BANGKOK METROPOLITAN
ADMINISTRATION (BMA)

PREPARATORY SURVEY
FOR
BANGKOK WASTEWATER
TREATMENT PROJECT
IN
THAILAND

FINAL REPORT (I)
CONCEPTUAL MASTER PLAN
VOL. 1 SUMMARY

JULY 2011

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

TOKYO ENGINEERING CONSULTANTS CO., LTD. (TEC)
NIPPON KOEI CO., LTD. (NK)

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1. INTRODUCTION

1.1 Objectives and Scope of the Survey

The Survey was implemented based on the S/W agreed between JICA and BMA. The objectives of the Survey are listed below.

(1) To confirm plans in the sewerage sector; to review the existing Master Plan; to study the status of sewerage system development and strategies; and to grasp the status of the organization system, etc.; in order to suggest strategy for developing the sewerage system and to select priority project.
(2) To conduct F/S for the project considered to be urgent based on the findings coming from the studies mentioned above.

1.2 Area under the Survey

The Survey area covers the entire BMA jurisdiction of Thailand.

1.3 Implementing Organizations in Thailand

The direct counterpart of this Survey is the BMA Drainage and Sewerage Department (DDS), and the division in charge within the DDS is the "Water Quality Management Office (WQMO)".

2. WORK SCHEDULE AND IMPLEMENTATION OF PHASE 1 WORK

2.1 Work Schedule for the Entire Survey

The Survey period (approx. 15 months) is divided into two phases as given below. The Survey flow chart is as shown in Figure 2.1.

Phase 1: Confirm plans in the sewerage sector; review the existing Master Plan; study the status of sewerage system development and strategies, grasp the status of the organization system, etc., in order to suggest strategy for developing the sewerage system. Also, select the priority project and confirm the essence of the plans. (About 6 months)

Phase 2: Implement the feasibility study (F/S) of the priority project. (About 9 months)

"Interim Report (I)" in Figure 2.1 was changed to "Final Report (I)" and "Final Report" was changed "Final Report (II)". Date of EIA Stakeholder Meeting (1) was changed from November 2010 to February 2011. Report Meeting (2) was cancelled.

2.2 Basic Policies for the Survey

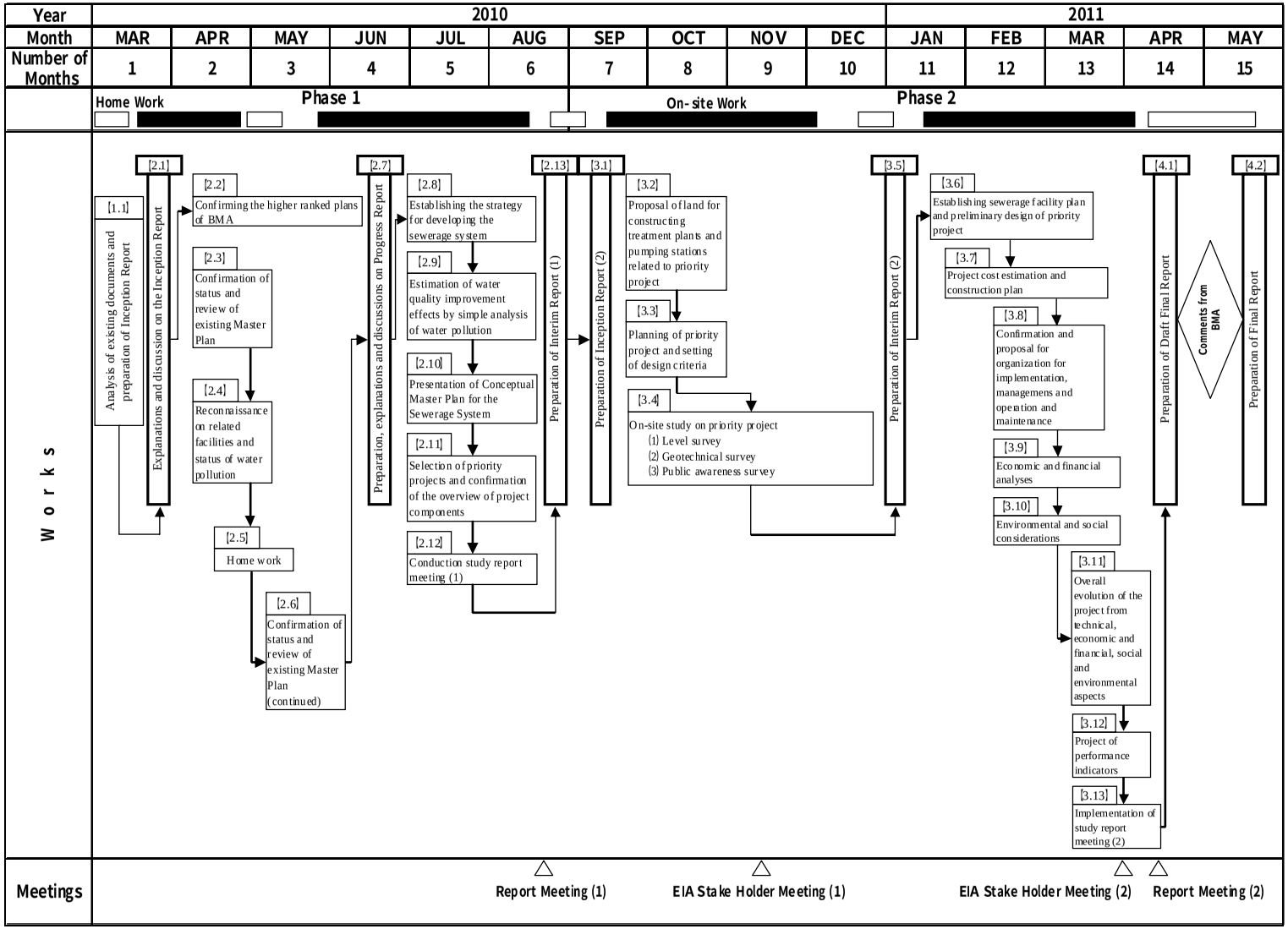
The Survey is implemented based on the basic policies described in the Inception Report. During the implementation of the Survey, the importance of points mentioned in JICA's TOR is taken into account.

2.3 Survey Organization

BMA established a Steering Committee chaired by Deputy Permanent Secretary to monitor the progress and to give suggestions for the implementation of the Survey.

A group of twelve (12) persons were designated as counterparts from members of Water Quality Management Office of DDS to support JICA Survey Team.

Consultant Survey Team is composed of 4 persons from Tokyo Engineering Consultants Co Ltd. and 3 persons from Nippon Koei Co., Ltd.



Source: JST

Figure 2.1 Flowchart of the Survey

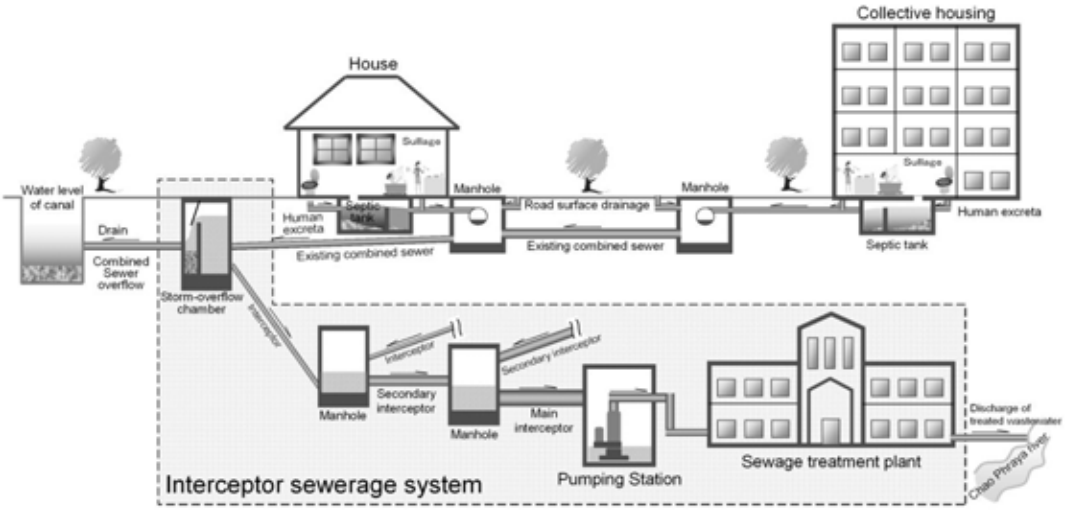
3. ISSUES OF SEWERAGE WORKS IN BMA

3.1 Sewerage System in Thailand

(1) Sewerage System in BMA (Interceptor Sewerage System, Thai Combined System)

Historically, sewerage system in BMA has been developed to aim at providing storm water drainage, and combined sewerage system which is shown in Figure 3.1, collecting both wastewater and storm water has been adopted generally. In dry weather all of wastewater is collected by interceptors and treated at WWTPs. In wet weather, wastewater and storm water flow in combined sewers and up to a certain volume of combined sewage (usually 5 times Dry Weather Flow, DWF) is collected by interceptors and treated at WWTPs, and excess sewage is discharged at interceptor chambers which were constructed near klongs. Combined sewage up to design capacity of the WWTP is treated and excess sewage is again discharged to klong or river after removing grits by screen. There are more than 1,000 interceptor chambers in BMA. In the areas where interceptor sewerage system is not provided, wastewater and storm water are discharged to klongs or rivers without treatment. Interceptor sewerage system utilizes the existing sewer pipes and reduction of pollution load in public water body can be expected. Therefore, interceptor sewerage system can be said as low-cost sewerage system.

Pollution load in wastewater is low because provision of septic tank to treat toilet wastewater is compulsory. Also unknown water to sewers such as backflow of klong water and groundwater infiltration is significant. Therefore, BOD concentration is as low as 1/2 to 1/3 that in Japan



Source: JST

Figure 3.1 Concept of Interceptor Sewerage

(2) Current Situation about Sewerage Project

Thai government published its cabinet resolution in 1998, according to stipulations of Environmental Conservation Act of 1992, to enable BMA implement sewerage projects in the central core district of 100 km^2 area with subsidy. Thai government agreed that it would give subsidy at 75:25 ratio to BMA. Since then five (5) WWTPs and more than 220 km interceptors have been constructed.

Currently, DDS operates seven (7) WWTPs (total design capacity 992,000 m^3/d) shown in Table 3.1. A total of 675,000 m^3/d of wastewater which is generated from the treatment areas of 192 km^2 is treated. Also DDS operates 12 small scale wastewater treatment plants transferred from NHA, and three small treatment facilities including purification plants of Makkason Pond and Rama IX Pond.

Table 3.1 Funds for Construction of Sewerage Facilities in BMA

Treatment Area	Area (km^2)	Population	Capacity (m^3/d)	Start Operation	Source of Fund (BMA. : GOV)	Cost (Million Baht)
1. Si Phraya	2.7	120,000	30,000	1994	BMA 100 %	464
2. Rattanakosin	4.1	70,000	40,000	2000	GOV. 100%	883
3. Din Daeng	37.0	1,080,000	350,000	2004	25 : 75	6,382
4. Chong Nonsi	28.5	580,000	200,000	2000	40 : 60	4,552
5. Nong Khaem	44.0	520,000	157,000	2002	40 : 60	2,348
6. Thung Khru	42.0	177,000	65,000	2002	40 : 60	1,760
7. Chatuchak	33.4	432,000	150,000	2005	60 : 40	3,482
8. 12-Community Plant			25,700			
Total	191.7	2,979,000	1,017,700			19,871
Planned BMA Wastewater Treatment Project (F/S basis)						
1. Bang Sue	21.0	250,000	120,000	2012	BMA 100 %	4,732
2. Klong Toei	56.0	485,000	360,000		60 : 40	11,046
3. Thon Buri	59.0	704,000	305,000			11,561
Total	136.0	1,439,000	785,000			27,339

Note: Cost includes those for WWTPs and interceptors

Source: JST

3.2 Current Sewerage Implementation Plan

In “Master Plan on Sewage Sludge Treatment and Reclaimed Wastewater Reuse” prepared by JICA in 1999, 13 new treatment areas are proposed together with reuse of sludge and reclaimed wastewater. BMA established sewerage implementation plan up to 2020 based on the Master Plan in which 20 treatment areas are planed.

BMA has been implementing sewerage projects based on the 1999 master plan, and seven (7) WWTPs are now in operation, Bang Sue WWTP is under construction, Klong Toei WWTP and

Thon Buri WWTP are in process of planning. Total design capacity of the existing WWTPs together is approximately 1 million m^3/d which accounts for 40 % of wastewater generated.

On the other hand, there is BMA Action Plan prepared in 2008 as higher ranked plan in which service ratio in 2012 is targeted to be 42 % and that of long term in 2020 is targeted to be 60 %. DDS is considering implementation program to realize these targets. According to the program, after completion of construction of Bang Sue WWTP, construction of Klong Toei WWTP and Thong Buri WWTP is planned and further construction of Nong Bon WWTP is expected. In addition, DDS secured next year budget to carry out F/S for Min Buri treatment area.

For the remaining 8 treatment areas among 20 treatment areas in the existing M/P, there is no concrete implementation plan due to non-availability of site. DDS should consider ways to materialize these projects. In addition, improvement and strengthening of function to intercept more wastewater for treatment, and expansion and modification of the existing WWTPs are required.

3.3 Exiting Sewerage Facilities

(1) Outline of Seven WWTPs

Seven existing wastewater treatment plants are in operation, of which two plants (Si Praya and Rattanakosin) are operated and maintained by DDS own staff and the other five plants are by O&M companies entrusted by DDS. Outline of seven wastewater treatment plants and interceptors are shown in Table 3.2.

Table 3.2 Outlines of Existing Seven WWTP and Interceptors

	Si Praya	Rattanakosin	Din Daeng	Chong Nonsi	Nong Khaem	Tung Khru	Chatuchak
1. Start of Operation	1994	2000	2004	2000	2002	2002	2006
2. Treatment Area	2.7 km^2	4.142 km^2	37 km^2	28.5 km^2	44 km^2	42 km^2	33.4 km^2
3. Served Population	120,000	70,000	1,080,000	580,000	520,000	177,000	432,500
4. Treatment Process	Contact Stabilization Activated Sludge	Two stage activated sludge N&P Removal	Activated Sludge with Nutrient N&P Removal	Cyclic Activated Sludge System N&P Removal	Vertical Loop Reactor Activated Sludge N&P Removal	Vertical Loop Reactor Activated Sludge (VLR-AS) N&P Removal	Cyclic Activated Sludge System (CASS) N&P Removal
5. Site	0.28 ha	0.6683 ha	2.72 ha	3.2 ha	8.64 ha	0.48 ha	1.12 ha
6. Construction Cost	464 M Baht	883 M Baht	6,382 M Baht	4,552 M Baht	2,348 M Baht	1,760 M Baht	3,482 M Baht
7. Length of Sewer Pipe	2.3 km	16.25 km	66 km	55 km	46 km	26 km	37.5 km
8. Treatment Capacity	30,000 m^3/d	40,000 m^3/d	350,000 m^3/d	200,000 m^3/d	157,000 m^3/d	65,000 m^3/d	150,000 m^3/d
9. Flow (Avearge in 2009)	18,213 m^3/d	28,791 m^3/d	204,931 m^3/d	124,282 m^3/d	132,605 m^3/d	63,980 m^3/d	120,470 m^3/d
10. O&M by	DDS	DDS	Private Company	Private Company	Private Company	Private Company	Private Company
11. Design Criteria for Influent Wastewater							
(1) BOD	150 mg/l	200 mg/l	150 mg/l	150 mg/l	150 mg/l	150 mg/l	150 mg/l
(2) COD	-	500 mg/l	-	-	-	-	-
(3) T-N	30 mg/l	40 mg/l	30 mg/l	30 mg/l	30 mg/l	30 mg/l	30 mg/l
(4) T-P	8 mg/l	10 mg/l	8 mg/l	8 mg/l	8 mg/l	8 mg/l	8 mg/l
(5) SS	150 mg/l	200 mg/l	150 mg/l	150 mg/l	150 mg/l	150 mg/l	150 mg/l
12. Design Criteria for Effluent							
(1) SS	$\leq$ 30 mg/l	$\leq$ 30 mg/l	$\leq$ 30 mg/l	$\leq$ 30 mg/l	$\leq$ 30 mg/l	$\leq$ 30 mg/l	$\leq$ 30 mg/l
(2) BOD	$\leq$ 20 mg/l	$\leq$ 20 mg/l	$\leq$ 20 mg/l	$\leq$ 20 mg/l	$\leq$ 20 mg/l	$\leq$ 20 mg/l	$\leq$ 20 mg/l
(3) T-N	$\leq$ 10 mg/l	$\leq$ 10 mg/l	$\leq$ 10 mg/l	$\leq$ 10 mg/l	$\leq$ 10 mg/l	$\leq$ 10 mg/l	$\leq$ 10 mg/l
(4) NH_3-N	$\leq$ 5 mg/l	$\leq$ 5 mg/l	$\leq$ 5 mg/l	$\leq$ 5 mg/l	$\leq$ 5 mg/l	$\leq$ 5 mg/l	$\leq$ 5 mg/l
(5) T-P	$\leq$ 2 mg/l	$\leq$ 2 mg/l	$\leq$ 2 mg/l	$\leq$ 2 mg/l	$\leq$ 2 mg/l	$\leq$ 2 mg/l	$\leq$ 2 mg/l
(6) DO	$\geq$ 5 mg/l	$\geq$ 5 mg/l	$\geq$ 5 mg/l	$\geq$ 5 mg/l	$\geq$ 5 mg/l	$\geq$ 5 mg/l	$\geq$ 5 mg/l

Remarks: Flow data of 2007 is shown for Chong Nonsi WWTP. Because some data of 2008 and 2009 are missing

Source: DDS

(2) Treatment Performance

Treatment performances of the seven WWTPs in 2009 are shown in Table 3.3. Total inflow to the seven plants was 693,300 m^3/d which accounted for 70 % of the total design capacities of 992,000 m^3/d. Inflow to Thung Khru WWTP was close to its capacity. On the other hand, inflows to the five WWTPs which are located on the east bank accounted 60 to 80 %, and thus there is room for receiving more wastewater.

BOD and SS concentrations of raw wastewater were 24~56mg/l, (average 38 mg/l) and 24~121 mg/l, (average 58 mg/l) respectively. These concentrations were very low for raw wastewater causing an obstacle to proper treatment. BOD and SS concentrations of effluent were 3.3~10.5mg/l, (average 6.2mg/l) and 5.6~11.7 mg/l (average 8.6mg/l) respectively. These concentrations well satisfy the discharge standards. Removal ratios are 82 % for BOD and 78 % for SS on average. Removal ratios are relatively low because of low concentrations of inflow, however, it indicates that treatment was performed satisfactorily.

