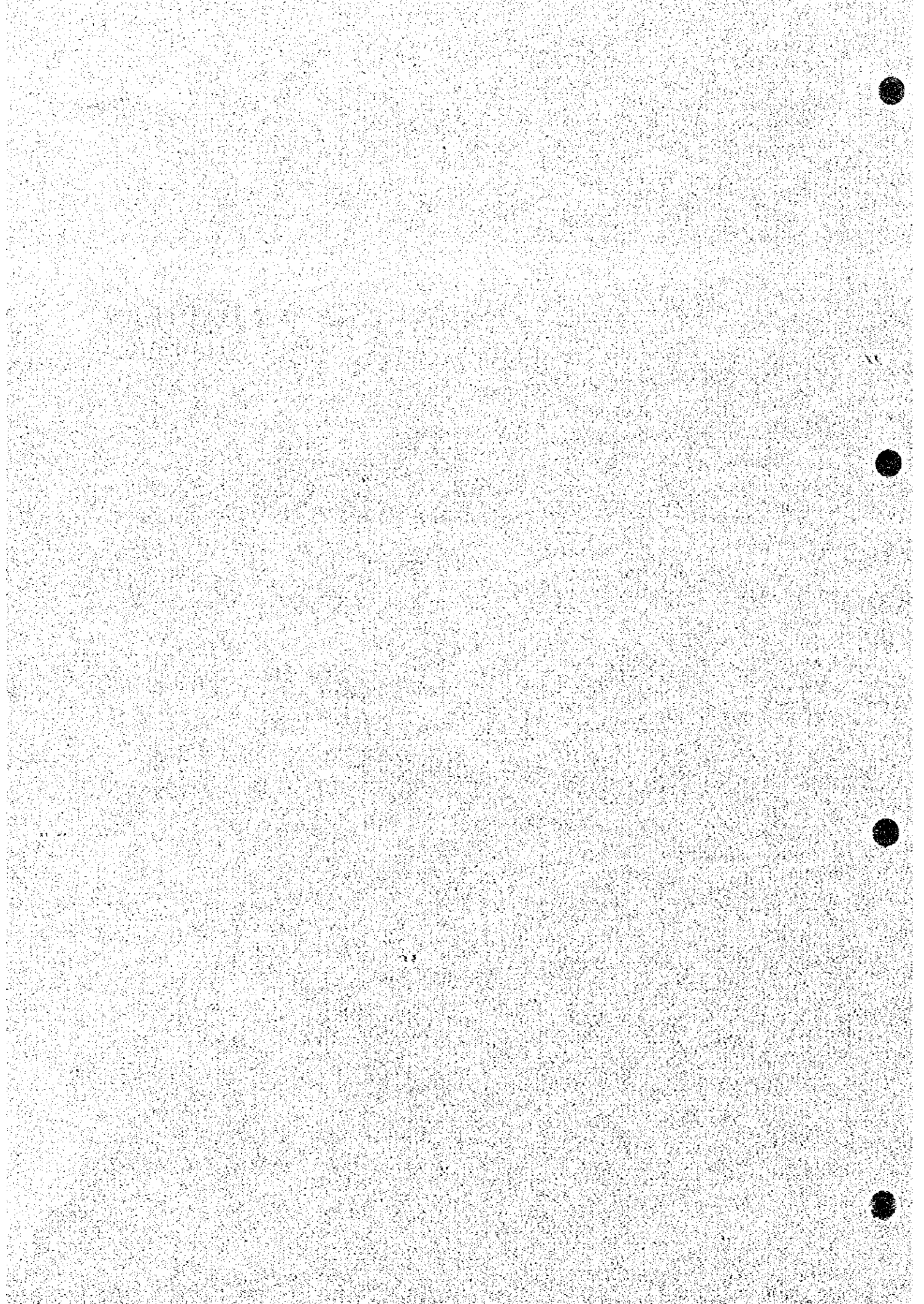


**CHAPTER 2**  
**STUDY AREA**



## CHAPTER 2 STUDY AREA

### 2.1 River Basins Related to the Project

#### (1) Kok and Ing Basins

The Kok and Ing basins, water sources for the proposed project, are located at the northwestern-most corner of Thailand near the Golden Triangle covering the total drainage area of 18,000 sq.km which can be divided into 10,900 sq.km for the Kok basin and 7,100 sq.km for the Ing basin.

##### (a) Kok Basin

The Kok river originates in the dense forest area of the elevation of 1,500 m, MSL belonging to Myanmar territory, joins large tributaries of the Fang and Lao in Thailand territory and empties finally into the Mekong river. The upper basins of Fang and Lao also are formed with high mountain areas elevated between 1,000 to 1,300 m, MSL. In the upper basin, flat area for agricultural use is very scarce except small slender spots extending along the river course. After passing through Chiang Rai city, the river flows down to the Mekong river forming meandering shape with the river slope of less than 1 to 3,000. The high and low water level at the conjunction point of the Kok river with the Mekong river are 360 and 350 m, MSL, respectively. The lower Kok basin has a little flat area with elevations 350 to 360 m, and is suffered from inundation during wet season influenced by the Mekong back water. There are many wetlands in a form of lake, swamp and inundated area along the river in the lower basin. The Nong Luang swamp among them is the notable one which will be developed by the proposed project.

##### (b) Ing Basin

The Ing river originates at the southern plateau with the elevations 450 to 500 m, MSL, flows down toward north direction collecting small tributaries, and reaches Amphoe Thoeng where a large tributary of the Lao joins to the Ing river. The Lao river originates in the eastern mountain area of elevations 1,000 to 1,500 m,MSL

having a drainage area of 1,300 sq.km. The Phayao lake is located in the upper Ing basin and is utilized for fish culture and irrigated agriculture. In the upper basin, flat area of 6 to 8 km wide with the elevation of 450 to 350 m is expanding along 70 km of river reaches and is used for agriculture. The Ing river flows down forming a very gentle slope of less than 1 to 5,000 in the upper reaches and about 1 to 10,000 in the lower basin with meandering shapes particularly downstream of Amphoe Thoeng. The Ing river empties finally into the Mekong river. The high and low water levels at the confluence with the Mekong are 350 and 340 m, MSL respectively. In the downstream reaches along a distance about 20 km, the area is used to be inundated during wet season due to the back water from the Mekong river.

In the Ing basin also, a number of wetlands are existing along the river. Most of them are, however, dried up in dry season due to no rainfall and less river runoff. The Nong Leng Sai swamp and Phayao lake are the famous wetland in the basin.

(c) Sub-Basins

The Kok and Ing river basins can be divided into the following sub-basins. They are blessed with potential water resources as compared to those in the Chao Phraya basin.

Sub-Basin Division of Kok and Ing River Basin

| Basin | Sub-Basin                | Drainage Area (sq.km) | Average Annual Runoff (MCM) | Specific Yield (mm) |
|-------|--------------------------|-----------------------|-----------------------------|---------------------|
| Kok   | Mae Kok (Myanmar)        | 2,980                 | 2,106                       | 725                 |
|       | Mae Fang                 | 2,160                 | 1,296                       | 600                 |
|       | Mae Lao                  | 3,110                 | 570                         | 184                 |
|       | Mae Suai (Lao Tributary) | 470                   | 200                         | 426                 |
|       | Lower Mae Kok            | 2,160                 | 1,108                       | 513                 |
|       | Total                    | 10,880                | 5,280                       | 490                 |
| Ing   | Upper Mae Ing            | 1,100                 | 270                         | 245                 |
|       | Middle Mae Ing           | 2,210                 | 670                         | 300                 |
|       | Nam Phung                | 1,130                 | 280                         | 250                 |
|       | Mae Lao                  | 1,260                 | 315                         | 250                 |
|       | Lower Mae Ing            | 1,420                 | 405                         | 285                 |
|       | Total                    | 7,120                 | 1,940                       | 272                 |

Sub-basin division and river profile are shown in the Database Map.

**(2) Nan Basin**

The Nan basin is primarily divided into two sub-basins by the Sirikit dam, the upper basin with the drainage area of 13,100 sq.km and the lower basin of 21,200 sq.km.

**(a) Nan Upper Basin**

The Nan river originates at the high mountain area of 1,000 to 1,500 m elevation which forms the international border of Thailand with Lao PDR and flows down into the Sirikit dam. The basin is formed by a slender shape of about 200 km long and 60 to 70 km wide with a number of tributaries flowing in deep valleys and dense forests. Farmland is very scarce extending on slender flat areas along the main stream of the Nan river and major tributaries, amounting to 84,000 ha or equivalent to only 8% of the total drainage area of the basin.

**(b) Nan Lower Basin**

The Nan lower basin, which is the beneficial area of the project, is lying along the Nan river downstream of the Sirikit dam. The river flows down the very flat area with the elevations between 100 to 30 m, MSL and reaches to the conjunction point with the Yom river.

The notable Naresuan barrage for the Phitsanulok irrigation project was constructed and is under operation at the middle point of the Nan lower reaches. Several large tributaries such as the Khwae Noi, Wang Thong, etc. are extending in the eastern hilly and mountainous area. Those tributaries often bring big floods during wet season, and as a result the downstream area of Nan lower basin mainly belonging to Phichit province always suffered from inundation. The large agricultural land of about 1 million ha is lying on the Nan lower basin.

(c) Sub-Basin Division

The Nan basin is divided into the following sub-basins in the NESDB's 25 River Basin Study. The upper basin has a large potential water resources as compared with the lower basin. The sub-basin division is also illustrated in the Database Map.

Sub-Basin Division of the Nan River Basin

| Basin     | Sub-Basin          | Drainage Area (sq.km) | Average Annual Runoff (MCM) | Specific Yield (mm) |
|-----------|--------------------|-----------------------|-----------------------------|---------------------|
| Upper Nan | Upper Part of Nan  | 2,220                 | 1,263                       | 569                 |
|           | Huai Nam Yao       | 640                   | 307                         | 480                 |
|           | Nam Wa             | 2,180                 | 1,612                       | 739                 |
|           | Second Part of Nan | 1,570                 | 566                         | 361                 |
|           | Nam Yao            | 600                   | 538                         | 897                 |
|           | Nam Samun          | 1,350                 | 113                         | 84                  |
|           | Nam Haeng          | 1,050                 | 115                         | 110                 |
|           | Third Part of Nan  | 3,370                 | 1,098                       | 326                 |
|           | Sub-Total          | 12,980                | 5,612                       | 432                 |
| Lower Nan | Nam Pat            | 1,960                 | 212                         | 108                 |
|           | Fourth Part of Nan | 3,230                 | 912                         | 282                 |
|           | Nam Phak           | 1,000                 | 365                         | 365                 |
|           | Khlong Tron        | 1,270                 | 146                         | 115                 |
|           | Nam Khwae Noi      | 4,680                 | 1,326                       | 283                 |
|           | Nam Wang Thong     | 2,300                 | 783                         | 340                 |
|           | Lower Part of Nan  | 6,920                 | 214                         | 31                  |
|           | Sub-Total          | 21,360                | 3,958                       | 185                 |
| Total     |                    | 34,340                | 9,570                       | 279                 |

(3) Chao Phraya Delta

The Chao Phraya delta, the largest beneficial area of the project, is located in the downstream-most part of the Chao Phraya basin occupying 33,800 sq.km of which some 15,000 sq.km are very flat with elevations from 8 to 10 m, MSL forming the notable paddy cultivation area of Thailand. Bangkok metropolitan area and satellite cities are involved in the delta area.

The delta area is divided by the Chao Phraya river into two parts, the eastern area

and western area. The eastern delta is served mainly by the Chainat-Pasak canal, while the western delta is served by the Noi, Tha Chin and other rivers. The Pasak river joins the Chao Phraya river in the eastern delta, while the Krasieo river in the western delta empties into the Tha Chin river. Both rivers often bring large floods during wet season.

#### **(4) Other Sub-Basins in Chao Phraya Basin**

There are Yom, Wang, Ping and Sakae Krung sub-basins in the Chao Phraya basin. These sub-basins have the drainage area of 73,000 sq.km in total. Their upper basins are formed by mountainous forest areas preserving the water resources, while the lower basins with the plateau and flat area where rainfed agriculture is dominant. The rivers in the above sub-basins join the Nan river and reach to the Chainat barrage, which is located at upstream most of the delta area playing an important role to distribute the Chao Phraya water to the delta area.

Although those sub-basins have no direct relation to the project, their potential water resources and water demand will be studied approximately to evaluate the water balance in the whole Chao Phraya basin.

