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

PREPARATORY SURVEY FOR GREATER YANGON WATER SUPPLY IMPROVEMENT PROJECT (PHASE II)

FINAL REPORT

FEBRUARY 2017

JAPAN INTERNATIONAL COOPERATION AGENCY

TEC INTERNATIONAL CO., LTD.
NIPPON KOEI CO., LTD.
NJS CONSULTANTS CO., LTD.

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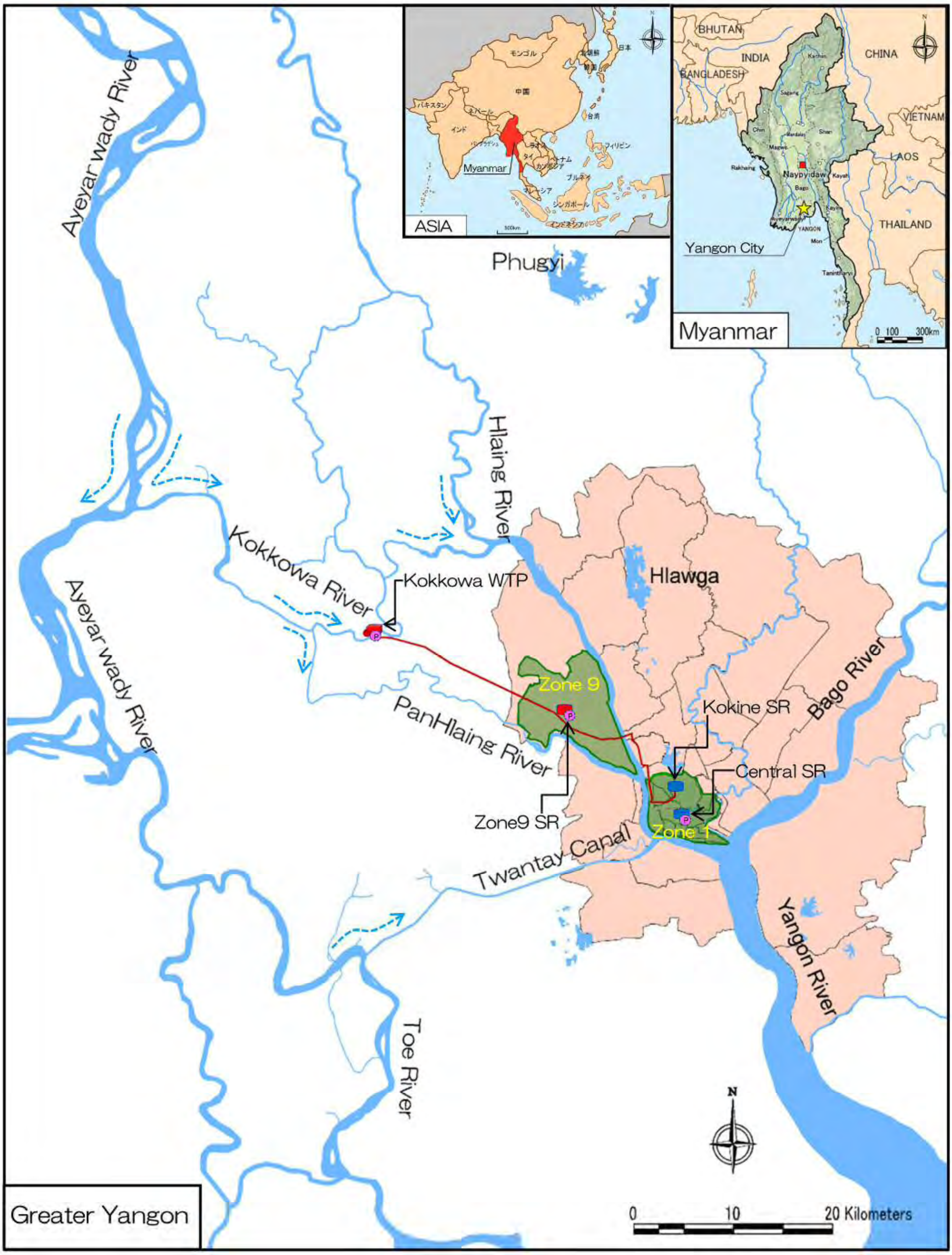
Foreign Exchange Rate

1 USD = 109.2 JPY
1 USD = 1183.0 Kyat
1 Kyat = 0.0923 JPY
(As of July 2016)



Location Map

<u>**Map of 33 townships in YCDC Area and 10 Water Supply Zones**</u>

PREPARATORY SURVEY FOR GREATER YANGON WATER SUPPLY IMPROVEMENT PROJECT (PHASE2)

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ACE	Assistant Chief Engineer
ACH	Aluminum Chlorohydrate
ACP	Asbestos Cement Pipe
ADB	Asian Development Bank
AE	Assistant Engineer
ARAP	Abbreviated Resettlement Action Plan
B/C	Cost Benefit Ratio
BOT	Build-Operate-Transfer
CAPEX	Capital Expenditure
CBD	Central Business District
CE	Chief Engineer
CIP	Cast Iron Pipe
DB	Design Build
DBO	Design Build Operation & Maintenance
DCIP	Ductile Cast Iron Pipe
DICA	Directorate of Investment and Companies Administration
DMA	District Metered Area
Dy CE	Deputy Chief Engineer
EC	Electric Conductivity
ECC	Environment Conservation Committee
EDWS	Engineering Department (Water & Sanitation)
EE	Executive Engineer
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
FC	Foreign Currency
FIL	Foreign Investment Law
FIRR	Financial Internal Rate of Return
FS	Feasibility Study
FY	Fiscal Year
GIS	Geographical Information System
GL	Ground Level
GL	Guideline
GPCD (or gpcd)	Gallons Per Capita per Day
GPS	Global Positioning System
HDPE	High-Density Polyethylene
HH	Hose Hold
HHWL	Highest High Water Level
HIS	Household Interview Survey
HIV	Human Immunodeficiency Virus
HWL	High Water Level
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IRP	Income Restoration Program
IRPSC	Income Restoration Program Implementation Sub-Committee
IUR	Inner Urban Ring
JICA	Japan International Cooperation Agency
JPY	Japanese Yen
IWA	International Water Association
Kyat	Myanmar Kyat

L/A	Loan Agreement
LC	Local Currency
LCC	Life Cycle Cost
LLWL	Lowest Low Water Level
LPCD (or lpcd)	Liters Per Capita per Day
LWL	Low Water Level
MCA	Myanmar Companies Act
M&E	Mechanical & Electrical
METI	Ministry of Economy, Trade and Industry (Japan)
MG	Million Gallons
MGD	Million Gallons per Day
MIC	Myanmar Investment Commission
ML	Million Liters
MLD	Million Liters per Day
MMK	Myanmar Kyat
MNPED	Ministry of National Planning and Economic Development
MoAI	Ministry of Agriculture, Livestock and Irrigation
MoC	Ministry of Construction
MoEE	Ministry of Electricity and Energy
MoFA	Ministry of Foreign Affairs
MoNREC	Ministry of Natural Resources and Environmental Conservation
MoPF	Ministry of Planning and Finance
MOU	Memorandum Of Understanding
MP	Master Plan
MS	Mild Steel Pipe
MVA	Megavolt-Ampere
MWL	Mean Water Level
N/A	Not Available
New SZ	New Suburbs Zone
NO_2	Nitrogen Dioxide
NPV	Net Present Value
NRW	Non Revenue Water
NTU	Nephelometric Turbidity Unit
NSZ	Northern Suburbs Zone
ODA	Official Development Assistance
OJT	On-the-Job Training
O&M	Operation & Maintenance
Old SZ	Older Suburbs Zone
OP	(World Bank) Operations Manual
OPEX	Operating Expenditure
ORZ	Outer Ring Zone
PAC	Polyaluminum Chloride
PAPRD	Project Appraisal and Progress Reporting Department
PAPs	Project Affected Persons
PCP	Prestressed Concrete Pipe
PCC	Project Coordination Committee
PIs	Performance Indicators
PM_{10}	Coarse Particulate Matter
PMU	Project Management Unit
ppm	parts per million
PPP	Public–Private Partnership
PS	Pumping Station
PSIF	Private Sector Investment Finance

PVC	Polyvinyl Chloride
QCBS	Quality and Cost Based Selection
RC	Reinforced Concrete
RFP	Request For Proposal
RPS	Relay Pumping Station
RISC	Resettlement Implementation Sub-Committee
ROW	Right of Way
RPF	Resettlement Policy Framework
SAE	Sub-Assistant Engineer
SCADA	Supervisory Control And Data Acquisition
SCBD	South of Central Business District
SEA	Strategic Environmental Assessment
SEZ	Special Economic Zone
SHM	StakeHolder Meeting
SMW	Soil-cement Mixing Wall
SO_2	Sulphur Dioxide
SP	Steel Pipe
SR	Service Reservoir
SS	Suspended Solids
TCU	True Color Unit
TDS	Total Dissolved Solids
ToR	Terms of Reference
TS	Township
TS	Total Solids
TSP	Total Suspended Particulate Matter
US$, USD	United States Dollars
VAT	Value Added Tax
VFD	Variable Frequency Drive
WHO	World Health Organization
WTP	Water Treatment Pant
YCDC	Yangon City Development Committee
YESC	Yangon Electricity Supply Corporation (formerly called YESB: Yangon Electricity Supply Board)
YRG	Yangon Region Government

ABBREVIATION FOR THE RELEVANT STUDIES

The Preparatory Study for Urban Development Programme in the Greater Yangon (JICA) Household Interview Survey (JICA)	2013-JICA Urban Development Plan (the urban development plan) 2013 JICA-HIS
The Study on Improvement of Water Supply System in Yangon City (JICA)	2002 JICA Water MP
The Project for the Improvement of Water Supply, Sewerage and Drainage System in Yangon City (JICA)	2014 JICA Water MP or Phase 1 FS
Greater Yangon Water Supply Improvement Project (Phase 1)	Phase 1 Project
The Project for Urgent Improvement of Water Supply System in Yangon City	Japanese Grant Aid Project
Preparatory Survey for Greater Yangon Water Supply Improvement Project (Phase 2)	This Study
Greater Yangon Water Supply Improvement Project (Phase 2)	This Project

UNIT

Area

1 Acre = 4046.86 m^2 (square meter) = 0.404686 ha (hectare)

Length

1 ft (foot) = 0.3048 m (meter)

1 mi (mile) = 1.61 km (kilometer)

Volume

1 Gallon (imperial gallon) = 0.004546 m^3 (cubic meter) = 4.546 l (liter)

1 MG (million imperial gallon) = 4546 m^3 (cubic meter)

Pressure

1 MPa (Mega Pascal) = 10 bar ≒ 100 mAq as water head

CHAPTER 1 INTRODUCTION

1.1 Background of The Study

1.1.1 Water Supply Service

Yangon City is the national center of economy, business and communication with a population of 5.21 million in 2014, which is about 10 % of the entire population of the country. YCDC is responsible for planning, operation and management of water supply system in Yangon. The water supply services in Yangon commenced in 1842, and they cover extensively the central Yangon now. The city center has been served relatively well with 24 hours water supply. However, the existing water supply system cannot cover the vast suburban areas fully. In many suburban areas water coverage ratio is relatively low with daily water supply duration of less than 3 hours. Average water supply duration is about 8 hours a day in the city. The overall water coverage ratio in Yangon is still as low as below 40 %.

As a result, many people are using less-reliable groundwater, rain water and pond water. In addition, transmission and distribution pipes have not been rehabilitated properly resulting in large quantity of non-revenue water. Water supply hours are not continuous; water supply pressures are low and so on. YCDC has managed to implement measures to expand water supply coverage to cater to the needs of development of new suburban areas; including 1 large WTP and 4 small plants.

The water sources of YCDC water supply services include 4 dams/ reservoirs and many tube wells. Total raw water capacity is about 215 MGD (0.97 million m^3/d) and about 60 % of this amount is estimated as non-revenue water (NRW) in 2014. With the ongoing development in city, the population and coverage ratio is expected to increase, and consequently water demand will increase as well. Hence, development of additional water resources and extension of the transmission and distribution facilities is needed. The existing transmission and distribution pipes have not been rehabilitated properly and NRW reduction measures have not been practiced well, resulting in high ratio of NRW. YCDC has mostly taken emergency measures against frequently occurring breakdowns of equipment and leakage in water distribution networks to restore water supply services, and the practice of construction of additional facilities or rehabilitation of the existing facilities to cope with the increasing water demand is rarely adopted.

The weaknesses in the existing services, i.e., low ratio of population covered with 24 x 7 water supply, high NRW ratio, low daily consumption amount, is clearly reflected in data of the following Table which compares the performance indicators of other cities in the Southeast Asian countries. It also shows low YCDC tariff, suggesting inadequate revenue to finance required system improvement.

Table 1-1 Performance Parameters of Water Utilities, End of 2011

City	City Population in Service Area	Total Connections	Service Coverage Ratio (%)	NRW (%)	Average Tariff (US$/$m^3$)	Operating Ratio	Daily Consumption (m^3/ connection)
Yangon	5,211,000	252,898	35	66	0.07	-	0.82
Phnom Penh	2,000,000	219,498	100	6	0.24	0.37	1.32
Jakarta East	4,595,099	388,166	63	47	0.75	N/A.	1.02
Jakarta West	4,500,000	414,470		40	0.88	0.67	1.03
Manila East	6,000,000	857,981	99	11	0.62	0.45	1.32
Manila West	9,379,449	1,005,350	84	42	0.77	0.42	1.20
Bangkok	8,000,000	2,017,531	100	25	0.39	0.67	1.75
Ho Chi Minh	7,541,000	856,655	100	42	0.35	0.71	1.00

Source: For Yangon: YCDC in 2014, For other cities; Urban Water Supply and Sanitation in Southeast Asia, A Guide to Good Practice, Arthur C. McIntosh, ASIAN DEVELOPMENT BANK

1.1.2 Master Plan (MP) and Feasibility Study (FS)

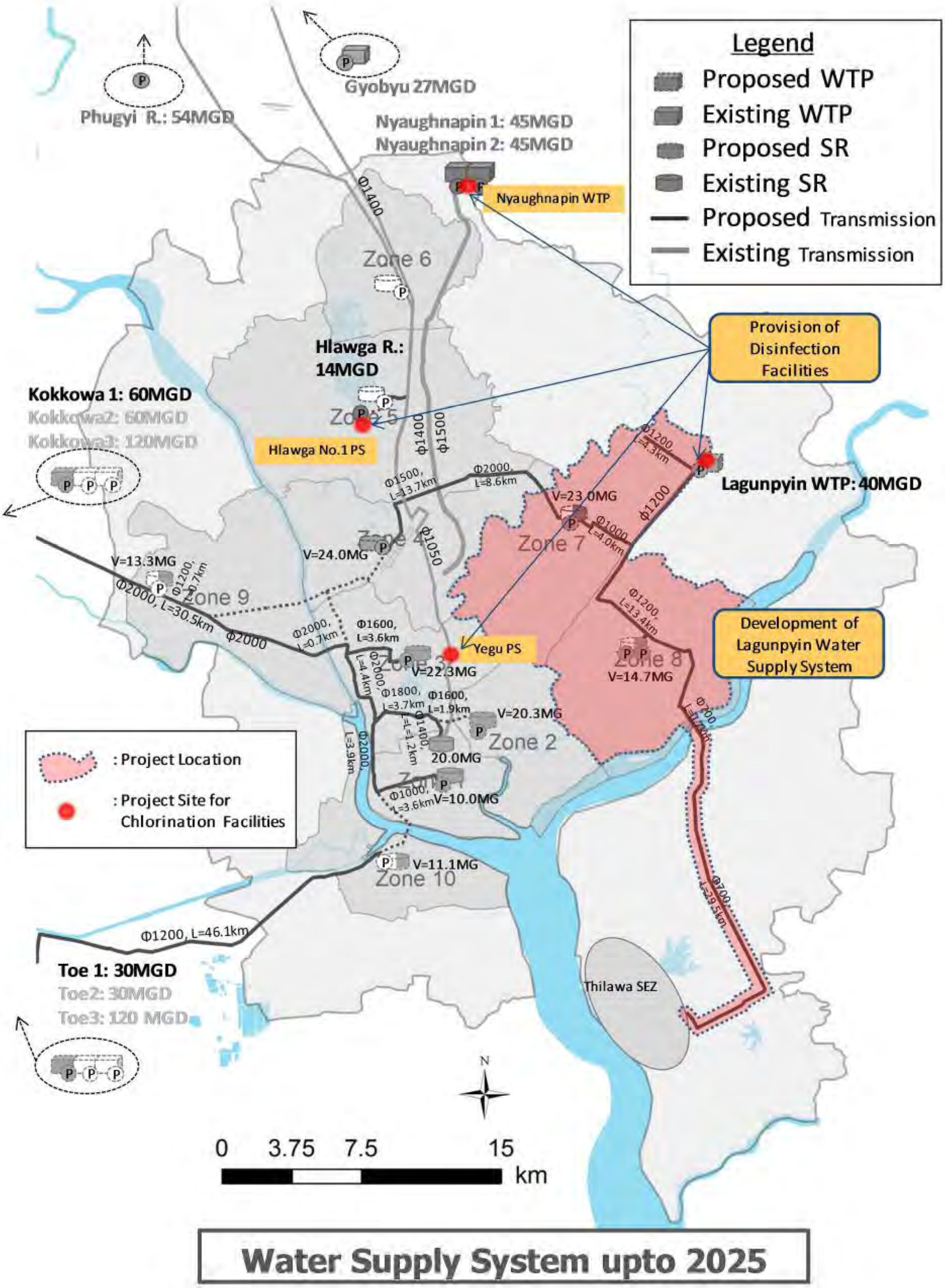
After adoption of new liberal policies in Myanmar, JICA initiated discussion with the Yangon regional government on formulation of comprehensive development plan including water supply, sewerage, drainage, electricity, road, railways, ports, etc., and the minutes were concluded concerning the various projects in 2012. The key project was “Project for the Strategic Urban Development Plan of the Greater Yangon (2013-JICA Urban Development Plan)”.

In parallel to the above project, water MP was formulated (it is called 2014 JICA Water MP or Phase 1 study in this report) between 2012 and 2014 with the assistance of JICA, using the frameworks developed in the above key project and targeting water demand in 2040. As a result, the following 4 priority projects are recommended in the MP and the feasibility study was carried out:

1) Development of Lagunbyin Water Supply System (to supply water to Zones 7, 8 and Thilawa special economic zone (SEZ) in the eastern Yangon),
2) Modernization of Water Supply System in Zone 1,
3) Provision of Disinfection Facilities, and
4) Capacity Development.

1.1.3 Japanese ODA Loan Project (Phase 1) - Lagunbyin Water Supply System

The Lagunbyin water supply system in the eastern suburbs was selected as the Japanese ODA loan project (Phase 1), supplying water to the eastern part of Yangon and Thilawa Special Economic Zone (SEZ). 40 MGD water treatment plant (WTP) is being constructed by YCDC with the assistance of JICA and the detailed design of the associated transmission/ distribution pumps and pipes started in 2015 under Japanese ODA loan project (see the Figure 1-1).



Source: Phase 1 FS

Figure 1-1 Outline of Japanese ODA Loan Project (Phase1)

1.1.4 Feasibility Studies Regarding Kokkowa Water Supply System

Two separate studies for development of Kokkowa system were conducted with the finance of China and Korea. Zone 9 was considered as supply area in both studies while Zone 1 is also included in one study. However, the results of these studies have not been utilized by YCDC except locations of the intake and WTP sites, and subsequently YCDC requested JICA a feasibility study of the Kokkowa water supply system including development of water supply system of Zone 9 and modernization of water supply system in Zone 1.

Development of the Kokkowa water supply system including Zone 9 and Zone 1 is being dealt in this study to produce materials for appraisal of ODA loan (Phase 2). However distribution facilities in Zone 9 will be constructed and financed by YCDC.

The contents of this Study covers the 1st stage Kokkowa water supply system proposed in the MP, which is planned to be constructed in 3 stages; 60 MGD each in the 1st and 2nd stages and 120 MGD in the 3rd stage. The 1st stage of the Kokkowa system was proposed in the MP with the target of water demand in 2022. The developed water in the 1st stage was to be transmitted to the city center (Zone 1) and Hlaing Tharyar TS (Zone 9) located in the western part of Yangon (See the “Location Map” in the beginning of this report).

1.2 Outline of Phase 2 Project

(1) Objectives

The project aims at improving water supply services to meet the increasing water demand by using raw water from the Kokkowa River and constructing a new WTP and construction and rehabilitation of associated transmission and distribution facilities, which in turn will contribute to the improvement of living environment and economic development of Yangon City.

(2) Scope

The scope of Phase 2 project includes construction of intake facilities to use raw water from the Kokkowa River and construction of WTP and associated transmission and distribution facilities for Zone 1 and Zone 9.

a) For Zone 1

- Intake facility/ Water treatment plant (40 MGD)
- Transmission pipe (19.9 km including 0.6 km river crossing)
- District metered area (37 Nos.)
- Distribution reservoir (2 Nos.)
- Distribution main pipe (61.4 km)
- Distribution pipe (430.3 km)

b) For Zone 9

- Intake facility
- Water treatment plant (20 MGD)
- Transmission pipe (21.4 km)
- District metered area (23 Nos.)
- Distribution reservoir (1 No.)
- Distribution main pipe (43.2 km)
- Distribution pipe (636.9 km)

(3) Implementing Organization

Engineering Department (Water and Sanitation), Yangon City Development Committee (YCDC)

(4) Assistance Activities Related to The JICA Project

- Japanese ODA Loans (Japanese ODA-loan) for "Greater Yangon Water Supply Improvement Project (Phase-1)"
- Japanese Technical Cooperation for "The Project for Improvement of Water Supply Management of YCDC"
- Advisor on Water Supply and Sanitation Improvement in Yangon City

1.3 Outline of This Study

(1) Study Objectives

JICA study team is to firstly study and analyze the background, objectives and scope of the Project to decide whether the Project is necessary or not. If the Project is confirmed necessary, JICA study team is to study on appraisal items required for implementing the Project under the ODA loan project, such as objectives, scope, cost, implementation schedule, implementation method (procurement and construction), implementing organization, operation and maintenance organization, environmental and social considerations, and so on. However, the Study itself does not mean that JICA promises ODA loan to Myanmar counterpart.

(2) Study Method and Schedule

"The project for the improvement of water supply, sewerage and drainage system in Yangon city" was conducted from 2012 to 2014 by JICA. It includes the preparation of water supply MP (2014 JICA Water MP) and feasibility study of Zone 1. In this study, JICA study team has reviewed the MP and updated in terms of future population, reflecting the 2014 census to confirm future water demand and water balance in Yangon. Based on the updated demand, facility plan of Zones 1 and 9 was formulated and compiled as Interim Report 1 and Interim Report 2. Considering the comments in the Interim Reports and outcome of financial analysis, Draft Final Report was prepared and submitted. Subsequently, the Final Report was prepared and submitted based on the result of all the study outcomes and considering comments of counterpart on the Draft Final Report.

Table 1-2 Report Submission

Report	Schedule	Contents
Interim Report 1	August 2015	Review of future water demand and water balance, and Facility plan (including cost scale)
Interim Report 2	February 2016	Outline design of facilities (including cost scale)
Draft Final Report	April 2016	All study outcome
Final Report	February 2017	All study outcome considering comments of counterpart on draft final report

CHAPTER 2 CHARACTERISTICS OF YANGON CITY

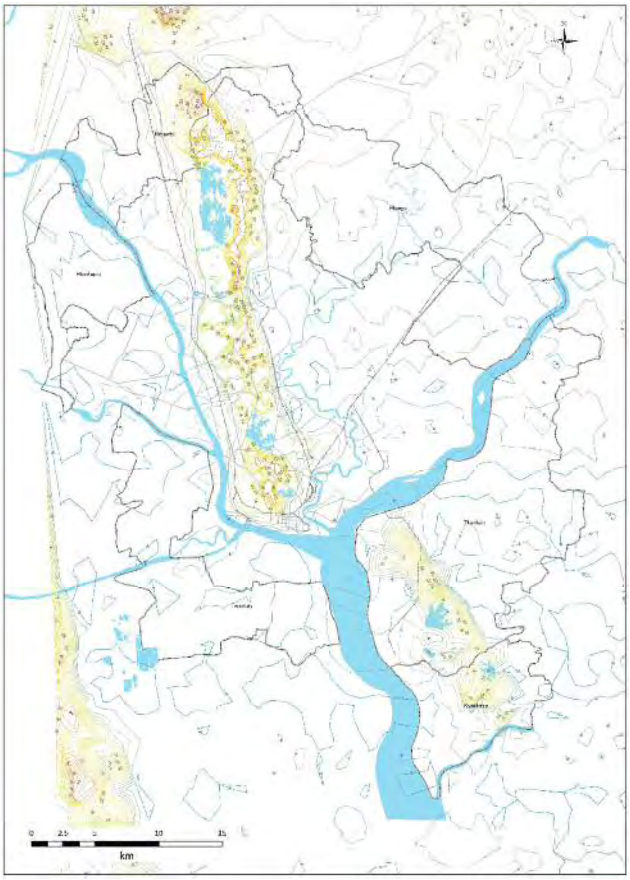
In this chapter, characteristics of Yangon city are described using the 2014-JICA Water MP.

2.1 Natural Condition

2.1.1 Topography

Yangon city is situated at 34 km inland from the mouth of the Yangon River which traverses parts of the Ayeyarwady delta. The relief of the city varies from flat plains to lowland hills in the central part as shown in the following Figure. Flat plains are extensive and occur mostly in the eastern and western parts as wide flat bottoms along the rivers. These flat lands is formed by delta deposits, areas of which are swampy and are almost occupied by paddy fields with elevation between about 3 m (10 ft) to 6 m (20 ft) above mean sea level.

Yangon city has, in the center, lowland hills commonly known as the faulty zone ponds with artificial dams namely Kandawgyi Lake, Inya Lake, Hlawga Reservoir, Gyobyu Reservoir and Phugyi Reservoir which used to be or are main sources of water supply system for YCDC. There are three service reservoirs are located on the hills. A long and narrow spur of Pegu Yomas in the central area runs almost in N-S direction with an average height of 30 m (100 ft) and slopes gradually into flat plains towards east and west.



Source: 2014 JICA Water MP

Figure 2-1 Topography in Yangon Region

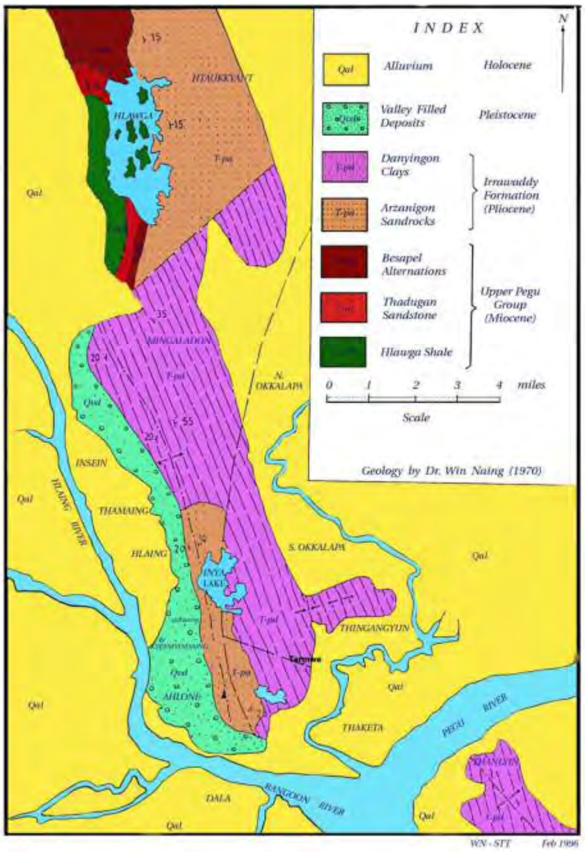
2.1.2 Geology

The geological Map of Yangon area is presented in following Figure. The geological structure of the city is attributed to moderate lowland hills. The rocks of the Tertiary age contain well-consolidated marine sandstone and shale of the Pegu Group and semi-consolidated, continental deltaic and marginal marine deposits of the Ayeyarwady Formation.

The synclinal valley west of the Yangon anticlinal ridge is filled with unconsolidated water laid deposit of Quaternary age.

Delta sediments consist of sands and gravels, remarkably free from clayey materials and lies upon the eroded surface of Ayeyarwady Series. Recent alluvium consists of gravels, clay, silt and laterite. These deposits are widely distributed surrounding the main City area.

The result of geological survey in target site is shown in the Appendix-4.



Source: Win Naing,1970

Figure 2-2 Geological Map of Yangon Area

2.1.3 Meteorology

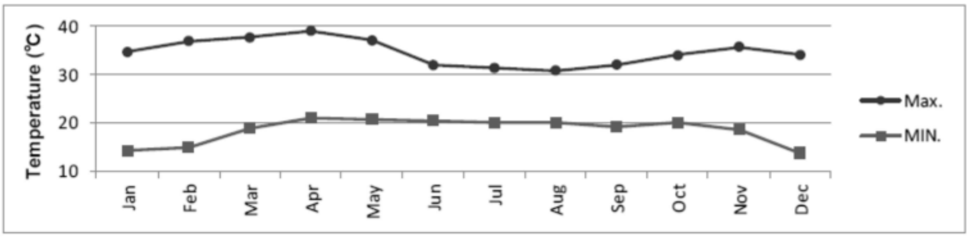
(1) Climate

Yangon has a tropical monsoon climate which consists of three seasons as listed below. It has an annual rainfall of 2,700 mm, annual evaporation of 1,347 mm, average temperature of 27.4 ^{o}C, maximum mean temperature of 33 ^{o}C, and minimum mean temperature of 21.8 ^{o}C.

- Summer season: March–mid May
- Rainy season: mid May–October
- Dry season: October–February

(2) Temperature

The following Figure shows the mean maximum and minimum temperatures in Yangon City (1991-2008). The difference between the monthly maximum and monthly minimum temperatures is more than 20 ^{o}C from December through February and around 10 ^{o}C from June through August.

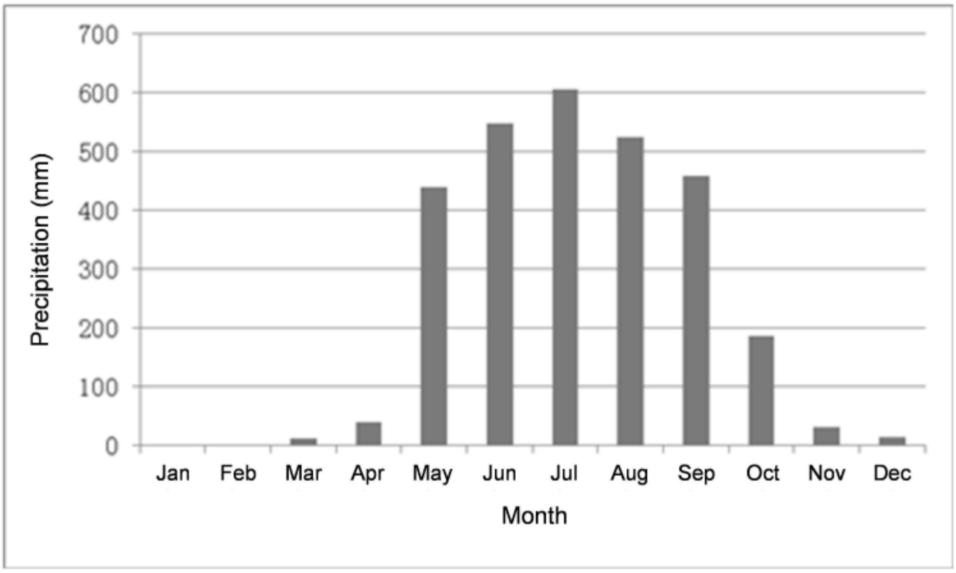


Source: 2014 JICA Water MP

Figure 2-3 Mean Maximum and Minimum Temperature in Yangon City (1991-2008)

(3) Rainfall

The following Figure shows the mean monthly rainfall from 2001 to 2008 in Yangon (Kaba Aye). From the graph, the annual mean rainfall is 2,700 mm. About 95% of the total annual rainfall occurs during the rainy season from May to October.



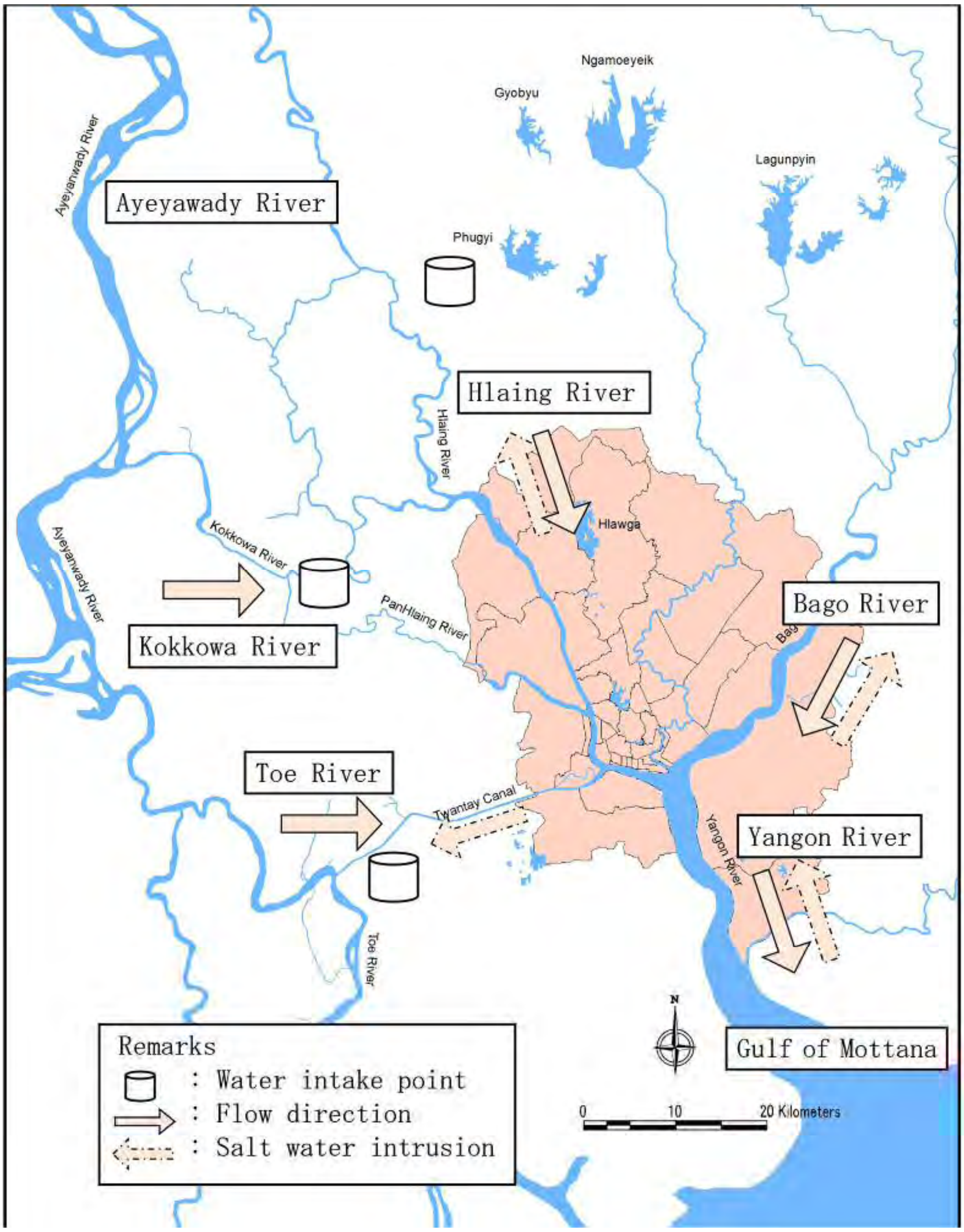
Source: 2014 JICA Water MP

Figure 2-4 Mean Monthly Rainfall (Yangon: Kaba Aye, 1991-2008)

2.1.4 Hydrology

(1) Rivers

The following Figure shows a map which contains the rivers surrounding Yangon City. Yangon City lies at the confluence of the Bago River and the Hlaing River. The two rivers downstream of the confluence is called as the Yangon River, which is connected to the Gulf of Mottama. The Pan Hlaing River and Twantay Canal, which converge and flow downstream the Yangon River, as well as the Kokkowa River which connects with the Hlaing River, all obtain its water from the Ayeyarwady River. Kokkowa, Pan Hlaing and Toe Rivers are candidate water sources for the expansion of Yangon City's water demand expected to increase in the future.



Source: 2014 JICA Water MP

Figure 2-5 Map Showing The Rivers Surrounding Yangon

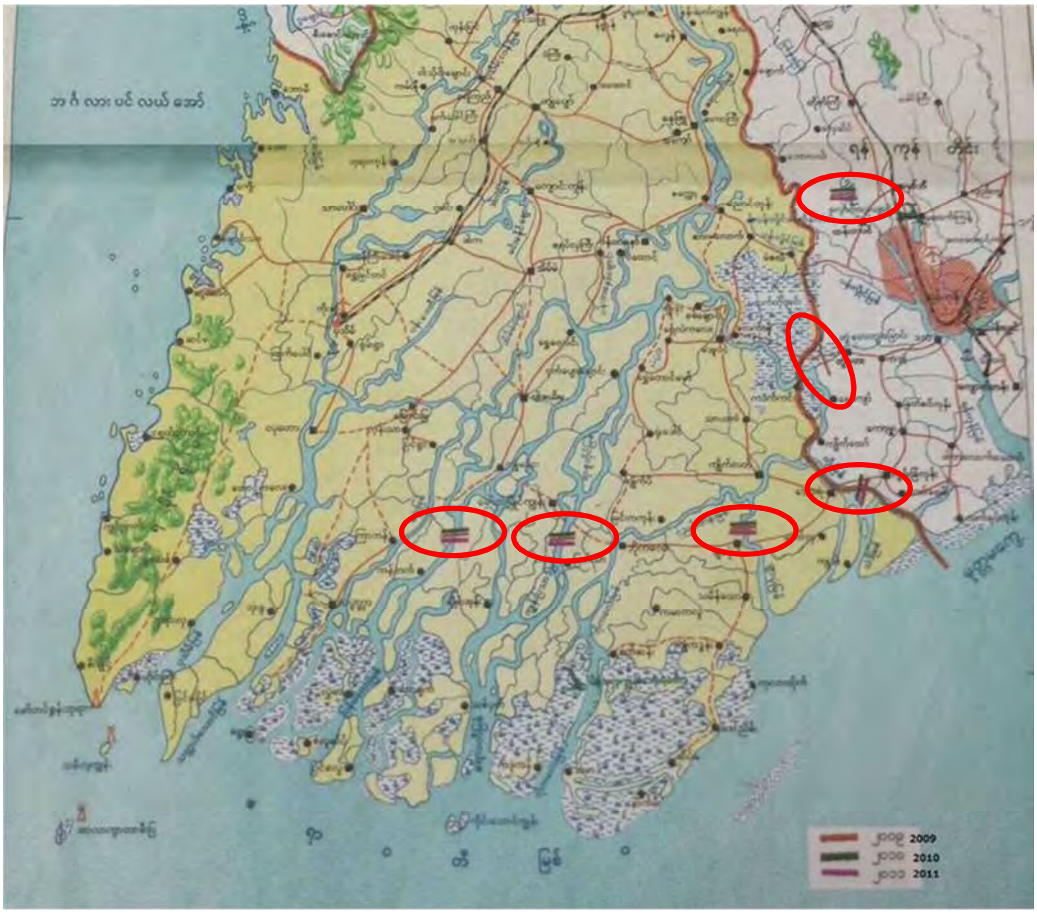
(2) Potential Water Sources

The result of water source survey on the MP is shown in the Appendix 2.

(3) Salinity Intrusion

The rivers mentioned are all tidal rivers. During dry season 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 Figure shows the salinity position having 1000 ppm concentration (circled in red) from 2009 to 2011.

At the proposed location of intakes along Kokkowa and Toe rivers, no problem related to salinity is expected based on MP.



Source: 2014 JICA Water MP

Figure 2-6 Salt Water Intrusion in The Rivers Surrounding Yangon City

(4) Tides

The following Table shows available tidal information taken from the Myanmar Port Authority (MPA). Data in the following 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). At 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 as 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 2-1 Tidal Information in Yangon Port

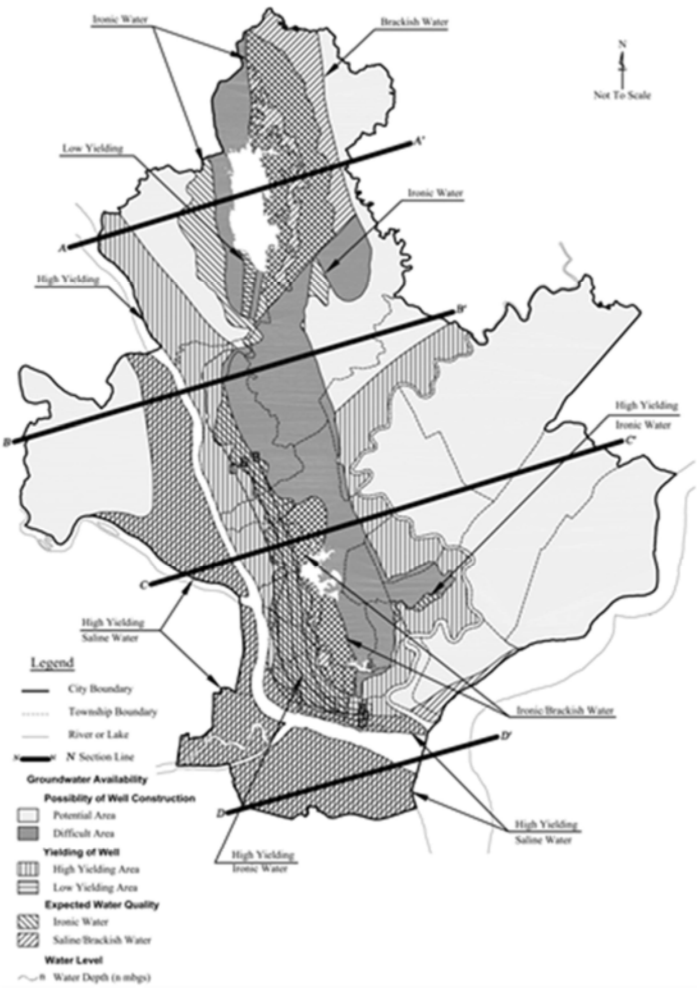
Items	Tidal Height (m)	Observed Dates
Highest High Water Level (HHWL)	+6.74	September 1899
Mean Water Level (MWL)	+3.121	Up to 1936
Lowest Low Water Level at Bo Aung Kyaw Street Wharf	-0.24	December 1902
Indian Spring Low Water Mark	+0.338	-

Source: 2014 JICA Water MP

2.1.5 Hydrogeology

From the study on groundwater potential (see the following Figure) 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.



Source: 2014 JICA Water MP

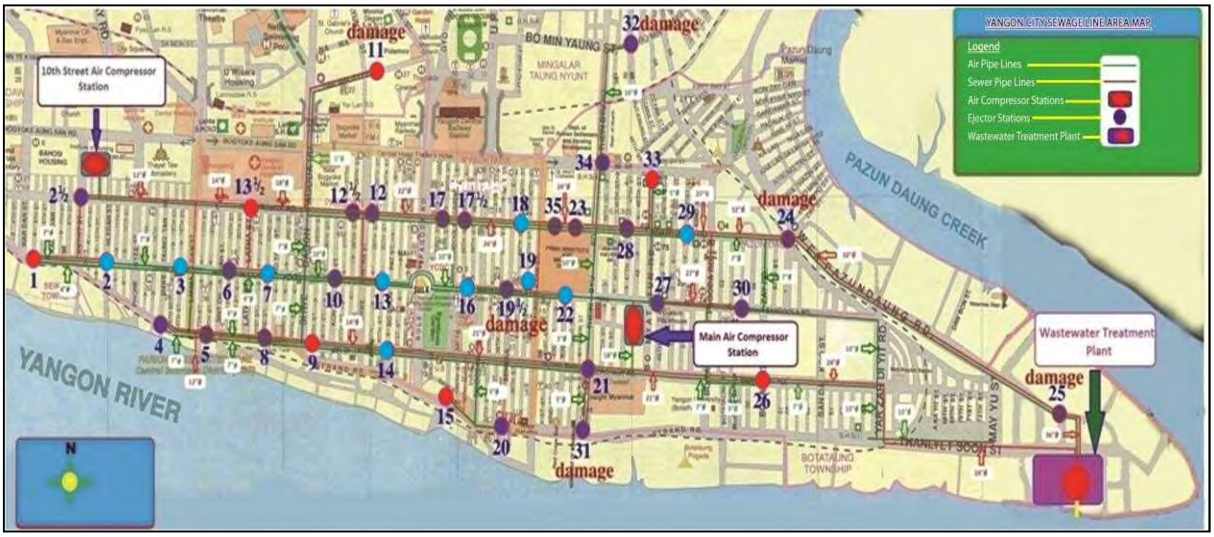
Figure 2-7 Groundwater Potential in Yangon City

2.2 Wastewater Management Services

2.2.1 Existing Wastewater Management Services

Wastewater management practices in Yangon are categorized into sewerage, septic tank, pour flush toilet, and other non-sanitary facilities. According to the "Water Supply Improvement Project Study for Yangon City and Pathein City, 2014", only a tiny portion of the population, as small as 7.3 % of total population is benefitted by sewerage services. Most of the middle and high class houses, public and commercial buildings are provided with mainly septic tanks, and low income houses in the peripheral areas are provided with various kinds of toilets without treatment.

The existing sewerage system was originally constructed in 1890 which collects only toilet wastewater (black water), and gray water is discharged to the nearby drains without any treatment. The ejector system is used in collection of sewage that has been utilized continuously with periodical modifications for approximately 120 years. Service area covers 8 townships in CBD. The ejector system 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 (see the following Figure). The current situation of wastewater treatment not only brings forth deteriorated living conditions but also involves potential health risks.



Source: 2014 JICA Water MP

Figure 2-8 Sewerage System in Yangon City

2.2.2 Outline of Development Policies on The MP

As for wastewater treatment including sewerage, existing YCDC organization is not capable enough to undertake full scale development, operation and management. Legal and regulatory framework concerning wastewater treatment and water environment has not been developed properly, and accordingly a firm basis for development and provision of finance is not 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 discussion, 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 the following Figure.

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 development by independent finacial sources • Revenue of sewerage service charge and government subsidies
Development policies for wastewater treatment facilities	In the sewerage planned areas (- FY2040)	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 (FY2040 -)	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: 2014 JICA Water MP

Figure 2-9 Basic Development Policies Concerning Wastewater Treatment

2.2.3 Priorities of Tasks To Be Implemented by YCDC

YCDC is supposed to go ahead with the development of wastewater treatment systems and facilities based on the above-mentioned development policies with the cooperation and support of 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 construction of treatment system. These required tasks are articulately listed as shown in the following Table.

Table 2-2 List of Tasks to be Implemented by YCDC and Their Priorities

Tasks to be implemented by YCDC	Priority				
	1 High	2	3	4	5 Low
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					

Tasks to be implemented by YCDC	Priority				
	1 High	2	3	4	5 Low
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					●

Source: 2014 JICA Water MP

2.3 Current State of Poverty Group

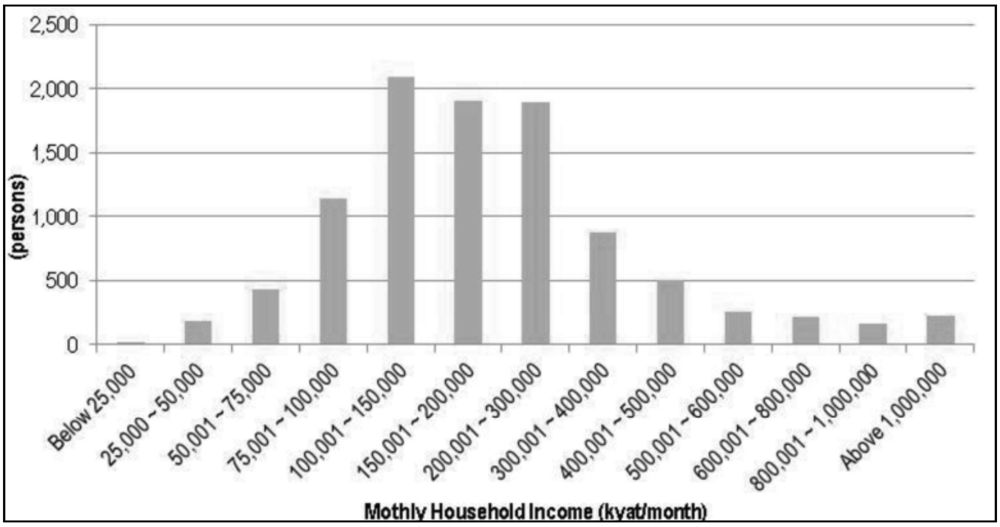
It is important to ensure sufficient and safe water supply to all household, and water tariff collection system be established with appropriate consideration to poverty level. The poverty threshold in Yangon used to identify poor people is defined as the earning of US$3 per day (equivalent to 100,000 kyat per month). This amount is considered as the minimum expenses required for survival on food and non-food commodities mentioned in 2013 JICA Urban Development Plan and JICA-HIS.

According to 2013 JICA-HIS, estimated average household income is 175,000 kyat per month in Yangon region area and the poor people comprise about 18 % of all household.

Unit rate for domestic water supply is 88 kyat/m^3 for metered customers. According to YCDC officials (Water and Sanitation Department), average cost to have a new water supply connection in a household is around 100,000 kyat, consisting of 50,000 kyat for permit fee for new connection and 50,000 kyat for plumbing work. Based on the unit rate of 88 kyat/m^3, average household expense for water supply is estimated at 1,289 kyat per month assuming household size of 4.4 persons/household and unit water consumption of 111 lpcd, whereas the flat rate for unmetered customers is set at 1,800 kyat per month.

An international report by OECD[1] states that national and international affordability criteria are often quoted around 3% to 5% of household income. Taking 75,000 kyat per month for the approximate average income among poor households, the above mentioned water supply expense (1,289 – 1,800 kyat per month) accounts for 1.7% - 2.4%. The current water tariff level is considered at affordable level among poor households.

1 "Managing Water for All – An OECD Perspective on Pricing and Financing" OECD, March 2009



Source: 2013-JICA Urban Development Plan

Figure 2-10 Monthly Household Income

Table 2-3 Monthly Household Income

Items (kyat/month)	Below 25,000	25,000 ~ 50,000	50,001 ~ 75,000	75,001 ~ 100,000	100,001 ~ 150,000	150,001 ~ 200,000	200,001 ~ 300,000	300,001 ~ 400,000	400,001 ~ 500,000	500,001 ~ 600,000	600,001 ~ 800,000	800,001 ~ 1,000,000	Above 1,000,000	No Answer	Total
Number	20	185	434	1,145	2,091	1,908	1,890	871	506	258	215	160	223	163	10,069
% of Total	0.2	1.8	4.3	11.4	20.8	18.9	18.8	8.7	5.0	2.6	2.1	1.6	2.2	1.6	100

Source: 2013-JICA Urban Development Plan

CHAPTER 3 REVIEW OF MASTER PLAN

Following a brief description of the outline of the water supply MP (2014 JICA Water MP) in section 1, the MP was reviewed in section 2. The population data of 2011 used in the MP was estimated and not reliable. Now the reliable data of 2014 census data, is available and the study team compared the census data with the data used in the MP in order to confirm whether the planning framework is still valid or need to be modified. After the review, the study team has confirmed that the framework is still valid with some minor modifications.

After the confirmation, water allocation up to 2040, target year of the MP, is revised in the third section and necessity of the project is described in the fourth section. The revised water allocation is almost the same as in the MP with some numbers changed and the study team has confirmed on the necessity of the 60 MGD Kokkowa system till 2025, target year of this feasibility study.

3.1 Outline of The Master Plan

3.1.1 Major Technical Issues of Water Supply Service

The water supply services in Yangon commenced in 1842, and they cover extensively the central Yangon now. However, the existing water supply system cannot cover the vast suburban areas fully so that the water coverage ratio is still as low as 40 % below. As a result, many people are using less-reliable groundwater, rain water and pond water. In addition, transmission and distribution pipes have not been rehabilitated properly resulting in large quantity of non-revenue water. Water supply hours are not continuous; water supply pressures are low.

The followings are identified as major technical issues:

- Low water coverage
- High non-revenue water ratio
- Poor water quality
- Ageing of facilities
- Inappropriate layout of facilities
- Insufficient of operation and maintenance of facilities

3.1.2 Service Level Targets

Overall service level targets are set in the MP as shown below.

Table 3-1 Overall Service Level Target

Item	By Area		Unit	2011 (Present)	Year 2018	Year 2025	Year 2040
Service Coverage rate	YCDC		%	38	48	58	80
	Region			35	41	49	69
Served Population	YCDC		Million	1.93	2.74	3.76	6.81
	Region			1.93	2.74	3.92	8.09
Per Capita Consumption	Domestic	YCDC	LPCD	95	117	135	178
		Region		95	117	133	173
	Non-domestic			40 % of total consumption			
Water Pressure			MPa	0.075	-	More than 0.15 MPa	
Supply Duration			Hour	8 on average	-	24	
Water Quality Improvement			-	Not drinkable	Drinkable		

Source: 2014 JICA Water MP

3.1.3 Non-revenue Water Ratio

Present (2013) non-revenue water ratio on the MP is estimated as 66 % in Yangon. YCDC has intention to reduce it and the target level is set as 15 % in 2040. Target levels of leakage with non-revenue water are shown in the Table below at 5 years interval.

Table 3-2 Target Level of Non-revenue Water Ratio and Leakage Ratio

Items	2013	2018	2020	2025	2030	2035	2040
Non-revenue Water Ratio (%)	66	51	46	35	26	20	15
Leakage Ratio (%)	50	37	33	25	18	13	10

Source: 2014 JICA Water MP

3.1.4 Population and Water Demand

(1) Population

Population estimated under the 2013-JICA Urban Development Plan was used for the water master plan.

(2) Water Demand

Water demand is estimated as shown in Table below. Daily maximum demand in 2025 and 2040 is 272 MGD and 543 MGD for Yangon City (YCDC area).

Table 3-3 Water Demand in Yangon City

Items	Year	2011	2025	2040
Population	person	5,142,128	6,463,609	8,519,527
Served Population	Person	1,933,689	3,764,310	6,810,338
Water Coverage Rate	%	38	58	80
Unit Consumption	Lpcd	95	135	178
Leakage Rate	%	50	25	10
Daily Average Water Demand	m^3/day	611,952	1,125,773	2,242,961
Daily Maximum Water Demand	m^3/day	673,148	1,238,351	2,467,258
Daily Average Water Demand	MGD	135	248	493
Daily Maximum Water Demand	MGD	148	272	543

Source: 2014 JICA Water MP

3.1.5 Water Source

(1) Current Water Source

The maximum water demand per day in Yangon City in 2025 and 2040 are 272 MGD and 543 MGD, respectively. On the other hand, existing reservoirs source is 215 MGD. Therefore, the development of potential water source from river is required to meet water demand in 2025 and 2040. About 8 MGD of groundwater is used for YCDC water supply system. However, groundwater abstraction need to be gradually reduced and considered only as back-up sources as surface water will be developed in the future.

Table 3-4 List of Existing Water Resources (Reservoirs)

Name	Water Source Capacity		Remark
	m^3/day	MGD	
Gyobyu Reservoir (Surface water)	123,000	27	
Phugyi Reservoir (Surface water)	245,000	54	
Hlawga Reservoir (Surface water)	64,000	14	
Ngamoeyeik Reservoir (Surface water)	410,000	90	45 MGD (Phase 2) commissioned in 2013.
Lagunbyin Reservoir (Surface water)	135,400	30	Excluding 10 MGD for Thilawa SEZ. Will be commissioned in 2018.
Total	977,400	215	Excluding 10 MGD for Thilawa SEZ.

Source: 2014 JICA Water MP

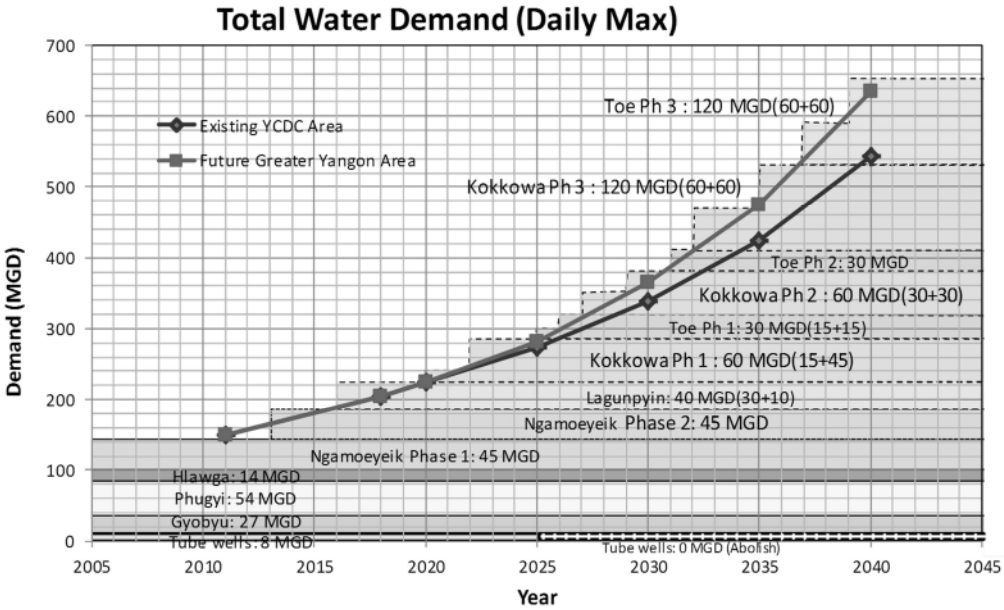
Table 3-5 Planned Groundwater Source

	2011	2020	2025	2030	2040
Intake volume (MGD)	8	8	0	0	0
Intake volume (m^3/day)	36,000	36,000	0	0	0

Source: 2014 JICA Water MP

(2) Future Water Source

New sources are sought to meet the increased demand. Abstraction of water from the nearest rivers is not feasible due to either high level of salinity in river water or small water quantity, and consequently the Kokkowa and Toe Rivers were selected. Firstly, the water supply system using water from Kokkowa River will be developed due to nearness to Yangon and favorable water quality than the Toe River.



Source: 2014 JICA Water MP

Figure 3-1 Staged Water Source Development on The MP

3.1.6 Policy of Water Supply Plan

(1) Target Area

Target areas of MP are greater Yangon (YCDC 33 Township and part of surrounding 6 Townships including Thilawa SEZ). Water sources and transmission facilities are developed for the Greater Yangon.

(2) Policy of Improvement of Water Supply

In order to solve the problems in water supply facilities of YCDC and achieve improvement in water supply services, the water supply facilities are planned based on the policies mentioned below.

