3. PRESENT STATUS

3.1 Agriculture

3.1.1 General Situation

The sector of Agriculture had kept the leading position in the gross domestic product (GDP) for long time, but weight of the sector occupying 15% of GDP as of 1991 year, because of rapid expansion in the sectors of manufacture and commerce. While the agricultural population ratio is still in majority that is occupied about sixty percent of the total population in 1991.

However the per capita of GDP in the agricultural sector is very low which is only 10% of the non- agriculture sector.

The present agricultural situation in Thailand and Chao Phraya river basin are shown in Table 3.1.1 to Table 3.1.3 which are the yield of agricultural products, the agricultural land use and the rice cultivation.

3.1.2 Cropping Pattern

In Thailand, the cropping patterns are arranged by Agricultural Extension Manual issued by Agricultural Extension Division in each agricultural region. Regional agricultural extension staffs lead their regional farmers based on the manual and their current technical Information.

The cropping pattern of typical crops in Chao Phraya river basin where is covered by North and Central regions are shown in Fig.3.1.1 and Fig.3.1.2.

As a reference, a mutual relationship of a reducing percentage of rice yield and a period of inundation in a flood occurred in Thailand which studied in RID Regional Office 7 is shown in Table.3.1.4.

3.1.3 Deepwater and Floating Rice Cultivation

Rice Research Institute (RRI) in BKK and Prachin Buri Rice Research Center (PCR) take charge of the research and verification on the Floating Rice (FR) and Deep Water Rice (DWR).

Current Floating Rice cultivation area is about 5% of the total rice cultivation area in Thailand. The area decrease to a half compared with the area of ten years ago. The area is a scattered in Chao Phraya River, Mekon River, Mae Klong River and Bang Pakong river flood plane. Floating Rice has been planted in the Sinburi, Angtong and Ayuttaya provinces in the Chao Phraya river basin. The location map of the Floating Rice planting area and the cultivation acreage provinces based are shown in Fig.3.1.3 and Table 3.1.5.

Floating Rice has varieties of 89 kind, including 4 improved varieties. The average yield of the Floating Rice is low. The yield is 2.2 ton/ha that is about 70% of the High Yield variety. PCR continues the research and improvement study to get the high yield variety of Floating Rice which target yield will be 3.0 ton/ha.

3.1.4 Agricultural Land Use

(1) Existing Agricultural Land Use Situation

The situation of agricultural land use in the Chao Phraya river basin has greatly changed these recent years around the Bangkok metropolitan area and in the provincial capitals.

This fact is particularly obvious for Bangkok where the developments of social infrastructures such as roads, river dikes, a new international airport, etc. are still on going. In this connection, the area devoted to commercial and industry development will gradually increase in the years ahead, consequently eating up the presently existing farmland.

For the agriculture in the river basin, it is observed a gradual shift from paddy cultivation to upland crops with a diversification including vegetables, flowers and fruits culture. Furthermore, agriculture is expected to evolve more in the future due to the habitual water shortage and enlargement of cities and industries. Under these considerations, it is necessary to draw up a land use plan.

The Chao Phraya delta area is still for Thailand a granary of food supply. And, the area acts as a temporary water reservoir in time of flood. However, owing to the above-mentioned changes in land use and social habits, it is expected a significant reduction of the water storage area in the delta. Therefore, this situation should be fully taken into consideration.

The land use in the total project area is discussed in the chapter "Land Use" introduced later in the text.

(2) Agricultural GIS System

The existing agricultural land use maps elaborated by the Department of Land Development (DLD), include all 8 regions and 76 provinces (Chanwat) of Thailand.

Furthermore, the Agricultural Information Center in the MOAC has a Geographic Information and Remote Sensing Branch. This branch proceeds a set up of range for a economical land use area and a selection of crops adopted every river basin divided in 25 in this country based on a following nine kinds of data using GIS.

- Basic GIS Data
- Watershed Boundary: 25 Watershed areas
- Soil Series: 37 types
- Irrigation Area
- Rainfall Data: 39 years average
- Forest Legal Boundary
- Road Network

- Administrative Boundary
- Present Land Use
- Saline Soil

3.1.5 Forestry

The change of the forest area in all of the Thailand is shown in Table 3.1.6. Concerning of the tree felling is prohibited in January 17th, 1989 by the notification of the Minister of the Ministry of Agriculture and Cooperation. Exceptional cases are as follow: in cases of dam construction, road construction and string of electric wire.

Royal Forest Department is operating the reforestation to do the land preservation of tree felled area. The actual result of reforestation until last year and the following five years (1997~2000) target area of reforestation are shown in Table 3.1.7 and Table 3.1.8, respectively.

3.1.6 Fisheries

Inland fisheries are also prosperous in Chao Phraya river basin. The changes of fisheries production and yield from freshwater culture in 11 years (1983-1993) are shown in Table 3.1.9 and Table 3.1.10, respectively. Both figures indicate the increase of tendency. The occupied percentage of the inland fisheries in total production and culture are low of about 5% as of 1993 year. The Department of Fisheries (DOF) manages three large swamps inland fisheries project, which are located in Kwan Phayao in Phayao Province, Bung Boraped in Nakhon Sawan province and Nong Han in Sakhon Nakhon province. The Bung Boraped Swamp is located in Chao Phraya river basin and it has the water storage area of 250 km^2. The water depth is very shallow; consequently this swamp became to the superior inhabit area for fishes and birds. To preserve the good environmental condition of this swamp, the application to the Ramsar Treaty is done already. The general layout of the Bung Boraped project is in progress is shown in Fig. 3.1.4.

3.1.7 Livestock Industry

The current rapid economic growth has brought a big change in the livestock industry. The number of people involved in handling and feeding livestock except buffalo is in the increase. This is due to the fact that livestock are now raised more for meat than for labor. In addition, poultry breeding is also in the increase. These situations are the results of the people's change of eating habits, specially in urban areas such as Bangkok where the suppliers of meat and eggs have shifted from small farm exploitation such as a home industry to a more commercialized form or broiler company. However, the traditional poultry breeding system still continue in the urban area.

The number of main livestock in the Chao Phraya river basin is shown in Table 3.1.11.

3.2 Irrigation and Drainage

3.2.1 Barrage and Intake Facilities

Five major rivers of Pin, Wang, Nam, Yom and Chao Phraya river are located in the Chao Phraya river basin have many Barrage and Intake facilities in each rivers. These facilities list is shown in Table 3.2.1.

3.2.2 Irrigation System

Chao Phraya river system is composed of four large tributaries; Pin, Wang, Yom and Nan rivers originated in the northern hilly area. Ping river joins with Wang river and Nan river joins with Yom river. The two join to form Chao Phraya river at Nakhon Sawan, which divide again four rivers and canal in upper stream at Chainat Dam. After Noi and Pasak rivers join to Chao Phraya river again at Ayutthaya again, Chao Phraya river runs through Bangkok Metropolitan area and reaches to the Gulf of Thailand.

The main rivers and canals network in Chao Phraya river basin show in Fig.3.2.1. The Operation and Maintenance works for main irrigation and related facilities in Chao Phraya river basin is managed by each regional offices of RID. The boundary of each regional office is shown in Fig.3.2.2.

Irrigation projects and main facilities managed by RID are shown in Table 3.2.2, and the location maps are shown in Fig.3.2.3 and Fig.3.2.4.

3.2.3 Irrigation Water Demand

The greater part of irrigation water to the command area in dry season between January and June is used a released water from Bhumiphol and Sirikit dams located In the upper basin of Chao Phraya river.

The proposed water demand program in weekly based for irrigation projects are made by RID at beginning of dry season and submit to EGAT that is actual operation organization. After considering the various factors, for Instance the remaining water volume in the reservoirs, EGAT decides the released water quantity in every week.

RID's water demand proposed to EGAT in this dry season is shown in Fig 3.2.5. As of January, the released water volume from two dams are same as scheduled. If regional offices request an extra water volume, RID headquarters adjust the request and inform the amended demand data to EGAT. Therefore, the final decision is done by EGAT. Each regional office controls the water allocation to each irrigation projects in each regional area.

3.2.4 Drainage System

Large scale drainage facilities in Chao Phraya river basin is about nothing. Because of the rivers and canals in the basin have partly on drainage role, surplus water in rainy season is removed by control gates and drainage pump belonging RID, BMA and other organizations.

At present, Chola Han Phihit 2 Drainage Project located in the eastern Bangkok is in

planning stage.

3.3 Flood Damage In Farm Land

3.3.1 Damages In Farm Land

Agricultural damaged area and value caused by Drought, Flood and Others (Pest, Decease and so on) between 1984 and 1993 year are shown in Table 3.3.1. Rice cultivation damage by flood in provincial based in Chao Phraya river basin by flood is shown in Table 3.3.2.

3.3.2 Flood and Damage Data Collection In Sample Area

In the early in January, the study team carried out the study tour to collect the flood damage data and the related information on 1995-year flood. Nine provinces in Chao Phraya river basin are selected as study area. Studied provinces were Sukhothai, Pitsanulok, Phichit, Nakhon Sawan, Chainat, Lop Buri, Sing Buri, Ang Thong and Ayutthaya provinces. In the each provinces, the study members are collected many useful data and information under the good cooperation of RID Regional offices, Provincial offices, Municipality offices, Agricultural Extension offices, and so on. The findings of each provincial level on the 1995-year flood are sent to the Ministry of Interior in BKK, then compiled as a whole country report on the flood damage in the division of disaster prevention.

While, the agricultural damage findings caused by flood is also collected through each Provincial Agricultural Extension office. A report that compiled these data is arranged by the Department of Agricultural Extension. For the reference, the agricultural damages data and the damaged area map in Ang Thong province, and the total damage data of whole country are shown in Table 3.3.3 and Table 3.3.4, respectively.

The Government is delivered the free seeds and fertilizer to the farmers whose suffered from flood damage based on the relief system.

The flood damaged to the fishery sector, too. The damage is shown in Table 3.3.5. Department of Fishery arranged seven million fry which are twice quantity of usual year for the inland fish culture, and delivered these fly to the fisherman in free of charge based on a relief system similar to the case of the Department of Agriculture.

4. STUDY OF RETARDING BASIN

4.1 Existing Lake and Large Swamp

4.1.1 Selection and study for retarding basin

Proposed area for retarding basin like as existing lake and large swamp in the Chao Phraya river basin were studied the storage capacity as retarding area for big flood such as 1995 and 1996 year occurred.

Proposed areas were selected from existing lakes and large swamps that are water storage areas of more than 3 ha and 100 ha respectively based on topographical maps which scale is 1 to 5,000 and drawn up from 1969 and 1993. However, most part of the maps is passed for long time therefore the information on the maps get old.

Accordingly, aero-photograph made in 1994 and 1995 are used for the study. Then these maps are used for the estimation of remaining water storage area and the proposed site survey.

As the result of the study, it is cleared that the number of lakes and large swamps are decreasing in resent years. Water storage areas of each lakes and swamps are estimated as below. Selected and studied areas are shown in Fig.4.1.1.

Area	Remained Water Area (km^2)	Remarks
Swampy area in Sukhothai North	0.3	1995 aero-photograph
Swampy area in Sukhothai South	0.2	ditto
Swampy area in Bung Ratchanok	1.0	ditto
Swampy area in Bung Sie Huai	0.7	ditto
Bung Boraphet Lake	219.8	ditto
Total	222.0	

At present, the available area as proposed retarding basin in these lakes and swamps remained when it occurred big flood are only Bung Boraphet lake except of small size lake and swamp

4.1.2 Present utilization and Management situation

Water utilization of above mentioned areas are as follows. Sukhothai North and Sukhothai South areas use for irrigation, fish culture and other purposes. In these areas, big lakes and swamps are managed by public administrative organ such as municipal government, and other small lakes and swamps are managed by local farmers organization.

Bung Ratchanok and Bung Sie Huai are remained quite a big areas due to the management was transferred to the municipal government as exception.

Bung Ratchanok is located in the west of Pitsanuloke City; the swamp area is remaining for flood storage area. This area is consolidated as water park and sport activity area.

Bung Sie Huai is located in southern area of Pichit City, the swamp area is secured for flood storage area and the whole area is consolidated to water amenity park. This pond is also using for fish culture and breeding, and matured fish is selling in the local market as a special products.

Both parks are managed by each municipal government, therefore further development for them is nothing, their retarding areas are made sure in future.

Bung Boraphet is a large-scale lake that has 219.8 km^2 of water storage area. The fisheries department manages this lake, inland fisheries activities like as fish cultivation is developed as one of priority lakes.

