PART I

WATER RESOURCES MANAGEMENT

1. WATER RESOURCES IN THE UCR

1.1 Water Resources in the Chao Phraya River Basin

1.1.1 Hydrology

The UCR is located in the Chao Phraya River basin. Area of the basin is 161,700 km^2, which is 32% of the national territory. An isohyet of the basin is shown in the Fig. 1.1. Approximately 80% of rainfall is brought in wet season from April to October.

The basin may be divided into upper, middle and lower basins; the areas and average annual rainfall of each sub-basin is shown below.

Upper basin	Middle basin	Lower basin
56,700 km^2	64,000 km^2	41,000 km^2
1,200 - 1,600	1,200 - 1,400 mm	1,200 mm

The four rivers, namely Pin, Wang, Yom, and Nan Rivers, drain the upper and middle basins and they merge into the Chao Phraya River at Nakhon Sawan. Nakhon Sawan is at the boundary of middle and lower basins.

Run-off ratio is rather small and it is 15 to 30% of annual rainfall. Total annual run-off volume of the Chao Phraya River basin is 30,300 million cubic meter (MCM) on the average. Fluctuations of the run-off is large and it varies from 14,500 MCM to 47,500 MCM. Annual run-off volume at Nakhon Sawan is 24,000 MCM which includes reservoir releases of 10,000 MCM. Annual run-off volume of Pasak River is 2,400 MCM at Kaeng Khoi which is equivalent to only 140 mm and it is the lowest run-off yield in the Chao Phraya River basin.

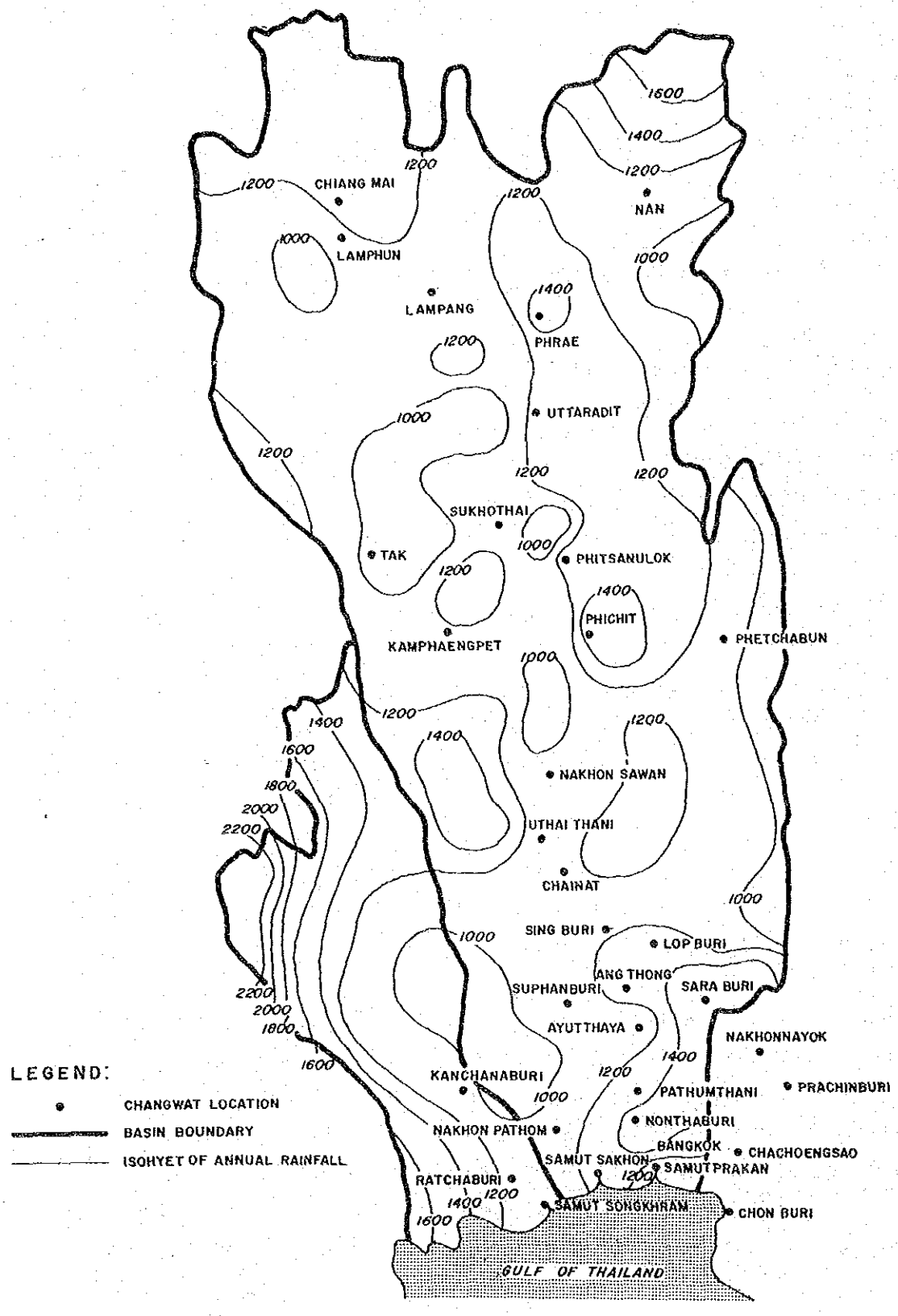

Fig. 1.1 Isohyet of Average Annual Rainfall

1.1.2 Water Resources Development

A number of water resources development projects have been implemented in the basin. The locations of those projects are shown in the Fig. 1.2. The total volume of gross storages developed to date is shown below.

Upper basin	Middle basin	Lower basin
787 MCM	22,5500 MCM	445 MCM

Major storages are Bumipol and Sirikit Dams located near the boundary of the upper and middle basins; and the volume of two dams together is 22,462 MCM in gross storage. This indicates the significance of two dams in the whole basin.

1.2 Characteristics of Water Resources in the UCR

1.2.1 Study Area

The area of UCR is 16,600 km^2 which is a part of the Chao Phraya River basin; and the UCR is approximately 10% of the total basin area and 40% of its lower basin area. The lower basin area is mainly a delta consisting of upper east, upper west, lower east, and lower west deltas. An upper part of the lower Chao Phraya River basin and upland areas including a part of Pasak River basin consist the UCR.

Watershed boundary in the delta area of UCR is not clear, however, irrigation canals and drainage canals may be looked at as entities of forming hydrological boundary. Hydrologically divided areas are shown in the map of Fig. 1.3. In the map, the areas surrounded by irrigation project boundaries are the delta area and its outside to the east and to the west is the upland. Areas of upland and delta are shown below;

Upland areas	10,105 km^2
West of Chai Nat Province	1,065 km^2
East of Chai Nat-Pasak canal	2,710 km^2
Pasak basin	4,960 km^2
Nakhon Nayok basin	500 km^2
East of lower east delta	870 km^2
Delta area	6,495 km^2

The delta area consists of 39% of the total UCR area.

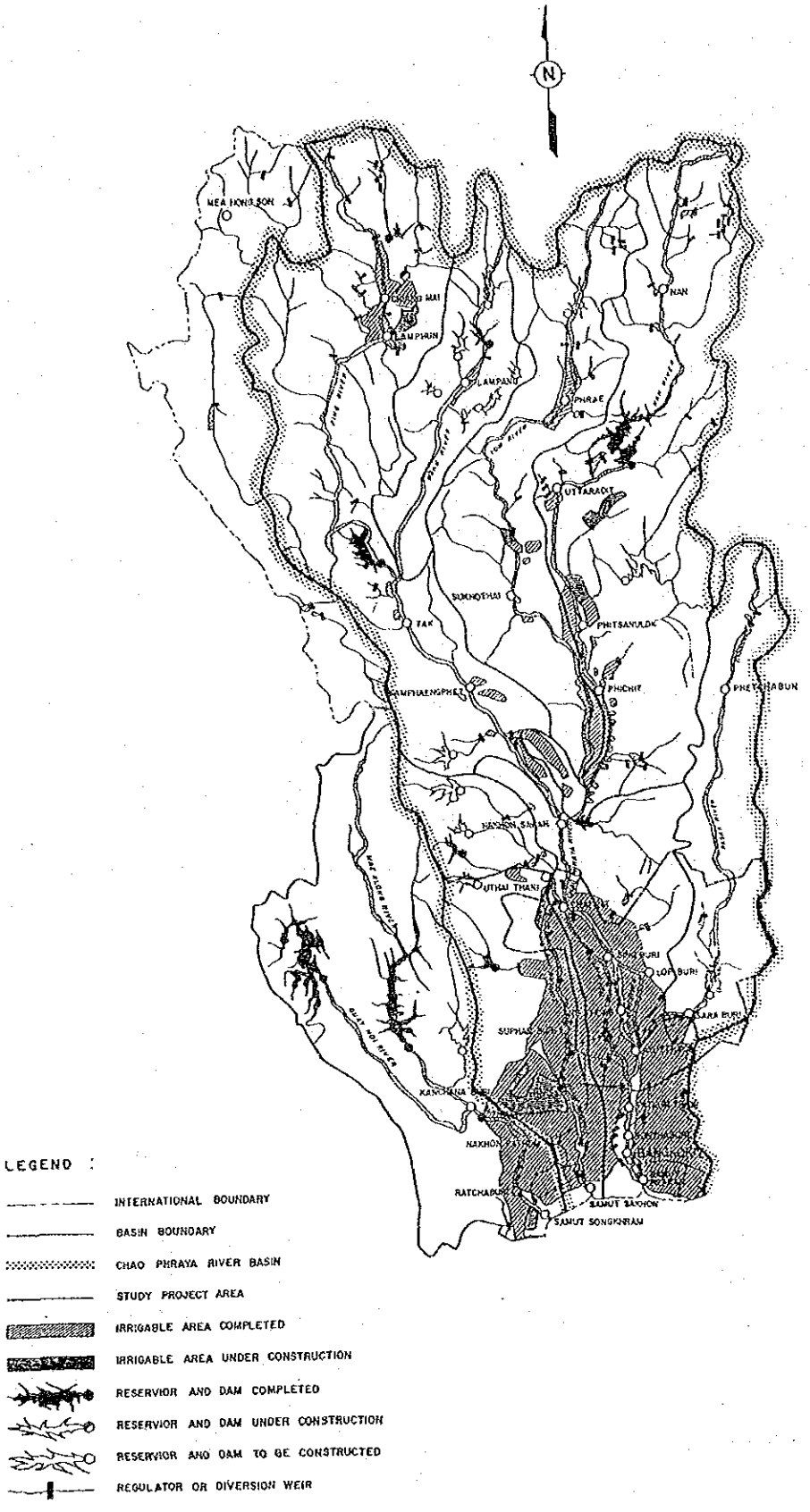

Fig. 1.2 Water Resource Projects in Chao Phraya River Basin

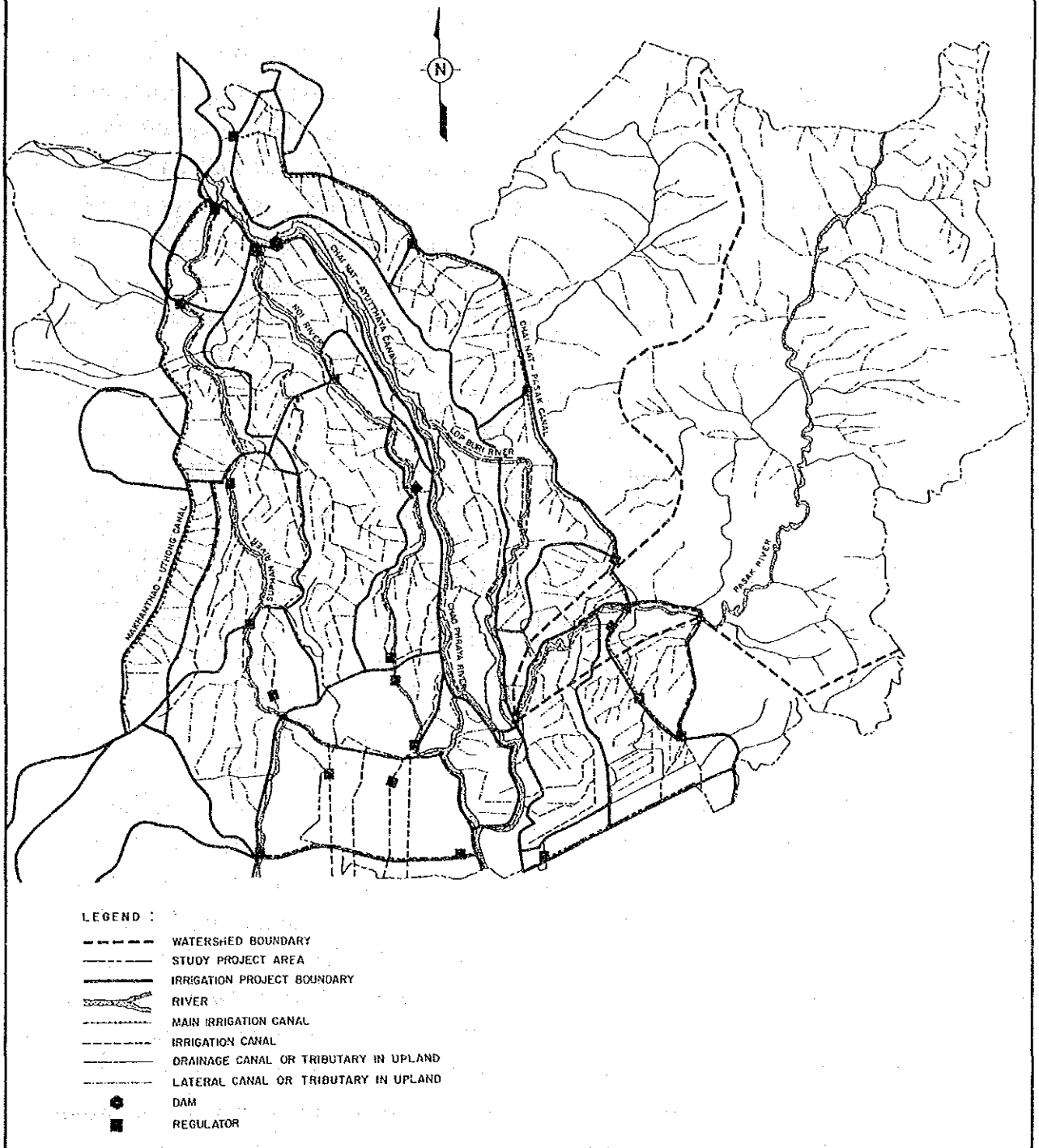

Fig. 1.3 Watershed and Project Boundary

1.2.2 Rainfall

Average rainfall in the UCR is 1200 mm/year with little areal variations. Most of rainfall, approximately 80%, is delivered in a rainy season from April to October, reaching its maximum in September. The rainy season is under the influence of Southwest monsoon which brings moisture from the Indian Ocean. Monthly rainfall in a rainy season increases from, on the average, 60 mm in April to 250 mm in September, with rather high yearly variations. The dry season starts from November and last till March. With the influence of cold and dry Northeast monsoon from Asian Continent, monthly rainfall is less than 30 mm. Monthly and annual rainfall is shown in Table 1.1 for each province.

Table 1.1 Monthly Rainfall in UCR Provinces

Province	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
CHAI NAT	2.6	9.8	15.9	44.1	141.8	85.2	152.7	159.3	278.3	155.5	41.0	10.7	1096.8
SING BURI	1.7	16.2	11.7	48.5	127.6	111.9	112.6	154.4	218.5	156.6	37.0	4.7	1001.3
ANG THONG	4.0	11.5	15.9	65.5	138.4	124.1	159.8	135.1	270.3	167.4	51.8	2.2	1145.9
AYUTTHAYA	1.9	14.4	5.9	63.3	110.8	94.8	159.6	131.1	243.9	74.1	20.0	0.0	919.6
LOP BURI	1.5	21.2	16.7	77.5	147.6	125.0	142.1	171.0	256.4	139.2	35.6	2.3	1136.0
SARA BURI	3.7	18.4	11.9	37.0	112.9	155.9	186.2	206.1	245.2	145.3	26.9	3.5	1152.9
Average	2.6	15.2	13.0	56.0	129.8	116.1	152.2	159.5	252.1	139.7	35.4	3.9	1075.5

1.2.3 Surface Water

Most of the UCR belongs to the Chao Phraya River basin except the southeast edge of Sara Buri province. The Region is located at the upper part of the Chao Phraya delta. The delta consists of upper delta (old delta) and lower delta (new delta). The upper delta coincides with the Region except upland areas of Lop Buri, Sara Buri and Chai Nat, which are terrace regions at the west and east side of the basin.The Chao Phraya River and its tributaries, Lop Buri River, Noi River and Suphan River, flow through the Region. Since the whole Chao Phraya basin has the similar seasonal rainfall pattern, seasonal river flow pattern in the basin agrees with the rainfall pattern : start to increase in April and reach its maximum in September or October. The volume of run off from the upper basin is one of the most important factors for the Region's water resource, since the delta is largely dependent on it particularly in a dry season. Amount of available surface water in the UCR is explained in Section 3.1.

