

The axial flow pump of vertical axial type is not available due to the difficulty in suction performance for irrigation (See Appendix 4-57). As a conclusion, the mixed flow pump of horizontal axial type is suitable from the view points of economy and performance.

(c) Pump Units

Capacities of pump required in each block are as shown below:

Block	Drainage		Irrigation	
	Area (ha)	Discharge (cu.m/sec)	Area (ha)	Discharge (cu.m/sec)
A	3,449	11.97	3,027	4.96
B	2,970	10.31	2,583	4.14
C	5,569	19.32	4,932	7.82

A big capacity of pump is required not for irrigation but for drainage in each block, so the hydraulic dimensions for pump units are determined based on the capacity for drainage. More than two units of pump are planned to be installed at a pumping station for dispersion of danger against emergencies. A pump discharge for supplemental irrigation is about 1/2.5 of that for drainage. So, this means that more than one unit are reserved in stand-by during the operation for supplemental irrigation.

From the economic point of view, the number of pump units should be possibly minimized. However, pumps must be operated through the year for the irrigation or drainage. Therefore, three units of pumps at one pumping station is recommendable so that one unit or two are reserved in stand-by for extension of their lives dispersion of danger and effective operation and maintenance as well as economy. The

proposed pump units should be of the same type with the same bore for easy check and repair and operation and maintenance. (See Appendix 4-53)

(d) Bore Diameter of Pump

The relation between the bore diameter and the delivery discharge of a low head pump is as shown below.

Bore (mm)	Delivery discharge (cu.m/min)
φ1,000	115 - 150
φ1,200	150 - 200
φ1,350	200 - 255
φ1,500	255 - 325
φ1,650	325 - 400
φ1,800	400 - 480

In calculating a necessary bore diameter of pump based on a designed delivery discharge, the following formula is applied;

$$\phi = 90\sqrt{Q}$$

where, Q: designed delivery discharge (cu.m/min)

(e) Selection of Prime Mover

The motor or diesel engine is used as a prime mover of pump. Their merits and demerits are as follows:

Comparison of Motor and Diesel Engine

Item	Motor	Diesel Engine
Installation cost	Not expensive except those of special specifications	Expensive (high cost per unit power)
Incidental facilities	Costly due to the necessity of inner and outer electric facilities	Various incidental facilities such as oil tank, cooler and water-supply system are required
Maintenance	Simple and easy	Periodic operating for maintenance is required
Vibration & Noise	Easy	Both severer due to combustion in engine
Operation	Simple	Operation system is complicated due to the existence of various incidental facilities
Foundation	Subsidence is small, if any, due to small vibration	Foundation is necessary to cope with severe vibration

Apart from the economic aspect, the motor is generally more advantageous than the diesel engine. There exists no power supply system in the Project Area at present. But the Provincial Electricity Authority (P.E.A.) has a plan to lay electric wires along Phraya Banlu canal to supply the power of 500 KW to the Project Area by 1979, and has already completed the related works up to the eastern dike of the Project Area. Thus, the electrification has steadily progressed recently. A sub-station is located at Rangsit about 25 km south-east of the Project Area.

The construction cost of transmission line from the sub-station to pumping stations and the transformer to be installed at each pumping station is estimated at ฿7 million approximately. Even if this construction cost is included in the initial cost for motors, the motors are more advantageous than the diesel engine under the condition that the cost for motors and that for diesel engines per year is almost the same. The motor whose operation and maintenance are easy is selected as the prime mover of pump. (See Appendix 4-54)

(f) Plan of Pumping Stations

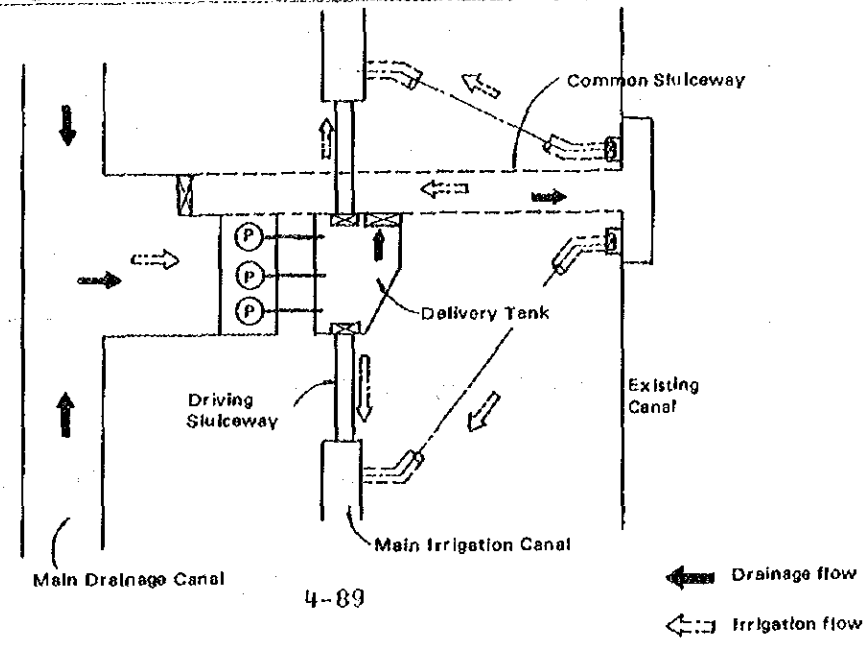
Civil Works

The installation of the dual purpose pumps requires to provide the dual purpose sluiceways for intake and outlet. Such dual purpose sluiceways should provide two gates, the ones at the inner end of the sluiceways and the others in the common wall for the sluiceways and the delivery tank as illustrated below, so that the direction of water flow in the sluiceways can be switched over by gate operation. The former gates are operated so that water of the existing canals may flow into the suction tank through the sluiceways while the pumps are operated for irrigation, while it is closed to prevent outer waters from introducing into the suction tank during pump operation for drainage. Apart from the sluiceway, two pipe culverts are laid to link the existing canals with the main irrigation canals for waters intake by gravity during water levels in the water source is kept high as shown in the

following. The suction tank should be given an enough capacity to prevent the rapid lowering of water level.

Furthermore, an enough space should be given around pits of the suction pipe lest problem occurs in suction performance. The screens are installed in front of the pits and the lower reaches from the screens are sheltered from the intrusion of refuses and rubbishes.

Diagram of Water Flow for Irrigation and Drainage



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Building

The buildings of a pumping stations comprise the pump rooms, the work rooms for assembling and overhauling and the operation rooms in which necessary operation boards are installed. The installation of the large bore pumps will require to provide overhead travelling hoist in respective pump rooms for easy mounting and/or dismounting of the machines for maintenance. And, the pillars and beams of reinforced concrete are used for pumping stations. Bricks are used for the walls. Typical design of the pumping station is detailed in Appendix 4-55.

(g) Major Dimensions of Pumps

The dimensions of the pumps are determined to meet the designed discharge for drainage. The major dimensions are as follows;

Items	Block A	Block B	Block C
Type	Mixed flow pump horizontal axial	"	"
Bore (mm)	φ1,350	φ1,350	φ1,650
Unit	3	3	3
Designed discharge (cu.m/min)	239	206	386
Total head (m)	2.70	2.50	3.20
	(3.60)	(3.50)	(3.80)
Suction water level(WL)	1.20	1.20	1.20
	(0.20)	(0.20)	(0.10)
Delivery water level (WL)	3.10	3.10	3.30
	(3.40)	(3.40)	(3.40)
Prime mover	motor	motor	motor
Power per unit (kw)	170	140	300

Note: The figures in parenthesis indicate the dimension of pumps for irrigation.
Detailed calculation is shown in Appendix 4-58.

Typical designs of pumping stations for each Block are given in Drawing No.4 and No.5.

4. Dikes

The existing canals, Phraya Banlu, IL-2, Khud Mai and Nai Chat that run across the Project Area, will be utilized for water sources, navigation canals, etc. even after completion of the project. In order to protect the cultivated area in each block from floods, the dikes having the elevation of 3.50 m above mean sea level are to be constructed on both banks of the canals and around the Project Area. An average height of the dikes in the Project Area is 1.50 m. Excavated materials for the construction of canals are used for the embankment materials of the dikes.

(a) Size and Type of Dikes

Dikes are classified into two types by their surface width, that is, eight meters wide and four meter wide. All of them will function as the flood protection dike as well as road networks for transportation in the Project Area and its vicinity.

The dike having eight meters surface wide along the southern bank of the Phraya Banlu canal is planned to function as the trunk road from the east to the west in Block C. The other dikes than the above are planned with width of four meters.

Areas along Phraya Banlu canal are the most densely housing area in the Project Area. The proposed dikes along this canal are to be constructed at a distance of about 50 m from the canal banks so that people can, if any need arises, continue their traditional life on water even after the complation of the Project.

(b) Typical Cross-sections

The berms of four meter wide will be provided on every dike slope facing the existing canal at the elevation of 2.75m. The berms will protect the dike bodies from waves raised by navigation.

Side Slopes

From a consideration of soil mechanics, the side slopes at 1:1.0 to 1:2.0 will be sufficiently bearable to the dike bodies. So, the side slopes facing to the existing canals are determined at 1:2.0 with prudence while those facing inside at 1:1.5. All the slope surfaces will be turfed as a rule.

Pavement

The dikes of eight meter wide have a function as provincial road, so their dike surfaces will be paved with laterite material with thickness more than 0.15 m.

Borrow Pit

Most of the main drainage canals with two meter depth will be provided by excavating or dredging the borrow pit which will be used for the dike construction. The berm of at least two meter wide will be constructed on the both sides of the drainage canals for safety of dikes and farm fields.

The typical designs of dikes are shown in Drawing No.11.

5. Roads

(a) Classification of Roads

Roads to be constructed in the Project are classified as follows: (See Appendix 4-43)

Provincial Roads

There are no means of transportation by land so called roads in the Project Area except two provincial ones constructed by the local government. One of them runs from the west to the east and the other from the north to the south, and they come across at the heart of the Project Area. The construction works have been already finished, but they cannot function properly due to poor maintenance. The improvement and extension involved in the plan of the Project so that they will function as the trunk road system to cover whole the Project Area. The provincial roads are structurally divided as follows:

- Roads provided on one side of main or lateral irrigation canals
- Roads provided on one side of main drainage canals
- Roads provided on irrigation canals at one side and a main drainage canals at the other side.

Main Roads

The main roads will function as the major road networks within each block or each dike-surrounded area. In principle, two main roads to cross each other at the right angle will be constructed in each

block. Bridges will be built over existing canals except Phraya Banlu canal to lead the main roads to the neighbouring dike-surrounded areas. Main roads are structurally divided as follows:

- Roads provided on the one side of lateral irrigation canals
- Roads provided on the both sides of leading drainage canals
- Roads provided on the both sides of drainage ditches
- Roads provided at lateral irrigation canals at one side and a leading drainage canals at the other side

Community Road

Community roads will be constructed in the direction of the length of run of farm fields at an interval of about 1,200 m. The major community roads are called the main roads. No bridge will be built to connect community roads to those in other blocks. The community roads are structural divided as follows:

- Roads provided on the one side of main or lateral irrigation canals
- Roads provided on the both side of drainage ditches
- Roads provided at lateral irrigation canals at one side and a leading draiange canals at the other side.

On-farm Roads

The on-farm roads for farmers to go to their farm fields will be constructed along the width of plot at an interval of 320 m.

(b) Typical Cross-sections

Slide Slopes

All roads are to be constructed in a dike-surrounded area. So, most dikes will have a height of about 1.00 m except some dikes located along irrigation canals. The dikes along irrigation canals will be a little higher than the others so that necessary head of the irrigation canal waters can be secured. Therefore, a side slope of 1:1.5 will be enough to bear road bodies from the soil mechanical

point of view. The height of embankment for on-farm roads will be in the order of 0.30 to 0.50 m. So, their side slope is determined at 1:1

Width

A road width more than 5.5 m is, in general, required for two-lane traffic. A width of roads is determined as follow by functions of each road.

Provincial road	8.0 m
Main road	6.0 m
Community road	4.0 m
On-farm road	3.0 m

Irrigation canals and drainage canals will be located along all roads. Therefore, all the roads except on-farm roads will be equipped with a marginal space of about 0.50 m on the top of the slopes facing irrigation canals, and the foot of the slopes facing drainage canals in order ot secure the stability of both roads and canals.

Road Pavement

The embankment of clayey soil cannot bear a big load if no treatment is provided. So, the provincial and main roads, where much traffic is expected as truck lines are paved with the laterite materials 0.15 m thick at least and 6.0 m wide.

Cross-grade

In general, a cross-grade of macadam or gravel pavement roads ranges in three to five per cent. So, all the proposed roads in the Project Area except on-farm ones will be given the cross-grade of four per cent, an average grade. The cross-grade of on-farm roads is determined by two per cent considering their narrow width.

(c) Related Structures

Bridges are one of the related structures for roads. Bridges are to be build for dikes, provincial roads and main roads, over existing

canals. The bridge width is determined in accordance with the width of roads;

Bridge for a dike	4.0 m or 8.0 m
Bridge for a provincial road	8.0 m
Bridge for a main road	6.0 m

The locations of bridges are determined as follows.

In Block A: Two bridges for dikes of four meters wide, one over IL-2 and the other over Nai Chat at the northern boundary of this block, and two bridges for main roads, one over IL-2 and the other over Nai Chat for transportation.

In Block B: Three bridges for provincial roads, the first one over IL-2 and the second one over Nai Chat for transportation from the west to the east and the third over Phraya Banlu canal, will be provided for the transportation to and from Block C. Two bridges for main roads, one over IL-2 and the other over Nai Chat canal, will be provided for the transportation from the west to the east. The dike will be equipped with no bridge because a provincial road running from the west to the east is available for transportation in this direction.

In Block C: One bridge at Khud Mai for the dike of eight meters wide along Phraya Banlu and also one bridge at Khud Mai for the dikes of four meters wide lead to the southern boundary of this block. One bridge for the main road at Khud Mai leads from the west to the east.

The reference is made to Appendix 4-59 on the standard design of bridges. Furthermore, the detail is shown in the Drawing No.12 attached to the end of this report.

6. Village Water Supply

The following were considered after studying the present conditions of water supply in and around the Project Area and discussing with the officials concerned.

i) One water supply facility by deep well may be enough at this moment to cover demands of each production unit, totalling four units.

ii) And, pumping facilities shall be provided with storage room, clean well and storage tank.

iii) Another facilities, if possible, such as water tank and pipe-line connected to the groups of houses are desirable so that people may enjoy fair supply and convenient use of water.

The typical layout is given in Appendix 4-60.

7. Volume of Construction Works

The work volumes of the major Project facilities are summarized in Table 4-3. The table reveals that land reduction ratio is estimated at 6.6 per cent by provision of such on-farm facilities as irrigation and drainage canals and roads, except for provincial roads, dikes and borrow pits. (See Appendix 4-61)

Table 4-3 Volume of Construction Works

Description	Block A	Block B	Block C	Total
1. Cultivated area (ha)	3,027	2,583	4,932	10,542
2. Irrigation Canals (km)				
Main	7.5	12.1	16.5	36.1
Lateral	34.3	19.9	47.8	102.0
Farm ditch	94.7	80.8	154.2	329.7
Total	136.5	112.8	218.5	467.8
(length per ha, m/ha)	(45.1)	(43.7)	(44.3)	(44.4)
3. Drainage canals (km)				
Main	9.0	13.5	7.0	29.5
Leading	43.5	26.9	69.2	139.6
Drainage ditch	105.0	77.2	172.6	354.8
Total	157.5	117.6	248.8	523.9
(length per ha, m/ha)	(52.0)	(45.5)	(50.5)	(49.7)
4. Pumping facilities				
Drainage area (ha)	3,449	2,970	5,569	11,988
Discharge (cu.m/min/unit)	239	205	386	831
ϕ(mm) x unit	1,350x3	1,350x3	1,650x3	
Pump type	mixed flow pump		(horizontal axial)	
Generator	Motor	Motor	Motor	
Required power (kw)	170x3	140x3	300x3	1,830
5. Dikes				
Width B=8.0m (km)	-	-	13.6	13.6
B=4.0	37.4	33.1	30.4	100.9
Total	37.4	33.1	44.0	114.5
(length per ha, m/ha)	(12.4)	(12.8)	(8.9)	(10.9)
6. Roads (km)				
Provincial roads	4.2	14.6	3.8	22.6
Main roads	14.5	16.3	24.9	55.7
Community roads	32.6	12.0	54.5	99.1
On-farm road	114.2	105.5	184.6	404.3
Total	165.5	148.4	267.8	581.7
(length per ha, m/ha)	(54.7)	(57.5)	(54.3)	(55.2)
7. Village water supply				
No. of facilities (place)	1	1	2	4
8. Deduction ratio (%)	6.9	6.5	6.5	6.6

E. Cost Estimate

The total investment, including the cost for price escalation during the construction period and excluding related interests, is estimated at $36.2 millions, $18.6 millions of foreign currency component and $17.6 million equivalent to local currency component. The following table shows the breakdown of the investment by major items. (See Appendix 4-62)

Investment Cost of the Project

(Unit: '000 US$)

Description	Foreign Currency	Local Currency	Total
1. Civil Works	4,700	8,850	13,550
2. Construction Equipment	6,650	70	6,720
3. Agricultural Development 1/	-	740	740
4. Project Administration & Facilities	70	1,070	1,140
5. Consulting Services	1,140	430	1,570
6. Land Acquisition	-	180	180
7. Contingency 2/	1,880	1,710	3,590
Total (1 - 7)	14,440	13,050	27,490
8. Price Escalation 3/	4,120	4,590	8,710
Grand Total (1 to 8)	18,560	17,640	36,200

Note: 1/ Consists of the required costs of facilities for supporting services
2/ 15% for the total cost (1 to 6) is taken
3/ Rate of price escalation is estimated at 8% per annum

The annual disbursement schedule for the investment costs is shown in Appendix 4-67.

