THE REPUBLIC OF THE UNION OF MYANMAR
YANGON CITY DEVELOPMENT COMMITTEE (YCDC)

PREPARATORY SURVEY REPORT
ON
THE PROJECT FOR
THE IMPROVEMENT OF
WATER SUPPLY, SEWERAGE
AND DRAINAGE SYSTEM
IN YANGON CITY
IN
THE REPUBLIC OF THE UNION OF MYANMAR

VOLUME V
SEWERAGE AND DRAINAGE SYSTEM
SUMMARY

< Advance Version >

MARCH 2014

JAPAN INTERNATIONAL COOPERATION AGENCY

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TOKYO SUIDO SERVICES CO., LTD.
TOYO ENGINEERING CORPORATION

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THE PROJECT FOR
THE IMPROVEMENT OF
WATER SUPPLY, SEWERAGE AND DRAINAGE SYSTEM
IN YANGON CITY

FINAL REPORT

MARCH 2014

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Abbreviation

B/C	Benefit per Cost
BDS	Back Drainage Space
BOD	Biochemical Oxygen Demand
CBD	Central Business District
CIP	Cast-Iron Pipe
COD	Chemical Oxygen Demand
DDA	Department of Development Affair
DEWS	Department of Engineering (Water Supply Sanitation)
DIP	Ductile Iron Pipe
DMA	District Metered Area
EC	Electrical conductivity
E/N	Exchange of Notes
ECC	Environment Conservation Committee
F/S	Feasibility Study
FC	Foreign Currency
FY	Fiscal Year
GPCD	Gallons Per Capita per Day
HHWL	Highest High Water Level
HWL	High Water Level
IEE	Initial Environmental Examination
IUR	Inner Urban Ring
JICA	Japan International Cooperation Agency
JICA-HIS	JICA Household Interview Survey
Kyat	Myanmar Kyat
LPCD (or Lpcd)	Liters Per Capita per Day
LWL	Low Water Level
M&E	Mechanical & Electrical
M/P	Master Plan
METI	Ministry of Economy, Trade and Industry
MG	Million Gallons
MGD	Million Gallons per Day
MIP	Mingaladon Industrial Park
ML	Million Liters
MLD	Million Liters per Day
MOAI	Ministry of Agriculture and Irrigation
MOECAF	Ministry of Environment Conservation and Forestry
MOF	Ministry of Forestry
MOFA	Ministry of Foreign Affairs
MOU	Memorandum of Understanding
MWL	Mean Water Level
N/A	Not Available
NCEA	National Commission for Environmental Affairs

NewSZ	New Suburbs Zone
NRW	Non Revenue Water
NS	Northern Suburbs
O&M	Operation & Maintenance
OldSZ	Older Suburbs Zone
ORZ	Outer Ring Zone
P/S	Pumping Station
PPP	Public–Private Partnership
PVC	Polyvinyl Chloride
R.	Reservoir
RC	Reinforced Concrete
S/R	Service Reservoir
SCADA	Supervisory Control And Data Acquisition
SCBD	South of CBD
SEA	Strategic Environmental Assessment
SEZ	Special Economic Zone
SS	Suspended Solids
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
T-N	Total Nitrogen
T-P	Total Phosphorus
TS	Township
TS	Total Solids
US$、USD	United States Dollars
VAT	Value Added Tax
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant
YCDC	Yangon City Development Committee
YCDL	Yangon City Development Law

Abbreviation for the Relevant Studies

The Preparatory Study for Urban Development Programme in the Greater Yangon (JICA)	JICA Urban Plan Study, 2012
Household Interview Survey (JICA)	2012 JICA-HIS
Data Collection Survey on Water Resources Potential for Thilawa Special Economic Zone and Adjoining Areas (JICA)	JICA Thilawa Water Study
The Study on Improvement of Water Supply and Wastewater Treatment in Yangon (METI)	METI Water Supply and Sewerage Study
The Study on Improvement of Water Supply System in Yangon City	2002 JICA-M/P

Unit

1 Gallon (British Gallon) = 4.546 liter
1 Acre = 4,047 m^2

Foreign Exchange Rate

For M/P (as of December 2012)

1 USD = 84.64 JPY

For F/S (as of June 2013)

1 USD = 101.1 JPY
1 USD = 885 Kyat
1 Kyat = 0.114 JPY

CHAPTER 1. INTRODUCTION

1.1 Background of the Study

Although the capital of Myanmar was moved to Naypyidaw in 2006, Yangon City is still the national center of economy, business and communication. Current population of Yangon City is approximately 5.1 million according to Yangon City Development Committee (YCDC).

Water supply system in Yangon has a long history, the water supply services commenced in 1842. However, the service ratio is still as low as 38 %. Transmission and distribution pipes have not been rehabilitated properly resulting in large quantity of non-revenue water, i.e. 66 % of total daily supply of 520,000 m^3/day. Approximately, 90 % of water comes from reservoirs, and two thirds of them is distributed directly without any treatment. In addition, water treatment at the water treatment plant is insufficient. Approximately, 70 % of connections are equipped with water meter, which is higher compared to other developing countries, but water charge is rather low, approximately 8 Yen/m^3 for metered houses and 180 to 300 Yen/month for houses without meter. It cannot be said that sufficient financial sources is secured for operation and maintenance of water supply system. Regarding technical capability of the undertaking, YCDC's capability is evaluated to be high, since they have been making efforts to design water supply facilities and to manufacture pipes by themselves. On the other hand, there remains much room for improvement in operation and maintenance of water treatment plant and in management of water quality. In the 6 townships located outside boundary of YCDC administrative area, water supply system, if it exists, is managed by the Yangon regional government.

Regarding water supply, JICA implemented a development study titled "The Study on Improvement of Water Supply System in Yangon City" in 2002, in which master plan was formulated and feasibility study was conducted to prepare development plan targeting year 2020. Estimation of future water demand, investigation of potential water resources, block distribution system, rehabilitation of pipe networks, construction of facilities such as new water treatment plant, transmission lines, and reservoirs, project cost estimation were included in the study. However, due to various reasons, most of the projects proposed in the plan are yet to be implemented. Alternatively, measures to expand water supply coverage have been implemented to cope with the needs of development of new suburban areas; including 1 large water treatment plant for which raw water source is Ngamoeyeik reservoir and 4 small plants using ground water as sources of water. In addition, many service meters have been equipped.

After adoption of new liberal policies in Myanmar, JICA initiated discussing with the Yangon regional government on formulation of comprehensive development plan including water supply, sewerage,

drainage, electricity, road, railways, ports etc., and the minutes were concluded concerning "the project for the strategic urban development plan of the greater Yangon" on May 1st 2012. Further minutes were concluded concerning water supply, sewerage and drainage, one of the umbrella projects on May 22nd 2012.

As a result, the following related projects are under progress through the Japanese assistance;

- Project for the Strategic Urban Development Plan of the Greater Yangon (JICA)
- Study on Water Resource Potentialities for Thilawa SEZ and its environs" (JICA)
- "Study on the Improvement of Water Supply and Wastewater Treatment in Yangon City" (Ministry of Economy, Trade and Industry (METI), Japan)
- "Study on Development of Sewerage System in Myanmar, 2012" (Ministry of Land, Infrastructure, Transport and Tourism, Japan)
- In addition, advisor for water supply has been dispatched from Fukuoka city, Japan, funded by JICA

1.2 Objectives of the Study

The objectives of this study are formulation of development plan for water supply, sewerage and drainage in greater Yangon and selection of priority projects in order to contribute to economic development and improvement of living environment of the Region.

1.3 Counterparts Organization

The main counterpart organization is Yangon City Development Committee (YCDC).

1.4 Study Area

The Study area[1] is greater Yangon, covering YCDC area (33 townships) and parts of the surrounding 6 townships (Thanlyin, Kyauktan, Hmawbi, Hleagu, Htantapin and Twantay).

[1] The study area was 33 townships belonging to YCDC at the beginning of the study as indicated in the study title. However, parts of 6 townships have been added for the study dung the course of study and they are called as "Greater Yangon".

CHAPTER 2. OUTLINE OF THE STUDY AREA

2.1 Population

Past populations together with the city area are shown in Table below. Population of 0.73 million in 1953 increased to 0.94 million (about 1 million) in 1963. Afterwards together with city area increase, population increased to 2 million in 1973, 3 million in 1993, 4 million in 2003 and 5.14 million in 2011. Average population growth rate has been about over 2%.

Table S. 1 Trend of Population in Yangon City

Year	Population (Mil.)	Average Population Growth (%)	Area (km^2)	Pop. Density (Person/km^2)	Remark
1953	0.73		123.3	5,925	
1963	0.94	2.5	164.2	5,725	
1973	2.01	7.9	221.4	9,077	Expansion of the City in 1965 and 1973
1983	2.51	2.2	346.0	7,254	Expansion of 1983
1993	3.09	2.1	603.5	5,120	
2003	4.10	2.8	794.3	5,161	Expansion of 1991
2011	5.14	2.9	794.3	6,471	Expansion of 2003

Source: YCDC

2.2 Hydrology

2.2.1 River System

Yangon City lies at the confluence of the Bago River and Hlaing River. The two rivers meet at the confluence of the Yangon River, which is connected to the Gulf of Mottama. The Pan Hlaing River and Twan Tay Canal, which converge and run downstream the Yangon River, as well as the Kokkowa River which connects with the Hlaing River, all of these rivers receive water from the Ayeyarwaddy River. These rivers are candidate water sources for the expansion of Yangon City's water demand which is expected to increase in the future. Pazuntaung River flows through the eastern part of the city CBD. The river upstream of this is called the Ngamoeyeik, where a Ngamoeyeik Reservoir has been built as part of the water source in YCDC.

2.2.2 Salt Water Intrusion

The rivers mentioned are all tidal rivers. During dry season periods when the river flow is low, salt water intrusion occurs. Therefore, it is necessary to consider salt water intrusion when developing potential water source, as salt water intrusion is possible in the area of performance around Yangon.

The following table shows available tidal information taken from the Myanmar Port Authority (MPA). The table indicates that tidal observations have not been carried out since several years ago. The

information is based on past observation records at Yangon Port (Sule Pagoda Wharf) and river mouth of Yangon River (Elephant point). In Yangon Port, highest high water level (HHWL) including tidal condition is +6.74 m, and mean water level (MWL) is + 3.121 m. Ground elevation is normally assumed to MWL, and the difference between HHWL and MWL around Yangon port is approximately + 3.619 m (= HHWL + 6.74 – MWL + 3.121 m) on ground elevation basis.

Table S. 2 Tidal Information in Yangon Port

Items	Tidal Height (m)	Observed Dates
Highest High Water Level (HHWL)	+6.74	September 1899
Mean Water Level (MWL)	+3.121	Up to 1936
Lowest Low Water Level at Bo Aung Kyaw Street Wharf	-0.24	December 1902
Indian Spring Low Water Mark	+0.338	-

Source: MPA

2.2.3 Hydrogeology

From the study on groundwater potential (refer to Figure below) in 2002 JICA-M/P, the followings are concluded;

- Groundwater potential is low in the central hilly areas.
- Iron contents might be high in groundwater in areas adjacent to hilly areas.
- Groundwater potential is high in the remaining low land areas.
- Groundwater potential is very high along the rivers.
- Salinity might be high in groundwater in CBD area.

2.3 Administrative Organization on Water, Sewerage and Drainage

2.3.1 Yangon Regional Government

Construction and operation/maintenance of irrigation canals and drainages are clearly defined in the Constitution as duties of the central and regional governments while the responsible agencies for construction of water supply, sewerage and urban drainage facilities is not explicitly defined under the Constitution. However, collection of water tax is defined as the regional government's responsibility. Department of Development Affairs in the regional government assumes the role of providing water supply systems. Among the 6 peripheral townships, there exist small-sized water supply systems in Thanlyin and Kyauktan townships. In addition, there is one small-sized water supply system for Thilawa Special Economic Zone (SEZ). There is no sewerage system in 6 peripheral townships.

However, as a result of restructuring of the organizations in July 2012, responsible organization for water supply system has been transferred to the Department of Rural Development Affairs of the Ministry of Border Affairs. Then in 2013, the Department of Rural Development Affairs is transferred to Ministry of Livestock, Fisheries, and Rural Development from Ministry of Border Affairs. So it is

not clear to us that the regional government still assumes water supply sector in Yangon region.

The Yangon City development Law clearly defines that YCDC has responsibility of construction and operation/maintenance of water supply and sewerage systems.

2.3.2 Yangon City Development Committee

(1) Yangon City Development Committee

YCDC was established based on the "City of Yangon Development Act" aiming to foster development project in Yangon city independently. The law defined that YCDC is authorized to implement their own project by using their own funding resources. However, YCDC is not appropriately able to exercise their authority under current procedure, for instance, 1) YCDC needs to apply permissions of projects to the central government, and 2) the funding sources of YCDC's activity are incorporated into the national budgetary system.

YCDC is responsible for water, sewerage and sanitation projects in 33 townships out of 45 townships of Yangon division. The law defines the role and the responsibility to establish policies, and to manage and implement them.

YCDC is headed by the mayor, and supported by the secretary and the joint-secretary. The committee members consist of mayor, secretary, joint-secretary, and other 2 members (committee 4 and 5). 20 departments in YCDC belong to these committees.

Department of Engineering (Water and Sanitation) (DEWS) is a central section to encompass water, sewerage and sanitation services in Yangon city. Water supply projects in 6 townships located outside Yangon city is handled by Department of Development Affairs (DDA), a part of regional government.

Meanwhile, storm water and drainage projects are under the responsibility of Department of Road and Bridge, water resource management is under the responsibility of water supply, and water quality test and monitoring of quality test results are conducted by Department of Health and water quality monitoring section in the Department of Engineering (Water and Sanitation) respectively.

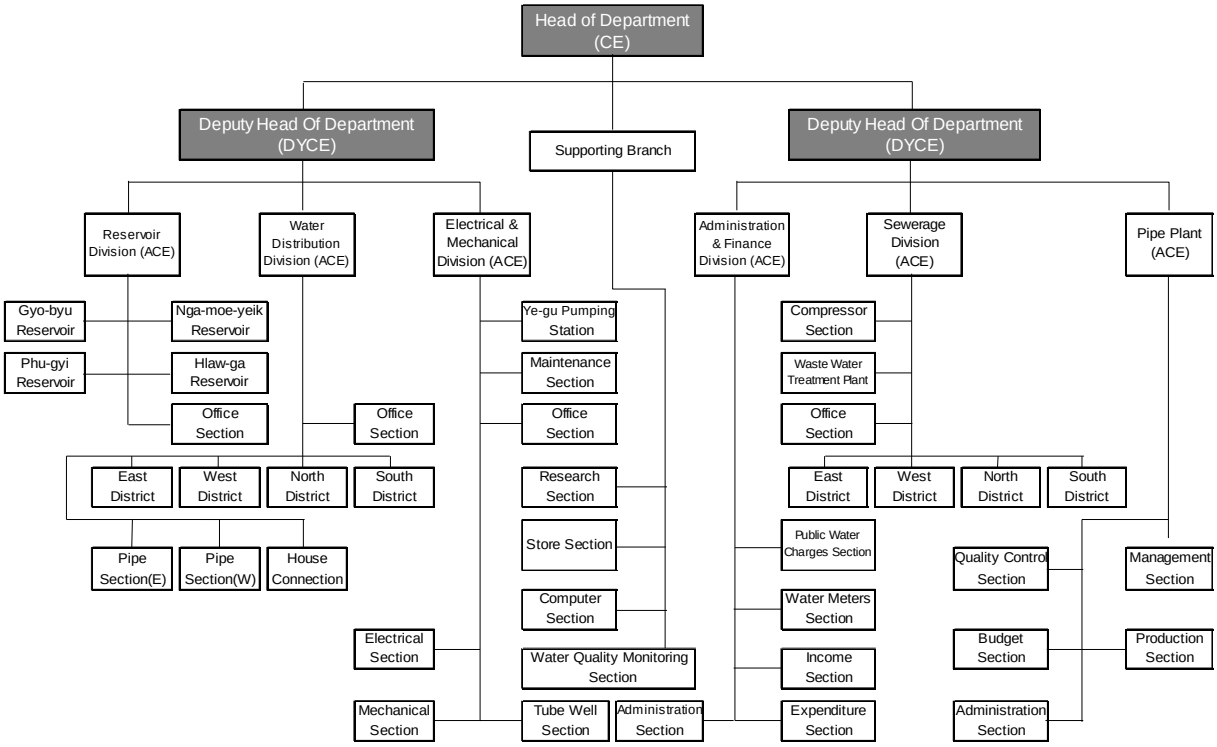
(2) Department of Engineering (Water and Sanitation)

Engineering Department (Water and Sanitation) consists of 6 divisions under the Head of Department and Deputy Head of Department: 1) Reservoir Division, 2) Water Distribution Division, 3) Electrical & Mechanical Division, 4) Finance & Administration Division, 5) Sewerage Division, 6) Pipe Plant Division.

Administrative support division including research section, store section, computer section, and water

quality monitoring section is also organized. Total number of staff members is 2,196 as of January 2013.

An organogram of DEWS is shown as follows



Source: YCDC DEWS

Figure S. 1 YCDC DEWS Organogram

2.4 Laws Related to Water and Sewerage in the City of Yangon

2.4.1 City of Yangon Development Law

"Chapter III Duties and Responsibilities of the Committee" of "the City of Yangon Development Law" clearly stipulates the businesses supervised by the YCDC including:

- Carrying out works for water supply;
- Construction of reservoirs and pipelines and maintenance thereof;
- Carrying out works for sanitation; and
- Carrying out works for public health.

On the other hand, Article 9 of Chapter IV "Powers of the Committee" sets forth the following provision that serves as grounds for exercise of autonomy by the YCDC:

- Demarcation and re-demarcation of the territorial limit;
- Right to operate works independently with funds owned by the Committee;
- Right to use foreign currency for development works; and

- Right to carry out works contributing to city development by making contracts with local and foreign organizations and with local and foreign individuals.

However, this study considers that most of Article 9 has lost its substance. The business activities of the YCDC shall be voluntarily performed pursuant to the City of Yangon Development Law; however, the YCDC currently prepares plans and estimates for each business and applies to the provincial government for permission. Particularly, with respect to the budget necessary for the performance of a business, the YCDC actually seems to be forced to perform the business based on the permission of the provincial government under the budgetary system of the federal government after April 2011.

Amendment and development of the legal system is considered to be urgently required in light of future prospects, including consistency between the City of Yangon Development Law and the relevant legal system.

2.4.2 Rules on Water Supply and Sanitation (Notification No.6/99)

The YCDC established the Rules on Water Supply and Sanitation, conferred by Section 33(a) of the "The City of Yangon Development Law", with the approval of the Chairperson of the State Peace and Development Council. The Rules for water and sanitation are proclaimed by the Notification No.6/99. In the Rules, the YCDC's role and the responsibilities on water and sanitation are described.

2.5 Budgetary System for Water Supply, Sewerage and Drainage

All revenue income including waterworks sales used to be incorporated into the account of YCDC, however that system has been transformed to the current system since October 2011.

After YCDC prepared and applied a budgetary forecast for a new fiscal year, the actual expenditure against the approved amount is paid to YCDC through the regional government. Thus it seems to be a structural challenge for YCDC that YCDC has a very limited authority to determine how the revenue income is used flexibly.

2.5.1 Budgetary Situation of the Regional Government

The fiscal account for the period 1st April to 31st March is settled every year. Although the detail information on budgetary situation of the regional government is not yet obtained, it is confirmed by the JICA Study team for Strategic Urban Development Plan that the Yangon Region Government received an allocation of more than Kyat 15.6 billion from the Union Government to cover expenses in the second half of the 2011-2012 fiscal years under the Yangon Region Government were thought to be running in deficits. Financial deficit situation with approximately 5 billion Kyat is reported. 20 out

of 25 departments working under the Yangon Region Government were thought to be running in deficits.

2.5.2 Budgetary Situation of the YCDC

(1) Budgetary Situation of YCDC and the Trend

The revenue income of YCDC is largely relied on the property tax consisting of general tax and environmental tax, etc. The main financial source of the property tax is particularly the income from condominium, hotel, market, golf club, vehicle tax.

Meanwhile, 20 departments of YCDC including water and sanitation department are not authorized to determine by themselves how revenue income is used. Also they have no authority to decide the capital expenditure such as construction investment, it is necessary to get the approval from the executive committee.

(2) Budget Allocation of YCDC and Income Flow

The budgetary flow of YCDC from application to approval can be shown as follows: (1) 20 departments prepare budget forecast and submit to the mayor, (2) The Yangon city mayor submits the proposal application to the chief minister of the regional government. The chief minister of the regional government discussed with the regional offices of the Ministry of Finance and Revenue. A negotiation between the Yangon city mayor, 7 committee members, and the department of budget and revenue is held, and the budget is determined and approved.