4.1.3 Study and evaluation on flood control ability

From above study, an effective retarding area is estimated to 219.8 km^2 of Bung Boraphet. The result of the study on flood control ability is as bellow.

Premise : Levee raising is 1m

- New flood control capacity : 219.8 km^2 × 1.0 m = 219.8 MCM

If the retarding period premises one to two months, the reduction ratio of flood discharge is as bellow

- Discharge cut ratio : 219.8 MCM ÷ 86,400 sec ÷ 30 day = 84.8 cms
- (One months) : 84.8 cms ÷ 4,500 cms = 0.019 ≒ 2 %
- Discharge cut ratio : 219.8 MCM ÷ 86,400 sec ÷ 60 day = 42.4 cms
- (One months) : 42.4 cms ÷ 4,500 cms = 0.009 ≒ 1 %

From above estimation, 80 cms of flood control volume at Bung Boraphet can be contributed to mitigate against 4,500 cms of flood discharge at Nakhon Sawan. Furthermore, Bung Boraphet is located in the middle stream of Chao Phraya basin, it is very good position for the flood control in viewpoint of the hydraulic aspect.

However, Bung Boraphet is used to the inland fisheries and rare genius of animal live in the lake. Considering these points, it is very difficult to use this lake for flood control artificially. Needless to say, it is necessary to need consultant and approval with the fisheries department of the managed agency.

It is assumed to degree the existing lakes and swamps due to the land development to housing, commercial and industry areas. However, remaining lakes and swamps are still available as retarding areas and irrigation water sources. As the occasion demands, it needs consolidation like as dike raising, access canal consolidation and so on.

4.2 Old River Course

4.2.1 Selection and Study for model area

Based on the topographic map which is the scale of 1to 50,000, many old river courses scatters along the river. Same as the case of the large lakes and swamps, the

flood control effect might be expected in flood occurred. Therefore, the old river courses in the river are scattered along the river in widely, it is difficult to summarize.

Therefore, for the summarize of the effective water storage areas is adopted to divide to three for the study area.

4.2.2 Present utilization and Management situation

Most of them are used presently for fishery, irrigation water storage, etc. However, they are being reduced in the area (50% or less roughly) and number rapidly as shown on the recent aero-photographs (Refer to Figs.4.1.1 and 4.2.1).

4.2.3 Study and Evaluation on Retarding Area Ability

Thus, the possible storage capacity to be used for flood mitigation may be estimated at not more than 50 mcm. Therefore, in this study, such small capacity will not be considered in the flood simulation. The role of these old river course and pond in the water use, however, is still very much essential.

4.3 Paddy Field including Fallow Area

To apply paddy fields as retarding basins, the following three (3) cases are considered:

- Case-1: Utilization of fallow area
- Case-2: Utilization of paddy field which inundates in flooding time
- Case-3: Utilization of paddy area through rise of paddy dike

(1) Selection of Fallow Area

The fallow period of paddy field is defined as the idle period between harvest and the next planting season. The area under a fallow period (the fallow area) can be used as retarding basin, if the period coincides with the flooding season. In this study, the fallow area is selected in the following conditions:

- The fallow period occurs in the flood season, based on the currently practicedcropping pattern (Refer to Fig. 4.3.1).
- From the topographic viewpoint, lowland, where diversion of the flood water is easy, is applicable
- The area had been used previously as a retarding basin during the fallow period.

Under the above condition, the fallow area of 850km^2 on the west bank of the Chao Phraya river which has been used as retarding basin, is selected (Refer to Fig. 4.3.2).

(2) Selection of Paddy Field which inundates in Flood Time

Some areas of paddy fields inundated in flood time can be used as retarding basin. In this study, the area in middle of the delta between Singburi and

Ayuthaya, where deep-water rice cultivation is practiced, is selected as a retarding basin because of the following reasons:

- The area is located in lowland, which has an advantage for utilization as a retarding basin from topographic viewpoint.
- The productivity of the area is relatively low, thus it has an advantage from economical viewpoint.

The area for such deep-water rice cultivation is about 2,800km^2 (Refer Fig. 4.3.3).

(3) Selection of Paddy Field in Case of Utilization with Raising of Paddy Dike

As for the utilization of paddy field with raising of paddy dike, the following two cases are considered:

- Case-a: Utilization of paddy field in low, flat land
- Case-b: Utilization of paddy field in sloping land

The models of two cases area shown in Fig.4.3.4. In the former case, raising of the paddy dike seems ineffective, because the area is mostly inundated at flooding time and, therefore, there is no more room to store floodwater by raising of paddy dike.

In the latter case, flood water ca be stored with the raising of paddy dike, thus, the effectiveness for flood control is expected.

In this study, only the latter case is further examined for applicability.

The area of the latter case is mostly located in the valley plain as shown in Fig. 4.3.5. The entire areas are roughly estimated at 7,430 km^2 as shown in Table 4.3.1.

Assuming that about 70% of the above total area is effective excluding the area of irrigation channels, houses and roads, it is considered that about 3,000 km2 is possible for the raise of paddy dike of 10cm in this study.

4.4 Evaluation of Applicability of Retarding Basin

Effectiveness for flood mitigation, when the conceivable sites, swampy area, ponds along old river course and paddy field, are utilized as retarding basin, is roughly evaluated in the following considerations:

- Assuming that the flood continues for one month, the volume to be regulated for 100 m^3/s discharge for one month amounts to around 260 million m^3 (100 m^3/s x 30 days x 86,400 sec.=259.2 million m^3).
- To store this volume in the retarding basin, the area required should be about 260 km^2, assuming that the water depth of the retarding basin is one (1) meter. (In case of the raise of paddy dike, the area will be 2,600 km^2, since the water depth is about 0.1 m.)

On the contrary, a 100 km^2 of the retarding basin (1,000 km^2 in case of raise of paddy dike) can only store a flood discharge volume of about 40 m^3/s for one month.

Judging from these figures, it is not realistic to use a retarding basin of 100 km^2 (1,000 km^2 in case of raise of paddy dike) or less in area considering that the flood discharge of the Chao Phraya River is in the order of 3,000 to 5,000 m^3/s. In this connection, the aforementioned possible for retarding basin is narrowed down as follows:

(1) Utilization of lake and swampy area

Among lakes and swampy areas, the possible areas for retarding basin are less than 1.0 km^2 in most cases and only Bung Buraphet is over 200 km^2. Therefore, further study is conducted only for the Bung Boraphet.

(2) Utilization of Ponds along Old River Course

The water areas of ponds along the old river course are far than 100 km^2, i.e., less than 1 km^2 each. Consequently, the effectiveness to control flood discharge is not expected from these ponds.

(3) Paddy Field

All the above-mentioned three cases of paddy fields are far over 100 km^2, therefore, the applicability of these area as a retarding basin is further examined.

4.5 Further Evaluation of Applicability of Retarding Basin

From the above examination, the possible retarding basins are summarized in the following table:

Item	Sub-item	Possible Area for Retarding Basin (km2)
Existing Lake and Large Swamp	Only Bung Boraphet Lake	219.8
Pond along Old river Course	-	Not Applicable
Paddy Field	Fallow Area	850
	Inundation Area (Case-BBbBBb)	2,800
	Raise of Paddy dike	5,000

Applicability of these retarding basins is further examined as discussed below:

(1) Applicability of Bung Boraphet

Applicability of Bung Boraphet Lake is considered as follows:

- Bung Borahpet Lake is currently used as large scale fishing farm under the administration of Fishery Department and a social problem will ensure to people engaged in the Fishing farm when the lake is used as retarding basin.
- The area surrounding the lake is a precious habitat for wildlife as designated in United Nations Convention for Wetland (Ramsar Convention). Therefore, to take any artificial actions for utilization of the lake as a retarding basin will also cause a significant environment problem.

In this connection, it is not advisable to apply the lake as a retarding basin.

(2) Applicability of Retarding Basin in Fallow Area

The West Bank of Bangkok, which contains 4 RID project offices, i.e., Chao Ched, Ban Yeehon, Phraya Banlue, Phrapimol and Pasicharoen from the north to the south as shown in Fig. 4.3.2, has long time played an important role as retarding basin to project Bangkok from the flood damage. However, recent urbanization. Which is in progress from Pasicharoen in the south, is expected to gradually extend toward north according to the newly completed highway of the East Rig Road. RID has, thus, recently started to protect the area recently by raising the O & M road along Khlong Phraya Banlue an irrigation canal along the boundary of the project office with approximate design scale of 25-year return period. However, under such circumstance, the function of the retarding in the said area is anticipated to be gradually lost. Therefore, in this Study, the retarding basin in a fallow area is not adopter as a permanent measure.

On the other hand, it may take a long time to put into effect some substantial mitigation measures. In this connection, the retarding basin in fallow period is examined as a provisional measure for a limited period until substantial mitigation measure are completed in the future.

(3) Retarding Basin in Paddy Field inundated during Flooding time

As the possible retarding basin in paddy field, the field with an inundation area of 2,800 km^2 is preliminary selected. To optimize the size of the retarding basin in paddy field, alternative cases are examined by narrowing down 2,800 km^2 area considering the following:

- Area adjoining the main course of the Chao Phraya River to inlet and outlet water easily;
- Areas surrounded by river dikes and trunk roads which function to confine inundation water from encroaching to other are not designated as retarding basin; and
- Transition point of the flow capacity from large to small.

The proposed areas for alternative cases are as follows (refer to Fig. 4.4.1):

- Case-1: the area of 2,800 km^2 with deep water rice and floating rice in the entire DWR areas delineated in DORAS (1966)
- Case-2: the are of 1,220 km^2 with deep water rice and floating rice in the same area of case-1, but excludes the areas of Khok Katiem sub-project, Nakhon Luan sub-project and riverine belts.
- Case-3: the area of 860 km^2 with deep water rice and floating rice in the areas between Noi and Lopburi Rivers.

In practical basis, the delineation of retarding basin in such paddy field results is artificial division of the paddy field into two areas; the area released from habitual inundation and the area still suffering from habitual inundation. Such situation causes social problems among the farmers working in such paddy field. From this viewpoint, it is necessary to take a careful arrangement to receive the understanding and agreement from farmers in such area for application of this concept.

(4) Retarding Basin in Paddy Field with Raising of Paddy Field Dike

There are two opinions for the raising of paddy dike, as discussed below:

- According to the Rice Research Institute, farmers prefer lower dikes to arrow recent introduction of mechanized farming. The average height of dikes in the Central Plain maintained by farmers is not more than 40 cm.
- On the other hand RID and MOAC recommend farmers to construct paddy field with a height up to 50 cm at maximum from viewpoints of water management in areas susceptible to water shortage.

Under the above conditions, the effectiveness of raising dike height is examined in the following manner:

- The case of raising of dike examined with a height of 50 cm.
- As a model field, an area with a size of 3,000 m^2 with an outlet of 40 cm wide and 20 cm deep is applied as illustrated in Fig. 4.3.4.
- As the rainfall pattern to examine the effectiveness, those for 20 years from 1977 to 1996 are applied.
- As the location of the model field, five (5) locations are selected (refer to Fig. 4.3.5).

The difference of the run-off condition between two cases: before and after raising of dike is mainly concerning the storage capacity below the height of the outlet of dike. The comparison results are shown in Fig. 4.3.2. As shown in this figure, the effectiveness after raising of dike is observed at the beginning of the flood season. When the storage water depth in the paddy field is still low, the rain is stored and rainfall water does not overflow from outlet and thus the effectiveness for flood control is expected during that time. On the other hand, after the paddy field is full of storage water, over flow is observed immediately after rainfall occurs and no more effectiveness is expected for flood control by raise of paddy field dike.

To evaluate from the probability of effectiveness for the raising of dike, the frequency analysis is made. The frequency of occurrence of overflow from the outlet for 20 years calculation is summarized in Table 4.4.1.

Judging from the table, the present paddy dike has effectiveness for a small scale flood with occurrence of once every two years, which is derived from the fact that only 11 times have over flow outlet for 20 years.

By raising of dike height from 40 cm to 50 cm, the occurrence of overflow decrease from once every two years to once every three years.

However, raising of dike height of only 10 cm is not effective for a big scale flood, because the rainfall after immediately overflows in the flood time as shown in Fig. 4.4.2.

