JAPAN INTERNATIONAL COOPERATION AGENCY

CHITTAGONG WATER SUPPLY AND SEWERAGE AUTHORITY

MINISTRY OF LOCAL GOVERNMENT, RURAL DEVELOPMENT AND CO-OPERATIVES

THE FEASIBILITY STUDY OF EXTENSION AND EXPANSION OF MOHARA WATER TREATMENT PLANT IN CHITTAGONG IN THE PEOPLE'S REPUBLIC OF BANGLADESH

FINAL REPORT

(MAIN REPORT)

DECEMBER 2000

NJS CONSULTANTS CO., LTD.

PREFACE

In response to request to from the Government of the People's Republic of Bangladesh, the Government of Japan decided to conduct a study on Extension and Expansion on Mohara Water Treatment Plant in Chittagong and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bangladesh a study team composed of individuals from NJS Consultants Co., Ltd. headed by Mr. Kenji Hori. The team visited Bangladesh two times between January and October 2000.

The team held discussions with the officials concerned of the Government of Bangladesh and conducted field surveys in the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that the report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Bangladesh for the close cooperation that they extended to the team.

December 2000

Kunihiko Saito, President
Japan International Cooperation Agency

December 2000

Mr. Kunihiko Saito, President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

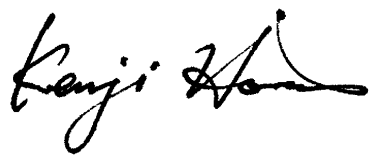
We are pleased to submit herewith the Final Report for the Study on Extension and Expansion on Mohara Water Treatment Plant in Chittagong.

The Study was completed through discussions with the officials of the Government of Bangladesh and field investigations during two visits from January and July 2000 and the homework thereafter.

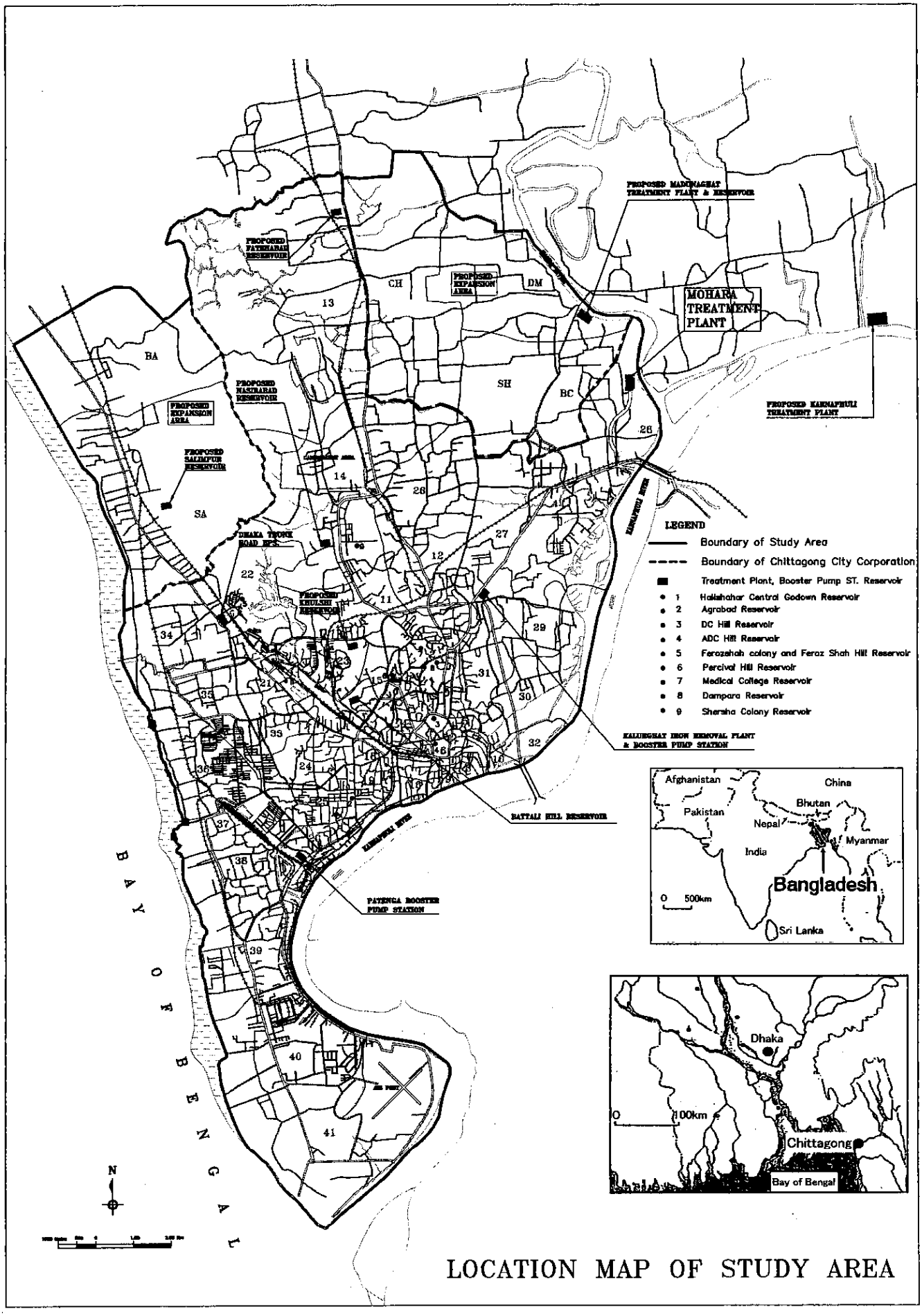
The Final Report consists of three volumes: 1) the Summary Report, which succinctly describes the study and its recommendations; 2) the Main Report, which covers the findings of the Basic Plan and the Feasibility Study on the proposed Priority Project; and 3) the Supporting Report, which contains data upon which the Basic Plan and the Feasibility Study are based.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs and Ministry of Health and Welfare. We also would like to show our appreciation to the officials of the Chittagong Water Supply and Sewerage Authority, the Embassy of Japan in Bangladesh and the JICA Bangladesh Office for their kind assistance throughout this study.

Very truly yours,



Kenji Hori, Team Leader
Study on Extension and Expansion on
Mohara Water Treatment Plant in Chittagong



LOCATION MAP OF STUDY AREA

FINAL REPORT

(MAIN REPORT)

TABLE OF CONTENTS

CHAPTER 8 FEASIBILITY STUDY ON PRIORITY PROJECT

CHAPTER 14 PROJECT EVALUATION

CHAPTER 15 CONCLUSIONS AND RECOMMENDATIONS

LIST OF TABLES

Page

CHAPTER 1 INTRODUCTION

CHAPTER 2 DESCRIPTION OF THE STUDY AREA

CHAPTER 3 POPULATION AND WATER DEMAND PROJECTION

CHAPTER 4 EXISTING WATER SUPPLY SYSTEM

CHAPTER 5 STUDY ON WATER SOURCES

CHAPTER 6 STUDY ON MANAGERIAL ASPECTS OF WATER WORKS

CHAPTER 7 BASIC PLAN FOR DEVELOPMENT OF WATER SUPPLY SYSTEM

CHAPTER 8 FEASIBILITY STUDY ON PRIORITY PROJECT

CHAPTER 9 OPERATION AND MAINTENANCE PLAN

CHAPTER 10 FINANCIAL ANALYSIS

CHAPTER 12 Organization Plan

CHAPTER 13 ENVIRONMENTAL IMPACT ASSESSMENT

LIST OF FIGURES

Page

CHAPTER 2 DESCRIPTION OF THE STUDY AREA

CHAPTER 3 POPULATION AND WATER DEMAND PROJECTION

CHAPTER 4 EXISTING WATER SUPPLY SYSTEM

CHAPTER 5 STUDY ON WATER SOURCES

CHAPTER 6 STUDY ON MANAGERIAL ASPECTS OF WATER WORKS

CHAPTER 7 BASIC PLAN FOR DEVELOPMENT OF WATER SUPPLY SYSTEM

ABBREVIATIONS AND ACRONYMS

1. Unit

A	Ampere
Cm	Centimeter
ft.	Foot
G	Gram
gpcd	gram per capita per day
ha	hectare (1 ha = 10,000m^2)
hr	Hour
kg	Kilogram
km	Kilometer
km^2 or sq.km	square kilometer
kV	Kilovolt
kVA	kilovolt ampere
kW	Kilowatt
kWh	kilowatt hour
L or l	Liter
l/day or l/d	liter per day
l/sec or l/s	liter per second
Lpcd or lpcd	liter per capita per day
m	Meter
m/s or m/sec	meters per second
m^2 or sq.m	square meter
m^3 or cu.m	cubic meter
m^3/d or cu.m/day	cubic meter per day
m^3/min	cubic meter per minute
m^3/s or cu.m/sec	cubic meter per second
MCM	million cubic meter
mgd or MGD	million gallon per day (= 4,546 m^3/day)
mg/l	Milligram per liter
mm	Millimeter
kPa	Kilopascal (pressure)
MPa	Megapascal (pressure)
ppm	parts per million
Taka , TK, Tk	Bangladeshi Money Unit
V	Volt

2. Water Quality

BOD_5	Biochemical Oxygen Demand (20^oC, 5 days)
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electric Conductivity
PH	Hydrogen ion potential
SS	Suspended Solids
TS	Total Solids
TSS	Total Suspended Solids

3. Organizations

ADB	Asian Development Bank
BBS	Bangladesh Bureau of Statistics
CCC	Chittagong City Corporation
CE	Chief Engineer
CWASA	Chittagong Water Supply and Sewerage Authority
DOE	Department of Environment, Ministry of Environment and Forest
DOF	Department of Forest
DWASA	Dhaka Water Supply and Sewerage Authority
EE	Executive Engineer
ERD	Economic Relations Division, Ministry of Finance
GOB	Government of Bangladesh
IBRD	International Bank for Reconstruction and Development (World Bank)
IDA	International Development Agency (soft loan facility of IBRD)
IMF	International Monetary Fund
JBIC	Japan Bank of International Cooperation
JICA	Japan International Cooperation Agency
LGRD	Ministry of Local Government, Rural Development and Co-operatives
MOD I	Maintenance and Operation Division I of CWASA
MOD II	Maintenance and Operation Division II of CWASA
MOEF	Ministry of Environment and Forest
MOF	Ministry of Finance
NJS	Nippon Jogesuido Sekkei Co., Ltd. / NJS Consultants Co., Ltd.
OECD	Organization for Economic Cooperation and Development
SE	Superintending Engineer
WDB	Water Development Board
WHO	World Health Organization

4. Finance

B/S	Balance Sheet
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
MIS	Management Information System
MLSS	Member of Lower Subordinate Staff
MOD	Maintenance and Operation Division Circle
MODS	Maintenance Operation and Service Division
P&C	Planning and Construction Circle
PIR	Physical Inventory Report
P/L	Profit and Loss /Income and Expenditure
SL	Store Ledger
TP	Treatment Plant Circle
UFW	Unaccounted for Water

5. Others

BDWS	Bangladesh Drinking Water Standard
BOT	Build - Operate - Transfer
BPS	Booster Pump Station
BWL	Bottom Water Level
CEPZ	Chittagong Export Processing Zone
CPI	Consumer Price Index
ECA	Environmental Conservation Act
ECC	Environmental Clearance Certificate
ECR	Environmental Conservation Rules
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMP	Environmental Management Plan
EPZ	Export Processing Zone
EQS	Environmental Quality Standards for Bangladesh
ETP	Effluent Treatment Plant
FIRR	Financial Internal Rate of Return
FY	Fiscal Year
GFF	Groundwater Flowing Flux
GL	Ground Level
GNP	Gross National Product
HWL	High Water Level

HHWL	High High Water Level
HH	Household
IEE	Initial Environmental Examination
IRP	Iron Removal Plant
KIP	Key Improvement Point
LLWL	Low Low Water Level
LWL	Low Water Level
M/M	Minute of Meeting
MSL	Mean Sea Level
NGO	Non-Governmental Organization
NOC	No Objection Certificate
NRW	Non-revenue Water
NWP	National Water Policy
O & M	Operation and Maintenance
ODA	Official Development Assistance
S/W	Scope of Work
STP	Sewage Treatment Plant
T.A	Technical Assistance
TOR	Terms of Reference
TW	Tube Well
TWL	Top Water Level
UFW	Unaccounted-For-Water
VAT	Value Added Tax
WSRP	Water Supply and Rehabilitation Project (of 2nd and 3rd Interim)
WTP	Water Treatment Plant

EXECUTIVE SUMMARY

Executive Summary

1. Background of the Study

Chittagong Water Supply and Sewerage Authority (CWASA) was established in 1963 and took over the public water supply utility from Chittagong Municipality. CWASA has taken his effort to reinforce the water supply capacity with IDA assistance and achieved the capacity of producing 40-MGD water.

According to remarkable population growth for last decade, the present water supply coverage rate is 44.7 % only. Moreover, due to shortage of water supply capacity the water pressure has been lowered and the water supply interruption area expanded. In order to cope with the present water shortage and future water demand, development of the water supply facilities is indeed required.

2. Objectives of the Study

The objectives of the Study are to formulate a Basic Plan for the target year 2010 and to conduct a Feasibility Study on the priority project. Preliminary design of urgent and priority project is also included as a part of the Study.

3. Study Area

The Study area was delineated to conform the Chittagong City including a part of surrounding two Thanas, Sitakunda (p) and Hathazari (p) Thanas.

4. Evaluation of the Existing Water Supply System

4.1 Existing Water Supply Facilities

There are two existing water treatment plants, namely Mohara WTP having a capacity of 91,000 m^3/d (20MGD) and Kalurghat IRP having a present distribution capacity of 61,000 m^3/d (13.5MGD), besides 20,000 m^3/d (4.4 MGD) by tube wells. The current distribution volume is 162,500 m^3/d (35.7MGD) and water served population is 1,140,000, coverage rate is 44.7% and water supply volume per capita per day is 142 lpcd.

4.2 Present Water Supply Conditions

The piped water is supplied through house-connections to 70% of served people and through public hydrants to the remainder. Presently, consumers receive water supply for 3 to 15 hours a day or once for several hours in two or three days depending on the location and area due to lack of water supply capacity, which resulting serious problems in social and economical sectors.

The hydraulic analysis was carried out to evaluate capacity of the existing distribution pipe network based on the existing data and information. It is definite that the distribution main and pipe network have insufficient hydraulic capacity to supply water to meet the water demand flow level, and thorough improvement and renovation on the existing system is necessary.

5. Evaluation on Management and Financial Conditions

5.1 Management and Financial Conditions

Basic indexes on the water supply management and financial conditions are presented in Table 1 and Table 2.

Table 1 Indexes on Management Aspect

Item	CWASA			DWASA
	1996	1997	1998	1999
I. Operation Indicators				
1) Daily average supply per capita per day (lpcd)	127	126	126	236
2) Accounted-for water after distribution (%)	65	70	65	69
II. Management Indicators				
1) Selling Cost (Tk/m^3)	5.52	5.68	5.66	5.27
2) Supply Cost (Tk/m^3)	6.58	6.36	6.67	5.04
3) Water Supply per Employee (1,000m^3/employee/year)	46	49	50	92
4) Operating Revenue per Employee (1000Tk/employ./yr)	254	279	280	389

Table 2 Indexes on Financial Aspect

Item	CWASA			DWASA
	1996	1997	1998	1999
Collection Ratio per year (%) (Collected Amount/Billing Amount) x 100	85.3	90.5	91.0	73.9
Working Ratio per year (%) (Operating Revenue/Working Expenditure) x 100	140.2	136.8	120.6	154.1
Operating Ratio per year (%) (Operating Revenue/Operating Expenditure) x 100	109.1	107.9	102.2	120.9
Salaries Ratio of Employee to Expenditure (%) (Salaries Cost/Working Expenditure) x 100	35.3	33.5	32.6	23.6
Current Ratio (%) (Current Assets/Current Liabilities)	1,824	1,858	1,678	1,221
Fixed Assets to Equity Capital Ratio (%) (Fixed Assets/Owned Capital & Surplus) x 100	278	245	250	78
Profit Ratio of Gross Capital (%) (Net Operating Profit/Liabilities & Capital) x 100	11	12	12	9

5.2 Evaluation on Management and Financial System

1) From the above-mentioned tables, Current Ratio, index standing for payment ability to liabilities, is evaluated as fine, Fixed Assets to Equity Capital Ratio, index standing for long-term credit ability, is insufficient while DWASA is good, and Profit Ratio of Gross Capital, index standing for profit ration against investment is good as well as DWASA.

2) It was observed that, as a whole, the CWASA operations seems to suffer from a lack of commercial / businesses orientation and accountability, insufficient management system and shortage of trained staff.

The operational performance is required to be improved through a series of training such as operation and maintenance, management of finance, management information system and computerization.

3) Recognition for improvement of Accounted-for Water is rather low so as to be scheduled an actual UFW reduction plan. The improvement light /easy plan may include the following:
   - Ledger book should be reviewed and improved,
   - Monthly meter repair should be increased, and
   - Standard of house-connection method should be improved by means of skilled workers and proper materials.

   In addition to the above, to reduce the system loss, appropriate methodology, appropriate management and accountability should be introduced in the revenue collection system.

6. Water Supply Development Plan

6.1 Water Demand Projection in 2005 and 2010

(1) Projection of Population

In due consideration on current population, potential urban development and the future land use plan, the population growth rate between 1991 to 2000 was estimated to be 4.5% based on the census population in 1991 and assuming the present city population at 2,350,000. The projection of population in target year was estimated using this rate.

The projected population in target year of 2005 for F/S project, and 2010 for the Basic Plan is summarized in Table 3.

Table 3 Project Population in Target Years

	2000	2005	2010
City Area	2,350,000	2,930,000	3,670,000
Outside Area	200,000	260,000	320,000
Total	2,550,000	3,190,000	3,990,000
Floating	400,000	500,000	700,000

Note; Floating means the population who does not included in the census population.

(2) Target of Water Supply Level

The water supply level was set up as CWASA's target.

Table 4 Target of Water Supply Level

Type of Supply	2000	2005			2010		
	Pucca, Semi-, Kutcha.	Pucca	Semi	Kutcha	Pucca	Semi	Kutcha
House-Connection	70 %	70 %	30 %	15 %	95 %	50 %	20 %
Public hydrant	30 %	10 %	30 %	20 %	5 %	50 %	20 %

(3) Water Demand Projection in Target Years

Assuming that unit water consumption per capita per day is 120 lpcd and 130 lpcd for 2005 and 2010, respectively, the water demand for domestic use was estimated. The other water demand for commercial, institutional, industrial use and UFW/leakage was estimated based on the existing data/information and CWASA's middle-long term plan.

The water demand, supply conditions at present and planned conditions for target years of 2005 and 2010 are summarized as shown in Table 5.

Table 5 Water Supply Condition and Projected Water Demand

	2000	2005	2010
1. Population in Study Area (ps)	2,550,000	3,190,000	3,990,000
2. Project Population to be served (ps)	-	1,940,000	3,370,000
3. Water Demand for above (m^3/day)	-	344,000	649,000
4. Planned Population with Water Supply Service (ps)	1,142,000	1,580,000	3,370,000
[Adjustment ratio]*	-	[82%]	[100 %]
5. Coverage Ratio (%)	44.7	50	84
6. Distribution (m^3/day)	162,500	281,000	649,000
(MGD)	**35.7**	**62**	**143**
1) House Connection	68,000	134,000	329,000
2) Hydrant	16,400	23,000	42,000
3) Commercial	7,600	16,000	37,000
4) Institutional	1,100	2,000	18,000
5) Industrial	11,800	36,000	80,000
6) UFW/Leakage	57,600	70,000	143,000
(incl. UFW)	(35.4%)	(25 %)	(22 %)
7. House Connection Water Consumption (lpcd)	85	120	130
8. Water Supply Volume per capita per day (lpcd)	142	178	193
Condition	*Present*	*F/S Plan*	*Basic Plan*

Note: Population is on the Census level and not includes floating people.
*: Ratio to adjust actual water demand against capacity of water sources.
(Planned population with service / Project population to be served)

6.2 Fundamentals for Planning of Basic Plan and Priority Project

(1) Target Year

The target year of the Basic Plan is 2010. In order to cope with rapid increase of water demand to the year 2010, the intermediate target year is set at the year 2005.

(2) Planned Water Supply Flow

The water demand in the service area in target year 2010 will be 649,000m^3/day or 143MGD on distribution base. While, water demand in the priority project area in 2005 will be 344,000m^3/day or 76MGD as show in Table 5.

Depending on the right of intake water from the present surface water source, Halda River, additional new water sources shall be secured from surface water source, i.e. Karnaphuli River, because ground water exploitation in the Study Area will be in near limitation after the under-planning and existing wells.

On the other hand, the distribution capacity of the existing and under-processing projects by CWASA including this particular project is 281,000 m^3/day or 62 MGD only. Since the planned water demand in 2005 exceeds said capacity, the projected population to be served was adjusted at 82 % so as to meet the water distribution capacity.

6.3 Outline of the Planned Facilities

(1) Water Treatment Facilities

Recommended Chittagong water supply system for the year of 2010 consists of three surface water treatment plants (WTP) and two ground water treatment plants (IRP) with a total capacity of 659,000 m^3/day or 145MGD as showing below.

Table 6 Treatment Plants in Recommended System (Outline)

Name	Production Capacity (m^3/day)	Implementation Stage (available source capacity)		
		Existing	Phase 1 (2005)	Phase 2 (2010)
Mohara WTP (old plant)	20 MGD (90,900)	20 MGD	20 MGD	20 MGD
Mohara WTP (new plant)	20 MGD (90,900)	-	20 MGD	20 MGD
Kalurghat IRP	20 MGD (90,900)	10 MGD	12 MGD	15 MGD
Madunaghat WTP (1st Phase)	10 MGD (45,500)	-	10 MGD	10 MGD
Madunaghat WTP (2nd phase)	10 MGD (45,500)	-	-	10 MGD
Fatehabad IRP*	10 MGD (45,500)	-	10 MGD	10 MGD
Karnaphuli WTP**	60 MGD (272,800)	-	-	60 MGD
MOD-I Tube wells***	7 MGD (31,800)	7 MGD	-	-
Total	157 MGD (713,800)	37 MGD	62MGD	145 MGD

Note: * : The Fatehabad IRP will be developed outside of the service area in 2005. It will be integrated with the recommended system by 2010.

**: Capacity of Karnaphuli WTP will be 60 MGD because of compensation for the balance between capacity of each WTP/IRP and demands of respective service block.

***: CWASA's Tube wells in MOD-1 area will be abolished after completion of Phase 1 Project.

Usage of the tube wells scattered in the MOD I area will be ceased soon after development of recommended system because of their high iron concentration and no iron removal plant on site.

(2) Distribution Facilities

Treated water of each WTP/IRP will be transmitted to 10 reservoirs and distributed to respective service blocks in 2010, while 6 reservoirs will be provided by the intermediate target year 2005. Capacities of those reservoirs are listed in Table 7.

Table 7 Recommended Distribution System (Outline)

Reservoir/Service Block	Water Source	Phase 1 (2005)	Phase 2 (2010)
1. Existing Mohara WTP Clearwater/Distribution Reservoir	Mohara WTP Exist.	6,700 m^3	10,000 m^{3*}
2. Khulshi Ground Reservoir	Mohara WTP Exp.	19,600 m^3	19,600 m^3
3. Khulshi Head Tank	Mohara WTP Exp.	1,780 m^3	1,780 m^3
4. Exist. Kalurghat IRP Clearwater/Distribution Reservoir	Kalurghat IRP Exist.	12,700 m^{3**}	14,400 m^{3**}
5. Exist. Battali Hill & ADC Hill Reservoir	Madunaghat WTP 1st phase	13,640 m^3 ADC 4,500 m^3	13,640 m^3 ADC 4,500 m^3
6. Patenga BPS Reservoir	Mohara WTP	12,000 m^3	24,000 m^3
7. Madunaghat WTP 2nd Phase Distribution Reservoir w/Head Tank	Madunaghat WTP 2nd Phase	—	G: 10,000 m^3 H: 1,530 m^3
8. Fatehabad IRP, Distribution Reservoir/Head Tank	Fatehabad IRP	—	G: 10,000 m^3 H: 1,530 m^3
9. Nasirabad Reservoir w/Head Tank	Karnaphuli WTP	—	G: 27,500 m^3 H: 3,620 m^3
10. Salimpur Reservoir	Karnaphuli WTP	—	11,200 m^3
Total		66,420 m^3	139,800 m^3

*: Existing clearwater reservoir and new plant clearwater reservoir will be interconnected to be used as an integrated distribution reservoir.

