3.5 Water Pollution Situation in BMA

3.5.1 Water Quality Monitoring by 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. However, number of monitoring points of which monitoring period exceed ten years is 133, and abolition and addition of the monitoring points have been done as needed. Based on the results of the analysis, the present water pollution situation of Chao Phraya River and klongs in BMA administrative area are described below.

3.5.2 Present Water Pollution Situation in Chao Phraya River in BMA

(1) Water Quality Standards for Surface Water

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.

(2) Present Water Pollution Situation

The results of water quality analysis in terms of BOD are summarized in Table 3.5.1 to describe the present pollution situation of Chao Phraya River in the Survey Area.

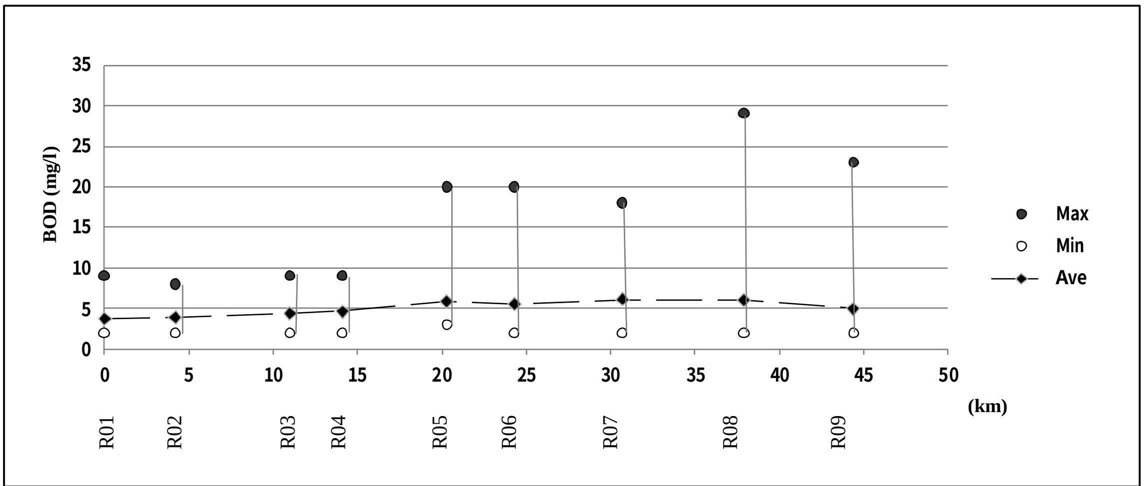
Table 3.5.1 BOD Concentrations in Chao Phraya River (2009)

Point No.	Min. (mg/l)	Max. (mg/l)	Median (mg/l)	Ave. (mg/l)	Number of data					
					Less than 5 mg/l	5 to 9 mg/l	10 to 14 mg/l	15 to 19 mg/l	More than 20 mg/l	Total
R01	2	9	4	4	37	8	0	0	0	45
R02	2	8	4	4	33	12	0	0	0	45
R03	2	9	4	4	27	18	0	0	0	45
R04	2	9	4	5	24	21	0	0	0	45
R05	3	20	5	6	22	14	3	2	1	42
R06	2	20	5	6	22	19	2	1	1	45
R07	2	18	5	6	19	17	4	2	0	42
R08	2	29	5	6	20	18	5	0	1	44
R09	2	23	4	5	26	17	1	0	1	45

Source: BMA (water quality data 2009)

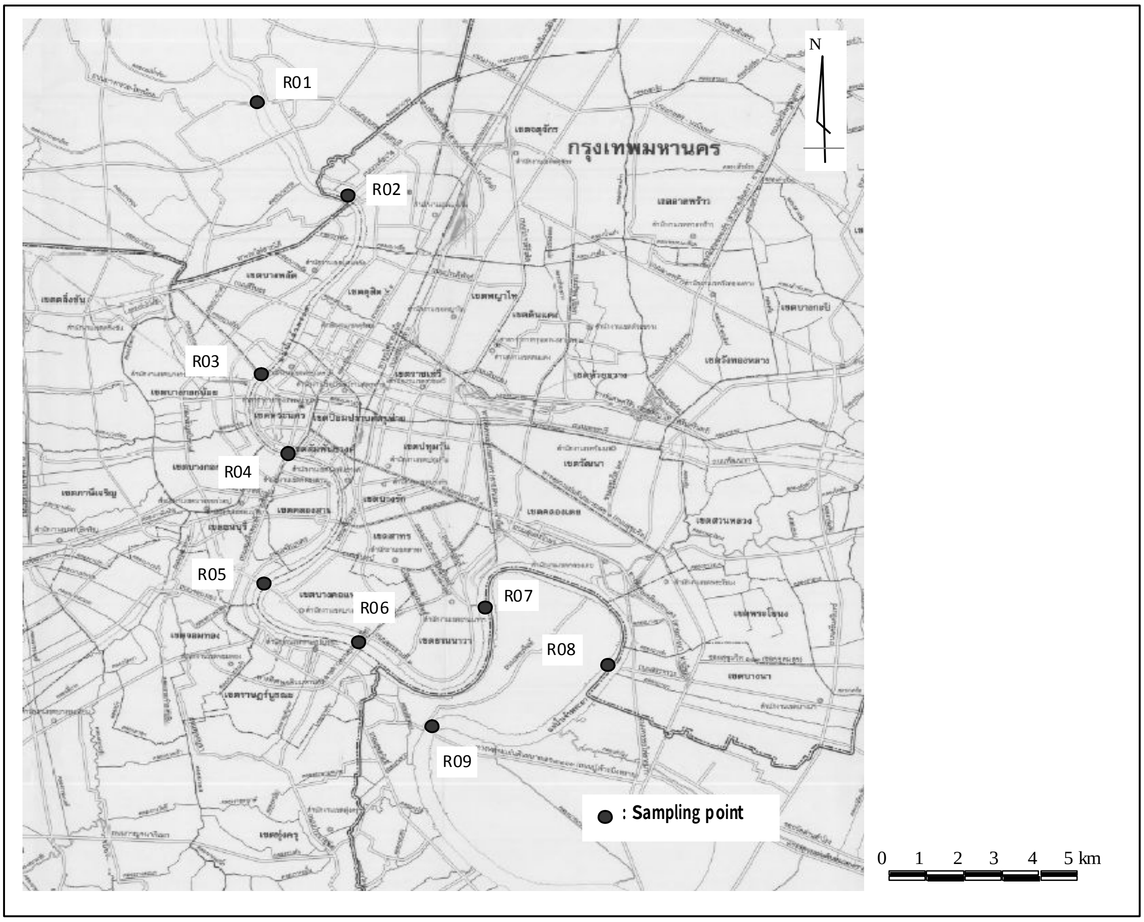
From Table 3.5.1, profile of BOD concentrations along the river is drawn as shown in Figure 3.5.1. More than 80% cases at point R01 the BOD concentrations are below 5 mg/l (37/45). It can be seen that water pollution gradually increases from R02 to R04. The ranges of fluctuation (difference between the minimum and the maximum) become wide from R05 and the number of data which shows BOD 5 mg/l or less is less than half, and maximum values reach to more than 20 mg/l. High BOD values (more than 15 mg/l) might be obtained from a mass of klong water (e.g. Klong Phrakanong) which is discharged to the river and not mixed well with river water. Therefore, high BOD values in Table 3.5.1 should be considered as extraordinary values under peculiar conditions. 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. Therefore, it can be judged that improvement of water quality is possible by reducing the inflow pollution load into Chao Phraya River.



Source: JST

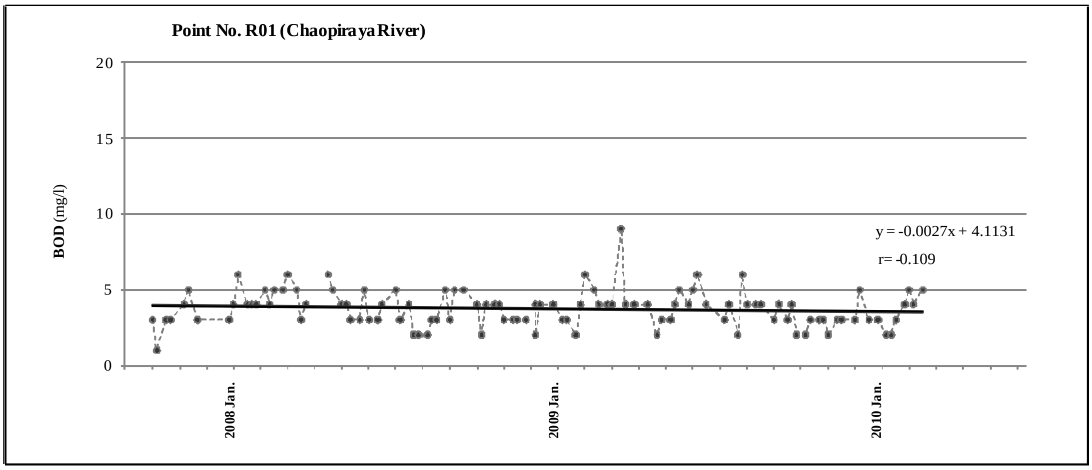
Figure 3.5.1 Profile of BOD Concentrations along Chao Phraya River

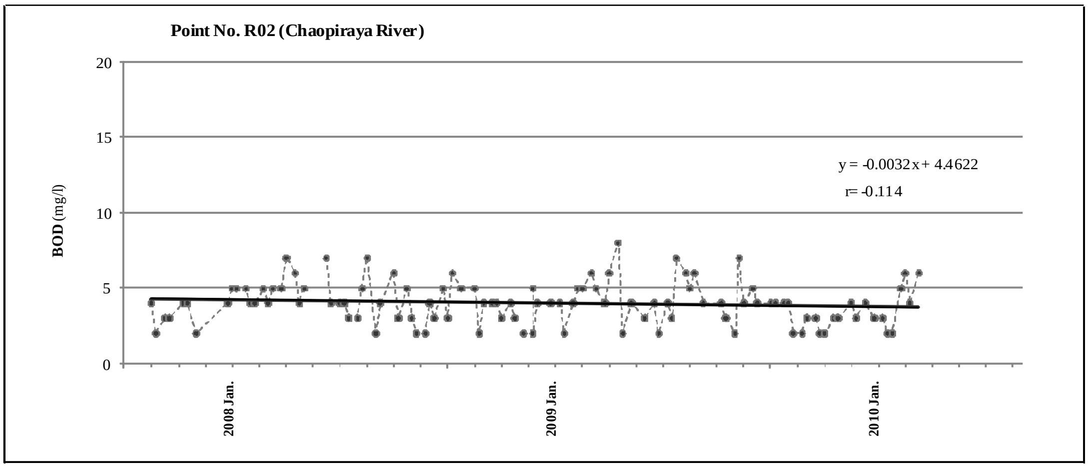


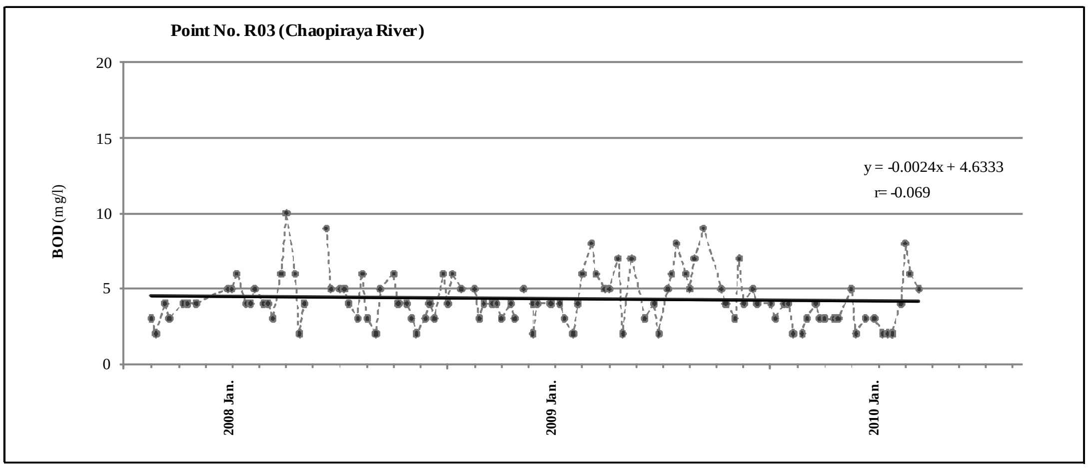
Source: JST

Figure 3.5.2 Location of Water Quality Monitoring Points in Chao Phraya River

Annual variations of BOD concentrations at all the monitoring points (R01 through R09) in Chao Phraya River are shown in Figure 3.5.3. From these Figures, distinct tendencies can not be recognized between R01 and R04. However, improvement of water quality is recognized between R05 and R09. Annual variation of water quality in Chao Phraya River is not clear. Similarly, although the flow of Chao Phraya River decreases in the dry season, it became clear that there was no seasonal variation in BOD concentrations. From these figures, improvement water quality of Chao Praya River is recognized in the last half of rainy season because of increased flow of the river.

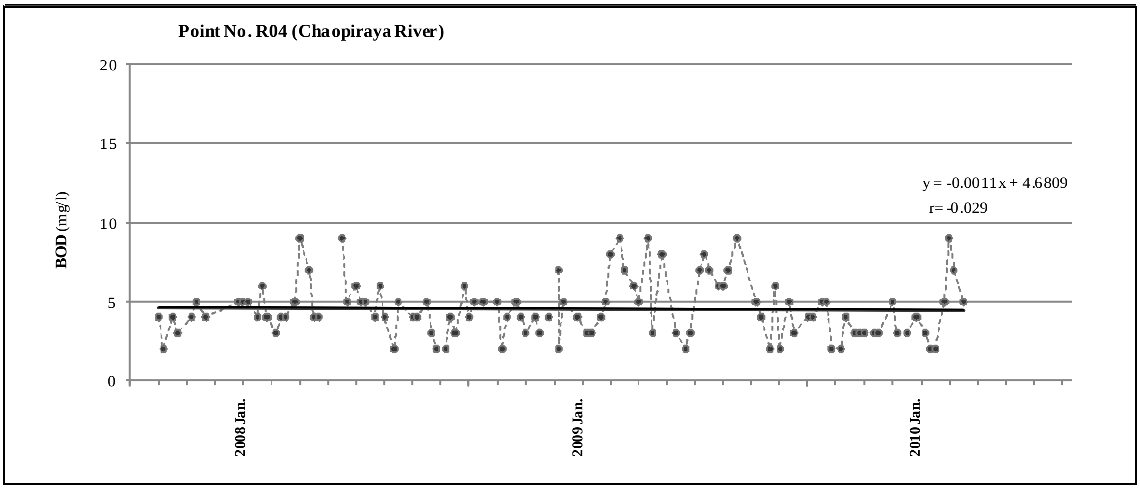


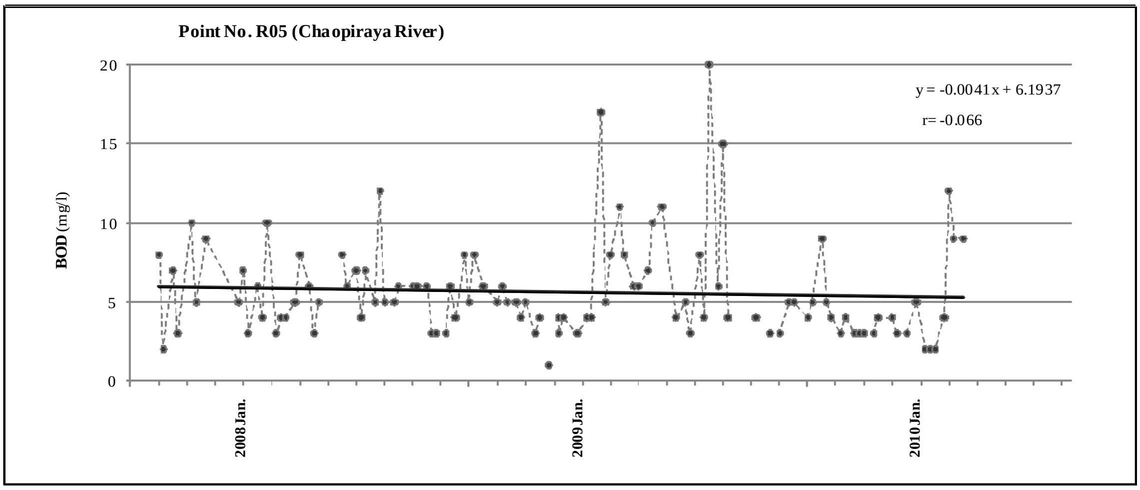


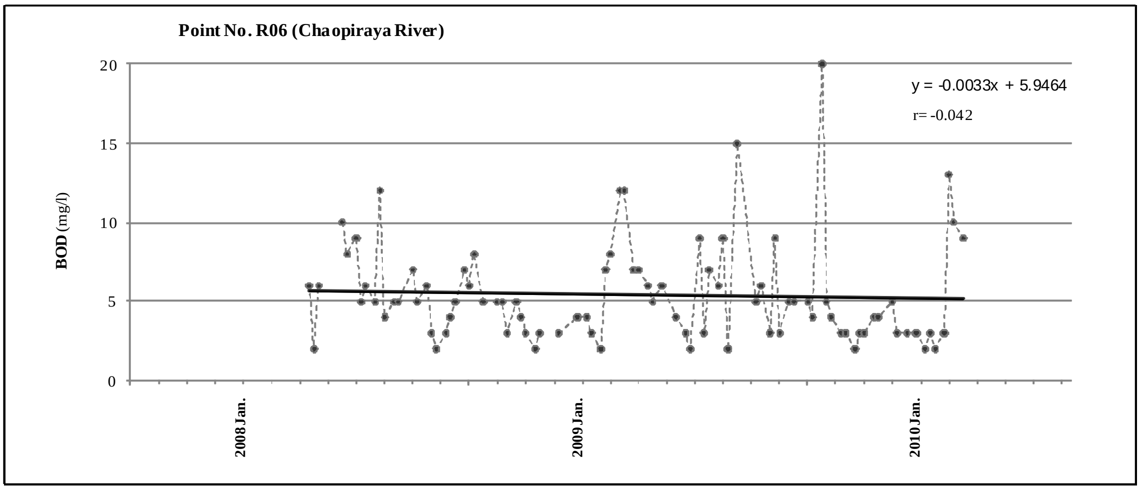


Source: JST

Figure 3.5.3 (1) Annual Variation of BOD Concentrations in Chao Phraya River (1/3)

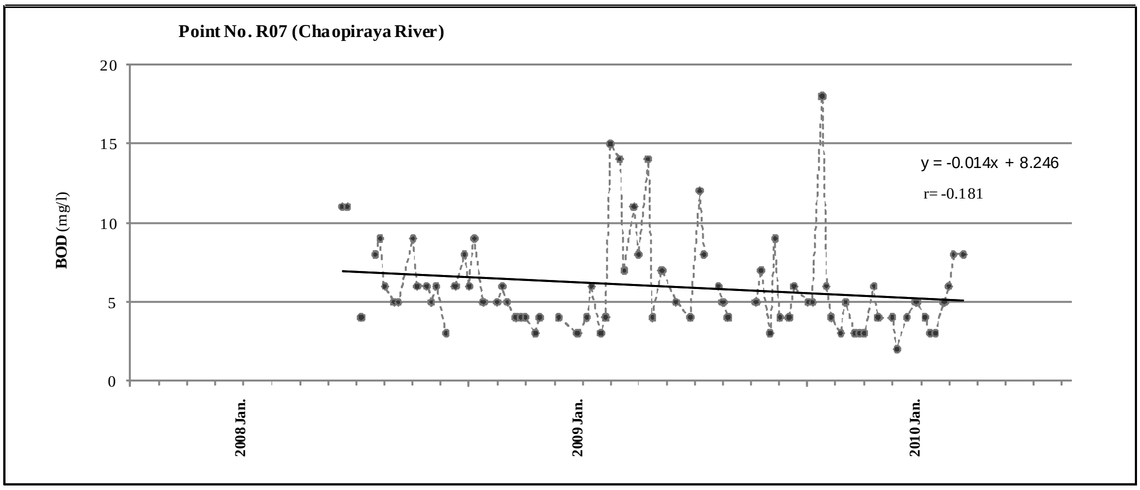


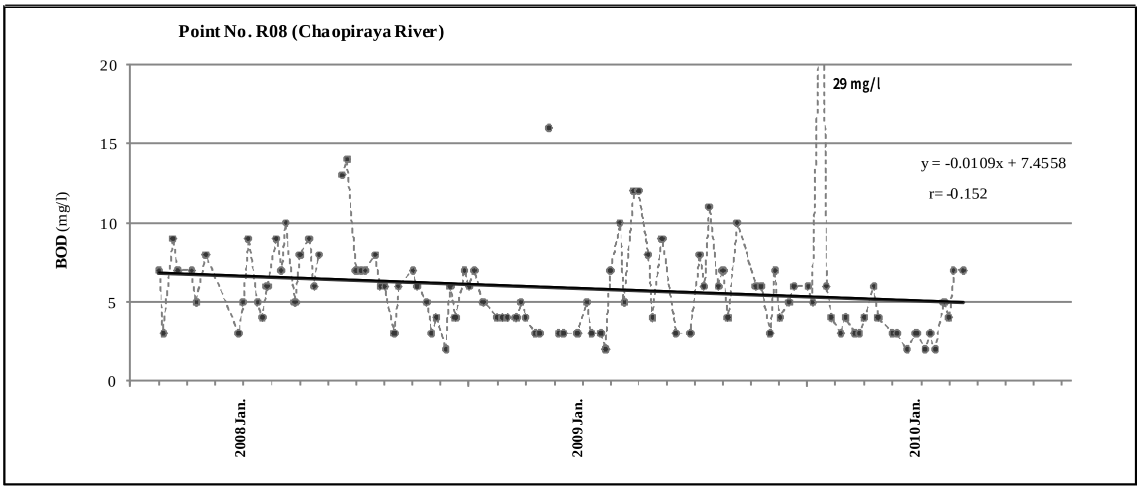


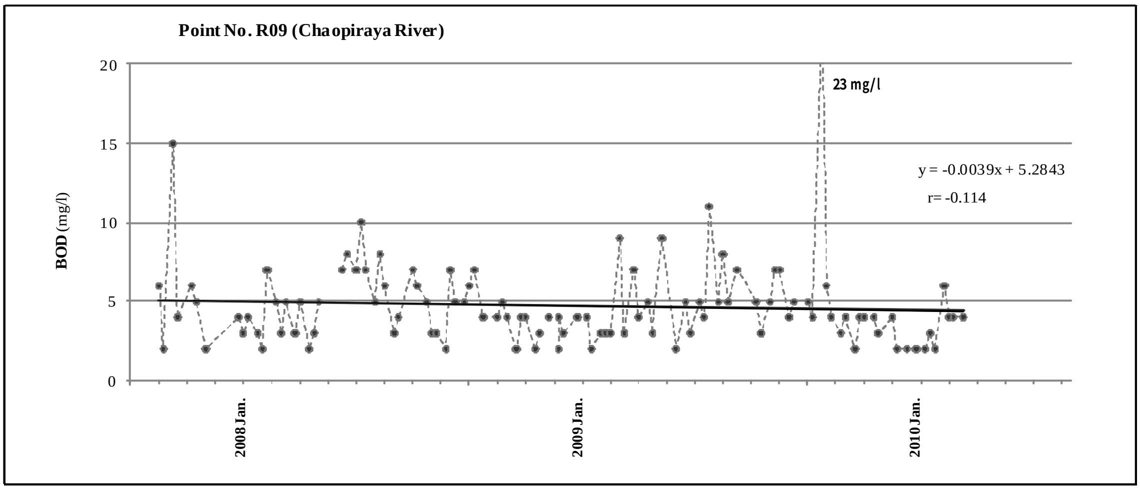


Source: JST

Figure 3.5.3 (2) Annual Variation of BOD Concentrations in Chao Phraya River (2/3)







Source: JST

Figure 3.5.3 (3) Annual Variation of BOD Concentrations in Chao Phraya River (3/3)

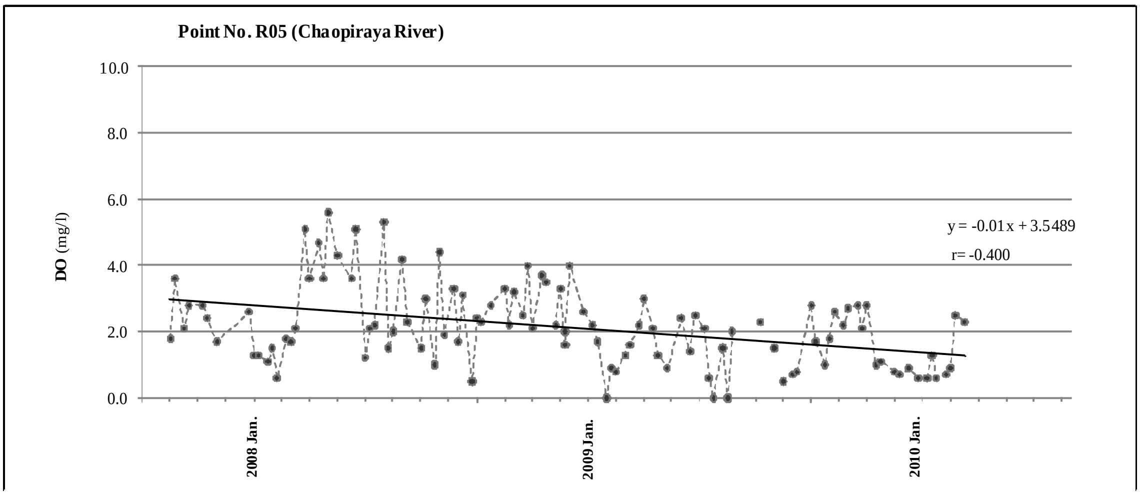
DO concentrations in Chao Phraya River are summarized in Table 3.5.2. The points which meet the surface water quality standards, i.e. DO more than 2 mg/l, are only two points out of nine points. Furthermore, minimum values of all the points are less than 1.0 mg/l.

Table 3.5.2 DO Concentrations in Chao Phraya River (2009)

Point No.	Minimum (mg/l)	Maximum (mg/l)	Average (mg/l)	Number of data			
				Less than 1 mg/l	From 1.0 to 1.9mg/l	More than 2.0 mg/l	Total
R01	0.6	3.6	2.1	2	17	26	45
R02	0.6	3.9	1.9	6	18	21	45
R03	0.5	3.5	1.7	10	15	20	45
R04	0.4	4.1	1.7	11	20	14	45
R05	0.0	3.0	1.6	13	12	17	42
R06	0.7	4.7	1.9	6	21	18	45
R07	0.3	5.2	2.1	6	15	21	42
R08	0.4	7.0	1.8	15	11	18	44
R09	0.5	6.0	1.9	9	16	20	45

Source: BMA (water quality data 2009)

Annual variation at R05 point which was the lowest in terms of DO concentration (average value) is shown in Figure 3.5.4. Although it is judged from this Figure that there is no clear seasonal variation, obviously DO concentrations have gradually decreased.



Source: JST

Figure 3.5.4 Annual Variation of DO Concentrations at RO5 point of Chao Phraya River

3.5.3 Present Water Pollution Situation in Klongs in BMA

(1) Water Quality Standards for Surface Water in Klongs

As for klongs in the Survey Area, the classification of the surface water quality standards is not specified. Therefore, it is assumed that the class 5 is applied as environmental standards for water quality. However, the target values of water quality items are not established other than color, odor and taste.

BMA has set up the target values in their Performance Plan as shown in Table 3.5.3 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 3.5.3 Target by Performance Plan (BMA)

	Current (2008)	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)

(2) Present Water Pollution Situation

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 3.5.5 to 3.5.9 and Table 3.5.4).

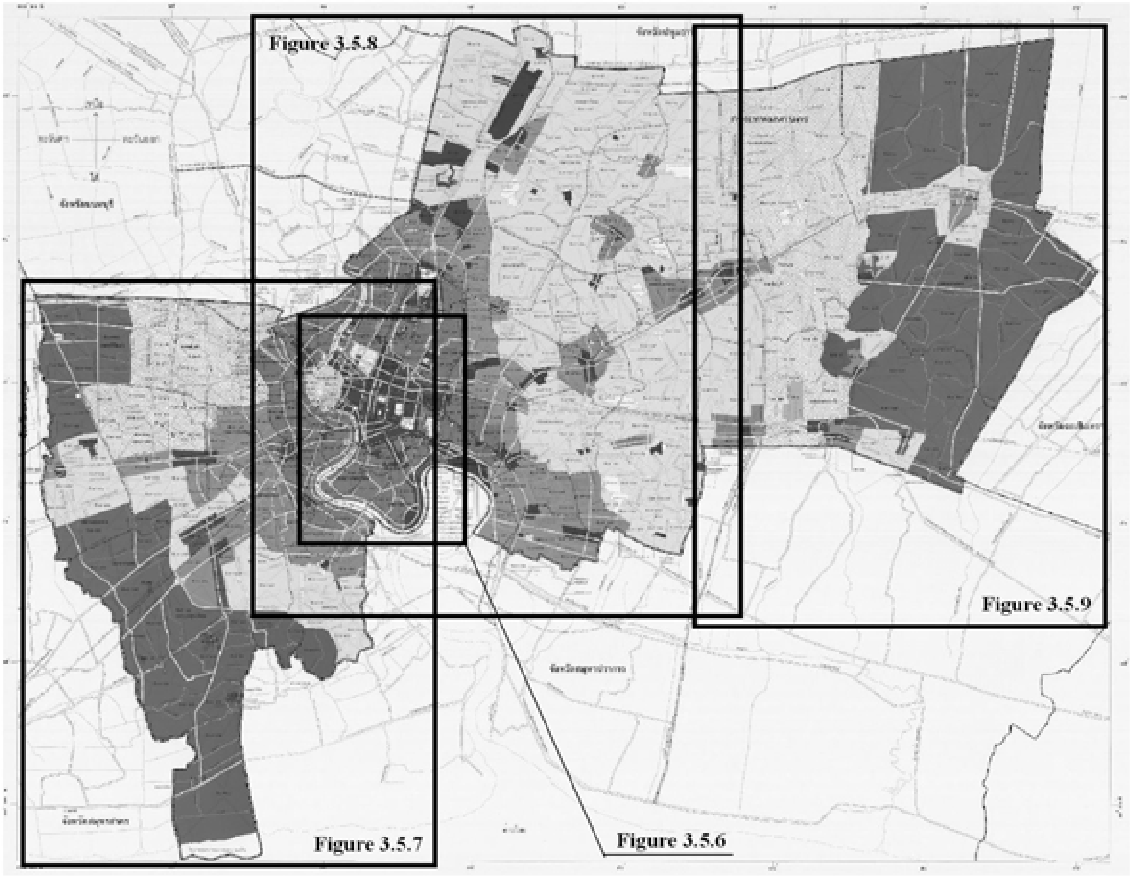
Most of the monitoring points for klongs at which BOD concentrations (annual average) exceed 15 mg/l are located in minor klongs, as shown in Table 3.5.4. These minor klongs discharge to main klongs or directly discharge to Chao Phraya River. In dry season, it is presumed that flows in these klongs are mostly wastewater. Water pollution condition in klongs located inside current treatment areas, viz. Klong Huai Khwang, Klong Phrayawek, Klong Nasong, Klong Suanlung 1, Klong Chon Nonsi, Klong Sathon, Klong Kwang, and Klong Suanlung, has not been improved yet because a small portion of wastewater escape from sewerage system discharge into these klongs; of which self flow is almost zero. In order to improve pollution condition in these klongs, not only pollutant reduction i.e. provision of sewerage system, but also other measures such as introduction of clean water and installation of purification facility might be necessary.