Under the above consideration, the case of raise of dike is not further examined as the alternative case for basin wide flood control. However, it is effective to raise a safety level for small-scale flood from 2 year return period to 3 year return period. Therefore, this measure will be considered for inland drainage system improvement plan

5. WATER USE PLAN IN DRY SEASON

5.1 Alternative Water Use Plans

As a flood mitigation measure, a new flood diversion channel is presently under study. This channel will be remove floodwater from the upper Ayutthaya basin and beyond. The facility will be seldom used except when flood breaks out. Its effective use in the dry season has to be considered. For example, it can be utilized as an irrigation channel in the dry season when the irrigation water is not enough. The planned flood diversion channel will have a gentle slope along its longitudinal section, as the ground in the lower delta area is almost flat.

The storage volume of this channel is shown as below.

Two case studies are considered;

"Case 4 of Pasak-Raphipat-Sea Div. (Mouth to 127 km)"
"Case 8 of Ayutthaya-East-Sea Division (Mouth to 96 km)"

In each case, 2 canal cross sections with respective design discharges of 500cms and 1,000cms are assumed.

	Discharge	Effective Cross Section	Total Storage Volume
Case 4	500 cms	300m2 (100m×3m)	38.1 mcm
Case 4	1,000 cms	600m2 (200m×3m)	76.2 mcm
Case 8	500 cms	300m2 (100m×3m)	28.8 mcm
Case 8	1,000 cms	600m2 (200m×3m)	57.6 mcm

The above total storage volume is estimated in the case of a flat invert. For an effective use of the stored water, control gates and division works will be set up where necessary. Furthermore, a good water management will be necessary for a sound operation of the proposed flood diversion channel and the already existing canal system. Further examination on intake facilities such as pump, head race to monitor flow and water availability in the channel-canal system network in necessary.

5.2 Conservation Area

The right bank area in the lower delta is called the Conservation Area; that is a storage area of irrigation water for the dry season to contribute as a countermeasure to irrigation water shortage. This area, which lies between Chao Phraya and Tha Ching rivers, is a natural depression with very poor drainage characteristics.

The available water in this area is utilized through the presently existing canal network. Around this area, the strengthening of canal dike such as dike raising, supply of drainage pump and so on in each irrigation projects. After the completion of the dike raising works, the canal storage volume increases. Therefore, it needs to study the possibility of utilization for increasing storage water using the regulators placed at both edge sites of link canal between Chao Phraya and Tha Ching rivers.

However, against next flood, it is necessary to supply drainage facility such as pump, regulator and so on against the following floodwater coming in advance. Under these situations, many projects on flood mitigation and effective utilization of flood water are either on going or in planning, which concern both banks of Chao Phraya river.

Two of the said projects are introduced below for reference.

(1) Chola Han Phichit Project

The Chola Han Phichit Project is located on the left bank of the Lower Delta and is present by in a planning stage. The area is affected by the tidal influence due to its proximity to the Gulf of Thailand and by poor drainage characteristics due to its low altitude and flat land configuration. Therefore, natural drainage is used along side with drainage by pump. This area changes the land use situation such as the urbanization, development of social infrastructures, changes on rural area and so on. Therefore, it seems that the drainage condition doesn't meet the land use changes. In this project, for the purpose the improvement of these systems, it is progressed the improvement of drainage and the strengthening of drainage pump.

(2) Monkey Cheek Project

The Monkey Cheek Project is located on the Right Bank of the Lower Delta. The project is designed to store the floodwater in the southern area of Pasicharoen Sub-Project. The area is effected by the sea tidal influence and is favorable for the development of prawn culture and salt pan.

This area lies between Chao Phraya and Tha Ching rivers and is crossed in every direction by many canals. These canal systems are used for the drainage of inland water and for transportation. Regulators set up along the systems are closed in case of high tide. Furthermore, drainage pumps are used to remove the floodwater.

5.3 Flood Plain

As one of the non-structure measure for flood mitigation, an alternative idea is to use a retarding basin for flood water storage. The idea is to use the water in the dry season to meet irrigation needs.

The flood plain is a major area for deep-water and floating rice cultivation. The irrigation water has to be removed from the paddy field during the mid-summer harvest, and to shift to reform into well-drained paddy field. However, the capacity in the dry season is a limit due to the available area has also a limitation as a flood plane.

Details of the retarding basin are given in chapter "4.3 (2) Selection of Paddy Field which inundates in Flood Time". A site of 2,800km^2 is proposed for the retarding basin, however, the purchase of the land too costly. Or it needs to take a measure such as to accept a rice cultivation in ordinal year, to storage a flood water in the area through the payment of the compensation and so on. Furthermore, For the purpose to secure the enough capacity, it needs a polder construction and provides a management facility.

As a point to notice, the water volume in the retarding basin will be reduced before the next dry season due to the evapo-transpiration loss. Furthermore, the flood plain is located in a lowland area, it prospect to need another facility such as a head race canal, a pump for water lifting and so on.

5.4 Utilization of Small Lake and Swamp

Many small lakes and swamps are not effective enough as a retarding basin, on the other hand they are effective as a storage facility of supplementary irrigation water for dry season. These measures are useful irrigation water sources for areas with poor irrigation facility and where the irrigation water is not enough. Number of these lakes and swamps are decreasing due to the basin development. However, for some lakes and swamps adjacent to the river, a tendency to enlarge the water storage capacity by dike heightening is growing among farmers from the point of view of water usage. However, other facilities such as a head race canal, a pump for water lifting and so on are needed. Furthermore, for some water management considerations the establishment of water users union or a confirmation of water right is necessary.

5.5 Ground Water Recharging

Water stored in the retarding basin, Conservation Area or flood diversion channel can be utilized as a supplementary irrigation water in the dry season resulting in groundwater recharging.

Near the Bangkok area, land subsidence still occurs due to the over drawing of ground water. Therefore the said water is effective in saving up the ground water and can shift industrial water use from ground water to the storage water. Therefore, it estimate to contribute the decrease the usage of the ground water.

6. DRAINAGE PLAN IN FARMLAND

6.1 General Condition for Study on Farmland Drainage Improvement

6.1.1 Objective Area of the Farmland Drainage Improvement

Inland drainage areas in this study area selected from the following areas, where the drainage problems are expected judging from the topographic conditions, land use condition, drainage condition, etc.:

- Farmlands in the floodplain which extend from the lower Yom and Nan rivers (approximately Sukhothai and Pitsanulok cities) to southern end of Chao Phraya Delta (mainly command areas of RID regional office No. 7 and 8),
- Farmland surrounded by river dikes, canal dikes or road which prevent inland water from free discharge of the local rainfall to the river, and
- Farmlands where water levels of adjoining rivers are frequently higher than the farmland.

The total objective area amounts to 29,000 km^2, which is obtained based on the topographic map with a scale of 1/250,000 considering the land use prepared by MOAC.

6.1.2 Division and Classification of Objective Areas

The objective area is broadly divided into 11 areas considering the following conditions: topography, river system, existing drainage system, land use. Fig. 6.1.1 shows the divided areas and Table 6.1.1 shows the outlines of the divided areas.

The divided areas are classified based on the cultivation condition and drainage outlet condition as follows:

(1) Classification by Cultivation Condition

Basically the divided areas are under the two cultivation conditions, which have an influence to improve the drainage system: (1) irrigation areas and (2) rainfed cultivation areas.

The major former areas are located in the following five (5) areas among the 11 divided areas: Pitsanulok irrigation project, the Old Delta, the East Bank, West Bank and Tha Chin West areas. In these irrigation areas, the major rice consists of the high yield variety (HYV), except the Old Delta area which has also areas of deep water rice (DWR) and floating rice (FR).

The latter areas, in general, are dominant in the remaining six (6) areas and in these areas, the major rice consists of the traditional varieties (TV) which includes water tolerable deep water rice floating rice.

(2) Classification by Drainage Outlet Condition

As one of major factors to decide the drainage system, the condition of drainage outlet is essential. For the divided 11 areas, the drainage outlets are classified into the following points:

- Drainage outlet is Yom or Nam Rivers
- Drainage outlet is Bung Boraphet Lake
- Drainage outlet is Sakae Krang River
- Drainage outlet is flood plain of Old Delta or existing irrigation canals of Chainat-Pasak and Makanthao-Uthong
- Drainage outlet is Chao Phraya down stream and its tributaries
- Drainage outlet is Tha Chin, Bang Pakong and Sea

(3) Consideration of Other Factory for Drainage System Improvement

To examine the drainage system improvement, other factors to be considered are as follows:

(a) Cropping Calendar

The major rice consists of the high yield varieties (HYV) traditional varieties (TV) which includes water tolerable deep water rice (DWR and floating rice.

The timing of planting the major rice in the paddy fields differs from each other varieties and the location (timing in the Yom-Nan basin is slightly earlier than in the Chao Phraya delta) but it can be roughly said from the end of May to the end of July and the harvesting is from November to January.

The cropping calendar from the end of transplanting or one moth after broadcasting to the end of harvesting is summarized in Table 6.1.2.

(b) Consumptive Use of Water for Paddy

Consumptive use of water (CUW) for paddy, herein defined as a sum of evapotranspiration and percolation. According to the study report for the Pitsanulok Stage II project, a 6 mm/day is applied for the study area except West and East Bank areas so-called conservation areas, where 5 mm/day is applied according to the feasibility study report by RID/ADB in 1992.

(c) Harmful Water Depth of Rice

Some precise record for the high yield variety (HYV) has been collected from RID regional office No. 7 as shown in Table 3.1.3. The information for various varieties, ie., HYV, TV (traditional variety) including DWR and FR are collected from the Rice Research Institute which is supported at the site for actual analysis, Based on these information, the maximum

harmless water depth and the water depths for the maximum damage in average are determined for typical rice varieties. (Refer to Table x.x.x)

6.2 Strategy for Study on Drainage System Improvement

As discussed above, there are many items to be clarified to example the drainage system improvement in the Study area. However, the available data such as detailed topographic data, water level at the drainage outlet, and so on to perform the study are very limited, while the area to be covered in this study is quite large. Under these circumstances, the study is conducted in the following strategy in this Master Plan Study:

- Among the 11 divided areas, the study is conducted for the typical model areas in which the basic data are available.
- For the model areas, inundation water volume is roughly calculated based on the relation between the rainfall depth and water level at the drainage outlet.
- On the basis of the calculated inundation water volume, the necessity of the drainage system improvement is identified putting emphasize on the point whether the installation of drainage pump is necessary or not.
- Considering the study results of the model areas, the necessity of the drainage system improvement of the remaining area is roughly evaluated.

6.3 Inland Drainage System Improvement in the Model Drainage Area

6.3.1 Selection of Model Drainage Area

Among the 11 divided areas, the following areas are taken as the model areas, considering the availability of the data.

- Pisanulok Irrigation Project area
- Nan River East area
- Old Delta area
- The East Bank area

6.3.2 Consideration of Water Level at Drainage Outlet

For the above model areas, the water level at the following points can be applied.

For the Pitsanulok irrigation and Nan River East areas, the water level at the point of N7 of Nan River is applied.

For the Old Delta area, the water level at the point of Angthong is applied.

For the East Bank area, the sea water level observed at Forth Chula point is applied.

Through the comparison between the ground height of each model area and water level at each drainage outlet, the following conditions are identified:

(1) Pitsanulok irrigation and Nan River East areas

The ground heights of these areas near N7 point are both El+36.0 m. Through the comparison between the ground heights and the observed water level at N7 point for 17 years from 1978 to 1995, it is identified that, only four (4) times, the water level was over the ground height as shown in Table 6.3.1 and Fig. 6.3.1. Consequently, for most of the years, inland water can be naturally drained by gravity.

For these 4 times, the periods over the ground height are 15 days at minimum and 71 days at maximum. In general, the inland water by local rainfall is inundated during these period.

(2) Old Delta area

The ground heights of the Old Delta area near C7A, Angthong, is about El+5.0 m. Likewise, compared with the water level data at C7A point for 20 years, it is revealed that the water level was over the ground heights at nine (9) times. (Refer to Table 6.3.1 and Fig. 6.3.1).

Consequently, it may be difficult to frequently drain the inland water by gravity.

The periods over the ground height are in the range from 20 days to 97 days.

(3) The East Bank area

The ground heights of the East Bank area near the drainage point as about 0.5 m, while the period for the tidal water level over the ground height is about 1/3 of a day. (Refer of Fig.x.x.x.) From the situation, it may be difficult to drain the inland water by gravity depending on the water volume from the drainage area.

