JAPAN INTERNATIONAL COOPERATION AGENCY

PUBLIC WORKS DEPARTMENT
MINISTRY OF INTERIOR
THE KINGDOM OF THAILAND

THE STUDY ON MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN IN THE KINGDOM OF THAILAND

VOLUME 1

SUMMARY REPORT

JANUARY 1994

NIPPON JOGESUIDO SEKKEI CO., LTD.
PACIFIC CONSULTANTS INTERNATIONAL

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PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Government of Japan decided to conduct a master planning and preliminary design study on Master Planning for the Sewerage Development Project for Lower Chao Phraya River Basin and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a study team headed by Mr. Masatoshi Momose, Nippon Jogesuido Sekkei co., Ltd., and composed of members from the said company and Pacific Consultants International 4 times between May 1992 and December 1993.

The team held discussions with the officials concerned of the Government of Thailand, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the government of the Kingdom of Thailand for their close cooperation extended to the team.

January 1994

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

January, 1994

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Yanagiya

Letter of Transmittal

We are pleased to submit herewith the final report of the study on Master Planning for the Sewerage Development Project for Lower Chao Phraya River Basin in the Kingdom of Thailand.

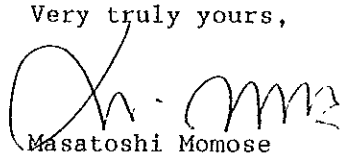
The field investigations and studies were conducted starting from the end of March 1992 and completed by the end of December 1993.

The final report consists of four volumes consolidating two times each of progress report and interim report: One-Summary report which succinctly describes the study and recommendations; Two-Main report which covers water pollution control plan, sewerage master plans for eight areas and preliminary design of two selected areas; Three-Supporting report including detailed analysis and relevant information; Four-Data report covering field findings and data.

We hope that the implementation of the proposed sewerage projects would greatly contribute to the improvement of water quality in the public water body and sanitation conditions in the study area.

We wish to take this opportunity to express our sincere gratitude to your Agency. We also would like to show our appreciation to the Public Works Department, Ministry of Interior, Thailand on the close cooperation and assistance extended to us during our study.

Very truly yours,



Masatoshi Momose
Team Leader
The Study on Master Planning
for the Sewerage Development
Project for Lower Chao Phraya
River Basin

EXECUTIVE SUMMARY

This project comprises three (3) parts. These are (1) Water Pollution Control Plan, (2) Sewerage Master Plan for Eight Areas and (3) Preliminary Sewerage Design of Two Areas.

PART I WATER POLLUTION CONTROL PLAN

1. Study Area : seven provinces (Chai Nat, Sing Buri, Ang Thong, Lop Buri, Ayutthaya, Pathum Thani and Nonthaburi) ; area coverage - 6,037.4 km^2, total length 380 km, 14 municipalities and 66 S.Ds, present population 3,350,000; typical tropical monsoon region

2. Water Quality Standard of Surface Water and Water Pollution Status

Control Areas (km from river mouth)	Water Classification	Water Quality Standard Point
142 - 379	Class 2	
62 - 142	Class 3	Pompetch, Ayutthaya beside previous Nonthaburi P. Office
7 - 62	Class 4	

Water Pollution Status

Class 4 section : It is difficult to achieve the standard under the present arrangements of sewerage facilities.

Class 2 and 3 sections : Presently satisfying the standard, but need urgent countermeasures

3.Sanitation Conditions and Sewerage Systems at Present and in the Future

- Sanitation Conditions : Average served percentage of both latrine and safe water are 92% and refuse disposal at 81%.

- Sewage Works : PWD is responsible for local areas in the sewage works. Thirteen systems were already constructed or under con-

struction, while 7 treatment plants are presently in operation. There are three on-going sewerage projects in the study area (Ayutthaya, Pathum Thani and Nonthaburi).

4. Population, Industry, Agriculture and Fishery in the Study Area at Present and in the Future

Year	1992	1996	2001	2011
Population	2,276,271	2,476,416	2,791,077	3,568,516
No. of Employees	652,388	713,802	716,601	742,320
No. of Livestock (head)				
Buffaloes	97,000	84,100	79,400	77,600
Cattle	411,900	443,400	476,400	534,000
Swine	395,600	464,500	526,800	601,700
Area of Fish Pond (m^2)	20,863,033	20,863,033	20,863,033	20,863,033
No. of Slaughtered Livestock (head)				
Buffaloes	47,110	43,730	40,510	33,150
Cattle	49,810	44,900	40,810	36,100
Swine	307,020	344,700	393,010	490,470

5. Water Use and hydrological Conditions of Rivers through the Future

- Water Use : domestic, industrial, agricultural and fishery uses; Bangkok water supply by the MWA - 1.25 million m^3/day and supply to the area from Pathum Thani to Somut Parakarn - 2.65 million m^3/day.

- Hydraulic Conditions of the Rivers : Discharge from the Chao Phraya river is usually maximum during September to November with a figure of 800 m^3/sec. The minimum flow is around 60 m^3/sec during dry season.

6. Projection of Water Quality at Water Quality Checking Point

Summary of Future Water Pollution Analysis

Water Qty Check Point	Location	Env. Std. (mg/l)	Calculation Result 1996	2001	2011
R1	Chao Phraya R., before diversion to Noi R.	1.5	1.3	1.3	1.3
R2	Chao Phraya R., before confluence of Pasak R.	1.5	0.9	1.1	1.5
R3	Chao Phraya R., after confluence of Noi R.	2.0	1.4	1.7	2.2
R4	Chao Phraya R., Nonthaburi	2.0	3.5	4.2	6.2
SP2	Chao Phraya R., Chai Nat Dam	1.5	1.2	1.2	1.2
No	Noi R., after diversion from Chao Phraya R.	-	1.2	1.3	1.3
SP3	Pasak R., before confluence of Chao Phraya R.	-	4.1	4.9	6.5
J4	Chao Phraya R., after confluence of Pasak R.	2.0	1.2	1.4	2.0
J10	Noi R., before confluence of Chao Phraya R.	-	1.5	2.9	3.6
IP3	Chao Phraya R., before intake of MWA	2.0	1.3	1.5	2.0
IP4	Chao Phraya R., before intake of irrigation	2.0	2.0	2.3	3.1

7. Recommendations on the Reduction of Pollution Load

(1) Domestic Wastewater

Potential areas to be sewered are assumed to be municipalities and S.Ds. Countermeasures shall be provided for other areas in terms of sanitation improvement. Sewered percentage required in section R3 - R4 is almost 100% immediately covering all municipalities and S.Ds.

(2) Industrial Wastewater and Slaughterhouse Wastewater

The provision of proper effluent control is necessary under the current effluent standard covering all factories. For Pathum Thani and Nonthaburi, more stringent effluent standard of 50 mg/l BOD is recommended.

(3) Livestock and Fish Pond Wastewater

Required reduction percentage of pollution load in section R3 - R4 is more than 100% in assumption of effluent control with 100 mg/l BOD. Relocation of livestock or compression of frame value are recommended.

PART II SEWERAGE MASTER PLAN FOR THE EIGHT MUNICIPALITIES/AREAS

1.Design Conditions, Assumptions and Fundamentals for Sewerage Master Planning

- Study Area : DTCP area

- Sewerage Mater Planning Area : Present municipality/S.D in addition to the area to be expanded in the near future

- Planning Area, and Present and Future Population (see the Table)

(1) Wastewater Collection Method and Treatment Method

The combined wastewater collection method was adopted in full use of existing drainage facilities for low cost construction.

Small scale and lower treatment level for upper and middle basins (BOD less than 40 mg/l)
Large scale and higher treatment level for the lower basin (BOD less than 20 mg/l)

Planning Area, and Present and Future Population

Project Area	Area & Population	Present Munici./SD	Future Exp. Area	Sewerage M/P Area	Study Area (DTCP Area)
1. Chai Nat	Area (km^2)	6.06	0.84	6.90	56.49
	Pop. in 1991	13,983	-	-	
	Pop. in 2011	19,765	2,035	21,800	
2. Sing Buri	Area (km^2)	9.02	2.89	11.91	31.33
	Pop. in 1991	22,570	-	-	
	Pop. in 2011	35,973	5,727	41,700	
3. Lop Buri	Area (km^2)	6.85	3.38	10.23	12.85
	Pop. in 1991	36,832	-	-	
	Pop. in 2011	49,320	11,980	61,300	
4. Ang Thong	Area (km^2)	3.73	1.45	5.18	23.98
	Pop. in 1991	9,607	-	-	
	Pop. in 2011	10,686	2,814	13,500	
5. Pa Mok	Area (km^2)	6.89	0.24	7.13	26.86
		(12.000)			
	Pop. in 1991	10,686	-	-	
	Pop. in 2011	12,857	443	13,300	
6. Sena	Area (km^2)	1.20	0.79	1.99	26.10
	Pop. in 1991	4,607	-	-	
	Pop. in 2011	7,790	1,610	9,400	
7. Rang Sit Prachatipat	Area (km^2)	33.30	0	33.30	33.30
	Pop. in 1991	100,600	-	-	
	Pop. in 2011	154,000	-	154,000	
8. Bang Bua Thong	Area (km^2)	1.60	11.90	13.50	13.50
	Pop. in 1991	45,786	-	-	
	Pop. in 2011	76,600	-	79,600	
Total	Area (km^2)	68.65	21.49	90.14	224.41
	Pop. in 1991	244,671	0	0	
	Pop. in 2011	369,991	24,609	394,600	

1) Present population out of the municipality area is estimated based on the current population density (20 persons/ha) and assumed to be constant through the future

2) Population in Rang Sit area is estimated in consideration of non-registered population (30% of registered population)

(2) Outline of Sewerage Plan and Cost Estimates (facility for 2011)

Service Area	Design Capacity (m^3/d)	Treatment Method WW	Sludge	No. of Operator (person)	Construction (Million Baht)	O&M (Million Baht)
Chai Nat	5,900	SP	DB	13	190.30	0.952
Sing Buri East	3,000	SP	DB	11	185.66	1.286
West	8,200	AL	DB	16	171.56	1.524
Sub-total	11,200			27	357.22	2.810
Lop Buri	16,500	AL	DB	21	372.16	4.902
Ang Thong East		SP	DB		93.36	0.666
West					60.39	0.429
Sub-total	3,700			11	153.75	1.095
Pa Mok East	2,000	SP	DB	8	117.97	0.432
West	1,700	SP	DB	8	97.34	0.313
Sub-total	3,700			16	215.31	0.745
Sena	2,600	SP	DB	9	84.80	0.241
Rang Sit Preli.		AS	DU		682.18	19.123
Rang Sit Others					1,065.19	29.854
Sub-total	75,000			50	1,747.37	48.977
Bang Bua Thong Preli.		AS	DU		352.28	8.189
North Others					237.33	5.523
Sub-total	23,600			30	589.61	13.712
Bang Bua Thong South	7,900	OD	DB	15	307.55	6.751
Bang Bua thong Total				45	897.16	20.463

Note : SP Stabilizaton Pond DB Drying Bed AL Aerated Lagoon
DU Dewatering Unit OD Oxidation Ditch AS Activated Sludge

(3) Administrative and Management Aspect

- Strengthening of OSW for implementation of sewerage projects
- Creation of National and Local Sewage Works Authorities
- High quality training courses for sewage works
- Rearrangement of legal system for establishment of sewage works authorities and water pollution control

(4) Financial Aspect

a) Self-finance by the central government as much extent as possible; In case of foreign loan utilization, appropriate composition to the total requirements shall be worked out.

b) Loan arrangements in combination of foreign and local loans may be done, as required, by the local government.

c) Sewage charge with less than one percent of the household income in low income household may be affordable. Staged construction will help make ligher the burden of beneficialies. Supplementary arrangements by the central government may be another measure.

(5) Economic Analysis and Project Justification

Project benefits are summarized including three major items.

a) Improvement of water quality in the public waterbody
b) Improvement of health and sanitation conditions
c) Increase of land value and economic promotion

(6) Interim Measures

Periodic review and updating of sewerage master plan are requisites as well as the followings:

- Improvement of nightsoil treatment facility and periodic sludge removal
- Improvement of refuse collection
- Treatment of sullage at WWTP expanding/improving existing drainage facilities
- Strengthening of effluent control regulation

(7) Project Implementation Plan and Environmental Protection

Four stage implementation plan was recommended from 1991 to 2011. Countermeasures against potential environmental problems are recommended focusing on offensive odour, insects and effluent quality control.

(8) DTCP Area

Sanitation improvement in rural areas was studied with a focus on nightsoil treatment. Among them, water sealed toilet entailing information dissemination to the inhabitants and finan-

cial assistance by central and local governments for facility construction are emphasized.

Outline of Sewage Collection Facilities

Area	Interceptor (m)	Manhole (No.)	Pump station (No.)	Siphon (No.)	River Crossing (No.)
Chai Nat	10,070	260	2	-	-
Sing Buri	16,883	401	6	-	-
Lop Buri	14,745	311	7	2	2
Ang Thong	9,780	245	6	-	1
Pa Mok	9,865	266	3	-	-
Sena	2,898	78	2	-	1
Rang Sit	21,332	390	9	5	-
Bang Bua Thong	18,252	425	8	1	-

PART III PRELIMINARY ENGINEERING DESIGN OF SEWERAGE SYSTEMS FOR THE TWO AREAS

1. Rangsit Area (Design area covers Phrachatipat and Klukot S.Ds with a total area of 1,288 ha.)

(1) Basic Conditions

- Population : presently 41,000 and in the future (2011) 62,380 in the design area

- Design quantity and BOD Load : 21,355 m^3/d (daily average), 4,497 kg/d BOD

- Wastewater Collection System : combined collection method, interceptors for the year 2011; 6 pump stations and 4 siphons

- Wastewater and Sludge Treatment : WWTP (3ha) is located 2 km far from klong Rangsit owned by private sector; activated sludge method and mechanical dewatering; six unit systems for 2011 and two systems for stage I

Design Flow (m^3/d)

Item	2001	2011
Daily Ave.	21,350	62,500
Daily Max.	25,700	75,000
Hourly Max.	33,200	97,500
Wet weather	100,000	292,500

Influent and Effluent Quality (mg/l)

Item	BOD	SS
Influent	175	150
Effluent	20	30

(2) Construction and O&M Cost

Construction Cost (Million Baht)

Item	Domestic	Foreign	Total
1) Direct Cost	348.3	248.7	597.0
2) Contingency	69.7	49.7	119.4
3) 1) + 2)	418.0	298.4	716.4
4) Engineering Cost	121.8	-	121.8
5) Land Acquisition	76.9	-	76.9
Total	616.7	298.4	915.1

O&M Cost (Thousand Baht)

1) Interceptor	847
2) Pump Station	6,178
3) WWTP	15,460
Total	22,485

(3) Project Implementation Schedule : starting from 1994 to complete by the end of 1997, construction period for WWTP - 2 years

(4) Administrative and Management Aspects

- National Level : OSW, PWD shall undertake policy-making matter. establishment of national sewage authority and relevant sewerage laws and regulations; considerable increase of engineers (civil, sanitary, mechanical, electrical and environmental specialists)

- Rangsit Area : establishment of local sewage authority, training courses for technical and management staff

(5) Financial Aspect

The following two alternatives are practical for financial arrangements of construction cost, which is the obligation of the central government.

- Self finance by the central government
- 30% foreign loan and 70% national budget allocation : FIRR arrived at 12% equivalent to capital investment opportunity (10-12%)

In case that the cost required for land acquisition (25%) and O&M cost would be financed through foreign and local loans (each 50%), FIRR may be about 10%. Assistance from the government allows for the burden of low income household to be less than 1%.

(6) Project Justification

The project will contribute to the improvement of water quality in the public waterbody, improvement of health and sanitation, upgrading of living standard and economical development. A trial calculation on EIRR showed comparatively high figure.

2. Bang Bua Thong Municipality

(1) Basic Conditions (Design area covers 438ha in Bang Bua Thong North area.)

- Population : Present population except for those in the estates is 13,973 and planned total population 32,110.

- Design Wastewater Quantity and BOD Load : 9,031 m^3/d (daily average), 1,580 kg/d BOD

- Wastewater Collection System : combined collection method, interceptor with a capacity for 2011 needs, two pump stations and one siphon

- Wastewater and Sludge Treatment : WWTP (1.8 ha) is located in Pimol Ratcha, behind Chol Lada estate; activated sludge treatment and mechanical sludge dewatering ; Four unit treatment systems of which two unit systems are for stage I Project

Design Flow (m^3/d)

Item	2001	2011
Daily Ave.	9,100	19,700
Daily Max.	10,900	23,600
Hourly Max.	14,200	30,700
Wet weather	42,600	92,100

Influent and Effluent Quality (mg/l)

Item	BOD	SS
Influent	180	150
Effluent	20	30

(2) Construction and O&M Cost

Construction Cost (Million Baht)

Item	Domestic	Foreign	Total
1) Direct Cost	118.9	101.2	220.1
2) Contingency	23.8	20.2	44.0
3) 1) + 2)	142.7	121.4	264.1
4) Engineering Cost	44.9	-	44.9
5) Land acquisition	150.5	-	150.5
Total	338.1	121.4	459.5

O&M Cost (Thousand Baht)

Item	Cost
1) Interceptor	366
2) Pump Station	1,405
3) WWTP	7,929
Total	9,700

(3) Project Implementation Schedule : starting from 1994 to complete by the middle of 1997; construction period of WWTP - 1.5 years

(4) Administrative, Management and Financial Aspects : same as Rangsit study

VOLUME I - SUMMARY REPORT

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PART II SEWERAGE NASTER PLAN FOR THE EIGHT MUNICIPALITIES/AREAS

GENERAL INTRODUCTION

1.1 Background of the Study

The Chao Phraya river flows from the Northern Valleys through the central plain and into the gulf of Thailand. The total length of the river is about 980 km with the basin area of 160,000 km^2 (32% of total land area of Thailand). The Chao Phraya River has been playing an important role for power supply, irrigation, water supply, navigations, fishing and wastewater disposal. However, water pollution of river, especially in the lower river basin, is considerable in recent years due to rapid urbanization and industrialization.

Water supply for the Bangkok Metropolitan area with a population of about 8 million is depending on the river for its water source (96.5%). The river water may not be maintained usable for the water supply purpose in the near future unless proper countermeasures are implemented. Under these critical situations in the water quality, the Government of the Kingdom of Thailand adopted water quality standards for the Chao Phraya River in 1986 and established several measures in 1988 in recognition of urgent needs of water pollution control.

The Government of Kingdom of Thailand requested the Japanese Government in August 1989 cooperation for preparation of Master Plan of the sewerage development project covering eight (8) municipalities/Sanitary Districts (S.Ds).

1.2 Objectives of the Study

The objective of the Study is to prepare a countermeasure plan for comprehensive water pollution control of the Chao Phraya River and to establish a master plan up to year 2011 for sewerage development along the river stretch between Chai Nat and Nontha Buri.

1.3 Study Area

The Study area shall cover lower Chao Phraya River basin between Chai Nat and Nontha Buri. The Master Planning for Sewerage development project shall

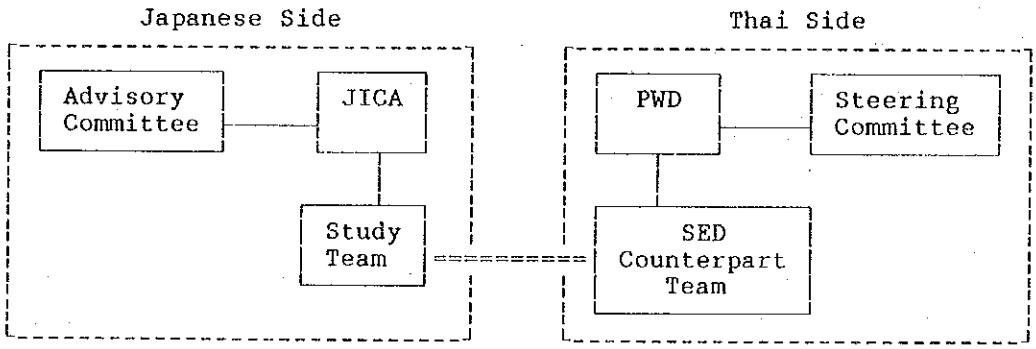
be done for the following municipalities/sanitary districts.