Table 3..3 Treatment Performance of Existing 7 WWTPs（2009）

	Design Capacity (m^3/d)	Inflow (m^3/d)	Effective Ratio (%)	BOD (mg/l)		Removal Ratio (%)	SS (mg/l)		Removal Ratio (%)
				In	Out		In	Out	
Si Praya	30,000	18,213	60.7	56	5	90.5	109	7	94.0
Rattanakosin	40,000	28,791	72.0	44	11	76.4	26	11	55.5
Din Daeng	350,000	204,931	58.6	27	5	80.6	31	8	73.4
Chong Nonsi	200,000	124,282	62.1	24	5	79.3	24	7	72.7
Nong Kaem	157,000	132,605	84.5	51	4	93.2	121	10	91.4
Thung Khru	65,000	63,980	98.4	28	3	88.5	59	6	90.6
Chatuchak	150,000	120,470	80.3	33	11	67.8	37	12	68.4

Source: JST

3.4 Water Pollution Situation in BMA

BMA is carrying out water quality monitoring and analysis for Chao Phraya River and klongs in BMA administrative area. The numbers of monitoring points are 9 for Chao Phraya River and 283 for klongs in 2009.

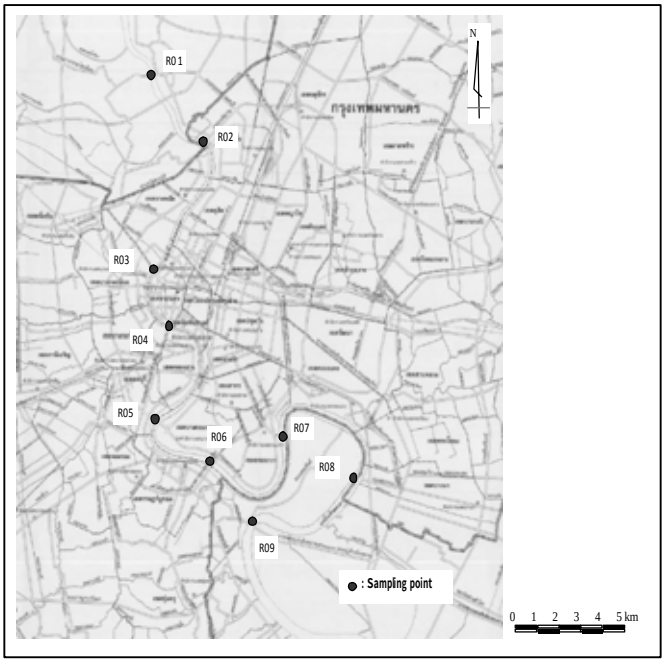
(1) Present Water Pollution Situation in Chao Phraya River in BMA

The water quality standards for surface water are established for Chao Phraya River. Chao Phraya River in the Survey Area is classified as class 4 of the standard, i.e. required values for BOD is less than 4 mg/l, and that for DO is more than 2 mg/l. The results of water quality analysis in terms of BOD and DO in 2009 are summarized in Table 3.4.

Table 3.4 Water Quality of Chao Phraya River

Point	BOD (mg/l)	DO (mg/l)
R01	4	2.1
R02	4	1.9
R03	4	1.7
R04	5	1.7
R05	6	1.6
R06	6	1.9
R07	6	2.1
R08	6	1.8
R09	5	1.9

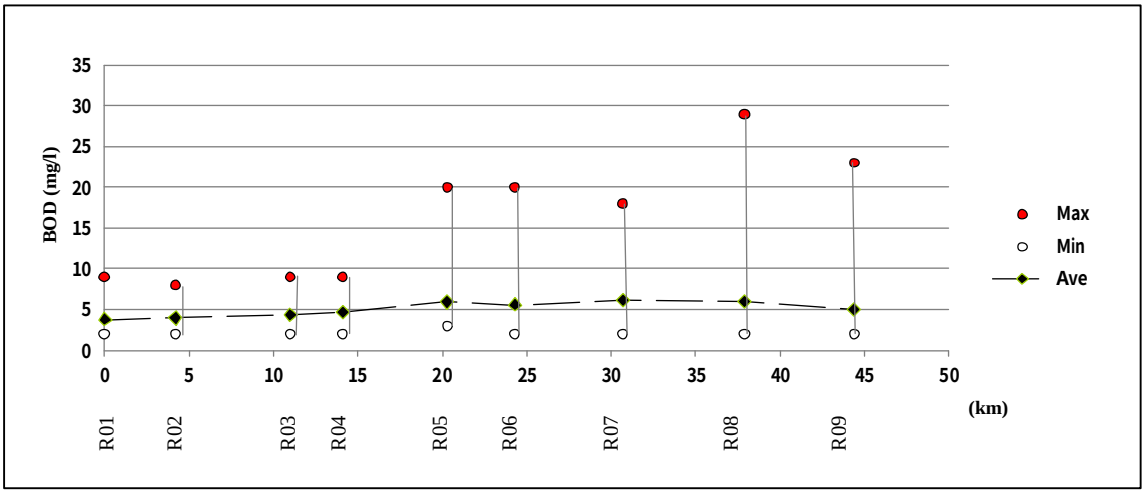
Source：BMA



Source: JST

Figure 3.2 Location of Water Quality Monitoring Points in Chao Phraya River

Profile of BOD concentrations along the river is drawn as shown in Figure 3.3. It can be seen that water pollution gradually increases from R02 to R04. The ranges of fluctuation (difference between the minimum and the maximum) become wide from R05. The tendency which shows this large range of fluctuation is continued up to R09 point which is the most downstream monitoring point in the Survey Area. It is thought that this water pollution situation is caused by both the amount of pollution load from the river basin through klongs and flow and tidal conditions of Chao Phraya River.



Source: JST

Figure 3.3 Profile of BOD Concentrations along Chao Phraya River

(2) Present Water Pollution Situation in Klongs in BMA

As for klongs in the Survey Area, the classification of the surface water quality standards is not specified. BMA has set up the target values in their Performance Plan as shown in Table 3.5 for water quality improvement. BOD concentrations are specified for treated effluent and DO concentrations are specified for receiving klongs. It is thought that BOD 10 – 15 mg/l and DO 1.0 – 2.5 mg/l are desirable as targeted values for water quality improvement of klongs.

Table 3.5 Target by Performance Plan (BMA)

	Current Situation	2009	2012	2020
2. Recovered water quality in the target canals.				
2.1 Enhancing the quality of effluent from the BMA's wastewater treatment plants (BOD mg/l)	Less than 15	Less than 15	Less than 10	Less than 10
2.2 Recovered water quality (DO mg/l)	More than 1	More than 1	More than 1.5	More than 2
2.3 Maintained water quality (DO mg/l)	More than 2	More than 2	More than 2	More than 2.5

Source: Performance Plan of Bangkok Metropolitan Administration, 2009-2012

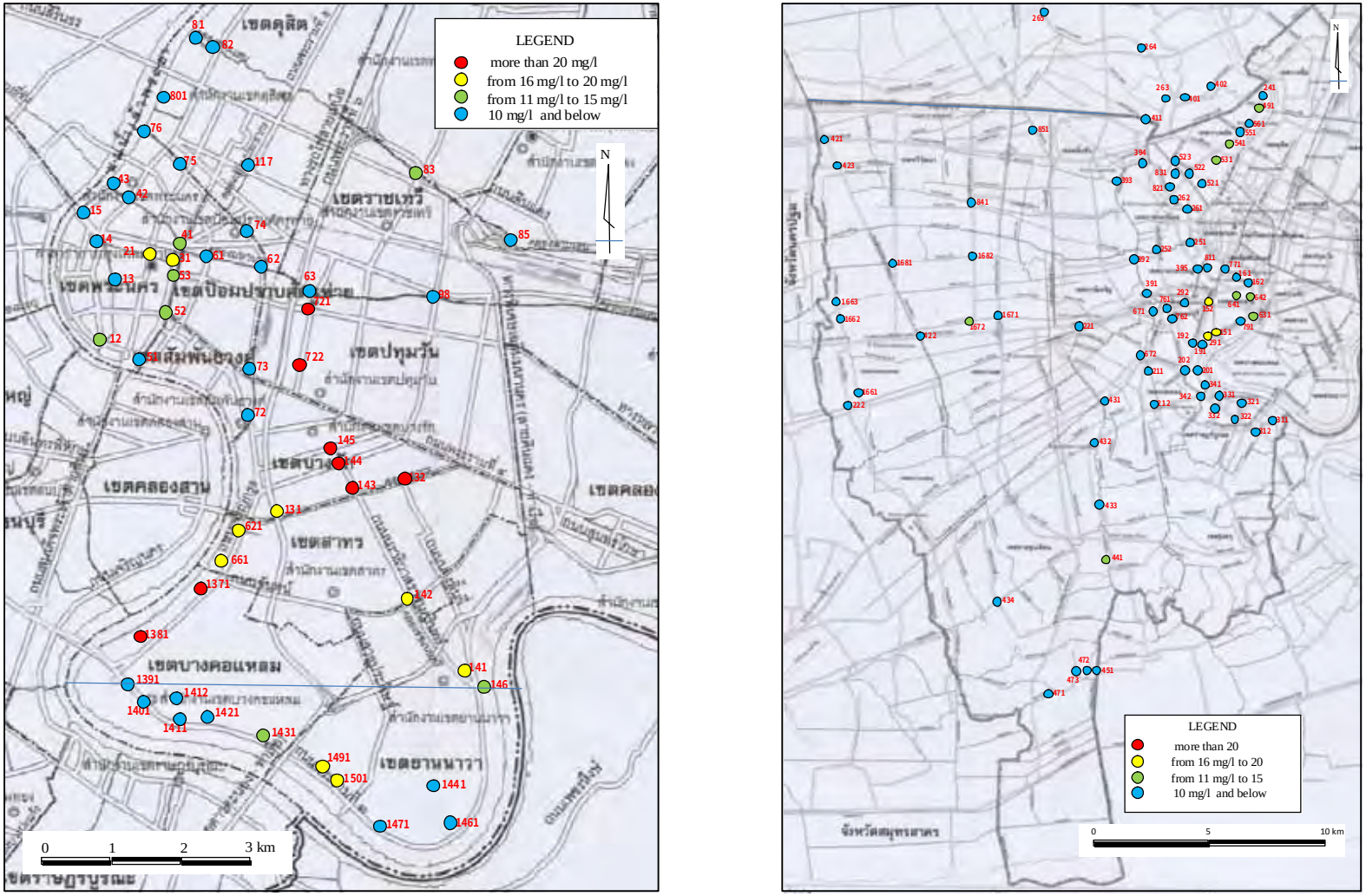
The numbers of monitoring points for klongs in 2009 are 283 points. The points at which BOD concentrations exceeding 15 mg/l (assumed as a provisional target of water quality improvement) out of all monitoring points are 55 on the east bank of Chao Phraya River (Bangkok side area), and three (3) on the west bank (Thon Buri side area). Among them twenty seven (27) points are in existing treatment areas (refer to Figures 3.4).

Correlations between BOD and DO is not significant (coefficient of correlation: r = -0.388). It is obvious that DO concentrations are influenced by other factors than BOD. However, negative correlation implies that reduction of BOD leads to improvement of DO level.

Table 3.6 Correlation of the BOD and DO in Klongs

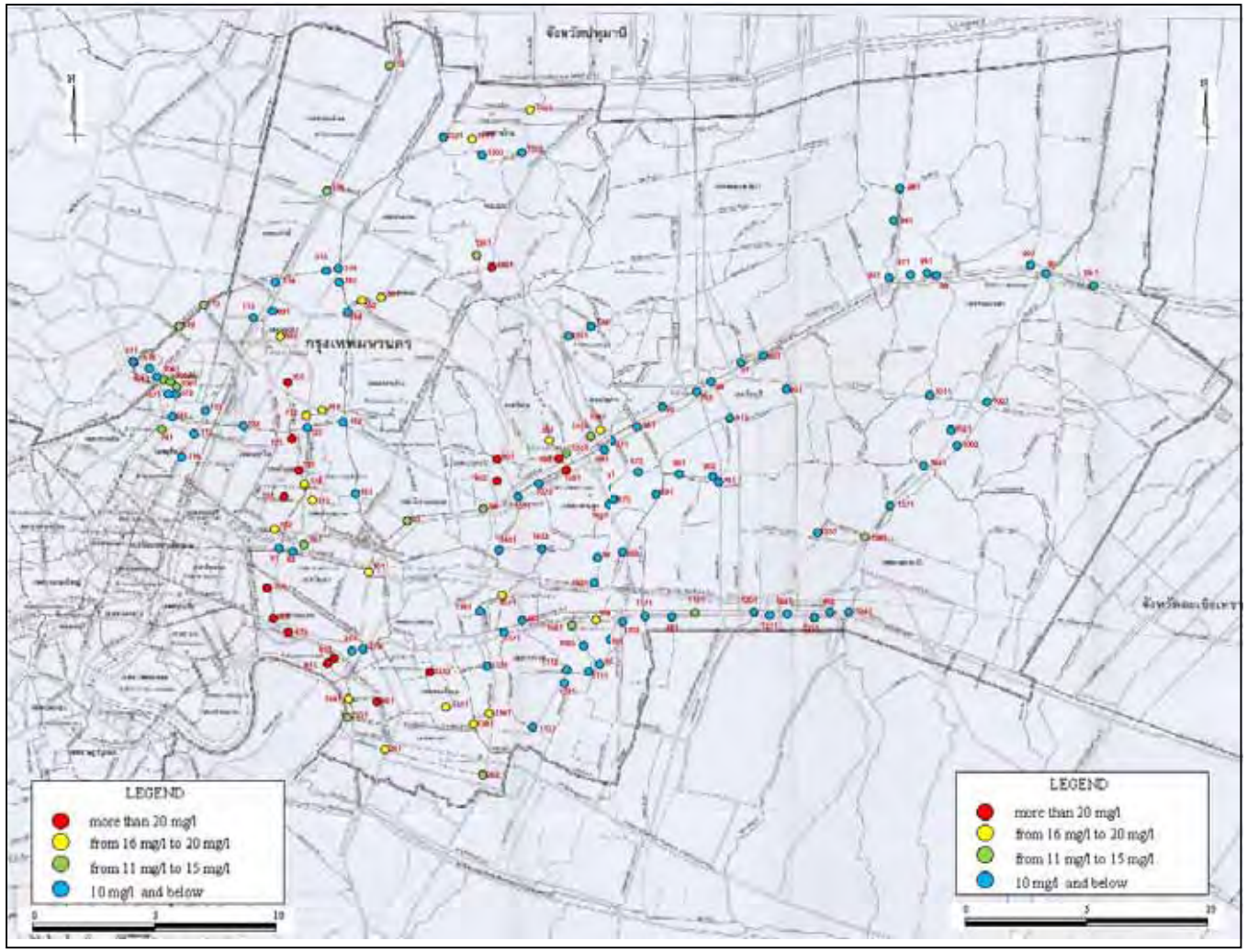
Classification of Water Quality (BOD)	Number of Data					Average DO (mg/l)
	Total	Less than DO 1 mg/l		DO 1mg/l or More		
10 mg/l and below	2,236	596	27%	1,640	73%	1.9
From 11 mg/l to 15 mg/l	524	275	52%	249	48%	1.3
From 16 mg/l to 20 mg/l	247	205	83%	42	17%	0.6
From 21 mg/l to 30 mg/l	208	206	99%	2	1%	0.1
More than 31 mg/l	177	177	100%	0	0%	0.0
Whole	3,392	1,459	43%	1,933	57%	-

Source: JST



Source: JST

Figure 3.4 (1) BOD Concentration in Klong (1/2)



Source: JST

Figure 3.4 (2) BOD Concentration in Klong (2/2)

3.5 Issues for Improvement of Water Environment and Sewerage System

Issues for sewerage projects have been identified from the examination of present situation of sewerage system and water pollution in Chao Phraya River and klongs in BMA area and are summarized below.

- Although measures for improving water quality have been implemented, the water quality improvement effects for Chao Phraya River and klongs are not noticeable. Expansion, speeding up of the measures, and making them more efficient are necessary.
- From the 20 planned treatment areas, WWTPs are being operated only in 7 areas, and the sewage collection rate is low. The sewage treatment rate has reached only about 40%.
- The main reasons for lacking progress are the limited availability of candidate sites for WWTPs and insufficient budget.
- The sewage collection system is a combined system; during rains, sewage together with storm water enters into the klongs and rivers.
- Even in current treatment areas, sewage that cannot be captured flows into the klongs.
- Because of the inadequate construction of interceptor chamber or the lack of maintenance, the klong water flows in the opposite direction in the interceptor pipes, or the sewage collected in the combined sewers flows into the klongs.
- Control over pollution source is not sufficient because of inadequate or cross connection from house connection to drainage pipes.
- Monitoring related to regulations, such as monitoring of business wastewater, is inadequate.
- Because of the above mentioned reasons, pollution concentrations in WWTP inflow are extremely low.
- Coordination between implementation measures against storm water flooding/inundation and countermeasures to improve water quality is inadequate.
- Sewerage service charge is not collected.
- Sewerage laws and ordinances related to compulsory connection to the sewerage system, discharge standards, maintenance and management of facilities, and so on, are inadequate.

Service level of the sewerage system in BMA is still low because of such reasons as inadequate interception of untreated wastewater by intercepting sewerage system, double burden of residents to install septic tanks and house connections, (as installation of septic tank is compulsory), higher priority of storm water runoff drainage for prevention of flooding and traffic congestion, and water pollution in so called “East Venice”.

In institutional aspect, sewerage system is not managed in a unified manner, and Public Works Department and Pollution Control Department are involved in sewerage management in addition to DDS. Regarding control of water quality, cooperation between implementing agency,

i.e. DDS and regulating agency, i.e. PCD is not enough. The current situation is described in the following Sub-Sections.

3.5.1 Technical Issues

(1) Untreated Wastewater Discharge

In the existing treatment areas, collected wastewater is discharged from interceptors resulting in water pollution in nearby klongs. Untreated wastewater is discharged from many existing drainage sewers in non-treatment areas, and flows into klong networks resulting in water pollution in treatment areas.

(2) Situation about Infiltration from Klongs

In many places, storm water drainage pipes are located near the surface of klongs. Necessary water head to flow cannot be obtained in these constructions. As a result, klong water infiltrates into sewer pipes causing problems. Thus, wastewater inside the interceptor is diluted. This is one of the reasons for very low BOD concentrations in inflow to WWTPs, as low as less than 50 mg/l. Low BOD concentrations are caused not only by decomposition of organic materials in septic tank, but also by dilution with infiltration of klong water. Low BOD concentrations of inflow affect operation cost because of additional flow caused by infiltration and result in low efficiency of treatment process due to lack of nutrition for activated sludge.

