Final Report

Feasibility Study of Chattogram Metropolitan Sewerage Project for Fatehabad Component

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Abbreviation

A2O	Anaerobic-Anoxic-Aerobic Process
ACI	American Concrete Institute
ADB	Asia Development Bank
AFD	Agence Francaise de Developpement
AIT	Advanced Income Tax
ANSI	American National Standards Institute
ASTM	American Society of Testing Materials
ATP	Affordability to Pay
AWWA	American Water Works Association
B/C	Benefit/Cost
BBS	Bangladesh Bureau of Statistics
BDT	Bangladeshi Taka
BOD	Biological Oxygen Demand
BOQ	Bills of Quantities
BPDB	Bangladesh Power Development Board
BS	British Standards
BWDB	Bangladesh Water Development Board
CAPEX	Capital Expenditure
CAS	Conventional Activated Sludge Process
CBD	Central Business District
CCC	Chattogram City Corporation
CCTV	Closed Circuit Television
CDA	Chattogram Development Authority
CDP	City Development Plan
CIF	Cost, Insurance and Freight
CMMP	Chittagong Metropolitan Master Plan (2008)
COD	Chemical Oxygen Demand
CPA	Chattogram Port Authority
CWASA	Chattogram Water Supply and Sewerage Authority
CWSISP	Chattogram Water Supply Improvement & Sanitation Project
DAC	Development Assistance Committee
DAP	Detailed Area Plan
DDC	Development Design Consultants limited
DOE	Department of Environment
DPHE	Department of Public Health Engineering
DPP	Development Project Proposal
DPZ	Detailed Planning Zone

DTW	Deep Tube Well
DWASA	Dhaka Water Supply and Sewerage Authority
DWFI	Dry Weather Flow Interceptor
ECC	Environmental Compliance Certificate
ECR	Effluent Conservation Rules
EDCF	Economic Development Cooperation Fund
EHS	Environment, Health and Safety
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMA	Environmental Management Act
EN	European code
ESF	Environmental and Social Framework
ESIA	Environmental and Social Impact Assessment
ESMP	Environment and Social Management Plan
F/M	Food to Microorganism
F/S	Feasibility Study
FGD	Focus Group Discussions
FIRR	Financial Internal Rate of Return
FOB	Free on Board
FSM	Faecal Sludge Management
GDP	Gross Domestic Product
GIS	Geographic Information System
GOB	Government of Bangladesh
Gpcd	Gram per Capita per Day
GRP	Glass-Fiber Reinforced Plastic
GWI	Groundwater Infiltration
H/C	Household Connection
HDPE	High Density Polyethylene
HRT	Hydraulic Retention Time
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical & Electronics Engineers
IEIA	Initial Environmental Impact Assessment
IESIA	Initial Environmental & Social Impact Assessment
IMF	International Monetary Fund
IRP	Iron Removal Plant
IRR	Internal Rate of Return
ISA	Instrument Society of America
ISO	International Organization for Standardization
IWA	International Water Association
JICA	Japan International Cooperation Agency
KDI	Korea Development Institute
KEPZ	Karnaphuli Export Processing Zone
KEXIM	The Export-Import Bank of Korea

KRW	Korean Won
L/A	Loan Agreement
LGD	Local Government Division
LGED	Local Government Engineering Department
Lpcd	Liter per Capita per Day
M/D	Man-Dates
M/M	Man-Months
MDB	Multilateral Development Bank
MLD	Million Litres per Day
MLE	Modified Ludzack-Ettinger Process
MLSS	Mixed Liquor Suspended Solids
MP	Master Plan
NEC	National Electrical Code
NEMA	National Electrical Manufactures Association
NFPA	National Fire Protection Association
NGO	Non-Governmental Organization
NHA	National Housing Authority
NOC	No Objection Certificate
NPV	Net Present Value
O&M	Operation & Maintenance
OD	Oxidation Ditch
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
OPEX	Operating Expenditure
PCR	Project Completion Report
PE	Population Equivalent
PEA	Project Executing Agency
PESSCM-1	Project for Establishment of Sewerage System in Chattogram Metropolitan (Phase-1)
PI	Profitability Index
PIU	Project Implementation Unit
PMU	Project Management Unit
PPA	Project Preparation Assistance
PPP	Public Private Partnership
PS	Pumping Station
PV	Present Value
PWD	Public Works Department
R/C	Revenue/Cost Ratio
RAP	Resettlement Action Plan
RAS	Return Activated Sludge
R&R	Roles & Responsibilities
RTK	Real Time Kinematic
SAS	Surplus Activated Sludge
SBR	Sequencing Batch Reactor

SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goal
SE	Superintending Engineer
SPT	Standard Penetration Test
SRT	Sludge Retention Time
SS	Suspended Solid
STP	Sewage Treatment Plant
TKN	Total Kjeldahl Nitrogen
T-N	Total Nitrogen
TOR	Terms of Reference
T-P	Total Phosphorus
TSS	Total Suspended Solids
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VAT	Value Added Tax
WB	World Bank
WSSP	Water Supply and Sanitation Programme
WTP	Water Treatment Plant

1 Introduction

1.1 Introduction

1.1.1 Introduction

The Consultant Dongsung Engineering, in association with Kunhwa Engineering & Consulting, has signed the contract on 1st September 2022 with the KEXIM on the consultancy assignment tilted "Feasibility Study of Chattogram Metropolitan Sewerage Project for Fatehabad Component" hereafter referred to as "the Project", which is one of the sub-projects under the "Sanitation & Drainage Improvement Strategy and Master Plan for the City of Chattogram". The execution agency the project is the Chattogram Water Supply and Sewerage Authority (CWASA).

The objective of the Final Report is to present the conclusion of the feasibility study, including the planning framework, technical feasibility and preliminary design, project cost estimate, economic & financial feasibility analysis, initial environmental & social impact assessment based on the options have been agreed during the feasibility study.

1.1.2 Project Background

Chattogram is the second largest city in Bangladesh and its premier sea port and industrialized city and one of the fastest growing cities in Bangladesh. Almost all of Bangladesh's industrial exports originate in Chattogram and majority percent of Bangladesh's exports and imports are routed through the port of Chattogram. Chattogram's population has been increasing continuously and at a very high rate since Bangladesh's independence. The rapid and haphazard urbanization is exerting immense pressure on Chattogram's urban environment, and city authorities are struggling to deal with pressing environment issues such as wastewater management.

Chattogram though shortly will have satisfactory water supply situation, there is a lack of sanitation infrastructures within Chattogram, and no part of the city is actually connected to any form of sewerage system, hence the majority of the population typically utilizes septic tanks and pour-flush sanitation systems. Septic tank effluent disposal has generally been very sporadic and septic sludge has not been collected on a regular basis. Currently there are no sludge treatment facilities as well. As Chattogram is surrounded by rivers, karnaphuli & Halda and inter-connected with canals/khals, the vast majority part of domestic and industrial wastewater enters Chattogram's surface waters becoming partly cause of pollution. Besides, the City's sanitation infrastructure needs to be established rapidly to cope with the rapidly swelling population – currently estimated at 2.9 million and expected to reach 3.7 million by 2030.

The Government of Bangladesh prepared a policy framework to provide 100% sanitation facilities to its citizen by 2015. Mandate of CWASA, second biggest wings of the government in the water sector is to provide necessary services for residents of the Chattogram to collect, treat and dispose safely the sewage generating or to be generated within its service area. The Government of Bangladesh requested EDCF Loan for the project to improve public health and sanitation through the establishment of sewage treatment infrastructure in Fatehabad. During the Korea-Bangladesh EDCF policy consultation ('21.04), this project was listed as a '21-'25 mid-term candidate project. Korean government's EDCF (Economic Development Cooperation Fund) loan will be used to expand the sewerage system in Chattogram City for development and improvement of environmental infrastructures.

1.1.3 Purpose of the Project

The purpose of the project is as following;

- Construction of sewage infrastructure to achieve Bangladesh national vision
  - Improvement of Sewage Service coverage in accordance with the Perspective Plan of Bangladesh (2021 ~2041)
- To improve living standard and sanitation of inhabitants in the project area
  - Improvement of hygiene and sanitary condition of the Chattogram City, Hathajari Upazila and Raozan Upazila
  - Improvement of river water quality and restoration of the ecosystem
- To promote cooperation and establishment of human network between Korea and Bangladesh
  - Increasing economic cooperation between the two countries
  - Training and O&M support for the technology transfer
- To promote the sustainable economic development of the Bangladesh
- Korea, as one of OECD countries, contributes to infrastructure development and welfare improvement of Bangladesh

1.2 Project Scope

The following conditions are considered preferentially to maximize the effects of the project.

- To place on the priority to improve the current sanitation situation of Chattogram City, Hathajari Upazila and Raozan Upazila.
- To set up the foundation of sewerage system of the project areas considering the future expansion.

Table 1-1 Project Scope

Category	Scope
Project Area	• 7 wards in Catchment-3 of Chattogram City Corporation • Hathazari Upazila & Raozan Upazila
Sewerage System	• Sewage Treatment Plant, Q=60,000m^3/d (Daily Average) • Faecal Sludge Treatment Plant, Q=100m^3/d • Sanitary Sewer, D200~1,600mm, L=58.3km • Household Connection, 10,000nos. • Operation & Maintenance Vehicles (Faecal sludge collection vehicles and O&M Vehicles, etc.)
Capacity Building	• Commissioning & Training • O&M Support after Construction Completion (2 years)
Consulting Service	• Detailed Design & Bidding Support • Construction Supervision

Note) The project scope is subject to change in according to the consultation between KEXIM and the project executing agency (CWASA).

1.2.1 Specific Request from PEA

There is specific request from PEA regarding household connection financing support, reserve facilities for sludge treatment, reduction of O&M cost. The Consultant have discussed with KEXIM and PEA during feasibility study, it is summarized as below.

Table 1-2 Specific Request from PEA

Category	Request from PEA	Review
Household Connection Financing	• Insufficient financial resources of GOB for household connection construction, financing support from EDCF loan is requested.	• Household connection is planned as GOB portion in FS, the procurement method will be decided to select the contractor during the detailed design stage.
Reserve Facilities for Sludge Treatment	• Reserve facilities for sludge treatment such as sludge drying bed, faecal sludge treatment plant, sludge cake storage facility can be an option to reduce the O&M cost of STP in dry season.	• Reserve facilities for sludge treatment are not included in the project scope because the construction cost is about 12 US$ million, so the initial investment cost is excessive.
Reduction of O&M cost	• O&M cost is a burden to PEA after project completion.	• Energy efficient equipments & power control system are considered • Biogas power generation (Phase 2) & Solar power generation (Phase 1) is planned as a renewable energy source for energy self-sufficient plant.

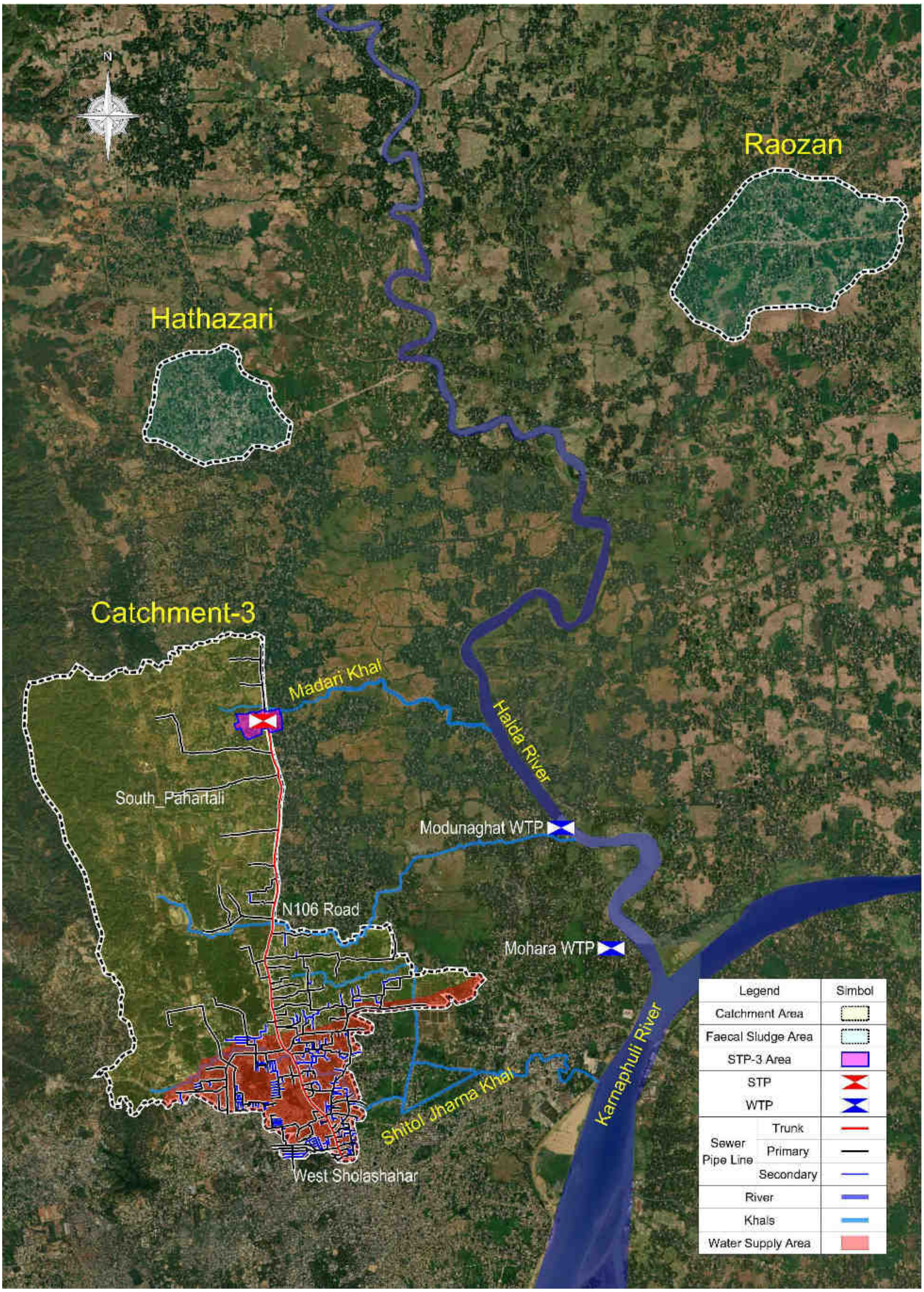


Figure 1-1 Layout of the Project

1.3 Planning Framework

Planning framework is a very important step in establishing a plan for the expansion of sewerage system by carefully estimating the future population, Sewage Service areas, and wastewater generation. Furthermore, appropriate facilities should be determined to avoid over-investment or insufficient facilities due to over-planning or under-planning.

Table 1-3 Planning Framework

Category			Unit	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Population	Projected Population		pers	388,585	473,904	598,614	810,008	1,048,808
	Sewage Service Coverage		%	-	60.0	65.0	72.5	80.0
	Sewage Service Population		pers	-	284,342	389,099	587,254	839,046
Unit Load	Unit Domestic Water Consumption		Lpcd	120	120	120	120	120
	Wastewater Generation Ratio		%	90.0	90.0	90.0	90.0	90.0
	Peak Factor	Daily Avg.	-	1.00	1.00	1.00	1.00	1.00
		Daily Max.	-	1.25	1.25	1.25	1.25	1.25
		Hourly Max.	-	1.875	1.875	1.875	1.875	1.875
	Unit Domestic Wastewater Generation	Daily Avg.	Lpcd	108	108	108	108	108
		Daily Max.	Lpcd	135	135	135	135	135
		Hourly Max.	Lpcd	162	162	162	162	162
	Non-Domestic Wastewater Generation Ratio		%	15	15	15	15	15
	Infiltration Ratio		%	15	15	15	15	15
Wastewater Generation	Domestic Wastewater	Daily Avg.	m^3/d	-	30,709	42,023	63,423	90,617
		Daily Max.	m^3/d	-	38,386	52,528	79,279	113,271
		Hourly Max.	m^3/d	-	57,721	78,987	119,213	170,326
	Non-Domestic Wastewater	Daily Avg.	m^3/d	-	4,606	6,303	9,513	135,925
		Daily Max.	m^3/d	-	5,758	7,879	10,940	15,632
		Hourly Max.	m^3/d	-	8,658	11,848	17,882	25,549
	Infiltration	Daily Avg.	m^3/d	-	5,297	7,248	10,940	15,632
		Daily Max.	m^3/d	-	5,297	7,248	10,940	15,632
		Hourly Max.	m^3/d	-	5,297	7,248	10,940	15,632
	Total	Daily Avg.	m^3/d	-	40,612	55,574	83,876	119,842
		Daily Max.	m^3/d	-	49,441	67,655	102,111	145,894
		Hourly Max.	m^3/d	-	71,676	98,083	148,035	211,507

1.4 Technical Feasibility Analysis

1.4.1 Sewage Treatment Plant

1.4.1.1 Phase Plan

This project plans to construct a sewage treatment facility with a capacity of 60,000m^3/d to treat the wastewater generated in the project area for the Phase 1 in target year 2040. Phase plan of the second and third phase is also established to treat the wastewater for the final target year 2070.

- Phase 1: Construction of STP with a capacity of 60,000m^3/d
- Phase 2: Expansion of STP with a capacity of 30,000m^3/d
- Phase 3: Expansion of STP with a capacity of 30,000m^3/d

Table 1-4 Phase Plan of Sewage Treatment Plant (m^3/d)

Category		2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Wastewater Generation (Daily Average)		40,612	55,574	83,876	119,842
STP Capacity	Daily Avg.	60,000	60,000	90,000	120,000
	Daily Max.	75,000	75,000	115,000	150,000
Expansion Capacity		-	-	30,000	30,000
Balance		19,388	4,426	6,124	158

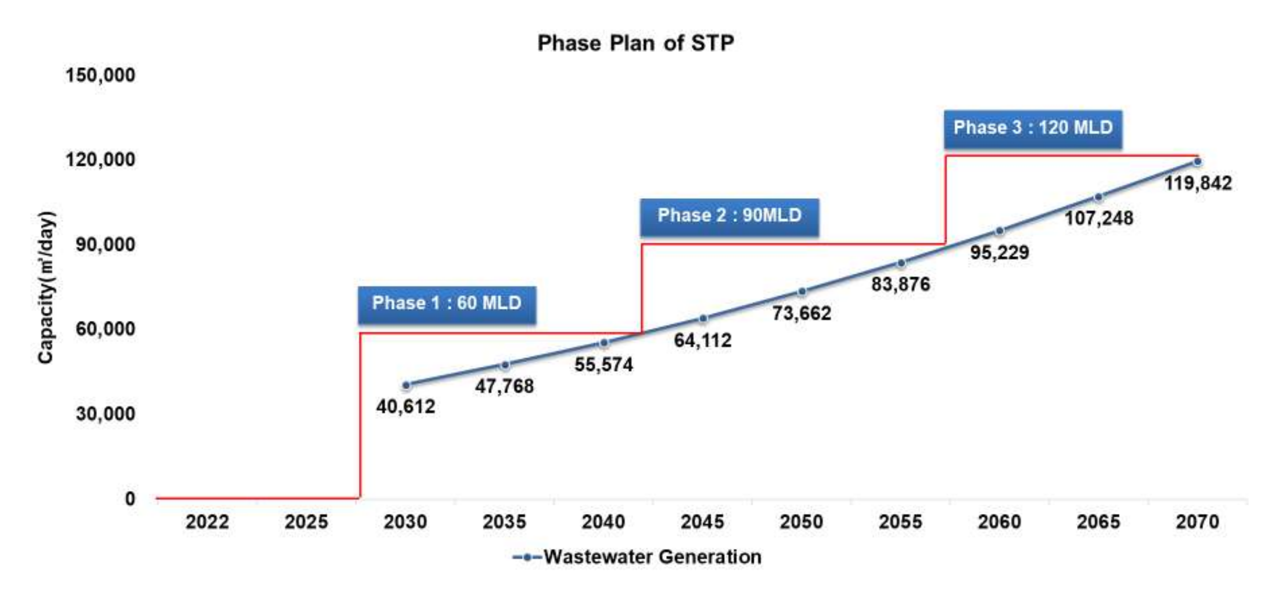


Figure 1-2 Phase Plan of Sewage Treatment Plant

1.4.1.2 Influent & Effluent Quality

1.4.1.2.1 Influent Quality

The Influent Quality is a design factor that serves as a standard for sewage treatment facility planning, such as treatment method and efficiency, and is calculated by considering the unit load within the Sewage Service area. In this feasibility study, it is planned in consideration of on-going sewerage projects, related master plans and water quality survey.

Table 1-5 Influent Quality (mg/L)

Category	Catchment 1 (PESSCM 1)	Catchment 5	Catchment 2&4	Catchment 3 (This project)
BOD	340	302	310	322
COD	756	605	-	644
SS	454	363	370	386
T-N	72	30	31	76
T-P	14	4	5	15

1.4.1.2.2 Target Effluent Quality

The Bangladesh Department of Environment (DoE) established the standard Sewerage discharge in 1997 and revised the standard in March 2023. Bangladesh mainly have regulated the removal of SS and BOD, COD contained in the wastewater and the discharge standards have been strengthened recently to remove T-N and T-P to prevent eutrophication in the public water body.

In the Catchment-1 project, which is under construction, a target effluent water quality was set up as stronger than the effluent standard. In this feasibility study, target effluent quality is set up in consultation with PMU as follows.

Table 1-6 Target Effluent Quality

Category	Unit	Standard Sewage Discharge		Target Effluent Quality	
		1997	2023	Catchment 1	Catchment 3
Temperature	℃	30	30	24	24
pH	-	-	6-9	6-9	6-9
BOD	mg/L	40	30	20	20
COD	mg/L	-	125	100	100
SS	mg/L	100	100	30	30
Oil and Grease	mg/L	-	10	-	-
NO3-N	mg/L	250	50	40 as T-N	40 as T-N
PO4-P	mg/L	35	15	10 as T-P	10 as T-P
Coliform	CFU/100mL	1,000	1,000	1,000	1,000

*Source: Standard Sewerage discharge in the Environment Conservation Rules (1997&2023, DOE)

1.4.1.3 Sewage Treatment Process

1.4.1.3.1 Unit Process

Sewage treatment plant is a comprehensive facility combining unit processes, and consists of sewage treatment process and sludge treatment process. It is planned considering the function and purpose of each unit process.

- The target year for the inlet sewer to the STP is set up as 2070, so civil structure of pre-treatment & inlet pumping station is planned to cater the influent wastewater for the Phase 3 and mechanical, electrical/instrumentation facilities are planned for the Phase 1.
- A2O process is applied as advanced sewage treatment process to comply with the target effluent quality.
- Sludge stabilization process (anaerobic digestion) is planned to be introduced in Phase 2 in the consideration of the difficulty of O&M.
- Primary sedimentation tank is planned to be introduced in Phase 2 with the sludge stabilization process in the consideration of the high concentration of organics in the raw sludge
- Faecal sludge is planned to treat with sewage sludge after pre-treatment and thickening.
- Actual O&M status of Phase 1 should be analyzed when the expansion of Phase 2 & Phase 3 of sewage treatment plant is implemented.

Table 1-7 Unit Process of Sewage Treatment Plant

Facility		Function	Unit Process	Phase 1	Phase 2	Phase 3
Sewage Treatment Process	Pre-Treatment & Inlet Pumping Station	Pre-treatment, equalization, securing hydraulic stability	• Screen & grit removal • Inlet pumping station, Equalization tank	◎	◎	◎
	Primary Treatment	Reduce the load of the secondary treatment process	• Primary sedimentation tank	-	◎	◎
	Secondary Treatment	Removal of organic and nutrients	• Bioreactor, • Secondary sedimentation tank	◎	◎	◎
	Tertiary Treatment	Removal of pathogens	• Disinfection facility	◎	◎	◎
Sludge Treatment Process	Thickening	Reduction of the sludge volume	• Thickening facility	◎	◎	◎
	Stabilization	Reduction of the potential for odour generation and pathogens	• Anaerobic digestion	-	◎	◎
	Dewatering	Reduction of the sludge volume	• Dewatering facility	◎	◎	◎
Faecal Sludge Treatment Process	Pre-Treatment	Pre-treatment, equalization	• Screen & grit removal	◎	◎	◎
	Thickening	Weight reduction for load reduction in subsequent processes	• Thickening facility	◎	◎	◎
Odour control		Removal of odour from sewage & sludge treatment process	• Odour control facility	◎	◎	◎

1.4.1.3.2 Facility of Sewage Treatment Plant

This project plans to construct a sewage treatment facility with a capacity of 60,000m^3/d to treat the wastewater generated in the project area for the Phase 1 (2040). Phase plan of the second and third phase is also established to treat the wastewater for the final target year (2070).

Table 1-8 Facility of Sewage Treatment Plant

Facility			Item	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Sewage Treatment Process	Pre-Treatment		Type	Coarse Screen + Vortex Grit Removal + Fine Screen		
			Spec.	D4.1m x H3.3m x 2	D4.1m x H3.3m x 3	D4.1m x H3.3m x 4
	Inlet Pumping Station		Type	Submersible Mixed Flow Pump		
			Spec.	31.3m^3/min x 2(1) 15.6m^3/min x 2	31.3m^3/min x 4(2) 15.6m^3/min x 2	31.3m^3/min x 4(2) 15.6m^3/min x 4
	Primary Sedimentation Tank		Type	-	Rectangular Tank	
			Spec.	-	W7.0m x L35.0m x H3.5m x 3	W7.0m x L35.0 x H3.5m x 4
	Biological Reactor	Anaerobic Reactor	Type	Rectangular Tank		
			Spec.	W14.4m x L18.0m x H5.0m x 4	W14.4m x L18.0m x H5.0m x 6	W14.4m x L18.0m x H5.0m x 8
		Anoxic Reactor	Type	Rectangular Tank		
			Spec.	W14.4m x L22.0m x H5.0 x 4	W14.4m x L22.0m x H5.0 x 6	W14.4m x L22.0m x H5.0 x 8
		Aerobic Reactor	Type	Rectangular Tank		
			Spec.	W14.4m x L90.0 x H5.0m x 4	W14.4m x L90.0 x H5.0m x 6	W14.4m x L90.0 x H5.0m x 8
	Second Sedimentation Tank		Type	Gravity Circular Tank		
			Spec.	D30.0m x H3.5m x 4	D30.0m x H3.5m x 6	D30.0m x H3.5m x 8
	Disinfection Facility		Type	Chlorine Disinfection		
			Spec.	W3.0m x L25.0m x H3.0m x 4	W3.0m x L25.0m x H3.0m x 6	W3.0m x L25.0m x H3.0m x 8
Sludge Treatment Process	Thickening Facility		Type	Mechanical Thickening		
			Spec.	70m^3/hr x 4	70m^3/hr x 6	70m^3/hr x 8
	Stabilization Facility		Type	-	Anaerobic Mesophilic Digestion	
			Spec.	-	Acid Phase D7.0m x H10.0m x 3 Methane Phase D20.5m x H16.0m x 3	Acid Phase D7.0m x H10.0m x 4 Methane Phase D20.5m x H16.0m x 4
	Dewatering Facility		Type	Mechanical Dewatering		
			Spec.	30m^3/hr x 2	30m^3/hr x 3	30m^3/hr x 4
Faecal Sludge Treatment Process	Pre-treatment		Type	Comprehensive Pre-Treatment Equipment		
			Spec.	50m^3/hr x 2(1)	50m^3/hr x 2(1)	50m^3/hr x 2(1)
	Thickening Facility		Type	Mechanical Thickening		
			Spec.	3m^3/hr x 2	3m^3/hr x 2	3m^3/hr x 2
Odour Control Facility			Type	Multi Stage Wet Scrubber		
			Spec.	500m^3/min x 3	500m^3/min x 4	500m^3/min x 5

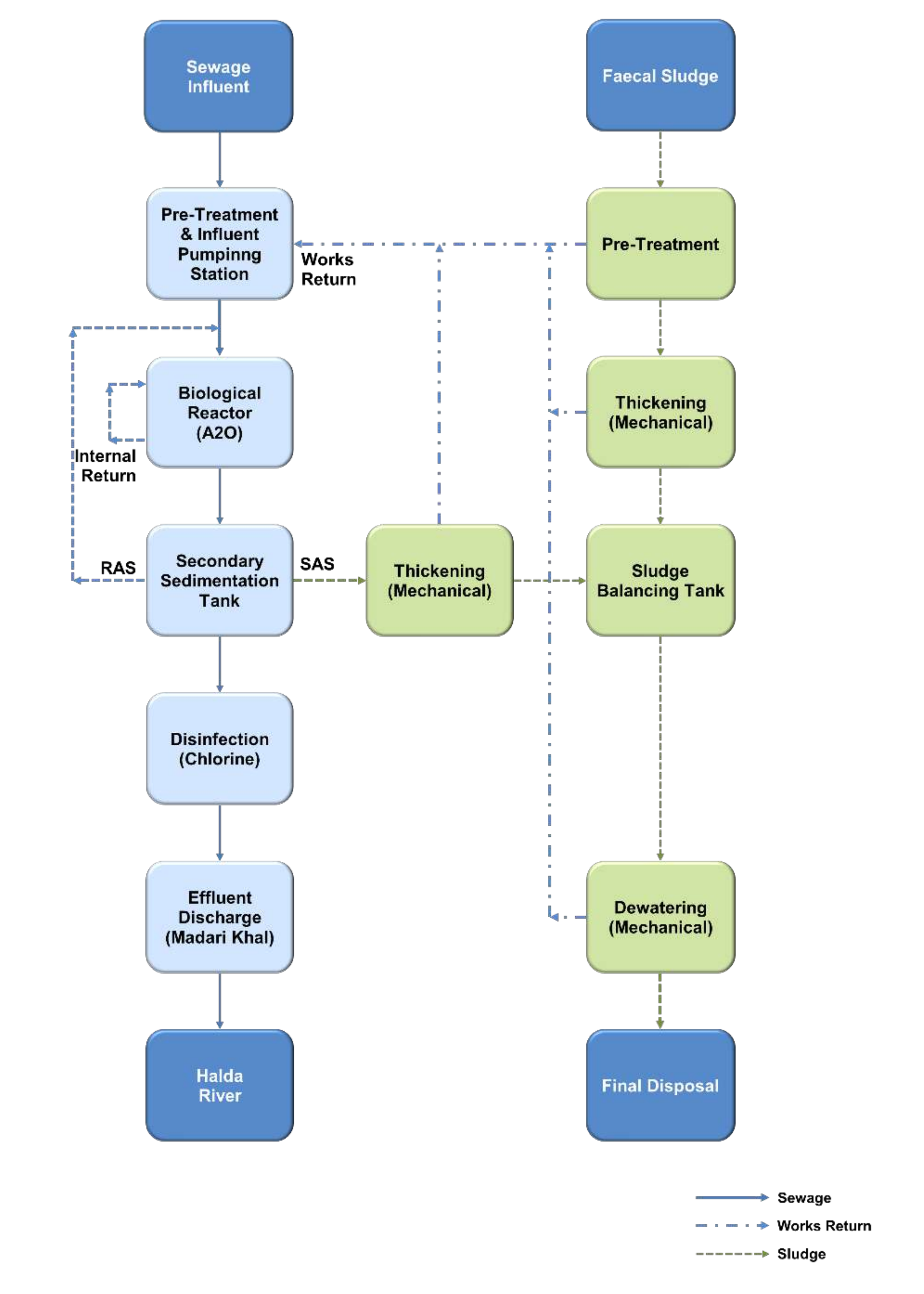


Figure 1-3 Process Flow Diagram of Phase 1

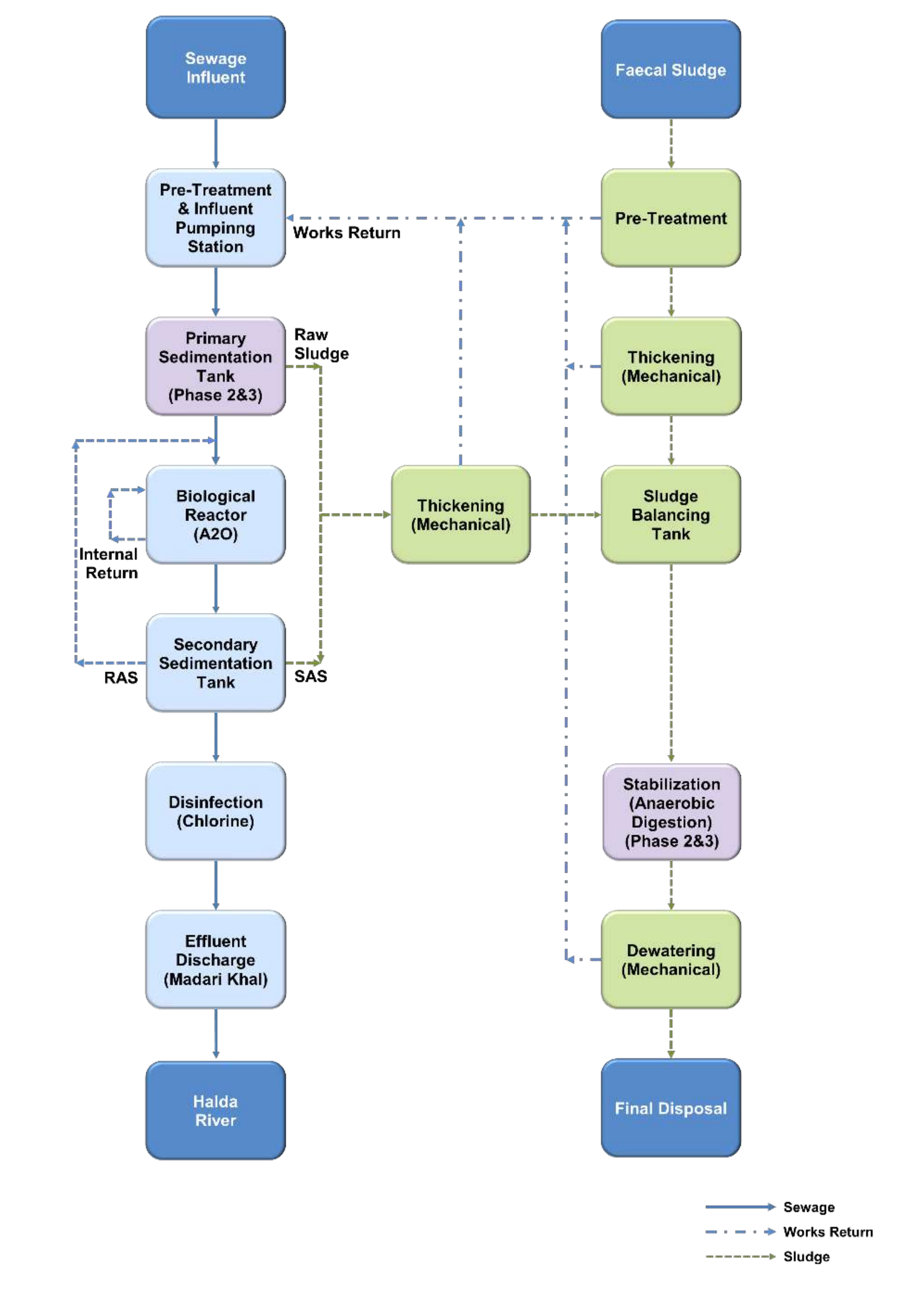


Figure 1-4 Process Flow Diagram of Phase 2&3

1.4.1.4 Proposed Site of Sewage Treatment Plant

Table 1-9 Review of Proposed Site of Sewage Treatment Plant

Category	Description
Land Acquisition	• It has been owned by CWASA since 1960s, so the land acquisition is not required.
Resettlement Action Plan	• There are some illegal residents and public facilities such as schools and mosques. ➔ Resettlement action plan shall be prepared during the detailed design stage by CWASA.
Treated Effluent Discharge	• It is located more than 10km from Karnaphuli River and Halda River. • Treated effluent will be discharged to Madari Khal and final receiving water body will be Halda River.
Future Expansion	• Sewage treatment plant with a capacity of Q=120,000m3/d for the final targe year of 2070 can be constructed in the A3 side of the proposed site.
Availability of Utility Service	• There is no water supply in the site & Ward No.1, so deep tube well will be utilized for the water supply of the STP. • Electrical power will be supplied from the 33kV sub-station located 1km from the site.
Accessibility	• It is located next to N106 road, so it is easy to access the site for the O&M vehicles and faecal sludge collection vehicles.

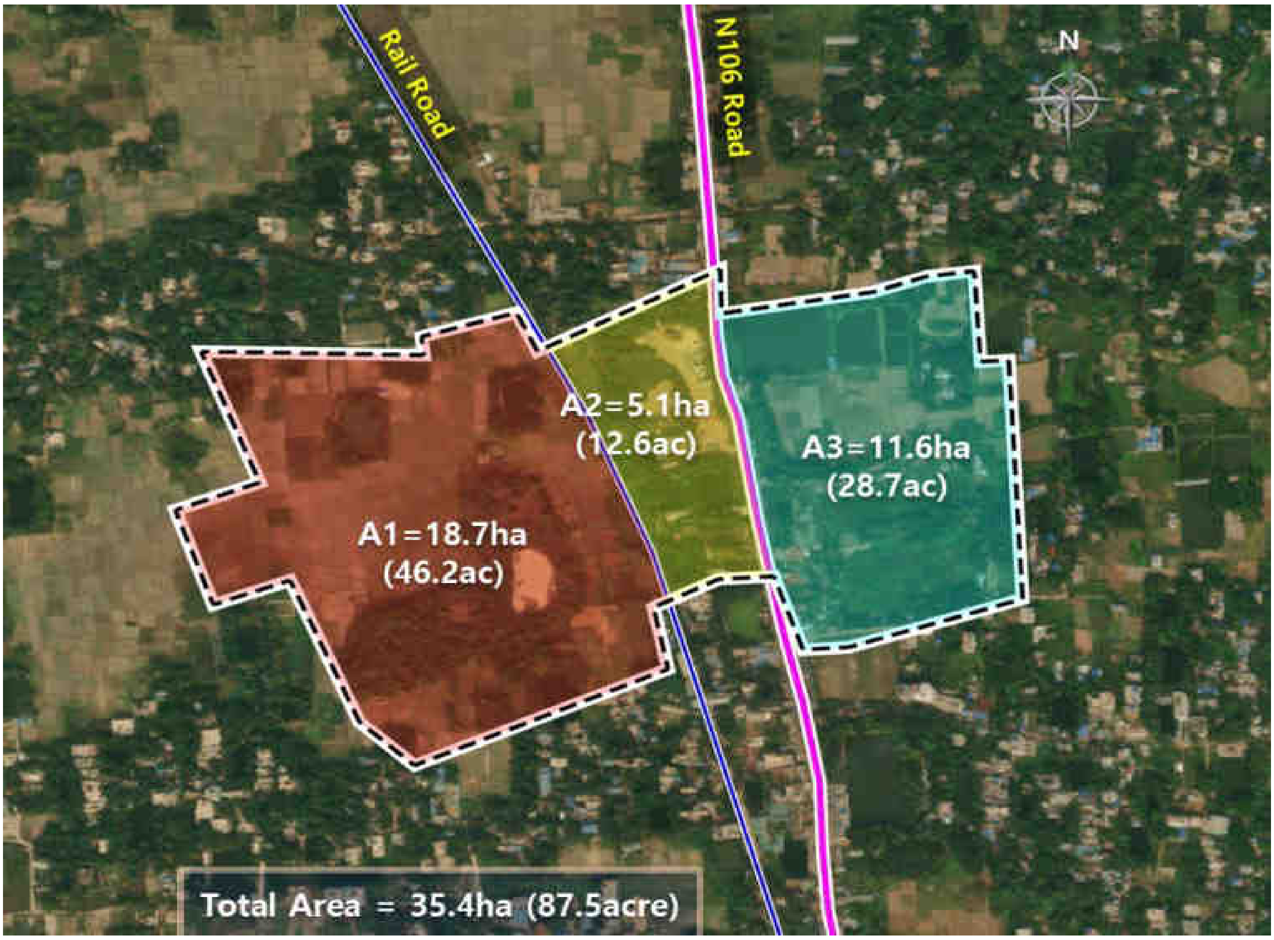


Figure 1-5 Proposed Site of Sewage Treatment Plant

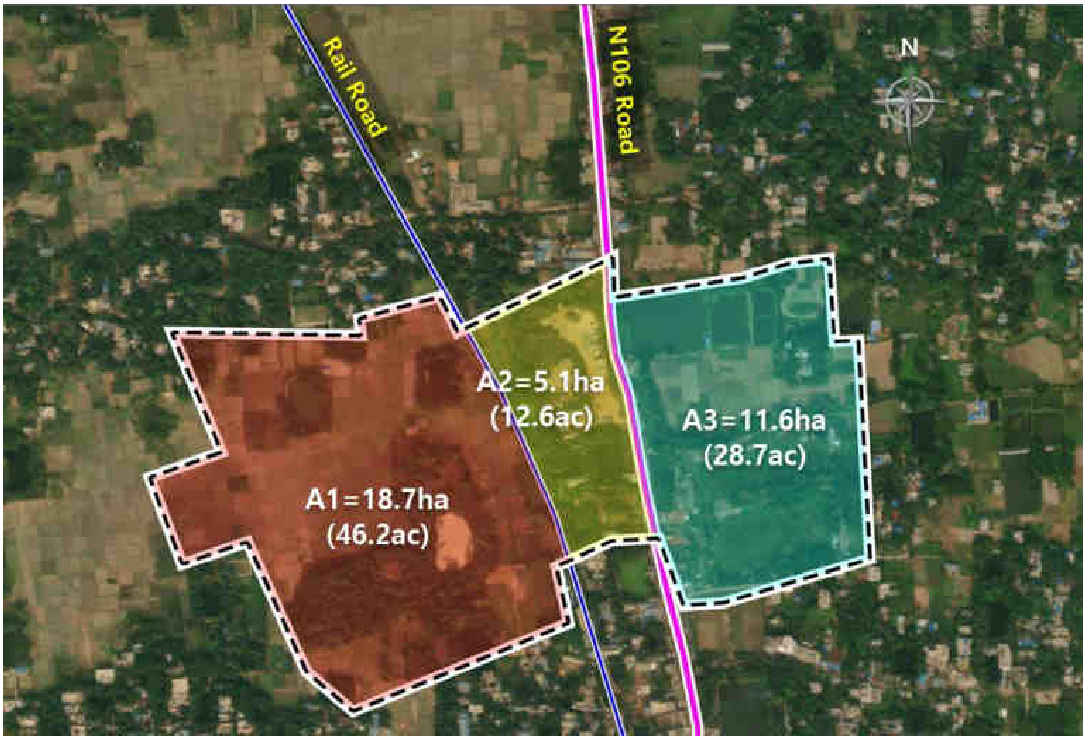
1.4.1.5 Layout of Sewage Treatment Plant

Option study of layout of sewage treatment plant is presented as below. Both options can accommodate the all facilities of STP up to Phase 3 in the final target year of 2070 in the proposed site.

- Option-1: Sewage treatment plant will be located in the on the right side of the N106 road (A3 site)
- Option-2: Sewage treatment plant will be located in the on the left side of the railway (A1 site)

As a result of the option study, Option-1 is selected because it is easy for O&M vehicles and faecal sludge collection vehicles to access to the STP.

Table 1-10 Option of Layout of Sewage Treatment Plant

Category	Option-1	Option-2
Summary	• Lay out on the right side of the N106 road • (A3 site)	• Lay out on the left side of the railway • (A1 site)
Site Status		
Required Area	• 80,000m^2	• Same as left
Hydraulic Aspects	• Hydraulic flow of sewage treatment process is gravity after inlet pumping station	• Same as left
Layout Aspects	• Sewage, sludge process and architectural building is planned separately. • The remaining site can be used as environmental infrastructure in the future. • Compared to Option-2, the length of the inlet and outlet sewer is shorter.	• Compared to Option-1, the length of the inlet and outlet sewer is longer.
O&M Aspects	• Easy access to Sewage treatment plant from NR106 road • Ease of maintenance with systemization • Good access for maintenance vehicle to each facility	• It is somewhat difficult to enter the sewage treatment facility by entering on the left side of the railway
ESIA Aspects	• Illegal residence in some houses (45 households) •	• Illegal residence in some houses (15 households)
Selection	O	

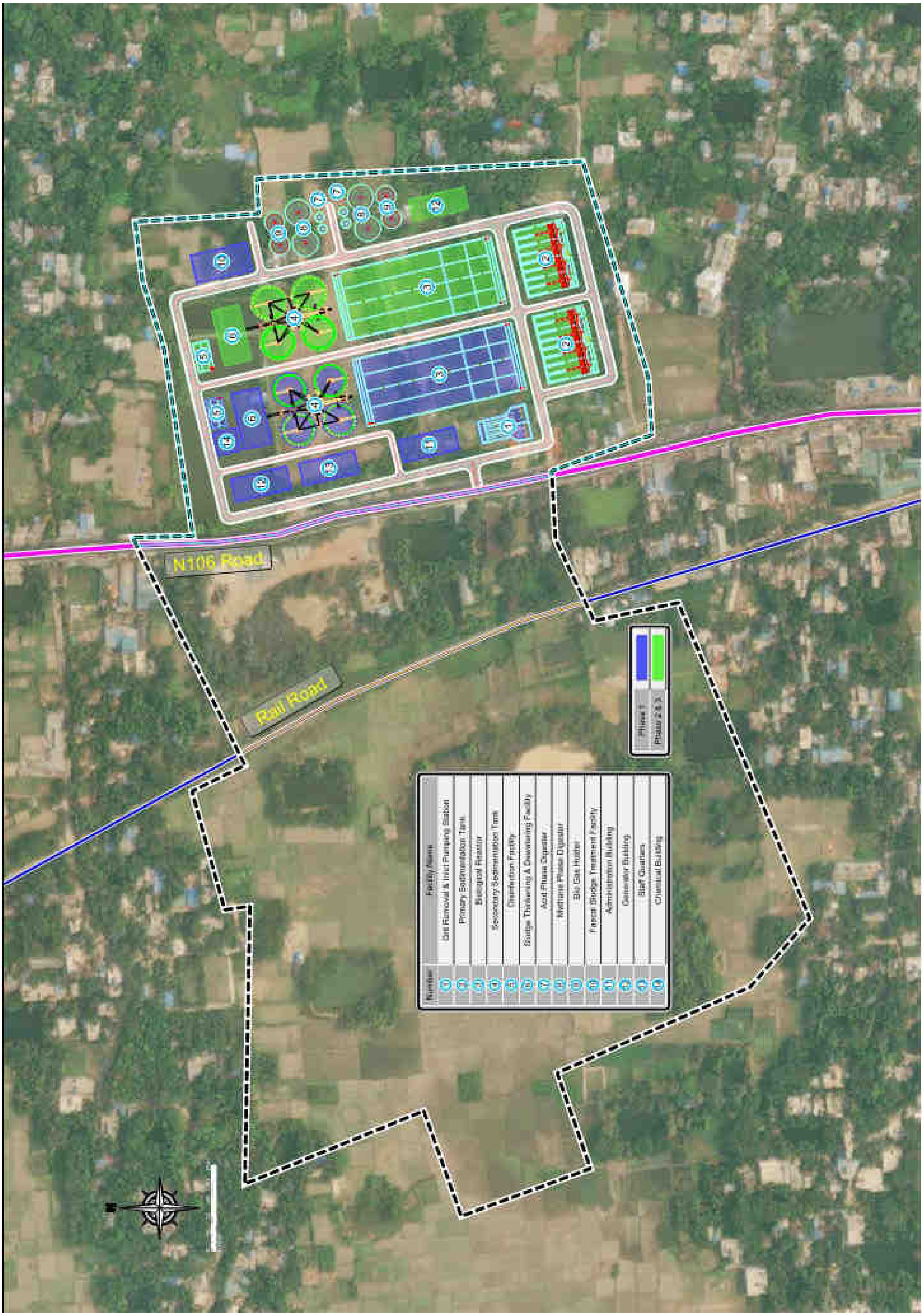


Figure 1-6 Layout of Sewage Treatment Plant

1.4.1.6 Treated Effluent Discharge

As the proposed site of sewage treatment plant is located in the middle of the CCC, option study of treated effluent discharge is presented to identify more rational and suitable option.

- Option-1: treated effluent is discharged by gravity flow to the Madari Khal which is located about 0.5km from STP site and final receiving water body is Halda River.
- Option-2: treated effluent is discharged by pumping to the Shitol Jharna Khal which is located about 7.0km from STP site and final receiving water body is Karnaphuli River.

As a result of the option study, Option-1 is selected for the treated effluent discharge option through the discussion with the CWASA by considering the site condition, financial and other factors. It is planned to obtain the environmental license through the environmental impact assessment during the detailed design stage.

- CAPEX and OPEX of Option-2 is much higher than Option-1, because additional effluent pumping station & about 7.0km of effluent discharge pipe is required for the Option-2 and OPEX is also required to operate a pumping station.
- Treated effluent will satisfy the standard Sewerage discharge of DOE, so it will contribute to improve the water quality of river and to preserve the ecosystem of river.
- Treated effluent discharge point of STP in Madari Khal is about 7.6km away from the intake facility of Modunaghat WTP and about 11.5km away from the intake facility of Mohara WTP, so the impact of effluent will be negligible to the intake of WTP. For instance, 4.0km of standard distance from the intake of WTP is considered when designating a water source protection area in Korea.

Table 1-11 Option of Treated Effluent Discharge

Category	Option-1	Option-2
Discharge Point	Madari Khal	Shitol Jharna Khal
Receiving Water Body	Halda River	Karnaphuli River
Discharge Pipe	D1000mm, L=0.5km	D1000mm, L=7.0km
Effluent Pumping Station	-	26.1 m^3/min x 2(1) + 13.0 m^3/min x 2
CAPEX	• Discharge Pipe: 385,175 USD	• Discharge Pipe: 5,392,000 USD • Discharge Pump Station: 1,563,000 USD • Total: 6,955,000 USD
OPEX	-	• Electricity Cost: 200,000 USD/year
Selection	O	

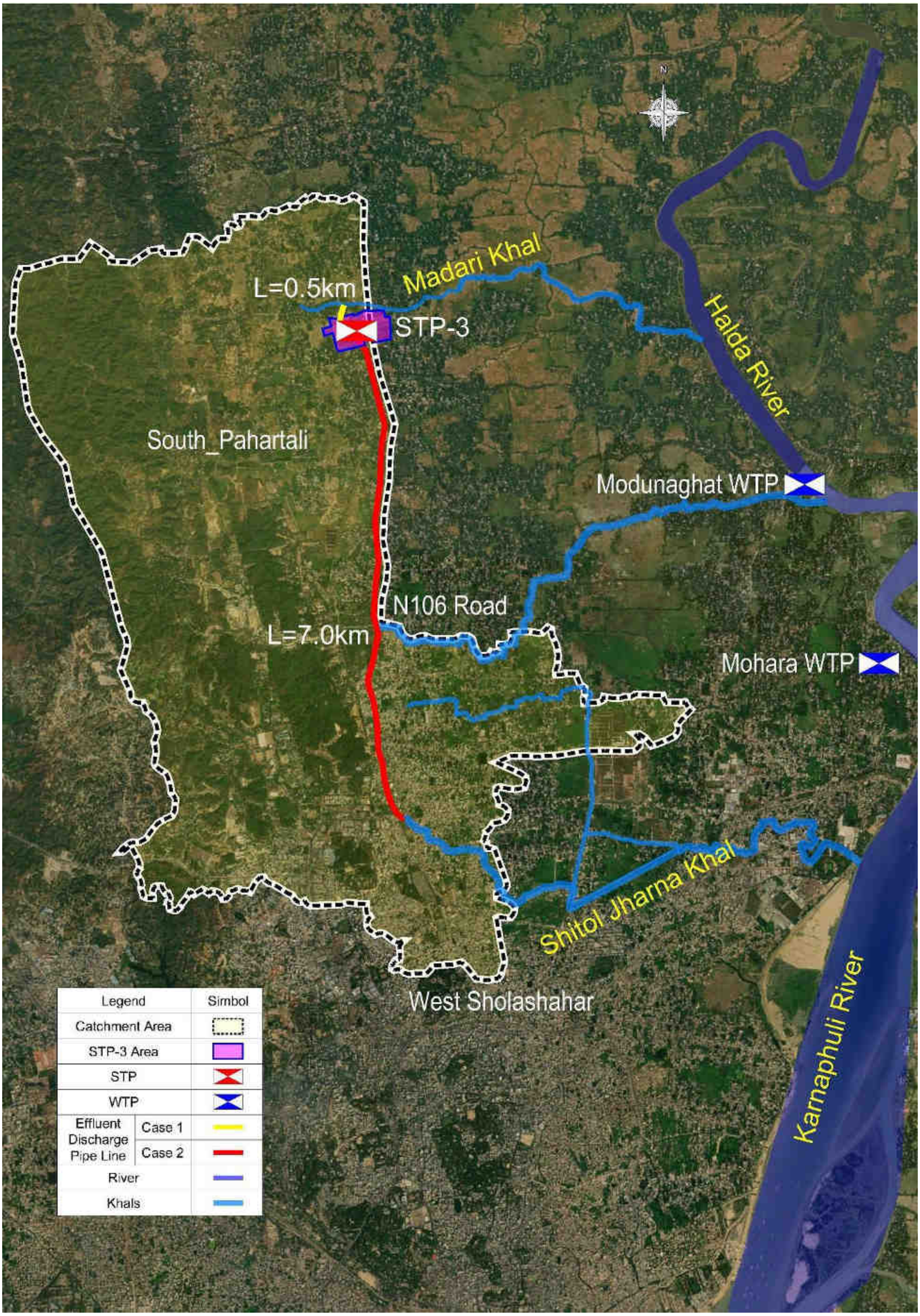


Figure 1-7 Review of Treated Effluent Discharge Options

1.4.1.7 Final Disposal of Sludge Cake

CCC operates two municipal solid waste landfills in Arefin Nagar and Halishahaar. Due to the lack of capacity of the existing landfills, CCC are planning for the alternative option for the solid waste management, but site selection is difficult due to the land acquisition and complaints from local residents.

There are many options to consider as the final disposal of sludge cake, but in reality, landfill is considered the most feasible option. But there is no landfill site to cater the sludge cake from Catchment-3 in CCC. Since there are currently 4 sewerage projects in progress in addition to this EDCF project in Chattogram City, CWASA have to set up the long-term perspective plan of sludge cake disposal in the consideration of whole 6 catchments of CCC.

Table 1-12 Municipal Solid Waste Landfills of Chattogram City

Arefin Nagar Landfill	Halishahaar Landfill
	

Table 1-13 Option of Final Disposal of Sludge Cake

Category	Landfill	Incineration	Composting
Introduction	• Landfill after Thickening and mechanical Dewatering	• Incineration after thickening and dewatering • Incinerated ash is disposed of at a nearby landfill	• Production of effective products by fermentation after thickening and dewatering
Advantage	• No additional facilities • The processing cost is relatively low • No additional operation management required	• Low pollution load on the environment • Possible to generate electricity using recovered heat	• Generation of effective products such as land improvement agents • Reduce operating and management costs by selling effective products
Disadvantage	• Need to secure an alternative landfill due to insufficient capacity of the existing landfill	• High facility investment cost • Operation management is difficult, so a separate manager is required • High operating cost	• Demand is limited due to the prejudice for the sludge cake • Facility investment and operation management cost are high • Operation management is difficult, so a separate managing is required
Select	O		

1.4.1.8 Reserve Facilities for Sludge Treatment

Option study of reserve facilities for sludge treatment such as sludge drying bed, faecal sludge treatment plant and temporary sludge cake storage facility is presented to reduce the operation & maintenance cost of sewage treatment plant as below.

- Sludge drying bed can be used for a sludge thickening and dewatering instead of mechanical thickening and dewatering facility during dry season.
- Gravity faecal sludge thickening tank and constructed wetland can be used for a faecal sludge treatment instead of mechanical thickening and dewatering facility during dry season.
- Sludge cake storage facility can be used as a short-term plan for the final disposal of sludge cake.

As a result of the option study, reserve facilities for sludge treatment are not included in the project scope because the construction cost is about 12 US$ million, so the initial investment cost is excessive and even considering the reduction in O&M cost, it is analyzed as economically not feasible.

Table 1-14 Reserve Facilities for Sludge Treatment

Category		Specification	Capacity	Construction Cost (US$ thousands)
Sludge Drying Bed		W20.0m x L40.0m x H0.7m x 48Nos.	26,880 m^3	7,539
Faecal Sludge Treatment	Thickening	W13.3m x L15.0m x H2.0m x 4Nos.	800 m^3	196
	Constructed Wetland	W20.0m x L25.0m x H1.0m x 2Nos.	1,000 m^3	191
Sludge Cake Storage Facility (A1 Site)		W20.0m x L40.0m x 1No.	46,000 m^2	4,171
Total				12,097

Sewage treatment plant will be located in the A3 site, sludge cake can be stored in the A1 site or A2 site as a tentative plan before CWASA set up the long-term perspective plan of sludge cake disposal.

Table 1-15 Storage Capacity in the STP Reserve Site

Category		Storage capacity			Sludge Cake (2030, m^3/d)	Storage Expectancy (year)
		Area (m^2)	Height (m)	Capacity (m^3)		
A1 Site	With Reserve	46,000	1.5	69,000	121	1.6
	Without Reserve	187,000	1.5	280,500	121	6.4
A2 Site		51,000	1.5	76,500	121	1.7

Process flow diagram and layout of reserve facilities for sludge treatment is as below.

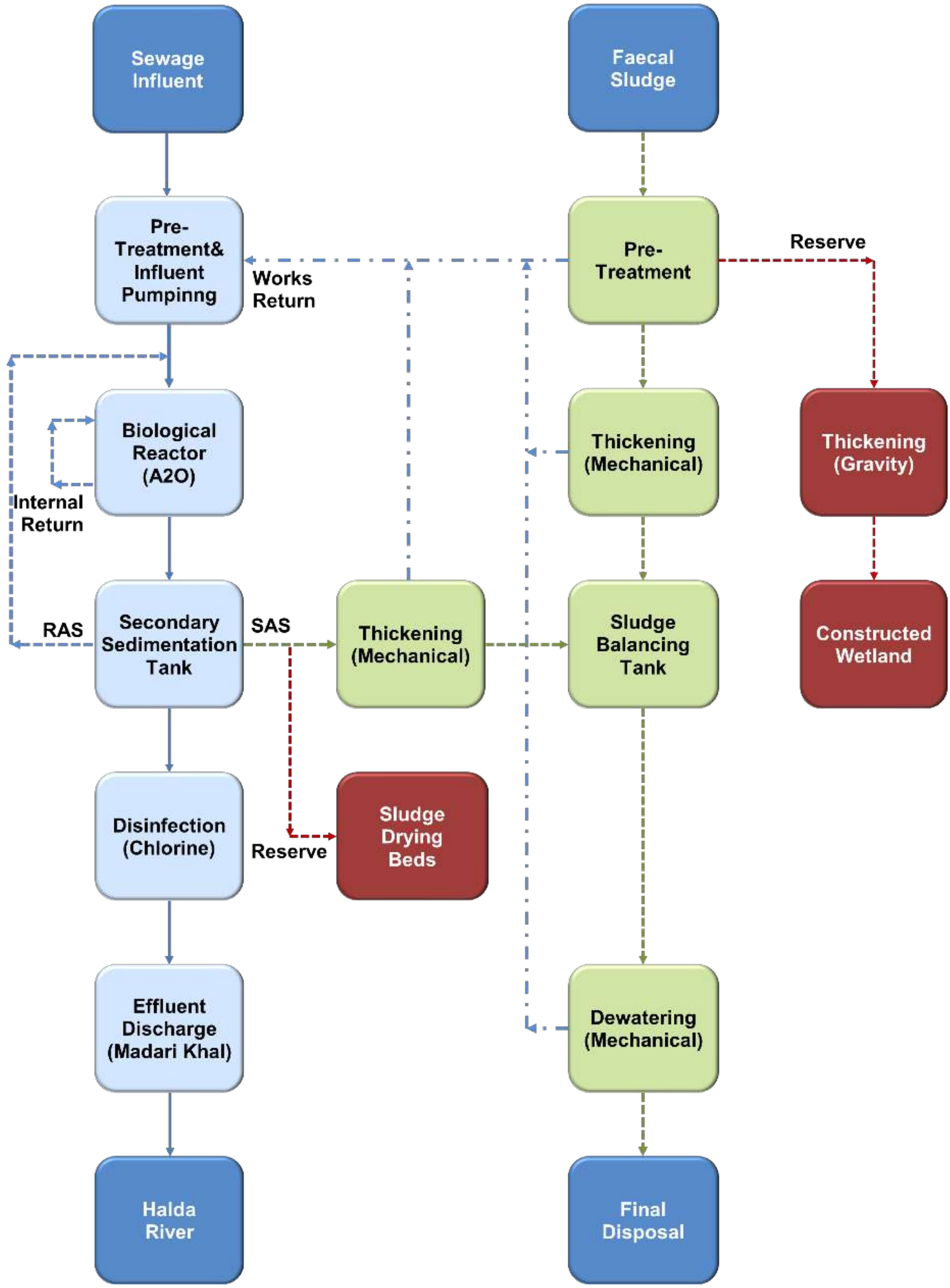


Figure 1-8 Process Flow Diagram including Reserve Facilities for Sludge Treatment

Figure 1-9 Layout of Reserve Facilities for Sludge Treatment

1.4.1.9 Faecal Sludge Management

1.4.1.9.1 Faecal Sludge Collection

Faecal sludge collection vehicle will be procured in the project to collect the faecal sludge from the on-site Sewage Serving area of Chattogram City, Hathazari Upazila and Raozan Upazila.

Table 1-16 Procurement of Faecal Sludge Collection Vehicle

Category	Capacity (m^3)	Quantity	Photo	Remarks
Type 1	10.0	1		
Type 2	5.0	2		
Type 3	3.0	2		
Type 4	0.7	2		
Type 5	0.5	7		

1.4.1.9.2 Faecal Sludge Treatment Plant

Faecal sludge treatment plant is planned to treat the faecal sludge after collection and transport to the sewage treatment plant. Faecal sludge will be co-treated with sewage sludge after pre-treatment and thickening. Anaerobic digestion as sludge stabilization process is planned to be introduced in Phase 2 in the consideration of the difficulty of O&M.

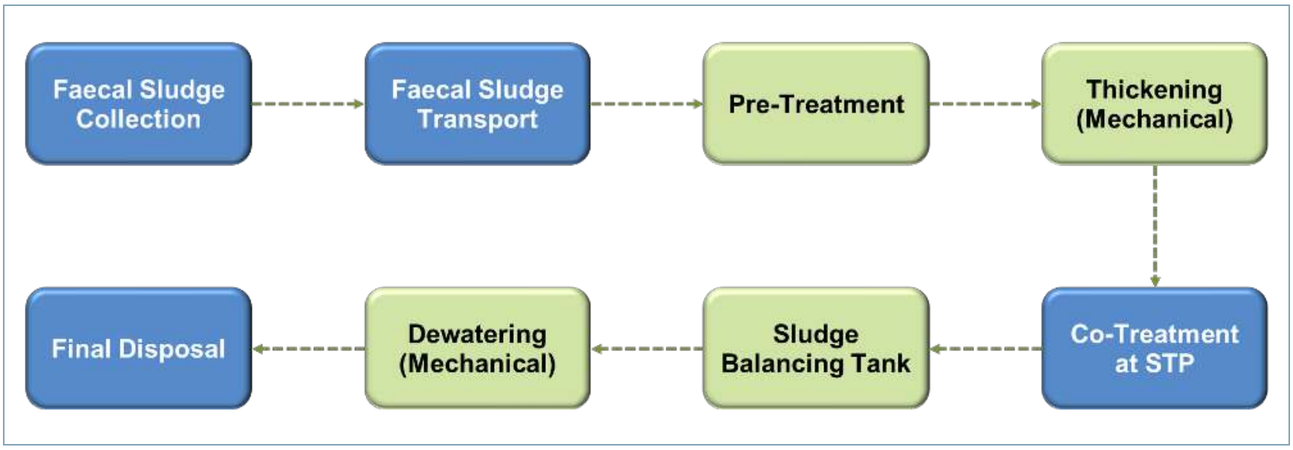


Figure 1-10 Faecal Sludge Treatment Process Diagram (Phase 1)

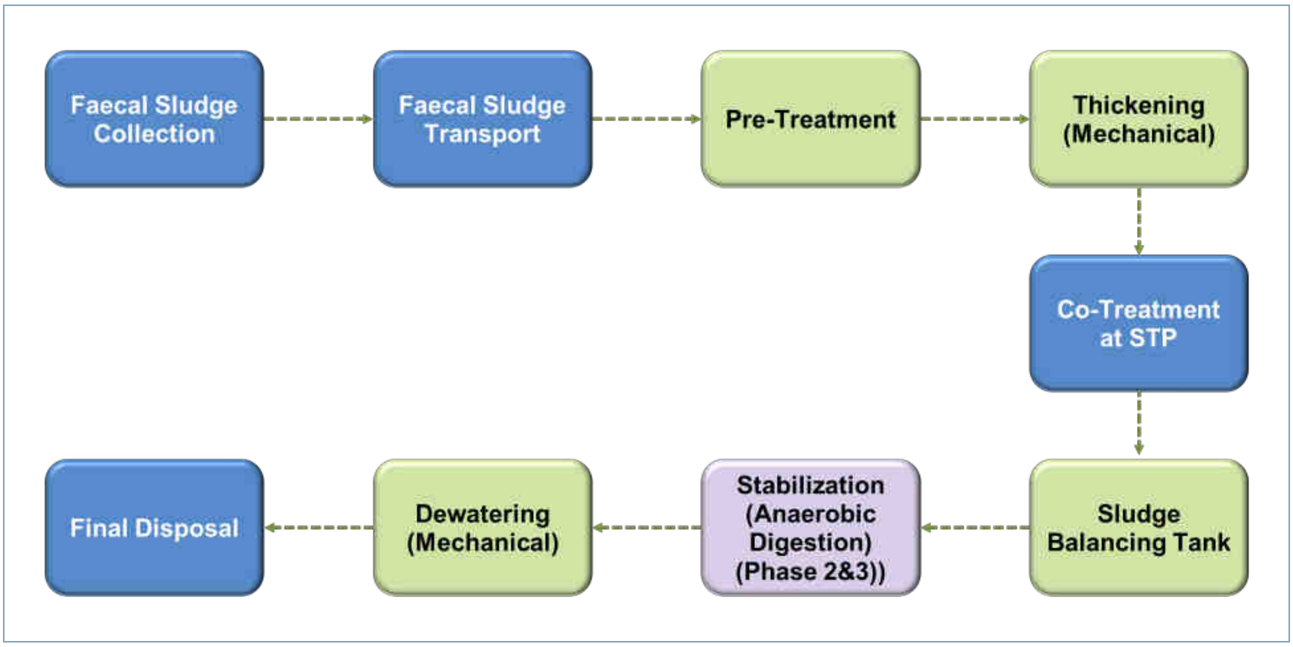


Figure 1-11 Faecal Sludge Treatment Process Diagram (Phase 2&3)

1.4.1.10 Energy Self-Sufficient Plan

Biogas power generation & Solar power generation is planned as a renewable energy source to contribute for the sustainable development by introducing green technology and reducing greenhouse gas emission.

- Anaerobic digestion for biogas power generation will be introduced in Phase 2.
- Solar panels will be installed on top of the biological reactors in Phase 1.

Energy self-sufficiency rate of STP is planned as 13.5% in Phase 1, 27.2% in Phase 2 and 23.9% in Phase 3 respectively and it is subject to change the project implementation of each phase.

Table 1-17 Detail of Solar Power Generation

Category	Description	Remarks
Required Area	3,100m^2	On top of the biological reactor
PV Module Capacity	567kW	315W/module X 1,800modules
Power Generation	207MW/year	567kW X 365days
Feed in Tariff Rate	0.096 USD/kWh	
Annual Income	USD 19,610	206,955kW/year X 0.096USD/kWh

Table 1-18 Energy Self-Sufficient Rate of STP

Category		Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Capacity of STP (m^3/d)		60,000	90,000	120,000
Power Consumption (MVA)		4.20	5.40	7.40
Power Generation (MVA)	Bigas	-	0.90	1.20
	Solar Power	0.57	0.57	0.57
	Total	0.57	1.47	1.77
Energy Self-Sufficient Rate (%)		13.5	27.2	23.9

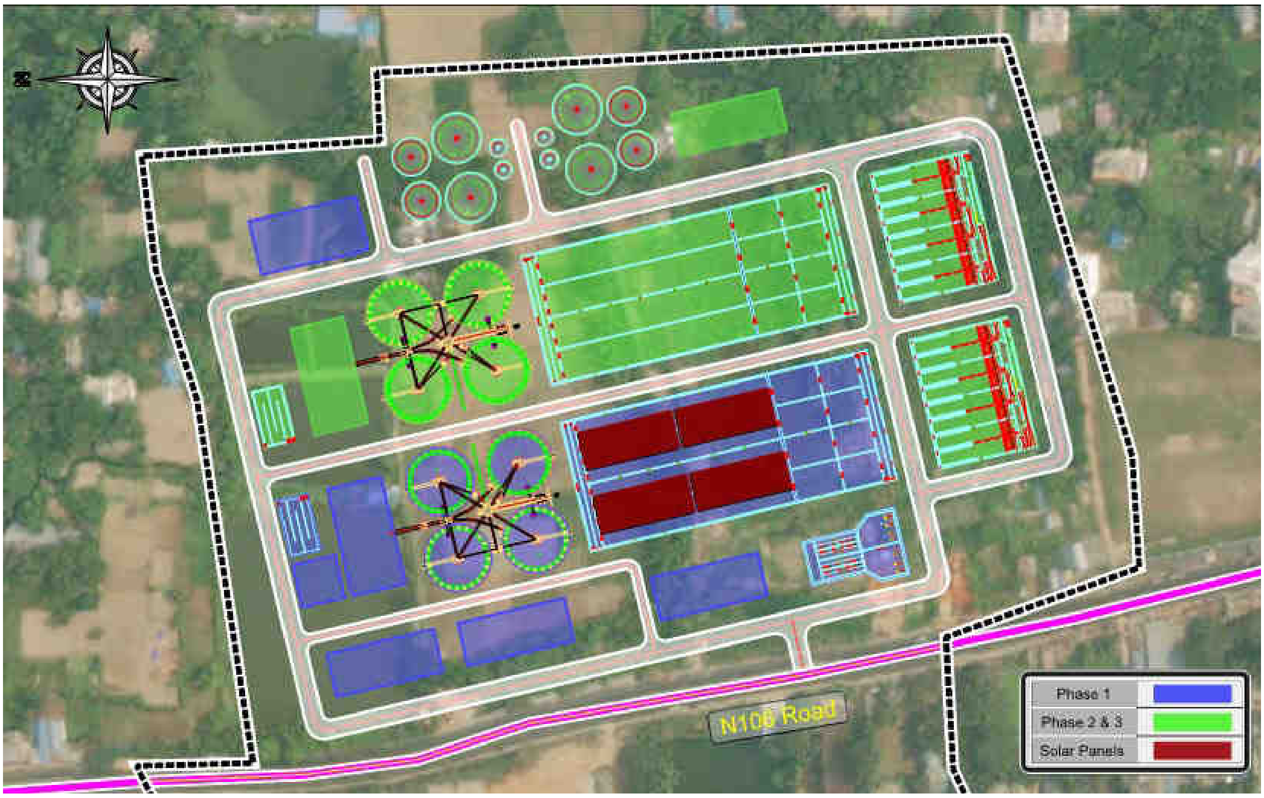


Figure 1-12 Layout of Solar Power Generation

1.4.1.11 Operation & Maintenance Vehicle

Operation & maintenance vehicle will be procured in the project for O&M of sewage treatment plant.

Table 1-19 Operation & Maintenance Vehicle

Type	Capacity (m^3)	Quantity	Photo	Remarks
Combined Backhoe/ Wheel Loader	0.6	3		
Truck with Hydraulic Hoist	7.5	2		
Truck with Hydraulic Hoist	20.0	1		

Note) Operation & Maintenance vehicles shall be confined to the vehicles controlled and operated by CWASA. Types of O&M vehicles is subject to change during the detailed design stage.

1.4.2 Sanitary Sewer & Pumping Station

1.4.2.1 Sanitary Sewer

Sanitary sewer is planned in five wards out of seven wards in Catchment-3 as priority where current water service coverage under CWASA is available in the consideration of project budget.

Table 1-20 Phase Plan of Sanitary Sewer (m)

Category	Total	Phase 1	Phase 2
Total	93,400	58,226	35,134
Trunk Sewer	8,900	8,900	-
Primary Sewer	58,991	29,335	29,656
Secondary Sewer	25,509	20,031	5,478

Table 1-21 Detail of Sanitary Sewer for Phase 1 (m)

Category	Total	Trunk Sewer	Primary Sewer	Secondary Sewer
Total	58,266	8,900	29,335	20,031
200mm	32,802	-	12,771	20,031
300mm	7,833	-	7,833	-
400mm	3,962	300	3,662	-
500mm	1,405	100	1,305	-
600mm	1,400	400	1,000	-
700mm	3,664	900	2,764	-
800mm	200	200	-	-
900mm	300	300	-	-
1,000mm	200	200	-	-
1,200mm	800	800	-	-
1,300mm	700	700	-	-
1,400mm	1,100	1,100	-	-
1,500mm	1,400	1,400	-	-
1,600mm	2,500	2,500	-	-

Table 1-22 Detail of Sanitary Sewer for Phase 1 by Excavation Depth (m)

Category	Total	Trench						Trenchless		
		Sum	~2m	2~3m	3~4m	4~5m	5~6m	Sum	6~10m	10m~
Total	58,266	45,962	15,802	16,517	6,599	4,313	2,731	12,304	10,504	1,800
200mm	32,802	32,322	15,402	12,299	2,814	1,407	400	480	280	200
300mm	7,833	6,839	400	2,418	1,100	1,940	981	994	894	100
400mm	3,962	3,396	-	1,000	1,430	466	500	566	566	-
500mm	1,405	1,305	-	300	755	100	150	100	100	-
600mm	1,400	1,200	-	400	500	200	100	200	200	-
700mm	3,664	800	-	100	-	200	500	2,864	2,864	-
800mm	200	-	-	-	-	-	-	200	200	-
900mm	300	-	-	-	-	-	-	300	300	-
1,000mm	200	-	-	-	-	-	-	200	200	-
1,200mm	800	-	-	-	-	-	-	800	800	-
1,300mm	700	-	-	-	-	-	-	700	700	-
1,400mm	1,100	-	-	-	-	-	-	1,100	900	200
1,500mm	1,400	-	-	-	-	-	-	1,400	1,300	100
1,600mm	2,500	100	-	-	-	-	100	2,400	1,200	1,200

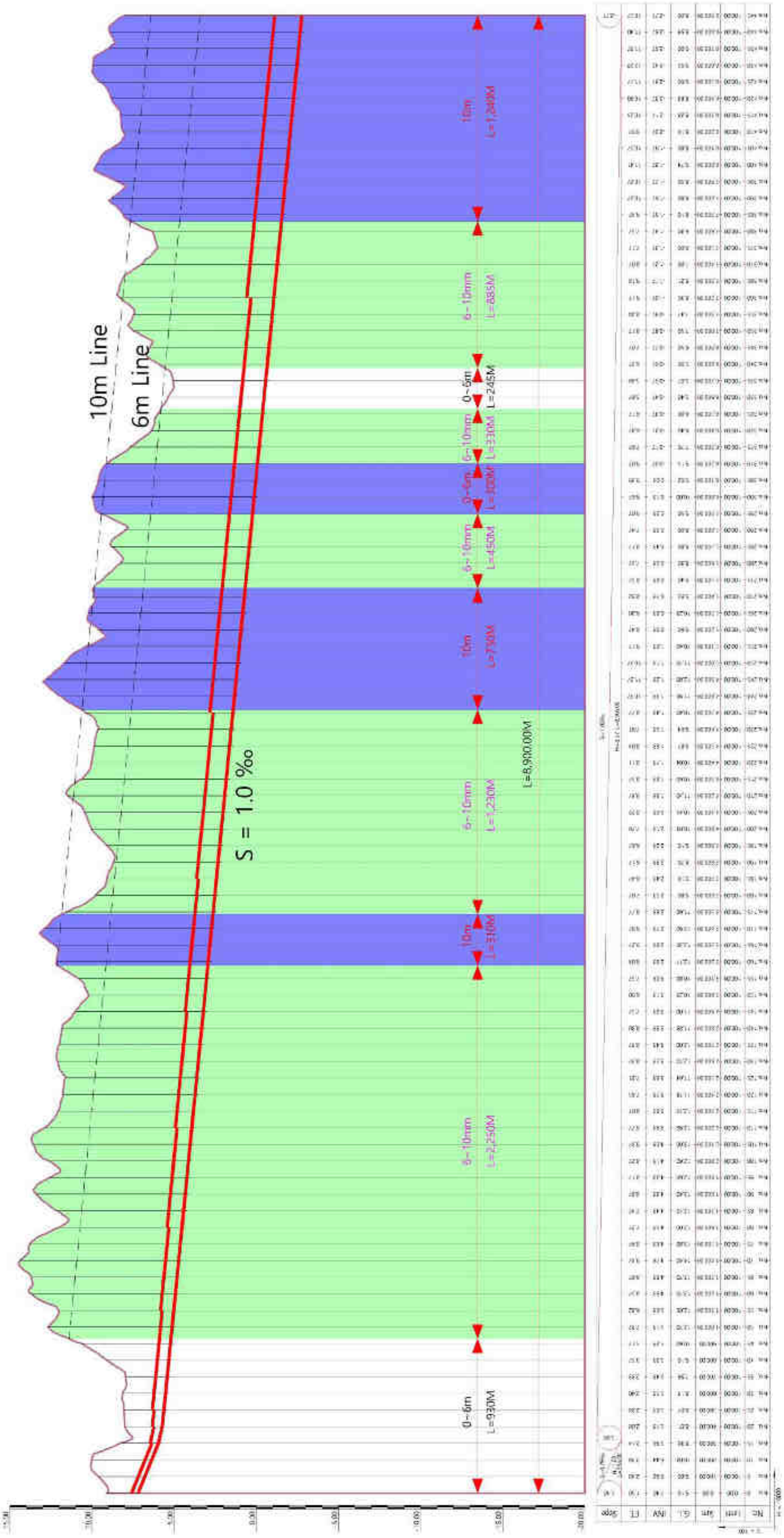


Figure 1-13 Longitudinal Profile of Trunk Sewer

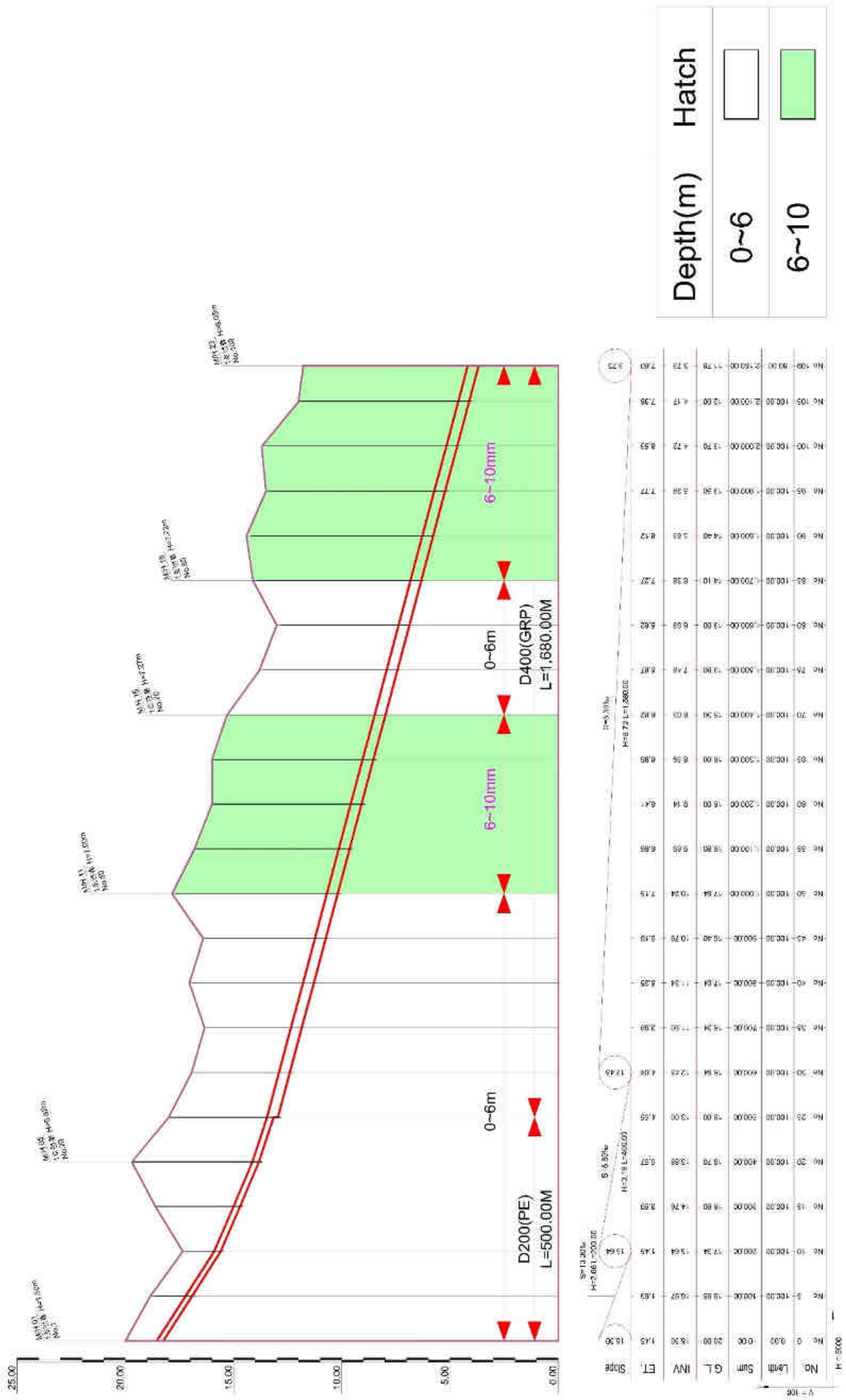


Figure 1-14 Longitudinal Profile of Primary Sewer (Representative)

1.4.2.2 Pumping Station (Phase 2)

Pumping station is planned for the low-lying area where gravity flow is not possible to transfer the wastewater to the higher elevation and it will be implemented in Phase 2 in the consideration of sewage service coverage of the project.

Table 1-23 Detail of Pumping Station

Site	Name	Capacity (m^3/min)	Start		End		Max. Elev. (m)	Specification
			Elev.	Inv.	Elev.	Inv.		
Ward 2	PS-1	1,410	6.25	2.25	8.90	7.00	8.90	1.41m^3/min x 9.75mH
Ward 2	PS-2	0.676	1.35	-2.65	6.50	4.50	7.70	0.68m^3/min x 12.15mH
Ward 3	PS-3	0.676	4.60	0.60	9.30	7.00	9.30	0.68m^3/min x 11.40mH
Ward 3	PS-4	0.676	4.10	0.10	10.00	8.30	10.00	0.68m^3/min x 13.20mH
Ward 3	PS-5	0.310	4.30	0.30	13.40	11.20	13.40	0.41m^3/min x 15.90mH
Ward 3	PS-6	0.155	23.30	19.30	29.00	27.30	29.00	0.16m^3/min x 13.00mH
Ward 7	PS-7	0.705	9.00	5.00	14.00	5.83	14.00	0.71m^3/min x 13.00mH

Figure 1-15 Location of Pumping Station

1.4.2.3 Household Connection

Household connection survey is conducted in the feasibility study for randomly selected 100 houses to categorize the household connection types as per the buildings in the project area for the project cost estimation. Detail household connection survey shall be implemented in the detailed design stage.

Table 1-24 Results of Household Connection Survey (Nos.)

Category	Building Type	Survey Results	Plan of This Project
Type 1	Residential Building with 8 or more floors	13	1,200
Type 2	Residential Building with 2-7 story	63	6,000
Type 3	Residential Building with single story	11	2,000
Type 4	Commercial Building	13	800
Total		100	10,000

Table 1-25 Phase Plan of Household Connection

Category	Unit	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Projected Population	pers.	473,904	598,614	810,008	1,048,808	
Sewage Service Coverage	%	60.0	65.0	72.5	80.0	
Sewage Service Population	pers.	284,342	389,099	587,254	839,046	
Household Connection	Nos.	10,936	14,965	22,586	32,271	26 pers. per connection

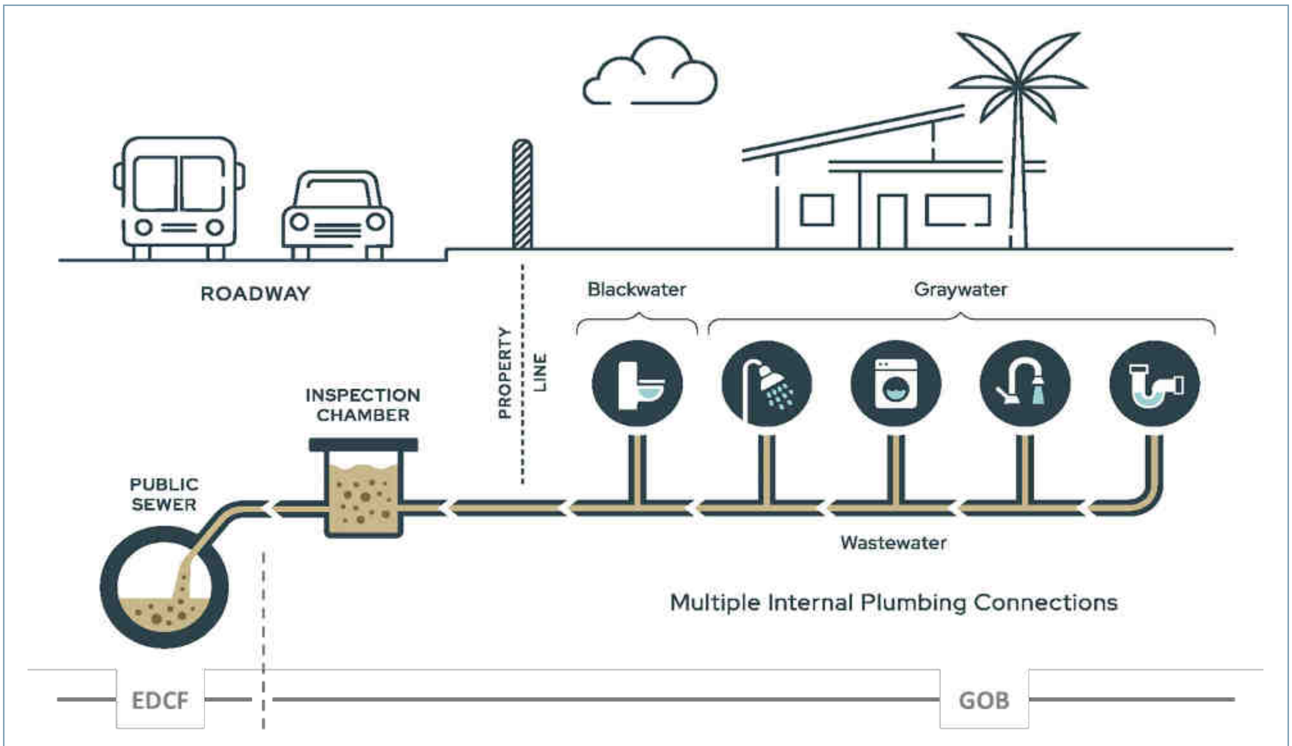


Figure 1-16 Detail of Household Connection

1.5 Project Executing Agency

1.5.1 Project Implementation Organization

Chattogram Water Supply and Sanitation Authority (CWASA) will be the Project Executing Agency (PEA) for the Project and will be in charge of planning, implementation, management, supervision, and coordination of the Project and forwarding relevant reports to the KEXIM. CWASA plans to establish a project management organization (PMU) during the project implementation period after the loan approval.

Table 1-26 R&R of Project Implementation Organizations

Organization	Roles and Responsibilities
PEA (CWASA)	• Overall day-to-day project management, monitoring and evaluation • Establishes and maintains Project Management Unit (PMU) • Provides technical and institutional capacity building support • Reports to KEXIM
PMU in CWASA	• Responsible for overall project management, implementation and monitoring • Monitors and ensures the compliance of covenants, particularly timely submission of audited project accounts and compliance with safeguard requirements • Maintaining project accounts and project financial records • Reviews the reports submitted by consultant with respect to detailed design, costs, safeguards, financial, economic, and social viability • Prepares, with the support of the consultant, bidding documents, request for proposals, bid evaluation reports and negotiations • Serves as point of contact with KEXIM, maintains project documents, and submits timely reports (quarterly progress reports and project completion report) to KEXIM • Organizes project orientation between stakeholder group including Chattogram municipality by elaborating scope of the project and sharing about their participation
MoF	• Financial oversight. Ensures flow of funds to the project execution agency to ensure adequate budget for successful implementation of the project
DoE	• Regulator for wastewater management and pollution control • Monitors compliance with environmental regulation
KEXIM	• Loan approval and financial support • Execution of project expenses for purchase approval, etc • Reviews executing agency and implementing agency's

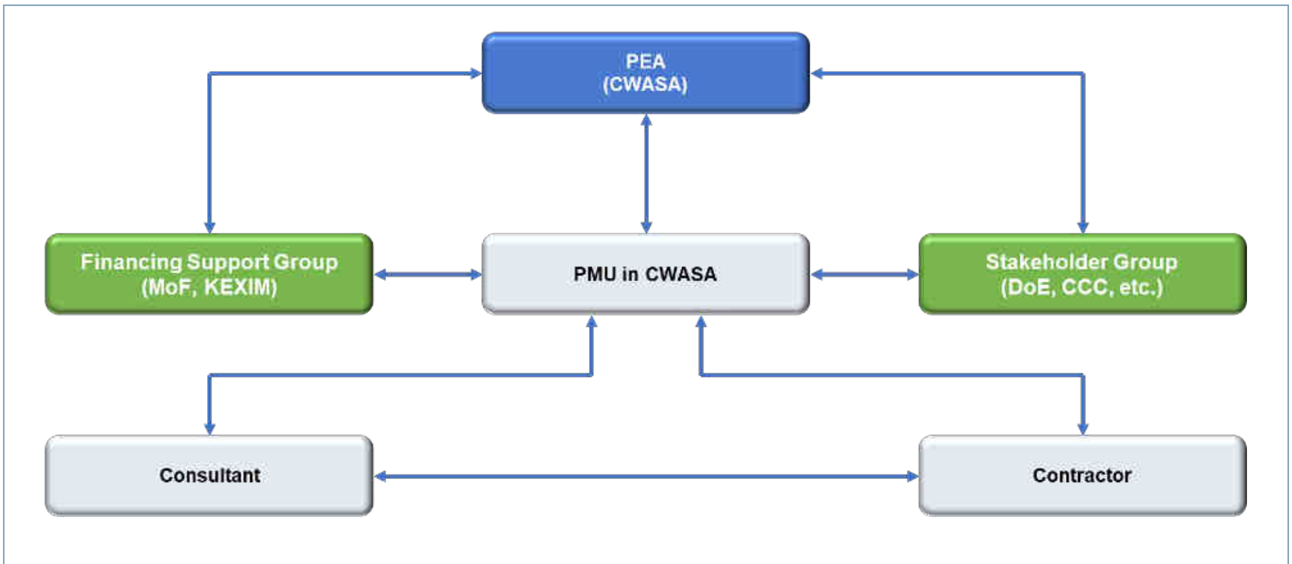


Figure 1-17 Project Organization Structure

1.5.2 Project Management Unit

CWASA plans to establish a project management organization (PMU) during the project implementation period after the loan approval. PMU of the project will be composed of 24 personnel, with a superintending engineer serving as the team leader, engineers in civil, mechanical, electrical & instrumentation, sanitary sewer section and supporting staffs as below.

Table 1-27 Personnel Composition of PMU

No.	Category	No. of Person	Remarks
Technical Staff	Superintending Engineer (Project Director)	1	
	Deputy Project Director	1	
	Executive Engineer	4	
	Assistant Engineer	4	
	Sub-Assistant Engineer	8	
	Sub-Total	18	
Supporting Staff	Office Manager	1	
	Accountant	1	
	Computer Operator	1	
	Office Assistant	2	
	Driver	6	
	Sub-Total	11	
Total		29	

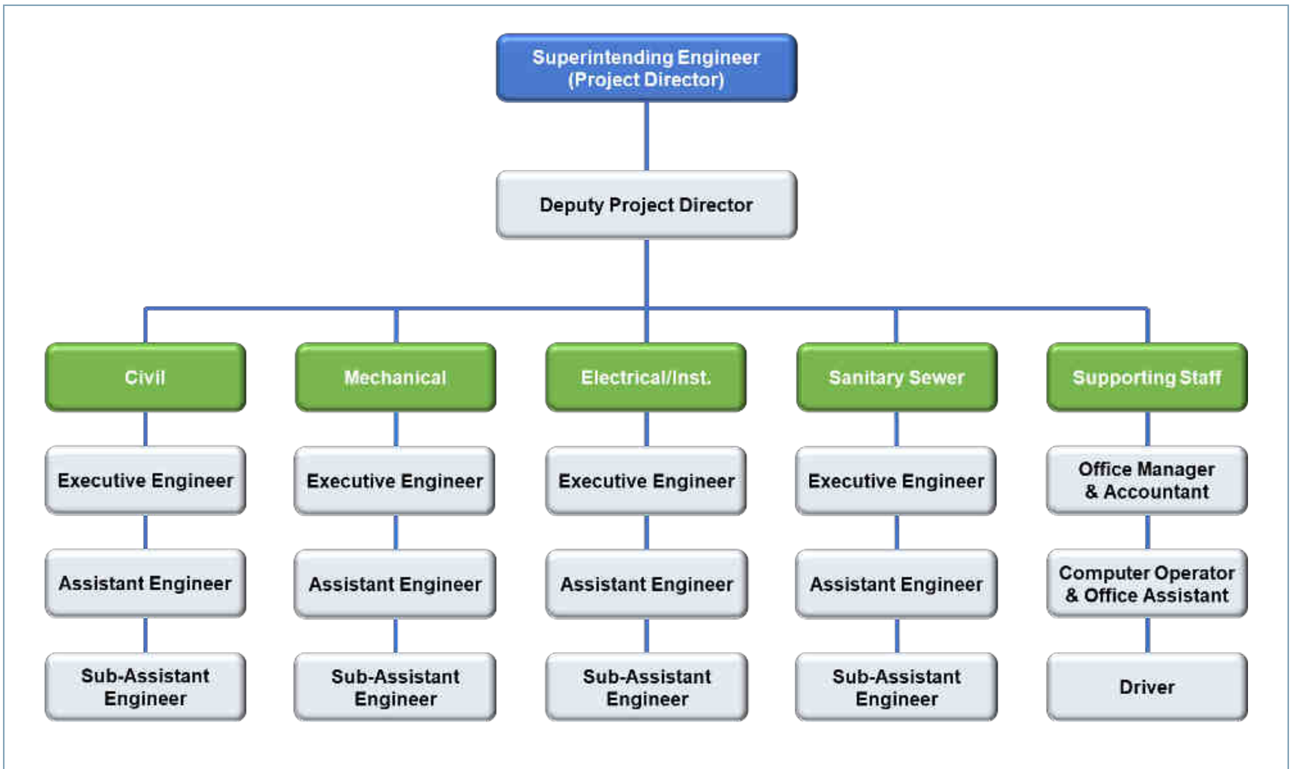


Figure 1-18 PMU Organization Chart

1.6 Project Cost Estimate

1.6.1 Introduction

Project cost is estimated at US dollar (USD) in accordance with 'EDCF Feasibility Study Guideline (March 2022)' and it is classified into EDCF portion and Government of Bangladesh portion.

Project cost is composed of direct project cost and indirect project cost. Components of direct project cost are construction cost, commissioning & training cost, O&M support cost after construction completion, consulting service cost, physical and price contingencies. Components of indirect project cost are Taxes & duties, land acquisition & resettlement cost, project management cost and EDCF service charge.

- Construction cost includes the material and construction costs of the sewerage system such as sewage treatment plant, sanitary sewer, Household Connection, faecal sludge treatment plant, O&M vehicle.
- Commissioning & Training cost covers the training of the operating staffs and commissioning of sewerage system for six months before construction completion.
- O&M support cost covers the training of the operating staffs for two years after construction completion.
- Consulting service cost covers a) remuneration of foreign and local engineers and b) out-of-pocket expenses during the detailed design, bidding support and construction supervision.
- Contingencies are made up of physical and price contingencies.
  - Physical contingency is calculated as 2 % of a total amount of EDCF loan.
  - Price contingency is calculated as 8 % of a total amount of EDCF loan.
- Tax and duties cover Value Added Tax, Advance Income Tax and Custom Duty.
- Land acquisition and resettlement cost covers the land acquisition cost of proposed site of STP and resettlement cost for the local residents.
- Project management cost covers the remuneration & out-of-pocket expenses of PMU during project implementation period.
- EDCF service charge is the loan handling fee to operate the EDCF loan and it is estimated as 0.1% of a total amount of EDCF loan.

In comparison of exchange rate between the average of previous 30 days (02.08.22~01.09.22) from the F/S contract (01.09.22) and the current day (10.05.23), exchange rate is fluctuated 0.3% for KRW to USD, 11.9% for KRW to BDT, and 13.1% for USD to BDT. In this project, the average exchange rate of previous 30 days from the date of F/S contract is applied in accordance with EDCF guideline.

- 1 USD = 94.95 BDT
- 1 USD = 1,325.50 KRW
- 1 BDT = 13.96 KRW

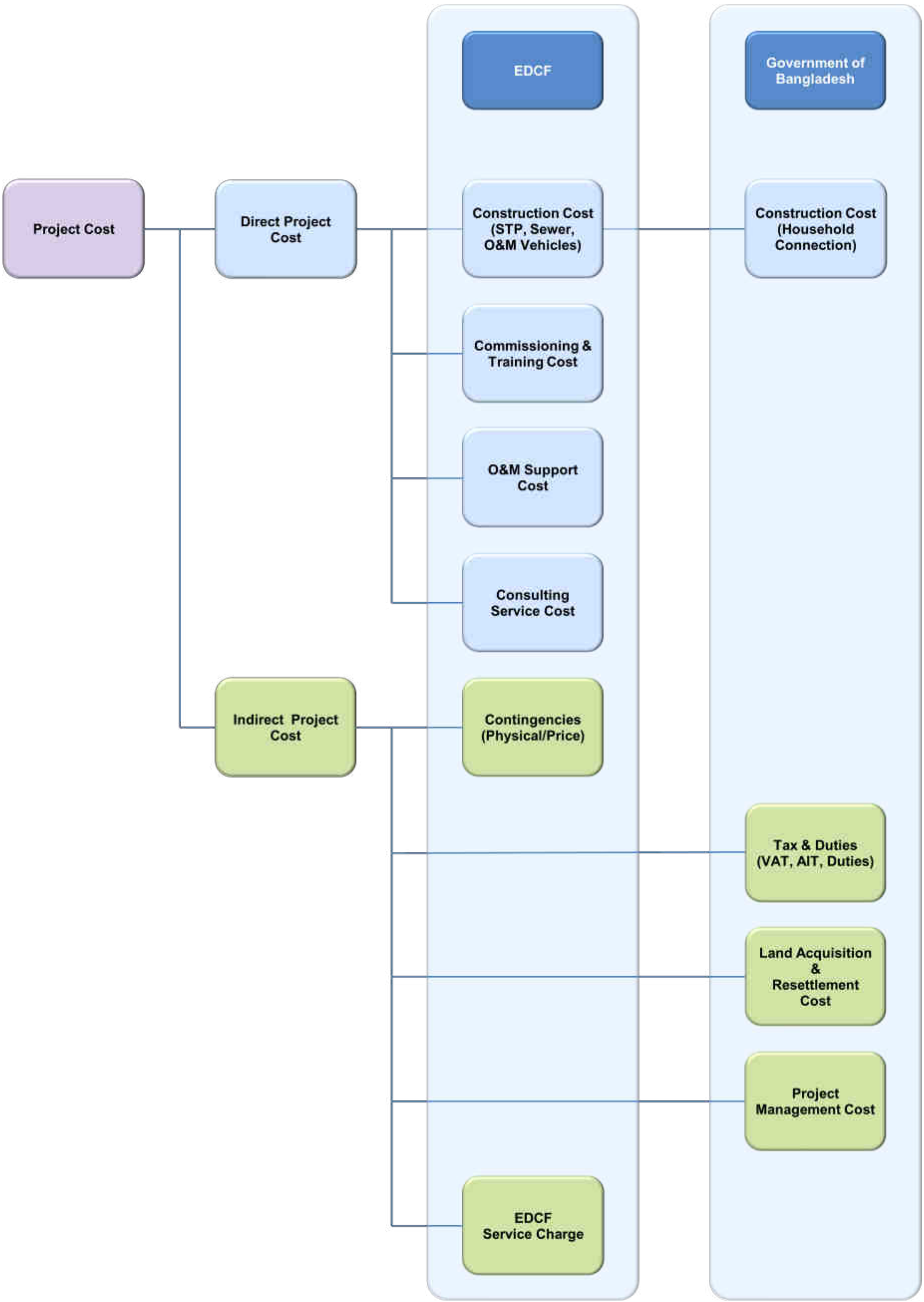


Figure 1-19 Project Cost Composition

1.6.2 Project Cost Components by Currency

Project cost components by currency is prepared in accordance with 'EDCF Feasibility Study Guideline (March 2022)' and it is classified into EDCF and Government of Bangladesh with the consideration of place of origin of materials and equipment and construction works of the sewerage system. In the feasibility study, it is not possible to specify the place of origin of the mechanical, electrical and instrumentation equipment, so it is planned to procure 70% of in foreign currency (Korea) and 30% in third countries.

Table 1-28 Project Cost Components by Currency

<table>
<tr><th colspan="2" rowspan="3">Category</th><th colspan="3">EDCF</th><th rowspan="3">GOB</th></tr>
<tr><th colspan="2">Foreign</th><th rowspan="2">Local</th></tr>
<tr><th>Korea</th><th>3rd Countries</th></tr>
<tr><td rowspan="4">Construction Cost</td><td>Civil Works</td><td>• Overhead & profit
• Sanitary Sewer (GRP)</td><td></td><td>• Ready-mixed concrete
• Reinforcing bar
• Aggregates & other construction materials
• Earthworks, structural works and trench works
• Pavement works
• Architectural works
• Landscaping works
• Sanitary Sewer (HDPE)
• Manhole</td><td>• Construction Cost (Household Connection)</td></tr>
<tr><td>Mechanical Works</td><td colspan="2">• Pre-treatment facility (Sludge, Faecal Sludge)
• Inlet pumping station facility
• Biological reactor facility
• Sedimentation facility
• Sludge thickening facility
• Sludge dewatering facility
• Odour control facility
• Chemical dosing facility</td><td>• Local transport
• Piping & Installation</td><td></td></tr>
<tr><td>Electrical Works</td><td colspan="2">• Incoming power facility
• Power distribution system
• Stand-by power system
• Power control facility</td><td>• Local transport
• Piping & Installation</td><td></td></tr>
<tr><td>Instrumentation Works</td><td colspan="2">• Monitoring and control facility
• Measuring instrument</td><td>• Local transport
• Piping & Installation</td><td></td></tr>
<tr><td colspan="2">Others</td><td>• Commissioning & Training cost
• O&M support after construction completion
• Consulting service cost
• Contingencies (physical/price)
• EDCF service charge</td><td>• Contingencies (physical/price)</td><td>• Consulting service cost
• Commissioning & Training cost
• O&M support after construction completion
• Contingencies (physical/price)</td><td>• Taxes & duties
• Land acquisition & resettlement cost
• Project management cost</td></tr>
</table>

Note) Project cost component is subject to change during the detailed design stage & construction stage.

1.6.3 Total Project Cost

1.6.3.1 Total Project Cost

In the total project cost of US$ 228,948 thousands, the EDCF will provide a loan of US$ 191,438 thousands and the GOB will bear the remaining US$ 37,510 thousands as below.

Table 1-29 Total Project Cost (US$ thousands)

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Korea	3rd Countries				
1. Construction Cost	37,532	7,114	110,945	155,591	6,515	162,106
1.1 Preliminary	276	-	1,566	1,842	-	1,842
1.2 Sewage Treatment Plant	20,277	7,114	30,290	57,681	-	57,681
a) Civil Works	2,923	-	16,561	19,484	-	19,484
b) Architectural Works	755	-	4,280	5,035	-	5,035
c) Mechanical Works	11,275	4,832	5,120	21,227	-	21,227
d) Electrical Works	3,316	1,421	3,135	7,872	-	7,872
e) Instrumentation Works	2,009	861	1,194	4,064	-	4,064
1.3 Sanitary Sewer	16,979	-	78,269	95,248	-	95,248
a) Trunk Sewer	9,622	-	41,927	51,549	-	51,549
- Open Trench	397	-	709	1,106	-	1,106
- Trenchless	9,224	-	41,218	50,442	-	50,442
b) Primary Sewer	6,380	-	30,802	37,182	-	37,182
- Open Trench	3,766	-	15,994	19,760	-	19,760
- Trenchless	2,613	-	14,808	17,421	-	17,421
c) Secondary Sewer	978	-	5,540	6,518	-	6,518
- Open Trench	978	-	5,540	6,518	-	6,518
1.4 Household Connection	-	-	-	-	6,515	6,515
1.5 O&M Vehicles	-	-	820	820	-	820
2. Commissioning & Training	420	-	831	1,251	-	1,251
3. O&M Support	1,652	-	444	2,096	-	2,096
4. Consulting Service	10,255	-	2,911	13,166	-	13,166
4.1 Detailed Design & Bidding Support	3,938	-	1,462	5,400	-	5,400
4.2 Construction Supervision	6,317	-	1,449	7,766	-	7,766
5. Direct Project Cost (1+2+3+4)	49,859	7,114	115,131	172,104	6,515	178,619
6. Contingencies	5,546	791	12,806	19,143	-	19,143
6.1 Physical Contingencies	1,109	158	2,561	3,828	-	3,828
6.2 Price Contingencies	4,437	633	10,245	15,315	-	15,315
7. Taxes and Duties	-	-	-	-	28,092	28,092
7.1 Value Added Tax (VAT)	-	-	-	-	13,895	13,895
7.2 Advance Income Tax (AIT)	-	-	-	-	9,264	9,264
7.3 Custom Duties	-	-	-	-	4,933	4,933
8. Land Acquisition & Resettlement Cost	-	-	-	-	500	500
9. Project Management Cost	-	-	-	-	2,403	2,403
10. EDCF Service Charge	191	-	-	191	-	191
11. Total Project Cost (5+6+7+8+9+10)	55,596	7,905	127,937	191,438	37,510	228,948

1.6.3.2 Financing Plan

Out of the total project cost of US$ 228,948 thousands, US$ 191,438 thousands will be financed through loan from EDCF, of which Korean portion is US$ 55,596 thousands, 3rd Countries portion is US$ 7,905 thousands and local portion is US$ 127,937 thousands while the GOB will bear the remaining US$ 37,510 thousands.

EDCF will provide a loan for the components such as construction cost, commissioning & training cost, O&M support cost, consulting service cost, contingencies, EDCF service charge and GOB will bear the cost for the components such as construction cost for household connection, Taxes & duties, land acquisition & resettlement cost, project management cost. Financing plan of the project is summarized as follows.

Table 1-30 Financing Plan

Category		EDCF				GOB	Total
		Foreign		Local	Sub Total		
		Korea	3rd Countries				
Total Project Cost (US$ thousands)		55,596	7,905	127,937	191,438	37,510	228,948
Percentage (%)	EDCF	29.0	4.1	66.8	100.0	-	-
	Total	24.3	3.5	55.9	83.6	16.4	100.0

1.6.3.3 Annual Disbursement Plan

The project is to be implemented over 104 months taking into account the period required for project preparation, consultant selection, detailed design, bidding support, contractor selection and construction supervision. Annual Disbursement plan during project implementation period is as follows.

Table 1-31 Annual Disbursement Plan (US$ thousands)

Category		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
EDCF	1. Construction Cost	-	-	7,780	38,898	38,898	38,898	31,117	-	-	155,591
	2. Commissioning & Training	-	-	-	-	-	-	1,251	-	-	1,251
	3. O&M Support	-	-	-	-	-	-	356	1,048	692	2,096
	4. Consulting Service	-	4,608	1,580	1,580	1,975	1,975	1,448	-	-	13,166
	5. Contingencies	-	-	957	4,786	4,786	4,786	3,828	-	-	19,143
	6. EDCF service Charge	-	5	10	45	46	46	37	1	1	191
	Sub-Total	-	4,613	10,327	45,309	45,705	45,705	38,037	1,049	693	191,438
GOB	1. Construction Cost (Household Connection)	-	-			2,605	1,955	1,955	-	-	6,515
	2. Taxes & Duties	-	-	1,405	7,023	7,023	7,023	5,618	-	-	28,092
	3. Land Acquisition & Resettlement Cost	-	500	-	-	-	-	-	-	-	500
	4. Project Management Cost	-	240	360	384	409	409	360	120	121	2,403
	Sub-Total	-	740	1,765	7,407	10,037	9,387	7,933	120	121	37,510
Total Project Cost		-	5,353	12,092	52,716	55,742	55,092	45,970	1,169	814	228,948
Disbursement Rate (%)		-	2.34	5.28	23.03	24.35	24.06	20.08	0.51	0.36	100.00
Cumulative Disbursement Rate (%)		-	2.34	7.62	30.65	54.99	79.06	99.13	99.65	100.00	-

1.7 Economic & Financial Feasibility Analysis

1.7.1 Economic Feasibility Analysis

1.7.1.1 Introduction

Economic feasibility analysis is compared and analysed by converting cost and benefit into monetary value to estimate economic feasibility. Benefit/cost ratio (B/C), net present value (NPV), and internal rate of return (IRR) are generally used for evaluation index of economic analysis.

The period of 68 months from consultant selection to construction completion and 40 years of operation of the sewage treatment plant after construction completion are the basic analysis period. A discount rate of 12% is applied in accordance with the GOB internal policy.

1.7.1.2 Cost Estimate

1.7.1.2.1 Project Cost for Economic Feasibility Analysis

In the economic feasibility analysis, project cost excluding the price contingencies, tax & duties are considered only according to the EDCF guideline.

Table 1-32 Project Cost for Economic Feasibility Analysis (US$ thousands)

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Korea	3rd Countries				
1. Project Cost	55,596	7,905	127,937	191,438	37,510	228,948
2. Price Contingencies	4,437	633	10,245	15,315	-	15,315
3.Tax & Duties	-	-	-	-	28,092	28,092
Applied Cost	51,159	7,272	117,692	176,123	9,418	185,541

1.7.1.2.2 O&M Cost

Table 1-33 O&M Cost (US$)

Category	O&M Cost		Remarks
	Annual	For 40 Years	
Electricity cost	2,201,741	88,069,640	
Chemical cost	782,560	31,302,400	
Labor cost	293,646	11,745,840	
Consumables & Repair Cost	228,401	9,136,040	
Replacement Cost	1,658,150	66,326,000	
Administrative Cost	104,409	4,176,360	
Total	5,268,907	210,756,280	

1.7.1.3 Benefit Estimate

Table 1-34 Summary of Benefit (US$ thousands)

Year	Total	Water Quality Improvement	Living Standard Improvement	Septic Tank Reduction	Public Hygiene Improvement
2030	19,783	15,649	1,109	144	2,881
2031	20,664	16,200	1,149	333	2,982
2032	21,357	16,752	1,188	333	3,084
2033	22,048	17,303	1,227	333	3,185
2034	22,740	17,855	1,266	332	3,287
2035	23,432	18,406	1,305	333	3,388
2036	24,218	19,008	1,347	364	3,499
2037	24,972	19,609	1,390	363	3,610
2038	25,728	20,211	1,433	363	3,721
2039	26,484	20,813	1,475	364	3,832
2040	27,237	21,414	1,518	363	3,942
2041	27,237	21,414	1,518	363	3,942
2042	27,237	21,414	1,518	363	3,942

Note) Benefit is assumed as constant after year 2040.

1.7.1.4 Economic Feasibility Analysis

As a result of the economic feasibility analysis B/C ratio is analyzed as 1.31 on discount rate of 12%, with total benefit US$ 197,610 thousands, total cost US$ 150,731 thousands, net present value US$ 46,879 thousands.

Table 1-35 Result of Economic Feasibility Analysis (US$ thousands)

Category	Benefit at Present Value	Cost at Present Value	Net present value	B/C Ratio
6%	377,103	209,190	167,913	1.80
7%	331,507	195,458	136,049	1.70
8%	294,225	183,838	110,387	1.60
9%	263,419	173,861	89,558	1.52
10%	237,706	165,181	72,525	1.44
11%	216,037	157,536	58,501	1.37
12%	197,610	150,731	46,879	1.31

1.7.1.5 Sensitivity Analysis

In sensitivity analysis, B/C Ratio is analyzed as 1.02, NPV US$ 2,472 thousands and E-IRR 12.39% and it shows that this project is economically feasible even in the worst scenario of Case 4 with 20 % cost increase and 20 % benefit decrease.

Table 1-36 Sensitivity Analysis by Variation of Benefit/Cost

Case	Sensitivity	NPV (US$ thousands)	B/C Ratio	IRR (%)
Base		46,129	1.30	20.10%
Case 1	20% increase in costs	41,992	1.27	19.50%
Case 2	20% decrease in benefits	6,609	1.04	13.04%
Case 3	20% decrease in costs	50,268	1.34	20.67%
Case 4	Combination of case 1 and 2	2,472	1.02	12.39%

1.7.2 Financial Feasibility Analysis

1.7.2.1 Basic assumption

The basic assumption of the financial feasibility analysis is the same as for the economic feasibility analysis, but only the sewage fee is applied as the benefit instead of the economic benefit in economic feasibility, and price contingencies, taxes & duties, interest during construction considered for the cost as follows.

Table 1-37 Basic Assumption of Financial Feasibility Analysis

Category			Assumption		Remarks
Financing	EDCF		US$ 191,439 thousands		• Construction cost • Commissioning & training cost • O&M support cost • Consulting service cost • Contingency • EDCF service charge
	GOB		US$ 37,538 thousands		• Taxes & duties, • Land acquisition & resettlement cost, • Project management cost, • Interest during construction
	Total		US$ 228,977 thousands		
Repayment	Repayment method		Uniform principal and interest repayment		• Grace period: 15 years • Term of loan: 40 years
Revenue	Sewage Tariff	Category	Wastewater Generation	Unit Cost	• Based on year 2029 • Inflation applied
		Domestic Wastewater	36,006 m³/d	0.24 USD/m³	
		Non-Domestic Wastewater	4,606 m³/d	0.50 USD/m³	
	Solar Power Generation		Power Generation	Unit Cost	
			206,955 kW/year	0.0952 USD/kWh	
Operating Cost	O&M Cost	Electricity cost	US$ 3,176 thousands		• Annual
		Chemical cost	US$ 1,129 thousands		• Annual
		Labor cost	US$ 424 thousands		• Annual
		Consumables& repair cost	US$ 329 thousands		• Annual
		Administrative cost	US$ 151 thousands		• Annual
		Replacement cost	US$ 33,163 thousands		• Every 15 years
	Inflation		6.30 %		

1.7.2.2 Financial Feasibility Analysis

As a result of the financial feasibility analysis, it is analyzed that this project is not financially feasible to recover the investment cost with the revenue from sewage tariff & solar power generation.

Table 1-38 Financial Analysis Result

Category	Result	Remarks
FIRR (%)	0.39%	Discount rate of 6.31%
FNPV (US$ thousands)	(149,738)	

1.7.2.3 Sensitivity Analysis

The result of sensitivity analysis for the change of investment cost and operating cost is as follows.

Table 1-22 Sensitivity Analysis for the Change of Investment Cost & Operating Cost

Category	-55%	-35%	-15%	BASE	20%
Total Investment cost (US$ thousand)	103,056	148,835	194,631	228,977	274,773
Total operating cost (US$ thousand)	474,032	655,235	836,437	972,339	1,153,542
Equity (US$ thousand)	16,908	24,400	31,907	37,538	45,045
EDCF (US$ thousand)	86,148	124,435	162,723	191,439	229,727
IRR	6.63%	4.11%	1.98%	0.39%	-1.99%
NPV	6,418	(50,365)	(107,150)	(149,738)	(206,523)
PI	1.05	0.74	0.58	0.49	0.41

The result of sensitivity analysis for the change of sewage tariff is as follows.

Table 1-23 Sensitivity Analysis for the Change of Sewage Tariff

Category	-20%	BASE	20%	70%	110%
Domestic	0.19 USD/m^3	0.24 USD/m^3	0.29 USD/m^3	0.41 USD/m^3	0.51 USD/m^3
Non-Domestic	0.40 USD/m^3	0.50 USD/m^3	0.60 USD/m^3	0.85 USD/m^3	1.05 USD/m^3
Equity (US$ thousand)	37,538	37,538	37,538	37,538	37,538
EDCF (US$ thousand)	191,439	191,439	191,439	191,439	191,439
IRR	-2.89%	0.39%	2.24%	5.03%	6.53%
NPV	(178,708)	(149,738)	(120,768)	(48,342)	9,599
PI	0.39	0.49	0.59	0.84	1.03

The result of sensitivity analysis for the annual increase of sewage tariff is as follows.

Table 1-24 Sensitivity Analysis of Annual Increase of Sewage Tariff

Category	BASE	2%	4%	6%	8%
Total Sewage Tariff (US$ thousand)	1,236,806	2,271,037	4,223,407	7,912,081	14,871,659
IRR	0.39%	4.96%	7.95%	10.46%	12.75%
NPV	(149,738)	(57,591)	106,171	400,484	933,207
PI	0.49	0.80	1.36	2.36	4.16
Short Term loan occur	38 years	24 years	14 years	10 years	8 years

1.8 Environmental & Social Impact Assessment

1.8.1 Categorization

Initial environmental and social impact assessment is conducted to identify and analyse the predictable environmental and social negative impacts and risks caused by the project implementation in advance. It contributes to sustainable development by identifying the negative effects of the EDCF loan support project on the environment and local residents and avoiding and minimizing them.

- Bangladesh Categorization: The project is categorized as "Red" according to Bangladesh's Environmental Conservation Rules (1997) and ESIA is required during the project implementation.
- EDCF Categorization: The project is categorized as "Category B+" according to the EDCF Environmental Social Impact Analysis Risk Classification under the EDCF safeguard policy (2020), so it is likely to have substantial adverse environmental and social impacts and risks that are less adverse than those of category A projects and ESIA is required during the project implementation.

1.8.2 Environmental Impact Assessment

In Phase 1 as a target year 2040, daily average wastewater generation of sewage treatment plant is 55,574 m^3/d is only 0.23% of 25,920,000 m^3/d which is the lowest flow rate of Halda river and Treated effluent is discharged to Madari Khal and final receiving water body is Halda River.

Treated effluent discharge point of STP in Madari Khal is about 7.6km away from the intake facility of Modunaghat WTP and about 11.5km away from the intake facility of Mohara WTP, so the impact of effluent will be negligible to the intake of WTP. For instance, 4.0km of standard distance from the intake of WTP is considered when designating a water source protection area in Korea.

Treated effluent will satisfy the standard Sewerage discharge of DOE, so it will contribute to improve the water quality of river and to preserve the ecosystem of river. It is planned to obtain the environmental license through the environmental impact assessment during the project implementation.

1.8.3 Social Impact Assessment

Proposed site of sewage treatment plant has been owned by CWASA since 1960s, so the land acquisition is not required. However, there are illegal residents in the proposed site even though there no schools and mosques, resettlement action plan should be prepared by CWASA during the project implementation.

There is no requirement for the buffer zone from STP to the resident area in the environmental regulation of Bangladesh, odour control facility will be constructed in the STP and odour mitigation measures shall be analyzed in the ESIA during the project implementation.

Table 1-39 Land Use of Sewage Treatment Plant Site

No.	Category	Total	A1	A2	A3	Remarks
1	Common House (Tin-roofed)	49	9	6	34	
2	Common House (Brick building)	11	2	5	4	
3	Cattle Farm	8	-	3	5	
4	Two-story Building	2	-	2	-	
5	Three-story Building	2	-	-	2	
6	One-story Building	1	1	-		
7	CWASA Storage	1	-	1	-	
8	School	1	1	-	-	
9	Toilet	1	1	-	-	
10	Religious Facility	2	1	1	-	
11	Cemetery	4	3	1	-	
12	Pond	25	-	-	-	
13	Khal	1	-	-	-	
14	Dirt Road	3	-	-	-	
15	Paved Road	4	-	-	-	
16	BFS Road	1	-	-	-	
17	RCC Road	2	-	-	-	
18	RHD Road	1	-	-	-	
19	Railroad	1	-	-	-	
20	Forest	-	-	-	-	
21	Bridge	2	-	-	-	
22	Culvert	-	-	-	-	
23	Street Lamp	26	-	-	-	
24	Tree	5000 +	-	-	-	
25	Rice Field	210	-	-	-	

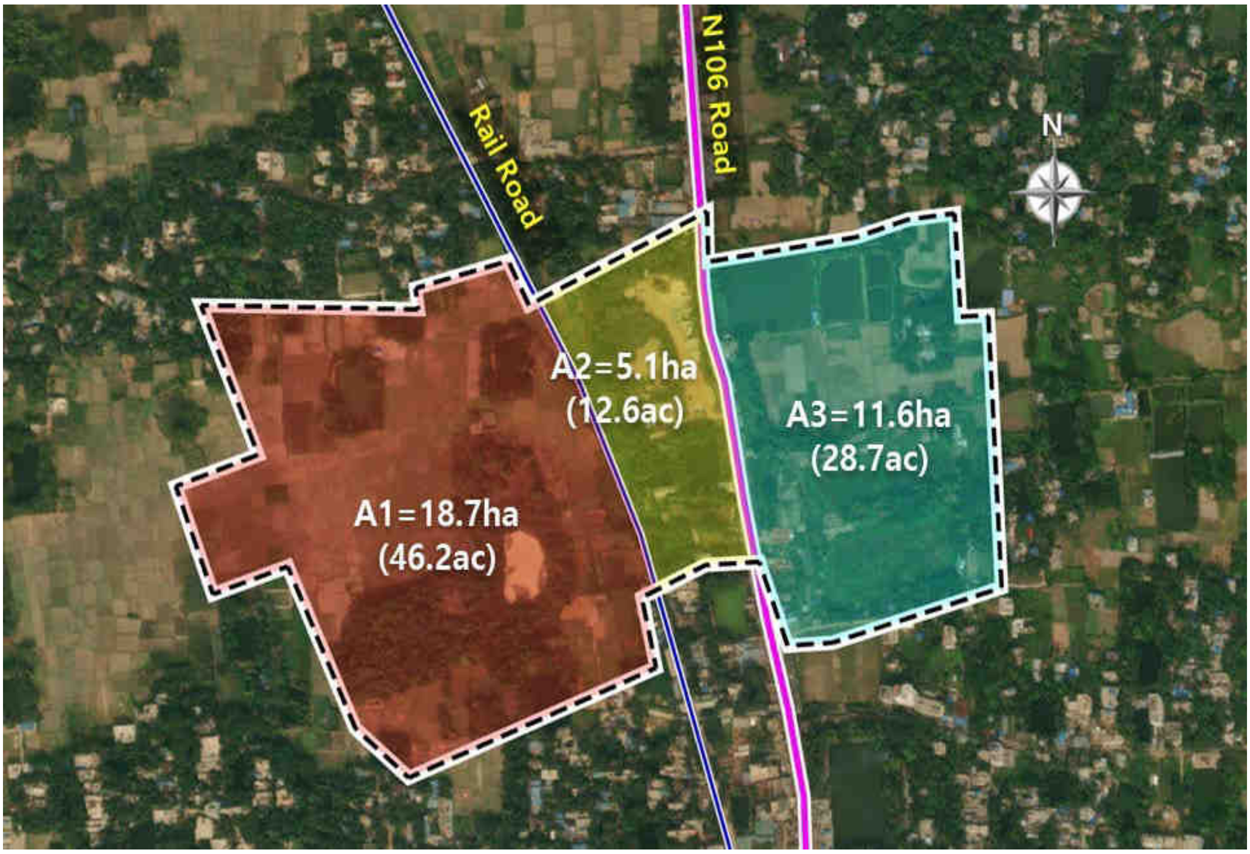


Figure 1-20 Proposed Site of Sewage Treatment Plant

1.9 Project Monitoring Framework

EDCF sets up the logical framework as the project monitoring framework (PMF) and it outlines the impact, outcomes and outputs of the EDCF projects and it is the basic project management tool for development results by including monitoring indicators and indicator definitions, targets, and primary beneficiary information.

Table 1-40 Project Monitoring Framework

Category	Indicators	Base	Targets	Source	Assumptions/ Risks
Impact *Improvement of water quality in river and Reduction of vulnerability to climate change*	Improvement of water quality in river	Organics in river (BOD, COD, SS) (6 months before construction completion)	Improvement of water quality in river (BOD, COD, SS) (5 years after construction completion)	CWASA O&M Report	<Assumption> • Policy support of GOB • Willingness of the PEA <Risk> • Lack of O&M resources and technology
	Greenhouse gas emission reduction	52,409 t CO^{2}eq/year (2022)	27,642 t CO^{2}eq/year (5 years after construction completion)	CWASA O&M Report	
	Reduction of vulnerable population to climate change	N/A (2022)	Sewage service population 334,435 (5 years after construction completion)	CWASA O&M Report	
Outcomes *Improvement of living standard and sanitation of inhabitants in the project area*	Sewage service coverage	N/A (2022)	60.0% (2 years after construction completion)	CWASA O&M Report	<Assumption> • Normal operation of the facility by the input of professional operating personnel • Completion of household connection construction <Risk> • Delayed response to facility failure • Delay of household connection construction
	Daily wastewater treatment of wastewater treatment plant	N/A (2022)	40,612m^3/d (2 years after construction completion)	CWASA O&M Report	
	Compliance with effluent discharge standard	Influent Quality BOD: 322mg/L COD: 644mg/L SS: 386mg/L T-N: 76mg/L T-P: 15mg/L	BOD: 20mg/L COD: 100mg/L SS: 30mg/L T-N: 40mg/L T-P: 10mg/L (After construction completion)	CWASA O&M Report	
	Number of STP operation suspension related to climate disasters	N/A (2022)	Zero (2 years after construction completion)	CWASA O&M Report	
Outputs *Construction of sewerage system with climate resilience*	Construction of sewerage system with climate resilience	N/A (2022)	• STP: Q=60,000m^3/d • FSTP: Q=100m^3/d • Sanitary Sewer: L=58.3km • HHC: 10,000nos	Project Completion Report	<Assumption> • Securing financial resources of PEA • Efficient project management • Completion of resettlement before construction <Risk> • Delay in approval/permission from relevant agencies • Unexpected design changer construction delay

Monitoring

- Consultant for detailed design, bid preparation and construction supervision will be selected within 4 months after L/A.
- Contractor will be selected within 16 months after selection of the Consultant
- Construction will be completed within 48 months (including 6 months of training and commissioning)

Project Objective

- To increase sewage service coverage through construction of sewerage system
- To improve living standard and sanitation of inhabitants in the project area
- To improve river water quality and restore the ecosystem by sewage treatment

Primary Beneficiary

- People of Chattogram City, Hathazari Upazila and Raozan who inhabits in the project area

Definition and Management of Indicator

Indicator	Definition	Source	Managed by
Water quality in river	Water quality measurement of organics such as BOD, COD, SS in rivers	CWASA O&M Report	CWASA
Greenhouse gas emission reduction	Calculation method of 2006 IPCC G/L	CWASA O&M Report	CWASA
Reduction of vulnerable population to climate change	Sewage service population	CWASA O&M Report	CWASA
Sewage service coverage	Sewage service population / Total population	CWASA O&M Report	CWASA
Daily sewage treatment of sewage treatment plant	Average daily sewage treatment quantity	CWASA O&M Report	CWASA
Compliance with effluent discharge standard	Standard Sewerage discharge in environment conservation rules (2023, DOE)	CWASA O&M Report	CWASA
Number of STP operation suspension related to climate disasters	$\sum$ (Number of STP operation of suspensions related climate change)	CWASA O&M Report	CWASA
Sewerage system with climate resilience	Infrastructure to convey and treat wastewater from its point of origin to a point of treatment and discharge	Project Completion Report	Consultant & Contractor
Sewage treatment plant	Facility to remove contaminants from wastewater to produce an effluent that is suitable for discharge to the public water body	Project Completion Report	Consultant & Contractor

1.10 Project Implementation Period

Project implementation period is planned as 92 months after loan approval as below. It may be extended upon the request of the GOB and with a prior consent from the KEXIM.

- Consultant selection: 4 months
- Detailed design & bidding support: 12 months
- Contractor selection: 4 months
- Construction and construction supervision: 48 months (including 6 months of commissioning & training)
- O&M support after construction completion: 24 months

Table 1-41 Project Implementation Period

	Activity	Duration (Month)	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6				Year 7				Year 8			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
EDCF	Consultant Selection	4M	■	■																														
EDCF	Detailed Design & Bidding Support	12M		■	■	■	■	■																										
EDCF	Contractor Selection	4M						■	■																									
EDCF	Construction	48M							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■									
EDCF	STP	36M							■	■	■	■	■	■	■	■	■	■	■	■	■													
EDCF	Trunk Sewer	38M								■	■	■	■	■	■	■	■	■	■	■	■	■												
EDCF	Primary Sewer	36M										■	■	■	■	■	■	■	■	■	■	■	■	■										
EDCF	Secondary Sewer	26M															■	■	■	■	■	■	■	■	■									
EDCF	Commissioning & Training	6M																					■	■	■									
EDCF	Construction Supervision	48M							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■									
EDCF	O&M Support	24M																							■	■	■	■	■	■	■	■	■	
GOB	Land Acquisition & Resettlement	6M				■	■	■																										
GOB	EIA approval	6M				■	■	■																										
GOB	Other permission	9M			■	■	■	■																										
GOB	Household Connection	30M													■	■	■	■	■	■	■	■	■	■	■									

Note) Household connection will be constructed sequentially by GOB according to the construction of sanitary sewer.