2.6 Current Wastewater Treatment

2.6.1 Type of Wastewater Treatment

Results of the Household Interview Survey conducted in October and November 2012 were summarized in Tables S.3 and S.4. Table S.3 shows type of toilet facility, and Table S.4 shows treatment of toilet wastewater (black water) and sullage (gray water). Pour flush toilet is the most dominant type of toilet, which accounts for 82.4 % and flush toilet accounts for 5.8 %.

Table S. 3 Type of Toilet, Results of Household Interview Survey

	Flush Toilet	Pour-flush Toilet	Pit Latrine	No Toilet	No Answer	Total
Number	580	8,278	1,098	58	31	10,045
(%)	5.8	82.4	10.9	0.6	0.3	100.0

Source: Strategic Urban Development Plan for the Greater Yangon

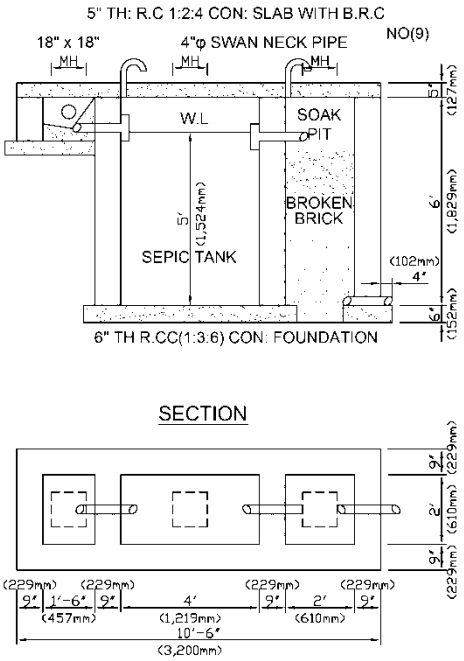
Table S. 4 Treatment of Black Water and Gray Water

Category		Sewerage System	Septic Tank	No Treatment	No Ansewer	Total
Black Water	Number	935	4,333	4,742	35	10,045
	(%)	9.3	43.1	47.2	0.3	100.0
Gray Water	Number	1,357	2,699	5,946	43	10,045
	(%)	13.5	26.9	59.2	0.4	100.0

Source: Strategic Urban Development Plan for the Greater Yangon

2.6.2 Current Status of On-site System

YCDC recommends septic tank system as wastewater treatment. Septic tank treat only toilet wastewater (black water), and gray water from kitchen, laundry and so on is discharged directly to storm water drains without treatment. Owner of a house or a building should submit an application to Sanitation Division, Department of Water Supply and Sanitation and needs to obtain its approval for wastewater treatment. YCDC has standard structure for septic tank. Figures S.2 shows standard structures of septic tanks for 10 persons for example. As shown in the Figure, effluent from septic tank infiltrates underground not being discharged to storm water drain.



Source: YCDC

Figure S. 2 Septic Tank for 10 Persons

2.6.3 Sewerage System

(1) Ejector System

Wastewater in YCDC is collected by ejector system which was constructed by British in 1890. This system has been utilized continuously with periodical modifications for approximately 120 years. Service area covers 8 townships in the Central Business District (CBD). Sewerage system adopted unique ejector system which consists of two compressor stations, a number of ejector stations and two force mains which run in east-west direction in the service area. Originally 40 ejector stations were constructed and 34 stations are in service at present (refer to Figure S.3).

Source: YCDC

Figure S. 3 Sewerage System in Yangon City

(2) Wastewater Treatment Plant

Since construction of the sewerage system, collected wastewater had been discharged to the Yangon River without treatment. Wastewater has been treated since the completion wastewater treatment plant in January, 2005. Design and construction of the wastewater treatment plant were carried out by YCDC. Construction cost was borne by several ministries including Ministry of Construction. Outline of the wastewater treatment plant is shown in Table S.5

Table S. 5 Outline of Wastewater Treatment Plant

Site area	2.25 ha (5.56 acres)
Start of construction	April, 2003
Completion	January, 2005
Design served population	300,000 persons
Design Capacity	14,775 m^3/day (3.25MGD)
Construction cost	1.96 million USD（2,065.7 M Kyat）
Characteristics of wastewater	BOD 600 mg/l, SS 700 mg/l (design)
Characteristics of treated effluent	BOD 60 mg/l, SS 40 mg/l (design)

Source: YCDC

2.7 Water Quality Investigation

Water quality investigation was carried out in this study, and results are summarized below.

2.7.1 Existing Wastewater Treatment Plant

Average removal efficiencies in rainy season are SS: 87 %, CODCr: 98 %, BOD5: 97 %, T-N: 89 % T-P: 27 %. Those in dry season are SS: 88 %, CODCr: 80 %, BOD5: 76 %, T-N: 94 % and T-P: 18 %.

2.7.2 Water Quality of Public Water Body

(1) Water Quality in Rivers and Drains

Results of water quality analysis on river and drain water are summarized below.

- Major drains in urban area are polluted by discharge of domestic wastewater. Moreover, drains are polluted by solid waste because the collection of solid waste is insufficient. From the view point of the improvement of living environment, water quality improvement of drains is necessary.
- In rainy season, the quality of river water (Hlaing River, Yangon River and Bago River) is more deteriorated than drains. Especially, high concentration of BOD and COD was observed in rainy

season.

- Water quality data is shown in the following Table. Both river and drain is highly polluted by organic pollutants.

Table S. 6 Water Quality of River and Drain in Rainy Season (CODCr and BOD5)

Sample	CODCr (mg/L)		BOD5 (mg/L)	
	Range	Average	Range	Average
River	96 - 2560	888	27 - 900	405
Drain	96 - 224	171	6 - 62	36

Table S. 7 Water Quality of River and Drain in Dry Season (CODCr and BOD5)

Sample	CODCr (mg/L)		BOD5 (mg/L)	
	Range	Average	Range	Average
River	110 - 985	658	50 - 520	328
Drain	100 - 322	207	28 - 96	56

(2) Water Quality in Kandawgyi Lake

Nitrogen and phosphorus concentrations in Kandawgyi Lake in rainy season and dry season are shown in Tables S.8 and S.9.

Table S. 8 T-N and T-P of Kandawgyi Lake (Rainy season)

No.	Location	T-N (mg/L)	T-P (mg/L)
WW-22	Kandawgyi Lake-1 (East)	2.17	0.13
WW-23	Kandawgyi Lake-2 (Middle)	1.98	0.13
WW-24	Kandawgyi Lake-3 (West)	1.69	0.14

Table S. 9 T-N and T-P of Kandawgyi Lake (Dry season)

No.	Location	T-N (mg/L)	T-P (mg/L)
WW-22	Kandawgyi Lake-1 (East)	19.9	0.19
WW-23	Kandawgyi Lake-2 (Middle)	11.3	0.17
WW-24	Kandawgyi Lake-3 (West)	7.74	0.03

Eutrophication in Kandawgyi Lake is apparent based on the criteria mentioned below.

Assessment criteria of eutrophication

Japan (Ministry of the Environment) T-N: 0.5 – 1.3 mg/L, T-P: > 0.02mg/L

OECD （1982） T-P: 0.035 – 0.1mg/L Eutrophic,

> 0.1 mg/L Hypereutrophic

2.8 Issues Relating to Wastewater Treatment and Disposal

2.8.1 Technical Aspects

Issues related to wastewater treatment and disposal from technical view point are summarized below.

(1) Wastewater treatment in general

① Sewerage coverage ratio in YCDC is as low as approximately 5 %.
② Water supply system coverage ratio is also low, i.e. 38 %. This is the reason for low demand for and low coverage ratio of sewerage system.
③ Under the circumstances mentioned above, wastewater treatment should rely on on-site systems. Currently served population by septic tank which is only one applicable on-site treatment system is estimated to be 43% of the total population.
④ Septic tank can only treat black water and gray water is discharged to storm water drains without treatment. Treatment efficiency of septic tank is considered to be 50 % at the utmost. Improvement of the existing septic tanks to receive gray water is very difficult because of their structures and locations.
⑤ Non-treatment population other than sewerage system and septic tanks is estimated as 52 % of the total population. Gray water together with black water from these households is discharged to the environment without treatment. As a result, storm water drains become actual open sewers, for which most of residents do not care. HIS conducted in 2012 reveals that very good, good and fair answers account for 67 % of the total, and bad and very bad answers account for 29 % about the condition of the storm water drain. Regarding odor problem very good, good and fair answers account for 74 % of the total compared to 26 % for bad and vary bad.
⑥ Currently residents' awareness is low, but concerns for odor and aesthetic matters will grow as peoples' living standards become high, and complaints from residents might increase.
⑦ Therefore, it is necessary to treat black water and gray water. Because development of sewerage system is assumed to take time, a tentative measure needs to be considered.

(2) Sewerage system

⑧ Discharge standards for effluent are not established
⑨ Monitoring of flow and wastewater characteristics at WWTP is not carried out. Monitoring of these items is necessary for proper operation of the plant since these items fluctuate. This together with the following reasons results in improper operation of WWTP.
⑩ Current flow to the WWTP is estimated to be approximately 2,300 m^3/day compared to the design capacity of 14,775 m^3/day. This low flow may be caused by defects of ejector system. However, true reason is not detected.
⑪ Sludge from septic tanks is dumped into the WWTP resulting in high concentrations.

⑫ It became difficult to obtain spare parts for ejector system which was introduced 120 years ago.

2.8.2 Organizational and Institutional Aspects

Because a sewerage law and other relevant laws are not sufficiently developed in overall in Myanmar, it is considered that the development is necessary. It could be crucial to develop laws and regulations on individual treatment system and monitor the development progress.
Main challenges of regulatory system are described below:

① Lack of definition of basic concept on sewerage
There is no definition of sewerage service and sewerage operating utilities, no basic concepts of sewerage, no authorization system of project plan. In Yangon city, implementation of sewerage development plan is an urgent challenge, therefore development of the basic law and regulation as a fundamental framework which enable to clear the position of sewerage is essential.

② Lack of rules for O&M of public sewerage system
There are no definition on management entity of O&M of sewerage facilities (sewer networks, treatment plant and pumping station), sewerage sludge treatment, and on engineers responsible for O&M works. To secure an appropriate O&M level and make these facilities sustainable, development of clear definition is desirable.

③ Necessity of establishment of quality standards of influent and effluent water
Regulatory framework on establishment of pretreatment facilities and on influent and effluent water is not developed. The awareness on these aspects is also not well cultivated. Severely aggravate wastewater causes deterioration of sewer line and functional decline of final wastewater treatment plant, thus regulations are necessary to secure the wastewater characteristics processable. In addition, this regulatory framework will necessarily contribute to secure environmental preservation and public sanitation environment for citizens which tend to be left behind, in accordance with intensifying firm’s economic activities.

④ Necessity of indicative laws and regulations on drainage facilities and the installation works, and beneficiaries-pay principle
A substantial legal framework are not developed concerning installation and connection methods of drainage facilities established by users, procedure of installation works of drainage facilities and registration of construction companies, definition of necessary technicians for the installation. In addition, sewerage tariff is currently not collected, so that it could be necessary to define tariff collection for sewerage based on the beneficiaries-pay principle from the viewpoint of sustainability.

⑤ Necessity of development of laws and regulations on individual treatment system (septic tank, private sewerage treatment tank (Johkaso), etc.)

In the general residential area where public sewerage treatment system is not developed, human waste is treated by septic tanks. It may be necessary to develop laws and regulations on dissemination and enhancement of private sewage treatment tank for individual houses if the Johkaso is considered to be effective. Furthermore, it will take time to develop and expand sewerage system, thus it is likely thought that laws and regulations on sludge treatment and disposal etc. needs to be developed.

2.9 Current Status of Drainage

2.9.1 Existing Drainage Facilities

Figure S.4 shows existing main drains in and around Yangon city. The runoff generated due to rainfall flows into the seven rivers/creeks/canal, i.e. Yangon river, Bago river, Hlaing river, Ngamoyeik creek, Pazundaung creek, Pan Hlaing river, Twantay canal, through about fifty open drains. The CBD area has fourteen main underground drains.

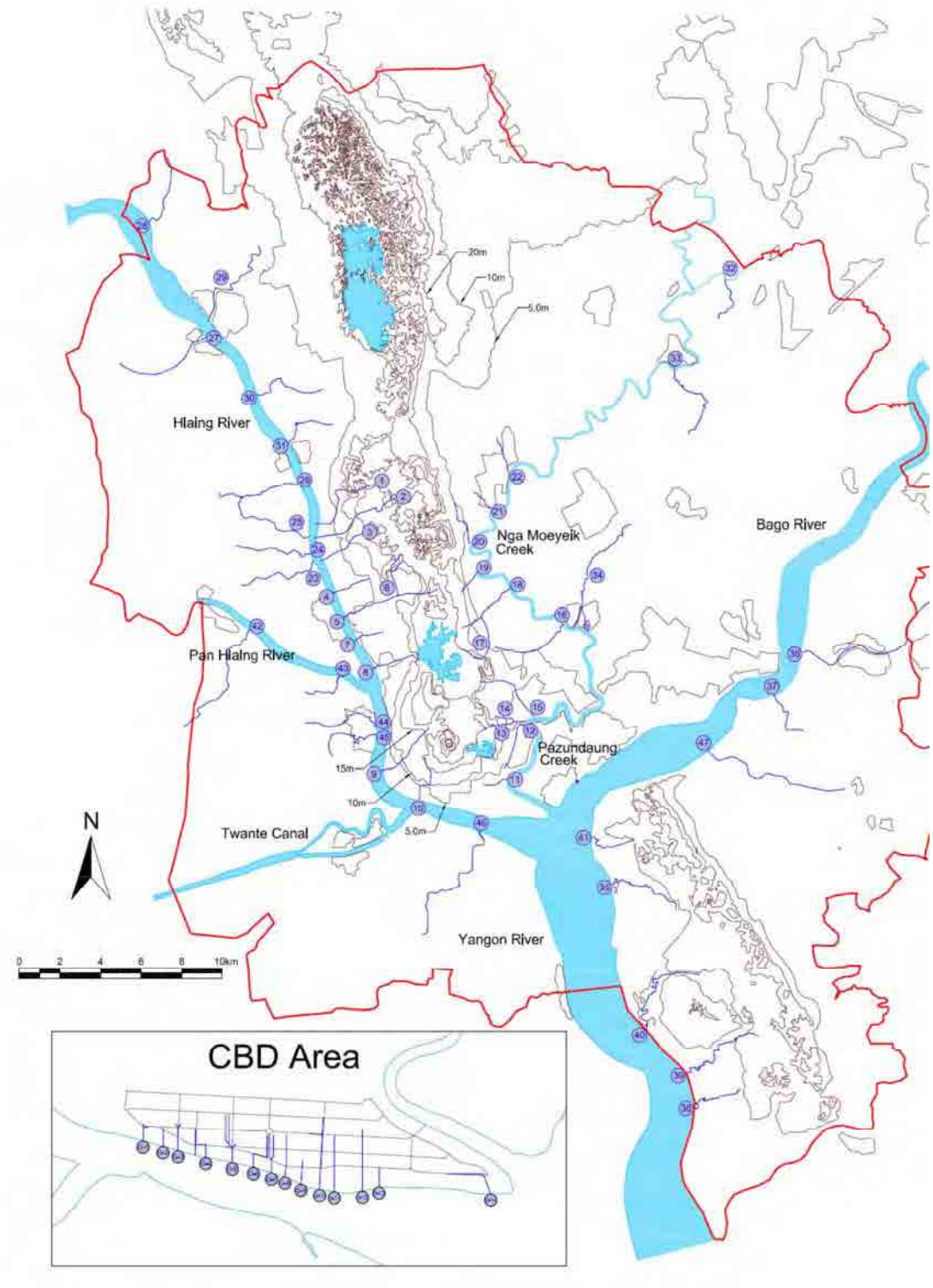
Hilly terrain with an elevation of 30 m lies along north-south direction in the central part of Yangon city, and it slopes down gently to low-lying areas in the east and the west.

Twenty two (No.1～22) main drains in the central area of the city run out from the hilly terrain to Hlaing river and Pazundaung creek. Storm water runs off by gravity utilizing the topographical features.

2.9.2 Current Flood Status

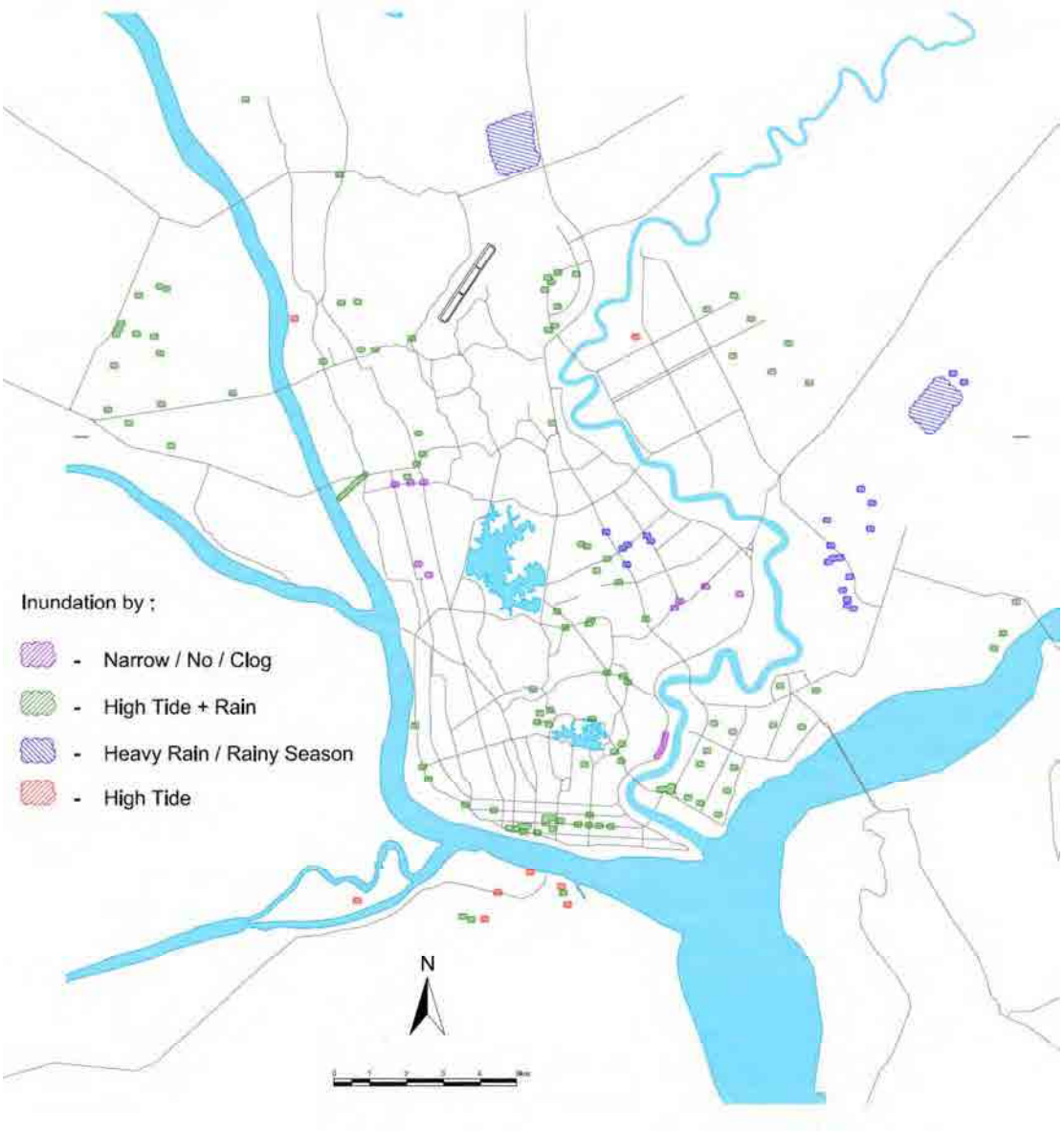
Figure S.5 shows current status of inundation in Yangon city. Small inundation occurs frequently but there is no serious damage, e.g. inundation above floor level. Many residents have no fear of crisis due to inundation because depth of inundation is below their knee level and it ends within 3~4 hours. Causes of inundation are listed below.

