NATIONAL DEVELOPMENT PLANNING AGENCY
MINISTRY OF PUBLIC WORKS
THE PROVINCIAL GOVERNMENT OF DKI JAKARTA
THE REPUBLIC OF INDONESIA

PREPARATORY SURVEY ON CENTRAL SEWERAGE TREATMENT SYSTEM IN JAKARTA

FINAL REPORT

VOLUME 2 : SUPPORTING REPORT

MARCH 2013

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIX CORPORATION
ORIENTAL CONSULTANTS
NIHON SUIDO CONSULTANTS
NIPPON KOEI
WATER AGENCY
YOKOHAMA WATER
PADECO
MARSH BROKER JAPAN

O S
J R
13-043

NATIONAL DEVELOPMENT PLANNING AGENCY
MINISTRY OF PUBLIC WORKS
THE PROVINCIAL GOVERNMENT OF DKI JAKARTA
THE REPUBLIC OF INDONESIA

PREPARATORY SURVEY ON CENTRAL SEWERAGE TREATMENT SYSTEM IN JAKARTA

FINAL REPORT

VOLUME 2 : SUPPORTING REPORT

MARCH 2013

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIX CORPORATION
ORIENTAL CONSULTANTS
NIHON SUIDO CONSULTANTS
NIPPON KOEI
WATER AGENCY
YOKOHAMA WATER
PADECO
MARSH BROKER JAPAN

Table of Contents

List of Figute

List of Table

Abbreviations and Glossary

ADB	Asian Development Bank
ATP	Affordability to Pay
ASP	Activated Sludge Process
BAPPEDA	Regional Development Planning Board
BAPPENAS	National Development Planning Board
BOD	Biochemical Oxygen Demand
BPLHD	Regional Environment Management Board
CIPTA KARYA	Directorate General of Human Settlements, PU
CVM	Contingent Valuation Method
Dinas PU (DKI)	Department of Public Works, Province of DKI Jakarta
DKI Jakarta	Jakarta Capital City
GOI	Government of Indonesia
IBRD	International Bank for Reconstruction and Development
IC	Interconnection Chamber
IPAL	Instalasi Pengolahan Air Limbah
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JPY	Japanese Yen
JWSRB	Jakarta Water Supply Regulatory Body
MBBR	Moving Bed Biofilm Reactor
MBR	Membrane Bioreactor
MLSS	Mix Liquor Suspended Solid
MP	Master Plan
O&M	Operation and Maintenance
ODA	Official Development Assistance
OJT	On-the-Job Training
PLN	Perusahaan Listrik Negara (State Electricity Company)
PPP	Public-Private Partnership
PU	Department of Public Works
Rp (IDR)	Indonesian Rupiah
SS	Suspended Solid
STP	Sewage Treatment Plant = Wastewater Treatment Plant
UFRP	Underground Flood Retention Pond
USD	US Dollar
WTP	Willingness to Pay
WWTP (=STP)	Sewage Treatment Plant = Wastewater Treatment Plant

Preface

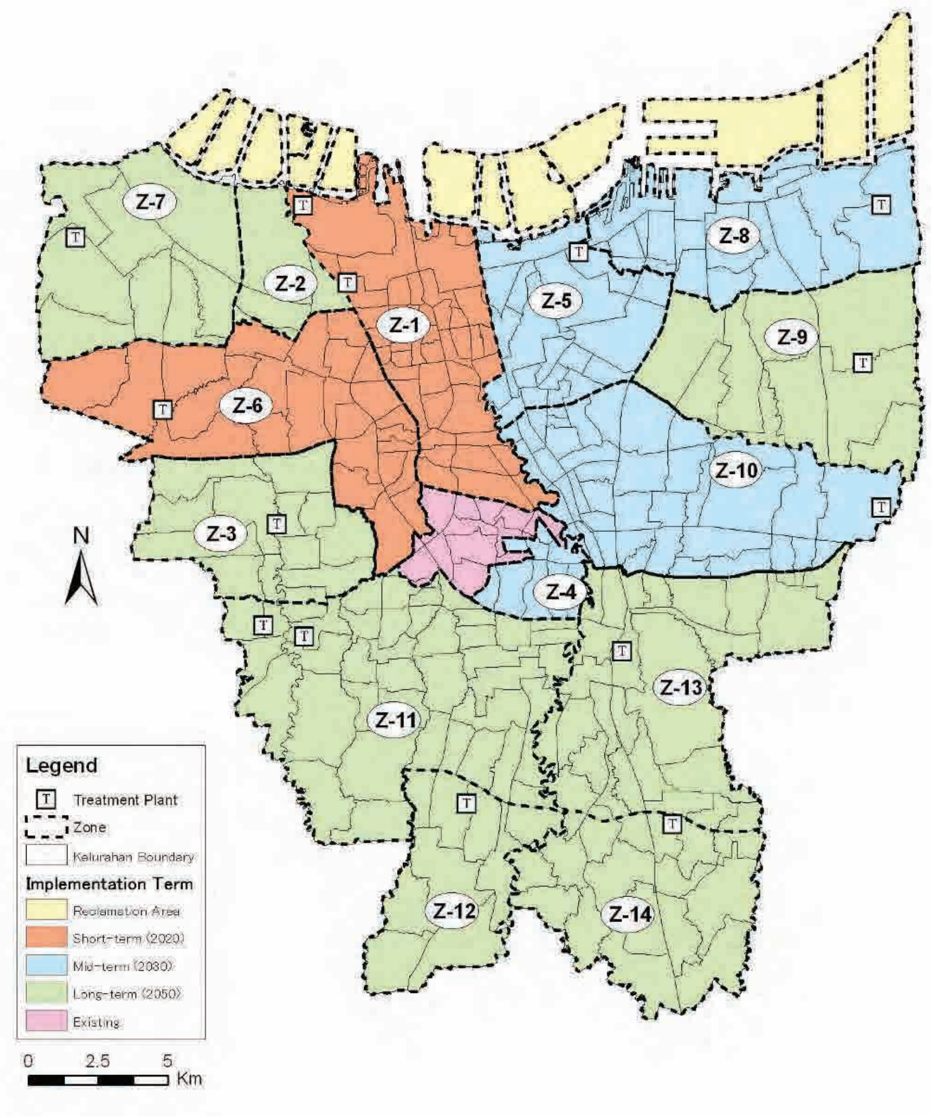
Volume 2 has been prepared as a supporting report of Volume 1 (Main Report) and mainly covers the design, study and survey results for a sewer system, a sewage treatment plant, treated water reclamation, sewage sludge recycling, storm water reservoir and an integrated monitoring system, based on which, in Volume 1, the Study Team proposes that the PPP Project should be composed of only the sewer system and sewage treatment plant.

Chapter 1 Sewer Development Plan

1.1 Outline of Sewer System

(1) General

The Project areas for DKI Jakarta sewerage development were decided by the “Project for Capacity Development of Wastewater Sector through Reviewing the Wastewater Management Master Plan in DKI Jakarta in the Republic of Indonesia” (hereinafter called the “MP Review”). Among these Project areas, Zone 1 has the highest priority. This zone covers an area of 4,901 ha.



Source: MP Review

Figure 1-1 Sewerage Areas and Zoning in the MP Review

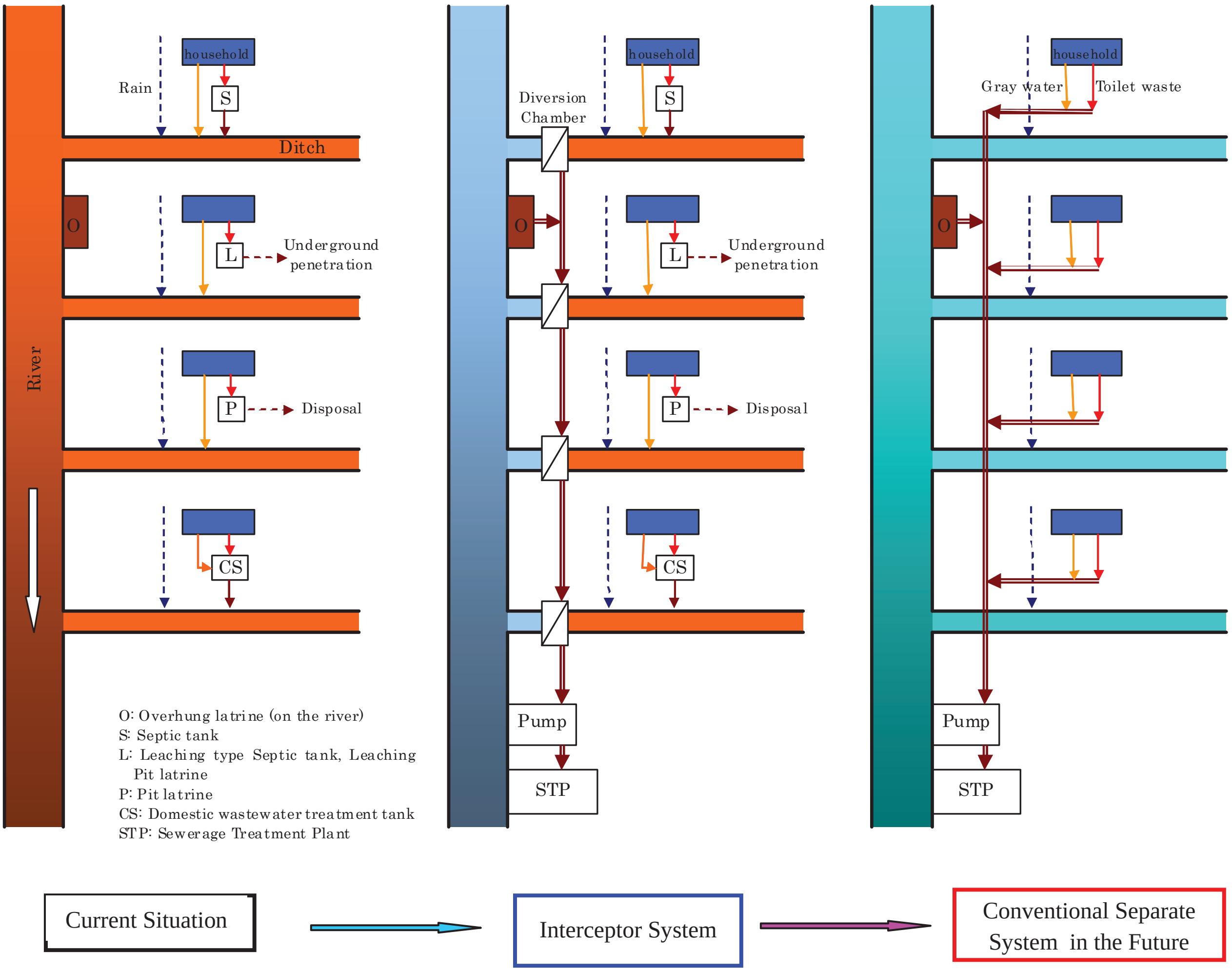
a) Target year in this Study: 2050 (Long-term), 2030 (Mid-term), 2020 (Short-term)

b) Target percentage of sewered population: 80%

c) Sewerage service population in Zone 1: 1,236,736 in 2030 (and up to 2050)

In this Study, development of an interceptor sewer system is recommended as the first step of step-wised sewerage development. This system will be further developed into a conventional separate sewer system in the future. (Refer to Chapter 5.1.1 of the Main Report.)

The image of step-wised sewerage development is as shown below:



Source: JICA PPP Study Team

Figure 1-2 Step-wised Sewerage Development

(2) Proposed Sewer Pipe Network Plan

The trunk sewer and sub-trunk sewer are planned considering the following principles:

a) Pipe flow shall basically be gravity flow. (To avoid pump stations as much as possible.)

b) Burial depth of pipe shall be as shallower as possible to avoid special construction methods such as shield and pipe-jacking methods.

c) The sewer route shall be well coordinated with the other development plans of infrastructures such as roads, subways, etc.

The following two pipeline network plans were considered in this Study.

1) Alternative 1: To avoid interference with the north–south subway line

2) Alternative 2: To install two trunk sewer lines along the north–south subway line.

Alternative 2 may provide the easiest method for collecting the wastewater from the most developed commercial area in Zone 1; however, it may interfere with the subway construction and may hamper smooth and timely implementation of the Project.

The wastewater from the commercial area along the north–south subway line is drained not to streets on the subway side, but to rivers on the opposite side. Therefore, it is reasonable to collect the wastewater from the commercial area at the river sides rather than collecting it at the main streets along the subway.

For the above reasons, Alternative 1 is recommended.

Source: JICA PPP Study Team

Figure 1-3 Trunk Sewer Network, Alternative 1 (avoiding North–South Subway Line)

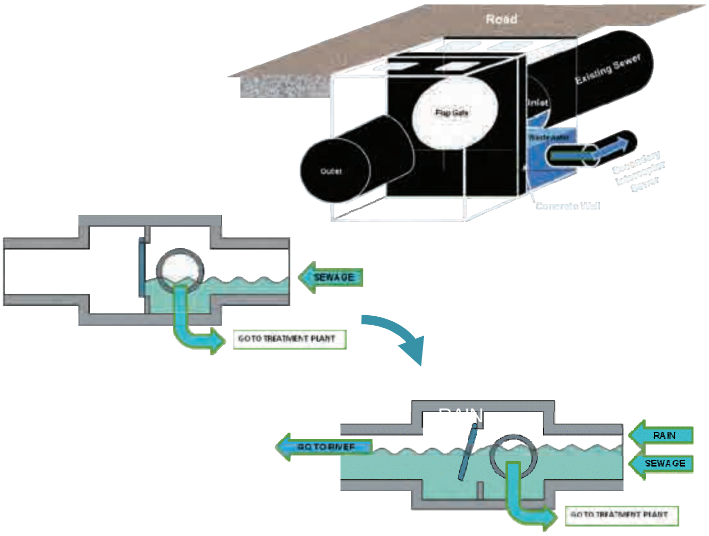
Source: JICA PPP Study Team

Figure 1-4 Trunk Sewer Network, Alternative 2 (along North–South Subway Line)

(3) Alignment of Trunk and Sub-trunk Sewers

Trunk and sub-trunk sewers shall be planned and designed considering the following points:

1) The following figure illustrates an example of a diversion chamber. Since wastewater flows into the existing drainage ditches (or culverts), diversion chambers shall be installed in close proximity to the outlets of the existing ditches in order to efficiently collect the wastewater. In addition, it is desirable to install at the location (elevation) where stormwater can be discharged promptly when the water level exceeds the design water level. At the stage of detailed design, locations of diversion chambers shall be examined considering the existing drainage network and the conditions of canals including the flood gates, pump stations, etc. Since the roads along the canals where the existing drainage outlets are generally narrow, diversion chambers need to be made a compact size.



2) Diversion chambers shall be a structure that only the sewage flows into the interceptor pipe at the fine weather and at the rain, the stormwater beyond the treatment capacity of STP shall be discharged into the canals through the drainage outlets. The diversion chambers shall have flap gates to prevent backflow of the stormwater during the rain or the canal water, level of which may be influenced by the tide. Countermeasures to prevent the overflood (inflow) at the pumping station in STP shall also be required. In addition, countermeasures such as providing a screen to prevent the inflow of gabage, etc. need to be examined because inflow of a large volume of gabage from the existing drainage ditch is expected. From these points of view, detailed structural examination of diversion chambers and consideration of maintenance are essential.

3) Trunk sewers shall be installed along the existing canals to efficiently connect diversion chambers and to enable economical connection of sewer pipes by shorter routes. However, if the road width along canals is too narrow to allow construction of trunk and sub-trunk sewers,

the sewers need to be shifted to the nearest road (red line in the figure below) that has enough width to accommodate them. In this case, connection pipes (yellow lines in the figure below) will be installed along small roads between trunk and sub-trunk sewers and diversion chambers located near the canals.

4) Interference with the existing structures (concrete sheet pile revetment, water pipes, power cables, etc.) along the route of sewers shall be avoided as much as possible. Where concrete sheet pile revetment exists at canals, only major trunk sewers should be allowed to cross the canals. Small diameter pipes (e.g., secondary and tertiary sewers) shall be installed to avoid interference with obstacles as much as possible.

5) The longitudinal height of the sewer shall be shallow enough to allow connection of wastewater collection systems when the conventional separate sewer is introduced in the future. Moreover, manholes, etc. shall be properly located for easy connection in the future.

A sewer network plan including the main trunk, sub-trunk sewer and tertiary sewer is proposed considering the above as shown in Figure 1-5. Table 1-1 shows sewer line length by diameter. (Lengths of the main trunk, sub-trunk sewer and tertiary sewer of φ200 mm are measured on the drawings. Collection pipes of φ150 mm are assumed as 50 m per a diversion chamber. Diameter of the collection pipes is assumed one.)

Table 1-1 Sewer Line Length by Diameter, Zone 1

Pipe Diameter (mm)	Distance (m)	Construction Method		Pipe Slope (‰)	Distance of Pipe Jacking Method							Distance of Pipe Open Trench Method				Nos of Manhole					Nos of Diversion Chamber	Remarks
		Pipe jacking method	Open trench method		3 m	5 m	7 m	9 m	10 m	>10m	SubTotal	1.5 m	3 m	5 m	SubTotal	Type 1	Type 2	Type 3	Type 4	SubTotal		
φ 150	168	0	168	3.0	0	0	0	0	0	0	0	168	0	0	168	2	0	0	0	2	5	Secondary & Tertiary Sewer
φ 200	1,397	713	684	3.0	100	613	0	0	0	0	713	0	684	0	684	7	14	0	0	21	15	
φ 250	1,478	508	969	2.8	0	508	0	0	0	0	508	0	969	0	969	11	8	0	0	19	8	
φ 300	5,972	1,891	4,082	2.8	0	1,891	0	0	0	0	1,891	2,471	1,610	0	4,082	42	31	0	0	73	30	
φ 350	7,830	2,996	4,835	4.0	800	2,196	0	0	0	0	2,996	588	4,247	0	4,835	51	49	0	0	100	54	Main Sewer
φ 400	10,931	5,658	5,273	3.5	100	1,324	1,734	0	2,500	0	5,658	752	4,521	0	5,273	44	106	0	0	150	69	
φ 450	5,113	1,820	3,293	3.0	246	500	1,074	0	0	0	1,820	602	2,691	0	3,293	38	30	0	0	68	50	
φ 500	7,104	3,441	3,663	2.8	0	665	0	1,220	814	742	3,441	2,434	1,228	0	3,663	33	53	0	0	86	58	
φ 600	6,520	5,222	1,298	2.6	0	637	1,222	2,951	411	0	5,222	0	1,298	0	1,298	13	67	0	0	80	24	
φ 700	10,915	10,850	65	2.4	1,616	560	2,537	2,558	803	2,776	10,850	65	0	0	65	0	0	139	0	139	30	
φ 800	9,399	8,610	789	2.2	0	3,723	278	0	1,368	3,241	8,610	0	789	0	789	0	0	53	0	53	23	
φ 900	4,371	4,371	0	2.0	0	704	1,116	0	0	2,552	4,371	0	0	0	0	0	0	18	0	18	36	Trunk Sewer
φ 1,000	7,165	7,165	0	1.8	0	1,647	1,285	0	38	4,196	7,165	0	0	0	0	0	0	20	0	20	32	
φ 1,100	3,283	3,283	0	1.6	0	0	629	0	0	2,654	3,283	0	0	0	0	0	0	11	0	11	2	
φ 1,200	1,810	1,810	0	1.6	0	0	0	0	0	1,810	1,810	0	0	0	0	0	0	7	0	7	0	
φ 1,350	1,130	1,130	0	1.5	0	0	0	0	0	1,130	1,130	0	0	0	0	0	0	4	0	4	6	
φ 1,500	466	466	0	1.4	0	0	0	0	0	466	466	0	0	0	0	0	0	2	0	2	0	
φ 1,650	970	970	0	1.3	0	0	0	0	0	970	970	0	0	0	0	0	0	4	0	4	0	
φ 1,800	0	0	0	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
φ 2,000	1,941	1,941	0	1.2	0	0	0	0	0	1,941	1,941	0	0	0	0	0	0	0	5	5	0	
φ 2,200	1,423	1,423	0	1.1	0	0	0	0	0	1,423	1,423	0	0	0	0	0	0	0	5	5	2	
Total	89,386	64,267	25,119		2,862	14,967	9,875	6,730	5,934	23,900	64,267	7,081	18,038	0	25,119	241	358	258	10	867	444	

BOQ Summary of Tertiary & Collecting Sewer Pipe

Pipe Diameter (mm)	Distance (m)	Nos of Manhole	Remarks
Tertiary Pipe (φ150-250)			
φ 200	27,877	627	Average diameter
Collecting Sewer Pipe			
φ 150	22,200	−	

Source: JICA PPP Study Team

Figure 1-5 Proposed Sewer Pipe Network in Zone 1

Source: JICA PPP Study Team

1.2 Design Conditions

(1) Design Wastewater Discharge

According to the MP Review, pollution loads per capita are as follows:

Table 1-2 Pollution Loads per Capita in the MP Review (2030 – 2050)

Domestic (LCD)	Non-domestic (Commercial, Governmental & Industrial) (LCD)	Total (LCD)
150	50	200

LCD: liter/cap. day

Source: MP Review

Design wastewater discharge (target year 2030 – 2050) is calculated from the planned population (administrative population x percentage of sewered population 80%) and the above pollution load in the MP Review.

Table 1-3 Design Wastewater Discharge in Zone 1 (2030 – 2050)

Administrative Population (2030) (cap.)	Percentage of Sewered Population (%)	Planned Population (2030) (cap.)	Unit Wastewater Consumption (LCD)	Design Wastewater Discharge (Average daily flow) (m^3/day)
1,236,736	80	989,389	200	198,000 (197,878)

Source: MP Review

(2) Design Criteria

1) Construction material

Pipe materials that are generally used as sewer pipes are a reinforced concrete (RC) pipes, unplasticized polyvinyl chloride (PVC) pipes, vitrified clay pipes, fiberglass reinforced plastic mortar (FRPM) pipes, etc.

PVC pipes are lightweight and have good construction workability. Moreover, the roughness coefficient is low and therefore, the water flow is smooth. However, the cost of PVC pipe with a diameter of more than 350 mm is high and reinforced concrete pipe is more economical than PVC pipe. Therefore, PVC pipe is recommended for sewer pipes smaller than φ300 mm and RC pipe is recommended for sewer pipes larger than φ 350 mm.

The manhole type adopted in this Study is a cast-in-place type in principle. There is an assembly manhole (system manhole) as another type although it is expensive. In the detailed design stage, usage of the assembly manhole shall be examined since it is beneficial in terms of "the reliability of quality," "the shortening of a construction period" and "the relief of traffic jams".

2) Peak flow factor

The following formula is adopted to estimate a (maximum hourly) peak flow factor to daily average wastewater discharge. The proposed formula is the same as one used in the 1991 Master Plan and JSSP that is located adjacent to the Project area, but not following the MP Review.

$F = 4.02\ (0.0864 \cdot Q)^{-0.154}$

Where,

F: Peak flow factor to daily average wastewater discharge
Q: Daily average wastewater discharge in l/s

3) Groundwater infiltration

Groundwater infiltration to sewer pipes is not considered in the design since it is considered that “the groundwater infiltration amount” and “the water loss due to watering for gardens, vehicle washing, etc. in water supply consumption” are almost equivalent.

4) Flow velocity

In the calculation of flow velocity, Manning’s Formula is applied for gravity flow and Hazen-Williams’ Formula is applied for pressure flow.

Manning’s Formula is as shown below:

$V = 1/n \cdot R^{2/3} \cdot I^{1/2}$

Where,

V: Mean velocity (m/s)
n: Roughness coefficient
R: Hydraulic radius (m)
I: Hydraulic gradient (m/m)

Roughness coefficient (n) is assumed as follows:

Pipe Material	n
RC Pipe	0.013
Vitrified Clay Pipe	0.013
PVC Pipe	0.010
FRPM	0.010

Hazen-Williams' Formula is as shown below:

$V= 0.84935C \cdot R^{0.63} \cdot I^{0.54}$

Where,

V: Mean velocity (m/s)

C: Coefficient (C=110 for PVC pipe, 100 for cast iron pipe)

R: Hydraulic radius (m)

I: Hydraulic gradient (m/m)

The minimum velocity should be 0.6 m/s in order to prevent sediment deposition and minimize sulfide formulation. The maximum velocity should be 3.0 m/s in order to prevent erosion of pipe material.

5) Allowance of sewer pipe capacity

Allowance of sewer pipe capacity to design peak discharge is determined as follows:

Sewer Diameter (m)	Allowance (%)
ϕ 150 – 300	100
ϕ 350 – 800	50
Larger than ϕ 900	30

6) Depth of sewer pipe laying

The minimum earth cover for laying sewer pipe should be 1.0 m.

7) Manhole interval

Sewer pipes with a diameter smaller than 800 mm are not large enough for personnel to enter. Since cleaning of such small pipes needs to be conducted by remote operation, the manhole interval shall be limited to 100 m.

On the other hand, the manhole interval for sewer pipes larger than 900 mm can be extended to 200 m.

Table 1-4 Flow Calculation

Line No.	Line No. of	Sewer Length (m)		Sewage Area (ha)		Population		Average Flow (m^3/d)			Peak	Max. Flow (m^3/s)			Sewer Line				Sewer Invert Elevation		Ground Elevation (m)		Earth Covering (m)	
	Lower Sewer	Increment	Total	Increment	Total	Increment	Total	Sewage	Inlet	Total	Factor	Sewage	Infilt.	Toatl	Diameter (mm)	Slope (‰)	V (m/s)	Cap. (m3/s)	Upper end	Lower end	Upper end	Lower end	Upper end	Lower end
ST - 1	ST - 2	2,434	2,434	125.5	125.5	15,768	15,768	3,154	0	3,154	3.368	0.123	0.000	0.123	500	2.8	1.018	0.200	9.550	2.394	11.60	4.60	1.51	1.66
ST - 2	ST - 3	389	2,823	13.9	199.1	1,749	20,566	4,113	0	4,113	3.233	0.154	0.000	0.154	600	2.6	1.107	0.313	-1.193	-2.429	4.60	3.28	5.14	5.06
ST - 3	ST - 4	40	2,863	0.0	273.4	0	29,906	5,981	0	5,981	3.052	0.211	0.000	0.211	700	2.4	1.179	0.454	-2.429	-2.600	3.28	3.28	2.86	5.13
ST - 4	ST - 5	520	3,383	14.0	303.7	1,757	33,707	6,741	0	6,741	2.996	0.234	0.000	0.234	700	2.4	1.179	0.454	-2.600	-4.148	3.28	2.09	5.12	2.94
ST - 5	MT - 1	278	3,662	0.0	335.3	0	45,665	9,133	0	9,133	2.860	0.302	0.000	0.302	800	2.2	1.234	0.620	-4.148	-4.911	2.09	4.20	5.37	8.24
MT - 1	MT - 2	939	4,600	0.0	425.4	0	70,215	14,043	0	14,043	2.676	0.435	0.000	0.435	900	2.0	1.273	0.810	-4.911	-7.313	4.20	9.80	8.14	16.14
MT - 2	MT - 3	108	4,709	0.0	479.8	0	87,002	17,400	0	17,400	2.589	0.521	0.000	0.521	900	2.0	1.273	0.810	-7.313	-7.605	9.80	8.60	16.14	15.23
MT - 3	MT - 4	621	5,330	0.0	587.0	0	99,290	19,858	0	19,858	2.537	0.583	0.000	0.583	900	2.0	1.273	0.810	-7.605	-9.222	8.60	2.43	15.23	10.68
MT - 4	MT - 5	38	5,368	0.0	621.8	0	106,547	21,309	0	21,309	2.510	0.619	0.000	0.619	1,000	1.8	1.295	1.017	-9.222	-9.366	2.43	2.68	10.57	10.96
MT - 5	MT - 6	803	6,171	6.1	731.6	3,289	126,192	25,238	0	25,238	2.445	0.714	0.000	0.714	1,000	1.8	1.295	1.017	-9.366	-11.186	2.68	3.60	10.96	13.70
MT - 6	MT - 7	710	6,880	7.2	835.7	3,892	131,369	26,274	0	26,274	2.430	0.739	0.000	0.739	1,000	1.8	1.295	1.017	-11.186	-12.763	3.60	2.60	13.70	14.28
MT - 7	MT - 8	1,588	8,468	14.1	892.2	7,590	139,522	27,904	0	27,904	2.408	0.778	0.000	0.778	1,100	1.6	1.301	1.237	-12.763	-15.904	2.60	2.60	14.17	17.32
MT - 8	MT - 9	113	8,582	0.0	925.8	0	147,372	29,474	0	29,474	2.387	0.814	0.000	0.814	1,100	1.6	1.301	1.237	-15.904	-16.160	2.60	2.60	17.32	17.57
MT - 9	MT - 10	118	8,700	35.2	994.3	8,218	163,380	32,676	0	32,676	2.350	0.889	0.000	0.889	1,100	1.6	1.301	1.237	-16.160	-16.424	2.60	1.58	17.57	16.82
MT - 10	MT - 11	37	8,737	0.0	1,019.8	0	174,083	34,817	0	34,817	2.327	0.938	0.000	0.938	1,200	1.6	1.379	1.559	-16.424	-16.559	1.58	1.63	16.71	16.89
MT - 11	MT - 12	293	9,031	0.0	1,111.0	0	193,609	38,722	0	38,722	2.289	1.026	0.000	1.026	1,200	1.6	1.379	1.559	-16.559	-17.178	1.63	3.60	16.89	19.48
MT - 12	MT - 13	1,479	10,509	0.0	1,216.8	0	225,162	45,032	0	45,032	2.237	1.166	0.000	1.166	1,200	1.6	1.379	1.559	-17.178	-20.144	3.60	1.60	19.48	20.45
MT - 13	MT - 14	33	10,543	0.0	1,365.8	0	353,097	70,619	0	70,619	2.087	1.706	0.000	1.706	1,500	1.4	1.497	2.645	-20.144	-20.266	1.60	1.60	20.10	20.23
MT - 14	MT - 15	642	11,184	0.0	1,504.8	0	478,435	95,687	0	95,687	1.991	2.206	0.000	2.206	1,650	1.3	1.537	3.286	-20.266	-21.325	1.60	1.23	20.07	20.76
MT - 15	MT - 16	329	11,513	0.0	1,525.1	0	492,342	98,468	0	98,468	1.983	2.260	0.000	2.260	1,650	1.3	1.537	3.286	-21.325	-21.903	1.23	1.38	20.76	21.48
MT - 16	MT - 17	417	11,930	0.0	2,740.5	0	809,165	161,833	0	161,833	1.837	3.440	0.000	3.440	2,000	1.2	1.679	5.274	-24.254	-24.904	1.38	2.02	23.46	24.75
MT - 17	MT - 18	1,524	13,455	96.7	3,303.1	53,919	939,525	187,905	0	187,905	1.795	3.904	0.000	3.904	2,000	1.2	1.679	5.274	-24.904	-27.183	2.02	1.60	24.75	26.61
MT - 18	MT - 19	34	13,489	0.0	3,321.8	0	944,726	188,945	0	188,945	1.793	3.922	0.000	3.922	2,200	1.1	1.713	6.510	-27.183	-27.296	1.60	2.60	26.41	27.52
MT - 19	STP	1,389	14,878	0.0	4,490.4	0	1,236,736	247,347	0	247,347	1.721	4.925	0.000	4.925	2,200	1.1	1.713	6.510	-27.296	-29.199	2.60	2.10	27.52	28.92
ST - 6	ST - 7	1,543	1,543	57.7	57.7	2,948	2,948	590	0	590	4.361	0.030	0.000	0.030	300	2.8	0.941	0.067	6.750	2.169	8.60	4.60	1.54	2.12
ST - 7	ST - 2	27	1,571	0.0	59.7	0	3,050	610	0	610	4.338	0.031	0.000	0.031	300	2.8	0.941	0.067	-1.041	-1.193	4.60	4.60	2.00	5.48
ST - 8	ST - 7	168	168	2.0	2.0	101	101	20	0	20	7.327	0.002	0.000	0.002	150	3.0	0.614	0.011	2.400	1.836	4.10	4.60	1.54	2.61
ST - 9	ST - 3	752	752	74.3	74.3	9,339	9,339	1,868	0	1,868	3.651	0.079	0.000	0.079	400	3.5	0.980	0.123	2.800	0.026	4.82	3.28	1.58	2.82
ST - 10	ST - 4	637	637	16.3	16.3	2,044	2,044	409	0	409	4.614	0.022	0.000	0.022	300	2.8	0.941	0.067	3.150	1.246	4.97	3.28	1.51	1.73
ST - 11	ST - 5	602	602	31.7	31.7	11,958	11,958	2,392	0	2,392	3.515	0.097	0.000	0.097	450	3.0	0.982	0.156	0.900	-1.006	2.93	2.09	1.54	2.61
ST - 12	MT - 1	653	653	90.1	90.1	24,550	24,550	4,910	0	4,910	3.146	0.179	0.000	0.179	600	2.6	1.107	0.313	1.650	-0.147	3.80	4.20	1.50	3.70
ST - 13	MT - 2	964	964	54.4	54.4	16,787	16,787	3,357	0	3,357	3.336	0.130	0.000	0.130	500	2.8	1.018	0.200	0.258	-2.967	5.80	9.80	2.00	12.23

Line No.	Line No. of	Sewer Length (m)		Sewage Area (ha)		Population		Average Flow (m^3/d)			Peak	Max. Flow (m^3/s)			Sewer Line				Sewer Invert Elevation		Ground Elevation (m)		Earth Covering (m)	
	Lower Sewer	Increment	Total	Increment	Total	Increment	Total	Sewage	Inlet	Total	Factor	Sewage	Infilt.	Toatl	Diameter (mm)	Slope (‰)	V (m/s)	Cap. (m3/s)	Upper end	Lower end	Upper end	Lower end	Upper end	Lower end
ST - 14	MT - 3	814	814	107.2	107.2	12,288	12,288	2,458	0	2,458	3.500	0.100	0.000	0.100	500	2.8	1.018	0.200	-3.010	-5.740	3.23	8.60	2.00	13.80
ST - 15	MT - 4	588	588	34.8	34.8	7,257	7,257	1,451	0	1,451	3.796	0.064	0.000	0.064	400	3.5	0.980	0.123	0.200	-2.013	2.17	2.43	1.54	4.01
ST - 16	MT - 5	634	634	65.5	65.5	8,379	8,379	1,676	0	1,676	3.713	0.072	0.000	0.072	400	3.5	0.980	0.123	-0.100	-2.550	1.87	2.68	1.54	4.79
ST - 17	MT - 5	1,001	1,001	38.2	38.2	7,977	7,977	1,595	0	1,595	3.741	0.069	0.000	0.069	400	3.5	0.980	0.123	2.550	-1.134	4.50	2.68	1.52	3.38
ST - 18	MT - 6	579	579	96.8	96.8	1,285	1,285	257	0	257	4.955	0.015	0.000	0.015	250	2.8	0.833	0.041	1.800	0.078	3.60	3.60	1.54	3.26
ST - 19	MT - 7	263	263	42.4	42.4	563	563	113	0	113	5.627	0.007	0.000	0.007	200	3.0	0.743	0.023	-2.607	-3.620	2.60	2.60	2.00	6.01
ST - 20	MT - 8	734	734	33.6	33.6	7,850	7,850	1,570	0	1,570	3.750	0.068	0.000	0.068	400	3.5	0.980	0.123	-3.335	-6.353	2.10	2.60	2.00	8.52
ST - 21	MT - 9	105	105	33.4	33.4	7,790	7,790	1,558	0	1,558	3.755	0.068	0.000	0.068	400	3.5	0.980	0.123	-3.832	-4.273	1.60	2.60	2.00	6.44
ST - 22	MT - 10	2,248	2,248	25.4	25.4	10,702	10,702	2,140	0	2,140	3.575	0.089	0.000	0.089	450	3.0	0.982	0.156	3.750	-3.574	5.74	1.58	1.51	4.67
ST - 23	ST - 24	1,124	1,124	28.4	28.4	5,025	5,025	1,005	0	1,005	4.017	0.047	0.000	0.047	350	4.0	0.959	0.092	0.550	-4.346	2.43	2.47	1.50	6.43
ST - 24	MT - 11	1,222	2,346	34.4	91.2	9,477	19,526	3,905	0	3,905	3.259	0.147	0.000	0.147	600	2.6	1.107	0.313	-4.346	-8.198	2.47	1.63	2.22	9.18
ST - 25	ST - 24	542	542	28.4	28.4	5,025	5,025	1,005	0	1,005	4.017	0.047	0.000	0.047	350	4.0	0.959	0.092	0.462	-1.862	2.34	2.47	1.50	3.95
ST - 26	ST - 27	1,048	1,048	49.6	49.6	8,778	8,778	1,756	0	1,756	3.686	0.075	0.000	0.075	400	3.5	0.980	0.123	1.650	-2.439	3.60	3.60	1.52	5.60
ST - 27	MT - 12	1,222	2,270	35.1	105.8	14,237	31,553	6,311	0	6,311	3.027	0.221	0.000	0.221	700	2.4	1.179	0.454	-2.439	-6.046	3.60	3.60	5.28	8.89
ST - 28	ST - 27	53	53	21.1	21.1	8,538	8,538	1,708	0	1,708	3.702	0.073	0.000	0.073	400	3.5	0.980	0.123	-1.580	-1.839	3.60	3.60	4.75	2.00
ST - 29	MT - 20	663	663	81.1	81.1	51,556	51,556	10,311	0	10,311	2.807	0.335	0.000	0.335	800	2.2	1.234	0.620	-3.730	-5.564	1.64	1.20	4.50	5.89
MT - 20	MT - 13	1,285	1,948	67.9	149.0	76,378	127,934	25,587	0	25,587	2.440	0.723	0.000	0.723	1,000	1.8	1.295	1.017	-5.564	-8.402	1.64	1.60	6.12	8.92
MT - 21	MT - 14	1,647	1,647	139.0	139.0	125,338	125,338	25,068	0	25,068	2.448	0.710	0.000	0.710	1,000	1.8	1.295	1.017	-2.482	-6.121	3.60	1.60	2.00	6.64
ST - 30	MT - 15	961	961	20.4	20.4	13,907	13,907	2,781	0	2,781	3.434	0.111	0.000	0.111	500	2.8	1.018	0.200	-1.450	-4.391	0.61	1.23	1.52	5.08
ST - 31	ST - 32	563	563	9.0	9.0	2,499	2,499	500	0	500	4.473	0.026	0.000	0.026	300	2.8	0.941	0.067	5.095	3.142	9.10	11.60	3.70	8.15
ST - 32	ST - 33	696	1,260	0.0	36.0	0	10,014	2,003	0	2,003	3.612	0.084	0.000	0.084	450	3.0	0.982	0.156	3.142	0.603	11.60	8.60	7.97	7.51
ST - 33	ST - 34	540	1,800	0.0	76.8	0	21,387	4,277	0	4,277	3.214	0.159	0.000	0.159	600	2.6	1.107	0.313	0.603	-1.102	8.60	9.60	7.35	10.05
ST - 34	ST - 35	60	1,860	0.0	76.8	0	21,387	4,277	0	4,277	3.214	0.159	0.000	0.159	600	2.6	1.107	0.313	-1.102	-1.333	9.60	9.60	10.05	10.28
ST - 35	ST - 36	351	2,211	0.0	99.6	0	27,081	5,416	0	5,416	3.099	0.194	0.000	0.194	600	2.6	1.107	0.313	-1.333	-2.470	9.60	8.10	10.28	9.92

Line No.	Line No. of	Sewer Length (m)		Sewage Area (ha)		Population		Average Flow (m^3/d)			Peak	Max. Flow (m^3/s)			Sewer Line				Sewer Invert Elevation		Ground Elevation (m)		Earth Covering (m)	
	Lower Sewer	Increment	Total	Increment	Total	Increment	Total	Sewage	Inlet	Total	Factor	Sewage	Infilt.	Toatl	Diameter (mm)	Slope (‰)	V (m/s)	Cap. (m3/s)	Upper end	Lower end	Upper end	Lower end	Upper end	Lower end
ST - 36	ST - 37	803	3,014	0.0	132.2	0	31,524	6,305	0	6,305	3.027	0.221	0.000	0.221	700	2.4	1.179	0.454	-2.470	-4.847	8.10	8.10	9.81	12.19
ST - 37	ST - 38	459	3,473	0.0	178.0	0	37,777	7,555	0	7,555	2.944	0.257	0.000	0.257	700	2.4	1.179	0.454	-4.847	-6.248	8.10	6.60	12.19	12.09
ST - 38	ST - 39	905	4,377	0.0	209.9	0	42,886	8,577	0	8,577	2.887	0.287	0.000	0.287	700	2.4	1.179	0.454	-6.248	-8.944	6.60	5.60	12.09	13.79
ST - 39	ST - 40	941	5,319	0.0	249.5	0	43,412	8,682	0	8,682	2.882	0.290	0.000	0.290	700	2.4	1.179	0.454	-8.944	-11.729	5.60	2.51	13.79	13.48
ST - 40	ST - 41	471	5,789	0.0	314.2	0	44,271	8,854	0	8,854	2.873	0.294	0.000	0.294	700	2.4	1.179	0.454	-11.729	-13.158	2.51	2.26	13.48	14.66
ST - 41	ST - 22	1,084	6,874	72.7	399.5	10,793	56,856	11,371	0	11,371	2.765	0.364	0.000	0.364	800	2.2	1.234	0.620	-13.158	-16.144	2.26	1.60	14.55	16.88
MT - 22	MT - 23	1,044	7,918	82.1	481.6	51,936	108,791	21,758	0	21,758	2.502	0.630	0.000	0.630	1,000	1.8	1.295	1.017	-16.144	-18.473	1.60	0.60	16.66	17.99
MT - 23	MT - 24	968	8,886	28.4	510.0	12,300	121,091	24,218	0	24,218	2.461	0.690	0.000	0.690	1,000	1.8	1.295	1.017	-18.473	-20.591	0.60	1.13	17.99	20.64
MT - 24	MT - 25	290	9,175	0.0	673.9	0	165,414	33,083	0	33,083	2.345	0.898	0.000	0.898	1,100	1.6	1.301	1.237	-20.591	-21.204	1.13	0.85	20.53	20.87
MT - 25	MT - 26	462	9,637	0.0	849.6	0	239,362	47,872	0	47,872	2.216	1.228	0.000	1.228	1,350	1.5	1.444	2.067	-21.204	-22.121	0.85	0.77	20.60	21.44
MT - 26	MT - 27	97	9,734	0.0	995.8	0	270,967	54,193	0	54,193	2.174	1.363	0.000	1.363	1,350	1.5	1.444	2.067	-22.121	-22.341	0.77	1.06	21.44	21.95
MT - 27	MT - 28	152	9,886	0.0	1,014.9	0	274,912	54,982	0	54,982	2.169	1.380	0.000	1.380	1,350	1.5	1.444	2.067	-22.341	-22.644	1.06	1.06	21.95	22.25
MT - 28	MT - 29	420	10,305	0.0	1,048.4	0	281,101	56,220	0	56,220	2.161	1.406	0.000	1.406	1,350	1.5	1.444	2.067	-22.644	-23.499	1.06	1.57	22.25	23.61
MT - 29	MT - 16	432	10,738	0.0	1,215.4	0	316,823	63,365	0	63,365	2.122	1.556	0.000	1.556	1,500	1.4	1.497	2.645	-23.499	-24.254	1.57	1.38	23.42	23.99
ST - 42	ST - 32	217	217	27.0	27.0	7,516	7,516	1,503	0	1,503	3.775	0.066	0.000	0.066	400	3.5	0.980	0.123	4.558	3.649	6.22	11.60	1.23	7.52
ST - 43	ST - 33	246	246	40.8	40.8	11,373	11,373	2,275	0	2,275	3.542	0.093	0.000	0.093	450	3.0	0.982	0.156	4.514	3.627	7.69	8.60	2.69	4.48
ST - 44	ST - 35	364	364	22.8	22.8	5,694	5,694	1,139	0	1,139	3.940	0.052	0.000	0.052	350	4.0	0.959	0.092	3.257	1.611	5.14	9.60	1.50	7.61
ST - 45	ST - 36	512	512	32.6	32.6	4,443	4,443	889	0	889	4.094	0.042	0.000	0.042	350	4.0	0.959	0.092	5.147	2.890	7.03	8.10	1.50	4.83
ST - 46	ST - 37	561	561	45.8	45.8	6,253	6,253	1,251	0	1,251	3.884	0.056	0.000	0.056	350	4.0	0.959	0.092	3.620	1.036	6.42	8.10	2.42	6.68
ST - 47	ST - 38	296	296	31.9	31.9	5,108	5,108	1,022	0	1,022	4.007	0.047	0.000	0.047	350	4.0	0.959	0.092	2.752	1.345	6.92	6.60	3.79	4.87
ST - 48	ST - 39	180	180	39.6	39.6	526	526	105	0	105	5.686	0.007	0.000	0.007	200	3.0	0.743	0.023	1.781	1.146	4.07	5.60	2.08	4.25
ST - 49	ST - 40	954	954	64.7	64.7	859	859	172	0	172	5.272	0.010	0.000	0.010	200	3.0	0.743	0.023	-0.193	-3.381	2.22	2.51	2.21	5.68
ST - 50	ST - 41	390	390	12.6	12.6	1,792	1,792	358	0	358	4.708	0.020	0.000	0.020	250	2.8	0.833	0.041	0.089	-1.083	2.24	2.26	1.90	3.09
ST - 51	ST - 52	1,542	1,542	61.5	61.5	3,237	3,237	647	0	647	4.298	0.032	0.000	0.032	300	2.8	0.941	0.067	0.840	-4.069	2.65	2.22	1.50	5.98
ST - 52	ST - 53	1,315	2,858	60.6	122.1	26,515	29,752	5,950	0	5,950	3.055	0.210	0.000	0.210	700	2.4	1.179	0.454	-4.069	-7.900	2.22	1.60	5.53	5.69
ST - 53	MT - 24	1,368	4,225	41.8	163.9	14,571	44,323	8,865	0	8,865	2.873	0.295	0.000	0.295	800	2.2	1.234	0.620	-7.900	-11.659	1.60	1.13	8.63	11.92

Line No.	Line No. of	Sewer Length (m)		Sewage Area (ha)		Population		Average Flow (m^3/d)			Peak	Max. Flow (m^3/s)			Sewer Line				Sewer Invert Elevation		Ground Elevation (m)		Earth Covering (m)	
	Lower Sewer	Increment	Total	Increment	Total	Increment	Total	Sewage	Inlet	Total	Factor	Sewage	Infilt.	Toatl	Diameter (mm)	Slope (‰)	V (m/s)	Cap. (m3/s)	Upper end	Lower end	Upper end	Lower end	Upper end	Lower end
ST - 54	MT - 30	583	583	130.1	130.1	56,200	56,200	11,240	0	11,240	2.770	0.360	0.000	0.360	800	2.2	1.234	0.620	-3.680	-5.263	0.60	0.60	3.41	2.00
MT - 30	MT - 25	1,116	1,699	45.6	175.7	17,748	73,948	14,790	0	14,790	2.655	0.454	0.000	0.454	900	2.0	1.273	0.810	-5.263	-8.094	0.60	0.85	4.89	5.82
ST - 55	ST - 56	65	65	125.3	125.3	28,802	28,802	5,760	0	5,760	3.070	0.205	0.000	0.205	700	2.4	1.179	0.454	-0.700	-0.877	1.60	1.60	1.54	1.72
ST - 56	MT - 26	1,616	1,681	20.9	146.2	2,803	31,604	6,321	0	6,321	3.026	0.221	0.000	0.221	700	2.4	1.179	0.454	-0.877	-5.580	1.60	0.77	1.72	5.60
ST - 57	MT - 27	817	817	19.1	19.1	3,945	3,945	789	0	789	4.169	0.038	0.000	0.038	350	4.0	0.959	0.092	0.000	-3.650	1.88	1.06	1.50	2.65
ST - 58	MT - 28	931	931	33.5	33.5	6,189	6,189	1,238	0	1,238	3.890	0.056	0.000	0.056	350	4.0	0.959	0.092	0.400	-3.593	2.30	1.06	1.52	4.27
ST - 59	ST - 60	508	508	31.9	31.9	1,577	1,577	315	0	315	4.802	0.018	0.000	0.018	250	2.8	0.833	0.041	-3.730	-5.528	0.73	1.22	2.00	6.49
ST - 60	ST - 61	378	886	31.9	78.3	4,275	7,795	1,559	0	1,559	3.754	0.068	0.000	0.068	450	3.0	0.982	0.156	-5.528	-6.962	1.24	1.26	6.28	6.81
ST - 61	MT - 29	256	1,142	9.2	122.1	1,512	15,002	3,000	0	3,000	3.394	0.118	0.000	0.118	500	2.8	1.018	0.200	-6.962	-7.829	1.26	1.57	7.68	8.85
ST - 62	ST - 60	291	291	14.5	14.5	1,943	1,943	389	0	389	4.650	0.021	0.000	0.021	300	2.8	0.941	0.067	-0.650	-1.524	1.19	1.22	1.53	2.44
ST - 63	ST - 61	625	625	34.6	34.6	5,695	5,695	1,139	0	1,139	3.940	0.052	0.000	0.052	350	4.0	0.959	0.092	-0.150	-2.772	1.75	1.26	1.52	3.65
ST - 64	ST - 65	365	365	28.0	28.0	13,980	13,980	2,796	0	2,796	3.431	0.111	0.000	0.111	500	2.8	1.018	0.200	-3.700	-4.947	1.37	0.65	4.53	2.01
ST - 65	MT - 29	248	613	9.2	44.8	1,512	20,720	4,144	0	4,144	3.230	0.155	0.000	0.155	600	2.6	1.107	0.313	-4.947	-5.742	0.65	1.57	4.95	6.66
ST - 66	ST - 65	171	171	7.6	7.6	5,227	5,227	1,045	0	1,045	3.993	0.048	0.000	0.048	350	4.0	0.959	0.092	-1.250	-1.973	0.65	0.65	1.52	2.24
ST - 67	ST - 68	645	645	92.8	92.8	25,842	25,842	5,168	0	5,168	3.122	0.187	0.000	0.187	600	2.6	1.107	0.313	-0.550	-2.328	1.60	1.60	1.50	3.28
ST - 68	MT - 31	1,227	1,872	74.4	167.2	20,707	46,549	9,310	0	9,310	2.851	0.307	0.000	0.307	800	2.2	1.234	0.620	-2.328	-5.702	1.60	1.07	3.06	5.90
MT - 31	MT - 17	884	2,756	55.4	465.9	15,418	76,441	15,288	0	15,288	2.641	0.467	0.000	0.467	900	2.0	1.273	0.810	-16.304	-18.522	1.07	2.02	13.96	19.56
ST - 69	ST - 70	3,335	3,335	193.5	193.5	9,572	9,572	1,914	0	1,914	3.637	0.081	0.000	0.081	400	3.5	0.980	0.123	-0.540	-13.852	1.40	1.40	1.51	14.82
ST - 70	MT - 31	742	4,077	10.6	243.3	2,964	14,475	2,895	0	2,895	3.413	0.114	0.000	0.114	500	2.8	1.018	0.200	-13.852	-16.304	1.40	1.07	14.71	16.83
ST - 71	ST - 70	1,368	1,368	39.2	39.2	1,939	1,939	388	0	388	4.651	0.021	0.000	0.021	300	2.8	0.941	0.067	-0.450	-4.795	1.40	1.40	1.54	5.89
ST - 72	MT - 18	482	482	18.7	18.7	5,200	5,200	1,040	0	1,040	3.996	0.048	0.000	0.048	350	4.0	0.959	0.092	-1.600	-3.795	1.60	1.60	2.82	2.01
ST - 73	MT - 32	756	756	55.0	55.0	50,178	50,178	10,036	0	10,036	2.818	0.327	0.000	0.327	800	2.2	1.234	0.620	-0.430	-2.433	3.60	3.60	3.16	2.17
MT - 32	MT - 33	704	1,460	30.3	96.0	15,933	71,734	14,347	0	14,347	2.667	0.443	0.000	0.443	900	2.0	1.273	0.810	-2.433	-4.215	3.60	3.10	5.06	6.34
MT - 33	MT - 19	629	2,088	81.1	262.1	23,087	149,449	29,890	0	29,890	2.382	0.824	0.000	0.824	1,100	1.6	1.301	1.237	-4.215	-5.521	3.10	2.60	6.13	6.93

Line No.	Line No. of	Sewer Length (m)		Sewage Area (ha)		Population		Average Flow (m^3/d)			Peak	Max. Flow (m^3/s)			Sewer Line				Sewer Invert Elevation		Ground Elevation (m)		Earth Covering (m)	
	Lower Sewer	Increment	Total	Increment	Total	Increment	Total	Sewage	Inlet	Total	Factor	Sewage	Infilt.	Toatl	Diameter (mm)	Slope (‰)	V (m/s)	Cap. (m3/s)	Upper end	Lower end	Upper end	Lower end	Upper end	Lower end
ST - 74	MT - 32	615	615	10.7	10.7	5,622	5,622	1,124	0	1,124	3.948	0.051	0.000	0.051	350	4.0	0.959	0.092	1.700	-0.936	3.60	3.60	1.52	4.15
ST - 75	MT - 33	1,283	1,283	85.0	85.0	54,628	54,628	10,926	0	10,926	2.782	0.352	0.000	0.352	800	2.2	1.234	0.620	-0.875	-4.153	1.60	3.10	1.61	3.39
ST - 76	ST - 77	567	567	110.1	110.1	13,582	13,582	2,716	0	2,716	3.447	0.108	0.000	0.108	500	2.8	1.018	0.200	-0.875	-2.543	1.60	1.60	1.93	3.60
ST - 77	ST - 78	2,558	3,125	116.9	291.5	14,417	35,945	7,189	0	7,189	2.967	0.247	0.000	0.247	700	2.4	1.179	0.454	-4.083	-11.573	1.60	1.50	4.93	12.32
ST - 78	ST - 79	128	3,253	0.0	331.6	0	47,096	9,419	0	9,419	2.846	0.310	0.000	0.310	800	2.2	1.234	0.620	-11.573	-11.930	1.50	1.50	9.21	12.56
ST - 79	MT - 34	836	4,089	0.0	404.3	0	62,788	12,558	0	12,558	2.723	0.396	0.000	0.396	800	2.2	1.234	0.620	-11.930	-14.218	1.50	1.50	12.56	14.85
MT - 34	MT - 35	671	4,760	40.0	834.4	11,121	122,011	24,402	0	24,402	2.458	0.694	0.000	0.694	1,000	1.8	1.295	1.017	-14.819	-16.327	1.50	1.60	15.24	16.85
MT - 35	MT - 19	545	5,305	72.2	906.5	20,551	142,562	28,512	0	28,512	2.400	0.792	0.000	0.792	1,100	1.6	1.301	1.237	-16.327	-17.424	1.60	2.60	13.74	18.84
ST - 80	ST - 77	787	787	64.4	64.4	7,946	7,946	1,589	0	1,589	3.743	0.069	0.000	0.069	400	3.5	0.980	0.123	-0.950	-4.083	2.60	1.60	3.12	2.25
ST - 81	ST - 78	468	468	40.1	40.1	11,151	11,151	2,230	0	2,230	3.553	0.092	0.000	0.092	450	3.0	0.982	0.156	-0.500	-1.985	1.50	1.50	1.51	3.00
ST - 82	ST - 79	790	790	29.4	29.4	3,624	3,624	725	0	725	4.224	0.035	0.000	0.035	350	4.0	0.959	0.092	-0.750	-4.216	1.15	1.50	1.52	5.33
ST - 83	ST - 79	475	475	43.4	43.4	12,068	12,068	2,414	0	2,414	3.510	0.098	0.000	0.098	450	3.0	0.982	0.156	-0.500	-2.004	1.50	1.50	1.51	3.02
ST - 84	ST - 85	2,411	2,411	190.2	190.2	23,449	23,449	4,690	0	4,690	3.169	0.172	0.000	0.172	600	2.6	1.107	0.313	-4.050	-11.594	1.60	1.45	2.00	12.39
ST - 85	MT - 34	1,193	3,604	144.0	390.1	17,755	48,102	9,620	0	9,620	2.837	0.316	0.000	0.316	800	2.2	1.234	0.620	-11.594	-14.819	1.45	1.50	12.18	15.45
ST - 86	ST - 85	1,677	1,677	55.9	55.9	6,898	6,898	1,380	0	1,380	3.826	0.061	0.000	0.061	400	3.5	0.980	0.123	-0.950	-7.541	1.00	1.45	1.52	8.56
		89,386	89,386	4,490	4,490	1,236,736	1,236,736																	

Source: JICA PPP Study Team

1.3 Cost Estimate (Initial Investment Cost)

(1) Construction Plan

1) Geology and topography

The Project area is located in the Jakarta plain and its geological condition is primarily deltaic. Most of the area is covered by either alluvium or young rocks. The alluvium soils are spread mostly along the rivers while the young volcanic rocks cover the rest of the Project area.