Table 3-6 Policies to Achieve Improvement Target of Water Supply Condition

Target items	New Facilities	Existing Facilities
1. Increase of the water service coverage	• New development of river surface water and new construction of water treatment plant (Water from reservoir: Lagunbyin R., Water from river: Kokkowa river and Toe river)	• Abandon the use of groundwater intake (Maintain it as backup water resource)
2. Achievement of 24 hr water supply with appropriate water pressure	• Rationalization of transmission and distribution facilities including division of transmission and distribution function • Improvement of transmission and distribution capacity • Establishment of distribution facilities in 10 Zones	• Rationalization of transmission and distribution facilities including division of transmission and distribution function • Enhancement of transmission and distribution capacity • Rehabilitation of the existing Central S/R and the existing Kokine S/R • Replacement of the existing pumps due to rationalization of distribution • Abolishment of the existing Yegu booster P/S

Target items	New Facilities	Existing Facilities
3. Provision of the treated water with chlorination	・ Installation of chlorination equipment in Hlawga ・ Chlorination in new service reservoir ・ Establishment of water quality control center	・ Rehabilitation of Gyobyu WTP ・ Rehabilitation of Nyaunghnapin WTP
4. Reduction of Leakage Ratio (from 50 % to 10 %)	・ Establishment of DMA in the served area ・ Installation of water meter in all household ・ Establishment of distribution management center	・ Establishment of DMA, Utilization of SCADA ・ Scheduled replacement of the old pipes in accordance with the establishment of DMA

Source: 2014 JICA Water MP

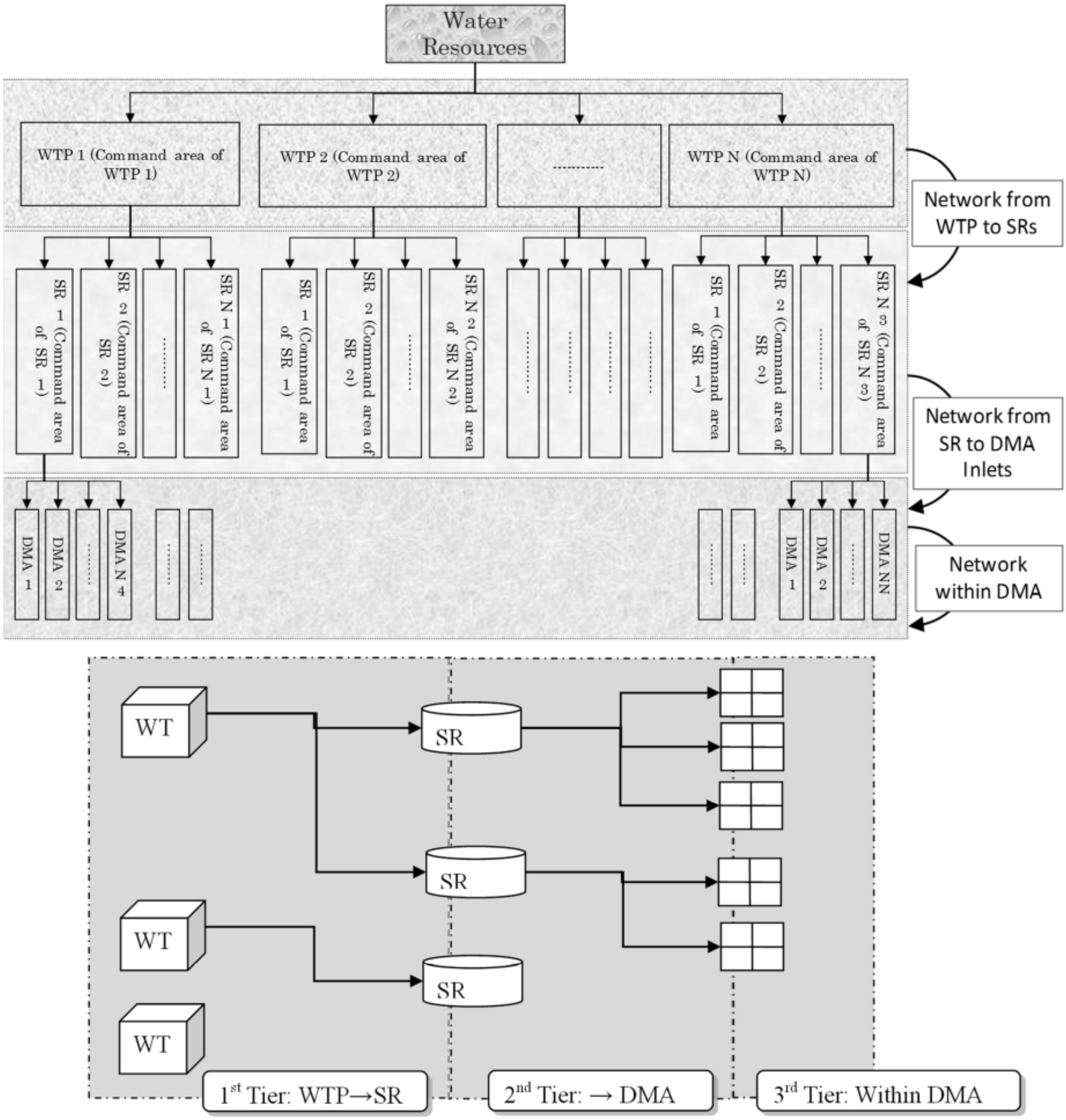
3.1.7 Water Supply Facility Plan

(1) Introduction of 3-Tier Water Distribution System

The water supply method to city center is currently direct distribution system except in south of the city. The transmission and distribution water amount from WTP and SR is certain fixed volume. Therefore, in the peak time of water demand, water is consumed in the areas near WTP or SR and shortage of water occurs in remote places or high altitude areas.

In order to implement equal water supply and non-revenue water control, the 3-tier water distribution system which consists of transmission from WTP to SR, transmission from SR to DMA and distribution within DMA to house connection is proposed. The conceptual diagram is shown in Figure below. The isolation between transmission and distribution function is planned by this 3-tier water distribution system. Water supply to households from transmission pipes which connect between WTP and SR is abolished and distribution is implemented from distribution branch pipes in DMA. Transmission pipes (from WTP to SR) and distribution main pipes (from SR or distribution P/S to DMA) are set as the specialized pipes.

Since the distribution zones are set up and SR for each zone is planned, the water supply system corresponds to time fluctuation of water demand. Furthermore, DMA is set up by dividing distribution zones, to monitor and control the transmission water amount to each distribution zone and water flow to DMA in distribution zone. Equal water supply and appropriate water pressure are secured by monitoring and control of water flow between steps. Distribution management is enabled by SCADA which is a tool of monitoring and control of these items.



Source: 2014 JICA Water MP

Figure 3-2 Conceptual Diagram of 3-Tier Water Distribution System

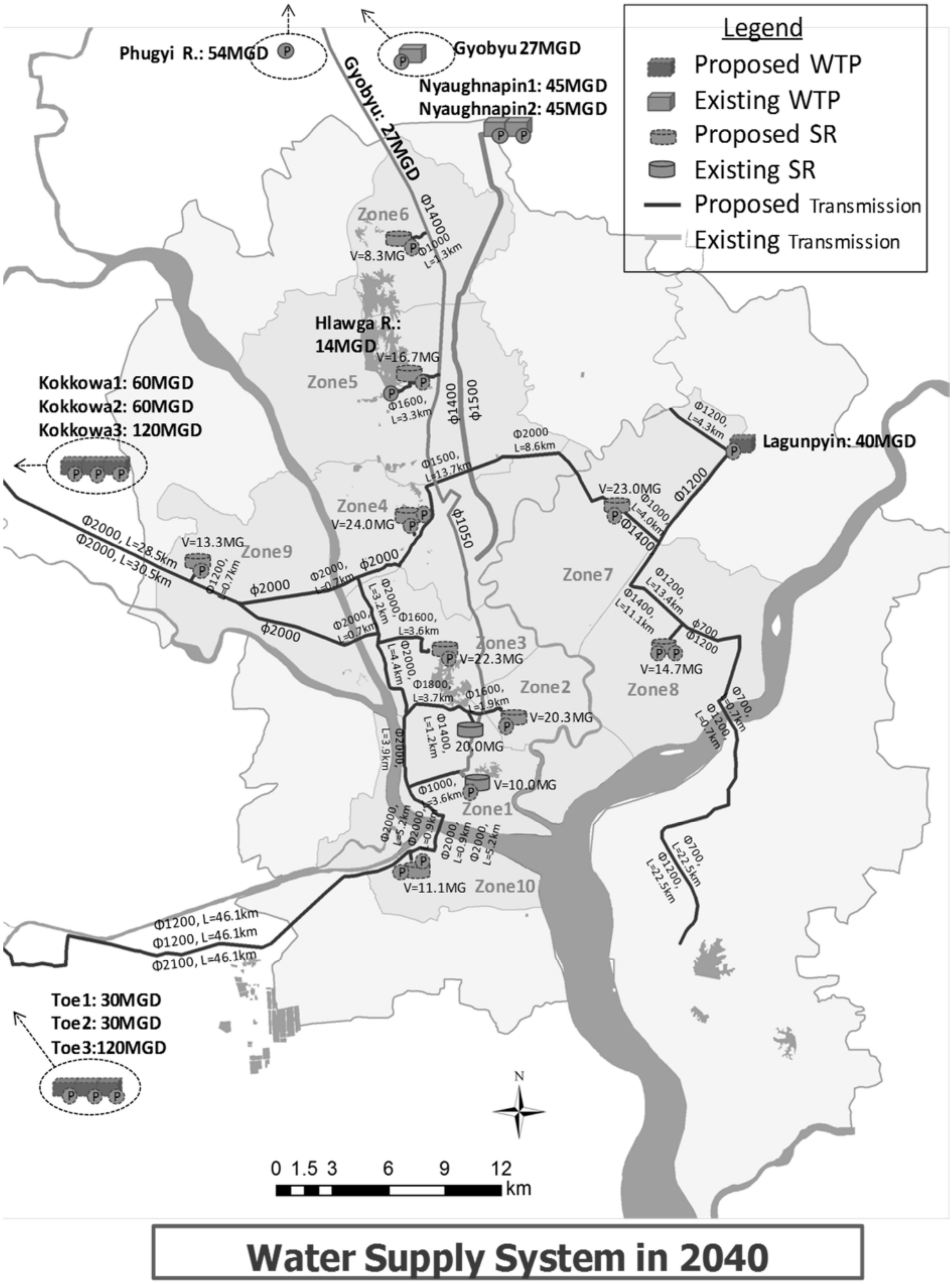
(2) Creation of Distribution Zone

Whole city is divided into several distribution zones with consideration to topographic condition and water demand. In each distribution zone, SR is constructed and enough capacity to meet the peak water demand is secured, it is possible to supply the required amount of water in the peak time of demand and it finally aims to achieve 24 hours water supply. If 24 hours water supply is actualized, people will be able to remove private wells, private pumps and roof tanks and it prevents intrusion of contaminants due to negative pressure in the pipes, thus, it is possible to achieve safe water supply. In order to secure water supply pressure in distribution zones, the water supply to low altitude area is done through gravity flow and distribution is done by pumping up to high altitude area.

(3) Setting Up of DMA

Inside distribution zone, the area is segmented into several blocks of appropriate scale and DMAs are set up. The inlet pipe to DMA is only one in principle and water pressure and inlet water amount are monitored and controlled, and then, equal water supply is planned. Another purpose of DMA is Non-revenue water control. It is easy to calculate non-revenue water by comparison between inlet water amount to DMA and water consumption in DMA. Commencement of Non-revenue water control from DMA that has high ratio of non-revenue water is effective method. The DMAs are set up depending on the pipelines condition and road condition.

YCDC area is divided into 10 water distribution zones each of which has SR and distribution main pipes leading to DMA with the zones. Water to the SR is conveyed through transmission pipes from one of the WTP. Following Figure shows transmission facilities connecting the WTP and the SR in 10 Zones.



Source: 2014 JICA Water MP

Figure 3-3 Planned Water Supply System in 2040

3.2 Review of Planning Framework

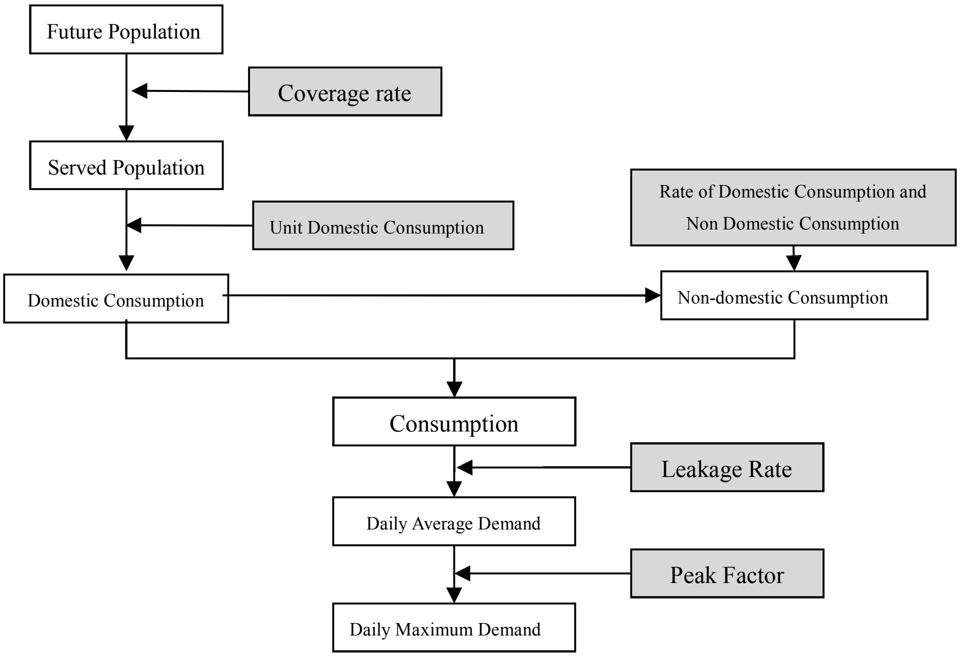
YCDC will supply water only to YCDC area and will not supply to the surrounding 6 townships[2]. Therefore, in this study, YCDC area or Yangon city is considered for the target area. When facilities are constructed to cover the surrounding townships, consensus should be reached between the regional government and YCDC in future. Water demand is reviewed and estimated through the following procedures described hereafter. This procedure is the same as the MP.

Table 3-7 Review of Water Demand and Estimation Procedures of The MP

Item	Procedure of Water Demand Estimation	Sections	Remarks
Population of Yangon			
		3.2.1 Population Growth	Describes estimation procedure of population in Greater Yangon including Yangon city in the 2013-JICA Urban Development Plan.
		3.2.2 Current Population and Overall Population	Population in Yangon city estimated in the above plan is employed after comparing with the census population.
Township Population	A	3.2.3 Population Allocation	Township populations are revised using that of the 2014 census.
Water Demand by Township			
		3.2.4 Water Demand by Township	
Service Coverage Ratio by Township	B	3.2.4(2) Service Coverage Ratio	Township service coverage ratio in 2014 is based on the census data
Served Population by Township	C = A x B	3.2.4(3) Served Population	
Per Capita Consumption	D	3.2.4(4) Per Capita Consumption	Reviewed using additional data from 2012 to 2014. Per Capita Consumption is the sum total of Domestic and Non-Domestic.
Leakage Ratio	E	3.2.4(5) NRW ratio and Leakage Ratio	The targeted values of YCDC
Peak Factor	110%	3.2.4(6) Peak Factor	Same as the MP
Maximum Water demand	F = (C x D) / (1 – E) x 110%	3.2.4(7) Water Demand Estimation	
Water Demand by Supply Zone			
	Converting township water demand into supply zone demand.	3.2.5 Water Demand by Water Supply Zone	Name and location of both township and supply zone is shown in Figure of page ii.

Source: 2014 JICA Study Team

[2] Townships with TS codes 34 to 39 are the surrounding 6 townships shown in Figure 3-7.



Source: 2014 JICA Water MP

Figure 3-4 Flow Chart of Water Demand Estimation

3.2.1 Population Growth

Water supply MP was formulated under the framework of the Preparatory Study for Urban Development Programme in the Greater Yangon (JICA) (2013-JICA Urban Development Plan). The study areas of the MP and the development plan was Greater Yangon extending over an area of about 1,500 km^2, covering YCDC area (784 km^2, 33 townships) and parts of adjoining peripheral 6 townships (Kyauktan, Thanlyin, Hlegu, Hmawby, Htantabin and Twantay). Target year for both of the plans is set as 2040 while that for feasibility study was set as 2025.

Due to absence of reliable data and anticipation of drastic economic development in future stimulated by the economic liberalization policy of the Myanmar government, the framework (future population) in the 2013-JICA Urban Development Plan was formulated based on

- 2011 estimated population and
- resemblance to economic development experienced in the cities of the Southeast Asian countries

The followings are the excerpts from the 2013-JICA Urban Development Plan;

“The JICA Study Team established appropriate socio-economic framework in Greater Yangon through the examination of various alternatives for socio-economic development from the viewpoint of different development scenarios.

(1) Three Demographic Alternatives for Greater Yangon

In the projection of the future population of Greater Yangon, JICA Study Team prepared three different scenarios using the examples from other Asian cities, e.g., the population growth rate in Bangkok was 2.61% (1975-2000), the rate in Hanoi was 2.75% (1975-2000), and the rate in Jakarta was 3.3% (1975-2000). These scenarios are low, middle, and high population growth scenarios, respectively. The differences of urban growth rates are described in the following table.

Table Assumption of Future Population Growth Rate

Population Growth Scenario	Assumption of Annual Growth Rate	Remarks
Low Scenario	2.4 %	Less than the past trend of YCDC
Middle Scenario	2.6 %	Past Trend of YCDC (Bangkok level)
High Scenario	3.3 %	Jakarta level

Source: 2013-JICA Urban Development Plan

Table Population Growth Rate of Major Cities in Neighboring Countries (1975-2000)

City/Country	Population Growth Rate
Bangkok/ Thailand	2.61 %
Hanoi Vietnam	2.75 %
Jakarta/ Indonesia	3.30 %

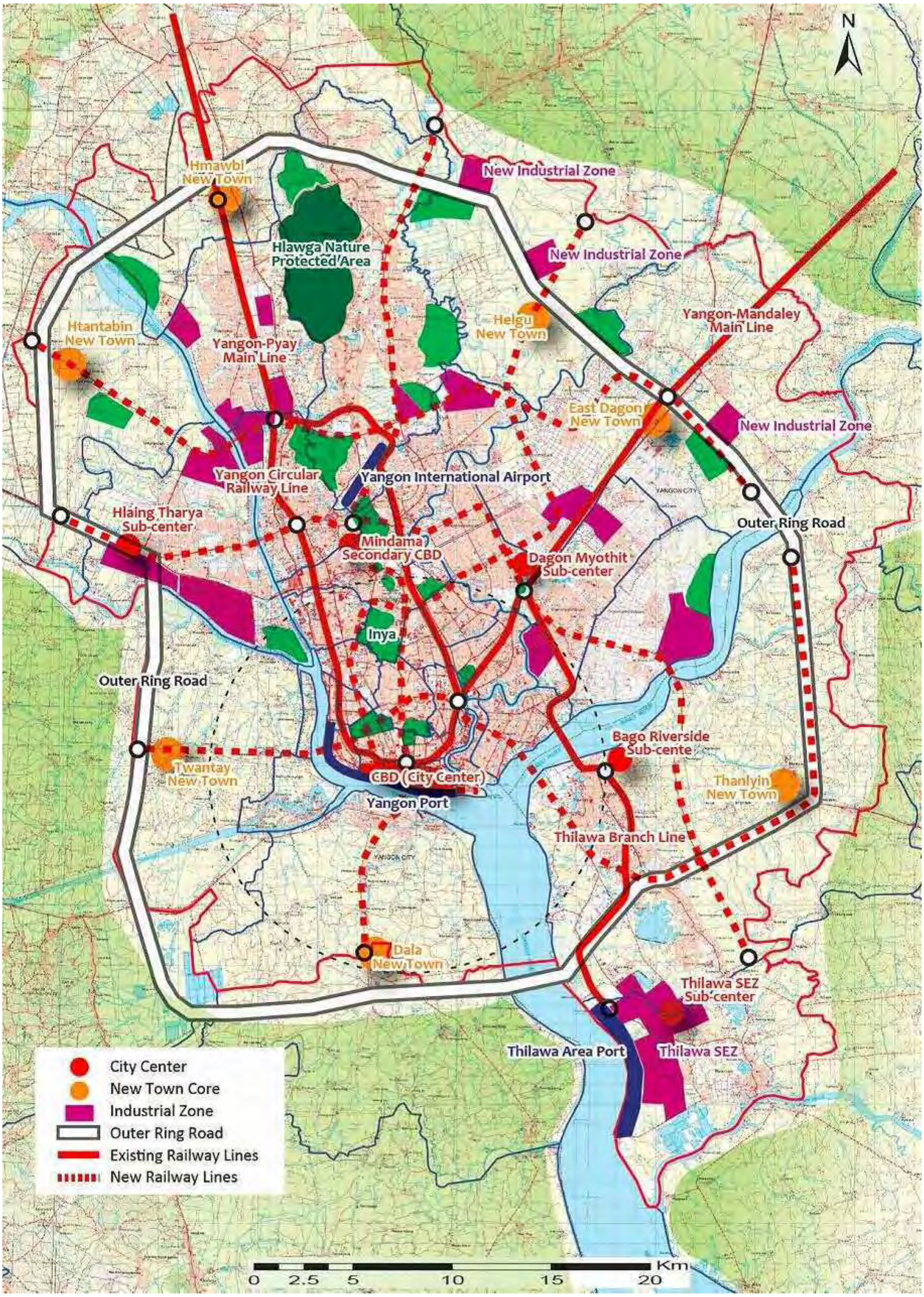
Source: 'World Urbanization Prospect (The 2001 Revision)', World Bank

The population volume in Bangkok City was 6.7 million in 2011 while the population in Bangkok Metropolitan Area, consisting of not only Bangkok City but also the suburban area, was estimated to be more than 10 million by the National Economic and Social Development Board (NESDB). Industrial infrastructure in the eastern seaboard region such as road, railway, seaport, industrial port, power, water resource, etc., namely the 'Eastern Seaboard Development Program (ESDP)' has progressed remarkably from the 1980s era to the first half of the 1990s era. At the same period of the progress of ESDP, the rapid rising yen after the Plaza Accord of 1985 has made the Japanese to invest capital intensively in Thailand especially in the eastern seaboard region. Furthermore, the worldwide huge production base has been formed with a central focus on the eastern seaboard region. The appearance of huge production area has brought about absorbing redundant workers in Bangkok City that have moved from the rural areas, and has influenced the formation of Bangkok Metropolitan Area remarkably.

The period from the timing of the rapid rising yen to the present time is about 30 years which is the same as the projection period of the socio-economic framework. Therefore, JICA Study Team assumed that the future socio-economic scenario of Greater Yangon would be comparable to the past trend of the Bangkok Metropolitan Area.

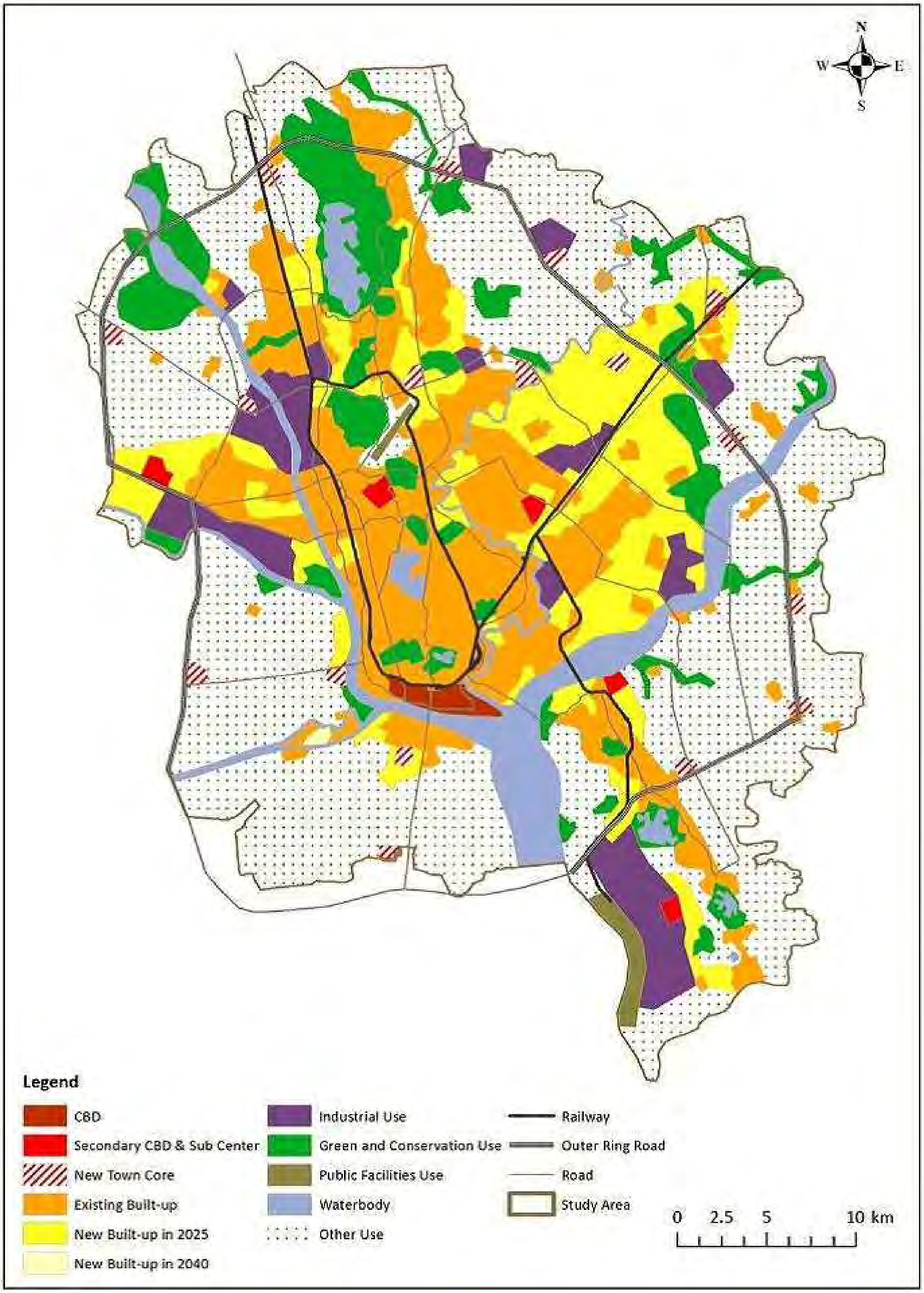
In consideration of the abovementioned circumstances, the 'Middle Scenario' is the recommendable scenario to be adopted for deliberation through consultation with JICA Study Team and YCDC officers."

The 2013-JICA Urban Development Plan envisages that Yangon will have extensive economic development and, proposed sub-centers and green islands system in the radius of 10 to 15 km from the CBD as shown in Figure 3-5. Urbanization has been taking place in agricultural land and “under developing” land. These lands are planned to use for developing housing, etc. Planned land use for 2025 is shown in Figure 3-6.



Source: 2013-JICA Urban Development Plan

Figure 3-5 Planned City Center/ Town Core Area and Main Infrastructure in 2040



Source: 2013-JICA Urban Development Plan

Figure 3-6 Future Urban Structure and Land Use of Greater Yangon

3.2.2 Current Population and Overall Population

The 2013-JICA Urban Development Plan used 2011 population as the base population for future population estimates. The 2011 population was estimated by the Myanmar side in absence of census data that was available only for 1983. The population in the Greater Yangon was estimated to increase from 5.57 million in 2011 to 11.73 million in 2040 while for Yangon city it will increase to 8.52 million in 2040 from 5.14 million in 2011.

In 2014, a national population and housing 2014 census was carried out and, Yangon city population in 2014 is higher than that in 2011. This is remarkable looking at the 2014 national population in Myanmar that decreased from those in 2011.

JICA study team has compared the 2014 census population with the 2014 projected population. The projected populations were calculated using the annual growth rate of 2.6 % for Greater Yangon in the urban development plan. Using the annual growth rates of 1.6 % for Yangon city that were derived from comparison of populations between 2011 and 2018, population was projected for 2014. Overall, the projected population in 2014 is higher than the 2014 census population by 3 % (Following Table).

Table 3-8 Estimated Population in 2011 and 2014

Items	2011	Annual growth rate used in the urban development plan	2014 (Projected in the urban development plan)	2014 (Census)
Yangon city	5,142,128	1.6 %	5,392,920	5,211,431
Peripheral 6 townships (Part)	430,114	11.5 %	597,346	N/A.
Greater Yangon	5,572,242	2.6 %	5,808,266	N/A.

Source: 2013-JICA Urban Development Plan for 2011 and Census for 2014

JICA study team considers that the base population and the economic development scenario used in Yangon can be effective and estimated total population with an annual growth rate of 2.6 % can be used in this study for the following reasons;

- This 2.6 % was set formally expecting economic development in Yangon and Myanmar based on the similar economic development taken place in the Southeast Asian nations.
- The population estimated in the urban development plan is widely used for not only the water sector but also for other sectors and, therefore the same population had better be used for all sectors.
- The margin of difference between the projected population and the census population in 2014 is minimal by 3 %. It is difficult to estimate future growth rate accurately so that we cannot forecast this 3 % may increase or decrease in future. Therefore, it is too early to change the projected figures.
- If population needs to be revised reflecting on the actual population, it should not be revised in a short-term basis but in a medium or long-term basis, say every 10 years.

If trend of future development differs from the future development scenario adopted in this study, e.g. population growth rates becomes low, estimated water demand will become lower. That means the estimated water demand in a specific year will be deferred by some years, depending on actual population growth. The projected water demand in 2025, for example, will become a water demand in some years after 2025 and the proposed 60 MGD Kokkowa system can eventually be utilized.

3.2.3 Population Allocation

The urban development plan allocated the increased population of 6.16 million between 2011 and 2040 in the Greater Yangon, taking into account of developable areas and land use. As a result, increased population was allocated extensively to developing areas, "New Suburbs Zone" and peripheral 6 townships and not in the existing built-up areas.

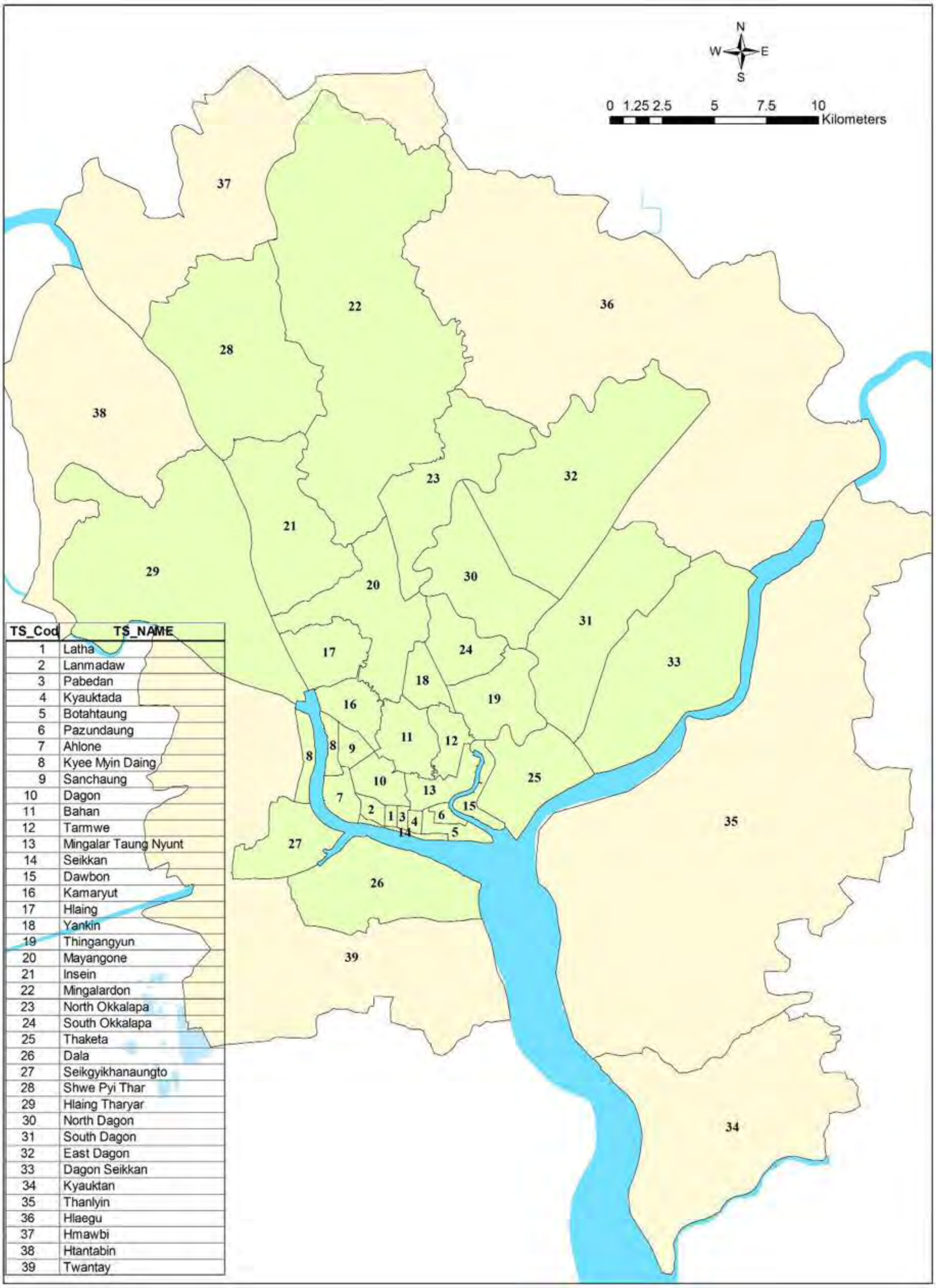
Township group population was calculated using the annual growth rates that were derived from the comparison of those in 2011 and 2018, and is shown in the following Table. The projected township group populations are larger than the 2014 census populations except in New Suburbs zone.

Table 3-9 Township Group Population in 2014 by Urban Development Plan and 2014 census

(Unit: 1,000 persons)

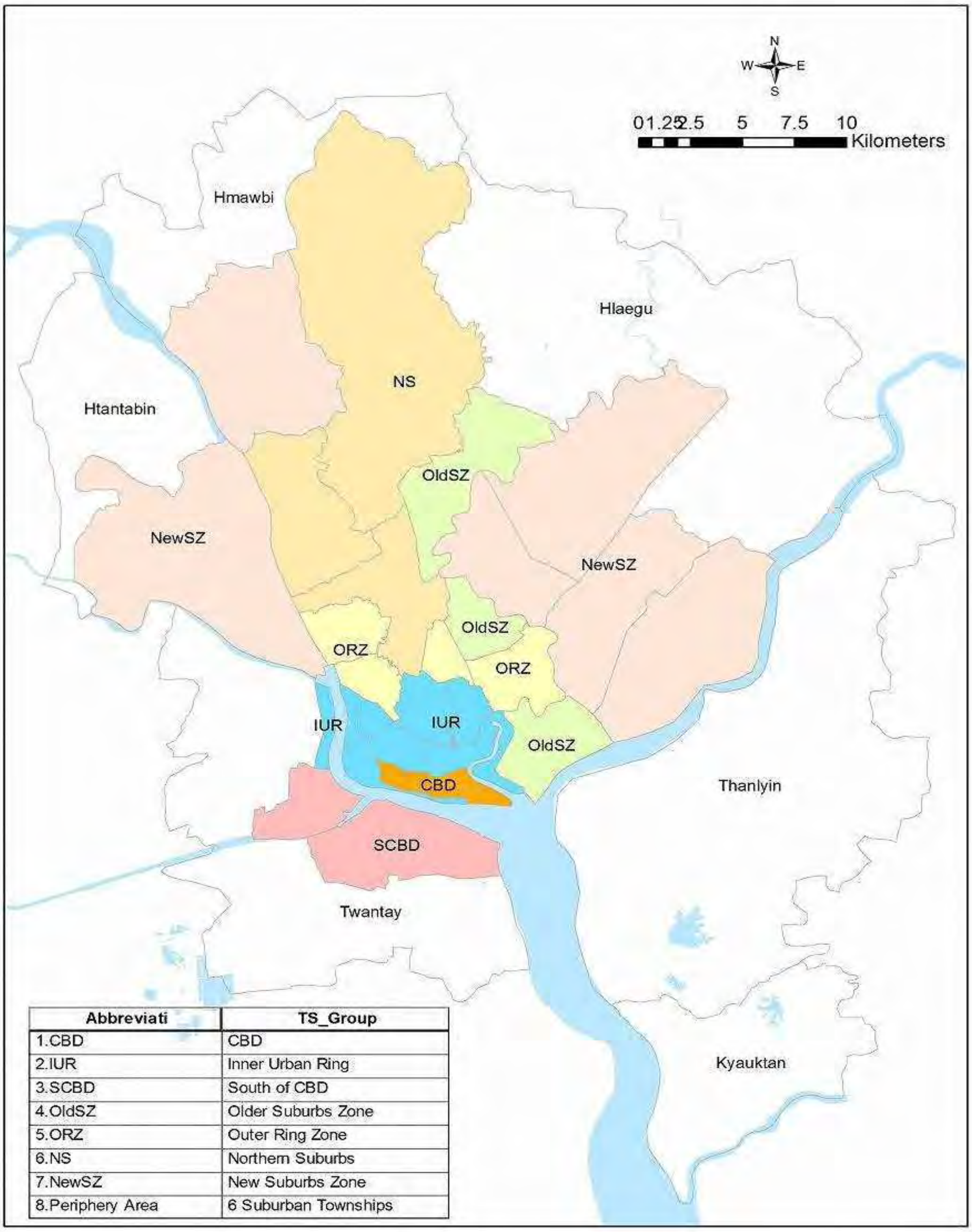
Township Group	1998	(A) 2011	(B) Calculated Annual Growth rate between 2011 and 2018 in the Urban Development Plan	2014 Projected using the growth rate of (A) x (B)	2014 Census
CBD	256	252	0.03 %	253	225
Outer Ring Zone	598	596	0.17 %	599	525
Inner Urban Ring	664	848	0.27 %	855	764
Older Suburbs Zone	689	778	0.40 %	788	715
South of CBD	103	220	3.59 %	244	207
Northern Suburbs	595	805	2.20 %	860	835
New Suburbs Zone	687	1,642	2.89 %	1,788	1,940
Yangon city Total	**3,592**	**5,142**	**1.59 %**	**5,391**	**5,211**
6 suburban TSs (all)	**-**	**1,072**	**7.18 %**	**1,320**	**1,289**
Grand Total	**-**	**6,214**	**2.60 %**	**6,711**	**6,500**
6 suburban TSs (part)	**-**	**430**	**11.57 %**	**926**	**N/A.**

Source: 2013-JICA Urban Development Plan and 2014 census



Note: Light green color areas indicate YCDC controlled area and light pink plus light green area is Greater Yangon
Source: 2014 JICA Water MP

Figure 3-7 Greater Yangon Area and YCDC Area (33 townships)



Note: City center is composed of CBD (Orange color), IUR (Light blue color) and a part of ORZ (Light yellow color) areas
Source: 2014-JICA Water MP

Figure 3-8 Township Group in YCDC Area

Future population in each township are either the projected population in the urban development plan or population in the 2014 census that is lower than the projected population. Then, decreased number of population is allocated to the New Suburban Zone.

The revision is made in the following manners;

- Firstly it is set that total projected population remains unchanged.
- Future population in CBD and Inner Urban Ring Zones of the built-up areas is considered to be

same as 2014 census population because population has continued decreasing since 1998 and has been fixed as that in 2014 census.

- (Inner Urban Ring Zone) Population in Dagon, Bahan and Dawbon is considered to be same as 2014 census population while the projected populations are employed in the remaining townships.

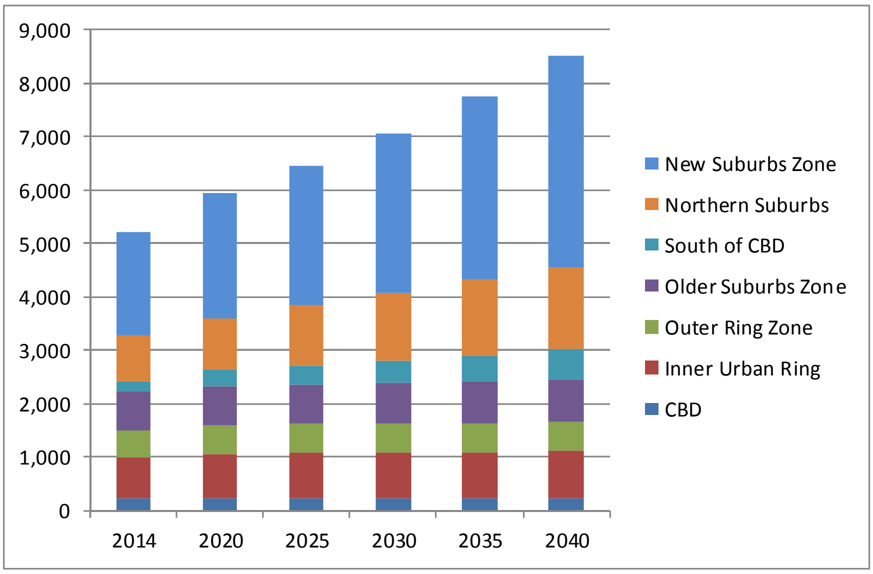
Populations in Outer Ring Zone and Older Suburbs Zone of the built-up areas will increase slightly.

- (Outer Ring Zone) Population in Yankin and Thingangyun is considered to be same as 2014 census population while the projected populations are employed in the remaining townships.
- (Older Suburbs) Population in South Okkalapa and Thakayta is considered to be same as 2014 census population while the projected population is employed in North Okkalapa township.

Population in Northern Suburbs Zone, South of CBD and New Suburbs Zone will increase considerably.

- (Northern Suburbs) Population in Mayangon township is adjusted downward while the projected population is employed in the remaining two townships.
- (South of CBD) The projected population is employed.
- (New Suburbs) The projected population, which is still lower than the 2014 census population, is employed in the 4 townships in east Yangon. Population in Shwepyitha and Hlaing Tharyar townships is considerably increased compared to the projected ones in Urban Development Study.

As is shown in the following Figure, future increased population is allocated to the developing areas; New Suburban Zone, Northern Suburban Zone and South of CBD Zones. The revised population is given in the following Table.



Source: JICA Study Team

Figure 3-9 Revised Population Projection by Township Group

Table 3-10 Revised Population of Township and Township Group in Yangon City

(Unit: 1,000 persons)

No	Township	District	Area (km^2)	2014	2020	2025	2030	2035	2040	Note
1	Latha	West	0.60	25	25	25	25	25	25	C
2	Lanmadaw	West	1.31	47	47	47	47	47	47	C
3	Pabedan	West	0.62	33	33	33	33	33	33	C
4	Kyauktada	West	0.70	30	30	30	30	30	30	C
5	Botahtaung	East	2.60	41	41	41	41	41	41	C
6	Pazuntaung	East	1.07	48	48	48	48	48	48	C
	CBD		**6.91**	**225**	**225**	**225**	**225**	**225**	**225**	
7	Ahlon	West	3.38	55	66	67	67	68	69	D
8	Kyimyindine	West	4.46	112	124	129	135	141	149	D
9	Sangyoung	West	2.40	100	106	106	107	108	108	D
10	Dagon	West	4.89	25	25	25	25	25	25	C
11	Bahan	West	8.47	97	97	98	98	99	99	C
12	Tamway	East	4.99	165	193	193	195	196	197	D
13	Mingala Taungnyunt	East	4.94	132	158	159	161	163	165	D
14	Seikkan	West	1.17	3	3	3	3	3	3	D
15	Dawbon	East	3.11	75	75	75	75	75	75	C
	Inner Urban Ring		**37.83**	**764**	**847**	**856**	**866**	**877**	**890**	
16	Kamayut	West	6.47	85	91	94	96	99	103	D
17	Hline	West	9.82	160	160	160	160	160	160	D
18	Yankin	East	4.79	71	71	71	71	71	71	C
19	Thingangyun	East	13.12	209	209	209	209	209	209	C
	Outer Ring Zone		**34.20**	**525**	**532**	**534**	**537**	**540**	**544**	
20	Mayangon	West	25.83	198	207	208	213	218	223	R
21	Insein	North	31.40	305	327	337	349	362	377	D
22	Mingaladon	North	127.96	332	427	576	704	832	907	D
	Northern Suburbs		**185.19**	**835**	**961**	**1,121**	**1,266**	**1,411**	**1,507**	
23	North Okkalapa	East	27.76	333	355	369	385	403	423	D
24	South Okkalapa	East	8.22	161	161	161	161	161	161	C
25	Thakayta	East	13.45	221	221	221	221	221	221	C
	Older Suburbs Zone		**49.42**	**715**	**736**	**750**	**766**	**785**	**805**	
26	Dala	South	98.41	173	254	302	357	419	490	D
27	Seikkyi/ Khanaungto	South	12.10	34	47	53	59	66	74	D
	South of CBD		**110.51**	**207**	**301**	**354**	**416**	**485**	**564**	
28	Shwepyitha	North	52.69	344	369	385	448	506	602	R
29	Hlaing Tharyar	North	77.61	688	741	769	794	854	962	R
30	Dagon North	East	24.18	204	237	247	259	272	287	D
31	Dagon South	East	37.51	372	413	441	473	509	550	D
32	Dagon East	East	170.87	166	390	552	736	945	1,183	D
33	Dagon Seikkan	East	42.04	167	186	229	279	335	399	D
	New Suburbs Zone		**404.90**	**1,940**	**2,335**	**2,623**	**2,988**	**3,421**	**3,985**	
	Total		**828.96**	**5,211**	**5,936**	**6,464**	**7,063**	**7,745**	**8,520**	**D**

Note:
C: 2014 Census population is used for population in 2014 which is lower than the projected population in the Urban Development Study.
D: The projected population in the Urban Development Study is employed for future population.
R: Population is re-allocated upward in Shwepyitha and Hlaing Tharyar townships while re-allocated downward in Mayangon township,
Source: JICA Study Team

3.2.4 Water Demand by Township

(1) Summary of Water Demand Estimation

Population and coverage ratio have been reviewed using the latest 2014 census results while per capita consumption has been reviewed using the latest YCDC data (April 2012 to March 2015). As a result, the frameworks used in the MP can be applicable with some modifications in this study. The revised frameworks are shown in Table 3-11 together with other service level targets. For reference, the frameworks used in the MP are presented in Table 3-12.

Table 3-11 Revised Water Demand and Service Level Targets for Yangon City

Item	Unit/ Year	2014	2025	2040
Population	1,000 person	*5,211*	6,464	8,520
Served Population	1,000 person	*1,845*	*3,618*	*6,661*
Water Supply Coverage Ratio	%	*35*	*56*	*78*
Unit Consumption (Domestic) City/suburbs*	Lpcd	111/69	150/100	200/150
Unit Consumption (Non-domestic) City/suburbs*	Lpcd	74/46	100/67	133/100
Leakage Ratio	%	50	25	10
Daily Average Water Demand	1,000 m^3/day	*643*	*1,072*	*2,174*
Daily Maximum Water Demand	1,000 m^3/day	*708*	*1,179*	*2,391*
Daily Average Water Demand	MGD	*142*	*237*	*477*
Daily Maximum Water Demand	MGD	*156*	*258*	*525*
Water Pressure	MPa	0.075	More than 0.15Mpa	
Supply Duration (average)	Hour	8	24	
Water Quality	-	Not drinkable	Drinkable	

Note: * The numbers in the Right are applied to South of CBD and New Suburbs Zone, and in the Left are for other area.
Source: JICA Study Team

Table 3-12 Water Demand for Yangon City as per The MP (reference)

Item	Year	2011	2025	2040
Population	1,000 person	5,142	6,464	8,520
Served Population	1,000 person	1,934	3,764	6,810
Water Supply Coverage Ratio	%	38	58	80
Unit Consumption (Domestic) *	Lpcd	95	150/100	200/150
Unit Consumption (Non-domestic) City/suburbs*	Lpcd	63	100/67	133/100
Leakage Ratio	%	50	25	10
Daily Average Water Demand	1,000 m^3/day	612	1,126	2,243
Daily Maximum Water Demand	1,000 m^3/day	673	1,238	2,467
Daily Average Water Demand	MGD	135	248	493
Daily Maximum Water Demand	MGD	148	272	543
Water Pressure	MPa	0.075	More than 0.15Mpa	
Supply Duration (average)	Hour	8	24	
Water Quality	-	Not drinkable	Drinkable	

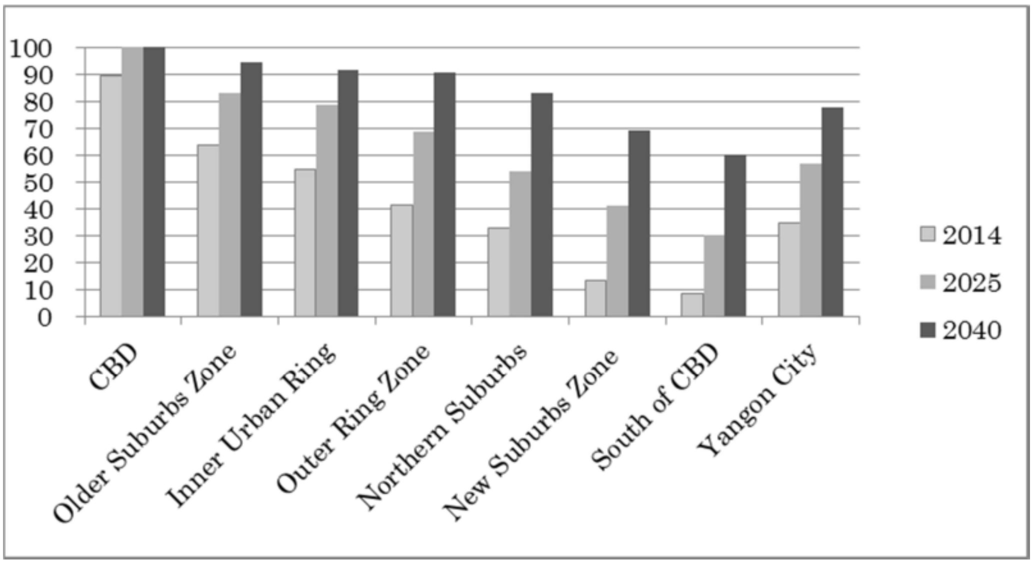
Note: * The numbers in the Right are applied to South of CBD and New Suburbs Zone, and in the Left are for other area.
Source: 2014-JICA Water MP

(2) Service Coverage Ratio

In the MP, the service coverage ratio of each township in 2011 was calculated using Household Interview Survey data in 2012 (2013 JICA-HIS), which is used for the service coverage ratio for 2011 in that project. In the MP, service coverage ratio in 2040 is set as 80%.

The actual data in 2014 based on the census reflects a difference in coverage ratio by township. For future forecast of the service coverage ratio to approach the target in 2040 set in the MP, increasing rate of 2% per year is applied to the actual service coverage ratio of each township in 2014. In addition, townships of Ahlon, Sangyoung, Kamayut and Hlaing Tharyar that have low actual coverage ratio in Zone 1 and Zone 9 (target area in this Study, and see the Appendix-1), will not have high coverage ratio in 2025 even if 2% increase per year is applied. Therefore, coverage ratio for these townships is considered as about 45% in 2025 which is same as coverage ratio of Zone 7 and 8 (including 4 TSs; Dagon North, Dagon South, Dagon East and Dagon Seikkan) of Phase 1 project under implementation, considering that these townships will also have same development pattern.

Using the population data in the 2014 census and the coverage ratio by township set above, the service coverage ratio for Yangon city is estimated as 35 %, which is comparable to the coverage ratio of 38 % in 2011 on the MP based on the 2013 JICA-HIS. With some adjustment in figures of a few townships, the modified service coverage ratios of township is used for the target coverage ratio in this Study as shown in the following Table. As a result, the coverage ratio in Yangon city is slightly changed to 56 % in 2025 and 78 % in 2040 from the corresponding MP figures of 58 % in 2025 and 80 % in 2040, respectively. This decrease results from the fact that more population is allocated to the developing areas where service coverage ratio is lower than the developed areas.



Source: JICA Study Team

Figure 3-10 Revised Water Supply Coverage Ratio by Township Group in Yangon City (%)

Table 3-13 Revised Water Coverage Ratio by Township Group in Yangon City (%)

No	Township	2014	2020	2025	2030	2035	2040
1	Latha	85	97	100	100	100	100
2	Lanmadaw	70	82	92	100	100	100
3	Pabedan	88	100	100	100	100	100
4	Kyauktada	96	100	100	100	100	100
5	Botahtaung	98	100	100	100	100	100
6	Pazuntaung	99	100	100	100	100	100
	CBD	**89**	**96**	**98**	**100**	**100**	**100**
7	Ahlon	20	32	*45*	55	65	75
8	Kyimyindine	4	16	26	36	46	56
9	Sangyoung	14	26	*45*	55	65	75
10	Dagon	47	59	69	79	89	99
11	Bahan	86	98	100	100	100	100
12	Tamway	87	99	100	100	100	100
13	Mingala Taungnyunt	96	100	100	100	100	100
14	Seikkan	66	78	88	98	100	100
15	Dawbon	29	41	51	61	71	81
	Inner Urban Ring	**55**	**66**	**72**	**77**	**82**	**86**
16	Kamayut	8	20	*45*	55	65	75
17	Hline	27	39	49	59	69	79
18	Yankin	89	100	100	100	100	100
19	Thingangyun	48	60	70	80	90	100
	Outer Ring Zone	**41**	**52**	**63**	**72**	**80**	**89**
20	Mayangon	48	60	70	80	90	100
21	Insein	26	38	48	58	68	78
22	Mingaladon	30	42	52	62	72	82
	Northern Suburbs	**33**	**45**	**54**	**64**	**74**	**84**
23	North Okkalapa	86	98	100	100	100	100
24	South Okkalapa	68	80	90	100	100	100
25	Thakayta	28	40	50	60	70	80
	Older Suburbs Zone	**64**	**77**	**83**	**88**	**92**	**95**
26	Dala	10	22	32	42	52	62
27	Seikkyi/ Khanaungto	0	12	22	32	42	52
	South of CBD	**9**	**20**	**31**	**41**	**51**	**61**
28	Shwepyitha	8	20	30	40	50	60
29	Hlaing Tharyar	3	15	*45*	55	65	75
30	Dagon North	34	46	56	66	76	86
31	Dagon South	25	37	47	57	67	77
32	Dagon East	16	28	38	48	58	68
33	Dagon Seikkan	14	26	36	46	56	66
	New Suburbs Zone	**14**	**26**	**42**	**51**	**61**	**71**
	Total	**35**	**46**	**56**	**63**	**71**	**78**

Source: 2014; Census data and 2020 to 2040; JICA Study Team

(3) Served Population

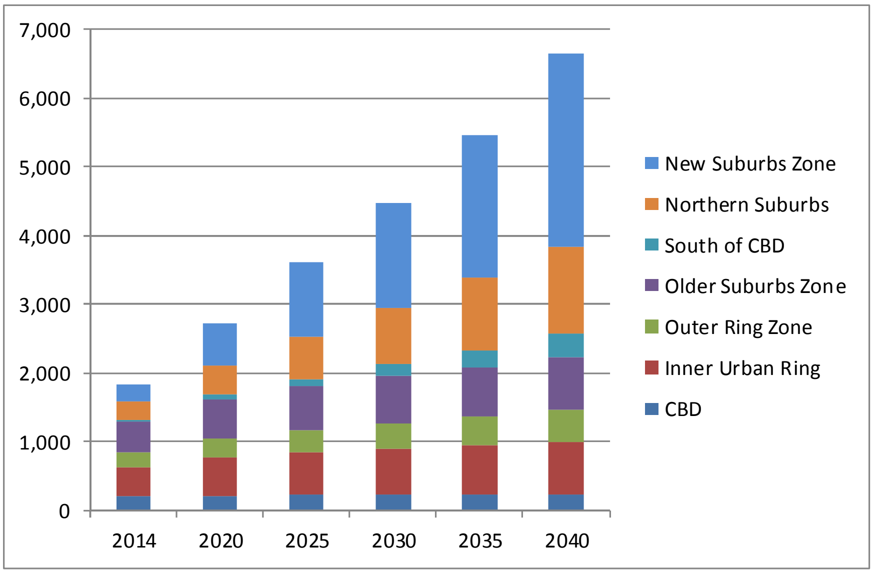
The served population up to 2040 is calculated using the coverage ratio and township population set above and shown in the following Table and Figure. The served population in Yangon city area in 2025 will be 3.6 million, which is corresponding to an increase of 1.8 million from that in 2014 or two times of that in 2014.

Table 3-14 Revised Water Served Population by Township in Yangon City

(Unit: 1,000 persons)

No	Township	2014	2020	2025	2030	2035	2040
1	Latha	21	24	25	25	25	25
2	Lanmadaw	33	39	43	47	47	47
3	Pabedan	29	33	33	33	33	33
4	Kyauktada	29	30	30	30	30	30
5	Botahtaung	40	41	41	41	41	41
6	Pazuntaung	48	48	48	48	48	48
	CBD	200	215	220	224	224	224
7	Ahlon	11	21	30	37	44	51
8	Kyimyindine	4	20	34	48	65	83
9	Sangyoung	14	28	48	59	70	81
10	Dagon	12	15	17	20	22	25
11	Bahan	83	96	98	98	99	99
12	Tamway	144	191	194	195	196	197
13	Mingala Taungnyunt	128	158	159	161	163	165
14	Seikkan	2	2	2	3	3	3
15	Dawbon	22	31	38	46	53	61
	Inner Urban Ring	420	562	620	667	715	765
16	Kamayut	7	18	42	53	65	77
17	Hline	43	63	79	95	111	127
18	Yankin	63	71	71	71	71	71
19	Thingangyun	101	126	147	168	189	209
	Outer Ring Zone	214	278	339	387	436	484
20	Mayangon	96	124	146	171	196	224
21	Insein	79	124	162	202	246	294
22	Mingaladon	98	180	299	436	599	744
	Northern Suburbs	273	428	607	809	1,041	1,262
23	North Okkalapa	287	348	369	385	403	424
24	South Okkalapa	110	129	145	161	161	161
25	Thakayta	61	88	110	132	154	176
	Older Suburbs Zone	458	565	624	678	718	761
26	Dala	18	56	97	150	218	304
27	Seikkyi/ Khanaungto	0	6	12	19	28	39
	South of CBD	18	62	109	169	246	343
28	Shwepyitha	29	74	115	179	253	361
29	Hlaing Tharyar	21	111	346	437	555	722
30	Dagon North	70	109	138	171	207	247
31	Dagon South	93	153	207	269	341	424
32	Dagon East	26	109	210	353	548	805
33	Dagon Seikkan	23	48	83	128	188	263
	New Suburbs Zone	262	604	1,099	1,537	2,092	2,822
	Total	1,845	2,714	3,618	4,471	5,477	6,661

Source: JICA Study Team



Source: JICA Study Team

Figure 3-11 Revised Township Group Water Served Population in Yangon City (Unit: 1,000 persons)

(4) Per Capita Consumption

In the MP, two types of per capita consumption was proposed; one for the relatively developed city area and another for the potential developing area, and the per capita consumption was planned to increase according to economic development and considering the current suppressed water supply condition, referring to the patterns of other capital cities in the Southeast Asian countries which experienced economic developments. This scenario is applicable to this study and the same per capita consumption as shown in the following is used in this Study.

Table 3-15 Target of Per Capita Average Consumption by Township Group (Lpcd)

	Township Group		2011	2014	2020	**2025**	2030	2035	**2040**
Yangon City	CBD, Inner Urban Ring Outer Ring Zone, Northern Suburbs, Older Suburbs Zone	Domestic Non-domestic Total	100 67 167	111 74 185	132 88 220	**150** **100** **250**	167 111 278	183 122 305	**200** **133** **333**
Yangon City - Suburbs	South of CBD, New Suburbs Zone	Domestic Non-domestic Total	60 40 100	69 46 115	86 57 143	**100** **67** **167**	117 78 195	133 89 222	**150** **100** **250**

Source: 2014-JICA Water MP

The study team has collected data of the number of water service connections and billed amount for years 2012/13 to 2014/15. Then these data are compared with the previous data for years 2009/10 to 2011/12 in the MP. Between 2009/10 and 2013/14 (Table 3-16), the number of connection and total consumption did not change so much reflecting no additional water source increase. Hence the study team uses the figures between 2009/10 and 2013/14 to estimate current per capita consumption. As a result, domestic and non-domestic per capita consumption is calculated as 115 lpcd and 82 lpcd, respectively[3]. These numbers are almost equal to the proposed numbers in years 2011 to 2014 on the MP and the study team decided to use the numbers in the MP. In addition, the Nyaunghnapin WTP Phase 2 (45 MGD) was started operation from 2014/15 (Table 3-17).