- Lack of drainage facility such as street gutter and storm sewer
- Lack of flow capacity of existing facilities, and decrease of flow capacity due to accumulation of sediments and solid waste
- Poor drainage due to influence of tidal level
- No tide gates (Inundation by backwater)



Source: JICA Study Team

Figure S. 4 Existing Main Drainage Channels in/around Yangon City



Source: JICA Study Team based on the data from YCDC Township Office and Interview of Residents

Figure S. 5 Present Status of Inundation in/around Yangon City

2.9.3 Operation and Maintenance (O & M)

Drainage facilities are managed based on "Yangon Municipal Act (1922)". Ministry of Agriculture and Irrigation (MOAI) manages the major seven rivers/creeks/canal (Yangon river, Bago river, Hlaing river, Ngamoyeik creek, Pazundaung creek, Pan Hlaing river, Twantay canal) which receive storm water runoff coming from drainage channels.

Engineering Department of Road and Bridge in YCDC and its branches located in each township manage main drainage channels in Yangon city. Some drainage channels in new suburban townships are managed by Yangon Region Department of Development Affair (DDA).

2.9.4 Major Issues of Urban Drainage

(1) Technical/ O&M Issues

As mentioned in the previous sections, small inundation occurs frequently in Yangon city. Even though damages due to inundation are not serious at present, the economic damage caused by inundation is expected to increase in future because of urbanization of Yangon city. Fundamentally, inundation is caused because of insufficient capacity of drainage facilities. Early development of drainage facility is required to solve inundation problems.

As regards operation and maintenance of facilities, YCDC has no particular section for management of drainage, and conducts limited works as stopgap and emergency measures. It is recommended that independent section for drainage management be established, and systematic O&M work for urban storm water drainage be conducted.

(2) Organizational and Institutional Issues

The Department of Road and Bridge is responsible for drainage works, however the number of staffs responsible for drainage sector is very limited. The O&M works and the improvement works of existing drainage is often lagging behind. Organizational restructuring such as an increase of relevant staff members may be required.

CHAPTER 3. SEWERAGE MASTER PLAN

3.1 Development Policies Concerning Wastewater Treatment

3.1.1 Outline of Development Policies

As for wastewater treatment including sewerage, YCDC is in the condition that management and operation organization is insufficient for full-scale development, legal system concerning wastewater treatment and water environment has not been developed properly, and accordingly a firm basis for development finance has not been made evident. With these conditions into consideration, establishment of institutional framework towards full-scale development, staged efforts for the securement of financial resources, and basic policies for development with due concern to phased employment of and/or shift among various wastewater treatment techniques for realizing cost-effective treatment are indispensable for realizing efficient wastewater treatment development.

Based on the above, basic policies and a road map are articulately presented for each time phase, i.e. short term up to FY 2025, middle term up to FY 2040, and long term from FY 2040 on, and for each development items are listed below. Outline of development policies is illustrated in Figure S.6.

Development items	Target year	Short term - FY 2025	Middle term - FY 2040	Long term FY 2040 -
Development policies for institutional framework	Institutional strengthening Sewerage plan (construction, management, finance)	• Utilization of JICA Vision and M/P • Formulation of organization Development of related legal system • Invitation of experts and engineers from advanced ountries	• Human resource development by YCDC staff trained in the short term period • Preparation of sewerage development plan by YCDC • Time of full-scale sewerage expansion	• Independent management • Revision of M/P by YCDC (for efficient development) • Continuous facility and business management system
	Establishment of laws	• Preparation of various basic policies • Establishment of Sewerage Law, sewerage ordinace, regulation concerning development activities, regulation for industrial effluent, *etc.*	• Implementation laws and expansion of enforcement regulations • Strengthening of supervision by regulation laws	
	Sewerage developmet plan	• No.1 projects by Japanese government loan with technical assistance • Implementation of C1 and W1 sewerage zones as much as possible	• Implement sewerage development projects in sevaral districts simultaneously • Target of 50% sewerage service ratio in terms of population in 2040	• Expansion of areas serviced by sewerage system • Up-grading of wasterwater treatment to sewerage system finally
	Finacial resources for development	• Utilization of Japanese government loan, *etc.*	• Utilization of Japanese government loan, *etc.* • Revenue of sewerage service charge and government subsidies	• Sewerage deveolpment by independent finacial sources • Revenue of sewerage service charge and government subsidies
Development policies for wastewater treatment facilities	In the sewerage planned areas (- FY 2040)	Pit latrine Existing septic tank	Development of interceptor sewerage Note 1 Improved septic tank Note 2 or on-site compact treatmeent fcilities (johkasou)	Separate sewerage system with individual connection
	Out of the sewerage planned areas (FY 2040 -)	Pit latrine Existing septic tank	Improved septic tank Note 2 or on-site compact treatmeent fcilities (johkasou)	Separate sewerage system with individual connection
	Large-scale development areas	Establishement of regulation laws and initiation of development supervision	Implmentation of supervision and its strengthening Sewerage development by private enterprises (such as in Malaysia) • Small sewerage system for housing development, say community plant • Individual wasterwater treatment facility for larg-sized building such as johkasou, *etc.*	
	Measures against industrial effluent	Establishement of regulation laws and initiation of development supervision	Strengthening of supervision Installation of pretreatment facility for the connection to sewerage	

Note 1: For the time being, increase of sewerage service ratio is targeted by temporary sewerage development. In the case of focusing on the increase of wasterwater volume to be treated, the construction of wastewater treatment plant will be progressed with interceptor system. On the contrary in the case of focusing on the improvemnet of nearby living environment, the construction of sewer network will be the first priority, leaving wastewater treatment later. Anyway in both cases, enlightment acitivites to citizens' understanding concerning sewerage such as prevention of garbage dumping to sewer, and sewerage charge (service charge or tax as evironmental imrovement fee) are indispensible.

Note 2: Basically, sptic tanks to be newly installed are to be improved type capable of treating gray water as well as black water and improved type will be introduced at the time of rebuilding of buildings or redevelopment of the area for the existing buildings in exsting urbanized areas for which improved sptic tank cannot be installed right now technically.

Source: JICA Study Team

Figure S. 6 Basic Development Policies Concerning Wastewater Treatment

3.1.2 Priorities of Tasks to be Implemented by YCDC for The Time Being

YCDC is supposed to go ahead with the development of wastewater treatment systems and facilities based on the above-mentioned development polies with the cooperation and support by JICA, etc. In order to realize quick development and early commencement of the operation of wastewater treatment systems, however, various tasks are to be implemented efficiently prior to the 1st stage construction of treatment system. These required tasks are articulately listed as shown in the following table:

Table S. 10 List of Tasks to be Implemented by YCDC for the Time Being and Their Priorities

Tasks to be implemented by YCDC for the time being	Priority (High → Low)					Remarks
1. Land acquisition or its outlook	●					
2. Preparation of policies on sewerage service operation						
a. Study on management organization for sewerage service (Administration, planning, and operation and maintenance)	●					
b. Role sharing for sewerage services between YCDC and townships	●					
c. Study on the method of securing of financial sources for construction upon consultation with national and regional governments	●					
d. Study on service charge system for sewerage		●				
e. Enactment of local ordinance for sewerage charge			●			
3. Basic policies on related laws and coordination with national government						
a. Study on existing related laws and regulations		●				
b. Drafting of legal systems for environment and wastewater treatment and consultation with national government		●				
c. Basic policies of laws and regulation concerning environment and wastewater treatment and consultation with national government		●				
4. Drafting of sewerage-related laws and regulations and consultation with national government						
a. Study on framework of Sewerage Law		●				
b. Drafting of Sewerage Law and consultation with national government		●				
c. Request to national government for the enactment of Sewerage Law		●				
d. Drafting of Sewerage Ordinances by YCDC and townships and consultation among them			●			
e. Enactment of Sewerage Ordinances			●			
5. Study on environmental and effluent standards and consultation with national government						
a. Drafting of ambient water quality standards			●			
b. Study on laws and regulation concerning solid waste treatment related to sludge treatment			●			
c. Consultation with national and regional governments, academics, and entrepreneurs			●			
d. Drafting of uniform effluent standards and request to national government for enactment				●		
e. Drafting of more stringent local effluent standards by YCDC and its enactment				●		
6. Study on law and regulation for other wastewater treatment facilities and establishment of subsidizing system						
a. Study on methods for improving septic tanks	●					
b. Study on laws and regulations for Johkaso and septic tanks (Structural standards) and consultation with national government	●					
c. Study on subsidizing system for septic tank improvement and Johkaso installation		●				
7. Basic policies concerning laws and regulations for development activities and consultation with national government						
a. Study on regulation required and items to be requested for cooperation to developers		●				
b. Coordination with City Planning Act concerning regulation and consultation with national government		●				
c. Study on regulation ordinance for developing activities concerning sewerage and its enactment			●			
8. Enactment of ordinance concerning the receipt of industrial effluent to sewerage system						
a. Water quality survey for industrial effluent for types of industries		●				
b. Consultation with interested parties such as national and regional governments, other departments of YCDC, and entrepreneurs			●			
c. Enactment of ordinance for the receipt of industrial effluent to sewerage system				●		
9. PR to citizens concerning sewerage and wastewater treatment						
a. Preparation of general enlightening materials, introduction of various related systems			●			
b. Holding of explanation meeting for citizens				●		
10. Procedures towards system commencement and project advancement						
a. Procedures and preparation of sewerage ledgers, daily and monthly reports for operation					●	
b. Preparation of water quality management plan					●	

3.2 Master Plan for Sewerage System

3.2.1 Planning Frame

(1) Population Projection

Population projection by township estimated under "JICA Urban Plan Study, 2012" is used which is the same projection as for water demand projection. Current population of YCDC which was 5.14 million in 2011 is estimated to increase to 6.46 and 8.52 million in 2025 and 2040, respectively. Total population of 39 townships which was 5.57 million in 2011 is estimated to increase to 7.98 and 11.73 million in 2025 and 2040, respectively.

(2) Wastewater Generation

Wastewater generated is estimated based on quantity of water distributed by water supply system. Wastewater is water consumed by houses, public and commercial establishments plus infiltration. Water consumed equals to water distributed minus leakage. Industrial wastewater produced by large scale factories which have their own water resources is not included in estimated wastewater amount. These factories should treat their wastewater by themselves to comply with discharging water quality standards.

Three kinds of wastewater generation are estimated, i.e. daily average, daily maximum and hourly maximum. Daily average is calculated by dividing annual total wastewater by 365, and this is used for calculation of sewerage fee revenue. Daily maximum is the largest one day wastewater generation, and this is used for design of WWTP. Hourly maximum is one hour peak flow at daily maximum flow, and this is used for design of pipe networks, pumps and conduits and pipes in WWTP. Daily maximum is 1.1 times daily average, and hourly maximum is 1.5 times daily maximum. These ratios are the same as those for water supply master plan.

Data or design criteria for infiltration are not available, thus 10 m^3/ha/day, which is adopted for Bangkok is adopted because of the similar characteristics of both the cities. However, amount of infiltration sometimes shows extremely high figures, since the amount is calculated based on the area. New development areas which are to be developed in the future are most likely to have huge vacant areas. Amount of infiltration in these areas tends to be excessively high. Therefore for these areas maximum infiltration is assumed to be 30 % of wastewater. Wastewater generation up to 2040 is shown in Table S.11 below. Infiltration is constant even for daily maximum and hourly maximum.

Table S. 11 Wastewater Generation (Daily Average)

Code	Township	2011			2025			2040		
		Wastewater	Infiltration	Total	Wastewater	Infiltration	Total	Wastewater	Infiltration	Total
1	Latha	13,373	600	13,973	15,513	600	16,113	15,167	600	15,767
2	Lanmadaw	17,938	1,310	19,248	19,609	1,310	20,919	19,171	1,310	20,481
3	Pabedan	20,076	610	20,686	17,069	610	17,679	16,689	610	17,299
4	Kyauktada	17,276	670	17,946	15,818	670	16,488	15,464	670	16,134
5	Botahtaung	11,776	2,580	14,356	15,633	2,580	18,213	21,837	2,580	24,417
6	Pazundaung	15,324	1,040	16,364	24,918	1,040	25,958	25,176	1,040	26,216
7	Ahlone	7,405	3,290	10,695	9,095	3,290	12,385	18,269	3,290	21,559
8	Kyee Myin Daing	3,703	4,520	8,223	17,558	4,520	22,078	39,689	4,520	44,209
9	Sanchaung	10,492	2,390	12,882	14,505	2,390	16,895	28,856	2,390	31,246
10	Dagon	6,438	4,640	11,078	10,782	4,640	15,422	21,551	4,640	26,191
11	Bahan	31,414	7,670	39,084	33,160	7,670	40,830	48,753	7,670	56,423
12	Tarmwe	58,662	4,990	63,652	79,142	4,990	84,132	87,607	4,990	92,597
13	Mingalar Taung Nyunt	26,459	600	27,059	50,682	600	51,282	73,229	4,780	78,009
14	Seikkan	0	0	0	305	92	397	597	134	731
15	Dawbon	2,289	610	2,899	12,064	610	12,674	24,076	2,950	27,026
16	Kamaryut	6,724	2,017	8,741	12,785	3,836	16,621	27,433	6,173	33,606
17	Hlaing	12,614	2,580	15,194	21,233	2,580	23,813	43,469	9,250	52,719
18	Yankin	27,724	1,040	28,764	28,615	1,040	29,655	44,767	4,780	49,547
19	Thingangyun	20,873	3,290	24,163	53,709	3,290	56,999	86,620	12,090	98,710
20	Mayangone	29,870	8,961	38,831	52,285	15,686	67,971	95,429	21,472	116,901
21	Insein	26,441	7,932	34,373	45,958	13,787	59,745	100,584	22,631	123,215
22	Mingalardon	14,751	4,425	19,176	72,358	21,707	94,065	241,800	54,405	296,205
23	North Okkalapa	51,073	7,670	58,743	117,313	7,670	124,983	188,209	26,460	214,669
24	South Okkalapa	25,473	7,960	33,433	44,031	7,960	51,991	70,183	7,960	78,143
25	Thaketa	6,454	12,600	19,054	35,978	12,600	48,578	74,743	12,600	87,343
26	Dala	1,176	353	1,529	27,451	8,235	35,686	98,007	22,052	120,059
27	Seikgyikhanaungto	4,108	1,232	5,340	11,140	3,342	14,482	24,807	5,582	30,389
28	Shwe Pyi Thar	3,751	1,125	4,876	34,696	10,409	45,105	102,991	23,173	126,164
29	Hlaing Thar yar	2,432	730	3,162	53,287	15,986	69,273	147,544	33,197	180,741
30	North Dagon	14,149	4,245	18,394	37,427	11,228	48,655	76,584	17,231	93,815
31	South Dagon	8,716	2,615	11,331	40,076	12,023	52,099	110,073	24,767	134,840
32	East Dagon	2,851	855	3,706	50,142	15,043	65,185	236,664	53,249	289,913
33	Dagon Seikkan	0	0	0	20,845	6,254	27,099	79,823	17,960	97,783
YCDC Sub-total		501,805	105,151	606,956	1,095,182	208,287	1,303,469	2,305,861	417,206	2,723,067
34	Kyauktan	0	0	0	1,493	448	1,941	15,345	4,604	19,949
35	Thanlyin	0	0	0	9,957	2,987	12,944	124,377	37,313	161,690
36	Hlaegu	0	0	0	3,995	1,199	5,194	53,370	16,011	69,381
37	Hmawbi	0	0	0	4,447	1,334	5,781	55,163	16,549	71,712
38	Htantapin	0	0	0	2,998	899	3,897	39,717	11,915	51,632
39	Twantay	0	0	0	2,410	723	3,133	33,088	9,926	43,014
Out of YCDC Sub-total		0	0	0	25,300	7,590	32,890	321,060	96,318	417,378
Total		501,805	105,151	606,956	1,120,482	215,877	1,336,359	2,626,921	513,524	3,140,445

Source: JICA Study Team

(3) Sewerage System

Sewerage system is in general divided into two categories, viz. separate system and combined system. Separate system collects wastewater and storm water runoff separately, and combined system collects both of them in the same pipes. Separate system is adopted for Yangon City for the reasons mentioned below. There are no YCDC regulations regarding sewerage system.

1 Existing sewerage system is separate system
2 Rainfall intensity is very high resulting in excessively large diameter of combined pipes
3 Rainfall runoff is easily collected and discharged to nearby rivers and creeks
4 Reduction of pollutant load is larger than that of combined system, and this is an advantage for water pollution control

In addition to separate and combined systems, interceptor sewerage system can be considered as

temporary system. Interceptor sewerage system is finally converted to conventional systems. This system consists of storm water overflow chambers and interceptors. The former intercepts dry weather flow flowing in the existing drains immediately before rivers and overflows excessive storm water runoff. The latter collects wastewater from storm water overflow chambers and convey it to a treatment plant. Construction of lateral sewers and house connection which require huge amount of investment can be avoided at initial stage resulting in earlier improvement of water pollution in water bodies. However mixed wastewater and storm water is discharged from storm water overflow chambers when it rains because both of them flow in the existing drains. Therefore, reduction of pollutant load is less than that of separate system.

For Yangon, interceptor sewerage system which collects 1Q as planned for Manila can be applied since provision of separate system is final target.

(4) Characteristics of Wastewater

In order to estimate future wastewater characteristics, per capita BOD load is assumed to be 40 g taking into account examples in neighboring countries. BOD concentration is calculated to be 173 mg/l based on average per capita wastewater flow in 2040, i.e. 221 lpcd (consumption 187 l + infiltration 43 l). For planning purposes, BOD concentration is determined to be 200 mg/l. SS concentrations is determined to be 180 mg/l taking into account BOD and SS ratio monitored in treatment plants in Japan, i.e. 1.125: 1.

3.2.2 Sewerage System Planning Area and Site for WWTP

YCDC administrative area is divided into 14 sewerage zones taking into account urbanization condition of townships and topography as shown in Figure S.7. Sewerage system planning area up to 2040 is selected based on the population density of each township. As a result, 25 townships are designated as sewerage system planning area. Total population of these 25 townships in 2011 and 2040 are 3.58 million persons (70 % YCDC) and 4.21 million persons (49 %) respectively. Table S.12 shows population, area and required area for WWTP.