1. Chai Nat Municipality, Chai Nat Province
2. Sing Buri Municipality, Sing Buri Province
3. Lop Buri Municipality, Lop Buri Province
4. Ang Thong Municipality, Ang Thong Province
5. Pa Mok Municipality, Ang Thong Province
6. Sena Municipality, Ayutthaya Province
7. Prachatipat and Kukhot Sanitary Districts (area so called Rang Sit), Pathum Thani Province
8. Bang Bua Thong Municipality, Nonthaburi Province

1.4 Study Organization

1.4.1 General Organization

The General organization for the Study is as shown below.



Note : JICA : Japan International Cooperation Agency
PWD : Public Works Department, Ministry of Interior
SED : Sanitary Engineering Division

1.4.2 Japanese Organization

The Japanese Organization consists of the Study Team under JICA headquarters and the Advisory Committee for JICA headquarters.

The members of the Study Team are as follows:

Name	Field in charge
1. Masatoshi Momose	Team Leader
2. Akio Takeuchi	Water Quality conservation /Sewerage Planning
3. Masami Kondo	Sewage Treatment Planning
4. Hiroshi Shiraishi	Facilities Design
5. Takafumi Kiguchi	Water Pollution Control
6. Chaisak Sripadungtham	Hydraulic/Hydrology
7. Kenji Kawada	Water Quality Analysis
8. Takamasa Katsuki	Construction Planning /Cost Estimate
9. Norihiro Noda	Organization/Management
10. Tatsuo Tsuchigane	Economist/Financial Analysis
11. Koichi Nakazato	Survey

The members of the Advisory Committee are as follows:

Name	Field in Charge	Present Post
Kunio Ichimura	Chairman	Director, Water Quality Control Dept., PWRI, MOC
Shigeru Miyahara	Sewerage Planning	Director, Sewage Works Bureau, The Municipal Government of Kurashiki Okayama Prefecture
Masatoshi Yamada	Water Pollution Analysis	Deputy Manager, Project Planning Dept., Japan Sewerage Works Agency

1.4.3 Thai Organization

The Thai organization consists of the SED Counterpart Team and the Steering Committee, operating in coordination with the Public Works Department of the Ministry of Interior.

The principal members of the counterpart Team are as follows:

Agency	Name	Related Field
PWD	Kreeta Soikeeree	Sanitary Engineering
PWD	Prenjit Honjunthanukula	Agricultural/Civil Engineering
PWD	Sekson Chorungsarit	Civil Engineering
PWD	Tepchai Sere-umnoi	Civil Engineering
PCD	Tawee Pienchalo	Environment
DIW	Kosol Jairungsee	Industry
RID	Virat Khao-Uppatum	Irrigation
DTCP	Somsanguan	City Planning

Note : PCD : Pollution Control Dept., Ministry of Science Technology and Environment
DIW : Department of Industrial Works
RID : Royal Irrigation Department
DTCP : Department of Town and Country Planning

The members of the Steering committee are as follows:

Name	Position
Prajaya Sutabutr (Chairman)	Director General, Public Works Department
Sujin Channarong	Deputy Director General, Public works Department
Siritan Pairojboriboon	Deputy Director General, Pollution control Dept., Ministry of Science Technology and Environment
Vichan Vongvivat	Director, SED Public Works Department
Thossaporn Suddhajinda	Deputy Director, SED Public Works Department
Sakchai Suriyajantathong	Department of Industrial Works

1.5 Reports

The Study reports prepared are as follows:

(1) Summary Report (Volume 1)

(2) Main Report (Volume 2-1, Volume 2-2)

(3) Supporting Report (Volume 3)

(4) Data Report (Volume 4-1)

(5) Drawings (Volume 4-2)

The Main report presents the results of the whole study. It consists of three Parts : Part (I) Water Pollution Control Plan, Part (II) Sewerage Master Plan for The Eight Municipalities/Areas, and Part (III) Preliminary Engineering Design of Sewerage Systems for Rang Sit Area and Bang Bua Thong Municipality.

Part (I) presents a water pollution analysis and recommendations on the required countermeasures for water pollution control in the Lower Chao Phraya River Basin. The findings and field measurement results conducted during the Stages I and II field work in Thailand formed the primary study base of this comprehensive basin-wide water pollution control plan. Some sectoral reports prepared by several agencies in Thailand were also fully reviewed in this study; the major portions of which were summarized in Volume IV - Data Report.

Part (II), Sewerage Master Plan, is arranged to consolidate eight separate plans and simplifies the contents with the provision of common conditions/assumptions, general approach and methodology in Chapter 2. Basic figures such as frame values and unit wastewater quantity and quality are projected in the water pollution control plan.

Part (III) presents a preliminary engineering design for Rang Sit area and Bang Bua Thong municipality which were selected among eight municipalities/areas.

PART 1

WATER POLLUTION CONTROL PLAN

PART I - WATER POLLUTION CONTROL PLAN

CHAPTER 1 INTRODUCTION

The comprehensive basin-wide water pollution control plan was prepared fully using the investigation results stemming from a series of 4 field works in Thailand carried out during Stages I and II. Secondary information, mostly from sectoral reports of the different agencies in Thailand were also utilized.

In coming up with the water pollution control plan, the following main components were covered:

(1) Establishment of fundamentals for water pollution analysis and sewerage master planning;

(2) Present water pollution analysis;

(3) Future water pollution analysis;

(4) Pollution load to be reduced by pollution source; and

(5) Recommendations on the reduction of pollution load.

CHAPTER 2 ADMINISTRATIVE COMPOSITION AND NATURAL CONDITIONS

2.1 Administrative Composition

The study area is located in the lower Chao Phraya river basin. It essentially covers five (5) provinces in the Upper Central Region (UCR) and two (2) provinces in the Bangkok Metropolitan and Vicinity Region (BMR). The provinces are Chai Nat, Sing Buri, Ang Thong, Lop Buri and Ayutthaya in the UCR and Pathum Thani and Nonthaburi in the BMR. Figure 2.1 shows the location of the study area by province.

Local autonomous administration units within the study area, consist of 14 municipalities and 66 sanitary districts (SDs). The study area can also be subdivided into 57 districts or amphoes comprising of 587 tambons. Total population of the study area was placed at 3,350,000 in 1990, about 38% of which resided within municipalities and SDs. Table 2.1 presents a summary of the population, land area, and the number of administrative units in the study area as of 1990.

2.2 Topography, Geology, and Meteorology

Chao Phraya river basin occupies an area of 162,600sqm, which is about one-third of the country's total area. The basin can be divided into 3: the upper basin of the northern highland, the middle basin in the middle flood plain, and the lower basin of the Chao Phraya delta. The upper part of the study area has an average ground elevation of about 16 meters above mean sea water level (amsl) gradually sloping down toward Ayutthaya to a level of 2amsl, and almost flat as it reaches the southern portion of Ayutthaya to Nanthaburi.

Active and former tidal flats of marine and brackish water deposits are found extensively in the southern coastal plain, along the coastline and the immediate area of Bangkok. Soil in this area is poorly drained and of gray colored hydromorphic alluvial soils with very fine clayey tropaquepts. Former tidal flats of older brackish deposits are found in the areas of textured hydromorphic alluvial soil. This area is usually flooded during

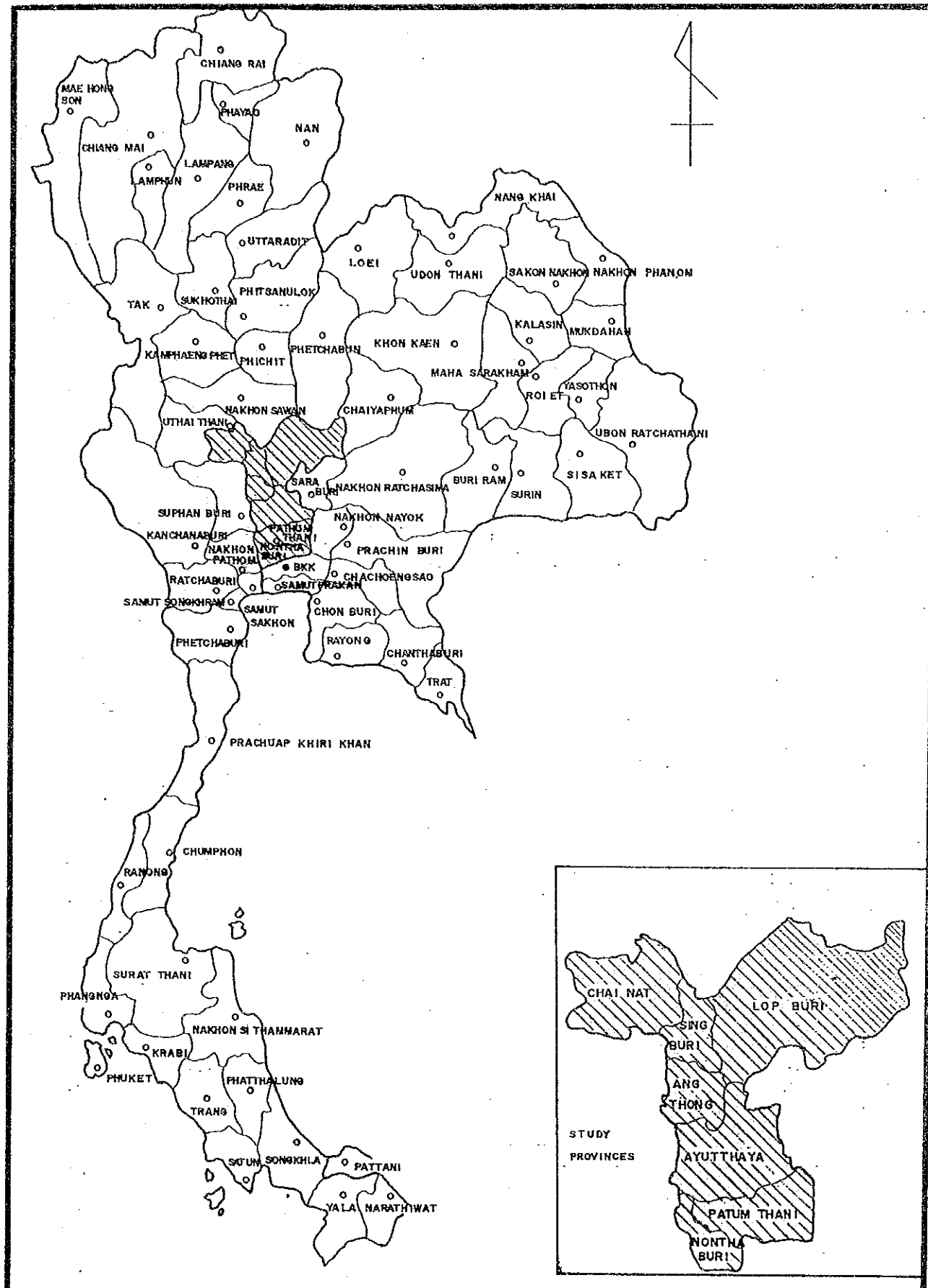


FIG. 2.1 LOCATION OF SUBJECT PROVINCES

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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Table 2.1 Present Population, Land Area and Administrative Units in the Study Area

PROVINCE			AMPHOE			MUNICIPALITY			SANITARY DISTRICT			OTHERS			
												Number			
Name	Area (sqm)	Popu-lation	Number	Area (sqm)	Popu-lation	Number	Area (sqm)	Popu-lation	Number	Area (sqm)	Popu-lation	(Tam)	(Tes)	Area (sqm)	Popu-lation
Chai Nat	2,469.70	355,155	6	2,469.75	355,151	2	8.06	18,705	6	9.53	17,297	50	425	2,452.15	319,149
Sing Buri	822.50	229,816	6	822.48	229,816	1	7.81	22,570	6	69.4	48,427	43	354	745.27	158,819
Lop Buri	6,199.00	704,432	10	6,199.75	704,432	3	9.03	44,401	10	66.5	80,915	110	969	6,124.23	579,116
Ang Thong	968.40	278,168	7	968.37	278,168	2	15.73	20,293	7	116.3	54,632	73	501	836.34	203,243
Ayutthaya	2,556.64	681,920	16	2,556.64	681,920	3	18.20	78,553	21	167.47	151,387	208	1,456	2,370.97	451,980
Pathum Thani	1,525.90	451,152	7	1,525.86	451,152	1	7.10	12,002	11	271.67	195,187	60	529	1,233.30	243,963
Nonthaburi	622.30	652,462	6	622.30	652,462	2	40.50	248,661	7	57.28	177,957	52	369	524.52	225,844

heavy rains. Flood plains of recent river alluvium are found along the river from Ayutthaya to Phitsanulok and Kamphean Ohet. Soil is moderately well-drained with loamy alluvial soil in the higher portion, while in the lower portion, soil is poorly drained with clayey hydromorphic alluvial soils. Low alluvial terraces of semi-recent and old alluvium are found in both sides of the flood plains. Soil on the lower portion is poorly drained with fine loamy to clayey textured low humic gray soils while in the higher portion, the soil is better drained with fine loamy and non-calcic brown soils.

The groundwater sources north of Sing Buri consist of both terrace and recent alluvium aquifers. Phreatic aquifers near the surface yield good water quality for irrigation use. The lower portion of the study area has a number of layers of terrace and recent alluvium aquifers with depths of about 650m.

Over-exploitation of this resource has already been observed in some areas especially the Bangkok Metropolitan area resulting to lowering of groundwater table which in turn causes land subsidence and salt water intrusion problems.

2.3 Meteorology and Physical Characteristics of the Chao Phraya River Basin

The Chao Phraya river basin is located in a typical monsoon region. About 85% of annual precipitation of 1,200mm is caused by the southwest monsoon from May to September. The northwest monsoon brings little rainfall from October to April. In general, there are 3 seasons: summer, from February to May; rainy, from may to October; and winter, from November to mid-February.

The river has a total length of about 380km and covers about 163,000sqkm drainage basin with an annual discharge of 30,000 million m^3 and a flow rate of more than 1,000 m^3/second. The upper basin covers majority of the northern region where it is mountainous and hilly with wide sloping valleys running along the basin. In the central valley, the upper plain located north of Chai Nat is formed by the lower river valley of the Ping, Yom and Nan rivers. The delta area is completely inundated during flooding period and during other times of the year, rice farming is very suitable.

In the downstream area from Chai Nat, the main river branches into several tributaries; Noi, Lop Buri and Pasak rivers. The river flows as a single channel from Ayutthaya southwards until it finally discharges into the Gulf of Thailand. The lower portion of up to 160km from the river mouth is tide-affected from the ocean. The total area of the lower Chao Phraya river basin for this study is 6,037.4 km^2. Figure 2.2 shows the area coverage of the study basin.

2.4 Inundation and Flood Control

Major flood damages along the rivers are caused by overflow of the rivers during rainy season and torrential rainfall. Flooding usually occurs in the lower and upper basins from Nakhon Sawan. Floods have affected a total area of 33,000ha in the upper basin from Nakhon Sawan, while in the lower basin, flooding has been extended to about 171,000ha. Tidal effects are also causes of flooding in the lower part of the basin.

Hydraulic structures in the Chao Phraya river are categorized into four types including dam/reservoir, diversion weir/barrage, regulator/gate and dike. River flow is controlled for flood prevention during rainy season and for irrigation use, saltwater intrusion control and navigation purposes during dry season.

There are 2 major dams in the upper basin, the Bhumibol Dam and the Sirikit Dam. For the lower basin, the major dams/weirs/barrage are the Chao Phraya Dam/Barrage and the Rama VI Dam/Barrage. Several major regulators and gates are found along Chao Phraya river and its tributaries for manual control of water discharge for irrigation and navigation purposes. Flood protection dikes are also found mostly along the Chao Phraya river and the lower portion of Pasak river to prevent damage in the surrounding agricultural areas.

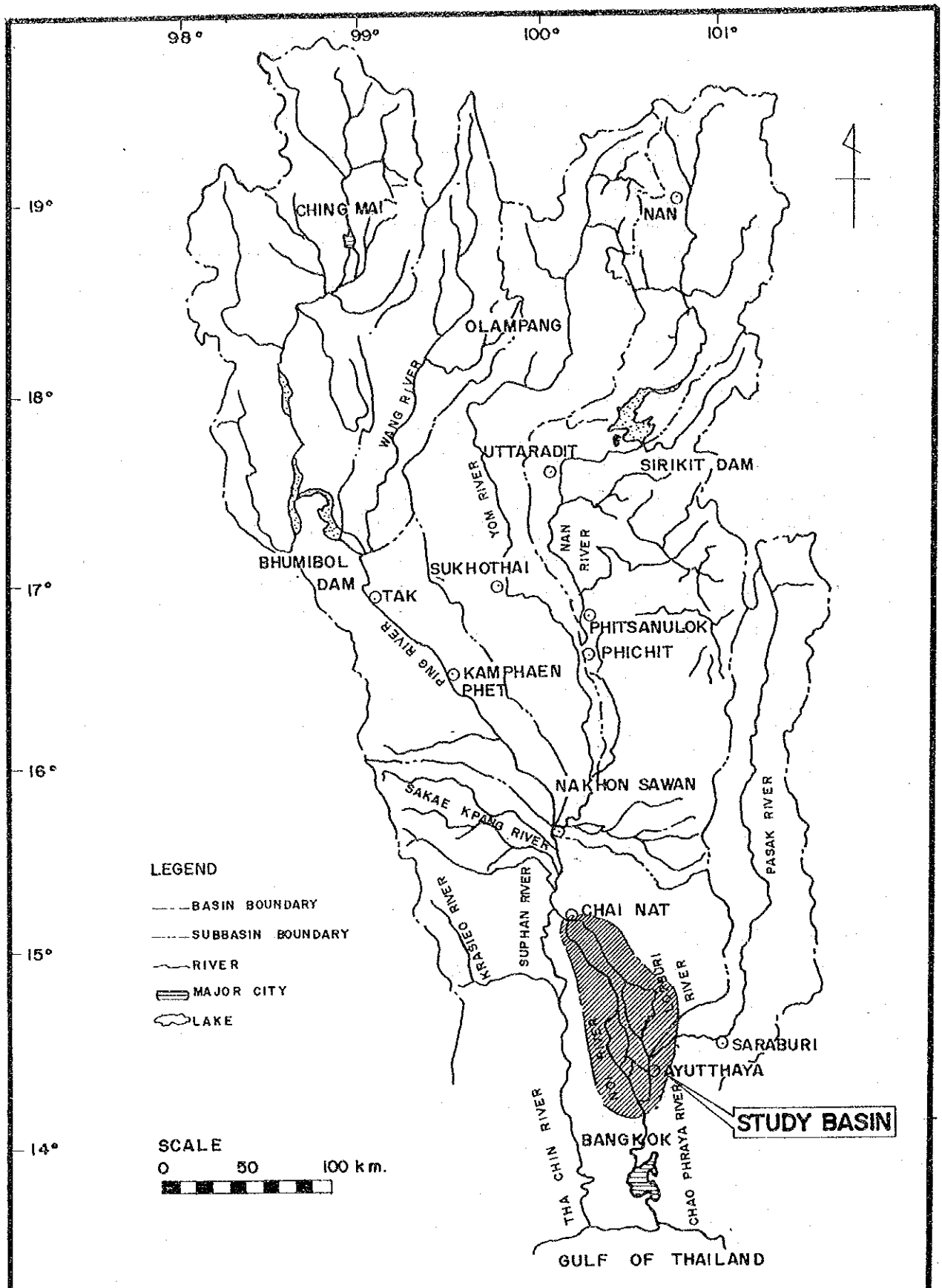

FIG. 2.2 CHAO PHRAYA RIVER BASIN

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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CHAPTER 3 LAWS AND REGULATIONS RELEVANT TO WATER POLLUTION CONTROL AND WATER POLLUTION STATUS

3.1 General

It has been acknowledged that economic progress has caused the deterioration of the environment. Industrialization and transformation of rural societies to urban communities have led to more serious pollution problems. In recognition of these problems, the Government has established organizations or agencies to take the responsibilities of water pollution control and environmental management in Thailand. Inter-agency coordination among the different agencies involved for the above-mentioned responsibilities is being undertaken. Specifically, the central government agencies involved in water environment management are: 1) National Economic and Social Development Board (NESDB); 2) Department of Industrial Works (DIW); 3) Department of Health (DOH); 4) Public Works Department (PWD); 5) Ministry of Science, Technology and Environment under which are the Office of Environmental Policy and Planning (OEPP), Pollution Control Division (PCD), and Environmental Promotion Department (EPD); 6) Royal irrigation Department; and 7) Local Administration.