The ground surface in the northern part is almost flat with a low elevation, which declines toward the north with a slope of 0.2 – 0.3 m per 1,000 m. The groundwater table level is high, especially in the northern coastal area. In the southern part of the Project area, the ground slope is rather steep with a surface slope of 1.0 – 2.0 m per 1,000 m.

In the Project area, geological surveys at Pluit Pond and along the Krukut River and Abdul Mus Rd. were conducted by local consultants in the years 1986 and 1987, respectively.

At the estuary of Pluit Pond, the condition of the top soil between the ground surface of P.P.+1.50 m and at level of P.P.-5.50 m is sandy silt with an N-value of zero (0). The subsoil strata between P.P.-5.50 m and P.P.-16.5 m are predominantly clay with some gravels and silty clay having an average N-value of five (5). At depths deeper than P.P.-16.5 m, the strata are of very hard silty clay with an N-value of more than 50. This layer is considered as the bearing stratum for structures.

The geologic conditions along the proposed sewer are summarized as follows:

a) The upstream layer of 0.5 – 1.5 m thickness has a variety of soils: organic humus, silty sand, clayey silt, sandy silt and sandy clay. The soil consistency varies from very soft to soft.

b) The thickness of subsoil layer at the southern part of the Project area is in the range from 9 to 13 m. However, it increases to more than 30 m between Kh. Hasyin Asyhari Rd. and the southern edge of Pluit Pond.

c) The subsoil strata mentioned in b) consist of silty clay, silty sand, organic clay, sandy clay, sandy silt and tuffaceous silt. Consistency of the subsoil is soft with an N-value of seven (7) on average.

d) The bearing stratum at the southern part consists of tuff, tuffaceous silt and tuffaceous sand. The N-value varies from 60 to more than 100.

Locations of the geological surveys conducted in 1986 and 1987 and geological profiles are shown in Figures 1-6 and 1-7.

Source: Master Plan of 1991

Figure 1-6 Boring Locations in Zone 1

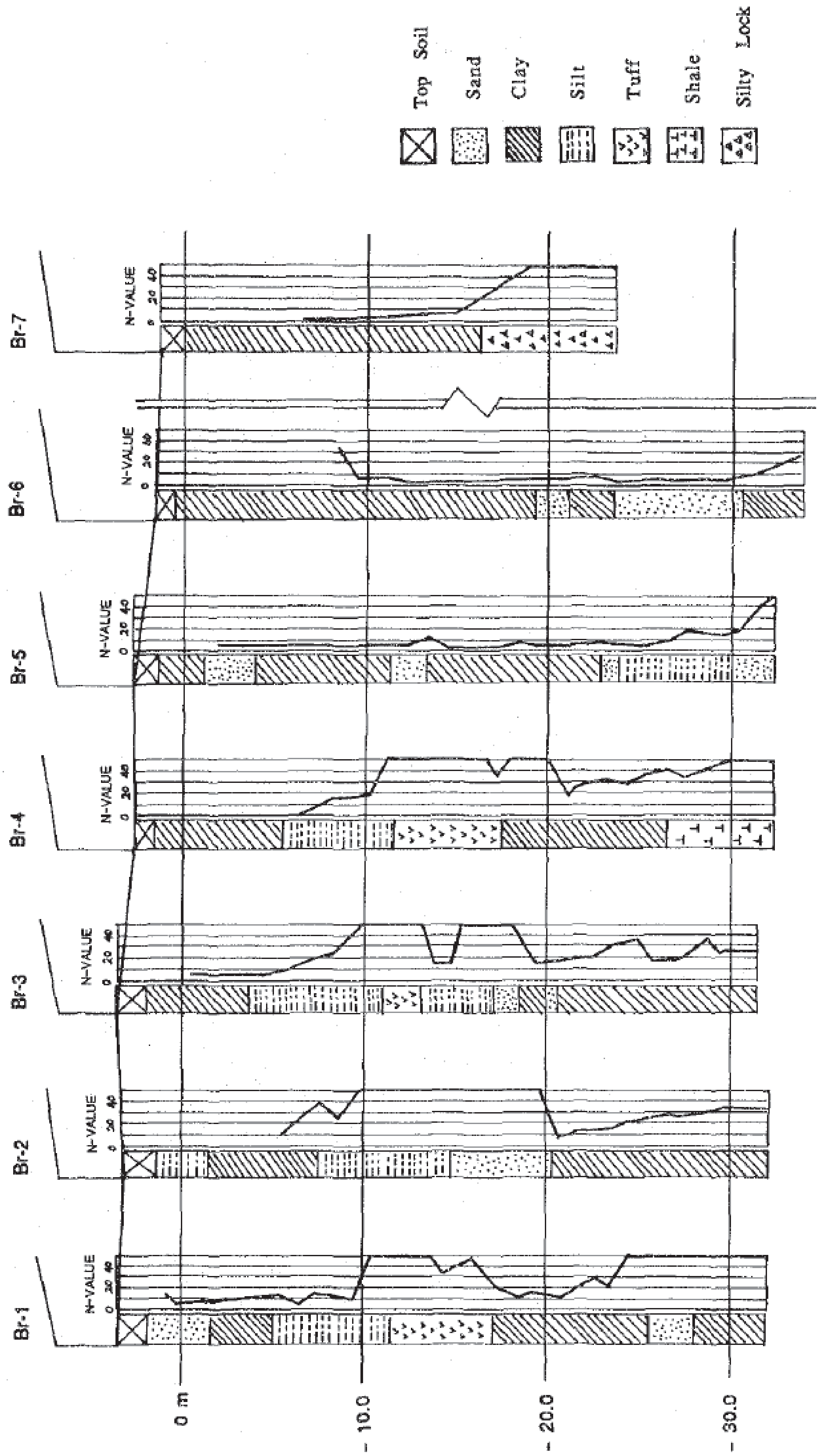


Figure 1-7 Geological Profiles

Source: Master Plan of 1991

2) Sewer pipe installation

The cut and cover (open trench) method is adopted for installation of sub-trunk and tertiary sewers in principle. All the tertiary sewers (including collecting sewer pipes to diversion chambers) of 50,077 m will be installed by this method. The main trunk sewer and some portions of sub-trunk sewer with a total length of 64,267 m will be constructed by the pipe-jacking method in order to cross rivers, main roads with heavy traffic and railways. The remaining 25,119 m of sub-trunk sewers will be constructed by the cut and cover method. If there is difficulty in constructing vertical shafts for certain portions of the main trunk sewer, the shield tunneling method should be examined in the detailed design stage although the construction cost by the shield tunneling method is high.

3) Required major construction equipment

Major construction works of sewerage development are installation of sewer pipes that require earth works. A closed face type mechanical tunneling machine is required for the pipe-jacking or the shield tunneling method. For the cut and cover method, heavy equipment such as backhoes, vibro-hammers and truck cranes are required for trench digging, setting and removing of sheet piles and pipe installation.

(2) Cost Estimate of Sewage Pipe

Construction costs for sewage pipes were estimated as follows:

1) Since there are no standards for cost estimates for the pipe-jacking and cut and cover methods in Indonesia, the standards in Japan were used to obtain the base unit prices. The following adjustment of the construction unit price level was made to conform to that in Indonesia:

a) The Denpasar sewerage development project used the following pipe diameters only:
Cut and cover works: 200 – 700 mm, Pipe-jacking works: 700 – 800 mm

The unit prices for construction of these pipes were increased by 29.6%, which corresponds to the cumulative inflation rate from 2007 to 2012. These adjusted unit prices were compared with the unit prices in Japan and the adjustment ratio was determined.

b) From the above comparison, it was found that the unit price levels in Bali and Japan were almost equivalent for construction by the pipe-jacking method. Therefore, it was decided to use the unit prices in Japan.

c) For the cut and cover method, the unit prices in Japan were adjusted using the adjustment ratio obtained in a) above.

2) As costs for the removal/restoration of obstacles and pavings, etc., 23.7% of the above sewer

construction costs were added in reference to the case of the Denpasar sewerage development project.

The summary of the cost estimate is as shown in Table 1-5.

Table 1-5 Summary of Cost Estimate for Sewer Construction in Zone 1

Summary Cost Estimate of Pipeline

IDR= 0.0085 JPY
1 USD= 9,012.50 IDR
1 USD= 76.21 JPY

Item	unit	Quantity	Cost (IDR)
Civil works			
1-1 (MT-16～MT－19）	Ls	1	265,873,621,439
1-2 (MT-1～MT－15）	Ls	1	285,094,176,299
2 （MT-20～MT-21、MT-31～MT-35）	Ls	1	202,532,516,666
4-1 （ST-1～ST-12, ST-14～ST-16）	Ls	1	109,596,080,306
4-2 （ST-13, ST-17～ST-19）	Ls	1	37,371,268,627
５ （ST-20～ST-30）	Ls	1	170,120,133,481
８ (ST-67～ST-68)	Ls	1	38,562,112,056
９ （ST-69～ST-83)	Ls	1	263,020,797,501
10 (ST-84～ST-86）	Ls	1	112,470,743,036
３ (MT-22～MT-30）	Ls	1	177,982,060,944
６ (ST-31～ST-50)	Ls	1	241,201,812,480
7-1 (ST-51～ST-58, ST-60～ST-61, ST64～ST-66）	Ls	1	193,121,545,819
7-2 (ST-59, ST-62～ST-63）	Ls	1	14,926,430,102
Pipe Line Sub-Total			2,111,873,298,756
Others for Sewer Construction & Restoration		23.68%	500,035,808,065
Pipe Line Total			2,611,909,106,821

Source: JICA PPP Study Team

Table 1-6 Breakdown of Cost Estimate

Section No	Item (Dia: mm)			Specification						unit	Quantity	Unit Price (IDR)	Total (IDR)
				Construction Method	Earth Covering Depth Type(m)	Length (m)	Construction Method	Earth Covering Depth Type(m)	Length (m)				
Civil works													
MT- 16-19	**Section 1-1**												
	Pipe	MT-16	2,000	PJ	>10m	417				m	417	71,949,458	30,021,115,862
		MT-17	2,000	PJ	>10m	1,524				m	1,524	74,842,271	114,070,775,644
		MT-18	2,200	PJ	>10m	34				m	34	170,015,590	5,803,664,674
		MT-19	2,200	PJ	>10m	1,389				m	1,389	83,497,527	115,978,065,259
	Sub total (Pipe)									m	3,365		265,873,621,439
MT- 1-15	**Section 1-2**												
	Pipe	MT-1	900	PJ	>10m	939				m	939	30,210,117	28,352,955,559
		MT-2	900	PJ	>10m	108				m	108	35,811,648	3,879,545,902
		MT-3	900	PJ	>10m	621				m	621	28,482,808	17,690,005,933
		MT-4	1,000	PJ	10 m	38				m	38	66,463,312	2,544,719,393
		MT-5	1,000	PJ	>10m	803				m	803	29,386,304	23,591,392,132
		MT-6	1,000	PJ	>10m	710				m	710	32,510,328	23,067,829,373
		MT-7	1,100	PJ	>10m	1,588				m	1,588	31,767,447	50,451,801,860
		MT-8	1,100	PJ	>10m	113				m	113	42,273,180	4,778,699,137
		MT-9	1,100	PJ	>10m	118				m	118	41,392,526	4,896,182,477
		MT-10	1,200	PJ	>10m	37				m	37	82,024,771	3,060,700,217
		MT-11	1,200	PJ	>10m	293				m	293	42,336,257	12,423,619,181
		MT-12	1,200	PJ	>10m	1,479				m	1,479	35,080,109	51,874,696,639
		MT-13	1,500	PJ	>10m	33				m	33	106,480,468	3,563,485,197
		MT-14	1,650	PJ	>10m	642				m	642	51,818,003	33,247,188,144
		MT-15	1,650	PJ	>10m	329				m	329	65,920,062	21,671,355,155
	Sub total (Pipe)									m	7,851		285,094,176,299
MT- 20-21 31-35	**Section 2**												
	Pipe	MT-20	1,000	PJ	7 m	1,285				m	1,285	31,990,031	41,104,597,103
		MT-21	1,000	PJ	5 m	1,647				m	1,647	30,622,848	50,427,557,368
		MT-31	900	PJ	>10m	884				m	884	34,528,696	30,529,542,593
		MT-32	900	PJ	5 m	704				m	704	25,098,099	17,661,887,596
		MT-33	1,100	PJ	7 m	629				m	629	38,628,595	24,288,421,994
		MT-34	1,000	PJ	>10m	671				m	671	30,953,497	20,774,741,156
		MT-35	1,100	PJ	>10m	545				m	545	32,560,919	17,745,768,855
	Sub total (Pipe)									m	6,364		202,532,516,666
ST- 1-12 14-16	**Section 4-1**												
	Pipe	ST-1	500				OC	2 m	2,434	m	2,434	6,817,763	16,597,062,412
		ST-2	600	PJ	5 m	389				m	389	21,977,136	8,546,212,579
		ST-3	700	PJ	5 m	40				m	40	29,922,317	1,198,156,031
		ST-4	700	PJ	5 m	520				m	520	26,621,116	13,842,994,270
		ST-5	800	PJ	7 m	278				m	278	39,868,356	11,101,343,335
		ST-6	300				OC	2 m	1,543	m	1,543	5,031,476	7,765,517,499
		ST-7	300	PJ	5 m	27				m	27	34,926,691	955,149,300
		ST-8	150				OC	2 m	168	m	168	9,507,319	1,596,267,645
		ST-9	400				OC	2 m	752	m	752	4,729,812	3,559,125,809
		ST-10	300				OC	2 m	637	m	637	4,823,921	3,073,914,454
		ST-11	450				OC	2 m	602	m	602	4,359,493	2,623,837,508
		ST-12	600				OC	3 m	653	m	653	7,322,093	4,778,254,447
		ST-14	500	PJ	10 m	814				m	814	23,697,176	19,292,064,666
		ST-15	400	PJ	3 m	100	OC	3 m	488	m	588	13,115,735	7,712,730,209
		ST-16	400	PJ	5 m	150	OC	3 m	484	m	634	10,961,528	6,953,450,141
	Sub total (Pipe)									m	10,081		109,596,080,306
ST- 13 17-19	**Section 4-2**												
	Pipe	ST-13	500	PJ	9 m	964				m	964	24,199,863	23,336,711,067
		ST-17	400				OC	3 m	1,001	m	1,001	6,711,632	6,720,070,015
		ST-18	250				OC	3 m	579	m	579	5,428,068	3,145,252,125
		ST-19	200	PJ	5 m	263				m	263	15,865,861	4,169,235,419
	Sub total (Pipe)									m	2,808		37,371,268,627
ST- 20-30	**Section 5**												
	Pipe	ST-20	400	PJ	7 m	734				m	734	28,307,478	20,765,611,504
		ST-21	400	PJ	5 m	105				m	105	28,321,383	2,964,143,067
		ST-22	450	PJ	5 m	500	OC	3 m	1,748	m	2,248	10,736,013	24,136,262,834
		ST-23	350	PJ	5 m	500	OC	3 m	624	m	1,124	11,462,574	12,883,607,881
		ST-24	600	PJ	7 m	1,222				m	1,222	24,557,521	30,010,289,158
		ST-25	350	PJ	3 m	100	OC	3 m	442	m	542	7,998,995	4,337,167,366
		ST-26	400	PJ	5 m	400	OC	3 m	648	m	1,048	10,695,936	11,213,836,976
		ST-27	700	PJ	7 m	1,222				m	1,222	25,354,346	30,974,605,808
		ST-28	400	PJ	5 m	53				m	53	30,829,619	1,619,766,244
		ST-29	800	PJ	5 m	663				m	663	30,167,451	20,006,271,539
		ST-30	500	PJ	5 m	300	OC	3 m	661	m	961	11,662,025	11,208,571,104
	Sub total (Pipe)									m	9,922		170,120,133,481
ST -67-68	**Section 8**												
	Pipe	ST-67	600				OC	3 m	645	m	645	8,352,762	5,391,053,308
		ST-68	800	PJ	5 m	1,227				m	1,227	27,039,887	33,171,058,749
	Sub total (Pipe)									m	1,872		38,562,112,056

Section No		Item (Dia: mm)		Specification						unit	Quantity	Unit Price (IDR)	Total (IDR)
				Construction Method	Earth Covering Depth Type(m)	Length (m)	Construction Method	Earth Covering Depth Type(m)	Length (m)				
	Section 9												
ST	**Pipe**	ST-69	400	PJ	10 m	2,500	OC	3 m	835	m	3,335	17,097,712	57,016,405,505
-69-83		ST-70	500	PJ	>10m	742				m	742	21,523,563	15,966,717,899
		ST-71	300	PJ	5 m	600	OC	3 m	768	m	1,368	10,515,328	14,384,488,700
		ST-72	350	PJ	5 m	300	OC	3 m	182	m	482	12,985,862	6,264,226,809
		ST-73	800	PJ	5 m	550	OC	3 m	206	m	756	25,701,185	19,425,683,016
		ST-74	350	PJ	3 m	100	OC	3 m	515	m	615	8,134,484	5,004,469,643
		ST-75	800	PJ	5 m	700	OC	3 m	583	m	1,283	18,141,860	23,275,182,877
		ST-76	500				OC	3 m	567	m	567	8,526,754	4,834,950,105
		ST-77	700	PJ	9 m	2,558				m	2,558	24,574,202	62,871,879,814
		ST-78	800	PJ	>10m	128				m	128	31,188,885	3,992,677,730
		ST-79	800	PJ	>10m	836				m	836	26,121,031	21,825,426,116
		ST-80	400	PJ	5 m	400	OC	3 m	387	m	787	15,060,215	11,846,490,465
		ST-81	450				OC	3 m	468	m	468	8,336,503	3,904,342,874
		ST-82	350	PJ	5 m	300	OC	3 m	490	m	790	10,753,499	8,497,671,111
		ST-83	450				OC	3 m	475	m	475	8,237,655	3,910,184,835
	Sub total (Pipe)									m	15,190		263,020,797,501
	Section 10												
ST	**Pipe**	ST-84	600	PJ	9 m	2,411				m	2,411	22,650,013	54,610,902,441
-84-86		ST-85	800	PJ	>10m	1,193				m	1,193	27,488,563	32,802,200,927
		ST-86	400	PJ	7 m	1,000	OC	3 m	677	m	1,677	14,938,062	25,057,639,668
	Sub total (Pipe)									m	5,282		112,470,743,036
	Section 3												
MT	**Pipe**	MT-22	1,000	PJ	>10m	1,044				m	1,044	29,850,436	31,153,812,104
22-30		MT-23	1,000	PJ	>10m	968				m	968	30,245,326	29,287,687,839
		MT-24	1,100	PJ	>10m	290				m	290	34,843,486	10,088,247,950
		MT-25	1,350	PJ	>10m	462				m	462	40,990,224	18,923,647,857
		MT-26	1,350	PJ	>10m	97				m	97	64,939,635	6,268,995,080
		MT-27	1,350	PJ	>10m	152				m	152	49,173,984	7,486,579,812
		MT-28	1,350	PJ	>10m	420				m	420	40,910,689	17,162,888,467
		MT-29	1,500	PJ	>10m	432				m	432	44,595,199	19,272,218,899
		MT-30	900	PJ	7 m	1,116				m	1,116	34,364,207	38,337,982,935
	Sub total (Pipe)									m	4,979		177,982,060,944
	Section 6												
ST	**Pipe**	ST-31	300	PJ	5 m	563				m	563	19,445,726	10,956,503,279
31-50		ST-32	450	PJ	7 m	696				m	696	22,974,924	15,998,731,366
		ST-33	600	PJ	9 m	540				m	540	23,597,091	12,749,679,101
		ST-34	600	PJ	10 m	60				m	60	25,405,173	1,524,888,748
		ST-35	600	PJ	10 m	351				m	351	21,472,313	7,537,694,332
		ST-36	700	PJ	10 m	803				m	803	23,617,370	18,959,602,866
		ST-37	700	PJ	>10m	459				m	459	28,258,334	12,966,665,993
		ST-38	700	PJ	>10m	905				m	905	25,645,116	23,196,321,633
		ST-39	700	PJ	>10m	941				m	941	26,735,819	25,170,762,512
		ST-40	700	PJ	>10m	471				m	471	29,207,053	13,747,726,266
		ST-41	800	PJ	>10m	1,084				m	1,084	27,087,660	29,374,268,840
		ST-42	400	PJ	5 m	217				m	217	40,941,533	8,879,558,406
		ST-43	450	PJ	3 m	246				m	246	42,752,803	10,499,097,448
		ST-44	350	PJ	5 m	200	OC	3 m	164	m	364	15,412,936	5,608,903,738
		ST-45	350	PJ	5 m	200	OC	3 m	312	m	512	17,839,925	9,127,543,021
		ST-46	350	PJ	5 m	400	OC	3 m	161	m	561	16,340,004	9,164,923,961
		ST-47	350	PJ	5 m	296				m	296	33,822,595	9,995,272,949
		ST-48	200	PJ	3 m	100	OC	3 m	80	m	180	22,709,161	4,084,191,251
		ST-49	200	PJ	5 m	350	OC	3 m	604	m	954	9,760,409	9,313,785,432
		ST-50	250				OC	3 m	390	m	390	6,015,036	2,345,691,339
	Sub total (Pipe)									m	10,592		241,201,812,480
	Section 7-1												
ST	**Pipe**	ST-51	300	PJ	5 m	700	OC	3 m	842	m	1,542	9,991,818	15,411,650,718
51-58		ST-52	700	PJ	7 m	1,315				m	1,315	27,121,714	35,667,349,102
60-61		ST-53	800	PJ	10 m	1,368				m	1,368	27,215,163	37,218,530,539
64-66		ST-54	800	PJ	5 m	583				m	583	31,134,889	18,153,798,650
		ST-55	700				OC	2 m	65	m	65	11,771,997	768,421,294
		ST-56	700	PJ	3 m	1,616				m	1,616	22,471,741	36,318,300,480
		ST-57	350	PJ	3 m	400	OC	2 m	417	m	817	11,098,998	9,072,699,409
		ST-58	350	PJ	3 m	200	OC	3 m	731	m	931	7,980,971	7,429,279,684
		ST-60	450	PJ	7 m	378				m	378	21,298,163	8,051,399,518
		ST-61	500	PJ	9 m	256				m	256	32,331,435	8,271,127,541
		ST-64	500	PJ	5 m	365				m	365	27,049,945	9,870,245,218
		ST-65	600	PJ	5 m	248				m	248	23,818,290	5,912,683,306
		ST-66	350				OC	2 m	171	m	171	5,717,136	976,060,361
	Sub total (Pipe)									m	9,656		193,121,545,819
	Section 7-2												
ST	**Pipe**	ST-59	250	PJ	5 m	508				m	508	21,452,460	10,906,412,777
59		ST-62	300				OC	2 m	291	m	291	3,390,810	985,690,368
62-63		ST-63	350				OC	3 m	625	m	625	4,851,151	3,034,326,957
	Sub total (Pipe)									m	1,425		14,926,430,102
	Total									m	89,386		2,111,873,298,756
	Others for Sewer Construction & Restoration											23.68%	500,035,808,065
	Grand Total												2,611,909,106,821

Source: JICA PPP Study Team

1.4 Construction Plan

(1) Workable Days

Annual workable days are estimated at 240 days based on the following considerations:

Sunday per annum:	12 months x 4 days = 48 days
National holidays per annum:	about 20 days
Rainy days per annum:	57 days (more than 10 mm/day rainfall)
Total work suspension days per annum:	125 days

Therefore, calendar days are calculated by multiplying workdays by 1.5 (=365 day / 240 days).

(2) Work Time

Sewer installation works by the cut and cover (open-cut) method along main roads should be undertaken during the nighttime only. Trenches should be covered by steel deck plates in the day time for traffic use. Construction by the pipe-jacking or shield tunneling method can be undertaken all day with two (2) shifts, each shift with eight (8) working hours in order to ensure a continued work pace.

(3) Estimate of Construction Time

Since there are no standards for cost estimate (construction time) for the pipe-jacking method in Indonesia, the following Japanese standards were used for reference:

a) Design and Cost Estimate Standards for Sewerage Pipe Facilities (Cut and Cover Method), (Pipe-Jacking Method), (Shield Tunneling Method) - Japan Sewage Works Association

b) Design and Cost Estimate Standard for Pipe-Jacking Method - Japan Microtunneling Association

The estimation of construction time for sewer pipe installation is shown in Table 1-7.

Table 1-7 Construction Time for Sewer Pipe Installation in Zone 1

Trunk / Sub-Trunk No.	Pipe Diameter	Distance	Construction Method		Pipe Parameters										Nos of Vertical Shaft				Nos of Manhole						Nos of	Construction time						Work section							Remarks
	(mm)	(m)	Pipe jacking method	Open trench method	Pipe Slope (‰)	Ground Elevation_Up (m)	Ground Elevation_Down (m)	River Bed Elevation (m)	Invert Elevation_Up (m)	Invert Elevation_Down (m)	Earth Covering Depth_Up (m)	Earth Covering Depth_Down (m)	Earth Covering Depth Type P.J.	Earth Covering Depth Type O.T.	Nos of Vertical Shaft	Nos of Departure Shaft	Nos of Arrival Shaft	Vertical Shaft Depth Type	NOS of Manhole	Manhole Depth Type	Nos of Type 1	Nos of Type 2	Nos of Type 3	Nos of Type 4	Diversion Chamber	Pipe Laying Construction Quantity per day (m/day)	Pipe Laying Construction days (days)	Vertical Shadt Construction days (days)	Manhole Construction days (days)	Total Construction days (days)	Construction months (months)	Total of Construction days	Jacking Construction Days/ 2	Nos of Construction Party	Construction months (months)	Percentage of sewered population (%)	Section. No.	Distance (m)	
																										including holidays. daytime construction.													
MT-1	φ 900	939	939		2.0	4.20	9.80		-4.911	-7.313	8.14	16.14	>10m		4.5	2.0	2.5	h=15.0	4	h=15.0			4			2.610	360	21	29			1,692.90	1,591.90	2.0	28.22	1.49%	1-2	7,851	
MT-2	φ 900	108	108		2.0	9.80	8.60		-7.313	-7.605	16.14	15.23	>10m		1.0	0.5	0.5	h=15.0	1	h=15.0			1			2.160	50												
MT-3	φ 900	621	621		2.0	8.60	2.43		-7.605	-9.222	15.23	10.68	>10m		3.0	1.5	1.5	h=15.0	3	h=15.0			3			2.540	245												
MT-4	φ 1,000	38	38		1.8	2.43	2.68	-4.89	-9.222	-9.366	10.57	10.96	10.0 m		1.0	0.5	0.5	h=15.0	1	h=10.0			1			1.350	28												
MT-5	φ 1,000	803	803		1.8	2.68	3.60		-9.366	-11.186	10.96	13.70	>10m		2.0	1.0	1.0	h=15.0	2	h=15.0			2		3	2.750	292												
MT-6	φ 1,000	710	710		1.8	3.60	2.60		-11.186	-12.763	13.70	14.28	>10m		3.0	2.0	1.0	h=15.0	3	h=15.0			3		4	2.580	275												
MT-7	φ 1,100	1,588	1,588		1.6	2.60	2.60		-12.763	-15.904	14.17	17.32	>10m		5.0	3.0	2.0	h=20.0	4	h=15.0			4			2.630	604												
MT-8	φ 1,100	113	113		1.6	2.60	2.60		-15.904	-16.160	17.32	17.57	>10m		1.0	0.5	0.5	h=20.0	1	h=20.0			1			2.130	53												
MT-9	φ 1,100	118	118		1.6	2.60	1.58		-16.160	-16.424	17.57	16.82	>10m		1.0	0.5	0.5	h=20.0	1	h=20.0			1			2.140	55												
MT-10	φ 1,200	37	37		1.6	1.58	1.63	-0.87	-16.424	-16.559	16.71	16.89	>10m		1.0	0.5	0.5	h=20.0	1	h=20.0			1			1.190	31												
MT-11	φ 1,200	293	293		1.6	1.63	3.60		-16.559	-17.178	16.89	19.48	>10m		2.0	1.0	1.0	h=20.0	2	h=20.0			2			2.200	133												
MT-12	φ 1,200	1,479	1,479		1.6	3.60	1.60		-17.178	-20.144	19.48	20.45	>10m		4.0	2.0	2.0	h=20.0	4	h=20.0			4			2.670	554												
MT-13	φ 1,500	33	33		1.4	1.60	1.60		-20.144	-20.266	20.10	20.23	>10m		1.0	0.5	0.5	h=25.0	1	h=20.0			1			1.060	32												
MT-14	φ 1,650	642	642		1.3	1.60	1.23	-2.00	-20.266	-21.325	20.07	20.76	>10m		2.0	1.0	1.0	h=25.0	2	h=20.0			2			2.250	285												
MT-15	φ 1,650	329	329		1.3	1.23	1.38	-1.10	-21.325	-21.903	20.76	21.48	>10m		3.5	1.5	2.0	h=25.0	2	h=20.0			2			1.760	187	51											
MT-16	φ 2,000	417	417		1.2	1.38	2.02		-24.254	-24.904	23.46	24.75	>10m		1.0	0.5	0.5	h=25.0	1	h=25.0				1		2.110	198	46	75			1,049.70	846.70	2.0	17.50	3.49%	1-1	3,365	
MT-17	φ 2,000	1,524	1,524		1.2	2.02	1.60		-24.904	-27.183	24.75	26.61	>10m		4.0	2.0	2.0	h=30.0	4	h=25.0				4		2.090	729												
MT-18	φ 2,200	34	34		1.1	1.60	2.60		-27.183	-27.296	26.41	27.52	>10m		1.0	0.5	0.5	h=30.0	1	h=30.0				1		0.870	39												
MT-19	**φ 2,200**	1,389	1,389		1.1	2.60	2.10	-2.50	-27.296	**-29.199**	27.52	28.92	>10m		3.5	2.0	1.5	h=30.0	4	h=30.0				4	2	1.910	727	82											STP inflow
MT-20	φ 1,000	1,285	1,285		1.8	1.64	1.60		-5.564	-8.402	6.12	8.92	7.0 m		4.5	2.0	2.5	h=10.0	4	h=10.0			4		7	2.680	479	100	40			798.00	538.00	2.0	13.30	16.38%	2	2,932	
MT-21	φ 1,000	1,647	1,647		1.8	3.60	1.60	0.60	-2.482	-6.121	2.00	6.64	5.0 m		4.0	2.0	2.0	h=10.0	4	h=5.0			4		6	2.760	597	100	20										
MT-22	φ 1,000	1,044	1,044		1.8	1.60	0.60		-16.144	-18.473	16.66	17.99	>10m		2.0	1.0	1.0	h=20.0	2	h=20.0			2		8	2.830	369	50	40			1,220.00	950.00	2.0	20.33	8.94%	3	4,979	
MT-23	φ 1,000	968	968		1.8	0.60	1.13		-18.473	-20.591	17.99	20.64	>10m		2.0	1.0	1.0	h=20.0	2	h=20.0			2		4	2.820	343												
MT-24	φ 1,100	290	290		1.6	1.13	0.85		-20.591	-21.204	20.53	20.87	>10m		1.0	0.5	0.5	h=25.0	1	h=20.0			1		2	2.590	112												
MT-25	φ 1,350	462	462		1.5	0.85	0.77		-21.204	-22.121	20.60	21.44	>10m		1.0	0.5	0.5	h=25.0	1	h=20.0			1		2	2.510	184												
MT-26	φ 1,350	97	97		1.5	0.77	1.06		-22.121	-22.341	21.44	21.95	>10m		1.0	0.5	0.5	h=25.0	1	h=20.0			1		3	1.790	54												
MT-27	φ 1,350	152	152		1.5	1.06	1.06		-22.341	-22.644	21.95	22.25	>10m		1.0	0.5	0.5	h=25.0	1	h=25.0			1			2.080	73												
MT-28	φ 1,350	420	420		1.5	1.06	1.57		-22.644	-23.499	22.25	23.61	>10m		1.0	0.5	0.5	h=25.0	1	h=25.0			1		1	2.480	169												
MT-29	φ 1,500	432	432		1.4	1.57	1.38		-23.499	-24.254	23.42	23.99	>10m		1.0	0.5	0.5	h=25.0	1	h=25.0			1			2.450	176	50											
MT-30	φ 900	1,116	1,116		2.0	0.60	0.85	-1.30	-5.263	-8.094	4.89	5.82	7.0 m		4.5	2.0	2.5	h=10.0	4	h=5.0			4		35	2.660	419	100	30										
MT-31	φ 900	884	884		2.0	1.07	2.02	-1.36	-16.304	-18.522	13.96	19.56	>10m		4.5	2.0	2.5	h=20.0	4	h=20.0			4		1	2.580	343	100	30			1,038.3	648.30	2.0	17.31	23.83%	2	3,433	
MT-32	φ 900	704	704		2.0	3.60	3.10		-2.433	-4.215	5.06	6.34	5.0 m		2.0	1.0	1.0	h=5.0	2	h=5.0			2			2.760	255	50											
MT-33	φ 1,100	629	629		1.6	3.10	2.60		-4.215	-5.521	6.13	6.93	7.0 m		2.0	1.0	1.0	h=10.0	2	h=5.0			2			2.620	240	50	30										
MT-34	φ 1,000	671	671		1.8	1.50	1.60		-14.819	-16.327	15.24	16.85	>10m		2.0	1.0	1.0	h=20.0	2	h=15.0			2			2.710	248	50											
MT-35	φ 1,100	545	545		1.6	1.60	2.60	-1.40	-16.327	-17.424	13.74	18.84	>10m		2.0	1.0	1.0	h=20.0	2	h=20.0			2			2.580	211	50	30										
Trunk Subtotal		22,560	22,560												80.0	40.0	40.0		76				66	10	78		9,150					5,798.90			96.65	54.13%		22,560	
ST-1	φ 500	2,434		2,434	2.8	11.60	4.60		9.550	2.394	1.51	1.66		1.5 m					19	h=3.0	19				29	2.571	947			947	31.57	115.63	2.00	3.0	19.27	4.54%	4-1	8,045	
ST-2	φ 600	389	389		2.6	4.60	3.28		-1.193	-2.429	5.14	5.06	5.0 m		5.5	3.0	2.5	h=5.0	5	h=5.0		5				2.940	132	105	49	286	9.53								
ST-3	φ 700	40	40		2.4	3.28	3.28	1.19	-2.429	-2.600	2.86	5.13	5.0 m		1.0	0.5	0.5	h=5.0	1	h=5.0			1			1.900	21	19	10	50	1.66								
ST-4	φ 700	520	520		2.4	3.28	2.09	-0.45	-2.600	-4.148	5.12	2.94	5.0 m		8.0	4.0	4.0	h=5.0	8	h=5.0			8			2.820	184	150	79	414	13.79								
ST-5	φ 800	278	278		2.2	2.09	4.20		-4.148	-4.911	5.37	8.24	7.0 m		2.0	1.0	1.0	h=10.0	2	h=10.0			2			2.460	113	72	36	220	7.35								
ST-6	φ 300	1,543		1,543	2.8	8.60	4.60		6.750	2.169	1.54	2.12		1.5 m					15	h=3.0	15				16	3.268	472			472	15.74								
ST-7	φ 300	27	27		2.8	4.60	4.60	1.27	-1.041	-1.193	2.00	5.48	5.0 m		2.0	1.0	1.0	h=5.0	1	h=5.0		1				1.590	17	36	18	71	2.38								
ST-8	φ 150	168		168	3.0	4.10	4.60		2.400	1.836	1.54	2.61		1.5 m					2	h=3.0	2				5	3.704	45			45	1.51								
ST-9	φ 400	752		752	3.5	4.82	3.28		2.800	0.026	1.58	2.82		1.5 m					9	h=3.0	9				6	2.874	262			262	8.73								
ST-10	φ 300	637		637	2.8	4.97	3.28		3.150	1.246	1.51	1.73		1.5 m					7	h=3.0	7				6	3.268	195			195	6.50								
ST-11	φ 450	602		602	3.0	2.93	2.09		0.900	-1.006	1.54	2.61		1.5 m					11	h=3.0	11				3	2.667	226			226	7.52								
ST-12	φ 600	653		653	2.6	3.80	4.20		1.650	-0.147	1.50	3.70		3.0 m					8	h=3.0	8				1	2.326	281			281	9.35								
ST-13	φ 500	964	964		2.8	5.80	9.80	2.80	0.258	-2.967	2.00	12.23	9.0 m		16.0	8.0	8.0	h=10.0	15	h=10.0		15			6	3.060	315	401	245	961	32.02	32.02	2.00	3.0	5.34	1.09%	4-2	964	
ST-14	φ 500	814	814		2.8	3.23	8.60	-0.47	-3.010	-5.740	2.00	13.80	10.0 m		14.0	7.0	7.0	h=10.0	13	h=10.0		13			4	2.780	293	351	214	858	28.59	47.74	2.00	3.0	7.96	1.81%	4-1	2,037	
ST-15	φ 400	588	100	488	3.5	2.17	2.43		0.200	-2.013	1.54	4.01	3.0 m	3.0 m	2.0	1.0	1.0	h=5.0	7	h=3.0	5	2			7	2.832	208	38	18	263	8.76								
ST-16	φ 400	634	150	484	3.5	1.87	2.68		-0.100	-2.550	1.54	4.79	5.0 m	3.0 m	3.0	2.0	1.0	h=5.0	8	h=3.0	5	3			3	2.816	225	60	27	312	10.39								
ST-17	φ 400	1,001		1,001	3.5	4.50	2.68		2.550	-1.134	1.52	3.38		3.0 m					17	h=3.0		17				2.874	348			348	11.61	27.45	2.00	3.0	4.57	0.64%	4-2	1,843	
ST-18	φ 250	579		579	2.8	3.60	3.60		1.800	0.078	1.54	3.26		3.0 m					7	h=3.0	7				3	3.460	167			167	5.58								
ST-19	φ 200	263	263		3.0	2.60	2.60	-0.40	-2.607	-3.620	2.00	6.01	5.0 m		6.0	3.0	3.0	h=5.0	6	h=5.0		6			2	1.820	144	110	53	308	10.25								
ST-20	φ 400	734	734		3.5	2.10	2.60	-0.90	-3.335	-6.353	2.00	8.52	7.0 m		14.0	7.0	7.0	h=10.0	7	h=10.0	7				9	2.830	259	351	214	824	27.47	217.68	2.00	3.0	36.28	5.91%	5	9,922	
ST-21	φ 400	105	105		3.5	1.60	2.60	-1.40	-3.832	-4.273	2.00	6.44	5.0 m		2.0	1.0	1.0	h=5.0	2	h=5.0		2			4	2.760	38	38	18	93	3.11								
ST-22	φ 450	2,248	500	1,748	3.0	5.74	1.58		3.750	-3.574	1.51	4.67	5.0 m	3.0 m	8.5	4.0	4.5	h=5.0	26	h=3.0	18	8			23	2.750	818	158	76	1,051	35.03								
ST-23	φ 350	1,124	500	624	4.0	2.43	2.47		0.550	-4.346	1.50	6.43	5.0 m	3.0 m	8.5	4.0	4.5	h=5.0	14	h=5.0	6	8			7	2.993	375	158	76	609	20.29								
ST-24	φ 600	1,222	1,222		2.6	2.47	1.63	-1.48	-4.346	-8.198	2.22	9.18	7.0 m		16.5	8.0	8.5	h=10.0	16	h=10.0		16			9	2.990	409	411	252	1,072	35.74								
ST-25	φ 350	542	100	442	4.0	2.34	2.47		0.462	-1.862	1.50	3.95	3.0 m	3.0 m	2.0	1.0	1.0	h=5.0	7	h=3.0	5	2			2	2.942	184	38	18	240	7.99								
ST-26	φ 400	1,048	400	648	3.5	3.60	3.60		1.650	-2.439	1.52	5.60	5.0 m	3.0 m	8.0	4.0	4.0	h=5.0	14	h=5.0	7	7			3	2.868	366	150	71	587	19.56								
ST-27	φ 700	1,222	1,222		2.4	3.60	3.60		-2.439	-6.046	5.28	8.89	7.0 m		16.0	8.0	8.0	h=10.0	15	h=10.0			15		2	3.130	390	401	286	1,078	35.92								
ST-28	φ 400	53	53		3.5	3.60	3.60	0.60	-1.580	-1.839	4.75	2.00	5.0 m		1.0	0.5	0.5	h=5.0	1	h=5.0		1			1	2.410	22	19	9	49	1.65								
ST-29	φ 800	663	663		2.2	1.64	1.20		-3.730	-5.564	4.50	5.89	5.0 m		4.0	2.0	2.0	h=5.0	4	h=5.0			4			2.550	260	104	40	404	13.46								
ST-30	φ 500	961	300	661	2.8	0.61	1.23		-1.450	-4.391	1.52	5.08	5.0 m	3.0 m	6.0	3.0	3.0	h=5.0	12	h=5.0	7	5			7	2.683	358	113	53	524	17.47								