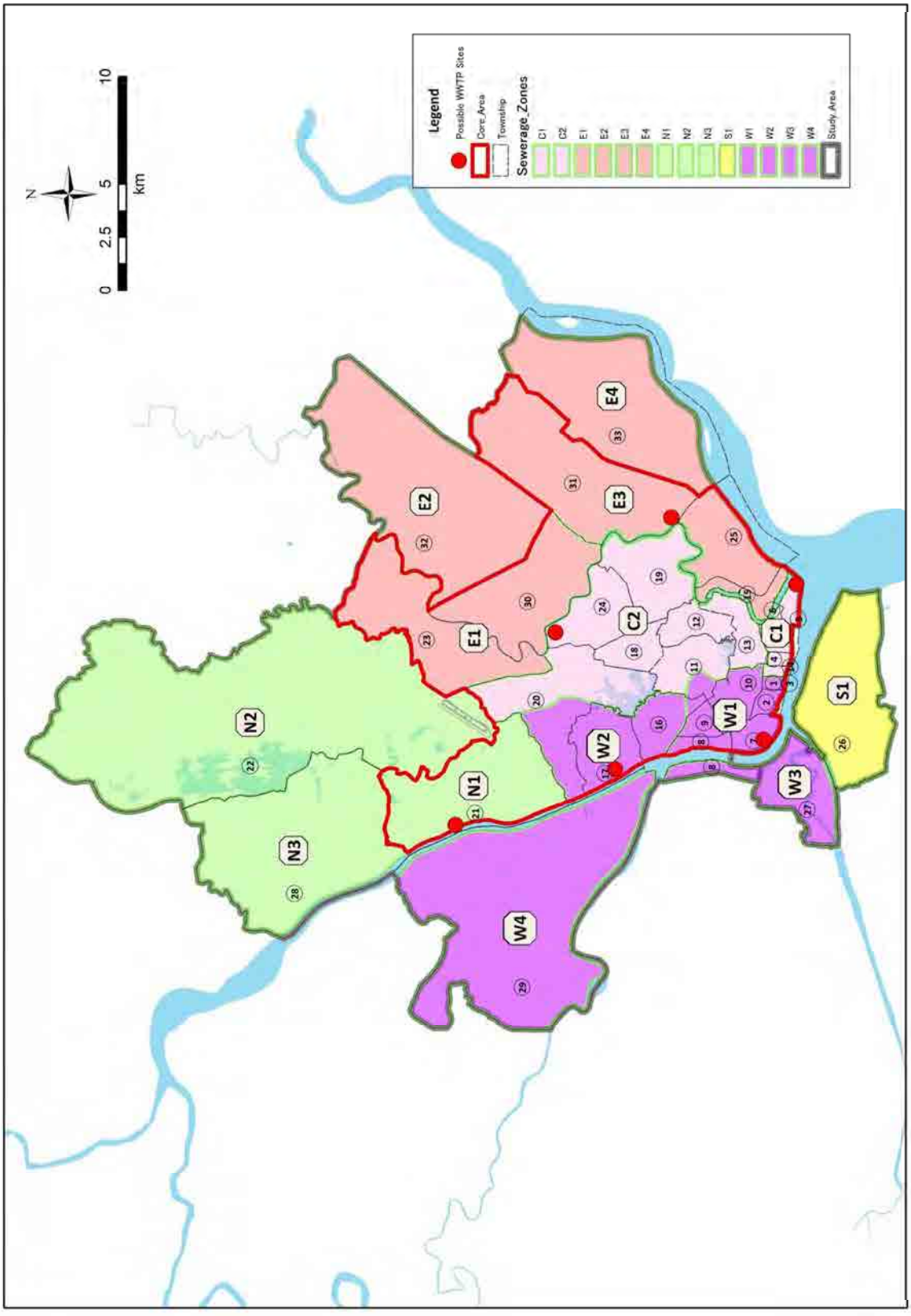


Figure S. 7 Sewerage Zones (Final Plan)

Source: JICA Study Team

Table S. 12 Population, Wastewater Flow and Area by Sewerage Zone

Sewerage Zone	Population (person)	W. Flow (m^3/day)		Area (ha)	WWTP Area (ha)	Township
		Daily Ave.	Daily Max.			
C 1	178,127	64,276	70,213	499	6.4	Pazundaung, Botahtaung, Kyauktada, Pabedan
C 2	1,191,499	452,548	492,264	6,102	21.4	a part of Bahan, Mingalar Taung Nyunt, Tamwe, South Okkalapa, Thingangyun, Yankin, a part of Mayangone
W 1	483,058	169,214	184,247	1,654	11.7	Lanmadaw, Latha, Dagon, a part of Bahan, a part of Kyee Myin Daing, Ahlone, Sanchaung, a part of Kamaryut
W 2	349,512	116,999	126,410	2,356	9.2	Hlaing, a part of Kamaryut, a part of Mayangon
W 3	74,419	14,512	15,628	1,485	2.5	A part of Kyee Myin Daing, Seikgyikhanaungto
W 4	737,724	191,809	206,563	7,761	12.5	Hlaing Tharyar
N 1	377,188	129,633	139,691	3,163	9.8	Insein
N 2	906,748	294,693	317,362	12,783	16.3	Mingaladon
N 3	514,954	100,416	108,140	5,271	8.4	Shwe Pyi Thar
E1	710,656	232,953	252,094	5,184	14.2	North Okkalapa, North Dagon
E 2	1,183,320	269,207	289,915	17,064	15.4	East Dagon
E 3	920,933	243,849	263,583	5,418	14.5	Dawbon, Taketa, South Dagon
E4	399,111	77,827	83,814	4,202	7.1	Dagon Seikkan
S 1	490,032	127,409	137,210	9,840	9.7	Dala
Out of SZ	2,241	971	1,046	117		Seikkan
Total	8,519,522	2,486,316	2,688,180	82,899	159.2	

Note: Shaded sewerage zones are core area. C2 and E1 are combined.
Source: JICA Study Team

Locations and capacities of major sewerage facilities are determined based on the flow calculation of trunk mains and design calculation of WWTPs for these 6 sewerage zones.

3.2.3 Phasing of Project Implementation

(1) Priority of Sewerage Zones

In order to prepare implementation program for sewerage system development, priority of each of 7 sewerage zones (sub-zones of C2 and E1 are treated as independent zone) has been evaluated. Selection criteria to determine order of sewerage system development are established. Three categories are selected for evaluation of priority, viz. status of urbanization, physical characteristics of sewerage zone, and contribution to water pollution control. Results of the evaluation are shown in Table S.13.

Table S. 13 Evaluation of Priority of Sewerage Zone

Sewerage Zone	Urbanization				Size and Road Length				Pollution Control		Total Points	Priority Order
	Population Density in 2012		Population Density in 2040		Area		Road Length		BOD Reduction			
	(persons/ha)	Point	(persons/ha)	Point	(ha)	Point	(km)	Point	(kg/day)	Point		
C 1	351	1	357	1	499	1	47	1	17,997	7	11	1
C 2	182	3	195	3	6,102	7	476	7	116,832	1	21	3
W 1	252	2	292	2	1,654	2	122	2	37,784	4	12	2
W 2	128	5	148	5	2,356	3	206	3	27,603	5	21	3
N 1	98	7	119	7	3,163	4	268	4	27,459	6	28	7
E1	107	6	137	6	5,184	5	386	5	67,840	2	24	6
E 3	131	4	170	4	5,418	6	462	6	55,156	3	23	5

Note: C2 and E1 are Sewerage Sub-Zones which formulate C2+E1 Sewerage Zone
Source: JICA Study Team

3.3 Water Quality Improvement of Kandawgyi Lake

3.3.1 Urgent Measures

Demonstration experiment of blue-green algae removal was implemented from May to June, 2013. Summary of this experiment is shown below.

(1) Summary of experiment

Experimental period: May 23 to June 21, 2013.

Location: Experiment was done in the small inlet of Kandawgyi Lake. (See below figure)

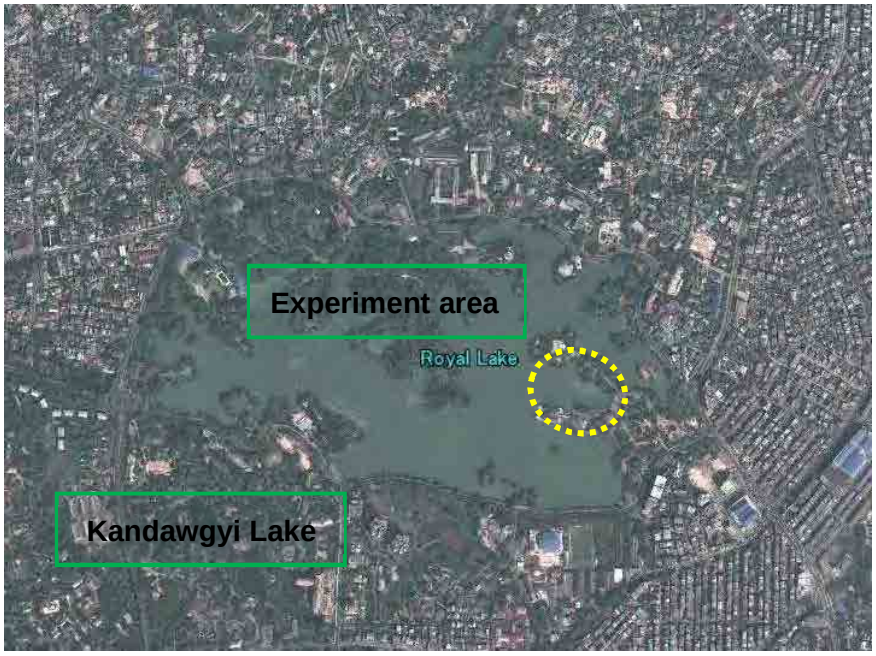


Figure S. 8 Location of Experiment Site (in the Yellow Dotted Circle)

Schematic diagram of experimental plant is shown in Figure S.9.

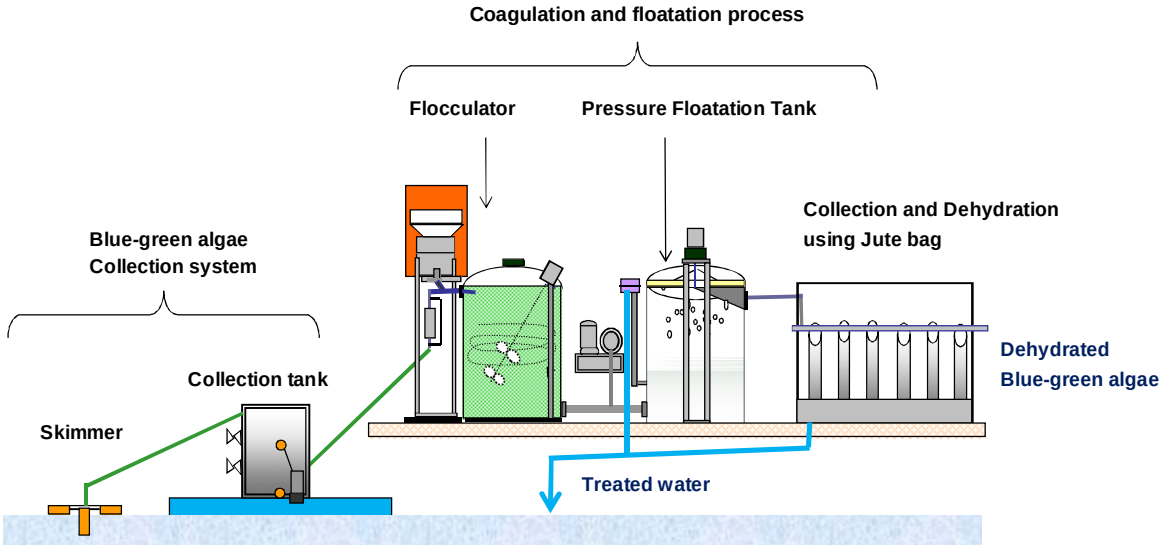


Figure S. 9 Scheme of Blue-green Algae Removal Plant

Experiment was conducted during rainy season and weather conditions were very bad. However, this plant was considered to be very effective for removal of algae and hence for improvement of water quality in the lake because removal efficiencies for SS, COD, T-N and T-P are very high.

3.3.2 Short Term and Mid / Long- Term Measures

The fundamental measures to reduce blue-green algae are removal of nutrient in sediment and prevention of nutrient inflow. Specific measures are as follows;

- Removal of nutrient by dredging of sediment

In order to prevent nutrient from inflowing to Kandawgyi Lake, there are three measures on domestic human wastewater as shown below.

- Installation of interceptor sewer connecting outlet points of drainage system (Figure S.9)
- Prevention of nutrient inflow
  Installation of household wastewater treatment tank in the restaurants around the lake (12 restaurants)
- Development of sewerage system

3.4 Institutional Development for Operation and Maintenance and Capacity Building

Currently operation and maintenance of ejector system and WWTP, and approval for application of septic tank is under responsibility of Sanitary Division. Institutional system should be strengthened substantially as sewerage system is developed. Organization which will be required in 2040 when sewerage system is developed as proposed in the previous Chapters is studied. Proposed organization is described in Figure S.10. Main points of the proposal are as follows.

- An additional Deputy Head should be appointed in addition to the current two Deputy Heads, and he is exclusively responsible for sewerage works.
- Under new Deputy Head, Office Section, Finance Section, Database & Tariff Section, Laboratory, Planning and Monitoring Section, Research and Development Section, Construction Section, Development Coordination Section, Customer Care and Public Relation Section, Industrial Wastewater Section and Laboratory which report to the Deputy directly should be established.
- Pipe Network and On-site Treatment Division which is responsible for operation and maintenance of pipe networks and on-site treatment facilities should be established. Under the Division, 4 District Offices are placed.
- WWTP Division which control 6 WWTPs should be established.
- Drainage Division should be established for operation and maintenance of drainage facilities and to control township or district offices once transfer of responsibility is agreed upon.

  (Note: Section or Division with underline are new establishments)

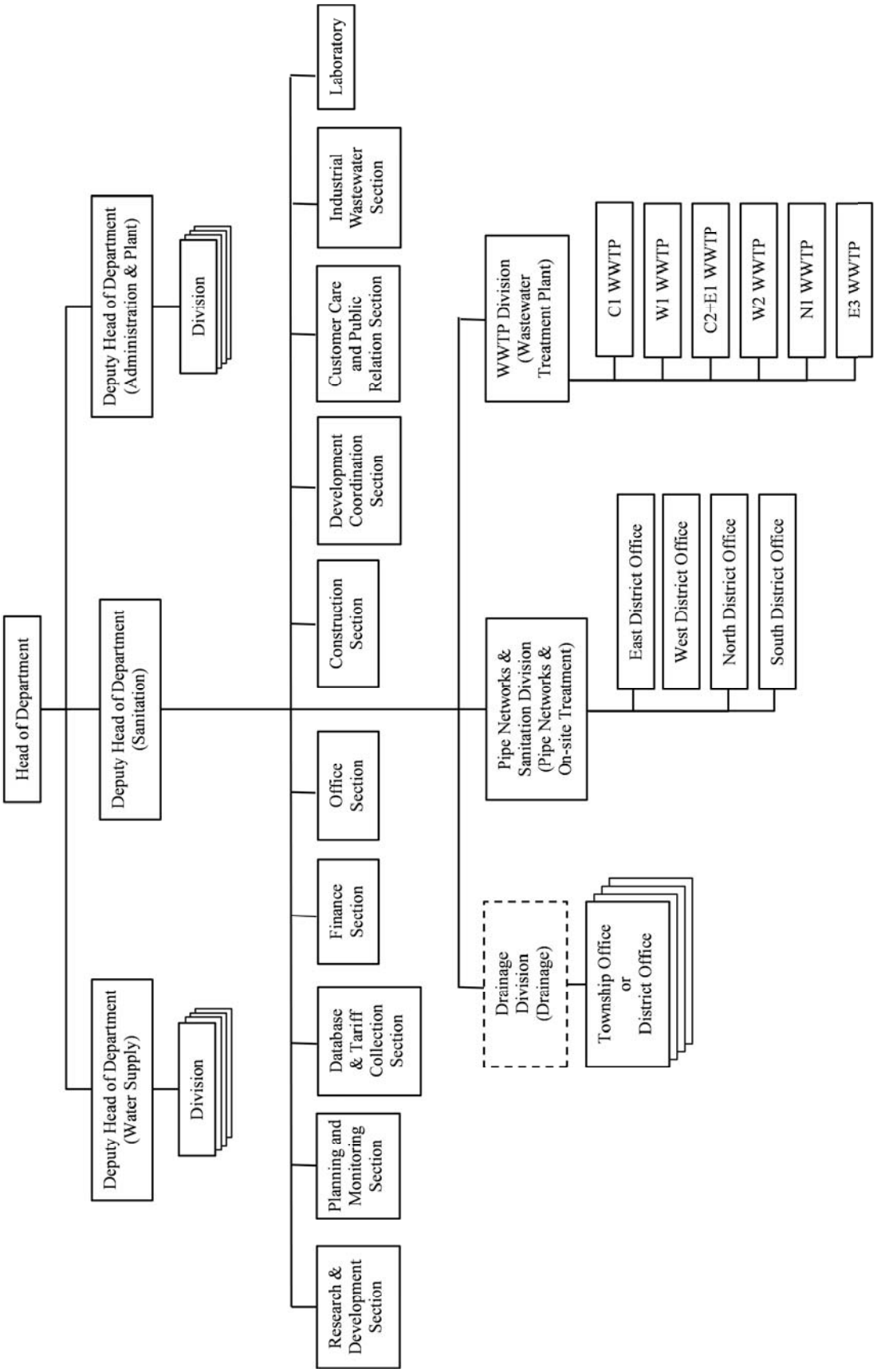


Figure S. 10 Organization Chart of Sewerage Department

Source: JICA Study Team

3.5 Project Implementation Plan and Cost Estimation

3.5.1 Phased Implementation Program Up to 2040

Implementation schedule up to 2040 is shown in Table S.14. Feasibility study (FS), preparation of project funding, detailed design (DD) are necessary to commence the construction. Period required for these activities are assumed to be 1 year, 2 years and 1 year respectively. There is no sewerage development plan, such as 5 year plan, therefore, 2 years are considered to be necessary for preparation of funding because funds from bilateral or multilateral funding institution might be necessary for projects which should be commenced earlier. Sewerage development plan which covers medium or long term period is established and funding is secured in the future, this activity can be neglected.

Construction period is estimated based on scale of sewerage facility. C2+E1 Sewerage Zone has different priorities, C2 is 2nd and E1 is 3rd. Therefore, sewerage facilities in C2 should be completed by 2030 and E1 by 2040. In addition, WWTP for C2+E1 Sewerage Zone has large design capacity. Thus the WWTP should be constructed in 4 phases, 1st phase by 2030 and the last 4th phase by 2040. WWTP for E3 Sewerage Zone should also be constructed in 2 phases, 1st by 2035 and 2nd by 2040.

Table S. 14 Implementation Plan of Sewerage Works

Sewerage Zone	Components		Year																												
			2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
C1	F/S			■																											
	Preparation of Fund				■	■																									
	WWTP	DD					■																								
		Construction						■	■																						
	Sewer Network	DD					■																								
		Construction						■	■																						
W1	F/S								■																						
	Preparation of Fund									■	■																				
	WWTP	DD												■																	
		Construction													■	■															
	Sewer Network	DD										■	■	■	■																
		Construction											■	■	■	■															
C2+E1	F/S												■																		
	Preparation of Fund													■	■																
	WWTP	DD														■			■					■					■		
		Construction															■	■		■	■				■	■				■	■
	Sewer Network	DD														■	■	■	■	■	■	■	■	■	■	■	■	■	■		
		Construction																■	■	■	■	■	■	■	■	■	■	■	■	■	■
W2	F/S									■																					
	Preparation of Fund										■	■																			
	WWTP	DD														■															
		Construction															■	■													
	Sewer Network	DD											■	■	■	■	■														
		Construction												■	■	■	■	■													
N1	F/S																	■													
	Preparation of Fund																		■	■											
	WWTP	DD																						■							
		Construction																							■	■					
	Sewer Network	DD																	■	■	■	■	■	■	■						
		Construction																		■	■	■	■	■	■	■					
E3	F/S																			■											
	Preparation of Fund																				■	■									
	WWTP	DD																						■					■		
		Construction																							■	■				■	■
	Sewer Network	DD																			■	■	■	■	■	■	■	■	■	■	
		Construction																				■	■	■	■	■	■	■	■	■	■

3.5.2 Policy and Condition of Cost Estimation

The price level and exchange rate are defined as shown below.

Price level: Average in December 2012

Exchange rate: 1USD=84.64JPY

Considering the condition listed below, the construction cost is calculated.

- It is possible to procure civil and building material, labor and construction machine within the country and the procurement in local country is set as basic policy for project cost estimation.
- The mechanical and electrical equipment is basically procured from overseas including third country; such as European Union (EU) etc. The equipment will be procured with consideration of quality, performance, economical efficiency and O&M, etc.
- The local contractors have enough experiences and ability for normal civil engineering work. On the other hand, they are not experienced in the specialized project regarding water supply and sewerage. However, Japanese experts and foreign experts are staffed in implementation system of the Project and construction is conducted by the local contractor.
- The local contractors are not experienced in the construction methods of pipe jacking and shield. The unit cost of these construction methods is collected from Thailand where many contractors have relevant experiences.
- The installation unit cost of house connection for sewerage is estimated by YCDC, based on the standard section drawings for pipe installation.
- The construction plan is established with the considerations of local natural condition (topographic aspects, geotechnical condition and meteorological condition) and legislation/custom.
- In case interceptor system is adopted, the project cost of primary or secondary treatment and sludge treatment in WWTP are calculated.
- In case interceptor system is adopted, operation and maintenance cost for primary or secondary treatment and sludge treatment is calculated.

3.5.3 Project Cost Estimation

(1) Capital Cost

Non-disclosure Information

Non-disclosure Information

Table S. 15 Result of Cost Estimation of Sewerage Project (As of 2040)

Non-disclosure Information

(2) Operation and Maintenance Cost

The required operation and maintenance cost for sewerage works is shown below. In the field of sewerage works, in case separate system is adopted in all sewerage zones, the annual total cost of operation and maintenance is approximately 1,903 million JPY. On the other hand, in the case that separate system is adopted in C1, W1 and a part of C2, and interceptor system with primary treatment is adopted in the others and interceptor system with secondary treatment is adopted, the annual total cost of operation and maintenance is approximately 1,152 million JPY and 1,840 million JPY, respectively.

Table S. 16 Annual Operation and Maintenance Cost for Sewerage Works

Unit: Million JPY/Year

Category	Operation and Maintenance Cost		
	Case that separate system is adopted in all sewerage zone	Case that separate system is adopted in C1, W1 and a part of C2,	
		Interceptor system is adopted in the others. (Primary treatment)	Interceptor system is adopted in the others. (Secondary treatment)
Labor cost	32.9 (0.4)	31.0 (0.4)	31.0 (0.4)
Electricity cost	535.5 (6)	331.0 (3.9)	535.5 (6.3)
Spare parts cost	431.1 (5.1)	224.1 (2.6)	431.1 (5.1)
Sludge disposal cost	165.4 (2.0)	115.3 (1.4)	165.4 (2.0)
Chemical cost	621.8 (7.3)	409.5 (4.8)	621.8 (7.3)
Sewer maintenance cost	80.3 (0.9)	19.2 (0.2)	19.2 (0.2)
Others	35.8 (0.4)	22.7 (0.3)	22.7 (0.4)
Total	1,902.8 (22.5)	1,152.4 (13.6)	1,839.8 (21.7)

Note: Figures in parentheses are Million USD

Source: JICA Study Team

3.6 Project Financing Plan

3.6.1 Sewerage Tariff Policy

Normally sewerage tariff is calculated according to the volume of water service consumption. It is partly due to administrative expediency in collecting user fees for sewerage. It is also rational as the treatment volume of sewage is almost equal to the consumption of water. According to economic theory, water supply and sewerage are complementary goods, i.e. the consumption of one service necessitates the other. Simultaneous provision of both services will allow the goal of providing lifeline with water supply while maintaining public sanitation through sewerage service.

