BANGKOK METROPOLITAN
ADMINISTRATION (BMA)

PREPARATORY SURVEY FOR BANGKOK WASTEWATER TREATMENT PROJECT IN THAILAND

FINAL REPORT (II)
FEASIBILITY STUDY
VOL. 2 MAIN REPORT

JULY 2011

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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

SAP
JR
11-021

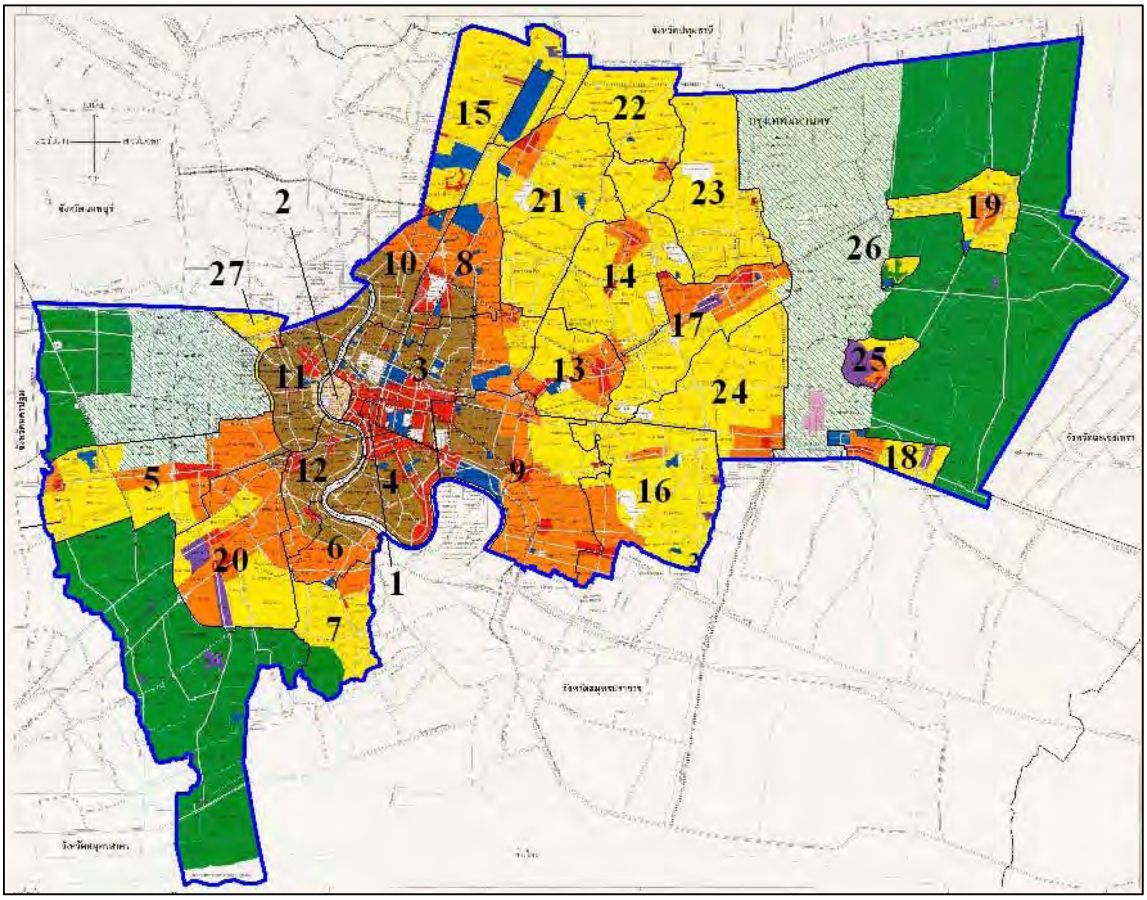
as of October 1, 2010

1 Baht = 0.0330 US dollar

1 Baht = 2.76 yen

Area, Served Population and Design Wastewater Flow in 2040

No.	Treatment Area	Area	Served Population	Design Wastewater Flow	No.	Treatment Area	Area	Served Population	Design Wastewater Flow
		(ha)	(person)	(m^3/day)			(ha)	(person)	(m^3/day)
1	Si Praya	226	57,495	30,107	15	Don Mueang	4,941	383,983	154,822
2	Rattanakosin	367	49,480	28,608	16	Nong Bon	6,385	264,883	133,501
3	Din Daeng	5,931	689,699	357,260	17	Min Buri	4,165	274,182	138,188
4	Chong Nonsi	2,872	372,960	202,332	18	Lat Krabang-1	1,258	59,502	29,989
5	Nong Khaem	6,239	590,483	232,450	19	Nong Chok-1	2,109	208,634	96,199
6	Thung Khru North	1,513	128,637	53,875	20	Jomthong	5,816	453,938	221,578
7	Thung Khru South	2,934	127,396	60,532	21	Lat Phrao	6,206	475,384	191,675
8	Chatuchak	3,645	239,653	139,980	22	Sai Mai	2,958	158,188	63,781
9	KhlongToei	7,309	579,670	323,508	23	KhlongSam Wa	5,015	310,738	156,612
10	Bang Sue	2,095	229,063	103,413	24	Lat Krabang-2	4,959	211,457	106,575
11	Thon Buri North	2,922	359,542	158,655	25	Lat Krabang-3	988	28,129	14,178
12	Thon Buri South	2,087	333,707	141,005	26	Nong Chok-2	309	20,908	10,538
13	Wangthonlang	2,872	246,098	117,315	27	Taling Chan	759	149,866	50,751
14	Bunkhum	5,639	340,430	137,262	Total Treatment Area		92,519	7,344,105	3,454,689
					Outside		62,939	281,895	113,660
					Total BMA		155,458	7,626,000	3,568,349



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Abbreviations

AIDS	Acquired Immune Deficiency Syndrome
ASRT	Aerobic Solids Retention Time
ATP	Affordability to Pay
B/C	Benefit Cost RAtio
BMA	Bangkok Metropolitan Administration
BMR	Bangkok Metropolitan Region
BOD	Biochemical Oxygen Demand
BOT	Build, Operate, and Transfer
CAASP	Carrier Added Activated Sludge Process
CF	Conversion Factor
COD	Chemical Oxygen Demand
C/P	Counterpart
CPI	Consumer Price Index
CSO	Combined Sewage Overflow
CVM	Contingent Valuation Method
DANIDA	Danish International Development Agency
DDS	Department of Drainage and Sewerage, BMA
DEQP	Department of Environmental Quality Promotion
DF/R	Draft Final Report
DO	Dissolved Oxygen
D.R.	Discount Rate
DS	Dry Solids
DWF	Dry Weather Flow
EAP	Extended Aeration Process
EIA	Environmental Impact Assessment
EIRR	Economic Internal Ratio of Return
F.C.	Foreign Currency
FIRR	Financial Internal Ratio of Return
F/R	Final Report
F/S	Feasibility Study
HIV	Human Immunodeficiency Virus
HRT	Hydraulic Retention Time
IBRD	The International Bank for Reconstruction and Development
IC/R	Inception Report
IDRC	International Development Research Center, Canada
IEE	Initial Environmental Examination
IT/R	Interim Report
ISO	International Organization for Standardization
JICA	Japan International Cooperation Agency

JST	JICA Survey Team
L.C.	Local Currency
L/A	Loan Agreement
MBR	Membrane Bioreactor
MLSS	Mixed Liquor Suspended Solids
MOF	Ministry of Finance
MOI	Ministry of Interior
MOIn	Ministry of Industry
MONRE	Ministry of Natural Resources and Environment
M/P	Master Plan
MWA	Metropolitan Water Works Authority
NEB	National Environment Board, MONRE
NESDB	National Economic and Social Development Board
NEQA	National Environmental Quality Act, 1992
NHA	National Housing Authority
NPV	Net Present Value
OASP	Oxygen Activated Sludge Process
OD	Oxidation Ditch Process
ODA	Official Development Aid
ONEB	Office of the National Environmental Board
ONEP	Office of Natural Resources and Environmental Policy and Planning
O&M	Operation and Maintenance
PAHO	Pan American Health Organization
PCD	Pollution Control Department, MONRE
PI	Performance Indicator
PLC	Programmable Logic Controller
PPP	Polluter Pays Principal
PPP	Public Private Partnership
PSMS	Project and Sludge Management Section, DDS
PWD	Public Works Department, BMA
RFP	Request for Proposal
RNDP	Recycled Nitrification Denitrification Process
SBR	Sequencing Batch Reactor
SCADA	Supervisory Control and Data Acquisition System
SRT	Solids Retention Time
SS	Suspended Solids
SVI	Sludge Volume Index
TDA	Trade and Development Agency, USA
T-N	Total Nitrogen
T-P	Total Phosphorus
TSP	Total Suspended Particles

WG	Working Group
WQMO	Water Quality Management Office
WTP	Willingness to Pay
WWTP	Wastewater Treatment Plant

1. WORK SCHEDULE AND IMPLEMENTATION OF PHASE 2 WORK

1.1 Work Schedule for the Entire Survey and Objectives of Phase 2 Work

The Preparatory Survey for Bangkok Wastewater Treatment Project was conducted dividing the whole period (approx. 15 months) into two phases, i.e. phase 1 (6 months) and phase 2 (9 months). The Survey flowchart is as shown in Figure 1.1.1.

The objective of the phase 2 work is feasibility study for the priority project selected under phase 1 work. The phase 2 work was carried out from September, 2010 to April, 2011.

"Interim Report (I)" in Figure 2.1.1 was changed to "Final Report (I)", "Final Report" was changed to "Final Report (II)". Date of EIA Stakeholder Meeting (I) was changed from November 2010 to February 2011, and Report Meeting (2) was cancelled.

1.2 Project Area of the Phase 2 Work

Phase 2 work was carried out for Nong Bon treatment area in BMA.

1.3 Implementing Organizations in Thailand

The implementing organization for the Survey is the Department of Drainage and Sewerage (hereafter refer to as "DDS") of BMA. Water Quality Management Office of DDS is the counterpart organization for the Survey.

1.4 Basic Policies for the Survey

The Survey work was conducted based on the basic policies described in Inception Report (2).

1.5 Survey Organization

The Steering Committee established by BMA and chaired by Deputy Permanent Secretary continued to monitor the progress and give suggestions in succession of phase 1 work. A group of twelve (12) persons designated from Water Quality Management Office of DDS supported JICA Survey Team following the phase 1 work. Consultant Survey Team is composed of 4 persons from Tokyo Engineering Consultants Co., Ltd., and 3 persons from Nippon Koei Co., Ltd. The Survey Team which carried out phase 1 work continued to carry out phase 2 work.

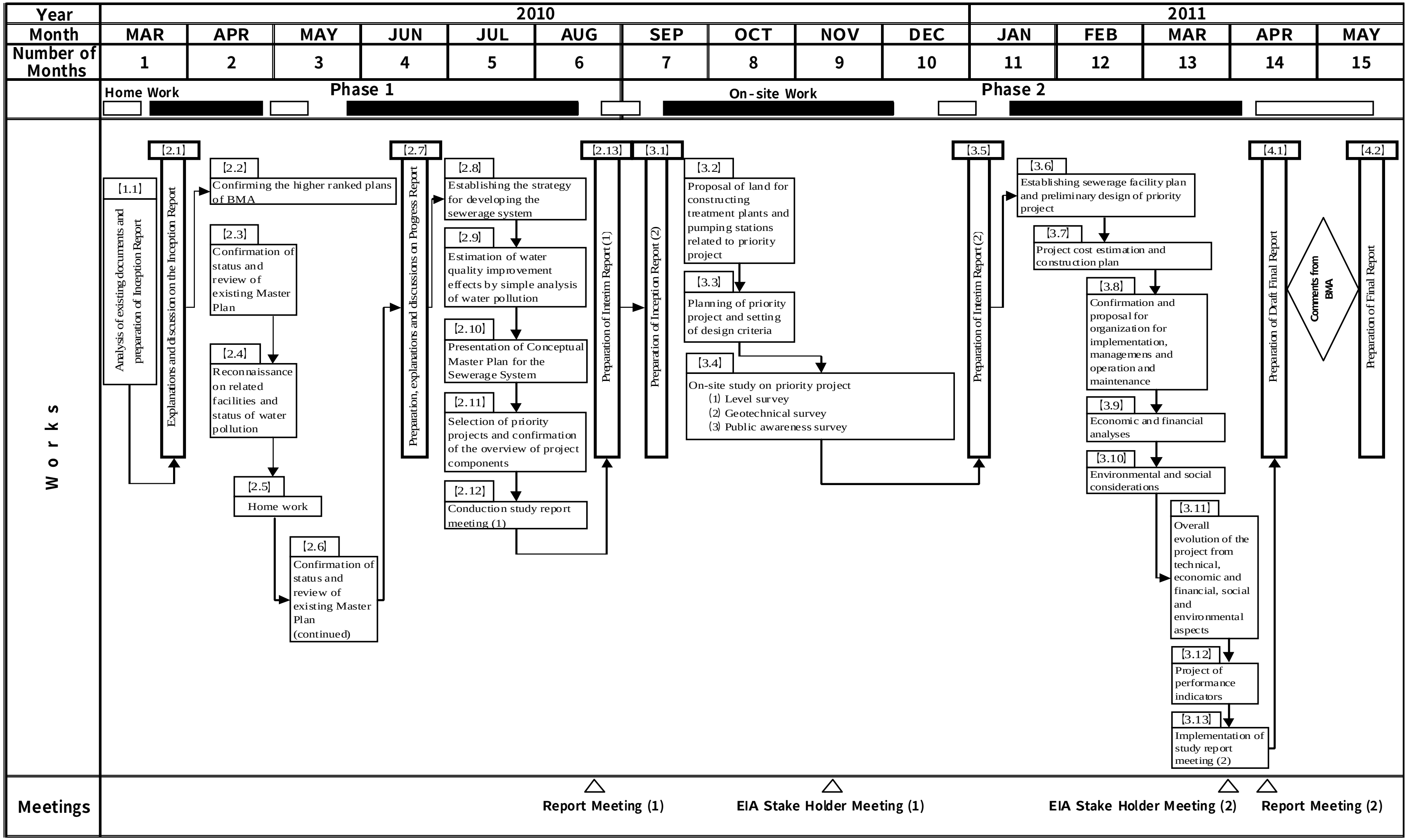


Figure 1.1.1 Flowchart of the Survey

1.6 Implementation of Phase 2 Work and Final Report

(1) Confirmation of Fundamental Items (Explanation and Discussion of IC/R)

IC/R(2) was prepared based on IC/R, since major modifications to the IC/R submitted at the beginning of the Survey are not considered to be necessary.

Kickoff meeting was held on 27th September with counterpart organization, i.e. DDS, and policy for the Survey, project area, Survey organization (deployment of counterpart personnel), policy for public awareness survey, policy for the stakeholder meetings and so on were confirmed (refer to the minutes of meeting in Appendix 1-1)

The second Steering Committee meeting was held on 30th September, and the consultant explained the study items of phase 2 work (refer to the minutes of the second Steering Committee in Appendix 1-4).

Request to Prawet District Office was made on 22nd October at the office for data collection about the existing drainage network, restrictions of city planning, and support to stakeholder meetings (refer to minutes of the meeting in Appendix 1-5).

(2) Implementation of Phase 2 Work

IT/R(2) was prepared based on the results of third on-site work. The fourth Working Group meeting was held on 26th January, 2011, and contents of the IT/R(2) were explained to DDS. Opinions and views on treatment process of Nong Bon WWTP, wastewater inflow, wastewater characteristics, and environmental and social considerations were exchanged at the meeting (refer to the minutes of the fourth Working Group meeting in Appendix 1-9).

The third Steering Committee was held on 31st January, and the contents of IT/R(2) were explained by the consultant. Views were exchanged on opinions from committee members on various matters, it was agreed that these opinions would be reflected in the Survey (refer to the minutes of the third Steering Committee Meeting in Appendix 1-10).

The fifth Working Group meeting was held on 30th March, and contents of the DF/R were explained. Views were exchanged on opinions from committee members, it was agreed that these opinions would be reflected in F/R (refer to the minutes of the fourth steering committee meeting in Appendix 1-16).

(3) Stakeholder Meetings

The first stakeholder meeting was held on 17th February to the representatives of the communities in Prawet District. Senior officers of DDS explained BMA policy for improvement of water environment, current status of sewerage projects in BMA and implementation of sewerage project for Nong Bon treatment area. A number of requests and questions were expressed from the participants. Comments and answers were presented courteously by senior officers of DDS. Intensive discussions were held at the meeting (refer to the minutes of the stakeholder meeting in Appendix 1-11).

The second stakeholder meeting was held on 29th March. Representatives of Suan Luang and Bang Na Districts were invited in addition to representatives of Prawet District (refer to the minutes of the second stakeholder meeting in Appendix 1-15).

(4) Final Report (II)

This Final Report (II) has been prepared to put together results of the phase 2 work, including F/S for Nong Bon treatment area.