The distribution system shall be improved and enhanced because the capacity of water sources will be augmented to about 1.7 times of present capacity in 2005 and about 4 times in 2010. Whole water supply system will be fractionalized into the said 6 service blocks by the year 2005 and 10 blocks in 2010 as shown in above Table 7.

Improvement of distribution main and a part of small diameter pipelines urgently needed will be provided under the project.

7. Project Cost and Implementation Schedule of Basic Plan

7.1 Project Cost

Project cost for Basic Paln by phase is presented in Table 8.

7.2 Implementation Schedule

Table 8 Project Cost of Basic Plan

(unit: US$)

Facilities	Phase 1 (2005)			Phase 2 (2010)			Total
	Local	Foreign	Total	Local	Foreign	Total	
I. Direct Construction Cost**							
1. Mohara WTP New Plant Service Area	6,584,000	13,857,000	20,441,000	0	0	0	20,441,000
2. Khulshi Distribution Reservoir Service Area	4,074,000	4,884,000	8,958,000	367,000	801,000	1,168,000	10,126,000
3. Mohara WTP Old Plant Service Area	355,000	2,275,000	2,630,000	49,000	86,000	135,000	2,765,000
4. Kalurghat BPS Service Area*	1,915,000	4,244,000	6,159,000	408,000	412,000	820,000	6,979,000
5. Battali Hill Reservoir Service Area*	-	-	-	55,000	117,000	172,000	172,000
6. Madunaghat 2nd Phase Reservoir Service Area	-	-	-	6,654,000	7,902,000	14,556,000	14,556,000
7. Fatehabad Reservoir Service Area	-	-	-	2,544,000	3,312,000	5,856,000	5,856,000
8. Karnaphuli WTP	-	-	-	26,968,000	46,044,000	73,012,000	73,012,000
9. Nashirabad Reservoir Service Area	-	-	-	7,284,000	15,448,000	22,732,000	22,732,000
10. Salimpur Reservoir Service Area	-	-	-	1,749,000	1,566,000	3,315,000	3,315,000
11. Patenga BPS Service Area*	1,381,000	2,331,000	3,712,000	2,638,000	4,557,000	7,195,000	10,907,000
12. Small Size Distribution Pipelines	5,878,000	8,469,000	14,347,000	20,246,000	29,171,000	49,417,000	63,764,000
13. Staff Quarters and Zone Offices	1,480,000	0	1,480,000	1,480,000	0	1,480,000	2,960,000
Sub-Total I	**21,667,000**	**36,060,000**	**57,727,000**	**70,442,000**	**109,416,000**	**179,858,000**	**237,585,000**
II. Overhead and Profit							
Overhead and Profit (ICB - 25% of DC 1 to 11)	0	10,475,000	10,475,000	0	32,240,000	32,240,000	42,715,000
Overhead and Profit (LCB - 12.5% of DC 12,13)	1,978,000	0	1,978,000	6,362,000	0	6,362,000	8,340,000
Sub-Total II	**1,978,000**	**10,475,000**	**12,453,000**	**6,362,000**	**32,240,000**	**38,602,000**	**51,055,000**
III. Procurement of Equipment							
1. Water Meter (20-150mmx25,000units) x 2 phases	0	589,000	589,000	0	589,000	589,000	1,178,000
2. Vehicles (Sedan x 2, 4WD x 2) x 2 phases	0	93,000	93,000	0	93,000	93,000	186,000
3. Computers (8 sets with printers) x 2 phases	0	22,000	22,000	0	22,000	22,000	44,000
Sub-Total III	**0**	**704,000**	**704,000**	**0**	**704,000**	**704,000**	**1,408,000**
IV. Administration							
1. CWASA Administration Cost	128,000	0	128,000	128,000	0	128,000	256,000
2. Land Acquisition Cost	3,370,000	0	3,370,000	8,715,000	0	8,715,000	12,085,000
Sub-Total IV	**3,498,000**	**0**	**3,498,000**	**8,843,000**	**0**	**8,843,000**	**12,341,000**
V. Duties, Taxes, and Charges							
1. Custom Duty and Other Import Charges	12,595,000	0	12,595,000	37,724,000	0	37,724,000	50,319,000
2. VAT for Civil Work (4.5%)	1,518,000	0	1,518,000	4,607,000	0	4,607,000	6,125,000
3. VAT for M&E Equipment	6,010,000	0	6,010,000	18,437,000	0	18,437,000	24,447,000
4. Pre-Shipment Inspection Fee	302,000	0	302,000	936,000	0	936,000	1,238,000
Sub-Total V	**20,425,000**	**0**	**20,425,000**	**61,704,000**	**0**	**61,704,000**	**82,129,000**
VI. Engineering Cost							
1. D/D + C/S (8% of I+II)	849,000	4,810,000	5,659,000	2,611,000	14,798,000	17,409,000	23,068,000
2. VAT for Engineering Cost (5.25%)	297,000	0	297,000	914,000	0	914,000	1,211,000
Sub-Total VI	**1,146,000**	**4,810,000**	**5,956,000**	**3,525,000**	**14,798,000**	**18,323,000**	**24,279,000**
VII. Contingencies							
1. Physical Contingency (10% of I+II+III+IV+V+VI)	**4,871,000**	**5,205,000**	**10,076,000**	**15,088,000**	**15,716,000**	**30,804,000**	**40,880,000**
2. Price Contingency (LCP: 0.7%p.a., FCP: 2%p.a.)	-	-	-	-	-	-	-
VIII. Total Project Cost	**53,585,000**	**57,254,000**	**110,839,000**	**165,964,000**	**172,874,000**	**338,838,000**	**449,677,000**

Note: Costs for Madunaghat WTP 1st phase, its transmission pipeline to Battali Hill Reservoir, Fatehabad IRP and wells are consideredas existing facilities.

*: Costs in 2005 for distribution pipelines outside of Khulshi S.A. excluding small size pipes are summed in the column of Kalurghat BPS service area.

**: Direct Cost of each category from 1 to 12 includes costs of all faciliteies such as transmission/main distribution pipelines, treatment plant, reservoirs, and booster pumps.

Phase - 1

2000 – 01	Preparation of Project Fund
2002 – 03	Detailed Design & Bidding
2003	Commencement of Construction & Procurement of Equipment
2003 – 05	Construction
2005	Commissioning

Phase - 2

2005 - 06	Preparation of Project Fund
2006 - 07	Detailed Design & Bidding
2008	Commencement of Construction & Procurement of Equipment
2008 - 10	Construction
2010	Commissioning

8. Selection of Priority Project

Present water supply population is 1,140,000 or 44.7% service coverage ratio with intermittent water supply due to shortage of water, and hence unit water supply per capita per day is 140 lpcd including commercial and industrial usage.

After completion of the under planned projects by CWASA and Italian government assistance, except this Mohara extension project, the distribute capacity will be at 205,000m^3/day or 45MGD, while the planned population to be served in 2010 in 3,370,000 which is equivalent to unit supply rate of 60 lpcd or 42% of the present water supply level.

To cope with such condition, the Mahara WTP extension project, which is one of the projected WTPs in the Basic Plan, is recommendable as an urgent project.

Together with the Mohara WTP expansion plant, augmentation of distribution system shall be conducted in the Priority Project, which has been presented in the preceding sub-section together with the Basic Plan as Phase 1.

9. Project Cost and Implementation Schedule of Priority Project

9.1 Project Cost

Project cost for priority project is presented in Table 9.

9.2 Implementation Schedule

Implementation of the priority project will be started in 2002 as detailed design, while arrangement of funding shall be started soon after this study.

Table 9 Cost Estimates for Priority Project

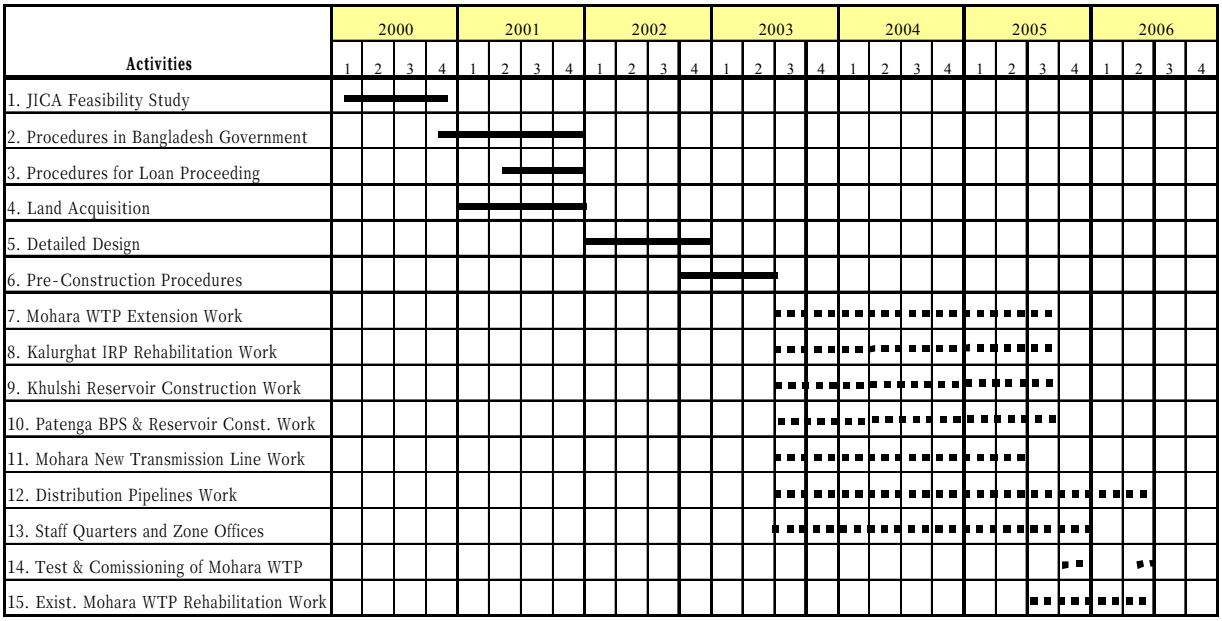
(unit: US$)

Facilities	Priority Project		
	Local	**Foreign**	**Total**
I. Direct Construction Cost			
1. Treatment Plant			
Mohara WTP Expansion Plant, Transmission Pumps	5,535,000	9,633,000	15,168,000
Mohara WTP Rehabilitation Work	355,000	2,275,000	2,630,000
Kalurghat IRP Rehabilitation Work, Reservoir	643,000	1,393,000	2,036,000
2. Distribution Reservoir and BPS			
Khulshi Distribution Reservoir, Pumps, Tank	3,031,000	2,151,000	5,182,000
Patenga Distribution Reservoir	1,381,000	2,331,000	3,712,000
3. Transmission / Distribution Pipeline			
Transmission Pipeline DCIP 900mm x 15,045m	1,049,000	4,224,000	5,273,000
Main Distribution Pipeline	2,315,000	5,584,000	7,899,000
4. Small Size Distribution Pipelines	1,986,000	2,861,000	4,847,000
5. Staff Quarters and Zone Offices	1,480,000	0	1,480,000
Total of Direct Construction cost	**17,775,000**	**30,452,000**	**48,227,000**
II. Overhead and Profit	**791,000**	**10,475,000**	**11,266,000**
III. Procurement of Equipment	**0**	**704,000**	**704,000**
IV. Administration			
1. CWASA Administration Cost	**128,000**	**0**	**128,000**
2. Land Acquisition Cost	**3,370,000**	**0**	**3,370,000**
V. Duties, Taxes, and Charges	**16,316,000**	**0**	**16,316,000**
VI. Engineering Cost			
1. D/D + C/S	782,000	4,022,000	4,804,000
2. VAT for Engineering Cost (5.25%)	252,000	0	252,000
Total of Engineering Cost	**1,034,000**	**4,022,000**	**5,056,000**
VII. Contingencies			
1. Physical Contingency (10% of I+II+III+IV+V+VI)	**3,941,000**	**4,565,000**	**8,506,000**
2. Price Contingency (LCP:0.7%p.a.,FCP:2%p.a.)	**1,376,000**	**4,129,000**	**5,505,000**
VIII. Total Project Cost excluding Price Contingency	**43,355,000**	**50,218,000**	**93,573,000**
Total Project Cost including Price Contingency	**44,731,000**	**54,347,000**	**99,078,000**

Note: Costs for Madunaghat WTP 1st phase, its transmission pipeline to Battali Hill Reservoir, Fatehabad IRP and wells are considered as existing facilities.

*: Costs for Distribution Pipeline in Kalurghat S.A includes all distribution pipelines outside of Khulshi S.A.

Figure 1 Implementation Schedule of Priority Project



10. Project Evaluation

10.1 Effects of Project Implementation

Effects of the project implementation are to continuous water supply with safety in quality and sable pressure, and to expand the supply area.

Even though completion of two projects planned by CWASA, namely Madunaghat WTP 1st phase and the 3rd interim rehabilitation project of Kalurghat IRP, the unit water supply quantity (supply volume per capita per day) will be at 120 lpcd in 2005, which will be lower than the present level and hence the city economy activities will be constrained. If CWASA would have an intention to maintain the planned target water level in 2005, no more house-connection would be allowed, which result serious socio-economic problems.

When the project is implemented, the water coverage rate will be 50%, and then the unit supply rate is expected to be 178 lpcd.

10.2 Result of Financial Analysis

Financial analysis was conducted on the basis of the Free Cash Flow applying the present weighted average tariff as the basic condition for revenue, which is Tk 6.0/m^3 shown as 100% in Table 10.

Table 10 Sensitivity Analysis

Cost		Revenue	IRR	NPV (at 7.5%)	B/C
Capital	O&M		(%)	(US$)	(at 7.5%)
100%	100%	100%	-2.50%	-62,690	0.26
100%	100%	165%	1.02%	-48,129	0.43
100%	100%	190%	2.01%	-42,529	0.50
100%	100%	200%	2.37%	-40,289	0.53
100%	100%	300%	5.46%	-17,888	0.79
100%	100%	380%	7.50%	32	1.00
100%	90%	380%	7.58%	715	1.01
100%	110%	380%	7.43%	-651	0.99
90%	100%	380%	8.42%	7,858	1.10
110%	100%	380%	6.72%	-7,794	0.92

Note; 100 % stands for the basic condition described in previous sub-section.

As shown in Table 10, if financial internal rate of return should be kept at 7.5 %, which is equivalent to the interest rate of the government's financial assistance, it will be required to keep the revenue at 380 % of the present tariff level.

According to the inhabitants' willingness survey, the water tariff will be tolerated to 1.5 times of the present tariff level, providing the service level will be improved. For cash receipt projection, a sensitivity analysis is made for tariff rate. A result of the analysis is presented in Table 11 and Figure 2.

Table 11 Relation between FIRR and Tariff

Base Tariff (Tk/m^3)		6.0 (100%)	6.6 (110%)	7.2 (120%)	7.8 (130%)	8.4 (140%)	9.0 (150%)	9.6 (160%)	**10.2 (170%)**	10.8 (180%)	11.4 (190%)	12.0 (200%)
Annual Increase Rate (%)	0	-2.50	-1.81	-1.19	-0.63	-0.12	0.36	0.80	**1.23**	1.63	2.01	2.37
	1	-0.76	-0.17	0.37	**0.87**	1.34	1.77	2.19	2.58	2.95	3.31	3.66
	2	**0.70**	1.24	1.74	2.20	2.64	**3.05**	3.44	3.81	4.17	4.51	4.85
	3	**2.00**	2.51	2.98	3.42	3.84	4.24	4.61	4.97	5.32	5.65	5.97
	4	3.20	3.69	4.14	4.57	4.98	5.36	5.73	6.08	6.42	6.74	7.06
	5	4.33	4.81	5.25	5.67	6.07	6.44	6.80	7.15	7.48	7.80	8.11
	6	5.42	5.88	6.32	6.73	7.12	7.49	7.85	8.19	8.52	-	-
	7	6.47	6.93	7.36	7.77	8.15	8.52	-	-	-	-	-
	8	7.49	7.95	8.38	-	-	-	-	-	-	-	-
	9	8.50	-	-	-	-	-	-	-	-	-	-

(Basic Tariff: Upper; Price, Lower; Ratio of Base Tariff to Price)

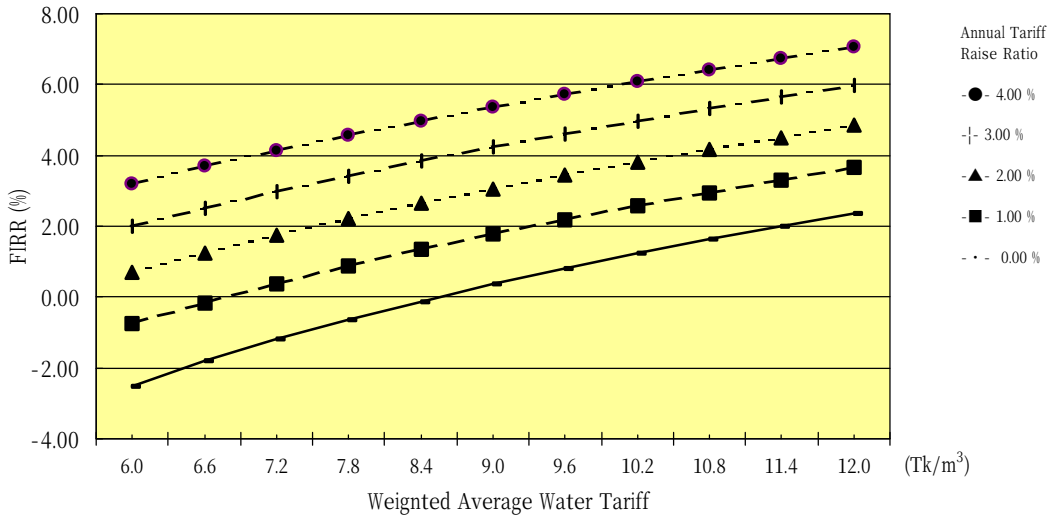


Figure 2 Relation between FIRR and Water Tarif

In due consideration on the financial complements for fulfillment of the project, the following options may be applicable. The final resolution of investment, though, depends on political considerations.

(1) When the internal rate of return is required to be the interest of the government financial aid at 7.5 %, it is needed to raise tariff up to 380 % of the present level, or as an instance;
- to raise up to 200 % and annual raise at 4.5 % every year, or
- to raise up to 150 % and annual raise at 6.0 % every year.

(2) On the premise that the internal rate of return for repayment to the government shall be 1.0 %, which is equivalent to the interest rate of JBIC, it is needed to raise up to 170 % of the present tariff level, or as an instance;
- to raise up to 130 % and annual raise at 1.2 % every year.

(3) On premise that 30 % of total project cost is assisted from the government financial aid, (grant) and the internal rate of return for repayment to the government is 2.5 %, which is a weighted average rate based on the foreign and local portions (75%: 25%) of the estimated project cost, it is needed to raise to 150 % of the present tariff, or as an instance;
- to raise up to 120 % and annual raise at 1.0 % every year.

11. Conclusion

(1) Based on this study, it may be concluded that the scale and scope of investment for the project

appear appropriate, and the effects of the investment seem satisfactory. Management systems necessary for the project operation are considered to be sufficient.

(2) However, it is difficult to fully recover the investment costs without substantial financial complements by the government financial subsidies. As a result, special considerations should be given on a finical scheme, which can fully fund the project.

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Preamble

The Feasibility study on Extension and Expansion on Mohara Water Treatment Plant in Chittagong in the People's Republic of Bangladesh (hereinafter referred to as "the study") was carried out in accordance with the Scope of Work agreed between the Ministry of Local Government, Rural Development and Co-operation (hereinafter referred to as "LGRD") and the Preparatory Study Team dispatched by the Japan International Cooperation Agency (hereinafter referred to as "JICA") on October 12, 1999.

JICA had organized the Japanese Study Team (hereinafter referred to as "the Study Team") and dispatched to commence the Study from January 2000. The Study was completed on December 2000 and all of the outcome was furnished in this Report.

1.2 Background of the Study

Chittagong City, the second large city in Bangladesh, is situated on a peninsula located on the west by the Bay of Bengal and on the east by the Karnaphuli River.

About 30% industrial products of the country produced in the Chittagong district alone and most of which come from the City area. A large numbers of subsidiary industries and business have developed to these industry sectors.

There are various industries such as textile, fertilizer, garment and gas production. These industries have brought new life in the City. In this decade's remarkable phenomena in the economy of the country is unprecedented growth of garment industry in Chittagong. Developing the industries in Chittagong has brought rapid increase of population, and the present population in the City is more than 3.0 Million including non-registered floating people.

Chittagong Water Supply and Sewerage Authority (hereinafter referred to as "CWASA") was established in 1963 and took over the public water supply utility from the Chittagong Municipality. CWASA has taken his effort to reinforce the water supply capacity with IDA assistance and achieved the capacity of producing 40 MGD water.

According to remarkable population growth for the last decade, the present water supply coverage rate

is 45% only. Moreover, due to shortage of water supply capacity, the water pressure has been lowered and the water supply interrupted area has expanded.

Under these circumstances, the Government of the People's Republic of Bangladesh (hereinafter referred to as "Bangladesh") requested to the Government of Japan to extend the technical cooperation on the development study aiming at extension of water supply capacity of Mohara water treatment plant in Chittagong.

In response to the request of the Government of Bangladesh, JICA, the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, conducted the Study on the Extension and Expansion of Mohara Water Treatment Plant in Chittagong and the Feasibility Study on the priority project.

1.3 Objective of the Study

The objectives of the Study are; (1) to formulate a basic plan for the target year 2010 with reviewing existing plans, and (2) to conduct a feasibility study on the priority project selected from the basic plan, and (3) to transfer technology on planning methods and skills to counterpart personnel in the course of the Study.

In the conduct of the Study, due attention and consideration were given to the following matters:

(1) Plan for improvement and development of the water supply system should be prepared from the viewpoint of effective utilization of the existing facilities and acceptability of stable water supply.
(2) Plans for extension of the facilities and financial arrangement should be prepared with reasonable and feasible range for the existing agency and excessively realistic plan was avoided.

1.4 Study Area

The Study Area was delineated to conform the Chittagong City with the land area of 20,004 ha and a part of the surrounding two Thanas with the land area of 6,911ha, namely a part of Sitakunda Thana, which has been covered by CWASA water supply service, and a part of Hathazari Thana, in which the Madunaghat Water Treatment Plant (WTP) is projected under financial assistance of the Government of Italy. Hence total land area of the Study is 26,915 ha.

1.5 Scope of Work

(1) The Study involves preparation of a basic plan for development of the water supply system in Chittagong for the target year of 2010. In the course of the preparation, planning of equipment and facilities, as a hard aspect, and review and analysis on the organization and financial arrangement as a soft aspect were conducted in the Study.

(2) Formulation of a Feasibility Project that was selected from the above mentioned basic plan as an urgent improvement project. The subject of feasibility study shall involve an extension of the existing Mohara W.T.P having the same capacity, and hydraulic analysis on the transmission and distribution main to be connected to the existing pipelines so as to function the whole water supply system, effectively.

(3) For the existing facilities, formulation of a rehabilitation plan was prepared, excluding the tube wells and transmission and distribution pipeline.

1.6 Formulation of the Study

1.6.1 General

The Study was carried out in accordance with the Scope of Work agreed upon between the LGRD and the JICA. CWASA was the implementation agency for the project and accomplished the Study in close cooperation with the Study Team. The overall set-up for the implementation of the Study is as discussed below.