#### **(5) Mekong River**

The Mekong river originates the eastern part of Tibetan highland in China, passes through the high mountain area in Lao PDR and Myanmar and reaches the Golden Triangle point, forming the upper Mekong basin. The lower Mekong starts at the Golden Triangle point and reaches to the river mouth in the Mekong delta. Gauging station to observe the Mekong river flow is set up at Chiang Saen located near the Golden Triangle. At Chiang Saen, the drainage area and average annual runoff is reported at 189,000 sq.km and 85,000 MCM, respectively.

## **2.2 Meteorological Conditions**

### **(1) General Meteorology**

The climate in the Kok, Ing and Chao Phraya basins is characterized by distinctive

dry and wet seasons created by the northeastern and southwestern monsoon air movements. The dry season lasts from November to March when the northeastern monsoon brings a dry stable airflow. March and April are the hottest months presenting temperature of more than 30°C. In May, the southwestern monsoon is established with prevailing southwestern winds and a moist potentially unstable airstream resulting in longer period of rainfall. As the wet season progresses, rainfall becomes more intense and prolonged until July, August and September, which are usually the months of the highest rainfall.

General meteorological condition such as temperature, humidity, evaporation, etc. in the Kok, Ing and Nan basins is shown in the Database Map, and as summarized below;

General Climatic Parameters in Kok, Ing and Nan Basin

| Basin     | Temperature (°C) | Relative Humidity (%) | Wind Speed (Knots) | Cloudiness (Deca) | Dew Point (°C) | Pan Evaporation (mm) |
|-----------|------------------|-----------------------|--------------------|-------------------|----------------|----------------------|
| Kok       | 24.8             | 73.9                  | 1.8                | 5.2               | 19.2           | 1,481                |
| Ing       | 25.4             | 72.7                  | 1.5                | 5.2               | 19.1           | 1,530                |
| Upper Nan | 25.3             | 78.7                  | 0.7                | 5.2               | 20.7           | 1,368                |
| Lower Nan | 27.5             | 71.7                  | 2.0                | 5.5               | 21.3           | 1,746                |

## (2) Rainfall

### (a) Gauging Stations and Rainfall Data

There are 101 rainfall gauging stations in and around the project area as shown below;

| River Basin | Number of Gauging Station |
|-------------|---------------------------|
| Kok         | 35                        |
| Ing         | 14                        |
| Nan         | 52                        |
| Total       | 101                       |

The completed data are available from early 1950's at many stations in the project area. The monthly rainfall data at the major stations are compiled in the Supporting Report with a summary as shown in Table 2.1. Based on the monthly



rainfall data, the rainfall charts and isohyetal maps are prepared as shown in the Database Map. The annual fluctuations of rainfall for a long term record of about 70 years are also analyzed as shown in the Database Map.

Table 2.1 Mean Annual Rainfall in the Project Area

| Basin | Station Name | Station Code | Rainfall (mm) |            |       | Maximum (mm) | Minimum (mm) |
|-------|--------------|--------------|---------------|------------|-------|--------------|--------------|
|       |              |              | Wet Season    | Dry Season | Total |              |              |
| Kok   | A. Fang      | 307102       | 1,043         | 277        | 1,320 | 1,968        | 832          |
| Kok   | Chiang Rai   | 308013       | 1,366         | 348        | 1,714 | 2,184        | 1,005        |
| Kok   | Mae Chan     | 308062       | 1,538         | 382        | 1,920 | 3,314        | 1,100        |
| Kok   | Chiang Saen  | 308112       | 1,294         | 336        | 1,630 | 2,383        | 1,057        |
| Ing   | Phayao       | 73013        | 702           | 235        | 937   | 1,600        | 395          |
| Ing   | Thoeng       | 308042       | 1,195         | 326        | 1,521 | 2,144        | 610          |
| Ing   | Chiang Kham  | 73022        | 1,042         | 312        | 1,354 | 2,004        | 466          |
| Nan   | Nan          | 28013        | 889           | 308        | 1,197 | 1,511        | 755          |
| Nan   | Uttaradit    | 70013        | 1,072         | 324        | 1,396 | 2,064        | 1,050        |
| Nan   | Phitsanulok  | 39013        | 1,027         | 295        | 1,322 | 1,813        | 919          |
| Nan   | Phichit      | 38012        | 1,085         | 259        | 1,344 | 2,428        | 736          |
| Nan   | Phetchabun   | 36013        | 811           | 285        | 1,096 | 1,709        | 731          |
| Nan   | Nakhon Sawan | 26013        | 823           | 258        | 1,081 | 1,577        | 598          |

(b) Rainfall Characteristics

The mean annual rainfall over the Kok basin increases from 1,000 mm in the southern district of Amphoe Wiang Pa Pao to 1,900 mm in the northern district of Amphoe Mae Chan. In the Ing basin, the annual rainfall varies from 1,000 mm at Changwat Phayao to 1,600 mm at Chiang Khong. On the other hand in the Nan basin, the highest annual amount of rainfall of exceeding 1,600 mm takes place in the upper basin, however, in the lower basin, rainfalls are generally small accounting for about 1,000 mm. About 70 to 80% of annual rainfall occurs in wet season and less rainfall is normally observed in dry season.

(c) Probability Rainfall

In the past 21 years from 1974 to 1995, the Chao Phraya basin occasionally suffered from such big floods occurred in 1975 and 1995 and severe droughts experienced in successive three years from 1991 to 1993. The probability rainfalls

which bring such a flood and drought are evaluated as shown in the Supporting Report and as summarized below;

**Probability Rainfalls at Major Stations**

| Station      | Flood Rainfall (mm/year) |        |        |        | Drought Rainfall (mm/year) |        |        |        |
|--------------|--------------------------|--------|--------|--------|----------------------------|--------|--------|--------|
|              | P=1/5                    | P=1/10 | P=1/20 | P=1/50 | P=1/5                      | P=1/10 | P=1/20 | P=1/50 |
| Nan          | 1,400                    | 1,510  | 1,610  | 1,740  | 1,030                      | 950    | 880    | 820    |
| Uttaradit    | 1,550                    | 1,640  | 1,730  | 1,820  | 1,230                      | 1,160  | 1,100  | 1,040  |
| Nakhon Sawan | 1,240                    | 1,320  | 1,430  | 1,540  | 910                        | 840    | 790    | 730    |

From the frequency analysis of rainfall it can be evaluated that flood rainfalls of 1975 and 1995 would occur once in 10 to 20 years hence not bringing serious problem in water management of the Nan river system, however the drought rainfall in 1991 to 1993 would occur once in 5 years then bringing frequent water shortages in the Nan basin.

## 2.3 Hydrological Conditions

### (1) Gauging Station and Runoff Data

The location and distribution of gauging stations and their runoff records in the project area and the Chao Phraya basin are collected as compiled in the Thai-side Study Report. The number of gauging stations are 8 in the Kok basin, 13 in the Ing basin, 73 in the Nan basin and 34 in the Chao Phraya delta area. In accordance with the collected data, the JICA Team has analyzed the monthly flow diagram of the river system, specific runoff yield, flood hydrograph, etc. For the major stations as compiled in the Supporting Report and the Database Map as well.

### (2) Runoff Characteristics in General

#### (a) Runoff Pattern in Wet and Dry Season

All rivers in Kok, Ing and Chao Phraya basins present relatively rich runoff, 80 to 85% of which concentrates in wet season from June to November. River runoff in

dry season is however very scarce. In the lower Nan and Ping basins located downstream of Sirikit and Bhumibol dams, there are relatively rich runoff in dry season because of water released from the dams. The Kok river also has a rich runoff even in dry season as compared with Ing and other rivers in the Chao Phraya basin, since the catchment of about 3,000 sq.km belonging to Myanmar territory is blessed with high rainfall and dense forest which can recharge wet season rainfall for release in dry season.

**(b) Return Period of Annual Runoff in Sirikit Reservoir**

The Sirikit reservoir has often suffered from shortage of inflow in wet season which is insufficient to fill the storage and would in turn result the shortage of water to be released to the Chao Phraya delta area in dry season. On the contrary, the reservoir has faced the flood problems in specific flood years of 1975 and 1995 when the flood inflow spilled over the reservoir uncontrolled resulting severe damages downstream in the Chao Phraya delta area. The frequency analysis of flood and drought runoffs was made on the basis of the runoff record collected from N1 station, which is located upstream of the Sirikit dam having the long term runoff record of more than 70 years. The results are summarized as under;

**Flood and Drought Runoff of Nan River at N1 Station (Unit: MCM)**

| Probability | Flood Runoff | Drought Runoff |
|-------------|--------------|----------------|
| P=1/5       | 3,400        | 2,000          |
| P=1/10      | 4,000        | 1,700          |
| P=1/20      | 4,400        | 1,360          |
| P=1/50      | 4,600        | 1,340          |

**(3) Runoff Characteristics of Major Rivers**

Runoff characteristics of the major rivers are studied in accordance with the runoff data as compiled in the Supporting Report and as summarized in Table 2.2.

Table 2.2 Runoff Characteristics of Major Rivers

| Basin and Gaging Station                       | Drainage Area (km <sup>2</sup> ) | Mean Annual Runoff |                  |             |                            | Specific Runoff Yield (mm) | Maximum Annual Runoff (MCM) | Minimum Annual Runoff (MCM) | Discharge                     |  |
|--|----------------------------------|--------------------|------------------|-------------|----------------------------|----------------------------|-----------------------------|-----------------------------|-------------------------------|--|
|  |                                  | Wet Season (MCM)   | Dry Season (MCM) | Total (MCM) | Mean (m <sup>3</sup> /sec) |                            |                             |                             | Maximum (m <sup>3</sup> /sec) |  |
|  |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| 1. Kok:  |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| (GN3) Myanmar Border                           | 2,980                            | 1,642              | 498              | 2,140       | 719                        | 3,034                      | 1,342                       | 68                          | 551                           |  |
| (G2A) Diversion Damsite                        | 6,053                            | 2,892              | 696              | 3,588       | 593                        | 5,686                      | 2,034                       | 114                         | 953                           |  |
| (GN1) River Mouth                              | 10,300                           | 4,208              | 992              | 5,190       | 504                        | 7,266                      | 3,430                       | 165                         | 874                           |  |
| 2. Lao:  |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| (GN15) Confluence of Kok                       | 3,080                            | 715                | 140              | 855         | 278                        | 1,338                      | 424                         | 27                          | -                             |  |
| 3. Ing:  |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| (IN <sub>2</sub> ) Existing Wair               | 3,450                            | 819                | 62               | 881         | 256                        | 1,383                      | 435                         | 28                          | 596                           |  |
| (IN <sub>1</sub> ) A. Thoeng                   | 5,700                            | 1,733              | 149              | 1,882       | 331                        | 3,926                      | 823                         | 60                          | 1,250                         |  |
| 4. Yao:  |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| (N51) Confluence of Nan                        | 774                              | 323                | 57               | 380         | 491                        | 606                        | 199                         | 12                          | 380                           |  |
| 5. Nan:  |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| (N17) Upper Nan                                | 1,156                            | 577                | 149              | 726         | 628                        | 1,096                      | 452                         | 23                          | 1,843                         |  |
| (N1) Nan City                                  | 4,609                            | 2,320              | 224              | 2,544       | 552                        | 4,748                      | 1,342                       | 81                          | 2,800                         |  |
| Sirikit Inflow                                 | 13,100                           | 4,419              | 705              | 5,124       | 391                        | 8,574                      | 3,119                       | 163                         | 3,378                         |  |
| Sirikit Outflow                                | 13,100                           | 2,131              | 2,721            | 4,852       | 370                        | 7,284                      | 2,405                       | 154                         | 1,963                         |  |
| (N12A) Uttaradit                               | 15,718                           | 2,891              | 2,466            | 5,375       | 342                        | 10,270                     | 2,486                       | 171                         | 3,300                         |  |
| (N5A) Phitsanulok                              | 25,286                           | 4,712              | 2,443            | 7,155       | 283                        | 12,131                     | 3,199                       | 286                         | 1,896                         |  |
| (N7) Phicit                                    | 29,153                           | 6,027              | 2,740            | 8,767       | 301                        | 14,288                     | 3,850                       | 278                         | 1,563                         |  |
| (N14) Chung Saeng                              | 33,197                           | 6,838              | 2,348            | 9,186       | 277                        | 15,874                     | 3,562                       | 292                         | 1,448                         |  |
| 6. Yom:  |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| (Y14) Sukothai                                 | 12,131                           | 2,323              | 204              | 2,527       | 209                        | 5,092                      | 840                         | 81                          | -                             |  |
| 7. Wang:                                       |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| (W4A) Tak                                      | 10,507                           | 965                | 412              | 1,077       | 147                        | 2,104                      | 408                         | 100                         | 445                           |  |
| 8. Ping:                                       |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| Bhumibol Inflow                                | 26,386                           | 4,559              | 686              | 5,245       | 199                        | 8,804                      | 2,562                       | 167                         | -                             |  |
| Bhumibol Outflow                               | 26,386                           | 1,917              | 3,021            | 4,938       | 188                        | 7,620                      | 2,790                       | 157                         | -                             |  |
| (P7A) Kamphaeng Phet                           | 42,700                           | 4,357              | 3,402            | 7,759       | 103                        | 12,221                     | 4,184                       | 35                          | 2,452                         |  |
| 9. Chao Phraya; (C <sub>2</sub> ) Nakhon Sawan | 110,569                          | 15,367             | 7,099            | 22,466      | 182                        | 36,917                     | 11,541                      | 246                         | 4,712                         |  |
| (C <sub>1</sub> ) Chainat Inflow               | 119,000                          | 16,028             | 6,381            | 22,409      | 188                        | 38,771                     | 8,587                       | 711                         | 4,360                         |  |
| Chainat Outflow                                | 119,000                          | 8,595              | 2,196            | 10,791      | 91                         | 26,055                     | 2,650                       | 343                         | -                             |  |
| Chainat Diversion                              | 119,000                          | 7,433              | 4,185            | 11,618      | 98                         | 14,577                     | 5,937                       | 369                         | -                             |  |
| 10. Pasak:                                     |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| Dam site                                       | 12,925                           | 1,835              | 156              | 1,991       | 204                        | 4,830                      | 609                         | 713                         | -                             |  |
| Confluence of Chao Phraya                      | 16,292                           | 2,224              | 189              | 2,413       | 149                        | 5,855                      | 738                         | 77                          | -                             |  |
| 11. Mekong:                                    |                                  |                    |                  |             |                            |                            |                             |                             |                               |  |
| Chiang Saen                                    | 189,000                          | 67,844             | 17,728           | 85,572      | 453                        | 126,682                    | 67,850                      | 2,714                       | 17,600                        |  |
| Chiang Khong                                   | 204,000                          | 75,993             | 19,508           | 95,501      | 468                        | 129,696                    | 75,328                      | 3,029                       | 18,000                        |  |