1.2.4 Groundwater

The groundwater potential is high in the delta especially along the Chao Phraya River. There are eight principal alluvial artesian aquifers in the upper 650 m depth of the delta and all of them are productive. Along the River the groundwater yield is 45 - 200 gpm from Chai Nat to Ayutthaya and extending approximately 10 km from the river to the both sides.

Although the yield is high in quantity, quality may be problematic depending on locations. In aquifers of 10 - 20 m depth from the ground surface, salt content is frequently found as well as iron. The eastern region of the UCR consists of limestone formation where highly productive wells of 100 to 500 gpm could be located in cavities. Such a yield has to be estimated by a pumping test at a particular location for the case of limestone formation since the yield depends on the size of each cavity.

Groundwater has to be developed carefully to avoid over exploitation. The rate of recharge was estimated as 3% of annual rainfall in the Central Region, which is not a high recharge rate. The Central Region is believed to be a recharge area for the aquifers providing groundwater to the Bangkok Metropolitan Region (BMR). This indicates that negative effects will not be limited to the areas of over exploitation, possibly in the UCR, but extended to the BMR where, even now, groundwater is a scarce resource. Groundwater potential is shown in Figure 1.4.

1.3 Surface Water Available in the UCR

1.3.1 Water Allocation to the Chao Phraya River Delta

The Chao Phraya River delta depends on the Bumipol and Sirikit dams for available surface water. Water available at the two dams has been allocated by the following procedures;

(1) water demand forecast is made by the RID,
(2) water allocation is determined by the RID for various irrigable areas,
(3) request of water releases is made to the EGATT Office by the RID Head Office based on the amounts of water allocation schedule,

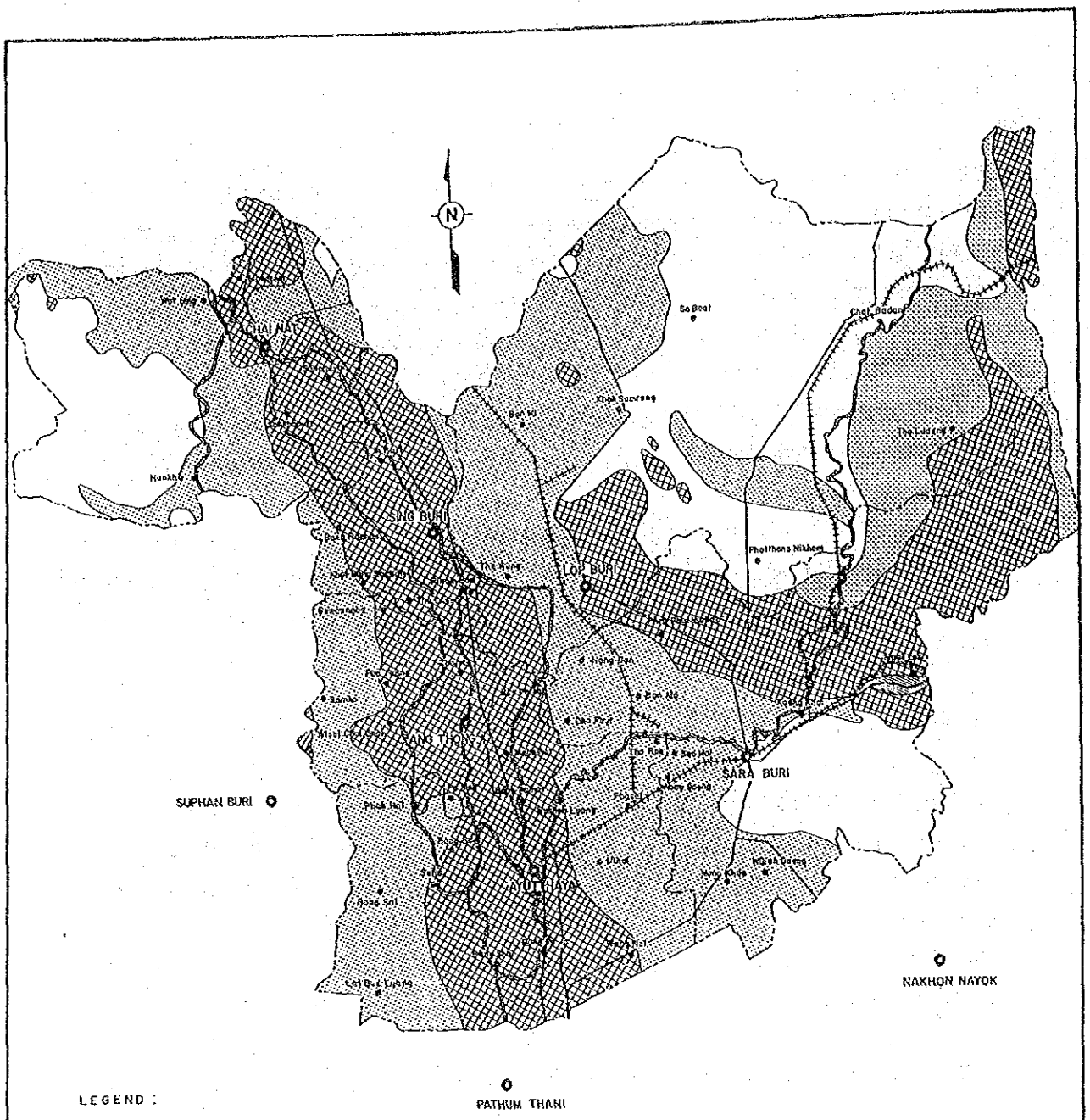

Fig. 1.4 Groundwater Potential

(4) the RID Regional Offices determine water allocation to each irrigation project areas, and

(5) Irrigation Project Offices operates water diversion regulators based on the Regional Office's water allocation.

Past studies on water management of Chao Phraya River indicate that actual performance of water releases at the two dams have been made by the EGATT in accordance with the amount requested by the RID.

1.3.2 Surface Water Available in the UCR

The Table 1.2 summarizes the water availability and potential at Chao Phraya River delta, Chao Phraya River itself, upland area, and Pasak River itself. In the table, wet season is from July to December and dry season is January to June.

Table 1.2 Present Water Resources Availability and Potential

(Unit : million cubic meter)

Surface water availability (1977~1986 avarage)	Wet Season	Dry Season
1. Chao Phraya delta		
Water release from Bumipol and Sirikit Dam	3,800	6,200
Water available at Nakhon Sawan and Rama VI	18,500	7,400
Water diverted to the whole delta at Chai Nat Dam	6,700	4,200
Water delivered to the UCR delta	3,790	1,450
2. Chao Phraya River : Water release at Chai Nat Dam		
Flow needs*	2,000	2,000
Flood spill**	10,760	1,060
3. Upland area water resources potential		
Chai Nat, Sara Buri and Lop Buri Provinces	1,176	785
4. Pasak River		
Water resources potential at Kaeng Khoi	2,146	206

Note * : Flow needs is the amount to satisfy downstream water demands.
**: Flood spill is unavailable to downstream demands due to unstable flow of released floods.

The water available at Chai Nat is diverted to 3 canals and 2 rivers at Chai Nat for the Chao Phraya Irrigation Project and it is also released to Chao Phraya River for domestic water supply, irrigation water supply and salinity control at the downstream of Chao Phraya River.

It should be noted that water available in the delta depends mainly on the water release from Bumipol and Sirikit Dams.

1) Chao Phraya Delta

Water available at Nakhon Sawan is approximately equivalent to the water available at Chai Nat dam. This amount of water plus available water at Rama VI Barrage is diverted to the Chao Phraya delta by canals and rivers. The diverted water is, then, delivered to 25 irrigation projects operated by the RID. The 25 irrigation projects are shown in Fig. 1.3.

The water delivered to the UCR is a part of water diverted for the delta at Chai Nat Dam. This amount of water was estimated for both wet and dry season and shown in the Table 1.2. The estimation was made based on water intake for each irrigation projects.

2) Chao Phraya River

Most of water available at Chai Nat is diverted to 3 canals and 2 rivers and the rest of water is released to Chao Phraya River at Chai Nat. Similarly, most of water available at Rama VI Barrage, in dry season, is diverted to the South Pasek irrigation project and the rest of water is released to Pasek River, then, it flows to Chao Phraya River. The combined volume of water released to the Chao Phraya River is shown in the Table 1.2. In the table, the flow needs of 2,000 MCM is equivalent to average discharge of 129 m^3/second, while the minimum discharge of 75 m^3/second is required for domestic water supply, irrigation water supply and salinity control at downstream of Chao Phraya River.

3) Upland Areas

The Upland area of UCR consists of five areas and estimated water resources potential, which is run-off from the areas, is shown below;

	wet season	dry season
West of Chainat Province	124 MCM	82 MCM
East of Chainat-Pasak canal	316 MCM	210 MCM
Pasak basin	577 MCM	385 MCM
Nakhon Nayok basin	58 MCM	39 MCM
East of lower east delta	101 MCM	68 MCM
Total	1,176 MCM	785 MCM

The run-off in the dry season is rather at a high side since the estimation was made with rainfall data of July to December for wet season and of January to June for dry season.

Part of the potential is already available for irrigation and domestic uses by existing storages of reservoirs and ponds as well as weirs. Total volume of the storages constructed by RID amounts to 78 MCM, which is 4 percent of the total run-off.

2. PRESENT WATER RESOURCES UTILIZATION

2.1 Irrigation Development at the Upstream of UCR

Irrigation projects have been implemented at the upstream areas of Chao Phraya River basin. There is still a trend of increases in the irrigated areas. Table 2.1 shows such increases in each upstream river basin. The increases are particularly evident in the Nan River basin, where Phase I Phitsanulok Project is located. The irrigation area of 111,153 ha was recently completed for this project. The progress of these upstream irrigation projects are important particularly with respect to the increases of water demand in Chao Phraya River basin.

Table 2.1 Irrigable Area in Northern Chao Phraya River Basin

(Unit : 1000 ha)

RID Region No.	Upper Ping I	Wang I	Upper Yom I	Upper Nan II	Lower Ping III	Lower Yom III	Lower Nan III	Sakaekrang VII	Pasak III,VIII
Year									
1976	139	16	37	17	29	6	69	3	22
1980	144	16	38	18	50	10	85	14	24
1981	145	25	38	18	53	10	85	14	31
1982	149	25	38	18	53	10	85	30	31
1983	149	25	38	18	53	10	85	30	32
1984	150	25	39	18	57	10	85	30	32
1985	158	26	39	18	73	10	167	30	32
1986	158	26	39	18	73	17	167	30	32

Source : Master Plan Study on the Water Management System and Monitoring Program in the Chao Phraya River Basin, March 1989.

2.2 Chao Phraya Irrigation Project in the Delta Area

2.2.1 History

The Western half of the UCR, mostly a delta area, is the upper part of command area of Greater Chao Phraya Project. It is essential to preasent the outline of the project prior to examining constraint and potential of water resources utilization. Development and settlement in the lower Chao Phraya delta was started in late 1700 after the capital of Thailand was moved to Bangkok.

Construction of canals in the delta was the essential part of land development and human settlement, since the delta was a flood plain in a wet season and a desert-like dry area in a dry season, and therefore no settlement was possible. The canals facilitated drainage in a wet season and provided domestic water in a dry season as well as access by water transport. From late 1800 land development in the delta was oriented toward rice paddy development by means of canal construction and paddy land was remarkably expanded as a consequence. Rice was a major export commodity with the share of 74% of the total export in 1887, indicating the significance of paddy land development. Unorganized paddy expansion necessitated the Thai government to establish the Canal Department.

The first Director-General of Canal Department (former body of Royal Irrigation Department), Mr. J. Howan Van de Heide, proposed a plan in 1902 to build a barrage across the chao phraya River at Chai Nat to divert water for supplementary irrigation in wet season. Implementation of the project was deferred indefinately due to its high cost. After serve droughts of 1911 and 1914, the project was reviewed by Sir Thomas Ward and a revised plan, with a reduced scale but basically supporting the Heide's plan, was proposed in 1915. Before the Chai Nat barrage project finally went ahead after the World War II, part of Greater Chao Phraya Project to divert water of Pasak River by Rama VI barrage, to Sara Buri and Ayutthaya Province started in 1915 and completed in 1924, and 10 irrigation projects, out of 25 Chao Phraya Projects at present, were constructed in the delta until 1950 along the plan proposed by Ward.

After the World War II, the Chao Phraya delta was considered as a food production center to save the world-wide food shortage; and a FAO mission recommended a development plan of Chao Phraya delta of the same concept as the Heide's. The construction of Chai Nat Dam, the key to the Greater Chao Phraya Project, was comissioned in 1952 with the finance of the World Bank and completed in 1957. As indicated by the Pasak Barrage Project, large-scale modern irrigation projects were implemented from the lower delta and proceeded to the upper delta as seen by the Chai Nat Project. All of 25 Chao Phraya Projects were completed until 1964 except Bang Ban Project completed in 1983. Modern irrigation project, started first in the lower delta is now taking place in the upper Chao Phraya basin, i.e., Northern Region of Thailand, implying some reduction in water supply for the downstream delta in the near future.

2.2.2 Present Irrigation Facilities, and their Operation and Maintenance

The Greater Chao Phraya Irrigation Project implemented by the Royal Irrigation Department (RID) since early in the 20th Century is now in the stage of operation and maintenance. The total project area is 1,249,248 ha (7,808,000 rai) which consists of 25 irrigation projects. The western half of the UCR is included in the Chao Phraya Project area; and all of six provinces are included in the project area with the varying extent as shown below.

Table 2.2 The Chao Phraya Project Area (Area in 1000 ha)

Province	Chainat	Singburi	Angtong	Ayutthaya	Lopburi	Saraburi	Total
Area of province	246	83	98	257	620	357	1,661
Area in the project	163	83	98	244	229	97	914
Percentile (%)	66	100	100	95	37	27	55

Out of 25 projects, two projects in the west and two projects in the south on the right bank of Chao Phraya River and one project in the East and two projects in the South on the left bank of Chao Phraya River do not belong to any provinces of the UCR, indicating 18 irrigation projects of the Chao Phraya Project have varying degrees of contribution to the UCR.

1) Irrigation Facilities

Many facilities were constructed as components of the Greater Chao Phraya Projects and they are being operated by RID. Those facilities are: Chao Phraya Dam at Chai Nat, Rama VI Barrage, six head regulators (five at Chao Phraya River and one at Pasak River), main canals (Chai Nat - Pasak canal, Chai Nat - Ayutthaya canal, Noi River, Suphan River, and Makamthao - Uthong canal), canal system including lateral, tertiary and other canal networks, regulators in the main canals and the canal system, pumping stations and flood protection dikes along main rivers and canals. The Fig. 2.1 shows locations of the facilities constructed for the Greater Chao Phraya Project. The most important facilities located outside of e two large dams at the upper Chao Phraya

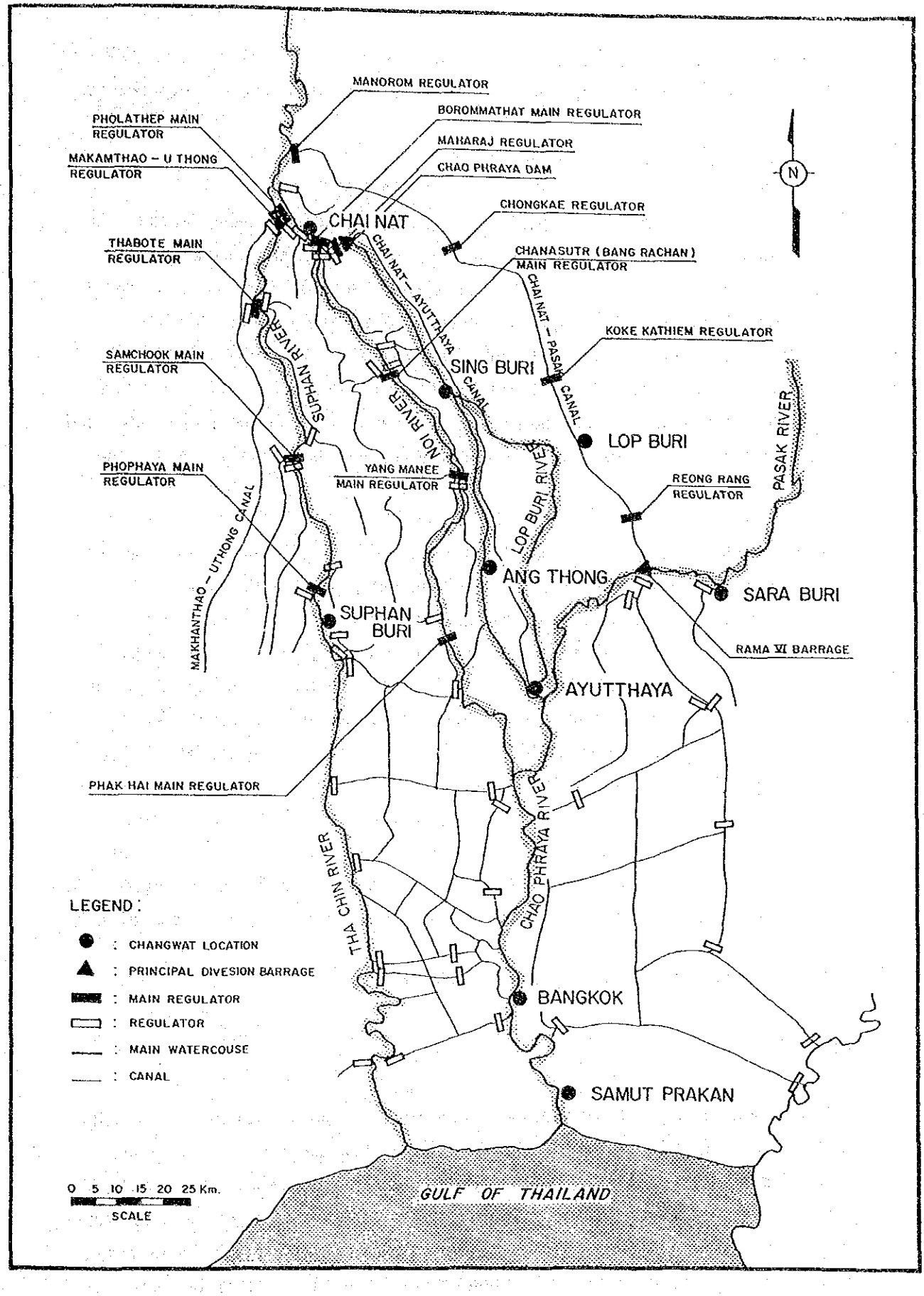

Fig. 2.1 Major Canals and Regulators in the Delta

basin: Bumipol dam and Sirikit dam. The amount of water supplied in the delta is dependent on the reservoirs particularly in the dry season.