1.6.2 Implementation Set-up byJapanese Side

The implementation set-up by the Japanese side consisted of the Study Team and the Advisory Committee under the general supervision of the JICA headquarter. The composition of the JICA Advisory Committee and the Study Team are shown below:

Table 1.6-1 Composition of JICA Advisory Committee

Member of Advisory Committee/JICA	Organization/Authority
Mr. Ryugo Nakahara	O & M Div. Waterworks Bureau, Okayama City
Mr. Yoshio Fukuda	Social Development Study Department, JICA

Table 1.6-2 Members of the Study Team

Name	Assignment
Mr. Kenji Hori	Team Leader / Management Planning
Mr. Takafumi Kiguchi	Water Supply Facility Planning / Design
Mr. Shigeo Sawai	Pipeline Design / Network Analysis
Mr. Satoshi Shibazaki	Mechanical Equipment Design

Mr. Masahiro Nohara	Electrical Equipment Design
Dr. Kenji Takayanagi	Hydrology / Groundwater / Water Quality-1
Dr. Abul Hasnat Golam Quddus	City Planning / Social Economics
Mr. Akio Kabasawa	Institution/Tariff System/Financial/Planning
Mr. Hiroshi Okada	Environmental Consideration / Water Quality-2
Mr. Kenji Kasamatsu	Coordination

1.6.3 Implementation Set-up by Bangladesh Side

The implementation set-up of the Bangladesh side consists of CWASA and its counterpart personal are shown in Table 1.6-3:

Table 1.6-3 Implementation Set-up by CWASA

Name	Assignment
CWASA	
Cap. M. Zakaria	Chairman
Mr. Abdul Hoque	Member Administration
Mr. Md. Wahidunnabi	Member Finance
Mr. Z.S.M. Bakhteyar	Member Engineering
Mr. Ataul Haque	Chief Engineer/Superintending Engr. (P&C)
Mr. Shahjahan	Commercial Manager
Mr. Mostafa Kamaluddin	Secretary
Mr. Md. Obaidullah	Chief Revenue Officer
Mr. Serajul Azim Khan	Chief Accountant
Mr. Md.Abul Kashem	Executive Engineer (Procurement)
Mr. Neazur Rahman Khan	Executive Engineer (CD-II)
Mr. Md. Safiullah	Executive Engineer (Sales)
Mr. Mostaqe Uddin Akhter	Executive Engineer (MOD-I)
Mr. Abdul Karim Chy	Executive Engineer (MOD-II)
Mr. Md. Abul Hashem	Executive Engineer (Booster Stn.)
Mr. Md. Arabinda Barua	Megistrate
Mr. Yuzo Fujishiro	JICA Expert
Counterpart	
Mr. Md. Shafiqul Islam	Project Director, Executive Engineer (CD-I)
Mr. Ejaz Rasul	Executive Engineer (Design)
Mr. Jane Alam Bhuiyan	Executive Engineer (Mohara WTP)

1.7 Organization of the Study Report

The report of the Study in English language was compiled the following three parts:

(1) Summary Report

(2) Main Report

(3) Supporting Report

The Summary Report was edited for the convenience to grasp overview of the major study results,

while the Main Report presented the overall results of the Study. Detailed discussions and field data were contained in the Supporting Report.

CHAPTER 2

DESCRIPTION OF THE STUDY AREA

CHAPTER 2 DESCRIPTION OF THE STUDY AREA

2.1 Natural Condition

2.1.1 General

Chittagong City is located at the eastern side of the Bangladesh, faced to the Bengal Bay. The city is bordered on the south and eastern parts by the Karnaphuli River that is issued from Kaptai Lake with the distance of 50 km. The center of the city is located near the river mouth that is utilized as a port harbor. In the northwest direction, hilly areas with the height of from 60 m to 90 m are distributed. In the eastern side of the hilly areas, a flat plain is widely distributed and is bordered by the Karnaphuli River that is the largest in the southeastern area of the Bangladesh.

2.1.2 Topography, Geology and Meteorology

The hilly areas are extended to NNW from the center of the city and consist of numerous dissected hills with round shapes. The hill formations are made up of alternating layers of mudstones and sand formations in the Tertiary age. The thickness of mudstones and sand formations is about 30 m, respectively, though it more and less differs in places. The formations have an anticline structure extending from NNW to SSE with steeper dip in the eastern wing along the eastern boundary between hilly area and alluvial area. On the other hand, the alluvium plain consists of alternating layers of soft clay and sand. Based on the existing deep wells owned by CWASA, alluvial sediments have the thickness of more than 130 m.

Chittagong City is located in the tropical zone, which is subject to tropical climate. It is characterized by high temperature, and heavy rainfall with often-excessive humidity. There are three distinct seasons. The hot season continues from March to May but has some wet days. The monsoon season begins in June and continues usually to September with maximum temperature. The monsoon season generally comes and ends with cyclones. The cold and dry season begins in November and extends to February. Annual rainfall in the city ranges from 2,100 mm to 3,800 mm in past nine years since 1990. Average annual rainfall is 2,859 mm. Especially, annual rainfall was a very little in the drought year of 1994 and 1995, ranging from 2,126 mm to 2,260 mm. Monthly rainfall data in Chittagong is shown in Table 2.1-1.

Monthly average rainfall is very little during cold and dry season ranging from 9 mm to 84 mm. Reversely, remaining seasons of hot and monsoon have comparatively abundant rainfall of from 125 mm to 705 mm per month in average.

Table 2.1-1 Monthly Average Rainfall in Chittagong for the Period from January 1990 to January 2000 **(Unit: mm)**

Month	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Avg.
Jan.	0	19	0	17	7	0	0	0	37	0	17	9
Feb.	39	0	119	71	8	12	106	32	103	0		49
Mar.	53	43	0	223	194	18	91	118	97	4		84
Apr.	250	-	1	100	264	51	234	40	184	0		125
May	205	-	127	667	208	268	251	270	387	463		316
Jun.	668	774	571	791	581	359	472	425	131	908		568
Jul.	1,038	818	412	437	380	685	465	1,033	1,291	492		705
Aug.	115	357	280	638	397	546	584	383	1,216	862		538
Sep.	141	360	291	273	100	130	340	530	193	212		257
Oct.	233	211	435	129	101	53	343	134	124	189		195
Nov.	74	99	4	14	20	3	3	49	93	24		70
Dec.	36	13	34	0	0	1	1	0	0	107		19
Total	2,852	2,694	2,274	3,360	2,260	2,126	2,890	3,014	3,856	3,261		2,859

Note、Source: Bangladesh Meteorological Department (March, 2000)

2.1.3 Rivers, Lake and Dam Condition

The Karnaphuli River originates from the eastern hilly areas and empties into the Bengal Bay passing the east-south rim of Chittagong City. The river is one of the main rivers in the southeast Bangladesh. The river has total length of about 58 km in main channel, originating from Kaptai Lake

The Halda River is one of the Karnaphuli River's tributaries and a confluence point between the Halda River and the Karnaphuli River is located about 17 km from the Karnaphuli River mouth. The river has total length of about 69 km and the river runs from hilly area near the national border between Bangladesh and India to north of Chittagong City. The river has a primary drainage area of about 1,540 km^2.

Foy's Lake is located in the hilly area with an elevation of about 90 m, northwest of the city. The lake was made for the water supply of railway-township before the year 1947. The lake surface has the area of approximately 0.53 km^2.

Kaptai Lake with the area of 680 km^2 is located about 50 km north-east of Chittagong City surrounded by fairly high mountains of hill track and is the largest lake in the country. The lake was formed with the construction of the Kaptai Dam in 1958. The dam is only one for hydraulic power generation in Bangladesh that discharges the lake water to the Karnaphuli River.

2.2 Socio-Economic Condition

2.2.1 Economic Condition and Policy of the Government

Bangladesh is primarily an agrarian country whose 80% of the total population lives in rural areas according to 1991 census (BBS, 1994). The contribution of agricultural sector to Gross Domestic Product (GDP) is about 40%. The major agricultural products of the country are rice, jute, potato, pulse, sugarcane, tobacco, and tea. A total of 50 million kg of tea is produced every year in 158 tea gardens of the country. The industrial sector of the country contributes only 7.5% to GDP. A total of 2.52 million men and women are employed in industrial sector of the country. Major industries of the country are jute, textile, garment, steel, tanneries, pharmaceuticals, fertilizer, machine tools, sugar, cement, cables, shipyard, shoe, cigarette, ceramic sanitary wares, marine diesel engine, steel mills, telephone etc. are well developed. Some of these industries are not only meeting national needs but also export their products. Two such industries are urea fertilizer factory and newsprint mills. Although GDP exceeded 7% sometimes immediately after the independence, it is hovering around 5% since 1990. Of these 5% growth over 3% is contributed by agriculture sector. Therefore, above economic statistics clearly point out that the present industrial growth rate of the country is inadequate for healthy economy and alleviation of poverty.

Bangladesh has adopted free market economic policies to keep pace with all other democratic countries. It provides all out support and incentives to private sector. Pressure is also created to improve efficiency and productivity to make the public sector enterprises profitable. Laws related to industries are being simplified for encouraging investment in private sector. Plans are taken to modernize textile industries to meet the needs of garment factories. Top priority is given to export oriented industries particularly the garment factories, which are 100% export oriented. Small, cottage, and labor-intensive industries are encouraged for creating employment for unemployed youths. Government is committed not to nationalize any industrial, financial, and commercial unit under private ownership.

Export is emphasized for balancing the high import of the country. For this purpose export oriented industries are receiving high attention from the Government. A number of Export Processing Zones are established in different parts of the country but Chittagong was the pioneer. In order to increase foreign investment special incentive packages are offered in the form of tax holiday for a particular time period, low or no import duty on the raw material, remittance of profit etc.

Industrial development no doubt is in the top of the development agenda but agriculture, which contributes 40% of the national GDP is also receiving attention in the national policy because 80% of the total population of the country live and depend on it for their livelihood. Government has undertaken land reform and land management programs, modernization of fish culture, and poultry and livestock rearing. Efforts are being made to ensure at fair price supply of fertilizer, irrigation equipment and other inputs and credit for the peasants and provide subsidies. However, the ultimate

goal of all these programs is poverty alleviation.

2.2.2 Social Infrastructure

(1) Economy

Chittagong City stands second to Dhaka in terms of industrial growth. About 30% industrial products of the country come from Chittagong district alone and most of which come from the city area. The city has four industrial estates, namely Kalurghat, Patenga, Nasirabad-Sholoshar, and Fouzdarhat. Both Chittagong Development Authority (CDA) and Bangladesh Small and Cottage Industries Corporation (BSCIC) have their industrial estates in the city area. As of today some of the distributed industrial plots are lying vacant. Chittagong City owns some very prestigious industrial enterprises. Chittagong Oil Refinery, Lubricating Grease Industry, Dockyard are the most important ones. Besides there are numbers of jute, textile, leather cigarette, edible oil, soap, glass, salt, fertilizer, garment, and gas industries are worth mentioning. At present, Chittagong City houses about 2060 industries of different sizes.

In recent year's most remarkable phenomena in the economy of the country is unprecedented growth of garment industry in Chittagong. Virtually there was no such industry in the country before two decades. At present Chittagong alone have 449 garment industries. A large number of them are in the EPZ. These industries have brought new life in the city. This is the only sector that has almost 90% of female employees. A large numbers of subsidiary industries and business have developed to these industries. These are textiles, shipping, C and F and stevedoring business, telephone and fax business, road transport business, and construction of factories. The annual rate of increase of garment industries is about 20%.

The Export Processing Zone at Chittagong, which houses export oriented industries began functioning in eighties in Chittagong. The planning commission estimates that by 2001-2002 the numbers of industries in the EPZ will reach 110 and have investment worth US$ 350.00. These industries are likely to generate about 50,000 jobs and earn about 600 million dollars (GB, 1995:461). BSCIC like CDA has its own four industrial estates having total 267 industries ranging from small to medium. A census of non-farm economic activities was published in 1986 (BBS, 1986) from which a detail breakdown of the employment structure of Chittagong city is presented Table 2.2-1 (This is adopted from CDA Master Plan prepared in 1995).

Table 2.2-1 Employment Structure

Sector	No. of Jobs City	No. of Jobs SMA	Sources
Manufacturing	161,000	201,000	CNFEA (1986)
Wholesale, retail and trade	121,000	133,000	CNFEA (1986)
Financial, insurance, and business services	27,000	28,000	CNFEA (1986)
Community, social, & personnel services	48,000	56,000	CNFEA (1986)
Public administration, defense & police	20,000		Team
Utilities	3,000		Team
Agriculture	8,000		Pop. Census (1991)
Transport (incl. 80,000 Informal)	120,000		Transport Team (Residual)
Rest of informal, floating jobs	152,000		
Total	660,000		(Derived)

* CNFEA: Census of Non Farm Economic Activities
Source: Working Paper on the Economy

The CDA Master Plan has further broken down manufacturing jobs by sectors for showing its greatest concentration at the present time. Breakdown of jobs has helped assessing the required infrastructure for the city development. Table 2.2-2 shows the CDA's estimated breakdown of manufacturing jobs. Table 2.2-2 is adopted from the CDA Master Plan prepared in 1995.

Table 2.2-2 Estimated Breakdown of Manufacturing Jobs

Sector	Manufacturing Jobs (%)	No. of Jobs City	No. of Jobs SMA
Food, beverages, and tobacco	9	14,000	17,000
Textiles and garments	57	91,000	114,000
Wood and wooden products	7	9,000	11,000
Paper, printing, and publishing	2	4,000	5,000
Chemical, rubber, and plastics	4	7,000	9,000
Metallic mineral products	4	6,000	7,000
Basic metallic industries	5	8,000	10,000
Metal products, machinery, & equipment	12	19,000	24,000
Other manufacturing	2	3,000	4,000
Total	100	161,000	201,000

Source: Working Paper on the Economy

The total industrial labor force is likely to increase about 68% (269,808) in 2000 and 149% (401,388) in 2010 over the 1986 non-farm economic census figure as per Finance Division's estimate. According to Finance Division, Ministry of Finance, industrial labor force was about 12% of the total population in 1996 (PC, 1996). If this rate remains constant over the years (which is very much likely to be higher because industrialization is only at its nascent stage in the country) the industrial labor force in 2000 and 2010 are likely to be 269,808 and 401,388, respectively in Chittagong City. The growth of this number of industrial labor force will put great strains on the infrastructure of the city in terms of their accommodation, work place, and amenities needed for day to day living. The

city is likely to get more pressure in future for industrialization because more and more export-oriented industries are being established in the city, which again is supported by liberal Government's industrial policy.

The economy of Chittagong City is going to get a further boost under a new industrial venture by a Korean Company at a distance of 21 km from Chittagong Port. The project is known as the Korean Export Oriented Zone (KEPZ). It is similar to present EPZ at Patenga within Chittagong City Corporation. The actual location of the project is outside the city, but the City Corporation can't escape the economic impact of the growth of such a large industrial estate. The project will house 30 large and 100 small and medium size industries in about 1,038,1851.00 hectares of land. An estimated 100,000 direct and 50,000 indirect jobs will be created through this project. Another private EPZ is also inaugurated at Rangunia Thana at a distance of 24 kilometer from Chittagong City.

During the British Rule Assam-Bengal Railways' headquarter was in Chittagong. Under the same tradition Chittagong is still the main center of meter gauge railway system of the country. It is the only Government Organization, which has the large amount of landed property in the city. It also employs a large number of employees. In recent years it is incurring a huge loss every year. The port city houses major Government offices and institutions. Anticipating the future growth of Chittagong City a plan is under execution to turn the local airport into an international one at the cost of Tk. 600 cores with Japanese help. This is likely to increase revenue earning and generate employment opportunities.

The review of present economic activities and anticipated ones indicate that the potentiality of economic growth of Chittagong City is very high particularly for two reasons; one for its advantage as seaport city, and second as land available in and around its present city boundary. The city is almost free of flooding although there are possibilities of occasional cyclone and tidal bore. Since there are great requirements of foreign currency and industrialization for improving the quality of life of the people, the economic importance of the city will continue to grow further because it has the seaport and land for spatial expansion of the city area. Therefore, any plan for the development of infrastructure should take into consideration its economic importance and potential of future growth from the point of view of national context, since it is the economic nerve center of the country for its unique geographical location.

(2) Tourism

Tourism has become the important source of revenue for many countries but this is not yet the case for Bangladesh particularly for attracting foreign tourists. Whatever tourist spots Bangladesh have

Chittagong definitely stands second to none. The greater Chittagong and Chittagong Hill Tracts have many things for tourist attraction. Within 1 to 3 hours drive one can reach most beautiful spots of the country, such as beach town Cox's Bazar, (3 hours drive) hill town Rangamati (2 hours drive), artificially created Kaptai lake resort (1 hour) etc. Besides all these distant attractive spots Chittagong has so many charming places that hold out attraction for tourists. For example the tomb of Muslim saint Sultan Bayazid Bostami, situated on the hillock at a distance of 6 km to the northwest of Chittagong City center, attracts a large number of visitors and pilgrims. A well-preserved Second World War cemetery is an important tourist attraction due to its picturesque location and quiet environment. A large number of devotees from the city and outlying districts visit the shrine of Hazrat Shah Amanat round the year to pay homage to the memory of the great saint. Chittagong is not only a place of pilgrims for the Muslim but also of Hindus. Sitakunda, an adjacent Thana, a part of which is proposed to be included in CWASA project also, attracts thousands of Hindu pilgrims every year. Sitakunda is blessed with many Hindu Temples of which Chandranath is most prominent.

The Court Building Museum situated at the Fairy Hill commands a panoramic bird's eye view of Chittagong City. Chittagong Metropolitan area has two sea beaches, one is known as Patenga, 22 km from the city center; and another known as Fouzdahat beach, 16 km from the city center. These beaches attract a large crowd almost everyday. Significant portions of these beach visitors are non-residents who come to Chittagong City for business or other purposes. They usually take out some of their off office hour times for relaxing in the beach. The ethnological museum, which is unique of its kind in the sub-continent, is situated at Agrabad. The primary goal of this institution is to preserve the cultural heritage of the tribes of the country. Such rare treasures are of interest to tourists, general public, and academics.

Chittagong has the largest numbers of hotels and motels only next to Dhaka. It is possibly true that most of these hotels house those who come for business purposes but that does not mean that visitors don't combine both business and travel. In recent years the Mayor of Chittagong City being convinced of possibility of high turn over of visitors in the near future have entered into two contracts for building hotels and entertainment facilities in the port city. A 5 star hotel will be constructed at the hilltop at the center of the City. This will be a joint project of Chittagong City Corporation and Nam Nam Corporation of North Korea. This Tk.500.0 crores' project (equivalent to US$100.0 million) includes construction of hotel, shopping complex and residential building for the employees. A memorandum of understanding (MOU) for the project has already been singed. In addition to this project the City Corporation has also entered into contract with Golden Bay Resort Ltd. to construct an International Amusement Center at Patenga Sea Beach at a cost of Tk.500.0 crores over 60.73 acres of land. The project includes construction of a 5 star hotel, international conference center, modern

health club, seminar room, golf club, children's park with modern amenities, sports field, observation tower, commercial building etc.

The above statistics related to tourism in the Chittagong City indicate that a large number people come to the city for business purposes for it being industrial as well as biggest port of the country. Most of the hotels and restaurants have developed to cater the needs of this population. People don't seem to visit the city purely for sight seeing or vacationing although there are significant numbers of things to see in the city. In fact the marketing of tourism is very little to attract the outsiders. However, it seems that the concerned authorities have realized this mistakes and made elaborate programs for promoting tourism by constructing 5 star hotels, building amusement park, and making wide publicity about the places of tourist attraction. Therefore, it seems the Chittagong City has a prospect of growing as a tourist town for its unique natural setting and proximity of numbers of beautiful sites.

(3) Education

The first primary school of the city was established in 1818 by East India Company under the British Rule to introduce new system of primary education in India. There are three institutional systems of early education of children in the city today, namely; Primary, Madrasha, and K.G. The primary School Education is basically secular and tailored to meet the national ideology. Both Government and Non-Government primary schools exist side by side in the city. There are two categories of Non-Government primary schools in the city, one of which is fully run by community resources and another run by City Corporation. Madrasha is basically a system of imparting Muslim religious education. Both Government and Non-Government resources support it. Two types of Madrasha education are prevalent in the country. Government prepares the syllabus of one and another by the clerics. Government officially recognizes only the former. The Christian Missionaries first introduced K.G. schools in Chittagong City. Today, K.G. schools have become very popular among the upper middle and upper class. There is a mushroom growth of K. G. schools in the city for its high demand. All these schools are growing in private sector attracting large numbers of students. The following table shows the numbers of different kinds of primary schools in Chittagong City:

The secondary education system is almost similar to primary education in Chittagong City. Four types of institutions provide secondary level education in the city. These are Government, Non-Government, English Medium, and Madrasha. Although the numbers of Government institutions surpass all other types of school at primary level, the scene is quite different at secondary level. The Chittgong City Corporation followed by community support finances the largest numbers of schools in the city. Detail information on this matter is given in Table 2.2-4.

Table 2.2-3 Different Kinds of Primary Schools in Chittagong City

Name of Thana	Govt. Primary School	Non-Govt. Primary School	K.G. School	Unregistered Primary School	Madrasha
Kotwali	30	-	15	-	-
Panchlaish	19	6	25	4	-
Chandgoan	33	9	12	1	2
D. Mooring	36	2	19	-	-
Bandar	23	5	9	3	5
Pahartali	15	5	12	6	-
Hathazati*	4	1	1	-	1
Sitakunda*	7	1	-	-	2
Total	167	29	93	14	10

Source: These data were collected from the District Primary Education Office at Chittagong

* Since only 2 unions of Hathazari and 4 unions of Sitakunda Thana are included in the study area, the educational institutions only of these unions are shown in the Table -3.

Table 2.2-4 Types of Institutions Providing Secondary Level Education

Name of Thana	Govt. Secondary School	Non-Govt. Secondary School	Madrasha
Kotwali	4	30	3
Panchlais	2	13	6
Chandgoan	1	14	5
D. Mooring	2	30	1
Bandar	-	18	3
Pahartali	-	14	2
Hathazari*	-	3	2
Sitakunda*		4	1
Total	9	126	23

Source: These data were collected from the Office of the District Secondary Education Officer at Chittagong.

* Since only 2 unions of Hathazari and 4 unions of Sitakunda Thana are included in the study area the educational institutions only of these unions are shown in the Table.

Besides these primary and secondary schools Chittagong city has 19 General colleges, 1 (one) Art College, 1 (one) Polytechnic Institute, 2 Medical Colleges (one Government and one private), 1 (one) Dental College, 2 Private Universities and branch of another Dhaka based Private University, 1 (one) Teacher's Training College, and 1 (one) Homeopathic College. It may be mentioned that Chittagong City Corporation sponsors 49 different types of educational institute in the city. In addition to all these City Corporation provides financial support to 410 Forkania Madrashas for expansion of religious education to Muslim Children and 6 Sanskrit Toles for Hindu religious teaching, and 4 night schools for mass education.

All these above-mentioned institutions possibly give an overall educational situation of Chittagong City but don't provide the statistics of total student strength. A complete survey is possibly needed to determine this number. Since this is not possible at this point of time we have estimated the total student strength in the year 2010 based on the 1991 census data. The total student population

between age 5 and 24 was 186,610 in 1991 (BBS, 1992:483). We have anticipated that population will increase at the rate of 4.5 in the city during the period 1991 and 2010. It is likely that the student's school attendance rate will increase more than this due to high national importance on school attendance of children. However, to be on safe side we have estimated student's growth rate as that of population ones. Even with such a conservative estimate the student population is likely to increase to 661,456, which means there will be 131% more students than 1991 by the year 2010. This should be a great concern on the part of the city planners because the infrastructure for accommodating this number of students will put tremendous strain on the limited resources of the city. CWASA should be doubly concern because doubling the numbers of schools will significantly increase water demand.