Trunk / Sub-Trunk No.	Pipe Diameter	Distance	Construction Method		Pipe Parameters										Nos of Vertical Shaft				Nos of Manhole						Nos of	Construction time						Work section							Remarks
	(mm)	(m)	Pipe jacking method	Open trench method	Pipe Slope (‰)	Ground Elevation_Up (m)	Ground Elevation_Down (m)	River Bed Elevation (m)	Invert Elevation_Up (m)	Invert Elevation_Down (m)	Earth Covering Depth_Up (m)	Earth Covering Depth_Down (m)	Earth Covering Depth Type P.J.	Earth Covering Depth Type O.T.	Nos of Vertical Shaft	Nos of Departure Shaft	Nos of Arrival Shaft	Vertical Shaft Depth Type	Nos of Manhole	Manhole Depth Type	Nos of Type 1	Nos of Type 2	Nos of Type 3	Nos of Type 4	Diversion Chamber	Pipe Laying Construction Quantity per day (m/day)	Pipe Laying Construction days (days)	Vertical Shadt Construction days (days)	Manhole Construction days (days)	Total Construction days (days)	Construction months (months)	Total of Construction days	Jacking Construction Days/ 2	Nos of Construction Party	Construction months (months)	Percentage of sewered population (%)	Section. No.	Distance (m)	
																										including holidays. daytime construction.													
ST-31	φ 300	563	563		2.8	9.10	11.60		5.095	3.142	3.70	8.15	5.0 m		10.0	5.0	5.0	h=5.0	9	h=5.0		9			2	3.050	185	182	89	456	15.19	297.84	2.00	3.0	49.64	3.68%	6	10,592	
ST-32	φ 450	696	696		3.0	11.60	8.60		3.142	0.603	7.97	7.51	7.0 m		12.0	6.0	6.0	h=10.0	12	h=10.0		12				2.900	240	301	184	724	24.14								
ST-33	φ 600	540	540		2.6	8.60	9.60		0.603	-1.102	7.35	10.05	9.0 m		8.0	4.0	4.0	h=10.0	8	h=10.0		8				2.870	188	200	122	511	17.04								
ST-34	φ 600	60	60		2.6	9.60	9.60		-1.102	-1.333	10.05	10.28	10.0 m		1.0	0.5	0.5	h=10.0	1	h=10.0		1				2.400	25	25	15	65	2.18								
ST-35	φ 600	351	351		2.6	9.60	8.10		-1.333	-2.470	10.28	9.92	10.0 m		4.0	2.0	2.0	h=10.0	4	h=10.0		4				3.180	110	100	61	272	9.06								
ST-36	φ 700	803	803		2.4	8.10	8.10		-2.470	-4.847	9.81	12.19	10.0 m		10.0	5.0	5.0	h=10.0	10	h=10.0			10			3.070	261	251	179	691	23.03								
ST-37	φ 700	459	459		2.4	8.10	6.60		-4.847	-6.248	12.19	12.09	>10m		6.0	3.0	3.0	h=15.0	6	h=15.0			6			3.000	153	186	173	512	17.06								
ST-38	φ 700	905	905		2.4	6.60	5.60		-6.248	-8.944	12.09	13.79	>10m		11.0	6.0	5.0	h=15.0	11	h=15.0			11			3.090	293	347	317	957	31.89								
ST-39	φ 700	941	941		2.4	5.60	2.51		-8.944	-11.729	13.79	13.48	>10m		12.0	6.0	6.0	h=15.0	12	h=15.0			12			3.000	314	372	346	1,031	34.38								
ST-40	φ 700	471	471		2.4	2.51	2.26		-11.729	-13.158	13.48	14.66	>10m		8.0	4.0	4.0	h=15.0	7	h=15.0			7		4	3.100	152	248	230	630	21.01								
ST-41	φ 800	1,084	1,084		2.2	2.26	1.60		-13.158	-16.144	14.55	16.88	>10m		6.0	3.0	3.0	h=15.0	5	h=15.0			5		3	2.600	417	273	173	863	28.76								
ST-42	φ 400	217	217		3.5	6.22	11.60		4.558	3.649	1.23	7.52	5.0 m		3.5	2.0	1.5	h=5.0	3	h=5.0		3			7	2.860	76	67	31	174	5.81								
ST-43	φ 450	246	246		3.0	7.69	8.60		4.514	3.627	2.69	4.48	3.0 m		4.5	2.0	2.5	h=5.0	4	h=5.0		4			9	2.900	85	83	40	207	6.91								
ST-44	φ 350	364	200	164	4.0	5.14	9.60		3.257	1.611	1.50	7.61	5.0 m	3.0 m	3.5	2.0	1.5	h=5.0	5	h=5.0	2	3			6	2.989	122	67	31	220	7.34								
ST-45	φ 350	512	200	312	4.0	7.03	8.10		5.147	2.890	1.50	4.83	5.0 m	3.0 m	3.5	2.0	1.5	h=5.0	6	h=3.0	3	3			6	2.996	171	67	31	269	8.97								
ST-46	φ 350	561	400	161	4.0	6.42	8.10		3.620	1.036	2.42	6.68	5.0 m	3.0 m	6.5	3.0	3.5	h=5.0	8	h=5.0	2	6			3	2.932	191	120	58	369	12.31								
ST-47	φ 350	296	296		4.0	6.92	6.60		2.752	1.345	3.79	4.87	5.0 m		5.5	3.0	2.5	h=5.0	5	h=5.0		5			15	2.950	100	105	49	254	8.46								
ST-48	φ 200	180	100	80	3.0	4.07	5.60		1.781	1.146	2.08	4.25	3.0 m	3.0 m	2.5	1.0	1.5	h=5.0	3	h=3.0	1	2			5	3.221	56	44	22	122	4.06								
ST-49	φ 200	954	350	604	3.0	2.22	2.51		-0.193	-3.381	2.21	5.68	5.0 m	3.0 m	6.5	3.0	3.5	h=5.0	12	h=5.0	6	6			8	2.991	319	117	58	494	16.46								
ST-50	φ 250	390		390	2.8	2.24	2.26		0.089	-1.083	1.90	3.09		3.0 m					4	h=3.0	4				3	3.460	113			113	3.76								
ST-51	φ 300	1,542	700	842	2.8	2.65	2.22		0.840	-4.069	1.50	5.98	5.0 m	3.0 m	13.5	6.0	7.5	h=5.0	19	h=5.0	8	11				3.229	478	240	120	838	27.92	174.18	2.00	3.0	29.03	5.57%	7-1	8,238	
ST-52	φ 700	1,315	1,315		2.4	2.22	1.60	-1.45	-4.069	-7.900	5.53	5.69	7.0 m		18.0	9.0	9.0	h=10.0	17	h=10.0			17		13	3.000	438	451	322	1,211	40.38								
ST-53	φ 800	1,368	1,368		2.2	1.60	1.13		-7.900	-11.659	8.63	11.92	10.0 m		6.0	3.0	3.0	h=10.0	6	h=10.0			6		2	3.100	441	215	107	763	25.44								
ST-54	φ 800	583	583		2.2	0.60	0.60	-2.40	-3.680	-5.263	3.41	2.00	5.0 m		3.5	2.0	1.5	h=5.0	3	h=5.0			3			2.550	229	94	35	358	11.92								
ST-55	φ 700	65		65	2.4	1.60	1.60		-0.700	-0.877	1.54	1.72		1.5 m					1	h=3.0			1		2	2.155	30			30	1.01								
ST-56	φ 700	1,616	1,616		2.4	1.60	0.77		-0.877	-5.580	1.72	5.60	3.0 m		20.5	10.0	10.5	h=5.0	20	h=5.0			20			3.050	530	383	203	1,116	37.18								
ST-57	φ 350	817	400	417	4.0	1.88	1.06	-0.62	0.000	-3.650	1.50	2.65	3.0 m	1.5 m	8.5	4.0	4.5	h=5.0	11	h=3.0	4	7			3	3.055	268	158	76	501	16.70								
ST-58	φ 350	931	200	731	4.0	2.30	1.06		0.400	-3.593	1.52	4.27	3.0 m	3.0 m	3.5	2.0	1.5	h=5.0	12	h=3.0	9	3			3	2.999	310	67	31	409	13.63								
ST-59	φ 250	508	508		2.8	0.73	1.22	-1.47	-3.730	-5.528	2.00	6.49	5.0 m		8.5	4.0	4.5	h=5.0	8	h=5.0		8			2	2.950	172	153	76	401	13.36	13.36	2.00	3.0	2.23		7-2	508	
ST-60	φ 450	378	378		3.0	1.24	1.26	0.33	-5.528	-6.962	6.28	6.81	7.0 m		6.0	3.0	3.0	h=10.0	6	h=10.0		6			3	2.600	145	150	92	387	12.92	22.74	2.00	3.0	3.79	0.97%	7-1	634	
ST-61	φ 500	256	256		2.8	1.26	1.57		-6.962	-7.829	7.68	8.85	9.0 m		5.0	3.0	2.0	h=10.0	4	h=10.0		4				2.900	88	130	77	295	9.82								
ST-62	φ 300	291		291	2.8	1.19	1.22		-0.650	-1.524	1.53	2.44		1.5 m					4	h=3.0	4				1	3.268	89			89	2.97	9.89	2.00	3.0	1.65		7-2	916	
ST-63	φ 350	625		625	4.0	1.75	1.26		-0.150	-2.772	1.52	3.65		3.0 m					6	h=3.0	6				1	3.012	208			208	6.92								
ST-64	φ 500	365	365		2.8	1.37	0.65	-2.40	-3.700	-4.947	4.53	2.01	5.0 m		8.5	4.0	4.5	h=5.0	6	h=5.0		6			3	2.950	124	158	76	357	11.90	20.30	2.00	3.0	3.38	1.34%	7-1	784	
ST-65	φ 600	248	248		2.6	0.65	1.57		-4.947	-5.742	4.95	6.66	5.0 m		4.0	2.0	2.0	h=5.0	3	h=5.0		3			2	2.930	85	75	36	195	6.51								
ST-66	φ 350	171		171	4.0	0.65	0.65		-1.250	-1.973	1.52	2.24		1.5 m					2	h=3.0	2					3.012	57			57	1.89								
ST-67	φ 600	645		645	2.6	1.60	1.60		-0.550	-2.328	1.50	3.28		3.0 m					5	h=3.0	5				6	2.326	278			278	9.25	30.78	2.00	3.0	5.13		8	1,872	
ST-68	φ 800	1,227	1,227		2.2	1.60	1.07		-2.328	-5.702	3.06	5.90	5.0 m		6.0	3.0	3.0	h=5.0	6	h=5.0			6		10	2.850	430	156	59	646	21.53								
ST-69	φ 400	3,335	2,500	835	3.5	1.40	1.40		-0.540	-13.852	1.51	14.82	10.0 m	3.0 m	41.5	21.0	20.5	h=10.0	46	h=10.0		46			10	2.668	1,250	1,042	635	2,927	97.55	351.19	2.00	3.0	58.53	0.34%	9	15,190	
ST-70	φ 500	742	742		2.8	1.40	1.07		-13.852	-16.304	14.71	16.83	>10m		10.0	5.0	5.0	h=15.0	10	h=15.0		10			2	2.950	251	310	249	810	27.02								
ST-71	φ 300	1,368	600	768	2.8	1.40	1.40		-0.450	-4.795	1.54	5.89	5.0 m	3.0 m	10.5	5.0	5.5	h=5.0	18	h=5.0	8	10			5	3.172	431	189	93	714	23.79								
ST-72	φ 350	482	300	182	4.0	1.60	1.60	-1.40	-1.600	-3.795	2.82	2.01	5.0 m	3.0 m	5.5	3.0	2.5	h=5.0	7	h=5.0	2	5			1	2.961	163	105	49	317	10.56								
ST-73	φ 800	756	550	206	2.2	3.60	3.60	0.60	-0.430	-2.433	3.16	2.17	5.0 m	3.0 m	4.5	2.0	2.5	h=5.0	6	h=5.0			6		4	2.455	308	114	45	466	15.54								
ST-74	φ 350	615	100	515	4.0	3.60	3.60		1.700	-0.936	1.52	4.15	3.0 m	3.0 m	2.5	1.0	1.5	h=5.0	7	h=3.0	5	2			3	3.010	204	45	22	272	9.06								
ST-75	φ 800	1,283	700	583	2.2	1.60	3.10	0.10	-0.875	-4.153	1.61	3.39	5.0 m	3.0 m	4.5	2.0	2.5	h=5.0	9	h=5.0			9		4	2.363	543	114	45	701	23.38								
ST-76	φ 500	567		567	2.8	1.60	1.60		-0.875	-2.543	1.93	3.60		3.0 m					7	h=3.0	7				7	2.571	221			221	7.35								
ST-77	φ 700	2,558	2,558		2.4	1.60	1.50		-4.083	-11.573	4.93	12.32	9.0 m		33.0	17.0	16.0	h=10.0	31	h=10.0			31		9	3.886	658	831	591	2,080	69.35								
ST-78	φ 800	128	128		2.2	1.50	1.50	-1.50	-11.573	-11.930	9.21	12.56	>10m		1.0	0.5	0.5	h=15.0	1	h=15.0			1			3.000	43	46	29	117	3.90								
ST-79	φ 800	836	836		2.2	1.50	1.50		-11.930	-14.218	12.56	14.85	>10m		4.0	2.0	2.0	h=15.0	4	h=15.0			4			2.600	321	182	115	619	20.62								
ST-80	φ 400	787	400	387	3.5	2.60	1.60	-1.40	-0.950	-4.083	3.12	2.25	5.0 m	3.0 m	8.5	4.0	4.5	h=5.0	11	h=5.0	4	7			10	2.867	274	158	76	508	16.92								
ST-81	φ 450	468		468	3.0	1.50	1.50		-0.500	-1.985	1.51	3.00		3.0 m					5	h=3.0	5				6	2.667	176			176	5.85								
ST-82	φ 350	790	300	490	4.0	1.15	1.50		-0.750	-4.216	1.52	5.33	5.0 m	3.0 m	6.0	3.0	3.0	h=5.0	10	h=5.0	5	5			4	2.981	265	113	53	431	14.37								
ST-83	φ 450	475		475	3.0	1.50	1.50		-0.500	-2.004	1.51	3.02		3.0 m					4	h=3.0	4				6	2.667	178			178	5.93								
ST-84	φ 600	2,411	2,411		2.6	1.60	1.45	-1.40	-4.050	-11.594	2.00	12.39	9.0 m		30.0	15.0	15.0	h=10.0	30	h=10.0		30			6	2.950	817	752	459	2,028	67.59	101.68	2.00	3.0	16.95		10	5,282	
ST-85	φ 800	1,193	1,193		2.2	1.45	1.50		-11.594	-14.819	12.18	15.45	>10m		7.5	4.0	3.5	h=15.0	7	h=15.0			7			2.600	459	348	216	1,023	34.08								
ST-86	φ 400	1,677	1,000	677	3.5	1.00	1.45		-0.950	-7.541	1.52	8.56	7.0 m	3.0 m	18.5	9.0	9.5	h=10.0	25	h=5.0	7	18			9	2.865	585	461	165	1,211	40.37								
Sub Trunk Subtotal		66,827	41,708	25,119											569.0	284.0	285.0		791		241	358	192		366		23,195	13,670	8,221	45,085	1,502.85	1,462.48			243.75	25.87%		66,827	
Total		89,386	64,267	25,119											649.0	324.0	325.0		867		241	358	258	10	444		32,345	13,670	8,221	45,085	1,502.85	7,261.38			340.40	80.00%		89,386	

Source: JICA PPP Study Team

(4) Implementation Schedule

The implementation schedule of sewer construction was estimated according to the following conditions:

a) Trunk and sub-trunk sewers are constructed simultaneously.

b) A maximum of 10 construction parties (10 sites) are employed.

Keeping the total construction period the same, the following three (3) cases were examined:

Case 1: Assuming that the total wastewater quantity is inflowed. (Case 1 in Chapter 5.2.1 of the Main Report)

Case 2: Assuming that 70% of the total wastewater quantity is inflowed. (Case 2 in Chapter 5.2.1 of the Main Report)

Case 3: Assuming that the wastewater quantity is inflowed only in the vicinity of vertical-shafts of the main trunk sewer.

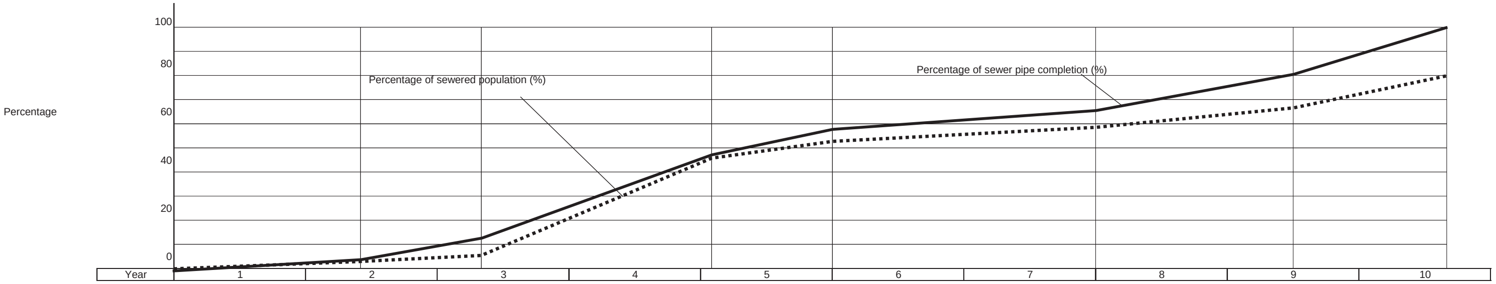
In Case 2, the operation can start in 2017 and sewer construction will be completed in 2025. Considering the collection rate of wastewater and step-wised construction of STP, it can be said that Case 2 is the most applicable one.

Construction Schedule and Disbursement (CASE-1_Inlet=All)

IDR=	0.0085	JPY
1 USD=	9012.5	IDR
1 USD=	76.21	JPY

	Type of works	Month	Year /Month Cost (Mil. IDR) Month Check (Mil. IDR)	0	1	2	3	4	5	6	7	8	9	10
					1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12
West Side	**1-1**	17.50	328,825 17 328,825	Design + Bidding	12 232,112	5 96,713	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
	1-2	28.22	352,597 28 352,597	Design + Bidding	12 151113	12 151113	4 50371	0 0	0 0	0 0	0 0	0 0	0 0	0 0
	2	30.61	250,487 31 250,488	Design + Bidding	0 0	7 56,562	12 96,963	12 96,963	0 0	0 0	0 0	0 0	0 0	0 0
	4-1	27.23	135,546 27 135,547	Design + Bidding	0 0	3 15,061	12 60,243	12 60,243	0 0	0 0	0 0	0 0	0 0	0 0
	4-2	9.91	46,220 10 46,220	Design + Bidding	0 0	0 0	0 0	0 0	0 0	0 0	0 0	10 46,220	0 0	0 0
	5	36.28	210,400 36 210,399	Design + Bidding	0 0	0 0	0 0	0 0	12 70,133	12 70,133	12 70,133	0 0	0 0	0 0
	8	5.13	47,693 5 47,693	Design + Bidding	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2 19,077	3 28,616	0 0
	9	58.53	325,297 58 325,297	Design + Bidding	0 0	0 0	0 0	0 0	11 61,694	12 67,303	12 67,303	12 67,303	11 61,694	0 0
	10	16.95	139,101 17 139,101	Design + Bidding	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	9 73,642	8 65,459
East Side	**3**	20.33	220,124 21 220,124	Design + Bidding	0 0	0 0	8 83,857	12 125,785	1 10,482	0 0	0 0	0 0	0 0	0 0
	6	49.64	298,312 49 298,312	Design + Bidding	0 0	0 0	0 0	0 0	7 42,616	12 73,056	12 73,056	12 73,056	6 36,528	0 0
	7-1	36.20	238,848 36 238,848	Design + Bidding	0 0	11 72,981	12 79,616	12 79,616	1 6,635	0 0	0 0	0 0	0 0	0 0
	7-2	3.87	18,461 4 18,461	Design + Bidding	0 0	0 0	0 0	0 0	4 18,461	0 0	0 0	0 0	0 0	0 0
	Total Cost	340.40	2,611,911 2,611,912		383,225	392,430	371,050	362,607	210,021	210,492	210,492	205,656	200,480	65,459

Million IDR	2,140,317		383,225	392,430	371,050	362,607	210,021	210,492	210,492	205,656	200,480	65,459
Million USD	283		43	44	41	40	23	23	23	23	22	7



Average daily wastewater flow (m3/day)		0.0% 8,627	12,305	114,180	130,580	145,943	165,357	197,878
Percentage of sewered population (%)		0.0% (43,135) 3.49%	(61,527) 4.97%	(570,900) 46.16%	(652,901) 52.79%	(729,715) 59.00%	(826,785) 66.85%	(989,389) 80.00%
Percentage of sewer pipe completion (%)		0.0% (3.36 km) 3.76%	(11.22 km) 12.55%	(42.30 km) 47.32%	(51.56 km) 57.69%	(58.23 km) 65.15%	(71.89 km) 80.42%	(89.39 km) 100.00%

- (989,389)m3/day is sewered population.
- (89.39)km is sewer pipe cpmpletion distance.

Nos of Construction Party		4 party	7 party	10 party	8	9 party	6 party	3 party

Source: JICA PPP Study Team

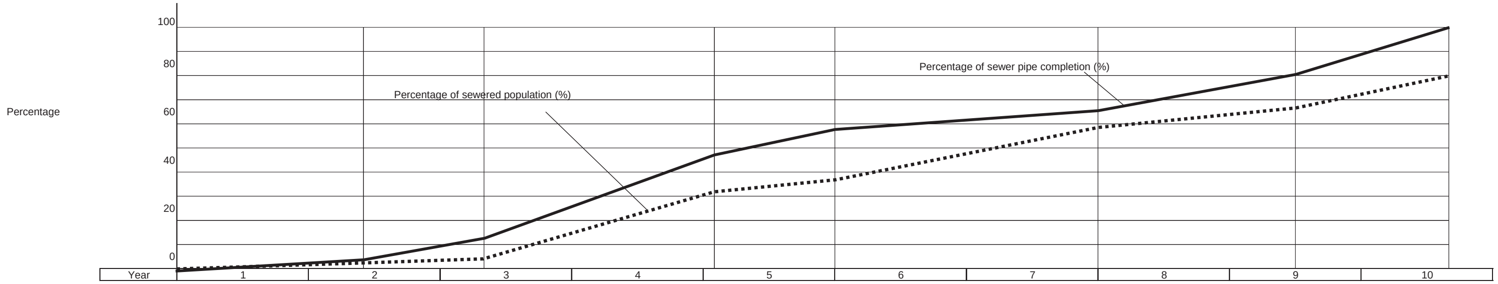
Figure 1-8 Construction Schedule and Disbursement (Case 1)

Construction Schedule and Disbursement (CASE-2_Inlet=70%)

IDR=	0.0085	JPY
1 USD=	9012.5	IDR
1 USD=	76.21	JPY

	Type of works	Month	Year /Month Cost (Mil. IDR) Month Check (Mil. IDR)	0	1	2	3	4	5	6	7	8	9	10
					1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12
West Side	**1-1**	17.50	328,825 17 328,825	Design + Bidding	12 232,112	5 96,713	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
	1-2	28.22	352,597 28 352,597	Design + Bidding	12 151113	12 151113	4 50371	0 0	0 0	0 0	0 0	0 0	0 0	0 0
	2	30.61	250,487 31 250,488	Design + Bidding	0 0	7 56,562	12 96,963	12 96,963	0 0	0 0	0 0	0 0	0 0	0 0
	4-1	27.23	135,546 27 135,547	Design + Bidding	0 0	3 15,061	12 60,243	12 60,243	0 0	0 0	0 0	0 0	0 0	0 0
	4-2	9.91	46,220 10 46,220	Design + Bidding	0 0	0 0	0 0	0 0	0 0	0 0	0 0	10 46,220	0 0	0 0
	5	36.28	210,400 36 210,399	Design + Bidding	0 0	0 0	0 0	0 0	12 70,133	12 70,133	12 70,133	0 0	0 0	0 0
	8	5.13	47,693 5 47,693	Design + Bidding	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2 19,077	3 28,616	0 0
	9	58.53	325,297 58 325,297	Design + Bidding	0 0	0 0	0 0	0 0	11 61,694	12 67,303	12 67,303	12 67,303	11 61,694	0 0
	10	16.95	139,101 17 139,101	Design + Bidding	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	9 73,642	8 65,459
East Side	**3**	20.33	220,124 21 220,124	Design + Bidding	0 0	0 0	8 83,857	12 125,785	1 10,482	0 0	0 0	0 0	0 0	0 0
	6	49.64	298,312 49 298,312	Design + Bidding	0 0	0 0	0 0	0 0	7 42,616	12 73,056	12 73,056	12 73,056	6 36,528	0 0
	7-1	36.20	238,848 36 238,848	Design + Bidding	0 0	11 72,981	12 79,616	12 79,616	1 6,635	0 0	0 0	0 0	0 0	0 0
	7-2	3.87	18,461 4 18,461	Design + Bidding	0 0	0 0	0 0	0 0	4 18,461	0 0	0 0	0 0	0 0	0 0
	Total Cost	340.40	2,611,911 2,611,912		383,225	392,430	371,050	362,607	210,021	210,492	210,492	205,656	200,480	65,459

Million IDR												
	2,140,317		383,225	392,430	371,050	362,607	210,021	210,492	210,492	205,656	200,480	65,459
Million USD												
	283		43	44	41	40	23	23	23	23	22	7



Average daily wastewater flow (m3/day)		0.0% 6,039	8,614	79,926	91,406	145,943	165,357	197,878
Percentage of sewered population (%)		0.0% (30,195) 2.44%	(43,069) 3.48%	(399,630) 32.31%	(457,030) 36.95%	(729,715) 59.00%	(826,785) 66.85%	(989,389) 80.00%
						- (989,389)m3/day is sewered population.		
Percentage of sewer pipe completion (%)		0.0% (3.36 km) 3.76%	(11.22 km) 12.55%	(42.30 km) 47.32%	(51.56 km) 57.69%	(58.23 km) 65.15%	(71.89 km) 80.42%	(89.39 km) 100.00%
						- (89.39)km is sewer pipe cpmpletion distance.		
Nos of Construction Party		4 party	7 party	10 party	8	9 party	6 party	3 party

Source: JICA PPP Study Team

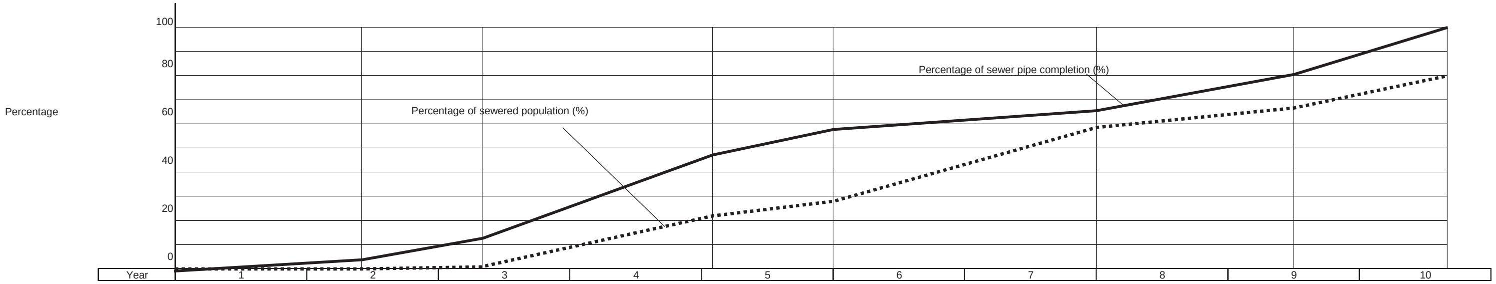
Figure 1-9 Construction Schedule and Disbursement (Case 2)

Construction Schedule and Disbursement (CASE-3_Inlet=Only Vertical Shaft)

IDR=	0.0085	JPY
1 USD=	9012.5	IDR
1 USD=	76.21	JPY

	Type of works	Month	Year /Month Cost (Mil. IDR) Month Check (Mil. IDR)	0	1	2	3	4	5	6	7	8	9	10
West Side	1-1	17.50	328,825 17 328,825	Design + Bidding	12 232,112	5 96,713	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
	1-2	28.22	352,597 28 352,597	Design + Bidding	12 151113	12 151113	4 50371	0 0	0 0	0 0	0 0	0 0	0 0	0 0
	2	30.61	250,487 31 250,488	Design + Bidding	0 0	7 56,562	12 96,963	12 96,963	0 0	0 0	0 0	0 0	0 0	0 0
	4-1	27.23	135,546 27 135,547	Design + Bidding	0 0	3 15,061	12 60,243	12 60,243	0 0	0 0	0 0	0 0	0 0	0 0
	4-2	9.91	46,220 10 46,220	Design + Bidding	0 0	0 0	0 0	0 0	0 0	0 0	0 0	10 46,220	0 0	0 0
	5	36.28	210,400 36 210,399	Design + Bidding	0 0	0 0	0 0	0 0	12 70,133	12 70,133	12 70,133	0 0	0 0	0 0
	8	5.13	47,693 5 47,693	Design + Bidding	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2 19,077	3 28,616	0 0
	9	58.53	325,297 58 325,297	Design + Bidding	0 0	0 0	0 0	0 0	11 61,694	12 67,303	12 67,303	12 67,303	11 61,694	0 0
	10	16.95	139,101 17 139,101	Design + Bidding	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	9 73,642	8 65,459
East Side	3	20.33	220,124 21 220,124	Design + Bidding	0 0	0 0	8 83,857	12 125,785	1 10,482	0 0	0 0	0 0	0 0	0 0
	6	49.64	298,312 49 298,312	Design + Bidding	0 0	0 0	0 0	0 0	7 42,616	12 73,056	12 73,056	12 73,056	6 36,528	0 0
	7-1	36.20	238,848 36 238,848	Design + Bidding	0 0	11 72,981	12 79,616	12 79,616	1 6,635	0 0	0 0	0 0	0 0	0 0
	7-2	3.87	18,461 4 18,461	Design + Bidding	0 0	0 0	0 0	0 0	4 18,461	0 0	0 0	0 0	0 0	0 0
	Total Cost	340.40	2,611,911 2,611,912		383,225	392,430	371,050	362,607	210,021	210,492	210,492	205,656	200,480	65,459

Million IDR											
	2,140,317		383,225	392,430	371,050	362,607	210,021	210,492	210,492	205,656	200,480	65,459
Million USD											
	283		43	44	41	40	23	23	23	23	22	7



Average daily wastewater flow (m3/day)		0.0% 0	818	54,918	71,318	145,943	165,357	197,878
Percentage of sewered population (%)		0.0% (0,000) 0.00%	(4,089) 0.33%	(274,588) 22.20%	(356,588) 28.83%	(729,715) 59.00%	(826,785) 66.85%	(989,389) 80.00%
Percentage of sewer pipe completion (%)		0.0% (3.36 km) 3.76%	(11.22 km) 12.55%	(42.30 km) 47.32%	(51.56 km) 57.69%	(58.23 km) 65.15%	(71.89 km) 80.42%	(89.39 km) 100.00%
Nos of Construction Party		4 party	7 party	10 party	8	9 party	6 party	3 party

- (989,389)m3/day is sewered population.

- (89.39)km is sewer pipe cpmpletion distance.

Source: JICA PPP Study Team

Figure 1-10 Construction Schedule and Disbursement (Case 3)

Chapter 2 Sewage Treatment Plant Development Plan

2.1 Overview of Wastewater Treatment Plant

(1) Overview

1) Site condition

The planned site for Wastewater Treatment Plant (STP) is located between Banjir Canal and the highway. The site is narrow and its size is limited because both the river and the highway structure determine the limits of its boundary. The land is not yet officially confirmed as the site for STP and is currently being used as a park. According to the circular notice from the secretary dated 16 December 2011, 3.3 ha can be utilized for the new STP out of the 6.9 ha of the park site.

Therefore, the construction area of the new STP must be minimized in light of the limited site area.

Source: JICA PPP Study Team

Figure 2-1 Planned Site for New STP

2) Selection of wastewater treatment system

Three treatment systems were reviewed as options in light of the need for an area-saving scheme.

a) Membrane Bioreactor (MBR): The biological process is similar to an Activated Sludge

System. But, this system adopts membrane separation for the solids-liquid separation process of sludge and treated water. A membrane is usually installed in the reaction tank. High MLSS in the reaction tank can be achieved by this process because the sludge is concentrated in the reaction tank and does not need to be returned. Detention time of the system is less than half of the Conventional Activated Sludge Process. In addition, a final sedimentation tank, which needs a wide area, is not needed for this process.

The treatment flow of this system is as below:

Inflow → Equalization Tank → Fine Screen → Reaction Tank → Membrane Separation → Discharge

b) Activated Sludge Process (ASP): The Conventional Activated Sludge System is the most widely used treatment process that uses activated sludge for biological treatment. The operation and maintenance scheme of the process is commonly established. A double-deck sedimentation tank and deep aeration are adopted as the area-saving options of the process.

The treatment flow of this system is as below:

Inflow → Grit chamber → Reaction Tank → Membrane Separation → Final Sedimentation Tank → Disinfection → Discharge

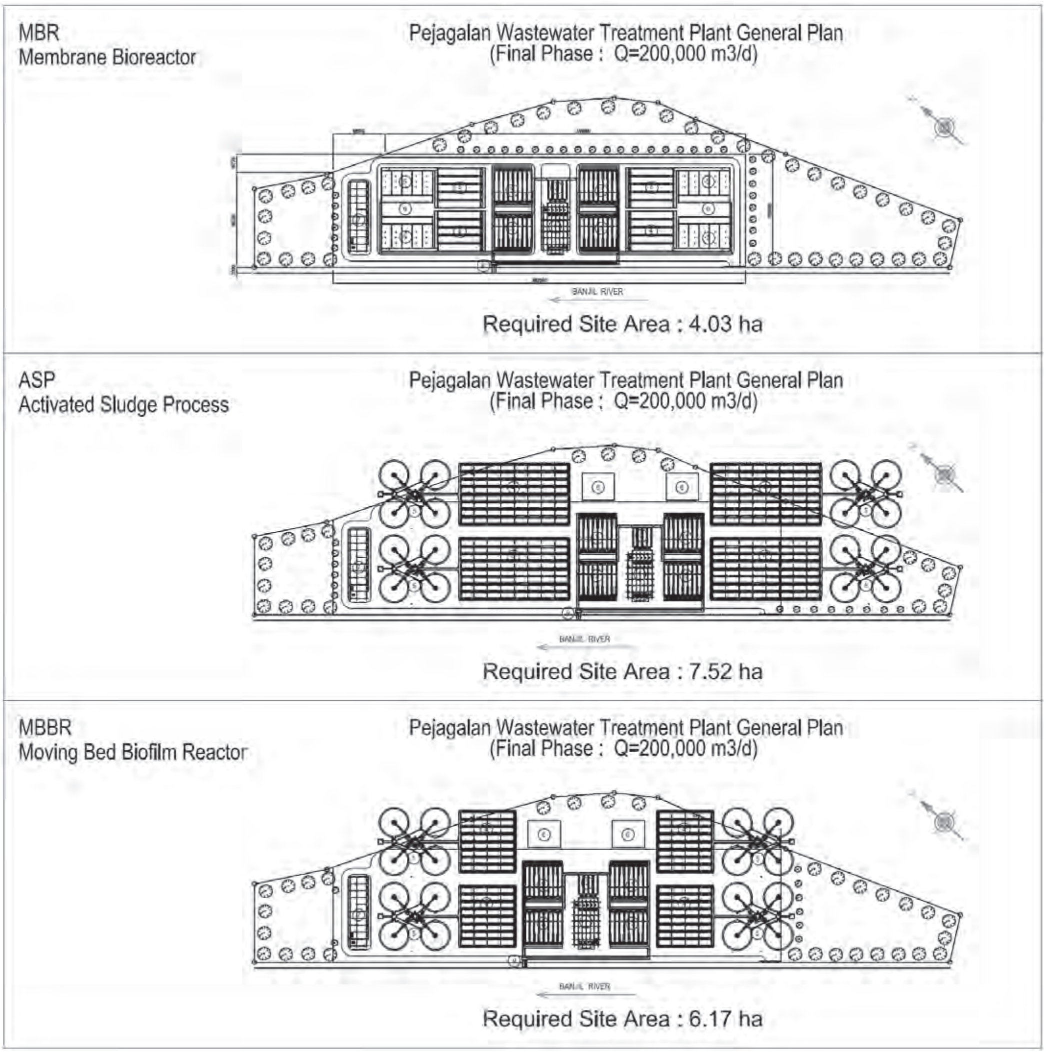
c) Moving Bed Biofilm Reactor (MBBR): MBBR is the treatment system that was adopted in 2012 at the Setiabudi STP of Jakarta City. The biological process of MBBR is done by the activated layer formed on the carrier, which fills up to 60% of the reaction tank. The tank is aerated and stirred by aeration. High retention time and MLSS in the tank are to be achieved by the carrier in the tank. However, the knowledge about actual performance of this treatment system is limited.

The treatment flow of this system is as below:

Inflow → Reaction Tank → Final Sedimentation Tank → Disinfection → Discharge

As a result of the comparison, it was found that only the MBR system would fit in the site area. The other options cannot satisfy the limitation of the sites and need double the land area for construction (Figure 2-2). The MBR system indeed needs a slightly larger land size of 4.03 ha, but it is reasonably feasible because it is considered that land can be acquired upon discussion with the site owner department.

Therefore, the MBR system has been selected as the treatment system of new the STP.



Source: JICA PPP Study Team

Figure 2-2 Layouts of Three Treatment Process Options for New STP

3) Sludge treatment system

The flow of this system is as shown below:

Reaction Tank -> Concentrator/Dehydrator -> to Dump Site

- The Gravity Concentrator may cause functional failure because: (1) the concentrate of the sludge is high up to 0.9%, (2) only the excess sludge is to be concentrated, and (3) the temperature of the sludge is high.
- The land to construct the Gravity Concentrator is not affordable.
- It is more reasonable to adopt a Screw Press Dehydrator equipped with the concentration function than to construct a mechanical concentrator separately. The type of dehydrator can be installed in the same construction area as the normal type of

dehydrator (only the height is slightly higher). Therefore, it is more suitable to adopt this type of dehydrator because the condition regarding the limited area for construction is important. Furthermore, the construction cost of the type of dehydrator is less than that of the option with separate mechanical concentrator.

2.2 Basic Design Condition

(1) Inflow Wastewater Quantity

Inflow rates based on the MP Review are as follows:

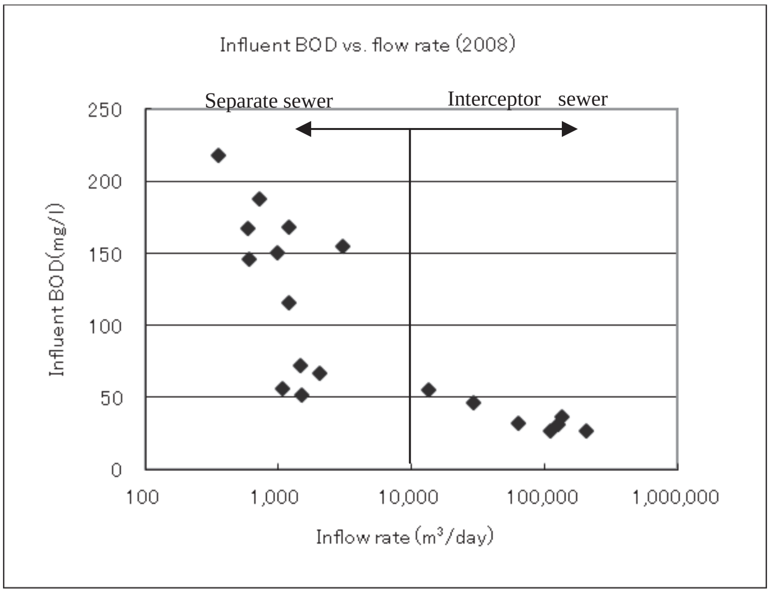
Average Daily Flow rate:	198,000	m^3/d
Maximum Daily Flow rate:	264,000	m^3/d
Maximum Hourly Flow rate:	396,000	m^3/d

According to the sewer construction plan, the planned STP should be constructed in two phases. The Phase 1 inflow rate is assumed to be a half of that of the final phase.

(2) Inflow Wastewater Quality

Inflow wastewater quality is determined as described below:

- nterceptor system sewerage, which includes the collection of miscellaneous drainage, is assumed for the sewerage system. The system is different from the combined sewerage system in regard to the point that black water does not flow in and the wastewater is affected of the dilution by rainwater and surface water.
- Influent BOD in the existing scheme in Bangkok Metropolitan City is 1/3 of that in the Separate Sewer System (Figure 2-3).
- The system will be transformed to the Separate Sewer System. When the system changes, the BOD concentration will be higher but the facilities are old and need rehabilitation. Thus, it is sufficient to assume that the rehabilitation design is to be done when the wastewater quantity and quality changes in the future.
- In conclusion, the wastewater quality of greywater is assumed to be BOD: 120 mg/l, SS: 120mg/l (cf. 140 mg/l in the MP Review).



Source: JICA PPP Study Team

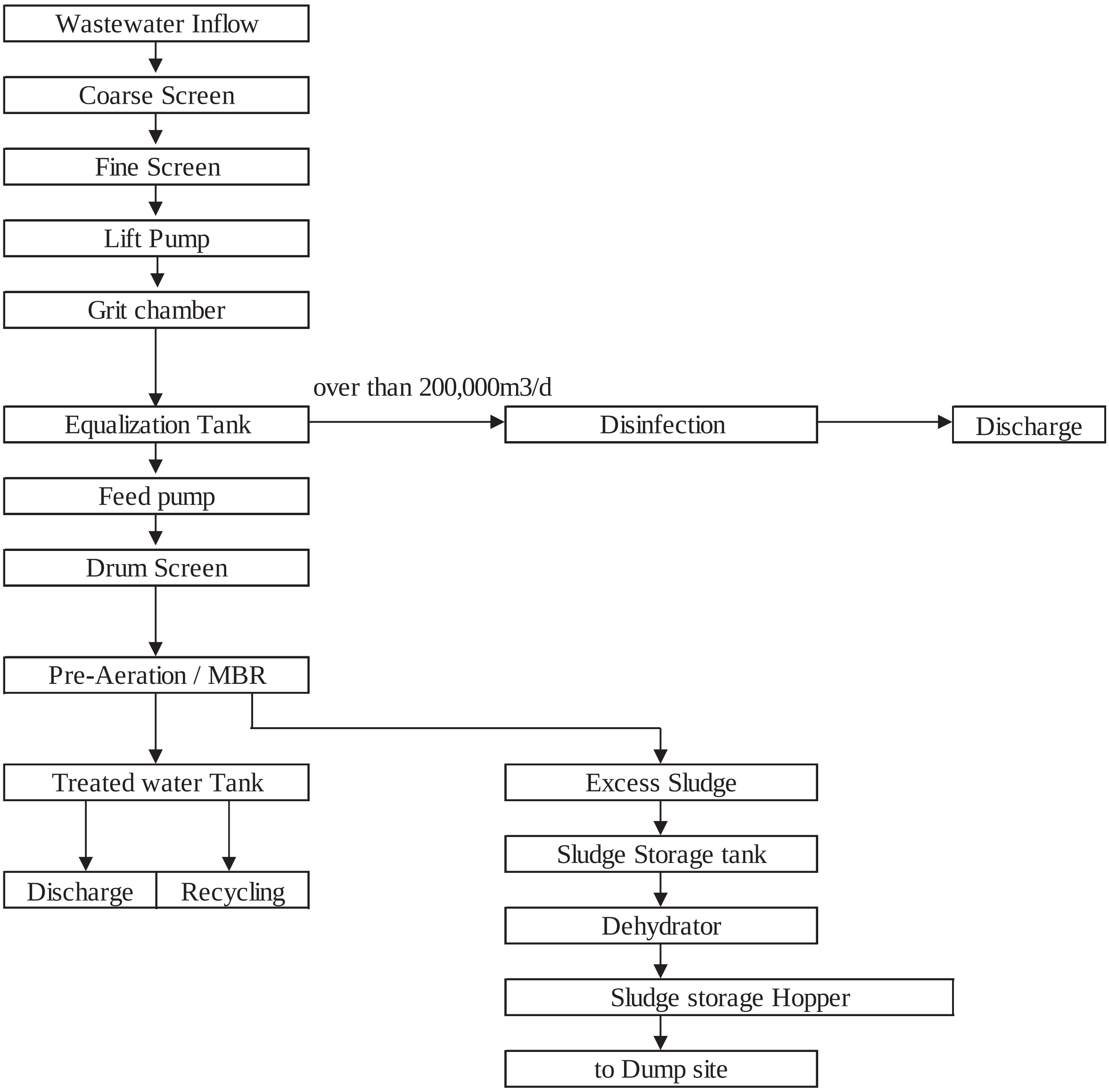
Figure 2-3 Inflow Wastewater Quality of Bangkok Metropolitan City

(3) Effluent Quality

Effluent qualities are set based on the Effluent Quality Standards established in Indonesia.

- BOD: 20mg/l
- SS: 20mg/l
- NH4: 10mg/l

(4) Process Flow Diagram



(5) Design Criteria for Facilities

1) Coarse screen:

Bar Screen, opening 100 mm, Operation: Manual

2) Fine screen:

Bar Screen, opening 100 mm, Operation: Mechanical

3) Lift pump:

Type: Volute type mixed flow pump

4) Grit chamber:

Type: Aerated grit chamber

Detention time:	3 minute (for maximum hourly)
Grit collector:	Screw type
Grit lifter:	Sand pump

5) Equalization tank:

Retention time:	4 hr
Surface load:	50 $m^3/m^2/d$

Having a function of spillway and disinfection

6) Drum screen:

Opening:	1 mm

7) Membrane bioreactor tank:

MLSS in reactor tank	9,000	mg/L
Design flux	0.4~0.6	$m^3/m^2/d$
Excess sludge production rate	70	%
BOD removal rate	0.12	kg-BOD/kg-SS/d
Nitrification rate	0.025	kg-N/kg-SS/d

8) Oxygen requirement:

a) BOD removal	0.5	kg-O2/kg-BOD
b) Nitrification	64/14	kg-O2/kg-N
c) Endogenous respiration	0.12	kg-O2/kg-VSS

9) Dewatering facility :

Dehydrator type: Pressing Rotary Outer Cylinder-Type Screw Press

Operation time	24	hr
Influent sludge concentration:	0.9	%
Dewatered sludge concentration:	83	%

(6) Overview of Each Facilities

1) Lift pump and grit chamber facility

The elevation of the bottom of the pipe in the lift pump is EL-29.20 m; thus, the depth from the GL (+4.5) is 33.7 m. In the light of this extreme deepness of the pipeline, the grid chamber is to be set after the lift pump to minimize the construction cost.

The overview of lift pump and grit chamber facilities is as follows:

a) Inflow pipe

φ2,200 x 1, BOP: -29.199 m, Gradient: 1.1o/oo

b) Coarse screen

Bottom of screen: -29.70 m, Screen canal width: 2.50 m, Opening: 100 mm

Nos: 4, Operation: Manual (retained in container, hoisted up to GL, disposed to dump site)

c) Fine screen

Bottom of screen: -29.70 m, Screen canal width: 2.50 m, Opening: 20 mm

Nos: 4, Operation: Mechanical (sequentially conveyed to GL, retained in hopper, disposed to dump site)

d) Lift pump

Vertical shaft volute type mixed flow pump: 700 mm x 70.0 m^3/min x 34.5 mH

Nos: 5 (1 for standby)

* Vertical shaft volute type is selected because the pump head is high up to 35m.

* Intermediate bearing is adopted because the motor is set on the ground.

* Ultrasonic flow meter is to be equipped at the outflow pipeline so that the inflow volume can be measured.

* Stirrer is to be installed in the clear well.

e) Grit chamber

Aerated grit chamber: W 4.0 m x L 17.5 m x H 8.5 m x 8

Screw type collector, submersible sludge pump, retained in container, disposed to dump site

2) Equalization tank facility

W 16.0 m x L 31.0 m x H 8.5 m x 8

Equalization tank is for the buffer of transmission quantity to MBR reactor tank. The tank volume is designed according to the actual data in Japan because actual data in Indonesia is not available. The volume is enough for four (4) hours of inflow. If the inflow exceeds the transmission flow (200,000 m^3/d/ 24 hours = 8,333 m^3/hour), the wastewater is to be overflowed from the trough to the Banjir Canal after disinfection. The total water quality of outflow from the STP can be kept at BOD 50 mg/l, SS 50 mg/l.

3) Disinfection facility

W 1.2m x L 70.0 m x H 2.1 m x 4

Detention time: 200,000 m^3/d (as overflow) x 5 minuites

4) Distribution pump

φ250 mm x 6.9 m^3/min x 14.0 m x 37 kW x 24 (4 for standby)
* 1 for each MBR chamber

5) Ultrafine screen

Drum screen, Opening: 1 mm, 420 m^3/hour, Nos: 20 (No Standby)
* 1 for each MBR chamber

6) Aeration tank

W 7.0 m x L 28.0 m x H 5.0 m x 20
V=19,600 m^3, DT=2.35 hour, Full floor aeration

7) MBR chamber

W 9.0 m x L 20.0 m x H 5.0 m x 20
V=18,000 m^3, DT=2.16 hour, Surface area > 477,000 m^2

8) Aeration blower

a) For BOD removal: Turbo blower φ250 mm x 120 m^3/min x 68 kps x 220 kW
   10 (2 for standby)

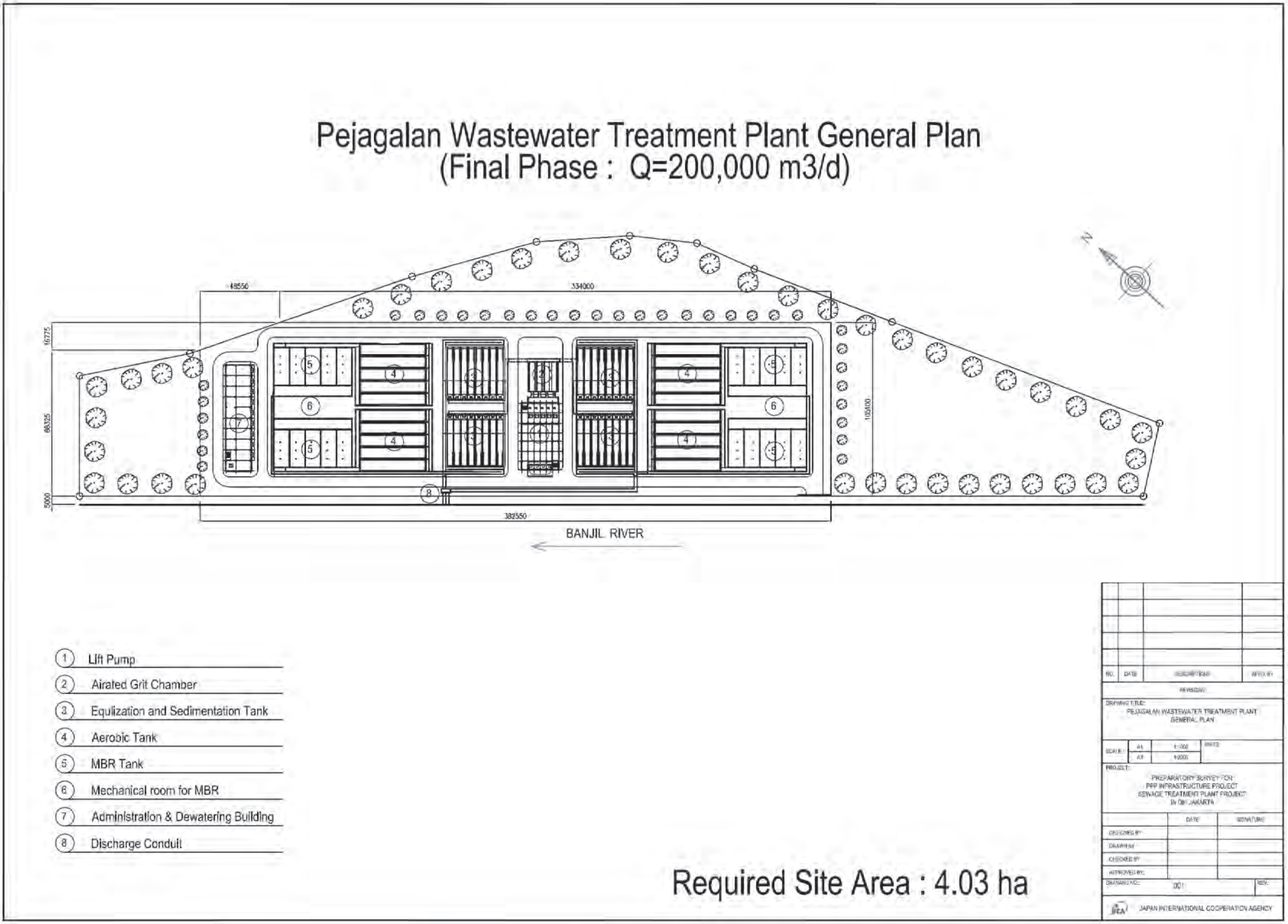
b) For membrane scrubbing: Turbo blower φ400 mm x 245 m^3/min x 68 kps x 450 kW
   14 (2 for standby)

9) Dewatering facilities

The Screw Press Dehydrator is equipped with the concentration function.
Operation duration is assumed to be 24 hrs because of the need to minimize the construction space in view of the site limitation.

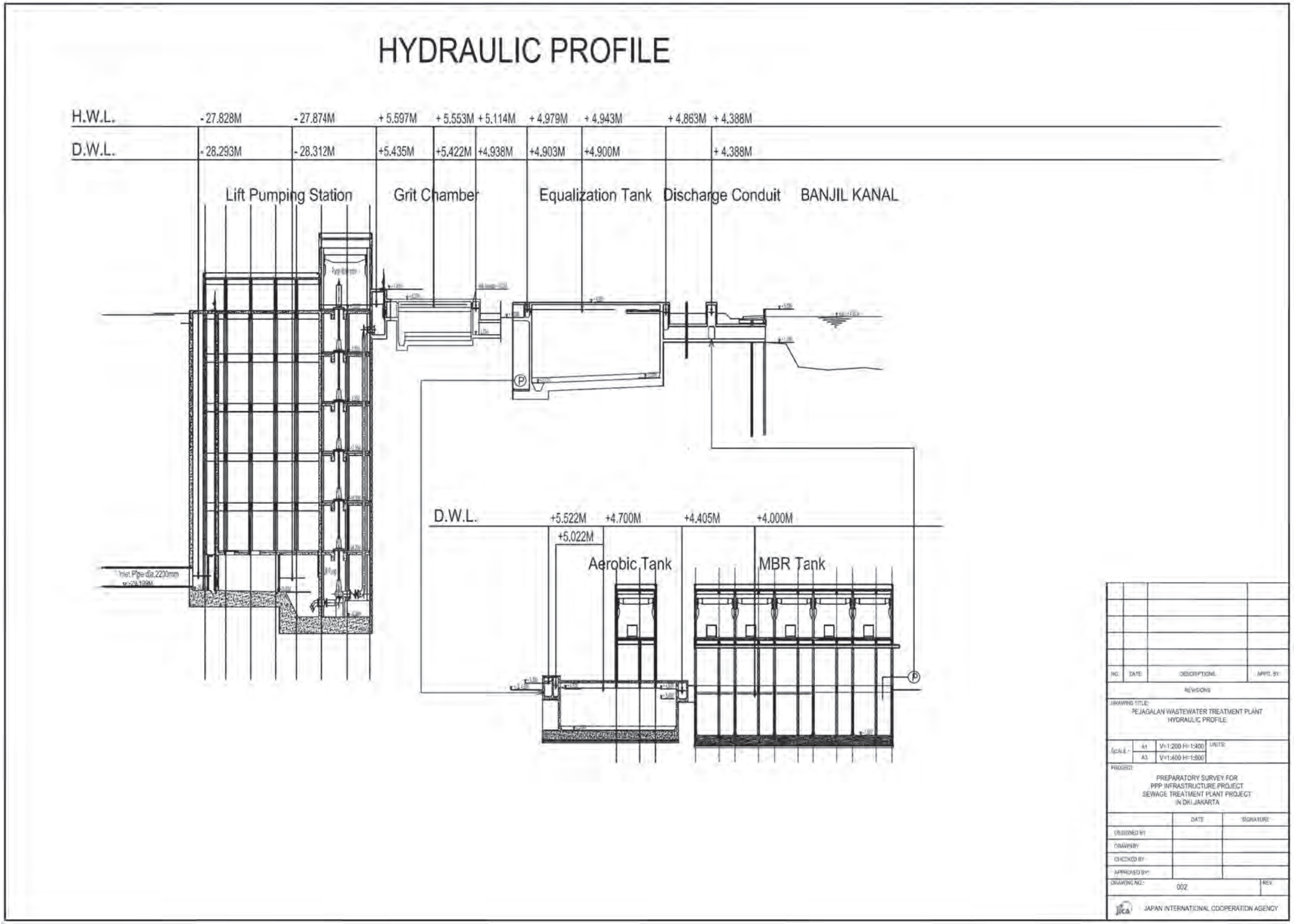
Dehydrator: φ800 mm x 320 kg-ds/hrs, Actual operation duration: 20 hrs
Nos: 5 (1 for Standby)

General layout of facilities (Figure 2-4) and transition diagram (Figure 2-5) are as shown below:



Source: JICA PPP Study Team

Figure 2-4 General Layout of Pejagalan STP



Source: JICA PPP Study Team

Figure 2-5 Transition Diagram of Pejagalan STP

(7) Determination of Formation Height

Formation Height is determined on the basis of the estimated high water level and the height of shore protection structure of Banjir Canal in which the effluent flows.