2) Operation and Maintenance

All of 25 Chao Phraya irrigation projects except Bang Ban Project completed the construction before mid 1960's and they have been operated for the period of 25 to 80 years. The west bank of Chao Phraya delta, consisting 14 irrigation projects, is administered by the RID region 7 office at Chai Nat, and in the east side of the delta, Region 8 Office administers 10 irrigation projects and only one project belongs to Region 9 Office. Each project has a project office in the project area and operation and maintenance of the project has been performed by the project office.

Operational activities of a project office are: observation of crop and water conditions, an interview with farmers, and rutine operation of farm-turn-out facilities as on-farm level activities; operation of regulators located at a main canal; and reporting of crop and water-related data to the RID Head Office either directly or through Regional Office. The data reported to the Head Office is used to predict water demand in the following week and subsequently a request of reservoir release is made to the EGAT, an operating agency of Bumipol and Sirikit dam. The operation of regulators by a project office is made by the instruction of the six head regulators are made by the instruction of the Head Office. Together with such operational activities, maintenance and improvement works are being performed for the irrigation facilities.

2.3 Water Allocation for Irrigated Agriculture

2.3.1 Rotating Irrigation

Before human settlement took place by means of canal construction, the delta used to be a vast lake due to flooding in a wet season and dry desert in a dry season; therefore, wet season paddy was the only possible cultivation. Even for the wet season cultivation, the delta frequently suffered from drought as well as flooding. The Greater Chao Phraya Project was planned to cope with such unstable cultivation by means of modern facilities, and therefore it was

designed for supplementary water supply for wet season rice as well as flood drainage. Since dry season rice cultivation was generally not feasible in the delta, there was no water demand in a dry season.

This situation, however, was changed by the construction of large dams in the upper basin. Dry season irrigation has become possible with the water stored in the reservoirs although all the irrigable areas cannot be watered. Once dry-season water is made available, water demand for dry season crops emerged and it has been increasing. This situation has created difficulties in water allocation and problems in social or economic equity among farmers and regional economy, since water available at upstream dams cannot meet all of the dry-season water demands.

At present, water allocation for the dry season is decided after the wet season based on the amount of available water in the two dams. Each RID project office make a plan of irrigation area, usually rotating or changing the area year by year, with agreement of farmers, since all the irrigable area cannot be irrigated in the dry season. Based on the irrigation plan, the RID decides water allocation for the coming dry season at a meeting held in Chai Nat participated by concerned representatives such as provincial agricultural officers of all the provinces in the delta. The decision is made rather from the top to diversification as well as the consideration of market price.

2.3.2 Water Utilization

Irrigable area in the whole delta is 7,808,000 rai. The cultivated area within the delta varies depending on water availability and other factors, as shown below;

Year	wet season	dry season
1974	6,241,000 rai	1,259,000 rai
1982	6,124,000 rai	3,326,000 rai
1987	6,068,000 rai	2,532,000 rai
Average (1976-86)	6,143,000 rai	2,714,000 rai

The cultivated area in the wet season does not change much, while dry season cultivation changes year by year. Water diverted in the wet season is 1.6 times more than that in the dry season. However, the cultivated area in the wet season is 2.3 times more than that in the dry season. This is due to the fact that

less water is needed per rai in the wet season. Irrigation facilities at the Chao Phraya Project were designed for supplementary irrigation during the wet season, therefore, the capacity of the irrigation system does not allow as large a dry season cultivation area, even if sufficient water is available in the dry season.

The irrigated areas in the UCR are estimated as;

	Wet season	Dry season
Average	3,238,000 rai	770,000 rai

A comparison between water delivered to the delta during the wet season versus the dry season is shown in Fig. 2.2. It also shows the irrigated area in the whole delta versus the UCR.

The share of cultivated area in the UCR is lower, particularly in dry season, than the share of water delivered to the UCR. This is because of a topographic constraint in the upper delta of UCR, where the land slope is steeper and water requirement is higher than the lower delta particularly in dry season. This is also because part of the water delivered to the upper delta returns back to canals and is utilized again at the lower delta. The upper delta is a gravity irrigation area and the lower delta is a water conservation area due to this topographic factor.

2.3.3 Problems Associated with Water Allocation

The rotation or alternation of dry season irrigation area is made annually by dividing a project area into parts such as upstream and downstream or right-hand side and left-hand side of an irrigational canal. Such a rotation has been practiced, since increasing water demand exceeded water availability, with the objective of achieving equity among farmers. As compared with the lower delta, water control is easier in the upper delta by the means of gravity system, and therefore, the artificial rotation is possible. However, artificial water control by the RID is difficult in the lower delta since the land is too flat to control by gravity and water stays stagnant in canals. Irrigation method which is possible in the lower delta is called conservation irrigation: utilize water conserved in a canal. Since water does not flow by gravity, each farmer has to pump water from a canal; consequently, water is available to those farmers who are close enough to canals for pumping. Unlikely to gravity system of the upper delta where rotation is possible, equity in water supply

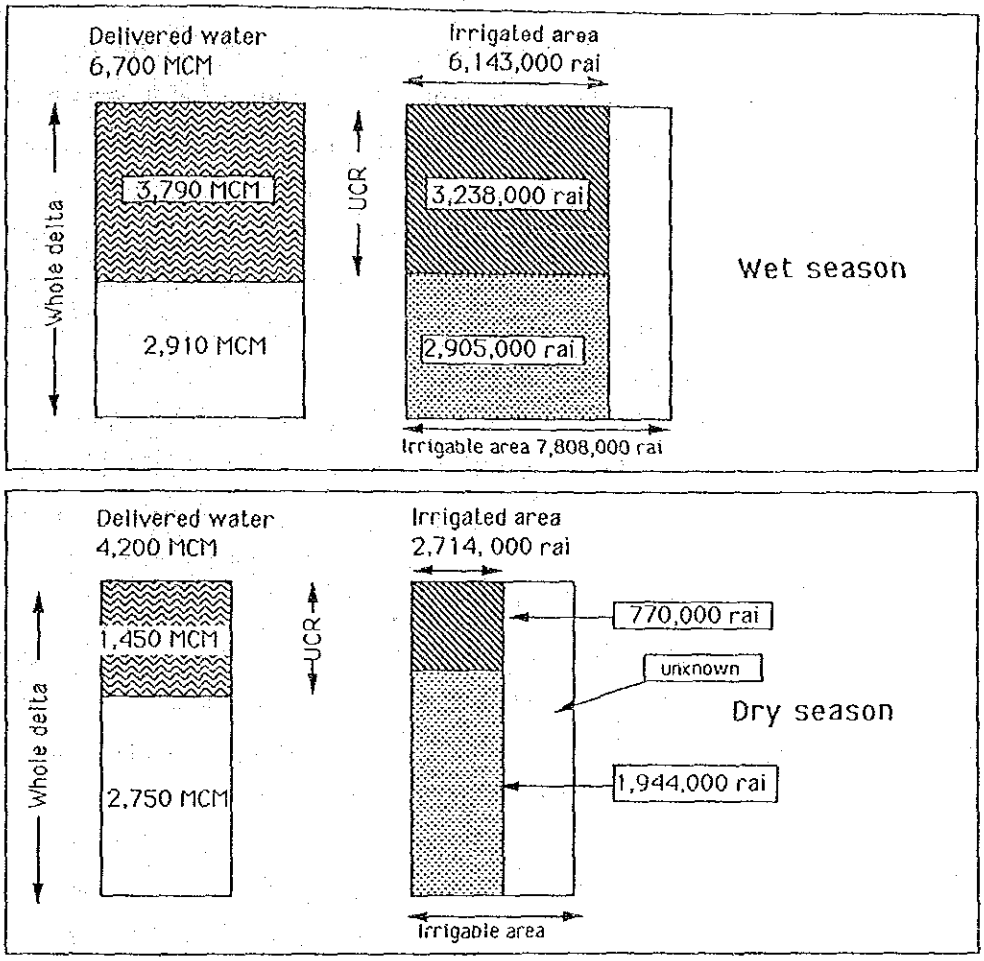

Fig. 2.2 Delivered Water and Irrigated Area in Wet and Dry Season

among farmers is difficult to achieve in the lower delta with conservation irrigation. In the UCR, such water conservation area includes Ayutthaya Province.

Water allocation practice by the RID is kind of land use control by the government since the government sets a target or a limit in dry season paddy areas by means of water supply. Fig. 2.3 shows such a government practice in dry season. The RID is finding a difficulty in such control over farmers. In a dry season of 1988, the RID set a target to irrigate 744,000 rai of paddy out of 3,811,000 rai of irrigable area in the Region 7. However, unplanned area for rice of additional 988,000 rai was planted with rice contrary to the Government target, due to high market price of rice. Similar situation was observed in the Region 8, i.e., actual planted area of 680,000 rai contrary to the Government plan of 200,000 rai. The additional paddy was made possible partly by good rain and uncontrollable water use by farmers such as pumping from a drainage canal.

As stated earlier, water allocation depend on water available in the upstream receivers and agricultural policy set by the Government. Such a gap, between the target set by the Government and actual production by farmers, may be indicating a necessity of institutional improvement either or both of the Government and farmers. This would be a very important aspect from the viewpoint of further promoting crop diversification in the UCR since irrigation water supply do have decisive effects on the diversification.

Another problem associated with the water allocation practice by the Government is increasing complication of landuse in the delta. Although the Great Chao Phraya Project was designed for wet season paddy, other agricultural production activities which require water supply are increasing, such as cash crops, vegetables, and fish culture. The varieties of agricultural activities related to water supply are: wet season paddy and dry season paddy (either transplanting or broadcasting), sugarcane, cash crops including orchard, vegetables, shrimp farm, and fish farm. Timing and the amount of water supply to these agricultural production are different each other and the water supply and control of the RID must be different as compared with the mono-culture of wet season paddy. The diversification of agricultural produce is now imposing difficulties to the RID, who is responsible to provide farmers with water when it is needed.

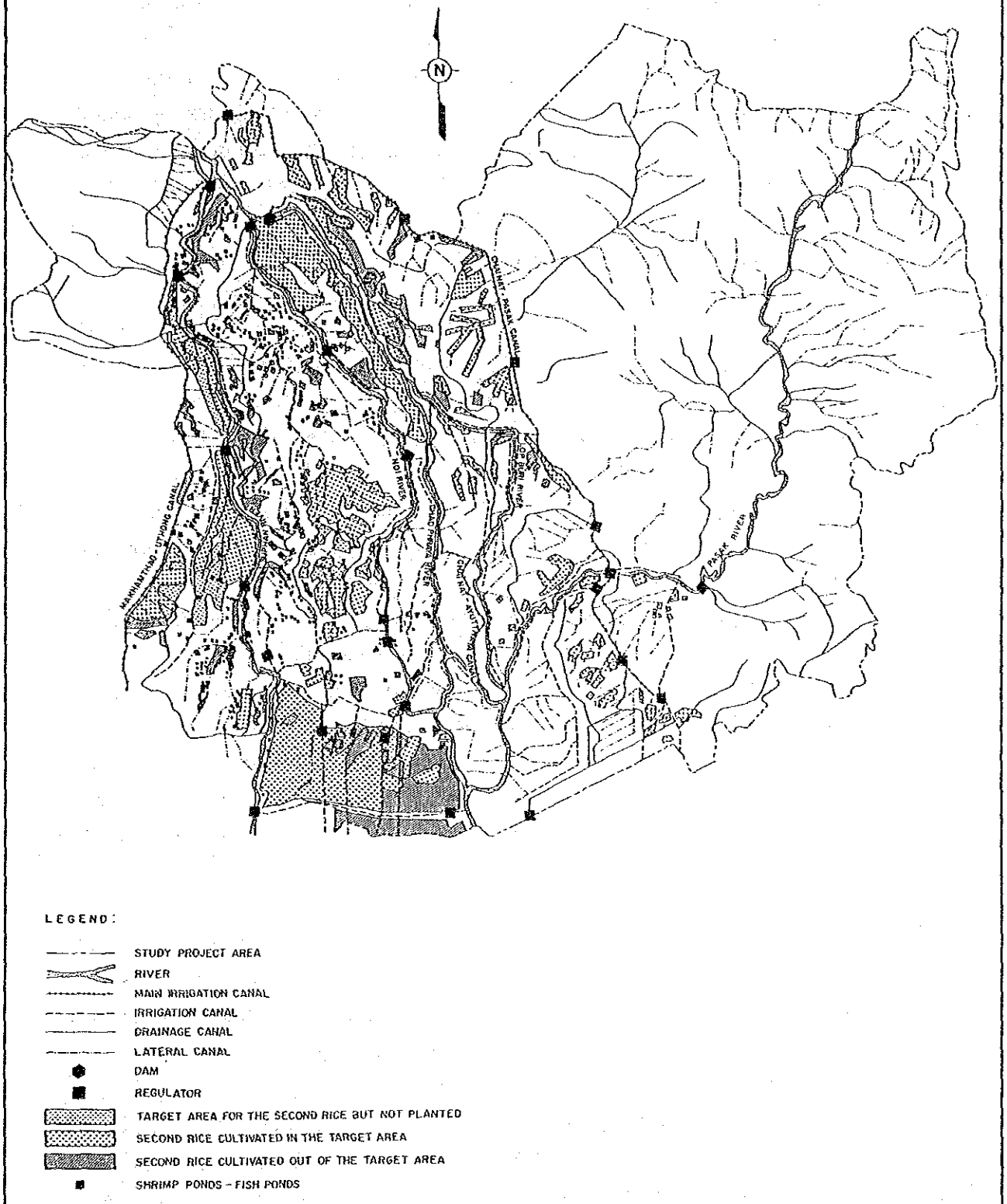

Fig. 2.3 Dry Season Irrigation in the Delta (1987/88)

For a large irrigation system like the Greater Chao Phraya Project, it would be impossible to satisfy all kinds of different water demands, since the control on the amount and timing of water supply cannot be made to meet with the complexity of varying local needs. This fact may be implying again the necessity of institutional measures for both the government and the private. Such a measure for the private may include an active role of farmers for water supply and water management.

2.3.4 Constraints for Further Development

The constraints regarding the irrigation practice in the delta may be discussed separately as structural constraints and institutional constraints.

The structural constraints include:

- Available amount of water for the delta cannot meeting with demand,
- the irrigation facilities were designed for supplementary irrigation of wet season paddy,
- the facilities are 20 to 80 years old and they require better maintenance and improvement for efficient water management,
- telecommunication facilities are still insufficient for efficient water management, made by means of communication between field personnels and the Regional or the Head Office, and
- the whole irrigation system is too large to control for timely meet with water demand since it takes two to three weeks from the upstream to the downstream of delta.

The institutional constraints include:

- farmers participation through Water User's Group or Water User's Association is very limited for the maintenance and operation of irrigation facilities,
- the priority of water supply is attached to paddy by the RID since facilities were designed for it (a constraint to diversification), and
- the field staff is not sufficient if the facilities (except major ones) are to be controlled directly by the RID.

Some structural constraints, such as maintenance and improvement of irrigation facilities and telecommunication system, can be solved by the continuous Government efforts and investment. Since the amount of available water resources are limited, water use efficiency has to be increased both by the improvement of facilities and by the institutional measures. The constraints regarding the size and design of whole system is inherent in the Chao Phraya Project and drastic change will not be possible, however, it may be possible to ease such constraints both by installing more control facilities and by encouraging farmers to participate in water management.

Farmers could organize themselves in the amount and timing of water demands for diversified agricultural activities since they need water in a dry season. Unless there is a need of forming Water User's Group among the farmers themselves, such a group cannot be grown by legislation alone. Farmers are now in need of water and it may be the time to encourage them for such a group to manage water use.

It should be noted that the requirement and improvement of irrigation facilities must be in line with a policy and direction of agricultural development in the delta. If the delta is expected to take the role of Rice Bowl, the increase of irrigation efficiency would be the major goal; while, if the agricultural diversification policy is to be promoted in the delta as well, the increase in controllability of water distribution system might be a more important goal.