(4) Hospital

The history of modern hospital is about 100 years old in Chittagong City. The modern hospital, which is known as Chittagong General Hospital was established in 1901. As of today, 6 Government and 2 private general hospitals are in function in the city with varying bed capacity. These hospitals are Chittagong General Hospital (Government, about 100 beds), Medical College Hospital (Government, about 500 beds, also render services to 1300 outpatients), Police Hospital (Government, 60 beds), Jail Hospital (Government, 60 beds), Chittagong Port Hospital (Government, 60 beds), Chittagong Railway Hospital (Government, 60 beds), Lion's General Hospital (Private, 150 beds), and Hospital of University of Science and Technology of Chittagong (USTC) (private, now 100 beds, it is going to be 300 beds soon). All these general hospitals altogether have about 1300 beds and provide service to about 10,000 to 12,000 outpatients.

Besides these general hospitals there are few specialized hospitals. Two private maternity hospitals are Jenison Maternity Hospital and Menon Hospital (This is run by Chittagong City Corporation). In addition to these two maternity hospitals, the Government runs 34 Family Planning Clinics at Chittagong City. There is also a 100-bed Shishu (Children) Hospital at Chittagong. Chittagong Eye Infirmary and Training Complex is an outstanding hospital for eye treatment. These 50-bed hospitals also render services to 500 patients every day at a very nominal price (US$ 0.50). Lion's International runs another eye hospital, namely Lion's Charitable Eye Hospital. It renders free services to poor patients. A tuberculosis hospital although not within the city boundary is situated adjacent to it and which is likely to be included in the proposed CWASA plan.

In addition to all these general and specialized hospitals there are about 30 private clinics having 30 to 45 beds each. These private clinics probably have over thousand beds and outpatient service facilities. To support these private clinics and practicing physician a significant number of

pathological laboratories are established in Chittagong City.

The above statistics have revealed the hash reality that the medical facility is extremely inadequate in Chittagong City. In a city over 2.5 million population the total hospital beds including Government and private is only around 3000. Since there is a big gap between the need and the availability of services there will be great deal of investment in the field, for example Diabetic and Kidney Hospitals are being built. Also a large general hospital worth an investment over 100 crores are being planned adjacent to present Eye Infirmary at Pahartali. Land for that hospital has also been purchased. Many such projects in private sector are likely in the offing because of the possibility of high profit. Therefore, the development planners should take into consideration the anticipated growth rate in medical sector.

(5) Transportation

Chittagong City is connected with other parts of the country by road, rail, air, and river. Among the main roads of Chittagong Dhaka Trunk Road, Ramghar Road, Rangamati Road, Kaptai-Chanraghona-Chittagong Road, Arakan Road, Chittagong Cox's Bazar Road, Chandpur Road, Rampur Road are remarkable. Other than the main roads of the Greater Chittagong District, there are many lanes and by-lanes inside the city. Most of these lanes and by-lanes are metalled and carpeted. Recently a Traffic and Transportation study (cited in CDA metropolitan Master Plan) has identified three problems constraining the development of the city, namely; the lack of hierarchy of roads within the city, with many of the roads unable to fulfil their intended functions adequately; the scarcity of reserves of land of future roads; and a tradition of encroachment in those areas where road reserves have been made.

Originally Chittagong Airport was a domestic one. Only recently it has been declared as an international one. At present the new airport is built at the cost of Tk. 600.0 crores. It is partially funded by Japan. Railway system is one of the oldest transportation systems in the county for inter-district communication in the absence of bus routes. It still carries large numbers of passengers throughout the country although its importance is declining due to the presence of long distance bus services. River transportation, which was once most important communication system in Chittagong virtually, lost its importance due to improved road communication. However, some heavy cargoes are still carried to different parts of the country through river transport.

2.2.3 Housing and Sanitation

Chittagong is one of the oldest cities of the country having bulk of its housing structure in private

sector. The CDA review team, who prepared the proposed Master Plan, (yet to be approved) found the figure around 85% (UNCHS, 1995). Of the remaining 15% housing units, about 7.6% are Government quarters for its employees and 7.4% are houses built on the plots distributed by the Government mostly to upper and middle-income groups. These housing plots are distributed through two Government organizations, namely CDA and Housing Settlement Department. The Government housing plots are distributed at Agrabad, Chandgaon, Halishohar, Salimpur, and left bank of the river Karnaphuli (this area is still not included in the CCC). Recently, a housing project is undertaken for low-income group at Kaiballaydham. According to Government priority lands should be made available for housing for specific target group. There is no Thana in Chittagong City where there is no slum or squatter settlement. CDA Master Plan shows that the present population of slum and squatter settlements together is around 300,000. They live in shanty houses, which are not permanent housing units as these are frequently demolished for being owned by Government or illegally owned by private persons.

The census of 1991 has given information of condition of existing housing stock of Chittagong City. We have classified here the housing structure by the materials used on the roof of the house rather than classifying them on the materials of wall and roof together for easy comprehension. About one-third of the houses of the Chittagong City is made of bamboo/straw/polythene while another one-third is semi-pucca. Only slightly less than one-third of the housing units of the city is pucca or made of brick and cement. Thana wise distribution shows that relatively older areas of the city have more pucca structure than the new ones that are included much later in the City Corporation (BBS, 1992).

The condition of sanitation is far below the international standard. The percentages of sanitary latrine vary in between 21% to 72%. The higher percentages of sanitary latrine are found in the older Thanas than the new ones that are included in the City Corporation in recent years. It seems sanitary latrine exists in all pucca houses and also in the majority of the semi-pucca houses because 54% households have sanitary latrine while 31% houses are pucca (BBS, 1992). However, it should be a matter of serious concern for city planners since nearly half of the households of the city don't have sanitary latrine. The census has not mentioned what kinds of other latrines the people are using. They possibly are using pit latrine. The situation in slums and squatters where more than 10% of the total population of the city live must be very bad because they live in make shift houses. This is not very clear whether sanitary condition of slums and squatter settlements were recorded in the census properly.

The situation with regard to electricity appears to be much better. In almost all Thanas nearly 70% or more households have electricity except Hathazari Thana, which is relatively rural compared to all other areas of the City Corporation.

Table 2.2-5 Conditions of Housing and Sanitation

Thanas	No.of Housing Units	Material of Roofs			Toilet			Electricity	
		Cement Tiles, Metal sheet	Galv. Iron	Straw, Bamboo, Polythene	Sanitary	Others	None	Yes	No
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Kotwali	32,593	47	35	18	72	23	5	88	12
D. Mooring	48,495	32	31	37	59	35	6	78	22
Panchlaish	29,851	27	30	43	55	39	6	68	32
Pahartali	31,736	29	30	41	46	48	7	71	29
Chandgaon	35,000	22	38	40	42	51	6	68	32
Port	27,023	35	39	26	50	45	5	77	23
Hathazari (p)	3,972	9	24	67	21	71	7	30	70
Total	208,670	31	34	35	54	40	6	74	26

Source: Bangladesh population Census 1991 (BBS:1992).

Traditionally, the lower income Chittagonions used to go to Middle East for employment and that number had increased in many-folds during the last two decades due to serious shortage of workforce there. The remittance of expatriate workers being a major source of foreign currency for the country the Government actively encourage to increase this expatriate workforce as much as possible. The vast majority of these workforce were of rural origin but many of them are now keeping their families in town either by Population.

2.2.4 Land Use

The Chittagong City is unique in the country in terms of natural beauty. There are hills and dales in the heart as well as around the city. The Bay of Bengal bound the city on the west, the hilly river Karnaphuli has created the natural boundary on the southwest, and an artificial lake was created long back inside the city boundary. Chittagong City like all other towns of the country has grown primarily on private initiative. However, the land use pattern is somewhat different than the capital city of Dhaka for its unique topography and existence of the biggest port of the country. Figure 2.2-1 shows the present urban area under the City Corporation.

Residential Area: About 80% of the city area is possibly residential. Until partition of India the city was simply a district town despite the existence of port because the major sea cargo was handled in Calcutta port (now in India). The residential areas of the city can be divided into three categories by density of population. The highest population density areas are the oldest parts of the city, which consists of Kotwali and Double Mooring Thanas. The projected population densities of the former and the latter Thanas are likely to be 732 and 554, respectively in the year 2010. The Thanas that fall into the second category in terms of population density are Panchlaish, Pahartali, Chandgaon, and Chittagong Port Thanas. These thanas are likely to have population densities below 200 in the year 2010. The projected difference of population density that is likely to occur in 2010 between the first

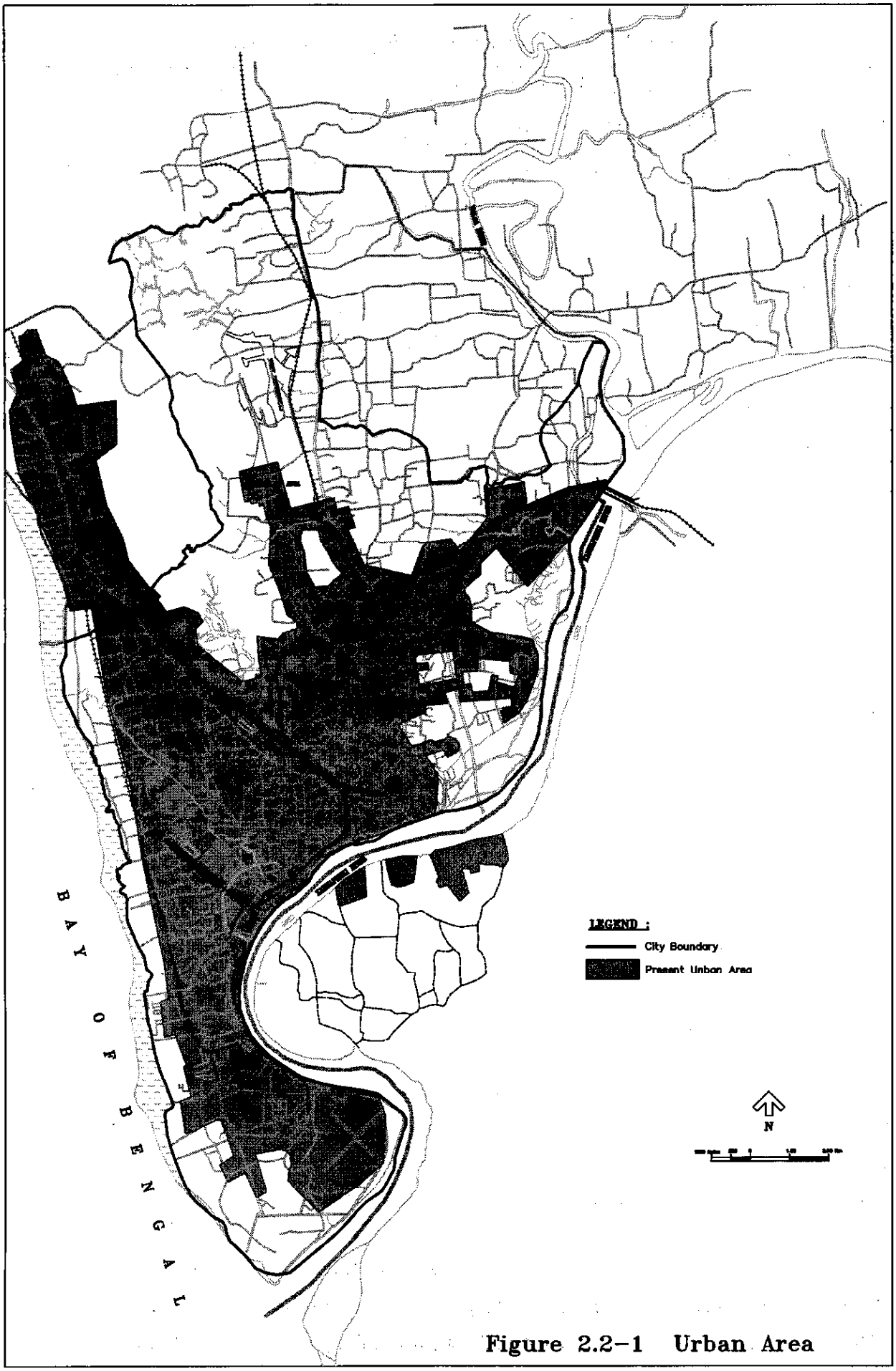


Figure 2.2-1 Urban Area

and the second category Thanas is as high as 300 or more. CWASA proposes to include 4 unions of Hathazari Thana and 2 unions of Sitakunda Thana as part of their service areas by the year 2010. The population densities of these areas are not expected to be very high because most them are still crops producing areas. The projected population densities of those two Thanas are less than 100 in the year 2010. The second and the third category Thanas will get most of the future population, as the first category does not have much space for further growth.

Industrial Area: The industrial history of Chittagong City is not very old. Manufacturing industries started emerging in 1950's but heavy ones came in 1960s. At present Chittagong City have 6 major industrial zones spread over the city. Figure 2.2-2 shows the distribution of industrial estates of the city. The approximate sizes of the industrial estates are given in Table 2.2-6.

Table 2.2-6 Approximate Size of Existing Industrial Areas

Name of the Estates	Hectares*
Fouzderhat – a	50
Fouzderhat – b	110
Nasirabad/Sholashahar	140
Kalurghat	100
Kalurghat Noxious	30
Export Processing Zone	150
Patenga	400
Total	980

* These statistics are quoted from the CDA report.

The above statistics and the Figure 2.2-2 indicate that the total area of industrial area of the city is very insignificant compared to the total residential area. There are 3 categories of industries, heavy, medium, and light. Figure 2.2-3 shows the distribution of categories of industries in different industrial estates. The team members who prepared the CDA Metropolitan Master Plan found that many of these plots are unused or underused although considerable time has elapsed after the distribution of these plots. This means that there is an opportunity of further industrial growth within the present industrial estates without encroaching upon existing agricultural or residential lands. Besides, Chittagong City has many small scale factories outside the designated industrial estates. No reliable statistics are available on the numbers of such industries and manpower engaged in them.

Chittagong has a long tradition of trade and commerce for a long time possibly because of seaport. The traditional business centers of the city were Sadarghat and Chkktai, which developed long back without any systematic planning. With the passage of time those centers did not die a natural death rather they are still vigorously alive for wholesale business. The physical expansion of these areas being constrained for lack of space these areas are getting congested day by day because of growing

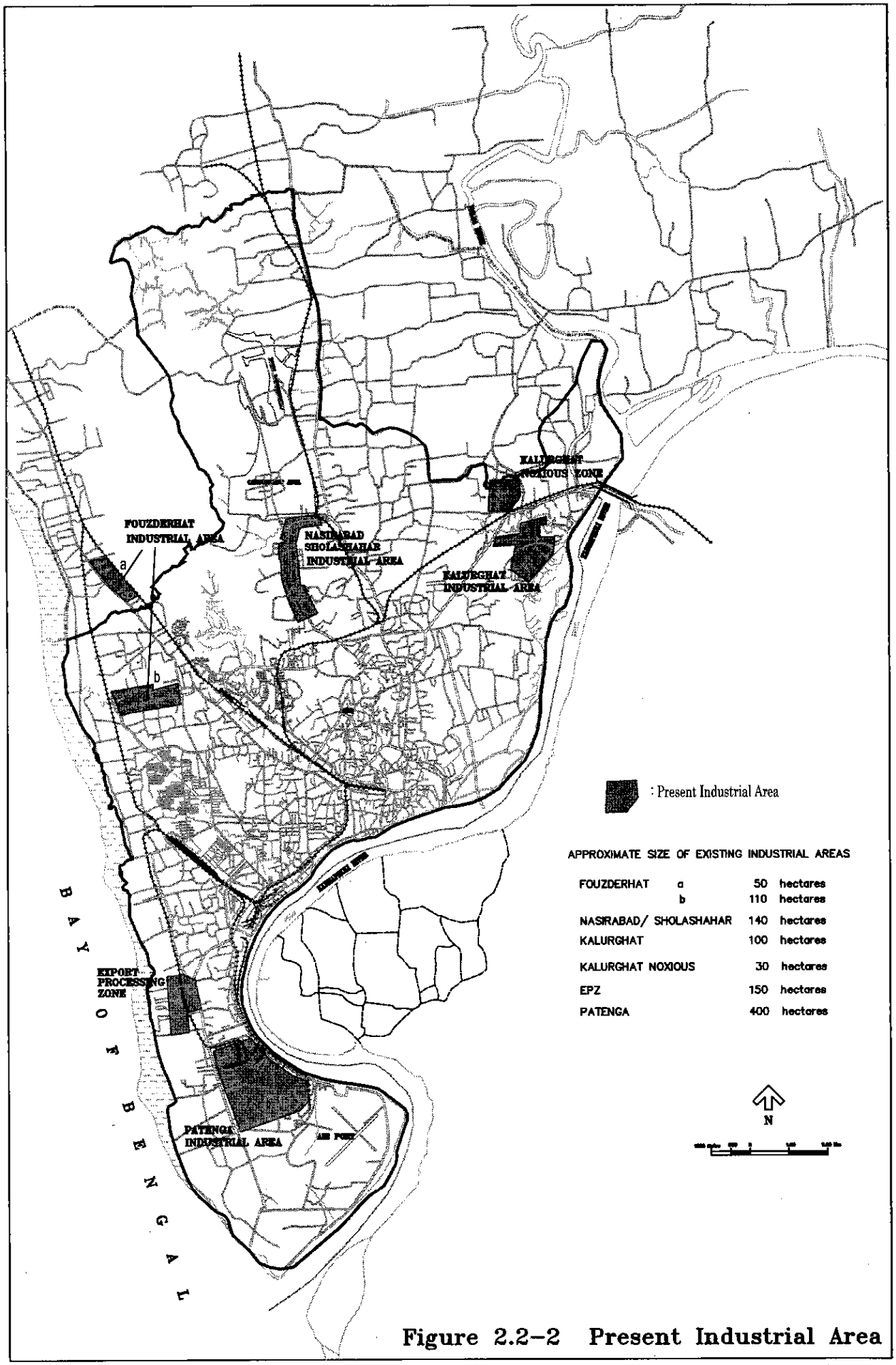


Figure 2.2–2 Present Industrial Area

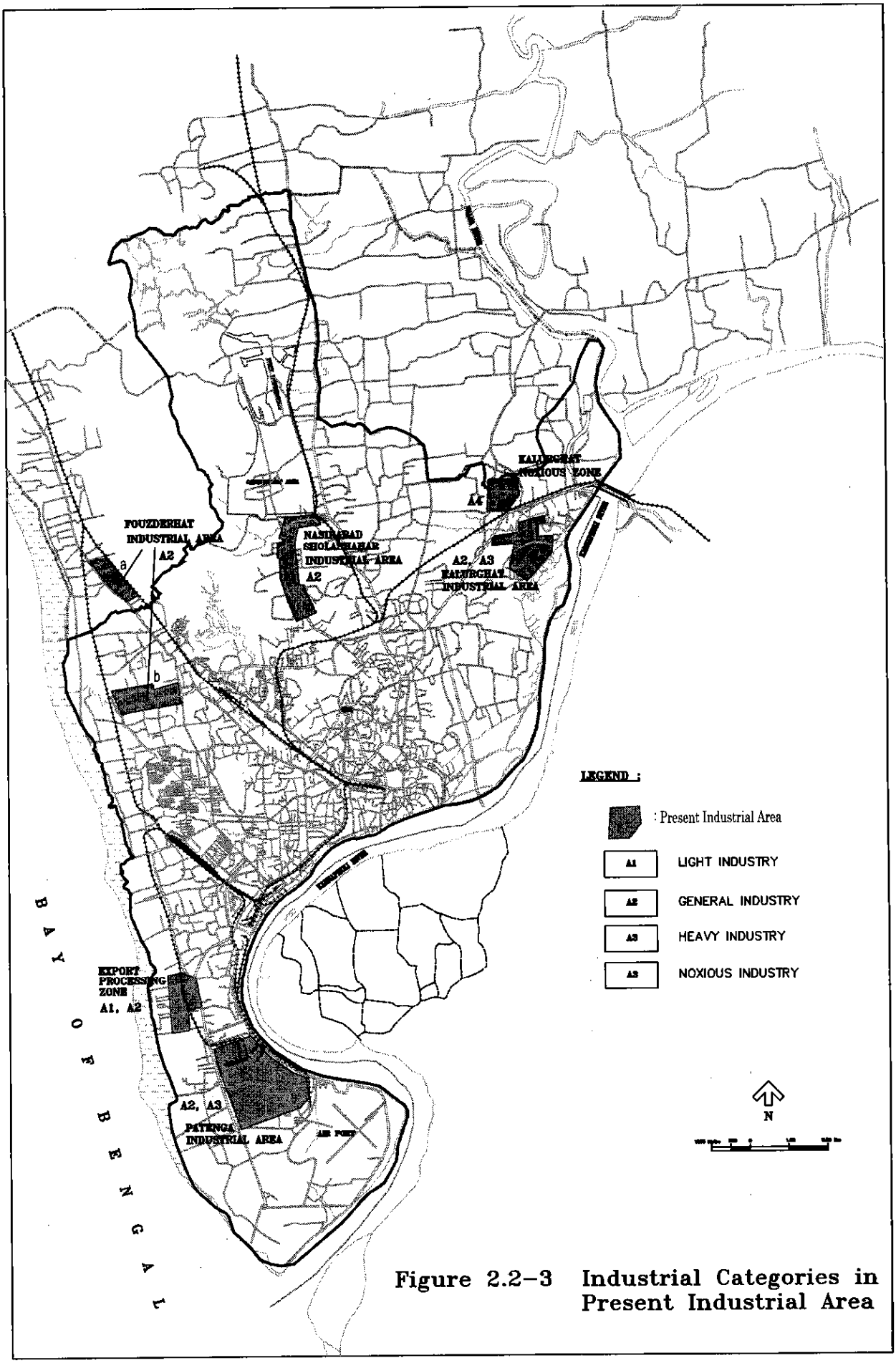


Figure 2.2–3 Industrial Categories in Present Industrial Area

business units. However, realizing the growing need of a modern commercial center, the CDA under its own initiative has developed Agrabad as a modern trade and commerce center for housing major financial institutions and relevant offices together. Today Agrabad Commercial Area has Stock and Exchange Center, office of the Chamber of Commerce and Industries, main branches of almost all banks etc. Anticipating the future growth of trade and commerce in Chittagong the Government has already inaugurated the construction of International Trade Center at Agrabad. Although modern facilities are far less than required, situation is gradually improving day by day. Figure 2.2-4 shows Sadarghat/Chakktai (traditional center of Trade and Commerce) and Agrabad Commercial Area (modern center of Trade and Commerce). Although Agrabad is specifically meant for providing modern office space, a significant numbers of buildings are being used as garment or other factories, which definitely defeats the main purpose of creating the area.

Open Space: Fortunately, there is some breathing space in Chittagong City. We have earlier pointed out that the density of population is high in old parts of the city, while considerable scope of growth is left in its new parts. However, within the city limits there is some open space, which deserves to be mentioned here particularly for the preservation of these areas as recreational centers. Foy's Lake is the most important of all. This is a man made lake named after Mr. Foy a Railway engineer, who designed for procuring water for railway area in 1924. It is situated at a distance of only 8 kg. from Chittagong City towards East of Pahartali Rail Station and West of Khulshi posh residential area.. A good number of hills remain scattered all around the Lake, which attract the minds of tourists. The area to the immediate north and east of the lake was designated as a Botanical and Zoological Garden. Since 1961 this garden has not been established. The area is shown in Figure 2.2-5.

Northern Hills are situated north of Foy's Lake. The area is quite large having numbers of hills and dales. Human habitation has not taken place in those areas in greater numbers because hill cutting is going on in full swing despite Government restrictions on it. These hills are cut first for selling sand (for construction purposes) and clay (for brick making) and second for developing sites for residential purposes. If the present level of hill cutting goes on for a very long time the hills might one day disappear from the area, which nature preserved for thousands of years. The total area of Northern Hills is quite substantial, which can be seen in the shaded portion of Figure 2.2-5.