3.2 Present Policies and Countermeasures for Water Pollution Control

Numerous policies and countermeasures were formulated for environmental management purposes including water pollution control, as aptly embodied in the 7th National Economic and Social Development Plan. More specific policies and countermeasures are formulated by bodies like the special committee for the formulation of policies and countermeasures to control water, air and noise pollution in Thailand.

Guidelines/policies pertinent to water pollution as formulated in the 7th Plan are: 1) reduction of water pollution load generated by communities, and industrial and agricultural activities; 2) enforcement of control measures and prevention of additional effluent discharges to public water bodies; and 3)investment in wastewater treatment systems.

The special committee for the formulation of policies and countermeasures to control water, air and noise pollution in Thailand has drawn up the follow-

ing guidelines and policies: 1) strict enforcement of existing laws and regulations for the planning and management of pollution control systems, strict application of land use plans, and adequate control over project implementation; 2) set-up monitoring and inspection systems to evaluate environmental quality vis-a-vis the set standards; 3) reduction of pollution load through wastewater management planning and construction of appropriate wastewater treatment systems; 4) utilization of financial mechanisms to support government investments in pollution control and management, and promotion of private investments in the same aspect; and 5) promotion of public awareness and involvement in pollution control and management.

3.3 Environmental Water Quality Standards, and Relevant Laws and Regulations

Formulated policies and countermeasures are mainly implemented through the enforcement of several standards, laws and regulations. For example, standards have been set for industrial, domestic and building effluents and a law prohibiting waste dumping into public water courses.

Surface waters in Thailand have been classified as to their objectives, conditions and beneficial usages. A water classification criteria has been established to this effect.

Surface water quality standards as presented in Table 3.1 have been set according to water classification as reflected in Table 3.2. In relation to this, a Cabinet Resolution had been passed defining a restricted zone for protecting the source of the Bangkok Metropolitan Region Water Supply. This regulation specifically requires that within the restricted zone, building and expansion of factories which discharged wastewater containing toxic substances or organic matter exceeding 1kg of BOD per day will not be permitted. Figure 3.1 indicates the Chao Phraya river water quality classification.

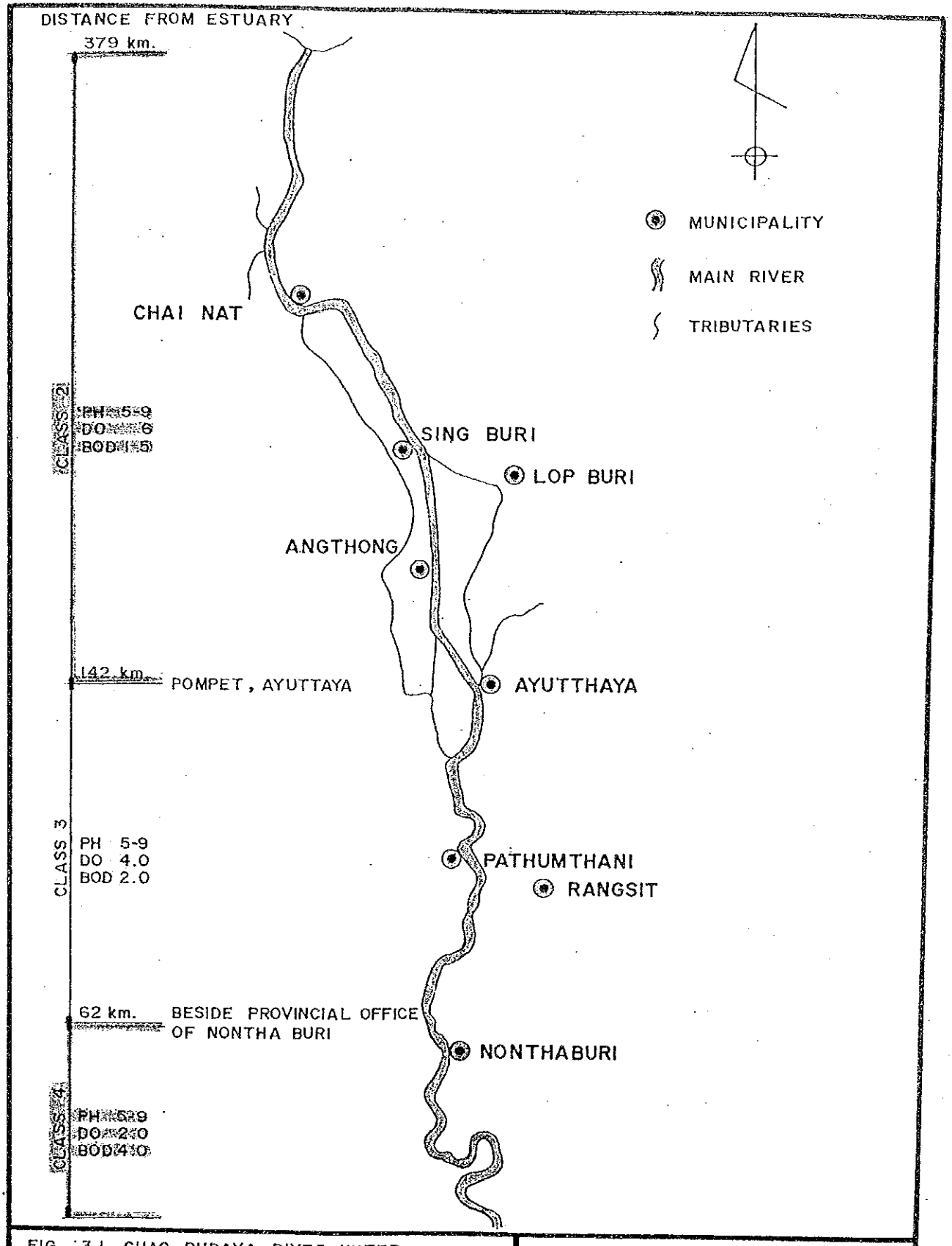

FIG. 3.1 CHAO PHRAYA RIVER WATER CLASSIFICATION

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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Table 3.1 Water Classification Criteria

Classification	Objectives, Conditions and Beneficial Usages
Class 1	Extra clean fresh surface water resources used for: (1) consumption (not necessary to pass through water treatment processes, require only ordinary process for pathogenic destruction) (2) ecosystem conservation, where basic living organisms can breed naturally
Class 2	Very clean fresh surface water resources used for: (1) consumption (require ordinary water treatment process before use) (2) aquatic organism conservation (3) fishery (4) recreation
Class 3	Medium clean fresh surface water resources used for: (1) consumption (need to pass through an ordinary treatment process before use) (2) agriculture
Class 4	Fairly clean fresh surface water resources used for: (1) consumption (require special water treatment process before use) (2) industry (3) other activities
Class 5	The resources which are not classified in Class 11-4 and used for: (1) navigation

Source: Notification of the Ministry of Science, Technology and Energy (B.E 2528 (1985)), published in the Royal Government Gazette, Vol. 103, Part 60, dated April 15, B.E 2529 (1986)

3.4 Water Pollution Status

Water pollution is being monitored mainly by the PCD, MWA, PWD and DOH. Water quality examination results at the lower reaches of the river conducted by the aforementioned agencies and through this field work show that water quality in terms of BOD and SS between Chai Nat and the confluence of the Chao Phraya and Noi rivers is still tolerable, but in the Nonthaburi area, it is already highly polluted. Figure 3.2 shows the present water pollution status of the Chao Phraya river.

In comparison with the classified standards by river section, it seems to be difficult to achieve the standards in the class 4 section (7 km from river mouth to 62 km upstream) under the present arrangements of sewerage facilities, and for class 2 (142 km from river mouth to 379 km upstream) and class 3 (62 km from river mouth to 142 km upstream) sections, water pollution countermeasures are urgently required.

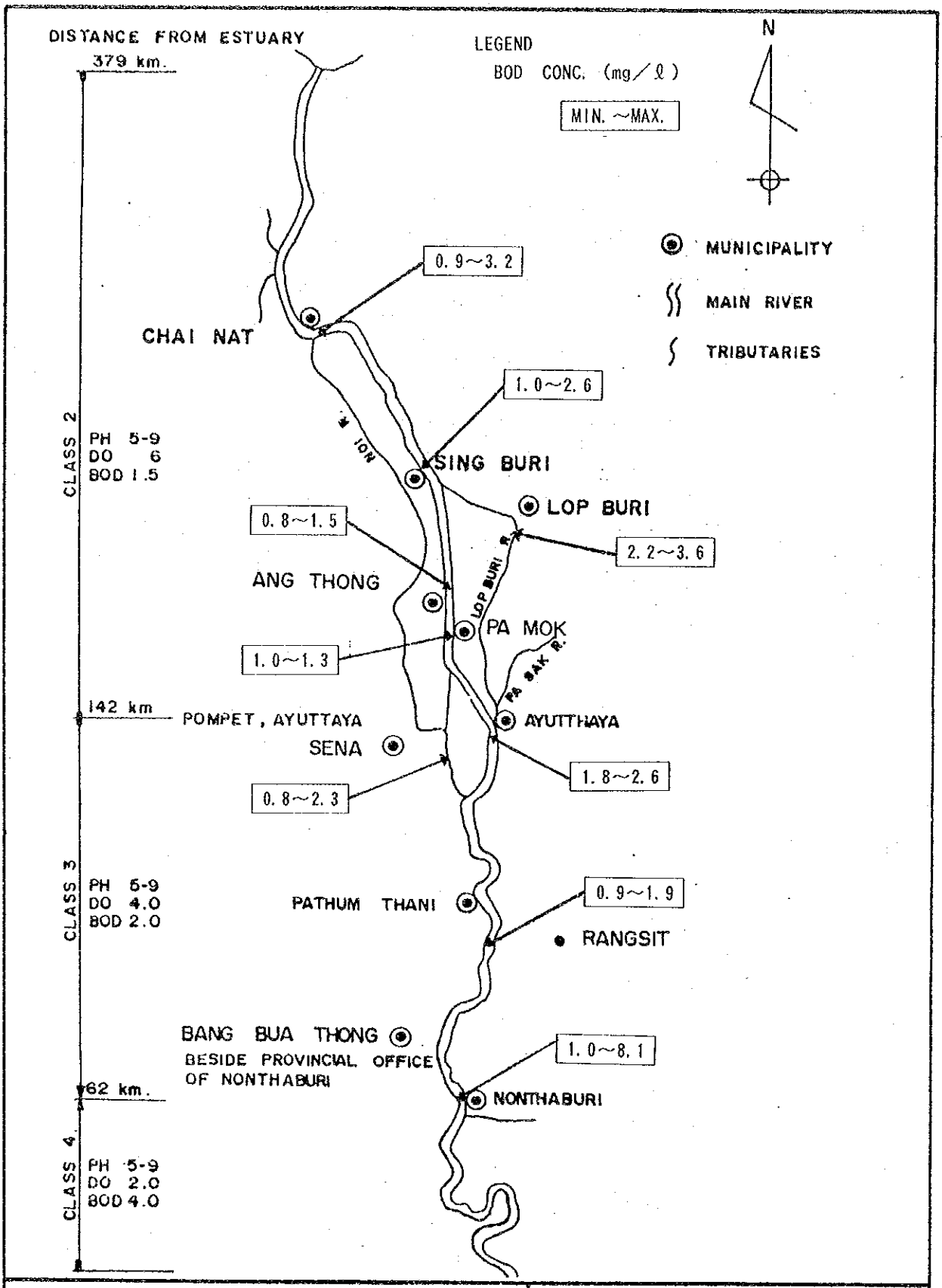

Figure 3.2 Present Water Pollution Status

STUDY ON MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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CHAPTER 4 SANITATION CONDITIONS AND SEWERAGE SYSTEMS AT PRESENT AND IN THE FUTURE

4.1 Sanitation Conditions

Present status of water supply and sanitation conditions, and recommendations for future improvements are presented in the "Thailand Country Profile on Drinking Water Supply and Sanitation" prepared in 1989.

About 74% of the population in 1988 were covered either by piped water supply or rainwater use. An assessment of population coverage with respect to both quantity and quality revealed that drinking water satisfaction level in quantity was 73%, while in quality (bacteriological index), it was 26%. Due attention should therefore be given to the improvement of drinking water quality in terms of reduction of bacteria levels.

Water-sealed type is a common latrine in use. In 1980, at the national level, 95% of the household in the urban areas was served by latrines, while in the rural areas, it was only 49%. In the study area, average served percentages of both latrine and safe water are 92 percent; and refuse disposal at 81 percent.

4.2 Existing Sewage Works in Thailand and On-going Pollution Control Plans in the Study Area

At present, the sewage works in Thailand is still under the initial stage of development. Six sub-projects in Bangkok are underway covering 155.3 km^2 for an aggregate service population of 1,955,000. The treatment method for three of the six sub-projects is the modified activated sludge treatment method. The treatment capacity of each six plants is between 30,000cum per day and 350,000cum per day for a total treatment needs of 776,000cum per day.

For local areas, PWD is responsible from planning to construction supervision of sewerage projects. Municipalities/local governments undertake the operation and maintenance of these systems.

There is a total of 34 sewerage systems in the local areas nationwide as presented in Figure 4.1. Of these, 13 systems were already constructed or under construction while 7 treatment plants are presently in operation. The remaining are still under planning or design stage. The capacity of the treatment plant in local area is small to medium size with a range of 2,200 to 32,000 m^3/day. Major treatment methods are RBC, OD and SP.

The areas covered by on-going sewerage plan/design in the study area are three (3) municipalities: Ayutthaya, Pathum Thani and Nonthaburi, and Rangsit area. Detailed design work for the industrial wastewater treatment plant in Rangsit area under the DIW was recently completed. Other projects are still under feasibility study stage (under PCD or PWD).

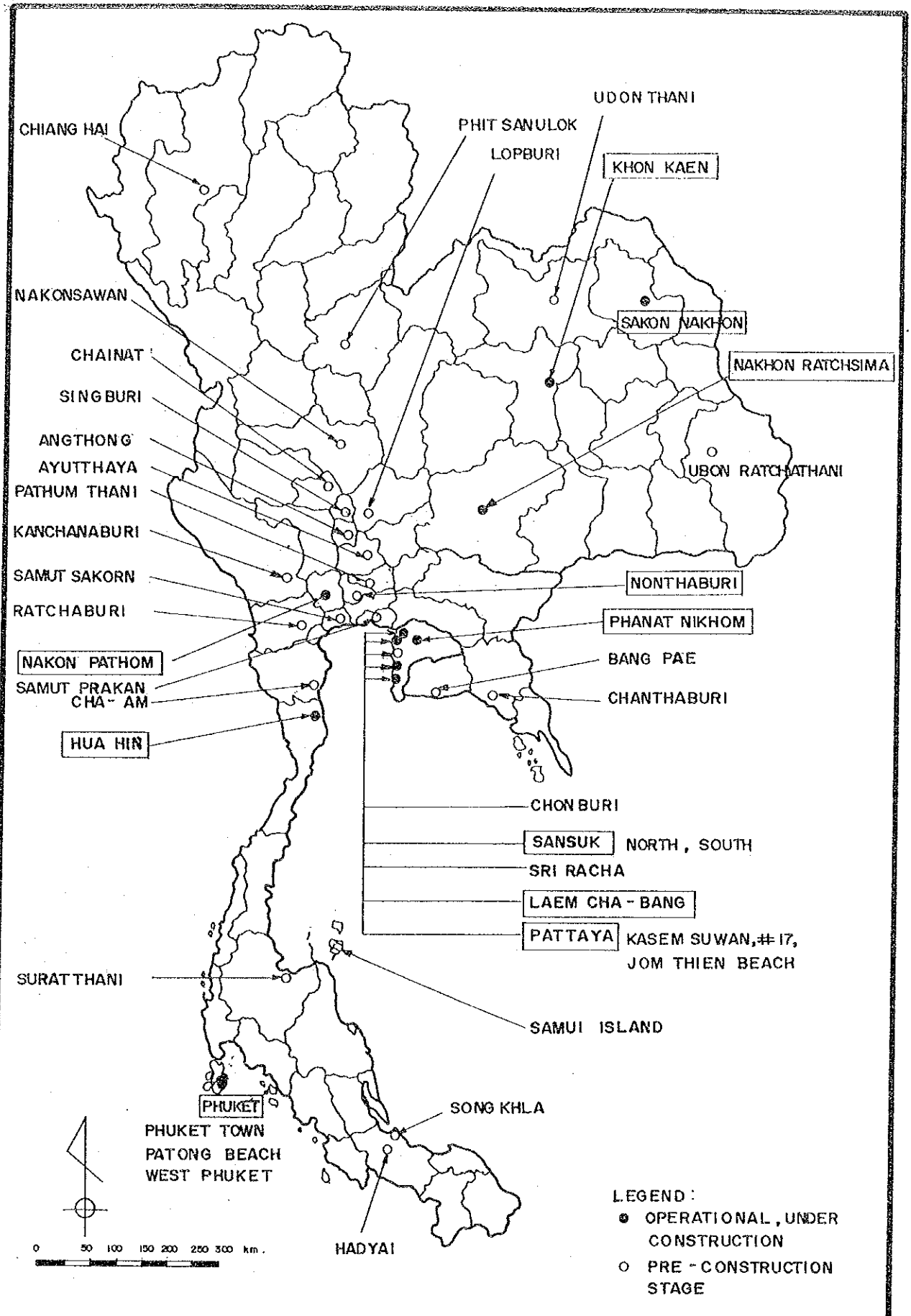

FIG. 4.1 SEWERAGE SYSTEM IN LOCAL AREA

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

CHAPTER 5 SOCIO-ECONOMIC PROFILE AND LAND USE AT PRESENT AND IN THE FUTURE

5.1 Socio-Economic Perspective

The Thai national economy has grown considerably during the past few years with the gross domestic product (GDP), increasing by an average of 10.5% during the 6th Plan Period (1987-1991). Particular sectors which have exhibited high growth rates are the export, investment and tourism sectors. International reserves reached nearly US$ 17 billion in 1991.

Through-out the rapid economic growth, there was a consistent shift from an agriculture-based economy to an industrial-based economy. Industrial GDP share to total GDP in 1991 was 26% against the agricultural sector share of 11.5%.

Despite the unprecedented economic success, income disparities among households of different socio-economic status and between rural and urban areas have increased. Income share of the top twenty percent of the income strata was 55% while that of the lowest twenty percent was a mere 4.5% share.

The main development objectives of the country are embodied in the 7th plan and are: 1) to maintain economic growth rates at appropriate levels to ensure sustainability and stability; (2) to redistribute income and decentralize development to the regions and rural areas more widely; and (3) to accelerate the development of human resources and upgrading of quality of life, the environment and natural resource management. Major economic and social development targets were set to attain these objectives.

The economic profile of the study area is characterized by a predominantly agricultural economy in the five provinces in the UCR and a high concentration of industry in Pathum Thani and Nonthaburi. The presence of vast lands with relatively good soil quality and abundant water resources makes the UCR rely on this sector of the economy. On the other hand, the industrial-based economy in the 2 areas is basically a peripheral part of the industrial zone of BMR.

The study area contributed around 7.4 percent of the gross domestic product (GDP) to the country's GDP. The 1989 average per capita GPP (gross provincial product) for the study area was 40,341 baht per capita, 26% higher than the national average of 32,028 baht/capita.