2.3.5 Potential for Further Development

As annual rainfall is only 1200 mm with seasonally skewed distribution, water resource in the UCR does not appear to be plenty. It is even a scarce natural resource in a dry season due to high water demand.Development potential with regard to water resources utilization, however, may be evaluated as higher in the UCR, above all in the delta area, as compared with only region of the Kingdom. The UCR have high potentiality in water utilization in the following three aspects. Firstly, the delta is the most advanced region with respect to water resources development, i.e., best equipped with irrigation facilities as 42% of farmland is irrigated in the Central Region while 18% is the national average value; as a result, 48% of total paddy and 84% of dry season paddy of the whole nation is produced in the Chao Phraya River basin. This fact should

be looked at as the UCR having the high potentiality of utilizing water resources further toward a more productive direction, rather than being looked at as surface water is already used up and no room for further development.

Secondary, improvement in the existing facilities will be able to augment the available amount of water as a result of increased water use efficiency. Facility improvement is generally much more cost effective than a new investment; therefore, an increase in efficiency should be looked at as important development potential.

Thirdly, water is literary abundant in a wet season causing floods in many depression areas. This fact, again, may be looked at negatively since floods are causing damage once in a few years and acting as the constraint in low crop yield and land use. However, abundant wet season water possibly be utilized for more production such as improved deep water rice or floating rice. More over, wet season water in the delta may be kept in many storages for a dry season crop, which is actually practiced even now especially in the lower delta. Such a water conservation method may be widely adopted in the upper delta as well.

2.4 Small and Medium Scale Water Resources Development

The upland areas depend mainly on rain-fed agriculture. Small and medium scale water resources projects have been implemented by the RID. Other government agencies have implemented smaller projects, however the total irrigable areas by such small projects are very minor as compared with the RID projects. Irrigable areas by the small and medium water resources development projects of RID, which were completed by the year 1987, are shown below:

Province	Medium Scale	Small Scale
Chai Nat	23,000 rai	157,000 rai
Lop Buri	47,000 rai	108,000 rai
Sara Buri	97,000 rai	25,000 rai
Total	167,000 rai	290,000 rai

The total irrigable area by these RID projects amounts to 457,000 rai in the upland, which was made available by reservoirs and weirs. It should be noted, however, the total irrigable area is not necessarily irrigated every year owing to the rain and a lack of facility maintenance. The locations of small and medium scale projects completed by the year 1986 and a few small scale projects under construction in 1987 are shown in the Fig. 2.4.

2.5 Urban and Industrial Water Uses

2.5.1 Domestic Water

Sources of urban water supply, in the UCR, are natural rivers, such as Chao Phraya River, Pasak River and Noi River, irrigation canals, and groundwater. Table 2.3 shows water supply systems operated by PWA and individual municipalities.

Table 2.3 Present Urban Water Supply

(Unit m^3/day)

Province	System Name	Source of water supply	Water demand
Chai Nat			
	Chai Nat	Borehole and Chao Phraya River	1,378
Sing Buri			
	Sing Buri	Boreholes or surface water	1,865
	Thon Samo	Boreholes	138
	Bang Rachan	Boreholes or Noi River	378
Ang Thong			
	Ang Thong	Chao Phraya River	1,127
	Pa Mok	Borehole or Chao Phraya River	476
	Wiset Chai Chan	Borehole or irrigation canal	661
Ayuttahya			
		estimated	14,820
Lop Buri			
	Lopburi-Phibun	Irrigation canal	20,844
	Ban Mi/ Khok Samrong	Irrigation canal	901
	Chai Badan	Pasak River	1,073
	Nong Muang	Boreholes	345
Sara Buri			
	Nong Don-Phuttabat	Irrigation canal	1,332
	Ban Mo/ Tha Rua	Irrigation canal	1,222
	Hin Kong/ Nong Khae	Irrigation canal	1,542
	Sara Buri/ Kaeng Khoi	Pasak River	6,702
Total			54,804

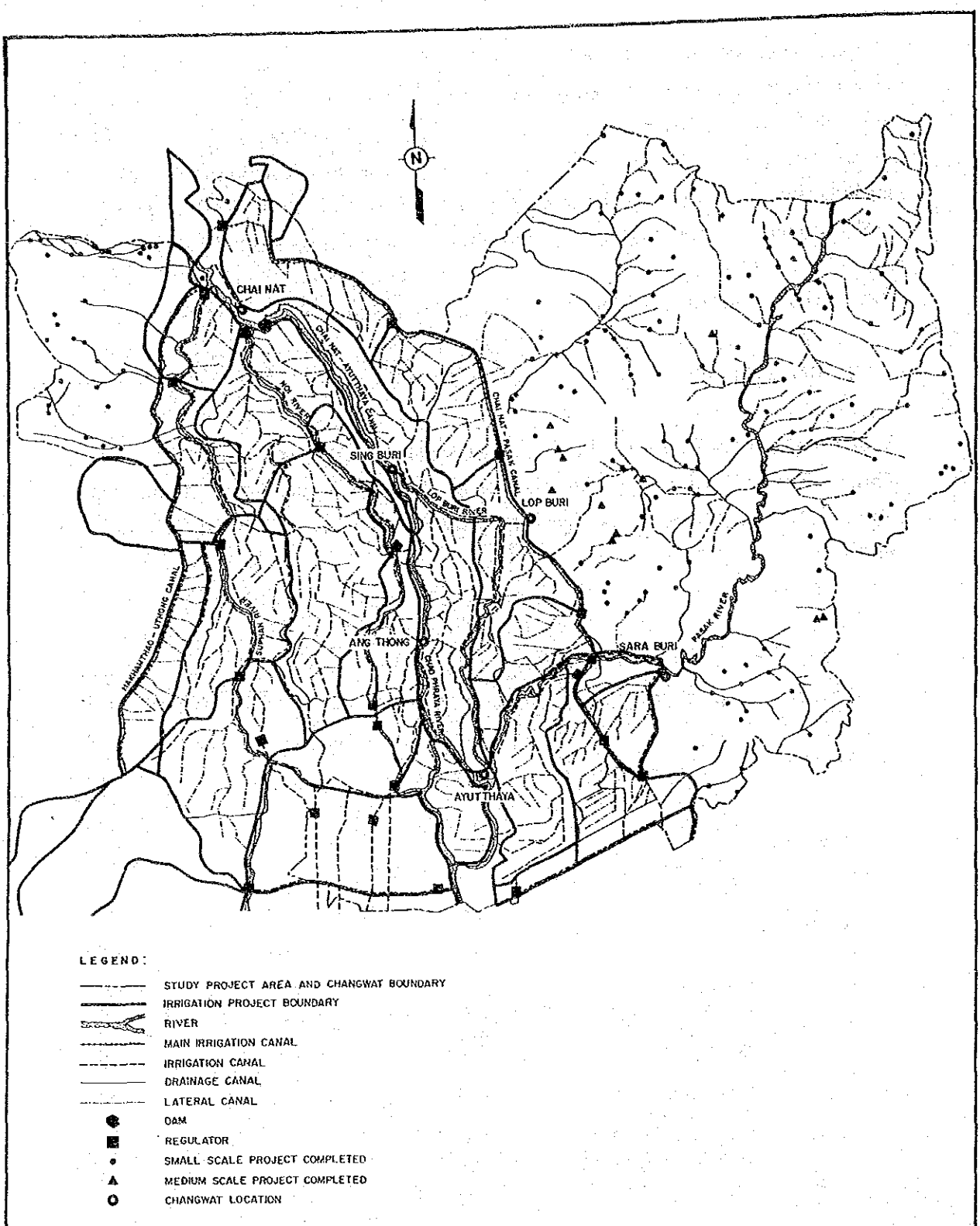

Fig. 2.4 Small and Medium Scale Irrigation Project

The total urban water supply in the UCR is 54,800 m^3/day, which is 20 MCM in total annual volume. This volume is equivalent to 0.63 m^3/second of intake rate on the average. Assuming daily use of 130 liter/capita, this amount of water supply is calculated as 57% of present urban population is provided with piped water supply. This is summarized below;

Urban Population	Per Capita Use	Service Ratio
741,900	130 liter/day/capita	57%

At present, quantities and qualities of these water sources are generally in good condition. Pasak River and small tributaries, however, occasionally experience low water quality in dry season.Rural settlements utilize water at natural rivers, irrigation canals, and rain water. The total amount of domestic water consumption by rural settlements may be estimated as 36 MCM/year by assuming 50 liter/capita/day, where rural population is approximately 2 million people.

Bangkok Metropolitan withdraws water from the Chao Phraya River and its amount is 25 m^3/second at average rate and 41 m^3/second at maximum rate at present, where annual intake volume amounts to 778 MCM.

2.5.2 Industrial Water

Sources of industrial water supply, in the UCR, are mainly groundwater, but Chao Phraya River and other natural rivers are also utilized as sources of industrial water supply. This tendency is indicated in the Industrial Survey conducted as a part of the UCR Development Study. According to the study, sample data shows the following results for the resources of industrial water uses.

	Ground Water	Urban Water Supply	River Water
Chai Nat	20%	60%	20%
Sing Buri	33%	27%	33%
Ang Thong	50%	25%	13%
Ayutthaya	32%	9%	45%
Lop Buri	59%	35%	6%
Sara Buri	42%	23%	19%

In Sing Buri and Ang Thong Provinces, the percentage totals do not amount to 100%, because questionnaire answers were not obtained from some factories. These results indicate accessibility to different sources of water; for example, high dependency is found on river water for Ayutthaya Province and on groundwater for Lop Buri and Sara Buri Provinces.

The total amount of industrial water uses, at present, was estimated as 50 MCM/year based on gross regional domestic product of 1986 in the UCR. This amount is equivalent to the intake rate of 1.6 m^3/second. According to the Industry Survey, 4 to 7% of factories in the UCR provinces except Chai Nat and Ang Thong answered that lack of water supply is a bottleneck to the factories.

Present legislations are hindering the efforts of private sector to secure water from natural sources of water. Such a situation is found in the absence of authority to give a permission, for example, to lay a pipeline at public facilities such as a road and bridge.

2.6. Balance of Water Availability and Utilization

Table 2.4 shows the present water availability and potential together with water uses in the UCR. It is clear that available water is sufficient to satisfy the water uses demand.

However, water availability in the delta (No. 1 in the Table) is not sufficient for potential dry season irrigation demand. Chao Phraya River release (No. 2 in the Table) is not sufficient for the river navigation where the navigation demand is 300 m^3/second, which is equivalent to 47,000 MCM in each season. The water shortage for these two water use sectors is now a problem in the UCR.

Table 2.4 Present Water Resources Availability/Potential and Uses

(Unit : million cubic meter)

Surface water availability 1977-1986 avarage	Wet Season	Dry Season
1. Chao Phraya delta		
Water delivered to the UCR delta	3,790	1,450
2. Chao Phraya River : Water release at Chai Nat Dam		
Flow needs*	2,000	2,000
Flood spill**	10,760	1,060
3. Upland area water resources potential		
Chai Nat, Sara Buri and Lop Buri Province	1,176	785
Upland (available storage)	78	78
4. Pasak River		
Water resources potential at Kaeng Khoi	2,146	206
Water uses	**Wet Season**	**Dry Season**
5. Irrigation water		
UCR delta	3,790	1,450
6. Domestic water		
Urban settlement	10	10
Rural settlement	18	18
7 Industrial water	25	25
8.Total volume of 6. and 7.	53	53

Balance :Volume of 8. is met by the available water of 1, 2, 3, 4 and groundwater.

* : Flow needs is the amount to satisfy downstream water demands.

**: Flood spill is unavailable to downstream demands due to unstable flow of released floods.

3. ISSUES AND STRATEGIES FOR WATER RESOURCES MANAGEMENT

The available water resources in the UCR were presented in the Chapter 1; then, present water utilization was presented in Chapter 2 based on these facts and analyses, issues and strategies for the water management have been made clear and presented in this chapter. These strategies form the basis of water resources balance of Chapter 4 as well as water resources management plan and recommendations of Chapter 5. It should be noted that the measures and recommendations corresponding to the issues and strategies are found in Chapter 5 as Water Resources Management Plan and Recommendations.

3.1 Basin-Wide Strategies

Necessity of inter-regional viewpoint

Water demand will increase in the Northern and Central Regions for agricultural, urban and industrial uses. Water storage and conflicts among different irrigable areas in Chao Phraya River basin is very likely to occur, particularly in drought years. Such conflicts are not restricted within agricultural water uses but continuing urban and industrial growth as seen at the BMR will also place a pressure on the available water resource in Chao Phraya River basin. In planning for the UCR development, a consideration to available water resources in the whole basin as well as in the UCR would be essential.

3.1.1 Water Resources Development at the Upstream of the Chao Phraya River

1) Issue and Strategy

Major water resources development at the upstream of Chao Phraya River Basin is a important issue for the whole basin including the Central Region. Although there are project plans and ideas of water

resources development in the Northern Thailand, the UCR planning adopts the following strategy. This strategy is followed by justifications.

- The UCR planning does not assume additional major sources of water will be made available to the UCR during the planning horizon up to year 2010.

2) Justifications

Major projects in the Northern Thailand

Existing project plans and ideas are Kang Sua Ten Dam, Kwae Noi Dam and water diversion from international rivers of Salaween River and Mae Khong River. These projects will bring benefits, with the various degrees, to the Central Region including the UCR.

Status of the projects

These project plans will bring benefits to the Chao Phraya River basin and it is desirable also for the UCR. The Kang Sua Ten Dam project is now being studied for environmental aspects such as resettlement, forest and mineral deposits, after EGAT finished its study from the viewpoint of electricity generation. The Kwae Noi Dam was studied by the National Energy Administration and the matter was sent to the EGAT for possible implementation, however, the project is not included in the EGAT's implementation plan of the next ten years. There is a influential opinion, expressed recently : a hydroelectric project costs too expensive and creates too much environmental problem in Thailand.

Significance to the UCR

These projects are expected to bring some benefits to the UCR. But they are not so significant since their dry season irrigable areas are 300,000 to 400,000 rai for each project for all the downstream regions, while 2,700,000 rai of the Chao Phraya delta is now irrigated in the dry season. Once the projects area implemented, the downstream regions will adapt themselves to use availed water and water demand will increase. It may

be more appropriate to look at these projects to benefit more the Northern Region than the Central Region when they are implemented.

Diversion of international rivers

Unlikely to the Kang Sua Ten Dam and the Kwae Noi Dam project, the trans-basin diversions from the international rivers will have significant impacts to the Central Region. The riparian countries related to the Salaween River diversion are only the Burma and Thailand and those of the Mae Khong River are China, Thailand, Laos, Cambodia, and Viet Nam. Considering this fact, water diversion from the Salaween River may be easier to implement and study should be made for this idea of water diversion.

Conclusion

Various problems have to be cleared before these projects and ideas are considered as inputs to the UCR planning. The Kang Sua Ten Dam and the Kwae Noi Dam projects are not directly and significantly beneficial to the UCR; and the water diversion from international rivers are very significant to the UCR, although possible but not likely to be realized in the near future; therefore, those projects and ideas are not considered as inputs to the UCR planning as the strategy indicates.

3.1.2 Inter-regional Issues and Strategies

1) Issue and strategy

Inter-regional water balance is the most important issue since the upstream and downstream regions of the UCR would increase water uses. Based on the strategy regarding the major water resources development, the following strategies are adopted for the UCR planning;

- the UCR delta will use, at least, the amount of water which has been allocated, and
- the irrigation development in the Northern Region should be made with its own water resources development.

These strategies apply to the UCR downstream region of the BMR as well, where domestic and industrial water demands are expected to increase. As for the BMR there is a possibility of decrease in the agricultural water use in the long run due to expansion of industrial and urban areas. This will enable the BMR to acquire more water for domestic and industrial water uses.

2) Justifications

These strategies should be most reasonable since the major projects in the Northern Region are uncertain in implementation and their effects are rather indirect to the UCR.

This premise may be looked at too pessimistic. Considering the facts that irrigation development are progressing at the Northern Region, there is a threat to the UCR of the decrease in water availability. Such an evidence was presented in the Chapter 2. In this respect the assumption made here could be optimistic rather than pessimistic. This is even more true due to the fact of depleting forest resources at the Northern Region, which is a "natural water reservoir".

3.2 Strategies to Increase Water Uses in the UCR

Water demands will increase in the UCR due to economic development and the issue is how to cope with such demand increases. Strategies to tackle the issue are different for the two sub-regions of UCR: the delta area and the upland area. This is because the delta area receives water from Chai Nat Dam, while the upland area does not receive it and essentially depends on water resources available within the upland.

1) Delta area

Based on the inter-regional strategies and discussions above, water resources management within the UCR delta includes the following strategy:

- the UCR delta will increase water use by means of efficient system operation and water conservation measures.

This strategy is justified by the fact that there is a necessity of improving water management system of the RID and by the possibility of more water conservation measures.

Major expansion of the physical structures of irrigation system can be made with rather significant investment. This will loosen the capacity constraint of facilities (refer to Section 2.3.2) and help fully utilize the irrigable areas for dry season. However, such a large investment can be justified only if major water resources development is taken place and much water is availed for the delta; and it is not recommended in the water resources management plan.