Another hilly area known as Battali Hill and adjoining hills is situated at the heart of the city (see Figure 2.2-5). Squatters have already encroached some areas of the hills. The numbers of these squatters are so numerous and many of them even have built cemented structures that are difficult to be dislodged given the socio-political condition. However, the vast majority of the area is still empty and that as far as possible, be maintained in their present status (Figure 2.2-5).

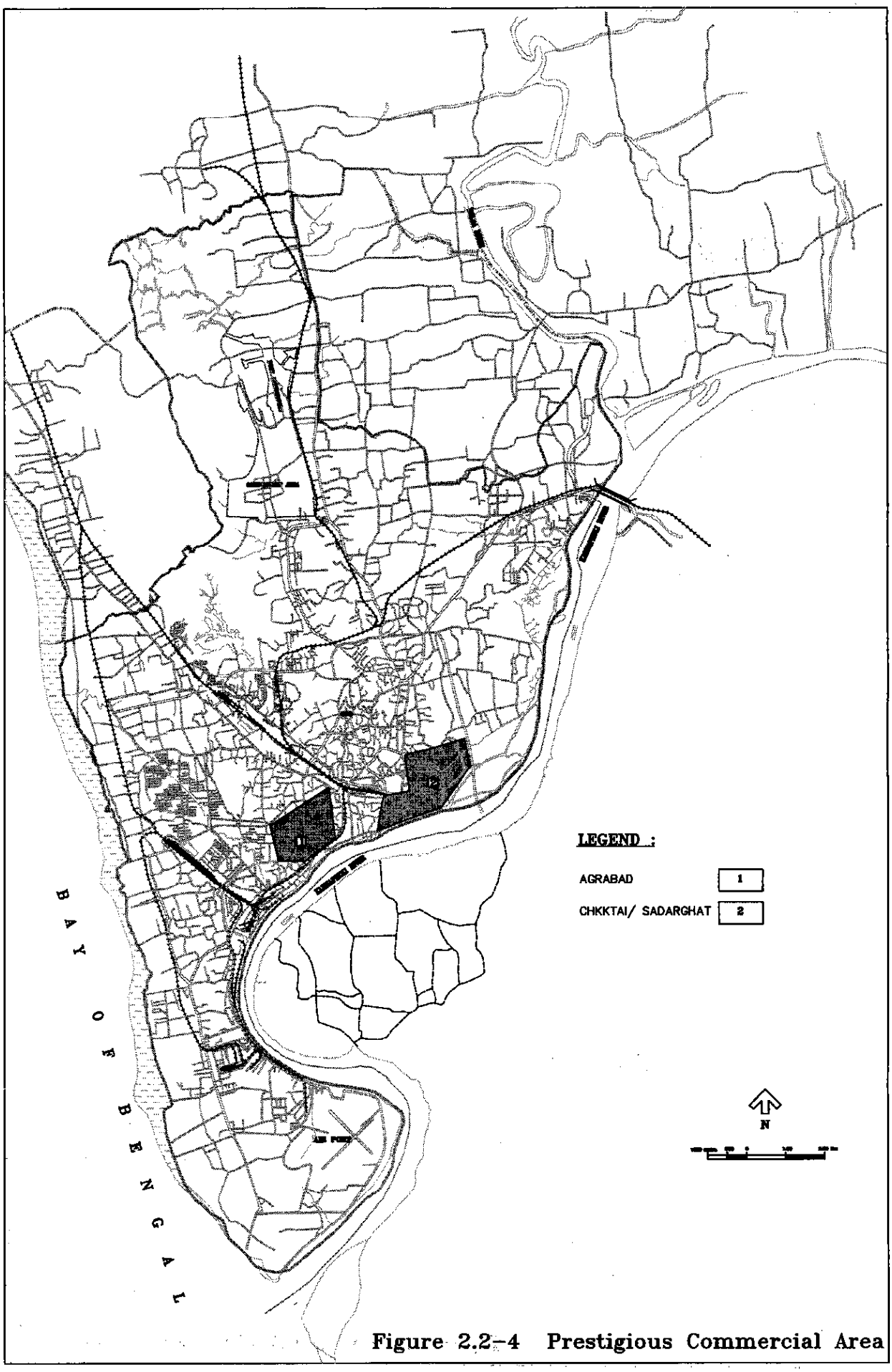


Figure 2.2-4 Prestigious Commercial Area

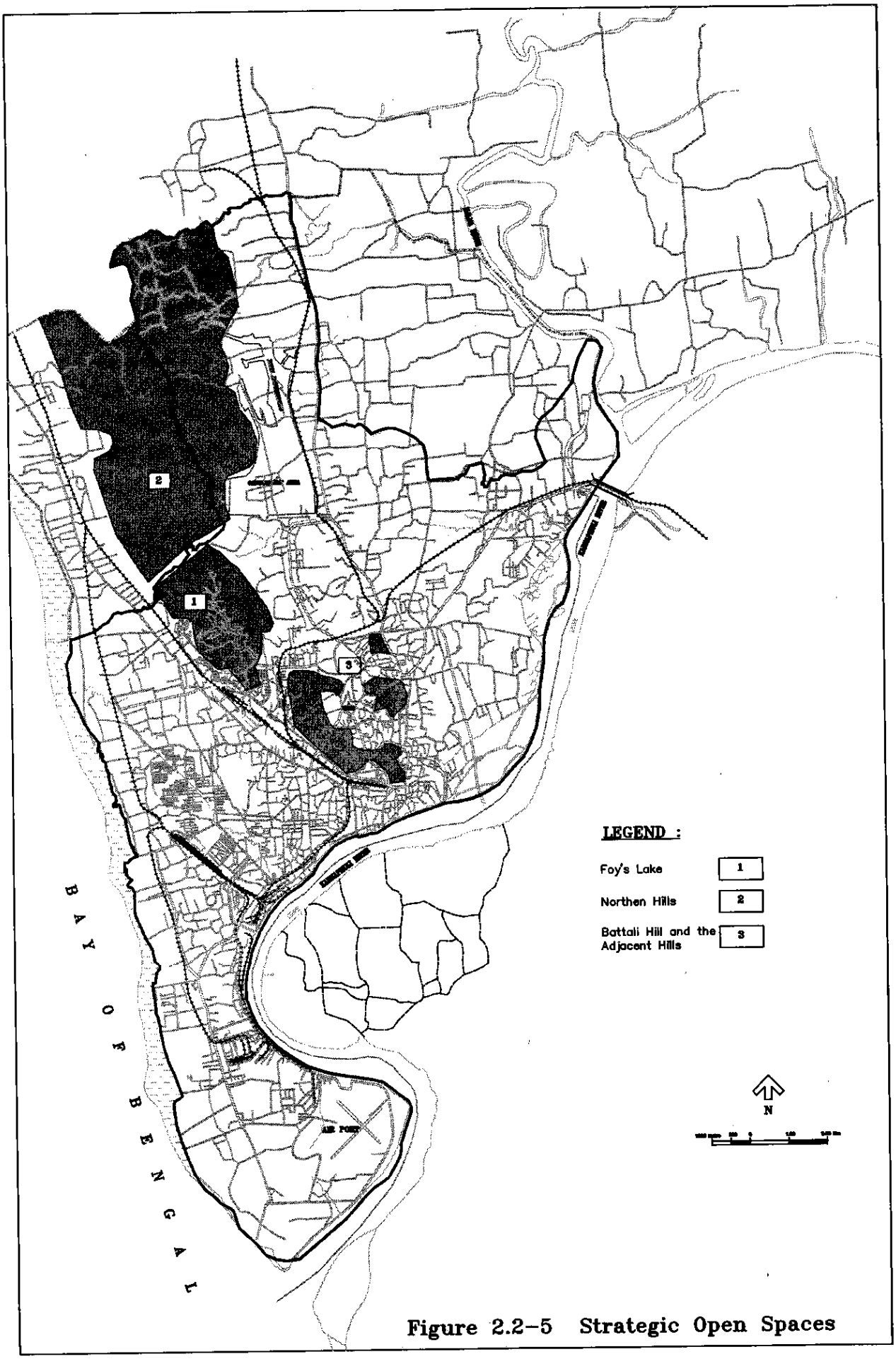


Figure 2.2–5 Strategic Open Spaces

Another attractive place of Chittagong City is its sea beach at Patenga, which is 22 kilometers South of Chittagong City and located at the meeting juncture of river Karnaphuli to the Bay of Bengal. The beach is not sandy and very suitable for bathing. Although the beach is not yet encroached the danger of it is there because the longest beach of the country at Cox's Bazar (at a distant of 140 kilometer from Chittagong) has largely been encroached by the migrants from all over the country. The Government is having difficulty to dislodge them despite the existence of Government laws and power.

Port Area: Chittagong City is known for Port than any other reason. The modern port was established in 1887 under the British Rule. It is situated at the estuary of the river Karnaphuli. Its steaming distance is 16 kilometers from outer bar to the Main Berths. It is now a very busy port round the year. It is spread over a considerable land space along the bank of the river Karnaphuli.

Agricultural and Farm Lands: Chittagong City is expanding fast since its independence in 1971. Until 1974, the city had only 25 unions. Now it has 41 wards (unions are renamed as wards after it has been declared as City Corporation), which means a large area is added to the city in a very short period. The inclusion of new areas does not mean that whole area has become urban overnight. The vast majority of the newly included wards are still having lot of agricultural lands, which provide livelihood of many families. However, with the expansion of non-farm economic activities the farmlands are being gradually transformed into commercial lands. Construction of garment factory and residential quarters is receiving priority in those areas. These urban growths unfortunately are taking place in a haphazard manner in the absence of clear direction from the CDA and whatever regulations they have are not enforced rigorously. Therefore, the land use pattern in newly included wards into the city is in a state of a mess. However, it may be predicted that the farmlands inside the City Corporation area will gradually turn into non-farm lands as value of the lands are increasing many fold. The owners are likely to try to maximize their income by alternative use of the lands, the scope of which has been created due to the expansion of the city.

Slums and Squatter Housing: Slums and squatter housing are part and parcel of Dhaka and Chittagong City. It is extremely difficult to estimate their number as they very often move from one place to another. All Thanas of the Chittagong City Corporation have slums/squatter areas of various sizes. These slums/squatter areas have grown either on the private lands or on the Government Khas lands (Lands owned by the Government but have no structure). Private owners rent out their properties to people, while squatter settlers also pay the rent but not to the Government (Who is the actual owner of the land) but to those who unofficially control the area. Housing and sanitary conditions of the slums and squatter settlements are extremely poor. The CDA feasibility team while preparing the Master Plan for Chittagong in 1995 estimated the slum and squatter population of Chittagong around 27,000

and 30,000, respectively. The present population is likely to be much higher than that as most of the new migrants from different parts of the country take shelter in those localities for being affordable for many.

2.2.5 Future Land Use Plan of CDA

A city plan was prepared in 1961 in which a guideline was given about the utilization of private land. It did not work well for lack of implementation of the plan. The Government programs for establishing housing, commercial and industrial estates went much better. However, utilization of the industrial plots was not up to the expectation. Even today a significant numbers of plots are lying vacant and many commercial plots are being used as factories and industries, which is against the basic principle laid down in the 1961 plan. A Chittagong Metropolitan Master Plan for CDA is prepared with the financial help from the United Nations Development Program, which has suggested some major policy change regarding spatial development of Chittagong City.

CDA being the prime organization for the development of the city, we can assume that their proposed plan is as good as the final one. We are assuming this because the plan is waiting for the final approval of the relevant authority. The proposed land use planning is more specific than the earlier one. The following main elements of development strategies are mentioned in the Metropolitan Master Plan (1995):

It proposes 'to concentrate urban development within the existing urban area and its immediate environs, rather than to disperse it throughout the study area.' The new Metropolitan Master Plan emphasizes maximization of utilization of the lands within the city area. This will increase population density but will optimize the use of limited resources of the country and save cost of infrastructure development.

It proposes, "to concentrate the growth of population and economic activity, that is expected in the study area outside the city, into a limited number of growth centers'. The study area refers to statistical metropolitan area, which covers the adjacent urban areas beyond the City Corporation. The plan emphasizes concentration of growth in already urbanized areas outside the city. This possibly will increase the urban area without putting much strain on the limited resources, as cost of infrastructure development will be minimal.

It proposes 'to make better use of vacant and underutilized land within the existing urban areas'. Chittagong City still has many vacant plots in many pockets. The new Metropolitan Master planners have noticed that and suggested utilizing those valuable lands possibly for saving the good quality

croplands, which exist at the periphery of the city.

It proposes to 'concentrate peripheral expansion of the urban area into a single or a limited number of locations'. The new plan suggests not expanding all peripheries of the urban areas because all areas may not be suitable for urban development for variety of reasons. Therefore, city planners should be selective for the expansion of the peripheries for the sake of economy as well as optimal utilization of lands.

The vital points suggested by the CDA are as follows: The land utilization policy in Chittagong City is not very efficient because considerable spaces are still vacant inside the city area. The new policy suggests ensuring optimal utilization of the empty lands for stopping unnecessary expansion of the city area. If people can be accommodated and their work place can be close to their living places that will save the construction of the cost of infrastructure, avoid the problem of transportation of the large number of people, save good quality crop lands around the city, and reduce traffic congestion. However, population density and water demand will increase, the problem of garbage disposal will multiply, and crime rate may rise for concentrating the urban growth at a limited space. If we compare the benefits with the problems certainly the former will outweigh the latter. The suggestion of encouraging growth centers within statistical metropolitan area outside the city is again may be very effective because these centers already have nucleus of town and potential of growing as full-fledged small towns. The growth of these centers will reduce unnecessary influx of population from the rural areas to city while they can get many city benefits staying in those centers due to their physical proximity to city. Another plan is not to indiscriminately expand the city area to the periphery, which may not be cost effective and beneficial for the people. The good agricultural lands at the periphery should not be converted into urban areas when alternative lands are available in the city or in the periphery because a well to do agricultural community may be destroyed. Therefore, peripheral growth should be selective and limited. The proposed Metropolitan Master Plan of CDA also suggests optimizing the use of lands under the direct supervision and control of the organization because the past experiences with laissez-faire growth of private sector did not yield desirable results.

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CHAPTER 3

POPULATION AND WATER DEMAND PROJECTION

CHAPTER 3 POPULATION AND WATER DEMAND PROJECTION

3.1 Population

3.1.1 Population Growth Rate of Chittagong City

The population growth of Chittagong City had ups and downs throughout the century. During the first two decades the percentage of population census growth rate was below 3 % but remained 4% and above for the period 1921 to 1941. The population growth sharply declined to 2% in the period 1951 to 1961. In the next two decades there was a phenomenal growth of population in the Chittagong City. The growth rates between 1961-1974 and 1974-1981 were 6.9 % and 9.7 %, respectively. This was the period of post-liberation when Chittagong as a Port City received a big boost as almost 80% of the sea cargo was handled through it. Besides, industrial growth also received momentum in the city for its unique geographical advantages. However, such a big boost did not last long. The annual population growth rate declined to 2.8 % during the period 1981-1991 as shown in Table 3.1-1. This was far lower than the annual growth rate of 4.7 % in the biggest 7 cities in the country during same period (BBS. 1994).

Table 3.1-1 Population Growth Rates of Chittagong City Corporation in Different Time Periods

Period	Annual Growth Rate in Percentage
1901 – 1911	2.7
1911 – 1921	2.3
1921 – 1931	4.0
1931 – 1941	5.7
1941 – 1951	4.5
1951 – 1961	2.0
1961 – 1971	6.9
1971 – 1981	9.7
1981 – 1991	2.8*

* The growth rates are calculated from the adjusted population of 1981 and 1991 censuses.

The population growth rate had declined during this period possibly because of general economic recession, lack of new investment, and too much concentration of everything in the Capital City of Dhaka.

In addition, there may be another reason of variations of population growth in different periods of the century. That was the change of boundary of the city. The city had 14 unions in an area of only 9.6-kilometer (6 square miles) in 1961. In 1974 the numbers of unions increased to 25 and the area expanded to 48 kilometer (30 square miles). By the year 1983 the city area expanded to 111 kilometers (69.58 square miles) increasing the absolute number of population to a great extent. At

present officially Chittagong City has 41 wards distributed in 7 Thanas. Of these 5 thanas namely, Kotwali, Double Mooring, Panchlaish, Chandgaon, and Pahartali are all part of the Chittagong City Corporation. A significant part of Port Thana, which lies on the left bank of the Karnaphuli river is not part of the City Corporation, while the Hathazari Thana is mainly outside the City Corporation, except for the Dakshin Pahartali ward. The Chittagong Metropolitan Master Plan that has been prepared by the Chittagong Development Authority (CDA) proposes much larger areas to be included in the metropolis. However, the CWASA has narrower view than that of CDA, because it has proposed to extend its service area only to four new unions of Hathazari Thana and two unions of Sitakunda Thana. The population of all these 6 new unions together is only 134,000, which means inclusion of these unions has not increased the population to a great extent, although there is a potential of such a growth.

CWASA is now facing great strain to cope up with the growing demand of water not only because of population growth but also for other factors, such as industrial growth, establishment of new institutions, and rise of water consumption of upper middle and upper income groups of society. However, population growth remains most important factor for the rise of water demand in Chittagong. Table 3.1-2 shows that the population of the city did not grow evenly in all parts of the city. The older and newer parts of the city experienced the lowest annual growth rate during 1981-1991. Kotwali Thana had the lowest annual growth rate of 1.23 % followed by newly proposed areas of Hathazari Thana (1.53 %), Double Mooring (1.80 %), proposed areas of Sitakunda Thana (2.15 %), Pahartali Thana (3.20 %), Chandgaon Thana (3.97 %), City Corporation area of Hathazari Thana (2.83 %), and Chittagong Port Thana (4.56 %).

It is observed that the old and the relatively rural thanas had lower population growth rates compared to thanas recently brought under City Corporation. This pattern of population growth is quite natural because the older Thanas are already crowded and have very little scope of new habitation. Construction of high-rise buildings is the only way of further growth of population in those areas, but such a venture would require demolition of existing structures, which is extremely complicated due to multiple ownerships of those holdings. The multiple ownerships of those holdings are natural because family kin are living in limited space for a long time. Besides construction of a multi-storied building requires a huge capital, which again is not possible to manage for most of the owners of the holdings.

A look at the density of population of old and newly included Thanas of the City Corporation (Table 3.1-2) will support our claim. On an average the density of Kotwali Thana, the oldest of all Thanas of Chittagong City Corporation had 453 persons per hectare in 1991. Even in one ward of the Kotwali Thana the density of population was as high as 1,449 per hectare in 1991.

Table 3-1-2 Projection of Population and Density by Wards and Thanas

Ward no.	Name of Ward	Area in Hectare	CENSUS Population in 1974	CENSUS Population in 1981	CENSUS Population in 1991	Adjusted Population in 1974*	Adjusted Population in 1981*	Adjusted Population in 1991*	Population in 1991 Adjusted for Yearbook**	Average Annual Rate of Increase 1974-91 (%)	Average Annual Rate of Increase 1981-91 (%)	Adopted Annual Rate of Increse (%)	Adopted Projected Population in 2000	Adopted Projected Population in 2005	Adopted Projected Population in 2010	Population Density in 1991 (p/ha)	Population Density in 2000 (p/ha)	Population Density in 2005 (p/ha)	Population Density in 2010 (p/ha)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Kotwali Thana																			
1	Bogmoniram	102	18,672	19,687	26,883	20,052	21,351	29,472	30,862	2.57%	3.75%	4.0%	43,900	53,400	65,000	303	430	524	637
2	Chawk Bazar	146	15,195	32,940	33,418	16,318	35,724	36,636	38,364	5.16%	0.72%	3.5%	52,300	62,100	73,800	263	358	425	505
3	Jamal Khan	62	23,115	31,266	33,976	24,823	33,909	37,248	39,004	2.69%	1.41%	1.5%	44,600	48,000	51,800	629	719	774	835
4	Enayet Bazar	51	16,134	21,031	25,158	17,326	22,809	27,581	28,881	3.05%	2.39%	2.5%	36,100	40,800	46,200	566	708	800	906
5	Dewan Bazar	22	13,672	30,131	28,087	14,682	32,678	30,792	32,244	4.74%	-0.13%	0.0%	32,200	32,200	32,200	1,466	1,464	1,464	1,464
6	Anderkilla	25	10,278	29,747	17,675	11,037	32,261	19,377	20,291	3.65%	-4.53%	0.0%	20,300	20,300	20,300	812	812	812	812
7	Alkaran	58	12,441	17,133	24,618	13,360	18,581	26,989	28,261	4.51%	4.28%	3.0%	36,900	42,700	49,600	487	636	736	855
8	Patherghata	78	10,043	29,747	26,180	10,785	32,261	28,701	30,055	6.21%	-0.71%	3.0%	39,200	45,500	52,700	385	503	583	676
9	Fringi Bazar	30	13,413	13,171	19,330	14,404	14,284	21,192	22,191	2.57%	4.50%	2.0%	26,500	29,300	32,300	740	883	977	1,077
10	Boxirhat	51	13,295	6,505	11,568	14,277	7,055	12,682	13,280	-0.43%	6.53%	5.0%	20,600	26,300	33,600	260	404	516	659
	Total	**625**	**146,258**	**231,358**	**246,893**	**157,064**	**250,913**	**270,670**	**283,433**	**3.53%**	**1.23%**	**2.6%**	**352,600**	**400,600**	**457,500**	**453**	**564**	**641**	**732**
Double Mooring Thana																			
15	Lalkhan Bazar	226	14,158	70,803	43,285	15,204	76,787	47,454	49,691	7.21%	-4.26%	4.0%	70,700	86,000	104,700	220	313	381	463
16	East Madarbari	85	22,292	28,418	30,563	23,939	30,820	33,506	35,086	2.27%	1.30%	2.0%	41,900	46,300	51,100	413	493	545	601
17	West Madarbari	111	24,365	46,860	37,452	26,165	50,821	41,059	42,995	2.96%	-1.66%	3.0%	56,100	65,000	75,400	387	505	586	679
18	Uttar Pathantoly	81	14,131	5,819	26,501	15,175	6,311	29,053	30,423	4.18%	17.03%	5.0%	47,200	60,200	76,900	376	583	743	949
19	Pathantoly	153	17,373	21,045	33,619	18,657	22,824	36,857	38,595	4.37%	5.39%	6.0%	65,200	87,300	116,800	252	426	571	763
20	Gosail Danga	126	10,225	20,773	19,819	10,980	22,529	21,728	22,752	4.38%	0.10%	4.5%	33,800	42,100	52,500	181	268	334	417
24	Uttar Agrabad	195	16,059	26,623	34,995	17,245	28,873	38,365	40,174	5.10%	3.36%	4.5%	59,700	74,400	92,700	206	306	382	475
25	D. Agrabad	341	24,544	52,367	71,210	26,357	56,793	78,068	81,749	6.88%	3.71%	4.5%	121,500	151,400	188,700	240	356	444	553
33	Rampur	181	9,637	10,612	22,501	10,349	11,509	24,668	25,831	5.53%	8.42%	5.5%	41,800	54,700	71,400	143	231	302	394
	Total	**1,499**	**152,784**	**283,320**	**319,945**	**164,072**	**307,267**	**350,757**	**367,296**	**4.85%**	**1.80%**	**4.4%**	**537,900**	**667,400**	**830,200**	**245**	**359**	**445**	**554**
Panchlaish Thana																			
11	Sulak Bohar	968	25,012	59,247	74,134	26,860	64,255	81,273	85,106	7.02%	2.85%	4.0%	121,100	147,400	179,300	88	125	152	185
12	West Sholoshahar	342	21,393	56,879	46,237	22,974	61,687	50,690	53,080	5.05%	-1.49%	3.0%	69,300	80,300	93,100	155	203	235	272
14	Jalalabad	648	N/A	N/A	39,836	N/A	N/A	43,672	45,732	N/A	N/A	4.0%	65,100	79,200	96,400	71	100	122	149
26	Panchlaish	643	N/A	N/A	33,150	N/A	N/A	36,342	38,056	N/A	N/A	4.0%	54,200	65,900	80,200	59	84	102	125
98	Chittagong Cantonme	N/A	N/A	N/A	(10,960)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Total	**2,601**	**46,405**	**116,126**	**193,357**	**49,834**	**125,941**	**211,978**	**221,974**	**9.19%**	**5.83%**	**3.8%**	**309,700**	**372,800**	**449,000**	**85**	**119**	**143**	**173**
Pahartali Thana																			
21	Saripara	243	20,347	74,961	46,540	21,850	81,297	51,022	53,428	5.40%	-4.11%	4.0%	76,000	92,500	112,600	220	313	381	463
22	North Pahartali	2,694	15,458	27,281	38,205	16,600	29,587	41,884	43,859	5.88%	4.02%	6.0%	74,100	99,200	132,700	16	28	37	49
23	Pahartali	304	23,504	51,350	43,560	25,241	55,690	47,755	50,007	4.10%	-1.07%	4.0%	71,200	86,600	105,400	164	234	285	347
34	Uttar Kattali	458	N/A	N/A	20,705	N/A	N/A	22,699	23,769	N/A	N/A	5.5%	38,500	50,300	65,700	52	84	110	143
35	Dakhin Kattali	440	N/A	N/A	22,655	N/A	N/A	24,837	26,008	N/A	N/A	5.0%	40,300	51,500	65,700	59	92	117	149
36	Uttar Halishahar	524	N/A	N/A	27,229	N/A	N/A	29,851	31,259	N/A	N/A	6.0%	52,800	70,700	94,600	60	101	135	181
	Total	**4,663**	**59,309**	**153,592**	**198,894**	**63,691**	**166,574**	**218,048**	**228,330**	**7.80%**	**3.20%**	**5.0%**	**352,900**	**450,800**	**576,700**	**49**	**76**	**97**	**124**
Chandgaon Thana																			
27	Chandgaon	1,035	24,674	37,695	43,724	26,497	40,881	47,935	50,195	3.83%	2.07%	3.0%	65,500	75,900	88,000	48	63	73	85
28	Mohara	908	24,010	34,767	47,089	25,784	37,706	51,624	54,058	4.45%	3.67%	4.5%	80,300	100,100	124,800	60	88	110	137
29	Purba Sholoshahar	218	9,836	22,338	15,730	10,563	24,226	17,245	18,058	3.20%	-2.90%	4.5%	26,800	33,400	41,700	83	123	153	191