(3) Water Pollution Caused by the Existing Treatment Facilities

Septic tank which treats only excreta functions as anaerobic process with hydraulic retention time (HRT) of 10 days to a few months. Reduction of pollutant load in septic tank is assumed to be 50 % as same as for anaerobic digester; a half pollution load of excreta is discharged as supernatant to public water body. As a result, 84.5% of pollutant load including sullage is discharged to public water body. Therefore, it is indispensable for conservation of water quality of public water body to collect and properly treat sullage which is currently discharged without treatment.

For newly constructed buildings or new developments, it is compulsory to obtain permission according to Building Control Act and to construct on-site treatment facility in accordance with provisions of Land Development Act to satisfy effluent standards (BOD 20 to 50 mg/l) stipulated depending on types of building. Responsibility to issue permission is assumed by Public Works Department through District Offices. Therefore, countermeasures against water pollution can be expected to a certain extent. For detached houses, provision of septic tanks is compulsory but sullage is discharged through only screen and oil trap without further treatment.

Sources of domestic pollution load can be classified as shown in Table 3.7. It can be said that it is very difficult to improve water environment without provision of treatment of sullage in the existing urban areas.

Table 3.7 Classification of Domestic Pollution Load Sources

Area	Status of Building	Treatment Facility
Existing Urban	Detached House	Excreta: Septic Tank Sullage: No Treatment
	Building	Insufficient treatment for excreta and sullage depending on type of building
New Urban	Detached House	Appropriate treatment for excreta and sullage, for development more than 10 houses
	Building	Appropriate treatment for excreta and sullage depending on type of building

Source: JST

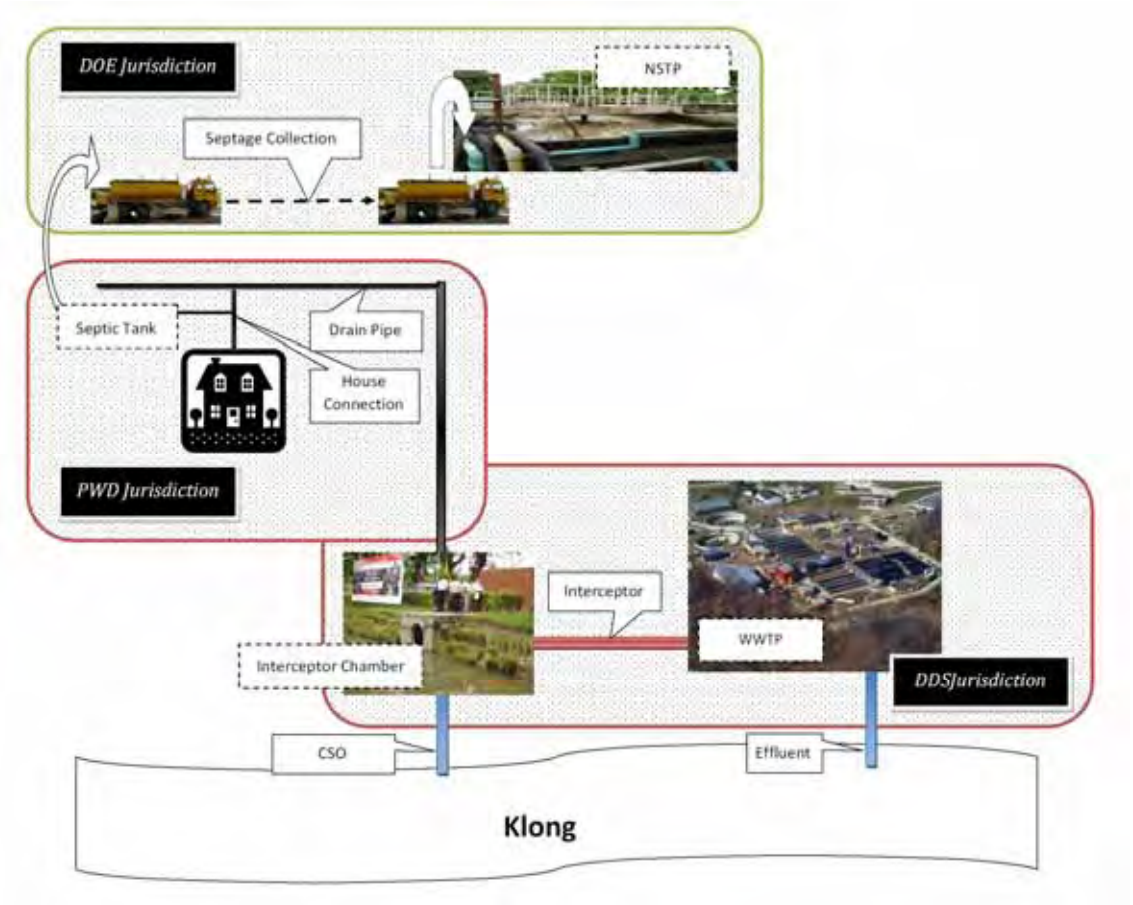
3.5.2 Management and Institutional Issues

(1) Legal Framework

Currently there is no direct sewerage ordinance for sewerage services in BMA. As explained earlier, both the Enhancement and Conservation of National Environmental Quality Act, 1992 and Environmental Quality Promotion and Prevention Act, 1992 specifies that the wastewater must be treated, but these are national level policy acts and do not explain specific operation procedure for Bangkok sewerage. Though BMA Service Administration Regulations Act, 1985 prescribed that BMA should provide sewerage service, it fall short to provide specific business model for sewerage service.

(2) Fragmented Responsibilities

The sewerage system is not managed by one single agency. Septic tank de-sludging and septage treatment are looked after by DOE. Septic tank, house connection and branch sewers are responsibility of PWD while planning and operation of interceptors, interceptor chambers, and WWTP is under DDS. This fragmented jurisdiction is shown in Figure 3.5. Even within the DDS's scope, WWTPs are managed by WQMO and sewers are managed by Sewerage System Division. And these 2 divisions of DDS are under separate administrative chain. Such fragmentation hinders close cooperation and efficient operation.



Source: JST

Figure 3.5 Management Responsibilities in Sewerage Service

4. SOLUTIONS AND STRATEGY FOR SEWERAGE SYSTEM DEVELOPMENT IN BANGKOK

4.1 Solutions for the Problems

Treatment Area		Technical Improvement	Sewerage System (Mid-Term) (Interceptor Sewerage System)	Sewerage System (Long-Term) (Conventional Sewerage System)	Strategy
Existing Urbanized Area	Existing Treatment Area	Measures for Storm Water (Pump Station, Storage) Improvement of CSO (Improvement of Interceptor Chamber)	Improvement of Water Environment Measures for Untreated Wastewater Measures for Infiltration Control Measures for Flood Control	Improvement of Water Environment Treatment of Excreta Measures for Flood Control	Strategy 1
	New Treatment Ares	Measures for Storm Water (Pump Station, Storage) Improved Interceptor	Improvement of Water Environment Measures for Flood Control		Strategy 2 Strategy 3
New Development Area		Criteria for Separate Sytem Criteria for Drainage	Separate Sewerage System Clean New Urbanized Area	Improvement of Water Envt. Measures for Flood Control	
New Role of Sewerage System			Understanding and Participation of Residents	Use of Sewerage Resources Countermeasures for Global Issues	
Institutional Arrangement			Compulsory Connection to Sewerage System Guidelines for Urban Development (Sewerage System is Stipulated in Land Development Act) Promotion of Constructors	Levy of Sewerage Tariff Control of Industrial Wastewater	Strategy 4
Management Body of Sewerage System			Unified Control of Wastewater and Storm Water	One-stop Service for Residents	

Source: JST

Figure 4.1 Step-Wise Sewerage Development

4.2 Strategy for Sewerage System Development

Strategy 1: Improve the Water Environment by Improving the Sewerage System

Strategy 1.1: Improvement of the Interceptor Sewerage System (Thai Combined Type Sewerage System)

Improvement measures for CSO in combined system, existing drainage facilities, and structures and operation of interceptor chamber will be proposed taking into account of the current situation of the interceptor sewerage system in BMA.

(1) Countermeasures for CSO in BMA

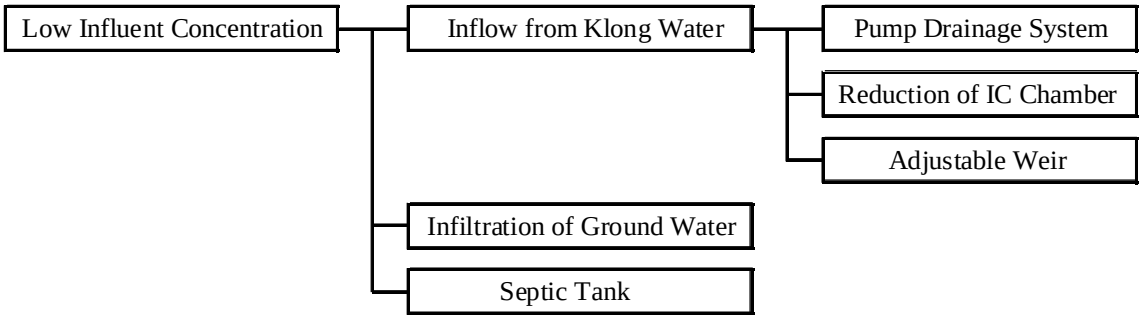
Interceptor sewerage system which collects wastewater together with storm water from combined sewers is adopted in BMA. Land is flat and it is difficult to secure enough head of water level from Chao Phraya River because of topography. Thus interceptors can not be operated to have free flow.

Countermeasures to prevent backflow from klongs and to collect wastewater properly are considered to be effective for sewerage system in BMA. Economical countermeasures include storm water infiltration facility which can be provided in conjunction with urban development project and use of deep tunnel as storage tank for storm water.

(2) Improvement of Storm Water Drainage in Parallel with Improvement of Water Quality in Klongs

Aim of improvement of combined sewerage system (Thai combined sewerage system) is to improve water quality in klongs. It is not too much to say that improvement of water quality in klongs depends on making concentrations of inflow to WWTPs higher than those which are very low at present.

The reasons for very low concentrations of inflow are i) back flow into interceptor chamber from klong, ii) infiltration of groundwater into sewers, iii) reduction of pollutants in septic tanks, and iv) decomposition of pollutants in sewers, as shown in Figure 4.2. Conversion to pump drainage and reduction of interceptor chamber which are described in the next Section are considered to be countermeasures for prevention of back water from klong.



Source: JST

Figure 4.2 Improvement of Low Concentrations of Inflow

Concept of storm water drainage system proposed herewith is described below and introduction of pump drainage system is consistent with urban flood control.

i) Close interceptor chambers as much as possible to prevent back flow from klongs.
ii) Transfer 2 to 5 DWF from existing interceptors to WWTPs.
iii) Storm water which is currently discharged from interceptor chamber is collected by new drainage pipes and pumped to klong.

(3) Countermeasures for Untreated Wastewater Discharge, Combination of Interceptor Chambers

Countermeasures for untreated wastewater discharge are described below. In addition, long term solutions are presented in this Section.

Main Reasons for Untreated Wastewater Discharge

Because of the following reasons, water level in interceptor chamber is high even in dry weather.

- High water level caused by operation of sewerage pump located at downstream end
- Opening of orifice is clogged with garbage

Main reasons for untreated wastewater discharge are not structure of interceptor but are operation of pumps and maintenance of interceptor chamber.

Temporary Countermeasures

Three countermeasures are proposed as follows.

- Lower water level in pump pit not to influence water level in interceptor
- Clean interceptor chamber periodically to prevent clogging with garbage
- Raise level of weir in interceptor chamber which discharges untreated wastewater in dry

weather

Main reasons for wastewater discharge are not structures of interceptor chambers, but operation of pumping stations and maintenance of interceptor chambers. For the moment, pumps should be operated to lower water level in pump pit and periodical cleaning of interceptor chamber should be carried out to prevent untreated wastewater flow in dry weather. Also investigation of structure of interceptor chamber should be carried out. If weir level is too low to cause discharge before flow reaches to 5DWF, weir should be raised.

Solutions for O&M Issues (and Long Term Countermeasures)

DDS carries out periodical cleaning of interceptor chambers. However, according to "Water Quality Management Office – Annual Report 2551 (2008)", Cleaning can not be carried out smoothly due to the following obstacles.

- Heavy traffic in day time, most work is carried out in night time
- Number of vehicles passing and parking prevent opening of manhole

There are more than 1,000 interceptor chambers in BMA. Significant labor and time are required for cleaning of them. For effective operation and maintenance of interceptor chambers, number of them should be reduced in future.

(4) Countermeasures for Backwater from Klong, Change to Discharge by Pump

Countermeasures for backwater from klong are described below. In addition, long term solutions are presented.

Main Reasons for Backwater from Klong

- Controlled water level in klong is higher than that of weir in interceptor chamber
- Flap gate is not completely closed.

Temporary Countermeasures

- Lower water level in klong than weir level in interceptor chamber
- Clean interceptor chamber periodically to prevent clogging with garbage

Controlled water level in klong is to be lowered in dry season than that of weir in interceptor chamber to prevent backflow from klong. Backwater can be prevented if water level is controlled below the recommended level.

However, for 29 interceptor chambers investigated (1 in Chatuchak, 1 in Din Daeng, and 27 in Chong Nonsi), it is difficult to prevent backflow by only lowering water level, periodical cleaning of interceptor chamber is also necessary to make flap gate function properly.

Long-Term Countermeasures

Controlled water level is higher than those of weirs in all interceptor chambers in Chong Nonsi treatment area, prevention of backwater is very difficult. In long-term, it is necessary to demolish all interceptor chambers and to change the drainage system in this treatment area to pump drainage system.

At five interceptor chambers in Rattanakosin treatment area, controlled water level in klong is higher than those of weirs in dry season. This treatment area includes main tourism area, and it is difficult to lower water level in klong because of aesthetic reasons. For this treatment area, demolishing of interceptor chambers and change of drainage system to pump drainage system will be necessary in future as proposed for Chong Nonsi treatment area.

(5) Collection of Untreated Wastewater and Investigation of Existing Drain Pipes for Improvement

Wastewater generated from households generally flows through drain pipes installed along the roads and is intercepted in interceptor chambers and conveyed to WWTPs in treatment areas or discharged to klongs directly in non-treatment areas in BMA. However, it was observed at many places that wastewater does not flow in drainage pipes, but is discharged directly to klongs where houses and buildings are located next to klongs. Also stagnation of wastewater in low lands is observed in some places.

It is very important to collect untreated wastewater and to connect to the sewerage system securely in treatment areas to improve living environment and water quality in public water bodies. Therefore, it is necessary to realize complete collection (100 %) of wastewater in the future by conpalsory connection to the sewerage system by law and subsidiary from BMA or district office for plumbing works inside houses.

(6) Short Term and Medium- and Long-Term Improvement Measures

Short term and medium- and long-term improvement measures for interceptor sewerage system are proposed as mentioned in Table 4.1 and showed in Figure 4.3.

Table 4.1 Short-Term and Medium- and Long-Term Improvement Measures

Treatment Area	Short-Term	Medium- and Long-Term
Existing	(Interceptor Sewerage System) *Hard* ・ Lower water level in pump pit at WWTP ・ Periodical cleaning of interceptor chamber (orifice and flap gate in particular) ・ Investigation of all interceptor chambers, and	(Conventional Sewerage System) ・ Demolishing or reducing of interceptor chambers ・ Separation of natural drainage area and pump drainage area (change to pump drainage area if water level in discharging water body is

Treatment Area	Short-Term	Medium- and Long-Term
	modification of level of weirs if overflow in dry weather occurs ・ Lower water level in klong in dry season *Soft* ・ Establishment of organization to discuss collection of untreated wastewater ・ Investigation of the existing drainage pipe networks for improvement	high) ・ Effective use of drainage facilities (e.g. use of deep tunnel in small rain fall)
New	・ Combine outlets of interceptor chambers as much as possible ・ Raise level of interceptor chambers higher than controlled water level in klong ・ Modify structure of interceptor chamber not to cause overflow in dry weather ・ Introduce separate system in a part of treatment area	Ditto as above

Source: JST

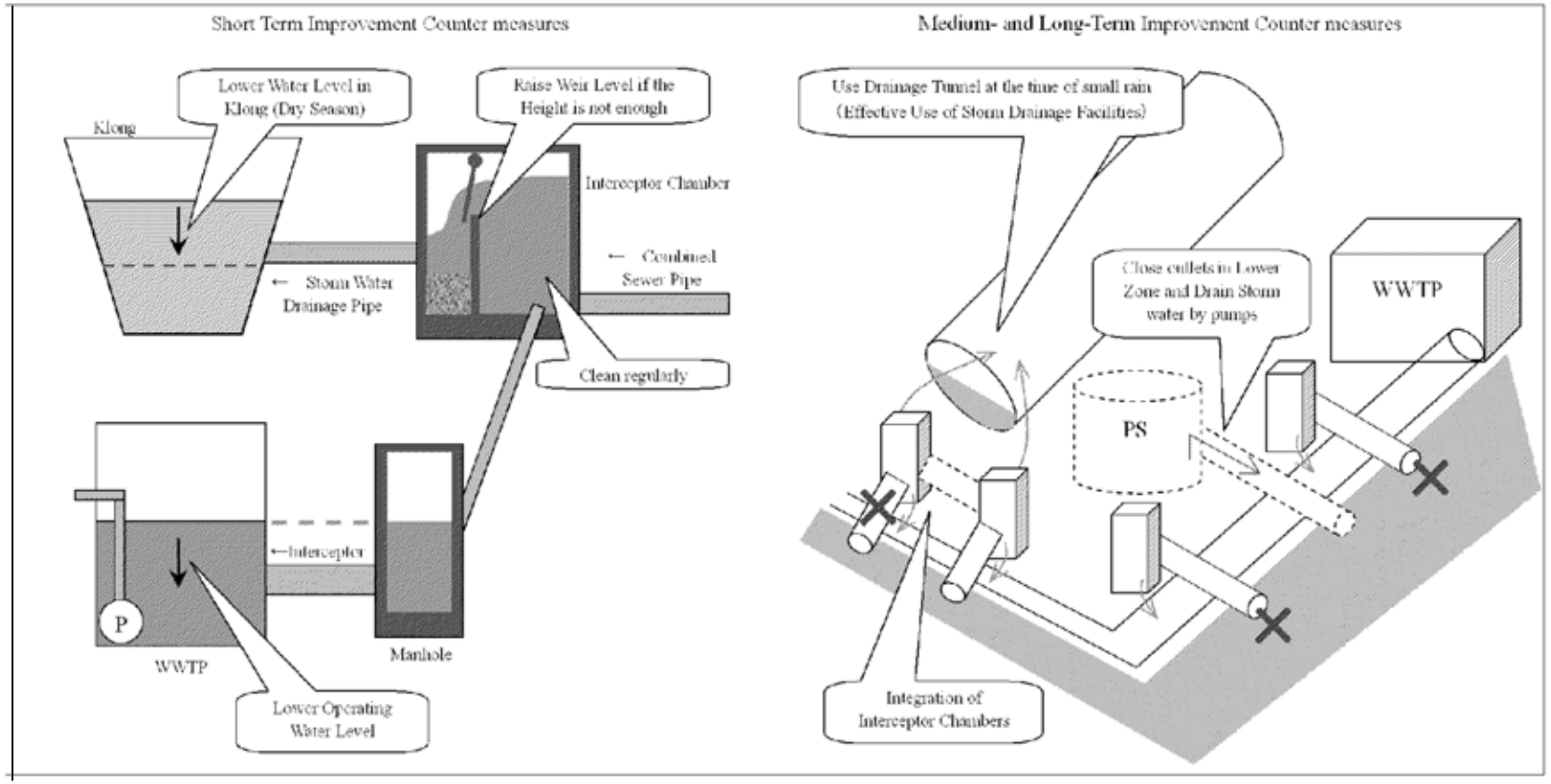
Strategy 1.2: Appropriate Treatment of Human Excreta and Septage

(1) Treatment at WWTP and Disposal of Septage

Septage can not be treated properly by activated sludge process and characteristics of effluent are not good as can be seen at On Nuch treatment plant. Combination of nitrogen removal and advanced treatment (coagulation, sand filtration, followed by activated carbon adsorption, or ultrafiltration) is adopted for septage treatment plant which discharges to a river. In large cities in Japan where sewerage system are provided, septage is usually received at WWTP and treated with wastewater.