The cost estimates of the Project have been made in the following ways:

(1) to estimate workers' wages and costs of materials on the basis of the actual costs as of October, 1976, prepared by ALRO and RID:

(2) to value the construction machineries, workshop equipment and materials, the other equipment than the above mentioned, and pumps based on CIF Bangkok, exclusive of the custom duties and the other local taxes to be imposed in Thailand;

(3) to evaluate the costs for such materials as cement, fuel oil reinforcing bars, etc., dividing these into two portions of the foreign procurement and local procurement as shown below;

Item	Foreign Procurement	Local Procurement
Cement	0.2	0.8
Fuel Oil	0.5	0.5
Reinforcing bar	0.6	0.4

(4) to employe the foreign exchange component for the civil works consisting of all the costs for the imported materials as mentioned in above items (2) and (3), whereas the local currency component consists of all the costs of labour, operation and maintenance of machineries, local materials and overhead, and to exclude the depreciation costs for the imported construction machineries and workshop equipment in the item of the civil works.

(5) to include the minor repair costs for construction machineries in the local currency portion, the major repair costs and depreciation costs in the foreign currency portion;

(6) to carry out the construction on the contract basis, for which Government purchases the construction machineries, pumps and other imported materials and supplies them to the contractors.

(7) to include the overhead charges not in the foreign currency portion but in the local currency portion at the rate of 25 per cent of the total local construction cost;

(8) to sum up 15 per cent of the contingency for items (1) to (6) as seen in the above table;

(9) to allow the price escalation of eight per cent per annum for both the foreign and local currency portions.

CHAPTER V. PROJECT IMPLEMENTATION AND OPERATION

A. Executing Agency and Coordination

It has been already decided that ALRO will function as the Executing Agency of the Project.

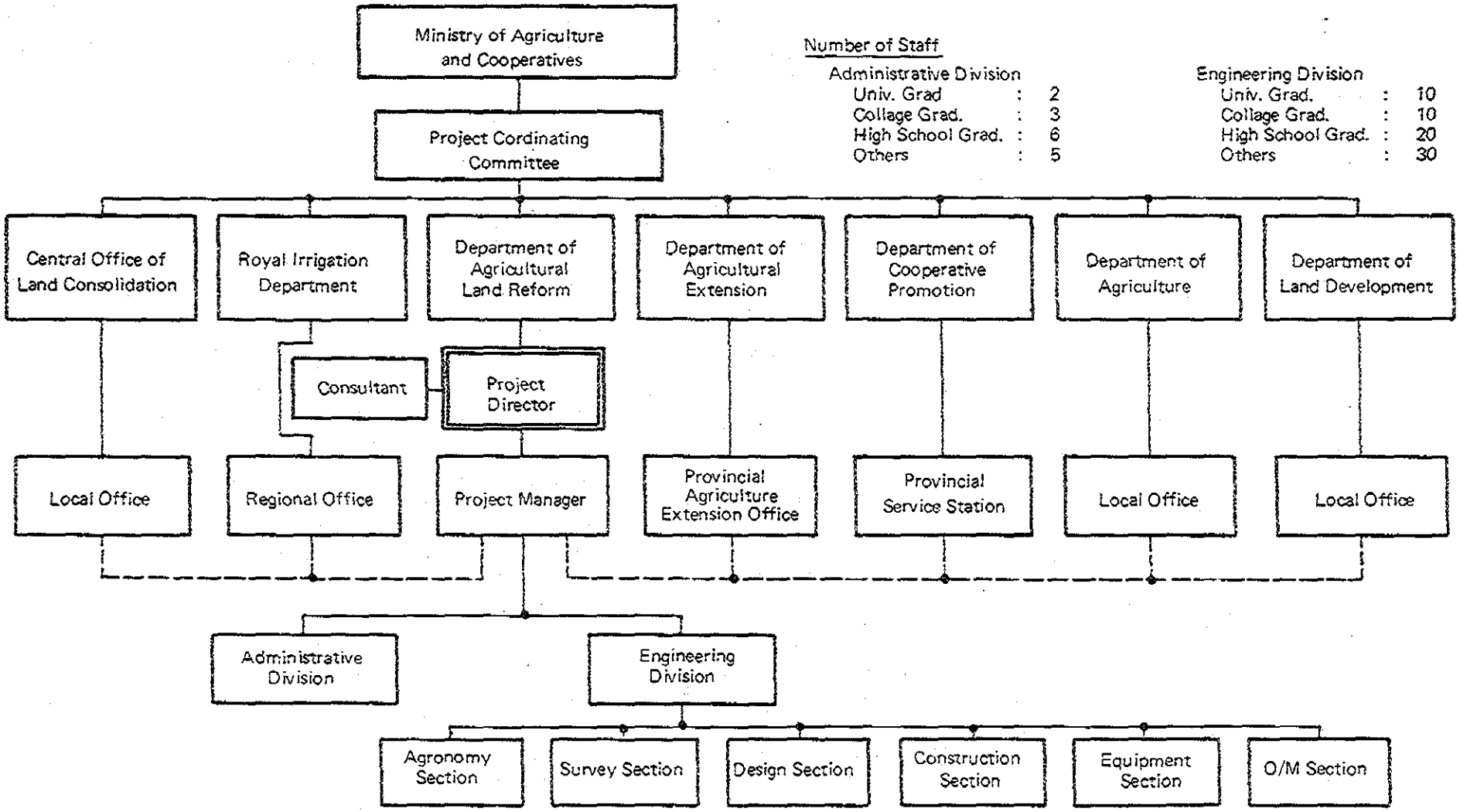
According to the requirements from ALRO, the Project Coordinating Committee will be organized as sub-organization of MOAC. It will make a good coordination among related Departments of MOAC, and request them to extend their assistances and advices directly or indirectly to ALRO, and also the committee will give advices to ALRO from the administrative point of view.

With these cooperations, ALRO with specifically nominated Project Director will be the direct executing agency. The Project Director is fully responsible to execute the Project works in keeping a close coodination among related Departments, and also directs the Project Manager who is fully responsible to the works in the job site.

Under the control of the Project Manager, the sections such as Agronomy, Survey, Design, Construction, Equipment, Operation & Maintenance and so on, will be provided. Those sections will keep close cooperation each other. Figure 5-1 indicates the proposed organization for the Project implementation.

Furthermore, the Project Manager will try to keep close contact with local offices of related departments so that the Project works may be smoothly executed.

FIGURE 5-1. PROPOSED ORGANIZATION CHART FOR PROJECT IMPLEMENTATION



B. Arrangement for Project Construction

The construction works of the main canals in the Project have been made in good progress under the supervision of the RID, and it has been decided that the land consolidation will be conducted by the ALRO.

The Project includes many kinds of civil works such as construction of pumping stations, dikes, farm roads, provincial roads, etc.

There are two ways to execute such civil works, execution by force account and contract basis. For the Project, the contract basis will be adopted due to the following reasons:

- Shortage in numbers of government-owned construction machinery.
- Shortage in numbers of engineers and skillful machine operators in the related organizations.
- Intention to bring up the local contractors.

Under the circumstances, the local contractors will execute the construction works, for which the machineries and materials to be imported by the Government will be supplied.

C. Construction Schedule

The Project Area has a total acreage of about 12,300 ha, which could be divided into three blocks from the viewpoints of the proposed irrigation and drainage systems.

Block A: about 3,490 ha in the upstream area
Block B: about 3,060 ha in the midstream area
Block C: about 5,740 ha in the downstream area

Since the civil works included in the Project are of considerably large scale, the construction period will inevitably depend upon the amount of rainfall. Furthermore, the paddy cropping by the flooding irrigation method, currently prevailing in the Project Area, will also restrain the works to a certain extent.

In consideration of these conditions, the annual construction schedule was made up as follows:

Construction of pumping stations:	early January to end August (8 months)
Dikes & provincial roads:	early January to end July (7 months)
On-farm works:	20th January to 20th June (5 months)

(Works available in the room of the pumping stations to be carried out throughout the year)

The construction methods of the works are given in Appendix 5-1.

The construction period is scheduled for six years including the final design at the first year, and the construction of the facilities will start in Fy 1979 and will complete in Fy 1983. For the completion of the Project in Fy 1983, due consideration shall be paid on the following items:

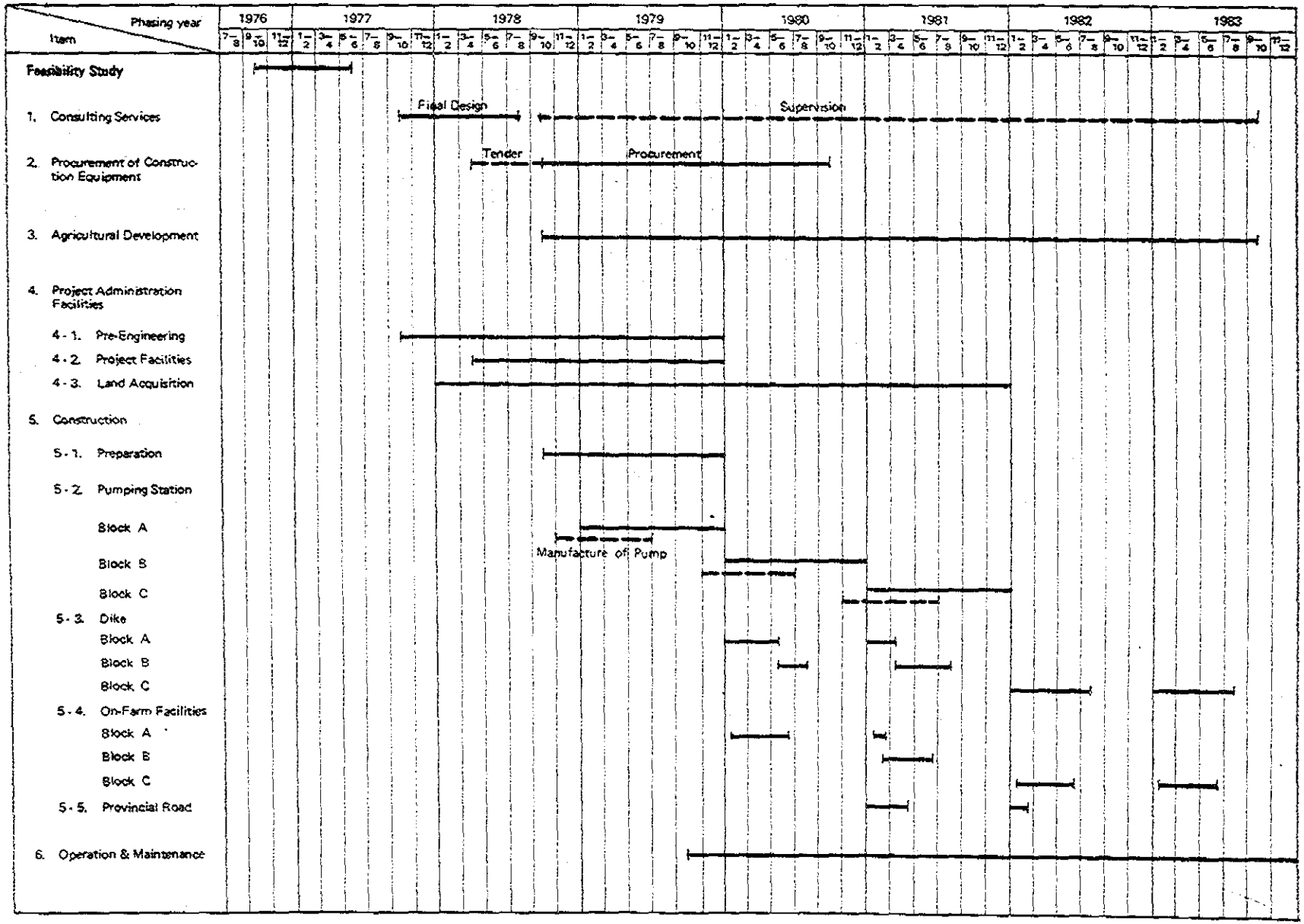
(1) Final design for the Project will be finished in July, 1978 and during that time the tender for the procurement of equipments and materials shall be finished.

(2) Surveying and geological investigation for the proposed pumping sites, bridges and other main facilities and also soil chemical analysis shall be finished up to the commencement of the final design.

(3) The construction of pumping stations and dikes will be executed in advance to those of on-farm facilities so as to expect smooth execution of the works under the flooding conditions in the wet season and to expect the attainment of quick yielding of agricultural products in the dry season as well.

(4) Immediately after the commencement of the civil works for the main facilities, the construction of the agricultural development facilities such as seed center, training center, agricultural land reform cooperatives, etc., shall be started for the

FIGURE 5-2 CONSTRUCTION SCHEDULE FOR THE PROJECT



completion of the Project within five years so that extension and training of the modernized farming practices to the farmers may be given adequately.

The construction schedule is shown in Figure 5-2.

D. Operation and Maintenance

1. Executing Agency and Organization

The entire project works, upon completion of the Project, will be turned over to the Changwat Ayutthaya Land Reform Office, and the responsibility of operation and maintenance of all irrigation and drainage facilities will fall under the Agricultural Land Reform Co-operative (ALRC) to be newly organized.

Operation and maintenance of the Project will be performed by the Production Unit under the jurisdiction of the ALRC. The proposed Organization Chart for Operation and Maintenance is shown in Figure 5-3.

2. Operation and Maintenance of Facilities

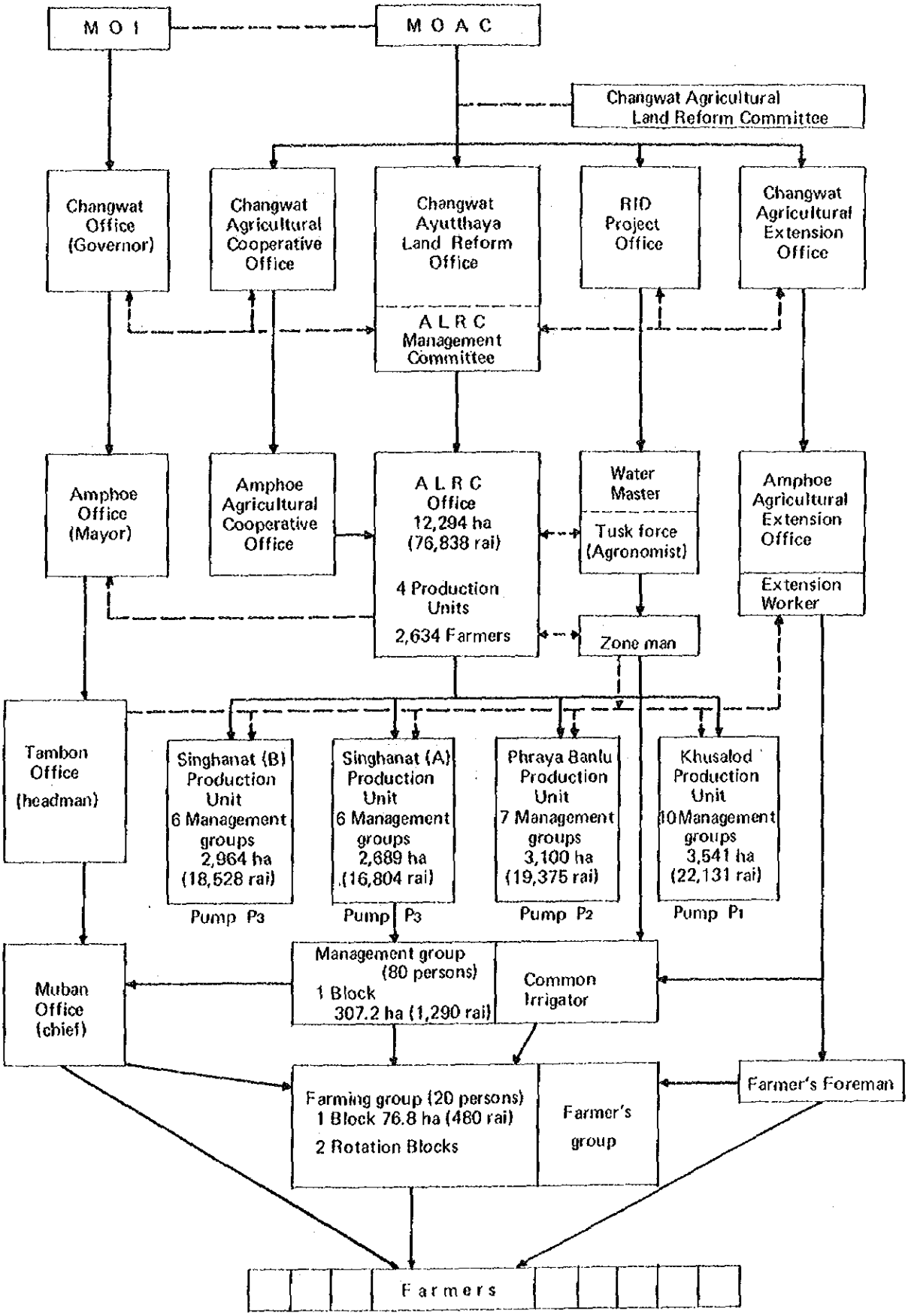
Operation and maintenance of irrigation and drainage facilities after the completion of the Project will be performed in accordance with the following informations (See Figure 5-3).