2) Upland area

The UCR upland includes two types of sub-region: west of Chai Nat Province and Pasak River basin have catchment areas outside of the UCR; other regions depends on catchment areas only inside of the UCR. The following strategies are adopted for the UCR planning:

Public investment has been comparatively small at the upland area and it deserves more attention than in the past. The strategies for the upland area are;

- a large scale water resources development should be implemented for the Pasak River basin, and
- a medium and small scale water resources development should be implemented at the upland region together with water conservation measures.

The first strategy is justified by the fact that public investment has been comparatively small at the upland area and it deserves more attention than in the past. The second strategy is justified by the limited water resources potential for a large scale project.

3.3 Issues and Strategies for Water Resources Management in the UCR

Water uses may be categorized into various types such as irrigation, domestic use, industrial use, river navigation, and stream need against sea water intrusion. In this section issues and strategies are stated for these types of water use. Water resources should be managed by both structural measures and institutional measures. The following issues and strategies focus on the structural measures.

3.3.1 Irrigation Water

Issues

Major issues in the irrigation water uses are the following:

- how to increase irrigation water uses,
- how to facilitate agricultural diversification, and
- how to improve operation and maintenance of irrigation facilities.

The first issue is tackled by the strategies stated previously to increase water uses in the UCR and they should not be repeated here. It is necessary to give explanations on these issues, particularly for the relation between the first and the second issues.

Effects of agricultural diversification on water demand increase Demand increase of water in the dry season is caused by the recent rise of rice. The effect of rice price is uncertain in the future since the rice price fluctuates depending on the world supply and demand. Another factor of water demand increase is crop diversification.

Crop diversification into vegetable crops, for example, will require more timely and frequent irrigation than rice growing, and the timing of irrigation is different from paddy irrigation. In order to satisfy such a requirement, the timing of water diversion to a main canal and water delivery to a lateral canal should also be different from the traditional water control practice made by assuming all paddy cropping at irrigable areas. The water diversion and delivery have been made by responding or assuming paddy growing and this practice will have to change to satisfy diversified water requirements.

It is very difficult and inefficient for the RID to respond different kinds of timing of water requirement and then to deliver water to lateral canals. (Reference should be made to Section 2.3.3 and 2.3.4 with respect to structural constraints of the irrigation system.) Therefore, there has to be available water always at a lateral or on-farm in order to satisfy various water demands created by diversified cropping patterns or by diversified farming activities. For this reason, water delivery to irrigable area of diversified cropping is not likely to reduce but more likely to increase the amount of water demand, although water requirement of vegetables or other cash crops are less than that of paddy.

Strategies

The issues should be tackled with the following strategies:

- increase flexibility of water management by storage facilities at later level and on-farm level;
- improve operation and maintenance of facilities by people's participation.

Justification

Storage facilities near on-farm can ease the constraints, imposed by such a large system as the Chao Phraya Project, of water control and can facilitate more flexible water management. People's participation is a national policy to manage local resources and it should be applied to the operation and maintenance of irrigation facilities near and at the on-farm level. Such people's participation will also facilitate agricultural diversification to be made by an individual farmer.

3.3.2 Domestic Water

Major issue is increasing water demand in the BMR. In order to minimize pressures on water resources in Chao Phraya river basin, a strategy is to take prompt actions by the MWWA; and necessary measures are explained in Chapter 5.

Domestic water demand of the UCR is presented in the nest chapter and it was found the demand will not be at a level of forcing a large change in the present water uses. This is true only if water quality of the rivers and canals are maintained in a good condition. Water quality conservation will be an issue, and therefore, water quality control is an important strategy for safe water supply in the UCR as well as in the BMR.

3.3.3 Industrial Water

Major part of the demand can be met by the groundwater as it is now. Some of the demand can be met by surface water sources if intake rate is high to pump from groundwater.

The major issue for industrial water use is not its quantity but the quality of effluent, and therefore water quality monitoring and law enforcement to control the factory effluents are the most important strategies.

Industries are likely to be located around Sara Buri and water supply from groundwater, Pasak River, and irrigation canals are possible alternatives. Discharge in Pasak river, however, is unreliable in dry season. If an intake rate is rather significant amount and the groundwater is not readily available, an irrigation canal may be the best source since the flow is controlled and reliable, approximately 100 m^3/second for Chai Nat -Pasak canal.

Water demand pressure to Chai Nat-Pasak canal will increase as urban and industrial development takes place in Sara Buri region. This may become a significant issue, although it is a local one. Implementation of Pasak Dam Project will contribute to solving the possible water shortage in the areas. From this viewpoint, as well as agricultural water demand in upland areas of Lop Buri and Sara Buri, implementation of the Pasak Dam Project should be the important strategy.

3.3.4 In-stream Flow Needs

Navigation

Shallow water between Ang Thong and Chai Nat will be a major issue if navigation needs are still significant in the future. In order to facilitate river

navigation at Chao Phraya River, water releases have to be increased at Chai Nat Dam. However, at present, water available at Chai Nat Dam is not sufficient to satisfy both irrigation and navigation water demands. If river navigation is to be improved, major water resources development has to be taken place at the upstream of the river, or else navigation locks and dams may be constructed near Ang Thong. Strategies are found in the Transportation Sector Technical Report.

Water quality

Water quality conservation is an important issue in the Chao Phraya River basin. Water quality in rivers and canals should not be deteriorated and it should be kept at least at the present level. This strategy in water quality management can be achieved with proper measures explained in the Technical Report of Environmental Management.

As such a measure, river flow has to be kept at more than a certain level. The strategy to satisfy the in-stream flow needs with regard to water quality conservation is to keep, at least, the present level of minimum discharge at Chao Phraya River and its tributaries. The minimum discharge of Chao Phraya River is 75 m^3/second.

4. WATER RESOURCES BALANCE OF 2010

Water demand will inevitably increase as economic development takes place towards the future. Agricultural diversification may requires more water since higher value-added products require resources such water, fertilizer and technologies. Urban population ratio was estimated to increase from 27% in 1987 to 31% in 2010 under the Alternative 2. Industrial expansion was assumed to take place at the rate of 7%/year.

Based on the strategies stated in Chapter 3, water uses of irrigation, domestic and industrial sectors in 2010 were estimated; and water resources balances are examined in this chapter.

4.1 Irrigation Water

4.1.1 Delta Area

Improvement in water management system

The major project for the delta area is "improvement in communication and data management system." After this project is completed, water use efficiency will rise 5 to 10% for the whole delta. Ten percent increase is equivalent to additional 145 MCM available for the UCR in dry season.

Water conservation

Water conservation at upper delta of the UCR will yield additional water at on-farm level, where such efforts should be made by individual farmers. This amount, available in dry season, may be assumed with the target of 50 MCM in the gravity irrigation area of the UCR.

A water balance calculation for the whole delta indicates that 2,518 MCM of water is stored in wet season and 632 MCM is utilized in dry season. Such a

storage function is mainly at the lower delta, which is called water conservation area, and the storage is made at creeks and low land areas. The target of 50 MCM is only 8% of 632 MCM and this should be a reasonable target.

4.1.2 Upland Area

Small and medium scale projects

The target of small and medium scale water resources development is to create storages for 10% of total annual run-off, which is equivalent to 200 MCM. The present level of storage, under the category of small and medium scale projects, is 4% of the annual run-off, which is equivalent to 78 MCM. This amount of storage together with diversion facilities have made 457,000 rai irrigable in wet season by the end of 1987. Additional storages to create until 2010 is set at 122 MCM as a target.

Large scale project

Pasak Dam may be constructed at kaeng Khoi of Sara Buri Province or at Phattana Nikhom of Lop Buri Province; the UCR study recommends the site of Phattana Nikhom. This site is more advantageous than the other since the UCR can receive more benefits from availed water. The amount of availed water will be different by the size of the dam and it may be assumed at 7 m^3/second, which is equivalent to approximately 100 MCM in dry season.

4.2 Domestic Water

The total amount of domestic water supply, in 2010, was estimated at 142 MCM/year by assuming following population, per capita use, and service ratio in the UCR.

Urban Population	Per capita use	Service ratio
1,072,000	200 liter/day/capita	80%
Rural Population	Per capita use	Service ratio
2,387,000	150 liter/day/capita	50%

Metropolitan Waterworks Authority will continue to withdraw water from Chao Phraya River, and it plans to intake water from Maeklong River. The

intake from Chao Phraya River is projected as 60 m^3/second in 2017. By assuming water intake of 55 m^3/second in 2010, the amount of intake will become 1700 MCM/year.

4.3 Industrial Water

The total amount of industrial water supply, in 2010, was estimated at 166 MCM/year by projected amount of GDP/year in 2010. This volume is approximately 3 times present supply, and it is at the similar level of domestic water supply.

4.4 Water Resources Balance

Table 4.1 present the water resources balance in 2010. The projected volume of water demand, in the year 2010, for domestic and industrial consumption is 154 MCM per year for each wet and dry seasons. The annual total is 308 MCM per year, which is approximately three times of the present amount. The amount of 154 MCM is 10% and 4% of water to be delivered to the UCR delta in wet and dry season, respectively. This share of 10% in dry season is rather significant amount.

Assuming 30% of 154 MCM may be met by groundwater, 108 MCM is to be met by the (1) delivered water to the UCR delta, (2) Chao Phraya River flow needs, (3) upland storages, (4) availed water by the Pasak Dam, (5) and Pasak River itself. The total of (1), (3), and (4) together with 10% of (2) and (5) amount to 2,166 MCM. This total should be sufficient to satisfy the increased water demand of domestic and industrial sectors, which is 5% of the available total.

Local water shortage may be foreseen at Sara Buri area since urban and industrial growth is expected to take place around Sara Buri. Groundwater, Pasak River and Chai Nat-Pasak canal are the alternative sources of water for the supply. The Pasak Dam will be able to ease a possible pressure on water balance of the east bank of Chao Phraya River.

Table 4.1 Water Resources Balance in 2010

(Unit : million cubic meter)

Surface water availability (2010)	Wet Season	Dry Season
1. Chao Phraya delta		
Water delivered to the UCR delta	3,790	1,595
Availed water storage by water conservation	50	50
2. Chao Phraya River : Water release at Chai Nat Dam		
Flow needs*	2,000	2,000
Flood spill**	10,760	915
3. Upland area water resources potential/availability		
Upland (potential)	1,176	785
Upland (available storage)	200	200
4. Pasak Dam		
Availed water resource	100	100
5. Pasak River		
Water resources potential at Kaeng Khoi	1,946	206

Water uses	Wet Season	Dry Season
6. Irrigation water		
UCR delta	3,790	>1,595
7. Domestic water		
Urban settlement	35	35
Rural settlement	36	36
8. Industrial water	83	83
9. Total volume of 7 and 8	154	154

Balance :Volume of 9. is met by the available water of 1, 2, 3, 4, 5 and groundwater.

Note * : Flow needs is the amount to satisfy downstream water demands.

**: Flood spill is unavailable to downstream demands due to unstable flow of released floods.

5. WATER RESOURCES MANAGEMENT PLAN AND RECOMMENDATIONS

Based on the issues and strategies stated in Chapter 3 and in line with the Master Plan, water resources management plan and recommendations are presented in this chapter. The following plans and recommendations focus on the structural measures for water resources management. Institutional measures are discussed in the Part II of this Technical Report.

5.1 Agricultural Water

5.1.1 Delta Area

The following measures should be taken in the UCR delta:

1) Improvement in communication and data management systems as well as in major structures of RID for more efficient operations of water management systems.

   This project consists of; (i) installation of equipment such as telemeters and radios at water level observation stations (ii) and civil works such as improvement of on-farm facilities and gate structures, and canals. The gate structures can be automated by replacing present manual operation. This project should be implemented by the RID after the completion of feasibility study.

2) Rehabilitation of irrigation facilities, such as lateral and sub-lateral canals as well as ditches and farm-turn-outs by people's participation.

   This project is intended to rescue the government investment in irrigation system. Lateral and sub-lateral canals have been deteriorated since they are 20 to 80 years old. This project should be performed with the participation of farmers organization, while the previous

improvement project is implemented by the RID. The RID's maintenance activities are limited with the resources to properly maintain all of its facilities from the main to sub-lateral canals. The maintenance of lateral and sub-lateral canals can be made by farmers without any technical difficulties. Although maintenance activities by farmers should be made by their own resources as they are the beneficiaries, a government's financial source may be utilized as a part of the resources. The government's Job Creation Programme may be such a financial source.

3) Implementation of land consolidation projects which incorporate water conservation measures by creating water storage at an on-farm level.

This project is intended to help farmers diversify agricultural productions mainly for dry season. Excess water in rainy season, either from irrigation ditches or rain may be saved in a storage pond to use it for a dry season crop. It could be used for fish pond as well. A small pond can be created by an individual farmers and a larger-sized pond can be created by a group of farmers. Since farmers have to sacrifice a piece of land to create such a pond of common use, a land consolidation project is a good opportunity to organize farmers to bring pieces of land together. A land consolidation project creates a farmers' organization and implemented by the expense of farmers, and therefore, the land consolidation project has a most suitable mechanism for this kind of water conservation measure.

4) Install intermediate storage facilities at a lateral canal level in order to make water management more flexible and to facilitate agricultural diversification.

This project is intended to make water management more flexible with the existing facilities of main and lateral canals. Diverted water through main canals may be stored in the intermediate storages near lateral canal; this will ease the constraint of long travel time of water, imposed by the large irrigation system with a long main and lateral canal. The travel time, for example, is a few days from Chai Nat to Rama Vi Barrage at Pasak River. It is, however, necessary to conduct a study to locate site of such intermediate storages and to find their costs and

benefits. Every lateral canal may not be equipped with such storage facilities. But most feasible sites, socially and economically, can be identified by the study. RID is the agency to implement the project.

5.1.2 Upland Area

The following measures should be taken in the upland area.

1) Implementation of small and medium scale water resources projects.

This project is intended to make more water available for various farming activities such as paddy, upland crops, orchard, livestocks, and fish culture. The upland areas area are traditionally dependent on rain-fed agriculture and are subject to unstable productions; however, the upland areas have received less water resources investment in the past. By implementing medium and small scale projects, storage may be increased from the present level of 4% to 10% of total run-off in the upland area.

It is recommended to conduct a study for identifying potential sites of medium scale projects in the upland areas. Small scale projects are to be requested by local people and submitted to the central government through local governments, and then the National Water Resources Committee makes coordination for their implementations by various agencies. Since the implementation of large scale Pasak Dam project is recommended by the UCR Study, coordination of medium and small scale projects with the Pasak Dam project will be necessary in terms of water resources development and beneficiaries. It should be noted the importance of avoiding possible overlaps among medium and small projects as well and the coordination role of the National Water Resources Committee will be very important.

2) Water conservation by creating water storages at an on-farm level.

This project is intended to make more water available for farming activities and at the same time to improve the environment by increasing vegetation on the upland areas. Water conservation may be

made by creating water storages in various forms such as a farm pond and raised-bed cultivation. This activity should be performed either by an individual farmer at on-farm level or by a farmers' group collectively and technical advices may be provided by the government agencies.

Water stored in the rainy season may not be sufficient for the whole dry season if catchment area and the storage size are small. After water conservation storages are created, needs of more stable water supply will become high among farmers since they have the measure of water storage and they are accustomed with using water for agricultural activities. Then, needs and preparedness of farmers to implement the medium or large scale reservoir projects will increase. With its implementation, the medium or large scale reservoirs may be connected with the farmers storages; and this arrange will result in high efficiency in the government investment of medium and large scale project.

3) Implementation of Pasak Dam and related irrigation projects, if its feasibility study indicates efficiency in investment.

This project is intended to increase water availability in the upper east delta and particularly at Sara Buri area. The original project objectives were to increase water availability in the lower east delta and to mitigate flood at the downstream of Rama VI Barrage and in the lower east delta. It is recommended to shift the major beneficial areas of water supply from the lower east delta to Pasak basin and upper east delta. The Pasak River basin deserves to receive the benefits from the project since a part of the basin has to sacrifice the area to be inundated by the reservoir.

There are two proposed sites for the Pasak Dam: at Phattana Nikhom as upstream site and Kaeng Khoi as downstream site. The UCR Study recommend the upstream site. This is because compensation would be less at the upstream site than the downstream site and the upland areas of Lop Buri and Sara Buri Provinces have a chance of utilizing the reservoir by both reservoir releases and pumping from the reservoir.

This project will increase the flexibility of water management in both the upper and lower east delta. Such flexibility will be gained by the following manner. After the completion of the dam, the upper east delta can utilize more water from the Chai Nat-Pasak Canal and this increased amount may be substituted by the Pasak Dam release for the lower east delta. By having two sources of water, the east delta will gain flexible water management.

The benefits of the dam are not only for the agriculture. It has multi-purpose benefits and more explanations are given in the following sections of domestic water and industrial water for the Pasak Dam Project. The responsible agency is RID.

5.2 Domestic Water

The following measures should be taken to facilitate domestic water supply

1) Water quality control measures for rivers and canals

This measure is intended to secure the sources of domestic water supply in the UCR. Natural rivers and irrigation canals play an important role for domestic water supply. Water quality conservation is vital for urban and rural populations in the UCR as well as its downstream region. Since groundwater in the UCR often contain iron and salt, it is difficult to replace surface water by groundwater even when surface water is polluted; and therefore, it will be essential to keep quality of surface water at the present level. Details of water quality monitoring and control are described in the technical paper of Environmental Management. The local government the ONEB and the RID should be the important agencies.