Table 3-1-2 Projection of Population and Density by Wards and Thanas

Ward no.	Name of Ward	Area in Hectare	CENSUS Population in 1974	CENSUS Population in 1981	CENSUS Population in 1991	Adjusted Population in 1974*	Adjusted Population in 1981*	Adjusted Population in 1991*	Population in 1991 Adjusted for Yearbook**	Average Annual Rate of Increase 1974-91 (%)	Average Annual Rate of Increase 1981-91 (%)	Adopted Annual Rate of Increse (%)	Adopted Projected Population in 2000	Adopted Projected Population in 2005	Adopted Projected Population in 2010	Population Density in 1991 (p/ha)	Population Density in 2000 (p/ha)	Population Density in 2005 (p/ha)	Population Density in 2010 (p/ha)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
30	Purba Bakulia	272		10,400	25,732		11,279	28,210	29,540		10.11%	6.5%	52,100	71,300	97,700	109	192	262	359
31	Paschim Bakulia	236	46,114	26,275	40,298	49,521	28,496	44,179	46,262	5.83%	4.96%	5.0%	71,800	91,600	116,900	196	304	388	495
32	D. Bakulia	545		26,038	47,068		28,239	51,601	54,034		6.70%	6.0%	91,300	122,200	163,500	99	168	224	300
	Total	**3,214**	**104,634**	**157,513**	**219,641**	**112,365**	**170,826**	**240,793**	**252,147**	**4.87%**	**3.97%**	**5.0%**	**387,800**	**494,500**	**632,600**	**78**	**121**	**154**	**197**
Chittagong Port Thana																			
37	U.P. Halishahar	410	35,834	17,851	32,276	38,482	19,360	35,384	37,053	4.28%	6.71%	6.5%	65,300	89,500	122,600	90	159	218	299
38	D.P. Halishahar	614		34,879	36,020		37,827	39,489	41,351		0.89%	5.0%	64,100	81,900	104,500	67	104	133	170
39	D. Halishahar	752	17,544	28,980	46,672	18,840	31,429	51,167	53,579	6.34%	5.48%	6.0%	90,500	121,100	162,100	71	120	161	216
40	U. Patenga	942	14,421	22,294	39,828	15,486	24,178	43,664	45,722	6.58%	6.58%	6.5%	80,600	110,400	151,300	49	86	117	161
41	D. Patenga	1,746	12,790	23,248	32,943	13,735	25,213	36,116	37,818	6.14%	4.14%	6.0%	63,900	85,500	114,400	22	37	49	66
	Total	**4,464**	**80,589**	**127,252**	**187,739**	**86,543**	**138,008**	**205,819**	**215,523**	**5.51%**	**4.56%**	**6.0%**	**364,400**	**488,400**	**654,900**	**48**	**82**	**109**	**147**
Hathazari (Munici) Thana																			
13	J.D. Pahartali	2,938	N/A	46,071	26,391	N/A	49,965	28,933	30,297	N/A	-4.88%	4.5%	45,000	56,100	69,900	10	15	19	24
	Total	**2,938**	**0**	**46,071**	**26,391**	**0**	**49,965**	**28,933**	**30,297**	**N/A**	**-4.88%**	**4.5%**	**45,000**	**56,100**	**69,900**	**10**	**15**	**19**	**24**
Municipality Total		**20,004**	**589,979**	**1,115,232**	**1,392,860**	**633,569**	**1,209,494**	**1,526,999**	**1,599,000**	**5.60%**	**2.83%**	**4.5%**	**2,350,300**	**2,930,600**	**3,670,800**	**80**	**117**	**147**	**184**
Hathazari (proposed)																			
	Burir Char	383	N/A	11,458	12,860	N/A	12,426	14,098	14,098	N/A	1.27%	4.5%	21,000	26,100	32,500	37	55	68	85
	Chikandandi	1,117	N/A	27,323	29,844	N/A	29,632	32,718	32,718	N/A	1.00%	4.5%	48,600	60,600	75,500	29	44	54	68
	Dakshin Madrasha	978	N/A	13,841	16,722	N/A	15,011	18,332	18,332	N/A	2.02%	4.5%	27,200	33,900	42,300	19	28	35	43
	Shikarpur	689	N/A	11,502	14,405	N/A	12,474	15,792	15,792	N/A	2.39%	4.5%	23,500	29,200	36,400	23	34	42	53
	Total	**3,167**	**0**	**64,124**	**73,831**	**0**	**69,544**	**80,941**	**80,940**	**N/A**	**1.53%**	**4.5%**	**120,300**	**149,800**	**186,700**	**26**	**38**	**47**	**59**
Sitakunda (proposed)																			
	Bhatiari	1,942	N/A	14,388	18,590	N/A	15,604	20,380	20,380	N/A	2.71%	5.0%	31,600	40,400	51,500	10	16	21	27
	Salimpur	1,802	N/A	21,611	30,065	N/A	23,438	32,960	32,960	N/A	3.47%	5.0%	51,100	65,300	83,300	18	28	36	46
	Total	**3,744**	**0**	**35,999**	**48,655**	**0**	**39,042**	**53,341**	**53,340**	**N/A**	**3.17%**	**5.0%**	**82,700**	**105,700**	**134,800**	**14**	**22**	**28**	**36**
Proposed Total		**6,911**	**0**	**100,123**	**122,486**	**0**	**108,586**	**134,282**	**134,280**	**N/A**	**2.15%**	**4.7%**	**203,000**	**255,500**	**321,500**	**19**	**29**	**37**	**47**
Grand Total		**26,915**	**589,979**	**1,215,355**	**1,515,346**	**633,569**	**1,318,080**	**1,661,281**	**1,733,280**	**6.10%**	**2.78%**	**4.5%**	**2,553,300**	**3,186,100**	**3,992,300**	**64**	**95**	**118**	**148**

Note: *: Adjusted CENSUS Population = (Enumerated Population - Erroneously Enumerated) / (Completion Rate)

(Municipal)	1974	1981	1991
Rate of Errouneously Enumeration:	0.00%	1.20%	2.10%
Completion Rate:	93.12%	91.10%	89.30%

**: Municipal Ward Population Adjusted for Statistical Yearbook '97 = Adjusted CENSUS Population by Ward x (Yearbook Total Municipal Population / Total Adjusted CENSUS Population)
1599000

Following to Kotwali Thana, Double Mooring had 245 persons per hectare in 1991, which again is one of the oldest Thana of the city.

Besides these two Thanas, all other existing or proposed Thanas of City Corporation had population per hectare less than 100. The density of city population of 1991 (as per census 1991), projected population of 2000, projected population of 2005, and projected population of 2010 has been shown in Figures 3.1-1 to 3.1-4, respectively.

Our projection is based on certain assumptions. There was no doubt that the country experienced an economic stagnation during 1980s, which continued until the beginning of 1990 for variety of reasons. From the beginning of 1990s we saw a growth of GDP at a reasonable rates, such as they hovered around 5 % and that is likely to continue or increase further for both private as well as Government initiative. The situation of Chittagong is unique because any economic growth in the country is likely to have some impact upon this Port City, which handles almost 80% of the import and export of the country.

Chittagong City was way behind Dhaka in terms of industrial growth from the very beginning of the partition of India in 1947 and that continued until mid-eighties. The situation began to change with the establishment of garment factories and Export Processing Zone (EPZ). Since all these industries are export oriented, the owners preferred to have their installations close to the port for quick shipment of manufactured goods. At present, the total garment factories in City Corporation area are 499 and that number is likely to increase in the future. It may be noted that the overwhelming majority of workers of these industries are migrant young women who specifically come to city for this job. Different statistics show that Bangladesh has about 1.5 million garment workers who are primarily concentrated in Dhaka and Chittagong Cities. Therefore, garment factories alone had significantly contributed to population growth of Chittagong City.

Also, the Chittagong Metropolitan Area is likely to a have big thrust of population growth because a new EPZ, namely Korean Export Processing Zone (KEPZ) is being built on the left bank of the river Karnaphuli. This industrial estate is situated at a distance of 21 kilometer from the existing port. A total of 150,000 industrial workers are likely to get jobs in two phases of the project. There may be many more jobs to support this huge industrial population. Since industries are unlikely to built infrastructure to house these populations many possibly will use the city infrastructure and commute from the city.

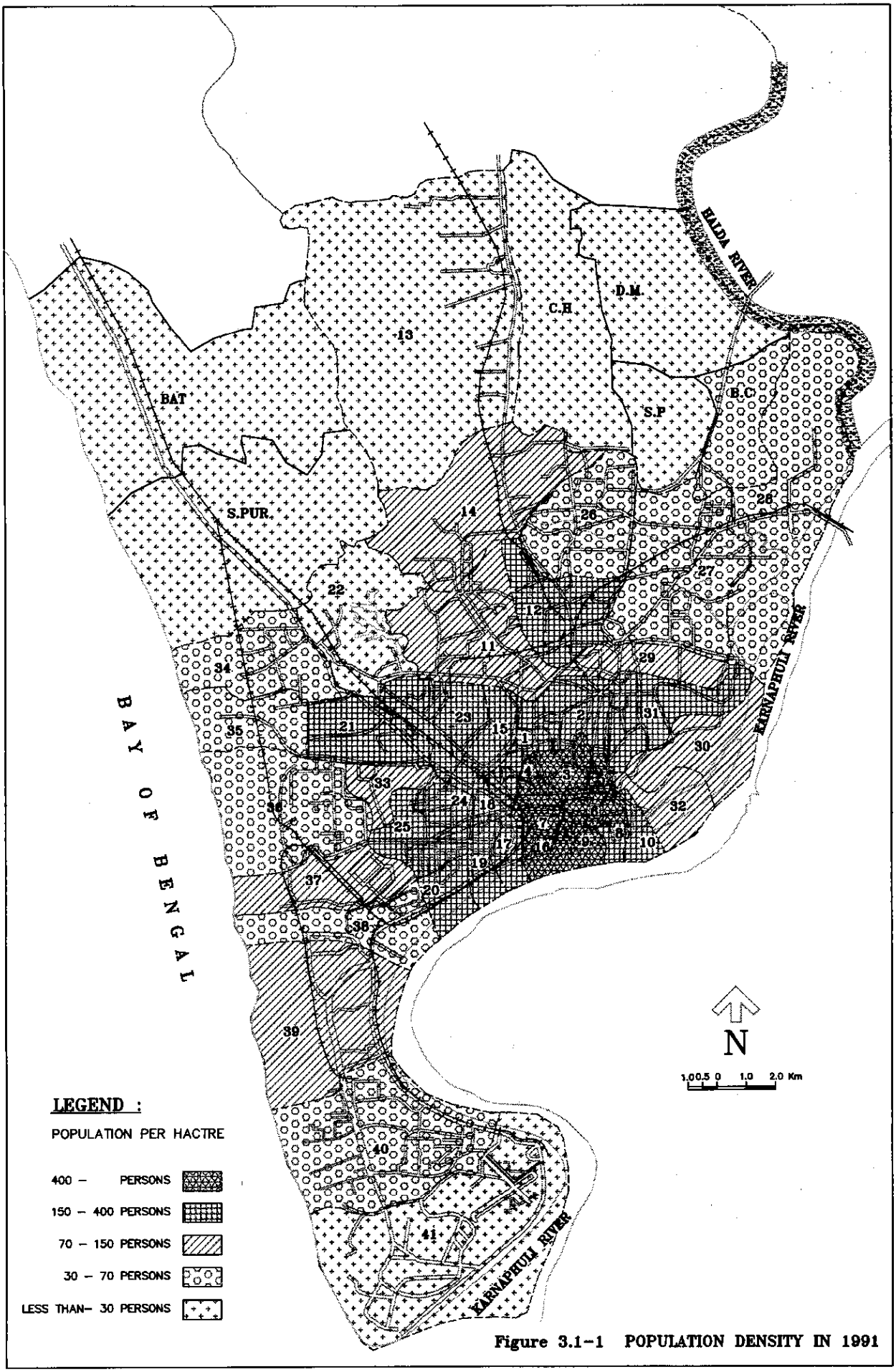

Figure 3.1-1 POPULATION DENSITY IN 1991

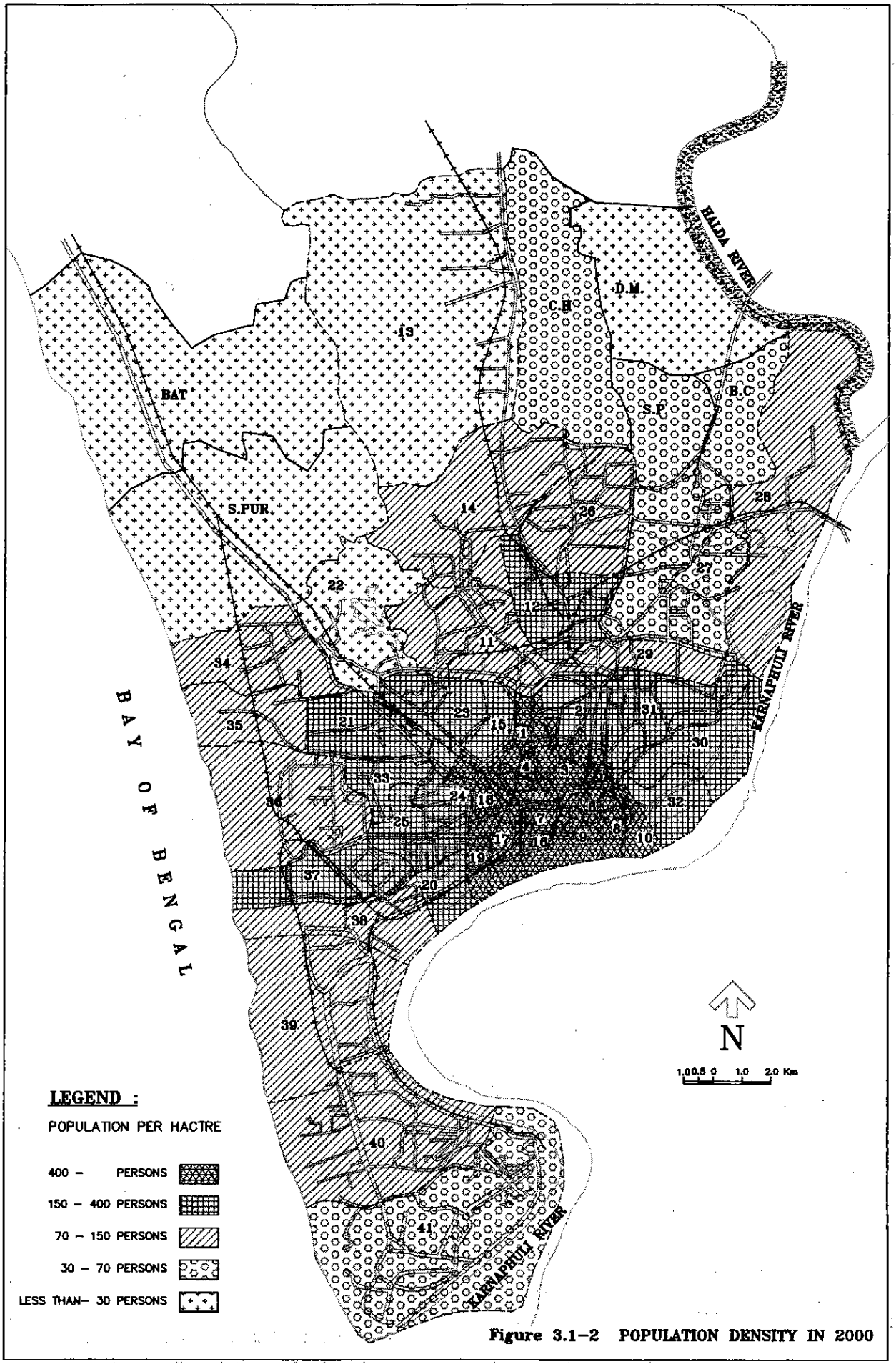

Figure 3.1-2 POPULATION DENSITY IN 2000

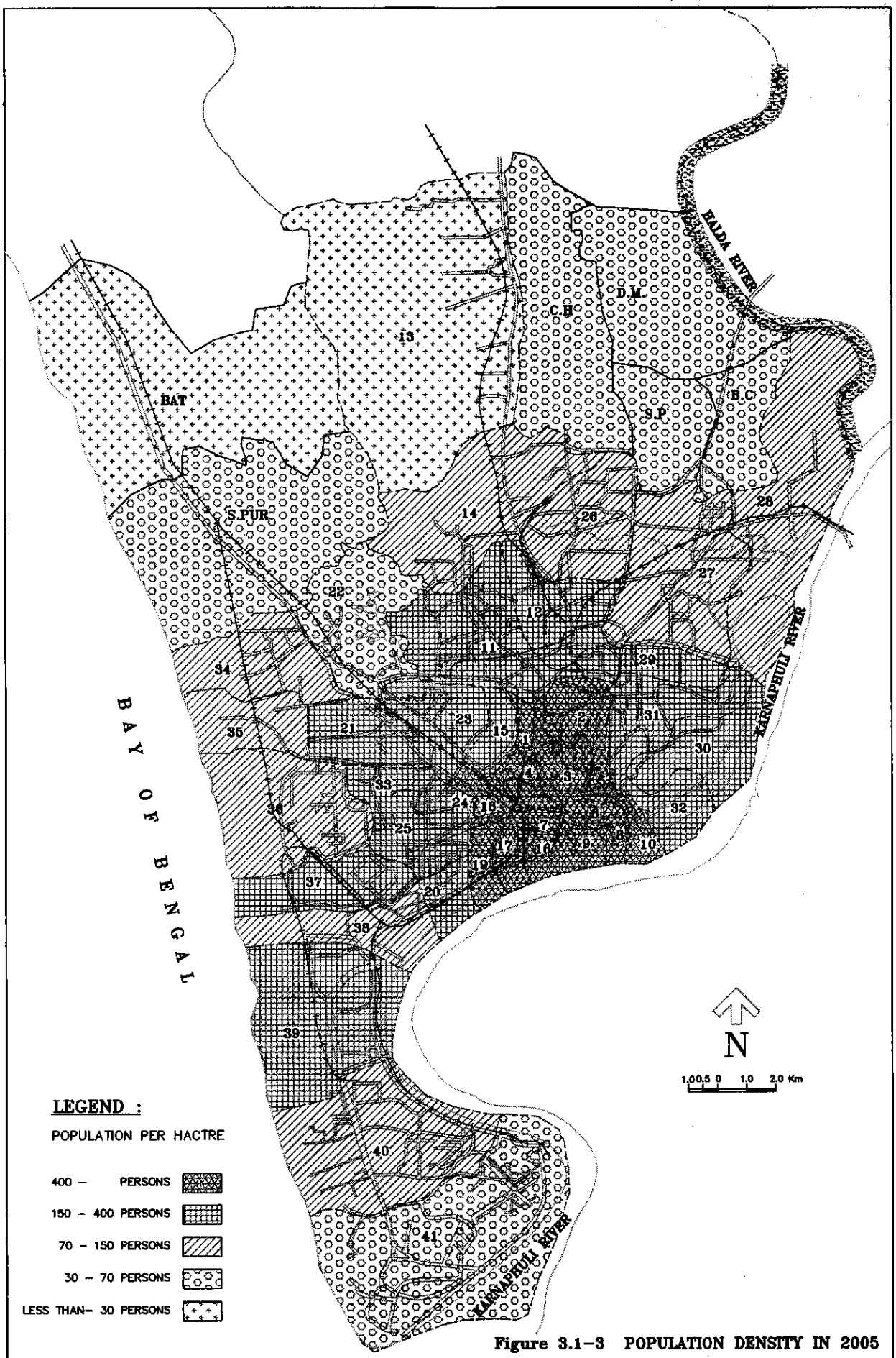

Figure 3.1-3 POPULATION DENSITY IN 2005

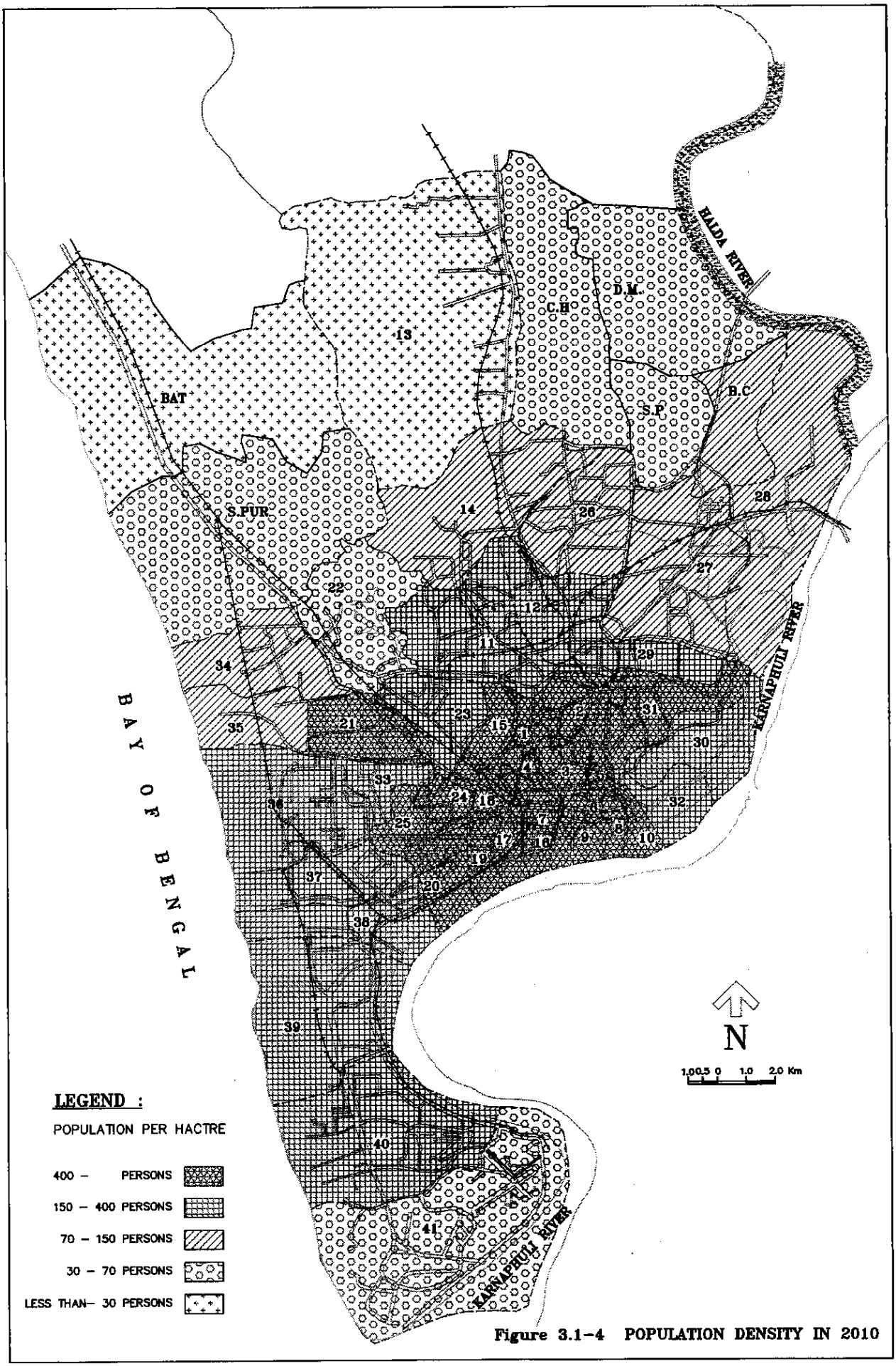

Figure 3.1-4 POPULATION DENSITY IN 2010

Rural poverty is another reason of population growth in urban areas as poor people migrate to urban areas in search of jobs. In 1980s, 85 % of the total population in the country were employed in agriculture but that number reduced to 59 % in 1992, which means the remaining population had to look for jobs in other sectors. Rahman (1996) points out that 40 % of the population in rural sectors is still living below poverty level. Therefore, migration from rural to urban is likely to intensify further with the growing poverty in rural sector. Again migrants usually chose the place where employment opportunity is the highest. From that point of view Dhaka and Chittagong attract most of the immigrants for having more industries than any other place. Since industrialization in Dhaka is reaching at a saturating point for lack of space and away from the port, Chittagong is likely to grow at a much faster rate resulting in accelerated population growth.