Table 3-16 Connection and Daily Consumption of YCDC between 2009/10 and 1013/14

Year	Domestic			Commercial			Department	Total
	Meter	Flat Rate	Sub total	Meter	Flat Rate	Sub total		
Connection								
2009/10	145,159	60,465	205,624	13,791	3,510	17,301	*1,168*	224,093
2010/11	152,405	56,938	209,343	13,749	3,239	16,988	*1,168*	227,659
2011/12	162,890	54,937	217,827	14,359	2,725	17,084	1,168	238,920
2012/13	178,483	54,000	232,483	17,112	3,797	20,909	*1,256*	254,648
2013/14	159,480	51,832	211,312	16,359	1,669	18,028	*1,256*	230,596
Average	**159,683**	**55,634**	**215,318**	**15,074**	**2,988**	**18,062**	**1,203**	**235,183**
Daily Consumption (m3)								
2009/10	69,544	38,670	108,214	19,942	6,778	26,720	*43,104*	179,908
2010/11	70,192	35,623	105,815	21,644	6,565	28,209	*43,104*	179,241
2011/12	75,782	35,552	111,334	25,139	5,828	30,967	43,104	187,186
2012/13	76,588	32,877	109,465	25,311	7,270	32,581	*50,250*	194,166
2013/14	79,953	31,505	111,458	25,837	3,313	29,150	*50,250*	192,728
Average	**74,412**	**34,845**	**109,257**	**23,574**	**5,951**	**29,525**	**45,962**	**186,646**

Note: Numbers in Italics are estimated one.
Source: JICA Study Team based on YCDC Data

Table 3-17 Connection and Daily Consumption of YCDC in 2014/15

Year	Domestic			Commercial			Department	Total
	Meter	Flat Rate	Sub total	Meter	Flat Rate	Sub total		
Connection								
2014/15	197,234	33,237	230,471	21,259	0	21,259	1,256	252,986
Daily Consumption (m3)								
2014/15	100,600	20,352	120,952	34,059	0	34,059	50,250	207,131

Source: JICA Study Team based on YCDC Data

(5) Non-revenue Water Ratio and Leakage Ratio

YCDC supplied water amounting 148 MGD (673,000 m^3/day) to 1.85 million people in 2013; and per capita supply amount is calculated as 365 liters per day. This amount should be adequate to consumers if delivered properly; however there are many consumers' complaints about supply pressure, supply hour and so on according to 2013 JICA HIS. In fact, revenue water ratio is low, estimated to be about 30 % according to the YCDC data from 2011/12 to 2013/14. YCDC has intention to reduce it and the target level is set as 15 % by 2040.

Leakage reduction requires continuous efforts and strong support from management side with investment costs for replacement of old pipes, etc. YCDC has set ambitious leakage level as 10 % in 2040[4]. Target levels of leakage with non-revenue water on the MP are shown below. Non-revenue water ratio and leakage ratio in 2025 are 35 % and 25 %, respectively.

[3] Using 4.4 persons per household in 2014 census.

[4] Various measures to reduce NRW have already been initiated with assistance of international institutions. In addition, old pipes will be replaced in Zone 1 proposed in this study and additional pipes will be installed in the eastern Yangon (JICA-Phase 1 project) and the western Yangon (JICA-Phase 2 project that is being studied in this study). Hence, leakage is expected to decrease considerably.
Currently, the JICA technical cooperation project, in addition to Japanese Grant Aid, assistance from France, Denmark and Manila Water are being implemented to formulate measures for leakage rate reduction.

Table 3-18 Non-revenue Water Rate and Leakage Rate

Items	2013	2020	**2025**	2030	2035	2040
Non-revenue Water Rate (%)	66	46	**35**	26	20	15
Leakage Rate (%)	50	33	**25**	18	13	10

Source: 2014-JICA Water MP

(6) Peak Factor

On the MP, referring to the past values of YCDC, Bangkok and the large cities in Japan, the peak factor is set at 110%. The factor is applicable of the same value on this Study.

(7) Water Demand Estimation

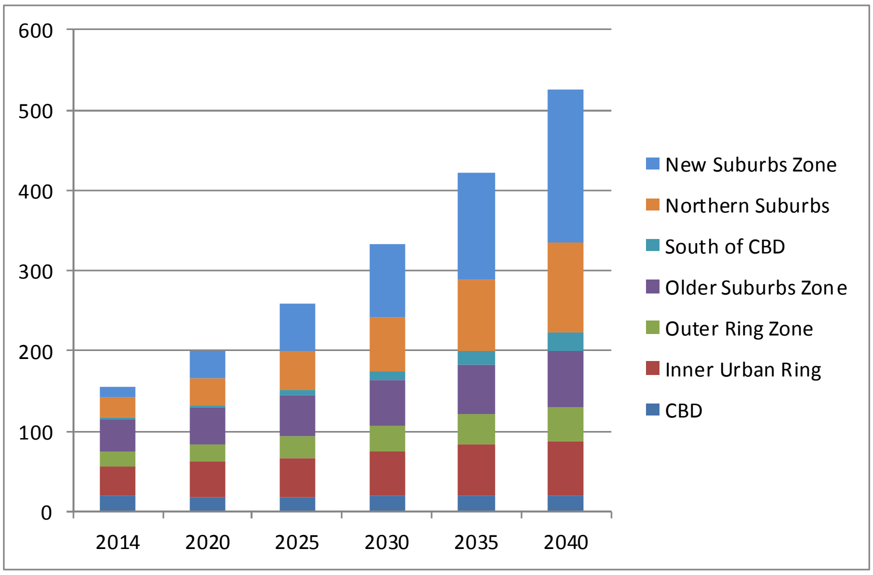
Water demand is estimated as shown below, using an annual peak factor of 110 %.

Table 3-19 Revised Water Demand by Township Group (Daily Maximum: MGD)

No	Township	2014	2020	2025	2030	2035	2040
1	Latha	2	2	2	2	2	2
2	Lanmadaw	3	3	3	4	4	4
3	Pabedan	3	3	3	3	3	3
4	Kyauktada	3	2	2	3	3	3
5	Botahtaung	4	3	3	3	4	4
6	Pazuntaung	4	4	4	4	4	4
	CBD	**19**	**17**	**17**	**19**	**20**	**20**
7	Ahlon	1	2	2	3	4	5
8	Kyimyindine	0	2	3	4	6	7
9	Sangyoung	1	2	4	5	6	7
10	Dagon	1	1	1	2	2	2
11	Bahan	7	8	8	8	9	9
12	Tamway	13	15	16	16	17	18
13	Mingala Taungnyunt	11	13	13	14	14	15
14	Seikkan	0	0	0	0	0	0
15	Dawbon	2	2	3	4	5	5
	Inner Urban Ring	**36**	**45**	**50**	**56**	**63**	**68**
16	Kamayut	1	1	3	4	6	7
17	Hline	4	5	6	8	10	11
18	Yankin	6	6	6	6	6	6
19	Thingangyun	9	10	12	14	16	19
	Outer Ring Zone	**20**	**22**	**27**	**32**	**38**	**43**
20	Mayangon	9	10	12	14	17	20
21	Insein	7	10	13	17	21	26
22	Mingaladon	9	14	24	37	52	67
	Northern Suburbs	**25**	**34**	**49**	**68**	**90**	**113**
23	North Okkalapa	26	28	30	32	35	38
24	South Okkalapa	10	10	12	14	14	14
25	Thakayta	5	7	9	11	13	16
	Older Suburbs Zone	**41**	**45**	**51**	**57**	**62**	**68**
26	Dala	1	3	5	9	14	20
27	Seikkyi/ Khanaungto	0	0	1	1	2	3
	South of CBD	**1**	**3**	**6**	**10**	**16**	**23**
28	Shwepyitha	2	4	6	11	16	24
29	Hlaing Tharyar	1	6	19	26	35	49
30	Dagon North	4	6	7	10	13	17

No	Township	2014	2020	2025	2030	2035	2040
31	Dagon South	5	8	11	16	22	28
32	Dagon East	1	6	11	21	35	54
33	Dagon Seikkan	1	3	4	8	12	18
	New Suburbs Zone	**14**	**33**	**58**	**92**	**133**	**190**
	Total	**156**	**199**	**258**	**334**	**422**	**525**

Source： JICA Study Team



Source: JICA Study Team

Figure 3-12 Revised Daily Maximum Water Demand by Township Group (Unit: MGD)

3.2.5 Water Demand by Water Supply Zone

Demand by township is converted to demand by water supply zone (see the MAP in the top page). The main futures of water demand by distribution zone in 2014, 2025 and 2040 are shown in Tables 3-20, 3-21 and 3-22, respectively.

Table 3-20 Revised Main Features by Distribution Zone in 2014 for Yangon City

Zone	Population	Coverage ratio	Served Population	Number of Connection	Daily Max. demand	**Daily Max. demand**
	1,000	%	1,000	1,000	mld	**MGD**
1	794	62	488	111	199	**44**
2	637	47	299	68	122	**27**
3	653	47	310	70	126	**28**
4	653	58	380	86	155	**34**
5	501	15	75	17	26	**6**
6	133	30	39	9	16	**4**
7	370	26	96	22	24	**5**
8	539	22	117	26	29	**6**
9	688	3	21	5	5	**1**
10	243	8	19	4	5	**1**
Total	**5,211**	**35**	**1,845**	**419**	**708**	**156**

Source: JICA Study Team

Table 3-21 Revised Main Features by Distribution Zone in 2025 for Yangon City

Zone	Population	Coverage ratio	Served Population	Number of Connection	Daily Max. demand	**Daily Max. demand**
	1,000	%	1,000	1,000	mld	**MGD**
1	866	77	667	152	245	**54**
2	655	68	445	101	163	**36**
3	673	69	463	105	170	**37**
4	746	75	562	128	206	**45**
5	659	39	258	59	80	**18**
6	231	52	120	27	44	**10**
7	799	44	348	79	85	**18**
8	670	43	290	66	71	**15**
9	769	45	346	79	85	**19**
10	397	30	119	27	30	**6**
Total	6,464	56	3,618	822	1,179	**258**

Source: JICA Study Team

Table 3-22 Revised Main Features by Distribution Zone in 2040 for Yangon City

Zone	Population	Coverage rate	Served Population	Number of Connection	Daily Max. demand	**Daily Max. demand**
	1,000	%	1,000	1,000	mld	**MGD**
1	896	89	793	180	323	**71**
2	658	91	599	136	244	**54**
3	697	91	632	144	258	**56**
4	875	90	791	180	322	**71**
5	1,034	69	715	163	255	**56**
6	364	82	298	68	122	**26**
7	1,471	72	1,052	239	321	**71**
8	950	72	687	156	210	**46**
9	962	75	722	164	221	**49**
10	613	60	370	84	116	**25**
Total	8,520	78	6,661	1,514	2,391	**525**

Source: JICA Study Team

3.3 Review of Water Allocation

3.3.1 Supply Capacity Development

The daily maximum demand in Yangon city will be 258 MGD in 2025. On the other hand, the existing water supply capacity in Yangon city is 215 MGD excluding water from well sources and 10 MGD (out of 40 MGD) of Lagunbyin system which will be sent to Thilawa SEZ, outside of Yangon city.

Hence, supply capacity and demand will be balanced in 2023 and additional water supply capacity is required to cater to the demand after 2023. Required additional capacity will be 43 MGD in 2025 and 58 MGD in 2026 and the facilities of 60 MGD capacity at the Kokkowa are planned in this study.

3.3.2 New Water Source (Pan Hlaing River)

Although the Kokkowa River (2nd stage) and the Toe River have been selected as additional water sources to meet the demand after 2025 in the MP, YCDC has identified the Pan Hlaing River as another water source after the MP study. The Pan Hlaing River branches off from the Kokkowa River and meets the Hlaing River downstream (see the location Map). In the MP, Pan Hlaing River was not considered as a water source due to presence of high salinity in river water. However, if tide gates are installed, salinity in river water is expected to reduce within drinkable level. YCDC is now considering to construct WTP in Zone 9 upon construction of tide gates in order to use Pan Hlaing river water as a source. This source can be a substitute of the Kokkowa River water source, and if the Pan Hlaing River water supply system has a capacity of 60 MGD, the required capacity of the Kokkowa would be reduced by 60 MGD.

Water treated at both Kokkowa and Pan Hlaing will be conveyed firstly to Zone 9 SR from where water will be either distributed to Zone 9 or conveyed further to Zone 1. Conveyance pipe from Pan Hlaing River is shorter in length than that from Kokkowa so that Pan Hlaing system is cheaper than Kokkowa system considering the construction, and operation and maintenance costs. However, Pan Hlaing system cannot be constructed immediately because long time is required for construction of tide gate and agreement of water allocation between YCDC (EDWS) and MoAI. Kokkowa 1st stage of 60 MGD should be constructed first to meet water demand in 2025. After the Kokkowa 1st stage and before the Kokkowa 2nd stage and Toe, Pan Hlaing (60 MGD) can be constructed.

3.3.3 Revised Supply Capacity Development

Considering the new water source of Pan Hlaing, water development scenario proposed in the MP is revised in this Study as below. Kokkowa 1st stage and Pan Hlaing are to be developed with 60 MGD capacity each by 2030. By 2040, river water supply system is to be developed for Kokkowa 2nd stage, Toe proposed in MP, and new Pan Hlaing. Final capacity of the Pan Hlaing system will be between 60 MGD and 100 MGD according to EDWS. Final capacity will be decided after study of MoAI and allocation agreement of MoAI.

EDWS has decided the combined capacity of the Kokkowa and Pan Hlaing as 240 MGD. Out of the required capacity of the river system of 310 MGD in 2040, the combined capacity of the Kokkowa and Pan Hlaing systems will be 240 MGD and Toe system will be 70 MGD. This combination of systems is called as option “Revision” (Figure 3-16 and Table 3-24). In option “Alternative” (Figure 3-16), the capacity of the Toe system is reduced to 25 MGD, equal to demand of Zone 10 in 2040, and 45 MGD is added to the Kokkowa system.

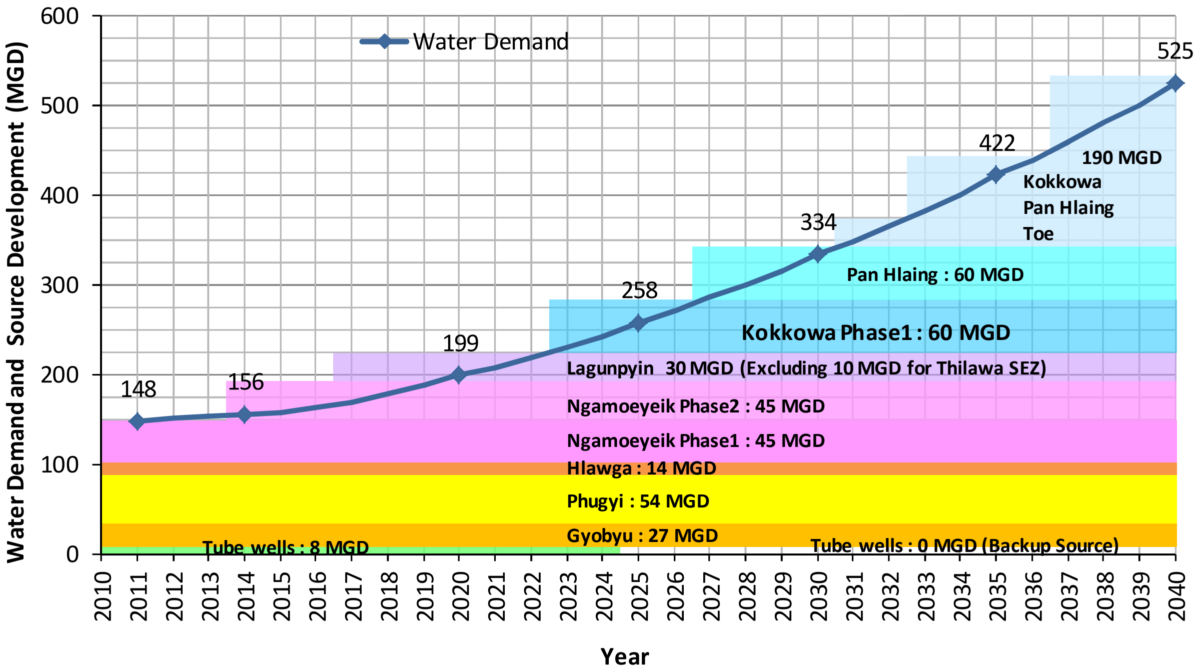
Table 3-23 Revised Water Source Development for Yangon City under This Study

(Unit: MGD)

Year	2014	2020	2025	2030	2035	2040
Daily Maximum Demand	**156**	**199**	**258**	**334**	**422**	**525**
Water Source						
(Reservoir (Dam) System)						
Gyobyu Reservoir	27	27	27	27	27	27
Phugyi Reservoir	54	54	54	54	54	54
Hlawga Reservoir	14	14	14	14	14	14
Ngamoeyeik Reservoir	90	90	90	90	90	90
Wells	8	8	0	0	0	0
Lagunbyin Reservoir*	-	30	30	30	30	30
Sub-total (1)	**193**	**223**	**215**	**215**	**215**	**215**
(River System)						
Kokkowa Ph 1	-	-	60	60	60	60
Pan Hlaing Ph 1	-	-	-	60	60	60
Kokkowa Ph 2 or Pan Hlaing Ph 2 or Toe	-	-	-	-	100	190
Sub-total (2)	-	-	**60**	**120**	**220**	**310**
Water Source Total	**193**	**223**	**275**	**335**	**435**	**525**
Balance (Supply – Demand)	**+37**	**+24**	**+17**	**+1**	**+13**	**0**

Note: * Excluding 10 MGD capacity for Thilawa SEZ,

Source: JICA Study Team



Source: JICA Study Team

Figure 3-13 Revised Water Source Development for Yangon City

Table 3-24 Proposed River System Capacity in 2040 (Unit: MGD)

Option	Combined system (Kokkowa and Pan Hlaing)	Toe	Total
Revision	240	70	310
Alternative	285	25	310

Source: JICA Study Team

3.3.4 Water Allocation to 10 Zones

(1) Allocation to 10 Zones

Figures 3-14, 3-15, and 3-16 show water source allocation to zones for 2014, 2025, 2030, 2035 and 2040. The areas in 10 zones proposed in the MP are not changed; however, locations of the two SRs for Zones 2 and 3 are changed by EDWS considering SRs' sites availability. Location of the Zone 2 SR is shifted from the western side to the eastern side of the zone with name change from Tamway to Thingangyun. As a result, transmission pipe route to Zone 2 will be changed. On the other hand, location of the Zone 3 SR is near to the originally proposed site. As is seen in 2025 water allocation, the Kokkowa water is allocated to the Kokine SR and the Central SR with transmission pipes from the Kokkowa to both SRs.

(2) Allocation to Zones 1 and 9 in 2025 as The Same as The Master Plan

Additional water source is required to meet water demand of Yangon city in 2025. According to the proposed water balance, water from the Kokkowa supply system (60MGD) will cover all demand of Zone 9 and partial demand of Zone 1 in 2025. The remaining demand will continue to be met by water from the reservoir system in the north of Yangon.

Out of the 60 MGD treated water, 20 MGD water and 40 MGD water will be conveyed respectively to Zone 9 and Zone 1 separately.

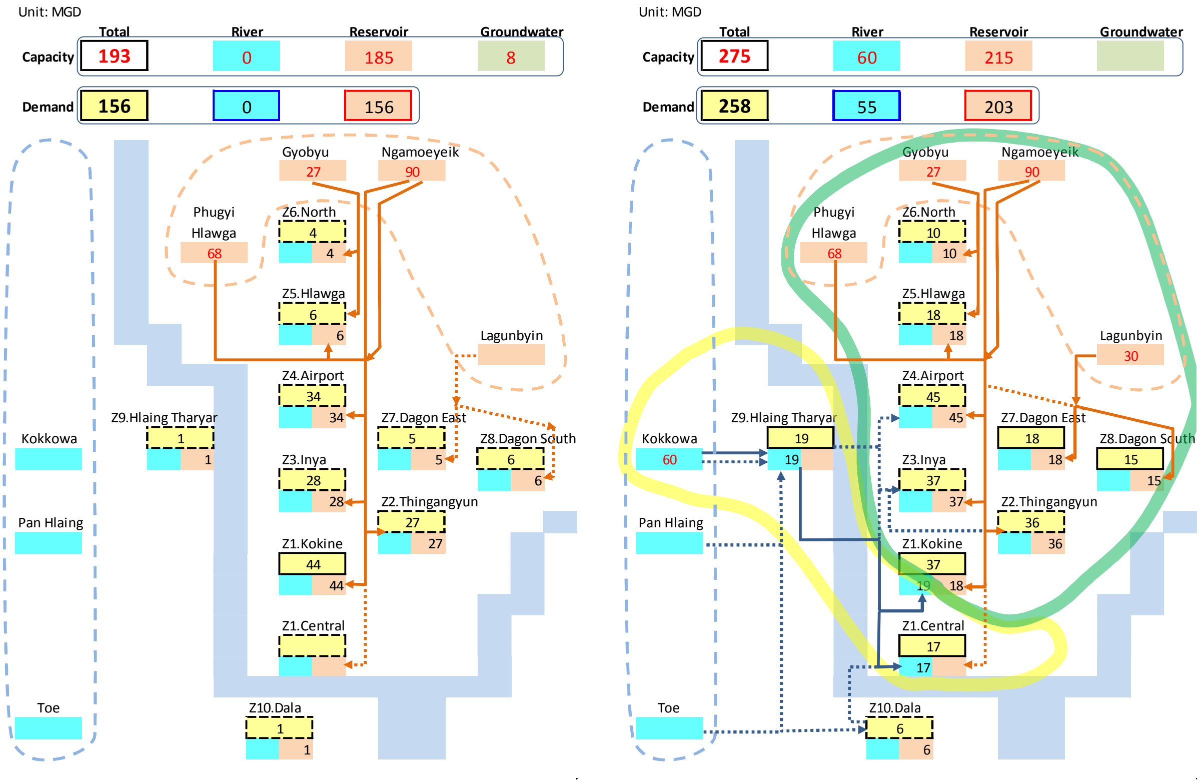
1) Zone 9

The existing water supply facilities in Zone 9 is very limited; covering only industrial zones and a small part of residential areas with 1 MGD WTP using groundwater and water from the reservoir system diverted through 300 mm diameter pipe. Similar to Zones 7 and 8 in the Lagunbyin water supply system, Zone 9 is a developing suburban area and distribution facilities together with new water source are needed.

2) Zone 1

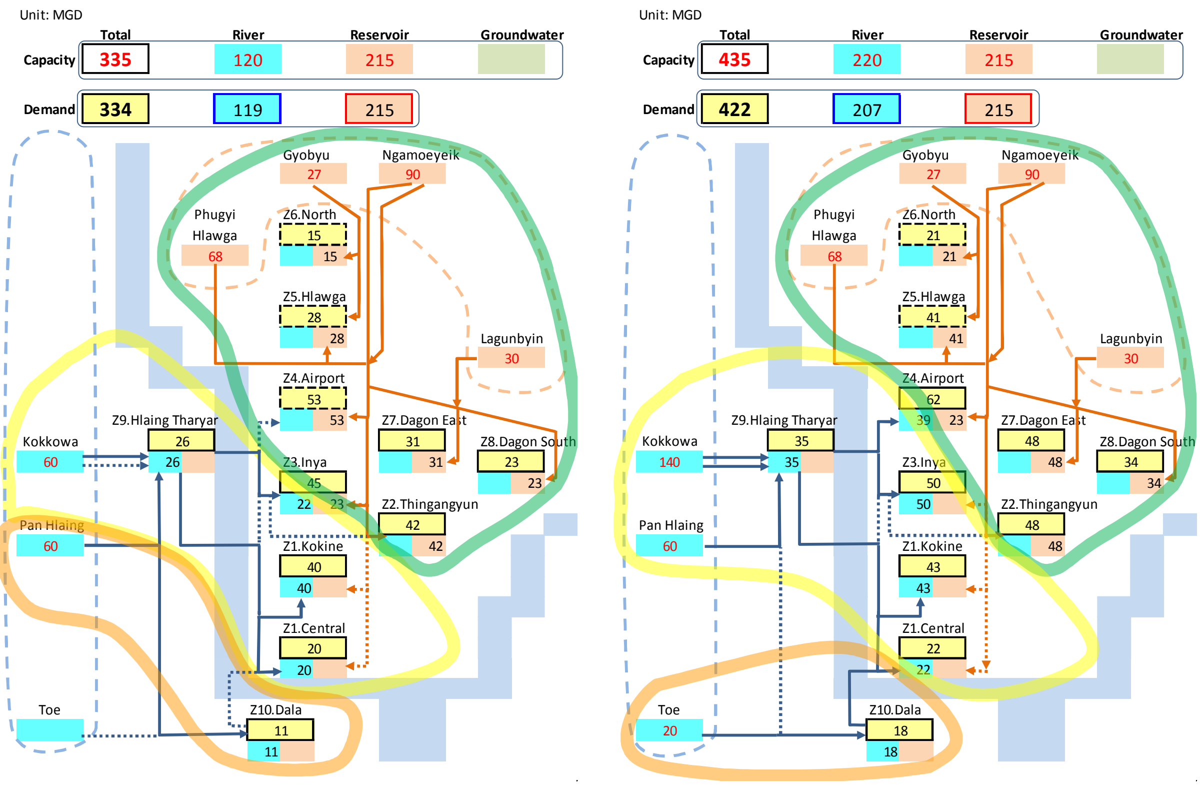
The distribution network in Zone 1 is widely developed but very old, which is causing frequent leaks and results in high NRW. Water to some areas in this zone is distributed from the Kokine SR through gravity and to some areas water is directly pumped from the reservoir system with inadequate pressure. This has resulted into uneven water distribution with low or negative pressure at customers end. In the water supply concept of the MP, water is proposed to be supplied through SR with adequate pressure aiming at equitable water supply to all customers.

The total water demanded of Zone 1 in 2025 is about 60MGD. Out of the allocated 40 MGD water, 20 MGD water is planned to be conveyed to the Central SR, high sub-zone that is equal to demand in the high sub-zone. On the other hand, the remaining 20 MGD water is planned to be conveyed to the Kokine SR, low sub-zone where demand is 40 MGD in 2025 and the remaining 20 MGD water will continue to be supplied via Yegu pumping station of the existing reservoir system.



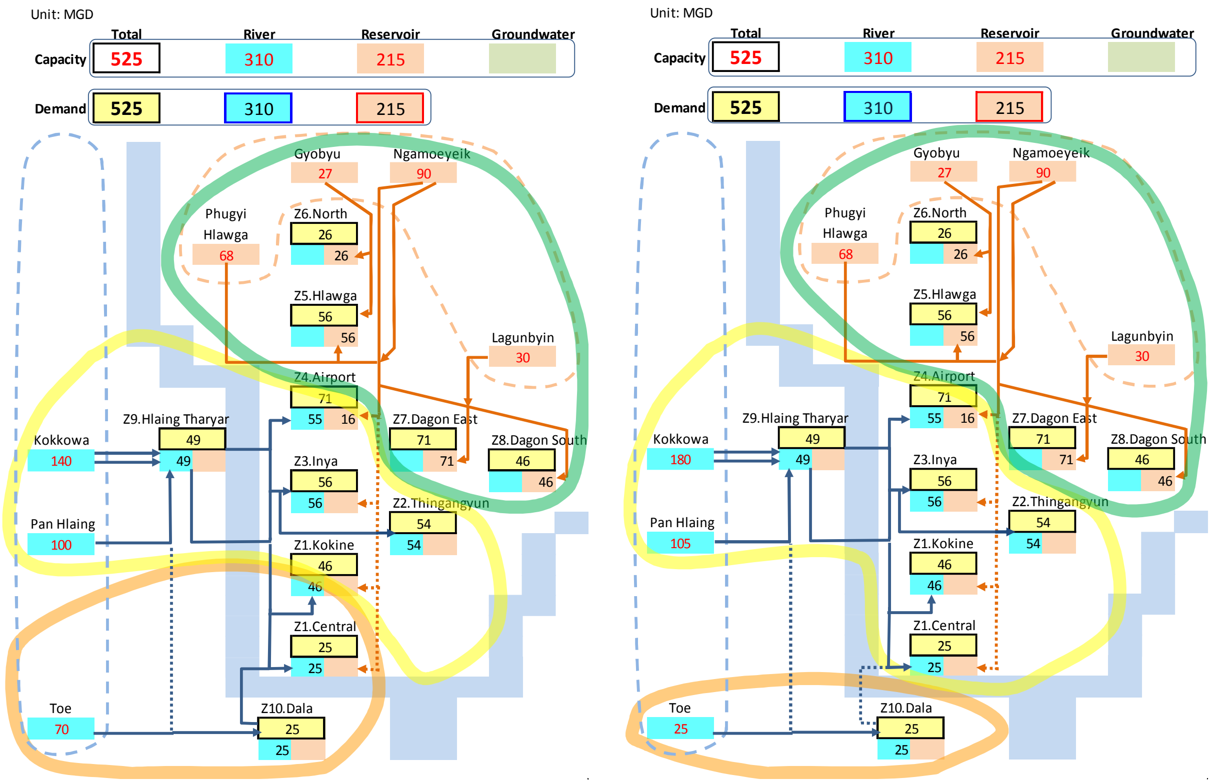
Source： JICA Study Team

Figure 3-14 Revised Water Allocation in 2014 (Left) and in 2025 (Right)



Source： JICA Study Team

Figure 3-15 Revised Water Allocation in 2030 (Left) and in 2035 (Right)

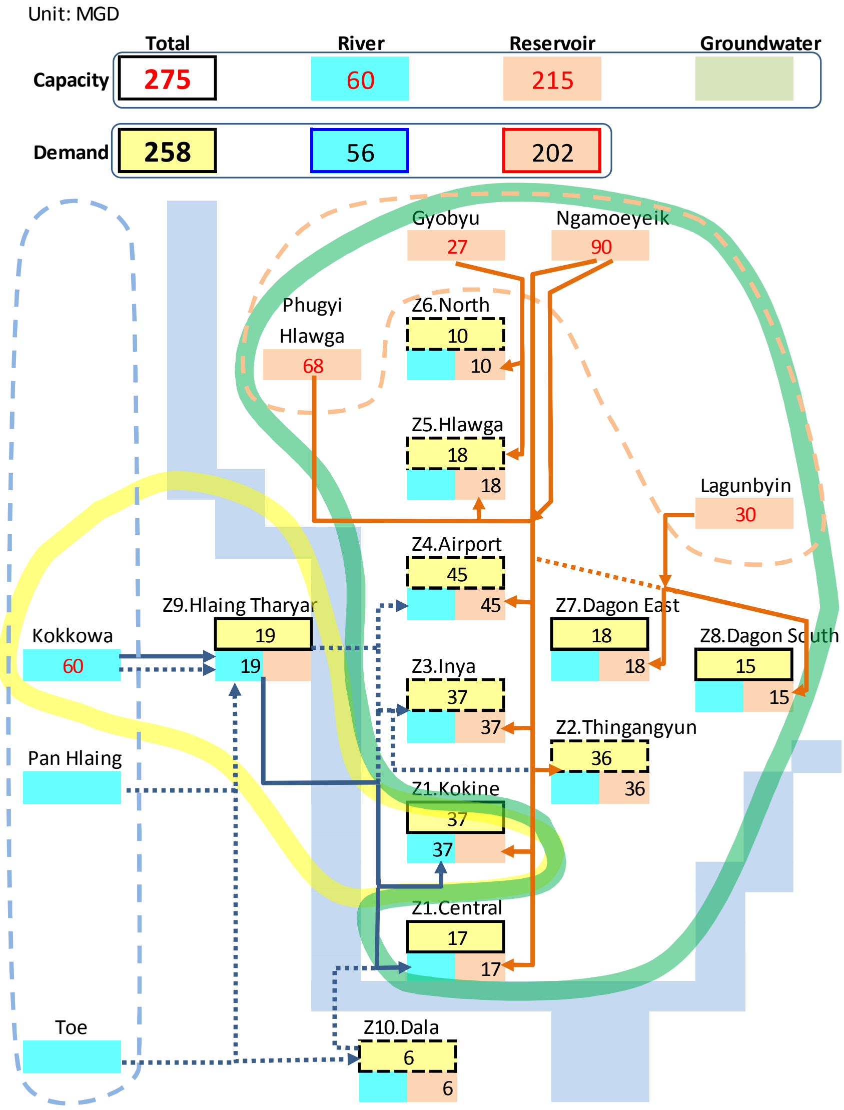


Source： JICA Study Team

Figure 3-16　Revised Water Allocation in 2040 (Revision: Left and Alternative: Right)

(3) Revised Allocation to Zone 1 in 2025 in This Project

During the study period, in consideration of safe water supply, additional method of water allocation to Zone 1 is considered to avoid mixing of the 40 MGD treated water from the Kokkowa system with the un-treated water from the Yegu pumping station. Instead, un-treated reservoir water via the Yegu pumping station will be conveyed to the Central SR. This revised water allocation will increase large number of population to be served by the treated clean water from Kokkowa system. The revised water allocation in 2025 is shown in following Figure.

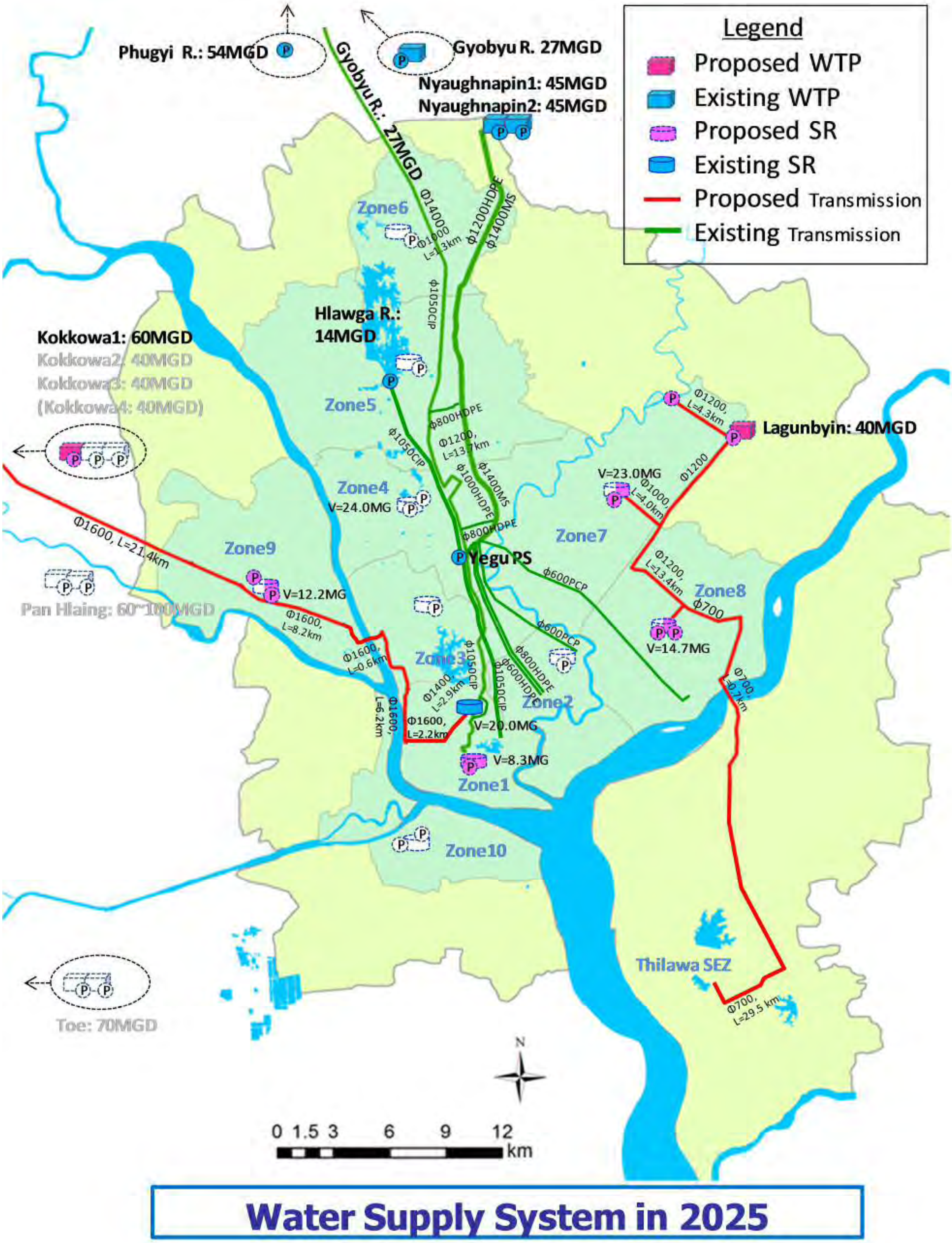


Source： JICA Study Team

Figure 3-17　Revised Water Allocation to Zone 1 for This Project in 2025

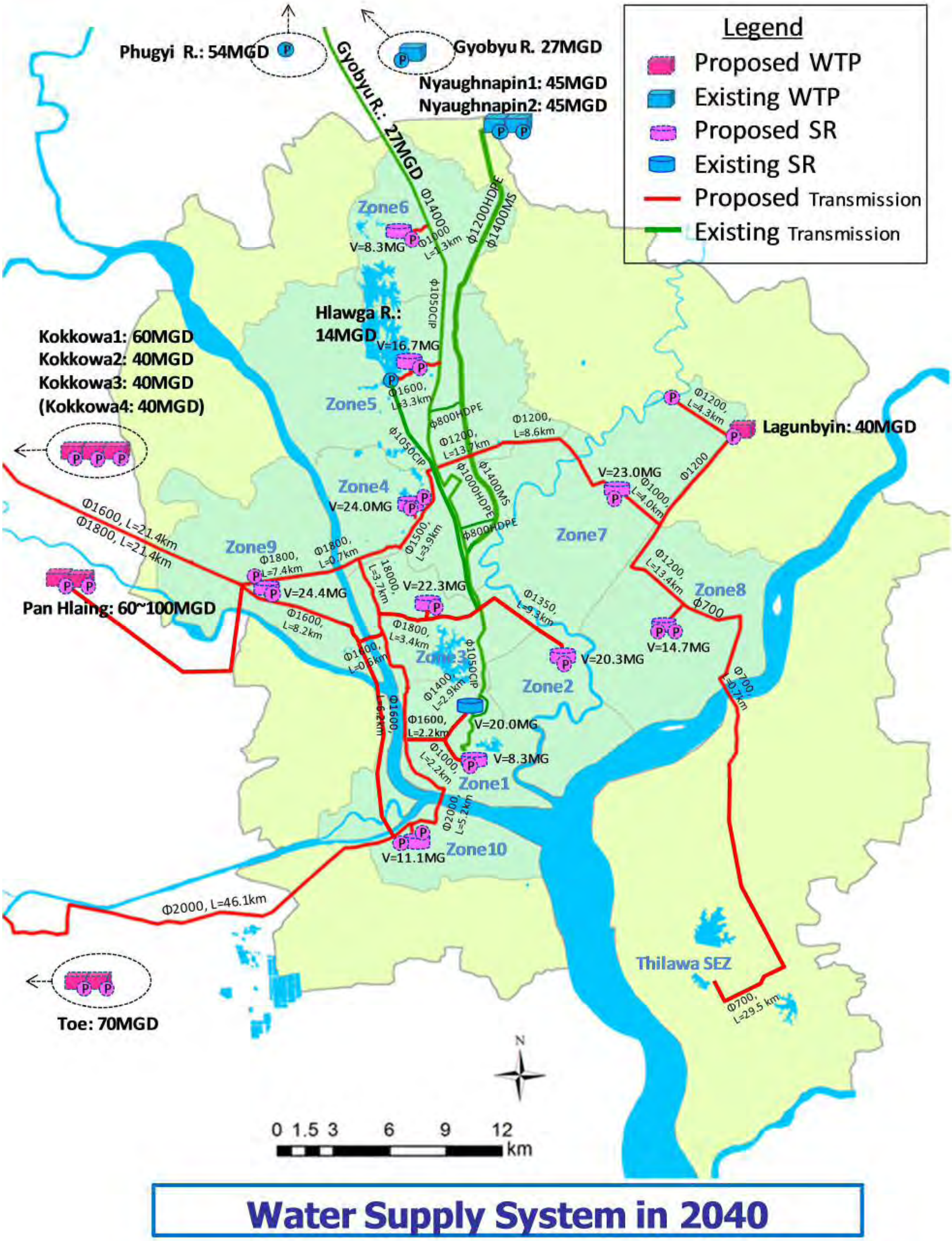
3.3.5　Revised Main Water Supply Facilities

The revised plans of facilities which will be built by 2025 and by 2040 are illustrated in Figures 3-18 and 3-19.



Source: JICA Study Team

Figure 3-18 Revised Water Supply System (2025) for This Project



Source: JICA Study Team

Figure 3-19 Revised Water Supply System (2040) for This Project

3.4 Necessity of The Project

For YCDC, increasing coverage ratio in Yangon suburbs is indispensable for improvement of water supply service, and for this purpose new water resource requires to be developed. Capital required for this development is huge and it is not easy for YCDC to accomplish this development on its own. Phase 1 project, which includes development of water supply facilities including Lagunbyin WTP for increasing water supply coverage ratio in Zones 7 and 8 in eastern part of Yangon City, is already being carried out by the Japanese ODA loan at low-interest rate for reduction of financial burden of YCDC.

The target of this Phase 2 project is increasing water supply coverage ratio of Zone 9 through construction of Kokkowa WTP. Furthermore, Zone 1 is unique compared to other Zones considering that piped water supply already exists and coverage ratio is also high. However, downtown area has been using old pipes of over 100 years from the colonial age, and high leakage ratio from old pipes is a big issue. The renewal of facilities is not so easy in Zone 1. YCDC is interested that the old water supply facilities of Zone 1 be updated by high technical and management capabilities of Japan.

In the MP, it was estimated that the amount of available water resources is less than the water demand in Yangon city. As a result, water resources development, construction of facilities from the sources to customers, and so on was proposed in the MP. Improvement of the poor water supply services such as decrease of leakage ratio and safe water supply were proposed. Shortage of the water resources amount is also confirmed in this study through review of water demand estimation based mainly on the 2014 census population, and the same measures are still valid and proposed again in this study as listed below.

- **Development of New Water Sources for Yangon City**
- **Achievement of Stable Water Supply in Yangon City Center (Distribution Zone 1) and Other Zones**
- **Decrease in Leakage in Yangon City Center (Distribution Zone 1)**
- **Provision of Safe and Clean Water Supply in Zone 1 and Zone 9**

(1) Development of New Water Sources for Yangon City

The maximum water demand per day in Yangon City in 2025 and 2040 are 258 MGD and 525 MGD, respectively. On the other hand, planned water source is 215 MGD only, which can be supplied from the existing reservoirs and the development of new reservoir is not possible anymore. To cope with rapidly increasing water demand, new water sources should be developed. In the MP, river water sources are planned to meet the increasing demand and at first Kokkowa River will be developed. In this project, Kokkowa River water system is planned. For this reason, the project requires to initiate the development of new water source for the Yangon City to meet the increasing water demand.

(2) Achievement of Stable Water Supply in Yangon City Center (Distribution Zone 1) and Other Zones

The city center has the largest population area (about 800,000 residents) and a business and economic center in Yangon City. However, the water supply condition in this area is the worst; low or negative water supply pressure and intermittent supply due to far distance from the existing water source of reservoir. Therefore, direct transmission line is required from the new source to this area to improve supply condition or stable water supply, for the purpose of improved city life and business opportunity as a center of the economic capital of Myanmar. If additional water is supplied to this area, the existing water volume supplied to this area will be transferred to the other areas, which indicates improvement of water supply condition in other areas.

(3) Decrease in Leakage in Yangon City Center (Distribution Zone 1)

The oldest pipe is located in the Yangon city center, which is equivalent to Distribution Zone 1. Many pipes are older than 100 years and the average age is estimated as 80 years or so in Zone 1. The life of pipes has expired long ago and pipes have frequent leakage. Currently, this area has low water pressure but if pressure will become higher for stable water supply in future, leakage will increase more. To reduce current and potential increasing leakage in future and to increase supply volume, aged pipes should be replaced by the project. Otherwise, increased water supply by the project will be reduced considerably by leakage.

(4) Provision of Safe and Clean Water Supply in Zone 1 and Zone 9

Currently, no disinfection is adopted to YCDC piped water supply so that safe and clean water is not achieved anywhere in Yangon city. To supply safe and clean water to Zone 1 and Zone 9, disinfection is required in the project. The project will construct new WTP using Kokkowa river water and disinfection will be adopted.

Implementation of the above measures will have the following effects;

- **Affordable Safe Water Supply for Poverty Group in Supply Area**
- **Decrease of Water Borne Diseases**
- **Increase of Water Coverage Ratio with Safe and Clean Water in Hlaing Tharyar (Distribution Zone 9)**
- **Improvement of Water Supply Services in Supply Area**

(5) Affordable Safe Water Supply for Poverty Group for Supply Area

Poverty group is most affected by bad water supply conditions; they have to purchase expensive bottled water for drinking purpose spending large share of their income or rely on unhygienic water for drinking purpose if they cannot buy bottled water. Therefore, possible water borne disease is more prevalent in poverty group than average income or richer group. This project is required to provide safe and clean water to the residents for drinking purpose, including poverty group, for which water tariff setting for poverty group will be considered.

(6) Decrease of Water Borne Diseases

The number of incident and frequency of water-borne and mosquito-borne diseases are shown in the following Table. Although the number and percentage of each disease is low, the resident are occasionally affected with diarrhea and dysentery. To reduce water borne disease, the project which adopts disinfection for safe and clean water supply is required.

Table 3-25 Experience of Water- and Mosquito-borne Diseases in 2012

Items	Diarrhea	Dysentery	Chorera	Infectious Hepatitis	Typhoid or Paratypoid	Malaria	Dengue Fever	Ogthers
No.	141	61	6	15	10	8	42	38
Disease Rate	1.4%	0.6%	0.1%	0.1%	0.1%	0.1%	0.4%	0.4%

Note: Sample number is 10,069 households
Source: 2013-JICA Urban Development Plan

(7) Increase of Water Coverage Rate with Safe and Clean Water in Hlaing Tharyar (Distribution Zone 9)

The population and YCDC piped water supply coverage rate in 2014 by township are shown in the Table 3-13. According to this, the piped water coverage in Hlaing Tharyar is only 3 % and one of the least in townships. In addition, the total population in Hlaing Tharyar is 688,000 and the largest township and the number of unserved population is approximately 660,000 the largest, most of whom are using unhygienic or low water quality shallow wells for living purposes. The project is required to supply safe and clean water to large un-served population.

(8) Improvement of Water Supply Service for Supply Area

The satisfaction level with water supply by YCDC piped water supply in Zone 1 and Zone 9 is shown in the following Table. The project is required to improve the satisfaction level of existing YCDC customers and potential customers, especially water quality in Zone 1 and all items of water supply condition in Zone 9.

Table 3-26 Unsatisfaction Level with Water Supply

Zone	No.	Township	Water Supply from YCDC				
			Water pressure	Hours of supply	Water quntity	Water quality	Price
Zone 1	1	Latha	△	△		×	
	2	Lanmadaw	△	△	△	×	
	3	Pabedan	×		△	×	△
	4	Kyauktada	△	△	△	×	△
	5	Botahtaung	△	△	△	×	
	6	Pazuntaung	△	△		×	
	7	Ahlone	△	△	△	×	
	8	Kyeemyindaing		△		△	
	9	Sanchaung		△		×	
	10	Dagon		△		△	
	11	Bahan	△	△		△	△
	12	Tarmwe	△	△		×	
	13	Mingalar Taung Nyunt	×	×		×	△
	14	Seikkan					
Zone 9	29	Hlaing Tharyar	×	×	×	×	

Note: ×indicates more than 20 % and ▵ indicates 10-20 % respondents are unsatisfied respectively with items given in Table above

Source: 2014 JICA Water MP

CHAPTER 4 WATER TREATMENT PLANT

4.1 Planning Conditions

4.1.1 Completed/ On-going Plan Related to Kokkowa Project

a) F/S for Kokkowa system in July 2013 by Capital Engineering & Research Incorporation Limited (China) [5]

b) F/S for Kokkowa system in March 2013 by SKEC (South Korea) [6]

c) Irrigation project of Pan-Hlaing River: MoAI has constructed two tide gates, one at the location upstream where river branches out of Kokkowa River and the other one at location just before its confluence with Hlaing River. The Netherlands prepared design of a downstream tide gate. The river will stop being affected by salt water intrusion due to high tide, and the river water is expected to have low salinity. YCDC is planning to obtain the water rights of 60-100MGD from MoAI to withdraw water from Pan-Hlaing River.

d) Out of 240 MGD of planned expansion of WTP in 2014 JICA Water MP, Kokkowa WTP is planned to be constructed with a capacity of 140-180 MGD considering that the capacity of Pan Hlaing project WTP will be about 60-100 MGD.

e) YCDC purchased a part of proposed land for 140 MGD Kokkowa WTP by the end of May 2015, and the site was surveyed by May 2015. They are planning to continue with purchase of additional required land.

f) Moreover, YCDC constructed the access bridge and expansion of the access road from route No. 5 to the WTP.

4.1.2 Expansion Plan of Kokkowa WTP

The overall capacity in the plan of Kokkowa WTP will be set to be 140-180 MGD as it changes depending on the amount of water rights which can be obtained for Pan-Hlaing River. Based on a series of discussions with EDWS, the following expansion plan is tentatively formulated for this Study.

- **Kokkowa Stage 1:** 60 MGD (Total 60 MGD)
- Construction of Pan-Hlaing WTP: Total 60-100 MGD (Under negotiation with MoAI)
- **Kokkowa Stage 2:** +40 MGD (Total 100 MGD)
- **Kokkowa Stage 3:** +40 MGD (Total 140 MGD)
- **Kokkowa Stage 4:** +40 MGD (Total 180 MGD) Will be decided depending on the capacity of Pan-Hlaing WTP.

Although Stage 4 is indefinite, YCDC’s current targets are 140 MGD until Stage 3. The target of this study is Stage 1 (60 MGD) from overall plan of Kokkowa WTP.

[5] The report is not disclosed.
[6] The report is not disclosed.

Source: JICA Study Team based on discussion between MoAI and YCDC

Figure 4-1 Expansion Plan of Kokkowa WTP and Pan-Hlaing WTP

4.1.3 Land Acquisition Status of YCDC

Existing situation of the land obtained by YCDC is as follows (as of July 2016). An illustration of the acquisition of the sites that would be required for Project facilities is shown in the following Figure.

- For Intake Facility : 16,187 m^2 (4 Acre)
- First obtained land for WTP : 137,593 m^2 (34 Acre)
- Additional obtained land for WTP : 31,379 m^2 (7.754 Acre)
- **Total of obtained land by YCDC : 185,159 m^2 (45.754 Acre)**

(1) Land Acquisition Status of the Project Sites

Existing situation of land acquisition of sites are described below. Main treatment facilities are planned in area along the body of Rat - shaped land.

According to YCDC, lands along riverbank for intake have been obtained with difficulty and negotiations for acquiring other lands has not been successful. Moreover, even for the currently obtained lands for WTP, in case of many landowners, agreement has not been reached in terms of expected price. Although the obtained land area is sufficient for construction of only the water treatment facility with the capacity of 60 MGD, the area of acquired land is insufficient with 20 Acres for 60MGD of pre-sedimentation pond with the required retention time of 48 hours as proposal of the studyteam (reasons are described in Section 4.1.6.(6)).

EDWS and JICA Study Team have carried out water quality tests for planning of pre-sedimentation pond, and discussed with EDWS about insufficient area. As a result, YCDC will re-start negotiation with land owners for the required land of 60MGD of pre-sedimentation pond with 48 hours retention time under 2016/17 budget.

Source: YCDC and edited by JICA Study Team

Figure 4-2 Land Acquisition Status of YCDC as of 31 July 2016

(2) Situation of Land Acquisition for Intake and WTP Site

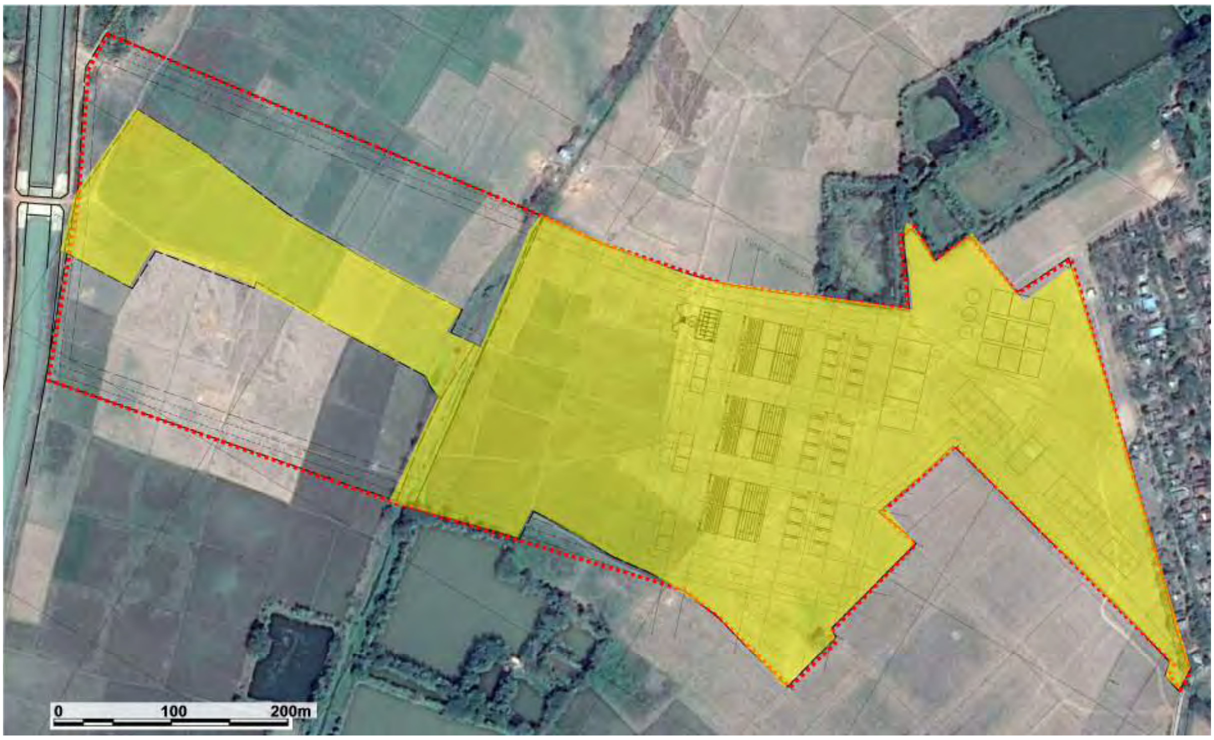
- 4 acres of land is already acquired for the construction of intake facility and 34 acres of land is acquired for the treatment facility. Both lands are already registered as YCDC property. Compensation has already been made to all 7 farmers.
- Additional 7 acres of land is already registered.
- Entire rat-shaped land area and access road has been raised up to + 3.5 m through land filling and levelled.
- There is no crop farming in the YCDC registered land.
- There exists a natural drain with about 1 m width in the land area proposed for Kokkowa WTP. Diversion drain to connect to the existing natural drain is planned in affected stretch (refer to Section 11.6.1 in Chapter 11 for details).

(3) Access Road to Sites

- MoAI's embankment with a top level of about 7 m is used as an access road to Intake/ WTP area.
- Access to WTP: can access from the Route No. 5 to WTP (the tip of rat nose) using the existing road towards ANYASU village. YCDC expanded the existing 1 lane village road to 2 lanes road and carried out road surface improvement.
- ANYASU village is situated to the north-east side of the proposed site for WTP. It has a population of 1,042 in 240 households, and a typical village in Yangon. Rice is the main crop there with some vegetables. In the village, pond is used as drinking water while the river water and salty tube well water are used for miscellaneous purposes.

(4) Additional Land Acquisition

The size of the acquired land up to July 2016 is adequate for the 60 MGD WTP including the pre-sedimentation pond (with retention time of 12 hours), sedimentation tank, filter, clear water reservoir, pumping station and so on, however, is not sufficient for the 60 MGD of pre-sedimentation pond which will require 48 hours of retention time. This is explained later (reasons are described in Section 4.1.6.(6)).



Source: JICA Study Team

Figure 4-3 Additional Land Acquisition with Already Registered Land of YCDC (Yellow Area)

4.1.4 Appropriateness of The Site Location

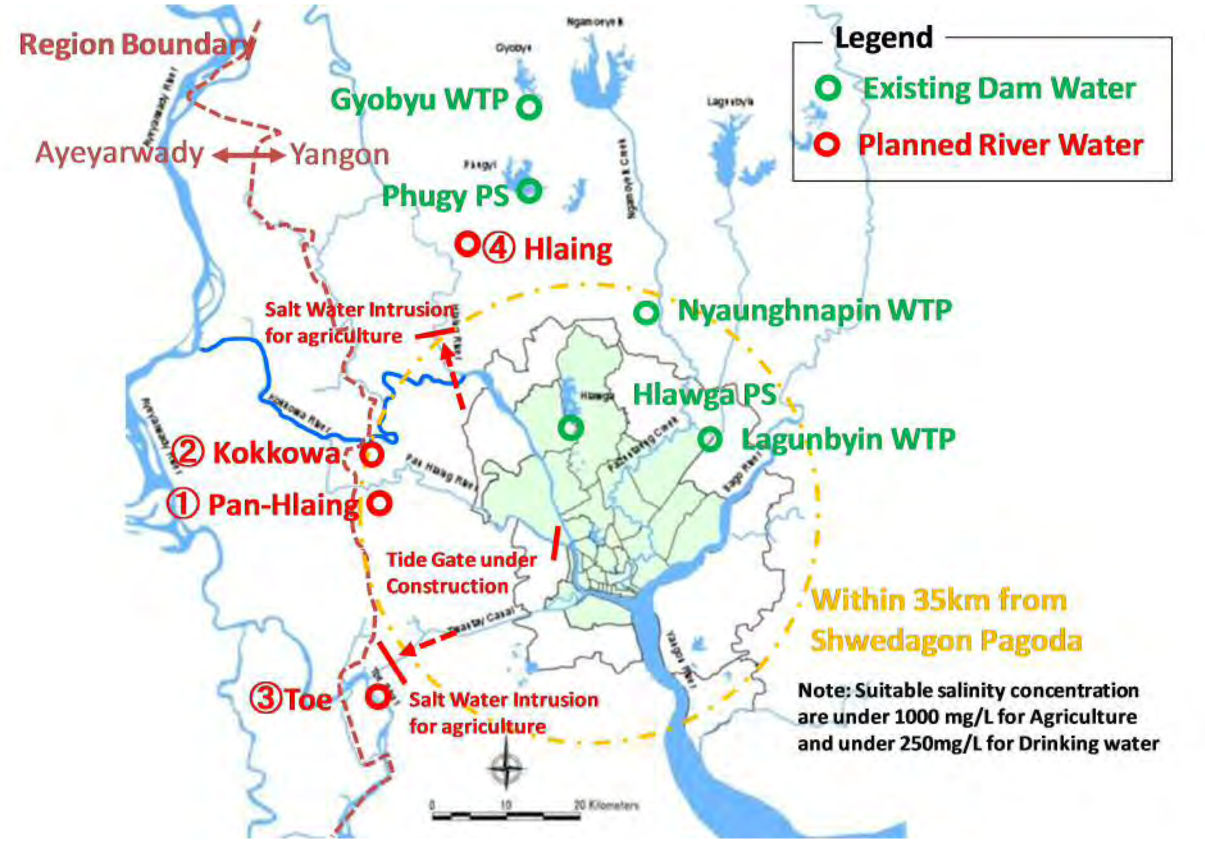
The above-mentioned obtained lands are selected based on following considerations. The considered location is one of the best options, and is determined to be appropriate in consideration of the technical viewpoint and O&M. Consequently, it is judged that the selected site is the most appropriate one.

(1) Since there is no appropriate place for development of dam as water source, River source needs to be developed newly for Yangon.

(2) High priority project within the proposed new resource developments

- Through survey of salt concentration in river stream of Ayeyarwady, MoAI investigated the locations with salt concentration of 1,000mg/L (Red lines in the following Figure 4-4) which influences rice crop (2008 to 2010). The salt concentration of less than 250 mg/L is the Myanmar standard of drinking water.

- Four (4) locations, Pan-Hlaing, Kokkowa, Toe, and Hlaing, which are not influenced by salt water intrusion, were proposed as candidate sites of intake. The order of these locations in terms of nearness to city center (Shwedagon Pagoda) is Pan-Hlaing, Kokkowa, Toe, and Hlaing (See Table 4-1 and Figure 4-4).