2 General Information

2.1 Natural Condition

2.1.1 Introduction

2.1.1.1 General

The Chattogram city which is located on Karnaphuli River is second largest city and number one harbor and industrial city in Bangladesh. Chittagong located about 150km southeast of Dhaka city, Capital of Bangladesh, is a social, economic and cultural center. Bangladesh located on the Ganges Delta has no suitable port inland allowing vessel to come alongside the quay. And it is only possible for vessels from the Indian Ocean to bring it alongside the quay and anchor at the dock, because of enough depth of Karnaphuli river. So many cities have been constructed in along the shores of Karnaphuli river, utilizing it as major hotspot for sailing the Indian Ocean, since B.C. Chattogram accounts for 12% of Bangladesh's GDP, including 40% of industrial output, 80% of international trade, and 50% of tax revenue.

Its population is continuously increasing by inflow from neighboring villages and by enlargement of city as well as natural increase of population, and its trend is expected to continue because of many advantages as a commercial and industrial city.

CCC (Chattogram City Corporation) is the main administrative body of local government and as the sub-governmental unit of MLG (Ministry of Local Government), it coordinates with the central government with regard to regional development. Chittagong started as a small region-centered city with a population of 25,000 in 1863 and promoted to CMC (Chattogram Municipality Corporation) in 1982 which was area the size of 4. 5sq.mile. And the current status of CMC (Chattogram Municipal Corporation) was granted in 1990 In April 2018, the Cabinet Division of the Bangladesh Government decided to change the city's name to Chattogram, based on its Bengali spelling and pronunciation.

2.1.1.2 Geography

Chattogram about 150km southeast of Dhaka city, it lies at 22°20′06″N 91°49′57″E. Chattogram Hill Track is located at Bandarban, Rangamati, Khagrachari in east, Noakhali and Bengal Sea in west, Cox's Bazar in south, Feni and Tripura of India in north.

The Karnaphuli River runs along the southern banks of the city, including its central business district. The river enters the Bay of Bengal in an estuary located 12 kilometers west of downtown Chattogram.

Figure 2-1 Location Map of Chattogram

2.1.1.3 Administrative Division

Bangladesh's administrative district consists of Division, District, Upazila/Thana, Union, Ward, Mauza, Mahallah and Village. Before to 2015, it consisted of seven divisions, but the Maiman Singh Division was separated from the Dhaka Division. And Thana and Ward correspond to 'Dong' or 'Gu' of Korea. There is an administration center which is called City Corporation in Division and Paurashavain in Upazila/Zila. The number and area of administrative districts for each division are as follows. The Chattogram Division, which includes the site of this project, is divided into a total of 11 Districts, 103 Upazila, and 949 Unions, with a total area of 33,908 km^2.

Table 2-1 Bangladesh Administrative Divisions

Division	Established Year	Districts	Upazilas	Union	Area (km^2)
Barishal	1993	6	42	333	13,225.2
Chattogram	1829	11	103	949	33,908.6
Dhaka	1829	13	88	1,248	20,593.7
Khulna	1960	10	59	270	22,284.2
Maiman Singh	2015	4	35	350	10,584.1
Rajshahi	1829	8	67	558	18,153.1
Rangpur	2010	8	58	536	16,185.0
Sylhet	1996	4	40	334	12,635.0
Total		64	492	4,578	147,569.1

*Source: Statistical Yearbook Bangladesh (2021, BBS)

2.1.2 Topography & Geography

2.1.2.1 Topography

Chattogram area lies along the western margin of tectonically active Chattogram – Tripura folded belt. On the basis of landforms, its genesis, evolution and morpho dynamics, Chattogram City can be divided into three broad distinct geomorphological divisions: (1) hilly area, (2) fluvio-tidal plain and (3) tidal plain.

The elevation of the hills ranges from 10m to 300m. The relief varies between very steeply dissected, linear hill ranges and gently rolling, non-linear landforms in different areas. The low range hills occupy the synclines between the high hill ranges and the tops of some lower anticlines. Most areas are strongly dissected, with short, steep slopes, but some low hills have rolling to nearly level relief.

2.1.2.2 Geography

Chattogram Hill Track is located at near to Bengal Sea in west, Sangu River in south and Rangamati hilly area in a way to the east. And Karnaphuli River located at Chattogram plain and originated in India and East hill area, traverses the east to west of Chattogram City Corporation. As Chattogram has developed as international exporting port since the Middle Ages, the river became driving force of development, on the other hand, the river acted as a barrier of transportation, the development of the left side of river was hindered. But in recent, as the modern bridges have been constructed, it is also expected to develop at left side of river.

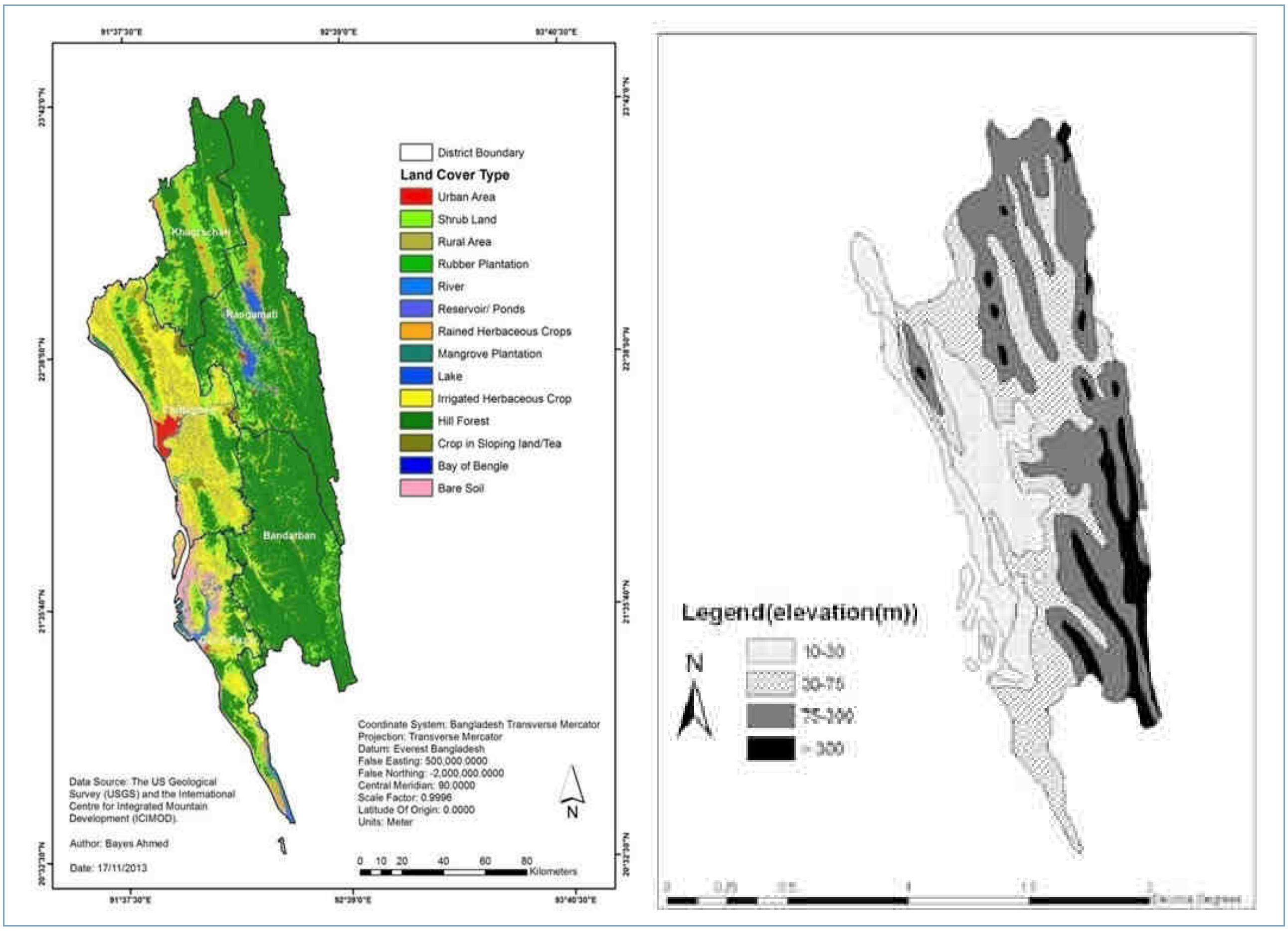


Figure 2-2 Topography and Elevation map

2.1.2.3 Geology

The hilly area is based on solid rock, mainly made of denatured or cement hardened material, and non-hardened sediments such as soil, sand, gravel and is mainly composed of alternating layers of sandstone, siltstone and shale.

The surface geology was formed by the Miocene and Pliocene centuries on mudstone formed in the Miocene. The hill track continues along the boundary between the alluvial plains and the sloping hill area to the east forming a steep anticlinal structure and leading to the Bengal Sea. On the other hand, the alluvial layer, which is a flat land was also formed by alternately stacking mud and sand layers with a thickness of about 30m and is composed of Dihing, Dupi Tila, Tipam and Boka Bil. The stratigraphic continuity and geologic characteristics of each formation are as follows.

Table 2-2 Stratigraphic Succession of Chattogram City

Name		Age	Rock Type	Geotechnical Characters
Dihing		Pliocene	• Reddish brown to brick red, massive, highly ferruginous, weathered sandy to clayey silt, clay and pebbly sandstone at places, oxidized iron incrustation. On top weathered residual soils.	• Very soft(30-10kg/cm^2) to soft(100-30kg/cm^2) in hardness, low-to-medium relative strength, uniaxial compressive strength of 1-2kg/cm^2.
Dupi Tila		Mid-Pliocene	• Sandstone and alternation of silty sand and silty shale. Sandstone massive and medium to fine grained, silty sand beds are gray to yellowish brown, thickly laminated to bedded. Silty shale is light gray to gray, very thinly laminated, fissile. Presence of iron incrustation.	• Longitudinal joints are present dipping almost parallel to the bedding, spacing varies from closed to 1.5cm, filled with ferruginous band with coarse sand. Soft(100-30kg/cm^2) in hardness. Low-to-medium relative strength.
Tipam	Upper	Mid Miocene	• Sandstone, siltstone and occasional shale, Sandstone cross-bedded and local unconformity at the base	• Soft in hardness (100–30 kg/cm^2), moderately weathered, faulted, conjugate (planar) joints are present with vertical and dipping orientation, spacing <1 cm, medium relative strength, uniaxial compressive strength >550 kg/cm^2
Tipam	Middle	Mid Miocene	• Silty shale and shale, bedded, shale relatively hard, at places calcareous.	• Moderate (250–100 kg/cm^2) to hard (700–250 kg/cm^2) in hardness, faulted, laminated, medium to high relative strength, uniaxial compressive strength varies from 550 to 1100 kg/cm^2.
Tipam	Lower	Mid Miocene	• Massive sandstone, yellowish brown to brown, medium to coarse grained, loose to dense, cross-bedded	• Moderate (250–100 kg/cm^2), at places hard (700–250 kg/cm^2) in hardness, slightly to highly weathered, faulted, planar and conjugate joints are seen with vertical and dipping orientation, spacing <1 cm, ferruginous and argillaceous filling, medium to low relative strength, uniaxial compressive strength varies from 275 to 750 kg/cm^2.
Boka Bil		Early Miocene	• Silty shale, siltstone, sandstone and alternation of sand and siltstone. Cross bedding, cross lamination, ripple marks and load casts are present.	• Moderate (250–100 kg/cm^2) to hard • (700–250 kg/cm^2) in hardness, fresh, faulted, planar diagonal to conjugate joints present, closed spacing, filled with mainly parent material, medium to high relative strength, uniaxial compressive strength varies from 250 to 700 kg/cm^2.

*Source: Landslide Susceptibility of Chittagong City (2018)

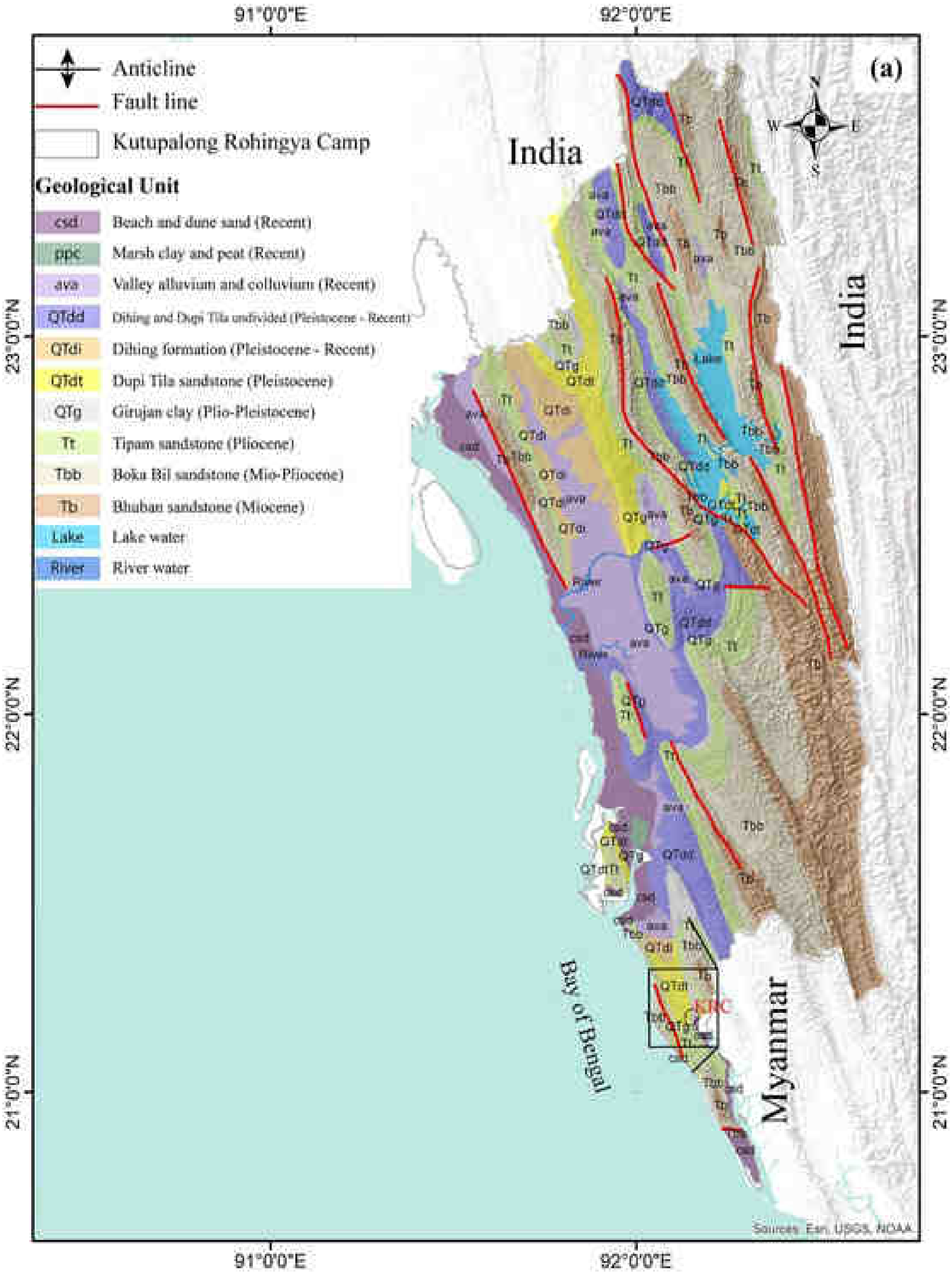


Figure 2-3 Geological map

2.1.3 Climate

Chattogram is a monsoon climate region located near the equator. The monsoon climate are high temperatures, humidity and heavy rain. This area is divided into a high-temperature dry period from March to May, a high-temperature period from June to October, and a dry and cool period from November to February.

As a result of temperature analysis over the last 30 years, the average temperature is 25.3°C, the highest temperature is 30.8°C, and the lowest temperature is 24.1°C, and the average temperature difference throughout the year is 6.7℃.

The average annual rainfall is 231.4mm. In terms of monthly average rainfall, 80% of the average annual rainfall is concentrated over five months. The highest monthly precipitation is 622mm in July and the lowest is 5.0mm in January.

Table 2-3 Monthly Average Temperature & Rainfall (1991~2021)

Category	Unit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Ave
Max.	°C	24.1	26.9	29.7	30.8	30.5	29.3	28.6	28.9	29.1	29.2	27.5	24.9	28.3
Min.		15.7	18.1	22.0	25.2	26.0	26.0	25.6	25.6	25.5	24.5	20.9	17.4	22.7
Avg.		19.8	22.5	25.8	27.9	28.1	27.4	26.9	27.0	27.1	26.6	24.0	21.0	25.3
Rainfall	mm	5	17	57	101	304	598	622	449	350	209	50	15	231.4
Humidity	%	72	68	71	79	83	87	88	88	87	85	79	76	80.3

*Source: Climate-Data.org

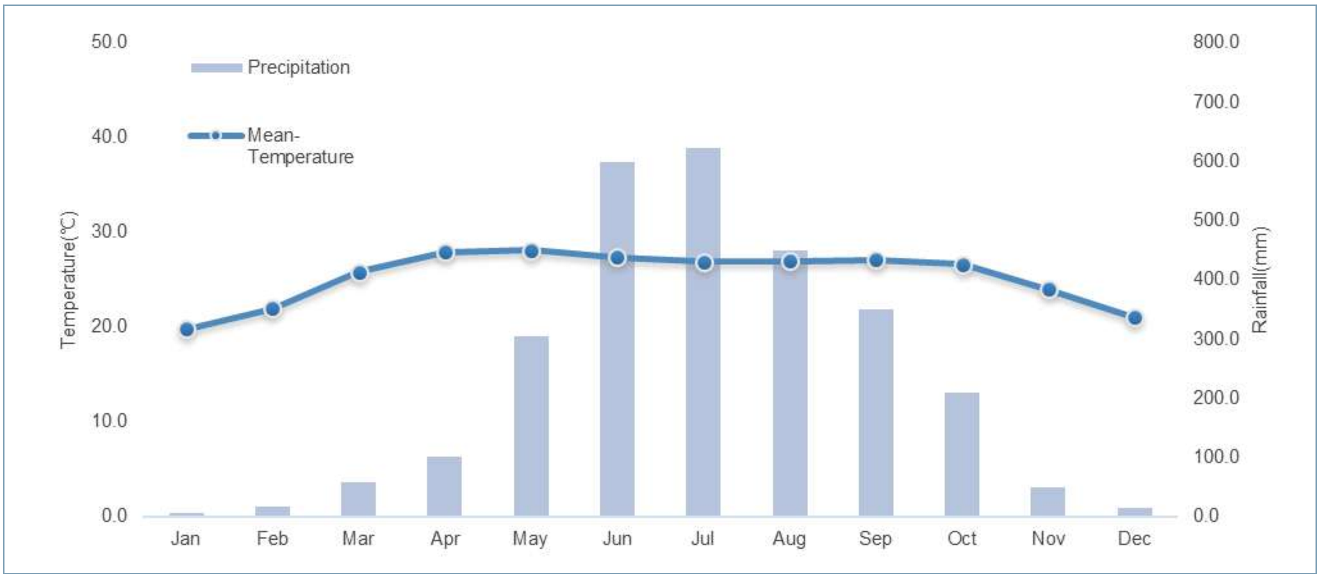


Figure 2-4 Monthly Average Temperature & Rainfall

2.1.4 River System

Chattogram division consists of Chattogram hill track, rivers traversing Hill track and alluvial plain formed by these rivers. As main channel, there are Feni river in North, Karnaphuli River in middle and Sangu River in south. And natural channel to flow water to sea directly and artificial channel are also developed.

Feni originates in the eastern hills of Tripura and enters Bangladesh at Belchhari of Matiranga upazila of Khagrachhari district, it flows through Ramgarh (Khagrachhari), Fatikchhari (Chattogram) and then flows along the border of Chattogram (Mirsharai upazila) and Feni (Chhagalnaiya, Feni, Sonagazi upazilas) districts and discharges into the Bay of Bengal near Sonagazia. The length of the river is 108km.

The Karnapuli, The principal river of the region. It originates in the Lushai Hills of Mizoram (India), flows through Rangamati and the port city of Chittagong and discharges into the Bay of Bengal near Patenga. The length of the river is 270km.

The Kaptai Dam is located upstream, Rainkhiang, Sublong, Thega, Kasalong, Ichamati and Halda are its main tributaries.

Sangu river originates in the Arakan Hills of Myanmar and enters Bangladesh near Remarki (Thanchi upazila of Bandarban district). It flows north through Thanchi Rowangchhari and Banshkhali upazilas of Bandarban district. Then it flows west through Satkania and Banshkhali upazilas of Chattogram district to meet the Bay of Bengal near Khankhanabad (Chattogram). The length of the river is 270km. Its main tributaries are the Chand Khali Nadi and Dolukhal, which connect with the Karnaphuli River through the Chand Khali River.

Table 2-4 Chattogram Division River System

Main Stream	Tributary	River Section				Length (km)	Remarks
		Start		End			
		Country	Source	Region	Inflow		
Feni		India	Tripura	Sonagazi	Bay of Bengal	108	
	Muhuri	India	Tripura	Parshuram	Feni	59	
Karnaphuli		India	Lushai Hill	Patenga	Bay of Bengal	270	
	Halda	Bangladesh	Batnatali Hill	Madhunaghat	Karnaphuli	88	
	Rainkhiang	Bangladesh	Rangamati	Belaichhari	Kaptai Lake	77	
	Kasalong	Bangladesh	Baghaichhari	Kedarmara	Karnaphuli	65	
	Ichamati	Bangladesh	Kawkhali	Rangunia	Karnaphuli	30	
Sangu		Myanmar	Arakan Hill	Khankhanabad	Bay of Bengal	270	
	Chand Khail Nadi	Bangladesh	Patiya	Satkania	Sangu	11	
	Dolukhal	-	-	Satkania	Sangu	-	

*Source: Banglapedia.org

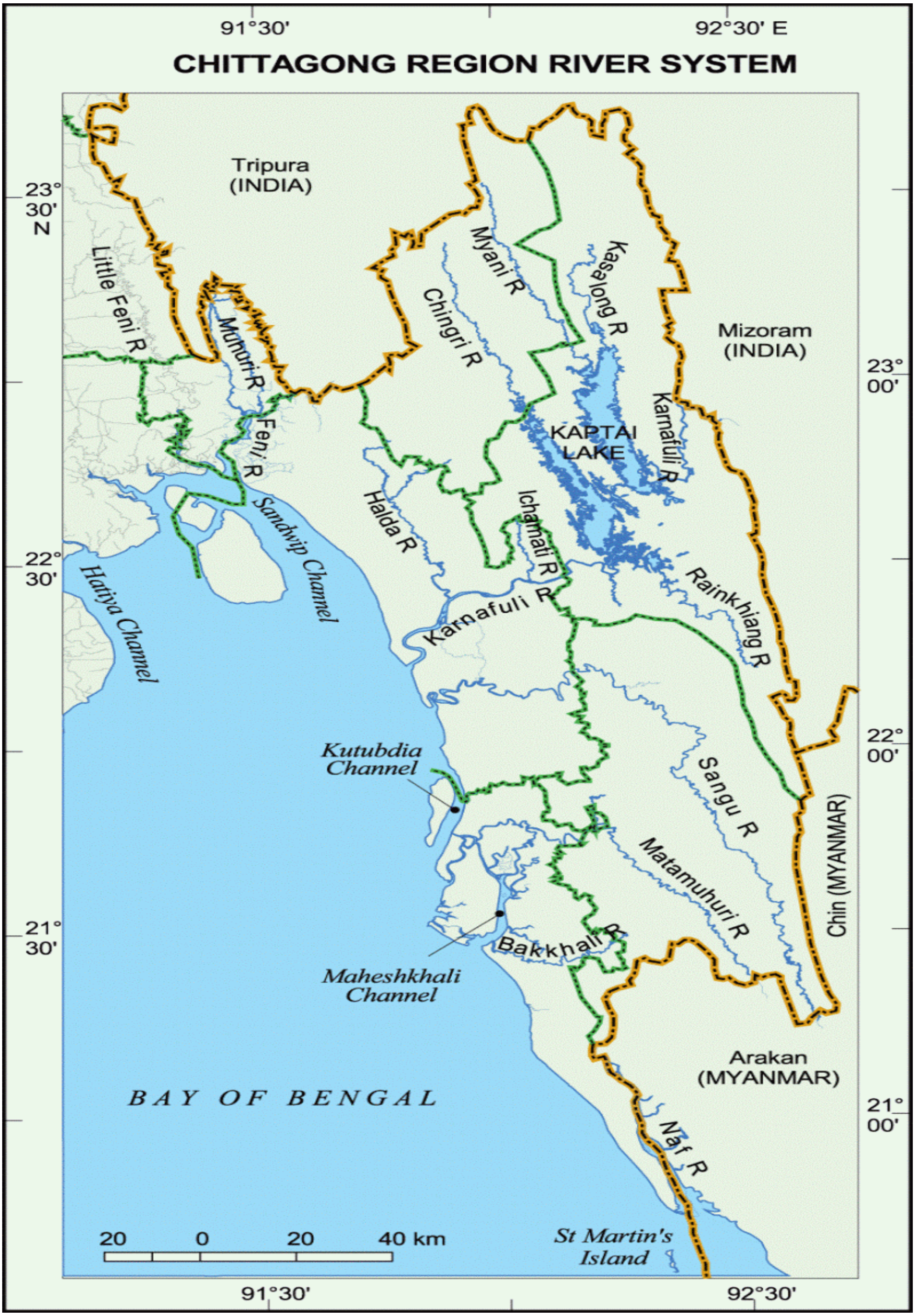


Figure 2-5 Rvier System Map

2.1.5 Water Resource & Land Use

2.1.5.1 Water Resource

Kaptai Lak is the largest lake in Bangladesh. It is located in the Kaptai Upazila. The lake was created as a result of building the Kaptai Dam on the Karnaphuli River, as part of the Karnaphuli Hydro-electric project. Kaptai Lake's average depth is 30m and maximum depth is 150m.

Kaptai Dam is on the Karnaphuli River at Kaptai, 65 kilometers upstream from Chattogram. The Kaptai dam, of which the catchment area is about 680km^2. As part of water catchment area is positioned in India, the amount of water flowing to the dam is reduced if an insufficient amount of water discharged from dam in India. Main source of water of the Karnaphuli river is from Kaptai dam. And when water discharge is ceased due to drought, salinity intrusion at high tide makes serious problems to water supply.

Figure 2-6 Kaptai Lake & Dam

2.1.5.2 Land Use

2.1.5.2.1 Introduction

Current landsite use, as presented in CDA's detailed area plan, can be summarized as follows. Most of the land developments in the urban area were done in an unplanned manner, and in the outskirts, only villages that look like a strap along the major traffic roads or a few main areas were developed, which has caused serious traffic problems.

The planned urban area developed by government, which was supposed to fit a specific land use purpose, is currently not fulfilling the original purpose due to the absence of government policy or regulation. Population density is increasing in the downtown city, but successively developed area shows varying density.

2.1.5.2.2 Land Use

Among the 69,080ha area covered, 16,741ha is restricted for residential, commercial, or industrial purposes. The detailed area plan subdivided this into 12 Development Processing Zones (DPZ), of which DPZ 1~6 is downtown and the rest are located in outskirts. Among the restricted area of 16,741ha, residential areas make up 58%, roads and public facilities 14%, factory space takes up 14%, and 4% are for the commercial use.

Table 2-5 Land Use Status

Category	DPZ 01	DPZ 02	DPZ 03	DPZ 04	DPZ 05	DPZ 06	DPZ 07	DPZ 08	DPZ 09	DPZ 10	DPZ 11	DPZ 12
Residential	1,345	1,346	339	411	662	521	168	720	875	1,149	1,028	1,168
Commercial	21	21	136	114	57	29	21	21	30	47	146	68
Educational	22	22	19	19	23	7	3	13	40	62	6	15
Industrial*1	536	739	13	219	139	64	209	66	14	21	27	324
Miscellaneous	17	17	10	161	20	28	13	30	13	19	20	34
Compound	2	2	102	274	32	8	2	5	10	15	1	3
Office	0	0	5	18	7	0	0	3	2	2	0	0
Public	15	13	17	60	19	6	39	33	14	33	49	13
Public Utilities	6	6	20	12	25	0	2	4	2	2	13	6
Roads & Transportation facilities	294	292	144	194	176	145	140	153	77	118	274	388
Total Public Utilities	2,257	2,459	806	1,481	1,161	807	593	1,047	1,076	1,470	1,564	2,019
	44%	60%	60%	45%	49%	21%	6%	10%	38%	33%	25%	14%
Others	2,884	1,622	540	1,835	1,232	3,079	9,745	9,712	1,789	2,975	4,702	12,225
Total area	5,141	4,081	1,346	3,316	2,393	3,886	10,338	10,759	2,865	4,445	6,266	14,244

*Source: DAP for CMMP

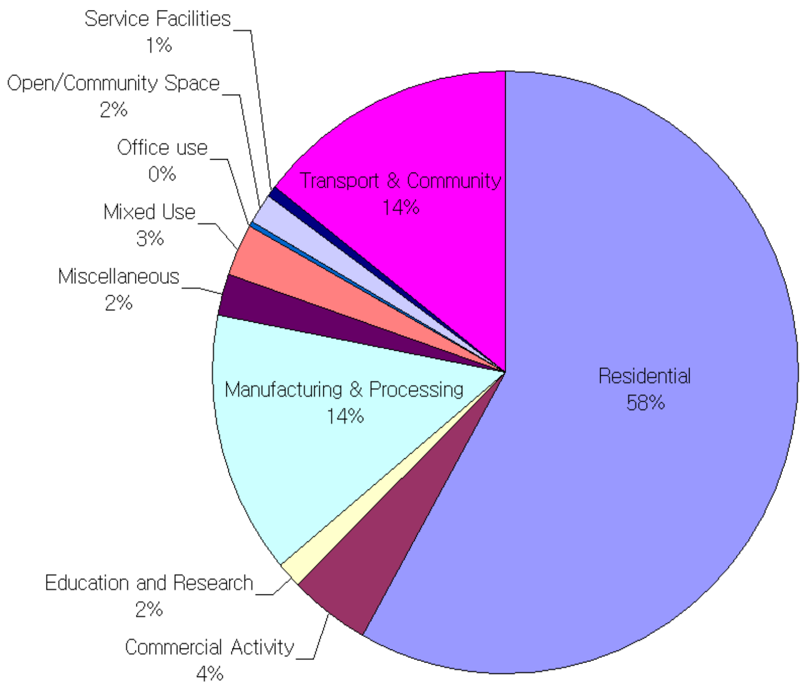


Figure 2-7 Land Use diagram

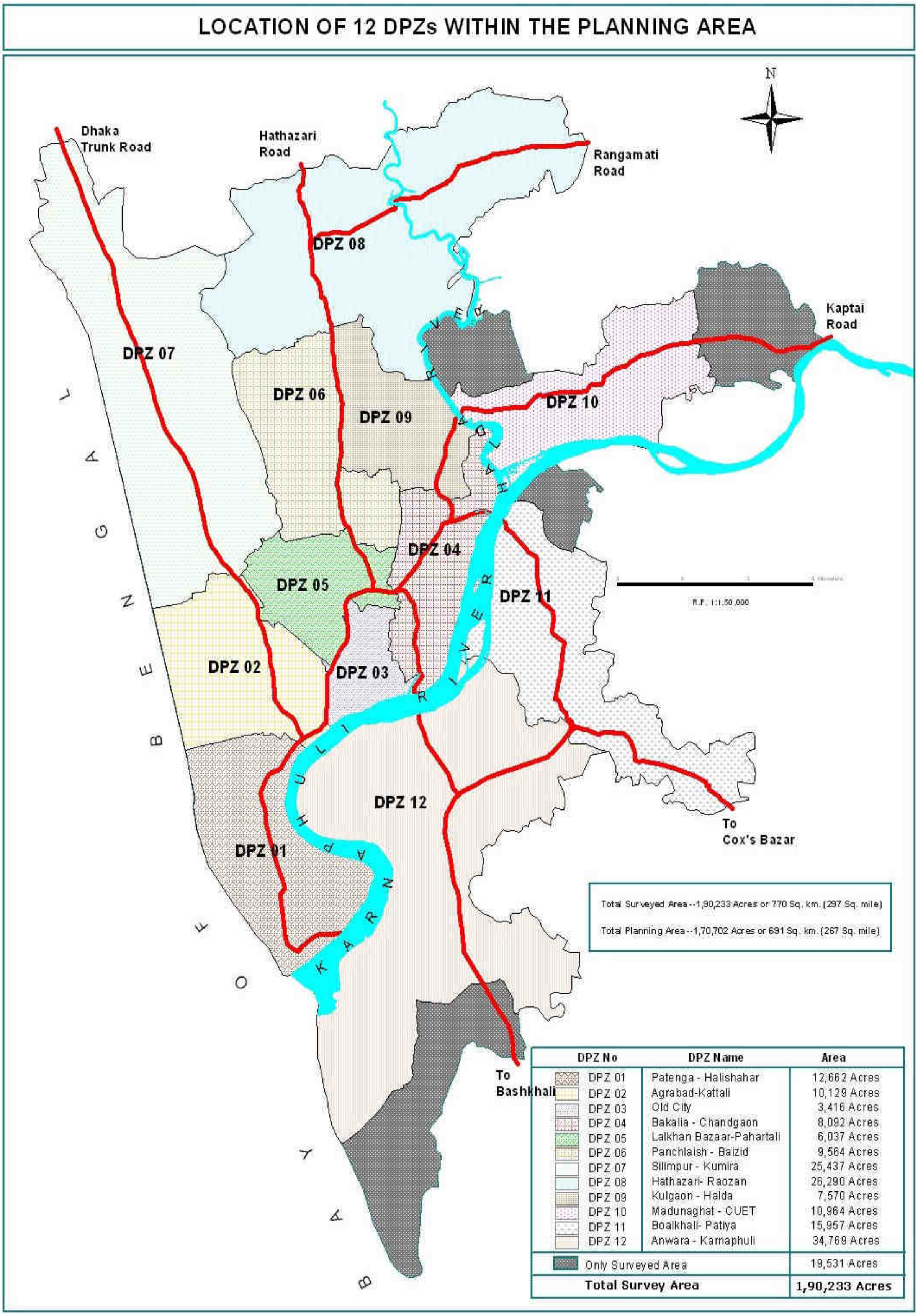


Figure 2-8   Map of urban planning district

2.1.5.2.3 Residential Area

Except for a few planned zones, most of the residential areas were developed in extremely disorderly manner, partially because development was done privately. According to the structure plan of CDA, 85% of development was performed privately, 15% was performed by the government which 7.6% of that was for government employees and the remaining 7.4% was supplied to upper and middle-class residents (SAPROF report, 2005). The government institution in charge of its distribution is the CDA and Housing Settlement Department. Residential complexes developed by the government are scattered around in Agrabad, Chandgaon, Halishohar, and Salimpur, located on the left side of the Karnaphuli river.

Recently, the residential complexes have been under construction in Kaiball and Aydham for the poor, and the government has established residence distribution policies targeting specific classes.

Table 2-6 Residential Status

No.	Institution in charge	Name	Area (Acre(ha))	Number of blocks	Construction period
1	CDA	Katalganj	6 (2.4)	51	1960 ~ 61
2	CDA	Agrabad	33 (13.4)	774	1962 ~ 63
3	CDA	Chandgaon	41 (16.6)	606	1962 ~ 63 1973 ~ 74
4	CDA	Chandgaon (2nd)	5.79 (2.3)	83	1978 ~ 80
5	CDA	Fauzderhat	13.62 (5.5)	164	1962 ~ 63 1980 ~ 81
6	CDA	Chandrima	11.97 (4.8)	183	1999 ~ 00
7	CDA	Halishahar	14.80 (5.9)	22	1963 ~ 64
8	CDA	Sholoshar	10.25 (4.1)	98	1960 ~ 61
9	CDA	Selimpur	98.93 (40.0)	1,029	1985 ~ 90
10	CDA	Karnaphuli	51.69 (20.9)	516	1991 ~ 96
11	CDA	Kalpalok (I, II)	129.42 (52.4)	1,700	2005 ~ 06
12	CDA	Annayana	62 (25.1)	1,521	2007
13	NHA	Shershai	-	330	-
14	NHA	Feroz Shah	-	944	-
15	NHA	Halishahar	-	3,419	-
16	NHA	Kaiballayandham	41.3 (16.7)	4,275	1988 ~ 97
17	CCC	Sughandah	-	194	-
18	PWD	Panchalish	-	139	-
19	Nasirabad HS	Nasirabad HC	42.11 (17.0)	165	-
20	Nasirabad HS	Kulsi HC	-	177	-

*Source: DAP for CMMP

2.1.5.2.4 Commercial & Industrial Area

Chattogram city had originated from Chattogram port, and the main commercial and industrial zone are developed around the port. As the number of people using Chittagong port, mostly the Turkish and the Dutch, had increased since the middle age, trading and business grew with port, factory blocks had started to form in modern ages, as the export processing industries prospered through use of cheap labor. Some of factory areas are collectively developed in the form of industrial complexes, but some are individually scattered inside the city.

Collective industrial zones in the form of industrial complexes are operating in six areas of Chattogram city, and the distribution of industrial complexes is as follows. The Patenga industrial complex used to be an area where steel mills were operated, but in recent years it has become impossible to operate due to the aging of the factory facilities. Therefore, Karnaphuli export complex was created through redevelopment.

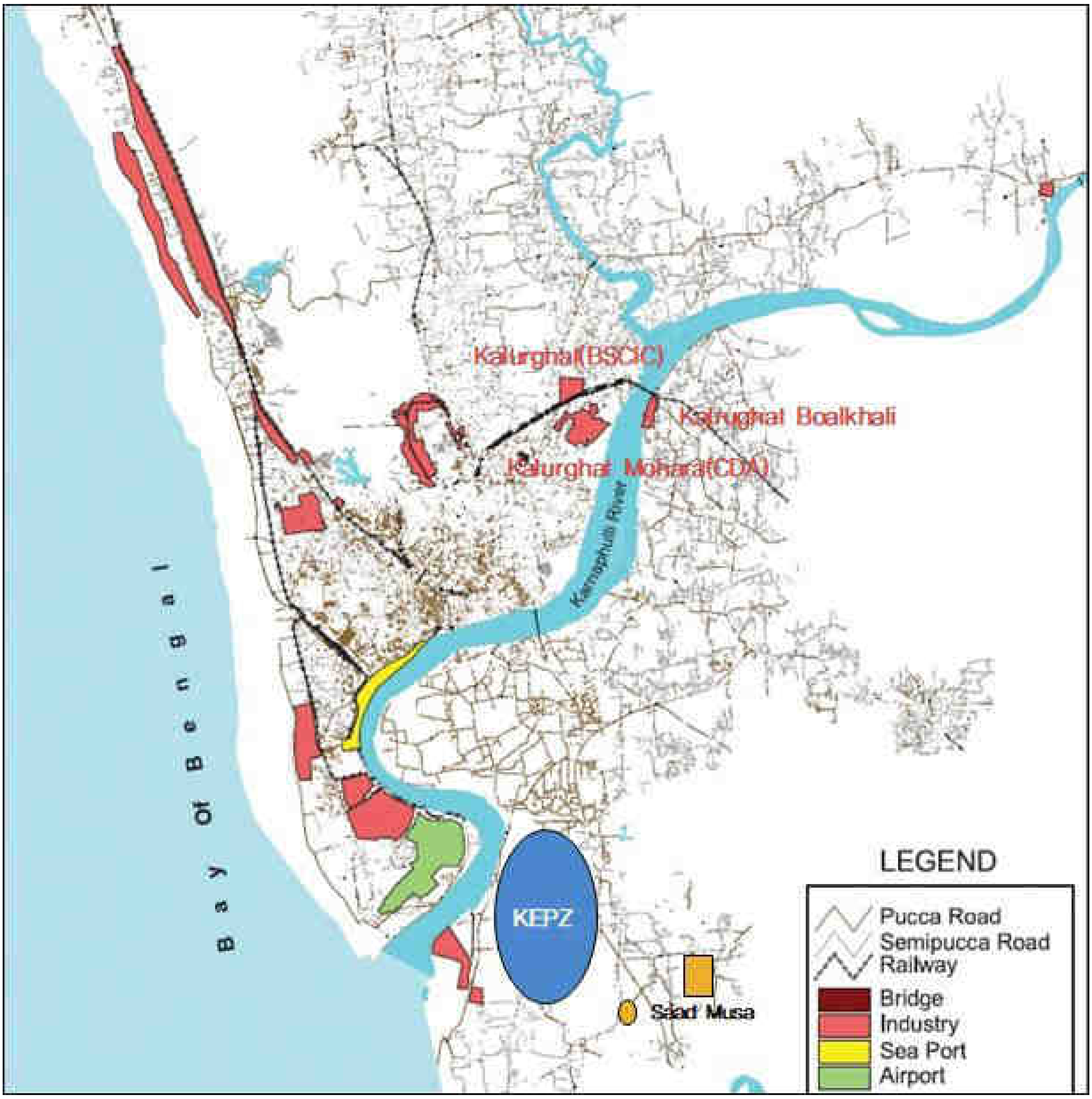


Figure 2-9 Status of industrial zone in Chattogram

2.2 Socio-Economic Conditions

2.2.1 Administrative District & Population

2.2.1.1 Administrative District

Bangladesh's administrative district consists of Zila, Upazila/Thana, Union/Ward, Mauza and Village from upper division, and city corporation in central government of urban area, Paurashava/Municipal Area (PSA) at local major area and other urban area of center of upazila if no existing Paurashava. In accordance with Statistical Yearbook Bangladesh 2021, there are 14 Upazila, 12 Thana, 11 Payrashava, 197 Union and 131 Ward in Chattogram zila.

Table 2-7 Administrative District of Chattogram

District	Area (km^2)	Composition (%)	Upazila / Thana	Union	Ward	Mauza / Maulah	Village	Paurashava
Bandarban	4,479.0	13.2	7	30	18	201	1,554	2
Brahmanbaria	1,881.2	5.5	9	100	39	1,033	1,324	4
Chandpur	1,645.3	4.9	8	87	72	1,240	1,230	7
Chattogram	5,282.9	15.6	26	197	131	1,378	1,288	11
Comilla	3,146.3	9.3	16	181	99	2,770	3,532	10
Cox's Bazar	2,491.9	7.3	8	71	39	346	989	4
Feni	990.4	2.9	6	43	54	597	553	5
Khagrachhari	2,749.2	8.1	8	38	27	276	1,702	3
Lakshmipur	1,440.4	4.2	5	58	39	525	547	4
Noakhali	3,685.9	10.9	9	91	72	1,035	967	8
Rangamati	6,116.1	18.0	10	49	18	252	1,555	2
Total	33,908.6	100	112	945	608	9,653	15,241	60

*Source: Statistical Yearbook Bangladesh (2021, BBS)

2.2.1.2 Chattogram City Corporation (CCC)

Chattogram City Corporation (CCC) is the main administrative body of the local government, and as the sub-governmental unit of the Ministry of Local Government, it coordinates with the central government regarding regional development. Chattogram started as a small region-centered city with a population of 25,000 in 1863. Its status was promoted to Chattogram Municipality in 1864 as its size grew to 4.5sq. mile, and was again elevated to the Chattogram Municipal Corporation (CMC) in 1982. The current status of Chattogram City Corporation (CCC) was granted in 1990. The CCC area consists of 11 Thana, 47 Ward.

Table 2-8 Ward & Upazila of CCC

No.	Ward	Area (km^2)	No.	Ward	Area (km^2)
1	South Pahartali	23.1	26	North Halishahar	5.9
2	Jalalabad	14.8	27	South Agrabad	1.4
3	Panchlaish	5.6	28	Pathantooly	1.4
4	Chandgaon	10.7	29	West Madarbari	0.8
5	Mohara	10.2	30	East Madarbari	1.1
6	East Sholashahar	2.4	31	Alkaran	0.8
7	West Sholashahar	3.2	32	Andarkilla	0.8
8	Sulakbahar	5.3	33	Firingee Bazaar	0.6
9	North Pahartali	6.4	34	Patharghata	0.9
10	North Kattali	4.9	35	Boxirhat	2.6
11	South Kattali	3.0	36	Gosaildenga	2.0
12	Saraipara	2.4	37	North Middle Halishahar	3.3
13	Pahartali	3.3	38	South Middle Halishahar	4.8
14	Lalkhan Bazaar	1.2	39	South Halishahar	6.6
15	Bagmoniram	2.1	40	North Patenga	10.5
16	Chawk Bazar	2.0	41	South Patenga	14.3
17	West Bakalia	1.9	Total		172.9
18	East Bakalia	5.1	Outside Upazila		
19	South Bakalia	0.8	Sitakunda Upazila		483.97
20	Dewan Bazar	0.4	Hathazari Upazila		246.32
21	Jamalkhan	0.8	Rangunia Upazila		361.54
22	Enayet Bazar	0.8	Boalkali Upazila		126.46
23	North Pathantooly	0.6	Patiya Upazila		211.85
24	North Agrabad	2.6	Anowara Upazila		164.10
25	Rampur	1.5	Raozan Upazila		246.60

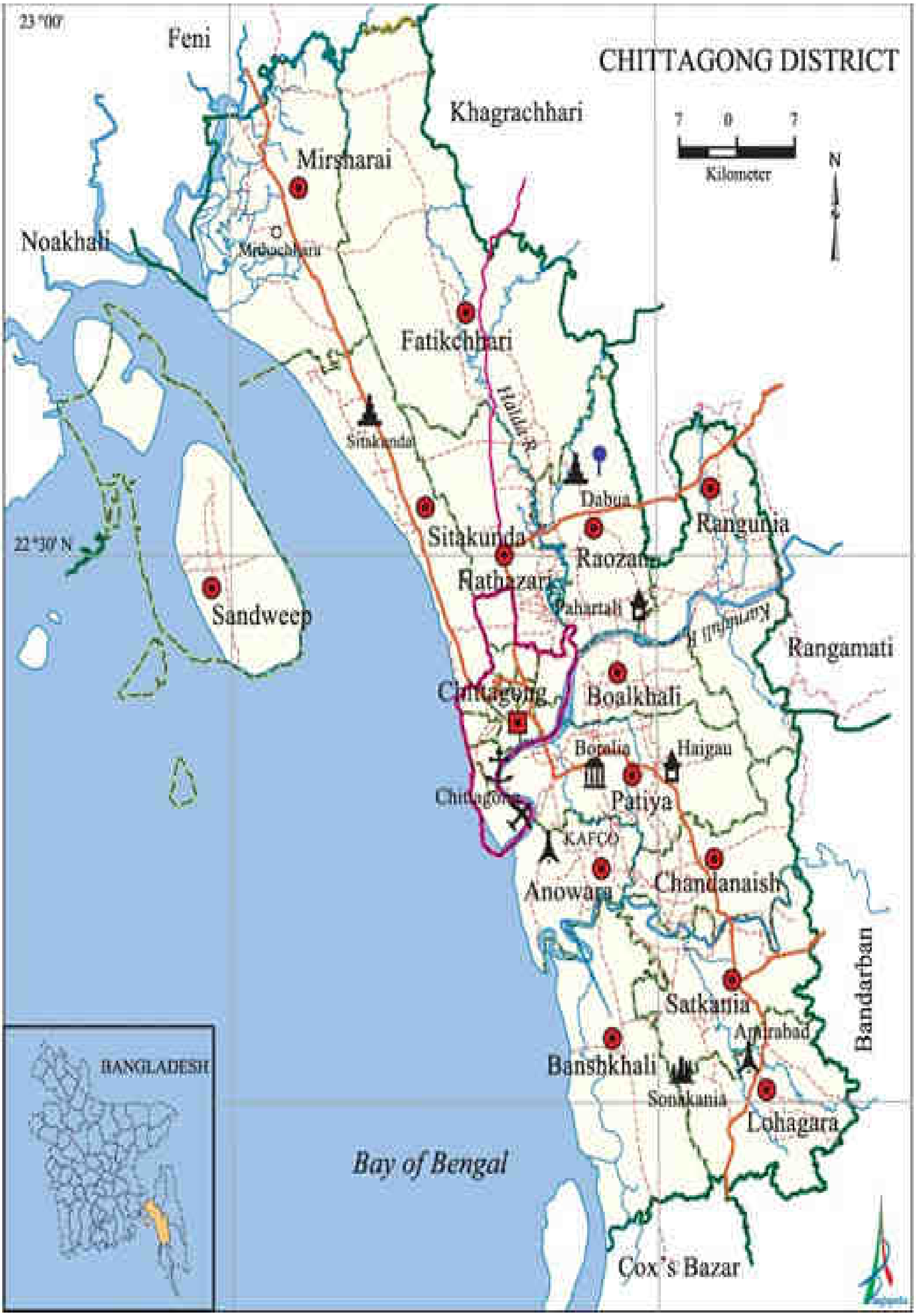


Figure 2-10 Administrative Map of Chattogram District

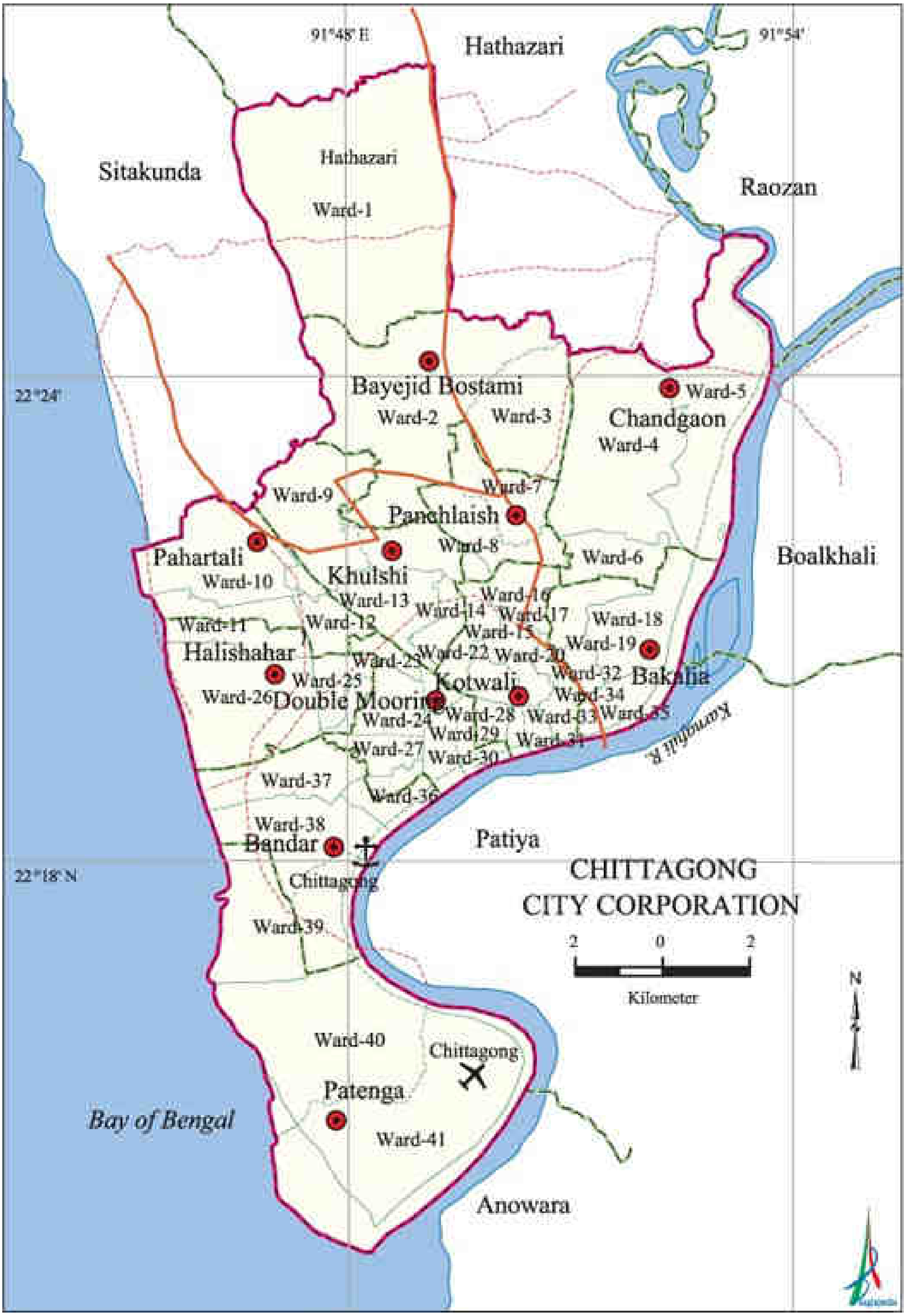


Figure 2-11 Administrative Map of Chattogram City Corporation

2.2.1.3 Current Population

2.2.1.3.1 Population Trend

In 2022, the population of Chattogram Division is 33,202,326. The population of the Chattogram District is 9,169,464 accounting for 27.62% of the total population of the Division. Intensive population increase in Chattogram zila in last 20 years is caused by a population explosion in Thana area, even though growth rate of population is decreasing, and population in rural area is constantly increasing.

Table 2-9 Population Trend of Chattogram Division

District	2001	2011	2022	Annual Average Growth (%) During 10 years	Annual Average Growth (%) During 20 years	Note
Bandarban	298,120	388,335	481,109	27.08	23.89	
Brahmanbaria	2,398,254	2,840,498	3,306,559	17.42	16.41	
Chandpur	2,271,229	2,416,018	2,635,748	7.73	9.09	
Chattogram	6,612,140	7,616,352	9,169,464	17.79	20.39	
Comilla	4,595,557	5,387,288	6,212,216	16.27	15.31	
Cox's Bazar	1,773,709	2,289,990	2,823,265	26.20	23.29	
Feni	1,240,384	1,437,371	1,648,896	15.30	14.72	
Khagrachhari	525,664	613,917	714,119	16.56	16.23	
Lakshmipur	1,489,901	1,729,188	1,938,111	14.07	12.08	
Noakhali	2,577,244	3,108,083	3,625,252	18.62	16.64	
Rangamati	508,182	595,979	647,587	12.97	8.66	
Total	24,290,384	28,423,019	33,202,326	16.91	16.81	

*Source: Statistical Yearbook Bangladesh (2021, BBS), Population & Housing Census (2022, BBS)

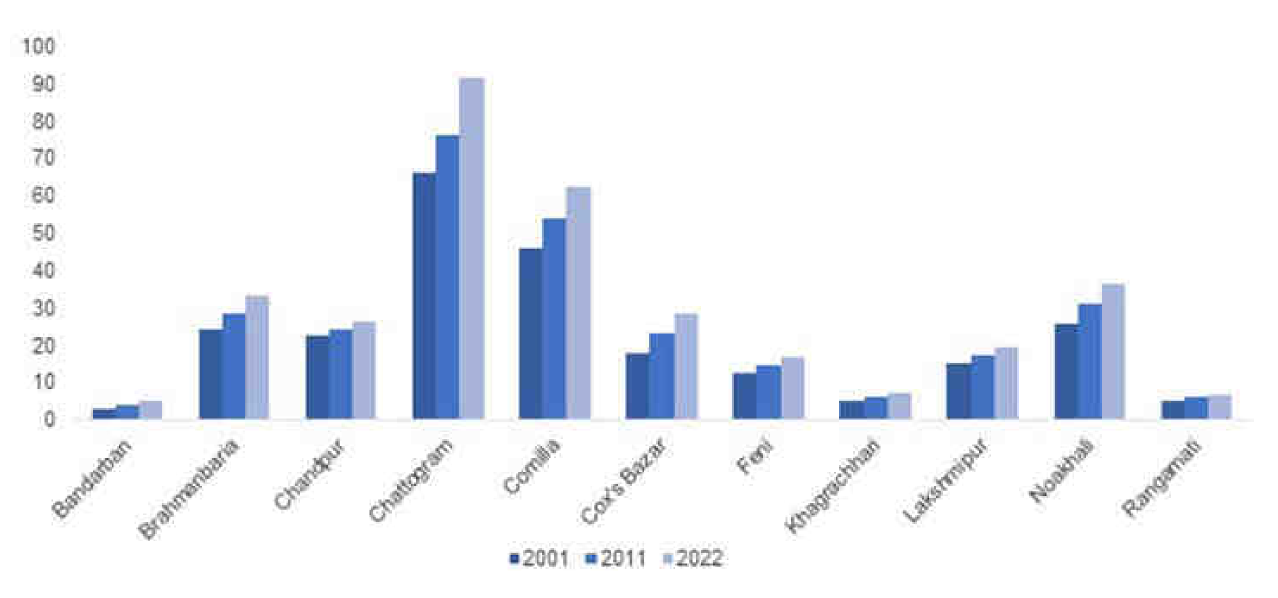


Figure 2-12 Chattogram Division Population trend

2.2.1.3.2 Household Trend

The household in Chattogram Division increased from 4,472,302 (2001) to 7,528,333 (2022), and Chattogram Zila accounts for 28.48% of the total households. As the population increases, the number of members per household gradually decreases, resulting in a rapid increase in the number of households.

Table 2-10 Household Trend

Zila	2001		2011		2022	
	Household	Size (pers/house)	Household	Size (pers/house)	Household	Size (pers/house)
Bandarban	60,141	5.0	80,102	4.9	106,167	4.5
Brahmanbaria	429,390	5.6	538,937	5.3	712,613	4.6
Chandpur	433,768	5.2	506,521	4.8	635,458	4.2
Chattogram	1,240,537	5.3	1,532,014	5.0	2,143,958	4.3
Comilla	828,168	5.5	1,053,572	5.1	1,407,396	4.4
Cox's Bazar	296,109	6.0	415,954	5.5	587,127	4.8
Feni	223,049	5.6	277,665	5.2	377,189	4.4
Khagrachhari	109,190	4.8	133,792	5.6	169,526	4.2
Lakshmipur	288,736	5.2	365,339	5.7	459,381	4.2
Noakhali	460,394	5.6	593,918	5.2	776,034	4.7
Rangamati	102,820	4.9	128,496	4.6	153,484	4.2
Total / Average	4,472,302	5.3	5,626,310	5.2	7,528,333	4.4

2.2.1.3.3 Birth & Death Rate

According to Statistical Yearbook of Bangladesh (2021, BBS), the birth rate and death rate per 1,000 people by residential area are as follows. In 2020, the crude birth rate was 18.1 in the country, 15.3 in the urban area, and 20.4 in the rural area. Population change over the past 20 years has shown that the birth rate is higher than the death rate regardless of region, and the population has continued to grow.

Table 2-11 Population Trend of Bangladesh

Year	Crude Birth Rate			Crude Death Rate			Population Trend		
	Country	Urban	Rural	Country	Urban	Rural	Country	Urban	Rural
2001	18.9	13.6	20.7	4.8	4.3	5.2	14.1	9.3	15.5
2002	20.1	16.6	21.0	5.1	3.8	5.4	15.0	12.8	15.6
2003	20.9	17.9	21.7	5.9	4.7	6.2	15.0	13.2	15.5
2004	20.8	17.8	21.6	5.8	4.4	6.1	15.0	13.4	15.5
2005	20.7	17.8	21.7	5.8	4.9	6.1	14.9	12.9	15.6
2006	20.6	17.5	21.7	5.6	4.4	6.0	15.0	13.1	15.7
2007	20.9	17.4	22.1	6.2	5.1	6.6	14.7	12.3	15.5
2008	20.5	17.2	22.4	6.0	5.1	6.5	14.5	12.1	15.9
2009	19.4	16.8	20.4	5.8	4.7	6.1	13.6	12.1	14.3
2010	19.2	17.1	20.1	5.6	4.9	5.9	13.6	12.2	14.2
2011	19.2	17.4	20.2	5.5	4.8	5.8	13.7	12.6	14.4
2012	18.9	17.1	20.0	5.3	4.6	5.7	13.6	12.5	14.3
2013	19.0	18.2	19.3	5.3	4.6	5.6	13.7	13.6	13.7
2014	18.9	17.2	19.4	5.2	4.1	5.6	13.7	13.1	13.8
2015	18.8	16.5	20.3	5.1	4.6	5.5	13.7	11.9	14.8
2016	18.7	16.1	20.9	5.1	4.2	5.7	13.6	11.9	15.2
2017	18.5	16.1	20.4	5.1	4.2	5.7	13.4	11.9	14.7
2018	18.3	16.1	20.1	5.0	4.4	5.4	13.3	11.7	14.7
2019	18.1	15.9	20.0	4.9	4.4	5.4	13.2	11.5	14.6
2020	18.1	15.3	20.4	5.1	4.9	5.2	13.0	10.4	15.2

*Source: Statistical Yearbook Bangladesh (2021, BBS)

2.2.2 Economic Condition

2.2.2.1 Economic Indicator

Bangladesh has achieved steady economic growth of more than 4% every year since 2000 until 2020, when COVID-19 broke out. Although the manufacturing base other than the sewing industry is weak, it is one of the world's fastest growing middle-class countries based on the government's active development policy and is expected to leave the poorest country in 2026.

Bangladesh Bank set a target for consumer price inflation in 2022 at 5.3%, but the prolonged Ukraine war from Russia in February 2022 caused a shortage of wheat and cooking oil, which accounted for a large portion of the two countries' supply, causing international prices to soar. Wheat is the second most consumed grain by Bangladeshi people, and overall inflation has been driven by rising prices of basic necessities.

Table 2-12 Economic Indicator of Bangladesh

Category	Unit	2018	2019	2020	2021	2022
Economic growth rate	%	7.9	8.2	3.5	5.0	6.4
Consumer price inflation	%	5.7	5.6	5.7	5.5	6.0
Fiscal balance / GDP	%	-4.8	-6.3	-5.6	-4.2	-6.2
Current account balance	US$ million	-7,095	-2,949	1,193	-15,563	-17,487
Current account balance / GDP	%	-2.6	-1.0	0.4	-4.4	-4.4
Goods balance	US$ million	-17,284	-15,929	-16,394	-32,522	-33,448
Export	US$ million	38,682	38,747	32,456	41,908	46,937
Import	US$ million	55,966	54,676	48,850	74,431	80,385
Foreign exchange reserve	US$ million	29,973	30,648	41,036	42,851	42,169
Foreign debt balance	US$ million	60,356	63,160	73,060	93,130	95,489
Foreign debt balance / GDP	%	22.0	20.9	22.6	26.1	24.1
Exchange Rate	(BDT/USD)	83.47	84.45	84.87	85.08	105

*Source: IMF

Table 2-13 Inflation Rate (%)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
2018	5.88	5.72	5.68	5.83	5.82	5.78	5.78	5.74	5.68	5.63	5.58	5.55	5.72
2019	5.51	5.49	5.48	5.47	5.56	5.52	5.62	5.49	5.54	5.47	6.05	5.75	5.58
2020	5.57	5.46	5.48	5.96	5.35	6.05	5.53	5.68	5.97	6.44	5.52	5.29	5.69
2021	5.02	5.32	5.47	5.56	5.26	5.64	5.36	5.54	5.59	5.70	5.98	6.05	5.54
2022	5.86	6.17	6.22	6.29	7.42	7.56	7.48	9.52	9.10	8.91	8.85	8.71	7.67

*Source: TRADING ECONOMICS

2.2.2.2 Economically Active Population

The economically active population of Bangladesh in 2010 was 56,607 thousands. This corresponds to 59.2% of the 95,585,000 people over 15 aged who can be economically active.

Table 2-14 Economically active population by division (1000 people)

Division	Over 15 aged	Economically Active Population	Economically Inactive Population	Participation Rate (%)
Brisal	5,964	3,347	2,617	56.1
Chattogram	17,394	9,470	7,924	54.4
Sylhet	5,612	3,326	2,286	59.3
Dhaka	30,451	18,143	12,308	59.6
Khulna	11,537	6,868	4,669	59.5
Rajshahi	13,565	8,243	5,322	60.8
Rangpur	11,062	7,210	3,852	65.2
Total	95,585	56,607	38,978	59.2

*Source: Statistical Yearbook of Bangladesh (2011, BBS)

The economically active population by district in the Chattogram Division is as follows. The economically active population of Chattogram District was 2,759 thousands. This corresponds to 56.2% of the 4,910,000 people over 15 aged who can be economically active.

Table 2-15 Economically active population of Chattogram Division (1,000 people)

District	Over 15 aged	Economically Active Population	Economically Inactive Population	Participation Rate (%)
Bandarban	205	163	42	79.5
Brahmanbaria	1,418	721	697	50.8
Chandpur	1,710	808	902	47.3
Chattogram	4,910	2,759	2,151	56.2
Comilla	3,107	1,780	1,327	57.3
Cox's Bazar	1,144	607	537	53.1
Feni	933	498	435	53.4
Khagrachhari	602	410	192	68.1
Lakshmipur	1,205	615	590	51.0
Noakhali	1,707	861	846	50.4
Rangamati	453	248	205	54.7
Total	17,394	9,470	7,924	54.4

*Source: Statistical Yearbook of Bangladesh (2011, BBS)

2.2.3 Industry Condition

2.2.3.1 General

Bangladesh supports a free market economy. The private sector has made rapid progress, led by many large companies. This high economic growth can be attributed to the active will and efforts of both the government and the private sector. The main industries are textiles, pharmaceuticals, shipbuilding, steel, electronics, energy, construction materials, chemicals, ceramics, food processing, and leather products. Since the 2010s, the proportion of agriculture, which accounted for the majority of the national economy, has been reduced to 10%, and the share of manufacturing and service industries was expanded.

Industry-related regulations have been simplified to attract the investment of private capital, and the textile industry is being modernized to encourage the apparel and sewing industry. The highest priority industry sectors include sewing, small textiles, and labour-intensive manufacturing industries, which are being used to promote exports and create more jobs for the younger population. The government is refraining from nationalizing manufacturing industry, commerce and financial businesses that are privately owned.

To encourage foreign investment, incentives such as Duty-Free Day for a certain period are designated, and low, or even no tariffs on raw materials import and overseas money transfer.

2.2.3.2 Industry Structure

The number of establishments and employees by industry in urban and rural areas of Chattogram District in 2013 are as follows. Total 380,550 establishment, 191,893 establishments are located in urban areas and the remaining 188,657 are located in rural areas. As for the number of workers, it was analysed that 1,392,149 (70.71%) of the total 1,968,862 worked in urban areas and 576,713 (29.29%) worked in rural areas. Both establishments and employees are concentrated in urban areas.

As a result of the classification, manufacturing, wholesale/retail, and service industries, which are the basis of the local economy, are the main sectors.

Table 2-16 Number of Establishments & Employees by Category

Category	Establishments			Employees		
	Total	Urban	Rural	Total	Urban	Rural
Mining and Quarrying	964	46	918	1,735	520	1,215
Manufacturing	58,620	15,716	42,904	965,165	814,874	150,291
Electricity, Gas, Steam and Air Conditioning Supply	181	89	92	2,066	1,085	981
Water Supply, Sewerage, Waste Management and Remediation Activities	146	106	40	1,510	1,386	124
Construction	207	173	34	2,218	2,127	91
Wholesale and Retail Trade, Repair Trade, Repair of Motor Vehicles and Motorcycles	196,984	118,774	78,210	570,273	336,447	233,826
Transportation and Storage	14,999	5,127	9,872	28,558	15,423	13,135
Accommodation and Food Service Activities	35,744	17,740	18,004	86,200	46,237	39,963
Information and Communication	1,278	981	297	6,727	5,281	1,446

Category	Establishments			Employees		
	Total	Urban	Rural	Total	Urban	Rural
Financial and Insurance Activities	2,458	1,604	854	32,015	21,629	10,386
Real Estate Activities	380	304	76	2,540	2,352	188
Professional, Scientific and Technical Activities	2,988	2,333	655	13,094	10,401	2,693
Administrative and Support Service Activities	3,647	2,076	1,571	12,043	6,878	5,165
Public Administration and Defense, Compulsory Social Security	1,022	676	346	28,867	26,039	2,828
Education	8,557	3,123	5,434	65,593	28,464	37,129
Human Health and Social Work Activities	3,736	1,932	1,804	19,591	12,504	7,087
Art, Entertainment and Recreation	644	391	253	2,658	1,636	1,022
Other Service Activities	47,995	20,702	27,293	128,009	58,866	69,143
Total	380,550	191,893	188,657	1,968,862	1,392,149	576,713

*Source: Economic Census District Report: Chittagong (2013, BBS)

The number of establishments and employees in the Chattogram City Corporation area is as follows. Compared to the District, establishments accounted for 49.99% and employees accounted for 64.72%.

Table 2-17 Number of Establishments & Employees in CCC

Thana	Establishments	Employees
Bayejid Bostami	10,729	110,890
Bakali	9,368	31,390
Chandgaon	12,521	91,786
Chittagong Port	13,534	532,008
Double Mooring	24,248	102,559
Halishahar	12,587	49,446
Kotwali	34,860	149,587
Khulshi	11,276	50,653
Pahartali	8,778	66,153
Panchlaish	8,756	33,553
Patenga	9,320	56,312
Total	155,977	1,274,337

*Source: Economic Census District Report: Chittagong (2013, BBS)

2.3 Relevant Plan

2.3.1 Long-Term Plan

2.3.1.1 Perspective Plan of Bangladesh 2021-2041 (PP 2041)

In March 2020, the Government of Bangladesh announced its long-term vision "Perspective Plan of Bangladesh 2021-2041 (PP2041)" as a strategy with development goals through 2041, and policies/programs to achieve them. Under PP2041, Bangladesh aims to become an Upper Middle-Income Country and eliminate extreme poverty1 by 2031, and to achieve a High-Income Country status by 2041 with poverty2 approaching extinction.

The main visions of PP2041 are (1) Bangladesh will be a developed country by 2041, with per capita income of over US$12,500 and fully in tune with the digital world, and (2) Poverty will become a thing of the past in Sonar Bangla. The transition can be realized through a process of rapid inclusive growth leading to the elimination of poverty while increasing the productive capacity, building an innovating knowledge economy and protecting the environment, with the following 9 strategic goals.

Table 2-18 PP 2041 Core Objectives and Targets for Environmental Management

Objectives/Targets	2018 Base Year Values	FY2041 Values
Share of urban population in total population (%)	30	80
Urban households with tap water connectivity (%)	40	100
Urban households with water-sealed sanitary toilets (%)	42	100
Urban households with modern sewerage connection (%)	N/A	100
Rural households with tap water connectivity (%)	0	50
Rural households with water-sealed sanitary toilets (%)	0	50
Rural households with safe sewerage connection	0	100
Incidence of poverty (%)	24	<3
Percent of population living in slums (%) Percent of household living in slums (UN definition)	55	0
Percent of urban centres with waste water treatment facilities	N/A	100
Core environmental spending (% of GDP)	1	3.5
Spending by environment coordinating entity (% of GDP)	0.005	0.5
Application of polluter pays principle (% of cases)	0	100
Carbon tax (% of fuel prices)	0	15
Green area for Dhaka-major cities (square meter per capita)	N/A	5-12
Disaster readiness (%)	N/A	100
Urban water bodies compliance with water quality standards (%)	0	100
Air quality (annual average, µg/m3 PM 2.5)	86	10
Percent of cities flood free with proper drainage	0	100
Percent of land degraded	18	5
Area under forest cover (% of land)	15	20
Protection of Habitat and Biodiversity International Ranking	Bottom 5%	Top 30%
Environmental Performance Index International Ranking	Bottom 5%	Top 30%

2.3.1.2 Eighth Five Year Development Plan 2020-2025 (8FYP)

In December 2020, the Government of Bangladesh announced the “8th FIVE YEAR PLAN July 2020-June 2025 ("8FYP")”. Based on the lessons learnt from the previous FYP, the 8FYP launches some concrete measures to achieve the main vision, strategic goals of PP2041, and Sustainable Development Goals (SDGs), and sets priority strategies & priority issues.

- Rapid recovery for COVID-19 to restore human health, confidence, employment, income and economic activities
- GDP growth acceleration, employment generation, productivity acceleration and rapid poverty reduction
- A broad-based strategy of inclusiveness with a view to empowering every citizen to participate fully and benefit from the development process and helping the poor and vulnerable with social protection-based income transfers
- A sustainable development pathway that is resilient to disaster and climate change; entails sustainable use of natural resources; and successfully manages the inevitable urbanization transition
- Development and improvement of critical institutions necessary to lead the economy to Upper Middle-Income Country status
- Attaining SDG targets and coping up the impact of LDC graduation.

Table 2-19 Performance Indicators and Targets of Water Supply & Sewerage Sector

Performance Indicator	Baseline (Year)	Target(2021)	Target(2022)	Target(2023)	Target(2024)	Target(2025)
Percentage of urban population having access to safe drinking water	78.0 (2016)	82.4	86.8	91.2	95.6	100.0
Percentage of urban populationhaving access to sanitary toilet facilities	80.0 (2016)	84.0	88.0	92.0	96.0	100.0
Percentage of households withsewerage connection	5.0 (2017)	6.0	7.0	8.0	9.0	10.0
Per cent of urban centres with modern waste disposal facilities	-	2.0	4.0	6.0	8.0	10.0
Per cent of urban centres with wastewater treatment facilities	-	2.0	4.0	6.0	8.0	10.0
Percentage of urban populationhaving access to public health service	87.0 (2016)	89.6	92.2	94.8	97.4	100.0

2.3.2 Sewerage System Master Plan

CWASA (Chattogram Water Supply and Sewerage Authority) established master plans related to sewerage system in the 1st (2009) and 2nd (2017) phases, and the main contents are as follows.

2.3.2.1 Sewerage Master Plan (2009)

2.3.2.1.1 Introduction

CWASA established a master plan to improve the quality of life of Chattogram City and to alleviate environmental problems by establishing an infrastructure system for sewage collection and treatment by setting 2031 as the planned target year.

2.3.2.1.2 Planning Framework

The population, penetration rate, and influent water quality of the main treatment plant (Right·Left Side South North) are as follows.

Table 2-20 Planning Framework of Master Plan (2009)

Category			2007	2011	2016	2021	2026	2031
Population (1,000 cap.)		RS STP	1,817	1,932	2,188	2,443	2,694	2,944
		RN STP	1,493	1,638	1,917	2,197	2,476	2,756
		LS STP	260	280	295	310	330	350
		LN STP	180	200	215	230	250	270
Penetration Rate (%)		RS STP	40	64	70	76	82	88
		RN STP	31	50	59	67	73	79
		LS STP	-	15	28	40	50	60
		LN STP	-	10	22	33	42	50
Daily Maximum (1,000m^3/d)		RS STP	54	110	175	240	357	473
		RN STP	33	67	118	168	270	371
		LS STP	-	42	67	92	102	113
		LN STP	-	2	5	9	16	23
Influent Water Quality (mg/L)	BOD	RS STP	504	454	390	381	328	312
		RN STP	523	479	404	403	334	317
		LS STP	-	228	236	249	254	263
		LN STP	-	489	382	405	327	317
	COD	RS STP	903	812	698	680	586	558
		RN STP	940	861	726	725	602	570
		LS STP	-	373	387	411	422	440
		LN STP	-	880	687	729	588	571
	TSS	RS STP	599	543	473	463	395	373
		RN STP	612	557	468	467	387	366
		LS STP	-	880	687	729	588	571
		LN STP	-	564	441	468	377	366

2.3.2.1.3 Expansion Plan

Considering the population growth and the increase in water demand, the capacity expansion of the treatment plant was planned in phase, and it was divided into three phases by 2031.

Table 2-21 Expansion Plan of STP of Master Plan (2009) (1,000m³/d)

Category	Total	Phase I (2011)	Phase II-I (2016)	Phase II-II (2021)	Phase III-I (2026)	Phase III-II (2031)
RS STP	460	220	-	240	-	-
RN STP	360	-	260	-	100	-
LS STP	110	-	110	-	-	-
LN STP	22	-	-	-	22	-
Total	952	220	370	240	122	-

2.3.2.1.4 Estimated Project Cost

Table 2-22 Estimated Project Cost of Master Plan (2009) (US$ thousands)

Category	Total	Phase I (2011)	Phase II-I (2016)	Phase II-II (2021)	Phase III-I (2026)	Phase III-II (2031)
Total Project Cost	1,830,779	135,358	404,985	529,018	448,057	313,361
I. Management and Others	104,573	7,874	21,354	31,373	25,389	18,583
- Design	65,357	4,921	13,346	19,608	15,868	11,614
- Supervision	39,216	2,953	8,008	11,765	9,521	6,969
II. Construction	1,437,863	108,263	293,599	431,370	349,111	255,520
- STP	421,797	88,427	157,400	92,848	83,122	-
- Sewer network	362,799	5,881	20,322	57,263	121,992	157,341
- Pumping Station	19,899	-	-	3,681	16,218	-
- Household connection	396,009	-	59,152	214,222	74,231	48,404
- Night Soil treatment	79,986	-	18,910	21,083	18,910	21,083
- Latrine improvement	26,659	4,113	11,125	3,058	2,900	5,463
- Direct operation	130,715	9,842	26,691	39,215	31,738	23,229
III. Q & M	77,124	5,807	15,748	23,138	18,725	13,706
IV. Reserve	143,786	10,826	29,267	43,023	35,118	25,552
V. Collection trucks	7,300	2,000	5,300	-	-	-
VI. Compensation	60,133	588	39,624	-	19,921	-

2.3.2.2 Sanitation & Drainage Improvement Strategy and Master Plan (2017)

2.3.2.2.1 Introduction

CWSISP develops comprehensive improvement strategies and master plans for the city's sanitation & drainage sectors with the support of the World Bank.

2.3.2.2.2 Sewerage Service Coverage

In the sanitation master plan, the sewerage service coverage of Chattogram City was divided into 6 areas.

Table 2-23 Sewerage Service Coverage of Master Plan (2017)

Category	Location	Area of STP (ha)	Capacity (m^3/d, 2030)	Remarks
Catchment-1 (PESSCM-1)	Halishahar	66	100,000	
Catchment-2	Kalurghat	19	100,000	
Catchment-3	Fatehabad	30	60,000	
Catchment-4	East Bakalia	33	70,000	
Catchment-5	North Kattali	22	80,000	
Catchment-6	Patenga	30	100,000	

2.3.2.2.3 Planning Framework

The final target year of the sanitation master plan is 2030, and the planning framework by sewerage service area is as follows.

Table 2-24 Planning Framework of Master Plan (2017)

Category		STP-1	STP-2	STP-3	STP-4	STP-5	STP-6	Total
Population		749,531	316,868	234,990	405,483	174,274	199,798	2,080,945
Daily Average	Domestic	68,957	29,152	21,619	37,304	16,033	18,381	191,447
	Non-Domestic	8,275	3,498	2,594	4,477	1,924	2,206	22,974
	Large consumer	5,052	7,858	3,929	2,245	6,736	37,870	63,690
	Underground Water	18,132	12,130	5,585	6,292	5,448	5,781	53,368
	Total	100,416	52,638	33,728	50,318	30,141	64,238	331,479
Rainwater Inflow		18,132	12,130	5,585	6,292	5,448	5,781	53,368
Daily Maximum	Babbit Factor	1.33	1.58	1.68	1.50	1.78	1.73	1.52
	Peak Factor	1.30	1.30	1.30	1.30	1.30	1.30	1.30
	Domestic	91,747	46,074	36,274	56,122	28,559	31,859	290,636
	Non-Domestic	11,010	5,529	4,353	6,735	3,427	3,823	34,876
	Large consumer	6,567	10,216	5,108	2,919	8,756	49,231	82,798
	Total	109,323	61,819	45,735	65,776	40,743	84,913	408,309
Grand Total		145,588	86,078	56,905	78,360	51,639	96,474	515,046

Table 2-25 Estimated Project Cost of Master Plan (2009) (US$ million)

Category	STP-1	STP-2	STP-3	STP-4	STP-5	STP-6	Total
Deep Sewers	13.55	4.79	2.00	5.43	0.00	0.00	25.77
Gravity Sewers	58.48	44.80	26.42	27.92	21.11	29.81	208.53
Manholes	10.78	8.03	4.42	4.63	3.80	4.61	36.26
Force Mains	1.70	0.35	3.03	0.04	0.54	0.94	6.18
Utility Realignment	17.54	13.44	7.93	8.37	6.33	8.94	62.56
Pump Stations	7.28	8.74	8.21	1.54	1.66	4.22	31.65
Service Lines	34.07	18.93	17.98	19.88	18.36	21.77	131.00
Household Connections	18.13	5.54	5.32	9.62	3.94	7.42	49.97
Interceptors	4.10	7.43	0.00	4.50	1.74	0.00	17.77
STPs	45.00	33.30	18.00	35.10	10.50	15.00	156.90
Total A	210.64	145.35	93.30	117.02	67.99	92.71	726.60
Physical Contingencies (5% of Total A)	10.53	7.27	4.66	5.85	3.40	4.64	36.33
Total B	221.17	152.62	97.96	122.87	71.39	97.35	762.93
Detailed Design & Construction Supervision (7% of Total A)	14.74	10.17	6.53	8.19	4.76	6.49	50.86
Total C	235.91	162.79	104.49	131.06	76.15	103.84	813.79
VAT (15% of Total C)	35.39	24.43	15.83	19.66	11.44	15.62	122.37
Total D	271.30	187.33	121.35	150.74	87.74	119.72	938.19
Price contingencies (10% of Total D)	27.13	18.73	12.14	15.07	8.77	11.97	93.82
Total E	298.43	206.07	133.49	165.81	96.52	131.69	1,032.01

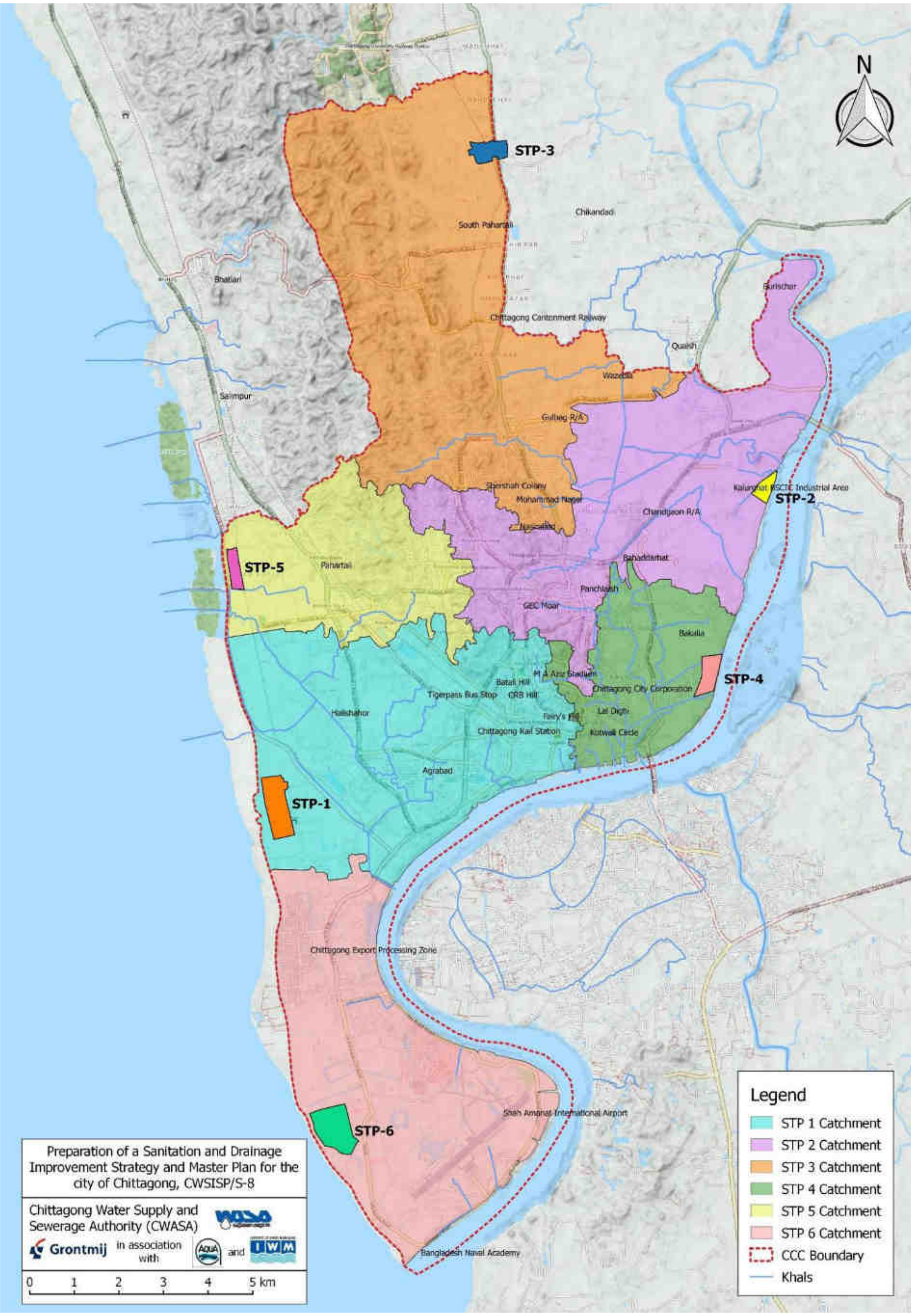


Figure 2-13 Sewerage Service Coverage of Master Plan (2017)

2.4 Existing Water Supply & Sewerage System

2.4.1 Statistics of Water Supply & Sewerage System

2.4.1.1 Introduction

According to statistical surveys, Bangladesh's population proportion of drinking water sources increased from 68% to 84%, from 1990 to 2014.

Table 2-26 Population Using Drinking Water Sources (%)

Year	Average	Urban	Rural
1990	68	81	65
1995	72	82	69
2000	76	83	74
2005	80	84	78
2010	84	85	83
2014	84	86	84

*Source: Millennium Development Goals, Bangladesh Progress Report (2015, General Economics Division)

Chattogram has facilities for water supply but no facilities for sewage treatment. The number of households supplying water supply in the CCC area managed by CWASA is showing a 147% increase from about 54,500 connections in 2014 to about 80,000 connections in 2022, and is divided into two MODs (Maintenance and Operation Division) for maintenance and operation. The existing water supply network consists of transmission and distribution network of about 574km, and there are various types of pipes.

Table 2-27 Water Supply Network

Diameter	Total	AC	CI	DI	GI	MS	PVC	Etc.
Total	574.22	137.40	1.52	43.55	0.35	2.01	388.97	0.42
40	0.06	-	-	-	-	-	0.06	-
50	5.08	-	-	-	-	-	5.08	-
100	249.17	5.81	-	0.01	0.35	0.34	242.25	0.41
150	92.10	10.61	-	0.07	-	0.68	80.74	-
200	83.29	32.34	-	0.10	-	0.29	50.56	-
225	0.78	0.02	0.76	-	-	-	-	-
250	0.41	0.25	-	-	-	0.16	-	-
300	70.18	54.73	0.76	5.81	-	0.08	8.79	0.01
450	32.39	17.88	-	12.58	-	0.46	1.47	-
600	26.88	15.76	-	11.10	-	-	0.02	-
750	1.81	-	-	1.81	-	-	-	-
900	10.26	-	-	10.26	-	-	-	-
1200	1.81	-	-	1.81	-	-	-	-

*Source: CWASA
*Asbestos Cement (AC), Cast Iron (CI), Ductile Iron (DI), Galvanised Iron (GI), Mild Steel (MS), Polyvinyl Chloride (PVC)

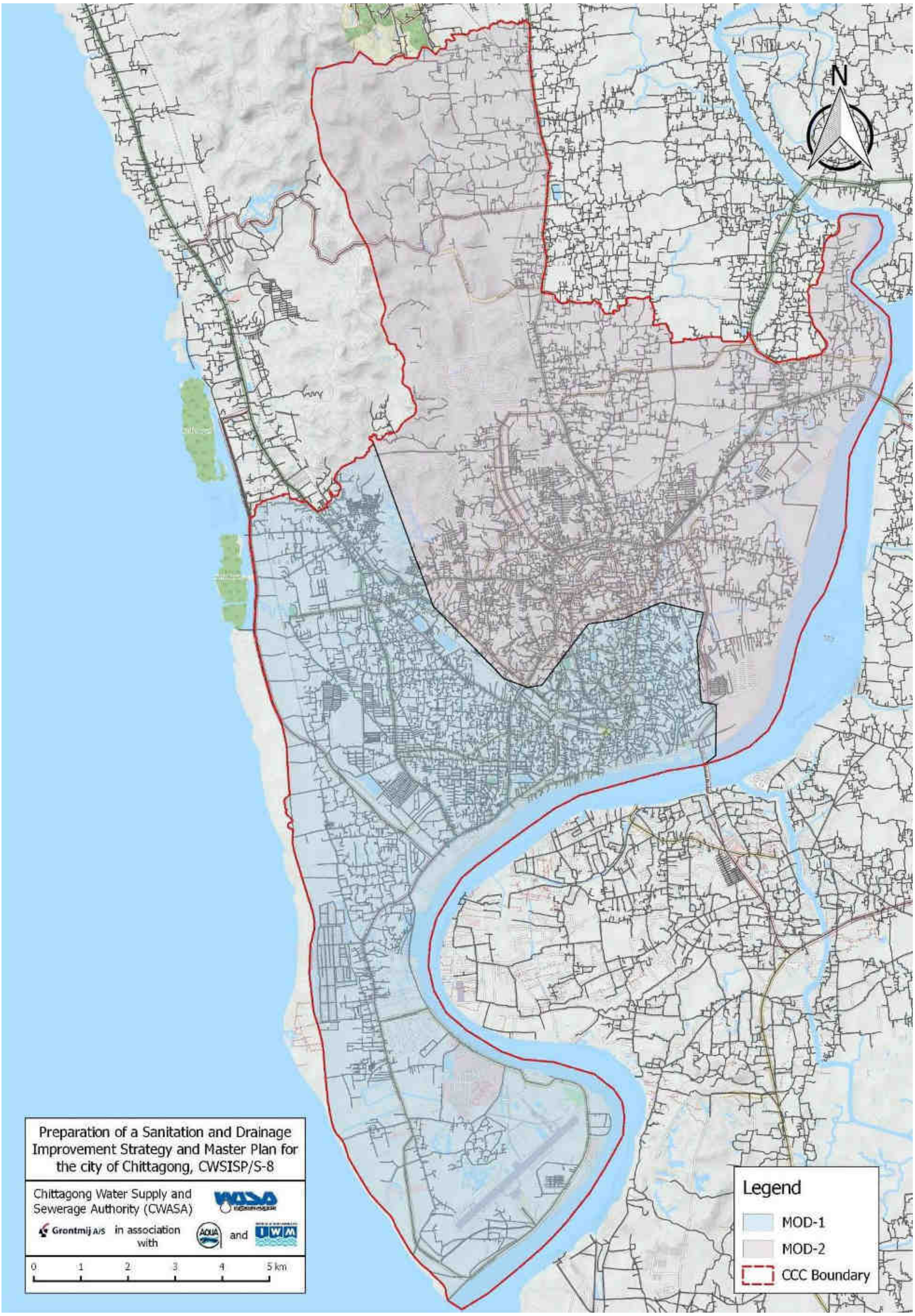


Figure 2-14 Water Supply Service Area of CCC

2.4.1.2 Statistics of Water Supply System

CWASA has been established statistic of water supply system for the non-revenue water, operation rate, number of water connections as below.

Table 2-28 Statistics of Water Supply System

Year	Month	Non-Revenue Water (%)	Operation Rate (%)	Water Supply Service Rate (%)	Water Connections (Nos.)	WTP Capacity (MLD)	Deep Tube Well (MLD)	Network Length (m)
2019	Apr	30	68	57	66,534	323	40	768
	Jun	28	119	57	67,027	323	40	768
	Sep	25	88	56	67,849	323	35	769
	Oct	26	99	56	68,122	323	35	769
2020	Jan	27	77	57	68,905	323	36	769
	Feb	25	68	57	69,109	323	36	769
	Mar	32	72	57	69,163	323	37	770
	Apr	33	428	57	69,159	323	37	770
	May	31	141	57	69,149	323	38	770
	Jul	25	52	56	69,551	323	37	770
	Aug	22	83	56	69,991	323	32	770
	Sep	22	69	57	70,747	323	37	770
	Oct	24	71	57	71,302	323	37	770
	Nov	17	64	58	71,552	323	37	770
	Dec	21	71	58	71,827	323	36	770
2021	Jan	23	79	58	72,282	323	38	770
	Feb	19	56	58	72,588	323	39	770
	Mar	29	41	59	72,858	323	38	770
	Apr	34	105	59	73,055	323	52	770
	May	30	88	59	73,556	323	61	770
	Jun	30	74	60	73,970	323	59	770
	Jul	28	70	60	74,918	323	49	962
	Aug	31	60	61	75,740	323	58	962
	Sep	31	76	61	75,821	323	63	962
	Oct	29	81	61	76,044	323	57	962
	Nov	28	71	60	76,161	323	66	962
	Dec	28	71	60	76,461	323	61	962
2022	Jan	30	73	60	76,809	323	59	962
	Feb	25	58	60	77,149	466	55	962
	Mar	32	55	61	77,422	466	51	962
	Apr	32	90	61	77,757	466	49	962
	May	35	71	61	78,263	466	49	962
	Jun	33	142	62	78,980	466	48	962
	Jul	33	66	62	79,431	466	48	962

*Source: CWASA MIS (Management Information System) Report

Water consumption and water connection of 7 wards in the project area is as below.

Table 2-29 Water Consumption and Water Connection in the Project Area

Category			2021						2022							
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Jun	Jul	Aug
South Pahartali	Dom.	Cons.	110	110	112	110	112	109	84	81	71	62	60	54	54
		Conn.	18	18	18	18	18	18	18	18	18	18	23	23	23
	Non-Dom.	Cons.	105	109	112	107	116	111	90	90	78	66	43	42	58
		Conn.	7	7	7	7	7	7	7	7	7	7	7	7	7
	Total	Cons.	215	219	223	217	228	220	175	171	149	129	103	96	112
		Conn.	25	25	25	25	25	25	25	25	25	25	30	30	30
Jalalabad	Dom.	Cons.	8,749	8,923	9,224	9,188	7,284	5,612	3,160	3,414	3,267	3,245	3,052	3,078	3,210
		Conn.	1,031	1,038	1,035	1,032	1,035	1,035	1,051	1,065	1,075	1,072	1,080	1,090	1,088
	Non-Dom.	Cons.	921	891	1,090	1,024	1,061	909	983	1,086	1,005	1,042	859	815	894
		Conn.	144	140	144	145	143	148	149	153	152	154	155	154	157
	Total	Cons.	9,670	9,814	10,313	10,212	8,344	6,521	4,144	4,500	4,272	4,287	3,911	3,893	4,104
		Conn.	1,175	1,178	1,179	1,177	1,178	1,183	1,200	1,218	1,227	1,226	1,235	1,244	1,245
Panchlaish	Dom.	Cons.	3,608	3,862	3,796	3,994	4,156	3,865	3,722	3,973	3,675	3,849	3,454	3,606	4,229
		Conn.	1,025	1,027	1,024	1,111	1,116	1,137	1,152	1,153	1,160	1,173	1,184	1,197	1,205
	Non-Dom.	Cons.	383	525	522	529	961	330	569	603	588	551	533	398	571
		Conn.	49	50	48	50	51	51	51	50	51	52	52	53	52
	Total	Cons.	3,991	4,387	4,318	4,523	5,117	4,195	4,291	4,576	4,263	4,400	3,987	4,004	4,799
		Conn.	1,074	1,077	1,072	1,161	1,167	1,188	1,203	1,203	1,211	1,225	1,236	1,250	1,257
Chandgaon	Dom.	Cons.	19,347	18,790	19,862	19,819	20,259	19,381	18,624	19,012	18,059	18,746	18,159	18,985	19,269
		Conn.	5,564	5,609	5,616	5,621	5,620	5,647	5,660	5,686	5,714	5,730	5,757	5,792	5,822
	Non-Dom.	Cons.	630	779	817	790	823	802	808	891	885	899	923	945	913
		Conn.	251	254	257	257	257	256	255	257	255	256	260	260	264
	Total	Cons.	19,977	19,569	20,679	20,609	21,082	20,184	19,432	19,903	18,944	19,645	19,082	19,930	20,182
		Conn.	5,815	5,863	5,873	5,878	5,877	5,903	5,915	5,943	5,969	5,986	6,017	6,052	6,086
West Sholashahar	Dom.	Cons.	9,202	9,277	9,467	9,625	9,861	9,686	9,727	10,394	9,537	9,945	9,478	9,796	10,490
		Conn.	2,853	2,848	2,855	2,865	2,877	2,886	2,902	2,914	2,920	2,933	2,944	2,946	2,977
	Non-Dom.	Cons.	604	647	666	663	690	684	720	726	657	654	739	673	698
		Conn.	177	177	176	177	175	178	178	177	175	173	176	175	182
	Total	Cons.	9,806	9,924	10,133	10,288	10,551	10,370	10,447	11,120	10,194	10,599	10,217	10,469	11,188
		Conn.	3,030	3,025	3,031	3,042	3,052	3,064	3,080	3,091	3,095	3,106	3,120	3,121	3,159
Sulakbahar	Dom.	Cons.	21,833	21,072	22,174	21,994	22,087	21,541	20,213	21,878	20,051	22,385	21,263	21,707	21,635
		Conn.	4,402	4,411	4,414	4,412	4,429	4,423	4,447	4,464	4,506	4,512	4,537	4,573	4,595
	Non-Dom.	Cons.	2,664	2,678	2,855	2,962	3,042	2,605	2,363	2,659	2,436	2,501	2,449	2,457	2,588
		Conn.	480	479	483	484	481	481	482	484	484	484	487	486	500
	Total	Cons.	24,496	23,750	25,029	24,957	25,129	24,146	22,576	24,537	22,487	24,886	23,712	24,164	24,223
		Conn.	4,882	4,890	4,897	4,896	4,910	4,904	4,929	4,948	4,990	4,996	5,024	5,059	5,095
North Pahartali	Dom.	Cons.	7,247	7,025	6,975	7,368	7,146	7,088	6,949	7,510	6,864	7,133	6,889	6,935	7,169
		Conn.	3,511	3,505	3,517	3,526	3,531	3,533	3,560	3,572	3,584	3,608	3,635	3,634	3,671
	Non-Dom.	Cons.	552	518	607	529	560	657	624	648	611	700	659	617	699
		Conn.	115	116	113	114	114	117	117	117	111	112	114	113	120
	Total	Cons.	7,799	7,542	7,582	7,897	7,706	7,745	7,573	8,159	7,475	7,833	7,548	7,552	7,867
		Conn.	3,626	3,621	3,630	3,640	3,645	3,650	3,677	3,689	3,695	3,720	3,749	3,747	3,791
Grand Total		Cons.	75,953	75,205	78,278	78,702	78,158	73,380	68,637	72,966	67,784	71,779	68,559	70,109	72,476
		Conn.	19,627	19,679	19,707	19,819	19,854	19,917	20,029	20,117	20,212	20,284	20,411	20,503	20,663

* Source: CWASA Ward Wise Monthly Summary Billing Report, Cons (Consumption, m^3/d), Conn (Connection, Nos)

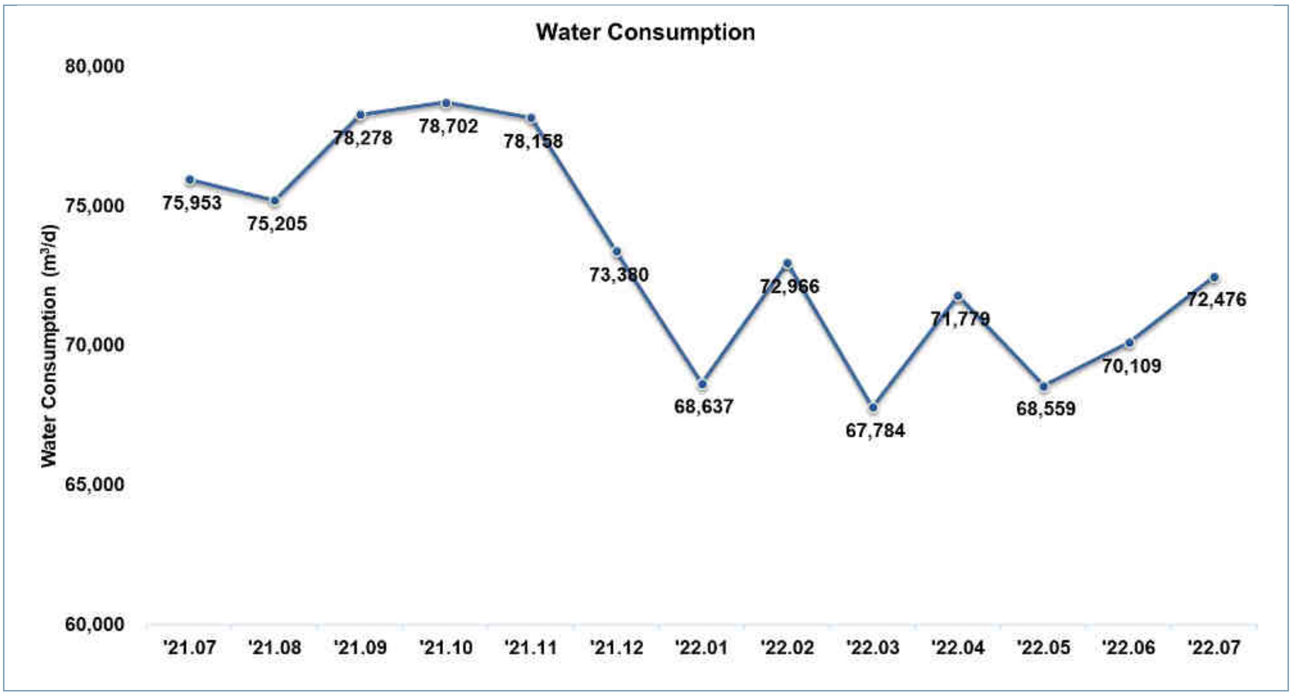


Figure 2-15 Water Consumption Trends of the Project Area

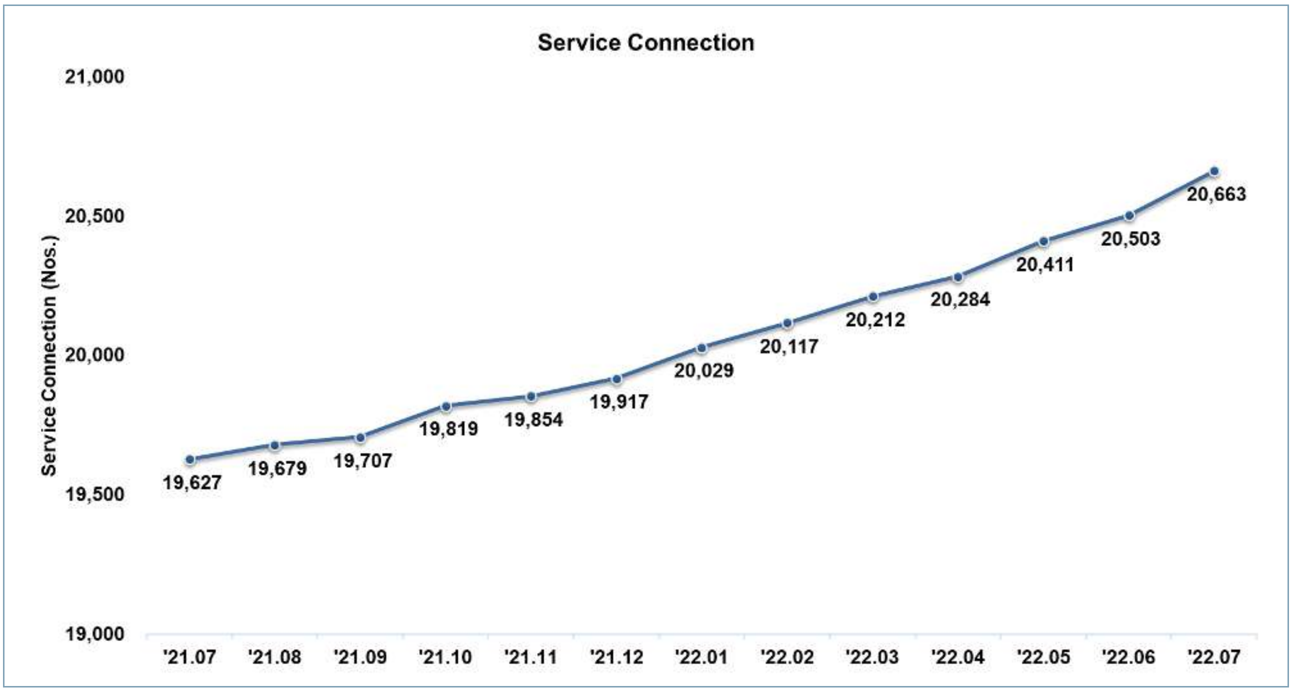


Figure 2-16 Water Connection Trends of the Project Area

2.4.1.3 Statistics of Sewerage System

As of 2022, statistics of sewerage system is not available because there is no centralized sewerage system installed in the Chattogram City, so all the domestic and non-domestic wastewater is discharged into nearby rivers or waterways after treatment in the on-site system with septic tanks or without any treatment. It will be expected to set up gradually when construction of the sewerage system of Catchment-1 (PESSCM-1) is completed which is currently under construction.

2.4.2 Existing Water Supply System

2.4.2.1 Introduction

CWASA is operating two WTP and one IRP (Iron Removal Plant) in 2023. Water supply service coverage of CCC under CWASA is about 62% as below.

Figure 2-17 Water Supply Service Coverage of CCC

2.4.2.2 Water Treatment Plant

2.4.2.2.1 Mohara Water Treatment Plant

Mohara water treatment plant has been operated since 1987. Raw water is intake directly from the nearby Halda River and pumped and transported to the water treatment plant for further treatment. The treated water by rapid filtration is sent to the reservoir in the CCC area and supplied through the distribution network.

Table 2-30 Summary of Mohara WTP

Category	Description
Facility	Mohara WTP
Location	Chandgaon, Chattogram
Water Source	Halda River
Capacity	90,000 m^3/d
Water Treatment Process	Rapid Filtration (Intake Pump → Sand Trap → Flocculation → Sedimentation → Rapid Sand Filtration → Disinfection → Clean Water Tank & Pump → Storage Tank → Water Supply)
Sludge Treatment Process	Sludge and Backwash Water discharge to Halda River

Table 2-31 Details of Mohara WTP

Category	Dimension	Capacity
Intake Pump	45min/d x 2, 110kW (132hp)	129,600m^3/d
Sand Trap	0.18mm/s x 2, 120 min	
Flocculation	10s/chamber x 2 nos, 5.6kW (7.5hp)	
Sedimentation	HRT 1.2hour, 24 nos, 0.75mm/s	
Rapid Filtration	B 2.44m x L 9.1m x H 1.22m x 8, 3.1mm/s	
Clean Water Tank	2.27ml x 5.0m, HRT 3 hour	11,400m^3
Emergency Generator	1000kW x 2	
Sludge transfer Pump	645L/s x 3, 22.4kW (30hp)	

Table 2-32 Function of Mohara WTP Facility

Facility	Function	Remarks
Intake Pump	Pump the raw water from river to the WTP	
Sand Trap	Remove sand and grit from the raw water	
Chemical Injection	In-line method using Diaphragm Pump to inject and rapidly mix chemicals in the pipe	
Flocculation	Coagulation and floc formation with the chemical injection to remove the colloid materials	
Sedimentation	Settling to remove colloid material	
Rapid Filtration	Provide the rapid and efficient removal of relatively large suspended particles	
Chlorine Disinfection	Chlorine is injected into the connection pipe between the rapid sand filtration and the clean water tank.	
Clean Water Tank & Pump	Store the treated water and pump the water to the storage tank	

Figure 2-18 Layout of Mohara WTP

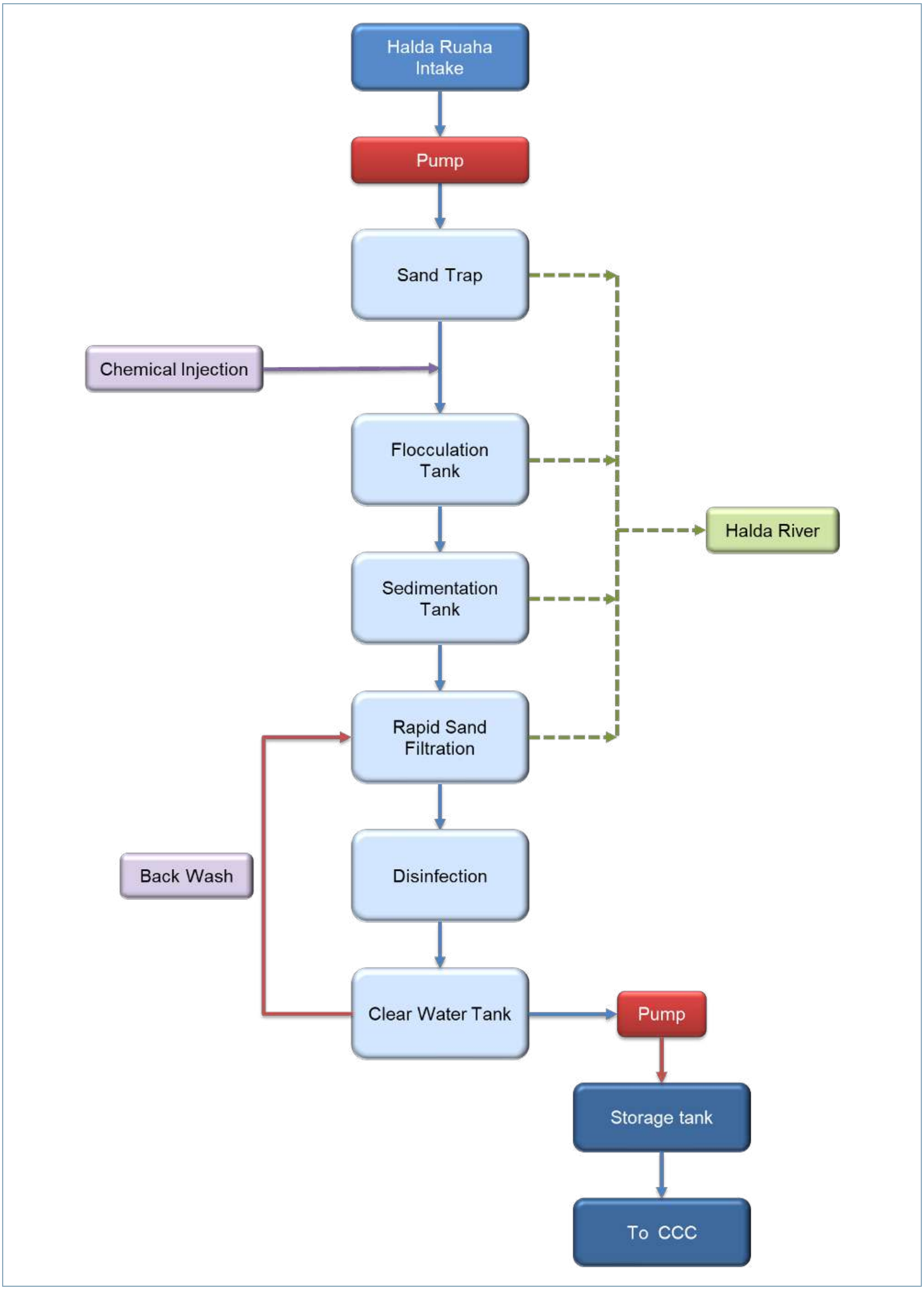


Figure 2-19 Process Flow Diagram of Mohara WTP

2.4.2.2.2 Modunaghat WTP

The Modunaghat water treatment plant began operation in 2017. Water is taken directly from the nearby Halda River and pumped and transported to the water treatment plant. The Water treated by rapid filtration is sent to the reservoir in the CCC area and supplied through the drainage pipe.

Table 2-33 Summary of Modunaghat WTP

Category	Description
Facility	Modunaghat WTP
Location	Hathazari, Chattogram
Water Source	Halda River
Capacity	90,000 m^3/d
Water Treatment Process	Rapid Filtration (Intake & Screen → Pump → Receiving Well → Mixing Tank → Flocculation → Sedimentation → Rapid Filtration → Disinfection → Clean Water → Storage Tank → Water Supply)
Sludge Treatment Process	Composting and sale after thickening and dewatering

Table 2-34 Details of Modunaghat WTP

Category	Dimension	Capacity
Intake	Civil Q=200,000m^3/d, Machine Q=100,000m^3/d	100,000m^3/d
Mixing Tank	W 5.0m x L 5.0m x H 6.0m	
Flocculation	W 1.7m x L 55.0m x H 4.0m (Volume=370m^3)	
Sedimentation	W 10.0m x L 21.0m x H 4.0m x 6	
Rapid Filtration	W 5.2m x L 13.0 x 10	
Clean Water Tank	W 35.0 x L 29m x H 3.0 x 2	6,000m^3/d
Sludge Thickening	Gravity Thickening, D 20m x H 5.0m x 4	6,300m^3
Sludge Dewatering	Centrifugal Dewatering	

Table 2-35 Function of Modunaghat WTP Facility

Facility	Function	Remarks
Intake & Screen	Water is taken directly from the river and impurities; sand and small stones are removed through a screen	
Intake Pump	Pump the raw water from river to the WTP	
Chemical Injection	In-line method using Diaphragm Pump to inject and rapidly mix chemicals in the pipe	
Flocculation	Coagulation and floc formation with the chemical injection to remove the colloid materials	
Sedimentation	Settling to remove colloid material	
Rapid Filtration	Provide the rapid and efficient removal of relatively large suspended particles	
Disinfection	Chlorine is injected into the connection pipe between the rapid sand filtration and the clean water tank.	
Clean Water Tank & Booster Pumping Station	Store the treated water and pump the water to the storage tank	
Sludge Thickening	Thicken the sludge generated in the water treatment process and reduces the volume of the sludge	
Sludge Dewatering	Sludge dewatering and composting	

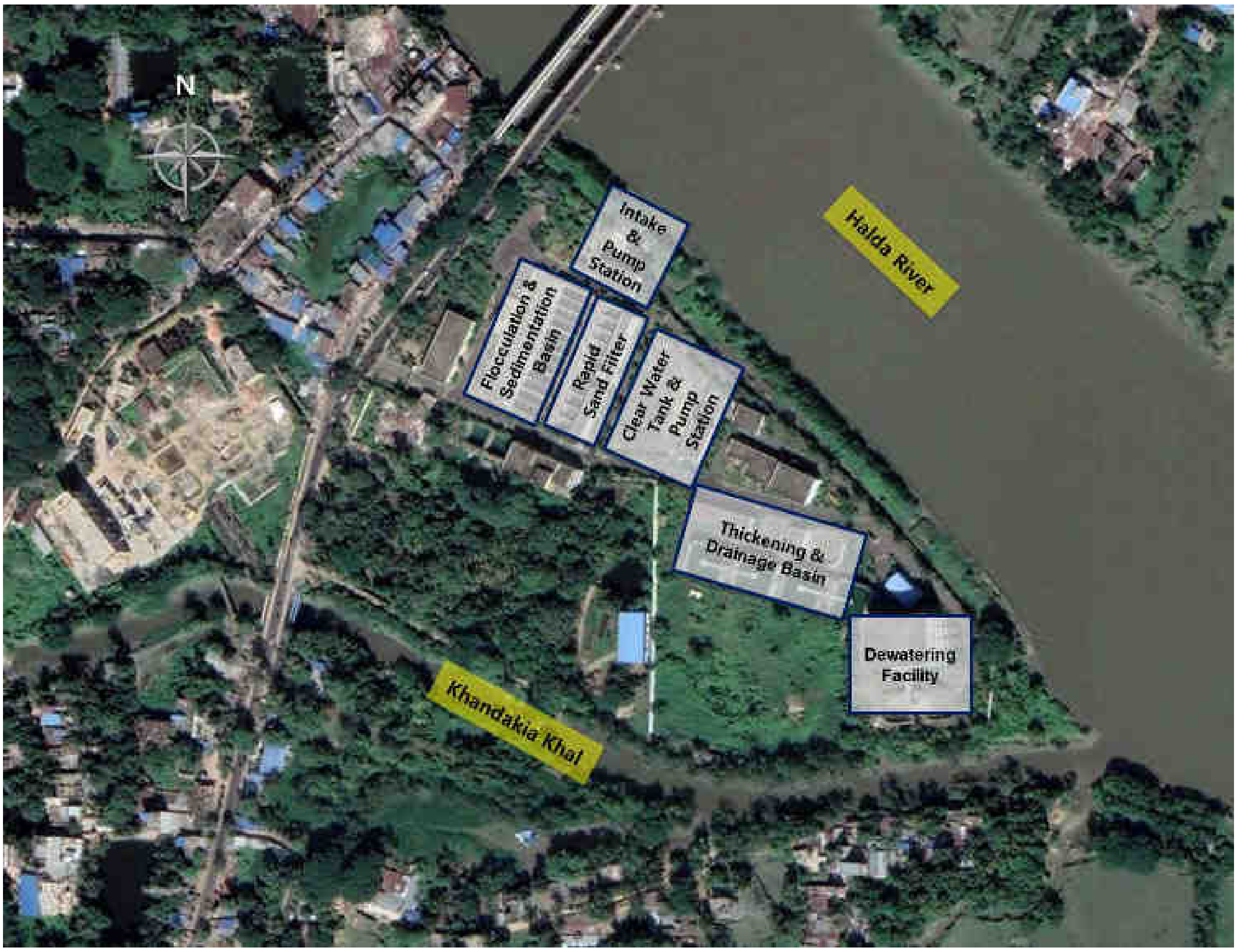


Figure 2-20 Layout of Modunaghat WTP

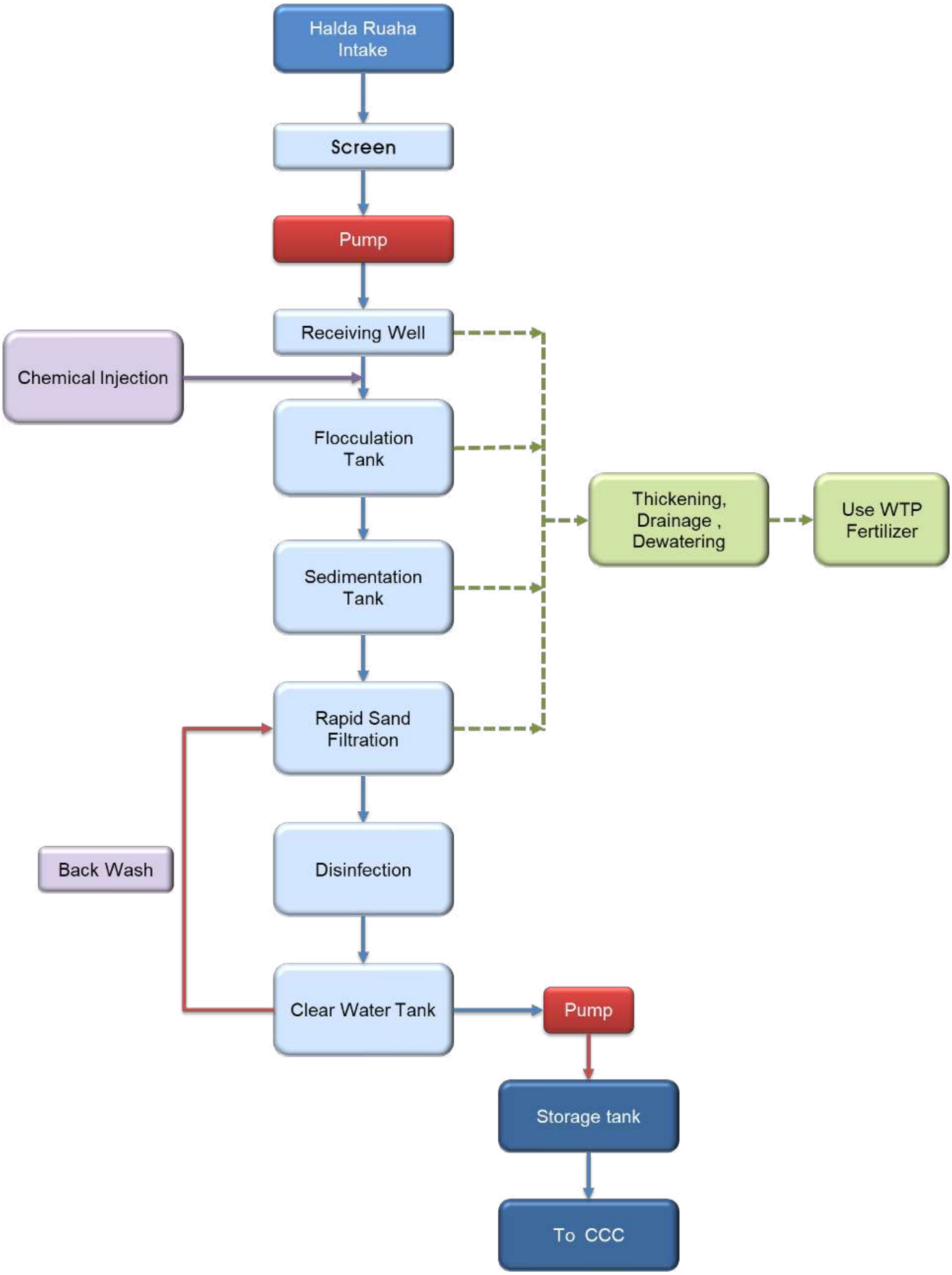


Figure 2-21 Process Flow Diagram of Modunaghat WTP

Table 2-36 Photo of Modunaghat WTP

Category	Photo		Status
Screen			• After taking water from the Halda Ruaha River, impurities are removed through a fine screen.
Intake Pump			• Transferring raw water from the screen to the receiving well through the pump facility.
Flocculation			• While transferring from the receiving well to the mixing tank, the coagulant is injected and mixed. • Form a floc from the flocculation and transfer it to the sediment. • Slowly precipitate the floc and transfer the treated water to a rapid filter.
Rapid Filtration			• Purified water is produced by filtering the microflocs that are not removed from the settling tank through a filter. • Perform periodic backwashing to maintain filter yarn quality and comply with water purification quality.
Disinfection			• Disinfection by injecting chlorine into the filtered water produced in the rapid filter. • The clear well consists of a closed structure to supply clean water and prevent foreign substances from entering.
Sludge Thickening & Dewatering Facility			• Thicken the sludge and utilize it after reduction and dewatering.

2.4.2.2.3 Kalurghat Iron Removal Plant

Chattogram has been operating Kalurghat IRP since 1977 to remove iron dissolved in groundwater. It collects raw water from 41 hearts and operates iron removal and water purification facilities, and produces an average of 35,000 to 45,000m^3/d per day.

Table 2-37 Summary of Kalurghat IRP

Category	Description
Facility	Kalurghat IRP
Locatiion	Chandgaon, Chattogram
Water Source	41 Deep well
Capacity	64,000 m^3/day
Water Treatment Process	Iron removal and Water treatment process (Deep well → Aerated Oxidized Pond → Sedimentation → Filtration → Disinfection → Clean Water → Storage Tank → Water Supply)

Table 2-38 Details of Kalurghat IRP

Category	Dimension	Capacity
Aerated Oxidized Pond	W 3.4m x L 13.2m x H 4.4m x 2 tower	37,800m^3/day
Sedimentation	W (46.4~34.2) m x L (79.2~68.5) m x H 3.1m x 2	37,800m^3/day
Filtration 1	W 4.9m x L 6.7m x 8 units	37,800m^3/day
Filtration 2	W 8.2m x L 13.3m x 4units	18,900m^3/day
Clean Water Tank	W 29.9m x L 98.5m x H 2.9m x 1 tank	Nominal V = 7,560m^3 Actual V = 6,800m^3
Moter Drive Pump	14.2m^3/min× 63m × 260 Kw × 1 units	
	8.1m^3/min× 63m × 200 Kw × 1 units	
	12.2m^3/min× 72m × 210 Kw × 2 units	
Engine Drive Pump	14.2m^3/min× 63m × 349 Kw × 1 units	
	8.1m^3/min× 63m × 200 Kw × 1 units	

Table 2-39 Function of Kalurghat IRP Facility

Facility	Function	Remarks
Aerated Oxidized Pond	Oxidation of iron and floc formation by supplying oxygen to raw water collected from deep wells	
Sedimentation	Sedimentation and removal of formed flocks	
Rapid Filtration	Removal of suspended particles not removed from the settling tank and water treatment	
Disinfection	Rapid filtration to clean water tank injection into the connector	
Clean Water Tank & Booster Pumping Station	Store clean water and transport it to a reservoir using a pump	

Figure 2-22 Layout of Kalurghat IRP

Table 2-40 Photo of Kalurghat IRP

Category	Photo	
Status		
Facility	Aerated Oxidized Pond & Sedimentation	Booster Pumping Station

2.4.2.3 Storage Tank

There are 10 Storage Tank used in the CCC area managed by the project implementation agency.

Table 2-41 Storage Tank Status

Facility	Capacity(m^2)	H. W. L(m)	L. W. L(m)	Remarks
Halishahar Tank 1 RC Elevated	455	29.3	24.7	
Halishahar Tank 2 RC Ground	227	10.0	N/A	
DC Hill RC Elevated Tank	455	48.8	43.9	
ADC Hill Ground Tank	4,546	38.1	33.5	
Percival Hill	455	42.7	38.1	
Dampara Waterworks RC Ground Reservoir	68	N/A	N/A	
Parade Corner RC Ground Reservoir	45	25.0	N/A	Self - Use
Medical College Water Tower RC Elevated Tank	455	43.6	40.2	Self - Use
Polytechnic Institute High Lift Pump Station	455	N/A	N/A	Self - Use
Total	7,616			

*Source: CWSISP Sanitation Master Plan (2017)

2.4.2.4 On-going Water Supply Project

As of 2022, CWASA is working on a water purification plant expansion project and a waterworks basic plan establishment project. Details are as follows.

Table 2-42 On-going Water Supply Project

Category	Introduction	Progress	Specification	Remarks
Bhandal Jhuri Water Supply Project Bangladesh	Water Treatment Plant Q=60,000m^3/d	On-going Construction	EDCF	Taeyoung
Chattogram water supply expansion and improvement project	Expansion of water supply and improvement of existing facilities	Establishment of Master Plan	WB	Suez

2.4.3 Existing Sewerage System

2.4.3.1 Introduction

Chattogram has facilities for water supply, but no facilities for sewage treatment. Most of the sewage in urban areas is discharged after the first treatment through septic tanks, but slums, living areas for low-income people, do not have a septic tank, so the sewage is discharged into nearby waterways or rivers without treatment, as a result water pollution is in serious issue.

2.4.3.2 On-going Sewerage Project

Currently five sewerage projects including this project are on-going in Chattogram City under CWASA. Although six sewage treatment plants were planned in the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP), number of STP is adjusted during the project implementation of each project due to the difficulty of the land acquisition of sewage treatment plant sites of Catchment-4, Catchment-5 & Catchment-6 as below.

- STP of Catchment-5 & Catchment-6 is planned to be integrated in the site of STP of Cathcment-1 (PESSCM-1).
- STP of Catchment-2 & Catchment-4 is planned to be integrated in the site of STP of Cathcment-2.

Table 2-43 On-going Sewerage Projects

Category	Location of STP	Capacity of STP (Final/Phase 1, m^3/d)	Fund Source	Current Progress
Catchment-1 (PESSCM-1)	Halishahar	100,000	GOB	Under Construction
Catchment-5		100,000 (50,000)	AFD	EOI
Catchment-6		100,000	PPP	Feasibility Study On-going
Catchment-2&4	Kalurghat	300,000 (60,000)	JICA	Feasibility Study Completed
Catchment-3	Fatehabad	120,000 (60,000)	EDCF	Feasibility Study Completed

2.4.4 Project Executing Agency

2.4.4.1 Introduction

CWASA started managing the water supply and sewage of Chattogram in 1964, and as of 2022, it consists of management, finance, technology and operation departments. The total number of employees is showing a 155% increase from 1,048 in 2016 to 1,624 as of 2022.