(a) Farmer who requires the irrigation water supply to his farm fields shall submit to the Leader of Farming Group the information of the place and acreage of land to be irrigated.

(b) The Leader of the Farming Group shall submit all members' applications in his group to the Leader of Management Group they belong.

(c) The Leader of Management Group shall submit all applications to the Leader of Production Unit by two days before the date of their use.

FIGURE 6-3. ORGANIZATION CHART OF OPERATION AND MAINTENANCE



(d) Chief of the Water Users' Section in ALRC shall accept the application by wireless telephone from the Leader of Production Unit after checking the areas, the payment status of levy, water charge and management of irrigation facilities of each Production Unit.

(e) Chief of the Water Users' Section shall count the water requirements of each lateral canal based on a certain method and make an order to the operator of pumps, if water is available in the main irrigation canals.

(f) But, if the water was not sufficient in the canals, the Chief of the Water Users' Section requests the Water Master in the Bhakhai, Chao-chet Bangyeehon and Phraya Banlu Irrigation Project Office under RID to operate the gates concerned to take water, by one day before the date of their use.

The communication among the Changwat Ayutthaya Land Reform Office, ALRC and each Production Unit will be made by wireless telephone, and the transportation between the ALRC and Production Unit by motorcycle.

3. Operation and Maintenance Cost

The operation and maintenance costs for irrigation and other facilities are summarized as follows:

Summary of Annual Operation & Maintenance Cost

Description	Total Cost (฿'000)
1. Maintenance Cost	5,382
2. Personnel Cost	2,964
3. Running Cost	3,583
4. Depreciation cost for vehicles and equipment	254
Total	฿12,183
	or ฿12,200 (US$610,000)

Note: Details are given in Appendix 5-2.

E. Consulting Services

The Consultant's services include the implementation of final design and supervision of the Project.

The Consultant's services are divided into the following three phases:

(1) The final detailed design of the Project as well as the preparation of tender document. It will cover about 10 months period starting from October 1977. Highly qualified experts will be engaged, including irrigation engineer, equipment engineer, design engineer, engineering geologist and topographic surveyor.

(2) Construction supervision and training of local counterpart personnel in all phases of the Project activities. The service period would extend over 60 months from October 1978 to September 1983. The required experts would be project engineer and construction engineer.

(3) A plan of agri-institutional establishment covering all agricultural institutional development program and training. It would cover about 32 months starting from January 1978. Highly qualified experts will also be engaged, including agronomist, agri-institutional expert and economist.

The Terms of Reference for the Consultant's Services and the required costs are given in Appendix 5-3 and 4-62, respectively.

CHAPTER VI. PROJECT JUSTIFICATION

The economic appraisal of the project, in general, has two objectives: one is to determine the project's contribution to the national economy, and the other to measure the benefits to be created by the Project which would accrue to the farmers in the area, who are the project's immediate beneficiaries. In both instances there are primary benefits, which can be measured in monetary terms. A number of indirect benefits which would be created by the Project are not counted in the evaluation, because it is difficult to measure them quantitatively.

This chapter deals with the economic evaluation of the project as a whole, farm budget and socio-impacts brought by the implementation of the project.

A. Economic Evaluation

1. Net Agricultural Benefit

Net agricultural benefit was computed as follows:

i) Net Production Value (NPV) without project was computed on the basis of the present cropping pattern and present yields, on the assumption that in future without the project the increase in the gross production value of crops would compensate for the increase in production costs, because of unfavorable situations such as flood in the wet season, poor facilities for irrigation in the dry season and lack of road net-work.

ii) Net Production Value (NPV) at full development with project was computed on the basis of the proposed cropping pattern and projected yields.

iii) Difference between the NPV without project and the NPV with project was calculated to obtain net agricultural benefit.

iv) In the above cases, the prices of traded commodities were derived from international prices based on the World Bank's commodity price forecast for the target year at 1985 in constant 1976 price. In deriving these prices, exchange rate of 20 Baht per one US dollar was adopted because the rate of the Thai currency has been almost constant over the past decade, fluctuating about one per cent around 20 Baht per one US dollar.

For non-traded goods, the single averages of farm gate prices of agricultural outputs in the latest three years 1974 to 1976 were applied and for input materials and farming machinery current retail prices in Changwat Ayutthaya were taken up.

v) For wage rate, marginal opportunity cost of labor per man-day was applied.

Through these procedures above, the net agricultural benefits were computed as follows:

Net Annual Agricultural Benefits by Crop at Full Development

(Unit: ฿'000)

Item	Rice	Vegetables	Cirtrus	Animals	Fish	Total
NPV without Project	20,248	1,060	6,257	0	0	27,565
NPV with Project	140,764	20,295	31,480	5,882	2,513	200,934
Agricultural Benefit before Labor	120,516	19,235	25,223	5,882	2,513	173,369
Incremental Labor Costs						21,831
Agricultural Benefit						151,538

2. Economic Costs

Economic investment costs used in the economic analysis are estimated by adjusting the required construction costs as mentioned below:

i) Land aquisition costs were excluded because they were transfer costs in the national economy.

ii) Costs of 40 Baht per man-day is applied for the unskilled labor in estimating construction costs, but in the economic analysis, the rate was converted to marginal opportunity cost of labor per man-day.

iii) Costs for domestic water supply system were excluded in the analysis, because they would not directly contribute to the agricultural production. The costs amount 1.4 million Baht of only 0.3% of total economic costs, therefore, it would hardly affect the results of the analysis even if they were included.

iv) Construction costs for orchards, barns, poultry houses and fish ponds are counted in farm management costs.

Based on the above premises, economic investment costs by year are estimated as follows:

Economic Costs

(Unit: ฿'000)

Item	Total	1978	1979	1980	1981	1982	1983
Construction Cost (excluding Labor Costs)	405,030	23,050	56,932	164,883	88,589	35,380	36,196
Costs for skilled Labor	32,793	0	4,038	8,317	10,313	5,124	5,001
Costs for unskilled Labor	19,416	0	1,374	5,095	5,891	3,673	3,383
Sub-total	475,239	23,050	62,344	178,295	104,793	44,177	44,580
Contingency (15%)	68,587	3,458	9,352	26,744	15,719	6,627	6,687
Total	525,826	26,508	71,696	205,039	120,512	50,804	51,267

v) Operation and maintenance costs consist of the cost for operation and maintenance of irrigation and drainage facilities and roads as well as costs for the Agricultural Land Reform Cooperatives which are proposed in the project to conduct supporting services. The required operation and maintenance costs are estimated at about 12.2 million Baht per annum (See Appendix 5-2).

3. Economic Internal Rate of Return

Economic internal rate of return was computed on the following assumptions:

i) Analysis period: The project life of 50 years was taken. Residual value of the Project facilities at the end of the period was neglected because it would not affect the results of the analysis.

ii) Development period: Full project benefits will be realized by 1988. In each part of the Project Area, the target yields of rice and other crops except citrus will be achieved for five years after provision of facilities for irrigation and drainage up to on-farm level. Citrus on the newly created orchards will reach the target yields for seven years after planting.

iii) Replacement Cost: Irrigation and drainage pumps are to be replaced in the 26th year after the installation, therefore costs for replacement were counted in the year in which they occur.

iv) Cost and benefit streams were made as follows based on the above assumptions.

Economic Cost and Benefit Stream

(unit: million Baht)

	Costs			Benefits	
	Construction Costs	OM Costs	Total	Agricultural Benefits	Project Benefits
1978	26.5	0	26.5	0	-26.5
1979	71.7	0	71.7	0	-71.7
1980	205.0	1.8	206.8	-7.6 2/	-214.4
1981	120.5	6.6	127.1	-1.7 2/	-128.8
1982	50.8	9.0	59.8	13.2	-46.6
1983	51.3	10.9	62.2	38.3	-23.9
1984	-26.0 1/	12.2	-13.8	75.3	89.1
1985	0	12.2	12.2	105.4	93.2
1986	0	12.2	12.2	130.5	119.3
1987	0	12.2	12.2	144.5	132.3
1988	0	12.2	12.2	151.5	139.3

Notes: 1/ Residual value of equipment and provisional facilities for the project construction. (See Appendix 4-66)

2/ These negative values are caused by the suspension of crop production during construction and expenditures on the construction of orchards, barns, poultry houses and fish ponds.

v) Internal rate of return: Based on the above table, the internal rate of return was computed at 16.0 per cent.

4. Sensitivity Test

To examine the impact of several assumptions made in the economic analysis on the rate of return, five cases of sensitivity test were made by several factors, which are partly based on cost overrun, rice price fall and benefit delay.

Results of the test are shown below:

Case	Internal Rate of Return (%)
a. A 20% increase in construction cost	14.1
b. A 20% fall in rice price	13.2
c. A two year delay in reaching full benefit	14.4
d. A 20% increase in construction cost and a 20% fall in rice price (a and b)	11.4
e. A 20% increase in construction cost, a 20% fall in rice price and two year delay in reaching full benefit (a, b and c)	10.4

B. Farm Income Analysis

1. Selection of Representative Farmers

For the farm income analysis, the farmers which are representative in the Project Area at present and in future are selected as follows:

Representative Farmers

Farm Size	Reasons for Selection
3 Ha	The farmers ranging 10 rai (1.6 ha) to 30 rai (4.8 ha) occupy about 50 per cent of all farmers in number at present
4 Ha	It is expected that about four hectares will be most prevailing size of farms after the performance of agricultural land reform
6 Ha	The number of farmers ranging 30 rai (4.8 ha) to 50 rai (8 ha) occupies 13 per cent of total farmers at present and it is expected that the farmers of this size will remain as a representative of comparatively large farmres

Though the farmers with the size of less than 10 rai (1.6 ha) occupy about 25 per cent in number, the representative of this group was not selected, because a greater part of their income has been gained by work outside their farms.

The analysis was made on the rice farming as well as the farming of rice plus other crops by farm size. The size and type of farms were determined considering the available family labor force. They are shown below:

Farm Size	Farm Type
3 ha	Rice alone, Rice + Vegetables Rice + Citrus, Rice + Animals + Fish
4 ha	Rice alone, Rice + Vegetables, Rice + Citrus
6 ha	Rice alone

2. Farm Income Analysis

Farm income by farm size of selected types was estimated under the premises as follows:

a. Yields of each crop, animals and fish which were used in this analysis were the same as those used in economic evaluation.

b. For the prices, current farm gate prices of outputs, current retail prices of inputs were applied in computing gross and net income.

c. Quantity of hired labor was measured in man-day as the excess of the labor requirement over the available family labor force in each month.

d. Wage rate of 15 Baht per man-day was taken.

The process and results of estimation were shown in Appendix 6-4.

3. Some Considerations

The results of farm income analysis are as follows:

i) Out of the cases analysed, under without project conditions the farmers of four hectares and six hectares who grow dry season rice can make a living merely by agriculture. Other farmers have had to earn money in non-agricultural sectors, and it is natural to do so, because the rice culture has not needed any work during the period of inundation. (see Table A.6-19; Appendix 6-4)

ii) In future under the situations with the project, the net agricultural income of every farmer of three hectares or more can meet all the living expenditures.

iii) Payment of Water Charge: Referring to water charge as operation and maintenance costs, water charge was estimated at about 1,150 Baht per hectare.

In the case of four hectares of farm land, the charge of 4,600 Baht will be levied. When the farmer will produce rice under the situation with the project, the net income from rice will be about 50,800 Baht. Then, the said amount of water charge represents only nine per cent of the net income, consequently the water charge will be easily born by farmers. (For other cases, see Table A.6-21, Appendix 6-4).

iv) Amortisation of Investment Costs: When the foreign currency portion of the project's investment costs is levied on farmers, the payment will be about 11,300 Baht for four hectares. The amount represents 24 per cent of the net income from rice after deduction of water charge.

When the said farmer pays the amortisation costs, about 34,900 Baht will still remain in his hand as living costs, therefore, it is likely to be payable.

It is recommendable that the Government should determine the rate of the levy through a careful follow up on the

increase in farmers' income after the completion of the project construction.

C. Socio-Economic Impact

Benefits which have been counted in the economic evaluation are limited to the ones accured from farming directly, however, the following indirect effects can be expected from the Project.

i) Creation of employment: It was estimated that 754 thousand man-days of farm labor per annum had been employed in the area and the employment in future with the project would reach 2,349 thousand man-days per annum at full development. It means that about 1.6 million man-days of employ will be created every year.

As for non-agricultural sector, on the other hand, it is expected to increase employment opportunities in trade and industry based on the increase agricultural production in the area.

ii) Contribution to balance of trade: Production of rice was estimated to be increased from 14,574 tons at present to 84,923 tons at the stage of full development. The increment is 45,940 tons which can be valued at US$14.1 million on the basis of US$307.6 per ton (Price FOB 1975, Bangkok).

iii) Improvement of Transportation Network: The transportation net work created by the project will produce a drastic change of transportation from navigation to overland transportation which will speed up productive and daily activities.