2. OUTLINE OF NONG BON TREATMENT AREA

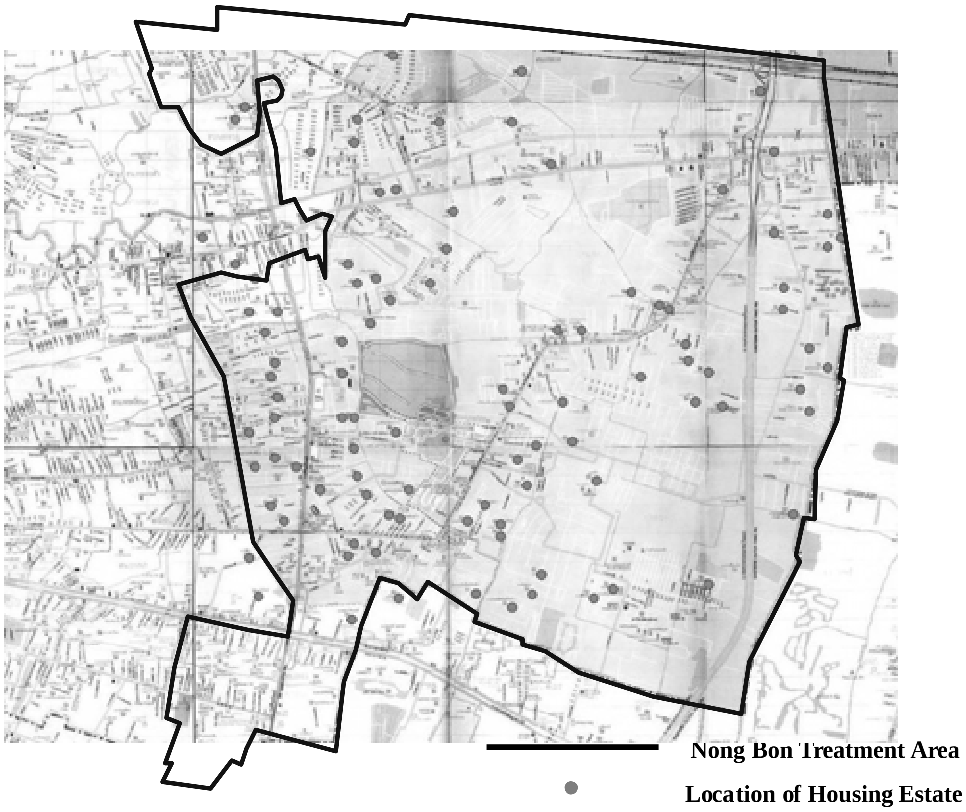
2.1 Present Condition of Nong Bon Treatment Area

2.1.1 Outline of the Treatment Area

Nong Bon treatment area is bordered with the motor way and airport link to the new airport and Pattaya on the north, with densely inhabited Klong Toei treatment area where sewerage system is to be developed on the west, and with Samut Prakan Province on the east and south.

In the city planning land use in Nong Bon treatment area is categorized as medium-density residential and commercial areas in south-western part and low-density residential areas in the remaining parts. Airport link has been put in operation in the northern part of the area, and an elevated railway is planned on the Srinakharin road in the western part. These two transportation systems are located in low-density residential areas. Population growth and development pressure are envisaged in future because the area is located in between developed urbanized area in the west (Klong Toei treatment area) and Suvarnabhumi airport in the east.

New housing developments have been progressed by private developers recently in Nong Bon treatment area, and many new housing estates are located as shown in Figure 2.1.1.

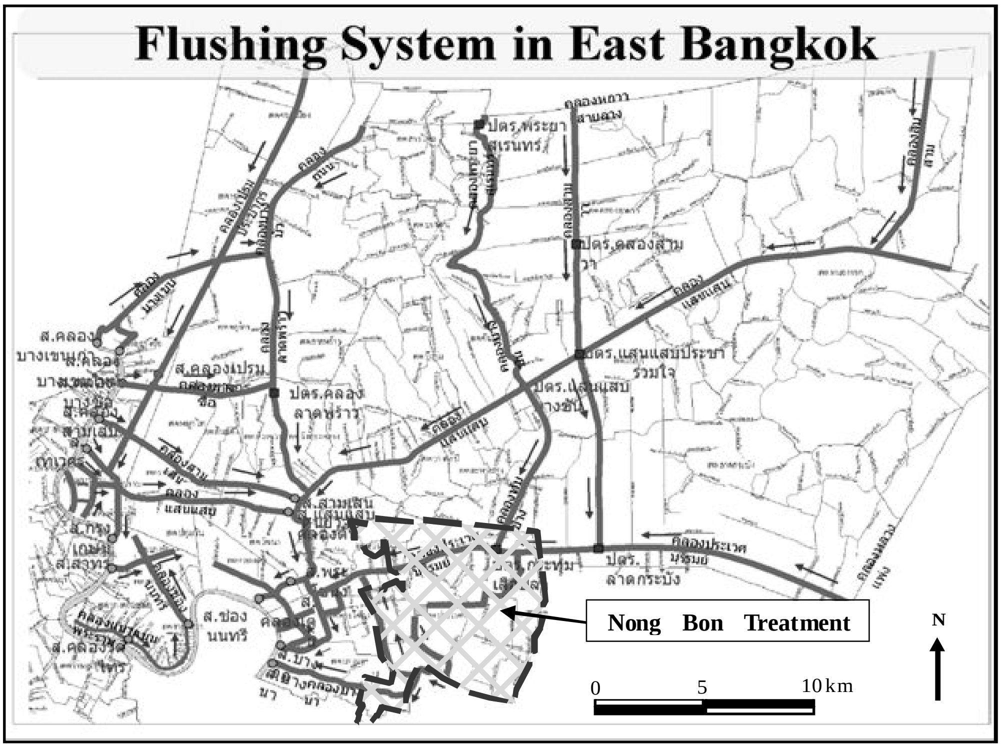


Source: JST

Figure 2.1.1 New Estate Developments in Nong Bon Treatment Area

2.1.2 Klong Network and Drainage Network

Klong network in the east Bangkok and flow directions of flushing conducted by DDS are shown in Figure 2.1.2. Major klongs which flow from northern and eastern suburbs through urban areas and to Chao Phraya River are shown in the figure. Among them, Klong Phra Khanon which run through northern part of Nong Bon treatment area plays important role in transportation, water environment and drainage. Flushing water is introduced from upstream of the klong and circulated in the treatment area, and again returned to the klong.



Source: JST

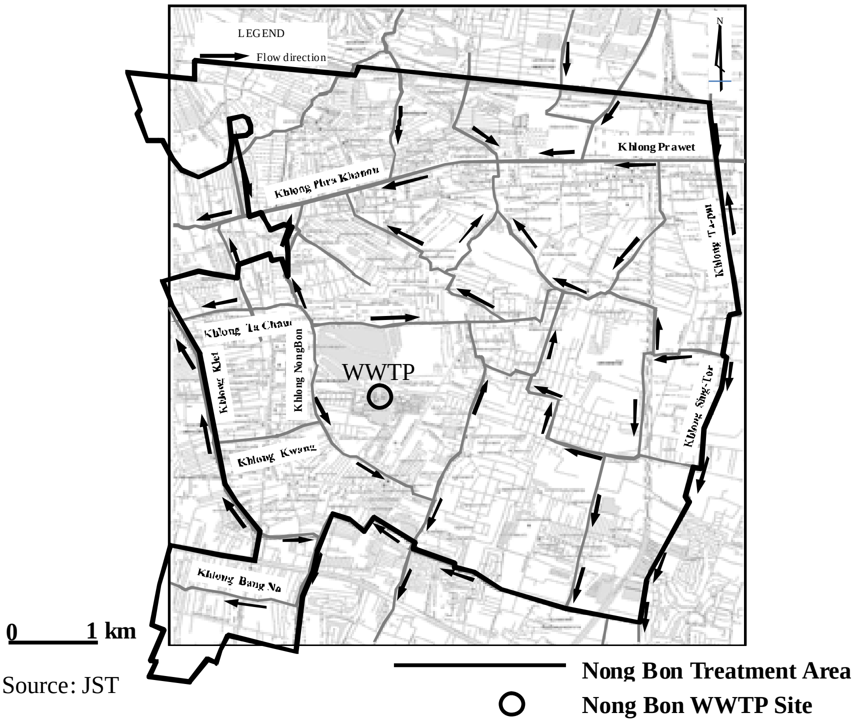
Figure 2.1.2 Klong Network and Flow Direction of Flashing in BMA

Klongs in the treatment area are rather small except for Klong Phara Khanon. These small klongs and their flow directions are shown in Figure 2.1.3. Gates are provided along Klong Phra Khanon to raise water level for flushing. Gates are also provided at important points and it can be understood from this that water levels are controlled.

Figure 2.1.4 shows the existing drain pipe networks in Nong Bon treatment area. Characteristics of the drain pipe networks are as follows.

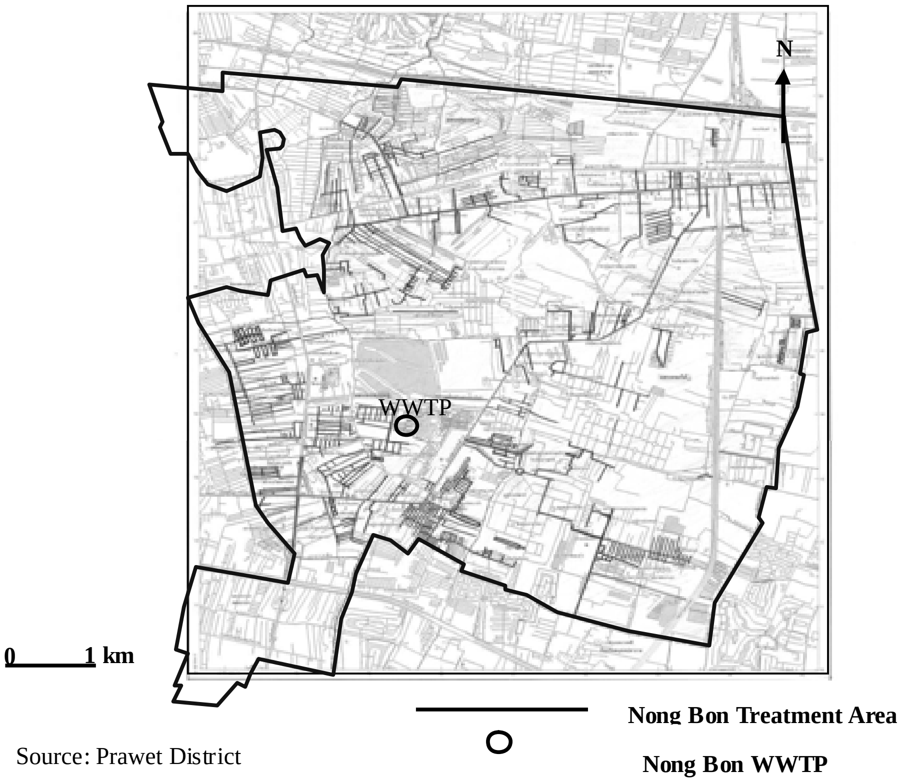
(1) Drainage pipes in lanes (soi) connect to larger diameter pipes installed under main roads

(2) Drainage pipes directly discharge into main klongs (those in south-western part of the area, to Klong Khlet).



Source: JST

Figure 2.1.3 Khlong Network and Flow Direction in Nong Bon Treatment Area



Source: Prawet District

Figure 2.1.4 Drain Pipe Network in Nong Bon Treatment Area (as of 2010)

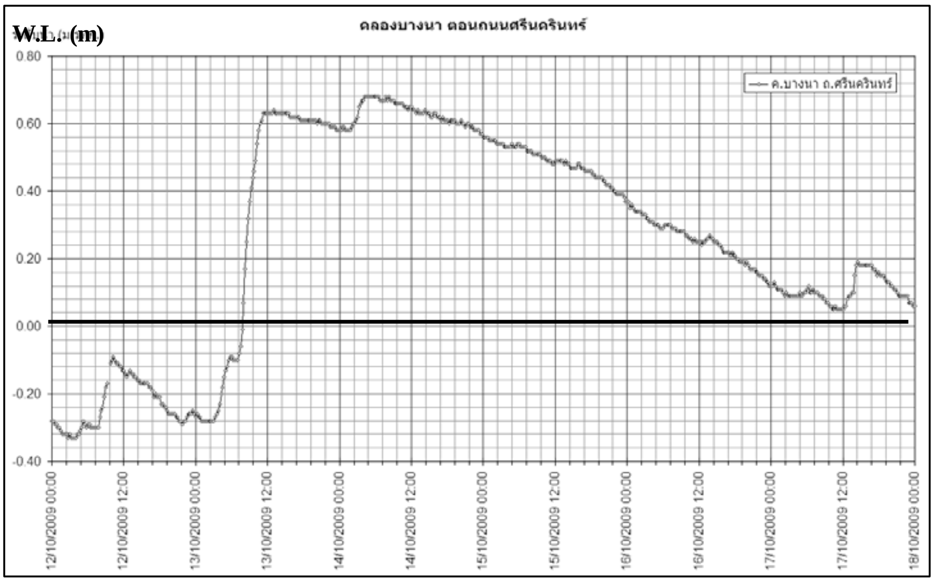
2.1.3 Flooding Condition and Storm Water Drainage Plan in Nong Bon Treatment Area

(1) Flooding Condition

Flood prone areas in BMA are shown in Figure 3.4.5 in Final Report (I). One of them is an area along Srinakharin road (between Klong Ta-chang and Klong Ta-sat, refer to Figure 2.1.6). Srinakharin road is an important main road running in north-south direction in the urbanized western part of the Nong Bon treatment area.

Recent flooding near Srinakharin road occurred on 13th and 14th October, 2009. Intensive rainfall was recorded from 7:00 to 12:00 on 13th and a total rainfall was 222.5 mm (continuously approximately 9 hours), (187.5 mm at Nong Bon storm water reservoir).

Water levels in the surrounding klong started to raise as rain started, and kept the high levels until 15th, and went down to usual level on 16th or 17th (refer to Figure 2.1.5).



Source: JST

Figure 2.1.5 Water Level of Klong Nong Bon in the Flood

Flooding situation and emergency countermeasures are shown in the following photos.

Photo 2.1.1 Flood along Srinakharin Road

Photo 2.1.2 Emergency Countermeasures (Mobile Pump and Sand Bags)

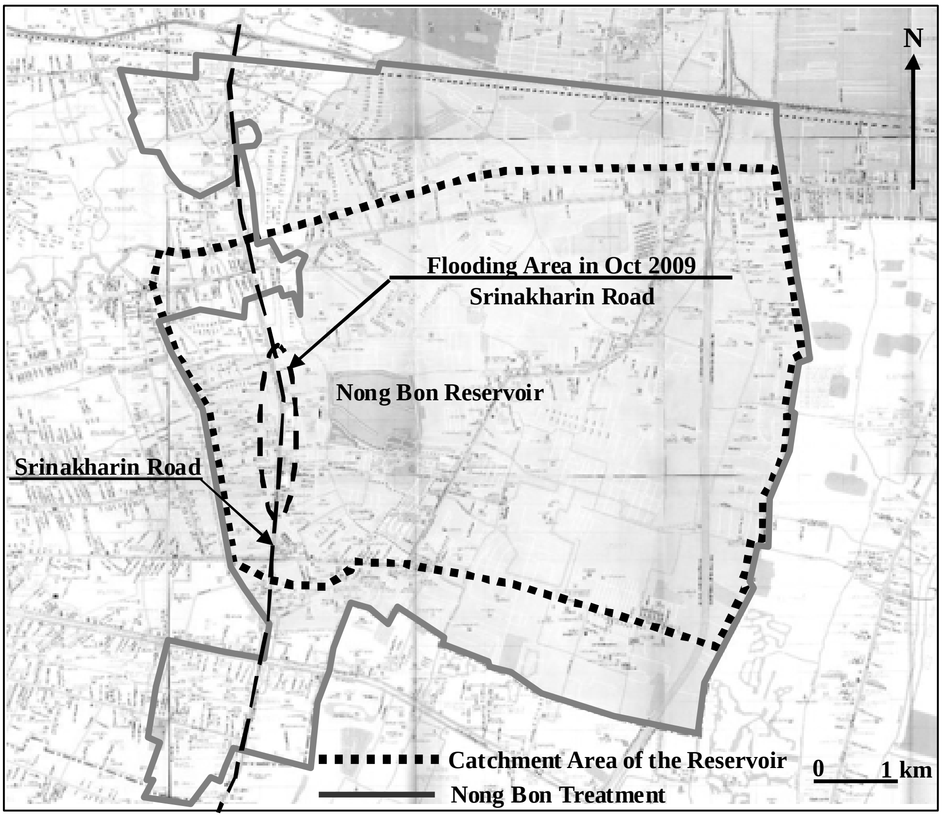
(2) Storm Water Drainage Plan

(A) Nong Bon Storm Water Reservoir

Catchment area of Nong Bon storm water reservoir and situation of the surrounding areas are shown in Figure 2.1.6 and Figure 2.1.7 respectively. Catchment area of the Nong Bon storm water reservoir is approximately 40 km^2 and forms a part of catchment area of deep tunnel which is described in the latter section. Almost all of Nong Bon treatment area is included in the catchment area of deep tunnel.