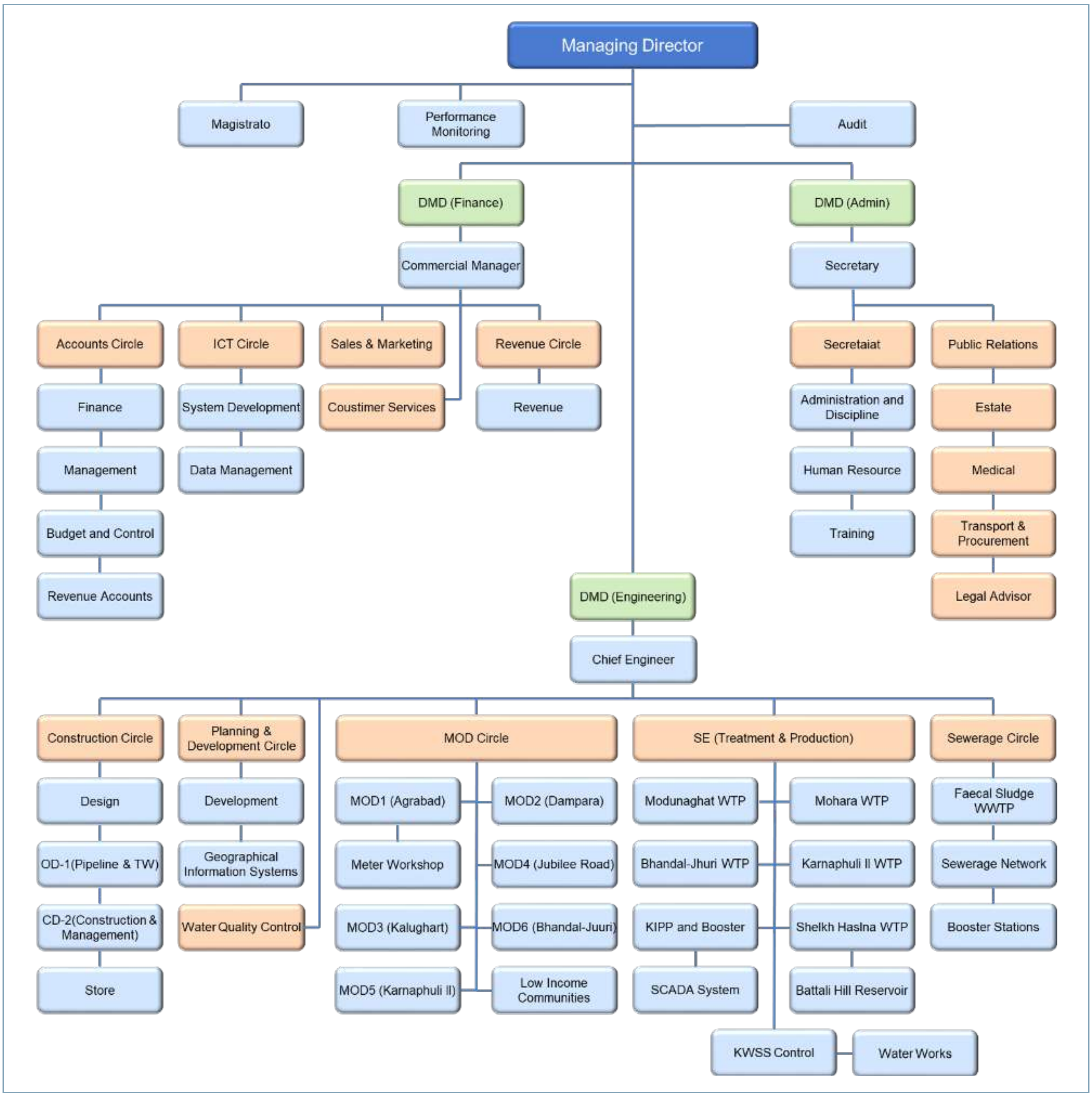


Figure 2-23 CWASA Organization Structure

2.4.4.2 History and Roles

CWASA was established as an autonomous organization to operate and manage water and sanitation in the CCC area of Chattogram city by Ordinance No. 19 promulgated in 1963. Through the WASA Act amended in 1996, CWASA was notified as a water supply management agency and in 2008 as a water supply and sewage management agency. CWASA has a board of 13 members and is responsible for providing Chattogram city's water supply, sanitation and drainage services. Its main functions and roles are as follows;

- Provides water supply for purposes required by law or other ordinances, performs water quality and environmental standards, and sewage management.
- Continuous water purification of raw water and ensuring continuous supply of water according to the Water Supply Act, such as monitoring, for the quality of water supplied.
- Water supply and sanitation facilities development and maintenance.
- Protect and manage water sources.
- Consultation to the Government in establishing relevant policies and guidelines in accordance with drinking water standards.
- Planning and implementing a new project for water supply and sanitation.
- Educate and provide information on public health aspects such as water conservation, sanitation and similar issues.
- Consultation with local governments for the preparation and implementation of plans related to the expansion of water supply and sewerage.
- Supply water and sewage to consumers and collect fees and charges.
- Calculation of Water and Sewage Charges.
- Providing convenience facilities to consumers who use the service.
- Performance to properly perform the water supply function under the Water Supply Act according to the judgment of the board of directors.

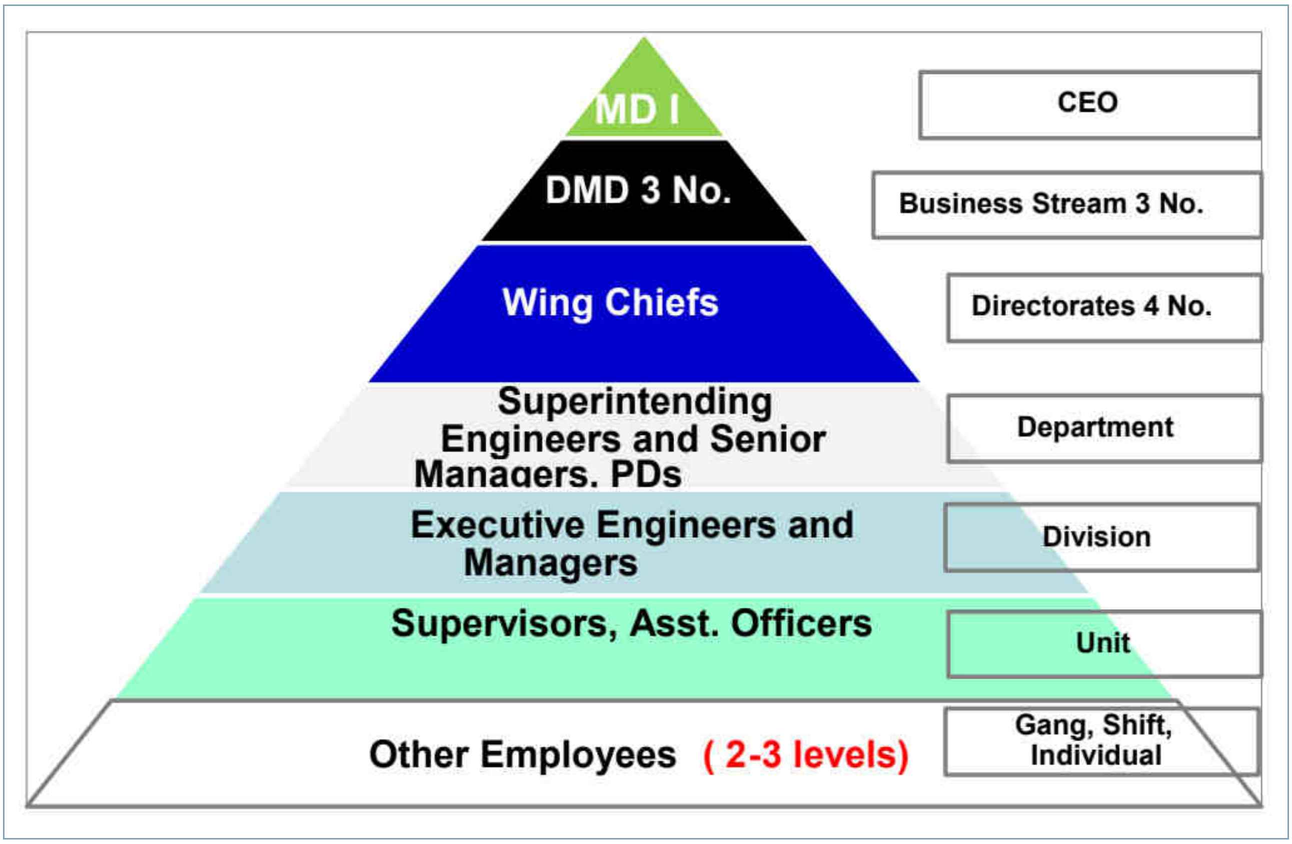


Figure 2-24 CWASA Organization Chart

2.4.4.3 Budget Operation

CWASA's revenue is divided into operating revenue, other revenue, and interest revenue, and details are as follows.

- Operating Revenue: Water tax, underground water using license fee
- Other Revenue: Materials and installation costs for water supply connection, water meter installation costs and commissioning costs
- Interest Revenue: Bank Deposit Interest

CWASA's profit and loss has been in the loss for the past five years, and the income statement from 2015 to 2019 is as follows.

Table 2-44 Income Statement of CWASA (million BDT)

Category	2015~2016	2016~2017	2017~2018	2018~2019	Change Rate
Total Revenue	831	1,052	1,259	1,422	71
1. Operating Revenue	641	845	1,050	1,210	89
(a) Water Tax	525	754	925	1,088	107
(b) Underground Water license fee	116	91	72	122	5
2. Other Revenue	52	90	72	58	12
3. Interest Revenue	138	117	137	154	12
Total Cost	1,189	1,731	2,130	2,491	110
1. Operating Cost	893	1,323	1,691	1,867	109
(a) Salary and benefit	85	110	124	137	58
(b) Electricity and Power	299	373	431	471	58
(c) Depreciation	388	701	956	1,059	173
(d) Chemical	24	20	64	61	154
(e) Others	97	119	116	142	46
2. General Expense	231	334	357	379	64
3. Collection Cost	36	45	75	59	64
4. Financial Cost	29	29	7	186	541
Pretax Net Profit (loss)	-358	-679	-871	-1,069	199
After tax Net Profit (loss)	-361	-683	-879	-1,079	199
Net Profit Tax without depreciation (loss)	30	22	85	-10	
Total Cost Recovery Level (Total / Revenue)	+43%	+65%	+69%	+75%	

2.4.5 Policy, Legislative and Administrative Framework

2.4.5.1 Background

Formal concern at national level regarding the state of the environment in Bangladesh can be traced back to Independence and the passing of the Water Pollution Control Act of 1973. Bangladesh has in the region of 200 laws and regulatory frameworks either directly or indirectly related to the environment. The laws and policies most relevant taking the proposed project into consideration are;

- Building Construction Act, 1952
- Town Improvement Act, 1953
- Water Supply and Sewerage Authority Ordinance, 1963
- Water Pollution Control Act, 1973
- Environmental Pollution Control Ordinance, 1977
- Chittagong City Corporation Ordinance, 1982
- Chittagong Development Authority Act, 1959
- Environmental Quality Standards of Bangladesh, 1991
- National Environment Policy, 1992
- National Conservation Strategy, 1992
- Environment Conservation Act, 1995
- Environment Protection Act, 1995
- National Environment Management Action Plan, 1995
- Water Supply and Sewerage Act, 1996
- Environment Conservation Rules, 1997
- National Water Policy, 1999
- National Land Use Policy, 2001
- Environment Court Act, 2000
- National Water Management Plan, 2004
- National Policy for Arsenic Mitigation, 2004
- National Sanitation Strategy, 2005
- Sector Development Program, 2006
- National Strategy for Accelerated Poverty Reduction II, 2009
- Bangladesh Climate Change Strategy and Action Plan, 2009
- National 3R (reduce, reuse and recycle) Strategy for Waste Management, 2010

2.4.5.2 National Policies and Regulations

Building Construction Act, 1952

The Building Construction Act (1952) and the subsequent Building Construction Rules (1984) seek to prevent the unplanned construction of buildings and other developments which may interfere with planning in other areas.

Town Improvement Act, 1953

Every construction/erection/excavation within the jurisdiction of the planning authority requires permission/approval from the Authorized Officer or appointed Building Construction Committee as per the provision of the Town Improvement Act of 1953. Any type of building construction, housing, commercial, industrial and whatsoever need planning permission and they should be in conformity with the land use provision of Master Plan/Urban Area Plan/Detailed Area Plans of different Strategic Planning Zones (SPZs). The Rules are updated/amended on a regular as well as on a required basis.

Water Supply and Sewerage Authority Ordinance, 1963

The Water Supply and Sewerage Authority Ordinance (1963) authorized the establishment of Water Supply and Sewerage Authorities (WASAs) by local governments to provide adequate and safe drinking water and sewerage services in urban areas. The Chittagong WASA was created pursuant to the ordinance, and tasked to construct, improve and operate water supply and sewerage works and other facilities.

Water Pollution Control Act, 1973

Under the 1973 Water Pollution Control Act, a small unit was established in the Department of Public Health Engineering (DPHE) to monitor pollution of ground water and surface water.

Environmental Pollution Control Ordinance, 1977

The Environmental Pollution Control Ordinance of 1977 provided for the establishment of the Environmental Pollution Control Board, which was charged with formulating policies and proposing measures for their implementation. The Environmental Pollution Control Board was subsequently renamed in 1982 as the Department of Environmental Pollution Control (DEPC), and then again in 1989 as the Department of Environment (DOE) which was placed under the newly formed Ministry of Environment and Forest (MoEF).

Chittagong City Corporation Ordinance, 1982

Chittagong City Corporation Ordinance of 1982, vested authority to the CCC to undertake the following relevant sanitation-related activities;

- Removal, collection and disposal of refuse.
- Provide and maintain a sufficient number of gendered public latrines and urinals.
- Adopt sufficient measures to prevent and control the spread of infection diseases within the city.
- Promotion of public health.
- Control, regulation and inspection of all private sources of water supply within the city.
- Provide public bathing and washing places at suitable locations.
- Provide adequate drainage system giving due consideration to public health and convenience.

Environmental Quality Standards of Bangladesh, 1991

The Environmental Quality Standards (EQS) were approved by the Technical Expert Committee of the DOE on 15 July 1991. The EQS includes standards covering water pollution (incl. drinking water, recreational water, fishing water, industrial water, irrigation water, livestock water and coastal water), air pollution (incl. dust, smoke, mist, fog, fume, sulphureous smog and photochemical smog), noise pollution (incl. setting out permissible levels of noise pollution as per locality i.e. residential, commercial, industrial or institutional, and setting out of regulations for motor vehicles), sewage pollution (incl. particular regulations on sewage pollution to prevent pollution in the public water bodies), and industrial pollution (incl. setting out of standard values for controlling the industrial wastewater categorized by point of discharge, such as inland surface water, sewerage system and on land, as well as for air pollution and odours caused by industrial emissions). Soil pollution standards have not been included in the EQS because at the time of approval, the soil quality criteria had not been established.

National Environment Policy, 1992

Bangladesh's National Environment Policy that was approved in May 1992 sets out the basic framework for environmental action together with a set of broad sector action guidelines. The key elements of the policy focus on maintenance of the ecological balance when considering national growth and development, protection against natural disasters, identification and regulation of all polluting and environmentally-degrading activities, ensuring sustainable utilization of all natural resources and active association with environmentally-oriented international agendas and initiatives. The health and sanitation sector related guidelines of the National Environment Policy set out the following specific objectives;

- To prevent activities which are harmful to public health in all spheres, incl. development activities within the country.
- To integrate environmental concerns into the national health policy.
- To ban the establishment of any industry that produces goods that cause environmental pollution, closure of existing industries in phases and discouragement of the use of such goods through the development and/or introduction of environmentally sound substitutes.
- To develop healthy environments in both rural and urban areas.

National Conservation Strategy, 1992

The National Conservation Strategy of 1992 was one measure undertaken by the government to integrate the environment with development in a policy framework with particular regard to sustainable development in the health and sanitation sectors. The report proposed various recommendations, in particular;

- The national programme 'health for all by the year 2000' should be consistent with the National Environment Policy.
- Course/subjects on environment and hygiene should be included in various levels of the education system.
- The mass media and NGOs should help create national consciousness and public awareness on community hygiene and health care.

Environment Conservation Act, 1995

The Environment Conservation Act of 1995, and all subsequent amendments, is currently the main legislative document relating to environmental protection in Bangladesh. The main objectives of the Act are conservation and improvement of the environment and control and mitigation of pollution of the environment. The main strategies of the Act can be summarized as follows;

- Identification of ecologically critical areas, and restriction on the operations which can be carried out in such areas.
- Regulation in respect to vehicular emissions.
- Environmental clearance.
- Regulation imposed on industries and other development activities, incl. discharge permits.
- Production of standards for quality of air, water noise and soil for different areas/purposes.
- Production of standard limits for discharge and emission of wastes.
- Formulation and declaration of environmental guidelines.

Under the Environment Conservation Act (1995), the DOE is mandated to enforce the Act and was given power under the Act, to;

- Close down the activities considered harmful to human life or the environment.
- Declare an area affected by pollution as an ecologically critical area.

Before any new development project can be implemented, the project proposer should first obtain Environmental Clearance from the DOE and procedures for doing so are in place. Failure to comply with any part of the Environmental Conservation Act of 1995 may result in punishment by a maximum of 5 years imprisonment or a maximum fine of Taka 100,000. The Environment Conservation Act (1995) also set the basis for creation of the National Conservation Strategy (1995).

Environment Protection Act, 1995

The Environment Protection Act (1995) authorized the DOE for the declaration of environmentally critical areas, the regulation of polluting industries through Environmental Impact Assessments (EIA) and standards. Through this Act, the DOE has the legal authority to perform as per rule against any person or group if they do something that will create environmental hazards by any means or activities.

National Environment Management Action Plan, 1995

The National Environment Action Plan (NEMAP) is a wide-ranging and multi-faceted plan, which builds on and extends the statements set out in the National Environmental Policy. NEMAP was developed to address issues and management requirements during the period 1995 to 2005 and sets out the framework within which the recommendations of the National Conservation Strategy are to be implemented. The broad objectives of NEMAP include identification of key environmental issues, identification of remedial actions necessary to halt or reduce environmental degradation, improvement of the natural and built environment, conservation of habitats and biodiversity, promotion of sustainable development, and improvement in the quality of life of the people.

Water Supply and Sewerage Act, 1996

The Water Supply and Sewerage Act of 1996 authorizes CWASA to provide adequate and safe drinking water and sewerage services in Chittagong City metropolitan area. Some of the general duties of CWASA include;

- Construction, improvement and maintenance of water works for collecting, purifying, pumping, storing and distributing potable water.
- Construction, improvement and maintenance of sewerage works for collecting, pumping, treating and disposing of sanitary and industrial wastes.
- Construction and maintenance of drainage works for drainage facilities, incl. storm water drainage.

Environment Conservation Rules, 1997

The Environment Conservation Rules were published in 1997 under the power vested by the Environment Conservation Act of 1995 for creation of by-laws as a means of implementing the provisions of the Act. The Rules mainly consist of;

- Categorized list (green, amber and red) of projects.
- Application format to take environmental clearance.
- Standards relating to water pollution, air pollution and noise, as well as permitted discharge/emission levels of water and air pollutants and noise by industries.

The 'Rules' incorporate "inclusion lists" of projects requiring varying degrees of environmental investigation e.g. all the new projects under red category generally will require two-steps assessment procedure, firstly an Initial Environmental Examination (IEE) for site clearance and secondly, if warranted, a EIA for technical clearance.

National Water Policy, 1999

Water resources have been of significant importance to the socio-economic development of Bangladesh. The National Water Policy was adopted in January 1999 to provide guidelines to all related Ministries, Agencies, Departments and non-government users and entrepreneurs, including local organizations who are involved in water resources development, maintenance, water supply and water related services in the country. The Water Resources Planning Organization (WARPO) centrally monitors the implementation of the National Water Policy and maintains a National Water Resources Database (NWRD) that preserves and disseminates information/data of the country's water resource and related sectors.

Environment Court Act, 2000

The Environment Court Act of 2000 was passed by Parliament on 6 April 2000 for the establishment of environmental courts for the trial of offences relating to the environmental pollution and matters incidental thereto. Under this Act, an Environment Court will be established in each Division and in addition one or more Environment Appeal Courts will be established. The Environment Appeal Court will be constituted with one judge and to date two Environment Courts and one Environment Appeal Court have been established in Dhaka.

National Land Use Policy, 2001

The optimum use of land and water is reliant on detailed and structured planning which is of particular importance in Dhaka and Chattogram where land availability is rapidly diminishing due to development. Recognizing these issues, the GOB approved the National Land Use Policy in June 2001 in addition to other national policies and measures to prevent land depletion.

National Water Management Plan, 2004

The NWMP was approved by the National Water Resources Council (NWRC) in 2004 and aims at implementing the NWMP within 25 years. It is expected to be reviewed and updated every five years. In 2005, the government included the improvement of water supply and sanitation as part of its agenda for reducing poverty. As of today, there is no information on the updating of the plan.

National Policy for Arsenic Mitigation, 2004

Complementing the NWP, the government adopted a National Policy for Arsenic Mitigation in 2004. The policy emphasizes public awareness, alternative safe water supply, proper diagnosis and management of patients, and capacity building. In terms of alternative supplies, it gives "preference to surface water over groundwater".

National Sanitation Strategy, 2005

The section 8.6 Strategies for Improved Urban Sanitation in National Sanitation Strategy (GoB, 2005) specifies that in large cities, sewage treatment technologies with greater emphasis on resources recovery and recycling should be given top priority in improving urban sanitation situate Emphasis should be on less energy intensive technologies e.g., constructed wet land, oxidation ditch, extended aeration, stabilization ponds, etc. Moreover, it has specified in the strategy that appropriate desludging of septic tanks and pit latrines should be enforced and effluent disposed of in a proper manner. Sludge emptying services by City Corporations and Pourashavas should be in place. The Strategy was superseded by the National Water Supply and Sanitation Strategy, 2014.

Sector Development Program, 2006

Water and Sanitation Sector in Bangladesh, 2006 (SDPWSSB) which drew together the relevant sector policies, strategies and targets and provided an avenue for the various policies to be incorporated onto a single platform.

The first SDP-WSSB was prepared by LGD in 2000 to provide a 10-year plan for water supply and sanitation (WSS) sector in Bangladesh. Afterwards, the next SDP for a period of 15 years from 2011 was prepared by the Policy Support Unit of LGD. The objective of the SDP is to provide a framework for planning, implementing, coordinating and monitoring all activities in the WSS sector. As a strategic planning document, it addresses the emerging and the future challenging of the WSS sector and provides a road map for the development of the sector and corresponding sector investment plan.

National Strategy for Accelerated Poverty Reduction II, 2009

"Moving ahead" which is the National Strategy for Accelerated Poverty Reduction II in Chapter 5.3.3 has clearly envisaged that the access to safe water and sanitation is fundamental for improved health.

Bangladesh Climate Change Strategy and Action Plan, 2009

It is envisaged in the Climate Change Strategy to ensure the existing assets (e.g., Coastal and river embankments) are well maintained and fit-to-purpose. It also envisages that urgently needed infrastructure (e.g., Cyclone Shelter and Urban Drainage) is put in place to overcome the impacts of Climate Change.

National 3R (reduce, reuse and recycle) Strategy for Waste Management, 2010

A National 3R (Reduce, Reuse, Recycle) Strategy was passed in 2010 establishing a 3R Department at the Ministry of Environment and Forests to implement waste prevention activities, and an inter-ministerial committee to coordinate activities across ministries. To stimulate private sector investment in waste recycling and treatment plants, the strategy calls for the government to provide tax holidays, soft loans, and available land for the facilities.

2.4.6 Water Supply and Sewage Tariff

2.4.6.1 Water Supply Tariff

The Chattogram's water supply is divided into household, non-household, public water, and religious institution rates. The water supply tariff, the unit price of household water per ton increased by about 181% from 9.92BDT in 2019 to 18.00BDT in 2022, and non-household water increased by about 134% from 27.56BDT in 2019 to 37.00BDT in 2022. The difference in rates between household and non-household use was found to be decreasing from 2.78 times to 2.06 times.

Table 2-45 Water Supply Tariff (BDT/m^3)

Category	2019.04	2019.12	2020.04	2020.12	2021.04	2022.01	2022.04	2022.07
Average	14.33	14.33	16.88	16.88	16.88	17.72	17.72	22.75
Domestic	9.92	9.92	12.40	12.40	12.40	13.02	13.02	18.00
Non-Domestic	27.56	27.56	30.30	30.30	30.30	31.82	31.82	37.00
Public	9.92	9.92	12.40	12.40	12.40	13.02	13.02	18.00
Religious Institution	9.92	9.92	12.40	12.40	12.40	13.02	13.02	18.00
Rate of Increase	0%	0%	25%	0%	0%	5%	0%	38%

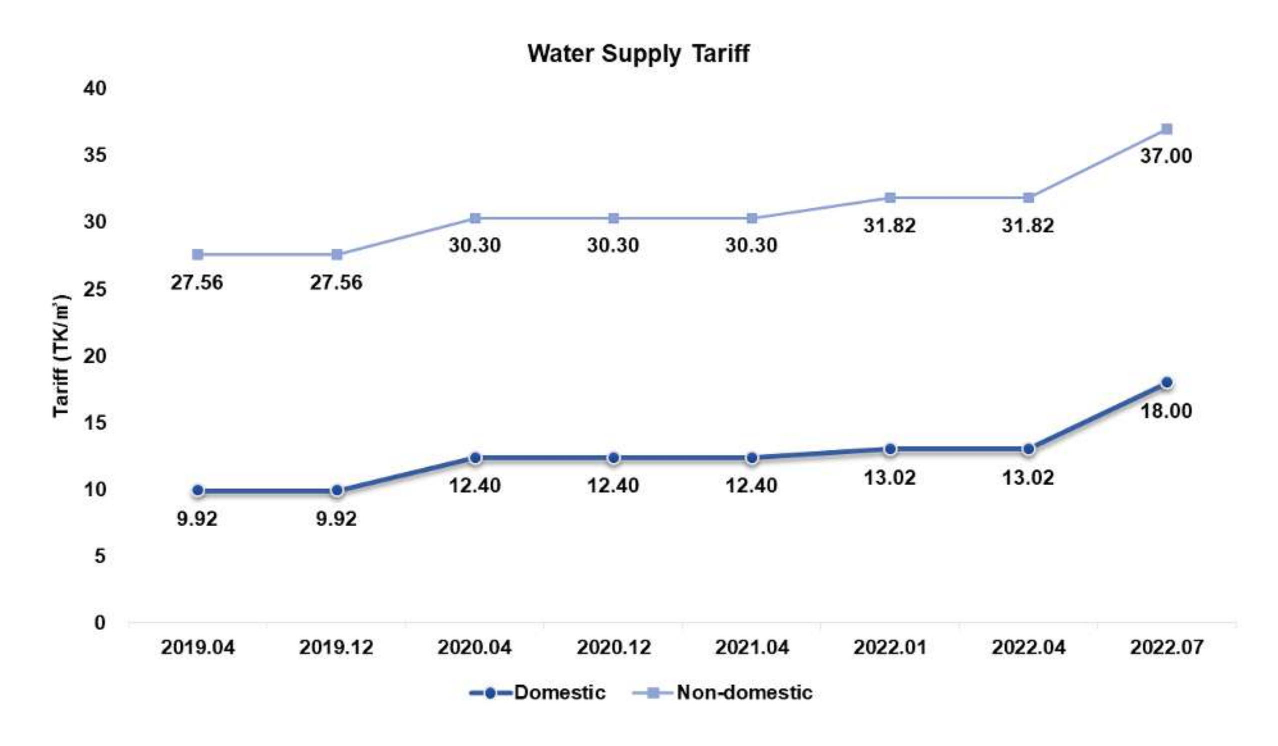


Figure 2-25 Trend of Water Supply Tariff

2.4.6.2 Sewage Tariff

Chattogram does not have a sewage tariff system because there is no sewage facility, but it is urgent to prepare a sewage tariff system as STP-1 construction and STP-2 to 6 feasibility studies are currently being conducted.

2.4.6.3 Bangladesh Water Supply and Sewerage Tariff

WASAs in four major cities that manage water and sewerage in Bangladesh have established and are collecting water tariff systems. Sewerage facilities are operated only in Dhaka WASA, and Dhaka WASA collects sewerage fees the same as waterworks.

Table 2-46 Bangladesh Water and Sewerage Bills (BDT/m^3)

Category		CWASA	Dhaka WASA	Khulna WASA	Rajshahi WASA
Water	Domestic	18.00	15.18	8.98	6.81
	Non-Domestic	37.00	42.00	14.00	13.62
Sewerage	Domestic	-	15.18	-	-
	Non-Domestic	-	42.00	-	-

2.5 Site Survey

2.5.1 Site Survey

2.5.1.1 Sewage Treatment Plant Site Survey

The project site owned by CWASA was investigated as being penetrated by the N106 road and railroad. The total area is 35.4ha, consisting of 18.7ha on the left bank of the railroad, 11.6ha on the right bank of the road, and 5.1ha in the middle of the road and railroad. Therefore, it was investigated that it would be difficult to utilize the total area.

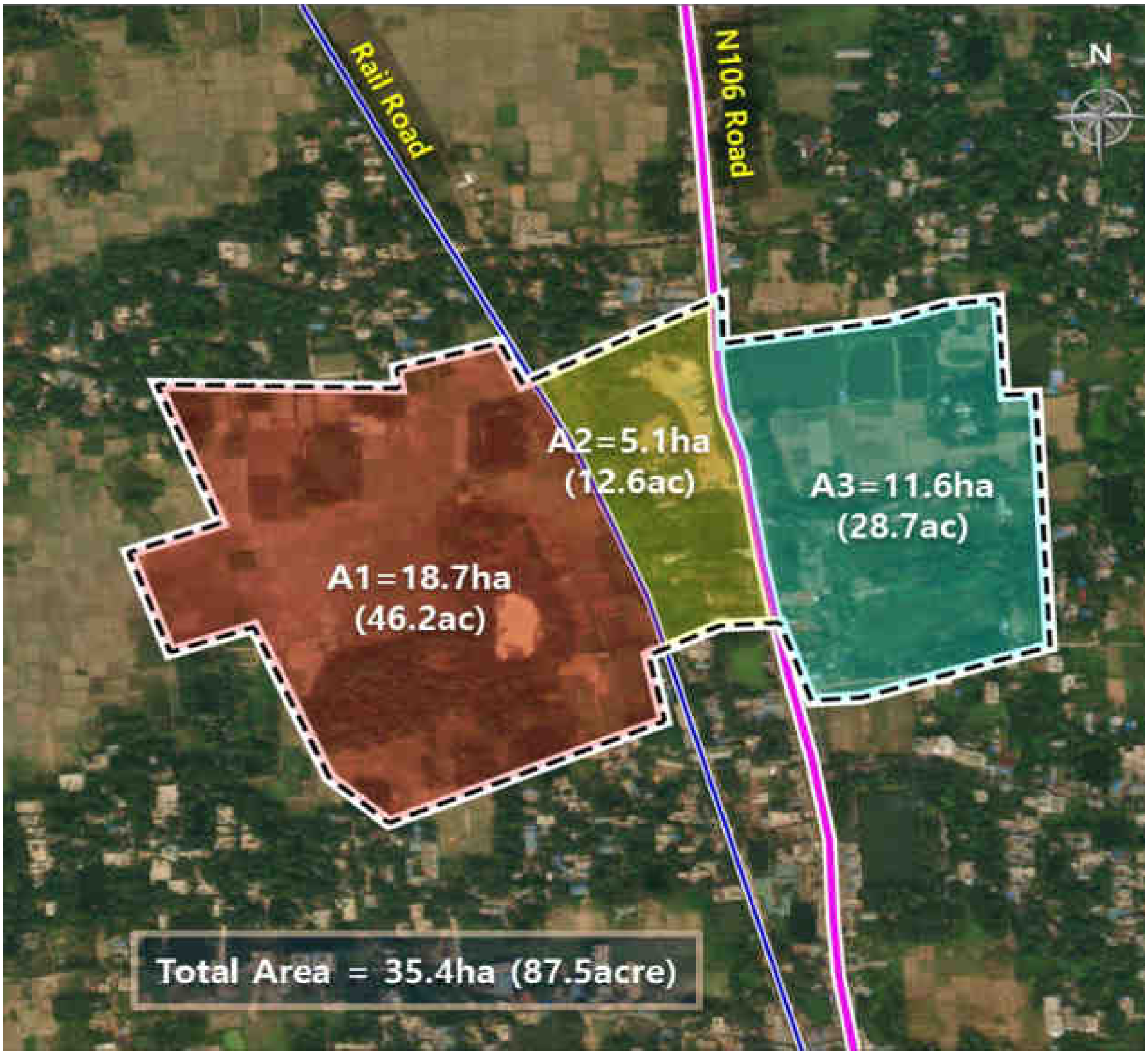


Figure 2-26 Sewage Treatment Plant Site

Table 2-47 Photo of STP Site

Photo	
	
Entrance of STP	Entrance Railway
	
STP Site 1	STP site 2
	
Site View	

2.5.1.2 Sewage Treatment Area and Sewer

The treatment area corresponds to Catchment-3 established in the Chattogram sewage maintenance master plan and includes a total of seven wards. The South Pahartali area is included in the 100 % treatment area and the rest of the area is included in part.

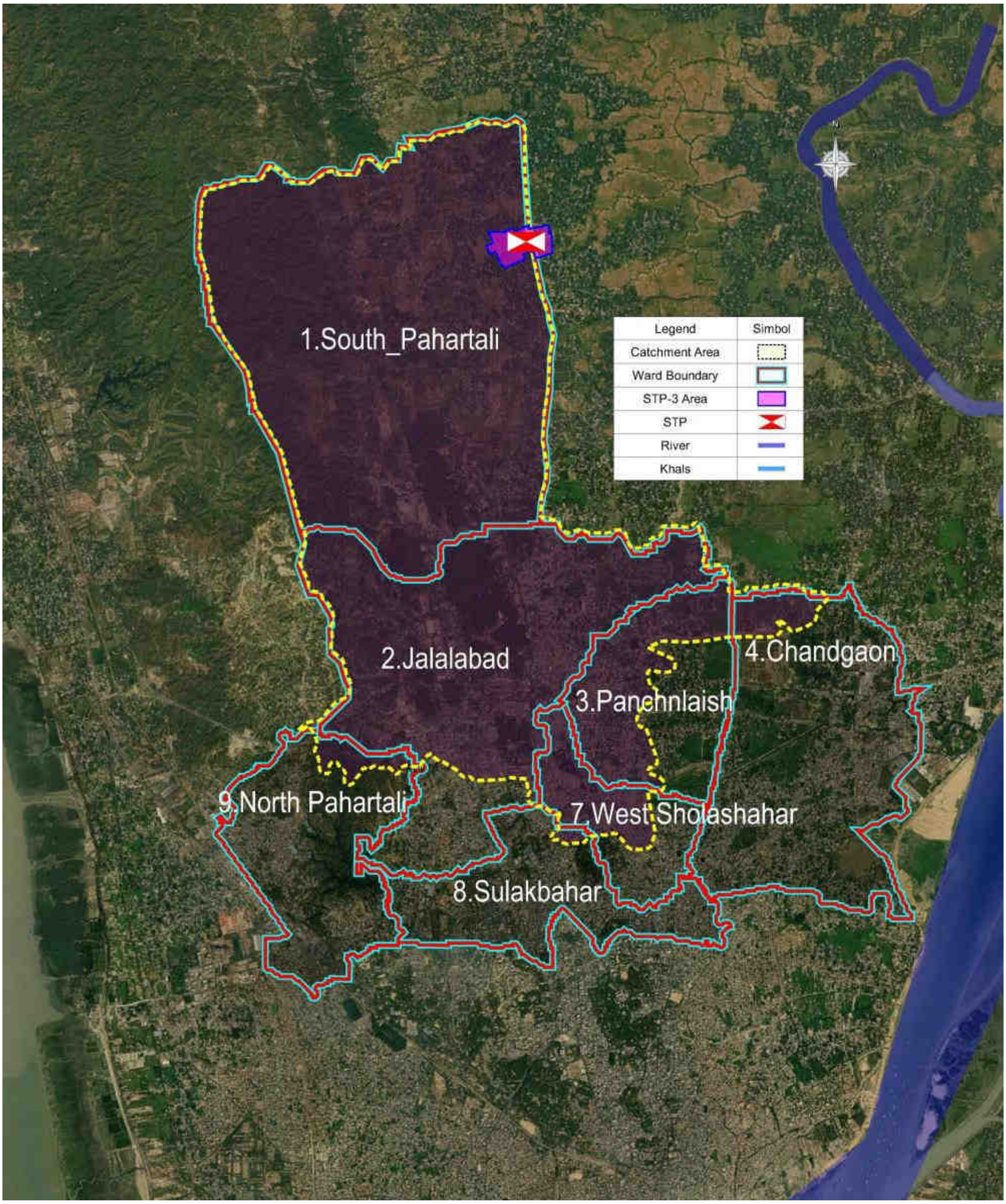


Figure 2-27 Sewage Treatment Area

Since the main route will be planned along the N106 road, a survey on the status of the route was conducted in the direction of Fatehabad from the time of West Sholashahar, the downtown area. The discharge sewer route was planned to be Shitol jharna khal in the Panchlaish region.

Table 2-48 Photo of Sewer Route

Item	Photo	
Sewer Route		
	Start Point	Oxygen Bus Station
		
	Sewer in Fatehabad 1	Sewer in Fatehabad 2
		
	Khandakia Khal	Sewer End Point

Item	Photo	
Discharge Point	 Shitol Jharna Khal 1	 Shitol Jharna Khal 2
	 Shitol Jharna Khal 3	 Shitol Jharna Khal 4
	 Madari Khal 1	 Madari Khal 2
	 Madari Khal 3	 Halda River

Item	Photo	
House hold Conn.		
	Existing Villa Drain Pipe	Existing Villa Septic Tank
		
	Septic Tank not installed	Existing sewer line

2.5.1.3 Faecal Sludge Collection Area

Faecal sludge collection areas scheduled to be established in this plan are outside the CCC managed by CWASA, Hathazari and Raozan.

Table 2-49 Photo of Faecal Sludge collection area

Photo of Faecal Sludge Collection Area	
	
Hathazari	Raozan

2.5.2 Topographical Survey

2.5.2.1 Introduction

2.5.2.1.1 Objective

Topographic Surveys are used to identify the contour maps of the ground and existing features on the surface of the earth or slightly above or below the earth's surface (i.e., trees, buildings, streets, walkways, manholes, utility poles, retraining walls etc.). Based on topographical and route survey, those are utilized to make layout, general and arrangement drawings and to estimate construction cost.

2.5.2.1.2 Scope of Survey

There are six Sewer Catchment areas in CWASA and in each Catchment there will be proposed six Sewage Treatment Plant (STP). Under the current project, STP-03 will be in Catchment No.03 covering the area of Fatehabad that occupies some portion agricultural land and sparsely located habitation. Fatehabad Catchment has seven Wards.

It can be seen that not all the seven wards will contribute entirely the sewage to the STP. Of the 7 Wards, Ward No.09 (North Pahartoli) and Ward No.04 are excluded from the initial selection. A small portion of Ward No.03 (Panchlaish) was included initially. However, the scope of Ward. No 09, Ward No.04 and part of Ward No.03 should be decided by CWASA.

2.5.2.1.3 Spatial Reference System Parameters

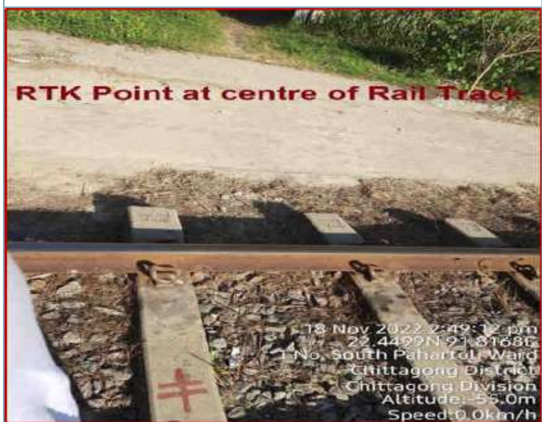
The following coordinate system parameters were employed for both horizontal and vertical coordinate information. The geodetic parameters used is as bellow.;

Table 2-50 Horizontal Coordinate System Parameters

Category	Contents
Reference Ellipsoid	WGS84
Flattening	1/298.257223563
Projection	UTM Zone 46 N
Latitude of Origin	0.0
Central Meridian (CM)	93.0
CM Scale Factor	0.9996
False Northing	0.0 m
False Easting	500,000 m
Units of Measurement	SI System (meters)

2.5.2.2 Site Survey

Table 2-51 Site Survey Photo

Category	Photo	
STP Site		
	Chakondandi Mouza (Nursery)	South Pahartoli Mouza (Rail Track)
Sewer Route		
	Bibirhat Cattle Market (Begin of Trunk Main)	Chakondandi (Nursery)
		
	Beside dilapidated CWASA Godown (Rail track)	Akbariva Mosque in Chharakul (End of Trunk Main)

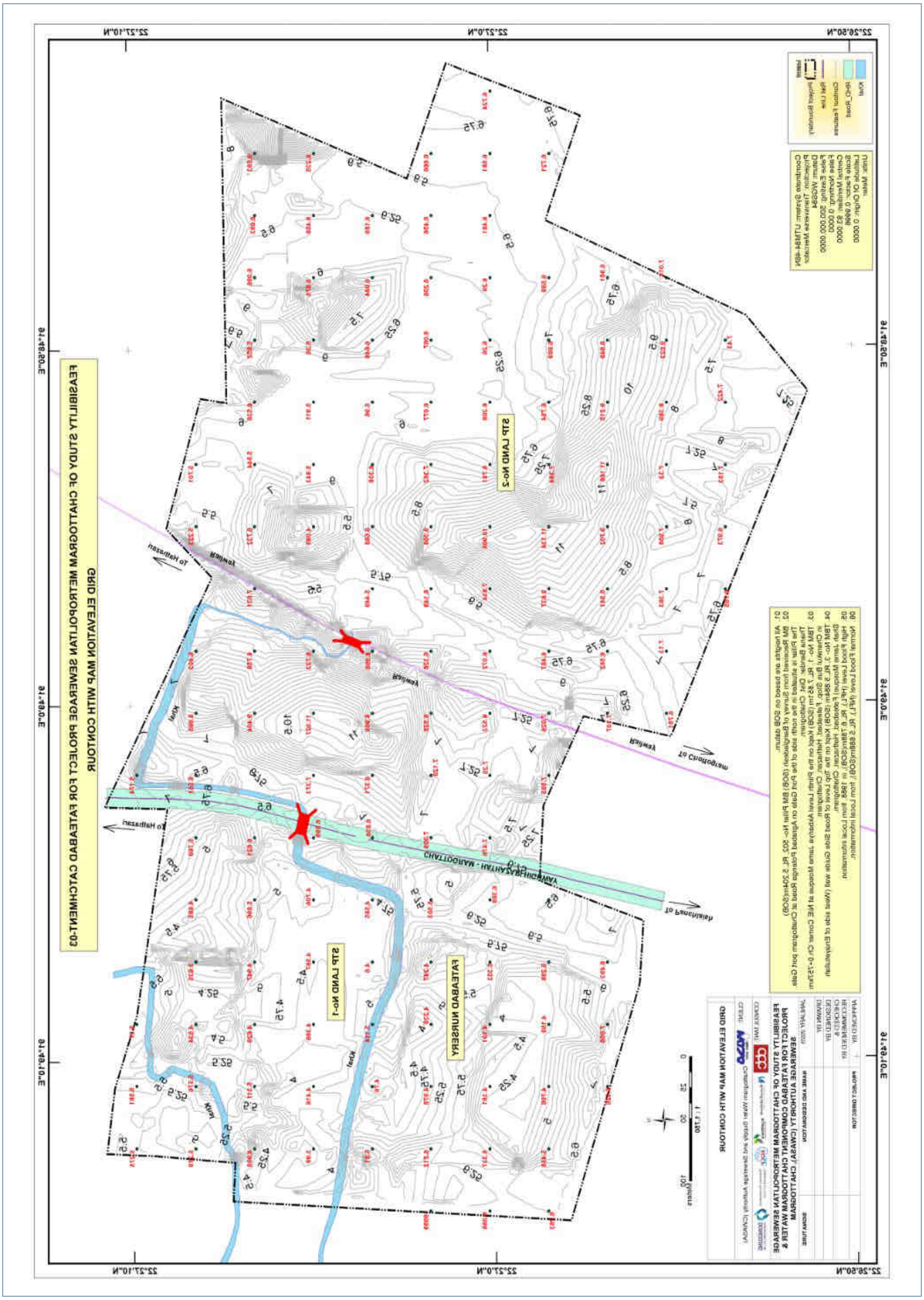


Figure 2-28 Result of Site Survey

2.5.3 Geotechnical Investigation

2.5.3.1 Introduction

2.5.3.1.1 Object

All the data gathered from boring investigation result and soil properties analysis is going to utilize for estimating construction cost in connection with planned site and foundation method, and also for design data of structure basis and excavation and banking.

2.5.3.1.2 Scope of Survey

The scope and contents of geological survey are as follows.

Table 2-52 Scope of Geotechnical Survey

Category	Geological Survey	Remarks
Scope of Survey	• Boring investigation at site of STP : 5 boreholes • Boring investigation sewer route : 5 boreholes (Trunk Main : 2 points, Sewage Lifting Station : 3 points)	
Contents of Survey	• Equipment : NX gauge • Boring investigation : Depth 15.3 ~ 25m, STP 1.5m interval • Laboratory Test : Natural Moisture Content/Density Test, Complete Grain Size Analysis, Atterberg Limits, Specific Gravity Test, Tri-axial Compression Test-U.U., Unconfined Compression Test	

2.5.3.1.3 Location

Table 2-53 Location of boreholes with coordinate

Location	BH No.	Coordinate	
		N	E
Near Oxygen Junction – Trunk Sewer	BH-01	2477061.00	378601.00
Infront of CWASA Godown – STP-50-acre land	BH-02	2483116.00	378339.00
Hathazari-Rangamati Highway at Akbaria Mosque, chharakul for Trunk Main	BH-03	2483336.00	378322.00
Nasirabad Reservoir CWASA for Pump Station (SLS)	BH-04	2475904.00	376961.00
PDB Sub-Station at DTW-38, Annanyan Housing for Pump/SLS Station	BH-05	2477747.00	381954.00
Near Pond West Side of Railway track - STP-50-acre land	BH-06	2483318.00	378061.00
West Side of Railway track - STP-50-acre land	BH-07	2483063.00	377891.00
Mid Position West Side of Railway track - STP-50-acre land	BH-08	2483177.00	378002.00
Mid Position West Side of Railway track- STP-50-acre land	BH-09	2483087.00	378048.00
Near Balu Tila West Side of Railway track - STP-50-acre land	BH-10	2482967.00	378070.00

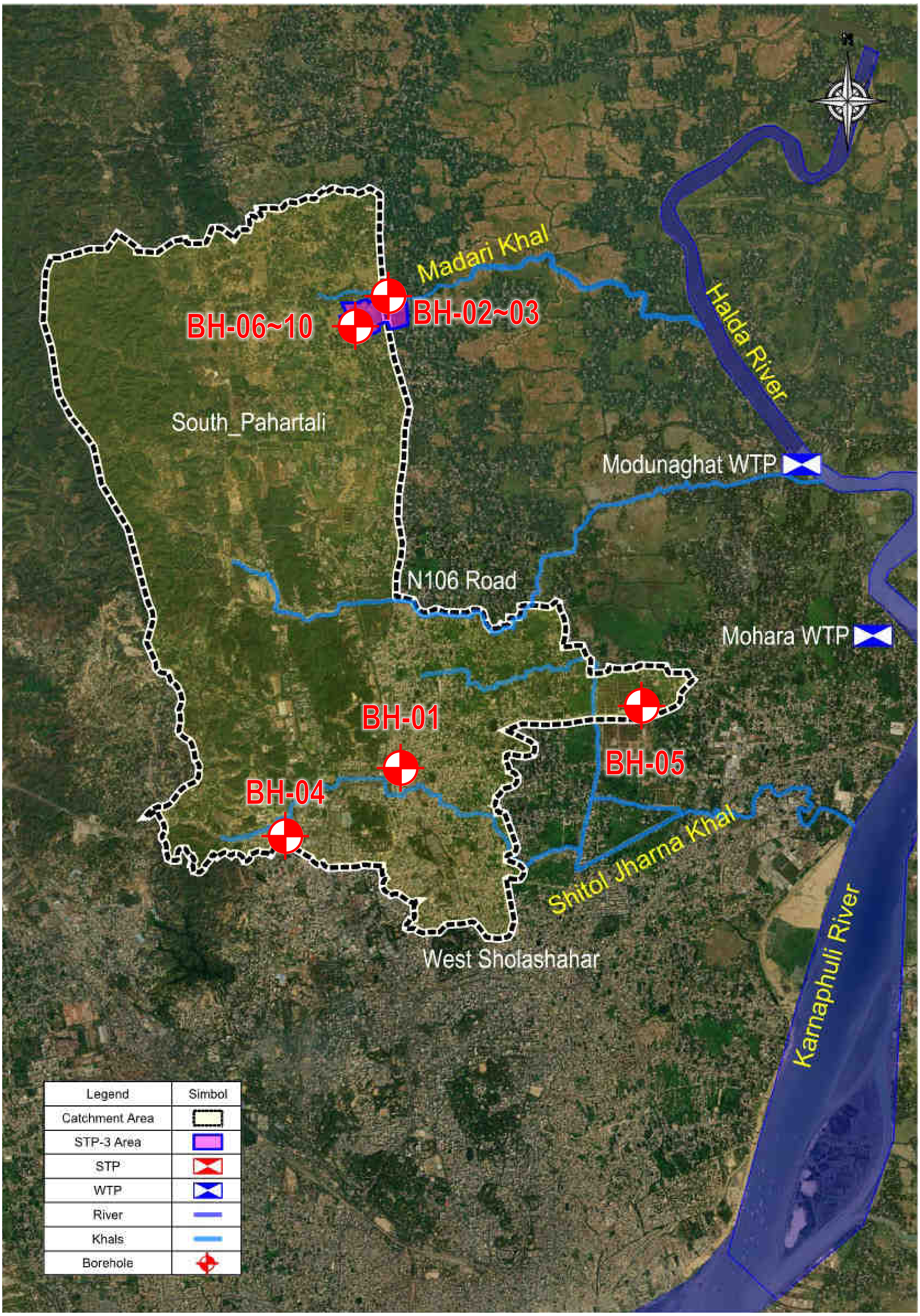


Figure 2-29 Location Map of Geotechnical survey

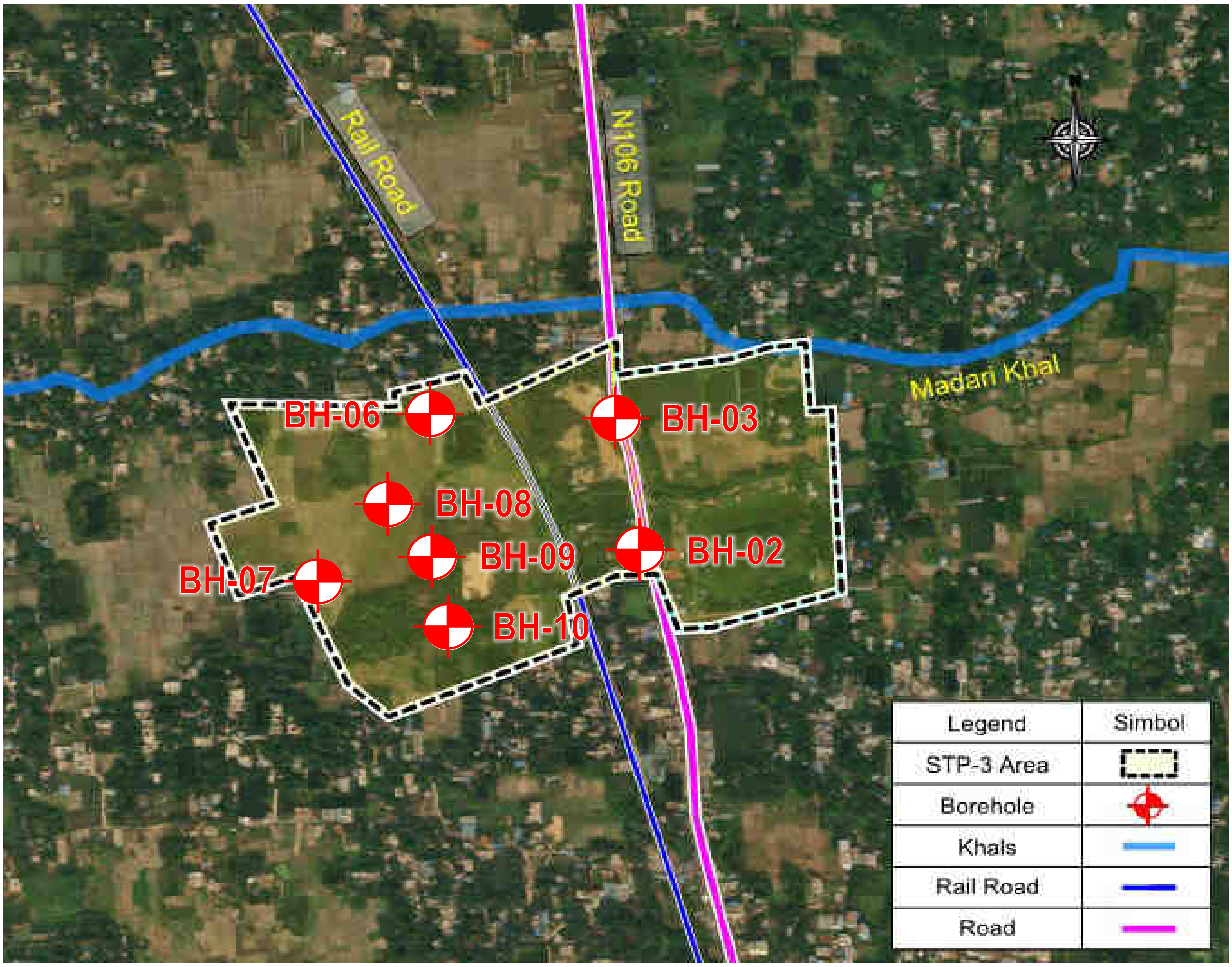


Figure 2-30 Location Map of Geotechnical survey

2.5.3.2 Site Survey

Table 2-54 Photo of Geotechnical survey

Photo of Geotechnical survey	
	
Mobilization of drilling equipment	Drilling activities in progress (BH-01)

Photo of Geotechnical survey

Drilling activities in progress (BH-03)

Drilling activities in progress (BH-05)

Drilling activities in progress (BH-07)

Drilling activities in progress (BH-09)

UD Sample Collection

UD Sample Collection

2.5.3.3 Result of Survey

2.5.3.3.1 Laboratory Test

In order to understand the physical characteristics of the stratum, samples collected by stratum depth during the drilling process were conducted, and the results of the liquid limit, plasticity limit, plasticity index (PI), particle size analysis, wet unit weight, dry unit weight, and compression test is as follows.

Table 2-55 Summary of Test Results

Borehole No.		BH-01				BH-02						
Sample No.		D02	UD01	D12	D14	D01	UD01	D06	D12	D15	D18	D24
Depth		3.0	8.35 ~ 8.85	18.0	21.0	1.5	3.85 ~ 4.35	9.0	18.0	22.5	27.0	36.0
Natural Water Content		22.2	29.3	25.3	-	22.0	26.1	42.6	37.9	35.8	31.0	21.5
Specific Gravity		2.670	2.682	2.673	-	2.670	2.687	2.697	2.693	2.689	2.697	2.671
Wet Unit Weight			1.830				1.811					
Dry Unit Weight			1.416				1.436					
Atterberg Limits	Liquid	35	43	38	NP	32	49	58	53	50	58	34
	Plastic	24	27	25	NP	23	27	30	28	26	30	24
	Plasticity Index	11	17	13	NP	9	22	28	25	24	28	10
Grain Size Analysis	Sand (%)	32.2	8.5	28.6	64.6	31.1	16.2	0.9	2.3	3.2	2.1	27.7
	Silt (%)	49.5	68.5	51.5	35.1	52.7	59.2	61.9	66.8	69.1	62.3	54.0
	Clay (%)	18.3	23.0	19.9	35.1	16.7	24.6	37.2	30.9	27.7	35.6	18.3
Compression Test	Strength (kPa)		56.3				54.6					
	Failure (%)		7.5				9.0					

Borehole No.		BH-03				BH-04		BH-05				
Sample No.		D02	UD01	D12	D19	D03	D07	UD01	D08	D15	D22	
Depth		3.0	6.85 ~ 7.35	18.0	28.5	4.5	10.5	3.85 ~ 4.35	12.0	22.5	33.0	
Natural Water Content		24.3	38.4	44.7	37.8	23.3	23.5	32.1	46.6	39.8	27.9	
Specific Gravity		2.668	2.692	2.690	2.682	2.688	2.686	2.693	2.691	2.690	2.689	
Wet Unit Weight			1.721					1.849				
Dry Unit Weight			1.243					1.399				
Atterberg Limits	Liquid	31	53	52	43	49	46	54	52	50	50	
	Plastic	22	29	28	26	28	26	29	27	28	27	
	Plasticity Index	9	24	24	17	21	20	25	25	22	23	
Grain Size Analysis	Sand (%)	30.6	2.1	1.5	2.7	1.2	0.7	14.4	1.4	2.0	8.8	
	Silt (%)	52.7	65.4	67.6	74.3	71.0	74.7	54.7	69.3	67.1	63.5	
	Clay (%)	16.7	32.5	30.9	23.0	27.8	24.6	30.9	29.3	30.9	27.7	
Compression Test	Strength (kPa)		50.8					80.3				
	Failure (%)		8.5					8.0				

Borehole No.		BH-06					BH-07					
Sample No.		D02	UD01	D07	D17	D22	D02	UD01	D08	D14	D20	D23
Depth		3.0	6.85 ~ 7.35	10.5	25.5	33.0	3.0	3.85 ~ 4.35	12.0	21.0	30.0	34.5
Natural Water Content		28.2	40.9	34.7	36.1	31.5	22.3	36.1	47.6	37.3	35.4	-
Specific Gravity		2.665	2.694	2.690	2.686	2.692	2.665	2.705	2.702	2.687	2.698	-
Wet Unit Weight			1.857					1.768				
Dry Unit Weight			1.317					1.299				
Atterberg Limits	Liquid	43	56	50	47	52	33	64	62	47	58	NP
	Plastic	25	29	28	27	28	23	31	31	27	30	NP
	Plasticity Index	18	27	22	20	24	10	33	31	20	28	NP
Grain Size Analysis	Sand (%)	35.2	7.0	2.9	0.4	2.9	29.3	1.0	1.3	0.5	1.9	69.3
	Silt (%)	45.1	60.5	69.6	73.7	68.0	53.3	59.3	60.1	73.6	62.7	30.7
	Clay (%)	19.7	32.5	27.5	25.9	29.1	17.4	39.7	38.6	25.9	35.4	30.7
Compression Test	Strength (kPa)		46.9					7.0				
	Failure (%)		12.0					0.0				

Borehole No.		BH-08					BH-09					
Sample No.		D01	UD01	D11	D19	D23	D02	UD01	D08	D13	D18	D24
Depth		1.5	5.35 ~ 5.85	16.5	28.5	34.5	3.0	5.35 ~ 5.85	12.0	19.5	27.0	36.0
Natural Water Content		-	32.6	32.9	30.2	21.2	22.9	33.5	46.9	39.9	45.7	34.7
Specific Gravity		-	2.688	2.682	2.687	2.675	2.672	2.625	2.699	2.696	2.701	2.681
Wet Unit Weight			1.819					1.817				
Dry Unit Weight			1.372					1.361				
Atterberg Limits	Liquid	NP	55	45	47	38	38	56	62	57	64	42
	Plastic	NP	29	26	27	24	24	29	31	30	31	25
	Plasticity Index	NP	26	19	20	14	14	27	31	27	33	17
Grain Size Analysis	Sand (%)	41.8	29.8	1.7	0.8	33.8	23.8	4.1	1.2	6.3	1.1	0.7
	Silt (%)	58.2	42.4	75.5	71.7	46.9	57.5	61.8	59.5	57.6	61.2	75.9
	Clay (%)	58.2	27.8	22.8	27.5	19.6	18.7	34.1	39.3	36.1	37.7	23.5
Compression Test	Strength (kPa)		41.2					70.5				
	Failure (%)		8.5					7.0				

Borehole No.		BH-10						
Sample No.		UD01	D10	D15	D17	D23	D26	D30
Depth		5.35 ~ 5.85	15.0	22.5	25.5	34.5	39.0	45.0
Natural Water Content		29.2	43.2	30.9	-	25.9	22.8	-
Specific Gravity		2.675	2.695	2.683	-	2.693	2.695	-
Wet Unit Weight		2.675						
Dry Unit Weight		1.452						
Atterberg Limits	Liquid	37	56	43	NP	54	57	NP
	Plastic	24	29	25	NP	29	30	NP
	Plasticity Index	13	27	18	NP	25	27	NP
Grain Size Analysis	Sand (%)	14.5	1.1	3.2	87.2	8.3	5.4	75.6
	Silt (%)	65.6	64.8	74.0	12.8	61.0	59.2	24.4
	Clay (%)	19.8	34.1	22.8	12.8	33.7	35.4	24.4
Compression Test	Strength (kPa)	45.4						
	Failure (%)	8.5						

2.5.3.3.2 Conclusion

As a result of soil investigation, it was found that the upper layer was mainly composed of clay. This layer requires attention to shallow foundations. The clay layer has a natural moisture content of 21.5 to 47.6%, plasticity index, plasticity limit and liquid limit of 9.0 to 33.0%, 22.0 to 31.0%, and 31.0 to 64.0%, respectively, specific gravity of 2.665 to 2.705, and compressive strength of 41.2 to 80.3 kPa.

The overall soil quality of the investigation area requires attention to construction and infrastructure, and except for BH-04, the allowable bearing capacity is low, so it should be developed after foundation reinforcement. The allowable bearing capacity was calculated at 1.52m (5.0ft), 3.05m (10ft), and 4.57m (15ft), and the results are as follows.

Table 2-56 Allowable bearing capacity

Category		Depth		
		1.52m	3.05m	4.57m
BH-01	Field SPT	4	6	3
	Square footing	0.609	0.921	0.542
	Continuous footing	0.482	0.729	0.447
BH-02	Field SPT	2	2	5
	Square footing	0.357	0.404	0.853
	Continuous footing	0.294	0.341	0.694

Category		Depth		
		1.52m	3.05m	4.57m
BH-03	Field SPT	-	1	4
	Square footing	-	0.273	0.721
	Continuous footing	-	0.241	0.594
BH-04	Field SPT	50	50	50
	Square footing	6.974	7.013	7.048
	Continuous footing	5.385	8.422	5.450
BH-05	Field SPT	9	10	2
	Square footing	1.318	1.492	0.424
	Continuous footing	1.032	1.174	0.361
BH-06	Field SPT	2	2	1
	Square footing	0.358	0.395	0.293
	Continuous footing	0.294	0.332	0.261
BH-07	Field SPT	3	2	11
	Square footing	0.495	0.404	1.680
	Continuous footing	0.399	0.341	1.330
BH-08	Field SPT	4	2	2
	Square footing	0.633	0.403	0.438
	Continuous footing	0.506	0.339	0.374
BH-09	Field SPT	7	6	6
	Square footing	1.045	0.956	0.990
	Continuous footing	0.824	0.765	0.800
BH-10	Field SPT	4	5	4
	Square footing	0.623	0.796	0.694
	Continuous footing	0.496	0.637	0.566

2.5.4 Water Quality Survey

2.5.4.1 Introduction

2.5.4.1.1 Object of Water Quality Survey

To investigate the water quality of inflow sewage and use it as basic data for selection of treatment method and analysis of water quality improvement effect.

2.5.4.1.2 Scope of Survey

Category	Water Quality Survey	Remarks
Scope	• Two Wards representing all Wards; Ward No. 02 : Jalalabad Ward No. 07 : West Sholoshar • Discharge Route: Madari Khal, Halda River	
Period	• Total: two times 1st: May 4, 2023 2nd: May 15, 2023	
Contents of Survey	• Analysis Item: pH, Temperature, BOD_5, COD, DO, TSS, TVS, Total Phosphorus, Total Nitrogen	

2.5.4.1.3 Location

Two wards representing all wards were selected in consideration of the following.

- Residential areas of having Apartment buildings
  - Inlet & outlet points of septic tank
  - Faecal sludge samples from one point at Inlet of Septic Tank (top & bottom)
  - Wastewater from surface drains nearby the septic tank

- Slum areas
  - Faecal Sludge of one sample from top of a single or twin pit Latrine
  - The end of the secondary/primary drains
  - Canal not contaminated by the discharges from wastewater carrying by surface drains of Apartments or combined primary/secondary

- STP Effluent Discharge Route
  - Kahgria Chara: 3.7km canal from the STP to the east across Chikondandi Mouza to Madari Khal
  - Madari Khal: 2.7km small river flowing from Kahgria Khal through Sluice Gate into Halda River

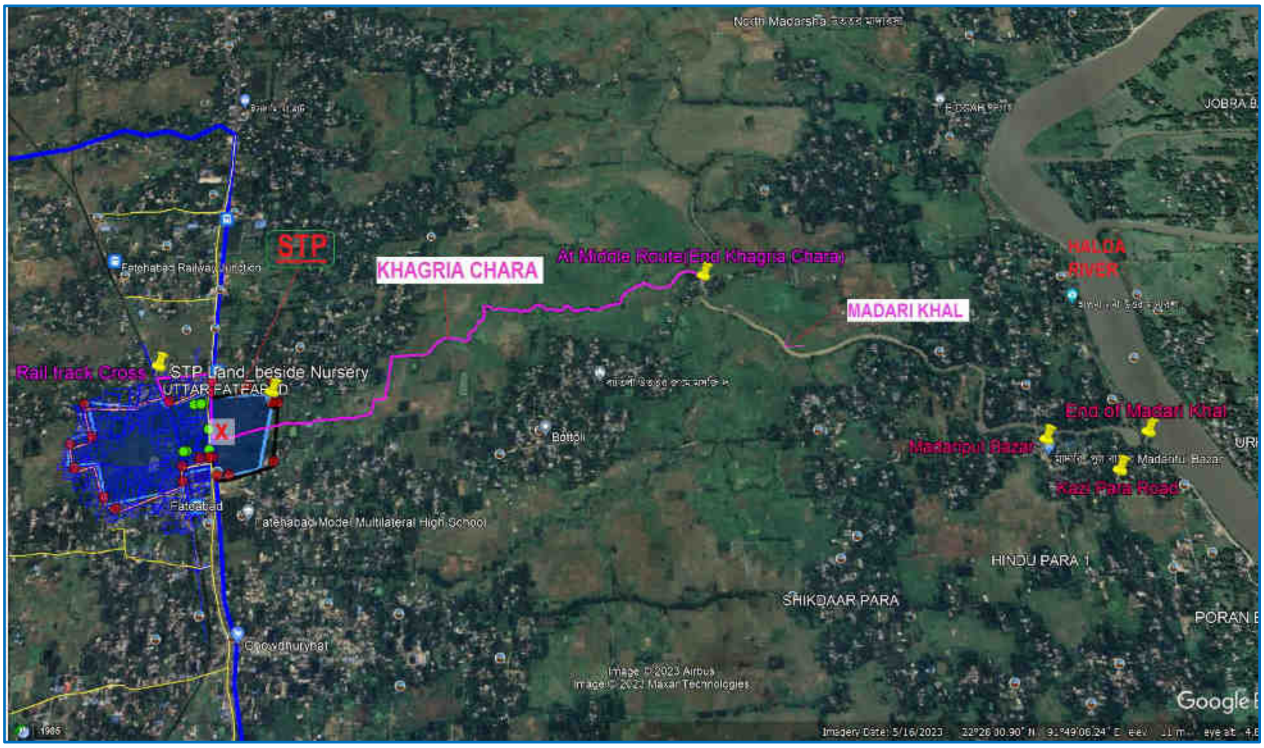


Figure 2-31 STP Effluent Discharge Route

Table 2-57   Location of Water Quality survey

Category	Location	No.	Coordinate	
			N	E
Residential areas of having Apartment buildings	Jalalabad	WQ-1	22.395273	91.812503
		WQ-2	22.394686	91.814675
	Sholoshahar	WQ-3	22.376186	91.831930
		WQ-4	22.376186	91.831811
Slum Areas	Jalalabad	WQ-5	22.382617	91.825168
		WQ-6	22.381335	91.825660
	Sholoshahar	WQ-7	22.391889	91.822080
		WQ-8	22.392286	91.821164
Effluent Discharge Route	Madari Khal	WQ-9	22.453428	91.814960
		WQ-10	22.457998	91.839427
	Halda River	WQ-11	22.449714	91.858922
		WQ-12	22.447997	91.860569

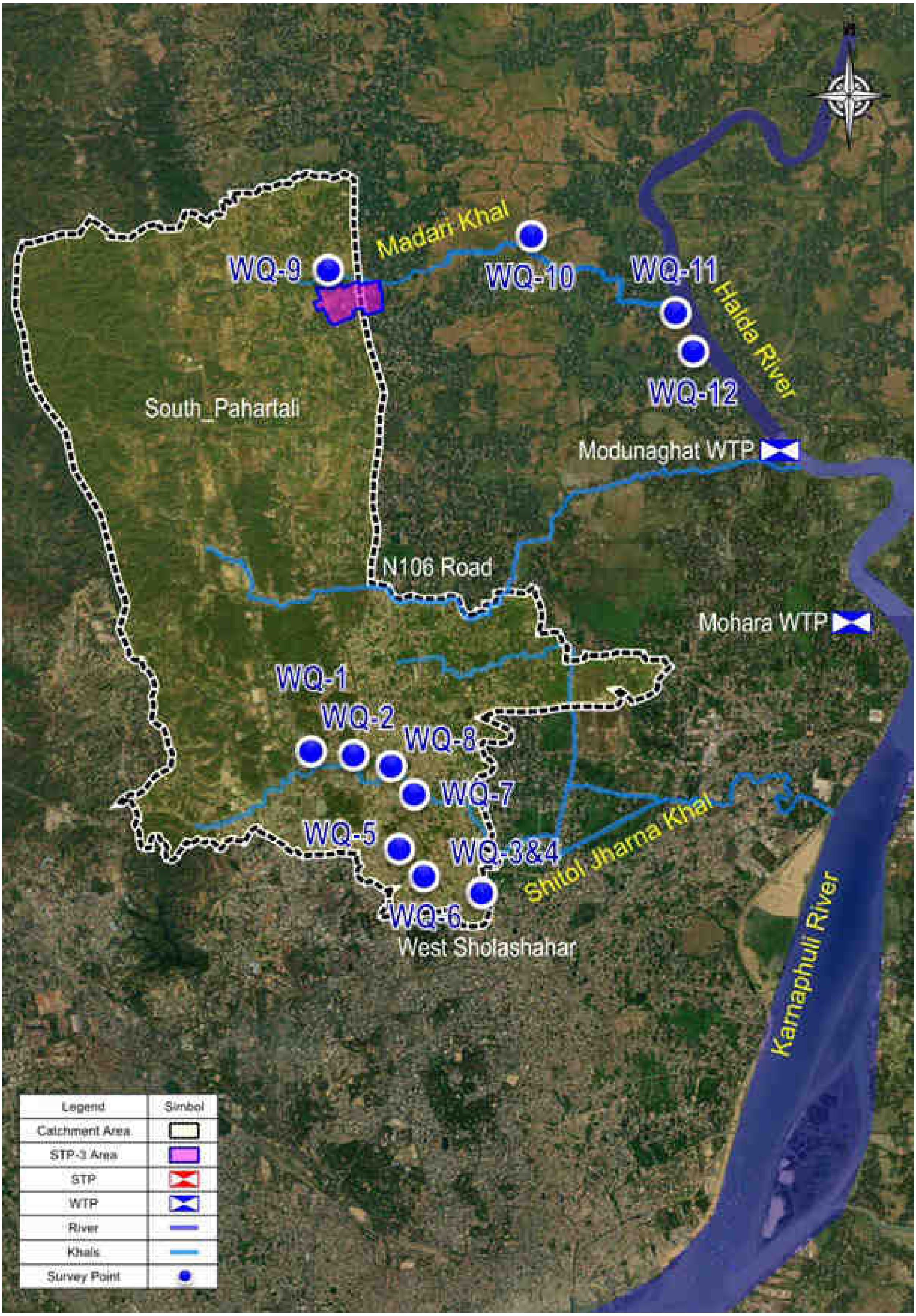
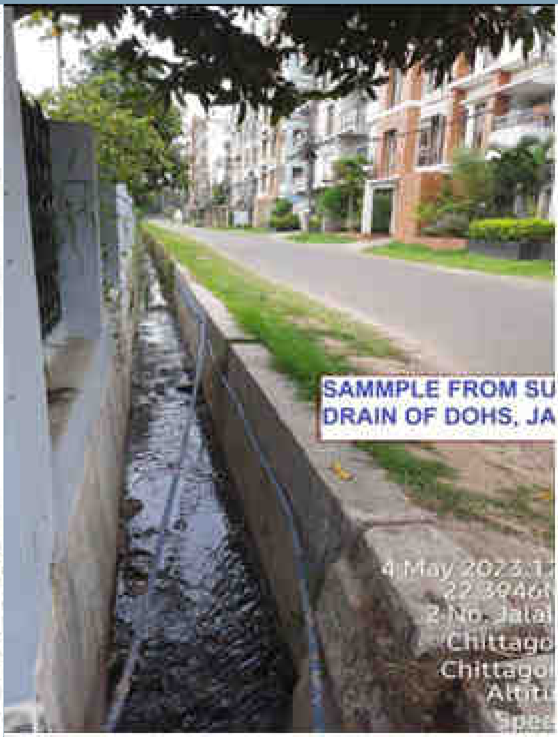


Figure 2-32 Water Quality Survey Location Map

2.5.4.2 Site Survey

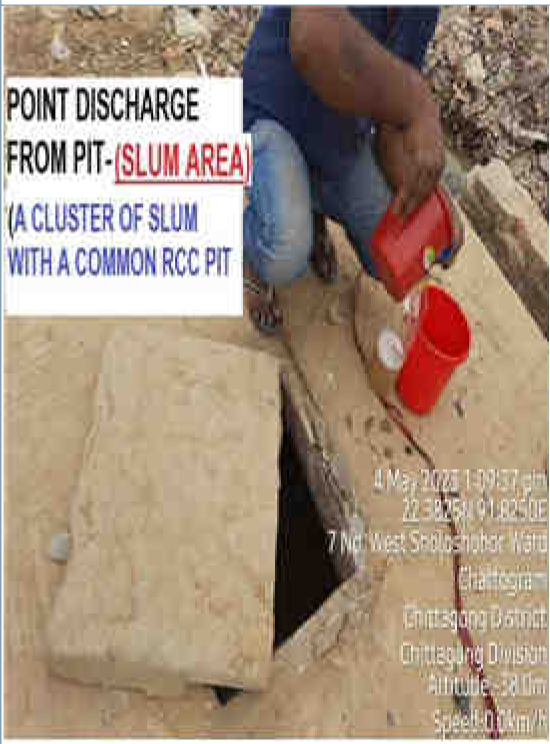
2.5.4.2.1 Residential areas of having Apartment buildings

Table 2-58 Photo of Water Quality Survey (Residential areas)

Category	Photo	
Jalalabad		
	Typical Apartment building	Surface drainage nearby septic tank
Sholoshahar		
	Inlet & Outlet of septic tank	Septic tank Faecal Sludge

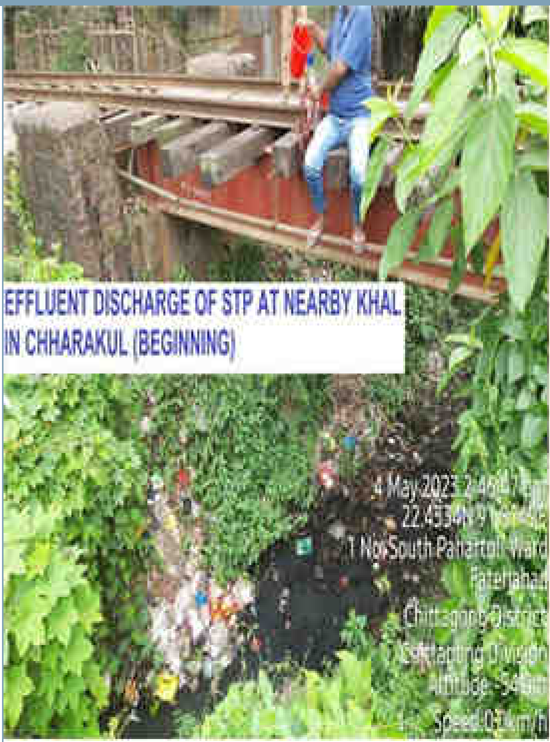
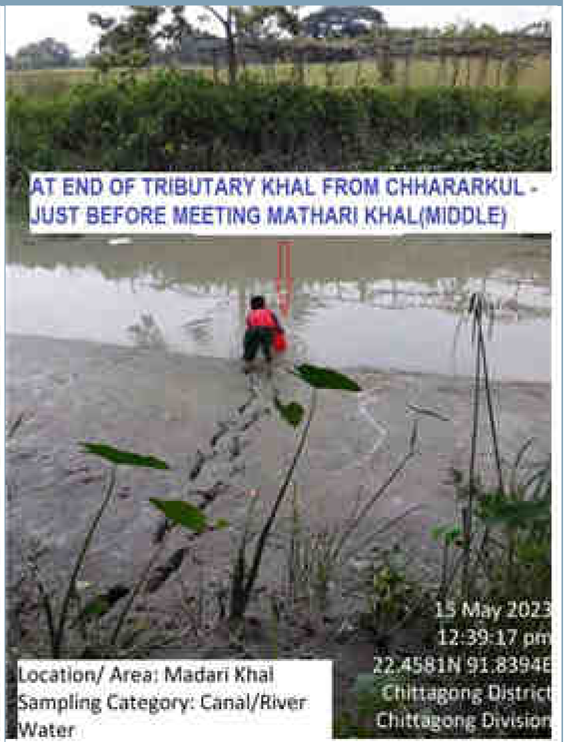
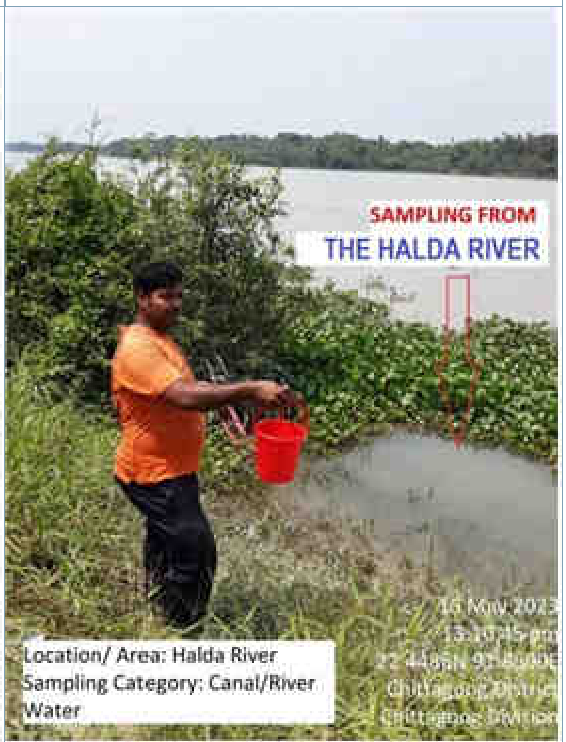
2.5.4.2.2 Slum areas

Table 2-59 Photo of Water Quality Survey (Slum areas)

Category	Photo	
Jalalabad		
	Sewage & Faecal Sludge from Pit	End of Primary Drain from Pit
Sholoshahar		
	Slum Communal Pit	Sewage from Slum Pit nearby Canal

2.5.4.2.3 Discharge Route

Table 2-60 Photo of Water Quality Survey (Discharge Route)

<table>
<tr><th>Category</th><th colspan="2">Photo</th></tr>
<tr><td rowspan="2">Khal</td><td></td><td></td></tr>
<tr><td>Effluent discharge of STP</td><td>Beginning point of Madari Khal</td></tr>
<tr><td rowspan="2">Halda River</td><td></td><td></td></tr>
<tr><td>End of Madari Khal</td><td>Halda River nearby Sluice Gate</td></tr>
</table>

2.5.4.3 Result of Survey

Samples were collected twice (2 days) at the same point at 10-day intervals. The first was conducted on May 4, 2023, and the second was conducted on May 15, 2023 with an interval of 10 days from the first collection. It rained once during the collection period, and it is judged that the rainy season began from this period.

Table 2-61 Water Quality Survey Result (First)

No.	Samples		Temp. °C	pH -	BOD mg/L	COD mg/L	T-P mg/L	T-N mg/L	NH3-N mg/L	TSS mg/L	VSS mg/L	DO mg/L
WQ-1	Septic tank Influent	Upper	31.25	6.99	512	694	56	198	-	3,541	-	-
		Bottom	29.00	6.79	1,005	1,381	58	233	-	4,041	-	-
	Septic tank Effluent		29.50	6.90	502	739	36	226	-	1,640	-	-
	Faecal Sludge	Upper	-	-	495	510	-	-	-	7,074	228.24	-
		Bottom	-	-	380	487	-	-	-	8,001	198.16	-
WQ-2	Nearby drain		-	-	118	355	19	-	35.65	2,030	149.72	0.54
WQ-3	Septic tank Influent	Upper	29.70	6.98	468	658	51	167	-	3,150	-	-
		Bottom	30.50	6.90	952	1,174	47	201	-	4,330	-	-
	Septic tank Effluent		30.10	6.85	475	612	37	159	-	1,210	-	-
	Faecal Sludge	Upper	-	-	517	654	-	-	-	6,580	380.16	-
		Bottom	-	-	480	547	-	-	-	7,720	228.48	-
WQ-4	Nearby drain		-	-	144	425	26	-	155	2,741	103.92	0.10
WQ-5	Pit	Effluent	31.90	7.07	288	490	61	333	-	2,741	-	-
		Rain water	30.80	6.48	107	380	22	21	-	2,654	-	-
	Faecal Sludge		-	-	1,096	1,541	-	-	-	6,330	242.32	-
WQ-6	Nearby canal		-	-	278	521	26	-	72.08	1,024	130.16	0.21
	200m away from Pit		29.80	6.58	156	318	25	-	61.23	1,752	-	0.22
WQ-7	Pit	Effluent	27.20	6.62	275	405	23	65	-	3,554	-	-
		Rain water	27.60	6.71	368	569	27	78	-	3,021	-	-
	Faecal Sludge		-	-	1,425	1,752	-	-	-	7,670	201.20	-
WQ-8	Nearby canal		-	-	236	455	24	-	28.68	1,400	124.08	0.08
	200m away from Pit		28.20	6.80	196	431	22	-	51.15	1,005	-	0.13
WQ-9	Beginning of Kahgria Khal		28.70	6.69	12	25	20	-	61.23	1,287	-	0.56
WQ-10	Beginning of Madari Khal		30.40	6.84	6	14	21	-	41.08	1,765	-	0.53
WQ-11	Beginning of Halda River		30.90	6.81	3	9	19	-	13.95	547	-	5.05
WQ-12	Bank of Halda River		29.40	6.97	5	11	21	-	20.15	407	-	5.84

Table 2-62 Water Quality Survey Result (Second)

No.	Samples		Temp. °C	pH -	BOD mg/L	COD mg/L	T-P mg/L	T-N mg/L	NH3-N mg/L	TSS mg/L	VSS mg/L	DO mg/L
WQ -1	Septic tank Influent	Upper	32.4	7.4	624	847	40	142	-	3,041	-	-
		Bottom	30.90	7.52	947	1,178	30	158	-	4,219	-	-
	Septic tank Effluent		31.80	7.52	588	940	36	158	-	1,424	-	-
	Faecal Sludge	Upper	-	-	514	710	-	-	-	6,124	185.84	-
		Bottom	-	-	365	580	-	-	-	6,898	191.36	-
WQ -2	Nearby drain		-	-	136	476	24	-	18.91	1,680	140.92	0.83
WQ -3	Septic tank Influent	Upper	30.70	7.3	502	954	38	115	-	2,941	-	-
		Bottom	30.90	7.20	997	1,645	38	126	-	3,458	-	-
	Septic tank Effluent		31.60	7.41	482	725	27	142	-	1,354	-	-
	Faecal Sludge	Upper	-	-	497	578	-	-	-	7,590	365.12	-
		Bottom	-	-	505	687	-	-	-	7,110	222.56	-
WQ -4	Nearby drain		-	-	116	912	27	-	26.30	2,354	125.12	0.04
WQ -5	Pit	Effluent	31.1	7.21	197	360	49	318	-	2,540	-	-
		Rain water	31.3	7	112	312	21	35	-	2,014	-	-
	Faecal Sludge		-	-	1,280	1,496	-	-	-	6,160	157.92	-
WQ -6	Nearby canal		-	-	174	480	63	-	55.08	985	128.28	0.5
	200m away from Pit		31	7.3	128	235	24	-	44.39	1,247	-	0.05
WQ -7	Pit	Effluent	31	7.55	201	460	29	82	-	2,741	-	-
		Rain water	30.8	7.33	274	480	26	64	-	2,941	-	-
	Faecal Sludge		-	-	1,451	1,980	-	-	-	6,870	270.84	-
WQ -8	Nearby canal		-	-	140	286	20	-	41.10	1,750	123.28	0.03
	200m away from Pit		31.8	7.2	172	350	21	-	30.42	874	-	0.6
WQ -9	Beginning of Kahgria Khal		30.9	6.2	40	56	17	-	4.11	1,474	-	3.67
WQ -10	Beginning of Madari Khal		31.4	7.88	20	110	20	-	5.75	1,058	-	7.81
WQ -11	Beginning of Halda River		31.7	7.6	11	26	18	-	4.11	421	-	7
WQ -12	Bank of Halda River		31.4	7.6	54	85	21	-	7.4	380	-	7.47

Table 2-63 Result Graph (Residential area)

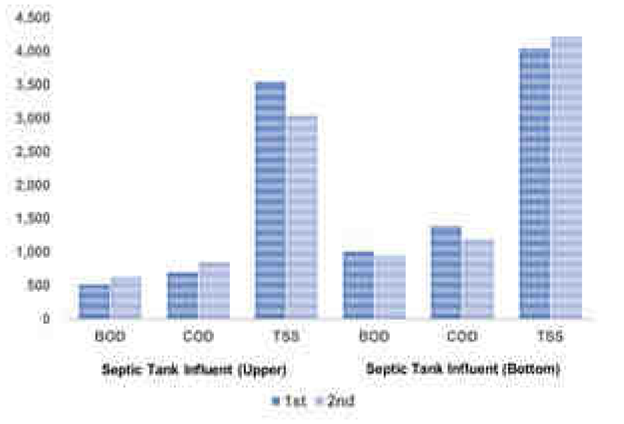
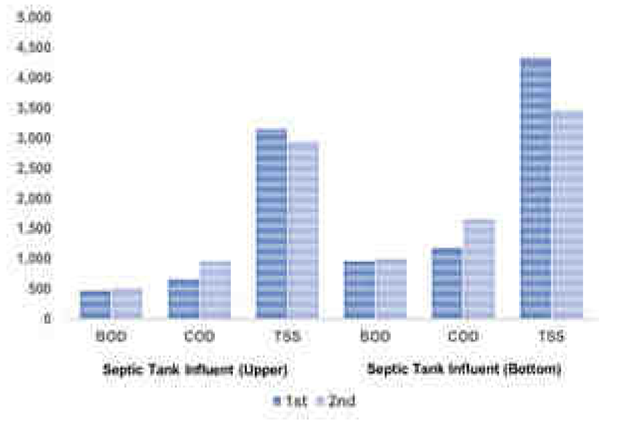
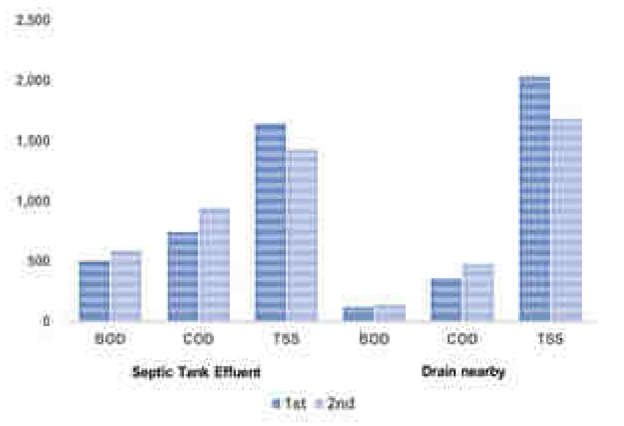
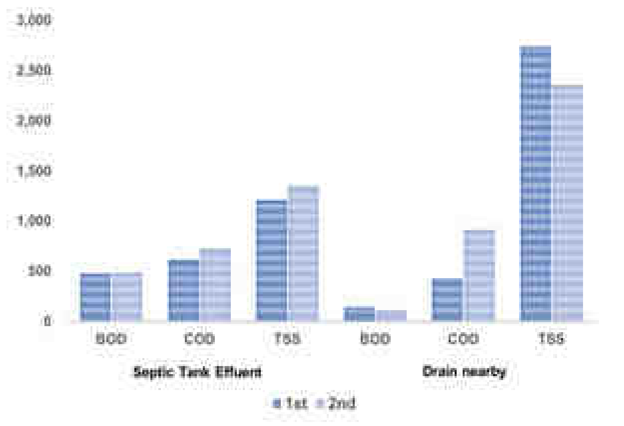
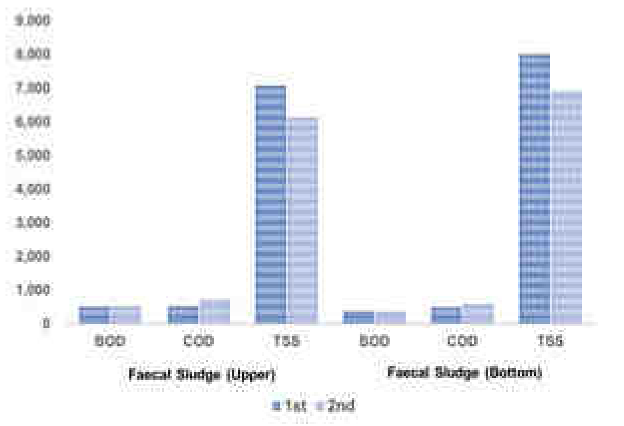
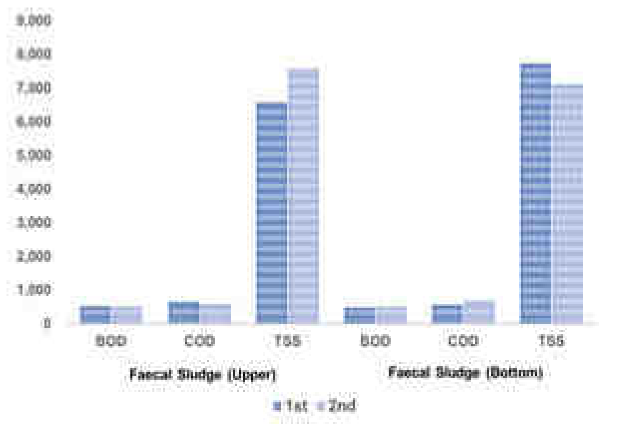
Jalalabad	Sholoshahar
	
Septic Tank Influent (WQ-1)	Septic Tank Influent (WQ-3)
	
Septic Tank Effluent (WQ-1) / Nearby Drain (WQ-2)	Septic Tank Effluent (WQ-3) / Nearby Drain (WQ-4)
	
Faecal Sludge (WQ-1)	Faecal Sludge (WQ-3)

Table 2-64 Result Graph (Slum area)

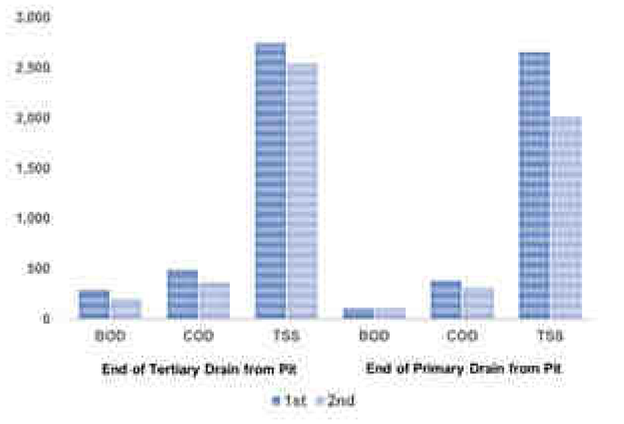
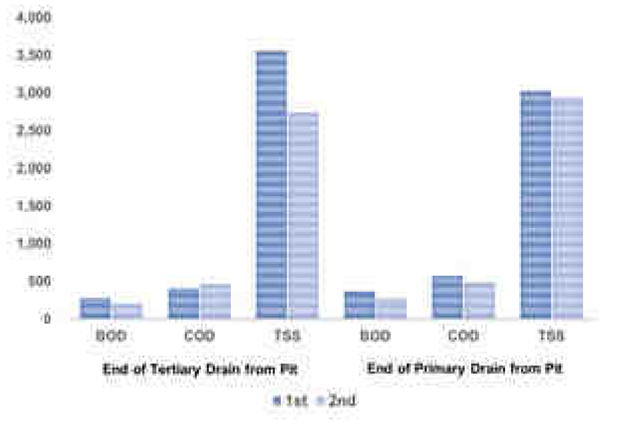
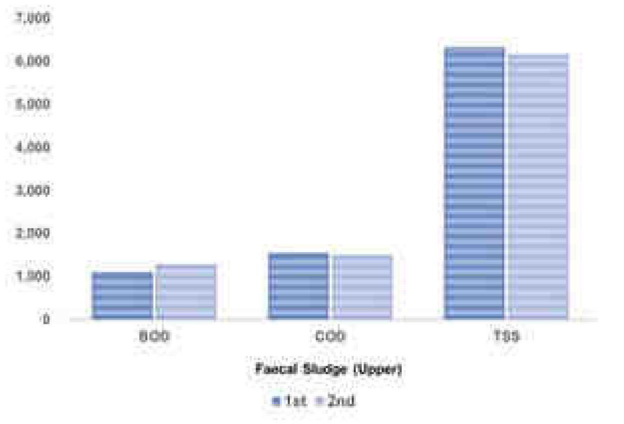
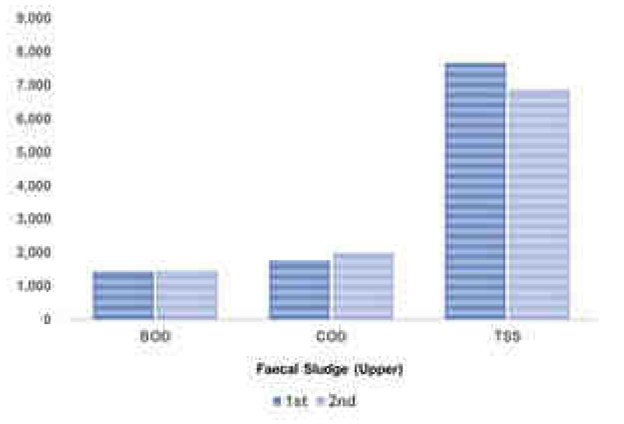
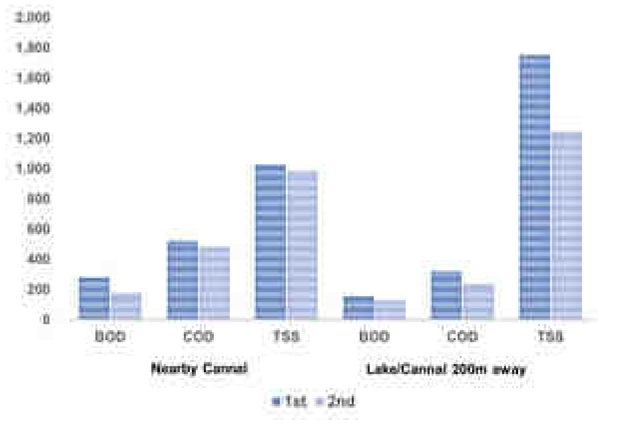
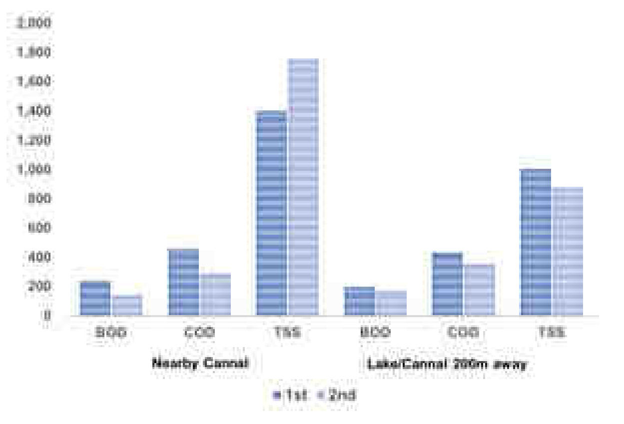
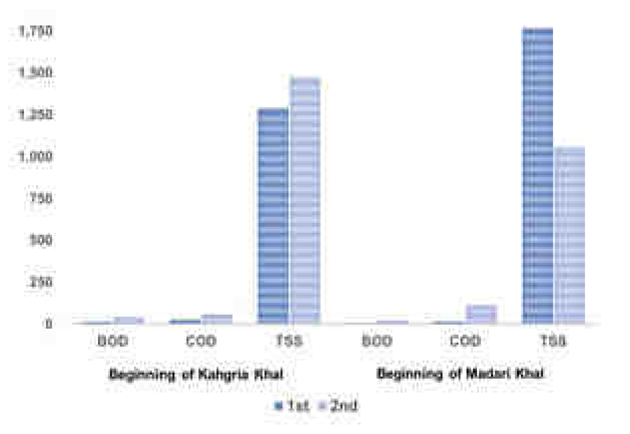
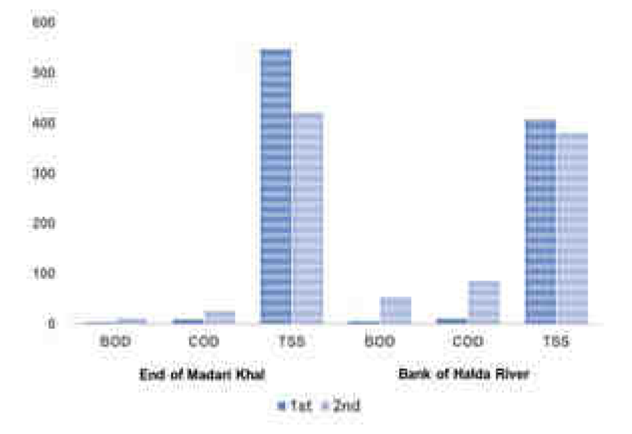
<table>
<tr><th>Jalalabad</th><th>Sholoshahar</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Pit Effluent & Confluence Pipe (WQ-5)</td><td>Pit Effluent & Confluence Pipe (WQ-7)</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Faecal Sludge (WQ-5)</td><td>Faecal Sludge (WQ-7)</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Nearby Canal / 200m away (WQ-6)</td><td>Nearby Canal / 200m away (WQ-8)</td></tr>
</table>

Table 2-65 Result Graph (Discharge Route)

<table>
<tr><th>Khal</th><th>Halda River</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Beginning of Kahgria Khal & Madari Khal (WQ-10)</td><td>End of Madari Khal (WQ-11) /
Bank of Halda River (WQ-12)</td></tr>
</table>

2.5.4.4 Conclusion and Recommendations

Since the water quality survey of this project was conducted twice at 10days intervals, it is judged to be difficult to define the water quality characteristics of the dry season and the rainy season. In future detailed design, it is necessary to select and implement a water quality survey period to have seasonal representativeness.

2.5.4.4.1 Residential areas

Analysis of septic tank sample results was performed on samples taken from the upper part. Samples from the bottom of the septic tank are inaccurate due to improper maintenance over a long period of time. BOD 468~624mg/L and COD 612~940mg/L were very high. The TSS was 1,210~3,541mg/L, which was about 68.1~89.1% higher than the influent wastewater quality of 386mg/L.

When the faecal sludge in the septic tank reaches a certain level, cleaning and sludge removal should be carried out. However, it is judged that the water quality is high because the maintenance of the septic tank is not properly performed in the project area.

2.5.4.4.2 Slum areas

As a result of water quality survey in the slum area, BOD 107~368mg/L and COD 286~569mg/L were found to be within the range of the sewage influent. However, in the case of Sholoshahar, T-N was 318~333mg/L, and the water quality was high because the maintenance of the septic tank in the public toilet was not properly maintained.

2.5.4.4.3 Effluent Discharge Route

The Effluent discharge route of this project is the Halda River discharge through Madari Khal. Water quality was investigated at the discharge point, the Madari Khal, the Halda River inlet, and the river bank. BOD 3~54mg/L, COD 9~85mg/L were analyzed lower than influent. This is considered to be low due to the dilution effect caused by rainwater as the survey was conducted in the rainy season, and TSS is judged to have increased to 380~1,765mg/L due to surface drainage and inflow of impurities.

2.5.5 Household Connection Survey

2.5.5.1 Introduction

2.5.5.1.1 Scope of survey

Household connection survey is conducted in the feasibility study for randomly selected 100 houses to categorize the household connection types as per the buildings in the project area for the project cost estimation. Detail household connection survey shall be implemented in the detailed design stage.

Table 2-66 Sample survey result

Category	Building Type	Survey Results	Plan of This Project
Type 1	Residential Building with 8 or more floors	13	1,200
Type 2	Residential Building with 2-7 storey	63	6,000
Type 3	Residential Building with single story	11	2,000
Type 4	Commercial Building	13	800
Total		100	10,000

2.5.5.1.2 Location

Among the 7 Wards in the Catchment-3 area, 3 Wards with representativeness were selected.

Table 2-67 Selection of Wards of Catchment-03 for Household Connection Survey

No.	Ward	Existing Water Service Coverage	Selection	Number of Sampling Point
1	South Pahartali			
2	Jalalabad	0%	✓	18
3	Panchlaish	38%	✓	42
4	Chandgaon	68%		
5	West Sholashahar	100%	✓	40
6	Sulakbahar	75%		
7	North Pahartali	100%		
		100%		100

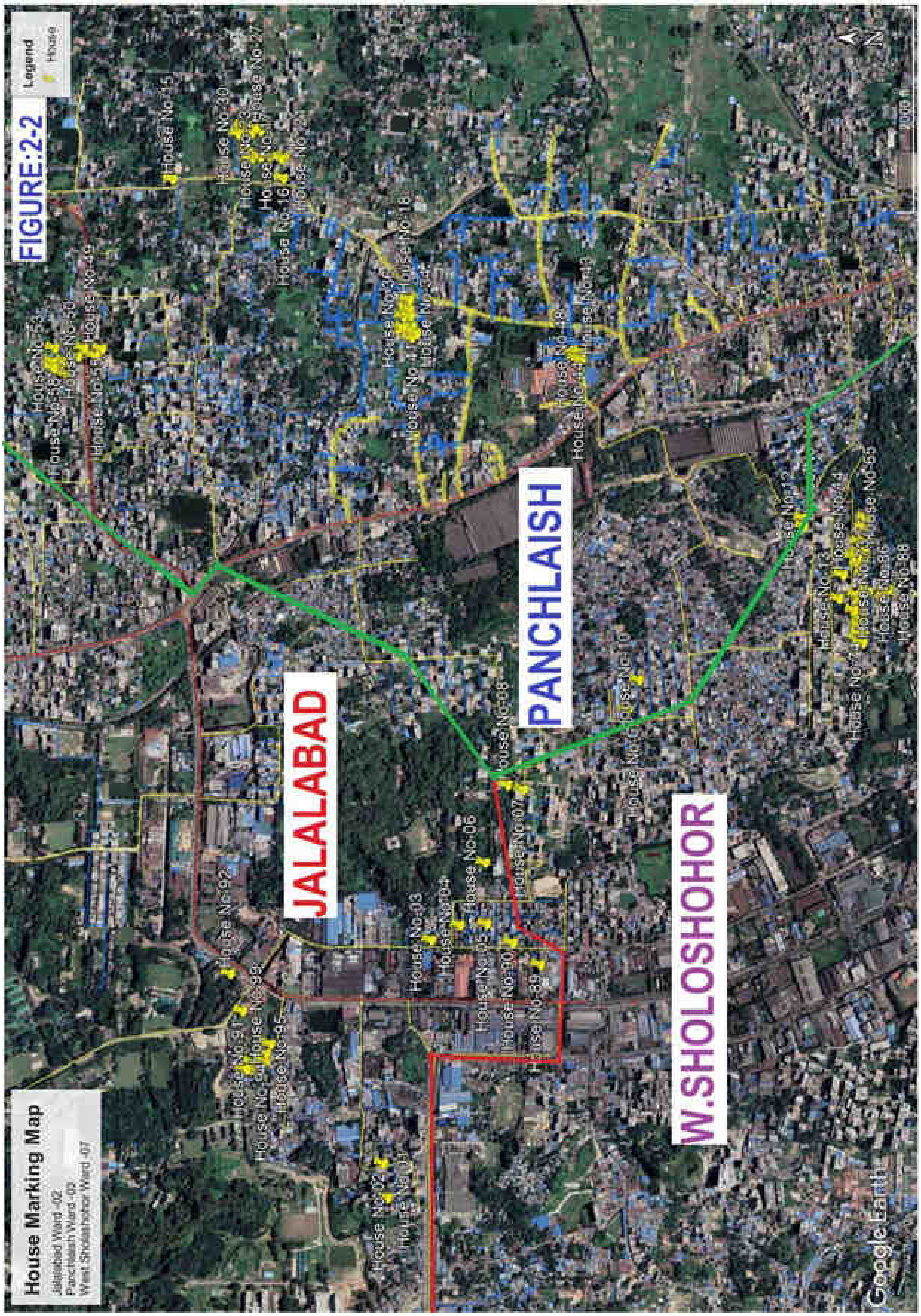


Figure 2-33 Household Connection Survey Location Map

2.5.5.2 Site Survey

Table 2-68 Photo of Household Connection Survey

<table>
<tr><th>Category</th><th colspan="2">Photo</th></tr>
<tr><td rowspan="2">Type 1</td><td>
</td><td></td></tr>
<tr><td>Perspective View of Building</td><td>Inside Sanitary fixing</td></tr>
<tr><td rowspan="2">Type 2</td><td>
</td><td>
</td></tr>
<tr><td>Perspective View of Building</td><td>Septic Tank</td></tr>
</table>

Table 2-69 Photo of Household Connection Survey

Category	Photo	
Type 3		
	Perspective Entry Gate	Perspective Toilet side
Type 4		
	Approach road & front View	Inside Surface Drain

2.5.5.3 Result of Survey

The sample survey was executed on 100 locations. Type 2 as 63% and the other three types are combinedly only represents only 37%. As such, the findings might not represent the real situation. Therefore, Detail household connection survey shall be implemented in the detailed design stage.

Table 2-70 Result of sample survey

No	Source of Water	Ward No.	House Type (Floor)	Nos of ppl.	Sanitary Plumbing Configuration					Septic Tank Size	Emptying	
					Grey Water	Black Water	Rain Water	Grey + Black	Grey + Rain		Manual	With CCC
1	DTW	02	5th	62	Yes	Yes	Yes			7.0 x 3.5 x 3.0		Yes
2	DTW	02	7th	85	Yes	Yes	Yes			7.0 x 4.0 x 3.0		Yes
3	CWASA	02	7th	55		Yes			Yes	6.0 x 4.0 x 3.0		Yes
4	CWASA	02	5th	35		Yes			Yes	5.5 x 3.5 x 3.0		Yes
5	CWASA+ DTW	02	6th	35		Yes			Yes	7.0 x 3.0 x 3.0		Yes
6	CWASA + DTW	02	6th	120	Yes	Yes	Yes			8.0 x 4.0 x 3.0		Yes
7	DTW	07	8th	75		Yes			Yes	7.5 x 4.5 x 3.0		Yes
8	DTW	07	8th	60	Yes	Yes	Yes			8.0 x 4.0 x 3.0	No	No
9	DTW	07	7th	100	Yes	Yes	Yes			5.5 x 4.5 x 3.0	No	Yes
10	DTW	07	5th	65	Yes	Yes	Yes			5.0 x 4.0 x 3.0	No	Yes
11	CWASA + DTW	07	9th	110	Yes	Yes	Yes			7.0 x 5.0 x 3.0	No	Yes
12	DTW	03	9th	80	Yes	Yes	Yes			7.0 x 5.0 x 3.0	No	Yes
13	DTW	07	9th	80	Yes	Yes	Yes			6.0 x 4.5 x 3.0		Yes
14	CWASA + DTW	07	9th	130	Yes	Yes	Yes			7.0 x 5.0 x 3.0	No	No
15	CWASA + DTW	03	5th	120		Yes			Yes	8.0 x 5.0 x 3.0	Yes	
16	CWASA + DTW	03	5th	120		Yes			Yes	8.0 x 5.0 x 3.0	Yes	
17	CWASA	03	5th	75	Yes	Yes	Yes			3.0 x 2.0 x 1.2		No
18	CWASA	03	1st	12	Yes	Yes	Yes			5.0 x 2.5 x 1.5		No
19	CWASA + DTW	03	Commercial	370	Yes	Yes	Yes			6.5 x 2.5 x 3.0		Yes
20	CWASA	03	9th	130	Yes	Yes	Yes			3.5 x 3.0 x 2.5		No
21	DTW	03	Commercial	110	Yes	Yes	Yes			2.0 x 2.0 x 1.2		Yes
22	CWASA	03	3rd	30	Yes	Yes	Yes			2.0 x 2.5 x 1.5		No
23	CWASA	03	4th	35	Yes	Yes	Yes			4.0 x 2.0 x 1.5		No

No	Source of Water	Ward No.	House Type (Floor)	Nos of ppl.	Sanitary Plumbing Configuration					Septic Tank Size	Emptying	
					Grey Water	Black Water	Rain Water	Grey + Black	Grey + Rain		Manual	With CCC
24	CWASA	03	1st	12		Yes			Yes			No
25	CWASA	03	1st	20		Yes			Yes	3.0 x 2.0 x 1.5		No
26	CWASA	03	2nd	30	Yes	Yes	Yes			3.0 x 2.0 x 1.5		No
27	CWASA	03	4th	69		Yes			Yes	3.0 x 2.0 x 1.5		No
28	CWASA	03	3rd	42	Yes	Yes	Yes			6.0 x 3.0 x 2.0		No
29	DTW	03	1st	22	Yes	Yes	Yes			3.0 x 2.0 x 1.2		No
30	CWASA	03	5th	45		Yes			Yes	5.0 x 3.5 x 2.0		No
31	DTW	03	3rd	50	Yes	Yes	Yes			7.0 x 2.5 x 2.5		No
32	CWASA	03	1st	10		Yes			Yes			Yes
33	CWASA	03	1st	10		Yes			Yes		Yes	
34	CWASA	03	2nd	30	Yes	Yes	Yes			3.0 x 2.0 x 1.5	Yes	
35	CWASA	03	3rd	25		Yes			Yes	3.0 x 2.0 x 1.5	Yes	
36	CWASA + DTW	03	3rd	30		Yes			Yes	2.0 x 2.0 x 1.2		No
37	CWASA	03	1st	7	Yes	Yes	Yes			5.0 x 2.8 x 1.8	Yes	
38	CWASA	03	3rd	25	Yes	Yes	Yes			3.0 x 2.0 x 1.2	Yes	
39	CWASA	03	4th	50	Yes	Yes	Yes			3.0 x 2.0 x 1.5		No
40	CWASA + DTW	03	1st	15	Yes	Yes	Yes			5.0 x 3.0 x 1.8		No
41	CWASA + DTW	03	5th	50		Yes			Yes	3.5 x 2.0 x 1.5	Yes	
42	CWASA	03	6th	70	Yes	Yes	Yes			4.0 x 3.0 x 2.0		No
43	CWASA	03	8th	140		Yes			Yes	6.5 x 3.0 x 2.5		No
44	CWASA + DTW	03	5th	90		Yes			Yes	6.0 x 4.0 x 2.0	Yes	
45	CWASA	03	4th	50	Yes	Yes	Yes			6.0 x 2.0 x 2.0		No
46	CWASA	03	6th	100	Yes	Yes	Yes			3.0 x 3.0 x 2.0		No
47	CWASA	03	5th	130	Yes	Yes	Yes			4.0 x 3.0 x 1.5		No
48	CWASA + DTW	03	6th	70	Yes	Yes	Yes			5.0 x 3.0 x 2.0		No
49	CWASA	03	6th	110		Yes			Yes	5.0 x 3.0 x 3.0	Yes	
50	CWASA	03	Commercial	60		Yes			Yes	4.0 x 3.0 x 2.5		No

No	Source of Water	Ward No.	House Type (Floor)	Nos of ppl.	Sanitary Plumbing Configuration					Septic Tank Size	Emptying	
					Grey Water	Black Water	Rain Water	Grey + Black	Grey + Rain		Manual	With CCC
51	CWASA + DTW	03	7th	110	Yes	Yes	Yes			4.0 x 3.0 x 2.5		No
52	CWASA	03	3rd	40	Yes	Yes	Yes			6.0 x 3.0 x 2.5		Yes
53	DTL	03	6th	100	Yes	Yes	Yes			4.0 x 3.0 x 2.5		No
54	CWASA	03	2nd	25		Yes			Yes	2.5 x 2.0 x 1.5		No
55	CWASA	03	Commercial	150		Yes				4.0 x 3.0 x 1.5		No
56	CWASA	03	8th	120	Yes	Yes	Yes			6.0 x 3.0 x 3.0		No
57	CWASA	03	4th	50	Yes	Yes	Yes			4.0 x 2.0 x 1.2	Yes	
58	CWASA + DTW	03	5th	70	Yes	Yes	Yes			4.0 x 3.0 x 2.5		No
59	DTL	07	9th	100	Yes	Yes	Yes			4.5 x 4.0 x 3.0		No
60	CWASA	07	5th	110	Yes	Yes	Yes			5.0 x 2.5 x 3.0		Yes
61	DTW	07	5th	60	Yes	Yes	Yes			3.0 x 2.5 x 2.5		No
62	DTW	07	4th	40	Yes	Yes	Yes			3.0 x 3.0 x 2.5		No
63	DTW	07	4th	60		Yes			Yes	3.0 x 2.5 x 2.5		Yes
64	DTW	07	4th	50	Yes	Yes	Yes			6.0 x 3.0 x 3.0		Yes
65	DTW	07	6th	70		Yes			Yes	6.0 x 4.0 x 3.0		Yes
66	DTW	07	5th	70	Yes	Yes	Yes			8.0 x 5.0 x 4.0		No
67	DTW	07	2nd	40	Yes	Yes	Yes			5.0 x 3.5 x 3.0		No
68	CWASA + DTW	07	2nd	30	Yes	Yes	Yes			4.0 x 2.5 x 2.5		Yes
69	CWASA + DTW	07	2nd	20	Yes	Yes	Yes			4.0 x 2.5 x 2.5		Yes
70	DTW	07	9th	120		Yes			Yes	5.0 x 4.0 x 3.0		No
71	CWASA + DTW	07	5th	90	Yes	Yes	Yes			6.0 x 4.0 x 3.0		Yes
72	CWASA + DTW	07	5th	100		Yes			Yes	6.0 x 4.0 x 3.0		Yes
73	DTW	07	5th	60	Yes	Yes	Yes			4.0 x 3.0 x 2.5		No
74	CWASA	07	3rd	40	Yes	Yes	Yes			6.0 x 2.5 x 3.0	Yes	
75	CWASA + DTW	07	3rd	30	Yes	Yes	Yes			3 x (5.0 x 2.5 x 2.5)		No
76	DTW	07	9th	140	Yes	Yes	Yes			9.0 x 3.0 x 3.0		No
77	DTW	07	5th	120		Yes			Yes	4.0 x 3.0 x 3.0	Yes	

No	Source of Water	Ward No.	House Type (Floor)	Nos of ppl.	Sanitary Plumbing Configuration					Septic Tank Size	Emptying	
					Grey Water	Black Water	Rain Water	Grey + Black	Grey + Rain		Manual	With CCC
78	DTW	07	9th	140	Yes	Yes	Yes			4.0 x 3.0 x 3.0		No
79	DTW	07	4th	60		Yes			Yes	4.0 x 3.5 x 3.0		No
80	DTW	07	5th	50	Yes	Yes	Yes			5.0 x 4.0 x 3.0		No
81	CWASA + DTW	07	3rd	60	Yes	Yes	Yes			6.0 x 4.0 x 3.0		No
82	DTW	07	10th	120	Yes	Yes	Yes			5.0 x 3.0 x 3.0		No
83	DTW	07	9th	150	Yes	Yes	Yes			8.0 x 9.0 x 3.0		No
84	DTW	07	4th	40		Yes			Yes	4.0 x 3.0 x 2.5	Yes	
85	DTW	07	10th	300		Yes			Yes	10.0 x 4.0 x 3.0	Yes	
86	CWASA + DTW	07	3rd	40	Yes	Yes	Yes			4.0 x 2.5 x 2.5	Yes	
87	DTW	07	9th	300	Yes	Yes	Yes			6.5 x 4.0 x 3.0		No
88	DTW	07	5th	50		Yes			Yes	4.0 x 3.0 x 3.0		No
89	CWASA + DTW	02	Commercial	3000	Yes	Yes	Yes			8.0 x 12.0 x 4.0 6.5 x 7.0 x 4.0		Yes
90	CWASA	02	Commercial	171	Yes	Yes	Yes			2.0 x 1.5 x 1.8		Yes
91	CWASA + DTW	02	Commercial	400	Yes	Yes	Yes			4.0 x 6.0 x 3.0		Yes
92	CWASA	02	Commercial	30		Yes				3.0 x 3.0 x 2.5		No
93	CWASA	02	Commercial	250	Yes	Yes	Yes			8.0 x 4.0 x 2.5	Yes	
94	CWASA	02	Commercial	150	Yes	Yes	Yes			6.5 x 4.0 x 3.0		No
95	CWASA + DTW	02	Commercial	42		Yes				1.5 x 1.5 x 1.5		Yes
96	CWASA	02	Commercial	160	Yes	Yes	Yes			4.0 x 1.5 x 1.5	Yes	
97	DTW	02	Commercial	220	Yes	Yes	Yes			4.0 x 2.5 x 3.0	Yes	
98	CWASA + DTW	02	3rd	40		Yes			Yes	4.0 x 2.5 x 3.0	Yes	
99	CWASA	02	3rd	50		Yes			Yes	4.0 x 2.5 x 2.5	Yes	
100	CWASA	02	3rd	50	Yes	Yes	Yes			4.0 x 2.5 x 2.5	Yes	

2.6 Review of Similar Project

2.6.1 Sewerage Projects of Project Area

2.6.1.1 Chattogram Sewage System Construction (Catchment 1) Project

The Chattogram Sewerage System Construction (Catchment 1) Project is under construction in 2022 with financial resources from Bangladesh. Corresponding to the Catchment-1 area, the location of the sewage treatment facility under construction is located near the Bay of Bengal.

This project is under construction after receiving an order from Taeyoung Construction, a Korean company. The construction period is scheduled for about 4 years, and the project status is as follows.

Table 2-71 Chattogram Sewage System Construction (Catchment 1) Project Status

Site	STP	Capacity	Sanitary Sewer	Finance	Construction Company	Bidding Method
Catchment –1	STP -1	100,000 m^3/d	D225 ~ 2,100mm L = 112,587m	GOB	Taeyoung	Design Build

The first stage of sewage treatment plant Q=100,000m^3/d construct, and the final capacity was planned to be Q=300,000m^3/d by collecting sewage from Catchment-3 & 5 sewage treatment areas in the future. The detailed plan is as follows;

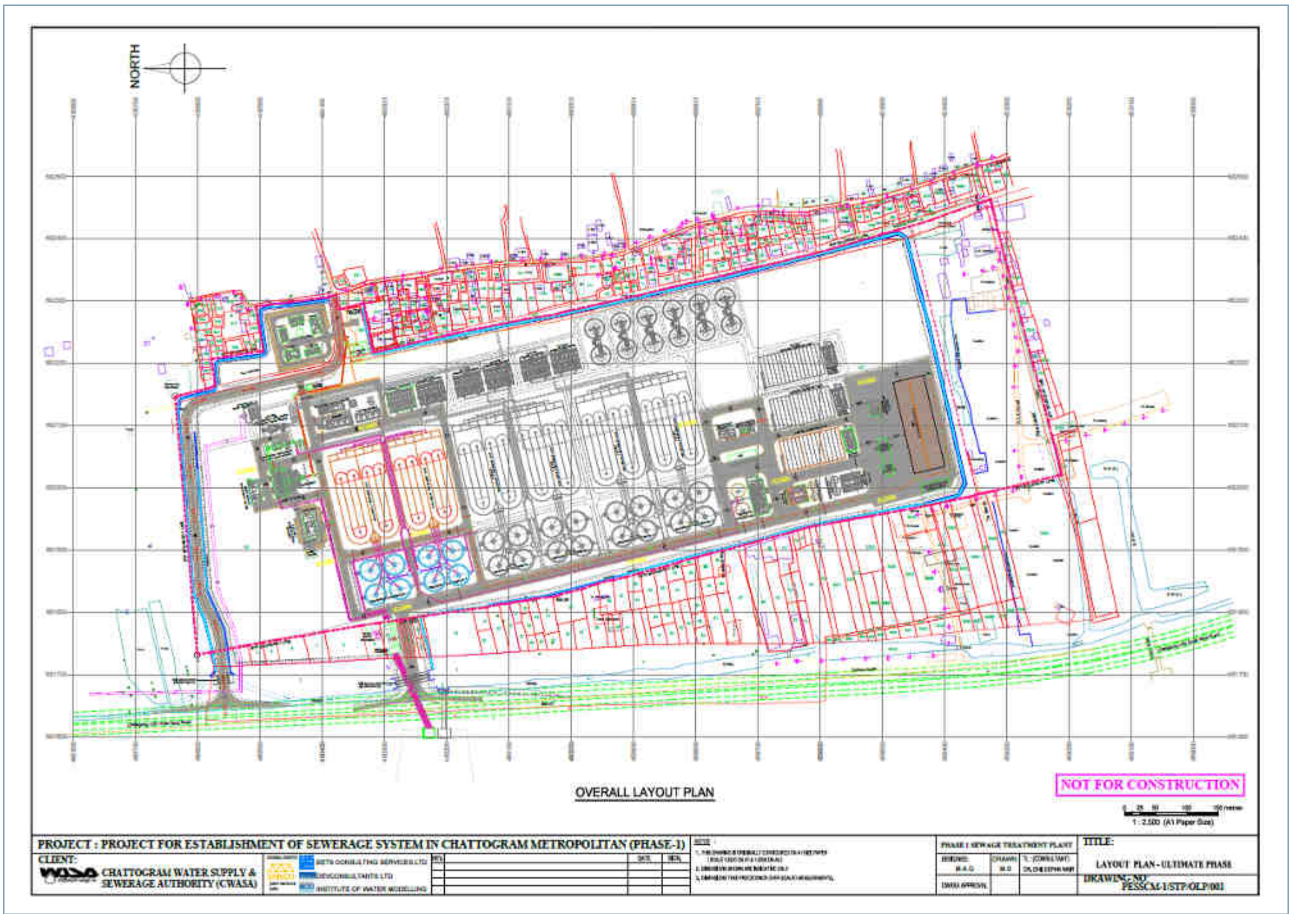


Figure 2-34 Layout Plan of Sewage Treatment Plant

Table 2-72 Introduction of Sewage Facility on Chattogram Sewage System Construction (Catchment 1)

Category	Process	Capacity (m^3/d)			
		Final	Catchment 1	Catchment 2	Catchment 3
Facility	A2O	300,000	100,000	100,000	100,000
Process	Inlet Pump → Screen → Primary Sedimentation → Biological Reactor → Secondary Sedimentation → Disinfection → Discharge Future Facility: Utilization of bio gas after concentration and digestion				

*MLE Process: Advanced sewage treatment method composed of a combination of an anoxic tank and an aerobic tank to treat nitrogen biologically

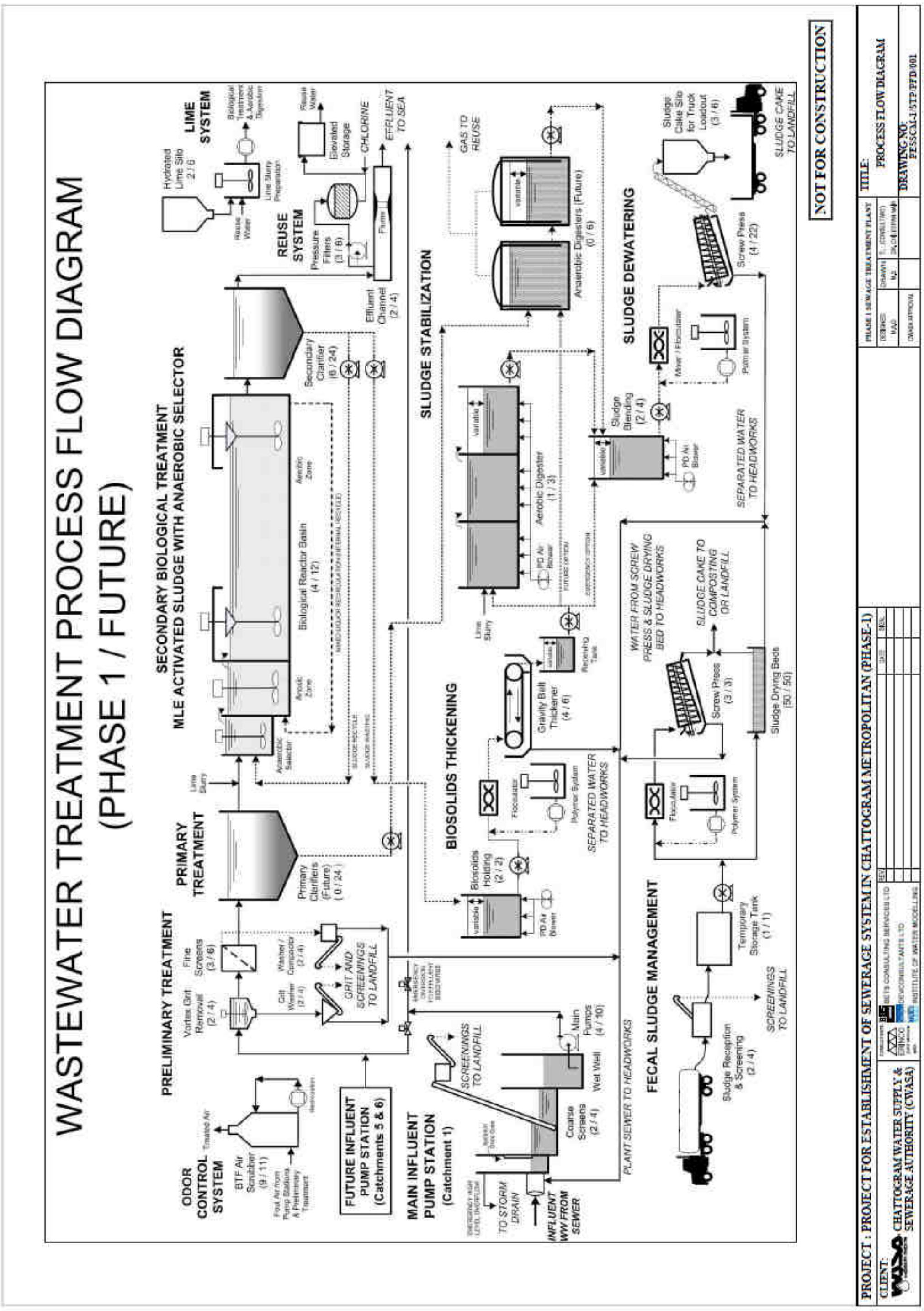


Figure 2-35 Sewage Treatment Process diagram

2.6.1.2 Chattogram Sewage System Construction (Catchment 5) Project

The Chattogram Sewerage System Construction Project (North Kattoli Catchment 5) is undergoing a feasibility study in 2022 with French AFD funding. It corresponds to the Catchment-5 area, and the sewage treatment facility was planned to be integrated and installed as STP-1.

Table 2-73 Chattogram Sewage System Construction (Catchment 5) Project Status

Site	STP	Capacity (m²/d)	Sanitary Sewer	Finance	Remarks
Catchment – 5	STP -1	1st: 60,000 2nd: 100,000	D200 ~ 1,400mm L = 97,560m	AFD	

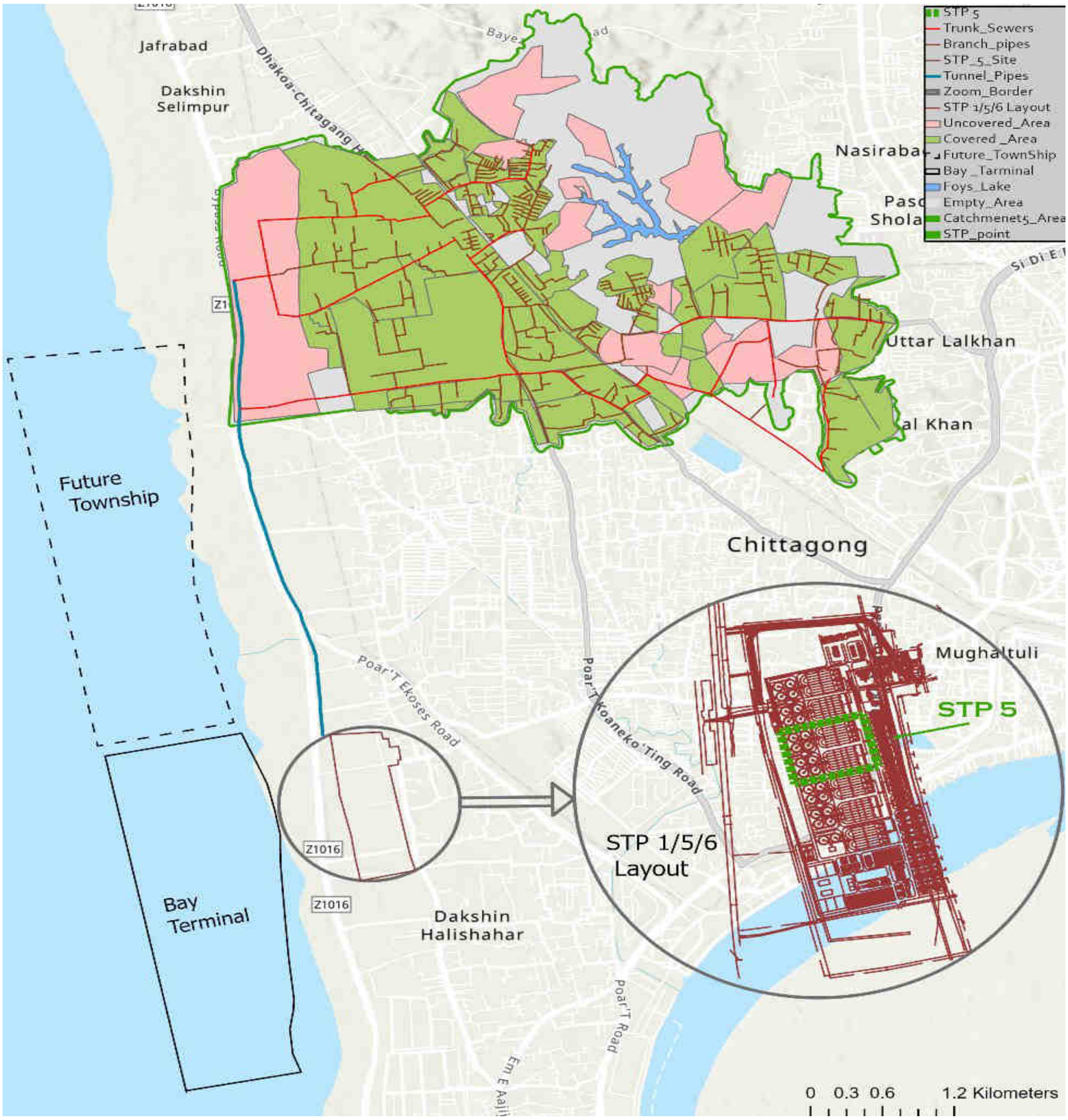


Figure 2-36 Layout Plan of Sewage Treatment area (Catchment 5)

2.6.1.3 Chattogram Sewage System Construction (Catchment 2&4) Project

The Chattogram Sewerage System Construction Project (North Kattoli Catchment 2&4) is undergoing a feasibility study in 2022 with Japan JICA funding. It corresponds to the Catchment-2&4 area, and the location of the sewage treatment plant was planned to be integrated and installed downstream of the Halda River.