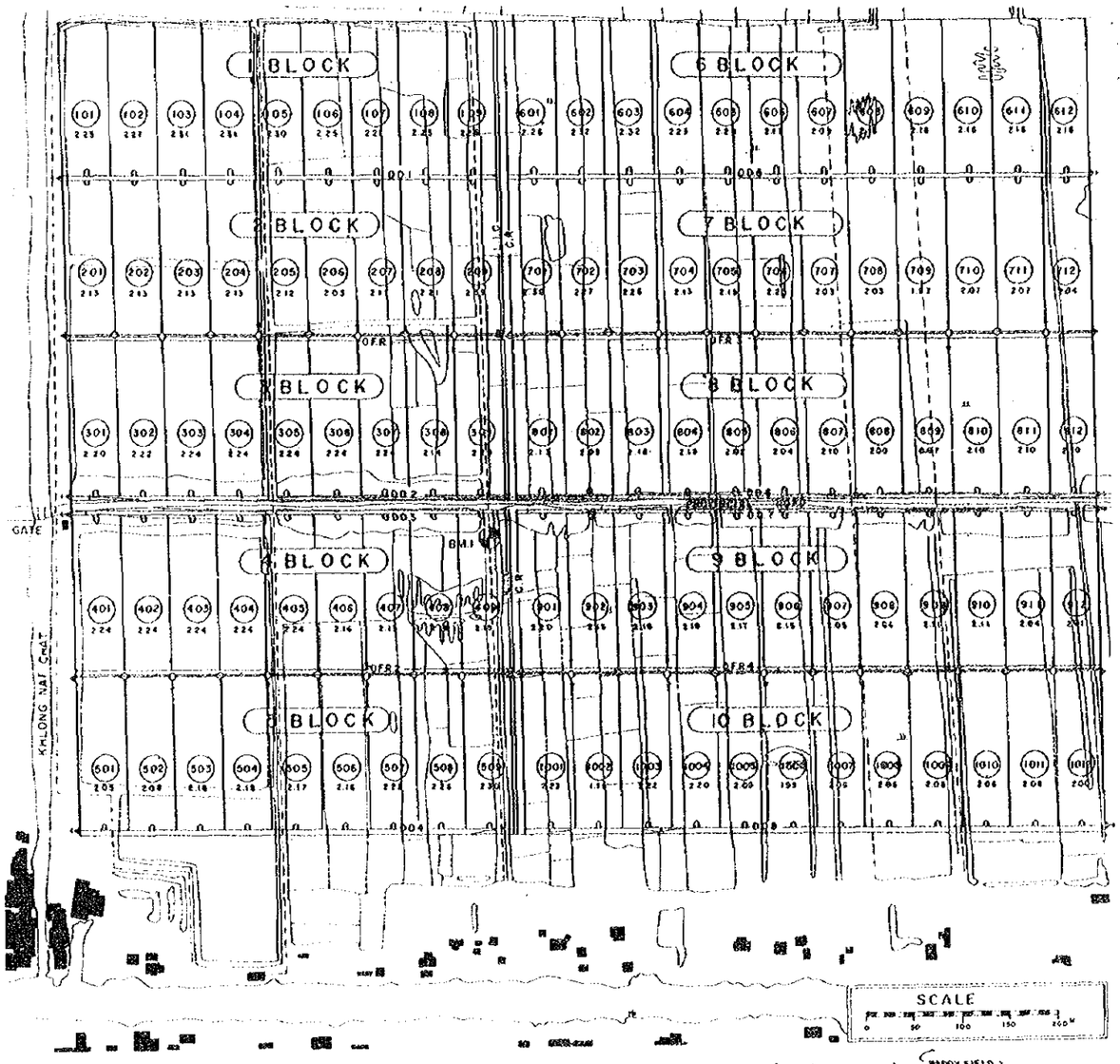
iv) Increased Adaptability to Market Demand: The improved irrigation and drainage systems will enable farmers to grow any more profitable crops than those presently projected, corresponding to changes in market demand.

v) Effect of Supporting Services: The functions and activities of the Agricultural Land Reform Cooperatives are expected to help farmers to buy agricultural inputs and sell their products at reasonable prices. And the custom to sell their produced paddy immediately after harvesting should be abolished at least.

vi) Effect of Training and Demonstration: This effect is important and expected to spread over the vast low-lying area in the Central Plain.

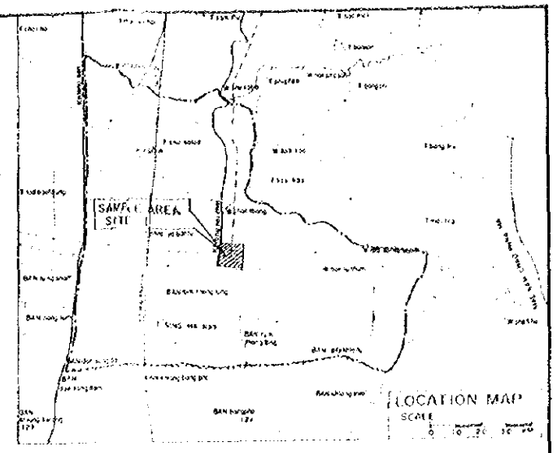
vii) Income Increase during Construction: Many farmers will be employed in the construction of the project. Required unskilled labor and wages are estimated at 633 thousand man-days and 25,313 thousand Baht which are needed for five years, and these amounts are about 84 per cent of total annual labor requirement for agriculture and about 80 per cent of the value of annual rice production at current price in the Project Area.

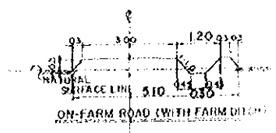
D R A W I N G S

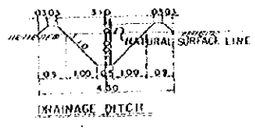


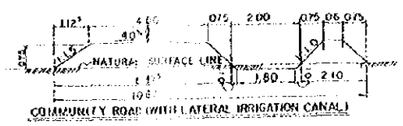
LEGEND

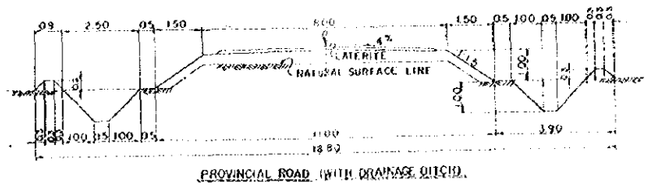
- BENCH MARK
- HOUSE
- DEPRESION AREA
- TRAIL
- DRAINAGE DITCH
- ON-FARM ROAD
- C.R. COMMUNITY ROAD
- 30 PROPOSED PLOT ELEVATION
- L.I.C. LATERAL IRRIGATION
- TURN-OUT
- INLET
- NOTCH
- CULVERT (1)
- CULVERT (2)
- CULVERT (3)
- CULVERT (4)

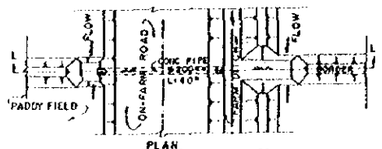


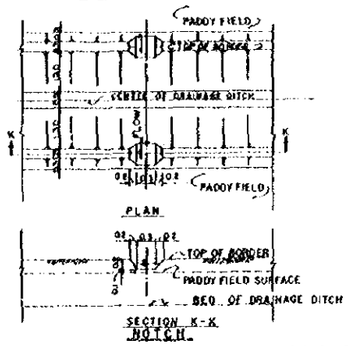










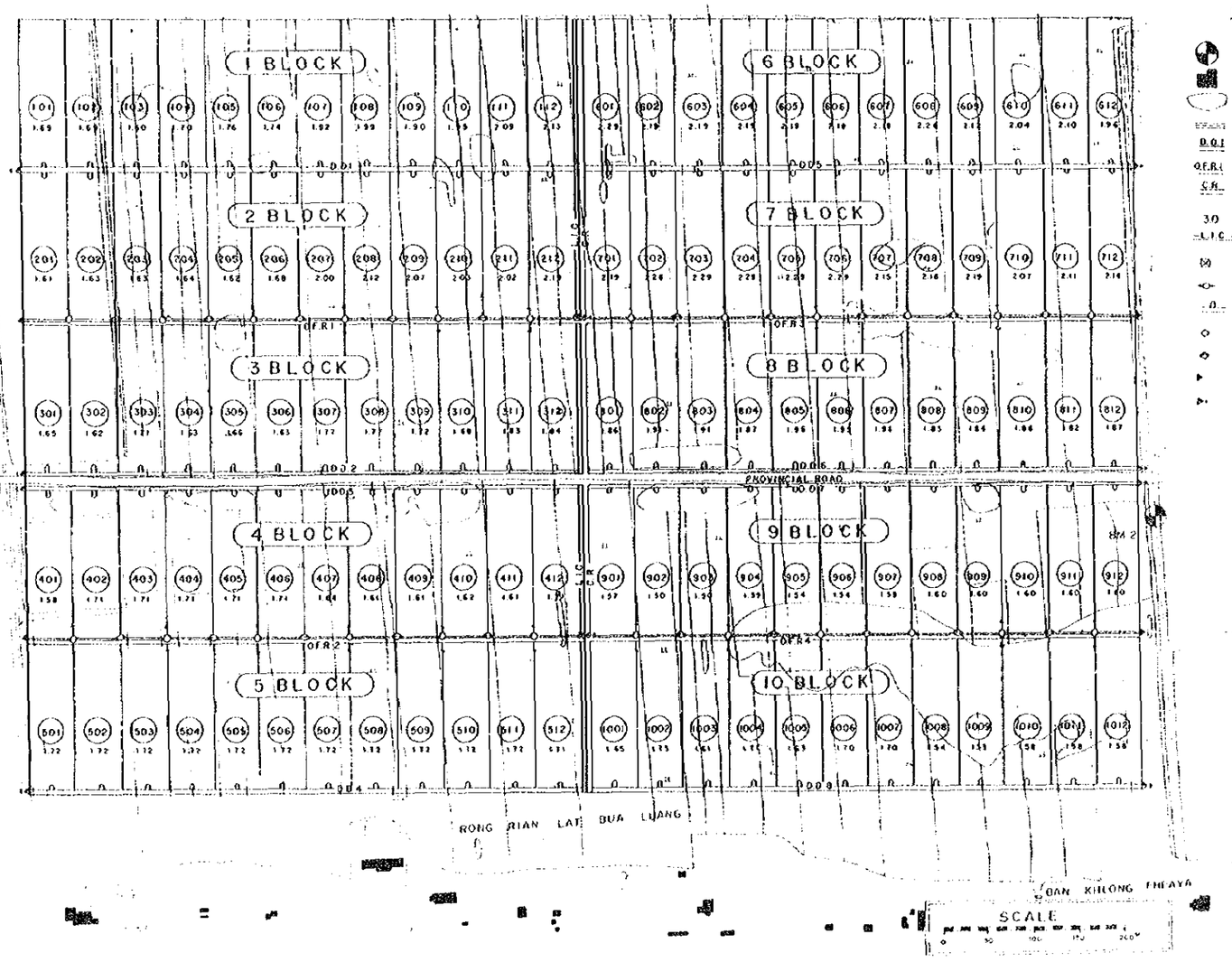


IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

TYPICAL DESIGN OF LAND CONSOLIDATION (SITE I)

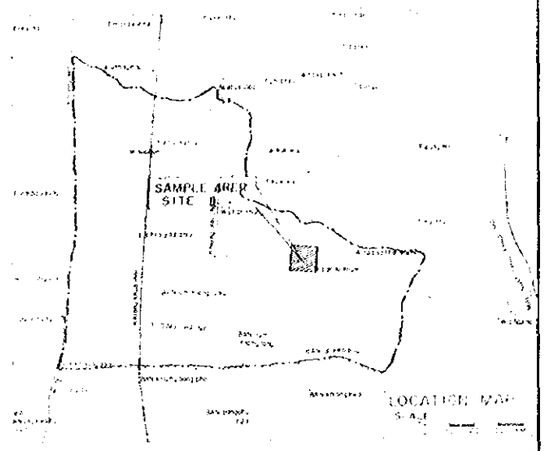
DATE	MAY 1977	D.W.G	1

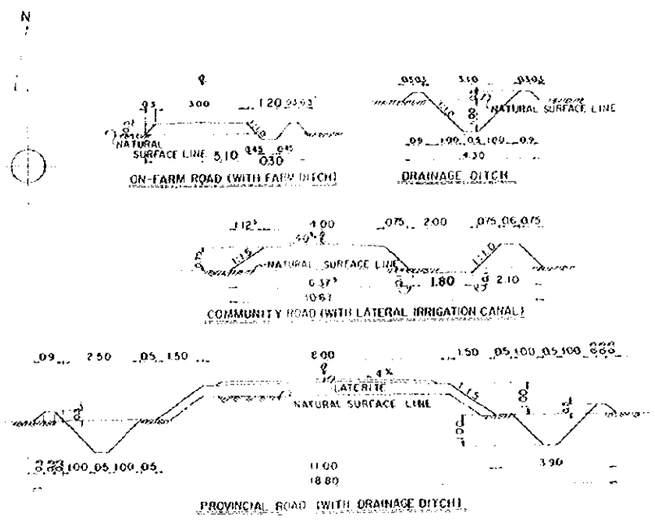
JAPAN INTERNATIONAL COOPERATION AGENCY

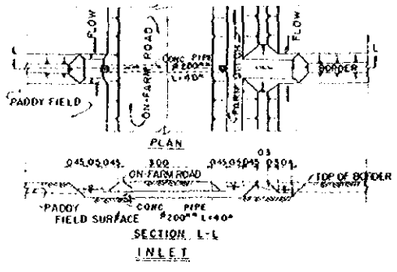


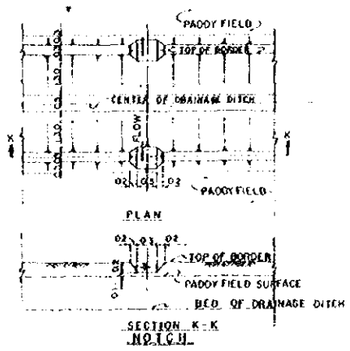
LEGEND

- BENCH MARK
- HOUSE
- DEPRESION AREA
- TRAIL
- D.D.I DRAINAGE DITCH
- O.F.R. ON-FARM ROAD
- C.R. COMMUNITY ROAD
- 30 PROPOSED PLOT ELEVATION
- L.I.C. LATERAL IRRIGATION
- TURN-OUT
- INLET
- NOTCH
- CULVERT (1)
- CULVERT (2)
- CULVERT (3)
- CULVERT (4)







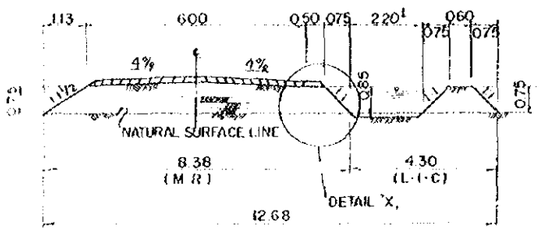


IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

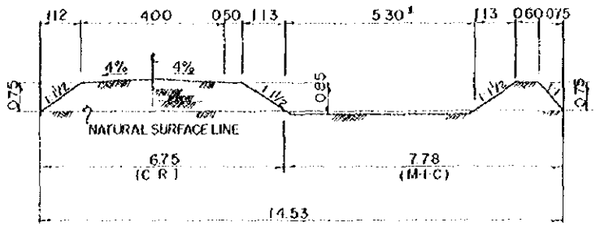
TYPICAL DESIGN OF LAND CONSOLIDATION (SITE II)

DATE	MAY 1977	D.W.G	2

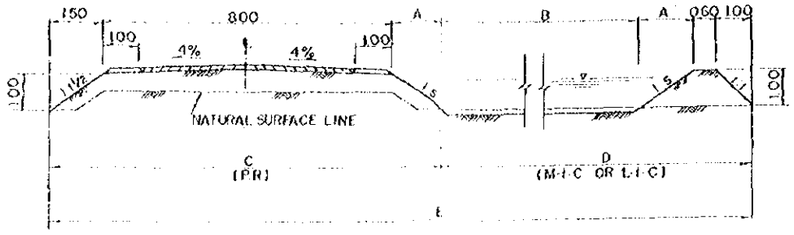
JAPAN INTERNATIONAL COOPERATION AGENCY



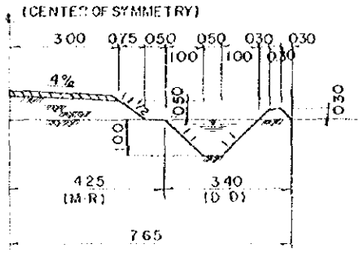
MAIN ROAD (WITH L.I.C)



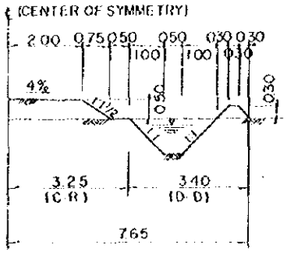
COMMUNITY ROAD (WITH M.I.C)



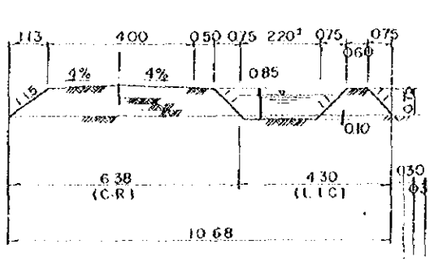
EXISTING PROVINCIAL ROAD



MAIN ROAD (WITH D.D)

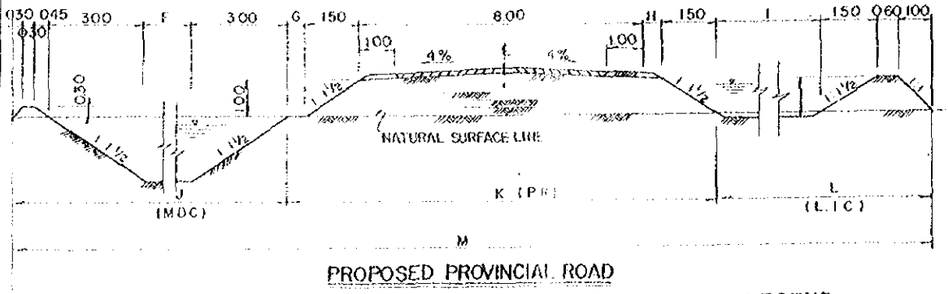


COMMUNITY ROAD (WITH D.D)