Source: JICA Study Team

Figure 4-4 Reasons for Selection of The Kokkowa WTP

Table 4-1 Comparison for Proposed WTP Site

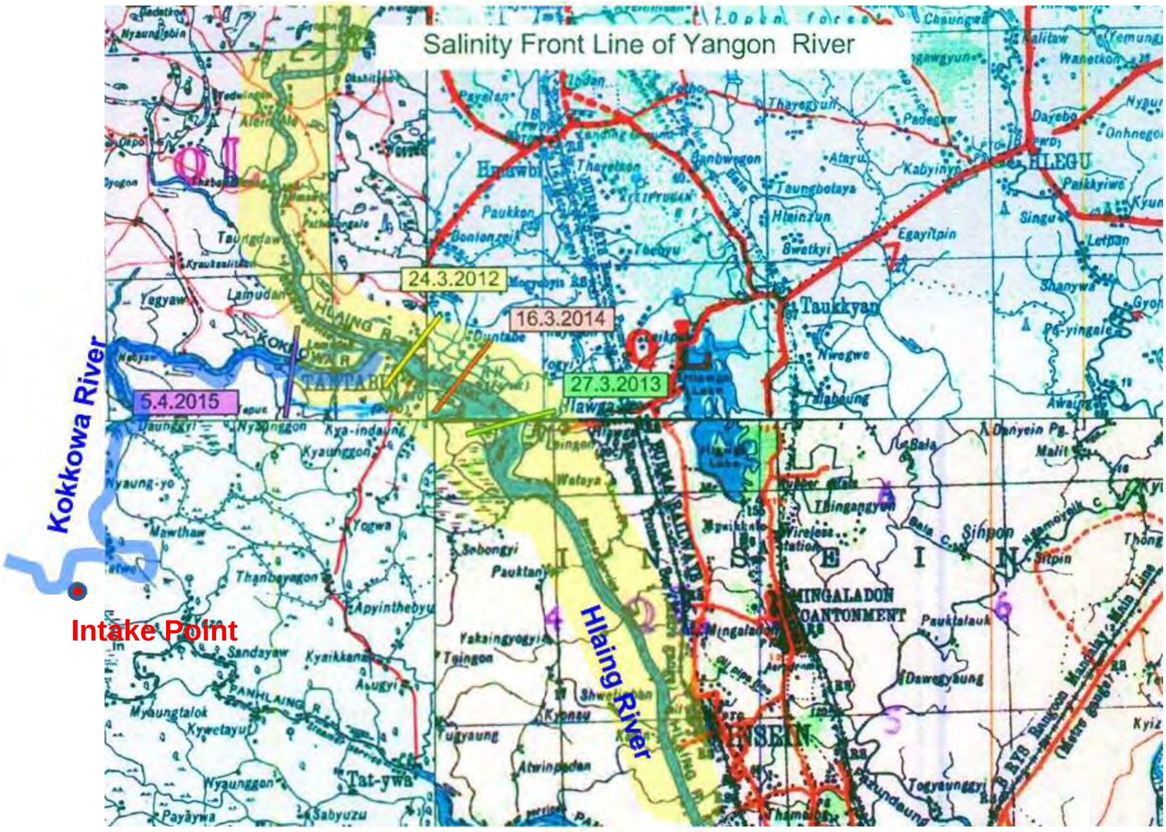
	River	Distance from the center	Comparison Examination	Conclusion
①	Pan-Hlaing	25 km	YCDC and MoAI are discussing to develop water supply source from Pan-Hlaing River, however, the location and capacity of system has not been decided yet.	
②	Kokkowa	35 km	The conditions of access to site, distance from city center, available water quantity, and land availability are all satisfied.	○
③	Toe	40 km	Toe river is distant from the city, therefore preference order of this option is after Kokkowa.	
④	Hlaing	50 km	Hlaing was proposed in 2000 MP, however, in 2014 JICA Water MP this option was not selected considering low volume.	

Source: JICA Study Team

(3) The raw water quality near intake point must satisfy standards in terms of salt concentration.

Development of Kokkowa has been decided by Yangon Region based on the result of comparison in the above Table. More detailed information on salt water concentration in Kokkowa River is described below.

- Data on salt water intrusion in Hlaing River was obtained from MoAI. MoAI carries out the water quality survey in dry season of every year and plots locations with salt concentration greater than 1000 mg/L. The Figure indicates that the junction of Kokkowa and Hlaing River has a salt concentration of 1000 mg/L. Although there is no data on salt concentration along longitudinal direction of Kokkowa River, it is considered that yellow color hatched section in Figure below is unsuitable for intake location considering standard value of 250 mg/L as source of drinking water.
- Water quality can be regarded as almost the same along the entire stretch of the Kokkowa River excluding the salt concentration. As is clear from Figure 4-4 and 4-5, salt water intrusion in Hlaing River is up to the stretch upstream of its confluence with the Kokkowa River, and water intake is preferable at a location upstream.
- The Kokkowa River is located in the delta region of Ayeyarwady River and Yangon (Hlaing) River. Since this river is a tidal stream, salinity intrusion occurs at low flow rates during the dry season. In the MP and this Study, situation of salinity intrusion was investigated during the dry season (September 2012, March 2013 and February 2016, refer to the Appendix-3). According to the results of investigation, measured chloride ion is under 100 mg/L at the candidate location of intake and in the stretch of river about 15-km downstream of the intake location in case of occurrence of high and low tide. It is confirmed that the water at these locations satisfies the level of salt concentration as a drinking water source.
- From these reasons, purchased land located in the upstream stretch of the Kokkowa River which is not influenced by salt water concentration,

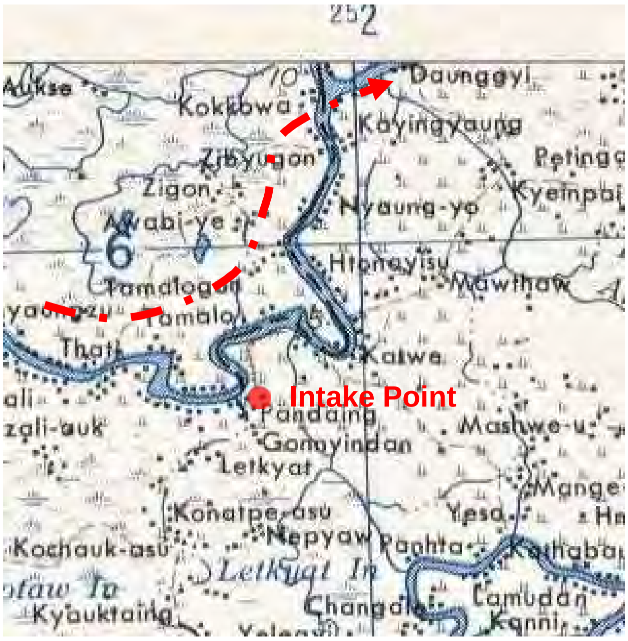


Source: MoAI and edited by JICA Study Team

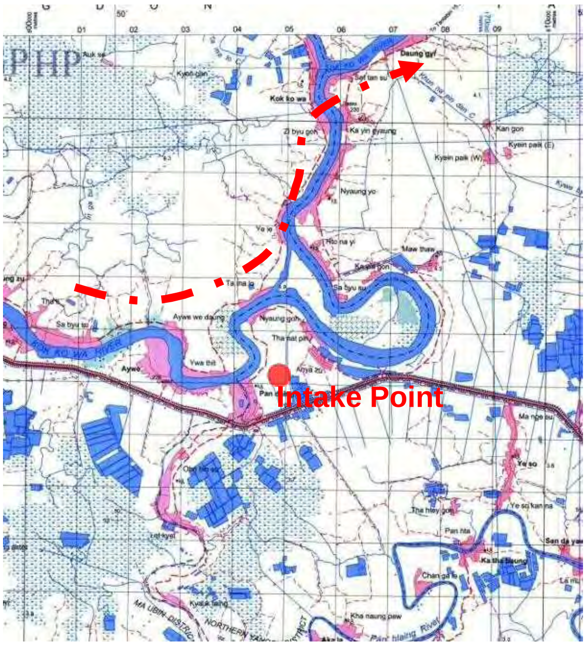
Figure 4-5 Salt Water Intrusion in The Hlaing River

(4) Stabilization of the River Course

The alignment of Kokkowa River in the past 50 years is shown in the following Figure for the years for which data is available. The width of river and its course near the intake point has not changed from the point upstream, and it is considered that river shape near the intake point is stabilized.



In the Year 1955
Source: (US) Army Map service, corps of engineers, University of Texas Libraries



In the Year 2000
Souce: JICA and Department Ministry of Forestry of Myanmar

Figure 4-6 Alignment of The Kokkowa River in Past 50 Years

(5) Downstream Water User

In the 2014-MP, in order to estimate flow of water, the water level and flow near proposed intake points were observed at the same time, and the relation of flow with water level was produced. This result estimates that flow of ten-year return-period is 1,045 m^3/s (9,861 MGD). It was found that downstream water use for irrigation is 12.0 m^3/s. The proposed WTP of 60 MGD (2025) and 140 MGD (2040) are only 0.6 % and 1.4 % of the flow of ten-year return period, respectively. For that reason, it is judged that the amount of water in the river is sufficient and withdrawal of water will not have large influence on the water availability of downstream users.

(6) Availability of large land area in the Yangon region.

Considering the availability of large land area in the Yangon region, and the land use plan of the Yangon region, construction of WTP is possible at this location.

(7) Location has good access using the Route No. 5.

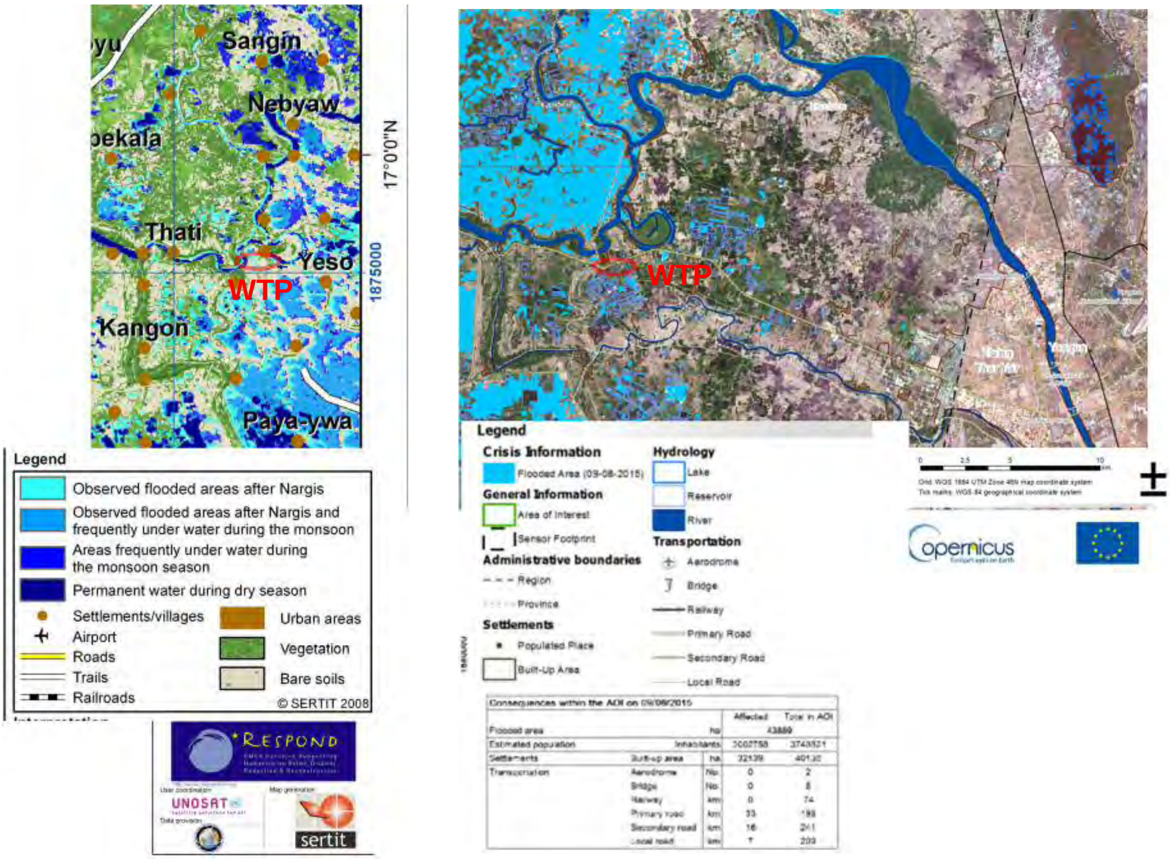
The distance between Yangon city, particularly Zone 9 and any location along the Kokkowa River is almost the same (considering Zone 9 SR) so that any intake point can be selected in terms of length of transmission pipe. The selected location of intake in this plan is near to the Route No. 5 that runs in the east-west direction in western Yangon. Therefore, access to the selected site for WTP is easy. Moreover, Intake facility which is to be installed near the river and treatment facility shall adjoin each other.

(8) Flood Protection

Western Yangon is a low-lying area with relatively small difference in ground elevation. Along the bank of the River Kokkowa near the selected site of WTP, there exists a flood protection embankment constructed by the MoAI. Its crest level is 7 m while the recorded highest water level in Kokkowa River at this location is about 6 m. Therefore, it is expected that the WTP will not have any impact due to flood. In addition, YCDC is raising the ground level of proposed area for WTP by 3.5 m to 7.1 m, to make the level same as the crest level. Consequently, the proposed site will be about 4 m higher than the surrounding area, and even if river water overflows the embankment, it will soon drain to the surrounding area. At the proposed location of WTP, there has been no damage caused by a flood, because land is protected by the embankment of MoAI.

The outcome of interview of residents in nearby Anyasu village and some of the photographs along with maps of historical events are given below.

- About 70 years-old man
  - Although living in the village since last 40 years, has never observed flood in the village.
  - Surrounding rice field is inundated with rain water during the rainy seasons.
  - The ditch crossing the proposed site of WTP is drainage canal for rice fields.
  - The elevation of village is higher than the rice fields. (Note: The elevation of raised ground of proposed WTP site and access road are same as the ground level of the village.)
- 28 years-old man, 28-year living, Farmer
  - Has never heard of flood damage in the rice field located in proposed WTP site.
- 40 years-old man, 7-year living, Farmer
  - Rice fields are inundated during rainy season and the footpath along border of fields breaks sometimes.
- 30 years-old man, 8-year living, Farmer
  - There is a depressed ground in village that gets inundated due to poor drainage.



In the Year 2008 In the Year 2015

Figure 4-7 Inundation Situation at The WTP Site in 2008 and 2015

Photo 4-1 Situation of the irrigation canal nearing high water level on 19th August 2015

Photo 4-2 Situation of the WTP site on the same time of Photo 4.1 (Not flooded)

Photo 4-3 Situation of the intake point after high water level on 19th August 2015

Source: JICA Study Team

4.1.5 Setting of Intake Location

The water level of the Kokkowa River almost reached the record maximum of +5.8 m due to occurrence of the Komen cyclone as mentioned above (refer to Photo 4-1 to 4-3). This flood level exceeded the existing ground level (+3.3 – 4.6 m) of the acquired land for intake by about 2 m at the maximum. On the other hand, the irrigation canal in the dry season causes the back flow to Kokkowa River and due to low water level in canal, sand accumulation is visible (refer to Photo 4-4).

Source: JICA Study Team

Photo 4-4 Situation of the irrigation canal nearing low water level on 23rd November 2015

In order to set the intake location considering above-mentioned conditions, JICA Study Team proposed EDWS to change intake point and then a series of meeting were held during August to December 2015 among the MoAI, EDWS and the Team. The result of discussion of these meetings is as follows.

(1) General

- Water right: There are no ministries and government offices which have jurisdiction over all rivers. MoAI has jurisdiction over water for irrigation, and Ministry of Transport and Communications has jurisdiction over the cruise of ships in rivers.
- It is expected that Yangon region government will allow the development of Kokkowa River water supply system with water rights in the same procedure as in case of Lagunbyin WTP. However, clear response is not visible at present.

(2) Intake Water Amount

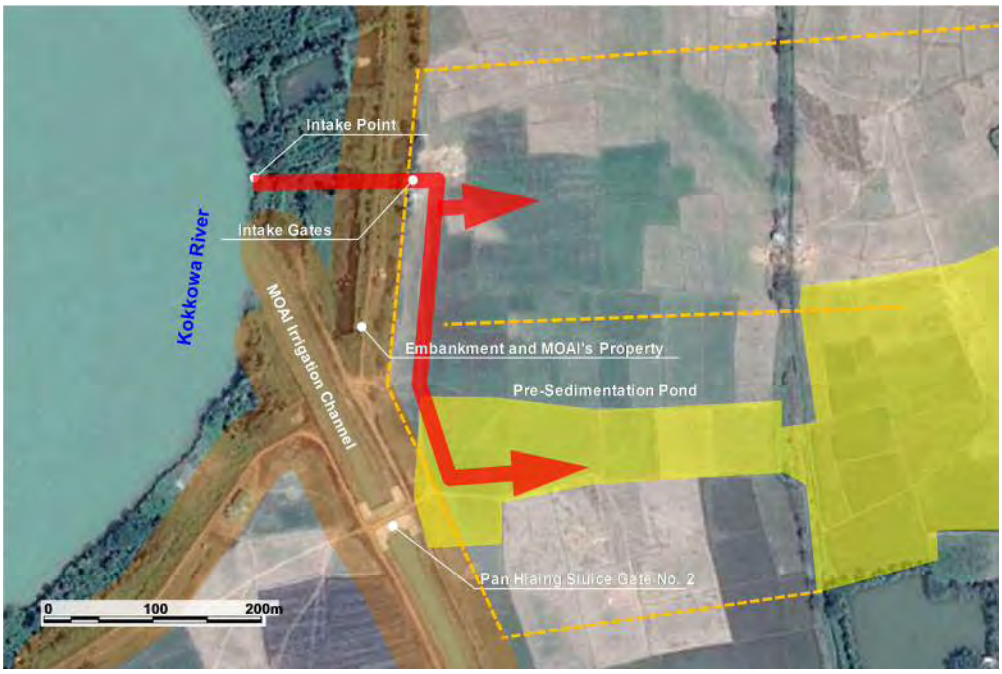
- The capacity of existing Kokkowa irrigation canal is about 900 ft^3/s (460 MGD). Total required flow amount is 1200 ft^3/s (614 MGD) including about 300 ft^3/s (154 MGD) of raw water for WTP.
- Since the total flow rate of 614 MGD is only 6.2% of the minimum water discharge of 9,861 MGD with ten years return period, the withdrawal of water from the Kokkowa River is feasible.

(3) Possibility of Intake from Irrigation Canal

- The following proposal was discussed in the meeting held in August 2015. If a leading canal for WTP is branch from the irrigation channel of MoAI, the location of intake point shall be more than 200 ft (about 60 m) upstream of the existing gate in the canal, and then the start point of irrigation canal in Kokkowa River shall be excavated and widened in order to secure sufficient channel width for this required flow (MoAI should construct it).
- In the meeting on 8 December 2015, MoAI claimed that the effect of amount decrease in the irrigation canal should be avoided. As a result, it agreed that intake point of WTP is shifted to Kokkowa River directly.

(4) Intake Point/ Form of Leading Canal for WTP

- In the above meeting, the Team proposed that the perpendicular alignment from the Kokkowa River is ideal form for leading canal (Refer the following Figure).
- The form of leading canal for WTP will be finally decided according to the availability of land form which will be purchased under 2016/17 budget of YCDC.

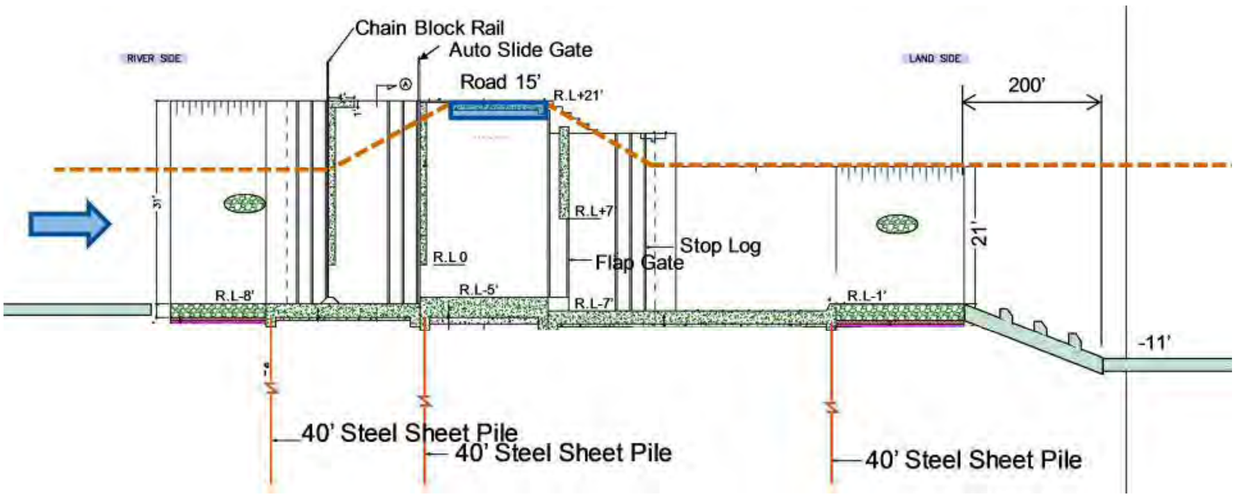


Source: JICA Study Team using background map of Google Earth

Figure 4-8 Setting of Intake Location under Consideration

(5) Proposed Drawing of Gates by MoAI

- In the above meeting, MoAI proposed that three steps of gates be installed. These gates include manual gate, electric gate for water level adjustment and flap gate on pre-sedimentation pond side. A flap gate is installed in order to prevent backflow when the water level in pre-sedimentation pond is higher than Kokkowa River in case of low water level in the River.
- Moreover, upon the proposal of MoAI, a removable stop log is set in front of each gate.
- As measures against the flood, the concrete structure attached to the gate will be built higher than the flood level (+19.3' and embankment level will be raised to 21'). Based on the following Figure.



Source: MoAI

Figure 4-9 Proposed Drawing of Intake Gates by MoAI

(6) Construction near the MoAI's Embankment

- From the center line of embankment, 30 m wide land on both sides is MoAI's property. Gate system within riverbank and concrete structure such as a box culvert for crossing embankment will be allowed by MoAI.
- MoAI has jurisdiction over the construction near a river embankment. Since there was no law and ordinance, they answered that MoAI determined all rules.
- Discussion with MoAI should be required continuously during detailed design stage.

4.1.6 Water Quality and Treatment Process

(1) Drinking Water Quality Standard

The target treated water quality is set as shown below, the same as in the 2014 JICA Water MP, considering standards in Myanmar and WHO.

Table 4-2 Target Water Quality after Treatment with Reference to Other Standards

Parameters	Allowable Value	WHO standards	Myanmar standards
pH	6.5 – 8.5	N/A	6.5 – 8.5
Taste	Foul smell and taste are not detected	Acceptable	Acceptable
Odor	Foul smell and taste are not detected	Acceptable	Acceptable
Color	5 true color units	15 true color units	15 true color units
Turbidity	5 NTU (1 NTU for target turbidity of treated water in WTP)	1 NTU for target	5 NTU
Standard plate count	< 100CFU/mL	N/A	N/A
Fecal coliforms	Not to be detected	Not to be detected	0
Residual chlorine	To be detected (at service tap by direct supply and before storage tank of customer) The residual chlorine at the exit of WTP shall be set separately, considering the travel time to the end of the service area.	< 5.0 mg/L	N/A
Zinc (Zn)	< 1.0 mg/L	N/A	< 3.0 mg/L
Aluminum (Al)	< 0.2 mg/L	N/A	< 0.2 mg/L
Iron (Fe)	< 0.3 mg/L	N/A	< 1.0 mg/L
Copper (Cu)	< 1.0 mg/L	< 2.0 mg/L	< 2.0 mg/L
Manganese (Mn)	< 0.05 mg/L	< 0.4 mg/L	< 0.4 mg/L
Hardness	< 100 mg/L	N/A	< 500 mg/L
Chloride ion	< 200 mg/L	N/A	< 250 mg/L
Sulfide	< 200 mg/L	N/A	< 250 mg/L

Source: 2014 JICA Water MP, WHO Guidelines for drinking-water quality, fourth edition and National drinking water quality standards Myanmar (September 2014)

(2) Raw Water Quality

EDWS's laboratory has started water quality tests of the Kokkowa River since May 2015. Report of EDWS laboratory and Study Team is attached as Appendix-3.

Water quality was also tested during Phase 1 study and other F/S(s). The combined quality results are shown in the following Table. Variation in average turbidity is 517 NTU in rainy season and 150 NTU in dry season based on the following Table.

The following salient features are observed in terms of water quality of Kokkowa River.

- In general, high level of Turbidity, Color and Iron are observed.
- These parameters generally increase during rainy seasons.

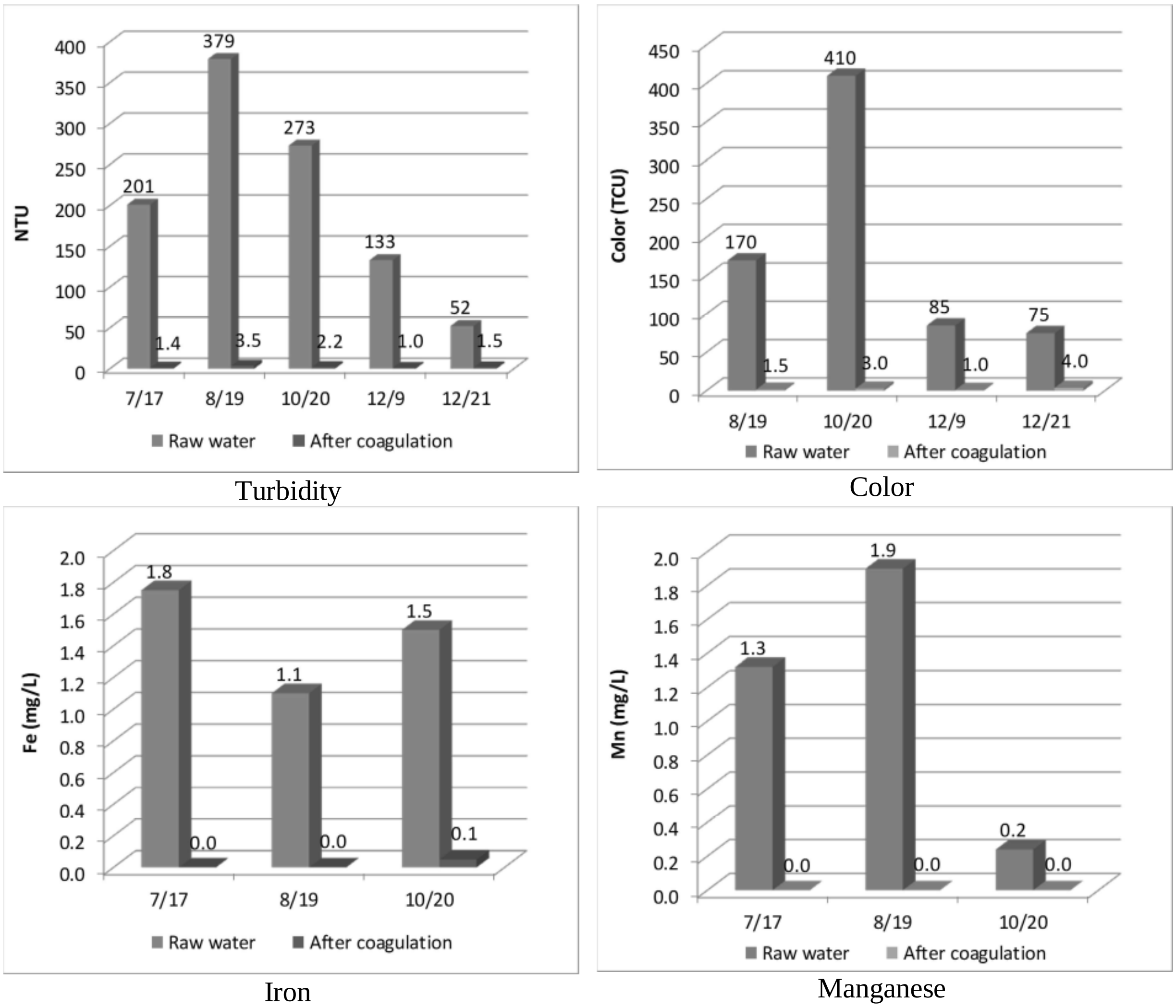
Table 4-3 Water Quality in Kokkowa River near Intake Point

Test by	No	Date	pH	TDS (mg/l)	SS (mg/L)	EC (μS/cm)	Total Hardness (mg/L)	Fe (mg/L)	Mn (mg/L)	Turbidity (NTU)	Color (TCU)	Total Alkalinity (mg/L)	Ca (mg/L)	Mg (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Salinity (mg/L)	Nitrite(NO2) (mg/L)	Nitrate(NO3)	Ammonia(NH4) (mg/L)	E-coli	Fecal Coli
China FS		14.6.2012	7.6				80.0	1.0		280.0	120.0					20.0						
JICA MP		9.12.2012	7.8	56.0		24.0	54.0	4.6	1.0	365.0	180.0					4.0		0.019	N.D.			
China FS		8.12.2012	8.2	99.0	113.0		90.0	2.9		116.0	60.0					6.0						
Korea FS		28.12.2012	7.5	146.0			50.0	1.0	< 0.01	100.0	25.0	71.0	13.2	4.1		13.0			<0.01		Detected	N.D.
JICA MP		8.3.2013	8.2	19.0		220.0	94.0	4.6	N.D.	75.0	20.0					4.0		0.006	N.D.		Detected	Detected
China FS		2.4.2013	8.0	69.0	382.0		98.0	1.8		236.0	80.0					17.0						
		5.4.2013	8.4	67.0	488.0		102.0	2.9		306.0	110.0					12.0						
YCDC	1	28.5.2015	7.5	74.9		149.9	68.0	1.2	0.2	57.0		8.0	11.2	9.6	8.0	31.0	70				Detected	Detected
	2	2.6.2015	7.2	89.7		179.4	108.0	1.2	0.4	120.0		12.0	33.7	5.7	12.0	19.0	90					
	3	8.6.2015	6.6	66.6		133.0	84.0	2.0	0.3	129.0		36.0	14.4	11.5	36.0	15.0	70					
	4	15.6.2015	7.1	65.9		114.9	64.0	1.9	0.5	204.0		42.0	12.8	7.7	42.0	24.0	70					
	5	22.6.2015	7.3	58.9		117.5	76.0	2.2	0.9	376.0		36.0	8.0	13.4	36.0	21.0	60					
	6	29.6.2015	7.4	42.1		84.8	84.0	1.6	1.0	685.0		40.0	6.4	9.6	40.0	31.0	40					
	7	6.7.2015	7.2	42.3		84.7	52.0	1.6	0.8	242.0		36.0	6.4	8.6	36.0	14.0	50					
	8	17.7.2015	7.0	20.4		26.1	76.0	1.8	1.3	523.0		56.0	9.6	12.5	56.0	20.0	20					
JICA Team		17.7.2015																0.0	0.3	0.3	Detected	Detected
YCDC	9	3.8.2015	6.9	53.9		10.8	68.0	1.1	0.7	214.0		40.0	4.7	10.6	40.0	17.0	60					
	10	10.8.2015	7.1	69.3		140.6	44.0	35.8	7.5	2520.0	1950.0	24.0	4.8	7.7	24.0	18.0	70					
	11	17.8.2015	6.7	71.0		142.8	72.0	0.9	2.8	1000.0		122.0	16.0	7.7	122.0	10.0	70					
	12	19.8.2015	7.4	93.3		193.3	84.0	1.1	1.9	1000.0		24.0	16.0	10.5	24.0	20.0	90					
JICA Team		19.8.2015								1190.0	513.0							0.0	1.1	0.1	Detected	Detected
YCDC	13	24.8.2015	7.3	62.8		125.7	68.0	1.1	1.3	496.0	210.0	24.0	12.8	8.6	24.0	14.0	60					
	14	31.8.15	7.2	50.4		100.9	72.0	0.7	1.4	524.0		56.0	16.0	7.7	56.0	9.0	50					
	15	7.9.15	7.1	46.1		93.0	48.0	0.8	2.4	570.0		52.0	11.2	4.8	52.0	13.0	50					
	16	21.9.15	6.9	44.0		88.1	48.0	4.5	1.0	245.0		86.0	11.2	4.8	86.0	12.0	50					
	17	28.9.15	7.0	58.1		116.5	56.0	0.3	0.5	186.0		88.0	8.0	8.6	88.0	25.0	60					
	18	6.10.15	7.2	52.9		104.5	48.0	2.1	0.6	205.0		80.0	9.6	5.8	80.0	6.0	50					
	19	12.10.15	6.9	61.6		123.0	44.0	1.8	0.6	188.0		80.0	10.4	4.3	80.0	14.0	60					
	20	20.10.15	8.3	75.0		150.6	76.0	1.5	0.2	410.0		112.0	16.0	8.6	112.0	14.0	80					
	21	2.11.15	7.3	79.3		163.6	76.0	1.4	0.4	227.0		94.0	17.6	7.7	94.0	15.0	80					
	22	9.11.15	7.0	103.2		206.0	76.0	2.6	0.4	141.0		106.0	14.4	9.6	106.0	19.0	100					
	23	16.11.15	6.7	95.6		191.7	92.0	1.5	0.5	59.0		114.0	24.1	7.7	114.0	20.0	90					
	24	23.11.15	6.6	83.3		166.6	80.0	4.8	0.6	124.0		116.0	19.2	7.7	116.0	11.0	80					
	25	30.11.15	7.7	88.8		177.7	80.0	0.4	0.0	102.0		114.0	17.6	8.6	114.0	13.0	90					
	26	7.12.15	6.6	80.0		144.6	70.0	4.0	0.6	118.0		110.0	19.0	7.0	110.0	10.0	80					
	27	14.12.15	7.0	95.6		190.8	104.0	1.8	0.3	59.0		110.0	25.7	9.6	110.0	12.0	90					
	28	21.12.15	7.5	103.6	283.5	211.0	80.0	1.8	0.5	124.0	120.0	94.0	20.8	6.7	94.0	21.0	100					
	29	28.12.15	6.7	37.6		74.8	92.0	0.4	0.0	134.0		94.0	19.2	10.5	94.0	14.0	40					
	30	11.1.16	7.4	105.4		208.0	80.0	0.2	0.1	217.0		84.0	25.7	3.8	84.0	16.0	100					
	31	18.1.16	6.9	105.8		211.0	124.0	1.4	0.4	64.0		120.0	30.5	11.5	120.0	28.0	100					
	32	25.1.16	7.4	104.8		210.0	92.0	2.1	0.4	71.0		100.0	22.4	8.6	100.0	20.0	100					
	33	22.2.16	7.1	104.9		214.0	120.0	0.5	0.1	298.0		96.0	24.1	14.4	96.0	16.0	100					
	34	25.2.16	7.6	110.8		226.0	100.0	0.7	0.2	52.0		96.0	22.4	10.6	96.0	20.0	110					
JICA Team		25.2.16									47.0							0.0	0.0	0.3		
Target values of YCDC Laboratory			6.5 to 8.5	<500 mg/L		<1000 μ S/cm	< 500 mg/L	< 1 mg/L	<0.4 mg/L	< 5 NTU	< 15 TCU		<250 mg/L	<150 mg/L	<250 mg/L	<250 mg/L	<250 mg/L				0 in 250 ml	

Source: Results compiled by EDWS Laboratory

(3) Water Treatment Process

The main aim of water treatment is to reduce turbidity, color, iron and manganese to acceptable levels. The removal of turbidity, color, iron and manganese by jar-test conducted by EDWS Laboratory and the Team are shown in the following Figures. High turbidity, color, iron and manganese concentration can be removed by process of coagulation-sedimentation and rapid sand filtration. Therefore, conventional treatment process is applicable considering raw water quality of Kokkowa River.



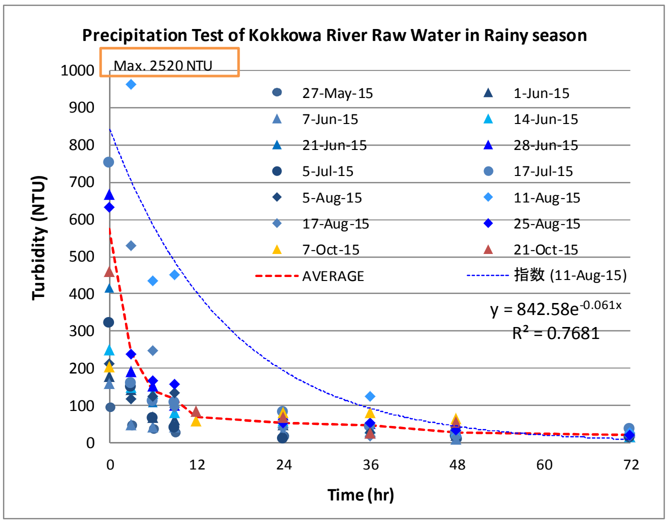
Source: EDWS Laboratory and JICA Study Team

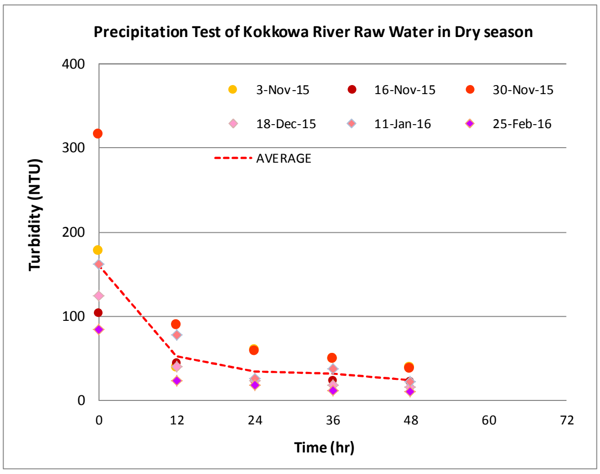
Figure 4-10 Removal of Turbidity, Color, Iron and Manganese from Raw Waters in 2015

(4) Sedimentation Characteristics

The sedimentation characteristic of Kokkowa River water is shown in the following Figure. The water sample was filled in measuring cylinder, and turbidity of surface water was measured at specified intervals of settling. The left graph shows trend of turbidity in rainy season (May – October, 2015), and the graph on right side is trend of turbidity in dry season (November, 2015- April, 2016).

Both these figures (red lines in the Figures) indicate that average turbidity reaches a constant level after 12 hours of settling. On the other hand, the turbidity of river water exceeding 1,000 NTU was observed during about ten (10) days when the long duration rain continued during the end of July to early August 2015. In case of such high level of turbidity, just after settlement of 36 hours the turbidity reduces to less than 100 NTU, and it attains steady value of nearly 50 NTU after 48 hours of settlement (blue dotted line in the left graph).





in Rainy Season (From May to Oct 2015) **in Dry Season (From Nov 2015 to Feb 2016)**

Source: JICA Study Team

Notes: Turbidity shown above is for water sample collected at 1 cm depth from the water surface in measuring cylinder.

Figure 4-11 Precipitation Test of Raw Water from Intake Point of Kokkowa River (May 2015 - February 2016)

The situation of precipitation test for 0 to 72 hours is shown in the following photographs. There is no photograph for case of 12 hours of settlement due to limitation of working hours. These photographs indicate that turbidity is settled gradually with time and surface water becomes clear compared to water at the bottom.

0hr	3hr	9hr	24hr	36hr	48hr	72hr

Source: JICA Study Team

Photograph 4-5 Situation of Precipitation Test (Sample water: 17 August 2015)

(5) Plan Turbidity and ACH Dosing Rate

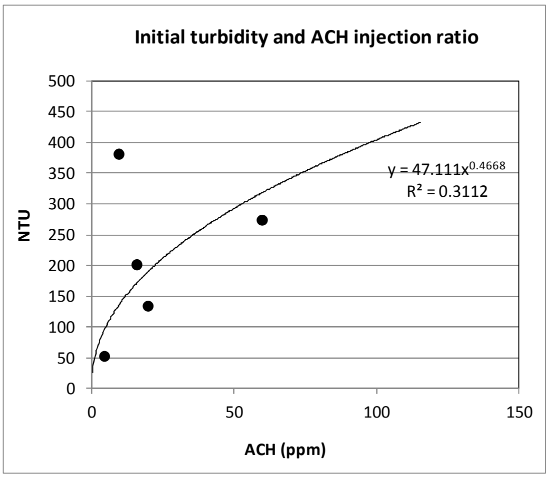
Raw water turbidity level for planning is set based on results indicated in the following Table and from precipitation curve of high turbidity situation in the above left figure (blue dotted line).

Table 4-4 Maximum Raw Water Turbidity for Facility Planning (NTU)

Season	Raw Water	After 12hrs	After 24hrs	After 36hrs	After 48hrs
Rainy	2500	400	200	100	50

Source: JICA Study Team

From the result of five jar tests which EDWS laboratory implemented during this study, relationship between raw water turbidity and ACH dosing rate is shown in the following Figure. Although, small number of data is available to define correlation coefficient and reliability is low, this graph shows a trend that ACH injection rate decreases with decrease in raw water turbidity. For inflow turbidity range of 0 - 200 NTU, flocculation and sedimentation can be done by injection-rate of less than 25 ppm in general.



Source: EDWS laboratory

Figure 4-12 Relation of Raw Water Turbidity and ACH Dosing Rate (Result of Five Jar Tests)

(6) Cost Comparison of Coagulant and Additional Land for Pre-sedimentation Pond

Pre-sedimentation pond with 48 hours retention time requires large areas of lands; however that could be compensated by small amount of ACH dosing that has a high-cost. Therefore, the land acquisition cost could be recovered in a short period of time.

As alternate method, the amount of coagulant will increase and as a result, operation cost of chemical will rise up. Based on the data collected in relation to chemical procurement cost in Yangon, the Team has estimated that chemical cost of 3.3 million USD/ year will be required for ACH injection at the rate of 10 mg/L for 60 MGD WTP.

Therefore, the team proposes that size of pre-sedimentation pond should be equivalent to 48 hours of storage volume based on the result of jar tests. The cost comparison of pre-sedimentation pond for 12 and 48 hours is shown in the following Table. Pre-sedimentation pond with 48 hours can reduce the chemical cost of about 28.2 million USD in ten years. Therefore, the study team proposed and agreed that size of pre-sedimentation pond should be equivalent to 48 hours of storage volume based on the result of jar tests by EDWS laboratory.

Table 4-5 Cost Comparison of Obtained Form and Ideal Form for 60 MGD WTP

	Obtained Land for 60 MGD WTP	**60 MGD WTP with 48hrs Pre-Sedimentation Pond (Ideal Form)**
Sketch		
Total Area	168,972 m2 (41.754 Acre)	About 250,000 m2 (62 Acre)
Pre-Sedim.	12 hrs for 60MGD, Area 37,000 m^2	48 hrs for 60MGD, Area 120,000 m^2
Technical viewpoint	Since the form is not good, sedimentation performance like tests is not expected.	Since form is good, sedimentation performance is expected to be same as test.
Land Acquisition		Additional area required is 81,028 m^2 (20.2 Acre)
Initial Cost Gap	--	-Excavation, Back filling and Disposal: 4.7 Mil. USD -Land price: 0.08 Mil. USD (3,850 USD/Acre)
Coagulant cost/year	**5.0 Mil. USD** /year as ACH dosing rate = 15 mg/L	**1.7 Mil. USD** /year as ACH dosing rate = 5 mg/L
Cost in 10 years	5.0*10 years =**50.0 Mil. USD**	4.7 +0.08+1.7*10 years =**21.8 Mil. USD**
Conclusion		Save 28.2 Mil. USD in 10 years (Ave. 2.8 Mil. USD/year)

Source: JICA Study Team

4.2 Planning Policy of WTP

(1) Facility Planning and Planning Parameters

The facilities are planned for 60 MGD of the daily maximum demand based on the Section 3.3.4 “Water Allocation to 10 Zones”. Treatment facilities are designed as 63 MGD including operational loss amount within WTP. Transmission facilities will be designed for daily maximum demand of 60 MGD. On the other hand, distribution facilities will be designed for 1.5 times of 60 MGD considering diurnal fluctuation of demand.

Treatment facilities can be designed for 60 MGD by 2025 and intake facilities are planned for 140 MGD, the final design capacity by Kokkowa WTP Stage 3, because repeated construction of the intake facilities is not preferable that might damage embankment structure.

Table 4-6 Parameters for Facility Planning

Item	Amount	Note	Remarks
Intake flow for gates	700,000 m^3/day	140MGD x110 %	Japanese design guideline
Intake flow for Pre-sedimentation pond	300,000 m^3/day	60MGD x110 %	Japanese design guideline
Treated flow	286,400 m^3/day	60MGD x105 %	Considering loss within WTP
Transmitted flow	272,800 m^3/day	60MGD	As same as maximum demand

Source: JICA Study Team

(2) Points of Concern in Design of WTP

The following items should be taken into consideration as policies related to design of WTP.

1) Selection of simple method

The type of equipment of facility is selected considering operation and maintenance aspects. Equipment with many mechanical functions requires periodical rest of equipment for maintenance and replacement work. Such equipment must stop for a significant period of time when the spare parts are not ready at the time of a breakdown. Therefore, less maintenance system shall be selected as much as possible.

2) Knowledge application from existing YCDC's WTPs

YCDC has constructed the Nyaunghnapin WTP (90 MGD), and the construction of Lagunbyin WTP (40 MGD) is now ongoing in 2015. For these WTPs, EDWS carried out or is carrying out detailed design, construction and supervision works. The pre-sedimentation ponds at these WTPs have been working and will work to remove high turbidity and same process will be planned in this study.

3) Weak Soil Layers and Pile-driving

WTP needs to be constructed in the western part of Yangon where layers of soil at surface and shallow depths are relatively weak in most cases. Pile-driving is a counter-measure against this and the bottom end of pile should reach a strong soil layer below the weaker layers such as bedrock or basal conglomerate to support weight of structures.

4) Consideration of YCDC and JICA loan scope

Planning of WTP will be decided considering YCDC's existing facilities and JICA ODA loan of Phase1 Project.

(3) Concept Related to Planning of Kokkowa WTP

For planning of Kokkowa WTP, the following 5 targets are considered to be achieved and this WTP can provide as a model in Myanmar.

Target- 1: Scalable System

- A simple train system with easy extension: One train unit is planned from lift pump to clear water tank, one train has the capacity of 20 MGD, and then, 7 trains will be installed to achieve the planned capacity of 140 MGD finally.

Target- 2: Stable Supply

- Secure stabilized amount of water from the river
- Secure the process of sludge treatment to deal with large amount of mud
- Raising up of WTP’s ground level as measure against flood and inundation

Target- 3: Water Quality Control

- Process that can treat raw water having high turbidity
- Water quality monitoring by introduction of automatic measuring equipment
- Avoiding dangerous chemicals by using sodium hypochlorite for disinfection

Target- 4: Operation and Maintenance

- Collection of data on flow rate in each treatment process by SCADA
- Adjustable equipment of chemical injection considering the fluctuation in raw water quality

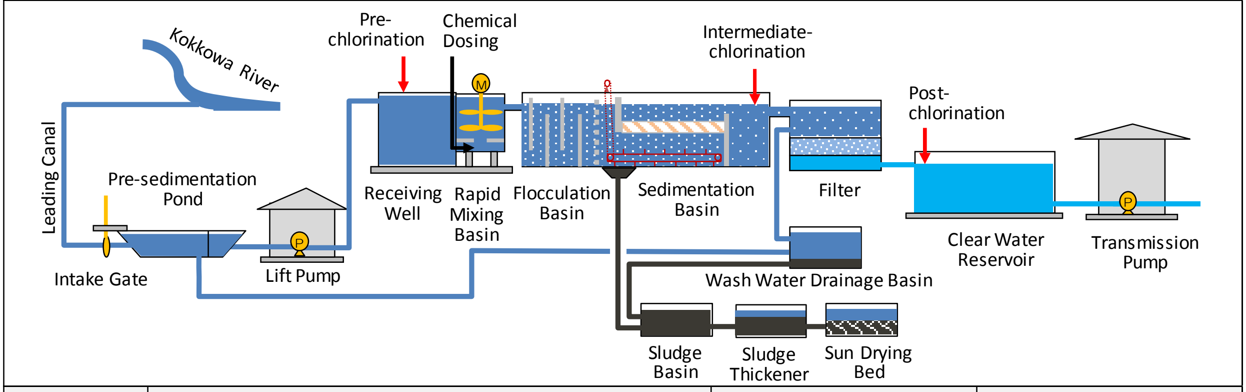
Target- 5: Environmental Consideration

- Reduction of power consumption of pump by inverter control
- Introduction of back-washing method for filters to reduce consumption of unnecessary pump power

(4) Scope of YCDC and Possible JICA Loan

JICA and YCDC agree the proposed scope of the facilities as follows;

Table 4-7 Proposed Allocation of Work of WTP Construction



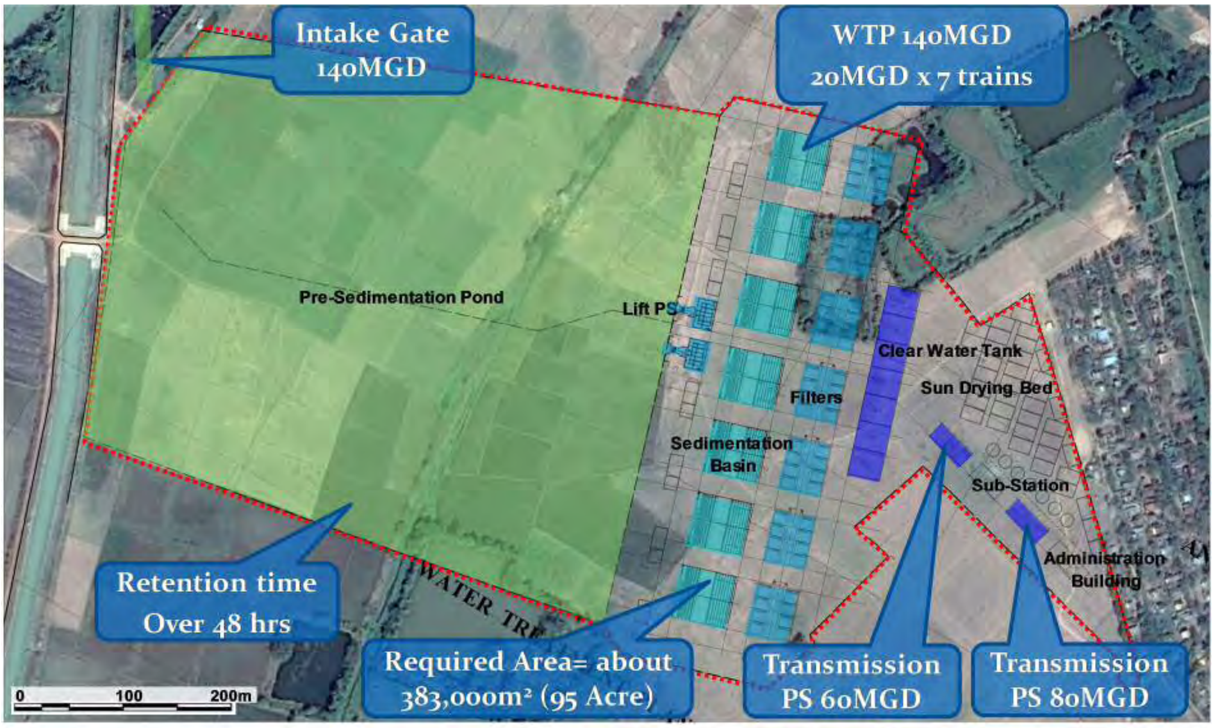
Described section	Facility	JICA Fund	YCDC Own Budget
4.3.4	Leading canal	140 MGD	-
4.3.3	Intake gate	140 MGD	-
4.3.5	Pre-sedimentation pond	60 MGD	-
4.1.4.(7)	Banking up to 7.1 m	-	60 MGD
4.3.6	Lift pump	60 MGD	-
4.4.3	Receiving Well cum Rapid Mixing Basin	60 MGD	-
4.4.4	Flocculation Basin and Sedimentation Basin	60 MGD	-

4.4.5	Filter	60 MGD	-
4.4.6	Clear water reservoir	60 MGD	-
5.3.4	Transmission pump	60 MGD	-
4.4.7	Sludge Treatment (Wash Water Drainage Basin, Sludge Basin, Sludge Thickener and Sun Drying Bed)	60 MGD	-
4.4.8	Chemical Dosing Facility	60 MGD	-
4.4.9	Chlorination Facility	60 MGD	-
4.4.10	Electrical Facility (Main Power Supply and Emergency Power Supply)	60 MGD	-
4.4.11	SCADA	60 MGD	-
4.4.12	Administration Facility	60 MGD	-

Source: JICA Study Team

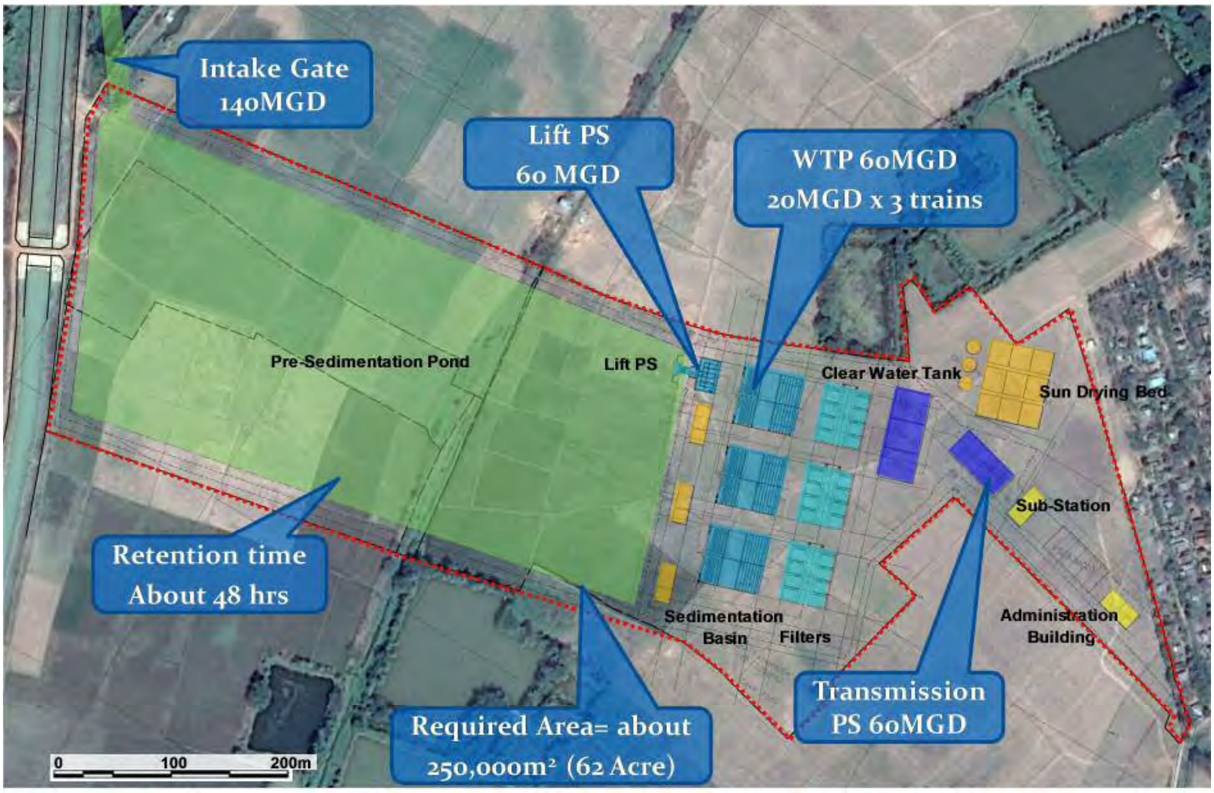
(5) Layout Plan of Kokkowa WTP

As is proposed in the preceding section and as YCDC has agreed to acquire additional land in the fiscal year 2016/17 to have 60 MGD of pre-sedimentation pond with 48 hours retention time, layout of the WTP is planned for 60 MGD capacity. Firstly, layout of the 140 MGD WTP (Kokkowa WTP 3rd Stage) is considered and then, layout of the 60 MGD WTP is proposed for this Study.



Source: JICA Study Team using background map of Google Earth

Figure 4-13 Proposed Layout of WTP (for 140 MGD)



Source: JICA Study Team using background map of Google Earth

Figure 4-14 Proposed Layout of WTP (1st Stage of 60 MGD)

4.3 Intake Facility

4.3.1 Planning Policy

(1) Policy of Intake Planning

The location of intake point and WTP in this study is close to the Kokkowa River. Since fluctuation in water level of the river is large, fluctuation in pump head is also large. However, using the river water level effectively as natural power at the time of high-water level in river, the pump head becomes small and electric power cost can be reduced. Therefore, Kokkowa water is led to WTP by gravity, and lift pumps are installed at the starting point of treatment process. In addition, policy of intake planning considering the below reason is as follows.

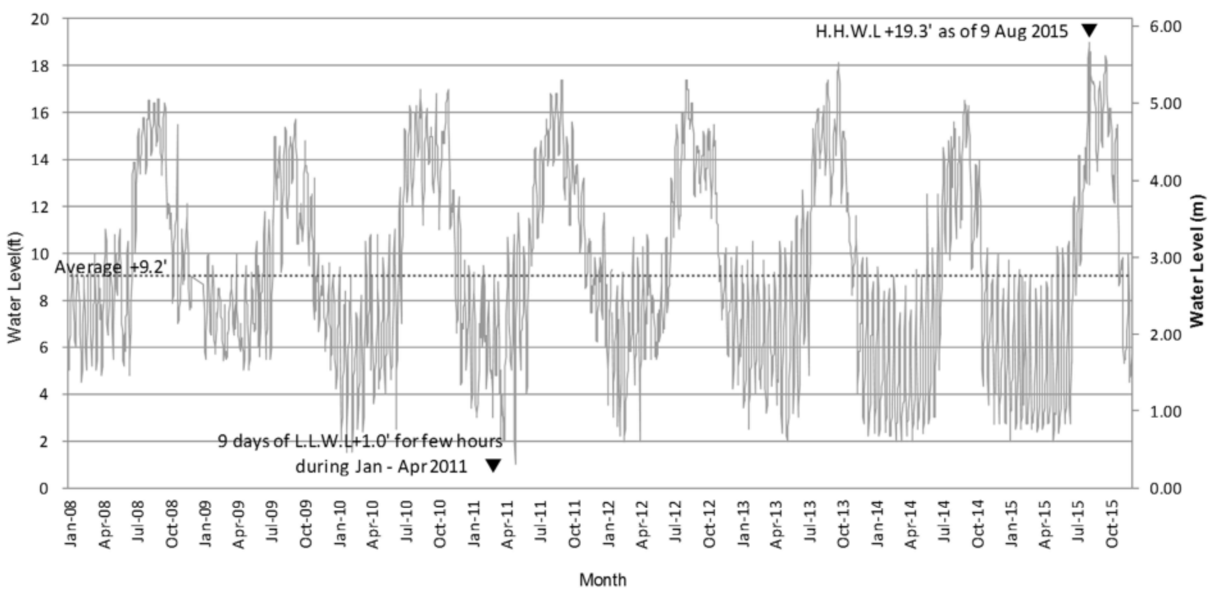
【Policy of Intake Planning】

- Effective use of natural power sources
- In order to avoid interruption in operation of WTP, intake gates are set below L.L.W.L of the Kokkowa River.
- High turbidity in raw water is reduced using pre-sedimentation pond in order to reduce consumption of chemical.
- To use surface water with low turbidity (of pre-sedimentation pond) than using low layer water.

(2) Fluctuation of the River Water Level

The periodical water level measurement in the Kokkowa River is carried out at the Pandaing village (Refer to Figure 4-2 for the village location) by MoAI. They record the river water level three (3) times (at 6:00, 12:00, and 18:00) every day. Based on the daily data obtained from MoAI, which was recorded at 12:00, following Figure shows that average water level is +2.81 m (+9.2 feet: January 2011 - November 2015), HHWL as +5.88 m (+19.3 feet in August 2015), and LLWL as +0.30 m (+1.0 feet on 9 days during January and April 2011) as the extreme value in the record. The range of fluctuation of water level is as high as about 5.6 m. The difference in water level during one day is about 2 m.

In recent years, many times water levels of about +1.0 m (about +3 feet) are observed in November - May, and occurrence of LLWL +0.30 m is expected also in the future. For this reason, leading canal, intake gates and lift pumps should be installed below LLWL in order to avoid interruption in operation of WTP.



Source: MoAI and edited by JICA Study Team

Figure 4-15 Fluctuation of Daily Water Level of The Kokkowa River at Pandaing Village (2008 to 2015)

(3) Measures against high turbidity

In the above Figure, the observed water levels exceeding the average level are occurring mainly during the months of July - October. In general, and the period of raw water turbidity exceeding 500 NTU (Table 4-3) overlaps with the above period. In addition, occurrence of the turbidity exceeding 1,000 NTU continued for ten days in 2015 and is expected to occur in the future also. Therefore, pre-sedimentation pond is planned for the purpose of reducing high turbidity in raw water.