Received septage is diluted with wastewater and treated. Sludge is received at the following three points:

Sewer network (manhole)
Wastewater treatment (grit chamber)
Sludge treatment (digester)



Source: JST

Figure 4.3 Concept of Short Term and Medium- and Long-Term Improvement Countermeasures

(2) Effects of Receiving Septage

Following effects can be expected if septage is received at WWTP.

- Characteristics of treated effluent will be improved because of proper septage treatment compared to effluent from the existing On Nuch treatment plant.
- Renewal of deteriorated and suspended facilities at present i.e. sand filtration and ozone treatment will not be needed.
- Double investment for common treatment facilities to septage and wastewater treatment can be avoided.
- Transfer of septage from smaller lorry (2 m^3、3 m^3) to large one (10 m^3) become unnecessary resulting in more efficient operation. Total running distance of lorries can be shortened because larger number of WWTPs are scattered than two existing septage treatment plants.
- Higher BOD and SS concentrations of inflow are expected at receiving WWTP, and design capacity of the existing WWTP can be utilized.

Strategy 1.3: Measures for Business Wastewater

There are many restaurants, food markets, hospitals, gasoline stands, cleaning shops and other business entities within sewerage treatment areas. Some of them discharge wastewater into sewers with high concentrations of organic matters, oils and grease, heavy metals and high water temperature which are difficult to be treated by biological treatment. These cause clogging of pipes, corrosion of concrete structures, and lowering of treatment function. If effluent from WWTP does not satisfy Effluent Standards (published in June, 2010) due to these factors, administrator of the sewerage system is to blame.

All business entities should be investigated regarding their production processes, characteristics of wastewater, existence of pre-treatment facility. In this regard, application and registration to sewerage administration authority, responsibility of installation of pre-treatment facility, and wastewater standards for discharging to sewerage system should be formulated. Sewerage ordinance in which wastewater standards, responsibility of installation of pre-treatment facility and its registration, inspection on the spot, management of wastewater are stipulated will authorize administration authority to assume its responsibility.

Strategy 2: Improve the Water Environment by Expansion of the Sewerage System

Strategy 2.1 Expansion of the Sewerage System

(1) Rearrangement of the Existing Treatment Areas

Investigation of existing treatment areas was carried out to grasp marginal treatment capacity and possibility of expansion of the existing WWTPs by reviewing current wastewater flow, design capacities and future wastewater flow. If a certain existing WWTP has marginal design capacity to accommodate wastewater flow from neighboring treatment areas, wastewater would be re-distributed so that construction cost of new WWTPs would be reduced.

Utilization of marginal treatment capacity of Din Daeng WWTP and other WWTPs would be investigated.

(2) Adoption of Compact and Energy Saving Treatment System

DDS has difficulty to secure sites for construction of WWTP in urbanized areas. Acquisition of land for WWTP is the key factor for successful implementation of the sewerage project. Under the circumstances multi-storied or underground WWTPs have been constructed in BMA neglecting efficient use of energy.

Comprehensive coordination with relevant authorities is required regarding acquisition of land for WWTPs. Also planned and effective use of publicly owned land should be considered. Prior investment for land acquisition should be investigated. At the same time, compact treatment system, enhancement of operation and maintenance and energy saving technology to utilize limited land should be investigated.

Strategy 2.2: Separate Sewerage System Pilot Project

Separate sewerage system is a potential technique to improve the interceptor sewerage system (Thai combined type sewerage system). It is easier to develop the separate sewerage system in new urban development area, where a pilot project of separate sewerage system will be proposed. The pilot project is to be a model case technically and institutionally for BMA.

Project site should be selected among the following areas to evaluate the effects of pilot project easily.

- New urban development area with residential/commercial area, (Individual WWTP)
- On going new urban development area and existing treatment area where it is possible to receive wastewater in public sewerage system (Flow into exiting interceptor)

- New urban development area close to existing interceptor where it is possible to improve interceptor chambers
- Exemplary area where people fully understand role/function of sewerage system, do not discharge garbage/oil into sewer and pay sewerage tariff

Strategy 3: Enhance the Level of Sewage Services for the Society

Sewerage system has a role of not only the improvement of public sanitation, water quality preservation and storm water drainage but also circulatory function to put back contaminant (organic matter) discharged by city activities to the natural environment. Using treated wastewater and sewage sludge which are generated every day in cities can contribute as resources to recycling society and prevention of global warming. Understanding of inhabitants is indispensable for not releasing oil to sewers and using treated wastewater as one of countermeasures against CSO. The following are suggestions to improve various roles and services of sewerage.

(1) Reuse of Treated Wastewater

In Bangkok, treated wastewater is used in a positive manner as sprinkling water for roadside trees and landscape water. In the dry season it is utilized as the water source of green area and parks of BMA, since excessive drawing of groundwater is regulated.

Treated wastewater is used for not only irrigation but also for cooling water of air conditioner and replacement of groundwater, and reclaimed water supply to new urban areas. Reuse for cooling water by hygienic operation will contribute to mitigate global warming because water has higher heat exchange rate than that of air.

(2) Use of Sewage Sludge

At the Nong Khaem WWTP, all of sewage sludge are transported from other six WWTPs and digested and dewatered. Experiment to use digestion gas for low cost generator with automobile engine is carried out. In addition, sewage sludge is used as soil conditioner for trees lining a streets and parks. All of the composted sewage sludge is taken over from composing site.

The following problems are expected along with expansion of sewerage system

i) Increase of sewage sludge volume
ii) Toxic substance contained in sewage sludge
iii) Composting of urban waste

The following uses of sewage sludge as resources are considered , i) use as biogas and solid fuel, paying attention to fuel value of sewage sludge, ii) increasing biogas by mixing treatment with urban waste, and iii) use as solid fuel, dry sewage sludge and send to factories having a coal boiler and/or the biomass boiler.

(3) Countermeasures for Global Warming Mitigation

In Action Plan on Global Warming Mitigation 2007-2012, construction of wastewater treatment plants to control emission of methane gas, and campaign for citizens not to dump wastes to klongs are planned.

Comprehensive effects of global warming mitigation measures are expected directly from improvement of wastewater treatment and sewerage system and indirectly from utilization of sewerage resources and cooperation with other authorities such as DOE which is responsible for septage treatment. Countermeasures in sewerage system are described in Table 4.2.

Table 4.2 Countermeasures on Global Warming Mitigation in Bangkok

Sewerage Facility	Effective Examples of the Countermeasures
Sewer System	Considering warming coefficient (CH_4 / CO_2 =21), reducing CH_4 generation in klong by means of collecting wastewater discharged into klong.
Treatment Facility	Energy saving design by setting lift head of lifting pump adequately Adoption of the energy saving machinery
	Energy saving operation like air control of reaction tank
	Prevention of N_2O generation by setting anaerobic and aerobic operation adequately in the reaction tank
Reuse of Treated Wastewater	Reduction of water supply by using treated wastewater
	Reduction of heat exchange energy by using treated wastewater for cooling water
Use of Sewage Sludge	Energy creation by digestion gas
	Reduction of fuel by using sewage sludge as solid fuel
	Considering warming coefficient (CH_4 / CO_2 =21), replacing CH_4 generation at sludge disposal site to CO_2 of solid fuel .
Acceptance of Septage	Energy consumption efficiency difference between septage treatment facility and wastewater treatment plant
	Reduction of the mileage of septage transportation tank car
Public Information and Public Hearing	Reduction of energy/electricity consumption by campaign to public to reduce environmental load such as edible oil or discharged wastewater

Source: JST

Strategy 4: Improve the Management of the Sewerage Works

Strategy 4.1: Management Improvement in Sewerage Services

Sewerage system needs a large amount of fund for construction and operation and maintenance of facilities. The most important thing is financial sustainability for continuing the sewage

project. In order to keep sustainable sewerage management, it is required to grasp about construction costs, operation/maintenance costs and future renewal costs, to reduce construction and operation and maintenance costs, and to collect sewerage charge from users. Understanding of sewerage users can be acquired when they understand their contribution and effects of sewerage system for improvement of environment.

(1) Capital Cost Financing

The magnitude of required financing to implement the sewerage M/P is significant. Until now, all WWTPs and sewers were constructed on the basis of Central Government grant and BMA own budget. To expedite the implementation, it is important to secure alternate financial source. Some of these options are explained here.

i) Central Government Allocations:
ii) BMA Allocations:
iii) Environmental Fund:
iv) International Financing Institutes:
v) ODA from Development Partners:

(2) Sewerage Tariff

On the other hand, operation cost recovery is essential for business sustainability. Until now, BMA has not introduced sewerage tariff. It is strongly recommended to introduce sewerage tariff as soon as possible.

In 2004, BMA obtained approval of "BMA Ordinance: Collection of Wastewater Tariff, 2004" from BMA Council and Minister of Interior. This ordinance mentions that whenever BMA set up a sewerage treatment area, BMA can ask anybody living within the area to pay the sewerage tariff. The charge volume is equal to the water consumption. Even in case of not using supply water, sewerage tariff has to be paid. The proposed tariff is shown in the following Table 4.3. It is proposed, 1 Baht/m^3 is applied for residence for the first 3 years and then increase by 0.25 Baht/m^3 every 6 months reaching to 2 Baht/m^3 by 5 years. Though BMA had an intention to introduce the sewerage tariff from 2004, it has not been implemented yet.

Level of tariff rates, i.e. rates for residence, government agencies, small scale commercial establishments and restaurants, are equal to operation and maintenance cost, and those for large commercial/business establishments, multi functioning buildings, industries and so on are equal to operation and maintenance cost plus a portion of initial cost recovery.

The rates were proposed in 2004, hence it is required to review to reflect price escalations. It is recommended that tariff rates should be reviewed every 3 years.

It is expected that the sewerage tariff will be collected together with the MWA bills. However, according to Database and Tariff Office of WQMO, no MOU has been signed with MWA yet. It may be noted here that there are only 2 user type defined for water tariff, residential and non residential. On the other hand, proposed sewerage tariff has many user categories. To solve this problem, Database and Tariff Collection Section under WQMO should carry out exercise to develop customer database similar to proposed sewerage tariff categories.

Table 4.3 Rates of Proposed Sewerage Tariff

User Category	Sewerage Tariff Rate (Baht/m^3)
Residence with water use over 10 m^3/month	2
Govt. agency, state enterprises, office	2
Religious places, educational institute, foundations	2
Hospitals	4
Hotels	4
Shopping Malls, Department Stores	4
Fresh Markets	4
Restaurants Space less than 100 m^2	2
Space more than 100 m^2	4
Massage Parlous and spa	4
Commercial/ Business Space less than 100 m^2	2
Space more than 100 m^2	4
Multi function building	4
Industry Wastewater less than 200 m^3	4
Wastewater between 200 and 500 m^3	6
Wastewater more than 500 m^3	8
Others	4

Source: Wastewater Tariff Code of Law, BMA, 2004

Affordability

In order to develop and operate effective sewerage system, sizeable amount of funds are required. From a viewpoint of 'polluter pays principle', all residents should share the cost of proper wastewater treatment to mitigate environmental impacts on downstream areas.

It was found that within Bang Sue WWTP area, only 60% of interviewees have a willingness to pay wastewater fee at 1.1 Baht/m^3 (Bang Sue Environmental Education and Conservation Project, Vol. 2, 2006). This is about half of the tariff proposed in 2004.

A more recent WTP study was carried out by Database and Tariff Collection Section of WQMO from 18th January to 12th February 2010 in 20 districts of existing sewerage area on 2,300 samples. According to results of the survey, only 56% of interviewees have a willingness to pay wastewater fee. Then a new interview on suitable tariff shows 2,186 interviewees (95%) have a willingness to pay a certain rate. However about 80% of the respondents mentioned that the rate should be between 0.5 and 1.0 Baht/m^3.

(3) Renewal and Rehabilitation Works for WWTPs

It is said that expected life time of machinery/electric facilities is about 20 years, and renewal and rehabilitation of facilities is repeated continuously. Si Praya WWTP starts operation in 1990, and 20 years has passed. The deterioration of pump and screen facilities, dewatering machine, etc. is progressing, and the time of renewal/rehabilitation will come soon. Then for the other WWTPs the renewal time will come in sequence.

(4) Performance Indicators (PIs) for Enhancement of Sewerage Service

Performance indicators (PIs) can be considered as a management tool to evaluate the degree of undertaking's efficiency and effectiveness. Efficiency is the extent to which the resources of an undertaking are utilized to provide the services, e.g. maximizing services delivery by the minimum use of available resources. Effectiveness is the extent to which declared or imposed objectives, such as levels of services, are achieved. PIs can also be used for quantitative comparative assessment of performance. This quantitative comparison can be conducted between undertakings, or historically within an undertaking comparing the past and present or actual performance against pre-defined target.

Performance of an undertaking can be evaluated from various aspects and wastewater services are composed of numerous complicated activities. Therefore, a number of PIs have been developed and made available. Wastewater services in different countries have different histories, and they have different roles. Therefore, selection of proper PIs for each undertaking is most desirable.

Strategy 4.2: Private Sector Cooperation

Public-private cooperation in following field is effective to reduce both initial cost and O&M cost of sewerage facilities.

(1) Cooperation with Urban Development Project

Building Law and Regulation 2001 and Land Development Act 2000 require urban development project to install sewerage facilities in project site. Layout and capacity of sewer pipes, connection to public sewerage system, use of rain water and treated wastewater should be enforced on or discussed with developer in order to harmonize the facilities with public sewerage system. This will also benefit developer, and win-win relation will be established.

(2) Promotion of Registered Plumbers

Installation of house connection is carried out with closest attention in Japan, because inadequate house connection cause breakdown of pipe, increasing of infiltration flow, and cross connection of wastewater pipes and storm water pipes.

Only registered plumbers are permitted to undertake house connection exclusively in Japan. Registered plumbers are requested to employ skilled engineers and workers, to have employee attend scheduled training sessions to obtain necessary qualifications, and to possess adequate equipments for work. Registered plumbers are expected to resolve minor troubles such as clogging of sewers in collaboration with public sector.

As mentioned above, it is important to promote registered plumbers in BMA since plumbers assume important role.

(3) Consignment of Operation and Maintenance Works to Private Company

Wastewater treatment plants, pumping stations and interceptor sewers of Si Praya and Rattanakosin treatment areas are operated and maintained by DDS own staff and facilities in other five treatment areas are by O&M companies which DDS entrusts to. The contract period of operation and maintenance works of the facility is five years. Operation and maintenance costs are categorized into fixed cost (personnel cost) and variable cost (power costs for pumping and wastewater treatment and sludge treatment). Variable costs are calculated and paid for based on volume of treated wastewater and sludge. Operation and maintenance know-how gained by DDS own staffs are disclosed to O&M company staffs for effective operation and maintenance.

Strategy 4.3: Improvement of Institution of Sewerage Works

Countermeasures to resolve these issues are presented below.