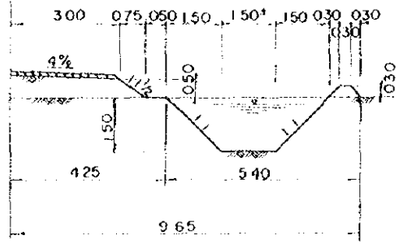
COMMUNITY ROAD (WITH L.I.C)

	S	A	B	C	D	E
WITH M.I.C	1½	1.50	7.00	11.00	10.10	21.10
WITH L.I.C	1	1.00	1.50	10.50	4.10	14.60
WITHOUT CANAL	1½	1.50	-	11.00	0	11.00

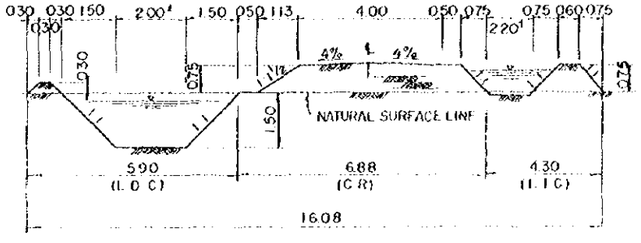


PROPOSED PROVINCIAL ROAD

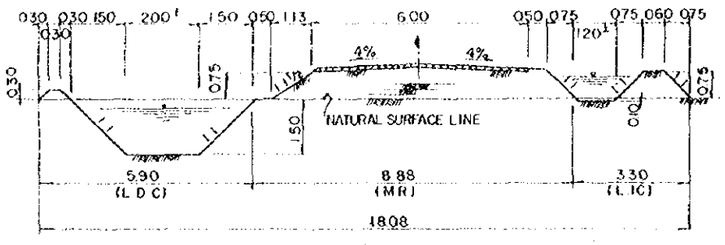
	F	G	H	I	J	K	L	M
WITH M.I.C AND M.D.C	5.00	0.50	0.50	5.00	12.05	12.00	8.10	21.15
WITH M.D.C	5.00	0.50	0	0	12.05	11.50	0	23.55
WITH M.I.C	0	0	0.50	7.00	0	11.00	10.10	21.10



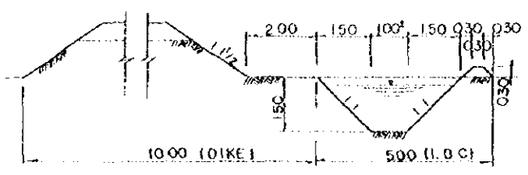
MAIN ROAD (WITH L.D.C)



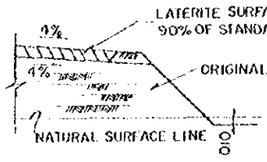
COMMUNITY ROAD (WITH L.I.C AND L.D.C)



MAIN ROAD (WITH L.I.C AND L.D.C)



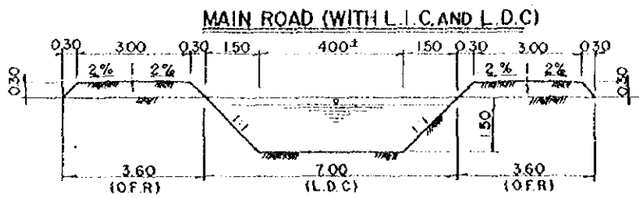
EXISTING DIKE (WITH L.D.C)



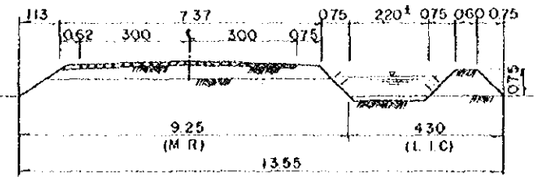
DETAIL 'X'

P.R	PROVINCIAL ROAD
M.R	MAIN ROAD
C.R	COMMUNITY ROAD
O.F.R	ON-FARM ROAD
M.I.C	MAIN IRRIGATION CANAL
L.I.C	LATERAL IRRIGATION CANAL
M.D.C	MAIN DRAINAGE CANAL
L.D.C	LEADING DRAINAGE CANAL
D.D	DRAINAGE DITCH
------	NATURAL SURFACE LINE
ZZZZZZ	LATERITE PAVEMENT

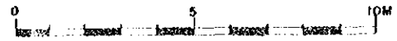
LEGEND



LEADING DRINAGE CANAL (WITH O.F.R)



EXISTING ROAD (WITH L.I.C)



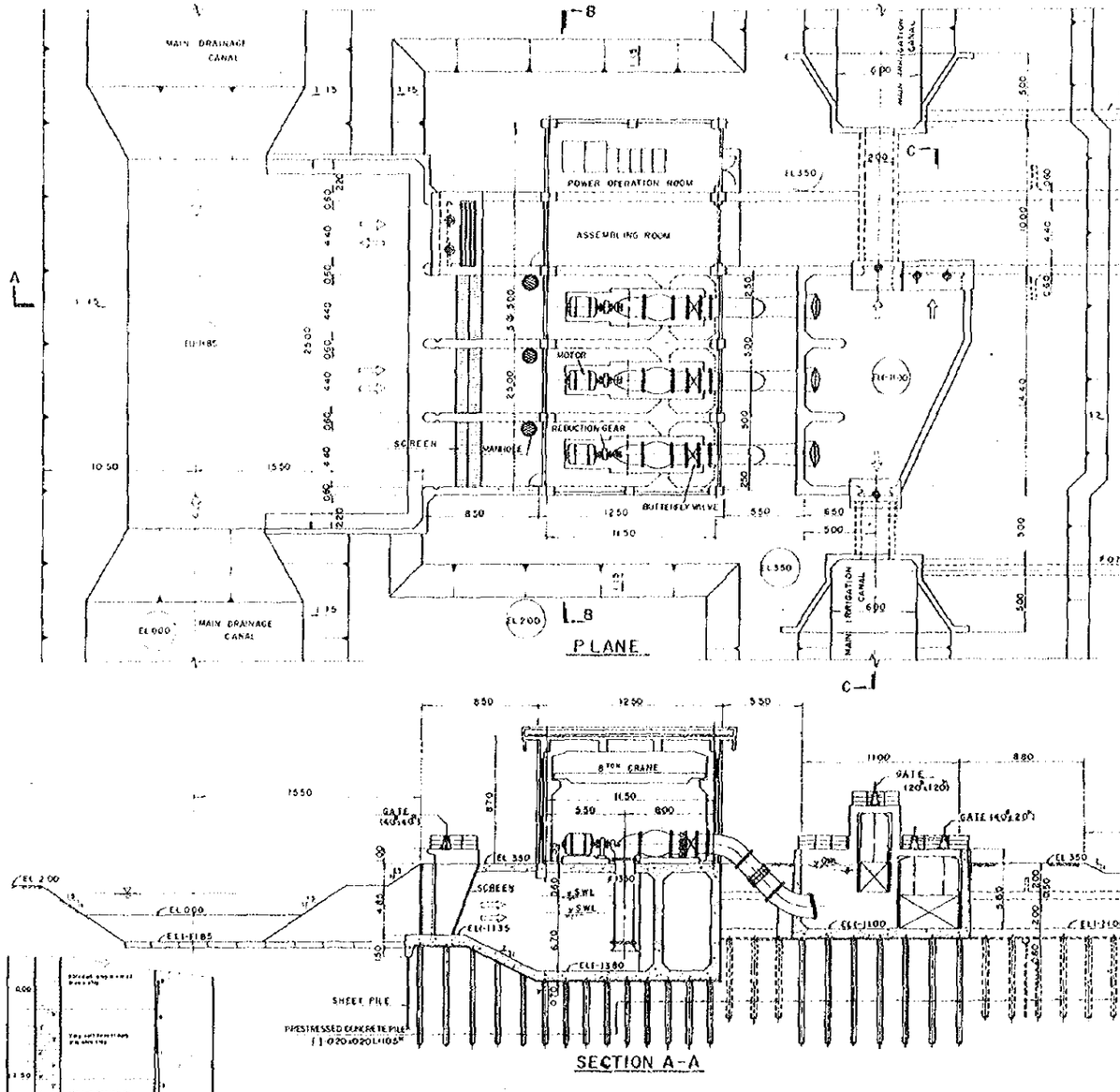
ALL DIMENSIONS ARE GIVEN IN METERS

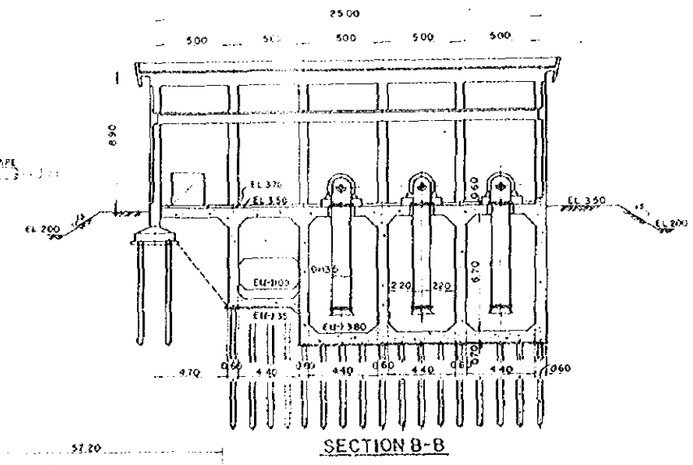
IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

TYPICAL CROSS SECTIO OF ROAD AND CANAL

DATE	MAY 1977	D.W.G	3

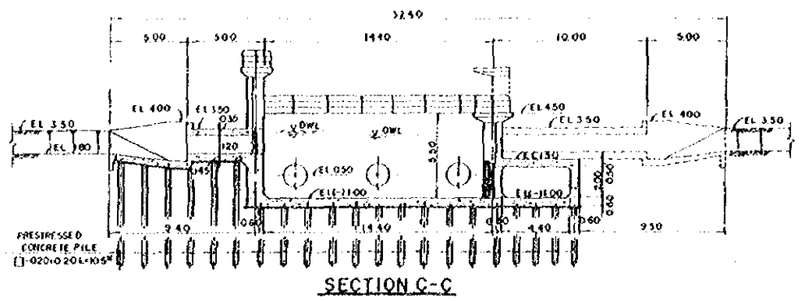
JAPAN INTERNATIONAL COOPERATION AGENCY

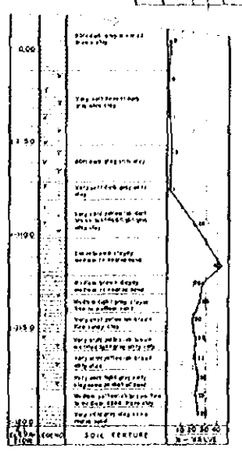




ITEM	UNIT	DIMENSION BLOCK A	DIMENSION BLOCK B
PUMP TYPE		HORIZONTAL MIXED FLOW	HORIZONTAL MIXED FLOW
PUMP BORE	MM	( ) 350	( ) 350
PUMP UNIT		3	3
LIFTING CAPACITY PER UNIT	M^3/MIN	239	206
SUCTION WATER LEVEL	SWL	120 (0.20)	120 (0.20)
DELIVERY WATER LEVEL	DWL	3.10 (3.40)	3.10 (3.40)
TOTAL HEAD	M	2.70	2.50
DRIVE MOVER TYPE		MOTOR	MOTOR
REQUIRED OUTPUT	KW	170	140

( ) IN CASE OF IRRIGATION





ALL DIMENSIONS ARE GIVEN IN METERS.

LEGEND

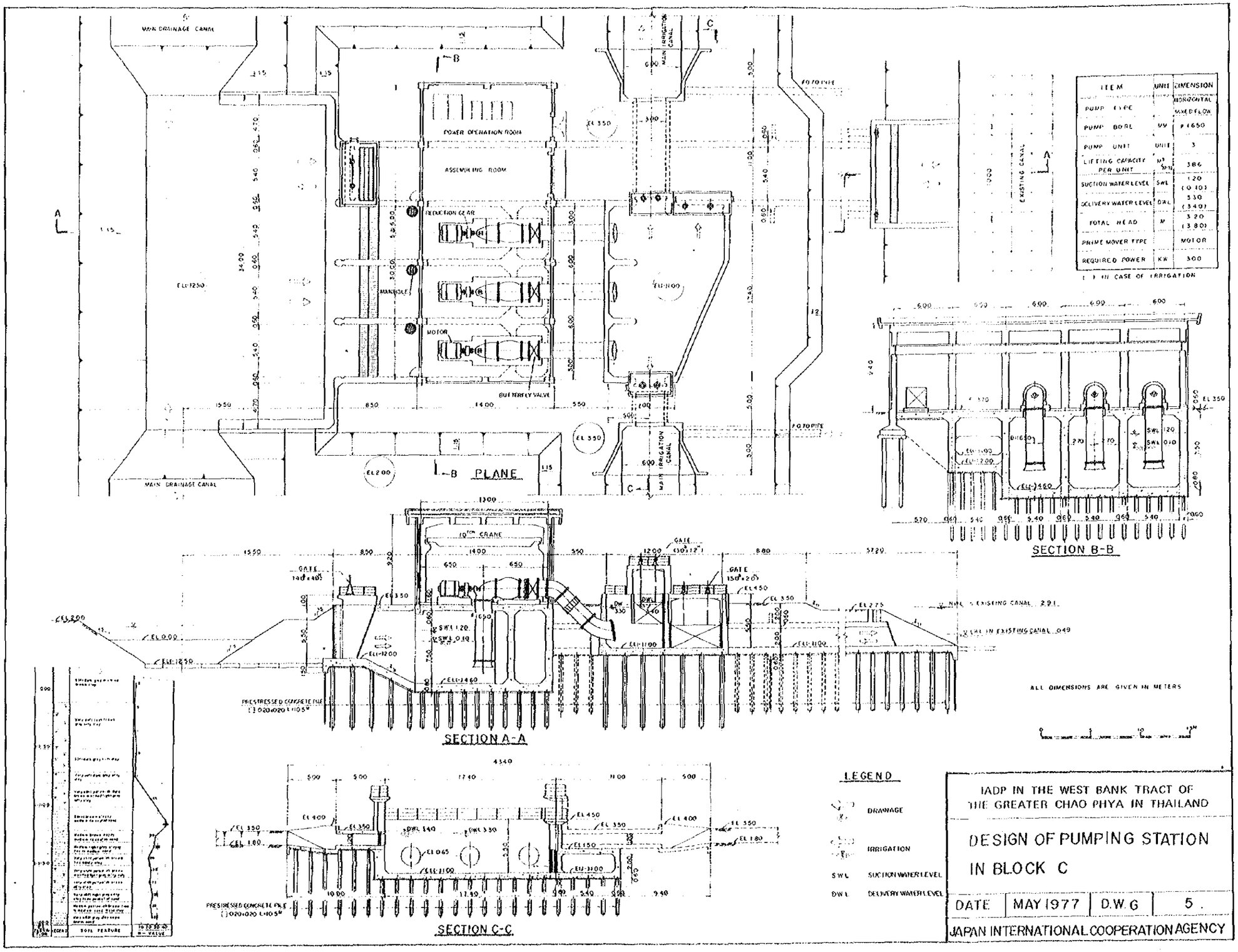
- DRAINAGE
- IRRIGATION
- SWL SUCTION WATER LEVEL
- DWL DELIVERY WATER LEVEL

IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

DESIGN OF PUMPING STATION IN BLOCK B

DATE	MAY 1977	D.WG	4

JAPAN INTERNATIONAL COOPERATION AGENCY



ITEM	UNIT	DIMENSION
PUMP TYPE		HORIZONTAL MIXED FLOW
PUMP BORE	MM	φ 1650
PUMP UNIT	UNIT	3
LIFTING CAPACITY PER UNIT	M^3/sec	386
SUCTION WATER LEVEL	SWL	1.20 (0.10)
DELIVERY WATER LEVEL	DWL	3.30 (3.40)
TOTAL HEAD	M	3.20 (3.80)
PRIME MOVER TYPE		MOTOR
REQUIRED POWER	KW	300