(a) Kok River

The Kok river, the water source for the project, has an abundant annual runoff of 2,140 MCM or 714 mm equivalent at the international border of Thailand with Myanmar, and 3,590 MCM or 593 mm at the proposed diversion damsite. The Kok river presents the dry season runoff of about 700 MCM at the proposed diversion damsite which is sufficient for irrigation use in dry season. In the Kok river, fluctuation of annual runoff is small showing the minimum annual runoff of 2,000 MCM which corresponds to 60% of the mean annual runoff. The Kok river has a sufficient annual runoff of 1,600 MCM supplied from tributaries in the lower reaches between the diversion damsite and river mouth. Accordingly the river maintenance flow will be fully secured even if the Kok water is diverted at the proposed diversion site by the project.

(b) Ing River

The Ing river, which is also the water source of the project, has an annual runoff of 1,880 MCM or 331 mm equivalent at the proposed diversion damsite. However, the dry season runoff is as small as 150 MCM which is less than 10% of annual runoff, because the drainage area is composed of the plateau with scarce vegetation and alluvial plain along the river where rain water can't be fostered in wet season. The minimum annual runoff of the Ing river at the proposed diversion site is about 820 MCM which corresponds to 40% of the mean annual runoff. Accordingly the annual fluctuation of the Ing river runoff is slightly larger than that of the Kok river. Although the runoff observation is not available, there are plenty of inflow from numbers of tributaries in the lower Ing basin. In addition, the backwater of the Mekong river reaches the middle part of the lower Ing basin keeping the water level at a high position in wet season. Accordingly a particular care for the river maintenance water in the lower Ing basin will not be needed, even if the proposed project diverts the Ing water at the diversion damsite.

(c) Upper Nan River

The upper Nan river is the source of water for the Sirikit dam. The river

presents a rich annual runoff of 2,540 MCM or 552 mm at the NI station of Nan city, however, the dry season runoff is as small as 220 MCM or only 8% of the annual runoff. The upper Nan basin is composed of small and steep mountainous area, so that the rain water in wet season used to be drained immediately into the river. A big flood discharge of 2,800 cu.m/sec is recorded at the station.

**(d) Sirikit Inflow**

The mean annual inflow to the Sirikit dam is 5,120 MCM, of which the dry season runoff is only 720 MCM. The wet season runoff is about 4,400 MCM which is insufficient to restore the effective storage capacity of 6,660 MCM. As the result, the Sirikit reservoir has not been filled with water at the end of wet season with the empty capacity of 2,000 to 3,000 MCM.

The annual inflow presents the wide variation year by year with the maximum of 9,500 MCM in the flood year and the minimum of 3,000 MCM in a dry year. Accordingly the reservoir has faced the difficulty to carry out the proper reservoir operation. Although the dry season inflow is so small as 720 MCM, the reservoir can release the dry season outflow of 2,720 MCM through a proper operation.

**(e) Runoff in the Lower Nan Basin**

Being located downstream of the Sirikit dam, the lower Nan basin produces the rich wet season runoff from many tributary basins of about 20,000 sq.km, however in dry season river flows are scarce or almost nothing. The wet season runoff in the Nan river increases as the flow goes down showing 2,900 MCM at Uttaradit, 4,710 MCM at Phitsanulok, 6,030 MCM at Phichit and 6,830 MCM at Chung Saeng located at the confluence with the Yom river, after collecting side flow from tributary sub-basins. The dry season runoff, however, does not increase so much presenting almost same values of 2,500 to 2,700 MCM with the Sirikit outflow at all stations along the river, since the small runoffs from tributary basins are mostly consumed for irrigation and other uses within the own catchment areas.

Accordingly the Nan river has the bulk surplus water to meet the water demand

in the Chao Phraya delta in wet season, however in dry season the limited water has no allowance to supply excess water to the delta area.

(f) Yom River

The Yom river, flowing adjacent on the west to the Nan river, has the mean annual runoff of 2,500 MCM (specific yield of 209 mm) at the Y14 station in Sukhothai city. The Yom runoff is much smaller than those of the Nan and Ping rivers with no room to contribute to the downstream Chao Phraya delta area.

The upper basin of the Yom river has been devastated due to slash-burn farming and tree felling so that a big flood with the peak discharge of 4,060 cu.m/sec takes place in a specific flood year bringing inundation damage to the downstream area.

(g) Wang River

The Wang river is the largest tributary of the Ping river having the mean annual runoff of 1,080 MCM at the W4A station in Tak city. The Wang runoff is also small and no room to supply excess water to the downstream area can be expected.

(h) Bhumibol Inflow

The mean annual inflow into the Bhumibol reservoir is 5,240 MCM of which the dry season runoff accounts for 670 MCM only, and the wet season runoff is as small as 4,550 MCM which is quite insufficient to restore the effective storage capacity of 9,660 MCM in the Bhumibol reservoir. Consequently the reservoir has never been filled with water presenting the empty storage volume of 3,000 to 5,000 MCM every year at the end of wet season.

The reservoir inflow varies year by year with a wide fluctuation between 8,800 MCM in the wettest year and 2,560 MCM in the driest year, making the operation of reservoir rather difficult.

The outflow from the reservoir is 1,920 MCM in wet season and 3,020 MCM in dry season on average, providing the similar amount of dry season water to the delta area as compared to that of the Sirikit reservoir.

**(i) Runoff of Lower Ping Basin**

The lower Ping basin, located downstream of the Bhumibol dam, consists of large tributary sub-basins of about 16,300 sq.km providing 2,800 MCM of the mean annual runoff. Even in dry season such tributary sub-basins contribute to increase the Ping river water to 3,400 MCM at the P7A station in Kamphaeng Phet from 3,020 MCM released from the Bhumibol reservoir.

The wet season runoff also increases from 1,920 MCM of the Bhumibol outflow to 4,350 MCM at the P7A station.

**(j) Runoff at Nakhon Sawan (C2 Station)**

All runoffs from the Nan, Yom, Wang and Ping rivers meet together at the C2 station located in Nakhon Sawan city upstream of the Chainat barrage. The mean annual runoff at the C2 station is 22,500 MCM, which can be divided into 15,400 MCM of wet season runoff and 7,100 MCM of dry season runoff. The wet season runoff increases remarkably as compared with the outflow of 4,050 MCM released from the both Bhumibol and Sirikit reservoirs, however in dry season, the runoff at the C2 station remains almost same as the outflow of 6,000 MCM from the both reservoirs.

**(k) Runoff at Chainat Barrage**

Being located at the entrance of the Chao Phraya delta area, the Chainat barrage controls the Chao Phraya river water and divert it to the delta area. Although the Sakae Krung river flows into the Chao Phraya river between Nakhon Sawan and Chainat, the mean annual runoff of the Chao Phraya river at Chainat is 22,400 MCM showing almost same value as that of Nakhon Sawan, since the runoff from the Sakae Krung catchment is small and used mostly within the sub-basin.



About 4,200 MCM is diverted from the Chao Phraya river at Chainat, conveyed through the Chainat-Pasak and other canals/ivers to the delta area for irrigation and other purposes in dry season. The downstream release of the Chao Phraya river at Chainat barrage accounts for only 2,200 MCM or 137 cu.m/sec on an average in dry season and used to decrease to 100 to 150 MCM/month or 63 to 90 cu.m/sec in dry months, which is insufficient to maintain the river course and to prevent the sea water intrusion.

(i) Mekong River

The Mekong river runoff has been observed at Chiang Saen near the Golden Triangle site and Chiang Khong near the Ing river mouth, showing the mean annual values of 85,500 MCM and 95,500 MCM respectively. At both stations, the fluctuation of river water levels between wet and dry seasons is observed at about 10m.

(4) Water Level and Peak Flood Discharge

The peak water level and discharge during flood, necessary for project planning, is collected at major stations in the Kok, Ing and Nan basins as summarized below;

Water Level and Discharge During Peak Flood

| Stations                       | Drainage Area (sq.km) | Discharge (cu.m/sec) | Water Level (m, MSL) | Return Period |
|--------------------------------|-----------------------|----------------------|----------------------|---------------|
| Chiang Rai (G2A), Kok River    | 6,063                 | 953                  | 392.8                | 30            |
| Thoeng (IN1), Ing River        | 5,700                 | 1,250                | 368.2                | 550           |
| Bang Wang Hit (N51), Yao River | 774                   | 380                  | 235.8                | 20            |
| Thung Chang (N17), Nan River   | 1,156                 | 1,843                | 1,014                | 30            |
| Nan (N1), Nan River            | 4,609                 | 2,800                | 200.5                | 20            |

## **(5) Water Quality**

### **(a) Sediment Transport**

The regression analysis for relationship between the mean annual suspended sediment discharge and its corresponding catchment area was carried out using data from selected 30 stations. The regression equation obtained is as follows;

$$Q_s = 82.175 \times A^{0.989}$$

where  $Q_s$  denotes the mean annual suspended sediment discharge in tons/year and  $A$  catchment area in sq.km.

From the above formula, suspended sediment discharge at Thoeng (IN1) is calculated as 425,892 tons/year. On the other hand, mean sediment discharge records from 1968 to 1994 at Thoeng shows 234,976 tons/year, and therefore it is necessary for facility design to check the calculated result in all aspects.

### **(b) Water Quality**

The O/M Division of RID measures the water quality of all rivers and canals in the province. Presently available three years data were collected. As for the dissolved oxygen (DO), data are available only for two months varying between 4 and 5 mg/liter, that is within the standard range.

## **2.4 Land Use and Capability**

### **(1) Land Use for Forest and Farm Area**

The land use for forest and farm area of the Chao Phraya basin and the project area of the Kok and Ing basins is studied based on the data on provincial level in Agricultural Statistics of Thailand and the provincial area rate being occupied by each sub-basin such as the Nan, Yom, Ping, Delta, etc. in the Chao Phraya basin and the Kok and Ing basins in the project area.