Table 2-74 Chattogram Sewage System Construction (Catchment 2&4) Project Status

Site	STP	Capacity(m^3/d)	Sanitary Sewer	Finance	Remarks
Catchment – 2&4	STP -2&4	1st: 60,000 2nd: 300,000	D200 ~ 2,400mm L = 227,500m	JICA	

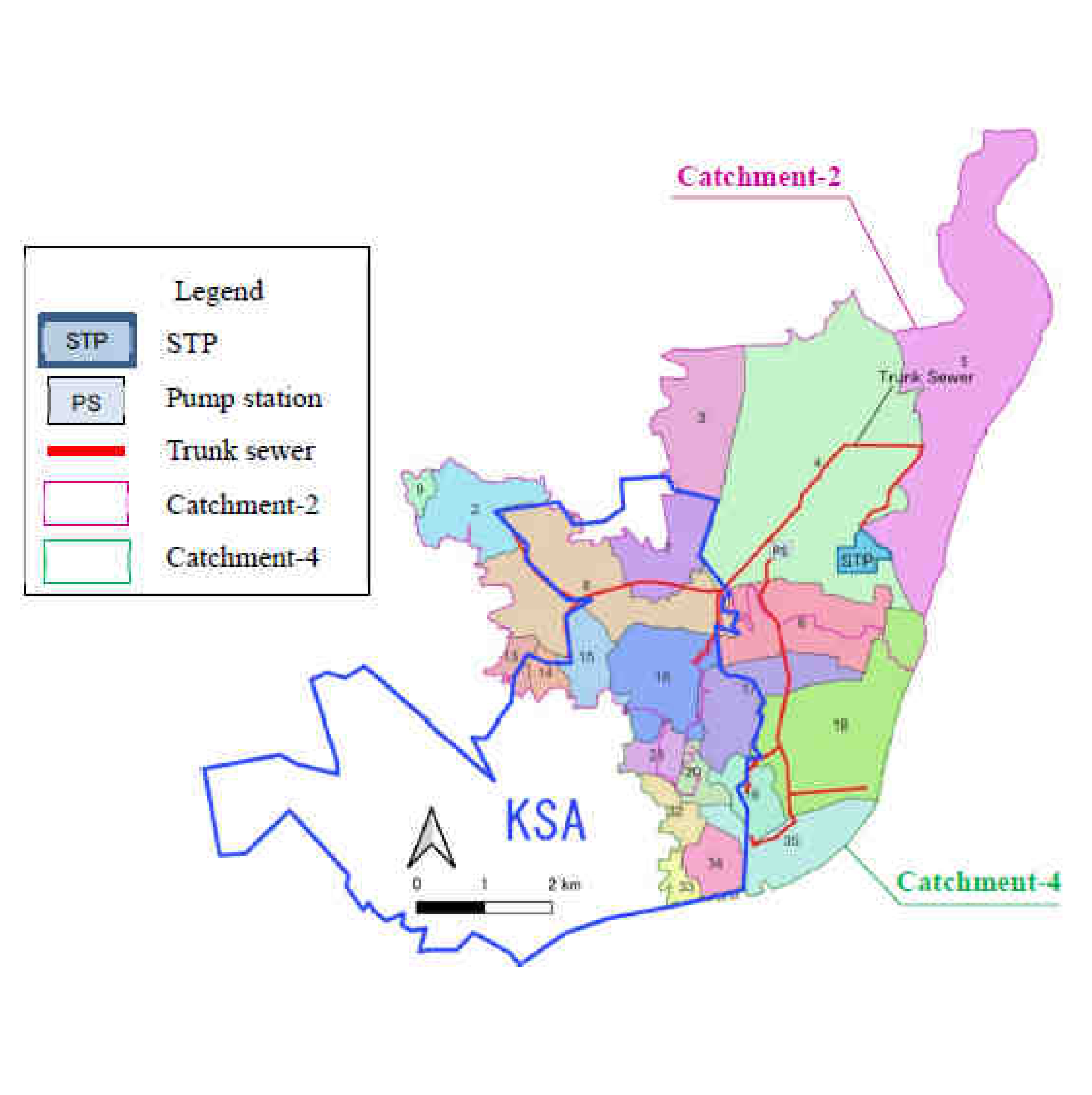


Figure 2-37 Layout Plan of Sewage Treatment area (Catchment 2&4)

Table 2-75 Introduction of Chattogram STP (Catchment 2&4)

Category	Process	Capacity (m³/d)			
		Final	Catchment 1	Catchment 2	Catchment 3
Facility	A2O	300,000	60,000	180,000	300,000
Process	Inlet Pump → Screen → Primary Sedimentation → Biological Reactor → Secondary Sedimentation → Disinfection → Discharge				

*Activated Sludge Process: A general method of sewage treatment that stabilizes active microorganisms and sewage in a reaction tank

*A2O: Advanced sewage treatment method that induces nitrate nitrogen removal and phosphorus release by configuring the reaction tank as an anaerobic tank, anoxic tank, and aerobic tank

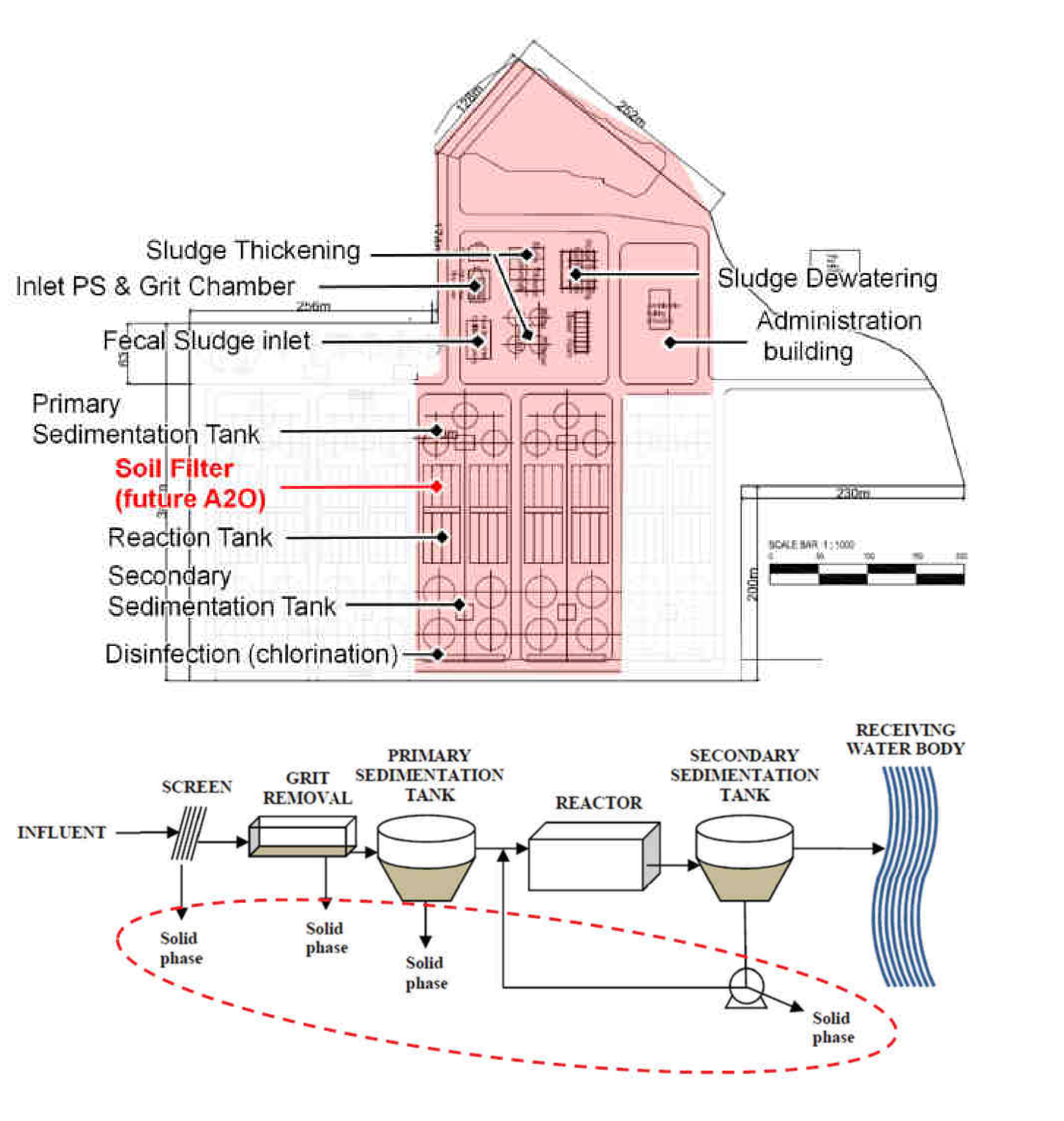


Figure 2-38 Sewage treatment facility layout and treatment process

2.6.2 EDCF Projects

According to the Export-Import Bank of Korea, the total amount of EDCF approved loans for 30 projects in Bangladesh since 2000 is USD 1,710 million, which is approximately KRW 2,169.2 billion. Among them, in the water supply and sewerage sector, there is one water supply project in Dhaka and one water supply project in Chattogram, and CWASA has sufficient capacity to carry out EDCF projects.

Table 2-76 EDCF Similar Project in Bangladesh

No.	Project	Cost (million won)	Year of approval
1	Dhaka Water Supply development project	46,906	2011
2	Bhandal Jhuri Water Supply development project	179,649	2014 & 2021
Total		226,555	

3 Planning Framework

3.1 Target Year

Planning framework is a very important step in establishing a plan for the expansion of sewerage system by carefully estimating the future population, Sewage Service areas, and wastewater generation. Furthermore, appropriate capacity of facilities should be determined to prevent over-investment or insufficient capacity of facilities due to over-planning or under-planning.

Since the target year of the sewerage system is the basis of social infrastructure, it is common to establish the target year as 20 years later in consideration of the lifetime of the facility, difficulty of facility expansion. The final target year should be set from a long-term perspective, taking into account the influent quantity of wastewater to STP, project feasibility in the consideration of investment cost.

In this study, year 2022 is set as the base year in the consideration of Bangladesh population & housing census 2022 (BBS) and year 2070 is set as the final target year considering the Sanitation & Drainage Improvement Strategy and Master Plan for the City of Chattogram prepared under CWSISP (2017), other on-going sewerage projects in Chattogram. Mid-term target year is divided into three Phases of 15 years from the base year for the project implementation considering the initial investment cost and O&M status of sewerage system.

Table 3-1 Target Year

Category	Base	Phase 1	Phase 2	Phase 3
Implementation Period	2022	2023-2040	2041-2055	2056-2070
Target Year		2040	2055	2070

3.2 Population Projection

Population projection is an important factor that is the basis for wastewater generation estimation in the consideration of water supply service coverage, Sewage Service coverage, urban development plan and long-term plan of the project area.

The calculation of the projected population should be established by grasping the past population trends and by taking into account the complex and diverse variables such as natural population growth and social population growth trends according to the urban development plan.

In this study, the future population is projected by comprehensively reviewing the factors of population increase and decrease considering the regional characteristics of the project area and future growth potential after comparing and analyzing the related planned population.

3.2.1 Current Population

The project area of this study is the Chattogram City (CCC) and surrounding areas of CCC such as Hathazari Upazila Paurashava and Raozan Upazila Paurashava.

Based on the 2022 census, the population of Chattogram City is 3,230,517, the population of Hathazari is 94,244, and the population of Raozan is 70,701 with an annual average increase of 2.02% in Chattogram, 3.79% in Hathazari and 1.64% in Raozan.

The population trend of the project area is as below.

Table 3-2 Population Trend of the Project Area

Category	Population Census 2011	Population Census 2022	Annual Average Growth Rate (%)	Remarks
Chattogram City (CCC)	2,592,439	3,230,517	2.02	
Hathazari Upazila Paurashava	62,588	94,244	3.79	
Raozan Upazila Paurashava	59,148	70,701	1.64	
Total	2,714,175	3,395,462	2.06	

Source: Population & Housing Census 2011 & 2022

Table 3-3 Population Trend of the Project Area by Ward

Ward			Area (km²)		Population Census (person)		Annual Average Growth Rate (%)	Population Density (person/km²)	
			Total	Effect	2011	2022		2011	2022
CCC	1	South Pahartali	23.1	9.6	39,247	61,679	4.20	4,088	6,425
	2	Jalalabad	14.8	7.7	103,314	163,705	4.27	13,417	21,260
	3	Panchlaish	5.6	5.6	68,794	101,615	3.61	12,285	18,146
	4	Chandgaon	10.7	10.3	107,807	157,612	3.51	10,467	15,302
	5	Mohara	10.2	5.1	86,491	107,920	2.03	16,959	21,161
	6	East Sholashahar	2.4	2.4	62,113	63,689	0.23	25,880	26,537
	7	West Sholashahar	3.2	2.7	125,517	164,553	2.49	46,488	60,946
	8	Sulakbahar	5.3	5.1	138,200	141,570	0.22	27,098	27,759
	9	North Pahartali	6.4	2.0	78,313	104,316	2.64	39,157	52,158
	10	North Kattali	4.9	3.7	41,685	61,802	3.64	11,266	16,703
	11	South Kattali	3.0	3.0	75,316	109,825	3.49	25,105	36,608
	12	Saraipara	2.4	2.4	73,636	86,820	1.51	30,682	36,175
	13	Pahartali	3.3	2.5	80,390	89,594	0.99	32,156	35,838
	14	Lalkhan Bazaar	1.2	0.9	75,335	69,617	-0.72	83,706	77,352
	15	Bagmoniram	2.1	1.4	51,603	49,166	-0.44	36,859	35,119
	16	Chawk Bazar	2.0	2.0	49,065	56,342	1.27	24,533	28,171
	17	West Bakalia	1.9	1.9	97,145	111,193	1.24	51,129	58,523
	18	East Bakalia	5.1	3.9	65,869	76,046	1.31	16,889	19,499
	19	South Bakalia	0.8	0.8	76,302	55,893	-2.79	95,378	69,866
	20	Dewan Bazar	0.4	0.4	32,633	34,982	0.63	81,583	87,455
	21	Jamalkhan	0.8	0.8	40,014	45,944	1.26	50,018	57,430
	22	Enayet Bazar	0.8	0.6	35,454	33,965	-0.39	59,090	56,608
	23	North Pathantooly	0.6	0.6	31,175	35,412	1.17	51,958	59,020
	24	North Agrabad	2.6	2.6	126,759	152,331	1.68	48,753	58,589
	25	Rampur	1.5	1.5	50,366	68,299	2.81	33,577	45,533
	26	North Halishahar	5.9	3.2	52,999	67,948	2.28	16,562	21,234
	27	South Agrabad	1.4	1.4	66,755	58,052	-1.26	47,682	41,466
	28	Pathantooly	1.4	1.1	50,410	50,816	0.07	45,827	46,196
	29	West Madarbari	0.8	0.6	44,348	36,805	-1.68	73,913	61,342
	30	East Madarbari	1.1	0.9	45,928	40,949	-1.04	51,031	45,499
	31	Alkaran	0.8	0.3	17,857	15,106	-1.51	59,523	50,353
	32	Andarkilla	0.8	0.6	24,423	30,290	1.98	40,705	50,483
	33	Firingee Bazaar	0.6	0.4	26,620	28,390	0.59	66,550	70,975
	34	Patharghata	0.9	0.8	34,835	32,814	-0.54	43,544	41,018
	35	Boxirhat	2.6	0.6	30,855	30,088	-0.23	51,425	50,147
	36	Gosaildenga	2.0	0.9	43,929	44,008	0.02	48,810	48,898
	37	North Middle Halishahar	3.3	1.3	41,998	51,620	1.89	32,306	39,708
	38	South Middle Halishahar	4.8	3.3	59,990	119,404	6.46	18,179	36,183
	39	South Halishahar	6.6	2.5	106,272	256,168	8.33	42,509	102,467
	40	North Patenga	10.5	3.8	88,593	97,015	0.83	23,314	25,530
	41	South Patenga	14.3	1.6	44,084	67,154	3.90	27,553	41,971
	Sub-Total		172.9	102.8	2,592,439	3,230,517	2.02	25,218	31,425
Hathazari Upazila Paurashava			14.7	4.4	62,588	94,244	3.79	14,241	21,443
Raozan Upazila Paurashava			27.2	8.1	59,148	70,701	1.64	7,262	8,680
Total					2,714,175	3,395,462	2.06		

Source: Population & Housing Census 2011 & 2022

3.2.2 Population Projection

3.2.2.1 Methodology of Population Projection

The population projection of the target year should be a reliable because it is an important factor for estimating wastewater generation. In principle, social population growth factors include complex and diverse variable factors such as past population growth trends and the urban development plan of the project area should be identified.

In Bangladesh, the population census is conducted every 10 years, so it is difficult to apply the statistical method considering past population changes commonly applied in developed countries such as Korea due to the lack of past population data.

In the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage project such as Catchment-1 (PESSCM-1) and Catchment 2&4, the population projection is calculated every five years by considering the population growth rate by population density per Ward. This method reflects the decrease in the acceptable population due to the limits of future development of land and housing when population density increases, and it is considered to be appropriate when applied to areas where the population is rapidly increasing such as Chattogram City.

Table 3-4 Annual Average Growth Rate by Population Density

No.	Population Density (person/km^2)		Annual Average Growth Rate (%)	Remarks
	From	To		
1	0	5,000	4.60	
2	5,000	10,000	3.90	
3	10,000	20,000	3.10	
4	20,000	30,000	2.50	
5	30,000	40,000	2.05	
6	40,000	50,000	1.70	
7	50,000	60,000	1.40	
8	60,000	70,000	1.15	
9	70,000	80,000	0.95	
10	80,000	90,000	0.75	
11	90,000	100,000	0.60	
12	100,000	110,000	0.45	
13	110,000	120,000	0.35	
14	120,000	130,000	0.30	

Source: Final Design Report of Catchment-1 (PESSCM-1)

3.2.2.2 Population Projection

In this study, population projection of each ward is estimated in the consideration of Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City.

- In the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP), population project is estimated to the target year 2030 in the consideration of the growth rate by population density based on population census 2011.
- In the on-going sewerage project such as Catchment-1 (PESSCM-1), population project is estimated to the target year 2070 in the consideration of the growth rate by population density based on population census 2011.

In this study, population projection is estimated to the target year 2070 in the consideration of the growth rate by population density based on the recent issued population census 2022 (BBS). Even though there are some differences from the planned population calculated based on the census 2011 of relevant plans, we can consider it is reasonable considering the urbanization of each Ward over the past 10 years (2011-2022).

Table 3-5 Population Projection (person)

Category		2011	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Relevant Plans	CWSISP	2,592,439	3,111,125	3,730,950	-	-	-
	Catchment-1 (PESSCM-1)	2,592,439	3,111,125	3,730,950	4,590,965	5,957,652	7,347,895
This Study (Catchment-3)	Chattogram City (CCC)	2,592,439	3,230,517	3,755,306	4,457,012	5,559,369	6,677,219
	Hathazari Upazila Paurashava	62,588	94,244	114,827	146,988	195,892	248,552
	Raozan Upazila Paurashava	59,148	70,701	96,018	130,299	200,054	283,433
	Total	2,714,175	3,395,462	3,966,151	4,734,299	5,955,315	7,209,204

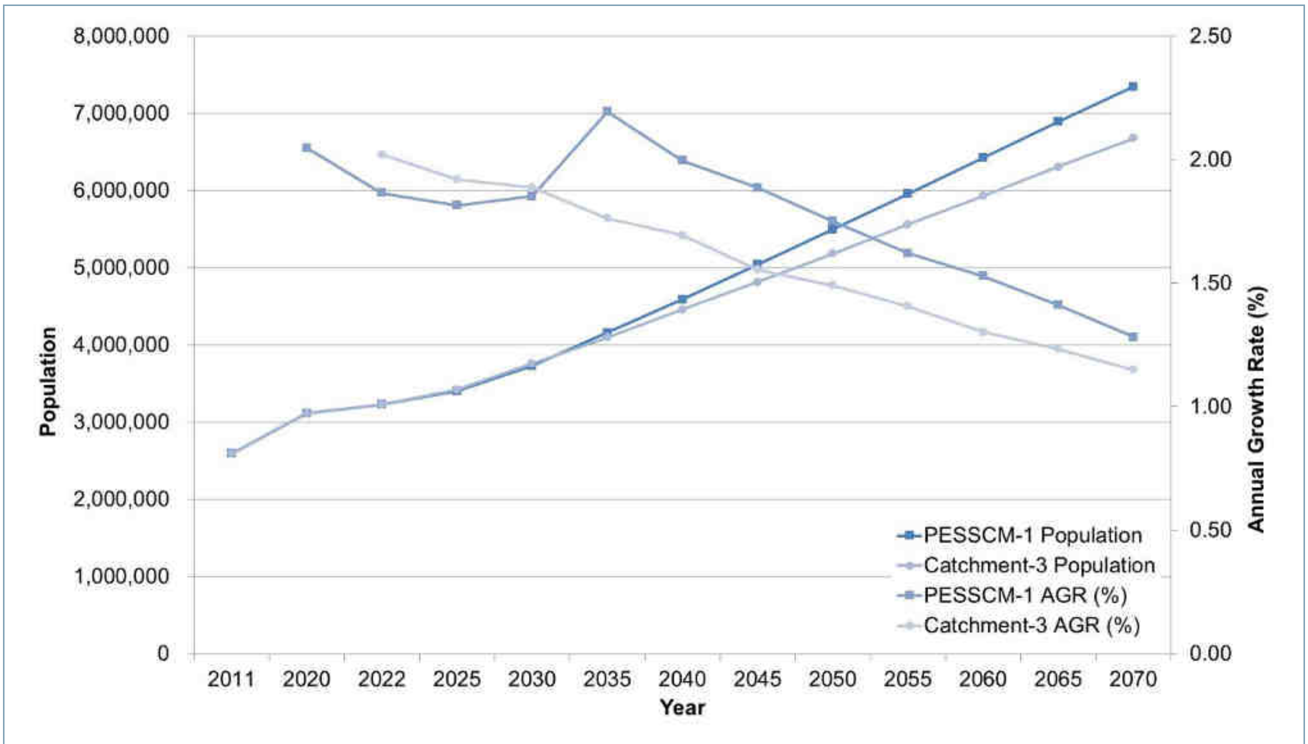


Figure 3-1 Comparison of Population Projection with Relevant Plans

Table 3-6 Population Projection by Ward (person)

Ward			2011	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
CCC	1	South Pahartali	39,247	61,679	83,765	118,150	186,773	278,513
	2	Jalalabad	103,314	163,705	199,458	255,323	340,272	431,743
	3	Panchlaish	68,794	101,615	129,726	166,060	230,152	296,366
	4	Chandgaon	107,807	157,612	201,214	265,199	375,730	492,210
	5	Mohara	86,491	107,920	131,490	168,318	224,319	284,620
	6	East Sholashahar	62,113	63,689	77,599	95,058	124,527	153,403
	7	West Sholashahar	125,517	164,553	180,316	200,168	228,392	251,699
	8	Sulakbahar	138,200	141,570	172,489	211,296	272,085	331,066
	9	North Pahartali	78,313	104,316	116,588	132,335	154,016	174,000
	10	North Kattali	41,685	61,802	78,900	100,999	139,980	183,374
	11	South Kattali	75,316	109,825	129,183	152,902	188,357	221,398
	12	Saraipara	73,636	86,820	102,123	120,874	148,902	176,762
	13	Pahartali	80,390	89,594	105,386	124,737	155,947	185,125
	14	Lalkhan Bazaar	75,335	69,617	75,087	80,912	87,849	93,969
	15	Bagmoniram	51,603	49,166	57,832	68,451	85,579	101,591
	16	Chawk Bazar	49,065	56,342	67,153	82,261	105,927	128,888
	17	West Bakalia	97,145	111,193	122,750	137,619	158,589	177,398
	18	East Bakalia	65,869	76,046	94,292	120,702	163,648	210,730
	19	South Bakalia	76,302	55,893	60,644	66,658	74,563	79,758
	20	Dewan Bazar	32,633	34,982	37,137	38,842	41,548	44,443
	21	Jamalkhan	40,014	45,944	51,349	57,569	66,341	74,209
	22	Enayet Bazar	35,454	33,965	37,961	42,560	49,045	54,862
	23	North Pathantooly	31,175	35,412	39,092	43,827	50,007	55,938
	24	North Agrabad	126,759	152,331	168,164	188,535	217,263	239,433
	25	Rampur	50,366	68,299	78,160	89,819	107,949	124,398
	26	North Halishahar	52,999	67,948	82,789	105,977	141,236	179,202
	27	South Agrabad	66,755	58,052	66,433	77,478	94,273	109,718
	28	Pathantooly	50,410	50,816	58,153	66,827	79,330	91,417
	29	West Madarbari	44,348	36,805	40,330	44,770	51,082	56,296
	30	East Madarbari	45,928	40,949	46,861	53,850	64,720	74,582
	31	Alkaran	17,857	15,106	16,883	19,163	22,525	25,700
	32	Andarkilla	24,423	30,290	33,853	38,425	45,166	51,535
	33	Firingee Bazaar	26,620	28,390	30,621	33,325	37,278	39,875
	34	Patharghata	34,835	32,814	37,551	43,794	53,288	62,019
	35	Boxirhat	30,855	30,088	33,627	38,169	44,865	51,191
	36	Gosaildenga	43,929	44,008	49,623	57,024	67,027	76,479
	37	North Middle Halishahar	41,998	51,620	59,684	70,643	85,955	100,037
	38	South Middle Halishahar	59,990	119,404	140,450	166,238	204,786	243,102
	39	South Halishahar	106,272	256,168	265,537	277,731	292,674	307,655
	40	North Patenga	88,593	97,015	118,204	144,798	189,687	237,149
	41	South Patenga	44,084	67,154	76,849	89,626	107,717	125,366
	Sub-Total		2,592,439	3,230,517	3,755,306	4,457,012	5,559,369	6,677,219
Hathazari Upazila Paurashava			62,588	94,244	114,827	146,988	195,892	248,552
Raozan Upazila Paurashava			59,148	70,701	96,018	130,299	200,054	283,433
Total			2,714,175	3,395,462	3,966,151	4,734,299	5,955,315	7,209,204

3.3 Sewage Service Coverage

3.3.1 Introduction

Sewage Service coverage is the basis of the sewerage system plan, so it should be decided carefully to ensure the project feasibility. In this study, most of the resident areas including slum area within the project area is considered including urban areas and sub-urban areas.

Sewage Service coverage of this study is determined in consideration of the following factors:

- Sewerage system is the social infrastructure as same as roads, parks, water supply system and rivers. In addition, long-term perspective plan should be considered in the planning of sewerage system because it is difficult to expand the capacity of sewerage system once it is constructed.
- Sewage Service coverage should be determined by closely reviewing and analysing relevant plans and urban development plans.
- Sewage Service coverage should be established in the consideration of natural conditions, social conditions, and financial conditions.
- Sewage Service coverage should include areas that may become urbanized in the future as well as existing urban areas to improve the hygienic and sanitary condition of the project area and to improve the water quality of the river and restoration of the ecosystem.

Considering the above factors, the Sewage Service coverage for this study is set based on the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City and site survey. In particular, in the selection of sewage treatment areas, areas requiring management in accordance with urban areas were preferentially incorporated into treatment areas in order to accommodate the population and industry of urban areas among urban landscape and management areas. In the case of rural settlements, it is planned in consideration of environmental characteristics for the preservation of the natural environment.

3.3.2 Current Sewage Service Coverage

3.3.2.1 Current Status

Sewage Service coverage refers to the percentage of the population served by the centralised sewerage system of the total population in the project area and it is used as a key indicator of environmental infrastructure development.

As of 2022, Sewage Service coverage is 0% because there is no centralized sewerage system installed in the Chattogram City, so all the domestic and non-domestic wastewater is discharged into nearby rivers or waterways after treatment in the on-site system with septic tanks or without any treatment.

Sewage Service coverage of the Chattogram City is expected to increase gradually when construction of the sewerage system of Catchment-1 (PESSCM-1) is completed which is currently under construction.

3.3.2.2 Sewage Service Coverage of Relevant Plans

In the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP), Sewage Service coverage area of Chattogram City is divided into six catchment areas as below.

Table 3-7 Sewage Service Coverage of Master Plan

Sewage Service Coverage	Location	Area of STP Site (ha)	Capacity of STP (m^3/d, 2030)	Remarks
Catchment-1 (PESSCM-1)	Halishahar	66	100,000	
Catchment-2	Kalurghat	19	100,000	
Catchment-3	Fatehabad	30	60,000	
Catchment-4	East Bakalia	33	70,000	
Catchment-5	North Kattali	22	80,000	
Catchment-6	Patenga	30	100,000	

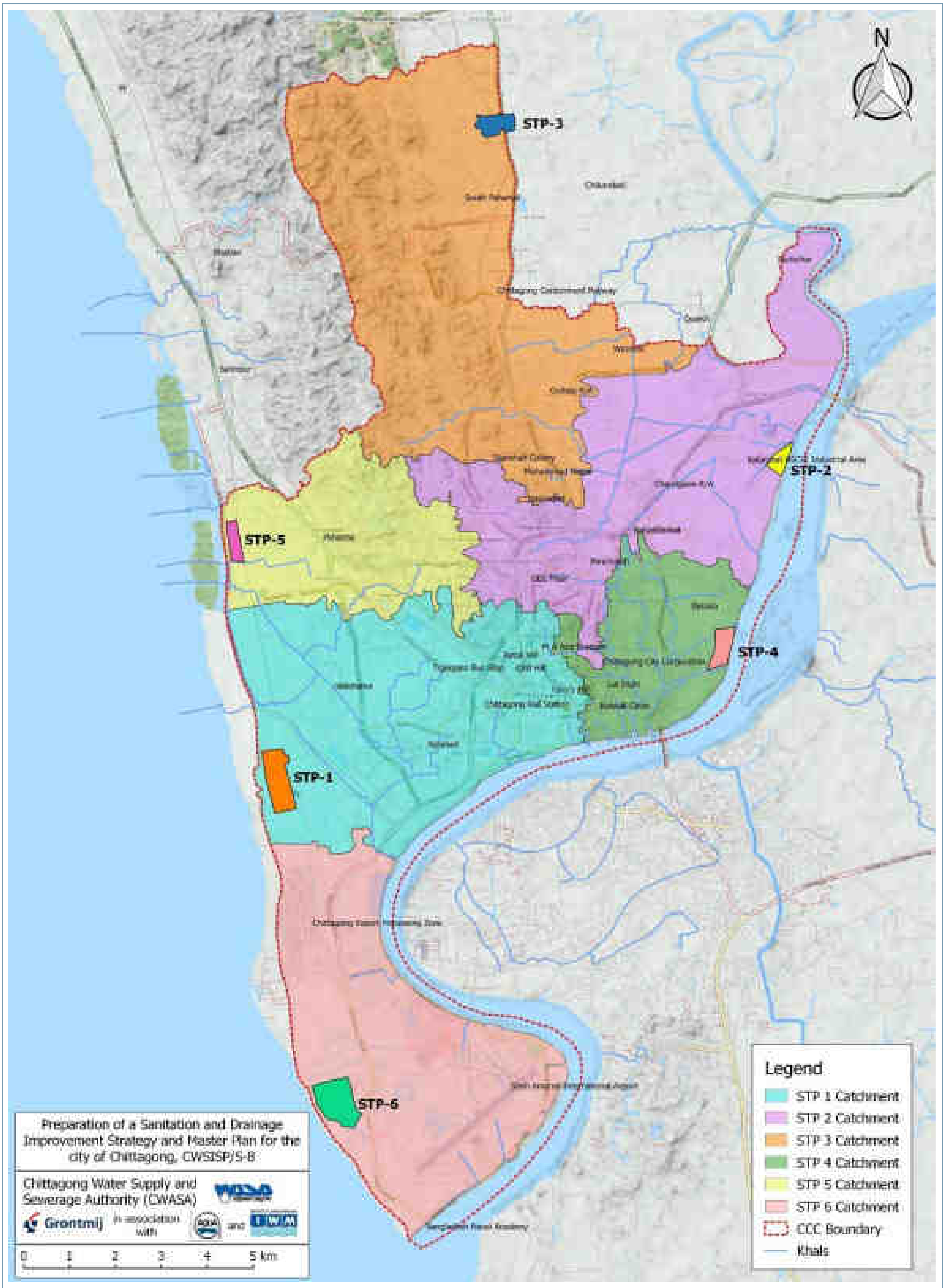


Figure 3-2 Sewage Service Coverage of Master Plan

3.3.3 Sewage Service Area

Currently five sewerage projects including this project are on-going in Chattogram City under CWASA. Although six sewage treatment plants were planned in the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP), number of STP is adjusted during the project implementation of each project due to the difficulty of the land acquisition of sewage treatment plant sites of Catchment-4, Catchment-5 & Catchment-6 as below.

- STP of Catchment-5 & Catchment-6 is planned to be integrated in the site of STP of Cathcment-1 (PESSCM-1).
- STP of Catchment-2 & Catchment-4 is planned to be integrated in the site of STP of Cathcment-2.

Table 3-8 On-going Sewerage Projects

Category	Location of STP	Capacity of STP (Final/Phase 1, m^3/d)	Fund Source	Current Progress
Catchment-1 (PESSCM-1)	Halishahar	100,000	GOB	Under Construction
Catchment-5		100,000 (50,000)	AFD	EOI
Catchment-6		100,000	PPP	Feasibility Study On-going
Catchment-2&4	Kalurghat	300,000 (60,000)	JICA	Feasibility Study Completed
Catchment-3	Fatehabad	120,000 (60,000)	EDCF	Feasibility Study Completed

Sewage Service area is set based on the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City and site survey.

Table 3-9 Sewage Service Area (% of Ward in Catchment)

Ward		Total	Catchment -1	Catchment -2&4	Catchment -3	Catchment -5	Catchment -6
1	South Pahartali	100.0			100.00		
2	Jalalabad	100.0		10.00	85.00	5.00	
3	Panchlaish	100.0		40.00	60.00		
4	Chandgaon	100.0		90.00	10.00		
5	Mohara	100.0		100.00			
6	East Sholashahar	100.0		100.00			
7	West Sholashahar	100.0		40.00	60.00		
8	Sulakbahar	100.0		70.00	5.00	25.00	
9	North Pahartali	100.0			5.00	95.00	
10	North Kattali	100.0				100.00	
11	South Kattali	100.0	80.00			20.00	
12	Saraipara	100.0	75.00			25.00	
13	Pahartali	100.0	30.00	10.00		60.00	
14	Lalkhan Bazaar	100.0	72.00	28.00			
15	Bagmoniram	100.0	62.00	38.00			
16	Chawk Bazar	100.0		100.00			
17	West Bakalia	100.0		100.00			
18	East Bakalia	100.0		100.00			
19	South Bakalia	100.0		100.00			
20	Dewan Bazar	100.0		100.00			
21	Jamalkhan	100.0	32.00	68.00			
22	Enayet Bazar	100.0	100.00				
23	North Pathantooly	100.0	100.00				
24	North Agrabad	100.0	100.00				
25	Rampur	100.0	100.00				
26	North Halishahar	100.0	100.00				
27	South Agrabad	100.0	100.00				
28	Pathantooly	100.0	100.00				
29	West Madarbari	100.0	100.00				
30	East Madarbari	100.0	100.00				
31	Alkaran	100.0	100.00				
32	Andarkilla	100.0	35.00	65.00			
33	Firingee Bazaar	100.0	42.00	58.00			
34	Patharghata	100.0		100.00			
35	Boxirhat	100.0		100.00			
36	Gosaildenga	100.0	100.00				
37	North Middle Halishahar	100.0	100.00				
38	South Middle Halishahar	100.0	75.00				25.00
39	South Halishahar	100.0					100.00
40	North Patenga	100.0					100.00
41	South Patenga	100.0					100.00

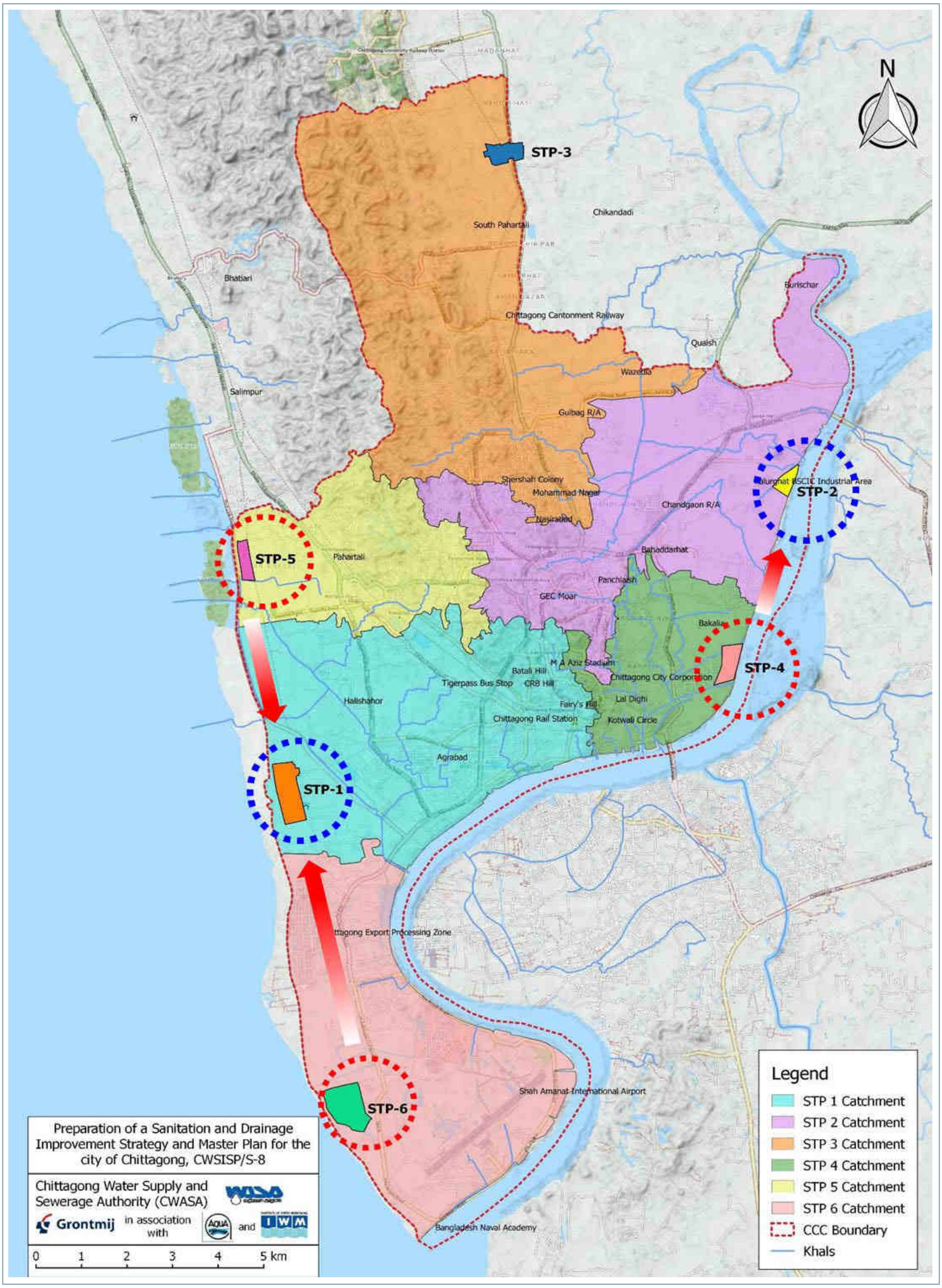


Figure 3-3 Sewage Service Area

3.3.4 Sewage Serving Option

Sewage serving options is reviewed to decide the Sewage Service coverage of the project area. Sewage Serving option is divided into centralized system and decentralized system. Centralized system collects domestic and non-domestic wastewater by sanitary sewer and treats in the sewage treatment plant. Decentralized system is divided into on-site system that treats wastewater from the single dwelling and cluster system that treats wastewater from multiple dwellings.

3.3.4.1 On-Site System

On-site sewage serving system refers to any system where wastewater produced from single dwelling is treated and returned to the ecosystem within the boundaries of that site. Currently, there is no centralized sewerage system in the project area, so most households and commercial facilities in the project area use on-site system such as septic tanks and conventional toilets.

3.3.4.2 Cluster System

Cluster Sewage Serving system is the community systems for two or more dwellings. They are generally much smaller in scale than a centralized system. The wastewater from each cluster of dwellings may be treated on-site by individual septic tanks before the septic tank effluent is transported through alternative sewer systems to a nearby off-site location for further treatment and ecosystem re-entry. In other situations, the full wastewater flow from each cluster may be reticulated off-site to a local treatment site. As in the case of an on-site system, sludge or bio-solids may be managed independently.

3.3.4.3 Centralized System

In a centralized system all wastewater is collected at its source and then transported through sanitary sewer to a central sewage treatment plant. After treatment, the resulting effluent and sludge is discharged at a particular point, thus re-entering the ecosystem. As in the case of cluster systems, some treatment may occur on-site prior to the wastewater being transported to the central treatment site. Although centralized system is the most expensive sanitation option it has proven long-term advantages particularly in densely populated urban areas. The operating costs of the various servicing systems need to be considered when choosing an appropriate technology. For centralized sewerage, the cost of pumping should be considered with who is going to pay for it.

3.3.4.4 Comparison of Sewage Serving Option

A comparison of the various servicing systems is presented as below.

- On-site sanitation is the first option when considering a sanitation intervention. Such systems have distinctive advantages because they are individual systems so the disposal of faecal materials is dispersed over a wide area. One of the main disadvantages with centralized system is that when they go wrong, the resulting problems can be very acute.
- Septic tanks are already widely used in the project area however; effluent disposal by percolation to soil is not always possible in high density areas where space is not available. In other areas the groundwater table is too high and soil has poor permeability. As a result, septic tank effluent is most often discharged to stormwater drains. This can be a public health problem mainly in high density urban areas and hotel zones where wastewater disposal is more concentrated.
- As population densities and water consumption increase with the development of the project area, a centralized servicing scheme would be more appropriate for the high-density urban areas and it will become technically and economically feasible to connect these other areas into the centralized system.

Table 3-10 Comparison of Sewage serving Option

Category	On-site System	Centralized System
Description	• Treatment of domestic wastewater from private households and commercial facilities in individual or communal septic tanks (up to about 50 households). • Discharge of effluents to soak pits where conditions are suitable or to storm water drains where groundwater table is too high	• Collection of all household wastewater and transportation using conventional sewerage to a central treatment facility
Advantages	• Simple and durable • Requires little space because it is underground. • Long-term sustainability, reliable with minimal maintenance and operational requirements	• Better health and better downstream environment if properly operated and maintained. • Lowest cost option in for higher density urban areas • Management and control are more easily centralized
Disadvantages	• Low treatment efficiency. Septic tanks do not remove pathogenic material therefore discharge to drains will contaminate the environment • Septic tanks need regular de-sludging and treatment of Faecal Sludge • Can be expensive in urban areas	• Will take a long time to build. • Breaks down quickly unless there is adequate capacity for O&M • When large centralized schemes do not work the resultant pollution and health problems are often severe
Suitability	• Appropriate in rural areas and urban areas low to medium density	• Reluctance to connect and poor cost recovery can jeopardize sustainability. • Collection system will require pumping

3.3.4.5 Selection of Sewage Serving Option

Sewage Serving option of the project area is selected as below after comparison of option.

- Chattogram City: Currently on-site system is used and centralized sewerage system will be introduced in the priority area after completion of the project. Other areas will remain as on-site system until the centralized system is introduced.
- Hathazari & Raozan Upazila Paurashava: Currently on-site system is used and it remain as on-site system until the centralized system is introduced. Through the project, faecal sludge management will be introduced to collect and treat the faecal sludge from septic tanks in this region.

Table 3-11 Sewage Serving Option

Category	Current Status	This Study	Remarks
Chattogram City	On-Site System	On-Site System & Centralized System	
Hathazari Upazila Paurashava Raozan Upazila Paurashava	On-Site System	On-Site System	

3.3.5 Sewage Service Coverage Projection

To improve the Sewage Service coverage in the project area, the expansion of sewerage system and the development of the existing urban area and low-density area served by on-site system should be implemented in parallel to improve the hygienic and sanitary condition of the project area and to improve the water quality of the river and restoration of the ecosystem.

In this study, it is planned to introduce the sewerage system to five wards in priority where current water service coverage under CWASA is available out of seven wards in Catchment-3 in the consideration of project budget. Sewage Service coverage of the Catchment-3 is 0% at the end of 2022 and is planned to achieve 60.0% by 2030 after completion of the project and to achieve 80.0% by 2070 in the final target year.

Table 3-12 Sewage Service Coverage Projection (%)

Ward		Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
1	South Pahartali	-	25.0	42.2	63.4	80.0	
2	Jalalabad	-	75.0	76.3	78.1	80.0	
3	Panchlaish	-	70.0	72.5	76.3	80.0	
4	Chandgaon	-	0.0	20.0	50.0	80.0	
7	West Sholashahar	-	70.0	72.5	76.3	80.0	
8	Sulakbahar	-	70.0	72.5	76.3	80.0	
9	North Pahartali	-	0.0	20.0	50.0	80.0	
Total			60.0	65.0	72.5	80.0	

3.3.6 Sewage Service Population

3.3.6.1 Population Projection

Seven Wards out of 41 Wards in the Chattogram is allocated to Catchment-3 Sewage Service area. Some wards are also included in the sewage service area of other on-going sewerage projects such as Catchment-2&4 and Catchment-5, so the population projection of Catchment-3 is estimated by multiplying the area ratio of Catchment-3 to the population projection of each ward.

Table 3-13 Population Projection of Catchment-3 (person)

Ward		Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Catchment-3 Area Ratio (%)
1	South Pahartali	61,679	83,765	118,150	186,773	278,513	100.00
2	Jalalabad	139,149	169,539	217,025	289,231	366,982	85.00
3	Panchlaish	60,969	77,836	99,636	138,091	177,820	60.00
4	Chandgaon	15,761	20,121	26,520	37,573	49,221	10.00
7	West Sholashahar	98,732	108,190	120,101	137,035	151,019	60.00
8	Sulakbahar	7,079	8,624	10,565	13,604	16,553	5.00
9	North Pahartali	5,216	5,829	6,617	7,701	8,700	5.00
Total		388,585	473,904	598,614	810,008	1,048,808	

3.3.6.2 Sewage Service Population

Sewage service population is estimated by multiplying the Sewage Service coverage of each ward to the population projection estimated above.

Table 3-14 Sewage Service Population of Catchment-3 (person)

Ward		Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
1	South Pahartali	-	20,933	49,913	118,426	222,810	
2	Jalalabad	-	127,154	165,590	225,889	293,586	
3	Panchlaish	-	54,485	72,236	105,363	142,256	
4	Chandgaon	-	-	5,304	18,787	39,377	
7	West Sholashahar	-	75,733	87,073	104,558	120,815	
8	Sulakbahar	-	6,037	7,660	10,380	13,242	
9	North Pahartali	-	-	1,323	3,851	6,960	
Total			284,342	389,099	587,254	839,046	

3.4 Wastewater Generation Projection

3.4.1 Introduction

Wastewater generation projection is an important factor that determines the capacity of the sewerage system and it is generated from the households, commercial, institutional and small & large industrial facilities in the project area.

Domestic wastewater from the households and non-domestic wastewater from commercial and institutional is estimated based on the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City. Large industrial wastewater generation is excluded in the planning framework because large industrial factories operate their own effluent treatment plant facility. In this study, wastewater generation factor is planned in the consideration of relevant plans as below.

Table 3-15 Wastewater Generation Factor of Chattogram Sewerage Projects

Category		Unit Dom Water Cons. (Lpcd)	WW Dom Gen. Ratio (%)	Unit Dom WW Gen. (Lpcd)	Peak Factor	Non-Domestic Ratio	Infiltration
Relevant Plans	CWSISP	115	80	92	Babbit Factor 1.33	15% of Unit Dom WW Gen.	15% of (Dom+ Non-Dom)
	Catchment-1 (PESSCM-1)	120	90	108	Daily Max 1.25 Hourly Max1.875	15% of Unit Dom WW Gen.	15% of (Dom+ Non-Dom)
	Catchment-5	120	90	108	Daily Max 1.25 Hourly Max 1.875	15% of Unit Dom WW Gen.	15% of (Dom+ Non-Dom)
	Catchment-2&4	120	90	108	Daily Max 1.25 Hourly Max 1.875	15% of Unit Dom WW Gen.	15% of (Dom+ Non-Dom)
This Study (Catchment-3)		120	90	108	Daily Max 1.25 Hourly Max 1.875	15% of Unit Dom WW Gen.	15% of (Dom+ Non-Dom)

Source: CWSISP & Chattogram Sewerage Project Reports

3.4.2 Domestic Wastewater Generation

3.4.2.1 Unit Domestic Water Consumption

Domestic wastewater defined as wastewater from residential settlements and services, such as houses; and which originates predominantly from toilets, bathrooms and kitchens and it takes charge of most of the wastewater generation in the municipality.

Although unit domestic wastewater generation should be obtained from the field survey, there are practical difficulties to obtain the reasonable data because the sewerage system is not available in the project area. Domestic wastewater generation is closely related to the water consumption, it can be estimated from the related water supply master plan or actual statistics of water supply system, however administration system is just introduced to the CWASA to manage the water consumption data of each household, so actual data is not available yet to apply for this project.

In this study, unit domestic water consumption is planned based on the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City.

As countries develop, it is common for unit water consumption to increase as social living standards improve, however annual increase of unit water consumption in the future was not considered in the relevant plan, so it is also not considered in this study, so it should be reviewed in the water supply master plan.

Table 3-16 Unit Domestic Water Consumption of Relevant Plans (Lpcd)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
CWSISP	115	115	-	-	-	
Catchment-1 (PESSCM-1)	120	120	120	120	120	
Catchment-5	120	120	120	120	120	
Catchment-2&4	120	120	120	120	120	

Table 3-17 Unit Domestic Water Consumption (Lpcd)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Unit Domestic Water Consumption	120	120	120	120	120	

3.4.2.2 Wastewater Generation Ratio

Wastewater generation is estimated by using a percentage of water consumption. It refers to vaporization of used water, discharge to other water systems, and consumption as finished goods with the remaining flowing into the sewerage system. Typical estimate used for wastewater generation is to utilize 90 percent of water consumption as wastewater.

In this study, wastewater generation ratio is planned based on the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City.

Table 3-18 Wastewater Generation Ratio (%)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Wastewater Generation Ratio	90.0	90.0	90.0	90.0	90.0	

3.4.2.3 Unit Wastewater Generation

In the guidelines of the sewerage system master plan (MOE) in Korea, unit wastewater generation should be estimated based on the statistical data of water supply system and water supply system master plan.

In this study, Unit wastewater generation is planned based on the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City due to the lack of statistical data. Unit wastewater generation is estimated by applying the wastewater generation ratio to the unit domestic water consumption as below.

Table 3-19 Unit Wastewater Generation

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Unit Domestic Water Consumption (Lpcd)	120	120	120	120	120	
Wastewater Generation Ratio (%)	90.0	90.0	90.0	90.0	90.0	
Unit Wastewater Generation (Lpcd)	108	108	108	108	108	

3.4.2.4 Peak Factor

Wastewater generation rate usually differs depending on days or hours and those changes are called peak factors. Peak factor is the proportion of the daily maximum flow and hourly maximum flow to the daily average flow. Daily maximum peak factor decides the capacity of sewage treatment plant and hourly maximum peak factor decides sanitary sewer and pumping station.

In general, peak factor is estimated based on the influent flow data & O&M data of existing sewage treatment plant, however there are practical difficulties to obtain the reasonable data because the sewerage system is not available in the project area.

In this study, peak factor is planned based on the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City.

- Daily Maximum: 125% of Daily Average
- Hourly Maximum: 150% of Daily Maximum

Table 3-20 Peak Factor

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Daily Average	1.00	1.00	1.00	1.00	1.00	
Daily Maximum	1.25	1.25	1.25	1.25	1.25	
Hourly Maximum	1.875	1.875	1.875	1.875	1.875	

Unit daily maximum wastewater generation and unit hour maximum wastewater generation is calculated by applying the peak factor to the unit daily average wastewater generation as below.

Table 3-21 Peak Domestic Wastewater Generation (Lpcd)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Daily Average	108	108	108	108	108	
Daily Maximum	135	135	135	135	135	
Hourly Maximum	203	203	203	203	203	

3.4.2.5 Domestic Wastewater Generation

Domestic wastewater generation for each Phase is estimated in the consideration of the sewage service population, Sewage Service coverage, unit water consumption, wastewater generation ratio and the peak factor as below.

Table 3-22 Peak Domestic Wastewater Generation (Lpcd)

Category		Unit	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Population Projection		person	388,585	473,904	598,614	810,008	1,048,808
Sewage Service Coverage		%	-	60.0	65.0	72.5	80.0
Sewage Service Population		person	-	284,342	389,099	587,254	839,046
Unit Water Consumption		Lpcd	120	120	120	120	120
Wastewater Generation Ratio		%	90.0	90.0	90.0	90.0	90.0
Unit Wastewater Generation		Lpcd	108	108	108	108	108
Peak Factor	Daily Avg.	-	1.00	1.00	1.00	1.00	1.00
	Daily Max.	-	1.25	1.25	1.25	1.25	1.25
	Hourly Max.	-	1.875	1.875	1.875	1.875	1.875
Domestic Wastewater Generation (m^3/d)	Daily Avg.	m^3/d	-	30,709	42,023	63,423	90,617
	Daily Max.	m^3/d	-	38,386	52,528	79,279	113,271
	Hourly Max.	m^3/d	-	57,721	78,987	119,213	170,326

3.4.3 Non-Domestic Wastewater Generation

Non-domestic wastewater is generated from commercial, institutional and small & large industrial facilities in the project area. In the guidelines of the sewerage system master plan (MOE) in Korea, non-domestic wastewater generation should be estimated based on the statistical data of water supply system and water supply system master plan.

In this study, non-domestic wastewater generation is planned based on the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City due to the lack of statistical data. Non-domestic wastewater generation is estimated as 15% of domestic wastewater generation.

Table 3-23 Non-Domestic Wastewater Generation (m^3/d)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Daily Average	-	4,606	6,303	9,513	13,593	
Daily Maximum	-	5,758	7,879	11,892	16,991	
Hourly Maximum	-	8,658	11,848	17,882	25,549	

3.4.4 Infiltration

Infiltration is the amount of underground water that enters into the sewers through poor joints, cracked pipes, walls and covers of manholes.

In the water supply system or pressurized sewer, it is not necessary to consider the inflow of groundwater. However, sanitary sewer system is gravity flow and it forms a free water surface underground, if the underground water level is higher than the water level in the sanitary sewer, there is a large amount of infiltration at the pipe joint. It is not easy to estimate the amount of groundwater flowing into a sewage pipe because it varies depending on the size, length, material, connection method, construction condition or age of the pipe, topography and geology, and groundwater level. Sewer pipes are difficult to be absolutely watertight due to their material and structure or construction, so groundwater infiltration is inevitable.

In the guidelines of the sewerage system of Korea, Japan and USA, Design criteria of Infiltration is estimated as below.

Table 3-24 Design criteria of Infiltration

Category		Design Criteria	Remarks
Korea	Design Manual of the Sewerage System	• Less than 20% of the daily maximum wastewater generation	
	Guideline of the Sewerage System Master Plan	• Less than 20% of the daily maximum wastewater generation • 0.2~0.4L/sec per 1km of sanitary sewer • 17,500~36,300L/day/ha on the basis of drainage area	
Japan	Design Manual of the Sewerage System	• 10-20% of the daily maximum wastewater generation	
USA	WEF (Water Environment Federation)	• 71m^3/km·d per km (less than D600mm) • 24~95m3/km·d (more than D600mm)	

In this study, infiltration is assumed to 15% of the daily average domestic & non-domestic wastewater generation without any daily and hourly variation based on the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City.

Table 3-25 Infiltration Ratio (%)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Infiltration Ratio (% of Daily Average)	15.0	15.0	15.0	15.0	15.0	

Table 3-26 Infiltration (m^3/d)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Domestic Infiltration	-	4,606	6,303	9,513	13,593	
Non-Domestic Infiltration	-	691	945	1,427	2,039	
Total	-	5,297	7,248	10,940	15,632	

3.4.5 Overall Wastewater Generation

Overall wastewater generation of the project area is estimated as below.

- In Phase 1, daily average wastewater generation is 55,574m^3/d with the domestic wastewater generation as 42,023m^3/d, non-domestic wastewater generation as 6,303m^3/d and infiltration as 7,248m^3/d in year 2040.
- In Phase 3, daily average wastewater generation is 119,842m^3/d with the domestic wastewater generation as 90,617m^3/d, non-domestic wastewater generation as 13,593m^3/d and infiltration as 15,632m^3/d in the final target year 2070.

Table 3-27 Overall Wastewater Generation (m^3/d)

Category		Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Domestic	Daily Avg.	-	30,709	42,023	63,423	90,617	
	Daily Max.	-	38,386	52,528	79,279	113,271	
	Hourly Max.	-	57,721	78,987	119,213	170,326	
Non-Domestic	Daily Avg.	-	4,606	6,303	9,513	13,593	
	Daily Max.	-	5,758	7,879	11,892	16,991	
	Hourly Max.	-	8,658	11,848	17,882	25,549	
Infiltration	Daily Avg.	-	5,297	7,248	10,940	15,632	
	Daily Max.	-	5,297	7,248	10,940	15,632	
	Hourly Max.	-	5,297	7,248	10,940	15,632	
Total	Daily Avg.	-	40,612	55,574	83,876	119,842	
	Daily Max.	-	49,441	67,655	102,111	145,894	
	Hourly Max.	-	71,676	98,083	148,035	211,507	

Table 3-28 Overall Wastewater Generation by Ward as Daily Maximum (m^3/d)

Ward		Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
1	South Pahartali	-	2,990	7,129	16,914	31,825	
2	Jalalabad	-	18,161	23,651	32,263	41,933	
3	Panchlaish	-	7,782	10,317	15,049	20,319	
4	Chandgaon	-	-	758	2,683	5,624	
7	West Sholashahar	-	10,817	12,436	14,934	17,256	
8	Sulakbahar	-	862	1,094	1,483	1,891	
9	North Pahartali	-	-	189	550	994	
Total		-	40,612	55,574	83,876	119,842	

3.4.6 Faecal Sludge Production

In this study, it is planned to introduce the sewerage system to five wards in priority where current water service coverage under CWASA is available out of seven wards in Catchment-3 in the consideration of project budget. Sewage Service coverage of the Catchment-3 is 0% at the end of 2022 and is planned to achieve 60.0% by 2030 after completion of the project and to achieve 80.0% by 2070 in the final target year.

This study proposes a concept for faecal sludge management in order to cope with the coming challenges connected to the rapid growth of the project area. Part of the concept includes the use of on-site system in low density urban areas of Chattogram City, Hathazari and Raozan where the installation of piped sewerage would not be cost effective as reviewed in the Sewage Serving option.

3.4.6.1 Population with On-Site System

Population with on-site system is estimated based on Sewage Service coverage of the project area in the above chapter. It is assumed that all the households, commercial, institutional facilities that are not connected to a centralized sewerage system will use on-site systems. These areas will remain as on-site system until the centralized system is introduced.

Table 3-29 Population with On-Site System (person)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Chattogram City	388,585	189,562	209,515	222,754	209,762	
Hathazari Upazila Paurashava	94,244	114,827	146,988	195,892	248,552	
Raozan Upazila Paurashava	70,701	96,018	130,299	200,054	283,433	
Total	553,530	400,407	486,802	618,700	741,747	

3.4.6.2 Unit Faecal Sludge Production

Unit faecal sludge production is the amount generated per person for one year and it should be calculated by considering the change in the amount of change depending on dietary habits, toilet structure, climate and living standards. Unit faecal sludge production is planned as below in the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP).

Table 3-30 Unit Faecal Sludge Production of CWSISP

Year	Projected Population	Unit Faecal Sludge Production (Liter/capita·year)	Faecal Sludge Production Yearly (m^3/year)	Faecal Sludge Production Daily (m^3/d)
2020	3,111,125	70	217,779	596
2030	3,730,950	70	261,166	715

In this study, unit faecal sludge production is planned based on the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City.

Table 3-31 Unit Faecal Sludge Production (Liter/capita·year)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Unit Faecal Sludge Production	70	70	70	70	70	

3.4.6.3 Faecal Sludge Production

Faecal sludge production is estimated considering the population with on-site system and unit faecal sludge production of the project area. In Phase 1 as of year 2040, faecal sludge production is 93m^3/d and in Phase 3 as of the final target year 2070, faecal sludge production is 142m^3/d.

Although low-density area of Chattogram City and sub-urban area such as Hathazari and Raozan is planned using the on-site system until the final target year 2070, centralized sewerage system can be introduced as the project area develops. In this study, capacity of faecal sludge treatment plant is planned as 100m^3/d for the Phase 1 and future expansion plan for the Phase 2&3 have to be established based on the actual faecal sludge collection and O&M status of FSTP.

Table 3-32 Faecal Sludge Production

Category		Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Annual (m^3/year)	CCC	27,201	13,269	14,666	15,593	14,683	
	Hathazari	6,597	8,038	10,289	13,712	17,399	
	Raozan	4,949	6,721	9,121	14,004	19,840	
	Total	38,747	28,028	34,076	43,309	51,922	
Daily (m^3/d)	CCC	75	36	40	43	40	
	Hathazari	18	22	28	38	48	
	Raozan	14	18	25	38	54	
	Total	107	76	93	119	142	
Capacity of FSTP (m^3/d)		100	100	100	100	100	

3.5 Wastewater Characteristic

Influent Quality is an important factor to determine the capacity of the sewage treatment plant, sewerage treatment process and treatment efficiency and it is estimated based on wastewater characteristics of the domestic wastewater and non-domestic wastewater of the project area.

3.5.1 Specific Loads

Wastewater is generated from the households, commercial, institutional and industrial facilities in the project area. Domestic wastewater defined as wastewater from residential settlements and services, such as houses; and which originates predominantly from toilets, bathrooms and kitchens and wastewater quality varies on the living standards of the project area. Non-domestic waster varies on the characteristics of the commercial, institution and industrial facilities, however wastewater quality is considered as equal to the domestic wastewater quality.

In this study, Influent Quality to the sewage treatment plant is decided based on the relevant plan such as Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP) and the on-going sewerage projects of Chattogram City and relative design manual of Korea, Japan and USA.

Table 3-33 Specific Loads (gpcd)

Category		BOD	COD	SS	T-N	T-P
Korea	Sewerage System Master Plan of Greater Seoul City (2018)	51.98	26.42	40.63	13.69	1.50
	Sewerage System Master Plan of Greater Daejeon City (2017)	50.0	30.0	55.0	10.2	1.55
Others	Wastewater Engineering (Metcalf & Eddy)	81.65	-	90.72	12.25	3.63
	Japan Design Manual of Sewerage System	39.0	18.0	23.0	3.00	0.30
	WEF Design Manual	80.0	190.0	90.0	13.00	3.20
CCC	Catchment-1 (PESSCM-1)	45.0	-	60.0	9.5	1.8
	Catchment-5	40.0	80.0	48.0	4.0	0.6
	Catchment-2&4	40.0	80.0	48.0	4.0	0.6
Dhaka	DBO of Pagla STP (2019)	40.0	86.0	46.0	7.0	-

Table 3-34 Specific Loads of This Study (gpcd)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
BOD	40.0	40.0	40.0	40.0	40.0	
COD	80.0	80.0	80.0	80.0	80.0	
SS	48.0	48.0	48.0	48.0	48.0	
T-N	9.5	9.5	9.5	9.5	9.5	
T-P	1.8	1.8	1.8	1.8	1.8	

3.5.2 Population Equivalent

Population equivalent is applied for the estimation of specific wastewater loads. Sewage service population is applied for the domestic wastewater load and ratio of non-domestic wastewater to the domestic wastewater is applied for the non-domestic wastewater load.

Table 3-35 Population Equivalent (P·E)

Category	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Domestic Population Equivalent	-	284,342	389,099	587,254	839,046	
Non-Domestic Population Equivalent	-	42,652	58,363	88,089	125,859	
Total	-	326,994	447,462	675,343	964,905	

3.5.3 Influent Quality

Influent Quality to the sewage treatment plan is estimated considering the specific loads and population equivalent with overall wastewater generation of the project area as below.

Table 3-36 Influent Quality of This Study

Category		Unit	Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Overall Wastewater Generation	Domestic	m^3/d	30,709	42,023	63,423	90,617	
	Non-Domestic	m^3/d	4,606	6,303	9,513	13,593	
	Infiltration	m^3/d	5,297	7,248	10,940	15,632	
	Total	m^3/d	40,612	55,574	83,876	119,842	
Population Equivalent	Domestic	P·E	284,342	389,099	587,254	839,046	
	Non-Domestic	P·E	42,652	58,363	88,089	125,859	
	Total	P·E	326,994	447,462	675,343	964,905	
Unit Specific Loads	BOD	gpcd	40.0	40.0	40.0	40.0	
	COD	gpcd	80.0	80.0	80.0	80.0	
	SS	gpcd	48.0	48.0	48.0	48.0	
	T-N	gpcd	9.5	9.5	9.5	9.5	
	T-P	gpcd	1.8	1.8	1.8	1.8	
Total Loads	BOD	kg/d	13,080	17,898	27,014	38,596	
	COD	kg/d	26,160	35,797	54,027	77,192	
	SS	kg/d	15,696	21,478	32,416	46,315	
	T-N	kg/d	3,106	4,251	6,416	9,167	
	T-P	kg/d	589	805	1,216	1,737	
Influent Quality	BOD	mg/L	322	322	322	322	
	COD	mg/L	644	644	644	644	
	SS	mg/L	386	386	386	386	
	T-N	mg/L	76	76	76	76	
	T-P	mg/L	15	14	14	14	

In this study, influent quality is planned in consideration of on-going sewerage projects, related master plans and water quality survey. Since currently there is no sewage treatment in operation in the project area, influent quality is estimated based on the on-going sewerage project. Influent quality should be re-evaluated with actual O&M status of Catchment-1 STP when it is in operation.

Table 3-37 Influent Quality of Relevant Plans (mg/L)

Category	Catchment 1 (PESSCM 1)	Catchment 5	Catchment 2&4	Catchment 3 (This project)
BOD	340	302	310	322
COD	756	605	-	644
SS	454	363	370	386
T-N	72	30	31	76
T-P	14	4	5	15

4 Technical Feasibility Analysis

4.1 Introduction

4.1.1 Introduction

Technical feasibility of the project analyses a basic plan of the sewerage system in accordance with the planning framework prior to implementing the EDCF project and analyze whether impletion of the project is technically feasible or not.

4.1.2 Project Scope

The following conditions are considered preferentially to maximize the effects of the project.

- To place on the priority to improve the current sanitation situation of Chattogram City, Hathajari Upazila and Raozan Upazila.
- To set up the foundation of sewerage system of the project areas considering the future expansion.

Table 4-1 Project Scope

Category	Scope
Project Area	• 7 wards in Catchment-3 of Chattogram City Corporation • Hathazari Upazila & Raozan Upazila
Sewerage System	• Sewage Treatment Plant, Q=60,000m³/d (Daily Average) • Faecal Sludge Treatment Plant, Q=100m³/d • Sanitary Sewer, D200~1,600mm, L=58.3km • Household Connection, 10,000nos. • Operation & Maintenance Vehicles (Faecal sludge collection vehicles and O&M Vehicles, etc.)
Capacity Building	• Commissioning & Training • O&M Support after Construction Completion (2 years)
Consulting Service	• Detailed Design & Bidding Support • Construction Supervision

Note) The project scope is subject to change in according to the consultation between KEXIM and the project executing agency (CWASA).

Table 4-2 Project Scope and R&R

Category		EDCF	GOB
Works	Construction	• Sewage Treatment Plant, Q=60,000m³/d (Daily Average) • Faecal Sludge Treatment Plant, Q=100m³/d • Sanitary Sewer, D200~1,600mm, L=58.3km • Operation & Maintenance Vehicles (Faecal sludge collection vehicles and O&M Vehicles, etc.)	• Household Connection: 10,000nos.
	Capacity Building	• Commissioning & Training • O&M Support after Construction Completion (2 years)	
Consulting Service		• Detailed Design & Bidding Support • Construction Supervision	
Contingencies		• Physical Contingencies • Price Contingencies	
Taxes and Duties			• VAT • AIT • Custom Duties
Land Acquisition & Resettlement Cost			• Land Acquisition Cost • Resettlement Cost
Project Management Cost			• PMU Operating Cost
EDCF Service Charge		• EDCF Service Charge	

4.1.3 Specific Request from PEA

There is specific request from PEA regarding household connection financing support, reserve facilities for sludge treatment, reduction of O&M cost. The Consultant have discussed with KEXIM and PEA during feasibility study, it is summarized as below.

Table 4-3 Specific Request from PEA

Category	Request from PEA	Review
Household Connection Financing	• Insufficient financial resources of GOB for household connection construction, financing support from EDCF loan is requested.	• Household connection is planned as GOB portion in FS, the procurement method will be decided to select the contractor during the detailed design stage.
Reserve Facilities for Sludge Treatment	• Reserve facilities for sludge treatment such as sludge drying bed, faecal sludge treatment plant, sludge cake storage facility can be an option to reduce the O&M cost of STP in dry season.	• Reserve facilities for sludge treatment are not included in the project scope because the construction cost is about 12 million USD, so the initial investment cost is excessive.
Reduction of O&M cost	• O&M cost is a burden to PEA after project completion.	• Energy efficient equipment & power control system are considered • Biogas power generation (Phase 2) & Solar power generation (Phase 1) is planned as a renewable energy source for energy self-sufficient plant.

4.2 Sewage Treatment Plant

4.2.1 Introduction

In this project, a sewage treatment plant is planned in accordance with the following basic directions to prevent water pollution in public waters, to reduce the pollution due to urban development, and to implement a reasonable long-term plan until 2070 as the final target year.

- Analysis of planning framework such as planned population, wastewater generation, influent quality and establishment of phase plan
- Set up of effluent quality by reviewing the standard sewage discharge and other sewage project of GOB

4.2.2 Phase Plan of Sewage Treatment Plant

4.2.2.1 Introduction

Sewage treatment plant is a part of the sewerage system that is the basis of urban life, and once they are constructed, it is difficult to rehabilitate. Therefore, long term phase plan should be established in consideration of the overall plan based on the target year of 2070

In particular, for the phase plan of sewage treatment plant should be determined reasonably according to the annual progress of sanitary sewer construction the amount of influent quantity by the target year and financial conditions.

4.2.2.2 Phase Plan

This project plans to construct a sewage treatment plant with a capacity of 60,000m^3/d to treat the wastewater generated in the project area for the Phase 1 in target year 2040. Phase plan of the second and third phase is also established to treat the wastewater for the final target year 2070.

- Phase 1: Construction of STP with a capacity of 60,000m^3/d
- Phase 2: Expansion of STP with a capacity of 30,000m^3/d
- Phase 3: Expansion of STP with a capacity of 30,000m^3/d

Table 4-4 Phase Plan of Sewage Treatment Plant (m^3/d)

Category		2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Wastewater Generation (Daily Average)		40,612	55,574	83,876	119,842
STP Capacity	Daily Avg.	60,000	60,000	90,000	120,000
	Daily Max.	75,000	75,000	115,000	150,000
Expansion Capacity		-	-	30,000	30,000
Balance		19,388	4,426	6,124	158

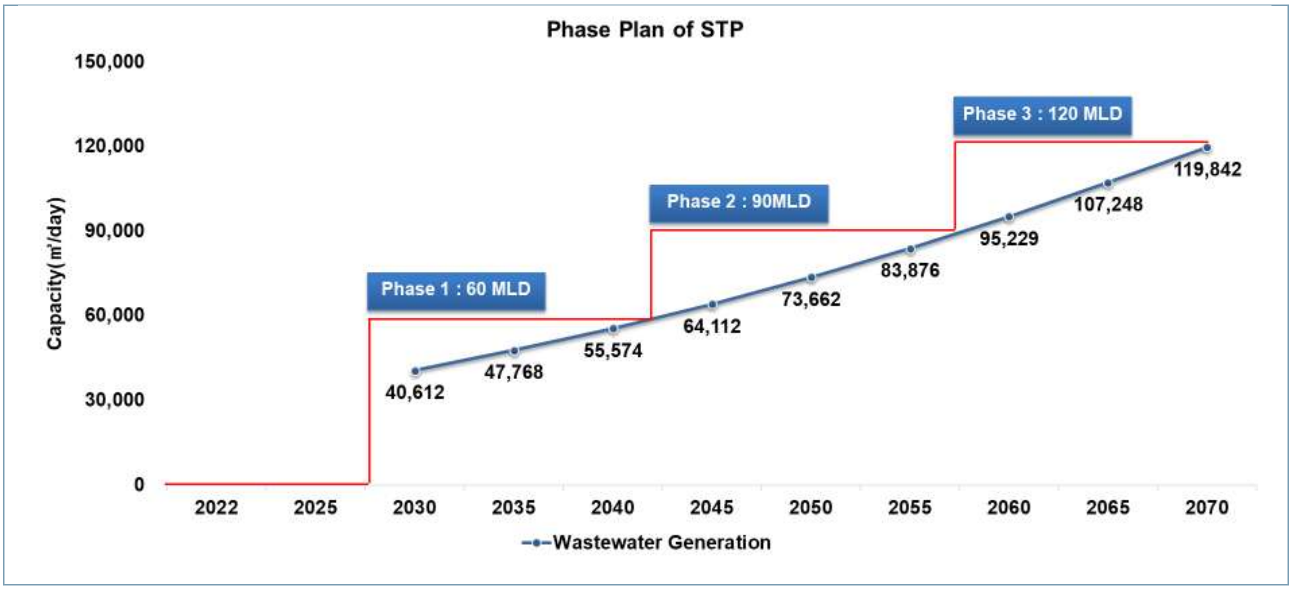


Figure 4-1 Phase Plan of Sewage Treatment Plant

4.2.3 Treatment Process of Sewage Treatment Plant

4.2.3.1 Introduction

Treatment process of sewage treatment plant is operated in close relationship with each other. In addition, since it is a basic urban facility, it is difficult to rehabilitate after construction and the derivative effect lasts for a long time, so it should be a treatment plant with good efficiency, high safety, and economically advantageous treatment process.

In this plan, treatment process of sewage treatment plant is established in consideration of the following items, such as planned influent quality, effluent quality standards, treatment performance stability, operation & maintenance, economic feasibility and environmental impact.

- Wastewater generation and Wastewater Influent Quality
- Effluent quality considering legal standard
- Easiness of operation and maintenance
- Suitable to local conditions
- Stable treatment efficiency
- Economic feasibility of construction cost and O&M cost

4.2.3.2 Influent & Effluent Quality

4.2.3.2.1 Influent Quality

The Influent Quality is a design factor that serves as a standard for sewage treatment plant planning, such as treatment method and efficiency, and is calculated by considering the unit load within the sewage service coverage. In this feasibility study, it is planned in consideration of on-going sewerage projects, related master plans and water quality survey.

Table 4-5 Influent Quality (mg/L)

Category	Catchment 1 (PESSCM 1)	Catchment 5	Catchment 2&4	Catchment 3 (This project)
BOD	340	302	310	322
COD	756	605	-	644
SS	454	363	370	386
T-N	72	30	31	76
T-P	14	4	5	15

4.2.3.2.2 Target Effluent Quality

The Bangladesh Department of Environment (DoE) established the standard Sewerage discharge in 1997 and revised the standard in March 2023. Bangladesh mainly have regulated the removal of SS and BOD, COD contained in the wastewater and the discharge standards have been strengthened recently to remove T-N and T-P to prevent eutrophication in the public water body. In the Catchment-1 project, which is under construction, a target effluent water quality was set up as stronger than the effluent standard. In this feasibility study, target effluent quality is set up in consultation with PMU as follows.

Table 4-6 Target Effluent Quality

Category	Unit	Standard Sewage Discharge		Target Effluent Quality	
		1997	2023	Catchment 1	Catchment 3
Temperature	℃	30	30	24	24
pH	-	-	6-9	6-9	6-9
BOD	mg/L	40	30	20	20
COD	mg/L	-	125	100	100
SS	mg/L	100	100	30	30
Oil and Grease	mg/L	-	10	-	-
NO3-N	mg/L	250	50	40 as T-N	40 as T-N
PO4-P	mg/L	35	15	10 as T-P	10 as T-P
Coliform	CFU/100mL	1000	1000	1000	1000

*Source: Standard Sewerage discharge in the Environment Conservation Rules (1997&2023, DOE)

4.2.3.3 Sewage Treatment Process

4.2.3.3.1 Unit Process

Sewage treatment plant is a comprehensive facility combining unit processes, and consists of sewage treatment process and sludge treatment process. It is planned considering the function and purpose of each unit process.

- The target year for the inlet sewer to the STP is set up as 2070, so civil structure of pre-treatment & inlet pumping station is planned to cater the influent wastewater for the Phase 3 and mechanical, electrical/instrumentation facilities are planned for the Phase 1.
- A2O process is applied as advanced sewage treatment process to comply with the target effluent quality.
- Sludge stabilization process (anaerobic digestion) is planned to be introduced in Phase 2 in the consideration of the difficulty of O&M.
- Primary sedimentation tank is planned to be introduced in Phase 2 with the sludge stabilization process in the consideration of the high concentration of organics in the raw sludge
- Faecal sludge is planned to treat with sewage sludge after pre-treatment and thickening.
- Actual O&M status of Phase 1 should be analyzed when the expansion of Phase 2 & Phase 3 of sewage treatment plant is implemented.

Table 4-7 Unit Process of Sewage Treatment Plant

Facility		Function	Unit Process	Phase 1	Phase 2	Phase 3
Sewage Treatment Process	Pre-Treatment & Inlet Pumping Station	• Pre-treatment, equalization, securing hydraulic stability	• Screen & grit removal • inlet pumping station, equalization tank	◎	◎	◎
	1st Treatment	• Reduce the load of the secondary treatment process	• Primary sedimentation tank	-	◎	◎
	2nd Treatment	• Removal of organic and nutrients	• Bioreactor, secondary sedimentation tank	◎	◎	◎
	3rd Treatment	• Removal of pathogens	• Disinfection facility	◎	◎	◎
Sludge Treatment Process	Thickening	• Reduction of the sludge volume	• Thickening facility	◎	◎	◎
	Stabilization	• Reduction of the potential for odour generation and pathogens	• Anaerobic digestion	-	◎	◎
	Dewatering	• Reduction of the sludge volume	• Dewatering facility	◎	◎	◎
Faecal Sludge Treatment Process	Pre-Treatment	• Pre-treatment, equalization	• Screen & grit removal	◎	◎	◎
	Thickening	• Weight reduction for load reduction in subsequent processes	• Thickening facility	◎	◎	◎
Odour control		• Removal of odour from sewage & sludge treatment process	• Odour control facility	◎	◎	◎

A2O process is applied as advanced sewage treatment process to remove the organics and nutrients to comply with the target effluent quality. Sewage treatment process is selected as per the consultation with CWASA in the consideration of on-going sewage projects in Chattogram and it is subject to change during the detailed design stage.

Table 4-8 Unit Process of On-going Sewerage Projects

Category	STP Site	Capacity (m^3/d)	Sewage treatment 1st	Sewage treatment 2nd	Sewage treatment 3rd	Sludge treatment Thickening	Sludge treatment Stabilization	Sludge treatment Dewatering	Odour Control
Catchment-1 (PESSCM-1)		100,000							
Catchment-5	Halishahar	100,000 (50,000)	Primary Sedimentation (Phase 2)	A2O	Not applied (Due to Coastal discharge)	Mechanical thickening	Aerobic Digestion (Phase 1) Anaerobic Digestion (Phase 2)	Mechanical dewatering	Micro organism
Catchment-6		100,000							
Catchment-2&4	Kalurghat	300,000 (60,000)	Primary Sedimentation (Phase 2)	A2O	Chlorine disinfection	Mechanical thickening	Anaerobic Digestion (Phase 2)	Mechanical dewatering	Soil filter
Catchment-3	Fatehabad	120,000 (60,000)	Primary Sedimentation (Phase 2)	A2O	Chlorine disinfection	Mechanical thickening	Anaerobic Digestion (Phase 2)	Mechanical dewatering	Chemical Cleaning Tower

4.2.3.3.2 Facility of Sewage Treatment Plant

This project plans to construct a sewage treatment facility with a capacity of 60,000m³/d to treat the wastewater generated in the project area for the Phase 1 (2040). Phase plan of the second and third phase is also established to treat the wastewater for the final target year (2070).

Table 4-9 Facility of Sewage Treatment Plant

Facility			Item	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Sewage Treatment Process	Pre-Treatment		Type	Coarse Screen + Vortex Grit Removal + Fine Screen		
			Spec.	D4.1m x H3.3m x 2	D4.1m x H3.3m x 3	D4.1m x H3.3m x 4
	Inlet Pumping Station		Type	Submersible Mixed Flow Pump		
			Spec.	31.3m³/min x 2(1) 15.6m³/min x 2	31.3m³/min x 4(2) 15.6m³/min x 2	31.3m³/min x 4(2) 15.6m³/min x 4
	Primary Sedimentation Tank		Type	-	Rectangular Tank	
			Spec.	-	W7.0m x L35.0m x H3.5m x 3	W7.0m x L35.0 x H3.5m x 4
	Biological Reactor	Anaerobic Reactor	Type	Rectangular Tank		
			Spec.	W14.4m x L18.0m x H5.0m x 4	W14.4m x L18.0m x H5.0m x 6	W14.4m x L18.0m x H5.0m x 8
		Anoxic Reactor	Type	Rectangular Tank		
			Spec.	W14.4m x L22.0m x H5.0 x 4	W14.4m x L22.0m x H5.0 x 6	W14.4m x L22.0m x H5.0 x 8
		Aerobic Reactor	Type	Rectangular Tank		
			Spec.	W14.4m x L90.0 x H5.0m x 4	W14.4m x L90.0 x H5.0m x 6	W14.4m x L90.0 x H5.0m x 8
	Second Sedimentation Tank		Type	Gravity Circular Tank		
			Spec.	D30.0m x H3.5m x 4	D30.0m x H3.5m x 6	D30.0m x H3.5m x 8
	Disinfection Facility		Type	Chlorine Disinfection		
			Spec.	W3.0m x L25.0m x H3.0m x 4	W3.0m x L25.0m x H3.0m x 6	W3.0m x L25.0m x H3.0m x 8
Sludge Treatment Process	Thickening Facility		Type	Mechanical Thickening		
			Spec.	70m³/hr x 4	70m³/hr x 6	70m³/hr x 8
	Stabilization Facility		Type	-	Anaerobic Mesophilic Digestion	
			Spec.	-	Acid Phase D7.0m x H10.0m x 3 Methane Phase D20.5m x H16.0m x 3	Acid Phase D7.0m x H10.0m x 4 Methane Phase D20.5m x H16.0m x 4
	Dewatering Facility		Type	Mechanical Dewatering		
			Spec.	30m³/hr x 2	30m³/hr x 3	30m³/hr x 4
Faecal Sludge Treatment Process	Pre-treatment		Type	Comprehensive Pre-Treatment Equipment		
			Spec.	50m³/hr x 2(1)	50m³/hr x 2(1)	50m³/hr x 2(1)
	Thickening Facility		Type	Mechanical Thickening		
			Spec.	3m³/hr x 2	3m³/hr x 2	3m³/hr x 2
Odour Control Facility			Type	Chemical Cleaning Tower		
			Spec.	500m³/min x 3	500m³/min x 4	500m³/min x 5

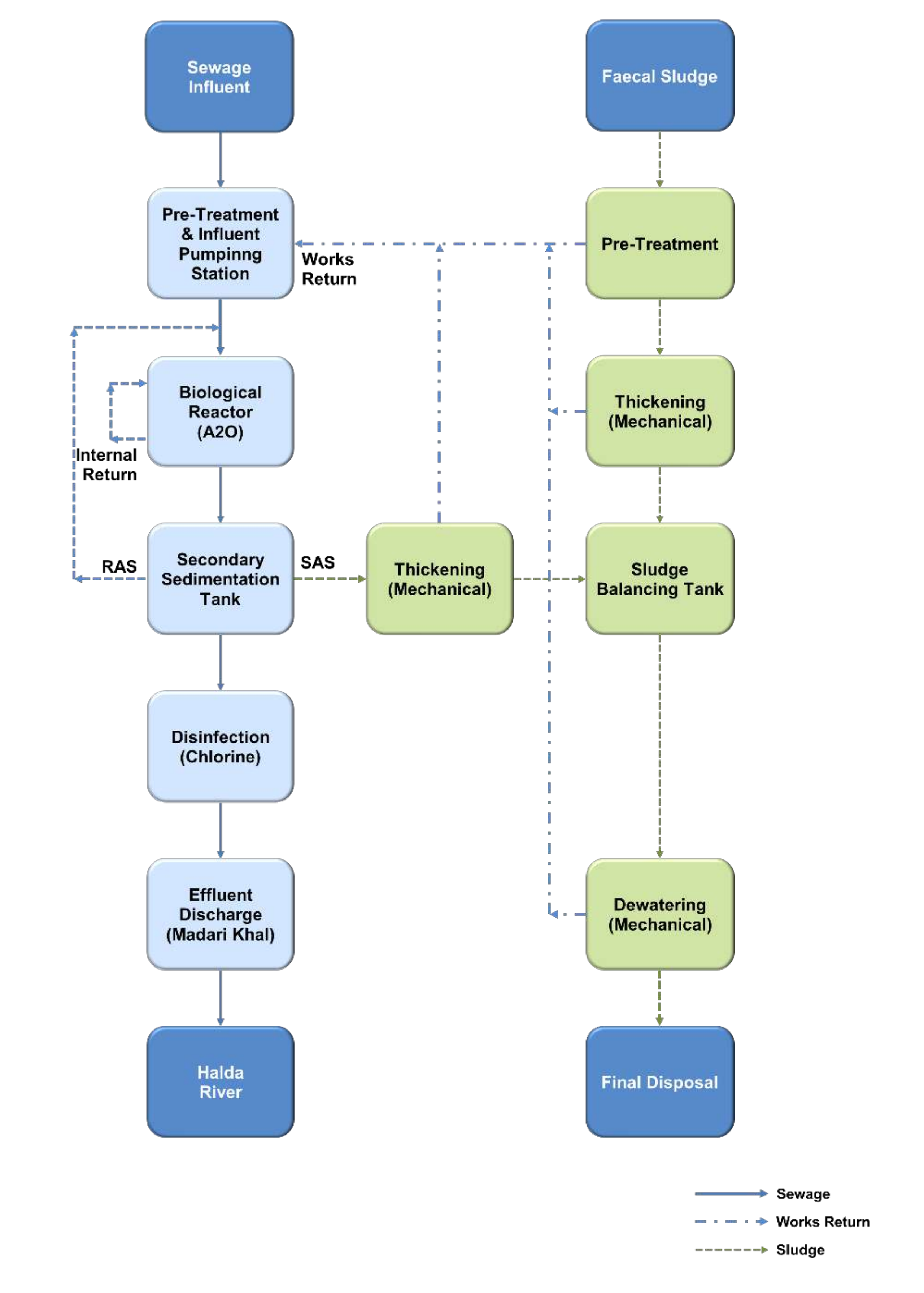


Figure 4-2 Process Flow Diagram of Phase 1

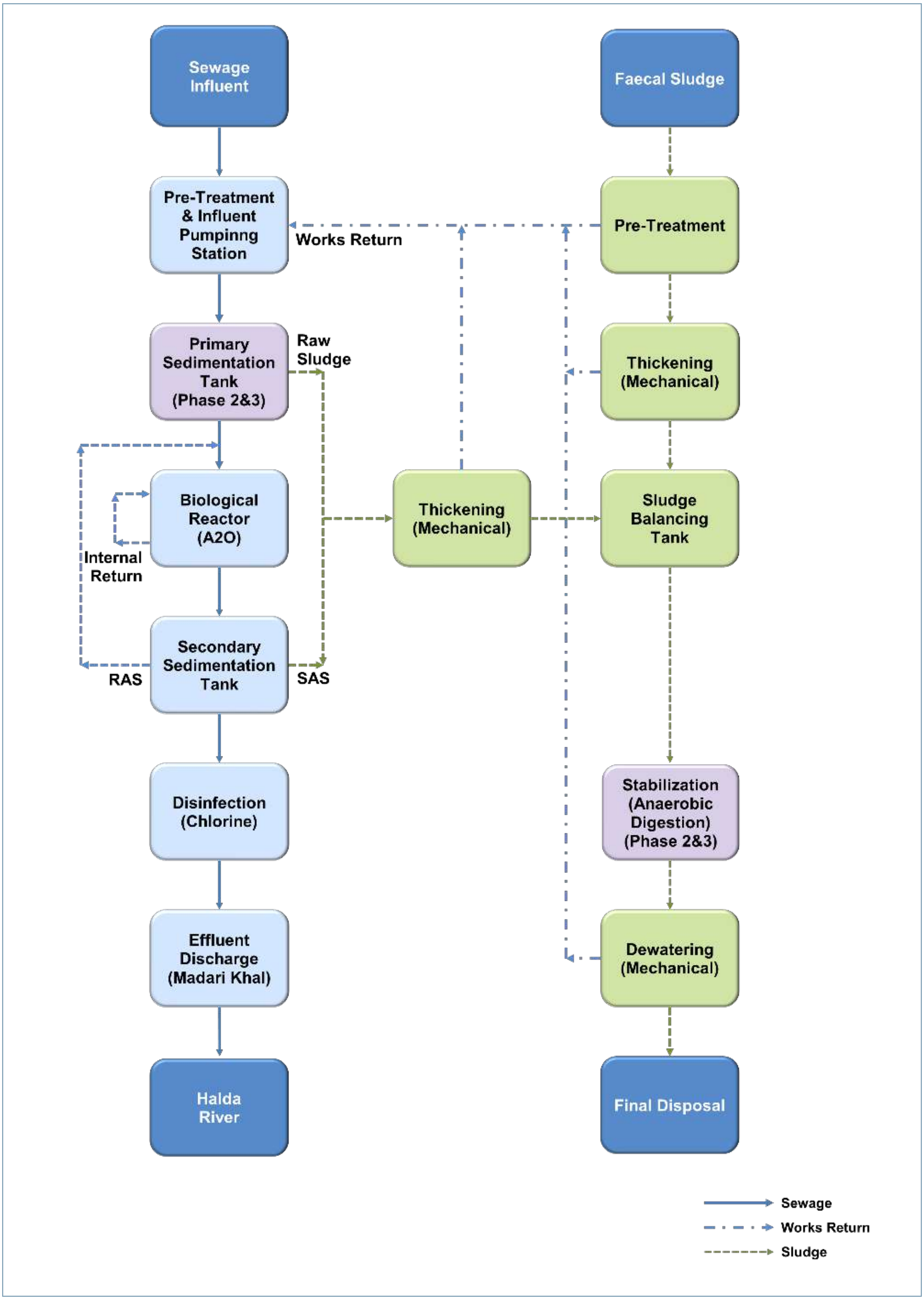


Figure 4-3 Process Flow Diagram of Phase 2&3

4.2.3.3.3 Mass Balance

In this feasibility study, a facility plan is established by STP process calculations for each phase. Actual O&M status of Phase 1 should be analyzed when the expansion of Phase 2 & Phase 3 of sewage treatment plant is implemented.

Table 4-10 Mass Balance of Sewage Treatment Process

Category		Q (m^3/d)	BOD		COD		SS		T-N		T-P	
			Load (kg/d)	Quality (mg/L)	Load (kg/d)	Quality (mg/L)	Load (kg/d)	Quality (mg/L)	Load (kg/d)	Quality (mg/L)	Load (kg/d)	Quality (mg/L)
Sewage Influent	Phase1	75,000	24,150	322.0	48,300	644.0	28,950	386.0	5,700	76.0	1,050	14.0
	Phase2	112,500	36,225	322.0	72,450	644.0	43,425	386.0	8,550	76.0	1,575	14.0
	Phase3	150,000	48,300	322.0	96,600	644.0	57,900	386.0	11,400	76.0	2,100	14.0
Primary Sedimentation	Phase1	-	-	-	-	-	-	-	-	-	-	-
	Phase2	116,497	38,541	330.8	78,160	670.9	49,723	426.8	9,102	78.1	1,721	14.8
	Phase3	155,286	51,329	330.5	104,022	669.9	66,203	426.3	12,130	78.1	2,293	14.8
Biological Reactor	Phase1	78,275	25,706	328.4	52,295	668.1	33,064	422.4	6,172	78.8	1,186	15.2
	Phase2	115,378	26,979	233.8	54,712	474.2	27,348	237.0	8,192	71.0	1,549	13.4
	Phase3	153,797	35,930	233.6	72,186	473.5	36,412	236.8	10,917	71.0	2,064	13.4
Secondary Sedimentation	Phase1	74,979	1,500	20.0	7,498	100.0	2,249	30.0	2,999	40.0	750	10.0
	Phase2	112,455	2,249	20.0	11,246	100.0	3,374	30.0	4,498	40.0	1,125	10.0
	Phase3	149,909	2,998	20.0	14,991	100.0	4,497	30.0	5,996	40.0	1,499	10.0
Treated Effluent	Phase1	74,979	1,500	20.0	7,498	100.0	2,249	30.0	2,999	40.0	750	10.0
	Phase2	112,455	2,249	20.0	11,246	100.0	3,374	30.0	4,498	40.0	1,125	10.0
	Phase3	149,909	2,998	20.0	14,991	100.0	4,497	30.0	5,996	40.0	1,499	10.0
Works Return (Sewage)	Phase1	2,703	923	341.5	2,370	853.7	2,637	975.6	316	117.1	92	34.1
	Phase2	3,012	1,975	655.6	4,391	1,457.7	4,576	1,519.1	372	123.4	99	32.9
	Phase3	4,008	2,629	655.9	5,842	1,457.8	6,090	1,519.6	495	123.4	132	32.9
Works Return (Faecal sludge)	Phase1	55	150	2,727.3	448	8,141.8	200	3,636.4	9	163.6	2	27.3
	Phase2	55	150	2,727.3	448	8,141.8	200	3,636.4	9	163.6	2	27.3
	Phase3	55	150	2,727.3	448	8,141.8	200	3,636.4	9	163.6	2	27.3
Dewatering Return (Faecal sludge)	Phase1	517	483	933.8	1,240	2,397.9	1,277	2,469.1	146	283.2	42	81.6
	Phase2	930	191	205.6	871	936.5	1,522	1,636.8	171	184.2	45	48.7
	Phase3	1,224	250	204.3	1,132	925.1	2,014	1,645.3	227	185.2	60	49.0
Total Return	Phase1	3,275	1,556	475.1	3,995	1,219.9	4,114	1,256.1	472	144.1	136	41.5
	Phase2	3,997	2,316	579.4	5,710	1,428.4	6,298	1,575.6	552	138.1	146	35.5
	Phase3	5,286	3,029	572.9	7,422	1,404.1	8,303	1,570.7	730	138.1	193	36.6

Table 4-11 Mass Balance of Sludge Treatment Process

Category		Q (m^3/d)	BOD		COD		SS		T-N		T-P	
			Load (kg/d)	Quality (mg/L)	Load (kg/d)	Quality (mg/L)	Load (kg/d)	Quality (mg/L)	Load (kg/d)	Quality (mg/L)	Load (kg/d)	Quality (mg/L)
Raw Sludge	Phase1	-	-	-	-	-	-	-	-	-	-	-
	Phase2	1,119	11,562	10,334.8	23,448	20,958.6	22,375	20,000.0	910	813.6	172	153.8
	Phase3	1,490	15,399	10,337.6	31,207	20,950.1	29,791	20,000.0	1,213	814.3	229	154.0
Surplus Sludge	Phase1	3,296	9,229	2,800.0	23,073	7,000.0	26,369	8,000.0	3,164	960.0	923	280.0
	Phase2	2,923	8,184	2,800.0	20,461	7,000.0	23,384	8,000.0	2,806	960.0	818	280.0
	Phase3	3,888	10,887	2,800.0	27,217	7,000.0	31,105	8,000.0	3,733	960.0	1,089	280.0
Mixed Sludge	Phase1	-	-	-	-	-	-	-	-	-	-	-
	Phase2	4,042	19,747	4,885.6	43,909	10,863.8	45,759	11,321.6	3,716	919.5	991	245.1
	Phase3	5,378	26,285	4,887.6	58,423	10,864.1	60,896	11,323.9	4,946	919.7	1,318	245.1
Thickened Sludge (Sewage)	Phase1	593	8,306	14,000.0	20,766	35,000.0	23,732	40,000.0	2,848	4,800.0	831	1,400.0
	Phase2	1,030	17,772	17,261.3	39,518	38,382.4	41,183	40,000.0	3,345	3,248.5	89	865.9
	Phase3	1,370	23,657	17,265.6	52,581	38,375.7	54,807	40,000.0	4,451	3,248.5	1,186	865.7
Faecal Sludge	Phase1	100	1,500	15,000.0	4,478	44,780.0	2,000	20,000.0	90	900.0	15	150.0
	Phase2	100	1,500	15,000.0	4,478	44,780.0	2,000	20,000.0	90	900.0	15	150.0
	Phase3	100	1,00	15,000.0	4,478	44,780.0	2,000	20,000.0	90	900.0	15	150.0
Thickened Sludge (Faecal sludge)	Phase1	45	1,350	30,000.0	4,030	89,560.0	1,800	40,000.0	81	1,800.0	14	300.0
	Phase2	45	1,350	30,000.0	4,030	89,560.0	1,800	40,000.0	81	1,800.0	14	300.0
	Phase3	45	1,350	30,000.0	4,030	89,560.0	1,800	40,000.0	81	1,800.0	14	300.0
Thickened Sludge Storage	Phase1	638	9,656	15,128.0	24,796	38,846.5	25,532	40,000.0	2,929	4,588.5	844	1,322.5
	Phase2	1,075	19,122	17,794.7	43,548	40,525.5	42,983	40,000.0	3,426	3,187.9	905	842.2
	Phase3	1,415	25,007	17,670.5	56,611	40,003.3	56,607	40,000.0	4,532	3,202.5	1,200	847.7
Stabilization (Anaerobic)	Phase1	-	-	-	-	-	-	-	-	-	-	-
	Phase2	1,075	3,824	3,558.9	17,419	16,210.2	30,443	28,330.4	3,426	3,187.9	905	842.2
	Phase3	1,415	5,001	3,534.1	22,645	16,001.3	40,273	28,457.9	4,532	3,202.5	1,200	847.7
Dewatering Cake	Phase1	121	9,173	75,640.0	23,556	194,232.3	24,255	200,000.0	2,782	22,942.5	802	6,612.3
	Phase2	145	3,633	25,124.6	16,548	114,436.9	28,921	200,000.0	3,254	22,505.0	860	5,945.2
	Phase3	191	4,751	24,837.4	21,512	112,456.0	38,259	200,000.0	4,305	22,506.8	1,140	5,957.9

4.2.3.4 Proposed Site of STP

4.2.3.4.1 Introduction

Conditions of site, current status of public water bodies, legal standards for effluent quality, collection of wastewater, inter-connection with related plans and environmental infrastructure, environmental impact, ease of construction, and easiness of O&M should be considered when selecting the site of sewage treatments plant as follows.

- Gravity flow of influent is preferred to forced main flow to reduce the O&M cost
- Areas within or adjacent to urban center and sewage service area to minimize the grievance and complaints for inhabitants
- Areas in the vicinity of public water bodies
- No risk of flooding
- Effluent should be sufficiently diluted and mixed, and avoid places where there is a risk of contamination such as raw water of water intake, underground water sources, and fishing grounds.
- Avoid areas near residential and commercial areas where there is a high risk of civil complaints.
- Consider final disposal methods of sludge cake
- Secure sufficient land for future expansion or additional facilities.

4.2.3.4.2 Site Review

The proposed site for sewage treatment plant in this project is in Ward No. 1 (South Pahartali), and the N106 road and railroad pass through the entire site. The planned site was selected in the Chattogram sanitation master plan (2017) and has been owned by CWASA since the 1960s, so land acquisition is not required. However, as the site is geographically located in the center of the Chattogram, construction and operating costs increase due to the inlet & outlet sewer.

Figure 4-4 Photo of STP Proposed Site

Table 4-12 Review of Proposed Site of Sewage Treatment Plant

Category	Description
Land Acquisition	• It has been owned by CWASA since 1960s, so the land acquisition is not required.
Resettlement Action Plan	• There are some illegal residents and public facilities such as schools and mosques. ➔ Resettlement action plan shall be prepared during the detailed design stage by CWASA.
Treated Effluent Discharge	• It is located more than 10km from Karnaphuli River and Halda River. • Treated effluent will be discharged to Madari Khal and final receiving water body will be Halda River.
Future Expansion	• Sewage treatment plant with a capacity of Q=120,000m³/d for the final targe year of 2070 can be constructed in the A3 side of the proposed site.
Availability of Utility Service	• There is no water supply in the site & Ward No.1, so deep tube well will be utilized for the water supply of the STP. • Electrical power will be supplied from the 33kV sub-station located 1km from the site.
Accessibility	• It is located next to N106 road, so it is easy to access the site for the O&M vehicles and faecal sludge collection vehicles.

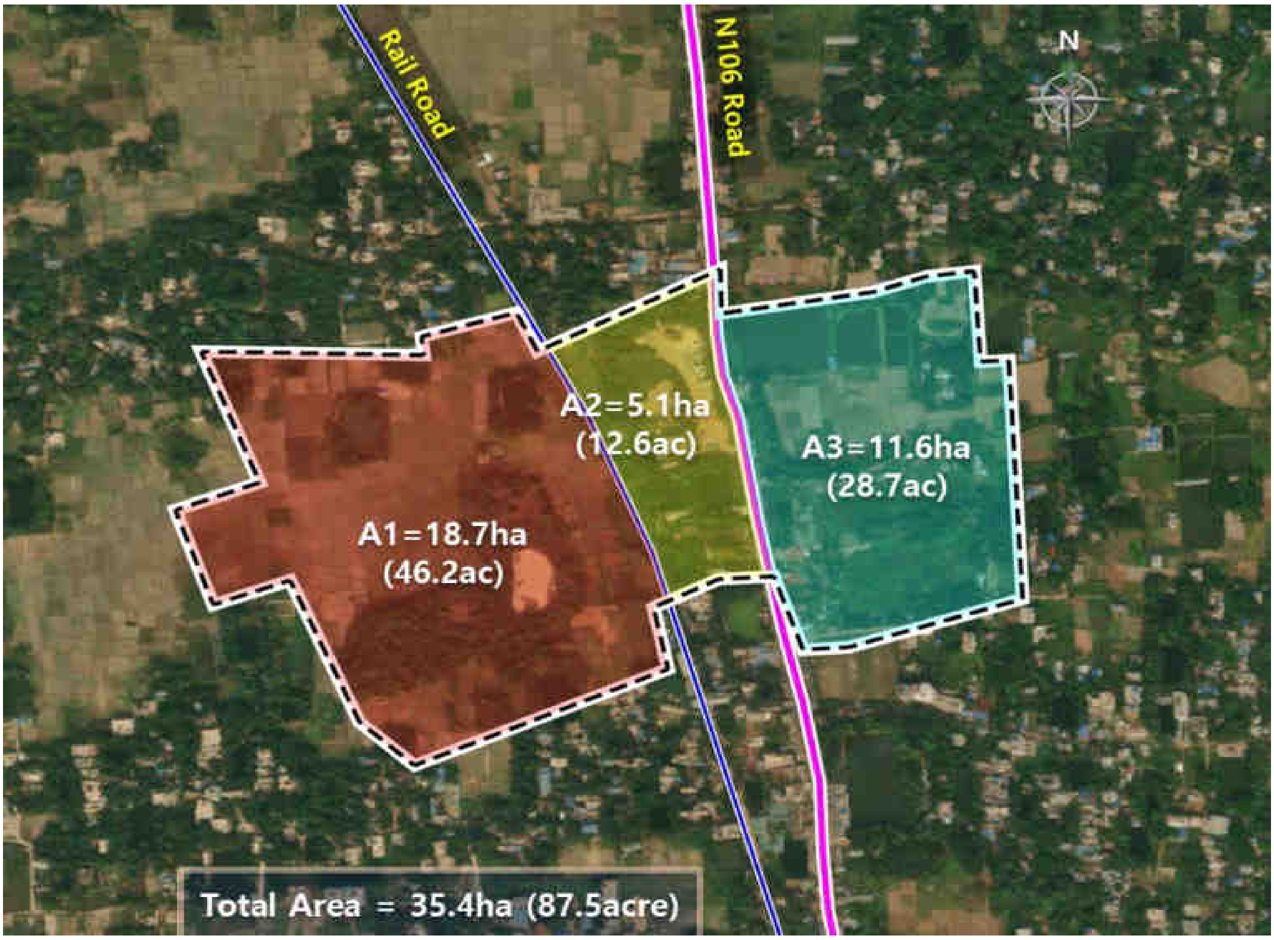


Figure 4-5 Proposed Site of Sewage Treatment Plant

4.2.3.5 Layout of Sewage Treatment Plant

4.2.3.5.1 Introduction

The layout of sewage treatment plant should consider the O&M of sewage treatment plant, systematized operation according to facility capacity, and should reflect future expansion plans. Major consideration for the layout of STP is as follows.

- Optimal O&M route plan for O&M staff
- Considering the relevance of unit process
- Administrative areas should be easily accessible from the visitors.
- Plan for inhabitants and surrounding environment-friendly facilities
- Arrangement plan considering the systematization of facilities
- Land use plan considering the future expansion
- Minimize secondary pollution such as odour, noise and vibration

4.2.3.5.2 Layout Characteristic

The STP layout plan can be divided into an administration area where the O&M staff works, a treatment area, and each area should be planned to maximize their usage.

Table 4-13 Layout Characteristic

Category	Description	Remarks
Administration Area	• Placed at the site entrance and at the center of the current and future expansion site - Improvement of work environment by separating the administration area and the Sewage & sludge treatment area. - Efficient O&M considerations with future expansion facilities • Manages the treatment facilities from the central control room • Layout considering the entry of O&M staffs and outside visitors	
Sewage Treatment Facility	• Systematized operation of treatment facilities and securing wastewater distribution • Minimize head loss by straightening facility layout • Maximization of site utilization and establishment of economical earthwork plan	
Sludge Treatment Facility	• Minimize piping flow by proximity to and concentration of sludge facility • Arrangement considering the future expansion	
Road and Parking lot	• Convenience for O&M staffs and visitors and simplification of vehicle circulation • Separation of traffic lines between O&M vehicles and general vehicles • Use the side entrance for the entry and exit of O&M vehicles in sludge treatment facilities	

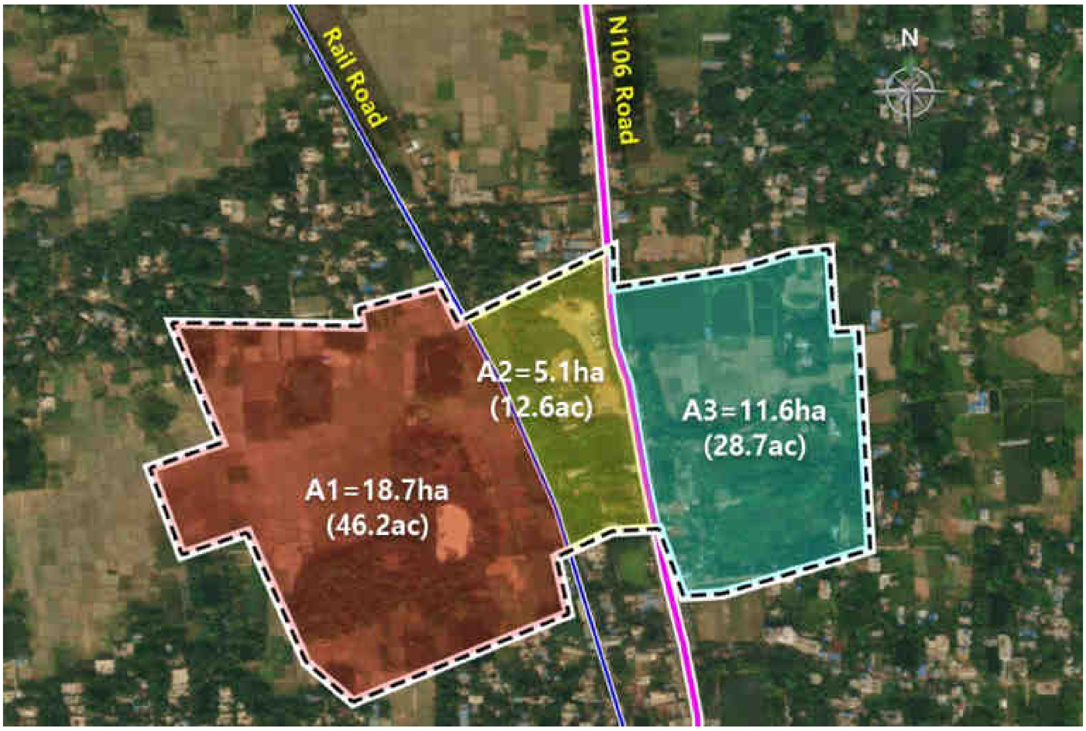
4.2.3.5.3 Layout of Sewage Treatment Plan

Option study of layout of sewage treatment plant is presented as below. Both options can accommodate the all facilities of STP up to Phase 3 in the final target year of 2070 in the proposed site.

- Option-1: Sewage treatment plant will be located in the on the right side of the N106 road (A3 site)
- Option-2: Sewage treatment plant will be located in the on the left side of the railway (A1 site)

As a result of the option study, Option-1 is selected because it is easy for O&M vehicles and faecal sludge collection vehicles to access to the STP.

Table 4-14 Option of Layout of Sewage Treatment Plant

Category	Option-1	Option-2
Summary	• Lay out on the right side of the N106 road (A3 site)	• Lay out on the left side of the railway (A1 site)
Site Status		
Required Area	• 80,000m²	• Same as left
Hydraulic Aspects	• Hydraulic flow of sewage treatment process is gravity after inlet pumping station	• Same as left
Layout Aspects	• Sewage, sludge process and architectural building is planned separately. • The remaining site can be used as environmental infrastructure in the future. • Compared to Option-2, the length of the inlet and outlet sewer is shorter.	• Compared to Option-1, the length of the inlet and outlet sewer is longer.
O&M Aspects	• Easy access to sewage treatment facilities from NR106 road • Ease of maintenance with systemization • Good access for maintenance vehicle to each facility	• It is somewhat difficult to enter the sewage treatment facility by entering on the left side of the railway
ESIA Aspects	• Illegal residence in some houses (45 households) • Concern about complaints from nearby residents	• Illegal residence in some houses (15 households)
Selection	◉	

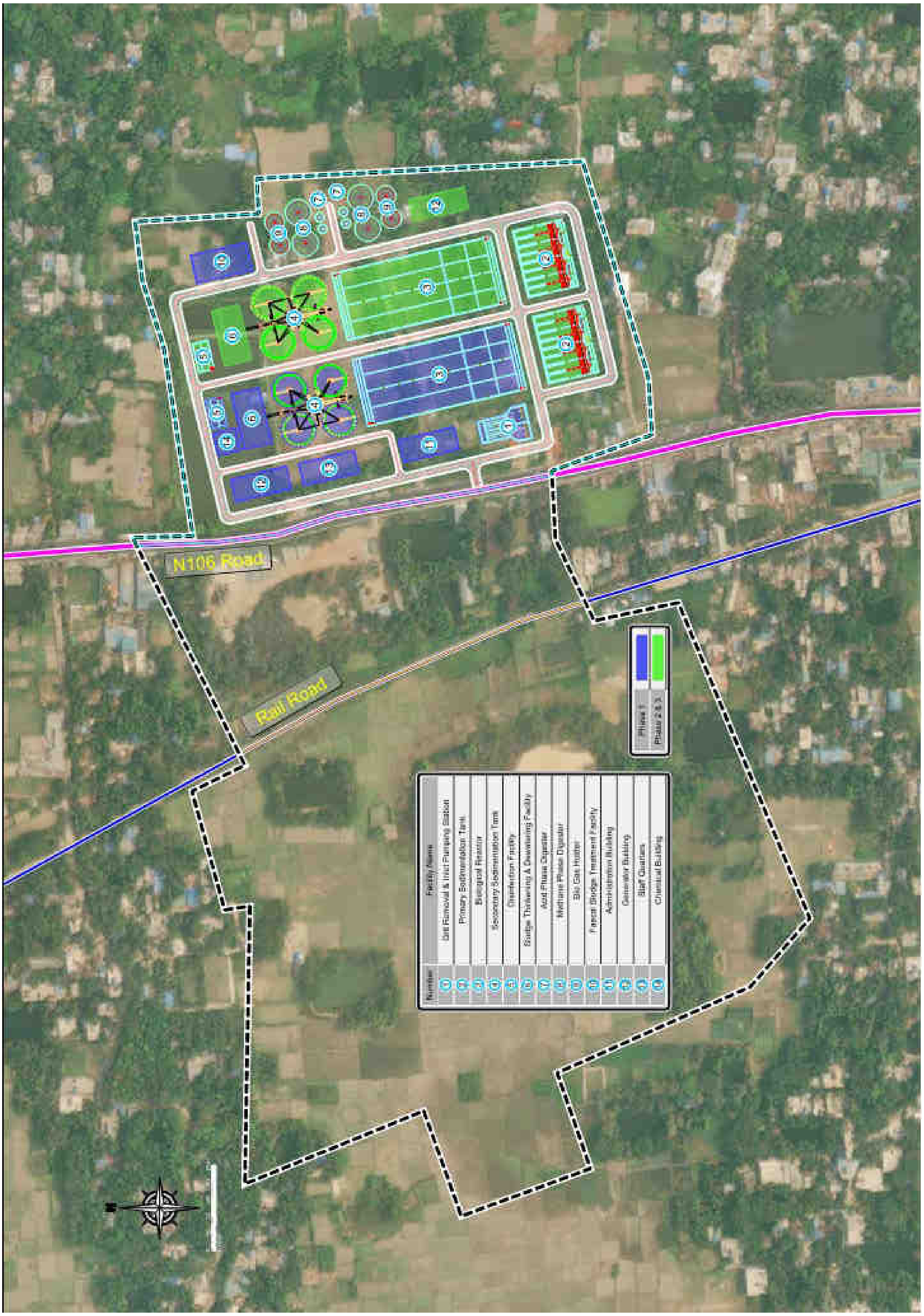


Figure 4-6 Layout of Sewage Treatment Plant (Option-1)

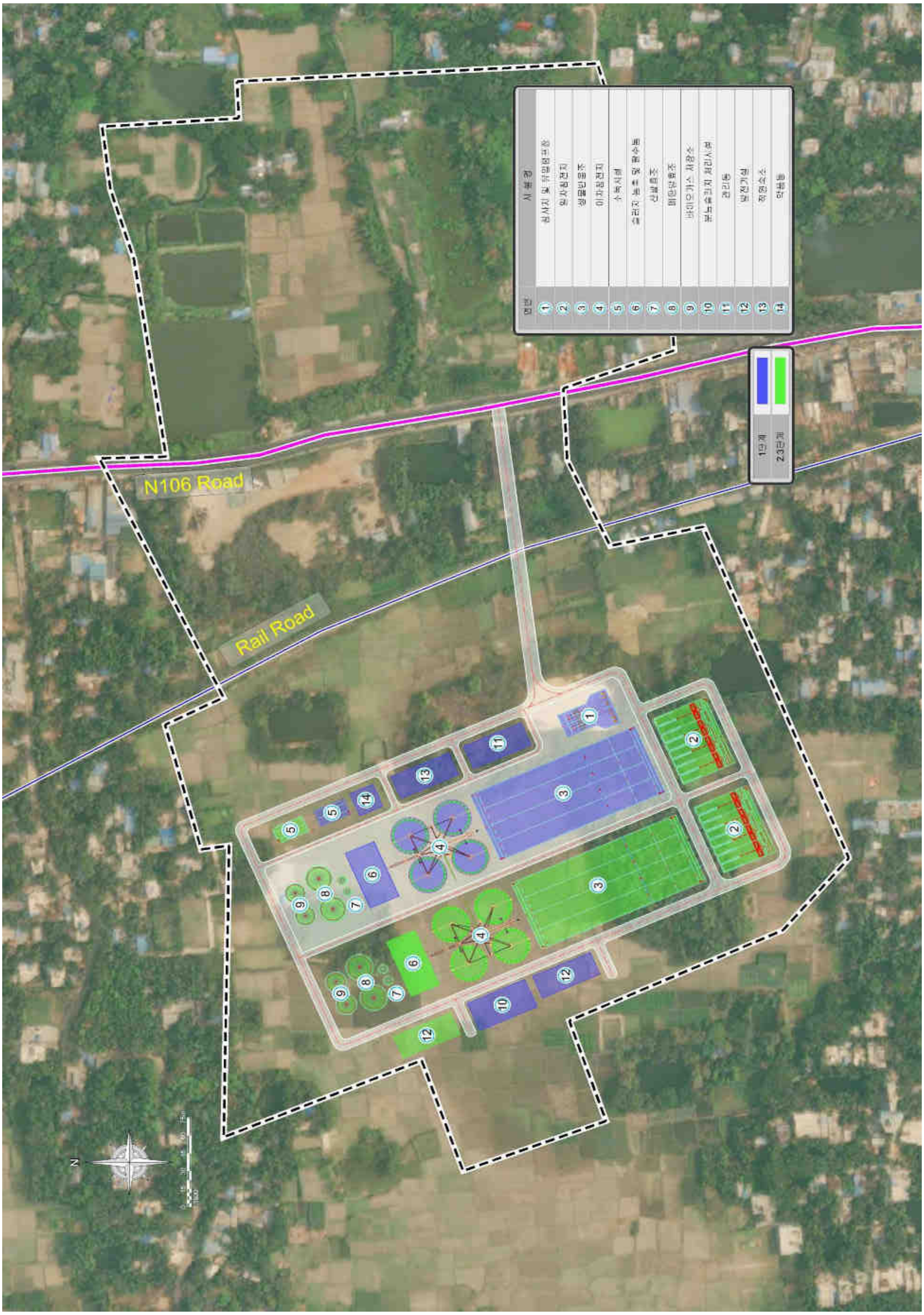


Figure 4-7 Layout of Sewage Treatment Plant (Option-2)

4.2.3.5.4 Ground Level of Sewage Treatment Plant

The ground elevation of sewage treatment plant is determined according to the flood level of the surrounded area to protect the facilities of STP and it acts as an important factor in establishing the hydraulic plan and earthwork plan. Since the sewage treatment plants is a facility to be safe from inundation, ground level is set up with an earthwork plan that considered the problem of sewage treatment function, ground elevation, flood level, surrounding environment and local conditions and current ground level of the STP site is investigated from EL (+) 4.25~4.90m.

The ground level for the ground level of STP of STP is proposed at EL (+) 6.50m to prevent flooding as 20-year frequency of the Bay of Bengal in the consideration of gravity flow discharge, prevention of inundation, economic feasibility and current ground level.

Table 4-15 Flood Level of Bay of Bengal (m)

Category	Frequency			
	10yr	20yr	50yr	100yr
Flood Level of Bay of Bengal	6.15	6.50	8.15	8.25

*Source: Bangladesh Water Development (BWDB)

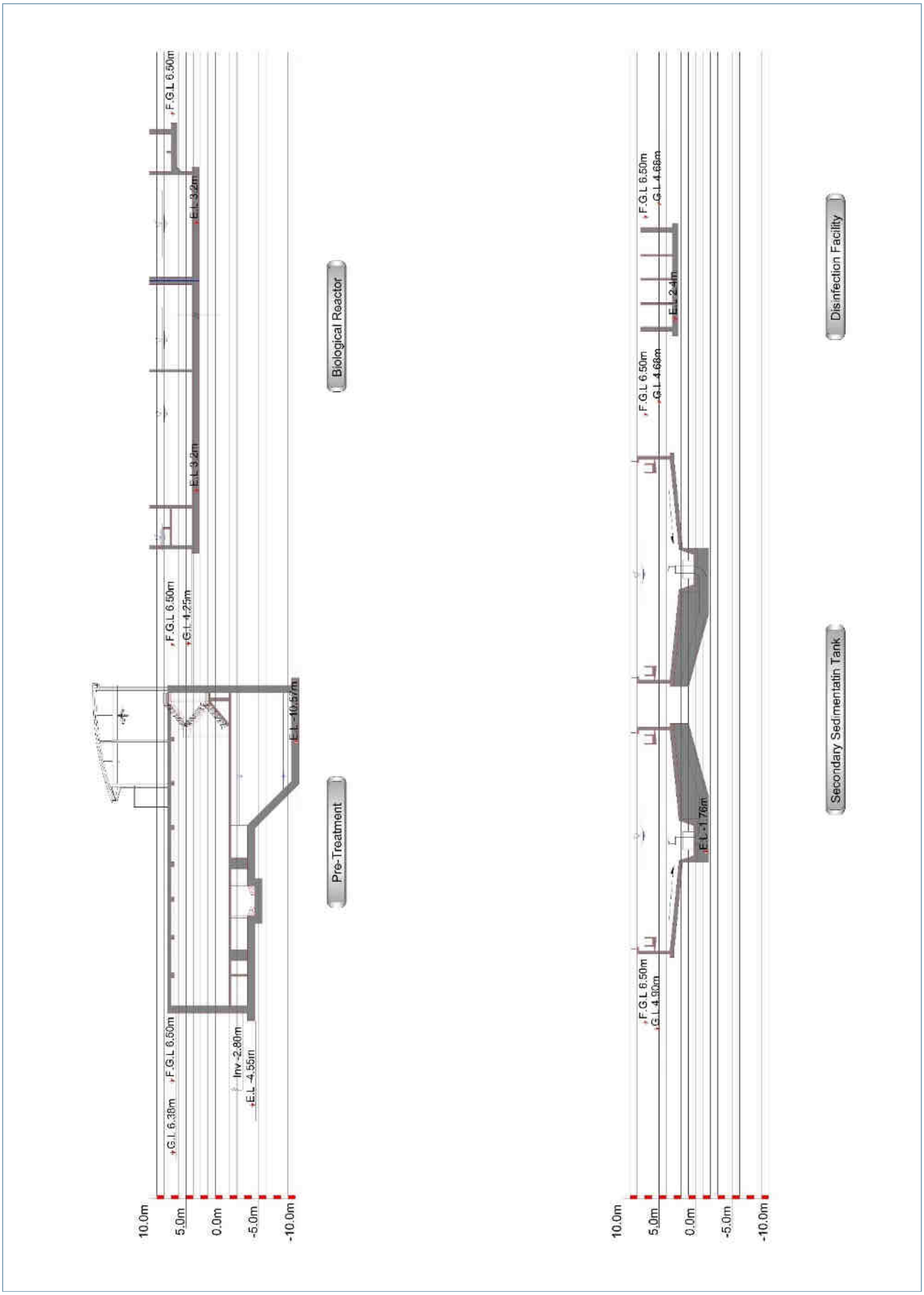


Figure 4-8 Hydraulic Profile of STP

4.2.3.6 Pre-treatment Facility

4.2.3.6.1 Function and Purpose

Sewage is expected to contain grits and sediments due to by-products discharged from homes or businesses and direct input of flush toilet water, so it should be removed before the main treatment process. Pre-treatment is for the removal of various impurities and sediments in the inflow sewage, and for stable supply and treatment of the subsequent treatment process, and includes the following facilities.

4.2.3.6.2 Facility

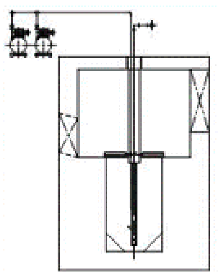
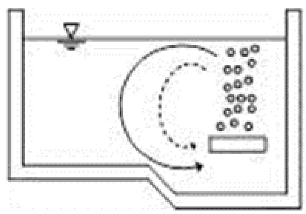
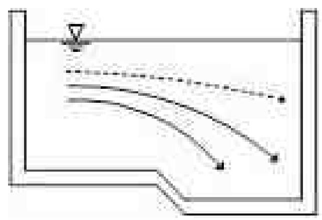
4.2.3.6.2.1 Screen

It is planned to install a coarse screen & fine screen to reduce potential operating and maintenance problems associated with rags and debris as a preliminary treatment step to protect pumps and downstream piping from potential damage or clogging.

4.2.3.6.2.2 Grit Removal

It is divided into gravity type, aeration type, and vortex type, and comprehensively reviewed treatment efficiency, installation cost, and ease of maintenance. The vortex type grit removal method was selected because it is applied to all on-going sewage projects of CWASA.

Table 4-16 Comparison of Grit Removal Methods

Category	Vortex	Aeration	Gravity
Figure			
Principle	• Removal by centrifugal force and pressure difference between the outside and the center by generating vortex flow by the rotating cylinder.	• A diffuser is installed to create swirling flow to separate and remove sediment by centrifugal force.	• Sediment is removed by gravity sedimentation according to each size at a specific flow rate.
Main Facilities	• Cylindrical Sediment • Grit Separator • Grit transport and Storage tank	• Aeration and air supply device • Grit remover • Grit transport and Storage tank	• Sediment remover • Cleaning device • Grit transport and Storage tank
Advantage	• Excellent efficiency • Minimize required area • Floats can be removed	• Cleaning and preliminary aeration effect • Reduce smell of sediment	• Loss of head is small • Low installation cost • Easy to maintain • Excellent energy saving
Disadvantage	• Requires a lift pump	• Increase in power cost • Increase in VOC generation	• Equipment is large
Select	◉		

4.2.3.6.2.3 Equalization Tank

Depending on the characteristics of the project area, lifestyle, and the works return of the treatment process, it is expected that the characteristics of the influent wastewater quantity will vary greatly over time. In this case, since it affects the treatment efficiency and effluent quality of the subsequent process, equalization tank is planned to secure from load fluctuations and induce stable treatment efficiency through equalization.

4.2.3.6.2.4 Inlet Pumping Station

If there is no inlet pumping station, the depth of the structure should be low according to the depth of the sewer network, so the installation of the inlet pumping station prevents excessive earthwork (excavation) planning. For the pump facility, a plan was established for the number and capacity of pumps that can effectively cope with the inflow fluctuation, have excellent energy efficiency, and minimize energy consumption.
The pump head was determined by considering the invert elevation (depth of excavation) of the inflow sewage pipe, the planned height and discharge water level of the sewage treatment facility, and the head loss in the field.

4.2.3.7 Primary Sedimentation Tank

4.2.3.7.1 Function and Purpose

Primary treatment refers to sedimentation and removal of suspended solids present in the influent wastewater. The main reason to provide primary clarifiers is to reduce solids and organic loadings to the secondary biological treatment system, so it can then be smaller.

However, primary sedimentation presents several designs and operating challenges, including greater odour potential and the need for separate handling and treatment of primary sludge. Primary sludge treatment is most economically done using anaerobic digestion, which is a complicated, capital-intensive, and potentially hazardous process. For these reasons, many smaller treatment plants are designed without primary clarifiers, and rely instead on secondary biological treatment of the entire influent wastewater flow.

Primary sedimentation tank is planned to be introduced in Phase 2 with the sludge stabilization process in the consideration of the high concentration of organics in the raw sludge.

Actual O&M status of Phase 1 should be analyzed when the expansion of Phase 2 & Phase 3 of sewage treatment plant is implemented. Space is reserved in the STP (and plant hydraulic profile) to allow possible addition of primary sedimentation is the future with capacity to treat up to the ultimate influent wastewater flow.

4.2.3.7.2 Tank Type

The type of the sedimentation tank can be installed in a circular, rectangular type depending on the size of the sewage treatment plant, the site area and the overall layout of the facility. Short circuiting or localized currents should not be generated in the sedimentation tank. In this plan, a rectangular sedimentation tank was selected after comprehensively reviewing all conditions, such as site area, facility capacity, and future expandability.

Table 4-17 Comparison of Primary Sedimentation Tank Type

Category	Rectangular	Circular
Figure		
Removal Principle	• Solid-liquid separation through gravitational settling of solid particles in horizontal flow	• Solid-liquid separation through gravitational settling of solid particles in radial flow
Characteristic	• The required area is small and the systemization is easy • Advantage for underground or upper cover • Easy to installation odour collection facilities due to dense arrangement	• The required area is wide • Complicated when underground or upper cover • Complicated installation of odour collection facilities due to distributed arrangement
Efficiency	• High and stable rectification effect with horizontal flow • Deterioration of vertical flow, little effect from wind • Long sludge collection time is concerned about bulking • Easy to intensive sludge drawn pipe	• With radial flow, it is vulnerable to channelling, density current, and wind influence. • Possibility of fine particle leakage due to deterioration of vertical flow is high • Relatively short sludge collection time • Difficulty in integrating sludge drawn pipe
Maintenance	• Comparatively complicated inspection of wear etc. • The mechanical operation is complicated and there are many breakdowns	• Easy access to maintenance such as wear • Simple mechanical operation and less failure
Select	◉	

4.2.3.8 Biological Reactor

4.2.3.8.1 Introduction

The Bangladesh Department of Environment (DoE) established the standard Sewerage discharge in 1997 and revised the standard in March 2023. Bangladesh mainly have regulated the removal of SS and BOD, COD contained in the wastewater and the discharge standards have been strengthened recently to remove T-N and T-P to prevent eutrophication in the public water body.

In the Catchment-1 project, which is under construction, a target effluent water quality was set up as stronger than the effluent standard. In this feasibility study, target effluent quality is set up as same as that of the Catchment-1 project in consultation with PMU, advanced wastewater treatment process is introduced to this project.

- Although the conventional activated sludge process mainly removes the organics, however nutrients such as T-N and T-P cannot be removed, so advanced treatment process is introduced as biological nutrient removal.

- Treated effluent is discharged by gravity flow to the Madari Khal which is located about 0.5km from STP site and final receiving water body is Halda River. Even though impact of effluent will be negligible to the intake of WTP, because discharge point is about 7.6km away from the intake facility of Modunaghat WTP and about 11.5km away from the intake facility of Mohara WTP, advance treatment process is introduced to protect the raw water intake.