( ) IN CASE OF IRRIGATION

LEGEND

DRAINAGE

IRRIGATION

SWL SUCTION WATER LEVEL

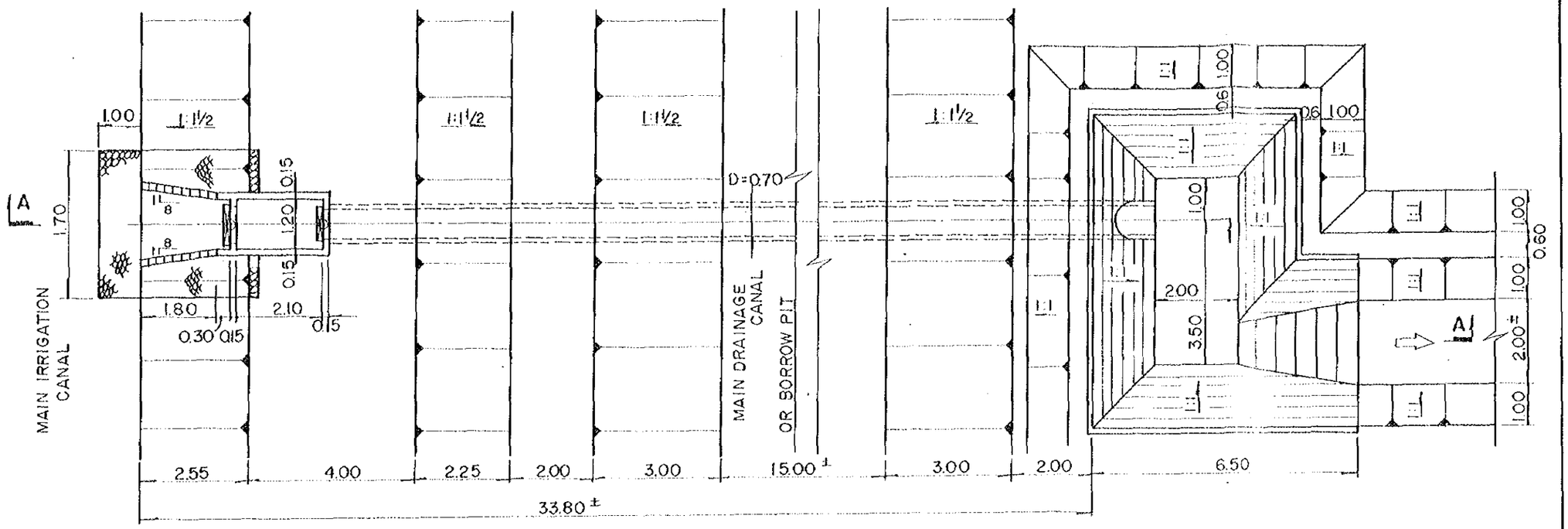
DWL DELIVERY WATER LEVEL

IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

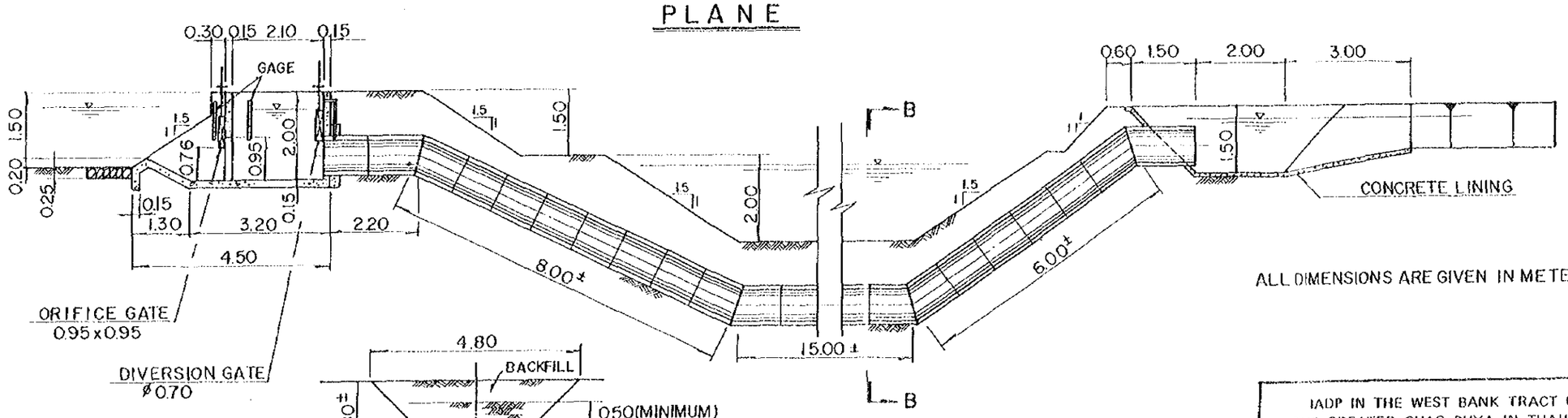
DESIGN OF PUMPING STATION IN BLOCK C

DATE	MAY 1977	D.W.G	5.

JAPAN INTERNATIONAL COOPERATION AGENCY



PLANE



SECTION A-A

SECTION B-B

ALL DIMENSIONS ARE GIVEN IN METERS.

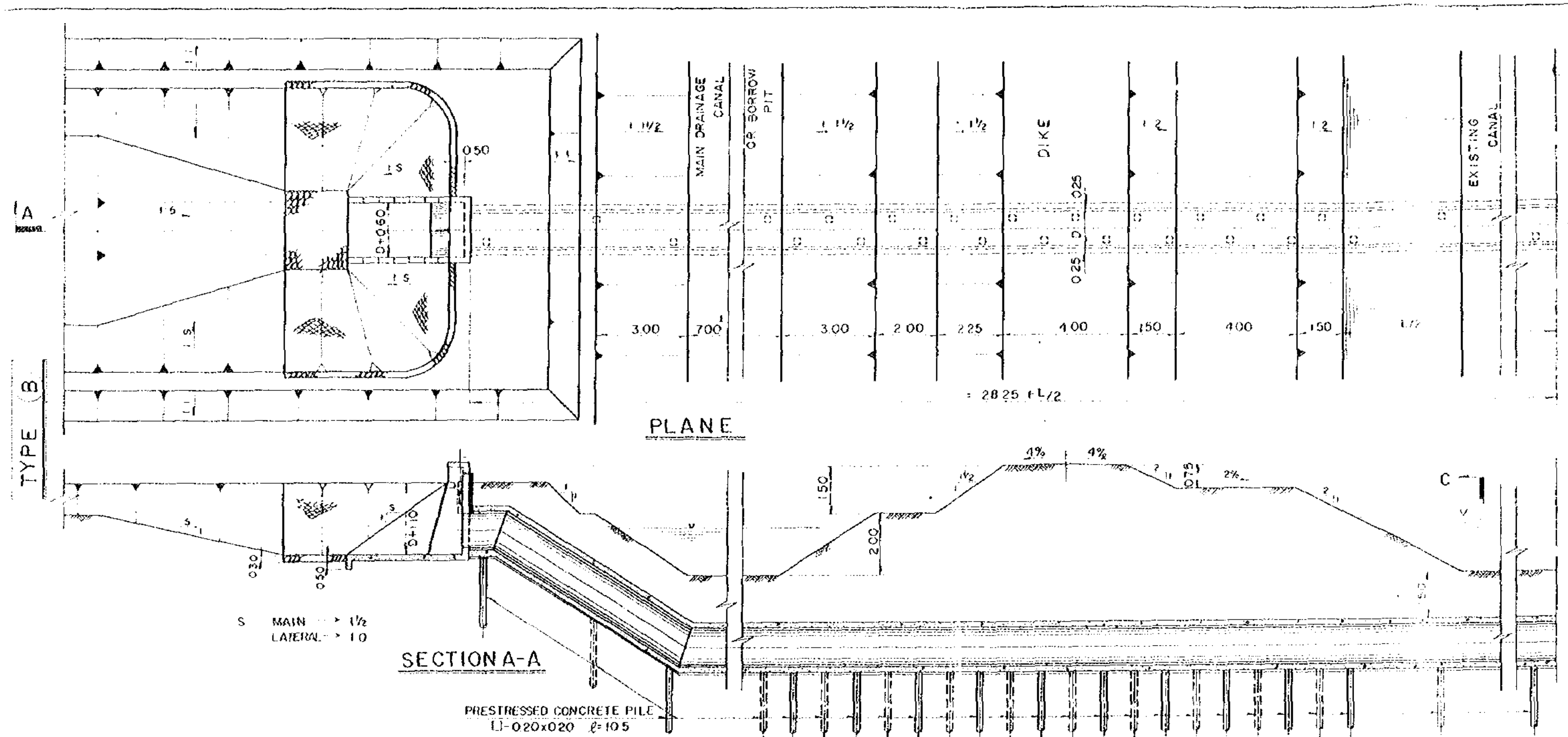
0 1 2 3 4 5M

IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

TYPICAL DESIGN OF DIVERSION BOX

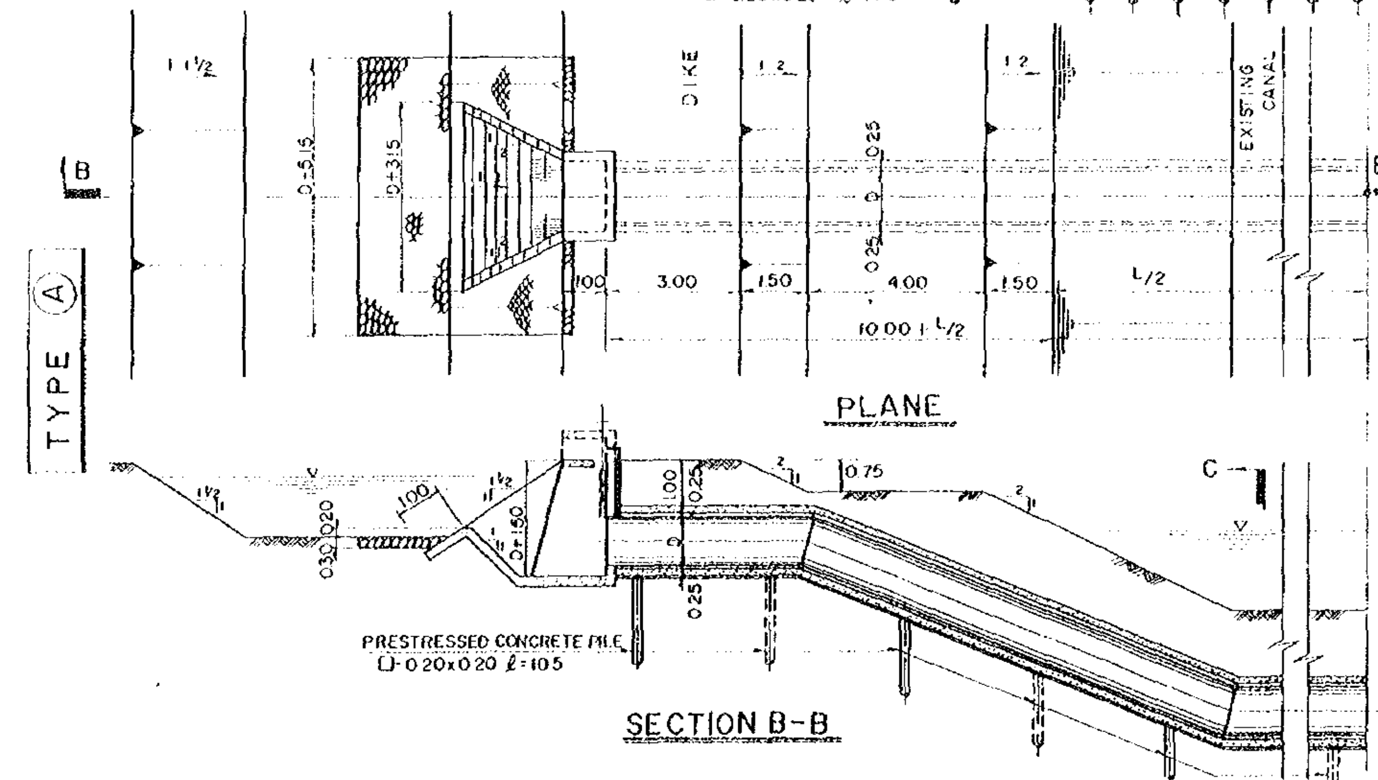
DATE	MAY 1977	D.W.G	6

JAPAN INTERNATIONAL COOPERATION AGENCY



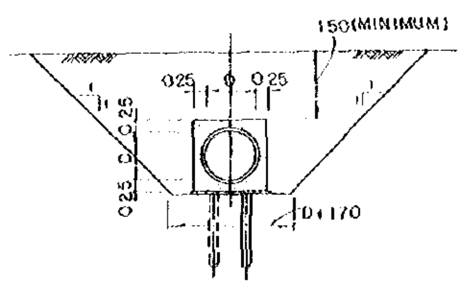
PLANE

SECTION A-A



PLANE

SECTION B-B



SECTION C-C

		BLOCK A		BLOCK B		BLOCK C
NAME OF EXISTING CANAL		IL -2	NAI CHAT	IL -2	NAI CHAT	KHUD MAI
CLASSIFICATION OF CANAL		MAIN	LATERAL	MAIN	MAIN	MAIN
DESIGN DISCHARGE $Q^{M^3/S}$		2485	0654	1042	1.930	1976
COMBINATION OF TYPE	UPSTREAM SIDE	(A)	(B)	(B)	(B)	(B)
	DOWNSTREAM SIDE	(A)	(B)	(A)	(A)	(A)
DIAMETER OF CULVERT D^M		1.50	0.90	1.10	1.50	1.50
LENGTH OF EXISTING CANAL L^M		30.0	25.0	30.0	25.0	30.0

NOTE

GATES WILL BE EQUIPPED AT THE UPSTREAM OF THE STRUCTURES TO KEEP THE EFFECTIVE WATER LEVEL AND ALSO TO DIVERT THE WATER.

ALL DIMENSIONS ARE GIVEN IN METERS

0 5 10M

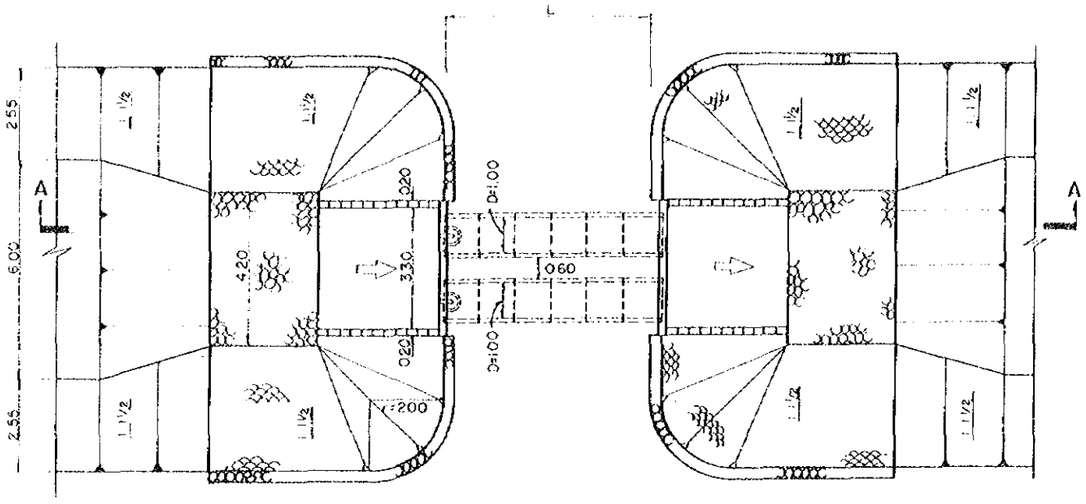
IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