There are three core issues to be taken into account in determining tariff for water and sanitation.

1) Majority of residents can afford the user charges.
2) The provider is capable of sustaining a long-term operation with the tariff revenue.
3) The service accomplishes public health and environmental protection.

3.6.2 Willingness-to-Pay and Affordability

(1) Willingness-To-Pay

A 10,000 sample survey on citizens undertaken by JICA, "Project for the Strategic Urban Development Plan of the Greater Yangon"**,** has a few questions concerning willingness-to-pay (WTP)

for improved and expanded water supply and sewerage services.

The median WTPs for water supply falls in the bracket 3, 1001 to 2000 Kyats and that for sewerage falls in the bracket 2, which ranges between 501 to 1000 Kyats. The townships that exhibit the WTP median at the bracket 3 are Botahtaung, Pazundaung, Sanchaung and Tarmwe. These towns have exhibited needs for drainage improvements. Since most of sewage is discharged into roadside drains, flooding and lack of sewerage system combined may be causing severe sanitation problems thus need to be further investigated.

(2) Sewerage Tariff Affordability

Another important aspect in tariff policy is to make certain the user charges are within the range of the payment capacity by the residents. So-called affordability to pay must be verified. Generally the maximum level of user tariff for water and sewerage services is 3-5% of income.

One yardstick for affordability is to target at 80% of population instead of the average citizen in measuring the affordability. In this case, the maximum affordable tariff needs to be linked to the income of the bottom 20% of the cumulative income distribution. Estimated income at the 20% cumulative level is 105,000 Kyats per month per household. The household income would grow in tandem with economic development. Assuming the annual growth rate of 5%, the household income would grow by the multiple of 3.7 by 2040. The 20% benchmark income would grow to 392,000 Kyats per month. Further assuming expending 4% of income on water and sewerage service is within the bounds of affordability, the limitation is 16,000 Kyats per month. Assuming the consumption of 200 liters of water per person per day with the average size of household of 5 in 2040, the maximum allowable expenditure for water and sewerage is 560 Kyats per m^3. By dividing this water and sanitation budget with the ratio of 1 to 0.8 between water and sewerage, the maximum tariff for sewerage service would be 240 Kyats per m^3. This is equivalent to 0.28 dollars per m^3.

3.6.3 Yangon Sewerage Financial Analysis

(1) Financial Simulation Model

The JICA Study Team has created a Sewerage Financial Simulation Model specially catered for the financial analyses of investments, service connections, operation and maintenance encompassing all the proposed projects up to the year 2040 and additional 40 years of operation, maintenance and replacement investments up to the year 2080. The model is equipped with the variables that can be instantly modified: sewerage tariff and its annual increase, interest rate on the capital, percentage of subsidy to investment, increase in fixed costs to determine the impacts on financial projects funding mechanism. Other model parameters concerning costs, volume, the size of family, sewerage coverage,

water consumption, and sewage infiltration can be modified if so required.

(2) Financial Simulation Results

The results of financial simulation are shown in Table S.17.

Table S. 17 Results of Financial Simulation According to Capital Subsidy and Type of Sewerage System

Capital Subsidy Ratio	Separate/Secondary	Interceptor/Secondary	Interceptor/Primary
80%	3.9%/Year= 0.22 /m^3 In 2040	2.7%/Year= \$ 0.16/m^3 In 2040	1.7%/Year= \$ 0.13/m^3 In 2040
60%	5.0%/Year= 0.30 /m^3 In 2040	3.9%/Year= \$ 0.22/m^3 In 2040	3.0%/Year= \$ 0.18/m^3 In 2040
40%	5.9%/Year= \$ 0.38/m^3 In 2040	4.9%/Year= \$ 0.29/m^3 In 2040	4.0%/Year= \$ 0.23/m^3 In 2040
0%	7.3%/Year= \$ 0.53/m^3 In 2040	6.3%/Year= \$ 0.41/m^3 In 2040	5.4%/Year= \$ 0.33/m^3 In 2040

Source: JICA Study Team

Description of the table is as follows e.g. in case 80 % capital subsidy.

Case-80% Capital Subsidy:

- For the option of adopting separate sewers and up to secondary treatment, the tariff needs to be increased by 3.9% from USD 0.08/m^3 in 2013 to USD 0.22/m^3 in 2040 and constant thereafter in order to repay all the principal and interests of the YCDC loan by the year 2080
- For the option of adopting interceptor and up to secondary treatment, the tariff needs to be increased by 2.7% from USD 0.08/m^3 in 2013 to USD 0.16/m^3 in 2040 and constant thereafter in order to repay all the principal and interests of the YCDC loan by the year 2080.
- For the option of adopting interceptor and up to primary treatment, the tariff needs to be increased by 1.7% from USD 0.08/m^3 in 2013 to USD 0.13/m^3 in 2040 and constant thereafter in order to repay all the principal and interests of the YCDC loan by the year 2080.

The above results show that depending on the level of capital subsidy, the consequent required tariff vary quite drastically.

(3) Evaluation of Possible Financial Sources

The macro framework for long−term investment in sewerage infrastructure is estimated at

The interceptor sewer systems with either primary or secondary treatment facilities do basically fulfill the macro guideline. On the other hand, full separate sewer and secondary treatment system will exceed the limitation. However, it is important to resort to micro-based evaluation beyond this rule of thumb. Financial simulation makes it possible to investigate the ability to repay the loans based on tariff and annual increases as described in the preceding sections. Furthermore, the exact limitation of financing through tariff using the maximum affordable level of USD 0.28/m^3 are examined as follows:

1) Separate Sewer/Secondary Treatment: capital subsidy of no less than 65%,
2) Interceptor/Secondary Treatment: capital subsidy of no less than 42%, and
3) Interceptor/Primary Treatment: capital subsidy of no less than 20%.

The results show that the choice of the system will depend on the level of the capital subsidy which is the manifestation of public consensus to publicly finance the maintenance of urban sanitation and environment. The interceptor sewer system with only primary treatment will offer the most economical financing option with the possibility of financing the entire development with tariff revenue with low capital subsidies. As the above affordability to pay analysis indicates, the income distribution of the city of Yangon is skewed to low income levels. Expenditure for water and sanitation has much larger economic impacts on low income households. The situation is quite likely to invite political intervention. It is necessary to further investigate the affordability of tariff and more detailed household income distribution. If a simple tariff is not affordable to a large proportion of low income households, it would be necessary to provide some mitigation measures such as a proposed progressive tariff system. It would be necessary to make financial investigation to weigh the needs for reducing expenditure for the poor against the needs to sustain adequate revenue for proper operation and maintenance.

(4) Financing Plan for Decentralized Sewerage Treatment System

The development of sewerage system will require large investment money over a long period of time. The proposed systems if all developed still only cover 50% of the total population of the city of Yangon. The disposal of household wastewater into drainages without treatment may cause serious pollution and sanitation problems. Since 1990s, the Japanese government has a policy to support decentralized sewerage system, namely Johkaso outside the coverage of centralized sewerage systems. In principle, the Johkaso system requires that the individual households and collective housing purchase and operate mini-sewage treatment tanks. The government is providing 40% of the investment cost to promote the adoption of the system. The rate of subsidy is commensurate with the subsidy that the government provides to local governments for the development of larger scale sewerage systems. As analyzed in the previous section, it is not practical to develop sewerage system by solely relaying on the revenue from tariffs. Similarly, if the promotion of a decentralized sewerage

system is left to the market mechanism, a large initial investment cost may inhibit widespread adoption of the system as was the case in Japan prior to 1990, causing much of water pollution. From social equity standpoint, the same level of capital subsidy should be provided to either system of large-scale centralized sewerage or decentralized sewerage system.

There are two important elements in promoting decentralized sewerage system as follows;

1) Clear demarcation of centralized sewerage areas within urban planning scheme, and
2) Allocation of the same level of capital subsidy to decentralized sewerage system as for centralized system.

For implementing the above policy, it may require the establishment of a legal framework.

3.7 Initial Environmental Examination (with SEA Concept)

3.7.1 Level of Environmental and Social Considerations in the Master Plan

The system of environmental impact assessment is under preparation in Myanmar. Thus till the regulations related to EIA will be enacted, JICA's Guidelines for Environmental and Social Considerations (April 2010) (hereinafter referred as "JICA Guidelines") is applied to the Project.

3.7.2 Alternative in the Master Plan

Evaluation at program level was conducted in this study considering wastewater treatment as a program based on the SEA basic concept, since legal system regarding social and environmental considerations are in the process of development in Myanmar at present.

3.7.3 Analysis of Alternatives

The alternatives are analyzed from the view point of environmental and social, financial and technical aspects.

Table S. 18 Evaluation Matrix of Alternatives

Item		Zero Option (no sewerage system)	Alternative 1 (sewerage system + septic tank)	Alternative 2 (sewerage system + community plant)
Environmental and social aspects	Land acquisition and involuntary resettlement	D	B-	A-
	Land use and utilization of local resources	D	B-	B-
	Living and livelihood	D	D	D
	Protected area / cultural heritage	D	B-	B-
	Landscape	D	D	D
	Indigenous, or ethnic people	D	D	D
	Water pollution	A-	B+ / B-	A+ / B-
	Waste	D	B-	B-
	Soil pollution	A-	B+	A+
	Odor	B-	B+ / B-	B+ / B-
	Ecology	A-	A+	A+
Financial aspect		D	B-	B-
Technical aspect		-	B-	A+ / B-
Overall evaluation		**Not recommended**	**Recommended**	**Highly recommended**

A+/-: Significant positive/negative impact is expected.
B+/-: Positive/Negative impact is expected to some extent.
D: No impact is expected.

3.7.4 Mitigation Measures

The mitigation measures are proposed for the identified optimal alternative.

(1) Land acquisition and involuntary resettlement

The involuntary resettlement may not happen. The locations where WWTP is proposed are the land which is not used at present or does not provide impacts on people's life. The responsible organization for land acquisition is YCDC and close discussion on the procedures and policies are required. If the land should be acquired, the resettlement action plan or abbreviated resettlement plan should be prepared based on JICA Guidelines.

(2) Land use and utilization of local resources

No impact may be expected on land use and utilization of local resources as the proposed site of WWTP are carefully chosen.

(3) Water quality

The effluent from WWTP and community plant which will be discharged into the drains and rivers should meet the effluent standards.

(4) Waste

The sludge will be generated from the WWTP and community plant. The present generated sludge is used in the parks as fertilizer. In 2040, considerable amount of sludge will be generated, the reuse of sludge in agriculture should be promoted considering safety. Unused sludge should be disposed at the final disposal site.

(5) Odor

The odor may be expected from WWTP and community plant. The location of WWTP and community plant should be carefully chosen and should be away from the residential area. If residential area is near the proposed location, the facilities to mitigate the odor should be considered.

CHAPTER 4. DRAINAGE MASTER PLAN

4.1 Target of Improvement of Inundation

As mentioned in the previous sections, small inundation occurs in Yangon city frequently but YCDC and many residents have no sense of crisis for inundation. Even though its damages are not serious at present, economic damage by inundation will increase in future because of urbanization of Yangon city. Furthermore, it is important to prevent flooding with wastewater from the aspects of hygiene and appearance. Thus, early development of drainage facilities is required to solve inundation problems, and its target is set as follows.

Target Year : 2040

Goals : Elimination of inundation in Yangon city
Inundation in Yangon city central area will be eliminated gradually by target year.

Target Area : Twenty two (22) drainage districts in the central area and CBD
Target areas for inundation improvement are twenty two (22) drainage districts in the central area and CBD. YCDC manages drainage facilities in these areas and should promote drainage system developments mainly.

4.2 Planning Conditions and Basic Policies

4.2.1 Basic Policies

Table S.19 shows general methods for development of drainage system. It is important to consider combination of these methods and coordination with related river plan for effective drainage system planning. For this purpose, coordination with relevant organizations, such as MOAI and DDA, is necessary for confirmation about planning conditions, etc. However, in relevant organizations, these design policies and conditions are not decided yet clearly at this moment. Therefore, in this study, drainage system planning is conducted based on conventional drainage system in order to confirm the project scale.

In the future, it is also required to develop related rules and regulations, by which for instance land development is controlled based on land use plan, installation of run off control facilities by private developers is obligated and ground water pumping causing ground subsidence is controlled to prevent inundation with high tide, for formulation of comprehensive drainage plan.

Table S. 19 Methods of Drainage System Developments

Categories	Methods
Conventional Drainage System	・Pipe/Channel ・Pumping Facility
Run-off Control System	・Storage Facility ・Infiltration Facility
Others	・Development of rules and regulations ・Land use control ・Rainfall information System

4.2.2 Planning Conditions

Table S.20 shows planning conditions for drainage system which is decided based on present conditions of drainage and results of discussions with YCDC.

Since project implementation takes long period, for the time being, it is important to conduct practical measures such as modification of bottleneck channels, dredging sand/sediments and educational campaign for quitting illegal dumping.

Table S. 20 Drainage System Planning Conditions

Items	Adoption	Remarks
(1) Target Year	2040	Coordination with Water Supply and Sewerage Master Plan
(2) Return Period	5 Year	Coordination with MOAI planning conditions (Source: "Study on Drainage System of Mingalar Taung Nyunt Area", Fukken Co., LTD, Nov 2002)
(3) Runoff Analysis	Rational Formula $Q = \frac{1}{360} C \cdot I \cdot A$ Here Q: Peak Runoff (m^3/s) C: Runoff Coefficient I: Rainfall Intensity (mm/hr) A: Catchments area (ha) < Rainfall Intensity formula> $I= 1{,}115/t^{0.7}$ t: Concentration time	<u>Note:</u> It is desirable to adopt long return period for safe drainage system. However, excessive project scale requires too much cost and long project implementation period. Therefore, 5-year is adopted as appropriate return period.
(4) Runoff Coefficient	CBD: 0.8 Other area: 0.4～0.6	Assumption based on population density at 2040
(5) Level of Receiving Water	+3.619 above mean sea level	Highest high water level

4.3 Drainage System Plan

4.3.1 Drainage System Planning

Drainage system development plan worked out based on the above basic policy and planning condition is shown in Figure S.11 and Table S.21.