4.2.3.8.2 Classification of Advanced Treatment Process

Advanced treatment process that can simultaneously remove nitrogen and phosphorus to prevent eutrophication are classified into A2O, SBR, media, microorganism, and membrane.

Table 4-18 Classification of Advanced Treatment Process

Category	Description	Remarks
A2O	• It is composed of anaerobic, anoxic, and aerobic tanks. • Many installation records and easy to operate	
SBR	• Inlet, reaction, sedimentation, and discharge are performed in one reactor • Strong against flow fluctuation and easy to operate.	
Media	• Keep MLSS high by media. • Required area is small	
Microorganism	• Treatment of sewage by culturing special microorganisms • Few application cases and difficult maintenance.	
Membrane	• Solid-liquid separation with a membrane, secondary sedimentation is not required • The composition of the bioreactor is similar to the A2O process • Excellent effluent quality, high energy consumption	

4.2.3.8.3 Sewage Treatment Plant in Korea adopting Advanced Treatment Process

4.2.3.8.3.1 Introduction

Ministry of Environment in Korea analyzes and inspects the O&M status of STP in Korea and announce the results in 2014. In this feasibility study, we analyzed the sewage treatment plants in Korea adopting Advanced Treatment Process as below.

4.2.3.8.3.2 Status of STP adopting Advanced Treatment Process

In 2014, there were 555 facilities operating with advanced treatment processes, an increase of 33 compared to 522 in 2013. Among the facilities operated with advanced treatment processes, SBR process was the most with 203 facilities (36.6%) and A2O process was the second with 135 facilities (24.3%).

Table 4-19 Status of STP adopting Advance Treatment Process

Category		Total	SBR	A2O	Media	Microorganism	Membrane	etc.
'14	Number	555	203	135	131	48	21	17
	Ratio (%)	100	36.6	24.3	23.6	8.6	3.8	3.1
'13	Number	522	192	133	123	37	21	16
	Ratio (%)	100	36.8	25.5	23.6	7.1	4.0	3.0

*Source: Results of Analysis on O&M of Sewage Treatment Plants in 2014 (Ministry of Environment)

In the STP adopting advanced treatment process, SBR, A2O, and media process are the most. For facilities with a capacity of less than 10,000m^3/d, SBR process was the most, and for facilities with a capacity of 10,000m^3/d or more, A2O process was the most as below.

Table 4-20 Categorization of STP adopting Advanced Treatment Process with Capacity

Category	Capacity (m^3/d, Daily Maximum)						
	Total	500 ~ 5,000	5,000 ~ 10,000	10,000 ~ 20,000	20,000 ~ 50,000	50,000 ~ 100,000	Over 100,000
A2O	134	32	19	18	28	11	26
Media	129	46	21	14	19	10	19
SBR	197	160	25	2	5	2	3
Microorganism	21	5	3	6	4	2	1
Membrane	40	27	4	7	-	1	1
Long-term Aeration	25	17	4	2	1	1	-
CAS	13	2	-	2	2	4	3
etc.	7	1	2	3	1	-	-
Total	566	290	78	54	60	31	53

*Source: Results of Analysis on O&M of Sewage Treatment Plants in 2014 (Ministry of Environment)

4.2.3.8.3.3 Unit O&M Cost of Advanced Treatment Process

As a result of O&M cost analysis of advanced treatment process, A2O process is 168.8 KRW/m^3 (100%), SBR process is 283.8 KRW/m^3 (168%), Media process is 176.1 KRW/m^3 (104%), Membrane process is 416.4 KRW/m^3 (247%), so A2O process is analyzed as the most economical in the advanced treatment process.

Table 4-21 Unit O&M Cost of Advanced Treatment Process

Category		Total	CAS	Long-term aeration	Oxidation ditch	Rotating disc	Advanced Treatment Process				
							SBR	A2O	Media	Membrane	etc.
14	Number	587	10	3	13	6	203	135	131	48	38
	Unit O&M Cost (KRW/m^3)	186.2	134.6	910.5	624.8	318.7	283.8	168.8	176.1	416.4	323.4
	Unit BOD Removal Cost (KRW/kg)	1,203.9	1,153.7	6,721.5	4,792.6	3,505.6	1,892.0	1,122.3	1,074.7	2,296.8	1,692.0
13	Number	557	13	3	13	6	192	133	123	37	37
	Unit O&M Cost (KRW/m^3)	169.7	101.6	1,242.9	634.3	278.7	276.7	158.5	170.9	371.0	287.6
	Unit BOD Removal Cost (KRW/kg)	1,145.0	882.8	10,064.1	5,488.1	3,983.7	1,953.5	1,076.8	1,066.3	2,095.0	1,587.5

*Source: Results of Analysis on O&M of Sewage Treatment Plants in 2014 (Ministry of Environment)

The effluent water quality of the facilities with the advanced treatment method was better than the facilities with non-advanced, and the unit O&M cost and the operating manpower are higher than the facilities with non-advanced treatment process.

Table 4-22 Comparison of O&M Cost

Category		Effluent Water Quality				Quantity (1,000 m^3/yr)	Treatment Cost (KRW/m^3)	BOD Removal Cost (KRW/kg)	O&M Staff (person/ 1,000m^3)
		BOD	SS	T-N	T-P				
'14	Total	4.1	3.3	11.44	0.55	7,100,164	186.4	1,205.1	0.25
	Advanced	4.1	3.3	11.31	0.55	6,857,976	187.0	1,197.9	0.25
	Non-Advanced	4.4	3.7	14.75	0.61	242,188	165.5	1,423.3	0.30
'13	Total	4.5	3.6	11.15	0.65	7,189,377	169.7	1,145.0	0.23
	Advanced	4.2	3.4	10.91	0.55	6,301,545	177.9	1,163.2	0.24
	Non-Advanced	6.8	4.7	12.88	1.36	887,832	111.3	971.4	0.17

*Source: Results of Analysis on Operation and Management of Sewage Treatment Plants in 2014 (Ministry of Environment)

4.2.3.8.3.4 Construction Cost

Ministry of Environment in Korea has established the functional formula with the data of operating sewage treatment plant to estimate the construction cost of sewage treatment process by sewage treatment process.

The construction cost calculated as a function formula is based on Korea construction standards and even though it is difficult to apply directly to this project, it was applied to analyze the construction cost for each advanced treatment process of this project. Since the facility capacity applied to the function formula is based on the daily maximum facility capacity, the construction cost was calculated by applying the facility capacity of the sewage treatment facility in this feasibility study as the daily maximum.

As a result of analysis, Construction cost of A2O process is 100%, SBR process is 97.5% and media process is 84.4%.

Table 4-23 Comparison of Construction Cost

Category	Functional Formula	Capacity (m^3/d, Daily maximum)	Construction Cost (million KRW)			Ratio (%)
			Year 2010	Price Correction	Year 2023	
A2O	$Y=97.804 \times Q^{0.5725}$	75,000	60,441	124.70	75,370	100.0
SBR	$Y=178.76 \times Q^{0.5165}$	75,000	58,916	124.70	73,468	97.5
Media	$Y=267.91 \times Q^{0.4676}$	75,000	51,000	124.70	63,597	84.4

Note) Y: Construction Cost, Q: Capacity of STP (m^3/d as daily max.)

4.2.3.8.4 Selection of Sewage Treatment Process

In this feasibility, A2O process is applied as sewage treatment process to remove T-N and T-P to prevent eutrophication in the public water body in the consideration of the legal standards, on-going sewage projects in Chattogram, construction cost and O&M cost, phase plan of sewage treatment plant.

Table 4-24 Comparison of Advanced Treatment Process

Category	A2O	SBR	Media	Microorganism	Membrane
Introduction	• Removal of phosphorus by denitrification of the returned sludge based on the A2O method	• Inflow, reaction, precipitation, and discharge proceed in one reactor	• Responds to high-concentration sewage with high MLSS and long SRT using medias	• Sewage treatment and odour removal by culturing special microorganisms	• Installation of a membrane in an aerobic tank instead of a secondary sedimentation
Characteristic	• Composed of anaerobic, anoxic and aerobic • Internal sludge return • Secondary sedimentation	• Performs anaerobic, anoxic, aerobic, and sedimentation roles in one reactor • Floating microorganisms • No secondary sedimentation • No internal sludge return	• It is composed of anaerobic, anoxic, and aerobic tanks and is filled with a media. • Floating + adhesiveness microorganisms • Internal sludge return	• Removal of nitrogen and phosphorus by dividing the aeration tank or intermittent aeration • Sewage treatment and odour removal by microorganisms	• Depending on the type of separator, hollow fiber membranes and flat membranes are largely used. • Requires backwashing and chemical cleaning
Advantage	• Suitable for large treatment plants • Many domestic and overseas operation records	• It is suitable for small-scale treatment plants because it requires less land and has good ability to cope with changes in flow rate and water quality. • Easy to secure technology due to many operational achievements • Compared to other methods, facility cost and power cost are low	• Excellent adaptability to changes in flow rate and water quality by using high-concentration microorganisms • Less sludge generation • Less land area required than A2O method	• Odour removal without separate facility • Good response to flow rate and water quality change • Improvement of sludge dewatering	• Good response to flow rate and water quality change
Disadvantage	• Inhibition of phosphorus release in the anaerobic tank • Need to internal sludge return	• A flow control tank or a treatment tank is required due to intermittent inflow and outflow • Difficulty in repair and replacement if major equipment is foreign-made	• High initial cost • Need to replace filter media Difficult to remove phosphorus due to long SRT • It is difficult to manage filter media	• Microorganism culture takes a lot of time • Need periodic maintenance	• Membrane replacement cost
Chattogram application case	Catchment-1&5&6 Catchment-2&4	-	-	-	-
Construction Cost	100%	97.5%	84.4%	-	-
O&M Cost	100%	168%	104%	-	247%
Selection	⦿				

4.2.3.9 Secondary Sedimentation Tank

4.2.3.9.1 Function

The function of secondary sedimentation is to separate the activated sludge solids from the mixed liquor. Solid separation is the final step in the production of a stable effluent low in BOD and SS.

4.2.3.9.2 Tank Type

In this feasibility study, circular type is applied to second sedimentation tank because activated sludge after biological nutrient removal usually shows a low sedimentation characteristic due to the long SRT and high MLSS concentration.

Table 4-25 Comparison of Secondary Sedimentation Tank Type

Category	Rectangular	Circular
Figure		
Removal Principle	• Solid-liquid separation through gravitational settling of solid particles in horizontal flow	• Solid-liquid separation through gravitational settling of solid particles in radial flow
Characteristic	• The required area is small and the systemization is easy • Advantage for underground or upper cover • Easy to installation odour collection facilities due to dense arrangement	• The required area is wide • Complicated when underground or upper cover • Complicated installation of odour collection facilities due to distributed arrangement
Efficiency	• High and stable rectification effect with horizontal flow • Deterioration of vertical flow, little effect from wind • Long sludge collection time is concerned about bulking • Easy to intensive sludge drawn pipe	• With radial flow, it is vulnerable to channelling, density current, and wind influence. • Possibility of fine particle leakage due to deterioration of vertical flow is high • Relatively short sludge collection time • Difficulty in integrating sludge drawn pipe
Maintenance	• Comparatively complicated inspection of wear etc. • The mechanical operation is complicated and there are many breakdowns	• Easy access to maintenance such as wear • Simple mechanical operation and less failure
Select		◉

4.2.3.10 Disinfection Facility

Disinfection refers to the selective destruction of disease-causing organisms. In this feasibility study, chlorine disinfection is applied which is generally more cost effective than other commonly used technologies, such as use of ozone, chlorine dioxide, hydrogen peroxide, or ultraviolet (UV) light and it can respond to the high turbidity of influent wastewater.

Table 4-26 Comparison of Disinfection

Category	Chlorine	Ozone	UV
Scale	All	Large, Medium	Medium, Small
Application Phase	All	Secondary	Secondary
Reliability	Good	Very Good	Very Good
Bacteria Killing	Good	Good	Good
Virus Killing	Bad	Good	Good
Toxicity	Toxic	No possibility	Non-toxic
Hazardous by-products	THM	Aldehyde	-
Persistent	Long	-	-
Contact Time	Normal (10~20 min)	Normal (10~20 min)	Short (1~5 second)
Dissolved Oxygen Contribution	-	Contributed	-
React with ammonia	Reaction	Reaction (High pH only)	No Reaction
Chromaticity Removal	Normal	Removed	Not removed
Increased dissolved solids	Increase	Increase	Not Increased
Effect on pH	Yes	Yes (High pH)	No
Maintenance	Least	High	Normal
Causticity	Yes	Yes	No
Select	◉		

4.2.3.11 Treated Effluent Discharge

4.2.3.11.1 Introduction

As the proposed site of sewage treatment plant is located in the middle of the CCC, option study of treated effluent discharge is presented to identify more rational and suitable option.

- Option-1: treated effluent is discharged by gravity flow to the Madari Khal which is located about 0.5km from STP site and final receiving water body is Halda River.
- Option-2: treated effluent is discharged by pumping to the Shitol Jharna Khal which is located about 7.0km from STP site and final receiving water body is Karnaphuli River.

4.2.3.11.2 Treated Effluent Discharge Plan

As a result of the option study, Option-1 is selected for the treated effluent discharge option through the discussion with the CWASA by considering the site condition, financial and other factors. It is planned to obtain the environmental license through the environmental impact assessment during the detailed design stage.

- CAPEX and OPEX of Option-2 is much higher than Option-1, because additional effluent pumping station & about 7.0km of effluent discharge pipe is required for the Option-2 and OPEX is also required to operate a pumping station.
- Treated effluent will satisfy the standard sewerage discharge of DOE, so it will contribute to improve the water quality of river and to preserve the ecosystem of river.
- Treated effluent discharge point of STP in Madari Khal is about 7.6km away from the intake facility of Modunaghat WTP and about 11.5km away from the intake facility of Mohara WTP, so the impact of effluent will be negligible to the intake of WTP. For instance, 4.0km of standard distance from the intake of WTP is considered when designating a water source protection area in Korea.

Table 4-27 Option of Treated Effluent Discharge

Category	Option-1	Option-2
Discharge Point	Madari Khal	Shitol Jharna Khal
Receiving Water Body	Halda River	Karnaphuli River
Discharge Pipe	D1000mm, L=0.5km	D1000mm, L=7.0km
Effluent Pumping Station	-	26.1 m^3/min x 2(1) + 13.0 m^3/min x 2
CAPEX	• Discharge Pipe: 385,175 USD	• Discharge Pipe: 5,392,000 USD • Discharge Pump Station: 1,563,000 USD • Total: 6,955,000 USD
OPEX	-	Electricity Cost: 200,000 USD/year
Selection	◉	

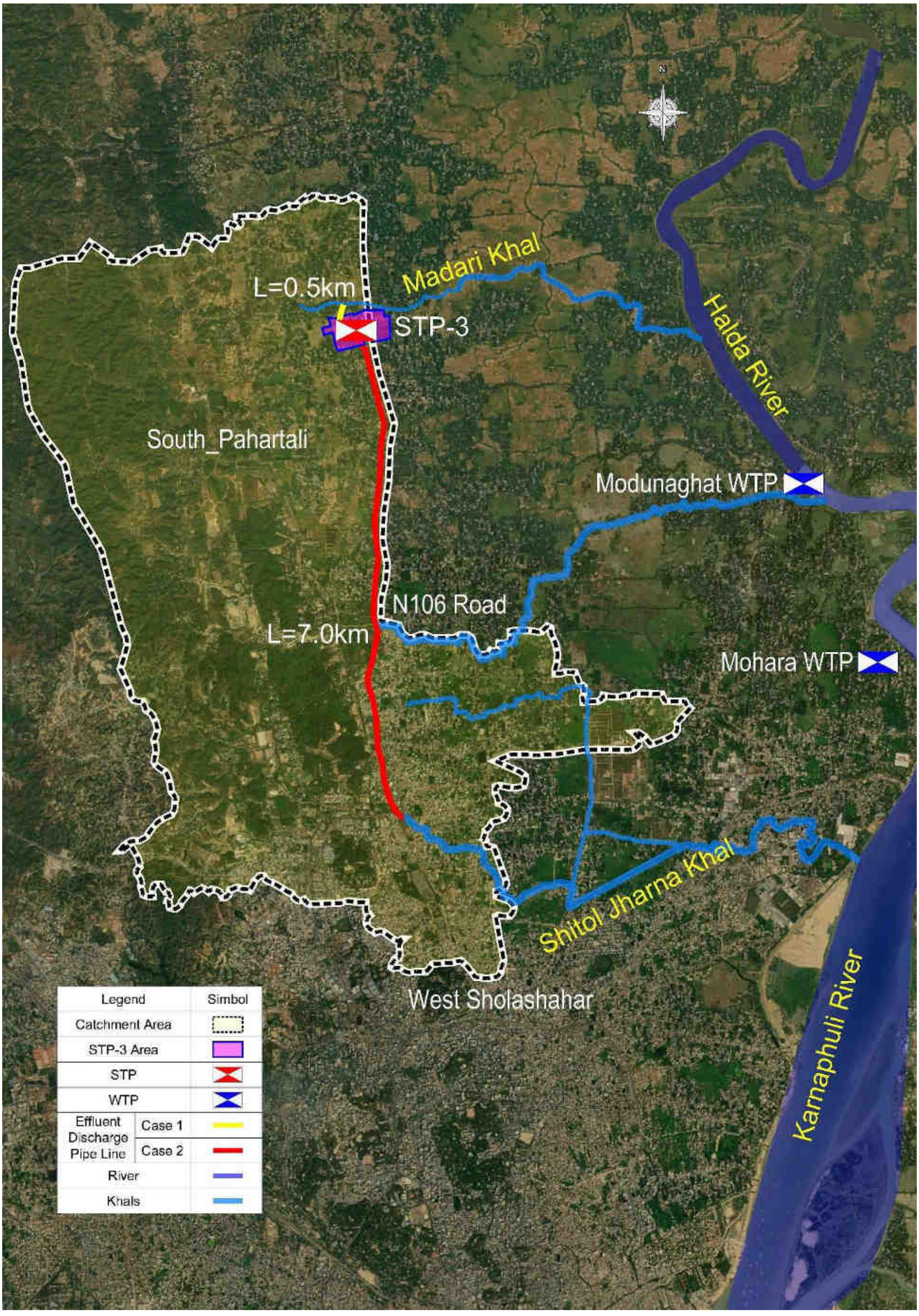


Figure 4-9 Review of Treated Effluent Discharge Options

4.2.3.11.3 Water Quality Prediction

4.2.3.11.3.1 Flow Rate of Halda River

In the Modunaghat water treatment plant design report, the future flow rate was predicted based on the Halda River flow rate from 2001 to 2014. Based on the dry season with the lowest river flow, the 50% probability flow rate was 645m^3/s and the 90% probability flow rate was 359m^3/s from November to May. In February, when the river flow rate was the lowest, the 50% probability flow rate was 576 m^3/s and the 90% probability flow rate was 300 m^3/s.

As of 2040, the target year for the first stage of this project, the daily average flow rate of sewage treatment facilities is 55,574m^3/d, which is only 0.23% of the 25,920,000m^3/d in February, the lowest river flow. Therefore, it is judged that there will be little impact on the Halda River due to discharge water.

Table 4-28 Halda river flow rate prediction

Category	50% probability flow rate		90% probability flow rate	
	m^3/s	m^3/d	m^3/s	m^3/d
Dry season (Nov to May)	654	55,728,000	359	31,017,600
Feb	576	49,766,400	300	25,920,000
Mar	599	51,753,600	299	25,833,600
Apr	639	55,209,600	322	27,820,800

*Source: Design Report of Feasibility Study, Design and Construction Supervision of Modunaghat WTP (CWASA)

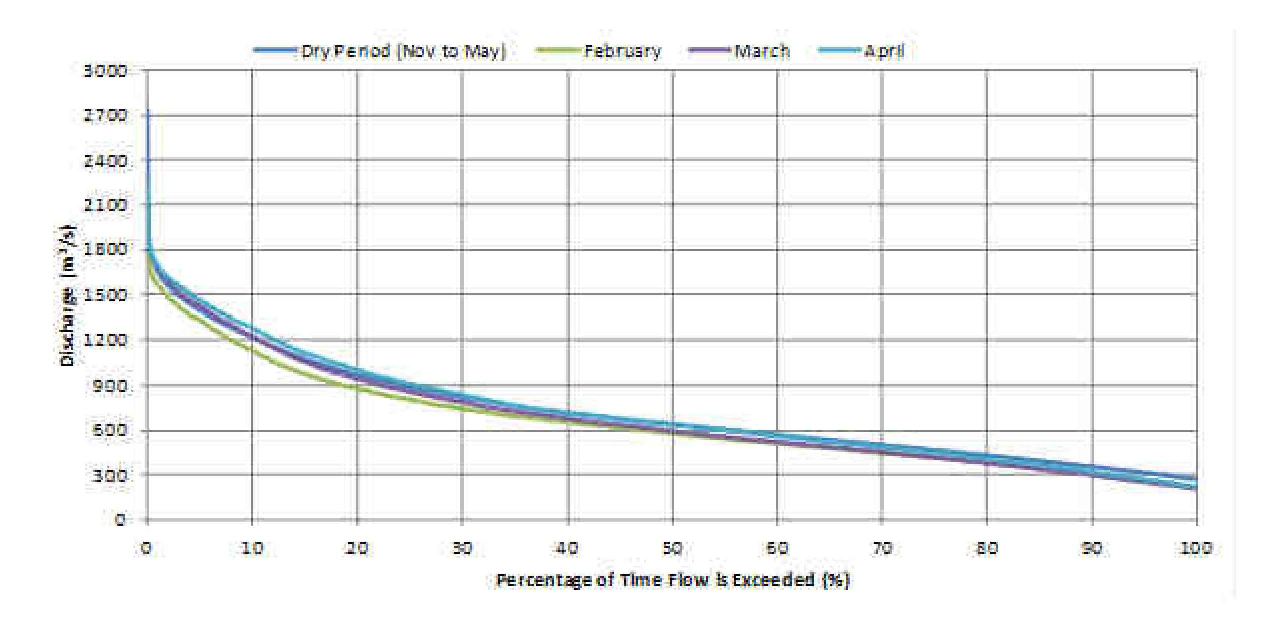


Figure 4-10 Halda river flow rate prediction

*Source: Design Report of Feasibility Study, Design and Construction Supervision of Modunaghat WTP (CWASA)

4.2.3.11.3.2 Water Quality Status

The water quality status of the Halda River was analyzed based on raw water quality data from the Modunaghat and Mohara water purification plants located downstream.

As a result of raw water quality analysis, most of the water quality items were found to be constant throughout the year, and turbidity increased in the dry season, the river level decreased, and the sea current reversed, resulting in high chloride ion concentration.

Table 4-29 Modunaghat WTP raw water

Year	pH		Turbidity (NTU)		T-Alkalinity (mg/L)		T-Hardness (mg/L)		Ca-Hardness (mg/L)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
2020	6.78	7.21	60.83	525.00	40.50	60.33	48.42	64.17	42.00	65.83
2021	6.95	7.38	30.00	630.00	32.00	58.00	49.00	70.00	52.00	74.00
2022	6.96	7.31	73.33	653.33	34.56	49.33	41.67	54.78	19.22	25.44
Average	6.90	7.30	54.72	602.78	35.69	55.89	46.36	62.98	37.74	55.09
Year	TDS		DO (mg/L)		BOD (mg/L)		COD (mg/L)		Chloride (mg/L)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
2020	50.42	316.08	5.61	6.77	0.86	1.53	23.92	36.33	13.92	186.50
2021	42.00	967.42	6.93	7.15	0.74	1.92	24.92	48.08	16.33	510.92
2022	27.56	365.56	6.27	6.51	0.59	1.70	27.33	44.78	13.89	181.89
Average	39.99	549.69	6.27	6.81	0.73	1.71	25.39	43.06	14.71	293.10

Table 4-30 Mohara WTP raw water

Year	pH		Turbidity (NTU)		T-Alkalinity (mg/L)		T-Hardness (mg/L)		TDS (mg/L)		Iron (mg/L)	NO_3 (mg/L)
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
2020	6.88	7.26	75.83	288.75	47.42	60.25	41.08	49.00	37.58	675.00	0.22	3.59
2021	6.86	7.19	91.67	487.92	46.50	55.42	36.33	42.92	39.58	1,531.67	0.34	2.72
2022	6.79	7.13	72.78	374.44	43.67	54.00	33.78	41.22	34.33	453.56	0.19	3.37
Average	6.84	7.19	80.09	383.70	45.86	56.56	37.06	44.38	37.17	886.74	0.25	3.23

Year	PO_4 (mg/L)	SO_4 (mg/L)	NH_3 (mg/L)	DO (mg/L)		BOD (mg/L)		COD (mg/L)		Chloride (mg/L)	
				Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
2020	0.29	15.83	0.16	6.28	6.83	1.00	1.33	20.92	31.83	9.00	407.83
2021	0.26	18.08	0.14	6.63	7.25	1.00	1.16	20.75	29.92	10.67	920.50
2022	0.36	16.56	0.17	6.59	7.19	0.98	1.14	20.00	29.56	7.33	261.44
Average	0.30	16.82	0.15	6.50	7.09	0.99	1.21	20.56	30.44	9.00	529.93

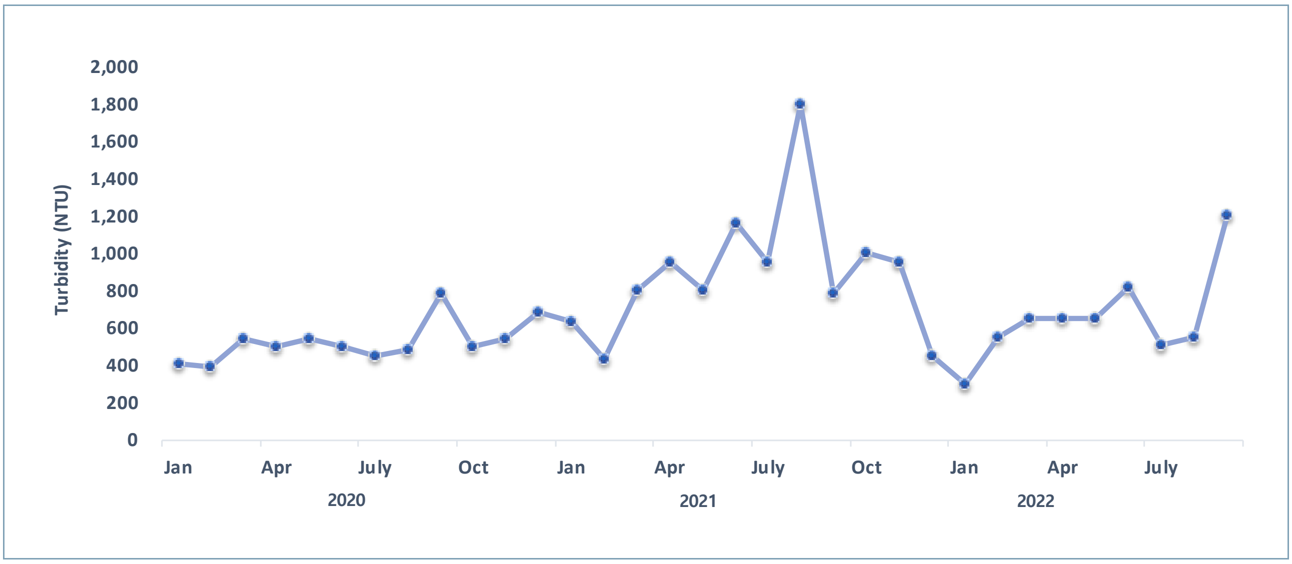


Figure 4-11 Modunaghat WTP Turbidity

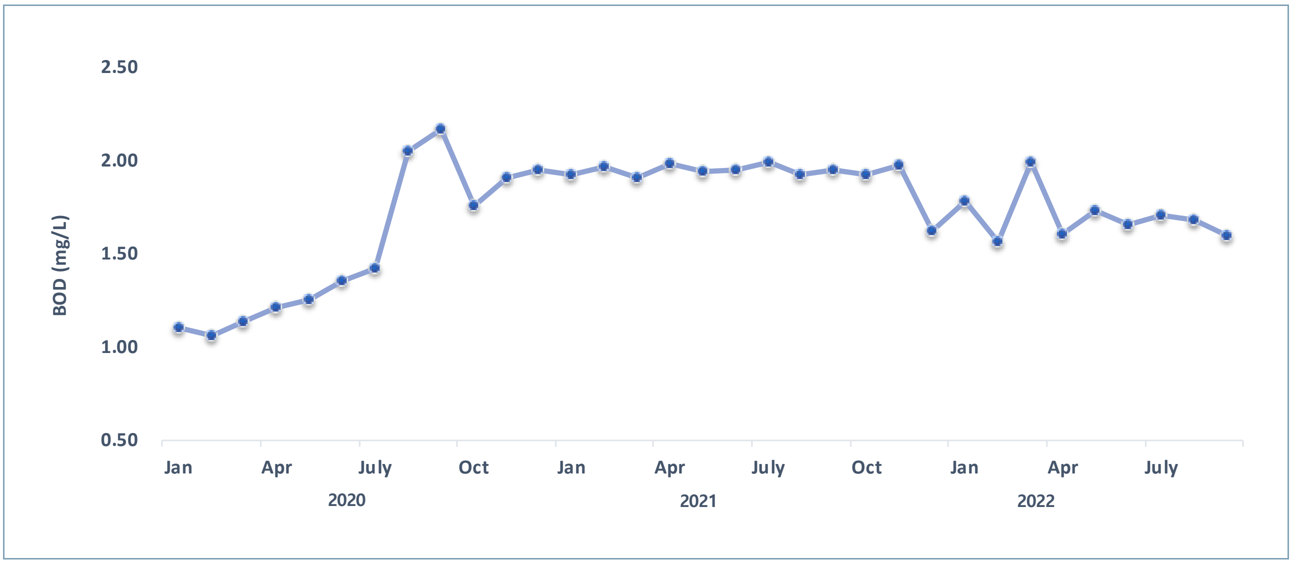


Figure 4-12 Modunaghat WTP BOD

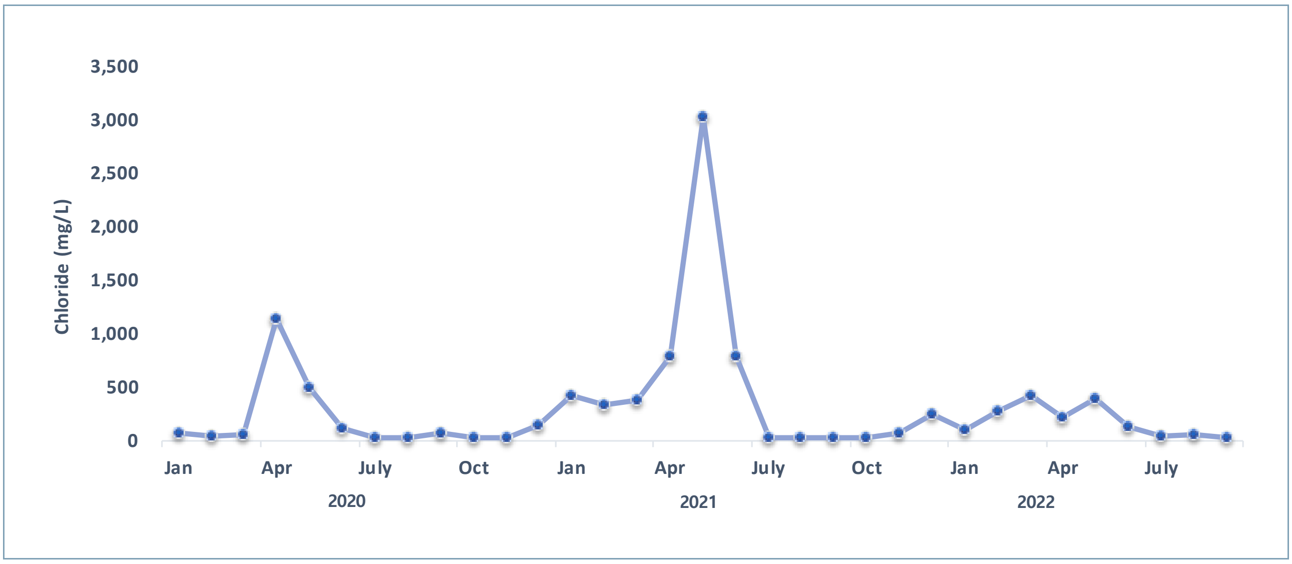


Figure 4-13 Modunaghat WTP Chloride

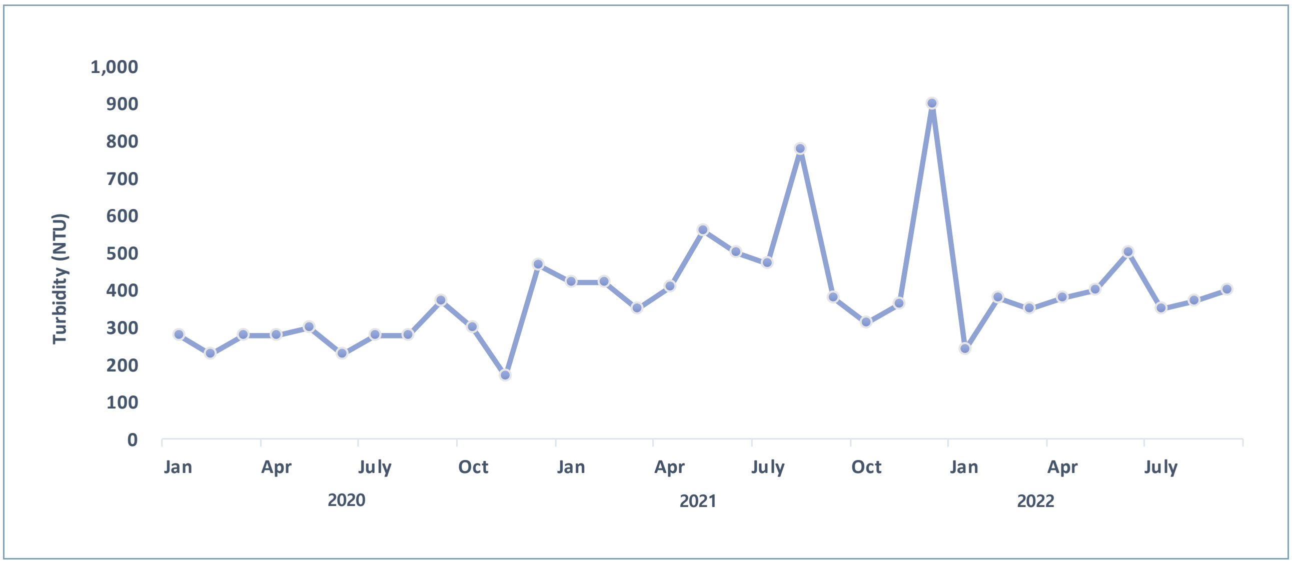


Figure 4-14 Mohara WTP Turbidity

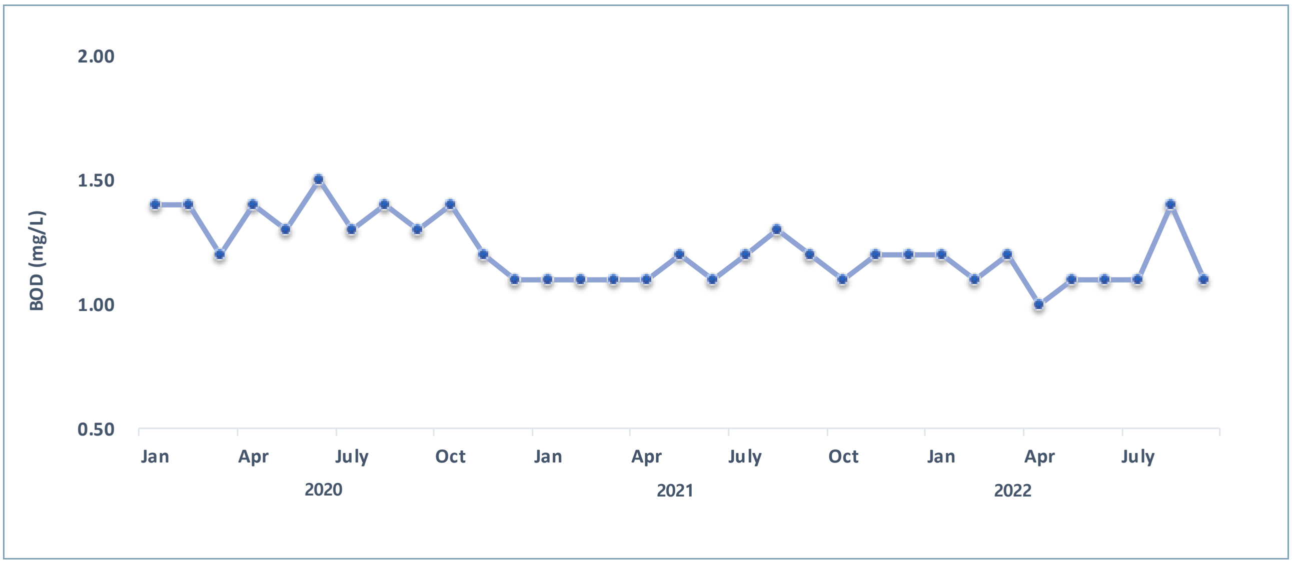


Figure 4-15 Mohara WTP BOD

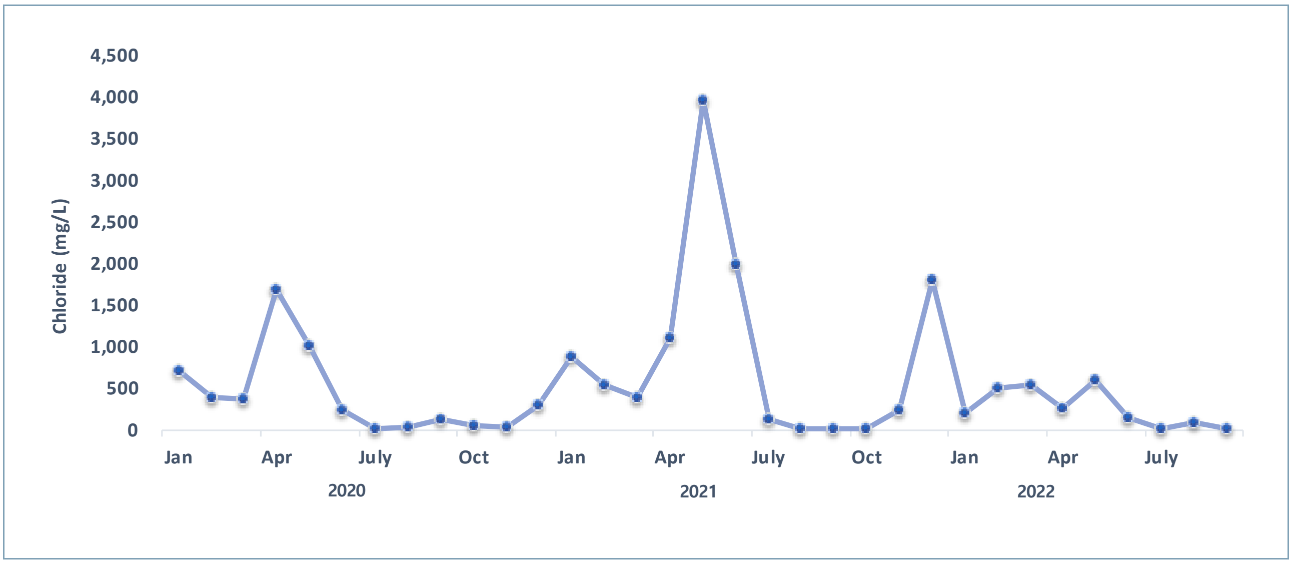


Figure 4-16 Mohara WTP BOD

Table 4-31 Modunaghat WTP raw water (2020 year)

2020 Year	pH		Turbidity (NTU)		T-Alkalinity (mg/L)		T-Hardness (mg/L)		Ca-Hardness (mg/L)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Jan	6.95	7.30	40	410	48	66	52	64	30	69
Feb	6.90	7.35	29	387	48	63	51	70	34	65
Mar	6.84	7.26	36	540	45	61	53	67	31	60
Apr	6.88	7.29	40	495	50	65	57	72	37	67
May	6.80	7.25	25	538	54	68	55	75	35	65
Jun	6.80	7.25	90	500	47	60	50	68	42	70
July	6.59	7.21	100	450	32	50	45	58	45	69
Aug	6.78	7.06	90	480	38	60	42	55	40	64
Sep	6.75	7.13	100	780	34	64	46	58	59	68
Oct	6.69	6.99	60	500	27	52	42	58	45	60
Nov	6.65	7.10	60	540	38	62	40	65	52	65
Dec	6.76	7.31	60	680	25	53	48	60	54	68
2020 Year	TDS		DO (mg/L)		BOD (mg/L)		COD (mg/L)		Chloride (mg/L)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Jan	64	192	5.20	6.10	0.95	1.10	17	21	19	64
Feb	62	107	5.20	6.90	0.82	1.06	18	21	19	47
Mar	54	96	5.40	7.10	0.84	1.13	9	24	29	62
Apr	54	1524	5.80	7.15	0.92	1.21	17	29	27	1138
May	50	879	6.20	7.30	0.85	1.25	22	35	12	500
Jun	40	198	6.20	6.70	0.80	1.35	25	40	10	120
July	54	85	5.30	6.30	0.92	1.42	29	45	8	25
Aug	48	69	5.50	6.80	0.95	2.05	35	49	8	22
Sep	52	129	5.20	6.90	0.85	2.16	32	55	9	65
Oct	39	82	5.50	6.70	0.98	1.75	30	44	8	20
Nov	48	72	5.60	6.10	0.66	1.90	24	35	10	25
Dec	40	360	6.25	7.22	0.82	1.95	29	38	8	150

Table 4-32 Modunaghat WTP raw water (2021 year)

2021 Year	pH		Turbidity (NTU)		T-Alkalinity (mg/L)		T-Hardness (mg/L)		Ca-Hardness (mg/L)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Jan	6.95	7.38	30	630	32	58	49	70	52	74
Feb	6.98	7.32	35	430	46	52	46	50	17	20
Mar	7.12	7.35	40	800	45	58	42	65	20	28
Apr	6.99	7.45	35	950	42	56	45	52	18	22
May	7.05	7.34	85	800	38	55	42	72	20	35
Jun	6.88	7.27	140	1165	30	45	45	58	18	25
July	6.82	7.23	85	955	30	53	42	55	22	26
Aug	6.92	7.30	90	1800	38	52	45	50	20	24
Sep	6.97	7.27	100	780	38	60	45	59	25	31
Oct	6.95	7.28	30	1000	33	48	42	54	22	29
Nov	6.95	7.27	30	950	38	60	45	56	25	28
Dec	7.03	7.28	40	450	36	64	42	61	20	25

2021 Year	TDS		DO (mg/L)		BOD (mg/L)		COD (mg/L)		Chloride (mg/L)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Jan	76	650	6.98	7.32	0.77	1.92	25	41	35	425
Feb	35	510	7.02	7.19	0.75	1.96	28	45	15	329
Mar	68	726	7.10	7.26	0.73	1.90	25	43	25	370
Apr	30	1975	7.05	7.20	0.80	1.98	24	48	16	785
May	81	5150	7.05	7.16	0.75	1.94	25	52	36	3025
Jun	65	1320	7.01	7.15	0.78	1.95	24	46	20	780
July	19	59	6.92	7.13	0.75	1.99	27	58	7	32
Aug	15	69	6.90	7.08	0.68	1.92	25	48	7	20
Sep	25	65	6.88	7.10	0.78	1.95	25	56	9	20
Oct	30	62	6.81	6.99	0.75	1.92	28	55	8	20
Nov	30	130	6.65	7.13	0.75	1.97	25	53	9	75
Dec	30	893	6.81	7.10	0.59	1.62	18	32	9	250

Table 4-33 Modunaghat WTP raw water (2022 year)

2022 Year	pH		Turbidity (NTU)		T-Alkalinity (mg/L)		T-Hardness (mg/L)		Ca-Hardness (mg/L)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Jan	7.04	7.29	40	300	38	50	45	60	22	28
Feb	7.01	7.30	45	550	37	51	42	58	20	24
Mar	7.02	7.29	45	650	36	51	45	55	22	29
Apr	6.97	7.38	60	650	36	51	44	58	20	28
May	7.01	7.31	85	650	44	52	42	53	18	25
Jun	6.95	7.33	90	820	34	50	42	55	20	24
July	6.87	7.29	100	510	30	49	36	52	16	23
Aug	6.91	7.29	110	550	30	48	40	52	19	25
Sep	6.85	7.30	85	1200	26	42	39	50	16	23
Oct	-	-	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-	-	-
Dec	-	-	-	-	-	-	-	-	-	-
2022 Year	TDS		DO (mg/L)		BOD (mg/L)		COD (mg/L)		Chloride (mg/L)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Jan	30	160	6.80	6.95	0.65	1.78	20	38	17	96
Feb	25	750	6.49	6.95	0.68	1.56	24	36	12	270
Mar	34	708	6.59	6.73	0.78	1.99	22	47	20	425
Apr	25	348	6.46	6.75	0.58	1.60	28	44	14	209
May	33	828	6.19	6.41	0.50	1.73	30	49	18	390
Jun	26	256	6.05	6.38	0.54	1.65	30	42	14	133
July	27	90	6.01	6.18	0.55	1.70	35	52	11	36
Aug	22	75	6.01	6.12	0.52	1.68	32	49	9	48
Sep	26	75	5.87	6.11	0.50	1.59	25	46	10	30
Oct	-	-	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-	-	-
Dec	-	-	-	-	-	-	-	-	-	-

Table 4-34 Mohara WTP raw water (2020 year)

2020 Year	pH		Turbidity (NTU)		T-Alkalinity (mg/L)		T-Hardness (mg/L)		TDS (mg/L)		Iron (mg/L)	NO_3 (mg/L)
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
Jan	7.29	7.39	90	280	52	80	50	66	36	1,120	0.33	3.7
Feb	7.15	7.35	70	230	56	60	40	46	46	650	0.23	3.3
Mar	7.14	7.35	80	280	50	64	40	44	41	600	0.14	3.9
Apr	7.10	7.33	60	280	52	64	36	42	35	2,800	0.15	4.0
May	7.02	7.28	80	300	50	60	36	47	45	1,620	0.17	3.8
Jun	6.99	7.24	70	230	50	58	48	56	36	415	0.21	3.6
July	6.5	7.17	80	280	43	57	35	46	34	45	0.25	3.9
Aug	6.63	7.04	120	280	43	54	54	58	38	46	0.13	3.3
Sep	6.53	7.29	80	370	42	56	34	46	33	200	0.43	2.4
Oct	6.69	7.12	70	300	40	56	42	48	35	68	0.20	2.3
Nov	6.74	7.26	50	170	43	58	40	45	38	56	0.16	6.5
Dec	6.80	7.28	60	465	48	56	38	44	34	480	0.25	2.4

2020 Year	PO_4 (mg/L)	SO_4 (mg/L)	NH_3 (mg/L)	DO (mg/L)		BOD (mg/L)		COD (mg/L)		Chloride (mg/L)	
				Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Jan	0.46	25	0.18	6.3	6.9	1.0	1.4	22	35	8	700
Feb	0.26	14	0.21	6.4	6.8	1.0	1.4	20	32	12	390
Mar	0.32	13	0.10	6.6	7.0	1.0	1.2	18	30	10	360
Apr	0.38	16	0.10	6.2	6.7	1.0	1.4	18	30	8	1,680
May	0.41	18	0.13	6.5	7.0	1.0	1.3	20	34	15	1,000
Jun	0.37	20	0.25	6.1	6.7	1.0	1.5	22	32	8	240
July	0.30	19	0.18	6.3	6.8	1.0	1.3	20	32	8	19
Aug	0.32	15	0.20	6.1	6.6	1.0	1.4	22	30	8	25
Sep	0.18	14	0.15	6.0	6.5	1.0	1.3	20	32	8	120
Oct	0.21	14	0.16	6.2	6.8	1.0	1.4	24	33	8	40
Nov	0.14	10	0.10	6.0	6.3	1.0	1.2	20	30	7	30
Dec	0.13	12	0.10	6.7	7.8	1.0	1.1	25	32	8	290

Table 4-35 Mohara WTP raw water (2021 year)

2021 Year	pH		Turbidity (NTU)		T-Alkalinity (mg/L)		T-Hardness (mg/L)		TDS (mg/L)		Iron (mg/L)	NO_3 (mg/L)
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
Jan	7.01	7.42	120	420	50	59	38	46	48	1,450	0.15	2.8
Feb	7.02	7.29	80	420	50	58	36	45	41	900	0.14	3.5
Mar	7.02	7.27	60	350	50	56	36	40	38	635	0.12	3.1
Apr	7.00	7.28	60	410	50	58	36	38	40	1,820	0.14	1.5
May	7.00	7.25	140	560	51	58	48	62	58	6,500	0.21	1.6
Jun	6.67	7.24	120	500	44	56	45	60	36	3,300	0.18	1.7
July	6.71	7.12	140	470	42	53	45	48	35	210	1.2	4.1
Aug	6.45	6.98	140	775	44	51	32	38	38	48	1.03	3.1
Sep	6.68	7.04	80	380	44	52	30	34	33	45	0.31	3.6
Oct	6.98	7.10	60	310	41	54	28	32	38	47	0.16	3.5
Nov	7.02	7.16	50	360	47	55	32	36	34	425	0.13	1.9
Dec	6.70	7.14	50	900	45	55	30	36	36	3,000	0.35	2.2

2021 Year	PO4 (mg/L)	SO4 (mg/L)	NH3 (mg/L)	DO (mg/L)		BOD (mg/L)		COD (mg/L)		Chloride (mg/L)	
				Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Jan	0.17	18	0.08	6.8	7.9	1.0	1.1	24	30	20	870
Feb	0.18	17	0.08	7.2	7.8	1.0	1.1	22	32	16	540
Mar	0.16	15	0.10	7.5	7.9	1.0	1.1	18	28	8	380
Apr	0.10	11	0.11	7.2	8.1	1.0	1.1	19	30	12	1,100
May	0.28	35	0.16	5.5	6.1	1.0	1.2	25	38	20	3,960
Jun	0.18	38	0.14	5.8	6.4	1.0	1.1	22	34	8	1,980
July	0.41	18	0.15	6.0	6.1	1.0	1.2	25	32	8	120
Aug	0.47	14	0.21	6.5	6.9	1.0	1.3	22	30	7	20
Sep	0.41	13	0.25	6.8	7.3	1.0	1.2	18	26	7	17
Oct	0.26	14	0.17	6.9	7.5	1.0	1.1	18	28	7	19
Nov	0.17	12	0.10	7.4	8.2	1.0	1.2	18	27	7	240
Dec	0.32	12	0.11	5.9	6.8	1.0	1.2	18	24	8	1,800

Table 4-36 Mohara WTP raw water (2022 year)

2022 Year	pH		Turbidity (NTU)		T-Alkalinity (mg/L)		T-Hardness (mg/L)		TDS (mg/L)		Iron (mg/L)	NO_3 (mg/L)
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
Jan	6.81	7.08	60	240	42	52	32	36	35	365	0.30	4.9
Feb	6.82	7.14	60	380	44	52	32	43	36	860	0.13	4.1
Mar	6.87	7.20	60	350	44	54	32	42	42	940	0.18	4.1
Apr	6.80	7.10	65	380	45	56	35	42	34	416	0.13	2.2
May	6.85	7.15	90	400	43	54	35	40	35	1020	0.22	3.3
Jun	6.71	7.17	80	500	44	55	35	44	33	265	0.15	2.4
July	6.75	7.10	70	350	43	52	40	46	33	48	0.15	3.6
Aug	6.81	7.09	80	370	44	57	33	42	33	132	0.16	2.3
Sep	6.70	7.12	90	400	44	54	30	36	28	36	0.26	3.4
Oct	-	-	-	-	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-	-	-	-	-
Dec	-	-	-	-	-	-	-	-	-	-	-	-

2022 Year	PO_4 (mg/L)	SO_4 (mg/L)	NH_3 (mg/L)	DO (mg/L)		BOD (mg/L)		COD (mg/L)		Chloride (mg/L)	
				Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Jan	0.23	12	0.13	6.3	6.5	1.0	1.2	18	22	8	200
Feb	0.24	16	0.07	7.6	8.1	1.0	1.1	20	28	8	500
Mar	0.36	22	0.10	6.5	7.4	1.0	1.2	22	28	10	540
Apr	0.28	15	0.13	7.1	7.5	0.93	1.0	18	26	8	250
May	0.32	18	0.18	6.5	7.2	0.94	1.1	18	32	8	600
Jun	0.45	17	0.18	6.3	6.9	0.95	1.1	18	32	6	150
July	0.48	14	0.28	6.6	7.4	1.0	1.1	22	30	6	19
Aug	0.43	18	0.24	6.2	6.8	1.0	1.4	24	36	6	80
Sep	0.47	17	0.23	6.2	6.9	1.0	1.1	20	32	6	14
Oct	-	-	-	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-	-	-	-
Dec	-	-	-	-	-	-	-	-	-	-	-

4.2.3.11.3.3 Water Quality Prediction

Based on the final target year of 2070, the water quality of the Halda River is predicted to be able to maintain BOD of 2.07mg/L and SS of 0.14mg/L. Therefore, it is judged that there is only minor effect to the Halda River due to the discharge of treated effluent.

Table 4-37 Prediction of Halda River water quality according to sewage treatment

Category			Unit	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Flow	Total		m^3/d	25,960,612	25,975,574	26,003,876	26,039,842
	Halda River		m^3/d	25,920,000	25,920,000	25,920,000	25,920,000
	Fatehabad STP		m^3/d	40,612	55,574	83,876	119,842
Load	Untreated	BOD	kg/d	64,660.80	69,478.80	78,594.80	90,176.80
		COD	kg/d	1,477,680.00	1,487,317.00	1,505,547.00	1,528,712.00
		SS	kg/d	15,696.00	21,478.00	32,416.00	46,315.00
		T-N	kg/d	3,106.00	4,251.00	6,416.00	9,167.00
		T-P	kg/d	589.00	805.00	1,216.00	1,737.00
	Treated	BOD	kg/d	52,393.04	52,692.28	53,258.32	53,977.64
		COD	kg/d	1,455,581.20	1,457,077.40	1,459,907.60	1,463,504.20
		SS	kg/d	1,218.36	1,667.22	2,516.28	3,595.26
		T-N	kg/d	1,624.48	2,222.96	3,355.04	4,793.68
		T-P	kg/d	406.12	555.74	838.76	1,198.42
Water Quality	Untreated	BOD	mg/L	2.49	2.67	3.02	3.46
		COD	mg/L	56.92	57.26	57.90	58.71
		SS	mg/L	0.60	0.83	1.25	1.78
		T-N	mg/L	0.12	0.16	0.25	0.35
		T-P	mg/L	0.02	0.03	0.05	0.07
	Treated	BOD	mg/L	2.02	2.03	2.05	2.07
		COD	mg/L	56.07	56.09	56.14	56.20
		SS	mg/L	0.05	0.06	0.10	0.14
		T-N	mg/L	0.06	0.09	0.13	0.18
		T-P	mg/L	0.02	0.02	0.03	0.05

4.2.3.11.4 Case Study of Korea

4.2.3.11.4.1 Water Source Protection area

The Ministry of Environment has established management rules for the purpose of preserving the water quality of water supply sources, and the designation standards for each water source are as follows.

Table 4-38 Designation Standard of Water Source

Category	Designation standard
Stream and Riverbed water	• The standard distance is 4 km from the water intake point. • The standard distance can be increased or decreased according to the standard distance adjustment standard rating table, taking into account water pollution conditions, water intake, water intake rate, and development potential of the surrounding area. • The width of the protection area shall be the catchment area, but the area where rainwater, sewage or wastewater does not flow directly into the water supply source through embankments is excluded.
Lake	• It is designated according to the same criteria as in the case of river water or subsurface water, but for water source-only dams, water sources with a daily water intake of 100,000 tons or more, or lakes deemed necessary due to the characteristics of the region, the standard distance calculation base is the full water level line of the lake. • If the area of the catchment area exceeds 150㎢ in the full water level area, the width can be determined separately in consideration of regional characteristics for the area exceeding 10km from the water intake point.
Underground water and Riverbank filtration	• From the water intake point, the standard distance is 200m radius for groundwater (20m radius in case of deep groundwater) and 2km for riverbank filtration water. • Designated starting from the intake point by considering the depth of the ground, water quality, water intake, land use conditions in adjacent areas, soil permeability coefficient, stratum structure, and subterranean water veins.
Exception	• Areas free of pollutants such as barns and factories, and areas deemed to have no potential for contamination and development within the next 10 years when reviewing designation of protected areas • In the vicinity of water intake facilities that take in deep underground water, in areas where it is recognized that there is no concern for water pollution due to geology or stratum structure • An area where water intake facilities are installed to supply only industrial water, and it is recognized that there is no obstacle to the use of industrial water even without designation of a protection area

*Source: Water Source Management Rules (Ministry of Environment No.994)

Treated effluent discharge point of STP in Madari Khal is about 7.6km away from the intake facility of Modunaghat WTP and about 11.5km away from the intake facility of Mohara WTP, so the impact of effluent will be negligible to the intake of WTP. For instance, 4.0km of standard distance from the intake of WTP is considered when designating a water source protection area in Korea.

Table 4-39 Distance from Water Source

Water Source	River	Flow Distance (From STP)	Remarks
Modunaghat WTP	Halda River	7.6km	
Mohara WTP	Halda River	11.5km	

4.2.3.12 Sludge Treatment Process

4.2.3.12.1 Thickening Facility

4.2.3.12.1.1 Function

Waste activated sludge or biosolids coming from the secondary sedimentation tank is fairly dilute, with a suspended solids concentration in the range of 0.5% to 1.2% dry solids (DS). Biosolids thickening is therefore needed to reduce the volume of biosolids that are sent to stabilization treatment and subsequent dewatering.

4.2.3.12.1.2 Thickening Type

Mechanical thickening and gravity thickening is compared and reviewed as follows. Mechanical Thickening is applied to this project considering with high solids recovery rate and stable operation.

Table 4-40 Comparison of Thickening Type

Category	Mechanical	Gravity
Introduction	• A method of mechanically thickening, separating and discharging sludge that is difficult to settle and thickening	• Condensation using gravity by retaining the sludge • A method of collecting and discharging the sludge settled on the floor at the outlet with a scraper
Advantage	• Required area is small • High solids recovery rate • Less bad smell due to closed structure	• Simple structure and easy maintenance • Suitable for primary sludge treatment as storage and Thickening are possible at the same time • Low noise and vibration
Disadvantage	• The initial facility cost is expensive and the maintenance cost is higher than that of the gravity type • A lot of noise and vibration • There are many mechanical devices, and the power cost is high.	• The treatment efficiency is not stable because it is affected by the temperature. • Bad smell • Required area is very large
Select	◉	

4.2.3.12.2 Stabilization Facility

4.2.3.12.2.1 Function

Waste Activated Sludge (WAS) or excess Biosolids produced by Biological Treatment is not stabilized. It has potential for putrefaction and contains a fairly high concentration of pathogens (fecal bacteria, viruses, helminths, etc.). Almost any reuse or disposal option requires further stabilization treatment to prevent odours and attracting disease vectors like flies and rats. Biological stabilization by either aerobic or anaerobic digestion is the most common

4.2.3.12.2.2 Stabilization Type

The stabilization method can be divided into anaerobic digestion and aerobic digestion, and should be selected in consideration of local weather conditions, electric power, and operating personnel. Aerobic digestion has high power costs due to the operation of a blower. Anaerobic digestion reduces power and maintenance costs through the production of methane gas, and has high Dewatering efficiency. Sludge stabilization process (anaerobic digestion) is planned to be introduced in Phase 2 in the consideration of the difficulty of O&M.

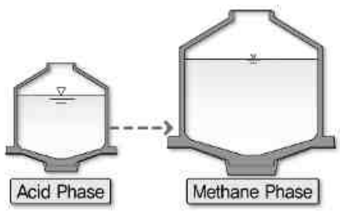
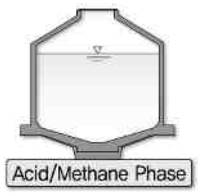
Table 4-41 Comparison of Stabilization Type

Category	Anaerobic	Aerobic
Introduction	• Organic matter is decomposed by microorganisms in the absence of dissolved oxygen	• Air reacts with microorganisms to decompose organic matter
By-product	• CH_4, CO_2, H_2O	• CO_2, H_2O
Advantage	• Product CH4 • Less sludge production after treatment • Low power and maintenance cost	• Reduce bed smell • Easy to operate • Supernatant water quality good
Disadvantage	• Need to maintain digestion temperature (35℃~55℃) • The growth rate of microorganisms is slow, so adaptation time is required. • Bad smells caused by ammonia and H_2S	• Poor dewatering of sludge • Power cost for aeration is high • Low organic matter reduction rate • There are no valuable by-products of production
Select	◉	

4.2.3.12.2.3 Anaerobic Digestion Process

In this plan, mesophilic two hase anaerobic digestion process is applied to this projection considering with a large amount of bio gas and high stability against shock loads.

Table 4-42 Comparison of Anaerobic Digestion Process

Category	Mesophilic Two Phase Anaerobic Digestion	Mesophilic One Phase Anaerobic Digestion
Introduction	 • Composed of acid phase digester and methane phase digester	 • All processes of anaerobic bacterial metabolism are conducted in one reactor
Advantage	• Bio gas production is high • Good stability against shock loads such as fluctuation in inflow properties • It is possible to maximize the operation of the process by dividing the digester	• Low initial installation cost and simple structure • Required area is small
Disadvantage	• Required area is large • Separate management of acid fermentation gas with high H_2S Thickening is required • Maintenance is difficult	• Low methane production efficiency • Weak to impact load • Difficulty optimizing the process due to acid and methane fermentation being carried out simultaneously
Select	◉	

4.2.3.12.3 Dewatering Facility

Dewatering of the thickened or digested sludge is required so the sludge can be handled as a solid material that does not release large amount of free water upon standing. It also reduces the total volume (and weight) of the material to be hauled for off-site reuse or disposal. To achieve this, a concentration of at least 18 - 20 percent dry solids is required.

Table 4-43 Comparison of Dewatering Type

Category	Mechanical	Sludge Drying Bed
Introduction		
	• Dewatering sludge using mechanical power	• Dewatering by evaporating sludge under natural conditions
Efficiency	• High efficiency	• Takes a long time using natural conditions • Low efficiency compared to mechanical methods
Maintenance	• Requires regular check • Less manpower required due to automation	• Compared to mechanical Dewatering, electricity and coagulant consumption are small. • Requires a lot of manpower
Required Area	• Small	• Large
Advantage	• Unaffected by seasons or climate • No problems caused by secondary pollution	• Low maintenance cost such as power cost • No breakdown, simple maintenance
Disadvantage	• High power and maintenance cost • Requires regular check	• Unusable in rainy weather, sensitive to seasons and climate • Occurrence of secondary pollution such as groundwater contamination, bed smell problems
Construction Cost	• Middle	• Small
Maintenance Cost	• Large (Electricity cost)	• Small (Manpower cost)
Select	◉	

4.2.3.13 Final Disposal of Sludge Cake

CCC operates two municipal solid waste landfills in Arefin Nagar and Halishahaar. Due to the lack of capacity of the existing landfills, CCC are planning for the alternative option for the solid waste management, but site selection is difficult due to the land acquisition and complaints from local residents.

There are many options to consider as the final disposal of sludge cake, but in reality, landfill is considered the most feasible option. But there is no landfill site to cater the sludge cake from Catchment-3 in CCC. Since there are currently 4 sewerage projects in progress in addition to this EDCF project in Chattogram City, CWASA have to set up the long-term perspective plan of sludge cake disposal in the consideration of whole 6 catchments of CCC.

Table 4-44 Municipal Solid Waste Landfills of Chattogram City

Arefin Nagar Landfill	Halishahaar Landfill
	

Table 4-45 Option of Final Disposal of Sludge Cake

Category	Landfill	Incineration	Composting
Introduction	• Landfill after Thickening and mechanical Dewatering	• Incineration after thickening and dewatering • Incinerated ash is disposed of at a nearby landfill	• Production of effective products by fermentation after thickening and dewatering
Advantage	• No additional facilities • The processing cost is relatively low • No additional operation management required	• Low pollution load on the environment • Possible to generate electricity using recovered heat	• Generation of effective products such as land improvement agents • Reduce operating and management costs by selling effective products
Disadvantage	• Need to secure an alternative landfill due to insufficient capacity of the existing landfill	• High facility investment cost • Operation management is difficult, so a separate manager is required • High operating cost	• Demand is limited due to the prejudice for the sludge cake • Facility investment and operation management cost are high • Operation management is difficult, so a separate managing is required
Select	◉		

4.2.3.14 Reserve Facilities for Sludge Treatment

Option study of reserve facilities for sludge treatment such as sludge drying bed, faecal sludge treatment plant and temporary sludge cake storage facility is presented to reduce the operation & maintenance cost of sewage treatment plant as below.

- Sludge drying bed can be used for a sludge thickening and dewatering instead of mechanical thickening and dewatering facility during dry season.
- Gravity faecal sludge thickening tank and constructed wetland can be used for a faecal sludge treatment instead of mechanical thickening and dewatering facility during dry season.
- Sludge cake storage tank can be used as a short-term plan for the final disposal of sludge cake.

As a result of the option study, reserve facilities for sludge treatment are not included in the project scope because the construction cost is about 12 US$ million, so the initial investment cost is excessive and even considering the reduction in O&M cost, it is analyzed as economically not feasible.

Table 4-46 Reserve Facilities for Sludge Treatment

Category		Specification	Capacity	Construction Cost (US$ thousands)
Sludge Drying Bed		W20.0m x L40.0m x H0.7m x 48Nos.	26,880 m^3	7,539
Faecal Sludge Treatment	Thickening	W13.3m x L15.0m x H2.0m x 4Nos.	800 m^3	196
	Constructed Wetland	W20.0m x L25.0m x H1.0m x 2Nos.	1,000 m^3	191
Sludge Cake Storage Facility (A1 Site)		W20.0m x L40.0m x 1No.	46,000 m^2	4,171
Total				12,097

Sewage treatment plant will be located in the A3 site, sludge cake can be stored in the A1 site or A2 site as a tentative plan before CWASA set up the long-term perspective plan of sludge cake disposal.

Table 4-47 Storage Capacity in the STP Reserve Site

Category		Storage capacity			Sludge Cake (2030, m^3/d)	Storage Expectancy (year)
		Area (m^2)	Height (m)	Capacity (m^3)		
A1 Site	With Reserve	46,000	1.5	69,000	121	1.6
	Without Reserve	187,000	1.5	280,500	121	6.4
A2 Site		51,000	1.5	76,500	121	1.7

Process flow diagram and layout of reserve facilities for sludge treatment is as below.

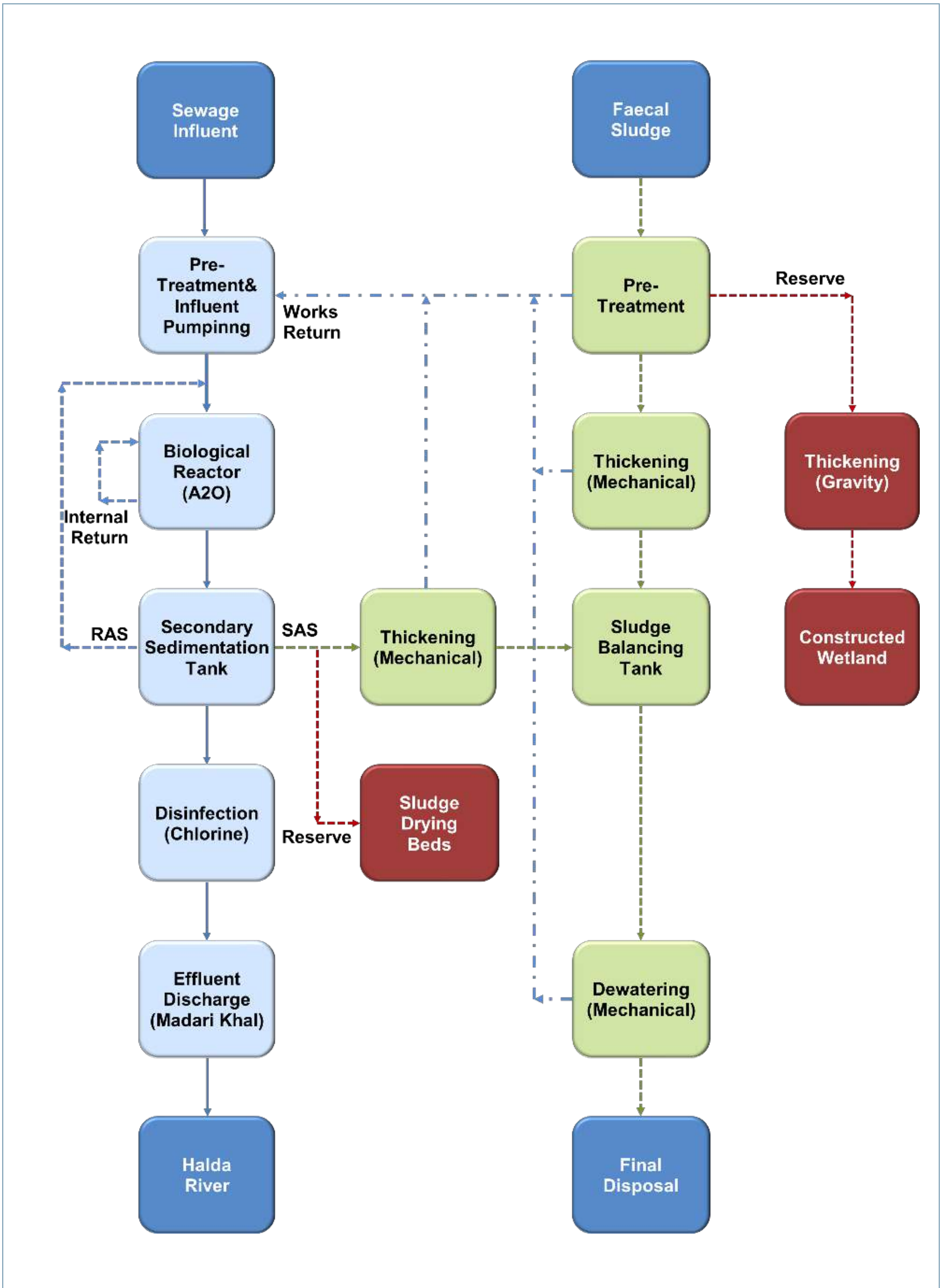


Figure 4-17 Process Flow Diagram including Reserve Facilities for Sludge Treatment

Figure 4-18 Layout of Reserve Facilities for Sludge Treatment

4.2.3.15 Faecal Sludge Management

4.2.3.15.1 Introduction

The component of faecal sludge management consists of faecal sludge collection, treatment and reuse or final disposal. Faecal sludge generated from the on-site system should be collected regularly to prevent the accumulation of sludge and the discharge of untreated water to public water body.

In this study, it is planned to introduce the sewerage system to five wards in priority where current water service coverage under CWASA is available out of seven wards in Catchment-3 in the consideration of project budget. Sewage service coverage of the Catchment-3 is 0% at the end of 2022 and is planned to achieve 60.0% by 2030 after completion of the project and to achieve 80.0% by 2070 in the final target year.

This study proposes a concept for faecal sludge management in order to cope with the coming challenges connected to the rapid growth of the project area. Part of the concept includes the use of on-site system in low density urban areas of Chattogram City, Hathazari and Raozan where the construction of sewerage system would not be cost effective.

Currently most of the faecal sludge in Chattogram City is collected by a private company and is treated unsanitary, so the long-term plan of faecal sludge management was presented in the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP). In the follow-up on-going sewerage project, faecal sludge management is included in the project scope of each project and CWASA is having a discussion with the CCC regarding the R&R of FSM.

In order to operate the FSM systematically, it is necessary to improve the capacity of the CWASA and the CCC.

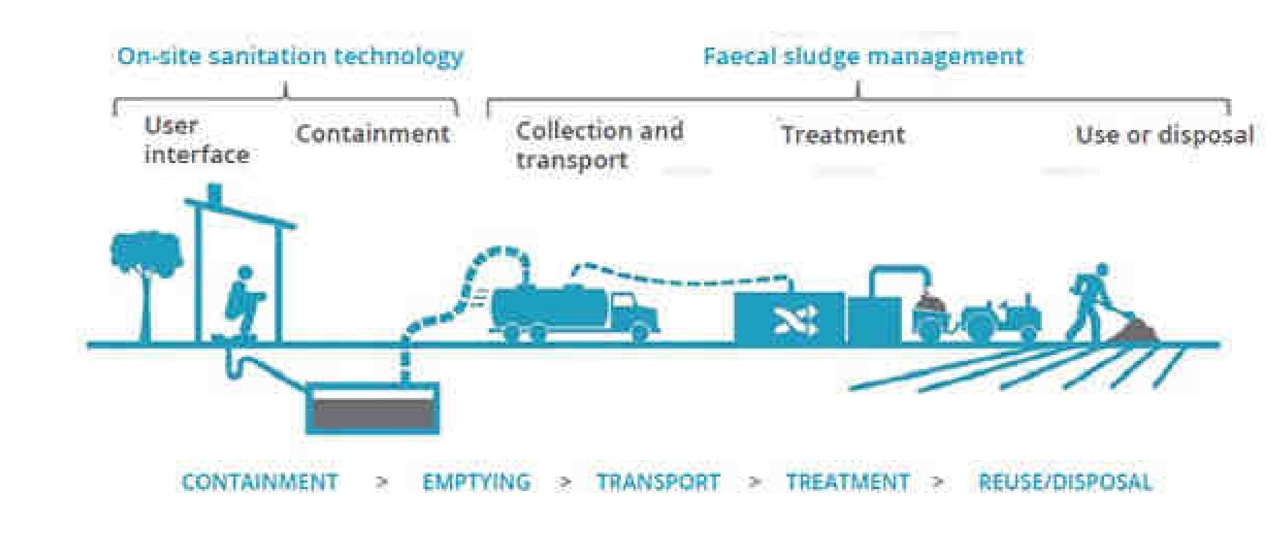


Figure 4-19 Faecal Sludge Management Process

4.2.3.15.2 Current Status

In terms of types of on-site system based on field survey of 400 households in the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP), 64.5% of the households have septic tanks, 17.0% have pit latrine and 2.0% have VIP latrines. The remaining 16.5% of the households do not have any proper type of on-site system, so the untreated wastewater is discharged to the public water body.

Table 4-48 Types of On-Site System in the CCC

Category		Frequency	Percentage (%)
Hygienic Toilet	Septic Tank	258	64.5
	Pit Latrine	68	17.0
	Ventilated Improved Pit (VIP) Latrine	8	2.0
	Sub-Total	334	83.5
Unhygienic Toilet	Flush directly to drain/khal	11	2.8
	Pit Latrine without slab directly to drain/khal	9	2.2
	Pour flush directly to canal	44	11.0
	Sub-Total	64	16.0
No Toilet, Open Defecation		2	0.5
Total		400	100

*Source: Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP)

In terms of on-site system emptying, the majority (91.8%) of households depend upon local sweepers. Only 6.2% of the households are currently using the service provided by the CCC and NGO using vacuum tanker. CCC is currently providing limited faecal sludge collection and transportation services. CCC has two vacuum trucks having a capacity of 3.6m^3. All the collected faecal sludge by CCC is transferred to the Halishahar landfill and disposed without any treatment.

Table 4-49 Faecal Sludge Collection Status

Category	Frequency	Percentage (%)	Remarks
Local Sweeper	90	91.8	
CCC	3	3.1	
NGO	3	3.1	
Others	2	2.0	
Total	98	100.0	

4.2.3.15.3 Regulatory Framework of FSM

According to the National Action Plan for implementation of Institutional and Regulatory Framework for Faecal Sludge Management for City Corporation (Local Government Division, 2021), the City Corporation shall be responsible for proper execution of the entire FSM service chain, including collection (emptying), transportation, treatment, disposal and end-use. The City Corporation shall carry out and/or oversee these operations, making sure that there are carried out in compliance with existing rules and regulations with the cooperation of relevant authorities and agencies as below.

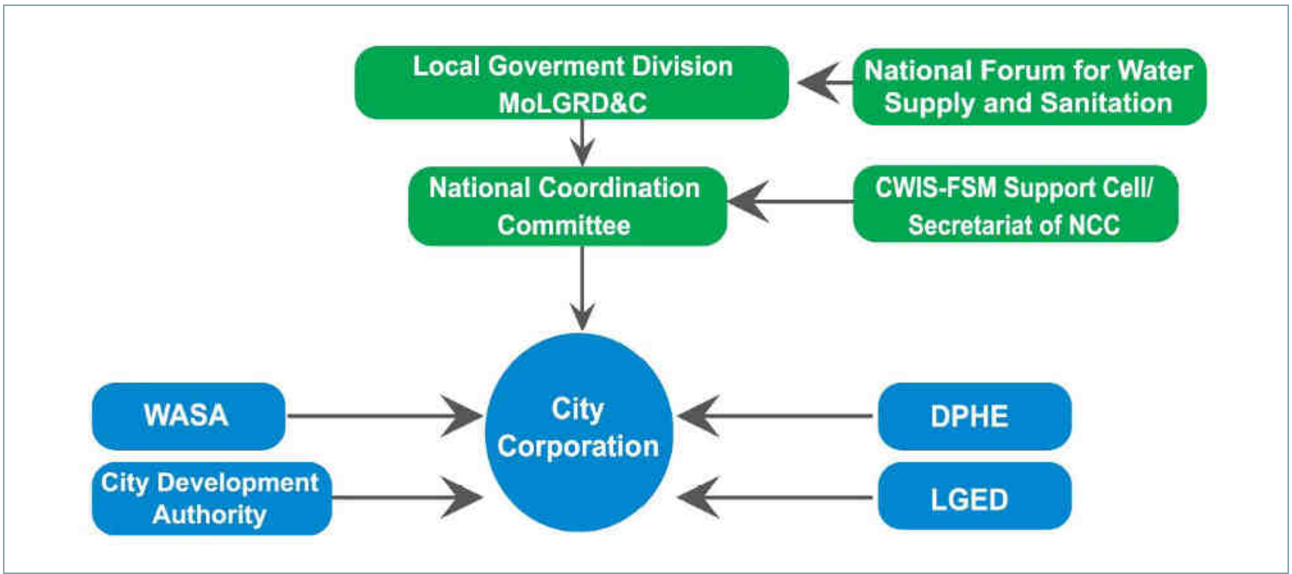


Figure 4-20 Implementation Structure for FSM at City Corporation

In the case of the Chattogram City, the R&R of sludge collection, treatment, and disposal among CCC, CDA, and CWASA was discussed with the support of World Bank and a Memorandum of Understanding (MoU) among these three parties was drafted in October 2022 as below.

CWASA may be responsible for the collection, transport, and treatment of faecal sludge for the entire CCC area on completion of each on-going sewerage projects.

Table 4-50 R&R of FSM in Draft MoU among CWASA, CCC, and CDA

Category	Scope
CWASA	• Conduct a baseline survey in CCC area to identify and demarcate areas / households to be served through on-site sanitation with a focus on FSM and also analyze the situation regarding FSM in low-income and other communities. • Prepare MIS on FSM (holding type, number of occupants, holding tax, desludging dates, and water connection) linked with GIS. • Share the MIS with CCC and regularly update the database. • Scale up the entire value chain FSM in CCC area as mentioned in MP and implement the entire value chain by 2025. • Arrange faecal sludge collection equipment and vehicles as well as construct, operate, and maintain FSTP. • On completion of FSTP, be responsible for the collection, transport, and treatment of faecal sludge for the entire CCC area. • Support and take part with CCC and CDA in awareness-raising programs regarding the disconnection of septic tanks and pits connected to drains, khals, and water bodies. • Pilot alternative sanitation schemes in the LICs and gradually scale them up in all 41 wards. • Prepare a business plan for O&M of the FSM project and share it with CCC.
CCC	• Continue FSM services until new FSTP is constructed by CWASA in 2025. • After 2025, CWASA will be responsible for the collection and treatment of faecal sludge. Subject to an agreement amongst the parties all assets (trucks and FSTPs) will be transferred to CWASA and they will be

Category	Scope
	responsible for their O&M of the aforesaid infrastructures. • Start scheduled emptying of septic tanks and pits as mentioned in Bangladesh National Building Code 2020. • Provide necessary data to CWASA for the preparation of the MIS. • Organize awareness-raising programs regarding the disconnection of septic tanks and pits connected to drains, khals, and water bodies with support from CWASA and CDA. • Start enforcing the disconnection of illegal connections from septic tanks and pits with drains and water bodies from January 2023. CDA and CWASA will support the program. This program shall be continuous and shall be continued until the desired results are obtained. • Provide necessary support to CWASA in piloting alternative sanitation schemes in the LICs and gradually scale them up in all 41 wards.
CDA	• Support CCC to start scheduled emptying of septic tanks and pits as mentioned in Bangladesh National Building Code 2020. • Support CCC to organize awareness-raising programs regarding the disconnection of septic tanks and pits connected to drains, khals, and water bodies. • Support CCC to enforce the disconnection of illegal connections from septic tanks and pits with drains and water bodies from January 2023. CWASA will also support the program. This program shall be continuous and shall be continued until the desired results are obtained. • Provide necessary support to CWASA in piloting alternative sanitation schemes in the LICs and gradually scale them up in all 41 wards. • Engage with CWASA during the approval of new building construction permits and development of new housing areas to ensure that the sanitation component of aforesaid new construction or development is in line with the MP of CWASA.

4.2.3.15.4 Faecal Sludge Production

In Phase 1 as of year 2040, faecal sludge production is 93m^3/d and in Phase 3 as of the final target year 2070, faecal sludge production is 142m^3/d.

Although low-density area of Chattogram City and sub-urban area such as Hathazari and Raozan is planned using the on-site system until the final target year 2070, centralized sewerage system can be introduced as the project area develops. In this study, capacity of faecal sludge treatment plant is planned as 100m^3/d for the Phase 1 and future expansion plan for the Phase 2&3 have to be established based on the actual faecal sludge collection and O&M status of FSTP.

Table 4-51 Faecal Sludge Production

Category		Base (2022)	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Annual (m^3/year)	CCC	27,201	13,269	14,666	15,593	14,683
	Hathazari	6,597	8,038	10,289	13,712	17,399
	Raozan	4,949	6,721	9,121	14,004	19,840
	Total	38,747	28,028	34,076	43,309	51,922
Daily (m^3/d)	CCC	75	36	40	43	40
	Hathazari	18	22	28	38	48
	Raozan	14	18	25	38	54
	Total	107	76	93	119	142
Capacity of FSTP (m^3/d)		100	100	100	100	100

4.2.3.15.5 Faecal Sludge Collection

Faecal sludge collection vehicle will be procured in the project to collect the faecal sludge from the serving area with on-site system in Chattogram City, Hathazari Upazila and Raozan Upazila.

Table 4-52 Procurement of Faecal Sludge Collection Vehicle

Category	Capacity (m^3)	Quantity	Photo	Remarks
Type 1	10.0	1		
Type 2	5.0	2		
Type 3	3.0	2		
Type 4	0.7	2		
Type 5	0.5	7		

4.2.3.15.6 Faecal Sludge Treatment Plant

Faecal sludge treatment plant is planned to treat the faecal sludge after collection and transport to the sewage treatment plant. Faecal sludge will be co-treated with sewage sludge after pre-treatment and thickening. Anaerobic digestion as sludge stabilization process is planned to be introduced in Phase 2 in the consideration of the difficulty of O&M.

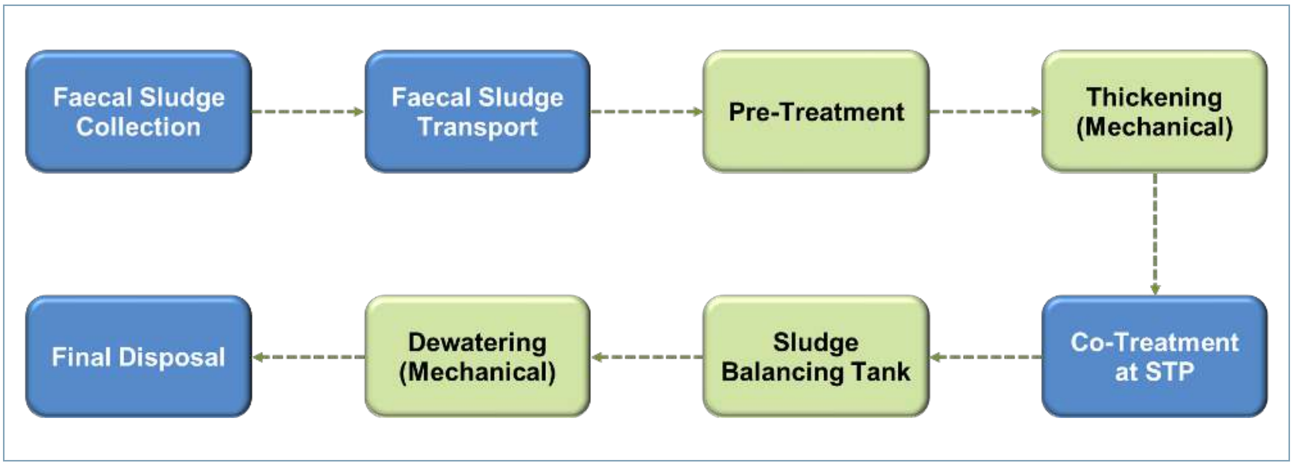


Figure 4-21 Faecal sludge treatment process diagram (Phase 1)

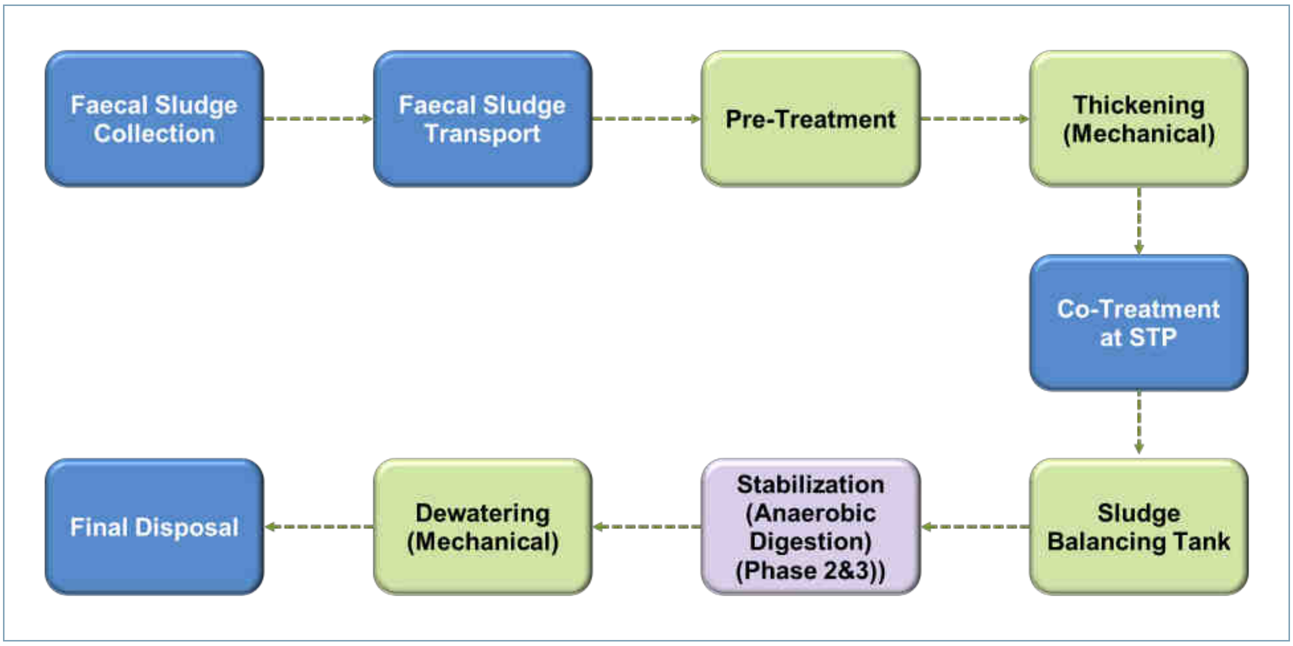


Figure 4-22 Faecal sludge treatment process diagram (Phase 2&3)

4.2.3.16 Energy Self-Sufficient Plan

Biogas power generation & Solar power generation is planned as a renewable energy source to contribute for the sustainable development by introducing green technology and reducing greenhouse gas emission.

- Anaerobic digestion for biogas power generation will be introduced in Phase 2.
- Solar panels will be installed on top of the biological reactors in Phase 1.

Energy self-sufficiency rate of STP is planned as 13.5% in Phase 1, 27.2% in Phase 2 and 23.9% in Phase 3 respectively and it is subject to change the project implementation of each phase.

Table 4-53 Detail of Solar Power Generation

Category	Description	Remarks
Required Area	3,100m^2	On top of the biological reactor
PV Module Capacity	567kW	315W/module X 1,800modules
Power Generation	207MW/year	567kW X 365days
Feed in Tariff Rate	0.096 USD/kWh	
Annual Income	USD 19,610	206,955kW/year X 0.096USD/kWh

Table 4-54 Energy Self-Sufficient Rate of STP

Category		Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Capacity of STP (m^3/d)		60,000	90,000	120,000
Power Consumption (MVA)		4.20	5.40	7.40
Power Generation (MVA)	Biogas	-	0.90	1.20
	Solar Power	0.57	0.57	0.57
	Total	0.57	1.47	1.77
Energy Self-Sufficient Rate (%)		13.5	27.2	23.9

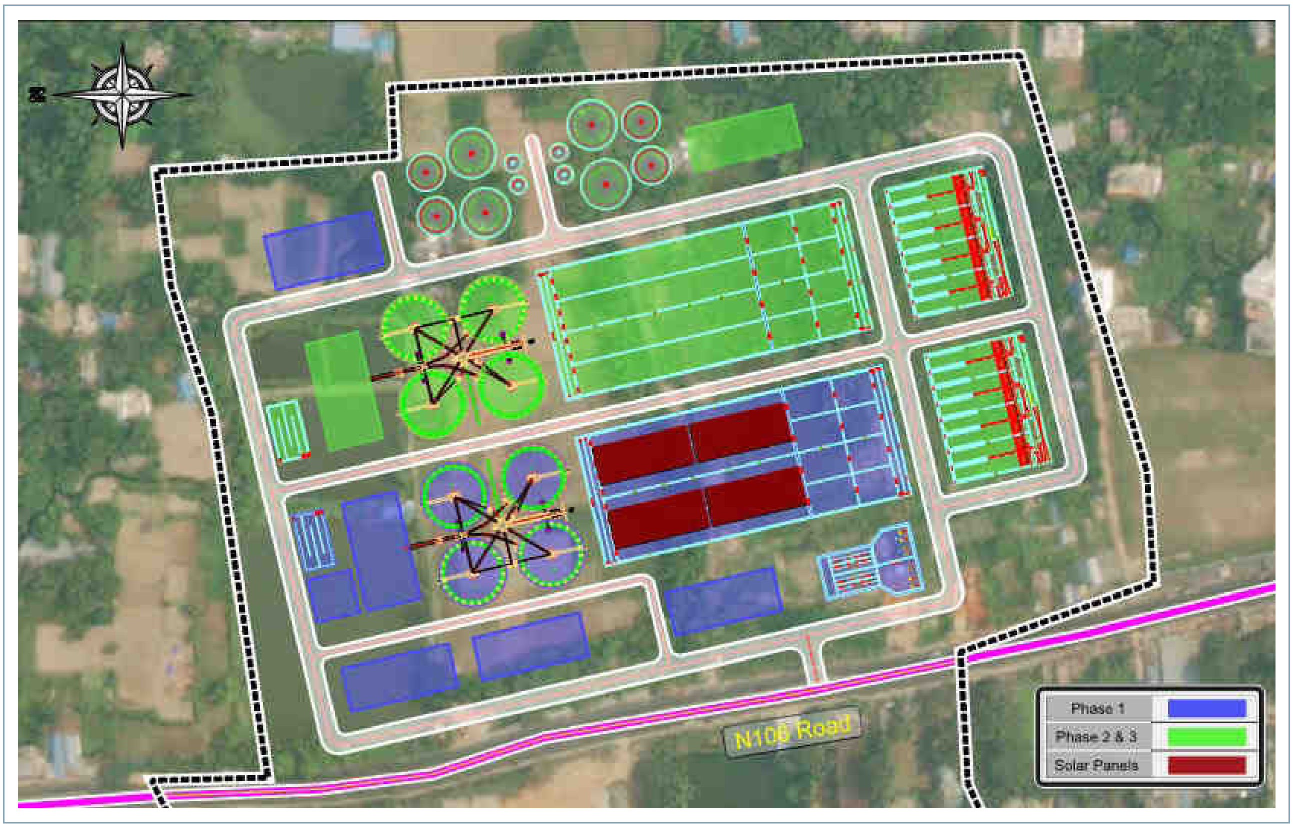


Figure 4-23 Layout of Solar Power Generation

4.2.3.17 Operation & Maintenance Vehicle

Operation & maintenance vehicle will be procured in the project for O&M of sewage treatment plant.

Table 4-55 Operation & Maintenance Vehicle

Category	Capacity (m^3)	Quantity	Photo	Remarks
Combined Backhoe/ Wheel Loader	0.6	3		
Truck with Hydraulic Hoist	7.5	2		
Truck with Hydraulic Hoist	20.0	1		

4.3 Sanitary Sewer & Pumping Station

4.3.1 Introduction

In the sewerage project, sanitary sewer planning has the function of collecting & transporting the sewage from the sewerage service area to the sewage treatment plant to improve the Living Standard and to preserve water quality in public waters. Therefore, in this plan, a sanitary sewer construction plan should be established in consideration of the local conditions within this planning area.

Chattogram is currently in a situation where sewage is discharged into the river from septic tanks or households without Sewage treatment plant, and it is urgent to construct new sanitary sewers and Sewage treatment plant. In this plan, the Sewerage Collection System in the planned sewage treatment area is planned based on the separate sewer system. The basic direction of the new sanitary sewer shall be to comprehensively review the collection of sewage from the main sewer in the treatment area, topographical characteristics, and conditions, and establish a maintenance plan.

4.3.2 Current Status and Problems

Chattogram is currently discharging sewage from septic tanks or households into stormwater pipes or rivers without Sewage treatment plant, so water pollution in rivers is serious. In addition, some of the untreated sewage discharged into the river is taken as raw water for water treatment facilities, and it is judged that it will adversely affect the Living Standard of local residents and public health. In this plan, it is planned to establish sewage treatment plant and sanitary sewer to transport sewage to the planned sewerage service area.

4.3.3 Sewerage Collection System

4.3.3.1 Introduction

In determining the Sewerage Collection System of the existing urban area, it is desirable to comprehensively review the characteristics and problems of each drainage method, constructability, economic feasibility, maintenance management, and water quality conservation to select an exclusion method that sufficiently converges the situation.

In this plan, based on the sewage treatment area established in the basic plan for sewage maintenance in Chattogram, the pros and cons of general sewage drainage methods are compared, and a solution that meets the local conditions of the sewage treatment area in consideration of economic feasibility, constructability, maintenance, and water quality preservation the Sewerage Collection System was determined.

4.3.3.2 Types of Sewerage Collection System

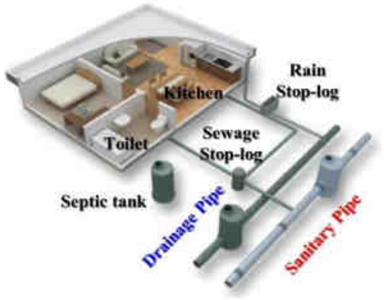
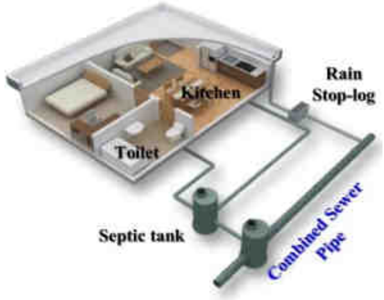
In addition to the combined and complete separate sewer system, there are incomplete separate sewer system and merged methods in the sewage exclusion method. Incomplete separate sewer system and merged methods are derived from combined and complete separate sewer system. A general overview of these four methods is as follows:

Table 4-56 Comparison of Sewerage Collection System

Category		Description	Remarks
Separate Sewer System	Complete Separate	• It is a method of separating rainwater and sewage and inflowing them into stormwater and sanitary sewers to exclude them. Sewage flows into the sewage treatment facility through the sanitary sewer for treatment, and rainwater is discharged into nearby rivers and lakes through the stormwater sewer. • Generally applied to new towns, housing development areas, and redevelopment areas.	
	Incomplete Separate	• Sewage is transported to Sewage treatment plant through sanitary sewer and treated, but rainwater is excluded by guttering or natural drainage. • In rural areas, it is applied when rainwater is excluded by maximally utilizing existing natural drainage channels or drainage facilities.	
Combined Sewer System		• A method of excluding rainwater and wastewater into a system of the same sewer. • In case of rain, a certain amount of flow is intercepted through the collection pipe and introduced into the sewage treatment facility, and the excess is discharged by overflowing. • If there is no rain, the entire amount of sewage is transported to a sewage treatment plant for treatment.	
Merged Methods		• Separate and combined Sewer System are mixed in the same area. • If some areas cannot be classified, the classification area and the confluence area coexist.	

In general, a general comparison of sewerage collection system that can be adopted for existing urban areas is as follows. In areas where new sewerage systems are newly installed, a separate Sewerage Collection System is adopted in terms of preventing water pollution in public waters, and in areas where existing combined sewage systems are supplied, the combined Sewerage Collection System is maintained in consideration of economic feasibility and construction.

Table 4-57 Comparison of Sewerage Collection Systems

Category		Separate Sewer System	Combined Sewer System
Schematic			
Construction	Design	• Sewage and rainwater are discharged into separate sewers	• Constructing a sewer network suitable for topographical conditions in order to quickly discharge rainwater
	Constructability	• Construction is complicated when burying two sewage and rainwater sewers on the same road	• It is difficult to construct a narrow road when a large-diameter pipe is used
	Cost	• The case of constructing two systems of sewage and storm water pipes is expensive, but constructing only sanitary sewer is economical	• Constructing one large-diameter sewer is cheaper than constructing two sewage and stormwater sewers, but is more expensive than constructing only the sewage sewer.
Maintenance	Connection	• Close monitoring is required	• None
	Sedimentation	• Less sedimentation in the sewer • No cleaning effect expected	• In clear weather, the water level is low and the flow speed is low, making it easy for dirt to settle. • Less cleaning frequency in sewer.
	Sediment Inflow	• There is little soil inflow	• When it rains, a large amount of soil flows into the treatment plant and deposits on the bottom of the waterway for a long time.
	Repair	• There is a risk of blockage due to small-diameter pipes, but cleaning is relatively easy. • In the case of guttering, management takes time and is often insufficient.	• No fear of closing • Inspection and repair are relatively easy • Cleaning is time consuming
	Management	• In the case of maintaining the existing rainwater sewer, it is necessary to clarify the manager.	• The manager can integrate and abolish unclear sewers, and the sewerage manager can manage the overall management.
Water Quality Preservation	Overflow During Rain	• None	• When it rains more than a certain amount, sewage overflows.
	Overflow During Dry	• None	• Occurs when there is an increase in the amount of sewage.
	Excellent Road Cleaning	• Washing water containing contaminants from the road surface is directly introduced into rivers.	• Improvements or improvements to parts of the facility can accommodate and treat contaminated rainwater during rainfall.
Environment	Dumping Garbage	• There is a case of illegal dumping of garbage in the stormwater sewer.	• None
	Land Use	• In case of maintaining the existing gutter, repair of the cover is required.	• In the case of abolishing the existing gutter, the road width can be effectively used.

4.3.3.3 Selection of Sewerage Collection System

4.3.3.3.1 Considerations

As suggested above, the Sewerage Collection System has its advantages and disadvantages, respectively, and therefore, a comprehensive review of construction, maintenance, water quality preservation, and environmental aspects should be conducted in consideration of the regional characteristics of the planned area.

Korea's sewage design standards (2017, Ministry of Environment) require Separate Sewer System to prevent flooding due to rainwater and water pollution in public waters. If it is difficult to adopt Separate Sewer System, such as the form of existing sewage facilities and underground excavation conditions, a combined sewer line may be considered.

The separate sewer system is a method of transporting only sewage to the treatment plant. It is advantageous in terms of water pollution because there is no discharge of sewage into the water area in case of rain. It is also possible to promote sewage supply. However, in the case of the separate sewer system, relatively polluted road drainage is directly discharged into public waters through rainwater pipes at the beginning of rainfall, so it is difficult to construct both rainwater pipes and sanitary sewer in existing urban areas with narrow roads.

As a result of comparing and reviewing sewage treatment methods in various aspects, it is not possible to say which method is advantageous, but in order to prevent water pollution of effluent water, a separate sewage exclusion method is currently adopted in Korea.

In this plan, the Sewerage Collection System is a classification method in principle, but in case of inevitable due to local conditions, incomplete classification method and merger method are set as selection criteria.

- Review of sewage separation pipes in various development plans, such as planned development areas and new housing site development areas
- Examination of classification type targeting the region as an extension of the new trunk sewer
- Review of classification formula targeting the vicinity of the newly established sewage main sewer area
- Review of classified sewage system in areas where sanitary sewer excavation is easy targeting areas where small-scale water system separation is possible.

4.3.3.3.2 Selection of Sewerage Collection System

In this plan, the step-by-step classification plan was set as follows;

Table 4-58 Decision on Sewerage Collection System

Category	Sewerage Collection System					Remarks
	2022	Phase1 (2040)	Phase2 (2055)	Phase3 (2070)	Target Year (2070)	
Catchment-3	Untreated	Separate	Separate	Separate	Separate	

4.3.3.3.3 Sewerage Collection System of On-going Sewerage Projects

The Sewerage Collection System of the on-going sewerage project in the Chattogram are as below.

Table 4-59 Sewerage Collection System of On-going Sewerage Projects

Category	Catchment Area	Sewerage Collection System	Progress	Remarks
STP-1	Halishahar	Separate Sewer System	On Construction	
STP-2	Kalurghat	Separate Sewer System	Feasibility Study Completed	
STP-3	Fatehabad	Separate Sewer System	Feasibility Study Completed	
STP-4	East Bakalia	Separate Sewer System	Feasibility Study Completed	
STP-5	North Kattali	Separate Sewer System	EOI	
STP-6	Patenga	Separate Sewer System	Feasibility Study On-going	

4.3.4 Sanitary Sewer

4.3.4.1 Introduction

Sanitary sewer transport sewage to Sewage treatment plant by efficiently collecting sewage. It should be established by reflecting the characteristics of the region to enable efficient management of infiltration and inflow of the sewer.

In this plan, basic concept of sanitary sewer plan for the trunk sewer, primary sewer and secondary sewer, pumping station and household connection plan has been established as below.

4.3.4.2 Design Criteria

4.3.4.2.1 Diameter

The planned wastewater generation for the sanitary sewer is the hourly maximum in 2070, the final target as explained in the planning framework.

The permissible amount of sewerage discharge is 100% for small (200~600mm), 50~100% for medium (700~1,500mm), and 25~50% for large (1,650~3,000mm). Since Bangladesh does not have an acceptable standard for sewage pipe volume, the pipe diameter is planned according to the Korean standard.

4.3.4.2.2 Applied Mathematical Equations

Sewage is suspended matter as compared to normal water is contained a lot, because it is not so much given trouble in actuarial and repair calculated in the same way as ordinary water. Thus, the formula is applied on the generally circular tube in gravity flow, using “Manning equation”, the stage pavilion, and uses “Kutter equation”.

- Manning equation

$$V = \frac{1}{n} \cdot R^{2/3} \cdot I^{2/3} \, (m/\sec)$$

$$Q = A \cdot V \ (\mathrm{m^3/sec})$$

Where, V: velocity(m/sec) n: coefficient of roughness: hydraulic grade
R: plowing depth(m) Q: quality($\mathrm{m^3}$/sec) A: cross sectional area of flow($\mathrm{m^2}$)

- Kutter equation

$$V=\frac{23+\frac{1}{n}+\frac{0.00155}{I}}{I+(23+\frac{0.00155}{I})\cdot\frac{n}{\sqrt{R}}}\sqrt{RI}\ (m/\sec)$$

$$Q = A \cdot V\ (m^3/sec)$$

Where, V: velocity(m/sec) n: coefficient of roughness: hydraulic grade
R: plowing depth(m) Q: quality(m^3/sec) A: cross sectional area of flow(m^2)

- Hazen-William's equation

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

Where, C: Hazen-Williams factor I: hydraulic grade R: plowing depth (m)

In this plan, when is a gravity flow, apply "Manning equation" to be used because it is the most commonly and the experimental value sufficiently Also, it is applied Hazen-William's equation for manhole pumping stations and force main sewer.

4.3.4.2.3 Coefficient of Roughness and Velocity

In the case of the equation Manning and Kutter for gravity flow, officially applied coefficient of roughness (n), 0.010~0.022 is applied depending on the material of the pipe and drain. Further, Hazen-William's equation for force main, it is applied 90~130 to coefficient of velocity(c) depending on the number of years elapsed tube and the material of the tube. The number of applied the coefficient of roughness and velocity in this plan is as follows.

Table 4-60 Coefficient of Roughness and Velocity

Category	Coefficient of Roughness (n)	Coefficient of Velocity (c)	Remarks
Gravity Flow	0.010	-	
Force Main	-	130	

4.3.4.2.4 Velocity

The flow velocity in the pipe is governed by the flow rate or the gradient. In general, it is economical to determine the slope of the sewer according to the slope of the surface, but in this case, if the flow velocity relative to the slope is too small, it is easy for dirt to settle on the bottom of the pipe, and dredging is always required, making maintenance difficult and increasing maintenance costs. On the other hand, if the flow velocity is too high, the sewer is worn out and damaged by sand or gravel, etc., shortening the durability of the sewer, and also causing an accident in which the cover is separated due to air entrainment due to running water colliding with the downstream manhole.

On the other hand, if the slope is too steep for the reason that the pipe cross-section becomes smaller due to the focus on economic aspects, the depth of excavation increases, the cost of earthwork increases, construction becomes difficult, and natural flow becomes difficult due to the relationship between the water level of the discharge water surface in the trench.

Therefore, the following conditions should be met to determine the slope of the sewer.

- Set the flow rate so that soil and sand do not settle or stagnate in the pipe.
- The flow velocity in the downstream pipe is higher than that in the upstream.
- The slope becomes gentler as you go downstream.
- Slopes with significant rapids are to be avoided as they may cause damage to sewers.

Table 4-61 Minimum Velocity Literature Survey

Category	Literature	Sewer Type	Standard
Korea	Sewerage Design Criteria (2022)	Storm Water Pipe	• 0.8m/s
		Sewer Pipe	• 0.6m/s • Securing a minimum slope of 5‰ or more at the starting point
Master Plan	Preparation of a Sanitation and Drainage Improvement Strategy and Master Plan for the City of Chittagong (2017)	Sewer Pipe	• 0.6m/s
Japan	Japan Sewage Works Association (2009)	Sewer Pipe	• 0.6m/s
	Japanese Sewerage Handbook	Sewer Pipe	• 0.61m/s • Particle movement limit flow velocity 0.26m/s
USA	American Society of Civil Engineers (1970)	Storm Water Pipe	• 0.75~0.9m/s
		Sewer Pipe	• 0.6m/s
	Wastewater Engineering Collection and pumping of wastewater (McGraw-Hill Book)	Sewer Pipe	• 0.6m/s • A flow rate of 0.3 m/s is sufficient to prevent sedimentation of organic solids. • 0.75 m/s is enough to prevent sedimentation of inorganic materials such as sand and gravel
UK	British Standard Institution (1987)	Storm Water Pipe	• 0.75m/s
		Combined Sewer System	• 1.0m/s
France	Minister of Interior (1977)	Sewer Pipe	• 0.3m/s
		Combined Sewer System	• 0.6m/s
EU	European Standard EN 752-4 (1997)	Sewer Pipe	• 0.7m/s
Germany	ATV-DVWK-Regelwerk (2001)	Sewer Pipe	• 0.48m/s • 10% increase from 300mm

In this plan, the minimum flow rate for the planned flow rate of the trunk sewer was determined to be 0.6 m/s.

The minimum flow velocity was set at 0.3 m/s to prevent the depth of the trunk pipe from increasing in the starting section and branch pipe with low flow. This criterion should be reviewed at the detailed design stage. The maximum speed was determined to be 3.0 m/s to prevent pipe damage due to excessive speed. Where the speed limit is exceeded, the speed is reduced by adjusting the slope at appropriate intervals.

Table 4-62 Plan of Velocity Standard Applied

Category	Gravity Flow		Force Main	Remarks
	Main Pipe	Branch Pipe		
Velocity	0.6~3.0m/s	0.3~3.0m/s	0.6~3.0m/s	

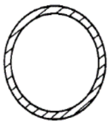
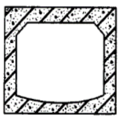
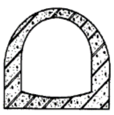
4.3.4.2.5 Cross Section of Pipe

In general, there are circular, rectangular, horseshoe, and egg shapes for the cross-sectional shape of sewers.

- Hydraulically advantageous
- Be economical for the load
- Construction cost will be low
- Maintenance will be easy
- Applicable to the circumstances of the construction site

The advantages and disadvantages of the commonly used round, rectangular, horseshoe and egg shapes are as follows.

Table 4-63 Comparison of Cross Section Shape

Category	Shape	Advantages	Disadvantages
Circle		• Hydraulically Advantageous • Factory products can be used up to an inner diameter of 3,000 mm, so the construction period is shortened • Simple mechanics calculation	• Foundation work may be required for safe support • Since it is a factory product, there are many junctions, so there is a risk of high groundwater penetration
Rectangle		• It is advantageous when the soil thickness and width of the construction site are restricted • Simple mechanics calculation • Hydraulically advantageous until full water	• When the rebar is damaged, it becomes very unstable for the upper load • In the case of on-site casting, the construction period is delayed
Horseshoe Shape		• Economical and advantageous for large landscape sewers • Hydraulically Advantageous • Mechanically advantageous by the arch action of the upper half	• Poor workability due to complex cross-sectional shape • In the case of on-site casting, the construction period is delayed
Egg Shape		• Hydraulically advantageous compared to circle when flow rate is small • Advantageous to earth pressure in the vertical direction compared to the circular shape	• Depending on the material, the manufacturing cost may increase • Accuracy is required for vertical construction, so meticulous construction is required

In this plan, the shape of the cross section was made in principle to use a circular pipe in consideration of the site conditions and constructability with high traffic volume. In the case of large pipes that are difficult to construct, install a reinforced concrete culvert and arrange an invert at the bottom to make it advantageous in terms of repair.

4.3.4.2.6 Sewer Excavation Location and Excavation Depth

It should be reviewed in consultation with the manager of roads, rivers, railroads, etc., taking into account the location of sanitary sewers and underground facilities or structures. The minimum cover for sewers is at least 1.0m for branch lines and at least 1.5m for trunk lines. When determining cover, consider the following;

- Minimum required cover in road planning
- Minimum depth for house hold connection and connection from the home
- Crossing problems with water pipes and other underground facilities
- Groundwater level and ground soil conditions

4.3.4.2.7 Manhole

Manholes should be installed not only for pipe inspection, cleaning, and ventilation, but also for pipe connections. Typical installation locations are the starting point of the pipe, the point where the direction, slope, and diameter of the pipe change, the point where the step occurs, and the maintenance of the pipe. The maximum manhole interval according to the pipe diameter set in this plan, such as necessary points, is as follows;

Table 4-64 Max Distance of Manhole

Diameter	>600mm	>1,000mm	>1,500mm	<1,650mm	Remarks
Distance(m)	75m	100m	150m	200m	

4.3.4.2.7.1 Type and Structure

The type of manhole is divided into No. 1 ~ No. 5 according to the diameter of the joint pipe. In addition, if special manholes are needed depending on the characteristics of the topography, relationship with underground facilities, pipe structure, etc., special Nos. 1 to 5, culverts and attached manholes are installed. The purpose of each manhole shape is as follows:

Table 4-65 Use of Standard Manholes by Shape

Category	Shape and Dimensions	Description
No.1 Manhole	Inner Diameter 90 cm Round	• The starting point of a pipe, the midpoint of a pipe with an inner diameter of 600 mm or less, and the joining point of a pipe with an inner diameter of up to 400 mm
No.2 Manhole	Inner Diameter 120 cm Round	• The midpoint of a pipe with an inner diameter of 900 mm or less, the joining point of a pipe with an inner diameter of 600 mm or less
No.3 Manhole	Inner Diameter 150 cm Round	• The midpoint of pipes with an inner diameter of 1,200 mm or less, the joining point of pipes with an inner diameter of 800 mm or less
No.4 Manhole	Inner Diameter 180 cm Round	• The midpoint of pipes with an inner diameter of 1,500 mm or less, the joining point of pipes with an inner diameter of 900 mm or less
No.5 Manhole	Inner Diameter 210 cm Round	• The midpoint of a pipe with an inner diameter of 1,800 mm or less

Table 4-66 Uses of Special Manhole Shapes

Category	Shape and Dimensions	Description
SN.1 Manhole	600 x 900	• If the cover is small or it is impossible to install the No. 1 manhole due to other buried objects, etc.
SN.2 Manhole	1,200 x 1,200	• In case a circular manhole is not installed at the midpoint of a pipe with an inside diameter of 1,000 mm or less
SN.3 Manhole	1,400 x 1200	• In case a circular manhole is not installed at the midpoint of a pipe with an inside diameter of 1,200 mm or less
SN.4 Manhole	1800 x 1,200	• In the case where a circular manhole is not installed at the midpoint of a pipe with an inner diameter of 1,500 mm or less
SN.5 Manhole	1200 x D	• When it is difficult to apply standard manholes and special No. 1, 2, 3, and 4 manholes due to site conditions, apply to Hume pipes of D600mm or less
Culvert Manhole	Ø900, Ø1,200	• The midpoint of the sewage pipe by the shield method
Manhole with Adjutant	-	• When the level difference of the sewer is 0.6 m or more

4.3.4.2.7.2 Small Manhole

Small manholes are installed where it is difficult to insert equipment into narrow existing roads and alleys, and it is difficult to relocate obstacles due to the large number of existing obstacles.

Table 4-67 Small Manhole Types and Applications

Category	Shape and Dimensions	Description
SN.1 Manhole	Inner Diameter 30 cm Round	• The starting point of a pipe, the midpoint of a pipe with an inner diameter of 150 mm or less, and the joining point of a pipe with an inner diameter of up to 250 mm
SN.2 Manhole	Inner Diameter 40 cm Round	• The midpoint of a pipe with an inner diameter of 200 mm or less, the joining point of a pipe with an inner diameter of 250 mm or less
SN.3 Manhole	Inner Diameter 50 cm Round	• The midpoint of pipes with an inner diameter of 250 mm or less, the joining point of pipes with an inner diameter of 300 mm or less
SN.4 Manhole	Inner Diameter 60 cm Round	• The midpoint of pipes with an inner diameter of 300 mm or less, the joining point of pipes with an inner diameter of 400 mm or less

4.3.4.2.7.3 Manhole Fitting

Manhole accessories include inverts, footsteps, and manhole covers, and consider the following when installing these.

(i) Invert

- The invert is the same as the pipe diameter and slope of the downstream pipe.
- The footing part of the invert has a cross slope of 10 to 20%.

- The width of the invert extends the downstream width the same width upstream.
- The level difference between the upstream pipe and the bottom of the invert should be about 3 to 10 cm.

(ii) Foot Step

- Footrests should be made of non-corrosive materials and installed for ease of use.

(iii) Manhole Cover

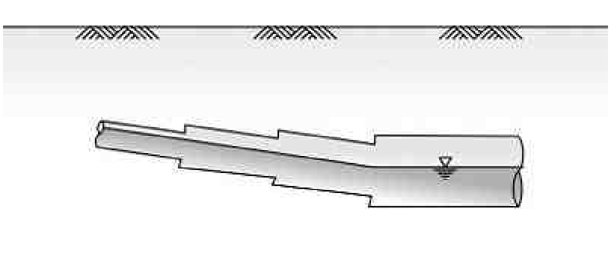
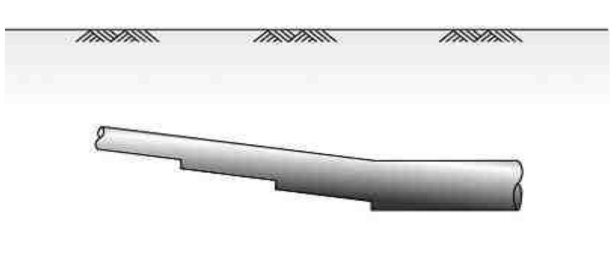
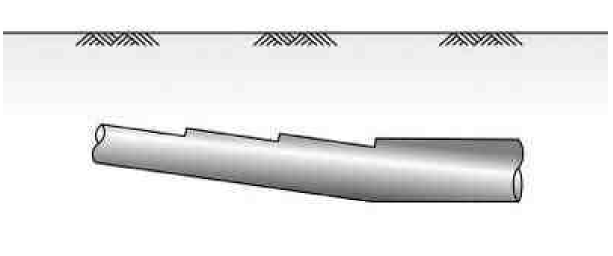
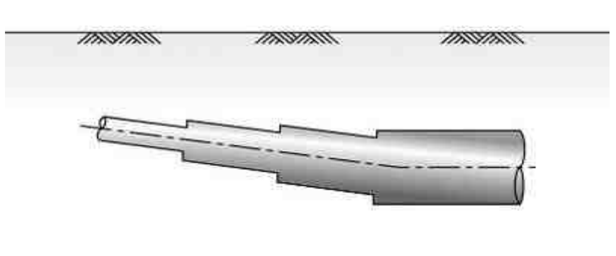
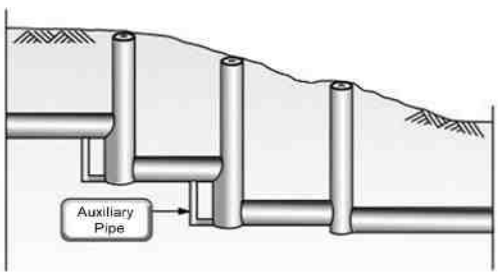
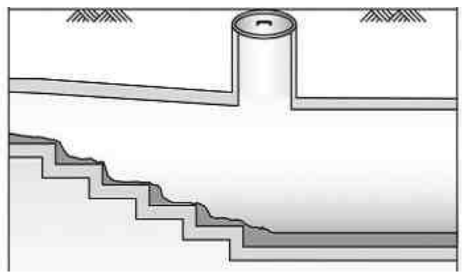
- The manhole cover is installed considering the convenience and safety of maintenance and watertightness to reduce the inflow of unknown water.

4.3.4.2.7.4 Pipe Connection Method

Manholes are installed and joined at the confluence of sewers and at the points of change in cross section, slope, direction, etc. At this time, a reasonable joining method should be used so that the running water in the sewer flows smoothly hydraulically. The connection of sewers should be determined by considering the following items.

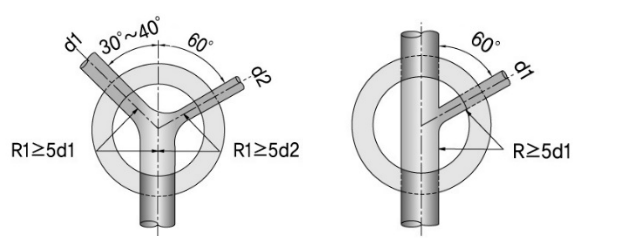
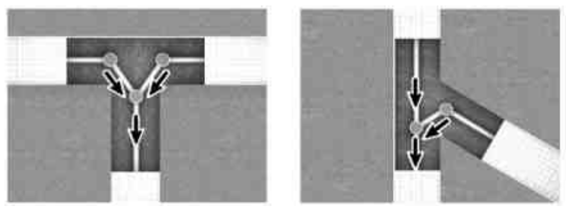
- When the diameter of a sewer changes or two sewers join, the joint method is usually a surface joint or a pipe joint. However, there are convergent joints and low-joint joints in addition to water surface joints and pipe joints, and each is determined by considering the topography of the drain, vertical slope, underground facilities and obstacles, etc., the water level of the discharge river, and the depth of sewer excavation.

Table 4-68 Pipe Connection Method

Water Surface Connection	Pipe Top Connection
	
Pipe Bottom Connection	**Pipe Center Connection**
	
Step Connection	**Stair Connection**
	

- Water face connection - A method of joining by matching the energy gradient line or planned water level hydraulically.
- Pipe top connection - A method of joining the pipe wells by matching them. The running water flows smoothly, but the digging depth increases, which increases the construction cost.
- Pipe bottom connection - A method of joining so that the inner bottom of the sewer matches. It can reduce the construction cost by reducing the excavation depth and prevent the water level from rising. Suitable for pumped areas.
- Pipe centre connection - It is not necessary to calculate the water level corresponding to the planned sewage volume, so it may be applied mutatis mutandis to the water surface junction.
- When two sewers join, the central pier angle should be between 30 and 45°, and should not exceed 60° as much as possible, and when merging with a curve, the radius of curvature should be at least five times the pipe diameter.
- The radius of curvature when small diameter sewers join is usually attached within the manhole, but the radius of curvature when large diameter sewers join is often attached only when special manholes or cast-in-place reinforced concrete sewers are installed. In addition, the sewer simply bends. In any case, such matters need to be taken into account.
- When the conduit bends in the opposite direction or when the conduit bends at an acute angle, the same considerations are taken into consideration, and ideally, it is desirable to bend in two stages.
- If the surface slope is steep, a stepped joint or a stepped joint is used according to the surface slope regardless of the change in pipe diameter.

Table 4-69 Pipe Connection Method (Curved Point)

Joining at Pipe Junction	Splicing when pipe bends
	

4.3.4.3 Excavation Method

4.3.4.3.1 Construction plan by excavation depth

In this project, it was planned to install a sanitary sewer from West Sholashahar in the south along the N106 road to Fatehabad in the north. As the project site is a densely populated and heavily trafficked area, it is expected that difficulties in excavation work.

Road N106 is a major road that is constantly congested, and there is no alternative road that can be bypassed during the construction of this project. It is expected that many difficulties will arise in excavating and constructing the main trunks, D400~D1600mm sewers. In addition, if the depth of the excavation is deep, open-cut is difficult, so the temporary facility method should be applied. When installing the temporary facility, additional pile equipment is input, and the construction period may be delayed due to the time required for supply and demand of materials and installation.

Oxygen Bus Stand

Hamjarbag Bus Stop

Figure 4-24 Traffic on the N106 road

Considering the fact that excavation work is difficult due to heavy vehicle traffic, CWASA decided to apply the trench method for excavation depths of less than 6m and the trenchless method for excavation depths of 6m or more. In this feasibility study, the construction plan for each depth of excavation was established as follows in consultation with the CWASA.

Table 4-70 Construction Plan by Excavation Depth

Category	STP-3 (This Project)	STP-1	STP-2&4	STP-5	Remarks
~ 6m	Trench	Trench	Trunk: Trenchless Branch: Trench	Trench	
6 ~ 10m	Trenchless	Trenchless		Trenchless	
10m ~	Trenchless	Trenchless		Trenchless	

4.3.4.3.2 Considerations for Selection of Excavation Method

The excavation method and earth retaining construction method are based on the excavation height and the stratum and local conditions as a result of geotechnical investigation. For trench excavation, prefabricated simple retaining wall, H-Pile + wooden retaining board, sheet pile method, and propulsion method, the best construction method according to the location should be selected by comprehensively reviewing the workability, economic feasibility, and site conditions.

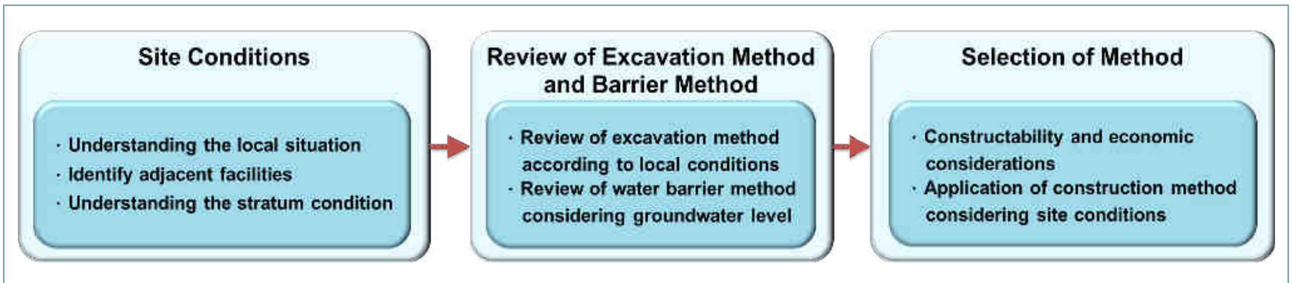


Figure 4-25 Excavation Method Selection Procedure

4.3.4.3.3 Comparison of Excavation Method

Chattogram City, the target area for this project, is a coastal city adjacent to the Bay of Bengal. Since the topography is flat, the depth of excavation is deep when laying sewers, and the groundwater level is estimated to be high because the Halda River & Bay of Bengal is adjacent to it.

In addition, since major roads and intersections in the city often cause traffic jams, the application of the trenchless method should be considered for sanitary sewer to be installed in these areas.

Commonly used excavation methods include the Open Trench method, which is easy and economical to construct, and the earth wall method, which can prevent ground deformation and inflow of groundwater and minimize the work space. The characteristics of excavation method were reviewed as follows.

Table 4-71 Comparision of Excavation Method

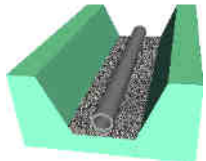
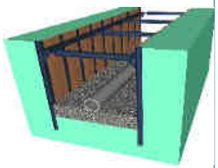
Category	Open Trench	Simple Retaining Wall	H-pile + Soil Retaining Plate	Sheet Pile	Trenchless
Schematic					
Overview of The Method	• Excavation on a natural slope using a slope that can be self-sustaining	• Ground excavation after formation of earth wall with prefabricated panels	• After inserting the H-Pile, install the soil plate while excavating	• Excavation after forming a barrier wall by installing a sheet pile	• Buried by propelling pipes by manpower or mechanically
Features	• Very good economic feasibility in case of easy site securing • Fast construction speed and simple process • The lowest cost of construction • Groundwater countermeasures required	• Advantageous for excavation in urban areas where the site is narrow • Easy to construct • Low construction cost compared to H-Pile • Groundwater countermeasures required	• Low construction cost compared to sheet pile • Steel can be reused • Groundwater countermeasures required • Boiling/Heaving measures required	• Excellent water barrier effect in areas with high ground water level • Steel can be reused • Groundwater countermeasures not required • Construction cost high	• There is little construction pollution due to construction • Long-distance construction possible • Construction period can be shortened • Need to pay attention to safety accidents • Construction cost is the most expensive
Depth	• Within 2m of excavation depth	• 2~5m of depth, if the level of ground water is lower than excavation depth	• 2m or more of excavation depth • If the level of ground water is higher than excavation depth	• 2m or more of excavation depth • If the level of ground water is higher than excavation depth	• traffic congested area • Intersections, road crossings

Table 4-72 Comparison of Trenchless Method

Category	Impact-type Steel pipe pressure method	Hydraulic-type Steel pipe pressure method	Semi-Shield
Schematic			
Overview of The Method	• A method of propulsion by making a launching base at the entrance and installing a propulsion pipe to strike the steel pipe with a hammer	• A construction method in which a starting base is made at the entrance, a propulsion pipe is installed, excavation is carried out by manpower and machinery, and then the steel pipe is press-fitted with a hydraulic jack.	• A method of filling the head cutter chamber with excavated soil to promote the stability of the face, and excavated soil is discharged by a screw conveyor and continuously propels the pipe by a jack at the rear of the pipe body in the head cutter chamber.
Advantage	• No acupressure wall required • No risk of subsidence during excavation • Construction period is short • No strain of the existing structure. • Excellent construction safety • Small diameter propulsion is possible • Construction cost is low	• Possible construction of obstacle confirmation • No noise and vibration • Possible to construct on bedrock layer	• Long-distance propulsion is possible • The range of application according to geology is wide. • The propulsion speed is fast and construction period can be shortened. • The effect of ground subsidence is small. • Plant equipment and work space for separation of slurry and soil are not required
Dis-advantage	• Difficult to construct bedrock and gravel layer • Concern about civil complaints due to noise • Pre-investigation of obstacles should be accurate • Depending on the geology, the construction precision decreases • It is not possible to change the direction while driving • Long-distance construction is not possible.	• Sufficient depth is required • Difficulty in small-diameter construction by manpower excavation • The construction period is long. • Existing structures may be damaged depending on site conditions (geological conditions, obstacles) • It is not possible to change the direction while driving	• It is difficult to respond when there are many trees and boulders in the ground • Initial investment cost is high
Select			◉
Reason	• Sewer extension is long, long-distance construction is possible, and the effect of ground subsidence is small. • It occupies a small work space, has a high propulsion speed, and shortens the construction period. • As a feasibility study step, a construction method with a wide range of application according to the ground is applied • The project site is an area with high traffic, so the construction period can be shortened, and the Semi-Shield method is applied, which enables propulsion and arrival base installation in a narrow space.		

Although the Semi-Shield construction method was selected in this plan, it is necessary to reexamine and select it through ground investigation and soil analysis through basic investigation during detailed design.

4.3.4.4 Pipe Protection and Foundation Work

When the soil thickness and loading exceed the load capacity of the sewer, when crossing under a railroad or crossing a river, the sewer should be protected against external pressure and buoyancy by building an outer circumference with concrete or reinforced concrete. If there is a risk of damage to the inner surface of the pipe due to corrosion and abrasion, consider this and use a pipe with excellent material or apply lining or coating to the inner surface of the pipe.

4.3.4.4.1 Pipe Foundation

The type of pipe foundation is determined by the type of pipe, soil quality, bearing capacity, construction method, load conditions, and excavation conditions. However, since the selection of the foundation method has a significant impact on the construction cost, it should be selected after sufficient review of the pipe's durability and economic feasibility.