6.3.3 Water Balance in Paddy Field During High Water Level

To identity the inland drainage problem, water balance in paddy field during the period while the water level is over the ground height is roughly examined in the following premises:

- As the inflow to drainage area, accumulated rainfall during the period of water level over the ground height is applied. (As the rainfall, average basin rainfalls is applied. (Refer to Fig. 6.3.2).)
- As the loss of inflow to drainage are, consumptive use of water (CUW) is deduced from the accumulated rainfall.
- The water depth in the field at the time of start of water balance calculation is assumed at 10 cm.

The calculation results for the area of Pitsanulok Irrigation project, Nan River West, and Old Delta areas are shown in Table 6.3.2.

Judging from the results, the following situations are identified:

(1) Pitsanulok Irrigation Project and Nan River West Area

In case of these areas, the period that the water level is higher than the ground height is observed four (4) times for 17 years. Out of these 4 times, rainfall can be confined three (3) timed in each paddy field assuming the possible storage rainfall depth is 10 cm, while, only one time, excess water from each paddy field is expected resulting in inundation problem in the lowest area in the drainage area.

Consequently, it seems to be not necessary to install pump to drain the inland water only one time for 17 years, but it may be necessary to improve the main drainage channel.

(2) Old Delta Area

In case of Old Delta area, the period that water level is higher than the ground height is observed nine (9) times for 20 years. Out of 9 times, rainfall can be confined six (6) times in each paddy field, while excess water from each paddy field is expected only (3) times. Moreover, in this drainage are, deepwater rice and floating rice are dominant in the lowland, so that the inland drainage problem is not so severe.

Consequently, it seem to be not necessary to install pump to drain the inland water only for three times for 20 years, but it may be necessary to improve the main drainage channel.

(3) The East Bank Area

As for the East Bank area, the inland water is drained to sea, where the period that the tidal level is over the ground height is 1/3 of a day. The water balance in the drainage area is roughly calculated in the following assumption:

- As the inflow to drainage area, total rainfall of 650 mm on an average for about three months is applied.
- As the outflow, 150 mm of CUW is reduced and 70% of remaining water is naturally drained and 30% is stored in the paddy field.

Consequently, the remaining amount in each paddy field is about 150 mm, which results in having an excess water of 50 mm assuming that the remaining storage capacity in each paddy field is about 100 mm.

The volume of 200 million m^3 (50 mm $\times$ drainage area of about 5,050 km^2) is expected to inundate in the lowland, which causes habitual inundation problem.

Thus, it is necessary to strengthen the drainage capacity to alleviate the inundation problem. As this area situated in the low and flat plain, however, it may be difficult to naturally drain by the drainage channel, because the channel bed gradient is too gentle, so that very wide channel width is required.

In this connection, it seems to be necessary to provide the drainage pump in addition to the existing ones to strengthen the drainage capacity keeping the relatively steep gradient lowering the water level at the drainage point.

6.4 Consideration of Inland Drainage System Improvement of the Other Areas

As discussed above, the necessity of the drainage pump is roughly evaluated in the model areas.

Based on the results, the drainage system improvement of the other areas is considered as follows:

(1) Yom River West Area

In Yom River West area, the drainage outlet is Yom River. In the River, the water level record is very limited; namely, only nine (9) years record is available.

Among these 9 years, the river water level was over the ground height four (4) tomes.

This is attributed to the poor flow capacity of the Yon River. Taking the same procedure of the calculation, the results of the water balance for these four times are shown in Table 6.3.3. As shown in this table, in most cases, excess water from the paddy field is expected, and thus, it seems to be necessary to improve the drainage system. This is attributed to the poor flow capacity of the Yon River.

However, in case of Yom River, it is necessary to improve not only the drainage system, but also Yom River channel, which causes habitual overtopping. Thus, it may be wasteful to improve only drainage system, unless river channel be improved first.

(2) Sakae Krang Basin

In the area, topographic data on water level at outlet are not available. Consequently, it is not realistic to discuss the drainage system improvement in this area in this stage.

However, judging from the poor flow capacity of the Sakae Krang River, it seems to be necessary to improve the river channel first.

(3) Chainat-Pasak Canal East and Suphanburi West

The inundation in these areas is attributed to the irrigation channels crossing the drainage channel, which hamper the smooth drain from the drainage are to the main drainage channels. To drain inland water in these areas, RID provides siphon/culvert under the irrigation channel of directly drains into the irrigation channel. In general, the situation can be solved through the improvement of the siphon/culvert with enough capacity and connect the main drainage channel in the down stream.

(4) The West Bank and Tha Chin West Areas

The drainage problem in these areas, in principle, is the same as the East Bank area.

Thus, the strategy of drainage system improvement in these areas follows the results of the East bank area. Namely, it is necessary to install drainage pump as well as improvement of drainage channel to strengthen the drainage capacity in these areas.

6.5 Coordination with Other Inland Drainage Plan

The Chao Phraya Lower Delta area has so far experienced serious damages related to flood. Therefore, various drainage plans are set forth and implemented for the Bangkok Metropolitan Administration area and other important areas of the Delta. This study will consider these plans thoroughly.

Furthermore, tidal barrages are planned for Bang Phakong and Tha Chin rivers, respectively. Consequently, some drainage plans need to be set forth with due consideration of this fact.

7. FARMLAND DRAINAGE IMPROVEMENT IN THE CHAO PHRAYA DELTA

In this chapter, based on "CHAPTER 6 STUDY OF FARMLAND DRAINAGE PLAN" which was studied in the master plan (M/P) stage, it examined the more detailed drainage system improvement for the agricultural land in the Chao Phraya Delta area is examined putting high priority on flood damage control because of the social and economic significance of the said area.

7.1 Study Procedure

The study procedure for the drainage system for farmland is in principle considered as follows:

- Confirmation of the study area
- Division of the study area and selection of model area
- Study on features of the area from drainage point of view considering topographic conditions and land use conditions
- Identification of main issues on flood in the drainage area
- Study on the measures to mitigate the flood damage
- Prioritization of the implementation of mitigation measures.

(1) Confirmation of Study Area

In the Chao Phraya River basin, the areas which hold inland drainage problem widely spread in the whole basin. Among the areas, the drainage improvement study in areas located in the Chao Phraya River delta in the down stream is discussed herein, since to cover the whole areas may not be realistic to come to the conclusion, while the drainage improvement problems in the down stream seems to be more affecting in terms of economic in the basin judging from the scale of areas.

(2) Division of the Study Area

Judging from the river channel system and topographic conditions, the study area can be broadly divided into two areas; higher delta and lower delta, which are further divided into the following areas:

(a) Higher Delta

- The northern part of the area surrounded by Tha Chin and Noi Rivers
- The area surrounded by Noi and Chao Phraya Rivers.
- The area surrounded by Chao Phraya and Lop Buri Rivers
- The area surrounded by Lop Buri and Pasak Rivers

(b) Lower Delta

- The East bank areas of the Chao Phraya River
- The West bank areas of the Chao Phraya River

These areas are further divided into several RID Project areas as shown in Fig.7.1.1, and the drainage network is shown in Fig.7.1.2.

(3) Study on features of the divided areas from drainage point of view considering topographic conditions and land use conditions

The features of the divided areas are examined from drainage point of view: catchment area, general slope of the areas, main drainage outlet, land use condition, etc.

(4) Identification of main issues on drainage

In the divided areas, the main issues on drainage from the aspects of main causes and drainage conditions will be identified as items below:

(a) Main Cause of Flood

From the aspect of the main causes of flood, the following issues are considered:

- Due to heavy local rainfall
- Due to water from the other project areas located in the upstream
- Due to overflow from the rivers

(b) Drainage Condition

- Due to poor inland drainage channel capacities, the flood discharge by local rainfall cannot be collected in the drainage channel
- Due to the flat plain, the inundation water is not hardly transferred to the drainage outlet
- Due to continuation of the high water level of outlet, the inland water cannot be drained to the out.

(5) Study on Measures to mitigate the Flood Damage

After the identification of main issues, the measures to cope with the flood damage are examined. The conceivable measures are as follows:

- Improvement of drainage channel
- Installation of drainage pump
- Provision of retarding basin
- Construction of new drainage channel
- Drainage to the area in the downstream

- Heightening of dike to protect overflow from the river channel

(6) Prioritization of Implementation of Drainage System Improvement

In general, prioritization is made considering the significance of the issue, the economic efficiency, etc. However, the area covered in this study is so large that the optimum measures as well as the construction cost and economic benefit can not be identified. In this study, prioritization of implementation of drainage system improvement is examined considering the drainage issues. And implementation schedule according to the priority is prepared.

7.2 Study on Higher Delta

(1) Northern Part of the Area surrounded by Tha Chin (Suphan Buri) and Noi Rivers

(a) Features of Area

Features of the areas are summarizes as follows:

- The area covers about 1,850 km2, where the dominant crops are high yield variety (refer to Fig.7.2.1).
- As the topographic features, the area forming flat plain slightly reclines toward to South-West direction with the slope gradient of about 1/4,000 (refer to Fig. 7.2.2 and 7.2.3).
- Irrigation canal distributed from the Chao Phraya, Noi and Suphan Buri Rivers. In these, Noi and Suphan Buri rivers intake a capacity of about 260 m3/s and 320 m3/s, respectively.
- On the other hand, the drainage channel system collecting the discharge supplied through irrigation channel and local rainfall is composed of six trunk channels: Noi Main Drain 3 and 4, and Suphan Main Drain 1 to 4.
- These drainage areas in principle correspond to the following RID Project areas: Pollathep, Boromathad, Chanasut, Samchuk, Yamanee and Phak Hai (refer to Fig.7.1.1).
- The main drainage outlet is to Tha Chin and Noi Rivers. At each outlet of these drainage channels, which are discharged to the Noi and Suphan Buri Rivers, a sluice with gates is installed with the capacity corresponding to that of drainage channel. Drainage pump is provided only in the Phak Hai Project area, with a capacity of 24m3/s (refer to Fig.7.2.4).
- The area does not receive the overflow from the rivers, which is revealed from the fact that even in 1995, the area did not suffer from severe flood damage.

Features of the area are summarized in Table 7.2.1.

(b) Identification of Main Issues on Flood in this Area

Based on the information collected and interview results, the issues on flood in this area is summarized as follows:

- In this area, flood damages have been scarcely reported so far.
- In general, local rainfall can be collected in the trunk drainage channel without causing serious inundation damage to the area along the drainage channel.
- Such collected rainfall water can be successfully drained through the sluice and gate to the Noi and Supan Buri rivers, since the river water level is not so high compared with that of drainage channel.
- Overflow from the Noi or Suphan Buri Rivers has also been scarcely reported and even in 1995 flood, overflow was not reported, because of the flow discharge control through operation of gates at diversion points from the Chao Phraya River to Noi and Suphan Buri Rivers.
- However, the drainage channel capacity is designed to receive the local rainfall corresponding to 3 year return period as the design criteria, it is expected that the inundation will occur in the event of local rainfall more than 3 year return period.
- Also, when such condition that water level of the Noi and Suphan Buri Rivers is higher than the water level of drainage channel at the out let point continues for a long time, the inundation comes out from near areas to the outlet point. Such condition according to the collected data is expected almost once every 2 years (refer to section 7.4).
- The inundation water in the upstream areas gradually tends to flow down to the downstream and detains therein.
- In 1995 flood, the water level of the Noi and Suphan Buri rivers was at almost bank full of the river channel for about 2 months. Eventually, the inland water could not drained and inundation was observed at several areas near the outlet points causing certain flood damage to the paddy field, mainly high yield variety.

Main issues of the area are summarized in Table 7.2.2 and Fig.7.2.5.

(c) Conceivable Measures for Drainage System Improvement

As discussed above, this area is in principle provided by the drainage system with the certain safety level, so that the flood problem has been not reported frequently in case the water level in the Noi and Suphan Buri Rivers is lower than that in the drainage area. Even the higher river water level continues, the flood damage due to local rainfall is relatively minor in the upstream area. But, in the downstream area, where the inundation water from the upstream flows down and is detained therein, flood damage is observed.

In this connection, to further enhance present safety level of the drainage system, it is considered to improve the following points:

- Improvement of drainage channel with the outlet facilities from about 3 year return period.
- To provide retarding basin in the area, where the inundation water is detained to minimize the water flowing to downstream or to receive the water from the upstream.

However, the current safety level for drainage system is not so low compared with the other areas as discussed later, and to enhance the present drainage capacity may not be urgent issues.

The conceivable measures are shown in Table 7.2.3 and Fig.7.2.6.