Table 3.5.4 Monitoring Points for Klongs

(Klongs of which BOD concentrations (2009 annual average) exceed 15 mg/l)

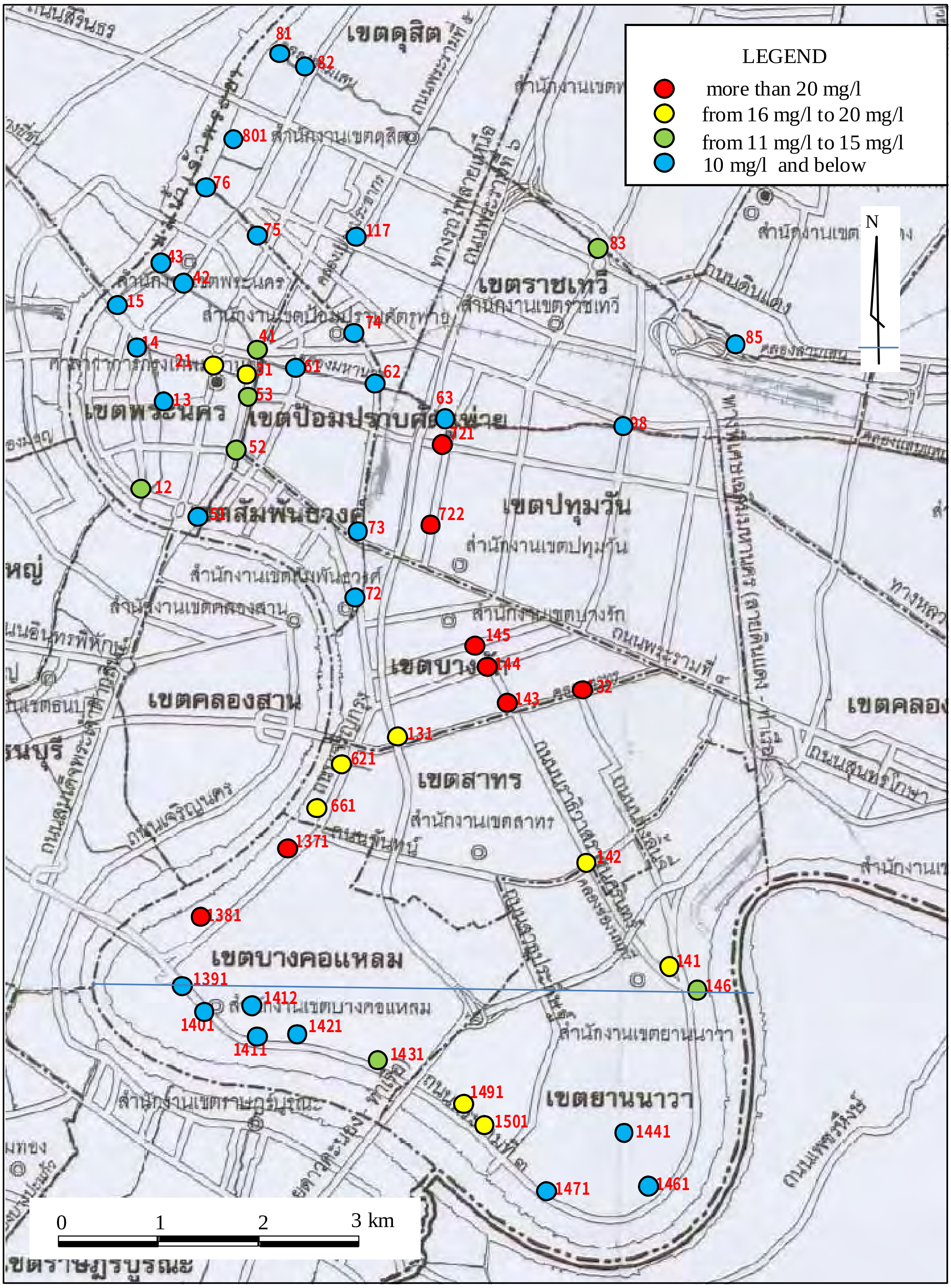
Name of Klong	District	Sewerage area	Point No.
K. Wat Theb Thida	Phra Nakhon	Rattanakosin	21
K. Watratchabopit	Phra Nakhon	Rattanakosin	31
K. Suang Lung 1	Pathum Wan	Din Deang	721, 722
K. Sathon	Sathon	Chon Nonsi	131-133
K. Chonnonsi	Yan Nawa, Bang Rak, Sathon	Chon Nonsi	141 - 145
K. Wat Don	Sathon	Chon Nonsi	621
K. Krui	Bang Kho Laem	Chon Nonsi	661
K. Khwang	Bang Kho Laem	Chon Nonsi	1371
K. Suanlung	Bang Kho Laem	Chon Nonsi	1381
K. Watdokmai	Yan Nawa	Chon Nonsi	1491
K. Rongnummun	Yan Nawa	Chon Nonsi	1501
K. Manao	Yan Nawa	Chon Nonsi	1651
K. Huai Khwang	Din Daeng, Huai Khwang	Din Daeng	171, 173-175
K. Ladyao	Chatuchak	Chatuchak	692
K. Phrayawek	Chatuchak	Chatuchak	701
K. Namkhew	Huai Khwang	Chatuchak	711, 712
K. Nasong	Din Daeng	Din Daeng	751, 752
K. Ton	Watthana	-	101
K. Phaisingha-tho	Klong Toei	-	301, 303
K. Toei	Klong Toei	-	611, 612
K. Wathualumpong	Klong Toei	-	651
K. Banglhai	Phra Khanong	-	1351, 1352
K. Bang chak	Phra Khanong	-	481
K. Jack	Phra Khanong	-	1341
K. Bang Na	Bang Na	-	281
K. Or-ngoen	Sai Mai	-	1301
K. Sam-ngam	Sai Mai	-	1311
K. Chaorakae	Bang Khen	-	1291
K. Lhumphai	Lat Phrao, Bang Khen	-	581, 582
K. Lumtonnoon	Khan Na Yao	-	1561
K. Kum	Bueng Kum	-	591, 592
K. Saphansung	Saphan Sung	-	1591
K. Pungpuoy	Bueng Kum, Bang Kapi	-	601, 602
K. Watkratumpsuephla	Prawet	-	1091
K. Bing	Suan Luang	-	1071
K. Ta-chang	Prawet	-	1141
K. Klad	Phra Khanong	-	1361
K. Bangsaikai	Thon Buri	-	151, 152
K. Samlay	Thon Buri	-	291

Source: BMA



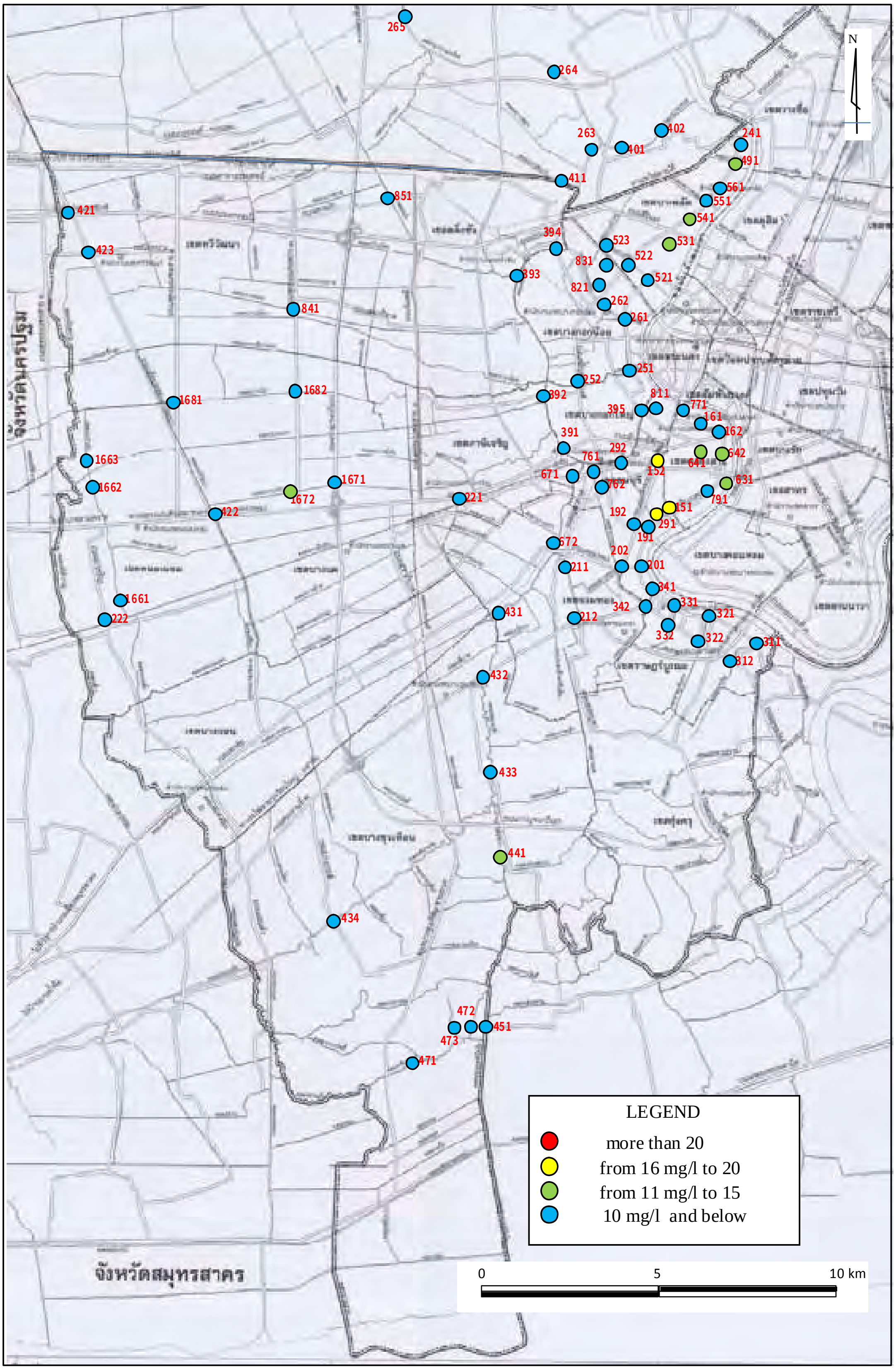
Source: JST

Figure 3.5.5 Guide Map for Figures 3.5.6 through 3.5.9



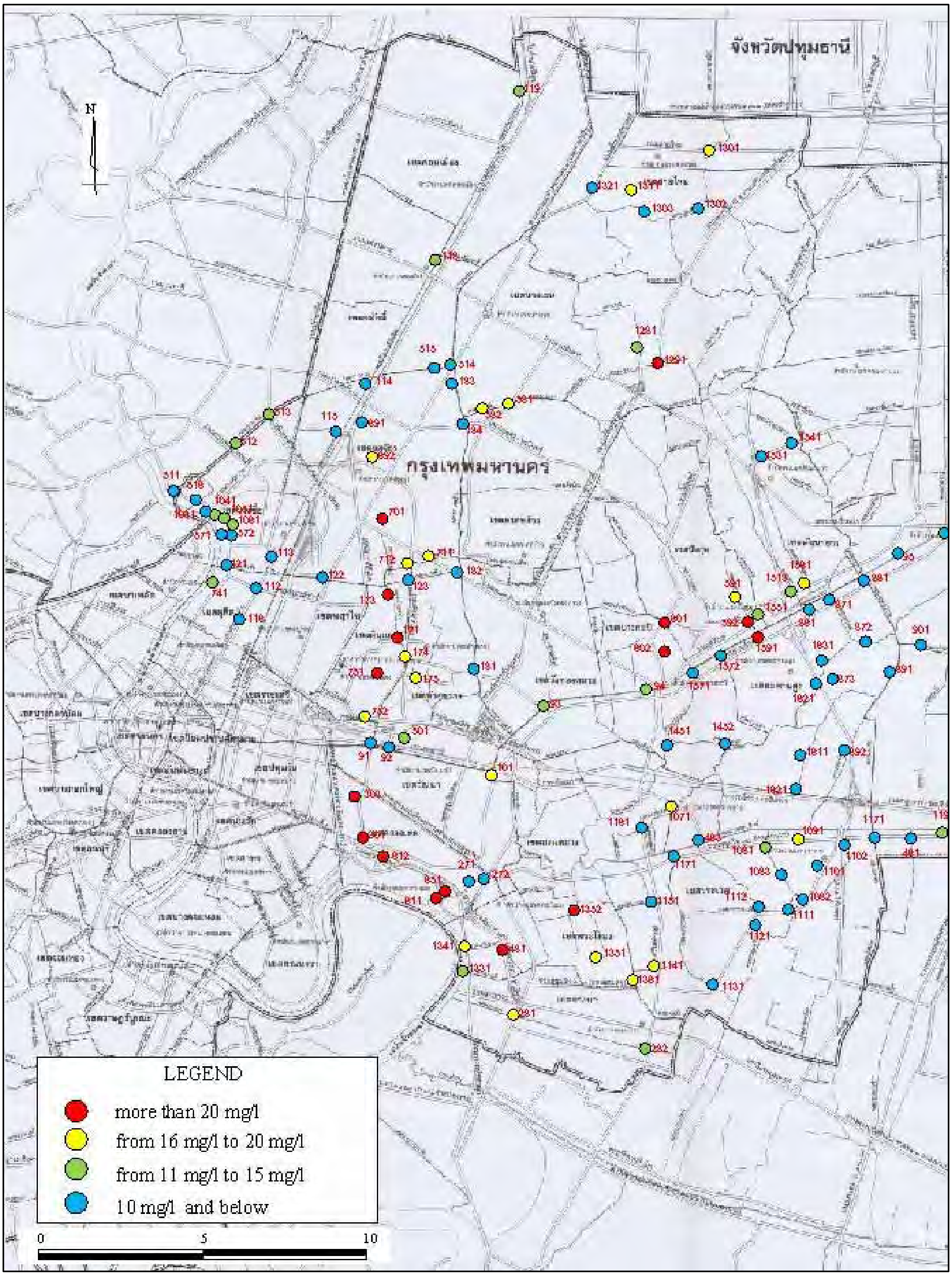
Source: JST

Figure 3.5.6 BOD Concentrations in Klongs (Average in 2009) (1)



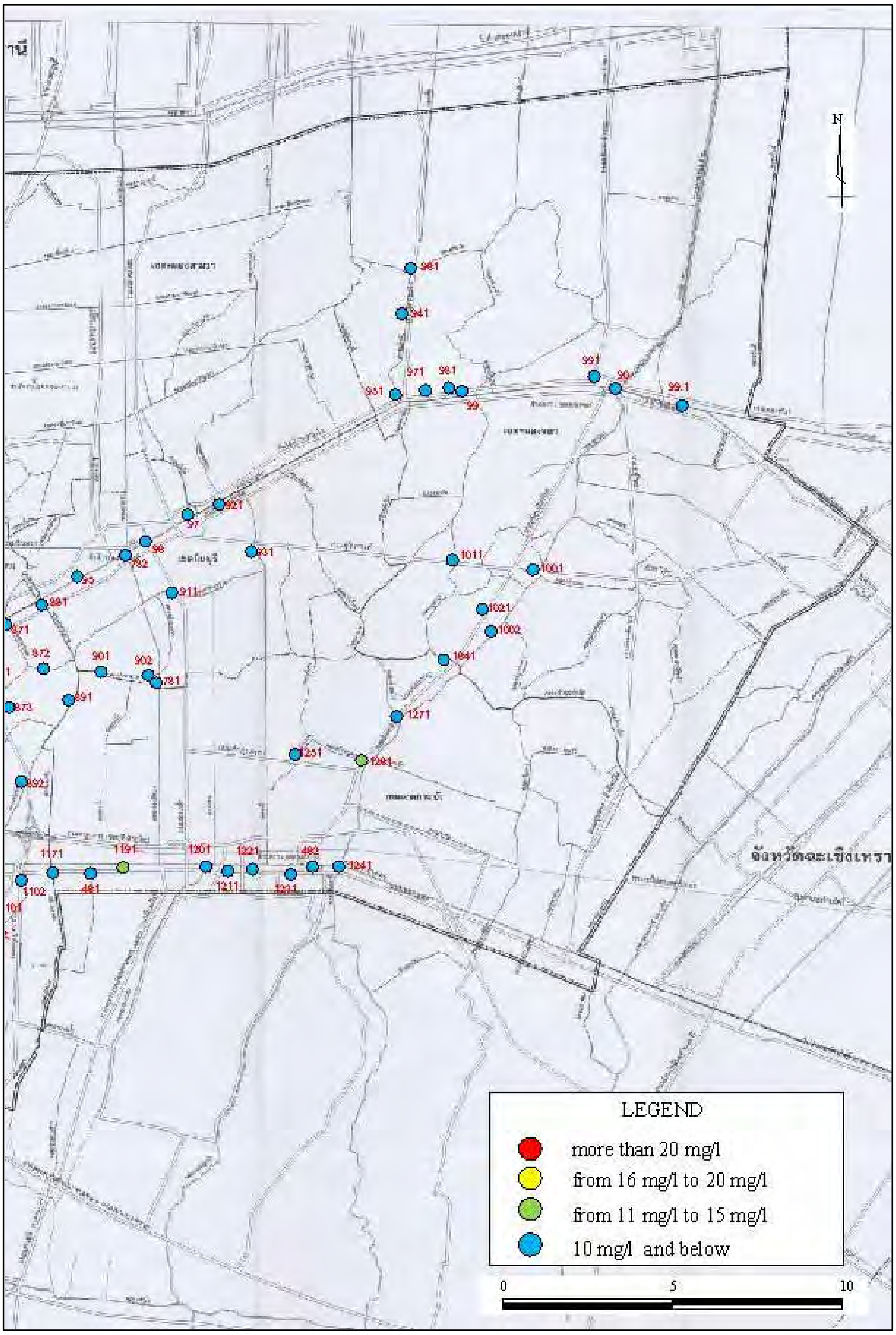
Source: JST

Figure 3.5.7 BOD Concentrations in Klongs (Average in 2009) (2)



Source: JST

Figure 3.5.8 BOD Concentrations in Klongs (Average in 2009) (3)



Source: JST

Figure 3.5.9 BOD Concentrations in Klongs (Average in 2009) (4)

Annual variation was examined for all monitoring points for which the monitoring has been continued for more than ten years. As a result, for some points water quality improvement is clearly recognized. Obviously BOD concentrations have been decreasing at these points until now, and fluctuations have also become small. These points are shown in Table 3.5.5.

Table 3.5.5 Monitoring Points Which Show Obvious Water Quality Improvement

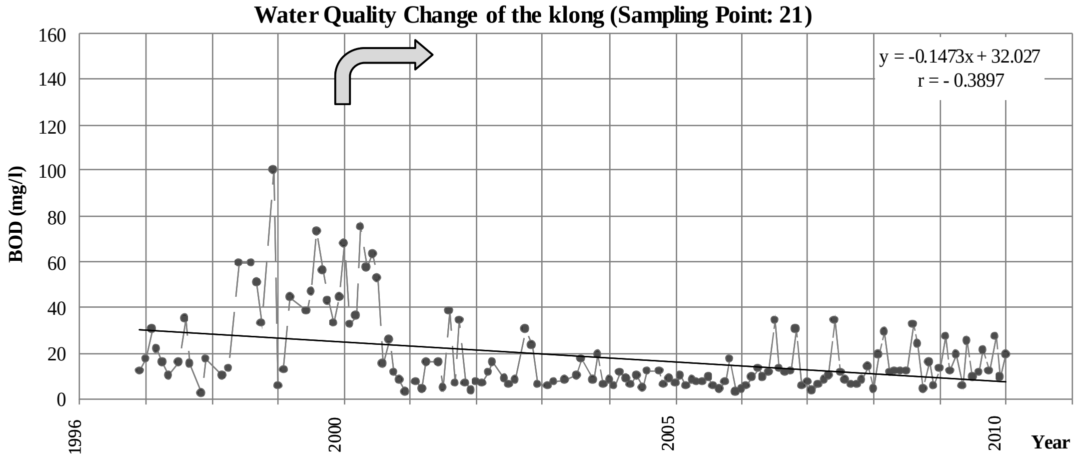
Name of Klong	District	Sewerage area	Point No.
Bangkok Side Area			
K. Wat Theb Thida	Phra Nakhon	Rattanakosin	21
K. Watratchabopit	Phra Nakhon	Rattanakosin	31
K. Sam Sean	Dusit, Phaya Thai, Din Daeng	Din Daeng	81, 82, 83, 85
K. Saen Saep	Ratchathewi	Din Daeng	98
K. Bang Sue	Phaya Thai, Din Daeng	Chatuchak	122, 123
K. Huai Khwang	Din Daeng, Huai Khwang	Din Daeng	171,(173, 174, 175)
K. Bangkapi	Huai Khwang		501
Thon Buri Side Area			
K. Bangpakok	Rat Burana	Thung Khru	331, 332
K. Bangsaikai K. Bangnamchon	Thon Buri Thon Buri		151, 152 191, 192
K. Samlay	Thon Buri		291
K. Bangrak	Bang Phlat		491
K. Bangyee-khan	Bang Phlat		521, 522
K. Bangjak	Bang Phlat		531
K. Bangphlu	Bang Phlat		541
K. Watthongpheng	Klong San		641, 642

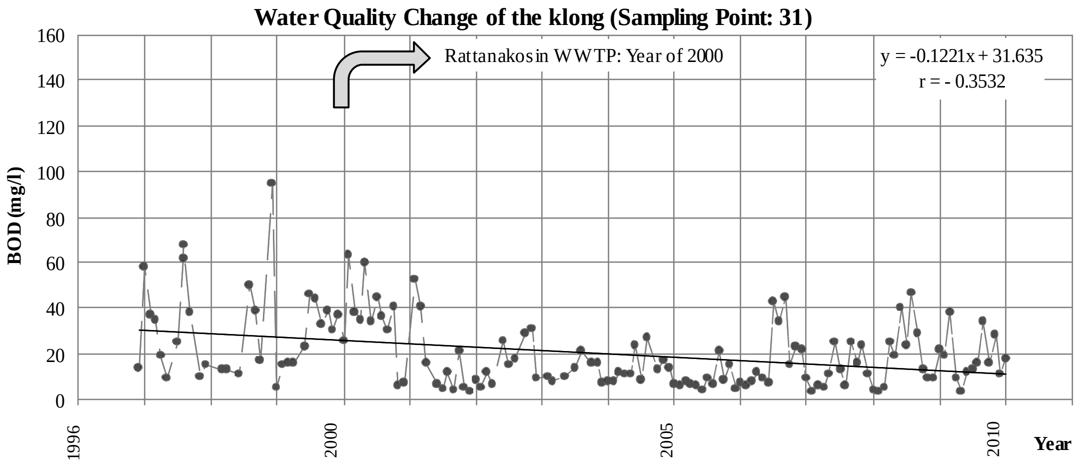
Source: JST

The situations of these points with tendency of water quality improvement are described below.

(A) Monitoring Points: Nos. 21 and 31（K. Wat Theb Thida and K. Watratchabopit）

Theses points are located in the treatment area of the Rattanakosin WWTP, which commenced its operation in 2000. Furthermore, purification water from Chao Phraya River was introduced to the klong. Therefore, possible reasons for water quality improvement might be the effects of both occurrences. At present, it is difficult to quantitatively evaluate the water quality improvement effect from the provision of the sewerage system.



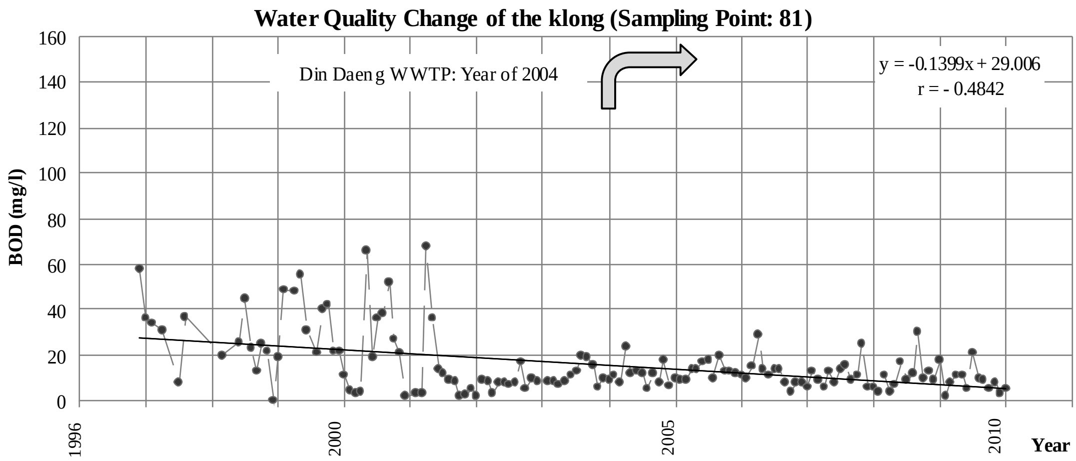


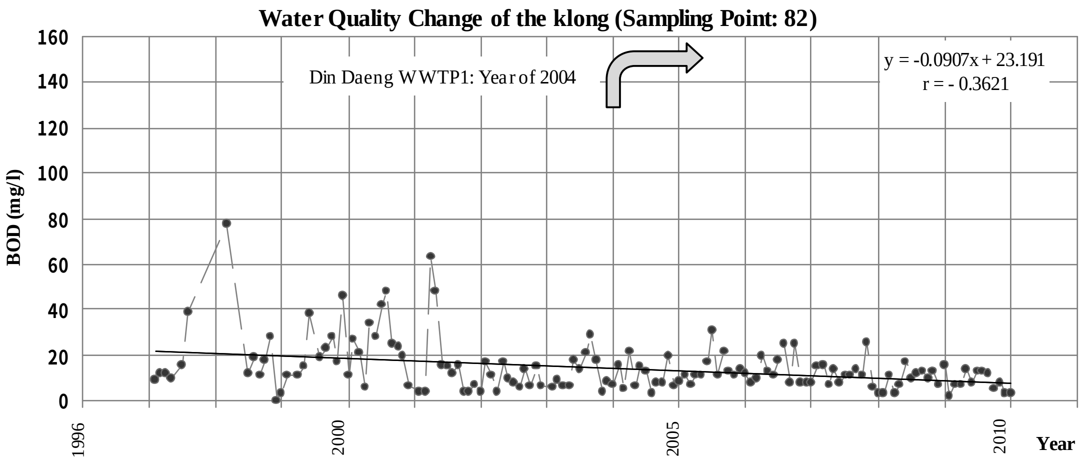
Source: JST

Figure 3.5.10 Annual Variation of BOD Concentrations of Klong Wat Theb Thida

(B) Monitoring Points: Nos. 81, 82, 83, and 85 (K. Sam Sean)

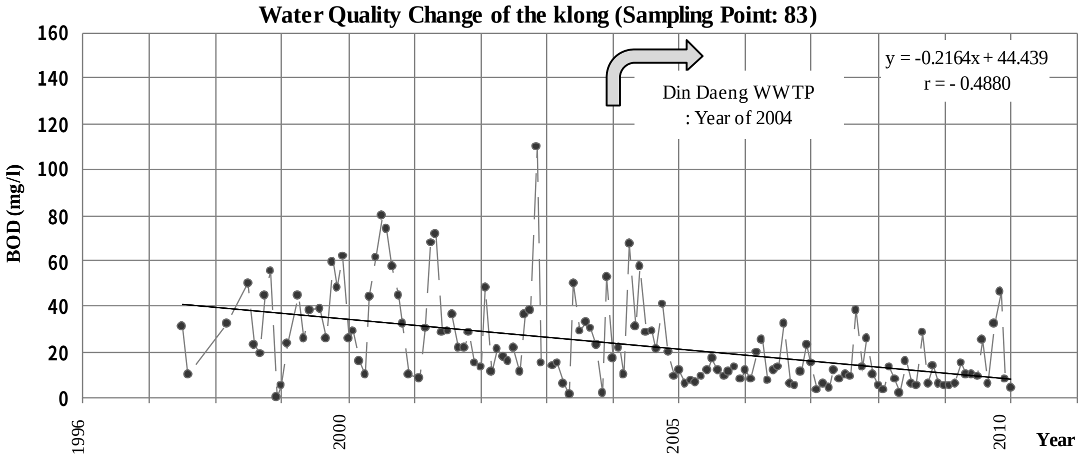
These points are located in the treatment area of the Din Daeng WWTP, which commenced its operation in 2004. The water quality improvement at monitoring points No.81 and No. 82 is recognized even before operation of the Din Daeng WWTP. Therefore, it can be judged that the reason for water quality improvement at points No.81 and 82 is an effect of purification water introduction. BOD concentrations showed decreasing tendency at points No.83 and No. 85, however, it is difficult to be judged that the reason for water quality improvement at these points is an effect of purification water introduction or operation of Din Daeng WWTP (refer to Figure 3.5.11).

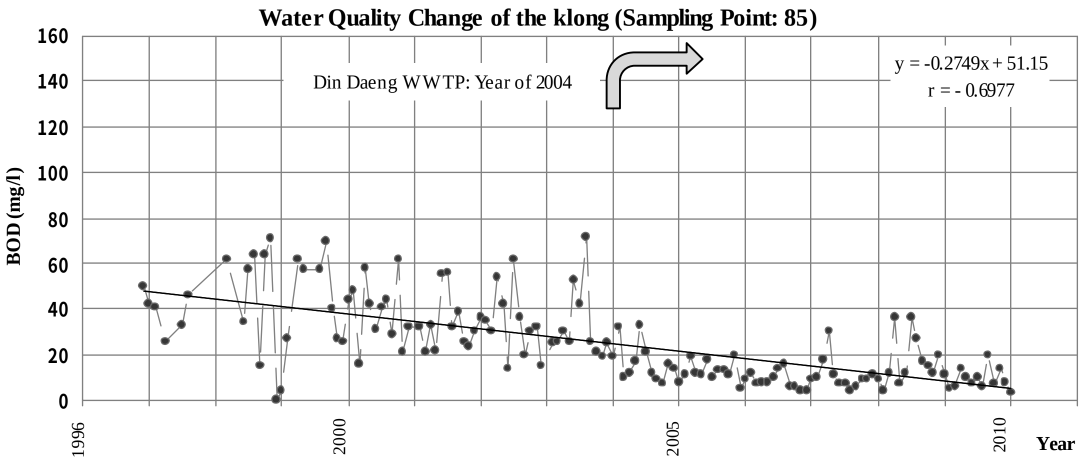




Source：JST

Figure 3.5.11 (1) Annual Variation of BOD Concentrations of Klong Sam Sean (1/2)



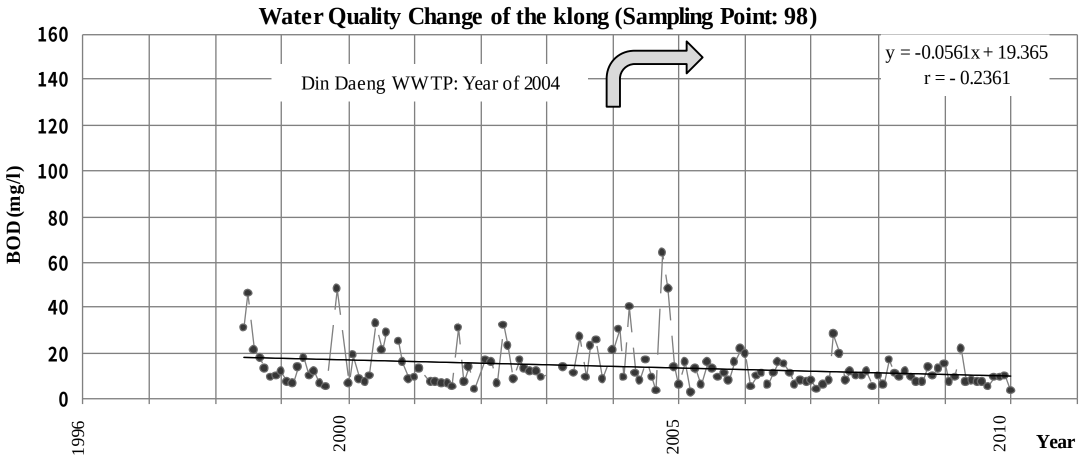


Source: JST

Figure 3.5.11 (2) Annual Variation of BOD Concentrations of Klong Sam Sean (2/2)

(C) Monitoring Point: No. 98 (K. Saen Saep)

Although water quality improvement at this monitoring point is not remarkable, range of fluctuation of BOD concentrations after 2005 has become small comparing to those of before 2005. This point is located in the treatment area of the Din Daeng WWTP, which commenced its operation in 2004. The reason for water quality improvement at this point is probably an effect of the provision of sewerage system (refer to Figure 3.5.12).