TYPILAL DESIGN OF CULVERT IN IRRIGATION CANAL CROSSING EXISTING CANAL

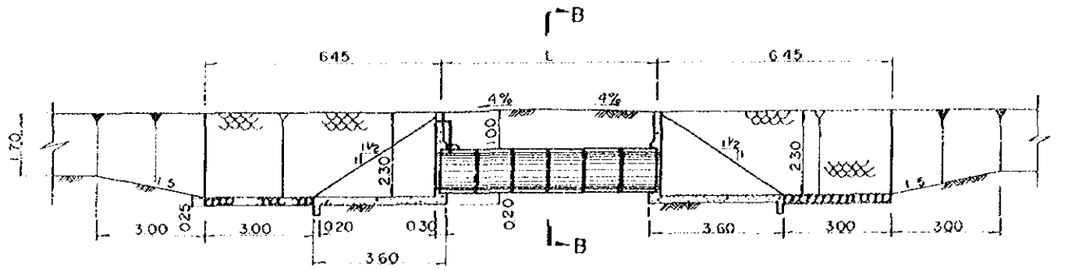
DATE	MAY 1977	D.W.G	7

JAPAN INTERNATIONAL COOPERATION AGENCY

IN CASE OF MAIN IRRIGATION CANAL

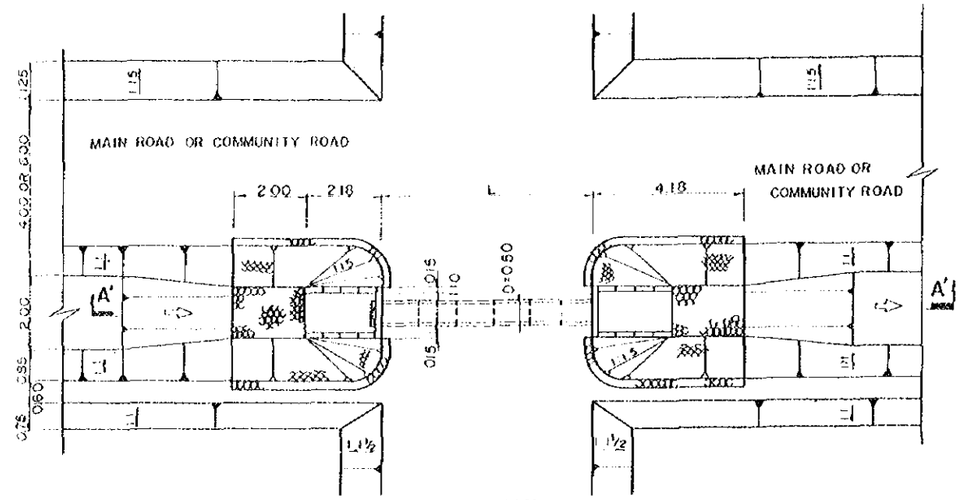


PLANE

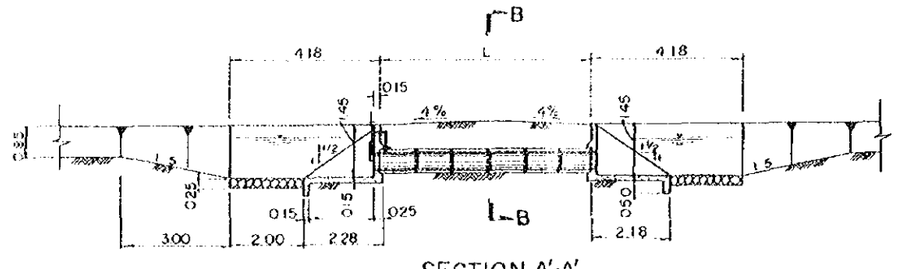


SECTION A-A

IN CASE OF LATERAL IRRIGATION CANAL

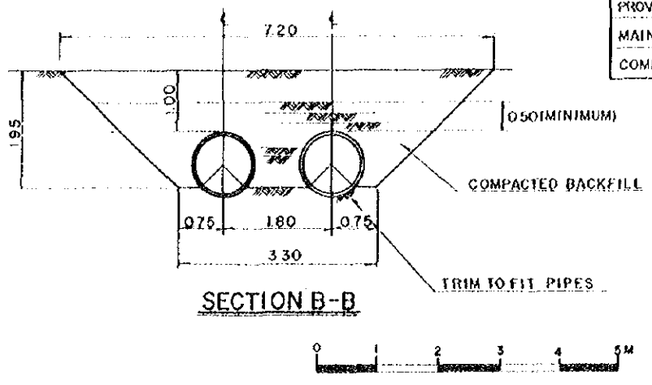


PLANE

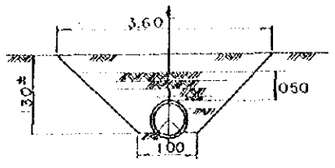


SECTION A'-A'

	L
PROVINCIAL ROAD	8.00
MAIN ROAD	6.00
COMMUNITY ROAD	4.00

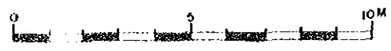


SECTION B-B



SECTION B'-B'

ALL DIMENSIONS ARE GIVEN IN METERS.



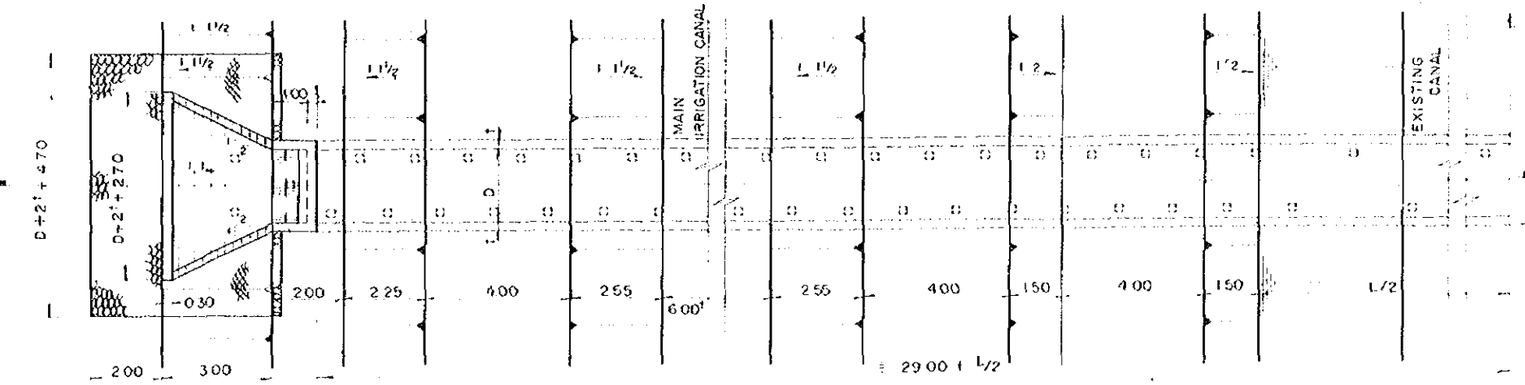
IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

TYPICAL DESIGN OF CULVERT IN IRRIGATION CANAL CROSSING ROAD

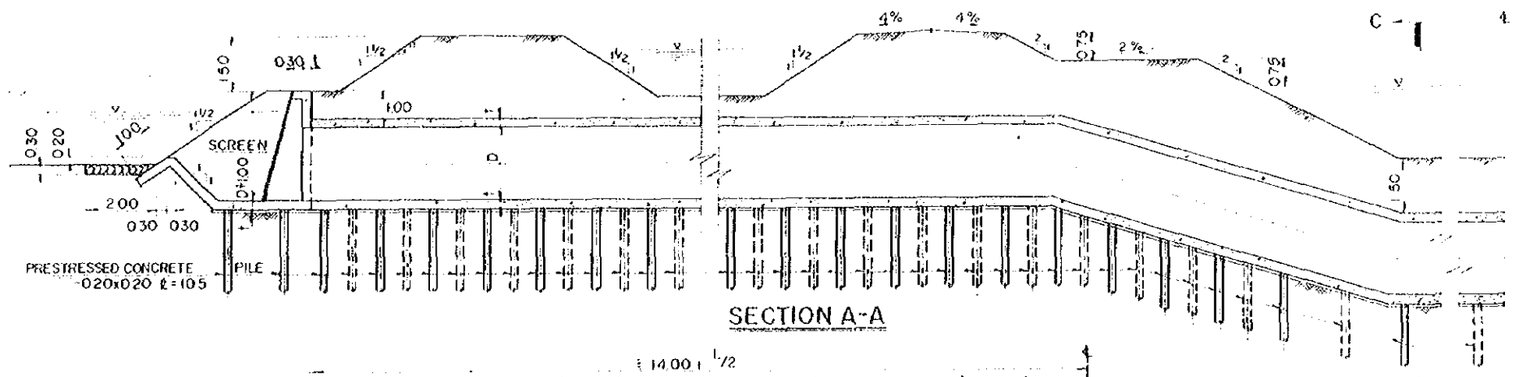
DATE	MAY 1977	D.W.G	8

JAPAN INTERNATIONAL COOPERATION AGENCY

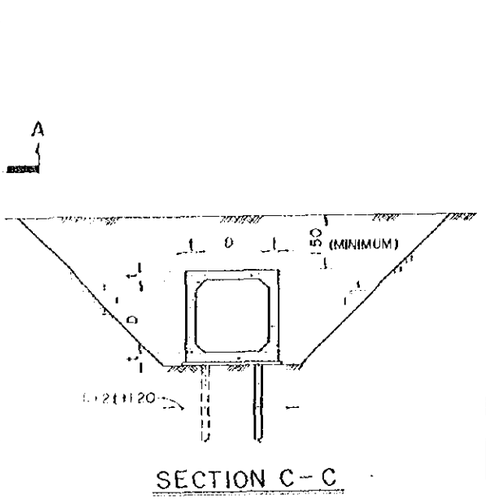
TYPE A



PLANE

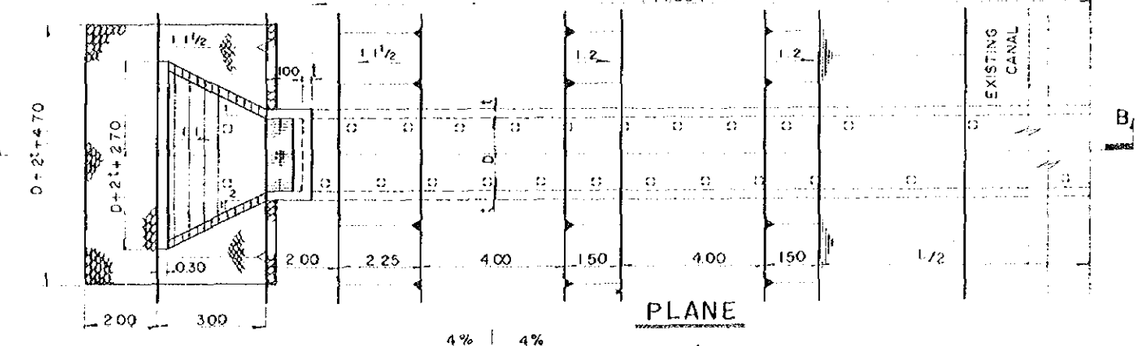


SECTION A-A

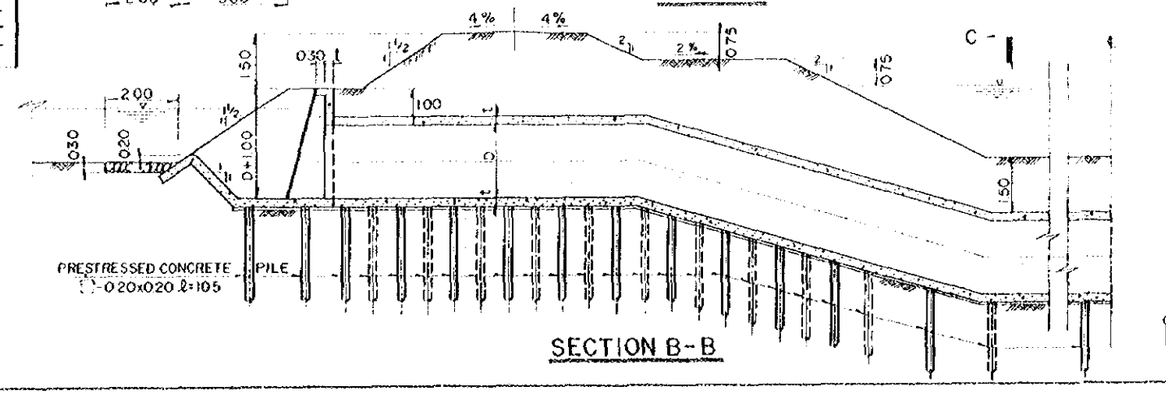


SECTION C-C

TYPE B



PLANE



SECTION B-B

	BLOCK A		BLOCK B		BLOCK C
NAME OF EXISTING CANAL	IL-2	NAI CHAT	IL-2	NAI CHAT	KHUD MAI
CLASSIFICATION OF CANAL	MAIN	LEADING	MAIN	MAIN	MAIN
DESIGN DISCHARGE $Q\ m^3/s$	10.288	3.032	4.508	8.247	8.312
CONDINATION OF TYPE: UPSTREAM SIDE	(A)	(B)	(B)	(A)	(A)
CONDINATION OF TYPE: DOWNSTREAM SIDE	(A)	(B)	(B)	(B)	(B)
DIAMETER OF CULVERT D^M	3.00	1.70	2.00	2.70	2.70
THICKNESS OF WALL t^M	0.30	0.25	0.25	0.30	0.30
LENGTH OF EXISTING CANAL L^M	30.0	25.0	30.0	25.0	30.0

ALL DIMENSIONS ARE GIVEN IN METER

5 10M

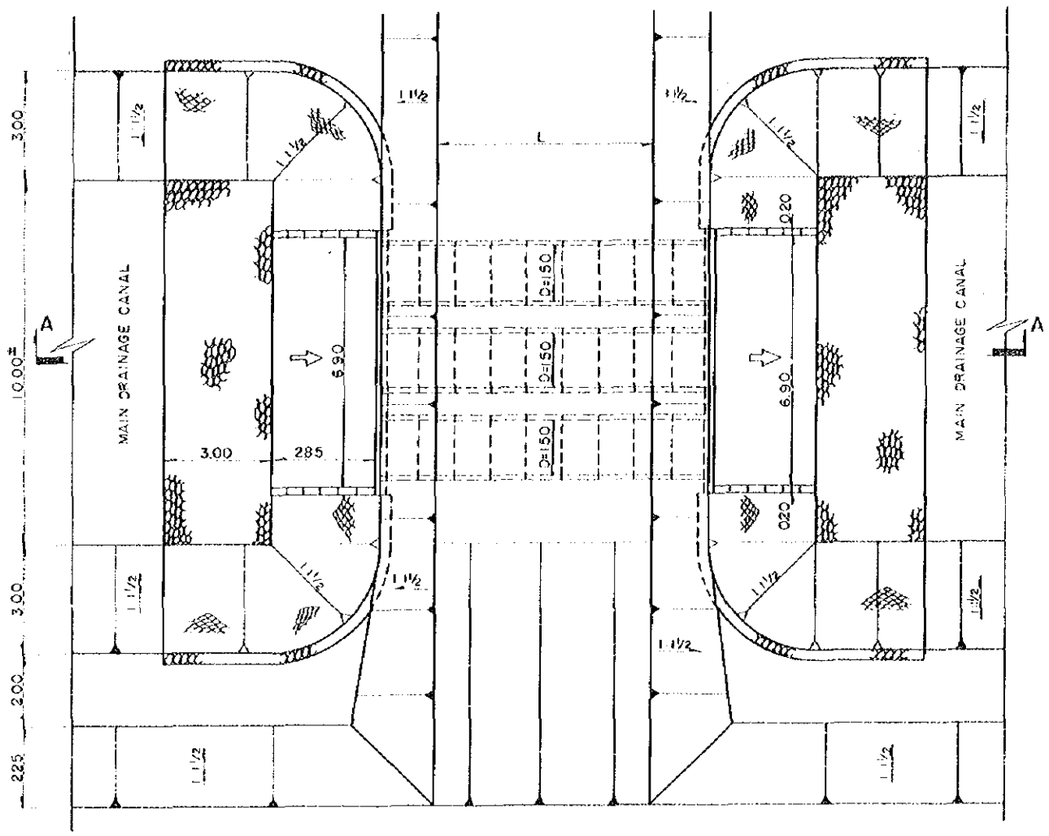
IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