The land use for forest and farm area in 1981 and 1992 is analyzed as shown in the Supporting Report and as summarized below;

Summary of Land Use for Forest and Farm Area (Unit: 1,000 ha)

| River Basin             | Total Area    | Forest Area   |               | Farm Area     |               | Other Area    |               |
|-------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                         |               | 1981          | 1992          | 1981          | 1992          | 1981          | 1992          |
| <b>1. Chao Phraya</b>   |               |               |               |               |               |               |               |
| Nan                     | 3,430         | 1,290         | 1,040         | 1,010         | 1,080         | 1,130         | 1,310         |
| Yom                     | 2,360         | 1,030         | 830           | 760           | 760           | 570           | 770           |
| Wang                    | 1,080         | 830           | 720           | 110           | 150           | 140           | 210           |
| Ping                    | 3,390         | 2,430         | 2,100         | 560           | 650           | 400           | 640           |
| Pasak                   | 1,630         | 330           | 230           | 880           | 910           | 420           | 490           |
| Sakae Krung             | 520           | 150           | 130           | 260           | 260           | 110           | 130           |
| Delta/Tha Chin          | 3,380         | 400           | 330           | 2,260         | 2,070         | 720           | 980           |
| Total                   | 15,790        | 6,460         | 5,380         | 5,840         | 5,880         | 3,490         | 4,530         |
| <b>2. Project Area</b>  |               |               |               |               |               |               |               |
| Kok & Ing               | 1,470         | 790           | 640           | 340           | 360           | 340           | 470           |
| Upper Nan               | 1,090         | 570           | 460           | 90            | 130           | 430           | 500           |
| <b>3. Whole Country</b> | <b>51,310</b> | <b>16,090</b> | <b>13,500</b> | <b>19,410</b> | <b>21,130</b> | <b>15,810</b> | <b>16,680</b> |

(a) Chao Phraya Basin

The Chao Phraya basin is the most important one in the agricultural sector of Thailand holding the forest area of 5.4 million ha occupying 40% of total forest area in the country and the farm area of 5.9 million ha corresponding to 25% of the national farm area. The characteristics of the land use for forest and farm area are summarized as follows;

- The upper basins of the Nan, Yom, Wang and Ping rivers are formed with the high mountainous area being covered with the dense forest which foster the water resources in the Chao Phraya basin. The forest area in the basin, however, has been decreased to 5.4 million ha in 1992 from 6.5 million ha in 1981 due to tree felling, slash and burn farming, conversion to farm land, etc. The large forest area of 250,000 ha in the Nan, 200,000 ha in the Yom and 330,000 ha in the Ping has been lost during 10 years from 1981 to 1992. In accordance with the decreasing forest area in those basins, the flood in wet season has increased, while the dry season runoff has decreased.

- Farm land area in the Chao Phraya basin is estimated at 5.9 million ha which is not changed from 1981 to 1992. The farm land in the Ping basin has increased from 1981 to 1992 but that in the delta area decreased due to conversion of the farm land to the urban and industrial development area in the delta area.
- Farm area in the Nan and delta which is the direct beneficial area of the water diversion project reaches to the large area of about 3 million ha in 1992 and requires the large amount of irrigation water at present and in future.
- The other land area which will be useless land for agriculture and belong to the urban and industrial area has been considerably increased and reaches to 4.5 million ha in 1992 for 3.5 million ha in 1981. Deforested area has lost the renewal capacity for vegetation due to soil and gully erosion, etc.

**(b) Project Area**

The project area consists of the Kok and Ing basins with the drainage area of 14,700 sq.km excluding the area of 3,000 sq.km in Myanmar, and the upper Nan basin with the area of 10,900 sq.km lying upstream of the Sirikit dam.

- The upper basin of the Kok and Ing as well as the upper Nan consists of high mountain with the dense forest and fosters the water resources in the area. Forest area in the project area, however, has been lost due to deforestation and is limited to 640,000 ha in the Kok and Ing basins and to 460,000 ha in the upper Nan basin which are 20% less than the forest area in 1981.
- Farm land in Kok and Ing basins has not been increased from 1981 to 1992, while the land in the upper Nan increased to 130,000 ha in 1992 from 90,000 ha in 1981.

**(2) Farm Land Use for Paddy, Field Crops, etc.**

Farm land use for paddy, field crops, etc. In the Chao Phraya and the project area also is studied by the same manner as applied for the land use for forest and farm area. The study result is shown in the Supporting Report and summarized as follows;

**Summary of Farm Land Use for Paddy, Field Crops, etc. (Unit: 1,000 ha)**

| River Basin           | Total        |              | Paddy        |              | Field Crops  |              | Tree Crops |            | Vegetable |           | Others     |            |
|-----------------------|--------------|--------------|--------------|--------------|--------------|--------------|------------|------------|-----------|-----------|------------|------------|
|                       | 1981         | 1992         | 1981         | 1992         | 1981         | 1992         | 1981       | 1992       | 1981      | 1992      | 1981       | 1992       |
| <b>1. Chao Phraya</b> |              |              |              |              |              |              |            |            |           |           |            |            |
| Nan                   | 1,010        | 1,080        | 650          | 590          | 290          | 360          | 30         | 60         | 1         | 5         | 39         | 65         |
| Yom                   | 760          | 760          | 520          | 440          | 180          | 240          | 30         | 40         | 1         | 4         | 29         | 36         |
| Wang                  | 110          | 150          | 70           | 75           | 30           | 50           | 3          | 10         | 0         | 2         | 7          | 13         |
| Ping                  | 560          | 650          | 325          | 305          | 170          | 215          | 30         | 75         | 3         | 17        | 32         | 38         |
| Pasak                 | 880          | 910          | 405          | 350          | 420          | 460          | 16         | 52         | 2         | 4         | 37         | 44         |
| Sakae Krung           | 260          | 260          | 160          | 140          | 45           | 100          | 4          | 10         | 0         | 2         | 51         | 8          |
| Delta/Tha Chin        | 2,260        | 2,070        | 1,600        | 1,310        | 480          | 490          | 80         | 140        | 13        | 22        | 87         | 108        |
| <b>Total</b>          | <b>5,840</b> | <b>5,880</b> | <b>3,730</b> | <b>3,210</b> | <b>1,615</b> | <b>1,915</b> | <b>193</b> | <b>387</b> | <b>20</b> | <b>56</b> | <b>282</b> | <b>312</b> |
| <b>2 Project Area</b> |              |              |              |              |              |              |            |            |           |           |            |            |
| Kok & Ing             | 340          | 360          | 250          | 220          | 60           | 90           | 11         | 27         | 1         | 6         | 8          | 17         |
| Upper Nan             | 90           | 130          | 40           | 40           | 40           | 70           | 5          | 13         | 0         | 1         | 5          | 6          |

**(a) Chao Phraya Basin**

- The paddy area in the whole Chao Phraya basin has decreased to 3.2 million ha in 1992 from 3.7 million ha in 1981, while the area for field crops, tree crops, vegetable, etc. has considerably increased from 1981 to 1992 because of achievement of crop diversification program promoted by Thai Government and increased market demand for various kinds of food.
- The field crops such as maize, soybean, etc. to be used for vegetable oil and livestock feed are increasing at the plateau and hilly area in the Nan, Yom and Sakae Krung basin as well as in the delta area in dry season.
- The tree crops, especially orchard plantation also is increasing at the area in the Nan and delta area which is the direct beneficial area in the project.
- In the delta area, orchard and vegetable plantation is prevailing in the recent year in accordance with the market demand for urban inhabitant in Bangkok Metropolis and other cities.
- The plantation area for field crops, orchard and vegetable will increase toward 21 century in parallel with increasing urban population, as a result the irrigation water in dry season will increase year by year.

**(b) Project Area**

Paddy plantation in the project area has also decreased but plantation for field crops and orchard increased.

### (3) Land Capability in the Project Area

Land capability for crops in the project area is approximately studied based on the soil map and land use map prepared by DLD as shown in the Database Map. Summary of land capability for each basin is shown in the Supporting Report and outlined below;

#### (a) Kok Basin

The land suitable for paddy cultivation consists of the soil units 3, 6, 8, 15 and 16 covering the area of 101,000 ha. The above land mainly extends on the low lying area along the Lao river and near Chiang Rai city. The land suitable for field crops and fruit trees belongs to the soil units 1, 6, 13, 18, 20 and 25 with the area of 191,000 ha. This land is mainly distributed in the foot of hilly area along the Lao and Kok rivers. Out of the paddy land of 101,000 ha, the area of 61,200 ha belongs to the first class land suitable for paddy and the remaining area to the second class. The land suitable for upland crops and fruits belongs mainly to the second class land due to some topographical problems.

#### (b) Ing Basin

There are the land of 203,100 ha suitable for paddy and 94,300 ha for field crops and fruits, belonging to the same soil units as in the Kok basin. The land suitable for paddy is mainly expanding on the large and flat alluvial plain along the Ing river, while the land suitable for field crops and fruits is distributed in the high land being scattered near the paddy area.

#### (c) Upper Nan Basin

The upper Nan basin is mostly consisted of the mountainous area with scattered flat area. Accordingly the land suitable for paddy is as small as 12,800 ha, which is mainly in a slender shape along tributaries flowing into the Nan river. The land suitable for field crops and orchard occupies a large area of 186,000 ha, however, they are under some topographical problems.

## **2.5 Agricultural Condition**

### **(1) Agricultural Development Policy**

The most important policy for agricultural development in Thailand is to promote the crop diversification program. The program was initially set up in the 6th National Economic Development Plan (1987 to 1991), has been emphasized in the 7th Plan (1992 to 1996) and the 8th Plan (1997 to 2001) and will continue in the 21 century, because of the following background and reasons;

#### **(a) Effective Use of Farm Land**

The agricultural development in the past was achieved mostly by expansion of the farm land area for paddy and cassava cultivation converting the forest area to farm land as explained in the paragraph 2.4(1), as a result the forest area has been lost year by year in the country. There is no more room for expansion of farm land in the country due to conservation of the forest area. Accordingly the agricultural development to meet the future food requirement shall rely on the effective and suitable utilization of the existing developed farm area. Namely the second crop plantation after wet season paddy shall be accelerated in order to achieve the maximum land utilization and increase the agricultural products to meet the increasing food demand.

#### **(b) Limited Water Resources**

According to the successful progress of the national economic development in the recent years, the water demand for agriculture and domestic and industrial uses has been largely increased, while the existing water resources are limited to respond to the increasing water demand. In addition, new projects for water resources development could not be implemented easily due to lack of the suitable damsites and severe environmental impact for the project. Accordingly the water shortage problem for agriculture and non agriculture sectors will take place in near future, especially in the Chao Phraya delta area where the high agricultural productivity has been achieved, and the rapid urban and industrial development will face the critical water shortage

problem. Therefore the crop diversification to introduce upland crops in dry season instead of dry season paddy cultivation which requires much water consumption shall be accelerated in future, in order to prevent the water shortage in dry season.

**(c) Reduction of Paddy and Cassava Area**

- Although the paddy is the prevailing crops in Thailand and familiar crops for farmers, the paddy production has increased year by year with the expansion of irrigation projects not only in Thailand but also in other countries in the Southeastern Asia, as a result the rice price in the world market in recent years has fallen down. Accordingly farmers' income depending on paddy mono culture has decreased. It will therefore be necessary in future to introduce crop diversification instead of the rice mono culture, in order to obtain higher agricultural income and to meet food demand.
- Cassava plantation shall also be replaced to other crops because of its destructive nature of soil fertility, long land occupation of more than 1 year for harvesting and low market price.

**(d) Increase of Various Food**

A number of various food demands including processed foods by use of agricultural products from upland crops, fruits, vegetables and livestock have been increased in recent years together with the economic growth not only in the urban and semi-urban districts but also in rural areas in Thailand. In addition, the export of these processed food has been increasing. It is therefore necessary to increase productivity of such materials under the crop diversification program.

**(e) Income Generation and Job Creation for Farmers**

Farmer's lively food is supported mostly depending on the income from paddy cultivation in wet season, however, there is no opportunity to work for income in dry season because of lack of irrigation water. It will be necessary to introduce the second crop plantation by means of providing water, in order to create job opportunity and to generate source of income in the rural area.