Rapid urbanization is taking place in the study area, especially in Nonthaburi and Pathum Thani, and in some areas of the UCR. Around 37% of the study area's population is within the boundaries of municipalities and sanitary districts.

5.2 Present and Future Land Use

At the country level, approximately 74% of the total land was used for agriculture (46%) and forestry (28%) as of 1988. In 1988, agricultural land share of 1,516,515ha to total land area of the seven provinces within the study area was a high 83%. Paddy fields occupied about 52% of the total land area.

It was noted that land for agricultural use as well as for residential and economic purposes has been increasing moderately, while orest land has decreased. Development of towns is expected to be accelerated in the future, especially in Pathum Thani and Nonthaburi provinces.

Table 5.1 indicates the land use plan for the subject municipalities/SDs for sewerage planning as per DTCP land use plans.

Table 5.1 Land Use Plan of the Subject Municipalities & Sanitary Districts

Area Unit: sqkm

Municipality	Present Pop. in Muni/SD (1990)	Present Area of Muni/SD	Future Expansion Area	Other Area	DTCP Area
Chai Nat	13.983	6.061	1.039	49.390	59.490
Sing Buri	22.570	7.810	2.890	20.626	31.326
Lop Buri	36.832	6.850	6.000	0.003	12.853
Ang Thong	9.607	3.750	1.450	18.775	23.975
Pa Mok	10.686	12.000	--	14.860	26.860
Sena	4.607	1.200	2.300	22.596	26.096
Rangsit	77.410	33.300	--	--	33.300
Bang Bua Thong	10.354	1.600	1.800	6.450	9.850
TOTAL	186.049	72.571	15.479	132.700	220.750

CHAPTER 6 POPULATION, INDUSTRY, AGRICULTURE AND FISHERY AT PRESENT AND IN THE FUTURE

6.1 Population Projection

Population projection covering subject seven provinces was made for the target years of 1996, 2001 and 2011. The base data were registered population investigated by the DOLA. The projected population will be used for preparation of water pollution control plan, while non-registered population was also considered for sewerage planning as practiced by the PWD.

Projection is made on provincial and amphoe levels, and for municipalities and sanitary districts under the two (2) categorized areas; the UCR and extended development area of Metropolitan Bangkok.

By group area, the recent projections made by the authorities in Thailand are basically used for this study. The projected figures are also examined based on collected data in 1970, 1980, 1985 and 1990 applying the average growth rate projection method, and confirmed the adaptability of the projections. The total population at present (1992 estimation) and in 2011 are 4,013,170 and 6,126,378 respectively.

Population in the study basin covering an area of 6,037.4 km^2 was estimated at 2,276,271 and 3,568,516 in 1992 and 2011, respectively. Table 6.1 indicates the area and projected population of the basin.

6.2 Industrial Development

Present industrial development and its features were analyzed, and previous studies were reviewed for a comprehensive approach and wide area/regional coverage. The study area is divided into two sub-areas, as mentioned in the population projection: the adjacent area of Bangkok (Pathum Thani, and Nonthaburi); and the UCR (Chai Nat, Sing Buri, Lop Buri, Ang Thong, Ayutthaya and Saraburi). In the UCR, major industries are mostly resource-based, while in Pathum Thani and Nonthaburi, apparel, textile and electrical machinery industries predominate.

Table 6.1 Area and Projected Population in the Basin

Provinces / Amphoes	Area (km2)			Population in 1992			Population in 1996			Population in 2001			Population in 2011		
	Total	Within Basin	Out of Basin	Total	Within Basin	Out of Basin	Total	Within Basin	Out of Basin	Total	Within Basin	Out of Basin	Total	Within Basin	Out of Basin
Chai Nat	2,460.7	624.3	1,845.4	359,998	151,628	208,370	370,691	154,689	215,411	397,556	159,934	237,622	416,009	166,847	249,162
** Muang Chai Nat	255.4	147.0	108.4	72,057	47,504	25,353	72,652	48,013	24,639	73,037	48,763	24,274	75,611	51,332	24,279
Manorom	225.6	0.0	225.6	35,913	0	35,913	36,044	0	36,044	38,639	0	38,639	40,402	0	40,402
Wat Sing	606.3	0.0	606.3	45,256	0	45,256	45,460	0	45,460	46,200	0	46,200	48,879	0	48,879
* Sankhaburi	354.8	249.0	105.8	69,500	50,488	19,044	71,255	51,775	19,480	74,248	53,951	20,297	77,085	56,079	20,986
* Sanphaya	228.3	228.3	0.0	53,548	53,548	0	54,892	54,892	0	57,220	57,220	0	59,436	59,436	0
Hankha	799.3	0.0	799.3	82,764	0	82,764	86,888	0	86,888	98,212	0	98,212	114,616	0	114,616
Sing Buri	822.5	822.5	0.0	234,635	234,635	0	244,689	244,689	0	260,869	260,869	0	290,239	290,239	0
** Muang Sing Buri	112.4	112.4	0.0	54,800	54,800	0	58,326	58,326	0	63,738	63,738	0	74,318	74,318	0
* Khai Bang Rachan	88.4	88.4	0.0	30,004	30,004	0	32,306	32,306	0	34,758	34,758	0	39,013	39,013	0
* Tha Chang	34.4	34.4	0.0	16,228	16,228	0	16,571	16,571	0	17,193	17,193	0	18,074	18,074	0
* Bang Rachan	190.5	190.5	0.0	40,110	40,110	0	42,460	42,460	0	46,067	46,067	0	53,013	53,013	0
* Prom Buri	82.5	82.5	0.0	25,657	25,657	0	25,130	25,130	0	24,752	24,752	0	23,445	23,445	0
* In Buri	314.3	314.3	0.0	66,936	66,936	0	69,796	69,796	0	74,341	74,341	0	82,316	82,316	0
Lop Buri	6,199.8	849.5	5,350.3	727,260	292,658	434,602	778,746	325,844	452,902	856,653	373,889	482,764	1,014,708	474,053	540,655
** Muang Lop Buri	585.6	426.8	158.8	267,209	215,307	51,902	302,165	241,980	60,185	352,978	280,723	72,255	451,681	363,651	90,030
Khok Samrong	982.5	17.5	965.0	75,827	1,013	74,814	66,256	800	65,456	56,003	572	55,521	38,535	148	38,387
Chai Badan	1,253.0	0.0	1,253.0	87,211	0	87,211	89,103	0	89,103	91,720	0	91,720	93,154	0	93,154
Tha Luang	538.9	0.0	538.9	25,500	0	25,500	29,415	0	29,415	35,239	0	35,239	48,475	0	48,475
* Tha Wung	242.8	242.8	0.0	52,627	52,627	0	56,664	56,664	0	62,777	62,777	0	73,337	73,337	0
Ban Mi	585.7	182.4	423.3	90,934	23,711	67,223	100,439	26,200	74,239	113,971	29,817	84,154	140,660	36,927	103,733
Pattana Nikorn	517.0	0.0	517.0	56,003	0	56,003	61,442	0	61,442	69,136	0	69,136	83,902	0	83,902
Sa Boat	304.7	0.0	304.7	24,802	0	24,802	25,092	0	25,092	25,668	0	25,668	25,745	0	25,745
Khok Charoen	317.1	0.0	317.1	23,995	0	23,995	24,303	0	24,303	24,912	0	24,912	25,018	0	25,018
Lam San Thi	447.0	0.0	447.0	23,202	0	23,202	23,587	0	23,587	24,129	0	24,129	24,201	0	24,201
Nang Muang	445.5	0.0	445.5	-	0	-	-	0	-	-	0	-	-	0	0
Ang Thong	968.4	888.2	80.2	280,307	262,613	17,694	284,702	266,821	17,881	293,709	275,292	18,408	305,950	287,019	18,931
** Muang Ang Thong	102.9	102.0	0.9	48,288	47,943	345	48,884	48,547	337	50,199	49,864	335	51,736	51,420	316
* Chaiyo	72.3	72.3	0.0	22,613	22,613	0	22,381	22,381	0	22,344	22,344	0	21,784	21,784	0
** Pa Mok	80.9	80.9	0.0	29,016	29,016	0	28,913	28,913	0	29,108	29,108	0	28,834	28,834	0
* Pho Thong	219.4	212.4	7.0	58,379	56,421	1,958	60,618	58,572	2,046	64,254	62,062	2,192	70,567	68,109	2,449
* Wiset Chai Chan	224.7	189.3	35.4	68,072	60,246	7,826	68,059	60,452	7,607	68,809	61,340	7,469	68,739	61,915	6,824
* Samko	86.9	50.0	36.9	17,815	10,250	7,565	18,563	10,692	7,891	19,810	11,398	8,412	22,003	12,660	9,343
* Sawaengha	181.3	181.3	0.0	36,124	36,124	0	37,264	37,264	0	39,176	39,176	-0	42,317	42,317	0
Ayutthaya	2,556.6	1,907.5	649.1	693,210	557,651	135,559	716,746	575,221	141,527	755,973	604,803	151,170	823,196	654,556	168,640
** Muang Ayutthaya	130.6	130.6	0.0	123,553	123,553	0	130,757	130,757	0	141,639	141,639	0	162,824	162,824	0
** Tha Rua	106.2	106.2	0.0	52,192	52,192	0	53,740	53,740	0	56,330	56,330	0	60,360	60,360	0
* Nakhon Luang	198.9	198.9	0.0	33,899	33,899	0	35,919	35,919	0	39,006	39,006	0	45,112	45,112	0
* Bang Sai	150.7	119.3	31.4	19,375	16,558	2,817	19,025	16,269	2,756	18,793	16,053	2,740	17,868	15,245	2,623
* Bang Sai	219.7	219.7	0.0	44,297	44,297	0	45,229	45,229	0	46,913	46,913	0	49,239	49,239	0
* Bang Ban	135.3	135.3	0.0	34,675	34,675	0	34,826	34,826	0	35,367	35,367	0	35,614	35,614	0
* Bang Pahan	121.9	121.9	0.0	37,077	37,077	0	37,948	37,948	0	39,479	39,479	0	41,684	41,684	0
* Bang Pa-In	229.1	189.1	40.0	64,908	55,888	9,020	68,829	59,475	9,354	74,849	64,898	9,951	86,352	75,547	10,805
* Ban Phraek	39.1	39.1	0.0	9,301	9,301	0	9,152	9,152	0	9,063	9,063	0	8,671	8,671	0
* Phak Hai	189.0	189.0	0.0	45,138	45,138	0	44,066	44,066	0	43,258	43,258	0	40,631	40,631	0
Phachi	104.5	0.0	104.5	29,691	0	29,691	30,190	0	30,190	31,152	0	31,152	32,360	0	32,360
* Maha Rat	120.1	120.1	0.0	23,614	23,614	0	24,103	24,103	0	24,992	24,992	0	26,206	26,206	0
Lat Bua Luang	199.9	136.9	63.0	33,302	21,742	11,560	34,694	22,723	11,971	36,878	24,293	12,585	40,674	27,029	13,645
Wang Noi	219.2	0.0	219.2	43,977	0	43,977	47,604	0	47,604	53,116	0	53,116	64,513	0	64,513
** Sena	205.6	198.9	6.7	60,499	59,257	1,242	61,677	60,494	1,183	63,650	62,716	1,134	66,757	65,811	946
Uthai	180.8	2.5	184.3	37,712	460	37,252	38,949	470	38,479	40,981	489	40,492	44,261	513	43,748
Pathum Thani	1,525.9	485.5	1,040.4	479,195	296,315	182,880	547,552	326,008	221,544	647,635	372,455	275,180	899,416	477,017	422,399
** Muang Pathum Thani	120.2	120.2	0.0	96,546	96,546	0	110,433	110,433	0	130,632	130,632	0	192,792	192,792	0
* Sam Khok	95.0	95.0	0.0	40,517	40,517	0	43,648	43,648	0	48,401	48,401	0	58,972	58,972	0
* Lat Lum Kaeo	188.1	188.1	0.0	36,664	36,664	0	39,752	39,752	0	43,981	43,981	0	53,836	53,836	0
* Thanyaburi	112.1	8.7	103.4	68,656	39,957	48,901	103,522	42,696	60,826	123,301	49,075	76,226	183,566	58,478	125,088
* Lam Luk Ka	297.7	6.0	291.7	69,749	26,308	63,441	105,365	27,922	77,443	128,760	31,170	97,590	192,287	36,326	155,961
* Khlong Luang	299.2	67.5	231.7	84,916	56,323	28,593	98,672	61,067	37,605	116,999	69,196	49,703	173,034	86,613	86,421
Nong Sua	413.6	0.0	413.6	41,915	0	41,915	45,960	0	45,960	51,571	0	51,571	84,929	0	84,929
Nonthaburi	622.3	273.6	348.7	715,310	449,979	265,331	861,108	553,429	307,739	1,089,195	714,281	374,914	1,757,952	1,192,834	565,128
** Muang Nonthaburi	77.0	42.3	34.7	318,579	202,595	115,984	393,748	252,632	141,116	513,121	329,631	183,490	871,414	559,451	311,963
Krue	57.4	0.0	57.4	81,652	0	81,652	93,353	0	93,353	110,364	0	110,364	154,252	0	154,252
Bang Yai	96.4	25.9	70.5	42,006	9,309	32,787	45,934	10,216	35,718	51,226	11,306	39,920	63,712	14,177	49,535
** Bang Bua Thong	116.4	116.4	0.0	68,406	68,406	0	79,203	79,203	0	95,127	95,127	0	137,225	137,225	0
* Pak Kret	89.0	89.0	0.0	169,669	169,669	0	211,376	211,376	0	278,217	278,217	0	481,981	481,981	0
Sai Noi	186.1	0.0	186.1	34,908	0	34,908	37,552	0	37,552	41,140	0	41,140	49,378	0	49,378
Total of 7 Provinces	15,165.2	5,851.1	9,314.1	3,489,915	2,245,479	1,244,436	3,803,696	2,446,692	1,357,004	4,291,581	2,761,523	1,530,058	5,517,480	3,542,575	1,974,905
Other															
Saraburi	3,576.6	186.3	3,390.3	523,255	30,792	492,463	537,024	29,724	507,300	579,249	29,564	549,695	608,898	25,941	582,957
Muang Saraburi	503.8	0.0	503.8	124,852	0	124,852	129,857	0	129,857	141,490	0	141,490	148,317	0	148,317
Kaeng Khoi	871.1	0.0	871.1	69,720	0	69,720	70,085	0	70,085	73,086	0	73,086	70,179	0	70,179
Don Phunt	65.6	65.6	0.0	5,541	5,541	0	5,005	5,005	0	4,573	4,573	0	3,370	3,370	0
Ban Mo	279.0	93.7	185.3	45,952	15,433	30,519	45,707	15,350	30,357	47,099	15,818	31,281	44,158	14,830	29,328
Phra Phutthabat	324.6	0.0	324.6	41,582	0	41,582	37,636	0	37,636	34,467	0	34,467	25,525	0	25,525
Muak Lek	752.5	0.0	752.5	73,194	0	73,194	85,750	0	85,750	108,419	0	108,419	153,035	0	153,035
Wihan Daeng	228.8	0.0	228.8	31,150	0	31,150	31,075	0	31,075	32,137	0	32,137	30,351	0	30,351
Seohai	125.1	0.0	125.1	24,180	0	24,180	23,174	0	23,174	22,797	0	22,797	19,478	0	19,478
Nong Khae	293.8	0.0	293.8	78,744	0	78,744	81,237	0	81,237	87,618	0	87,618	89,995	0	89,995
Nong Saeng	97.4	0.0	97.4	15,579	0	15,579	15,388	0	15,388	15,719	0	15,719	14,493	0	14,493
Nong Don	34.9	27.0	7.9	12,691	9,818	2,873	12,109	9,368	2,741	11,844	9,163	2,681	10,006	7,741	2,265
7 Prov + Sara Buri	18,741.8	6,037.4	12,704.4	4,013,170	2,275,271	1,736,899	4,340,720	2,476,416	1,864,304	4,870,830	2,791,077	2,079,753	6,126,378	3,568,516	2,557,862

Note: "*" refers to amphoes that have a municipality within the basin.
" **" refers to amphoes that have sanitary district/s within the basin.
"-" means data is not available

A comprehensive development study for the UCR, "The Upper Central Region Study" carried out by JICA for NESDB, was utilized for the projection of frame values (parameters) with reference to the unit pollution loading parameter. The gross regional product (GRP) is used as a basic factor for the projection of the frame value. The number of employees derived from the projected GRP was selected as the frame value in practice. Projection of number of employees by province and by industrial group (5 categories) was made for the target years as indicated in Tables 6.2 and 6.3.

6.3 Livestock and Fishery Development

The field work revealed that pollution load generated by livestock does not usually reach to channels in the dry season. However, wastes of livestock like swine have a possibility as a pollution source. Fresh fish cultivation pond, situated mainly in the southern part of the study area, is also one of the pollution sources as considered in the ONEB report. For fish pond, the utilized areas were investigated covering seven (7) provinces. Present fish pond area is assumed to be constant through the future (average depth of 1.5 m). Projection of these frame values was made to estimate the potential pollution load generated in the study area.

Tables 6.4 and 6.5 show the projection in number of buffaloes, cattle and swine employing a linear trend method using data during the last five (5) years; and area of fish pond by municipality and amphoe in 1990, respectively.

6.4 Slaughterhouse and Fresh Market

Slaughterhouse and fresh market were identified as major point sources of pollution. Projection of number of livestock slaughtered by province was made using data during the last four (4) years. It is assumed that the number of slaughterhouses and fresh markets is one each and one to two for each municipality/SD, respectively. Constant and uniform pollution load is assumed for a large-size market for each municipality due to limited information. Table 6.6 indicates the number of slaughtered livestock (past record and future projection).