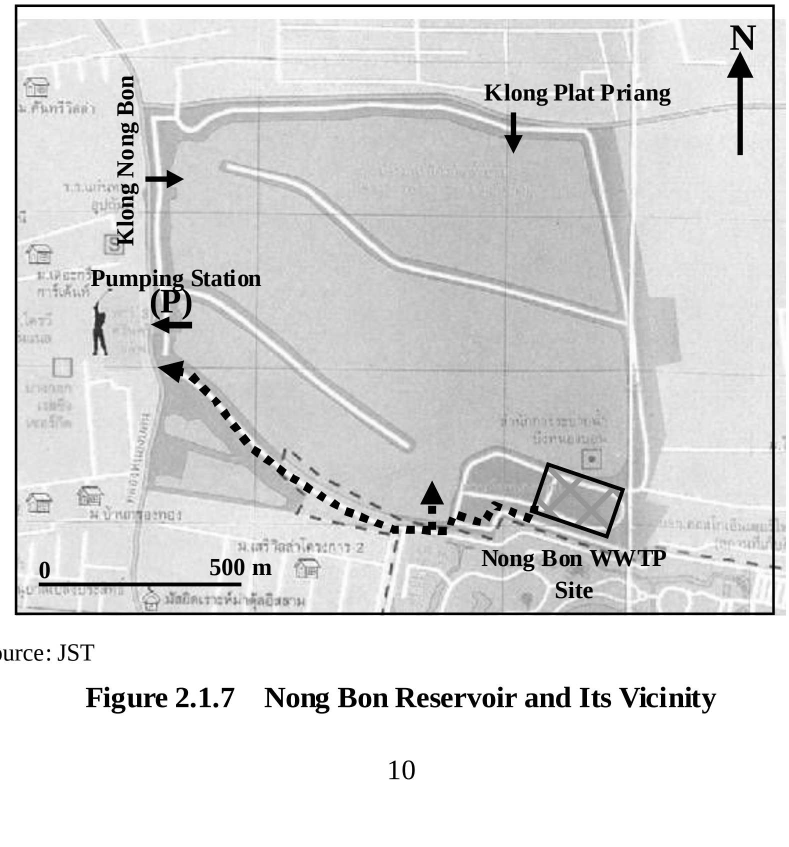
As shown in Figure 2.1.7, Nong Bon storm water reservoir receives water from Klong Nong Bon and Klong Plat Priang when water levels in these klongs raise to prevent flooding in the surrounding areas.

Water retained in the reservoir is pumped up to Klong Nong Bon by the existing pumping station (capacity 20 m^3/sec) when water level in Klong Nong Bon goes down. Water from the reservoir is also drained to the deep tunnel after completion of the tunnel to assure safety of the surrounding areas. Table 2.1.1 shows outline of Nong Bon storm water reservoir.



Source: JST

Figure 2.1.6 Catchment Area of Nong Bon Reservoir



Source: JST

Figure 2.1.7 Nong Bon Reservoir and Its Vicinity

Table 2.1.1 Outline of Nong Bon Storm Water Reservoir

		Remarks
Completion of reservoir	Year 1992	
Completion of pumping station	Year 1999	Partially completed in 1992
Catchment area (final)	40 Km^2	Less than this at present because of non-availability of drains
Water surface (HWL)	0.92 km^2	
Water surface (LWL)	0.36 km^2	
High water level (HWL)	0.00 m	
Low water level (LWL)	-7.00 m	
Storage capacity	5,430,000 m^3	Between HWL and LWL
Pumping capacity	20 m^3/sec	

Source: JST

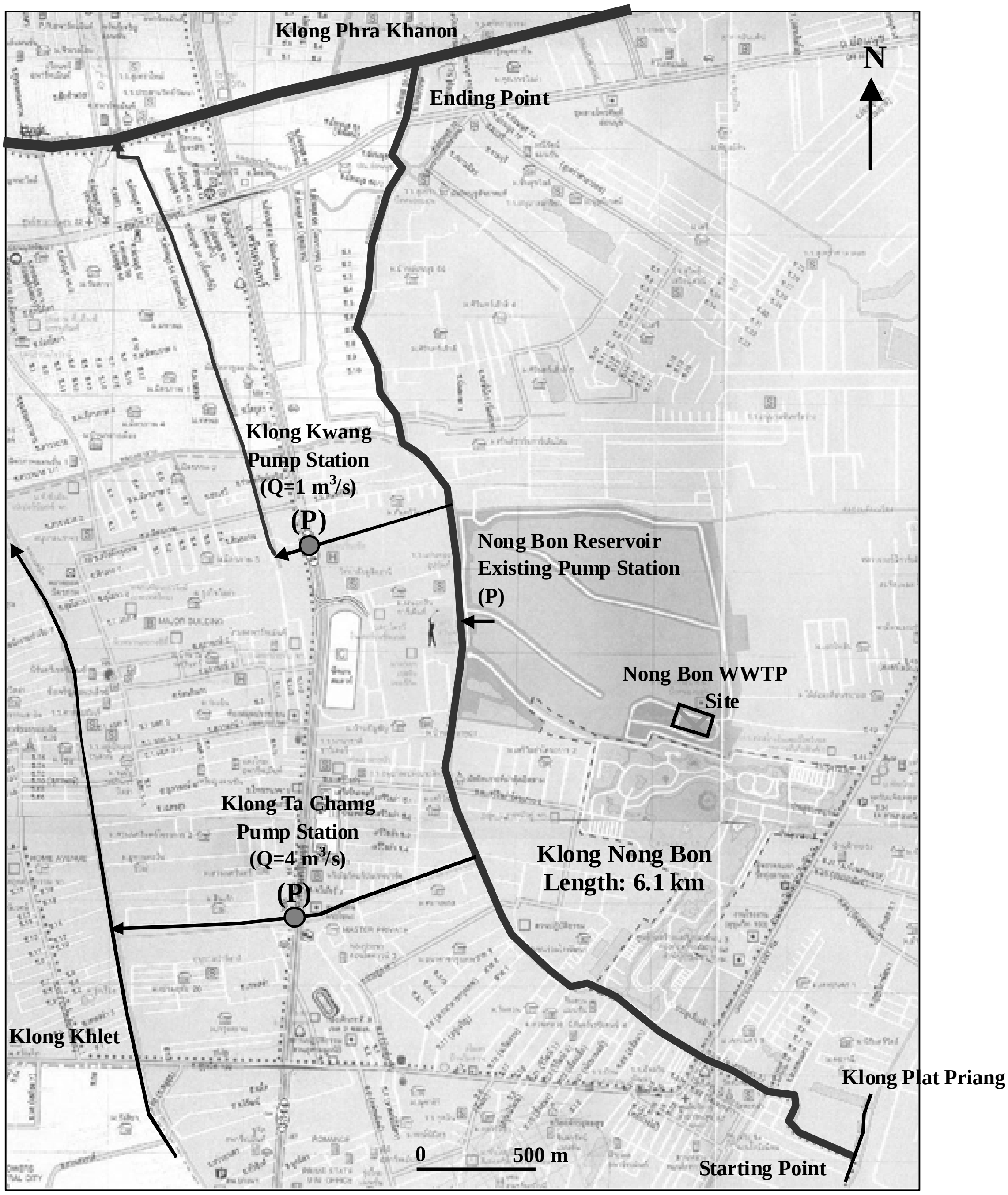
(B) Klong Nong Bon

Klong Nong Bon flows on the west side of Nong Bon storm water reservoir to Klong Phra Khanon, and its total length is approximately 6.1 km. In addition to the function to drain storm water runoff from surrounding areas, this klong discharges water from Nong Bon storm water reservoir to Klong Phra Khanon.To complement function to drain to Klong Phra Khanon, a route from Klong Nong Bon to Klong Phra Khanon through Klong Ta Chamg and Klong Kwang exists. When water level in Klong Nong Bon raises, Klong Ta Chamg pumping station and Klong Kwang pumping station are put into operation and storm water is discharged from Klong Nong Bon. Klong Nong Bon, Klong Ta Chamg and their surrounding areas are shown in Figure 2.1.8. Outline of Klong Nong Bon is shown in Table 2.1.2.

Table 2.1.2 Outline of Klong Nong Bon

Item	Description	Remarks
Start point	Klong Plat Priang	
End point	Klong Phra Khanon	
Total length	Approximately 6.1 km	
Cross section (at end point)	Rectangular (with hunch)	Surface width: 10.0 m, bottom width: 8.0 m, depth: 2.3 m, area: 22.5 m^2
Cross section (2.6 km from start point)	Trapezoidal	Surface width: 7.5 m, bottom width 4.0 m, depth 1.5 m, area: 8.6 m^2
Nong Bon reservoir pumping station	Inflow at 3.6 km from start point	Operation: high water in the reservoir
Klong Ta Chamg pumping station	Outflow from 2.3 km from start point	Operation: high water in Klong Nong Bon, capacity: 4 m^3/sec
Klong Kwang pumping station	Outflow from 3.9 km from start point	Operation: high water in Klong Nong Bon, capacity: 2 m^3/sec

Source: JST



Source: JST

Figure 2.1.8 Klong Nong Bon and Its Vicinity

(C) Nong Bon Drainage Tunnel Plan

Nong Bon drainage tunnel will be constructed to aim at providing countermeasures for flooding around Srinakharin road which runs through Nong Bon treatment area. The tunnel connects Nong Bon storm water reservoir and Chao Phraya River. Catchment area totals approximately 85 km^2 as shown in Figure 2.1.9, and entire catchment area of Nong Bon storm water reservoir is included in it.

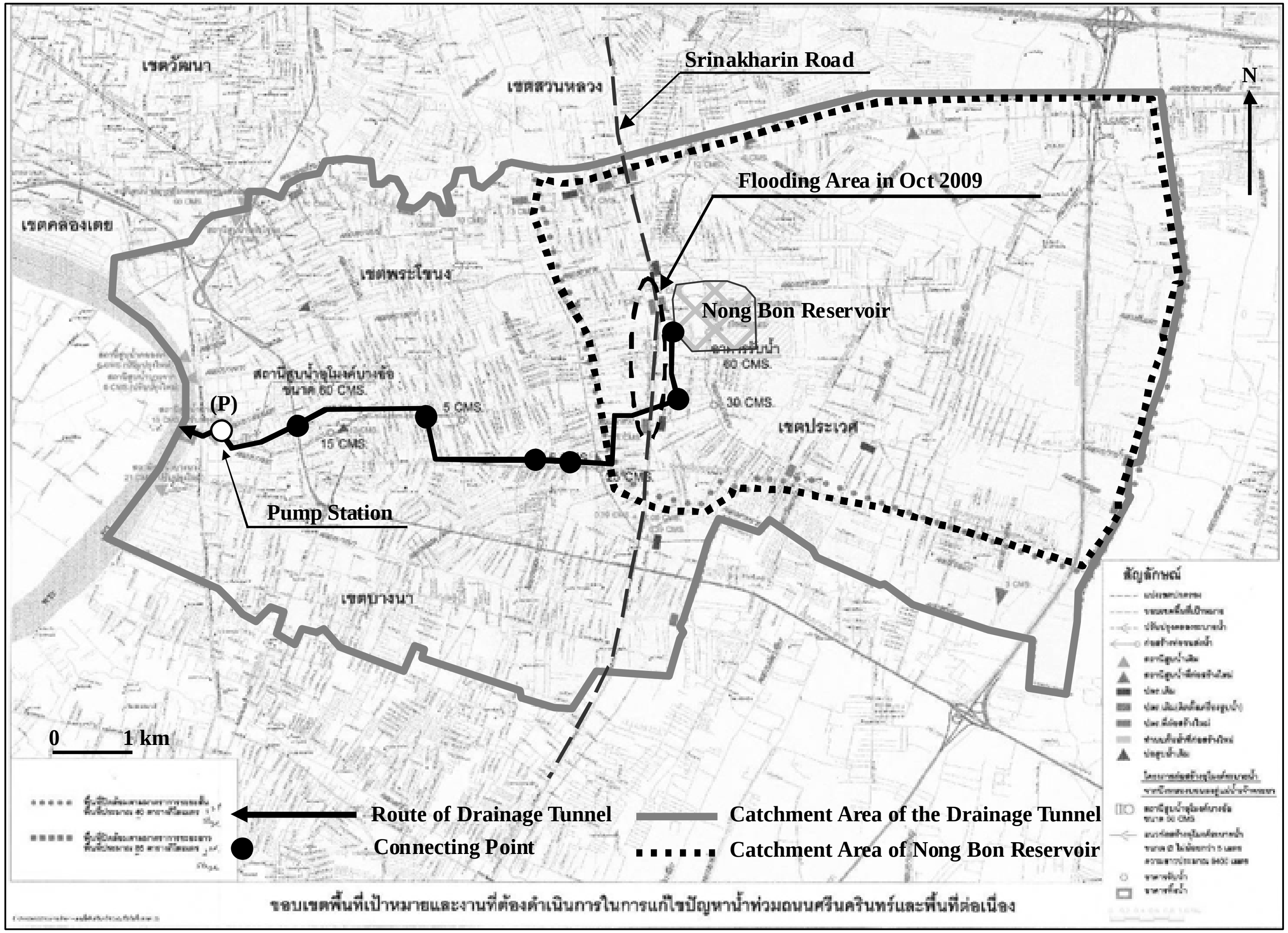
Total length of the tunnel is approximately 10 km, and 6 storm water inlets and one pumping station which discharges to Chao Phraya River will be constructed. The first inlets receives water from Nong Bon storm water reservoir and the second inlet receives water from Klong Nong Bon. With completion of the tunnel, water from Nong Bon storm water reservoir will be discharged safely without passing through the existing Klong Nong Bon. Storage capacity of Nong Bon storm water reservoir, i.e. approximately 5.4 million m^3, can be utilized fully. Flooding condition of the Nong Bon treatment area which is a part of tunnel catchment area is expected to be improved significantly.

Flow capacity of the tunnel is 60 m^3/sec with catchment area of approximately 85 km^2. Detailed design of the tunnel is currently being carried out by DDS and construction is expected to be completed within 5 years. Outline of the plan is described in Table 2.1.3, and catchment area is illustrated in Figure 2.1.9.

Table 2.1.3 Outline of Nong Bon Drainage Tunnel Plan

		Remarks
Expected completion	2015 (Target year)	Detailed design in preparation
Catchment area	Approximately 85 km^2	Entire Nong Bon treatment area is included
Length of tunnel	Approximately 10 km	
Diameter of tunnel	5 m	
Flow capacity	60 m^3/sec	
Depth of tunnel (center of pipe)	-30 m	At Nong Bon storm water reservoir
Inlet	6 locations	At Nong Bon storm water reservoir, Klong Nong Bon, and Srinakharin road etc.
Pumping capacity	60 m^3/sec	Located near Chao Phraya River

Source: JST



Source: DDS and JST

Figure 2.1.9 Catchment Area of Nong Bon Drainage Tunnel

2.2 Treatment Area and Design Criteria

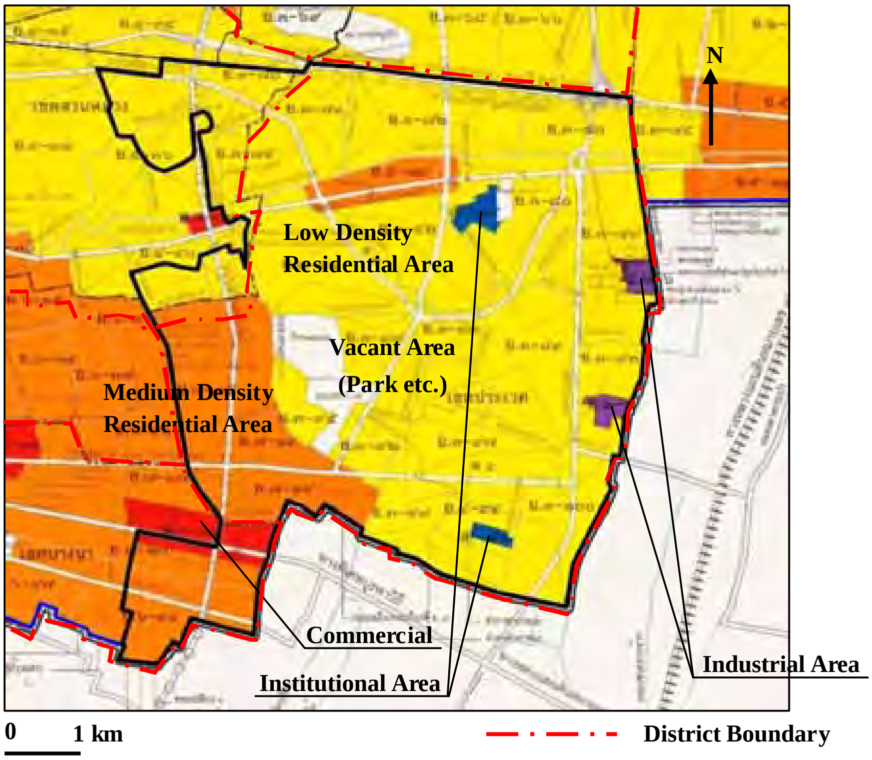
2.2.1 Target Year, Planning Area, Wastewater Collection System, Reuse of Treated Effluent and Sludge

(1) Target Year

The target year of M/P for Bangkok Wastewater Treatment Project is set at 2040, and its aim is to treat 80% of all wastewater generated in BMA by that time. The target year of the priority project, Nong Bon Wastewater Treatment Project is set at 2020. However, for design of interceptors which is difficult to expand its capacity by stages, wastewater flow in 2040 is used. On the other hand, for design of mechanical and electrical equipment of the WWTP which can be expanded easily by stages, wastewater flow in 2020 is used.