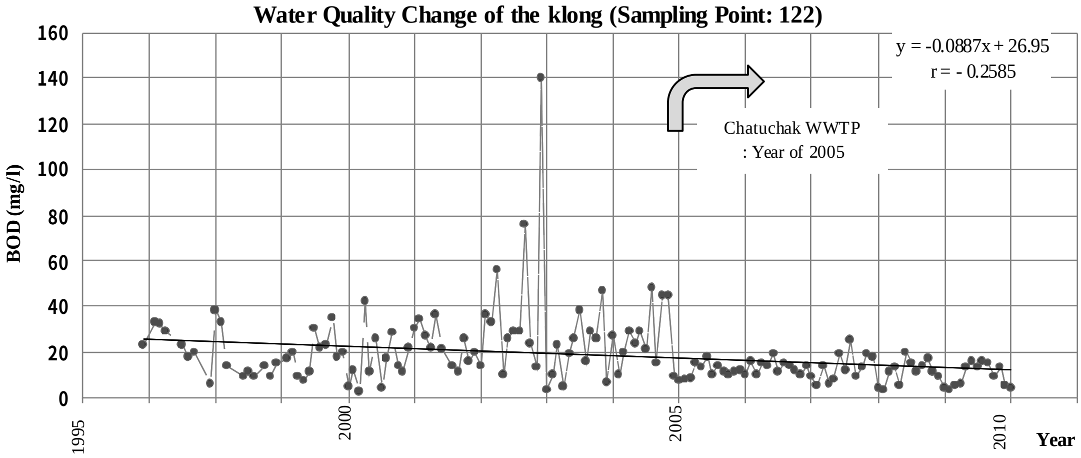


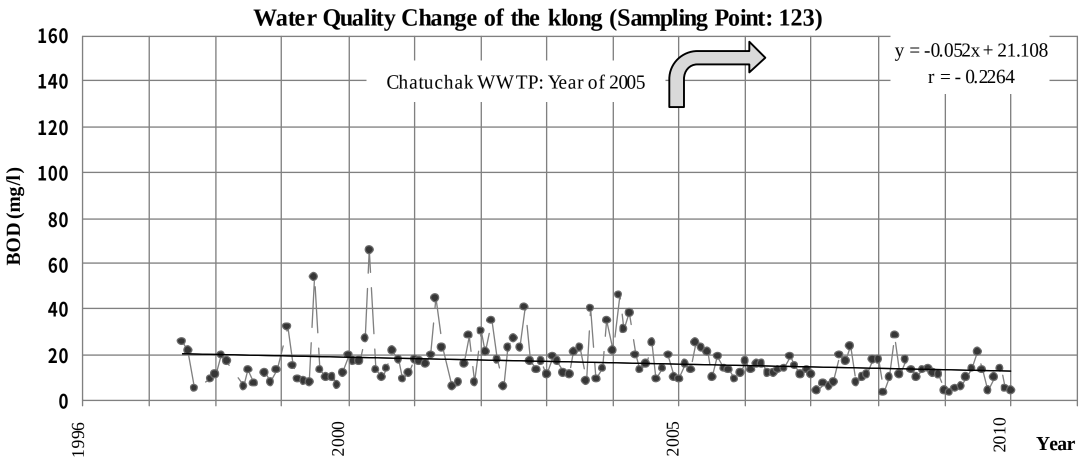
Source: JST

Figure 3.5.12 Annual Variation of BOD Concentrations of Klong Sean Saep

(D) Monitoring Points: Nos. 122 and 123 (K. Bang Sue)

These points are located in the treatment area of the Chatuchak WWTP, which commenced its operation in 2005. The water quality improvement effect can be seen after the commencement of the WWTP operation, and the water quality improvement at these points might be an effect of the wastewater project. However, at the same time, the possibility of the effect of the purification water introduction cannot be denied (refer to Figure 3.5.13).



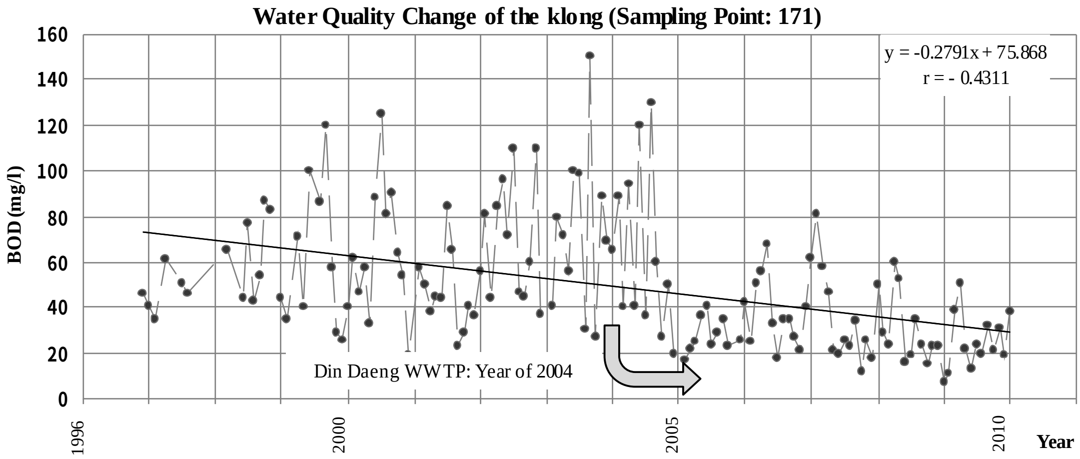


Source: JST

Figure 3.5.13 Annual Variation of BOD Concentrations of Klong Bang Sue

(E) Monitoring Points: Nos. 171, 173, 174, 175 (K. Huai Khwang)

These points are located in the treatment area of the Din Daeng WWTP, which commenced its operation in 2004. However, results of water quality analysis were obtained for No.171 point only. The water quality improvement at this point is presumed to be an effect of the sewerage project. However, the possibility of the effect of the purification water introduction through K. Bang Sue cannot be denied (refer to Figure 3.5.14).

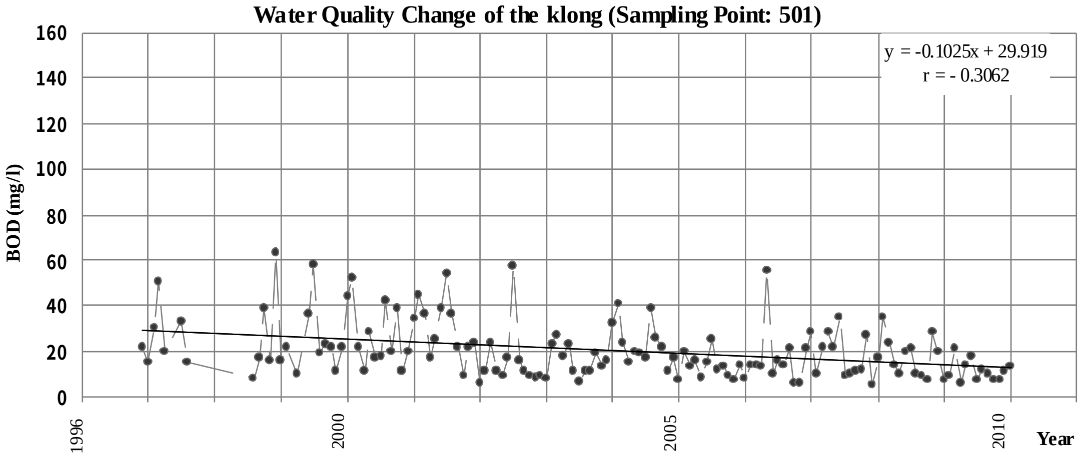


Source: JST

Figure 3.5.14 Annual Variation of BOD Concentrations of Klong Huai Khwang

(F) Monitoring Points: No. 501 (K. Bangkapi)

This monitoring point is located in K. Bangkapi which connects K. Sam Sean and K. Saen Saep. The basin of K. Bangkapi is outside of treatment area. It is judged that the reason for water quality improvement of the klong is due to the influence of the two above-mentioned klongs (refer to Figure 3.5.15).

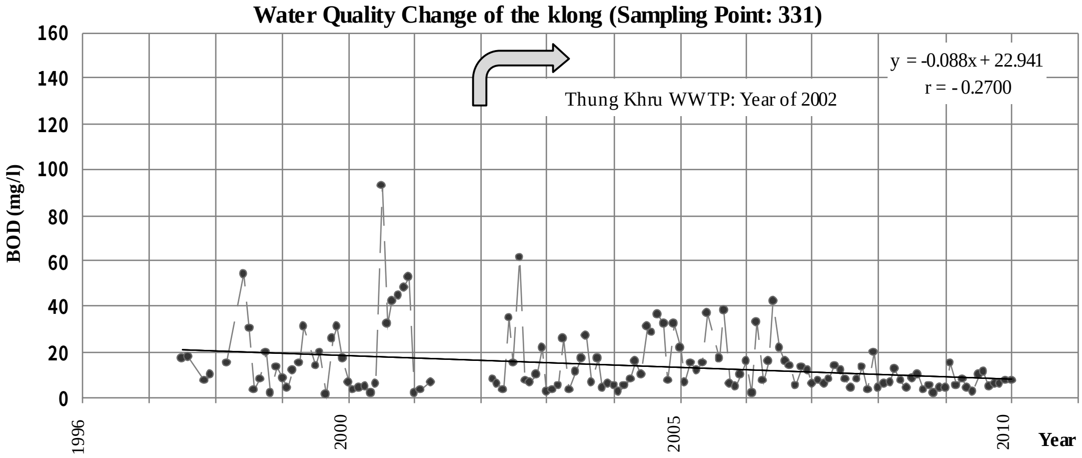


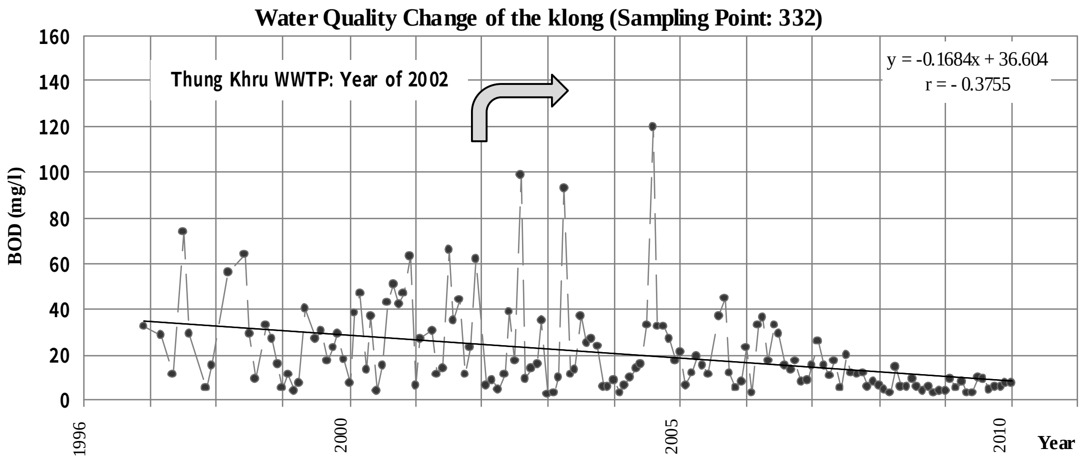
Source: JST

Figure 3.5.15 Annual Variation of BOD Concentrations Klong Bangkapi

(G) Monitoring Points: Nos. 331, 332 (K. Bangpakok) and Eight Klongs on Thon Buri side

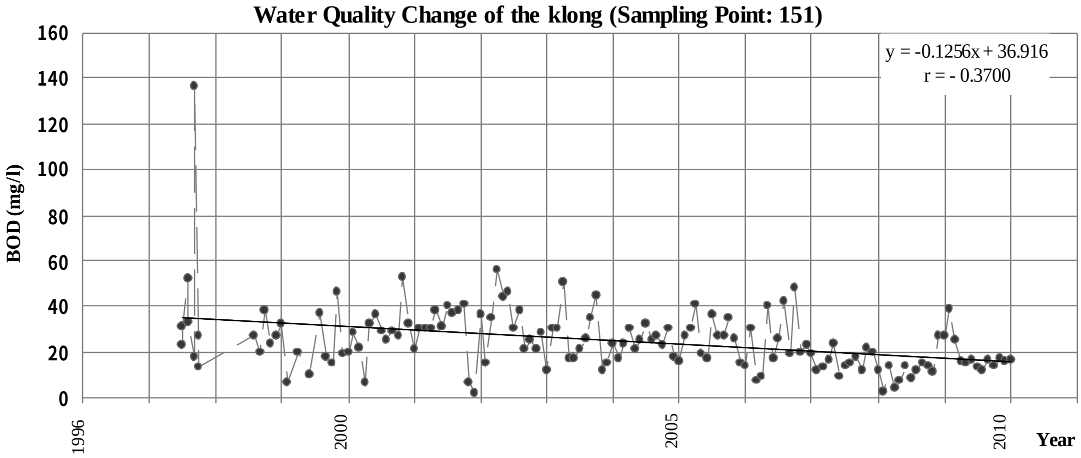
These points (No. 331 and No. 332) are located in Klong Bangpakok district near Chao Phraya River, and in the treatment area of the Thung Khru WWTP, which commenced its operation in 2002. Water quality improvement is found in the period between 2007 and 2009. If this water quality improvement has been caused by an effect of the sewerage project, the reason for the delay of water quality improvement is not known (refer to Figure 3.5.16). Similarly, in eight klongs on Thon Buri side, water quality improvement is also found between 2007 and 2009 (refer to Figure 3.5.17). Considering water pollution condition mentioned above, common reasons for water quality improvement at Nos. 331 and 332 and in eight klongs are introduction of Chao Phraya River water.

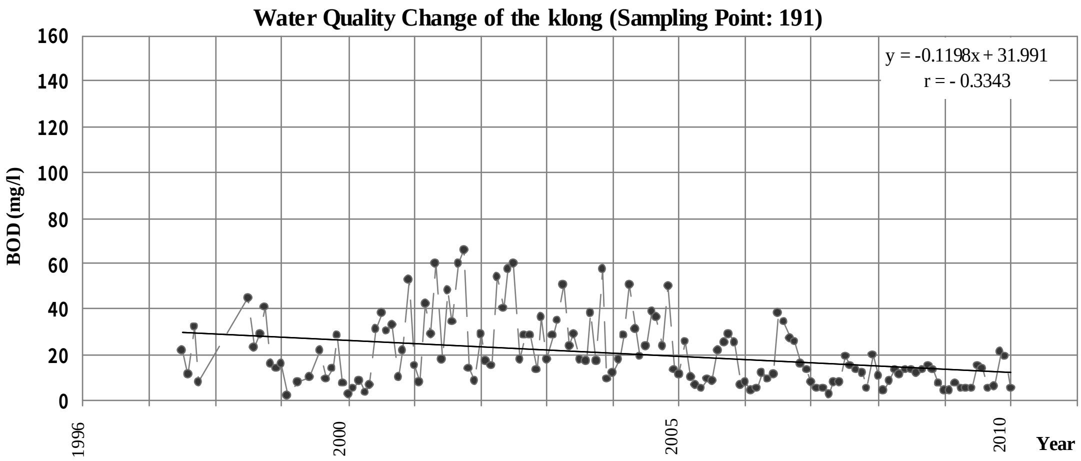




Source: JST

Figure 3.5.16 Annual Variation of BOD Concentrations of Klong Bangpakok





Source: JST

Figure 3.5.17 Annual Variation of BOD Concentrations of Klong Bangsaikai and Klong Bangnamchon

(H) Dissolved Oxygen (DO) Concentrations in Klongs

DO concentrations in klongs are summarized in Table 3.5.6. The number of points at which DO concentrations (annual average in 2009) were less than 1 mg/l, i.e. provisional improvement target, accounted for about 30% of all the monitoring points. These monitoring points are distributed only over the Bangkok side. Distribution of the annual average values of DO is shown in Figures 3.5.19 to 3.5.22.

Table 3.5.6 Dissolved Oxygen Concentrations in Klongs

Range of Dissolved Oxygen Concentrations	Number of Monitoring Points（Annual Average in 2009）
Less than 0.5 mg/l	53 points (18.8%)
From 0.5 to 0.9 mg/l	32 points (11.3%)
More than 1.0 mg/l	197 points (69.9%)
Whole Range	282 points (100.0%)

Source: DDS

DO concentrations are changed mainly by the following actions.

Reduced by :

- Oxidization of organic matter by aquatic microorganisms (respiration)
- Oxidization of inorganic substances

Increased by :

- Oxygen transfer from the air
- Supply of oxygen by photosynthetic activity of aquatic plants

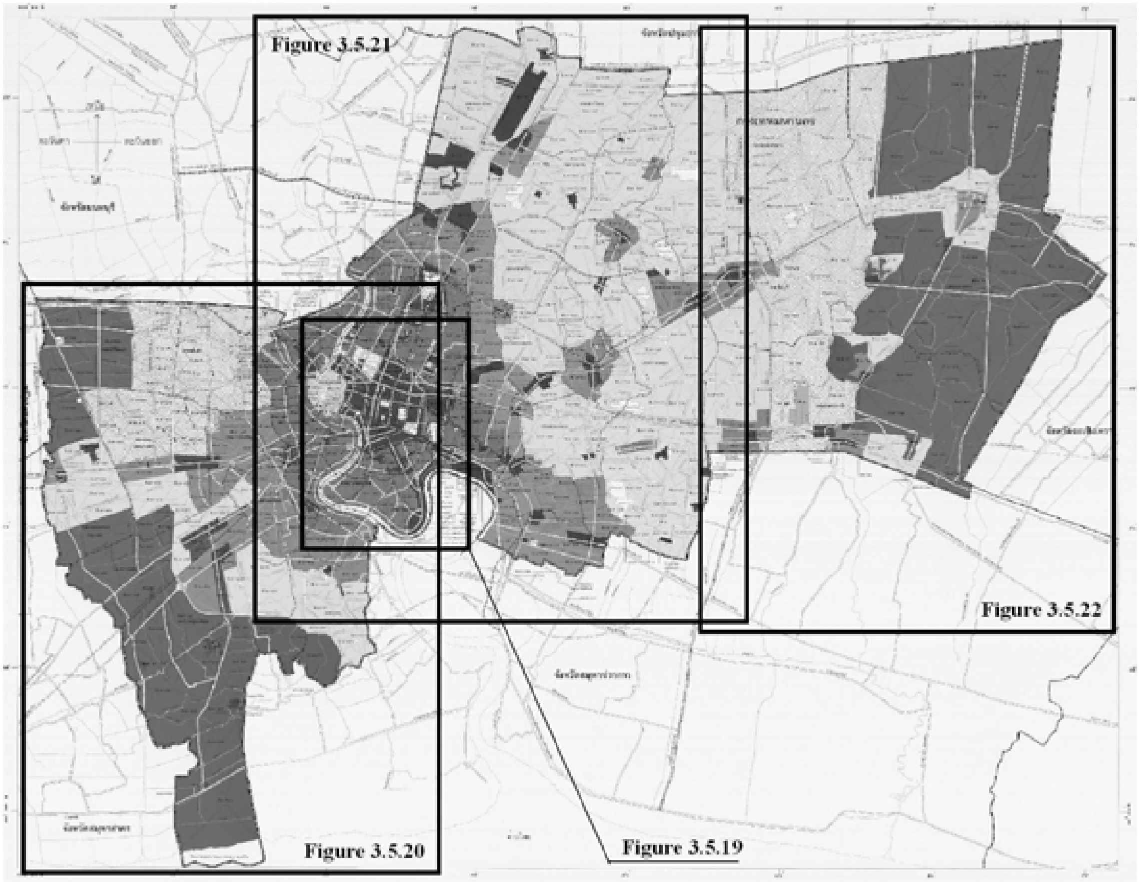
DO concentration is determined by the balance of these actions. Usually, in the water bodies where BOD concentration is low, dissolved oxygen concentration is stabilized at 5 mg/l to 7 mg/l. Based on the results of water quality analysis for klongs, correlation between BOD and DO is shown in Table 3.5.7 and Figure 3.5.23. From Table 3.5.7 and Figure 3.5.23, in the water bodies where their BOD concentrations are below 10 mg/l, about 73% cases, the DO concentrations exceed 1 mg/l. Similarly, 48% cases the DO concentrations exceed 1 mg/l where BOD concentrations are 11 mg/l to 15 mg/l. However, if BOD concentrations exceed 16 mg/l, DO concentrations fall rapidly. Furthermore, when BOD concentrations are over 21 mg/l, DO concentrations obviously fall extremely low.

Correlations between BOD and DO is not significant as shown in Figure 3.5.21 (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 3.5.7 Correlation of the BOD and DO in Klongs

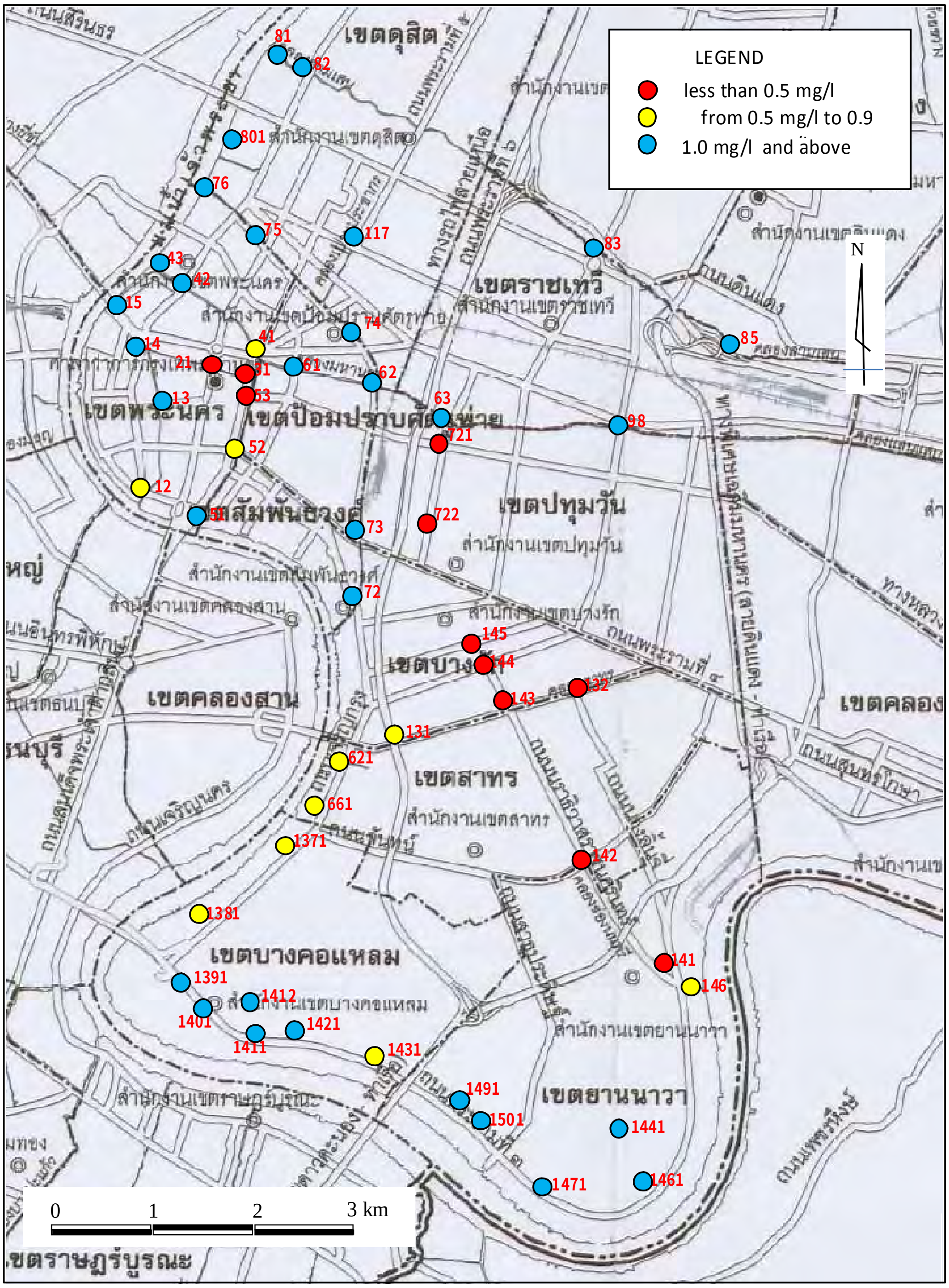
Classification of Water Quality (BOD)	Number of Data					Average DO (mg/l)
	Total	Less than DO 1 mg/l		DO 1mg/ orMore		
10 mg/l and below	2,236	596	27%	1,640	73%	1.9
From 11 mg/l to 15 mg/l	524	275	52%	249	48%	1.3
From 16 mg/l to 20 mg/l	247	205	83%	42	17%	0.6
From 21 mg/l to 30 mg/l	208	206	99%	2	1%	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



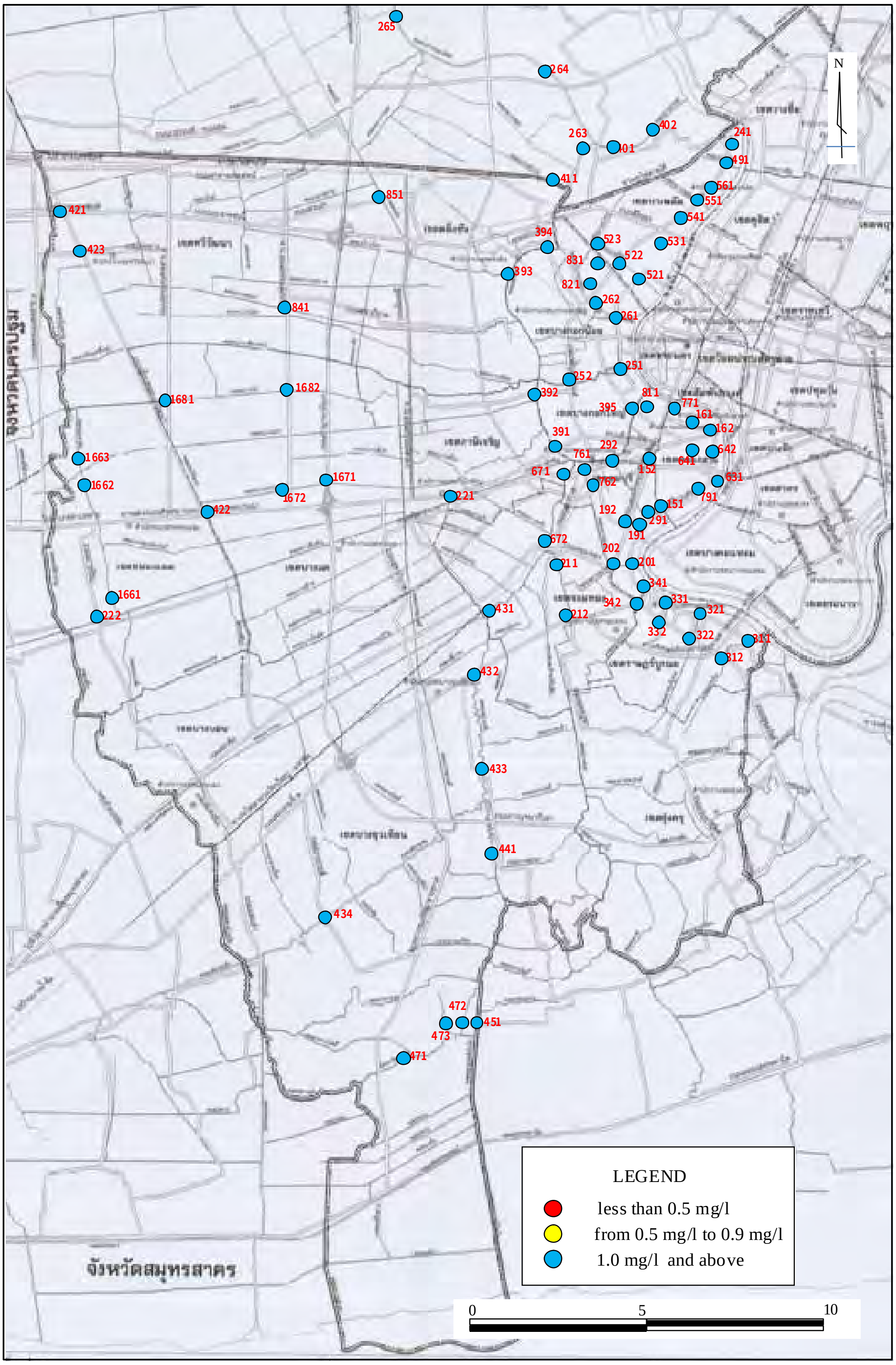
Source: JST

Figure 3.5.18 Guide Map for Figures 3.5.19 through 3.5.22



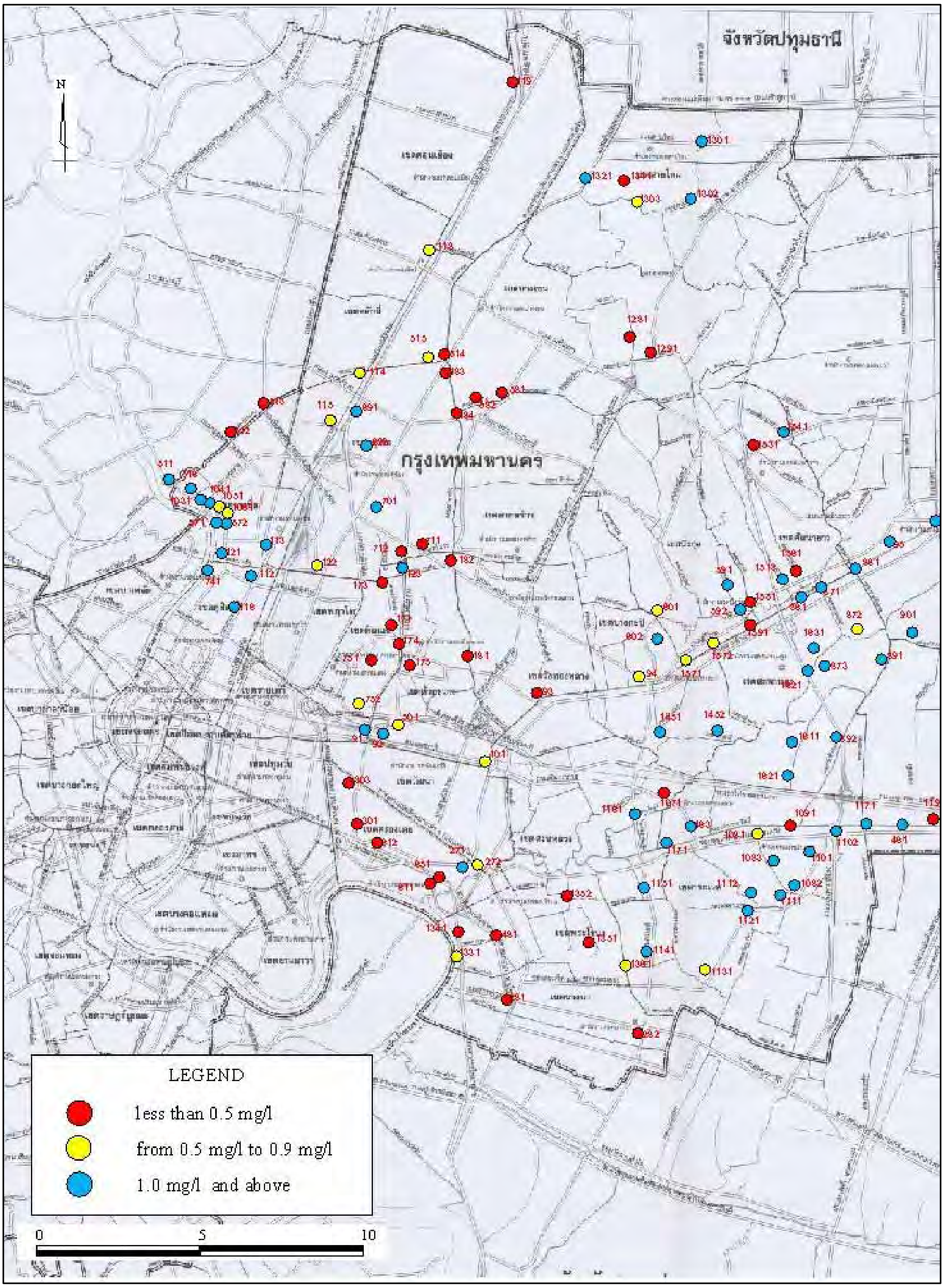
Source: JST

Figure 3.5.19 DO Concentrations in Klongs (Average in 2009) (1)