Table 6.2 Projected No. of Employees by Province by Industrial Group

(1992)

Industrial Group	Whole UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	56,230	4,547	6,378	6,091	2,459	18,895	17,860
MIN/CEMENT/CERAM.	64,648	226	896	2,447	4,672	6,892	49,515
LIGHT PROCESSING	73,749	205	795	686	8,051	10,481	53,531
MACHINE/ELECT.	106,001	240	671	4,908	424	83,148	16,610
OTHERS	49,575	478	839	1,942	2,898	29,183	14,235
TOTAL	350,203	5,696	9,579	16,074	18,504	148,599	151,751

(1996)

Industrial Group	Whole UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	65,839	5,324	7,468	7,132	2,879	22,124	20,912
MIN/CEMENT/CERAM	54,777	192	759	2,073	3,959	5,840	41,954
LIGHT PROCESSING	87,885	244	947	817	9,594	12,490	63,793
MACHINE/ELECT.	137,872	312	873	6,384	551	108,148	21,604
OTHERS	55,288	533	936	2,165	3,232	32,546	15,876
TOTAL	401,661	6,605	10,983	18,571	20,215	181,148	164,139

(2001)

Industrial Group	Whole UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	79,382	6,419	9,004	8,599	3,472	26,675	25,213
MIN/CEMENT/CERAM	50,708	177	703	1,919	3,665	5,406	38,838
LIGHT PROCESSING	99,616	277	1,074	926	10,875	14,157	72,307
MACHINE/ELECT.	149,948	340	949	6,943	599	117,621	23,496
OTHERS	60,011	579	1,016	2,350	3,508	35,326	17,232
TOTAL	439,665	7,792	12,746	20,737	22,119	199,185	177,086

(2011)

Industrial Group	Whole UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	91,459	7,396	10,374	9,907	4,000	30,733	29,049
MIN/CEMENT/CERAM	49,462	173	685	1,872	3,575	5,273	37,884
LIGHT PROCESSING	107,021	298	1,153	995	11,684	15,209	77,682
MACHINE/ELECT.	150,187	340	951	6,954	600	117,808	23,534
OTHERS	61,690	595	1,044	2,416	3,606	36,315	17,714
TOTAL	459,819	8,802	14,207	22,144	23,465	205,338	185,863

Table 6.3 Projected No. of Employees in Pathum Thani and Nonthaburi

Industrial Group	Pathum Thani				Nonthaburi			
	1992	1996	2001	2011	1992	1996	2001	2011
FOOD PROCESSING	4,244	4,385	3,891	3,971	2,470	2,551	2,264	2,309
MIN./CEM./CERAMIC	10,485	10,795	9,565	9,703	4,230	4,369	3,876	3,954
LIGHT PROCESSING	69,751	72,065	63,944	65,255	40,595	41,929	37,199	37,941
MACHINE/ELEC.	86,517	89,389	79,314	80,940	50,353	52,008	46,140	47,061
OTHERS	21,201	21,905	19,436	19,835	12,339	12,745	11,307	11,532
TOTAL	192,198	198,539	176,150	179,704	109,987	113,602	100,786	102,797

Table 6.4 Number of Livestock (past record and future projection)

Province	Livestock	Past Record 1986	1987	1988	1989	1990	Projection 1992	1996	2001	2011
Chai Nat	Buffaloes	22,408	20,581	19,948	20,887	23,052	22,000	22,700	23,400	25,000
	Cattle	50,171	50,979	51,378	54,278	51,136	53,700	55,800	58,400	63,600
	Swine	38,361	38,970	36,573	33,830	39,573	36,400	35,300	33,900	31,200
Sing Buri	Buffaloes	6,924	4,987	4,713	4,454	3,075	2,500	1,900	1,600	1,300
	Cattle	17,026	17,340	21,251	27,758	26,934	32,600	42,700	51,100	61,400
	Swine	40,483	32,252	26,675	31,337	28,237	22,900	17,100	14,300	12,000
Lop Buri	Buffaloes	40,292	25,612	24,202	22,212	19,910	16,100	12,100	10,100	8,400
	Cattle	156,899	159,797	164,750	172,157	166,569	176,700	189,400	205,200	236,900
	Swine	82,019	84,215	97,123	87,726	77,672	83,700	81,600	79,000	73,800
Ang Thong	Buffaloes	12,381	9,170	7,442	5,924	7,547	6,100	4,600	3,800	3,200
	Cattle	32,689	33,293	32,639	33,651	36,057	36,500	39,300	42,900	50,000
	Swine	28,878	29,143	28,132	36,432	40,903	45,200	57,800	73,400	93,200
Ayutthaya	Buffaloes	31,882	34,277	29,043	26,997	27,872	23,900	17,800	14,100	11,800
	Cattle	33,008	33,618	34,265	35,527	33,249	34,900	35,800	37,000	39,400
	Swine	25,827	25,980	25,612	40,273	43,362	52,000	68,800	82,300	98,800
Pathum Thani	Buffaloes	4,207	5,086	4,806	5,846	6,923	7,900	10,300	13,400	15,800
	Cattle	4,528	4,612	4,701	7,117	9,178	10,700	14,600	17,400	20,900
	Swine	3,195	13,316	34,435	39,949	37,395	45,200	59,300	71,000	85,200
Nonthaburi	Buffaloes	1,012	1,175	1,442	1,318	1,383	1,600	2,000	2,400	3,200
	Cattle	3,156	3,334	3,322	3,313	3,340	3,400	3,600	3,700	4,100
	Swine	1,897	1,989	3,770	2,831	3,751	4,500	6,000	7,100	8,500
Saraburi	Buffaloes	41,737	33,890	27,485	24,432	20,920	16,900	12,700	10,600	8,900
	Cattle	63,398	64,569	66,389	68,260	60,075	63,400	62,200	60,700	57,700
	Swine	53,558	54,719	98,225	88,759	87,322	105,700	138,600	165,800	199,000
TOTAL	Buffaloes	160,843	134,778	119,081	112,070	110,682	97,000	84,100	79,400	77,600
	Cattle	360,875	367,542	378,695	402,061	386,538	411,900	443,400	476,400	534,000
	Swine	274,218	280,584	350,545	361,137	358,215	395,600	464,500	526,800	601,700

Source: Office of Agricultural Economics and Department of Livestock Development, Ministry of Agriculture and Cooperatives (MOAC)
JICA Study Team (projection)

Table 6.5 Area of Fish Pond by Municipality and Amphoe in 1990

Province / Amphoe	Area (m^2)
Chai Nat	
Muang Chai Nat	276,237
Manorom	136,588
Wat Sing	138,400
Sankhaburi	383,200
Sanphaya	165,236
Han Kha	231,785
Total	1,331,446
Ratio to G. Total	6.4%
Sing Buri	
Muang Sing Buri	90,776
Khai Bang Rachan	90,730
Tha Chang	32,452
Bang Rachan	109,148
Phrom Buri	75,613
In Buri	62,155
Total	460,874
Ratio to G. Total	2.2%
Lop Buri	
Muang Lop Buri	263,113
Khok Samrong	131,055
Chai Badan	37,360
Tha Wung	79,015
Ban Mi	279,477
Phatthana Nikhom	412,975
Sa Boat	1,600
Total	1,204,595
Ratio to G. Total	5.8%
Ang Thong	
Muang Ang Thong	124,986
Chaiyo	15,804
Pa Mok	75,745
Pho Thong	173,318
Wiset Chai Chan	277,756
Samko	2,800
Sawaengha	25,010
Total	695,419
Ratio to G. Total	3.3%

Province / Amphoe	Area (m^2)
Ayutthaya	
Muang Ayutthaya	37,200
Tha Rua	14,100
Nakhon Luang	56,050
Bang Sai	1,886,350
Bang Shai	481,900
Bang Ban	46,209
Bang Pahan	135,931
Bang Pa-in	146,676
Ban Phraek	33,148
Phak Hai	1,580,472
Phachi	43,370
Maha Rat	307,044
Lat Bua Luang	633,520
Wang Noi	4,700
Sena	2,689,554
Uthai	22,400
Total	8,118,624
Ratio to G. Total	38.9%
Pathum Thani	
Muang Pathum Thani	470,150
Sam Khok	740,590
Lat Lum Kaeo	1,864,051
Thanyaburi	545,914
Lam Luk Ka	1,456,540
Klong Laung	1,534,756
Nong Sua	440,760
Total	7,052,761
Ratio to G. Total	33.8%
Nonthaburi	
Muang Nonthburi	653,600
Kruai	150,670
Bang Yai	133,140
Ban Bua Thong	589,764
Pak Kret	94,000
Sai Noi	378,140
Total	1,999,314
Ratio to G. Total	9.6%
Grand Total	20,863,033

Source: Department of Fisheries, MOAC

Table 6.6 Number of Slaughtered Livestock
(past record and future projection)

Province	Livestock	Past Record 1986	1987	1988	1989	Projection 1992	1996	2001	2011
Chai Nat	Buffaloes	892	1,811	1,943	1,689	1,570	1,330	1,020	690
	Cattle	2,337	1,179	944	692	500	390	330	280
	Swine	16,062	14,937	15,674	16,866	17,300	18,560	20,140	23,280
Sing Buri	Buffaloes	255	252	122	120	90	70	60	50
	Cattle	2,249	1,857	1,019	695	510	390	330	280
	Swine	17,478	14,528	10,634	9,071	6,610	5,060	4,320	3,700
Lop Buri	Buffaloes	401	298	276	275	240	190	130	110
	Cattle	8,226	8,017	8,094	7,493	7,000	6,150	5,090	3,050
	Swine	23,899	24,408	26,190	24,447	26,280	27,650	29,360	32,790
Ang Thong	Buffaloes	1,286	1,188	1,463	1,115	1,160	1,060	940	700
	Cattle	3,933	3,422	2,909	1,971	1,440	1,100	940	800
	Swine	17,741	22,474	23,879	20,675	25,790	29,870	34,970	45,180
Ayutthaya	Buffaloes	3,680	4,031	4,000	5,314	6,450	8,400	10,690	12,590
	Cattle	4,998	5,558	4,871	6,947	7,920	9,980	12,560	16,460
	Swine	43,307	44,196	43,321	47,525	49,890	54,600	60,490	72,270
Pathum Thani	Buffaloes	33,802	35,306	33,905	31,233	29,460	25,820	21,270	12,720
	Cattle	28,228	26,113	25,345	25,743	22,660	19,370	15,260	10,490
	Swine	64,733	72,790	64,418	79,391	86,350	100,590	118,400	154,000
Nonthaburi	Buffaloes	11,580	11,559	9,404	8,607	6,270	4,800	4,100	3,510
	Cattle	8,585	8,357	7,531	7,294	5,830	4,070	3,470	2,970
	Swine	33,494	35,645	37,719	37,390	42,250	47,760	54,640	68,400
Saraburi	Buffaloes	1,474	1,706	1,878	1,576	1,870	2,060	2,300	2,780
	Cattle	4,761	4,466	4,460	4,348	3,950	3,450	2,830	1,770
	Swine	40,004	42,150	46,464	45,286	52,550	60,610	70,690	90,850
TOTAL	Buffaloes	53,370	56,151	52,991	49,929	47,110	43,730	40,510	33,150
	Cattle	63,317	58,969	55,173	55,183	49,810	44,900	40,810	36,100
	Swine	256,718	271,128	268,299	280,651	307,020	344,700	393,010	490,470

Source: Office of Agriculture Economics, MOAC
JICA Study Team (Projection)

CHAPTER 7 WATER USE AND HYDROLOGICAL CONDITIONS OF RIVERS THROUGH THE FUTURE

7.1 Water Use in the Chao Phraya River

Major water uses in the Chao Phraya river basin are for domestic and industrial water supplies, and irrigation and fishery.

The MWA uses water for Bangkok water supply with an amount of 1.25 million m^3/day of the total use of 2.65 million cum/day for domestic and industrial purposes. Raw water intake facilities with a pump station are located in Tambon Samlae, Pathum Thani. Other domestic and industrial users are concentrated on the lower part of the basin from Pathum Thani to Samut Prakarn provinces. The estimated total consumption of these users is 2.65 million cum per day.

There are several intake gates/pump stations, mainly located between Ang Thong and the upper part of Bangkok Metropolis along the Chao Phraya river. About 1,100 million cum per month is utilized for farmlands in the whole basin during the wet season. For the lower part from Chai Nat to Nontha-buri, an estimated 200 million m^3/month is used for paddy fields. During dry season, water is also used for agricultural production. The estimated amount of water is 700 million cum per month for the whole basin and 120-130 million cum per month in the lower part. The RID is in-charge of water management for irrigation. Efforts have been exerted by this agency to ensure the availability of the required water for irrigation use throughout the year for both irrigated and non-irrigated areas. Provision of irrigation canal networks, intake gates, and pumping stations was undertaken. Figure 7.1 shows the location of these facilities and the flow pattern in the study area.

7.2 Hydrological Conditions of the Rivers

Rainfall observation is conducted by the RID and other relevant agencies. Monthly maximum rainfall in the whole basin occurs in September with a range of 200 to 300 mm and a minimum rainfall from December to February, with a range of 0 to 20mm. Maximum rainfall in the lower reaches, from the river

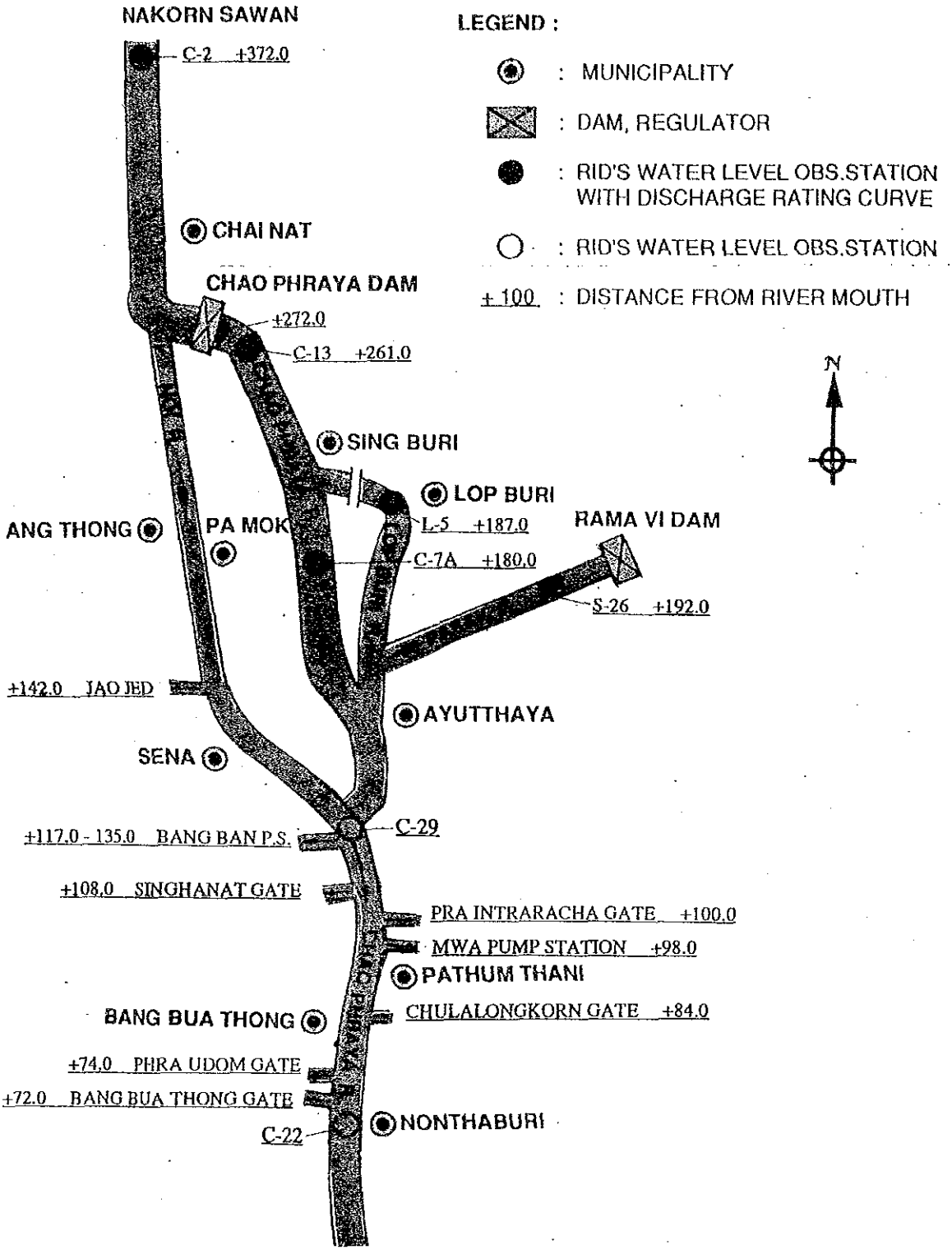

FIG. 7.1. FLOW PATTERN IN THE STUDY AREA

STUDY ON MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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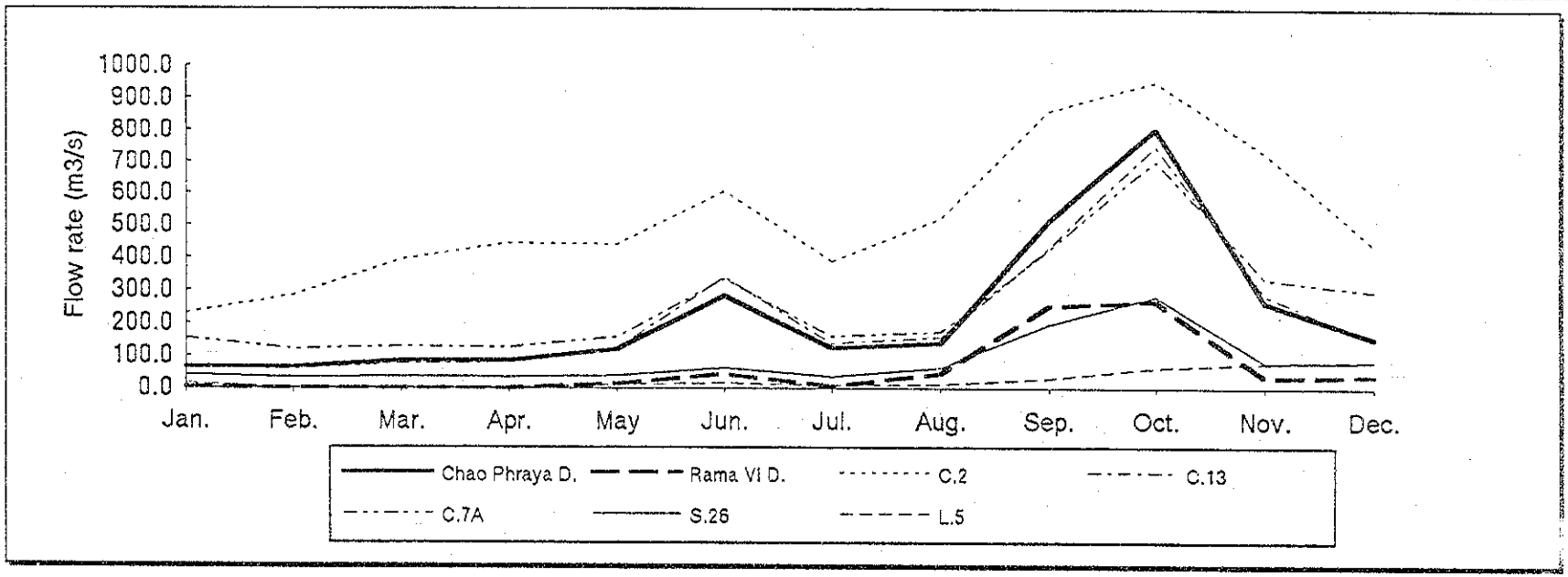
mouth to Ayutthaya, is higher than that in the upper reaches, which is affected by the monsoon from the Gulf.

Flow pattern of the Chao Phraya river was studied using the data from RID as shown in Table 7.1. Flow rates at the stations upstream of Ayutthaya are calculated by a rating curve. However, in the downstream section of the river, from Bang Shai to the Gulf which is affected by tidal action, only water level is useful. The AIT formulated harmonic flow model, which is generally applicable in tidal affected section of the river.

The run-off model during flood period is complicated, but during dry season it is much simpler because of flow controls at dams, regulators and gates. Under the limited number of discharge rating stations flow rates at strategic points of the river with water level by return period was investigated.

TABLE 7.1 FLOW RATE IN CHAO PHRAYA RIVER AND ITS TRIBUTARIES OBSERVED BY RID
(Averaged between 1988-1992)

Station	Dist (km)	Average flow rate (m3/s) Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
C.2, A.Muang, Nakorn Sawan	372.0	230.7	284.9	392.5	442.5	438.5	605.2	386.2	519.0	860.4	951.2	727.8	436.8
C.7A, A.Muang, Ang Thong	180.0	152.5	119.9	128.6	125.5	157.2	334.7	159.4	173.5	422.0	700.9	334.5	297.4
C.13, A.Sanphaya,Chai Nat	261.0	60.6	58.5	75.9	78.0	123.5	340.2	137.5	155.8	428.0	747.9	286.3	147.3
S.26, A.Tha Rua,Ayutthaya	192.0	40.2	33.0	34.8	34.6	38.6	63.0	34.8	63.1	196.4	282.6	78.9	81.3
L.5, A.Ban Phreak,Ayutthaya	187.0	14.6	0.9	0.9	2.7	11.6	16.0	8.5	11.4	29.0	62.4	77.6	82.5
Chao Phraya Dam, Chai Nat	272.0	63.4	64.2	84.0	84.0	118.4	283.6	123.2	137.2	510.4	803.2	263.2	153.2
Rama VI Dam, Ayutthaya	-	0.6	0.0	0.0	0.0	11.8	42.4	4.7	43.8	251.4	267.0	32.6	37.6



CHAPTER 8 UNIT WASTEWATER QUANTITY AND QUALITY

8.1 Domestic Wastewater

Unit wastewater quantity and quality of respective pollution sources are studied both for water pollution analysis and sewerage planning.

Wastewater quantity is estimated, in principle, using the data on water consumption or discharged wastewater amount on a measurement basis. For water quality, BOD loading is used as a representative index of the organic substances. The unit figures are derived from investigation results conducted by concerned agencies in Thailand, referring to the experiences in Japan and other countries.