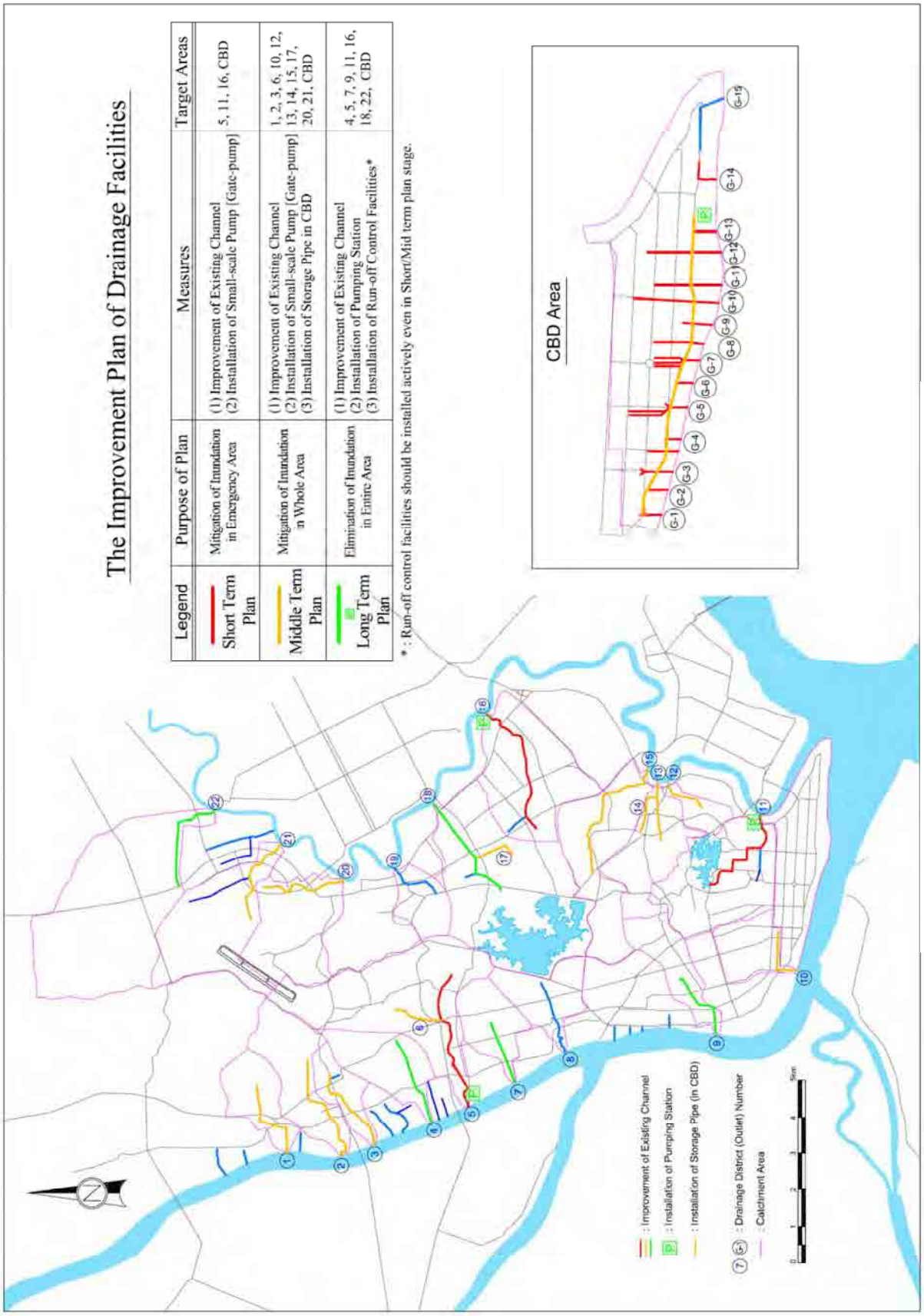


Figure S. 11 General plan of Drainage System

Table S. 21 Summary of Planned Drainage System

No.	Drainage District		Outfall No.	Phasing Plan								Remarks						
				Short Term Plan (～2020) 【Mitigation of Inundation in Emergency Area】		Middle Term Plan (～2030) 【Mitigation of Inundation in Whole Area】			Long Term Plan (～2040) 【Elimination of Inundation in Entire Area】			Pipe/Channel		Pumping Facility				Storage Facility
														Gate Pump		Pumping Station		
				Pipe/Channel	Pumping Facility	Pipe/Channel	Pumping Facility	Storage Facility	Pipe/Channel	Pumping Facility	Storage Facility	Dimension (m)	Length (m)	Design Flow (m3/min)	Nos.	Design Flow (m3/min)	Nos.	Design Capacity (m3)
				・Improvement of Existing Channel	・Installation of Gate Pump	・Improvement of Existing Channel	・Installation of Gate Pump	・Installation of Trunk Sewer	・Improvement of Existing Channel	・Construction of Pumping Station	・Installation of On-site Run-off control facility							
1	CBD以外	Ywa ma Chaung Area	①			○	○				On-site Run-off control facilities should be installed actively together with redevelopment of existing urban area and urbanization of suburbs.	4.50×2.25 ～5.50×3.25	2,770	200	2			
2		Ka thwe Chaung Area	②			○						6.50×3.25 ～8.00×4.00	2,610					
3		Pauk taw Chaung Area	③			○	○					4.50×2.25 ～5.50×2.75	2,460	200	2			
4		Yoe gyi Chaung Area	④						○			6.00×3.00 ～7.00×3.50	2,050					
5		Tha maing Chaung Area	⑤	○	○					○		5.00×2.50 ～10.00×5.00	4,410	200	4	5,370	1	
6		Aung theik Chaung Area	⑥			○						8.50×4.25 ～9.50×4.75	1,250					
7		Pa dauk Chaung Area	⑦						○			5.50×2.75 ～7.50×3.75	1,490					
8		Kamayut Chaung Area	⑧						△			4.50×2.25 ～7.00×3.50	2,360					
9		Kwin Chaung Area	⑨						○			5.50×2.75 ～6.00×3.00	1,840					
10		Ywa thit Chaung Area	⑩			○						4.00×2.00 ～7.00×3.50	1,630					
11		Thebyu Chaung Area	⑪	○	○					○		8.50×4.25 ～9.50×4.75	3,420	200	5	4,470	1	
12		Aung mingalar myopat Chaung Area	⑫						○			3.50×1.75 ～5.00×2.50	1,330					
13		Moemaka Chaung Area	⑬			○	○					5.00×2.50 ～8.00×4.00	1,800	200	1			
14		Nat Chaung Area	⑭			○	○					5.50×2.75 ～6.50×3.25	1,340	200	2			
15		Kunitpinlain Chaung Area	⑮			○	○					7.00×3.50 ～8.50×4.25	4,740	200	3			
16		Kyaiksan Chaung Area	⑯	○	○					○		6.00×3.00 ～9.50×4.75	4,370	200	3	5,300	1	
17		Senyaung Chaung Area	⑰			○	○					8.00×4.00	1,120	200	2			
18		Yeipauk-kyi Chaung Area	⑱						○			8.00×4.00 ～12.00×6.00	3,230					
19		Zwezon Chaung Area	⑲						△			3.50×1.75 ～6.50×2.75	1,320					
20		Shwehle Chaung Area	⑳			○	○					4.00×2.00 ～7.50×3.75	1,990	200	4			
21		Thunandar Chaung Area	21			○	○					5.00×2.50 ～7.50×3.75	4,480	200	4			
22		Danityoe	22						○			6.50×3.25 ～8.50×4.25	9,010					
23	CBD	War Dan St. Area	G-1	○				○ (φ6250mm) (L=4450m) Utilization of Trunk Sewer to PS as Storage Pipe			On-site Run-off control facilities should be installed actively together with redevelopment of existing urban area and urbanization of suburbs.	□2.20×2.20	295					136,500m3 (Mid term Plan) 68,000m3 (Long term Plan)
24		Lanthit St. Area	G-2	○								□2.40×2.40	348					
25		Phone Gyi St. Area	G-3	○								□2.60×2.60	386					
26		Lanmadaw St. Area	G-4	○	○							□3.20×3.20	637	200	1			
27		Bo Ywe St. Area	G-5	○	○							□3.20×3.20	889	200	1			
28		Sule Pagoda Rd. Area	G-6	○	○							□3.20×3.20	1,220	200	1			
29		Maha Bandoola Garden St. Area	G-7	○	○							□2.20×2.20	984	200	1			
30		Pansodan St. Area	G-8	○						○		□2.80×2.80	1,009			2,280	1	
31		Bo Aung Kyaw St. Area	G-9	○								□2.60×2.60	1,164					
32		Thein Phyu Rd. Area	G-10	○	○							□3.40×3.40	1,223	200	1			
33		Bo Myat Tun St. Area	G-11	○	○							□3.00×3.00	1,134	200	1			
34		Bouhtaung Pagoda Rd. Area	G-12	○								□3.00×3.00	1,209					
35		Bouhtaung Rd. Area	G-13	○								□4.40×4.40	1,033					
35		Mya Nandar Yeik Thar St. Area	G-14	○								□4.40×4.40	520					
36		Mya Nandar Yeik Thar St. Area	G-14	○								□3.20×3.20	632					

Note1 : "○" means implementation of each measure

Note2 : "△" means implementation if necessary, based on the status of urbanization

4.3.2 Recommendations from the Environmental and Social Considerations

Most of the drains are stuck by the solid waste dumped into the drain illegally and when the rain starts, it worsens the flooding situation. The houses / huts / buildings are constructed along the drains and it will disturb the cleaning of the drains and expansion of the drains in the future. Thus, for the smooth implementation of the M/P, the following actions should be taken by YCDC.

- Awareness activities to make the people understand the impacts on drains by the illegal dumping, and enhance the changes of attitudes towards the solid waste management, etc.
- Establishment of the laws and regulations to tackle the illegal inhabitants (squatters) and the illegal buildings,
- Compensation payment based on the laws and regulations when the involuntary resettlement may be caused by the expansion of the drains.

4.3.3 Recommendations for Drainage System Development in New Development Areas

Urbanization in Yangon city is spreading. Especially it is remarkable in suburban townships. Since storm water runoff will increase with urbanization, appropriate development of drainage system is required in these areas.

For drainage system development in future, it is effective to employ not only the conventional drainage system, which drains storm water immediately through drainage facilities, but also the runoff control system, which reduces storm water runoff by infiltration and storage.

The runoff control system includes land use management such as control of urbanization based on land use plan and conservation of paddy/green fields for flood control areas. Land development should be controlled by government instructions and regulations to reduce the storm water runoff by appropriate land use. For that purpose, it is important to coordinate with relevant organizations such as river, road and land development departments for formulation of comprehensive drainage system.

Table S.22 shows categories and examples of runoff control facilities.

Table S. 22 Categories of Runoff Control Facilities

Categories		Methods
Storage System	On-site Storage	・Storage at park, schoolyard ・Storage at parking area, open space ・Storage at individual house ・Storage at public land
	Off-site Storage	・Storm water storage pipe ・Storm water reservoir ・Green space for flood control
Infiltration System		・Infiltration trench, street gutter ・Infiltration inlet ・Infiltration pavement etc.

4.4 Operation & Maintenance and Capacity Development of Drainage System

4.4.1 Operation and Maintenance

Drainage sections are organized under each YCDC township office or district office since drainage facilities are located in each township. Water Supply & Sanitation Department in YCDC head office manages database/information of drainage facilities in all townships with a GIS section.

YCDC and township offices shall hire necessary staff members in conjunction with drainage system development. For an efficient organization, outsourcing of O&M works should also be considered if necessary.

4.4.2 Capacity Developments

There is no independent section for drainage management in YCDC at present. To establish the O&M organization for drainage system, YCDC shall hire new staff members in addition to existing staff members coming from water supply & sanitation department. Since newly employed staff members have no skill and experience for O&M works of drainage system, capacity development for new personnel is essential to conduct appropriate O&M works continuously.

A capacity development will be implemented with following steps.

- Assessment of training needs for target staff members
- Implementation of classroom and/or on the job trainings by experts
- Monitoring and evaluation of results of capacity development program

4.5 Project Cost of Improvement of Drainage System

4.5.1 Condition of Cost Estimation

Conditions of cost estimation are the same as those in Section 3.5.2.

4.5.2 Project Cost Estimation

(1) Capital Cost

Non-disclosure Information

Table S. 23 Cost Estimation of Drainage System

Non-disclosure Information

(2) Operation and Maintenance Cost

The required operation and maintenance cost for drainage works is shown below. In the field of drainage works, the annual cost of operation and maintenance except for electricity cost is approximately 4.6 hundred million JPY. This cost consists of annual labor cost and spare parts cost. Electricity cost will be added depending on the operational status of storm water pump and pump gate. The daily electricity cost is 201.5 million JPY, when all proposed pumps are operated full day.

Table S. 24 Annual Operation and Maintenance Cost for Drainage Works

(Unit: Million JPY/Year)

Category	Cost
Labor cost	23.4 (0.3)
Spare parts cost	436.0 (5.2)
Sludge disposal cost	0 (0)
Chemical cost	0 (0)
Others	13.2 (0.2)
Total	459.4 (5.7)

Note: Figures in parentheses are Million USD
* The daily electricity cost is 201.5 million JPY, when all proposed pumps are operated.
Source: JICA Study Team

4.5.3 Financing Plan

Non-disclosure Information

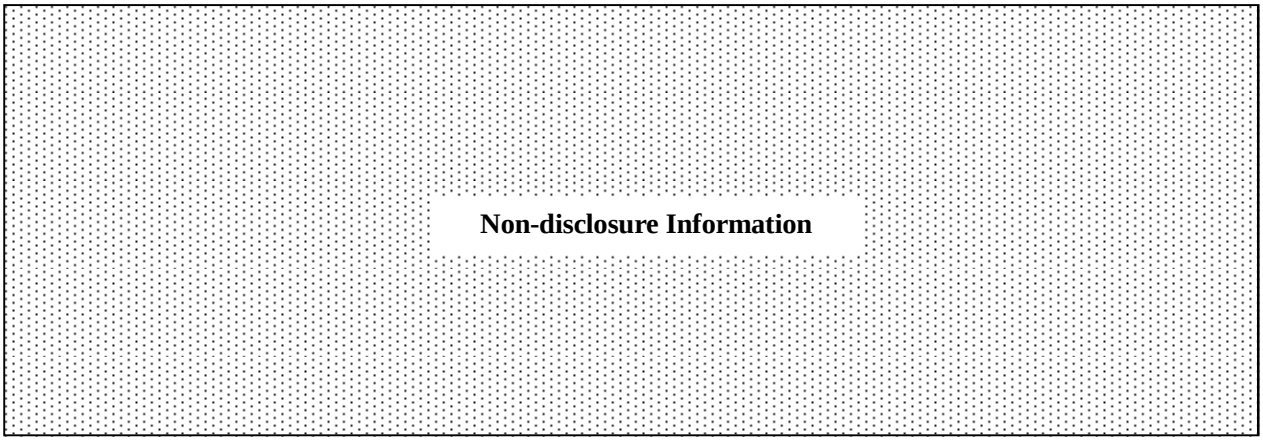
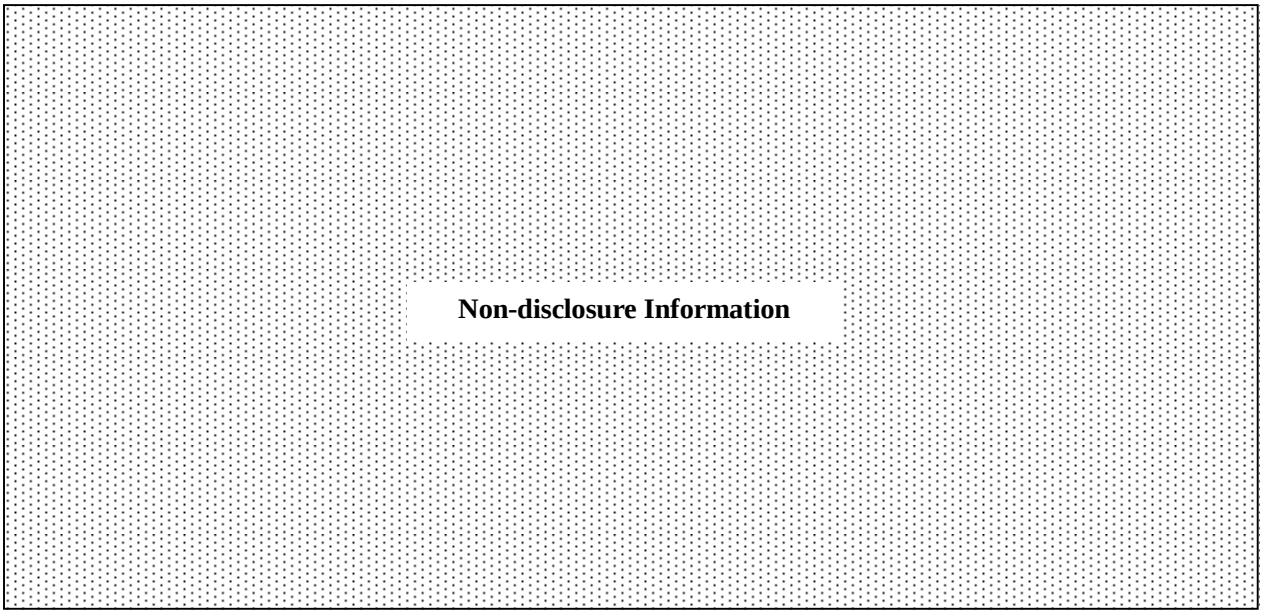


Table S. 25 Investment Cost by Priorities



CHAPTER 5. SEWERAGE AND DRAINAGE FEASIBILITY STUDY

5.1 Scope of the Feasibility Study (F/S)

Objectives of the feasibility study (F/S) include sewerage facilities in C1 sewerage zone. Because C1 sewerage zone is the current sewerage service area, improvements and expansion of the existing systems are to be studied. The existing sewerage system collects and treats only toilet wastewater (black water), and gray water is discharged to storm water drain without treatment. In addition wastewater collecting system is unique so called “ejector system” which was introduced by British in 19th century. Original equipment has been used except for driving system which was transferred from steam engine to electric motor in 1960s. Ejector system was designed based on the design wastewater flow, 14,775 m^3/day and the capacity of the system will be insufficient for the design wastewater flow in 2040. In addition, force main has been used till now far beyond its useful life time, and the deterioration of pipe interior and sediments in pipe cannot be investigated. Procurement of spare parts becomes difficult currently. Taking into account these conditions, entirely new pipe network is to be planned. As regards house connection, existing pits, which are usually provided as one for black water and one for gray water for each building are determined to be used from observation. Branch sewers and manholes to be connected to these pits will be planned and constructed.

On the other hand, civil works of the existing WWTP, which was designed based on extended aeration process, are determined to be used since the plant was commissioned recently in 2006, and site investigation confirmed this. Mechanical equipment will be changed entirely, because useful life time of these components will be expired at expected commissioning of the plant and treatment process will be changed to conventional activated sludge. Exiting structures will be used as much as possible, and expansion is designed to cover insufficient portion.

In addition to the sewerage system in C1 sewerage zone, water quality improvement of Kandawgyi Lake which was requested strongly by YCDC is included in FS. Kandawgyi Lake is a valuable recreation area for citizens of Yangon, which is confirmed in HIS conducted by JICA in 2012. Eutrophication has been progressing in the lake water because of wastewater from households and restaurants in the surrounding areas, and blue-green algae are blooming. Exchange of water cannot be expected even in rainy season, and accumulation of nutrients is progressing. Therefore, to thoroughly improve water quality in the lake, various measures should be taken systematically. Kandawgyi Lake and surrounding areas are included in C2 sewerage zone. C2 sewerage zone is included in sewerage planning area up to 2040, and commission of C2+E1 WWTP is planned in 2027. Thorough water quality improvement cannot be expected until the provision of the sewerage system, temporary measures should be taken to prevent further deterioration of water quality in the lake. Otherwise valuable water resource will be lost. Possible measures, their effects, and costs will be studied here.

5.2 Water Quality Improvement of Kandawgyi Lake

5.2.1 Outline of Plan

Four measures which are considered to be effective for improvement of water quality in the lake, viz. construction of interceptor sewer, installation of Johkaso, dredging of sediment and water transmission from Inya Lake were examined about their feasibility.
In these alternatives, installation of Johkaso and water transmission from Inya Lake poses following problems. Therefore, construction of interceptor and dredging of sediment are proposed.

Installation of Johkaso

- Price of Johkaso is very expensive (for BOD and N/P removal type: 120 million -300 million Kyats/Johkaso）
- Backup power source (e.g. generator) in case of electricity failure is necessary
- Periodical maintenance by trained engineer is necessary
- Establishment of subsidy system and securement of financial resource are necessary

Water transmission from Inya Lake

- Water transmission with 119 MGD capacity is necessary to inhibit reproduction of blue-green algae
- Difficulty of construction of water transmission facility for119 MGD
- Difficulty in securement of water source

On the contrary, interceptor sewer and dredging have following features;

Interceptor sewer

- Small diameter and shallow covering depth
- Construction cost is smaller than usual sewer construction
- Construction period is shorter than usual sewer construction

Dredging

- Commonly used construction machinery (backhoe, raft) can be utilized
- Purchasing of new dredging equipment is not necessary
- Implementation cost is small

5.2.2 Construction of Interceptor

(1) Design Conditions of Interceptor

Design conditions of interceptor sewer facility are as follows.

1) Target facility to be intercepted

Existing drainage channels which discharge wastewater into Kandawgyi Lake are the target of interceptor sewer system. Based on the site survey of existing drains, five (5) drainage channels are selected. In addition, wastewater from restaurants located between the interceptor and the lake is collected.

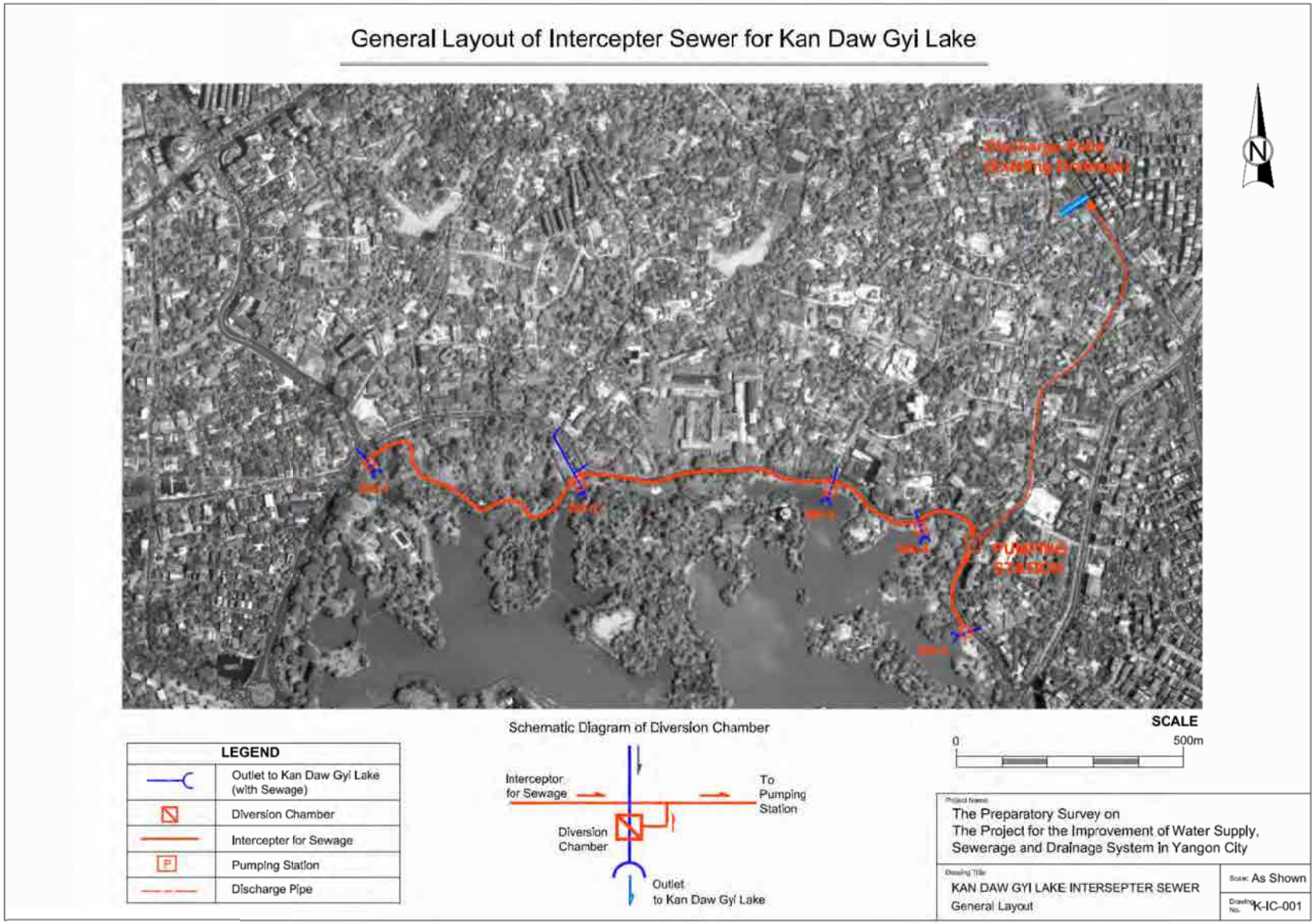
2) Discharge point

Collected wastewater flows into pumping station and is sent to discharge point by pressure pipe. The discharge point should be selected carefully because it has an effect on operation cost of pumping station and untreated wastewater has to be received safely.

The discharge point has been selected upon discussion and confirmation with YCDC.

(2) Facility Design

Locations of interceptor, discharging point and pumping station are illustrated in Figure S.12.