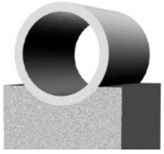
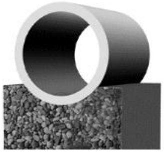
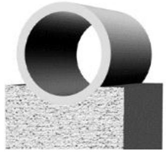
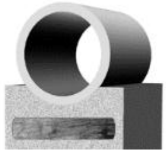
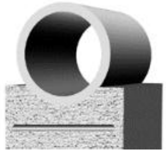
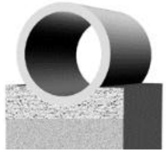
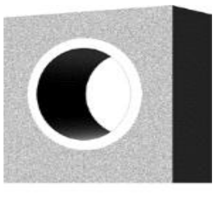
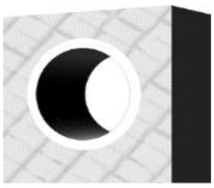
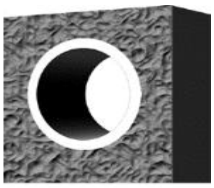
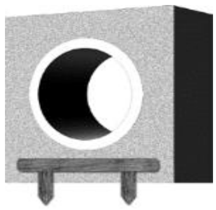
The pipe foundation type is designed as direct foundation, sand foundation, rubble foundation, pile foundation, substitution, etc. It is important that the foundation work of the sewer is constructed with care. Differential subsidence of sewers causes stagnation of sewage, decay and odour. Cracks in sewers cause leaks and intrusion of groundwater, which is an obstacle in maintenance, so foundation work should be given special attention.

In addition, in the case of a concrete foundation, it is safe to surround the lower part of the pipe, and the greater the angle of the concrete, the higher the strength of the pipe. Depending on the type of sewage pipe, it is advantageous to properly construct it.

If the foundation ground is weak and cannot support the pipe load, or if there is a case of differential settlement in the trunk pipe, a reinforced concrete foundation is planned.

When buried sewers, not only does foundation work have a significant impact on the construction cost, but also if uneven settlement of the sewer occurs due to improper construction of the foundation work, the surrounding area may collapse in severe cases. Therefore, the durability and economic feasibility of the sewer should be sufficiently reviewed to select an appropriate method. In general, the foundation work is determined according to the pipe type, soil quality, bearing capacity, construction method, load condition, and excavation condition, and the general foundation type is as follows.

Table 4-73 Foundation Type by Ground

<table>
<tr><th>Category</th><th colspan="6">Hard Soil</th><th colspan="6">Soft Soil</th><th colspan="6">Extremely Soft Soil</th></tr>
<tr><td rowspan="3">Hard Pipe</td><td colspan="6">• Sand support foundation
• Crushed rock foundation
• Wooden support foundation</td><td colspan="6">• Concrete foundation
• Crushed rock foundation</td><td colspan="6">• Pile foundation
• Reinforced concrete foundation</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">• Sand</td><td colspan="3">• Crushed Rock</td><td colspan="3">• Concrete</td><td colspan="3">• Wooden Support</td><td colspan="3">• Reinforced Concrete</td><td colspan="3">• Concrete + Sand</td></tr>
<tr><td rowspan="3">Soft Pipe</td><td colspan="6">• Sand foundation</td><td colspan="6">• Sand support foundation
• Bed earth work fiber foundation
• Soil cement foundation</td><td colspan="6">• Bed earth work fiber foundation
• Soil cement foundation
• Ladder support foundation
• Pile foundation
• Concrete + sand foundation</td></tr>
<tr><td colspan="4"></td><td colspan="5"></td><td colspan="4"></td><td colspan="5"></td></tr>
<tr><td colspan="4">Sand</td><td colspan="5">Bed Earth Work Fiber</td><td colspan="4">Soil Cement</td><td colspan="5">Sand + Ladder Support</td></tr>
</table>

In this plan, the foundation type is sand foundation in principle, and the appropriate foundation type is selected according to the ground type.

4.3.4.4.2 Sewer Pipe Type Selection

Sewage pipe types should be selected through consultation with the client at the detailed design stage. In the feasibility study, applicable pipe types are recommended in consideration of pipe types that can be produced in Bangladesh, smooth supply of materials when supplied from overseas, and convenience of maintenance such as repair and replacement after sewer installation. Pipe types applicable to this project are as follows;

It was investigated that HDPE pipes and uPVC pipes can be produced in Bangladesh. In the case of branch sewage pipe D300mm or less, HDPE pipe was applied in consideration of future maintenance and replacement. In the case of trunk line and D400mm or more, GRP applied in Catchment-1, which has high watertightness and is universal in overseas regions and is being implemented by the project implementing agency, was applied.

Table 4-74 Comparison of Sewer Pipe Type

Category	GRP	DCIP	uPVC	HDPE
Overview	• Pipes with improved toughness and pressure resistance by adding polymer or unsaturated polyester resin, fillers, and fiber-reinforced materials	• Pipes manufactured by melting materials suitable for ductile cast iron, spheroidizing graphite and centrifugal casting, and then applying cement lining	• Circular pipe molded into an O-ring shape by Caterpillar Mold by mixing PVC resin and additives	• As a product made of HDPE COMPOUND, the inner and outer surfaces of the pipe are smooth. • Production of polyethylene by extrusion
Shape				
Standard	• D150 ~ D2400mm	• D80~D1200mm	• D100~D400mm	• D110~D630mm
Bonding Method	• Rubber ring socket connection	• KP mechanical bonding	• Rubber ring socket connection	• Butt fusion or electronic socket connection
Advantages	• High impact strength and low elasticity • Salt Resistant • Easy connection • High water tightness • Universality in overseas regions	• Easy bonding, high watertightness and internal and external strength • Flexibility for various types and field conditions • Same standard	• High strength and physical properties • Corrosion resistance, durability and easy joining • High water tightness and cost efficiency • Easy socket connection reduces cost and time • Wrinkled and easy to cut	• Easy to transport due to light weight, flexible piping for easy handling • Simple connection and easy construction
Disadvantage	• Expensive glass fiber material	• Heavy, transport and lifting equipment required • High cost and used as a transfer pipe	• Only 600mm or less is possible, so it is not applicable to large sizes	• Heat-sealing expertise required • Electronic socket method joints are expensive
Selection	• Applied to sewers of 400mm or more			• Applied to sewers of 300 mm or less

4.3.4.4.3 Sanitary Sewer Plan

4.3.4.4.3.1 Sanitary Sewer Plan

For the sanitary sewer of this project, it was established to enable gravity flow, and a pump facility is planned to collect sewage by pumping it in the case of a low-lying lands area with a large difference in ground elevation.

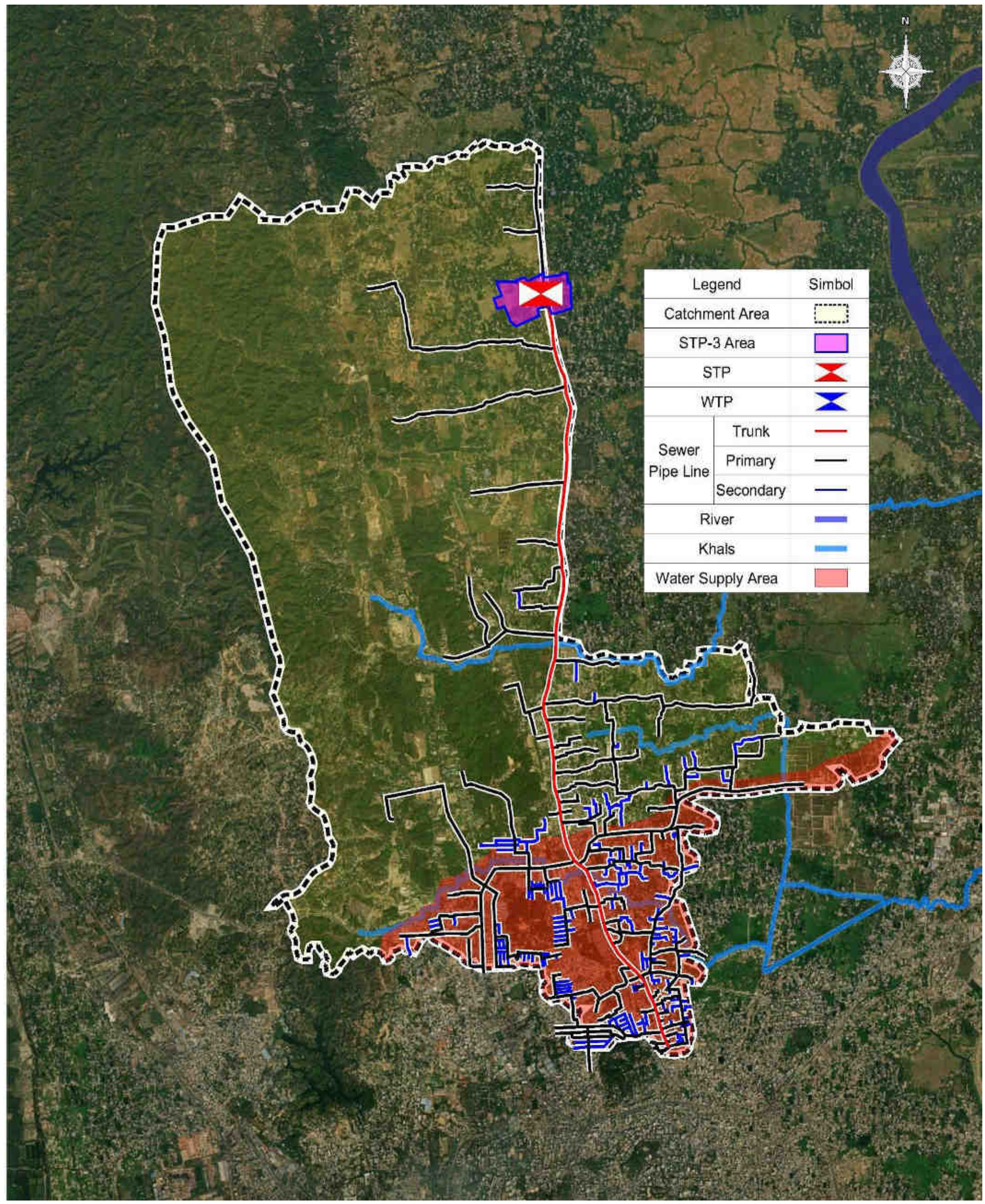


Figure 4-26 Sewer Pipe Facility Plan (Total)

In this study, it is planned to introduce the sewerage system to five wards in priority where current water service coverage under CWASA is available out of seven wards in Catchment-3 in the consideration of project budget. Sewerage system for low-lying area require pumping station will be installed in the Phase 2.

Table 4-75 Phase Plan of Sanitary Sewer (m)

Category	Total	Phase1	Phase2	Remarks
Total(m)	93,400	58,226	35,134	
Trunk Sewer	8,900	8,900	-	
Primary Sewer	58,991	29,335	29,656	
Secondary Sewer	25,509	20,031	5,478	

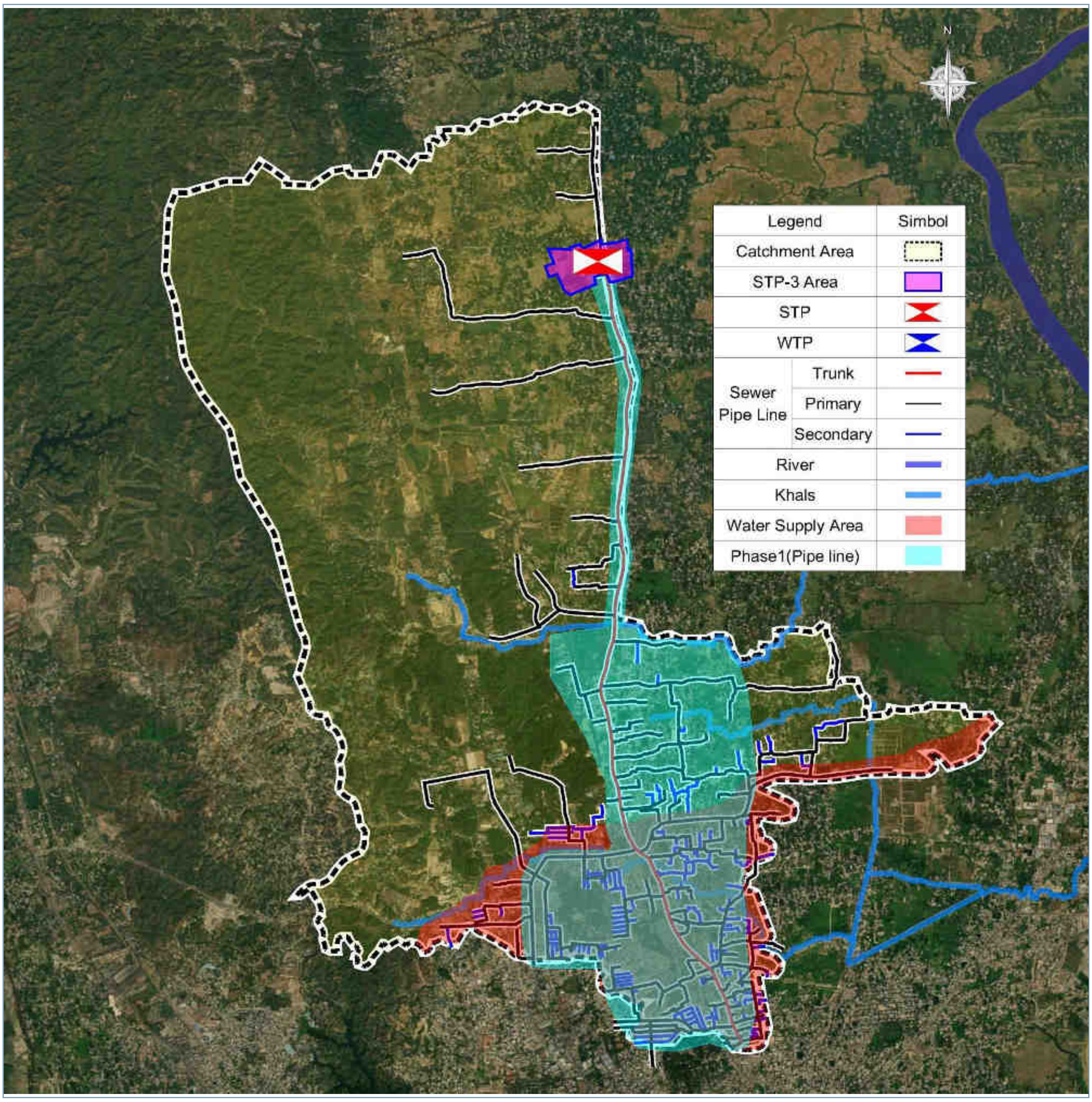


Figure 4-27 Phase Plan of Sanitary Sewer

In this project, a sanitary sewer will be installed for gravity flow. Trunk sewer, primary sewer and secondary sewer is planned in the consideration of topography and design factor of sewers. Excavation method is planned as trench method for the less than 6m depth and trenchless method for the more than 6m depth. Detail of sanitary sewer of Phase 1 is as below.

Table 4-76 Detail of Sanitary Sewer for Phase 1

Category	Total (m)	Trunk	Primary	Secondary
Total(m)	58,266	8,900	29,335	20,031
D200mm	32,802	-	12,771	20,031
D300mm	7,833	-	7,833	-
D400mm	3,962	300	3,662	-
D500mm	1,405	100	1,305	-
D600mm	1,400	400	1,000	-
D700mm	3,664	900	2,764	-
D800mm	200	200	-	-
D900mm	300	300	-	-
D1000mm	200	200	-	-
D1200mm	800	800	-	-
D1300mm	700	700	-	-
D1400mm	1,100	1,100	-	-
D1500mm	1,400	1,400	-	-
D1600mm	2,500	2,500	-	-

Table 4-77 Detail of Sanitary Sewer for Phase 1 by Excavation Depth (m)

Category	Total	Trench						Trenchless		
		Sub-T	<2m	2~3m	3~4m	4~5m	5~6m	Sub-T	6~10m	>10m
Total(m)	58,266	45,962	15,802	16,517	6,599	4,313	2,731	12,304	10,504	1,800
D200mm	32,802	32,322	15,402	12,299	2,814	1,407	400	480	280	200
D300mm	7,833	6,839	400	2,418	1,100	1,940	981	994	894	100
D400mm	3,962	3,396	-	1,000	1,430	466	500	566	566	-
D500mm	1,405	1,305	-	300	755	100	150	100	100	-
D600mm	1,400	1,200	-	400	500	200	100	200	200	-
D700mm	3,664	800	-	100	-	200	500	2,864	2,864	-
D800mm	200	-	-	-	-	-	-	200	200	-
D900mm	300	-	-	-	-	-	-	300	300	-
D1000mm	200	-	-	-	-	-	-	200	200	-
D1200mm	800	-	-	-	-	-	-	800	800	-
D1300mm	700	-	-	-	-	-	-	700	700	-
D1400mm	1,100	-	-	-	-	-	-	1,100	900	200
D1500mm	1,400	-	-	-	-	-	-	1,400	1,300	100
D1600mm	2,500	100	-	-	-	-	100	2,400	1,200	1,200

4.3.4.4.3.2 Trunk Sewer

Route of trunk sewer planning in this project is planned to be laid along the N106 road, starting from West Sholashahar, the downtown area, in the direction of Fatehabad, the sewage treatment facility. Layout of trunk sewer is as below.

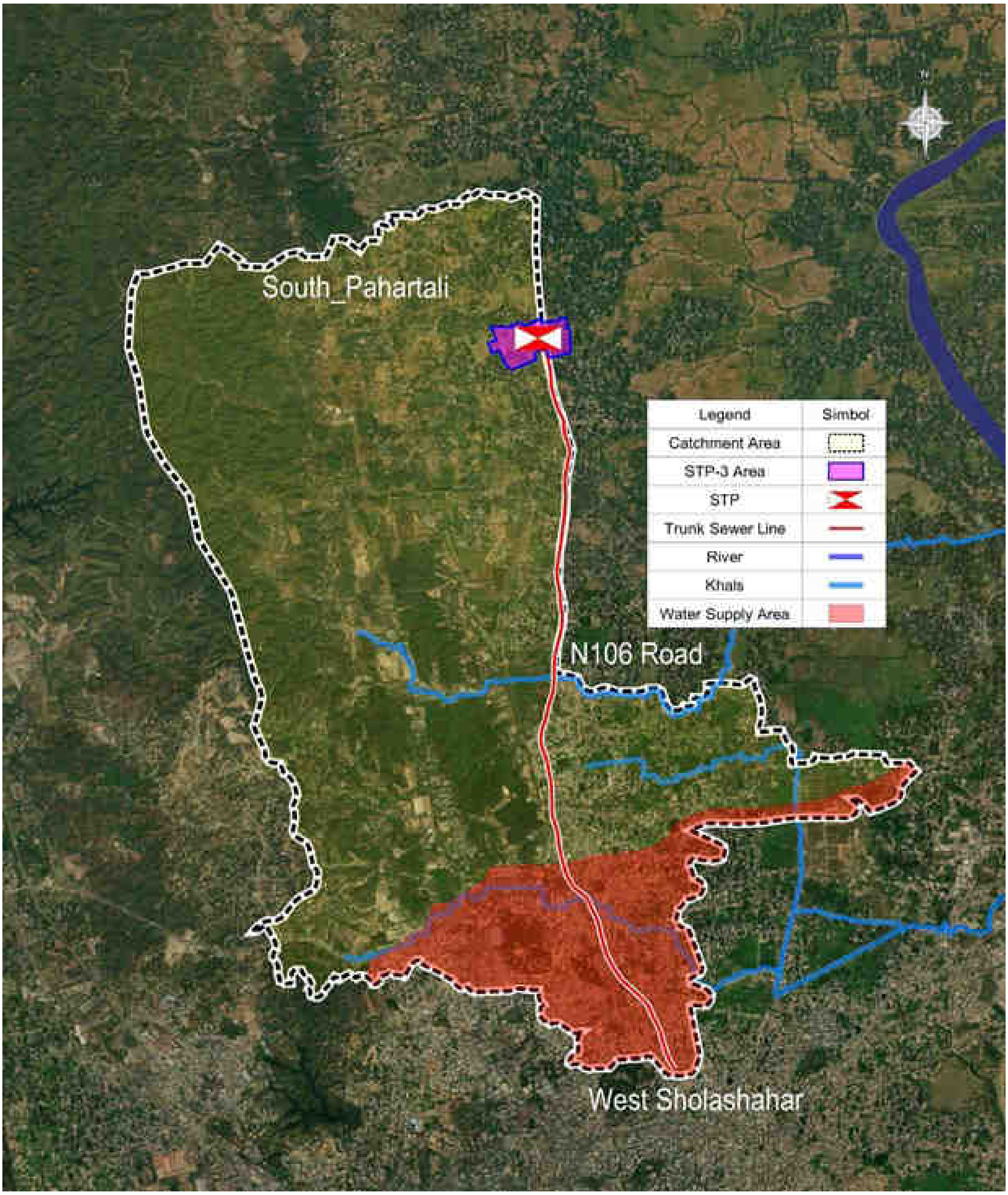


Figure 4-28 Layout of Trunk Sewer

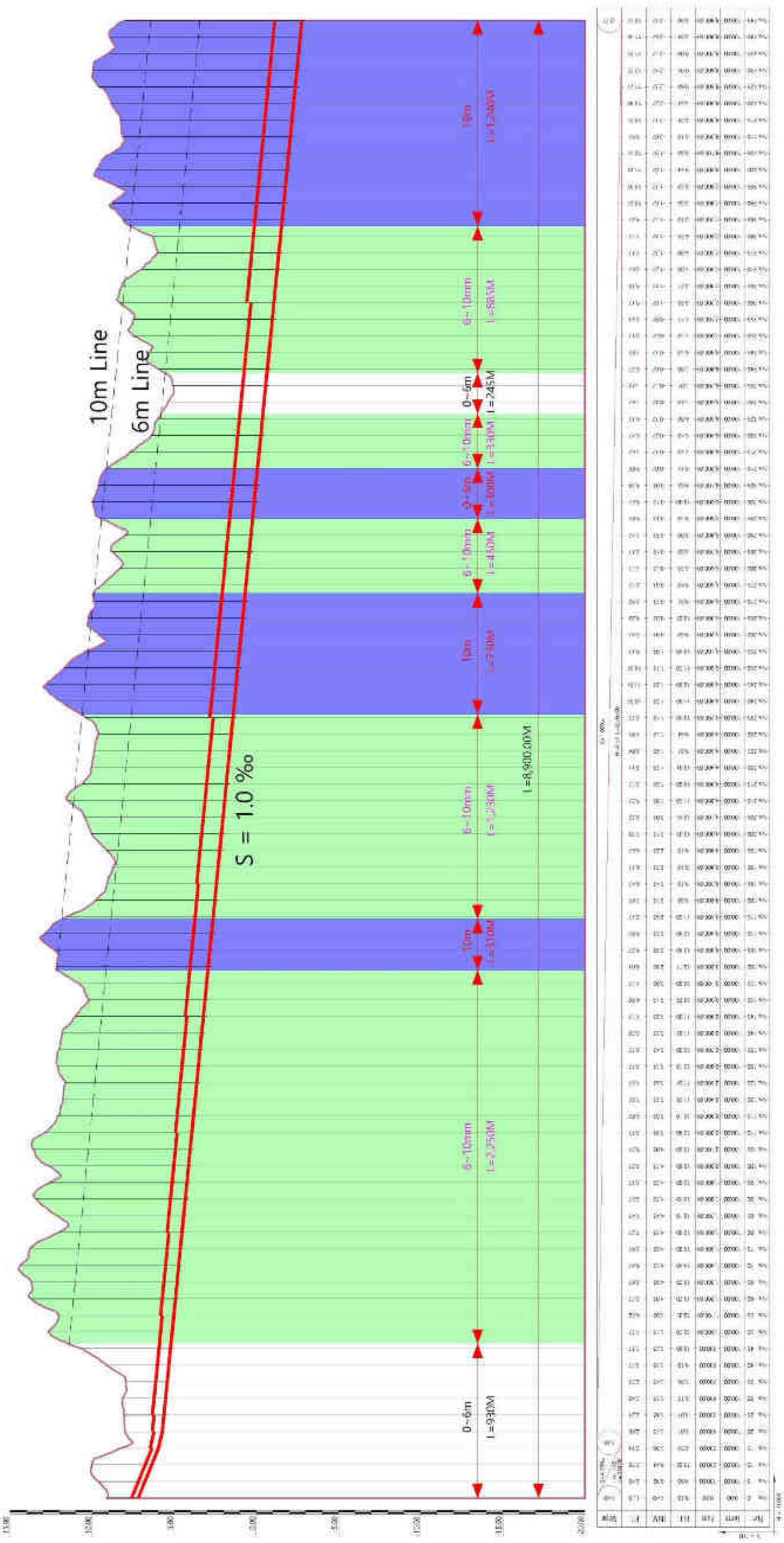


Figure 4-29 Longitudinal Plan for Trunk Sewer Pipe

Trunk sewer is planned as a gravity flow with the diameter of D400~D1600mm, longitudinal plan of sewer is be maintained at 1‰.

The depth of the trunk sewer is planned to be installed up to 12m due to the topographical characteristics. It is planned to implement trench excavation for a depth of 0 to 6m, and to install a trenchless method for sewers over 6m.

Table 4-78 Detail of Trunk Sewer for Phase 1 by Excavation Depth (m)

Category	Total	Trench						Trenchless		
		Sub-T	<2m	2~3m	3~4m	4~5m	5~6m	Sub-T	6~10m	>10m
Total(m)	8,900	1,000	-	500	300	100	100	7,900	6,400	1,500
D200mm	-	-	-	-	-	-	-	-	-	-
D300mm	-	-	-	-	-	-	-	-	-	-
D400mm	300	300	-	100	200	-	-	-	-	-
D500mm	200	200	-	200	-	-	-	-	-	-
D600mm	300	300	-	200	100	-	-	-	-	-
D700mm	900	100	-	-	-	100	-	800	800	-
D800mm	200	-	-	-	-	-	-	200	200	-
D900mm	300	-	-	-	-	-	-	300	300	-
D1000mm	200	-	-	-	-	-	-	200	200	-
D1200mm	1,500	-	-	-	-	-	-	1,500	1,500	-
D1300mm	-	-	-	-	-	-	-	-	-	-
D1400mm	1,100	-	-	-	-	-	-	1,100	900	200
D1500mm	1,400	-	-	-	-	-	-	1,400	1,300	100
D1600mm	2,500	100	-	-	-	-	100	2,400	1,200	1,200

4.3.4.4.3.3 Primary & Secondary Sewer

It is planned to install primary & secondary sewer for the gravity flow for Phase 1. Branch sewer of the low-lying land will be installed with pumping station in the Phase 2.

Diameter of the primary & secondary sewer is D200 ~ D700mm, and the flow velocity of the sewer is planned to be maintained at 0.3m/s or more and the longitudinal gradient of the initial pipe is maintained at 5‰ or more.

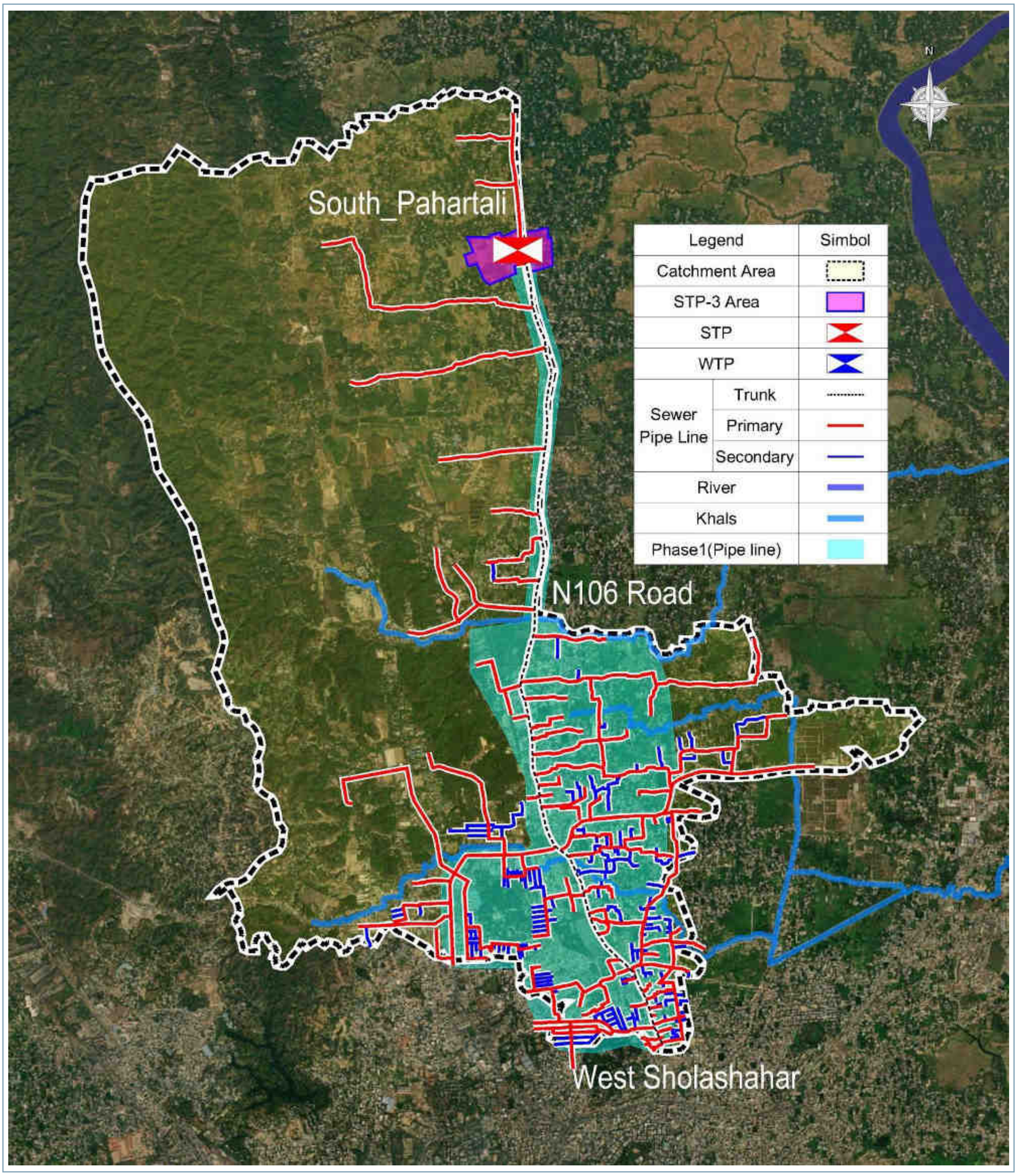


Figure 4-30 Layout of Primary & Secondary Sewer

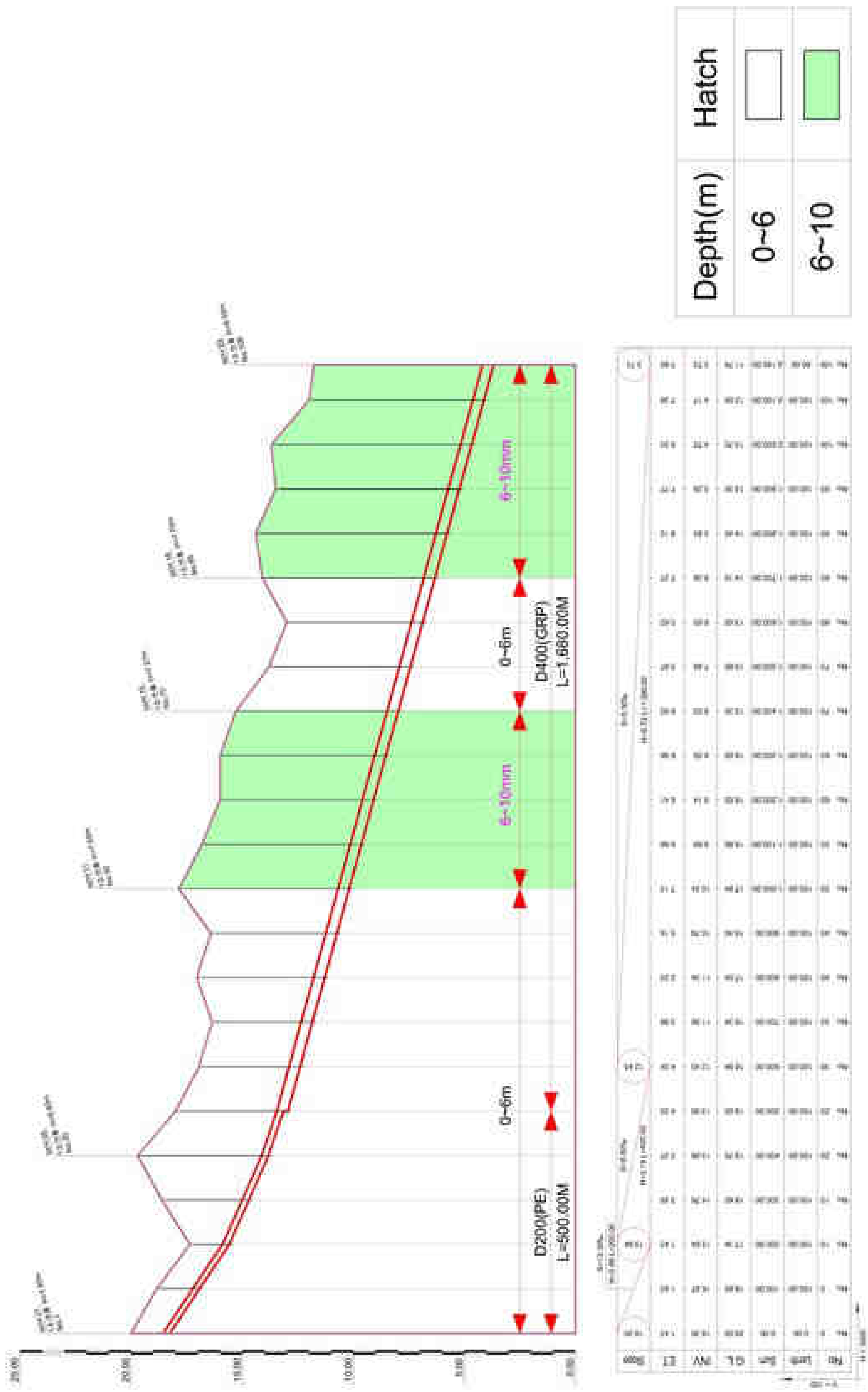


Figure 4-31 Longitudinal Plan for Primary Sewer (Representative)

Primary sewer & secondary sewer is planned to be connected to trunk sewer. It is planned to implement trench excavation for a depth of 0 to 6m, and to install a trenchless method for sewers over 6m. Manhole is planned to be installed at intervals of 75 to 100m, and the detail of manhole is as follows.

Table 4-79 Detail of Primary & Secondary Sewer for Phase 1 by Excavation Depth (m)

Category	Total	Trench						Trenchless		
		Sub-T	<2m	2~3m	3~4m	4~5m	5~6m	Sub-T	6~10m	>10m
Total(m)	49,366	44,962	15,802	16,017	6,299	4,213	2,631	4,404	4,104	300
Sub-Total (Primary)	29,335	24,931	1,780	10,008	6,299	4,213	2,631	4,404	4,104	300
D200mm	12,771	12,291	1,380	6,290	2,814	1,407	400	480	280	200
D300mm	7,833	6,839	400	2,418	1,100	1,940	981	994	894	100
D400mm	3,662	3,096	-	900	1,230	466	500	566	566	-
D500mm	1,305	1,205	-	200	755	100	150	100	100	-
D600mm	1,000	800	-	100	400	200	100	200	200	-
D700mm	2,764	700	-	100	-	100	500	2,064	2,064	-
Sub-Total (Secondary)	20,031	20,031	14,022	6,009	-	-	-	-	-	
D200mm	20,031	20,031	14,022	6,009	-	-	-	-	-	

Table 4-80 Detail of Manhole for Phase 1 (nos)

Type	Diameter	Total	<2m	2~3m	3~4m	4~5m	5~6m	6~10m	>10m
Total		801	213	225	92	60	40	145	26
No.1 (D900mm)	D200mm	441	207	164	38	19	6	4	3
	D300mm	108	6	33	15	26	14	12	2
	D400mm	56	-	14	20	7	7	8	-
	D500mm	22	-	5	11	2	2	2	-
	D600mm	22	-	6	8	3	2	3	-
No.2 (D1200mm)	D700mm	52	-	3	-	3	7	39	-
	D800mm	3	-	-	-	-	-	3	-
	D900mm	4	-	-	-	-	-	4	-
No.3 (D1500mm)	D1000mm	3	-	-	-	-	-	3	-
	D1200mm	11	-	-	-	-	-	11	-
No.4 (D1800mm)	D1300mm	10	-	-	-	-	-	10	-
	D1400mm	15	-	-	-	-	-	12	3
	D1500mm	20	-	-	-	-	-	18	2
No.5 (D2100mm)	D1600mm	34	-	-	-	-	2	16	16

4.3.5 Pumping Station (Phase 2)

4.3.5.1 Introduction

Wastewater Pumping stations are used to lift wastewater from lower to higher elevation, particularly where the elevation of the source is not sufficient by gravity flow and/or when the use of gravity conveyance will result in excessive excavation depths and high sewer construction costs.

In this study, it is planned to introduce the sewerage system to five wards in priority where current water service coverage under CWASA is available out of seven wards in Catchment-3 in the consideration of project budget. Sewerage system for low-lying area require pumping station will be installed in the Phase 2.

4.3.5.2 Pumping Station Planning

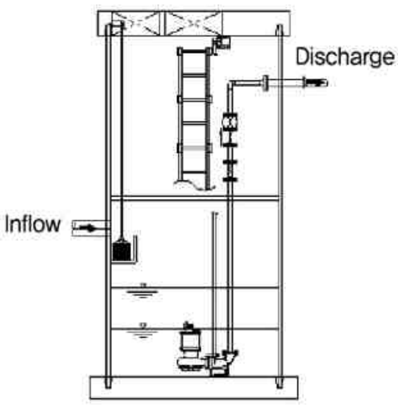
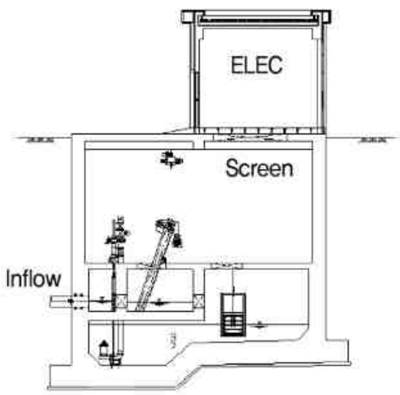
4.3.5.2.1 Design Standard and Installation Plan

Table 4-81 Pumping Station Design Criteria & Installation Plan

Category	Design Criteria	Installation Plan
Pump Discharge Volume	• Maximum sewage volume per hour	• Maximum sewage volume per hour
Pump operating method	• Automatic and alternate operation by the level of suction ponds	• Automatic and alternate operation by the level of absorbing wells
Pump type	• Select types in consideration of maintenance and closure	• Submersible grinder pump / non-clogging type of submersible pump
No. of pumps	• 2 sets or more including reserve	• Plan 2 sets or more including stand-by
Capacity of suction wells	• Consider the frequency of pump operation	• Secure the capacity of suction wells in consideration of the frequency of pump operation

4.3.5.2.2 Pump Station Type Selection

Table 4-82 Pump Station Type Selection

Category	Circular Manhole Type	Square Manhole Type
Figure		
Characteristics	• Possible of up to 3.0m^3/min but up to 1.6 m^3/ min is applied, in general • Installation of simple screen facilities (brief basket, etc.)	• Apply pump stations in 1.6 m^3/min or more for the facility capacity of this round • Installation of automatic screen facilities
Recommendation	◉	

4.3.5.2.3 Pumping Station

Pumping station is planned for the low-lying area where gravity flow is not possible to transfer the wastewater to the higher elevation and it will be implemented in Phase 2 in the consideration of sewage service coverage of the project.

Table 4-83 Detail of Pumping Station

Site	Name	Capacity (m^3/min)	Start		End		Max. Elev. (m)	Specification
			Elev.	Inv.	Elev.	Inv.		
Ward 2	PS-1	1,410	6.25	2.25	8.90	7.00	8.90	1.41m^3/min x 9.75mH
Ward 2	PS-2	0.676	1.35	-2.65	6.50	4.50	7.70	0.68m^3/min x 12.15mH
Ward 3	PS-3	0.676	4.60	0.60	9.30	7.00	9.30	0.68m^3/min x 11.40mH
Ward 3	PS-4	0.676	4.10	0.10	10.00	8.30	10.00	0.68m^3/min x 13.20mH
Ward 3	PS-5	0.310	4.30	0.30	13.40	11.20	13.40	0.41m^3/min x 15.90mH
Ward 3	PS-6	0.155	23.30	19.30	29.00	27.30	29.00	0.16m^3/min x 13.00mH
Ward 7	PS-7	0.705	9.00	5.00	14.00	5.83	14.00	0.71m^3/min x 13.00mH

Figure 4-32 Location of Pumping Station

4.3.6 Household Connection

4.3.6.1 Introduction

In this feasibility study, a household connection plan was established in order to flow sewage generated from residential, commercial buildings in the project area into the sewage system. If the household connection is not installed, the generated sewage is not transported to the sewage treatment plants, resulting in problems such as a decrease in the amount of inflow sewage and a decrease in treatment efficiency due to a decrease in the quality of the inflow water.

4.3.6.2 Relevant Regulation

CWASA is drafting the water and sewerage connection regulation (CWASA, 2023) with the cooperation of the JICA and major clauses regarding the household connection fee is as below.

- All owners of holdings shall take sewerage connection within six months of the completion of sewerage system in an area constructed by the Authority.
- The applicant shall bear the expense of purchasing pipes and other materials and the cost of construction/ replumbing work. The applicant shall be exempted from the payment of the cost of construction/ plumbing work if the applicant applies for property connection in parallel to the sewerage construction by the Authority in the area where the holding of the applicant is located or within six months of the completion of sewerage system in the area.

4.3.6.3 Finance of Household Connection

In the previous ODA projects implemented in the developing countries, household connection was implemented separately with the cost of the recipient countries. However, as the completion of household connection was delayed, the wastewater from the project area was not transferred to the sewage treatment plant and operation efficiency of the STP was decreased. Lessons learned from the previous project, household connection is financed and implemented by MDB in the recently in Bangladesh.

In this feasibility study, the GOB will bear the cost of household connection with the discussion of KEXIM and CWASA, the procurement method will be decided to select the contractor during the detailed design stage.

Table 4-84 Finance of Household Connection

Category		Fund Source	Finance of Household Connection	Remarks
Relevant Plans	Catchment-1 (PESSCM-1)	GOB	GOB	
	Catchment-5	AFD	AFD	
	Catchment-2&4	JICA	JICA	
This Study (Catchment-3)		EDCF	GOB	

4.3.6.4 Household Connection

Household connection survey is conducted in the feasibility study for randomly selected 100 houses to categorize the household connection types as per the buildings in the project area for the project cost estimation. Detail household connection survey shall be implemented in the detailed design stage.

In this study, it is planned to introduce the sewerage system to five wards in priority where current water service coverage under CWASA is available out of seven wards in Catchment-3 in the consideration of project budget. Sewage Service coverage of the Catchment-3 is 0% at the end of 2022 and is planned to achieve 60.0% by 2030 after completion of the project and to achieve 80.0% by 2070 in the final target year.

In this project, household connection is composed of the property connection from trunk/primary/secondary sewer to the public inspection chamber and realignment within the property from public inspection chamber to plumbing work within the property including closure of septic tank for the efficient utilization of the wastewater plant and ultimately successful achievement of the project outcome.

Table 4-85 Results of Household Connection Survey (Nos.)

Category	Building Type	Survey Results	Plan of This Project
Type 1	Residential Building with 8 or more floors	13	1,200
Type 2	Residential Building with 2-7 story	63	6,000
Type 3	Residential Building with single story	11	2,000
Type 4	Commercial Building	13	800
Total		100	10,000

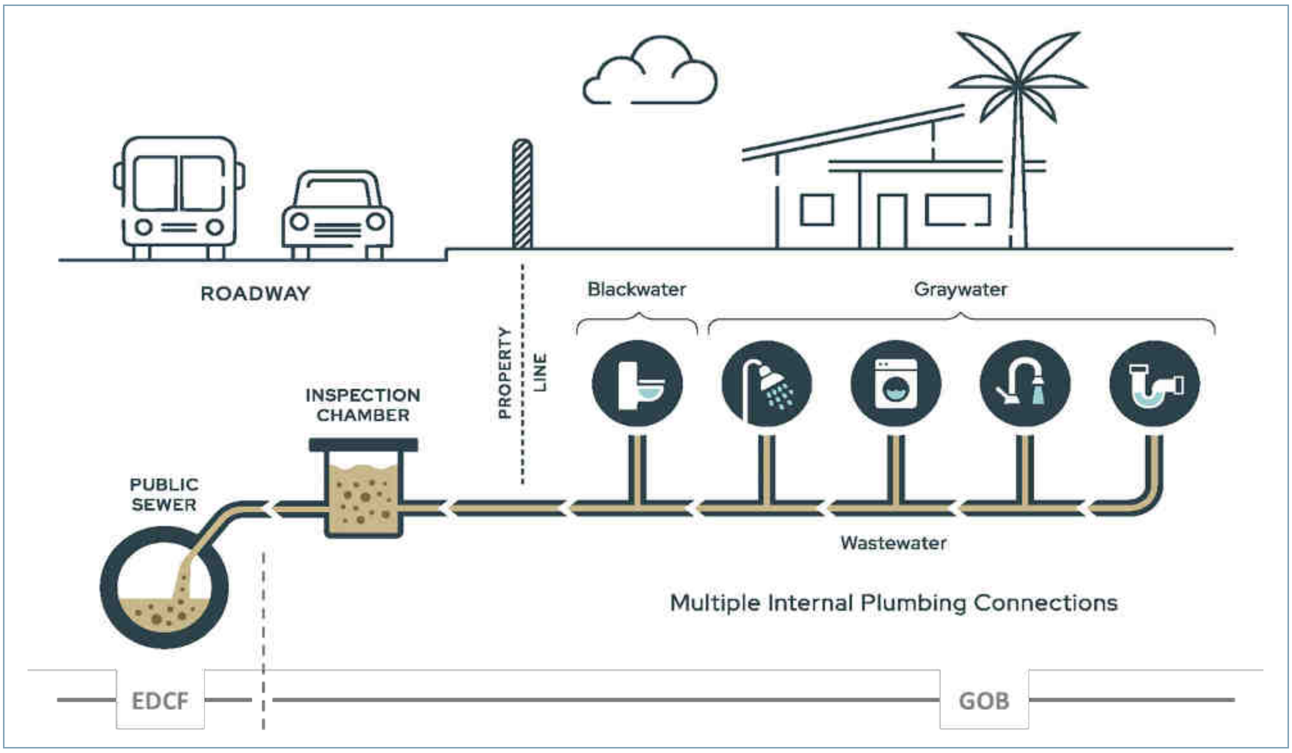
Type 1	Type 2	Type 3	Type 4
			

Table 4-86 Phase Plan of Household Connection

Category	Unit	2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)	Remarks
Projected Population	pers.	473,904	598,614	810,008	1,048,808	
Sewage Service Coverage	%	60.0	65.0	72.5	80.0	
Sewage Service Population	pers.	284,342	389,099	587,254	839,046	
Household Connection	Nos.	10,936	14,965	22,586	32,271	26 pers. per connection

Table 4-87 Scope of Household Connection

Category		Remarks
Property Connection	From trunk/primary/secondary sewer to the public inspection chamber	
Realignment within the property	From public inspection chamber to plumbing work within the property including closure of septic tank	



4.4 Architectural, Mechanical, Electrical & Instrumentation Works

4.4.1 Architectural Works

4.4.1.1 General

Architectural plan should ensure that the basic functions of sewage facilities, which are the purpose of this project, can be performed most faithfully and smoothly, and maintenance and management according to the performance of the functions can be performed reasonably and economically. Major consideration of architectural works is as below.

- Layout of facilities that prioritizes the sewage treatment process
- Traffic line and space planning considering the organic relationship between Sewage treatment plant
- Traffic line and architectural plan considering maintenance convenience
- Emphasis on a clean image as a sewage treatment facility
- Land use and layout plan considering scalability of facilities to be expanded in the future
- Maximization of land efficiency by arranging required facilities by area
- Increased usability of buildings through integrated arrangement of related facilities
- Organic connection with treatment facilities considering maintenance
- Structural planning considering maximum load conditions
- Basic design utilizing the surrounding conditions and ground conditions to the maximum
- Minimization of maintenance costs through rational selection of building materials
- Securing economic feasibility by reducing buildings through an integrated layout plan
- Introduction of an economical facility system that is easy to maintain
- Pleasant indoor environment plan for workers

4.4.1.2 Architectural Plan

Architectural buildings of the project are grit removal and inlet pumping station, sludge thickening and dewatering facility, faecal sludge treatment building, administration building, blower and generator room, staff quarters, chemical buildings and all of buildings are planned as reinforced concrete structure.

Table 4-88 Plan of Major Building

No.	Name	Specification	Remarks
1	Grit Removal and Inlet Pumping Station	B29.88m X L12.90m X 10m X 1 Floor	
2	Sludge Thickening and Dewatering	B39.90m X L15.15m X 10m X 1 Floor	
3	Faecal Sludge Treatment Building	B39.90m X L15.15m X 7m X 1 Floor	
4	Administration Building	B49.80m X L20.10m X 3m X 2 Floor	
5	Blower and Generator Room	B39.90m X L15.15m X 7m X 1 Floor	
6	Staff Quarters	B48.67m X L15.40m X 3m X 1 Floor	
7	Chemical Building	B25.05m X L20.10m X 6m X 1 Floor	

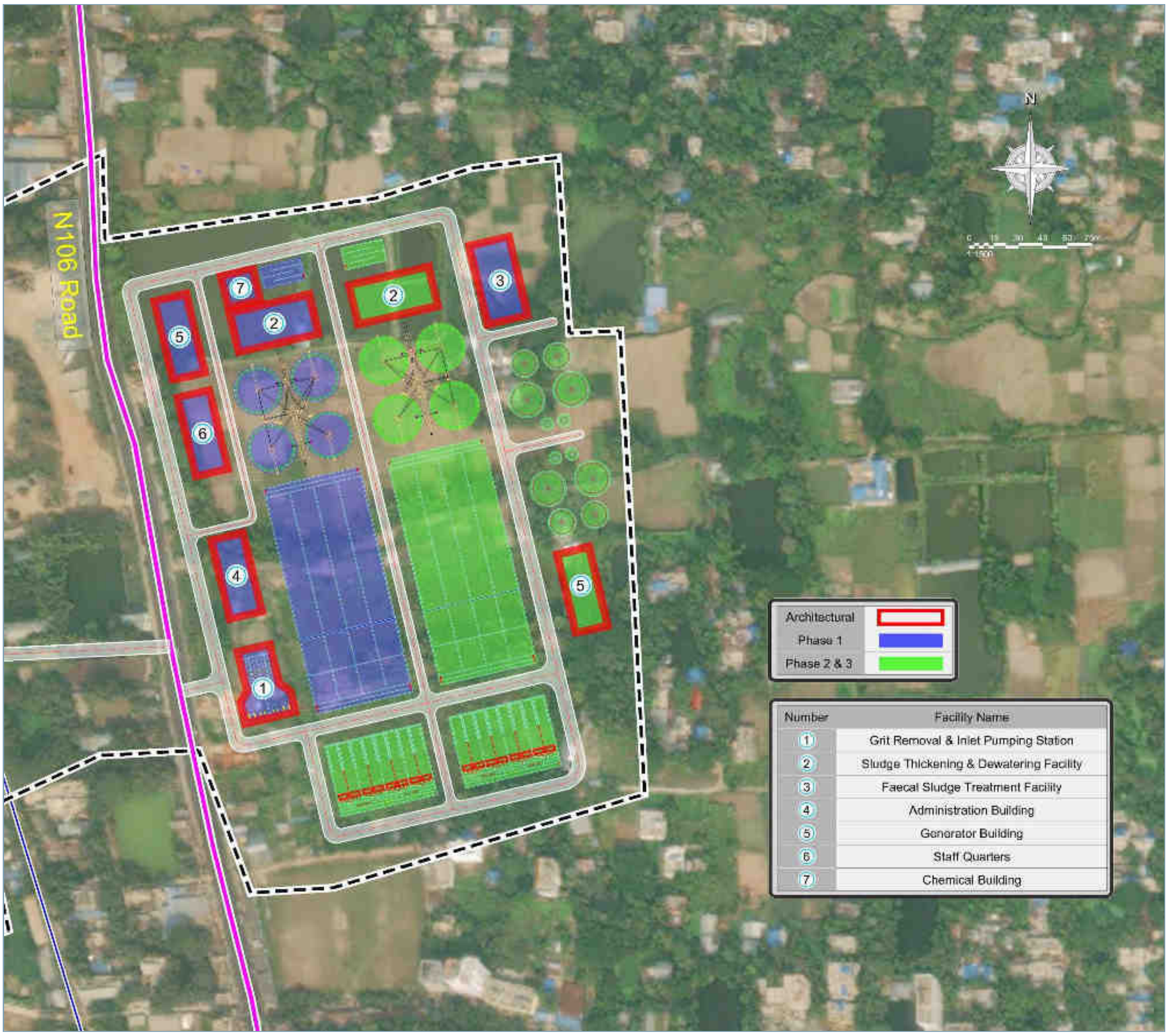


Figure 4-33 Layout of Major Building

4.4.1.3 Structural Plan

In this project, the structural plan of the architectural building is planned in consideration of the following matters, and the structural planning standards should be established according to the site conditions during the detailed design.

4.4.1.3.1 Safety

- Appropriate foundation selection by geological survey
- Structural design considering natural disasters
- Consider predictable loads

4.4.1.3.2 Economics

- Application of unified structure system
- Reduced construction period by using standardized members
- Considering the maintenance management of structures

4.4.1.3.3 Constructability

- Simplification of members and connections
- Minimization of temporary work and field work
- Reducing the construction period and securing skilled manpower
- Adoption of structural form considering constructability

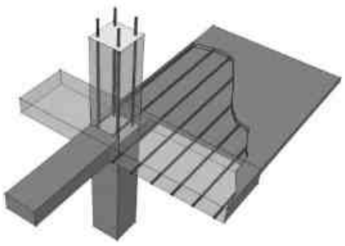
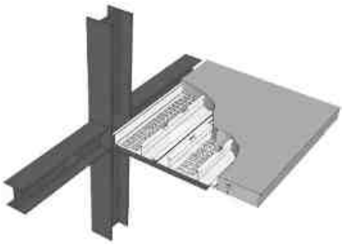
4.4.1.3.4 Usability

- Minimization of vibration and long-term deflection of long-span structural parts
- Vertical and horizontal displacement review

4.4.1.3.5 Analysis of Frame Structure Type

The frame structure type of a building structure can be largely classified into three types. In this feasibility study, the reinforced concrete structure type is planned, but during the detailed design, the frame structure type should be applied according to the site conditions, material supply and demand, and the function of the structure.

Table 4-89 Frame Structure of Building

Category	Concrete type	Steel Type	Block Type
Structure Type			
Advantages and Disadvantages	• Unified steel structure, stable type • Suitable for span within 12m • Increased architecture period due to the wet structure	• Fixture type of structures, good at flexibility • Simple architecture at the site due to fabrication in the factory • Separate actions required due to the weak flame resistance	• Suitable for lower floors and simple buildings • Possible of fabrication at the site with simple works • Separate reinforcing required due to the week traversal force

4.4.1.3.6 Analysis of the Floor Structure

The floor structure type of a building structure can be largely classified into three types, and the floor structure type should be applied according to the structure's function and working load.

Table 4-90 Floor Structure of Building

Category	Beam & Girder System	Wide Girder System	Flat Slab System
Structure Type			
Advantages and Disadvantages	• Advantageous for drooping and vibration • Reduced slab thickness • Increased structure quantity for small span	• Advantageous for constructing forms • Increased slab thickness • Decreased structure quantity for small span	• Advantageous for constructing forms • Reduced floor height and increased structure quantity • Need of architecture control for the distribution of rebar

4.4.2 Mechanical Works

4.4.2.1 Introduction

Mechanical equipment is an important facility for the operation and maintenance of sewage treatment plants, and it should be trouble-free and convenient to operate. Therefore, each system and each mechanical facility should have high stability and reliability, simple facility configuration, and easy operation and maintenance through automation. In addition, an economical facility plan that can reduce construction and operating costs while satisfying the function should be established.

Looking at the water treatment method, the current facility capacity is 75,000m³/day, and the standard activated sludge method is used, and it is planned to expand to 75,000m³/day in the future in the same way. The disinfection facility is planned to be disinfected by introducing liquid chlorine, and the sludge treatment process adopted the Thickening→digestion→Dewatering process.

4.4.2.2 Design Scope

Mechanical design is applied to various mechanical facilities such as water treatment and sludge treatment necessary for final discharge by treating sewage flowing into the sewage treatment plant.

4.4.2.3 Design Consideration

Stability of treated water quality, guarantee of performance and connectivity of equipment, energy saving and economic efficiency, convenience of maintenance, prevention of environmental pollution, proper facility arrangement, and convenience of work environment were reflected as key elements of the design.

Table 4-91 Mechanical Design Consideration

Category	Consideration
Stability of treated water quality	• Ensuring shock load responsiveness according to flow rate and water quality fluctuations • Operation by series and rational design of equipment type and capacity
Performance guarantee and connectivity	• Appropriate design (optimal machine, appropriate material selection) • Consideration of equipment protection safety system, corrosion prevention, minimization of work flow • Considering connectivity with planned expansion facilities
Energy saving and economical	• Selection of energy-saving equipment and reuse of treated water • Minimizing initial investment and maintenance costs and maximizing device performance
Maintenance	• Considering the integrated operation management system • Equipment layout considering maintenance and check-in/out of equipment • Secure spare parts and select compatible devices
Prevention of Environmental Pollution	• Prevention of secondary pollution (odour control, noise, vibration and waste treatment) • Comply with the water quality standards set forth in the relevant laws and regulations and harmonize with the surrounding environment
Arrangement of equipment	• Equipment layout that facilitates vehicle, piping and maintenance circulation planning • Equipment layout considering maintenance and operation management aspects
Working environment	• Proper working space secured • Design that does not cause environmental pollution • Safety and hygiene facilities are fully equipped in accordance with relevant laws and regulations.

4.4.2.4 Criteria for Selecting Major Equipment

When selecting facilities for Sewage treatment plant, construction cost, maintenance cost, performance, etc. should be compared and reviewed considering the design method of the entire treatment plant, construction and maintenance conditions, etc. To ensure process efficiency and efficient circulation route for maintenance.

In addition to the function of the sewage treatment plant, facilities and materials should be selected by comprehensively reviewing the facility's overall uniqueness, image improvement, economic feasibility, and maintenance convenience. To consider smooth operation of hydraulic.

Plan the selection of major facilities and determine their capacity so that they can be connected with the operation and maintenance of Sewage treatment plant, and select facilities that are economical and can promote energy conservation.

4.4.2.5 Key Points of Mechanical Facility Configuration

In this chapter, prior to design, the main issues in the process composition of the mechanical field, such as facility design and installation (including piping work) are summarized as below.

Table 4-92 Key Points of Mechanical Facility Configuration

Category	Design Focus	Facility
Grit chamber facility	• Plans for screen equipment to protect impurities and machinery • Reduces the load of the downstream treatment process and homogenizes the sewage properties • Speed control or selection of two or more pumps with different capacities	• Screen facilities • Round Sand Remover • Submersible Mixed Flow Pump
Settling basin facility	• Configuration of automatic extraction system for sludge extraction	• Electric gate valve + sludge pump
Biological reactor facility	• Installation of a variable control blower and air conditioning control device • Full-scale aeration system installation	• Gear booster blower • Plate Diffuser
Disinfection and discharge facilities	• Removal of pathogenic bacteria and consideration of field conditions • Pump selection suitable for low head and high flow operation conditions • Improved with an electric crane	• Liquid chlorine disinfection equipment • Overhead crane • Double suction volute pump
Anaerobic digestion facility	• Production of bio gas using an anaerobic digestion tank	• Anaerobic digestion tank
Power generation and heat source supply facilities	• Temporary storage of bio gas generated from anaerobic digestion tank • Maintaining optimal operating conditions for bio gas purification • Establishment of stable refinery facilities and simplification of facilities • Composition of bio gas power generation facilities that can maximize power generation efficiency • Configuration of hot water supply facilities for heating the digester	• Extinguishing gas reservoir • Dehumidification facility • Desulfurization facility • Fire Gas Generator • Hot water boiler
Odour removal equipment	• Improving the working environment of the driver and blocking residents' perception of facilities that they hate • Ease of maintenance and reduction of maintenance costs • Complete odour collection and accurate odour control air volume calculation	• Chemical liquid washer and deodourizer

4.4.2.6 Sewage Treatment Plant

4.4.2.6.1 Grift System

Since the influent sewage contains various impurities and sand, impurities and sediments should be removed so as not to adversely affect subsequent water treatment and sludge treatment processes. It is therefore designed for chip removal by coarse and fine particle screens and sand removal by sand recovery machines.

4.4.2.6.1.1 Screen Equipment

Large impurities are removed by a dense and fine sieve installed at the front of the settling paper, and small-sized impurities are removed by a fine screen installed at the rear of the settling paper. Conveyors, containers, hoists, etc. are installed to facilitate carrying out and processing of foreign substances lifted by the screen. This process is configured to work automatically. Automatic screens generally include double chain type screens, hydraulic screens, and rotary screens. For this treatment, the screen and the conveyor to remove impurities are automatically interlocked.

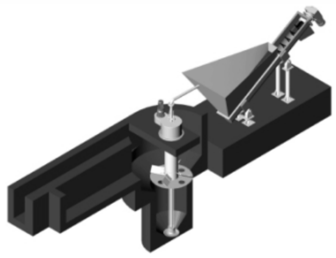
Table 4-93 Comparison of Screen Equipment

Category	Double Chain Screen	Hydraulic Screen	Rotary Screen
Shape			
Structure	• Rakes connected to guide rails on either side of the frame and a chain that continuously rotates up and down remove debris from the front of the bar.	• As the hydraulic screen moves through each waterway, a rake is used to move the impurities in the water to the water surface to remove the impurities.	• The rake attached to the chain that rotates by the driving device descends to the back of the screen, rotates to the front, and raises, scrapes the impurities caught on the screen, and lifts and removes them to the top.
Advantage	• Rake-up is continuous. • Easy sealing with casing • Most installations	• Maintenance is easy as the mechanical part is above water • Able to scrape out large impurities	• Remove a large number of impurities in a short time • Individual operation is possible, so there is no damage due to inoperability
Disadvantage	• Stroke adjustment is • required by extending the chain. • Maintenance is difficult • because there are gears in the water.	• Raking is intermittent • The effective screen width is narrow compared to the paper width.	• Inconvenient maintenance in the case of parts failure in the underwater part • High initial investment cost compared to other equipment
Selection	⦿		

4.4.2.6.1.2 Grit Removal Equipment

Grit removal equipment should facilitate the subsequent process by removing precipitated soil and non-perishable inorganic substances from the inflow sewage that has passed through the front screen, and by securing the efficiency of pretreatment, treatment efficiency such as facility closure due to wear and deposition of facilities degradation should be avoided. When selecting equipment, work environment such as abrasion resistance, corrosion resistance, and odour should be considered.

Table 4-94 Comparison of Grit Removal Equipment

Category	Vortex Type	Driving Type T-Bucket Lifting Machine	Double Chain Conveyor (V-Bucket Anti-Excavation Prevention Type)
Shape			
Structure	• Sewage and sediment are separated by centrifugal force in the cylindrical grit tank, and when a certain amount of sediment accumulates, the sediment is lifted with a pump.	• A rail is installed on the upper part of the grit, and the bridge rail drives left and right, and the grit is lifted while moving the upper rail by attaching a V-bucket to the endless track chain.	• By attaching and circulating several V-buckets on the caterpillar track, the deposited soil is continuously lifted from the end of the waterway and transported to the conveyor on the ground.
Advantage	• Constant removal efficiency regardless of flow rate fluctuations • Odour collection and easy maintenance	• Continuous operation is possible and suitable for large-capacity sewage treatment plants	• Continuous operation and large-capacity sand removal is possible • Easy to operate automatically • Many installations record
Disadvantage	• Caution is required in the selection of sediment lifting facilities • Difficult to construct	• Not possible to cover the grit pad • Sand or sewage from the bucket makes the surroundings unclean	• There are many worn places such as chains, shoes and sprockets, so it is not easy to repair and inspect
Selection	◉		

4.4.2.6.2 Inlet Pumping Station Facilities

The inflow pump facility is planned to pump the sewage from which impurities and sediment have been removed from the grit pond to the subsequent process (primary settling basin) at the pumping station.

4.4.2.6.2.1 Inlet Pump

The pump facility capacity is planned based on the hourly maximum sewage volume, and the number of pumps is determined by considering the planned sewage volume and Phased construction. Since the type of pump has a great influence on the size and maintenance of the pump room, the characteristics of each pump should be thoroughly reviewed before selecting a pump suitable for the purpose of use. etc. should be considered.

In selecting a model, after reviewing pump efficiency and characteristics, select a suitable type, and plan to enable transfer amount control (number control, rotation speed control, etc.) according to inflow fluctuations.

Table 4-95 Comparison of Inlet Pump

Category	Submersible Mixed Flow Pump	Submersible Centrifugal Pump	Vertical Mixed Flow Pump
Shape			
Structure	• The motor and pump are installed underwater in a completely sealed state in a suction vertical cylindrical casing, pumping through the circular casing by the centrifugal force of the impeller and the lifting force of the guide vane	• Composed of an underwater motor and an automatic separation device, installed underwater • Casing, rotor, motor all-in-one	• The form in which the flow of fluid discharged from the impeller is on the conical surface with the center of the main axis as the axis
Advantage	• Less change in quantity due to change in suction lift • Variance range of flow rate according to head change is large, so the range of flow control by rotation speed control is wide • Excellent efficiency when pumping large capacity	• Pumping station building may be small • The pump is always below the water level, so there is no need to manipulate the water level and noise is low • Simple structure and easy to install, disassemble and assemble	• Variety of quantity is small for change of suction lift • Easy to repair as the driving part of the electric pole is outside the submerged area • Extremely high efficiency under large-capacity pumping conditions
Disadvantage	• Difficulty shut off driving • Unsuitable for lifting conditions over 20m in terms of structure	• Since it is installed underwater, safety devices such as motor leakage detection are required. • In the case of the automatic detachable device type, leakage occurs at the junction and the efficiency is lowered	• A shaft sealing device and a lubricating device are required, and there are many attached machines • The pumping station is the largest
Selection	◉		

Table 4-96 Inlet Pump Capacity and Operation

Category		Planned Sewage Volume m³/d	Planned Sewage Volume m³/min	Pump Operation Plan 31.3 m³/min				Pump Operation Plan 15.6 m³/min				Discharge Volume (m³/min)
Phase 1	Daily avg.	60,000	41.7	◐	◎			●	◎			46.9
	Day max.	75,000	52.1	◐	◎			●	●			62.5
	Hourly max.	90,000	62.5	●	◎			●	●			62.5
Phase 2	Daily avg.	90,000	62.5	●	◎	◎	◎	●	●			62.5
	Day max.	112,500	78.1	●	●	◎	◎	●	◎			78.2
	Hourly max.	135,000	93.8	●	●	◎	◎	●	●			93.8
Phase 3	Daily avg.	120,000	83.3	◐	◎	◎	◎	●	●	●	●	93.7
	Day max.	150,000	104.2	◐	●	◎	◎	●	●	●	◎	109.4
	Hourly max.	180,000	125.0	◐	●	◎	◎	●	●	●	●	125.0

Note) ●: constant speed, ◐: Inverter operation, ◎: spare

4.4.2.6.2.2 Agitator

The agitator is used to prevent sedimentation of sludge and to make the water quality uniform in the flow control tank. The agitator should be designed in such a way that the agitation effect of the flow control tank is good and operation and maintenance are easy.

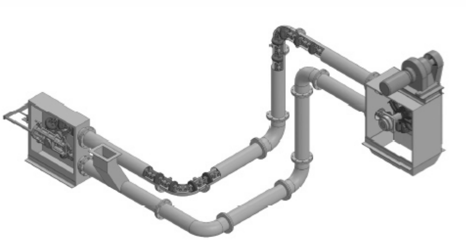
Table 4-97 Comparison of Agitator

Category	Submersible Horizontal Agitator	Upright Agitator
Shape		
Structure	• The motor and impeller are installed in the corner of the water as an integral type to form a swirling flow	• There is a driving device at the top of the tank, and the impeller is connected by a shaft to form vertical swirling flow
Advantage	• Relatively low maintenance cost due to low power and high efficiency • Built-in motor protection device makes it possible to check when a motor problem occurs • There is no vibration and noise as the driving part is underwater • Low price compared to other types	• Convenient maintenance as the driving part is exposed at the top • As the impeller is located in the center of the tank, there is little turbulence, so the flow of the mixed solution in the reaction tank is maintained in the form of a plug flow to prevent short-circuit flow • Prevents leakage of structures due to less work on anchor bolts during installation
Disadvantage	• Water flow occurs in one direction, which can lead to stagnation of sediment and floc breakage • If the diameter of the impeller is increased to increase the agitation range, the power increases due to high-speed rota	• The deeper the water, the longer the • shaft and the larger the shaft diameter • As the impeller is installed in the center of the water, it is necessary to maintain the flow speed at least 0.3m/sec to prevent sedimentation of debris
Selection	◉	

4.4.2.6.2.3 Grit Transfer Facility

It is a transfer facility for easy final disposal of grits discharged from the screen and grit removal equipemnt, and odour prevention is considered. Representative models applicable to Sewage treatment plant were compared and reviewed.

Table 4-98 Comparison of Grit Transfer Facility

Category	Link Conveyor	Pneumatic Conveyor
Shape		
Composition	• Drive device • Tension device • Pipe & Fitting • Link chain • Sprocket • Control panel	• Body • Air cylinder • Air compressor • Pipe & Fitting • Air Receiver Tank • Control panel
Transfer Distance	• 60m	• 80~100m
Advantage	• There is no odour and scattering dust because it is transported through a pipe. • Possible to freely move 3-dimensionally by • pipe • Minimal installation area and unmanned transfer possible regardless of location • Easy maintenance.	• Because it is transported through a pipe, it is effective in preventing odour and scattering. • Possible to freely move 3-dimensionally by pipe • Possible to minimize installation area regardless of location • Hygienic
Disadvantage	• Crusher equipment is required when • transporting large impurities • A lot of power required	• Cannot be transported to high places as it is transported by air • Less amount of transport due to intermittent transport instead of continuous transport • Accessories are required (air compressor and air receiver tank) • Hole damage caused by deposits in the bend
Selection	◉	

4.4.2.6.3 Primary and Secondary Sedimentation Facilities

The facility is planned to improve the treatment efficiency by precipitating and removing the precipitable solids present in the sewage. A sludge collector is planned to collect and remove the precipitated sludge, a scum remover to remove scum generated on the top of the settling tank, and pumps to transport the sludge were planned.

4.4.2.6.3.1 Sludge Collector

As a model used as a sludge collector for Sewage treatment plant, there are chain flight type, underwater bogie type, and running beam siphon type in the case of rectangular water tanks. There is a peripheral driving type of a holding position.

Table 4-99 Comparison of Primary Sedimentation Tank Sludge Collector (Phase 2)

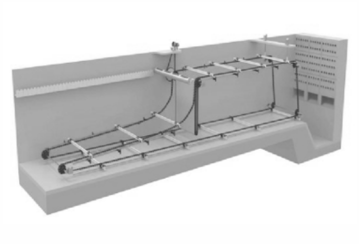
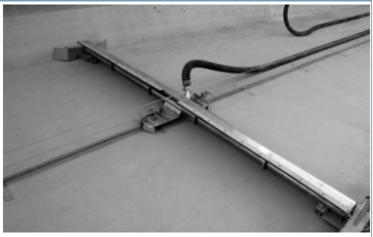
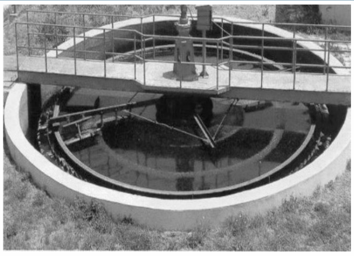
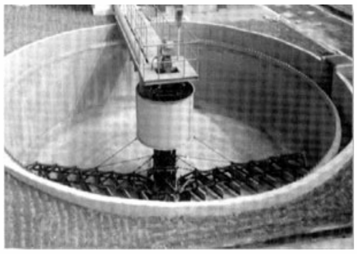
Category	Non-Metal Chain Flight Type	Underwater Bogie Type	Vacuum Suction Type
Shape			
Description	• The flight fixed to the circulation chain running along the rail in the water continuously collects the sludge into the hopper part while rotating the weir.	• A bogie equipped with a scraper on a rail running in the water collects the sludge to the hopper part by reciprocating motion by the wire rope.	• It moves along the guide rail underwater by compressed air, and the sludge is suctioned and discharged by vacuum.
Advantage	• Process the largest amount • Excellent collection ability as the collection speed is constant and continuous, • Low-speed operation is possible • Excellent wear resistance and corrosion resistance by using non-metallic materials	• As the sludge is discharged when the scraper reaches the hopper, it is possible to discharge high-concentration sludge and less discharge of unnecessary treated water. • Possible to install inclined plate of settling tank • Easy maintenance • Operation by forward / reverse driving is possible	• Since the sludge is removed by the vacuum suction of the underwater sludge suction pipe, there is little concern about sludge injury • Since sludge can be directly discharged to the outside, no sludge hopper or draw valve is required
Disadvantage	• Restrictions on chain strength and channel width • Difficulty in maintenance and inspection when chain is broken while driving in water • The sedimented sludge is disturbed by the rotation and vibration of the flight plate • Flights get in the way when cleaning the settling tank	• There is sagging of the rope due to tension, so intermittent adjustment is required • Difficulty in handling a large amount of sludge	• Condensation in the air supply line • Restrictions on suction pressure and suction amount • Low-concentration sludge is sucked, resulting in a large amount of sludge • Water flow obstruction due to floating air and sludge take-out pipes
Selection	◉		

Table 4-100 Comparison of Secondary Sedimentation Tank Sludge Collector

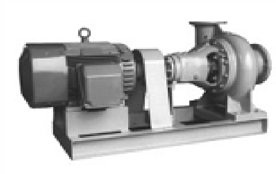
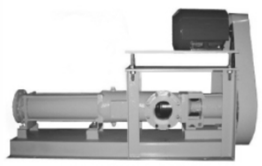
Category	Peripheral Driven Type	Center Driven Suspension Type	Center Driven Support Type
Shape			
Description	• The central steel frame and beam are made integral and rotated by a driving device installed on the circumference of the jaw. • The rake arm attached to the central steel frame rotates to scrape the sludge toward the center.	• A driving device is installed in the center of the support beam (combined with a check foot) installed along the diameter of the jaw, and a rake arm is hung on it to rotate, and the sludge is scraped to the center with a rake.	• A pillar is installed in the center of the jaw, a driving device is installed on top, and a rake arm is attached to the central steel frame below it to rotate, so that the rake scrapes the sludge toward the center.
Jaw Diameter Usable Range	• 20 ~ 50m	• 4 ~ 12 m	• 10 ~ 25m
Advantage	• Simple mechanical device • Relatively less precision in equilibrium is required • Less mechanical damage even if the precision of the floor finish is slightly lowered	• Advantageous for small-scale treatment plants • Simple structure • Excellent collection ability	• Advantageous for medium-sized treatment plants • Excellent collection ability • The usable jaw diameter is the normal size • The most commonly used model
Disadvantage	• The rotating device is complicated because the inspection plate rotates. • Decreased collection ability • (Possible blind spots)	• Damage to the collector if the floor finish is not precise • The equilibrium should be set correctly • Can only be used with narrow diameter jaws	• Large bearing device of driving part • Damage to the collector if the finished floor is not precise • The equilibrium should be set correctly
Selection	◉		

4.4.2.6.3.2 Sludge Transfer Pump

The sludge pump of the sewage treatment facility should be free from foreign substances and should be planned as a device with long life, convenient maintenance, and high efficiency.

Models that are applied as sludge pumps for Sewage treatment plant include horizontal axis non-closed type screw centrifugal pumps, horizontal axis positive displacement twin pumps, and single axis spiral pumps (Progressive Cavity type). In general, Vortex pumps and Screw pumps were mainly used, and recently, screw pumps are being used a lot.

Table 4-101 Comparison of Sludge Transfer Pumps

Category	Horizontal Axis Non-Closed Spiral Centrifugal Pump	Positive Displacement Twin Pump	Single Screw Pump
Shape			
Description	• The impeller consists of a spiral part and a centrifugal part and was developed to be suitable for sludge transfer by harmonizing the advantages of a centrifugal pump and a volumetric pump	• Vacuum state is created and transported by the rotation of the piston inside the casing with constant volume on the suction and discharge sides	• The cavity formed between the round stator and the rotor moves from the suction side to the discharge side as the rotor rotates, transporting the sludge
Advantage	• Less chance of foreign matter being wound around the impeller • Excellent suction power, suitable for transporting large solids • Higher efficiency than other types • Equipped with advantages of both centrifugal and volumetric pumps • Less performance deterioration due to concentration change	• Excellent suction performance • Discharge volume schedule • Flow rate control by number of revolutions possible • Can be used even with very high solids concentration • Easy flow control • Very little vibration	• Easy to control discharge amount • Very little vibration • Easy to drive • Suitable for small doses • Transportation of high-viscosity solutions is possible • Forward/reverse rotation can be repeated
Disadvantage	• Equipment cost is higher than other models • Discharge volume control is disadvantageous compared to metering pumps	• Low efficiency • There is a limit on the lift • Wide installation space	• High maintenance cost • Abrasion of the stator and rotor due to sand in the sludge is a concern
Selection	◉		

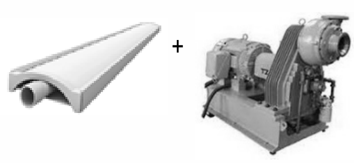
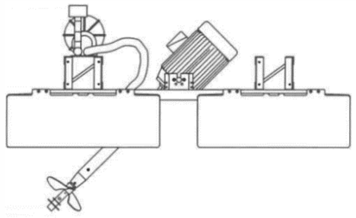
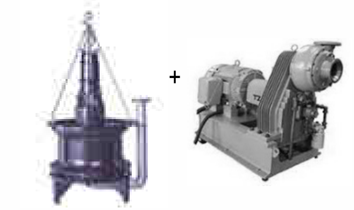
4.4.2.6.4 Bioreactor Facility

As the core process of the sewage treatment process, it is a process that removes organic matter and nutrients, nitrogen, phosphorus, etc., and the main facilities, the aeration method and the blower facility, are planned. Aeration is a facility that requires a lot of power compared to other facilities in the treatment plant, and power requirements can vary greatly depending on the method.

4.4.2.6.4.1 Aeration Method

- Micro-bubbles of the front aeration method have superior oxygen transfer efficiency and mixing ability compared to surface aeration methods or submersible aeration methods. It should be planned in consideration of management and economic aspects.
- Compared to the front aeration method, the surface aeration method requires 10 to 30% of the air volume due to the larger bubble size, so construction and maintenance costs increase as the number of installation units increases.
- Mechanical aeration in water has high oxygen transfer efficiency, complete mixing is possible, and aerobic and anaerobic stirring operations are possible, but the equipment cost is rather high compared to other equipment.

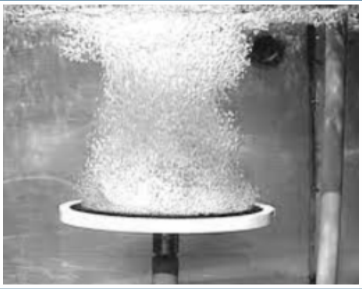
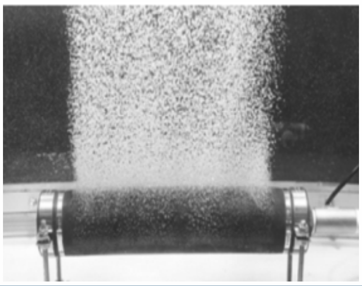
Table 4-102 Comparison of Aeration Method Type

Category	Front Aeration Device (Diffusion Pipe + Blower)	Surface Aeration Method	Submersible Aerator + Blower
Shape			
Description	• The body of the diffuser is made of polyurethane or membrane and is connected to the fan in the shape of a square or circular disc • Equipment is regularly arranged on the bottom of the tank and mixed by the rotating flow of unit bubbles generated in the diffuser	• Blower (Ring Brewer) and high-speed agitator are installed to create air bubbles by forced suction of the blower by high-speed rotation of the agitator • The diffuser is installed at the top of the tank, and the rotational flow in one direction is made in the tank for mixing, and oxygen is dissolved by mixing air and sewage in the tank	• Consists of an axial flow impeller and a fixed diffuser • The low-speed turbine installed at the bottom of the aeration tank and the air pipe are connected to crush the injected air with mechanical agitation of the turbine to increase the surface area of the air and increase the oxygen transfer rate and agitation
Advantage	• Power cost is saved because oxygen solubility is high • Easy to control the air volume according to the DO in the tank • Possible to increase treatment efficiency in winter by preventing water temperature drop in the tank by the air injected from the blower • High oxygen transfer efficiency • Easy to cover when deodourizing	• Simple structure and easy installation • The installation height of the diffuser can be freely adjusted • Installation cost is cheaper and more advantageous than total abandonment • Less breakdown and easy maintenance	• Aerobic and aerobic operation possible as aerobic and agitator can be mixed • High oxygen transfer efficiency with excellent agitation • Completely mixed • Easy to install and maintain • Glass in deep water
Disadvantage	• Oxygen supply capacity is limited, reducing treatment efficiency due to changes in water quality and flow rate • When injecting air, dust should be removed through an air filter • Regular maintenance is required due to the closing of the diffuser	• Poor oxygen transfer efficiency increases power cost	• High construction cost compared to other types • Inconvenient maintenance as major facilities are underwater • High power cost
Review The Amount of Air Required	• Oxygen transfer rate: 25~30% • AOR: 40,308.5kg/d • Required air volume: about 1,450m³/min • 10% safety factor applied	• Oxygen transfer rate: 20% • AOR: 40,308.5kg/d • Required air volume: about 1,810m³/min • 10% safety factor applied	• Oxygen transfer rate: 20% • AOR: 40,308.5kg/d • Required air volume: about 1,810m³/min • 10% safety factor applied
Equipment Components	• Blower: 730m³/min × 7,000mmAq × 3 (1) units • Diffusion tube: 600EA/paper × 4 sheets = 2,400EA • Aeration rate = 500~800ℓ/min EA	• Surface aeration equipment (forced blowing) 21 units/group × 4 units = 84 units • Oxygen delivery per unit = 68kgO2/hr	• Blower: 905m³/min × 7,000mmAq × 3 (1) units • Underwater aerator: 17 units/G×4 = 68 units • Aeration rate = 3,600ℓ/min unit
Construction Cost	• 100	• 136	• 109
Power Cost	• 100	• 160	• 186
Selection	◉		

4.4.2.6.4.2 Diffuser

It is a facility that forms microbubbles from the air supplied from the blower and supplies them into the tank. Representative types used in sewage treatment plants include microbubble plate type, membrane disc type, and membrane rod type.

Table 4-103 Comparison of Diffuser Type

Category	Membrane Plate Diffuser	Membrane Disk Diffuser	Membrane Rod Diffuser
Shape			
Outline	• When air is supplied underwater using a membrane made of Poly Urethane, ultra-fine bubbles are created through pores formed in the plate-shaped membrane, and the body is made of STS316.	• When air is supplied underwater using a membrane made of EPDM, microbubbles are created through the pores formed in the membrane, and when the air supply is stopped, the pores are blocked to prevent backflow.	• EPDM membrane is used to supply air from the water, and it is composed of rod-shaped pipe, saddle, wedge, and microporous membrane rubber membrane.
Oxygen Transfer Efficiency	• 20~30% (fresh water, 4~5M water depth)	• 15~20% (Clean water, 4~5M water depth)	• 15~20% (Clean water, 4~5M water depth)
Pressure Loss	• 800mmAq	• 300mmAq	• 400mmAq
Aeration Range	• 650ℓ/min	• 120ℓ/min	• 180ℓ/min
Exchanging Periods	• 10-15 years	• 5-7 years	• 5-7 years
Merits	• High oxygen delivery efficiency by generating ultra-fine bubbles of 1 mm or less. • It is made of EPDM PU material and has a long lifespan. • High oxygen delivery efficiency reduces the amount of air required and lowers the driving force of the blower. • There is almost no decrease in oxygen delivery efficiency over time. • The main body is made of STS316 material and has excellent durability. • Simple piping configuration.	• Good oxygen delivery efficiency due to the generation of fine bubbles of 2-3 mm • Membrane material is flexible, so pores open and close, preventing back flow of sewage	• Good oxygen delivery efficiency due to the generation of fine bubbles of 2-3 mm • Membrane material is flexible, so pores open and close, preventing back flow of sewage
Demerits	• The pore size of the membrane is very small, so the discharge pressure is somewhat higher than that of other diffusers.	• Membrane film is EPDM, and efficiency declines quickly due to hardening over time. • Bubble concentration occurs at the top of the diffuser.	• Membrane film is EPDM, and efficiency declines quickly due to hardening over time. • Bubble concentration occurs at the top of the diffuser.
Selection	◉		

4.4.2.6.4.3 Blower Equipment

It is installed to supply the necessary oxygen to the bioreactor and operates 24 hours a day, so performance safety and ease of maintenance are important factors.

In general, models used in Sewage treatment plant are largely classified into turbo type and volume type, and in this plan, rotary roots blowers, multi-stage turbo blowers, and single-stage turbo blowers were compared and reviewed.

The blower should be connected with the DO system of the biological reactor to automatically control the air volume, energy-saving and easy-to-maintain models.

Table 4-104 Comparison of Blower Type

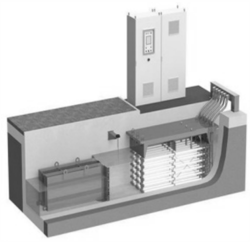
Category	Gear Booster Blower	Rotary Roots Blower	Air Bearing Blower
Shape			
Structure	• One rotor is rotated at high speed to generate air volume and pressure that meet the specifications, and the number of revolutions is increased using a gearbox.	• Volume type blower that sucks and discharges air as much as the space (volume) between the impeller and the casing by rotating two impellers maintained at regular intervals (non-contact) in the cast iron casing in opposite directions	• One rotor is rotated at high speed to generate air volume and pressure that meet the specifications, and the number of revolutions is increased using an inverter.
Advantage	• Variable discharge diffuser and helical gear reducer used to control the number of revolutions and air volume.	• When the intake air moves by a certain amount by the rotation of the impeller The air volume is proportional to the number of revolutions, and the pressure increases due to the resistance on the discharge side. • Discharge flow rate is independent of pressure ratio when the number of revolutions is constant.	• Uses a high-speed BLDC motor and air bearing to lift the rotating shaft and adjusts the number of revolutions and air volume using an inverter.
Disadvantage	• Lubricating oil and cooling water are used for cooling	• Noise and vibration • Difficult to control wind volume	• Air-cooled separate fan for inverter cooling • Inverter failure in case of odour and gas inflow
Driving Range	• 45~100%	• Consistent air volume can be supplied without any change in efficiency even when the discharge pressure changes	• 70 to 100%
Maintenance	• Since it rotates at high speed, vibration and noise are somewhat high, but it can be reduced below the noise standard by installing a silencer and soundproof cover	• Simple structure and fewer • disassembly/assembly parts, making maintenance easy • No separate lubrication device is required, and it is • advantageous to use a general purpose (squirrel cage) motor	• Since it rotates at high speed, vibration and noise are somewhat high, but it can be solved by applying a soundproof ventilation room
Selection	⦿		

4.4.2.6.5 Disinfection Facility

Disinfection Facility were planned to increase the hygienic safety of treated water by killing pathogenic bacteria that may survive in treated water.

Disinfection facilities include chlorine injection methods that inject disinfectants into discharged water in sewage treatment plants, ozone, and ultraviolet disinfection facilities.

Table 4-105 Comparison of Disinfection

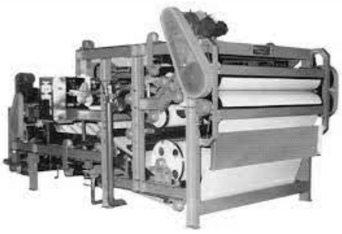
Category	Liquefied Chlorine (Cl_2) Disinfection Facility	Ultraviolet (UV) Disinfection Facility	Ozone (O_3) Disinfection Facility
Shape			
Structure	• Chlorine gas is compressed under high pressure, cooled, liquefied, and stored, then evaporated to oxidize the chlorine.	• Ultraviolet rays (UV) are irradiated with a UV lamp to destroy nucleic acid (DNA) in cells through contact with microorganisms and sterilize.	• Compressed, cooled, and dried air is injected into the ozone generator and sterilized by mixing the ozonized air in the contact tank.
Advantage	• Low installation cost • Excellent disinfection effect with strong oxidizing power • Excellent residual effect of disinfection prevents re-growth of microorganisms in sewers	• High virus sterilization effect • Strong adaptability to flow and water quality fluctuations • Short contact time • No risk to human body and easy to install • Requires low power	• Processing biologically recalcitrant organic matter • Sterilizes both bacteria and viruses • Color can be removed • Sterilization action without affecting turbidity
Disadvantage	• Technology and experience in handling chlorine gas are required • Leakage of liquid chlorine may cause severe corrosion of equipment and damage to surrounding areas. • Unpleasant odour caused by chlorine disinfection	• No residual effect after treatment • If the water is turbid or the turbidity is high, the disinfection ability is affected.	• Because it cannot be stored, it should be produced on site • Initial investment and auxiliary facilities are expensive • No residual effect after treatment • High maintenance cost • Subject to the High-Pressure Gas Safety Management Act
Selection	◉		

4.4.2.6.6 Sludge thickening facility

The sludge generated in the water treatment process is thickened to improve the treatment efficiency of the digester and Dewatering facility.

Sewage treatment facility the type of enrichment facility following the introduction of the advanced treatment process should consider the site conditions of the sewage treatment facility, and since the amount of sludge generated and the Thickening method can vary greatly depending on each method, it is suitable for the advanced treatment method at the basic design stage of sludge. Enrichment facility It should be selected by reviewing the capacity and Thickening method.

Table 4-106 Comparison of Thickener

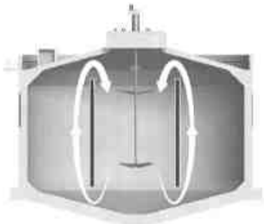
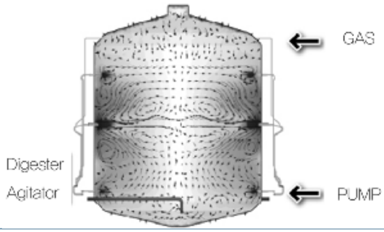
Category	Centrifugal Thickener	Belt Type Gravity Thickener	Multi-Disc External Cylinder Thickener
Shape			
Structure	• The centrifugal force is used to thicken and separate the sludge, and the outer and inner cylinders are separated, so the sludge is transported at the speed of the screw.	• With a structure in which only the upper part of the belt-type thickener is removed, the sludge mixed with the coagulant is thickened by gravity while passing through the rotating filter cloth.	• With a structure in which only the upper part of the belt-type thickener is removed, the sludge mixed with the coagulant is thickened by gravity while passing through the rotating filter cloth.
Advantage	• Minimal components and compact, small installation area • No separate odour control facility required • Unmanned operation is possible	• Mixed Thickening of second hand and activated sludge is possible, and operation and maintenance costs are low due to low power • No noise, no vibration • Continued treatment efficiency is guaranteed	• Low power consumption • Low rotation, low vibration, low noise • The number of screws can be adjusted, so there is no need to increase the number.
Disadvantage	• Generation of noise and vibration due to high-speed rotation • Large power consumption • Precisely manufactured, difficult to maintain	• Requires washing water and compressed air • A deodourizing cover is required for odour control. • Large area required compared to centrifugal concentrators	• Low driving record • Large installation area compared to centrifugal concentrators • In case of large capacity, initial investment cost is high
Selection	◉		

4.4.2.6.7 Anaerobic Digestion

Organic solids contained in the sludge generated in the water treatment process are gasified or liquefied by anaerobic bacteria in the digester and decomposed into stable sludge, reducing weight and volume.

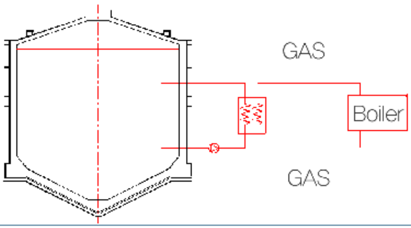
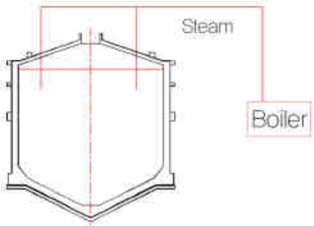
Digester tank agitation methods include recirculation by bio gas, mechanical mixing method, sludge recirculation method by pump, etc., and an appropriate agitation method should be selected in consideration of the characteristics of the digester and site conditions.

Table 4-107 Comparison of Digester Agitation

Category	Mechanical Agitation	Pump Agitation
Shape		
Structure	• Mechanical mixing method and can be mixed using an impeller, and constant mixing can be maintained	• A method of mixing and stirring by moving gas and sludge with a pump to circulate the sludge
Advantage	• Consistent mixing is possible • Low construction cost • Easy to maintain water level in digester to prevent scum from accumulating	• Upper and lower circulation possible through pump • Existing treatment plant can be easily remodelled by installing the digester outside
Disadvantage	• Sludge short circuit occurs • Tank should be emptied during repair • Confidentiality of the driving device should be excellent	• Power cost is relatively unfavourable compared to other methods
Selection	◉	

There are direct heating and indirect heating methods for heating the digester, and the indirect heating method, which is advantageous when using the waste heat of the generator, was applied.

Table 4-108 Comparison of Digester Heating Method

Category	Indirect Heating Method	Direct Heating Method
Shape		
Structure	• Heated and circulated the sludge using a heat exchanger	• Injecting high-temperature steam directly into the digester
Advantage	• No concerns about sludge dilution • High temperature digestion is possible • High thermal efficiency	• Low facility cost • Easy to operate
Disadvantage	• High facility cost • Pump facility added	• Partial overheating may occur • There is a risk of sludge dilution
Selection	◉	

4.4.2.6.7.1 Bio Gas Utilization Plan

The method of using extinguishing gas should be appropriately selected from among various methods in consideration of equipment costs, operating costs, and profitability.

Supplying bio gas to a generator to generate electricity to generate profits and heat the digestion tank using surplus waste heat is considered the most realistic and reasonable solution.

Most of the bio gas is composed of methane and carbon dioxide, and the use of this bio gas largely depends on whether or not carbon dioxide is separated. It is used as power generation or boiler fuel, and when carbon dioxide is separated, it is used as transportation fuel or city gas supply for automobiles and railroads.

Table 4-109 Comparison of Bio Gas Utilization Plan

Category	Power Generation / Hot Water Supply in Parallel	Electricity Generation	Hot Water Supply
Outline	• Method of pre-processing bio gas (50% methane purity) and supplying it to boilers and gas engine generators seasonally to produce electricity or steam and supply it to consumers	• Method of pre-processing bio gas (methane purity 50%) to produce electricity from a gas engine generator and then supplying it to customers	• Method of pre-processing bio gas (methane purity 50%) and using it as boiler fuel • A method of producing hot water in a boiler and supplying it to nearby places
Process	Bio gas Production and storage Pretreatment (Dehumidification, Desulfurization) Biomethane production (Power or hot water)	Bio gas Production and storage Pretreatment (Dehumidification, Desulfurization) Electricity production (Utilization within the treatment plant)	Bio gas Production and storage Pretreatment (Dehumidification, Desulfurization) Steam production from boilers (Hot water supply)
Features	• Energy recovery efficiency is average • Increased installation cost (generator and boiler installation, insulated piping, etc.) • Power generation in summer and boiler operation in winter to supply heat • Easy to respond to the needs of energy consumers	• Reduction of facility installation cost • Generator waste heat can be used as a heat source for digestion tanks and eco-friendly energy town greenhouses • Limited heat source supply in winter • Low energy recovery efficiency • Low generator operating hours per year	• Somewhat high energy recovery rate • Increased installation cost (insulated double insulation pipe installation, etc.) • Energy demand is low (1 location), and hot water consumption is variable, making it economically unfavourable • Increase in plumbing work such as hot water supply piping and condensate recovery piping
Selection	◉		

4.4.2.6.8 Bio Gas Recovery and Storage Facility

Bio gas generated in an anaerobic digestion tank is mainly composed of methane (CH_4) and carbon dioxide (CO_2), and trace gas within 1%. This trace gas is composed of ammonia (NH_3) and hydrogen sulfide (H_2S), and also contains small amounts of other volatile substances. Among them, H2S is a subject to be removed because it acts as a cause of corrosion of gas piping pipes, gas meters, and other used devices.

4.4.2.6.8.1 Moisture Removal Facility

For stable operation of gas pretreatment facilities by dry desulfurization or activated carbon adsorption, it is effective to reduce and supply moisture in gas. In particular, in the high-temperature fermentation method, since the relative humidity in the gas is high, failures due to condensate in equipment or pipes occur, so moisture removal and drain measures are important.

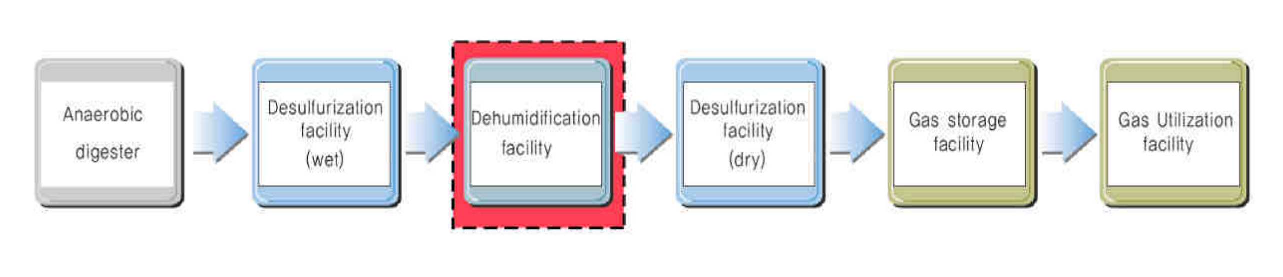


Figure 4-34 Moisture Removal Facility

Table 4-110 Moisture Removal Facility

Category	Cooling Dehumidification	Absorption Method	Compression Cooling
Principle	• Water is removed by cooling the gas temperature by 1~5deg.C through a heat exchange	• Moisture is absorbed and removed by an absorbent such as glycol, etc., and is regenerated by applying heat of about 200℃ or more when regenerating the absorbent	• A facility that removes moisture contained in digested gas by installing it at the end of the wet desulfurization facility during the process of using methane gasification by anaerobic digestion
characteristic	• A large amount of moisture can be treated • In the case of fire extinguishing gas, when used alone, it is suitable for cogeneration process • It cannot be used as an independent process for the upgrade process	• High energy consumption • Few application cases	• Since the temperature rises, the effect is great when combined with cooling • High power consumption Suitable for small-scale plant industry
Selection	◉		

4.4.2.6.8.2 Types of Desulfurization Methods

Methods for removing hydrogen sulfide contained in bio gas can be largely divided into physical, chemical, and biological treatment methods, and in detail, can be divided into dry, wet, and biological treatment methods.

The desulfurization facility is installed to prevent corrosion of facilities such as boilers and generators caused by H2S during the combustion process of CH4 by removing H2S contained in flue gas in order to efficiently utilize CH4 gas generated from the sludge digester.

Table 4-111 Comparison of Desulfurization Method

Category	Dry Desulfurization	Bio Desulfurization	Wet Desulfurization
Shape			
Hydrogen sulfide treatment concentration	• A method of cleaning a gas containing a large amount of hydrogen sulfide with an alkaline chemical and reacting with the chemical to remove the hydrogen sulfide component	• A technology that removes sulfur from hydrogen sulfide in biogas using sulfur oxidizing microorganisms. It consists of a desulfurization reaction tank and other mechanical devices to simultaneously remove hydrogen sulfide and ammonia	• A method of adsorbing / oxidizing hydrogen sulfide (H2S) by passing bio gas through a desulfurization tower filled with a desulfurization agent containing iron oxide (FeO3)
Hydrogen sulfide treatment concentration	• Less than 5ppm	• Less than 150ppm	• Less than 10~30ppm
Advantage	• Excellent H2S removal efficiency • Simple operation method and structure • Low power consumption compared to wet type	• No need to replace or replenish filter media • Driving cost is low	• Excellent H2S removal efficiency • Consistent high efficiency • Inexpensive operation and maintenance costs • Suitable for removing high-concentration H2S
Disadvantage	• In the case of high concentration inflow, the treatment efficiency is drastically lowered • Condensation of the desulfurizer due to moisture (increase in pressure loss) • Periodic replacement and replenishment of desulfurization agent is required • Incurred waste treatment cost of the replaced desulfurization agent	• Keep the oxygen concentration of the inflowing gas above 1.5~2%. • Insulation is required to maintain the temperature of the facility • Add nutrients for microbes • Excessive waste liquid generation	• Concerns about secondary contamination due to wastewater generation • The reacted salt precipitates as a solid and settles out of the reactor • High power consumption compared to dry type • Periodic maintenance required
Selection	◉		

4.4.2.6.8.3 Bio Gas Storage Tank

It is installed to temporarily store the bio gas that has passed through the desulfurization device and supply it to the boiler and gas generator at the sewage treatment plant, and the generated bio gas is scheduled to be stored for half a day.

Table 4-112 Comparison of Bio Gas Storage Facility

Category	Double Membrane Method	Resin Material Balloon Method Inside the Steel Tank
Shape		
Characteristic	• PVC coating on polyester fibers is used as a representative method of dry atmospheric gas storage • Biogas is stored inside the inner membrane, and air is blown into the space between the outer membrane and the inner membrane with a pressurized fan to adjust the pressure of the bio gas in the inner membrane while maintaining the shape of the outer membrane in a hemispherical shape • The outer membrane maintains a shape that is resistant to wind and snowfall, so the bio gas pressure can be maintained almost constant	• As one of the dry atmospheric gas storage methods, it is a type in which plastic balloons such as polyethylene are stored in a steel tank • Blowing air into the space around the built-in balloon and the steel tank using a pressurized fan to adjust the pressure of the fire extinguishing gas of the balloon almost constant • Competitive price compared to Double Membrane
Selection	⦿	

4.4.2.6.8.4 Power generation and heat source supply facilities

Using bio gas, the main component of which is methane gas, as fuel to drive a generator and generate electricity. Generator waste heat is recovered and reused for heating the anaerobic digester. Waste heat from power generation recovered through the heat exchanger is reused for heating the anaerobic digester. A gas turbine method and a gas engine method are carefully reviewed to enable stable operation and are planned with many domestic applications.

Table 4-113 Characteristics of Bio Gas Power Generation

Category	Features
Gas engine type	• Excess heat can be recovered from engine cooling water or exhaust gas • A boiler should be installed to recover heat from the exhaust gas • Generation efficiency 25-35%, total efficiency 55-75% including surplus heat consumption (when using city gas) • The carbon gas in biogas is inert, so it won't cause engine problems • The method of using the remaining heat is "Hot water only" or "Hot water + steam (approx. 8kg/cm2)" • Low NOx operation by three-way catalyst method or lean burn method
Gas turbine type	• Generation efficiency 20-30%, total efficiency including surplus heat consumption 70-80% (when using city gas) • As the exhaust gas temperature is high, the use of surplus heat is “steam (approx. 8~10 kg/cm2)” • Because it is a rotary motion generator, vibration is virtually non-existent • Generating capacity (city gas) is not economical unless it has a large capacity of 1,000 kW or more
Micro gas turbine type	• It is a compact turbine generator with a non-contact air bearing for the bearing of the high-speed rotating body, which makes it easy to manage and extends the life of the bearing • Generation efficiency 15-30%, total efficiency including surplus heat use 60-80% (when using city gas) • Using surplus heat can be either “hot water only” or “hot water + steam (about 7 to 8 kg/cm2)” • Equipment cooling water facilities or lubrication facilities of the prime mover are unnecessary, and maintenance costs are low • Because of lean combustion, low NOx operation is possible and exhaust gas treatment is unnecessary • The turbine itself does not cause problems with hydrogen sulfide or ammonia

Table 4-114 Comparison of Bio Gas Power Generation Equipment

Category	Gas Engine	Gas Turbine	Micro Gas Turbine
Shape			
Generation efficiency	25 ~ 40 %	20 ~ 30 %	15 ~ 30 %
Output range	20 ~ 1,000 kW	500 ~ 100,000 kW	20 ~ 300 kW
Overall thermal efficiency	80 ~ 90 %	75 ~ 80 %	75 ~ 90 %
NOx generation amount	150 or less	100 or less	50 or less
Selection	◉		

4.4.2.6.9 Sludge Dewatering Facility

Dewatering treatment is planned as a final treatment plant to dewater the sludge into a cake.

4.4.2.6.9.1 Equipment type review

Sludge dewatering equipment is a facility for further reducing the amount of digested sludge and facilitating final treatment, and representative models were compared and reviewed in consideration of their advantages.

Table 4-115 Comparison of Dewatering Facility

Category	Dewatering Facility (Centrifuge type)	Dewatering Facility (Filter press type)	Dewatering Facility (Belt type)
Shape			
Structure	• As the internal rotary cylinder of the main body rotates, the sludge is thickened and dewatered, and solid-liquid separated by centrifugal force with a gravitational acceleration of 2,000G or more.	• Bubble-type dewatering method, which uses an inlet pump through the hole in the middle of two Dewatering plates to introduce sludge into each Dewatering chamber and then pressurizes it to extrude and return water.	• Add a polymer coagulant to the sludge to coagulate it, then supply the coagulated sludge between the filter cloths and dewater it with the compressive force of the roller.
Moisture content	• 80% or less	• 55-65%	• 80% or less
Coagulant injection rate	• Polymer coagulant, about 1%, (per1kgDS)	• Ca (OH)2 25 to 40% • FeCl3 7-12%	• Polymer coagulant, 0.5~0.8% (per1kgDS)
Advantage	• Less components, less noise, and compact. • Completely unmanned and automated operation possible in conjunction with sludge and chemical supply facilities	• The moisture content of the cake is low • Excellent durability • High chemical stability • Low resistance coefficient • Concentration of desorbed liquid is low • Less required	• Easy handling in case of failure
Disadvantage	• Concerns about vibration and wear due to high-speed rotation • Increased maintenance cost due to high electricity bill	• Low domestic driving record • High initial investment cost • High power cost • Frequent clogging by coagulants	• Large space required for installation • A large amount of filter cloth washing water is required. • Spray phenomenon and large amount of odour due to washing the filter cloth
Selection	◉		

4.4.2.6.10 Odour Control Facility

Odour control facility is planned as a process to remove hydrocarbon decomposition intermediates such as hydrogen sulfide (H_2S), ammonia, inorganic compounds, aldehydes, ketone oil, and other organic compounds generated in the treatment facility.

Odours of Sewage treatment plant include sediment and inflow pump facilities, and sludge treatment facilities. The outline is as follows, and the device differs somewhat depending on the closed state and the presence or absence of a cover.

The intensity of odour generation varies somewhat depending on the operating conditions and site, but the highest concentration of odour occurs in sludge treatment facilities, manure and septic tank treatment facilities.

Moderate odour emissions are expected from the pre-treatment plant.

Table 4-116 Odour source

Category	Pretreatment Facility	Water Treatment Facility	Sludge Treatment Facility
Odour source	• Grit Chamber • Grit Remover Equipment • Inlet Pumping Station • Hopper, etc.	• Various inflow and outflow channels • Primary sedimentation tank • Aeration Tank (if necessary)	• Faecal Sludge Treatment Facility • Sludge Retention Tank • Sludge Thickening Facility • Sludge Dewatering Facility

4.4.2.6.10.1 Odour control method

Odour control equipment should have a clear odour control effect, and be selected so that equipment and maintenance costs are low and secondary pollution does not occur.

Deodourizing air volume should be planned to minimize the spread of odourous gases by using a ventilation system and a separate system.

Table 4-117 Odour control method

Category	Chemical Cleaning Method	Biofilter Method	Activated Carbon Adsorption Method
Shape			
Structure	• Absorbs odour gas into chemical solution to chemically neutralize it, and removes odour gas by dissolving it in chemical solution.	• The captured odour is used as a source of carbon and energy for microorganisms and is decomposed into water and carbon dioxide.	• Adsorbs, decomposes, and removes odourous substances through physical adsorption and chemical reactions of activated carbon.
Odour removal target	• Acids: Alkaline gases such as ammonia and amines • Alkali cleaning: hydrogen sulfide, mercaptan, acid gas, etc. • Odour is not reduced by chemical reaction	• Applicable to treatment of almost all odours and volatile organic compounds • Effective for various odours from low concentration to high concentration, and excellent efficiency in removing complex	• According to the combination of adsorbents, odour can be selectively applied (deposition + neutral activated carbon)

Category	Chemical Cleaning Method	Biofilter Method	Activated Carbon Adsorption Method
		odours	
Advantage & Dis-advantage	• Can remove dust and dirt at the same time. • Effective for odours of specific ingredients, but not suitable for complex odour removal. • Need to treat discharged water after washing (secondary pollutants occur) • Relatively many auxiliary • facilities such as drug dilution storage tank	• Simple equipment, easy • maintenance • No secondary pollutants • Cheap equipment and maintenance costs • Uncontrollable operation is impossible because it is difficult to cultivate microorganisms. • Relatively high initial facility investment	• Effective for low-concentration odours • No water or chemicals are • used, so there is no need for • a separate drainage facility. • Relatively low initial investment • High maintenance cost due to long-term replacement of activated carbon • Depending on the absorbent properties of activated carbon, it is vulnerable to high humidity environments
Selection	◉		

4.4.2.6.11 Faecal Sludge Treatment Facility

4.4.2.6.11.1 Pre-treatment facility

The faecal sludge brought into the impurities treatment system removes coarse impurities from the rotary screen (6mm), sediment from the centrifugal separator, and fine impurities from the fine seed screen (2.5mm or less) to reduce the load of the subsequent process, prevent pipe blockage, and wear of facilities.

The removed impurities and sediment were planned to be transported to the hopper by a transfer conveyor, temporarily stored, and then taken out of the premises. In order to prevent the diffusion of high-concentration odours in the processing unit and storage tank, a closed room was installed to collect and deodourize. It was planned to install a diffuser in the storage tank to prevent sedimentation.

Table 4-118 Faecal pretreatment facility

Category	Comprehensive concomitant disposal machine	
Shape		• Filtration of medium and large concomitant • Filtration of micro concomitant • Filtration of sand • Auxiliary equipment such as hopper • Remove with rotary screen • Remove with fine seed screen • Separation by centrifugal separator, dewatering

4.4.2.6.11.2 Thickening facility

The thickening facility consists of a centrifugal thickening, polymer melting device, sludge and polymer supply pump, and other auxiliary facilities. Two thickener, solids recovery rate of 90% or more, and sludge concentration of 3-5% were planned. In addition, an automated system for unmanned operation was established so that the thickener and the sludge supply pump could operate 1:1.

The sludge and chemical supply pump were applied as a variable propulsion cavity type metering pump that can adjust the supply amount according to the load variation of the thickener. In case of emergency, a reserve pump is used to operate the thickener, and a flowmeter is installed in the discharge pipe of the sludge and chemical supply pump to accurately measure and input the amount of sludge and chemicals to facilitate sludge thickening. The thickened sludge is transported to the mixed sludge storage tank by a transfer pump.

Table 4-119 Faecal Sludge thickening facility

Category	Centrifugal thickener	Transfer Pump
Shape		
Characteristic	• It has few components and is compact, so the installation area is small • No separate odour control facility is required • Unmanned operation possible • Noise and vibration due to high-speed rotation • Power consumption is high	• Easy to control the discharge amount • Vibration is very low • Easy operation • Suitable for small capacity • High-viscosity solutions can be transported • Forward/reverse rotation can be repeated

4.4.3 Electrical Works

This plan aims that the treatment facilities could be operated stably and economically by an efficient installation and operation plan on electrical works such as power substations, electric supply system, instrumentation, IT (Information Technology) and firefighting facility, etc. Electrical and control work plan should consider the local conditions after the completion of the project. Major consideration for electrical and control work is as shown below table.

Table 4-120 Basic direction of Electrical and Instrumentation Control Facilities

Category	Description
Automation	• Introducing limited automation to ease the maintenance While it is operating the facility. • Improving the efficiency of the facility operation by introducing the minimum field measurement facilities required for the operation. • It plans to improve the level of automation facilities, depending on future facility upgrades.
Reliability	• Choosing an equipment reliable and easy to operate • Selecting equipment safe from surrounding environments such as chemicals, caustic gases, dust and salt stress, etc. • Considering appropriate explosion proof equipment located at places where fire or explosion is likely to occur.
Stability	• Planning the treatment process which is easy to be operated and repaired and is not worried about mal-operation. • Protecting a shutdown of treatment process by preparing a standby equipment on major system. • Prevention of fire and electric shock, etc.
Extensibility	• Select PLC system compatible for interface considering future integrated managements. • Configure the system with ease software and hardware extension during enlargements or change of treatment process. • Facility has functions to respond to informatization, etc. • The international standard IEEE 802.3 Ethernet with ease interface is applied for the communication protocol.
Economic Efficiency	• Designing to minimize the operation expense by automated facilities. • Energy saving by choosing equipment which is efficient and good for energy efficiency. • Planning an economical system and reducing the personnel expenses.
Durability	• Choosing durable equipment. • Selecting simple structural equipment which is prone not to be broken down. • Choosing waterproof and dustproof equipment in case of outdoor installation.
Maintenance	• Planning to minimize instruction frequency. • Selecting compatible equipment. • Rational placement of equipment and securing an enough space.

4.4.3.1 Site Survey of Power Receiving System and Considerations

An on-site investigation was coordinated to check factors required in designing electrical and measure /control units. Based on survey results, a power supply plan within the substation bus was considered in this project.

Power supply of Bangladesh Fatehabad is supplied by connecting to the National Power Grid. National Power Grid Company is being operated by Power Corporation, PDB. As in Korea, small power demand is connected in a neighborhood distribution lines, large-scale demand for electricity has been supplied from the adjacent substation.

3Φ 33kV Substation	3Φ 33kV Switchgear
	

Figure 4-35 Status of the 33Kv substation

The sewage treatment plant consumes a large amount of power, and it was agreed that the power supply of the sewage treatment plant at the Fatehabad would be available on the 33kV primary line, as a result of a visit to PDB Substation, the Bangladesh Electric Power Corporation. Power supply in this review from the substation to the sewage treatment plant was commissioned in the PDB. Breakers and transformers in the sewage treatment plant are included in the electrical construction. In particular, the power supply at the Fatehabad sewage treatment plant, which requires the most power during this project, will be supplied from a substation about 1km (power inflow distance) away from the task site.

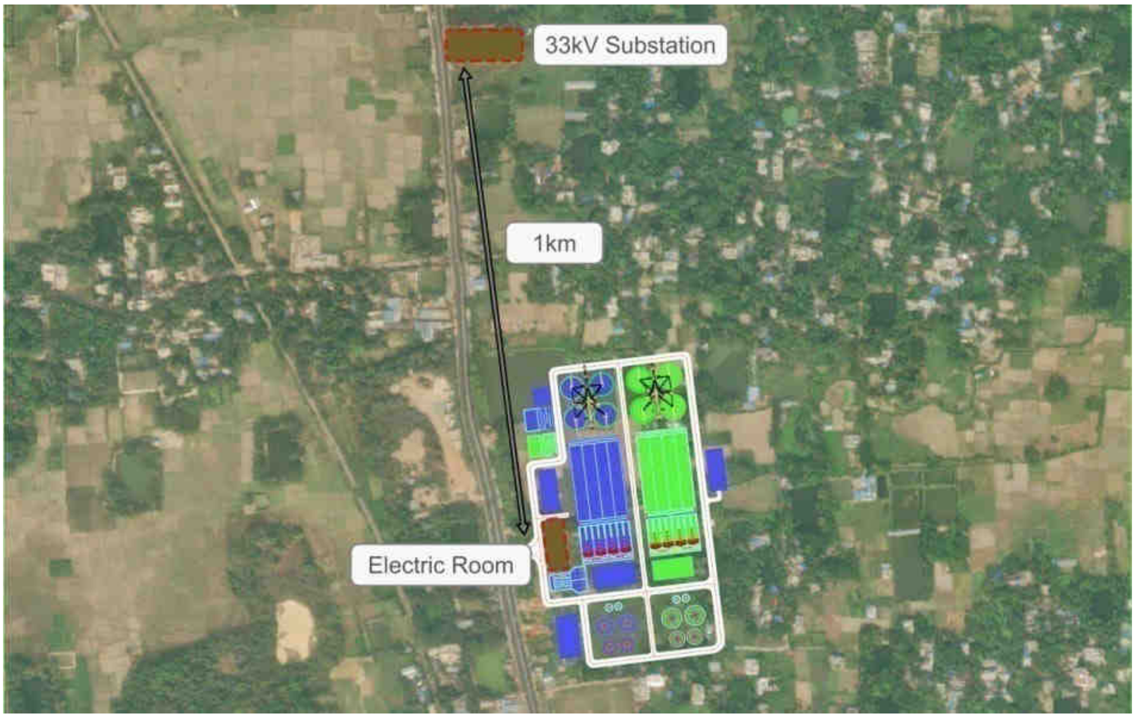


Figure 4-36 33Kv Substation Location

BPDB Work Scope will be as bewlo.

- Design, licensing and construction cost about electric power supply: 1 LOT
- Detailed work scope and costs will be negotiated during detailed design

4.4.3.2 Standard and Regulations

Standard and regulations to be applied in the process of designing and installation of electrical and measure/control devices are as shown below

- IEC: International Electro-technical Commission
- ANSI: American National Standards Institute
- IEEE: Institute of Electrical & Electronics Engineers
- ISA: Instrument Society of America
- ISO: International Organization for Standardization
- NEC: National Electrical Code
- NEMA: National Electrical Manufactures Association
- NFPA: National Fire Protection Association

4.4.3.3 Electrical Equipment

Selection of an electricity intake method suitable to a service voltage and its supply method in Bangladesh.

4.4.3.3.1 Facility Capacity

Table 4-121 Planning of Electrical Facilities

Category	STP1(Fatehabad)
Facility Capacity	Phase 1 (Q=60,000m^3/day), Phase 2 (Q=90,000m^3/day), Phase 3 (Q=120,000m^3/day)
Power Connection	3Phase 33kV 50Hz 1Line + Generator
Voltage	3Phase 33kV 50Hz
Capacity	About 8,000kVA
Transformer Capacity	33kV/6600V 5,000kVA (Normal 1EA) 33kV/400-230V 1,500kVA (Normal 2EA)

Table 4-122 Expected Power Demand

Category	Capacity [kVA]
Pre-Treatment / Inlet Pumping Station Facility	689.52[kVA]
Biological Reactor Facility	246.9[kVA]
Secondary Sedimentation Tank Facility	108.87[kVA]
Disinfection Facility	27.64[kVA]
Blower Building Facility	2,253.86[kVA]
Faecal Sludge Treatment / Sludge Thickening Facility	504.03[kVA]
Dewatering Facility	134.38[kVA]
Odour Control Unit Facility	198.45[kVA]
Other Facility	65.65[kVA]
Total	4,229.3[kVA]

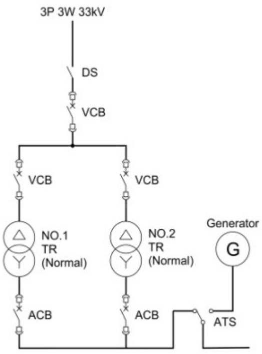
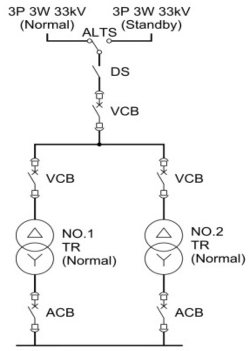
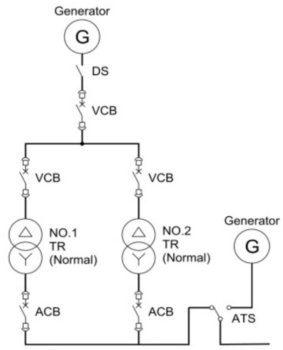
Table 4-123 Transformer Capacity

Category	STP (60,000m³/day)			
	Power Demand (kVA)	Voltage Drop (kVA)	Selection (kVA)	Voltage Drop (%)
Transformer Capacity 33kV/6600V	2,245.62[kVA]	4,222.15[kVA]	5,000[kVA]	10[%]
Transformer Capacity 33Kv/400-230V	1,081.17[kVA]	469.62[kVA]	1,500[kVA	10[%]
Transformer Capacity 33Kv/400-230V	902.51[kVA]	644.38[kVA]	1,500[kVA	10[%]

4.4.3.3.2 Power Connection System and Facility

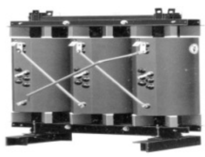
The power supply will be connected one (1) line to national grid and additional one (1) line will be connected in emergency generator to ensure stable power supply. The power of high quality shall be ensured to prevent lowered treatment efficiency from long power-off and to improve reliability as a public facility.

Table 4-124 Review of Power Connection

Category	1 Line Income + Emergency generator	2 Line Income	2 Emergency generator
Configuration			
Advantages	• Able to prepare for planned power-off by power company. • Reduction of high voltage equipment.	• Uninterrupted power incoming is possible for route and substation accidents. • Equipment is simple and maintenance is easy.	• Stable power supply regardless of incoming power condition. • Transformer not needed.
Disadvantage	• Limited load operation. • Generator room separate.	• Increased high voltage equipment (ALTS, etc) • High costs of initial route construction.	• Highest initial and operation cost. • Requirement of skilled Maintenance staff.
Selection	◉		
Reason for Selection	• Choosing a system composed of 1 line connection and emergency power generator because 2 lines connection is impossible and power outage would occur frequently.		

Among mold and oil transformer, mold transformer is selected based on the comparison results summarized in Table. As described in the table, mold transformer is safe against explosion and allow small amount of electrical loss.

Table 4-125 Review of Transformer Type

Category	Mold Transformer	Oil Type Transformer
External form		
Inflammability /Explosiveness	• Flame-retardant, self-extinguishing, • Non explosive	• Inflammable and has the risk of explosion
Noise Degree	• Medium	• Low
Power Loss	• Low	• Medium
Advantages	• Excellent moisture resistance and stain resistance • Installation area so small	• Makes little noise • Price is inexpensive
Disadvantages	• The price is high	• Installation area is large and is heavy
Selection	◉	◉
Reason for Selection	• The mold transformer was chosen because it is more efficient, quiet and easy to operate and maintain. • The oil transformer was chosen because it is easy cooling effect and suitable for large capacity.	

Digital distribution panel is selected according to the comparison results summarized in following table. Digital distribution panel is more accurate than conventional induction distribution panel because of digital protection relay. The installation of the selected distribution panel should be implemented in a way to minimize external influences such as vibration and physical impact

Table 4-126 Review of Distribution Board Type

Category	Digital Distribution Panel	Conventional Induction Type Distribution Panel
External form		
Outline	• Centralized indication in front of distribution panel by unification of various measuring instrument, etc as digital method	• Scattered arrangement of various measuring instruments, operation switches and induction type relays, etc at the front of distribution board
Advantage	• Has excellent reliability using digital method • Simplicity of operation and maintenance changing CT/PT ration	• Familiar to existing users because there are many examples of its usage • Low equipment cost
Disadvantages	• The price is little high	• Low accuracy of measurements • Wiring is complicated and maintenance is inconvenient
Selection	◉	
Reason for Selection	• The digital distribution panel was selected since it is strong on vibration and shock.	

Vacuum circuit breaker is selected based on the comparison results summarized in Table VCB are relatively more stable and easier to repair in case of failure than other types of circuit breakers.

Table 4-127 Review of High Voltage Circuit Breaker

Category	Vacuum Circuit Breaker (VCB)	Oil Circuit Breaker (OCB)
Principle of interruption	• Interruption from the expansion of electrons by intercepting the arc within sealed vacuum container	• At the under-oil interruption room, the oil gets decomposed with high temperature to create hydrogen and gas of good heat conduction, then cools and interrupts the arc
Rated Voltage	• 3.6kV~84kV	• 3.6kV~300kV
Breaking Current	• 8kA~40kA	• 8kA~50kA
Breaking Time	• 3Hz	• 5~8Hz
Breaking Ability	• Excellent	• The arc time is long at the low current band
Interruption Characteristics	• Completely non triggering • Has risk of excessive voltage • Arc time is the shortest	• Completely non triggering • No risk of excessive voltage • Arc time is little long
Maintenance/ Inspection	• Simple	• Treatment of oil is inconvenient
Selection	◉	
Reason for Selection	• The VCB was chosen because not only it is durable and easy to maintain but also it has been applied in many cases.	

Circuit breakers selected for this project are compared in Table. Different types of circuit breaker will be applied for different purposes depending on the magnitude of current. The criteria are set as 600A.

Table 4-128 Review of Low Voltage Circuit Breaker Models

Category	Air Circuit Breaker (ACB)	Mold Case Circuit Breaker (MCCB)
Frame Current	• 3Phases, 4Phases, 600AF~5,000AF	• 2Phases, 3Phases, 4Phases, • 30AF~1,200AF
Protection Functions	• Over current, shouts circuit faults, ground faults	• Over current, shout circuit faults
Applied Load	• Suitable for large current	• Suitable for low current
Installation Area	• Large	• Small
Economic Efficiency	• 400%	• 100%
Maintenance/ Inspection	• Partial replacement of components during breakdown	• Complete replacement during • breakdown
Selection	◉	◉
Reason for Selection	• The ACB was chosen since it is durable and suitable to the short circuit protection and a case of more than 600A • The MCCB was selected because it is easy to operate and suitable to a circuit less than 600A.	

Table 4-129 Review of Emergency Generator

Category	Diesel Engine	Gas Engine
External form		
Fuel	• Diesel, Heavy oil	• LNG, LPG, Bio gas etc.
Power Generation range	• About 20 – 15,000 KW	• About 20 – 3,000 KW
Maintenance Costs	• Middle • (Part supply and Easy to Repair)	• Low • (Part supply and Easy to Repair)
Start-up Time	• Within 10seconds	• Within 15seconds
Fuel ratio	• 345L/hr	• 515m3/hr
Cost	• Low	• Middle
Characteristic	• Initial investment cost is low • Suitable to a sewage treatment plant which has a short operation time. • It has been applied in many cases domestically.	• Stable supply of LNG • No need to install a fuel storage facility • No problem on air pollution • It could be used for the cogeneration and peak-cut in department stores, hospitals and various other buildings for self-supply of electricity
Selection	◉	
Reason for Selection	• The diesel engine was selected because it has been applied in many cases and it is easy to supply a fuel and it is economical on its initial investment.	

4.4.3.3.3 Stand by Power Supply System

The stand-by direct current (DC) power supply system is to be installed to supply power to high and low voltage distribution panels in case of emergency. The type of rectifier to be used at the plant is 3-Phase full wave rectifier. The output voltage and current need to be monitored and controlled at the central control room. The capacity of sealed lead-acid battery is determined to meet the criteria for supplying power for minimum 30 minutes.

4.4.3.3.4 Power Monitoring and Control System

It is planned to manage the power effectively with remote monitoring and control of power system and to improve reliability with alarm printer output and data management during trouble of power system.

Table 4-130 Overview of Power Monitoring and Control

Category	Description
Purpose	• Establishment of effective power monitoring and control system • Reduction of manpower by the operation of power Installation's remote monitoring and control • Efficient operation of substation facilities through constant monitoring of load power
Monitoring Function	• Status indication of equipment (Run, Stop) • Indication of equipment's faults and break down • Measurements • (Voltage, current, power, power factor, frequency and watt-hour, etc)
Control Function	• Operation of equipment: run, stop
Protection Function	• Over current, shout circuit faults, ground fault, low voltage

It is planned to install the condenser separately at the starting circuit of motor (90% the improved power factor) and install transformer no-load compensation condenser.

4.4.3.3.5 Power Control Unit

The rated voltage of motor is selected by considering the purpose of usage and loading characteristics to minimize voltage drop in the route and guarantee smooth starting of the motor. It is also selected by considering simplicity of producing the instrument, maintenance, stability and economic efficiency.

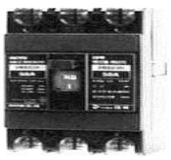
Table 4-131 Rated Voltage of Motor

Motor Capacity	Selection	Remark
Below 0.4kW	AC Single Phase 230V	-
Below 0.4kW ~ 150kW	AC three Phase 400V	-
Above 150kW	AC three Phase 400V or high voltage	-

Table 4-132 Starting Method Selection

Starting Methods	Motor Classification	Remark
Full Voltage (Line Starting)	Low voltage motors below 15kW	-
Y-Δ	Low voltage motors below 15kW~150kW	-
Soft Starting (VVCF)	Motors with frequent startup among low voltage motors of 15kW~150kW	-
Inverter (VVVF)	Equipment that needs change of speed according to the process	-
Reactor	High voltage motors above 150kW	-

Table 4-133 Main Materials Specification of MCC

Appearances	Type	Item	Description
	Metal Clad Circuit Breaker (MCCB)	Rated Voltage	AC 400V
		NO. of Poles	3 or 4
		Trip Method	Thermal trip
	Protective Relay	Type	Digital electronic type (Integrated type of control section and indication section)
		Protection Function	Over current, open-Phase, negative-Phase, ground fault and unbalance protection, etc.
		Communication Method	RS-484(Modbus)
		Control Method	ON/OFF
	Inverter	Rated Input	3Phase 400V 50Hz
		Control Method	Variable voltage variable frequency (VVVF)
		Control Power Supply	AC 230V

4.4.3.3.5.1 Local Operating Panel (LOP)

A local operating panel (LOP) is installed near the instrument to monitor and operate the instrument on-site. LED lamps indicating the status of the instrument such as on, off, and fault, on/off switch will be located on the front. The LOPs, which are to be installed outdoor, are to be encapsulated within a box as shown in the figure in Table.