The rising numbers of high school and college graduates possibly will also contribute to population growth of the city. Although the proportion of these graduates to the total population of the country is not very significant their absolute number is quite substantial. The vast majority of these graduates normally migrate to urban centers in search of employment and business and the obvious choice of most of these graduates will be Chittagong and Dhaka because of availability of relatively greater numbers of jobs and business opportunities. Of course, Dhaka being the capital of the country will receive the major share of these educated young population compared to Chittagong but the latter is likely to receive the second highest number.

Traditionally the lower income Chittagonions used to go to Middle East for employment and that number had increased in many-folds during the last two decades due to serious shortage of workforce there. The remittance of expatriate workers being a major source of foreign currency for the country the Government actively encourages increasing this expatriate workforce as much as possible. The vast majority of these workforce were of rural origin but many of them are now keeping their families in town either by hiring or buying houses for giving better education of their children or providing higher standard of living for the family members or greater security to them. These deolocal families (families in which husband and wife live in two separate locations for occupational reasons) are already in substantial numbers in Chittagong City and that are likely to increase in future because more and more expatiate workers are likely to move their families to town for the above mentioned reasons. Another latent reason of movement of families in town could be the fear of the expatriate workers that they would not be able to adjust to rural environment on their return home after living too many years in modern metropolis (Most of these workers work in large metropolis). Therefore, we anticipate that a large number of families of expatriate workers of different parts of greater Chittagong District will continuously settle in the City Corporation area.

3.1.2 Projection of Population in 2005 and 2010

Considering all the above-mentioned factors we anticipate that the population of Chittagong City Corporation will be much higher than that of 2.78 % (Table 3.1-1) of the last decade (1981-1991). We project a population growth rate of 4.5 %, which should be considered very conservative because even during the period of economic recession of 1981-1991 the national urban growth rate was 4.67 % (BBS, 1994: xi). However, our projection may look quite inflated compared to the prediction of CDA, which was made in the year 1995. They have projected a growth rate of only 2.23 % (CDA, 1995: Table 5.2) for existing area of Chittagong City Corporation throughout 1991 to 2010, which is even lower than the population growth of 2.83 % (adjusted) of census period of 1981-1991. Therefore, we believe that our projection is more realistic than that of CDA ones.

The population growth rate of all Thanas of the city will not be same. Some areas of the city are old, some are new, and some are proposed to be included in the future plan. The old city areas have grown for long time and have virtually no space for further human habitation while relatively new areas will have more scope for population growth because of availability of empty lands. In addition to it we have calculated the population growth rates of the periods between 1974 to 1991 and 1981 to 1991 to make a realistic estimation of population growth rate. The two most important points that we have taken into consideration in making the differential population projection by wards are densities of population of respective ward and population growth trends of last two census periods.

Here on the bases of this Figure the population in 2000 is put at 1,910,000, which is quite a bit of disparity between the present probable population of 2,400,000. The reason is to be considered due to unforeseen rapid city development depending upon Export Processing Zone (EPZ), garment and other industries. In due consideration of the stated current population, potential urban development plan and the future land use plan, the population growth rate between 1991 to 2000 was estimated to be 4.5% based on do census population in 1991 and assuming the present population to be 2,350,000.

As a result of the study on the population forecast, population in the year 2005 and project target year of 2010 is estimated to be 3,186,000 and 3,992,000 respectively, as shown in Table 3.1-2.

3.2 Present Water Demand

3.2.1 Present Water Supply Condition

(1) General

The Chittagong Water Supply and Sewerage Authority (CWASA) was established in 1963 to be

responsible for the planning, implementation and operation of the water supply and sewerage system in the Chittagong Municipality. By the great effort of CWASA the water supply of the City has been improved. CWSA has currently two water treatment plants, one is Mohara Water Treatment Plant (MWTP) having a capacity of 90,000 m^3/day (20 MGD) and other is Kalurghat Iron Removal Plant (KWTP) having a capacity of 68,000 m^3/day (Old 10+ New 5 MGD, Total 15 MGD). And also he has initial and expanded city tube wells having a capacity of 32,000 m^3/day (7 MGD), and then total plant capacity is 192,000 m^3/day (42 MGD). However, total current production capacity is 162,000 m^3/day (35.7 MGD) due to power failure and deterioration of the facilities.

Population served water is presently 1,142,000, which are about 45 % out of total population in the Study Area. To cope with shortage water supply capacity, the water supply service is regulated to half day supply, by means of in day time or evening/night time supply, depending upon the characteristics of the service area. Resultant from this situation, the actual per capita consumption is quite limited.

(2) Definition of Water Production and Distribution

In CWASA, the words of "production and distribution" are usually used for internal managerial information. Produced clear water at the Mohara WTP is all distributed and then production flow is equal to distribution flow. Pumped water from the city tube wells in MOD II is also all distributed through the distribution pipe network, and then production flow is equal to distribution flow. While pumped water from the city tube wells for KIRP in MOD I is used a part of the water at filtration process itself for back washing. Therefore, there is some gape between production and distribution flow for which the gape is treated as "authority use" in the statistical record.

3.2.2 Study on Present Water Supply Situation

Present water supply situation in the Study Area is scrutinized and future water demand was then estimated for the water supply system planning.

The estimation method and major out come on these subjects are as follows:

(1) Fundamental Data Collected

Collected available data for estimation of the water consumption and Unaccounted-for Water are:

a) Yearly consumption list, classified to domestic, non-domestic and public hydrant

b) Consumption and amount of billing for December 1999

c) Daily water production and distribution for January 2000

These data are summarized as below:

Table 3.2-1 Summary of Collected Data Regarding Production and Distribution

Data Source	Domestic (m^3/d)	Non-Domestic (m^3/d)	Hydrant (m^3/d)	UFW (m^3/d)	Total Consump. (m^3/d)	Total Distribut. (m^3/d)
1) Yearly av. Consumption In 1999	68,900 (67.0 %)	21,500 (20.9 %)	12,400 (12.1 %)		102,800 (100 %)	
2) Consumption in December 1999	72,100 (67.1 %)	22,500 (21.0 %)	12,800 (11.9 %)		107,400 (100 %)	
3) Daily Water Distribution in January 2000						162,500 (35.7MGD)
Average Distribution Rate in January 2000 got from the above data (prepared by the Study Team)	70,500 (43.3 %)	22,000 (13.5 %)	12,600 (7.8 %)	57,400 (**35.4 %**)		162,500 (100 %)

From the above table, the following is observed:

- Total water consumption is 105,000 m^3/day (23.1 MGD) in average.
- Share of average water consumption is 67 %, 21 % and 12 % for domestic, non-domestic and hydrant, respectively, and
- Unaccounted-for water (UFW); (distribution) – (consumption), is 57,400 m^3/day or 35.4 % out of the total distribution volume including leakage.

(2) Study on Present Water Supply Condition

Assuming to physical leakage at 13 % out of the distribution, unit consumption for house connection, public hydrant and other usage rate are estimated in order to overview the present water supply conditions.

1) Water supply volume

Assuming that number of house connection and public hydrant are 32,000 units and 900 units in function respectively, and some factors underlined below, the present water supply volume is supposed as follows:

a) House connection: 32,000 units x 25 ps/unit x @ 85 lpcd = 68,000 m^3/day

b) Hydrant: 900 units x 4,000 gallon/unit/d (= 18.2 m^3/unit.d) = 16,400 m^3/day

[Actual consumption was 12,400 / 12,800m^3/day in Table 3.2-1]

c) Commercial: (a + b) x 9 % = 7,600 m^3/day [Assumed at 18 % in CWASA III]

d) Institution: (a + b) x 1.3 % = 1,100 m^3/day

[Actual consumption was 1,080 m^3/day in Dec. 1999]

e) Industrial: (a + b) x 14 % = 11,800 m^3/day

[Actual consumption was 9,800 m^3/day in Dec.1999, and assumed at 5,8000 m^3/day in CWASA III]

Sub-total 104,900 m^3/day

f) UFW: 35.5 % of total distribution 57,600 m^3/day

Total 162,500 m^3/day (35.7 MGD) (Distribution as of 3, January 2000)

2) Confirmation of the above assumption

In order to confirm the propriety of the above assumption against actual water supply conditions, the following items are discussed for reference.

a) Population served water:

- House connection: 32,000 units x 25 ps/unit = 800,000 persons
- Public hydrant: 900 units x 380 ps/unit = 342,000 persons

Total population served water 1,142,000 persons

b) Coverage ratio: (Population served water) / (Population in the Study Area)

1,142,000 ÷ 2,550,000 = 44.7 %

c) Unit consumption:

- Hose connection: (68,000 m^3/d + 8,700 m^3/d) ÷ 800,000 ps = 95.9 lpcd
- Public hydrant: 16,400 ÷ 342,000 ps = 48.0 lpcd

Assuming that a third of 500,000 persons of floating people and day-time worker, who came to the city as to obtain the job from the surround, also use the hydrants, the above unit consumption rate is 32.2 lpcd (= 16,400 / (342,000 + 167,000)).

3.3 Water Demand Projection in Target Years

3.3.1 Water Demand Projection in 2005 (refer to Table 3.3-7)

(1) Fundamentals for Projection

1) Population:

Priority project selected from the projects in the Basic Plan (F/S project) is expected to be completed by 2005. Population projection in the Study Area in 2005 is estimated to be 3,186,000.

2) Assumed share of housing type:

The following is the present and projected share of housing types in 2005.

Table 3.3-1 Share of Housing Type in 2005

Type of Housing	Population Census 1991*[1]	Assumed by the Study Team for 2005*[2]		
		Municipality	Outside	Project Area Total
Pucca	31 %	44 %	16 %	42 %
Semi-Pucca	34 %	27 %	47 %	28 %
Kutcha	35 %	29 %	37 %	30 %

*1: Chittagong Metropolitan Master Plan (Structure Plan; 1995)
*2: Average ratio by category. Actual assumption was made for each ward / union.

3) Target of water supply level:

The followings are water supply levels at present and in target year 2005.

Table 3.3-2 Target Water Supply Level in 2005

Type of Supply	2000			2005		
	Pucca	Semi	Kutcha	Pucca	Semi	Kutcha
House Connection	70.0 % *[1]			70 %	30 %	15 %
Public Hydrant	30.0 % *[2]			10 %	30 %	20 %

*1: House connection: 800,000 ps ÷ 1,142,000 ps = 70.0 %
*2: Public hydrant: 342,000 ps ÷ 1,142,000 ps = 30.0 %

(2) Domestic Water Demand by Type of Water Supply System

Seventy percent (70 %) of the inhabitants living in Pucca houses will demand a house connection as well as 30 % of the inhabitants living in Semi-pucca houses and 15 % inhabitants living in Kutcha. While the remaining inhabitants of Pucca and Semi-pucca houses will rely on public hydrant supply as well as 20 % of the people living in Kutcha houses. The remaining inhabitants will use the public hydrants, private tube wells or shallow wells. Thereby, water demand is summed up using assumed unit water consumption per capita per day as follows:

- H C: (Pucca 0.42 x 70 %) + (Semi-pucca 0.28 x 30%) + (Kutcha 0.30 x 15 %)
  = 3.186 Million ps x 42.3 % = 1.34 million ps
  1.34 million ps x @ 120 lpcd = 160 thousand m^3/day
- Hydrant: (Pucca 0.42 x 10 %) + (Semi- pucca 0.28 x 30 %) + (Kutcha 0.30 % x 20 %)
  = 3.186 Million ps x 18.6 % = 0.59 million ps
  0.59 million ps x @ 50 lpcd = 30 thousand m^3/day

(3) Water Demand for Commercial, Institutional and Industrial Use

Present water distribution for commercial use is about 9 % of domestic water distribution. Taking account of increase of commercial activities in the future with sufficient water supply after project, commercial water demand in 2005 was projected to be 10 % of domestic water demand.

Institutional water demand in 2005 was projected at same percentage of present institutional water use against total of domestic and commercial water use.

Owing to development of industries of EPZ and other industrial areas, water demand for industrial use has been remarkably increased. They are using water not only from CWASA but also private wells. However, because of water shortage of CWASA water and deteriorated water quality of private wells, there are strong request for sufficient and good quality water supply by CWASA. Table 3.3-3 shows the present water supply volume and additional water demand requested by the industries.

Table 3.3-3 Potential Water Demand for Industrial Use (2000)

	Present Water Supply	Additional Requirement Requested by Industries	Potential Water Demand for Industrial Use
1) EPZ 2) Others 3) Shipping	1.0 MGD 0.8 MGD 0.2 – 1.6 MGD (Depend on shipping)	2.5 MGD 1.3 MGD 1.0 MGD	3.5 MGD 2.1 MGD 1.2 – 2.6 MGD
Total	2.0 – 3.4 MGD (9,100 – 15,500 m^3/d)	4.8 MGD (21,800 m^3/d)	6.8 – 8.2 MGD (30,900 – 37,300 m^3/d)

As shown in the above table, potential industrial use water demand is estimated at about 36,000 m^3/day at present. If restriction in water supply status is solved completely in 2005, it may be assumed that the industrial use water demand will be further increased. Assuming the annual increase rate of said potential water demand will be at 5%, potential industrial use water demand in entire project area in 2005 will be about 10 MGD or 45,500 m^3/day.

Unaccounted-for water (UFW) and leakage are assumed to be improved from 34.5 % at present to 25 % in 2005 after completion of the F/S project, based on CWASA's plan.

(4) Planned Water Supply Flow

The planned water supply condition and the breakdown of the consumption in each category are shown in Table 3.3-6 in succeeding sub-section. Entire water demand to be served in the project area in 2005 is summed up to 344,000 m^3/day (75.7 MGD). However, a total of existing and planned plant capacity including Mohara WTP expansion project and Madunaghat WTP new construction project is 282,000 m^3/day (62 MGD) in 2005. Consequently, the planned water supply flow and the water demand for this project is adjusted or restricted so as to meet the said total plant

capacity. The adjustment ratio is about 82 %. (Refer to Table 3.3-7 in detail.)

(5) Service Ratio

Planned water service population after completion of the phase 1 project in 2005 will be about 1,580,000 or 50 % against population in whole project area.

3.3.2 Water Demand Projection in 2010 (refer to Table 3.3-8)

(1) Fundamentals for Projection

1) Population:

Population projection in the Study Area in 2010 is estimated to be 3,992,000.

2) Assumed share of housing type:

The following is the present and projected share of housing types in 2010.

Table 3.3-4 Share of Housing Type in 2010

Type of Housing	Population Census 1991*[1]	Assumed by the Study Team for 2010*[2]		
		Municipality	Outside	Project Area Total
Pucca	31 %	50 %	18 %	47 %
Semi-Pucca	34 %	25 %	48 %	27 %
Kutcha	35 %	25 %	34 %	26 %

*1: Chittagong Metropolitan Master Plan (Structure Plan; 1995)
*2: Average ratio by category. Actual assumption was made for each ward / union.

3) Target of water supply level

The following is the present and target of water supply level in 2010.

Table 3.3-5 Target of Water Supply Level in 2010

Type of Supply	2000			2010		
	Pucca	Semi-	Kutcha	Pucca	Semi-	Kutcha
House Connection	70.0 % *1			95 %	50 %	20 %
Public Hydrant	30.0 % *2			5 %	50 %	20 %

*1: House connection: 800,000 ps ÷ 1,142,000 ps = 70.0 %
*2: Public hydrant: 342,000 ps ÷ 1,142,000 ps = 30.0 %

(2) Domestic Water Demand by Type of Water Supply System

Ninety five percent (95 %) of inhabitants living in Pucca houses will demand a house connection as

well as 50 % of the inhabitants living in Semi-pucca houses and 20 % of inhabitants living in Kutcha. While the remaining inhabitants of Pucca and Semi-pucca houses will rely on hydrant supply as well as 20 % of the population living in Kutcha houses. The remaining other inhabitants will use the hydrants, private tube wells or shallow wells. Thereby, water demand is summed up as follows.

- H.C: (Pucca 0.47 x 95 %) + (Semi- pucca 0.27 x 50 %) + (Kutcha 0.26 x 20 %)
  = 3.99 Million ps x 63.35 % = 2.53 Million
  2.53 Million ps x @ 130 lpcd = 329 thousand m^3/day
- Hyd't: (Pucca 0.47 x 5 %) + (Semi- pucca 0.27 x 50 %) + (Kutcha 0.26 x 20 %)
  = 3.99 Million ps x 21.05 % = 0.84 Million
  0.84 Million ps x @ 50 lpcd = 42 thousand m^3/day

(3) Water Demand for Commercial, Institutional and Industrial Use

As same as the projection for year 2005, commercial water demand in 2010 was projected at 10 % of domestic water demand.

Institutional water demand in 2010 was also projected at same percentage of present institutional water use against total of domestic and commercial water use. Water demand of 3 MGD, however, for the Chittagong University and the Cantonment was added as institution water demand.

Industrial water demand in 2010 was projected at almost same percentage as the one in 2005 against total of domestic and commercial water demand.

Unaccounted-for water (UFW) and leakage are assumed to be improved from 34.5 % at present to 22 % after completion of the project.

(4) Planned Water Supply Flow

The planned water supply condition and the breakdown of the consumption in each category are summarized in Table 3.3-6. Entire water demand to be served in the project area in 2010 is summed up to about 649,000 m^3/day (143 MGD). This water demand will be fulfilled by provision of new water treatment plant as required.

(5) Service Ratio

Planned water service population in 2010 after completion of the Phase 2 project of B/P will be about

3,270,000 or 84 % against population in whole project area.

3.3.3 Comparison of Water Supply Condition between Present and Target Year

The water demand and supply conditions at present, in 2005 and in 2010 are summarized as shown in Table 3.3-6.

Tables 3.3-7 and 3.3-8 present projected water demand by ward / union in the years 2005 and 2010, respectively. The figures in the table are calculated based on the projected population and aforementioned conditions relating to water supply level and unit water consumption.