(1) Bringing of Fragmented Responsibilities of Sewerage Services into One Agency

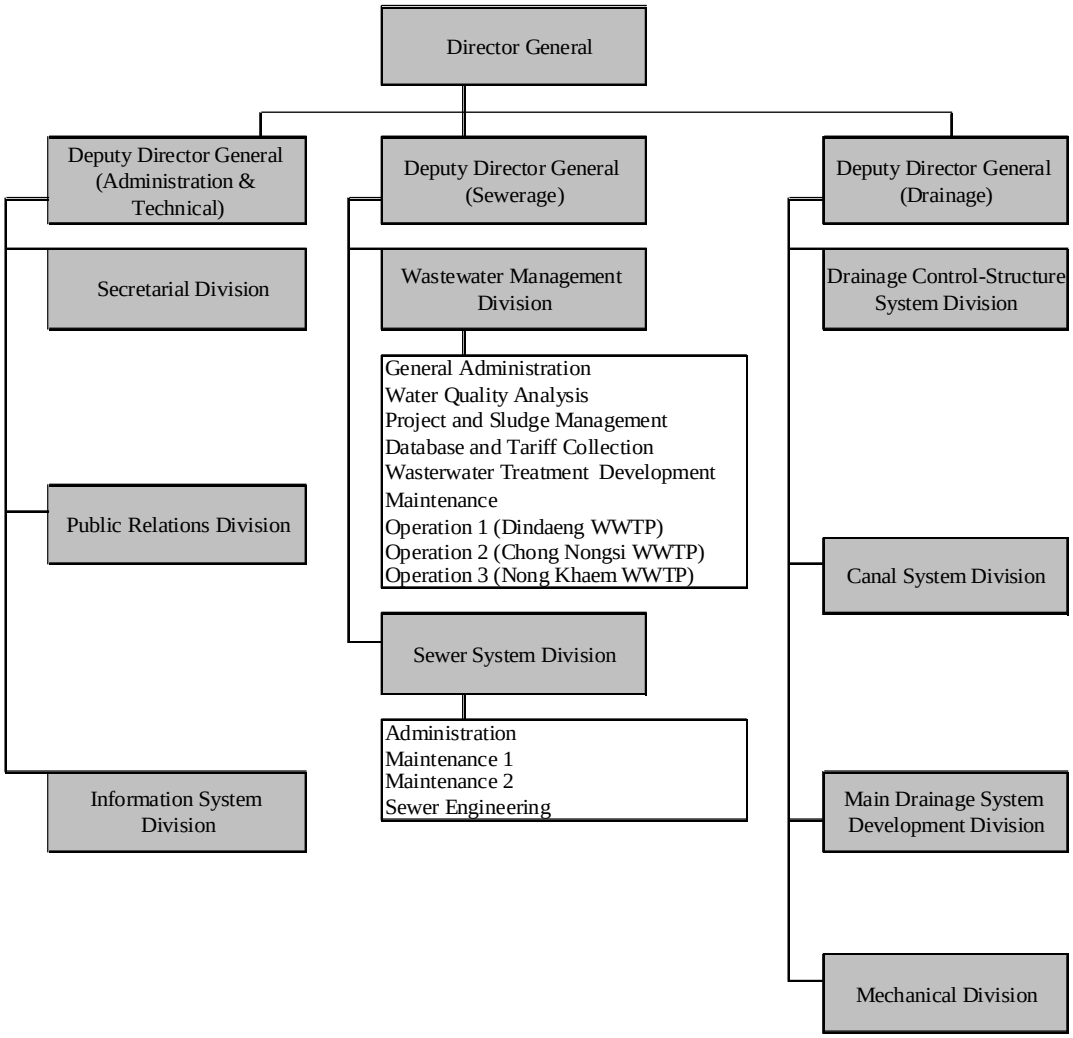
To introduce one stop service for the entire sewerage sector, it is recommended to bring entire sewerage related services under the umbrella of one responsible agency. Relevant tasks currently undertaken by PWD are proposed to be transferred to WQMO of DDS.

To bring the entire sewerage service under one roof, modification in DDS organogram is recommended. The proposed organogram is shown below. Also, legal instruments are needed to shift sewerage related responsibilities of PWD to DDS.

In this proposal, divisions are streamlined on the basis of similar work responsibility. Also, names of some sections are updated to reflect their actual tasks. A new Public Relations Division is proposed to maintain customer satisfaction. PWD's responsibility to maintain house

connections and small sewers is proposed to transfer to Sewer System Division.

There should be certain numbers of branch offices or sections of WQMO located conveniently throughout the service area. This should also act as a claim section or customer service office. This will be a necessary arrangement when WQMO assume entire service from the household to the treatment and disposal.



Source: JST

Figure 4.4 Proposed Organogram of DDS

(3) Public Private Partnerships (PPP)

Public-private partnership (PPP) describes a service or business venture which is funded and operated through a partnership of government and one or more private sector companies. Currently, 5 of the BMA's 7 treatment scheme are operated by private companies through 5 year management contracts. To increase the functional efficiency, it is proposed to consider the use of

private firms for specialized operation like periodic inspection of large diameter sewers. This will reduce the need of BMA permanent staff and also ensure higher quality.

However, the agreement should be made very carefully to tap the maximum benefit. For example, in a management contract for a WWTP, there should be performance indicator (PI); that is, if the effluent quality exceeds a certain limit, there should be penalty clause.

Various forms of PPP as shown in Table 4.4.

Table 4.4 PPP Forms and Their Features

PPP Form	Main Features
Service Contract	Specific tasks only in return to fixed and variable fee. For example, installing meter, meter reading, sampling, repair, staff training, etc.
Management Contract	Operation and maintenance of a facility with management decisions made by private firm. The utility finances both capital and working funds. For example, WWTP, pumping station, routine sewer cleaning, etc.
Lease Agreement	O&M, but private firm mobilizes working fund. The lease holder usually retains a part of tariff and assumes assets of limited life time.
Concession Agreement	O&M, but private firm mobilizes both working fund and capital fund. Assumes fee collection rights. More suitable for water supply.
Built-Operate-Transfer (BOT)	Public sector finances, operates with fee collection rights, transfers to public sector. Possible for sewerage sector.
Built-Operate-Own (BOO)	Public sector finances, operates with fee collection rights, but never transfers to public sector. Not suitable for sewerage sector.
Alliance	Public sector, constructor, and operator assume equity of a 'special purpose vehicle' on profit risk sharing basis. Not suitable for sewerage sector.
Public Finance Initiative (PFI)	Private investment, private ownership. Public sector operates by taking lease. More costly than commercial bank financing but no public sector risk for asset.

Source: JST

For complete implementation of this M/P, it is thus proposed to investigate the potential of PPP in the form of Lease agreement for O&M, and BOT for new plant. Some of simple and repetitive tasks should be out-sourced.

Strategy 4.4: Stipulation of Sewerage Ordinance

Currently there is no direct sewerage ordinance for sewerage services in BMA. To implement this master plan and sewerage woks, necessary legal envelope is a must. It is indispensable to set Sewerage Ordinance of BMA which is fundamentals of sewerage management. Thus it will be possible to impose duty, regulation and user charge for inhabitants and an enterprise for usage of sewer system. The ordinance should cover, at least:

- Sewerage service connection,
- Status of onsite treatment,

- Sewerage treatment,
- Sewerage tariff, and
- Authority of DDS

In addition, it is desirable that the Sewerage Law of Thailand will be established through MONRE as jurisdiction ministry, because it becomes the higher rule of the sewerage ordinance of the local government.

Individual strategies classified by the above categories are summarized in Table 4.5 together with responsible agencies.

Table 4.5 Strategy for Sewerage System Development and Responsible Agency

	Individual Strategy for Sewerage System Development	Responsible Agency	Issues and Requirements
Strategy 1.1	1) Countermeasures for CSO	DDS	Coordination with Related Drainage Development Division, DDS
	2) Improvement of storm water drainage in parallel with improvement of water quality in klongs	DDS	Coordination with Related Drainage Development Division, DDS
	3) Countermeasures for untreated wastewater discharge, combination of interceptor chambers	DDS	Coordination with Related Drainage Development Division, DDS
	4) Countermeasures for backwater from klong, change to discharge by pump	DDS, BMA	Secure budget Coordination with Related Drainage Development Division, DDS
	5) Intercepting rate 6) Collection of untreated wastewater and investigation of existing drain pipes for improvement	DDS DDS, PWD	Coordination with Related Drainage Development Division, DDS Coordination with Related Drainage Development Division, DDS Coordination with other concerned departments of BMA
	7) Short term and medium- and long-term Improvement measures	DDS, PWD, BMA	Secure budget Coordination with Related Drainage Development Division, DDS Coordination with other concerned departments of BMA
Strategy 1.2	1) Strengthening of human excreta treatment	DOE, DDS	Coordination with other concerned departments of BMA
	2) Reception of septage to WWTP	DOE, DDS	Coordination with other concerned departments of BMA
Strategy 1.3	1) Measures for business wastewater	DOE, DDS, PCD	Coordination with other concerned departments of BMA Coordination with government authorities concerned Establishment of new institutions or amendments regulations
Strategy 2.1	1) Rearrangement of the existing treatment areas	DDS	
	2) Compact and energy saving treatment system	DDS	

	Individual Strategy for Sewerage System Development	Responsible Agency	Issues and Requirements
Strategy 2.2	1) Verification of separate sewerage system pilot project	DDS, PWD, PCD	Coordination with other concerned departments of BMA Coordination with government authorities concerned Establishment of new institutions or amendments of regulations
Strategy 3	1) Reuse of treated wastewater	DDS, PWD	Coordination with other concerned departments of BMA
	2) Use of sewage sludge	DDS, PWD	Coordination with other concerned departments of BMA
	3) Global warming mitigation	DDS, BMA, MONRE	Coordination with other concerned departments of BMA Coordination with government authorities concerned
Strategy 4.1	1) Capital cost financing	DDS, BMA, MOF	Secure budget Coordination with government authorities concerned
	2) Sewerage tariff	DDS, BMA, MWA, MONRE	Coordination with government authorities concerned
	3) O&M cost projection	DDS, BMA,	Secure budget
	4) Renewal and Rehabilitation Works for WWTPs	DDS, BMA, MOF, MONRE	Coordination with government authorities concerned
	5) PIs for enhancement of sewerage service	DDS, BMA,	Secure budget Coordination with government authorities concerned
Strategy 4.2	1) Cooperation of urban development project	DDS, PWD, BMA	Coordination with other concerned departments of BMA
	2) Promotion of registered plumbers	DDS, PWD, PCD	Coordination with other concerned departments of BMA Coordination with government authorities concerned
	3) Consignment of O&M works to private company	DDS	
Strategy 4.3	1) Integration of fragmented responsibilities	DDS, PWD, DOE	Coordination with other concerned departments of BMA Coordination with government authorities concerned
	2) Onsite treatment standard	DDS, PWD, DOE	Coordination with other concerned departments of BMA Coordination with government authorities concerned
	3) PPP	DDS, BMA	Coordination with other concerned departments of BMA
	4) Public participation	DDS, BMA	Coordination with other concerned departments of BMA
	5) Staff and human resource development	DDS	

	Individual Strategy for Sewerage System Development	Responsible Agency	Issues and Requirements
Strategy 4.4	1) Sewerage ordinance	DDS, BMA, PCD	Coordination with other concerned departments of BMA Coordination with government authorities concerned Establishment of new institutions or amendments of regulations

Source: JST

Followings are details of the Strategies.

5. CONCEPTUAL SEWERAGE MASTER PLAN

5.1 Target Year and Treatment Area

According to Performance Plan of Bangkok Metropolitan Administration 2009 – 2012, prepared in 2008, treatment ratio of wastewater was targeted to be 60 % in 2020.
In this Conceptual Master Plan, target years of long term master plan and medium term are set at 2040 and 2020 respectively. Treatment ratio is considered to be raised gradually and objective treatment ratio in 2040 is targeted to be 80 % .

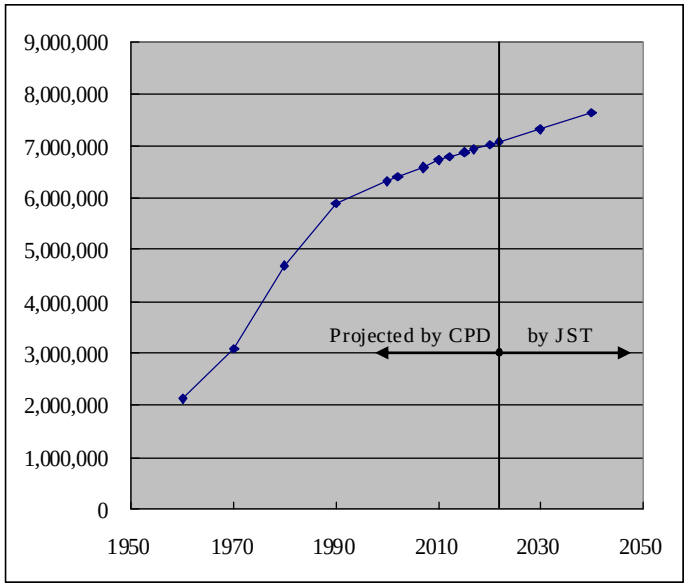
To achieve this objective, entire urbanized area will be included in the treatment area principally. Although, some isolated industrial areas surrounded by agricultural area are the exceptions.

5.2 Population Projection

(1) Population of BMA

City Planning Department estimated future population of BMA up to 2022 based on the census data. Their population projection is shown in Figure 5.1 and Table 5.1. According to the projection annual increase of approximately 30,400 people was estimated from 2010 to 2022.

Population in 2030 and 2040 was estimated by extrapolation on the assumption that this tendency would continue until 2040. Population projection up to 2040 is shown in Figure 5.1 and Table 5.1, since population growth was stabilized from 1990 after rapid increase during 70s' and 80s'.



Source: JST and City Planning Department, BMA and JST

Figure 5.1 Population Projection by City Planning Department and JST

Table 5.1 Projected Population (2030 and 2040)

Year	Projected Population	Population Increment	Growth Rate	Remarks
2010	6,714,954	30,361 person/year	0.44%/year (an average for 12 years)	City planning Department
2012	6,775,676			
2017	6,927,480			
2020	7,018,563			
2022	7,079,285			
2030	7,322,390	Same as above	-	JICA Survey Team
2040	7,626,000			

Source: JST and City Planning Department, BMA and JST

(2) Population Projection by Administrative Districts

Population projection by districts has been carried out taking into account projected future population of BMA shown in Table 5.1 and population growth tendencies of districts. Future populations of districts whose population has decreased are assumed to maintain present population (2008). And those of other districts will increase depending on population growth tendency.

5.3 Water Supply Plan of MWA

(1) Water Supply Plan

Water supply in BMA is solely managed by Metropolitan Waterworks Authority (MWA). Service area of MWA covers BMA area and neighboring provinces. Amounts of supplied water from 2000 to 2009 were obtained from the annual reports. Projection of water production until 2057 was also obtained in interview with the authority. These figures are shown in Table 5.2.

(2) Water Supply by MWA Branches and by Uses

According to water supply data by MWA braches and uses of 2007, 2008 and 2009, ratios of residential use, commercial use and industrial use to total are 47.6%, 32.3% and 4.0% respectively. Ratios of commercial use to residential use of 2007 to 2009 do not vary substantially, but it varies by MWA branches significantly. In branches which cover Thai cultural conservation area and commercial area mainly, water supply for non-residential use is more than double of residential use. Table 5.2 shows water supply of MWA.

Table 5.2 Water Supply of MWA

Year	Served Population (person)	Water Production (Mm^3/y)	Supply/ Product Ratio (%)	Water Supply (Mm^3/y)	Water Supply (m^3/d)	Unit Water Supply (lpcd)	Remarks
2000	7,535,825	1,438.6	61.2	880.3	2,411,781	320	Actual
2001	7,621,972	1,481.6	62.7	929.5	2,546,575	334	
2002	7,715,075	1,505.0	64.4	969.4	2,655,890	344	
2003	7,815,347	1,516.2	66.9	1,013.9	2,777,808	355	
2004	7,625,840	1,538.4	69.9	1,076.0	2,947,945	387	
2005	7,708,756	1,628.0	69.5	1,131.0	3,098,630	402	
2006	7,802,639	1,699.7	69.0	1,173.0	3,213,699	412	
2007	7,867,379	1,739.4	70.4	1,224.0	3,353,425	426	
2008	7,910,699	1,765.7	70.8	1,250.6	3,426,301	433	
2009	7,958,163	1,736.4	72.0	1,250.3	3,425,479	430	
2010	8,253,151	1,800.8	72.1	1,299.2	3,559,485	431	Planned
2020	8,799,507	2,184.1	73.6	1,607.0	4,402,692	500	
2030	9,382,031	2,350.4	75.0	1,762.8	4,829,517	515	
2040	10,003,118	2,500.5	75.0	1,875.4	5,138,018	514	

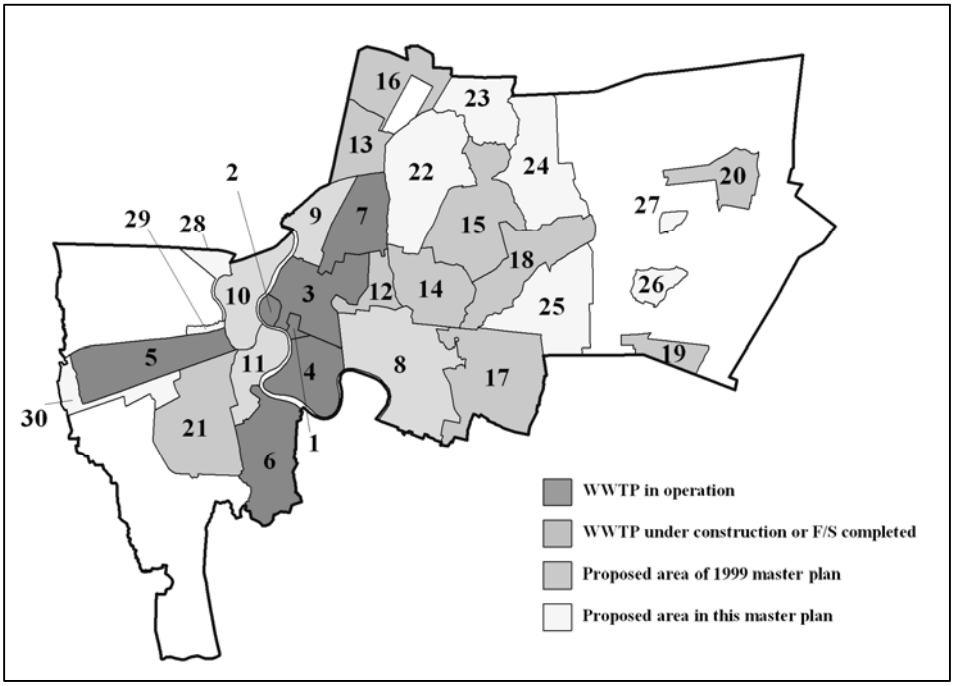
Source: MWA

5.4 Proposal on Treatment Areas

At present seven (7) WWTPs are in operation and Bang Sue WWTP is under construction. Feasibility study on Klong Toei and Thong Buri Sewerage Projects were completed. In addition to these WWTPs, other ten (10) WWTPs were proposed in mater plan prepared in 1999. In this conceptual Master Plan, first additional nine (9) new treatment areas are proposed to cover urbanized area of BMA in addition to dividing Thon Buri area into two. These newly proposed treatment areas are set as temporary ones for case study on treatment area rearrangement. These will be checked against wastewater generation and current plants capacity before concluding new treatment areas. Proposed temporary treatment areas are shown in Figure 5.2.

5.5 Population by Proposed Temporary Treatment Areas

Population by proposed treatment area is calculated based on population by administrative districts considering land use plan and estimated population density of land use categories set by city planning department.



Source: JST

Figure 5.2 Proposed Treatment Areas

5.6 Wastewater Generation

5.6.1 Present Wastewater Generation

(1) Water Supply by Proposed Treatment Areas

Water supply by proposed treatment areas are calculated based on that by MWA branches. Ratios of non-residential use to residential use vary by treatment areas significantly depending on commercial activity of each treatment area. Maximum aggregate unit water supply is 572 lpcd of Rattanakosin treatment area and minimum one is 284 lpcd of Sai Mai and some other treatment areas.