Table 4-134 Main Materials Specification of Local Operating Panel (LOP)

Appearance	Item	Description
	Type	2 Door, pipe support type, wall mounted
	External Case Material	Stainless (STS 304)
	Switch	Operation method selection switch (local/remote), on/off switch (start/stop)
	Indication LED lamp	Start, stop, fault

4.4.3.3.6 Indoor Electric Facilities

4.4.3.3.6.1 Lighting and Receptacle Facilities

It is used energy saving materials in lamps, stabilizers and lamp instruments applied to STP and planned energy saving by using lamp instruments and control method.

Table 4-135 Lighting and Receptacle Facilities

Category	Item	Description
Lamp	LED lamp	LED lamp
Lighting	Reflector	High illumination reflector
Lamp Control Method	Circuit Structure	Forms separate circuit for lighting equipment near window (Lights can turn off in daylight)
	Outdoor Lighting	Automatic on/off control by automatic switch of streetlight

- Panel board: Select entire panel as STS in case of exposed type and select front section as STS for the sealed type
- Main Circuit Breaker: Use metal clad circuit breaker (MCCB)
- Feeder Circuit Breaker: Ensure reserve breaker of 20 % or greater using earth leakage breaker (ELB).

4.4.3.3.6.2 Firefighting Facility

The automatic fire detection facilities are planned by applying international NEPA CODE standards.

Table 4-136 Information and Communication Facilities

Category	Main Points of the Design	Main Reflected Contents of the Design
Telephone Facility	• Built integrated wiring system to prepare for information age of future	• Integrated wiring system configuration for future high-speed information and communication services (Telephone, FAX, PC communication), etc.
Broadcasting Facility	• Installed P.A System within building	• Composed of exclusive broadcasting in which delivery of notifications, background music (BGM) for break time and transmission of emergency broadcasting is possible • Formed linked circuit with fire reception panel so that the emergency broadcasting can have priority in transmission during fire
TV Public Viewing Facility	• Installed antenna to receive regular programs	• Installed antenna for TV reception and antenna for satellite broadcast reception at the roof of management section

4.4.3.3.6.3 Lightening Protection System

The lightening protection method is planned by selecting appropriate lightening protection method for IEC 62305 regulations and the lightening protection method comparison table is as follows.

Table 4-137 Lightening Protection System

Category	Lightning Rod Method	Ion Discharge Method
Principle for protection	• Faraday principle	• Discharge principle of receding streamer
Characteristic	• Small sized equipment, simple installation • Continuous maintenance is necessary because it hits on lightning	• Large sized equipment. • Installation and repair are inconvenient • Reduction of lightening protection from the expansion of protection range
Selection	◉	

Category	Lightning Rod Method	Ion Discharge Method
Reason for Selection	• The lightning rod method was selected because its initial investment is cheap and its installation and maintenance is easy.	

It is planned that the reliability of grounding system is improved (maintaining total grounding resistance of 5Ω) by applying common grounding and structure grounding systems.

It is planned the method that secures stability, having excellent construction and economic efficiency as well as being appropriate for IEC regulation based on equipotent structure. The grounding method comparison is as follows.

Table 4-138 Grounding System

Category	Common Grounding	Individual Grounding
Grounding Method	• The method of commonly connecting various subjects to one system	• The method of individual grounding for various grounding subjects
Characteristics	• Prevents creating polar difference between each equipment • Discharges abnormal current of equipotent structure to the earth at the same time • Equipment is damaged when exceeds system limitation	• Creates potential difference during inflow of abnormal current • Needs adequate spacing and complete insulation • Not restricted to grounding site
Additional Applications	• Install the earth resistance low considering equipment characteristics, etc • Parallel grounding of structure • Install potential difference settlement device for equipotent structure	• Inappropriate for IEC (common grounding) regulation •
Selection	◉	
Reason for Selection	• The common grounding was chosen because it is suitable to recent standards and it is good for safety and stability.	

4.4.4 Instrumentation Works

4.4.4.1 Monitoring and Control Facility

The monitoring and control method should apply the central monitoring and decentralized control method for effective monitoring at the central control room. The PLC system with excellent compatibility and maintenance efficiency should be selected for the monitoring and control facility and fiber optic cable should be applied to secure data processing speed and reliability of data in case of the data transmission facility.

- Monitoring and Control Facility: 1Lot
- CCTV Facility: 1Lot
- Instrument Facility: 1Lot

4.4.4.2 Monitoring and Control Facility Configuration of Monitoring and Control Facility

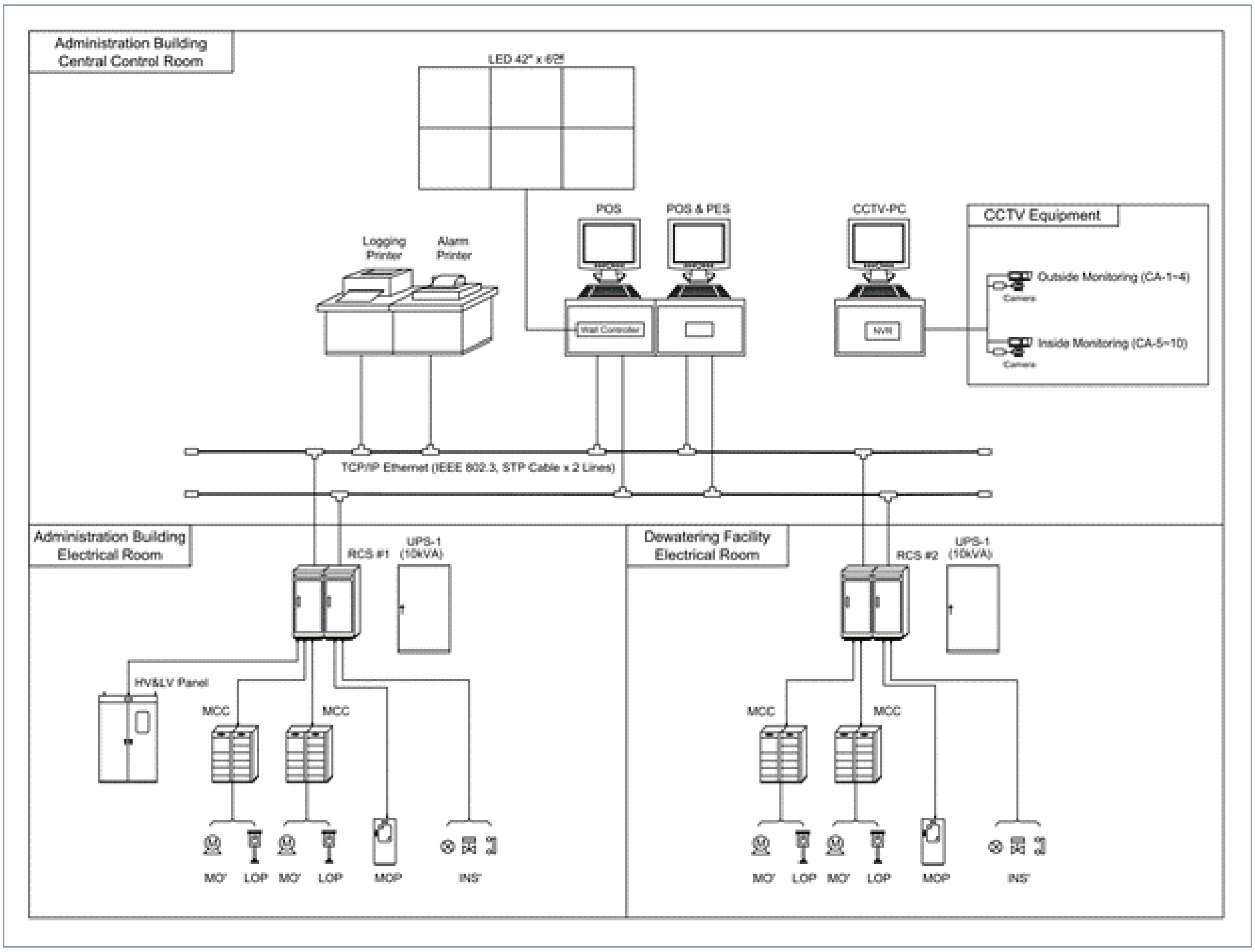


Figure 4-37 Configuration of Monitoring and Control Facility

4.4.4.3 Arrangement of Central Control Room

The LFD is installed by considering operation conditions for the selection of central monitoring panel and the parabolic louver lighting lamp is selected for prevention of blinding the operator's vision for the selection of lighting equipment. Also, the UPS is installed separately to each equipment section to secure reliability through abnormal operation.

Table 4-139 Functions of Each Monitoring and Control Facility

Category	Items	Description
	Operator	• Securing centralized monitoring, decentralized control and simplicity of controls • Automatic and manual operation of facility • Structured to make restarts easy during recovery from emergency situations • Prompt handling at abnormal state of process and facility
	Data Gathering	• Automatic storage of operation data and promptness of data search • Reasonable data interpretation and analysis • Records facility failure time and run time
Monitoring and Control (POS & PES)	Maintenance	• Established duplication of main facility and backup system • Maximization of device compatibility through installation of PLC system • Screen editing, program editing and Report editing, etc.
	Alarm Printer	• Records failure message of the device that has created the event • Records contents of event and occurred time
	Logging Printer	• Records daily, weekly, monthly and yearly reports • Records instant value, average value, max value, min value, addition value, calculation value and others
Data Printing Devices	Color Hard Copier	• Prints plant screen and trend screen, etc.

Table 4-140 Monitoring and Control Facility Functions

Category	Items	Description
Operation And Monitoring Functions	Process Status Monitoring	• Group, Trend, Overview, Graphic Display • Monitors operation status of process and equipment • Monitors status of receiving substation and distribution system and System Network
	Alarm/Event Monitor Logging	• Process alarm and monitoring of equipment failure • Event and operation manipulation monitoring • Process data, analogue measurements and highest or lowest value monitoring
Control Functions	Loop Control	• PID, Feed Back Control • Ratio Control, Cascade Control, Program Control
	Sequence Control	• Arithmetic Logic Control, Time Chart Control, Interface Control
Data Record And Preservation Function	Data Preservation and search	• Historical Data collection, Trend, store and search function • Historical Database store function
	Logging & Report	• Prints daily, monthly and yearly reports • Prints operation history of facility • Prints alarm record and operation data
Operation Management Function	System Failure Diagnosis	• Indicates system device operation status and failure alert
	Emergency alarm function	• The function of notifying operator automatically through SMS during abnormalities of systems with high importance

The system compatibility and future integrated management system have been considered and it has been planned by selecting the PLC system with excellent maintenance efficiency.

Table 4-141 Review of Monitoring and Control Facility

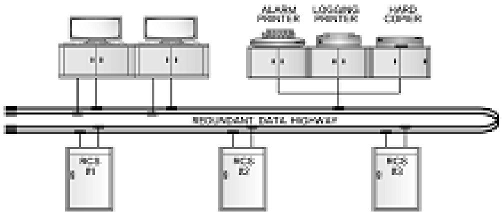
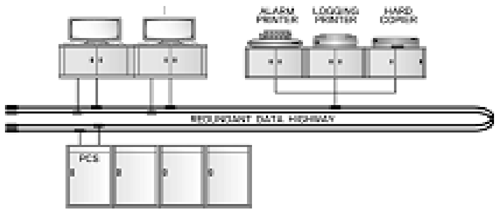
Category	PC+PLC	DCS
Structure Outline	• System is developed for factory automation • Manipulation is performed with MMI software • Input and output are performed with PLC hardware	• System is developed for process controls • Manipulation and I/O are configured with DCS exclusive software and hardware
Duplication	• Stable implementation of CPU, power and communication is possible	• Stable implementation of CPU, power and communication is possible
Extensibility	• Easy extension with open type structure	• System extension is complicated with closed structure
Control Function	• Interlock control function is very excellent • Successive control function is weak but settled with PID module	• Interlock function is excellent • Loop control and calculation control functions are excellent
Maintenance	• Prompt maintenance is possible	• Delayed delivery time of main parts
Credibility	• Interlock control function is excellent	• Process control function is excellent
Selection	◉	
Reason for Selection	• The PC & PLC system was selected since it is good for operation and maintenance as an open system.	

Select and plan windows operating system with interface familiar to user, open and of easy maintenance. The operating system comparison table is as follows.

Table 4-142 Review of Operator System

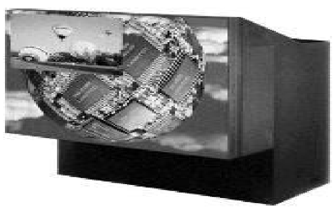
Category	Windows	Unix
System Integration	• High (Uses common hardware, has wide range of selections)	• Low (Operates only in certain hardware for each vendor)
Program Management	• Good (The program which is same as the one for tasks can be used)	• Bad (Almost impossible to use common programs)
Convenience	• Because the interface is same for general offices, even beginners can handle easily	• Because user interface is different from the one for general offices, it is difficult to use and need high technological ability
Characteristics	• Very economical compared to Unix hardware • Continuous upgrade with low cost is possible because the hardware development speed is very quick	• H/W platform is expensive, but performance is very high • Hardware upgrade is limited to specific vendors and hardware development speed is very slow
Selection	◉	
Reason for Selection	• The windows operation system was selected because its operation and installation are easy and good for expandability.	

Table 4-143 Review of Monitoring and Control Method

Category	Central Monitoring, Decentralized Control Method	Central Monitoring, Centralized Control Method
Composition Drawing		
Outline	• Monitors information of each facility by centralizing them at one center and place control devices by scattering them near the facility	• Monitors information of each facility by centralizing them at one center and centralized placement of control device to 1 center
Controllability	• Performs monitoring & control function of each process by installing local control facility by processes	• Performs monitoring & control function of all facility at the main control facility at the integrated management room
Extensibility	• Partial facility increase is easy	• The overall facility being shut down is unavoidable during extensions
Construction Efficiency	• Easy construction with centralized placement of control cable	• Complicated construction with centralization of control cable to 1 center
Selection	◉	•
Reason for Selection	• The central monitoring and decentralized control methods were selected, with consideration for minimization of the operators, operation convenience and expandability of facilities.	

It is planned it by selecting the LFD method with comparatively low demand power, excellence in the maintenance aspect and no vibrations.

Table 4-144 Review of Central Monitoring Panel Type

Category	Large Format Display	DLP Projector	Beam Projector
Appearance			
Image Expression Method	• Displaying an image by a light incident on pixels after gathering the light penetrating liquid crystal	• Reflection ray control method by Digital Micro-mirror Device (DMD)	• Displaying an image on a flat light by a structural arrangement of liquid crystal element penetrating a liquid panel.
Application Environment	• Able to control for 24 hours a day	• Able to control for 24 hours a day	• Able to control for less than 8 hours a day only
Advantage	• Its initial investment cost is relatively cheap.	• Most stable in case of continuous operation	• Its initial investment cost is cheap.
Disadvantage	• When it breaks down its whole panel should be replaced.	• Its initial investment and O&M cost are high.	• Its stability would be decreased in case of using it continuously.
Selection	◉		
Reason for Selection	• The LFD was selected since its initial investment cost is low and it is able to control and operate stably for 24 hours a day.		

It is planned to maximize the readability with image monitoring using high resolution and low illumination camera while selecting lamp attachment type for cameras installed outdoors for effective monitoring at nighttime. Also, the monitoring vulnerable areas are minimized by installation of remote-controlled rotation type cameras and planned to be protected from thunder by installing thunder arrester at the power and signal line of outdoor cameras.

Table 4-145 CCTV Facility

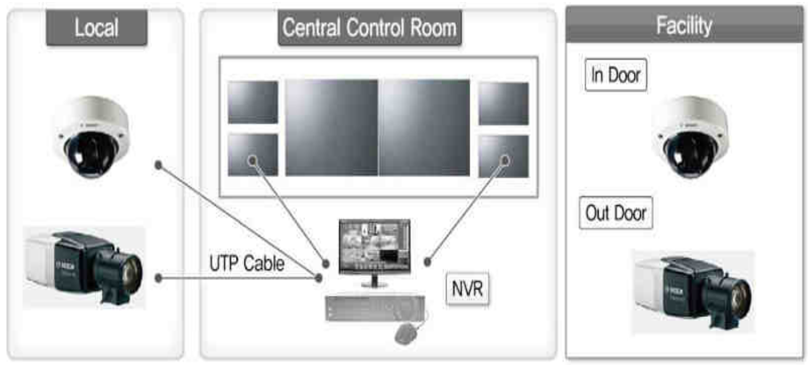
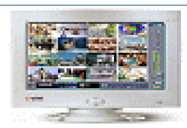
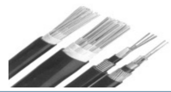
CCTV Configuration	Main Facility
	
	Network Video Recorder
	
	LED floodlight

Table 4-146 Specifications of CCTV Components

Category	Materials Specification	Qty.	Appearances	
Camera	• Minimum illumination: Above 0.002Lux • Outdoor: LED Floodlight • Camera Pole or Bracket	10Set		
Network Video Recorder	• CPU: Above I5 3.0GHz • Memory: Above 4.0GB • Hard Disk: Above 1TB • Channel: Above 16CH	1Set		
Monitor	• Type: Above Color LED 23Inch • Resolution: Above 1,280 x 1,024	1Set		
Data way	• Optical cable: Single Mode, Outdoor • UTP cable: Above Cat. 5e, 4Cores	1Lot		

4.4.4.4 Measuring Instruments

Table 4-147 Selection Contents of Measuring Instruments

Category	Selection Criteria	Applied Measuring Instrument
Durability	• Selecting waterproof and dust proof structure • Selecting material of STS 304 or better for brackets	• All Instruments
Corrosion Resistance	• Selecting material of STS 316 or better for water contacting section	• Electrode, Diaphragm
Maintenance	• Selecting auto cleanser attached type for water quality meter	• Water quality meter
Lightening Protection	• Installation of the SPD to protect instruments from lighting damage	• All Instruments

Table 4-148 List of Measuring Instruments

Category	Item	Type	Qy.	Remark
Pre-Treatment / Inlet Pumping Station Facility	Grit Chamber Inflow Level meter	Ultrasonic Type	2	
	Grit Chamber Outflow Level meter	Ultrasonic Type	2	
	Primary Sedimentation Tank Inflow Flow meter	Ultrasonic Type, 1300A	1	
Biological Reactor Facility	Biological Reactor DO Analyzer	Optical Type	4	
	Biological Reactor MLSS Analyzer	Infrared Transmitted light Type	4	
	Biological Reactor Air Flow Meter	Thermal Mass Type, 350A	4	
Secondary Sedimentation Tank Facility	Return Sludge Flow Meter	Electronic Type, 350A	4	
	Return Sludge Density Analyzer	Infrared Type, 350A	4	
	Surplus Sludge Flow Meter	Electronic Type, 250A	1	
	Surplus Sludge Density Analyzer	Infrared Type, 250A	1	
	Drain PIT Level Switch	Quick Float type	2	
Disinfection Facility	Disinfection Tank Level Meter	Ultrasonic Type	1	
	Caustic Soda Inflow Flow meter	Electronic Type, 250A	1	
	Discharge Water Flow meter	Ultrasonic Type, 700A	1	
	Discharge Water COD Analyzer	Potassium Permanganate Method	1	
	Discharge Water SS Analyzer	Infrared Scattered light Method	1	
	Discharge Water PH Analyzer	Glass Electrode Type	1	
	Discharge Water TP Analyzer	Absorbance Method	1	
	Discharge Water TN Analyzer	Absorbance Method	1	
	Drain PIT Level Switch	Quick Float type	2	
Blower Building Facility	Biological Reactor Air Flow Meter	Thermal Mass Type, 500A	2	
Faecal Sludge Treatment	Faecal Sludge Tank Level Meter	Ultrasonic Type	1	
	Supernatant Liquid Tank Level Meter	Ultrasonic Type	1	
	Thickened Sludge Tank Level Meter	Ultrasonic Type	1	
	Polymer Feed Density Analyzer	Infrared Type, 250A	1	
	Polymer Feed Flow meter	Electronic Type, 250A	1	
	Centrifuge Inflow Density Analyzer	Infrared Type, 250A	1	
	Centrifuge Inflow Flow meter	Electronic Type, 250A	1	
	Thickened #1 Flow meter	Electronic Type, 65A	1	
Sludge Thickening Facility	Thickened Inflow Flow meter	Electronic Type, 150A	4	
	Thickened Inflow Density Analyzer	Infrared Type, 150A	4	
	Dewatering Centrifuge Flow meter	Electronic Type, 150A	2	
	Dewatering Centrifuge Inflow Density Analyzer	Infrared Type, 150A	2	
	Sludge Balancing Tank Level Meter	Ultrasonic Type	1	
	Sludge Balancing Tank Density Analyzer	Infrared Type, 150A	1	
	Mixed Sludge Flow meter	Electronic Type, 150A	4	
	Mixed Sludge Density	Infrared Type, 150A	4	
	Thickened Sludge Tank Level Meter	Ultrasonic Type	1	
	Sludge Tank Flow meter	Electronic Type, 150A	1	
	Thickened #2 Flow meter	Electronic Type, 150A	2	
Dewatering Facility	Digestion Sludge Flow meter	Electronic Type, 150A	2	
	Digestion Sludge Density Analyzer	Infrared Type, 150A	1	

4.5 Capacity Building

This feasibility study planned to strengthen the capacity of the agency through commissioning and training, technology transfer, and operational support after completion for the sustainability of Sewage Service in the project target area.

4.5.1 Commissioning & Training

CWASA has no experience in operating sewage treatment plants. Commissioning & Training should be carried out because the lack of professional manpower can cause problems in facility operation management and reduce the effectiveness of the project. In this F/S, the commissioning and training plans are proposed as follows, and detailed plans for smooth facility operation of the recipient country should be established in the implementation stage.

4.5.1.1 Training

Training plan including safety management training, technical training and water quality analysis training is proposed as below and training will be conducted by the above-mentioned professional operators mobilized for commissioning.

Table 4-149 Training Plan

<table>
<tr><th colspan="2">Category</th><th>Target</th><th>Description</th></tr>
<tr><td colspan="2">General</td><td>Operator</td><td>• Risk of water quality accidents
• Emergency management measures
• Importance of environmental pollution prevention
• Responsibility
• Building cooperative relationship with local residents</td></tr>
<tr><td colspan="2">Safety Management</td><td>Operator Maintenance & Repair Staff</td><td>• Seasonal safety training
• Education on accident response (suspension of water supply, power outage, flood, hazardous substance, fire)</td></tr>
<tr><td rowspan="3">Technical Skills</td><td>Theory</td><td>Operator / Maintenance & Repair Staff</td><td>• Facility management
• Operational response in emergency
• Guidelines for the operation of the STP in emergency
• Pump operation tips in emergency
• Principle of biological treatment process and operational skill
• Sludge treatment technology</td></tr>
<tr><td>Practice</td><td>Operator / Maintenance & Repair Staff</td><td>• Determination of capacity and specification of equipment
• Cautions on operation
• Cause of and countermeasures to trouble
• Equipment and instrument control</td></tr>
<tr><td>On-site</td><td>Operator Maintenance & Repair Staff</td><td>• On-site operation
• Inspection methods and analysis</td></tr>
<tr><td colspan="2">Commissioning</td><td>Operator / Maintenance & Repair Staff</td><td>• Operation of unit equipment, no-load operation, pre-operation, operation
• Inspection on sewage treatment, sludge treatment facilities</td></tr>
<tr><td colspan="2">Pipe Management</td><td>Pipe Management Staff</td><td>• Technical understanding of sanitary sewer
• General maintenance of sanitary sewer
• Operation and maintenance of sanitary sewer</td></tr>
<tr><td colspan="2">Water Quality Survey</td><td>Water Analyst</td><td>• Laboratory management
• Management of laboratory equipment
• Management of test result</td></tr>
<tr><td colspan="2">Administration</td><td>Administrative Staff</td><td>• Management of STP
• General education on administration of sanitation</td></tr>
</table>

4.5.1.2 Commissioning

Commissioning is the final stage of construction to check whether the facility is operating normally and to solve problems that are identified as well as preventing future problems. In addition, it aims to derive optimal operation factors through the verification of the treatment efficiency, thereby realizing the original objectives of the operating public sewerage system.

Commissioning consists of pre-inspection, no-load operation test and load operation test, and the details are as shown below:

- Load operation test on civil, mechanical and electrical facilities
- Analysis of water quality of influent and between treatment processes
- Analysis treatment efficiency of each unit process
- Inspection of mechanical, electrical and instrumentation equipment, and monitoring operational condition
- Education of operators and transferring technical skills on operation and maintenance
- Preparation of commissioning report

4.5.1.3 Manpower and Required Mobilization Plan

It is recommended that the Contractor mobilize professional human resources for commissioning consisting of pre-inspection, no-load operation and load operation test of facilities, and educate operational workers to transfer technical skills for operation and maintenance. The mobilization plan for the commissioning is shown in Table as below.

Table 4-150 Mobilization Plan for Commissioning & Training

Position	Foreign		Local		Total
	No.	Staff Input (M/M)	No.	Staff Input (M/M)	
Commissioning Manager	1	6			6
Deputy Manager			1	6	6
Process Engineer	1	6	1	6	12
Mechanical Engineer	1	3	1	6	9
Electrical & Instrumentation Engineers	1	3	1	6	9
Total	4	18	4	24	42

42 M/M (18 M/M for foreign engineers, 24 M/M for local engineers) is planned for commissioning. The input manpower consists of a commissioning manager, deputy manager, process engineer, engineer by field.

Table 4-151 Commissioning Manpower Input Plan - Foreign

Category		Staff Input						Number	Staff Input (M/M)
		1	2	3	4	5	6		
Commissioning Manager	Field	1	1	1	1	1	1	1	6
Process Engineer	Field	1	1	1	1	1	1	1	6
Mechanical Engineer	Field		1		1		1	1	3
Electrical & Instrumentation Engineer	Field		1		1		1	1	3
Total									18

Table 4-152 Commissioning Manpower Input Plan - Local

Category		Staff Input						Number	Staff Input (M/M)
		1	2	3	4	5	6		
Deputy Manager	Field	1	1	1	1	1	1	1	6
Process Engineer	Field	1	1	1	1	1	1	1	6
Mechanical Engineer	Field	1	1	1	1	1	1	1	6
Electrical & Instrumentation Engineer	Field	1	1	1	1	1	1	1	6
Total									24

4.5.1.4 Technology Transfer

Technology transfer of skills and knowhow of commissioning and O&M is necessary for local O&M staffs to be technically independent in order to enable the efficient O&M of facilities. For this reason, both theoretical training and practical training are proposed to achieve the goal of the technology transfer plan. The technical transfer plans are explained in Table below.

Table 4-153 Technology Transfer Plan

Category		Description
Sewage Treatment Process	Engineers	• Process Calculation • Hydraulic calculation
Construction	Engineers	• Installation of equipment and cautions • Construction skills on main structures
Operation of Control System	Operators and Instrument Controller	• Control and operation skills on sewage treatment process and sludge treatment process • Operation skill in different case of emergency
Operation & Management	Commissioning Engineers and Operators	• Learning on O&M manual of treatment process • Analysis of no-load and load tests • Interconnection operation between existing and new STPs as per variation of flow and quality • The time and methods of safety diagnosis

4.5.2 O&M Support after Construction Completion

As per the EDCF evaluation manual (20.12, KEXIM), Ex-post evaluation will be conducted after two years from the project completion to evaluate the effectiveness, impact, and sustainability of the project to obtain lessons and suggestions for future EDCF project support.

In the previous EDCF sewerage project, there was insufficient O&M support after construction completion. Even though commissioning & training was implemented during the project, the PEA had several O&M problems due to the lack of technical specialties and lack of financial resources.

In this project, to achieve the long-term effect of the project in accordance with the EDCF framework, O&M support for training and technology transfer for two years after construction completion is proposed as follows.

Table 4-154 O&M Support after Construction Completion

Position	Foreign		Local		Total
	No.	Staff Input (M/M)	No.	Staff Input (M/M)	
O&M Manager (Process Engineer)	1	24			24
Deputy Manager			1	24	24
Process Engineer			1	24	24
Mechanical Engineer	1	24	1	24	48
Electrical & Instrumentation Engineers	1	24	1	24	48
Total	4	72	4	96	168

168 M/M (72 M/M for foreign engineers, 96 M/M for local engineers) is planned for O&M support plan after construction completion. The input manpower consists of a O&M manager, deputy manager, process engineer, engineer by field.

Table 4-155 O&M Manpower Input Plan - Foreign

Category		Staff Input												Number	Staff Input (M/M)
		2	4	6	8	10	12	14	16	18	20	22	24		
O&M Manager (Process Engineer)	Field	2	2	2	2	2	2	2	2	2	2	2	2	1	24
Mechanical Engineer	Field	2	2	2	2	2	2	2	2	2	2	2	2	1	24
Electrical & Instrumentation Engineer	Field	2	2	2	2	2	2	2	2	2	2	2	2	1	24
Total															72

Table 4-156 O&M Manpower Input Plan - Foreign

Category		Staff Input												Number	Staff Input (M/M)
		2	4	6	8	10	12	14	16	18	20	22	24		
Deputy Manager	Field	2	2	2	2	2	2	2	2	2	2	2	2	1	24
Process Engineer	Field	2	2	2	2	2	2	2	2	2	2	2	2	1	24
Mechanical Engineer	Field	2	2	2	2	2	2	2	2	2	2	2	2	1	24
Electrical & Instrumentation Engineer	Field	2	2	2	2	2	2	2	2	2	2	2	2	1	24
Total															96

Table 4-157 Technology Transfer Plan

Category		Description
O&M Manager	Director of O&M support	• Director of O&M support • Facility O&M support and training of local technicians
Deputy Manager	Executive Director of O&M support	• Executive Director of O&M support • Facility O&M support and training of local technicians
Process Engineer	Process of O&M support	• Director of Facility O&M support • Preparation and training of treatment process maintenance manual • Training on operation plans for each situation in case of emergency in the water treatment process
Mechanical Engineer	Mechanical O&M support manager	• Training on equipment installation technology and precautions • Training on an equipment maintenance plan • Training on operation plan for each situation in case of emergency in the water treatment process
Electrical & Instrumentation Engineers	Electrical & Instrumentation O&M support manager	• Training on water treatment control panel operation technology • Training on Emergency (power outage, etc.) operation plan for each situation

4.6 Consulting Service

4.6.1 Necessity of the Consultant

Since this project is supported by EDCF and subject to binding aid conditions, project management as an aid project different from general financial projects is required.

In addition, the project includes sewerage system thorough project management in association with the consulting service is essential.

For this reason, a foreign consultant, who is well aware of EDCF procedure, is required to carry out activities such as project preparation, detailed design, bidding support, construction supervision and commissioning.

4.6.2 Scope of Works of the Consultant

The services of consultants shall be utilized in the carrying out 2of the Project, particularly with regard to the detailed de2sign, preparation and evaluation of bidding documents assisting the PEA and project supervision. The Consultant shall carry out the necessary activities as described below but not necessarily limited to the following:

4.6.2.1 Detailed Design

- Data Collection
- Topographic survey, geotechnical investigation, water quality survey and household survey
- Detailed Design for sewerage system
- Cost estimates and establishment of construction implementation plan
- Environmental & Social Impact assessment
- Other technical assistance to the Client in regard to the Project

4.6.2.2 Bidding Support

- Preparation of bidding documents
- Assistance in bid evaluation
- Assistance in preparation of contract documents
- Assistance in contract negotiation

4.6.2.3 Supervision of Works

- Supervision on safety, quality, and construction management
- Inspection and approval for quality management
- Training and commissioning
- Project management

4.6.2.4 Others

- Preparation of the of Project Progress Reports & Schedule Management
- Other PEA support services
- Preparation of the Project Completion Report

4.6.3 Procedures for Selection of Consultants

4.6.3.1 General

KEXIM normally requires the PEA to adopt the following procedures in the selection and employment of consultants:

- Preparation of the Terms of Reference and cost estimates
- Preparation of a Short List of Consultants
- Invitation to submit proposals
- Evaluation of proposals
- Negotiation of a contract

4.6.3.2 Terms of Reference

The Terms of Reference are the initial statement to the consultant of the work that is required to and, with eventual modifications, form an integral part of the contract which governs the work that the consultant is to perform. Normally, the Terms of Reference should contain the following:

- a precise statement of the objectives of the assignment
- the scope and timing of the required services
- the inputs to be provided by the PEA
- particulars of the output (i.e., reports, drawings, etc.) required by the consultant

4.6.3.3 Short List of Consultants

The selection of a consultant for a particular assignment usually begins with the preparation of a Short List of Consultants to be invited to submit proposals. Such a Short List shall normally consist of not less than three and not more than five consultants. Should the PEA find it difficult to compile a satisfactory Short List of qualified consultants from the information available to it from its own past experience and other sources, the KEXIM shall, at the request of the PEA, make available information on consultants, from which the PEA may draw up its own Short List.

4.6.3.4 Invitation for Proposals

After the completion of a Short List of Consultants, the Letter of Invitation shall be sent to the "short-listed" consultants to submit their proposals. The Letter of Invitation shall include the Terms of Reference and any other supplementary information (which may include estimated man-months) concerning the proposed work and the conditions under which the work is to be performed.

The Letter of Invitation shall clearly indicate that financial terms are not to be included in the proposals at this stage, that the selection shall be made on the basis of qualifications to perform the work, and that financial terms shall be discussed and agreed only at the time of contract negotiations with the selected consultant.

The Letter of Invitation shall also stipulate the details of the selection procedure to be followed, including the technical evaluation categories and an indication of the weight to be given to each.

PEA shall use the applicable Standard Request for Proposals under the EDCF Loan (Standard RFP) of the latest version issued by the Bank with minimum changes, acceptable to the Bank, as necessary to address project- specific conditions.

4.6.3.5 Evaluation of Proposals

Proposals received by PEA in response to the invitation shall be evaluated in accordance with the criteria stipulated in the Letter of Invitation. Such criteria shall normally include:

- The consultant's general experience and performance record in the field covered by the Terms of Reference
- The adequacy of the proposed approach, methodology and work plan
- The experience and records of the staff members to be assigned to the work.

The relative importance of the above-mentioned three factors will vary with the type of consulting services to be performed, but in the overall rating of the proposals most weight shall normally be given either to the qualifications of the staff members to be assigned to the Project or to the approach and methodology, rather than to the reputation or fame of the consultant.

The qualifications of the staff members to be assigned to the Project should be evaluated on the basis of the following three criteria:

- General qualifications (education, length of experience, types of position held, duration of service with the consultant, etc.)
- Suitability for the Project (experience in performing the duties which will be assigned to them in the Project)
- Familiarity with the language and the conditions of the country in which the work is to be performed, or experience in similar environments.

In its evaluation of the proposals, PEA shall use numerical ratings and prepare an evaluation report. Such evaluation report should normally give detailed information on the organization responsible for the evaluation, selection criteria and relative weight distribution.

4.6.3.6 Contract Negotiation

After the evaluation of the proposals has been completed, PEA shall invite the first-ranked consultant to enter on negotiations on the conditions (including costs and financial terms) of a contract between them.

If the two parties are unable to reach agreement on a contract within a reasonable time, PEA shall terminate the negotiations with the first-ranked consultant and invite the consultant who ranked second in the evaluation to enter on negotiations. This procedure will be followed until PEA reaches agreement with a consultant.

4.6.4 Required Mobilization Plan

Consultant mobilization plan is classified into Phases and the assigned engineers should be selected considering the suitability of works by the area of expertise.

4.6.4.1 Detailed Design & Bidding Support (Phase 1)

In this F/S, it is planned that 371 M/M (foreign staff 191 M/M, local staff 180 M/M) of professional staff will be mobilized for 16 months of detailed design and bidding support.

The Consultant’s team will be composed of a project manager, deputy team leader and the following key staff; sewage process engineer, sanitary sewer engineer, structural engineer, geotechnical engineer, mechanical engineer, electrical & instrumentation engineer, architect/landscape specialist, social specialist, environmental specialist, procurement specialist, quantity surveyor.

Table 4-158 Mobilization Plan for Detailed Design and Bidding Support-Foreign Staff

No.	Position		Staff Input 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	No.	Staff Input (M/M)
			Detailed Design												Bidding Support					
1	Project Manager	Home																	1	-
		Field	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		16
2	Sewage Process Engineer (1)	Home																	1	-
		Field	1	1	1	1	1	1	1	1	1	1	1	1						12
3	Sewage Process Engineer (2)	Home	1	1	1				1	1	1								1	6
		Field				1	1	1				1	1	1						6
4	Sewage Process Engineer (3)	Home	1	1	1	1	1	1	1	1	1	1	1	1					1	12
		Field																		-
5	Sanitary Sewer Engineer (1)	Home																	1	-
		Field	1	1	1	1	1	1	1	1	1	1	1	1						12
6	Sanitary Sewer Engineer (2)	Home	1	1	1				1	1	1								1	6
		Field				1	1	1				1	1	1						6
7	Sanitary Sewer Engineer (3)	Home				1	1	1				1	1	1					1	6
		Field	1	1	1				1	1	1									6
8	Structural Engineer (1)	Home				1	1	1			1	1							1	5
		Field							1	1			1	1						4
9	Structural Engineer (2)	Home				1	1	1	1	1	1	1	1	1					1	9
		Field																		-
10	Geotechnical Engineer (1)	Home				1	1	1			1	1							1	5
		Field		1	1				1	1			1	1						6
11	Geotechnical Engineer (2)	Home		1	1				1	1			1	1					1	6
		Field				1	1	1			1	1								5
12	Mechanical Engineer (1)	Home						1	1	1	1								1	4
		Field				1	1					1	1	1						5
13	Mechanical Engineer (2)	Home				1	1	1	1	1	1	1	1	1					1	9
		Field																		-
14	Electrical & Inst. Engineer (1)	Home						1	1	1	1								1	4
		Field				1	1					1	1	1						5
15	Electrical & Inst. Engineer (2)	Home				1	1	1	1	1	1	1	1	1					1	9
		Field																		-
16	Social Specialist	Home							1	1	1								1	3
		Field										1	1	1						3
17	Environmental Specialist	Home							1	1	1								1	3
		Field										1	1	1						3
18	Procurement Specialist	Home									1	1	1						1	3
		Field												1	1	1	1	1		5
19	Quantity Surveyor	Home						1	1	1									1	3
		Field									1	1	1	1						4
	Total																		Home	93
																			Field	98
																			Total	191

Table 4-159 Mobilization Plan for Detailed Design and Bidding Support-Local Staff

No.	Position		Staff Input																No.	Staff Input (M/M)
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
			Detailed Design												Bidding Support					
1	Deputy Team Leader	Field	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
2	Sewage Process Engineer	Field	1	1	1	1	1	1	1	1	1	1	1	1					2	24
3	Sanitary Sewer Engineer	Field	1	1	1	1	1	1	1	1	1	1	1	1					3	36
4	Structural Engineer	Field				1	1	1	1	1	1	1	1	1					1	9
5	Geotechnical Engineer	Field				1	1	1	1	1	1	1	1	1					2	18
6	Mechanical Engineer	Field				1	1	1	1	1	1	1	1	1					2	18
7	Electrical & Inst. Engineer	Field				1	1	1	1	1	1	1	1	1					2	18
8	Architect/Land. Specialist	Field							1	1	1	1	1	1					1	6
9	Social Specialist	Field				1	1	1	1	1	1	1	1	1					1	9
10	Environmental Specialist	Field				1	1	1	1	1	1	1	1	1					1	9
11	Procurement Specialist	Field												1	1	1	1	1	1	5
12	Quantity Surveyor	Field							1	1	1	1	1	1					2	12
	Total																		Field	180
																			Total	180

4.6.4.2 Construction Supervision (Phase 2)

In this F/S, it is planned that 624 M/M (foreign staff 306 M/M, local staff 318 M/M) of professional staff will be mobilized for 48 months of construction supervision, and the Consultant's team will be composed of a project manager, deputy team leader and the following key staff; sewage process engineer, sanitary sewer engineer, structural engineer, geotechnical engineer, mechanical engineer, electrical & instrumentation engineer, architect/landscape specialist, quantity surveyor.

Table 4-160 Mobilization Plan for Construction Supervision – Foreign Staff

No.	Position		Staff Input																No.	Staff Input (M/M)
			3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48		
			Construction Supervision																	
1	Project Manager	Home																	1	-
		Field	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		48
2	Sewage Process Engineer (1)	Home																	1	-
		Field	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		48
3	Sewage Process Engineer (2)	Home																	1	-
		Field	3		3		3		3		3		3		3		3			24
4	Sanitary Sewer Engineer (1)	Home																	1	-
		Field	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		48
5	Sanitary Sewer Engineer (2)	Home																	1	-
		Field	3		3		3		3		3		3		3		3			24
6	Structural Engineer	Home																	1	-
		Field	2		2		2		2		2		2		2		2			16
7	Geotechnical Engineer	Home																	1	-
		Field			3	3	3	3	3	3	3	3	3	3	3	3	3	3		42
8	Mechanical Engineer	Home																	1	-
		Field					2		2		2		2		3	3	3	3		20

No.	Position		Staff Input Construction Supervision																No.	Staff Input (M/M)
			3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48		
9	Electrical & Inst. Engineer	Home																	1	-
		Field					2		2		2		2		3	3	3	3		20
10	Architect/Land. Specialist	Home																	1	-
		Field									2		2		3	3	3	3		16
	Total																		Home	-
																			Field	306
																			Total	306

Table 4-161 Mobilization Plan for Construction Supervision – Local Staff

No.	Position		Staff Input Construction Supervision																No.	Staff Input (M/M)
			3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48		
1	Deputy Team Leader	Field	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	48
2	Sewage Process Engineer	Field	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	48
3	Sanitary Sewer Engineer	Field	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	48
4	Structural Engineer	Field		3		3		3		3		3		3		3		3	1	24
5	Geotechnical Engineer	Field	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	48
6	Mechanical Engineer	Field				2	2	2	2	2	2	2	2	2	2	2	2	2	1	26
7	Electrical & Inst. Engineer	Field				2	2	2	2	2	2	2	2	2	2	2	2	2	1	26
8	Architect/Land. Specialist	Field				2	2	2	2	2	2	2	2	2	2	2	2	2	1	26
9	Quantity Surveyor	Field													3	3	3	3	2	24
	Total																		Field	318
																			Total	318

4.6.4.3 Overall Mobilization Plan

In this F/S, total 995 M/M (foreign staff 497 M/M, local staff 498 M/M) of professional staff will be mobilized during 64month for the project implementation period (16 months for detailed design & bidding support, 48 months for construction supervision). In the detailed design and bidding support stage, it is planned to input 371 M/M (foreign staff 191 M/M, local staff 180 M/M). In the construction supervision stage, it is planned to input 624 M/M (foreign engineer 306 M/M, local staff 318 M/M).

Table 4-162 Overall Mobilization Plan

Phase	Category	Input (M/M) Home	Input (M/M) Field	Input (M/M) Total
Detailed Design & Bidding Support	Foreign Staff	93	98	191
	Local Staff	-	180	180
	Sub-Total	93	278	371
Construction Supervision	Foreign Staff	-	306	306
	Local Staff	-	318	318
	Sub-Total	-	624	624
Total	Foreign Staff	93	404	497
	Local Staff	-	498	498
	Total	93	902	995

4.7 Contractor Selection

4.7.1 Selection Method

The selection of contractors for EDCF loan projects is carried out through the recipient country procurement system under the responsibility of the Bangladesh government. In principle, a competitive bidding method is applied based on economic feasibility, efficiency, and fairness. The recipient country assumes all responsibilities for projects ordered by the recipient country, and the EDCF checks whether the entire process is properly implemented according to the procedures set forth in the loan agreement.

4.7.1.1 Contract Method

Contract methods for selecting a contractor include Design-Bid-Build Contract and Design-Build Contract. This project is designed and constructed in consultation with the implementation agency and EDCF, and sufficient review of sewage treatment process, facilities, materials and constructability for each unit process is possible. Therefore, it was agreed to adopt the Design-Bid-Build Contract method, which is expected to produce high-quality results.

Table 4-163 Contract Method

Category	Description
Design-Bid-Build Contract	• After selecting a consultant from the ordering organization and carrying out the design, the construction is separated and the order is placed. A method of having a consultant prepare a design document, bidding based on it, and selecting a contractor to construct the construction object. • Procedures such as ordering, project implementation, and follow-up management are somewhat complicated and the project period is long. • It is economical because it can reflect the uniqueness of the ordering organization, and is advantageous in solving existing problems. • In general, it is difficult to apply new technologies because a lot of proven technologies are applied. • When a problem occurs, it is possible to respond quickly because the ordering organization directs and consults with the service company. It is possible to check mutually between design and construction.
Design-Build Contract	• The contractor provides all services of design and construction to the ordering organization, and the ordering agency concludes a contract to perform design and construction with a single contractor. • As the construction is carried out under one main contract, the limits of responsibility for the overall construction become clear. Since the overall contractor is responsible for design and construction, it is possible to guarantee design and construction. • It is difficult to check and adjust by the ordering organization, so you may not know about design or construction problems that can greatly affect construction cost or process. The final result may not satisfy expectations due to minimal involvement of the ordering organization.

4.7.1.2 Bidding Method

Bidding methods for selecting a contractor include Single Stage One Envelope Bidding Procedure, Single Two Envelope Bidding Procedure, Two Stage Two Envelope Bidding Procedure, and Two Stage Bidding Procedure. The bidding method for this project is finalized through EDCF approval after the consultant selects it in consultation with the implementing agency and the recipient country procurement agency at the stage of detailed design and bidding support.

Table 4-164 Bidding Method

Category	Description
Single Stage, One Envelope Bidding Procedure	• In the single proposal method, bidders participate in bidding by enclosing a price proposal and a technical proposal in one envelope. • Bidding documents are disclosed on the date and time posted in the bidding notice, and the implementing agency evaluates and undergoes the EDCF approval process for the evaluation results. In general, the participant who offered the lowest price is selected.
Single Stage, Two Envelope Bidding Procedure	• A method of submitting the technical proposal and pricing proposal simultaneously in separate envelopes. • Under the same method, the implementing body first opens and evaluates the technical proposal, and then evaluates the pricing proposal separately. This is to evaluate the proposals by focusing on the technical capabilities of the proposers without being influenced by the price. • The bidder cannot change the technical specifications while the evaluation is being conducted. • When the evaluation of the implementing body and the EDCF approval are completed, the price proposals of companies that have passed the technical proposals are released. Among these companies, companies that offer competitive prices are selected as contractors.
Two Stage, Two Envelope Bidding Procedure	• A method of submitting the technical proposal and pricing proposal simultaneously in separate envelopes. The implementing body first opens and evaluates the technical proposal, and then evaluates the pricing proposal separately. • At this time, unlike the Single Stage method, bidding companies are given an opportunity to change the technical standards according to the conditions of the implementing agency. This is to give all bidders a chance to meet the technical standards required by the implementing agency, and once the 1st technology evaluation is completed, the participating companies submit the 2nd bidding documents. • Based on the final submitted technology and price proposal, a competitive company is selected as a contractor.
Two Stage Bidding Procedure	• In the two-step method, only the technical proposal is submitted first, and then the price is reviewed. • When a bidder submits a technical proposal, it is disclosed on the bidding date, and consultations are conducted with ADB and implementing organizations based on the bidding details. At this time, the bidders are notified of the defects or deficiencies found, and can change them. This is to give all bidders a chance to meet the technical standards required by the implementing agency. • After the 1st technology evaluation is completed, the participating companies submit the 2nd bidding documents. Price changes are also possible according to changes in technical specifications, and sufficient preparation period is given before the submission of the secondary bidding documents. • Based on the final submitted technology and price proposal, the participant with the highest score is selected as the contractor.

4.7.2 Contractor Selection Process

4.7.2.1 Bidding

General bidding documents include bidding guidelines and guidance, bid forms and appendices, (secret) agreements, bid guarantee forms, performance guarantee forms, advance payment guarantee forms, general contract conditions, special contract conditions, matters to be added to and modified from general contract conditions, specifications, quantity statement, bidding drawing, bidding submission form, supplementary information, and bidding document supplementation/modification.

The owner holds a pre-tender meeting and arranges a site survey to explain the site conditions, and all answers to questions received from bidders and minutes of the site briefing meeting (MOM, Minutes of Meeting) are gathered and distributed.

The bidder will pay the total construction cost, including material costs, equipment costs, labor costs, subcontracting costs, overhead costs, other expenses and profits required to complete the construction in accordance with the specifications and contract documents, at a competitive price through the application of feasible construction methods, etc. A price proposal, which is a series of work to derive, should be prepared and submitted within the bidding deadline.

4.7.2.2 Contract

After the bid evaluation, the final successful bidder is selected and the contract is concluded, and the contractor should prepare for the start of construction within the deadline when a letter of award or letter of intent is issued from the owner. When signing a contract, Performance Security and Advance Payment Guarantee should be submitted.

4.7.3 Contractor Work Scope

The main tasks that the contractor will be responsible for in this project are as follows, and the scope of the contractor's work will be confirmed after the execution of the detailed design.

4.7.3.1 Construction of Sewerage System and Defect Liability

- Sewage Treatment Plant, Q=60,000m3/d (Daily Average)
- Faecal Sludge Treatment Plant, Q=100m3/d
- Sanitary Sewer, D200~1,600mm, L=58.3km
- Household Connection, 10,000Nos.
- Operation & Maintenance Vehicles
- Defect Liability

4.7.3.2 Commissioning and Training

- Commissioning
- Training

4.7.3.3 Operation Support after Construction Completion

- Operational support after construction completion of sewerage system (2 years)

4.8 Operation and Maintenance

4.8.1 General

Sewerage are facilities that aim to prevent water pollution by treating sewage and wastewater discharged from human life and discharging it to the discharge area. However, since direct recovery from investment and installation is impossible and the effect does not appear in a short period of time, maintenance of Sewage treatment plant aims to comply with effluent water quality standards. In addition, the sewerage project requires a considerably long period of time and a large amount of investment from establishment of the plan to start of use. Therefore, the preservation of water quality and the improvement of the sanitary environment of residents can be achieved when operation and maintenance are appropriate after the start of use.

- Plan for sewer, sewage treatment plant, and faecal sludge treatment facilities to be suitable for each purpose and to fully demonstrate their functions organically.
- Establishment of a sewage facility integrated maintenance management system establishment plan.
- Establishment of directions for efficient operation and maintenance of sewerage facilities and basic policies for sewerage informatization.

Table 4-165 Operation & Maintenance (O&M)

Category	Description
Main Issues	• Economical operation with safety and efficiency • Maintaining and improving performance • Establishing working system • Safety and sanitation • Economical management on facility operation • Operation considering energy saving
Labor Saving	• Adoption of centralized monitoring and distributed control method • Facility automation
Operation & Maintenance	• Conduct daily inspection, intermediate inspection and regular repair • Establishment of emergency measures • Recording and analysis of performance of various equipment • Establishment of operational plan through periodic analysis of wastewater • Overload prevention • Securing and maintain spare parts for repair works • Preparation and analysis of daily report
Energy Saving	• Establishment of operational plan as per operational or load variation • Facility automation
Working System & Safety	• Securing qualified or appropriate staffs • Establishment of command system • Securing stability of equipment and safety of working environment • Regular training for capacity building • Compliance with regulations
Cooperative Relationship with Residents	• Respect and listen to residents • Building up trust through public disclosure of information • Settlement of resident-friendly facilities through facility tours

4.8.2 O&M Cost Estimate

4.8.2.1 Total O&M Cost

O&M cost of the sewerage system in this project is composed of electricity cost, chemical cost, labor cost, consumables & repair cost, replacement cost and administrative cost. Total O&M cost for 40 years is estimated at US$ 210,756 thousands and Annual O&M cost is estimated at US$ 5,269 thousands as below.

Table 4-166 O&M Cost Estimate (US$)

Category	Annual	Total (40 years)
Electricity cost	2,201,741	88,069,640
Chemical cost	782,560	31,302,400
Labor cost	293,646	11,745,840
Consumables & Repair Cost	228,401	9,136,040
Replacement Cost (15year)	1,658,150	66,326,000
Administrative Cost	104,409	4,176,360
Total	5,268,907	210,756,280

Note) Administrative Cost is assumed as 20% of sum of Labor Cost and Consumables & Repair Cost

4.8.2.2 Electricity Cost

Electricity cost was calculated as follows by calculating the amount of electricity required for the operation of the sewage treatment plants, such as inlet pumping station, bioreactor, secondary sedimentation tank, and sludge treatment facility.

Table 4-167 Electricity Cost

Category	Consumption (kWh/Day)	Unit Cost (US$/kWh)	Cost	
			(US$/Day)	(US$/year)
Fatehabad STP	63,200	0.09545	6,032	2,201,741

4.8.2.3 Chemical Cost

Chemical costs for the operation of sewage treatment plants and sludge treatment facilities is calculated as follows.

Table 4-168 Chemical Cost

Category	Consumption (kg/Day)	Unit Cost (US$/kg)	Cost	
			(US$/Day)	(US$/year)
Polymer (Sludge concentrate, 0.4%)	104.80	6.97	730	266,450
Polymer (Dewatering, 0.8%)	74.00	6.97	516	188,340
Polymer (Faecal sludge concentrate, 0.4%)	4.80	6.97	33	12,045
Chlorine Gas	224.80	0.27	61	22,265
NaOH (STP odour control)	694.00	0.70	486	177,390
NaOCl (STP odour control)	34.00	0.28	10	3,650
NaOH (Faecal Sludge odour control)	347.00	0.70	243	88,695
NaOCl (Faecal Sludge odour control)	17.00	0.28	5	1,825
H_2SO_4 (Faecal Sludge odour control)	94.00	0.64	60	21,900
Total			2,144	782,560

4.8.2.4 Labor Cost

Labor costs is calculated as follows considering the local conditions and the need for professional manpower for the facility.

Table 4-169 Estimated Labor Cost

Category	Number of Staff	Unit Cost (US$/month)	Cost (US$/year)
Superintending Engr.	1	1,127	13,529
Executive Engr.	5	1,106	66,362
Assistant Engr.	7	840	70,575
Sub-Assistant Engr.	7	612	51,395
PA-cum-Computer Operator	5	391	23,448
Driver	6	421	30,315
Security	5	317	19,011
Office Helper	5	317	19,011
Total	41		293,646

4.8.2.5 Consumables & Repair Cost

Consumables & repair cost is calculated by applying the rate according to the operating period to the construction cost for each field, considering the facility conditions, durability period, and replacement frequency for civil/structural, mechanical, electrical and instrumentation works.

Table 4-170 Consumables & Repair Cost

Category		Construction Cost (US$)	Repair Rate (%)	Cost (US$/year)
STP	Civil/Structural	24,519,000	0.12	29,423
	Mechanical	21,227,000	0.60	127,362
	Electrical & Inst.	11,936,000	0.60	71,616
	Total	57,682,000		228,401

*Source: Guidelines for operation and management of public sewerage (Ministry of Environment in Korea)

4.8.2.6 Replacement Cost

Replacement cost is the cost required for replacement of mechanical, electrical and instrumentation equipment. It is calculated assuming that equipment is replaced every 15 years.

Table 4-171 Replacement Cost

Category		Construction Cost (US$)	Replacement Cycle	Cost (US$)	
				Annual (US$/year)	40 years
STP	Mechanical	21,227,000	15 years	1,061,350	42,454,000
	Electrical & Inst.	11,936,000	15 years	596,800	23,872,000
	Total	33,163,000		1,658,150	66,326,000

4.8.3 Measures When a problem occurs

Unexpected situations can occur when operating sewage treatment plants. Since there are many things that cannot be artificially controlled, appropriate follow-up measures should be taken to prevent deterioration in the quality of treated water. Possible problems and countermeasures are as follows.

4.8.3.1 Insufficient Inflow

If the inflow rate is less than the design value, the residence time of the bioreactor is excessively extended, and the F/M ratio is maintained very low than the design value, and efficient nitrogen and phosphorus removal is difficult, the quality of treated water may be deteriorated. Therefore, if this phenomenon continues, reduce the number of series operated to maintain the residence time by using the fact that the reactors are designed and constructed for each series. For example, when operating with 3 series, if the inflow flow rate is too low and the residence time is extended by more than twice the design value, take an action by stopping the operation of 1 series to reduce the residence time and operate only with 2 series, so that the stay time and F/M is operated within the appropriate range.

4.8.3.2 Excessive Inflow

Excessive inflow can be seen in two cases: the inflow of infiltrate due to heavy rain during the rainy season and the excessive flow generated in the sewage treatment area.

4.8.3.2.1 The inflow of infiltrate due to heavy rain during the rainy season

In case of excessive inflow of inflow water, the flow rate increases, but the concentration of influent water significantly decreases, so in most cases the total inflow load is the same as the average value. The turbidity of the effluent increases due to the inflow of soil, but it does not significantly affect the effluent quality because it is not a substance that causes BOD. Therefore, it is treated within the range that does not exceed the capacity, and if the inflow load is excessive after analyzing the influent properties, the aeration time of the aeration/non-aeration cycle is extended so that pollutant treatment is not over-loaded.

4.8.3.2.2 The excessive flow generated in the sewage treatment area

If excessive flow occurs due to problems such as population growth in the treatment area, a step-by-step sewage treatment facility expansion plan should be established to increase the sewage treatment capacity. However, in the short term, it is necessary to devise a plan to discharge the discharged water by processing the maximum amount of generated flow through appropriate measures in the sewage treatment facility. Therefore, the total pollutant load is reviewed through accurate property analysis of the inflow water, and the treatment capacity is calculated. In addition, changes in BOD, COD, NH4-N, NO3-N, and PO4-P during the aeration/non-aeration cycle are analyzed, and if the removal is not smooth, the aeration/non-aeration cycle is recalculated by extending the aeration time.

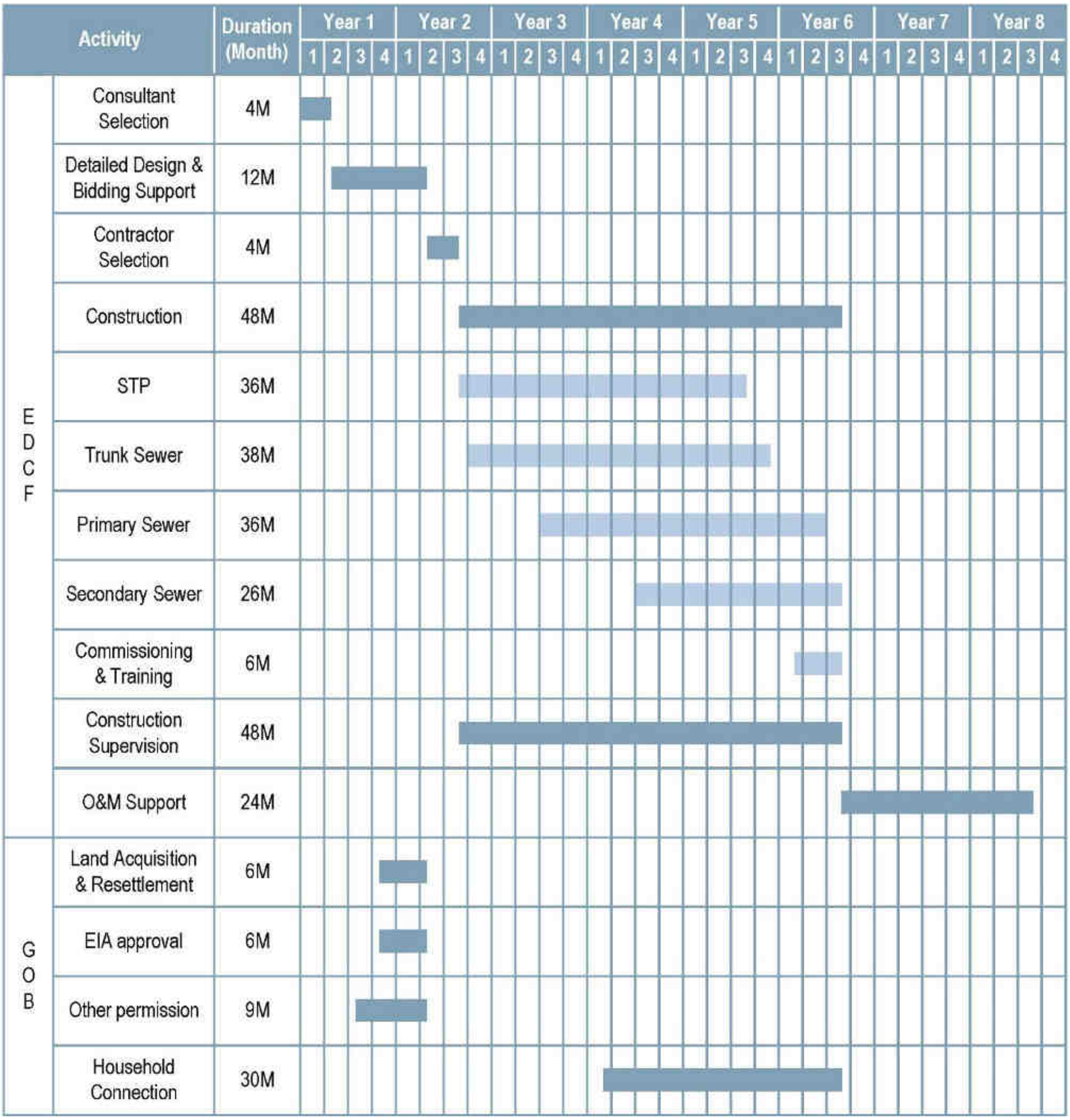
When the inflow rate is temporarily excessive, it is possible to treat it with a simple operation because the microorganisms in the sewage treatment facility can decompose the temporarily increasing pollutants to some extent. However, in the case of a long-term phenomenon that lasts for several months, a stable treatment plan should be sought through the above measures.

4.9 Project Implementation Period

Project implementation period is planned as 92 months after loan approval as below. It may be extended upon the request of the GOB and with a prior consent from the KEXIM.

- Consultant selection: 4 months
- Detailed design & bidding support: 12 months
- Contractor selection: 4 months
- Construction and construction supervision: 48 months (including 6 months of commissioning & training)
- O&M support after construction completion: 24 months

Table 4-172 Project Implementation Period



Note) Household connection will be constructed sequentially by GOB according to the construction of sanitary sewer.

5 Project Executing Agency

5.1 Project Executing Agency

5.1.1 General

CWASA was established in the CCC area of Chattogram City by Ordinance No. 19 announced in 1963 as a municipality with overall responsibility for the operation and management of water and sanitation. Through the WASA Act revised in 1996, CWASA was announced as a water supply management agency, and in 2008, it was announced as a water supply and sewage management agency. CWASA is composed of a board of directors of 13, and its main roles are water source management, water supply and management.

5.1.2 Organization

CWASA has been managing Chattogram's water supply and sewerage since 1964. It consists of management, finance, technology and operations departments, and the total number of employees increased from 1,048 in 2016 to 1,624 in 2022.

CWASA's organizational structure consists of seven to nine positions, and the CEO is appointed by the board of directors.

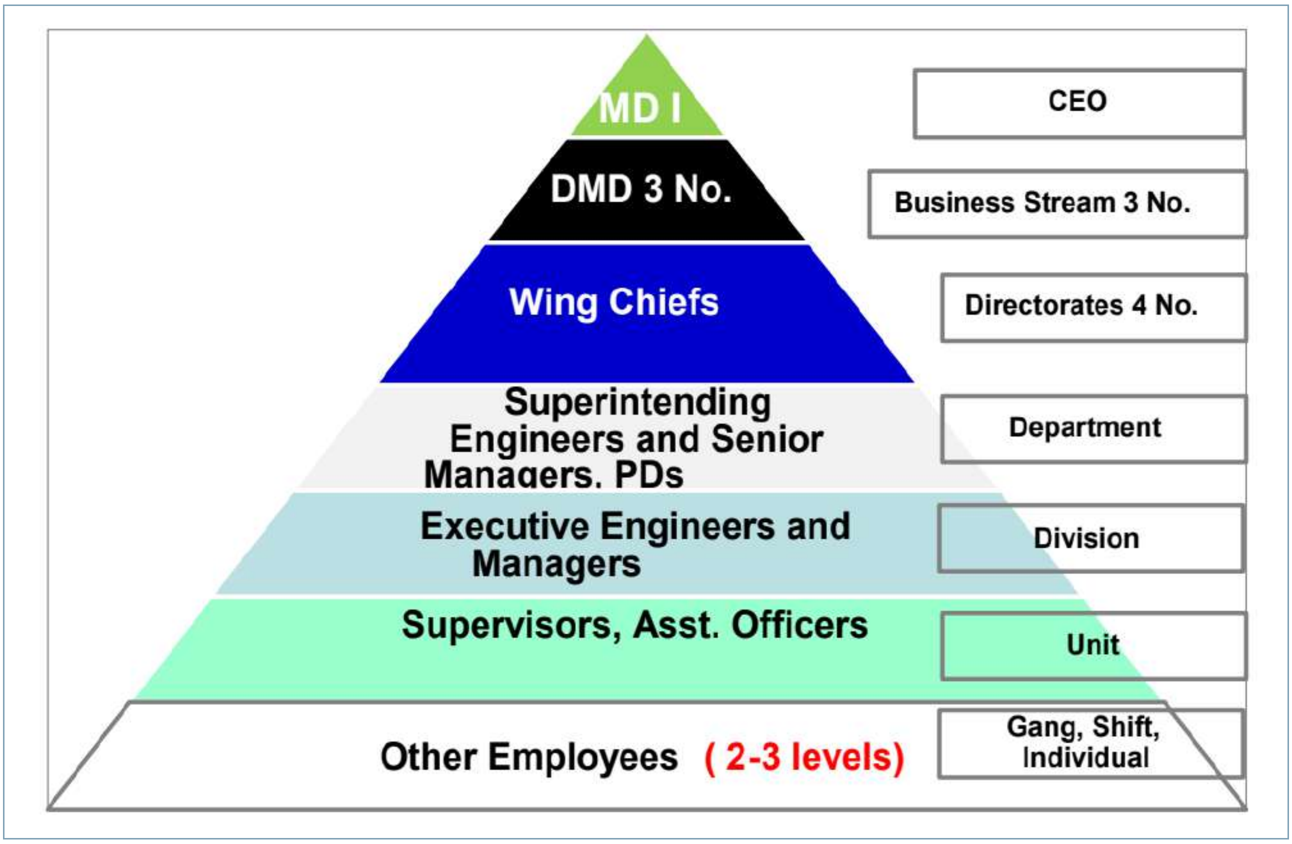


Figure 5-1 CWASA Organization Structure

CWASA consists of 1,624 employees in 2022, an increase of 345 compared to 2020. The detailed increase or decrease is as follows.

Table 5-1 CWASA's Employees

Category	Employees			
	2020	Inlet	Outlet	2022
First Class	116	38		154
Second Class	67	19		86
Third Class	553	230	20	763
Fourth Class	543	78		621
Total	1,279	365	20	1,624

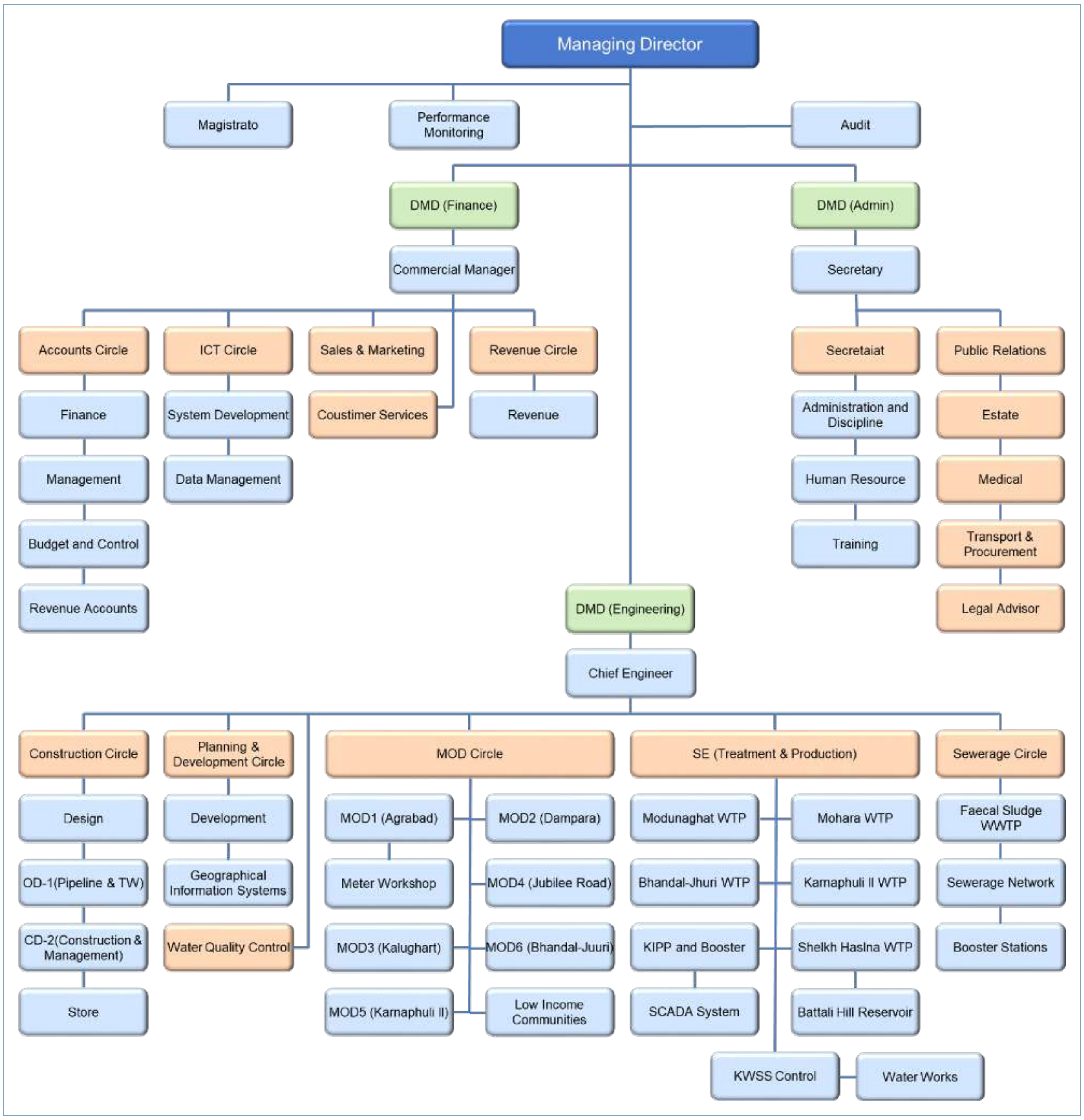


Figure 5-2 CWASA Organization diagram

5.1.3 Similar Project Experiences

5.1.3.1 EDCF Project

According to the Export and Import Bank of Korea, EDCF's total approved loan amount for 30 projects in Bangladesh since 2000 is 1,710 million USD as below. There is one water supply and sewerage similar project in Dhaka and one in Chattogram, so CWASA has enough capacity to perform EDCF projects.

Table 5-2 List of EDCF Project

No.	Project	Project Cost (Million USD)	Loan Approval Year
1	Dhaka Water Supply development project	46,906	2011
2	Bhandal Jhuri Water Supply development project	179,648	2014 & 2021
Total		223,109	

5.1.3.2 WASA Project in Bangladesh

The main projects of WASA in Bangladesh are as follows. There are five similar projects carried out by CWASA in the last 10 years. It is judged that there will be no difficulties in implementing the project as he has experience in project implementation funded by MDBs such as WB and AFD.

Table 5-3 CWASA Project List

No.	Project	Loan	Period	Construction cost (million)
1	Chattogram Metropolitan Sewerage Project for North Kattoli Catchment	AFD	2021-2026	Proceeding
2	Additional Financing to Chittagong Water Supply Improvement and Sanitation Project	World Bank	2017–2020	$47.50
3	Urban Water Supply and Sanitation in 23 Pourashava Project	IDB	2017–2021	$82.30
4	Dhaka Water Supply Network Improvement Project	AFD	2016–2021	$275.00
5	Saidabad Water Treatment Plant Project (Phase 3)	AFD, Danida, EIB	2015–2020	$360.00
6	Dahserkandi Sewage Treatment Plant Project	Government of the PRC	2015–2019	$258.00
7	Karnaphuli Water Supply Project (Phase 2)	JICA	2013–2021	¥34,847.0
8	Dhaka Environmentally Sustainable Water Supply Project	AFD, AFD, EIB	2013–2020	$450.00
9	Padma Water Treatment (Phase 1)	Government of the PRC	2013–2019	$269.00
10	Bandar–Juri Water Supply Project	EDCF	2015–2020	$97.00
11	Khulna Water Supply Project	AFD, JICA	2011–2019	AFD: $75.0 JICA: ¥15,729
12	Chittagong Water Supply Improvement and Sanitation Project	World Bank	2010–2020	$170
13	Dhaka Water Supply Sector Development Program	AFD	2007-2020	$200

5.1.3.3 Lessons learned and Suggested

Referring to the ex-post evaluation of the aforementioned EDCF project and the Chattogram water supply and sanitation project, lessons and recommendations are proposed for the smooth progress of this project as follows.

5.1.3.3.1 Lesson learned

5.1.3.3.1.1 Success Factor Review

- Maintaining closeness with the government policy of the recipient country and establishing a sense of ownership
  - The sewerage project is a high-priority project among the national goals in Bangladesh, and efforts were made to ensure that the project proceeds appropriately in connection with the policy goals.
  - Bangladesh government and CWASA tried to effort even after the detailed design was completed by promoting the project with a sense of ownership.
  - CWASA efforts to install sewage and drainage facilities, expand supply, and improve consumer convenience.
- Setting project goals that reflect reality
  - The project goal was set so that it could become a realistic plan by reviewing and verifying the sewerage coverage rate and project scope established in the feasibility study at the detailed design stage.

5.1.3.3.1.2 Limiting Factor Review

- Delay in land acquisition administrative procedures
  - Since land acquisition is not completed before the start of construction, measures such as strengthening the verification procedure for land acquisition and improving the land acquisition administrative procedure in the recipient country are necessary for efficient project management.
- Increasing project period
  - The project management should be thoroughly managed so that the project period does not increase due to delays in the recipient country's administrative processing, delays in bid evaluation, difficulty in supplying materials, and diversion of contingencies costs.

5.1.3.3.2 Suggestions

5.1.3.3.2.1 EDCF

- Efforts to complete within the project period
  - In general, the project period is often delayed due to various factors. Nevertheless, based on the feasibility study, efforts should be made to minimize changes in project implementation such as detailed design and construction.
  - The EDCF and the contractor should make efforts to efficiently carry out the project and shorten the construction period by reducing uncertainty in the project process through close consultation with the PEA and enhancing the understanding of the local situation.
- Capacity building for the recipient country
- Establishment of the logical framework and management point

- Preparation of measures to prevent delays in the loan project period

5.1.3.3.2.2 The recipient country

- Establishment of a cooperative system between government agencies and ministries in Bangladesh
- Expansion of supply of sewage and drainage facilities and establishment of long-term sanitation-related plans

5.1.3.3.2.3 CWASA

- Prepare measures to the logical framework indicators and enhance reliability
  - For a smooth evaluation of the logical framework, the recipient country should continuously manage the data that is the basis for the evaluation of each performance indicator, and in this case, efforts are needed to secure the reliability of the related data.
- Reinforcement of on-site training and secure financial resources
  - Since there is a possibility that the continuity of work in the relevant field may be hindered due to the high turnover rate of technical workers, on-site training for technical workers should be strengthened.
  - Considering that it is difficult to adequately supply the required drainage and water supply lines with only the current income, it is important to strengthen the profit base and make an effort to secure investment resources stably for the sustainability of fiscal soundness.
- Promotion of installation of drainage facilities and efforts to protect water resources
  - The untreated sewage from the project site is discharged into the river upstream of the water supply source. There is a possibility of causing pollution, and as a countermeasure against this, it is necessary to prepare effective measures to protect water resources, such as active publicity and support measures for installation of drainage facilities.

5.2 Project Organization Structure

5.2.1 Project Implementation Organization

Chattogram Water Supply and Sanitation Authority (CWASA) will be the Project Executing Agency (PEA) for the Project and will be in charge of planning, implementation, management, supervision, and coordination of the Project and forwarding relevant reports to the KEXIM. CWASA plans to establish a project management organization (PMU) during the project implementation period after the loan approval.

Table 5-4 R&R of Project Implementation Organizations

Organization	Roles and Responsibilities
PEA (CWASA)	• Overall day-to-day project management, monitoring and evaluation • Establishes and maintains Project Management Unit (PMU) • Provides technical and institutional capacity building support • Reports to KEXIM
PMU in CWASA	• Responsible for overall project management, implementation and monitoring • Monitors and ensures the compliance of covenants, particularly timely submission of audited project accounts and compliance with safeguard requirements • Maintaining project accounts and project financial records • Reviews the reports submitted by consultant with respect to detailed design, costs, safeguards, financial, economic, and social viability • Prepares, with the support of the consultant, bidding documents, request for proposals, bid evaluation reports and negotiations • Serves as point of contact with KEXIM, maintains project documents, and submits timely reports (quarterly progress reports and project completion report) to KEXIM • Organizes project orientation between stakeholder group including Chattogram municipality by elaborating scope of the project and sharing about their participation
MoF	• Financial oversight. Ensures flow of funds to the project execution agency to ensure adequate budget for successful implementation of the project
DoE	• Regulator for wastewater management and pollution control • Monitors compliance with environmental regulation
KEXIM	• Loan approval and financial support • Execution of project expenses for purchase approval, etc • Reviews executing agency and implementing agency's

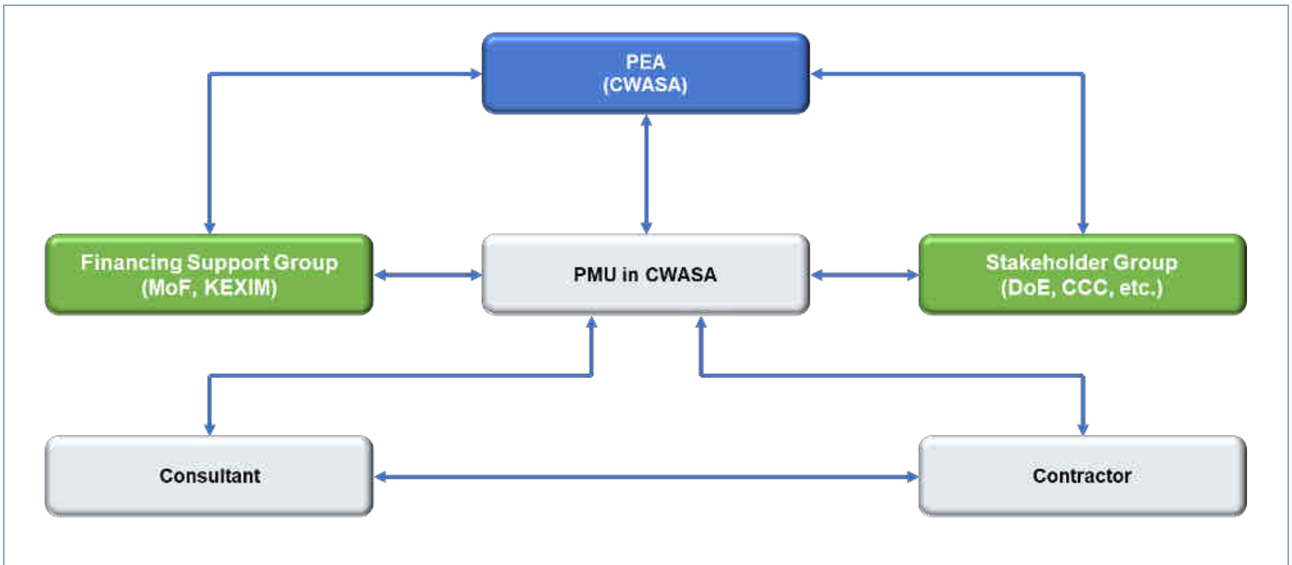


Figure 5-3 Project Organization Structure

5.2.2 Project Management Unit

5.2.2.1 Role of PMU

PMU will act as a key player in this project as well as a coordinator to communicate with relevant authorities. The PMU will be supported by consultants for project management, capacity building, monitoring, and technical supervision support. Consulting firms will be recruited under the project to support project management, design and construction supervision, capacity building, and community awareness.

- Serve as a core unit in project implementation and management
- Plan work activities and budgets based on project implementation schedule
- Manage, prepare and assign administrative works, and human resources
- Manage, review and monitor contract performance of consulting and construction firm
- Coordinate the implementation of environmental and social impact addressing plan
- Manage and review monitoring and evaluation of project implementation
- Coordinate and cooperate with other ministries, institutions, and relevant authorities for the project implementation
- Organize regular meetings to discuss progress with project team-members and all stakeholders including construction firm, consulting firm, development partners, etc.
- Preparation of reports on major issues, such as information documents, environmental social impact assessment reports, financial reports, etc., and reporting to the board of directors, etc.

5.2.2.2 PMU Organization

CWASA plans to establish a project management organization (PMU) during the project implementation period after the loan approval. PMU of the project will be composed of 24 personnel, with a superintending engineer serving as the team leader, engineers in civil, mechanical, electrical & instrumentation, sanitary sewer section and supporting staffs as below.

Table 5-5 Personnel Composition of PMU

No.	Category	No. of Person	Remarks
Technical Staff	Superintending Engineer (Project Director)	1	
	Deputy Project Director	1	
	Executive Engineer	4	
	Assistant Engineer	4	
	Sub-Assistant Engineer	8	
	Sub-Total	18	
Supporting Staff	Office Manager	1	
	Accountant	1	
	Computer Operator	1	
	Office Assistant	2	
	Driver	6	
	Sub-Total	11	
Total		29	

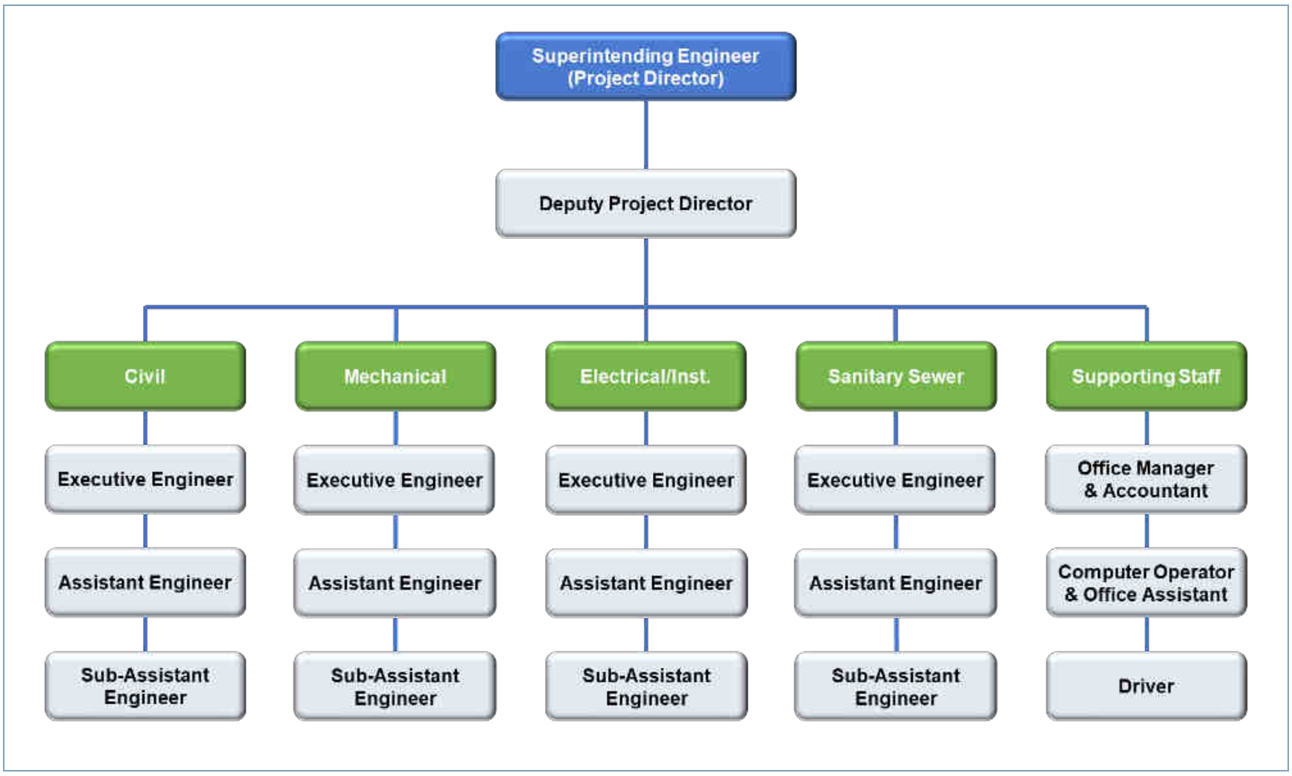


Figure 5-4 PMU Organization Chart

5.2.3 Case Study of PMU in similar project

5.2.3.1 Sanitation Master Plan

It consists of a total of seven employees, including the Chief Engineer proposed in the sewerage master plan, and is composed as follows to perform various tasks such as design and construction supervision.

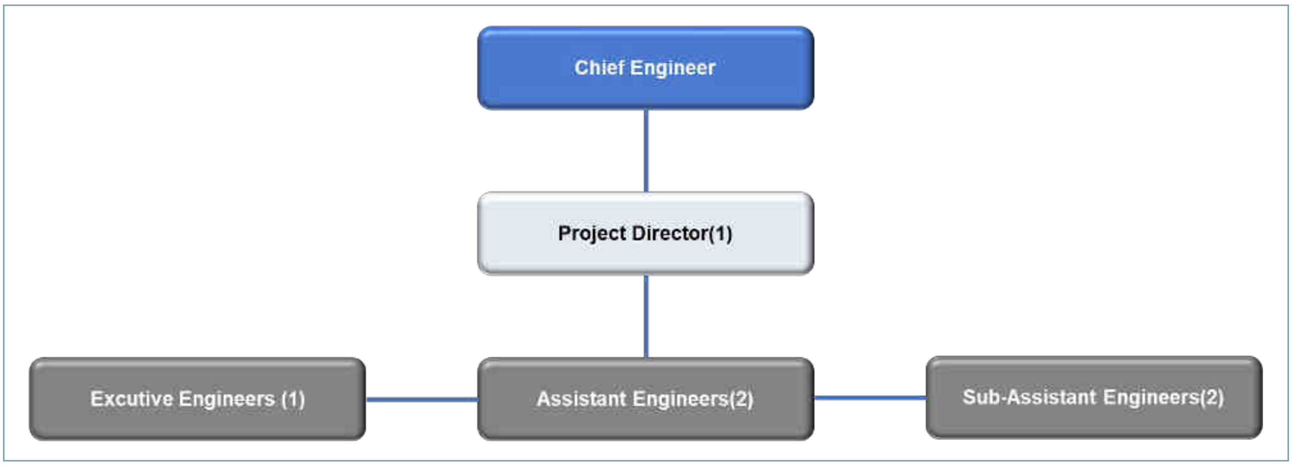


Figure 5-5 PMU composition in Sanitation Master Plan

5.2.3.2 Karnaphuli Water Supply Project (Phase 2) (KWSP-2)

The PMU composition of the Karnaphuli water supply project consisted of a total of 26 people, among which 21 contract workers were composed of 17 assistant engineers, 1 accountant, and 3 office assistant and computer assistants. Among the 22 engineers, 12 were civil engineers, 3 were mechanical engineers, and 7 were electrical engineers in the PMU.

Table 5-6 KWSP-2 PMU

No.	Category	Stay	Non-Stay	Contract Worker	Total	Remarks
1	Chief Engineer (Project Director)	-	1	-	1	Mechanical: 1
2	Superintending Engineer (Deputy Project Director)	1	-	-	1	Mechanical: 1
3	Executive Engineer	-	2	-	2	Civil: 1 Electrical: 1
4	Assistant Engineer	-	1	5	6	Civil: 5 Electrical: 1
5	Sub-Assistant Engineer	-	-	12	12	Civil: 6 Mechanical: 1 Electrical: 5
6	Accountant	-	-	1	1	
7	Office Assistant cum Computer Typist	-	-	3	3	
Total		1	4	21	26	

*Source: CWASA

5.2.3.3 Chattogram Sewerage System Establishment Project (Phase 1) (PESSCM-1)

The PMU composition of the Chattogram Sewerage System Establishment Project (Phase 1) consisted of a total of 17 people, among which 11 contract workers were composed of 7 assistant engineers, 1 driver, 2 office assistants and 1 computer operator. By field, among the 13 engineers, 4 were civil engineers, 4 were mechanical engineers, and 5 were electrical engineers.

Table 5-7 PESSCM-1 PMU

No.	Category	Stay	Non-Stay	Contract Worker	Total	Remarks
1	Chief Engineer (Project Director)	-	1	-	1	Electrical: 1
2	Superintending Engineer (Deputy Project Director)	1	-	-	1	Mechanical: 1
3	Assistant Engineer	1	1	1	3	Mechanical: 1 Electrical: 1
4	Sub-Assistant Engineer	-	2	6	8	Civil: 4 Mechanical: 2 Electrical: 2
5	Computer Operator	-	-	1	1	
6	Driver	-	-	1	1	
7	Office Assistant	-	-	2	2	
Total		2	4	11	17	

*Source: CWASA

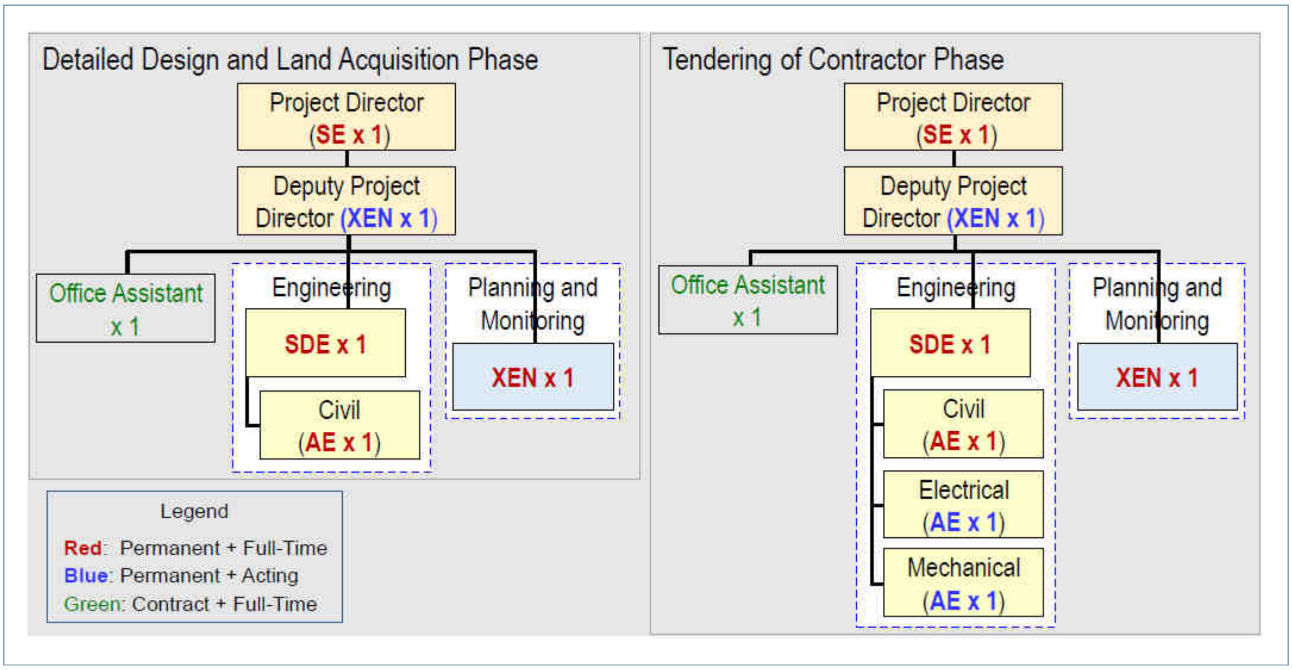
5.2.3.4 Chattogram Sewerage System Establishment Project (Catchment 2&4)

The PMU of the Chattogram sewage system establishment project (Catchment 2&4), which is undergoing a feasibility study, was divided into detailed design stage, bidding stage, and construction stage, and consisted of 41 people.

Table 5-8 Catchment 2&4 PMU

No.	Category	Detailed Design			Bidding			Construction			Total
		Stay	Non-Stay	Contract Worker	Stay	Non-Stay	Contract Worker	Stay	Non-Stay	Contract Worker	
1	Superintending Engineer	1	-	-	1	-	-	1	-	-	3
2	Executive Engineer	1	1	-	1	1	-	1	1	-	6
3	Assistant Engineer	1	-	-	1	-	-	1	-	-	3
4	Assistant Engineer	1	-	-	1	2	-	1	2	3	10
5	Sub-Assistant Engineer	-	-	-	-	-	-	-	3	9	12
6	Accountant	-	-	-	-	-	-	1	-	-	1
7	Computer Operator	-	-	-	-	-	-	-	-	1	1
8	Driver	-	-	-	-	-	-	-	-	-	1
9	Office Assistant	-	-	1	-	-	1	-	-	2	4
Total		4	1	4	4	3	1	5	6	16	41

*Source: JICA Survey Team



*Source: JICA Survey Team

5.3 Project Readiness

5.3.1 Readiness of PEA

5.3.1.1 Organization & Project Experience

5.3.1.1.1 Organization

CWASA has a total of 1,624 employees, 79% of which are technical and support teams. In carrying out this project, it is judged that there will be no setbacks in project management, supervision, detailed design direction determination, and technical support for construction.

Table 5-9 CWASA Employee Composition

Category	Total	Overall	Inspection	Finance	Management	Technology	Operate
Total	1,624	5	17	117	193	451	841
Leader	72	1	3	14	13	24	17
Member	1,552	4	14	103	180	427	824
Composition Ratio (%)	100.0	0.3	1.0	7.2	11.9	27.8	51.8

5.3.1.1.2 Project Experience

Since its establishment, CWASA has been steadily carrying out loan projects related to water supply and sewage, and is currently ready to carry out six sewage treatment zones at the same time. Therefore, it is judged that there will be no difficulties in carrying out this project in CWASA.

5.3.1.2 Readiness of PEA

CWASA plans to establish a project management organization (PMU) during the project implementation period after the loan approval. PMU of the project will be composed of 24 personnel, with a chief engineer serving as the team leader, engineers in civil, mechanical, electrical & instrumentation, sanitary sewer section and supporting staffs.

5.3.2 Land Acquisition & Resettlement

Proposed site of sewage treatment plant has been owned by CWASA since 1960s, so the land acquisition is not required. However, there are illegal residents in the proposed site even though there no schools and mosques, resettlement action plan should be prepared by CWASA during the project implementation.

There is no requirement for the buffer zone from STP to the resident area in the environmental regulation of Bangladesh, odour control facility will be constructed in the STP and odour mitigation measures shall be analyzed in the ESIA during the project implementation.

Table 5-10 Land Use of Sewage Treatment Plant Site

No.	Category	Total	A1	A2	A3	Remarks
1	Common House (Tin-roofed)	49	9	6	34	
2	Common House (Brick building)	11	2	5	4	
3	Cattle Farm	8	-	3	5	
4	Two-story Building	2	-	2	-	
5	Three-story Building	2	-	-	2	
6	One-story Building	1	1	-		
7	CWASA Storage	1	-	1	-	
8	School	1	1	-	-	
9	Toilet	1	1	-	-	
10	Religious Facility	2	1	1	-	
11	Cemetery	4	3	1	-	
12	Pond	25	-	-	-	
13	Khal	1	-	-	-	
14	Dirt Road	3	-	-	-	
15	Paved Road	4	-	-	-	
16	BFS Road	1	-	-	-	
17	RCC Road	2	-	-	-	
18	RHD Road	1	-	-	-	
19	Railroad	1	-	-	-	
20	Forest	-	-	-	-	
21	Bridge	2	-	-	-	
22	Culvert	-	-	-	-	
23	Street Lamp	26	-	-	-	
24	Tree	5000 +	-	-	-	
25	Rice Field	210	-	-	-	

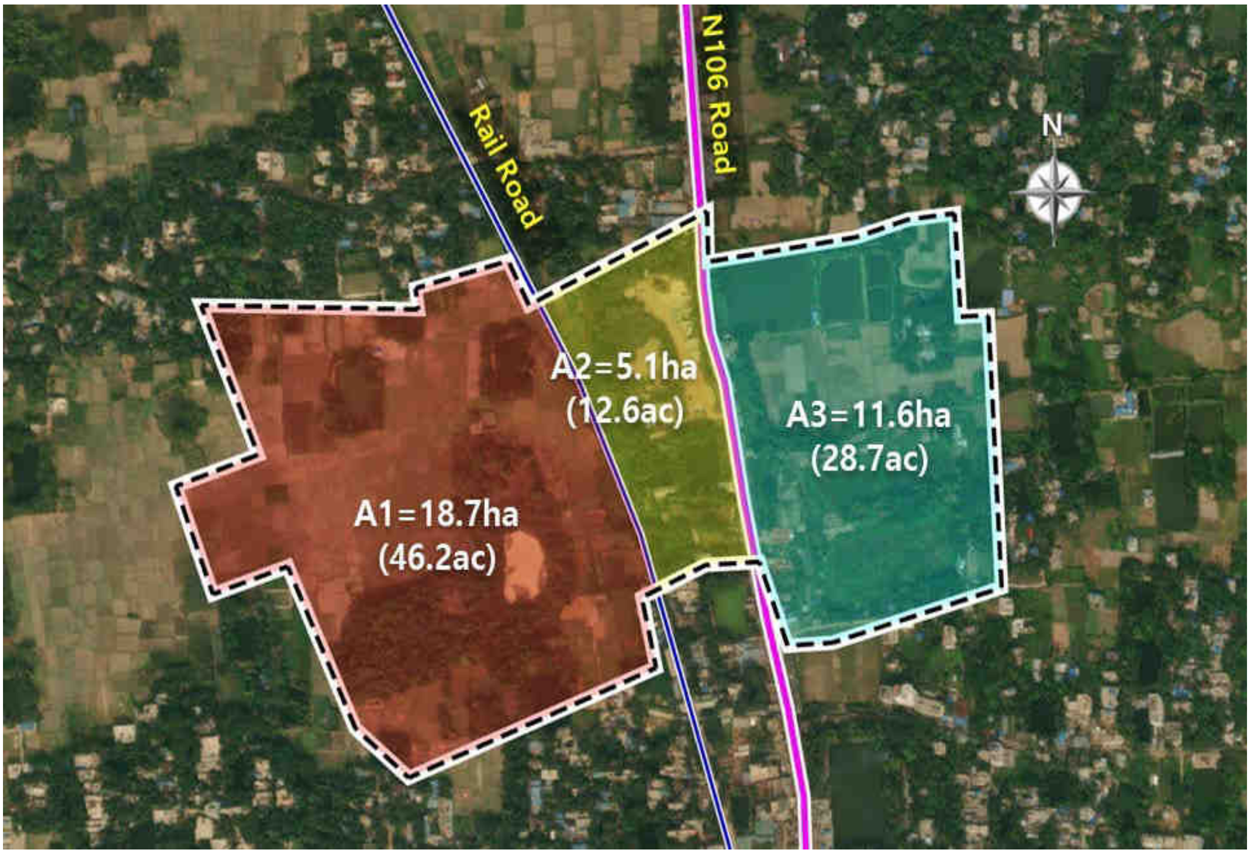


Figure 5-6 Proposed Site of Sewage Treatment Plant

6 Project Cost Estimate

6.1 Introduction

6.1.1 General

Project cost is estimated at US dollar (USD) in accordance with 'EDCF Feasibility Study Guideline (March 2022)' and it is classified into EDCF portion and Government of Bangladesh portion.

Project cost is composed of direct project cost and indirect project cost. Components of direct project cost are construction cost, commissioning & training cost, O&M support cost after construction completion, consulting service cost, physical and price contingencies. Components of indirect project cost are Taxes & duties, land acquisition & resettlement cost, project management cost and EDCF service charge.

- Construction cost includes the material and construction costs of the sewerage system such as sewage treatment plant, sanitary sewer, Household Connection, faecal sludge treatment plant, O&M vehicle.
- Commissioning & Training cost covers the training of the operating staffs and commissioning of sewerage system for six months before construction completion.
- O&M support cost covers the training of the operating staffs for two years after construction completion.
- Consulting service cost covers a) remuneration of foreign and local engineers and b) out-of-pocket expenses during the detailed design, bidding support and construction supervision.
- Contingencies are made up of physical and price contingencies.
    - Physical contingency is calculated as 2 % of a total amount of EDCF loan.
    - Price contingency is calculated as 2 % of a total amount of EDCF loan.
- Tax and duties cover Value Added Tax, Advance Income Tax and Custom Duty.
- Land acquisition and resettlement cost covers the land acquisition cost of proposed site of STP and resettlement cost for the local residents.
- Project management cost covers the remuneration & out-of-pocket expenses of PMU during project implementation period.
- EDCF service charge is the loan handling fee to operate the EDCF loan and it is estimated as 0.1% of a total amount of EDCF loan.

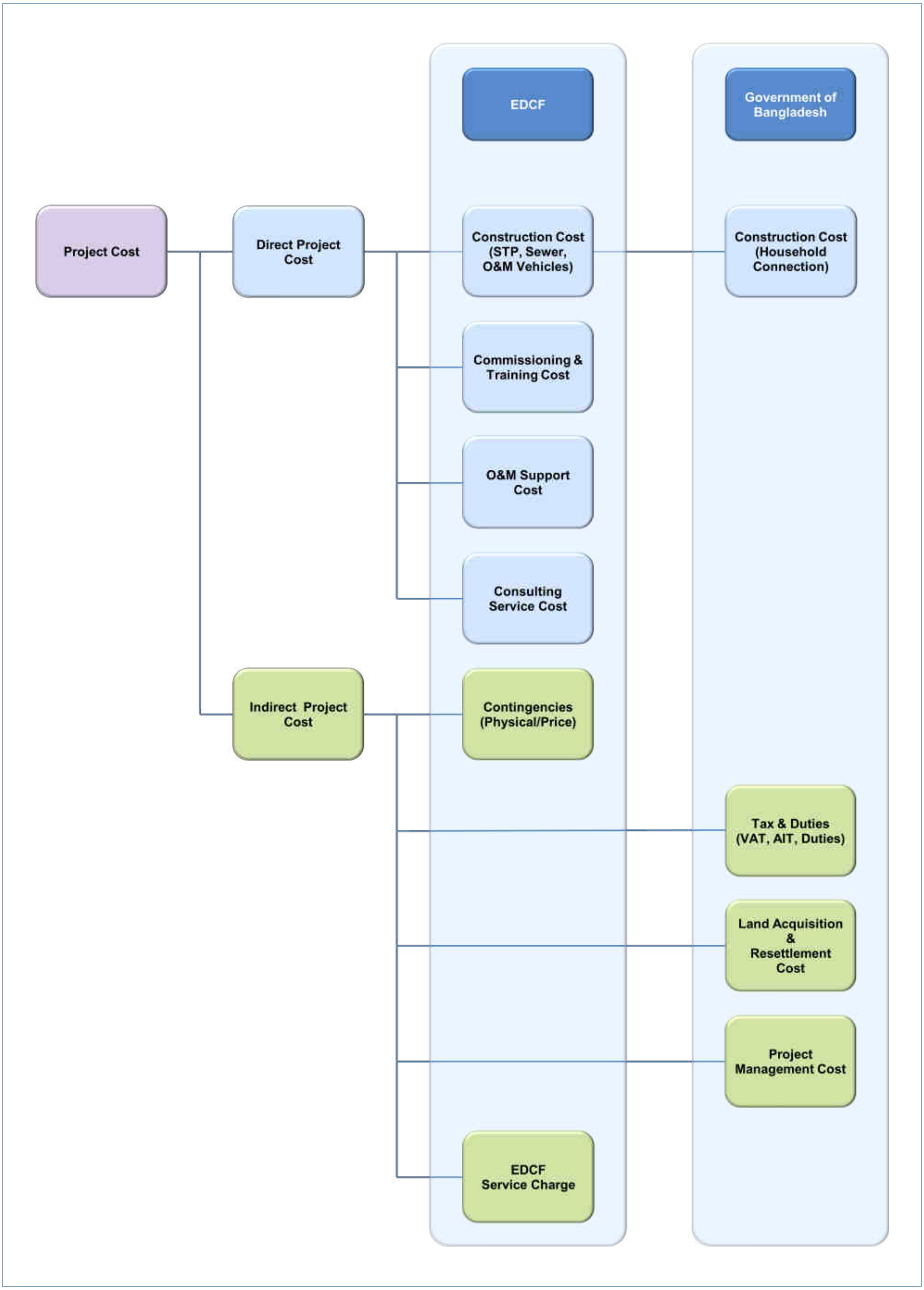


Figure 6-1 Project Cost Composition

6.1.2 Exchange Rate

6.1.2.1 Related Guide line

Applying the exchange rate of the 'EDCF Feasibility Study Guideline (March 2022)' for the project cost is as follows.

- KRW to USD: Average basic rate of exchange for previous 30 calendar days from the F/S contract from KEB Hana Bank as a final quote notification
- BDT to USD: Average basic rate of exchange for previous 30 calendar days from the F/S contract from KEB Hana Bank as a final quote notification
- In the case of an unnoticed exchange rate, KEB Hana Bank's unnoticed exchange rate for the same period
- However, if the exchange rate fluctuates by 3% or more compared to the exchange rate calculated by the above method during the F/S period, the latest applicable exchange rate (average basic rate of exchange for 15 days) may be applied.

6.1.2.2 Exchange Rate

In comparison of exchange rate between the average of previous 30 days (02.08.22~01.09.22) from the F/S contract (01.09.22) and the current day (10.05.23), exchange rate is fluctuated 0.3% for KRW to USD, 11.9% for KRW to BDT, and 13.1% for USD to BDT. In this project, the average exchange rate of previous 30 days from the date of F/S contract is applied in accordance with EDCF guideline.

- 1 USD = 94.95 BDT
- 1 USD = 1,325.50 KRW
- 1 BDT = 13.96 KRW

Table 6-1 Exchange Rate

Category	USD/KRW	BDT/KRW	USD/BDT	Remark
Average Rate (02.08.22~01.09.222)	1,325.50	13.96	94.95	Average of previous 30 calendar days from the F/S contract
Exchange Rate (10.05.23)	1,321.00	12.30	107.40	
Fluctuation Rate	-0.3%	-11.9%	13.1%	
Exchange Rate of the Project	1,325.50	13.96	94.95	

*Source: KEB Hana Bank

6.1.3 Project Cost Components by Currency

Project cost components by currency is prepared in accordance with 'EDCF Feasibility Study Guideline (March 2022)' and it is classified into EDCF and Government of Bangladesh with the consideration of place of origin of materials and equipment and construction works of the sewerage system. In the feasibility study, it is not possible to specify the place of origin of the mechanical, electrical and instrumentation equipment, so it is planned to procure 70% of in foreign currency (Korea) and 30% in third countries.

Table 6-2 Project Cost Components by Currency

<table>
<tr><th rowspan="3" colspan="2">Category</th><th colspan="3">EDCF</th><th rowspan="3">GOB</th></tr>
<tr><th colspan="2">Foreign</th><th rowspan="2">Local</th></tr>
<tr><th>Korea</th><th>3rd Countries</th></tr>
<tr><td rowspan="4">Construction Cost</td><td>Civil Works</td><td>• Overhead & profit
• Sanitary Sewer (GRP)</td><td></td><td>• Ready-mixed concrete
• Reinforcing bar
• Aggregates & other construction materials
• Earthworks, structural works and trench works
• Pavement works
• Architectural works
• Landscaping works
• Sanitary Sewer (HDPE)
• Manhole</td><td>• Construction Cost (Household Connection)</td></tr>
<tr><td>Mechanical Works</td><td colspan="2">• Pre-treatment facility (Sludge, Faecal Sludge)
• Inlet pumping station facility
• Biological reactor facility
• Sedimentation facility
• Sludge thickening facility
• Sludge dewatering facility
• Odour control facility
• Chemical dosing facility</td><td>• Local transport
• Piping & Installation</td><td></td></tr>
<tr><td>Electrical Works</td><td colspan="2">• Incoming power facility
• Power distribution system
• Stand-by power system
• Power control facility</td><td>• Local transport
• Piping & Installation</td><td></td></tr>
<tr><td>Instrumentation Works</td><td colspan="2">• Monitoring and control facility
• Measuring instrument</td><td>• Local transport
• Piping & Installation</td><td></td></tr>
<tr><td colspan="2">Others</td><td>• Commissioning & Training cost
• O&M support after construction completion
• Consulting service cost
• Contingencies (physical/price)
• EDCF service charge</td><td>• Contingencies (physical/price)</td><td>• Consulting service cost
• Commissioning & Training cost
• O&M support after construction completion
• Contingencies (physical/price)</td><td>• Taxes & duties
• Land acquisition & resettlement cost
• Project management cost</td></tr>
</table>

Note) Project cost component is subject to change during the detailed design stage & construction stage.

6.2 Direct Project Cost

Direct project cost is composed of construction cost, commissioning & training cost, O&M support cost after construction completion and consulting service cost.

6.2.1 Construction Cost

6.2.1.1 General

Construction Cost has been prepared for the sewerage system of the project scope for civil works, architectural works, mechanical works, electrical works and Instrumentation works incorporated with carry the construction materials and equipment into the site, site preparation, mobilization, dismantle work etc. Construction cost also involves earthwork for excavation, filling of earth, concrete, Pipe work, Pilling work, internal road works, installation of mechanical equipment and electrical equipment etc. There are some Indirect Cost accounted for Construction cost such as contractor's overhead & profit as per the International and Bangladesh applicable regulations.

Construction cost is estimated according to common engineering practices by multiplying of unit rates of respective component with quantities. Bills of quantities are prepared based on the preliminary design deliverables such as process calculation of sewage treatment plants, hydraulic calculation of sanitary sewer, preliminary design drawings.

Calculation of the unit rates of respective component is estimated based on relevant data on costs of labour, materials, consumables, equipment and estimates for general items collected in Bangladesh and at international market.

6.2.1.2 Preliminary

Construction preparation cost of the contractor are directly related to the running of the project that are not accounted for construction works such as performance bond, insurance, site office & vehicles, etc. are included in the Preliminary category of the Bills of Quantities.

6.2.1.3 Civil & Architectural Works

The basic cost of each major type of civil and construction work was calculated by referring to on-going sewerage project in Chattogram and the schedule of rates updated by different department of Bangladesh. In some cases, analysis of rates has conducted due to unobtainability of rate prepared by different department.

Although Chattogram Water Supply and Sewerage Authority (CWASA) doesn't have the Schedule of rates, Consultant has followed some alternative sources items rate for construction materials, labor, equipment, etc., The sources of basic data are as follows.

- Public Works Department (PWD), Bangladesh schedules of rates (2022)
- Local Government Engineering Department (LGED), Bangladesh schedules of rates (2022)
- Roads & Highways Department (RHD), Bangladesh schedules of rates (2022)
- Bangladesh Water Development Board (BWDB), Bangladesh schedules of rates (2022)
- Bangladesh Bureau of Statistics report (2022.12)
- Material & Equipment supply rates from Vendors in International Market

The construction cost of trenchless method is estimated by applying the quotation of a Korean specialized company because there was no company in Bangladesh that could perform the construction of trenchless. The cost of materials was calculated by applying the average of the estimated cost of Korean companies, and by applying 5% of the cost of ocean transportation and insurance as other expenses.

6.2.1.4 Mechanical, Electrical & Instrumentation Work

Mechanical, electrical & instrumentation works are estimated based on the quotation from various manufacturers. Average rate of quotation is adopted for basic cost. In the feasibility study, it is not possible to specify the place of origin of the mechanical, electrical and instrumentation equipment, so it is planned to procure 70% of in foreign currency (Korea) and 30% in third countries (OECD members). Other costs of imported equipment were calculated by applying the following rates.

- Shipping and Insurance: 5.0%
- Local Transportation: 1.5%
- Installation: 10.0%
- Pipes and accessories: 15.0%

6.2.1.5 Overheads

Overheads are costs that are not directly required to complete the construction object, but are incurred to manage the construction, and include the following items:

- Head office costs: stationery, stamps, Communications cost, depreciation of office owned furniture's, head office salaries, Legal consultation.
- Head office building: rent, lighting, heating, depreciation, repairs, insurances, etc.
- Finance costs: interest on bank overdrafts, bank charges, etc

In general, 3.5% of indirect cost is applied to local construction performed by a local company in Bangladesh, but 10% of the construction cost was applied as indirect cost considering the characteristics of this project, which is constructed by a Korean company as an EDCF loan project.

6.2.1.6 Profits

In general, 10% profit is applied to local construction performed by a local company in Bangladesh, but 15% of the construction cost was applied as profit considering the characteristics of this project, which is constructed by a Korean company as an EDCF loan project.

6.2.1.7 Construction Cost

Construction cost of the sewerage system of the project scope for civil works, architectural works, mechanical works, electrical works and Instrumentation works is estimated at US$ 162,106 thousands.

Table 6-3 Construction Cost

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Korea	3rd Countries				
1. Construction Cost	37,532	7,114	110,945	155,591	6,515	162,106
1.1 Preliminary	276	-	1,566	1,842	-	1,842
1.2 Sewage Treatment Plant	20,277	7,114	30,290	57,681	-	57,681

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Korea	3rd Countries				
a) Civil Works	2,923	-	16,561	19,484	-	19,484
b) Architectural Works	755	-	4,280	5,035	-	5,035
c) Mechanical Works	11,275	4,832	5,120	21,227	-	21,227
d) Electrical Works	3,316	1,421	3,135	7,872	-	7,872
e) Instrumentation Works	2,009	861	1,194	4,064	-	4,064
1.3 Sanitary Sewer	16,979	-	78,269	95,248	-	95,248
a) Trunk Sewer	9,622	-	41,927	51,549	-	51,549
- Open Trench	397	-	709	1,106	-	1,106
- Trenchless	9,224	-	41,218	50,442	-	50,442
b) Primary Sewer	6,380	-	30,802	37,182	-	37,182
- Open Trench	3,766	-	15,994	19,760	-	19,760
- Trenchless	2,613	-	14,808	17,421	-	17,421
c) Secondary Sewer	978	-	5,540	6,518	-	6,518
- Open Trench	978	-	5,540	6,518	-	6,518
1.4 Household Connection	-	-	-	-	6,515	6,515
1.5 O&M Vehicles	-	-	820	820	-	820

6.2.2 Commissioning & Training Cost

Commissioning & Training cost covers the training of the operating staffs and commissioning of sewerage system for six months before construction completion. The cost consists of: a) remuneration for engineers, b) direct cost and c) out-of-pocket expenses. The remuneration is based on 18 M/M of foreign engineer and 24 M/M of local engineer in accordance with mobilization plan.

Table 6-4 Commissioning & Training Cost

Description	Description	Cost (US$ thousands)		
		Foreign	Local	Total
Remuneration	Mobilization of experts	295	111	406
Direct Cost	Water quality analysis	-	720	720
Out-of-Pocket Expenses	Per-diem Allowances, Accommodation, Air Fare, Rental Car	125	-	125
Total		420	831	1,251

6.2.3 O&M Support Cost after Construction Completion

O&M support cost covers the training of the operating staffs for two years after construction completion of the project for two years in order to enhance the project effectiveness. The cost consists of: a) remuneration for engineers, b) out-of-pocket expenses. The remuneration is based on 72 M/M of foreign engineer and 96 M/M of local engineer in accordance with mobilization plan.

Table 6-5 O&M Support Cost after Construction Completion

Description	Description	Cost (US$ thousands)		
		Foreign	Local	Total
Remuneration	Mobilization of experts	1,179	444	1,623
Out-of-Pocket Expenses	Per-diem Allowances, Accommodation, Air Fare, Rental Car	473	-	473
Total		1,652	444	2,096

6.2.4 Consulting Service Cost

Consulting service cost consisting of detailed design, bidding support and construction supervision is calculated based on followings.

- It is calculated by adding up the direct labor cost calculated based on the manpower required for each task (detailed design & bidding support, construction supervision, etc.).
- Consulting service cost is US$ 13,166 thousands, of which 77.9% is allocated to remuneration of foreign staffs including project manager in each area of expertise and relevant direct costs, and of which 22.1% is distributed to remuneration of local staffs having responsibility of assistance work and direct cost in connection with field survey works, i.e., topographic survey, household connection survey, geotechnical investigation, water quality survey, etc.
- Man-month rate of foreign staff is computed by combing Unit Labor Cost of Engineers (Korean Engineering & Consulting Association, 2022), technical cost, which is 110 % of the Unit Labor Cost of Engineers, and overhead & profit, which is 30 % of the Unit Labor Cost of Engineer and technology fee. The rate of local engineers is based on local market survey.

Table 6-6 Consulting Service Cost

Category		Staff Input (Man-Month)			Cost (US$ thousands)		
		Foreign	Local	Sub-Total	Foreign	Local	Total
Remuneration	Foreign Staff	191	306	497	8,721	-	8,721
	Local Staff	180	318	498	-	2,031	2,031
	Sub-Total	371	624	995	8,721	2,031	10,752
Out-of-Pocket Expenses		Topographical Survey & Household Connection Survey			-	100	100
		Geotechnical Investigation			-	100	100
		Water Quality Survey			-	100	100
		FEIA			-	300	300
		Business Trip			1,534	-	1,534
		Other Expense			-	280	280
		Sub-Total			1,534	880	2,414
Total					10,255	2,911	13,166

In this F/S, total 995 M/M (foreign staff 497 M/M, local staff 498 M/M) of professional staff will be mobilized during 64 months for the project implementation period (16 months for detailed design & bidding support, 48 months for construction supervision). In the detailed design and bidding support Phase, it is planned to input 371 M/M (foreign staff 191 M/M, local staff 180 M/M). In the construction supervision stage, it is planned to input 624 M/M (foreign staff 306 M/M, local staff 318 M/M).

Table 6-7 Summary of Mobilization Plan

Phase	Category	Input (M/M)		
		Home	Field	Total
Detailed Design & Bidding Support	Foreign Staff	93	98	191
	Local Staff	-	180	180
	Sub-Total	93	278	371
Construction Supervision	Foreign Staff	-	306	306
	Local Staff	-	318	318
	Sub-Total	-	624	624
Total	Foreign Staff	93	404	497
	Local Staff	-	498	498
	Total	93	902	995

6.2.5 Direct Project Cost

Direct project cost is estimated at US$ 178,619 thousands, which includes construction cost, commissioning & training cost, O&M support cost after construction completion and consulting service cost.

Table 6-8 Direct Project Cost (US$ thousands)

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Korea	3rd Countries				
1. Construction Cost	37,532	7,114	110,945	155,591	6,515	162,106
1.1 Preliminary	276	-	1,566	1,842	-	1,842
1.2 Sewage Treatment Plant	20,277	7,114	30,290	57,681	-	57,681
a) Civil Works	2,923	-	16,561	19,484	-	19,484
b) Architectural Works	755	-	4,280	5,035	-	5,035
c) Mechanical Works	11,275	4,832	5,120	21,227	-	21,227
d) Electrical Works	3,316	1,421	3,135	7,872	-	7,872
e) Instrumentation Works	2,009	861	1,194	4,064	-	4,064
1.3 Sanitary Sewer	16,979	-	78,269	95,248	-	95,248
a) Trunk Sewer	9,622	-	41,927	51,549	-	51,549
- Open Trench	397	-	709	1,106	-	1,106
- Trenchless	9,224	-	41,218	50,442	-	50,442
b) Primary Sewer	6,380	-	30,802	37,182	-	37,182
- Open Trench	3,766	-	15,994	19,760	-	19,760
- Trenchless	2,613	-	14,808	17,421	-	17,421
c) Secondary Sewer	978	-	5,540	6,518	-	6,518
- Open Trench	978	-	5,540	6,518	-	6,518
1.4 Household Connection	-	-	-	-	6,515	6,515
1.5 O&M Vehicles	-	-	820	820	-	820
2. Commissioning & Training	420	-	831	1,251	-	1,251
3. O&M Support	1,652	-	444	2,096	-	2,096
4. Consulting Service	10,255	-	2,911	13,166	-	13,166
4.1 Detailed Design & Bidding Support	3,938	-	1,462	5,400	-	5,400
4.2 Construction Supervision	6,317	-	1,449	7,766	-	7,766
5. Direct Project Cost (1+2+3+4)	49,859	7,114	115,131	172,104	6,515	178,619

6.3 Indirect Project Cost

Indirect project cost is composed of contingencies, tax and duties, land acquisition & resettlement cost, project management cost, EDCF service charge.

6.3.1 Contingencies

Contingencies are composed of physical and price contingencies of which are divided into Korea, 3rd countries and local currencies related to the project cost composition in accordance with the GOB internal policy and EDCF guideline.

6.3.1.1 GOB Internal Policy

Contingency of the total project cost is calculated in accordance with internal policy of the GOB as below.

- Physical contingency is calculated as 2 % of a total amount of EDCF loan.
- Price contingency is calculated as 8 % of a total amount of EDCF loan.

6.3.1.2 EDCF Guideline

6.3.1.2.1 Physical Contingencies

Physical contingency is calculated as 5 % of direct project cost to accommodate the difference between the quantities in the F/S stage and the implementation stage due to design changes and material specification change.

6.3.1.2.2 Price Contingencies

Price contingency is calculated by applying the inflation and fluctuation of exchange rate to sum of direct project cost and physical contingency.

- For foreign (Korea): applied the average inflation rate for project implementation period.
- For local (Bangladesh) and third country (OEDC member) currency: applied an aggregate of the average inflation rate for project implementation period and the fluctuation of exchange rate for past 3 years.

For price contingency, the average of inflation rates for the last 3 years is reflected as the inflation rate in 1st year, or commencement year of project implementation period.

Table 6-9 Inflation Rate for the Last 3 Years (%)

Category	2020	2021	2022	Average
Foreign (Korea)	0.54	2.50	5.09	2.71
Local (Bangladesh)	5.69	5.55	7.70	6.31
Foreign (3rd Countries) (OECD Member)	0.73	2.82	8.24	3.93

*Source: World Bank Open Data

The arithmetic means of annual inflation rates for the project preparation and implementation period, computed at compound interest on the basis of the average inflation rate for the last 3 years, is adopted as the inflation rate in this F/S.

- The project implementation period is planned as 104 months including 12 months for project preparation, 4 months for consultant selection, 12 months for detailed design, 4 months for contractor selection, and 48 months for construction work.

Table 6-10 Yearly Average Inflation Rate (%)

Category	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Avg.
Foreign (Korea)	2.71	5.49	8.35	11.29	14.30	17.40	20.58	23.85	26.09	14.45
Local (Bangladesh)	6.31	13.03	20.16	27.75	35.81	44.39	53.50	63.19	70.03	37.13
Foreign (3rd Countries) (OECD Member)	3.93	8.01	12.26	16.67	21.26	26.02	30.97	36.12	39.68	21.66

In addition to the average inflation rate, 50% of average exchange rate of USD to KRW for last 3 years is considered in estimating price contingency of local currency and 3rd Countries according to EDCF Guideline.

Table 6-11 Fluctuation of Exchange Rate

Category	2018	2019	2020	2021	2022	Average	Adopted
Exchange Rate (USD/KRW)	1,100.30	1,165.65	1,180.05	1,144.42	1,291.95		
Exchange Rate Change from Previous Year		65.35	14.40	35.63	147.53		
Fluctuation of Exchange Rate (%)		5.94	1.24	3.02	12.89	5.72	2.86

*Source: Economic Statistics System, Bank of Korea

Price contingencies rate of the project is estimated as below.

Table 6-12 Price Contingencies Rate (%)

Category	Price Contingencies Rate (1+2)	Average Inflation Rate (1)	Fluctuation of Exchange Rate (2)
Foreign (Korea)	14.45	14.45	
Local (Bangladesh)	39.99	37.13	2.86
Foreign (3rd Countries) (OECD Member)	24.52	21.66	2.86

6.3.1.2.3 Contingencies Calculated by EDCF Guideline

Physical contingencies and price contingencies of the project calculated by EDCF guideline are as below.

Table 6-13 Contingencies calculated by EDCF Guideline (US$ thousands)

Category		EDCF				GOB	Total
		Foreign		Local	Sub Total		
		Korea	3rd Countries				
Direct Project Cost		49,859	7,114	115,131	172,104	6,515	178,619
Contingencies	Total	10,060	2,187	54,098	66,345	-	66,345
	Physical Contingencies	2,493	356	5,757	8,606	-	8,606
	Price Contingencies	7,567	1,831	48,341	57,739	-	57,739

6.3.1.3 Contingencies

Contingencies calculated by internal policy of the GOB is applied to the project after discussion with the GOB.

Table 6-14 Contingencies (US$ thousands)

Category		EDCF				GOB	Total
		Foreign		Local	Sub Total		
		Korea	3rd Countries				
EDCF Loan Amount		55,596	7,905	127,937	191,438	-	228,948
Contingencies	Total	5,546	791	12,806	19,143	-	19,143
	Physical Contingencies	1,109	158	2,561	3,828	-	3,828
	Price Contingencies	4,437	633	10,245	15,315	-	15,315

6.3.2 Taxes & Duties

6.3.2.1 Rate of Taxes & Duties

Tax and duties considered in the Project includes Value Added Tax, Advance Income Tax and Custom Duty, which are estimated as per the Bangladesh tax regulation as follows.

- Value Added Tax (VAT): 7.5% of construction cost and 15.0% of consulting service cost
- Advance Income Tax (AIT): 5.0% of construction cost and 10.0% of consulting service cost
- Custom Duty: 25.0% of material and equipment cost of civil, mechanical, electrical and instrumentation works where place of origin is foreign (Korea) or a third country (OECD member)

Table 6-15 Taxes & Duties Rate (%)

Category	Construction Cost		Consulting Service Cost	
	Foreign	Local	Foreign	Local
VAT	7.5	7.5	15.0	15.0
AIT	5.0	5.0	10.0	10.0
Custom Duty	25.0			

6.3.2.2 Taxes & Duties

In accordance with the Framework arrangement between the GOK and GOB concerning loans from EDCF for the years 2021 through 2025 (Oct, 2021), taxes & duties for the implementation of the Projects will be borne by the GOB.

- Article 6.1 Consular fees, duties, taxes and any other charges of a similar nature, as well as the requirements of obtaining import licenses and any other documents of a similar nature on the equipment, machinery and materials imported for the implementation of the Projects shall be exempted or borne by the Bangladesh Government.
- Article 6.2 Taxes including value added tax and other obligatory charges on the equipment, machinery and materials purchased in the People's Republic of Bangladesh for the implementation of the Projects shall be exempted or borne by the Bangladesh Government.

Table 6-16 Taxes & Duties (US$ thousands)

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Korea	3rd Countries				
Taxes & Duties	-	-	-	-	28,092	28,092
VAT	-	-	-	-	13,895	13,895
AIT	-	-	-	-	9,264	9,264
Custom Duty	-	-	-	-	4,933	4,933

6.3.3 Land Acquisition & Resettlement Cost

Proposed site of sewage treatment plant has been owned by CWASA since 1960s, so the land acquisition is not required. However, there are illegal residents in the proposed site even though there no schools and mosques, resettlement action plan should be prepared by CWASA during the project implementation and detail breakdown of the land acquisition & resettlement cost will be estimated through RAP.

In this feasibility, tentative land acquisition & resettlement cost is included in the project cost as below through the discussion with CWASA and it will be borne by the GOB.

Table 6-17 Land Acquisition & Resettlement Cost (US$ thousands)

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Foreign	3rd Countries				
Land Acquisition & Resettlement Cost	-	-	-	-	500	500

6.3.4 Project Management Cost

Project management cost covers the remuneration & out-of-pocket expenses of PMU in CWASA during project implementation period and it will be borne by the GOB.

Table 6-18 Project Management Cost

Category		Number of People	M/M	Unit Cost (US$/M)	Project Management Cost (US$)		
					Total	Remuneration	Out-of-Pocket Expenses
Essential	Project Director	1	92	750	103,500	69,000	34,500
	Deputy Project. Director	1	92	736	135,424	67,712	67,712
	Executive Engineer	4	368	736	541,696	270,848	270,848
	Assistant Engineer	4	368	559	411,424	205,712	205,712
	Sub-Assistant Engr.	8	736	407	599,104	299,552	299,552
	Sub-Total	18	1,656	3,188	1,791,148	912,824	878,324
Support	Office Manager	1	92	407	74,888	37,444	37,444
	Accountant	1	92	407	74,888	37,444	37,444
	Computer Operator	1	92	407	74,888	37,444	37,444
	Office Assistant	2	184	211	77,648	38,824	38,824
	Driver	6	552	280	309,120	154,560	154,560
	Sub-Total	11	1,012	1,712	611,432	305,716	305,716
Total		29			2,402,580	1,218,540	1,184,040

Table 6-19 Project Management Cost (US$ thousands)

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Korea	3rd Countries				
Project Management Cost	-	-	-	-	2,403	2,403

6.3.5 EDCF Service Charge

EDCF service charge is the loan handling fee to operate the EDCF loan and it is estimated as 0.1% of a total amount of EDCF loan and it will be borne by the EDCF.

Table 6-20 EDCF Service Charge (US$ thousands)

Category	EDCF				GOT	Total
	Foreign		Local	Sub Total		
	Korea	3rd Countries				
EDCF Service Charge	191	-	-	191	-	191

6.4 Total Project Cost

6.4.1 Total Project Cost

In the total project cost of US$ 228,948 thousands, the EDCF will provide a loan of US$ 191,438 thousands and the GOB will bear the remaining US$ 37,510 thousands as below.