## **(2) Improvement of Agricultural Production Structure and System**

The following policy was set up in the 7th Plan to improve the agricultural production structure and system and to accelerate and achieve successful crop diversification program. Its implementation was approved by the Cabinet in December 1993;

- Plantation area for dry season paddy, cassava, coffee and pepper shall be reduced and diverted to areas for upland crops, fruits, vegetables and grass land for livestock breeding. Total crop diversification area during three years from 1994 to 1996 was planned at 786,000 ha, of which paddy reduction area was as large as 560,000 ha.
- In order to achieve the above crop diversification program, the Government provided 39,000 million Baht during these three years, of which 25,800 million Baht was allocated to convert paddy area to others crop land. Additional budget of about 26,900 million Baht is scheduled to be provided for crop diversification from 1997 to 2010.
- For crop diversification of paddy and cassava, the Government will provide the credit with low interest of 5% per annum with a repayment period of 15 years, instead of the ordinary interest of 8%.
- For reduction of coffee and pepper, the Government will pay 6,800 Baht/rai (42,500 Baht/ha) for agricultural subsidies.
- For fruit plantation, the Government will provide the credit for water resources facilities such as farm pond and irrigation system on farm level.

## **(3) Agricultural Productivity**

Agricultural productivities involving cropped area and production as well as livestock breeding in 1995 in the Chao Phraya basin and the project area of the Kok and Ing basins are studied based on the Agricultural Statistics of Thailand, Crop Year 1994/95 as shown in the Supporting Report. The outlines are summarized as follows;

(a) Area and Production of Major Crops

Crop Area and Production of Major Crops

| Basin/Crops      | Wet Paddy |        | Dry Paddy |       | Maize |       | Cassava |        | Sugarcane |        | Soybean |     |
|------------------|-----------|--------|-----------|-------|-------|-------|---------|--------|-----------|--------|---------|-----|
|                  | A         | P      | A         | P     | A     | P     | A       | P      | A         | P      | A       | P   |
| 1. Whole Country | 8,295     | 18,161 | 680       | 2,950 | 1,351 | 3,956 | 1,297   | 18,164 | 923       | 50,597 | 395     | 528 |
| 2 Chao Phraya    |           |        |           |       |       |       |         |        |           |        |         |     |
| Nan              | 430       | 1,168  | 71        | 315   | 131   | 390   | 40      | 548    | 30        | 1,553  | 70      | 91  |
| Yom              | 323       | 838    | 34        | 154   | 58    | 148   | 13      | 190    | 43        | 2,420  | 87      | 109 |
| Ping/Wang        | 340       | 1,044  | 19        | 79    | 66    | 189   | 41      | 566    | 54        | 3,139  | 62      | 82  |
| Sakae Krung      | 108       | 281    | 8         | 36    | 38    | 111   | 21      | 299    | 26        | 1,518  | 12      | 18  |
| Pasak            | 269       | 716    | 8         | 33    | 259   | 822   | 13      | 201    | 31        | 1,544  | 33      | 47  |
| Delta            | 991       | 3,129  | 373       | 1,747 | 159   | 457   | 64      | 915    | 199       | 11,606 | 26      | 38  |
| Total            | 2,461     | 7,176  | 513       | 2,364 | 711   | 2,117 | 192     | 2,719  | 383       | 21,780 | 290     | 385 |
| Rate (2/1) (%)   | 30        | 40     | 75        | 80    | 53    | 53    | 15      | 15     | 41        | 43     | 73      | 73  |
| 3 Kok & Ing      | 156       | 473    | 3         | 9     | 49    | 147   | 2       | 29     | -         | -      | 8       | 10  |

Notes: A: Harvested area in 1,000ha, P: Production in 1,000ton.

- The Chao Phraya basin is the largest crop production area in the country occupying 40% of wet season paddy and sugarcane, 50% of maize and 70% of soybean against the total production of the country.
- Especially the Nan basin and delta area, the direct beneficial area of the project, have a large paddy production of 1.5 million tons and 4.9 million tons respectively.
- Maize production in three basins of the Nan, Pasak and delta reaches about 1.7 million tons occupying 80% and 45% of the total production in the Chao Phraya basin and the whole country.
- Soybean, which has been expanding in recent years, is harvested in all sub-basins in the Chao Phraya basin and its production reaches 385,000 tons corresponding to 70% of the country's production.
- In the Kok and Ing basin, the wet season paddy prevails under rainfed and supplemental irrigation condition. There is very scarce irrigated agriculture in dry season because of no or less rainfall and river runoff. Upland crops such as maize and soybean are planted in dry season in a limited area by use of soil water saturated during wet season.
- In the Nan basin there is a large paddy area of 430,000 ha, of which about 300,000 ha lying on the flat alluvial plain along the Nan river will be the beneficial area for the project. The remaining 100,000 ha is scattered mostly in tributary basins. Upland crops such as maize, sugarcane and soybean are

largely planted under rainfed condition in wet season and semi-irrigated condition in dry season.

The Chao Phraya delta area, which is the beneficial area for the project too, has the irrigation area of 1.2 million ha. The present irrigation area is, however, limited to 1.0 million ha due to lack of water. The wet season paddy of 1.0 million ha and dry season paddy of 370,000 ha are presently under cultivation. In addition, the area of 80,000 ha is cultivated in dry season for upland crops, fruits, vegetables, etc. and the area of 23,000 ha is used for fishery ponds. If sufficient water is available, the dry season area could be increased to at least 600,000 ha corresponding to the irrigation intensity of 50%.

(b) Livestock Breeding

Livestock Breeding (1,000 Heads)

| Basin/Livestock  | Buffalo | Cattle | Swine |
|------------------|---------|--------|-------|
| 1. Whole Country | 4,754   | 6,360  | 4,985 |
| 2. Chao Phraya   |         |        |       |
| Nan              | 129     | 324    | 236   |
| Yom              | 165     | 293    | 220   |
| Ping/Wang        | 175     | 394    | 371   |
| Sakae Krung      | 70      | 335    | 152   |
| Pasak            | 26      | 66     | 137   |
| Delta            | 145     | 674    | 818   |
| Total            | 650     | 2,086  | 1,834 |
| Rate (2/1) (%)   | 14      | 33     | 37    |
| 3. Kok & Ing     | 98      | 138    | 158   |

Buffalo, which is used for cultivation, is decreasing year by year in all basins due to promotion of agricultural machines for cultivation works.

Cattle breeding for milk and meat production and also swine breeding have been expanded in sub-basins in the Chao Phraya basin in accordance with increasing livestock products, as a result requirement for animal feed such as maize, soybean has also been increased.

(c) Fresh Water Fish Culture

The fresh water fish culture in Thailand has been expanded in all regions and its production and value have also been increased country-wide as follows;

Quantity: 167,000 tons in 1985 to 274,000 tons in 1992

Value: 4,134 million Baht in 1985 to 6,477 million Baht in 1992

The condition for fish culture in the Chao Phraya and Kok and Ing basins is outlined as follows;

Fish Culture Condition

| Basin/Item       | No of Farm | Units   | Area (ha) | Production (Ton) | Value (1,000 Baht) |
|------------------|------------|---------|-----------|------------------|--------------------|
| 1. Whole Country | 108,400    | 158,000 | 32,300    | 110,950          | 2,834,000          |
| 2. Chao Phraya   |            |         |           |                  |                    |
| Nan              | 5,280      | 6,780   | 650       | 2,990            | 63,400             |
| Yom/Ping/Wang    | 18,610     | 24,880  | 2,980     | 18,040           | 392,700            |
| Pasak            | 1,510      | 2,190   | 420       | 3,590            | 69,000             |
| Delta            | 13,230     | 25,130  | 14,240    | 58,050           | 1,658,900          |
| Total            | 38,630     | 58,980  | 18,290    | 82,670           | 2,184,700          |
| Rate (2/1) (%)   | 36         | 37      | 57        | 75               | 77                 |
| 3. Kok & Ing     | 5,520      | 8,390   | 960       | 1,040            | 29,300             |

- Although the number of farms and units engaging in fish culture in the Chao Phraya basin is 35% of the whole country, the production and value of fish culture in the basin is considerably high showing the average production of 4.6 tons/ha and average value of 120,000 Baht/ha.
- Since the Kok and Ing basins have the wetlands in the basin, the fish culture is prevailing. However its production and value are still low presenting 1.1 tons/ha and 30,000 Baht/ha, due to lack of water to be supplied to fishery ponds and low fish culture technology.

#### **(4) Cropping Pattern**

The cropping pattern in Thailand is generally different in wet and dry seasons and in irrigated and rainfed areas. The representative cropping pattern in Thailand is described as follows;

- In wet season from June to October, the wet season paddy is cultivated in principal except the perennial crop area such as orchard area and hilly area where are suitable for upland crops only. The wet season paddy is cultivated generally under rainfed and supplemental irrigation condition using effective rainfall.
- The dry season paddy is cultivated in the period from December to March under irrigated condition whenever irrigation water is available. Upland crops in dry season are cultivated in the area where soil moisture is enough saturated with rain water during wet season.
- Upland crops such as maize, soybean, mungbean and cassava are cultivated not only in dry season but also in wet season in hilly areas where paddy plantation is difficult due to topographic condition.
- In the farm land area located near urban and semi-urban areas, various kinds of vegetable are planted throughout a year. Three times a year of vegetable cultivation is possible in the area throughout a year.
- Orchard, sugarcane and cassava is planted throughout a year.

##### **(a) Cropping Pattern in Kok and Ing Basin**

The wet season paddy from June to October is largely planted over the basin. Irrigated paddy area however is limited to the low land along the Lao tributary in the Kok basin and in small areas developed by the small scale irrigation project. In dry season, upland crops such as maize, soybean, groundnut, mungbean, tobacco, etc. and sub-tropical crops such as potato, onion, etc, are planted. Although some dry season paddy is cultivated in the area where irrigation water and natural stream water is available. Representative cropping pattern in the Kok and Ing basin is shown in the Database Map.

**(b) Cropping Pattern in Nan Basin**

The similar cropping pattern as in the Kok and Ing basins is prevailing in the Nan basin. The wet and dry season paddy cultivation is dominant in the Uttaradit pump irrigation areas and Phitsanulok gravity irrigation area. Upland crops are also cultivated extensively under rainfed condition in wet season and intensively under irrigation condition in dry season. In accordance with the limited dry season irrigation water being supplied from the Sirikit reservoir and the increasing market demand for various food in urban and semi-urban districts, Thai Government intends to accelerate the crop diversification program in the irrigated agricultural area instead of the dry season paddy cultivation.

**(c) Cropping Pattern in Chao Phraya Delta**

The Chao Phraya delta holds the most important and productive farm area under full irrigation system in the country. Many agricultural commodities both for local consumption and export to the world market are mainly produced in the delta area. In wet season, the farm land area in delta is cultivated mostly with irrigated paddy presenting a high yield except small areas where vegetables are cultivated to obtain high cash income. Dry season paddy is also cultivated in the area where is not suitable for upland crops because of heavy texture soils and poor drainage problems. Upland crops, orchard and vegetable plantations are dominant in wet and dry season achieving the high yield blessed with sufficient water for irrigation, skillful farmers, easily available farm inputs, high market demands and prices. The crop diversification program will be accelerated also in the delta area in future. The representative cropping patterns are shown in the Database Map.

**(5) Net Production Value of Crops and Fish**

The net production value of crops and fish is studied based on data of Agricultural Statistics of Thailand in 1994/1995 and other reports available, as shown in Table 2.3.