(2) Wastewater Generation Based on Water Supply Amount

Table 5.3 shows wastewater generation and estimated flow at existing seven WWTP. Sewage return ratio from water supply is assumed to be 0.80. Sewer coverage ratio is assumed to be 0.80 in this Survey considering actual condition that some wastewater is discharging into Klong even in an area where interceptors are installed. Here “Sewer Coverage Ratio” is difined as a ratio of wastewater collected by sewer to wastewater generated.

Table 5.3 Wastewater Generation and Estimated Flow at WWTP

	Treatment Area	Area	Population	Water Supply	Return Ratio	Wastewater Generation	Sewer Coverage Ratio	Estimated Flow
		(ha)	(person)	(m^3/d)		(m^3/d)		(m^3/d)
1	Si Praya	270.0	57,466	31,106	0.80	24,885	0.80	19,678
2	Rattanakosin	414.2	49,457	28,303	0.80	22,642	0.80	18,270
3	DinDaeng	2,700.0	498,402	265,731	0.80	212,585	0.80	171,480
4	ChongNonsi	2,850.0	372,765	172,803	0.80	138,242	0.80	109,447
5	Nong Khaem	4,400.0	335,240	117,343	0.80	93,874	0.80	66,951
6	ThungKhru	4,200.0	240,207	74,534	0.80	59,627	0.80	54,187
7	Chatuchak	3,340.0	209,055	96,323	0.80	77,058	0.80	62,101
Total		18,174.2	1,762,592	786,143		628,913		502,114

Source: JST

(3) Ground Water and Infiltration Flow from Klong

Inflow to WWTP includes flow from Klong through interceptor chambers in addition to ground water infiltration in Bangkok. Therefore infiltration in this M/P includes ground water and klong water. Average infiltration ratios are around 10 m^3/d/ha against treatment area or 40% of wastewater inflow at WWTP respectively. These ratios vary significantly by treatment areas.

5.6.2 Estimated Flow at WWTP in 2040

(1) Population by Treatment areas

Population by treatment areas in 2040 is shown in Table 5.5.

(2) Unit Per Capita Water Supply

Unit per capita water supply for residential use is assumed to be 200 lpcd. Non-residential unit water supply is divided into four levels based on degree of commercial activity in treatment areas shown in Table 5.4.

Table 5.4 Unit Water Supply by Category (2040)

(lpcd)

	Non-R /Residential Ratio	Residential	Non-Residential	Total	Particular Treatment Area
A	2.5	200	500	700	Si Praya, Rattanakosin, Chong Nonsi,
B	2.0	200	400	600	Dig Daeng, Klong Toei
C	1.5	200	300	500	Refer to Table 5.5
D	1.0	200	200	400	Refer to Table 5.5

Source: JST

(3) Return Ratio

Sewage return ratio from water supply in 2040 is set to be 0.80 same as present condition.

(4) Sewer Coverage Ratio

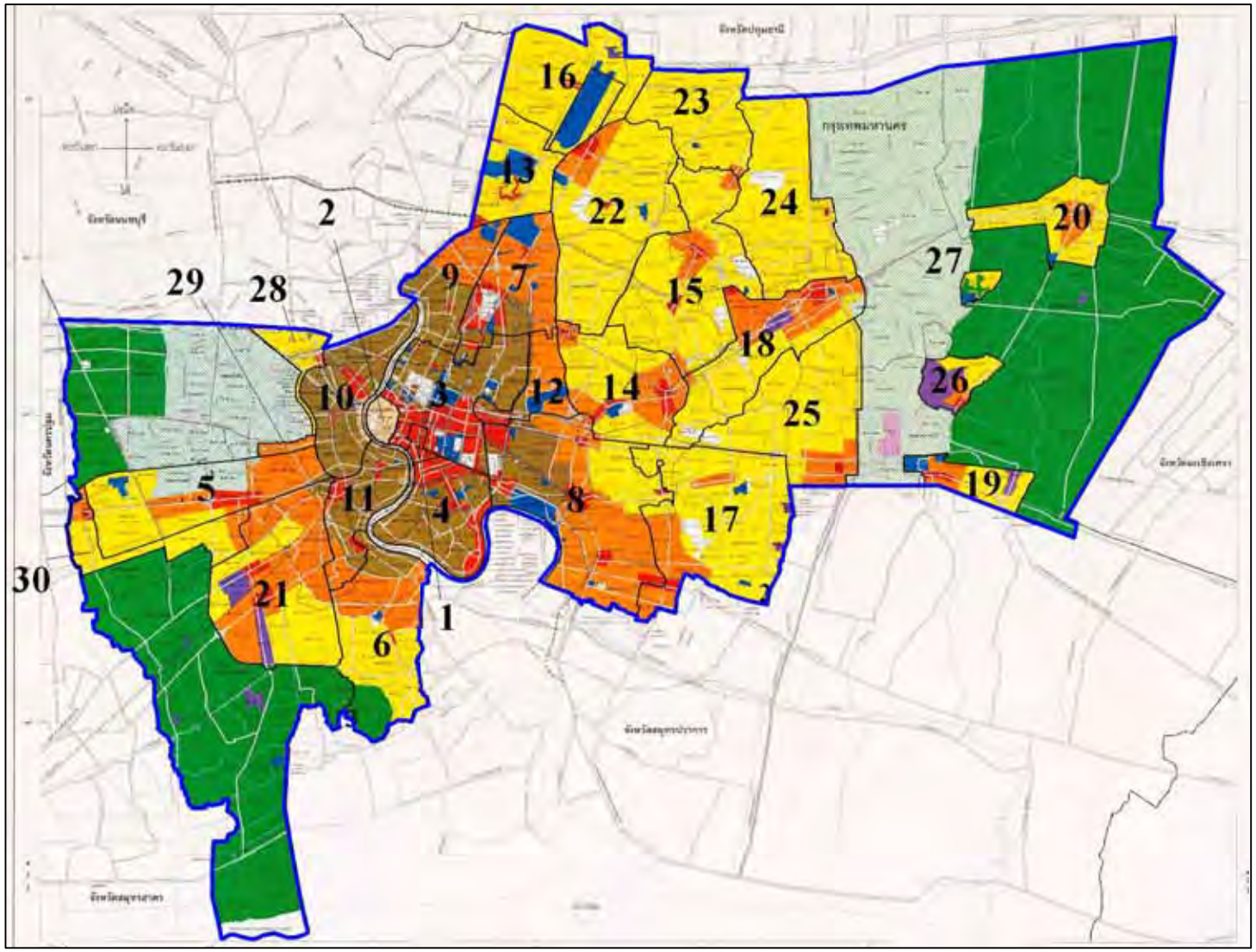
Sewer coverage ratio in 2040 is set to be 0.90.

(5) Infiltration Flow

Infiltration flow is assumed to be principally proportional to area of each treatment area and infiltration ratio is set to be 10 m^3/d/ha considering present condition of existing seven WWTPs. However, there are many vacant spots in new treatment areas, and infiltration flow calculated based on the above rule may be excessively high. Thus infiltration flow should be calculated based on effective treatment area excluding park, open space, water surface and so on. Therefore, limit for infiltration flow is set to be 40% of wastewater flow to avoid excessively high infiltration flow in this M/P.

(6) Estimated Flow at WWTP in 2040

Figure 5.3 shows proposed treatment area and estimated flows at WWTP in 2040 by treatment areas are shown in Table 5.5.



Source: JST

Figure 5.3 Proposed Treatment Area Arrangement (Based on Existing Treatment area)

Table 5.5 Estimated Flow at WWTP by Treatment Areas in 2040

Sr. No.	Tratment Area	Area	Person in Sewer District	Unit Water Supply					Unit Sewage Generation	Water Supply Amount	Sewage Generated	Flow at WWTP	UKF1 Ratio	UKF1	UKF2 (Limit)	UKF Adopted	Total Inflow
				Ratio Category	Commercial / Residential Ratio	Residential	Commercial	Total									
		(ha)				lpcd	lpcd	lpcd	lpcd	(m^3/d)	(m^3/d)	(m^3/d)	(m^3/d/ha)	(m^3/d)	(m^3/d)	(m^3/d)	(m^3/d)
1	Si Praya	226	57,495	A	2.50	200	500	700	560	40,247	32,197	28,977	5	1,130	11,591	1,130	30,107
2	Rattanakosin	367	49,480	A	2.50	200	500	700	560	34,636	27,709	24,938	10	3,670	9,975	3,670	28,608
3	Din Daeng	3,923	513,145	B	2.00	200	400	600	480	307,887	246,310	221,679	10	39,230	88,672	39,230	260,909
4	Chong Nonsi	2,872	372,960	A	2.50	200	500	700	560	261,072	208,858	187,972	5	14,360	75,189	14,360	202,332
5	Nong Khaem	4,384	405,487	D	1.00	200	200	400	320	162,195	129,756	116,780	10	43,840	46,712	43,840	160,620
6	Thung Khru	4,447	256,033	C	1.50	200	300	500	400	128,017	102,413	92,172	5	22,235	36,869	22,235	114,407
7	Chatuchak	3,073	209,575	B	2.00	200	400	600	480	125,745	100,596	90,536	10	30,730	36,214	30,730	121,266
8	Klong Toei	7,309	579,670	B	2.00	200	400	600	480	347,802	278,242	250,418	10	73,090	100,167	73,090	323,508
9	Bang Sue	2,095	229,063	C	1.50	200	300	500	400	114,532	91,625	82,463	10	20,950	32,985	20,950	103,413
10	Thon Buri North	2,922	359,542	C	1.50	200	300	500	400	179,771	143,817	129,435	10	29,220	51,774	29,220	158,655
11	Thon Buri South	2,087	333,707	C	1.50	200	300	500	400	166,854	133,483	120,135	10	20,870	48,054	20,870	141,005
12	Huaykwang	1,333	109,358	B	2.00	200	400	600	480	65,615	52,492	47,243	10	13,330	18,897	13,330	60,573
13	Lak Si	2,263	133,310	C	1.50	200	300	500	400	66,655	53,324	47,992	10	22,630	19,197	19,197	67,189
14	Wangthonlang	3,547	313,296	C	1.50	200	300	500	400	156,648	125,318	112,786	10	35,470	45,114	35,470	148,256
15	Bunkhum	5,639	340,430	D	1.00	200	200	400	320	136,172	108,938	98,044	10	56,390	39,218	39,218	137,262
16	Don Mueang	3,250	280,749	D	1.00	200	200	400	320	112,300	89,840	80,856	10	32,500	32,342	32,342	113,198
17	Nong Bon	6,385	264,883	C	1.50	200	300	500	400	132,442	105,953	95,358	10	63,850	38,143	38,143	133,501
18	Min Buri	4,165	274,182	C	1.50	200	300	500	400	137,091	109,673	98,706	10	41,650	39,482	39,482	138,188
19	Lat Krabang-1	1,258	59,502	C	1.50	200	300	500	400	29,751	23,801	21,421	10	12,580	8,568	8,568	29,989
20	Nong Chok-1	2,109	208,634	C	1.50	200	300	500	400	104,317	83,454	75,109	10	21,090	30,044	21,090	96,199
21	Jomthong	5,816	453,938	C	1.50	200	300	500	400	226,969	181,575	163,418	10	58,160	65,367	58,160	221,578
22	Lat Phrao	6,206	475,384	D	1.00	200	200	400	320	190,154	152,123	136,911	10	62,060	54,764	54,764	191,675
23	Sai Mai	2,958	158,188	D	1.00	200	200	400	320	63,275	50,620	45,558	10	29,580	18,223	18,223	63,781
24	Klong Sam Wa	5,015	310,738	C	1.50	200	300	500	400	155,369	124,295	111,866	10	50,150	44,746	44,746	156,612
25	Lat Krabang-2	4,959	211,457	C	1.50	200	300	500	400	105,729	84,583	76,125	10	49,590	30,450	30,450	106,575
26	Lat Krabang-3	988	28,129	C	1.50	200	300	500	400	14,065	11,252	10,127	10	9,880	4,051	4,051	14,178
27	Nong Chok-2	309	20,908	C	1.50	200	300	500	400	10,454	8,363	7,527	10	3,090	3,011	3,011	10,538
28	Taling Chan	759	149,866	D	1.00	200	200	400	320	59,946	47,957	43,161	10	7,590	17,264	7,590	50,751
29	Nong Khaem North	208	17,374	C	1.50	200	300	500	400	8,687	6,950	6,255	10	2,080	2,502	2,080	8,335
30	Nong Khaem South	1,647	167,622	D	1.00	200	200	400	320	67,049	53,639	48,275	10	16,470	19,310	16,470	64,745
	Sub-total	92,519	7,344,105							3,711,446	2,969,156	2,672,243				785,710	3,457,953
	Out of Service Area	62,939	281,895	D	1.00	200	200	400	320	112,758	90,206	81,185	10	629,390	32,474	32,474	113,659
	Total / Average	155,458	7,626,000							3,824,204	3,059,362	2,753,428				818,184	3,571,612

Source: JST

5.7 Rearrangement of Treatment Areas

In Din Daeng and Chatuchak treatments areas treatment capacities have some margins. On the contrary, there are shortage of treatment capacities in Thung Khru and Nong Khaem treatment areas. Rearrangement of treatment areas is considered to mitigate this unbalance.

Si Praya, Rattanakosin, Chong Nonsi, Klong Toei and Bang Sue in which design treatment capacities in 2040 are judged to be appropriate are excluded from rearrangement of treatment areas. F/S for Thon Buri treatment area was completed, however, site for WWTP could not be secured and updating of F/S is currently underway by dividing the area into two treatment areas, viz. Thon Buri North and Thon Buri South.

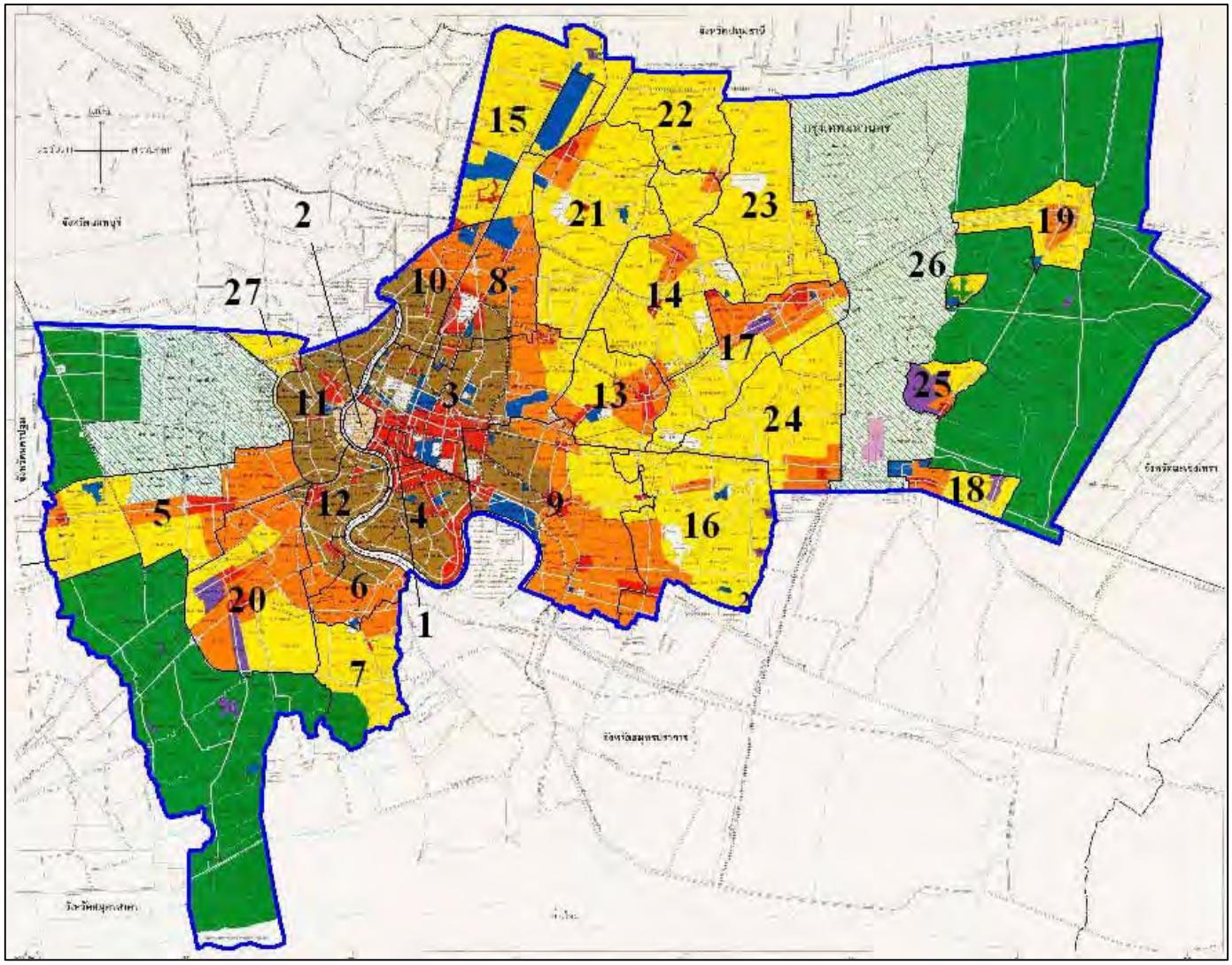
Table 5.6 shows outlines of proposed rearrangement.

Table 5.6 Summary of Treatment Area Rearrangement

	Original	Rearranged	Remarks
1	Din Daeng	Din Daeng	Divert to Chong Nonsi partly Integrate whole Huaykwang and part of Wangthonlang
	Chong Nonsi	Chon Nonsi	Integrate part of Din Daeng
	Huaykwang	-	Divert to Din Daeng totally
	Wangthonlang	Wangthonlang	Divert to Din Daeng partly
2	Chatuchak	Chatuchak	Integrate part of Lak Si
	Lak Si	-	Divert to Chatuchak and Don Mueang totally
	Don Muaeng	Chatuchak	Integrate part of Lak Si
3	Thung Khru	Thung Khru	Divert to Jomthong partly
	Thon Buri South	-	Divert to Jomthong totally
	Jomthong	Jomthong	Integrate whole Thon Buri South and part of Thug Khru
4	Nong Khem	Nong Khaem	Integrate whole Nong Khaem North and South
	Nong Khaem North	-	Divert to Nong Khaem totally
	Nong Khaem South	-	Divert to Nong Khaem totally

Source: JST

Rearranged treatment area and wastewater flow are shown in Figure 5.4 and Table 5.7.