2) Implementation of Pasak Dam Project to augment dry season flow for Sara Buri and Kaeng Khoi urban water supply.

This project was originally intended to irrigation water supply and flood control. However the project's implementation will augment water available for Sara Buri and Kaeng Khoi sub-region, where urban and industrial development is planned in the UCR development study.

Therefore, this project should aim at multi-purpose water supply as well as flood control.

3) Water diversion from Maeklong River to BMR

This project is intended to obtain a new source of water from Maeklong River for the BMR water supply. At Chai Nat Dam, water is diverted to the Tha Chin (Suphan) River for irrigation and against salt water intrusion. When water diversion from Maeklong River to Tha Chin River is made at the rate of 45 m^3/second through Klong Tha San Bang Pla, water diversion to the Tha Chin River can be reduced and more water can be diverted to the Chao Phraya River. This diversion from the Maeklong River to the Tha Chin River is expected to complete in 1989 by the RID.

After its completion, Metropolitan Water Works Authority plans to increase intake rate, from 25 - 30 m^3/second of the present level, to 60 m^3/second of the year 2017 demand level. This future demand is for the east bank of the BMR and future demand of the west bank of BMR, at the rate of 25 m^3/second, is expected to be met by the diversion from the Maeklong River to the Tha Chin River. The MWWA will have to construct a diversion canal, from the Tha Chin River to the BMR, and a treatment plant at the west bank to implement this plan.

5.3 Industrial Water

Industrial water supply will be made mainly by a private sectors and possibly by the Industrial Estate Authority of Thailand. Therefore, the public sector may play roles of: (i) to develop water resources by a major storages; and (ii) to facilitate the access to the water sources by the industries, either individually or collectively. The second role should be conducted by institutional arrangements. The following measures should be taken to facilitate and to control industrial water supply.

1) Implementation of the Pasak Dam Project

As the first role of developing water resources by a major storages, the Pasak Dam Project will contribute to industrial water supply by

increasing water availability near Sara Buri. This will allow more flexible water resource management with the existing water source at Chai Nat - Pasak Canal. The project will contribute to the urban and industrial growth at GSIC, i.e., Greater Sara Buri Industrial Center, which will have a significant impact to the regional economy. Therefore, the Pasak Dam Project should be promoted from the view point of needs in regional economy.

2) Study of groundwater potentials in Sara Buri Province.

This project is intended to facilitate and to control groundwater use by the industries. As described above, industrial water uses are expected to increase in the Sara Buri Province. It is always beneficial to have alternative sources of water supply and surface water and groundwater can be used conjunctively, which is safe for industry and for resource conservation as well. By evaluating groundwater potentials in terms of locations and safe yield, it will facilitate industries to secure a source of water supply and, more importantly, it will restrict the industries from over-exploitation of groundwater. This study should be conducted by the Department of Mineral Resources.

5.4 River Navigation

Considering the fact that river navigation is obstructed by shallow water depth both in Chao Phraya River and Pasak River, it would be necessary to take some measure for this problem. In order to facilitate river navigation, however, a considerable amount of investment has to be made either by constructing a navigation lock and dam or by low flow augmentation with water resources development at the upstream of Chao Phraya River and/or international trans-basin diversion.

Consideration has to be provided to these alternatives regarding different benefits: a navigation lock and dam is beneficial for navigation only, while water resources development for many purposes. A study should be conducted to find the future needs of navigation and what measure will be necessary to facilitate navigation, if investment is justifiable. For the navigation lock and dam, the justification may be made in terms of cost sharing and increase of

navigation needs in the future. The harbor Department is the responsible agency.

5.5 Flood Mitigation

Flood mitigation is made by a structural measure and a non-structural measure. The structural measure is provided mainly by constructing dikes along rivers and canals. The RID has been implementing the measure to protect agricultural land from flood water overtopping. Considerations should be given to a flood retaining function of the upper and lower delta. This activity of RID will be continued as a part of operation and maintenance for the Chao Phraya Project.

Urban Areas of Chai Nat, Sing Buri, Ant Thong, Ayutthaya, and Lop Buri are subject to floodings. Projects are proposed in a technical paper of urban and human settlement development. Reference should be made to the paper regarding urban flood mitigation. Although such a mitigation measure is implemented by municipal governments, coordination should be made with the RID's activities.

Addition to these structural measures, a new project is proposed as follows:

1) Improvement in operation system of water control facilities of the RID.

   This project is intended to facilitate effective drainage through rivers and canals. Components of the project consists of rainfall and water level gauging stations, telecommunication, data management, and a flood forecasting center. The project should be implemented, by the RID, in a coordinated manner with the improvement of water management system recommended as a project of irrigation water. Master plan study was conducted by the JICA under the name of Flood Forecasting System in the Chao Phraya River Basin in 1988. Reference should be made to the report.

5.6 Water Resources Development for the Chao Phraya River Basin

Project plans and ideas of water resources development at the upstream of Chao Phraya River Basin should be promoted for the benefits of the whole basin including the UCR. These projects are: Kang Sua Ten Dam, Kwae Noi Dam and water diversion from international rivers of Salaween River and Mae Khong River. Various problems have to be cleared before these projects are considered for implementation. Although the achievement water diversion from the international rivers is not in the planning horizon of year 2010, such a project idea should be promoted in the international dialogue due to the significant benefits to the Central Region.

PART II

WATER MANAGEMENT INSTITUTIONS

1. ORGANIZATIONAL STRUCTURE OF WATER RESOURCES MANAGEMENT

There is awareness of the crucial role of the institutions and organization playing in the process of water resources development in the UCR. Most frequently institution and organization have been discussed with reference to irrigation water management. But in terms of the UCR, two more aspects will be discussed; industrial water and water supply for urban use.

In order to have better understanding of the management of water resources in the UCR, it is useful to examine the whole picture of the organizational structure of the government agencies which are involved in water resources development.

1.1 Government Organization for Irrigation Water

The Royal Irrigation Department (RID) in the Ministry of Agriculture and Cooperatives is directly responsible for irrigation planning. The various divisions and offices under this department are illustrated in Fig. 1.1.

By law, the RID is responsible for the development of water resources for the purposes of agriculture, industry, domestic water, transport, energy, water retention, drainage, flood control and land development, and for drawing the master plan for the development of water resources throughout the country. The plan is implemented by construction of dams, reserviors, weirs, irrigation canals and ditches. Its responsibilities also include pumping irrigation, the management of equipment, water distribution, arrangements and the maintenance of irrigation programs.

There are 12 Irrigation Regional Offices (IRO) throughout the country. The IRO 7 and 8 have responsibility in operation and maintenance of the irrigation projects in the UCR. The division of responsibility is that IRO 7 covers the right bank of the Chao Phraya River whereas the IRO 8 the left bank. The

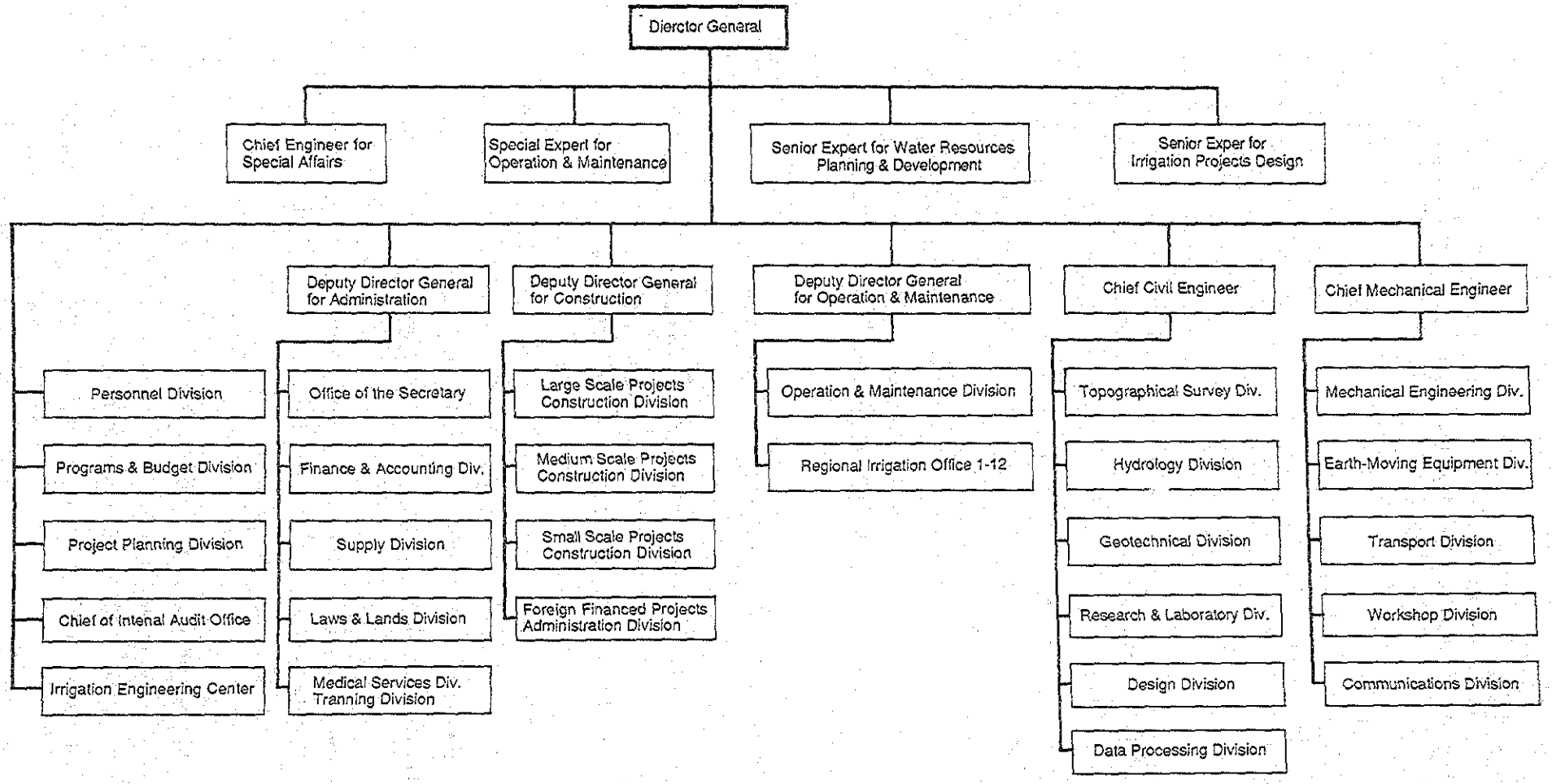

Fig. 1.1 Organization of Royal Irrigation Department

irrigated area of the two Regions are approximately 4 and 3.5 million rai respectively.

The organizational structure of the Operation and Management (O&M) tasks of the RID, as shown in Fig. 1.2, consists of three main levels: O&M at Bangkok Center Office, O&M at IRO and O&M at the farm level

RID office in Bangkok has Division of Operation and Maintenance which is responsible for the tasks concerning administration, engineering, water control and allocation, rehabilitation and repairment of irrigation facilities, water fee collection, irrigated agriculture, ditch and dike construction, water use at farm level including the cooperation and coordination with other related agencies.

O&M at the regional level, which is under each IRO, compries two sections. One section administers O&M of the large scale irrigation project and it is called "Project O&M office", while another section called "Provincial Irrigation Office" is responsible O&M of the medium and small scale irrigation project.

In the UCR, each sub-irrigation project under the Great Chao Phraya Scheme is in the line of command of "Project O&M office", which has organization to control their project areas separately as shown in Fig. 1.3. The project engineer is the head of the sub-project and administrates responsible area through the water master and "zone man", who has 10,000 rai for his supervision.

At a farm level, O&M have been managed by farmers themselves. The "Water User Group" is organized at the clearing and repairment. One water user group consists of the farmers who use irrigation water from the same ditch. Every water user group in the same sub-lateral is formed into a sub-lateral group which is called formally by the RID that "Administrative Group for Using of Irrigation Water" These two groups work under supervision of the RID through the zone man.

Zone man who works most closely with the farmer, has responsibility of supervising water delivery in lateral and sub-lateral canals together with various structures. Its specific duties are controlling water use, ensure sufficient ample irrigation water of fields, opening or closing of farm turnout

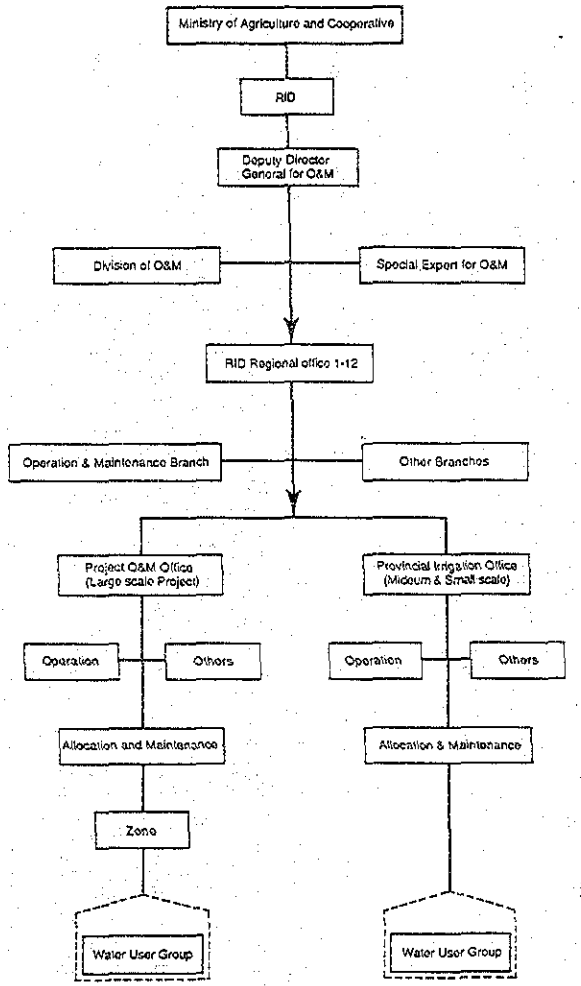

Fig. 1.2 Organizational Structure for Operation and Maintenance of Irrigation Project

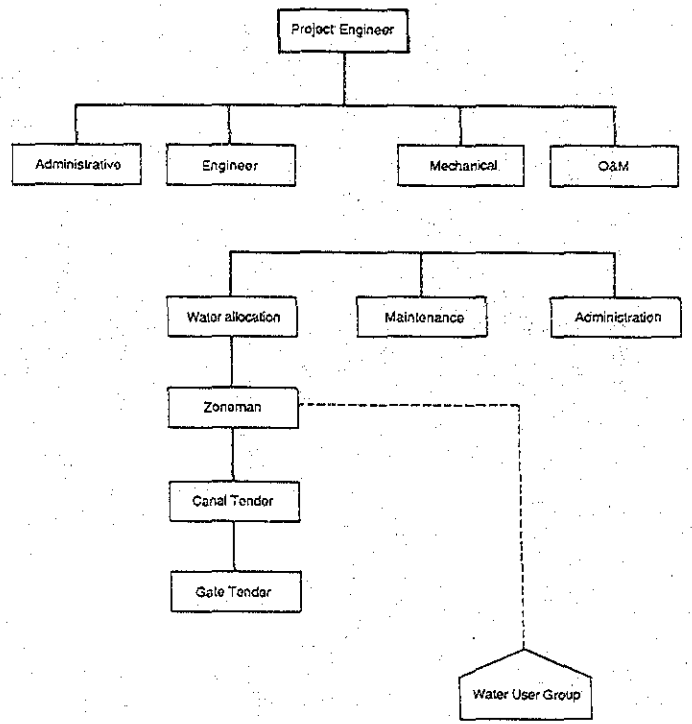

Fig. 1.3 Organization of Sub-Irrigation Project in Chao Phraya Scheme

regulator, water requisition by ditch leader or sub- lateral leader, scheduling weed eradication.

For the medium and small irrigation projects which are under the administration of Provincial Irrigation office, O&M are left to the farmer. Water user association is, then, encouraged by RID guidance to carry out water management. In 1984, Mobile Campaign Unit (MCU) was established as an advisor to the farmers for providing technical assistance and guidance on water use and management in the irrigated area of medium and small scale irrigation project. MCU is nonlegislative unit. Therefore, no budget has been provided. The performance of the Unit in the UCR has thus been minimal.

1.2 Government Organization for Industrial and Domestic Water

In the UCR, the industries tap water from both irrigation canal and groundwater. Though the industrial water demand is found less than the available supply, more industries are likely to be located around Sara Buri, so that water demand for groundwater, Pasak River and irrigation canals will increase. Farmers have also shown an increasing interest in using groundwater for their cultivation. This is a result from the experience of Sukhothai and Phichit groundwater for irrigation. It can be predicted that private irrigation wells will become more popular in the upland of UCR.

Department of Mineral Resources (DMR) is the responsible agency in controlling the utilization of groundwater under the Groundwater Act of 1977.