(2) Planning Area

Nong Bon treatment area was determined in updated M/P, is composed of tree districts, i.e. Bang Na, Prawet and Suan Luang Districts, and totals 6,385 ha. The treatment area is composed of residential, commercial, institutional and industrial land use areas according to land use plan 2020 prepared in 2006 by City Planning Department of BMA. Figure 2.2.1 shows land use areas in the treatment area, and Table 2.2.1 shows area of each land use area.



Source: JST

Figure 2.2.1 Land Use Plan in Nong Bon Treatment Area

Table 2.2.1 Area of Land Use Category in Nong Bon Treatment Area

(ha)

Low Density Residential	Medium Density Residential	Commercial	Industrial	Institutional	Vacant, Park etc.	Road, Klong	Total
4,671	1,207	87	35	55	205	125	6,385

Source: JST

(3) Wastewater Collection System

Combined system (interceptor sewerage system) is adopted to utilize effectively the existing drainage system.

An exceptional new housing area where wastewater can be directly connected to interceptor without septic tank is proposed to be developed in the treatment area. Estimation of cost for the new system is presented in Appendix 11.

(4) Reuse of Treated Effluent and Sludge

Treated wastewater is effectively used for sprinkling trees and for beautification of scenery in BMA. Reuse of treated effluent from Nong Bon WWTP for these purposes in adjacent Rama IX Park is to be considered.

Whole sludge produced in all WWTPs in BMA is to be treated at Nong Khaem WWTP. Reuse of sludge by composting and generation of electricity by digestion gas have been experimented. Sludge produced at Nong Bon WWTP is also planned to transfer to Nong Khaem WWTP.

2.2.2 Design Frame

Planning basis for Nong Bon sewerage system is summarized below. Rationale for planning basis, please refer to Chapter 5 Conceptual Master Plan in the Final Report (I).

(1) Design Population

Design population of Nong Bon treatment area is shown in Table 2.2.2 Two of three districts which formulate Nong Bon treatment area, viz. Prawet and Suan Luang show population increase.

Table 2.2.2 Design Population of Nong Bon Treatment Area

(person)

	2020	2030	2040
Bang Na	27,432	27,432	27,432
Prawet	191,670	203,770	216,470
Suan Luang	19,762	20,371	20,981
Total Nong Bon	238,863	251,574	264,883

Source: JST

Design population and population density in land use category are as shown in Table 2.2.3.

Table 2.2.3 Design Population and Population Density by Land Use Category

(a) 2020

	Low Density Residential	Medium Density Residential	Commercial	Industrial	Institutional	Others	Total
Area (ha)	4,671	1,207	87	35	55	330	6,385
Population (person)	154,918	68,851	12,853	55	2,186	0	238,863
P. Density (person/ha)	33	57	148	2	40	0	37

(b) 2030

	Low Density Residential	Medium Density Residential	Commercial	Industrial	Institutional	Others	Total
Area (ha)	4,671	1,207	87	35	55	330	6,385
Population (person)	164,060	72,277	12,853	60	2,324	0	251,574
P. Density (person/ha)	35	60	148	2	42	0	39

(c) 2040

	Low Density Residential	Medium Density Residential	Commercial	Industrial	Institutional	Others	Total
Area (ha))	4,671	1,207	87	35	55	330	6,385
Population (person)	173,625	75,873	12,853	63	2,469	0	264,883
P. Density (person/ha)	37	63	148	2	45	0	41

Source: JST

(2) Design Wastewater Flow

(A) Unit Water Supply per Person

Unit water supply per person for residential and non-residential uses in Nong Bon treatment area is shown Table 2.2.4.

Water supply for industrial use is considered to be a part of non-residential use. However industrial wastewater from large scale factories located in industrial estate should be treated by factories and is excluded from wastewater to WWTP. The discharge standard of industrial wastewater is presented in Appendix 12.

Table 2.2.4 Unit Water Supply per Person for Residential and Non-residential Uses

(lpcd)

	Residential	Non-residential	Total
2020	186	279	465
2030	197	296	493
2040	200	300	500

Source: JST

(B) Sewage Return Ratio

Sewage return ratio from water supply to wastewater flow is 0.80.

(C) Sewer Coverage Ratio

For the Conceptual Master Plan, current sewer coverage ratio was determined to be 80 % based on the analysis of the inflow data to the existing WWTPs. Sewer coverage ratio is expected to be raised to reach 90 % in 2040. Nong Bon treatment area is a new treatment area and interceptors are to be provided in future. Current sewer coverage ratio is thought to be lower than those of the existing service areas. Taking into the situation of the existing drainage pipes, sewer service ratio is determined to be slightly lower figure, i.e. 70 % in 2020. Sewer coverage ratio is assumed to be raised to 80 % in 2030 and 90 % in 2040 as brunch sewers are expected to be provided gradually in the future. Sewer coverage ratios are shown in Table 2.2.5.

Table 2.2.5 Sewer Coverage Ratio in Nong Bon Treatment Area

	2020	2030	2040
Sewer Coverage Ratio	70%	80%	90%

Source: JST

(D) Infiltration Flow

Infiltration of groundwater and back flow of klong water from interceptor chamber are assumed as 40 % of wastewater flow.

(E) Design Wastewater Flow

Design wastewater flow in Nong Bon treatment area is as shown in Table 2.2.6.

Table 2.2.6 Design Wastewater Flow in Nong Bon Treatment Area

	Population (person)	Unit Water Supply (lpcd)			Water Supply (m^3/day)	Return Ratio (%)	Wastewater Generated (m^3/day)
		Residential	Non-residential	Total			
2020	238,863	186	279	465	111,071	80	88,857
2030	251,754	197	296	493	124,026	80	99,221
2040	264,883	200	300	500	132,442	80	105,953

	Wastewater Generated (m^3/day)	Sewer Coverage Ratio (%)	Wastewater Collected (m^3/day)	Infiltration Ratio (%)	Infiltration (m^3/day)	Design Wastewater Flow (m^3/day)
2020	88,857	70	62,200	40	24,880	87,080
2030	99,221	80	79,377	40	31,751	111,128
2040	105,953	90	95,358	40	38,143	133,501

Source: JST

(3) Design Characteristics of Wastewater

Design characteristics of wastewater flowing to Nong Bon WWTP is determined as shown in Table 2.2.7. The characteristics of wastewater are the same as those of all WWTPs in BMA except for Rattanakosin WWTP.

Table 2.2.7 Design Characteristics of Wastewater to Nong Bon WWTP

Parameters	Design Value
Biochemical Oxygen Demand (BOD)	150 mg/l
Suspended Solids (SS)	150 mg/l
Total Nitrogen (T-N)	30 mg/l
Total Phosphorus (T-P)	8 mg/l

Source: JST

(4) Design Characteristics of Treated Effluent

Design characteristics of treated effluent of the existing WWTPs and effluent standards for discharge are shown in Table 2.2.8. Design characteristics of treated effluent for Nong Bon WWTP were determined as shown in the most right raw of the Table taking into account these characteristics and standards.

Table 2.2.8 Design Characteristics of the Existing WWTPs and Effluent Standards

Parameters	Unit	Design of Existing WWTPs	Effluent Standards 1	Effluent Standards 2	Design for Nong Bon WWTP
pH	-		5-9	5.5-9	5.5-9
Biochemical Oxygen Demand (BOD)	mg/l	20	20	20	20
Suspended Solids (SS)	mg/l	30	30	30	30
Total Nitrogen (T-N)	mg/l	10	10	20	10
Ammonia Nitrogen (NH_3-N)	mg/l	5	5	-	5
Total Phosphorus (T-P)	mg/l	2	2	2	2
Dissolved Oxygen (DO)	mg/l	5	5	5	5
Oil and Grease	mg/l	-	-	5	5
Effluent Standards 1: stipulated by BMA Effluent Standards 2: National Standards approved by NEB and came into effect on 2nd June, 2010					

Source: JST

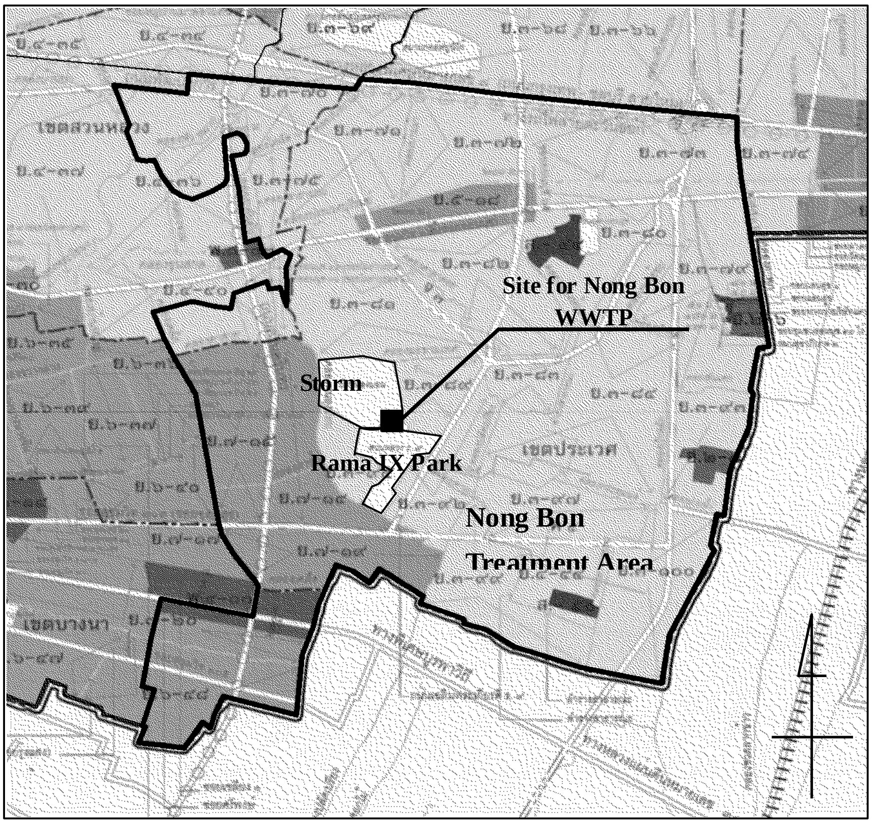
2.2.3 Outlines of the Nong Bon Treatment Area and Nong Bon WWTP

Outlines of Nong Bon treatment area and Nong Bon WWTP is shown in Table 2.2.9 and Figure 2.2.2. Construction site for WWTP is located adjacent to Rama IX Park in the neighborhood of storm water reservoir constructed under Monkey Cheek Project.

Table 2.2.9 Outlines of Nong Bon Treatment Area and Nong Bon WWTP

		Remarks
Area of the Treatment Area Planned Population	6,385 ha 265,000 persons	Including areas of parks, vacant lands and water surfaces Year 2040
Design Capacity of WWTP	135,000 m^3/day	
Area for WWTP	3.5 ha (22 Rai) 1.1 ha for above ground facilities	In neighborhood of Rama IX Park and adjacent to storm water reservoir constructed by Monkey Cheek Project. Compact biological treatment should be adopted. Most of the treatment facilities are to be constructed underground, and administration facilities are to be constructed above ground.

Source: JST



Source: JST

Figure 2.2.2 Location of Nong Bon Treatment Area and WWTP

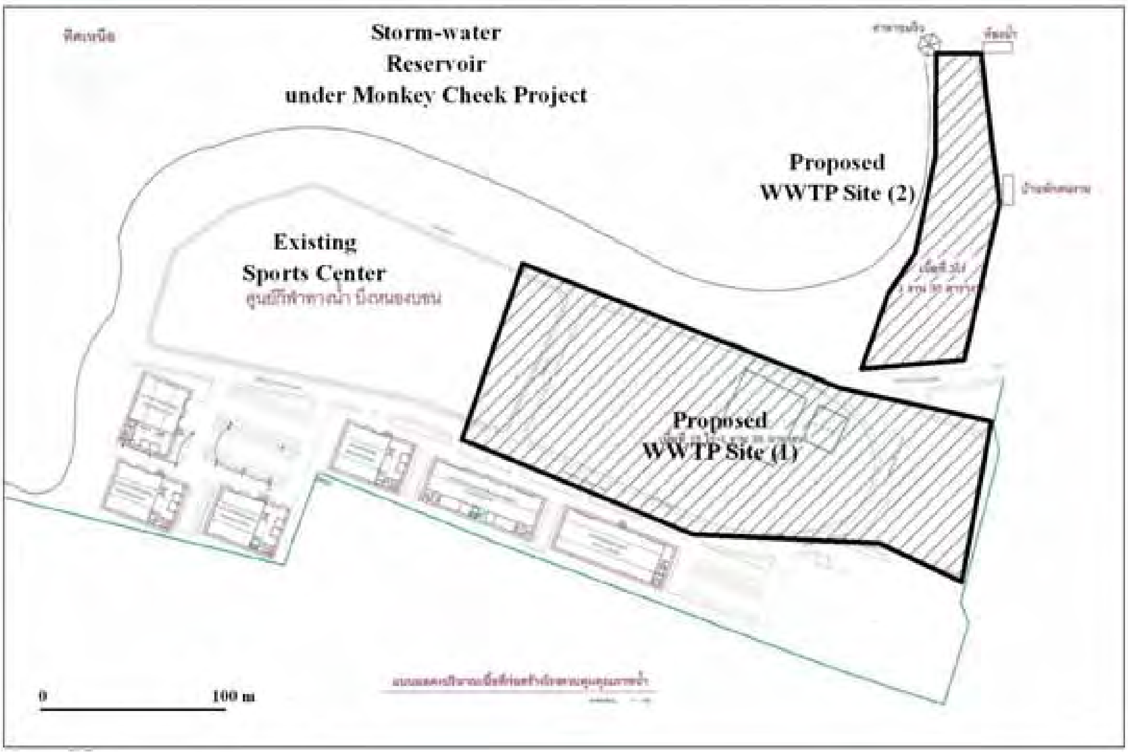
2.3 Site for Construction of WWTP

Outline of the site for Nong Bon WWTP is shown in Figure 2.3.1.

Site for construction of WWTP is located in the neighborhood of Rama IX Park and in the site of storm water reservoir constructed under Monkey Cheek Project which is administrated by DDS. Water sports center which is managed by Culture, Sports and Tourism Department of BMA was constructed and a part of the reservoir is opened to the public. Construction of an administration building of DDS (Mechanical Division and Drainage Control Structures System Division) and workshops has been started in a part of DDS administration site.

Only a remaining part of the site, with an area of approximately 3.5 ha can be used for construction of WWTP. Out of 3.5 ha, only 1.1 ha can be used for above ground facilities. This area is very narrow for the WWTP with design capacity of 135,000 m^3/day. Compact type treatment facilities are to be adopted, and efficient use of underground and above ground is required.

According to the results of geotechnical survey, there exists a layer with N value more than 40 at 30 m depth and bearing layer with N value more than 50 appears at 40 m depth.



Source: JST

Figure 2.3.1 Proposed Site of Nong Bon WWTP

3. PRELIMINARY DESIGN OF INTERCEPTOR

3.1 Facilities Designed

In this Chapter, preliminary design of interceptors and their related facilities mentioned below is carried out. Outlines of these facilities, i.e. capacity, and number and location of facilities are determined.

- Interceptors (trunk and lateral)
- Interceptor chambers
- Pumping stations

3.2 Design Criteria

Design criteria are determined as follows by reference to F/S Reports for Klong Toei and Bang Sue Projects since no clear BMA design criteria is available.

Minimum diameter of pipe

Basically minimum diameter of pipe is 300 mm.
However, pipe diameter can be expanded to 600 mm if pipes are to be laid as shallow as possible to reduce number of pumping stations, even if flow capacity is more than actual flow.

Flow friction formula

Manning formula shown below is used.

$$v = \frac{1}{n} R^{\frac{2}{3}} I^{\frac{1}{2}}$$

Where

v: velocity (m/sec)
n: Manning's friction factor
R: hydraulic radius
I: pipe gradient

Manning's friction factor n is taken as 0.013 assuming that all interceptors are concrete pipe.

Minimum and maximum velocity

Generally flow in a sewer is gravity flow. Minimum velocity is determined not to accumulate sediments in pipes. Maximum velocity is determined to prevent erosions of pipes and manholes by excessively high velocity. Proper diameter and gradient should be determined considering minimum and maximum velocities. For preliminary design, minimum and maximum velocities are determined as follows.

Minimum velocity = 0.6 m/s,   Maximum velocity = 3.0 m/s

Diameter and gradient of an interceptor are determined assuming v = 1.0 m/s in full flow.

Minimum covering depth and minimum clearance to the existing structure

Minimum covering depth and minimum clearance are determined as follows.

- Minimum covering depth at upstream end manhole of interceptor = 2.0 m
- Under-crossing of klong, minimum clearance = 2.0 m
- Minimum covering depth under highway = 2.5 m

Arrangement and interval of manholes

Manholes are necessary for workers to go into a sewer for inspection, cleaning and repair and maintenance works. Manholes are provided at the following points.