(2) The Area Surrounded by Noi and Chao Phraya Rivers

(a) Features of Area

Features of the areas are summarized as follows:

- The area covers about 930 km2, where the dominant crops are high yield variety of about 47 % in the northern part, and deep water rice and floating rice in the southern area(refer to Fig.7.2.1).
- As the topographic features, the area forming flat plain slightly reclines toward to South-West direction with the slope gradient of about 1/4,000(refer to Fig. 7.2.2 and 7.2.3).
- Main irrigation canal (same as Noi River) diverged from the Chao Phraya River at Borommathat Regulator of 270 km point from the river mouth by Chainat, and at Chanasutr Regulator and Yangmmanee Regulators point in Noi River distributed the irrigation water distributed to each command areas .
- On the other hand, the drainage channel system collecting the discharge supplied through irrigation channel and local rainfall is composed of six trunk channels: Noi Main Drain 1, 2 and 5 to 8.
- These drainage areas correspond to the following RID Project areas: Boromathad, Yangmanee, Phak Hai and Bang Ball(refer to Fig.7.2.1).
- The main drainage outlet is to Noi and Chao Phrayar Rivers. At each outlet of these drainage channels, a sluice with gates is installed with the capacity corresponding to that of drainage channel. No drainage pump is provided in the area.
- The area sometime receives the overflow water from the Chao Phraya River, resulting in severe flood damage.

Features of the area are summarized in Table 7.2.1.

(b) Identification of Main Issues on Flood in this Area

Based on the information collected and interview results, the issues on flood in this area is summarized as follows:

- In this area, flood damages have been sometimes reported.
- In general, local rainfall can be collected in the trunk drainage channel without causing serious inundation damage to the area along the drainage channel.
- Such collected rainfall water can be drained through the sluice and gate to the Noi and Chao Phraya rivers, when the river water level is not so high compared with that of drainage channel.
- However, the water level of the Chao Phraya river is sometimes relatively high during flood season, so that inland water can not be easily drained.
- Also, overflow from the Chao Phraya River has been sometimes reported, and it was very severe in 1995 flood. On the other hand, that from the Noi River has been scarcely reported, and even in 1995 flood, overflow was not reported, because of the flow discharge control through operation of gates at diversion points from the Chao Phraya River to Noi River.
- The drainage channel capacity is designed to receive the local rainfall corresponding to 5 year return period as the design criteria, it is expected that the inundation will occur in the event of local rainfall more than 5 year return period.
- Also, when such condition, that water level of the Noi and Chao Phraya Rivers is higher than the water level of drainage channel at the out let point, continues for a long time, the inundation comes out from near areas to the outlet point. Such condition according to the collected data is expected almost once every 3 years.
- In addition, when the inundation water volume becomes quite large in such near areas to the outlet point, excess inundation water flows down towards downstream and is confined and stored in the area at the confluence point between the Noi and Chao Phraya Rivers. The area is used for cultivation of floating rice endurable to the inundation.
- In 1995 flood, the water level of the Noi and Chao Phraya rivers was at bank full of the river channel for about 2 months. Eventually, the inland water could not drained and inundation was observed at several areas near the outlet points causing certain flood damage to the paddy field, mainly high yield variety.

Thus, the issues of the flood problem in this area are emphasized with the overflow from the Chao Phraya River and continuation of high water level in the outlet river channel, but not capacity of drainage channel.

Main issues of the area are summarized in Table 7.2.2 and Fig.7.2.5.

(c) Conceivable Measures for Drainage System Improvement

As discussed above, this area is provided by the drainage system with the safety level of about 3 year return period, so that flood problem may not be so severe in case the water level in the Noi and Chao Phraya Rivers is lower than that in the drainage area.

However, such drainage system is paralyzed, when it receives overflow water from the Chao Phraya River. Also, such drainage system cannot cope with the situation that the higher water level of the Chao Phraya and Noi Rivers continues for a long time.

To cope with the situation, the following measures are in principle considered:

- Heightening the dike along the Chao Phraya River.
- To provide the drainage pump to enhance the drainage capacity when the water level in the Noi and Chao Phraya Rivers is higher than that of drainage channel.
- Improvement of drainage channel with the outlet facilities from about 3 year return period.
- To provide retarding basin in the area, where the inundation water is detained.

For these measures, however, the following consideration is made:

- Heightening the dike along the Chao Phraya River naturally causes increase of flood discharge to the down stream, resulting in the increase of flood damage in the down stream. Therefore, the measures will not be accepted, unless it is assured that such influence would be within the safety level and be absorbed in the downstream.
- Provision of drainage pump also results in the increase of flood discharge in the downstream, when the flood discharge is full of the Chao Phraya and Noi Rivers. Consequently, the measures will not be accepted in the same reason as mentioned above.
- Improvement of drainage system may be necessary to enhance the safety level of the area. However, compared with the safety level of the Chao Phraya River with about 5 year return period, that of the drainage system is not so low. Therefore, the drainage system improvement should not be in a hurry, compared with the enhancement of the safety level of the Chao Phraya River itself.

Thus, the drainage system improvement in the area will not be given a higher priority compared with that in the other areas, though it may be higher than the area surrounded by Tha Chin and Noi Rivers.

The conceivable measures are shown in Table 7.2.3 and Fig.7.2.6.

(3) The Area surrounded by Chao Phraya and Lop Buri Rivers

(a) Features of Area

Features of the areas are summarized as follows:

- The area covers about 500 km2, where the dominant crops are deep water rice in the northern area and floating rice in the southern area(refer to Fig.7.2.1).
- As the topographic features, the area forming flat plain slightly reclines toward to South-West direction with the slope gradient of about 1/5,000(refer to Fig. 7.2.2 and 7.2.3).
- Irrigation canal distributed from the Chao Phraya River and Lop Buri Rivers.
- On the other hand, the drainage channel system collecting the discharge supplied through irrigation channel and local rainfall is composed of three trunk channels: Maharaj Main Drain 1 to 3.
- These drainage areas correspond to the Maharata and Khok Katiem Project areas of RID(refer to Fig.7.1.1).
- The main drainage outlets are to the Chao Phraya and Lop Buri Rivers. At each outlet of these drainage channels, a sluice with gates is installed with the capacity corresponding to that of drainage channel.
- The area sometime receives the overflow water from the Chao Phraya River and Lop Buri Rivers, resulting in severe flood damage.

Features of the area are summarized in Table 7.2.1.

(b) Identification of Main Issues on Flood in this Area

Based on the information collected and interview results, the issues on flood in this area is summarized as follows:

- In this area, flood damages have been sometimes reported.
- In general, local rainfall can be collected in the trunk drainage channel without causing serious inundation damage to the area along the drainage channel in the northern areas.
- Such collected rainfall water can be drained through the sluice and gate to the Chao Phraya and Lop Buri Rivers, when the river water level is not so high compared with that of drainage channel.
- However, the water level of the Chao Phraya and Lop Buri Rivers is sometimes relatively high during flood season, so that inland water can not be easily drained.
- Also, overflow from the Chao Phraya and Lop Buri Rivers has been sometimes reported. In 1995 flood, overflow from both rivers

was very severe causing inundation in wide area and with a long duration.

- The drainage channel capacity is designed to receive the local rainfall corresponding to 3 year return period as the design criteria, it is expected that the inundation will not occur in the event of local rainfall less than 3 year return period.
- When such condition, that water level of the Chao Phraya and Lop Buri Rivers is higher than the water level of drainage channel at the out let point, continues for a long time, the inundation comes out from near areas to the outlet point.
- In addition, when the inundation water volume becomes quite large in such near areas to the outlet point, excess inundation water flows down towards downstream and is confined and stored in the area at the confluence point between the Chao Phraya and Lop Buri Rivers. The area is used for cultivation of floating rice endurable to the inundation.
- In 1995 flood, the water level of the Chao Phraya and Lop Buri Rivers was at bank full of the river channel for about 2 months. Eventually, the inland water could not drained and inundation was observed at several areas near the outlet points, but not causing severe flood damage to the paddy field cultivating floating rice.

Thus, the issues of the drainage system in this area are emphasized with the overflow from the Chao Phraya River and Lop Buri Rivers, and continuation of high water level in the outlet river channel, but not capacity of drainage channel.

Main issues of the area are summarized in Table 7.2.2 and Fig.7.2.5.

(c) Conceivable Measures for Drainage System Improvement

As discussed above, this area is in principle provided by the drainage system with the safety level of about 3 year return period, so that flood damage due to local rainfall is not so severe in case the water level in the Chao Phraya and Lop Buri Rivers is lower than that in the drainage area.

However, such drainage system is paralyzed, when it receives overflow water from the Chao Phraya and Lop Buri Rivers. Also, such drainage system cannot cope with the situation that the higher water level of the Chao Phraya and Noi Rivers continues for a long time.

To cope with the situation, the following measures are in principle considered:

- Heightening the dike along the Chao Phraya and Lop Buri Rivers.
- To provide the drainage pump to enhance the drainage capacity when the water level in the Chao Phraya and Lop Buri Rivers is higher than that of drainage channel.

- Improvement of drainage channel with the outlet facilities from about 3 year return period.
- To provide retarding basins in the area, where the inundation water is detained.
- To provide the drainage channel to drain the inundation water to the area in the further downstream. However, it is not an acceptable measures when the severe inundation problem in the down stream is considered.

For these measures, however, the following consideration is made:

- Heightening the dike along the Chao Phraya River naturally causes increase of flood discharge to the down stream, resulting in the increase of flood damage in the down stream. Therefore, the measures will not be accepted, unless it is assured that such influence would be within the safety level and be absorbed in the downstream.
- Provision of drainage pump also results in the increase of flood discharge in the downstream, when the flood discharge is full of the Chao Phraya and Noi Rivers. Consequently, the measures will not be accepted in the same reason as mentioned above.
- Improvement of drainage system may be necessary to enhance the safety level of the area. However, compared with the safety level of the Chao Phraya River with 5 year return period, that of the drainage system is not so low.
- To provide the drainage channel to drain the inundation water to the area in the further downstream may not be an acceptable measure, when the severe inundation problem in the down stream is considered.

Therefore, the drainage system improvement may not be in a hurry, compared with the enhancement of the safety level of the Chao Phraya River itself. But a higher priority will be given among the areas in higher delta.

The conceivable measures are shown in Table 7.2.3 and Fig.7.2.6.

(4) The Area surrounded by Lop Buri and Pasak Rivers and Chainat-Pasak Irrigation Canal

(a) Features of Area

Features of the areas are summarized as follows:

- The area covers about 500 km2, where the high yield variety is cultivated in the relatively higher area, while deep water and floating rice are planted in the low land near confluence point between the Lop Buri and Pasak Rivers(refer to Fig.7.2.1).

- As the topographic features, the area forming flat plain slightly reclines toward to South-East direction with the slope gradient of about 1/5,000(refer to Fig. 7.2.2 and 7.2.3).
- Irrigation canal distributed from the Pasak-Chai Nat canal and the Chai Nat-Ayutthaya canal with a capacity of about 210 m3/s and 75 m3/s at maximum, respectively.
- On the other hand, the drainage channel system collecting the discharge supplied through irrigation channel and local rainfall is composed of three trunk channels:Maharaj Main Drain 1 to 3.
- These drainage areas in principle correspond to the Khok Katiem and Roeng Rang Project areas of RID(refer to Fig.7.1.1).
- The main drainage outlets are to Lop Buri and Pasak Rivers. At each outlet of these drainage channels, a sluice with gates is installed with the capacity corresponding to that of drainage channel. No drainage pump is provided in the area.
- The area sometime receives the overflow water from the Lop Buri and Pasak Rivers, resulting in severe flood damage.

Features of the area are summarized in Table 7.2.1.

(b) Identification of Main Issues on Flood in this Area

Based on the information collected and interview results, the issues on flood in this area is summarized as follows:

- In this area, flood damages have been sometimes reported.
- In general, local rainfall can be collected in the trunk drainage channel without causing serious inundation damage to the area along the drainage channel in the north-eastern areas.
- Such collected rainfall water can be drained through the sluice and gate to the Lop Buri and Pasak Rivers, when the river water level is not so high compared with that of drainage channel.
- However, the water level of the Lop Buri and Pasak Rivers is sometimes relatively high during flood season, so that inland water can not be easily drained.
- Overflow from the Pasak River and Lop Buri River has been sometimes reported. In 1995 flood, overflow from both rivers was very severe causing inundation in wide area and with a long duration.
- The drainage channel capacity is designed to receive the local rainfall corresponding to 3 year return period as the design criteria. Therefore, it is expected that the inundation will not occur in the event of local rainfall less than 3 year return period.
- When such condition, that water level of the Lop Buri and Pasak Rivers is higher than the water level of drainage channel at the out

let point, continues for a long time, the inundation comes out from near areas to the outlet point.