According to the Act, the direction on the technical principles of groundwater management is issued as;

1) Specifications for drilling and the construction of wells are provided under the Act. Standard forms for daily drilling reports, well records and other information are prescribed,
2) Methods of groundwater extraction and conservation are outlined,
3) Technical measures to protect groundwater from pollution are deseribed and drinking standards have been issued, and
4) Technical principles are given for the disposal or injection of water or liquids into an aquifer through a well. The emphasis is placed on the monitoring of water quality in the affected aquifer and neighboring

aquifer through a network of observation wells. (Thailand Natural Resources Profile:65).

The UCR has been developed without sufficient consideration of the effect which might give adverse effect in the long run. In some areas, the pollution of grounwater by pesticide, fertilizer and underground waste may effect. This should be controlled before situation become worse.

The water demand for urban use appeared to be in the same situation as industrial water in terms of the demand and supply which will face little problem. The rural pipe water supply is under the responsibility of the Provincial Water Work Authority (PWWA), established by the Provincial Water Work Authority Act of 1979. At present there are 674 rural water supply service areas, which only serve about 5.1 percent of the national rural population. There are also approximately 20,000 small-scale piped rural water supply schemes serving additional four million people, which increase the total of the rural population served to 14.9 percent.

PWWA is a public enterprise under the Ministry of Interior, administered by a committee which consists of, DG of Public Works Department, DG of Department of Health, and other 7 appointed persons (Fig. 1.4). This committee has functions on policy planning and oversee all the piped water supply operation. There are 2 kinds of rural piped water supply; large scale and small scale. The large scale rural piped water supply is implemented in the municipality area and administered by PWWA whereas small scall one is implemented in Sanitary District, and administered by a sanitary district or a community.

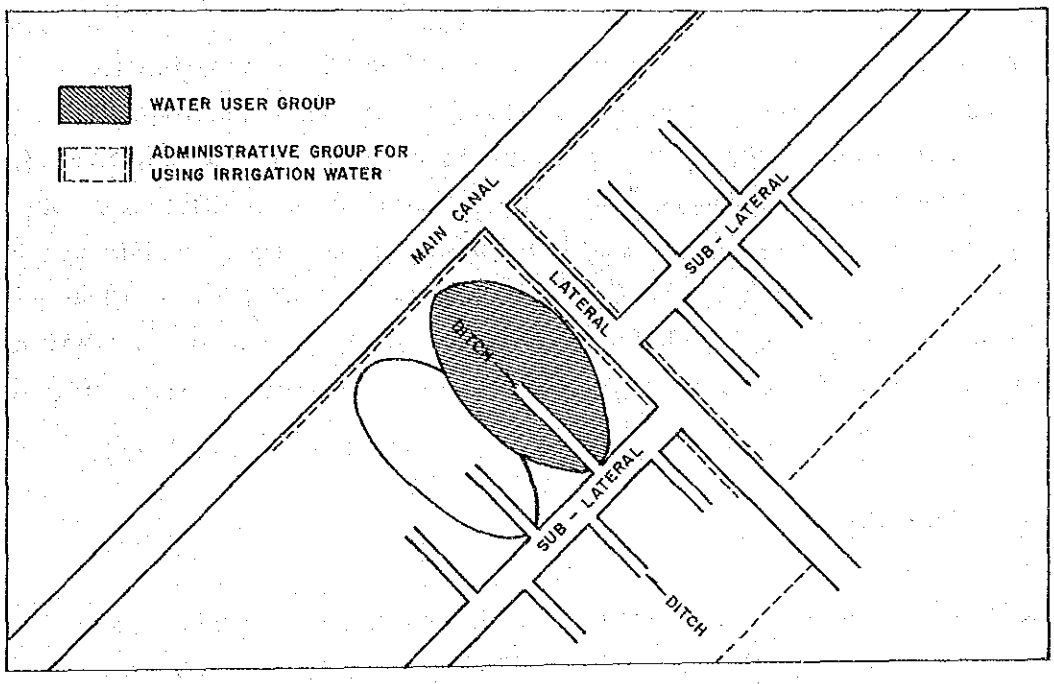

Fig. 1.4 Physical Structure of Irrigation Canal

2. WATER USER'S ORGANIZATION

It has been recognized that the water user organization had played an important role in water resource development, especially in irrigated agricultural development. The formations of organization and objective of establishment are dependent on the agency concerned or initiated and type of water resource development project. For instance, the large, medium and small project undertaken by RID, pumping irrigation of the NEA or CPD. Nevertheless, the major objectives of all are to take responsibility on O&M of irrigation system at some level in order to make the efficient water utilization from the project.

2.1 Historical Background

The water users have been the traditionally prestigious water utilization organization with a long history of about 160 years in Chai Mai Valley. That was called People Irrigation. There are about 2,000 units of People Irrigation at present, of which command area range from 3,000 to 5,000 rai. The organization is further divided into sub-groups, where a sub-group covers 500 to 1,000 rai. One sub-group has its own chief to control diversion works. As a general rule, the members of the sub-group shall present paddy to the chief by 7 to 20 kg per rai as remuneration for operation of facilities in case of achieving good yield. The operation and maintenance of the water distribution facilities are practised habitually by members themselves. There are also some rules imposed on the water allocation and on the repair work for the facilities.

The first formal organization under the attempt of RID, was established in 1963. This organization was the Water User Association (WUA) at Ban Kud Ling Ngeo Reservoir in Muang district of Udonthani especially for WUA. The organization of such a WUA is shown in Fig. 2.1. Major aims of the association are as: to promoting farmers understanding on value of water, water allocation and maintenance of canal system and appurtenant structure, to mediate

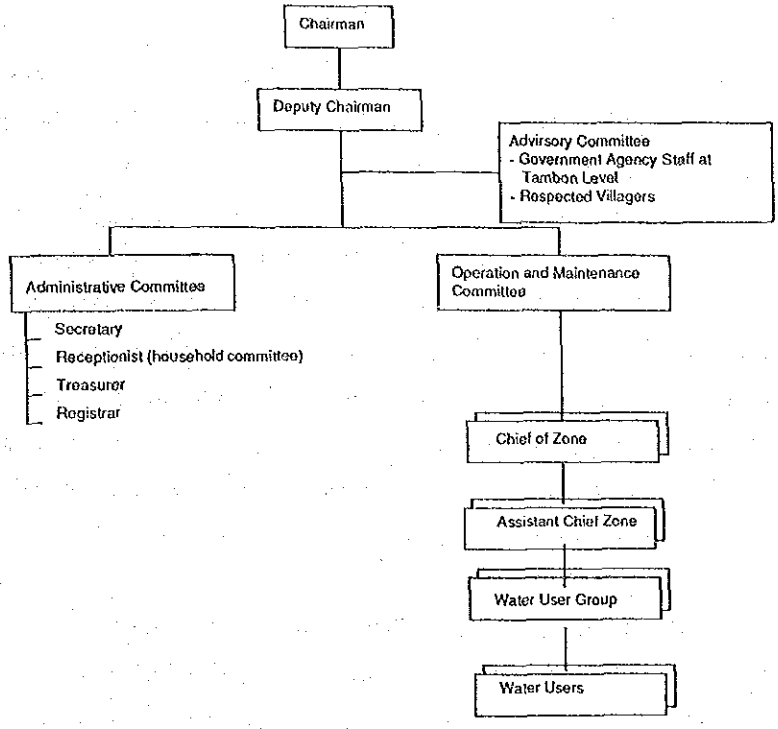

Fig. 2.1 The Organization of Existing Water User Association

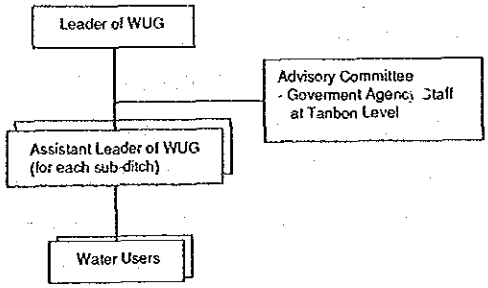

Fig. 2.2 The Organization of Existing Water User Group at Farm Ditch Level (Basic Group)

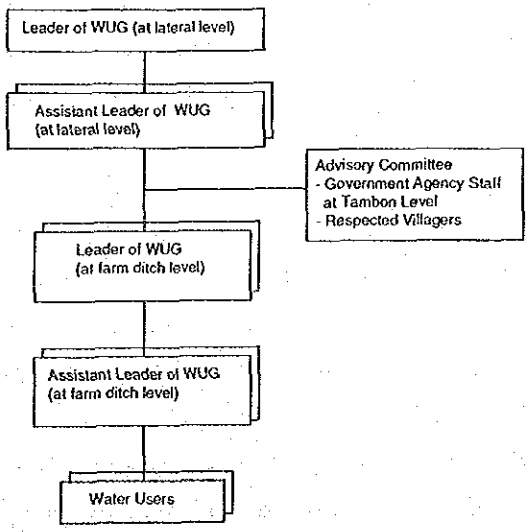

Fig. 2.3 The Organization of Proposed Water User Group (at lateral level)

conflicts among farmers in water use, to help the members in buy and sell agricultural product including the preparation of farm equipment as well as other farm inputs.

At present, there are 167 associations scattered throughout the country. RID had found out that WUA did not function well. It covered too large in area and composed of many members. Therefore, it was too difficult to communicate and oversee thoroughly. The other reason which RID pointed out was lack of a law to enforce the one who broke rules or regulations. So in 1974, RID had proclaimed their attempt to promote and establish Water User Group (WUG) as a basic group (or basic unit) and to delay WUA's promotion.

WUG is known as the organization among the farmers within the same farm ditch. The covered area is so small with simple organization function (see Fig. 2.2). Therefore, RID expects that the farmers can learn faster and will be the first step of development process. The aims of WUG are to work on water distribution, ditch cleaning and repairing at on-farm level.

After WUGs at farm ditch level or basic group functions well, every WUGs in the same lateral is formed up into a lateral group which is called WUG at lateral level (see organization in Fig. 2.3). Furthermore, all WUGs within the same main canal or the same zone is formed as the Administrative Group for Using Irrigation Water (AGUIW). This new group has similarity in organization structure as WUA, except that the AGUIW does not legally register. This strategic approach has initiated since 1989 under the guidance of Working Group IV of RID's Irrigation Improvement Programme which is part of the process in strengthening WUG. The Water User Organizations like WUG, AGUIW, WUA, engaged by RID have the major aims on the irrigation activities. The others such as agricultural extension and cooperative promotion are the secondary.

Another form of Water User Organization is the Water User Cooperative (WUC), which is registered by the Cooperative Promotion Department. WUC exists in the area under the water resource development of CPD herself, pumping irrigation under the National Energy Administration (NEA) and some of RID area within the land consolidation project. The major task is to work in the water allocation and maintenance at various levels even upto main canal level.. As one kind of the agricultural cooperatives, it may attempt to include

the other activities such as farm input distribution and farm credit provision. It helps in collecting electricity charge in the pumping irrigation and also collecting O&M fee in land consolidation area. The organization structure and the size of covered area are similar to WUA. WUC will have one cooperative in each pumping scheme of either NEA or CPD area. At present, there are WUC of 101 under NEA, 17 within land consolidation area and 11 under CPD scattered throughout the country,

Presently, there are limitation of both numbers and activities of water user organization within the Chao Phraya Project as indicated in Table 2.1. There are only 7 WUCs covering 33,800 rai out of 551,000 rai under land consolidation area, even though, this type of on-farm development has the highest potential in agricultural development. The highest numbers of legally formation belong to WUA which was the first attempt of RID in promoting 25 years ago. The 217 WUGs, gathered from the source of information, might not be the exactly number. There is just only one AGUIW in the UCR.

2.2 Existing Performance of Organization

There are some numbers of organizations which have successful performance in Chao Phraya Project. Teang Tae Water User Cooperative is one of them which won a fourth prize of annual contest under RID program last year. It is in Boronmathat Project (see the location in Fig. 2.1 of Part I, composes of 19 groups and 46 sub-group (farm ditch). Cooperative area covers 1 zone of 8,000 rai in intensive land consolidation project. The active performance area is as follows: cooperative handle the water allocation by themselves within the zone under the guidance of zoneman, the members clean the farm ditch twice a year before beginning of growing reason. The farm ditch need to be dredged once within 2-3 years by hiring a backhoe from the private and the members in the same ditch will share the expenditure. An other one with good performance and should be mentioned is Ban Rom Water User Association which had won the first prize of annual national contest last year. It located within 2 zones of Roeng Rang Project, coverage area of 22,772 rai under ditch and dike program. The outstanding activities were as follows: the members helping in dredging the 9 farm ditches of 9.696 km. long, cleaning the farm ditch twice a year, the budget and labour in constructing the association's office, negotiated with the Lop Buri Seed Center to make the contact for the mangbean seed production, collecting O&M with the rate of 3 Baht/rai, seting

Table 2.1 Present Numbers of Water User's Organizations and Areas under Each Types of On-Farm Development within Chao Phraya Project

Project	Area under On-Farm Development (1,000 rai)				Number of Organization and Area Covered (1,000 rai)							
	Int	Ext.	Others	Total	WUG	Area	AGUIW	Area	WUA	Area	WUC	Area
Region 7												
1. Pholathep	-	-	96.3	96.3	-	-	-	-	2.0	40.0	-	-
2. Thabote	-	-	179.4	179.4	-	-	-	-	2.0	31.5	-	-
3. Somchook	51.9		253.1	305.0	-	-	-	-	3.0	16.1	2.0	13.9
4. Don Chedi	26.5	9.6	108.4	144.5	-	-	-	-	2.0	26.4	-	-
5. Pho Phya	-	-	370.0	370.0	-	-	-	-	4.0	71.2	-	-
6. Borommathat	150.4	2.3	212.3	365.0	49.0	13.6	1.0	5.8	7.0	225.4	1.0	5.8
7. Chanasutr	135.6	25.4	313.3	474.3	56.0	18.1	-	-	7.0	179.7	2.0	5.7
8. Yang manee	-	-	232.9	232.9	21.0	11.1	-	-	5.0	70.0	-	-
9. Phak Hai	-	-	206.0	206.0	-	-	-	-	1.0	9.4	-	-
10. Bang Ban	-	-	144.2	144.2	-	-	-	-	-	-	-	-
11. Chaoched-Byh	-	-	406.0	406.0	3.0	1.1	-	-	-	-	-	-
12. Phrya Banlu	-	-	437.5	437.5	-	-	-	-	-	-	-	-
13. Phra Pimon	-	-	261.4	261.4	-	-	-	-	-	-	-	-
14. Phasi Charoen	-	-	200.0	200.0	-	-	-	-	1.0	10.0	-	-
Region 8												
15. Manorom	78.2	5.7	152.1	236.0	23.0	6.4	-	-	3.0	27.0	1.0	4.5
16. Chong Kae	-	-	292.4	292.4	-	-	-	-	3.0	11.1	-	-
17. Khok Kathiem	41.9	24.0	154.3	220.2	-	-	-	-	3.0	39.6	1.0	3.9
18. Roeng Rang	-	-	183.0	183.0	65.0	25.8			2.0	24.5	-	-
19. Maharaj	-	-	476.3	476.3	-	-	-	-	3.0	22.6	-	-
20. Pasak Tai	-	-	240.6	240.6	-	-	-	-	1.0	8.4	-	-
21. Nakorn Luang	-	-	267.0	267.0	-	-	-	-	3.0	17.1	-	-
22. Rangsit Nua	-	-	454.0	454.0	-	-	-	-	2.0	135.6	-	-
23. Rangsit Tai	-	-	577.9	577.9	-	-	-	-	-	-	-	-
24. Klong Dan	-	-	527.9	527.9	-	-	-	-	-	-	-	-
Region 9												
25. Phro-Ong CYCH	-	-	510.0	510.0	-	-	-	-	-	-	-	-
Total	484.5	67.0	7256.3	7807.8	217.0	76.1	1.0	5.8	54.0	965.6	7.0	33.8

Remarks:

1. Informations taken from On-farm Water Use Branch, O & M division, RID, but not confirmed by the Branch.
2. Notation in the table come from as following:
   - Int. = Intensive on-farm development
   - Ext. = Extensive on-farm development
   - Others = On-farm development under ditch & dike or conservation area
   - WUG = Water User Group
   - AGUIW = Administrative Group for Using Irrigation Water
   - WUA = Water User Association
   - WUC = Water User Cooperative
3. Locations of each project should be reffered to Figure 2.1 of Part I.

up the irrigation rotation schedule among the members. Upon the success of this association, project staffs of RID gave very strong encouragement to the WUA committee.

From the previous studies, it was mentioned that the performance of the water user organizations were found to be largely unsuccessful. The possible reasons which might limit performance are collectively as following:

1) Farmers' Attitude

(1) Farmers do not have confident to obtain benefit from the activities.
(2) Non-members have the same opportunity in using the water as member (no penalty by law).
(3) Rule and regulation can not impose within organization.
(4) Water is free for farmers.
(5) All of irrigation infrastructures belong to government, so the government has the responsibility to undertake maintenance accordingly.

2) Inefficient Service from Irrigation Agency

(1) Improper design, layout, construction and maintenance of irrigation system.
(2) Inability to deliver adequate crop water requirement.
(3) Inequitable and uneven distribution of water.
(4) Inter-related activities of concerned organization are not systematically performed.
(5) Lack of co-ordination and co-operation with key external institution.
(6) Reluctant support to water user organization.
(7) Lack of clearly stated functions and objective.
(8) Inadequate trained and motivated staffs.