- Starting point of sewer
- Meeting point of sewers
- Changing point of diameter, gradient and direction

Manholes should be provided for maintenance work at a straight line with the following maximum intervals shown in Table 3.2.1.

Table 3.2.1   Maximum Intervals of Manhole

Diameter (mm)	Maximum interval (m)
D 300	100
450 = D < 800	150
800 < D	200

Source: JST

Other design criteria

Other design criteria used for preliminary design are as follows.

- Gradient of sewer between manholes is constant.
- In a manhole, crown of outlet sewer is leveled with the lowest crown of inlet

sewers.

- Diameter of downstream sewer is equal to or larger than that of upstream sewer.

Intercepting rate

Combined sewerage system (interceptor sewerage system) is adopted in all the existing treatment areas in BMA, and this system is also adopted in Nong Bon treatment area. Therefore, intercepting rate significantly influences the capacity of sewer networks and treatment plant. For the existing seven treatment areas, intercepting rate of 5 has been adopted and all interceptors have been designed to flow 5 times average dry weather flow (5DWF).

On the other hand, varied intercepting rates (2 to 5, 3.5 on an average) have been adopted for Bang Sue Project which is under construction and Klong Toei Project for which F/S was completed. The reasons for adoption of varied rates described in F/S report for Klong Toei Project are as follows.

- Construction cost is very high when all interceptors are designed for 5DWF.
- If interceptors are designed for 2DWF, hourly maximum flow in dry weather can be carried.
- If 5DWF is intercepted at interceptor chamber in wet weather, down stream pipes are pressurized. However, it is confirmed by unsteady flow analysis that overflow to the surface does not occur.
- Difference of annual amount of pollutant loads discharged to the water body is only 0.6 % in cases of 2 to 5DWF varied rates and 5DWF rate.
- Literature investigation revealed that varied rates are adopted in many foreign countries

Above reasons are judged appropriate, and Bang Sue and Klong Toei Projects have been implemented based on the thought, varied rates should be adopted for the future projects. Therefore, intercepting rates for design, 5DWF at interceptor chamber and 2 to 5 for interceptors are adopted.

3.3 Design of Interceptors

3.3.1 Design Wastewater Flow

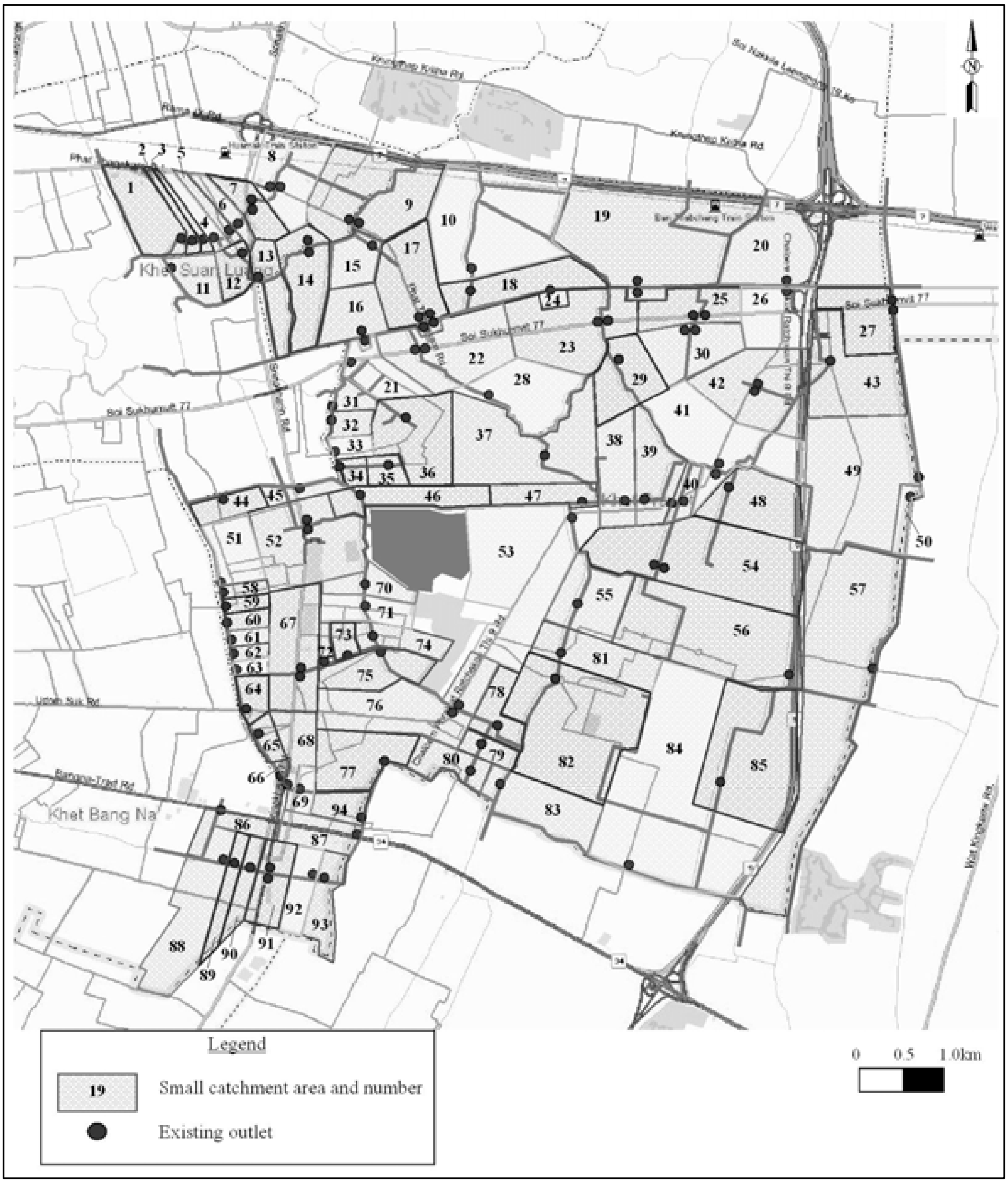
(1) Division of Catchment Areas by Existing Outlets

Wastewater from households and buildings is partially treated by septic tank and discharged into klongs through drainage pipes as explained in the former Section 2.2.1 Klongs and Drainage Pipes.

There are 136 outlets which are discharging points to klongs exist in Nong Bon treatment area (refer to Appendix 3). Interceptor chambers are to be constructed before outlets to intercept wastewater not to be discharged to klongs (interceptor sewerage system). The treatment area can be divided into small 94 catchment areas by each of these outlets or a group of outlets which are located at both sides of the road or klong or closely each other as shown in Figure 3.3.1. A total of wastewater generated in these 94 small catchment areas is design wastewater in Nong Bon treatment area. In addition, it is necessary for DDS to confirm the location of existing outlets in the stage of detail design by surveying.

(2) Wastewater by Small Catchment Areas

Design population and design wastewater flow is presented in the former Section 2.1.2 Design Frame. Design wastewater flows by small catchment areas are estimated based on the design frame. Results of the estimation are shown in Table 3.3.1.



Source: JST

Figure 3.3.1 Catchment Areas of the Existing Outlets

Table 3.3.1 (1) Design Wastewater Flow by Small Catchment Areas (1/2)

No.	Area	Daily Average Fry Weather Flow (DWF)			Hourly Maximum Dry Weather Flow (2DWF)			Intercepting Wet Weather Flow (5DWF)		
		2020	2030	2040	2020	2030	2040	2020	2030	2040
	km^2	m^3/day			m^3/sec			m^3/sec		
1	1.76	641.09	799.38	940.65	0.015	0.019	0.022	0.037	0.046	0.054
2	0.37	132.77	165.59	194.83	0.003	0.004	0.005	0.008	0.010	0.011
3	0.26	93.31	116.37	136.92	0.002	0.003	0.003	0.005	0.007	0.008
4	0.51	183.85	229.28	269.78	0.004	0.005	0.006	0.011	0.013	0.016
5	0.42	154.16	192.25	226.20	0.004	0.004	0.005	0.009	0.011	0.013
6	0.53	192.62	240.25	282.66	0.004	0.006	0.007	0.011	0.014	0.016
7	0.82	292.72	365.13	429.55	0.007	0.008	0.010	0.017	0.021	0.025
8	1.13	372.02	463.64	545.68	0.009	0.011	0.013	0.022	0.027	0.032
9	1.33	884.89	1129.22	1359.65	0.020	0.026	0.031	0.051	0.065	0.079
10	1.60	1959.34	2521.45	3059.25	0.045	0.058	0.071	0.113	0.146	0.177
11	0.81	295.17	368.46	433.24	0.007	0.009	0.010	0.017	0.021	0.025
12	0.66	238.90	298.22	350.65	0.006	0.007	0.008	0.014	0.017	0.020
13	0.95	346.77	432.87	508.99	0.008	0.010	0.012	0.020	0.025	0.029
14	1.18	343.87	427.92	503.05	0.008	0.010	0.012	0.020	0.025	0.029
15	0.33	407.87	524.92	636.87	0.009	0.012	0.015	0.024	0.030	0.037
16	0.47	573.94	738.64	896.17	0.013	0.017	0.021	0.033	0.043	0.052
17	0.75	939.67	1209.35	1467.23	0.022	0.028	0.034	0.054	0.070	0.085
18	0.65	789.13	1015.50	1232.10	0.018	0.024	0.029	0.046	0.059	0.071
19	2.10	2570.35	3307.64	4013.14	0.059	0.077	0.093	0.149	0.191	0.232
20	1.61	1960.00	2523.00	3060.00	0.045	0.058	0.071	0.113	0.146	0.177
21	0.37	446.00	573.91	696.34	0.010	0.013	0.016	0.026	0.033	0.040
22	1.00	1574.26	2026.16	2457.76	0.036	0.047	0.057	0.091	0.117	0.142
23	1.09	1792.49	2307.12	2798.44	0.041	0.053	0.065	0.104	0.134	0.162
24	0.07	133.70	172.10	208.73	0.003	0.004	0.005	0.008	0.010	0.012
25	0.44	538.62	693.19	840.96	0.012	0.016	0.019	0.031	0.040	0.049
26	0.52	639.80	823.42	998.94	0.015	0.019	0.023	0.037	0.048	0.058
27	0.54	656.07	844.43	1024.52	0.015	0.020	0.024	0.038	0.049	0.059
28	0.76	926.31	1192.06	1446.19	0.021	0.028	0.033	0.054	0.069	0.084
29	0.56	738.75	950.47	1153.76	0.017	0.022	0.027	0.043	0.055	0.067
30	0.57	749.87	964.78	1171.20	0.017	0.022	0.027	0.043	0.056	0.068
31	0.12	150.74	193.97	235.35	0.003	0.004	0.005	0.009	0.011	0.014
32	0.16	195.28	251.29	304.90	0.005	0.006	0.007	0.011	0.015	0.018
33	0.12	152.37	196.07	237.89	0.004	0.005	0.006	0.009	0.011	0.014
34	0.10	122.76	157.96	191.66	0.003	0.004	0.004	0.007	0.009	0.011
35	0.15	187.13	240.80	292.17	0.004	0.006	0.007	0.011	0.014	0.017
36	0.82	1002.86	1290.47	1565.77	0.023	0.030	0.036	0.058	0.075	0.091
37	0.91	1116.01	1436.07	1742.43	0.026	0.033	0.040	0.065	0.083	0.101
38	0.53	646.04	831.33	1008.76	0.015	0.019	0.023	0.037	0.048	0.058
39	0.54	653.33	840.68	1020.20	0.015	0.019	0.024	0.038	0.049	0.059
40	0.17	211.18	271.73	329.81	0.005	0.006	0.008	0.012	0.016	0.019
41	1.12	1371.62	1765.28	2141.66	0.032	0.041	0.050	0.079	0.102	0.124
42	0.95	1165.46	1499.96	1819.73	0.027	0.035	0.042	0.067	0.087	0.105
43	0.99	1213.80	1562.28	1895.45	0.028	0.036	0.044	0.070	0.090	0.110
44	0.25	608.62	783.29	950.36	0.014	0.018	0.022	0.035	0.045	0.055
45	0.15	368.24	473.94	575.02	0.009	0.011	0.013	0.021	0.027	0.033
46	0.48	699.86	900.65	1092.77	0.016	0.021	0.025	0.041	0.052	0.063
47	0.30	371.71	478.31	580.35	0.009	0.011	0.013	0.022	0.028	0.034

Source: JST

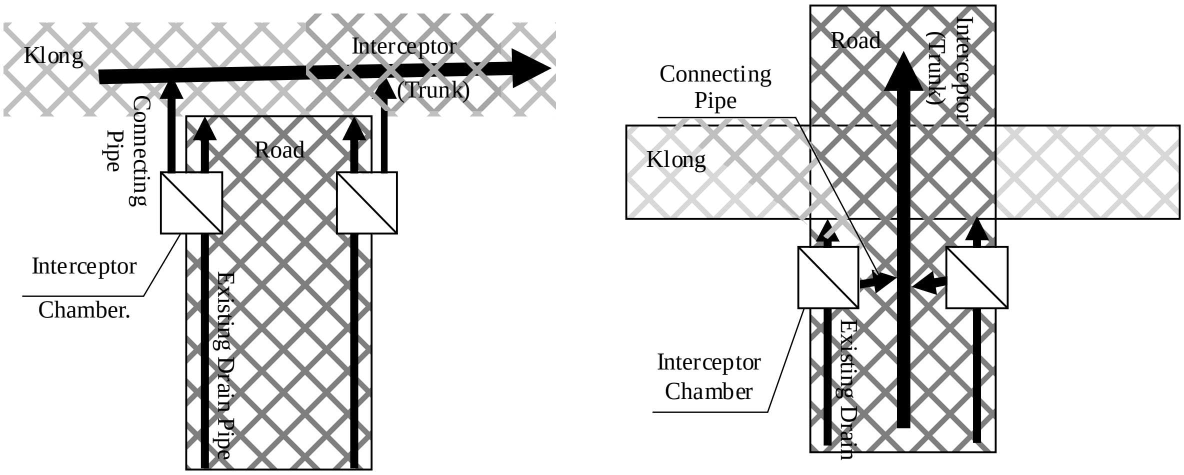
Table 3.3.1 (2) Design Wastewater Flow by Small Catchment Areas (2/2)

No.	Area	Daily Average Fry Weather Flow (DWF)			Hourly Maximum Dry Weather Flow (2DWF)			Intercepting Wet Weather Flow (5DWF)		
		2020	2030	2040	2020	2030	2040	2020	2030	2040
	km^2	m^3/day			m^3/sec			m^3/sec		
48	0.76	930.81	1197.80	1453.45	0.022	0.028	0.034	0.054	0.069	0.084
49	1.73	1870.10	2407.29	2920.06	0.043	0.056	0.068	0.108	0.139	0.169
50	0.10	125.52	161.56	196.01	0.003	0.004	0.005	0.007	0.009	0.011
51	0.42	1026.70	1321.35	1603.19	0.024	0.031	0.037	0.059	0.076	0.093
52	1.15	2815.87	3624.16	4397.15	0.065	0.084	0.102	0.163	0.210	0.254
53	1.84	2243.17	2886.05	3502.08	0.052	0.067	0.081	0.130	0.167	0.203
54	1.79	2187.13	2814.28	3415.62	0.051	0.065	0.079	0.127	0.163	0.198
55	0.57	701.74	903.01	1095.63	0.016	0.021	0.025	0.041	0.052	0.063
56	1.77	2162.27	2782.53	3376.38	0.050	0.064	0.078	0.125	0.161	0.195
57	2.99	3503.90	4510.64	5472.91	0.081	0.104	0.127	0.203	0.261	0.317
58	0.09	214.77	276.41	335.36	0.005	0.006	0.008	0.012	0.016	0.019
59	0.10	238.72	307.22	372.75	0.006	0.007	0.009	0.014	0.018	0.022
60	0.11	276.26	355.55	431.39	0.006	0.008	0.010	0.016	0.021	0.025
61	0.10	239.65	308.42	374.21	0.006	0.007	0.009	0.014	0.018	0.022
62	0.08	185.79	239.11	290.11	0.004	0.006	0.007	0.011	0.014	0.017
63	0.09	207.69	267.29	324.30	0.005	0.006	0.008	0.012	0.015	0.019
64	0.18	443.37	570.62	692.33	0.010	0.013	0.016	0.026	0.033	0.040
65	0.13	312.63	402.38	488.18	0.007	0.009	0.011	0.018	0.023	0.028
66	0.03	62.53	80.48	97.64	0.001	0.002	0.002	0.004	0.005	0.006
67	0.85	2085.27	2683.81	3256.24	0.048	0.062	0.075	0.121	0.155	0.188
68	0.30	734.08	944.81	1146.28	0.017	0.022	0.027	0.042	0.055	0.066
69	0.16	421.12	518.95	603.82	0.010	0.012	0.014	0.024	0.030	0.035
70	0.26	409.00	526.18	638.32	0.009	0.012	0.015	0.024	0.030	0.037
71	0.31	539.72	694.44	842.47	0.012	0.016	0.020	0.031	0.040	0.049
72	0.07	159.28	205.01	248.73	0.004	0.005	0.006	0.009	0.012	0.014
73	0.12	291.74	375.49	455.58	0.007	0.009	0.011	0.017	0.022	0.026
74	0.30	439.58	565.45	685.95	0.010	0.013	0.016	0.025	0.033	0.040
75	0.41	831.89	1070.56	1298.83	0.019	0.025	0.030	0.048	0.062	0.075
76	1.02	2185.76	2813.17	3413.04	0.051	0.065	0.079	0.126	0.163	0.198
77	0.61	1496.73	1926.39	2337.17	0.035	0.045	0.054	0.087	0.111	0.135
78	0.30	416.58	536.07	650.33	0.010	0.012	0.015	0.024	0.031	0.038
79	0.17	423.36	544.89	661.08	0.010	0.013	0.015	0.025	0.032	0.038
80	0.31	758.26	975.93	1184.04	0.018	0.023	0.027	0.044	0.056	0.069
81	0.70	858.73	1105.20	1340.83	0.020	0.026	0.031	0.050	0.064	0.078
82	1.81	2227.77	2866.84	3478.48	0.052	0.066	0.081	0.129	0.166	0.201
83	0.71	964.93	1241.65	1506.66	0.022	0.029	0.035	0.056	0.072	0.087
84	3.06	3937.58	5067.48	6149.06	0.091	0.117	0.142	0.228	0.293	0.356
85	1.61	1989.54	2560.43	3106.85	0.046	0.059	0.072	0.115	0.148	0.180
86	0.86	1070.98	1295.86	1479.98	0.025	0.030	0.034	0.062	0.075	0.086
87	0.74	1914.71	2316.99	2646.18	0.044	0.054	0.061	0.111	0.134	0.153
88	1.89	633.04	766.03	874.84	0.015	0.018	0.020	0.037	0.044	0.051
89	0.61	210.38	254.53	290.69	0.005	0.006	0.007	0.012	0.015	0.017
90	0.60	207.04	250.47	286.05	0.005	0.006	0.007	0.012	0.014	0.017
91	1.13	397.75	481.17	549.53	0.009	0.011	0.013	0.023	0.028	0.032
92	0.83	292.58	353.94	404.22	0.007	0.008	0.009	0.017	0.020	0.023
93	0.88	305.75	369.89	422.44	0.007	0.009	0.010	0.018	0.021	0.024
94	0.43	1125.22	1361.64	1555.09	0.026	0.032	0.036	0.065	0.079	0.090

Source: JST

3.3.2 Structure of Interceptor Chamber

In Nong Bon treatment area, interceptors will be constructed either under the klongs or under the roads. Disposition of a new interceptor and interceptor chambers with the existing drain pipes, in both cases of road and klong is illustrated in Figure 3.3.2.