Domestic water is defined in this study to include basic domestic water (residential water), and business water (institutional, small-size industrial, and commercial and others).

Regarding per capita water consumption, classification of municipalities/SDs was made, and future projection by class was conducted based on the present consumption rate and existing projections of similar municipalities/SDs. Table 8.1 shows the projected water consumption rate by category.

Reference information/reports on per capita BOD loading were reviewed. For this study, a total of 53gpcd (generated base) is recommended as a present figure, broken down into: nightsoil, 11gpcd; and sullage, 41gpcd. For future projection, an annual increase of 0.1gpcd is employed for sullage, while nightsoil load of 11gpcd is assumed to be constant.

Aside from generated BOD load, unit discharged BOD load is calculated by administrative unit with the removal ratio of 50 percent at the septic tank for nightsoil. Tables 8.2 and 8.3 show unit BOD load on generated and discharged domestic wastewaters.

8.2 Industrial Wastewater

Present unit quantity of industrial wastewater per employee by industrial type was derived from the data of about 300 factories in Pathum Thani.

Table 8.1 Water Consumption Rate by Category

Category	Province	Municipality / S. D.	Consumption Rate (lcpd)											
			1991	1992			1996			2001			2011		
				dome.	busi.	Total	dome.	busi.	Total	dome.	busi.	Total	dome.	busi.	Total
Manicipality	Chai Nat	Muang Chai Nat	179	131	53	184	146	58	204	164	65	229	200	80	280
		Wat Sing	(120)	104	21	125	121	24	145	142	28	170	180	40	220
	Sing Buri	Muang Sing Buri	149	111	45	156	130	52	182	154	61	215	200	80	280
	Lop Buri	Muang Lop Buri	280	200	80	280	200	80	280	200	80	280	200	80	280
		Khok Samrong	128	111	22	133	126	25	151	145	29	174	180	40	220
		Muang Bang Mi	128	111	22	133	126	25	151	145	29	174	180	40	220
	Ang Thong	Muang Ang Thong	159	118	47	165	135	54	189	156	63	219	200	80	280
		Pa Mok	113	86	35	121	111	44	155	141	56	197	200	80	280
	Ayutthaya	Muang Ayutthaya	314	211	105	316	217	109	326	225	112	337	242	118	360
		Muang Sena	200	146	58	204	157	63	220	171	69	240	200	80	280
		Tha Rua	128	111	22	133	126	25	151	145	29	174	180	40	220
	Pathum Thani	Muang Pathum Thani	294	198	99	297	207	104	311	218	109	327	242	118	360
	Nonthaburi	Muang Nontheburi	226	155	78	233	173	87	260	195	98	293	242	118	360
		Pak Kret	226												
		Muang Bang Bua Thong	226												
S. D.s in Rangsit area	Pathum Thani	Prachatipat	181	127	63	190	151	75	226	181	90	271	242	118	360
		Thanyaburi													
		Khu Kot													
		Klong Luang													
S. D.	S.Ds except for Rangsit area		120	104	21	125	121	24	145	142	28	170	180	40	220
Rural Area	Rural Communities		95	96	-	96	101	-	101	108	-	108	120	-	120

Note : ( ) present average consumption rate in class B.

Table 8.2 Unit Generated BOD Load of Domestic Wastewater

Category	Province	Municipality / S. D.	Unit BOD Load gpcd															
			1992				1996				2001				2011			
			Sullage	N.S	Busi.	Total	Sullage	N.S	Busi.	Total	Sullage	N.S	Busi.	Total	Sullage	N.S	Busi.	Total
Manicipality	Chai Nat	Muang Chai Nat	42	11	6.4	59.4	42.4	11	7.0	60.4	42.9	11	7.8	61.7	43.9	11	9.6	64.5
		Wat Sing	42	11	2.5	55.5	42.4	11	2.9	56.3	42.9	11	3.4	57.3	43.9	11	4.8	59.7
	Sing Buri	Muang Sing Buri	42	11	5.4	58.4	42.4	11	6.2	59.6	42.9	11	7.3	61.2	43.9	11	9.6	64.5
	Lop Buri	Muang Lop Buri	42	11	9.6	62.6	42.4	11	9.6	63.0	42.9	11	9.6	63.5	43.9	11	9.6	64.5
		Khok Samrong	42	11	2.6	55.6	42.4	11	3.0	56.4	42.9	11	3.5	57.4	43.9	11	4.8	59.7
		Muang Bang Mi	42	11	2.6	55.6	42.4	11	3.0	56.4	42.9	11	3.5	57.4	43.9	11	4.8	59.7
	Ang Thong	Muang Ang Thong	42	11	5.6	58.6	42.4	11	6.5	59.9	42.9	11	7.6	61.5	43.9	11	9.6	64.5
		Pa Mok	42	11	4.2	57.2	42.4	11	5.3	58.7	42.9	11	6.7	60.6	43.9	11	9.6	64.5
	Ayutthaya	Muang Ayutthaya	42	11	12.6	65.6	42.4	11	13.1	66.5	42.9	11	13.4	67.3	43.9	11	14.2	69.1
		Muang Sena	42	11	7.0	60.0	42.4	11	7.6	61.0	42.9	11	8.3	62.2	43.9	11	9.6	64.5
		Tha Rua	42	11	2.6	55.6	42.4	11	3.0	56.4	42.9	11	3.5	57.4	43.9	11	4.8	59.7
	Pathum Thani	Muang Pathum Thani	42	11	11.9	64.9	42.4	11	12.5	65.9	42.9	11	13.1	67.0	43.9	11	14.2	69.1
	Nonthaburi	Muang Nonthaburi	42	11	9.4	62.4	42.4	11	10.4	63.8	42.9	11	11.8	65.7	43.9	11	14.2	69.1
		Pak Kret	42	11	9.4	62.4	42.4	11	10.4	63.8	42.9	11	11.8	65.7	43.9	11	14.2	69.1
		Muang Bang Bua Thong	42	11	9.4	62.4	42.4	11	10.4	63.8	42.9	11	11.8	65.7	43.9	11	14.2	69.1
SDs in Rangsit area	Pathum Thani	Prachatipat	42	11	7.6	60.6	42.4	11	9.0	62.4	42.9	11	10.8	64.7	43.9	11	14.2	69.1
		Thanyaburi	42	11	7.6	60.6	42.4	11	9.0	62.4	42.9	11	10.8	64.7	43.9	11	14.2	69.1
		Khu Kot	42	11	7.6	60.6	42.4	11	9.0	62.4	42.9	11	10.8	64.7	43.9	11	14.2	69.1
		Khlong Luang	42	11	7.6	60.6	42.4	11	9.0	62.4	42.9	11	10.8	64.7	43.9	11	14.2	69.1
S. D.	SDs except for Rangsit area		42	11	2.5	55.5	42.4	11	2.9	56.3	42.9	11	3.4	57.3	43.9	11	4.8	59.7
Rural Area	Rural Communities		42	11	-	53.0	42.4	11	-	53.4	42.9	11	-	53.9	43.9	11	-	54.9

Table 8.3 Unit Discharged BOD Load of Domestic Wastewater

Category	Province	Municipality / S. D.	Unit BOD Load gpcd											
			1992			1996			2001			2011		
			Sullage & Busi.	N.S	Total	Sullage & Busi.	N.S	Total	Sullage & Busi.	N.S	Total	Sullage & Busi.	N.S	Total
Manicipality	Chai Nat	Muang Chai Nat	48.4	5.5	53.9	49.4	5.5	54.9	50.7	5.5	56.2	53.5	5.5	59.0
		Wat Sing	44.5	5.5	50.0	45.3	5.5	50.8	46.3	5.5	51.8	48.7	5.5	54.2
	Sing Buri	Muang Sing Buri	47.4	5.5	52.9	48.6	5.5	54.1	50.2	5.5	55.7	53.5	5.5	59.0
	Lop Buri	Muang Lop Buri	51.6	5.5	57.1	52.0	5.5	57.5	52.5	5.5	58.0	53.5	5.5	59.0
		Khok Samrong	44.6	5.5	50.1	45.4	5.5	50.9	46.4	5.5	51.9	48.7	5.5	54.2
		Muang Bang Mi	44.6	5.5	50.1	45.4	5.5	50.9	46.4	5.5	51.9	48.7	5.5	54.2
	Ang Thong	Muang Ang Thong	47.6	5.5	53.1	48.9	5.5	54.4	50.5	5.5	56.0	53.5	5.5	59.0
		Pa Mok	46.2	5.5	51.7	47.7	5.5	53.2	49.6	5.5	55.1	53.5	5.5	59.0
	Ayutthaya	Muang Ayutthaya	54.6	5.5	60.1	55.5	5.5	61.0	56.3	5.5	61.8	58.1	5.5	63.6
		Muang Sena	49.0	5.5	54.5	50.0	5.5	55.5	51.2	5.5	56.7	53.5	5.5	59.0
		Tha Rua	44.6	5.5	50.1	45.4	5.5	50.9	46.4	5.5	51.9	48.7	5.5	54.2
	Pathum Thani	Muang Pathum Thani	53.9	5.5	59.4	54.9	5.5	60.4	56.0	5.5	61.5	58.1	5.5	63.6
	Nontha Buri	Muang Nonthaburi	51.4	5.5	56.9	52.8	5.5	58.3	54.7	5.5	60.2	58.1	5.5	63.6
		Pak Kret	51.4	5.5	56.9	52.8	5.5	58.3	54.7	5.5	60.2	58.1	5.5	63.6
		Muang Bang Bua Thong	51.4	5.5	56.9	52.8	5.5	58.3	54.7	5.5	60.2	58.1	5.5	63.6
SDs in Rangsit area	Pathum Thani	Prachatipat	49.6	5.5	55.1	51.4	5.5	56.9	53.7	5.5	59.2	58.1	5.5	63.6
		Thanyaburi	49.6	5.5	55.1	51.4	5.5	56.9	53.7	5.5	59.2	58.1	5.5	63.6
		Khu Kot	49.6	5.5	55.1	51.4	5.5	56.9	53.7	5.5	59.2	58.1	5.5	63.6
		Khlong Luang	49.6	5.5	55.1	51.4	5.5	56.9	53.7	5.5	59.2	58.1	5.5	63.6
S. D.	SDs except for Rangsit area		44.5	5.5	50.0	45.3	5.5	50.8	46.3	5.5	51.8	48.7	5.5	54.2
Rural Area	Rural Communities		42.0	5.5	47.5	42.4	5.5	47.9	42.9	5.5	48.4	43.9	5.5	49.4

Labor productivity increasing factors and saving of industrial water are taken into account for future projection. The basic figures for these factors are from the UCR study and the JICA study on effective use of industrial water in Samut Phrakan area. Wastewater related to water use by employees of the factory is also considered with an average of 280 lpcd. The investigation results by DIW on BOD load generated/discharged from major 250 factories, located along the Chao Phraya river between Nakhon Sawan and Samut Phrakan, are referred to. Table 8.4 summarizes these results.

For future projection, increase of labor productivity is considered, while promotion in saving of industrial water use is disregarded. Unit generated/discharged loads are projected by type of industry for each target year. In consideration of actual conditions on the wastewater treatment as well as existence of small-scale industries without treatment facilities, half of the generated load is assumed to be discharged without treatment. Tables 8.5 and 8.6 present the computation results of the projected generated and discharged unit BOD load per employee for each type of industrial group as revised considering inclusion of small-scale and non-registered factories, respectively.

8.3 Other Wastewater Sources

Unit wastewater quantity and quality generated by livestock, slaughterhouse, fresh market and fish pond were studied referring to the guideline used in Japan and existing study in Thailand. The unit figures for fresh market and fish pond are assumed using fully the investigation results of the water pollution study in this country. For fresh water, a constant wastewater volume discharged of 40cum per day is assumed for each municipality with BOD concentration of 1,000mg/l. Effluent quantity and quality (BOD concentration) of fishpond are assumed to be 93.8cum per hectare per day and 20mg/l, respectively. Tables 8.7 and 8.8 show the unit pollution load of livestock and of slaughterhouse, respectively.

Natural pollution is also referred to with discussions on the results from field work and common practices for planning purposes (0.5 - 1.0 kg/km^2 on concentrated load basis).

Table 8. 4 BOD Load of Industrial Wastewater by Industrial Type

Industrial Type	No. of Fac.	Wastewater Quantity (m3/day)	BOD Concentration (mg/l)		BOD Load (kg/d)	
			Generated	Discharged	Generated	Discharged
Beverage	18	16,710	1,972.0	10.7	32,952.9	178.3
Food	73	19,916	872.0	24.0	17,366.0	478.2
FOOD PROCESSING TOTAL	91	36,626	1,373.9	17.9	50,318.9	656.5
Non-metallic	9	940	371.7	3.2	349.4	3.0
MIN/CEMENT/CERAMIC TOTAL	9	940	371.7	3.2	349.4	3.0
Apparel	1	90	400.0	55.0	36.0	5.0
Leather	3	603	473.5	277.1	285.5	167.1
Textiles	89	33,633	462.9	35.7	15,568.4	1,200.2
LIGHT PROCESSING TOTAL	93	34,326	462.9	40.0	15,889.9	1,372.3
Basic Metal	1	100	240.0	5.0	24.0	0.5
Transport Equipment	1	100	250.0	30.9	25.0	3.1
Others	2	210	61.9	6.4	13.0	1.4
MACHINE/ELECTRIC. TOTAL	4	410	151.2	12.0	62.0	4.9
Chemical	20	4,668	390.1	40.2	1,820.9	187.5
Paper	20	41,620	623.3	31.2	25,942.5	1,297.5
Plastics	1	12	0.0	0.0	0.0	0.0
Others	12	2,732	606.1	48.3	1,655.9	132.1
OTHERS TOTAL	53	49,032	600.0	33.0	29,420.7	1,617.3
GRAND TOTAL	250	121,334	791.5	30.1	96,040.8	3,654.1

Source: Department of Industrial Works

Table 8.5 Projected Unit BOD Load per Employee (Generated)

Industrial Group	Avg. BOD Concen'n (mg/l)	Unit I.W.W. Quantity (m3/d/head)	Unit BOD Load (g/d/head)	Projected Unit BOD Load (g/day/head)			
				1992	1996	2001	2011
Food Processing	1,374	0.768	1,055	1,115	1,354	1,655	2,404
Min./Cement/Ceramics	372	0.322	120	126	154	188	273
Light Processing	463	0.261	121	128	155	189	275
Machine/Electrical.	151	0.081	12	13	16	19	28
Others	600	0.665	399	421	512	626	909

Table 8.6 Revised Unit BOD Load per Employee (Discharged)

Industrial Group	Unit BOD Load from Factory w/WWTP. (g/d/head)	Unit BOD Load from Factory w/o WWTP. (g/d/head)	Average Unit BOD Load from Factory (g/d/head)	Projected Unit BOD Load per Employee (g/day/head)			
				1992	1996	2001	2011
Food Processing	14	1,055	544	567	684	839	1,219
Min./Cement/Ceramics	1	120	61	64	77	95	138
Light Processing	10	121	66	69	84	103	149
Machine/Electrical.	1	12	7	7	8	10	15
Others	22	399	211	223	269	330	480

Table 8.7 Unit Pollution Load of Livestock

Item	Generated		Discharged	
	Cattle	Swine	Cattle	Swine
Wastewater (l/head/day)	90 (45-135)	13.5	-	13.5
BOD (g/head/day)	640	200	0	100

Note : Discharged BOD load for Cattle is assumed to be zero percent, while for swine 50 percent

Data source: Guideline for comprehensive Basin-Wide Water Pollution Control plan, Japan

Table 8.8 Unit Pollution Load of Slaughterhouse

Item	Quantity (l/head/d)	BOD (g/head/d)
Raw wastewater	1,166	2,200
Effluent from WWTP	1,450	160

Note: Effluent quality is based on the experience in Thailand (110 mg/l).
The figures are in case of swine and conversion rate of cattle to swine is 3:1.

CHAPTER 9 PRESENT WATER POLLUTION ANALYSIS

9.1 Run-off Model of Pollution Load with Water Quality Checking Points

Present water pollution analysis is undertaken to establish a run-off model and basic factors as the basis of future pollution study. The base data for the analysis are run-off load at the survey points in the field works during Stages I and II, and discharged load calculated using frame values and unit BOD loading. Figure 9.1 presents the conceptual flow system of the pollution load.

A total of five (5) water quality checking points along the main river from Chai Nat to Nonthaburi were established as shown in Figure 9.2. Most of the survey points which were used for analysis, coincided with the checking points.

Frame values and generated/discharged load are distributed to each area of water quality checking point/pollution load inflow point (one each for respective provinces by sub-basin). The composition of related basins by province is shown in Table 9.1.

Table 9.1 Composition of Related River Basins by Province

Province	Noi River	Lop Buri River	Pasak River	Main R. (R0-R1)	Main R. (R1-R2)	Main R. (R2-R3)	Main R. (R3-R4)
Chai Nat	N1	--	--	C1	C2	--	--
Sing Buri	N2	L1	--	--	C3	--	--
Lop Buri	--	L2	--	--	C4	--	--
Ang Thong	N3	--	--	--	C5	--	--
Ayutthaya	N4	L4	P2	--	C6	C7	C8
Pathum Thani	--	--	--	--	--	--	C9
Nonthaburi	--	--	--	--	--	--	C10
Sara Buri	--	L3	P1	--	--	--	--