Source: JST

Figure 5.4 Proposed Treatment Area Arrangement

Table 5.7 Estimated Flow at WWTP by Treatment Area in 2040

No.	Treatment Area	Area	Population	Inflow to WWTP		
				Watewater	Infiltration	Total
		(ha)	(Person)	(m^3/d)		
1	Si Praya	226	57,495	28,977	1,130	30,107
2	Rattanakosin	367	49,480	24,938	3,670	28,608
3	Din Daeng	5,931	689,699	297,950	59,310	357,260
4	Chong Nonsi	2,872	372,960	187,972	14,360	202,332
5	Nong Khaem	6,239	590,483	170,060	62,390	232,450
6	Thung Khru North	1,513	128,637	46,310	7,565	53,875
7	Thung Khru South	2,934	127,396	45,862	14,670	60,532
8	Chatuchak	3,645	239,653	103,530	36,450	139,980
9	KhlongToei	7,309	579,670	250,418	73,090	323,508
10	Bang Sue	2,095	229,063	82,463	20,950	103,413
11	Thon Buri North	2,922	359,542	129,435	29,220	158,655
12	Thon Buri South	2,087	333,707	120,135	20,870	141,005
13	Wangthonlang	2,872	246,098	88,595	28,720	117,315
14	Bunkhum	5,639	340,430	98,044	39,218	137,262
15	Don Mueang	4,941	383,981	110,587	44,235	154,822
16	Nong Bon	6,385	264,883	95,358	38,143	133,501
17	Min Buri	4,165	274,182	98,706	39,482	138,188
18	Lat Krabang-1	1,258	59,502	21,421	8,568	29,989
19	Nong Chok-1	2,109	208,634	75,109	21,090	96,199
20	Jomthong	5,816	453,938	163,418	58,160	221,578
21	Lat Phrao	6,206	475,384	136,911	54,764	191,675
22	Sai Mai	2,958	158,188	45,558	18,223	63,781
23	KhlongSam Wa	5,015	310,738	111,866	44,746	156,612
24	Lat Krabang-2	4,959	211,457	76,125	30,450	106,575
25	Lat Krabang-3	988	28,129	10,127	4,051	14,178
26	Nong Chok-2	309	20,908	7,527	3,011	10,538
27	Taling Chan	759	149,866	43,161	7,590	50,751
Sub-total		92,519	7,344,103	2,670,563	784,126	3,454,689
	Out ofService Area	62,939	281,897	81,186	32,474	113,660
Total		155,458	7,626,000	2,751,749	816,600	3,568,349

Note: Total wastewater flow in Table 5.5 and in this table slightly differ because infiltration rate is different by treatment areas, and therefore unit wastewater flow is different due to rearrangement of treatment areas.

Source: JST

5.8 Construction Cost

Construction cost for sewerage system to be implemented was estimated by using unit costs of Bang Sue and Klong Toei sewerage projects. Unit costs including construction costs for interceptors, pumping stations and WWTPs per treatment area, population and wastewater flow were worked out. Construction cost for each treatment area was calculated as an average of those estimated by three unit costs. Construction costs for treatment areas are shown in Table 5.8. A total construction cost including Bang Sue and Klong Toei sewerage systems is estimated to be 102 billion Baht, and that excluding two sewerage systems is to be 86 billion Baht

Table 5.8 Construction Cost

No.	Treatment Area	Area	Population	Wastewater Flow	Construction Cost				
					(area)	(population)	(wastewater)	(average)	
		(ha)	(person)	(m^3/day)	(milliom Baht)	(milliom Baht)	(milliom Baht)	(milliom Baht)	
1	Si Praya	226	57,495	30,107	-	-	-	-	
2	Rattanakosin	367	49,480	28,608	-	-	-	-	
3	Din Daeng	5,931	689,699	357,260	-	-	-	-	
4	Chong Nonsi	2,872	372,960	202,332	-	-	-	-	
5	Nong Khaem	6,239	590,483	232,450	-	-	-	-	
6	Thung Khru North	1,513	128,637	53,875	2,515	2,486	1,972	2,324	
7	Thung Khru South	2,934	127,396	60,532	-	-	-	-	
8	Chatuchak	3,645	239,653	139,980	-	-	-	-	
9	KhlongToei	7,309	579,670	323,508	-	-	-	11,046	*1
10	Bang Sue	2,095	229,063	103,413	-	-	-	4,584	*2
11	Thon Buri North	2,922	359,542	158,655	4,857	6,949	5,809	5,871	
12	Thon Buri South	2,087	333,707	141,005	3,469	6,449	5,162	5,027	
13	Wangthonlang	2,872	246,098	117,315	4,773	4,756	4,295	4,608	
14	Bunkhum	5,639	340,430	137,262	9,372	6,579	5,025	6,992	
15	Don Mueang	4,941	383,981	154,822	8,212	7,421	5,668	7,100	
16	Nong Bon	6,385	264,883	133,501	10,612	5,119	4,888	6,873	
17	Min Buri	4,165	274,182	138,188	6,922	5,299	5,059	5,760	
18	Lat Krabang-1	1,258	59,502	29,989	2,091	1,150	1,098	1,446	
19	Nong Chok-1	2,109	208,634	96,199	3,505	4,032	3,522	3,686	
20	Jomthong	5,816	453,938	221,578	9,667	8,773	8,112	8,851	
21	Lat Phrao	6,206	475,384	191,675	10,315	9,188	7,017	8,840	
22	Sai Mai	2,958	158,188	63,781	4,916	3,057	2,335	3,436	
23	KhlongSam Wa	5,015	310,738	156,612	8,335	6,005	5,734	6,691	
24	Lat Krabang-2	4,959	211,457	106,575	8,242	4,087	3,902	5,410	
25	Lat Krabang-3	988	28,129	14,178	1,642	544	519	902	
26	Nong Chok-2	309	20,908	10,538	514	404	386	434	
27	Taling Chan	759	149,866	50,751	1,262	2,896	1,858	2,005	
	Total	92,519	7,344,103	3,454,689	101,221	85,195	72,362	101,889	

Note: *1 estimated by F/S
*2 contract price
Source: JST

5.9 Simple Analysis of Water Pollution

The purpose of this simple analysis of water pollution is to evaluate approximately the effects of sewerage projects proposed in the Master Plan on the water environment.

(1) Object Water Bodies and Points of Water Quality Estimation

Object water bodies are Chao Phraya River and main klongs in the Survey Area. The 7 points at Chao Phraya River and 25 points at main klongs have been selected among the existing monitoring points of DDS as points of water quality estimation.

(2) Flow Direction of Klongs for Pollution Model

Topography of the Survey Area is generally flat, and flow in klongs is affected by tide and also influenced strongly by pump and gate operation in wet weather. Flow is often stagnated and sometimes reverse flow may occur. For simplification of pollution model, regular flow direction is assumed for each klong.

(3) Water Quality Items to be Evaluated

Water quality item to be estimated is Biochemical Oxygen Demand (BOD).

(4) Representative BOD Values for Pollution Model

Representative BOD values for pollution analysis are determined to be annual average values in 2009.

(5) Simulation Conditions

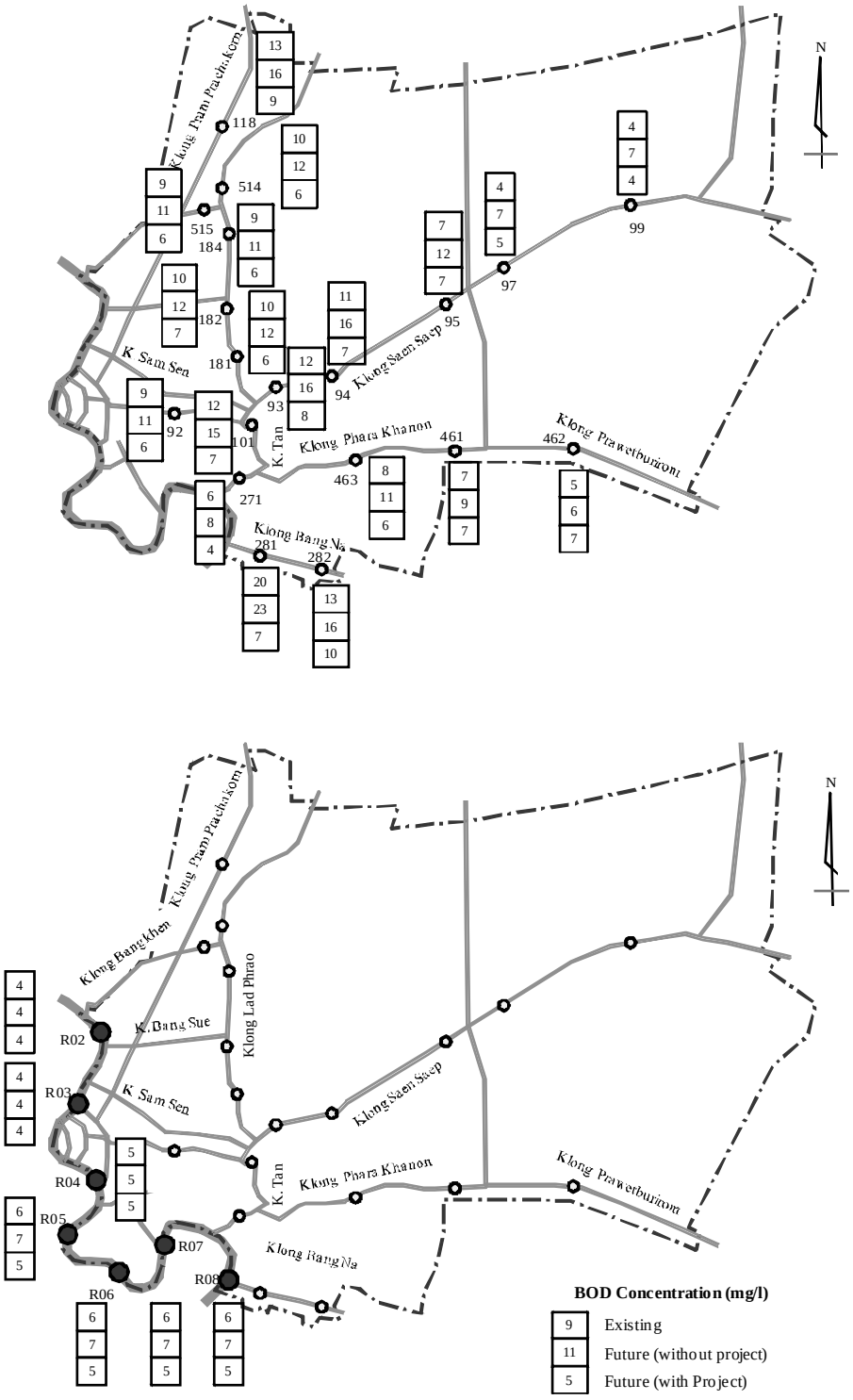
Based on the explanation mentioned above, an Excel based simplified model was developed by the JST. Using the model, BOD concentrations in Chao Phraya River and klongs in future are estimated for the flowing two cases.

i) Without project case:
Sewerage system in BMA will remain the same as it is at present until 2040.
ii) With project case
Sewerage system will be developed as proposed in this Master Plan.

(6) Simulation Result

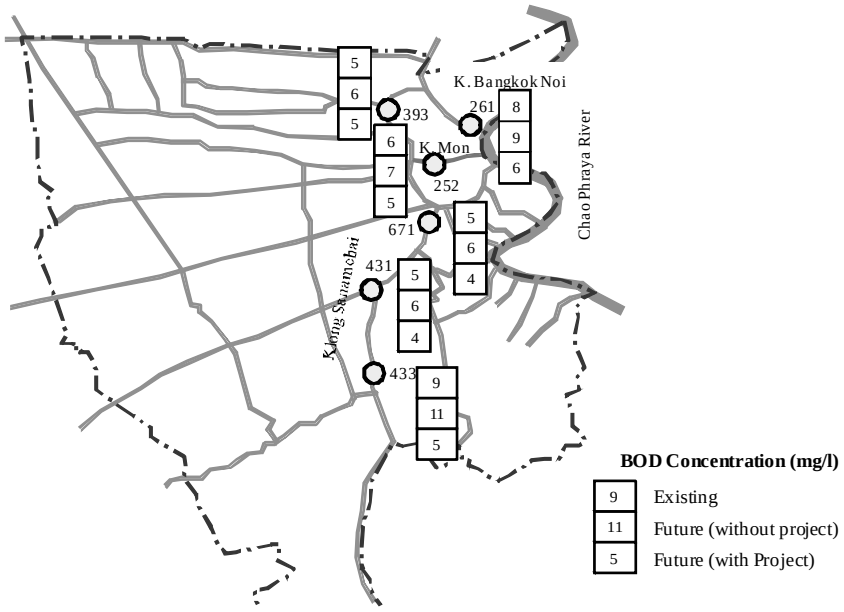
- BOD concentrations in main klongs on the east bank, viz. Klong Saen Saep, Klong Lad Phrao, Klong Prawetburirom and Klong Phra Khanong will rise to 1.4 times the current values on average (1.2 to 1.7 times) if sewerage system remains the same as it is now.
- BOD concentrations in the same klongs as mentioned above will be less than 10 mg/l if sewerage system is developed as proposed.
- If BOD concentrations are less than 10 mg/l, conservation of ecosystem and prevention of emission of foul smell from sediments can be assured in klongs since a certain DO level is maintained (average DO value is 1.9 mg/l if BOD concentrations are less than 10 mg/l, and DO values of 73 % of total samples exceed 1.0 mg/l.)
- If sewerage system remains the same as it is now, BOD pollutant load is estimated to increase to 1.3 times the current level (2008). As a result, BOD concentrations in Chao Phraya River will increase to 7 mg/l from current 6 mg/l.
- On the other hand, if sewerage system is developed as proposed in this Master Plan, BOD concentrations in Chao Phraya River will be improved to 5 mg/l from 7 mg/l in case of

without project.



Source: JST

Figure 5.5 (1) Results of Estimation of BOD Concentrations by Simplified Pollution Model (1/2)



Source: JST

Figure 5.5 (2) Results of Estimation of BOD Concentrations by Simplified Pollution Model (2/2)

5.10 Selection of Priority Project

5.10.1 Candidate Treatment Areas for Priority Project

Sewerage system has been provided or projects are expected to be started shortly in 11 treatment areas in BMA and 7 WWTPs of 11 are currently in operation. In addition to 7 WWTPs, Bang Sue WWTP is under construction, F/S for Klong Toi was completed and F/S for Thon Buri North and Thon Buri South is currently being carried out. Eight (8) treatment areas which satisfy the following criteria were selected as candidate areas for selection of priority project.

Criteria for candidate area

i) Wastewater is discharging to such main klongs as Lat Phrao, Saen Saep, Phra Khanon, Bang Na, Sanamchai, Bangkok Noi, or Bangkok Yai, resulting in water pollution in these klongs
ii) There exist urbanized areas which are located in the neighborhood of the existing treatment areas
iii) Population increase is expected due to housing development and provision of transportation networks

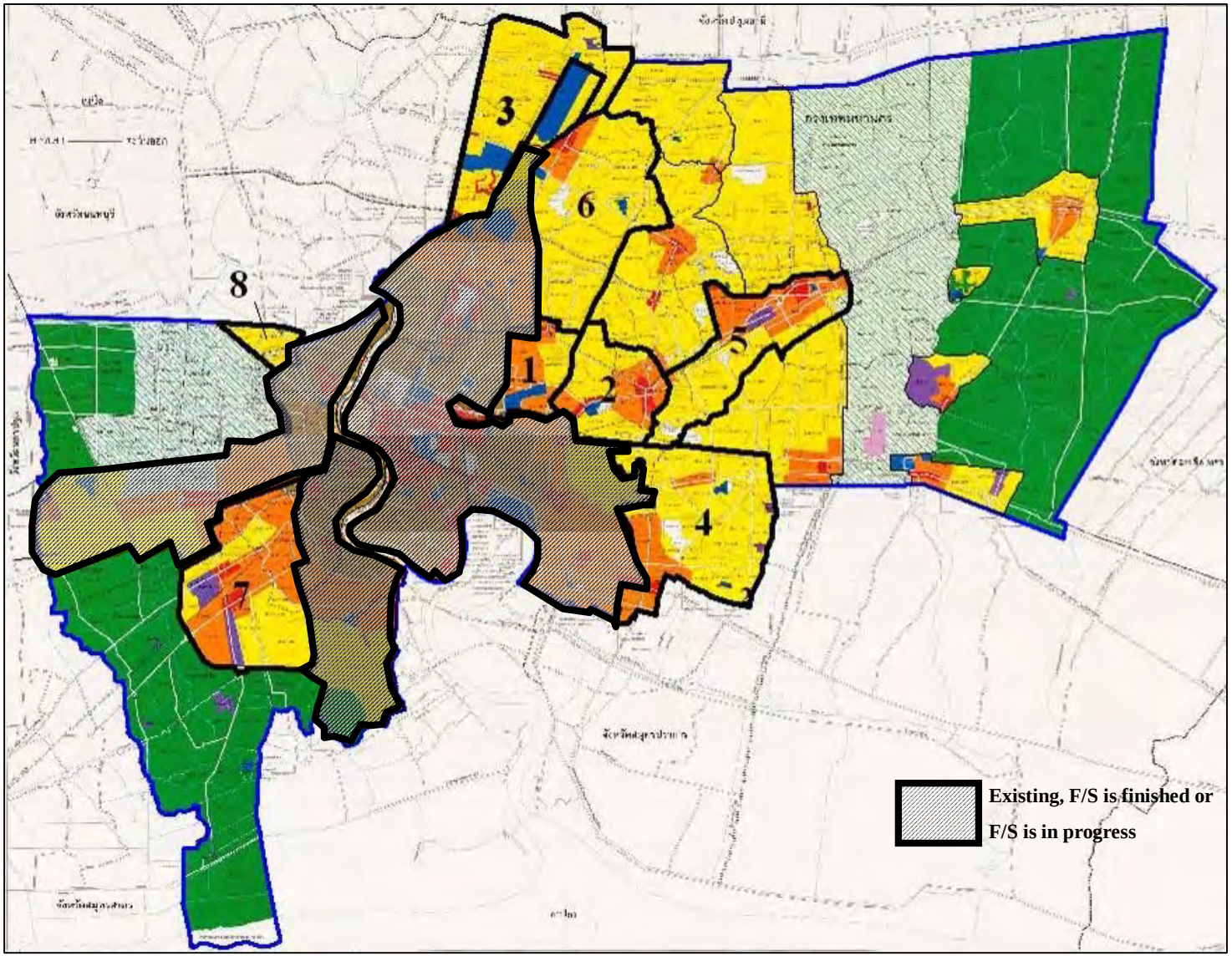
Outlines of treatment areas and result of the selection are shown in Table 5.9, and their locations are shown in Figure 5.6.