The construction site is on the right bank of Banjir Canal. The overview of the height of shore protection structures is as below:

Table 2-1 Shore Protection of Banjir Canal

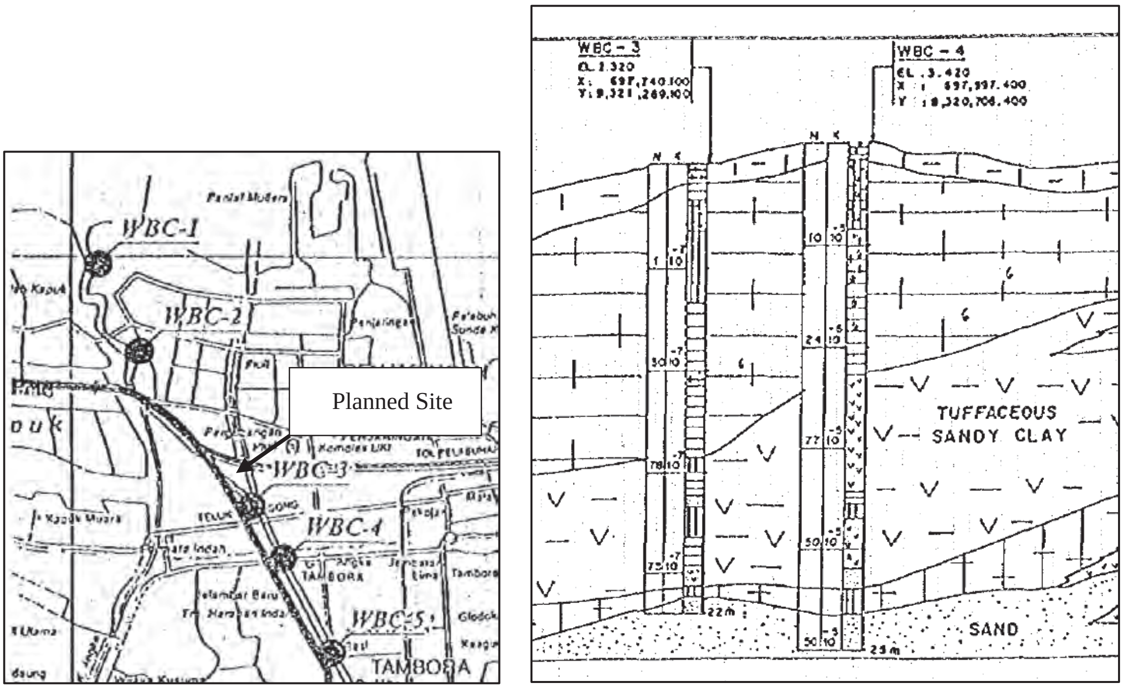
Site No.	Top Height	FGL (on road)	H.W.L	Note
P 135	+5.104 m	+4.259 m	+4.243 m	Upflow site along the river from STP
P 136	+5.100 m	+4.255 m	+4.234 m	Upflow site along the river from STP
P 154	+4.940 m	+4.095 m	+4.076 m	Downflow site along the river from STP
P 156	+4.929 m	+4.084 m	+4.067 m	Downflow site along the river from STP

Source: Pekerjaan Peningkatan Kapasitas Dan Perkuatan Tebing BANJIR Kanal Barat Hilir

The ground level around the site is gently inclined along the Banjir Canal flow from the top of the river to the end of the river. On the basis of GL and HWL, the formation level of the new STP site is determined at +4.50 m.

(8) Planning of Foundation

The new STP site is located on the alluvial delta area of the Jakarta Plain. The soil of the area is mainly composed of alluvial soil. Figure 2-6 shows the location of the existing geological survey and the geological section conducted in 1986 and 1987.



Source: MP Review

Figure 2-6 Location of Existing Geological Survey and Geological Section around the Site

Boring log No. WBC-3 in Figure 2-6 is the result of soil investigation at the nearest place to the site. The logs show that there is a sequential shell-laden silty clay layer from the top to 15 m. The bottom layer is 6 m of a tuffaceous sandy clay layer. A sandy layer is below that layer. The clay layers cannot be expected to be sufficient as the bearing strata for the foundation because they are composed of alluvial soil. Therefore, we adopted the pile foundation for planning of this stage. The top depth of bearing strata is assumed at GL -22.0 m.

The foundation of lift pumping station in the STP can be assumed as spread foundation because the level of its deck slab is below the top depth of bearing strata. Soil investigations are needed at the detailed design stage because they were not implemented in this report.

2.3 Estimation of Construction Cost (Initial Capital Cost)

(1) Phasing of Construction

Two scenarios are assumed for the construction staging as below:

Case 1: Construct the final capacity of 200,000 m^3/d facilities all at once.

Case 2: Divide the construction into two phases in accordance with the progress of sewer pipe/culvert construction and the growth of the water volume of treatment.

Phase 1: All the civil and architectural works for 200,000 m^3/d and mechanical and electrical works for 100,000 m^3/d

Phase 2: Remaining mechanical and electrical works for 100,000 m^3/d

* Cost premium as a result of the split of construction is expected in the Case 2 scenario.

(2) Estimation of Construction Cost

The construction cost is estimated based on the results of interviews with the local contractors and manufacturers.

The results of the cost estimates are as shown below:

Table 2-2 Results of Cost Estimate (Case 1)

Category	Phase 1		Phase 2		Total	
	USD	IDR (mil.)	USD	IDR (mil.)	USD	IDR (mil.)
Civil	64,506,338	581,363	-	-	64,506,338	581,363
Architectural	9,292,862	83,752	-	-	9,292,862	83,752
Mechanical	70,306,755	633,640	-	-	70,306,755	633,640
Electrical	14,534,045	130,988	-	-	14,534,045	130,988
Total	158,640,000	1,429,743	-	-	158,640,000	1,429,743

Source: JICA PPP Study Team

Table 2-3 Results of Cost Estimate (Case 2)

Category	Phase 1		Phase 2		Total	
	USD	IDR (mil.)	USD	IDR (mil.)	USD	IDR (mil.)
Civil	64,506,338	581,363	-	-	64,506,338	581,363
Architectural	9,292,862	83,752	-	-	9,292,862	83,752
Mechanical	37,734,019	340,077	38,450,105	346,532	76,184,124	686,609
Electrical	9,231,412	83,198	6,035,263	54,393	15,266,675	137,591
Total	120,764,631	1,088,390	44,485,368	400,925	165,250,000	1,489,315

Source: JICA PPP Study Team

The breakdowns of the cost estimate for each category are as shown in Table 2-4.

Table 2-4 Breakdowns of Cost Estimate for Each Category

Works	Item	Lift Pumping St. (USD)	Grit Chamber (USD)	Equalization (USD)	Reactor(MBR) (USD)	Sludge Storage (USD)	Total (USD)
Civil	Concrete	3,511,352	231,306	5,888,708	13,077,472	431,680	23,140,518
	Earth	1,023,988	7,780,832				8,804,820
	Temporary	17,000,000	6,000,000				23,000,000
	Foundation	0	9,561,000				9,561,000
	Total	21,535,340	42,970,998				64,506,338

		Lift Pumping St. (USD)	Grit Chamber (USD)	Equalization (USD)	Reactor(MBR) (USD)	Sludge Storage (USD)	Total (USD)
Architectural		883,000	1,040,000	1,027,584	1,317,840	5,024,438	9,292,862

Works	Item	Case-1	Case-2		
			Phase 1	Phase 2	Total
		(USD)	(USD)	(USD)	(USD)
Mechanical	Lift Pump	3,297,441	2,090,214	1,397,699	3,487,913
	Coarse Screen	54,144	27,219	31,059	58,278
	Fine Screen	439,560	220,958	252,158	473,116
	Ultra Fine Screen	674,389	338,962	386,890	725,852
	Grit Chamber Facilities	570,770	321,290	288,171	609,460
	Equalization Facilities	1,860,976	935,537	1,067,537	2,003,074
	MBR Facilities	31,608,580	16,531,919	18,247,519	34,779,438
	Screen for MBR	1,123,974	564,932	644,812	1,209,745
	Blower for Aeration	1,404,968	706,165	806,016	1,512,181
	Blower for MBR	3,401,556	1,710,056	1,951,256	3,661,312
	Disinfection Facilities	435,542	218,912	249,866	468,778
	Dewatering Facilities	2,107,470	1,271,110	967,226	2,238,336
	Deodorization facilities	2,590,783	1,741,420	984,959	2,726,379
	Miscellaneous (with piping)	20,736,602	11,055,325	11,174,937	22,230,262
	Total	70,306,755			76,184,124

Works	Item	Case-1	Case-2		
			Phase 1	Phase 2	Total
		(USD)	(USD)	(USD)	(USD)
Electrical	Power receiving equipment	11,004,403	7,167,149	4,370,920	11,538,069
	Control system	3,529,642	2,064,264	1,664,342	3,728,606
	Total	14,534,045			15,266,675

1) Exchange rate (IDR/USD): 9,012.5

2) The estimated cost is the value as of June of 2012.

3) The above cost excludes VAT.

Source: JICA PPP Study Team

2.4 Construction Plan

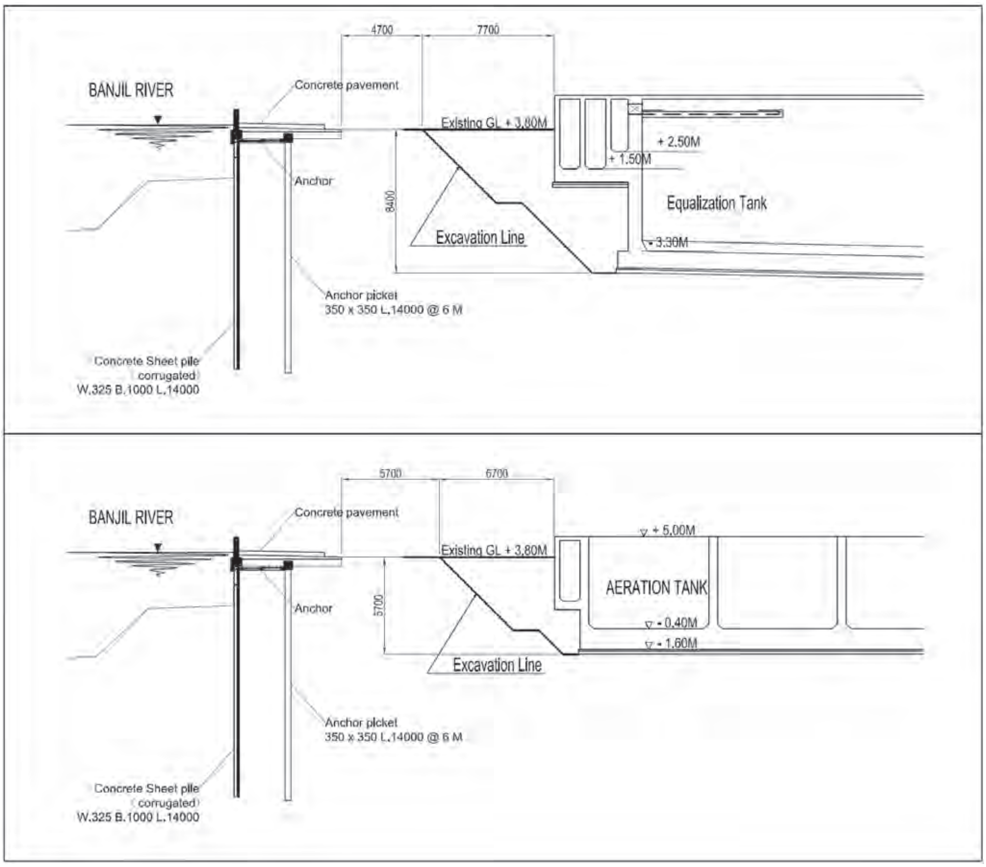
(1) Earth Works and Temporary Works

1) Construction of pump house

The pump house requires a maximum excavation depth of about 40 meters. For the planning of facilities with extra deep excavation, special attention should be paid to the conditions of the soil itself and the utilization of the surrounding area because the ground change due to excavation will have a considerable impact on the other structures around it. The retaining wall for the accumulated soil of excavation must be sufficiently stiff, and for this purpose, it is considered that construction of a continuous underground type concrete wall will be effective. Thus, the continuous underground type concrete wall is adopted in this plan for pump house construction.

2) Construction of facilities for STP and sludge treatment plant

The facility constructed at the deepest elevation is the equalization tank, but its excavation depth is only about 9 m, which can be achieved by the open-cut earth work method for the slope of excavation. Thus, from the standpoints of economical aspects and feasible construction, the open-cut earth work method is adopted in this plan. The slope of open-cut earth work is 1 in 1. The cross section of each facility and the embankment of Banjir Cannel are presented in Figure 2-7.



Source: JICA PPP Study Team

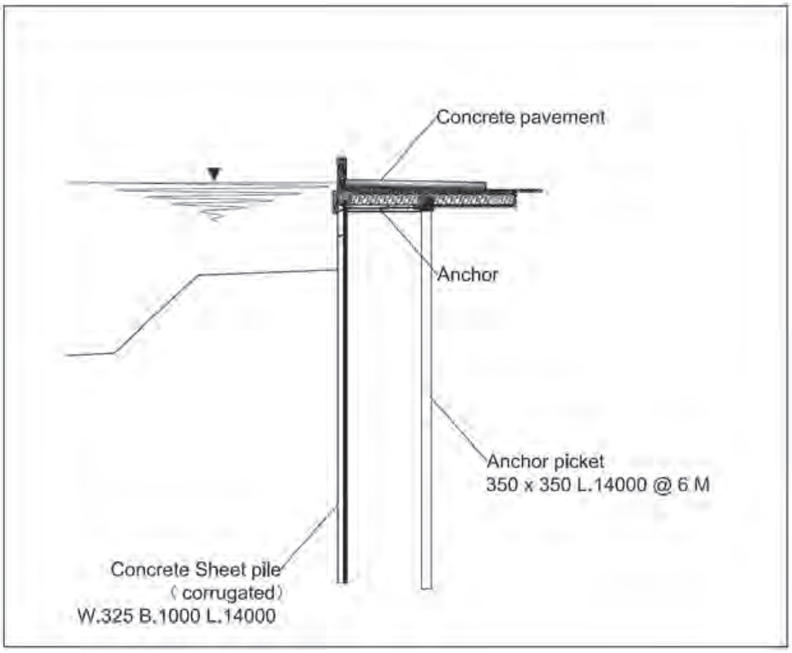
Figure 2-7 Cross Sections of Excavation for Wastewater Treatment Facilities and Shore Protection of Banjir Canal

There is about 5.0 m between the top of slope and the embankment of river. Therefore, the construction of facilities is possible. However, it is necessary to confirm the possibility of construction and make a construction plan based on the results of soil investigation conducted in the stage of detailed design because the soil investigation for the construction site has not been conducted yet.

3) Temporary access road

The access road for the construction site is the road along the Banjir Canal.

The sectional view of the access road is as shown in Figure 2-8. The embankment consists of a 5 m wide paved road with pre-cast concrete-panel wall along with supporting piles. The access road is only for single lane traffic but it is not expected to cause differences from the current traffic conditions. It is also assumed that construction vehicles may run on the access road, although the structural study of the access road has not been done yet.



Source: Pekerjaan Peningkatan Kapasitas Dan Perkuatan Tebing BANJIR Kanal Barat Hilir

Figure 2-8 Shore Protection of Banjir Canal and Road Section

(2) Construction Schedule

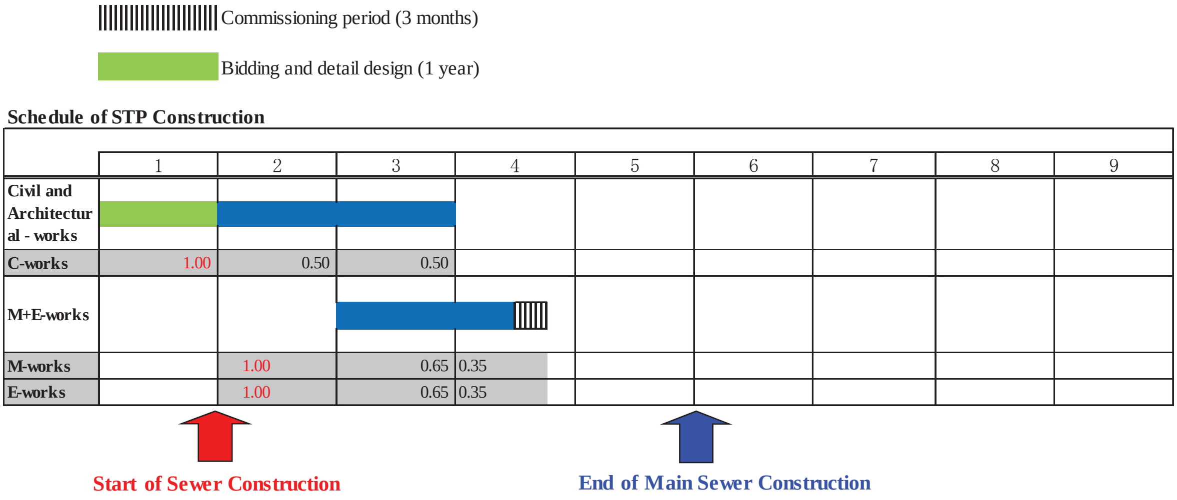
Construction period for STP is as follows:

* Case- 1: 2 years for Civil works, 1.5 years for Mechanical/Electrical works and
0.25 year for testing/pre-commissioning works

* Case- 2: Phase-1; 2 years for Civil works, 1.5 years for Mechanical/Electrical works and
0.25 year for testing/pre-commissioning works
Phase-2; 1 year for Mechanical/Electrical works and
0.25 year for testing/pre-commissioning works

In both cases, one year is reserved for the period of the detail design and the bidding prior to the civil works. In case 2, 0.5 year is reserved for the period of the detail design and the bidding prior to the mechanical and the electrical works.

The construction period and disbursement plan for each case are shown in Figure 2-9 and Figure 2-10 respectively.



▥ Commissioning period (3 months)

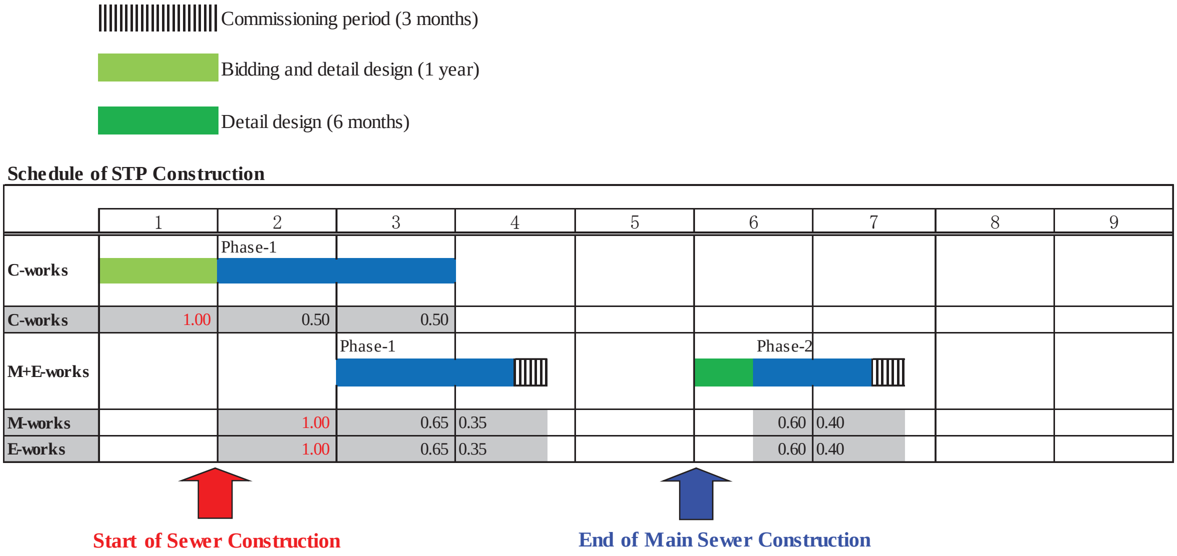
🟩 Bidding and detail design (1 year)

Schedule of STP Construction

	1	2	3	4	5	6	7	8	9
Civil and Architectural - works									
C-works	1.00	0.50	0.50						
M+E-works									
M-works		1.00	0.65	0.35					
E-works		1.00	0.65	0.35					

Source: JICA PPP Study Team

Figure 2-9 Construction Schedule and Annual Spending Plan (Case 1)



▥ Commissioning period (3 months)

🟩 Bidding and detail design (1 year)

🟩 Detail design (6 months)

Schedule of STP Construction

	1	2	3	4	5	6	7	8	9
C-works		Phase-1							
C-works	1.00	0.50	0.50						
M+E-works			Phase-1			Phase-2			
M-works		1.00	0.65	0.35		0.60	0.40		
E-works		1.00	0.65	0.35		0.60	0.40		

Source: JICA PPP Study Team

Figure 2-10 Construction Schedule and Annual Spending Plan (Case 2)

Chapter 3 Results of the Study on Reclaimed Wastewater Reuse

3.1 Outline of the Study

Reclaimed wastewater (RWW) is receiving more attention as a new water resource in urban areas. In this Study, the need for RWW reuse in the Central Business District of Jakarta was estimated and a preliminary design of the reclaimed water facility was also conducted for future projects.

3.2 Results of the Study

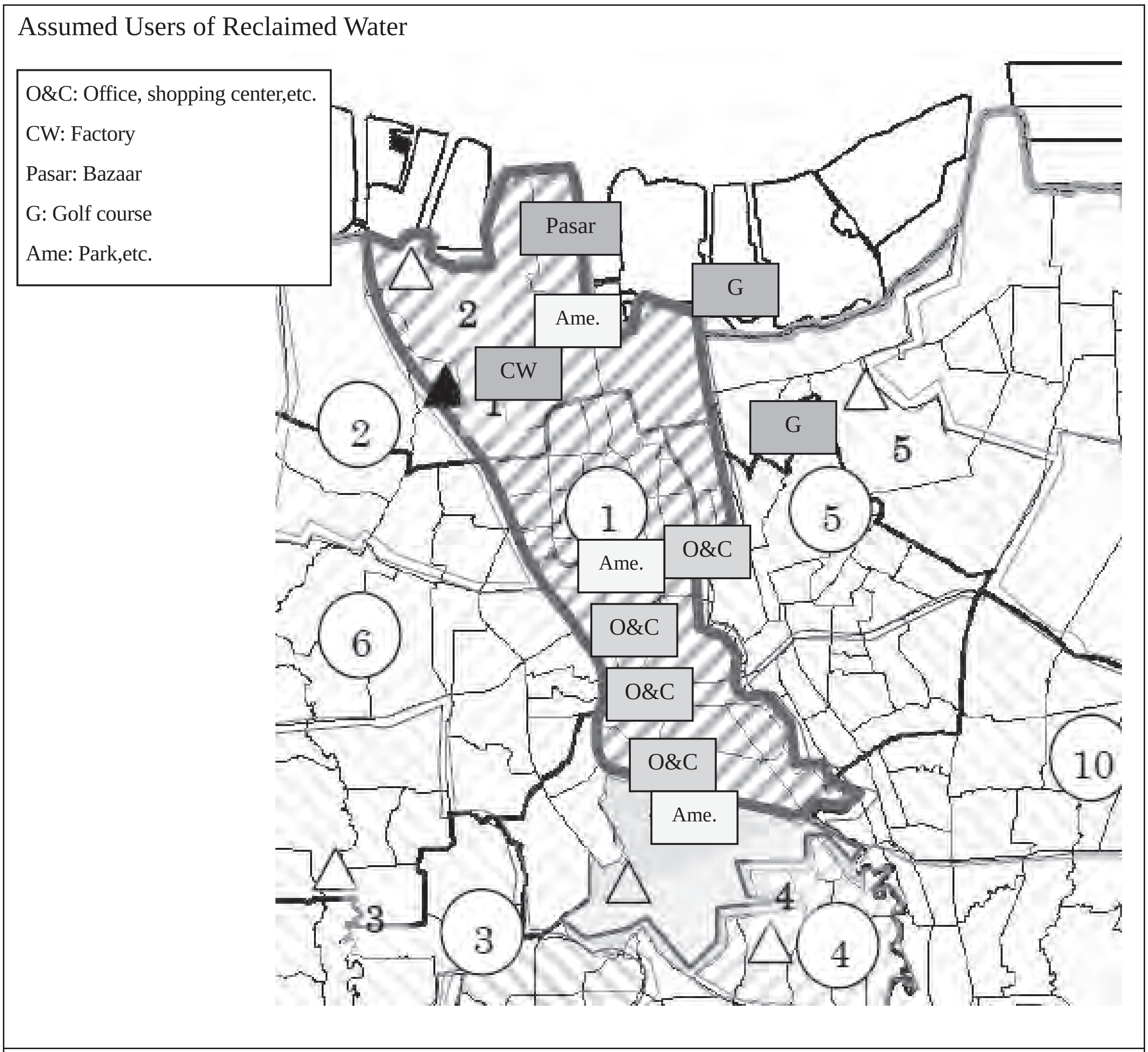
(1) Needs for RWW Reuse

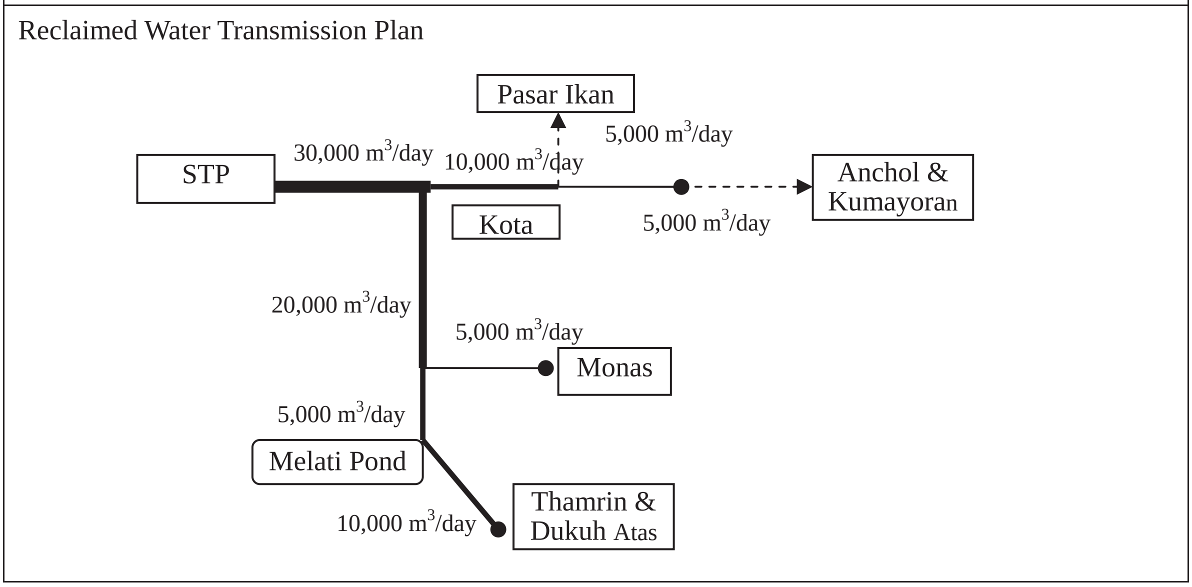
The needs for RWW reuse in the Central Business District of Jakarta are shown in Table 3-1. The reclaimed water transmission plan is shown in Figure 3-1.

Table 3-1 Needs for Reclaimed Wastewater Reuse in the Central Business District

Assumed Users of Reclaimed Water	Potential Demand	Use
Office building, shopping center	100-300 m^3/day/site	Toilet-flushing, spraying, washing water
Urban redevelopment area	5,000-10,000 m^3/day/site	Toilet-flushing, spraying, washing water
Bazaar, factory	Pasar Ikan 3,000-5,000 m^3/day/site	Cooling, toilet-flushing, washing water
Golf course	500-1,000 m^3/day/site	Toilet-flushing, spraying water
River, canal, park	100- m^3/day/site	Water environment restoration, landscape

Source: JICA PPP Study Team


Assumed Users of Reclaimed Water


Reclaimed Water Transmission Plan

Source: JICA PPP Study Team

Figure 3-1 Reclaimed Water Transmission Plan

(2) Proposed Reclaimed Water Facility of the Study

1) Design maximum daily flow of the reclaimed water facility

Final plan: 30,000 m^3/day

Phase 1 plan: 10,000 m^3/day

Phase 2 plan: 20,000 m^3/day

Remarks: The hourly changes in the reclaimed water usage due to user demand will be mitigated by installation of a receiving tank to avoid an excessive investment to the reclaimed water facility. For example, the receiving tank capacity is 40% to 60% of reclaimed water daily usage (Source: Tokyo Metropolitan Government reclaimed water use project implementation guidelines, enforced on April 1, 1995)

2) Step-wised development plan

Considering the reclaimed water demand, two phased developments shall be appropriate as shown below. The reclaimed water facility will consist of the reclaimed water transmission pipes and the reclaimed water transmission facility comprising the civil facility and the mechanical & electrical equipment such as the transmission pumps.

Phase 1 Plan:

- Transmission pipes for the final plan (30,000 m^3/day) will be constructed.
- Civil facility for the final plan (30,000 m^3/day) will be constructed.
- Mechanical and electrical equipment for the Phase 1 plan (10,000 m^3/day) will be installed.

Phase 2 Plan:

Mechanical and electrical equipment for the Phase 2 plan (20,000 m^3/day) will be installed.

3) Use and quality of reclaimed water

The proposed treatment process of the Jakarta central sewage treatment plant (STP) is MBR. Based on the operation results (*) of MBR in Japan, the treated water quality of MBR process could meet water quality for toilet flushing, spraying and landscape in the Technical Standards for Reclaimed Water Use described below.

Therefore, the MBR treated water of the Jakarta central STP could be reused for the purposes mentioned above.

The reclaimed water should be used only for the following purposes, considering the possibility of direct drinking by mistake.

- Toilet flushing water
- Spraying water for gardens, roads, etc.

- Washing water for trains, cars, floors, etc.
- Landscape water for parks, etc.

If the reclaimed water is used for the other purposes, such as boiler water which requires a low concentration of chloride ions and so on, the reclaimed water users have to treat the reclaimed water with additional processes, such as a reverse osmosis (RO) membrane system.

*Guidelines for Introducing Membrane Technology in Sewage Works: The 2nd Edition, Sewage Technical Meeting on Membrane Technology, March 2011

4) Technical standards for reclaimed water use

In Indonesia, the quality standards for reclaimed water have not been established yet. The Reclaimed Waste Water Committee between the Government of Indonesia and Japan is now in progress. Therefore, in this Study, the Technical Standards for Reclaimed Water Use (Standards for Water Quality and Facilities) in Japan as shown in Table 3-2 are applied temporarily for the reclaimed water use and quality.

Table 3-2 Technical Standards for Reclaimed Water Use

(Standards for Water Quality and Facilities)

Use Item	Toilet Flushing	Spraying	Landscape Use	Hydrophilization
E. Coli	Not detected /100 mL		Number of coli group bacteria: 1000 CFU/100 mL*1	Not detected /100 mL
Turbidity	2 degrees or less *2 *7			2 or less *2
pH	5.8 to 8.6			
Appearance	Not unpleasant			
Chromaticity	Not specified (Set the standard values according to the user requirements, etc.)		40 degrees or less *3	10 degrees or less *3
Odor	Not unpleasant (Set the odor intensity according to the user requirements, etc.)			
Standards for the facility	The facility must function at a level equal to or superior to that for sand filtration.			Coagulation-sedimentation and sand filtration
Residual Chlorine	Free: 0.1 mg/L or combined: 0.4 mg/L *5 *7	Free: 0.1 mg/L or combined: 0.4 mg/L *4 *5 *7	Not specified *6	Free: 0.1 mg/L or combined: 0.4 mg/L*4 *5 *7
Notes	Standard application points: Residual chlorine is at the responsibility boundary, and the other items are at the exit of the reclaimed water facility.			

*1: Tentative standards

*2: Unit: mg-kaolin equivalent /L

*3: Set higher standard values according to the user requirements, etc.

*4: Not applied when residual chlorine is not necessary.

*5: If chlorine is additionally injected at the destination, the process may be conducted according to a separate agreement, etc.

*6: Not specified, because this type of water may be treated with a process other than chlorination from the viewpoint of ecosystem conservation, and is not supposed to be touched by humans.

*7: Targeted control value: Different from the standard value, which must always be satisfied; the target value to be satisfied to the extent possible during operation of the reclamation facility.

Source: Cited from the "Manual for Standards for Reclaimed Sewage Water Quality (2005.4)" prepared by the Ministry of Land, Infrastructure, Transport and Tourism

(3) Preliminary Design of Reclaimed Water Facility

1) Reclaimed water transmission pipe

a) Proposed reclaimed water transmission pipelines

The reclaimed water will be supplied from the reclaimed water transmission facility located in the Jakarta central STP to the above mentioned areas as shown in Table 3-3.The proposed reclaimed water transmission pipe network in Zone 1 is shown in Figure 3-2.

Table 3-3 Reclaimed Water Transmission Pipelines

Name of Pipeline	Serviced Areas	Design Maximum Daily Flow (Final Plan)
Southwest line (SW)	Monas, Melati Pond, Thamrin & Dukuh Atas	20,000 m^3/day
Northeast line (NE)	Kota, Pasar Ikan, Anchol & Kumayoran	10,000 m^3/day

Source: JICA PPP Study Team

b) Alternative study on installation method of reclaimed water transmission pipe

The following two cases are set up for alternative study.

Case A: Reclaimed water pipes will be placed in new trenches and so on. A single pipeline will supply the reclaimed water to the NE pipeline and the SW pipeline in sections R1 and R2 as shown in Figure 3-2.

Case B: Reclaimed water pipes will be placed inside new sewer pipes.

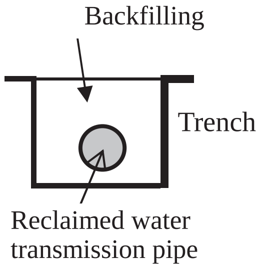
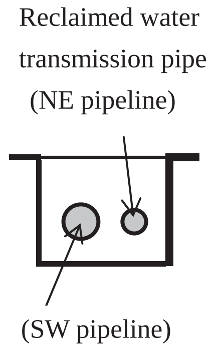
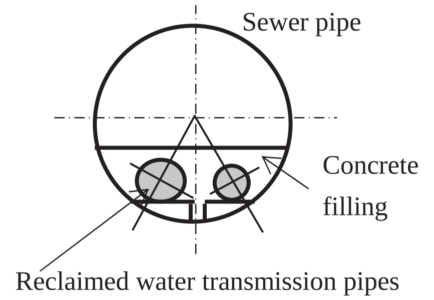
Upon preliminary estimation, it was clarified that the construction cost of the reclaimed water transmission pipes in Case A is 13% lower than that of Case A'(*).

*Case A': Reclaimed water pipes will be placed in new trenches and so on. Two separate pipelines will each supply the reclaimed water to the NE pipeline and the SW pipeline in all sections.

Then, the construction cost of the reclaimed water facility in Case B will be compared with that in Case A.

As shown in Table 3-4, it is estimated that the construction cost of the reclaimed water transmission pipes in Case A, in which the pipes are placed in trenches, is 71% lower than that in Case B, in which they are placed inside sewer pipes.

Table 3-4 Installation Method of Reclaimed Water Transmission Pipe

	Case A (*1)	Case A' (*2)	Case B
Installation method of reclaimed water transmission pipe	Reclaimed water pipes will be placed in new trenches and so on.		Reclaimed water pipes will be placed inside new sewer pipes.
			
	・ Pipes will be placed in new trenches excavated by the cut and cover (open trench) method. At sections where pipelines are required to cross large roads, rivers or canals, a special construction method such as pipe-jacking, pipe bridge, and so on will be used. ・ The depth from the road surface to the top of the pipe shall be 1.5 m in the open cut method and 5 m in the pipe jacking method.		・ The reclaimed water pipes will be laid on the inside bottom of the new sewer pipe and then filled with concrete to protect the reclaimed water pipe and to ensure smooth stream sewage. ・ Two pipelines will be installed at the inside bottom of the new sewer pipe to use the inside space effectively.
Pipe material	Poly-vinyl chloride: PVC S-12.5 (pressure work at temp. 25-35 degrees: 0. 8 MPa)		
	Remarks: At the sections where the special construction methods such as pipe-jacking, pipe bridge, and so on will be required, pipe material, which is suitable for the installation method and has the internal water pressure bearing capacity equivalent to the above, shall be used.		
Velocity	Considering the economic efficiency, the velocity ranges from 0.8 to 1.2 m/s for pipes with diameter 200 mm–700 mm.		
Estimated construction cost (*3)	29% (87%)	33% (100%)	100% (*4)

*1: A single pipeline will supply the reclaimed water to the NE pipeline and the SW pipeline in section R1 and section R2 as shown in Figure 3-2.

*2: Two separate pipelines will each supply the reclaimed water to the NE pipeline and the SW pipeline in all sections.

*3: Construction cost of the reclaimed water transmission pipe was estimated using the construction unit prices (IDR/m-pipe) obtained in Chapter 1 Sewer Development Plan.

*4: The estimated cost in Case B consists of the amount of increase in the construction cost of the new sewer pipe by placing the reclaimed water transmission pipe inside the new sewer pipe, the filling cost of the concrete and the installation cost of the reclaimed water transmission pipe.

Source: JICA PPP Study Team

2) Reclaimed water transmission facility

a) Case A

The equipment list of reclaimed water transmission facility (Case A) is shown in Table 3-5. The civil works quantity of reclaimed water transmission facility (Case A) is shown in Table 3-6. The proposed layout of the reclaimed water transmission facility is shown in Figure 3-3.

Table 3-5 Equipment List of Reclaimed Water Transmission Facility (Case A)

No.	Equipment	Specification	Quantity			Motor Output (kW)	Remarks
			Phase1	Phase2	Final		
1	Reclaimed water transmission pump(*1)	Volute type pump 250 mm x 150 mm x 7 m^3/min x 57 mH	2	2	4	110	Including 1 standby
2	Flow meter	Ultrasonic type Diameter 600 mm	1	0	1	-	-
3	Hoist	Electrical motor operation hoist lifting capacity: 5ton	1	0	1	5.9 (hosting) 0.7 (traveling)	-
4	Sodium hypochlorite dosing pump	Diaphragm pump 100-500 mL/min x 1 MPa	4	4	8	0.2	Including 2 standby
5	Sodium hypochlorite storage tank	Polyethylene tank 3 m^3	1	0	1	-	-

*1: The supply pressure of the reclaimed water is more than 50 kPa at the end of the reclaimed water transmission pipe.

Source: JICA PPP Study Team

Table 3-6 Civil Works Quantity of Reclaimed Water Transmission Facility (Case A)

Item	Quantity
Civil Work Concrete Volume	660 m^3
Civil Work Earthwork Volume	
Excavation	3,690 m^3
Disposal	1,650 m^3
Back-filling	2,040 m^3
Foundation Pile (diameter: 400 mm, Length: 21 m)	56 piles

Source: JICA PPP Study Team

b) Case B

The equipment list of reclaimed water transmission facility (Case B) is shown in Table 3-7. The civil works quantity of reclaimed water transmission facility (Case B) is shown in Table 3-8.

Table 3-7 Equipment List of Reclaimed Water Transmission Facility (Case B)

No.	Equipment	Specification	Quantity			Motor Output (kW)	Remarks
			Phase1	Phase2	Final		
1	Reclaimed water transmission pump for Southwest (SW) Line (*1)	Volute type pump 200 mm x 125 mm x 4.7 m^3/min x 59 mH	2	2	4	75	Including 1 standby
2	Reclaimed water transmission pump for Northeast (NE) Line (*1)	Volute type pump 150 mm x 125 mm x 2.4 m^3/min x 53 mH	2	2	4	45	Including 1 standby
3	Flow meter for SW line	Ultrasonic type Diameter 600 mm	1	0	1	-	-
4	Flow meter for NE line	Ultrasonic type Diameter 400 mm	1	0	1	-	-
5	Hoist	Electrical motor operation hoist lifting capacity: 5 ton	1	0	1	5.9 (hosting) 0.7 (traveling)	-
6	Sodium hypochlorite dosing pump	Diaphragm pump 100-500 mL/min x 1 MPa	4	4	8	0.2	Including 2 standby
7	Sodium hypochlorite storage tank	Polyethylene tank 3 m^3	1	0	1	-	-

*1: The supply pressure of the reclaimed water is more than 50 kPa at the end of the reclaimed water transmission pipe.

Source: JICA PPP Study Team

Table 3-8 Civil Works Quantity of Reclaimed Water Transmission Facility (Case B)

Item	Quantity
Civil Work Concrete Volume	760 m^3
Civil Work Earthwork Volume	
Excavation	4,200 m^3
Disposal	1,960 m^3
Back-filling	2,250 m^3
Foundation Pile (diameter: 400 mm, Length: 21 m)	62 piles

Source: JICA PPP Study Team

(4) Cost Estimate of the Reclaimed Water Facility(Initial Investment Cost)

Construction cost of the reclaimed water transmission facility was estimated using the quantities shown in Tables 3-5 to 3-8 and the estimated unit prices in Indonesia. Construction cost of the reclaimed water transmission pipe was estimated using the construction unit prices (IDR/m-pipe) obtained in Chapter 1 Sewer Development Plan. The cost estimates are shown in Table 3-9 (Case A) and Table 3-10 (Case B). It is estimated that the construction cost of the reclaimed water facility in Case A, in which the reclaimed water transmission pipes are placed in trenches, is 69% lower than that in Case B, in which they are placed inside sewer pipes.

Table 3-9 Cost Estimate of Reclaimed Water Facility (Case A)

Phase1 Plan

Name of facility	Total Cost (mil. IDR)	F/C (mil. USD)	L/C (mil. IDR)
Reclaimed Water Transmission Facility	9,160	0.156	7,752
・Civil Works (30,000 m^3/day)	(3,812)	(0)	(3,812)
・Mechanical Works (10,000 m^3/day)	(3,565)	(0.156)	(2,158)
・Electrical Works (10,000 m^3/day)	(1,783)	(0)	(1,783)
Reclaimed Water Transmission Pipe (30,000 m^3/day)	130,504	0	130,504
Total	139,664	0.156	138,256

Phase2 Plan

Name of facility	Total Cost (mil. IDR)	F/C (mil. USD)	L/C (mil. IDR)
Reclaimed Water Transmission Facility	4,403	0.156	2,996
・Civil Works (30,000 m^3/day)	(0)	(0)	(0)
・Mechanical Works (10,000 m^3/day)	(2,935)	(0.156)	(1,528)
・Electrical Works (10,000 m^3/day)	(1,468)	(0)	(1,468)
Reclaimed Water Transmission Pipe (30,000 m^3/day)	0	0	0
Total	4,403	0.156	2,996

Final Plan

Name of facility	Total Cost (mil. IDR)	F/C (mil. USD)	L/C (mil. IDR)
Reclaimed Water Transmission Facility	13,563	0.312	10,748
・Civil Works (30,000 m^3/day)	(3,812)	(0)	(3,812)
・Mechanical Works (10,000 m^3/day)	(6,500)	(0.312)	(3,685)
・Electrical Works (10,000 m^3/day)	(3,251)	(0)	(3,251)
Reclaimed Water Transmission Pipe (30,000 m^3/day)	130,504	0	130,504
Total	144,067	0.312	141,252

Remarks: 1 USD=9012.5IDR, 1 USD=76.21 JPY

Source: JICA PPP Study Team

Table 3-10 Cost Estimate of Reclaimed Water Facility (Case B)

Phase1 Plan

Name of facility	Total Cost (mil. IDR)	F/C (mil. USD)	L/C (mil. IDR)
Reclaimed Water Transmission Facility	11,958	0.22	9,975
・Civil Works (30,000 m^3/day)	(4,342)	(0)	(4,342)
・Mechanical Works (10,000 m^3/day)	(5,077)	(0.22)	(3,094)
・Electrical Works (10,000 m^3/day)	(2,539)	(0)	(2,539)
Reclaimed Water Transmission Pipe (30,000 m^3/day)	448,379	0	448,379
Total	460,337	0.22	458,354

Phase2 Plan

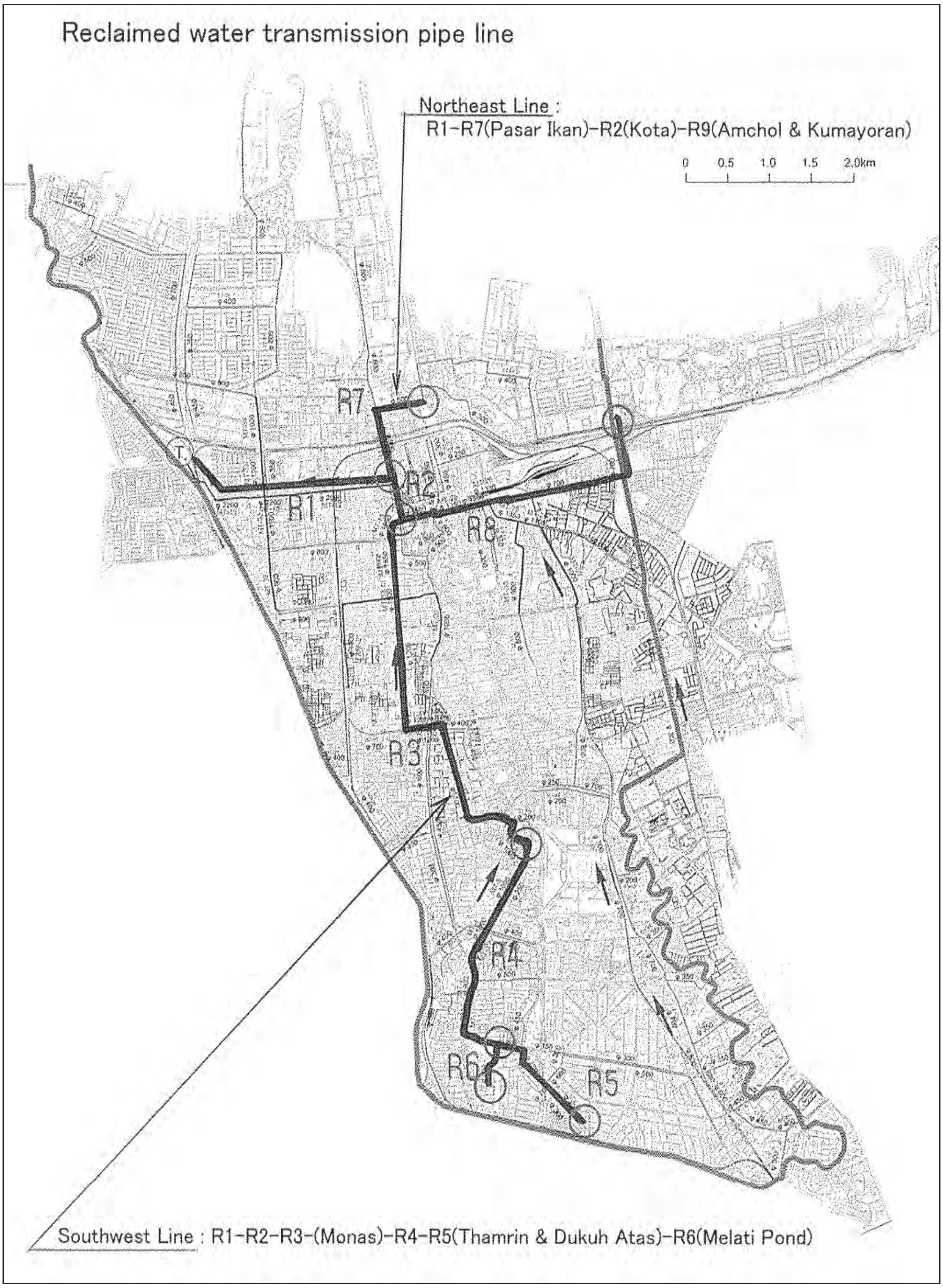
Name of facility	Total Cost (mil. IDR)	F/C (mil. USD)	L/C (mil. IDR)
Reclaimed Water Transmission Facility	6,131	0.22	4,148
・Civil Works (30,000 m^3/day)	(0)	(0)	(0)
・Mechanical Works (10,000 m^3/day)	(4,087)	(0.22)	(2,104)
・Electrical Works (10,000 m^3/day)	(2,044)	(0)	(2,044)
Reclaimed Water Transmission Pipe (30,000 m^3/day)	0	0	0
Total	6,131	0.22	4,148

Final Plan

Name of facility	Total Cost (mil. IDR)	F/C (mil. USD)	L/C (mil. IDR)
Reclaimed Water Transmission Facility	18,089	0.44	14,122
・Civil Works (30,000 m^3/day)	(4,342)	(0)	(4,342)
・Mechanical Works (10,000 m^3/day)	(9,164)	(0.44)	(5,197)
・Electrical Works (10,000 m^3/day)	(4,583)	(0)	(4,583)
Reclaimed Water Transmission Pipe (30,000 m^3/day)	448,379	0	448,379
Total	466,468	0.44	462,501

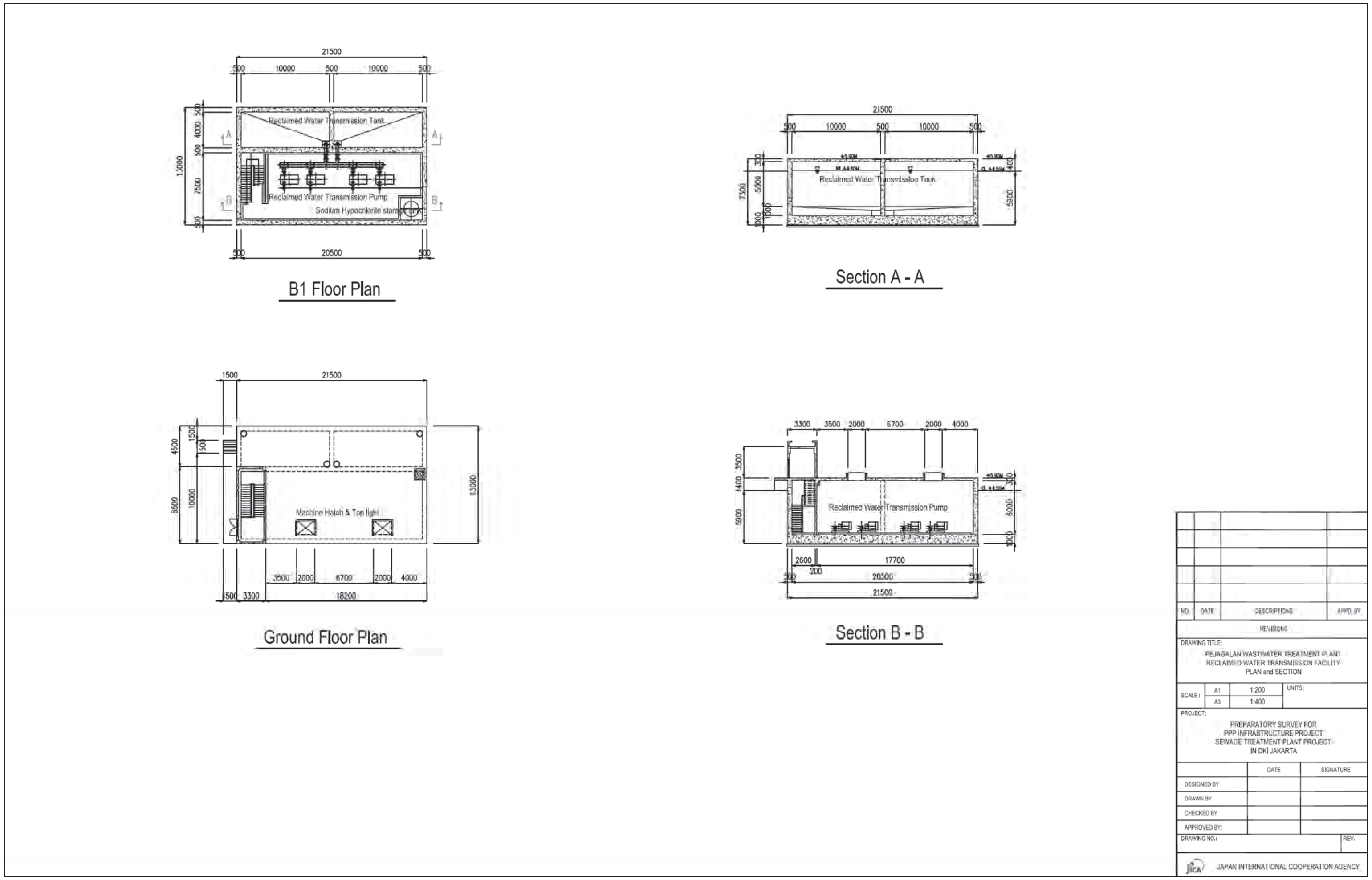
Remarks: 1 USD=9,012.5IDR, 1 USD=76.21 JPY

Source: JICA PPP Study Team



Source: JICA PPP Study Team

Figure 3-2 Proposed Reclaimed Water Transmission Pipe Network in Zone 1



Source: JICA PPP Study Team

Figure 3-3 Proposed Layout of Reclaimed Water Transmission Facility (Case A)

Chapter 4 Sewage Sludge Recycling

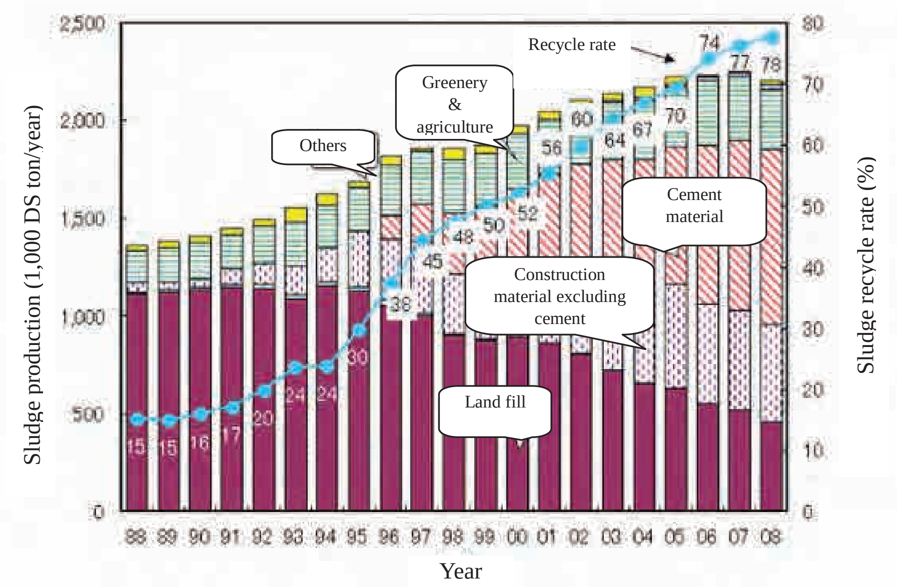
4.1 Study Objectives

(1) Historical Experience on Sewage Sludge Reuse in Japan

Sewage sludge shall be treated appropriately to ensure sustainable wastewater management. Sewage sludge has been reduced and stabilized through treatment processes of thickening - digestion - dewatering and land reclamation. However, land reclamation has been restricted since land acquisition for landfill sites attracts serious social concerns.