Case1: Interceptor under klong

Case 2: Interceptor under road

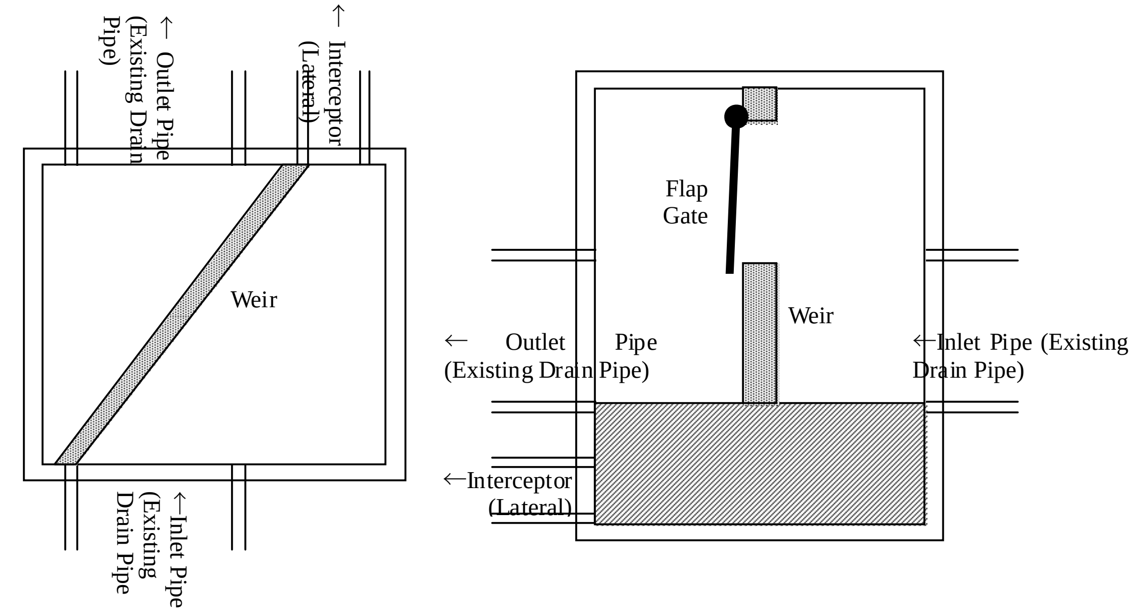
Source: JST

Figure 3.3.2 Disposition of Interceptor and Interceptor Chamber with Existing Drain Pipe

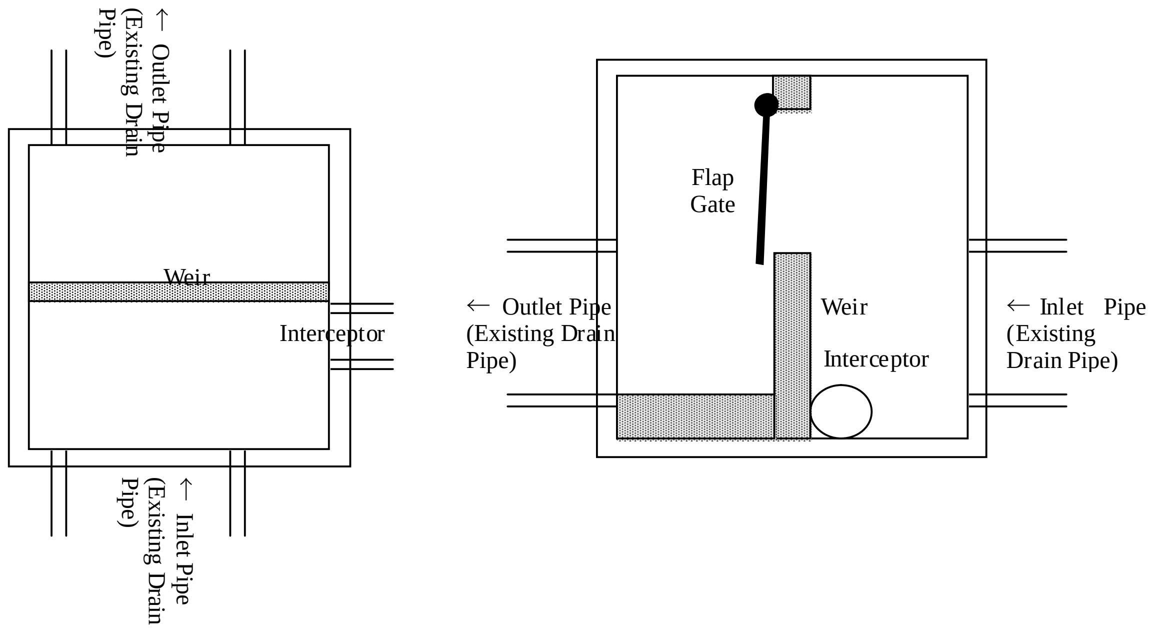
Lateral interceptor runs in parallel with the existing drain pipe in case 1 when wastewater is intercepted to new interceptor (trunk) which is constructed under klong. On the other hand, lateral interceptor crosses new interceptor (trunk) constructed under road which is shown in case 2. Taking into account this, structures of interceptor chamber for both cases are considered as shown in Figure 3.3.3.

There are many places in Nong Bon treatment area as well as in the other treatment areas, where level of outlet of the existing drain pipe is lower than water level in klong. A flap gate is provided in the interceptor chamber to prevent backwater from klong.

(Case 1: Intercept to interceptor under klong)



(Case 2: Intercept to interceptor under road)

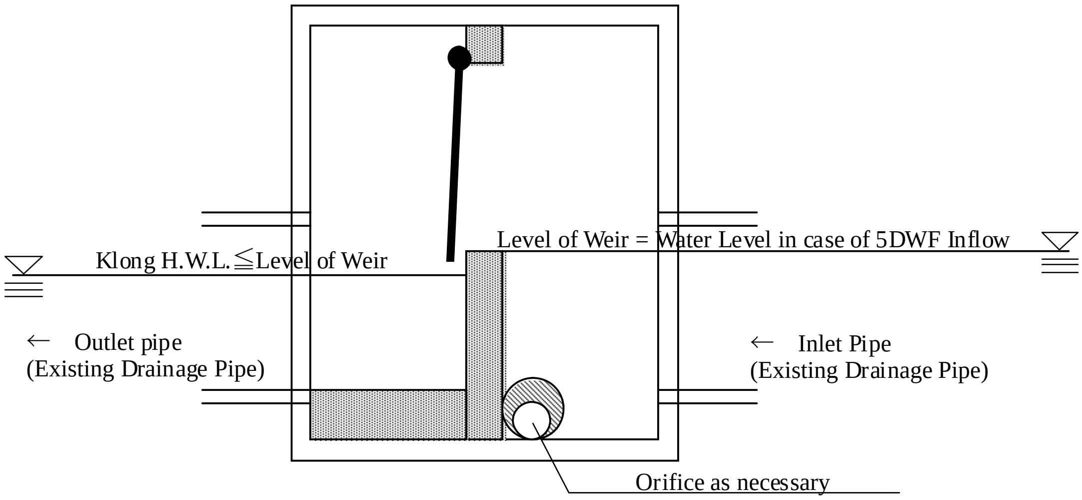


Source: JST

Figure 3.3.3 Structure of Interceptor Chamber

Wastewater currently generated in Nong Bon treatment area flows into the existing drain pipes and is discharged from 136 outlets to klongs. It is necessary to construct interceptor chambers which fit to shapes and sizes of the drain pipes and to water level in klongs to intercept untreated wastewater from all of the outlets. The followings should be noted for the design of interceptor chamber.

1) Weir height and diameter of the interceptor should be designed so that level of the weir is the same as level of water in an interceptor chamber when flow from the existing drain pipes is 5DWF. An orifice should be provided, if necessary.
2) A flap gate should be provided to prevent back flow from klong. It does not function properly when clogged with garbage. Level of weir should be designed higher than high water level in klong, if possible.

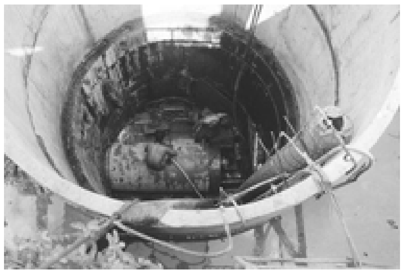


Source: JST

Figure 3.3.4 Points to be Noted in Design of Interceptor Chamber

3.3.3 Laying of Interceptors (Under Klong or Road)

Most of the interceptors in the existing 7 treatment areas in BMA were laid under roads, in particular roads running along klongs. It is general practice in not only BMA but also in other countries to lay sewers under the roads. Easy access by vehicles for maintenance work of sewers is the advantage of this practice. However, adverse effects on traffic in construction and maintenance work are disadvantage. On the other hand, for Bang Sue and Klong Toei Projects an idea that interceptors are laid under klongs as well as under roads was adopted. For Bang Sue Project, which is now under construction, 75 % of interceptors are laid under klongs. An advantage that adverse effects on traffic in construction and maintenance work can be significantly reduced when interceptors are laid under klongs can be expected. A disadvantage that a boat must be used to access to a manhole for inspection or bringing in of equipment and materials is envisaged. For construction of interceptors under klong, pipe jacking method or shield tunneling method with vertical shafts in klong should be adopted because open cut method can not be applied. Construction of a vertical shaft in klong in BMA is shown in Photo 3.3.1.

Source: Website “2Bangkok.com, 14th Dec. 2002”

Photo 3.3.1 Vertical Shaft Constructed in Klong

There are advantages and disadvantages for both cases of laying interceptors under roads and klongs. Optimal routes of interceptors have been selected regardless of whether laying under roads or klongs for the on-going project in BMA. Taking into account the present practice, in this F/S the same idea should be applied for Nong Bon treatment area.

3.3.4 Pipe Laying Method

In general, pipe laying method is selected among three methods, viz. open cut, pipe jacking and shield tunneling depending on depth of pipe, working environment and construction cost. Features of the three methods are described below.

Open cut method

Pipes are laid in a trench excavated manually or by machines and earth is backfilled. In many cases, bracing and sheeting are used. All works can be done in the open air. It is the easiest method and most economical when pipe laying depth is shallow. However, pipe laying depth is deep it is not an economical method. Also influence to the traffic is largest.

Pipe jacking method

This is a method that a pipe is pushed by jacking machine set in a vertical shaft, excavated earth is removed and a new pipe is added. Works which is done in the open air is limited in a vertical shaft. There are various jacking methods which can be applied to almost all soil types. An area required for construction of a vertical shaft is smaller than that for shield tunneling. However, this method is not applied for long distance construction exceeding 1 km or sharp curve construction.

Shield tunneling method

A vertical shaft provides working space for constructing a tunnel the same as pipe jacking method. Instead of pushing a pipe in case of pipe jacking method, shield machine equipped at the head of tunnel excavates earth and advances by fabricating segments which form a pipe later. This method is suitable for long distance construction or for a structure with large cross section. This method is often applied for construction of metro line. This is the most expensive method among the three methods.

Comparison of the three methods is described in Table 3.3.2.

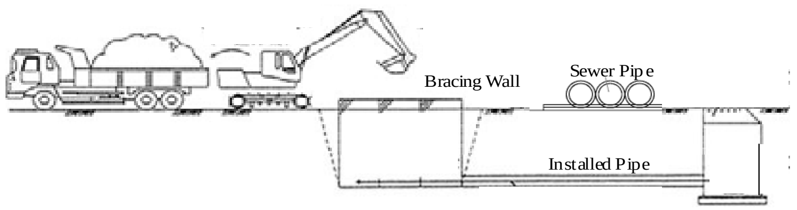
Open cut method should be used as much as possible because of its easiness and economy. However, this method can not be applied for various reasons mentioned below, and pipe jacking or shield tunneling method is adopted.

- Heavy traffic condition at construction site and influence is expected to be very significant
- Road under which pipes are laid is very narrow and houses are congested
- Pipe laying depth is very deep and cost for open cut method becomes high
- Pipes cross under klongs, rivers, railways, large diameter water pipes and other underground structures

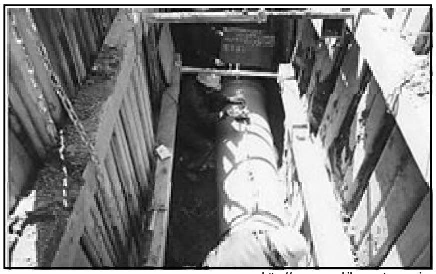
Interceptors constructed under klongs account for 70 % of the total length in Nong Bon treatment area. Also pipe laying depths at upstream and downstream end of the pipe line are very deep because pipe line crosses klongs. Taking into account these conditions, open cut method can not be adopted for construction of interceptors in Nong Bon treatment area.

Appropriate construction method is selected from pipe jacking method or shield tunneling method depending on pipe diameter and length of construction. Generally cost for pipe jacking method is less expensive than that for shield tunneling method if pipe diameter is less than 2,000 mm. Pipe jacking method can be applied for pipe laying distance less than 1 km. Pipe diameters of all interceptors in Nong Bon treatment area are less than 2,000 mm as described later in Section 3.4 Routing of Interceptors. Manholes are provided at maximum interval of 200 m for collecting wastewater from scattered interceptor chambers and for maintenance work. Therefore, there are many vertical shafts and consequently pipe laying distance becomes shorter. Taking into the above, pipe jacking method is applied for pipe laying.