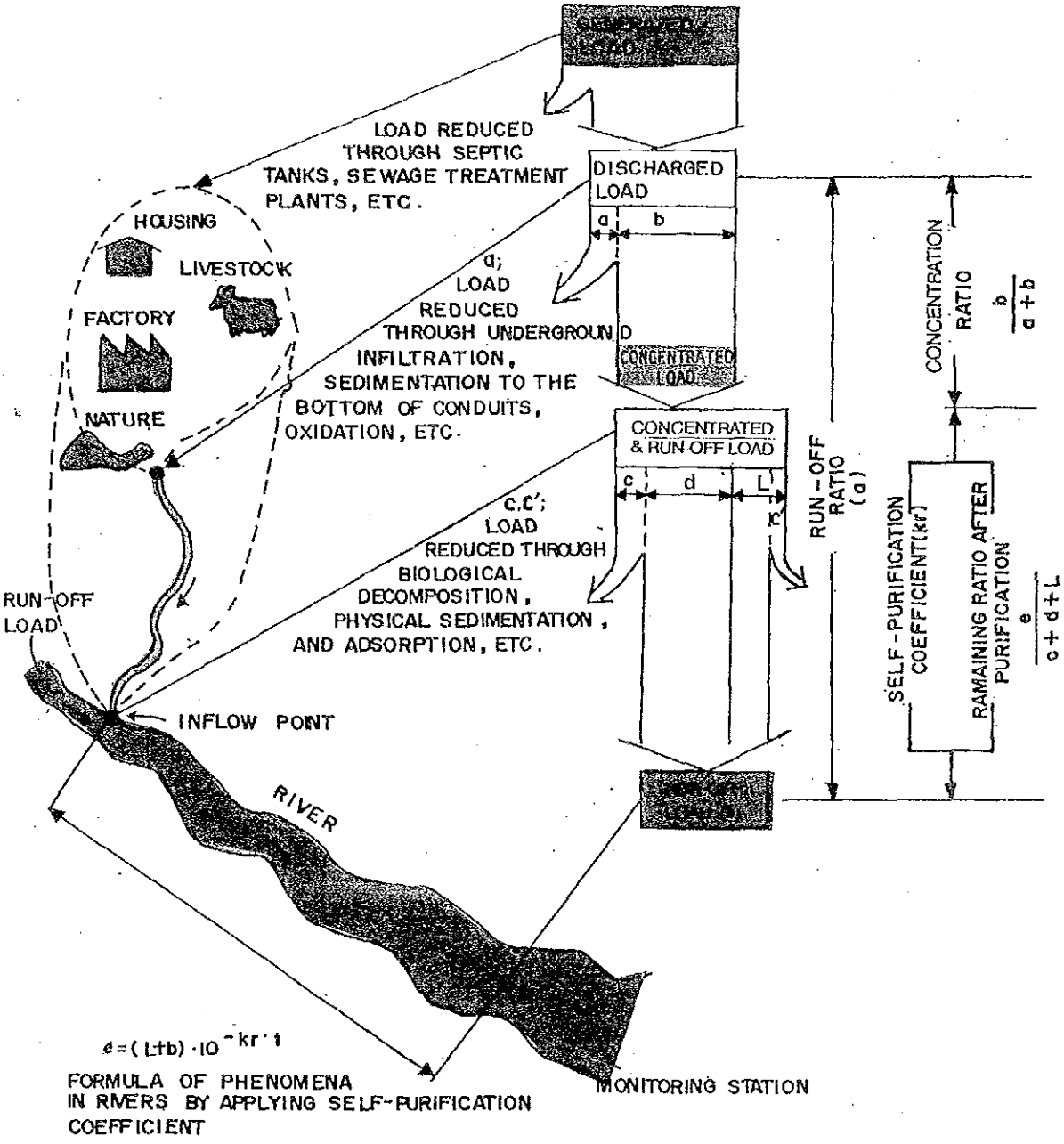


FIG. 9.1. FLOW SYSTEM OF THE POLLUTION LOAD

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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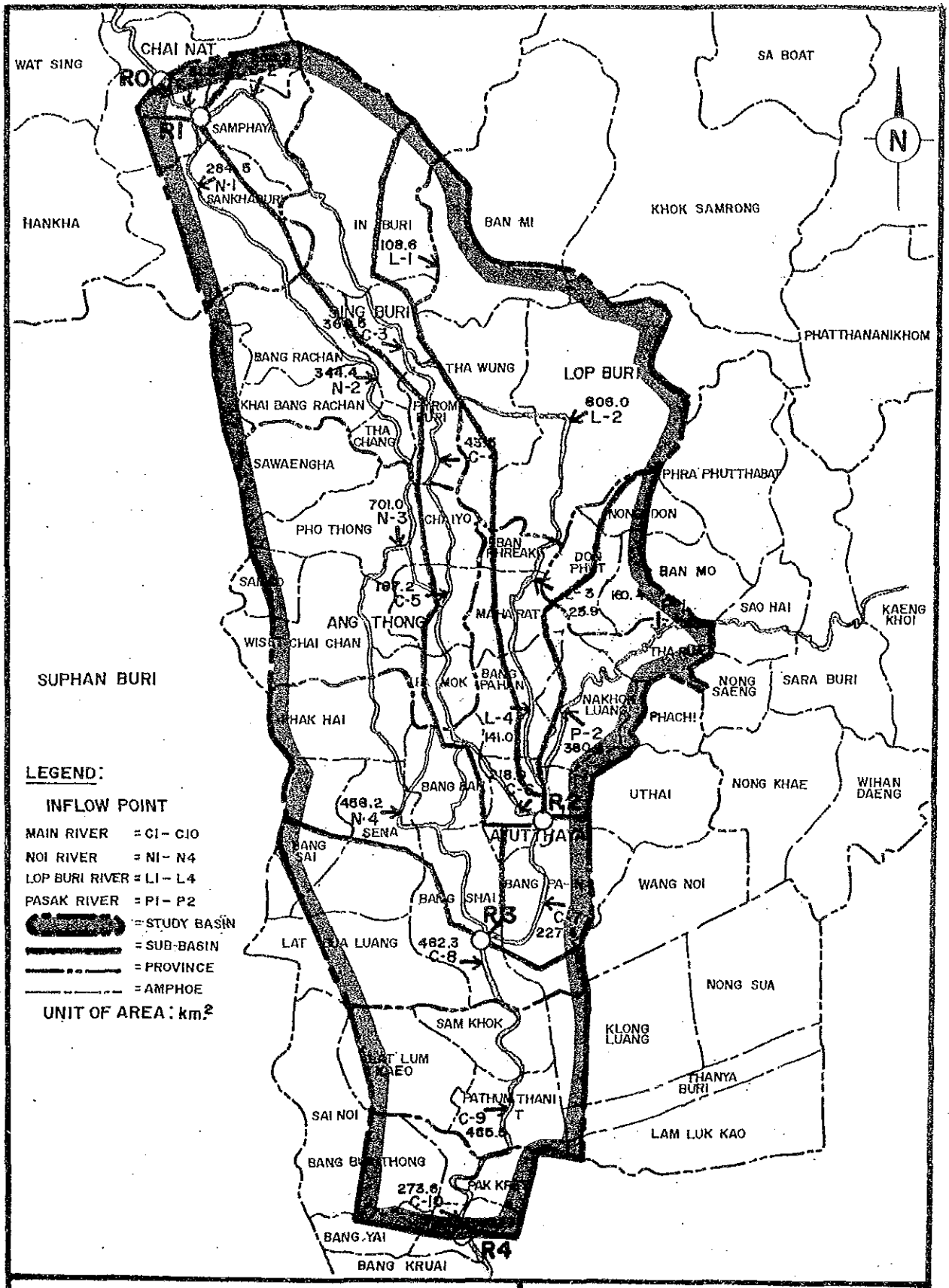

FIG. 9.2

SUB-BASIN IN THE STUDY AREA

MASTER PLANNING FOR THE SEWERAGE DEVELOPMET PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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9.2 Study on Concentration and Purification Ratios

Concentration ratios during dry season in UCR and BMR are derived considering Japanese standards, studies conducted in Thailand and findings from Stage II field work. The ratios are further categorized in terms of location/land use of discharged area of pollution load. Based on the results of the computation on discharged BOD load and concentrated BOD load, concentration ratios have close relationship with population density as shown in Figure 9.3. Table 9.2 indicates the concentration ratios by land use type under the existing conditions in UCR and BMR reflecting the survey results.

Flow rates at strategic points of the river for the analysis are summarized in addition to the calculations on specific wastewater discharged rate by sub-basin to be utilized for future pollution analysis. Figure 9.4 presents the flow rates at strategic points of the main river.

Run-off ratio/remaining ratio after purification was finally estimated for each river section. Arrived ratios reveal that the main river and tributaries (Noi, Pasak and Lop Buri rivers) are different from each other, seemingly affected by respective concentrations of pollution load/population density and flow conditions both in physical and biological aspects.

Figure 9.5 summarizes the major elements of pollution analysis including run-off load and concentrated load, while Table 9.3 presents the recommended self-purification coefficient.

Table 9.3 Recommended Self-Purification Coefficients

River Section (Water quality Checking Point	Self-Purification Coefficient	Remarks
Main River		
R0 - R1	0.08	Same ratio as the Section of R1 - R2
R1 - R2	0.08	
R2 - R3	0.00	
R3 - R4	0.00	
Tributaries		
Noi river	0.02	Noi, Lop Buri and Pasak rivers are regarded to have same assimilation capacity
Lop buri and Pasak rivers	0.02	

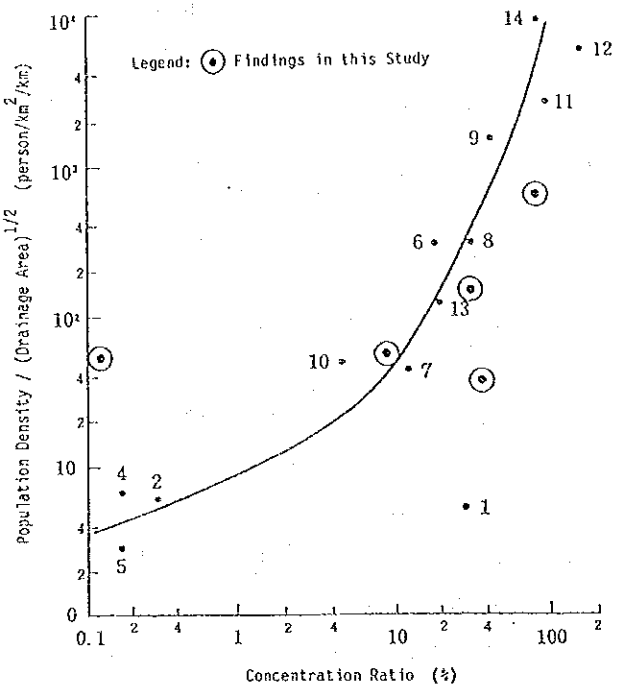

Figure 9.3 Relationship between Concentration Ratio and Population Density

Table 9.2 Recommended Concentration Ratio

Land Use Type	Application for the Study	Concentration Ratio UCR	BMR
Rural Area	Outside area of municipality and S.D., fish pond	0.1	0.1
Urban Area			
1) Med.-Low population density	S.D., factory, slaughterhouse	0.2	0.5
2) High population density	Municipality including Rangsit area, fresh market	0.4	0.9
Sewerage System		1.0	1.0

Note: BMR includes Pathum Thani and Nonthaburi.

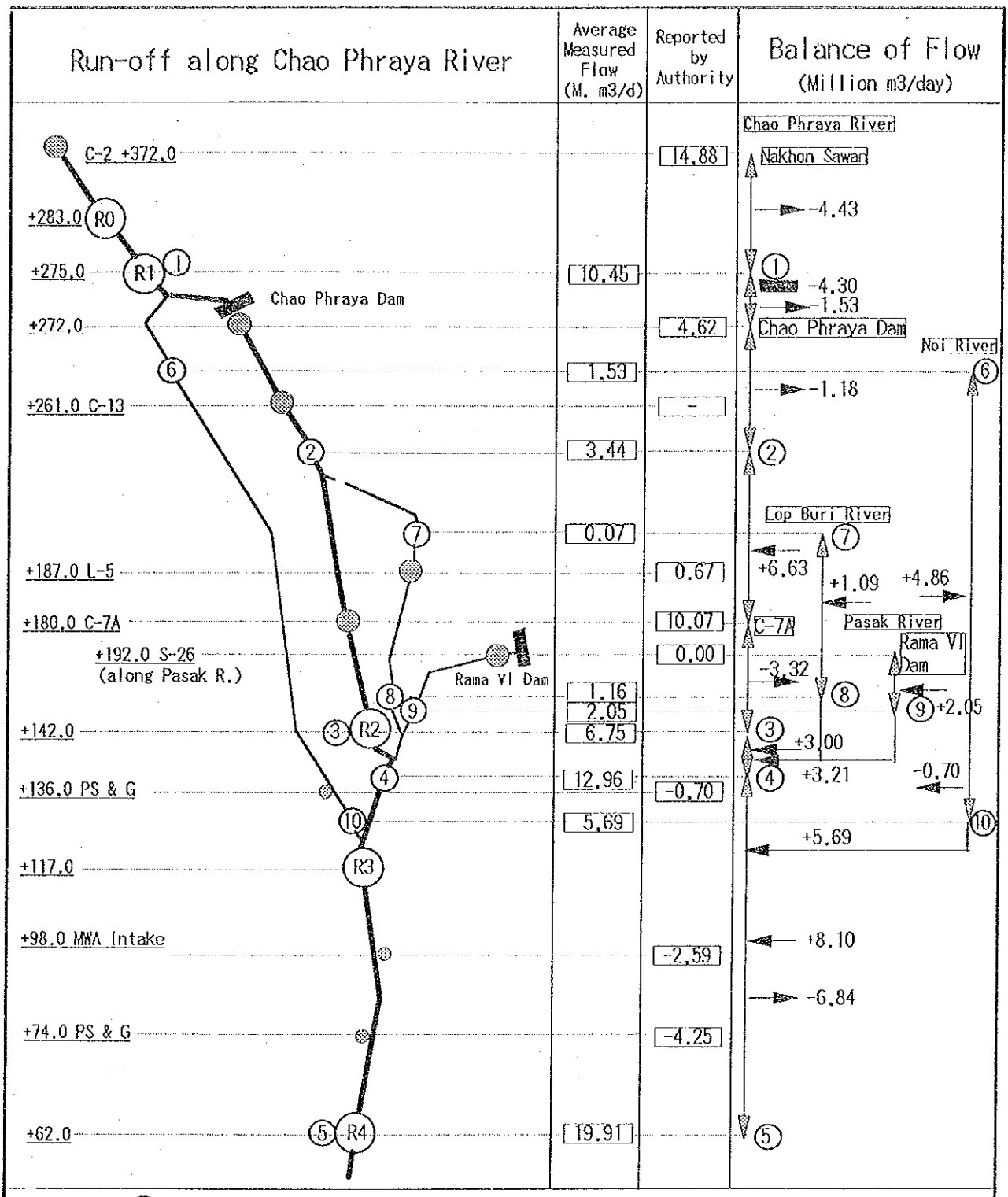

Figure 9.4 Flow Rates at Strategic Points of Main River

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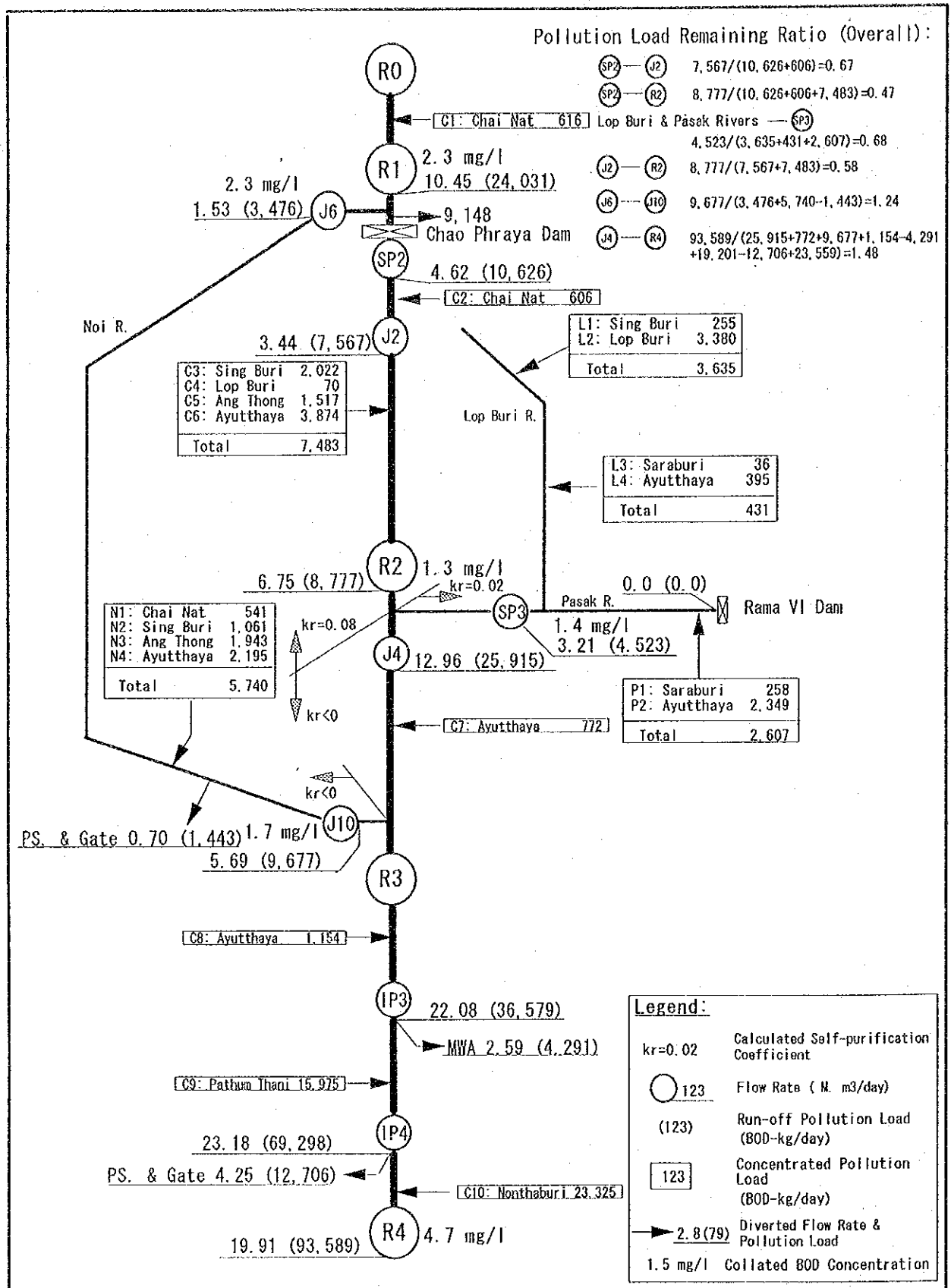

Figure 9.5

Present Water Pollution Analysis (1992)

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CHAPTER 10 FUTURE WATER POLLUTION ANALYSIS

10.1 Flow Rate for Future Pollution Analysis

The flow model and basic factors established through present water pollution analysis are employed in application of the flow rates for each water quality checking point, which are estimated from the average figures at some RID observation stations during March and April in the last 4 years. Figure 10.1 indicates the flow rate for future water pollution analysis.

10.2 Projection of Water Quality at Water Quality Checking Points

Water quality (BOD concentration) at water quality checking points in addition to some supplementary points was projected for the years of 1996, 2001 and 2011. The calculation results of the future water pollution analysis are summarized in Table 10.1. Comparing with the environmental water quality standard, the predicted water quality (BOD concentration) from R1 to R4 revealed that only checking point R4 will find difficulty in meeting the required water quality with its present arrangements on various water pollution sources up to the year 2001. Furthermore, BOD concentration in R3 would exceed the standard quality by the year 2011. Figures 10.2, 10.3, and 10.4 show the BOD load by sub-area and run-off load at different water quality checking points for years 1996, 2001, and 2011, respectively.