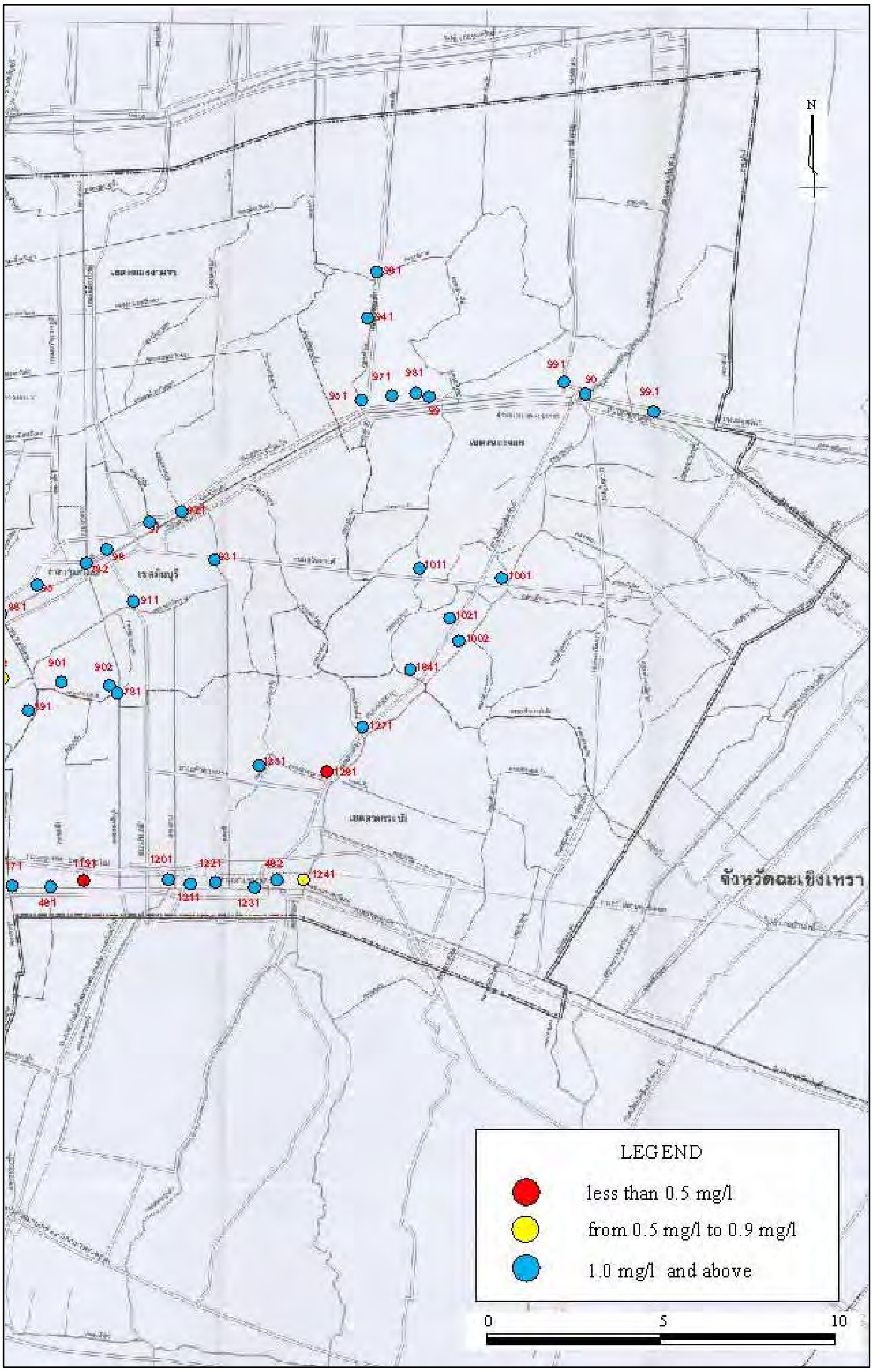
Source: JST

Figure 3.5.20 DO Concentrations in Klongs (Average in 2009) (2)



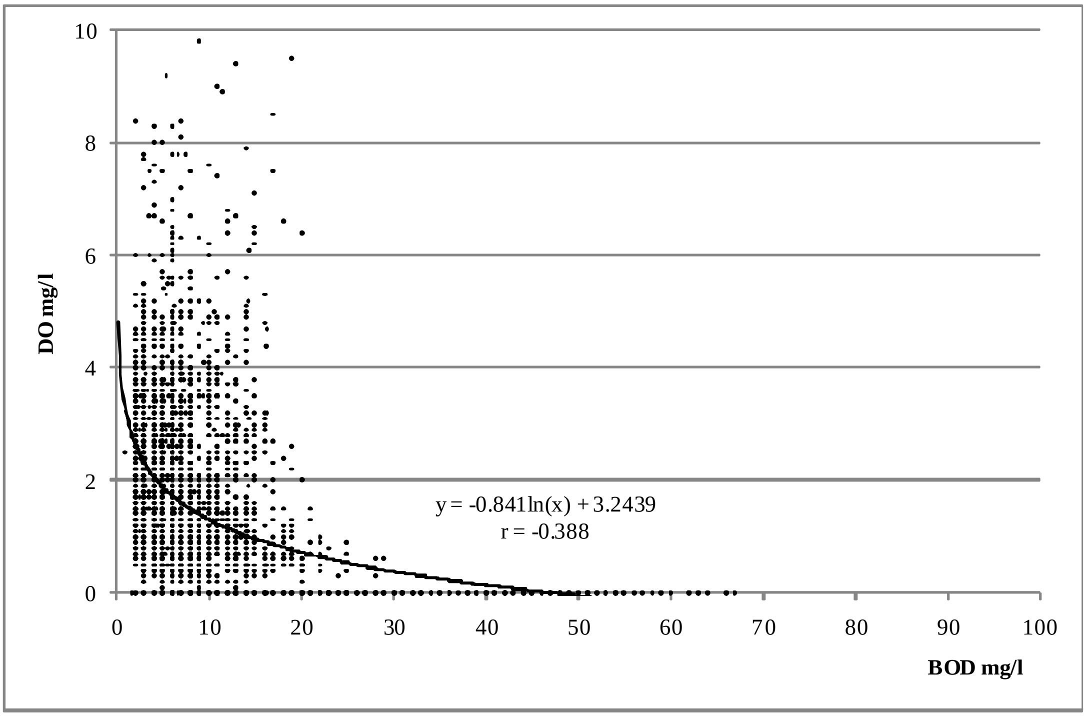
Source: JST

Figure 3.5.21 DO Concentrations in Klongs (Average in 2009) (3)



Source: JST

Figure 3.5.22 DO Concentrations in Klongs (Average in 2009) (4)



Source: JST

Figure 3.5.23 Correlation of the BOD and DO in Klongs

3.6 Issues for Improvement of Water Environment and Sewerage System

Water pollution in rivers and klongs in BMA has become serious due to rapid economic development and urbanization in recent years. Development of sewerage system has been progressing as countermeasures against the main source of pollution, i.e. domestic wastewater. However, improvement of water quality in the public water bodies, such as klongs is still far from satisfaction, and sewerage system development is urgent issue to assure healthy and sound living of residents.

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.

3.6.1 Technical Issues

(1) Problems Observed

(A) Untreated Wastewater Discharge

In the existing treatment areas, collected wastewater is discharged from interceptors resulting in water pollution in nearby klongs.

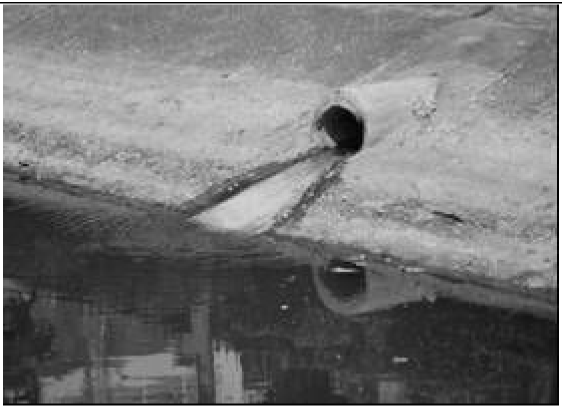


Photo 3.6.1 Un-connected Combined Sewer

Photo 3.6.2 Untreated Wastewater Discharge near an Interceptor

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.

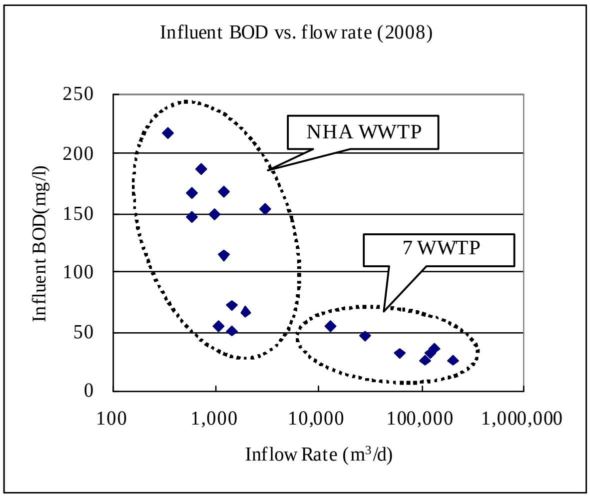
(B) Situation about Infiltration from Klongs

In many places, storm water drainage pipes are located near the surface of klongs as shown in Photos 3.6.3 and 3.6.4 below. 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 (refer to Figure 3.6.1).

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.

Photo 3.6.3 Interceptor under Water

Photo 3.6.4 Drain Pipe under Water



BOD concentrations in inflow to WWTPs

- BOD concentrations in inflow to WWTPs constructed by DDS are as low as 50 mg/l as an average compared with those in inflow to community plants in system constructed by NHA (some of them are separate system).
- Present Design value of BOD is 150 mg/l (only Rattanakosin WWTP is 200 mg/l)

Source: JST

Figure 3.6.1 BOD Concentrations in Inflow to WWTPs

(C) Water Pollution Caused by the Existing Treatment Facilities

Domestic pollution load can be divided into two categories, viz. excreta and sullage. As for BOD pollution load, excreta and sullage account for 30 % and 70 % respectively by reference to an example in Japan. There is no this kind of data in Thailand. Therefore an example in Japan is referred to (refer to Table 3.6.1).

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 (refer to Table 3.6.2 and Figure 3.6.2). 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.

Table 3.6.1 Breakdown of Domestic Pollution Load

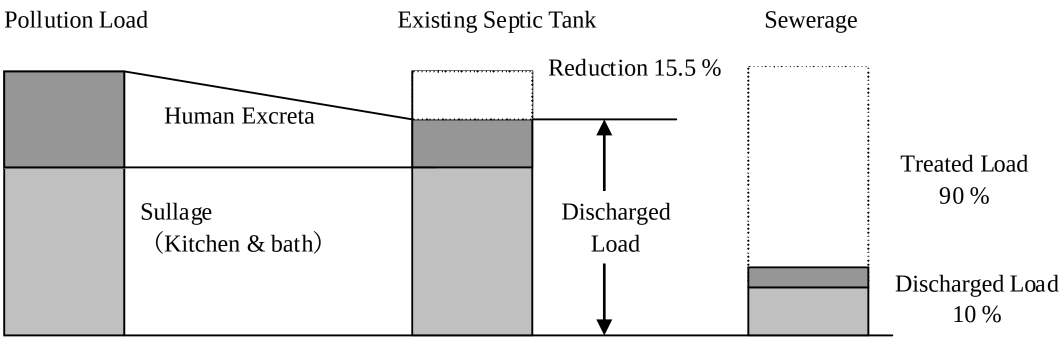
Item	Ave. Load (g/cap./d)	Standard deviation (g/cap./d)	Sample No.	Break down (g/cap/d)	
				Human Excreta	Sullage
BOD	58	17	169	18	40
COD	27	9	153	10	17
SS	45	16	169	20	25
T-N	11	3	29	9	2
T-P	1.3	0.4	25	0.9	0.4

Source: Design and Planning Manual of Sewerage System, Japan Sewage Works Association

Table 3.6.2 Reduction of Pollution Load (BOD) by Septic Tank and Sewerage System

Pollution Source	Load (g/cap/d)	Treatment Efficiency (%)	Effluent Load (g/cap/d)	Removal Rate (%)	Sewerage
Human Excreta	18	50	9	—	Removal rate 90%
Sullage	40	0	40	—	
Total	58	—	49	15.5	

Source: JST



Source: JST

Figure 3.6.2 Efficiency of Septic Tank Treatment

Existing houses and buildings are provided with septic tanks or other kind of treatment systems, and there is no room in their lots for expansion of these facilities or for installation of drainage system. And it is almost impossible to install an additional treatment facility for sullage in the lot other than reconstruction of the building because installation of such a facility requires additional space or modification of the building.

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 3.6.3. 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 3.6.3 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

(2) Reasons for Problems and Technical Countermeasures

(A) Overflow of Untreated Wastewater from Interceptor Chamber

Examination of two existing interceptor chambers in Din Daeng treatment area was conducted, to grasp reasons for wastewater overflow in dry weather (refer to Appendix-5). Because two examined samples are typical construction of interceptor chamber in BMA, the same reasons for wastewater overflow to klong in dry weather can be assumed for other interceptor chambers. Examination made clear that the reasons for wastewater overflow to klongs in dry weather are neither low height of weir nor small diameter of orifice.

The wastewater overflow to klong was confirmed in dry weather as shown in Photo 3.6.5 (taken on 9th June, 2010, at field visit to manhole in Din Daeng treatment area).

Inside of the interceptor chamber (IPC199A) from which wastewater overflow in dry weather was confirmed is shown in Photos 3.6.6.

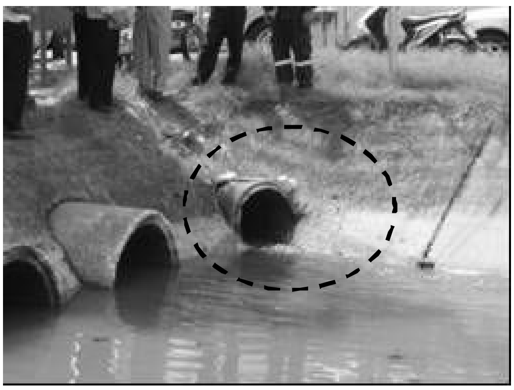


Photo 3.6.5 Wastewater Discharge in Dry Weather 2 (9th June, 2010)
(Din Daeng Treatment Area IPC199A)

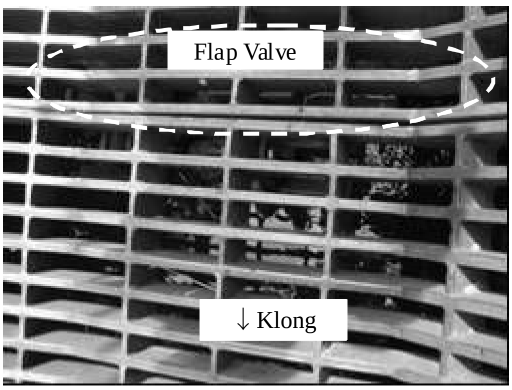
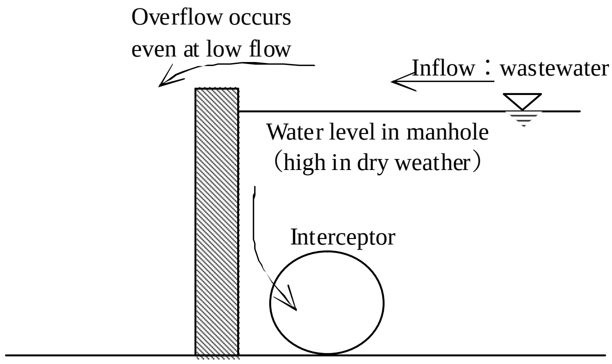


Photo 3.6.6 Interceptor Chamber (9th June, 2010)
(Din Daeng Treatment Area IPC199A)

In this interceptor chamber, water level inside the chamber was higher than weir height even though no storm water inflow, and overflow was confirmed.



Source: JST

Figure 3.6.3 Wastewater Discharge in Dry Weather

The reason for wastewater overflow in dry weather is high water level in manhole. Photos 3.6.7 and 3.6.8 show condition of manhole which connects to the interceptor chamber (IPC199A in Din Daeng treatment area).

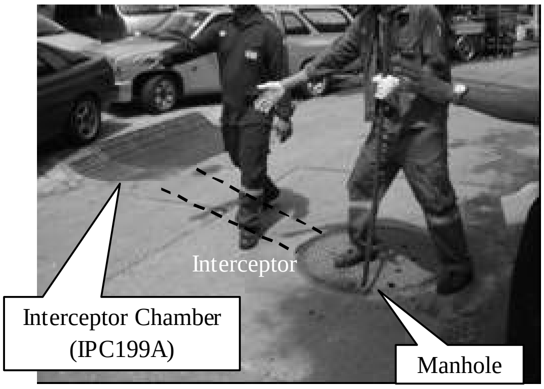
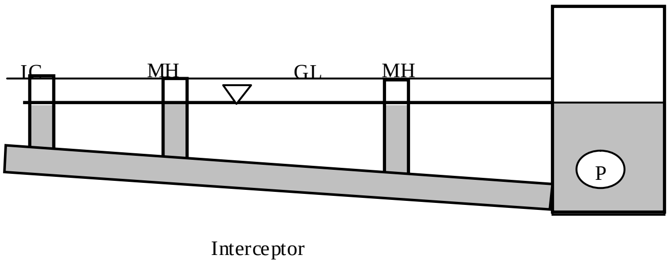


Photo 3.6.7 Location of Manhole

Photo 3.6.8 Inside of Manhole in Dry Weather

As shown in Photo 3.6.7 and Photo 3.6.8, water level inside the manhole was 30 to 50 cm below ground level. In case wastewater overflow in dry weather occurs, it becomes clear that water level in manhole is also high as well as in interceptor chamber. The reason for high water level in manholes is the fact that water level for pump operation was set at high level and interceptors were under pressurized condition as shown in Figure 3.6.4. This fact was confirmed at Din Daeng pumping station (refer to Photo 3.6.9).



Source: JST

Figure 3.6.4 Water Levels in Upstream Manholes

Photo 3.6.9 Pump Well (June 9 2010) (Din Daeng WWTP)

Based on the results of examination mentioned above, causes for wastewater discharge and countermeasures are described below.

Causes

High water level in interceptor chamber due to:

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

*Temporary Co*untermeasures

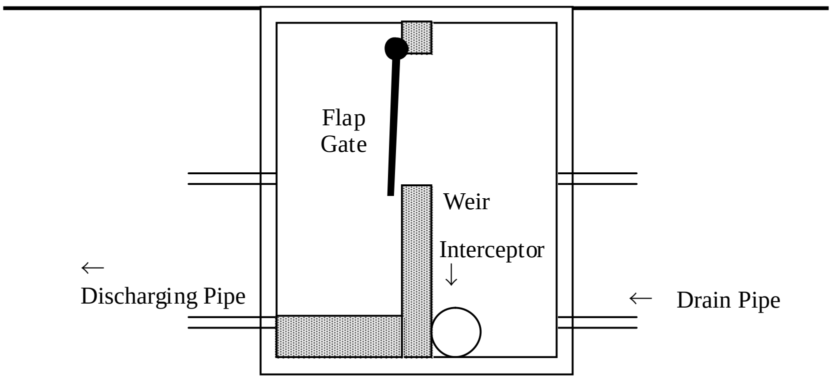
- Lower water level in pump pit not to influence water level in interceptor
- Clean interceptor chamber periodically to prevent clogging with garbage
- Raise weir level of interceptor chamber which discharges untreated wastewater in dry weather

(B) Backwater from Klong

1) Countermeasures up to Now

Flap gate

Flap gates have been provided inside interceptor chambers to prevent backwater from klong in BMA. General setting up of flap gate is shown in Figure 3.6.5. Fixed weir type interceptor chambers were constructed in Rattanakosin treatment area and stop-log type in Chong Nonsi treatment area in the past. Flap gate type which can be seen in Din Daeng treatment area became popular recently.

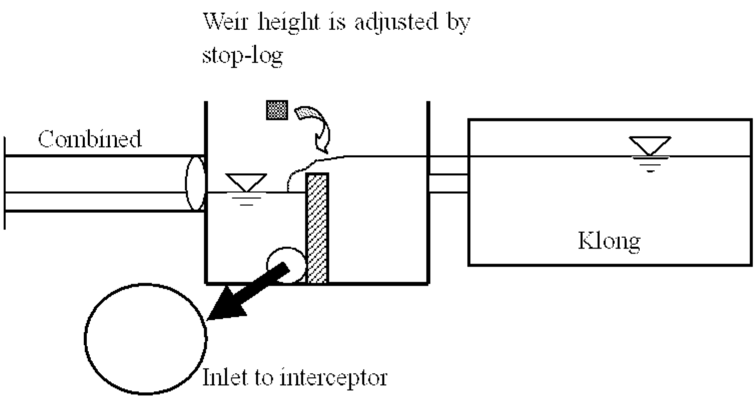


Source: JST

Figure 3.6.5 General Construction of Interceptor Chamber in BMA

Raising of weir level

Weir level has been raised by stop-log when weir height is insufficient or weir level is lowered due to land subsidence.

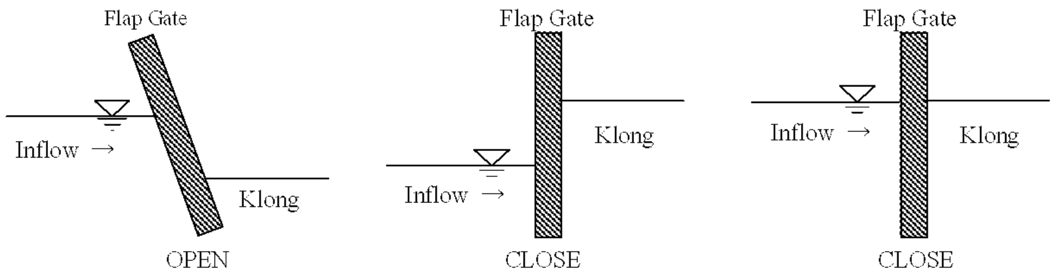


Source: JST

Figure 3.6.6 Adjustment of Weir Level by Stop-log

2) Examination of Flap Gate

Flap gates provided in interceptor chambers in BMA are usually open when water level in upstream is higher than that in downstream (klong) as shown in Figure 3.6.7. When water level in downstream (klong) is equal to or higher than that in upstream, flap gates are not open.



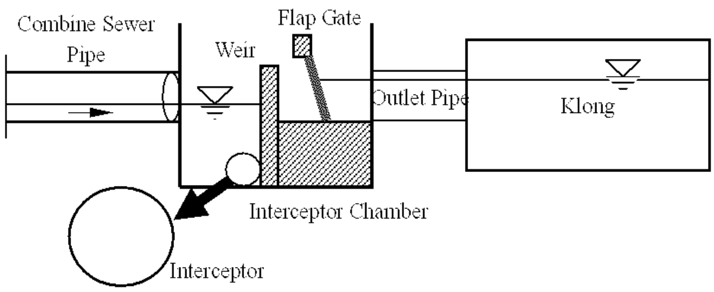
Source: JST

Figure 3.6.7 Open and Close of Flap Gate in Relation to Water Levels

However, it was confirmed that a flap gate is open when water level inside and outside of a chamber were even, and that wastewater was discharged to klong, as shown in Photos 3.5.12 and 3.5.13 The reason for this was that flap gate could not be closed completely because flap gate was clogged with garbage. If flap gate is not closed completely, backwater from klong cannot be avoided. Thus periodical cleaning of interceptor chambers is important.

3) Examination of Existing Interceptor Chamber and Water Level in Klong

Relations between positions and levels of interceptor chamber, outlet pipe and klong are shown in Figure 3.6.8.



Source: JST

Figure 3.6.8 Positions and Levels of Interceptor Chamber, Outlet Pipe and Klong

All wastewater from existing combined sewers discharging into an interceptor chamber flows into an interceptor until when overflow occurs due to rising of water level. Also, all wastewater is collected to an interceptor even when water level rises if a flap gate is not open.

On the other hand, when water level in klong is higher than that of outlet pipe, backwater from klong tends to flow into interceptor chamber. If flap gate is closed completely, klong water cannot flow into an interceptor, but if it is not closed completely because of clogging with garbage and the backwater level is higher than the weir, klong water is collected into an interceptor.

Water levels in main klongs in BMA are regulated by pump operation controlled by Flood Control Center of DDS.

- Wet season: Water levels in klongs are set at low level to prevent inundation in BMA, storm water is pumped to Chao Phraya River.
- Dry season: Water levels in klongs are set at high level for aesthetic purposes; water from Chao Phraya River is introduced to klongs. (Klong Water Purification Project)

Latest data regarding controlled water levels in klongs and levels of weirs in seven (7) existing treatment areas in BMA are presented in Table 3.6.4 (as of June, 2010).

There are 44 spots out of 108 spots where water level in klong is higher than weir level of interceptor chamber in dry season when water level in klong is regulated at high level as shown in Table 3.6.4. If flap gate is completely closed in each interceptor chamber, there exists no problem, but flap gate is not closed completely because of clogging with garbage or other reasons, backwater from klong occurs and it flows into an interceptor. In order to prevent backwater from klong in dry season, it is necessary to lower water level in klong than weir level. Recommended water level for this purpose is presented in Table 3.6.4.

Table 3.6.4 Water Level in Klong and Weir Level in the Existing 7 Treatment Areas

(m)

No.	Klong in wastewater treatment area of each the water control plant	Klong max. Level (Normal) (A)	Klong max.level (Dry Season) (B)	Weir Level of IPC (C)	Position for reading the water level	Remark	Recommended Klong level (Dry Season)
1	Chatuchak						
	1. Entry of Vibhavadi	-0.50	+0.00	+0.08			
	2. Exit of Vibhavadi	-0.50	+0.00	+0.06			
	3. Klong Bang sue	-0.30	+0.30	+0.03	Front of pump st. Bangsue	B > C	+0.00
	4. Klong Lad yaow	-0.50	+0.00	+0.11	Front of pump st. Klong ladyaow		
	5. Klong Bang bao			+0.66			
	6. Klong Phaya Wek	-0.80	+0.20	+0.10	Front of water-gate Klong Phaya Wek	B > C	+0.10
	7. Klong Num Kaew	-0.80	+0.20	-1.00	Front of water-gate Klong Num Kaew	B > C	-1.00
	8. Klong Lad phrao			+0.45			
2	Din Daeng						
	1. Klong Mahanak	+0.00	+0.20		Panfa pier		
	2. Klong Saen saeb	-0.30	-0.20	+0.11			
		+0.00	+0.20		Front of pump st.Thewet		
	3. Klong Ong Ang	+0.00	+0.20	+0.49	Front of water-gate Klong Ong Ang		
	4. Klong Banglumpu	+0.00	+0.20	+0.75	Front of water-gate Klong banglumpu		
	5. Klong Perm prachakorn	-0.80	+0.30	+0.27		B > C	+0.20
	6. Klong Sam sen	-0.80	+0.30	+0.03	Front of pump st. Samsen	B > C	+0.00
		-0.50	-0.20				
	7. Klong Huai Khwang	-1.00	+0.00	-0.76	Front of pump st.Huai Khwang	B > C	-0.80
	8. Klong Na song	-1.00	+0.00	-0.23	Front of pump st. Na song	B > C	-0.30
	9. Klong Phadung Krungkasem	+0.00	+0.20	+0.67	Front of pump st. Thewet		
	10. Klong Suan Laung	+0.50	+0.50	+0.54	Front of water-gate Suan Laung		
	11. Klong Rang Ngoen			+0.67			
	12. Klong Jool nak						
	13. Klong Wasukree	-0.20	+0.30	+1.19	Front of water-gate Tha wasukree		
	14. Both mae pra			+0.14			
	14. Klong Pai sing tor	+0.20	+0.50	-0.04		B > C	-0.10
	15. Klong Yai soon			-0.01			
	16. Klong Ongkarak			-0.57			
	17. Klong Suay ooi	-0.50	-0.10				
	18. Klong Som poy			+0.91			
	19. Koo-num Soi somkid						
	20. Koo-num Vibhavadi entry-exit from Samlaem dindaeng to Suthisarn intersaction						
3	Tungkru						
	1. Klong Tating			+0.86			
	2. Klong Nong ree			+0.87			
	3. Klong Rang trong			+0.50			
	4. Klong Rang chak		+0.45	+0.48	Front of water-gate Klong Rang chak		
	5. Klong Saphan-Khwai			+0.92			
	6. Klong next soi mitmaitri			+0.64			
	7. Klong Ratchburana			+0.63			
	8. Klong Khwang			+0.88			
	9. Klong next Kachonroj school			+0.61			
	10. Klong Soi wichien			+0.87			
	11. Klong Chaengron		+0.55	+0.85	Front of pump st. Klong Chaeng ron		
	12. Klong pak-ratyanyong			+0.78			
	13. Klong Ton-sai			+0.79			
	14. Klong Rangyai			+0.77			
	15. Klong Ta-mung			+0.61			
	16. Klong next the post office			+0.66			
	17. Klong Ratchburana		+0.58		Front of pump st. Klong ratchburana		
	18. Klong Ton-tago			+0.83			
	19. Klong Watprasert			+0.80			
	20. Klong Ton-sok			+0.78			
	21. Klong Bangboon		+0.52	+1.23	Front of water-gate Klong bangboon		
	22. Klong Bangprakok		+0.48	+0.55	Front of pump st. Klong Bangprakok		
	23. Klong Bangprakaew		+0.49	+0.63	Front of pump st. Klong Bangprakaew		
	24. Khong Bangpieng			+0.85			
	25. Klong Dao-kanong		+0.88	+0.80	Front of pump st. Klong Dao-kanong		

<Legend>

(dark grey) ：Water level in klong in dry season ＞ Weir level in interceptor（44 spots）

(light grey) ：Recommended water level in dry season ＜ water level in wet season, thus it is impossible to prevent backwater by regulating water level（30 spots）

(m)

No.	Klong in wastewater treatment area of each the water control plant	Klong max. Level (Normal) (A)	Klong max.level (Dry Season) (B)	Weir Level of IPC (C)	Position for reading the water level	Remarks	Recommended Klong level (Dry Season)
4	Ratthanakosin						
	1. Klong Koo mueng doem	+0.00	+0.50	+0.04	Front of water-gate Pin klao	B > C	+0.00
	2. Klong Bang lumpoo	+0.00	+0.20	+0.03	Front of water-gate Bang lumpoo	B > C	+0.00
	3. Klong Ong-ang	+0.00	+0.20	+0.16	Front of water-gate Ong-ang	B > C	+0.10
	4. Klong Wat ratchbophit	+0.00	+0.50	+0.01	Front of water-gate Pin klao	B > C	+0.00
	5. Klong Wat thep thida	+0.00	+0.50	+0.03		B > C	+0.00
5	Sipraya						
	1. Klong Padung krung kasem	+0.00	+0.20	+0.20	Front of pump st. Thewet		
6	Nong Khaem						
	1. Klong Mahasorn		+0.49	+0.88	Front of pump st. Klong Mahasorn		
	2. Klong Thawee watthana		+0.74	+0.70	Front of water-gate KlongThaweewattha	B > C	+0.70
	3. Klong Ratch charoensuk			+0.84			
	4. Klong Bangwaek		+0.69	+0.74	Front of pump st. Klong Bangwaek		
	5. Klong Ratch samakkee		+0.58	+0.56	Front of pump st. Klong Bangkae	B > C	+0.50
	6. Klong Phasee charoen		+0.77	+0.55	Front of pump st. Klong Phawee charoe	B > C	+0.50
	7. Klong Bangchak			+0.64			
	8. Klong Bangkee-kaeng		-	+0.70			
	9. Bing Sai song		-		construct the road		
	10.Klong Yamtiem		-	+0.83			
	11.Klong Ratchmontri		+0.46	+0.91	Front of pump st. Klong Ratchmontri		
	12. Klong Yai-pien			+0.66			
	13. Klong Bangwha			+0.72			
	14. Klong Rong-yaow			+0.83			
	15. Klong Watpradoo			+0.82			
	16. Klong Bangpai-lek			+0.74			
7	Chong Nonsi						
	1. Klong Wat chongnongsee						
	2. Klong Ta-roek	+0.50	+0.80	-0.68	Front water-gate	B > C	-0.70
	3. Klong Yai-rhang	+0.50	+0.80	-0.61	Front water-gate	B > C	-0.70
	4. Klong Ta-haung	+0.50	+0.80	+0.06	Front water-gate	B > C	+0.00
	5. Klong Suan	+0.50	+0.80	-0.60	Front water-gate	B > C	-0.60
	6. Klong Heeb	+0.50	+0.80	-0.77	Front water-gate	B > C	-0.80
	7. Klong Phoom	+0.50	+0.80	-0.39	Front water-gate	B > C	-0.40
	8. Klong Mai	+0.50	+0.80	-0.48	Front water-gate	B > C	-0.50
	9. Klong San	+0.50	+0.80	-1.14	Front water-gate	B > C	-1.20
	10. Klong Both	+0.50	+0.80	-0.31	Front water-gate	B > C	-0.40
	11. Klong Watdan	+0.50	+0.80	-1.25	Front water-gate	B > C	-1.30
	12. Klong Watdan-nuen	+0.50	+0.80	-1.18	Front water-gate	B > C	-1.20
	13. Klong Fad	+0.50	+0.80	-1.05	Front water-gate	B > C	-1.10
	14. Klong Watpariwat	+0.50	+0.80	-0.24	Front water-gate	B > C	-0.30
	15. Klong Bangpongpangtai	+0.50	+0.80	-0.75	Front water-gate	B > C	-0.80
	16. Klong Bangpongpang	+0.50	+0.80	-0.22	Front water-gate	B > C	-0.30
	17. Klong Watthongbon	+0.50	+0.80	-0.75	Front water-gate	B > C	-0.80
	18. Klong Watdokmai	+0.50	+0.80	-0.75	Front water-gate	B > C	-0.80
	19. Klong Rongnummon	+0.50	+0.80	-1.19	Front water-gate	B > C	-1.20
	20. Klong Sao-hin	+0.50	+0.80	-1.19	Front water-gate	B > C	-1.20
	21. Klong Ma-nao	+0.50	+0.80	-0.40	Front water-gate	B > C	-0.40
	22. Klong Watsai	+0.50	+0.80	-0.57	Front water-gate	B > C	-0.60
	23. Klong Bangkhlo	+0.50	+0.80	-0.57	Front water-gate	B > C	-0.60
	24. Klong Bangkhlo-noi	+0.50	+0.80	-0.57	Front water-gate	B > C	-0.60
	25. Klong Watchan	+0.50	+0.80	-0.40	Front water-gate	B > C	-0.40
	26. Klong Ka-wong (Charoenkrung Rd.,)	+0.50	+0.80	-0.54	Front water-gate	B > C	-0.60
	27. Klong Gruai	+0.50	+0.80	-0.23	Front water-gate	B > C	-0.30
	28. Klong Kwang	+0.50	+0.80		Front water-gate		
	29. Klong Watpai-noen	+0.50	+0.80	-1.30	Front water-gate	B > C	-1.30
	30. Klong Kwangtungmahamek	+0.50	+0.80	-1.02		B > C	-1.10
	31. Klong Wat yannawa	+0.50	+0.80				

<Legend>

(dark grey): Water level in klong in dry season ＞ Weir level in interceptor（44 spots）

(light grey): Recommended water level in dry season ＜ water level in wet season, thus it is impossible to prevent backwater by regulating water level（30 spots）

Source: JST

4) Reasons for Infiltration and Countermeasures

Based on the results of examination mentioned above, causes for infiltration and temporary countermeasures against it are summarized below.