**Table 2.3 Net Production Value for Crops and Fish Financial**

| Items                             | Unit Yield (ton/ha) | Unit Price (B/ton) | Gross Production Value (B/ha) | Production Cost (B/ha) | Net Value of Production (B/ha) |
|-----------------------------------|---------------------|--------------------|-------------------------------|------------------------|--------------------------------|
| <b>1. Paddy</b>                   |                     |                    |                               |                        |                                |
| Wet Season Paddy, Rainfed         | 2.0                 | 3,700              | 7,400                         | 5,000                  | 2,400                          |
| - Do -, Irrigated                 | 3.8                 | 3,700              | 14,000                        | 7,000                  | 7,000                          |
| Dry Season Paddy, Irrigated       | 4.5                 | 4,000              | 18,000                        | 10,000                 | 8,000                          |
| <b>2. Upland Crops, Irrigated</b> |                     |                    |                               |                        |                                |
| Maize                             | 3.5                 | 2,900              | 10,200                        | 6,500                  | 3,700                          |
| Soybean                           | 2.0                 | 8,000              | 16,000                        | 8,000                  | 8,000                          |
| Sugar Cane                        | 43.3                | 440                | 19,100                        | 12,400                 | 6,700                          |
| Groundnut                         | 1.8                 | 9,100              | 16,400                        | 10,000                 | 6,400                          |
| <b>3. Vegetable, Irrigated</b>    | <b>10.0</b>         | <b>8,000</b>       | <b>80,000</b>                 | <b>35,000</b>          | <b>45,000</b>                  |
| <b>4. Fruits</b>                  | <b>5.0</b>          | <b>15,000</b>      | <b>75,000</b>                 | <b>40,000</b>          | <b>35,000</b>                  |
| <b>5. Fresh Fish</b>              | <b>4.0</b>          | <b>25,000</b>      | <b>100,000</b>                | <b>50,000</b>          | <b>50,000</b>                  |

## 2.6 Water Resources Development in Chao Phraya Basin

The water resources development plan in Thailand is generally set up for irrigated agriculture to control the rich runoff in wet season and use it for supplemental irrigation of wet season paddy and full irrigation of dry season crops such as paddy, upland crops, orchard, vegetable, etc. The hydropower generation and flood control are considered to be by-products. Agencies responsible for water resources development for irrigated agriculture are RID, ARD and DEDP implementing the following projects;

- Large and medium scale irrigation project by RID
- Small scale irrigation program by RID and ARD
- Pump irrigation project by DEDP

### (1) Existing Water Resources Development Project

Many water resources development projects for irrigated agriculture consisting of dams, weirs, pumps, canals, etc have been planned, implemented and operated in the Chao Phraya basin. The location of existing large dams with their commanded areas are shown in the Database Map. The largest existing dams in Thailand are the Bhumibol dam with the active capacity of 9,660 MCM on the Ping river and the Sirikit dam with the capacity of 6,660 MCM, as outlined in Table 2.4. Other large scale dams in the Chao Phraya basin are listed in Table 2.5.

There are about 90 existing large/medium scale dams with total active capacity of 17,500 MCM and total irrigation area of 1.54 million ha. In addition, about 1,600 small scale irrigation projects are under operation with total storage capacity of 230 MCM and irrigable area of 620,000 ha. Pumping irrigation projects covering the area of 79,500 ha have been developed and under operation in the Chao Phraya basin.

All reservoirs except the Sirikit and Bhumibol reservoirs with large capacities are so operated that the rich runoff in wet season is stored in the reservoir and released for supplemental irrigation of wet season paddy in June to July when rainfall is insufficient for paddy cultivation. Accordingly, the reservoir water to be used for dry season irrigation is quite limited.



**Table 2.4 Outline of Bhumibol and Sirikit Dams**

| Dimension                 | Unit                | Bhumibol Dam | Sirikit Dam |
|---------------------------|---------------------|--------------|-------------|
| <b>Reservoir</b>          |                     |              |             |
| Catchment Area            | km <sup>2</sup>     | 26,100       | 13,130      |
| Average Annual Rainfall   | mm                  | 1,100        | 1,200       |
| Average Annual Inflow     | MCM                 | 5,250        | 5,120       |
| Maximum Annual Inflow     | MCM                 | 8,707        | 8,574       |
| Minimum Annual Inflow     | MCM                 | 2,276        | 3,119       |
| High Water Level          | m                   | 260          | 166         |
| Full Water Level          | m                   | 260          | 162         |
| Low Water Level           | m                   | 213          | 123         |
| Storage Capacity at HWL   | MCM                 | 13,462       | 10,503      |
| Storage Capacity at FWL   | MCM                 | 13,462       | 9,510       |
| Storage Capacity at LWL   | MCM                 | 3,800        | 2,850       |
| Active Capacity           | MCM                 | 9,660        | 6,660       |
| Reservoir Surface Area    | km <sup>2</sup>     | 318          | 260         |
| <b>Structure</b>          |                     |              |             |
| Dam Type                  |                     | Arch         | Earth Fill  |
| Dam Crest Elevation       | m, MSL              | 261          | 169         |
| Dam Height                | m                   | 154          | 113.6       |
| Dam Length                | m                   | 486          | 800         |
| Spillway Capacity         | m <sup>3</sup> /sec | 6,000        | 3,250       |
| Average Outflow for Power | m <sup>3</sup> /sec | 616          | 500         |
| Effective Power Head      | m                   | 100          | 85          |
| Power Plant Capacity      | MW                  | 70×6+115=535 | 125×4=500   |
| Produced Annual Energy    | GWh                 | 1,560        | 1,200       |

Table 2.5 Outline of Existing Large and Medium Dams

| Basin                  | Dam              | Drainage Area (km <sup>2</sup> ) | Annual Runoff (MCM) | Active Capacity (MCM) | Irrigable Area (ha) |
|------------------------|------------------|----------------------------------|---------------------|-----------------------|---------------------|
| <b>1. Large Scale</b>  |                  |                                  |                     |                       |                     |
| Ping                   | Bhumibal         | 26,386                           | 5,250               | 9,660                 | 649,000             |
| -- Do --               | Mae Ngat         | 1,281                            | 290                 | 243                   | 4,800               |
| -- Do --               | Mae Kuang        | 569                              | 210                 | 249                   | 28,000              |
| Wang                   | Kiu Lom          | 2,700                            | 590                 | 108                   | 25,600              |
| Nan                    | Sirikit          | 13,130                           | 5,120               | 6,660                 | 649,000             |
| Sakae Krung            | Tap Salao        | 534                              | 200                 | 152                   | 23,000              |
| Chao Phraya            | Krasieo          | 1,200                            | 170                 | 201                   | 20,800              |
| Subtotal               | 7                | 45,800                           | 11,830              | 17,273                | 1,400,000           |
| <b>2. Medium Scale</b> |                  |                                  |                     |                       |                     |
| Ping                   | Mae Tub          | 126                              | 24.6                | 39                    | 4,160               |
| Wang                   | Mae Yao          | 35                               | 3.2                 | 3.5                   | 960                 |
| -- Do --               | Mae Arb          | 35                               | 4.4                 | 7.5                   | 640                 |
| -- Do --               | Mae Prik         | 45                               | 5.5                 | 4.2                   | 620                 |
| Yom                    | Mae Kam Pong     | --                               | 13.9                | 2.6                   | 960                 |
| -- Do --               | Mae Man          | --                               | 23.3                | 18.8                  | 2,320               |
| -- Do --               | Khlong Khang Nai | 28                               | 3.0                 | 10.4                  | 320                 |
| Nan                    | Huai Head        | 40                               | 6.0                 | 4.1                   | 1,230               |
| -- Do --               | Khlong Tron      | 265                              | 38.0                | 10.4                  | 3,740               |
| -- Do --               | Nam Haeng        | 227                              | 30.2                | 18.8                  | 960                 |
| -- Do --               | 7 Sub-Projects   | --                               | --                  | 41.7                  | 1,230               |
| Sakae Krung            | 7 Sub-Projects   | --                               | --                  | --                    | 15,700              |
| Pasak                  | 19 Sub-Projects  | --                               | --                  | 108.0                 | 79,400              |
| Chao Phraya            | 38 Sub-Projects  | --                               | --                  | 26.0                  | 31,700              |
| Subtotal               | 81               | --                               | --                  | 295.0                 | 143,940             |
| <b>Total</b>           | <b>88</b>        | <b>--</b>                        | <b>--</b>           | <b>17,568</b>         | <b>1,544,140</b>    |

In the Chao Phraya basin, only the Bhumibol and Sirikit dams can supply not only the supplemental irrigation water for wet season paddy but also irrigation water for dry season crops. In accordance with the past operation result of both dams, dry season runoff of about 6,000 MCM are released from reservoirs for various uses in the Chao Phraya delta at the Chainat barrage. Except these two dams, there exists no dam which can store and release this bulk amount of dry season water, and as a result the wet season runoff of 16,000 MCM out of 22,000 MCM of annual runoff is flowing down to the delta area without control.

The Sirikit and Bhumibol dams were originally planned and constructed for the irrigation purpose to cover a large area of 1.2 million ha in the Chao Phraya delta in addition to the Uttaradit and Phitsanulok irrigation project areas of 250,000 ha located downstream of the Sirikit dam in the lower Nan basin and the lower Ping irrigation area of 100,000 ha downstream of the Bhumibol dam in the lower Ping basin. However, the reservoir inflow of both dams has not been sufficient to fill the large storage capacity and to supply water for the large demand in the proposed irrigation project areas. Accordingly, the existing irrigation system is limited only to cover the Phitsanulok right bank area of 108,000 ha, and other areas in the lower Nan basin have been left under rainfed conditions.

Most of the other large/medium scale dams are constructed on the tributaries for irrigation use in the agricultural area along tributaries. These dams therefore have no function to supply surplus water to the irrigation areas in the lower Nan, lower Ping and Chao Phraya delta basins.

## **(2) Future Water Resources Development Project**

RID has set up the water resources development plans, mostly for large and medium scale irrigation dams, up to the year of 2006 on feasibility and pre-feasibility level. Outlines of these proposed dams in future are given in Table 2.6.

**Table 2.6 Outline of Proposed Large and Medium Dams**

| Basin                    | Dam                      | Drainage Area (km <sup>2</sup> ) | Annual Runoff (MCM) | Active Capacity (MCM) | Irrigable Area (ha) |
|--------------------------|--------------------------|----------------------------------|---------------------|-----------------------|---------------------|
| <b>1. Large Scale</b>    |                          |                                  |                     |                       |                     |
| Ping                     | Mae Khan                 | 1,085                            | 181                 | 165                   | 3,200               |
| Wang                     | Kiew Kho Ma              | 1,275                            | 265                 | 190                   | 4,400               |
| Yom                      | Kaeng Sua Ten            | 3,583                            | 933                 | 1,175                 | 48,800              |
| Nan                      | Khwaie Noi               | 4,254                            | 1,449               | 769                   | 24,900              |
| -- Do --                 | Nam Khek                 | 854                              | 489                 | 345                   | 10,800              |
| Sakae Krung              | Mae Wong                 | 615                              | 221                 | 250                   | 46,700              |
| Pasak                    | Pasak                    | 12,929                           | 2,100               | 785                   | 37,000              |
| Subtotal                 |                          | 24,595                           | 5,638               | 3,679                 | 175,800             |
| <b>2. Medium Scale</b>   |                          |                                  |                     |                       |                     |
| Ping                     | Huai Mae Khon Reservoir  | 34                               | 9.6                 | 2.7                   | 800                 |
|                          | Huai Mae Kon Reservoir   | 44                               | 10.3                | 5.6                   | 1,700               |
|                          | Khlong Khayang Reservoir | 20                               | 6.7                 | 4.6                   | 600                 |
|                          | Khlong Prai Reservoir    | 51                               | 17.1                | 13.0                  | 600                 |
|                          | Nam Lai Reservoir        | 74                               | 18.5                | 15.0                  | 1,600               |
|                          | Khlong Khlung Reservoir  | 95                               | 20.6                | 18.0                  | 1,800               |
| Wang                     | Ban Lu Reservoir         | —                                | —                   | 24.5                  | 2,700               |
| Yom                      | Mae Song Reservoir       | 305                              | 75.7                | 65.8                  | 8,200               |
|                          | Mae Tang Reservoir       | 120                              | 29.8                | 30.6                  | 3,500               |
|                          | Huai Mae Song Reservoir  | 60                               | 6.3                 | 12.4                  | 1,300               |
|                          | Huai Ta Pae Reservoir    | 287                              | 30.3                | 58.0                  | 3,200               |
|                          | Mae Mok Reservoir        | 728                              | 85.0                | 96.0                  | 8,500               |
|                          | Wang Deang Reservoir     | 179                              | 34.1                | 12.0                  | 1,300               |
|                          | Mae Sai Reservoir        | 177                              | 43.9                | 24.3                  | 3,700               |
|                          | Huai Suang Reservoir     | 47                               | 5.0                 | 5.6                   | 700                 |
|                          | Mae Khong Kai Reservoir  | 70                               | 8.2                 | 9.0                   | 1,100               |
|                          | Nan                      | Mae Khaning Reservoir            | 229                 | 34.0                  | 62.0                |
| Huai Nam Klung Reservoir |                          | 184                              | 63.2                | 12.4                  | 4,500               |
| Khlong Chomphu Reservoir |                          | 364                              | 63.5                | 13.0                  | 5,900               |
| Mae Chaey Reservoir      |                          | 18                               | 6.8                 | 4.3                   | 600                 |
| Sakae Krung              | Khlong Pho Reservoir     | 376                              | 97.0                | 67.5                  | —                   |
|                          | Huai Nam Dung Reservoir  | 40                               | 8.2                 | 5.0                   | 600                 |
|                          | Huai Kan Yao Reservoir   | 85                               | 17.5                | 5.0                   | 800                 |
| Subtotal                 |                          | 3,587                            | 691.3               | 566.3                 | 56,100              |
| <b>Total</b>             |                          | <b>28,182</b>                    | <b>6,329.3</b>      | <b>4,245.3</b>        | <b>231,900</b>      |

As shown in Table 2.6, the total active capacity of about 4,000 MCM could be developed by proposed 7 large scale dams and 23 medium scale dams.