The turbidity of inflow to WTP can be reduced, as observed in the precipitation tests (Figure 4-11), by increasing the retention time from the Kokkowa River to entrance of WTP. Based on the results of tests carried out for high turbidity water in the rainy season (left graph in Figure 4-11), retention time of pre-sedimentation pond is set to over 48 hours where turbidity is stabilized. On the other hand, in the dry season, river water level is also low, and average turbidity of 150 NTU is within the range of flocculation, consequently retention time is set to over 12 hours only.

(4) To take Supernatant Water

The result of sedimentation in Figure 4-11 shows that surface water has low turbidity. In order to use the surface water of low turbidity, the structure of pump well is accordingly planned.

4.3.2 Proposed Capacities

There exists the MOAI's embankment along the Kokkowa River that is an important facility to protect against flood water. No facilities had better be constructed across the embankment that might weaken the embankment. Therefore, repeated construction of the intake facilities should be avoided and one-time construction is proposed. Hence, intake facilities need to be constructed with 154 MGD (140 MGD x 110%) capacity which is the final capacity at this moment. It is considered that pre-sedimentation pond and lift pumps of 66 MGD (60 MGD x 110%) be the candidate under this plan.

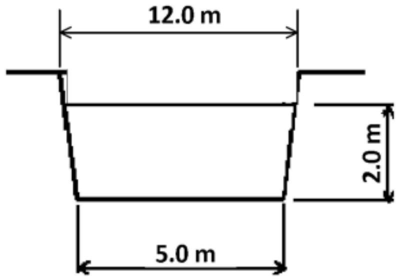
Table 4-8 Proposed Planned Capacities

Facility	Overall plan	Capacity
Total Intake Flow	700,000 m^3/day (154 MGD)	154 MGD
Intake point and leading canal		154 MGD
Intake Gate		154 MGD
Pre-sedimentation Pond		66 MGD
Lift Pump		66 MGD

Source: JICA Study Team

4.3.3 Intake Point and Leading Canal

Raw water is to be directly taken from Kokkowa River for WTP. The section of leading canal is calculated using the following Manning formula.



$$V=1/n \cdot R^{2/3} \cdot I^{1/2} = 0.7 \text{ m/s}$$

Flow rate=A x V=11.92 m^3/s > 8.10 m/s =154 MGD

Where:

V: velocity (m/s), n: Gauckler-Manning coefficient 0.017 (as gravel bottom), R: Hydraulic radius=A/P (A: cross sectional area 17.0 m^2, P: wetted perimeter (m)), I: slope of the hydraulic grade line (1/10,000)

4.3.4 Intake Gate

In order to withdraw water continuously for 24 hours, intake gates are to be installed below LLWL. Six (6) gates are installed as described below. An intake gate is used in the constantly open condition.

- Planned flow : 154 MGD
- Gate Size : 1500 mm x 1500 mm
- Installation level : G.L.-1.2 m ～ +0.3 m as LLWL
- Bottom level of leading canal : G.L.-2.2 m (Height of a margin as 0.5～1.0 m as Japanese guideline)
- Planned velocity : 0.4～0.8 m/s (as Japanese guideline)
  - 4 Duty+2 Standby : 0.90 m/s > 0.8 m …NG
  - 5 Duty+1 Standby : 0.72 m/s < 0.8 m …OK
  - 6 Duty+0 Standby : 0.60 m/s < 0.8 m …OK

River water level changes by several meters within the same day. Flap gate is installed in order to prevent backflow when the water level of pre-sedimentation pond is higher compared to Kokkowa River in case of low water level in Kokkowa River.

Table 4-9 Outline of Intake Gate

No	Facility	Specification	Quantity	
			Target	In future
1	Intake Gate	W 1500 mm x H 1500 mm of Square Gate with Screen	6 units	-
2	Flap Gate	W 1500 mm x H 1500 mm	6 units	-

Source: JICA Study Team

4.3.5 Pre-sedimentation Pond

Pre-sedimentation pond is planned between intake gates and lift PS to improve raw water quality. This facility will reduce consumption of high-cost coagulant.

As measures against the high-water level in Kokkowa River, the top level of dam body for pre-sedimentation pond is set to +7.10 m as equivalent to the MoAI embankment level.

Since the target of this plan is only 66 MGD of total volume 154 MGD by the 3rd Stage, increasing the number of pre-sedimentation pond should be reviewed according to area available for these facilities in the future. For this purpose, bypass pipe of dia. 1800 mm RC is to be installed between intake gates and pit of lift pumps.

The result of water quality test of SS indicates that about 20 cm of sediment will accumulate at the bottom of pond in one year. YCDC backhoes will dredge mud at the bottom during dry season when water level is low. Before starting the dredging work, a bypass pipe will be used for WTP and pre-sedimentation pond will be emptied. Therefore, the slope for heavy machines is to be installed in the pond.

【Design conditions】

- Design flow: 66 MGD
- Average velocity of pond: 2 - 7 mm/s < 20 - 70 mm/s as the velocity which does not cause settled sand to float again, as Japanese guidelines
- Retention time in case of High turbidity and the highest water level: About 64 hrs > 48 hrs

- Retention time in case of Average water level: About 40 hrs
- Retention time in case of the lowest water level: About 20 hrs > 12 hrs

【Design】

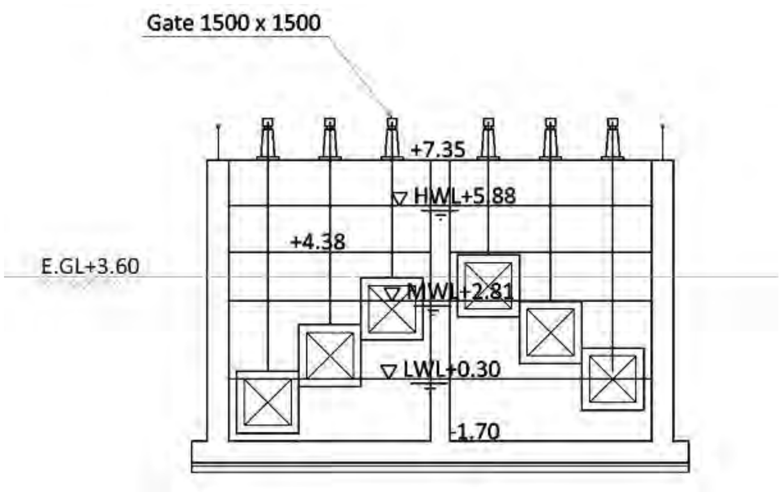
- Surface Area: 100,000 m^2
- Mud Pocket: 0.5 m Height (Not including effective depth)
- HWL: +5.88 m (+15.0’), Effective depth 8.12 m (excluding Mud pocket) → Storage volume = 812,000 m^3
- MWL: +2.81 m (+9.2’), Effective depth 5.05 m →Storage volume =505,000 m^3
- LWL: +0.30 m (+1.0’), Effective depth 2.54 m →Storage volume =254,000 m^3
- Bottom Level: -2.74 m (-9.0’): LWL+0.3 m - Effective depth 2.54 m - Mud pocket 0.5 m
- Top Level: +7.10 m > Level of MoAI embankment +7.00 m
- Accessories: Bypass pipe; dia. 1800 mm and Slope for heavy machines.

4.3.6 Lift Pumping Equipment

The lift pump equipment consists of auto screen, lift gate and lift pump (see the Table 4-10). The screen will be installed to prevent fallen leaves or garbage entry into the receiving well.

(1) Lift Gate

Fluctuation in the water level of Kokkowa River is large, and in order to withdraw surface water of low turbidity (see the Photo 4-5), two or more inflow gates are planned. Here, if maximum water level fluctuation is 5.6 m, and opening is 1.5 m in height, the number of gates is three tiers (5.6 m / 1.5 m = 3.7≒3). The lift gates are respectively installed in zigzag alignment as shown in the following Figure. Motor operated gates are employed for easy operation. However, for design of gates operation, the water level data of Kokkowa River with frequency of at least 5-minute interval is required. Therefore, water level data shall be collected during the detailed design stage. The automatic water level measuring instrument, which uses computer is effective for this kind of data collection.



Source: JICA Study Team

Figure 4-16 Layout Planning of Lift Pump Gates

(2) Auto Screen

A screen is to be installed in order to protect the pump from inflowing trash. The height of this equipment is 9 m, and since manual operation is difficult, automatic type is adopted.

(3) Lift Pump

5 lift pumps (3 duty and 2 standby) will be installed. Each duty pump should send raw water to the corresponding attached receiving well one-to-one in order to make easy operation of each of the 3-trains (sedimentation-filter-clear water tank). Standby pumps should be able to send raw water not only to its corresponding receiving well but also to another well by switching valves, whenever required.

Because water level fluctuation in the pre-sedimentation pond is large, horizontal double suction volute pump with variable-frequency drive (VFD) is selected considering the following key points and the Table 4-11 and 4-12;

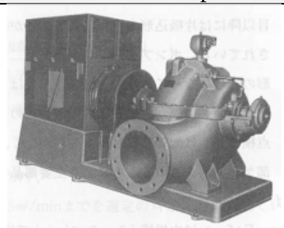
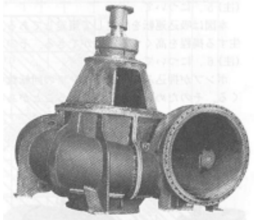
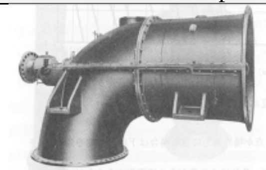
- Horizontal double suction volute pump has high efficiency.
- Horizontal double suction volute pump is widely used at existing WTPs and Pump Stations in Yangon city and operators of YCDC are skillful in maintenance of this type of pumps.
- VFD can follow fluctuation in the water level, and thereby power costs can be reduced.

Table 4-10 Outline of Lift Pump Equipment

No.	Facility	Specification	Quantity	
			Duty	Standby
1	Motor operated Lift Gate for HWL	W 1500 mm x H 1500 mm	2 units	-
2	Motor operated Lift Gate for MWL	W 1500 mm x H 1500 mm	2 units	-
3	Motor operated Lift Gate for LWL	W 1500 mm x H 1500 mm	2 units	-
4	Auto Screen	Auto Fine Screen	2 units	-
5	Lift Pump	Double suction volute pump with VFD 67 m^3/min x H 18 m x Approx. 300 kW	3 units	2 unit
6	Water gauge in the pre-pond	Ultrasonic type for pump control	1 unit	1 unit

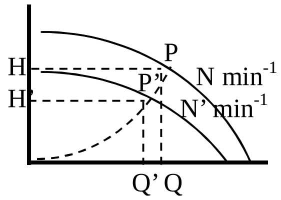
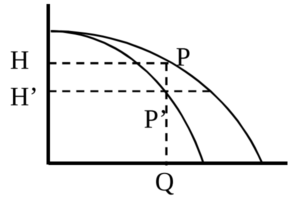
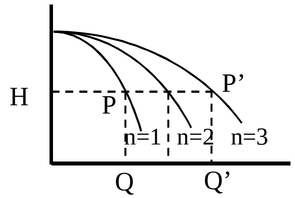
Source: JICA Study Team

Table 4-11 Comparison of Lift Pump

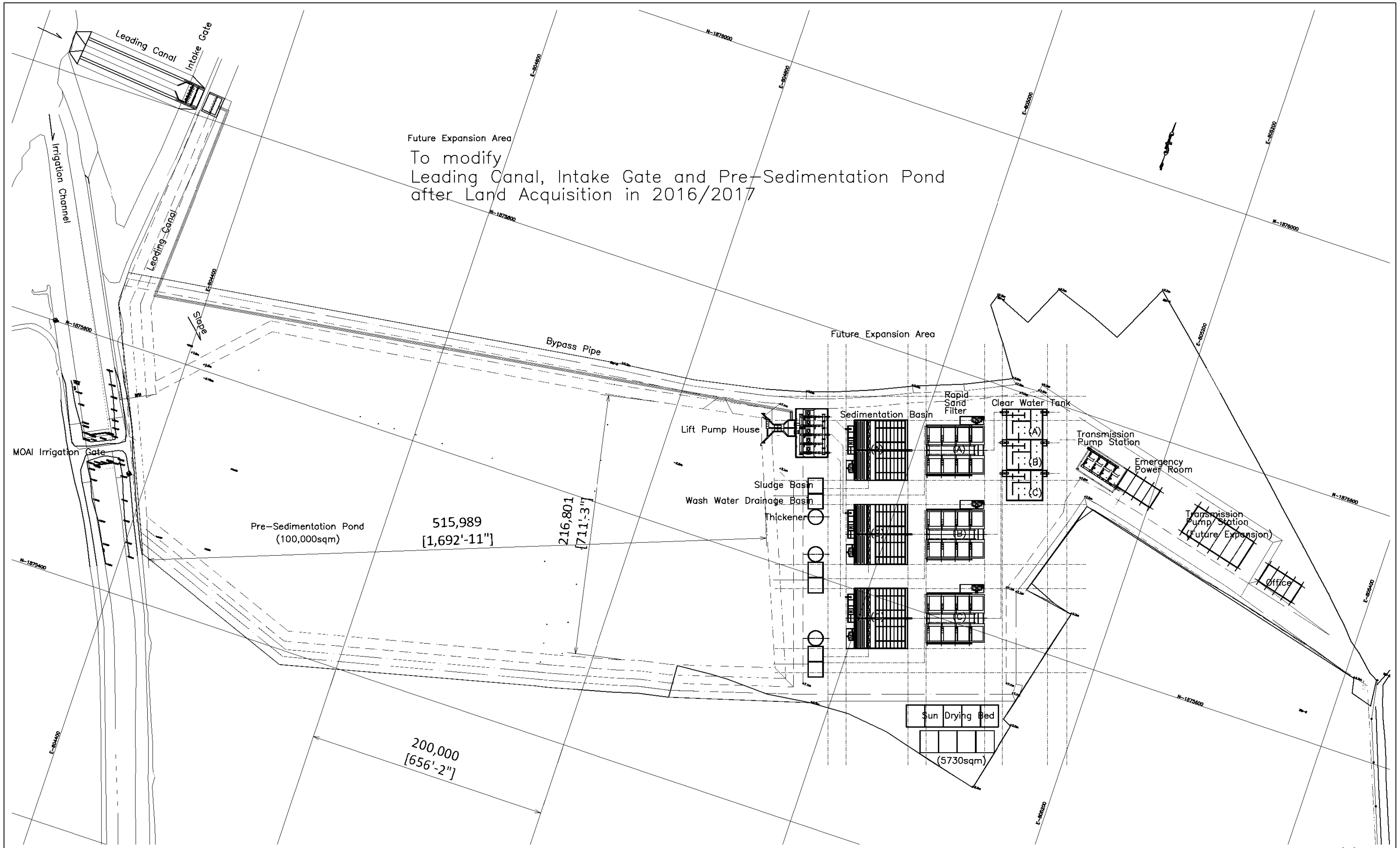
	Volute Pump		Mixed Flow Pump		Axial Flow Pump	
Appearances	 Double Suction Horizontal shaft type  Single Suction Vertical shaft type		 Horizontal shaft type  Vertical shaft type		 Horizontal shaft type  Vertical shaft type	
Pump Weight	Heavy	△	Medium	○	Light	◎
Required Area for Installation	Large	△	Less than Volute Pump	◎	Almost same as Mixed Flow Pump	◎
Pump Head	Horizontal shaft: 10-150 m	◎	Horizontal shaft: 2.5-15 m	×	Horizontal shaft: 6 m or less	×
	Vertical shaft: 10-200 m	◎	Vertical shaft: 4-60 m	◎	Vertical shaft: 8 m or less	×
Pump Efficiency	High efficiency in a wide range of water discharge	◎	Slightly lower than Volute Pump	○	Slightly lower than Mixed Flow Pump	△
Shaft Power	Low in a region of a small water discharge	○	Constant in a wide range of water discharge	◎	Shutoff power is more than twice as large as that of rated value	○
Suction Performance	High	◎	Slightly lower	○	Low	△
Operational Range	Wide	◎	Narrower than Volute Pump, Wider than Axial Flow Pump	○	Narrow (Approx. 140% or less than designed pump head)	△
Experiences in Yangon	Many	◎	Little	△	Little	△
Overall	◎		○		×	

Source: JICA Study Team

Table 4-12 Methods of Pump Operation Control

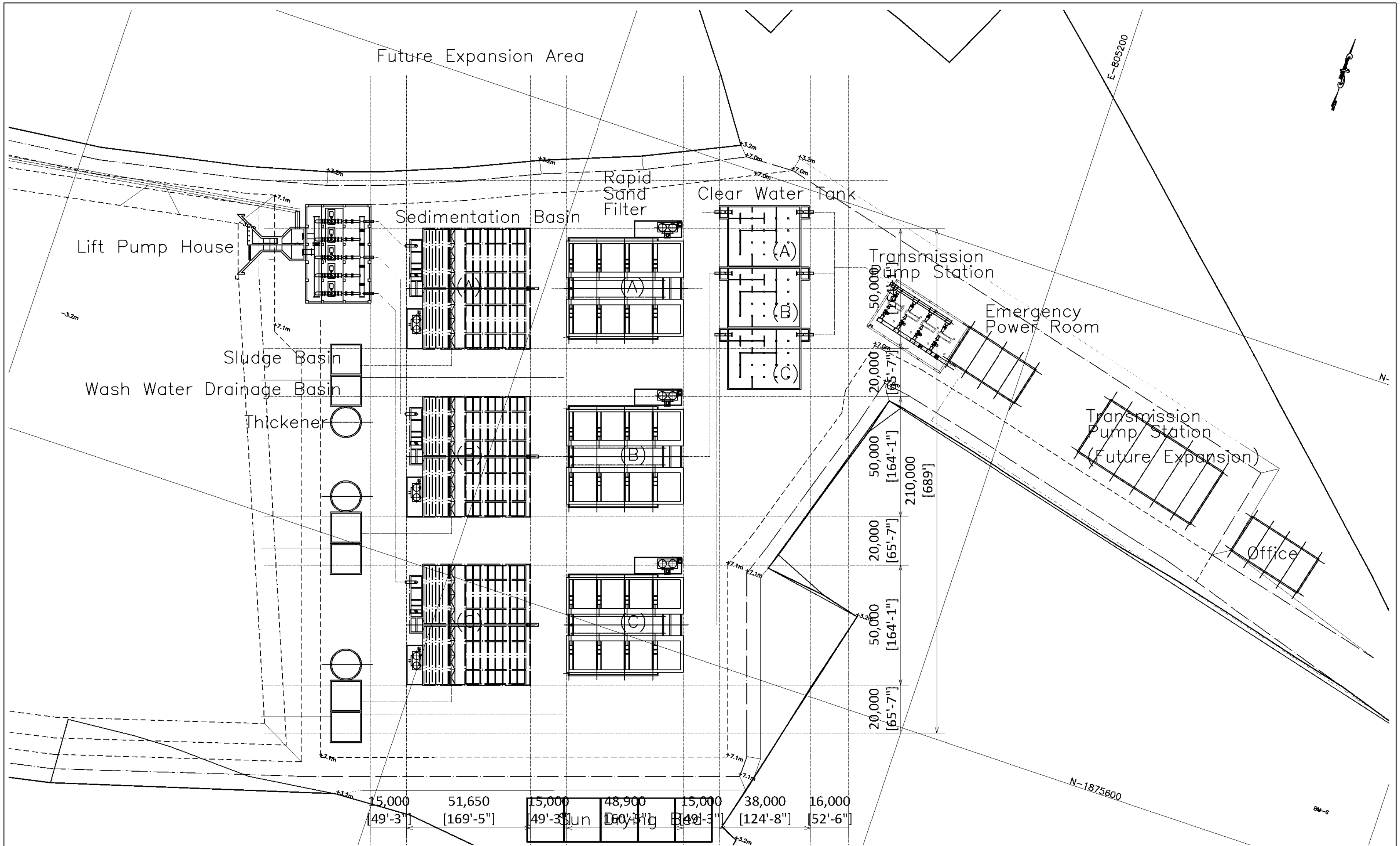
	Speed Control (VFD)	Valve Control	Number of Operating Pumps Control
Outline	 $Q' = N'/N \times Q$ $H' = (N'/N)^2 \times H$ $L' = (N'/N)^3 \times L$ *N, N' : Revolution speed The discharge quantity should be controlled by the changing revolution speed of motor.	 $Q' = Q$ $H' = H – KQ^2$ $L' = L$ *K : Coefficient based on valve opening The discharge quantity should be controlled by changing the valve opening.	 $Q' = n \times Q$ $H' = H$ *n : Number of operating pumps The discharge quantity should be controlled by the number of operating pumps.
Advantage	• Continuous flow setting is possible. • Power cost will be saved. • Pump will be operated effectively. • To cope with the variation of water level is possible.	• Continuous flow setting is possible. • Operation is simple. • Equipment cost will be small. • To cope with the variation of water level is possible.	• Special devices are not required. • Operation is simple. • The risk distribution will be possible by increasing pump number.
Disadvantage	• Equipment cost will be slightly expensive. • Required area for installation of the related equipment will increase.	• Power cost will be wasteful. • Vibration and noise will occur. • In case that the valve-outlet pressure is low, cavitation will occur.	• Continuous flow setting is impossible. • To cope with the variation of water level is impossible.
Running Cost*	1.0 ○	1.4 △	- (relation condition is different) -
Overall	◎	○	△

* Numbers show comparative number assuming Speed Control as 1.0.
Source: JICA Study Team



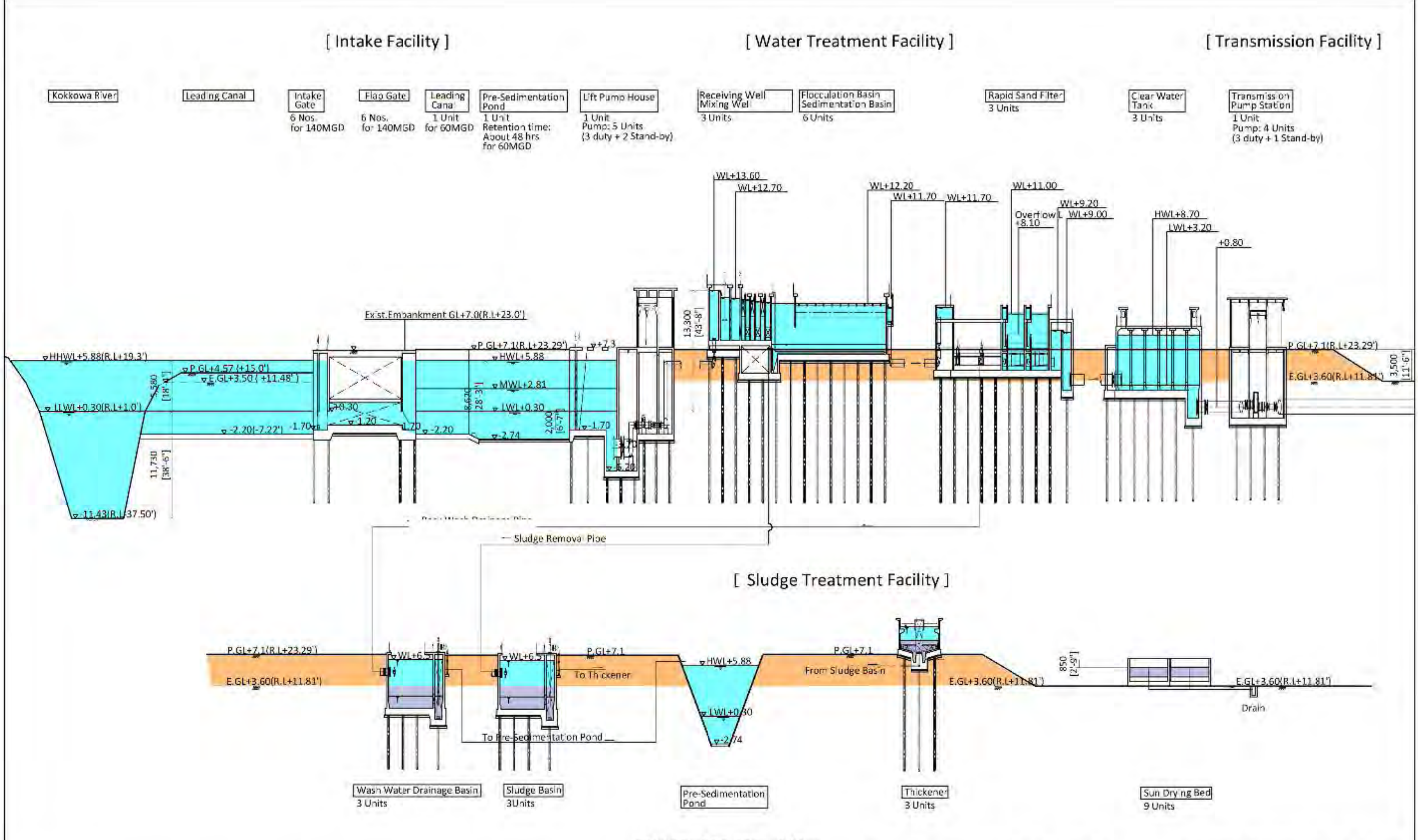
Note : The values are indicative, and detailed values shall be decided in detailed design.

JAPAN INTERNATIONAL COOPERATION AGENCY YANGON CITY DEVELOPMENT COMMITTEE		JICA Study Team ENGINEERING DEPARTMENT (WATER & SANITATION)		PROJECT: Preparatory Survey for Greater Yangon Water Supply Improvement Project Phase II (Kokkowa River)	Scale: A3; S=1:3000
DRAWN BY -	DESIGNED BY -	CHECKED BY -	APPROVED BY -	TITLE: Kokkowa Water Treatment Plant Layout Plan(1/2)	Drawing No.: WTP-1 Date: 30 June 2016



Note : The values are indicative, and detailed values shall be decided in detailed design.

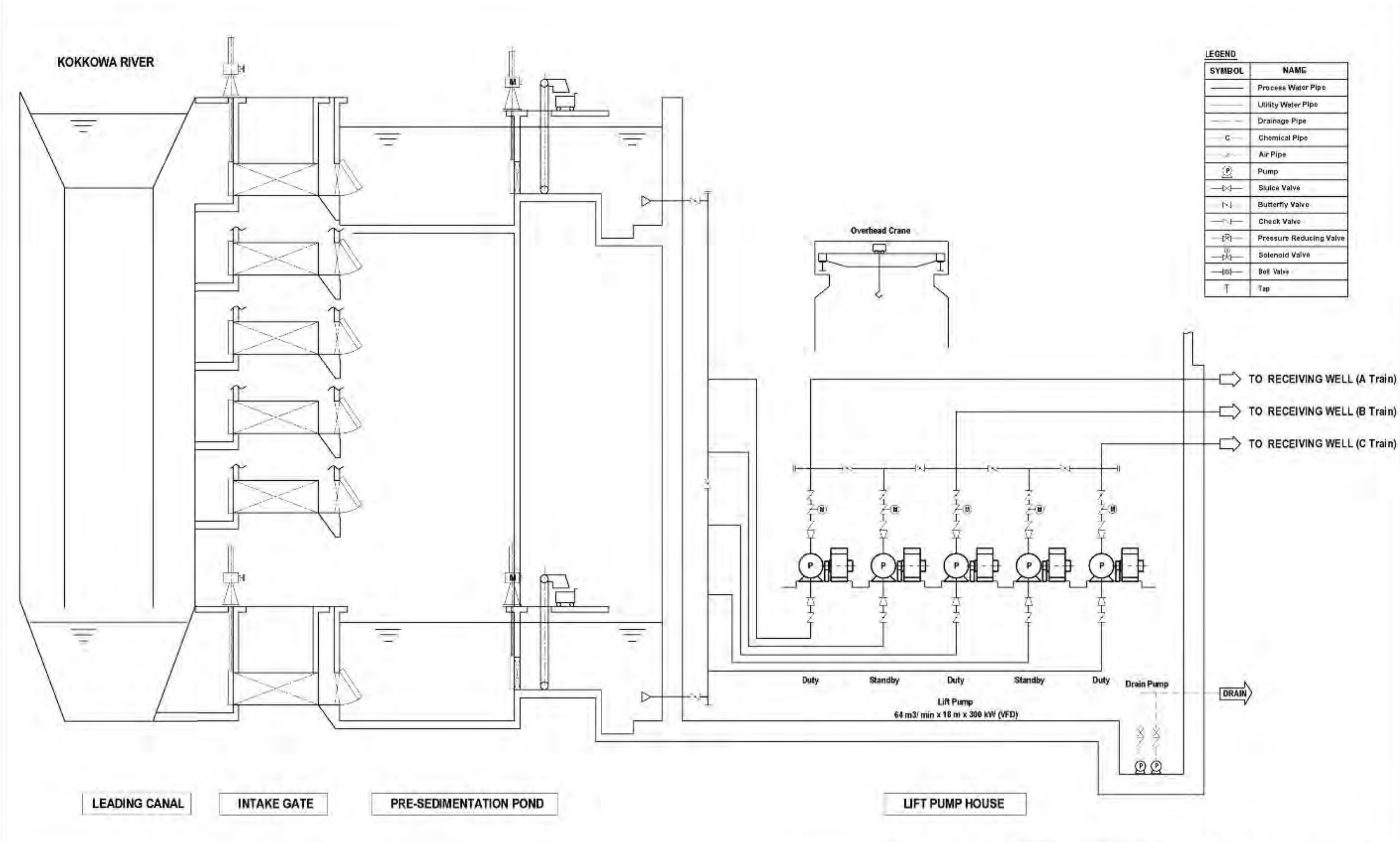
JAPAN INTERNATIONAL COOPERATION AGENCY YANGON CITY DEVELOPMENT COMMITTEE		JICA Study Team ENGINEERING DEPARTMENT (WATER & SANITATION)		PROJECT: Preparatory Survey for Greater Yangon Water Supply Improvement Project Phase II (Kokkowa River)	Scale: A3; S=1:1500
DRAWN BY -	DESIGNED BY -	CHECKED BY -	APPROVED BY -	TITLE: Kokkowa Water Treatment Plant Layout Plan (2/2)	Drawing No.: WTP-2 Date: 30 June 2016



60MGD=286,400m3/day

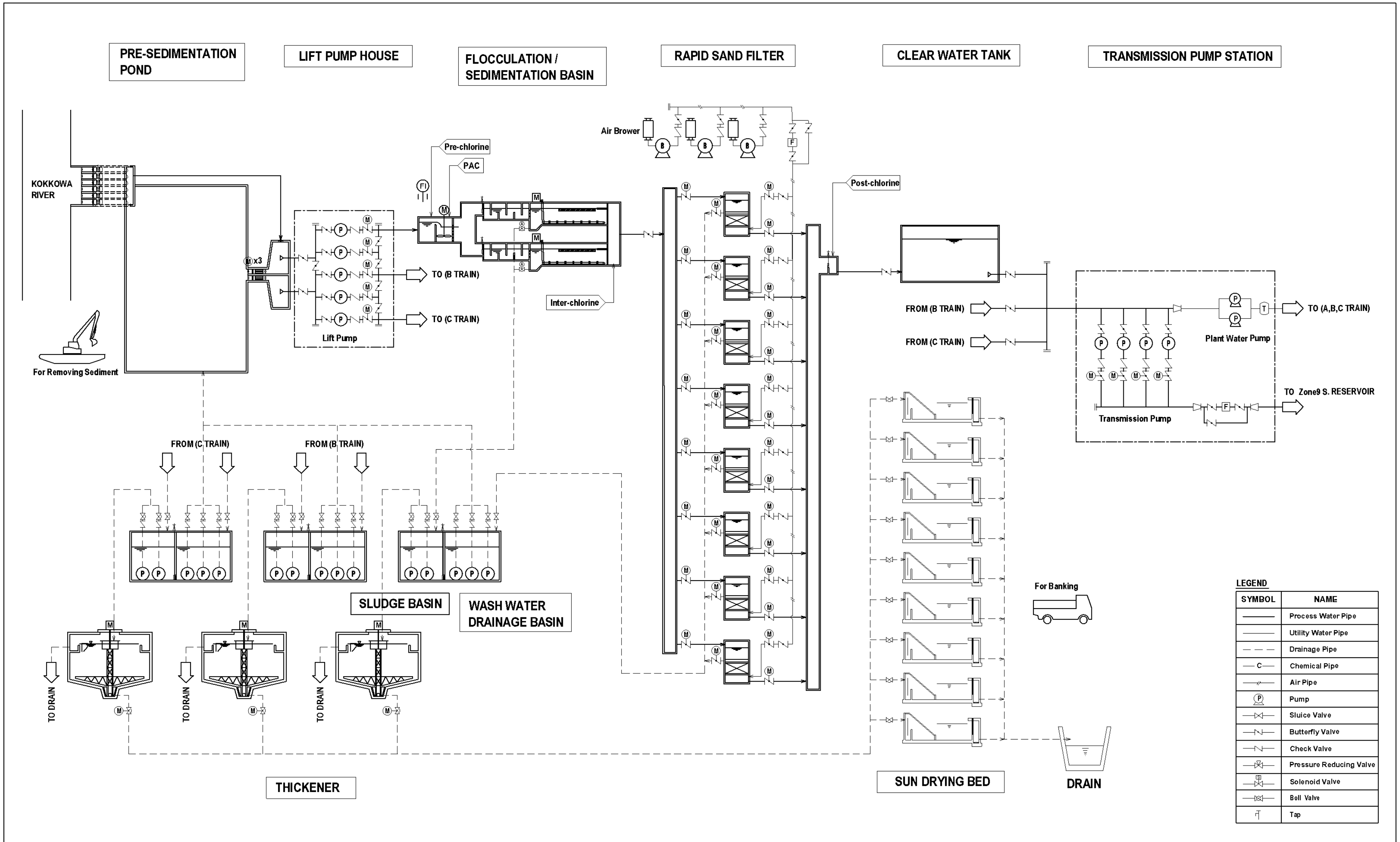
Note : The values are indicative, and detailed values shall be decided in detailed design.

JAPAN INTERNATIONAL COOPERATION AGENCY YANGON CITY DEVELOPMENT COMMITTEE		JICA Study Team ENGINEERING DEPARTMENT (WATER & SANITATION)		PROJECT	Preparatory Survey for Greater Yangon Water Supply Improvement Project Phase II (Kokkowa River)	Scale	None
DRAWN BY -	DESIGNED BY -	CHECKED BY -	APPROVED BY -	TITLE	Kokkowa Water Treatment Plant Water Level Chart	Drawing No.	WTP-3
						Date	30 June 2016



Note : The values are indicative, and detailed values shall be decided in detailed design.

JAPAN INTERNATIONAL COOPERATION AGENCY YANGON CITY DEVELOPMENT COMMITTEE		JICA Study Team ENGINEERING DEPARTMENT (WATER & SANITATION)		PROJECT	Preparatory Survey for Greater Yangon Water Supply Improvement Project Phase II (Kokkowa River)	Scale: A3; None
DRAWN BY -	DESIGNED BY -	CHECKED BY -	APPROVED BY -	TITLE	Kokkowa Water Treatment Plant Flow Sheet (Intake)	Drawing No.: WTP-4 Date: 30 June 2016



Note : The values are indicative, and detailed values shall be decided in detailed design.

JAPAN INTERNATIONAL COOPERATION AGENCY YANGON CITY DEVELOPMENT COMMITTEE		JICA Study Team ENGINEERING DEPARTMENT (WATER & SANITATION)		PROJECT: Preparatory Survey for Greater Yangon Water Supply Improvement Project Phase II (Kokkowa River)	Scale	A3; None
DRAWN BY -	DESIGNED BY -	CHECKED BY -	APPROVED BY -	TITLE: Kokkowa Water Treatment Plant Flow Sheet (WTP)	Drawing No.	WTP-5
					Date	30 June 2016

4.4 Treatment Facility

4.4.1 Proposed Facilities for WTP

Summary of the proposed facilities are shown in Table below and calculation sheet is attached as Appendix-5.

Table 4-13 Summary of The Proposed Facilities for WTP

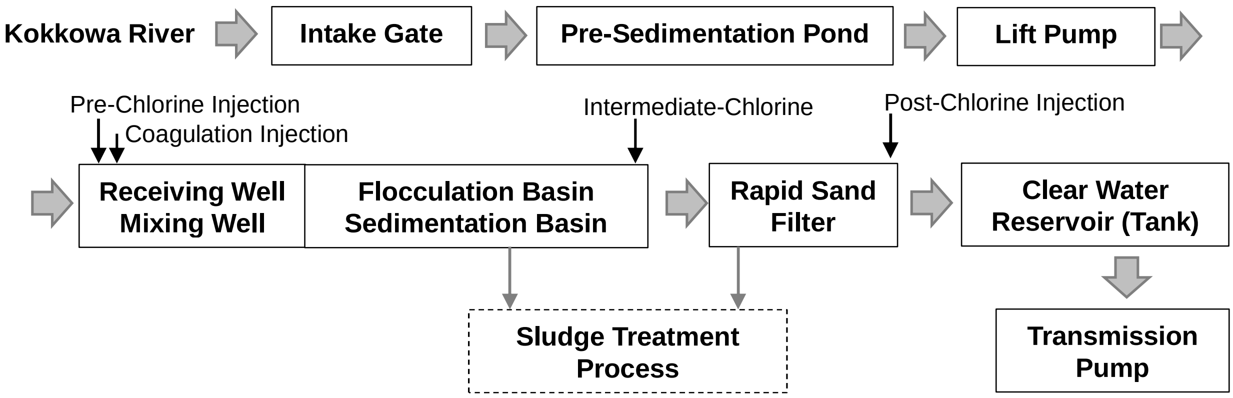
	Facility	Size per unit	Total
	Design Capacity : 63MGD		
1	Receiving Well	W 4.5 m x L 4.5 m x H 6.0 m	3
2	Rapid Mixing Basin	W 4.5 m x L 4.5 m x H 5.1 m	3
3	Flocculation Basin	Average W 1.08 m x L 145.2 m x H 4.35 m	3
4	Sedimentation Basin	W 24.2 m x L 31.1 m x H 4.0 m Tube settler of dimension W 23.9 m x L 24.4 m	6
5	Filter	W 9.5 m x L 12.0 m	24
6	Clear Water Reservoir	W 25.0 m x L 30.0 m x H 5.5 m = Vol. 4,125m^3	3
7	Wash Water Drainage Basin	W 12.0 m x L 12.0 m x effective depth 3.0 m	3
8	Sludge Basin	W 12.0 m x L 12.0 m x effective depth 3.0 m	3
9	Sludge Thickener	Diameter 12.0 m x effective depth 1.5m	3
10	Sun Drying Bed	15.0 m x 18.0 m = Area 270 m^2	9
11	Chemical Dosing		3
12	Sub Power Station Facilities		1
13	Administration Facilities		1

Source: JICA Study Team

4.4.2 Treatment Process

Soluble components such as odor, color, organic, inorganic substances and by-products of disinfection, and insoluble components such as turbidity, algae and microorganism are to be removed in treatment process. Process of “Coagulation – Sedimentation – Filtration” is generally used for treating surface water with higher turbidity. This treatment process is employed for the Nyaunghnapin WTP, judging from the raw water quality analysis. This process has been adopted in other WTPs in Yangon.

The type of chemicals to be used and their dosing rates will be decided based on “jar tests” during the detailed design stage. For planning purpose, ACH (PAC) as a coagulant is considered. Sodium hypochlorite is recommended for disinfection in water distribution networks. In addition, three steps of chlorine injection in treatment process is planned to remove iron/manganese in case if concentration of these elements are high or coagulation process is not able to remove these elements effectively. The following is the treatment process adopted for Kokkowa WTP.



Source: JICA Study Team

Figure 4-17 Treatment Process

4.4.3 Receiving Well cum Rapid Mixing Basin

The raw water is to be conveyed from pre-sedimentation pond to receiving well. Receiving well cum rapid mixing basin is attached to sedimentation basin. Chlorine (as pre-chlorination) and coagulant (ACH) shall be injected and mixing shall be carried out in the receiving well.

Rapid mixing will be made utilizing turbulent flow energy by mechanical mixing because reliable mixture is required for water with high turbidity (the turbidity of water remains high although it is reduced significantly by passing it through pre-sedimentation pond).

However, since Myanmar has few suppliers of such equipment, if equipment breaks down, repair will require long time. Therefore, hydraulic jump for rapid mixing is also adopted between rapid mixing basin and flocculation basin in consideration of occurrence of any mechanical trouble. In addition, it is installed with the main purpose of flow rate measurement by overflow weir.

【Design conditions】

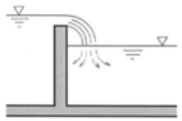
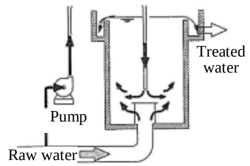
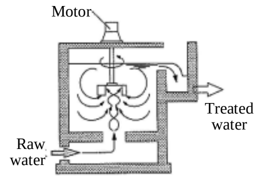
- Retention time (more than 1- 5 minutes as Japanese guidelines)
  - Receiving well: 1.8 minutes
  - Rapid mixing basin: 1.8 minutes

【Design】

- Receiving well: W 4.5 m x L 4.5 m x H 6.0 m x 3 nos., RC Structure
- Rapid mixing well: W 4.5 m x L 4.5 m x H 5.1 m x 3 nos., RC Structure
- Accessories: Flash mixer, Overflow weir, ACH/Chlorine injection point

The following Table shows comparison for selecting rapid mixing method.

Table 4-14 Coagulant Mixing Method

	Hydraulic Jump		Pump Mixing		Mechanical Mixing	
Structure						
Mixing Effect	Large due to large water falling	◎	Flexible due to change of water circulation volume	◎	Flexible due to change of impeller rotation speed	◎
Effect by Flow Volume Change	Agitation Index will change	△	Agitation Index will slightly change	○	Agitation Index will be constant.	◎
Operation and Maintenance	Easy due to no mechanical parts.	◎	Needs operation and maintenance of mechanical parts.	△	Needs operation and maintenance of mechanical parts.	△
Required Motive Power	1.5	△	1.4	○	1.0	◎
Required Area	Small	◎	Large (Need Pump Room)	△	Small	◎
Initial Cost*	0.1	◎	1.6	△	1.0	○
Operation Cost*	1.5	△	1.4	○	1.0	◎
Experiences	Large	◎	Small	△	Large	◎
Overall	○		△		Reliable mixture is required for high turbidity and Advantage of running cost ◎	

* Numbers show comparative number assuming mechanical mixing method which has been used widely in Japan, as 1.0.
Source: JICA Study Team

4.4.4 Flocculation Basin and Sedimentation Basin

(1) Flocculation Basin

Micro flocs will be produced after injection and rapid mixing of coagulants with raw water. These micro flocs need to be developed into large ones so as to settle down effectively in sedimentation basin. Flocculation basin is planned for this development after rapid mixing basin and before sedimentation basin.

Of the mechanical and non-mechanical flocculation methods, non-mechanical one is employed in this WTP. Horizontal and vertical zigzag flow flocculation method is adopted in which water after rapid mixing is guided to the flocculation basin from bottom.

【Design conditions】

- Retention time: 20.5 minutes (more than 20~40 minutes as per Japanese Guidelines)

【Design】

- Dimension: Average W 1.08 m x L 145.2 m x H 4.35 m x 3 nos., RC Structure
- Mixing method: Horizontal and vertical zigzag flow
- Accessories: Up-and down weir

【Selection reasons (see Table 4-16)】

- Since Myanmar has few suppliers of plant equipment, mechanical employment has a high risk at the time of trouble.
- Low initial cost
- Low operation cost compared to mechanical type when enough water drop is possible

(2) Sedimentation Basin

Large flocs formed in flocculation basin are settled in sedimentation basin. In general, sedimentation basin is categorized as three main types: horizontal-flow basin, horizontal-flow basins with inclined plate or tube settler, and high-speed accelerator (flocculent settling basin).

Horizontal flow with inclined plate and upward flow with tube settler are recommended as sedimentation basin for raw water with wide fluctuation in turbidity. Horizontal-flow sedimentation basins with inclined plates require much maintenance in cleaning when sludge is accumulated on the plates in case of high turbidity raw water. There is high possibility of breaking and falling of inclined plates. Therefore, inclined tube settler should be selected to reduce required land for sedimentation.

【Design conditions】

- Retention time: 1.5 hours (more than 1 hour as per Japanese Guidelines)
- Average flow velocity: 0.4 m/min
- Average up-flow velocity: less than 80 mm/min
- Surface load: less than 7 to 14 mm/min

【Design】

- Dimension: W 24.2 m x L 31.1 m x H 4.0 m with Tube settler of dimension W 23.9 m x L 24.4 m x 2 units x 3 trains = 6 basins, RC Structure
- Sedimentation method: Upflow type with tube settler and Mechanical sludge collector

- Sludge discharge valve: Automatic eccentric valve with timer control
- Accessories: Inclined tube settler, guiding walls, collecting troughs for water collection, monorail type sludge collector, de-sludging equipment (valves, pipes)

【Selection reasons (see Table 4-17)】
- Requires relatively smaller land area
- Many examples of use in neighboring countries

The purpose of installing the tube settler is to help the settlement of coagulated flocs effectively using a small surface area of sedimentation basin. The settled sludge is collected at the pit at the bottom by sludge collector, and discharged into the sludge basin periodically through the de-sludging valve.

Table 4-15 Outline of Sedimentation Equipment

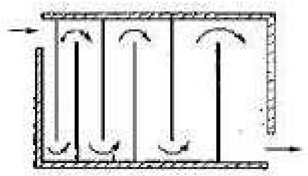
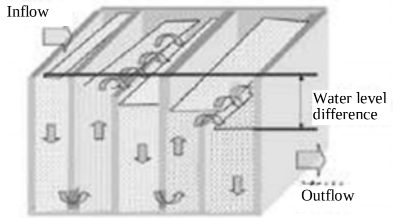
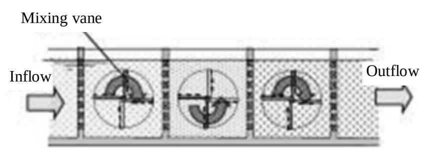
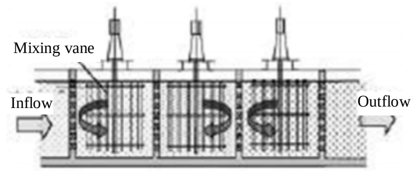
No	Facility	Specification	Quantity	
			Duty	Standby
1	Tube Settler	Upflow type	6 units	-
2	Sludge Collector	Monorail type	6 units	-

Source: JICA Study Team

(3) Intermediate Chlorination

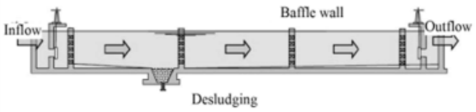
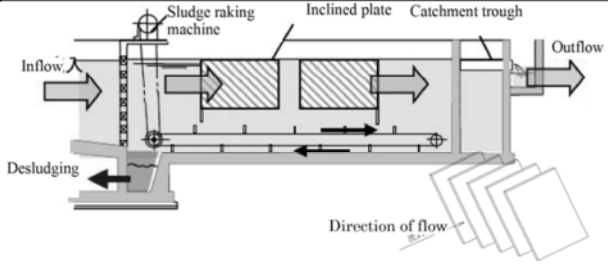
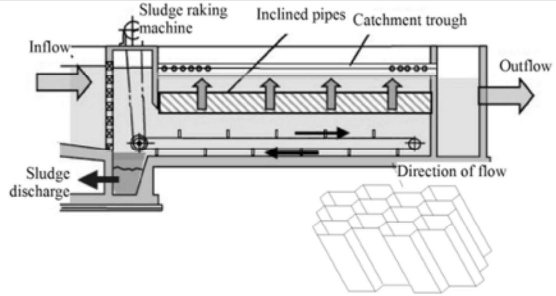
Chlorine will be also injected into settled water channel in the sedimentation basin to remove iron and manganese and prevent formation of hazardous tri-halo-methane, when raw water contains high amount of organic compound. The injection point of chlorine will be set as the end of sedimentation basin.

Table 4-16 Mixing Method of Flocculation Basin

	Method Using Flow Energy				Mechanical Mixing Method			
	Horizontal Zigzag Flow		Vertical and Horizontal Zigzag Flow		Horizontal Shaft Paddle		Vertical Shaft Paddle	
Structure	 (2) Horizontal baffled channel method (top view)							
Mixing Effect	0.5 meters water level difference is required.	○	0.5 meters water level difference is required.	○	Better by adjusting rotation numbers in each stage.	◎	Better by adjusting rotation numbers in each stage.	◎
Effect by Flow Volume Change	Agitation Index will change	△	Agitation Index will change (mixing is stronger than horizontal baffling)	○	Agitation Index will be constant.	◎	Agitation Index will be constant.	◎
Operation and Maintenance	Easy due to no mechanical parts.	◎	Easy due to no mechanical parts.	◎	Needs operation and maintenance of mechanical parts. Drive part is submerged and durability is not so good.	△	Needs operation and maintenance of mechanical parts. Drive part is not submerged and durability is good.	○
Required Motive Power	0.1	◎	0.1	◎	1.0	△	1.0	△
Required Area	Large	△	Medium	○	Small	◎	Small	◎
Initial Cost*	0.2	◎	0.2	◎	1.0	△	0.6	○
Running Cost*	0.1	◎	0.1	◎	1.0	△	1.0	△
Overall	○		Easy due to no mechanical parts and Advantage of running cost ◎		△		○	

* Numbers show comparative number assuming horizontal-shaft paddle mixing method which has been used widely in Japan, as 1.0.
Source: JICA Study Team

Table 4-17 Sedimentation Method

	Conventional Horizontal Flow		Horizontal Flow with Sedimentation Effect Enhancement			
			Horizontal Flow with Inclined Plate		Upward Flow with Tube Settler	
Structure						
Retention Time	3-5 hours		Approximately 1 hour		Approximately 1 hour	
Surface Load	15-30 mm/min		4-9 mm/min		7-14 mm/min	
Velocity	Less than 0.4 m/min		Less than 0.6 m/min		Less than 0.08 m/min	
Basin Depth	3-4 m		4-5 m		4-5 m	
Required Area	Large (100 %)	△	Small (30 to 40 %)	◎	Medium (50 to 70 %)	○
Turbidity of Settled Water	Low due to intermediate flow guiding wall, however, sometimes not low due to short-circuit and/or density flows	△	Low due to uniform flow	◎	Low due to uniform flow	◎
Flexibility to variation	Not good for variation in raw water turbidity. Not good for variation in raw water temperature. Good for variation in raw water flow volume.	△	Good for variation in raw water turbidity. Good for variation in raw water temperature. Good for variation in raw water flow volume.	◎	Good for variation in raw water turbidity. Good for variation in raw water temperature. Good for variation in raw water flow volume.	◎
Operation and Maintenance	Continuous monitoring is required because density flow and short-circuit flow may occur often. Cleaning is easy.	◎	Periodical cleaning is required to remove settled sludge on the plates. Removal of plates is required during cleaning.	△	Periodical cleaning is required to remove settled sludge on the tubes. Cleaning is not difficult.	○
Initial Cost*	1.0	◎	2.5	△	2.0	○
Running Cost*	0	◎	0	◎	0	◎
Experiences	Many	◎	Little (however many in Japan)	△	Relatively many	◎
Overall	△		○		◎	

* Numbers show comparative number assuming conventional horizontal flow basin as 1.0.
Source: JICA Study Team

4.4.5 Filter

Micro flocs which cannot be settled down in sedimentation basins should be separated out in filters. Two-layer filter media of anthracite and sand is employed in the Nyaunghnapin WTP. However, its operation in the existing Nyaunghnapin WTP does not show good results; since particles in the filter media are small and backwashing speed is high, resulting in filter media being washed away. To overcome this issue, single-layer filter media (silica sand) is adopted for this WTP. Filter bed thickness is set as 600 mm considering the particle diameter which can be procured in the Yangon suburbs. And filtration speed will be reduced to the maximum level of 150 m/day for single layer filter.

A first example in Yangon, self-back-washing method is adopted for this WTP considering energy saving. Conventionally, the pump backwash system is employed in other WTPs. In Nyaunghnapin WTP, valves operation is conducted manually and heavy manpower of operators is required. Therefore, filtration and backwash processes in this WTP are automatically operated with the sequence control using motor-operated valve as same as Lagunbyin WTP.

The duration of washing of each filter is considered as 30 minutes, such that back-washing of all the proposed 24 filters can be finished during daytime within 12 hrs for 60 MGD WTP.

【Design conditions】

- Filter flow speed: Less than 150 m/day
- Conventional rapid sand filter

【Design】

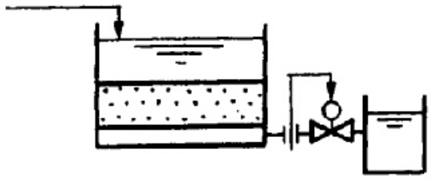
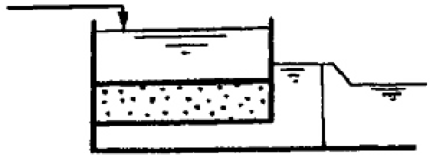
- Dimension: W 9.5 m x L 12.0 m x 8 filters x 3 trains =24 filters, RC Structure
- Filter media: Single layer (Silica sand: 600 mm thickness), Uniformity coefficient: less than 1.7 mm
- Washing method: Self-backwashing (see Table 4-19) with Air washing or Surface washing
- Accessories: Air wash equipment (blower), under drain plate (porous block), drain trough, drain pipe, inlet, outlet and drain valves (electrically driven)

Table 4-18 Outline of Rapid Sand Filter Equipment

No	Facility	Specification	Quantity	
			Duty	Standby
1	Rapid Sand Filter	Gravity and Single Media Filtration	24 units	-
2	Air Blower (Example)	Rotary Blower	6 units	3 units

Source: JICA Study Team

Table 4-19 Back Washing Method of Filtration Basin

	Constant Rate Filtration with Back wash pump or Elevated tank		Self-Balancing Filtration with Self-washing	
Schematic diagram				
Configuration	Consists of catchment, inflow culvert, various motor-operated valves, drain trough, etc.		Same as in left column	
	Filters are independent of each other.		All Filters are connected to each other.	
Flow Speed	120 - 150 m/day		120 - 150 m/day	
Backwashing Speed and Method	0.6 - 0.8 m/minute Backwashing is performed by pressurized water by pumps or elevated tank via motor-operated valves.	○	0.6 - 0.8 m/minute Backwashing is performed using filtered water by clear water with other filters connected, utilizing the difference in water level in clear water weir and drain trough. Backwashing pump or elevated water tank is not required.	◎
Flow Control	Requires valves to balance inflow and outflow volume.	○	Inflow and outflow volume balance naturally.	◎
Operation and Maintenance	Requires various valves of inflow, outflow, drainage and back-washing.	○	Requires various valves of inflow, outflow and drainage.	◎
Initial Cost*	1.0	○	0.8	○
Running Cost*	1.0	○	0.3	◎
Experiences	Many	◎	Relatively many	○
Overall	○		Advantage of running cost ◎	

* Numbers show comparative number assuming constant rate filtration control as 1.0.
Source: JICA Study Team

4.4.6 Clear Water Reservoir (Tank)

Theoretically, the amount of treated water and treated water pumping should be the same. However, in case that the two flows are not same, clear water tank will be required to adjust the flows difference. The design volume is set as one hour of the daily treatment capacity according to the Japanese Design Guidelines. Three trains with horizontal-flow mixing by baffle wall are proposed with 1 injection point per train for post-chlorination.

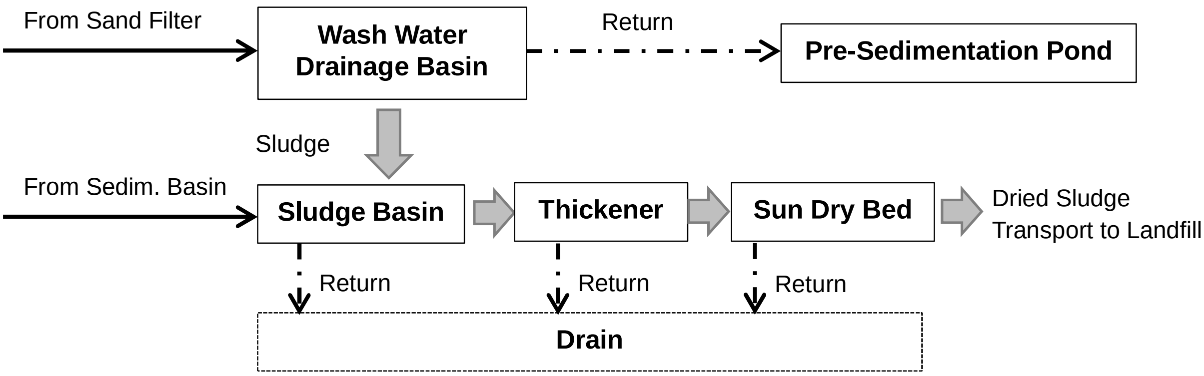
【Design conditions】
- Retention time: 1.0 hour of the daily treatment capacity (more than 1 hour as Japanese Design Guidelines)
- Mixing method: Horizontal zigzag flow type

【Design】
- Dimension: W 25.0 m x L 30.0 m x H 5.5 m (Volume 4,125 m^3) x 3 trains, RC Structure
- Accessories: Chlorine injection point, water level gauge, overflow pipe, drain equipment (pipe and valve) and ventilator

4.4.7 Sludge Treatment

Sludge treatment method is decided considering raw water quality, quantity and quality of waste or washed water, characteristics of sludge, disposal method of generated sludge, operation requirements, land size of each method, construction cost of each method and so on. Sludge treatment facilities generally consist of sludge basin (for sludge from sedimentation basins), wash water drainage basin (from filters), sludge thickener and dehydration facilities such as lagoon, sun drying bed or mechanical facilities.

Since satisfactory concentration of sludge is confirmed by the jar test, use of sun drying bed for dehydration is a cheaper option. Thickened sludge is transferred to sun drying bed where sludge is dried under natural sunlight. Its supernatant is discharged to drain.



Source: JICA Study Team

Figure 4-18 Sludge Treatment Process

(1) Wash Water Drainage Basin (from Filter)

Wash water drainage basin temporarily stores back-wash water from filters. Volume of basins should be equal to at least one day's back-washed water volume. Discharge pumps are provided for the basins.

【Design】

- Dimension: W 12.0 m x L 12.0 m x effective depth 3.0 m x 3 trains

【Facilities Specifications】

- Design Parameter: 3 basins, RC Structure
- Discharge Pump: 6 duty and 3 standby (2 duty and 1 stand-by for each basin)

(2) Sludge Basin (for sludge from Sedimentation basins)

Sludge basins are installed before thickeners to adjust flow and quality of sludge discharged from sedimentation basins. Volume of the basins are planned to receive one day's discharged volumes from the above basins during rainy season when raw water turbidity is high.

【Design】
- Dimension: W 12.0 m x L 12.0 m x effective depth 3.0 m x 3 trains

【Facilities Specifications】
- Design Parameter: 3 basins, RC Structure
- Sludge Withdrawal Pump: 3 duty and 3 standby (1 duty and 1 stand-by for each basin)

(3) Sludge Thickener

Thickeners are provided to accelerate dehydration of sludge and reduce sludge volume. Of the three types of commonly used sludge thickening processes; gravity thickening, floating thickening, and filtration thickening, generally used gravitational thickening is selected for this WTP. The thickener will be provided with rotational sludge rake system. Collected sludge at the bottom will be sent to sun drying beds by gravity flow.

【Design】
- Dimension: Diameter 12.0 m x effective depth 1.5m x 3 trains

【Facilities Specifications】
- Design Parameter: 3 tanks, RC Structure, Cylindrical-shape type with rotational sludge rake system
- De-sludging valve: 3 duty (1 duty for each tank)

(4) Sun Drying Bed

Sun drying bed is planned to store and settle sludge discharged from thickeners. Supernatant from the sun drying bed is discharged to canal by gravity. Sludge is dried in the beds, settled and accumulated sludge is raked and collected. Access road is provided for that purpose. Dried sludge may be used for land reclamation purpose as land filling for extension area of WTP or as covering materials.

【Design】
- Design Parameter: W15.0 m x L18.0 m x 9 basins =Total Area 2,430 m^2, RC Structure

4.4.8 Chemical Dosing Facility

(1) ACH Dosing Equipment

Alum and ACH (PAC) are generally used as coagulants. Although expensive, the use of ACH is suitable when large variation in raw water quality is expected, and therefore, it is used in YCDC systems. For this WTP, ACH is recommended same as in other existing WTPs. Accordingly, storage tanks and dosing pumps are provided for ACH dosing.