Table 3.3.2 (1) Comparison of Pipe Laying Methods (Open Cut)

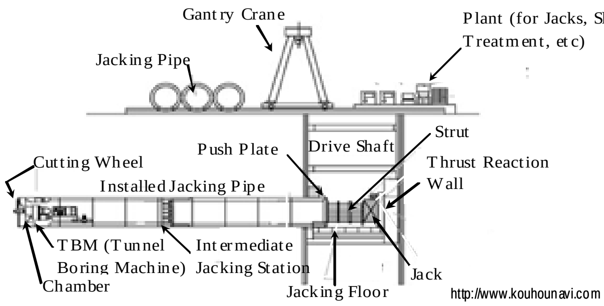
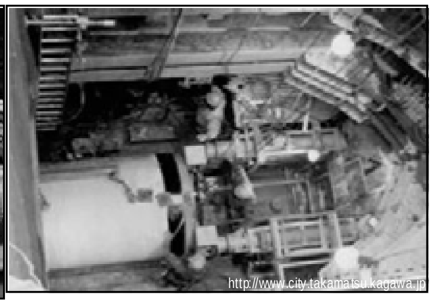
<table>
<tr><th colspan="2">Items</th><th>Open Cut Method</th></tr>
<tr><td rowspan="2">Outline</td><td>Diagram</td><td>

http://park6.wakwak.com/~shokaisaku/



http://www.asahikensetsu.co.jp</td></tr>
<tr><td>Description</td><td>Open cut method is to install pipe in the trench by manual or mechanical excavation. Excavation work is carried out by slope open cut or with earth retaining wall such as sheet pile. All construction works are done above ground.</td></tr>
<tr><td colspan="2">Diameter Range</td><td>Up to 3,000 mm</td></tr>
<tr><td colspan="2">Maximum Length</td><td>No limit</td></tr>
<tr><td colspan="2">Cost</td><td>・ It is the most cost-effective when the depth of cover is small. In Japan, for example, if the depth of cover is smaller than approximately 4m and large structures do not disturb the construction, open cut method is generally more economic than trenchless method.</td></tr>
<tr><td colspan="2">Impact on Environment</td><td>・ If the construction site is a road with much traffic, it affects transportation significantly.
・ Noise and vibration by excavation works often affect living conditions around the construction site.</td></tr>
<tr><td colspan="2">Difficulty of Construction Works</td><td>・ It is the most common and easy method of pipe installation.
・ It is easy to accommodate the changes of the construction conditions and newly revealed conditions after construction commencement such as soil condition, groundwater level, and existence of underground structures.
・ If the groundwater level is much higher than excavation depth, lowering of groundwater level is difficult resulting in deteriorated working conditions.</td></tr>
<tr><td colspan="2">Construction Term</td><td>・ Generally construction term is shorter than trenchless method, if there are no large structures to be removed and re-constructed.</td></tr>
<tr><td colspan="2">Others</td><td>・ If the construction site is a newly constructed road, open cut method is difficult to allow.
・ If it crosses under rivers or large structures which are impossible to move, open cut method can not be applied.</td></tr>
</table>

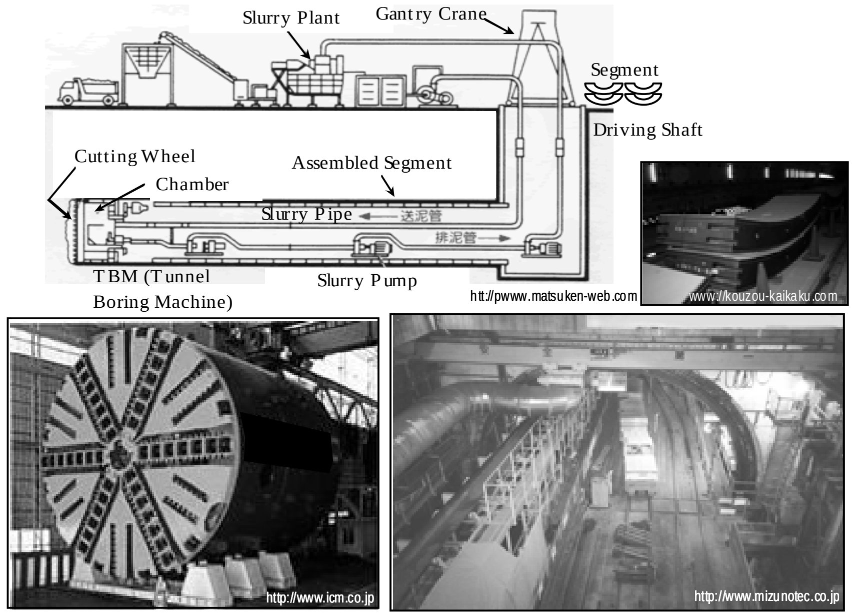
Source: JST

Table 3.3.2 (2) Comparison of Pipe Laying Methods (Pipe Jacking)

Items		Pipe Jacking Method
Outline	Diagram	   
	Description	Pipe jacking method is a trenchless technology method to install a prefabricated pipe through the ground from a drive shaft to a reception shaft. The pipe is propelled by jacks located in the drive shaft. Excavation work is necessary in shaft construction time.
Diameter Range		150mm - 3,000mm
Maximum Length		Approximately 1,000 m by one drive (150 m to 500 m is common)
Cost		・ If depth of cover is large, it is more cost-effective than open cut method. ・ If the face ground is unstable or groundwater level is high, soil reinforcement work such as chemical grouting is necessary, which often requires much cost. ・ Generally, if pipe diameter is under 2,000mm, construction cost is lower than shield tunneling method under the same conditions.
Impact on Environment		・ It can minimize adverse affect on traffic, because excavation work is confined to the vertical shaft sites. ・ It can prevent vibration and noise except those generated by excavation to prepare vertical shafts, which is confined to limited sites. ・ If the ground is soft, it sometimes causes ground subsidence.
Difficulty of Construction Works		・ Amount of excavated soil is smallest among the pipe construction methods. ・ Required area for vertical shafts and plant is smaller than shield tunneling method. ・ It is difficult to accommodate unexpected condition, such as local adverse soil condition and existence of structures revealed after commencement of construction.
Construction Term		・ Construction term is shorter than shield tunneling method, because it uses prefabricated pipe.
Others		・ Jacking method for pipes with diameter of under 800 mm is called microtunneling method. Jacking method for pipes with diameter of over 700 mm can be classified into open type and closed type. Closed type includes slurry type, earth pressure type and mud pressure type.

Source: JST

Table 3.3.2 (3) Comparison of Pipe Laying Methods (Shield Tunneling)

<table>
<tr><th colspan="2">Items</th><th>Shield Tunneling Method</th></tr>
<tr><td rowspan="2">Outline</td><td>Diagram</td><td>
</td></tr>
<tr><td>Description</td><td>Shield tunneling method is a trenchless technology to construct tunnel at the work station of vertical shaft as well as pipe jacking method. In this method, a shield is advanced in accordance with excavation of face ground, and progressively pre-built sections of tunnel wall, so-called segments, are assembled to formulate the complete tunnel structure. This method is suited to long distance drive and large diameter pipe construction works.</td></tr>
<tr><td colspan="2">Diameter Range</td><td>1,350 mm - more than 10,000 mm
(14 m maximum in Japan)</td></tr>
<tr><td colspan="2">Maximum Length</td><td>Approximately 2,000 m by one drive
(Longer drive is possible with special machine)</td></tr>
<tr><td colspan="2">Cost</td><td>・ Generally, construction cost is higher than open cut method and pipe jacking method.</td></tr>
<tr><td colspan="2">Impact on Environment</td><td>・ It can minimize adverse affect on traffic, because excavation work is confined to the vertical shaft sites.
・ It can prevent vibration and noise except those generated by excavation to prepare vertical shafts, which is confined to limited sites.
・ If the ground is soft, it sometimes causes ground subsidence.</td></tr>
<tr><td colspan="2">Difficulty of Construction Works</td><td>・ Amount of excavated soil is larger than pipe jacking method.
・ Required area for vertical shaft and plant is larger than pipe jacking method.
・ It is difficult to accommodate unexpected condition, such as local adverse soil condition and existence of structures revealed after commencement of construction.
・ Long distance and sharp curving drives are possible.</td></tr>
<tr><td colspan="2">Construction Term</td><td>・ Construction term is longer than pipe jacking method.</td></tr>
<tr><td colspan="2">Others</td><td>・ Shield tunneling method is classified into open type and closed type. Open type includes manual type and mechanical type. Closed type includes slurry shield and earth pressure balanced shield.</td></tr>
</table>

Source: JST

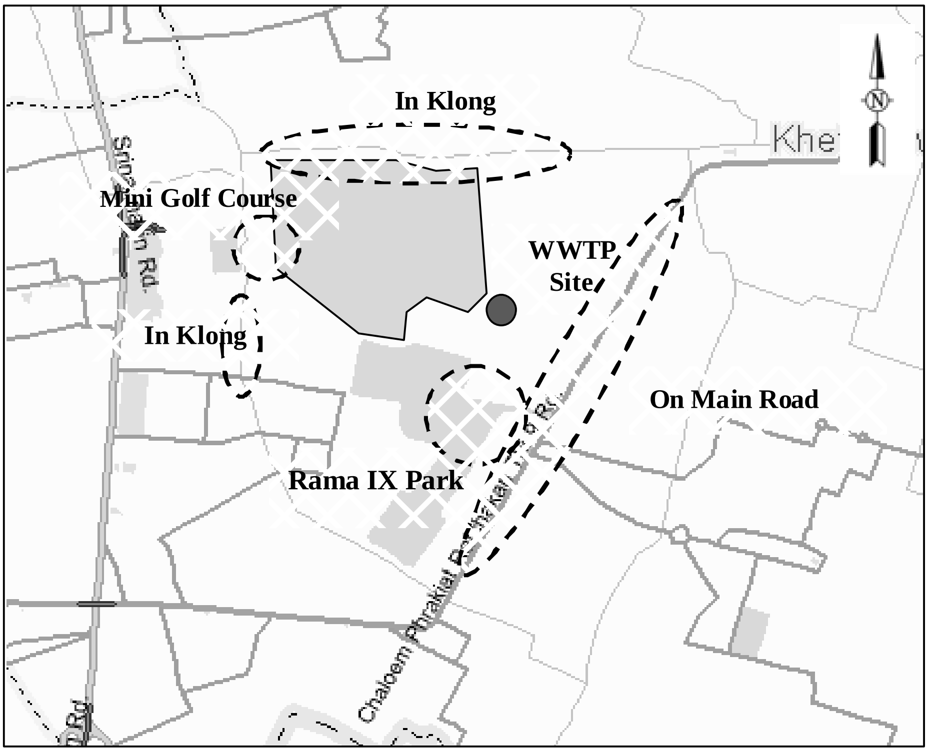
3.3.5 Sites for Pumping Stations

(1) Necessity of Pumping Stations

Newly constructed interceptor gradually increase its depth since wastewater intercepted flows by gravity to the WWTP in dry weather. In case interceptor is excessively deep, a pumping station is to be provided to raise the interceptor. Provision of a pumping station requires construction, operation and maintenance costs for equipment which is not necessary for gravity interceptor. Therefore, number of pumping stations should be minimized.

(2) Possible Sites for Pumping Stations

Manhole type pumping stations which can be constructed under roads can be applied in upstream portion of interceptor network in Nong Bon treatment area. However, in downstream portion of the network, where wastewater flow and depth of interceptor increase, manhole type pumping station can not be applied and a sizable site is required for construction of pumping station. Since Nong Bon WWTP is located near Rama IX Park, pumping stations are most likely to be located near Rama IX Park. Possible sites for pumping stations are shown in Figure 3.3.5.



Source: JST

Figure 3.3.5 Possible Sites for Pumping Stations

(3) Selection of Sites for Pumping Stations

Possible sites for pumping stations near WWTP are on main road (Charon Phrakiat Ratchakan Thi 9 Road), in klongs, in the mini golf course and in Rama IX Park. Problems for each site are as follows.

1) There is heavy traffic on the main road, and traffic jam occurs every time. Construction of a pumping station and maintenance work will worsen traffic condition. It is therefore considered not appropriate to construct a pumping station on main road.
2) Klongs near WWTP site are very narrow in width, and it is difficult to construct a pumping station in these klongs.
3) There is enough space for pumping station in mini golf course. However, this land is privately owned and acquisition of land may hinder smooth implementation of the project. This site is not considered appropriate for pumping station.

Taking into account the above, appropriate site for pumping station is found only in Rama IX Park. Since Nong Bon WWTP is located adjacent to Rama IX Park, pumping station is provided in WWTP and no pumping station is planned near WWTP site.

3.3.6 Current and Future Plan of Other Large Underground Structures

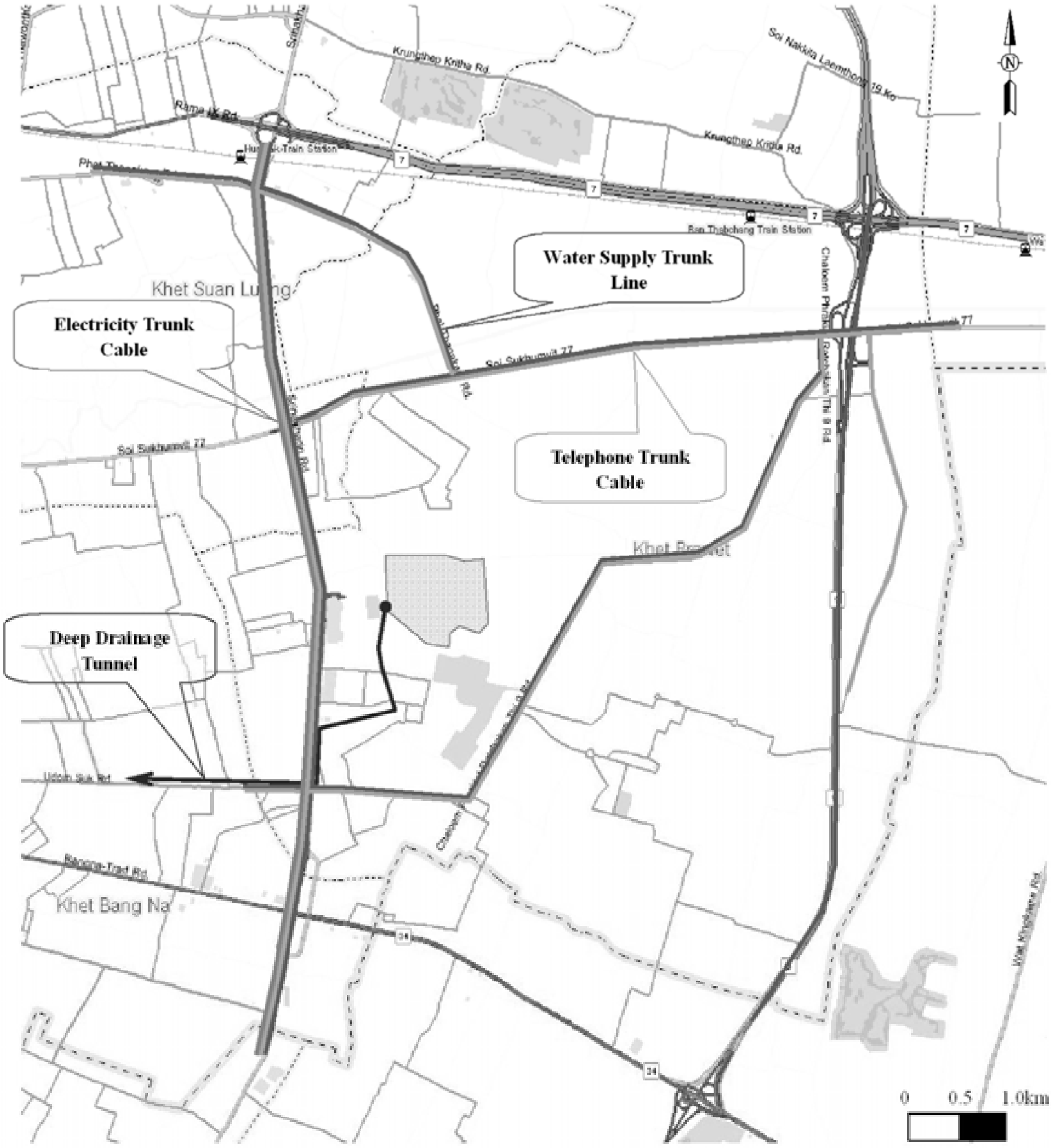
Public utilities other than drain pipes are constructed under roads and klongs in Nong Bon treatment area. Also future plan of these public utilities exists. Public utilities such as water supply, telephone, electricity are laid underground in Nong Bon treatment area. Construction of a deep drainage tunnel in future is planned. Mass transportation system, Yellow Line is planned in the area. However, this line is not metro but elevated rail in the area. Locations of these existing and planed large underground utilities are shown in Figure 3.3.6.

Under the main roads in Nong Bon treatment area, such as Srinakharin Road, On Nuch Road, Phat Thanakan Road, Chaloen Phrakiat Ratchakan Thi 9 Road and Udon Suk Road, the following large underground utilities are laid.

- Water supply pipes: depth less than 2 – 3 m
- Telephone cable: depth less than 2 m
- Electricity cable: depth less than 2 – 3 m

Depths of interceptors planned in this Survey under these main roads are 8 to 18 m. Therefore, these existing underground utilities are not obstruction for pipe laying. However, attention should be paid to these underground utilities to determine locations of vertical shafts at detailed design stage.

A deep drainage tunnel is planned near Klong Nong Bon. Depth of the tunnel is 20 to 30 m. Depths of interceptors near Klong Nong Bon are 5 to 10 m. Therefore, tunnel will be constructed more than 10 m deeper than interceptors, and interceptors are not obstruction.