In the Nan basin, the storage capacity of about 1,200 MCM could be available from the large scale dams of Khwae Noi and Nam Khek and three other medium scale dams. The available reservoir outflow taking into account the carry over capacity, reservoir losses, etc. will be assumed at about 70% of total storage capacity or 800 MCM, of which about 400 MCM will be used for supplemental irrigation for wet season paddy and 200 MCM for dry season upland crops in the area to be newly expanded along the Nan tributaries. Accordingly the surplus dry season water usable in the areas along the Nan main stream and the Chao Phraya delta area will be limited to some 200 MCM.

In the Ping basin, only 200 MCM of storage capacity will be available for runoff control at the Mae Khan large scale dam and 6 other medium scale dams to be constructed in tributary basins. After controlled, waters are used mostly for irrigation in tributary basins and will not be allocated to the Chao Phraya delta area.

In the Yom, Wang and Sakae Krung basins, about 2,600 MCM of storage capacity will be developed. However, outflow from reservoirs will be used mostly in their own tributary basins where large scale agricultural areas are existing under rainfed condition, presenting no contribution to the delta area.

As mentioned above, water resources to be developed by the proposed storage dams are mostly used for irrigation in their own tributary basins and may not be allocated to the water demand in the delta area. Accordingly the Chao Phraya delta could not obtain additional water in future from upstream basins even if all of the proposed development has been implemented.

The Thai Government has therefore surveyed and studied transbasin water diversion projects in order to effectively utilize the Mekong and Salwin water in the delta area through the Sirikit and Bhumibol reservoirs where a large empty space of storage is available.

## 2.7 Irrigation Area in Chao Phraya Basin

The existing and future proposed irrigation areas are studied based on the NESDB's 25 Basin Study Report as summarized in Table 2.7. More details are given in the Supporting Report.

Table 2.7 Irrigation Area at Present and in Future

| Basin                              | Irrigation Area (1,000 ha) |            |              | Irrigation Intensity (%) |
|------------------------------------|----------------------------|------------|--------------|--------------------------|
|                                    | Wet Season                 | Dry Season | Total        |                          |
| <b>I. Existing Irrigation Area</b> |                            |            |              |                          |
| Nan                                | 278                        | 60         | 338          | 121                      |
| Yom                                | 132                        | 26         | 158          | 120                      |
| Wang                               | 68                         | 16         | 84           | 122                      |
| Ping                               | 260                        | 53         | 313          | 120                      |
| Sakae Krung                        | 92                         | -          | 92           | 100                      |
| Pasak                              | 121                        | -          | 121          | 100                      |
| Delta                              | 1,281                      | 370        | 1,651        | 129                      |
| <b>Total</b>                       | <b>2,235</b>               | <b>645</b> | <b>2,877</b> | <b>129</b>               |
| <b>I. Future Irrigation Area</b>   |                            |            |              |                          |
| Nan                                | 437                        | 111        | 548          | 125                      |
| Yom                                | 285                        | 48         | 333          | 117                      |
| Wang                               | 138                        | 22         | 160          | 116                      |
| Ping                               | 482                        | 93         | 575          | 119                      |
| Sakae Krung                        | 126                        | -          | 126          | 100                      |
| Pasak                              | 179                        | -          | 179          | 100                      |
| Delta                              | 1,315                      | 650        | 1,965        | 150                      |
| <b>Total</b>                       | <b>2,962</b>               | <b>924</b> | <b>3,886</b> | <b>131</b>               |

Remark: irrigation area in delta is based on the actual irrigated area collected from RID O/M Division.

### (1) Existing Irrigation Area

The existing irrigation area in the Chao Phraya basin reaches as large as 2.2 million ha in total with the irrigation intensity of 35% within the total farmland area of 5.9 million ha. Paddy is mainly cultivated in wet season, while various crops such as paddy, upland crops, vegetables, etc are planted in dry season with orchard and sugarcane as a perennial crops. Characteristics of the existing irrigation area in each sub-basin is summarized as follows;

(a) Nan Basin

The largest irrigation project in the Nan basin is the large scale Phitsanulok area covering the irrigable area of 108,000 ha on the right bank of Nan river in the Phitsanulok and Phichit provinces. The irrigation water for the project is supplied from the Sirikit dam and diverted at the Naresuan barrage constructed crossing the Nan river. Although the Phitsanulok project was originally planned with the area of about 200,000 ha expanding on both banks of the Nan river in the Phitsanulok province and the area of 100,000 ha in the Uttaradit province. However, the Phitsanulok irrigation area of 108,000 ha on the right bank has only been developed and under operation. The development for other irrigation areas have been suspended due to lack of water in the Sirikit reservoir from where the Chao Phraya delta area has been receiving outflow contribution.

According to the data from the O/M Division of RID, the Phitsanulok irrigation project has irrigated the area of 90,800 ha in wet season and 37,000 ha in dry season on an average in the past 10 years. The project area has suffered from water shortage always in dry season due to insufficient water supply from the Sirikit dam. In 1996, the project achieved the dry season irrigation area of 94,600 ha when the Sirikit reservoir kept the full storage level at the end of wet season. The Phitsanulok irrigation area including the future area of 100,000 ha on the left bank in addition to the existing area of 108,000 ha should be irrigated by the proposed Kok-Ing-Nan water diversion project.

Uttaradit pump irrigation project by DEDP has been developed along the Nan river covering the area of 48,000 ha at present. A number of floating pumps are installed along the river to withdraw the Nan river water which presents the large water level fluctuation in wet and dry seasons. These pump irrigation projects have also suffered from water shortage problems in dry season because of less water in river system. The additional water for irrigation could be supplied from the proposed project in order to expand the wet season irrigable area.

The area of 118,000 ha has been developed by SSIP up to present. These areas are however distributed mostly in the high land along small tributaries, and therefore

no relation with the proposed water diversion project has been observed.

(b) Delta Area

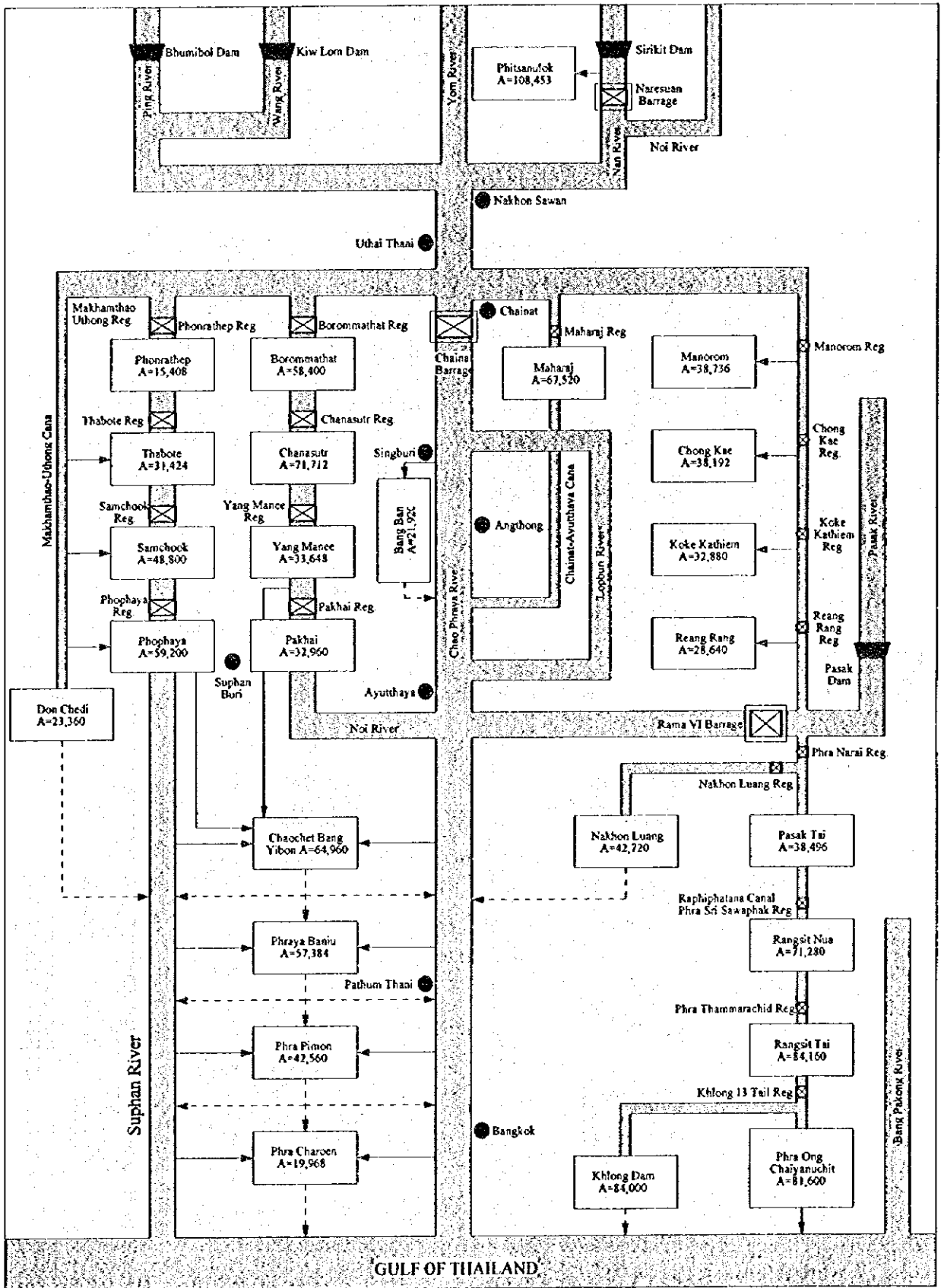
The irrigable area in the delta is about 1.2 million ha which composes the largest and most important agricultural area not only in the Chao Phraya basin but also in the whole country given an important role to support the national food security. The irrigation water is supplied from the Chainat greater barrage, which was constructed 80 years ago on the Chao Phraya river at Chainat and has been operated well by RID. The Chao Phraya river water consists of outflows from the Sirikit and Bhumibol dams and sideflows from many tributaries in the upper Chao Phraya basin, flows down to the Chainat barrage and is diverted to the irrigation area in the delta through large irrigation canals of Chainat-Pasak, Tha Chin, Noi, etc. The irrigation system in the delta area is shown in Figure 2.1.

Although the irrigation area of 1.2 million ha is planned with 100% intensity of wet season paddy and more than 50% for dry season crops such as paddy, upland crops, vegetables, fruits, etc., the actual irrigation area is about 950,000 ha (80%) in wet season and 370,000 ha (31%) in dry season according to the past 20 years record collected from O/M Division of RID. The irrigation area in the delta has also suffered from water shortage problem due to insufficient flow of the Chao Phraya river at Chainat as shown in Figures 2.2 and 2.3. Accordingly, the developed water by the Kok-Ing-Nan water diversion project should be supplied to cover the water shortage in the delta area with the top priority, because the irrigation area in the delta is formed with fertile soil, skillful farmers with deep and long experience, large market such as Bangkok and satellite cities, etc. and can achieve the highest agricultural benefit in the country without improvement of existing irrigation system, if sufficient irrigation water could be supplied in dry season.