Recently cement material and sewage sludge fuel of dried or carbonated sludge have prevailed from the viewpoints on global environment preservation and energy reuse replacing coal.

The Study is to survey the recycling methodology of sewage sludge in Jakarta in accordance with the restricted land reclamation due to increased sewage sludge production in the future.



Source: Ministry of Land, Infrastructure, Transportation and tourism, Japan

Figure 4-1 Change of Sewage Sludge Disposal and Recycling in Japan

(2) Sewage Sludge Treatment Plan

The MP Review prescribes, “Sewage sludge is processed to recycle and/or landfill through coagulation/thickening, digestion (bio-gas exploitation) and dewatering. Sludge recycling consists of composting, cement material, gravel, bricks or sludge fuels. Wastewater treatment plant shall not facilitate recycling facilities at present.”

This Study provides future direction and methodology of sewage sludge reuse in accordance with the MP Review.

STP of Zone 1 in the public park site can only house a wastewater treatment facility of 264,000 m^3/day including sludge thickening and dewatering. Accordingly, the site for sludge recycling shall be provided by Pejagalan STP.

The PPP project applies a sludge treatment process of "thickening - dewatering - land reclamation" that treats sewage sludge and septage produced in Zone 1.

Table 4-1 Step-wised Plan of Sewage Sludge Treatment and Recycling

Component	PPP Project (Short term)	Mid & Long term
Treatment plant	Pejagalan STP	Regional sludge treatment plant
Sludge reuse	Land reclamation	Sludge fuel (dried sludge) Sludge fuel (carbonized sludge) Co-combustion with solid waste Greenery use
Treatment process	Thickening – dewatering	Thickening - dewatering - fuelization or composting

Source: JICA PPP Study Team

Mid and long-term plans of sewage sludge reuse shall consider the following in the future in view of sustainable sewage sludge management on land acquisition and cost for reclamation site, regional sewage sludge project, the global environment and utilization of sewage sludge resources.

- Possibility of land acquisition and sludge recycling
- Environmental affordability on regional sewage sludge treatment
- Possibility of land reclamation and/or sludge utilization manner
- Selection of sludge treatment process

4.2 Study Content and Proposal

4.2.1 Methodology of Sludge Reuse and Disposal

Low cost sludge treatment processes such as drying beds and sludge lagoons are not practicable since a large site for the treatment plant cannot be acquired in Jakarta.

Existing sludge disposal costs are shown in table below. Mechanical treatment processes for sludge fuel, etc. will be alternatives since increased sewage sludge in accordance with sewerage service development will be difficult due to issues with land reclamation.

Table 4-2 Cost on Sewage Sludge Disposal

Type of Sludge	Cost	Remarks
Liquid sludge	200,000 IDR/m^3 (2 USD/m^3)	Disposal cost
Dewatered sludge	100 USD/ton	Including transportation cost

Source: JICA PPP Study Team

Sewage sludge reuse and disposal plants in the Jakarta Metropolitan Region are shown in the table below. A composting plant is not recommended due to the limited capacity for sewage sludge recycling.

Table 4-3 Potential Sewage Sludge Reuse and Reclamation

Facility	Location	Capacity	Type of sludge
DKI land fill site (Bandar Gebang)	Bekasi	Un-known due to residential awareness	Dewatered sludge
PPLi	Bogor	10,000 ton/month	Dewatered sludge
Cement factory	Bogor	Sufficient	Dewatered sludge Sludge fuel
Coal power station	Tangerang, Cirebon Cilegon, etc.	Sufficient	Sludge fuel

Source: JICA PPP Study Team

4.2.2 Sewage Sludge Examination

Characteristics of sewage sludge produced in commercial buildings were examined in order to predict the potential of sewage sludge use in the future.

Substances of sewage sludge will change in accordance with sewerage development and lifestyle changes; however, only the present sewage sludge is available and brings indispensable features.

Results of sewage sludge examination are evaluated regarding greenery use (as fertilizer and soil conditioning), sludge fuel and cement material. Potential sewage sludge use shall not be restricted in accordance with obtained results of the existing wastewater treatment facility.

(1) Evaluation on Fertilizer and Soil Conditioning

Results of sludge examination on fertilizer and soil conditioning are shown in the following table:

Table 4-4 Physics-and-Chemistry-1 of Dried Sludge

(Elemental composition, other soil manure study items)

Parameter	Unit	Results	Method
Moisture in Analysis	% adb	3.4	ASTM D 3173-08
pH (10%)		5.94	
Cation Exchange Capacity (CEC)	meq/100g adb	63.21	SNI 13-3494-1994
Electric Conductivity (EC)	mS/cm	6.77	BP TANAH BOGOR
Ash Content	% adb	8.5	ASTM D 3174-04
Carbon (C)	% adb	43.75	ASTM D 3178-02
Nitrogen (N)	% adb	0.79	ASTM D 3179-02
Phosphorus (P)	%	1.35	ASTM D 4208-02
Potassium (K)	%	0.52	ASTM D 3683-08
Chloride (Cl)	%	0.09	ASTM D 3683-08
Aluminum (Al)	%	0.40	ASTM D 3683-08

Source: JICA PPP Study Team

Table 4-5 Physics-and-Chemistry-2 of Dried Sludge

(Heavy metal concentration)

Parameter	Unit	Results	Method
Arsenic (As)	ppm	5.16	ASTM D 4606-08
Cadmium (Cd)	ppm	0.95	ASTM D 3683-08
Chromium (Cr)	ppm	28.96	ASTM D 3683-08
Copper (Cu)	ppm	143.63	ASTM D 3683-08
Lead (Pb)	ppm	16.47	ASTM D 3683-08
Mercury (Hg)	ppm	0.79	ASTM D 3684-01
Nickel (Ni)	ppm	11.83	ASTM D 3683-08
Zinc (Zn)	ppm	0.17	ASTM D 3683-08
Thallium (Ti)	ppm	1.08	ASTM D 6349-08

Source: JICA PPP Study Team

1) Organic matter

The amount of organic matter in dried sludge is not measured directly. However, residuals excluding ash are assumed to be organic matter, which are presumed to make up 90% of the dry solid. The tested sludge is richer in organic substances than sewage sludge in Japan.

2) T-C (Total Carbon)

T-C is 43.75%. If 91.5% is organic matter, T-C is equivalent to approximately 48% of this. This value is close to 48% of C in carbohydrate and 44% of human waste sludge. Average raw sludge in Japan has a slightly larger percentage of C and less lipid content compared to the tested sludge.

3) T-N (Nitrogen)

T-N is 0.79%. The tested sludge has lower levels than raw sludge in Japan.

N is the most important nutrient for fertilizer use.

Fertilizer use is difficult in cases where T-N is 2% or less, and this sludge shall be used for soil conditioning.

4) C/N rate

The C/N rate is as high as 55.4. Organic fertilizer with a high C/N ratio generally has a slow-acting fertilizer effect.

In the case of a high C/N rate, nitrogen in the soil is easily absorbed by microbes through fertilizer decomposition and plants imitate nitrogen starvation.

The tested sludge has a C/N rate too high for nitrogen starvation; therefore, the tested sludge is not recommended for fertilizer use and a reduced C/N rate through composting can be applied for soil conditioning.

5) T-P (Phosphorus)

T-P (Phosphorus) is 1.35%, which is equivalent to 3.09% of P_2O_5 and is higher than T-N. Plants generally have N>P; however, P in raw sludge sometimes exceeds N and digested sludge is usually at a remarkable level.

The tested sludge is at a little lower level than the 3-5% of raw sludge in Japan.

6) T-K (Potassium)

T-K is 0.52%, which is equivalent to 0.63% of K_2O. The tested sludge is the same level as raw sludge in Japan, which is rich in P and less rich in K. Use as fertilizer is not recommended.

7) Al (Aluminum)

The Al concentration is 0.4% (4,000 ppm). Excessive free Al is harmful to plants. In the case of low levels of Al as a convertibility ingredient, Al may be allowable.

8) Cl (Chlorine)

The Cl concentration is 0.09% (900 ppm). Cl of plants is generally equivalent to 2,000 - 20,000 mg/kg as a Ds base. In cases where seawater is entrapped, the osmotic pressure becomes high and water absorption may be prevented. However, the tested Cl concentration is at an acceptable level.

9) Heavy metals

All tested heavy metals are at applicable levels to soil in accordance with Japanese standards for soil application (refer to Tables 4-6, 4-7 & 4-8).

As long as excessive dosing is not done, tested sludge is at an acceptable level. Since dried sludge contains organic matter, the heavy metal concentration increases in accordance with sludge decomposition.

In respect to the Soil Pollution Control Measures Law, the usual dosing manner will not exceed the standards. If incinerated ash is dosed excessively, the soil pollution may increase.

Table 4-6 Fertilizer Control Law, Japan

Parameter	Permissible concentration
Arsenic	50 ppm (0.005 %)
Cadmium	5 ppm (0.0005%)
Mercury	2 ppm (0.0002%)
Nickel	300 ppm (0.03%)
Chrome	500 ppm (0.05%)
Lead	100 ppm (0.01%)

Table 4-7 Soil Standards of Land for Agricultural Use, Japan

Parameter	The law about pollution control of the soil of land for agricultural use (1970)	Criteria of control concerning the prevention from accumulation of the heavy metal in the soil in land for agricultural use, etc. (1984)
Cadmium and its compounds	1 mg /rice 1 kg (sulfuric acid decomposition method)	
Copper and its compounds	125 mg/soil 1 kg (0.1 N-HCL soluble)	
Arsenic and its compounds	15 mg/soil 1 kg (0.1 N-HCL soluble)	
Zinc	—	120 mg / soil 1 kg (strong acid decomposition, atomic absorption luminous-intensity method)

Table 4-8 Soil Pollution Control Measures Law, Japan

Parameter	Initial listing requirements
Cadmium and its compounds	150 ppm or less
Sexavalent chrome compounds	250 ppm or less
Mercury and its compounds	15 ppm or less
Selenium and its compounds	150 ppm or less
Lead and its compounds	150 ppm or less
Arsenic and its compounds	150 ppm or less
Fluoride and its compounds	4000 ppm or less
Boron and its compounds	4000 ppm or less

(2) Evaluation as Fuel

The test results for calorie and combustion are shown in Table 4-9.

Table 4-9 Physics-and-Chemistry-3 of Dried Sludge

(Quantity of heat, the item in connection with combustion)

Parameter	Unit	Results	Method
Moisture in Analysis	% adb	3.4	ASTM D 3173-08
Ash Content	% adb	8.5	ASTM D 3174-04
Fixed Carbon	% adb	13.0	ASTM D 3172-07
Total Sulfur	% adb	1.77	ASTM D 4239-10
Gross Calorific Value	Kcal/kg adb	4812	ASTM D 5865-10

Source: JICA PPP Study Team

The calorific value is 4,812 Kcal/kg, which is equivalent to 80% of coal (approximately 6,000 Kcal/kg). Because more than 90% of ingredients are presumed to be organic matter, tested sludge will result in high calories.

(3) Evaluation as Cement Material

Principal substances of incinerated ash are SiO_2, Al_2O_3, Fe_2O_3 and P_2O_5, with SiO_2 making up the majority. Test results for cement material are shown in Table 4-10, and are almost the same level as incineration ashes of polymer dosed dewatered sludge in Japan.

The analysis results on the evaluation criteria as a cement matrix are shown in Table 4-10. The candidates for analysis are sludge burning ashes (ash obtained by ash measurement).

Table 4-10 Composition of Dried Sludge Incineration Ashes

Evaluation criteria as a cement matrix

Parameter	Unit	Results	Method
Silicone Dioxide (SiO_2)	%	22.42	ASTM D 6349-09
Aluminum Trioxide (Al_2O_3)	%	8.02	ASTM D 6349-09
Iron Trioxide (Fe_2O_3)	%	7.55	ASTM D 6349-09
Calcium Oxide (CaO)	%	12.47	ASTM D 6349-09
Magnesium Oxide (MgO)	%	5.08	ASTM D 6349-09
Sodium Oxide (Na_2O)	%	1.59	ASTM D 6349-09
Phosphorus Pentoxide (P_2O_5)	%	33.67	ASTM D 6349-09
Sulphur Trioxide (SO_3)	%	0.03	ASTM D 1757-03
Loss On Ignition (LOI)	%	0.47	Gravimetric

Source: JICA PPP Study Team

1) CaO

CaO was 12.47%, which differs from the dehydration sludge using lime.

CaO produces and hardens $CaCO_3$ through hydration and carbonation. As a result, composed SiO_2 becomes hardened, and the internal pH remains at alkalinity and prevents oxidation of reinforced bars. Portland cement generally contains approximately 65% CaO.

Tested sludge can be processed into cement material through mixing with CaO based materials.

2) MgO (Magnesium oxide)

MgO expands itself and may explode in concrete when MgO changes to Mg (OH_2) through reacting with water.

3) SO_3 (Sulfur trioxide)

Richer SO_3 is unsuitable for cement material. JIS standards define levels of not more than 4.5% for eco-cement and 3.5% for port land cement respectively.

The tested value is 0.03%.

4) Cl (Chlorine ion)

Cl causes reinforced bar corrosion in concrete. JIS standards define levels of not more than 0.1% for eco-cement and 0.035% for port land cement, respectively.

The tested result is 0.09%.

5) Na_2O (Sodium oxide)

Rich Na_2O may explode in concrete after hardening. JIS standard defines levels of not more than 0.75%. The tested result was 1.59%, which exceeds the standard.

As for the concrete containing expansion, destruction may occur after hardening.

According to the JIS standard, the level must be 0.75% or less. The measured value of the sample is 1.59% and is above the standard.

The solution is confined in the hardened concrete (called “fine-pores solution”). In the case of high alkalinity in the fine-pores solution, the OH-concentration increases, the silica of aggregate reacts and may explode concrete (alkali aggregate reaction).

In order to prevent this alkali aggregate reaction, the Na_2O concentration, which supplies OH- of fine-pores solution, shall be controlled to less than the allowable level.

6) MgO, SO_3 and Cl

MgO, SO_3 and Cl, which deteriorate cement quality, are at acceptable levels for cement material. If the sewage sludge remains stable, the tested sludge can be applied to cement material mixed with other appropriate additives.

Compared with various cement matrices, it cannot be said that composition of the incineration ashes of this sludge is suitable for cement. If the content of phosphorus is high, it turns out that hardening of cement is controlled.

In order to remove the phosphorus, a few ingredients can be added if needed; however, this will incur some costs. On the other hand, it will be possible to use the separated phosphorus as manure.

4.2.3 Concept of Regional Sewage Sludge Treatment

Two or three regional sewage treatment plants are recommended in Jakarta. Sewage sludge produced in Pejagalan STP is recommended to be processed through the following options.

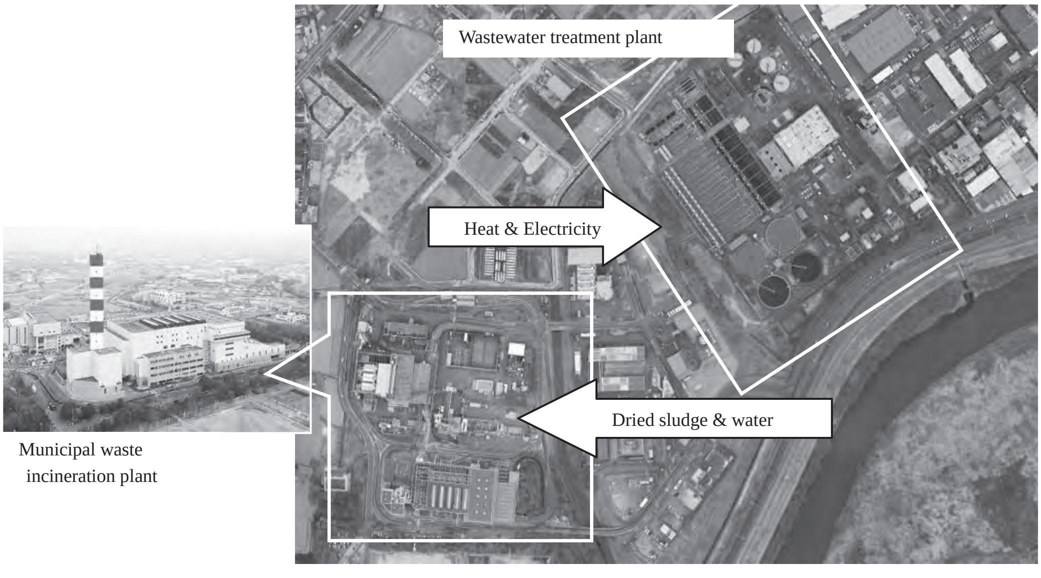
Option-1: Co-combustion of sewage sludge with municipal solid waste
Option-2: Regional sludge treatment of plural STPs

Co-combustion of sewage sludge with municipal solid waste utilizes wasted heat of the incineration plant and treated effluent of STP with each other.

Regional sludge treatment is commonly facilitated with wastewater treatment plants and is advantageous due to the scale of economics and countermeasures on environmental issues. The regional sludge treatment plan shall carefully be provided in accordance with requirements of sewage sludge users, transportation, coordination of relevant projects and cost.

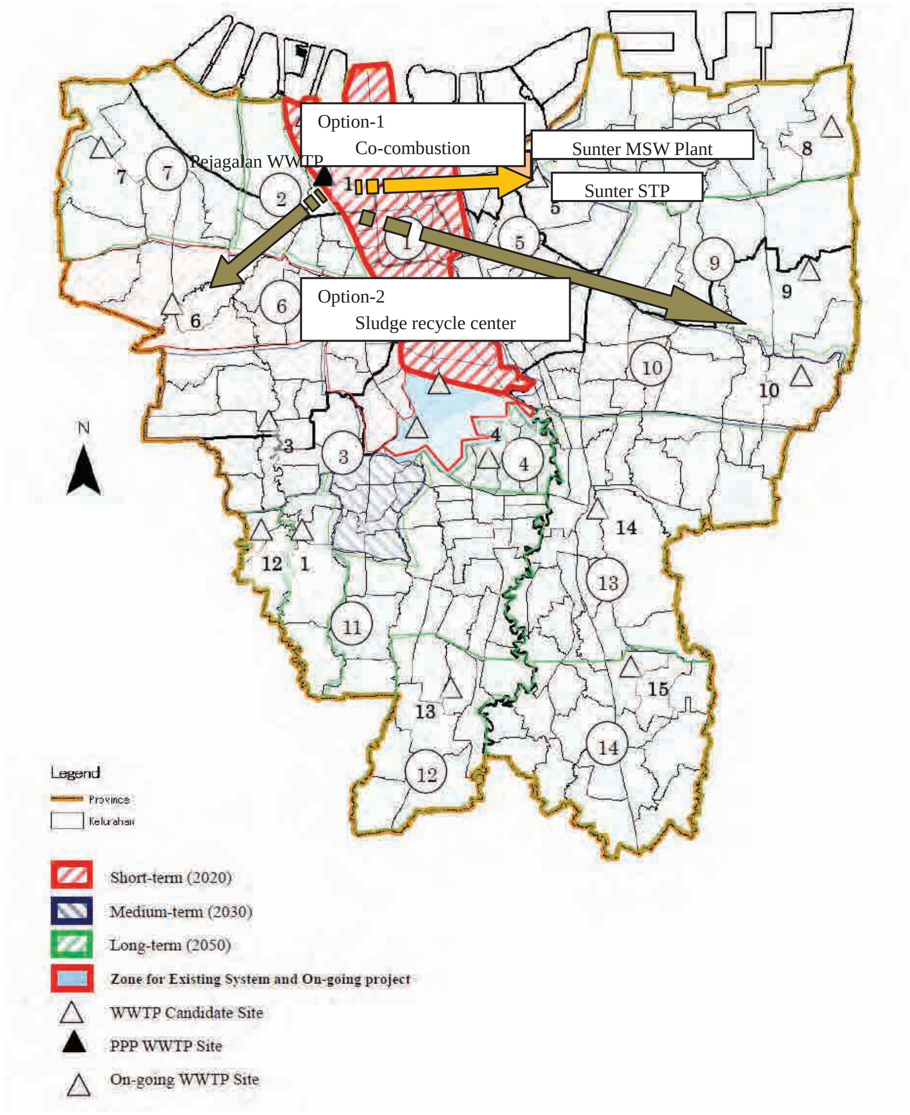
(Study subjects)

Potential sewerage project area (Mid-term planned)
Requirement of sewage sludge users
Site area and applied technology
Transportation and counter measures on environmental issues
Energy efficiency
Layout plan of sludge processing facility



Source: JICA PPP Study Team

Figure 4-2 Colaboration of Sewerage and Solid Waste



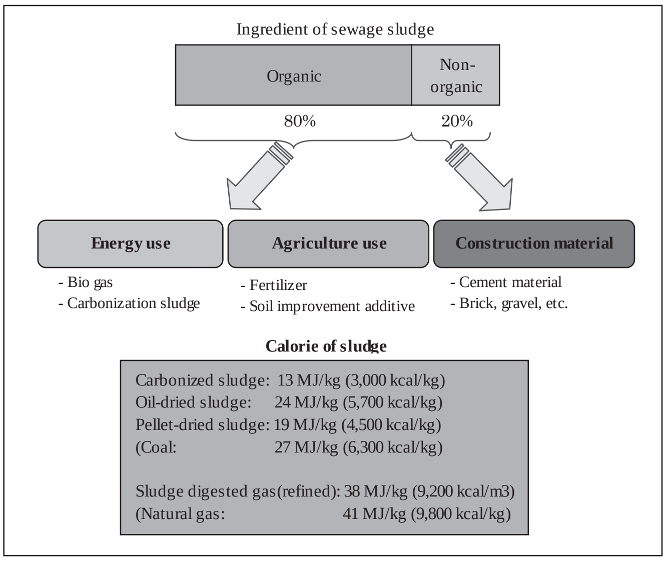
Source: JICA PPP Study Team

Figure 4-3 Regional Sewage Sludge Treatment Plan

4.2.4 Mid and Long-Term Plan of Sewage Sludge Recycling

(1) Sewage Sludge Reuse Plan

Sewage sludge is used in ways such as for cement material of dewatered sewage sludge/incinerated ash, and for replacing coal with dried/carbonated sludge from the viewpoint of non-organic substances and biomass energy. Sewage sludge reuse in Jakarta is recommended for cement material, fuel for coal power plants, fertilizer for flower growing and as a soil conditioner for land development projects. Sewage sludge use will contribute to sustainable management of wastewater that is released from the land reclamation site.

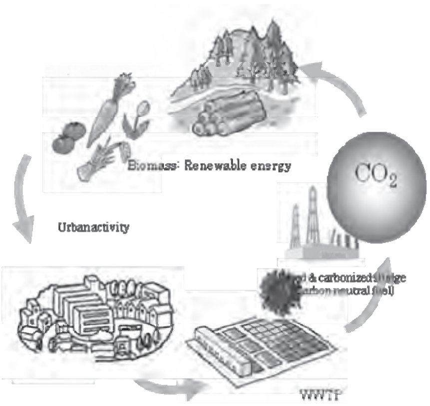


Source: Ministry of Land, Infrastructure, Transportation and Tourism, Japan

Figure 4-4 Calorie of Sewage Sludge (Example in Japan)

The global warming potential of sewage sludge fuel is 21 times lower than that of land reclamation that produces CH_4 gas.

Gas	Global warming potential
CO_2	1
CH_4	21
N_2O	310

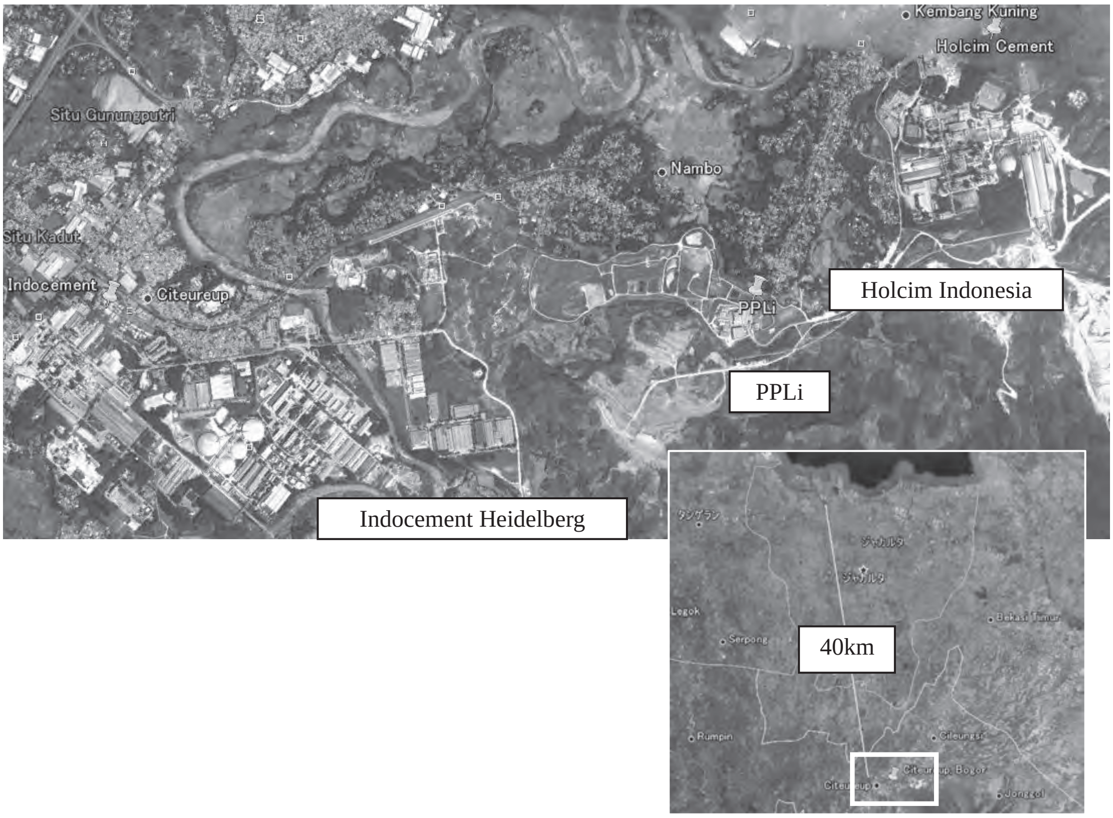


Source: JICA PPP Study Team

Figure 4-5 Global Environmental Effect of Sewage Sludge

(2) Potential Sewage Sludge Users in Jakarta Region

Cement factories and land reclamation plants are operating waste recycling and disposal within 40 km of STP in the Jakarta Metropolitan Region.



Source: JICA PPP Study Team

Figure 4-6 Cement Factory and Private Land Reclamation

1) Cement material

Cement factories in the Jakarta Metropolitan Region have enough potential for sewage sludge reuse, which is only 7,000 Ds-ton/year and is equivalent to cement product of 1,400 thousand ton/year, in the case where 5% of coal is replaced by sludge fuel.

Holcim Indonesia has implemented a Geocycle project, which is a waste management business, and is interested in sewage sludge reuse. The cost of sewage sludge is 100 CHF/ton (110 USD/ton) at present. Wasted energy sources such as rice hulls (5 USD/ton) replaces coal fuel. Sewage fuel may have the potential to mitigate waste cost with a free alternative if the value of dried sewage fuel is acknowledged.

Table 4-11 Receiving Wastes of Holcim Indonesia

Recycled Waste Type		
• Freon CFC (refrigerants) • Refinery catalyst • Plastics • Expired products • Off-specification consumer products	• Packaging materials • Rubber wastes • Textile wastes • Refinery wastes • Paint wastes • Resin wastes	• Oil sludge • Oil filters **• Waste water treatment filter cake** • Contaminated materials • Foundry sand • Fly ash/bottom ash • Plus many others – on application

Source: Holcim Indonesia Co. Ltd.

Table 4-12 Condition of Sewage Sludge Fuel Holcim Indonesia

Parameter	Condition
Calorie	2,500 kcal and more
Water content	10-20 %

Source: JICA PPP Study Team

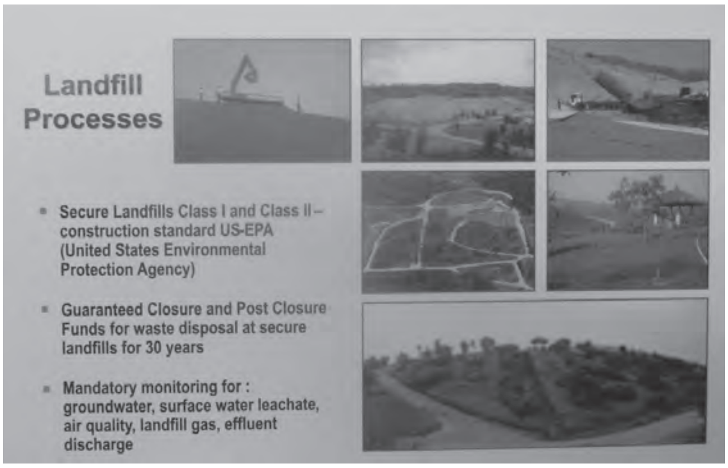
Table 4-13 Cement Factories in Jakarta Metropolitan Region

Factory	Province	Cement Production (2010)
Indocement Heidelberg Cement Group		
Citeureup Factory	Bogor, West Java	8,169,815 ton/year
PT Holcim Indonesia Tbk		
Narogong Factory	Bogor, West Java	5,650,000 ton/year

Source: JICA PPP Study Team

2) PPLi land reclamation plant

PPLi (PT Prasadha Pamunah Limbah Industri) is a private company with government shareholding that provides the business of waste treatment/disposal, fuel recycling and soil/factory remediation. PPLi also facilitates land reclamation sites and refinery plants for oil and liquid wastes. The land reclamation capacity is 10,000 tons/month, which is sufficient for sewage sludge disposal.



Landfill Processes

- Secure Landfills Class I and Class II – construction standard US-EPA (United States Environmental Protection Agency)
- Guaranteed Closure and Post Closure Funds for waste disposal at secure landfills for 30 years
- Mandatory monitoring for : groundwater, surface water leachate, air quality, landfill gas, effluent discharge

Source: PT. PPLi

Figure 4-7 Land Reclamation Process PPLi

3) Coal power plant

Coal consumption is almost 2,300 thousand ton/year per 1 MW power plant.

Coal power plant of 100 kW consumes coal equivalent to 7,000 Ds-ton/year of produced sewage sludge in the case where 5% of coal is replaced by sludge fuel.

Table 4-14 Coal Power Plants in West Java and Banten Provinces

Power station	Operator	Location	District	Province	Sector	Capacity per Unit	Installed Capacity
						(MW)	(MW)
Operating							
Suralaya Coal-fired Power Plant	PT. PLN	Suralaya	Cilegon	Banten	Government	4 x 400 3 x 600 1 x 625	4,025
Cirebon Coal-fired Power Plant	PT. Cirebon Electric Power	Kanci Kulon	Cirebon	West Java	Private	1 x 660	660
Indramayu Coal-fired Power Plant	PT. PLN	Sumur Adem	Indramayu	West Java	Government	3 x 330	990
Labuan Coal-fired Power Plant	PT. PLN	Labuan	Pandeglang	Banten	Government	2 x 300	600
Lontar Coal-fired Power Plant	PT. PLN	Lontar	Tangerang	Banten	Government	3 x 315	945
Under Construction							
Bojonegara Coal-fired Power Plant	PT. PLN	Bojonegara	Cilegon	Banten	Government	3 x 740	2,220
Tanjung Jati-A Coal-fired Power Plant	PT. Bakrie Power	Cirebon	Cirebon	West Java	Private	2 x 660	1,320
Anyer Coal-fired Power Plant	PT. PLN	Anyer	Bangka	Banten	Government	1 x 330	330

Source: JICA PPP Study Team

Chapter 5 Study on Drainage Sector

5.1 Study Objectives

5.1.1 Background and Necessity

Damage due to habitual inundation in DKI Jakarta is especially prevalent in January and February during the rainy season. DKI Jakarta suffered from three torrential floods in 1996, 2002 and 2007. Among these, the floods in 2002 and 2007 caused serious damage. Therefore, it is necessary to mitigate such frequent damage due to inundation urgently. To cope with this serious issue, a number of plans for flood control and drainage management were prepared in the past; however, most of these planned projects have so far not been implemented.

This Study summarizes the future direction on the drainage sector in DKI Jakarta, taking into consideration: 1) results of actual studies such as the JETRO study in 2007, 2) current conditions of DKI Jakarta, 3) basic approach of the drainage plan and 4) issues to be solved on DKI Jakarta.

5.1.2 Summary of Drainage Sector

(1) Existing Studies of Drainage Sector

In this Study, implementation of the following plans was reviewed:

1) Review of Actual Underground Flood Retention Pond (UFRP) Design

2) Review of Existing Master Plans and Related Study by Site Survey

3) Summarization of Future Direction on the Drainage Sector in DKI Jakarta

(2) Result of Drainage Sector

1) Due to habitual inundation in DKI Jakarta, it is urgently necessary to mitigate such serious damage. Additionally, the updated master plan on urban drainage in DKI Jakarta is reviewed regarding progress.

2) The most appropriate counterparts to implement the drainage projects such as flood retention ponds and underground rivers in Jakarta are the proposed “Departments of Public Works, Province of DKI Jakarta (Dinas PU DKI).”

3) It was described in the basic approach to formulate a master plan on the drainage sector in Japan, and implement plans along with related facilities as well as “storm water control

runoff" including a) facilities for storage of storm water, b) storm water infiltration facilities, c) land use planning and d) non-structural measures.

4) It is proposed that an underground flood retention pond (UFRP) is one of the potential methods to mitigate the current flood and inundation damages, which do not require large land acquisition. This Study focuses on the Monas project site, the reviewed UFRP design on actual study, and the updated contents to implement the potential project.

5.1.3 Current Condition related to Drainage Sector

(1) Existing Master Plans and Related Study

Master plans (MPs) on flood control and urban drainage in DKI Jakarta were set up by NEDECO (1973) and JICA (for urban drainage in 1991 and for flood control in 1997). In addition, the study and design for drainage management in DKI Jakarta were conducted under an IBRD loan, and were completed in 2005. The respective reports should be referred to for the outline of the MPs.

Additionally, updated MPs on urban drainage in DKI Jakarta are reviewed regarding progress, especially for those areas in DKI Jakarta that have been severly damaged by recent inundations. The following are the current MPs in DKI Jakarta.

1) Mater Plan for Drainage and Flood Control of Jakarta, December 1973, NEDECO (1973 NEDECO MP)
2) The Study on Urban Drainage and Wastewater Disposal Project in the City of Jakarta, Master Plan Study, March 1991, JICA (1991 JICA MP)
3) The Study on Comprehensive River Water Management Plan in JABOTABEK, March 1997, JICA (1997 JICA M/P)
4) Outline Plan for Major Drainage and Small Lakes Management in JABOTABEK-BOPUNJUR Area, WJEMP PUSAT 3-10, June 2005, IBRD Loan (WJEMP 3-10)
5) Drainage Management for Jakarta: Strategic Action Program Development, WJEMP DKI 3-9, December 2005, IBRD Loan (WJEMP 3-9)

(2) Basic Principles for Implementation of this Project by Counterparts

hree governmental organizations in Indonesia are responsible for the implementation and contents of the projects. The most appropriate organization to implement the drainage projects such as flood retention ponds and underground rivers in Jakarta is the "Department of Public Works, Province of DKI Jakarta (Dinas PU DKI)." The principles of each organization are as described below:

1) Directorate General of Human Settlements, Ministry of Public Works (Cipta Karya)

Cipta Karya is in charge of “planning and design of flood control and urban drainage improvement for the main rivers and drainages inside DKI Jakarta” in cooperation with the Department of Public Works, Province of DKI Jakarta. The temporal storage of floodwaters by retention ponds is included as one of the countermeasures as a basic principle to mitigate inundation damage by Cipta Karya.

2) Directorate General of Water Resources, Ministry of Public Works (DGWR)

“Flood control works for the macro drainage system which flows into DKI Jakarta from outside” are under the responsibility of the Directorate of Rivers Lakes and Reservoirs in DGWR. Balai Besar Wilayah Sungai Ciliwung-Cisadane (CILCIS) has been established in the Ciliwung-Cisadane River basins as the implementation unit of flood control. The basic principle of flood control by DGWR is to carry out such projects that would be beneficial for wider areas. For example, construction of the Eastern Banjir Canal (EBC) and rehabilitation of the Western Banjir Canal (WBC) are prioritized by DGWR. In particular, the budget for the construction of the EBC has recently increased to complete it urgently.

3) Dinas PU DKI

Dinas PU DKI, especially as an agency of public works, is in charge of “operation and maintenance of flood control and urban drainage facilities for macro drainage system within DKI Jakarta.” In DKI Jakarta, out of the macro drainage system, secondary/tertiary drains are planned and designed by Dinas PU DKI, while these are maintained by the Department of Public Works at the municipality level. Dinas PU DKI has been coping with two priority issues, namely mitigation of inundation and traffic jams, and is positive regarding implementation of the project.

(3) Review of Project Site on Drainage Sector

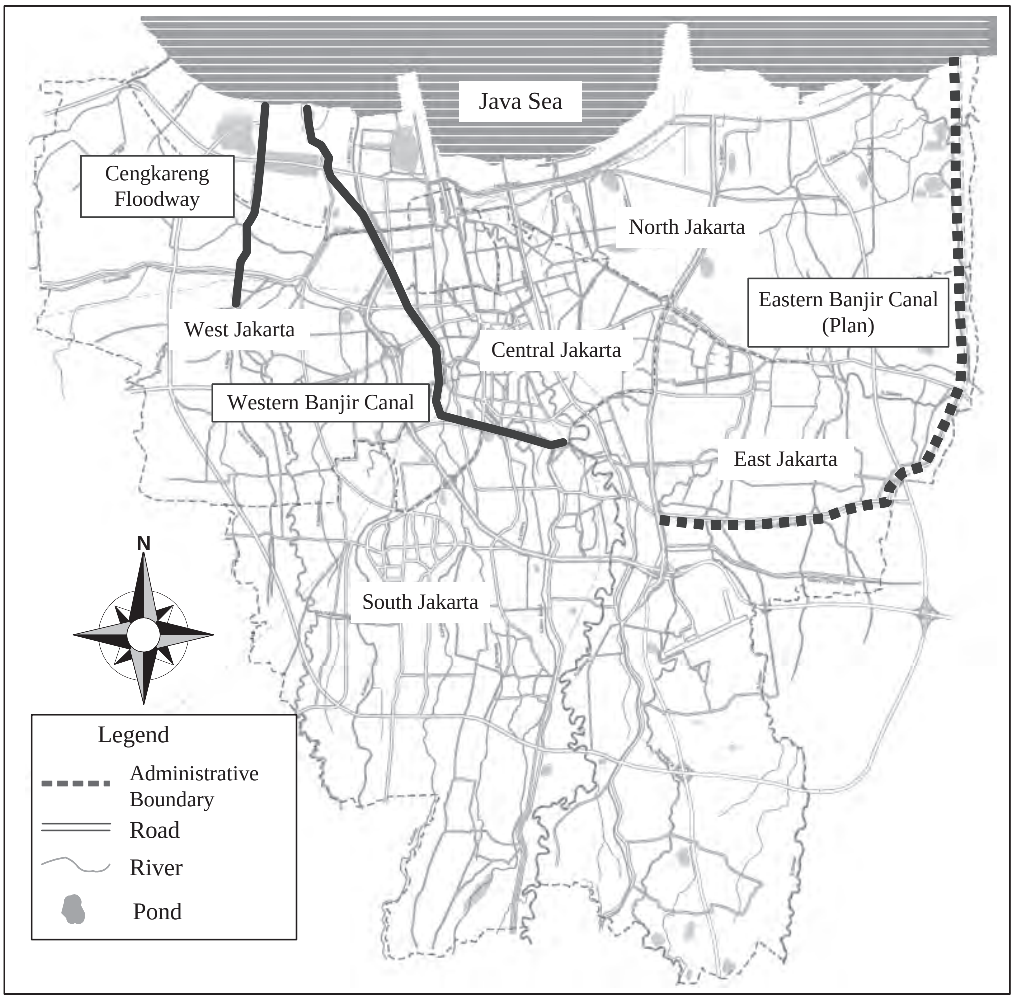
The review of the Project site on the drainage sector was based on the site survey and the JETRO study in 2007 (hereinafter “actual report”), and the results are summarized in 1) to 3) below. It is described that alternative measures to mitigate flood/inundation damages without acquisition of land are needed.

1) A number of plans for flood control and drainage management were prepared in the past. However, most of those planned projects have not been implemented to date.

2) Construction of the Eastern Banjir Canal (EBC) has been delayed and diversion works from the Ciliwung River to the Java Sea have not been implemented yet. Figure 5-1 shows the floodways in DKI Jakarta included in the project area of EBC.

3) Major reasons for the delay are the difficulties in issues on the land acquisition and

resettlement of the residents.



Source: JETRO Study in 2007

Figure 5-1 Floodways in DKI Jakarta

5.2 Study Content and Proposal

5.2.1 Basic Approach of Drainage Plan

(1) Basic Approach to formulate Master Plan in Japan

As described in 5.1.3 above, project implementation on the drainage sector in DKI Jakarta would be urgently required in order to prevent floods in the center of the city of Jakarta. However, it’s assumed that the current MPs provide a comprehensive approach for DKI Jakarta. This Study proposes a basic approach to formulate an MP on the drainage sector in Japan, and will apply any positive impacts to current MPs in DKI Jakarta.

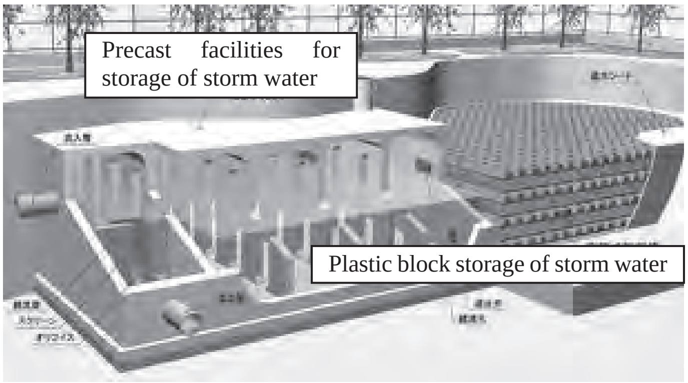
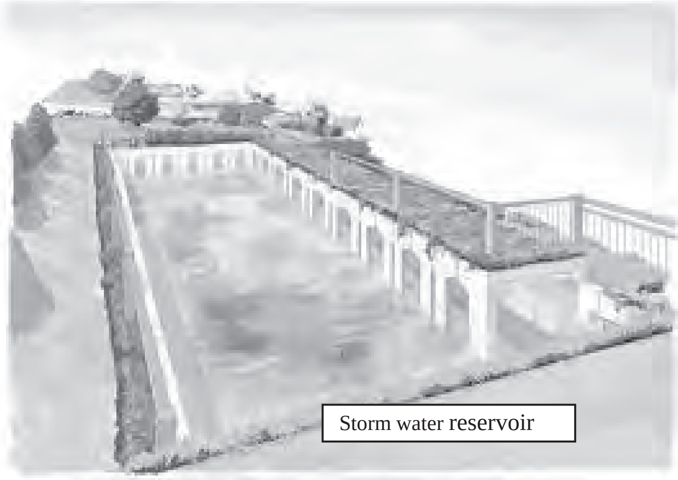
In Japan, MPs on drainage are formulated as below, considering that the overall system includes not only rivers and drainages, but also drainages for agriculture, etc.

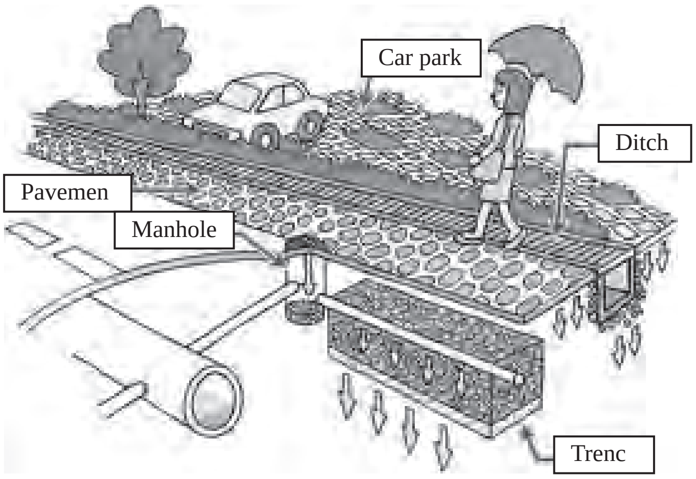
1) Setting the level of facility development on drainage
2) Facilities on drainage are planned corresponding to the peak flow of storm water runoff. If the capacity is not sufficient, it would be requested that the MP on drainage include a plan for “storm water control runoff.” If necessary, the conservation function of water circulation and utilization of rainwater will be considered.
3) In case serious damage exceeds the set development goals, the development level will be higher than the original one, and soft-components will be provided for the entire city such as flood information warnings and hazard maps and land use for storm water retention.

The basic approach of the MP on drainage is to eliminate the amount of peak runoff as soon as possible. Rapid urbanization, intensive use of land and declined watershed conservation such as forests and fields in recent years cause the increased peak flow of storm water and thus cause flood disaster to the concentrated assets, inhabitants and economic activities in cities. Recently, goal setting of river improvement and drainage is affected by local heavy rains due to global climate change.

Therefore, a comprehensive approach is required on drainage along with related facilities and “storm water control runoff” including 1) facilities for storage of storm water, 2) storm water infiltration facilities, 3) land use planning and 4) soft-components (non-structural measures). Table 5.2.1 shows the summary of methods of storm water runoff control, and principal facilities that will implement drainage.