Table 5.9 Outlines of Candidate Treatment Areas for Priority Project

	Candidate treatment area	Location	Area (ha) Population in 2040 (persons) Population density (persons /ha)	Tendency of population growth (2004-08)	Land use plan (Dominant land use)	Receiving klong	Reasons for candidate area
1	Huaykwang Sub-treatment area	East bank of Chao Phraya River	2,008 164,800 82	Increase 0 - 10%/year	Medium- and high-density residential Commercial	Downstream of Klong Lat Phrao	Existing urbanized area Water quality deterioration in Klong Lat Phrao
2	Wangthonlang		2,872 246,100 86	Increase 0 - 10%/year	Low- and medium-density residential Commercial	Downstream of Klong Saen Saep	Existing urbanized ares Water quality deterioration in Klong Saen Saep
3	Dong Mueang		4,941 384,000 78	Decrease	Low-density residential Public (airport)	Upstream of Klong Pram Prachakom, and Klong Lat Phrao	Existing urbanized area Water quality deterioration in Klong Lat Phrao
4	Nong Bon		6,385 264,900 41	Increase 0 - 10%/year	Low- and medium-density residential Commercial	Upstream of Klong Bang Na Downstream of Klong Phra Khanong	Existing urbanized area Population growth due to development Closeness to international airport Water quality deterioration in Klong Bang Na, and Klong Phra Khanong
5	Min Buri		4,165 274,200 66	Increase 0 - 10%/year	Low- and medium-density residential Commercial	Upstream of Klong Saen Seap	Existing urbanized area Water quality deterioration in Klong Saen Saep
6	Lat Phrao		6,206 475,400 77	Increase 0 - 10%/year	Low- and medium-density residential Commercial	Upstream of Klong Lat Phrao	Existing urbanized area Water quality deterioration in Klong Lat Phrao
7	Jomthong	West bank of Chao Phraya River	5,816 453,900 78	Increase, an area with 10%/year is included	Low- and medium-density residential Commercial	Klong Sanamchai	Existing urbanized are, population growth expected
8	Taling Chan		759 149,900 197	Increase 0 - 10%/year	Low-density residential	Klong Bangkok Noi and Klong Bangkok Yai	Existing urbanized are, population growth expected

Note: Location of treatment areas, refer to Figure 5.6

Source: JST


3
6
8
1
2
4
7
Existing, F/S is finished or
F/S is in progress

5.10.2 Selection of Priority Project Area

Priority project is selected from among eight (8) treatment areas shown in Table 5.9 taking into account the various factors comprehensively such as future situation of the area, current water pollution in klongs, improvement effects of water pollution due to provision of sewerage system, availability of land for WWTP, and DDS's intention

Selection of priority project is described in the following and summarized in Table 5.10.

There are many reaches in Klong Bang Na, Klong Lat Phrao and Klong Saen Saep where BOD concentrations exceed 10 mg/l, in particular in Klong Bang Na BOD concentrations exceed 15 mg/l. This means that urgency of implementation sewerage project is obvious in these treatment areas related to the above klongs.

As for improvement effects on water quality in klongs, effect of an individual treatment area is not so significant for large klongs such as Klong Lat Phrao and Klong Saen Saep because catchment areas of these klongs cover many treatment areas. On the other hand, Klong Bang Na is a small klong flowing through congested residential areas. Improvement effect on water quality due to implementation of sewerage project can be expected to be significant. Among the candidate treatment areas only Nong Bon treatment area is included in catchment area of Klong Bang Na.

To conduct F/S, construction site for WWTP must be secured beforehand, because preliminary design of sewerage facilities such as trunk sewers and WWTP is indispensable element of the study. Treatment areas which satisfy this requirement are Nong Bon and Min Buri treatment areas.

DDS's intention is that sewerage system will be provided in all urbanized areas except for agricultural areas by 2040. To realize the aim, DDS will implement the sewerage projects as soon as possible from where preparation for implementation is completed.

DDS's thought was that implementation of sewerage projects for Klong Toie, Thon Buri North and Thon Buri South for which F/S was completed would be followed by implementation of sewerage projects in Min Buri and Nong Bon treatment areas. Currently budget for F/S, detailed design and construction for Min Buri project was secured by DDS and F/S for Nong Bon is desired.

According to the results of strategic environmental assessment, it is judged that there is no obstacles to prevent smooth implementation of the project in both Nong Bon and Min Buri treatment areas and that there is no problem to select these areas as priority project area.

In conclusion, Nong Bon treatment area in which provision of sewerage system is expected to contribute to improvement of water quality in Klong Bang Na and Klong Phra Khanon, of which construction site for WWTP is secured is selected as priority project area. The selection is also confirmed with the results of the strategic environmental assessment. Contents and results of the selection are presented in Table 5.10.

Therefore, F/S will be conducted at the second stage of the Survey for selected Nong Bon treatment area.

Table 5.10 Selection of Priority Project Area

	Candidate treatment area	Area (ha) Population (persons) Population density (persons/ha)	Land use plan (dominant land use)	Receiving klong	Water quality in klong (BOD mg/l)	(1) Urgency of project	(2) Effects of provision of sewerage system	(3) Construction site for WWTP	(4) Strategic environmental assessment	Remarks
1	Huaykwang sub-treatment area	2,008 164,800 82	Medium- and high-density residential Commercial	Downstream of Klong Lat Phrao	10～12	Medium	Medium	To be integrated to Din Daeng Treatment area	Can not be done	
2	Wangthonlang	2,872 246,100 86	Low- and medium-density residential Commercial	Downstream of Klong Saen Saep	11～12	Medium	Low	Not determined	Can not be done	
3	Dong Mueang	4.941 384,000 78	Low-density residential Public (airport)	Upstream of Klong Pram Prachakom	13	Medium	Medium	Not determined	Can not be done	
				Upstream of Klong Lat Phrao	10					
4	Nong Bon	6,385 264,900 41	Low- and medium-density residential Commercial	Upstream of Klong Bang Na	13～20	**High**	**High**	**Secured**	**No problem**	**Selected as priority project**
				Downstream of Klong Phra Khanong	7～8					
5	Min Buri	4,165 274,200 66	Low- and medium-density residential Commercial	Upstream of Klong Saen Seap	7～11	Medium	Medium	**Secured**	No problem	
6	Lat Phrao	6,206 475,400 77	Low- and medium-density residential Commercial	Upstream of Klong Lat Phrao	9～13	Medium	**High**	Site is under consideration by DDS	Can not be done	
7	Jomthong	5,816 453,900 78	Low- and medium-density residential Commercial	Klongs on the west bank	5～9	Low	Low	Not determined	Can not be done	
8	Taling Chan	5,816 453,900 78	Low- and medium-density residential Commercial	Klongs on the west bank	5～6	Low	Low	Not determined	Can not be done	

5.10.3 Outlines of Nong Bon Treatment Area

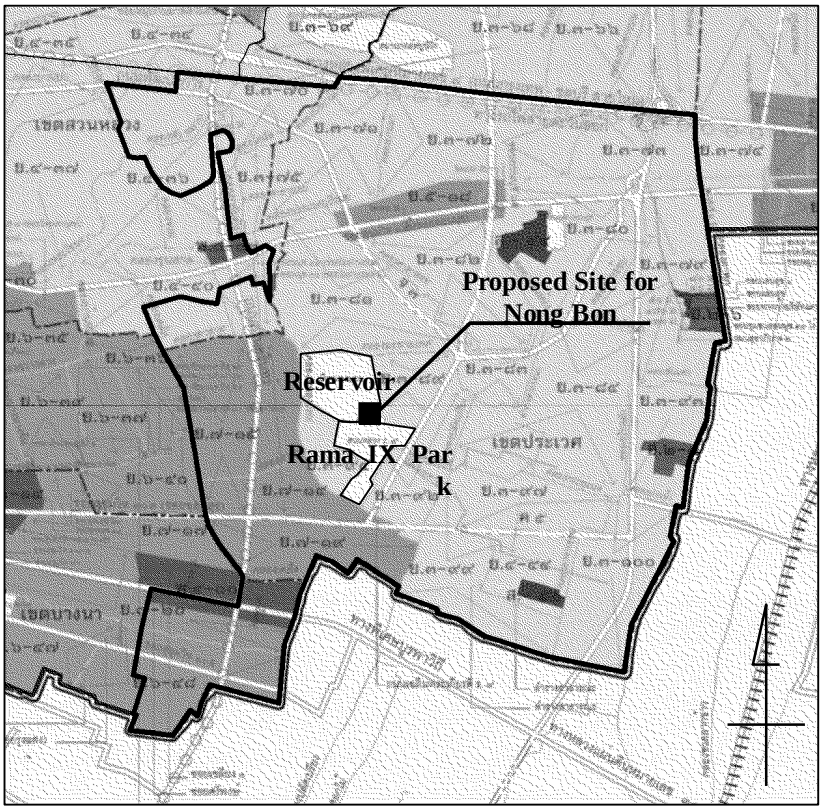
Although population density in Nong Bon treatment area is comparatively low at present, population has been increasing because of opening of airport link which connects central part of the city and a new airport and consequent enhancement of convenience. Many housing developments of relatively high class houses by private companies have been progressing. A new elevated railway line is planned to be constructed along Sri Nakharin Road in the western part of the area resulting in further enhancement of convenience. Nong Bon treatment area is close to the new international airport. Population growth and needs for development are expected in the area.

Outlines of Nong Bon treatment area and Nong Bon WWTP are shown in Table 5.11. Construction site for WWTP is located in the neighborhood of Rama IX Park, adjacent to storm water reservoir constructed under Monkey Cheek Project. Construction site for WWTP is shown in Figures 5.7 and 5.8.

Table 5.11 Outlines of Nong Bon Treatment Area and Nong Bon WWTP

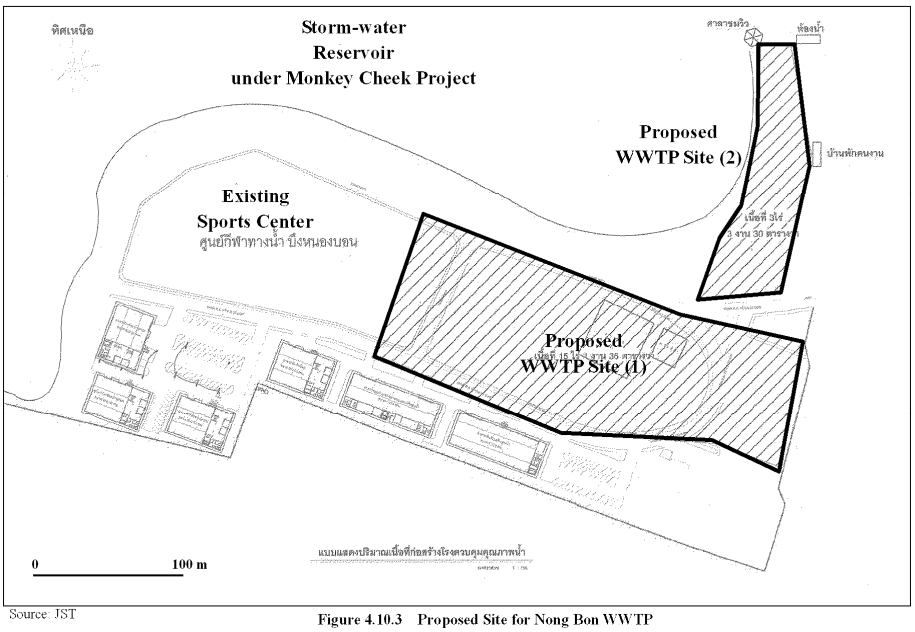
	Design figure	Remarks
Area of treatment area	6,385 ha	Including areas of parks, vacant lands and water surfaces
Design population (2040)	265,000 persons	
Design capacity (2040)	135,000 m^3/day	
Area of WWTP site	3.5 ha (22 Rai) (1.1 ha for above ground facilities)	Adjacent to storm water reservoir constructed under Monkey Cheek Project, in the neighborhood of Rama IX Park Biological treatment: adoption of compact treatment process A part of the facilities is to be constructed underground, administration building is to be constructed above ground

Source: JST



Source: JST

Figure 5.7 Location of Nong Bon WWTP



Source: JST

Figure 4.10.3 Proposed Site for Nong Bon WWTP

Source: JST

Figure 5.8 Proposed Site for Nong Bon WWTP

5.11 Strategy for Sewerage System Development

Long term sewerage system development plan up to 2040 was developed classifying 27 treatment areas into the following four groups.

Group 1: Existing treatment areas (7)
Si Praya, Rattanakosin, Din Daeng, Chong Nonsi, Nong Khaem, Thung Kru South, and Chatuchak

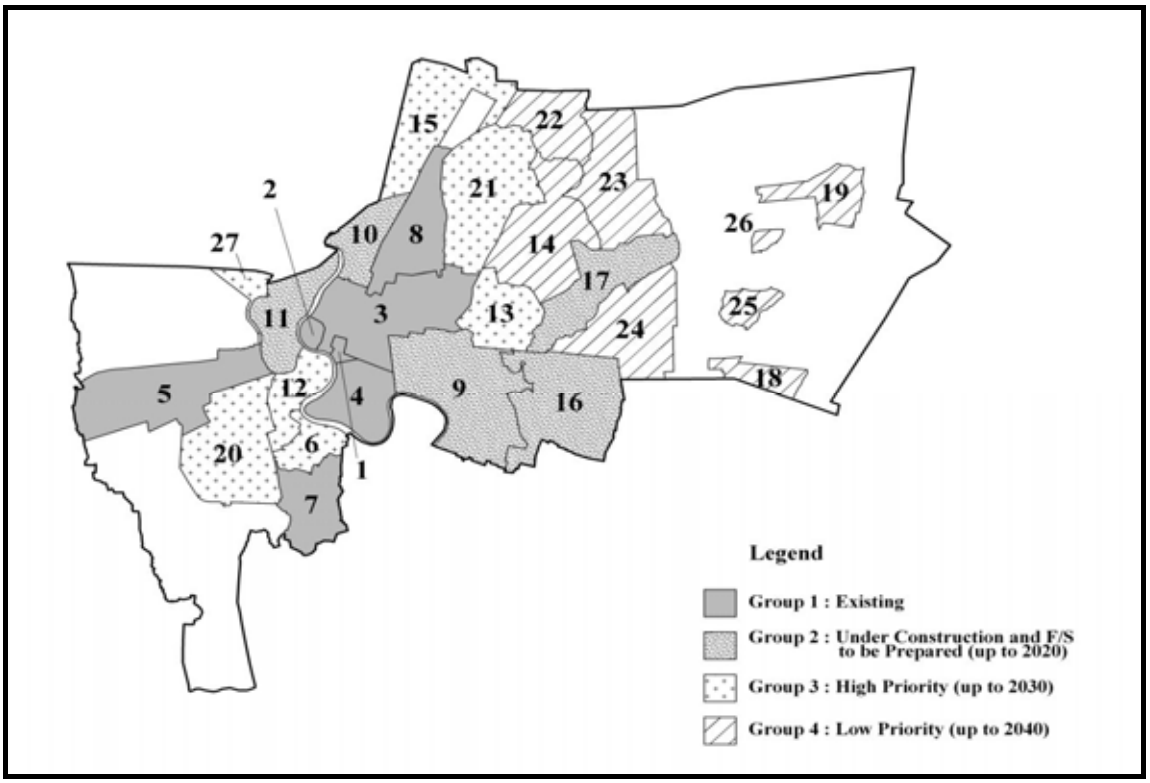
Group 2: Under construction and F/S to be prepared (5)
Bang Sue, Klong Toei, Thon Buri North, Nong Bon and Min Buri

Group 3: High priority treatment areas (7)
Thon Buri South, Thung Kru North, Wangthonlang, Don Muaeng, Lat Prao, Jomthong, and Taling Chan

Group 4: Low priority treatment areas (8)
Bunkhum, Sai Mai, Lat Krabang-2, LatKrabang-1, Nong Chok-1, Klong Sam Wa, Lat Krabang-3, Nong Chok-2

Table 5.12 and Figure 5.9 show sewerage system development plan based on the classification of treatment areas. Since a total construction cost to complete all the sewerage projects by 2040 is estimated to be 101.9 billion Baht, and an annual average of initial investment is calculated to be 3.4 billion Baht (approximately 3 times DDS's annual budget for recent years), significant increase of budget is necessary to achieve long term goal of M/P until 2040.

In order to cover a tremendous amount of investment, introduction of loans from bilateral or multilateral financial institutions such as JICA together with increase of budget of BMA and central government is recommended. It is proposed that implementation of sewerage projects in 5 treatment areas including on going project and for which F/S is prepared should be completed by 2020, 7 treatment areas with higher priority by 2030, and the remaining 8 treatment areas by 2040 on an assumption that budget will be significantly increased.



Source: JST

Figure 5.9 Implementation Plan of Sewerage Projects

Table 5.11.1 Sewerage System Development Plan

Existing		Under construction and F/S to be prepared (up to 2020)			High priority treatment areas (up to 2030)			Low priority treatment areas (up to 2040)		
Treatment area	Treatment capacity (m^3/day)	Treatment area	Treatment capacity (m^3/day)	Construction cost (million Baht)	Treatment area	Treatment capacity (m^3/day)	Construction cost (million Baht)	Treatment area	Treatment capacity (m^3/day)	Construction cost (million Baht)
1. Si Praya	30,000	10. Bang Sue [2)]	120,000	4,584	12. Thon Buri South	142,000	5,027	14. Bunkhum	138,000	6,992
2. Rattanakosin	40,000	9. Klong Toei [3)]	360,000	11,046	6. Thung Kru North	54,000	2,324	22. Sai Mai	64,000	3,436
3. Din Daen	350,000	11. Thon Buri North	160,000	5,871	13. Wangthonlang	117,000	4,608	24. Lat Krabang-2	107,000	5,410
4. Chong Nonsi	200,000	16. Nong Bon	134,000	6,873	15. Don Muaeng	155,000	7,100	18. Lat Krabang-1	30,000	1,446
5. Nong Khaem [1)]	234,000	17. Min Buri	140,000	5,760	21. Lat Prao	192,000	8,840	19. Nong Chok-1	97,000	3,686
7. Thung Kru South	65,000				20. Jomthong	222,000	8,851	23. Klong Sam Wa	157,000	6,691
8. Chatuchak	150,000				27. Taling Chan	51,000	2,005	25. Lat Krabang-3	15,000	902
								26. Nong Chok-2	11,000	434
Total	1,069,000		914,000	34,134		933,000	38,755		619,000	28,997

Note: 1) Current capacity of 157,000 m^3/day is to be expanded

2) Contract amount

3) Estimated by F/S

Source: JST