(2) ACH Dosing Rate

For this WTP, pre-sedimentation pond with 48 hours of retention time is planned to reduce high turbidity in raw water. Based on the water quality tests, the raw water turbidity level is reduced to 50 NTU after pre-sedimentation. Considering these values and jar test result, dosing rates are planned in the range as given below.

Theoretically, alkalinity of 0.15 mg/L is consumed per ACH 1 mg/L, in case of the proposed injection rate, alkalinity is expected to drop by 1 - 4 mg/L. Based on the available water quality data it is analyzed that the alkalinity of raw water is about 20 mg/L, and it is determined that Alkali aid is unnecessary in this plan.

Table 4-20 Proposed ACH Dosing Rate

Expected turbidity after pre-sedimentation pond	Dosing rate
Less than 50 NTU	5 - 25 mg/L

Note: Dosing rate is tentative and needs verification during detailed design period.
Source: JICA Study Team

(3) Design Value of Chemical Dozing Equipment

The chemical dosing facility is designed considering following design criteria.

- Chemicals: Liquid ACH
- Doing rate: 1 to 30 mg/L
- Injection Pump: (1 duty and 1 standby) x 3 trains
- Incidental equipment: Chemical storage tank

4.4.9 Chlorination Facility

Chlorination facility is planned to provide safe water to consumers and holding of disinfection in water distribution pipelines. Moreover, three steps of chlorine injections are recommended for iron/ manganese removal. Key points related to dosing and purposes are as follows:

- Pre-chlorination: Average dosing rate is set as the minimum rate in order to prevent algae generation/ growth and removal of iron/manganese based on the result of chlorine demand test.
- Intermediate-chlorination: Removal of iron/manganese and used as an alternative of pre-chlorination when the raw water is polluted by wastewater along the intake canal.
- Post-chlorination: Providing residual chlorine to take care of potential pollutants seeping into the distribution system.

Chlorine injection rates are set based on the result of water quality test by EDWS and the Study Team as given in the following Table.

Table 4-21 Chlorine Dosing Rate

Item	Dosing Rate(mg/L)		
	Maximum	Average	Minimum
Pre-chlorination	6.0	3.0	1.5
Intermediate chlorination	6.0	3.0	1.5
Post chlorination	1.0	0.5	0.25

Note: Dosing rate should be decided based on water quality tests in the detailed design.
Source: JICA Study Team

Avoiding dangerous chemicals by adopting use of sodium hypochlorite for disinfection, Liquid sodium hypochlorite is planned as chlorination agents based on the comparison shown in the following Table. Although hypochlorite’s costs are relatively high, dosing facilities are simple.

However, considering the outcome of implementation of Phase 1 Project, it is necessary to review again in detailed design of Phase 2 Project.

Table 4-22 Chlorination Agents

	Liquid Chlorine (Gas)	Liquid Sodium Hypochlorite	On-site Sodium Hypochlorite Generator
Characteristics	Liquid Chlorine contained in Gas Cylinder	Liquid	Liquid, Produced from salt by electrolysis
Effective Chlorine Concentration	More than 99.4 %	Approximately 12.0 %	Approximately 1 % by non-diaphragm type Approximately 5 % by diaphragm type
Stability	Stable	High Alkalinity More unstable when effective chlorine concentration is higher. More dissolved when salt concentration is higher.	Low Alkalinity Less stable than Liquid Chlorine but more stable than purchased liquid hypochlorite.
Storage	Should follow “Safety regulation on general high-pressure gas” etc. in Japan.	Concentration may become lower, Long-term storage is difficult.	Long-term storage is possible as salt.
Dosing Devices	Complex	Simple	Relatively Complex
Handling Remarks	Careful handling is required due to strong poisonous gas with irritating odor.	- Air bubble is generated by electrolyzing sodium hypochlorite. - So consideration should be taken to prevent pumps and pipes from airlock generation.	- Small chances of obstacles from air bubble and scale generation - Discharge after dilution of hydrogen generated during electrolysis.
Measures Against Leakage	Lead to heavy accidents when chlorine gas leaks. Gas detector, neutralizer and absorbers are mandatory for small-sized facility. In addition, neutralizing reaction towers are required for large-sized facility.	Barrier is required to prevent overflow. Prevention of mixing with ACH is required, which generates poisonous chlorine.	Barrier is required to prevent overflow. Hydrogen should be discharged sufficiently otherwise it will explode or catch fire.
Operation and Maintenance	Chlorine dosing device, vaporizer, detector, neutralizer, absorbers etc.	Dosing device	Electrolyzer
Running Cost*	0.3	1.0	1.6
Overall	○	Safest and Simple Devices ◎	○

* Numbers show comparative number assuming Liquid Hypochlorite as 1.0.
Source; Guideline of Treatment Technology 2010, Waterworks Technology Research Center, Japan

4.4.10 Electrical Facility

(1) Basic Philosophy of Electrical Facilities

It is strongly advisable to adopt electrical equipment conforming to IEC standards and/or Japanese standards (JIS, JEC & JEM) with the type test records, in order to assure the quality and personnel safety. On the contrary, products of electrical manufacturers in Myanmar are generally used in the existing YCDC's WTPs as these products have advantages to EDWS personnel in operation, maintenance and upgrading. Based on the results of survey, the type-tested electrical equipment is limited to low capacity transformers only, and therefore there is less chance to apply those until they proceed with the type tests and pass them. The proposed WTP does not have any critically unsafe facilities in the system, electrical facilities should have very basic fundamental protection only, and the WTP does not require any special devices.

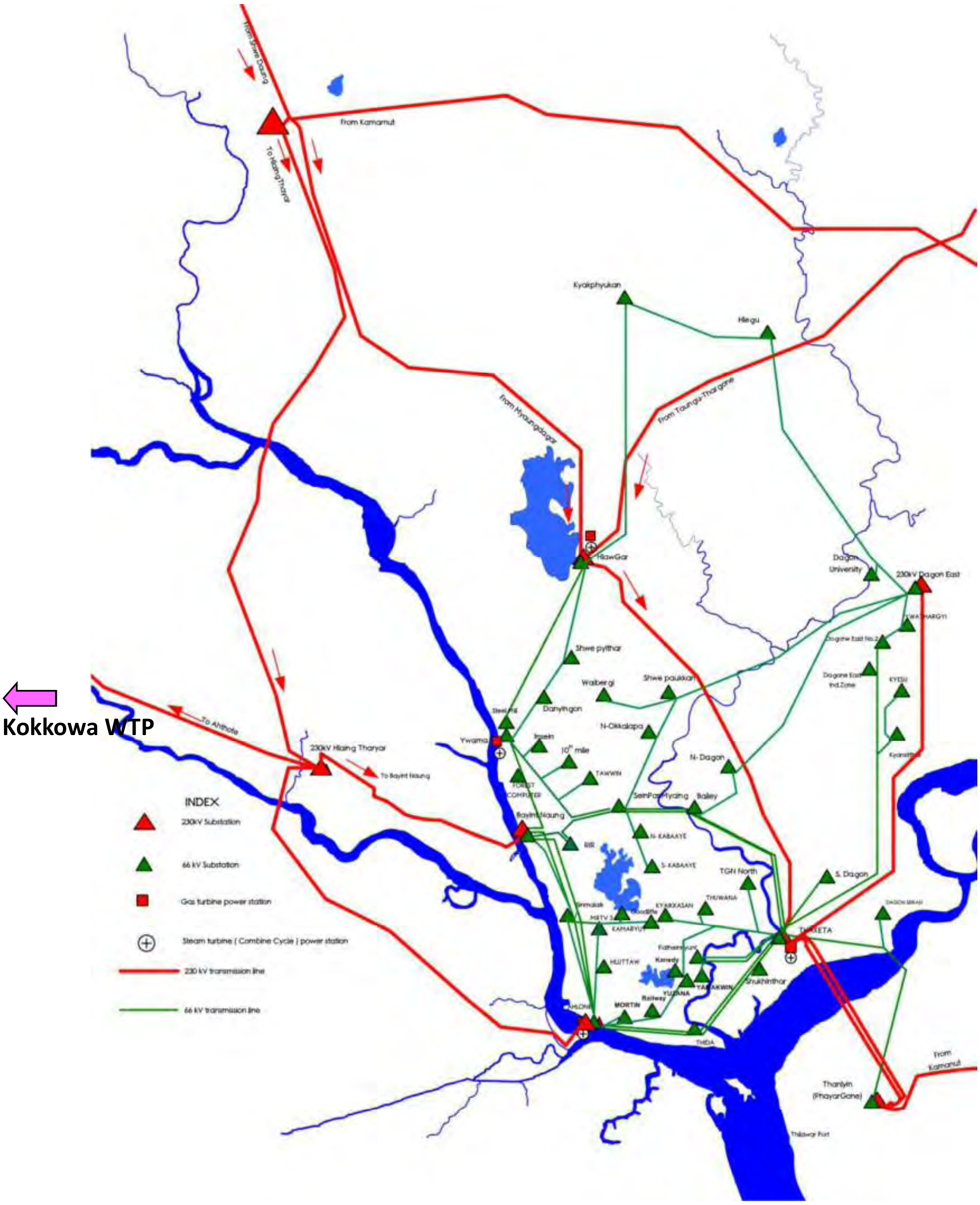
Electrical cables have large impact on the WTP operation by their product quality. Cables from India, China, etc., are normally used in electrical construction in Myanmar, but for many of these, the factory inspection records for quality control cannot be traced. The cables provided with individual test records in accordance with IEC standards and/or Japanese standards shall be used in these WTPs.

As for electrical construction, there are several companies involved in the existing YCDC's WTP constructions. They are recommended to participate in this WTP construction for YCDC scope so that they will help EDWS to proceed with proper maintenance and upgrading after start-up. However, these construction companies shall be strictly evaluated in view of construction safety control.

(2) Electricity Supply in Yangon

YESC governs the electricity transmission and distribution in the area of the proposed WTP located in Yangon. Their main transmission network is 230kV and the sub network is 66kV and 33kV. YESC Electricity Network Diagram is shown in the following Figure. The town distribution for industry and home is 6.6kV and 400V, respectively, and there are planned or accidental power shutdowns very often. Electricity is available during working hours in the day time in some industrial areas, and the main receiving switches have been open for several months in some other industrial areas.

The WTP should receive electricity from 33 kV sub network transmission line which corresponds to the YESC regulation for the WTP with the receiving transformer capacity of 1 MVA and above but less than 10 MVA. There are existing YESC 33 kV overhead lines dedicated for public utilities such as existing YCDC's WTPs, and they are supplying electricity for 24 hours.

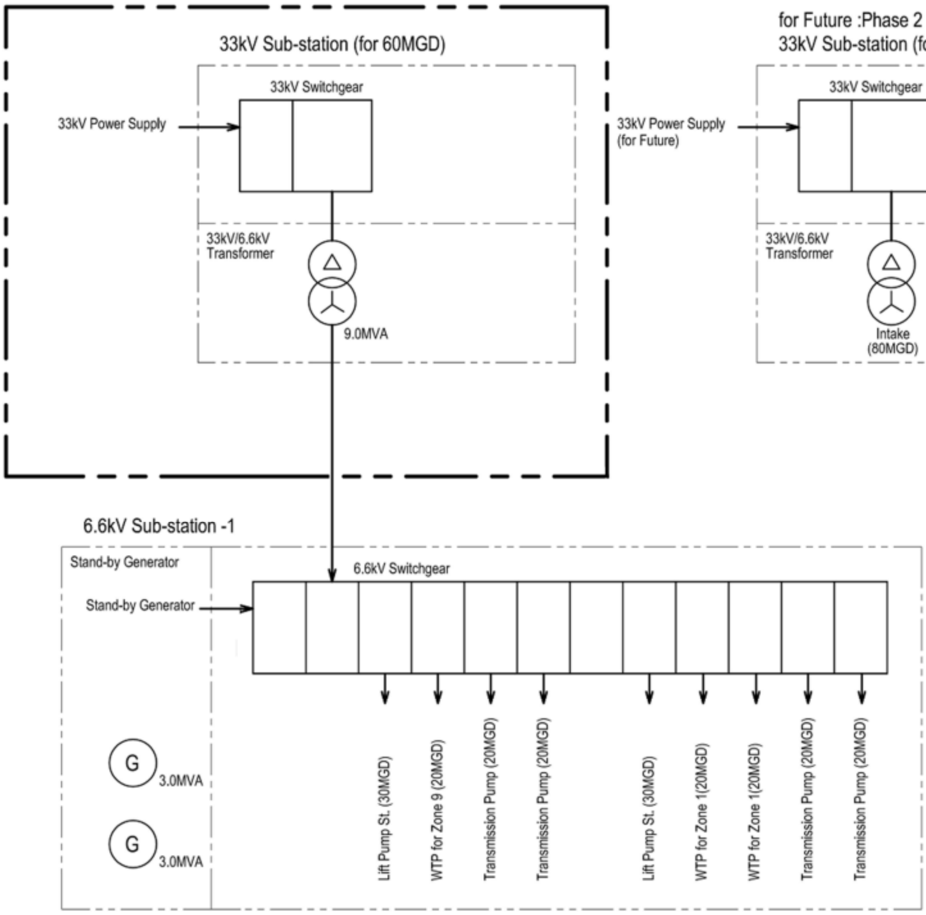


Source: YESB (now YESC) Infrastructure of Yangon City Electricity Supply Board in July 2013

Figure 4-19 230 kV & 66 kV Network Diagram of YESC in 2015-16

(3) Main Power Supply

Incoming power will be supplied by YESC in 3 phase 33 kV 50 Hz. A sub-station will be located in WTP. The power received at 33 kV will be stepped down to 6.6 kV by a main transformer to meet the motor voltage requirement of pump motor. The transformer will be of the outdoor, oil immersed, and natural cooling type. The capacity of the main transformer is estimated as 6.0 MVA for 60 MGD WTP. Power Supply Diagram is shown below.



Note: The component inside thick line indicates the construction to be undertaken by YCDC.
Source: JICA Study Team

Figure 4-20 Main Power Supply for Zone 9 (Prior Construction)

(4) Electricity (Incoming Line)

YCDC has already obtained YESC's permission for new power line for the project provided that YCDC extend 20 km of transmission line themselves for 33 kV. The permitted capacity by YESC is for 10.0 MVA instead of required capacity of 6.0 MVA.

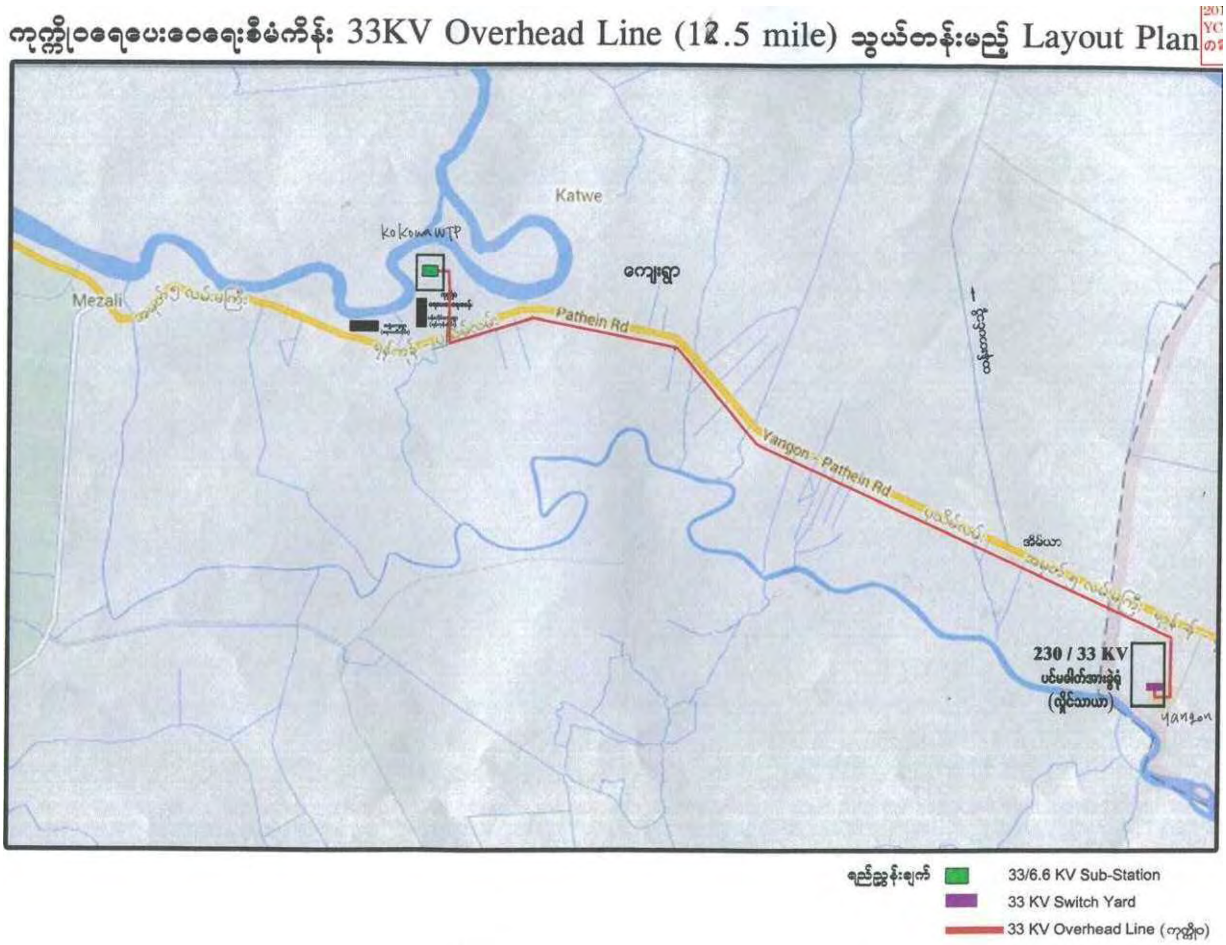
The detail of power line and its construction schedule are shown in the following Table and Figure.

Table 4-23 Detailed Power Line and Construction Schedule by YCDC

Transmission Voltage	33 kV 3 Phase 50 Hz
Transmission Method	Overhead Line
Transmission Capacity	10.0 MVA (approved)
Short Circuit Capacity	31.5 kA
Expected Commencement Date	August 2015
Expected Completion Date	August 2016

Source: JICA Study Team

After completion of the work, this transmission line will be handed over to YESC and operation and maintenance will be conducted by YESC. Therefore, main power supply is out of scope of the Japanese ODA loan.



Notes: Yangon – Pathein road is National Highway No. 5
Source: YCDC

Figure 4-21 Electrical Transmission Line for Kokkowa WTP

(5) Emergency Power Supply

Although there is new plan of power transmission for the future expansion of facilities, there is no plan to make electrical main power supply more reliable such as way of duplex supply or looping supply. The result of investigation related to power outage in similar facilities in the past 10 years, where the power is supplied by overhead line, indicate that the longest record of outage was more than one month due to terrible cyclone “Nargis”. Excluding the case of Nargis, there were 72 outages for which duration was more than 10 hours and in case of 9 of these 72 outages the duration was more than 24 hours. The reasons of outage were accidents in the transmission line or power cuts by the power company. Although supply condition is improving year by year, in consideration of the current situation, stand-by power generator will be required for stable water supply. Especially, planned water supply system will use pumps for water transmission and distribution and the interruption of main power supply will cause total interruption of water supply immediately. Therefore, stand-by generator will be planned in this study.

Type of generator will be diesel engine generator, built-in radiator that is required for easy operation and maintenance and also being used in Yangon in many cases. The capacity of generator will cover the power requirements of facilities from water intake to water distribution because duration of outage is much longer than the retention time of tanks. Fuel tank capacity of generator needs to be sufficient for 72 hours operation in order to cope with 24 hours outage by supplying additional fuel the next day.

Stand-by generators will be included in the scope of Japanese loan because the manufacturer of all generators should be unified and be synchronized together as single power source.

4.4.11 SCADA

SCADA system will be planned for purposes of monitoring with centralization, automatic control and supporting better O&M. SCADA System will be divided into three systems which are SCADA for WTP, SCADA for Zone 9/Relay Pump Station and SCADA for Zone 1. The systems will be installed in Administration Building at WTP, Relay Pump Station in Zone 9 SR and PS in Central SR, respectively (see the following Figure).

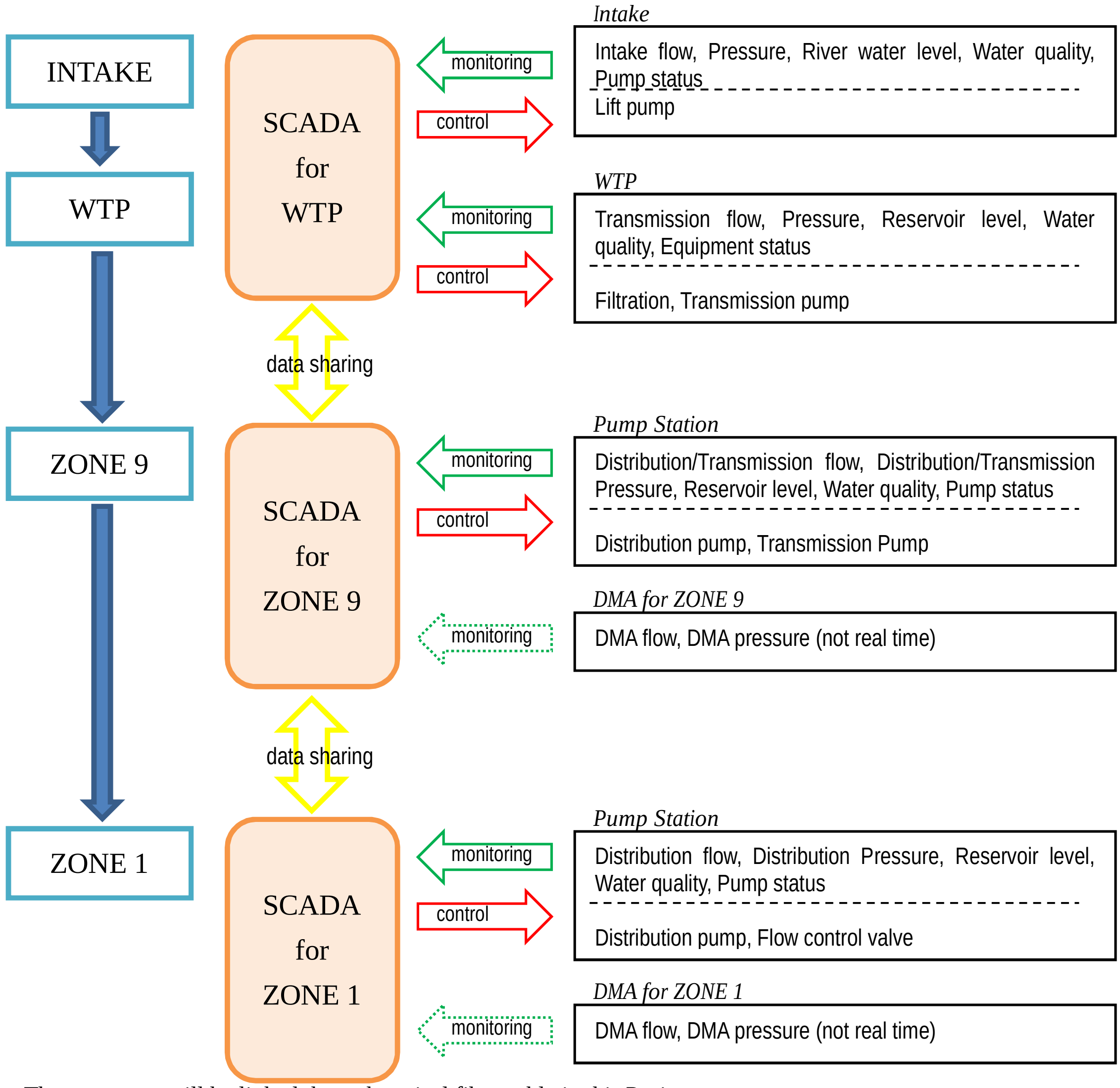
These systems will be connected with each other by a data backbone which has high speed data transmission (laying cost of optical fiber cable is included in this project). Important data, such as equipment alarms and transmission flow, will be shared in real time in each system. Main monitoring and control items for each SCADA System are shown below.

Water quality monitoring should be carried out continuously for producing good quality treated water to meet the water quality standards. The water quality parameters and flow to be monitored at different locations are listed in the following Table.

Table 4-24 Monitoring Points of Water Quality

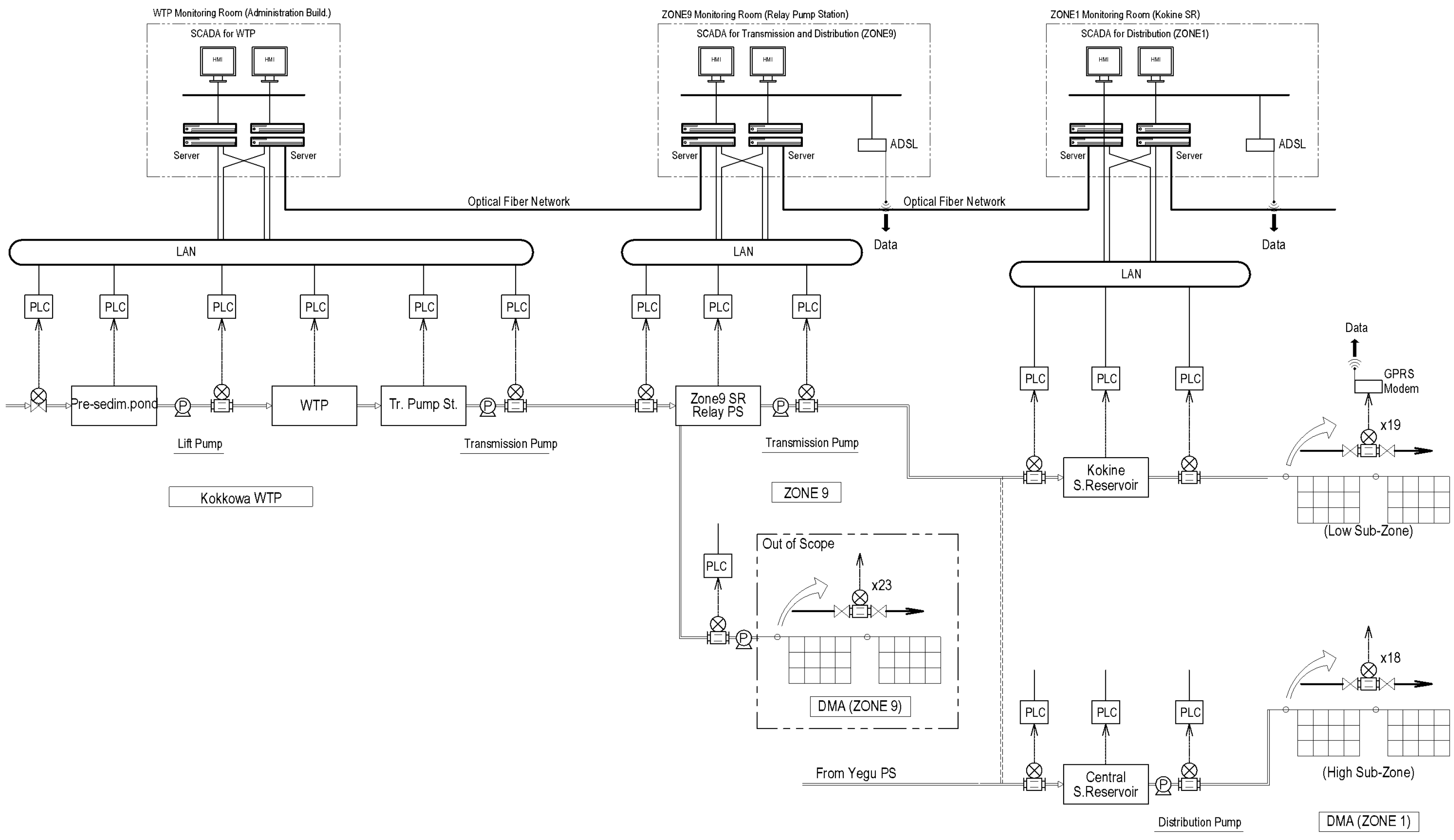
Item	Monitoring location	Monitoring items
Raw water	- Pre-sedimentation pond	・Turbidity: ACH dosing rate control ・pH: ACH dosing rate control
Settled water	- In settled water channel	・Turbidity ・pH ・Residual chlorine
Filtered water	- Filtered water channel	・Turbidity ・pH
Treated water	- After pumping	・Turbidity ・pH ・Residual chlorine
Distributed water	- At the distribution points	・Turbidity ・pH ・Residual chlorine

Source: JICA Study Team



Note: These systems will be linked through optical fiber cable in this Project.
Source: JICA Study Team

Figure 4-22 Proposed SCADA System for WTP, Transmission, Distribution and DMAs

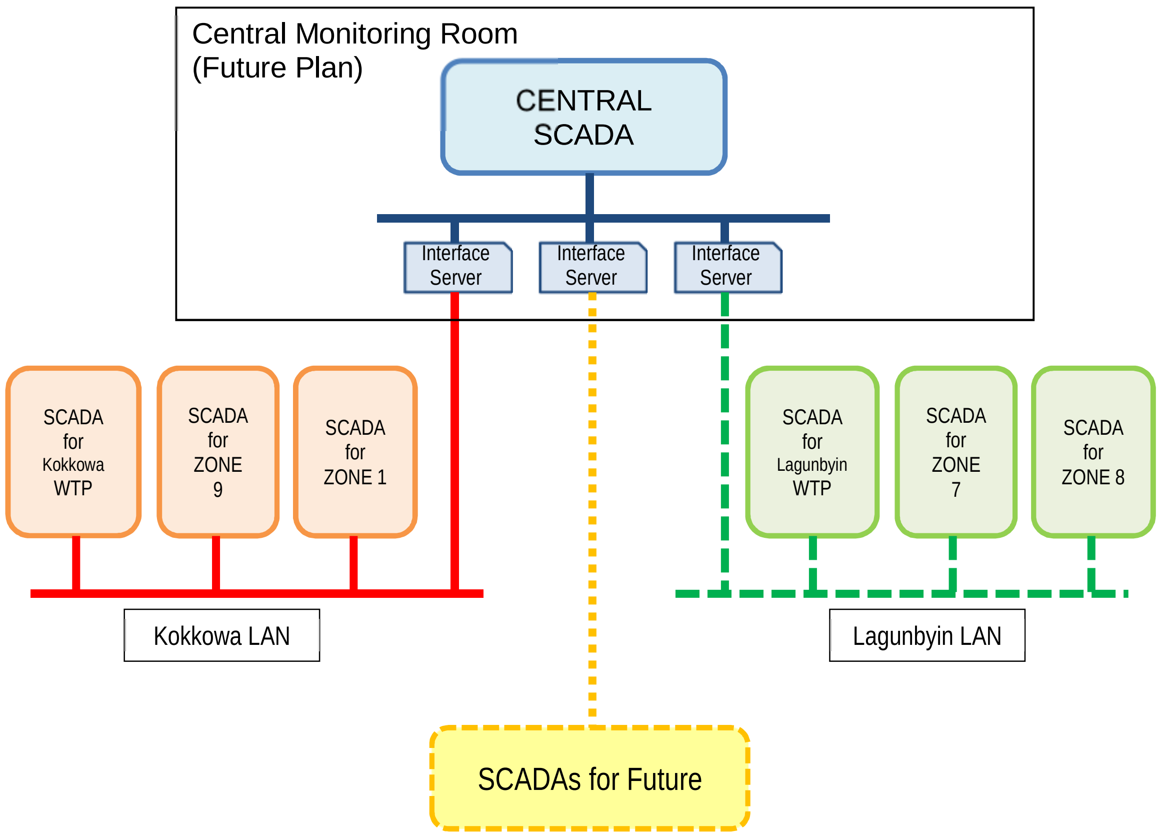


Flow Monitoring Diagram

Note : The values are indicative, and detailed values shall be decided in detailed design.

JAPAN INTERNATIONAL COOPERATION AGENCY YANGON CITY DEVELOPMENT COMMITTEE		JICA Study Team ENGINEERING DEPARTMENT (WATER & SANITATION)		PROJECT: Preparatory Survey for Greater Yangon Water Supply Improvement Project Phase II (Kokkowa River)	Scale	NTS
DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY	TITLE: General Flow Monitoring Diagram	Drawing No.	SCADA
-	-	-	-		Date	30 June 2016

It is assumed that in future there will be many individual SCADA Systems for each WTP and each distribution zone and these systems will be scattered widely in Yangon city. To monitor water balance in each supply zone and control water supply comprehensively, centralization of SCADA integrating each system is recommended. To integrate systems easily in future, it is required to use open system such as open protocol, open data base and open hardware through the use of OPC server. In this Project, SCADA system will be designed using such a standard system for future provision and it is recommended to use open system for other projects also. Concept of SCADA system integration is shown in the following Figure.



Source: JICA Study Team

Figure 4-23 Proposed Concept of SCADA System Integration in The Future

4.4.12 Administration Facility

Administration facilities are planned as shown in the following Table.

Table 4-25 Administration Facility

Item	Contents
Central Administration Building	Water control room for SCADA with UPS (Uninterruptible Power Supply)
Water Quality Laboratory	Space for Jar test and simple water quality test
Water Supply	Small pumps units are installed in transmission PS
Warehouse	For chemicals storage
Workshop	For pump maintenance
Parking Lot	
Security Room and Guard Post	
Temporary Road	Concrete pavement and green buffer belt: Settlement of landfill is taken into consideration
Fence	Steel and/or brick fence along the boundary

Source: JICA Study Team

CHAPTER 5 TRANSMISSION FACILITY

5.1 Outline of Planning

(1) Outline of Planning

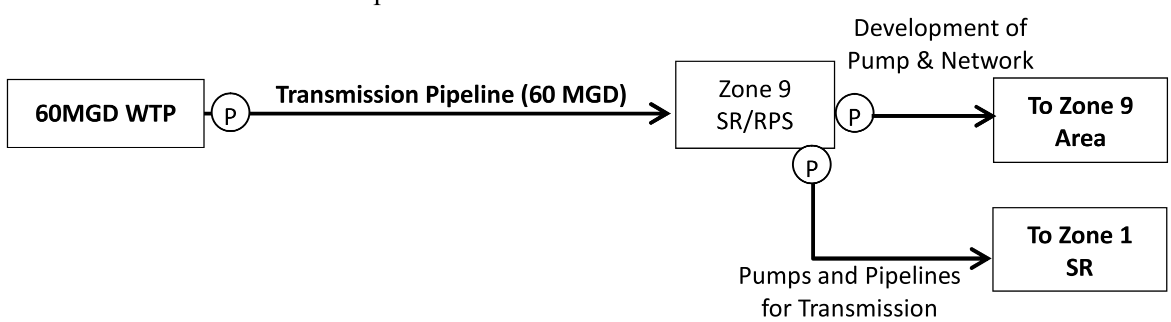
This facility is planned to convey treated water from Kokkowa WTP to Zone 9 SR. In the JICA Water M/P, Kokkowa WTP, with capacity of 60 MGD, is planned to be constructed and convey water from WTP to Zones 1 and 9 in 2025. In the future plan, the WTP will be expanded to convey water to some other Zones on the eastern side of Hlaing River.

From the WTP, all treated water is planned to be conveyed to Zone 9 SR because of the geographical conditions; therefore water which is to be conveyed to the Zones on the eastern side of the River passes through Zone 9. The distance between WTP and Zones is far.
As a result, Zone 9 SR is planned to perform both as a service reservoir for Zone 9 and as a Relay PS (hereinafter referred to as "RPS") to convey water to other Zones.

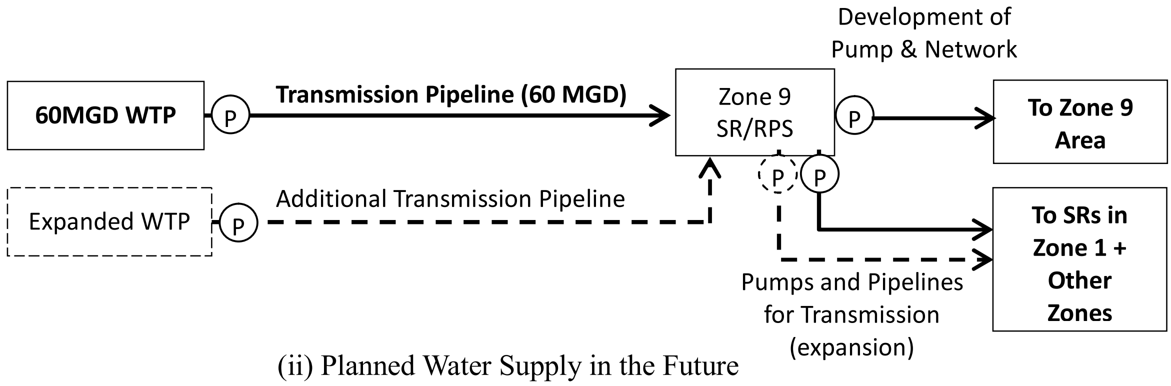
(2) Outline of Water Operation

A total of 56 MGD of treated water is to be conveyed to Zone 9 SR/RPS from the WTP, of which 19 MGD water is to be distributed to Zone 9 by pumps, and 37 MGD water is to be conveyed to Kokine SRs in Zone 1. Therefore, required capacity of transmission facility in this Study is 60 MGD.

In future, Kokkowa WTP will be expanded to capacity of 140 MGD. Additional transmission facility will be constructed when the WTP is expanded.



(i) Planned Water Supply in 2025 (For This Project)



(ii) Planned Water Supply in the Future

Source: JICA Study Team

Figure 5-1 Stepwise Transmission Plan to Zone 9 SR/RPS

(3) Route and Laying Position of Transmission Pipeline

During the 60 MGD Kokkowa WTP development by 2025, following large diameter pipelines are planned to be laid along the Route No. 5;

- Transmission pipeline from the WTP to Zone 9 SR/RPS (This Project)
- Transmission pipeline from the Zone 9 SR/RPS to Zone 1 SRs (This Project)
- Distribution main from Zone 9 SR to Zone 9 area (YCDC Project)

Since Route No. 5 is the only road connecting between the WTP and Zone 9 SR, pipelines mentioned above are planned to be laid along the Route No. 5. Detail of route and laying position of these pipelines are described in the Appendix-7.

In the first section, the transmission facilities for Zone 9 are described while in the following section those for Zone 1 are described.

5.2 Transmission Facility for Zone 9

5.2.1 Planning Policy

(1) Planned Scale of Transmission Facility

Capacity of Kokkowa WTP is planned to be 60 MGD by 2025. In this Study, 60 MGD of transmission facility is planned for Zone 9 and Zone 1. Transmission pumps are required due to the ground elevation difference between the WTP and Zone 9 SR. Therefore, transmission pump equipment and approximately 21.4 km of transmission pipeline is planned.

(2) Planning Diameter of Transmission Pipe

Pipe diameter in case of pumping flow is planned considering the velocity range of 1 to 3 m/s and the required pump head.

(3) Planning of Transmission Pump Facility

a) Selection of Pump Type

Basically, double suction volute pump is used considering the type of the existing pumps in Yangon city. This type of pump is efficient, economical, and easy to maintain. Also, EDWS is familiar with handling of this type of pumps.

b) Number of Transmission Pump Units

Number of pump units is decided considering installation cost. Minimum units of pumps installed are two (2) in conformity with the fluctuation in water demand.

c) Countermeasure against Water-Hammer

Generally, if countermeasure against water-hammer is required, flywheel or surge tank are considered as candidate for selection of the countermeasure. In this Study, the flywheel method is basically recommended considering the ease of maintenance and competitiveness of Japanese technology. This method has been already installed at Intake PS of Lagunbyin WTP.

d) Corresponding to Fluctuation of Water Demand

Basically, advanced control system, such as variable speed control, is not required for transmission PS at the Kokkowa WTP because relation between WTP and SR/RPS is one-to-one.

5.2.2 Transmission Facility

(1) Transmission Pipeline

a) Diameter of Pipeline and Pump Head

Pipeline diameters and pump head are planned based on the result of the hydraulic calculation. As a result of the calculation, φ1600 mm is planned as the suitable diameter of pipe for 60 MGD of Transmission.

【Hydraulic calculation sheet is attached as Appendix-6】

- Transmission flow : 60 MGD
- LWL of Kokkowa WTP : +3.20 m
- HWL of Zone 9 SR : +3.00 m
- Length of transmission pipeline : 21,350 m
- Formula : Hazen-Williams formula, flow rate coefficient C=110
- Residual water head : minimum 5.0 m
- Water head loss around pumps : 0.5 m
- Upper limit of pump head : 100 m

Table 5-1 Result of Hydraulic Calculation

Item	Result
Diameter of pipeline	φ1600 mm
Velocity	1.57 m/s
Friction loss	32.39 m
Transmission pump head	38.0 m

Source: JICA Study Team

(2) Selection of Pipe Material

SP, DCIP and HDPE are selected as candidate materials for transmission pipe. Since this pipeline is one of the most important facilities for water supply to Zone 9 and Zone 1 and requires durability, HDPE is excluded and comparison is made between SP and DCIP. Comparison of pipe material of φ1600 mm is shown in the following Table. As a result of the comparison, SP is recommended as material for φ1600 mm pipeline because construction cost of SP is reasonable and Japanese manufacturer has a comparative advantage for manufacturing of SPs. Since the price of iron is always fluctuating, the material will be decided after the studies of cost and detailed construction method during the design stage.

Table 5-2 Comparison of Pipe Material of 1600 mm

Item	Steel Pipe (SP)	Ductile Cast Iron Pipe (DCIP)	Comparative Evaluation
Strength	High strength of pipe body, sufficient in toughness and strong in shock	High strength of pipe body, sufficient in toughness and strong in shock	Equivalent
Durability	Durable	Durable	Equivalent
Workability	Welded joints require expertise.	Good workability	DCIP is preferable
Unit price (Direct Cost)	222 thousand JPY/m	276 thousand JPY/m	SP is preferable
Recommen-dation	Although, pipe joining is more difficult than DCIP, construction cost is reasonable and having a comparative advantage.	Construction cost and comparative advantage are worse than steel.	SP is preferable

Source: JICA Study Team

(3) Transmission Pump Facility Plan

a) Planned Transmission Flow

60 MGD water is to be conveyed to Zone 9 SR/RPS in 2025. In future after 2025, a PS will be added with expansion of WTP.

b) Pump Equipment Plan

Three (3) units of operational pumps and one (1) stand-by pump are planned.

Table 5-3 Transmission Pump Plan for Zone 9

Item	Specification	Remarks
Pump	20 MGD (63.1 m^3/min)×38 m×720 kW×4 units (including 1 stand-by) Horizontal Double Suction by On/off control method	All pumps under ODA loan

Source: JICA Study Team

5.3 Transmission Facility for Zone 1

5.3.1 Outline of Planning

This facility, to be constructed under JICA loan project, is planned to convey water from Zone 9 SR/RPS to Kokine SR in Zone 1 in 2025 - the target year of this project. In the M/P, water from Kokkowa WTP is planned to be transmitted to both Kokine and Central SR, and Kokkowa water and Reservoir water is planned to be mixed at Kokine SR in 2025. YCDC is planning to supply water with turbidity level of 1 NTU according to the WHO guidelines, and to achieve the target, JICA and YCDC agreed that the Kokkowa and Reservoir water is to be conveyed separately to Kokine SR and Central SR respectively in order to avoid mixing water from two sources. Therefore, water is transmitted from Kokkowa WTP to Zone 9 SR/RPS, then from the RPS to Kokine SR. On the other hand, Reservoir water from Yegu is transmitted to Central SR.

Pumping is required due to the ground elevation difference between the RPS and Kokine SR in Zone 1. Therefore, transmission pump facility at the RPS with approximately 20 km of transmission pipeline from the RPS to Kokine SR shall be planned. Since Transmission to the other Zones besides Zone 1 is planned in the future, facility plan shall consider the future water operation plan as well.

5.3.2 Outline of Water Operation

(1) Change in Transmission Plan Caused by the Change in WTP Construction Plan

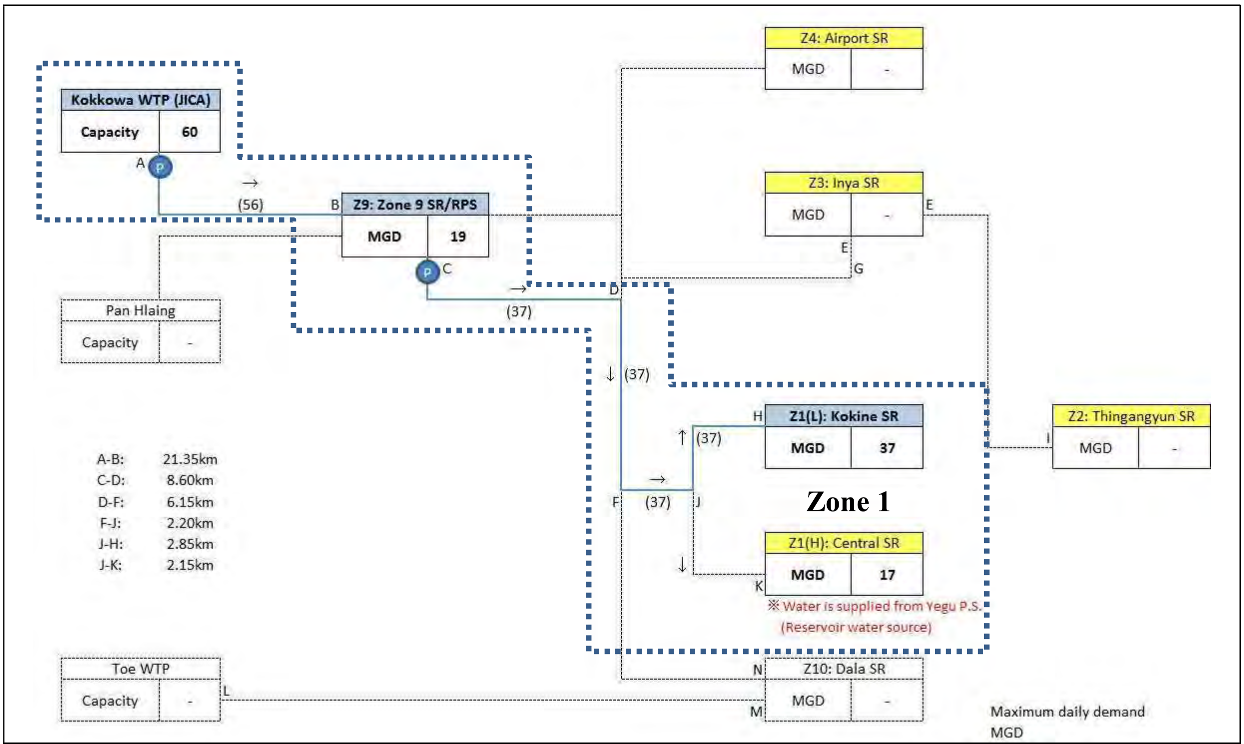
In the MP, it is planned to expand the capacity of Kokkowa WTP to 60 MGD by 2025 and to 240 MGD by 2040. However, as mentioned earlier in Chapter 4, YCDC intends to construct both Kokkowa WTP and Pan Hlaing WTP. Therefore, Zone 9 and some Zones in Yangon city area will be supplied water from the two (2) WTPs in the future.

In general, operation and control of pumps become complicated in case of Transmission from multiple numbers of WTPs to multiple numbers of SRs. Therefore, all water conveyed from the two WTPs should be received once at the RPS in the same site of Zone 9 SR for easy operation. Separate pipes are also planned; one is along the route No. 5 from the Kokkowa WTP, and another one is along the YCDC roads within Zone 9 from Pan Hlaing WTP. Consequently, RPS is planned to convey water from two WTPs to SRs in Zone 1 and some other Zones of Yangon city area in the future.

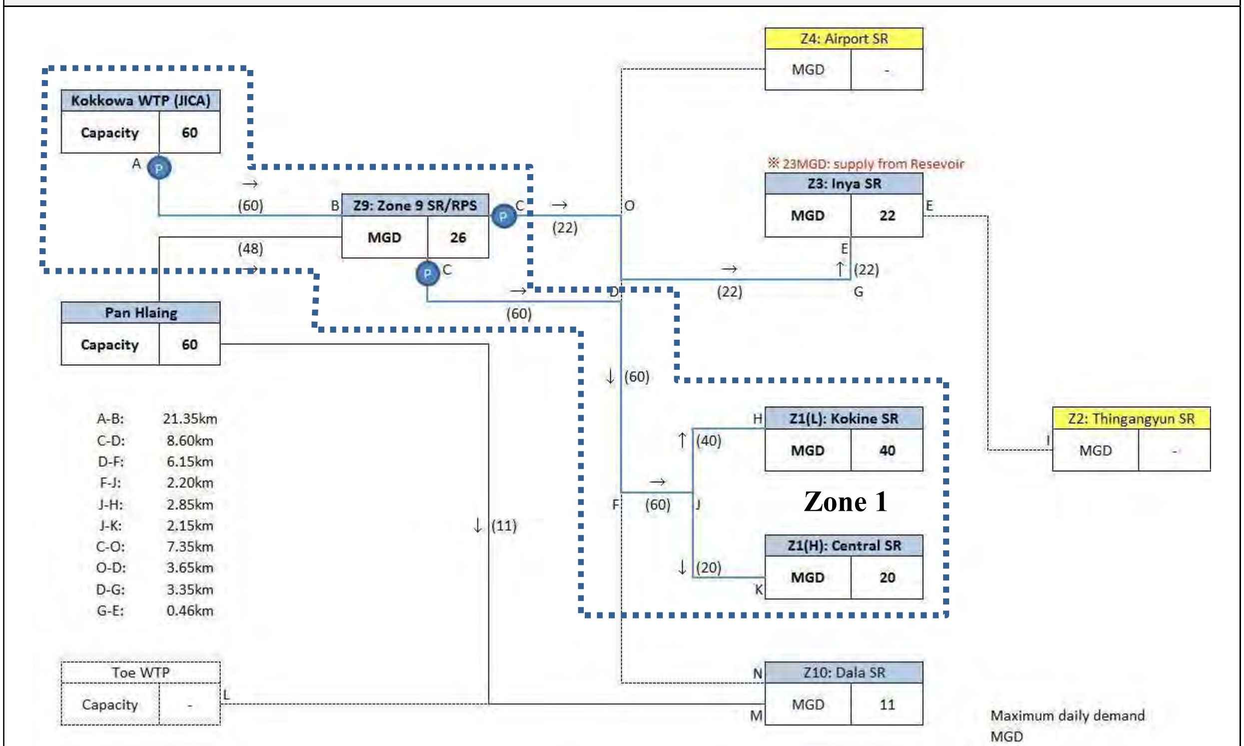
(2) Water Operation for Zone 1

Transmission facilities are planned based on increase in water demand and capacity of WTP from 2025 to 2035. The water operation for each step is as follows:

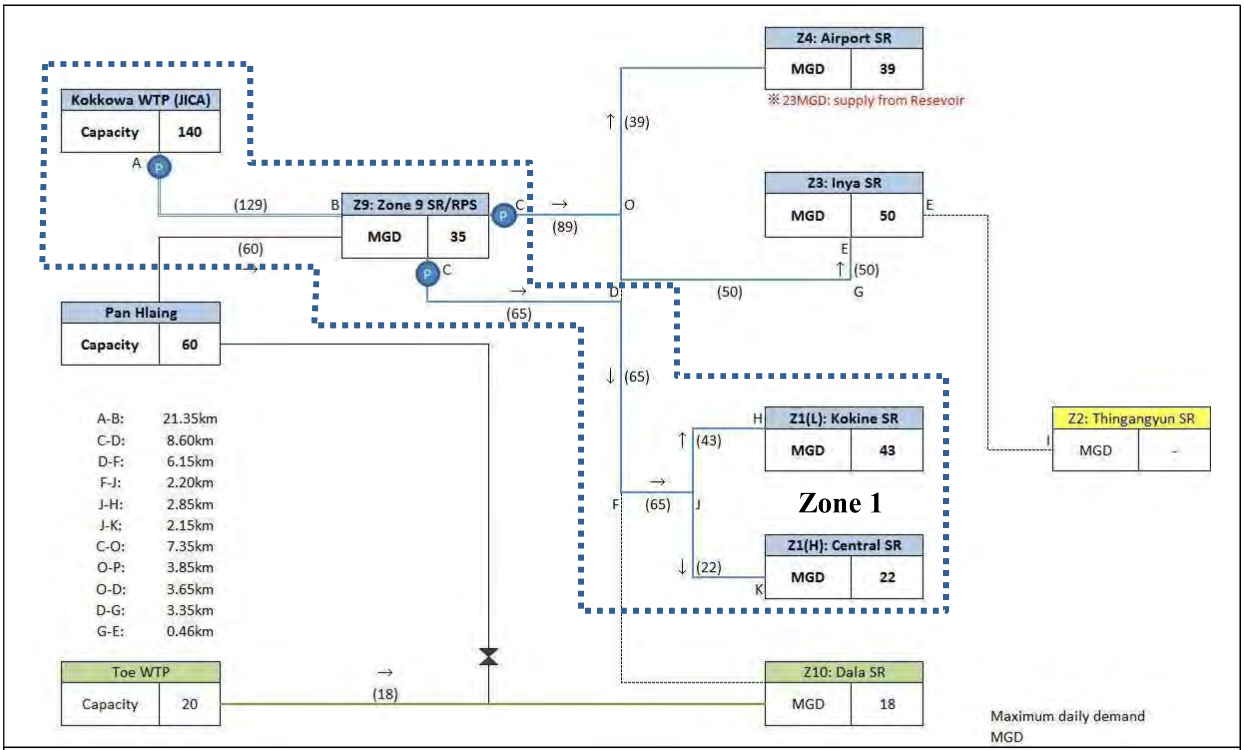
- **2025:** 56 MGD of clear water is to be transmitted from Kokkowa WTP to Zone 9 SR/RPS. Then, the 37 MGD water is to be transmitted to Kokine SR by transmission pumps. 17 MGD of Reservoir water is to be transmitted from Yegu PS to Central SR.
- **2030:** 60 MGD and 48 MGD of clear water is to be transmitted from Kokkowa WTP and Pan Hlaing WTP respectively to Zone 9 SR/RPS of which 26 MGD water is to be distributed to the Zone 9 supply area by pumping. The remaining water is to be transmitted to the Zone 1 SRs and Zone 3 SR by transmission pumps.
- **2035:** 129 MGD and 60 MGD of clear water is to be transmitted from Kokkowa WTP and Pan Hlaing WTP respectively to Zone 9 SR/RPS of which 35 MGD water is to be distributed to the Zone 9 supply area by pumping. The remaining water is to be transmitted to the Zone 1 SRs, Zone 3 SR and Zone 4 SR by transmission pumps.



Year 2025



Year 2030



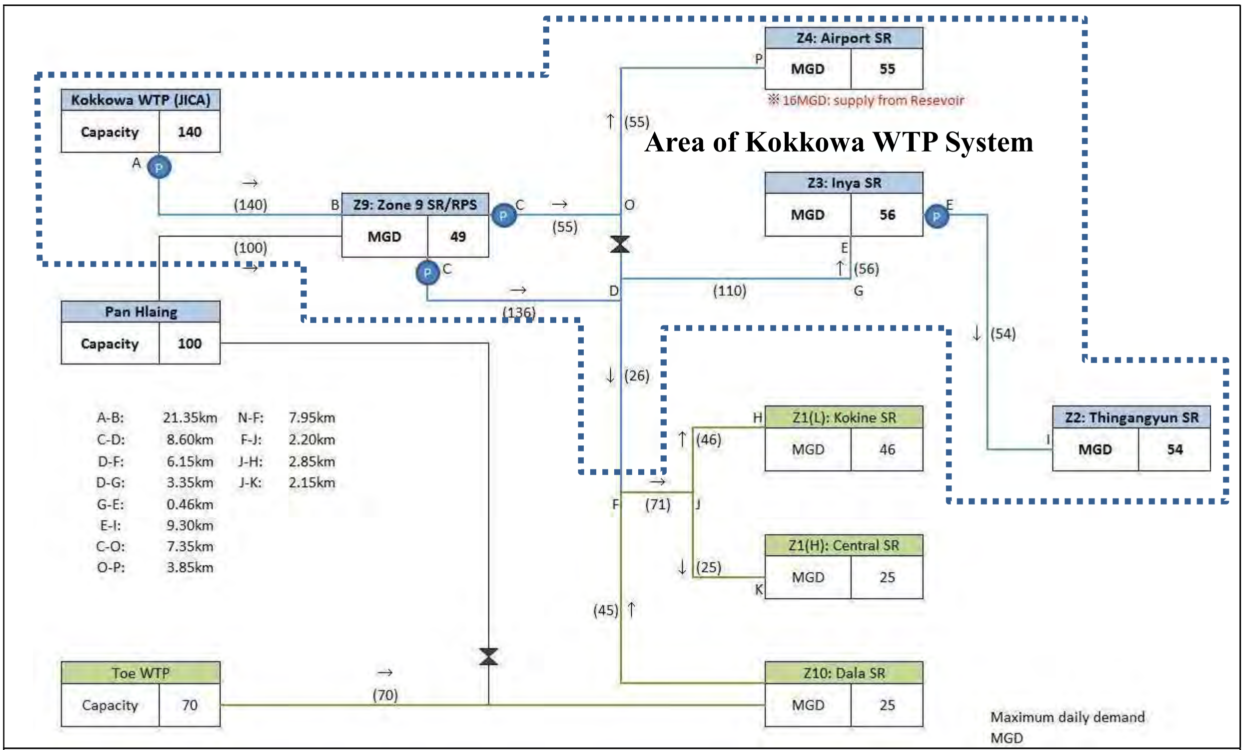
Year 2035

Source: JICA Study Team

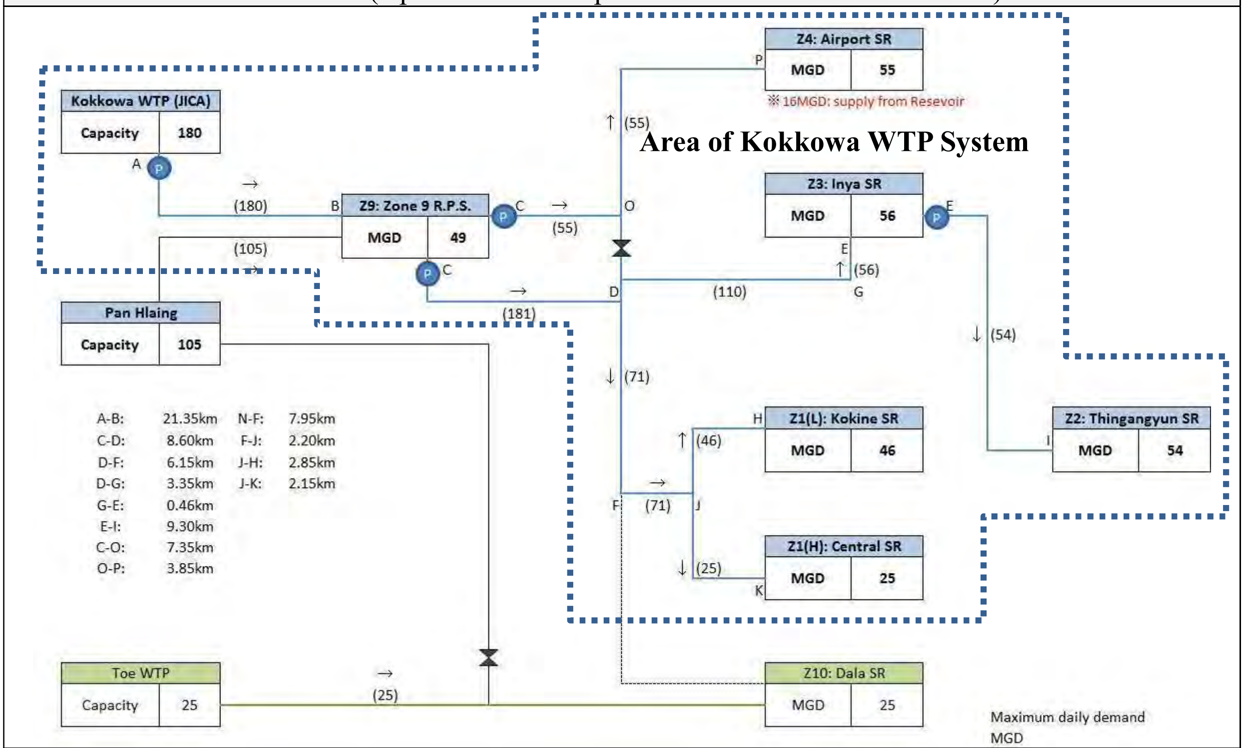
Figure 5-2 Water Operation Diagram from 2025 to 2035

(3) Water Operation for Zone 1 in 2040

There are two ways of Transmission to Zone 1 in 2040. One option is from Toe WTP and another one is from RPS. It is too early to decide on it at this stage. Therefore, transmission facilities in this Study are planned based on the water operation until 2035, and the water operation in 2040 is examined as a reference.