Table 6-21 Total Project Cost (US$ thousands)

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Korea	3rd Countries				
1. Construction Cost	37,532	7,114	110,945	155,591	6,515	162,106
1.1 Preliminary	276	-	1,566	1,842	-	1,842
1.2 Sewage Treatment Plant	20,277	7,114	30,290	57,681	-	57,681
a) Civil Works	2,923	-	16,561	19,484	-	19,484
b) Architectural Works	755	-	4,280	5,035	-	5,035
c) Mechanical Works	11,275	4,832	5,120	21,227	-	21,227
d) Electrical Works	3,316	1,421	3,135	7,872	-	7,872
e) Instrumentation Works	2,009	861	1,194	4,064	-	4,064
1.3 Sanitary Sewer	16,979	-	78,269	95,248	-	95,248
a) Trunk Sewer	9,622	-	41,927	51,549	-	51,549
- Open Trench	397	-	709	1,106	-	1,106
- Trenchless	9,224	-	41,218	50,442	-	50,442
b) Primary Sewer	6,380	-	30,802	37,182	-	37,182
- Open Trench	3,766	-	15,994	19,760	-	19,760
- Trenchless	2,613	-	14,808	17,421	-	17,421
c) Secondary Sewer	978	-	5,540	6,518	-	6,518
- Open Trench	978	-	5,540	6,518	-	6,518
1.4 Household Connection	-	-	-	-	6,515	6,515
1.5 Faecal Sludge Management	-	-	820	820	-	820
2. Commissioning & Training	420	-	831	1,251	-	1,251
3. O&M Support	1,652	-	444	2,096	-	2,096
4. Consulting Service	10,255	-	2,911	13,166	-	13,166
4.1 Detailed Design & Bidding Support	3,938	-	1,462	5,400	-	5,400
4.2 Construction Supervision	6,317	-	1,449	7,766	-	7,766
5. Direct Project Cost (1+2+3+4)	49,859	7,114	115,131	172,104	6,515	178,619
6. Contingencies	5,546	791	12,806	19,143	-	19,143
6.1 Physical Contingencies	1,109	158	2,561	3,828	-	3,828
6.2 Price Contingencies	4,437	633	10,245	15,315	-	15,315
7. Taxes and Duties	-	-	-	-	28,092	28,092
7.1 Value Added Tax (VAT)	-	-	-	-	13,895	13,895
7.2 Advance Income Tax (AIT)	-	-	-	-	9,264	9,264
7.3 Custom Duties	-	-	-	-	4,933	4,933
8. Land Acquisition & Resettlement Cost	-	-	-	-	500	500
9. Project Management Cost	-	-	-	-	2,403	2,403
10. EDCF Service Charge	191	-	-	191	-	191
11. Total Project Cost (5+6+7+8+9+10)	55,596	7,905	127,937	191,438	37,510	228,948

6.4.2 Financing Plan

Out of the total project cost of US$ 228,948 thousands, US$ 191,438 thousands will be financed through loan from EDCF, of which Korea portion is US$ 55,596 thousands, 3rd Countries portion is US$ 7,905 thousands and local portion is US$ 127,937 thousands while the GOB will bear the remaining US$ 37,510 thousands.

EDCF will provide a loan for the components such as construction cost, commissioning & training cost, O&M support cost, consulting service cost, contingencies, EDCF service charge and GOB will bear the cost for the components such as construction cost for household connection, tax & duties, land acquisition & resettlement cost, project management cost. Financing plan of the project is summarized as follows.

Table 6-22 Financing Plan

Category		EDCF				GOB	Total
		Foreign	3rd Countries	Local	Sub Total		
Total Project Cost (US$ thousands)		55,596	7,905	127,937	191,438	37,510	228,948
Percentage (%)	EDCF	29.0	4.1	66.8	100.0	-	-
	Total	24.3	3.5	55.9	83.6	16.4	100.0

6.4.3 Annual Disbursement Plan

The project is to be implemented over 104 months taking into account the period required for project preparation, consultant selection, detailed design, bidding support, contractor selection and construction supervision. Annual Disbursement plan during project implementation period is as follows.

Table 6-23 Annual Disbursement Plan (US$ thousands)

Category		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
EDCF	1. Construction Cost	-	-	7,780	38,898	38,898	38,898	31,117	-	-	155,591
	2. Commissioning & Training	-	-	-	-	-	-	1,251	-	-	1,251
	3. O&M Support	-	-	-	-	-	-	356	1,048	692	2,096
	4. Consulting Service	-	4,608	1,580	1,580	1,975	1,975	1,448	-	-	13,166
	5. Contingencies	-	-	957	4,786	4,786	4,786	3,828	-	-	19,143
	6. EDCF service Charge	-	5	10	45	46	46	37	1	1	191
	Sub-Total	-	4,613	10,327	45,309	45,705	45,705	38,037	1,049	693	191,438
GOB	1. Construction Cost (Household Connection)	-	-			2,605	1,955	1,955	-	-	6,515
	2. Tax & Duties	-	-	1,405	7,023	7,023	7,023	5,618	-	-	28,092
	3. Land Acquisition & Resettlement Cost	-	500	-	-	-	-	-	-	-	500
	4. Project Management Cost	-	240	360	384	409	409	360	120	121	2,403
	Sub-Total	-	740	1,765	7,407	10,037	9,387	7,933	120	121	37,510
Total Project Cost		-	5,353	12,092	52,716	55,742	55,092	45,970	1,169	814	228,948
Disbursement Rate (%)		-	2.34	5.28	23.03	24.35	24.06	20.08	0.51	0.36	100.00
Cumulative Disbursement Rate (%)		-	2.34	7.62	30.65	54.99	79.06	99.13	99.65	100.00	-

7 Economic & Financial Feasibility Analysis

7.1 Economic Feasibility Analysis

7.1.1 General

Economic feasibility analysis measures project cost and management cost needed for national policy project and estimated economic benefit. This is to analyze whether economic benefit exceeds cost by comparing two factors above.

In economic feasibility analysis, all measurable costs and benefits are measured to decide on validity of project. On the other hand, unmeasurable social benefits cannot be included in adequacy analysis.

Therefore, adequacy of national policy project cannot be judge only with measurable economic benefit, and noneconomic benefit and monetarily unmeasurable benefits should be in consideration to make final conclusion. This analysis uses internal rate of return (IRR) and cost-benefit analysis, which analyzes social profit and cost, to examine economic feasibility of this project.

7.1.2 Analysis Condition

7.1.2.1 Premise

- Analysis standard year: 2023
- Construction period including design period: 2024 ~ 2029 (6 years)
- Operation period of sewage facility: 2030 ~ 2069 (40 years)
- This project is a Phase 1, and benefits are the same after 2040

7.1.2.2 Discount Rate

To decide on economic feasibility of investment, benefits and costs calculated above should be compared but costs occur in early period and benefits in latter period. If benefits and costs of each year are simple added and compared, it would ignore time factor. Therefore, it is needed to turn future benefits and costs into present value and it could be done by discounting future benefits and costs with suitable discount rate.

Discount rate, in theory, is reasonable an expected income rate in present year and as for public enterprise, unlike private enterprise, it cannot use the actual interest of interbank rate as the expected rate of return. (For example, the three-year maturity distribution earning rate for corporate bonds, etc.) Therefore, social discount rate is used for interest rate discounting benefits and costs into present value.

Discount rate is generally set lower than market rate because the one who uses social discount rate to evaluate project validity normally becomes government and government would evaluate importance of future projects higher.

In the EDCF Feasibility Study Guideline (March, 2022), it is recommended to apply a discount rate of 9% for the economic feasibility analysis, the GOB have internal policy to apply a discount rate of 12% for the foreign funded projects.

In this feasibility study, discount rate of 12% is applied in the consideration of the GOB internal policy.

7.1.2.3 Inflation

In case of analyzing cost and benefits, when evaluating costs and benefits occurring in a period of time in future, a problem about how to handle effects of inflation occurs. But in this analysis, future benefits and costs are assumed as constant price of standard year to ignore inflation effect. That is because expecting future inflation is impossible and even if unexpected inflation occurs, it effects identically on costs and benefits, giving no change to net present value.

7.1.3 Analysis Method

7.1.3.1 General

Economic feasibility analysis is compared and analyzed by converting cost and benefit into monetary value to estimate economic feasibility. In the process of analysis, there is low chance for supervision of examiner to intervene and comparable cost and benefit are analyzed with uniform scale.

Benefit/cost ratio (B/C), net present value (NPV), and internal rate of return (IRR) are generally used for evaluation index of economic analysis.

7.1.3.2 Benefit/Cost Analysis (B/C)

Benefit/cost ratio is divided value of present value for total estimated benefit divided by present value of total estimated cost. It is considered to be economic if B/C ≥ 1.

Benefit-Cost Ratio (B/C ratio) = $$\sum_{t=0}^{n} \frac{B_t}{(1+r)^t} \Big/ \sum_{i=0}^{n} \frac{C_t}{(1+r)^t}$$

where,

- B_t = Present Value of Benefit
- C_t = Present Value of Cost
- r = Discount rate
- n = Number of Years of Project Endurance

7.1.3.3 Net Present Value Analysis (NPV)

Net present value equals present value for total estimated benefit subtracted by present value of total estimated cost. It is considered to be economic if NPV ≥ 0.

Net Present Value (NPV) = $$\sum_{t=0}^{n} \frac{B_T}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_T}{(1+r)^t}$$

7.1.3.4 Internal Rate of Return Analysis (IRR)

Internal rate of return equals present value for total estimated benefit being equal with present value of total estimated cost (NPV = 0). It is considered to be economic if IRR is greater than social discount rate.

Internal Rate of Return Analysis (IRR) = $\sum_{t=0}^{n} \frac{B_T}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_T}{(1+r)^t}$

7.1.3.5 Comparison between strengths and weaknesses of analysis methods

Strengths and weaknesses of benefit/cost analysis, net present value, and internal rate of return analysis methods are roughly shown below

Table 7-1 Comparison of method for economic feasibility analysis

Analysis method	Judgment	Strength	Weakness
Benefit/Cost Analysis	B/C ≥ 1	• Easily understandable • Project scale considered • Benefit/cost occurring considered	• Difficult to clearly differentiate between benefit and cost • Possibility of error occurrence of mutually exclusive method selection • Social discount rate realization
Net Present Value	NPV ≥ 0	• Specific standard suggested when alternatives are chosen • Present value of future benefit suggested • Limited net present value considered • Usable in other analysis	• Difficult to clearly realize discount rate • Difficulty in understanding • Possibility of error in alternative priority selection
Internal Rate of Return	IRR ≥ r	• Able to measure profitability of project • Comparable with other methods • Evaluation process result is easily understandable	• Does not consider absolute scale of project • Possibility of multiple internal rates of return occurrence

7.1.3.6 Economic feasibility analysis method applied in this project

As shown in table above, in analysing economic feasibility, many methods such as benefit/cost ratio, new present value, and internal rate of return could be used but, in this project, economic feasibility would be analysed by widely used benefit/cost ratio analysis.

7.1.4 Cost Estimate

7.1.4.1 Project Cost Estimate

In the total project cost of US$ 228,948 thousands, the EDCF will provide a loan of US$ 191,438 thousands and the GOB will bear the remaining US$ 37,510 thousands as below.

Table 7-2 Total Project Cost (US$ thousands)

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Korea	3rd Countries				
1. Construction Cost	37,532	7,114	110,945	155,591	6,515	162,106
1.1 Preliminary	276	-	1,566	1,842	-	1,842
1.2 Sewage Treatment Plant	20,277	7,114	30,290	57,681	-	57,681
a) Civil Works	2,923	-	16,561	19,484	-	19,484
b) Architectural Works	755	-	4,280	5,035	-	5,035
c) Mechanical Works	11,275	4,832	5,120	21,227	-	21,227
d) Electrical Works	3,316	1,421	3,135	7,872	-	7,872
e) Instrumentation Works	2,009	861	1,194	4,064	-	4,064
1.3 Sanitary Sewer	16,979	-	78,269	95,248	-	95,248
a) Trunk Sewer	9,622	-	41,927	51,549	-	51,549
- Open Trench	397	-	709	1,106	-	1,106
- Trenchless	9,224	-	41,218	50,442	-	50,442
b) Primary Sewer	6,380	-	30,802	37,182	-	37,182
- Open Trench	3,766	-	15,994	19,760	-	19,760
- Trenchless	2,613	-	14,808	17,421	-	17,421
c) Secondary Sewer	978	-	5,540	6,518	-	6,518
- Open Trench	978	-	5,540	6,518	-	6,518
1.4 Household Connection	-	-	-	-	6,515	6,515
1.5 Faecal Sludge Management	-	-	820	820	-	820
2. Commissioning & Training	420	-	831	1,251	-	1,251
3. O&M Support	1,652	-	444	2,096	-	2,096
4. Consulting Service	10,255	-	2,911	13,166	-	13,166
4.1 Detailed Design & Bidding Support	3,938	-	1,462	5,400	-	5,400
4.2 Construction Supervision	6,317	-	1,449	7,766	-	7,766
5. Direct Project Cost (1+2+3+4)	49,859	7,114	115,131	172,104	6,515	178,619
6. Contingencies	5,546	791	12,806	19,143	-	19,143
6.1 Physical Contingencies	1,109	158	2,561	3,828	-	3,828
6.2 Price Contingencies	4,437	633	10,245	15,315	-	15,315
7. Taxes and Duties	-	-	-	-	28,092	28,092
7.1 Value Added Tax (VAT)	-	-	-	-	13,895	13,895
7.2 Advance Income Tax (AIT)	-	-	-	-	9,264	9,264
7.3 Custom Duties	-	-	-	-	4,933	4,933
8. Land Acquisition & Resettlement Cost	-	-	-	-	500	500
9. Project Management Cost	-	-	-	-	2,403	2,403
10. EDCF Service Charge	191	-	-	191	-	191
11. Total Project Cost (5+6+7+8+9+10)	55,596	7,905	127,937	191,438	37,510	228,948

7.1.4.1.1 Project Cost for Economic Feasibility Analysis

In the economic feasibility analysis, project cost excluding the price contingencies, tax & duties are considered only according to the EDCF guideline.

Table 7-3 Project Cost for Economic Feasibility Analysis (US$ thousands)

Category	EDCF				GOB	Total
	Foreign		Local	Sub Total		
	Korea	3rd Country				
1. Total Project Cost	55,596	7,905	127,937	191,438	37,510	228,948
2. Price Contingencies	4,437	633	10,245	15,315	-	15,315
3.Tax & Duties	-	-	-	-	28,092	28,092
Applied Cost	51,159	7,272	117,692	176,123	9,418	185,541

7.1.4.1.2 Annual Disbursement Plan

The project is to be implemented over 104 months taking into account the period required for project preparation, consultant selection, detailed design, bidding support, contractor selection and construction supervision. Annual Disbursement plan during project implementation period is as follows.

Table 7-4 Annual Disbursement Plan (US$ thousands)

Category		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
EDCF	1. Construction Cost	-	-	7,780	38,898	38,898	38,898	31,117	-	-	155,591
	2. Commissioning & Training	-	-	-	-	-	-	1,251	-	-	1,251
	3. O&M Support	-	-	-	-	-	-	356	1,048	692	2,096
	4. Consulting Service	-	4,608	1,580	1,580	1,975	1,975	1,448	-	-	13,166
	5. Contingencies	-	-	957	4,786	4,786	4,786	3,828	-	-	19,143
	6. EDCF service Charge	-	5	10	45	46	46	37	1	1	191
	Sub-Total	-	4,613	10,327	45,309	45,705	45,705	38,037	1,049	693	191,438
GOB	1. Construction Cost (Household Connection)	-	-			2,605	1,955	1,955	-	-	6,515
	2. Tax & Duties	-	-	1,405	7,023	7,023	7,023	5,618	-	-	28,092
	3. Land Acquisition & Resettlement Cost	-	500	-	-	-	-	-	-	-	500
	4. Project Management Cost	-	240	360	384	409	409	360	120	121	2,403
	Sub-Total	-	740	1,765	7,407	10,037	9,387	7,933	120	121	37,510
Total Project Cost		-	5,353	12,092	52,716	55,742	55,092	45,970	1,169	814	228,948
Disbursement Rate (%)		-	2.34	5.28	23.03	24.35	24.06	20.08	0.51	0.36	100.00
Cumulative Disbursement Rate (%)		-	2.34	7.62	30.65	54.99	79.06	99.13	99.65	100.00	-

7.1.4.2 O&M Cost Estimate

O&M cost of the sewerage system in this project is composed of electricity cost, chemical cost, labor cost, consumables & repair cost, replacement cost and administrative cost. Total O&M cost for 40 years is estimated at US$ 210,756 thousands and Annual O&M cost is estimated at US$ 5,269 thousands as below.

Table 7-5 O&M Cost Estimate (US$)

Category	Annual	Total (40 years)
Electricity cost	2,201,741	88,069,640
Chemical cost	782,560	31,302,400
Labor cost	293,646	11,745,840
Consumables & Repair Cost	228,401	9,136,040
Replacement Cost (15year)	1,658,150	66,326,000
Administrative Cost	104,409	4,176,360
Total	5,268,907	210,756,280

7.1.5 Benefit Analysis

7.1.5.1 General

Benefit occurred in sewage project process is composed of direct benefit, which can easily be measured in monetary value, and indirect benefit, which is difficult to measure in monetary value, and benefits gained differs by beneficiaries.

Economic benefit is assumed to be reduction effect of cost by constructing sewage system, and additional direct/indirect effect. Economic effect is segmented into consumer benefit, area society and economic benefit, and public benefit. Since it is difficult to quantify monetary values in each item so, among effects and benefits of sewage project, items which are measurable and monetarily valuable at the same time are put in priority in selection.

7.1.5.2 Benefit Analysis Method

There are various methods of estimating the benefits of environmental policies that are not easy to measure in terms of currency. Benefit estimation based on economic theory is divided into market method, revealed preference method, and stated preference method. All three methods are methods of estimating the benefits of environmental improvement by analyzing the actions each individual takes to maximize their satisfaction. Therefore, it is different from the replacement cost method, which evaluates value through the cost of replacing the function performed by the environment with another artificial method.

In this feasibility study, analysis methods are appropriately applied to estimate non-monetary benefits.

Table 7-6 Benefit Analysis Method

Method	Analysis Model	Benefit
Opportunity method	Estimating the value of river water for non-environmental uses	• All kinds of water quality improvement benefits
Alternate expense method	Estimation of engineering costs for water purification	• All kinds of water quality improvement benefits
Market method	Damage function	• Market benefits provided by industrial and agricultural water
	Production function	
	Cost function	
Revealed preference method	Recreation demand model	• Recreational Value, Landscape Value
	Characteristic price model	• Reduced risk of death, disease • Pleasantness, Recreational Value, Landscape Value
	Avoidance behavior model	• Reduced risk of death, disease • Pleasantness, Recreational Value, Landscape Value • Ecosystem preservation, facility preservation
Stated preference method	Contingent valuation method	• All kinds of water quality improvement benefits
	Contingent rank method	
	Choice experiment	
Mixed method	Mix of revealed and stated method	• All types of benefits to which the revealed preference method may be applied
Virtual Market Analysis	Experimental Auction	• All kinds of water quality improvement benefits

*Source: A study on revising and supplementing the standard guidelines for preliminary feasibility studies of water resources sector projects (2008, KDI)

7.1.5.3 Benefit Analysis

7.1.5.3.1 Benefit from Water Quality Improvement

Environmental goods such as water quality are not traded in the market, and have externalities or public goods characteristics, so even if the effect of water quality improvement is quantified, it is difficult to obtain objective indicators that can be used to derive economic value. It is usually evaluated using market prices, but since water quality is not traded in the market, it is difficult to judge it as an indicator that accurately reflects the value, even if there is no price.

If the environmental infrastructure of this sewerage system project is abandoned, sewage will flow into the lake or ponds in the urban area, causing eutrophication that worsens the water quality, creating sanitary problems and environmental pollution. As such, a sewer system is essential at this time, and given the extra cost required for water quality improvement.

In this feasibility study, the approach by production function and the alternate expense method proposed by KDI were applied in order to calculate the benefits of water quality improvement. Since there is no sewage treatment plant in Bangladesh, the unit cost is calculated considering the unit cost of a sewage treatment facility of a similar size in Korea.

Table 7-7 Unit Cost of STP in Korea

STP	Capacity (m^3/d)	Standard Cost (1 million KRW)	(US$ thousands)	Unit Cost (US$ thousands/m^3)
Namhang	125,000	292,293	222,784	1.78
Mansu	70,000	116,877	89,083	1.27
Eonyang	60,000	108,284	82,534	1.38
Water Quality Restoration Center (A)	50,000	111,626	85,081	1.70
Yeokgok	65,000	178,938	136,386	2.10
Jangdang	65,000	176,319	134,389	2.07
Poseung	58,000	154,619	117,850	2.03
Wolgojekopia	68,000	203,948	155,448	2.29
Gimpo	80,000	239,519	182,560	2.28
Sincheon	70,000	136,953	104,385	1.49
Gangreung	75,000	158,982	121,175	1.62
Chungju	75,000	205,512	156,640	2.09
Asan	72,000	212,624	162,061	2.25
Jeongeup	58,600	124,009	94,519	1.61
Yeosu	110,000	285,150	217,340	1.98
Gimcheon	80,000	261,301	199,162	2.49
Andong	54,000	134,592	102,585	1.90
Jinhae	60,000	175,435	133,715	2.23
Tongyeong	54,000	141,734	108,029	2.00
Jangyu	97,000	232,474	177,190	1.83
Hwamok	145,000	369,350	281,517	1.94
Yangsna	146,000	395,878	301,736	2.07
Average				1.93

*Source: 2018 Sewage Treatment Facility Operation Results (Ministry of Environment in Korea)

Benefit from water quality improvement is estimated as the 20% of multiplying the average unit of STP to the capacity of STP in the project and benefit is assumed as constant after year 2040.

Table 7-8 Benefit from Water Quality Improvement (US$ thousands)

Unit	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Benefit	15,649	16,200	16,752	17,303	17,855	18,406	19,008	19,609	20,211	20,813	21,414

7.1.5.3.2 Benefit from Living Standard Improvement

As a result of the improvement of living standard by this project, residents' leisure activities are expected to increase. As a way to evaluate the improvement effect, data from "Study on Quantification of Social Cost of Water Pollution – Focusing on Han River water system (Korea Environment Institute)," was used, which applied a Contingent Valuation Method and asked residents if they were willing to pay for the environmental improvement. Environmental value was quantified as a monetary value and leisure expenditure per capita was estimated at US$ 3.63~4.17 per visit and on average the number of annual visits was 9.6 times; thus, the value in use was estimated at US$ 34.9~40.0 annually.

In this project, leisure expenditure per capita is assumed as US$ 3.90 in the consideration of the characteristic of the project area and benefit from living standard improvement is estimated as below.

Table 7-9 Benefit from Living Standard Improvement

Category	2030	2031	2032	2033	2034	2035
Sewage Service Population	284,342	294,361	304,379	314,398	324,416	334,435
Leisure Expenditure (US$/person)	3.90	3.90	3.90	3.90	3.90	3.90
Benefit from Living Standard (US$ thousands)	1,109	1,149	1,188	1,227	1,266	1,305
Category	**2036**	**2037**	**2038**	**2039**	**2040**	
Sewage Service Population	345,368	356,301	367,233	378,166	389,099	
Value of leisure use when visiting (Person/USD)	3.90	3.90	3.90	3.90	3.90	
Value of leisure use when visiting (US$ thousands)	1,347	1,390	1,433	1,475	1,518	

Note) Benefit is assumed as constant after year 2040.

7.1.5.3.3 Benefit from Septic Tank Reduction

Household sewerage connection will be constructed by this project, so it will reduce the number of septic tank installation & maintenance in the project area. Septic tank reduction is considered as benefit and Installation cost of septic tank is assumed as US$ 900/connection, maintenance cost is assumed as US$ 30/connection. Benefit from septic tank reduction is estimated as below.

Table 7-10 Benefit from Septic Tank Reduction (US$ thousands)

Category	2030	2031	2032	2033	2034	2035
Sewage Service Population	284,342	294,361	304,379	314,398	324,416	334,435
Number of Connection	10,155	10,513	10,871	11,229	11,586	11,944
Sewage Service Coverage (%)	60	61.0	61.0	62.0	62.0	63.0
Increase in number of Tanks installed	155	358	358	358	357	358
Septic Tank Maintenance Cost (US$)	4,650	10,740	10,740	10,740	10,710	10,740
Septic Tank Installation Cost (US$)	139,500	322,200	322,200	322,200	321,300	322,200
Amount Saved (US$ thousands)	144	333	333	333	332	333
Category	**2036**	**2037**	**2038**	**2039**	**2040**	
Sewage Service Population	345,368	356,301	367,233	378,166	389,099	
Number of Connection	12,335	12,725	13,115	13,506	13,896	
Sewage Service Coverage (%)	63.0	64.0	64.0	65.0	65.0	
Increase in number of Tanks installed	391	390	390	391	390	
Septic Tank Maintenance Cost (US$)	11,730	11,700	11,700	11,730	11,700	
Septic Tank Installation Cost (US$)	351,900	351,000	351,000	351,900	351,000	
Amount Saved (US$ thousands)	364	363	363	364	363	

Note) Benefit is assumed as constant after year 2040.

7.1.5.3.4 Benefit from Public Hygiene Improvement

This project will improve the public hygienic and sanitary condition of the Chattogram City, Hathajari Upazila and Raozan Upazila, so health expenditure of each household can be reduced and health expenditure per capita of Bangladesh in 2020 is US$ 50.66 (World Bank), 20% of health expenditure is considered as the benefit from public hygiene improvement.

Table 7-11 Benefit from Public Hygiene Improvement (US$ thousands)

Category	2030	2031	2032	2033	2034	2035
Sewage Service Population	284,342	294,361	304,379	314,398	324,416	334,435
Health Expenditure per capita (US$/capita)	50.7	50.7	50.7	50.7	50.7	50.7
Benefit from Public Hygiene Improvement (US$ thousands)	2,881	2,982	3,084	3,185	3,287	3,388
Category	**2036**	**2037**	**2038**	**2039**	**2040**	
Sewage Service Population	345,368	356,301	367,233	378,166	389,099	
Health Expenditure per capita (US$/capita)	50.7	50.7	50.7	50.7	50.7	
Benefit from Public Hygiene Improvement (US$ thousands)	3,499	3,610	3,721	3,832	3,942	

Note) Benefit is assumed as constant after year 2040.

7.1.5.3.5 Summary of Benefit

Summary of benefit is presented as below.

Table 7-12 Summary of Benefit (US$ thousands)

Year	Total	Water Quality Improvement	Living Standard Improvement	Septic Tank Reduction	Public Hygiene Improvement
2030	19,783	15,649	1,109	144	2,881
2031	20,664	16,200	1,149	333	2,982
2032	21,357	16,752	1,188	333	3,084
2033	22,048	17,303	1,227	333	3,185
2034	22,740	17,855	1,266	332	3,287
2035	23,432	18,406	1,305	333	3,388
2036	24,218	19,008	1,347	364	3,499
2037	24,972	19,609	1,390	363	3,610
2038	25,728	20,211	1,433	363	3,721
2039	26,484	20,813	1,475	364	3,832
2040	27,237	21,414	1,518	363	3,942
2041	27,237	21,414	1,518	363	3,942
2042	27,237	21,414	1,518	363	3,942

Note) Benefit is assumed as constant after year 2040.

7.1.6 Economic Feasibility Analysis

7.1.6.1 Benefit/Cost Analysis (B/C Ratio)

As a result of the economic feasibility analysis B/C ratio is analyzed as 1.31 on discount rate of 12%, with total benefit US$ 197,610 thousands, total cost US$ 150,731 thousands, net present value US$ 46,879 thousands.

Table 7-13 Result of Economic Feasibility Analysis (US$ thousands)

Category	Benefit at Present Value	Cost at Present Value	Net Present Value	B/C Ratio
6%	377,103	209,190	167,913	1.80
7%	331,507	195,458	136,049	1.70
8%	294,225	183,838	110,387	1.60
9%	263,419	173,861	89,558	1.52
10%	237,706	165,181	72,525	1.44
11%	216,037	157,536	58,501	1.37
12%	197,610	150,731	46,879	1.31

7.1.6.2 Net Present Value (NPV)

Based on discount rate of 12%, total benefit was analyzed as US$ 197,610 thousands, total cost was analyzed as US$ 150,731 thousands and net present value was analyzed as US$ 46,879 thousands.

7.1.6.3 Economic Internal Return Rate (EIRR)

EIRR is the discount rate when NPV becomes zero that means total benefit at present value equals total cost at present value. EIRR is estimated as 20.30% when cost/benefit is constant, which is greater than 12 %, and thus the project is considered to be economically feasible.

7.1.6.4 Sensitivity Analysis

In sensitivity analysis, B/C Ratio is analyzed as 1.02, NPV US$ 3,170 thousands and EIRR 12.51% and it shows that this project is economically feasible even in the worst scenario of Case 4 with 20 % cost increase and 20 % benefit decrease.

Table 7-14 Sensitivity Analysis by Variation of Benefit/Cost

Case	Sensitivity	NPV (US$ thousands)	B/C Ratio	IRR (%)
Base		46,879	1.31	20.30
Case 1	20% increase in costs	42,690	1.28	19.70
Case 2	20% decrease in benefits	7,359	1.05	13.14
Case 3	20% decrease in costs	51,072	1.35	20.88
Case 4	Combination of case 1 and 2	3,170	1.02	12.51

7.1.6.5 Analysis Result

As the result of feasibility analysis, this project is analyzed as economically feasible by the benefits that are expected from water quality improvement, living standard improvement, septic tank reduction and public hygiene improvement to the residents of the project by this project.

Table 7-15 Benefit/Cost Analysis (US$ thousands)

Year	Benefit		Cost				(a)-(c)	NPV (b)-(d)
	Benefit (a)	Present Value (b)	Project Cost	O&M Cost	Sub Total (c)	Present Value (d)		
2024			5,353		5,353	5,353	-5,353	-5,353
2025			9,921		9,921	8,858	-9,921	-8,858
2026			41,864		41,864	33,374	-41,864	-33,374
2027			44,890		44,890	31,952	-44,890	-31,952
2028			44,240		44,240	28,115	-44,240	-28,115
2029			37,290		37,290	21,159	-37,290	-21,159
2030	19,783	17,663	1,169	3,611	4,780	2,422	15,003	15,241
2031	20,664	16,473	814	3,611	4,425	2,002	16,239	14,471
2032	21,357	15,201		3,611	3,611	1,458	17,746	13,743
2033	22,048	14,012		3,611	3,611	1,302	18,437	12,710
2034	22,740	12,903		3,611	3,611	1,163	19,129	11,740
2035	23,432	11,871		3,611	3,611	1,038	19,821	10,833
2036	24,218	10,955		3,611	3,611	927	20,607	10,028
2037	24,972	10,086		3,611	3,611	828	21,361	9,258
2038	25,728	9,278		3,611	3,611	739	22,117	8,539
2039	26,484	8,527		3,611	3,611	660	22,873	7,867
2040	27,237	7,830		3,611	3,611	589	23,626	7,241
2041	27,237	6,991		3,611	3,611	526	23,626	6,465
2042	27,237	6,242		3,611	3,611	470	23,626	5,772
2043	27,237	5,573		3,611	3,611	419	23,626	5,154
2044	27,237	4,976		36,774	36,774	3,812	-9,537	1,164
2045	27,237	4,443		3,611	3,611	334	23,626	4,109
2046	27,237	3,967		3,611	3,611	298	23,626	3,669
2047	27,237	3,542		3,611	3,611	266	23,626	3,276
2048	27,237	3,162		3,611	3,611	238	23,626	2,924
2049	27,237	2,824		3,611	3,611	212	23,626	2,612
2050	27,237	2,521		3,611	3,611	190	23,626	2,331
2051	27,237	2,251		3,611	3,611	169	23,626	2,082
2052	27,237	2,010		3,611	3,611	151	23,626	1,859
2053	27,237	1,794		3,611	3,611	135	23,626	1,659
2054	27,237	1,602		3,611	3,611	121	23,626	1,481
2055	27,237	1,431		3,611	3,611	108	23,626	1,323
2056	27,237	1,277		3,611	3,611	96	23,626	1,181
2057	27,237	1,140		3,611	3,611	86	23,626	1,054
2058	27,237	1,018		3,611	3,611	77	23,626	941
2059	27,237	909		36,774	36,774	696	-9,537	213
2060	27,237	812		3,611	3,611	61	23,626	751
2061	27,237	725		3,611	3,611	55	23,626	670
2062	27,237	647		3,611	3,611	49	23,626	598
2063	27,237	578		3,611	3,611	43	23,626	535
2064	27,237	516		3,611	3,611	39	23,626	477
2065	27,237	461		3,611	3,611	35	23,626	426
2066	27,237	411		3,611	3,611	31	23,626	380
2067	27,237	367		3,611	3,611	28	23,626	339
2068	27,237	328		3,611	3,611	25	23,626	303
2069	27,237	293		3,611	3,611	22	23,626	271
Total	1,048,536	197,610	185,541	210,766	396,307	150,731	652,229	46,879
Discount Rate				12.00		B/C Ratio		1.31

7.2 Financial Feasibility Analysis

7.2.1 General

This financial feasibility analysis is intended to identify whether the project will bring value and revenue to the project implementation agency, rather than all of society that is, to determine if return on investment is feasible and then check the feasibility by comparing the financing capacity of the project implementation agency with the financial status of the project and the effect on the financial status of the project implementation agency; essentially, financial feasibility analysis is based on the concept of profitability analysis.

The purpose of financial analysis is to analyse the feasibility of the investment using the estimated profit and loss and cash flow that is expected to be coming from the implementation of this project and is to present reference materials for investment decision making

7.2.2 Analysis Method

7.2.2.1 Net Present Value (NPV) Method

The net present value method (NPV) is a method of using the “Net present value (NPV) that can be obtained by discounting the cash flows generated from an investment project at an appropriate discount rate” for decision-making.

With regard to the investments with NPV > 0, the alternative with the largest NPV is selected among mutually exclusive investments while the investment proposals are evaluated in the order of the size of the NPV if the investment proposals are independent from each other.

Table 7-16 Characteristic of NPV Method

Category		Descriptions
Calculation Formula		NPV = $\sum_{t=0}^{n}\frac{R_t}{(1+r)^t} - \sum_{t=0}^{n}\frac{C_t}{(1+r)^t}$ • Rt: Revenues (Incomes) at time t • Ct: Costs (or expenses) at time t • r: Discount rate (interest rate) • n: Duration (years) of the project (analysis period)
Characteristic	Strength	• Considers the time value of money • Considers profitability • Can apply the sum of values principle
	Weakness	• Difficult to determine an appropriate discount rate reflecting the characteristics of the business

7.2.2.2 Internal Rate of Return (IRR) Method

The internal rate of return method calculates a discount rate (internal rate of return, IRR) that matches the present value of future cash inflows that are expected to be generated from the implementation of the investment plan and the present value of cash outflows as the investment costs (NPV = 0), and compares the obtained discount rate with the internal rate of return of an alternative investment or with the required rate of return of the business, wherein if the internal rate of return of the investment is greater than the internal rate of return of the alternative investment or the required rate of return of the business, the investment plan is evaluated as a possible investment. If there are multiple investment plans, the higher the internal rate of return is, the more economically feasible the investment is.

Table 7-17 Characteristic of IRR Method

Category		Descriptions
Calculation Formula		IRR = $\sum_{t=0}^{n} \frac{R_t}{(1+r)^t} = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$ • Rt: Revenues (Incomes) at time t • Ct: Costs (or expenses) at time t • r: Discount rate (interest rate) • n: Duration (years) of the project (analysis period)
Characteristic	Strength	• Considers time value of money and profitability • Internal rate of return means the rate of return on investment
	Weakness	• IRR may not be calculated • The reinvestment assumption is optimistic

7.2.2.3 Profitability Index method (PI)

The profitability index method is the value that is obtained by dividing the ‘present value of the total revenue expected from the implementation of the project’ by the ‘present value of the total cost’. If PI≥1, it is evaluated as having financial feasibility.

Table 7-18 Characteristic of R/C

Category		Descriptions
Calculation Formula		PI = $\sum_{t=0}^{n} \frac{R_t}{(1+r)^t} / \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$ • Rt: Revenues (Incomes) at time t • Ct: Costs (or expenses) at time t • r: Discount rate (interest rate) • n: Duration (years) of the project (analysis period)
Characteristic	Strength	• Can do a systematic and objective comparison • Can calculate the revenues (incomes and costs expenses) of a long-term business at present value.
	Weakness	• The output of the alternatives to be compared should be the same

7.2.2.4 Procedures of Financial Analysis

As the method to evaluate the financial feasibility of a business, the internal rate of return (IRR) method, which is calculated based on the cash flows expected to be generated by the project in the future, was used in this analysis, a financial feasibility analysis related to the project was performed using the internal rate of return method.

- Estimation of operating cash flows
  - By analysing the investment cost and profit/loss structure of this project individually for each item, the operating cash flow that is expected from each operating activity is estimated on a yearly basis.
  - The operating income and expenses were calculated by reflecting the project period, project structure, and project method.
  - Major assumptions for financial analysis such as inflation, taxes, and annual expenditure plans were reviewed.
- Estimation of financial cash flows
  - After calculating the cash surplus/deficit by year in line with the operating cash flow of the project, and based on this, the cash flows reflecting annual borrowing and repayment of the funds required for this project were estimated.

- Annual investment and financing plans were reviewed
- Review of borrowing principal and interest repayment plan reflecting cash flow during operating period and analysis of debt repayment ratio were conducted.

▪ Calculation of financial expenses and corporate tax expenses

- Interest expenses related to borrowing and corporate tax expenses to be paid in the future were calculated based on the operating cash flows and financial cash flows of this project.
- Financial expenses are reflected in the internal rate of return (IRR) of the business.
- The calculated financial expenses and corporate tax expenses are reflected in the estimated financial statements.

▪ Cash flow analysis and IRR calculation

- Based on annual operating cash flows, financial cash flows, and corporate tax expenses that are calculated in this analysis, annual cash flows of each year have been estimated, and on the basis of the estimated cash flow, the net cash flow and IRR of the project were calculated.
- The net present value (NPV) reflecting the target required rate of return was calculated.
- Estimated financial statements for the analysis period were prepared reflecting cash flow analysis, financing plan, and principal and interest repayment plan including financial expenses.

7.2.3 Financial Feasibility Analysis

7.2.3.1 Basic Assumption

The basic assumption of the financial feasibility analysis is the same as for the economic feasibility analysis, but only the sewage fee is applied as the benefit instead of the economic benefit in economic feasibility, and price contingencies, taxes & duties, interest during construction considered for the cost as follows.

Table 7-19 Basic Assumption of Financial Feasibility Analysis

Category			Assumption		Remarks
Financing	EDCF		US$ 191,439 thousands		• Construction cost • Commissioning & training cost • O&M support cost • Consulting service cost • Contingency • EDCF service charge
	GOB		US$ 37,538 thousands		• Taxes & duties, • Land acquisition & resettlement cost, • Project management cost, • Interest during construction
	Total		US$ 228,977 thousands		
Repayment	Repayment method		Uniform principal and interest repayment		• Grace period: 15 years • Term of loan: 40 years
Revenue	Sewage Tariff	Category	Wastewater Generation	Unit Cost	• Based on year 2029 • Inflation applied
		Domestic Wastewater	36,006 m³/d	0.24 USD/m³	
		Non-Domestic Wastewater	4,606 m³/d	0.50 USD/m³	
	Solar Power Generation		Power Generation	Unit Cost	
			206,955 kW/year	0.0952 USD/kWh	
Operating Cost	O&M Cost	Electricity cost	US$ 3,176 thousands		• Annual
		Chemical cost	US$ 1,129 thousands		• Annual
		Labor cost	US$ 424 thousands		• Annual
		Consumables& repair cost	US$ 329 thousands		• Annual
		Administrative cost	US$ 151 thousands		• Annual
		Replacement cost	US$ 33,163 thousands		• Every 15 years
	Inflation		6.30 %		

The differences between an economic feasibility analysis and financial feasibility analysis can be summarized as follows.

Table 7-20 Comparison of Economic Feasibility Analysis & Financial Feasibility Analysis

Category	Economic Feasibility Analysis	Financial Feasibility Analysis
Benefit	Social cost reduction or social benefit	Revenue from sewage tariff & solar power generation
Cost	Initial investment cost, operating cost	Initial investment cost, operating cost
Discount Rate	12%	6.31%

7.2.3.2 Financial Feasibility Analysis

As a result of the financial feasibility analysis, it is analyzed that this project is not financially feasible to recover the investment cost with sewage tariff alone.

Table 7-21 Financial Analysis Result

Category	Result	Remarks
FIRR (%)	0.39%	Discount rate of 6.31%
FNPV (US$ thousands)	(149,738)	

Annual cash flow to estimate profitability is as follows. Service charge and interest expenses are excluded from Construction Cost

Table 7-22 Annual Cash Flow (US$ thousands)

Category	Total	2024	2025	2026	2027	2028	2029
Cash In	1,241,749	-	-	-	-	-	1,087
Sewage tariff	1,236,806	-	-	-	-	-	1,078
Solar system income	4,944	-	-	-	-	-	9
Cash Out	1,201,096	5,348	12,082	52,671	55,696	55,045	47,672
Construction cost	228,757	5,348	12,082	52,671	55,696	55,045	45,936
Operating cost	972,339	-	-	-	-	-	1,736
Net cash flow	40,653	(5,348)	(12,082)	(52,671)	(55,696)	(55,045)	(46,585)

Category	2030	2031	2032	2033	2034	2035	2036	2037
Cash In	3,466	3,813	4,191	4,600	5,045	5,527	6,065	6,650
Sewage tariff	3,436	3,781	4,157	4,564	5,006	5,486	6,022	6,604
Solar system income	30	32	34	36	39	41	44	46
Cash Out	6,705	6,697	6,256	6,651	7,070	7,515	7,988	8,492
Construction cost	1,168	812	-	-	-	-	-	-
Operating cost	5,537	5,886	6,256	6,651	7,070	7,515	7,988	8,492
Net cash flow	(3,239)	(2,884)	(2,066)	(2,051)	(2,025)	(1,988)	(1,923)	(1,842)

Category	2038	2039	2040	2041	2042	2043	2044	2045
Cash In	7,284	7,972	8,718	9,550	10,453	11,430	12,491	13,639
Sewage tariff	7,235	7,920	8,662	9,491	10,390	11,364	12,419	13,563
Solar system income	49	52	56	59	63	67	71	76
Cash Out	9,027	9,595	10,200	10,842	11,525	12,252	46,186	13,844
Construction cost	-	-	-	-	-	-	-	-
Operating cost	9,027	9,595	10,200	10,842	11,525	12,252	46,186	13,844
Net cash flow	(1,742)	(1,623)	(1,482)	(1,292)	(1,073)	(821)	(33,696)	(205)

Category	2046	2047	2048	2049	2050	2051	2052	2053
Cash In	14,928	16,325	17,838	19,478	21,254	23,216	25,341	27,643
Sewage tariff	14,847	16,239	17,748	19,382	21,151	23,107	25,225	27,520
Solar system income	80	85	91	96	103	109	116	123
Cash Out	14,716	15,643	16,629	17,676	18,790	19,974	21,232	22,570
Construction cost	-	-	-	-	-	-	-	-
Operating cost	14,716	15,643	16,629	17,676	18,790	19,974	21,232	22,570
Net cash flow	212	681	1,210	1,802	2,464	3,243	4,109	5,073

Category	2054	2055	2056	2057	2058	2059	2060	2061
Cash In	30,133	32,827	35,837	39,094	42,620	46,434	50,561	55,098
Sewage tariff	30,002	32,688	35,689	38,936	42,453	46,257	50,372	54,898
Solar system income	131	139	148	157	167	178	189	201
Cash Out	23,991	25,503	27,110	28,818	30,633	65,726	34,614	36,795
Construction cost	-	-	-	-	-	-	-	-
Operating cost	23,991	25,503	27,110	28,818	30,633	65,726	34,614	36,795
Net cash flow	6,141	7,325	8,727	10,276	11,987	(19,292)	15,947	18,303

Category	2062	2063	2064	2065	2066	2067	2068	2069
Cash In	60,868	65,314	71,052	77,254	84,044	91,382	99,310	71,917
Sewage tariff	60,655	65,087	70,810	76,998	83,771	91,092	99,002	71,699
Solar system income	213	227	241	256	273	290	308	218
Cash Out	39,113	41,577	44,197	46,981	49,941	53,087	56,432	39,991
Construction cost	-	-	-	-	-	-	-	-
Operating cost	39,113	41,577	44,197	46,981	49,941	53,087	56,432	39,991
Net cash flow	21,755	23,737	26,855	30,273	34,103	38,295	42,878	31,926

7.2.3.3 Sensitivity Analysis

7.2.3.3.1 Introduction

The calculations of cash inflows and cash outflows used in the financial feasibility assessment process contain many uncertainties. To mitigate these uncertainties, a sensitivity analysis is carried out. The analysis attempts to see how the changes affect the final outcome variable values by changing the values of various variables used in the feasibility study process in order to reflect anticipation against various unexpected changes in the future situation. For example, with respect to construction cost, operating cost, fee, facility capacity, discount rate, etc., the impact on investment cost or business performance can be identified as each variable changes.

In this feasibility study, sensitivity analysis was performed according to changes in project cost and fee, focusing on the cash inflow and outflow of the financial feasibility analysis.

7.2.3.3.2 Sensitivity Analysis

The result of sensitivity analysis for the change of investment cost and operating cost is as follows.

Table 7-22 Sensitivity Analysis for the Change of Investment Cost & Operating Cost

Category	-55%	-35%	-15%	BASE	20%
Total Investment cost (US$ thousand)	103,056	148,835	194,631	228,977	274,773
Total operating cost (US$ thousand)	474,032	655,235	836,437	972,339	1,153,542
Equity (US$ thousand)	16,908	24,400	31,907	37,538	45,045
EDCF (US$ thousand)	86,148	124,435	162,723	191,439	229,727
IRR	6.63%	4.11%	1.98%	0.39%	-1.99%
NPV	6,418	(50,365)	(107,150)	(149,738)	(206,523)
PI	1.05	0.74	0.58	0.49	0.41

The result of sensitivity analysis for the change of sewage tariff is as follows.

Table 7-23 Sensitivity Analysis for the Change of Sewage Tariff

Category	-20%	BASE	20%	70%	110%
Domestic	0.19 USD/m^3	0.24 USD/m^3	0.29 USD/m^3	0.41 USD/m^3	0.51 USD/m^3
Non-Domestic	0.40 USD/m^3	0.50 USD/m^3	0.60 USD/m^3	0.85 USD/m^3	1.05 USD/m^3
Equity (US$ thousand)	37,538	37,538	37,538	37,538	37,538
EDCF (US$ thousand)	191,439	191,439	191,439	191,439	191,439
IRR	-2.89%	0.39%	2.24%	5.03%	6.53%
NPV	(178,708)	(149,738)	(120,768)	(48,342)	9,599
PI	0.39	0.49	0.59	0.84	1.03

The result of sensitivity analysis for the annual increase of sewage tariff is as follows.

Table 7-24 Sensitivity Analysis of Annual Increase of Sewage Tariff

Category	BASE	2%	4%	6%	8%
Total Sewage Tariff (US$ thousand)	1,236,806	2,271,037	4,223,407	7,912,081	14,871,659
IRR	0.39%	4.96%	7.95%	10.46%	12.75%
NPV	(149,738)	(57,591)	106,171	400,484	933,207
PI	0.49	0.80	1.36	2.36	4.16
Short Term loan occur	38 years	24 years	14 years	10 years	8 years

8 Environmental & Social Impact Assessment

8.1 General

The purpose of the environmental and social impact assessment is to contribute to sustainable development by identifying the negative effects of the EDCF loan support project on the environment and local residents and avoiding and minimizing them.

The environmental and social impact assessment is conducted to identify and analyse the predictable environmental and social negative impacts and risks caused by the project implementation in advance, to find ways to reduce them, and to avoid or minimize them. In addition, executes and measures, such as appropriate compensation, should be prepared to ensure that the project proceeds smoothly.

In this chapter, basic contents such as relevant laws, institutions, necessary procedures and processes, field conditions analysis, and expected environmental social impact and mitigation measures is reviewed, and full environmental social impact assessments will be conducted in the detailed design stage.

8.2 Related Laws and Policies

The government of Bangladesh has formulated various policies, laws and regulations to protect and preserve the natural environment.

Table 8-1 Related Laws and Policies

Policy	Description
National Environment Policy 1992	• Established the National Environmental Policy (NEP) in 1992 to plan the way for the country's sustainable development. It presents a basic framework for environmental action, along with a broad set of sectoral action guidelines. NEP 2018 contains policy outlines for 24 sectors, including agriculture, water, wildlife and chemicals. It provides guidelines for the planning process of any development project.
National Environment Action Plan (NEMAP) 1995	• The action plan recommends safe drinking water supply as a main goal in the health and hygiene sector.
Environment Conservation Act 1995 and subsequent amendments in 2000, 2002 and 2010	• Laws for Environmental Conservation, Improvement of Environmental Standards, and Control and Mitigation of Environmental Pollution. The details of the environmental permitting procedure are laid down in ECR 1997.
Environment Conservation Rules 1997 and subsequent amendments in 2002 and 2003	• According to the 1997 Environmental Conservation Regulations, project components are classified into one of four categories (Red, Orange-A, Orange-B, Green). According to ECR 1997, sewage systems including fecal sludge treatment plants, sewage treatment plants and pumping stations fall into the “Red” category. An environmental permit should be obtained from the DoE for that category.
Environment Court Act 2010	• If a project adversely affects a region or an individual, the affected party may seek remedies in the Environmental Court in accordance with the procedures set out in the Environmental Court Act 2010.

Policy	Description
National Land-use Policy 2001	• Stated to take measures to prevent land pollution and to ensure minimum use of land for the construction of governmental and non-governmental buildings applicable to the proposed project.
National Water Policy 1999	• Require each water resource development project or rehabilitation program to consider environmental protection, restoration and improvement measures. The National Environmental Management Action Plan and National Water Management Plan comply with a formal environmental impact assessment process when required by government.
National Agricultural Policy 1999	• One of the specific goals of the National Agricultural Policy is to take necessary measures not only for 'environmentally friendly and sustainable agriculture' but also for environmental protection by increasing the use of organic fertilizers and strengthening integrated pest control programs.
Bangladesh Wildlife (Conservation and Security) Act 2012	• Under the jurisdiction of the Ministry of Forestry, it protects and preserves the wildlife of Bangladesh.
National Safe Drinking Water Supply and Sanitation Policy 1998	• The National Safe Drinking Water Supply and Sanitation Policy provides a basic framework for ensuring public health quality improvement and an improved environment, with a broad set of sectoral measures.
National 3R (Reduce, Reuse, Recycle) Strategy for Waste Management 2010	• The national 3R goal for waste management is to completely treat waste from open-air landfills, rivers, floodplains, etc. through mandatory source separation of waste by 2015, create a recycling market, and provide waste recycling incentives. Its main goal is to provide unified guidance to all stakeholders, explaining how and by which national 3R goals will be achieved.
Bangladesh Standards and Guidelines for Sludge Management 2015	• Bangladesh Sludge Management Standards and Guidelines were published in 2015 to ensure protection of human health and environment from the negative impacts of sludge management. Sludge management responsibility lies with sludge producers as described in standards and guidance documents.
Institutional and Regulatory Framework for Faecal Sludge Management 2017	• The main objective of the FSM framework is to promote appropriate FSM across the country.
Noise Control Act 2006	• Provide acceptable noise limits based on land use category.
Bangladesh National Building Code (BNBC)	• Regulate the technical details of building construction and maintain standards.
Bangladesh Labour Law, 2006, Act, 2013 And Rules, 2015	• Including rules on worker registration, misconduct rules, income and benefits, and health and safety. Children under the age of 18 cannot be employed during the project period, and this law should comply with Bangladesh Labor Law.
Bangladesh Climate Change Strategy and Action Plan 2009	• Comprehensive Strategy to Address Climate Change Challenges in Bangladesh. The Climate Change Strategy and Action Plan (BCCSAP) is expanded based on the National Adaptation Action Plan (NAPA). BCCSAP has 44 programs proposed under the six themes.
National Disaster Management Act 2012	• Establishing a framework for disaster management in a comprehensive way.

*Source: Bangladesh Government Rules & Regulation books

8.3 Environmental & Social Impact Procedure

8.3.1 Environmental Impact Assessment Procedure

The Environmental Impact Assessment (EIA) process in Bangladesh proceeds in three stages to optimize the resources required for the survey.

- Preliminary Screening
- Initial Environmental Examination (IEE)
- Environmental Impact Assessment (EIA)

The preliminary review determines whether the EIA process should be applied to the development project and determines whether a preliminary environmental investigation (IEE) or an environmental impact assessment (EIA).

Sewerage project is categorized as "Red" requiring implementation of IEE and EIA according to EIA guidelines of the DOE. EIA procedure is described as below.

Table 8-2 Environmental Impact Assessment Procedure

Stage	Orange B	Red
Feasibility Study	• IEE	• IEE
Detailed design	• Create EMP, update IEE and obtain environmental approval	• Obtain site permit and prepare EIA and finalize Range of Task (TOR) for approval by DOE • EIA update and ECC acquisition with site-specific EMP
Development Project Proposal (DPP)	• EIA Approval and Inclusion of EIA Recommendations in DPP	
Project approval and Construction	• Establishment of construction stage Environmental Management Plan (EMP)	
Operation	• Implementation of the monitoring plan established by the Environmental Management Plan (EMP) in the operational Phase	

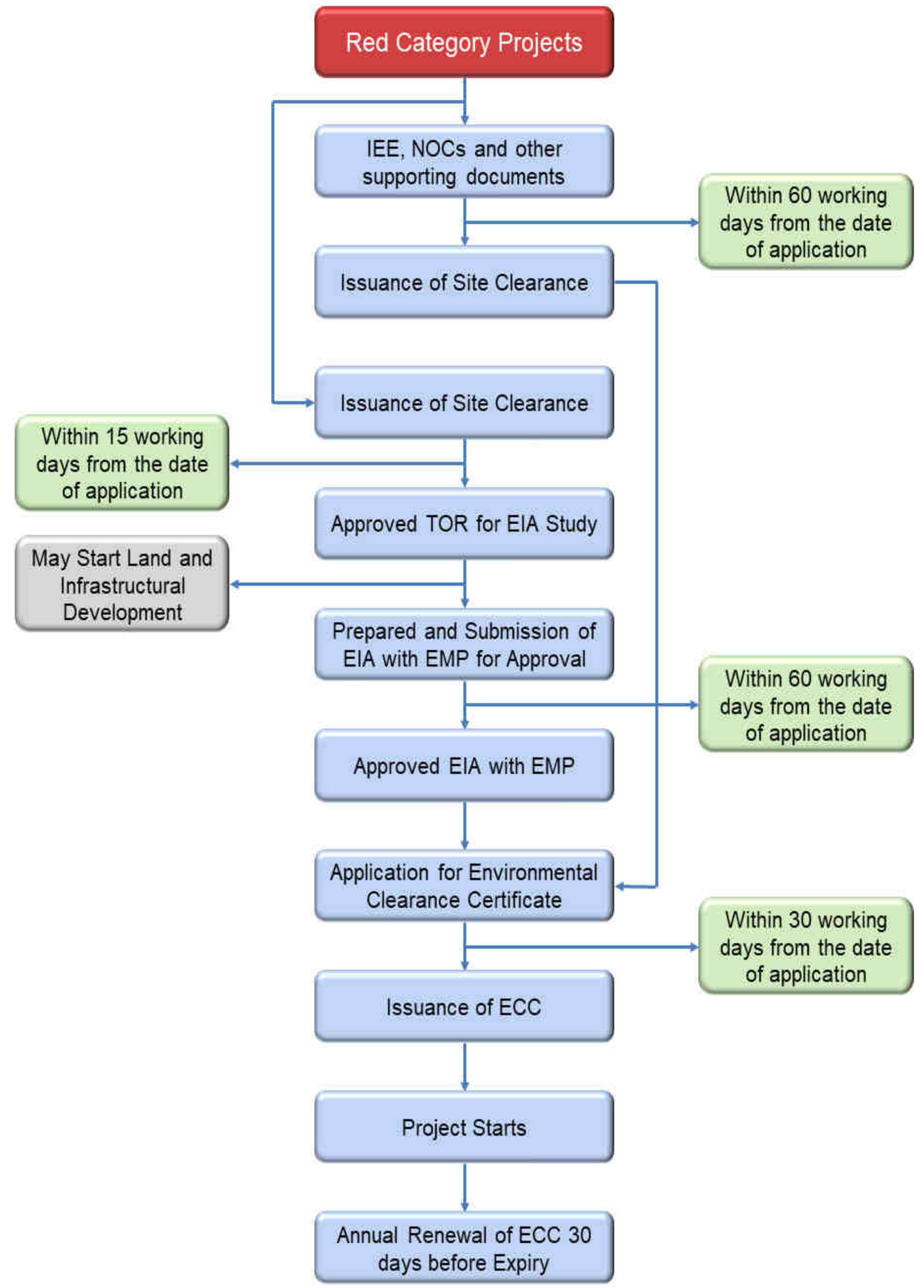


Figure 8-1 Red Project Environmental Assessment Procedure

8.3.2 Social Impact Assessment Process

8.3.2.1 Land Acquisition Process

The Acquisition and Requisition of Immovable Property Act 2017 (ARIPA) is the principal legislation governing eminent domain for land acquisition and requisition in Bangladesh. ARIPA 2017, detailed the land acquisition process from section 4 to section 19 and land requisition process from section 20 to section 28. According to ARIPA 2017, compensation to be paid for affected land, structures, trees, crops and any other damages caused by such acquisition.

Under the ARIPA 2017, The Deputy Commissioner (DC) determines the value of the acquired assets as at the date of issuing the notice of acquisition under section 4 (1). The DCs there after enhance the assessed value by 200% and another 100% premium for loss of standing crops, structures and income due to compulsory nature of the acquisition. The compensation such determined is called the Cash Compensation under Law (CCL). If the land acquired has standing crops cultivated by a tenant (Bargadar) under a legally constituted written agreement, the law requires that compensation money be paid in cash to the tenants as per the agreement. ARIPA 2017 under section 4 (13) permits the acquisition of the community properties if it is for a public purpose provided that project for which the land is acquired provides for similar types of assets in some other appropriate place or reconstruct the community properties.

Table 8-3 Land Acquisition Process Under ARIPA (2017)

Relevant Section	Steps in the Process	Responsibility
Section 4 (1)	• Publication of preliminary notice of acquisition of property for a public purpose	Deputy Commissioner
Section 4 (3) (1) (i)	• Prior to the publication of section 4(1) notice; Identify the present status of the land, structures and trees through videography, still pictures or appropriate technology.	Deputy Commissioner
Section 4 (3) (1) (ii)	• After the publication of the section 4(1) notice a joint verification should be conducted with potentially affected households and relevant organizations.	Deputy Commissioner
Section 4 (7)	• After publication of preliminary notice under the section 4(1), if any household has changed the status of the land for beneficial purposes, changed status will not be added to the joint verification notice.	Deputy Commissioner
Section 4 (8)	• If the affected person is not happy with the joint verification assessment, he/she can complain to Deputy Commissioner within 7 days of issuing sec 4(1) notice.	Affected Person
Section 4 (9)	• Hearing by Deputy Commissioner within 15 working days after receiving the complaints. In case of government priority projects, hearing will be within 10 working days.	Deputy Commissioner
Section 5 (1)	• Objections to acquisition by interested parties, within 15 days of the issue of section 4 (1) Notice	Affected Person
Section 5 (2)	• Deputy Commissioner submits hearing report within 30 working days after the date of the sec 5(1) notice. In the case of government priority projects, it will be within 15 working days.	Deputy Commissioner
Section 5 (3)	• DC submits his report to the (i) Government (for properties that exceed 16.50 acres; (ii) Divisional Commissioner for properties that do not exceed 50 standard bighas. Deputy Commissioner makes the final decision If no objections were raised within 30 days of inquiry. In case of government priority project, it will be 15 Days	Deputy Commissioner

Relevant Section	Steps in the Process	Responsibility
Section 6 (1) (1)	• Government makes the final decision on acquisition within 60 working days • After receiving report from the Deputy Commissioner under sec 5(3) notice.	Government
Section 6 (1) (2)	• Divisional Commissioner makes the decision within 15 days or with reasons within 30 days since the submission of the report by Deputy Commissioner under sec 5(3) notice.	Divisional Commissioner
Section 7 (1)	• Publication of the Notice of final decision to acquire the property and notifying the interested parties to submit their claims for compensation	Deputy Commissioner
Section 7 (2)	• Interested parties submit their interests in the property and claims for compensation within 15 working days (in case of priority project 7 days).	Affected Person
Section 7 (3)	• Individual notices have to be served to all interested persons including the shareholders within 15 days of issuing Section 7(1) notice	Deputy Commissioner
Section 8 (1)	• Deputy Commissioner makes a valuation of the property to be acquired as at the date of issuing Section 4 Notice; determine the compensation; and apportionment of compensation among parties interested.	Deputy Commissioner
Section 8 (3)	• DC informs the award of compensation to the interested parties and sends the estimate of compensation to the requiring agency/person within 7 days of making the compensation decision	Deputy Commissioner
Section 8 (4)	• The requiring agency/person deposits the estimated award of compensation with the Deputy Commissioner within 120 days of receiving the estimate.	Deputy Commissioner
Section 9 (1)	• During valuation of assets, Deputy Commissioner will consider the following: (i) Average market price of land of the same category in the last 12 months; (ii) Impact on existing crops and trees; (iii) Impact on other remaining adjacent properties; (iv) Impact on properties and income; and (v) Relocation cost for businesses, residential dwellings etc.	Deputy Commissioner
Section 9 (2)	• Additional 200% compensation on current mouza rate is added to the estimated value. If private organizations acquire, added compensation will be 300%.	Deputy Commissioner
Section 9 (3)	• Additional 100% compensation on top of the current market price for impacts mentioned under sec 9(1) and (2)	Deputy Commissioner
Section 9 (4)	• Appropriate action should be taken for relocation on top of the above-mentioned sub-sections.	
Section 10 (2)	• If an entitled person does not consent to receive compensation, or if there is no competent person to receive compensation, or in the case of any dispute with the title to receive compensation, Deputy Commissioner deposits the compensation amount in a deposit account in the Public Account of the Republic and Deputy Commissioner acquires the land. But if any person complains about the ownership of the land, with appeal, he/she will be able to collect the amount from Deputy Commissioner. There is no fixed time for this.	Deputy Commissioner
Section 11 (1)	• Deputy Commissioner awards the compensation to entitled parties within 60 days of receiving the deposit from the requiring agency/person.	Deputy Commissioner
Section 12	• When the property acquired contains, standing crops cultivated by bargadar (shareholders), such portion of the compensation will be determined by the Deputy Commissioner and will be paid to the bargadar in cash.	Deputy Commissioner

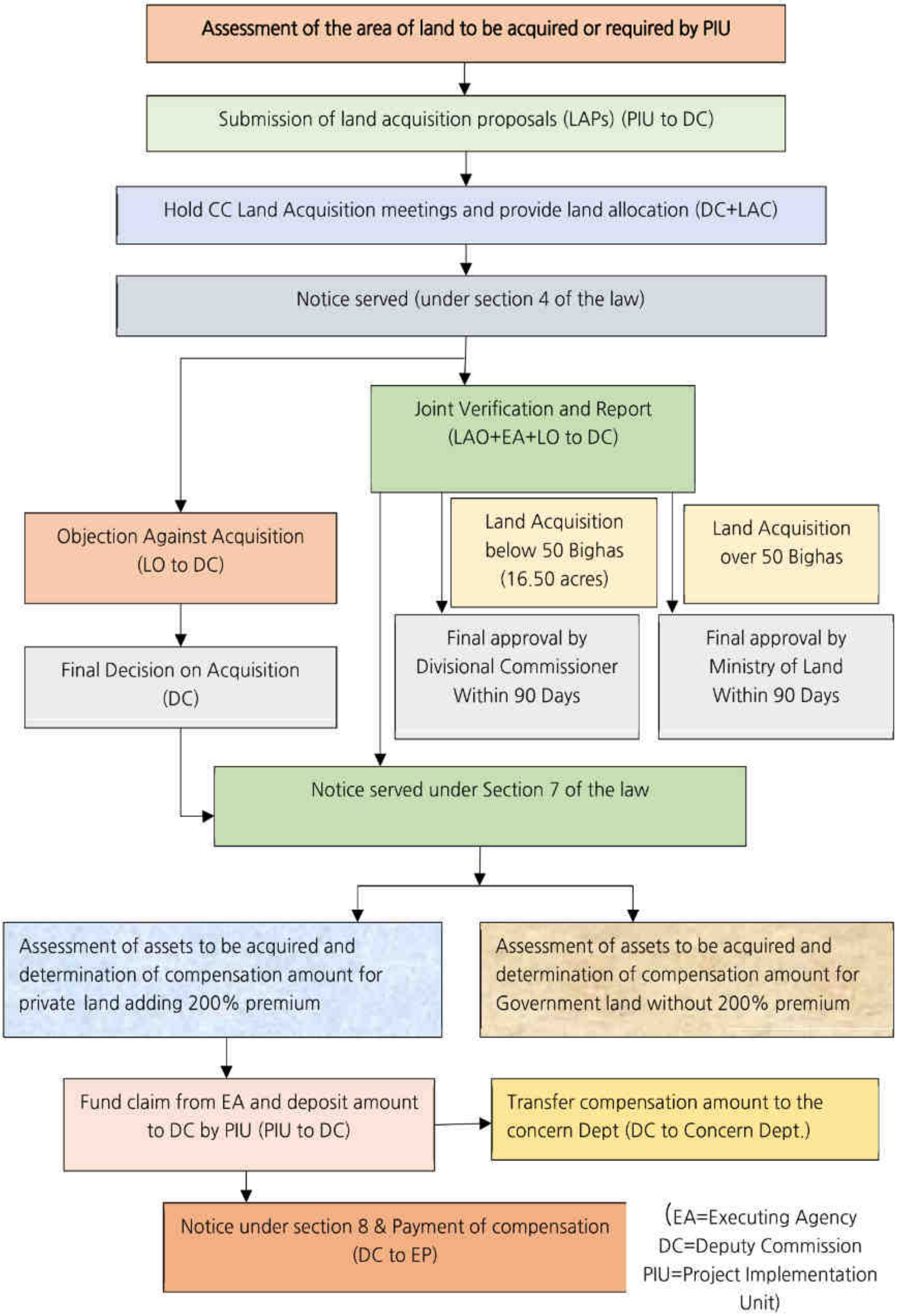


Figure 8-2 Land Acquisition Process

8.3.2.2 Resettlement Process

8.3.2.2.1 General

The smooth progress of resettlement is a prerequisite determining whether the project can be completed on schedule. Any lag in resettlement will delay the construction period and increase the construction cost. Therefore, the first thing is to compare and demonstrate the resettlement plan in details so as to ensure the minimum resettlement requirements; the second thing is to communicate with the clients to do well in resettlement assessment and resettlement action plan, if any assessment on resettlement is required.

8.3.2.2.2 Methods for Ensuring the Minimum Resettlement Requirements

Detailed investigation on building and land conditions: It is required to investigate in details the local building conditions, collect land information for classification research, and start design on this basis. Resettlement and land acquisition shall be taken as important criteria for selecting the project schemes.

Detailed demonstration of project site selection: Site selection is most difficult for designers, as it cannot be realized by purely technical optimization, but more importantly it is influenced by numerous non-technical factors such as the Detailed Area Plan of Chattogram, natural and cultural landscape protection, policies of local government, etc. Hence, for the purpose of ensuring the minimum resettlement or resettlement requirements, it is requisite to do profound research by combining other influential factors, conduct repeated comparison and demonstration, and finally determine the reasonable site selection schemes, under the precondition of complying with Bangladesh design codes and standards.

8.3.2.2.3 Assessment on Compensation for Resettlement

In accordance with relevant Bangladesh laws, regulations and policies concerning the compensation for resettlement, the principles, methods and procedures include:

- Principles: firstly, to determine the compensation amount according to the assessment value on the real estate market; secondly, to determine the compensation amount in reference to such factors as the location, usage, building structure, area, newness rate, storey and decoration.
- Methods and procedures: The chief officer of Chattogram will determine compensation under law (CCL, Cash Compensation under Law) that includes 50% premium for land on the basis of transacted deeds for last twelve months from the date of serving notice under section 3 as per Acquisition and Requisition of Immovable Property Ordinance-1982 and subsequent amendment in 1994. Value (RV, Replacement Value) of the affected properties would be assessed through collection of current market price by interviewing different categories of people from the affected area and considering transacted price recorded price etc.

8.3.2.2.4 Resettlement Action Plan

The Consultant will provide assistance to the client (CWASA) to plan and implement the resettlement action plan, help with resettlement of the households affected by the project and the communities affected by land acquisition. The resettlement plan shall follow the following steps:

- Conduct Census survey and inventory of assets: For preparation of the Resettlement Action Plan the Consultant will conduct census survey of the final alignment covering all affected persons. An inventory survey of the affected assets will also be taken place for preparation of the database and resettlement action plan. The census and inventory survey will cover number of affected households with demographic and socio-economic information, quantity and quality of the affected properties, relocation options, etc.

- Disclosure and Public Consultation (DPC): Goals and objectives of the project should be disclosed to the affected people and other stakeholders through focus group discussion and public consultation meetings. Cut-off dates will be declared in the consultation meetings i.e., notice for legal owners of the property and date of commencement of census or any designated date fixed by the CWASA for the squatters/unauthorized occupants in the polder areas.
- Consultation: Consultation of resettlement and rehabilitation issues with all level stakeholders and gather feedback on potential risks and probable mitigation measures. Encourage all level stakeholders to participate in the consultation by receiving views from representatives from different groups including directly and indirectly affected households, land owners, structure owners, squatters, fishermen, local traders, women and vulnerable groups etc.
- Updating of Resettlement Plan: The resettlement plan should be updated according to changes in the planning and detailed design of facility components.

Table 8-4 Resettlement Process

Process	Responsibility
Establishment of Resettlement Units in PMU Appointment of PD, CRO & ROs	PMU
Engagement of Detailed Design Consultant	PMU
Fielding of International Resettlement Specialist	PMU
Fielding of Domestic Resettlement Specialist	PMU
Organizing Resettlement Training Workshop	PMU
Social Assessment and Updating of Core RAP Preparation of Non-core RAP	PMU / Resettlement Specialist / Design Consultant
Submission of RAP to Funding Agency for Approval	PMU / Funding Agency
Hiring of NGOs	PMU
Public Consultation and Disclosure of RP	PMU / Design Consultant / NGO
Formation of GRC, RAC, PVAT	PMU / NGO / Resettlement Specialist
Coordination with District Administration of Land Acquisition	PMU / NGO / Resettlement Specialist
Declaration of Cut-Off Date	District Commissioner / PMU
Submission of Land Acquisition Proposals to District Commissioner	District Commissioner / PMU / NGO / Resettlement Specialist
Compensation Award and Payment of Compensation	District Commissioner / PMU / NGO / Resettlement Specialist
Payment of Replacement Value Allowance and Resettlement Assistance to Titled and Non-Title Holders	District Commissioner / PMU / NGO / Resettlement Specialist
Relocation of APs to Resettlement Sites and Assisting in Self Relocation	District Commissioner / PMU / NGO / Resettlement Specialist
Taking Possession of Acquired Land and Structures	District Commissioner
Handing over the Acquired Land to Contractors for Construction	PMU
Notify the Date of Commencement of Construction to APs	PMU
Internal Monitoring of Overall RP Implementation	PMU / NGO / Resettlement Specialist
External Monitoring and Evaluation (M&E)	PMU

8.4 Classification of Environmental and Social Impacts

8.4.1 Bangladesh Categorization

According to the Bangladesh Environmental Conservation Regulations (1997), the criteria for classifying impact types classified into four levels of colour are as follows, and this project corresponds to the “Red” grade according to the classification of the Bangladesh Environmental Conservation Regulations.

As specified in Clause 7 of the ECR, the necessary documents attached with an application for Environmental Clearance Certificate (ECC) by the red category are as follows.

- Feasibility study report: report on the feasibility of the industrial unit or project (applicable only for proposed industrial unit or project).
- IEE report/EIA report: IEE which is linked with business and industry, Environmental impact evaluation prepared on the basis of terms of reference or DOE (Department of Environment), are all previously approved by the Department of Environment, along with the preparation of the Environmental Impact Assessment report, the Layout Plan (showing location of Effluent Treatment Plant), Process Flow Diagram, design and time schedule of the Effluent Treatment Plant of the unit or project).
- EMP report: report on the Environmental Management Plan (EMP) for the industrial unit or project, and also the Process Flow Diagram, Layout Plan (showing location of Effluent Treatment Plant), design and information about the effectiveness of the Effluent Treatment Plant of the unit or project (these are applicable only for an existing industrial unit or project).
- NOC issued by the local authorities: no objection certificate of the local authority.
- Pollution minimization plan: emergency plan relating adverse environmental impact and plan for mitigation of the effect of pollution.
- Outline of relocation, rehabilitation plan (where applicable).

Table 8-5 Classification of industries and projects based on environmental impact

Category	Industries and Projects
Green	• Manufacturing: artificial leather goods, TV, radio, watches & clocks, telephones, toys, sport goods, musical instruments and etc • Assembling: motorcycles, bicycles and etc
Orange A	• Livestock: dairy farm, poultry (small scale) and etc • Manufacturing: leather goods, plastic & rubber goods, agricultural machinery and equipment and etc • Service: restaurant, cinema hall and etc
Orange B	• Livestock: dairy farm, poultry (mid and large scale) and etc • Manufacturing: PVC, glass, aluminium, garment and sweater, edible oil, animal feed and etc. • Service: hotel and etc • Project: local road, bridge (length below 100m) and etc
Red	• Manufacturing: fertilizer, paper and pulp, cement, power plant, iron and steel, ship and etc • Service: hospital and etc • Project: national road, bridge (length 100m and above), water treatment plant, Sewage Treatment Plant, sewer of water / sewerage / power and gas and etc

*Source: Environmental Conservation Rules (1997)

8.4.2 EDCF Categorization

Under the EDCF Safeguard Policy (2020), the Export-Import Bank of Korea categorizes the proposed project into four categories: type, location, sensitivity, scale, and the magnitude and nature of potential impacts and risks. Projects in Category, which are high due to their potential impact and complexity in a broad-sense environment, should include research and mitigation plans for performance.

This project is assessed as "Category B+" according to the classification of EDCF environmental and social impact analysis risk.

Table 8-6 Category of EDCF Environmental and Social Impact Analysis Risk

Categorization	Description
Category A (High Risk)	• A proposed project is classified as category A if it is likely to have significant adverse environmental and social impacts and high risks that are irreversible, diverse, or unprecedented. • These impacts may affect an area larger than the sites or facilities. Category A, in principle, includes projects in sensitive sectors or located in or near sensitive areas such as those composed of large-scale dam construction which involves a large number of involuntary resettlement, biodegradable risks, and/or negative impacts and risks to indigenous peoples. • PEA will be required to conduct full-scale ESIA (draft or final) and KEXIM ensures ESIA execution by the PEA.
Category B+ (Substantial Risk)	• A proposed project is classified as category B+ if it is likely to have substantial adverse environmental and social impacts and risks that are less adverse than those of category A projects. • These impacts and risks can be managed and predicted in a manner consistent with the EDCF Safeguard Policy. • ESIA (draft, final, framework, strategy, plan, and/or environmental impact assessment) is required.
Category B (Moderate Risk)	• A proposed project is classified as category B if its potential adverse environmental and social impacts are less adverse than those of category B+ projects. • These impacts are site-specific, few if any of them are irreversible, and in most cases mitigation measures can be designed more readily than for category B+ projects. KEXIM ensures execution of IESE by the PEA. • IESE (draft, final, framework, strategy, plan, and/or environmental impact assessment) is required.
Category C (Low Risk)	• A proposed project is classified as category C if it is likely to have minimal or no adverse environmental and social impacts. • SIA and IESE are not required for category C projects.

*Source: EDCF Safeguard Policy (2020, KEXIM)

8.5 Stakeholder Consultations

The Consultant conducted stakeholder consultations on environmental & social aspect. Stakeholders are knowledge of the project at the National and local authorities, communities or non-governmental organizations. At the stakeholder consultations, potential impacts such as benefits of the project, roles and responsibilities of the project owner, land use patterns, affected population, land purchase, resettlement, water supply, wastewater treatment, etc. were discussed together. The opinions and influences derived are as follows.

Table 8-7 Stakeholder Consultations on Environmental Aspects

Environmental Issues	Opinion	Suggestions
Treated Effluent Standard	• Environmental regulation (ECR' 97) is high compare to proposed draft standard (draft revised ECR'2017). • Additional Cost is involved if we follow the new draft standard as it is not gazette. • As we are in feasibility stage, the stakeholder asked for a reply on which option we will follow.	• Deputy Director, DoE suggested that the project team shall follow new draft standard as the draft standard will be gazette within short of time. • Revised DoE discharge standard is issued on March, 2023 and it is incorporated in the feasibility study.
Air Pollution	• The Environmental Specialist, DDC informed the proposed location of treated effluent discharge point is Madani khal which is connected with Halda River. Now it is public interest, as Halda River is declared Bangabandhu Fisheries Heritage. • At present, untreated sewerage waste is discharge directly to Halda River. • The Fatehabad Catchmen-03 of Sewerage STP project will treat the untreated sewerage waste.	• Deputy Director, DoE answered, with the declaration of Bangabandhu Fisheries Heritage, some restriction has been application there like: Nobody can discharge any garbage into the Halda River and the river can be used only for research work. • Impact on treated effluent discharge on Halda River is reviewed in the Feasibility Study and it will be confirmed during the detailed design stage by EIA.

Table 8-8 Stakeholder Consultation on Social Aspects

Category	Description
Positive Impact	• According to the FGD participants, the implementation of the project will Improve the sewerage management capacity of CWASA. • Strengthen sewerage infrastructure to avoid intrusion of sewage into water supply sewer and help to prevent pollution of drinking water. • Improvement of health, sanitation, environment, and further with quality of life by improving on-site sanitation and decentralized system. • If standard sewerage system is introduced local people would like to get their houses connected with the new sewerage line and will pay tariff at the reasonable rate to the authority concern. • With the installation of new sewerage lines, there would not be any difficulty in passing refuse carried off by sewers and draining out the stagnant polluted water on the road. • There would not be any possibility of submerging the road on account of rain. • Pollution of environmental will come down and waterborne diseases go down. • No extra money will need to be spent on cleaning the household sewers.
Negative Impact	• During construction work, some shops, vendors may be affected temporarily. Some of them will face trouble to get alternative space for business. Business activities will have to be closed. • Income of the traders will be reduced remarkably. • People will face enormous difficulties during their movements for different purposes and transportation of goods. • If the installation/construction works of new sewerage line is prolonged, it will create serious difficulties for the local people as well as the visitors.

8.6 Environmental & Social Impact Assessment

Initial environmental and social impact assessment is conducted to identify and analyse the predictable environmental and social negative impacts and risks caused by the project implementation in advance. It contributes to sustainable development by identifying the negative effects of the EDCF loan support project on the environment and local residents and avoiding and minimizing them.

8.6.1 Environmental Impact Assessment

In Phase 1 as a target year 2040, daily average wastewater generation of sewage treatment plant is 55,574 m^3/d is only 0.23% of 25,920,000 m^3/d which is the lowest flow rate of Halda river and Treated effluent is discharged to Madari Khal and final receiving water body is Halda River.

Treated effluent discharge point of STP in Madari Khal is about 7.6km away from the intake facility of Modunaghat WTP and about 11.5km away from the intake facility of Mohara WTP, so the impact of effluent will be negligible to the intake of WTP. For instance, 4.0km of standard distance from the intake of WTP is considered when designating a water source protection area in Korea.

Treated effluent will satisfy the standard Sewerage discharge of DOE, so it will contribute to improve the water quality of river and to preserve the ecosystem of river. It is planned to obtain the environmental license through the environmental impact assessment during the project implementation.

8.6.2 Social Impact Assessment

Proposed site of sewage treatment plant has been owned by CWASA since 1960s, so the land acquisition is not required. However, there are illegal residents in the proposed site even though there no schools and mosques, resettlement action plan should be prepared by CWASA during the project implementation.

There is no requirement for the buffer zone from STP to the resident area in the environmental regulation of Bangladesh, odour control facility will be constructed in the STP and odour mitigation measures shall be analyzed in the ESIA during the project implementation.

Table 8-9 Land Use of Sewage Treatment Plant Site

No.	Category	Total	A1	A2	A3	Remarks
1	Common House (Tin-roofed)	49	9	6	34	
2	Common House (Brick building)	11	2	5	4	
3	Cattle Farm	8	-	3	5	
4	Two-story Building	2	-	2	-	
5	Three-story Building	2	-	-	2	
6	One-story Building	1	1	-		
7	CWASA Storage	1	-	1	-	
8	School	1	1	-	-	
9	Toilet	1	1	-	-	
10	Religious Facility	2	1	1	-	
11	Cemetery	4	3	1	-	
12	Pond	25	-	-	-	
13	Khal	1	-	-	-	
14	Dirt Road	3	-	-	-	
15	Paved Road	4	-	-	-	
16	BFS Road	1	-	-	-	
17	RCC Road	2	-	-	-	
18	RHD Road	1	-	-	-	
19	Railroad	1	-	-	-	
20	Forest	-	-	-	-	
21	Bridge	2	-	-	-	
22	Culvert	-	-	-	-	
23	Street Lamp	26	-	-	-	
24	Tree	5000 +	-	-	-	
25	Rice Field	210	-	-	-	

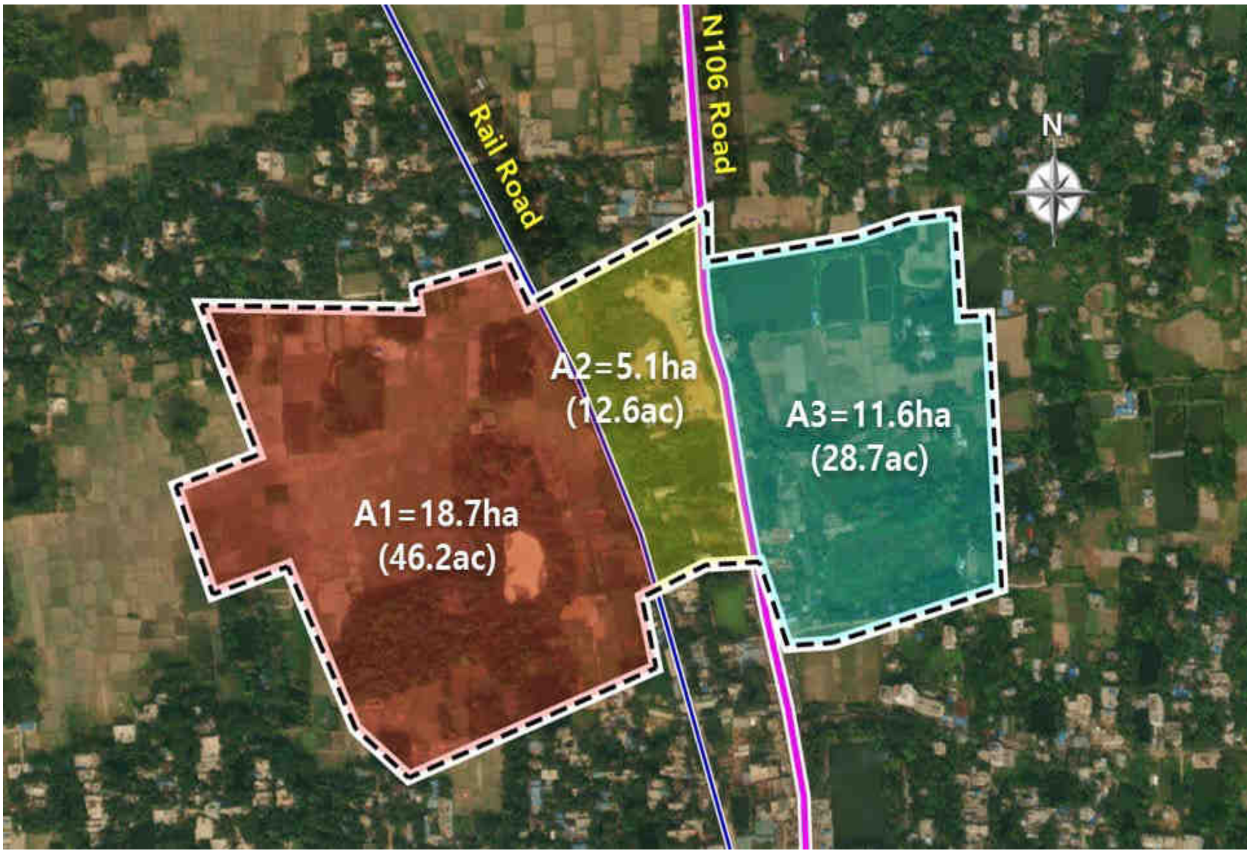


Figure 8-3 Proposed Site of Sewage Treatment Plant

9 Project Feasibility Analysis

9.1 Policy & Strategic Aspects

The government of Bangladesh is working to increase the supply of water resources and water supply as mentioned in Perspective Plan of Bangladesh 2021-2041, as well as to expand the supply of sewage. As for the sewage system, it is planned to supply 100% sanitary toilets and install Sewage treatment plant in urban areas by 2041.

Table 9-1 Target of Perspective Plan (%)

Description		Standard (2018)	Target (2041)
Ratio of urban population to total population		30	80
Urban Household	Tap water connection	40	100
	Sanitary Toilet	42	100
	Water closet connections	N/A	100
Rural Household	Tap water connection	0	50
	Sanitary Toilet	0	50
	Water closet connections	0	100
Poverty Rate		24	Under 3%
Percentage of population living in slums		55	0
Percentage of cities with Sewage treatment plant		N/A	100
Environmental Performance Index International Ranking		Bottom 5%	Top 30%

Chattogram's CCC area corresponds to an urban area, but the Fatehabad area, which is the sewage treatment area of this project, was found to include part of the city's outer area and slums. In the Sanitation Master Plan, 2017, the sewage basic plan of the Chattogram Water Supply Improvement and Sanitation Project (CWSISP), it is planned to set up six treatment areas and build Sewage treatment plant.

The site of this project is Catchment-3, and the location of the sewage treatment facility is planned to be located in the north of the CCC area, and the current status is as follows.

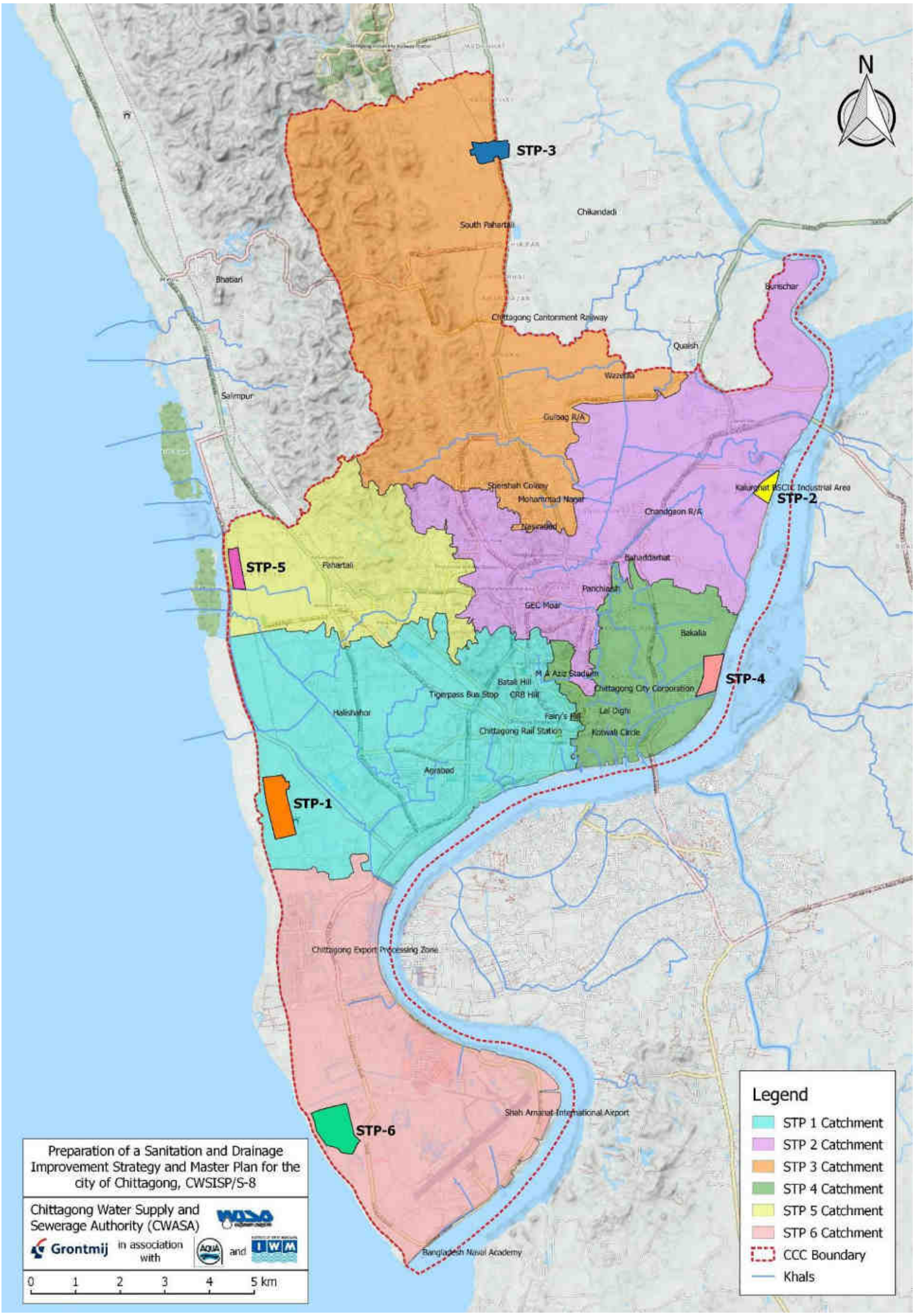


Figure 9-1 Sewage treatment area and facility location on Sanitation Master Plan

9.2 Legal Aspect

9.2.1 Laws & Policies

The government of Bangladesh classified and organized ratings and approval management agencies by level to establish a national water supply & sanitation strategy. The ratings are classified into four major categories: related laws, policies and rules, national strategies, plans and guidelines, and the contents are as follows.

Table 9-2 Level of Law & Policy

No.	Category	Description	Approval
1	Laws	Environment Conservation Act, 1995	Parliament
2	Policies and Rules	Environment Conservation Rules, 1997 National Policy for Safe Water Supply & Sanitation 1998	Ministry
3	National Strategies	National Strategy for Water Supply and Sanitation 2014	Department
4	Plans and Guidelines	Eighth Five Year Plan 2020-2025 Perspective Plan of Bangladesh 2021-2041 Sanitation Master Plan 2017	Agency

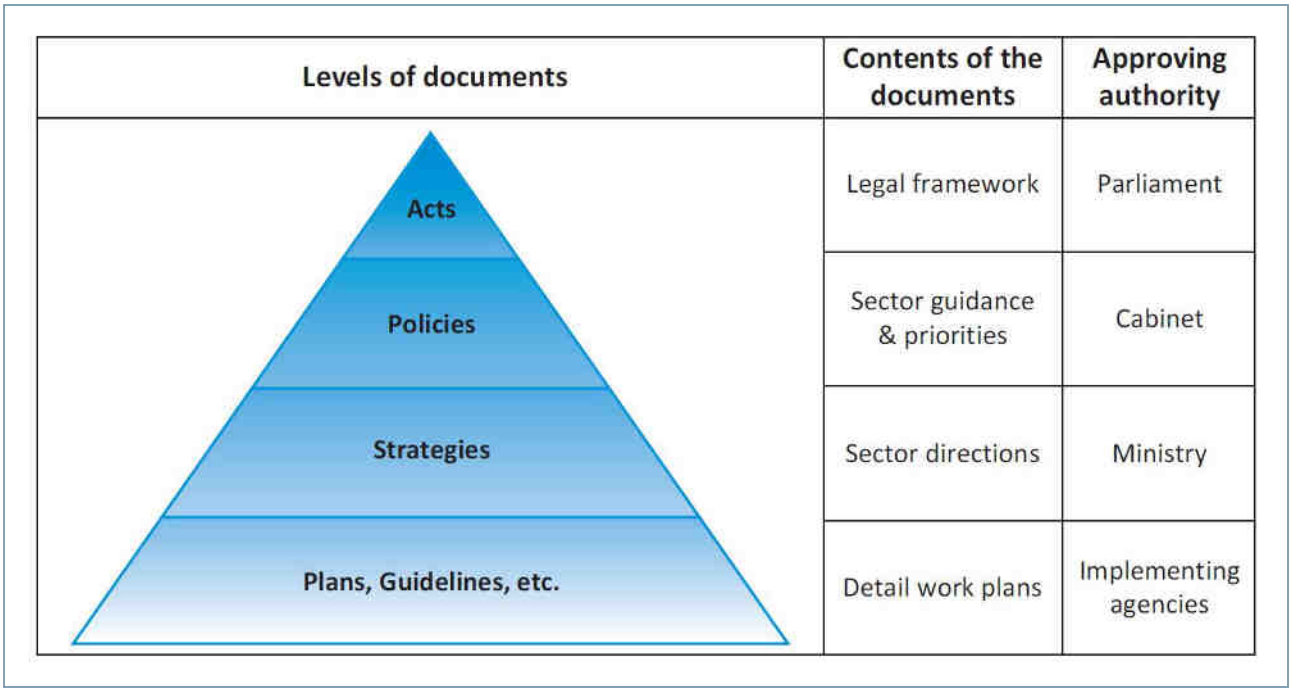


Figure 9-2 Rating Composition for National Water supply & Sanitation Strategy

9.2.1.1 Environment Conservation Act, 1995

The Environment Conservation Act of 1995, and all subsequent amendments, is currently the main legislative document relating to environmental protection in Bangladesh. The main objectives of the Act are improvement of the environmental health and environment standard, and control and mitigation of pollution of the environment. DoE is empowered to enforce the Act, and the main strategies of the Act can be summarized as follows.

- Identification of ecologically critical areas, and restriction on the operations which can be carried out in such areas.
- Regulation in respect to vehicular emissions.
- Environmental clearance.
- Regulation imposed on industries and other development activities, incl. discharge permits.
- Production of standards for quality of air, water and soil for different areas/purposes.
- Production of standard limits for discharge and emission of wastes.
- Formulation and declaration of environmental guidelines.

9.2.1.2 Environment Conservation Rules

The Bangladesh Department of Environment (DoE) established the standard Sewerage discharge in 1997 and revised the standard in March 2023. Bangladesh mainly have regulated the removal of SS and BOD, COD contained in the wastewater and the discharge standards have been strengthened recently to remove T-N and T-P to prevent eutrophication in the public water body.

In the Catchment-1 project, which is under construction, a target effluent water quality was set up as stronger than the effluent standard. In this feasibility study, target effluent quality is set up in consultation with PMU as follows.

Table 9-3 Target Effluent Quality

Category	Unit	Standard Sewage Discharge		Target Effluent Quality	
		1997	2023	Catchment 1	Catchment 3
Temperature	℃	30	30	24	24
pH	-	-	6-9	6-9	6-9
BOD	mg/L	40	30	20	20
COD	mg/L	-	125	100	100
SS	mg/L	100	100	30	30
Oil and Grease	mg/L	-	10	-	-
NO_3-N	mg/L	250	50	40 as T-N	40 as T-N
PO_4-P	mg/L	35	15	10 as T-P	10 as T-P
Coliform	CFU/100mL	1000	1000	1000	1000

*Source: Standard Sewerage discharge in the Environment Conservation Rules (1997&2023, DOE)

9.2.1.3 National Policy for Safe Water Supply & Sanitation 1998

This policy is established to ensure that all people have access to safe sanitation services through the provision of clean water at an affordable cost and the promotion of public health development. The goals to achieve this are as follows:

- Facilitating access of all citizens to basic level of services in water supply and sanitation.
- Bringing about behavioural changes regarding use of water and sanitation.
- Reducing incidence of water-borne diseases.
- Building capacity in local governments and communities to be effective with problems.
- Promoting sustainable water and sanitation services.
- Ensuring proper storage, management and use of surface water and preventing its contamination.
- Taking necessary measures for storage and use of rain water.
- Smooth drainage in urban areas during rainfall.

To achieve the overall goal, the short-term plan was established as follows.

- Increasing the present coverage of safe drinking water in rural areas by lowering the average number of users per tube-well from the present 105 to 50 in the near future.
- Ensuring the installation of one sanitary latrine in each household in the rural areas and improving public health standard through cultivating the habit of proper use of sanitary latrines.
- Making safe drinking water available to each household in the urban areas.
- Ensuring sanitary latrine within easy access of every urban household through technology options ranging from pit latrines to water borne sewerage.

9.2.1.4 National Strategy for Water Supply and Sanitation 2014

This strategy is established to promote better health through safe and sustainable water supply, sanitation and sanitation services for all. The following guidelines are in principle.

- Regard water supply and sanitation as human rights.
- Consider water as a public good that has economic and social value.
- Ensure drinking water security through integrated water resource management.
- Setting up programs in an integrated way for all water source development
- Recognize importance of gender in all WASH activities.
- Ensure equity in services by giving priority to arsenic affected areas, hard-to-reach areas, water-stressed areas and vulnerable people.
- Protect human health and water supply and sanitation facilities from the adverse impact of natural and manmade disasters and climate change.
- Recycle the potential resources from solid and liquid wastes.
- Promote technical innovations to address social needs.
- Promote transparency and accountability at all stages of service delivery.
- Undertake a gradual approach to improve the quality and service levels.
- Promote enhanced private sector participation.

9.2.1.5 Eighth Five Year Plan 2020-2025

The sustainable development goals and strategies related to environmental climate change and forest management established in the 8th Five-Year Plan are identical to the long-term goals presented in the Perspective Plan of Bangladesh 2021-2041. The main goals of environmental management according to this plan are as follows.

Table 9-4 Goals for Environmental Management (2020-2025)

Description	Standard (2018)	Target (2025)
Percentage of cities with Sewage treatment plant	N/A	50
Water Quality Standards Compliance Rate in Urban Areas	Bottom 5%	Top 50%
Environmental performance index international rankings	Bottom 5%	Top 50%

9.2.1.6 Perspective Plan of Bangladesh 2021-2041

In this plan, it is planned to supply 100% sanitary toilets and install Sewage treatment plant in urban areas by 2041.

Table 9-5 Goals for Environmental Management (%)

Description		Standard (2018)	Target (2041)
Ratio of urban population to total population		30	80
Urban Household	Tap water connection	40	100
	Sanitary Toilet	42	100
	Water closet connections	N/A	100
Rural Household	Tap water connection	0	50
	Sanitary Toilet	0	50
	Water closet connections	0	100
Poverty Rate		24	Under 3%
Percentage of population living in slums		55	0
Percentage of cities with Sewage treatment plant		N/A	100
Environmental Performance Index International Ranking		Bottom 5%	Top 30%

9.2.1.7 Sanitation Master Plan 2017

The project target for this feasibility study set in Sanitation Master Plan, 2017, the basic plan for sewerage of the Chattogram water supply improvement and sanitation project (CWSISP), is planned to include seven wards as Catchment-3. The location of the sewage treatment facility is to the north of the project site, and the current status is as follows.

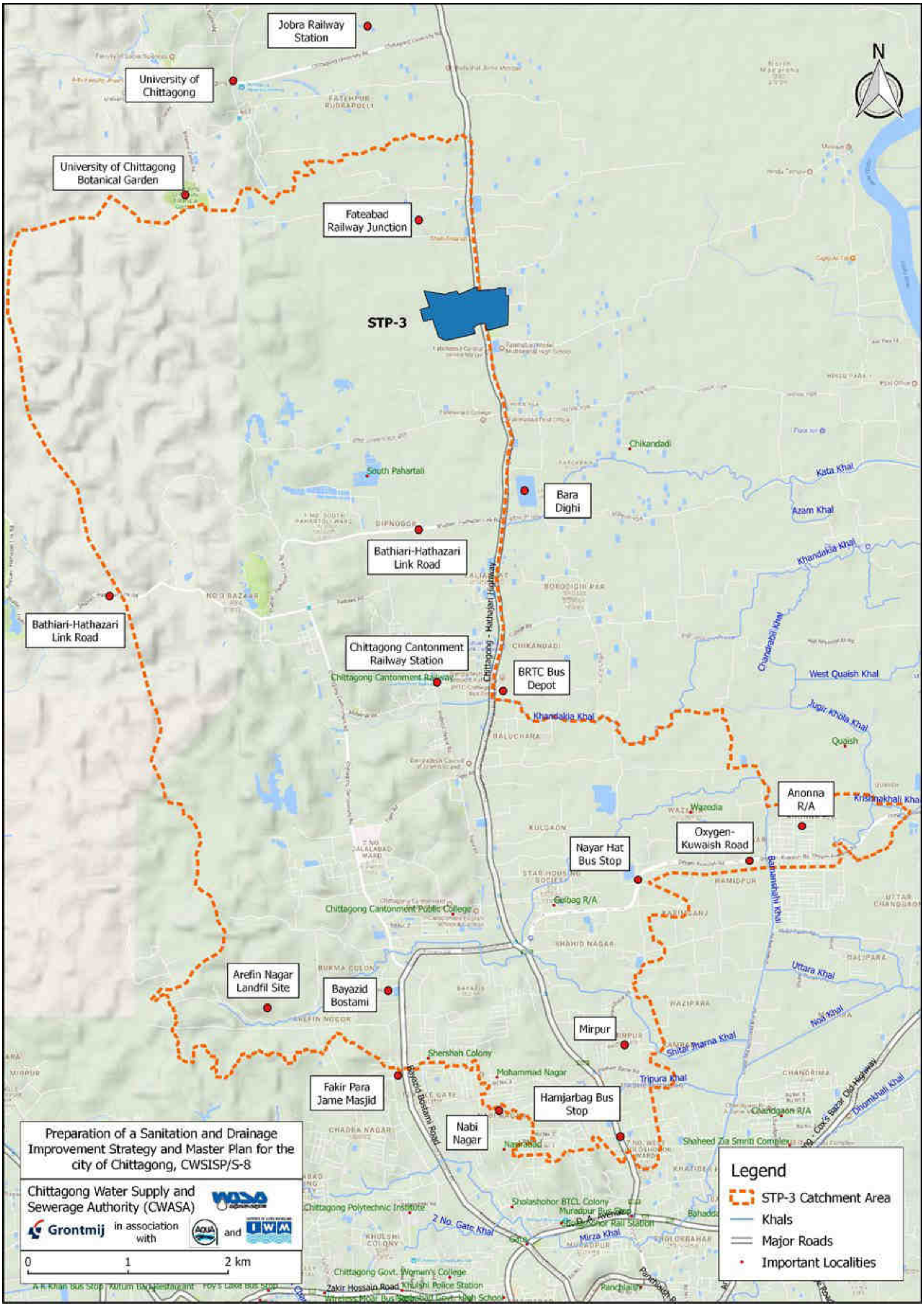


Figure 9-3 Location of Sewage Treatment Plant

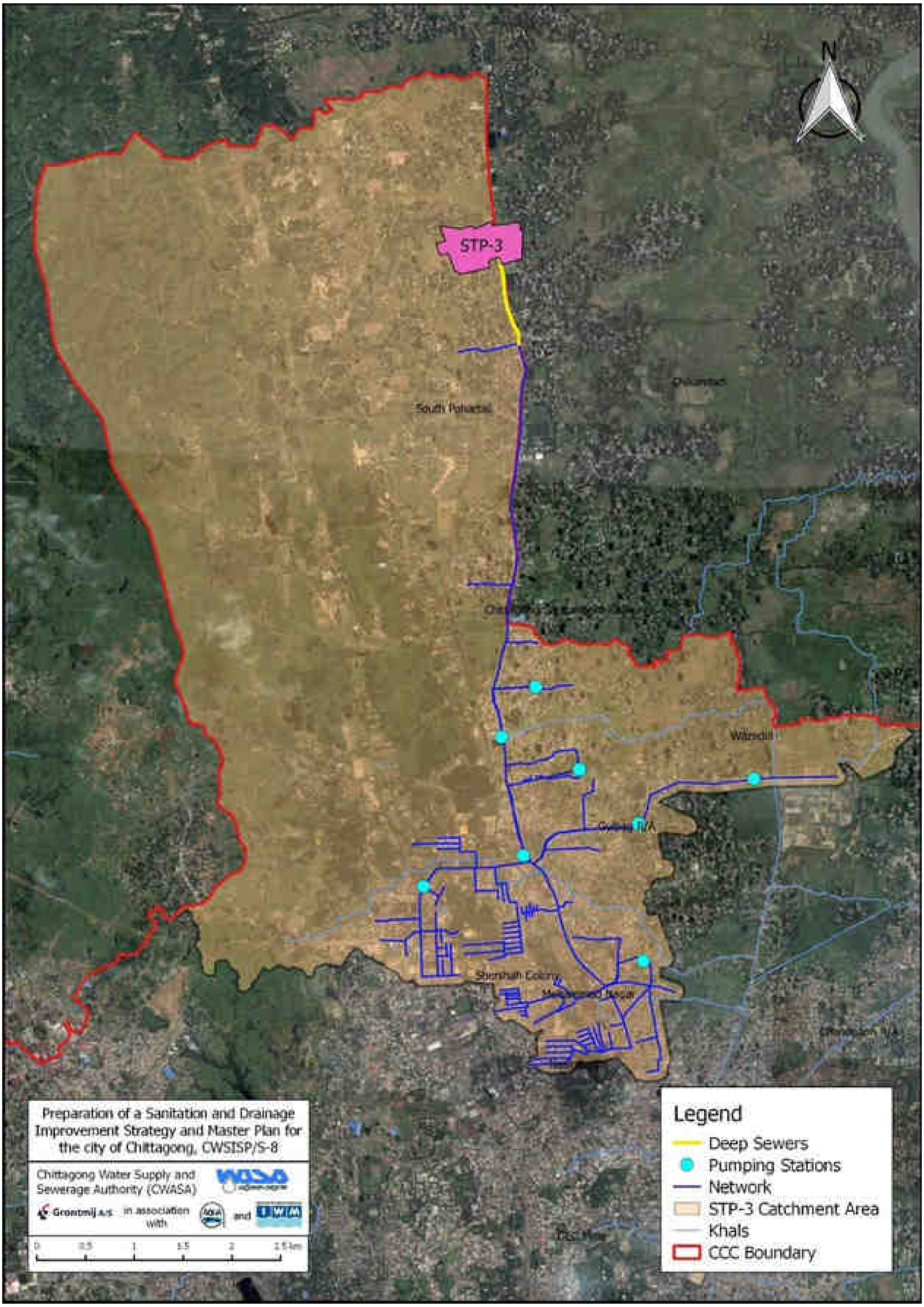


Figure 9-4 Main Trunk Plan

9.2.2 Legal Feasibility

9.2.2.1 Legal and Policy Compliance

In this feasibility study, it is planned to improve the water quality of the discharge river by setting it to be more stringent than the effluent water quality standards set by laws and policies. The water quality standards set this time are as follows.

Table 9-6 Quality of treated water and discharged water (mg/L)

Category	Discharge Water Quality			Target Discharge	Remarks
	1997	2017	2023		
COD	-	125	125	100	Reinforcement
BOD	40	30	30	20	Reinforcement
SS	100	100	100	30	Reinforcement
TKN	-	-	50	25	Reinforcement
T-P	-	-	15	4	Reinforcement
Nitrate	250	250	-	-	
Phosphate	35	35	-	-	
Total Coliform	1,000 MPN/100mL	1,000 MPN/100mL	1,000 MPN/100mL	1,000 MPN/100mL	

9.2.2.2 Consistency with Relevant Plan

In this feasibility study, the sewage treatment area and facility location set in the sewerage master plan, which is the upper-level plan, is applied identically. It is planned to construct a sewage treatment facility with a facility capacity of 60,000m^3/d to treat the average planned sewage volume per day in the first stage (by 2040), and expanded to 90,000m^3/d in the second stage and 120,000m^3/d in the third stage. Finally, a reasonable expansion plan is established by the final target year 2070.

9.2.2.3 Legal Feasibility

In this feasibility study, a detailed plan is established according to the laws, policies and regulations established by the government of Bangladesh, and the plan set in the upper-level plan. In line with the environment-related goals established in the 8th Five-Year Plan and Perspective Plan of Bangladesh 2021-2041, 100% penetration rate of Sewage treatment plant in urban areas is planned to be achieved.

It is judged to be legally appropriate by complying with relevant laws and planning according to policies and regulations, and upper-level plans.

9.3 Technical Aspects

9.3.1 Feasibility of Project Area

9.3.1.1 Project Area

The sewage treatment area corresponds to Catchment-3 established in the Chattogram sewerage maintenance master plan, and has an area of 42.70 km^2, and includes seven wards out of 41 wards belonging to the Chattogram CCC in the administrative district.

It is planned that 100% of the South Pahartali area would be incorporated into the sewage service area and the remaining areas would be partially incorporated, and the status of the sewage service area is as follows.

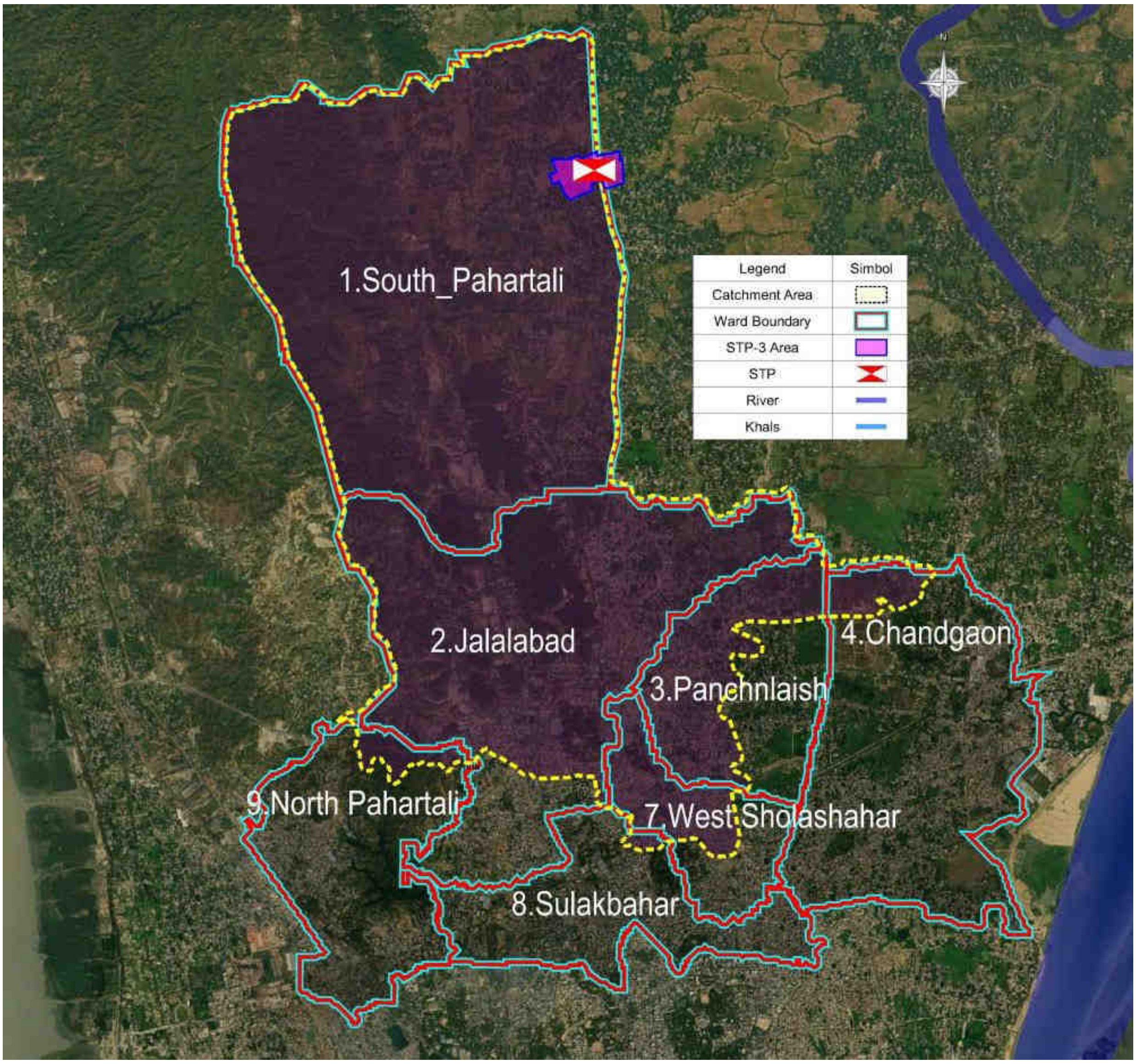


Figure 9-5 Sewage Service Area

Currently five sewerage projects including this project are on-going in Chattogram City under CWASA. Although six sewage treatment plants were planned in the Sanitation & Drainage Improvement Strategy and Master Plan (CWSISP), number of STP is adjusted during the project implementation of each project due to the difficulty of the land acquisition of sewage treatment plant sites of Catchment-4, Catchment-5 & Catchment-6 as below.

- STP of Catchment-5 & Catchment-6 is planned to be integrated in the site of STP of Cathcment-1 (PESSCM-1).
- STP of Catchment-2 & Catchment-4 is planned to be integrated in the site of STP of Cathcment-2.

Table 9-7 On-going Sewerage Projects

Category	Location of STP	Capacity of STP (Final/Phase 1, m^3/d)	Fund Source	Current Progress
Catchment-1 (PESSCM-1)	Halishahar	100,000	GOB	Under Construction
Catchment-5		100,000 (50,000)	AFD	EOI
Catchment-6		100,000	PPP	Feasibility Study On-going
Catchment-2&4	Kalurghat	300,000 (60,000)	JICA	Feasibility Study On-going
Catchment-3	Fatehabad	120,000 (60,000)	EDCF	Feasibility Study Completed

9.3.1.2 Appropriateness of Project Area

Three sewage treatment plant are scheduled to be built in six catchments within the Chattogram. Catchment 1 is under construction with funding from Bangladesh, and feasibility studies are underway for the rest of the region. The Catchment-3 area, the site of this project, is planned to install a sewage treatment plant of 60,000m^3/d, a sanitary sewer of 93.4km, and seven sewage pumping stations. The sewer supply rate is planned to be improved by 0.5% every year in consideration of the willingness of local residents to pay and the progress of the drainage facility connection construction. So, starting from 0% in 2022, it is planned to achieve 60% in 2030, and 80% in 2070, the final target year.

Feasibility studies are underway for five regions except Catchment 1, and the 8th Five-Year Plan and Perspective Plan of Bangladesh 2021-2041 of Bangladesh aim to achieve 100% penetration of Sewage treatment plant in urban areas by 2041. Therefore, it is expected that the sewer supply rate will gradually increase. Currently, untreated sewage flows into the city's rainwater drainage channels and the Halda River, which has water sources, causing environmental pollution, water-borne diseases, and spoiling the beauty of the city. Therefore, it is necessary to improve the quality of raw water, urban Living Standard, and public health hygiene according to the supply of sewage systems. In addition, it is possible to promote employment of local residents and revitalize the economy according to the supply of sewage system. Considering these environmental, sanitary, and economical aspects, it is judged appropriate to select Fatehabad as the target area for this project.

9.3.2 Feasibility of Sewerage System

9.3.2.1 Phase Plan

In this feasibility study, it is planned to expand the sewage treatment facility step by step, taking into consideration the expansion of the urban area according to the development of the project area. In the first phase (2040), a sewage treatment facility with a facility capacity of 60,000m^3/d is constructed to treat the average daily planned sewage volume and secure a spare capacity of 4,426m^3/d. An expansion plan is established to secure 158m^3/d of spare capacity in 2070, the final target year, by expanding 30,000m^3/d in the 2nd phase and 30,000m^3/d in the 3rd phase.

- Phase 1: Construction of STP with a capacity of 60,000m^3/d
- Phase 2: Expansion of STP with a capacity of 30,000m^3/d
- Phase 3: Expansion of STP with a capacity of 30,000m^3/d

Table 9-8 Phase Plan of Sewage Treatment Plant (m^3/d)

Category		2030	Phase 1 (2040)	Phase 2 (2055)	Phase 3 (2070)
Wastewater Generation (Daily Average)		40,612	55,574	83,876	119,842
STP Capacity	Daily Avg.	60,000	60,000	90,000	120,000
	Daily Max.	75,000	75,000	115,000	150,000
Expansion Capacity		-	-	30,000	30,000
Balance		19,388	4,426	6,124	158

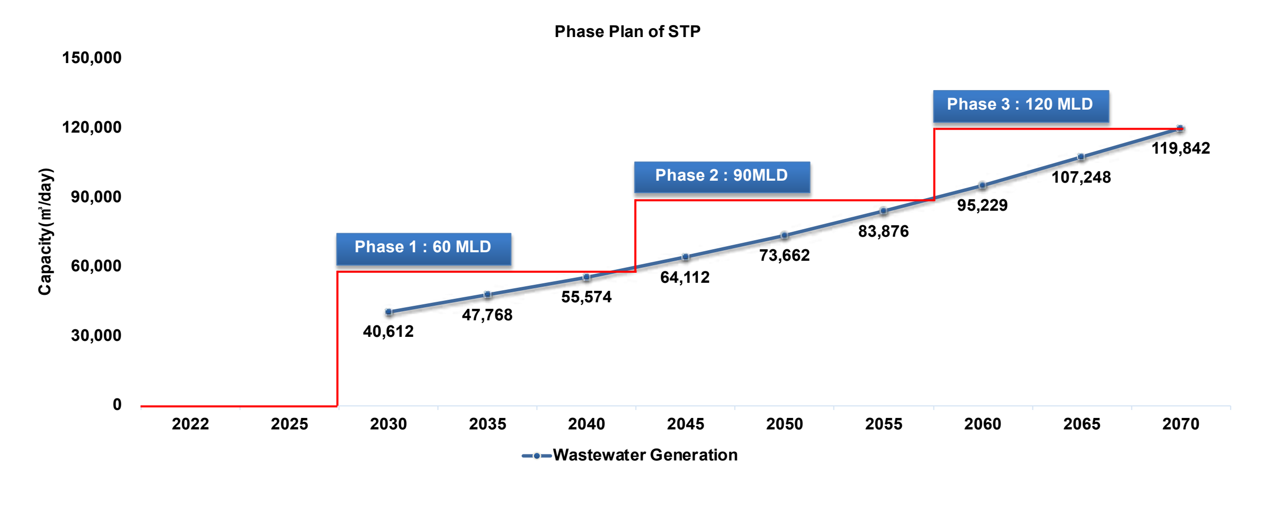


Figure 9-6 Phase Plan of Sewage Treatment Plant

9.3.2.2 Feasibility of Cost Estimate

The estimated construction cost of this project is reviewed as follows, based on the construction cost of a sewerage project of a similar scale in Korea, sewerage project in progress at Chattogram.

9.3.2.2.1 Sewage Treatment Plant

The sewage treatment method applied in this plan is A2O. The estimated cost of STP-3 (Q=60,000m^3/d) is US$ 57,861 thousands. The construction cost of the Sewage Treatment Plant of similar size in Korea is as follows, but the construction method is different and there are more mechanical and electrical equipment. Therefore, the unit cost is US$ 1.25~2.45 thousands/m^3 and average is US$ 1.90 thousands/m^3, showing a large variation in construction cost.

Table 9-9 Unit Cost of STP in Korea

STP	Capacity (m^3/d) (Daily Max.)	Operation Start	Project Cost (Million KRW)	Inflation Correction Rate	Correction Project Cost (US$ thousands)	Unit Cost (US$ thousands/m^3)
Namhang	125,000	2008	221,590	1.32	219,238	1.75
Mansu	70,000	2005	80,746	1.45	87,665	1.25
Eonyang	60,000	2004	72,804	1.49	81,220	1.35
Water Quality Restoration Center	50,000	2012	95,153	1.17	83,727	1.67
Yeokgok	65,000	2006	126,393	1.42	134,215	2.06
Jangdang	65,000	1998	100,278	1.76	132,250	2.03
Poseung	58,000	2000	90,654	1.71	115,974	2.00
Wolgojekopia	68,000	2017	184,890	1.10	152,974	2.25
Gimpo	80,000	2003	155,457	1.54	179,654	2.25
Sincheon	70,000	2006	96,737	1.42	102,724	1.47
Gangreung	75,000	1998	90,418	1.76	119,247	1.59
Chungju	75,000	1995	99,207	2.07	154,147	2.06
Asan	72,000	1996	107,694	1.97	159,482	2.22
Jeongeup	58,600	1999	71,101	1.74	93,015	1.59
Yeosu	110,000	2005	197,000	1.45	213,881	1.94
Gimcheon	80,000	1999	149,818	1.74	195,992	2.45
Andong	54,000	1999	77,169	1.74	100,953	1.87
Jinhae	60,000	2001	107,041	1.64	131,587	2.19
Tongyeong	54,000	1994	65,485	2.16	106,309	1.97
Jangyu	97,000	2004	156,302	1.49	174,370	1.80
Hwamok	145,000	2000	216,552	1.71	277,036	1.91
Yangsna	146,000	1998	225,148	1.76	296,934	2.03

Table 9-10 Comparison of Unit Cost of STP with Sewerage Projects of Chattogram

No.	STP	Capacity (m^3/d)		CAPEX (US$ thousands)	Unit Cost (US$ thousands/m^3) (Daily Max.)
		Daily Max.	Daily Avg.		
1	STP-1	125,000	100,000	82,847	0.66
2	STP-2&4	75,000	60,000	104,546	1.39
3	STP-5	62,500	50,000	35,627	0.57
4	STP-3	75,000	60,000	57,681	0.77

The unit price of US$ 0.77 thousands/m^3 of STP-3 is reviewed as about 31-62% of the level of similar sewage treatment plants in Korea, and about 57-135% of the level of sewage treatment plants in progress in Chattogram. It is considered that unit cost of STP-3 is similar to the unit cost of on-going sewerage projects in Chattogram.

When compared to the sewage treatment plant in progress in the Chattogram, it is found to be 117 to 135% higher than STP-1 and STP-5. In the case of STP-1 and STP-5, the integrated sewage treatment facility is planned to be installed in the vicinity of the Bay of Bengal step by step, and earthworks and disinfection facilities are excluded, so the construction cost is judged to be less than this project. Compared to STP-2&4, it is reviewed at 55.6% level.

In the case of Sewage treatment plant, since the construction cost is influenced by the characteristics of the treatment method, water quality standards, topographical conditions, and surrounding conditions, there is a large variation in construction cost by region and construction method. The construction cost is reflected in appropriate equipment and materials according to the sewage treatment method, and the level of construction cost is judged to be appropriately calculated when comparing and reviewing Chattogram's ongoing project and the status of construction costs of a similar scale in Korea.

9.3.2.2.2 Sanitary Sewer

In the case of sanitary sewer construction cost, the HDPE pipe is applied for D300mm or less, and GRP pipe is applied for D400mm or more. Unit cost of this project is compared with the unit cost of Korea schedules of rates from MOE and it is also compared with unit cost of other sewerage projects of Chattogram as below.

Table 9-11 Comparison of Unit Cost of Sanitary Sewer

Diameter	Korea Standard Unit Cost (US$/m, MOE) (A)	Chattogram Sewerage Projects Unit Cost		This Project Unit Cost (US$/m) (D)	Ratio (%) (A/D)
		STP-1 (US$/m)	STP-5 (US$/m)		
200	611	119	266	161	26.4
300	658	599	402	248	37.7
400	749	-	712	622	83.0
500	827	-	730	648	78.4
600	928	3,376	751	672	72.4
700	1,025	-	780	728	71.0

When comparing the unit cost of this project to the unit cost of Korea schedule of rates, it is analyzed that the D300mm or less pipe diameter was 26.4~37.7% and D400mm or larger pipe diameter was 71.0~83.0%.

In the case of HDPE, it is a product that can be produced locally, and it is judged appropriate when considering the local economic level. In the case of GRP pipe, domestic material cost is applied. In the case of Korea, the larger the pipe diameter, the smaller the unit price range due to the use of construction equipment, whereas in the case of the local case, the cost of manpower installation is high. Considering localization, it is judged to be calculated at an appropriate level.

9.3.3 Appropriateness of Project Implementation Period

The project implementation period of this project is planned for a total of 92 months, including 4 months for consultant selection, 12 months for detailed design, 4 months for contractor selection and 48 months for construction & construction supervision, 6 months for commissioning & training, and 24 months for O&M support after construction completion. Considering the local construction conditions such as sewage treatment plant 60,000m^3/d, 58.3km of sanitary sewers, distinct seasonal characteristics of dry and wet seasons, and the complexity of construction of house connections, the construction period is 48 months and the total project implementation period is 92 months. the project implementation period is considered appropriate.

Table 9-12 Project Implementation Period

	Activity	Duration (Month)
EDCF	Consultant Selection	4M
EDCF	Detailed Design & Bidding Support	12M
EDCF	Contractor Selection	4M
EDCF	Construction	48M
EDCF	STP	36M
EDCF	Trunk Sewer	38M
EDCF	Primary Sewer	36M
EDCF	Secondary Sewer	26M
EDCF	Commissioning & Training	6M
EDCF	Construction Supervision	48M
EDCF	O&M Support	24M
GOB	Land Acquisition & Resettlement	6M
GOB	EIA approval	6M
GOB	Other permission	9M
GOB	Household Connection	30M

Note) Household connection will be constructed sequentially by GOB according to the construction of sanitary sewer.

9.4 Project Monitoring Framework (PMF)

EDCF sets up the logical framework as the project monitoring framework (PMF) and it outlines the impact, outcomes and outputs of the EDCF projects and it is the basic project management tool for development results by including monitoring indicators and indicator definitions, targets, and primary beneficiary information. The purpose of the logical framework is to clarify the logical relationship between the purpose of the EDCF project and the support provided to achieve the objective, and to present precisely defined quantitative goals as indicators so that stakeholders can clearly understand the contents of the project.

EDCF uses the logical framework to assist the borrowing country in specifying project goals & project scopes with output mid- to long-term effect by establishing logical feasibility that contributes to the upper development goals of the borrowing country's government. Therefore, logical framework is an important task for all stakeholders to clearly understand and share the contents of the project during the entire stages of the project from F/S, mission for loan approval, consulting services, procurement, project completion evaluation, and ex-post evaluation.

Table 9-13 Project Monitoring Framework

Category	Indicators	Base	Targets	Source	Assumptions/ Risks
Impact *Improvement of water quality in river and Reduction of vulnerability to climate change*	Improvement of water quality in river	Organics in river (BOD, COD, SS) (6 months before construction completion)	Improvement of water quality in river (BOD, COD, SS) (5 years after construction completion)	Bangladesh Environmental statistics and CWASA O&M Report	• <Assumption> • Policy support of GOB • Willingness of the PEA • • <Risk> • Lack of O&M resources and technology
	Greenhouse gas emission reduction	52,409 t CO^2eq/year (2022)	27,642 t CO^2eq/year (5 years after construction completion)	CWASA O&M Report	
	Reduction of vulnerable population to climate change	N/A (2022)	Sewage service population 334,435 (5 years after construction completion)	CWASA O&M Report	
Outcomes *Improvement of living standard and sanitation of inhabitants in the project area*	Sewage service coverage	N/A (2022)	60.0% (2 years after construction completion)	CWASA O&M Report	• <Assumption> • Normal operation of the facility by the input of professional operating personnel • Completion of household connection construction • • <Risk> • Delayed response to facility failure • Delay of household connection construction
	Daily wastewater treatment of wastewater treatment plant	N/A (2022)	40,612m^3/d (2 years after construction completion)	CWASA O&M Report	
	Compliance with effluent discharge standard	Influent Quality BOD: 322mg/L COD: 644mg/L SS: 386mg/L T-N: 76mg/L T-P: 15mg/L	BOD: 20mg/L COD: 100mg/L SS: 30mg/L T-N: 40mg/L T-P: 10mg/L (After construction completion)	CWASA O&M Report	
	Number of STP operation suspension related to climate disasters	N/A (2022)	Zero (2 years after construction completion)	CWASA O&M Report	
Outputs *Construction of sewerage system with climate resilience*	Construction of sewerage system with climate resilience	N/A (2022)	• STP: Q=60,000m3/day • Sanitary Sewer: L=58.3km • HHC: • 10,000nos. • FSTP: Q=100m3/day	Project Completion Report	• <Assumption> • Securing financial resources of PEA • Efficient project management • Completion of resettlement before construction • • <Risk> • Delay in approval/permission from relevant agencies • Unexpected design changer construction delay

Monitoring			
• Consultant for design, bid preparation and construction supervision will be selected within 4 months after L/A. • Contractor will be selected within 16 months after selection of the Consultant • Construction will be completed within 48 months (including 6 months of training and commissioning)			
Project Objective			
• To increase sewage service coverage through construction of sewerage system • To improve living standard and sanitation of inhabitants in the project area • To improve river water quality and restore the ecosystem by sewage treatment			
Primary Beneficiary			
• People of Chattogram City, Hathazari Upazila and Raozan who inhabits in the project area			
Definition and Management of Indicator			
Indicator	**Definition**	**Source**	**Managed by**
Water quality in river	Water quality measurement of organics such as BOD, COD, SS in rivers	Environmental statistics and CWASA O&M Report	CWASA
Greenhouse gas emission reduction	Calculation method of 2006 IPCC G/L	CWASA O&M Report	CWASA
Reduction of vulnerable population to climate change	Sewage service population	CWASA O&M Report	CWASA
Sewage service coverage	Sewage service population / Total population	CWASA O&M Report	CWASA
Daily sewage treatment of sewage treatment plant	Average daily sewage treatment quantity	CWASA O&M Report	CWASA
Compliance with effluent discharge standard	Standard Sewerage discharge in environment conservation rules (2023, DOE)	CWASA O&M Report	CWASA
Number of STP operation suspension related to climate disasters	$\sum$ (Number of STP operation of suspensions related climate change)	CWASA O&M Report	CWASA
Sewerage system with climate resilience	Infrastructure to convey and treat wastewater from its point of origin to a point of treatment and discharge	Project Completion Report	Consultant & Contractor
Sewage treatment plant	Facility to remove contaminants from wastewater to produce an effluent that is suitable for discharge to the public water body	Project Completion Report	Consultant & Contractor

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