Table 5-1 Methods of Controlling Storm Water Runoff

Fields	Name	Positive effects	Negative effects
Facilities for storage of storm water	Facilities on site 1) Park 2) School yard 3) Parking 4) House 5) Other public area	1) Storm water tends to have a decreased peak flow and be averaged by storage on site.	1) Large area to be provided. 2) It is necessary to evaluate required volumes and effects of decreased peak flow by diversified storage on site.
			
	Facilities off site 1) Storm water reservoir for flood control 2) Storm water storage pipe 3) Retention pond for disaster prevention	1) Storm water tends to have a decreased peak flow and be averaged by storage off site. 2) Land acquisition is not required.	1) It takes much time to complete facilities construction and start operation. 2) Evaluation of cost estimate is a priority issues. 3) It's important to confirm land acquisition before establishment of facilities. 4) Countermeasures for wastewater odor and sludge would be required if a combined sewerage system is implemented.
			
Storm water infiltration	1) Chamber 2) Trench 3) Pavement for road 4) Drainage ditch	1) Total flow volume decreases. 2) Ground water is restored.	1) It takes much time to complete facilities construction. 2) Inundation prevention effects are limited. Evaluation of cost estimate is a priority issue. 3) Project implementation area is carefully designed due to unexpected ground water spill out.

Fields	Name	Positive effects	Negative effects
			
Land use planning		1) Effective development is feasible by preparation of land use planning in advance.	1) Total flow volume is decreasing by infiltration of storm water to underground. 2) Reconciliation among stakeholders is required.
Non−structural measures	1) Hazard map 2) IT contact system 3) Collaboration with sewerage and river field staff 4) Support for disaster planning 5) Awareness activity	1) Non-structural measures are a lower cost than hard ones.	1) It’s difficult to explain the effects. 2) Awareness activity and collaboration of stakeholders is required continuously.

Source: JICA PPP Study Team

(2) Classification of Countermeasures for Drainage

Figures 5-2 to 5-4 show the images of drainage facility planning.

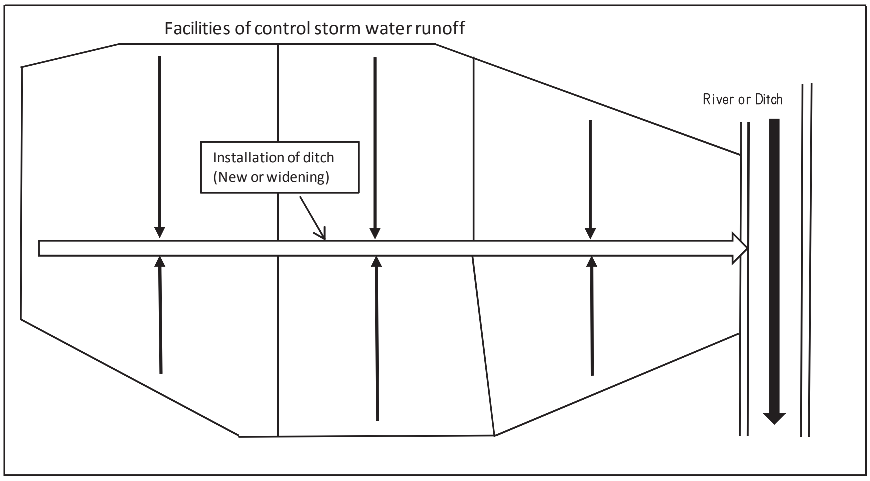
Version 1: MP on drainage can eliminate the amount of peak runoff as soon as possible.

Version 2: Drainage and storm water retention ponds are facilitated up-stream, and storm water control runoff is applied in cases where congested urban areas cannot provide sufficient land and river improvement takes a long time.

Version 3: Comprehensive measures are provided including storm water control runoff in cases where river improvement takes a long time.

Among these three versions, Version 2 is the most appropriate for DKI Jakarta.

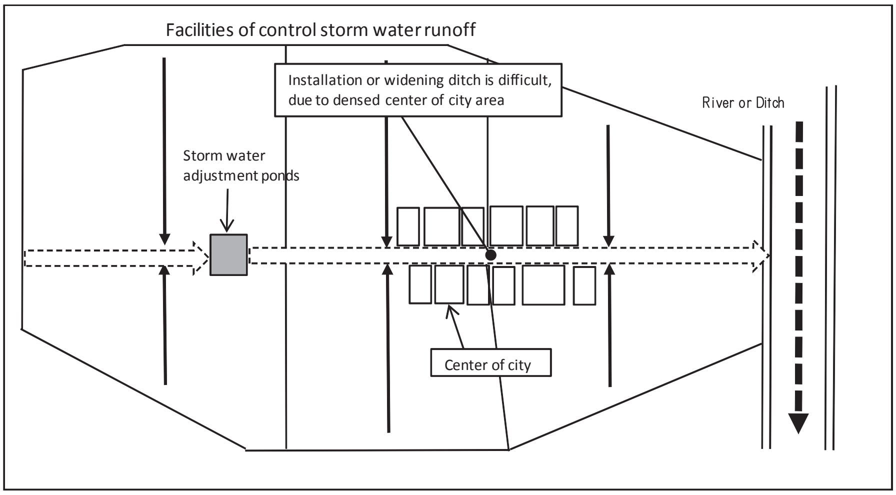
Version 1 corresponds to the case in which a new zoning district or large-scale development is implemented, or when construction of a new sewer is available.



Source: JICA PPP Study Team

Figure 5-2 Images to Implement Countermeasures for Drainage (Version 1)

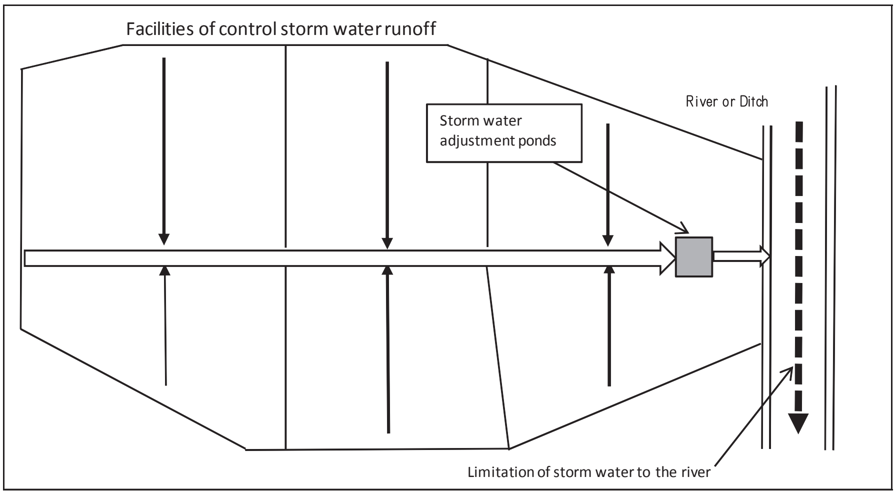
Version 2 corresponds to the case in which new or expanded sewerage drainages are difficult to install in dense urban areas and storm water control runoff like storm water retention ponds are economically reasonable.



Source: JICA PPP Study Team

Figure 5-3 Images to Implement Countermeasures for Drainage (Version 2)

Version 3 corresponds to the case that lacks a balance of appropriate rivers and sewerage facilities to implement flood control, like limitation of storm water to the river as below.



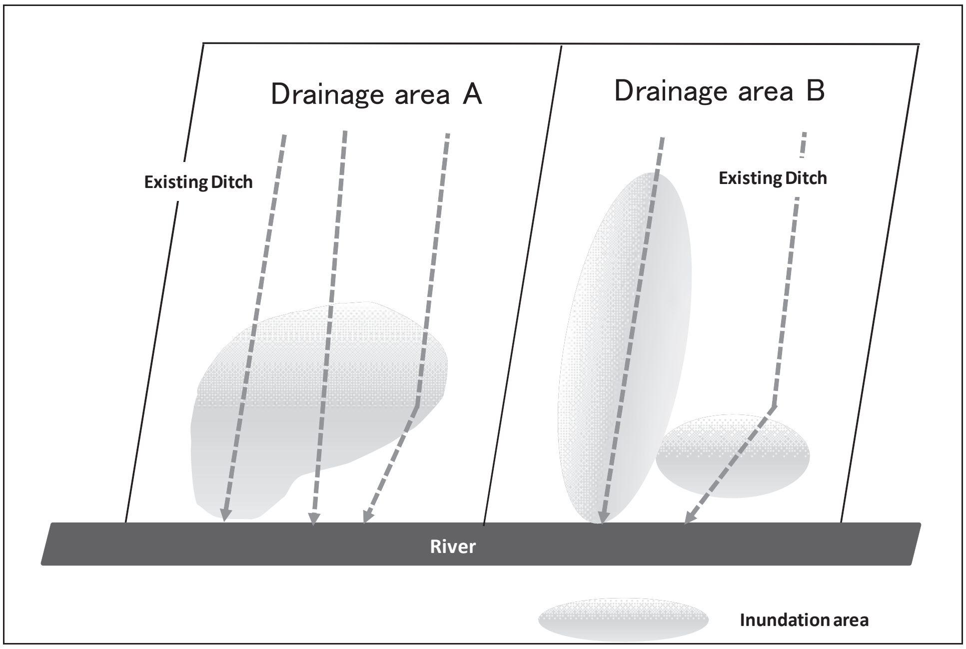
Source: JICA PPP Study Team

Figure 5-4 Images to Implement Countermeasures for Drainage (Version 3)

(3) Master Plan for Drainage by Step-wised Development

Storm water drainage systems are large in scale in general, and it takes much time for land acquisition. It is desirable to provide a comprehensive approach including effective facility construction and storm water retention technology. Figures 5-5 to 5-8 show an example of step-wised development. This example consists of four steps from the current condition to the development target.

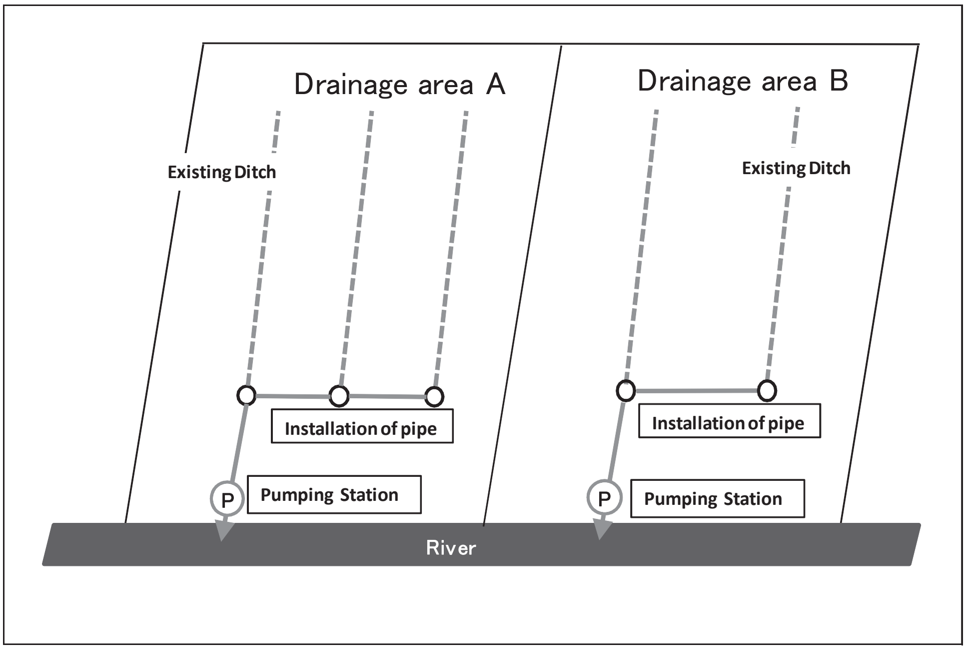
Step 0: Current condition before the staged development



Source: JICA PPP Study Team

Figure 5-5 Example of Facilities for Drainage by Staged Development (Step 0)

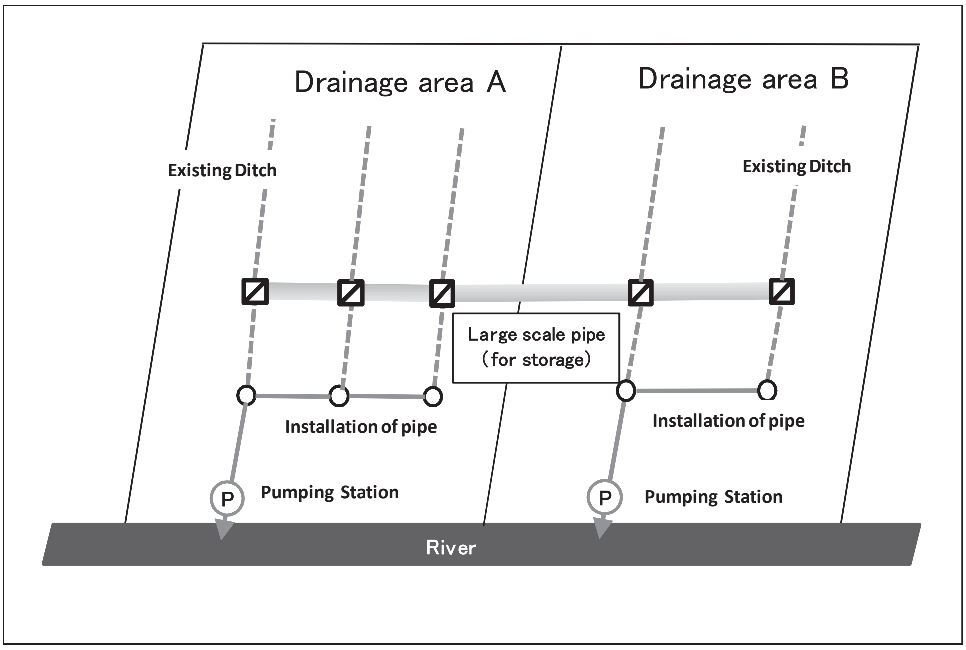
Step 1: Storm water volume to the river can be calculated based on the sewerage MP. Parts of new pipes are installed and parts of new pumping stations are constructed.



Source: JICA PPP Study Team

Figure 5-6 Example of Facilities for Drainage by Staged Development (Step 1)

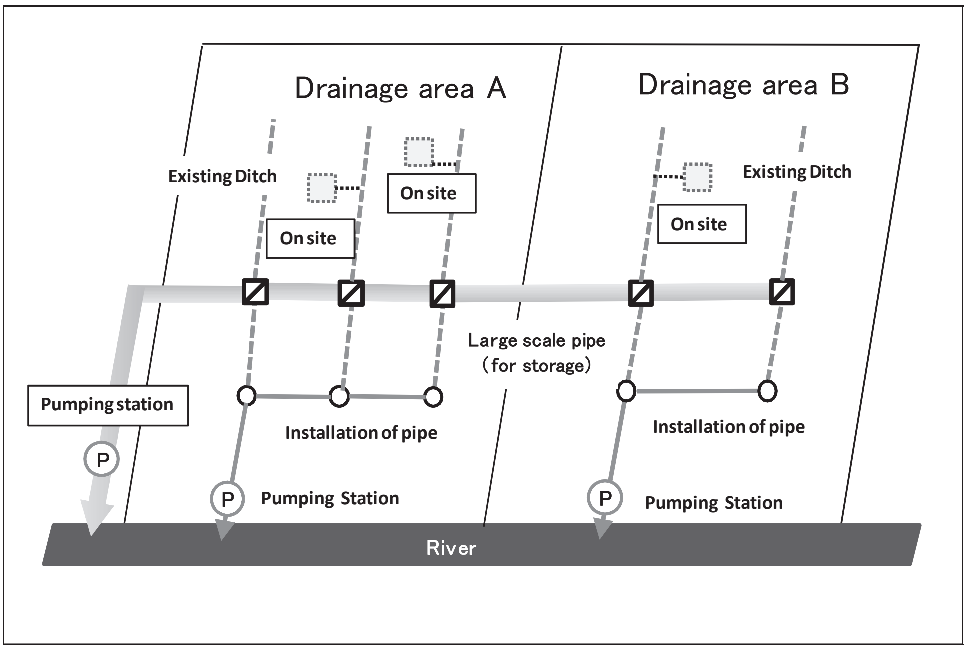
Step 2: New large-scale pipes included in the facilities for storage of storm water are constructed.



Source: JICA PPP Study Team

Figure 5-7 Example of Facilities for Drainage by Staged Development (Step 2)

Step 3: Facilities for storage of storm water and supplemental pumping stations are constructed.



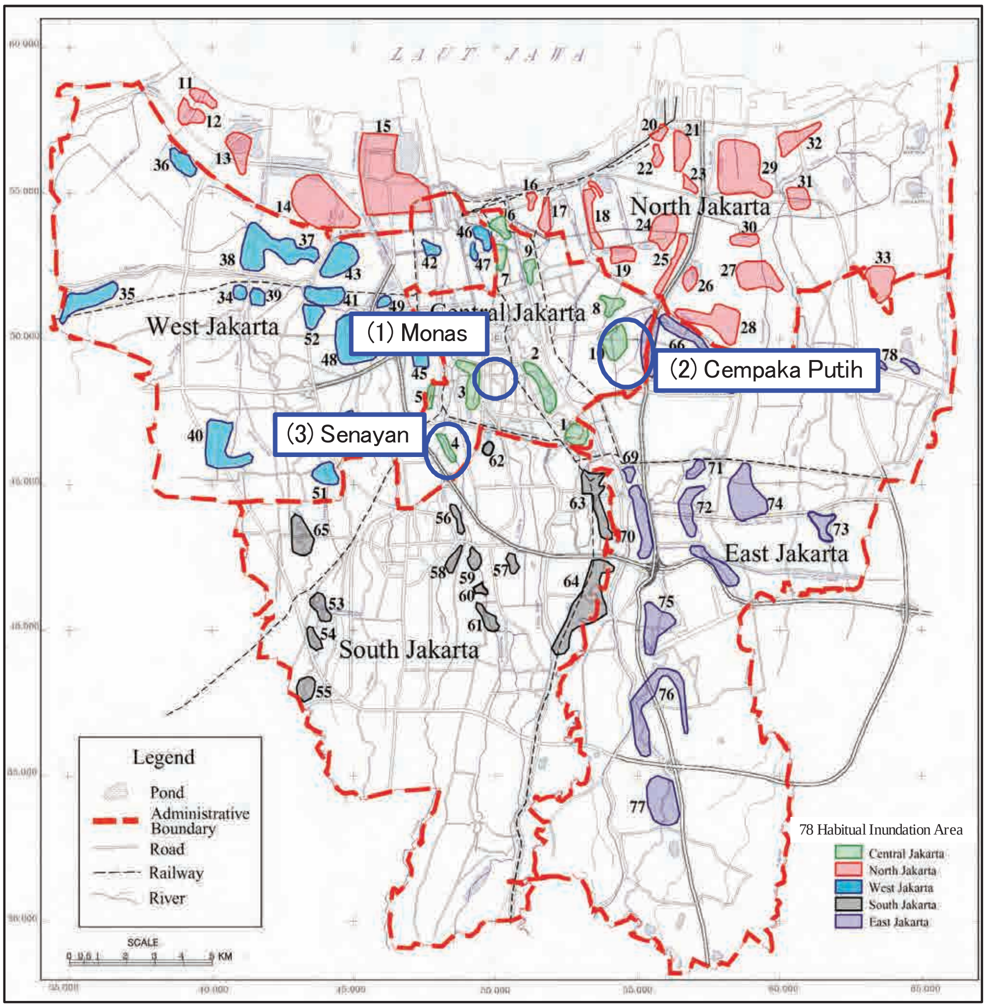
Source: JICA PPP Study Team

Figure 5-8 Example of Facilities for Drainage by Staged Development (Step 3)

5.2.2 Potential Projects of Drainage in Jakarta

The actual study (JETRO Study in 2007) proposed that the construction of an underground flood retention pond (UFRP) was considered realistic and effective to achieve the objective in (1) Monas, (2) Cempaka Putih and (3) the Senayan area (see Figure 5-9). UFRP is one of the useful methods to mitigate the current flood and inundation damages, which does not require large land acquisition. These areas were identified by the geography and infrastructures related to the basin division such as roads, drainage channels or rivers.

This Study focused on the Monas project site, reviewed the UFRP design in the actual study and updated the contents to implement the potential Project. This site has been developed, and most of the land in this area was occupied by commercial buildings, houses, and main roads. It therefore, was difficult to identify proper lands for widening of the drainage channel for the purpose of safe flood water control.



Source: JETRO Study in 2007

Figure 5-9 Project Sites

(1) Current Condition of Monas Project Site

1) Characteristics of Monas project site

Table 5-2 shows the Monas project site selected and determined after the discussion with the counterparts of the actual study.

Table 5-2 Monas Project Site

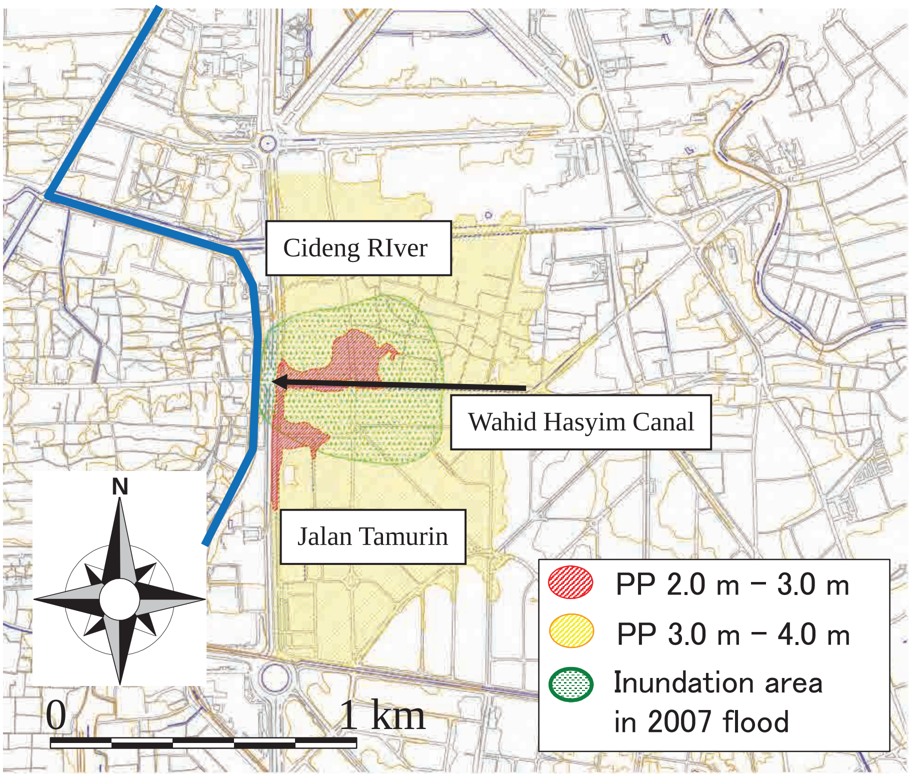
	Project Site	Inundation Site	Catchment Area (ha)	Kecamatan (District)	Kelurahan (Sub-district)	Population in Site *1
1	Monas	West Kebon Sirih (along with Jl.Thamrin)	40	Menteng	- Kebon Sirih - Gondangdia	3,000

*1: Estimated based on the population data in each kelurahan (BPS, 2005) and catchment area.

Source: JETRO Study in 2007

a) Existing drainage system (Figure 5-10)

The main drainage in the Monas project site is the Wahid Hasyim Canal flowing from east to west. The storm water from the canal is drained into the Cideng River at the two gates located on the right side of the Cideng River. Storm water cannot be sufficiently drained by the Wahid Hasyim Canal due to the rising of the water level in the Cideng River during floods. When the water level in the Cideng River reaches the top of the bank, it is assumed that the storm water would not be drained from the Wahid Hasyim Canal to the Cideng River.



Source: JICA PPP Study Team

Figure 5-10 Existing Drainage System in Monas Project Site

b) Existing flow capacity

Table 5-3 shows the estimated flow capacity in the Monas project site. It is assumed that the locations where inundation occurred in the past floods have very small flow capacity in the drainage system. The estimated existing flow capacity was verified by comparing the probable inundation volume to the inundation volume in the past floods.

Table 5-3 Estimated Flow Capacity in Monas Project Site

	Project Site	Inundation Site	Location	Minimum Flow Capacity	Remarks
1	Monas	Western Kebon Sirih	Gate at the lowest point of Wahid Hasyim Canal	0 m^3/s	Water level reached the top of bank in the Cideng River in 2002 and 2007 floods.

Source: JETRO Study in 2007

2) Records of inundation damage in the Monas project site

Current characteristics of inundation in the Monas project site were examined based on recorded inundation damage, the drainage system, and topographic conditions in order to study the drainage plan as described in the following sub-sections.

a) Records of inundation damage

Table 5-4 shows the inundation damage in the 2002 and 2007 floods. Not all of the records on inundation conditions were available in the Monas project site; therefore, the data were arranged based on previous studies, interviews with local residents, and site investigations during the actual survey.

Table 5-4 Inundation Damage in 2002 and 2007 Floods

	Project Site	Inundation in 2002 Flood			Inundation in 2007 Flood			
		Area *1 (ha)	Depth *1 (cm)	Duration *2 (day)	Area *3 (ha)	Depth *4 (cm)	Duration *2 (day)	Remarks
1	Monas	-	-	1	22.6	40	1	Kel.Kebon Sirih (Max. 40 cm)

"-": No data available

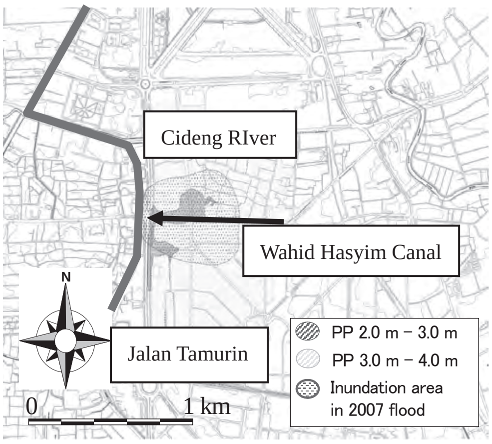
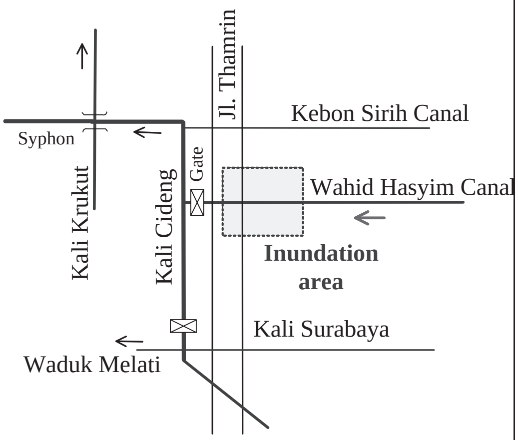
*1: Basic Design Study Report on the Project for Improvement of Pump Drainage in Poverty District in Jakarta, JICA, 2004, *2: Interview to local residents by JETRO Study Team, *3: DPU DKI、*4: SATKORLAK of DKI Jakarta

Source: JETRO Study in 2007

b) Characteristics of inundation damage

Table 5-5 shows the estimated characteristics of inundation damage in the Monas project site. It was analyzed based on previous studies, collected data, site investigation, interviews with local residents and hydraulic and hydrologic analyses.

Table 5-5 Characteristics of Inundation in Monas Project Site

Relation of Inundation Site and Elevation	Drainage System and Cause of Inundation
	
Western Kebon Sirih (along with Jl. Thamrin)	Storm water is inadequately drained by Wahid Hasyim Canal due to rising of water level in the Cideng River during flood.

Note: PP m shows elevation above Peil Priok Benchmark.

Source: JETRO Study in 2007

The existing report recommends that the total discharge from the whole drainage area of the Wahid Hasyim Canal by storm water or flood should be diverted and stored in a retention pond, and stored water should be pumped out from the retention pond to the close drainage system after termination of flooding in order to mitigate the inundation damage. At that time, the underground flood retention pond (UFRP) was proposed as a method to mitigate the inundation damage, and was located under the south-western parking inside Monas considering the land availability. The discharge point was selected on the right side of the Krukut Lama River which was the nearest main drainage canal to the project site. Additional drainage pipes would be installed for diversion to and from the pond.

This Study reviewed: 1) Basic Principle, 2) Determination of Required Volume, and 3) Proposed Drainage Facilities based on the existing report.

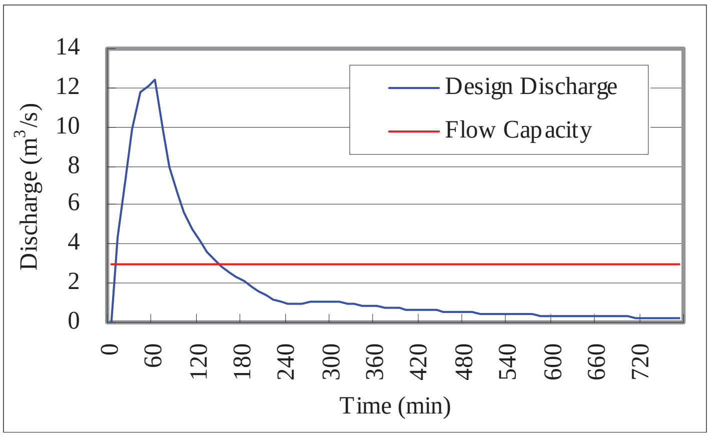
5.2.3 Facility Plan

(1) Basic Principle of Required Volume of UFRP

A summary of conditions to estimate the required volume of the UFRP is described below and other basic conditions are explained in Appendix-1 of this chapter.

1) Basic principle to determine required scale of facilities

The basic principle of the drainage plan in the actual study was that the UFRP would be installed to mitigate inundation damage in the Project site. Figure 5-11 shows the concept of the required volume for the UFRP estimated as design discharge, which exceeds the flow capacity of the drainage system.



Source: JETRO Study in 2007

Figure 5-11 Concept of Estimation of Required Volume for Retention Pond

2) Model hyetograph

Table 5-6 shows the applied model hyetograph based on catchment area of the Monas project site.

Table 5-6 Model Hyetograph in Monas Project Site

	Project Site	Model Hyetograph
1	Monas (40 ha)	- Rainfall Intensity Formula (at BMG Jakarta rainfall station) - Peak at the beginning of rainfall - Duration is 24 hours (applied in 1991 JICA M/P)

Source: JETRO Study in 2007 (Appendix-1)

3) Design scale

Table 5-7 shows the different standard design scales for urban drainage improvement in DKI Jakarta corresponding to catchment area. In accordance with the standard, the return period of design rainfall would be 2 to 5 years in the Monas project site (40 ha). However, the same design scale with a 10-year return period is applied for the Monas project site considering the importance of the area. Table 5-8 presents the design scale applied in the Monas project site.

Table 5-7 Standard Design Scale for Urban Drainage in DKI Jakarta

Catchment Area (ha)	10	10-100	100-500	>500
Return Period (year)	1-2	2-5	5-10	10-25

Source: Flood Control Manual Volume II, 1993

Table 5-8 Design Scale Applied in Monas Project Site

No.	Project Site	Catchment Area	Return Period of Design Rainfall	Remarks
1	Monas	40 ha	10-year	Standard design scale shall be 2 to 5-year probable rainfall based on the catchment area. However, the design scale is upgraded to 10-year probable rainfall taking into account the importance of the area.

Source: JETRO Study in 2007 (Appendix-1)

4) Runoff model and design hydrograph

Table 5-9 shows the runoff model applied for this Study in accordance with the previous master plan. Design rainfall was transformed to design discharge using the runoff models.

Table 5-9 Runoff Model

	Project Site	Runoff Model
1	Monas (40 ha)	Rational Method (used in 1991 JICA M/P)

Source: JETRO Study in 2007 (Appendix-1)

5) Inundation model

In this Study, a simplified inundation model was developed based on the concept of the pond model because the data on topography, river channels, drainage canals and so on, were limited. The relationship of H (elevation) – A (inundation area) – V (inundation volume) was established for each inundation site using a 1:5000 topographic map. Then, probable inundation area and depth were estimated from the inundation volume by assuming that the inundation volume was equal to the excess volume of design discharge over the flow capacity.

The flow of inundated water and duration time of the inundation are not considered in the established simplified inundation model. It is necessary to develop a more accurate inundation model with detailed related data and calibrate it with the past floods in order to analyze the inundation phenomena in the Monas project site.

6) Estimated inundation volume

Probable inundation volume, depth and area for each return period were estimated in each project site using the assumed flow capacity. Design rainfall, runoff mode and inundation model, which are explained in the item (v) of this sub-section, were also utilized. The inundation conditions in the 2002 and 2007 floods were estimated using the recorded inundation depth and the relation of H (elevation) – A (inundation area) – V (inundation volume) established in this Study. Table 5-10 shows the estimated inundation volume, depth and area for probable and actual floods. The return period of the 2002 flood would be 10 years from the viewpoint of scale of the maximum daily rainfall. It is judged that the estimated 10-year probable inundation volume would be reasonable compared to that of the 2002 flood because there is no significant difference.

Table 5-10 Estimated Inundation Volume, Depth and Area for Probable and Actual Floods

Return Period T (Year)	Pond Volume V (m^3)	Depth D (m)	Area A (ha)
2	27,372	0.36	19.1
5	41,094	0.41	23.5
10	49,146	0.42	24.7
25	63,282	0.45	26.9
Past Flood			
2002 flood*	32,900	0.40	22.6
2007 flood	32,900	0.40	22.6

*Assuming the inundation depth is the same as the 2007 flood

Note: Inundation depth and area were estimated from recorded inundation depth using H-A-V relation.

Source: JETRO Study in 2007

(2) Determination of Required Volume of Drainage Facilities

1) Volume of underground flood retention pond (UFRP)

Table 5-11 shows the estimated required volume of the UFRP based on 10 years, the return period of design scale.

Table 5-11 Estimated Required Volume of UFRP

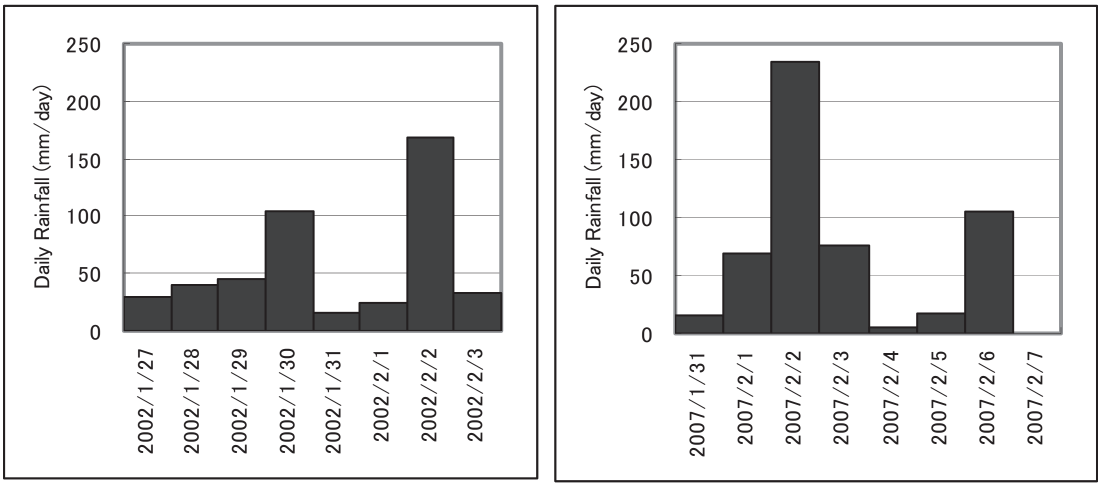
	Retention Pond	Return Period of Design Scale	Volume (1,000 m^3)
1	Monas	10 years	49.2

Source: JICA PPP Study Team

2) Method of drainage from UFRP and pump capacity

Inundation occurred in the downstream area of the Project sites in the 2002 and 2007 floods. It is possible that an increase in discharge from the Project site in future floods would make inundation damage in the downstream areas severer than the existing condition. Therefore, it is determined that stored water in the retention pond is not drained for the duration time of design rainfall, which is 24 hours. Pumping drainage shall start just after the end of rainfall.

The duration time of pumping drainage is set based on the characteristics of heavy rainfall. The BMG Jakarta rainfall station data represents the rainfall characteristics in central Jakarta. Figure 5-12 shows that the interval of heavy rainfall of more than 100 mm/day, which is approximately equivalent to 2-year probable rainfall at the station, was more than 2 days in the past flood events in 2002 and 2007. Table 5-12 shows the drainage by pumping facility which is the duration of pumping drainage is set at 1 day to 2 days based on the scale of retention ponds.



Source: BGM, 2007

Figure 5-12 Daily Rainfall at BMG Jakarta Rainfall Station in 2002 and 2007 Floods

Table 5-12 Drainage by Pumping Facility

No.	Underground Flood Retention Pond	Required Volume (1,000 m^3)	Duration of Pumping Drainage	Average Discharge (m^3/s)
1	Monas	49.2	24 hours	0.57

Source: JICA PPP Study Team

(3) Proposed Drainage Facilities of the Project

The proposed drainage facilities under the aforesaid basic principles for the Project are:

1) Intake facilities in order to trap storm-water or flood water
2) Inlet pipeline facilities
3) Underground flood retention pond (UFRP)
4) Outlet pipeline facilities
5) Pumping station
6) Power supply system for gates at intake facilities, garbage traps and removal equipment and pumping equipment

Appendix-II of this chapter shows the general layout of the proposed drainage facilities, and the detail of the proposed facilities. Table 5-13 shows the specifications and main features of proposed facilities in the Monas project site, and the characteristics of each facility are summarized as below.

Table 5-13 Specifications and Main Features of Proposed Facilities in Monas Project Site

Facilities	Specification	Main Features
1) Intake Facilities	- Use of vertical shaft - Reinforced concrete	Quantity: 4 tunnels Diameter. 4 m x Depth 5 m
2) Inlet Channel	Pre-stressed concrete pipe by pipe-jacking	Diameter. 0.9 - 2.5 m x 1,160 m (Underground of 2 m in maximum)
3) Underground Flood Retention Pond	Reinforced concrete structure	Volume: 49,200 m^3 Length 120 m x Width 50 m x Depth 16 m,
4) Pumping Facilities	Submersible pump	Total discharge capacity: 0.57 m^3/s No. of pumps : 2 nos. Discharge capacity : 0.29 m^3/s per pump
5) Outlet Drainage Pipeline	Pre-stressed concrete pipe by open-cut method	Diameter. 0.7 m x 750 m
6) Power Supply	Low voltage power supply	Quantity: 1 supply Pumping station: 380 V Pump equipment: 300 kVA

Source: JICA PPP Study Team

1) Intake facilities

An intake facility is to be built on the riverbank in order to trap storm water or floods in the existing drainage channel or canals. This facility is constructed with reinforced concrete, applying side-over flow spillway type, and a gated weir. Garbage trap and removal structures are considered, taking into account flow control under normal conditions and measures for garbage flowing in the channels or canals.

2) Inlet channel

The proposed inlet channels with a diameter of 3.0 m and a depth of 5.0 m underground are to be constructed by the open-cut method and/or trenchless method.

3) Underground flood retention pond (UFRP)

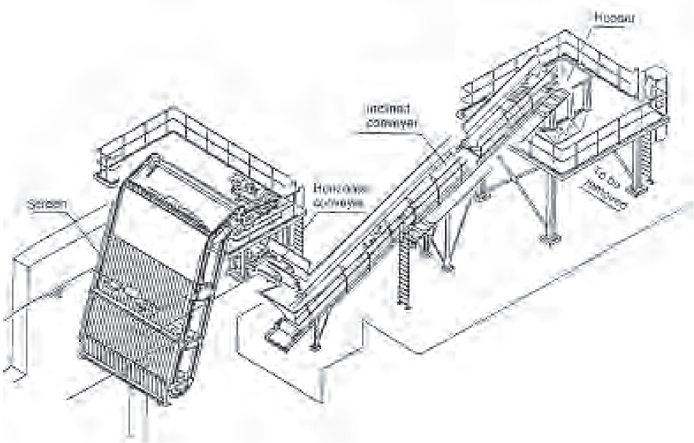
The proposed retention pond is assumed to be a deep reinforced concrete tank and the multi-purpose use for parking and storm water reservoir pollution control will be recommended.

4) Pumping station

Proposed pumping facilities are designed by applying the criteria and standards in Japan. In design of the pumping facilities, main issues are:

a) Selection of type of pumps in case of high hydraulic head
b) Environmental impact due to noise and vibration of pump operation
c) Countermeasures for sand and garbage conveyed by storm water

A submersible pump is applied in the Study because a similar pump type has been applied for the existing pumping stations and O&M have been sufficiently undertaken by the Ministry of Public Works and DKI Jakarta. It is reported by DKI Jakarta that a large amount of garbage flows into the existing pumping station and gate structures with the daily amount ranging from 5 m^3/day during the dry season to 100–200 m^3/day during the rainy season. In order to cope with the large amount of garbage, it is necessary to provide mechanical and automatic trash and removal equipment as shown below.



Source: JICA PPP Study Team

Figure 5-13 Trash Removal Equipment

5) Outlet drainage pipeline

The type of structure shall be pre-stressed concrete pipe and it shall be laid under the existing road by the open-cut method.

6) Power supply facilities

Power supply facilities are required for gate operation at the intake facilities, garbage trash and removal equipment and pumping facilities. The power for these facilities shall be supplied from the existing commercial power line of PLN, which is a sufficient power source for these facilities; therefore, no electricity transmission lines or switchyards are planned in the Study. Taking into account an emergency case such as stoppage of existing power supply during floods or heavy rainfall, a diesel generator shall be provided for each pumping station.

(4) Estimate of the Project Cost

It is conceivable that construction materials and laborers for the civil works of the Project are basically procured in and around Jakarta in Indonesia. Therefore, the construction costs of the civil works are determined based on these in previous studies considering price escalation to the January 2012 price level.

However, the following items will be procured from Japan.

1) Pipe-jacking Method: Japanese advanced technology should be applied to the construction works in order to transfer the technology to Indonesia. Drainage pipe of Monas (scheme: 0.9 – 2.5 m diameter and 1,160 m long) will be applied.
2) Pump Equipment
3) Cleaning Equipment for UFRP and Pipes

Table 5-14 shows the estimated Project costs.

Table 5-14 Cost Estimate for Monas Scheme

Item		unit	Quantity	Unit Price		Total		
				F/C (USD)	L/C (IDR)	F/C (USD)	L/C (IDR)	Total (IDR)
a	Inlet Channel							
	Civil works							
	Vertical shaft (ϕ 4,000)	nos	4	918,510		3,674,040		33,112,285,500
	Dia 2,500 mm,PC (Pipe jacking)	m	773	6,920		5,349,160		48,209,304,500
	Dia 1,200 mm,PC (Pipe jacking)	m	260	2,510		652,600		5,881,557,500
	Dia 900 mm,PC (Pipe jacking)	m	130	2,550		331,500		2,987,643,750
	Total- a (Civill)					10,007,300	0	90,190,791,250
b	Flood Retention Pond							
	Civil works							
	Temporary work	nos	1	4,959,970		4,959,970		44,701,729,625
	Soil works							
	1)Excavation	m3	111,000		159,060		17,655,660,000	17,655,660,000
	2)Soil disposal (including 1) Excavation)	m3						
	3)Backfiling	m3	15,000		27,260		408,900,000	408,900,000
	Concrete works	m3	44,200		3,029,780		133,916,276,000	133,916,276,000
	Building Work (including Concrete works)	nos						
	Sub total (Civil)					4,959,970	151,980,836,000	196,682,565,625
	Mechanical Works							
	Pumping facility=0.29m3/sec,	unit	2	1,023,430		2,046,860		18,447,325,750
	Sub total (Mechanical)					2,046,860	0	18,447,325,750
	Electrical Works							
	Power Receiving (300kVA)	unit	2	682,290		1,364,580		12,298,277,250
	Sub total (Electrical)					1,364,580	0	12,298,277,250
	Total-b					8,371,410	151,980,836,000	227,428,168,625
c	Outlet Channel							
	Civil works							
	Dia 700 mm,PC (Open cut Method)							
	1)Excavation	m3	3,105		37,870		117,586,350	117,586,350
	2)Backfiling	m3	2,800		287,820		805,896,000	805,896,000
	3)Installation of drainage pipe	m	750		6,665,530		4,999,147,500	4,999,147,500
	(Maximum Depth 3m, wide2m)							
	Total c (Civil)					0	5,922,629,850	5,922,629,850
	Total					18,378,710	157,903,465,850	323,541,589,725
	Total Civil work					14,967,270	157,903,465,850	292,795,986,725
	Total Mechanical work					2,046,860	0	18,447,325,750
	Total Electrical work					1,364,580	0	12,298,277,250

Exchange rates are applied for USD 1 = JPY 76.21 = Rp. 9,012.5; thus, JPY 1 = Rp. 118.25.

Source: JICA PPP Study Team

(5) Issues to Determine Contents of the Project

Issues to be examined to determine contents of the Project are identified as follows:

1) Soft soil

The Study area, DKI Jakarta, is located on the lowland plain with soft soil. The area is prone to inundation damage. Advanced technology on development of underground facilities is required in order to construct the UFRP and related structures.

In this connection, the pipe-jacking method must be used for construction of underground facilities in such urban areas on alluvial plains with soft soil. Therefore, it is expected that the pipe-jacking method will be applied for the implementation of the Project.

2) Land availability for UFRP

Installation of a UFRP requires enough open space. Land availability for the UFRP was discussed as an important issue during the meetings with counterparts in the course of this Study.

The candidate sites of the UFRP in this Study are located on public land owned by government agencies. Therefore, the lands shall be available as construction sites. However, detailed study and coordination with related agencies are required before the implementation of the Project, because the utilization of the construction site should be permitted by the Ministry of State Secretariat, a large-scale pond would be required for the site, and detailed environmental assessment is necessary.

3) Coordination with the existing studies/projects

Coordination with existing studies/projects is required to determine the contents of the Project in each site. In particular, the progress of construction of EBC and rehabilitation of WBC affects the contents of the Project. Therefore, the contents of the Project shall be reviewed and modified if necessary depending on the progress of the on-going projects.

Appendix-1 Condition on Hydrologic and Hydraulic Analysis

A1.1 Probable Rainfall

The rainfall intensity formula was utilized for the Monas and Cempaka Putih project sites and probable basin mean rainfall was used for the Senayan project site based on the catchment area and the applied runoff model.

A1.1.1 Rainfall Intensity Formula

The following formula has been established at BMG Jakarta rainfall station:

Rainfall Intensity Formula: $$r = \frac{a}{t^n + b}$$

Where, r: rainfall intensity (mm/hr)
t: duration of rainfall (min)
a,b,n: constants

Table A1.1 Constants of Rainfall Intensity Formula for Short Duration Rainfall (t ≤ 180 min)

Constants	Return Period (year)			
	2	5	10	25
a	10,490	7,946	8,571	6,271
b	76.3	48.8	50.1	31.2
n	1/0.90	1.00	1/1.02	1/1.12

Source: 1991 JICA M/P

Table A1.2 Constants of Rainfall Intensity Formula for Long Duration Rainfall (t > 180 min)

Constant	Return Period (year)			
	2	5	10	25
a	12,692	8,756	8,973	6,090
b	172.8	93.5	68.0	31.5
n	1/0.90	1.00	1/1.02	1/1.12

Source: 1991 JICA M/P

In addition, the following area reduction factor is applied to estimate the basin mean rainfall from the point rainfall:

Table A1.3 Area Reduction Factor

Time of concentration (tc, hr)	Catchment Area (A, km^2)					
	0	5	10	30	50	70
1/6	1.00	0.94	0.91	0.81	0.74	0.69
1/2	1.00	0.95	0.92	0.83	0.77	0.73
1	1.00	0.96	0.93	0.86	0.81	0.76
2	1.00	0.96	0.94	0.88	0.82	0.79
3	1.00	0.96	0.94	0.88	0.83	0.79
4	1.00	0.96	0.94	0.88	0.83	0.79
5	1.00	0.97	0.94	0.88	0.84	0.80
12	1.00	0.98	0.97	0.92	0.89	0.87
24	1.00	0.99	0.98	0.96	0.94	0.93

Source: 1991 JICA M/P

A1.1.2 Basin Mean Rainfall in the Krukut Basin

The following basin mean rainfall pattern was applied as the design rainfall for the Senayan project site as well as 1997 JICA M/P.

Table A1.4 Probable Basin Mean Rainfall Pattern in the Krukut River Basin (Unit: mm)

Time (Hour)	Return Period							
	2-year	5-year	10-year	20-year	25-year	30-year	50-year	100-year
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	37.2	43.6	48.5	53.2	55.6	57.1	61.0	64.6
2	43.2	53.7	61.7	65.9	70.7	71.9	76.9	90.2
3	46.7	59.7	68.2	76.2	80.9	82.6	87.9	101.8
4	49.1	64.5	73.1	83.4	88.8	90.4	96.5	109.1
5	51.5	67.4	77.2	89.4	94.2	96.3	103.2	114.6
6	53.2	70.5	80.9	94.2	98.5	101.0	108.7	119.5
7	54.5	72.2	84.4	97.3	102.1	104.6	112.3	123.8
8	55.6	74.0	86.9	99.7	105.1	107.6	116.0	128.0
9	56.8	75.2	88.9	102.1	107.6	110.6	119.7	131.7
10	57.9	76.4	90.8	103.9	110.0	112.9	122.1	134.7
11	58.6	77.6	92.5	105.7	111.8	115.3	124.6	137.7
12	59.2	78.8	94.0	107.6	113.6	117.1	126.7	140.2
13	59.8	80.0	95.5	109.4	115.4	118.9	128.5	142.7
14	60.4	81.1	96.7	110.9	116.9	120.7	130.3	144.5
15	60.9	82.4	97.9	112.4	118.4	122.4	131.9	146.3
16	61.5	83.6	99.1	113.9	119.6	123.6	133.4	148.2
17	62.1	84.8	100.3	115.4	120.8	124.8	134.9	150.0
18	62.7	85.6	101.5	116.6	122.0	126.0	136.5	151.8
19	63.3	86.5	102.7	117.8	123.2	127.2	138.0	153.6
20	63.9	87.5	103.9	119.1	124.4	128.4	139.5	155.4
21	64.5	88.3	105.1	120.3	125.6	129.5	141.0	156.6
22	65.1	89.2	106.0	121.5	126.9	130.8	142.2	157.9
23	65.3	90.1	106.9	122.7	128.1	132.0	143.5	159.1
24	65.7	91.0	107.8	123.9	129.0	133.2	144.7	160.3

Source: 1997 JICA M/P

A1.2 Runoff Model

A1.2.1 Rational Formula

(1) Time of Concentration

The time of flood concentration is calculated as follows:

tc (time of concentration) = t1 (overland time) + t2 (travel time)

The overland time (t1) was assumed as 10 minutes considering the land use condition in the Project site. The travel time (t2) was calculated based on the length of canal/river and the following flow velocity, which was applied in 1991 JICA M/P.