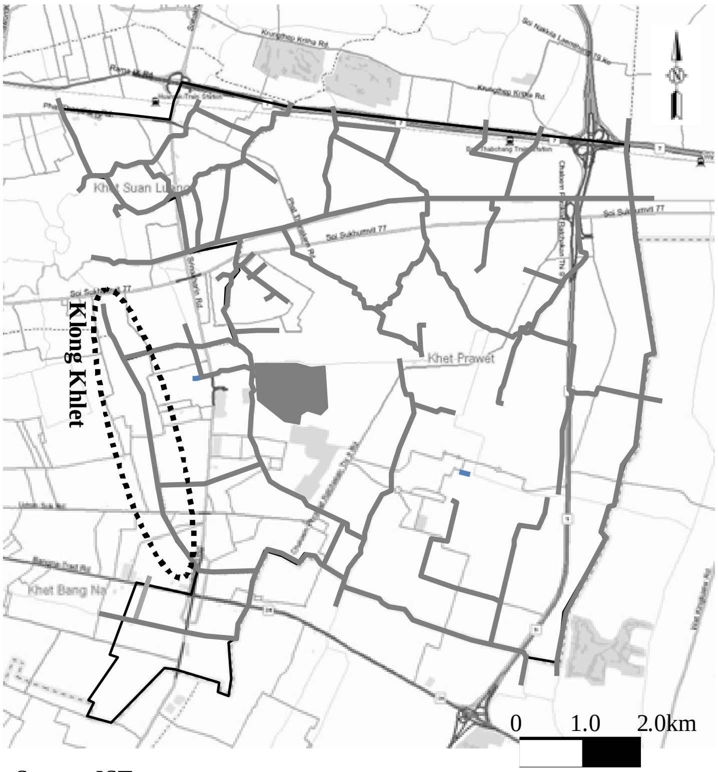


Source: JST

Figure 3.3.6 Location of the Existing and Future Large Underground Utilities

3.3.7 Wastewater Collection Method for Direct Discharge to Klong

In Nong Bon treatment area, most of wastewater from households is discharged to klongs through the existing drain pipes installed along the road same as in the other existing treatment areas in BMA. However from households and apartment houses built in adjacent to klongs, wastewater is discharged to the klongs directly not through the drain pipes. There are many houses along Klong Khlet which runs in the western part of the treatment area (refer to Figure 3.3.7 and Photo 3.3.2).



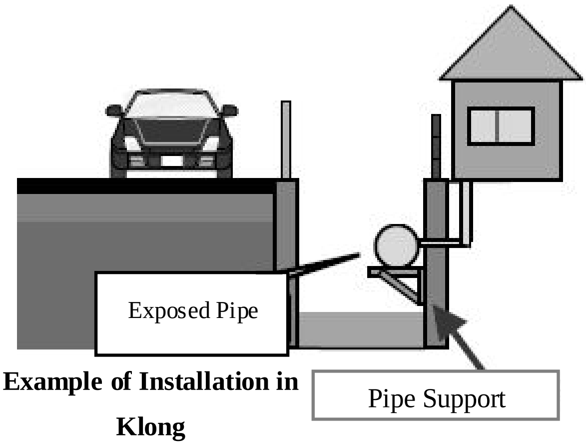
Source: JST

Figure 3.3.7 Location of Klong Khlet

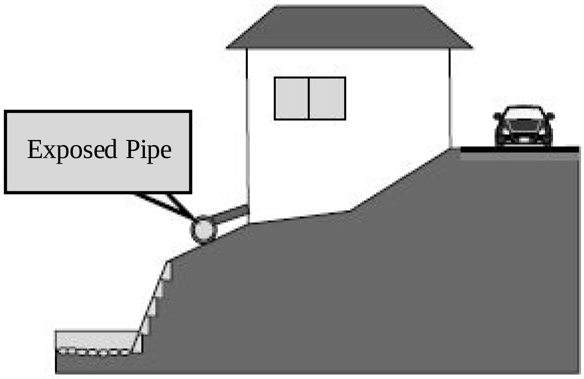
Photo 3.3.2 Direct Discharge from Houses along Klong Khlet

Combined system (interceptor sewerage system) is adopted in Nong Bon treatment area as well as in the other treatment areas in BMA. An interceptor chamber is constructed at upstream of outlet to intercept wastewater to interceptor. Construction of an interceptor chamber is difficult at the point where wastewater is discharged from a house to klong directly.

It is proposed that a method to collect wastewater by exposed pipes installed along a klong and intercepted at downstream be adopted, which is often seen in the mountainous areas in Japan. Pipe materials which is robust against external impact, such as polyester pipes should be used. An image of exposed pipe is shown in Figure 3.3.8.



Example of Installation in Klong



Example of Installation behind House

Source: JST

Figure 3.3.8 Example of Installation of Exposed Pipe

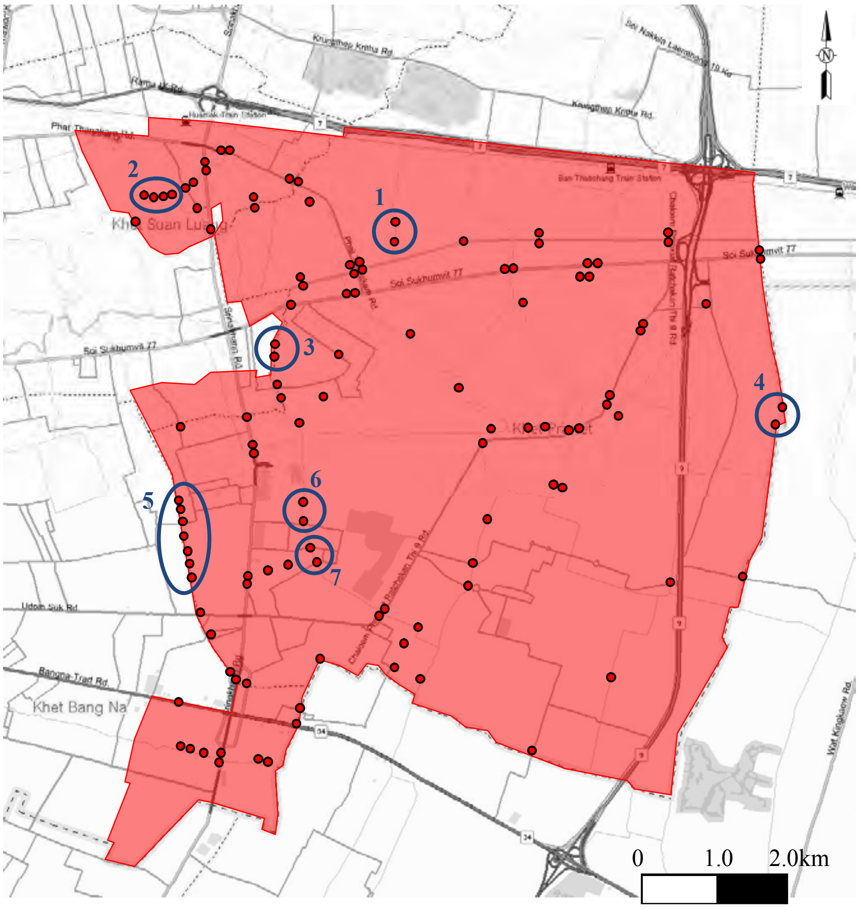
3.3.8 Reduction of Number of Interceptor Chamber

Topographical features of Nong Bon treatment area is flat and low-lying as well as other treatment areas in BMA. Many submerged outlet pipes are observed even in dry weather among 136 outlets in the area. Interceptor chambers are to be constructed to intercept wastewater in Nong Bon treatment area. It is the same system adopted in the other treatment areas in BMA. A flap gate is to be provided to prevent backwater from klong as shown in Figure 3.3.2. Level of the weir in an interceptor chamber is to be designed above water level in klong if possible. However, if a flap gate is not closed completely by clogging with garbage, back flow from klong can not be stopped. Therefore periodical cleaning of interceptor chambers are required.

Although periodical cleaning of interceptor chambers is conducted in the other treatment areas, it takes considerable time and effort because of number of interceptor chambers and heavy traffic on main roads. It is therefore important to reduce number of interceptor chambers by integrating them in order to make operation and maintenance easy and to solve problems such as klong water back flow and untreated wastewater discharge.

The method to reduce interceptor chamber is that a few of interceptor chambers closely located are integrated into one chamber and close all the outlets of the remaining chambers. Seven places where this method can be applied in Nong Bon treatment area are shown in Figure 3.3.9. Explanation how to reduce interceptor chambers in there seven places is shown in Figure 3.3.10.

Total number of interceptor chambers can be decreased from 136 to 121 by this method. However, since the existing drain pipes and outlets are under the responsibility of PWD, consultation and coordination with PWD would be required to apply this method.



Source: JST

Figure 3.3.9 Seven Places Proposed for Reduction of Interceptor Chambers

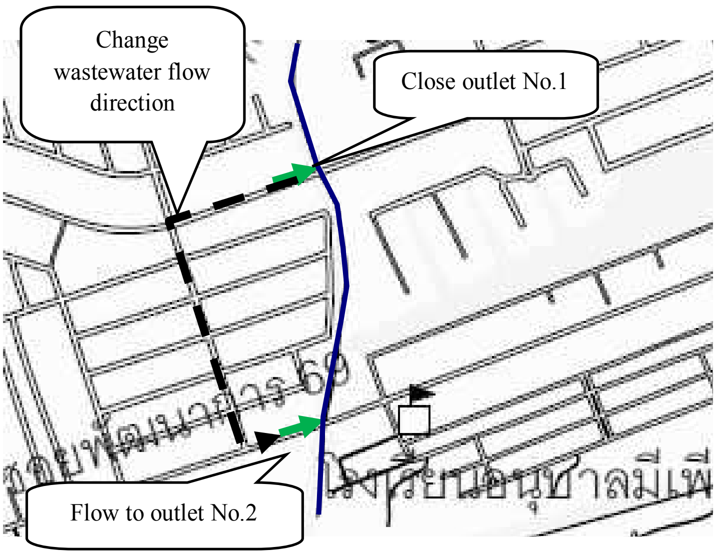
No.	Method of Reduction	Explanation
1		1) Close outlet No.1 2) Change wastewater flow from outlet No.1 to outlet No.2 by replacing the existing drain pipe or installation of new pipe.

Figure 3.3.10 (1) Methods to Reduce Interceptor Chambers

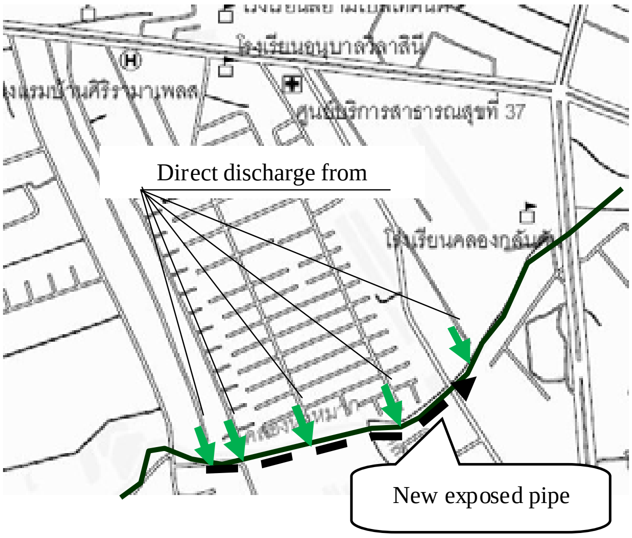
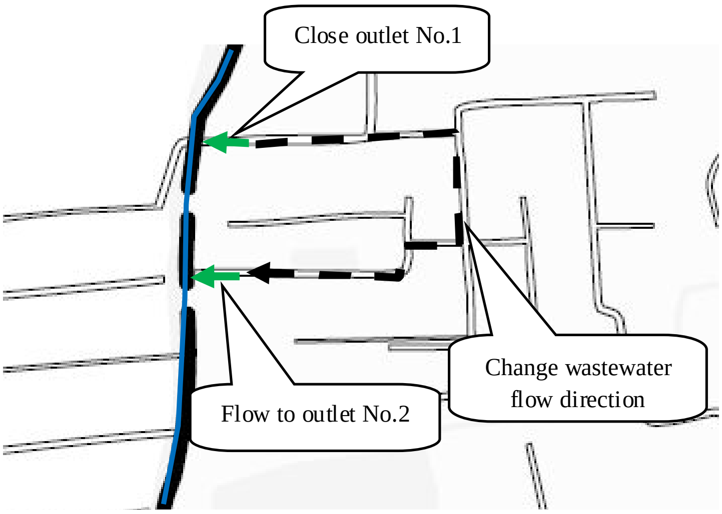
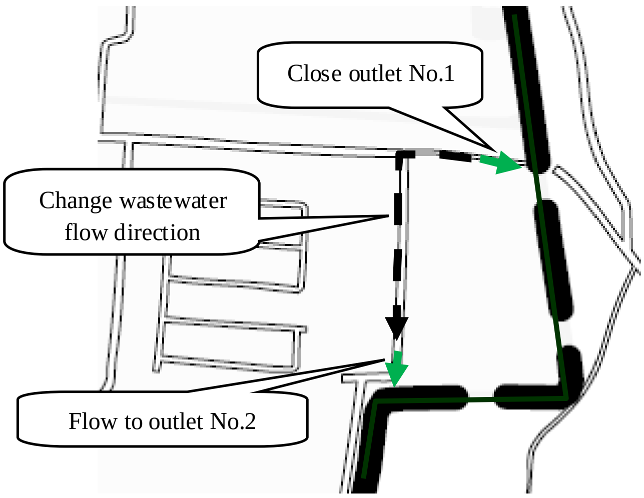
No.	Method of Reduction	Explanation
2		1) Five outlets discharge wastewater from households. New exposed pipes are installed to collect wastewater. 2) A new interceptor chamber is constructed to collect wastewater from exposed pipe.
3		1) Close outlet No.1. 2) Change wastewater flow from outlet No.1 to outlet No.2 by replacing the existing drain pipe or installation of new pipe.
4		1) Close outlet No.1. 2) Change wastewater flow from outlet No.1 to outlet No.2 by replacing the existing drain pipe or installation of new pipe.

Figure 3.3.10 (2) Methods to Reduce Interceptor Chambers

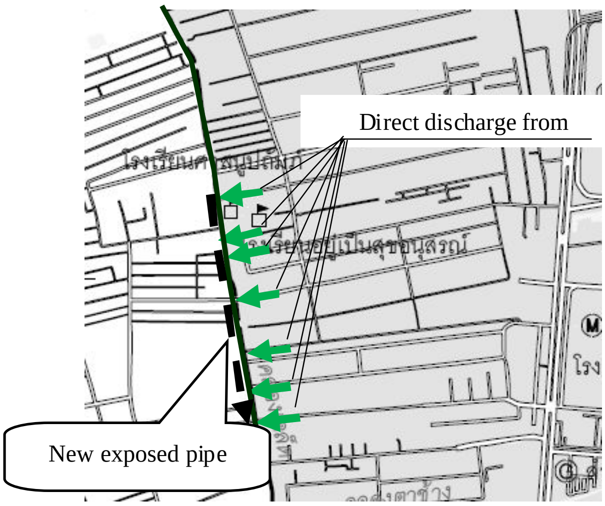
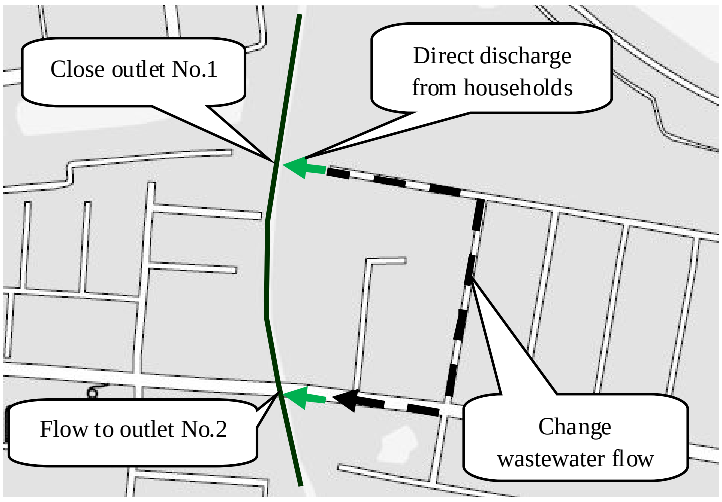
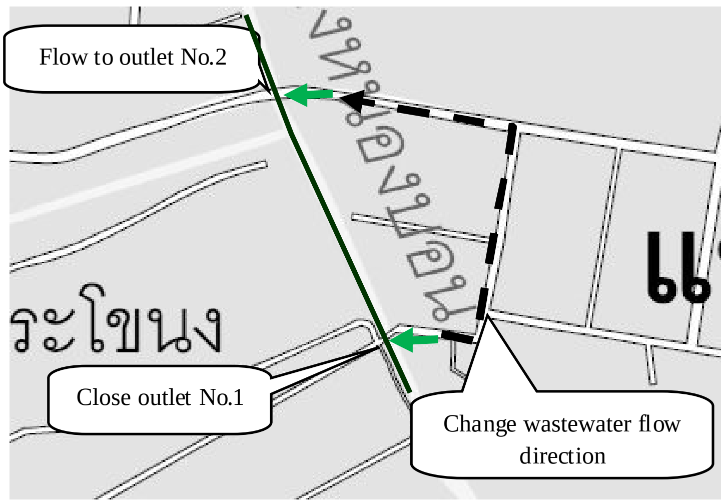
No.	Method of Reduction	Explanation
5		1) Seven outlets discharge wastewater from households. New exposed pipes are installed to collect wastewater. 2) A new interceptor chamber is constructed to collect wastewater from exposed pipe
6		1) Close outlet No.1. 2) Connect to the existing drain pipe correctly. 3) Change wastewater flow from outlet No.1 to outlet No.2 by replacing the existing drain pipe or installation of new pipe.
7		1) Close outlet No.1. 2) Change wastewater flow from outlet No.1 to outlet No.2 by replacing the existing drain pipe or installation of new pipe.

Figure 3.3.10 (3) Methods to Reduce Interceptor Chambers