- In addition, when the inundation water volume becomes quite large in such near areas to the outlet point, excess inundation water flows down towards downstream and is confined and stored in the area at the confluence point between the Lop Buri and Pasak Rivers. The area is used for cultivation of floating rice endurable to the inundation.
- In 1995 flood, the water level of the Lop Buri and Pasak Rivers was at bank full of the river channel for about 2 months. Eventually, the inland water could not be drained and inundation was observed at wide area near the outlet points, causing severe flood damage to the paddy field cultivating high yield variety but not floating rice.

Thus, the issues of the drainage system in this area are emphasized with the overflow from the Lop Buri and Pasak Rivers, and continuation of high water level in the outlet river channel, but not capacity of drainage channel.

Main issues of the area are summarized in Table 7.2.2 and Fig.7.2.5.

(c) Conceivable Measures for Drainage System Improvement

As discussed above, this area is in principle provided by the drainage system with the safety level of about 5 year return period, in case the water level in the Lop Buri and Pasak Rivers is lower than that in the drainage area.

However, such drainage system is paralyzed, when it receives overflow water from the Lop Buri and Pasak Rivers. Also, such drainage system cannot cope with the situation that the higher water level of the Lop Buri and Pasak Rivers continues for a long time.

To cope with the situation, the following measures are in principle considered:

- Heightening the dike along the Lop Buri and Pasak Rivers.
- To provide the drainage pump to enhance the drainage capacity when the water level in the Lop Buri and Pasak Rivers is higher than that of drainage channel.
- Improvement of drainage channel with the outlet facilities from about 3 year return period.
- To provide the drainage channel to drain the inundation water to the area in the further downstream.

For these measures, however, the following consideration is made:

- Heightening the dike along the Lop Buri and Pasak Rivers naturally causes increase of flood discharge to the down stream,

resulting in the increase of flood damage in the down stream. Therefore, the measures will not be accepted, unless it is assured that such influence would be within the safety level and be absorbed in the downstream.

- Provision of drainage pump also results in the increase of flood discharge in the downstream, when the flood discharge is full of the Lop Buri and Pasak Rivers. Consequently, the measures will not be accepted in the same reason as mentioned above.
- To provide the drainage channel to drain the inundation water to the area in the further downstream may not be an acceptable measure when the severe inundation problem in the down stream is identified.

Improvement of drainage system may be necessary to enhance the safety level of the area. However, compared with the safety level of the Lop Buri and Pasak Rivers with 5 year return period, that of the drainage system is not so low. Therefore, the drainage system improvement may not be in a hurry, compared with the enhancement of the safety level of the Lop Buri and Pasak Rivers themselves. In case implementation of drainage system improvement, a higher priority of implementation will be given among the drainage areas in higher delta.

The conceivable measures are shown in Table 7.2.3 and Fig.7.2.6.

7.3 Study on Lower Delta

(1) East Bank Area of the Chao Phraya River

(a) Features of Area

The outline of existing drainage system in the East Bank Area is shown in Fig.7.3.1 and the features of the areas are summarized as follows (refer to Table 7.2.1 and Fig.7.2.5):

- The area covers about 4,400 km2, where the high yield variety is in general cultivated in the paddy field and plantation of tree crops is dominant with amount of 70 % of the total agricultural areas(refer to Fig.7.2.1). In the most down stream areas, many fish ponds are also operated, though these agricultural areas in the most down stream areas tend to decrease in accordance with the expansion of urban areas.
- As the topographic features, the area forming flat plain, but slightly reclines toward coastal line with the slope gradient of about 1/50,000(refer to Fig. 7.2.2 and 7.2.3). Compared with that of the upstream areas, the gradient is further more gentle, so that direction of water flow is hardly identified. In the flat plain, several depression areas due to land subsidence or other reasons are observed.

- In this area, three major irrigation canals with direction from east to west have been provided from the Pasak-Raphipat Irrigation Canal. The area is divided by these irrigation canals into 4 major project areas, among which two areas are further divided into two areas, forming 6 project areas in total. They are Nakhon Luan, Pakak Tai, Rangsit Nua, Rangsit Tai, Khlong Dan and Phra Ong Chai Ya Nuchit project areas(refer to Fig.7.1.1).
- From the major irrigation canals, secondary irrigation canals in parallel with drainage channels, have been provided in the direction from North to South. Among the above project areas, the irrigation canal system in the areas of Rangsit Nua and Rangisit Tai has been well developed.
- The drainage channel system collecting the discharge supplied through irrigation canal and local rainfall is composed of six trunk channels: K. Rapeepat, K. Rangsit, K. Hok Wa, K. Sansab, K.Pravet Buriram and K. Sumrong. Since the gradient of the drainage channel is quite gentle, these channels can hardly transfer the discharge toward to the direction of the outlets.
- The major outlets of these drainage channels are to the Chao Phraya River, Bang Pakong River including Nakhon Nayok, and Sea passing through the other project areas located in the down stream. The share of the drainage in case of Rangsit Tha Irrigation Project is roughly evaluated as shown in Table 7.3.1 (14 % to the Chao Phraya River, 18 % to Bang Pakong River including Nakhon Nayok and 46 % to the Sea).
- In these channel, capacities of Raphipat and Rangsit canals are 50 m3/s and 50 m3/s, respectively. In this connection, the channel capacities connecting the upstream area to down stream area are presented as in Fig. 7.3.1.
- At each outlet of these drainage channels, which are connected to the Choa Phraya and Bang Pakong Rivers and Sea, sluices with gates are installed with the capacity corresponding to that of drainage channel. Besides, at the outlets to the Nakhon Nayok and Sea, drainage pump with the capacity of 501.5 m3/s in total, 303m3/s to the sea, 102m3/s to Bang Pakong and 96.5m3/s to the Chao Phraya River, has been provided (refer to Fig.7.2.4).

(b) Inundation Condition in Past Floods

Inundation conditions in past floods are as follows:

- In the areas, recent severe inundation occurred in 1983, 1990 and 1995. Those in 1983 and 1990 were caused by continuing local heavy rainfall for several weeks in the area. While that in 1995 was caused by overflow from the Pasak and Chao Phraya Rivers as well as heavy local rainfall.
- The flood inundation were first observed in the areas along the three irrigation canals, and these inundation water gradually moved

toward lower area along the coastal line and retained for a long time because of difficulty to drain to the sea.

- Inundation also occurs near the outlet points to the Chao Phraya, Nakon Nayok and Bang Pakong Rivers due to continuation of high water level of these rivers.

(c) Identification of Main Issues on Flood in this Area

Based on the information collected and interview results, the issues on flood in this area are discussed dividing into basin wide ones and individual ones of six (6) project areas follows (refer to Table 7.2.1 and Fig.7.2.5):

Basin-wide Issues on Flood

The issues on flood from basin-wide points of view are summarized as follows:

- As mentioned above, one of the flood issues is poor capacity of drainage channels to transfer local rainfall mainly due to too much gentle gradient.
- Also, poor drainage facilities to drain the inundation water to the river or sea which is attributed to so much water collected to the outlet.
- The overflow from the Chao Phraya and Pasak Rivers are also one of causes of the severe inundation.

Individual Issues of Six (6) Project Areas

Issues of each project area are summarized as follows:

(i) Nakhon Luang Project Area

Issues in Nakhon Luang Project Area are as follows:

- In the project area, the irrigation and drainage system is relatively well arranged, but no drainage pump is installed in the area.
- However, the inland water is hardly drained to the Chao Phraya River when the water level is high.
- The drainage facility to directly drain to the downstream project area of Rangsit Nua is controlled so that the flood water flows down within an allowable extent which will not cause the inundation problem in the downstream area.
- As the major issue on drainage system, overflow from the Pasak and Chao Phraya Rivers is emphasized, though this area plays a role of retarding basin to mitigate the flood discharge to the Chao Phraya River.

(ii) Pasak Tai Project Areas

Likewise with the Nakhon Luang project area, the main issues in the project area are as follows:

- In the project area, the irrigation and drainage system is relatively well arranged, but no drainage pump is installed in the area.
- However, the inland water is hardly drained to the Nakhon Nayok River when the water level is high, so that only the way to soften the inundation problem is to drain the inundation water to drain to the downstream project area during such period.
- The drainage facility to directly drain to the downstream project area of Rangsit Nua is controlled so that the flood water flows down within an allowable extent which will not cause the inundation problem in the downstream area.
- One of the main issues is overflow from the Pasak River and discharge coming from outside basin through Pasak-Raphipat irrigation channel.

(iii) Rangsit Nua Project

The main issues in these project areas are specified as follows:

- In this area, drainage system is well arranged, so that inundation due to local rainfall is not so severe. Local rainfall can be collected by the drainage channels and transferred to the outlets, mainly to the Chao Phraya River and the other project area (Rangsit Tai) located in the down stream.
- However, the inland water is hardly drained to the Chao Phraya River when the water level is high, so that drainage pump with the capacity of 15m3/s to Nakon Nayok has been provided.
- The drainage facility to directly drain to the downstream project area of Rangsit Tai is also controlled, so that the flood water flows down within an allowable extent which will not cause the inundation problem in the downstream area.
- The main issues in this area are emphasized with the continuation of high water level in the Chao Phraya River, so that inundation water can hardly be drained. Installation of drainage pump to cope with the situation has the constraints since the drainage to Chao Phraya River may cause the influence to the Bangkok Metropolitan Area.
- Therefore, it is no other measures than drainage to the other project area located in the down stream, although such excess inundation water to the downstream project area also causes damage in downstream area.

(iv) Rangsit Tai

The main issues in these project areas are specified as follows:

- In this area, drainage system is well arranged, so that inundation due to local rainfall is not so severe. Local rainfall can be collected by the drainage channels and transferred to the outlets, mainly to the Nakhon Nayok River, and also to the Choa Phraya River.
- The local rainfall is also drained to the other project areas (Khlong Dan and Phra Ong Chai Ya Nuchit) located in the down stream.
- However, the inland water is hardly drained to the Nakhon Nayok and Cho Phraya Rivers when the water level is high, so that drainage pump with the capacity of 33m3/s and 96.5m3/s, respectively, has been provided to cope with the situation.
- Due to the topographic constraint, it is very difficult to drain the inundation water to the Nakhon Nayok. Eventually, some of the inundation water is drained to the down stream project areas.
- Although the drainage to the downstream project areas of Khlong Dan and Phra Ong Chai Ya Nuchit is controlled, sometimes it has no choice but to drain to the downstream to mitigate flood damage, which may cause the adverse influence in the down stream areas.
- So, the main issue in this area is emphasized with the less possibility to drain the inundation water to the outer areas, without causing the adverse influence.

(v) Phra Ong Chai Ya Nuchit Area

The main issues in these project areas are specified as follows:

- In this area, drainage system is not well arranged because of the topographic constraint; the area is very low and flat forming a depression area surrounded by slightly higher project area in the up-steam and coastal terraced land. Consequently, it is very difficult to have a gradient of channel to drain to the sea.
- Even the mechanical drainage by pump faces the difficulty to collect the inundation water in the area. Only the water near around of the pump can be collected but the water in further area cannot be collected because of the less gradient of the drainage channel.
- Some of inundation water can be drained to the Bangphakon River by gravity and by pump. The pump capacities to drain Bamapkong River and the sea are 48m3/s and 96m3/s, respectively.

- However, when the water level of Bangphakon River is at the full bank level for a long time, drainage by pump can not be used, though the situation does not come out so often.

(vi) Khlong Dan Project Area

The main issues in these project areas are specified as follows:

- This area is located between Bangkok Metropolitan Area to the West Border and Phra Ong Chia Ya Nuchit Project area to the East. In this area, the sea is the only one possible outlet to drain the inundation water without causing an adverse influence.
- In this area as well as Phra Ong Chai Ya Nuchit Project area, drainage system is not well arranged because of the topographic constraint; the area is very low and flat forming a depression area surrounded by slightly higher project area in the up-steam and coastal terraced land in the down stream. Consequently, it is very difficult to drain the discharge by gravity because of too gentle gradient of channel, so that it is necessary to provide drainage pump. The pump capacity to drain the sea is 207m3/s in total.
- Even the mechanical drainage by pump faces the difficulty to collect the inundation water in the area. Only the water near around of the pump can be collected but the water in further area cannot be collected because of the gentle gradient of the drainage channel.