Source: JICA Study Team

Figure S. 12 General Layout of Interceptor Sewer Facility

5.2.3 Dredging

(1) Dredging Work Using YCDC Equipment

1) Capacity of dredging pump

Capacity of dredging pump is as follows;

- Pump capacity: 140-170m^3/h
- Pump head: 20-28m

2) Necessary operation period

Daily amount of dredging sediment

Pump capacity: 140m^3/hour
Operating time: 6 hour /day

i.e. amount of dredging sediment / day is;

Pump capacity: 140m^3/hour × Operating time: 6 hour /day
＝840m^3/day

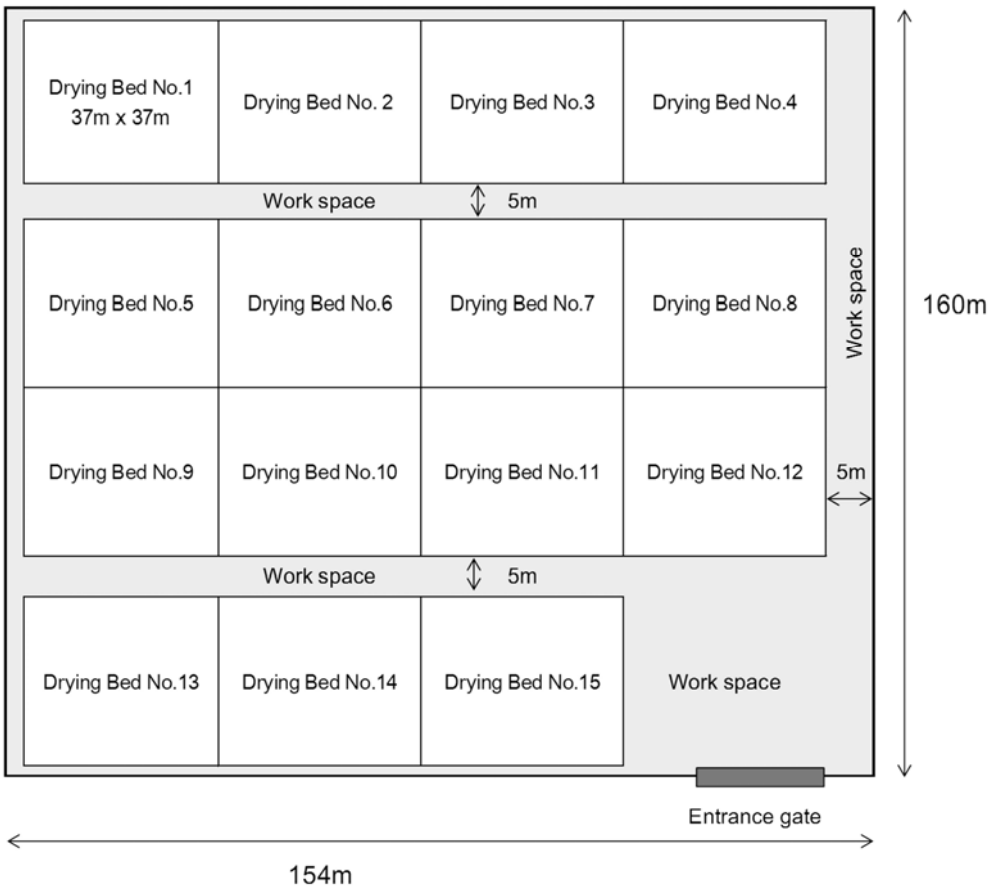
Required dimensions of drying bed

Daily amount of dredging sediment：840m^3/day

Depth of drying bed is 0.6m. Therefore, required dimension of drying bed for one-day operation is;

840m^3/day / 0.6m = 1,400m^2 (approx. 37m×37m)

Total amount of sludge in Kandawgyi Lake is estimated to be 323,749m^3. Therefore, total work period is estimated as 26 work cycles (26 months). Operation period of drying bed is limited within dry season (from November to May, about 6 months). Therefore, 5 years of operation period is required for complete dredging work in Kandawgyi Lake.



Source: JICA Study Team

Figure S. 13 Site Plan of Drying Bed

5.2.4 Cost Estimation

(1) Estimation of Project Cost

Non-disclosure Information

Table S. 26 Project Cost (Interceptor)

Non-disclosure Information

The required O&M cost for operation and maintenance of the proposed facilities for interceptor is shown in the following table. The O&M cost comprises labor cost, electrical cost, maintenance cost and cleaning cost for interceptor. The annual total cost of operation and maintenance is approximately 17.6 thousand USD (1.8 million JPY).

Table S. 27 O&M Cost

Items	Amount（thousand USD/Year）
Labor cost	1.1
Electrical cost	11.6
Maintenance cost	4.3
Cleaning cost for interceptor	0.3
Others	0.3
Total	17.6

Source: JICA Study Team

5.2.5 Economic Analysis

(1) Economy of Kandawgyi Lake

Table S.28 shows the current economic activities and estimated revenues within the park of the Kandawgyi Lake. The estimates are based on the information collected by interviewing the managers of the major business entities on the lake.

The visitors to the park need to pay for entrance. The customers to the hotel and restaurants can enjoy the lake environment without entrance fee. The total estimated expenditure by these visitors is 13 billion Kyat (approximately USD 15 million) per year. The estimate does not include the economic activities that take place in the vicinity of the lake. Thus the total economic domain of the lake is quite large. Even 10% influence to the estimated economic values would equal to the required investment for the project.

Table S. 28 Estimated Number of Visitors and Economic Impacts

Category	Number of Visitors (No/day)	Unit Expenditure (Kyat)	Value (Kyat/day)	Value (Million Kyat/Year)
Park Visitors	2000	300	600,000	219
（Café Visitors）	(800)	2000	1,600,000	584
Restaurants	1300	5000	6,500,000	2,373
Hotel	200	140000	28,000,000	10,220
total	3500		36,700,000	13,396

Source: JICA Study Team

(2) Economic Analysis

The visitor to the lake in 2015 after the completion of the project is assumed to be 3500 visitors per day as is the case at present. However, due to the mid-year completion date, the annual visitors will be halved. Thereafter the number of visitors is assumed to increase at 2% per year. The economic benefit per visitor is assumed to be 300 Kyat, regardless of type of visitors. Those who stay at the lakeside hotel spend prolonged hours and are willing to pay a much higher premium to the improvement. However, taking the lower value indicated by the interview survey conforms to the conservativeness principle of economic analysis.

The project period is assumed as 40 years after the completion of the project. The Economic Internal Rate of Return, EIRR, is 18% according to the cash flow. The result indicates a good economic

viability of the project.

(3) Financial Analysis

Sewerage Tariff

It requires thorough discussion among stakeholders whether it is possible to collect some kind of tariff from the residents or entities that discharge wastewater into the lake. The proposed project does not treat the wastewater but only divert it from the lake. Nevertheless, the project will reduce the pollution in the lake that is so close to the heart of the citizens. For financial analysis, the tariff is set at USD 0.02/m^3 to the residents that are currently discharging wastewater into the lake. Based on the tariff, financial cash flow is worked out and the financial return on investment (FIRR) is calculated to be 1.6%. The return is marginally positive on the investment. Therefore, the project is feasible as a public project with financing by soft loans such as provided by the Japanese government.

The parties that would benefit most from the improvement of the water quality in Kandawgyi Lake are the business entities providing services to the visitors to the lake such as restaurants. An option in tariff setting is to limit the charge to the commercial entities in and around the lake. A financial simulation with a target of 10% FIRR, the tariff only levied to the commercial sector would have been as high as USD 0.57/m^3. The simulated tariff may be too high to be implemented.

5.3 Improvement of Sewerage System in C1 Sewerage Zone

5.3.1 Design Conditions and Basis

(1) Basis for Design

Basis for facility design is shown below.

Table S. 29 Basis for Facility Design

Items	Basis
(1) Target Year	2040
(2) Service Area	499 ha
(3) System	Separate system
(4) Service population	178,129 person
(5) Design flow	64,300 m^3/d (Daily Average) 70,200 m^3/d (Daily Maximum) 102,900 m^3/d (Hourly Maximum)
(6) Design Sewage Characteristics	BOD_5 200 mg/L SS 180 mg/L

Source: JICA Study Team

(2) Expansion of WWTP Site

Construction site for C1 WWTP is shown below. The existing WWTP site will be expanded to 3.9 ha. Yangon city mayor is now requesting acquisition of expansion area to government.

Source: JICA Study Team

Figure S. 14 Construction Site for C1 WWTP

5.3.2 Design of Sewer Net Work

Layout plan of trunk mains in C1 sewerage zone is shown in Figure S.15.

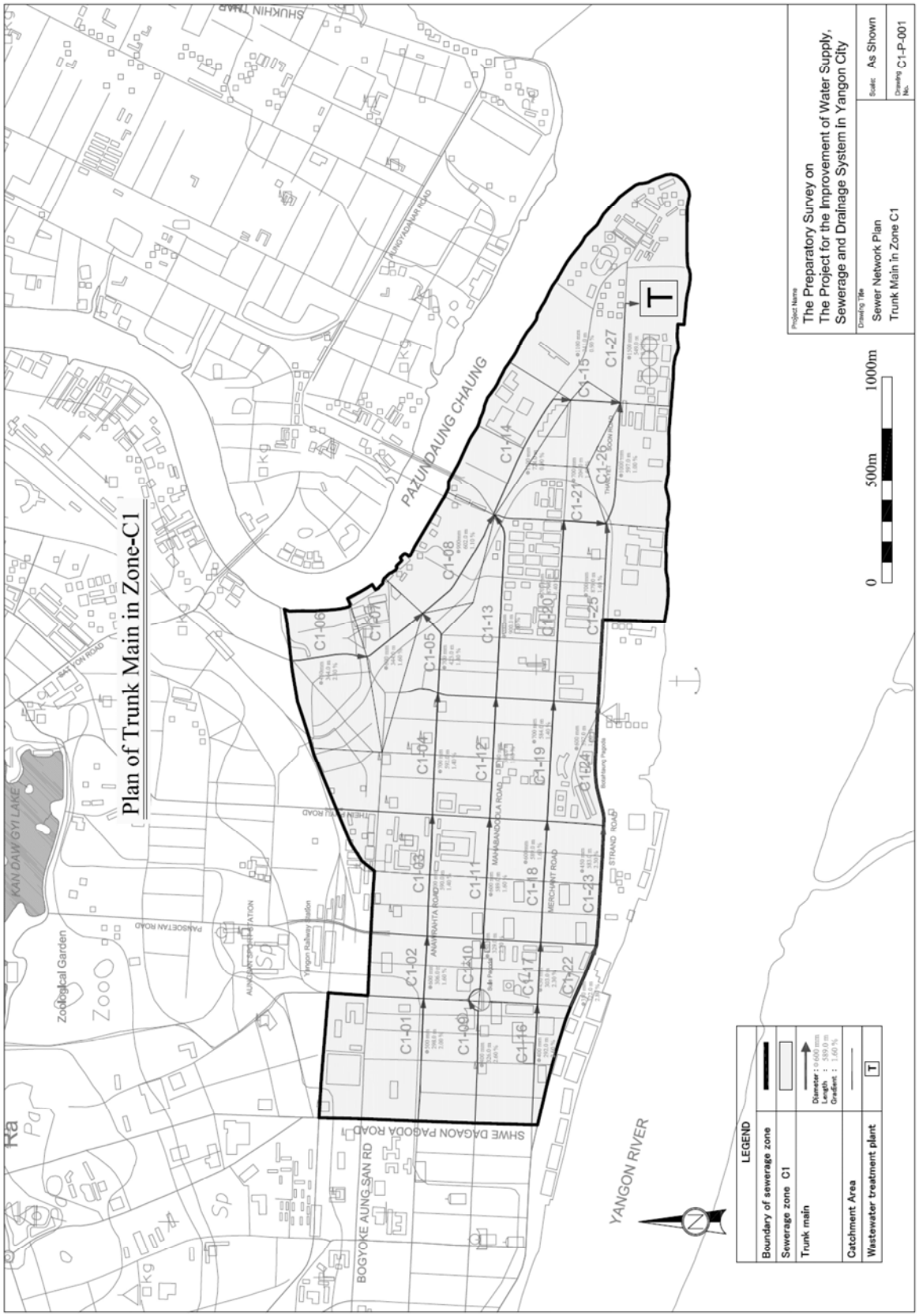


Figure S. 15 General Layout of Trunk Main in C1 Sewerage Zone

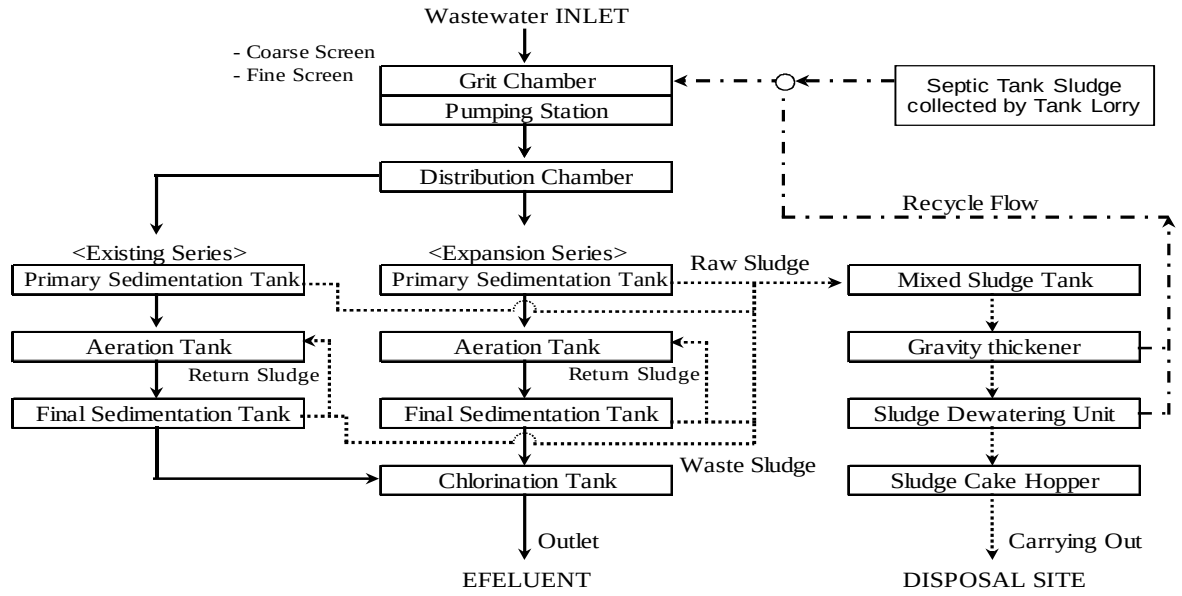
Source: JICA Study Team

5.3.3 WWTP Design

(1) Basis for Design

1) Selection of Treatment Method (Wastewater and Sludge)

Flow diagram of C1 WWTP is shown below.

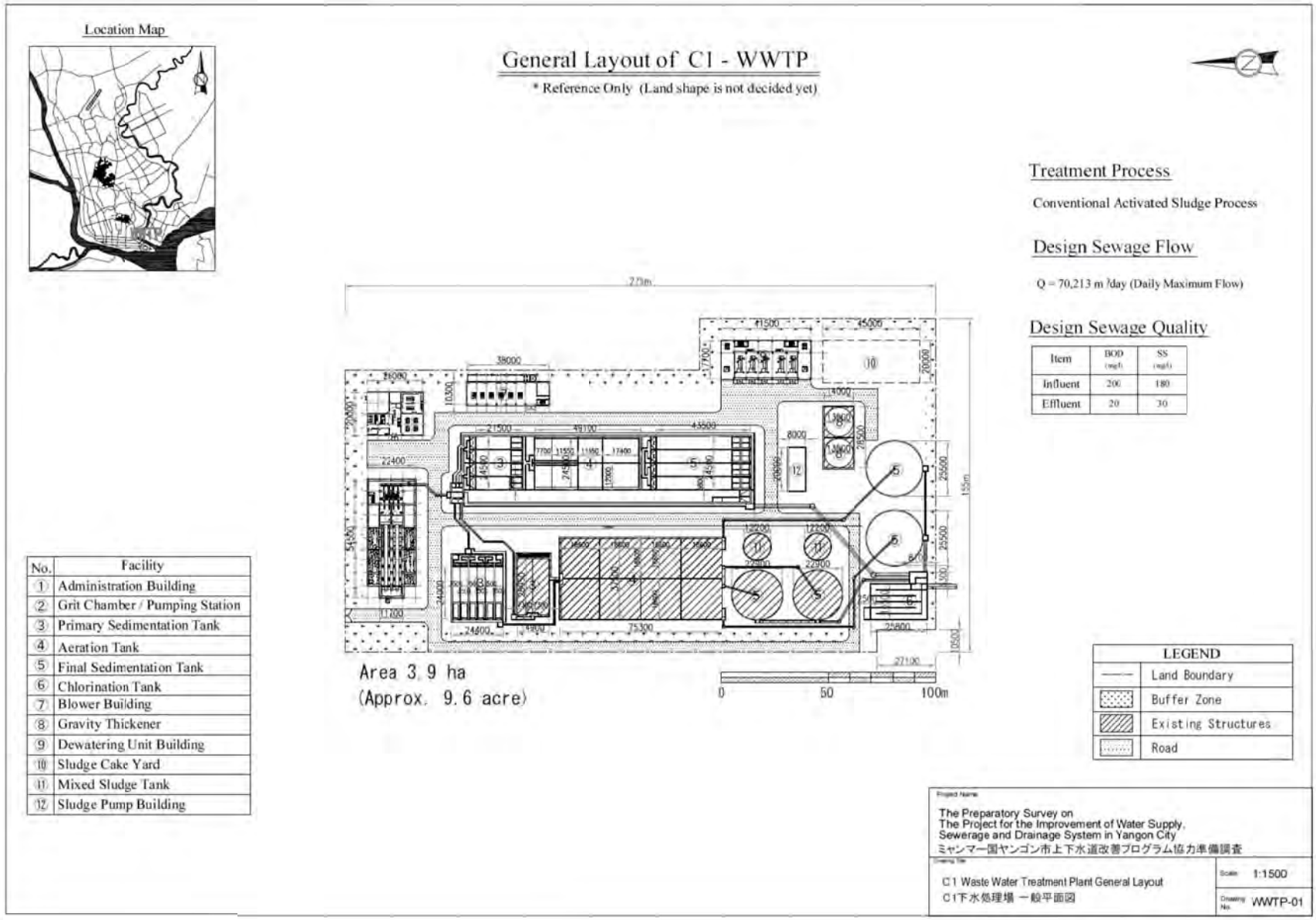


Source: JICA Study Team

Figure S. 16 Flow Diagram of C1 WWTP

(2) WWTP Facility Design

General layout plan of C1 WWTP is shown in Figure S.17.



Source: JICA Study Team

Figure S. 17 General Layout of C1 WWTP

5.3.4 Cost Estimation and Implementation Schedule

(1) Condition of Cost Estimation

Based on condition mentioned below, the Project cost is estimated.

- The project cost comprises construction cost, administration cost, consulting cost, contingency (physical and price escalation), land acquisition and compensation, interest during construction, commitment charge and relevant tax.
- The project cost is composed of the local currency potion (L.C.) and foreign currency portion (F.C.).
- Administration cost in recipient country is assumed to be 5.0 percent of the construction cost.
- Consulting cost is estimated based on man-months of consulting services.
- Physical contingency is considered as 5.0 percent of total of construction cost, consulting cost, land acquisition and compensation.
- Price escalation of 6.1 percent per annum for the local currency portion and 1.2 percent per annum for the foreign currency portion are applied based on implementation schedule.
- The base period of cost estimation is June 2013 and the exchange rate considered is 1 Kyat=0.114 Yen, 1 USD=101.1 Yen and 1USD=885Kyat.
- Interest during construction is estimated taking into consideration that Project cost is financed by Japanese ODA loan. (Loan condition: Preferential terms / Standard, Interest rate of main components=0.01%, Interest rate of consulting services=0.01%, Repayment period=40year, Grace period=10year)
- Commitment charge is not added.
- Instead of VAT, commercial tax rate is added in Myanmar and rate is 10%. Import tax is 2.0%.
- Construction cost, consulting cost, contingency (physical and price escalation) are eligible portions while interest during construction, administration cost, land acquisition and compensation, and relevant tax are non-eligible portions taking into consideration that Project cost is financed by Japanese ODA loan.
- Project cost will be determined based on JICA's guideline at the time of loan and it has possibility to change.

(2) Condition of Construction Cost

- It is possible to procure civil and building material, labor and construction machine within the country and the procurement in local country is set as basic policy for project cost estimation.
- The mechanical and electrical equipment is basically procured from overseas including third country; such as European Union (EU) etc. The equipment will be procured with consideration of

quality, performance, economical efficiency and O&M, etc.

- The local contractors have enough experiences and ability of normal civil engineering work. On the other hand, they are not experienced in the specialized project regarding water supply and sewerage. However, Japanese experts and foreign experts are staffed in implementation system of the Project and construction is conducted by the local contractor.
- The local contractors don't have any experiences in the construction methods of pipe jacking and shield. The unit cost of these construction methods is collected from Thailand where many contractors have relevant experiences.
- The construction plan is established with the considerations of local natural condition (topographic aspects, geotechnical condition and meteorological condition) and legislation/custom.