Table 10.1 Summary of Future Water Pollution Analysis

Water Qty Check Point	Location	Env. Std. (mg/l)	Calculation Result 1996	2001	2011
R1	Chao Phraya R., before diversion to Noi R.	1.5	1.3	1.3	1.3
R2	Chao Phraya R., before confluence of Pasak R.	1.5	0.9	1.1	1.5
R3	Chao Phraya R., after confluence of Noi R.	2.0	1.4	1.7	2.2
R4	Chao Phraya R., Nonthaburi	2.0	3.5	4.2	6.2
SP2	Chao Phraya R., Chai Nat Dam	1.5	1.2	1.2	1.2
No	Noi R., after diversion from Chao Phraya R.	-	1.2	1.3	1.3
SP3	Pasak R., before confluence of Chao Phraya R.	-	4.1	4.9	6.5
J4	Chao Phraya R., after confluence of Pasak R.	2.0	1.2	1.4	2.0
J10	Noi R., before confluence of Chao Phraya R.	-	1.5	2.9	3.6
IP3	Chao Phraya R., before intake of MWA	2.0	1.3	1.5	2.0
IP4	Chao Phraya R., before intake of irrigation	2.0	2.0	2.3	3.1

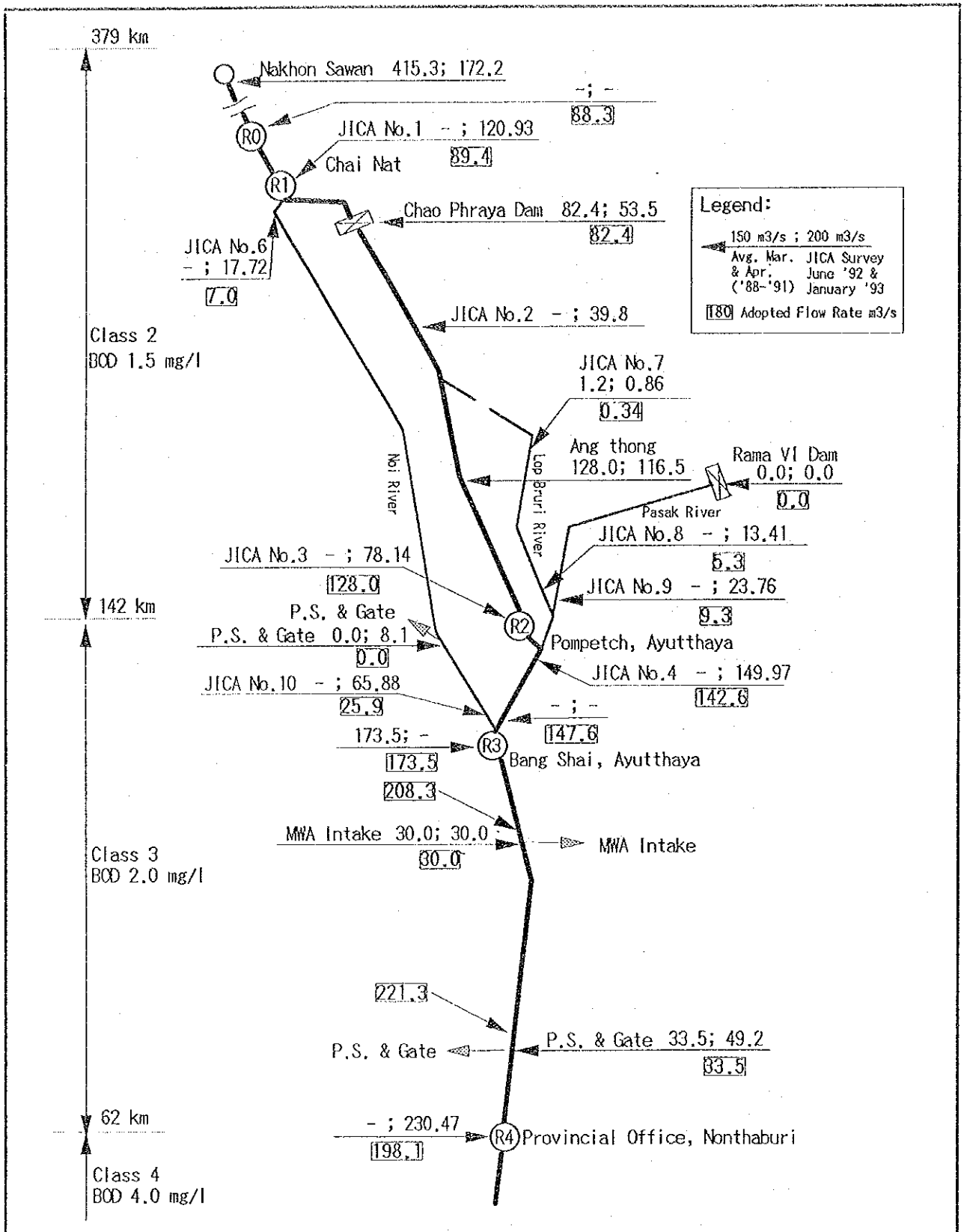

Figure 10.1 Flow Rate for Future Water Pollution Analysis

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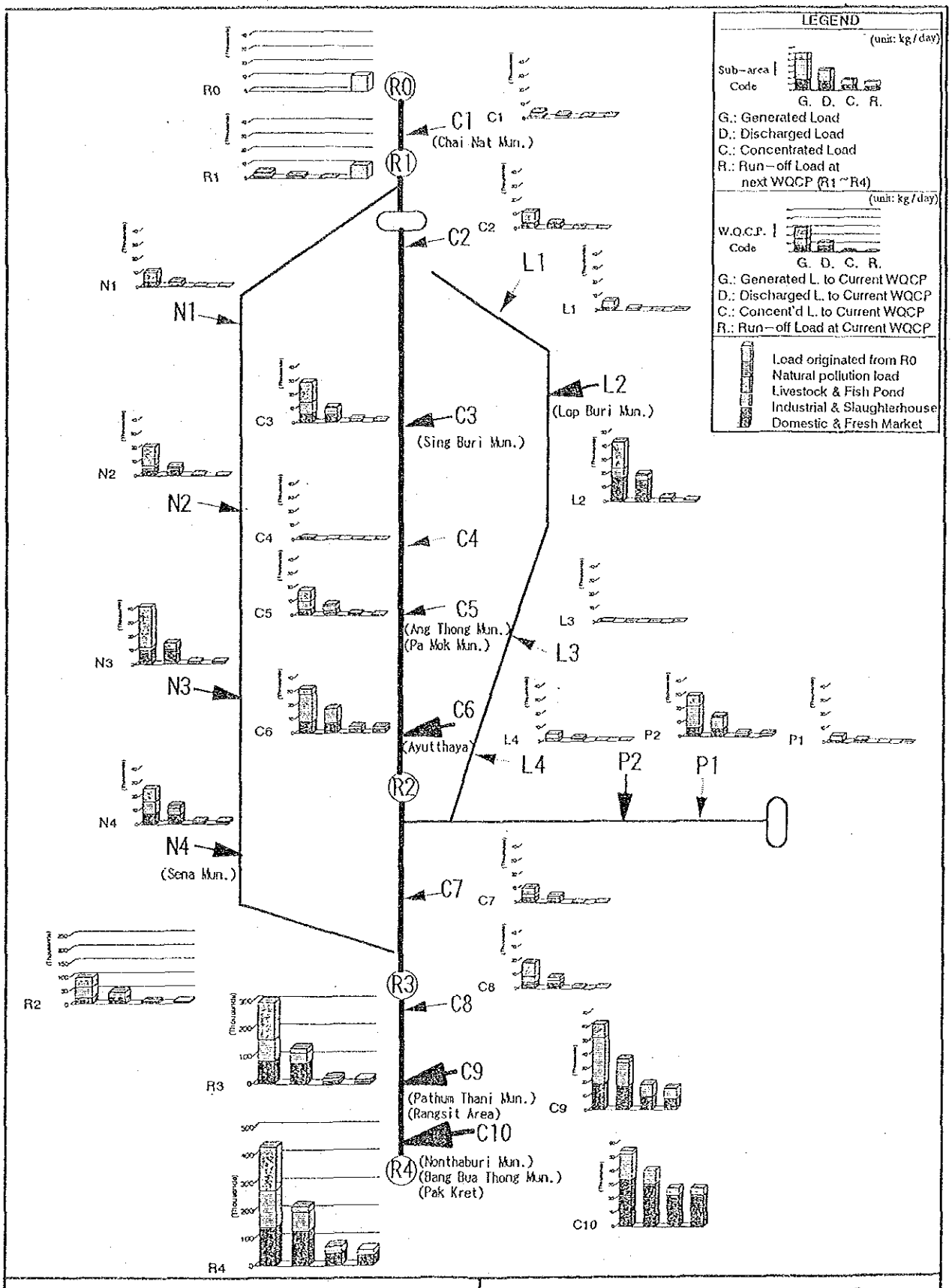

Figure 10.2 BOD Load by Sub-area and Run-off Load at W.Q.C.P.(1996)

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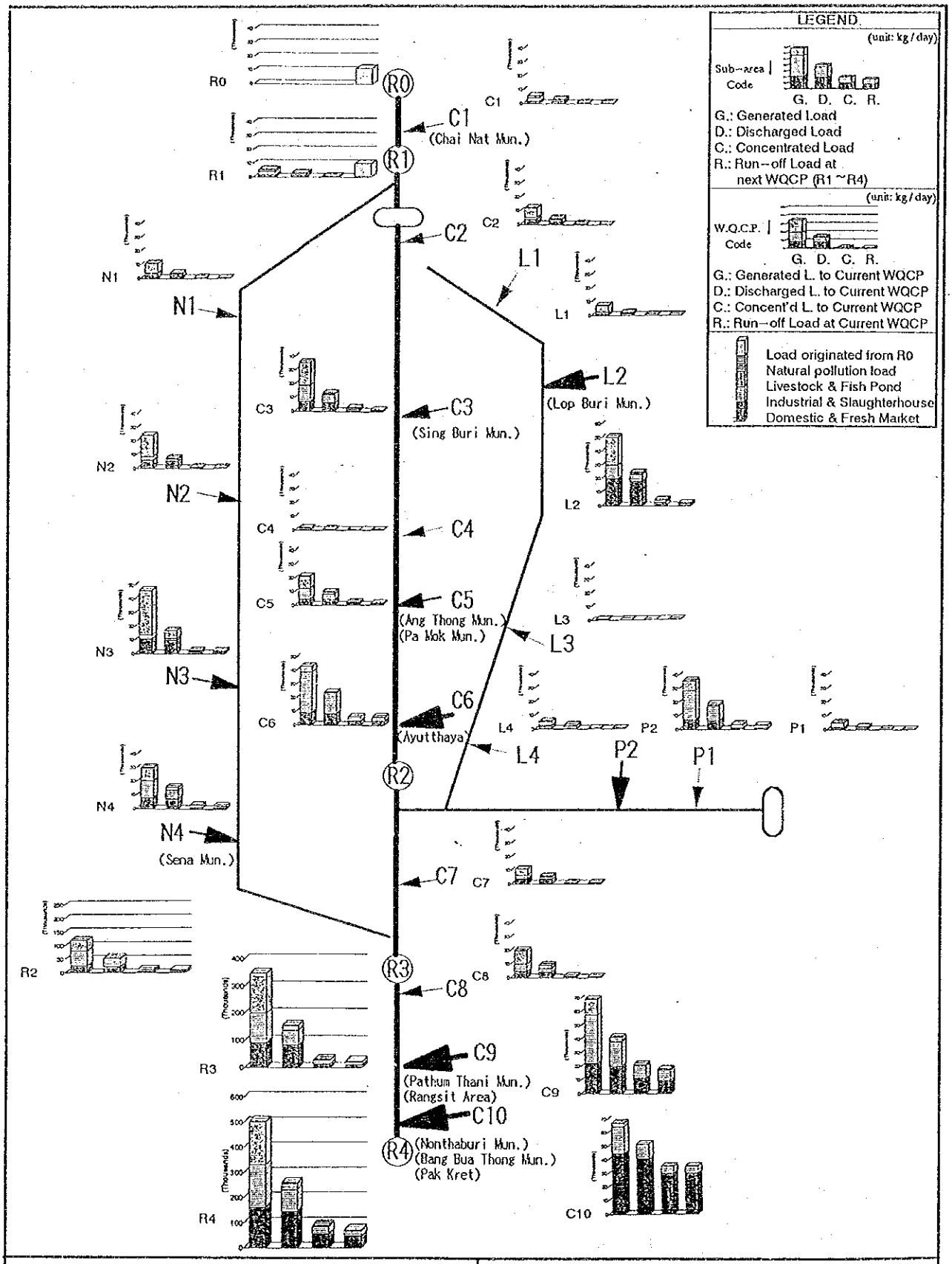

Figure 10.3 BOD Load by Sub-area and Run-off Load at W.Q.C.P.(2001)

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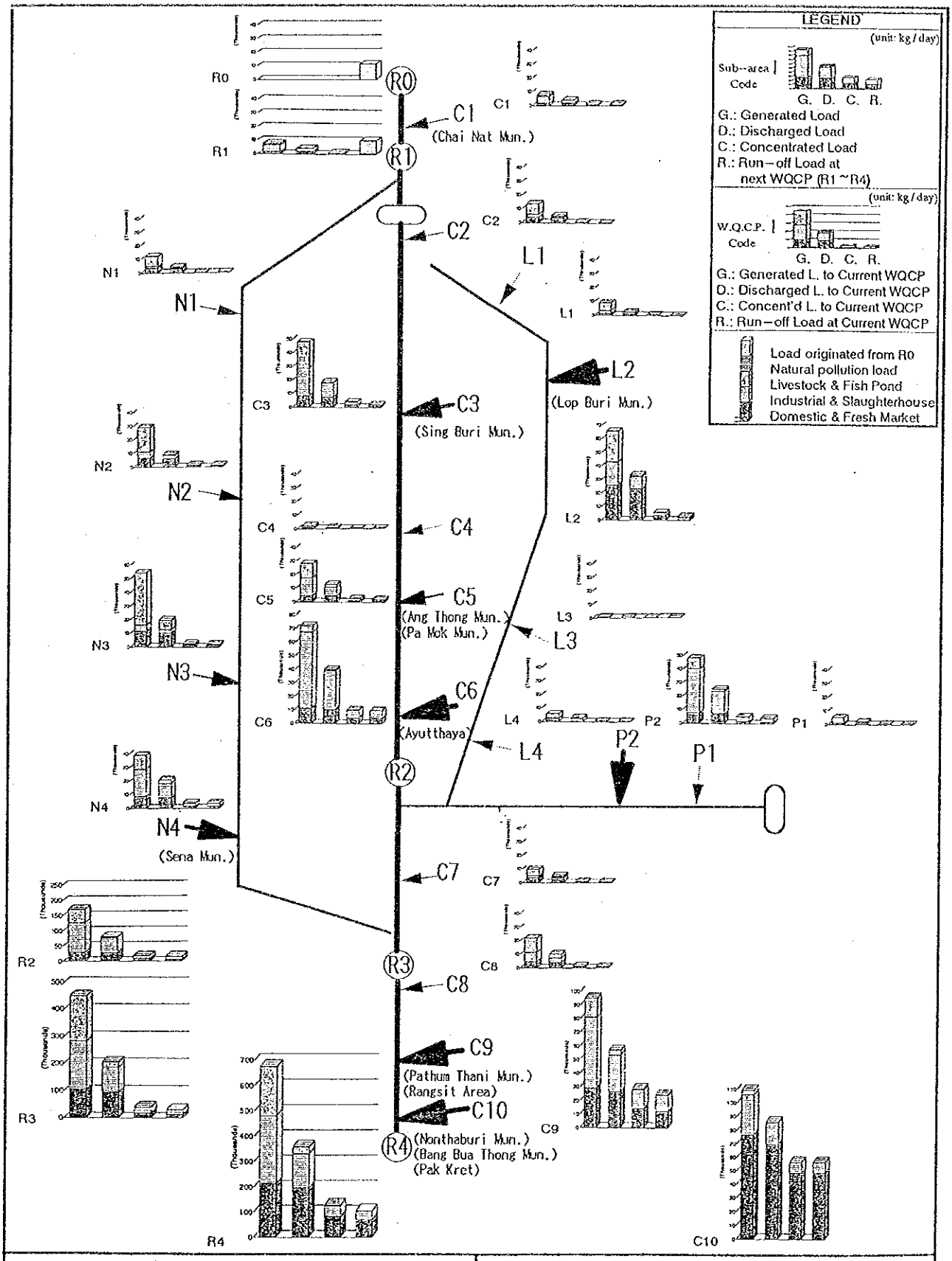

Figure 10.4 BOD Load by Sub-area and Run-off Load at W.Q.C.P.(2011)

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The following findings were derived from Table 10.1

- water quality at R4 exceeds the environmental water quality standard from the year 1996 up to the final target year.

- water quality at R3 exceeds the environmental water quality standard on the final target year.

- water quality of Pasak river at the confluence of Chao Phraya river (SP3) exceeds 2.0 mg/l from the year 1996.

- water quality of Noi river at the confluence of Chao Phraya river (J10) exceeds 2.0 mg/l from the year 2001.

- at the intake point of MWA, water quality is less than 2.0 mg/l through-out the target years.

CHAPTER 11 POLLUTION LOAD TO BE REDUCED BY POLLUTION SOURCE

11.1 Allowable Pollution Load Determination

An allowable pollution load by different pollution source was estimated at each water quality checking point in proportion to the existing composition of their run-off load. This is directly related to the urgent need to reduce pollution load at present because water quality at some portions of the subject basin is already critical and has to meet the water quality standards. Figure 11.1 shows the manner of calculation for allowable pollution load by pollution source.

The following are reduction requirements by pollution source through-out the future, except for the natural pollution load which is considered fixed.

- Domestic wastewater including that from fresh market

  The section R3-R4 needs to reduce pollution load from the year 1996 up to the final target year. It will be extended to the section R2-R3 in 2011.

- Industrial and slaughterhouse wastewater

  In the section R3-R4, reduction of pollution load is necessary starting from the year 1996. These requirements are extended to the section R2-R3 in 2001 and further to R1-R2 in 2011.

- Livestock and fish pond wastewater

  The sections R2-R3 and R3-R4 are required to reduce pollution load from the year 1996. Allocation of the pollution load reduction required in these section may be distributed to the upstream area to meet water quality standard.

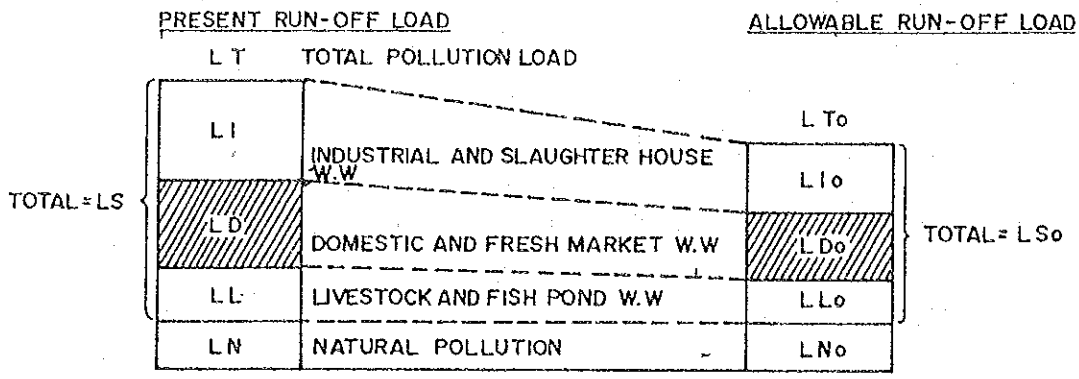

Figure 11.1 Manner of Calculation for Allowable Pollution Load by Pollution Source

CHAPTER 12 RECOMMENDATIONS ON THE REDUCTION OF POLLUTION LOAD

It is assumed that the reduction of pollution load required shall be done by the respective pollution sources responsible, in proportion to their degree of contribution to the pollution.

Public sewerage systems are major countermeasures against pollution load caused by domestic wastewater. The provision of more stringent effluent control is a possible countermeasure against industrial and other pollution sources. In general, the relocation and compression of frame values may be one of the alternatives as the conclusive/final selection. The following are the summary of the recommendations by pollution source category.

- Domestic wastewater including fresh market wastewater

  Potential areas to be sewered are assumed to be municipalities and SDs. Countermeasures shall be provided for other areas in terms of sanitation improvement (toilet facilities). The sewered percentage required in section R3-R4 is almost 100 percent, immediately covering all municipalities and SDs in the subject sub-area. The provision of sewerage systems in the upstream area of section R3-R4 may help achieve water quality standard at R4 checking point.

- Industrial and slaughterhouse wastewater

  In view of the serious pollution condition in section R3-R4 and to conserve water quality, the required percentage of wastewater treatment for factories without treatment (50% of generated load is assumed to be discharged without treatment) was estimated.

  The provision of proper effluent control under the current effluent standard covering all factories, the required reduction of pollution load could be realized except for Pathum Thani and Nonthaburi which need an introduction of a more stringent effluent standard of an average BOD concentration of 50 mg/l.

- Livestock and fish pond wastewater

Required reduction percentage of pollution load for this category in section R3-R4 is more than 100%, considering the difficulty to reduce generated load (effluent from treatment facilities is assumed to be 100 mg/l BOD). Recommendation includes the relocation of the livestock from section R3-R4 to other areas and/or extend allocation of the load to the upstream area of the said section in the overall study area. Table 12.1 presents a summary findings and recommendations for pollution load reduction.

PART 2

SEWERAGE MASTER PLAN FOR THE EIGHT MUNICIPALITIES/AREAS

PART II SEWERAGE MASTER PLAN FOR THE EIGHT MUNICIPALITIES/AREAS

CHAPTER 1 INTRODUCTION

The Sewerage Master Plan for the selected eight municipalities/areas was prepared covering the following subject areas: Chai Nat, Sing Buri, Lop Buri, Ang Thong, Pa Mok, Sena, Rangsit and Bang Bua Thong. Planning fundamentals and conditions/assumptions for each of the sewerage system were discussed and agreed between the JICA Study Team and the PWD staff members.

The presentation of the Sewerage Master Plan in Part II is arranged in such a way as to consolidate the eight plans with common conditions/assumptions, and general approach and methodology spelled out in Chapter 2. Basic figures such as frame values and the projected unit water quantity and quality in the water pollution control plan were also consolidated.