(d) Conceivable Measures for Drainage System Improvement

As discussed above, this area is facing the serious inundation problem with frequent from damage. To cope with the situation, it seems to be necessary to approach the whole six (6) project areas, which have close relation on the inundation problem each other.

Consideration of Topographic Constraint in the Area

Judging from the discussion above, the following constrains for improvement of drainage system in the area, are considered:

- As the outlets to drain the inundation water, it may be difficult to apply the Chao Phraya, Nakhon Nayok and Bangphakhon Rivers, since the water level of these rivers are at almost full bank water level due to tidal influence in combination of flood discharge. Furthermore, discharge to these rivers may cause an adverse influence in the down stream.
- Only the possible outlet, which will not cause the adverse influence, is to the sea.

- However, to drain inundation water to the sea may require the installation of drainage pump, since the inundation water level is lower than sea water level during high tide.
- Besides, to collect the inundation water at the drainage outlet to the sea is also difficult due to gentle gradient.

Conceivable Measures to cope with the Constraint

Under the above circumstances, the following measures are conceived to cope the constraint

(i) Measures to enhance the Retarding Function

To alleviate the volume to be drained to the sea, it is considered to enhance the retarding function in the following manner:

- To share the inundation water in each project area as long as possible, but not to discharge to the project area in the downstream resulting in the concentration of inundation water in the most downstream.
- To provide retarding areas in each project area.
- To provide large scale retarding area concentrating in the most downstream.

(ii) Measures to enhance the Drainage Capability to the Sea

To enhance the drainage capability, the following measures are conceived:

- Increase the capacity of existing drainage channel together with drainage pump.
- To provide a new drainage channel connecting the relatively higher area to the sea, so that inundation water can be drained by gravity, while only inundation water in a lowland area is drained by pump.
- To provide a new drainage channel in a manner of underground pipe to directly drain the inundation water to the sea.
- To provide a large scale drainage channel collecting the inundation water from the whole inundation area by pump, and the inundation water collected in such a drainage channel is drained by gravity. (This large scale drainage channel can also play a role as a flood diversion channel from the Chao Phraya river.)

(iii) Combination of (i) and (ii)

Combination of the measures of (i) and (ii) is also conceived.

(iv) Enhancement of the Drainage Capacity to Nakhon Nayok and Bang Pakong Rivers

It is also worth studying the possibility to enhance the drainage capacity of existing drainage system to Nakhon Nayok and Bang Pakong Rivers.

To select the optimum measures among several conceive measures, it is necessary to conduct further detail study, since the inundation condition in the area is very sensitive and complicated. In this study, only general consideration of the measures is made as shown in Table 7.2.3 as well as the conceivable measures. (Refer to Fig.7.2.6)

(2) West Bank Area of the Chao Phraya River

Similarly to the East Bank Area of the Chao Phraya River, the drainage problem in this area is discussed as follows:

(a) Features of Area

Features of the areas are summarized as follows:

- The area covers about 2,400 km2, where the high yield variety is in general cultivated in the paddy field and plantation of tree crops is dominant with amount of 92 % of the total agricultural areas (refer to Fig.7.2.1). In the most down stream areas, many fish ponds are also operated, though these agricultural areas in the most down stream areas tend to decrease in accordance with the expansion of urban areas.
- As the topographic features, the area forming flat plain, but slightly reclines toward coastal line with the slope gradient of about 1/60,000(refer to Fig. 7.2.2 and 7.2.3). Compared with that of the upstream areas, the gradient is further more gentle, so that direction of water flow is hardly identified. In the flat plain, several depression areas are observed.
- In this area, six (6) major irrigation canals with direction from east to west have been provided from the Tachin or Chao Phraya Rivers: K.Bnag Yeehon, K.Phraya Bunlue, K.Phraypimol, K.Maha Sawat, K. Sri Wa Pasawat and K.Chok Krabu(refer to Fig.7.1.1).
- The area is divided by these irrigation canals into 4 major project areas. They are Chao Ched Bang Yeehon, Phrayabunlue, Phrapimol and Pasichroen.
- From the major irrigation canals, secondary irrigation canals network in parallel with drainage channels have been provided in the direction from North to South as well as from East to West.
- The drainage channel system collecting the discharge supplied through irrigation canal and local rainfall is composed of six trunk channels: K.Bang Yeehon, K. Phraya Banlue, K. Prapimol, K. Mahasawat, K. Pasri Charoen and K.Maha Chai. Since the gradient

of the drainage channel is quite gentle, these channels can hardly transfer the discharge toward to the direction of the outlets.

- The major outlets of these drainage channels are to the Chao Phraya River, Tha Chin River and Sea passing through the other project areas located in the down stream.
- In above-mentioned channels, the canal capacities of K.Bang Yeehon, K. Phraya Banlue, K. Prapimol, K. Mahasawat and K. Pasri Charoen are 80 m3/s, 100m3/s, 75m3/s, 50m3/s and 120m3/s, respectively. In this connection, the channel capacities connecting the upstream area to down stream area are presented as in Fig.7.3.1.
- At each outlet of these drainage channels, which are connected to the Choa Phraya and Tha Chin Rivers and Sea, sluices with gates are installed with the capacity corresponding to that of drainage channel. Besides, to drain the inland water to the Tha Chin and Sea, drainage pump with the capacity of 140 m3/s in total has been provided.

Features of the area are summarized in Table 7.2.1.

(b) Inundation Condition in Past Floods

Inundation conditions in past floods are as follows:

- In the areas, recent severe inundation occurred in 1983, 1990 and 1995. Those in 1983 and 1990 were caused by continuing local heavy rainfall for several weeks in the area, but compared with that of East bank area, the inundation was not so severe. While that in 1995 was caused by overflow from the Chao Phraya Rivers.
- The flood inundation were first observed in the areas along the three irrigation canals, and these inundation water gradually moved toward lower area along the coastal line and retained for a long time because of difficulty to drain to the sea.
- Inundation also occurs near the outlet points to the Chao Phraya and Tha Chin Rivers due to continuation of high water level of these rivers.

(c) Identification of Main Issues on Flood in this Area

Based on the information collected and interview results, the issues on flood in this area are discussed dividing into basin wide ones and individual ones of four (4) project areas follows (refer to Table 7.2.2 and Fig.7.2.5):

Basin-wide Issues on Flood

The issues on flood from basin-wide points of view are summarized as follows:

- As mentioned above, one of the flood issues is poor capacity of drainage channels to transfer local rainfall mainly due to quite gentle gradient.
- Also, poor drainage facilities to drain the inundation water to the river or sea which is attributed to so much water collected to the outlet.
- The overflow from the Chao Phraya and Tha Chin Rivers are also one of causes of the severe inundation.

Individual Issues of Four (4) Project Areas

Issues of each project area are summarized as follows:

(i) Chao Ched Bang Yechon Project Area

Issues in Choa Ched Bang Yeehon Project Area are as follows:

- In the project area, the irrigation and drainage system is relatively well arranged. and drainage pump with a capacity of 24 m3/s is provided to drain to the Tha Chin River.
- However, the inland water is hardly drained to the Chao Phraya River when the water level is high.
- The drainage facility to directly drain to the downstream project area of Phrayabantue is controlled so that the flood water flows down within an allowable extent which will not cause the inundation problem in the downstream area.
- As the major issue on drainage system, overflow from the Tha Chin and Chao Phraya Rivers is emphasized, though this area plays role of retarding area to mitigate the flood discharge to the Chao Phraya River.

(ii) Pharayabantue Project Areas

Likewise with the Chao Ched Bang Yeehon project area, the main issues in the project area are as follows:

- In the project area, the irrigation and drainage system is relatively well arranged.
- However, the inland water is hardly drained to the Tha Chin and Chao Phraya Rivers when the water level is high, so that drainage pump with a capacity of 24m3/s has been provided to drain only to the Tha Chin River.
- The drainage facility to directly drain to the downstream project area of Phrapinmol is controlled so that the flood water flows down within an allowable extent which will not cause the inundation problem in the downstream area.
- One of the main issues is overflow from the Tha Chin and Chao Phraya Rivers.

(iii) Pharpimol Project Area

The main issues in the project area are specified as follows:

- In this area, drainage system is well arranged, so that inundation due to local rainfall is not so severe. Local rainfall can be collected by the drainage channels and transferred to the outlets, mainly to the Tha Chin and Chao Phraya Rivers and the other project area (Pasicharoen) located in the down stream.
- However, the inland water is hardly drained to the Tha Chin and Chao Phraya Rivers when the water level is high, so that drainage pump with a capacity of 18m3/s has been provided to drain only to the Tha Chin River.
- The drainage facility to directly drain to the downstream project area of Pasicharoen is also controlled, so that the flood water flows down within an allowable extent which will not cause the inundation problem in the downstream area.
- The main issues in this area is emphasized with the continuation of high water level in the Tha Chin and Chao Phraya Rivers, so that inundation water can hardly be drained. Therefore, it is no other measures than drainage to the other project area located in the down stream. Eventually, excess inundation water to the downstream project area causes damage in such downstream area.

(iv) Pachicharoen Project Area

The main issues in these project areas are specified as follows:

- In this area, drainage system is not well arranged because of the topographic constraint; the area is very low and flat forming a depression area surrounded by slightly higher project area in the up-steam and coastal terraced land in the down stream. Consequently, it is very difficult to drain the discharge by gravity because of too gentle gradient of channel, so that it is necessary to provide drainage pump.
- The drainage pump capacity provided to drain the sea is 36m3/s in total.
- Even the mechanical drainage by pump faces the difficulty to collect the inundation water in the area. Only the water near around of the pump can be collected but the water in further area cannot be collected because of the gentle gradient of the drainage channel.

(d) Conceivable Measures for Drainage System Improvement

As discussed above, this area is facing the serious inundation problem with frequent from damage. To cope with the situation, it seems to be

necessary to approach the whole four (4) project areas, which have close relation on the inundation problem each other.

Consideration of Topographic Constraint in the Area

Judging from the discussion above, the following constrains for improvement of drainage system in the area, are considered:

- As the outlets to drain the inundation water, it may be difficult to apply the Tha Chin and Chao Phraya Rivers, since the water level of these rivers are at almost full bank water level due to tidal influence in combination of flood discharge. Furthermore, discharge to these rivers may cause an adverse influence in the down stream.
- Only the possible outlet, which will not cause the adverse influence, is to the sea.
- However, to drain inundation water to the sea may require the installation of drainage pump, since the inundation water level is lower than sea water level during high tide.
- Besides, to collect the inundation water at the drainage outlet to the sea is also difficult due to gentle gradient.
- And the other possible alternative is to enhance the flow capactiy of the Tha Chin River by heightening the dike and to drain the inundation water to the Tha Chin River by pump, though it also involves the difficulty of collection of inundation water.

Conceivable Measures to cope with the Constraint

Under the above circumstances, the following measures are conceived to cope with the constraint:

(i) Measures to enhance the Retarding Function

To alleviate the inundation water volume to be drained to the sea, it is considered to enhance the retarding function in the following manner:

- To share the inundation water in each project area as long as possible, but not to discharge to the project area in the downstream, which results in the concentration of inundation water in the most downstream.
- In this connection, it is considered to provide retarding areas in each project area.
- To provide large scale retarding area concentrating in the most downstream.

(ii) Measures to enhance the Drainage Capability to the Tha Chin River

To enhance the drainage capability, the following measures are conceived:

- Increase the flow capacity of the Tha Chin River through embankment of theTha Chin River.
- Increase the capacity of existing drainage channel together with drainage pump to drain the Tha Chin River.

(iii) Measures to enhance the Drainage Capability to the Sea

To enhance the drainage capability to the Sea, the following measures are conceived:

- Increase the capacity of existing drainage channel together with drainage pump.
- To provide a new drainage channel connecting the relatively higher area to the sea.
- To provide a large scale drainage channel collecting the inundation water from the whole inundation area by pump. (This large scale drainage channel can also play a role as the diversion channel from the Chao Phraya river, when such a large scale drainage channel is connected to the Chao Phraya River.)

(iv) Combination of (i), (ii) and (iii)

Combination of the measures of (i), (ii) and (iv) is also conceived.

To select the optimum measures among several conceivable measures, it is necessary to conduct further detail study, since the inundation condition in the area is very sensitive and complicated. In this study, general consideration of these measures are described as shown in Table 7.2.3 as well as the conceivable measures (refer to Fig.7.2.6).