Table A1.5 Flow Velocity to Estimate Travel Time

Flow Velocity (m/s)	Gradient: S
2.0	1/200 < S
1.5	1/500 < S ≤ 1/200
1.0	1/1,000 < S ≤ 1/500
0.5	S ≤ 1/1,000

Source: 1991 JICA M/P

(2) Runoff Coefficient

(3) The runoff coefficient in 1991 JICA M/P and in the urban drainage guidelines and technical design standard prepared by the Canadian International Development Agency (CIDA) in 1994 are shown in Tables A1.6 and A1.7, respectively. In this Study, the land use classification and runoff coefficient are set as shown in Table A1.8 based on the land use plan in 2005 collected from the Department of Spatial Planning of DKI Jakarta.

Table A1.6 Runoff Coefficient in Master Plan for Urban Drainage in DKI Jakarta

Land Use	Runoff Coefficient
Residential Area	0.50
Commercial and Institutional Area	0.70
Industrial Area	0.60
Other Areas (farmland/open space)	0.20

Source: 1991 JICA M/P

Table A1.7 Runoff Coefficient in Urban Drainage Guidelines

Land Use Type	Characteristics	Runoff Coefficient
Business District and Shopping Center		0.90
Industrial	Fully built-up	0.80
Residential (medium-high density)	20 houses/ha 30 houses/ha 40 houses/ha 60 houses/ha	0.48 0.55 0.65 0.75
Residential (low density)	10 houses/ha	0.40
Parks	Flat area	0.30

Source: Urban Drainage Guidelines and Technical Design Standard, Vol. II, Part 3, 1994

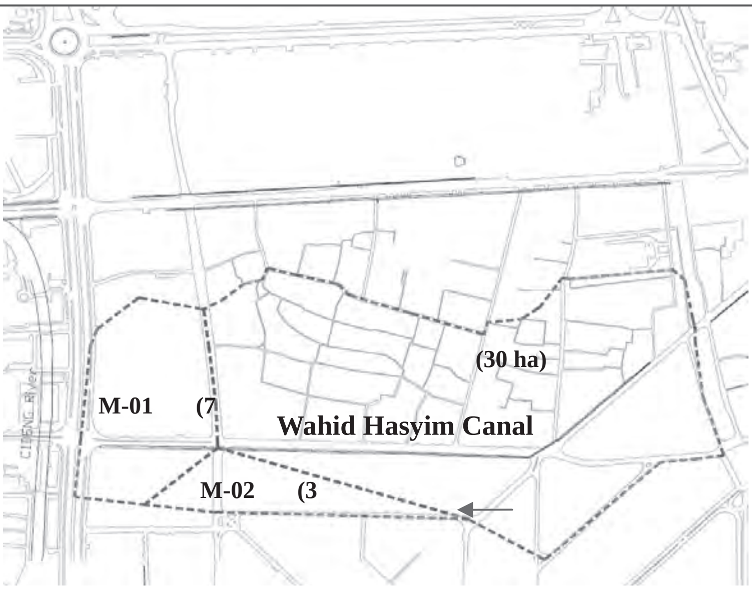
Table A1.8 Runoff Coefficient Applied in Monas and Cempaka Putih Sites

Project Site	Major Land Use Type	Runoff Coefficient
Monas	Business District/Shopping Center/ Medium-high Density Residential	0.75

Source: JICA PPP Study Team

A1.3 Subdivision of Drainage/Catchment Area

A single basin model was applied for the whole drainage area of the Wahid Hasyim Canal (40 ha) in the Monas project site. The whole drainage area was further subdivided into three sections in order to estimate the design discharge in each sub-basin to determine the scale of drainage pipes to be additionally installed.



Source: WJEMP 3-10, 2005

Figure A1.1 Basin Subdivision in Monas Project Site

A1.4 Inundation Model

A1.4.1 H-A-V Relation

In this Study, the following relation among elevation in inundation site (H), inundation area (A) and inundation volume (V) was established based on a 1:5000 topographic map. Table A1.9 shows the relations of H-A-V.

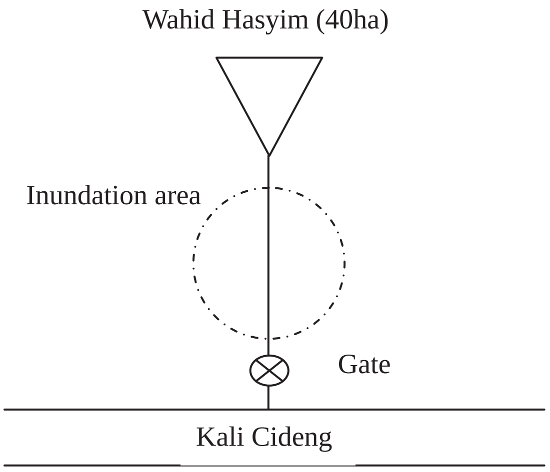
Table A1.9 H-A-V Relation (Monas)

H (PP+m)	A (ha)	V (m^3)
2.8	0	0
3.0	5.2	5,100
3.2	22.6	32,900
4.0	91.2	488,100

Source: JICA PPP Study Team

A1.4.2 Runoff-Inundation Model

A simple inundation model was established in this Study in which the inundation volume was estimated using the calculated discharge with the runoff model and flow capacity. The schematic diagram of the runoff-inundation model in each Project site is illustrated in Figure A1.2.



Source: JICA PPP Study Team

Figure A1.2 Schematic Diagram of Runoff-Inundation Model

A1.5 Hydraulic Analysis

Flow capacity of each canal and river was estimated by uniform flow computation. The following roughness coefficient was applied in the computation:

Table A1.10 Roughness Coefficient for Uniform Flow Computation

Canal/River	Roughness Coefficient	Remarks
River (Existing)	0.025	Protection by wet-masonry
Drainage Canal	0.020	Concrete
River (after improvement)	0.015	Utan Kayu River

Source: JICA PPP Study Team

A1.6 Calculation Results

A1.6.1 Monas Project Site

Table A1.11 shows the estimated design discharge for the existing condition without additional drainage facilities for the 10-year return period. The comparison of the estimated flow capacity of the existing canal to design discharge is presented in Table A1.12. It is judged that Wahid Hasyim Canal, the main drainage canal in the Monas project site, has enough capacity against the estimated design discharge.

Table A1.11 Design Discharge in Monas Project Sites (10-year Return Period)

Drain Line (Wahid Hasyim)	
Length, Ld (m)	1,150
Sub-Area, a (ha)	40
Total Area, A (ha)	40
Runoff coefficient, C	0.75
Average Slope, S	1/700
Cumul Length, L (m)	1,150
Average Velocity, V (m/s)	1.0
Overland Time, t1 (min)	10
Drain Time, t2 (min)	19
Concentration Time tc (min)	30
Intensity Curve (mm/hr)	109.7
Area Reduction Factor, Cs	1.00
Rainfall Intensity (mm/hr)	109.70
Peak Discharge (m^3/s)	9.14

Source: JICA PPP Study Team

Table A1.11 Design Discharge in Monas Project Sites (10-year Return Period)

Drain Line (Wahid Hasyim)	
Category of Canal	Canal
Manning Coefficient	0.020
Top width, B (m)	2.5
Bed width, b (m)	2.5
Drain depth, d (m)	2
Long slope, S	1/700
Flow capacity, Q (m^3/s)	7.93
Velocity, V (m/s)	1.59
Design Discharge (m^3/s)	6.86

Source: JICA PPP Study Team

Appendix-2 Conceptual Drawings of Drainage Facilities

Figure A2.1 General Layout of Drainage Facilities in Monas Area

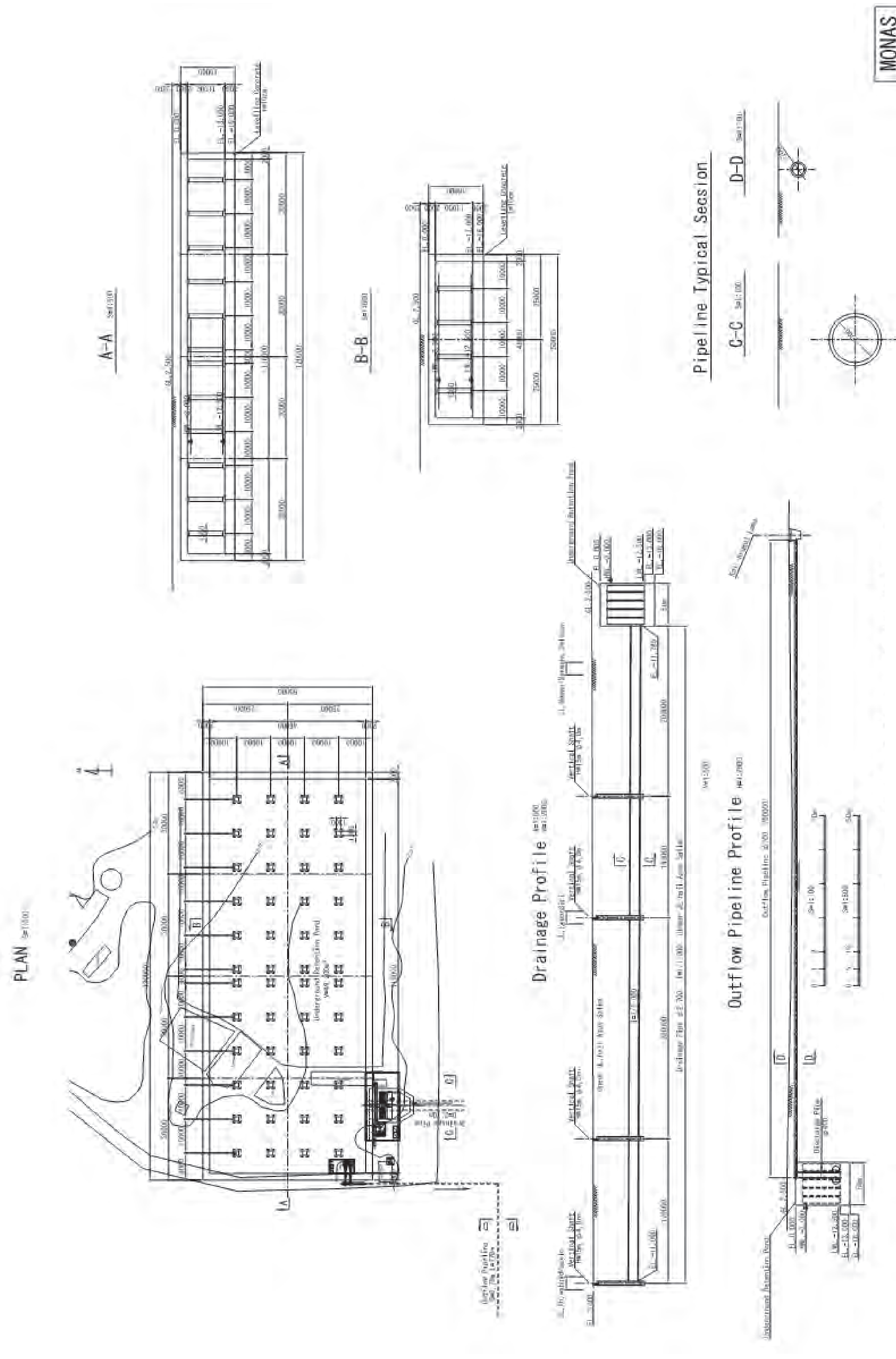


Figure A2.2(1) Detail of Drainage Facilities in Monas Area

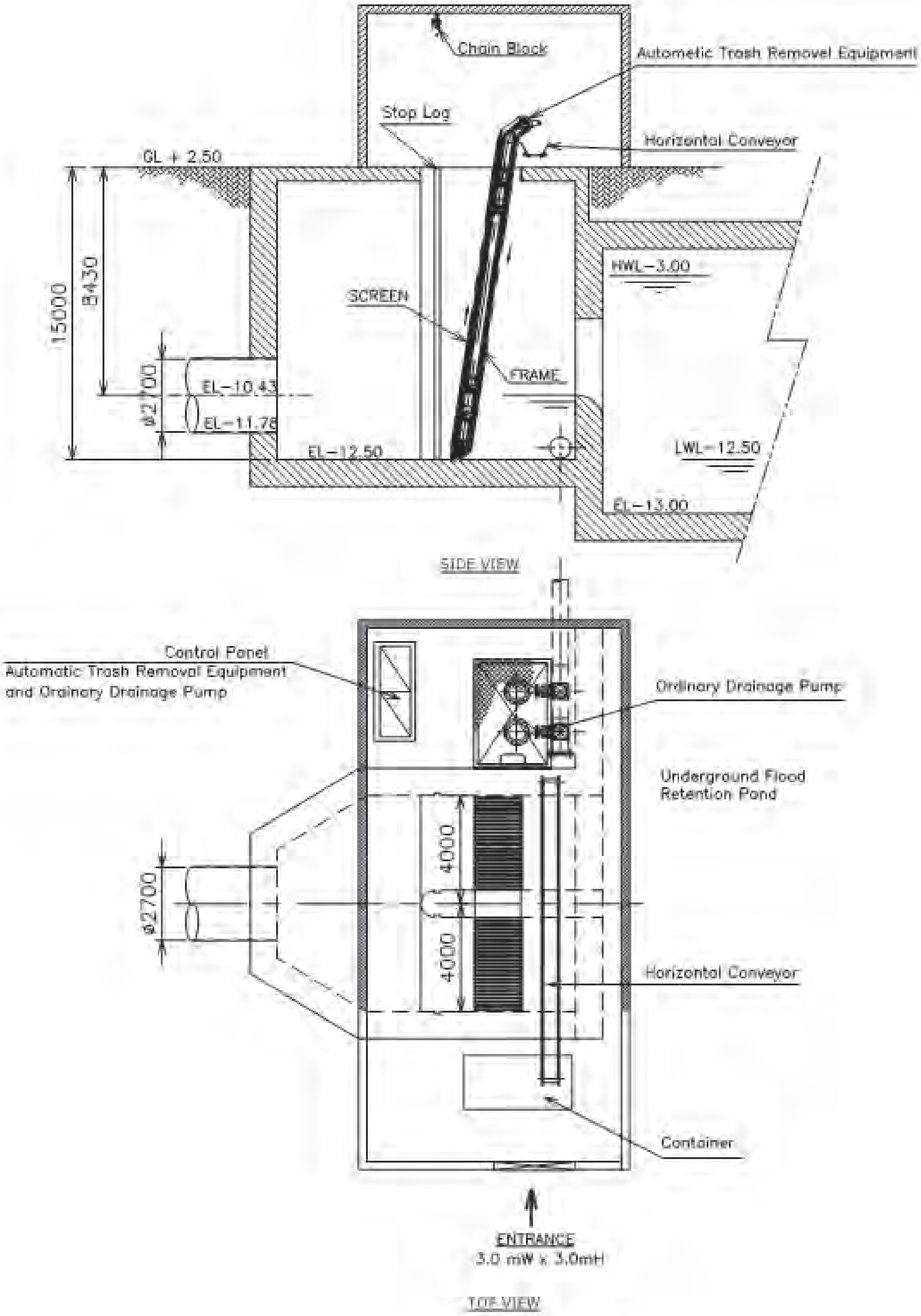


Figure A2.2(2) Monas UFRP Intake Facility

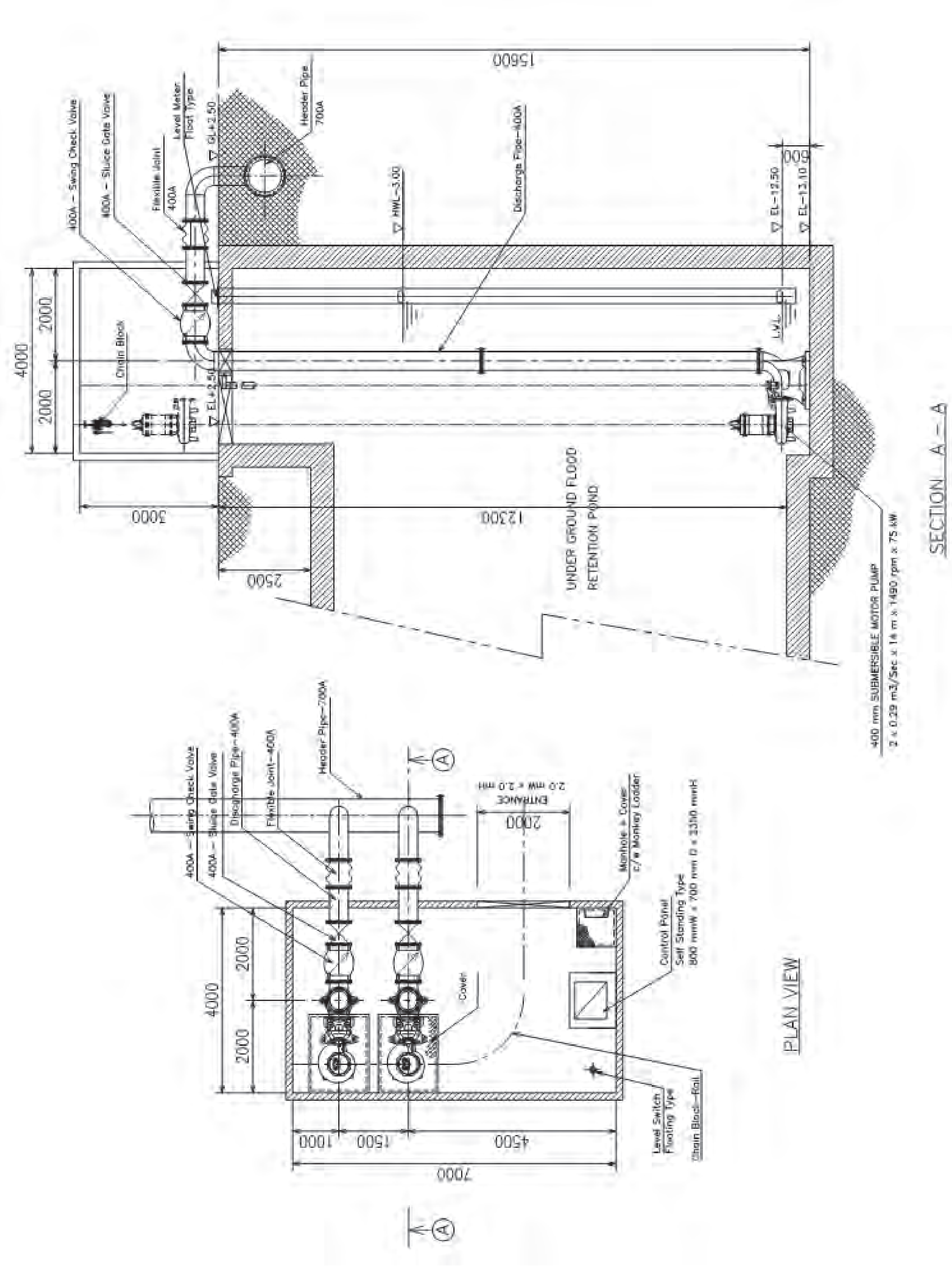


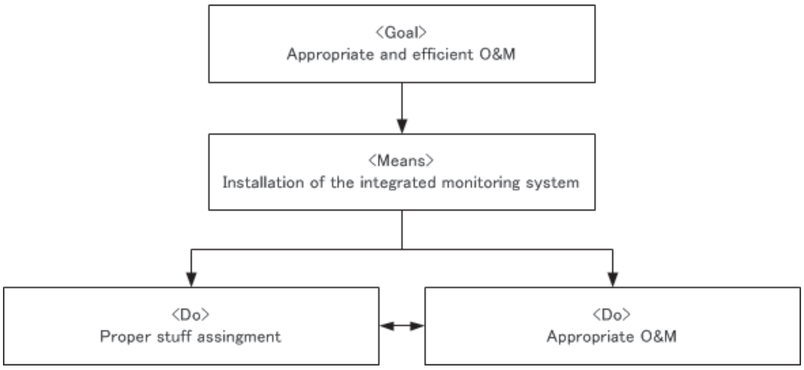
Figure A2.2(3) Monas UFRP Pump Facility

Chapter 6 Integrated Monitoring System

6.1 Necessity of Integrated Monitoring System

In DKI Jakarta, there is a plan to build many STPs (wastewater treatment plants). To operate these STPs appropriately and efficiently, it is necessary to organize a consolidated management system. The system will also make it possible to realize safe and stable operation easily. In order to do this, it is essential to introduce an integrated monitoring system. Furthermore, monitoring not only STPs, but also other facilities (e.g., storm water pumping stations) at the same time increases efficiency.

It is important to install the monitoring system at an early stage. Installing the system in each plant where a system already exists requires excessive labor and expense to integrate (change) the existing system. Figure 6-1 shows the process for the installation of the integrated monitoring system.



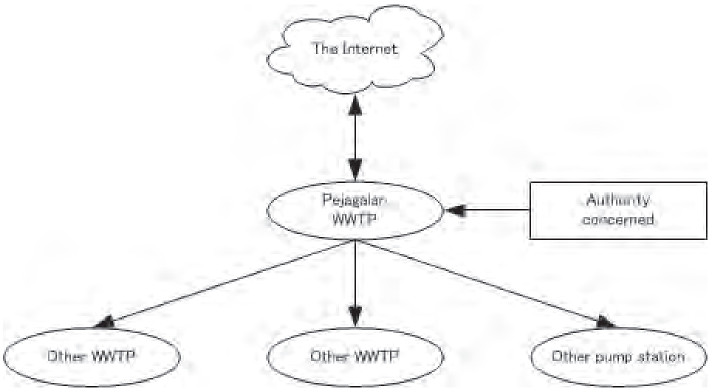
Source: JICA PPP Study Team

Figure 6-1 Process for Installation of Integrated Monitoring System

6.1.1 Object

The object is to realize appropriate and efficient O&M of STPs and other facilities (e.g., storm water pumping stations) planned in DKI Jakarta by installing the integrated monitoring system as a tool.

The system enables authorized people to monitor the status of each plant via the Internet anytime, anywhere.



6.1.2 Advantages

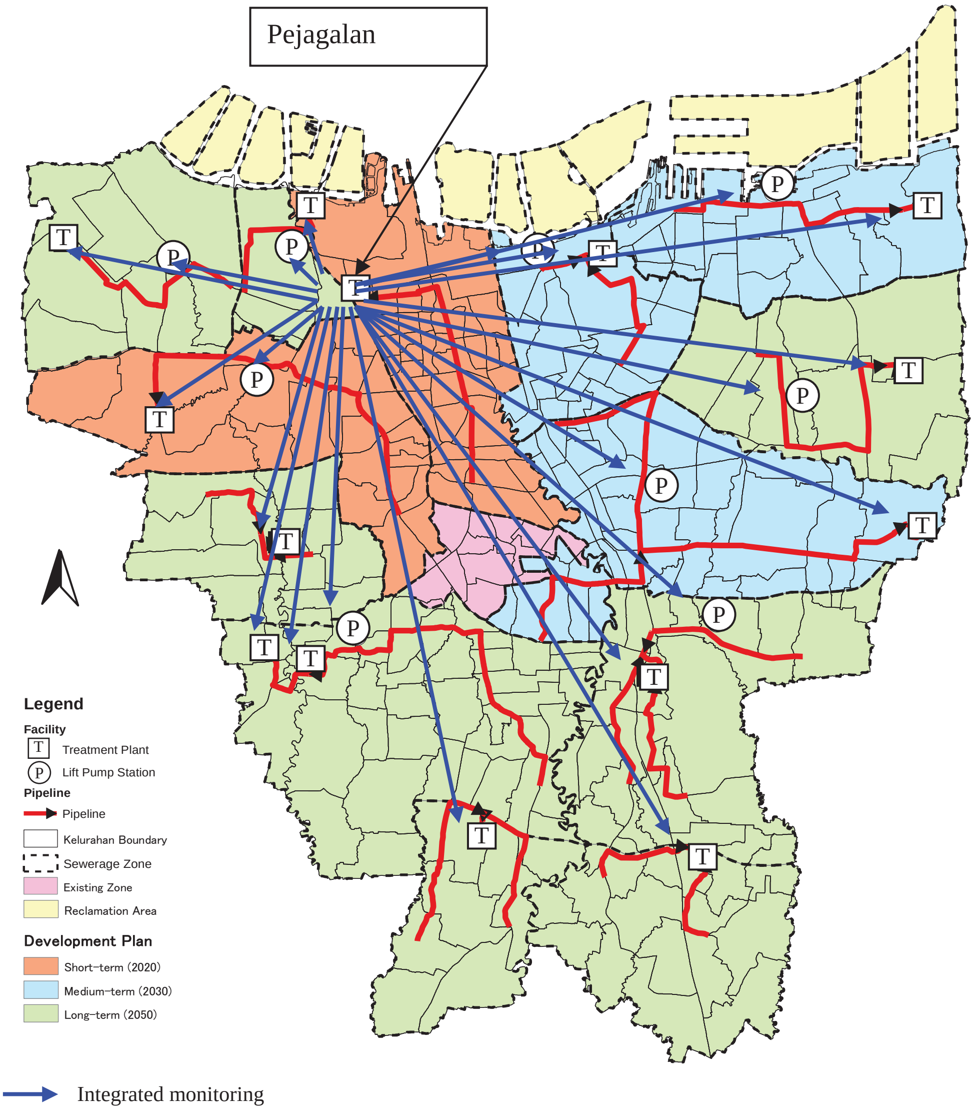
The following effects of the system are expected.

Improvement of O&M performance	Improvement of treated water quality	Improve treated water quality by choosing optimal treatment from trend graph of inflow water quality and treated water quality.
	Flexible work	Take appropriate measures by having a clear grasp of the present trend from measured data. Example: Personnel assignment ,schedule adjustment
	Appropriate countermeasures for emergencies	Take measures against emergencies (accidents) correctly and quickly.
	Laborsaving	Save labor by installing a computer system.
	Prevention of human errors	Prevent human error (e.g., unsuccessful behavior, miscalculation) by installing a computer system.
	Information sharing	Execute operation without problem or difficulty by sharing information among all operators when the person in charge is out.
Costs reduction	Repair cost	Reduce repair cost by preventing unexpected machine trouble with appropriate maintenance.
	Renewal cost	Reduce renewal cost by prolonging equipment's lifetime with appropriate repair plan.
	Personnel expenses	Reduce personnel expenses by deploying staff in the right place in a timely manner with consolidated management.
	Chemicals	Reduce volumes of chemicals by grasping the present treatment status.
	Electric energy	Reduce electric energy consumption by appropriate operation.
	Consumables and spares	Reduce extra consumables and spares by appropriate inventory management.

6.2 Proposal of Appropriate Integrated Monitoring System in DKI Jakarta

6.2.1 Scope

In this report, it is assumed that Pejagalan STP will be the main monitoring facility because it may be built initially, and other STPs and PSs (for sewage) may be built subsequently as local monitoring facilities. The figure below shows the layout of major STPs and PSs involved.



Source: MP Review

Figure 6-2 Layout of Major STPs and PSs

6.2.2 Features of the System

(1) System Architecture

The system is the client/server model of computing. Servers are built (e.g., Web server, data server) in each plant, so each plant can be monitored with a Web browser (e.g., Microsoft Internet Explorer, Google Chrome) remotely.

(2) Security

Only Pejagalan STP will have the Internet access point for security reasons. Other facilities will connect to Pejagalan STP with IP-VPN and access the Internet via Pejagalan STP.

Each plant will build a firewall and limit access from the outside.

Access to the Web server will require a user ID and password.

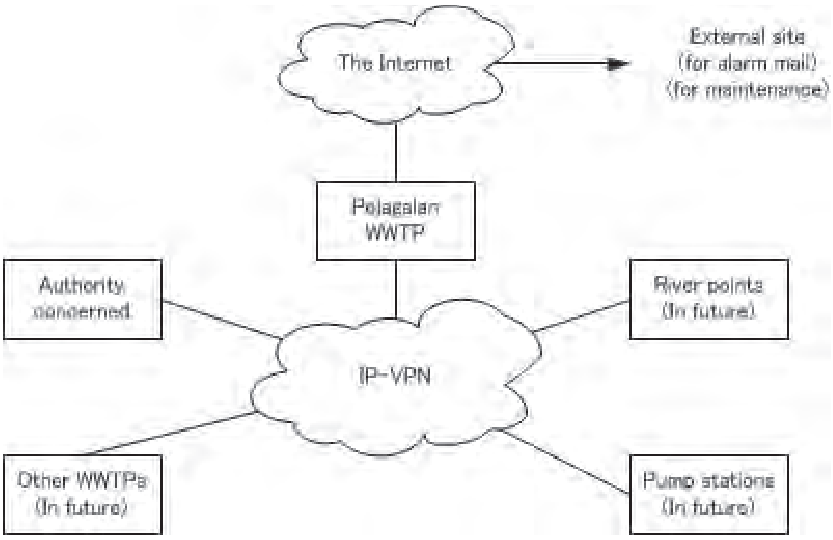
(3) Equipment

Equipment that can be procured in Jakarta and easily procured should be preferentially selected. Procurement of equipment from local suppliers enables getting support on site and shortens the downtime required to repair or replace failed equipment.

Equipment that will not be affected by power breakdown should be selected. For example, as client PCs, laptop PCs which have batteries are appropriate.

6.2.3 Network Structure

The figure below shows the network structure.



Source: JICA PPP Study Team

Figure 6-3 Network Structure

It is recommended to choose a network communication service that has high reliability and good cost-performance. Also, optical fiber cable of 50 Mbps – 100 Mbps is preferable.

6.2.4 System Structure

(1) Pejagalan STP

Operators always stay in the monitoring room at the Pejagalan STP and monitor all facilities in DKI Jakarta.

It is recommended:

1) To select a system structure that can prevent the system from missing data measured at Pejagalan STP when the network communication lines are down. This can be realized by setting up a data server at each STP/PS to store its own data.

2) To set up PLCs that receive analog and digital signals to monitor the status of water treatment process.

3) To set up a Web server that can be accessed and controlled manually from other sites.

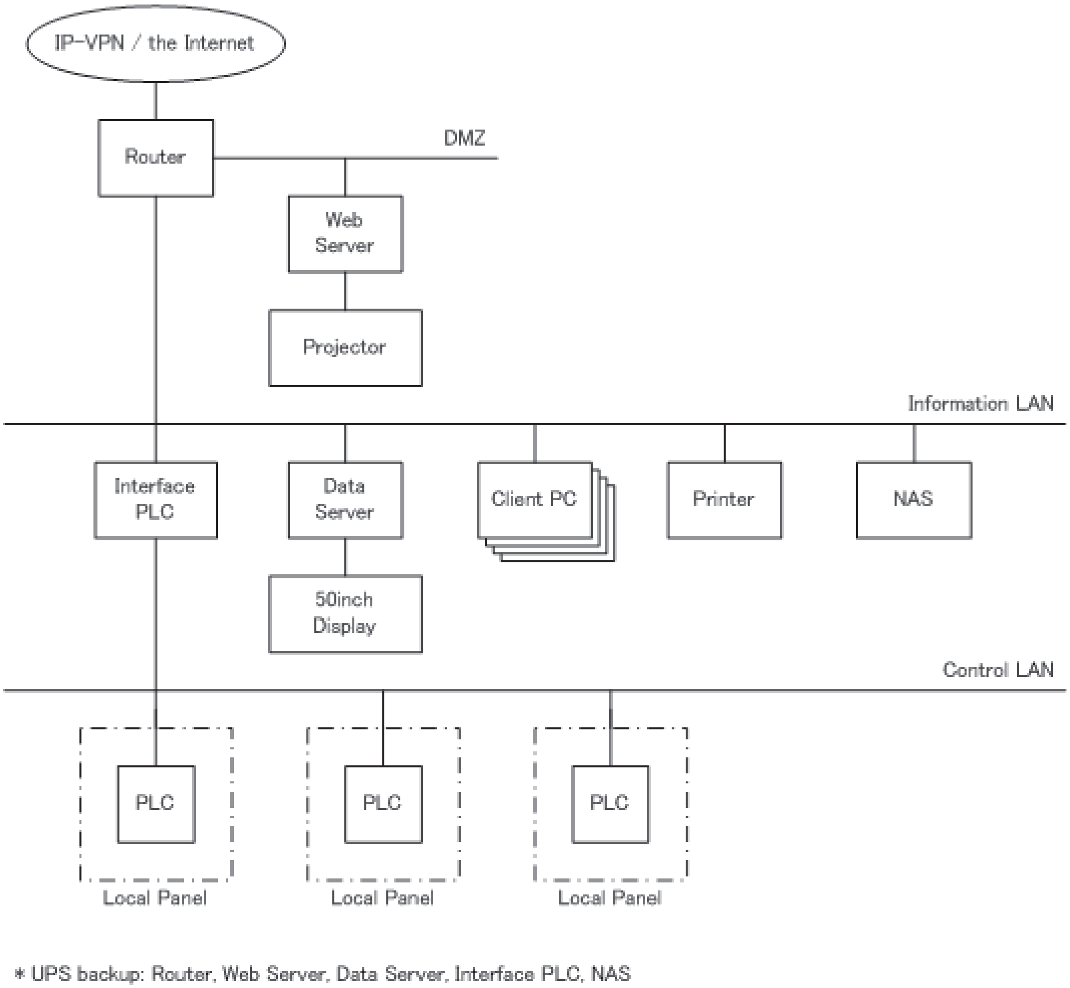
4) To set up a display (large monitor) on which the status of river points can be monitored (in the future).

5) To set up a projector on which the treatment process is displayed.

6) To set up a UPS to secure stable power supply to a Web server, a data server, an NAS, and an interface PLC.

7) To choose a high-speed communication service fast enough to transmit sufficient data.

The following is the system structure of the Pejagalan STP.



Source: JICA PPP Study Team

Figure 6-4 System Structure of the Pejagalan STP

(2) Other STPs (An example)

Basically, other STPs should have the same system structure as the Pejagalan STP excluding a projector, a large display and client PC.

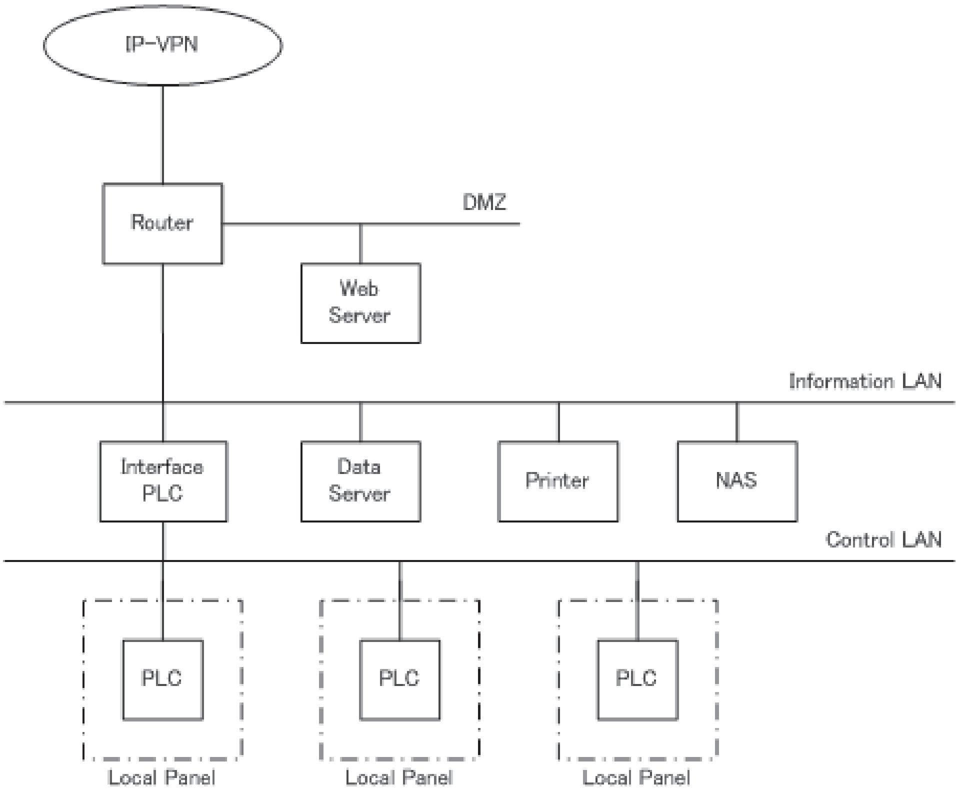
1) To set up PLCs that receive analog and digital signals to monitor the status of water treatment process.

2) To set up a Web server that can be accessed and controlled manually from other sites.

3) To set up a UPS to secure stable power supply to a Web server, a data server, an NAS, and an interface PLC.

4) To choose a middle-speed communication service that is fast enough to transmit sufficient data at a lower cost.

The following is the system structure of other STPs.



＊ UPS backup: Router, Web Server, Data Server, Interface PLC, NAS

Source: JICA PPP Study Team

Figure 6-5 System Structure of Other STPs.

(3) Other Pumping Stations (An example of small-scale plants)

1) To set up PLCs that receive analog and digital signals to monitor the status of pumps.

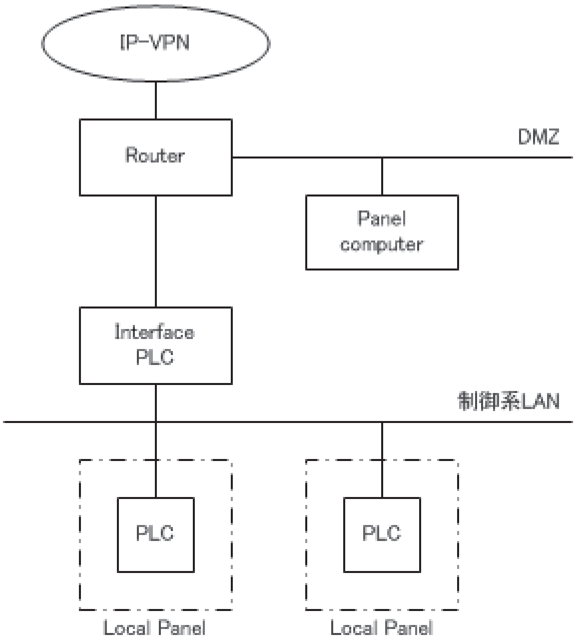
2) To set up a panel computer so that operational condition can be monitored and controlled manually from other sites.

3) Server PCs (e.g., Web server, data server) are not deployed.

4) The panel computer has functions to monitor and store measured data and to send emergency emails.

5) To choose a middle-speed communication service fast enough to transmit sufficient data with low cost.

The following is the system structure of other pumping stations.



Source: JICA PPP Study Team

Figure 6-6 System Structure of Other Pumping Stations

6.2.5 System Functions

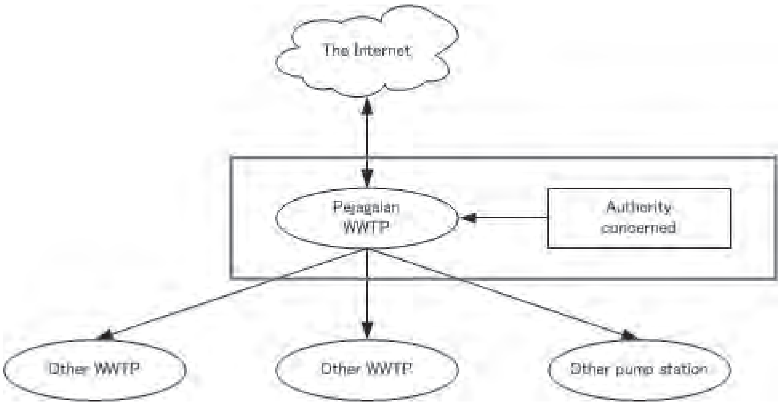
The following are functions in the system.

Supervision	
Treatment flow diagram	Display measured values and equipment's status symbols (on, off, breakdown) on treatment flow diagrams.
Trend graph	Graph measured values and equipment's status (on, off). Include a real time trend and a historical trend.
Measured data list	List measured values and equipment's status symbols (on, off, breakdown).
Alarm notification	Voice alarms in case of troubles (e.g., equipment breakdown, bad water quality).
Alarm summary	Display on-status alarms.
Alarm history	List an alarm history.
Operation history	List an operation history.
Emergency call	Alert person in charge by phone call or email.
Control	
On-off control	Enable operators to control equipment remotely.
Target value setting	Enable operators to control equipment by setting target values.

Automatic data acquisition	
Periodic data	Record measured values and on-time total time by hour or minute.
Alarm data	Record alarm logs.
Operation data	Record operation logs.
Data management	
Equipment	Manage equipment. Help to figure out inspection and maintenance records compared with expected lifetime, and ensure the appropriate condition of equipment to operate institutions properly.
Materials & spare parts	Manage materials and spare parts. Help to figure out inventory to ensure adequate quantity of those parts.
Data storage	
Structures	Store the information of institutions.
Operation work	Help to plan, do and report routine activities and urgent responses.
Maintenance work	Store records of maintenance work.
Technical document	Store records of documents (e.g., design drawings, manuals).
Water quality	Store data of water quality.
Reporting	
Daily report	Display hour-by-hour data as daily reports.
Monthly report	Display daily data as monthly reports.
Yearly report	Display monthly data as yearly reports.
Structures	Display details or lists of institutions.
Equipment	Display details or lists of equipment.
Operation work	Display details or lists of facilities inspection.
Maintenance work	Display details or lists of maintenance work (repair and renewal of facilities).
Materials & spare parts	Display details or lists of materials and spare parts.
Technical documents	Display details or lists of documents (drawings).
Other functions	
Software remote maintenance	Support to fix troubles from remote site (e.g., from Japan)

6.2.6 Rough Cost Estimation

(1) Case targeting only Pejagalan STP and the authority concerned (Scope: Within the box below)



a) Installation cost of the system

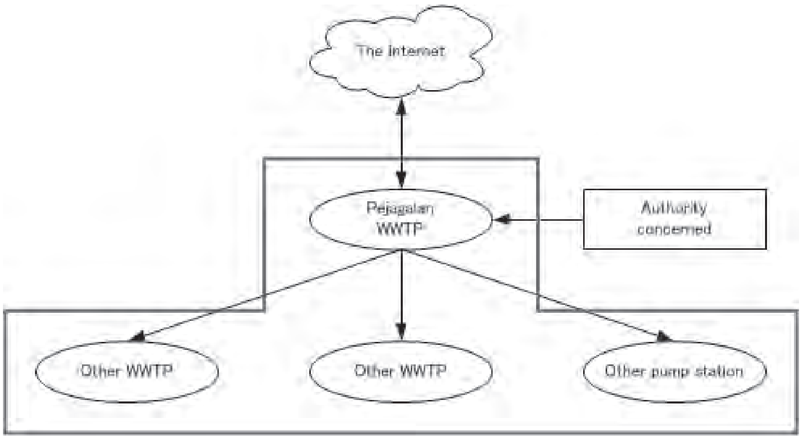
The system should be introduced when the Pejagalan STP is constructed so that no additional costs would be required.

b) Network service fee

(Unit: Mil IDR / year)

Facility name	Network service fee
Pejagalan STP	282
Authority concerned	212
Total	494

(2) Case targeting all planned STPs and PSs (in the future)
(Scope: Within the box below)



a) Installation cost of the system

The system should be introduced when the STPs and PSs are constructed so that no additional costs would be required.

b) Network service fee

(Unit: Mil IDR/year)

Facility name	Qty	Network service fee	Sub total
Pejagalan STP	1	282	282
Authority concerned	1	212	212
Other STPs	13	212	2,756
Other pump stations	9	212	1,908
		Total	5,158

Chapter 7 Training in Japan

7.1 Training Schedule

Date	Time	Program	Person in charge	Accommodation
30 Sep 2012	am	Arrival at Fukuoka Move to Kitakyushu		Kitakyushu
	pm	Off / (Observation in the city)		
1 Oct 2012	9:00-11:00	Briefing	JICA	Kitakyushu
	11:00-12:00	Program Orientation	Mr.Kozo HAYASHISHITA, Yokohama Water Co.	
			Mr.Kenichi YAMAMOTO, Orix Co.	
	13:30-14:45	(Lec) The history of improving Kitakyushu City's water quality and natural environment	Mr. Masaaki YAMADA, Manager, Water supply and Sewage Bureau, City of Kitakyushu	
	15:00-16:00	(Obs) Environmental Museum of Water		
2 Oct 2012	9:00-10:00	(Obs) Hiagari Wastewater Treatment Plant, Kitakyushu	Mr. Yasushi KAKIGI, Assistant Manager, WSSB, City of Kitakyushu	Kyoto
	10:00-11:00	(Obs) Water Plaza Kitakyushu	Mr. Hideaki HAMADA, Manager, Global Water Recycling and Reuse Solution Technology Research Association	
	pm	Move to Kusatsu via Kyoto (2hr 30min. by SHINKANSEN, the bullet train, and 1hr by chartered bus)		
	15:30-17:00	(Obs) Lake Biwa Museum, Kusatsu	Mr. Yasushi KUSUOKA, Museum Researcher	
		Move to Kyoto (1hr by bus)		
3 Oct 2012		Move to Sakai (1hr by bus)		Kobe
	10:00-10:15	Courtesy visit to the Mayor of Sakai City, Mr. Osami TAKEYAMA (with the Waterworks and Sewage Administrator (Director General), Mr. Sachio MORITA)	Mr. Kazuhiro MUKAI, Manager, Waterworks and Sewage Bureau, Sakai City	
	10:30-12:00	(Obs) Sambo Wastewater Treatment Plant, Sakai		
		Move to JICA Kansai, Kobe (40min. by bus)		
	14:00-15:00	Evaluation Meeting	JICA Kansai	
	15:00-15:30	Closing Ceremony	JICA Kansa	
4 Oct 2012	am	Move to Itami Airport		
		Departure to Jakarta		

7.2 Participants

Name	Post
M.Nafi	Head of Sub directorate Regional Investment and Regional Capacity / Directorateof Regional Finance and Capacity, General of Fiscal Balance (DGFB), Ministry of Finance
SIMATUPANG Delthy Sugriady	Legal Advisor / Deputy Minister of Infrastructure on PPP Issues, Deputy of Infrastructure, Ministry of National Development Planning
MARDIKANTO Aldy Kharisma	Planning Staff / Directorate of Settlements and Housing, Ministry of National Development Planning
SOERANTO Dwityo Akoro	Deputy Director for Foreign Cooperation / Directorate General of Human Settelments, Ministry of Public Works
RACHMAN Ade Syaiful	Section Head of Minitoring Evaluation at Sub Directorate of Technical Planning / Directorate of Environmental Sanitation Development, Directorate, DGHS, Ministry of Public Works
KUSUMASTUTI Diana	Head Section of Program Building Development and Environment / Directorate General of Human Settlements, DGHS, Ministry of Public Works
TIWANG Michael Fansiscus	Sub Project Manager in Working Unit of Environmental Sanitation for Jabodetabek Area / Directorate of Environmental Sanitation Development, DGHS, Ministry of Public Works
WIBOWO Arianto	Head of Division of Business Development / Indonesia Infrastructure Guarantee Funds
SUKANDAR Erwin Setiadi	Senior Vice President of Business Development / Indonesia Infrastructure Guarantee Funds
YUSA Sulthan Muhammad	Head, Business Development / Portfolio Investment Division, Indonesia Investment Agency, Ministry of Finance
Sri Mahendra Satria Wirawan	Vice Head, Regional Development Planning Board (Bappeda), DKI Jakarta Province
DATIR Tarjuki Sarman	Vice Head, Public Works Agency, DKI Jakarta Province
WARIH Andono	Vice Head, Environmental Management Board, DKI Jakarta Province
INDARDO Yudi	Director of Administration & Finance, PD Pal Jaya

7.3 Photos

1/10 lecture by Mr. YAMADA (City of Kitakyushu)

1/10 Storm Overflow Chamber at Kimachi Park

1/10 Storm Overflow Chamber at Kimachi Park

1/10 Environmental Museum of Water

2/10 Hiagari Wastewater Treatment Plant

2/10 Hiagari Wastewater Treatment Plant

2/10 Water Plaza Kitakyushu

2/10 Lake Biwa Museum

3/10 Courtesy visit to the Mayor of Sakai

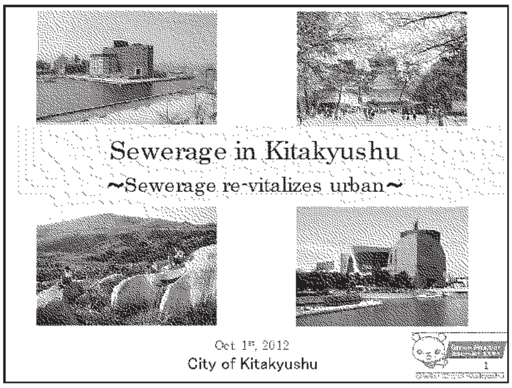
3/10 Sambo Wastewater Treatment Plant

3/10 Evaluation Meeting at JICA Kansai, Kobe

3/10 Closing Ceremony at JICA Kansai, Kobe

Attachment: Lecture Material

1 October 2012
Lecture material :
The history of improving Kitakyushu City's water quality and natural environment

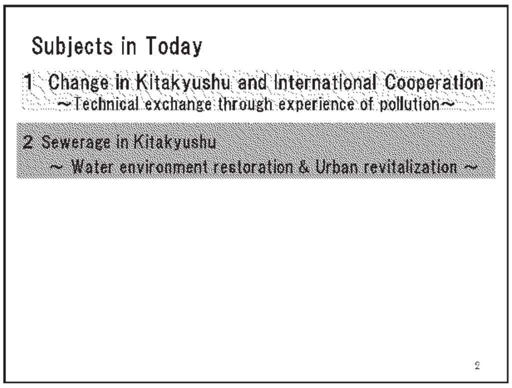


Sewerage in Kitakyushu

~Sewerage re-vitalizes urban~

Oct. 1st, 2012
City of Kitakyushu

1



Subjects in Today

1 Change in Kitakyushu and International Cooperation
~Technical exchange through experience of pollution~

2 Sewerage in Kitakyushu
~ Water environment restoration & Urban revitalization ~

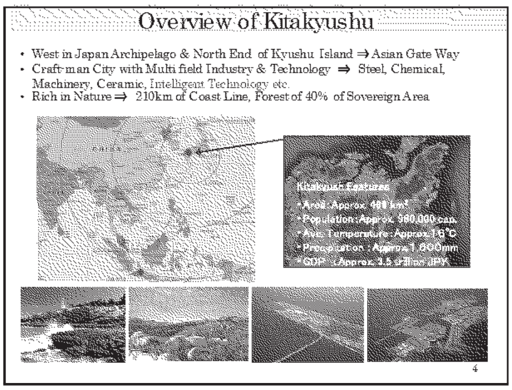
2

1 1 Change in Kitakyushu and International Cooperation

~Technical exchange through experience of pollution~

- ･Industrization vs. Pollution epidemic
- ･Activities to overcome pollution
- ･International Cooperation in Environment

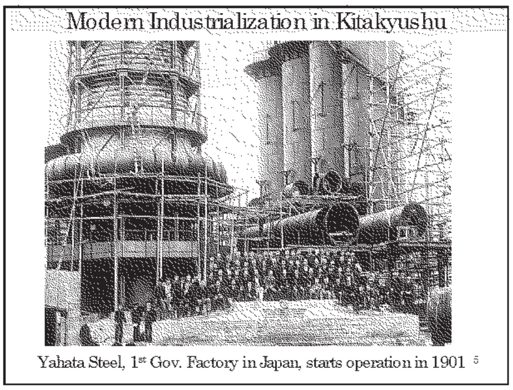
3



Overview of Kitakyushu

- West in Japan Archipelago & North End of Kyushu Island ⇒ Asian Gate Way
- Craft-man City with Multi field Industry & Technology ⇒ Steel, Chemical, Machinery, Ceramic, Intelligent Technology etc.
- Rich in Nature ⇒ 210km of Coast Line, Forest of 40% of Sovereign Area

4



Modern Industrialization in Kitakyushu

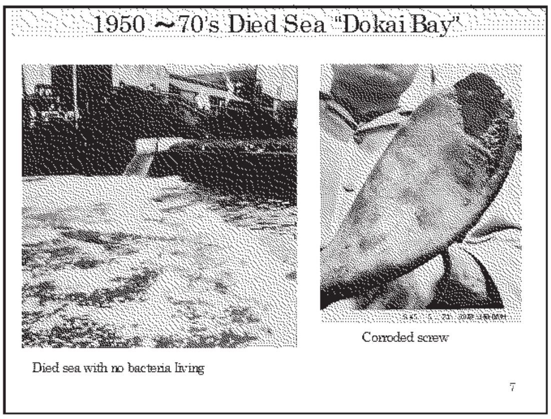
Yahata Steel, 1st Gov. Factory in Japan, starts operation in 1901

5

Environment of Kitakyushu in 1950's

Bristle Chimneys with Soot & Dust primary in Japan (108 ton/day/km^2)

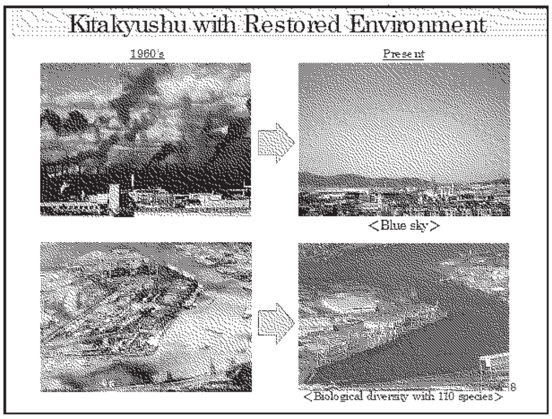
6



1950～70's Died Sea "Dokai Bay"

Corroded screw

Died sea with no bacteria living



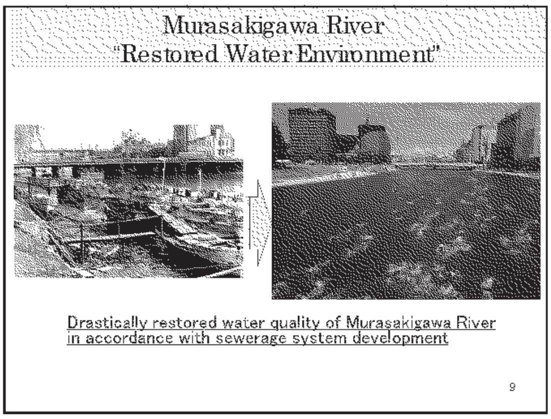
Kitakyushu with Restored Environment

1960's

Present

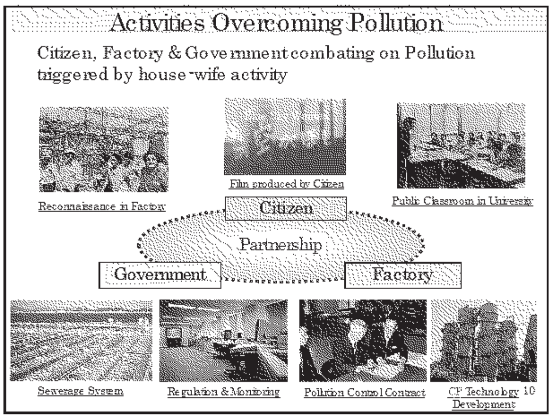
<Blue sky>

<Biological diversity with 110 species>



Murasakigawa River "Restored Water Environment"

Drastically restored water quality of Murasakigawa River in accordance with sewerage system development



Activities Overcoming Pollution

Citizen, Factory & Government combating on Pollution triggered by house-wife activity

Reconnaissance in Factory

Film produced by Citizen

Public Classroom in University

Citizen

Partnership

Government

Factory

Sewerage System

Regulation & Monitoring

Pollution Control Contract

CP Technology Development

International Cooperation in Environment

Contribution on Environment Restoration Overseas with Experience & Knowhow through Overcoming Pollution

Training Course ： 140 countries 6,638 participants
Dispatch Experts ： more than 160 professionals

Technical Cooperation in Indonesia

○ Dispatch Experts(Wastewater Management)
Long Term: 2 professionals(PD PAL JAYA)
(July1995 through July1999)
Short Term: 6 professionals
(July1995 through July1999)

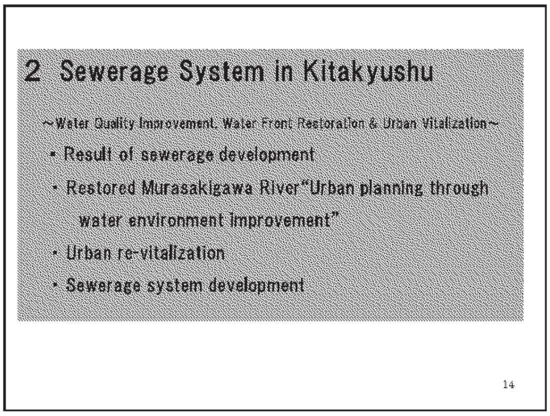
○Training Course
64 participants(Up to today since 2004)
Training Course in JICA Kyushu
Training Course in City Office

Technical Cooperation in Indonesia

<Environmental Improvement in Surabaya>

Technology of Kitakyushu to Surabaya

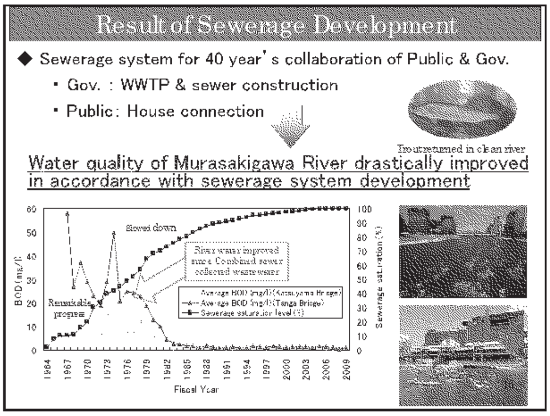
Composting garbage prevalent in more than 20,000 households



2 Sewerage System in Kitakyushu

~Water Quality Improvement, Water Front Restoration & Urban Vitalization~

- Result of sewerage development
- Restored Murasakigawa River"Urban planning through water environment improvement"
- Urban re-vitalization
- Sewerage system development



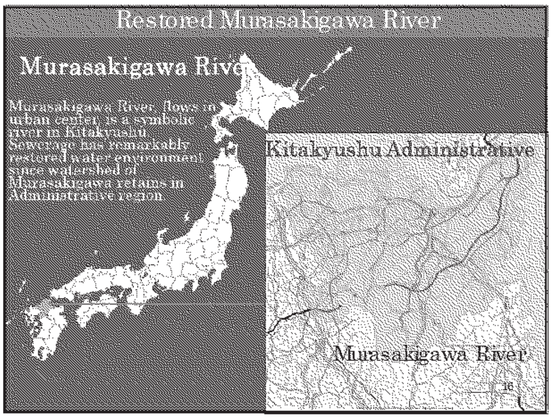
Result of Sewerage Development

◆ Sewerage system for 40 year's collaboration of Public & Gov.