Causes

- 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.

3.6.2 Management and Institutional Issues

This Section provides available information about the institutions relevant to sewerage service and their inter relationship.

(1) Relevant Organizations

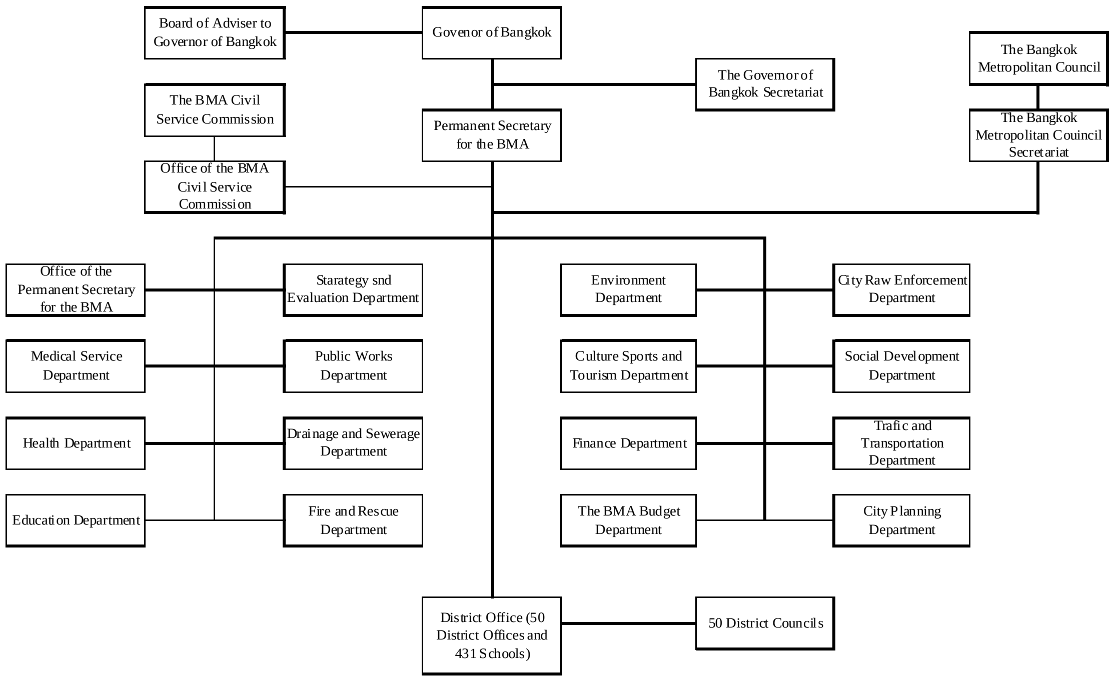
(A) Bangkok Metropolitan Administration (BMA)

The Bangkok Metropolitan Administration (BMA) is the name of the local government of Bangkok Province, which is the capital of the Kingdom of Thailand. The passage of the Administration of Bangkok Province Act of 1975 created the Bangkok Metropolitan area to replace Bangkok Province. The BMA government is composed of two branches, the executive (i.e., the Governor of Bangkok) and the legislative (i.e., Bangkok Metropolitan Council). The Administration's roles are to formulate and implement policies regarding the management of Bangkok; these include: transport services, urban planning, waste management, housing, roads and highways, security services and the environment.

The Governor is the head of the local government of Bangkok Province. The Governor is also the chief executive of the Bangkok Metropolitan Administration (BMA). The Governor position is a directly elected executive office for a renewable term of four years.

The Bangkok Metropolitan Council or BMC is the legislative branch of the BMA. It is vested with primary legislative powers as well as the power to scrutinize and advise the Governor. The Council is headed by the Chairman of the Bangkok Metropolitan Council. The Council is made up of 57 members elected from 50 districts of Bangkok (some districts elect more than one member).

Permanent Secretary of the BMA is the Chief Operating Officer and reports to the Governor. Currently there are 15 departments each headed by a Director General. Also, there are 6 Deputy Permanent Secretary (DPS), each looking after a number of departments. For example, Public Works Dept, Drainage and Sewerage Dept. and Environment Dept. are under same DPS. In addition, there is Office of the Permanent Secretary which acts as an internal monitoring and auditing body. The overall organizational set up of BMA is given in Figure 3.6.9.



Source: JST, Website http://www.bangkok.go.th/info

Figure 3.6.9 Overall Organization Set up of BMA

(B) Department of Drainage and Sewerage (DDS)

The Department of Drainage and Sewerage (DDS) is one of the 15 departments of the BMA and is responsible for planning, designing, constructing, operating and maintaining the facilities for flood protection, rainwater drainage and wastewater treatment in Bangkok Metropolis. DDS was founded in 1977 under the Royal Decree on Division of Governmental Units, Power and Responsibilities of the BMA (May, 1977) by separating from the Public Cleansing Department.

The Department has been divided into one office and seven divisions. The organizational set up of DDS and staff number for each section is given in Figure 3.6.10. Brief description of the responsibilities of each division is given below.

i) Secretarial Division: The responsibilities include general administration, and personal, fiscal, legal and contracts management.

ii) Canal System Division: Their scope covers canal maintenance, improving and dredging, construction of canal retaining walls, and removing garbage.

iii) Drainage Information System Division: This division compiles relevant data from field stations and from other agencies. Also they develop mathematical models for operation planning.

iv) Water Quality Management Office: This office is responsible for the quality control of wastewater, and wastewater treatment plants.

v) Main Drainage System Development Division: The main responsibility is to plan, design, construct and evaluate major flood protection facilities.

vi) Drainage Control-Structure System Division: This division controls pumping stations, water gates and water flushing.

vii) Sewerage System Division: Their responsibilities include sewers, manholes, sewerage system, sewerage pumping, etc.

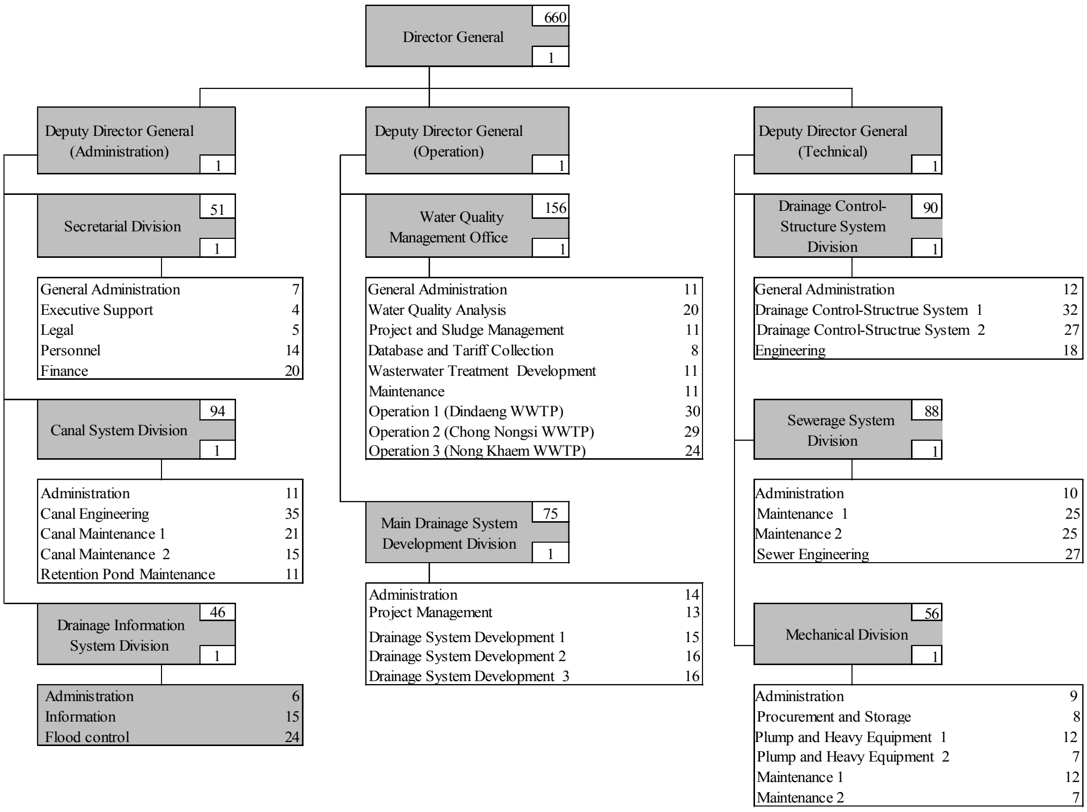
viii) Mechanical Division: The responsibilities are procuring, controlling and servicing pumps, machinery, mechanical tools, and vehicles.

The manpower of DDS by staff type is given in Table 3.6.5.

Table 3.6.5 Manpower of DDS by Staff Type

Division	Officers			Workers		
	Technical	Non-technical	Total	Permanent	Temporary	Total
DDS (Executives)	4	0	4	0	0	0
Secretarial Division	0	51	51	26	2	28
Canal System Division	63	31	94	782	1,039	1,821
Drainage Information System Division	33	13	46	12	1	13
Water Quality Management Office	127	29	156	289	113	402
Main Drainage System Development Division	58	17	75	24	2	26
Drainage Control-Structure System Division	82	8	90	854	489	1,343
Sewerage System Division	53	35	88	843	466	1,309
Mechanical Division	37	19	56	254	70	324
Total	457	203	660	3,084	2,182	5,266
Grand Total	5,926					

Source: JST based on DDS, 2010.



Source: JST, Website http://DDS.Bangkok.go.th

Figure 3.6.10 Organization Set up of DDS

(C) Water Quality Management Office (WQMO)

This is the largest office of DDS with 156 officers. The main task of this section is to manage surface water quality by reducing water pollution through wastewater treatment. Current activities include,

- Operation of 7 large-scale wastewater treatment plants
- Operation of 12 community wastewater treatment plants
- Operation of aerated lagoon system in 2 ponds
- Operation of a leachate treatment plant
- Lum Pini Park natural water circulation system

In addition, this Office is also responsible for planning and constructing future WWTP. Currently 3 WWTPs are either under construction or waiting to start construction. This Office is also responsible for future sewerage system planning. Thus, they are the counterpart of this JICA study of sewerage M/P review.

There are nine sections (working groups) in the Water Quality Management Office. Their roles are described briefly.

i) General Administration Sub-Office: Responsible for general administrative jobs, budgets and payment, assets and materials, etc.

ii) Water Quality Analysis Sub-Office: The responsibilities include analysis of water and sediment sample for Chao Praya River, major canals, effluent from WWTP, etc.

iii) Project and Sludge Management Sub-office: Their main scope is carrying out master planning, feasibility study, designing and implementation of wastewater and sludge management projects. Their scope also includes operation of sludge composting.

iv) Database and Tariff Collection Sub-Office: They are entrusted with the tasks of data collection and analysis for water quality management, WWTP operation. They are expected to cooperate with MWA to maintain a user database for tariff collection. They use the information technology for water quality management.

v) Wastewater Treatment Development Sub-Office: Their scope covers study of WWTPs for upgrade and improvement; and preparation and modification of standard code for WWTP. They also act as in house design and construction consultant for small and medium scale WWTP.

vi) Maintenance Sub-Office: Their main duty is to repair and service of sewers, interceptor chambers, pumping stations, etc.

vii) Operation 1 Sub-Office (Din Daeng): They are responsible for operation and maintenance for WWTPs located at Din Daeng, Rattanakosin, Chatuchak, Rama 9, Makkasan, Huay Kwang, Ram Indra, Tung Song Hong, Ta Sai and Bang Bua.

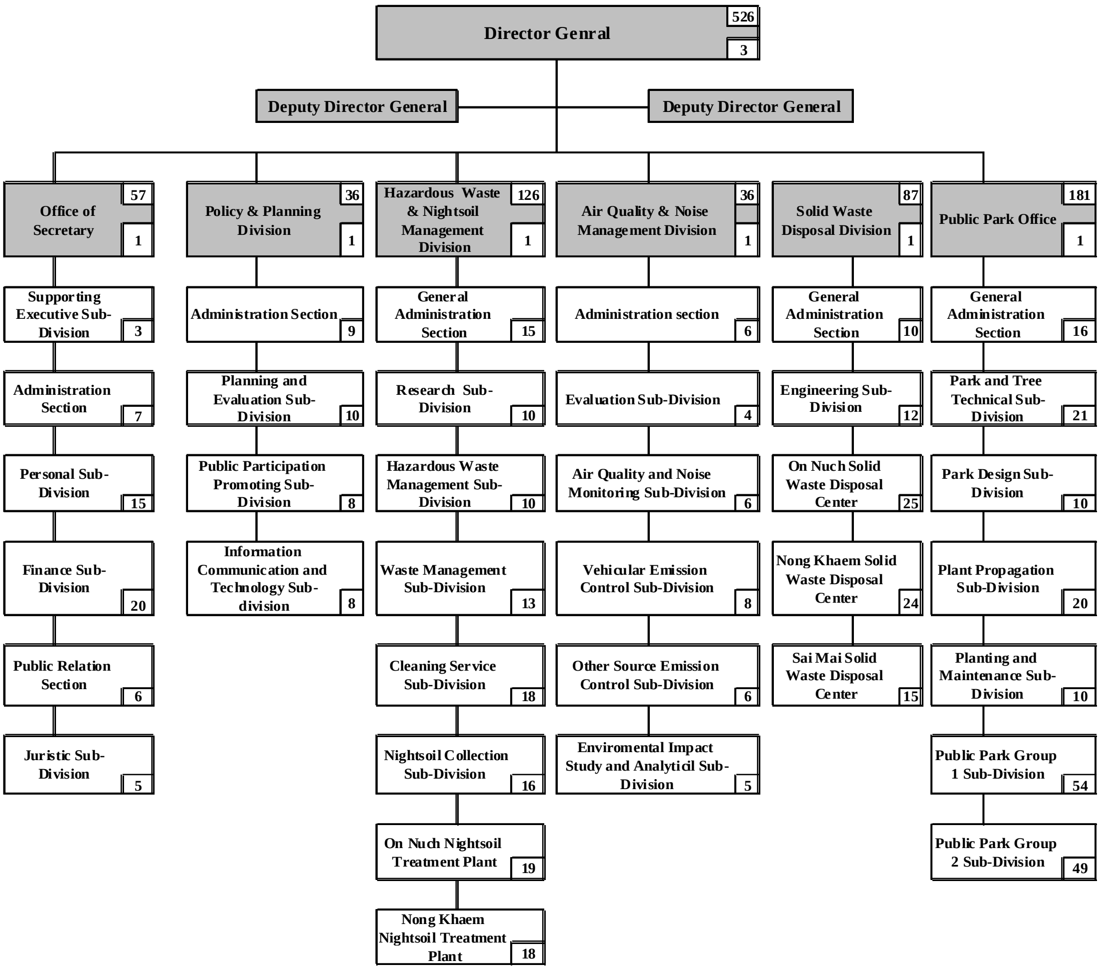
viii) Operation 2 Sub-Office (Chong Non Si): They are responsible for operation and maintenance for WWTPs located at Chong Non Si, Si Praya, Bon Kai, Klong Toei, Klong Chan, On Nuch, Romkloao, Hua Mak and Praknong.

ix) Operation 3 Sub-Office (Nong Khaem): They are responsible for operation and maintenance for WWTPs located at Nong Khaem and Tung Khru.

(D) Department of Environment (DOE)

This department is one of 15 departments of BMA, and responsible for air and noise pollution control, park and greenery, solid waste management and nightsoil management. Because of their role in septage collection and treatment, this department is a direct party of the Bangkok sewerage service. The organization set up of DOE and staff strength of each section is shown in Figure 3.6.11 The scope of Hazardous waste and nightsoil management division extends also into managing 2 nightsoil treatment plants in addition to septage collection. The septage collection is carried out through district offices.

This department is also responsible for evaluating Environmental Impact Assessment (EIA) for all BMA projects.

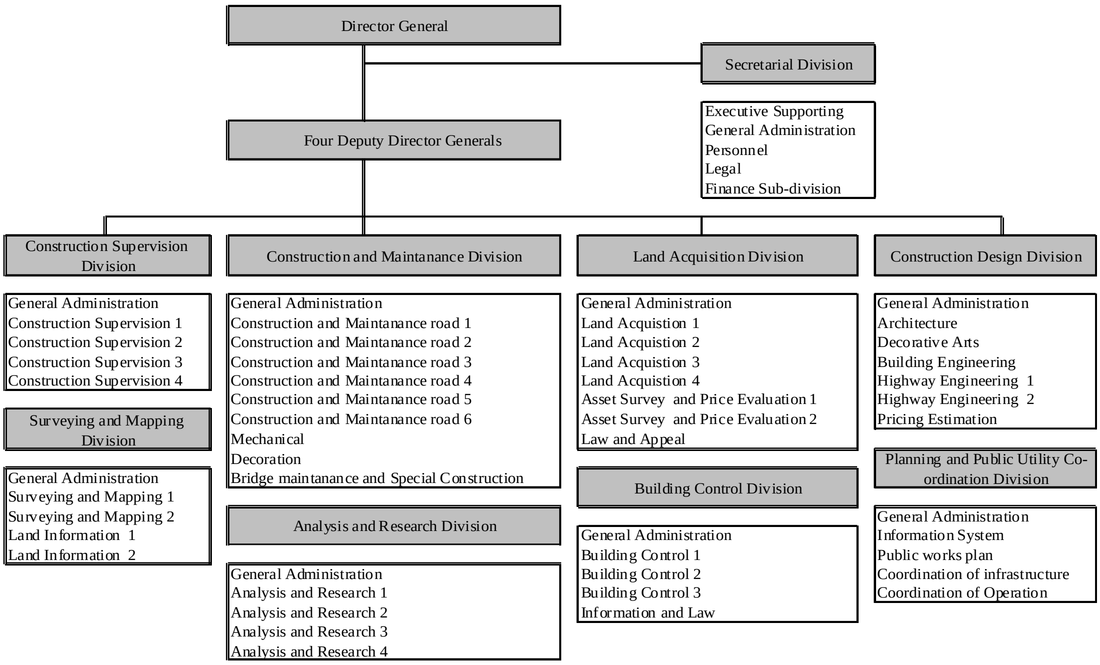


Source: JST based on data from DOE and website (http://office.bangkok.go.th/environment)

Figure 3.6.11 Organization Set up of DOE

(E) Public Works Department (PWD)

This department is one of 15 departments of BMW, and responsible for construction and maintenance of road, bridges and buildings. Under current demarcation, all sewers and drains on secondary and tertiary roads are constructed and maintained by this department as part of their road work. The organizational set up of PWD is shown in Figure 3.6.12.

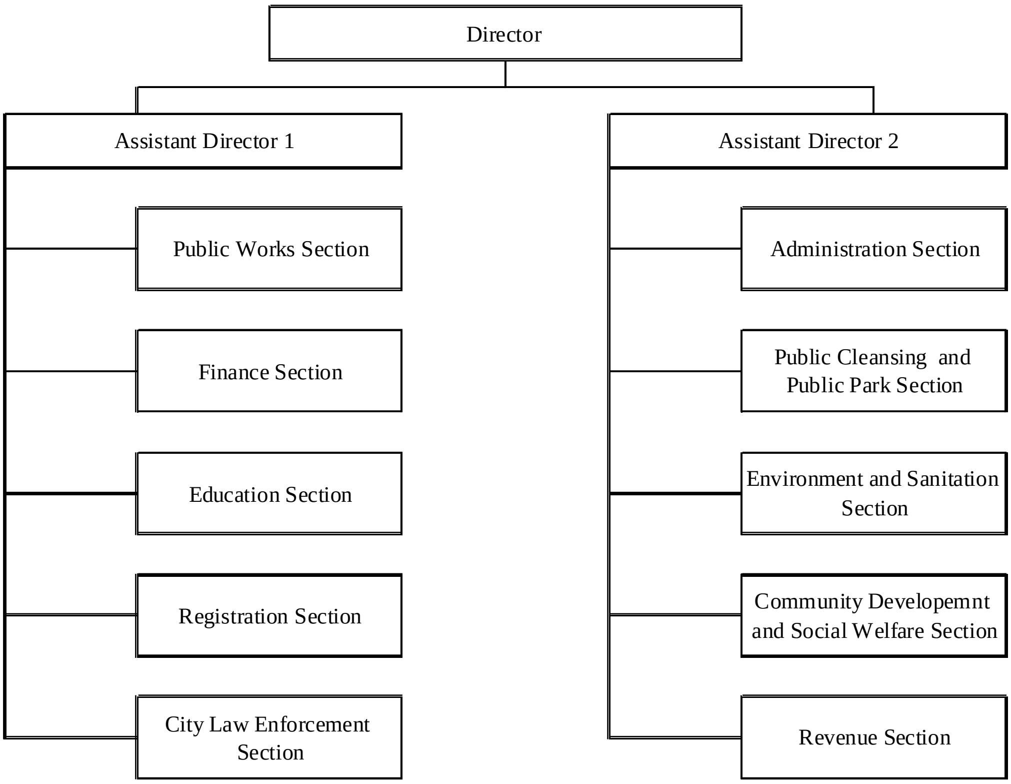


Source : JST, Website http://www.bangkok.go.th/yota/

Figure 3.6.12 Organization Set up of PWD

(F) District Offices

There are 50 districts within BMA. Each district has a district council and a district administration office. While district council is an elected body, the district administrative office is a localized branch office of BMA. Each district office is headed by a Director. There are sections replicating central BMA departments. However, not all districts have same 15 sections like the central office. Availability of sections depends on local condition. Sometimes one district section coordinates with 2 central departments. For example, the district Public Works Section works together with central PWD and DDS. Central DOE's local arm is Public Cleaning and Public Park Section. Septage collection from household is implemented by this section. As an example of a typical district organization set up, organization of Din Daeng District Office is shown in Figure 3.6.13.



Source: JST, http://portal.bangkok.go.th/subsite/index.php?strOrgID=001008&strSection=aboutus_org

Figure 3.6.13 Organization Set up of Typical District Office

(G) Other Relevant Institutions

Apart from the institutions mentioned above, there are some additional entities which have some role in the wastewater management. They include,

- National Environmental Board,
- Environmental Fund,
- Pollution Control Committee,
- Ministry of Natural Resources and Environment,
    - Office of Environmental Policy and Planning,
    - Pollution Control Department,
    - Department of Environmental Quality Promotion,
- Wastewater Management Authority,
- Metropolitan Waterworks Authority, and
- Industrial Estate Authority of Thailand.

Some organizations relevant to this Survey are briefly described in the following.

Pollution Control Department (PCD):

PCD was established to assist NEB to perform its duties. One of the seven divisions of PCD is Water Quality Management Bureau. This has a mandate for wastewater management that requires it to establish standards for surface water quality and effluent from pollution sources. This bureau also provides target and direction of wastewater management (Policy and Target Area of Municipal Wastewater Management, 2010-2041, PCD, April, 2010).

Wastewater Management Authority (WMA):

WMA is a state enterprise under MOSTE established in 1995 The main objective is to provide technical services to the local governments in Thailand. The scope includes providing guidance and advise, facilitating planning and designing, providing training, and accepting on trust for WWTPs construction and operation.

Metropolitan Waterworks Authority (MWA):

This is the state enterprise established under MOI in 1967 by merger of four water authorities, viz. Bangkok, Tonburi, Nonthaburi and Samut Prakan water authorities. In 2009, MWA served about 1.92 million customers with an average of 4.76 million m^3/d of water, average water consumption per customer being 248 lpcd. Net profit in 2009 was 4.5 billion Baht based on average water charge of 11.94 Baht/m^3 with a NRW ratio of 28%. The total staff number is 4,081, which gives 2.13 staff per 1000 connection. This shows good operation efficiency (MWA Annual Report, 2009).

(2) Constrains and Challenges

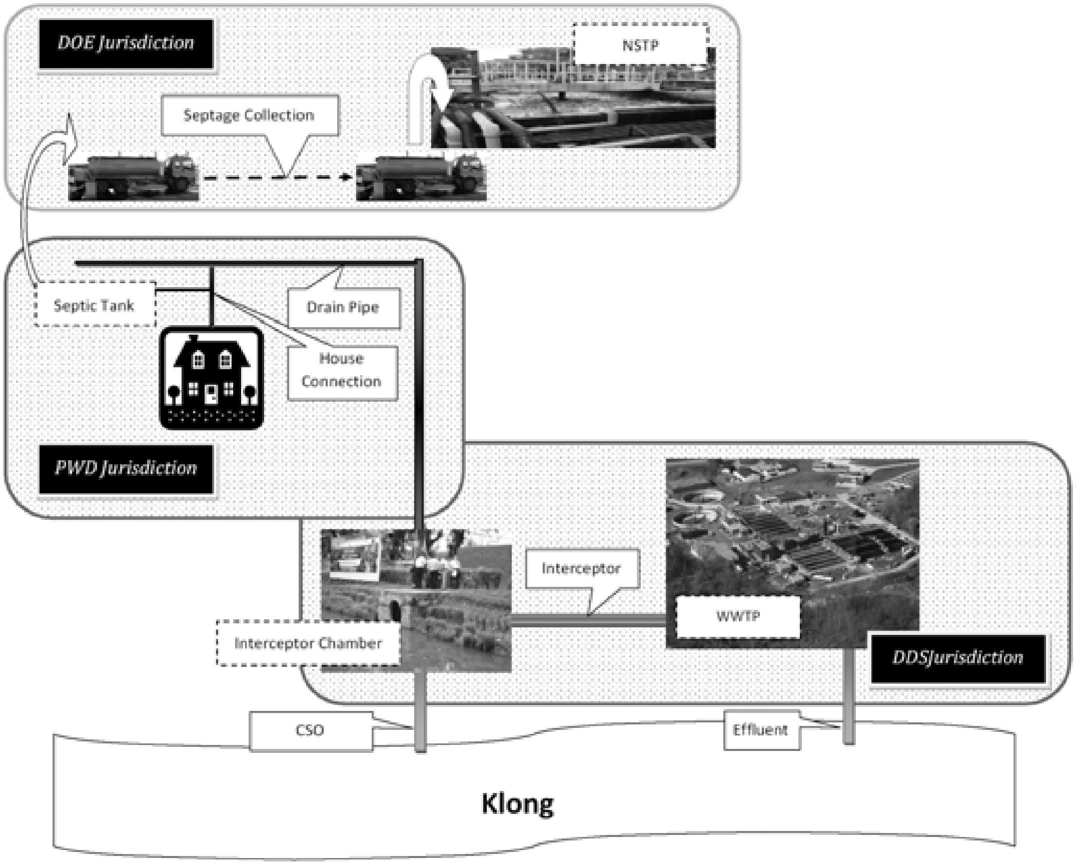
There are certain management and institutional issues that pose constrains in the effective and efficient business operation of the sewerage sector. These are explained in the following. Strategies to overcome these challenges are explained in next section.

(A) 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.

(B) 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 3.6.14. 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 (Figure 3.6.10). Such fragmentation hinders close cooperation and efficient operation. For example, a broken house connection and drainage pipe can introduce huge infiltration even on a dry day and cause diluted dry weather flow in WWTP. However, since the WWTP operation and maintenance of sewers are scope of 2 different agencies, this situation might not be solved in a timely manner. It is, therefore, recommended to bring entire sewerage related services under the umbrella of one responsible agency.



Source: JST

Figure 3.6.14 Management Responsibilities in Sewerage Service

(C) Low Treatment Efficiency

Originally, the basic scheme of Bangkok sewerage was to have a sewer network of interceptors that would collect wastewater from existing street drains at interceptor chambers initially, and then from wastewater sewers. It was planned that at some time of development, all wastewater sewers will be directly connected to the WWTP. As a result, the design influent load of the earlier WWTP was set as full strength sewage. However, the development didn't follow that path and now it is mandatory to have individual septic tank or some other type of onsite treatment before discharging into sewer. Although the newer WWTPs now adopted lesser design influent concentrations, older WWTPs were designed with higher influent design load. As a result, older plants are running at a lower efficiency. There are some other reasons of such low treatment efficiency and earlier chapters focused on potential solutions. Improvements of house connections and sewers connecting to interceptors can open opportunities for better WWTP operation. In this context also, entire sewerage service should be transformed into one stop service.

(D) Septage Management

Septage collection is carried out by Public Cleansing and Public Park Section of the BMA District Offices. The service is provided as customer request basis. Vacuum tracks of 12 m^3 collects the septage and delivers to 2 existing septage treatment plants (NSTP) located at On Nuch and Nong Khaem. As big trucks cannot enter into narrow alleys, district offices also have smaller size trucks of 4 m^3 or less. The contents of the small truck are transferred to big truck for transferring to NSTP. People are charged at 250 Baht/m^3. All collected fee is first transferred to BMA central coffer, and BMA allocates operation cost for septage collection. In one district, Survey Team found that collected fee can barely cover the truck operation cost and all other operational cost including personnel cost is subsidized. Previously septage collection was out sourced as a pilot scale for Klong Toei districts. However, it was failed due to higher charge and lack of public confidence. Two NSTPs are operated by DOE. A visit by Survey Team found one of the NSTP not functioning and effluent BOD was in the orders of few thousands.

(E) Onsite Treatment Standard

This is one of the crucial issues in future planning. As explained in earlier chapters, for the short term onsite treatment systems are used even in the current treatment area. However, the required effluent quality from these onsite plants as stipulated in the BMA Code of Law is too strict in case the outflow from the plants are connected to the central plant. This is not only a big burden for users but also it would lead to very low strength influent to central treatment plant. Thus, it is proposed to consult with authorities concerned such as PCD and PWD to relax those standards for a central plant area.

4. SOLUTIONS AND STRATEGY FOR SEWERAGE SYSTEM DEVELOPMENT IN BANGKOK

4.1 Solutions for the Problems

(1) Policies for Urban Wastewater in Thailand

PCD (Pollution Control Department, MONRE) drew up "National Sewerage Development 32 Year Plan, (2010-2041)", described in Section 3.1.2. In this Plan, management of wastewater in the country is described as follows.

- Almost all wastewater is discharged without treatment, and water quality investigation for main rivers revealed that rivers of which water quality was classified as good account for 32%, moderate 34 %, and deteriorated 34 % in 2009.
- Only 3.2 million m^3/d out of total wastewater generation of 14 million m^3/d is treated.
- As a result, many municipalities require assistance regarding urban wastewater management.