Year 2040 (Option 1: Water Operation based on the Master Plan)



Year 2040 (Option 2: Alternative Water Operation)

Source: JICA Study Team

Figure 5-3 Water Operation Diagram in 2040

(4) Water Operation of System Switching

Direct water distribution from the RPS to Zone 1 is necessary during the process of switching from the existing system to Kokkowa system due to suspension of using Kokine SR for inspection and repair works. Therefore, pumps and other facilities at RPS should have sufficient capacity to enable temporary water supply to Zone 1 during that period (See the Chapter 7).

(5) Transmission Pipeline for Zone 1

RPS will transmit water not only to Zone 1 SRs but also to other Zones in the future, and two (2) transmission pipelines are planned for Zone 1, 2, 3 and 4 in the M/P. As mentioned in 5.3.4 (3), to avoid excessive initial investment, one (1) transmission pipeline out of two (2) is planned as exclusive-use transmission pipeline for Zone 1 in this Study. Transmission facility for other Zones will be planned and constructed in the future.

5.3.3 Planning Policy

(1) Planned Scale of Transmission Facility

a) Transmission Facility from Kokkowa WTP to RPS

Capacity of Kokkowa WTP will be 60 MGD by 2025, and 140 MGD by 2035. In the future, additional transmission pipeline to transmit 80 MGD of water will be constructed. As a result, two (2) transmission pipelines, with capacity of 60 MGD and 80 MGD respectively, are planned between the WTP and Zone 9 SR/RPS.

Table 5-4 Planned Transmission Flow (From the WTP to Zone 9 SR/RPS)

Year	Flow	From	Destination	Diameter/Fund
2025	**56 MGD**	Kokkowa	Zone 9 SR/RPS	**①φ1600/JICA**
2030	**60 MGD** 48 MGD	Kokkowa Pan Hlaing		**①φ1600/JICA** ②φ1600*/YCDC
2035	**60 MGD** 60 MGD 80 MGD	Kokkowa Pan Hlaing Kokkowa		**①φ1600/JICA** ②φ1600*/YCDC ③φ1800/YCDC

*Diameter calculation condition: critical hydraulic gradient under 2 per mille
Source: JICA Study Team

b) Transmission Facility from RPS to Zones 1, 3 and 4

Transmission flow in years 2025, 2030, and 2035 from RPS to Yangon city area is planned as shown in the following Table. Transmission facilities are planned to be available for increased flow and planned destinations.

Table 5-5 Planned Transmission Flow (From Zone 9 SR/RPS to SRs in Zone 1, 3 and 4)

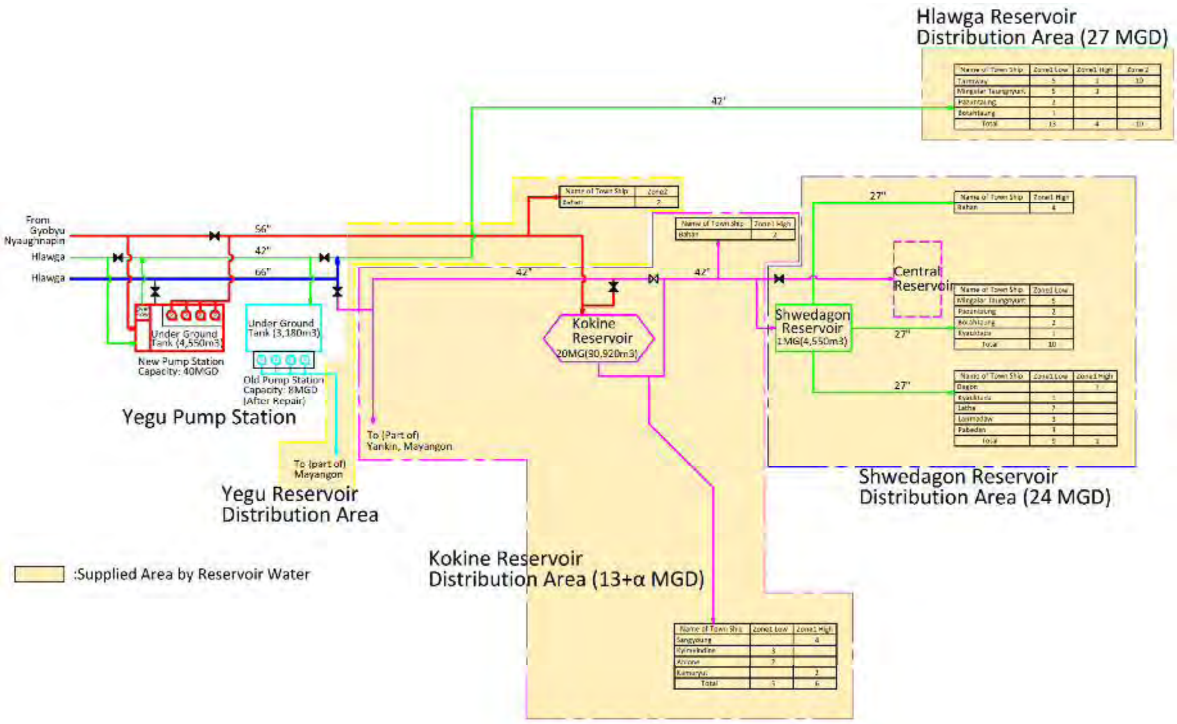
Year	Flow	From	Destination SR	Diameter/Fund
2025	**37 MGD**	Zone9 SR and RPS	Kokine SR (Zone 1)	**①φ1600,1400/JICA**
2030	**40 MGD** 20 MGD 22 MGD		Kokine SR (Zone 1) Central SR (Zone 1) Inya SR (Zone 3)	**①φ1600,1400/JICA** ②φ1000/YCDC ③φ1800,1600/YCDC
2035	**43 MGD** 22 MGD 50 MGD 39 MGD		Kokine SR (Zone 1) Central SR (Zone 1) Inya SR (Zone 3) Airport SR (Zone 4)	**①φ1600,1400/JICA** ②φ1000/YCDC ③φ1800,1600 /YCDC ④φ1500/YCDC

Source: JICA Study Team

c) Transmission Facility from Yegu PS to Central SR

There are two (2) existing PSs (old and new) in Yegu PS. Reservoir water from Gyobyu, Hlawga and Nyaughnapin is received at underground tank of the new PS in Yegu PS, and then transmitted to Kokine SR through 56" transmission pipe. Furthermore, water is transmitted to Shwedagon SR, and distributed to downtown area from there. These transmission pipelines distribute water to a part of Bahan TS on the way.

Overflow from the tank of the new PS is transmitted to underground tank of the old PS in Yegu PS, then, distributed to the part of Mayangon TS.



Source: JICA Study Team

Figure 5-4 Existing System of Yegu PS

Transmission flow in year 2025 from Yegu PS to Central SR is planned as shown in the following Table. In the future, Transmission from Yegu is not necessary because Central SR is planned to receive Kokkowa water.

Table 5-6 Planned Transmission Flow from Yegu PS

Year	Flow	Destination SR
2025	17 MGD	Zone 1 (Central SR)

Source: JICA Study Team

(2) Planning Diameter of Transmission Pipeline

Refer to the section 5.2.1 (2).

(3) Planning of Transmission Pump Facility

a) Transmission facility scale considering increasing transmission flow

Scale of pump facility is planned based on the water operation shown in Figure 5-2.

b) Selection of Pump Type

Refer to the section 5.2.1 (3), a).

c) Number of Transmission Pump Units

Refer to the section 5.2.1 (3), b).

d) Countermeasure against Water-Hammer

Refer to the section 5.2.1 (3), c).

e) Pump Control Method at RPS

Since the RPS is expected to transmit water to two (2) SRs by 2030, pumps should be operated with monitoring water level of tank and transmission flow. Therefore, automatic pump operation by on/off control method cannot be used. Furthermore, operation of transmission pump becomes complex because transmission flow to each SR fluctuates depending on the season and status of distribution network development. To ease the pump operation and reduce the energy consumption, advanced pump control which enables complex control shall be selected for Pumps at RPS.

f) Pump Control Method at Yegu PS

Relation between Yegu PS and Central SR is one-to-one and existing pump control is through on/off control method, therefore on/off control method is adopted for the transmission pump at Yegu PS.

5.3.4 Transmission Facility

(1) Transmission Pipeline

a) Diameter of Pipe and Pump Head between RPS and Kokine SR

- Transmission flow from RPS to Zone 1 SRs
  - 2025 : 37 MGD
  - 2030 : 60 MGD
  - 2035 : 65 MGD
- LWL of Relay Tank : -3.00 m
- HWL of destination
  - Kokine SR in Zone 1 : +42.60 m
  - Central SR in Zone 1 : +41.94 m
- Formula : Hazen-Williams formula, flow rate coefficient C=110
- Residual water head : minimum 5.0 m
- Water head loss around pumps : 0.5 m
- Upper limit of pump head : 100 m

Table 5-7 Result of Hydraulic Calculation between RPS and Kokine SR

Item	Outline of Facilities	Remarks
Diameter/length	φ1600 mm x 16.95 km φ1400 mm x 2.85 km φ1000 mm x 2.15 km	Total: 21.95 km
Pump head	87.0 m	Based on the calculation result in 2035

Source: JICA Study Team

b) Diameter of Pipe and Pump Head between Yegu PS and Central SR

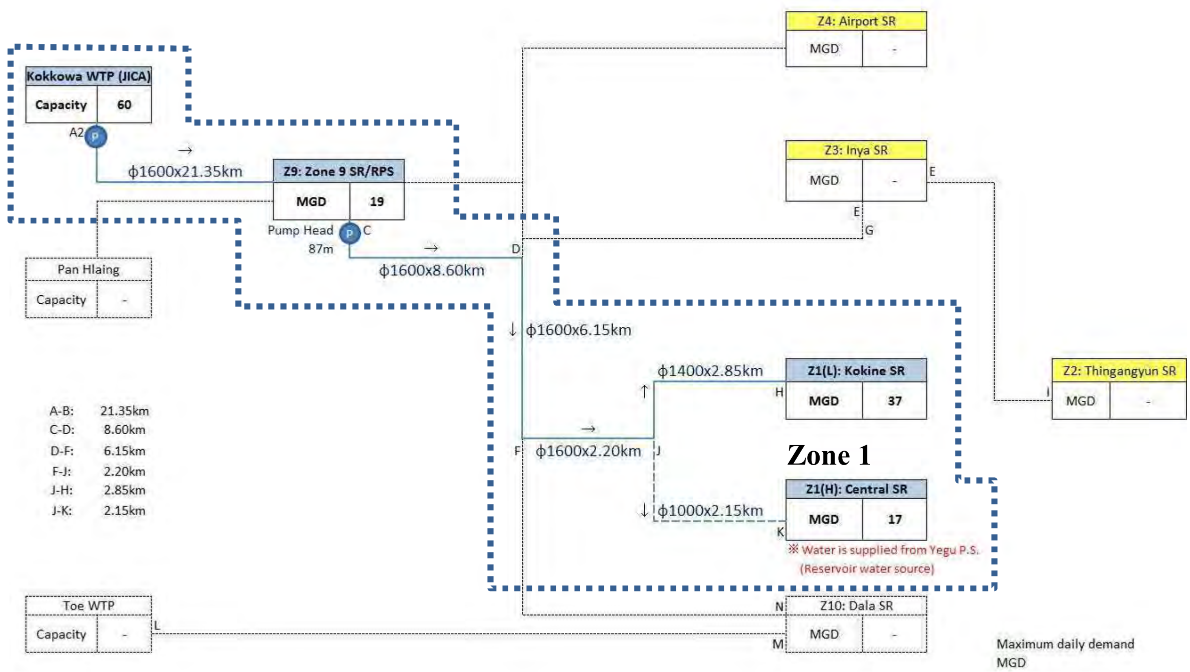
As a result of calculation, replacement of pumps is required to transmit water by using existing pipeline. Furthermore, pipeline construction between existing φ1400 and φ1050, and branching by using non-stoppable tapping method are necessary.

- Transmission and Distribution flow from Yegu PS to Central SR in 2025
  - Transmission : 17 MGD
  - Distribution : 5.1 MGD (for Bahan Township)
- Pipe Diameter/Length : φ1400 x 5,360 m, φ1050 x 2,670 m (Existing)
- Pump Head : 47.0m (Existing)
- LWL of Yegu P.S : +3.70 m
- HWL of destination : +41.94 m
- Formula : Hazen-Williams formula, flow rate coefficient C=110
- Residual water head : minimum 5.0 m
- Water head loss around pumps : 2.0 m

Table 5-8 Result of Hydraulic Calculation between Yegu PS and Central SR

Item	Outline of Facilities	Remarks
Diameter/length	φ1400 mm x 5.36 km φ1050 mm x 2.67 km φ1050 mm x 0.15 km	Existing Pipeline (Yegu – Kokine SR) Existing Pipeline (Kokine SR- Central SR) New Connection Pipeline with non-water suspension branch
Pump head	53.0 m	Pump replacement is necessary.

Source: JICA Study Team



Source: JICA Study Team

Figure 5-5 Diameter of Transmission Pipeline for Zone 1 in 2025

(2) Selection of Pipe Material

Steel and DCIP are selected as candidate materials for φ1600 mm and φ1400 mm transmission pipes. Comparison of pipe material is shown in the following Table. As a result of the comparison, SP is recommended as material for φ1600 mm, φ1400 and φ1000 mm pipeline because construction cost of SP is reasonable and Japanese manufacturer has a comparative advantage for manufacturing of SPs. Since the price of iron is always changing, the material will be decided after the studies of cost and detailed construction method during the design stage.

Table 5-9 Comparison of Pipe Material

Item	Steel Pipe (SP)	Ductile Cast Iron Pipe (DCIP)	Comparative Evaluation
Strength	High strength of pipe body, sufficient in toughness and strong in shock	High strength of pipe body, sufficient in toughness and strong in shock	Equivalent
Durability	Durable	Durable	Equivalent
Workability	Welded joints require expertise.	Good workability	DCIP is preferable
Unit price (Direct Cost)	241 thousand JPY/m: φ1600 204 thousand JPY/m: φ1400 118 thousand JPY/m: φ1000	295 thousand JPY/m: φ1600 244 thousand JPY/m: φ1400 153 thousand JPY/m: φ1000	SP is preferable
Recommen-dation	Although pipe joining is more difficult than DCIP, construction cost is reasonable and having a comparative advantage.	Construction cost and comparative advantage are worse than steel.	SP is preferable

Source: JICA Study Team

(3) Transmission Pump Facility Plan at Relay Pump Station

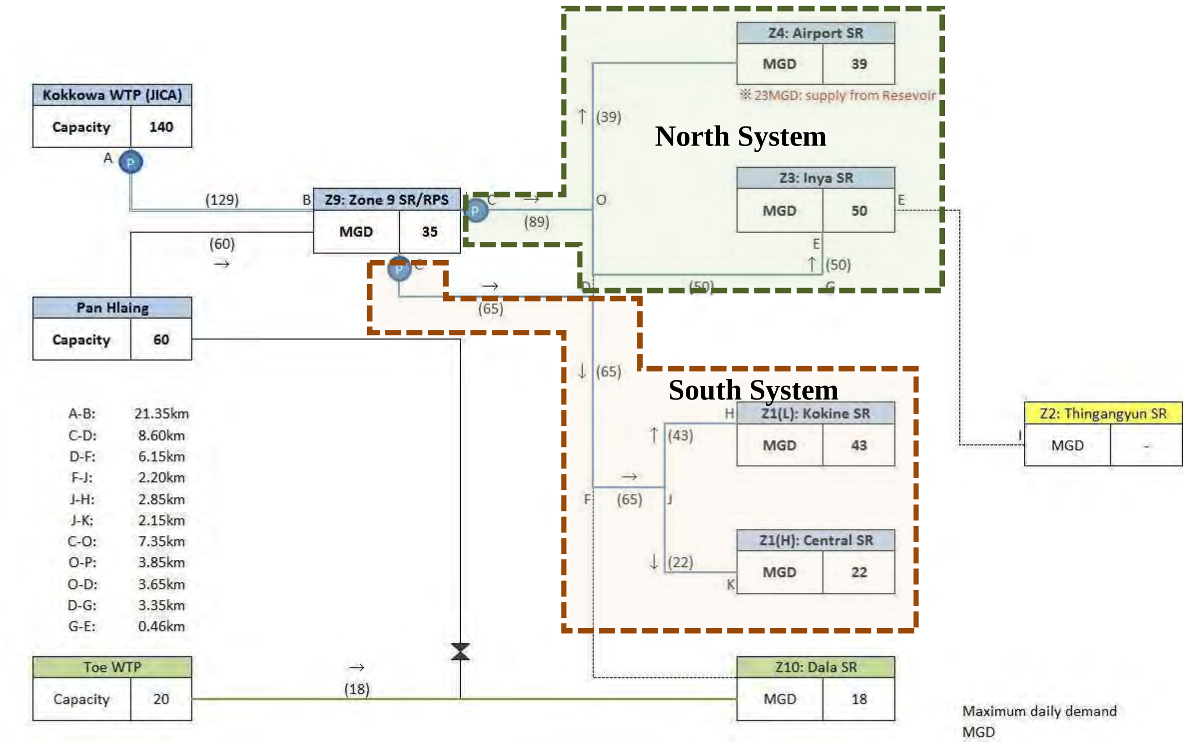
a) Separation of Transmission System

In the future, two (2) lines of transmission pipelines from RPS will be installed. One is toward south-east of RPS, and another is toward north-east of RPS. Furthermore, these two (2) lines will be connected together. Therefore, there are following 2 plans as Transmission facility structure.

- 1 transmission system: transmit water from RPS as one system
- 2 transmission systems: transmit water from RPS using divided 2 systems (south and north systems)

As shown in the following Table, Two (2) transmission systems have advantage especially in terms of energy efficiency because pump head can be decided in accordance with elevation difference between RPS and destination SRs of each system. On the other hand, 1 transmission system has advantage especially in terms of emergency water supply operation because pump head of both lines is same.

To emphasize energy efficiency at ordinary times is better than to emphasize emergency water supply operation which occurs rarely. Therefore, plan of 2 transmission systems is recommended, and transmission facility of south line is planned for Zone 1 Transmission in this plan.



Source: JICA Study Team

Figure 5-6 Schematic Flow of Transmission in 2035

Table 5-10 Comparison of Transmission Systems

Item	1-System (Integrate North and South)	2-Systems (North and South)
Basic idea	Pumps of same head are used	Pumps of different heads are used in north and south system
Destinations of Transmission	Zone 1: Kokine, Central SR of Zone 2 to 4	North: Zone 2 to 4 South: Kokine, Central in Zone 1
Ordinary Time	Large residual water head is expected to occur at University, Airport and Thingangyun SR.	Energy efficiency is better than in case of 1-system because pump head of north system is lower than 1-system.
	×	○
Emergency	Since pump head of all pumps is same, water supply in emergency between north and south line is easy when accidents occur on the pipeline.	Since pump head of each system is different, water supply in emergency between north and south system is restricted when accidents occur on the pipeline
	○	×
Facility Planning	In this system, stand-by pump can be shared. Therefore, number of pump units becomes few.	Each system requires a stand-by pump. Therefore number of pump units becomes large.
	○	△
Operation	Water operation is conducted in a lump. Since number of destinations is larger than the 2-system, operation becomes complex and difficult.	Water operation is conducted in each system. Since number of destinations of each system is few than the 1-system, operation is easier than the 1-system.
	△	○

Source: JICA Study Team

b) Planned Transmission Flow

RPS is main transmission facility to convey clear water from Kokkowa and newly planned Pan Hlaing WTP to the center of Yangon city. Destination of Transmission in 2025 is Kokine SR, then, Central (Zone 1), Inya (Zone 3) and Airport (Zone 4) SR will be added as the destinations in 2030 and 2035, respectively.

The maximum flow is 65 MGD in case of south route from Zone 9 SR in 2035. Therefore, number of pump units is decided to convey water in 2035. And then, number of pumps meeting the flow in 2025 is considered as the facility that is planned in this Study for installation in 1st stage. Number of pump units of north route is decided considering the water demand in 2035.

Table 5-11 Transmission Flow from RPS (for Southern Route)

Year	Flow	Destination
2025	36 MGD	to Zone 1 (Kokine SR)
2030	60 MGD	to Zone 1 (Kokine and Central SR)
2035	65 MGD	to Zone 1 (Kokine and Central SR)

Source: JICA Study Team

Table 5-12 Transmission Flow from RPS (for Northern Route)

Year	Flow	Destination
2030	22 MGD	to Zone 3 (Inya SR)
2035	89 MGD	to Zone 3 and 4 (Inya and Airport SR)

Source: JICA Study Team

c) Pump Equipment Plan for Southern Route

(i) Comparison of pump specification and cost

Comparison of transmission pump specific plans has been made as shown in the following Table. As a result of the comparison, Plan-B is considered as better option in terms of cost.

Table 5-13 Comparison of Transmission Pump Specific Plan (for Southern Route)

Item	Plan-A: 3 operational units	Plan-B: 4 operational units	Plan-C: 5 operational units
Discharge flow	21.6 MGD (68.2 m^3/min)	16.3 MGD (51.5 m^3/min)	13.0 MGD (41.0 m^3/min)
Pump head	87 m	87 m	87 m
Pump type	Double suction centrifugal single stage pump		
Approx. Motor output	1600 kW	1250 kW	1050 kW
Number of units	4 units (3 duty + 1 stand-by)	5 units (4 duty +1 stand-by)	6 units (5 duty +1 stand-by)
Rough estimation	1,378 million JPY (335 million JPY/unit)	**1,085 million JPY** (217 million JPY/unit)	1,107 million JPY (185 million JPY/unit)

Source: JICA Study Team

(ii) Plan of Transmission pump equipment

As the detail is described in Chapter 7, this planned pump facility is required to have sufficient capacity to distribute water to Zone 1 directly and temporarily during the period when system is changed from the existing to Kokkowa. Required pump discharge capacity for temporary distribution is 1.875 MG/hr (45 MGD, hourly maximum demand). This demand can be sufficiently covered if three (3) units of pumps are operated. Furthermore, Plan-B pumps mentioned above have adaptability to water demand fluctuation. Therefore Plan-B is adopted.

Table 5-14 Proposed Transmission Pump of RPS (for Southern Route)

Item	Specification	Remarks
Pump	16.3 MGD (51.5 m^3/min) × 87 m×1250 kW × 5 units (4 duty +1 stand-by), Horizontal Double Suction by Variable Speed Control Method	4 pumps under ODA loan

Source: JICA Study Team

d) Pump Equipment Plan for Northern Route

(i) Comparison of pump specification and cost

Comparison of transmission pump specific plan is as shown in the following Table. As a result of the comparison, Plan-B is better option in terms of cost.

Table 5-15 Comparison of Transmission Pump Specific Plan (for Northern Route)

Item	Plan-A: 3 operational units	Plan-B: 4 operational units	Plan-C: 5 operational units
Discharge flow	29.7 MGD (93.8 m^3/min)	22.3 MGD (70.4 m^3/min)	17.8 MGD (56.2 m^3/min)
Pump head	50 m	50 m	50 m
Pump type	Double suction centrifugal single stage pump		
Approx. Motor output	1500 kW	1000 kW	820 kW
Number of units	4 units (3 duty +1 stand-by)	5 units (4 duty +1 stand-by)	6 units (5 duty +1 stand-by)
Rough estimation	1,623 million JPY (406 million JPY/unit)	**1,457 million JPY** (291 million JPY/unit)	1,494 million JPY (249 million JPY/unit)

Source: JICA Study Team

(ii) Plan of Transmission Pump Equipment

As a result of the study, Plan-B is adopted. Transmission pumps for Northern route are planned to transmit water to Zone 3 SR (near Inya lake) in 2030, and to Zone 3 SR and Zone 4 SR (near Airport) which will be constructed in location with different elevation. Therefore, Transmission flow and destinations are different by the year. Consequently, variable speed control method is proposed because the method can transmit water flexibly under the changing Transmission condition and thereby can reduce electricity consumption.

Table 5-16 Proposed Transmission Pump of RPS (for Northern Route)

Item	Specification	Remarks
Pump	22.3 MGD (70.2 m^3/min) × 58 m×1000 kW×5 units (4 duty + 1 stand-by), Horizontal Double Suction By Variable Speed Control Method	In the future

Source: JICA Study Team

e) Plan of Relay Tank

(i) Capacity of the Relay Tank

Relay tank of Zone 9 SR/RPS should have the capacity for water distribution to Zone 9 and Transmission to SRs in Zone 1 and other Zones. Therefore, design capacity of the tank is planned considering 8 hours of retention time for water distribution and 1 hour retention time for Transmission.

There are two (2) options of planned transmission flow in 2040, option 1 and 2, for planning of the relay tank capacity as shown in Figure 5-3. In this plan, 191 MGD based on the option 1 that conform to the MP is adopted as the planned Transmission flow to avoid overinvestment. Required capacity in each year is shown in Table below.

Table 5-17 Required Capacity of Zone 9 SR

Item	2025	2030	2035	2040
Daily Maximum Demand in Zone 9 (MGD)	19	26	35	49
Planned Transmission Flow (MGD)	37	82	154	191
Required Capacity for SR (MG)	6.33	8.67	11.67	16.33
Required Capacity for Transmission (MG)	1.54	3.42	6.42	7.96
Required Capacity of the Tank (MG)	7.87	12.09	18.09	24.29

Source: JICA Study Team

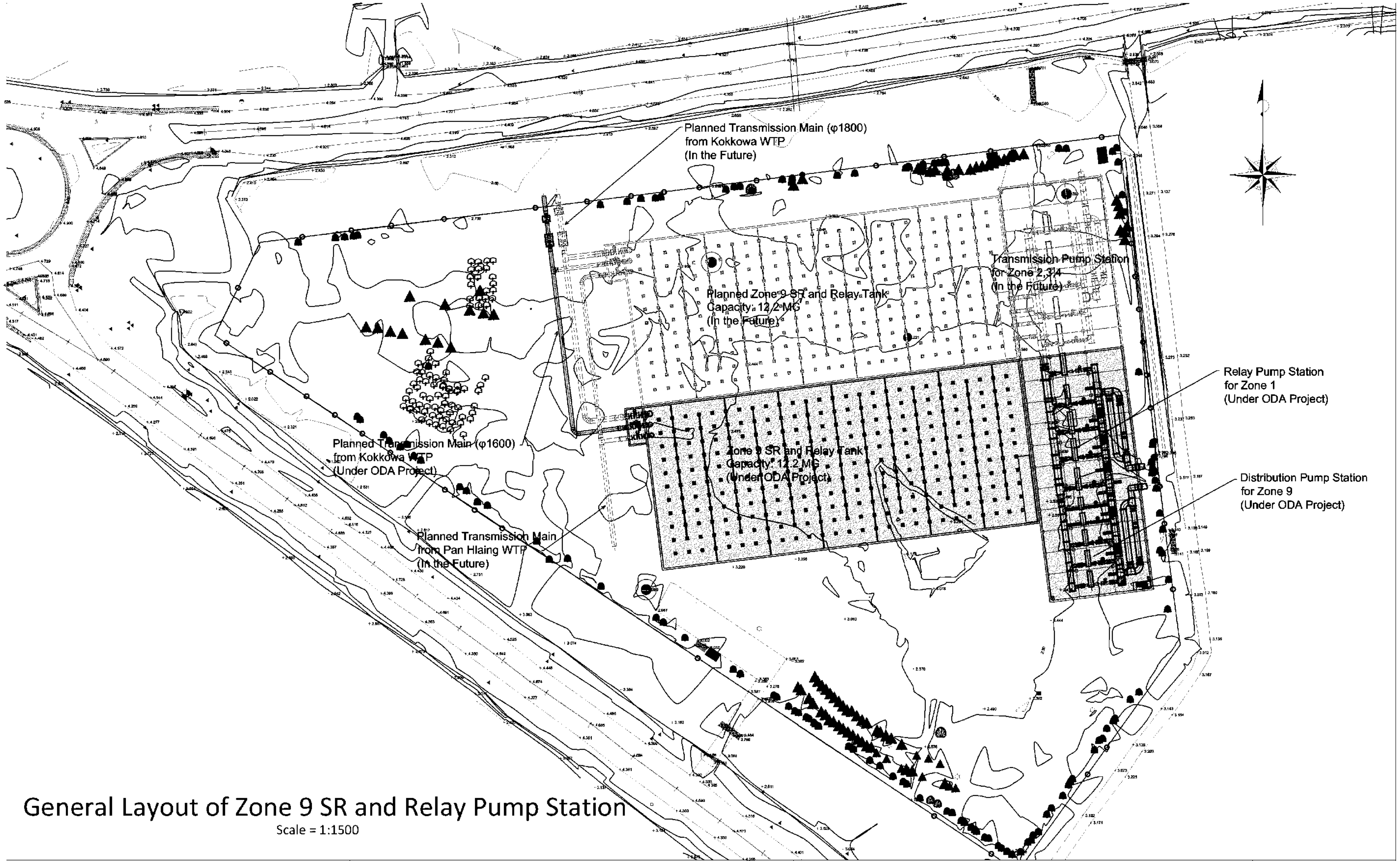
24.3 MG capacity in 2040 and 7.9 MG capacity in 2025 is required. Therefore, following 2 plans were extracted;

- 3 Tanks Plan: 8.1 MG×1 tank (3 tanks in the future, 24.3 MG)
- 2 Tanks Plan: 12.2 MG×1 tank (2 tanks in the future, 24.4 MG)

In the case of 3 tanks plan, capacity of the tank to be constructed in 1st stage is almost same as the required capacity in 2025. However, it is not rational that continuous construction of tanks be carried out in the short period in response to the increase in the required capacity. Therefore, Tanks is proposed and 12.2 MG tank for SR/RPS is planned.

(ii) Capacity verification of the Relay Tank under the Temporary Water Distribution to Zone 1

Temporary water distribution from the Relay Tank to Zone 1 will be implemented at the first step of the distribution system switching shown in 7.5.3, and planned distribution flow at the time is 30 MGD. At this time, retention time of the Relay Tank is 9.8 hours, and it meets the necessary capacity.



General Layout of Zone 9 SR and Relay Pump Station

Scale = 1:1500

JAPAN INTERNATIONAL COOPERATION AGENCY YANGON CITY DEVELOPMENT COMMITTEE		JICA Study Team ENGINEERING DEPARTMENT (WATER & SANITATION)		PROJECT Preparatory Survey for Greater Yangon Water Supply Improvement Project Phase II (Kokkowa River)	Scale 1:1500
DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY	TITLE General Layout of Zone 9 SR and Relay Pump Station	Drawing No. Z9SR-1
-	-	-	-		Date June 2016

(4) Plan of Transmission Pump Facility at Yegu Pump Station

a) Planned Transmission Flow

Planned transmission and distribution flow of planned pipeline from Yegu PS to Central SR is 22.1 MGD including 5.1 MGD of distribution flow for Bahan Township in 2025. Central SR is planned to receive Kokkowa water from RPS in the future.

Table 5-18 Transmission Flow from Yegu PS to Central SR

Year	Flow	Remarks
2025	22.1 MGD	Including distribution flow

Source: JICA Study Team

b) Pump Equipment Plan

Existing four (4) pumps is planned to be removed, and two (2) new operational pumps and one (1) stand-by pump are planned to be installed for Transmission to Central SR.

Table 5-19 Proposed Transmission Pump at Yegu PS

Item	Specification	Remarks
Pump	11 MGD (35 m^3/min)×53 m×450 kW×3 units (2 Duty + 1 stand-by), Horizontal Double Suction by On/off control method	Existing pumps to be removed by YCDC

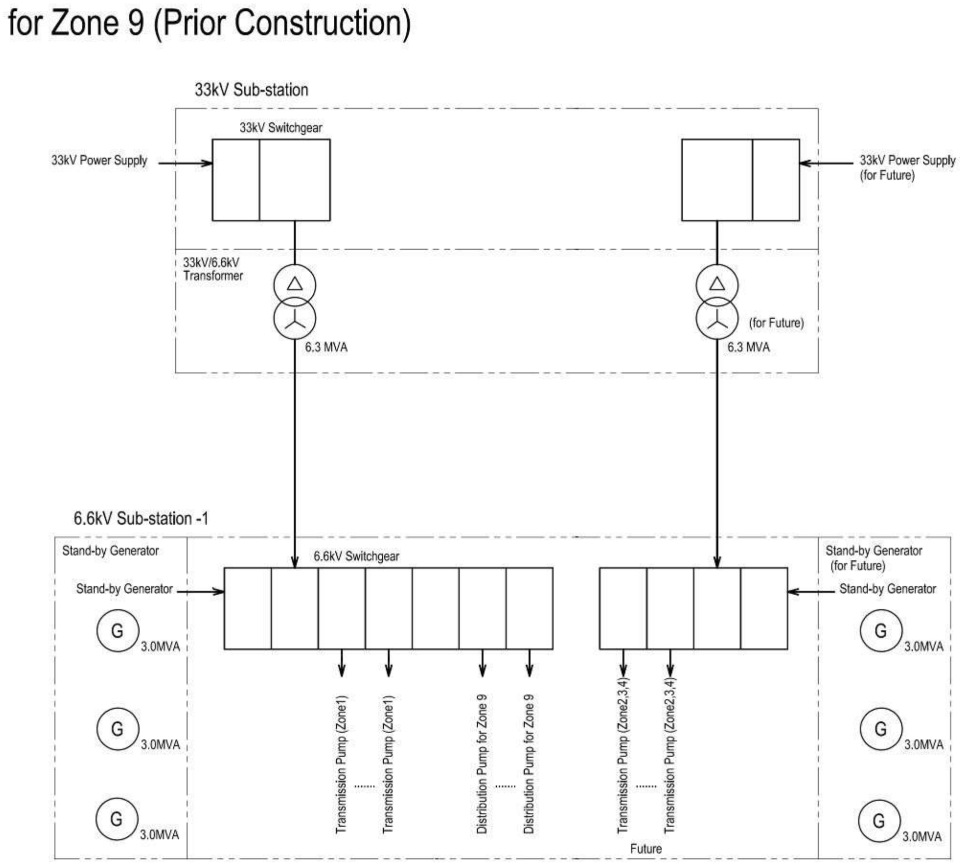
Source: JICA Study Team

5.3.5 Electrical Facilities for Relay Pump Station

(1) Main Power Supply

Incoming power will be common for both water distribution in Zone 9 and Transmission to Zone 1 and will be supplied by YESC in 3 phase 33 kV 50Hz. The power received at 33 kV will be stepped down to 6.6 kV by a main transformer to meet the motor voltage requirement of MV motor such as distribution pump and transmission pump. Type of transformer will be of the outdoor, oil immersed, and natural cooling type, similar to the case of WTP. Required capacity of transformer in 2025 is estimated as 9 MVA. Negotiations with YESC to obtain main power supply for Zone 9 SR/RPS will be under the scope of YCDC. Main power supply will be included under the scope of Japanese ODA loan. Power Supply Diagram is shown below.

For transmission pumps of Northern line, additional incoming power and transformer will be necessary in future (2035).



Source: JICA Study Team

Figure 5-7 Main Power Supply Diagram

(2) Emergency Power Supply

As mentioned in the plan of WTP, stand-by power generator will be required for stable water supply. Especially, planned water supply system will use pumps for Transmission and distribution and the interruption of main power supply will cause total interruption of water supply immediately. Therefore, stand-by generator is planned in this Study.

Type of generator will be diesel engine generator, built-in radiator that is required for easy operation and maintenance and also being used in Yangon in many cases. The capacity of generator will cover the total power requirement of the PS and it is estimated as 9.0 MVA (3.0 MVA x 3 sets) considering the planned facilities in 2025. Fuel tank capacity of generator needs to be sufficient for 72 hours operation in order to cope with 24 hours outage by supplying additional fuel the next day.

Stand-by generators will be included in the scope of Japanese loan because the manufacturer of all generators should be unified and be synchronized together as single power source.

5.3.6 SCADA

Description on SCADA is made in 4.4.11 in Chapter 4.

5.4 Laying Position of Transmission Pipe

For the 60 MGD of Kokkowa WTP development by 2025, following large diameter pipelines shall be laid along the route 5;

- Transmission pipeline from the WTP to Zone 9 SR/RPS (φ1600: 60 MGD capacity constructed under ODA loan)
- Transmission pipeline from the Zone 9 SR/RPS to Zone 1 SR (φ1600: 65 MGD capacity constructed under ODA loan)
- Distribution main from Zone 9 SR to Zone 9 area (constructed by YCDC)

For the future expansion plans of Kokkowa WTP, the following large diameter pipelines are planned.

- Transmission pipeline from the WTP to Zone 9 SR/RPS (φ1800: 80 MGD capacity future plan)

Since Route No. 5 is the only road connecting between the WTP and Zone 9 SR, pipelines mentioned above are planned to be laid along the Route No. 5.

5.4.1 Route of Transmission Pipeline from Kokkowa WTP to Hlaing River

(1) Pipeline Development Plan and Outline of the Route 5

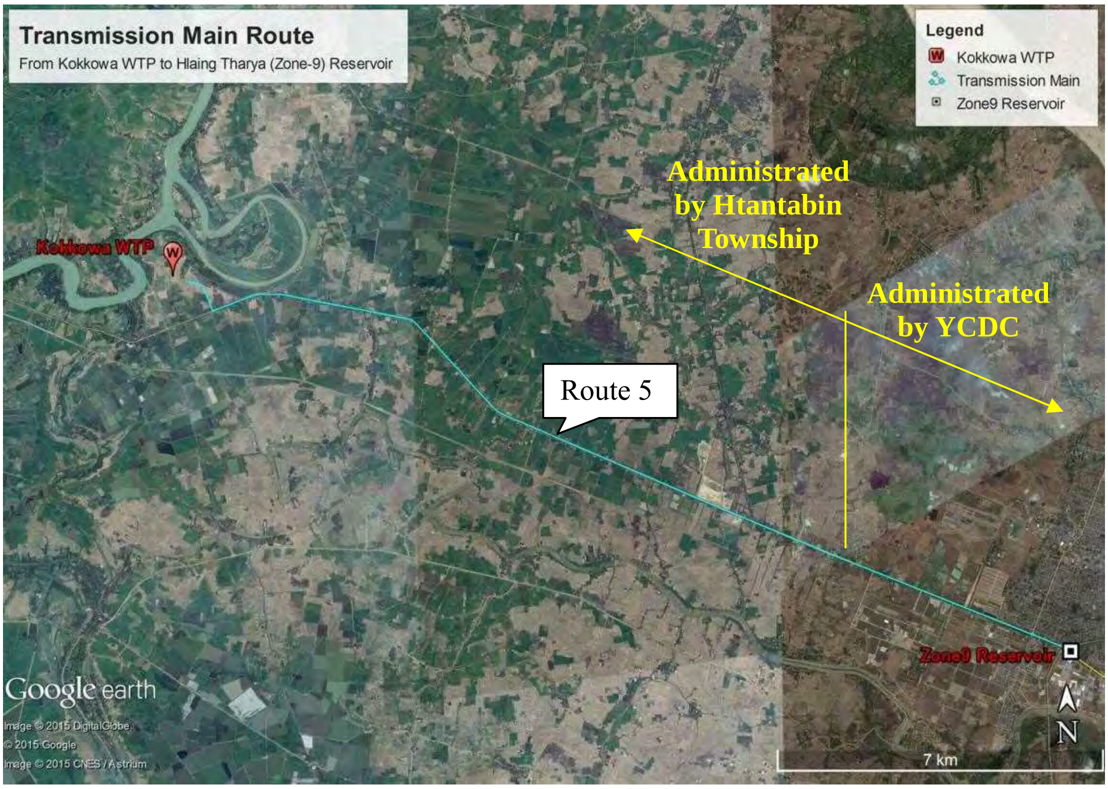
As shown in the following Table, proposed transmission pipelines of φ1600 mm will be laid in section-1, and φ1800 mm of transmission pipeline will be additionally laid when the Kokkowa WTP is expanded. Therefore, pipeline laying position is decided considering the availability of space for the additional pipelines which shall be laid by 2035.

Table 5-20 Proposed Pipeline and Jurisdiction Area of The Route 5

Section	Jurisdiction Area	Pipeline Planned to be Laid
Section-1: From the WTP to Zone 9 SR (Pipeline length: approx. 21 km)	Yangon Region (Htantabin TS)	・ φ1600 mm new transmission ・ φ1800 mm new transmission (future plans)
	YCDC (Hlaing Tharyar TS)	・ φ1600 mm new transmission ・ φ1800 mm new transmission (future plans) ・ φ1000 mm - φ1600 mm new distribution main
Section-2: From Zone 9 SR to Hlaing River (Pipeline length: approx.10 km)	YCDC (Hlaing Tharyar TS)	・ φ1600 mm new transmission ・ φ1000 mm - φ800 mm new distribution main

Source: JICA Study Team

As shown in the following Figure, section-1 is divided into YCDC jurisdiction area (Hlaing Tharyar TS) and Regional Government jurisdiction area (Htantabin Township TS). Entire stretch of section-2 is located in the YCDC jurisdiction area.



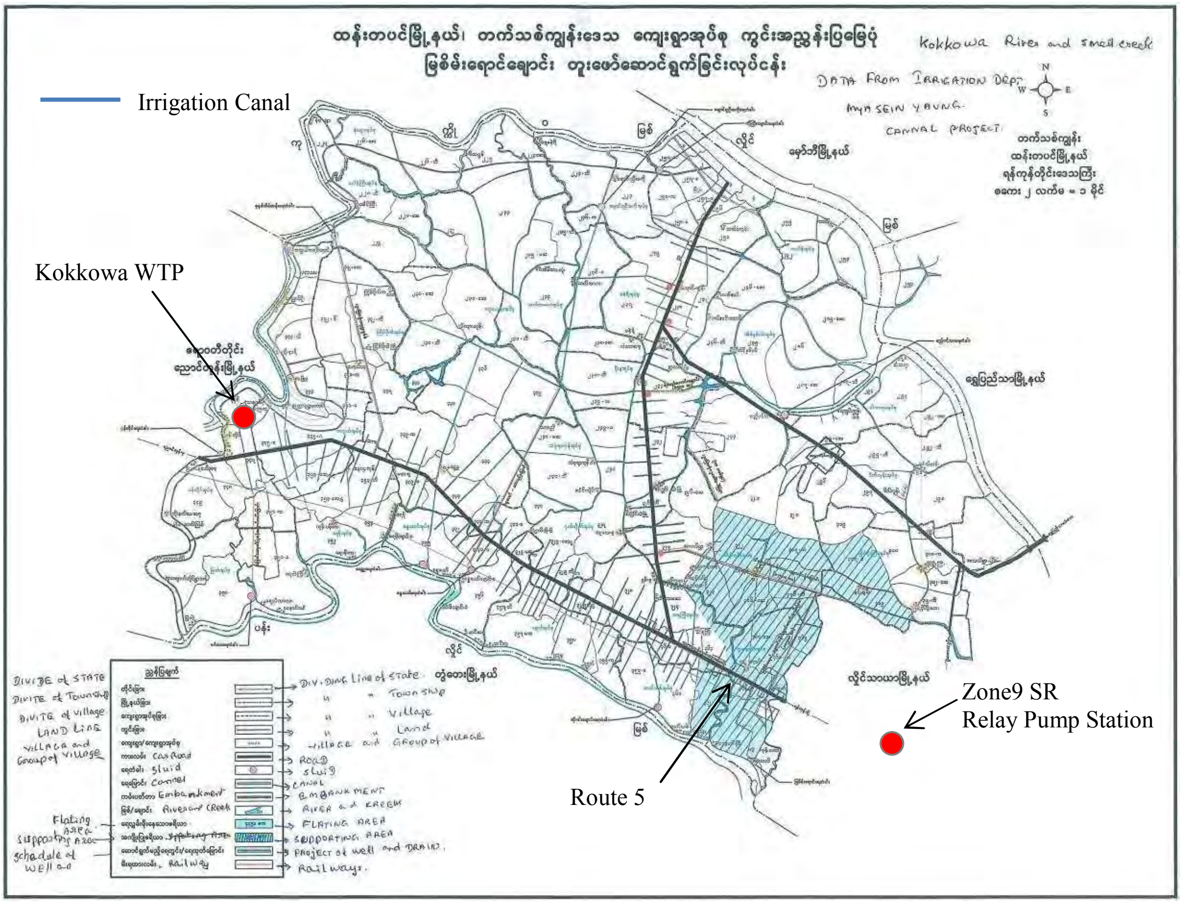
Source: JICA Study Team using background map of Google Earth

Figure 5-8 Transmission Pipeline Route to Zone 9 SR

Basically, width of ROW of the route 5 is approximately 150 feet (45 m) as shown in Figure 5-10. Route 5 is a combination of a 9.1 km paved 4-lane road and a 17.6 km paved 2-lane road running from Hlaing River. As a general rule, the 75 feet area of the both sides of ROW is public land as described below.

- Htantabin TS: Both north and south sides belong to regional government
- Hlaing Tharyar TS: North side – YCDC, south side - MoC

The land on both sides of ROW in Htantabin TS is used as an irrigation canal (Figure 5-9). In Hlaing Tharyar, the sides are formed as diches but not used for irrigation.



Source: MoAI

Figure 5-9 Irrigation Canals along with Route 5

(2) Basic Policy of Pipe Laying Position

As indicated in Table 5-20 above, two or three large diameter pipelines will be laid along the Route 5. Therefore, decision on pipe laying locations is made ensuring space for future pipes. Following basic policies are proposed in terms of pipeline laying position.

(a) Common for All Areas

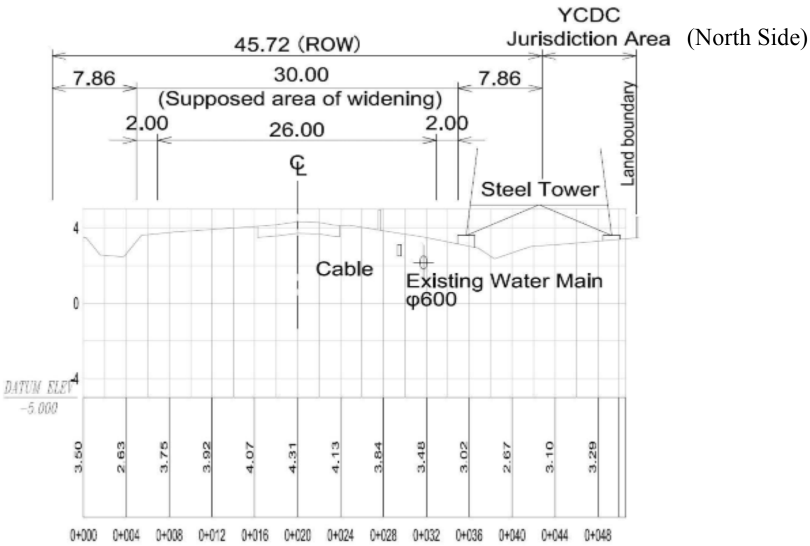
Route 5 is a major main road with industrial areas and long-distance bus terminals along the route, hence the traffic is heavy with large vehicles. For this reason, laying pipelines under the road will have a large influence on the traffic. The possibility of pipeline damage for the pipes after construction beneath the road is higher than the pipes laid outside the roads because of the weight of the vehicles, and works for repair/maintenance of the pipes will be difficult and may have negative effects on the traffic.

The main policy is to not lay pipes under Route 5. And since there are future plans to expand the road width (although it is not currently concrete), said policy shall be adopted in the areas which are expected to be included in the future expansion plan.

(b) Within Yangon Region Area (Htantabin TS)

As mentioned before, one transmission pipe of φ1600 is planned for this area by 2025, and in the future a plan for another φ1800 pipeline shall also be carried out following the Kokkowa WTP expansion. The details are mentioned in the following item (c), but it is better if the Htantabin TS pipeline is laid in the north side of the road, since the pipeline for Hlaing Tharyar TS is also planned on the north side and it will not be necessary to cross Route 5. However, according to the field survey, there are many obstructions in pipe laying on the northern side of the road through entire length of this stretch, such as trees, electric poles, communication cable, irrigation channels and so on.

On the other hand, obstruction (gas pipe only) on the southern side of the road is less than the northern side. For these reasons, the transmission pipe of φ1600 constructed by the loan project and of φ1800 constructed by future plans are planned to be laid on the relatively spacious southern side of Route 5.



Source: JICA Study Team

Figure 5-10 Cross-section Drawing of Limited Laying Area, North Side

Southern Side of Route 5

Northern Side of Route 5

Photo 5-1 Yangon Region Jurisdiction Area (Htantabin TS)


Steel Tower and Blue Boundary Wall Existing 600 Dia. Pipe Next to the Steel Tower

Photo 5-2 Obstruction in Pipeline Installation in Htantabin TS

(c) Within YCDC Jurisdiction Area (Hlaing Tharyar TS: Zone 9)

The land south of route 5 is a jurisdiction area of MoC, and the north belongs to YCDC. For the upper stream area of Zone 9 SR, the south side of the street does not belong to YCDC and in addition, it is heavily populated by illegal squatters.

For the lower stream area of Zone 9 SR, the south side of the route 5 is the industrial area where many factories are located and new factories are expected to be established in future. The north side of the road is residential area. Pipe laying on the southern side of the road is not preferable because the area does not belong to YCDC, and in addition, many heavy vehicles is expected to cross over the pipeline to enter the construction site, and high voltage power transmission line and steel towers are also located on southern side of road in this stretch. Furthermore, number of illegal squatters on the southern side of route 5 in MOC's property is much larger than the northern side. Therefore, in this stretch, the northern side of the road is proposed as the pipeline laying position.


Northern Side of Route 5 Southern Side of Route 5

Photo 5-3 YCDC Jurisdiction Area (Hlaing Tharyar TS: Zone 9)

(3) On-Site Confirmation of Number of Illegal Houses

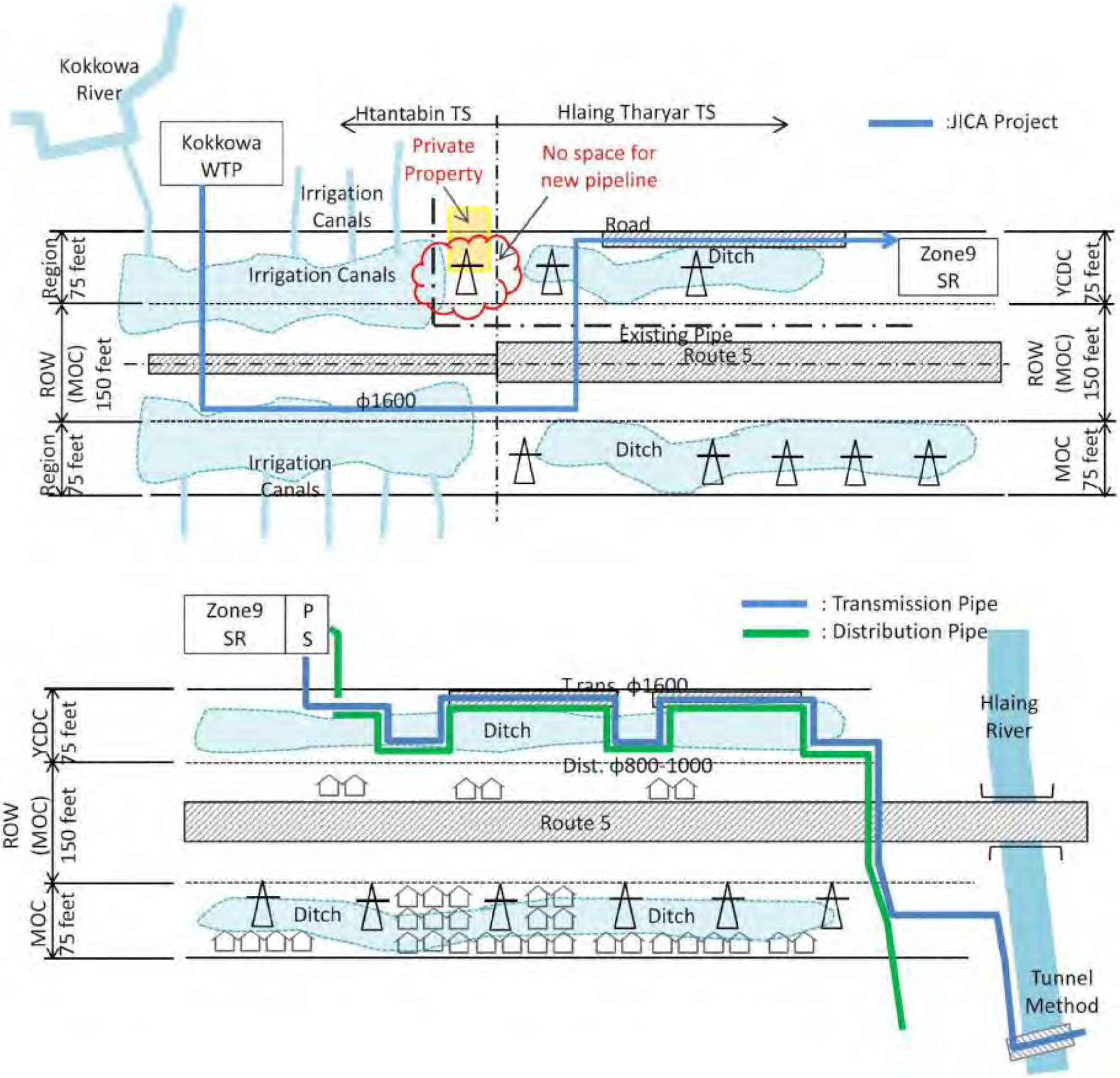
Illegal houses are occupying on the proposed pipeline from Htantabin TS to Hlaing Tharyar TS along Route 5. This survey detailed is later described in 11.8.2.

(4) Conclusion

From the result of comparative evaluation and further study (see the Appendix-7), pipe laying location for Htantabin TS shall be inside the road land south of Route 5, since it will not have an impact on irrigation canals.

For Hlaing Tharyar TS, in areas which have side roads, the transmission pipes are to be laid under the side roads to avoid relocation of residents and removal of bridges crossing the canals along Route 5. In areas which do not have side roads but have crossing bridges, the pipe position shall be shifted toward Route 5 by crossing the canals to avoid the removal of the bridge superstructures of the bridges.

YCDC informed the result of the study and had discussions about this matter with institutions concerned, such as MoC, MoAI, MoEE, and land administration. As a result of the discussion, the laying plans mentioned above have been agreed.



Source: JICA Study Team

Figure 5-11 Schematic Diagram of Transmission Pipeline Route

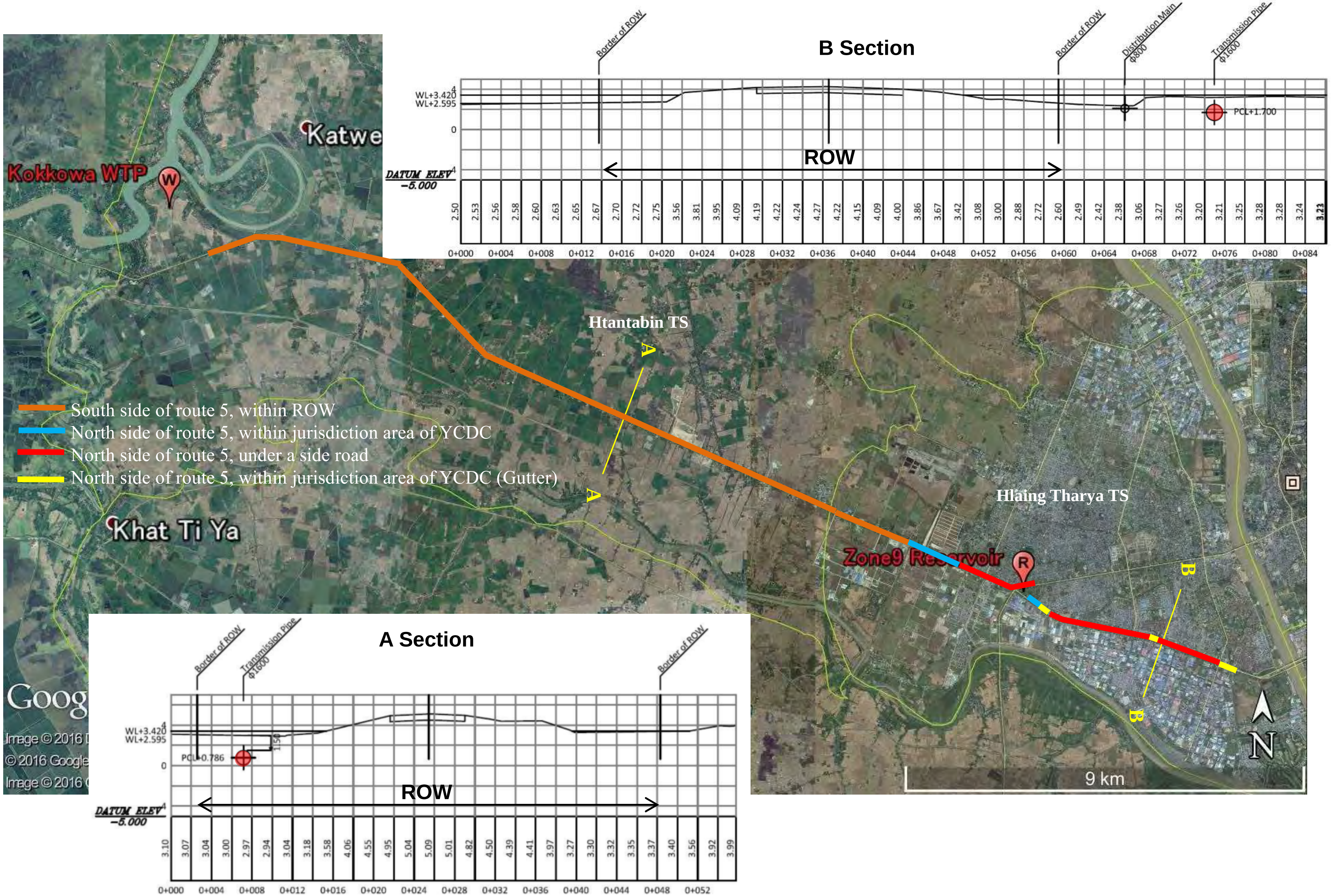


Figure 5-12 Plan of Transmission Pipeline Position and Sections

5.4.2 Route of Transmission Pipeline from Hlaing River to Zone 1

Route Plan of transmission pipeline is shown in the following Figure 5-13. Yellow line shows routes proposed in the MP. As shown in red line in Figure 5-13, some parts of the route are modified based on route confirmation through field visit conducted by EDWS and the Team in this Study. The reasons of route modification are described below.

a) Reviewed Route-1

This portion is near the Hlaing river crossing, and pipeline route is restricted by the location of the river crossing. As mentioned in 5.4.3, shield tunnel method is selected as the method of the crossing, and this method requires space for departure and arrival shafts. As a result of the field confirmation, planned route is selected to ensure availability of necessary space for shield tunnel construction.

b) Reviewed Route-2

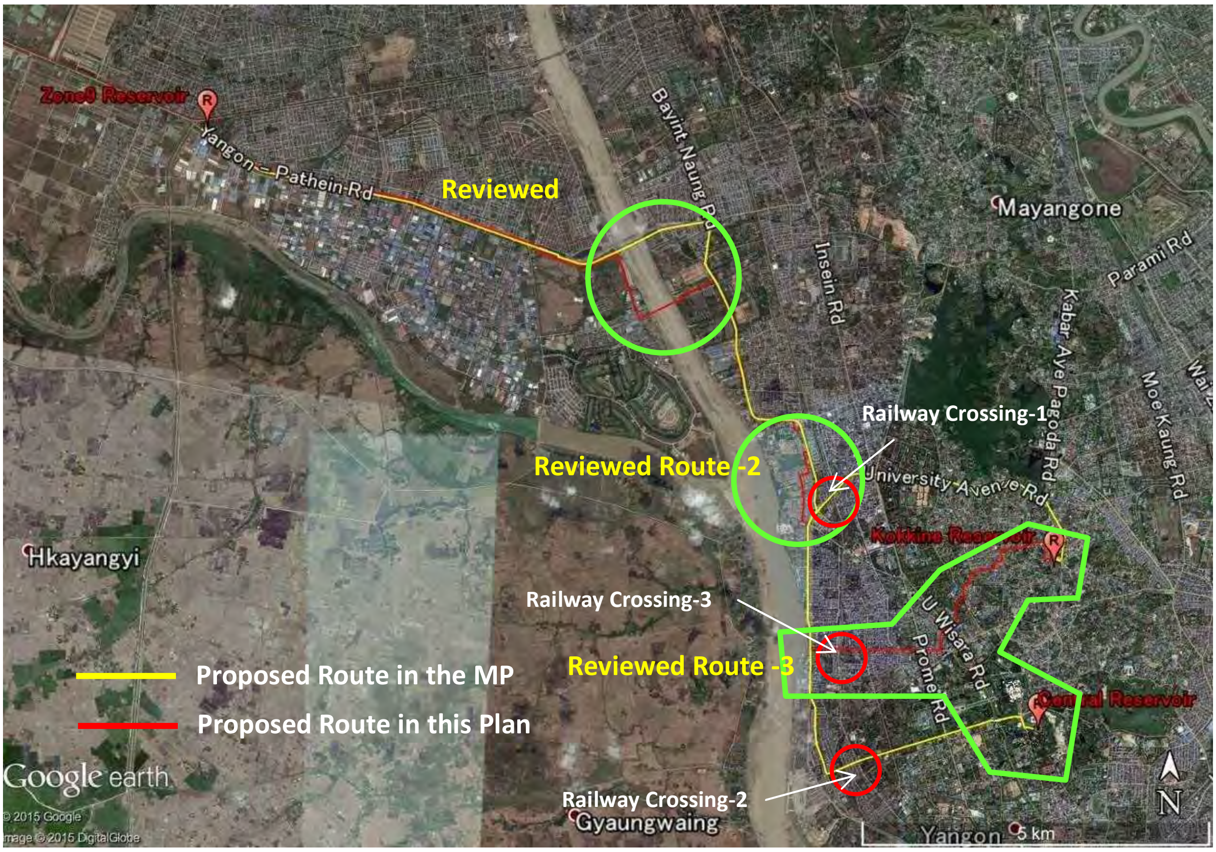
In the master plan, transmission pipeline route is planned along Bayint Naung road. Although traffic volume on this road is heavy, pipeline has to be laid under the roadway because there is no space for laying a pipeline beside the roadway. Especially, traffic jam occurs every day at the intersection of Bayint Naung road and University Avenue road. To alleviate the occurrence of traffic jam around this intersection even to some extent, an alternative route is selected.

c) Reviewed Route-3

MP's route includes two crossing places of railway as shown in Photos 5-6 to 5-8. As a result of site reconnaissance, especially crossing of railway at site-1, it is expected to have difficulties in installation work due to lack of enough space for the work.