In the delta area, the crop diversification and inland fishery development has progressed in recent years by promotion of the Thai Government, as a result the orchard area of 52,300 ha, sugarcane of 21,800 ha, vegetable of 6,000 ha, fishery pond of 23,100 ha, etc have been under operation and farmers have achieved the high productivity and income. These area will be expanded year by year due to the



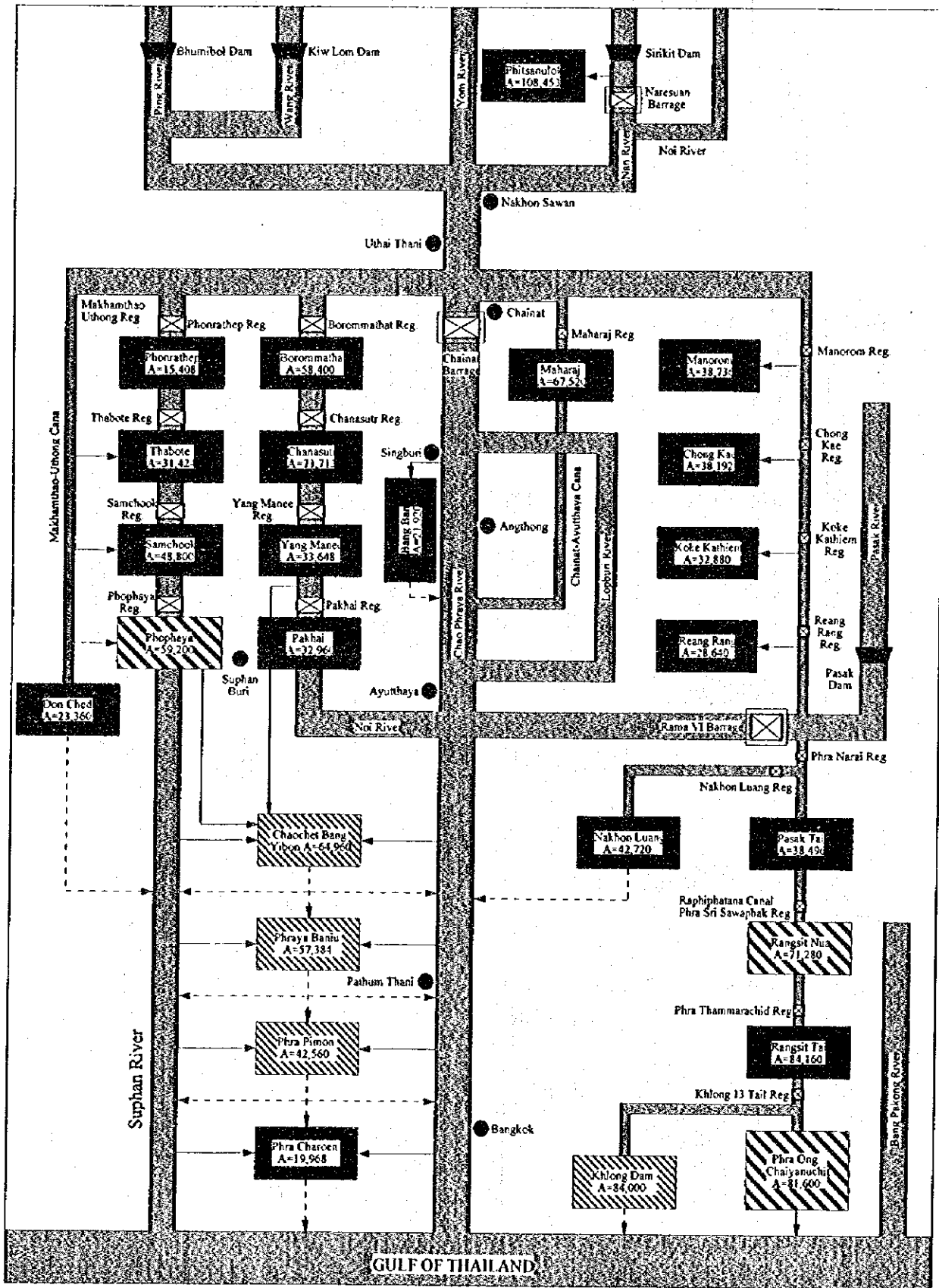
Figure 2.1 Water Supply System in Chao Phraya Delta



A = Irrigable Area in ha

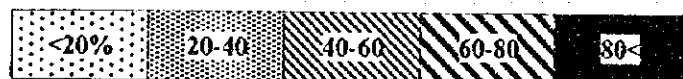
Data Source ; O/M Division, RID

Figure 2.2 Irrigation Intensity in Wet Season

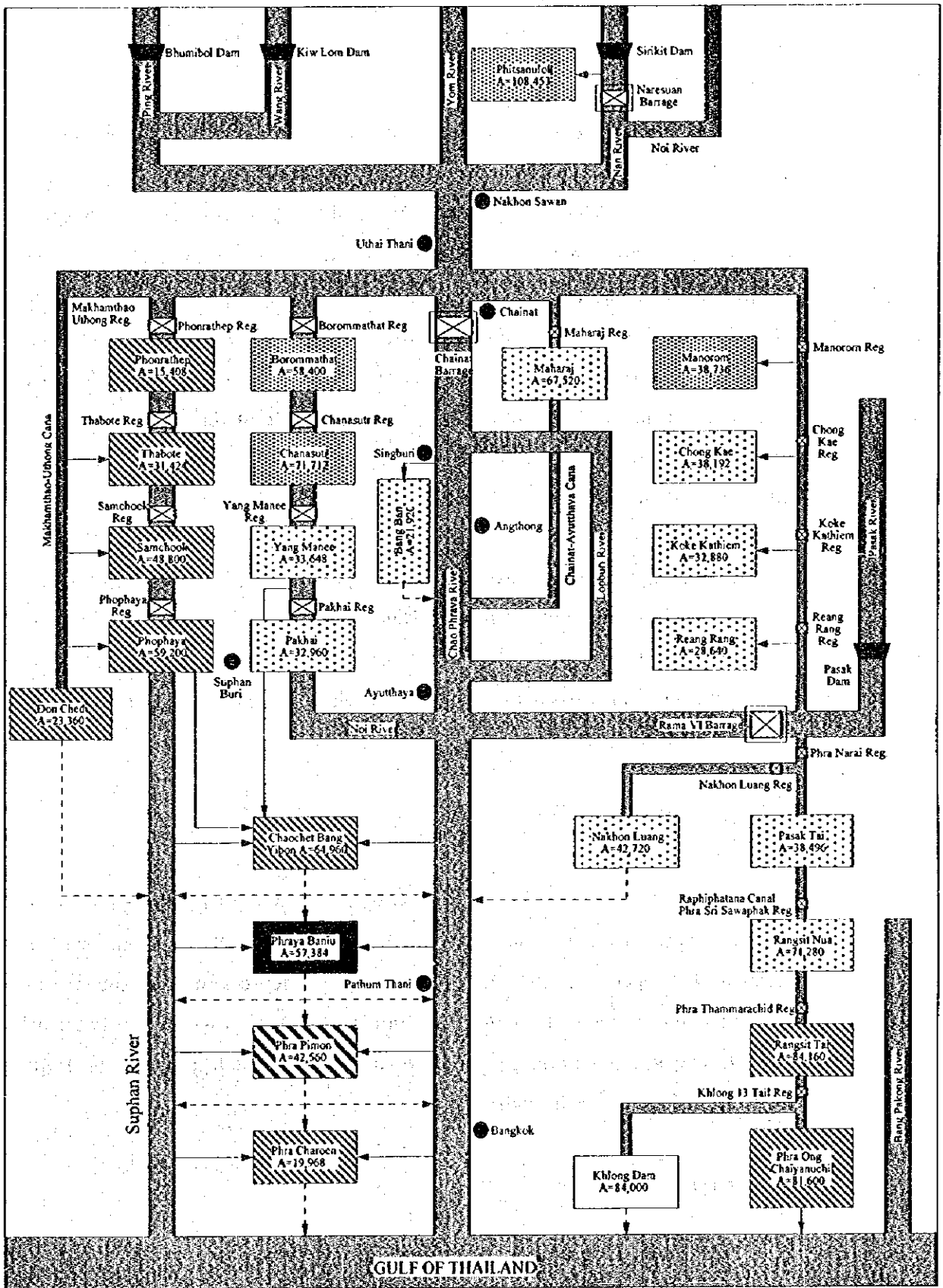


A = Irrigable Area in ha

Data Source ; O/M Division, RID



### Figure 2-3 Irrigation Intensity in Dry Season



A = Irrigable Area in ha

Data Source ; O/M Division, RID



high market demand caused by increasing population and food variety in the area.

(c) Ping Basin

There are large existing irrigation project area of 113,000 ha developed by large and medium scale dams and weirs in the basin. These areas are mostly located in the upper basin belonging to the Chiang Mai and Lampang provinces. Although the Bhumibol dam with a large storage capacity is existing upstream of the lower basin, the irrigated agriculture in the lower basin belonging to the Tak and Khamphaeng Phet provinces has been suspended because the water from the Bhumibol reservoir should be used for the delta area with first priority, and is not sufficient to cover the irrigation area in the lower basin. The irrigation water in the lower basin may be supplied in future by the transbasin water diversion project from the Salwin river through the Bhumibol dam.

If the surplus water is available in dry season from the Kok-Ing-Nan water diversion project after utilized for the Nan and Chao Phraya delta area, a part of water presently released from the Bhumibol dam to the delta area could be shifted to irrigate the lower Ping basin. Possibility of this water allocation will be further studied in the Phase II Study of the project.

(d) Other Basins

The large, medium and small scale as well as pumping irrigation projects have been developed in other basins including the Yom, Wang, Sakae Krung and Pasak basins in the upper Chao Phraya basin. The water resources in these sub-basins are however limited in amount and there are no room to supply excess water to the delta area. Developed water by the proposed irrigation project will be primarily used within the beneficial area in each sub-basin.

(2) Future Irrigation Area

The proposed irrigation area in future is scheduled to be about 3.0 million ha in the Chao Phraya basin with increase of about 800,000 ha as compared to that under the

existing condition. The dry season irrigation area is assumed to be 900,000 ha corresponding to 30% of the total irrigable area. The crop diversification program will be further accelerated in each sub-basin by converting dry season paddy area to the full irrigation areas for upland crops, fruits and vegetables in dry season. Characteristics of the proposed irrigation area in each sub-basin are summarized as follows;

(a) Nan Basin

The proposed irrigation area in future will increase to 437,000 ha as compared with the existing area of 278,000 ha, as shown in the following table.

Existing and Proposed Irrigation Area in Nan Sub-Basin (Unit: 1,000 ha)

| Project            | Existing | Proposed | Increase |
|--------------------|----------|----------|----------|
| Large/Medium Scale | 112.3    | 158.1    | 45.8     |
| Small Scale        | 117.3    | 179.4    | 62.1     |
| Pump Irrigation    | 48.4     | 99.5     | 51.1     |
| Total              | 278.0    | 437.0    | 159.0    |

The large and medium scale irrigation project area of 45,800 ha is to be newly developed by the Khwae Noi, Nam Khek and Khlong Chumphu dams as well as by the Ban Nong weir, etc. These dams and weirs are developed mainly in tributary basins and developed water is used for irrigation only in the tributary basins, and therefore there is no room to supply excess water to the downstream irrigation area in the Phitsanulok and Chao Phraya delta. Expansion of irrigable area in the existing irrigation project and development of new irrigable area on the left bank of the Phitsanulok project will be contributed by the proposed Kok-Ing-Nan water diversion project.

The new SSIP area of 62,100 ha is distributed in high land of the small tributary basins and has no relation to the Kok-Ing-Nan project. Some area of 51,100 ha to be newly developed by pumping irrigation projects will be located along the main stream of the Nan river. Accordingly some of water developed by the Kok-Ing-Nan project will be used unavoidably by the proposed pumping irrigation projects.

**(b) Delta Area**

The irrigation area in delta in future is assumed at 1.32 million ha with increase of only 40,000 ha as compared with the existing area of 1.28 million ha. Within the existing irrigation system covered by the Chainat-Pasak and other canals, there are no irrigable area to be newly developed. Some area distributed in high land will be irrigated in future by SSIP.

In the delta area, the dry season cropping area for upland crops, fruits and vegetables will increase to a large extent supported by the Government's crop diversification program and the increasing market demand. In addition the fish culture activity will also be expanded in the delta, especially in the area along the coastal line in the lower delta where large scale fishery ponds have already been developed.

At present the dry season cropping area is limited to only 370,000 ha due to lack of irrigation water. Accordingly the area requires more dry season water from the proposed Kok-Ing-Nan project. The dry season cropping area could be increased easily up to 600,000 ha (50% of cropping intensity in dry season) if sufficient volume of irrigation water is available in dry season.

**(c) Other Basins**

Although the proposed irrigation area in other basins will reach 1,210,000 ha with increase of 530,000 ha as compared with the existing area of 680,000 ha, most of these area is located in tributary basins and therefore will have no relation with the proposed Kok-Ing-Nan project. Among them, only some area located in the lower Ping basin would be developed by water from the Bhumibol dam, if surplus water is available from the proposed Kok-Ing-Nan project.