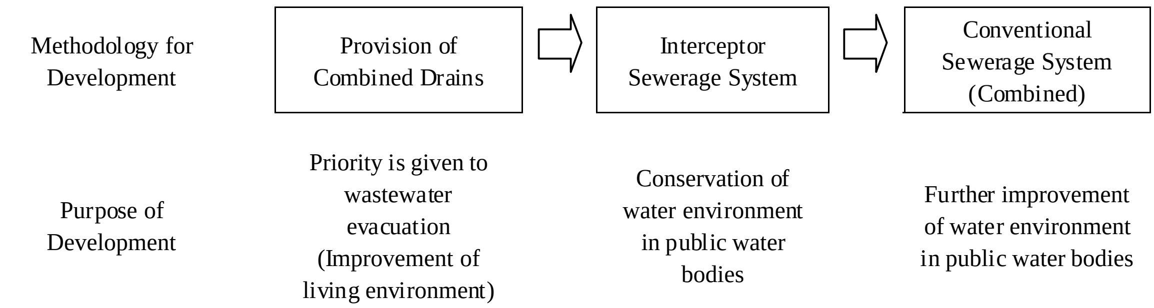
Outline of policy for urban wastewater management is described below.

- Provision of preliminary wastewater treatment such as grease trap is compulsory for each pollution source i.e. house or building.
- Designate areas for urban wastewater treatment, and implement public sewerage system or small scale treatment system depending on status and issues of the municipality, water resources and management capability.
- Central government manages budget for subsidiary or loan to be utilized for construction of sewerage system. Committee of Decentralization to Local Government should allocate budget to assist local municipalities for their environment management.
- Management of wastewater treatment system is to be monitored and evaluated.
- "Municipal Sewage Management System" is to be implemented and water quality monitoring network is to be provided.
- Sewerage management body is to be authorized to collect sewerage service tariff in treatment areas.
- Wastewater treatment at pollution source is to be stipulated in accordance with National Environmental Quality Act.
- Other measures, utilization of private company, study on wastewater treatment, water pollution data base , diffusion of environmental knowledge, etc. should be undertaken.

(2) Interceptor Sewerage System

Interceptor sewerage system is adopted for improvement of water pollution in public water bodies. Human excreta are treated by on-site systems. Interceptor sewerage system is considered as provisional system to conventional sewerage system in developed countries (combined or separate sewerage system composed with house connections, sewer networks and wastewater treatment facilities). The sewerage system in BMA is also considered at a transitional stage since the existing drainage pipes are utilized to flow wastewater from house connections which is the starting point of the sewerage system.

In order to enhance the service level of the sewerage system, improvements of structures of the existing facilities to prevent deposit in pipes and to minimize untreated wastewater discharge are indispensable.



Source: JST

Figure 4.1.1 Evolution of Sewerage System

(3) Recommended Solutions

It is important to form a strategy for sewerage system development in BMA based on national policy for urban wastewater treatment, taking into account improvement of interceptor sewerage system (Thai sewerage system) and management of sewerage system including new system for future. Role of sewerage system includes improvement of public health, storm water drainage, conservation of water quality, reuse of sewerage resources, and conservation of desirable water environment (refer to Figure 4.1.2). Regarding BMA’s environmental policy, sewerage system has obtained results on wastewater collection and treatment, however its service level remains at low level in view of non-treated wastewater discharge, human excreta treatment, countermeasures against flooding and conservation of water environment.

Medium- and long-term targets for sewerage system development are determined as shown below while maintaining the existing sewerage system.

1) Desirable management of sewerage system

- Unified management of wastewater treatment, discharge regulation and storm water runoff by DDS
- One-stop service for residents regarding sewage collection, complaint and so on

2) Enhancement of sewerage service
- Improvement of water environment, improvement of interceptor sewerage system
- Human excreta treatment, house connection
- Countermeasures against inundation

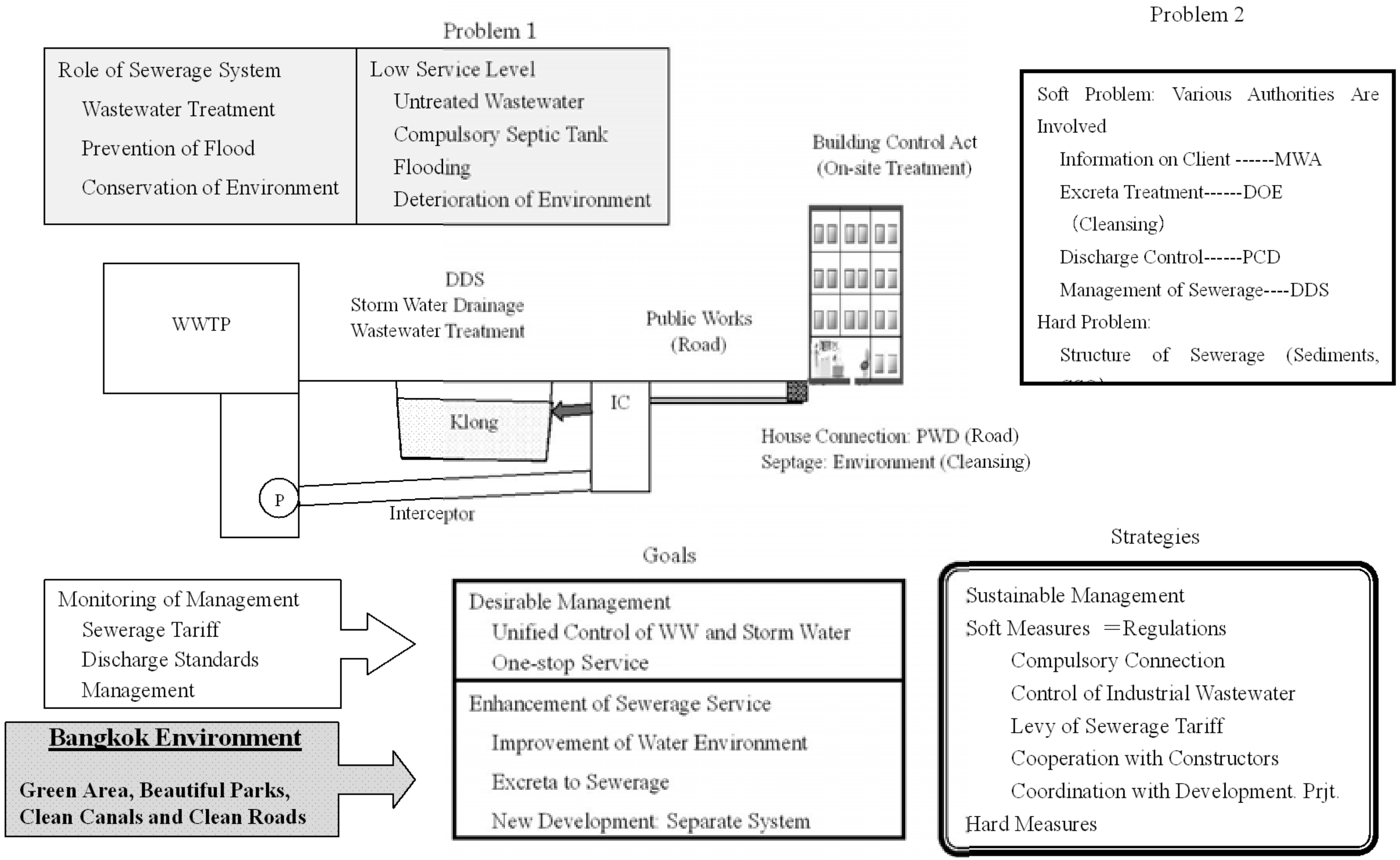
In order to solve the technical and management problems and to achieve medium- and long-term targets for the sewerage system, sewerage ordinance on which institutional arrangement is to be based should be stipulated, and nontechnical measures should be taken together with technical measures such as improvement of structures of sewerage system (Figure 4.1.3). Nontechnical measures include such important activities as public relations, enhancement of residents' awareness and promoting understanding of residents for sewerage tariff, control of discharge, and management of sewerage system.

It will take huge amount of money and time to implement measures to enhance service level such as expansion of sewerage system, provision of drainage pipes and pumping stations for prevention of flooding, and improvement of interceptor sewage system. It is important that implementation of measures should be carried out taking into account characteristics of the area and with medium- and long-term perspective (Figure 4.1.4). In case of the existing treatment areas, improvement of the existing facilities should be carried out. For the new sewerage system, application of improved facilities is to be provided. In newly developing areas, application of latest technology should be considered. New role of the sewerage system, such as global environmental issues and effective use of sewerage resources should also be considered at the same time, resulting in prevention of possible double investment. Institutional arrangements, such as unified control of wastewater and storm water and establishment of a sewerage management body which can create improved water environment are indispensable. These institutional arrangements can be seen in large cities in developed countries such as Japan.

Role of sewerage in Bangkok
- Sanitation
- Storm water drainage
- Water pollution control
- Reuse and recycling
- Amenity, Sound Water Environment

Source: JST

Figure 4.1.2 Change of Role of Sewerage Works in Japan



Source: JST

Figure 4.1.3 Target and Strategy for Sewerage System Development

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 4.1.4 Step-Wise Sewerage Development

4.2 Strategy for Sewerage System Development

Strategy for sewerage system development is proposed as categorized into four groups.

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

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

Improve the interceptor sewerage system (Thai combined type sewerage system) in order to improve water quality in klongs by reducing pollutant loads caused by combined sewage overflow (CSO). Integration of interceptor chambers and outlets should be implemented to prevent wastewater discharge from them. The system should be changed to pump drainage system to prevent back flow from klongs as long-term measure. These measures are not inconsistent with flood control projects in Bangkok.

Darinage pipes existing upstream of interceptor chambers should be investigated to graspe their conditions, deteriorated conditions in particular. In addition, improvement measures of the existing drainage pipe networks such as collection of untreated wastewater currently discharged to klongs to sewerage system, should be taken.

Strategy 1.2 Proper Human Waste Treatment and Septage Treatment

Strengthen human waste treatment together with reception of septage to WWTPs.

Strategy 1.3 Countermeasures for Industrial Wastewater

Strengthen the current countermeasures for industrial wastewater, and institutionalize these measures in view of administrator of sewerage system.

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

Strategy 2.1 Expansion of the Sewerage System

Utilize marginal capacities of the exisiting WWTPs to reduce construction cost of new WWTPs. Study wastewater treatment processes which are effient and can be constructed in limited areas.

Strategy 2.2 Separate Sewerage System Pilot Project

Verify a model separate sewerage system in newly developed urban area on a pilot project base.

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

Expand the re-use of resources generated from treated effluent and sludge, and adopt measures against climate change in WWTPs.

Strategy 4: Improve the Management of the Sewerage Works

Strategy 4.1 Improvemrnt of Management

Continue to receive subsidies from the central government related to construction funds for promoting sewerage system development. Enhance the awareness of users related to the sewerage system, and introduce the sewerage service charge system.

Introduce performance indicator (PI) and improve operation and maintenance services for the sewerage system. Assume reconstruction and renewals henceforth, and study income and expenditure estimates for sewerage works in the long-term.

Strategy 4.2 Cooperation of Public and Private Sectors

Enhance efficient sewerage system development with cooperation with private developers, and cooperation with private sector such as promotion of constructors of drainage facilities and outsourcing of operation and maintenance work to private companies.

Strategy 4.3 Improvement of Institutional System for Sewerage Project

It is necessary to bring entire sewerage related services currently fragmented between many authorities under the umbrella of one responsible agency, i.e. DDS. Study the applicable fields and contractual methods of Public Private Partnership (PPP), and promote PPP.

Strategy 4.4 Stipulation of Sewerage Ordinace

Stipulate sewerage ordinance to be basis for sewerage system management

Indivisual strategies classified by the above categories are summarized in Table 4.2.1 together with responsible agencies.

Table 4.2.1 Strategy for Sewerage System Development and Responsible Agency

	Individual Strategy for Sewerage System Development	Responsible Agency	Issues and Rquirements
Strategy 1.1	1) Countermeasures for CSO	DDS	Coordination with Main Drainage Development Division, DDS
	2) Improvement of storm water drainage in parallel with improvement of water quality in klongs	DDS	Coordination with Main Drainage Development Division, DDS
	3) Countermeasures for untreated wastewater discharge, combination of interceptor chambers	DDS	Coordination with Main Drainage Development Division, DDS
	4) Countermeasures for backwater from klong, change to discharge by pump	DDS, BMA	Secure budget Coordination with Main Drainage Development Division, DDS
	5) Intercepting rate	DDS	Coordination with Main Drainage Development Division, DDS
	6) Collection of untreated wastewater and investigation of existing drain pipes for improvement	DDS, PWD	Coordination with Main 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 Main 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 toWWTP	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 of regulations
Strategy 2.1	1) Rearrangement of the existing treatment areas	DDS	
	2) Compact and energy saving treatment system	DDS	
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
Strategy 3	3) Global warming mitigation	DDS, BMA, MONRE	Coordination with other concerned departments of BMA

	Individual Strategy for Sewerage System Development	Responsible Agency	Issues and Rquirements
			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	
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.

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)

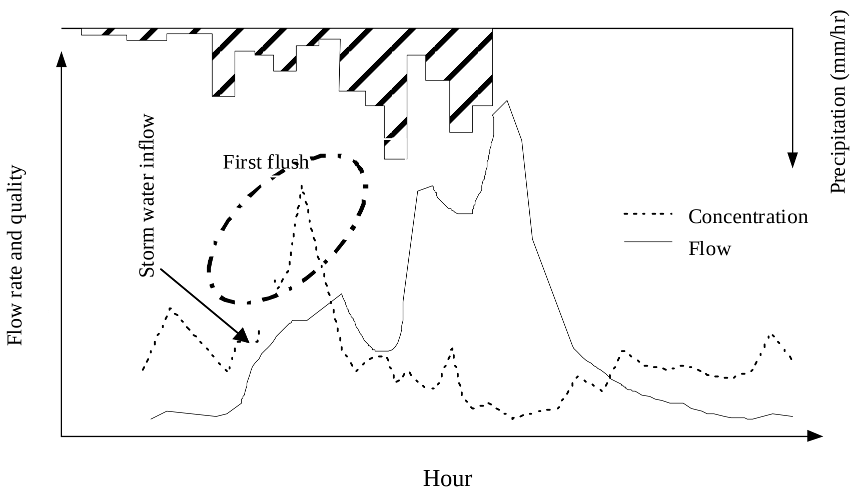
Improvement measures for CSO in combined system, existing drainage facilities, and structures and operation of interceptor chamber will be proposed taking into account of the current situation of the interceptor sewerage system in BMA.

(1) Improvement for Combined Sewage Overflow (CSO)

(A) Issues of CSO

CSO (Combined Sewage Overflow) is the untreated sewage discharged from the interceptor chamber in wet weather when sewage flow exceeds capacity of interceptor. CSO is main pollution source in combined sewerage system together with other pollution sources. CSO causes public health problem due to pathogenic bacteria and aesthetic problem due to garbage flown out.

One of the features of wastewater characteristics in combined sewerage system in wet weather is that initial flow of storm water or so called first flash includes very high concentrations of substances (refer to Figure 4.2.1). This phenomenon occurs when sediments deposited during dry weather is flushed by storm water runoff which has strong dragging power. Concentrations go down rapidly after initial rain fall. It is important no to discharge this first flush from interceptor chamber in view of water pollution control.



Source: JST

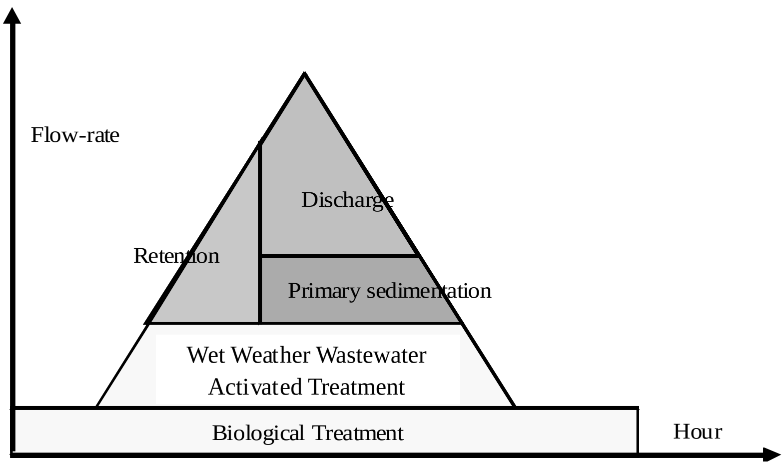
Figure 4.2.1 Change of Flow and Concentration of CSO

Photos 4.2.1 (left) and 4.2.2 (right)   Example of CSO in Japan
Dry Weather (Left) and Wet Weather (Right)

(B) Available Countermeasures for CSO Issues

Countermeasures for CSO, such as capture of first flush, reduction of occurrence of CSO, and prevention of flowing of pollutant into sewers by cleaning of road surface, are practiced. Increase of treatment capacity in wet weather (by Wet Weather Wastewater Activated Sludge Treatment Process) in addition to the capacity in dry weather as shown in Figure 4.2.2, storage of first flush and primary treatment in primary settling tank are considered as technology for reduction of pollutant. Usually excess flow which can not be treated by these techniques is discharged.

Wet Weather Wastewater Activated Sludge Treatment Process is a secondary process to receive a part or all of preliminary treated combined wastewater to latter part of reactor and to treat it by utilizing initial adsorption capacity. This process is one of combined sewerage system improvement technologies with very high cost performance.



Source: JST

Figure 4.2.2   Hydrograph CSO Abatement

(C) 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.

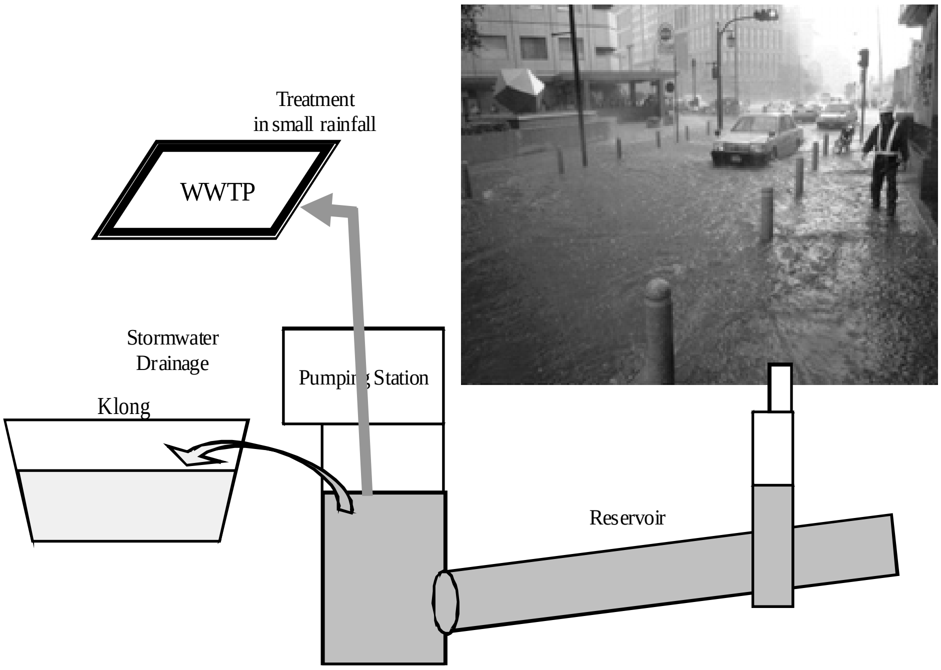
Improvement of interceptor sewerage system aims to improvement of water quality in klongs by collecting untreated wastewater and by reducing pollution load caused by CSO. Also, O&M cost is expected to be reduced by reducing infiltration which leads to reduction of load to WWTP.

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.

(D) Usage of Storm Water Drainage Facilities as Countermeasures for CSO

Deep drainage tunnel with pumping station project has been implemented in flood prone areas. Storm water and wastewater should be completely separated in the areas where these kind of drainage facilities are implemented. Wastewater is to be collected by the existing drain pipes and interceptors and treated at WWTP. Storm water is to be collected from klongs to the deep tunnel and discharge directly to Chao Phraya river by pumps (Figure 4.2.3).

Use of the deep tunnel as storage of storm water caused by small rain fall or first flush is a useful measure to control water pollution.



Source: JST

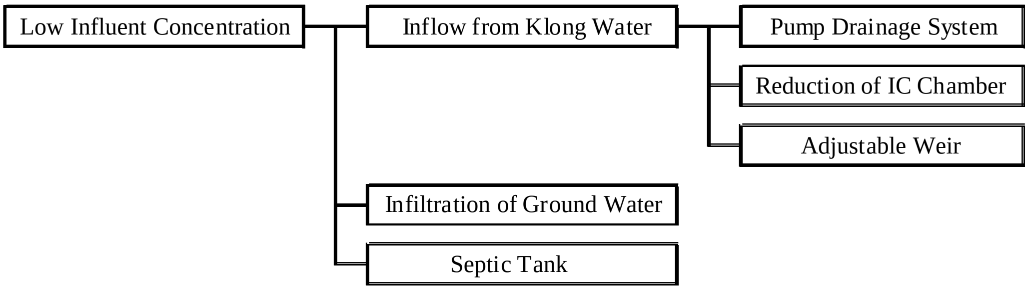
Figure 4.2.3 Countermeasure for CSO by Utilizing Deep Tunnel

(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 4.2.4. Conversion to pump drainage and reduction of interceptor chamber which are described in the next Section are considered to be countermeasures for prevention of backwater from klong.

Reduction or integration of interceptor chambers is not contradictory with urban flood control which has highest priority in BMA.



Source: JST

Figure 4.2.4 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.

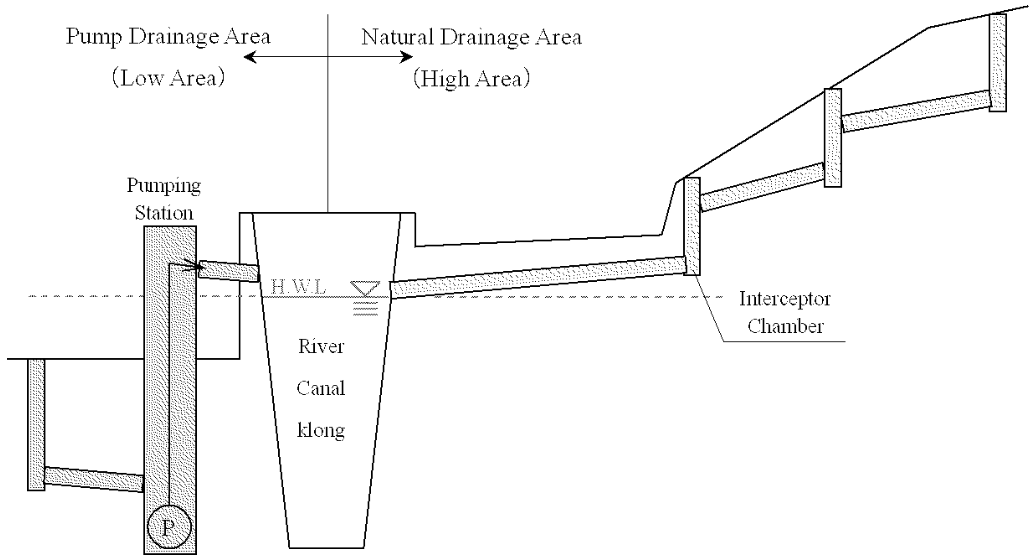
Difference between combined sewerage systems in Thailand and in Japan.

Difference between two combined sewerage systems is compared below to describe a general idea of introducing Pump Drainage Area.

In all existing WWTP treatment areas in BMA, storm water is discharged to klongs from interceptor chambers by gravity without using pumps. However, in lowlands like Rattanakosin treatment area, water level of klong is higher than the weir level of interceptor chamber. In these areas, if flap gate is not completely closed, it is very difficult to stop the backwater from klongs.

On the other hand, in Japan highlands and lowlands are classified. In highlands, where sewers are laid higher than the water levels of rivers, storm water is discharged to rivers by gravity without pump, and these areas are called “Natural Drainage Area”. In lowlands, where sewers are laid lower than the water levels of rivers, storm water is forced to discharge to rivers by pumps, and these areas are called “Pump Drainage Area”.

Concept of classification of the Natural Drainage Area and the Pump Drainage Area is presented in Figure 4.2.5 below.



Source: JST

Figure 4.2.5 Schematic Diagram of Natural Drainage Area and Pump Drainage Area

The idea of the pump drainage is never unique to Japan. This idea has been introduced generally in western countries. For example in the Netherlands, because a quarter part of country is lower than the sea; storm water was drained by pumps driven by windmills in the past, and now is drained by motorized pumps.

Difference between Thai and Japanese storm water drainage systems is presented in Table 4.2.2.

Table 4.2.2 Difference between Thai and Japanese Drainage Systems

	Thai	Japanese
Storm water Drainage System	All area: Natural Drainage Area (With flap gate)	High area: Natural Drainage Area Low area: Pump Drainage Area
Advantages	・ It is not necessary to maintain pumping stations.	・ The backwater doesn't flow to interceptor. ・ In lowlands untreated wastewater isn't discharged, so it contributes to improve water quality in receiving water. ・ Even when the outside water level is high because of high tides, it is possible to discharge storm water. So the risk of inundation is low.
Disadvantages	・ If the flap gate is not completely closed, it is very difficult to stop the backwater from outside when the outside water level is high. ・ When it rains and the outside water level is high, the risk of inundation is high because	・ Construction of new pumping stations and drainage pipes are necessary. ・ It is necessary to maintain pumping stations.

	Thai	Japanese
	storm water isn't forced to discharge to outside. ・ It is very hard to maintain so many interceptor chambers.	

Source: JST

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

Countermeasures for untreated wastewater discharge are described in Section 3.6.1 and repeated 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)

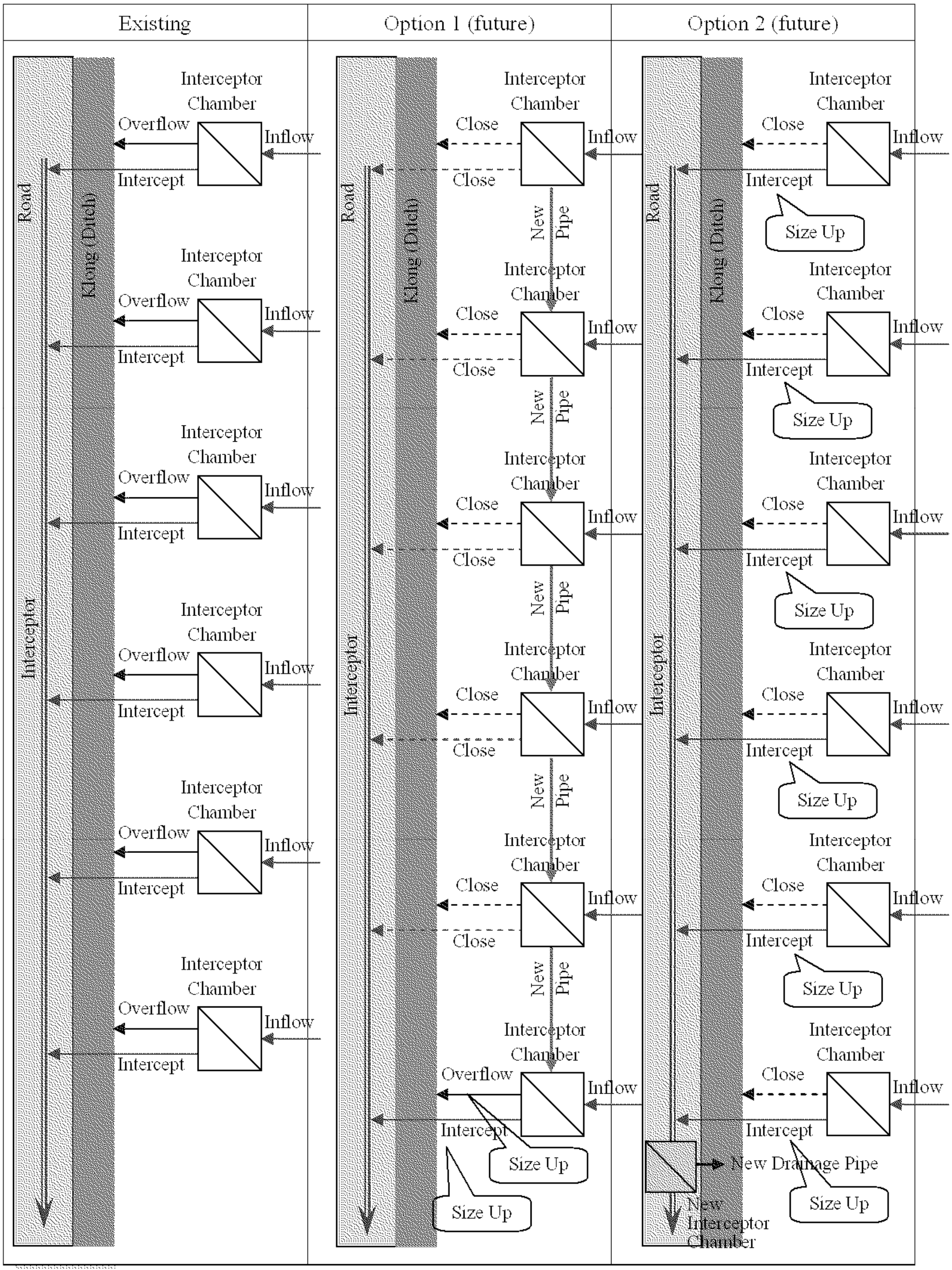
DDS carries out periodical cleaning of interceptor chambers. However, according to "Water Quality Management Office – Annual Report 2551 (2008)", Cleaning can not be carried out smoothly due to the following obstacles.

- 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. An example of reduction by combination of six interceptor chambers located along Vipravadee Rangsit Road in Din Daeng treatment area is shown in Figure 4.2.6. There could be two ways of doing this as shown below.

Option 1:
Overflow pipes, interceptors and overflow weirs in five upstream chambers except most downstream one are closed. Pipes to connect chambers are installed.

Option 2:
All overflow pipes and overflow weirs are closed. New interceptor chamber and overflow pipe are constructed.



Source: JST

Figure 4.2.6 Example of Reduction of Interceptor Chamber (Din Daeng Treatment Area)

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

Countermeasures for backwater from klong are described in Section 3.6.1 and repeated below. In addition, long term solutions are presented below.

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 level recommended in Section 3.6.1.

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.

Photo 4.2.3 Outlet Pipe in Dry Weather 1 (June 29 2010,Rattanakosin Treatment Area)

Photo 4.2.4 Outlet Pipe in Dry Weather 2 (June 29 2010,Rattanakosin Treatment Area)

Photo 4.2.5 Outlet Pipe in Dry Weather 3 (June 29 2010,Rattanakosin Treatment Area)

Photo 4.2.6 Outlet Pipe in Dry Weather 4 (June 29 2010, Chong Nonsi Area)

Change of Drainage System to Pumping System, An Example for Rattanakosin Treatment Area

In all the existing treatment areas in BMA, overflows from interceptor chambers are discharged to klongs by gravity without pump. These are so called “natural drainage system”. However, it is very difficult for areas such as Rattanakosin and Chong Nonsi treatment areas where water level in klong is higher than those of wires in interceptor chambers, to prevent backflow from klong unless flap gates are completely closed. High water level in klong in these “natural drainage areas” is not only a reason for backflow but also a reason for flooding.

Concept of a pump drainage system is depicted in Figure 4.2.7, and this system can be introduced in small treatment area of Rattanakosin as an example. This idea is proposed based on the following considerations.

i) Current interceptor chambers should in principal be closed.
ii) Wastewater up to 2 to 5 DWF is conveyed to WWTP through interceptor, there is no modification to the existing interceptors.
iii) Rain water will inundate roads or low lands in rainy season due to the close of interceptor chambers.