On the other hand, the alternative route plan shown as red line in the Figure 5-13 includes railway crossing at only one location (Railway crossing-3; as shown in Photo 5-9). Excavation work at this location is possible because railway is crossing over the road. Furthermore, in this case it is economical and has lower friction head loss due to shorter total length of transmission pipeline.

Considering the above and based on the discussion with EDWS, alternative route plan is selected.



Source: JICA Study Team using background map of Google Earth

Figure 5-13 Proposed Transmission Pipeline Route

Photo 5-6 Railway Crossing-1 (North side)

Photo 5-7 Railway Crossing-1 (South side)

Photo 5-8 Railway Crossing-2

Photo 5-9 Railway Crossing-3

5.4.3 Hlaing River Crossing

(1) Applicable Methods

Installation of the transmission pipeline from Zone 9 SR to Zone 1 area requires crossing of Hlaing River. Pipe-bridge method and tunnel method are conceivable as the possible options for the river crossing.

(2) Outline Plan of Pipe-Bridge and Tunnel Method

(a) Pipe-Bridge Method

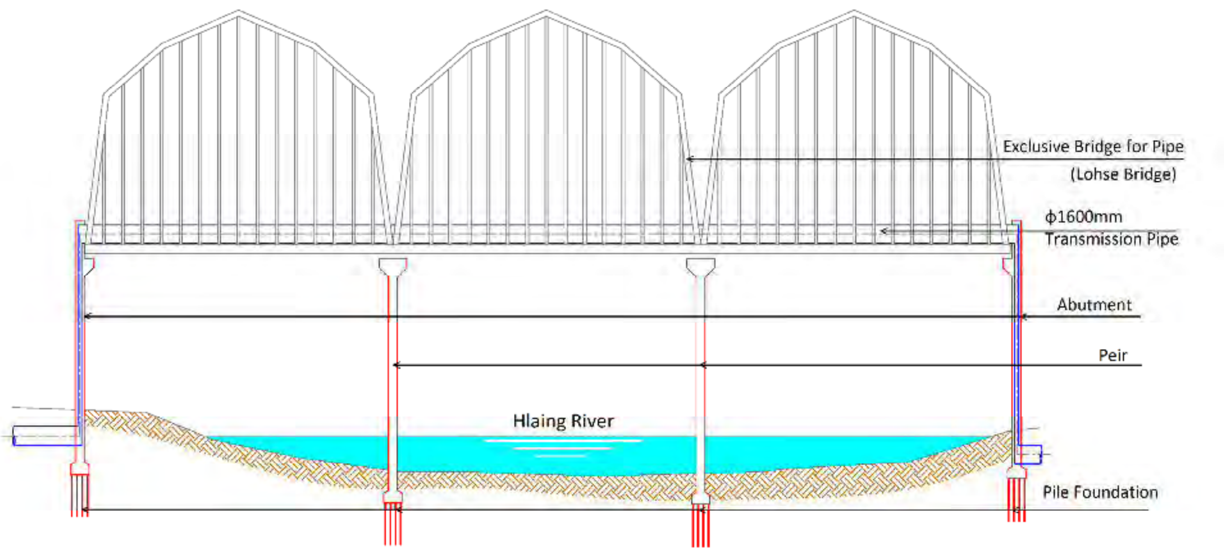
(i) Type of pipe-bridge

Since the pipe diameter is large and pipe weight filled fully with water is heavy, bridge-attached type cannot be adopted. Therefore, independent pipe-bridge type is selected. There are many types of independent pipe-bridge such as pipe-beam bridge, stiffened pipe bridge and dedicated bridge for water pipe. Dedicated bridge for water pipe is selected among these types referring to the condition of existing road bridge crossing Hlaing River.

- Type of bridge: Dedicated bridge for water pipe
- Diameter of water pipe: φ1600 mm
- Number of span: 3 spans
- Length of span: 160 meters

(ii) Structure of the bridge

The dedicated bridge is required to be reinforced due to the length of span of the bridge. Stiffening underside of the bridge is not preferable because it might obstruct traffic of ships. Considering the above explanation, Lohse bridge is selected.



Source: JICA Study Team

Figure 5-14 Plan of Pipe Bridge

(b) Tunnel Method

(i) Type of tunnel method

Tunnel is used for casing of the transmission pipe as premise. In general, shield method and pipe-jacking method are conceivable as tunnel methods. Shield method is selected of these two methods considering the site conditions (see the following Table).

- Tunnel method: Shield method
- Diameter of water pipe: φ1600 mm
- Length of tunnel: 550 meters
- Water pipe laying method: Pipe laying inside casing tunnel

Table 5-21 Comparison of Pipe-jacking and Shield Method

	Pipe-jacking Method	Crossing of Hlaing River	Shield Method
Diameter of pipe (mm)	Inner Diameter 3,000 or less	1,600 (lies in range of 1350~3000 so both method applicable)	Inner Diameter 1,350 or more
General Length (m)	20～400 [7]	550 (Only Shield method can be adopted as length exceeds upper limit of Pipe-jacking method)	For any Length

Source: Construction Prices Research Institute in Japan, Actual Sewer Construction Integration,

(ii) Planning of shield method

- Type of shield method

  High ground water pressure is expected because tunnel passes under the river. Therefore, reverse circulation type shield method is selected.

- Diameter of the casing tunnel

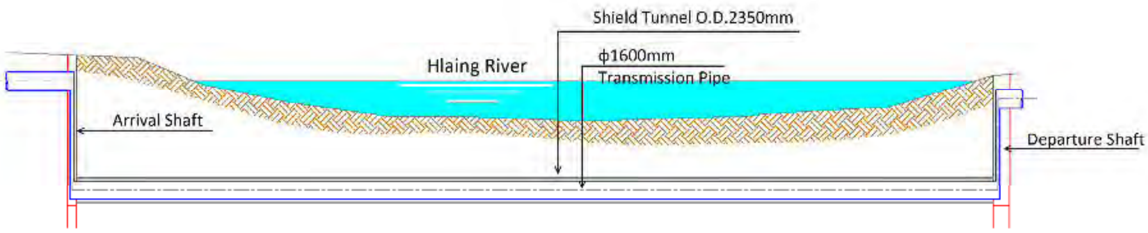
  Standard shield tunnel and reduction diameter shield tunnel are conceivable if the tunnel is used as a casing tunnel of the transmission pipe. Since the alignment of the tunnel is almost straight, reduction diameter shield tunnel is to be adopted. Outer and internal diameter of the reduction tunnel is 2350 mm and 2200 mm respectively.

- Cover of tunnel from the river bed

  Cover of tunnel shall be decided by 2.0 m of scour margin of river bed plus 1.5 times of O.D. of tunnel or 5.0 m, whichever is larger. Since O.D. of the tunnel is 2.35 m, minimum tunnel depth becomes 5.525 m. Planned cover of tunnel is set as 6.0 m leaving some leeway.

  Cover of Tunnel = 2.0 m + 2.35 m x 1.5 = 5.525 m ≒6.0 m > 5.0 m

[7] Pipe-jacking method also has particular methods of 400 m over, however these methods have limitation of soil condition, and it needs verification to adopt.



Source: JICA Study Team

Figure 5-15 Plan of Shield Tunnel

(3) Comparison of Each Method

In this Study, shield method, which has competitiveness in terms of technology of Japan, is recommended as a result of the comparison of each method as shown in the following Table.

The site for arrival shaft on the right bank of the river is administrated by YCDC, and the site for departure shaft on the left bank of the river is administrated by MoAI. Accordingly, land acquisition is not necessary. YCDC already obtained the verbal permission for land use and occupying pipeline in the land from MoAI.

Table 5-22 Comparison of River Crossing Method

Item	Pipe-Bridge Method	Shield Tunnel Method
Advantage	・It is possible to appeal to people about Japanese assistance because the pipe-bridge is exposed.	・No effect on landscape ・No effect on traffic of ships during the construction ・Basically, maintenance-free
Disadvantage	・Since repainting of pipe and bridges is necessary, maintenance cost will be required. ・Since construction of temporary bridge and coffering need to consider the traffic of ships, construction workability is poor. ・Consideration of effect on landscape is necessary.	・It is difficult to appeal to people about Japanese assistance because the tunnel is underground and invisible.
Approximate construction cost (Direct cost base) (unit: Mil. JPY)	・Superstructure: 997 ・Substructure: 205 ・Temporary work: 309 ・Piping work: 240 Total 1,751	・Vertical Shaft: 50 ・Shield Tunnel: 950 ・Pipe laying: 495 Total 1,495
Comprehensive evaluation	Comparing to the shield tunnel method, construction cost is more expensive, the construction work is more difficult and maintenance is laborious. ×	Comparing to the pipe-bridge method, construction cost is cheaper and there are some advantages on workability of construction and maintenance. ○

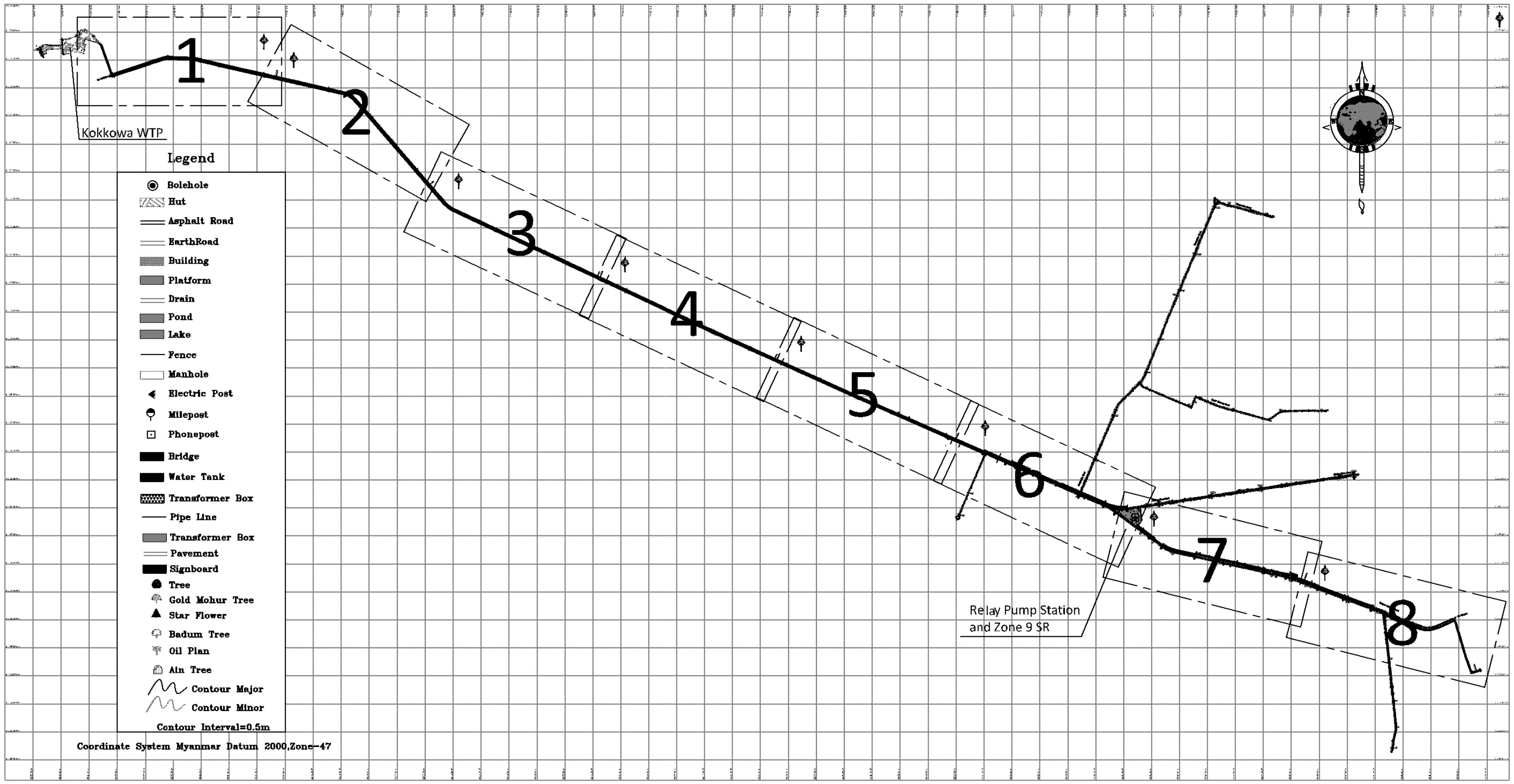
Source: JICA Study Team

Source: JICA Study Team using background map of Google Earth

Figure 5-16 Location of The River Crossing Site

Photo 5-10 Site for Departure Shaft

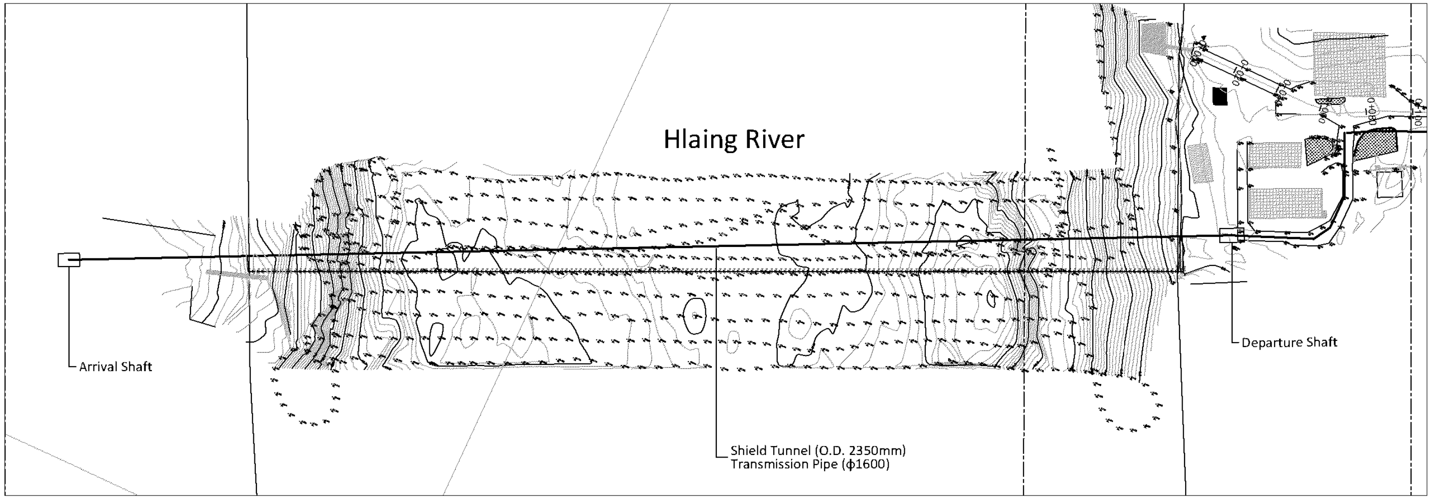
Photo 5-11 Site for Arrival Shaft



Index Map (1)

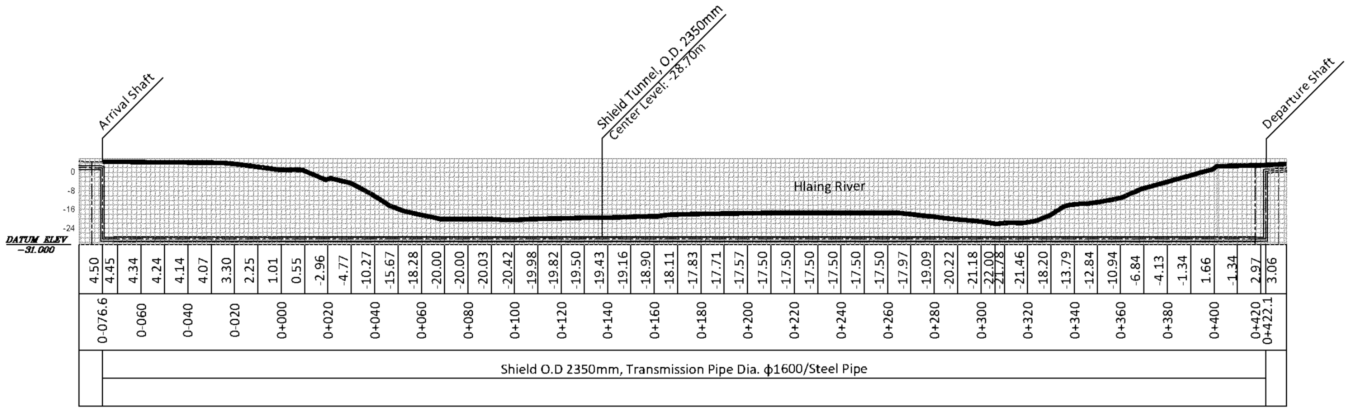
Scale = 1: 80000

JAPAN INTERNATIONAL COOPERATION AGENCY YANGON CITY DEVELOPMENT COMMITTEE		JICA Study Team ENGINEERING DEPARTMENT (WATER & SANITATION)		PROJECT Preparatory Survey for Greater Yangon Water Supply Improvement Project Phase II (Kokkowa River)	Scale: 1:80000 Drawing No.: TRM-PL-001
DRAWN BY -	DESIGNED BY -	CHECKED BY -	APPROVED BY -	TITLE Transmission Pipe to Zone 9 Index Map (Hlaing Tharyar TS)	Date: June 2016



Hlaing River Crossing Plan

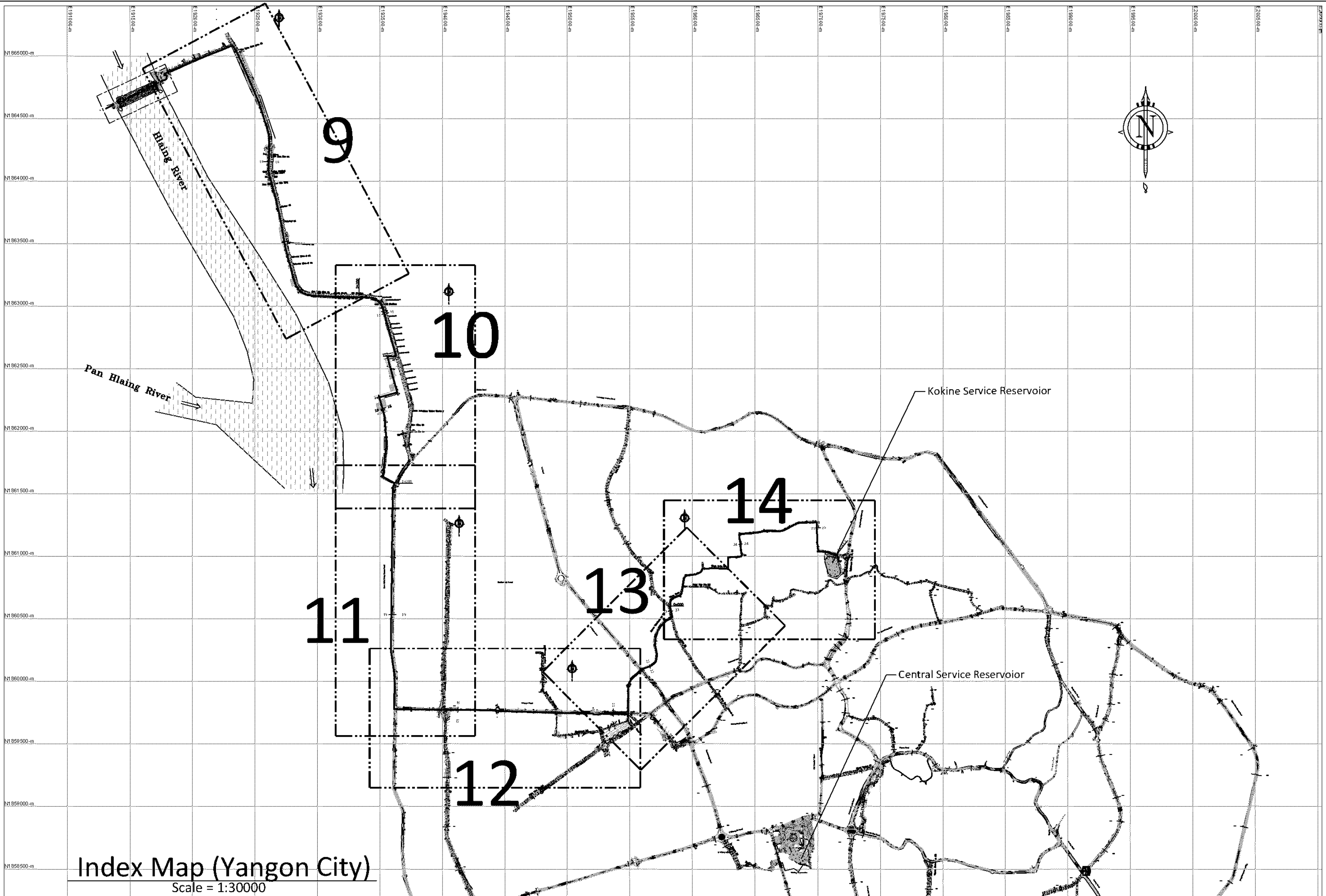
Scale = 1:1000



Hlaing River Crossing Longitudinal Section

Scale: H=V= 1:1000

JAPAN INTERNATIONAL COOPERATION AGENCY YANGON CITY DEVELOPMENT COMMITTEE		JICA Study Team ENGINEERING DEPARTMENT (WATER & SANITATION)		PROJECT Preparatory Survey for Greater Yangon Water Supply Improvement Project Phase II (Kokkowa River)	Scale 1:1000
DRAWN BY -	DESIGNED BY -	CHECKED BY -	APPROVED BY -	TITLE Transmission Pipe for Zone 1 Hlaing River Crossing Plan and Longitudinal Section	Drawing No. TRM-PL-013 Date June 2016



Index Map (Yangon City)
Scale = 1:30000

JAPAN INTERNATIONAL COOPERATION AGENCY YANGON CITY DEVELOPMENT COMMITTEE		JICA Study Team ENGINEERING DEPARTMENT (WATER & SANITATION)		PROJECT Preparatory Survey for Greater Yangon Water Supply Improvement Project Phase II (Kokkowa River)	Scale 1:30000
DRAWN BY -	DESIGNED BY -	CHECKED BY -	APPROVED BY -	TITLE Transmission Pipe for Zone 1 Index Map (Yangon City)	Drawing No. TRM-PL-014 Date June 2016

CHAPTER 6 DISTRIBUTION FACILITIES OF ZONE 9

6.1 Outline of Planning

Zone 9 consists of township of Hlaing Tharyar. This township is mainly comprised of residential areas and industrial Zones. Currently water is supplied to this area through 600 mm pipe from Thephyu Station (small WTP) located in another township (in the north-west of Hlaing Tharyar TS) and through 300 mm pipe receiving water from Hlawga PS. Existing water distribution pipelines are shown in the following Figure.

The water is mainly distributed to Industrial Zones 1 to 4 and ward number 10, and Dagon Ayeyar Highway station area. Existing distribution networks is located mainly in areas south of Route No. 5 and in ward 10 north of this route only. In wards 15 and 19, water is distributed from the local tube wells of YCDC. The existing network is not old and most of them are installed in 2009 or later. Total length of existing distribution mains is about 17 km (diameter 300-600 mm) and distribution pipes are 126 km in length (diameter 50-150 mm). The total length of existing pipes is about 143 km only.

The area lies in suburbs of Yangon with many industries located in this Zone and the industries and residential areas are expected to extend widely in this area. Therefore, this Zone is expected to have high population growth in future also. Most of the inhabitants are still relying on water from local tube-wells due to lack of distribution networks of YCDC pipes water supply.

6.1.1 Concept of Distribution System

In Zone 9, the existing distribution network does not include any SR. The water is directly supplied through pipe from Thephyu Station and Hlawga PS. Some of the areas have low water pressure specially the areas in ward number 10 (north of Route No. 5) due to insufficient capacity of distribution networks.

In this plan, a new SR is proposed in Zone 9 which will receive water from Kokkowa WTP. Water of this SR will be distributed through distribution pumps to Zone 9. The existing pipes are not very old so will continue to be used. However, a large part of the area does not have any distribution network yet. New distribution pipes are planned in all the areas that do not have any distribution network in the existing situation.

6.1.2 Planning Parameters

Planning parameters for Zone 9 are given below in the following Table. Existing coverage ratio of supplied water of 3 % is expected to increase to 45 % by year 2025 and to 75 % by year 2040. Consequently, the daily maximum demand of 1 MGD will increase to 19 MGD by 2025 and to 49

MGD by 2040 considering the increasing population and industrial units in this Zone.

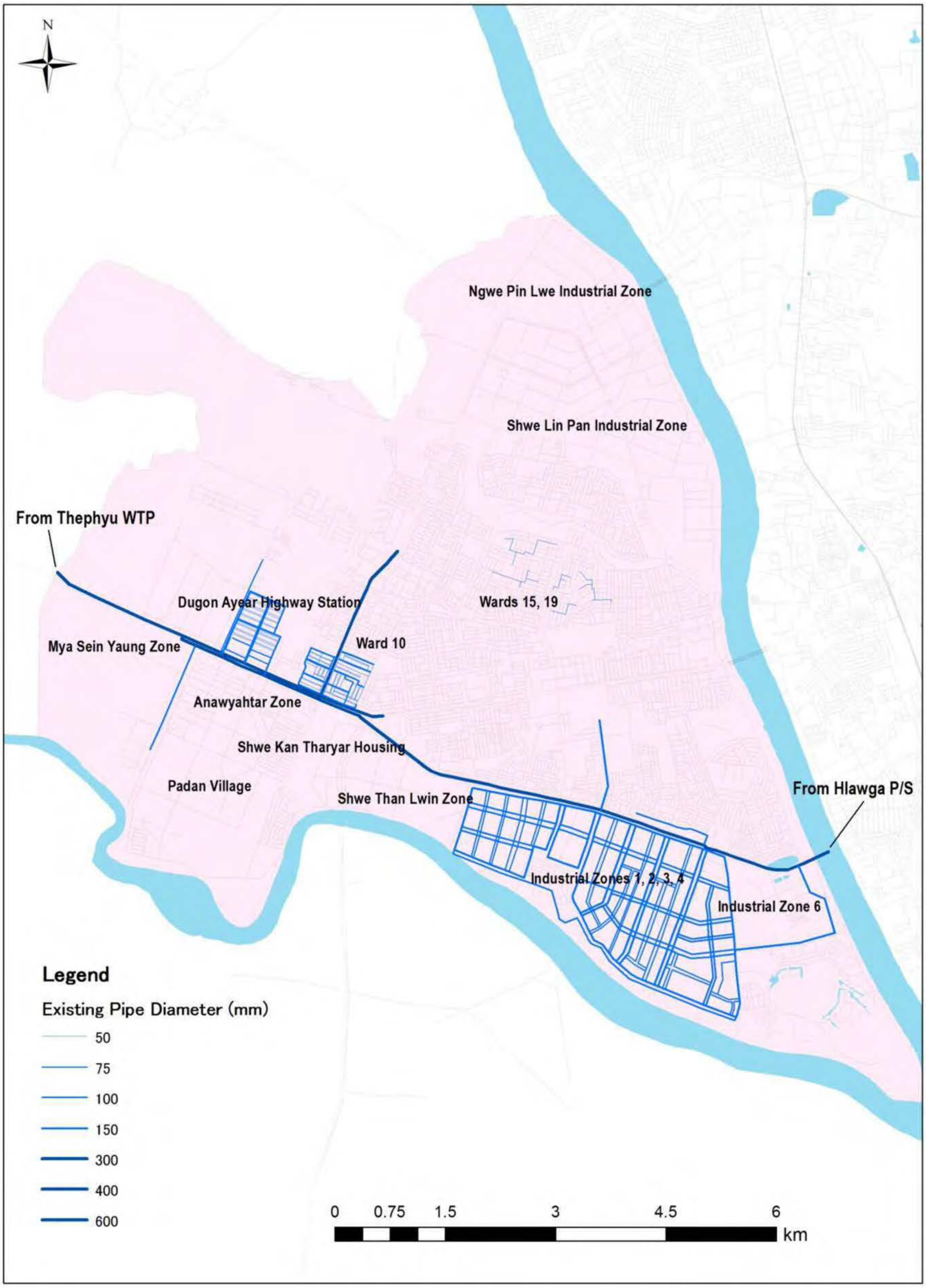
Table 6-1 Main Features in 2014, 2025 and 2040

Year	Population	Coverage rate	Served Population	Daily Max. demand	Daily Max. demand
	1,000	%	1,000	mld	MGD
2014	688	3	21	5	1
2025	769	45	346	85	19
2040	962	75	722	221	49

Source: JICA Study Team

6.1.3 Water Amount for Distribution

In 2025 and 2040, water will be conveyed to the planned SR in this Zone from Kokkowa river system. Pumps at planned WTP in Kokkowa will be used to convey entire 20 MGD of water to Zone 9 SR through planned transmission pipelines.



Source: JICA Study Team

Figure 6-1 Existing Water Supply Pipes in Hlaing Tharyar (Zone 9)

6.2 Service Reservoir

6.2.1 Zone 9 SR and Distribution Pump

A SR is planned in Zone 9 to receive water conveyed from Kokkowa WTP. The required volume depends on diurnal demand pattern; however, due to lack of accurate demand pattern data, 8 hours demand volume is recommended. It is planned to be constructed at the location of existing Park which is owned by the YCDC. SR is planned as underground structure based on request of YCDC and the top of SR will be used as park and landscape.

[Facilities Specifications]

- Park in the area
- Structure: Underground RC made with flow guiding walls
- Distribution Pump Room: RC made
- Inlet Valve: Motor operated valve, controlled by SCADA
- Outlet Valve: Motor operated valve, Amount of outflows is controlled by SCADA

[Volume or Capacity]

- For Zone Demand: Daily Maximum Demand x (8 hours/ 24 hours)
- For Transmission Demand: 1 hour retention capacity
- Volume is set as 12.2 MG including Relay pump tank (Two cases have been considered from following the Table).

Table 6-2 Considered Capacity of Zone 9 SR

Item	2025	2030	2035	2040	Remark
Zone 9 Water Distribution Amount (MGD)	19	26	35	49	*
Zone 1 Water Transmission Amount (MGD)	37	60	65	26	**
Other Zones Water Transmission Amount (MGD)		22	89	165	**
Necessary Distribution Reservoir Capacity (MG) (8 hrs* capacity of Zone 9 and 1 hr** capacity of Zone 1 and Other Zones)	7.8	12.1	18.1	24.3	
In case of Total 2 Tanks (MG)	**12.2**	12.2	24.4	24.4	1 Tank in 2025, 1 Tank in 2035
In case of Total 3 Tanks (MG)	8.1x2=16.2	16.2	24.3	24.4	2 Tanks in 2025, 1 Tank in 2035

Source: JICA Study Team

6.2.2 Distribution Pump

Distribution facilities consist of distribution pumps (see the following Table). The distribution pumps, horizontal double suction volute pump with VFD, are planned for controlling the pressure to set value.

Table 6-3 Outline of Distribution Facilities at Hlaing Tharyar SR

No.	Facility	Specification	Quantity	
			Duty	Standby
1	Inflow control valve	Motorized Flow Control Valve	1 unit	-
2	Outflow control valve	Motorized Flow Control Valve	1 unit	-
3	Distribution Pump (large)	76 m^3/ min x 40 m x 720 kw, Horizontal Double Suction Volute Pump with VFD	1 unit	1 unit
4	Distribution Pump (small)	32 m^3/ min x 40 m x 375 kw, Horizontal Double Suction Volute Pump with VFD	1 unit	1 unit

Source: JICA Study Team

6.3 Distribution Main Pipes

For equitable distribution of water, the entire area of Zone 9 is divided into 27 DMAs (excluding the area of Golf course located in the south eastern corner of this Zone). Also, one demand point is considered for Kyimyindine TS assuming that water to the part of this township lying in west of Hlaing River will be supplied water from Zone 9 SR till 2025. The DMAs have been delineated considering the topography, roads, number of customers, and administrative boundaries. For easy operation of distribution, the size of DMAs has been kept large initially.

The water demand has been allocated to each DMA of Zone 9, for both 2025 and 2040 considering the total demand as 19 MGD and 49 MGD in these years, respectively. It is reported in the MP that about 17 % of water is consumed by the industrial sector, the remaining 83 % of water is consumed by domestic, department and expatriates. It is expected that in 2025, all the wards in the central part will accommodate increasing population till it is saturated (to about 80 households/ha) and in 2040, the wards located in the peri-urban areas will accommodate increased population. Industrial demand is allocated considering existing level of average industrial demand. Considering the above key points, demand has been allocated to each DMA.

Network hydraulic analysis has been carried out using EPANET2 to decide the suitable diameter of distribution main pipes that will enable water supply at appropriate pressures to DMA inlet. The minimum water pressure at the DMA inlet is considered as 18 m. The results of network analysis for year 2025 and 2040 are shown in Figures 6-2 and 6-3, respectively.

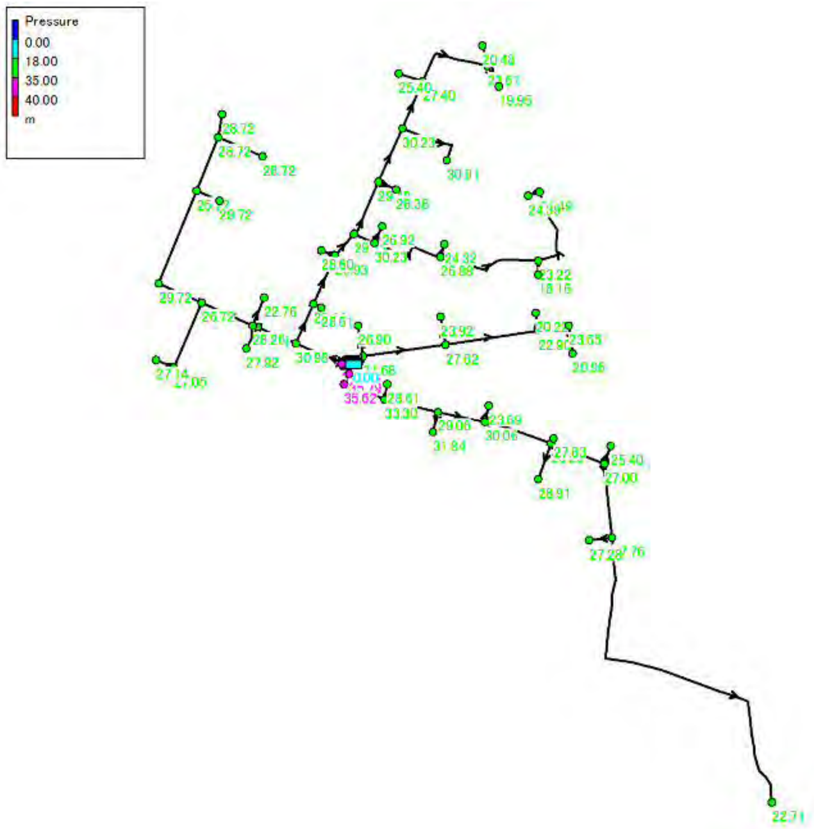
As a result of the hydraulic analysis, distribution main pipe network for the demands of 2025 and 2040 have been decided. The length and diameter of proposed pipes in this plan is given in the following Table and the alignment of proposed pipes is shown in Figures 6-4 and 6-5, respectively. Subsequently, the following table shows the pipes length of distribution main in 2025 and in 2040.

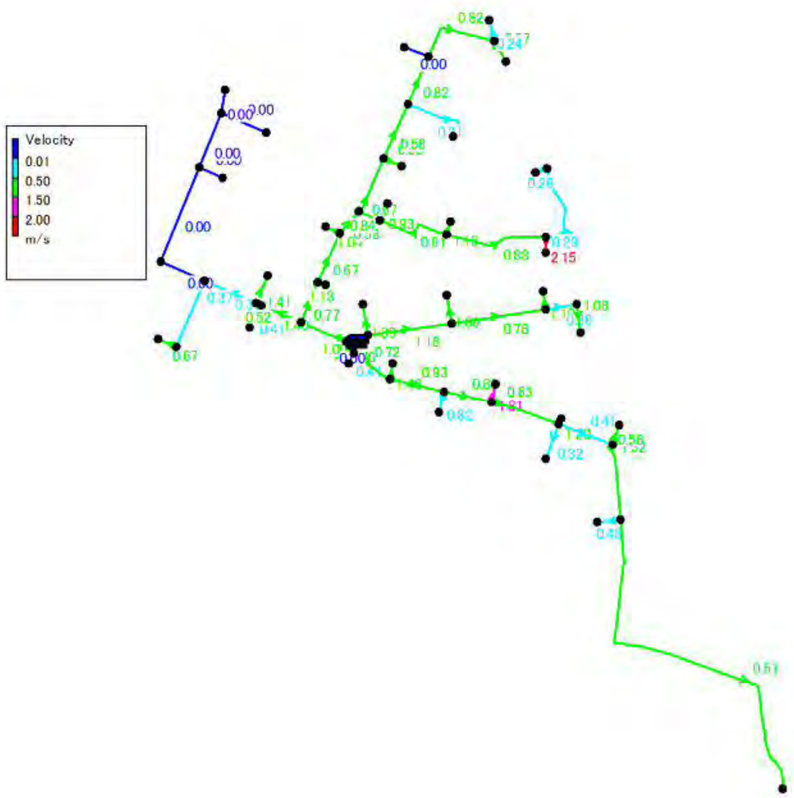
Existing distribution pipes are not suitable in terms of capacity for required demand in 2025 and 2040 and therefore are not used among the planned distribution pipes and hence new pipes are planned. The diameter of planned distribution main pipes considering demand of 2025 is 800 mm where currently 300 mm pipe exists and diameter of planned pipe is 1000 mm where 400 mm pipe exists. Existing 400 mm and 600 mm pipes are concrete pipe and will be abandoned. Existing 300 mm pipe is PVC pipe installed in 2002 and is planned to be used as distribution pipes.

Table 6-4 Length of Distribution Main Pipe for Zone 9 in 2025 and in 2040

Pipe Diameter (mm)	Total Length of Existing Pipe to be Abandoned (m)	Length of Existing Pipe to be Used (m)	New Pipe Length in 2025 (m)	Additional New Pipe for 2040 Demand (m)	Notes
300			13,691	921	Existing 300 mm pipe is PVC pipe installed in 2002 which is not sufficient to be used as distribution mains and will be used as distribution pipe.
400	1,095	**0**	4,164	2,278	Existing pipe is concrete pipe and will be abandoned.
450			6,743	1,519	This pipe is only for 2025 as Kyimyindine is assumed to receive water from other side after 2025.
500			7,894	1,735	
600	6,086	**0**	1,376	3,329	Existing pipe is concrete pipe and will be abandoned.
700			399	2,894	
800			4,545	5,897	
900					
1000			4,180	1,849	
1200					
1400				883	
2000			198		
Total	**7,181**	**0**	**43,190**	**21,305**	

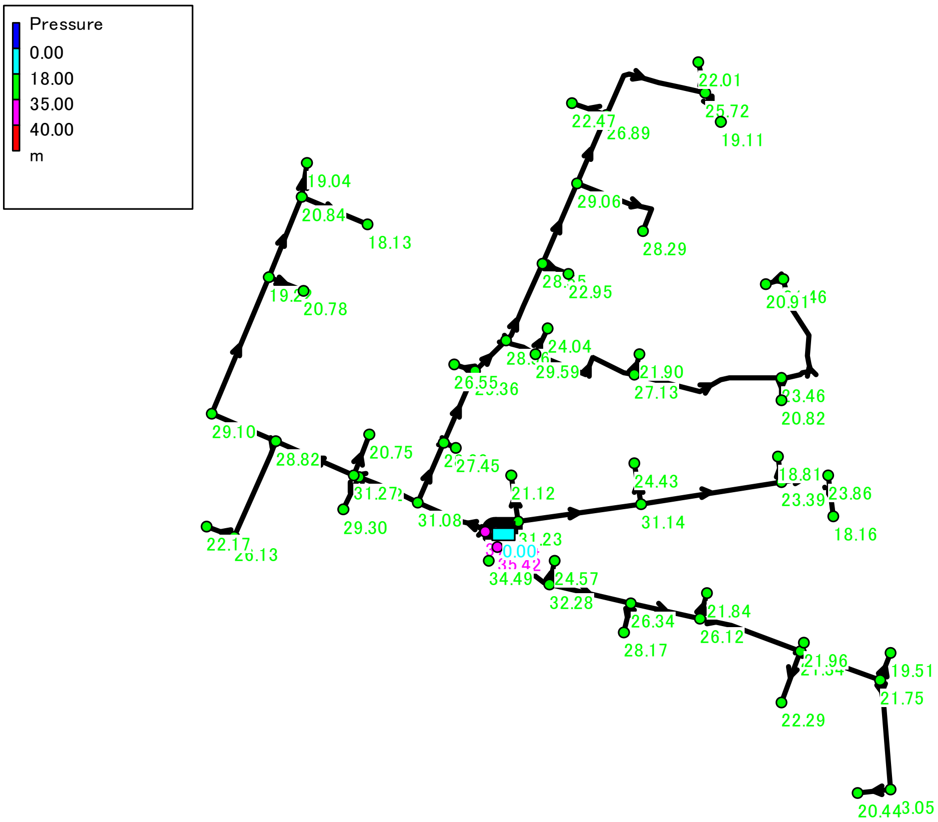
Source: JICA Study Team

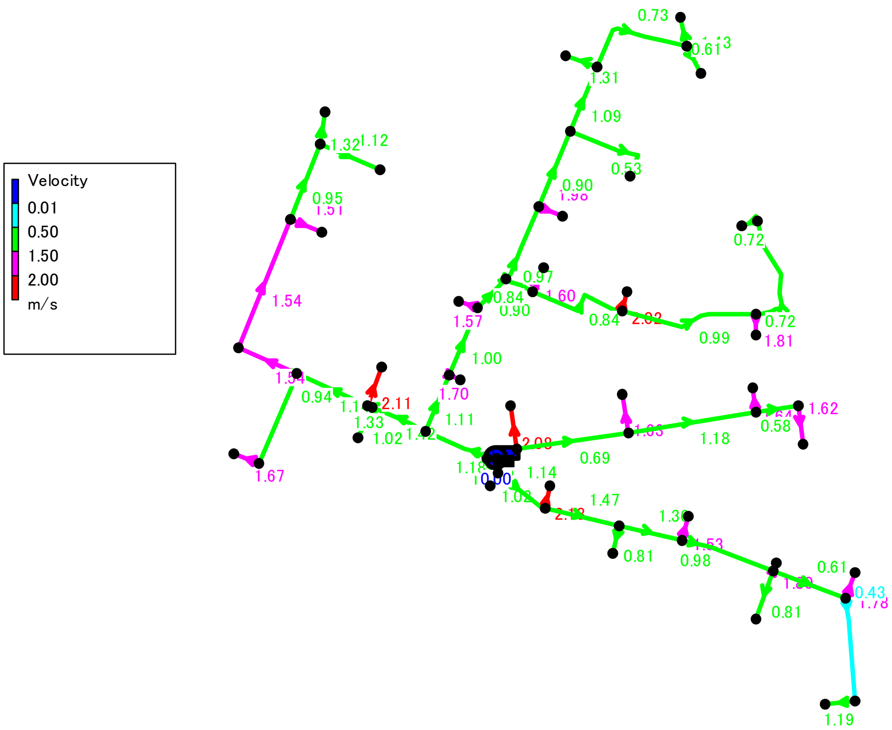




Source: JICA Study Team

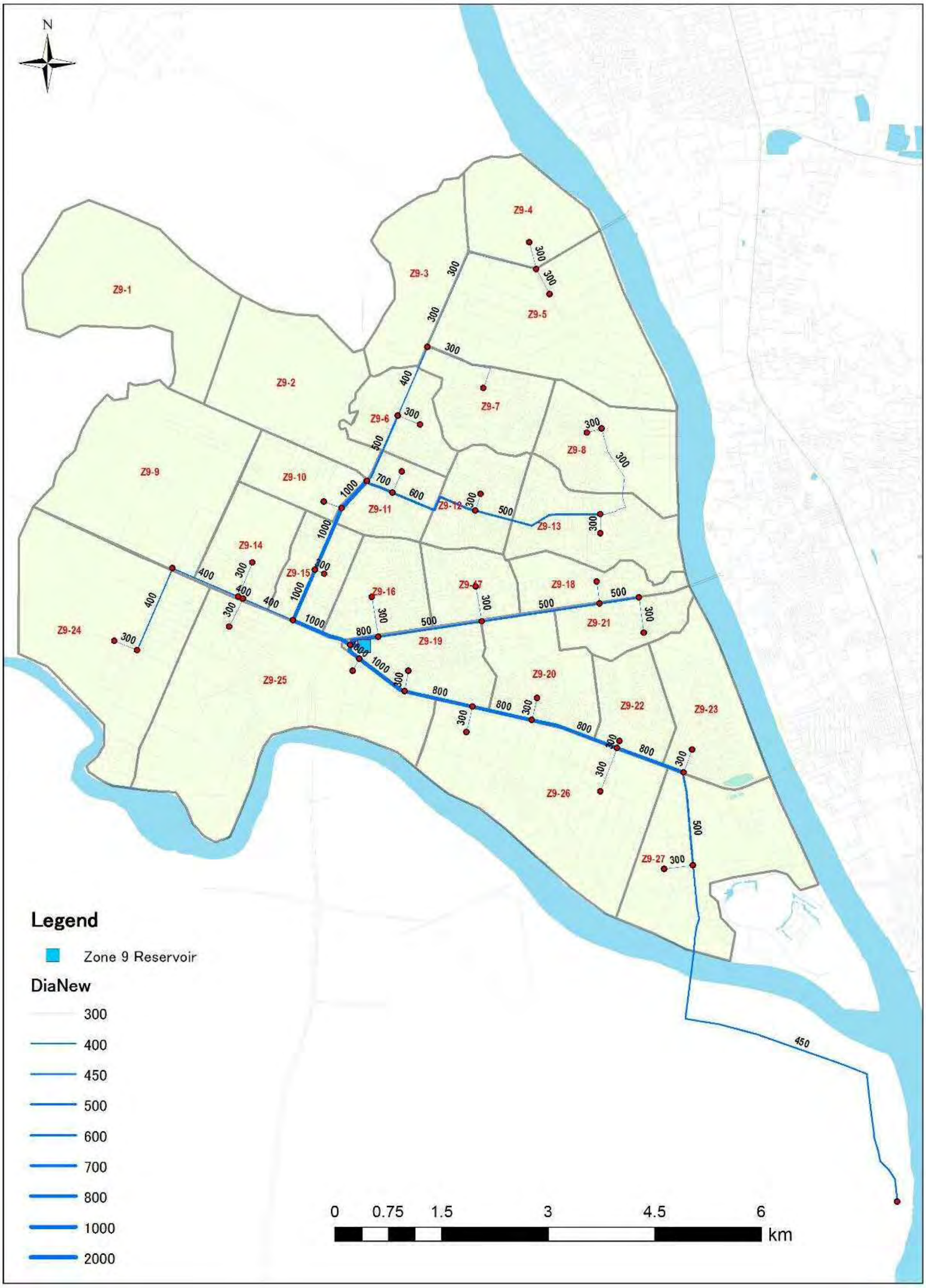
Figure 6-2 Simulated Network Analysis Result for Demand of 2025 in Zone 9





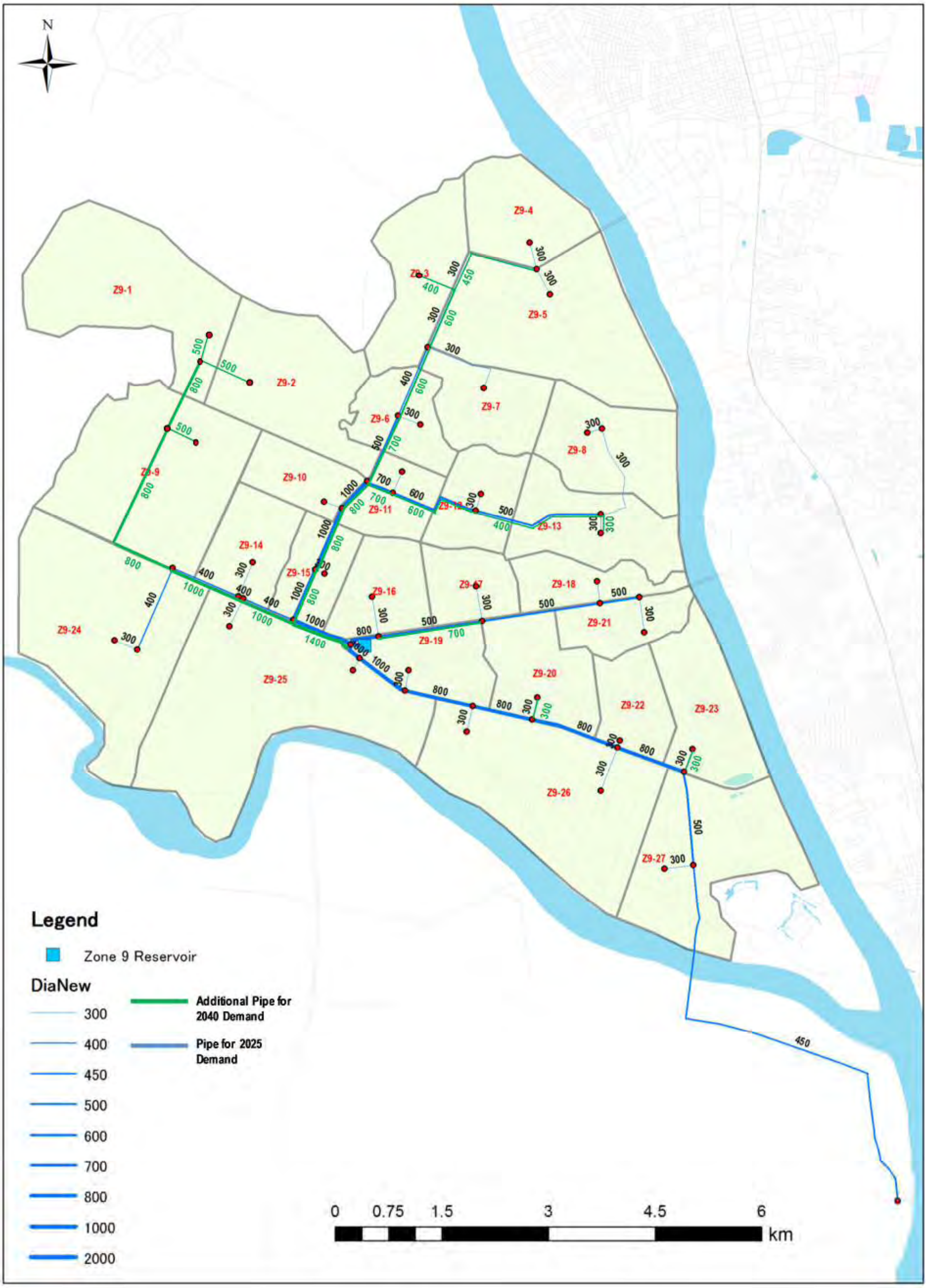
Source: JICA Study Team

Figure 6-3 Simulated Network Analysis Result for Demand of 2040 in Zone 9



Source: JICA Study Team

Figure 6-4 Distribution Main Pipe for Zone 9 in 2025



Source: JICA Study Team

Figure 6-5 Distribution Main Pipe for Zone 9 in 2040

6.4 Distribution Pipes

6.4.1 DMA and Distribution Pipe

(1) DMA Plan

DMA is planned within Zone 9 for equitable water distribution by monitoring and controlling inflow to each DMA. The planned DMA can also be utilized to monitor NRW for each DMA by comparing inflow amount with total consumed amount. The smaller the DMA size, the more equal is water distribution to each DMA. However, to start with an attempt towards efficient distribution, considering ease of distribution operation, larger DMA size has been considered at initial stage.

Boundaries of DMA are planned considering the ground elevation, natural drains, roads, number of customers and administrative boundaries for ease in operation and to have equitable distribution. Initially, DMA is planned to have on average about 3,435 connections for Zone 9 as shown in the following Table.

Table 6-5 DMA Planning in Zone 9 by 2025

Demand in 2025 (m^3/d) and (MGD)	Service population in 2025 (1000 person)	Estimated No. of Service connection *	No. of Connection/DMA
86,374 m^3/d, (19 MGD)	346	79,000	3,435

Number of DMA	Bulk Meter with Chamber	Household survey & Data Handling	Installation of Service Connection with Customer Meter
	Qty. (Nos.)	Qty. (Nos.)	Qty. (Nos.)
23	23	79,000	79,000

Note: * 4.38 person/connection
Source: JICA Study Team

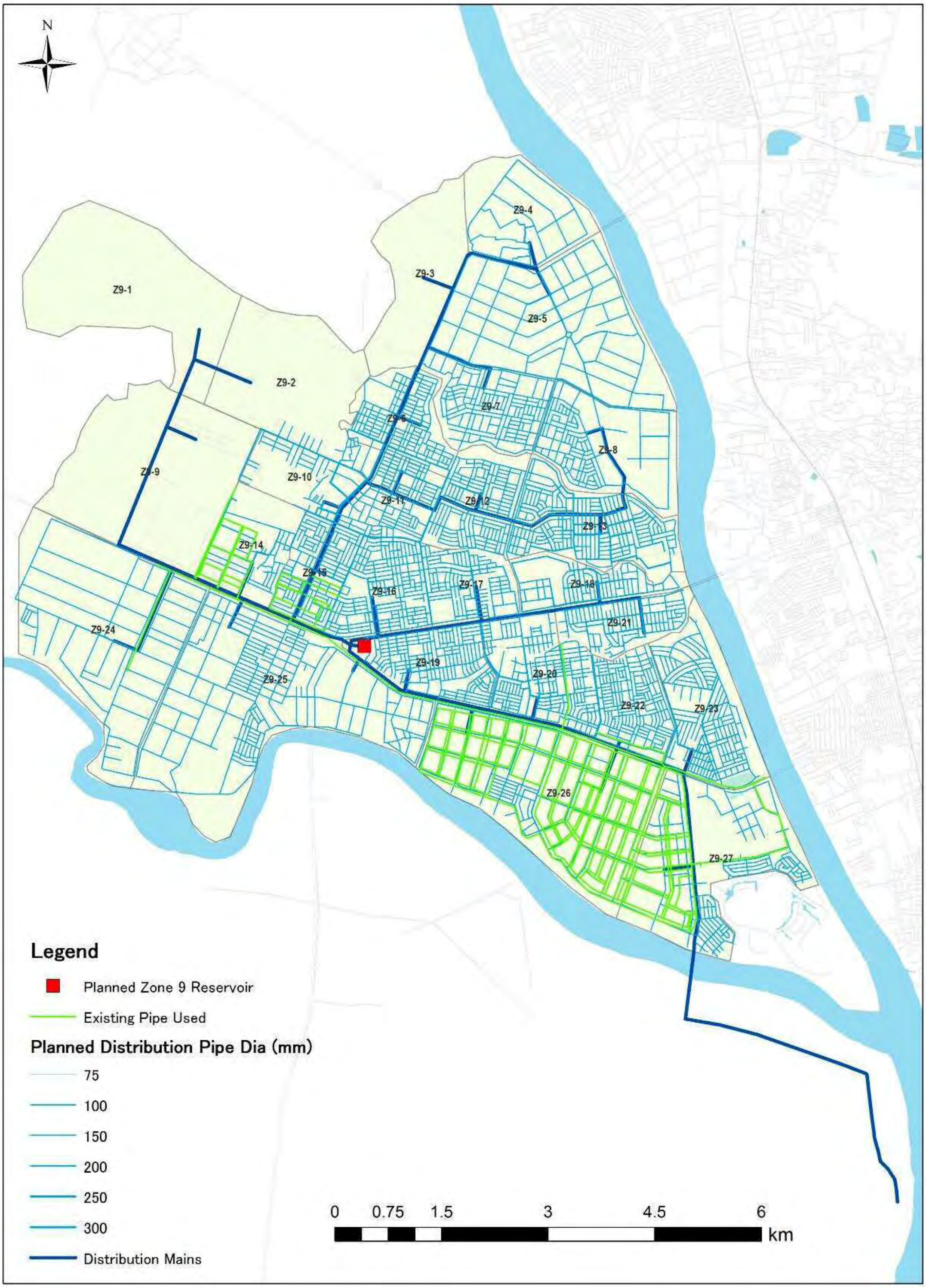
(2) Distribution Pipe within DMAs for Zone 9

Length of distribution pipe is planned as shown below based on the network analysis. Distribution pipe layout is shown below together with DMA. Use of existing pipes that are new is considered along with new pipes planned in this Study as indicated in the following Table and shown as green lines in the Figure below.

Table 6-6 Length of Distribution Pipe for Zone 9

Pipe Diameter (mm)	Total Length of Existing Pipe to be Abandoned (m)	Length of Existing Pipe to be Used (m)	New Pipe Length (m)	Total Length of Proposed Distribution Pipe (m)
	(1)	(2)	(3)	(2+3)
50	27,179			
75	0	31,395		31,395
100	0	35,327	577,513	612,840
150	0	32,540	33,834	66,374
200			17,821	17,821
250			6,482	6,482
300		9,570	1,256	10,826
Total	27,179	108,832	636,906	745,738

Source: JICA Study Team



Source: JICA Study Team

Figure 6-6 DMA and Distribution Pipe for Zone 9

6.4.2 SCADA

Refer to 4.4.11 in Chapter 4.

The flow and operation status to be monitored by SCADA at different locations are listed in the following Table.

Table 6-7 Monitoring Items by SCADA for Zone 9

Item	Contents	Quantity
Central monitoring system	RPS in Zone 9 SR	1 unit
Zone 9 SR/RPS	Water level meter Inlet flow meter from Kokkowa WTP Outlet flow meter of Transmission Outlet flow meter of Distribution Open rate of inlet valve from Kokkowa WTP Open rate of outlet valve of Transmission Open rate of outlet valve of Distribution Pump Status Water pressure of Transmission Water pressure of Distribution	1 unit 1 unit 1 unit 1 unit 1 unit 1 unit 1 unit 1 set 1 unit 1 unit
Inlet pipe of DMA	Flow meter and Water pressure	23 DMA

Source: JICA Study Team