3) Low Participation from the Numbers

(1) Establishment is not initiated from the farmers themselves.

(2) Certain political influence brought in by organization have obstruct organization structure.
(3) Members are ignorant about their rights and are selfish.
(4) Farmers are not accustomed to a formal organization operated by certain rules and regulations.
(5) Organization structures introduced by government agency are too complex and difficult to understand.
(6) Layout of canal and drains governed only by topography and soils.
(7) Farmers do not obey the leader and government staff.
(8) No law enforcement for imposing rule and regulation.
(9) Some of them are part time work in the farm.

4) Lack of Strong Leaderships

(1) No incentive for them, such as remuneration
(2) Lack of knowledge and skill
(3) Lack of leader character
(4) No confident in administration

5) Lack of Management Skill

(1) Lack of basic management skills
(2) Lack of Coordination between administrators and members
(3) Lack of communication with agencies concerned
(4) Lack of financial mobilization skill

6) The Other Unfavorable Environments

(1) Lack of continuous support from the officials
(2) Poor farming practices and inappropriate crop types
(3) Lack of capital or credit facilities as well as marketing
(4) Expansion of urban and industrial zone into agricultural area

It is noted that there are differences in the level and nature of irrigation as well as water resource development across the UCR, and the variations in organization and institutional arrangement, So, an inadequate performance in one place may caused by only some of shortcomings mentioned above.

2.3 Proposed Water User's Organization

Management of irrigation systems can be one of three basic forms as: 1) management by government personnel (or by some private agency), 2) management by users themselves and 3) some form of joint management by users and agency staff. (At the most is in the third form which shares responsibility). The attempt of this proposal will describe in categories as followings: the role and responsibility for the water users and agency concerned, process in strengthening water user organization, stage development on operation and maintenance responsibility, and recommendation.

2.3.1 Role and Responsibility

The prospective degree of sharing in management between the water users and agency staff are mainly dependent on the project types and policy of agency concerned. Under gravitational system of large and medium scale project engaged by RID, the physical irrigation system is complex. Generally, the water users need to undertake O&M at on-farm level as the WUG. At this level, RID staffs will take O&M responsibility from a water source down to a turn-out and also supervise the WUGs relevant their activities at on-farm. The WUG is a fundamental form. Therefore, the organization structure must be as simple as possible. It may compose of one leader and one or two assistant leaders depend upon the coverage area size.

The water user organization at a sub-lateral in large scale project and at main canal or the whole project in the medium scale project is called WUC and WUA. In forthcoming years, the responsibility of O&M for the organization could be at this level also. The main tasks of organization will be a set up of the crop plan, water allocation plan and implementation, and to clean and minor repair of the canal. The technical advise in those activities will be supported by RID and relevant agencies. This kind of organization has the common interest in utilizing irrigation water from the same source for the agricultural production. The major aims must be move emphatic in water allocation, solving the water use conflict and maintenance work. The others like economic activity such as marketing, farm input distribution and farm credit provision will be the secondary. WUC will be the most suitable one which presently had been organized in the area under Land Consolidation Project. It

should be set up even outside of land consolidation area wherever agricultural potential is high in the future. The organization structure can be simplified from the original one as shown in Fig. 2.4. The function of organization can be mentioned as follows:

Administrative Central Committee: administer the organization work, policy making, negotiation and communication with government agencies concerned as well as others interested private sector, protect the rule and regulation, solve the conflict among the members.
Advisory Committee: giving the advice to central committee
Subcommittee in Irrigation Activity: in charge with crop plan, water allocation plan and implementing, maintenance work, solve the irrigation conflict, collecting the O&M fee and electricity charge in pumping irrigation.
Subcommittee in Economic Activity: in charge with farm input distribution, farm credit provision, contract farming, marketing, and the other interested aspects besides irrigation activity. This subcommittee should be set up after irrigation activity has been functioning effectively, but exceptions depending on locality.
Water User Group: the WUG in this organization means both the WUG at on-farm level and at lateral or main canal level as well. The tasks and duties would be the same as previously mentioned.

WUC should be also implied in pumping irrigation as well. One pumping scheme will need only one WUC. For small scale project, the objective, is to provide water mainly for domestic use of villagers, secondary for agricultural purpose such as livestock raising, growing vegetables during dry season, and fishery. After construction is completed, the responsibility in maintenance and water allocation is transferred to the Tambon Council which jurisdiction is over the site of the project. Formation of existing WUG structure over the site should be enough. The reasons of having inadequately utilized or improperly maintained, come from low participation from the members. So, it need to set up the suitable strategy in strengthening the existing organization.

2.3.2 Process in Strengthening Water User's Organization

From historical background, the People's Irrigation in the North has been well managed as an organization contributing to rural society with historical

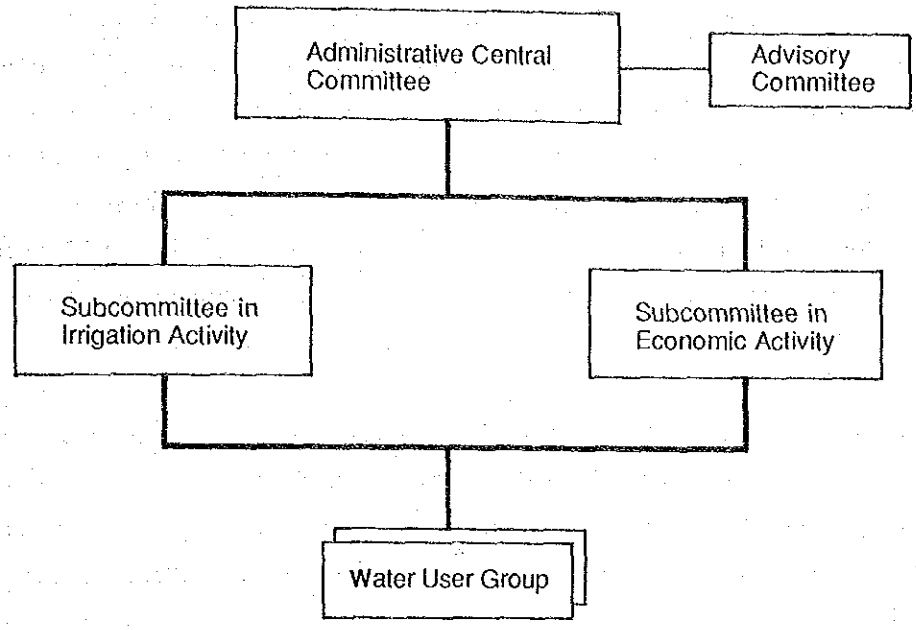

Fig. 2.4 Proposed Organization Structure for Water User Cooperative or Water User Association

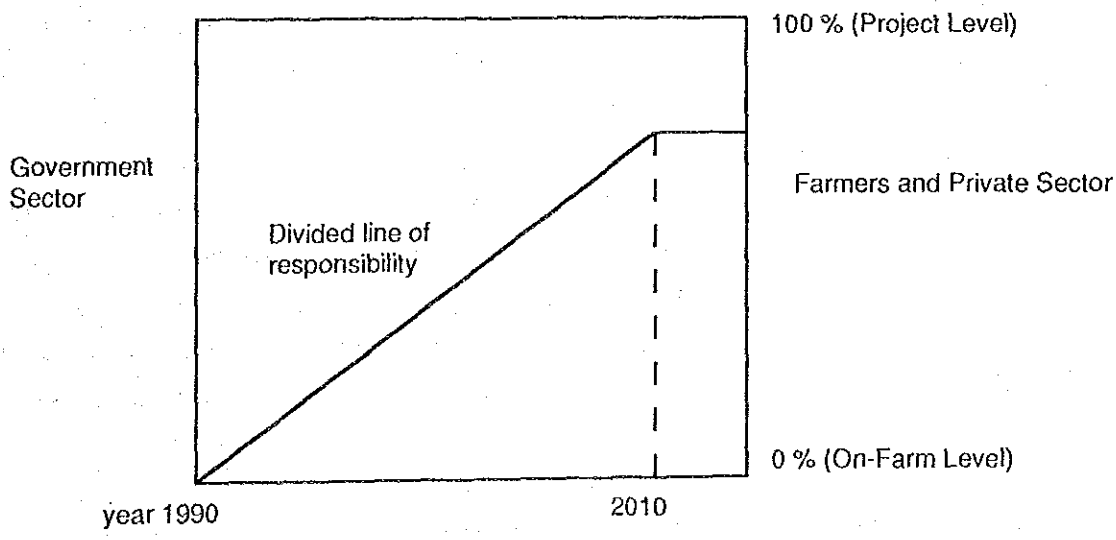

Fig. 2.5 Progressive Development on O&M Responsibility

some of them has been dissolved already. The one of main reasons for failure come from the top-down policy which attempt to establish WUG with a blue print within a limit of time. The context affecting the nature of farmers for participating in the activity are social, political, cultural, physical and economic characteristic of communities. The water user organization is a kind of community development which need some time in the process and should start from their own circumstances. The process in strengthening may express as follows:

1) Community Preparation: study all the existing contexts affecting the nature of farmers' participation in the activity, learn to know them, giving the knowledge and encourage them in managing the use of water by group. Look for the one who might be the leader of that group.
2) Form up the water user group as the fundamental group at on-farm level. The designed management function of water user group at this stage must be as simple and indigenous as possible.
3) Enlarge the water user group at lateral level and up to main canal or the whole project later on, whenever the previous ones are well functioning organize.
4) Register as legal institution, either WUC or WUA depending on agency concerned. WUC would be more favorable.

In the processes, they need intensive dialogue and support by concerning agencies based on the philosophy of "learning by doing". Training via study tour and demonstration are also necessarily undertaken. The phase in water resource development may categorize as: project planning, project design, construction, operation and maintenance and modernization. The processes in strengthening could be introduced in as earlier stage of development as possible.

2.3.3 Periodical Development on O&M Responsibility

The higher degree of involvement in O&M activity coming from water users especially in agricultural production sector, may need some period of time in development and process. The private sector should be encouraged involving in the activity also. Nevertheless, there are numerous components concerned such that the completeness of physical infrastructure, water quantity and

quality, budgetary, social and economic background of human resource concerned, etc. The overall view of the strategic plan may be expressed in term of percentage involvement from agencies concerned and time scale as shown in Fig. 2.5. The pumping scheme, medium scale project and the area under land consolidation project may have the higher potential in this strategy.

Further recommendation for proposal water user organization are the following:

1) Try to promote water user organization in such a way that they are not only social organization but also economic or producers' organization.
2) It should be realized that the success of a given irrigation project requires effective participation of strong farmers' organization, and should use the systematic approach in which irrigation system is designed to fit people's needs and capacities.
3) Farmers should be treated as a key participants, not just a supplementary element of the system.
4) Irrigation projects should be initiated by the majority of water users.
5) Specialized agency of government should play their major role in concerned activities such that the community preparation and development should be undertaken by Community Development Department, etc.
6) It should include the subject relevant irrigated agriculture in curriculum of secondary school. That will be basic knowledge of the new generation.

3. LOCAL PARTICIPATION IN WATER ALLOCATION FOR CHAO PHRAYA DELTA

Chao Phraya delta is located in the lower Chao Phraya basin. The total project area is 7,808,000 rai, consists of 25 irrigation projects which is administered by RID. The main sources of water come from Bumiphol and Sirikit dam which are the multipurpose reservoirs locating outside of the delta at upper Chao Phraya basin. The water released from these two reservoirs passing turbine to generate electricity. Partial flow reaches Chao Phraya dam. this amount of flow plus available water at Rama VI Barrage is diverted to the Chao Phraya delta by canals and rivers. The diverted water will be utilized for irrigation, domestic, industrial, navigation, water quality and salt intrusion control.

The project covers quite large area with complexity in land use, irrigation facilities, and also consisting of numerous agencies concerning water ement and utilization. The problem of water shortage are in the present and future particularly in the dry season. Therefore, it is necessary to improve the institutions relevant to water allocation.

3.1 Present Institutional Organization and Procedure in Water Allocation

The main tasks of responsibility in water allocation within the Chao Phraya delta belong to RID. It consists of 25 irrigation projects; 14 of them located as the west bank of Chao Phraya river, is administered by RID region 7 office at Chainat; and on the east side, Region 8 office administered 10 irrigation projects and one project belongs to Region 9 office. Each project has the project office in the project area under the responsibility of Project Engineer. Each project area is divided into several sections, where in a water masters are assigned. The area is also divided, within a section, into the zone with in charge of zoneman. The size of zone may vary from 6,000 to 12,000 rai

depending on the type of on-farm development. At farm level, the responsibility belong to the farmers themselves.

Due to water shortage in the Chao Phraya basin, a mathematical simulation model was developed by RID with help of the ACRES INTERNATIONAL INC. of Canada. The purpose is to set up a program of water release from reservoirs and allocation to project areas. Even though, the computer program was introduced in water allocation, it still had a serious water shortage because most farmers planted second rice in the dry season more than the available water can supply whenever the rice price was very high. To deal with this situation, MOAC had set up a committee called "Committee for Promotion and Supervision of Dry Season Crop Program" to make a target plan, promotion methodology and regulating the plan for crop diversification during the dry season. Minister of MOAC is a chairman. The committee members consist of representatives from agencies concerned. This committee was established in 1981. There is a subcommittee under this committee called "Subcommittee for Planning and Promotion of Dry Season Crop" to be s supporting institution of the major committee. The director general of DOAE is a chairman and the director of Planning and Special Program division of DOAE sitting as secretary in the subcommittee.

The subcommittee had set up the policy in making the crop plan for dry season as followings:

1) The areas, which were not planted in the previous wet season, would be the first priority.
2) The damaged area causing by other flood, drought or the others obtaining the production less than 50 percent in the previous wet season which cover the area greater than 300 rai. This whole area will allow to grow.
3) The area is inturm of rotation will be considered in the third priority.
4) The other areas under the completion of on-farm development would be taken as the last priority.

At present, water allocation for the dry season is decided after the wet season based on the amount of water available in the two main reservoirs. The procedure will start with the crop and water allocation plan as followings:

1) Each irrigation project office makes target crop area within the project. The target area would be taken from the historical datas of inturn rotational area. The weekly water demands for the whole season are also estimated (during early of September).

2) RID regional office collecting target crop area from all of irrigation projects. The weekly water dam and for the whole season at the main regulators of the region and at each project as well are also estimated. These matters are submitted to the main RID office in Bangkok. (during September)

3) Subcommittee for Planning and Promotion of Dry Season Crop holds the first meeting in Bangkok. Subcommittee will oversee all the issues concerned such as amount of available water from the reservoirs, the size of target crop are, the price of production as well as the water need to supply for the other uses, and set up the strategy. (during October)

4) Working group of RID to study and make adjustment on target crop area and water allocation plan basically from the informations obtained from the regional office, EGAT, and strategic plan from the subcommittee. (during October)

5) Subcommittee for Planning and Promotion of Dry Season Crop holds the second meeting in Bangkok. The meeting decides a certain numbers of areas, and kind of crops to be grown, and set up the definite plan submitting to the committee. (during November)

6) The committee for Promotion and Supervision of Dry Season Crop Program holds annual meeting in Bangkok. The crop dry season plan will be approved. (during November)

7) Workshop is held in the region by Planning and Special Program Division of DOAE. The dry season crop plan is informed and discussed in the meeting. (during December)

8) RID regional office adjust the crop and water allocation plan for each irrigation project within its region and in form irrigation project office. (during December)

9) The irrigation project office adjust the crop and water allocation plan within the responsible area. The public relation will be made in some ways or the others as: submitting the plan to the local agencies concerned, inform in the monthly meeting of Provincial Development Committee, District Development Committee, Tambon Council; meeting with head of the villages, head of WUC, the water users in the village at least once in one zone.

Working Group for Promotion of Dry Season Crop is set up year by year in some province. The deputy governor sits in at a chairman and assistant of provincial agricultural extortionist as a secretary. The main aims of this working group are to make dry season crop promotion plan, monitoring and controlling the planted area within the province, collecting all informations and problem rising concerned to be submitted to the governor.

For water allocation, RID set priority criteria of utilize water from the reservoirs as multipurpose use. The priority for the water supply will be in the order as followings:

1) Domestic use for BMA as 2.5 MCM a day with partially use in urban area under PWA.
2) Salt intrusion control for Chao Phraya and Tha Chin river as 7.7 MCM a day.
3) Domestic and industrial use
4) Navigation in Noi, Supan and Chao Phraya rivers all year round
5) The rest of water using for dry season crop, fish and shrimp pond, and etc.

The water for planting the crop is the last priority. The RID main office set up weekly water allocation plan at the 6 main head regulators for the delta (4 under Region 7 and 2 under Region 8). Furthermore, the regional office set up the weekly water supply plan at main regulators of each irrigation project.

During the dry irrigation season, the water allocation in the delta has been implemented in the process as followings.

1) Water demand forecast is made by the RID main office based on the weekly past progressive cultivation area submitted from the projects.
2) Request of water releases is made to EGAT office by the RID main office based on the amount of water allocation schedule.
3) The RID main office determine water allocation at 6 main regulators.
4) The RID regional offices determine water allocation to each irrigation project area, based on the ratio of water allocation plan and amount of water available, and