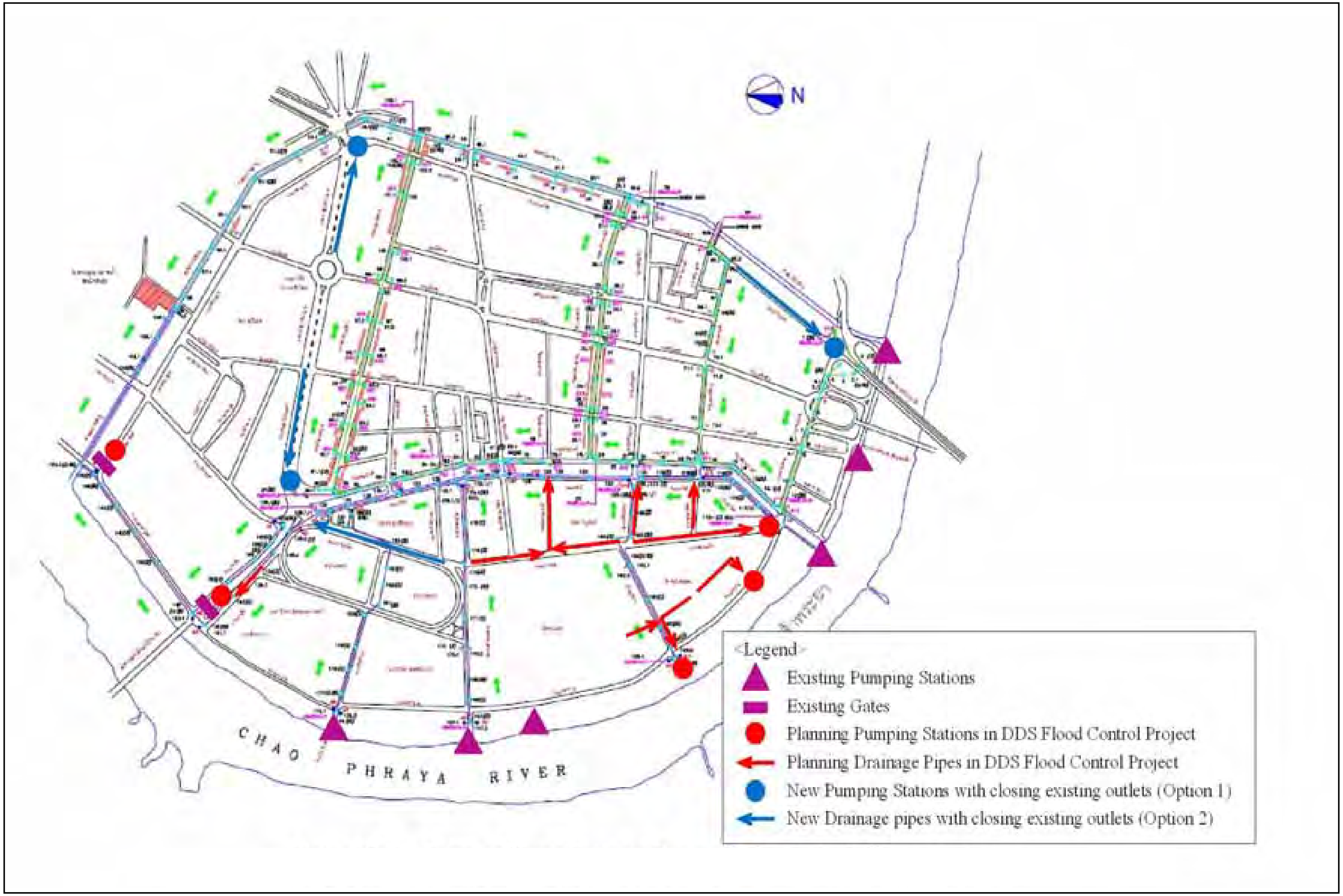
iv) Then the above rain water will be drained through new storm sewers, and discharged at storm water pumping station.

The concept proposed by the Survey Team is that the existing and planned pumping stations located near conjunctions of klongs and Chao Phraya River should be utilized to the fullest extent and only a certain drainage/pumping capacity should be added to cover the closed interceptor chamber. Thus, sewerage system and storm water drainage system can be operated in cooperation with each other, and not operated independently.

Figure 3.7.11 shows a concept of pump drainage system. Actual design of pumping stations and drainage pipes should be conducted based on the analysis of storm water run-off and study on these facilities. For efficient implementation of pump drainage system, these facilities constructed for flood control project shown in Photos below should be utilized as much as possible.

Photo 4.2.7 Existing Manhole Pump (Phetchaburi Street)

Photo 4.2.8 Existing Storm water Pumping Station (Nara Thiwat Rajanagarindr Street)



Source: JST

Figure 4.2.7 Concept for Pump Drainage System for Rattanakosin Treatment Area

(5) Intercepting Rate

The combined sewerage system (the interceptor sewerage system) is adopted in all existing treatment areas in BMA, so that the intercepting rate of combined wastewater in rainy weather has a significant effect on the sizes of sewer pipes and WWTPs.

In 7 existing treatment areas, the intercepting rate is 5 times the Average Dry Weather Flow (DWF), and all interceptors are designed to flow 5DWF by gravity. Meanwhile, in Ban Sue and Klong Toei treatment areas where construction of interceptors and WWTPs are under construction or planned, 5DWF is intercepted at interceptor chambers, but variable intercepting rates from 2DFW to 5DFW (3.5 on average) are adopted for design of interceptors. This method is adopted widely all over the world and results in significant reduction of construction cost because smaller diameter and shallower pipes can be designed compared with pipes designed for constant 5DFW flow. This method allows pressurized condition for downstream part of interceptors unless overflow occurs and is proposed based on the following reasons.

- It is possible to flow the dry weather hourly max flow if all interceptors are designed to flow at least 2DWF by gravity.
- When 5DWF is intercepted at interceptor chambers in rainy weather, the down stream interceptors become pressurized. However, it is confirmed that the wastewater doesn't overflow to the ground by the unsteady run-off analysis.
- From the water pollution analysis the difference of the total annual pollution load caused by CSO between the case of designing all interceptors to flow 5DWF and the case of designing all interceptors to flow 2-5DWF is only 0.6%. Therefore, an effect of designing all interceptors to flow 5DWF by gravity is comparatively small.
- This method is used widely in other foreign countries.

It is proposed that in the new treatment areas in BMA, the intercepting rate of all interceptor chambers should be 5DWF, and intercepting rate for design of interceptors should be 2-5DWF.

(6) 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 compulsory connection to the sewerage system by law and subsidiary from BMA or district office for plumbing works inside houses.

Sewerage facilities are not managed by the sole agency. Septic tanks and drainage facilities in households are under responsibility of PWD (buildings) and drainage pipes (lateral drainage pipes) installed under roads which receive wastewater and storm water runoff are under responsibility of PWD. Construction and management of interceptor chambers, interceptors and WWTPs are carried out by DDS. Thus, all sewerage related services should be integrated under one agency. If it is difficult to realize this, establishment of close cooperation by agencies concerned is required. Investigation of the existing drainage pipes on the following issues should be carried out to establish improvement countermeasures.

i) Management of information about pipe networks (e.g. preparation of sewerage ledger)
ii) Grasp of current status of pipe networks (e.g. grasp of deterioration of the existing drainage pipes)
iii) Grasp of flow capacities of pipe networks (e.g. investigation of flow capacity of the existing catchment area)

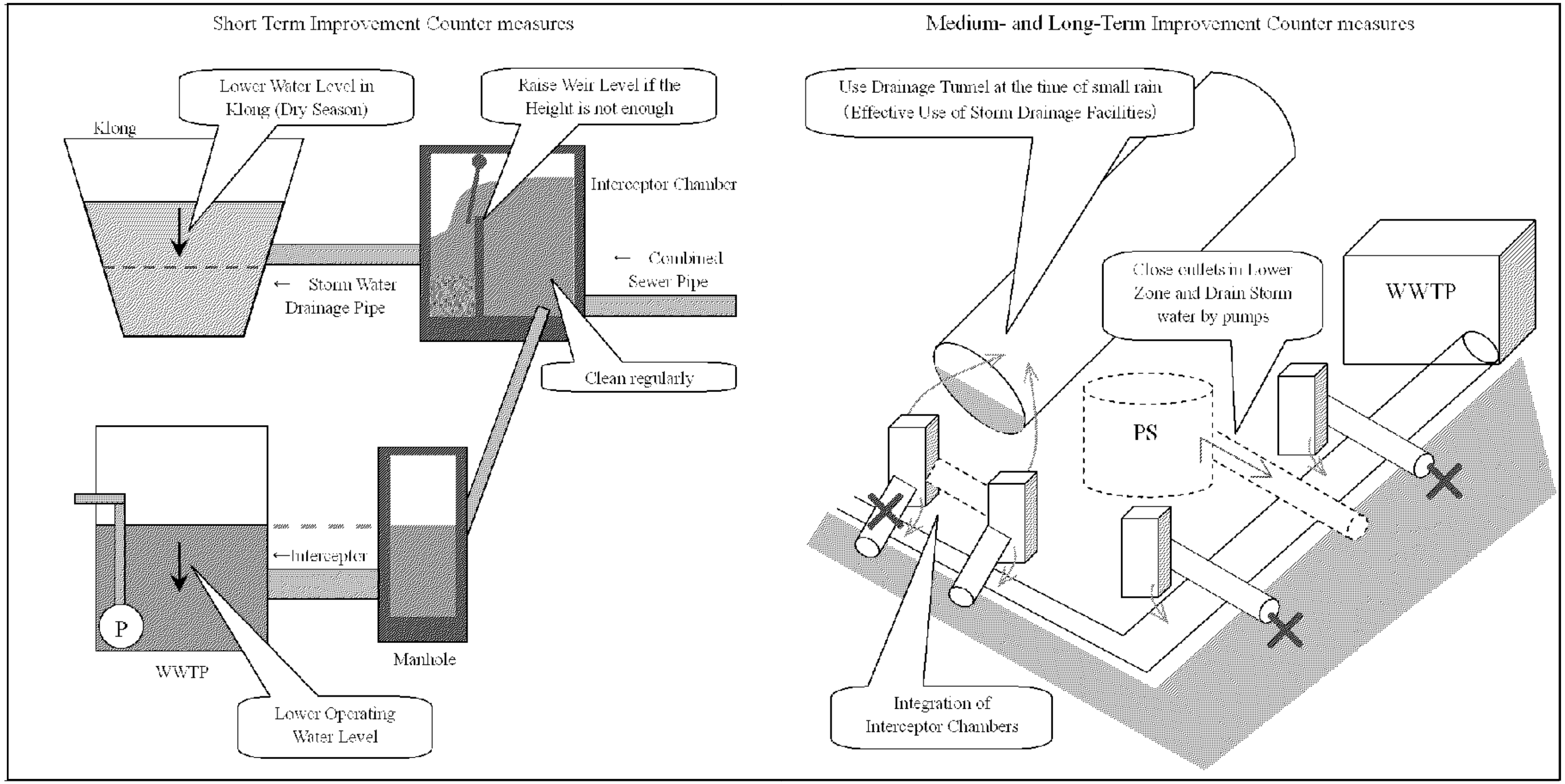
(7) Short Term and Medium- and Long-Term Improvement Measures

Short term and medium- and long-term improvement measures for interceptor sewerage system are proposed as mentioned in Table 4.2.3 and showed in Figure 4.2.8.

Table 4.2.3 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 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	(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 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



Source: JST

Figure 4.2.8 Concept of Short Term and Medium - and Long-Term Improvement Countermeasures

Strategy 1.2: Appropriate Treatment of Human Excreta and Septage

(1) Strengthening of Human Excreta Treatment

Septic tank is a facility to treat human excreta and supernatant from it is discharged to klong. Sedimentation or penetration type tank is usually adopted, and treatment efficiency is considered to be approximately 50% in terms of BOD, same as anaerobic digester. Septic tanks from which sludge is never removed account for about 50% and those from which sludge is removed every 1 to 3 years account for the remaining 50 %, as mentioned in Section 3.4.3. Thus, volume of tank is reduced as sludge is accumulated in tank resulting in flowing out of sludge. This causes organic and pathogenic bacteria contamination in klong. A large quantity of effluent is discharged into klongs from those of large scale business entities such as commercial complexes, and this effects water environment significantly. Septic tanks remain even after sewerage system is constructed. Pollutants in supernatant from septic tank settle in sewer pipes and cause odor and CSO in wet weather. Therefore, proper management of septic tanks, e.g. periodical removal of sludge is indispensable.

Monitoring of effluent from business entities located outside of treatment area for which effluent standards are applied, and guidance for improvement of treatment facilities if they discharge unsuitable wastewater are important. Effluent standards which will be explained in the following Strategy 1.3 for discharging to sewerage system should be stipulated.

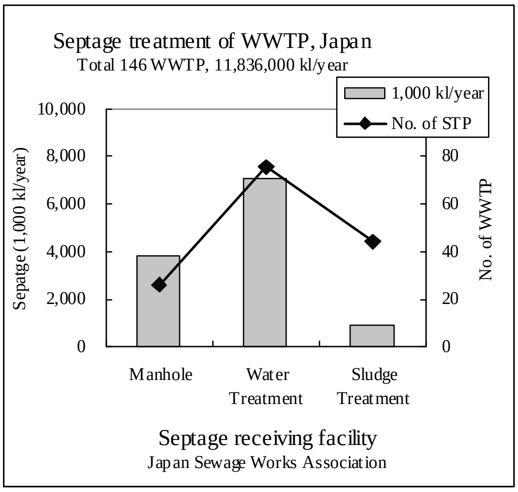
(2) Treatment at WWTP and Disposal of Septage

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, as shown in Figure 4.2.9.

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)

Provision of screens to remove screenings for protection of machines such as pumps and mixers and pipes is desirable from technical and economic view points. Septage receiving facility should be constructed at a convenient location of the existing WWTP or sludge treatment plant where impact to the surrounding residential areas is considered to be minimum.



Source: JST

Figure 4.2.9 Septage Treatment at WWTP

Table 4.2.4 Characteristics of Septage from Septic Tank

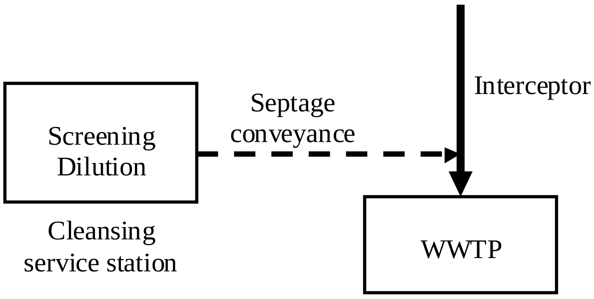
Parameter	On Nuch Septage Treatment Plant Concentrations of Sludge (mg/l)	Dehydrator Seepage Concentrations (Average) (mg/l)	Septage Concentration (Average) (mg/l)
SS	―	120～3,700（1,460）	12,000
COD (Mn)	8,000～12,000	1,750～3,570（2,240）	4,000
BOD	6,000	711～6,340（1,900）	6,000
T-N	―	2,900～3,910（3,210）	1,000
T-P	―	161～275（235）	500

Remarks: COD of On Nuch Plant is in COD (Cr)

Source: DDS and Japan Sewage Works Agency

Septage is received at WWTP as follows.

- Grits are removed by screen installed at receiving facility
- Septage should be diluted with treated effluent so that concentrations of BOD, SS, N and P are equal to those of raw wastewater



Source: JST

Figure 4.2.10 Model of Septage Receiving

(3) 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.

Examples of measures for business wastewater are described below.

(1) Purpose of Control of Wastewater Characteristics

Wastewater characteristics should be controlled to assure proper function of entire sewerage system.

i) Preservation of Sewerage Facilities
Most of sewerage facilities are concrete structures, and these can be eroded by wastewater with strong acidity or alkalinity. Erosion of structure causes accidents such as collapse of road. Floating materials and oils and grease cause clogging of pipes resulting in flooding of wastewater. Wastewater with cyanides or sulfates can cause toxic gases, endangering pipe cleaning persons.

ii) Preservation of Treatment Function
Wastewater treatment utilizes microbes. Inflow of toxic materials or sudden change of pH effects microbes resulting in lowering of treatment function. Biological treatment is applied for treatment of organic materials and it is not suitable for other materials. Also high concentrations of organic materials results in inadequate treatment. If pollution load which can hamper function of microbes enter into WWTP, these materials are inadequately treated and discharged causing pollution of receiving water environment.

iii) Reuse of Sewerage Resources
Reuse of treated effluent, and use of digestion gas, heat energy and incinerated ashes contribute for savings of energy and recycling of resources. If wastewater contains hazardous materials, these remain in effluent or are condensed in sludge, and reuse of effluent or sludge can not be realized.

(2) Matters to be Stipulated for Control of Business Wastewater

For control of business wastewater, following matters should be stipulated.

i) Standards for Characteristics of Wastewater (refer to Table 4.2.5)

ii) Standards for structure of inspection pit or facility

iii) Monitoring, and reporting of characteristics of wastewater, inspection on the spot

iv) Installation of pre-treatment facility

Change of production process, collection of wastewater at generating point and so on

v) Management of wastewater

Appointment of person responsible for wastewater management of pre-treatment facility, management of operation, record of Operation

vi) Common knowledge for wastewater management

Enhancement of awareness of all employee, guidance about proper management of pre-treatment

Table 4.2.5 Example of Standards for Wastewater Characteristics for Discharge to Sewerage System

Material or Item			Discharge more than $50m^3/d$	Discharges less than $50m^3/d$
Hazardous Substances	Cadmium		Less than 0.1mg/l	Less than 0.1mg/
	Cyan		Less than 1mg/l	Less than 1mg/l
	Organic Phosphorus		Less than 1mg/l	Less than 1mg/l
	Lead		Less than 0.1mg/l	Less than 0.1mg/l
	Six Equivalent Chromium		Less than 0.5mg/l	Less than 0.5mg/l
	Arsenic		Less than 0.1mg/l	Less than 0.1mg/l
	Total Mercury		Less than 0.005mg/l	Less than 0.005mg/l
	Alkyl mercury		Not detected	Not detected
	Polychlorobiphenyl		Less than 0.003mg/l	Less than 0.003mg/l
	Trichloroethylene		Less than 0.3mg/l	Less than 0.3mg/l
	Tetrachloroethylene		Less than 0.1mg/l	Less than 0.1mg/l
	Dichloromethane		Less than 0.2mg/l	Less than 0.2mg/l
	Carbon tetrachloride		Less than 0.02mg/l	Less than 0.02mg/l
	1,2-Dichloroethane		Less than 0.04mg/l	Less than 0.04mg/l
	1,1-Dichloroethylene		Less than 0.2mg/l	Less than 0.2mg/l
	cis-1,2-Dichloroethylene		Less than 0.4mg/l	Less than 0.4mg/l
	1,1,1-Tricholoroethane		Less than 3mg/l	Less than 3mg/l
	1,1,2-Trichloroethane		Less than 0.06mg/l	Less than 0.06mg/l
	1,3-Dichlotobenzene		Less than 0.02mg/l	Less than 0.02mg/l
	Thiuram		Less than 0.06mg/l	Less than 0.06mg/l
	Simazine		Less than 0.03mg/l	Less than 0.03mg/l
	Tiobencarb		Less than 0.2mg/l	Less than 0.2mg/l
	Benzene		Less than 0.1mg/l	Less than 0.1mg/l
	Selenium		Les than 0.1mg/l	Less than 0.1mg/l
	Boron and its compounds	to river	Less than 10mg/l	Less than 10mg/l
		to sea	Less than 230mg/l	Less than 230mg/l
	Fluoride and its compounds	to river	Less than 8mg/l	Less than 8mg/l
		to sea	Less than 15mg/l	Less than 15mg/l
Environmental and Other Parameters	Total chromium		Less than 2mg/l	Less than 2mg/l
	Copper		Less than 3mg/l	Less than 3mg/l
	Zinc		Less than 2mg/l	Less than 2mg/l
	Phenolic compounds		5mg/l	-
	Iron (soluble)		Less than 10mg/l	-
	Manganese (soluble)		Less than 10mg/l	-
	BOD	General	Les than600mg/l	-
		Manufacture, gas	Less than 300mg/l	
	SS	General	Less than 600mg/l	-
		Manufacture, gas	Less than 300mg/l	
	Normal Hexane Extract	Mineral oil	Less than 5mg/l	-
		Animal and vegetable oil	Less than 30mg/l	-
	Nitrogen		Less than 120mg/l	-
	Phosphorus		Less than 16mg/l	-
	pH	general	5 to 9	5 to 9
		Manufacture, gas	5.7 to 8.7	5.7 to 8.7
	Temperature	general	Less than 45℃	Les than 45℃
		Manufacture, gas	Less than 40℃	Less than 40℃
	Iodine consumption		Less than 220mg/l	Less than 220mg/l

Source: Example of ordinary city of Japan

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. Detailed description is made in the following Chapter 5.

(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.

Unit treatment capacity per unit of land space is more than 100,000 m^3/d/ha for three WWTPs in BMA. This figure is as high as almost two times that of Ochiai WWTP which is located in most congested area of Metropolitan Tokyo in Japan (capacity 450,000 m^3/d, site area 8.5 ha). It is understood from the fact that WWTPs in BMA have been constructed in narrow sites.

Comprehensive coordination with relevant authorities is required regarding planned and effective use of publicly owend land and acquisition of land for WWTPs should be done in advance. If limited area of land is acquired, appropriate treatment method which satisfies required treatment level and is effective for energy saving and prevention of global warming should be selected. For this purpose adoption of compact treatment processes (e.g. carrier added activated sludge, membrane bioreactor), enegy saving technologies or energy recovery technologies (e.g. micro hydro power generation) should be investigated. Collective sludge treatment at a treatment plant located in suburb is more effective comparing indivisual sludge treatment at each WWTP located in central part of the city.

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

Technical Requirements

i) Drainage facilities in household is suitably provided for separate system

ii) Flow velocity in interceptors is assured to be more than the minimum velocity to prevent deposit of solids in pipes. Pumps should be operated to assure free surface of water in pipes

iii) All wastewater should be collected and sent the treatment plant bypassing interceptor chambers in dry weather

iv) Treatment to satisfy discharge standards should be provided at the treatment plant

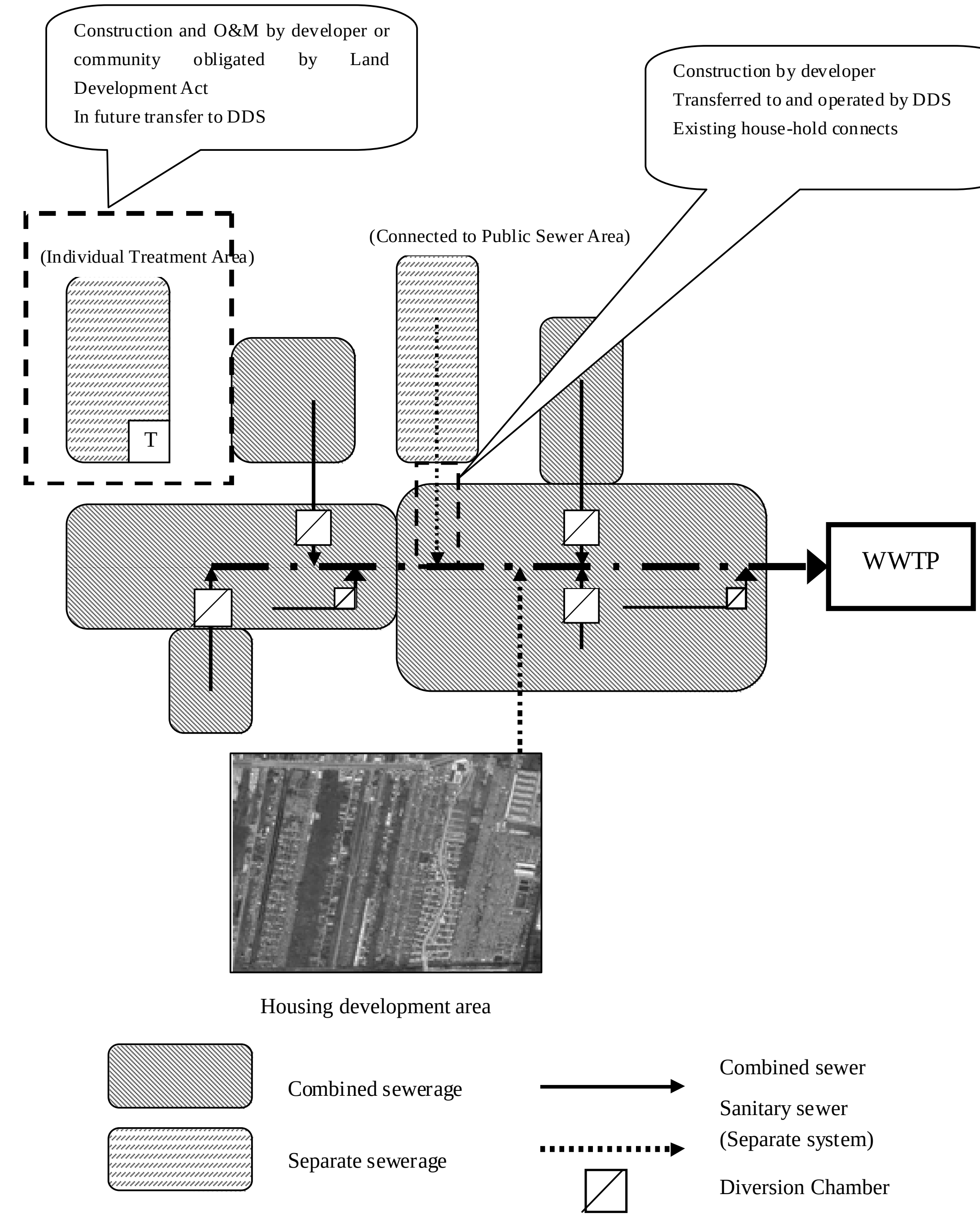
Institutional Requirements

i) Building Control Act 1979: Wastewater shall be treated by public sewerage system or on-site system (amendment of Act).

ii) Excreta Treatment: Wastewater including excreta should be connected compulsory to the public sewerage system, and this should be stipulated in sewerage regulations

iii) Sewerage Regulations: For urban development and redevelopment projects, consultation with DDS should be mandated regarding their sewerage plans (wastewater and storm water)

iv) Guidance for Development: Sewerage system can be constructed by developer, and the facilities should be transferred to DDS for management. This should be stipulated either in guidelines for development or in sewerage regulations



Source: JST

Figure 4.2.11 New Housing Development Project Connecting to Public Sewerage

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.

Photo 4.2.9 Use of Treated Wastewater (Tank Truck)

Photo 4.2.10 Landscape Use of Treated Wastewater

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 streets and parks. All of the composted sewage sludge is taken over from composing site as shown in Photo 4.2.12.

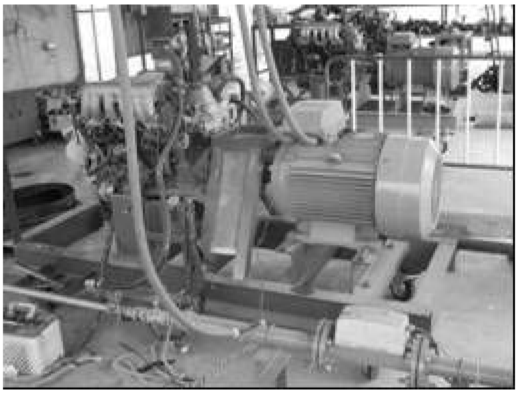


Photo 4.2.11 Digestion Gas Generator

Photo 4.2.12 Sewage Sludge Composting Site

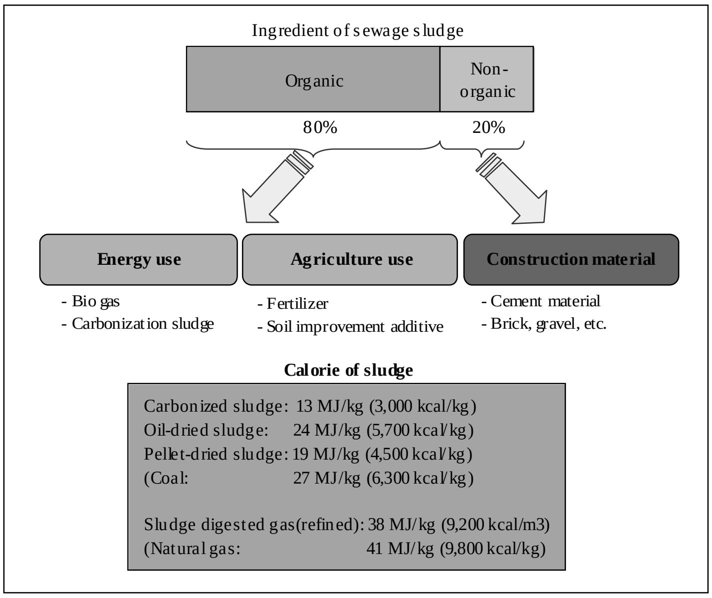
The following problems are expected along with expansion of sewerage system

i) Increase of sewage sludge volume
Sewage sludge volume will increase due to increase of wastewater treatment quantity, intercepting wastewater by the interceptor chamber improvement and septage treated at WWTP.

ii) Toxic substance contained in sewage sludge
Heavy metals and chemical substances are contained in sewage sludge if industrial wastewater are not properly pre-treated before discharging into public sewer. Monitoring about behavior of toxic substances is indispensable in case of agricultural use of sludge. If sludge contains these materials in excess of permissible limits, sludge can not be used for agricultural purpose.

iii) Composting of urban waste
In Bangkok composting facility for urban waste is operated and the compost is used for agriculture. This will be competitive with composting of the sewage sludge in future.

The following uses of sewage sludge as resources are considered although contents of organic components are rather low, 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. The following Figure 4.2.12 shows experiences in Japan.



Source: Sewerage and Wastewater Management Dept., Ministry of Land, Infrastructure, Transport and Tourism of Japan

Figure 4.2.12 Values of Sludge from Sewerage as Energy Resources

(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 as mentioned in Section 3.2.2.

Key points to reduce green house gases in sewerage system are as follows.

- i) Objective green house gases are three, viz. CO_2, CH_4 and N_2O.
- ii) Reduce green house gases due to energy consumption by improvement of energy efficiency of equipment.
- iii) Reduce CH_4 and N_2O generated at the wastewater and sludge treatment processes by improving treatment processes.
- vi) Reduce consumption of electricity and fuel by utilization of sewerage resources.

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 4.2.6.

Table 4.2.6 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.

(A) Possible Financial Sources

Central Government Allocations: Prior to the establishment of Environmental Fund, wastewater projects were financed by central government's budgetary allocation. It is still expected to continue the role.

BMA Allocations: BMA participated in a cost sharing arrangement with central government for funding of BMA 1 project, when BMA contributed 25% of the total. Similar arrangement can be applied for future projects.

Environmental Fund: Under the Enhancement and Conservation of National Environmental Quality Act (NEQA, 1992), the Environment Fund was established to finance environmental infrastructures including wastewater projects. The Fund is to be derived from (i) transfers from Fuel Oil Fund, (ii) transfers from Revolving Fund for Environmental Development and Quality of Life, (iii) fees and penalties under the NEQA, (iv) government grants, (v) donations, (vi) accrued interest of this Fund, and (vii) others.

International Financing Institutes: IFIs like International Finance Corporation (under World Bank) can make equity investment. The importance of such funding is not the value of the finance, but rather in the ability of this funding to enhance the credibility of the project and therefore, attract private sector investment.

ODA from Development Partners: Grants and loans from bilateral and multilateral development partners can also be channeled to finance the implementation of this master plan.

Private Sector: According to the Private Sector Participation Act (1992), it is now possible for private sectors to participate in the provision of public services. However, lack of full cost recovery tariff will hinder direct investment. PFI method can be applied to attract investment. It is to be noted that PFI is more costly than commercial bank lending but there is no risk on assets to be borne by the utility.

(B) Capital Cost Recovery

Most multi-lateral development partners recommend for total cost recovery for sewerage sector, however, it might not be a suitable approach for an economy like Thailand. BMR Wastewater Management Action Plan and F/S (ADB, June 1996) calls for recovery of administrative, operating and maintenance costs plus part of capital cost. However, until now, capital cost recovery has never been performed for sewerage infrastructures in BMA. Similar situation is also prevailing in the neighboring countries like Vietnam. In addition, from the oriental social value, sewerage service is considered as a social infrastructure. Hence, it is not recommended for capital cost recovery in near future. However, during the next review of sewerage MP, partial capital cost recovery should be investigated.

(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.

The study for charging user fee based on polluter pay principle was first conducted long ago (Wastewater Tariff Feasibility Study, BMA, 1998, in Thai language). Later Pollution Control Department and Wastewater Management Authority made similar study in 2000. The concept is new to Thailand and only few municipalities are currently utilizing this tool, like Pattaya, Sansuk, Patong and Hatyai (Environmental Financing Strategies: User Charges in the Wastewater Sector in Thailand, W. Simachaya, paper for OECD workshop in Malaysia, 2003). Among these, Pattaya and Hatyai use a percentage of land tax as sewerage charge.