- Gov. : WWTP & sewer construction
- Public: House connection

Trout returned in clean river

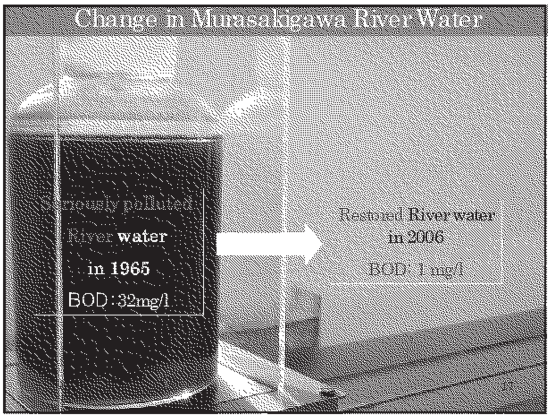
Water quality of Murasakigawa River drastically improved in accordance with sewerage system development



Restored Murasakigawa River

Murasakigawa River

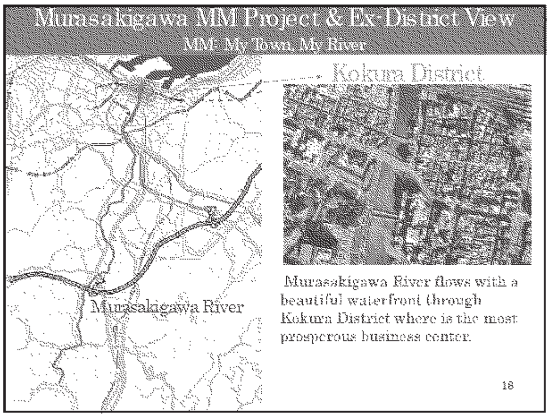
Murasakigawa River, flows in urban center, is a symbolic river in Kitakyushu. Sewerage has remarkably restored water environment since watershed of Murasakigawa retains in Administrative region.



Change in Murasakigawa River Water

Seriously polluted River water in 1965 BOD:32mg/l

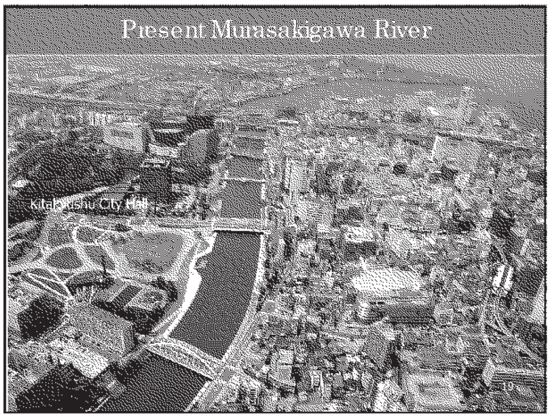
Restored River water in 2006 BOD: 1 mg/l



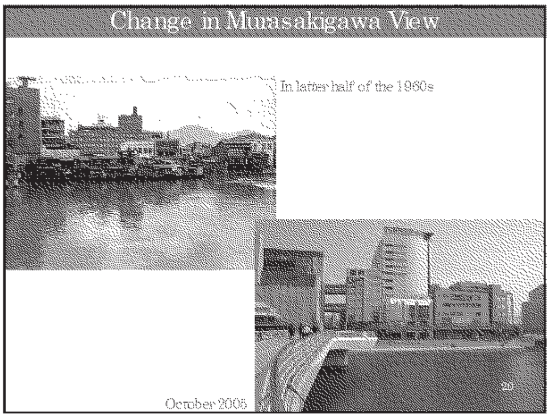
Murasakigawa MM Project & Ex-District View

MM: My Town, My River

Murasakigawa River flows with a beautiful waterfront through Kokura District where is the most prosperous business center.



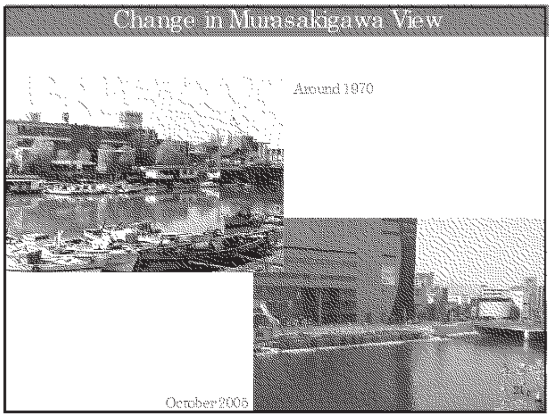
Present Murasakigawa River



Change in Murasakigawa View

In latter half of the 1960s

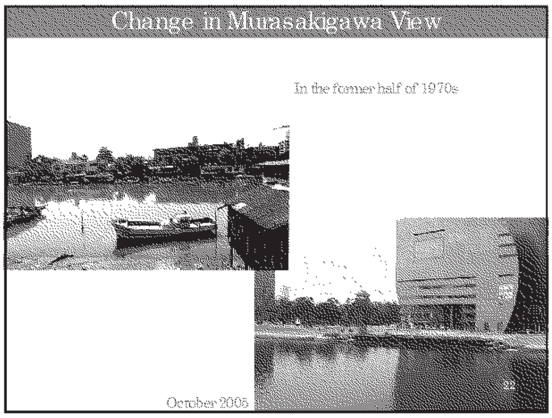
October 2005



Change in Murasakigawa View

Around 1970

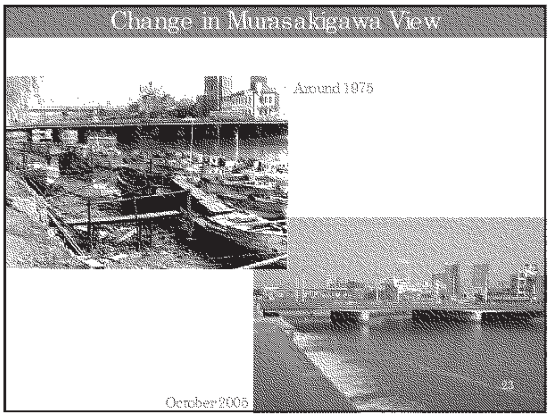
October 2005



Change in Murasakigawa View

In the former half of 1970s

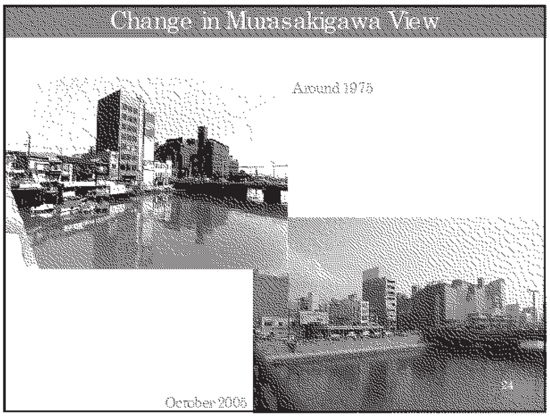
October 2005



Change in Murasakigawa View

Around 1975

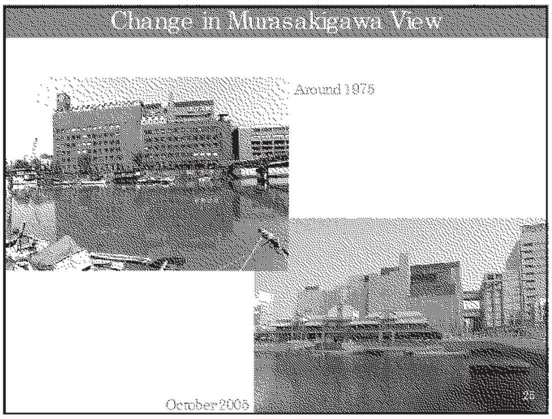
October 2005



Change in Murasakigawa View

Around 1975

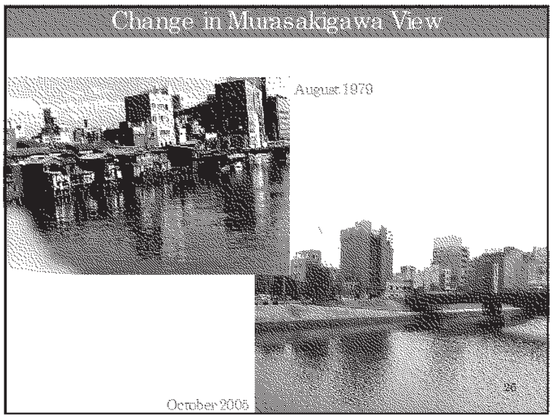
October 2005



Change in Murasakigawa View

Around 1975

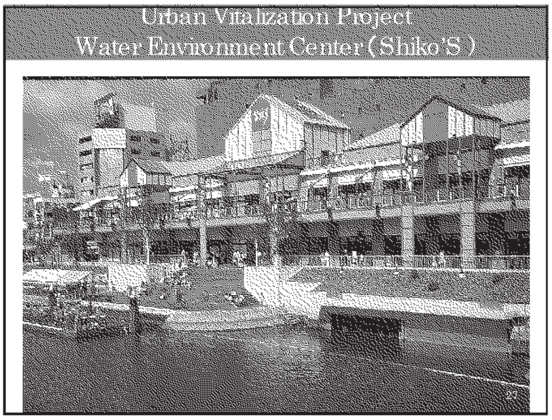
October 2005



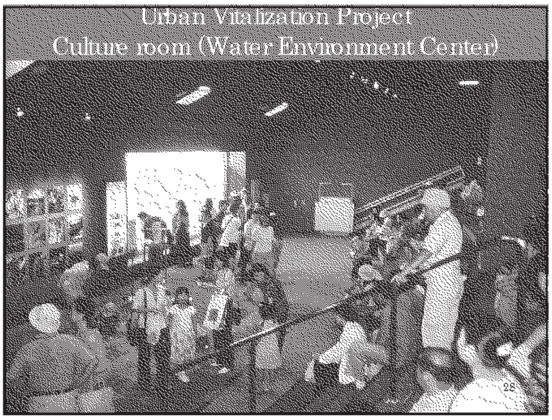
Change in Murasakigawa View

August 1979

October 2005

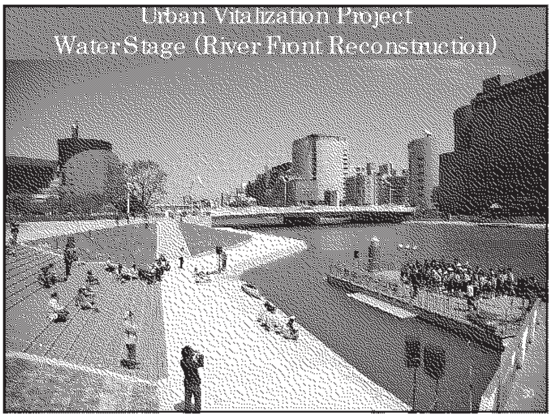


Urban Vitalization Project
Water Environment Center (Shiko'S)



Urban Vitalization Project
Culture room (Water Environment Center)

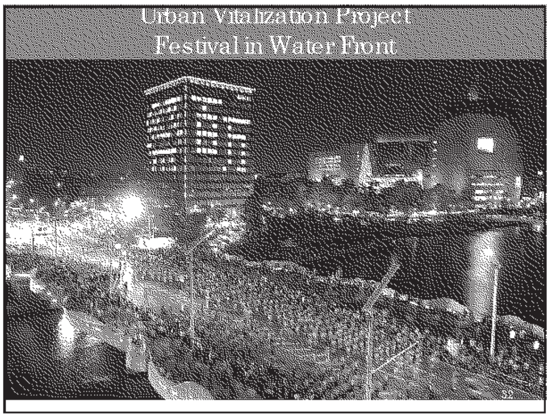
Urban Vitalization Project
River peeping (Water Environment Center)



Urban Vitalization Project
Water Stage (River Front Reconstruction)

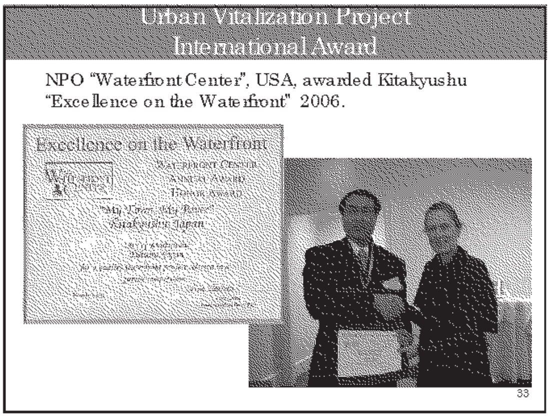
Urban Vitalization Project
Walking Path & Urban Development Building

31



Urban Vitalization Project
Festival in Water Front

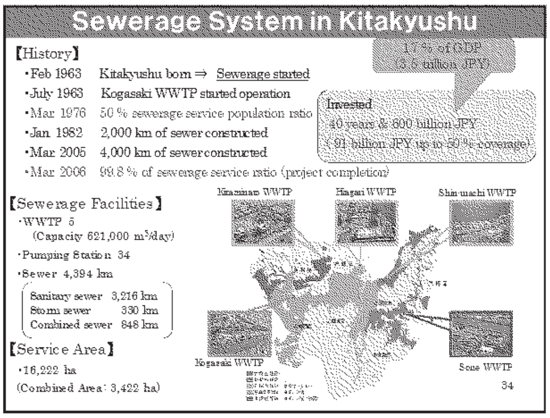
32



Urban Vitalization Project
International Award

NPO "Waterfront Center", USA, awarded Kitakyushu "Excellence on the Waterfront" 2006.

33



Sewerage System in Kitakyushu

【History】
- Feb 1963 Kitakyushu born ⇒ Sewerage started
- July 1963 Kogasaki WWTP started operation
- Mar. 1976 50 % sewerage service population ratio
- Jan. 1982 2,000 km of sewer constructed
- Mar. 2005 4,000 km of sewer constructed
- Mar. 2006 99.8 % of sewerage service ratio (project completion)

17 % of GDP
(3.5 trillion JPY)

Invested
40 years & 800 billion JPY
(91 billion JPY up to 50 % coverage)

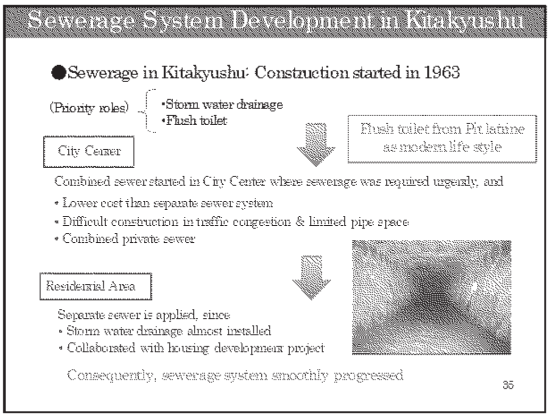
【Sewerage Facilities】
- WWTP 5
  (Capacity 621,000 m³/day)
- Pumping Station 34
- Sewer 4,394 km

Sanitary sewer	3,216 km
Storm sewer	330 km
Combined sewer	848 km

【Service Area】
- 16,222 ha

(Combined Area: 3,422 ha)

34



Sewerage System Development in Kitakyushu

●Sewerage in Kitakyushu: Construction started in 1963

(Priority roles)
- Storm water drainage
- Flush toilet

Flush toilet from Pit latrine as modern life style

City Center

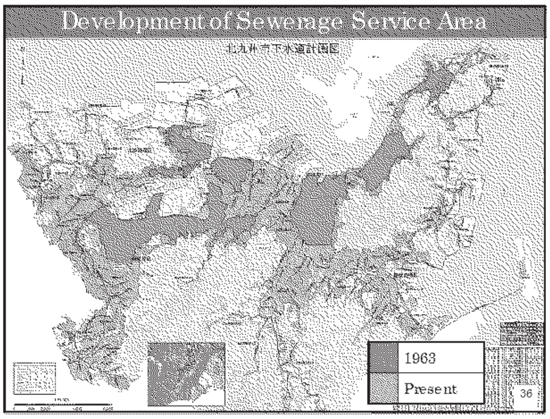
Combined sewer started in City Center where sewerage was required urgently, and
- Lower cost than separate sewer system
- Difficult construction in traffic congestion & limited pipe space
- Combined private sewer

Residential Area

Separate sewer is applied, since
- Storm water drainage almost installed
- Collaborated with housing development project

Consequently, sewerage system smoothly progressed

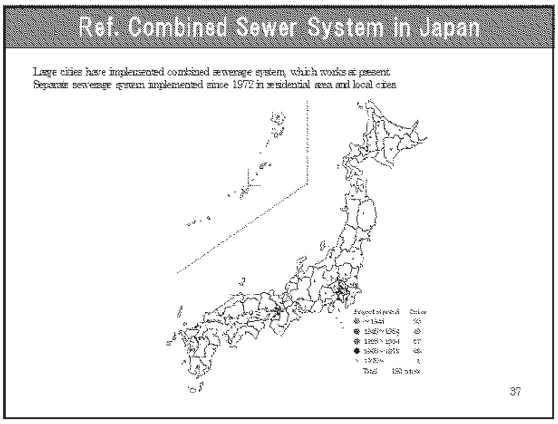
35



Development of Sewerage Service Area

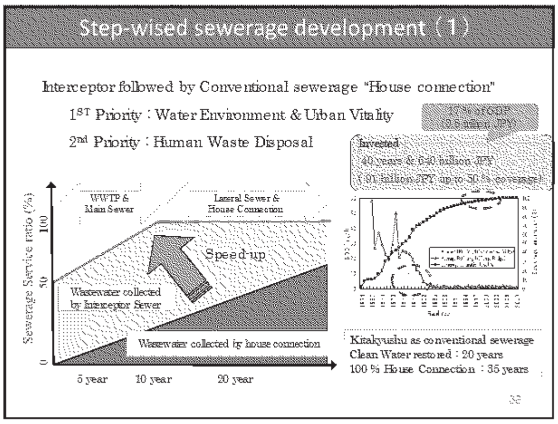
▨	1963
▨	Present

36



Ref. Combined Sewer System in Japan

Large cities have implemented combined sewerage system, which works at present
Separate sewerage system implemented since 1972 in residential area and local cities



Step-wised sewerage development（1）

Interceptor followed by Conventional sewerage "House connection"

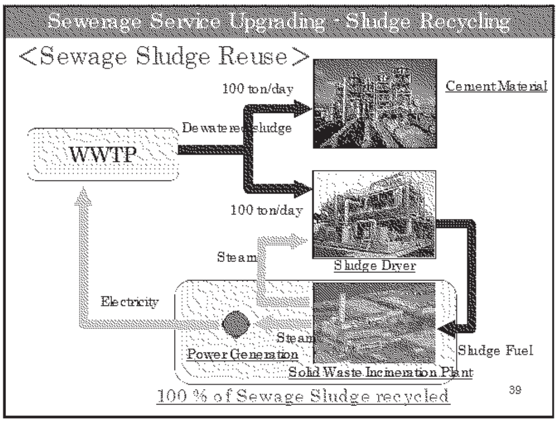
1ST Priority：Water Environment & Urban Vitality

2nd Priority：Human Waste Disposal

17 % of GDP
(9.8 billion JPY)

Invested
40 years & 640 billion JPY
(91 billion JPY up to 50 % coverage)

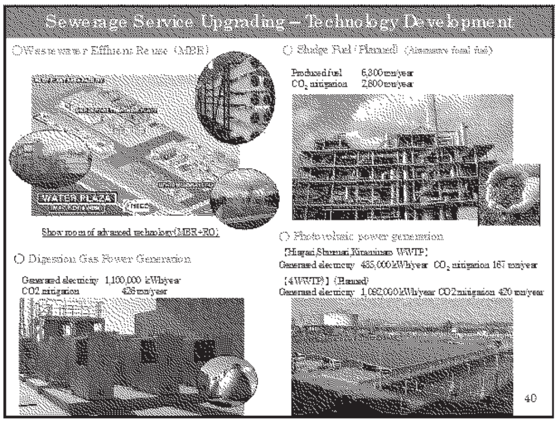
Kitakyushu as conventional sewerage
Clean Water restored：20 years
100 % House Connection：35 years



Sewerage Service Upgrading - Sludge Recycling

＜Sewage Sludge Reuse＞

100 % of Sewage Sludge recycled



Sewerage Service Upgrading – Technology Development

○Wastewater Effluent Reuse (MBR)

Show room of advanced technology(MBR+RO)

○ Digestion Gas Power Generation

Generated electricity 1,100,000 kWh/year
CO2 mitigation 426 ton/year

○ Sludge Fuel (Planned) (Alternative fossil fuel)

Produced fuel 6,300 ton/year
CO_2 mitigation 2,800 ton/year

○ Photovoltaic power generation

[Hiagari,Shinmai,Kitaminato WWTP]
Generated electricity 435,000 kWh/year CO_2 mitigation 167 ton/year

[4 WWTP] (Planned)
Generated electricity 1,092,000 kWh/year CO2 mitigation 420 ton/year

Mission of Kitakyushu

Water Environment Restoration in DKI Jakarta

Private
・Technology

Government
・Operation Knowhow
・Reliability

◆ Human Resource Development
・On the Job Training
・Training in Kitakyushu

Supporting by Kitakyushu

◆ Show case & Information
・ Supporting private sector through providing business matching
・ Japanese technology to the world

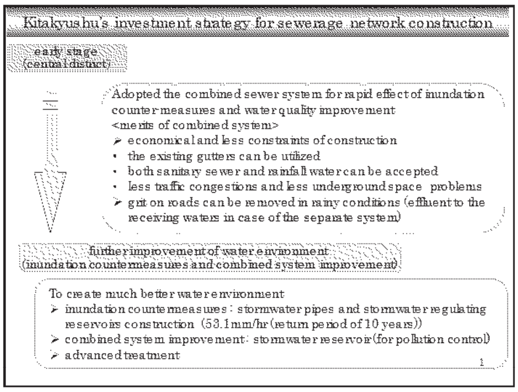
◆ Institutional Design
・Providing knowhow on Project operation & institutional design
・Supporting policy making

Kitakyushu willingly supports
Sewerage Development
in
DKI Jakarta

Thank you dan Terima Kasih

http://www.city.kitakyushu.lg.jp/

1 October 2012
Lecture material (annex) City of Kitakyusyu



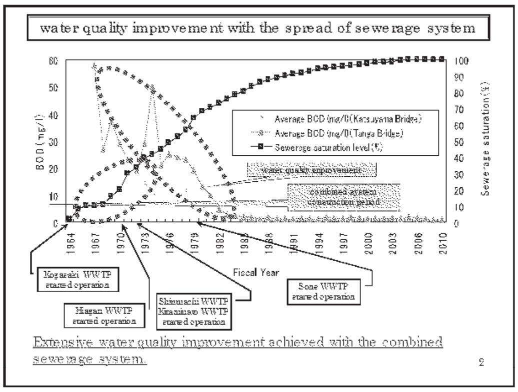
Kitakyushu's investment strategy for sewerage network construction

early stage
(central district)

Adopted the combined sewer system for rapid effect of inundation counter measures and water quality improvement
<merits of combined system>
- ➢ economical and less constraints of construction
- ・ the existing gutters can be utilized
- ・ both sanitary sewer and rainfall water can be accepted
- ・ less traffic congestions and less underground space problems
- ➢ grit on roads can be removed in rainy conditions (effluent to the receiving waters in case of the separate system)

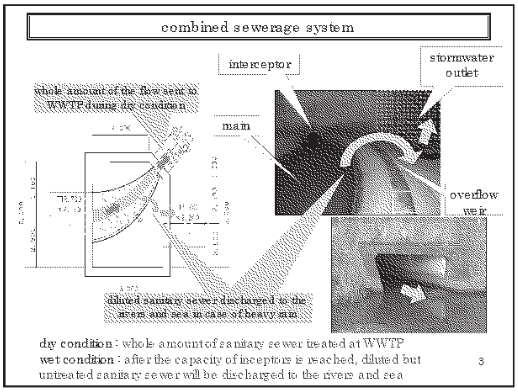
further improvement of water environment
(inundation countermeasures and combined system improvement)

To create much better water environment
- ➢ inundation countermeasures : stormwater pipes and stormwater regulating reservoirs construction (53.1mm/hr (return period of 10 years))
- ➢ combined system improvement : stormwater reservoir (for pollution control)
- ➢ advanced treatment



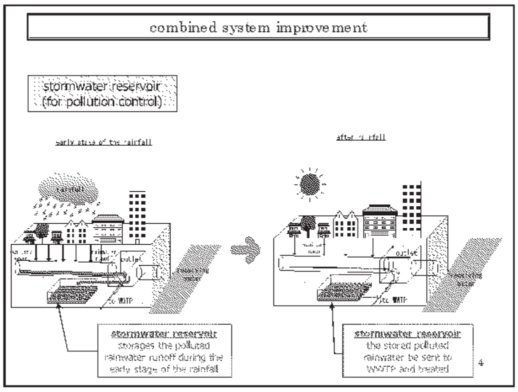
water quality improvement with the spread of sewerage system

Extensive water quality improvement achieved with the combined sewerage system.



combined sewerage system

dry condition : whole amount of sanitary sewer treated at WWTP
wet condition : after the capacity of inceptors is reached, diluted but untreated sanitary sewer will be discharged to the rivers and sea

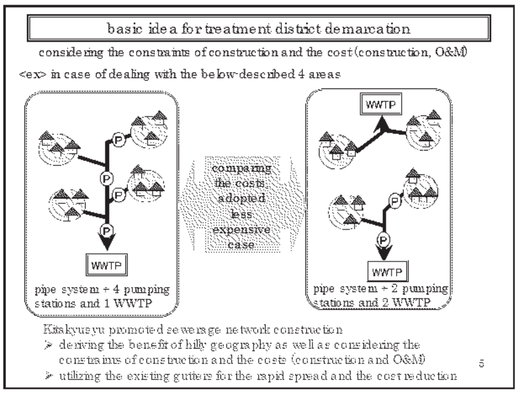


combined system improvement

stormwater reservoir
(for pollution control)

stormwater reservoir
storages the polluted rainwater runoff during the early stage of the rainfall

stormwater reservoir
the stored polluted rainwater be sent to WWTP and treated



basic idea for treatment district demarcation

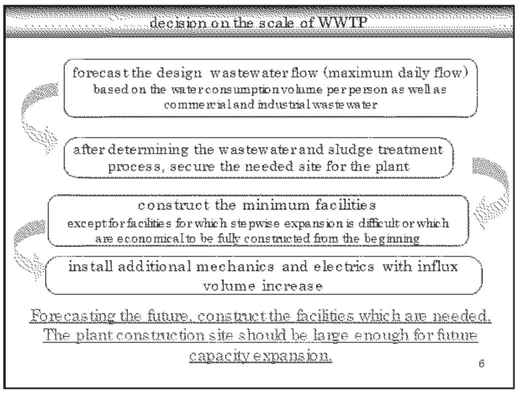
considering the constraints of construction and the cost (construction, O&M)

<ex> in case of dealing with the below-described 4 areas

pipe system + 4 pumping stations and 1 WWTP

pipe system + 2 pumping stations and 2 WWTP

Kitakyusyu promoted sewerage network construction
- ➢ deriving the benefit of hilly geography as well as considering the constraints of construction and the costs (construction and O&M)
- ➢ utilizing the existing gutters for the rapid spread and the cost reduction



decision on the scale of WWTP

forecast the design wastewater flow (maximum daily flow)
based on the water consumption volume per person as well as commercial and industrial wastewater

after determining the wastewater and sludge treatment process, secure the needed site for the plant

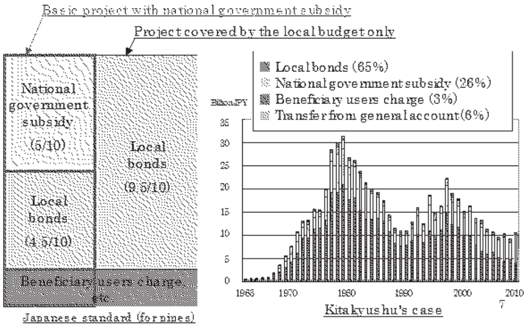
construct the minimum facilities
except for facilities for which stepwise expansion is difficult or which are economical to be fully constructed from the beginning

install additional mechanics and electrics with influx volume increase

Forecasting the future, construct the facilities which are needed. The plant construction site should be large enough for future capacity expansion.

financial support from national government

- ◆ Proper cost-sharing by national government and local residents



Japanese standard (for pipes)

Kitakyushu's case

"Beneficiaries pay" principle

- ◆ Adoption of system in which beneficiaries bear part of construction costs

⇒ After adoption by Kitakyushu (1968), other local governments in the country followed suit

※City staff thorough explanations to residents → Organization of local information sessions, individual visits

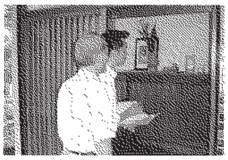
(Outcomes): Staff→Contribution to human resources development

Residents→Raising awareness of businesses and promoting understanding

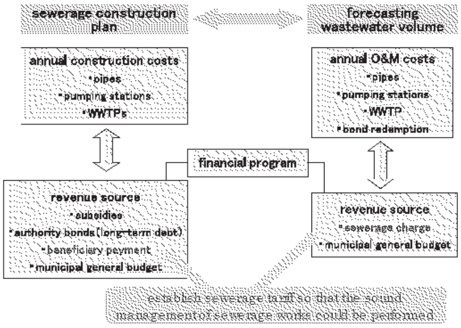
developers' burden rate for sewerage
- ・66～182 JPY/m^2 (1967-1975)
- ・185 JPY/m^2 (1976-)

accumulated amount of payment (1967-2011)
- ・16,765,298,000 JPY

accumulated burden-imposed development area
- ・11,320 ha



basic concept of sewerage tariff



sewerage construction plan ⇔ **forecasting wastewater volume**

annual construction costs
- ・pipes
- ・pumping stations
- ・WWTPs

annual O&M costs
- ・pipes
- ・pumping stations
- ・WWTP
- ・bond redemption

financial program

revenue source
- ・subsidies
- ・authority bonds(long-term debt)
- ・beneficiary payment
- ・municipal general budget

revenue source
- ・sewerage charge
- ・municipal general budget

establish sewerage tariff so that the sound management of sewerage works could be performed

water tariff (water, sewerage charge)

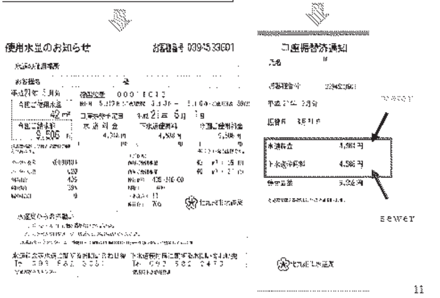
(bimonthly)

(m³)	PipeDiameter 20mm	total (yen)	(m³)	PipeDiameter 20mm	total (yen)
0	water 1,890 waste water 1,331	3,221	55	water 6,762 waste water 6,864	13,626
10	1,995 1,331	3,326	100	14,133 16,692	30,825
20	2,100 1,331	3,431	200	35,973 43,677	79,650
30	3,381 2,811	6,192	300	57,813 70,662	128,475
40	4,662 4,292	8,954	500	109,893 129,882	239,775
50	5,943 5,772	11,715	1,000	261,093 291,057	552,150
53	6,434 6,428	12,862	2,000	563,493 613,407	1,176,900
54	6,598 6,646	13,244	5,000	1,539,993 1,895,457	3,435,450

water bill(water consumption and sewage charge)

bimonthly bill of water consumption and sewage discharge

receipt for an account transfer



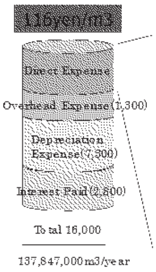
使用水量のお知らせ

お客様番号 0394533601

口座振替済通知

Sewage Treatment Cost

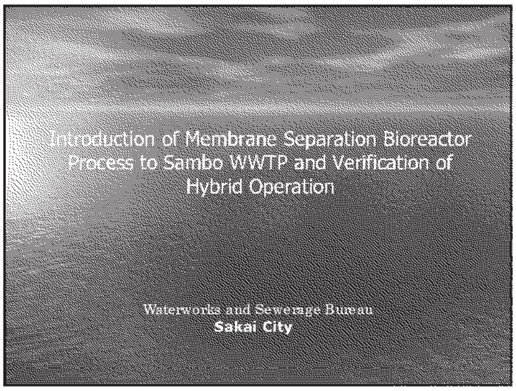
2010 fiscal year



(unit : Million yen)

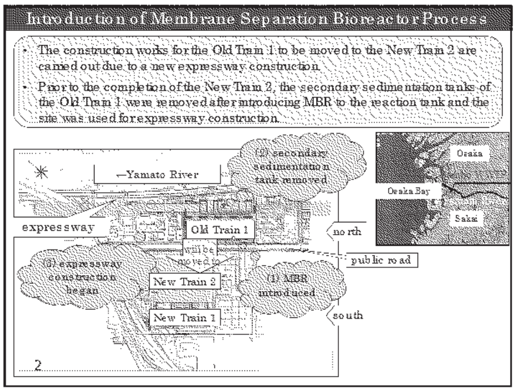
Content	Maintenance Cost
Treatment Cost	4,419.0
Transportation Cost	1,694.0
Sewer Pipe Cost	1,218.0
Pump Station Cost	476.0
Treatment Plants Cost	2,725.0
Water Quality Control Cost	163.0
Total	**4,582**

3 October 2012
Lecture material : Introduction of Membrane Separation Bioreactor Process to Sambo WWTP and Verification of Hybrid Operation, Sakai City



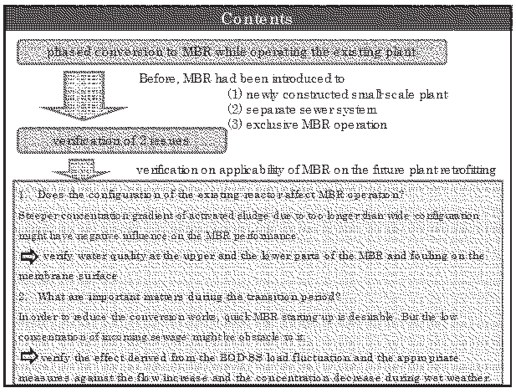
Introduction of Membrane Separation Bioreactor Process to Sambo WWTP and Verification of Hybrid Operation

Waterworks and Sewerage Bureau
Sakai City



Introduction of Membrane Separation Bioreactor Process

- The construction works for the Old Train 1 to be moved to the New Train 2 are carried out due to a new expressway construction.
- Prior to the completion of the New Train 2, the secondary sedimentation tanks of the Old Train 1 were removed after introducing MBR to the reaction tank and the site was used for expressway construction.



Contents

phased conversion to MBR while operating the existing plant

Before, MBR had been introduced to
(1) newly constructed small-scale plant
(2) separate sewer system
(3) exclusive MBR operation

verification of 2 issues

verification on applicability of MBR on the future plant retrofitting

1. Does the configuration of the existing reactor affect MBR operation?

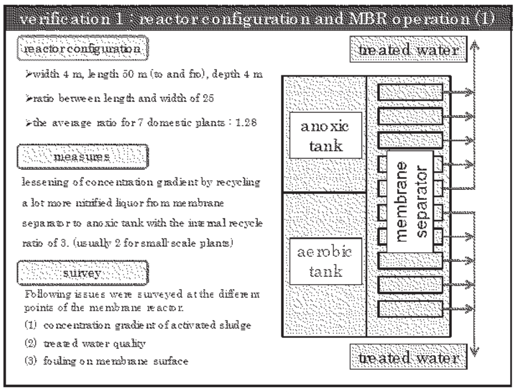
Steeper concentration gradient of activated sludge due to too longer than wide configuration might have negative influence on the MBR performance

⇨ verify water quality at the upper and the lower parts of the MBR and fouling on the membrane surface

2. What are important matters during the transition period?

In order to reduce the conversion works, quick MBR starting-up is desirable. But the low concentration of incoming sewage might be obstacle to it.

⇨ verify the effect derived from the BOD-SS load fluctuation and the appropriate measures against the flow increase and the concentration decrease during wet weather.



verification 1 : reactor configuration and MBR operation (1)

reactor configuration

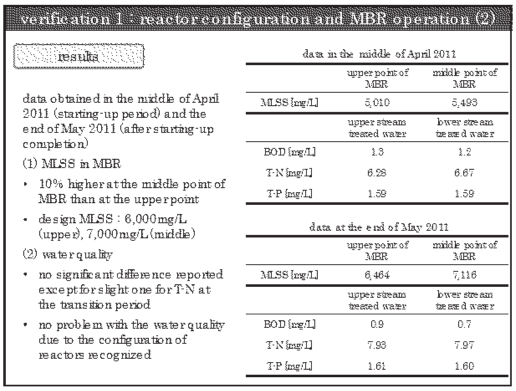
- width 4 m, length 50 m (to and fro), depth 4 m
- ratio between length and width of 25
- the average ratio for 7 domestic plants : 1.28

measures

lessening of concentration gradient by recycling a lot more nitrified liquor from membrane separator to anoxic tank with the internal recycle ratio of 3. (usually 2 for small-scale plants)

survey

Following issues were surveyed at the different points of the membrane reactor.
(1) concentration gradient of activated sludge
(2) treated water quality
(3) fouling on membrane surface



verification 1 : reactor configuration and MBR operation (2)

results

data obtained in the middle of April 2011 (starting-up period) and the end of May 2011 (after starting-up completion)

(1) MLSS in MBR
- 10% higher at the middle point of MBR than at the upper point
- design MLSS : 6,000mg/L (upper), 7,000mg/L (middle)

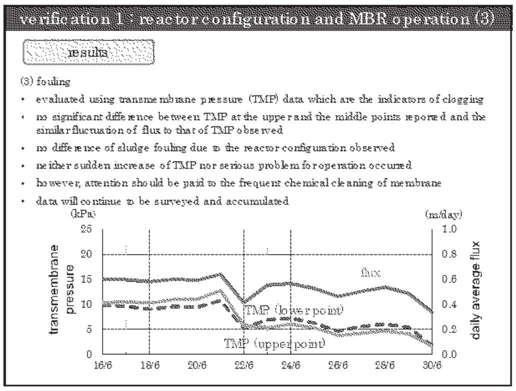
(2) water quality
- no significant difference reported except for slight one for T-N at the transition period
- no problem with the water quality due to the configuration of reactors recognized

data in the middle of April 2011

	upper point of MBR	middle point of MBR
MLSS [mg/L]	5,010	5,493
	upper stream treated water	lower stream treated water
BOD [mg/L]	1.3	1.2
T-N [mg/L]	6.28	6.67
T-P [mg/L]	1.59	1.59

data at the end of May 2011

	upper point of MBR	middle point of MBR
MLSS [mg/L]	6,464	7,116
	upper stream treated water	lower stream treated water
BOD [mg/L]	0.9	0.7
T-N [mg/L]	7.93	7.97
T-P [mg/L]	1.61	1.60



verification 1 : reactor configuration and MBR operation (3)

results

(3) fouling
- evaluated using transmembrane pressure (TMP) data which are the indicators of clogging
- no significant difference between TMP at the upper and the middle points repored and the similar fluctuation of flux to that of TMP observed
- no difference of sludge fouling due to the reactor configuration observed
- neither sudden increase of TMP nor serious problem for operation occured
- however, attention should be paid to the frequent chemical cleaning of membrane
- data will continue to be surveyed and accumulated

verification 2 : transition to MBR and hybrid operation (1)

challenges

(1) Starting-up would take a long time due to the low concentration of influent since Sampo WWTP accepts combined sewage and high proporion of industrial wastewater.

(2) Increasing volume of influent flow due to rainfall would affect the MBR operation.

measures

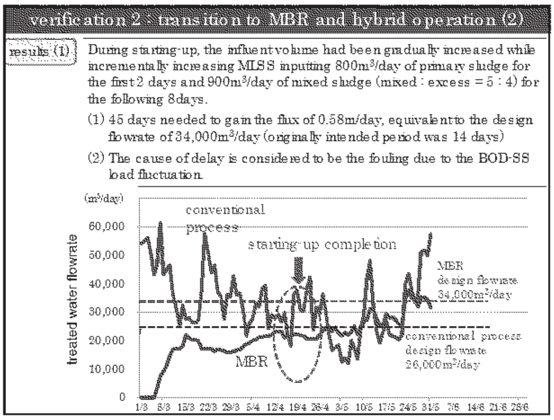
(1) Since the starting-up period was required to be shortened due to the constraint upon work schedule, a mix of excess and primary sludge were used as seed to compensate low load.

(2) Increasing volume due to rainfall was supposed to be treated by the conventional process of the train and/or the advanced process at another train (New Train 1).

survey

(1) starting-up period using mixed sludge

(2) the effect of fluctuating quality of influent on the MBR which accepted the constant volume even during rainfall

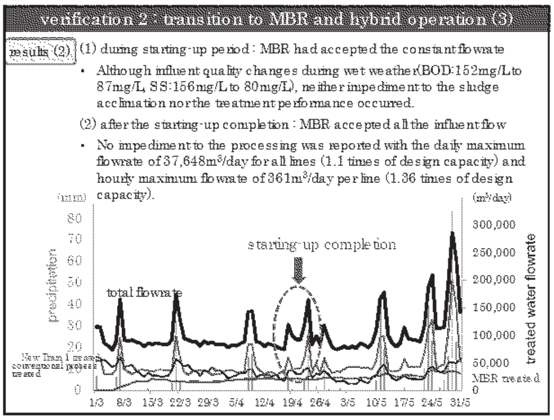


verification 2 : transition to MBR and hybrid operation (2)

results (1) During starting-up, the influent volume had been gradually increased while incrementally increasing MLSS inputting 800m³/day of primary sludge for the first 2 days and 900m³/day of mixed sludge (mixed : excess = 5 : 4) for the following 8days.

(1) 45 days needed to gain the flux of 0.58m/day, equivalent to the design flowrate of 34,000m³/day (originally intended period was 14 days)

(2) The cause of delay is considered to be the fouling due to the BOD-SS load fluctuation.



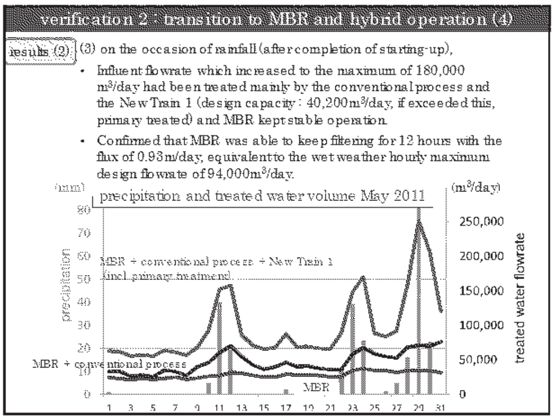
verification 2 : transition to MBR and hybrid operation (3)

results (2) (1) during starting-up period : MBR had accepted the constant flowrate

- Although influent quality changes during wet weather(BOD:152mg/L to 87mg/L, SS:156mg/L to 80mg/L), neither impediment to the sludge acclimation nor the treatment performance occurred.

(2) after the starting-up completion : MBR accepted all the influent flow

- No impediment to the processing was reported with the daily maximum flowrate of 37,648m³/day for all lines (1.1 times of design capacity) and hourly maximum flowrate of 361m³/day per line (1.36 times of design capacity).



verification 2 : transition to MBR and hybrid operation (4)

results (2) (3) on the occasion of rainfall (after completion of starting-up),

- Influent flowrate which increased to the maximum of 180,000 m³/day had been treated mainly by the conventional process and the New Train 1 (design capacity : 40,200m³/day, if exceeded this, primary treated) and MBR kept stable operation.
- Confirmed that MBR was able to keep filtering for 12 hours with the flux of 0.93m/day, equivalent to the wet weather hourly maximum design flowrate of 94,000m³/day.

summary

- Introduction of MBR regardless of configuration of reactors is considered to be possible based on the results that no significant difference of water quality had been found, even though the concentration of activated sludge differed by 10% between the upper and the lower points of the reactors.
- A flexible schedule is needed since the starting-up would take time due to the fouling caused by BOD-SS load fluctuation during the transition period from the conventional process to MBR in case the influent load is low or the combined sewage is significantly affected by rainfall.
- Hybrid operation of MBR and the conventional process is considered to be effective to deal with the increasing volume of influent in case of rainfall.