7.4 Consideration of Priority of the Areas for Implementation

In this section, priority of the areas for implementation of the drainage system improvement is discussed. In the area, the drainage problem is very severe and complicated, so that it is not easy task to put the priority for implementation of drainage system improvement, unless more detailed survey is undertaken.

Herein, the priority is put in the rough evaluation of flood inundation as shown below:

(1) Rough Evaluation based on the Hydraulic Conditions

For the prioritization of the divided areas, hydraulic condition is roughly examined to evaluated the seriousness of the drainage system improvement in the following procedure:

- Comparison of ground height of the drainage areas and river water level at the drainage outlet point: (the difficulty of the drainage is roughly identified through this comparison.)
- Rough evaluation of water balance in the Paddy field during high water level: (the inundation volume can be roughly estimated through the examination of water balance in the paddy field)
- Rough evaluation of inundation area based on the water balance

Since the data available to perform the above evaluation, the typical areas among the divided areas are picked up as discussed below:

(a) Higher Delta

In higher delta, the area is divided into four (4) areas, among which the area surrounded by Choa Phraya and Lop Buri Rives seems to have the most severe drainage problem, since the water level of the drainage outlet is of the Choa Phraya River.

Herein, the area surrounded by Chao Phraya and Lop Buri Rivers is picked up to evaluate the seriousness of the inundation problem:

(i) Comparison of River Water Level and Ground Height

There exists only one water level at Angthong, which has a relatively long term water level record of the Chao Phraya River. The ground height of the drainage area near the Angthong is about EL+5.0 m. The comparison of the water level at the Angthong and ground level for 20 years is shown in Fig. 7.4.1 and Table 7.4.1. As revealed from the comparison, the water level of the Chao Phraya River was over the ground height at nine (9) times. The duration over the ground height is in the range between 20 days and 97 days and about 45 days on an average.

Thus, the area has a difficulty of drainage to the Chao Phraya River for relatively a long time and frequently.

(ii) Water Balance in Paddy Field During High Water Level

The water balance in paddy field during the period while the water level is over the ground height is roughly examined to know the inundation volume in the drainage area in the following premises (refer to Fig. 7.4.2):

- The water balance is examined in one unit of paddy field with an area of 1 ha.
- As the inflow of drainage area, accumulated rainfall during the period of water level over the ground height is applied. As the rainfall, average basin rainfalls is applied.

- As the loss of inflow to drainage area, consumptive use of water (CUW) of 6 mm is deducted from the accumulated rainfall.
- The water depth in the field at the time of start of water balance calculation is assumed at 10 cm.

According to the water balance, rainfall can be detained six (6) times out of nine (9) times for 20 years in the paddy field, while excess water from each paddy field is expected only four (4) times. These are in the cases of 1978, 1979, 1983 and 1995 floods. The excess water volume for 100 km2 of paddy field would be 0.9, 1.9, 14.0 and 8.0 million m3, respectively, which are inundated in the lowland around the outlet.

With this inundation water volume, the maximum inundation water depth is examined in a sample area of Ban Bal with the drainage area of 92.5 km2, one of the lowest areas in the higher delta, applying water level (H) and inundation volume (V) relation. (Refer to Fig.7.4.3)

The maximum water levels for these floods are 0.2m, 0.4m, 0.8m and 0.6 m of water depth, while the inundation areas are 2km2, 6km2, 45km2 and 30km2, respectively.

In general, in such inundation area, a variety of paddies endurable to a long term inundation such as floating rice and deep water rice is cultivated, so that the inundation damage is minimal. Furthermore, such frequency to have inundation due to local rainfall is not high only 4 times for 20 years.

Thus, the inundation condition by local rainfall may not be so serious unless the overflow from the Chao Phraya or other rivers occurs.

(b) Lower Delta

In lower delta, the area is broadly divided into two (2) areas; East Bank side and West Bank side. Since the drainage condition of both sides is similar, that of East Bank is mainly discussed herein. The East Bank area is further divided into 6 project areas. To identify the drainage problem among these project areas, two typical areas, Rangsit Tai and Khlong Dan project areas, are examined:

Rangsit Tai Project Area (A=925km2)

(i) Comparison of Water Level at Outlet and Ground Height

According to the information, the inundation water is drained to three directions: to Chao Phraya River, to Nakhon Nayok River and the other project area located downstream, Khlong Dan.

Among these drainage directions, the possibility of Chao Phraya River is examined through the comparison between ground level and water level of the Chao Phraya River.

As the ground level, M.S.L+1.0 m is applied based on the topographic map, while the water level at Memorial Bridge is adopted as that of the Chao Phraya River. According to the water level data at Memorial Bridge, the following features are pointed out:

- The data for 82 years from 1914 to 1996 shows the water levels of the recorded maximum, average and minimum are M.S.L.+2.27 m, 1.64 and 1.17, respectively (refer to Fig.7.4.4).
- The fluctuation of the water level during the flood is about 1m, and duration of flood lasts about three months.
- From the situation, even in the average flood event, water level at the Choa Phraya River is higher than the ground height for several days.
- Thus, the gravity drainage at this point is in principle difficult during the period while the water level is higher than the ground level. Even the time the water level is lower than the ground level, the water volume drained by gravity is very limited due to quite gentle drainage channel gradient.
- Such situation may be verified from the fact that drainage by pump is indispensable for the Bangkok Metropolitan Area during flood. Furthermore, it is not recommendable to drain inundation water from farmland to the Chao Phraya River by pump, which results in raise of water level and causes the flood damage in Bangkok Metropolitan Area.

Since the situation seems to be similar in Nakhon Nayok River, which is also affected by tidal influence during flood, the conceivable way of drainage of inundation water is to drain to the other project areas in the downstream or to reserve the excess inundation water in the retarding areas inside the project area.

(ii) Water Balance in the Drainage Area

To roughly evaluate the water balance in the drainage area, those of several floods for these 21 years from 1976 to 1996 are examined assuming the period to detain the inundation water is about three month. Table 7.4.2 shows the results of water balance. According to the results, the following conditions are observed:

- During these 21 years, the overflow from the paddy dike is observed at 14 times, roughly corresponding to once every 1.5 years. The maximum inundation occurred in 1983, and 1990 and 1995 are followed.

- However, among these, relatively serious inundation with the inundation area more than 100 km2 is observed at 7 times, roughly corresponding to once every three years, assuming that all overflow water inundates in the downstream without drainage to the river or downstream.
- Actually, most of the inundation water is to drain to the down stream and the inundation due to local rainfall may not be so severe as long as the project area concerned.
- However, when the area receives the additional flood water from the other area such as the project area in the upstream or from the Chao Phraya River, the situation will be worsened.

Khlong Dan Project Area (A=910km2)

(i) Comparison of Water Level at Outlet and Ground Height

Due to topographic and land use constraint, the inundation water in this project area is drained to only the sea.

The possibility to drain to the sea is examined through the comparison between ground level and water level of the sea.

As the ground level, M.S.L+0.5 m is applied based on the topographic map, while the tidal level at Pom Phrachul is adopted as that of the sea. According to the water level data at Pom Phrachul, the following features are pointed out:

- The data for 57 years from 1940 to 1996 shows the tidal levels of the maximum, average and minimum among the annual maximum water levels are M.S.L.+2.11 m, 1.76 and 1.53, respectively (refer to Fig.7.4.5).
- The fluctuation of the water level is between 1 and 2 m, which implies the duration of higher tidal level than ground level of 0.5m is about 50% of a day.
- From the situation, the gravity drainage to the sea is in principle difficult during higher tidal level.
- Even the time the tidal level is lower than the ground level, the water volume drained by gravity is very limited due to quite gentle drainage channel gradient.
- Such situation may be verified from the fact that drainage by pump is applied in the coastal areas. However, drainage by pump is also constrained, since the inundation water is hardly collected at the pump station due to quite gentle drainage channel gradient.

(ii) Water Balance in the Drainage Area

The water balance in the drainage area is similar to that in the Rangsit Thai Project area, which shows the following features:

- During these 21 years, the overflow from the paddy dike is observed at 14 times, roughly corresponding to once every 1.5 years (Table 7.4.3).
- The inundation volume, assuming that the total water volume of the above overflow causes inundation, is 240 million m3 in 1983 at maximum with the inundation area of 580 km2 and 140 million m3 in 1990 and 130 million m3 in 1995 follow.
- Since the most of inundation volume may be drained by drainage pump with the total capacity of 303 m3/s to the sea, corresponding to the capacity of about 30 million m3/day. However, judging from the topographic condition, the issue is to be difficult to collect the all inundation water so smoothly.
- Furthermore, the area is obliged to receive the additional flood water from the other area such as the project area in the upstream and overflow from the Chao Phraya River. The total of the project areas in the upstream is about 4 times of this project area, while the overflow water from the Chao Phraya River amounts to the order of 600 million m3 in case of 1996 flood and 1,200 million m3 in case of 1995 flood. Thus, the inundation situation will be worsened.

(2) Priority for Six (6) Divided Areas

As discussed earlier, the objective drainage areas are broadly divided into two areas: higher delta and lower delta, which are further divided into four (4) areas in a higher delta and two (2) areas in a lower delta.

(a) Priority Among Higher and Lower Delta

In comparison between higher and lower delta to put the priority, the following consideration is made:

- In general, the slope gradient in the lower delta is much more gentle, so that inundation water is hardly collected to the outlet points.
- Furthermore, the inundation water naturally flows down to lower delta from higher delta during a long-term inundation and finally retained in the lower delta.
- In the relation between ground height in the drainage area and water level of the outlets, that in higher delta is relatively easy to drain, while that in lower delta is quite difficult due to continuation of higher water level of outlets compared with the ground height of drainage area.
- Thus, inundation condition form hydraulic point of view seems to be more serious.
- For the situation, the land development has been promoted from the lower delta, where the land use condition is generally vulnerable to flood damage resulting in increase of flood damage.

Under the above conditions, the drainage system improvement is more urgent in lower delta compared with the higher delta.

(b) Comparison between East Bank and West Bank

There is not much difference in inundation conditions between east bank and west bank. However, the following points are specified in comparison:

- Historically, land development in the east bank has been promoted earlier than the west bank, so that retarding effect in the east bank has been loosing resulting in the increase of flood damage potential.
- Also, the economical damage is more severe in east bank.
- Furthermore, land subsidence caused by land development, which is remarkable in the east bank has been aggravating the drainage condition.

Thus, a higher priority will be given to the drainage system improvement in east bank area.

In the east bank area, the higher priority will be given to the project area located in the most down stream, where the inundation water from up-steam tends to concentrate, while the drainage condition is worse due to low ground height of drainage area against the high tide.

(c) Comparison among the Four (4) Divided Areas in Higher Delta

In higher delta, the drainage conditions among four (4) divided areas are similar, but there may be slightly different in the following points:

- The area surrounded by irrigation channel such as Tha Chin and Noi Rivers, which have regulator at the diversion points from the Chao Phraya River, so that flood discharge can be controlled with in the flow capacity. On the other hand, the area surrounded by the Chao Phraya, Lop Buri and Pasak Rivers will have discharge over the flow capacity, so that the area will have damage by the overflow discharge.
- Furthermore, the condition under higher water level will last long in the Chao Phraya, Lop Buri and Pasak Rivers, so that drainage condition is worse than the area surrounded by irrigation channels of Tha Chin and Noi Rivers.

Under the circumstances, the areas surrounded by the Chao Phraya, Lop Buri and Pasak Rivers should be given a higher priority. In side these areas, those located in the dowstream should be given a higher priority, since the inundation water naturally flows down towards downstream and retains in the downstream areas.

The priority thus given to the areas is shown in Table 7.4.4.

7.5 Consideration of Implementation Schedule

Implementation schedule, in general, is prepared based considering work volume and capability of contractors. However, the work volume is not identified in this study due to difficulty to select the optimum measures to solve the drainage problem. In this connection, the implementation schedule is prepared under the following premises:

- The total drainage system project will be completed within the target year of the Master Plan, the year of 2018.
- The implementation schedule is arranged based on the above priority of the project area.
- The implementation period for each project areas is assumed to be 7 years in the lower delta in addition to three years for F/S and D/D, while that in the higher delta is 5 years in addition to two years for F/S and D/D considering the size of the project area and also difficulty of the drainage system improvement.

The implementation schedule based on the above premises is prepared as shown in Fig.7.5.1.