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. The proposed tariff is shown in the following Table 4.2.7. 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. Even in case of not using supply water, wastewater flow is to be calculated based on the formula shown in Table 4.2.8 and sewerage tariff has to be paid. 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.

Table 4.2.7 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 Space more than 100 m^2	2 4
Massage Parlous and spa	4
Commercial/ Business Space less than 100 m^2 Space more than 100 m^2	2 4
Multi function building	4
Industry Wastewater less than 200 m^3 Wastewater between 200 and 500 m^3 Wastewater more than 500 m^3	4 6 8
Others	4

Source: Wastewater Tariff Code of Law, BMA, 2004

Table 4.2.8 Wastewater Estimation Formulae for Source without Water Metering (Water calculation based on 30 days/month)

Type of Wastewater Source	Wastewater Estimation Formulas
1. Resident with water consumption more than 10 cubic meter per month	Number of residence (capita) × 0.30 m^3/day
2. Government office, government unit, public enterprise, office and station	Number of employee (capita) × 0.10 m^3/day
3. Temple and Monetary, Non Government Organization, Educational Institute	Number of participant (capita) × 0.1 m^3/day
4. Hospital, Clinic	Number of overnight bed (bed) × 0.75 m^3/day
5. Hotel	Number of room (room) × 0.80 m^3/day

Type of Wastewater Source	Wastewater Estimation Formulas
6. Department Store, Shopping Mall, Exhibition Center	Business surface area (exclude car park) (m^2) × 0.005 m^3/day
7. Market	Business surface area (exclude car park) (m^2) × 0.020 m^3/day
8. Restaurants, food hall	Overall area (m^2) × 0.075 m^3/day
9. Massage Parlors	Number of room × 0.80 m^3/day
10. Business and Trading Firm	Overall area in (m^2) × 0.005 m^3/day
11. Complex Building	Business surface area (exclude car park) (m^2) × 0.005 m^3/day
12. Factory under factory act	Number of employee (capita) × 0.30 m^3/day
13. Others	Surface area used (m^2) × 0.005 m^3/day

Source: DDS

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. Since MWA already has extensive customer data, it is very logical to use that as a basis for sewerage billing purpose. WQMO already received that database. It may be noted here that there are only 2 user type defined for water tariff, residential and non residential (MWA Annual Report, 2009). 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.

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. Attached table (Table 4.2.9) shows that only 56% of interviewees have a willingness to pay wastewater fee. Then a new interview on suitable tariff (Table 4.2.10) 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.

Understanding of residents to the wastewater tariff advances by explaining progress of wastewater treatment and water environment improvement point by point. This shows importance of the publicity work about the water environment improvement.

Table 4.2.9 Willingness to Pay Wastewater Treatment Tariff

Willingness to Pay the Tariff	Number	%
Willing	1,290	56
Un-willing	1,010	44
Total	2,300	100

Source: DDS

Table 4.2.10 Suitable Tariff Rate of Wastewater Treatment

Suitable Tariff Rate	Number	%
0.5 – 1.0 Baht/m^3	1,746	80
1.0 – 1.5 Baht/m^3	308	14
1.5 – 2.0 Baht/m^3	132	6
Total	2,186	100

Source: DDS

In this JICA Survey, detail study on tariff is carried out in later stage. In that study, required tariff is first to be calculated to cover the O&M cost. After that affordability analysis is made from 3 aspects as follows,

WHO 5% rule:

WHO recommends that total water and sewerage charge should not exceed 5% of disposable average monthly household income. Considering average monthly water bill, maximum affordable sewerage tariff is set.

Willingness to pay survey:

A household survey was carried out in this JICA Survey. By carefully designing questionnaire, willingness to pay for sewerage service and willingness to pay for clean water environment was found out. Details are given in the F/S report.

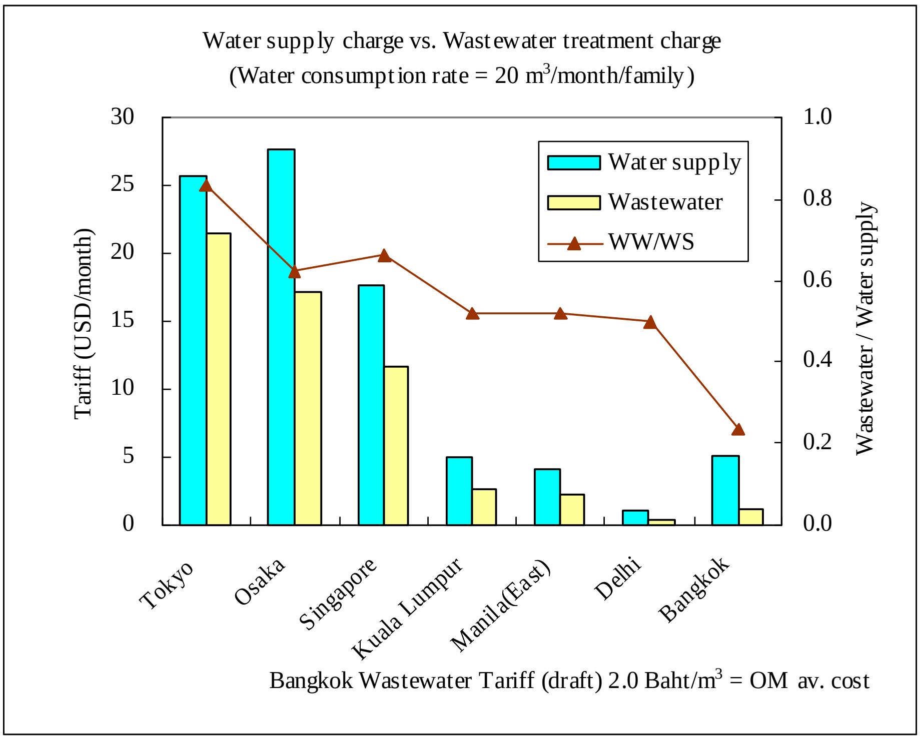
Comparison with other tariff:

Proposed sewerage tariff is compared with other utilities tariff. This includes water supply, solid waste disposal, electricity, telephone, etc.

Minimum affordability is then compared with minimum tariff required to cover full operation cost. A new tariff structure is then proposed.

Under the current Law, all households/properties are required to build a septic tank/onsite system. After the Law is amended and septic tanks became unnecessary in the new urban areas, operation and maintenance cost of a septic tank/onsite system might be sifted to wastewater tariff.

Proposed wastewater tariff in Bangkok is low level compared with Asian cities and wastewater tariff accounts for only 20% of water tariff; as shown in Figure 4.2.13.

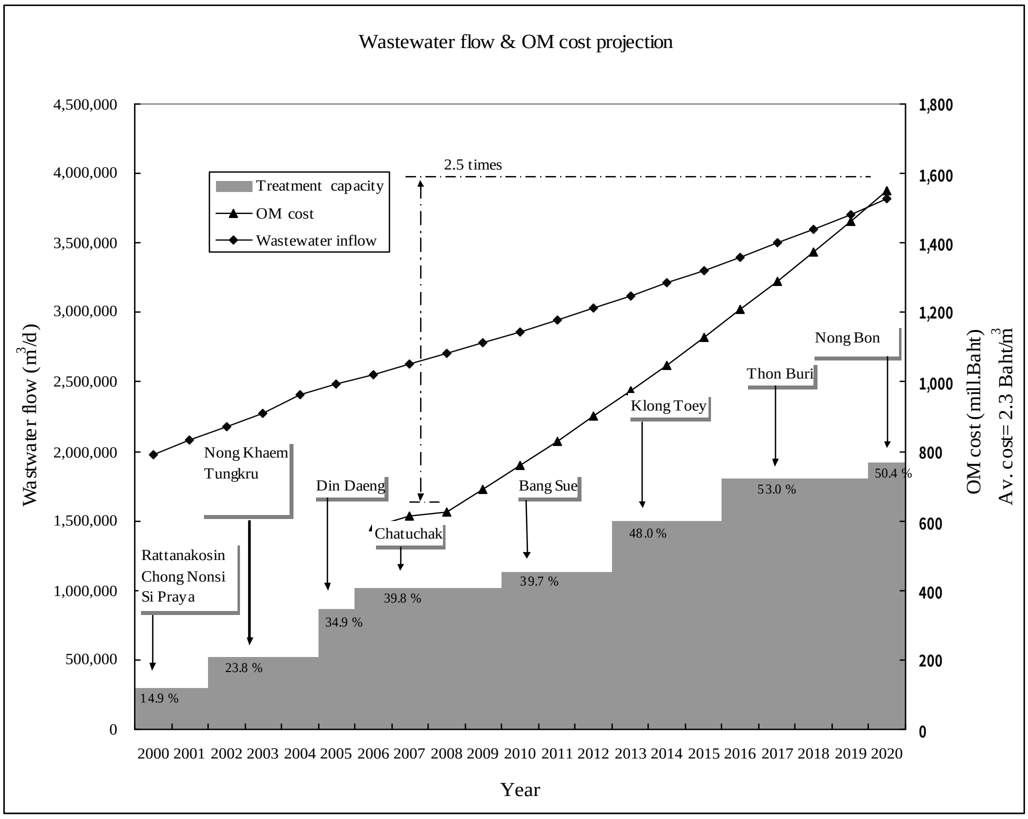


Source: JST

Figure 4.2.13 Water and Wastewater Tariff in Asian City

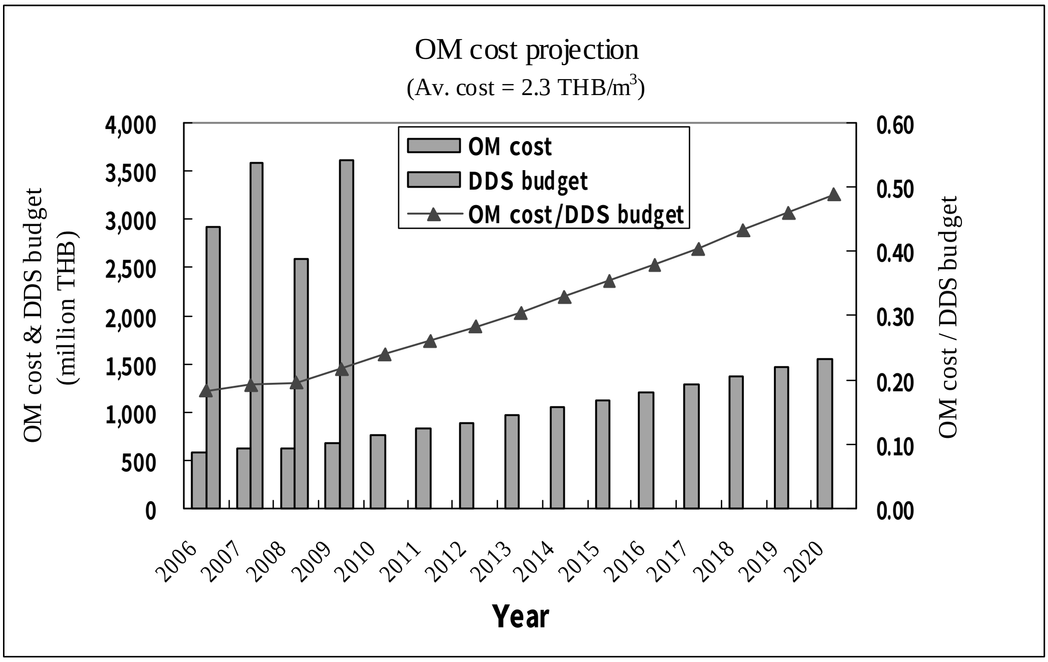
(3) O&M Cost Projection

A trial calculation of future operation and maintenance cost was performed by using the current cost and results of WWTP developing plan and maintenance plan. This trial shows that operation and maintenance cost increase with the increase of treated wastewater flow of WWTPs, as shown in Figure 4.2.14. Operation and maintenance cost in the past four years accounted for approximately 20% of DDS Budget (Figure 4.2.15). It is expected to increase up to 50% according to increase of treated wastewater flow as Bag Sue, Klong Toei, Thon Buri and Nong Bon WWTPs will start operation.



Source: JST

Figure 4.2.14　Increase of O&M Cost in Developing WWTPs（Trial）



Source: JST

Figure 4.2.15　Comparison between O&M Cost and DDS Budget

(4) Water Tariff

Water tariff system of MWA is progressive commodity charge system and divided into two groups of Residential and Non-residential, as shown in Table 4.2.10. The tariff system is considered for average family and small enterprise. Higher water tariff by approximately 30 % is applied to Non-residential use. In addition, it is decided that wastewater tariff collection is to be consigned to MWA (Metropolitan Water Authority) .

Table 4.2.11 Water Tariff

Residence		Business, State Enterprise, Government Agency and Industrial	
Volume(m^3)	Baht/m^3	Volume(m^3)	Baht/m^3
0-30	8.50	0-10	9.50
Not less than 45.00 Baht		Not less than 90.00 Baht	
31-40	10.03	11-20	10.70
41-50	10.35	21-30	10.95
51-60	10.68	31-40	13.21
61-70	11.00	41-50	13.54
71-80	11.33	51-60	13.86
81-90	12.50	61-80	14.19
91-100	12.82	81-100	14.51
101-120	13.15	101-120	14.84
121-160	13.47	121-160	15.16
161-200	13.80	161-200	15.49
Over 200	14.45	Over 200	15.81

Source: JST

(5) 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.

As new construction and renewal/rehabilitation of WWTP will proceed simultaneously, the investment cost will increase. It is necessary to predict the sewerage construction cost in mid- and long-term, as shown in Table 4.2.12

Table 4.2.12 Prediction of Construction and Renewal by WWTP

WWTP (Start Operation Year)	1990	2000	2010	2020	2030	2040
Si Praya (1994)	★		☆		☆	
Rattanakosin (2000)		★		☆		☆
Chong Nonsi (2000)		★		☆		☆
Nong Khaem (2002)		★		☆		☆
Tung Khru (2002)		★		☆		☆
Din Daeng (2004)		★		☆		☆
Chatuchak (2006)		★		☆		☆
Bang Sue			★		☆	
Klong Toei			★		☆	
Thon Buri			★		☆	
Nong Bon			★		☆	

★ Start operation ☆ Renewal of facilities

Source: JST

(6) 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.

International Water Association (IWA) developed PIs for water supply services and published "Performance Indicator for Water Supply Services" in 2000, and wastewater services namely "Performance Indicator for Wastewater Services" in 2003, respectively. International Organization for Standardization (ISO) developed international standards regarding activities related to drinking water and wastewater services and published "Guidelines for the Assessment and for the Improvement of the Service to Users: ISO 24510", "Guidelines for the Management of Wastewater Utilities and for the Assessment of Wastewater Services: ISO 24511" and "Guidelines for the Management of Drinking Water Utilities and for the Assessment of Drinking Water Services: ISO 24512" in 2007. ISO24500s are guidelines for evaluation of entire wastewater services, and their aim is to enhance the efficiency of undertakings and services. PIs used for evaluation are key factors.

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.

In Japanese national guideline namely “Guideline for Improving O&M of Wastewater Systems”, 2007 Japan Sewage Works Association, PIs are composed of Context Information (CI) for undertaking, system and district, Performance Indicators (PI) for operation, users, services, management and environment and References. CIs and PIs of the Japanese guideline are shown in Table 4.2.13.

Table 4.2.13 CIs and PIs of Japanese Guideline

Context Information (CI)

Context information means background information of a district about legal framework, geological conditions, population, and capacity of facilities, conditions for operation and maintenance, and environment. CIs are composed of 25 items and categorized as follows.

(i) Characteristics of an undertaking

9 items (name of undertaking, application of local public entity law, name of project, scale of project, number of employee, etc.)

(ii) Characteristics of a project

12 items (population in administrative district, served population, population density, service ratio, etc.)

(iii) Characteristics of a district

4 items (annual rainfall, average temperature, future population (100 in 2000), classification of receiving water body, etc.)

Performance Indicators (PI)

Performance indicator means indicator to evaluate quantitatively results and levels of operation and maintenance service. PIs are composed of 56 items, and categorized as follows.

Category	Performance Indictor (PI)	Calculation Formula	Improvement
1. Operation (sewers) (7 items)			
Op10	Ratio of age of facility (sewer)	Total length of sewers exceeding life time / Total length of sewers maintained × 100	↓
Op20	Ratio of inspected sewer	Total length of inspected sewers / Total length of sewers maintained × 100	↑
Op30	Ratio of repaired sewer	Total length of repaired sewers / Total length of sewers maintained × 100	↑
Op40	Ratio of inspected house connection	Number of inspected house connection / Total number of house connection × 100	↑
Op50	Number of repaired house connection (per 100,000))	Number of repaired house connection / Total number of house connection × 100,000	↑
Op60	Number of collapse per 1 km of sewer	Number of collapse / Total length of sewers maintained	↓
Op70	Maintenance cost per 1 m of sewer	Maintenance cost for sewers / Total length of sewers	↓
2. Operation (wastewater treatment) (12 items)			
Ot10	Ratio of age of main equipment	Total age of main equipment / Total average life time of main equipment × 100	↓
Ot20	Ratio of marginal wastewater treatment capacity	(1- Daily maximum DWF / Design capacity for DWF) × 100	↑

Category	Performance Indictor (PI)	Calculation Formula	Improvement
Ot30	Ratio of emergency power source security	Number of WWTPs with emergency power source / Total number of WWTPs × 100	↑
Ot40	Ratio of earthquake-resistant facilities	Number of earthquake-resistant buildings / Number of buildings to be earthquake- resistance × 100	↑
Ot50	Compliance with discharge standard (BOD)	Number of tests complied with standard (BOD) / Total number of tests (BOD) × 100	↑
Ot60	Compliance with standard (COD)	Number of tests complied with standard (COD) / Total number of tests (COD) × 100	↑
Ot70	Compliance with standard (SS)	Number of tests complied with standard (SS) / Total number of tests (SS) × 100	↑
Ot80	Compliance with standard (T-N)	Number of tests complied with standard (T-N) / Total number of tests (T-N) × 100	↑
Ot90	Compliance with standard (T-P)	Number of tests complied with standard (T-P) / Total number of tests (T-P) × 100	↑
Ot100	Compliance with standard of odor	Number of tests complied with standard of ordor / Total number of tests of odor × 100	↑
Ot110	Unit power consumption (wastewater treatment)	Power consumed (wastewater treatment) / Total wastewater treated	↓
Ot120	Unit disinfection chemical usage	Annual consumption of chemical / Total wastewater treated	↓
3. User Service (17 items)			
U10	Provision of storm water drainage	Area with storm water drainage / Total planning area × 100	↑
U20	Compliance with legal water quality standard for water body (BOD)	Number of samples complied with legal standard (BOD) / Total number of legal tests (BOD) × 100	↑
U30	Compliance with legal water quality standard for water body (COD)	Number of samples complied with legal standard (COD) / Total number of legal tests (COD) × 100	↑
U40	Compliance with legal water quality standard for water body (SS)	Number of samples complied with legal standard (SS) / Total number of legal tests (SS) 100	↑
U50	Compliance with legal water quality standard for water body (T-N)	Number of samples complied with legal standard (T-N) / Total number of legal tests (T-N) × 100	↑
U60	Compliance with legal water quality standard for water body (T-P)	Number of samples complied with legal standard (T-P) / Total number of legal tests (T-P) × 100	↑
U70	Compliance with legal water quality standard for water body (E-coli)	Number of samples complied with legal standard (E-coli) / Total number of legal tests (E-coli) × 100	↑
U80	Sewer Blockages (per 100,000 persons)	Number of sewer blockages / Served population × 100,000	↓
U90	Third party accidents (per 100,000 persons)	Number of third party accidents / Served population × 100,000	↓
U100	Complaints (per 100,000 persons)	Number of complaints / Served population × 100,000	↓
U110	Response to complaints	Number of complaints responded within one week / Total number of complaints × 100	↑
U120	Service charge (residential)	According to local government	—
U130	Unit operating cost per person (O&M)	Operating cost (O&M) / Served population	↓

Category	Performance Indictor (PI)	Calculation Formula	Improvement
U140	Unit capital cost (capital)	Capital cost (wastewater) / Served population	↓
U150	Unit cost (O&M + capital)	Cost (wastewater) / Served population	↓
U160	Unit revenue per staff	Revenue / Number of staff	↑
U170	Unit revenue water per staff	Annual volume of revenue water / Number of staff	↑
4. Management (13 items)			
M10	Unit revenue water per person per day	(Annual revenue water / number of days) / Served population	↑
M20	Accounted-for water	Annual accounted-for water / Total treated wastewater × 100	↑
M30	Current balance	Gross earning / Total cost × 100	↑
M40	Transfer ratio (profitable earning)	Transfer / Profitable earning × 100	↓
M50	Transfer ratio (capital earning)	Transfer / Capital earning × 100	↓
M60	Unit revenue	Total revenue / Total accounted-for water	↑
M70	Unit wastewater treatment cost	Wastewater treatment cost / Total accounted-for water	↓
M80	Unit wastewater treatment cost (O&M)	Wastewater treatment cost (O&M) / Total accounted-for water	↓
M90	Unit wastewater treatment cost (capital)	Wastewater treatment cost (capital) / Total accounted-for water	↓
M100	Cost covering ratio	Service charge revenue / Wastewater treatment cost × 100	↑
M110	Cost covering ratio (O&M)	Service charge revenue / Wastewater treatment cost (O&M) × 100	↑
M120	Cost covering ratio (capital cost)	Service charge revenue / Wastewater treatment cost (capital) × 100	↑
M130	Working accidents (per 1 million m^3 treated wastewater)	Number of accidents which caused 4 days of absence or more / Total wastewater treated × 1,000,000	↓
5. Environment (7 items)			
E10	Pollutant reduction ration in dry weather (BOD)	(1 - Effluent BOD / Inflow BOD) × 100	↑
E20	Wastewater reuse	Wastewater reused / Total wastewater treated by advanced treatment × 100	↑
E30	Sludge recycle ratio	Sludge recycled / Total sludge generated × 100	↑
E40	GHG emission per person	GHG emission by sewerage service in terms of CO_2 / Served population	↓
E50	Compliance with standard for discharge to sewerage	Number of compliance with standard / Total number of samples × 100	↑
E60	Service ratio of advanced treatment for environmental standard	Population served by advanced treatment / Served population × 100	↑
E70	Improvement of combined system	Area for which combined system was improved (ha) / Total area of combined system (ha) × 100	↑

"References"

References mean indicators which are utilized for determination of higher policy or measure such as fulfillment of environmental policy, and enhancement of accountability and understanding of customers. References are composed with 34 items and categorized as follows.

(i) Indicators for management analysis

8 items (Annual facility improvement ratio, total cost coverage ratio, average depreciation ratio, etc. indicators

required when local public entity act is applied)
(ii) Indicators for high degree analysis
12 items (Rehabilitation of aged sewers, ratio of earthquake resistant sewers, cost for countermeasures against flooding, etc. indicators for enhancement of various users understanding)
(iii) Other indicators
14 items (energy cost, qualification holding ratio, repair cost for wastewater treatment plant, etc. indicators for more detailed management analysis)

Source: Guideline for improving O&M of wastewater systems Japan Sewage Works Association

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.

Land Development Act, 2000 is applied to housing development with more than 10 units in Thailand. Provision of storm water drainage and wastewater treatment is required by the Act. Developer should discuss with DDS at planning stage. Building Control Act, 2004 require Building Approval for development project, and one of the requirements is provision of sewerage system. District Office of PWD guides developer for wastewater treatment facilities depending on type of building. A hearing with DDS reveals, they also guide developer regarding connection to public sewerage system based on location and scale of building and capacity of sewer pipes.

(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

Management and institutional issues are described in Section 3.6.2. Countermeasures to resolve these issues are presented below.

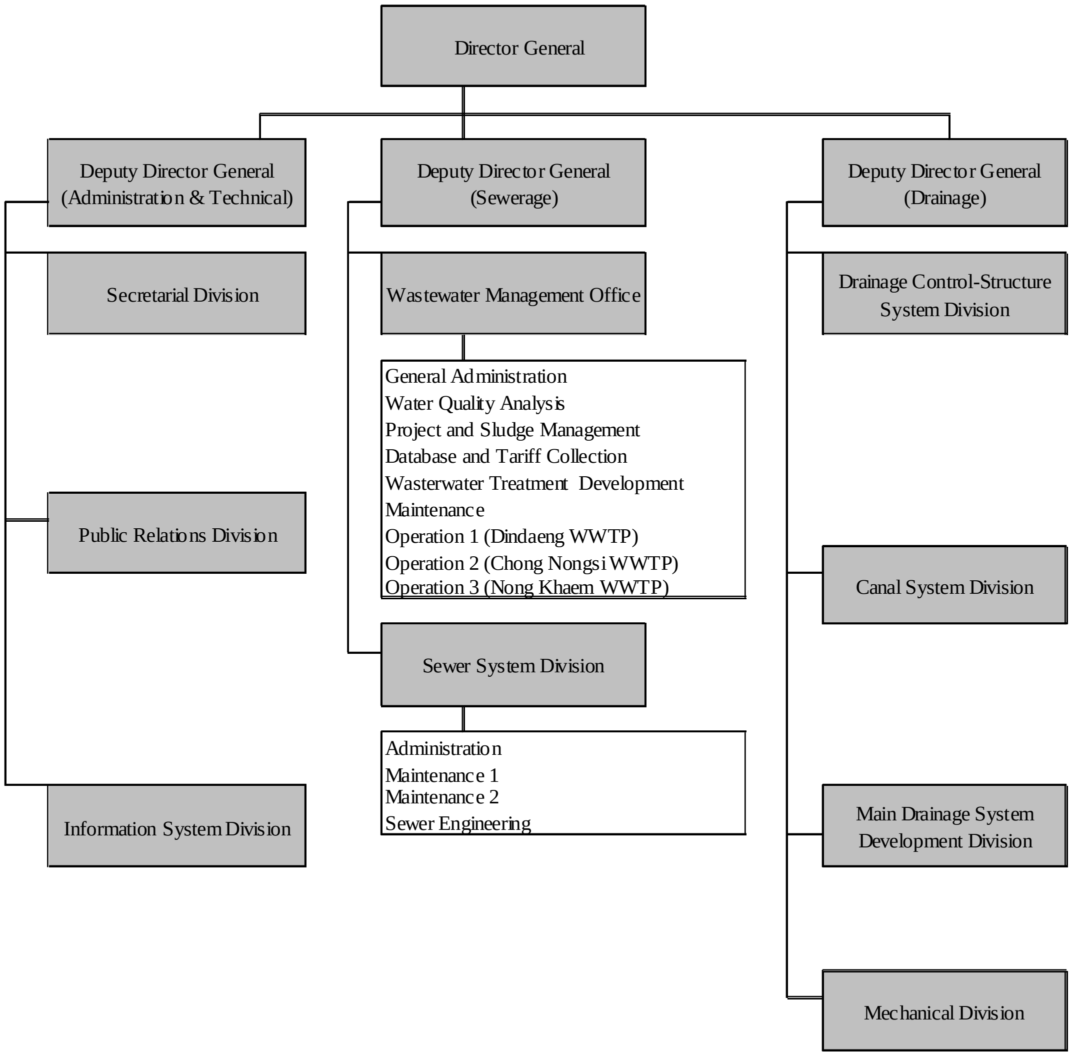
(1) Bringing of Fragmented Responsibilities of Sewerage Services into One Agency

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 4.2.16 Proposed Organogram of DDS

(2) Onsite Treatment Standard

The standards for the onsite treatment should be relaxed within the treatment area to reduce the burden on the users and also to improve the WWTP treatment efficiency. For example, currently, the effluent standard for a commercial complex is stricter than residential household. Since there will be WWTP, this extra costly onsite treatment will not give any benefit to the WWTP operation. New such standard should be prepared and supported by legal endorsements.

(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. Si Praya and Rattanakosin treatment schemes are operated and maintained by DDS own staff. To increase the functional efficieny, 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. It is also recommended to continue using the management contractor for WWTP operation and review the possibility to bring the other 2 also under similar system in the future, though there is a merit of operation and maintenance by DDS own staff in the meantime.

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. Another example could be if electric cost is paid at cost, there would be no incentive for energy saving. Similarly, if sludge treatment is paid at cost, there would be no incentive to reduce sludge. In future, other forms of PPP should be investigated and implemented. Various forms of PPP are shown in Table 4.2.14 below.

Table 4.2.14 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

Conceivable PPP forms for BMA sewerage service as shown in Table 4.2.15.

Table 4.2.15 Potential PPP for BMA Sewerage Service

Service	PPP type	Applicability	Benefit
WWTP	Service contract: Specific tasks like monitoring, repair, pumping station	High	Low
WWTP	Management Contract: Operation and maintenance	High	Medium
WWTP	Lease Agreement: Operation and maintenance	High	High
WWTP	PFI: Investment for new plant	High	Medium
WWTP	BOT: Investment and operation	High	High
Sewer and Pumping Stations	PFI: Investment for new facilities	Medium	Medium
Sewer Cleaning	Service Contract	High	High
Septage Collection	Service Contract	Medium	High
Meter Reading	Service Contract	High	High
Tariff Collection	Management Contract	High	Medium

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.

Clauses and terms of contract are very crucial from the utility aspect. For example, a management contract should be made in a way so that contractor would be more innovative to reduce the sludge volume or reduce the energy consumption.

A pilot scale septage collection by private company once adopted in Klong Toei district, however that was failed due to higher service charge and lack of public confidence. Main reason of failure was that it was a concession agreement. Because of high service charge, such agreement cannot work. Service contract or management contract should be used for septage collection.

(4) Public Participations and Awareness

Currently, all major projects of BMA are required by law to hold public hearings as well as chance for public participation, so that objectives and details can meet people’s necessity. These are usually carried out by opening of project facilities to the public, public discloser meeting, website, brochures, videos, etc. However, there is currently no mechanism for public participation in operation stage. There should be both ‘pull’ and ‘push’ methods. In ‘pull’ mechanism, WQMO should have avenues to collect public opinion like, opinion box, mail, email, SMS, fax, website, etc. Opinion box should be placed in the district offices also. In the ‘push’ option, WQMO should arrange periodic events to draw public opinion. This can be done by open house, exhibition, community meeting, etc.

For awareness building and public relations campaign, WQMO arranges periodic lecture sessions through the Database and Tariff Collection Section. They provide this service to 20 secondary schools each year covering water pollution problem, preserving water resources, and wastewater reuse.

(5) Staff and Human Resources Development

In case of water utilities, low-to-mid single digit numbers per 1,000 connections are generally considered ideal. Although such a rule of thumb does not apply to sewerage, experiences say the number of staff of a sewerage/drainage sector tends to be similar to or slightly smaller than that of the water sector in the same place. In 2009, MWA has 2.13 staff per 1,000 connections. Thus, it is proposed that total staff number for sewerage service should not exceed 3 per 1,000 connections in short term and reduce to 2 in long term.

The O&M works are quite important for the proper functioning of the treatment equipments and machinery. Therefore, competent O&M staffs are required for project sustainability. Although adequate staff number is very important requirement to carry out the stipulated job responsibilities, proper training is also equally important to ensure efficient work execution. In fact, two types of human resources should be developed, officials at the managerial level in charge of policy, planning, designing, management information system, tariff, customer service and asset management, and core members of operating staffs carrying out operation, maintenance, monitoring, etc.

The human resources development program can be implemented through the following steps:

- To decide the necessity of the human resources development through the analysis of the problems affecting the organization.
- To decide the goal of the human resources development from the perspective of the entire organization.
- To select the suitable method like on the job training, workshop, etc.
- To select the method of communication depending on requirements.
- To implement the human resources development program, and
- To make appraisal to evaluate the effectiveness of the program.

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.

Example of sewerage ordinance is shown bellow;

Article 1: The jurisdiction matter of the sewerage ordinance
Article 2: The definition of the words and terms
Article 3: Connection method to sewer, setting of public inlet, sewer capacity/shape
Article 4: Notification of house connection setting; notification of pretreatment facility setting and the structure/usage
Article 5: Technical criteria of house connection; instructions for setting and structure modification of house connection
Article 6: Notification about the succession of proprietary rights of pretreatment facility
Article 7: Authorization, registration, duty/reporting of house connection enterprise, and an examination organization
Article 8: Exclusion of excreta
Article 9: Discharge criteria to public sewer system from industries
Article 10: Improvement order of pretreatment facility
Article 11: Notification about the change of user (tariff collection)
Article 12: Sewerage tariff system, tariff calculation and the collection
Article 13: Calculation of sewage discharge based on water supply and well use
Article 14: Tariff collection method and reduction of the tariff
Article 15: Collection of construction and connection charge
Article 16: Permission for usage of sewerage facility
Article 17: Fees for application
Article 18: Penal regulations