TYPILAL DESIGN OF CULVERT IN DRAINAGE CANAL CROSSING EXISTING CANAL

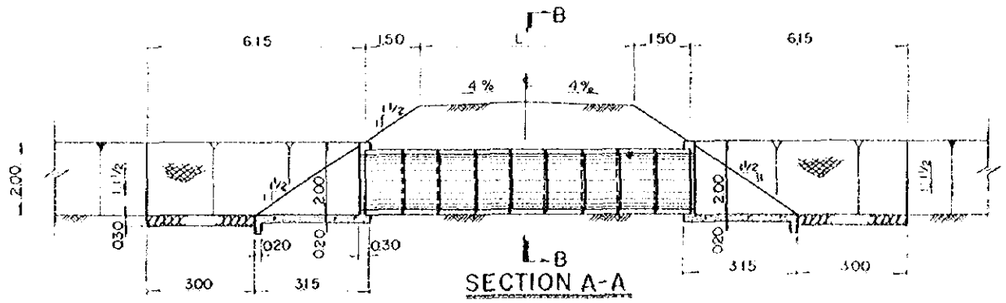
DATE	MAY 1977	D.W.G	9

JAPAN INTERNATIONAL COOPERATION AGENCY

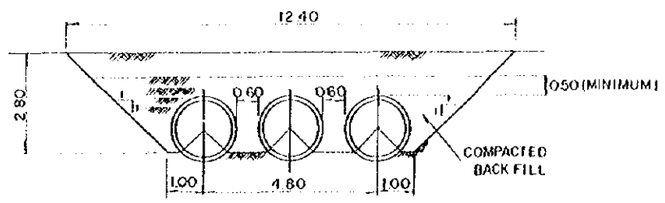
IN CASE OF MAIN DRAINAGE CANAL



PLANE

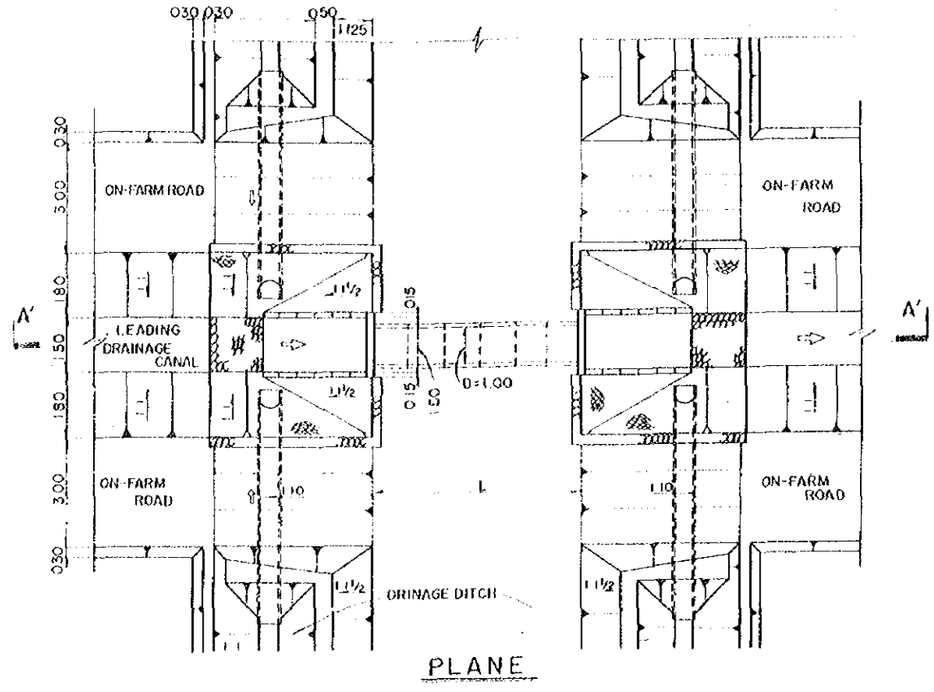


SECTION A-A

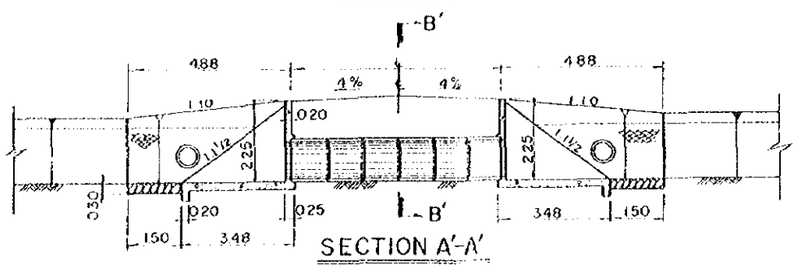


SECTION B-B

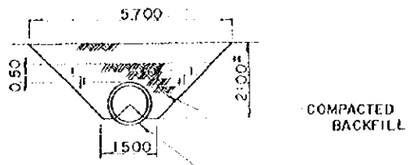
IN CASE OF LEADING DRAINAGE CANAL



PLANE



SECTION A'-A'



SECTION B'-B'

	L
PROVINCIAL ROAD	8.00
MAIN ROAD	6.00
COMMUNITY ROAD	4.00

ALL DIMENSIONS ARE GIVEN IN METERS

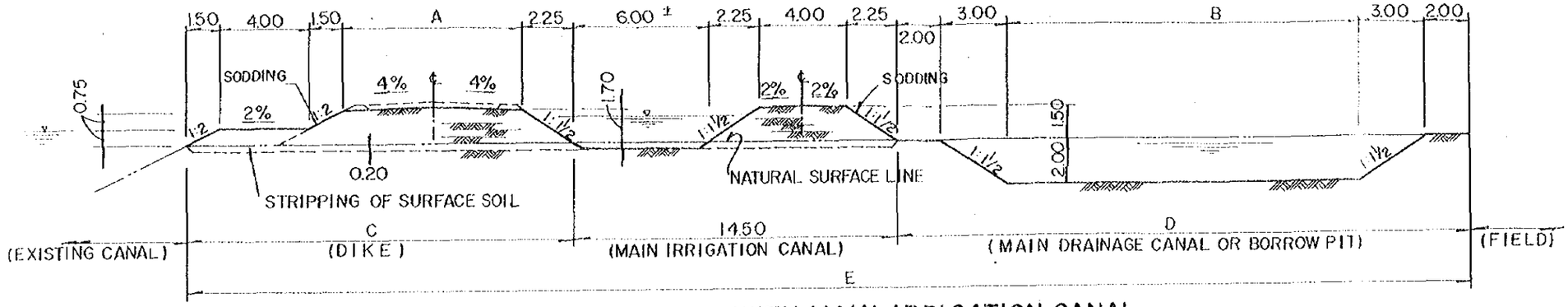
0 10M

IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

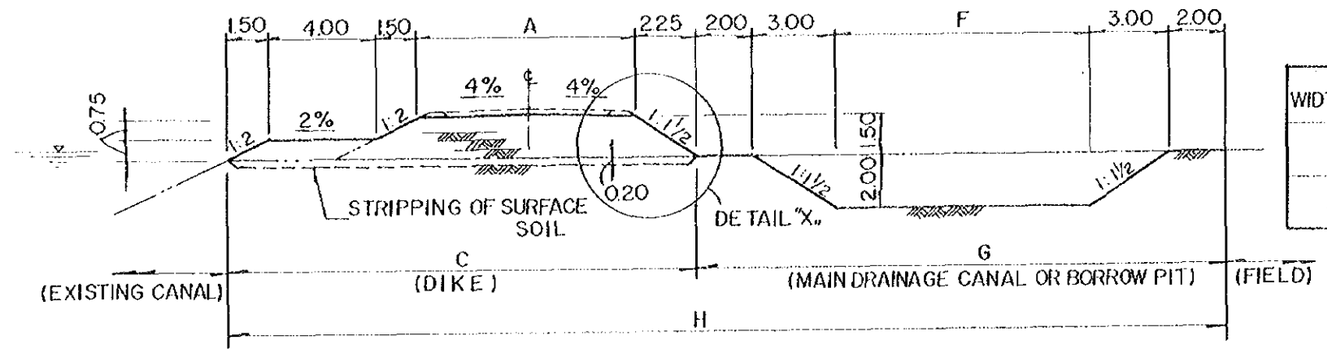
TYPICAL DESIGN OF CULVERT IN DRAINAGE CANAL CROSSING ROAD

DATE	MAY 1977	D.W.G	10

JAPAN INTERNATIONAL COOPERATION AGENCY

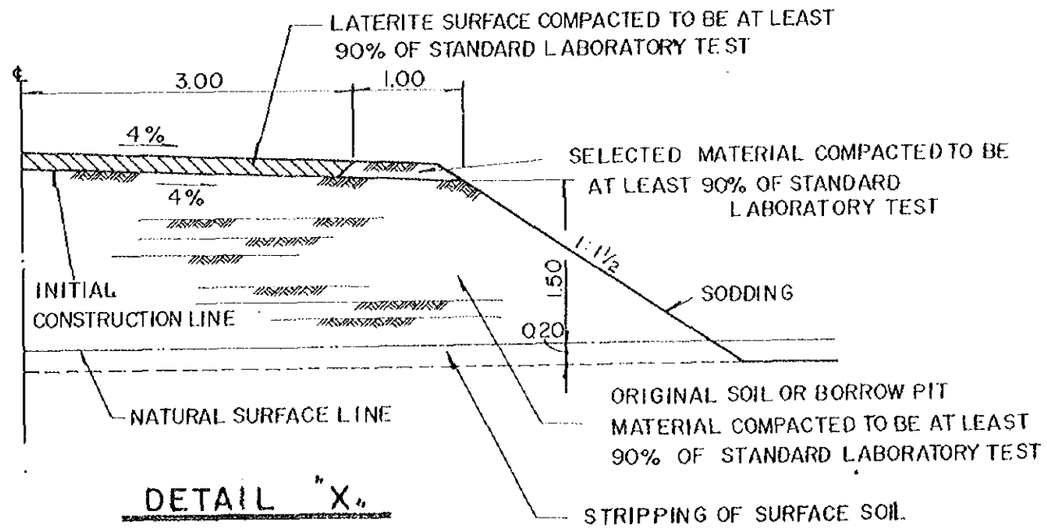


WITH MAIN IRRIGATION CANAL



WIDTH OF DIKE	A	B	C	D	E	F	G	H
8.00	8.0	16.10	17.25	26.10	57.85	9.40	19.40	36.65
4.00	4.0	13.60	13.25	23.60	51.35	6.80	16.80	30.05

WITHOUT MAIN IRRIGATION CANAL



DETAIL "X"

ALL DIMENSIONS ARE GIVEN IN METERS.

0 1 2 3 4 5M

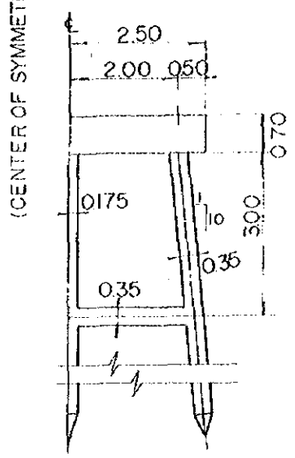
IADP IN THE WEST BANK TRACT OF
THE GREATER CHAO PHYA IN THAILAND

TYPICAL DESIGN OF DIKE

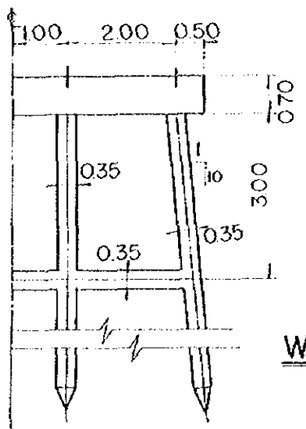
DATE	MAY 1977	D.W.G	11

JAPAN INTERNATIONAL COOPERATION AGENCY

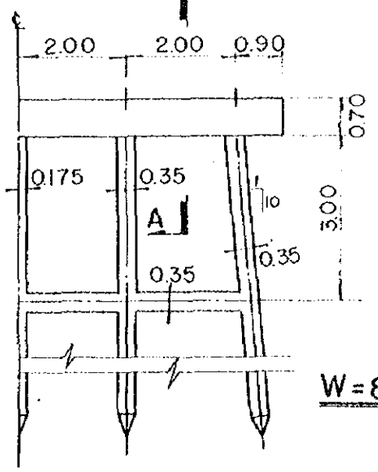
PIER



W = 4.00

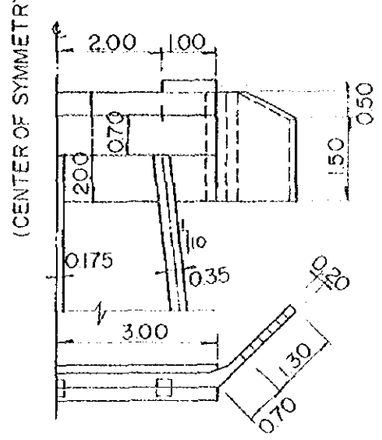


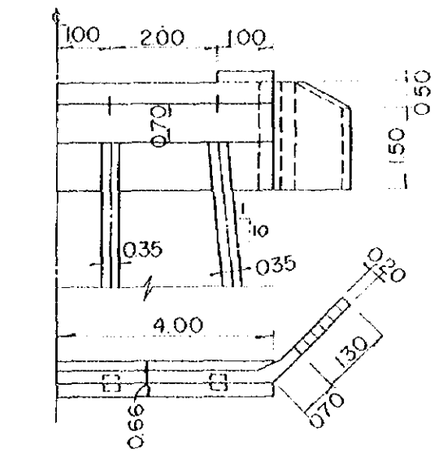
W = 6.00

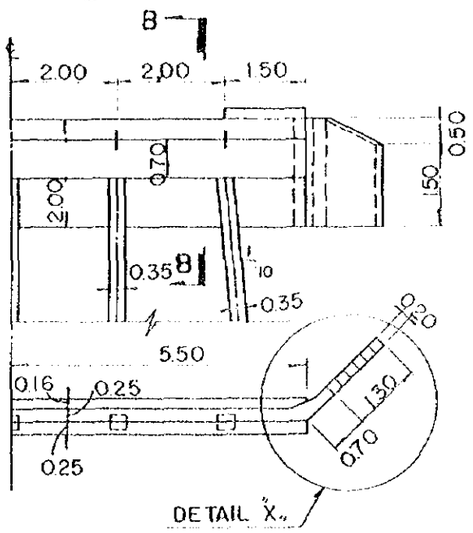


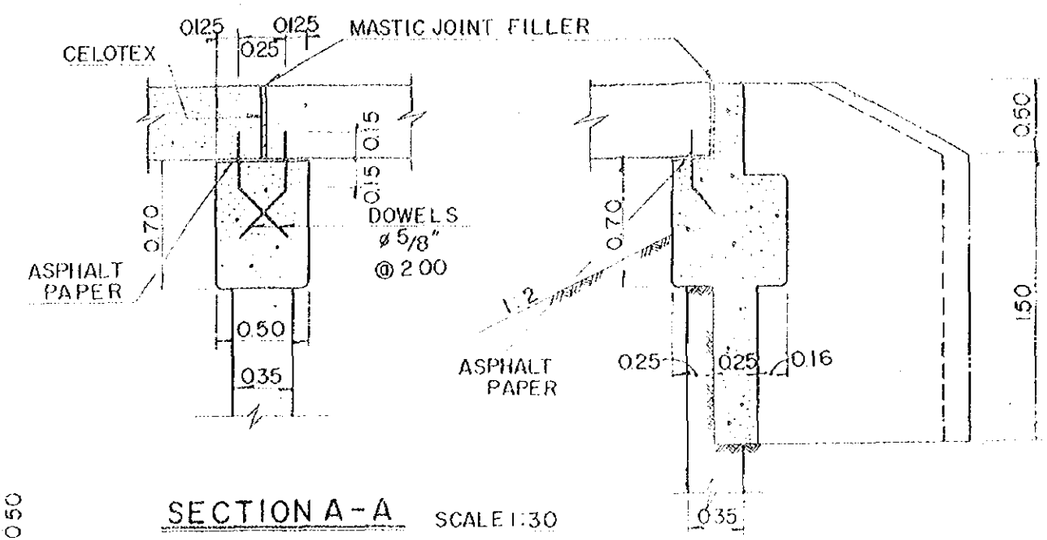
W = 8.00

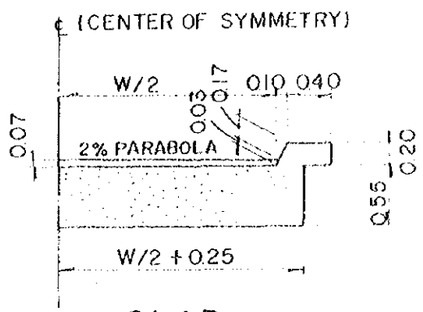
ABUTMENT



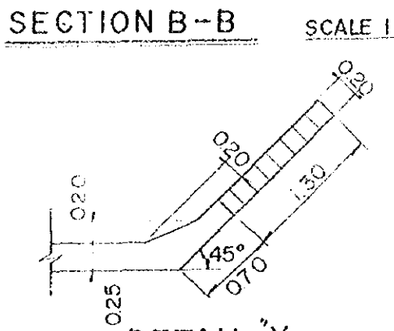




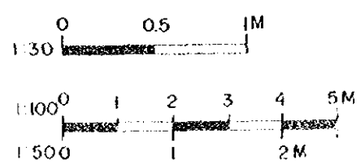




SLAB SCALE 1:50



DETAIL "X" SCALE 1:50



NOTE :

BRIDGES WILL BE PROVIDED TO CROSS THE EXISTING CANALS. AND THEY ARE DESIGNED BY SLAB TYPE. OF WHICH ONE SPAN IS 8 M

FOLLOWING THREE TYPES OF BRIDGES ARE PLANNED

- WIDTH W = 4 M ..... FOR DIKES OF 40 M.
- WIDTH W = 6 M ..... FOR MAIN ROADS.
- WIDTH W = 8 M ..... FOR DIKES AND PROVINCIAL ROADS

ALL DIMENSIONS ARE GIVEN IN METERS

IADP IN THE WEST BANK TRACT OF THE GREATER CHAO PHYA IN THAILAND

DESIGN OF CONCRETE BRIDGE CROSSING EXISTING CANAL

DATE	MAY 1977	D.W.G	12

JAPAN INTERNATIONAL COOPERATION AGENCY