(3) Cost Estimation of the Project

Non-disclosure Information

Table S. 30 Project Cost

Non-disclosure Information

(4) Implementation Schedule

If the Project is financed through Japanese ODA loan, the Government of the Republic of the Union of Myanmar must follow JICA procurement guidelines for the selection of the consultants and contractors to implement the Project.

Implementation schedule starting from signing of Loan Agreement has been developed as shown in Table S.31 taking into account necessary steps that would be required. Implementation of the project has been estimated to extend over 105 months (8.8 years) in total. Herewith Loan Agreement should be signed in the beginning of 2014 for operation to start in 2022.

Table S. 31 Implementation Schedule

	Period	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Signing of L/A	-									
Selection of Consultant	9 months									
Detailed Design	15 months									
Preparation of Specification & Bidding Documents	11 months									
Selection of Contractor	10 months									
Construction Works	68 months									
Trial Operation Period	12 months									

Source: JICA Study Team

(5) Estimation of O&M Cost

The required operation and maintenance cost for sewerage works is shown below. The O&M cost comprises labor cost, electrical cost, maintenance cost (check and repair), sludge cake disposal cost, consumable supplies cost and other cost. The annual total cost of operation and maintenance is approximately 1,118 thousand USD (110 million JPY).

Table S. 32 O&M Cost

Items	Amount（thousand USD/Year）
Labor cost	40.9
Electrical cost	281.6
Maintenance cost	543.6
Sludge cake disposal cost	89.2
Chemical cost	100.5
Cleaning cost for sewer	41.4
Others	21.1
Total	1,118.3

Source: JICA Study Team

(6) Organizational Structure for Implementing the Project

An organizational structure for the Project consists of Project Executing Agency (PEA), Project Management Unit (PMU), and Project Coordination Committee (PCC) and is shown in Table S.33.

Table S. 33 Project Organization and Their Responsibility

Project organization	Institutions responsible	Role and responsibility
Project Executing Agency: PEA	YCDC DEWS	• Comprehensive management of project implementation according to a loan contract • Allocation of budget • Guidance to project management unit
Project Management Unit: PMU	YCDC DEWS	• Project management • Supervision • Monitoring and coordination • Budgetary management
Project Coordination Committee : PCC	Regional government, YCDC, Ministry of Environment, Ministry of Construction	• Project coordination for planning and implementation

Source: JICA Study Team

5.3.5 Capacity Development Plan

Considering succeeding 5 or 10 years after, there are various areas in technical, managerial and financial for capacity development of staff members in sewerage division.

In sewerage and drainage sector, the main areas for capacity development of sewerage division for short-term up to 2025 are summarized as following table. Priority is given to the training areas in the range of high and low.

Table S. 34 Necessary Training Areas for Capacity Development of YCDC

Large	Small	Training Subjects for Capacity Development	Priority		
			High		Low
Technical Capacity (Technical Aspect)	General	1. Sewerage treatment basic	●		
		2. Development of assets database of sewerage facilities	●		
		3. Information management system （SCADA）			●
	Design	4. Design of sewers pipeline facilities			●
		5. Design of wastewater treatment facilities			●
		6. Design of electrical and mechanical equipment			●
	O&M	*O&M of treatment and pumping facilities*			
		7. - Development of wastewater treatment and sludge treatment plan	●		
		8. - Development of an operational plan for equipment	●		
		9. - Recording and management of operation (daily, monthly, yearly)		●	
		10. - Development of repair and maintenance of mechanical and electrical equipment		●	

Large	Small	Training Subjects for Capacity Development	Priority		
			High		Low
		11. - O&M of mechanical and electrical equipment		●	
		12. - Development of rehabilitation and renovation work plan		●	
		13. - Continuous and efficient management of treatment facilities			●
		O&M of pipeline facilities			
		14. - Inspection and survey of pipeline infrastructure		●	
		15. - Cleansing and dredging of pipeline facilities		●	
		16. - Rehabilitation and repair of pipeline facilities		●	
		17. - Recording and management of O&M		●	
		18. - Continuous and efficient management of pipeline facilities			●
		19. Development of O&M manuals	●		
	Water quality management	20. Development of water quality management plan	●		
		21. Usage and O&M of water quality analysis equipment		●	
		22. Implementation of water quality test		●	
		23. Implementation of industrial effluent characteristics test		●	
		24. Recording and analysis of water quality data and reporting			●
Core-Capacity（Non-technical Aspect）	Institutional issues	25. Organizational arrangement and expansion	●		
		26. Definition of duties and responsibilities	●		
		27. Human resource management		●	
		28. Human resource development plan		●	
		29. Good governance and prevention of corruption			●
	Management / Business efficiency	30. Development of plan and strategy for short-, middle- and long-term.	●		
		31. Setting of performance indicators (PIs) and waterworks management	●		
		32. Performance monitoring and evaluation	●		
		33. Computerization of business operation, and processing and editing of data		●	
		34. Quality management（ISO9001, ISO14001）			●
		35. Public procurement management and construction supervision			●
		36. Industrial health and safety			●
	Financial performance	37. Budgetary planning for wastewater treatment	●		
		38. Consideration of sewerage tariff policy	●		
		39 Socio-economic situation of local people and sewerage tariff	●		
		40. Setting of sewerage tariff rates and cost analysis, projection of profit and loss		●	
		41. Billing and collection of sewerage tariff			●
		42. Assets management			●
	Public & Society	43. Social responsibility and accountability	●		
		44. Customer service and public relation	●		
		45. Household awareness survey (public health, development of sewerage facilities, existing sewerage work service)	●		
		46. IEC activities to residents on public health and environmental conservation	●		
		47. Development of IEC materials	●		
		48. Public awareness of improved septic tank/ on-site compact treatment facilities (Johkaso) and PR activities of a funding subsidy system		●	
		49. Public awareness on development of sewerage system			●
		50. Guidance of installation of small-scale wastewater treatment facilities (e.g. community plant) (large scaled development area)		●	
		51. Guidance on installation of wastewater treatment facilities for high rise building		●	
		52. Participatory development and gender			●
Surrounding Environment	Law & regulatory system	53. Establishment of policy, laws and regulatory framework on sewerage and drainage sector	●		
		54. Law and regulatory framework of planning, construction, operation, management and supervision for wastewater treatment facilities (including sewerage)	●		
		55. Standards and institutions of improved septic-tank/ on-site	●		

Large	Small	Training Subjects for Capacity Development	Priority		
			High		Low
		compact treatment facilities (Johkaso)			
		56. Establishment of by-law/ ordinance on sewerage		●	
		57. Regulation on water quality standards for public water bodies and effluent standards		●	
		58. Regulation on development activities		●	
		59. Laws and regulations related to solid waste treatment and on environmental pollution （Air pollution prevention, noise regulation, vibration regulations, hazardous odor prevention, etc.）		●	
		60. Establishment of by-law/ ordinance on sewerage tariff setting		●	
	Enhancement of monitoring & regulation	61. Enhancement of monitoring and regulation of water quality standards for public water bodies and effluent standards			●
		62. Enhancement of monitoring and regulation of development activities			●

Source: JICA Study Team

5.3.6 Economic Analysis

(1) Economic Benefit

The economic benefit used for economic analysis is based on the value of willingness-to-pay (WTP) following standard economic welfare theories.

A general rule of thumb in analyzing affordability-to-pay for water and sewerage tariffs is the expenditure of 3-5% of income. It is assumed that the economic willingness-to-pay will be close to the upper value of 5% of income. For economic analysis, the demand for water changes every year, thus the fixed monthly value needs to be converted to a unit volumetric value. According to the HIS, the average size of the household is 4.3. Using the current water consumption of 100 liters per person per day, the demand curve to the volumetric tariff is derived. The average tariff WTP for water and sewerage is 937Kyat/ m^3 by dividing the average WTP for water and sewerage of 12,950 Kyat/household/month by the household size of 4.3, 100 liter consumption per day per person, and 30 days. The tariff is then divided by 1:0.8 between water and sewerage to arrive at 418 Kyat/ m^3 or USD 0.47/ m^3 for sewerage economic benefit in 2013. At present the tariff for household is set at 88 Kyat/ m^3 while that for commercial customer is 110 Kyat/ m^3. Applying the same price differential of 1.25 to the household value, the commercial benefit value in 2013 is USD 0.59/ m^3.

(2) Economic Analysis

Economic analysis requires the development of cash flow table over the project period of 40 years, comprising of cash inflow from tariff revenue, the cash outflow by investment and OM expenditures. The net cash flows are calculated by taking the difference between the cash inflow and cash outflow.

The evaluation indicator of Economic Internal Rate of Return is the discount rate that equates the net present value of the net cash flows to zero. First, the operation costs are calculated based on the treatment volume of wastewater. The cash outflow is calculated by adding OM costs to the investment costs. The tariff revenue, cash inflow, is calculated by tabulating the revenues from household and commercial customers by multiplying each tariff to the corresponding forecast water demands.

The EIRR is calculated to be 6.3%. In comparison to a standard benchmark of 12% for public projects, the return is half the level of the benchmark. One important reservation is that the evaluation is based on the WTP benefit of individuals and does not include economic external benefits of environmental protection or public health improvements. Also the WTP is predicated on the current income level. At a low income level, the people will place higher priorities for economic development over environmental protection. In many cases, environmental degradation is irreversible and it would be too late to wait for economic development in the future. It is important to embody environmental policy early on for cities such as Yangon which expect rapid urbanization and economic development.

5.3.7 Financial Analysis

(1) Financial Affordability to Pay

In case of assuming affordability, the benchmark will be set at 80% of the residents who can afford the payment for water and sewerage. The tariff set affordable for the bottom 20% income group is affordable for 80% of the city. The income level of bottom 20% of the respondents from HIS is 105,000 Kyat/month. If 4% of income is expendable for water and sewerage, the limit would be 4,200 Kyat/month in total. The average household size is 4.3 and assuming 100 liter per day per person consumption, the volumetric tariff limit would be 326 Kyat/m^3. Allocating the tariff between water and sewerage with-1: 0.8 allocation ratio, the maximum limit for sewerage tariff would be 145 Kyat/m^3, equivalent to USD 0.16/m^3. Since the commercial tariff is set at 1.25 times higher than household tariff, the same ratio is applied for the commercial tariff. The tariffs[2] adopted for financial analysis are USD 0.16/m^3 for household and USD 0.20/m^3 for commercial customers on the basis of the year 2013.

(2) Financial Evaluation

In order to derive financial return on investment, the financial cash outflow, inflow, net inflow are tabulated over the project period of 40 years after commissioning. The financial internal rate of return

[2] Financial simulations undertaken in the Master Plan are based on the initial tariff of US 0.08/m^3 and constant annual rate of increase. The framework is based on the notion that there are a series of projects that are scheduled in later stages, thus the future income growth has to be incorporated over the time. The evaluation for C1 district is based on the assumption that the project will be undertaken immediately, thus the prices are fixed at the prevailing prices of 2013 and income levels of the customers without incorporating the future income growth.

on investment (FIRR) is -1.2%. The evaluation result indicates that it is difficult to recover the investment and operation costs solely with tariff revenue of USD 0.16/m^3. As the column for the net cash inflow suggests, the sustained operation is quite possible solely with the tariff revenue as it shows surplus in regular years.

(3) Sustainable Tariff Setting

Sewerage tariff is required to sustain sewerage project calculated for each of the following three cases. Results are described in Table S.35.

1) Tariff revenue balances the O&M cost for 2025, zero subsidy from government
2) Tariff revenue recover investment and O&M cost by 2053, zero subsidy from government
3) Tariff revenue recover investment and O&M cost by 2053, subsidy from government 50 % of investment

Table S. 35 Financial Goals and Required Tariffs

Financial Goals	Target Year	Capital Subsidy	Tariff （USD/ m^3）	
			Household	Commerce
Revenue/OM Cost Balance	2025	0%	0.07	0.09
Zero Liability	2053	0%	0.23	0.29
Zero Liability	2053	50%	0.15	0.18

Source: JICA Study Team

(4) Tariff Setting Strategy

Currently YCDC does not charge any tariff for sewerage services, YCDC charges 88 Kyat for water and nothing for sewerage service. Small population coverage of less than 6% of the population of the whole city of Yangon makes it possible to offer free service.

The reasons why the developing countries fail to impose sewerage tariff are that people are willing to pay for water but throwing out wastewater is someone else's problem. However, water pollution accumulates, as sedimentation of polluted sludge at the bottom of sea or river.

The following four elements of sewerage tariff strategies are proposed.

- Introduce Small Fee Immediately
- Charge it with Water Bill Together
- Create Public Awareness for Environmental Protection
- Increase Sewerage Tariff Keeping Pace with Economic Development

5.3.8 Project Evaluation

(1) Summary of Economic and Financial Analysis

In summarizing the project evaluations, the Economic Internal Rate of Return on Investment of the project is 6.2% while the Financial Internal Rate of Return on Investment is 0.98%. The value for the EIRR is relatively high for a sewerage project. However amongst other public investment projects in the country it is less than the standard level of EIRR. However, there is a large economic externality to a sewerage project. Therefore the evaluation by WTP alone may not even cover the half of the social benefits that the project may generate. The following discussion will add these extra dimensions to the project evaluation on less quantifiable merits. These benefits include environmental protection benefits, improvements in public health and boosting of location values of the areas with access to sewerage.

(2) Economic Externality of Environment Protection

A large portion of an environmental project's benefits accrues to the society as a whole beyond each customer. Individuals can enjoy life so long as solid waste and wastewater is disposed. However as seen above, it is difficult to cover the full cost of the project through tariff revenues. Therefore, delays in implementation may lead to the deterioration of environment. Viewed from an overall societal well-being, there may be more negative effects. In fact, the histories of advanced countries demonstrate the tragedy of inaction to environmental protection. Often true WTP for environmental protection reveal itself after the destruction of environment becomes evident. It is no more than hindsight. However, it is difficult to impose high tariffs to individuals when income levels are still low without clear perception of risks in the future. In Japan, for example, the government has provided a subsidy of approximately 50% to the investment costs to provide incentives for early implementation of sewerage projects.

(3) Rise in Land Values and Fundamentals for International City

Yangon is now witnessing once in a century land speculation period. With international attention focused on Myanmar as the last frontier in Asia, expectation for the future rental values of land in Yangon has increased by a large degree. Faced with rising land prices, the existing owners will withhold their land for future price gains. Speculators try to purchase land also for future gains. Once speculative motives start to prevail, the prices embark on a upward spiral. Though the project may affect increases in land values, but it is difficult to forecast the land prices impacted by the project under the present volatile market.

From a perspective of economic development policy, it should be noted that lack of access to sewerage in the international district of the capital city deprives the investors of fundamental urban amenities. Foreign investors and businesses catering for foreigners may be forced to make an extra investment for sewerage treatment and disposal. Such an extra investment may reduce the investment incentives. Promotion of foreign investment is one of key economic development policies in Myanmar at present. Provision of modern sewerage service to foreign investors will not only provide the amenities but also will present a great showcase to display the societal capacities of Myanmar.

5.4 Environmental and Social Considerations

During construction of the priority project, some effects are envisaged such as traffic disturbances, accidents, air pollution, wastes, and noise/vibration. However, these effects are limited for construction period and can be mitigated by proposed mitigation measures. During operation of the facilities, generation of sludge and noise/vibration is expected. However, these effects can also be mitigated by mitigation measures. In addition, monitoring based on the monitoring pan is necessary.

5.5 Conclusion and Recommendations

Feasibility study was conducted on the first priority sewerage project, i.e. improvement of the sewerage system in C1 sewerage zone, and on the water quality improvement in Kandawgyi Lake project which was requested by YCDC. C1 sewerage zone is included in CBD, and bustling area of Yangon city where central and local government buildings and high rise commercial buildings such as high class hotels and shopping centers exist. On the other hand, Kandawgyi Lake is a small lake located in the center of the city and provides citizens of Yangon with valuable recreation area together with surrounding park and restaurants.

Kandawgyi Lake has been eutrophicated due to wastewater inflow from surrounding areas and restaurants and blue-green algae bloom in lake has resulting in emission of foul smell. Water quality in the lake will be worsened unless countermeasures are taken resulting in loss of valuable asset. In order to control eutrophication of the lake, interception of wastewater inflow and at the same time removal of nutrients already accumulated in the lake is essentially required. Provision of sewerage system is the ultimate solution for purification of lake water. However, it requires large amount of investment and several years to provide sewerage system. Therefore, temporary measures such as interceptor sewer facility and dredging are planned in the study. It takes a few years to realize effects of the project, nutrients level will be lowered less than eutrophication level and blooming of blue-green algae will be prevented.

Interceptor sewer facility is proposed for improvement of water quality in Kandawgyi Lake. However,

it is clarified that water level in the lake would be lowered in dry season when this system is in operation. Transmission of water from Inya Lake and/or keeping higher water level in rainy season should be considered. In case interceptor sewer facility is constructed, water level control plan should be considered in advance.

C1 sewerage zone is included in the existing sewerage service area. However, the existing system has serious problems and does not function properly. Firstly, the existing system collects only black water and gray water is discharged to drains and finally to the river without any treatment. Ejector system which collects wastewater was constructed in 19th century and has been used until now with occasional minor repairs. Corrosion of the force main is about a matter of concern, but investigation is difficult to find real conditions. Procurement of spare parts is difficult because of obsolete system. Taking into account increased future wastewater flow, it is determined that the existing ejector system is abandoned and new sewer network is to be constructed because rehabilitation of the existing system is uneconomical. On the other hand, the existing wastewater treatment plant is relatively new, completed in 2005, and investigation revealed that most of civil structures can be utilized in future. Therefore, existing facilities should be used as much as possible and new facility which meets shortage of the capacity is to be constructed. When entire planned sewerage facilities are completed all wastewater generated in C1 sewerage zone is collected and treated resulting in improvement of citizens living conditions and water quality in the river.

Construction cost of sewerage facilities in C1 sewerage zone is estimated to be [redacted] USD, and total project cost is [redacted] USD. This estimation was made based on introduction of low interest loan and includes tax and duty levied in Myanmar. The site for WWTP is to be expanded, however land acquisition cost is not included because the site for expansion is government property. Operation and maintenance cost is estimated to be 1.1 million USD/year. It takes 68 months (5 years and 8 months) for construction of the sewerage system, and total project period including detailed design, selections of consultant and contractor, technology transfer and so on is estimated to be 117 months (9 years and 9 months). Total cost of Kandawgyi Lake water quality improvement is estimated to be [redacted] USD which is only for interceptor sewer facility since dredging is carried out by YCDC. Operation and maintenance cost is estimated to be 18,000 USD/year. It takes 1.5 year from commencement of detailed design to complete construction.

Project evaluation for C1 sewerage zone shows that EIRR is 6.25% and FIRR 0.98%. The EIRR for Kandawgyi Lake Project is 18% and the FIRR is 1.6%. The tariff for sewerage is not levied to the customer. However, it is highly desired to introduce the tariff at the earliest point in view of long-term sustainability of sewerage operation. If the government is willing to cover the investment cost for C1 sewerage zone, the required tariffs to pay off the operation and maintenance costs are USD 0.07/m^3 for household and USD 0.09/m^3 for commercial customers. On the other hand, if all the investment is to

be recovered by tariff itself over 40 years after commissioning, the required tariffs are USD 0.23/m^3 for household and USD 0.29/m^3 for commercial customers. Given the economic externality that sewerage projects impart to the maintenance of social environment, advanced countries also provide subsidies to the development of sewerage system. If the government provides money for half of the investment and the rest is left for the tariff to recover over 40 years, the required tariffs are USD 0.15/m^3 for household and USD 0.18/m^3 for the commercial customers.

Sanitation division of DEWS is in charge of operation and maintenance of the existing sewerage system and providing approval of on-site treatment systems. However the division does not have any experience of planning and implementation of full scale sewerage system development. Further, legal and institutional system for sewerage system development is not provided sufficiently. Therefore, institutional strengthening of YCDC together with cooperation with the central government for development of legal system should be carried out. Low interest loan such as Japanese Yen Loan should be introduced for development of sewerage system in C1 sewerage zone taking into account magnitude of required amount of investment. Consultation with the central government in this regard is recommended and necessary actions should be taken. It takes some time to realize loan proceedings, earliest action is desirable. Moreover, for development of sewerage system, at early stage of development in particular, subsidy from the central government is considered to be indispensable. YCDC should appeal to the central government to establish subsidy system. In addition, appropriateness of sewerage tariff from beneficiary should be confirmed, its collection system should be investigated and policy for these should be determined. It is recommended that YCDC should request JICA's assistance for establishment of legal system, institutional strengthening and introduction of sewerage tariff.