Table 3.3-6 Water Supply Conditions at Present and Target Years

	2000	2005	2010
1.Population in Study Area (ps)	2,553,000	3,190,000	3,990,000
2.Projected Population to be served Water (ps)	-	1,940,000	3,370,000
3.Water Demand for above (m^3/day)	-	344,000	649,000
4.Planned Population with Water Supply Service (ps)	1,142,000	1,580,000	3,370,000
[Adjustment ratio]*	-	[82 %]	[100 %]
5.Coverage Ratio (%)	44.7	50	84
6.Distribution (m^3/day)	162,500	281,000	649,000
(**MGD**)	**35.7**	**62**	**143**
1) House Connection	68,000	134,000	329,000
2) Hydrant	16,400	23,000	42,000
3) Commercial	7,600	16,000	37,000
4) Institutional	1,100	2,000	18,000
5) Industrial	11,800	36,000	80,000
6) UFW / Leakage	57,600	70,000	143,000
	(35.4 %)	(25 %)	(22 %)
	(incl. UFW)		
	142 lpcd	178 lpcd	193 lpcd
Condition	*Present*	*F/S Plan*	*Basic Plan*

Note: Population is on the Census level and not includes floating people.
*: Ratio to adjust actual water demand against capacity of water sources.
(Planned population with service / Project population to be served)

Table 3.3-7 Projection of Water Demand by Ward and Union (2005)

Ward No.	Name of Ward	1991				2005																															
		Population	Type of Housing			Adopted Increase Rate	Population	Type of Housing						Service Target Population								Service Target Water Demand								System Service Coverage							
			Pucca (%)	Semi (%)	Kutcha (%)			Pucca (%)	Pucca Population	Semi-Pucca (%)	Semi-Pucca Population	Kutcha (%)	Kutcha Population	House Connection				Hydrant				House Con. (m^3/day)	Hydrant (m^3/day)	Commertial (%)	Commertial (m^3/day)	Institutional (%)	Institutional (m^3/day)	Industrial (%)	Industrial (m^3/day)	Leakage (m^3/day)	Total (m^3/day)	Ratio (%)	Demand (m^3/day)	Population			Service Ratio
														Pucca	Semi-Pucca	Kutcha	Total	Pucca	Semi-Pucca	Kutcha	Total											H.C.	Hydrant	Total	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Kotwali Thana																																					
1	Bogmoniram	30,862	47%	35%	18%	4.0%	53,400	58%	31,000	24%	12,800	18%	9,600	21,700	3,800	1,400	26,900	3,100	3,800	1,900	8,800	3,238	443		714		93		0	1,496	5,984	100%	5,984	26,900	8,800	35,700	67%
2	Chawk Bazar	38,364	47%	35%	18%	3.5%	62,100	58%	36,000	24%	14,900	18%	11,200	25,200	4,500	1,700	31,400	3,600	4,500	2,200	10,300	3,762	516		830		108		0	1,739	6,955	100%	6,955	31,400	10,300	41,700	67%
3	Jamal Khan	39,004	47%	35%	18%	1.5%	48,000	58%	27,800	24%	11,500	18%	8,700	19,500	3,500	1,300	24,300	2,800	3,500	1,700	8,000	2,906	399		641		83		0	1,343	5,372	100%	5,372	24,300	8,000	32,300	67%
4	Enayet Bazar	28,881	47%	35%	18%	2.5%	40,800	58%	23,700	24%	9,800	18%	7,300	16,600	2,900	1,100	20,600	2,400	2,900	1,500	6,800	2,475	339		546		71		0	1,144	4,575	100%	4,575	20,600	6,800	27,400	67%
5	Dewan Bazar	32,244	47%	35%	18%	0.0%	32,200	58%	18,700	24%	7,700	18%	5,800	13,100	2,300	900	16,300	1,900	2,300	1,200	5,400	1,952	267		430		56		0	902	3,607	100%	3,607	16,300	5,400	21,700	67%
6	Anderkilla	20,291	47%	35%	18%	0.0%	20,300	58%	11,800	24%	4,900	18%	3,600	8,300	1,500	500	10,300	1,200	1,500	700	3,400	1,232	169		272		35		0	569	2,277	100%	2,277	10,300	3,400	13,700	67%
7	Alkaran	28,261	47%	35%	18%	3.0%	42,700	58%	24,800	24%	10,200	18%	7,700	17,400	3,100	1,200	21,700	2,500	3,100	1,500	7,100	2,589	354		571		74		0	1,196	4,784	100%	4,784	21,700	7,100	28,800	67%
8	Patherghata	30,055	47%	35%	18%	3.0%	45,500	58%	26,400	24%	10,900	18%	8,200	18,500	3,300	1,200	23,000	2,600	3,300	1,600	7,500	2,758	378		608		79		0	1,274	5,097	100%	5,097	23,000	7,500	30,500	67%
9	Fringi Bazar	22,191	47%	35%	18%	2.0%	29,300	58%	17,000	24%	7,000	18%	5,300	11,900	2,100	800	14,800	1,700	2,100	1,100	4,900	1,775	243		391		51		0	820	3,280	100%	3,280	14,800	4,900	19,700	67%
10	Boxirhat	13,280	47%	35%	18%	5.0%	26,300	58%	15,300	24%	6,300	18%	4,700	10,700	1,900	700	13,300	1,500	1,900	900	4,300	1,597	218		352		46		0	738	2,951	100%	2,951	13,300	4,300	17,600	67%
	Total	**283,433**	**47%**	**35%**	**18%**	**2.6%**	**400,600**	**58%**	**232,500**	**24%**	**96,000**	**18%**	**72,100**	**162,900**	**28,900**	**10,800**	**202,600**	**23,300**	**28,900**	**14,300**	**66,500**	**24,284**	**3,326**	**30%**	**5,355**	**30%**	**696**	**0%**	**0**	**11,221**	**44,882**	**100%**	**44,882**	**202,600**	**66,500**	**269,100**	**67%**
Double Mooring Thana																																					
15	Lalkhan Bazar	49,691	32%	31%	37%	4.0%	86,000	45%	38,700	25%	21,500	30%	25,800	27,100	6,500	3,900	37,500	3,900	6,500	5,200	15,600	4,489	774		805		90		0	2,053	8,211	100%	8,211	37,500	15,600	53,100	62%
16	East Madarbari	35,086	32%	31%	37%	2.0%	46,300	45%	20,800	25%	11,600	30%	13,900	14,600	3,500	2,100	20,200	2,100	3,500	2,800	8,400	2,415	417		433		48		0	1,104	4,417	100%	4,417	20,200	8,400	28,600	62%
17	West Madarbari	42,995	32%	31%	37%	3.0%	65,000	45%	29,300	25%	16,300	30%	19,400	20,500	4,900	2,900	28,300	2,900	4,900	3,900	11,700	3,397	585		609		68		0	1,553	6,212	100%	6,212	28,300	11,700	40,000	62%
18	Uttar Pathantoly	30,423	32%	31%	37%	5.0%	60,200	45%	27,100	25%	15,100	30%	18,000	19,000	4,500	2,700	26,200	2,700	4,500	3,600	10,800	3,144	542		564		63		0	1,438	5,751	100%	5,751	26,200	10,800	37,000	61%
19	Pathantoly	38,595	32%	31%	37%	6.0%	87,300	45%	39,300	25%	21,800	30%	26,200	27,500	6,500	3,900	37,900	3,900	6,500	5,200	15,600	4,558	786		817		91		0	2,084	8,336	100%	8,336	37,900	15,600	53,500	61%
20	Gosail Danga	22,752	32%	31%	37%	4.5%	42,100	45%	18,900	25%	10,500	30%	12,700	13,200	3,200	1,900	18,300	1,900	3,200	2,500	7,600	2,194	379		394		44		0	1,004	4,015	100%	4,015	18,300	7,600	25,900	62%
24	Uttar Agrabad	40,174	32%	31%	37%	4.5%	74,400	45%	33,500	25%	18,600	30%	22,300	23,500	5,600	3,300	32,400	3,400	5,600	4,500	13,500	3,885	670		697		78		0	1,777	7,107	100%	7,107	32,400	13,500	45,900	62%
25	D. Agrabad	81,749	32%	31%	37%	4.5%	151,400	45%	68,100	25%	37,900	30%	45,400	47,700	11,400	6,800	65,900	6,800	11,400	9,100	27,300	7,902	1,363		1,417		158		0	3,613	14,453	100%	14,453	65,900	27,300	93,200	62%
33	Rampur	25,831	32%	31%	37%	5.5%	54,700	45%	24,600	25%	13,700	30%	16,400	17,200	4,100	2,500	23,800	2,500	4,100	3,300	9,900	2,855	493		512		57		0	1,306	5,223	100%	5,223	23,800	9,900	33,700	62%
	Total	**367,296**	**32%**	**31%**	**37%**	**4.4%**	**667,400**	**45%**	**300,300**	**25%**	**167,000**	**30%**	**200,100**	**210,300**	**50,200**	**30,000**	**290,500**	**30,100**	**50,200**	**40,100**	**120,400**	**34,839**	**6,009**	**35%**	**6,247**	**30%**	**696**	**0%**	**0**	**15,932**	**63,725**	**100%**	**63,725**	**290,500**	**120,400**	**410,900**	**62%**
Panchlaish Thana																																					
11	Sulak Bohar	85,106	27%	30%	43%	4.0%	147,400	40%	59,000	25%	36,900	35%	51,500	41,300	11,100	7,700	60,100	5,900	11,100	10,300	27,300	7,211	1,364		706		92		2,588	3,987	15,948	100%	15,948	60,100	27,300	87,400	59%
12	West Sholoshahar	53,080	27%	30%	43%	3.0%	80,300	40%	32,100	25%	20,100	35%	28,100	22,500	6,000	4,200	32,700	3,200	6,000	5,600	14,800	3,926	743		384		50		1,409	2,171	8,683	100%	8,683	32,700	14,800	47,500	59%
14	Jalalabad	45,732	27%	30%	43%	4.0%	79,200	40%	31,700	25%	19,800	35%	27,700	22,200	5,900	4,200	32,300	3,200	5,900	5,500	14,600	3,874	733		379		49		1,391	2,142	8,568	70%	5,998	22,610	10,220	32,830	41%
26	Panchlaish	38,056	27%	30%	43%	4.0%	65,900	40%	26,400	25%	16,500	35%	23,000	18,500	5,000	3,500	27,000	2,600	5,000	4,600	12,200	3,226	610		316		41		1,158	1,784	7,135	70%	4,995	18,900	8,540	27,440	42%
98	Chittagong Cantonment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-		-		-	-	-	-	-	-	-	-	-
	Total	**221,974**	**27%**	**30%**	**43%**	**3.8%**	**372,800**	**40%**	**149,200**	**25%**	**93,300**	**35%**	**130,300**	**104,500**	**28,000**	**19,600**	**152,100**	**14,900**	**28,000**	**26,000**	**68,900**	**18,237**	**3,450**	**10%**	**1,785**	**10%**	**232**	**15%**	**6,546**	**10,084**	**40,334**	**88%**	**35,623**	**134,310**	**60,860**	**195,170**	**52%**
Pahartali Thana																																					
21	Saripara	53,428	29%	30%	41%	4.0%	92,500	42%	38,900	24%	22,200	34%	31,400	27,200	6,700	4,700	38,600	3,900	6,700	6,300	16,900	4,632	842		220		29		1,344	2,356	9,423	100%	9,423	38,600	16,900	55,500	60%
22	North Pahartali	43,859	29%	30%	41%	6.0%	99,200	42%	41,700	24%	23,800	34%	33,700	29,200	7,100	5,100	41,400	4,200	7,100	6,700	18,000	4,966	903		236		31		1,441	2,526	10,103	70%	7,072	28,980	12,600	41,580	42%
23	Pahartali	50,007	29%	30%	41%	4.0%	86,600	42%	36,400	24%	20,800	34%	29,400	25,500	6,200	4,400	36,100	3,600	6,200	5,900	15,700	4,336	788		206		27		1,258	2,205	8,820	100%	8,820	36,100	15,700	51,800	60%
34	Uttar Kattali	23,769	29%	30%	41%	5.5%	50,300	42%	21,100	24%	12,100	34%	17,100	14,800	3,600	2,600	21,000	2,100	3,600	3,400	9,100	2,516	458		119		16		730	1,280	5,119	80%	4,095	16,800	7,280	24,080	48%
35	Dakhin Kattali	26,008	29%	30%	41%	5.0%	51,500	42%	21,600	24%	12,400	34%	17,500	15,100	3,700	2,600	21,400	2,200	3,700	3,500	9,400	2,576	469		122		16		747	1,310	5,240	80%	4,192	17,120	7,520	24,640	48%
36	Uttar Halishahar	31,259	29%	30%	41%	6.0%	70,700	42%	29,700	24%	17,000	34%	24,000	20,800	5,100	3,600	29,500	3,000	5,100	4,800	12,900	3,539	644		168		22		1,027	1,800	7,200	80%	5,760	23,600	10,320	33,920	48%
	Total	**228,330**	**29%**	**30%**	**41%**	**5.0%**	**450,800**	**42%**	**189,400**	**24%**	**108,300**	**34%**	**153,100**	**132,600**	**32,400**	**23,000**	**188,000**	**19,000**	**32,400**	**30,600**	**82,000**	**22,565**	**4,104**	**6%**	**1,071**	**6%**	**139**	**15%**	**6,546**	**11,477**	**45,905**	**86%**	**39,362**	**161,200**	**70,320**	**231,520**	**51%**
Chand Gaow Thana																																					
27	Chandgaon	50,195	22%	38%	40%	3.0%	75,900	34%	25,800	33%	25,000	33%	25,100	18,100	7,500	3,800	29,400	2,600	7,500	5,000	15,100	3,519	755		164		21		804	1,754	7,017	70%	4,912	20,580	10,570	31,150	41%
28	Mohara	54,058	22%	38%	40%	4.5%	100,100	34%	34,000	33%	33,000	33%	33,100	23,800	9,900	5,000	38,700	3,400	9,900	6,600	19,900	4,640	996		217		28		1,060	2,314	9,255	70%	6,479	27,090	13,930	41,020	41%
29	Purba Sholoshahar	18,058	22%	38%	40%	4.5%	33,400	34%	11,400	33%	11,000	33%	11,000	8,000	3,300	1,700	13,000	1,100	3,300	2,200	6,600	1,552	332		72		9		354	773	3,092	100%	3,092	13,000	6,600	19,600	59%
30	Purba Bakulia	29,540	22%	38%	40%	6.5%	71,300	34%	24,200	33%	23,500	33%	23,600	16,900	7,100	3,500	27,500	2,400	7,100	4,700	14,200	3,304	710		154		20		755	1,648	6,591	70%	4,614	19,250	9,940	29,190	41%
31	Paschim Bakulia	46,262	22%	38%	40%	5.0%	91,600	34%	31,100	33%	30,200	33%	30,300	21,800	9,100	4,500	35,400	3,100	9,100	6,100	18,300	4,245	912		198		26		970	2,117	8,468	80%	6,774	28,320	14,640	42,960	47%
32	D. Bakulia	54,034	22%	38%	40%	6.0%	122,200	34%	41,500	33%	40,300	33%	40,400	29,100	12,100	6,100	47,300	4,200	12,100	8,100	24,400	5,664	1,216		265		34		1,294	2,824	11,297	70%	7,908	33,110	17,080	50,190	41%
	Total	**252,147**	**22%**	**38%**	**40%**	**5.0%**	**494,500**	**34%**	**168,000**	**33%**	**163,000**	**33%**	**163,500**	**117,700**	**49,000**	**24,600**	**191,300**	**16,800**	**49,000**	**32,700**	**98,500**	**22,924**	**4,921**	**6%**	**1,071**	**6%**	**139**	**12%**	**5,237**	**11,430**	**45,720**	**74%**	**33,778**	**141,350**	**72,760**	**214,110**	**43%**
Chittagong Port Thana																																					
37	U.P. Halishahar	37,053	35%	39%	26%	6.5%	89,500	48%	43,000	30%	26,900	22%	19,600	30,100	8,100	2,900	41,100	4,300	8,100	3,900	16,300	4,933	815		327		64		4,641	3,593	14,373	80%	11,498	32,880	13,040	45,920	51%
38	D.P. Halishahar	41,351	35%	39%	26%	5.0%	81,900	48%	39,300	30%	24,600	22%	18,000	27,500	7,400	2,700	37,600	3,900	7,400	3,600	14,900	4,511	746		299		58		4,245	3,286	13,145	80%	10,516	30,080	11,920	42,000	51%
39	D. Halishahar	53,579	35%	39%	26%	6.0%	121,100	48%	58,100	30%	36,300	22%	26,700	40,700	10,900	4,000	55,600	5,800	10,900	5,300	22,000	6,668	1,102		442		86		6,274	4,857	19,429	100%	19,429	55,600	22,000	77,600	64%
40	U. Patenga	45,722	35%	39%	26%	6.5%	110,400	48%	53,000	30%	33,100	22%	24,300	37,100	9,900	3,600	50,600	5,300	9,900	4,900	20,100	6,081	1,005		403		79		5,722	4,430	17,720	80%	14,176	40,480	16,080	56,560	51%
41	D. Patenga	37,818	35%	39%	26%	6.0%	85,500	48%	41,000	30%	25,700	22%	18,800	28,700	7,700	2,800	39,200	4,100	7,700	3,800	15,600	4,708	779		312		61		4,430	3,430	13,720	50%	6,860	19,600	7,800	27,400	32%
	Total	**215,523**	**35%**	**39%**	**26%**	**6.0%**	**488,400**	**48%**	**234,400**	**30%**	**146,600**	**22%**	**107,400**	**164,100**	**44,000**	**16,000**	**224,100**	**23,400**	**44,000**	**21,500**	**88,900**	**26,901**	**4,447**	**10%**	**1,785**	**15%**	**348**	**58%**	**25,312**	**19,596**	**78,387**	**80%**	**62,479**	**178,640**	**70,840**	**249,480**	**51%**
Hathazari Thana																																					
13	J.D. Pahartali	30,297	9%	24%	67%	4.5%	56,100	18%	10,100	23%	12,900	59%	33,100	7,100	3,900	5,000	16,000	1,000	3,900	6,600	11,500	1,909	575		535		70		0	1,030	4,119	0%	0	0	0	0	0%
	Total	**30,297**	**9%**	**24%**	**67%**	**4.5%**	**56,100**	**18%**	**10,100**	**23%**	**12,900**	**59%**	**33,100**	**7,100**	**3,900**	**5,000**	**16,000**	**1,000**	**3,900**	**6,600**	**11,500**	**1,909**	**575**	**3%**	**535**	**3%**	**70**	**0%**	**0**	**1,030**	**4,119**	**0%**	**0**	**0**	**0**	**0**	**0%**
Municipality Total		**1,599,000**	**32%**	**33%**	**35%**	**4.5%**	**2,930,600**	**44%**	**1,283,900**	**27%**	**787,100**	**29%**	**859,600**	**899,200**	**236,400**	**129,000**	**1,264,600**	**128,500**	**236,400**	**171,800**	**536,700**	**151,659**	**26,832**	100%	**17,849**	100%	**2,320**	100%	**43,641**	**80,770**	**323,072**	**87%**	**279,850**	**1,108,600**	**461,680**	**1,570,280**	**54%**
Hathazari (proposed)																																					
	Burir Char	14,098	13%	51%	36%	4.5%	26,100	18%	4,700	50%	13,100	32%	8,300	3,300	3,900	1,200	8,400	500	3,900	1,700	6,100	1,016	303		132		17		198	555	2,221	0%	0	0	0	0	0%
	Chikandandi	32,718	13%	51%	36%	4.5%	60,600	18%	10,900	50%	30,300	32%	19,400	7,600	9,100	2,900	19,600	1,100	9,100	3,900	14,100	2,356	703		306		40		459	1,288	5,152	0%	0	0	0	0	0%
	Dakshin Madrasha	18,332	13%	51%	36%	4.5%	33,900	18%	6,100	50%	17,000	32%	10,800	4,300	5,100	1,600	11,000	600	5,100	2,200	7,900	1,319	394		171		22		257	721	2,884	0%	0	0	0	0	0%
	Shikarpur	15,792	13%	51%	36%	4.5%	29,200	18%	5,300	50%	14,600	32%	9,300	3,700	4,400	1,400	9,500	500	4,400	1,900	6,800	1,138	339		148		19		222	622	2,488	0%	0	0	0	0	0%
	Total	**80,940**	**13%**	**51%**	**36%**	**4.5%**	**149,800**	18%	**27,000**	50%	**75,000**	32%	**47,800**	**18,900**	**22,500**	**7,100**	**48,500**	**2,700**	**22,500**	**9,700**	**34,900**	**5,829**	**1,739**		**757**		**98**		**1,136**	**3,186**	**12,745**	**0%**	**0**	**0**	**0**	**0**	**0%**
Sitakunda (proposed)																																					
	Bhatiari	20,380	7%	32%	61%	5.0%	40,400	13%	5,300	42%	17,000	45%	18,100	3,700	5,100	2,700	11,500	500	5,100	3,600	9,200	1,383	463		185		24		277	777	3,109	0%	0	0	0	0	0%
	Salimpur	32,960	7%	32%	61%	5.0%	65,300	13%	8,500	42%	27,400	45%	29,400	6,000	8,200	4,400	18,600	900	8,200	5,900	15,000	2,230	748		298		39		447	1,254	5,016	30%	1,505	5,580	4,500	10,080	15%
	Total	**53,340**	**7%**	**32%**	**61%**	**5.0%**	**105,700**	13%	**13,800**	42%	**44,400**	45%	**47,500**	**9,700**	**13,300**	**7,100**	**30,100**	**1,400**	**13,300**	**9,500**	**24,200**	**3,613**	**1,211**		**483**		**63**		**724**	**2,031**	**8,125**	**19%**	**1,505**	**5,580**	**4,500**	**10,080**	**10%**
Proposed Total		**134,280**	**11%**	**43%**	**46%**	**4.7%**	**255,500**	**16%**	**40,800**	**47%**	**119,400**	**37%**	**95,300**	**28,600**	**35,800**	**14,200**	**78,600**	**4,100**	**35,800**	**19,200**	**59,100**	**9,442**	**2,950**		**1,239**		**161**		**1,859**	**5,217**	**20,870**	**7%**	**1,505**	**5,580**	**4,500**	**10,080**	**4%**
Grand Total		**1,733,280**	**30%**	**34%**	**35%**	**4.5%**	**3,186,100**	**42%**	**1,324,700**	**28%**	**906,500**	**30%**	**954,900**	**927,800**	**272,200**	**143,200**	**1,343,200**	**132,600**	**272,200**	**191,000**	**595,800**	**161,101**	**29,782**		**19,088**		**2,481**		**45,500**	**85,987**	**343,942**	**82%**	**281,355**	**1,114,180**	**466,180**	**1,580,360**	**50%**

Note: Demand of Ward No. 98 Chitagtagong Cantonment is 3MGD based on the request. Since the Fatehabad Preoject will cope with it, it is not shown in this table.

Table 3.3-8 Projection of Water Demand by Ward and Union (2010)

Ward No.	Name of Ward	1991				2010																										Service	
		Population	Type of Housing			Adopted Increase Rate	Population	Type of Housing						Served Population								Water Demand										Pop.	Ratio
			Pucca	Semi	Kutcha			Pucca		Semi-Pucca		Kutcha		House Connection				Hydrant				House Con.	Hydrant	Commertial		Institutional		Industrial		Leakage	Total		
			(%)	(%)	(%)			(%)	Population	(%)	Population	(%)	Population	Pucca	Semi-Pucca	Kutcha	Total	Pucca	Semi-Pucca	Kutcha	Total	(m^3/day)	(m^3/day)	(%)	(m^3/day)	(%)	(m^3/day)	(%)	(m^3/day)	(m^3/day)	(m^3/day)	(no.)	(%)
1	2	3	4	5	6	7	8	9	10	11	12	13	14									15	16	17	18	19	20	21	22	23	24	25	26
Kotwali Thana																																	
1	Bogmoniram	30,862	47%	35%	18%	4.0%	65,000	66%	42,900	22%	14,300	12%	7,800	40,800	7,200	1,600	49,600	2,100	7,200	1,600	10,900	6,430	543		1,474		192		0	2,437	11,076	60,500	93%
2	Chawk Bazar	38,364	47%	35%	18%	3.5%	73,800	66%	48,700	22%	16,200	12%	8,900	46,300	8,100	1,800	56,200	2,400	8,100	1,800	12,300	7,299	616		1,674		218		0	2,766	12,573	68,500	93%
3	Jamal Khan	39,004	47%	35%	18%	1.5%	51,800	66%	34,200	22%	11,400	12%	6,200	32,500	5,700	1,200	39,400	1,700	5,700	1,200	8,600	5,126	433		1,175		153		0	1,942	8,829	48,000	93%
4	Enayet Bazar	28,881	47%	35%	18%	2.5%	46,200	66%	30,500	22%	10,200	12%	5,500	29,000	5,100	1,100	35,200	1,500	5,100	1,100	7,700	4,573	386		1,049		136		0	1,733	7,877	42,900	93%
5	Dewan Bazar	32,244	47%	35%	18%	0.0%	32,200	66%	21,300	22%	7,100	12%	3,800	20,200	3,600	800	24,600	1,100	3,600	800	5,500	3,191	269		732		95		0	1,209	5,496	30,100	93%
6	Anderkilla	20,291	47%	35%	18%	0.0%	20,300	66%	13,400	22%	4,500	12%	2,400	12,700	2,300	500	15,500	700	2,300	500	3,500	2,010	170		461		60		0	762	3,463	19,000	94%
7	Alkaran	28,261	47%	35%	18%	3.0%	49,600	66%	32,700	22%	10,900	12%	6,000	31,100	5,500	1,200	37,800	1,600	5,500	1,200	8,300	4,903	414		1,124		146		0	1,858	8,445	46,100	93%
8	Patherghata	30,055	47%	35%	18%	3.0%	52,700	66%	34,800	22%	11,600	12%	6,300	33,100	5,800	1,300	40,200	1,700	5,800	1,300	8,800	5,216	440		1,196		155		0	1,976	8,983	49,000	93%
9	Fringi Bazar	22,191	47%	35%	18%	2.0%	32,300	66%	21,300	22%	7,100	12%	3,900	20,200	3,600	800	24,600	1,100	3,600	800	5,500	3,193	270		732		95		0	1,210	5,500	30,100	93%
10	Boxirhat	13,280	47%	35%	18%	5.0%	33,600	66%	22,200	22%	7,400	12%	4,000	21,100	3,700	800	25,600	1,100	3,700	800	5,600	3,327	281		763		99		0	1,261	5,731	31,200	93%
	Total	**283,433**	**47%**	**35%**	**18%**	**2.6%**	**457,500**	66%	**302,000**	22%	**100,700**	12%	**54,800**	**287,000**	**50,600**	**11,100**	**348,700**	**15,000**	**50,600**	**11,100**	**76,700**	**45,268**	**3,822**	30%	**10,380**	30%	**1,349**	0%	**0**	**17,154**	**77,973**	**425,400**	**93%**
Double Mooring Thana																																	
15	Lalkhan Bazar	49,691	32%	31%	37%	4.0%	104,700	52%	54,400	23%	24,100	25%	26,200	51,700	12,100	5,200	69,000	2,700	12,100	5,200	20,000	8,966	1,001		1,527		170		0	3,290	14,954	89,000	85%
16	East Madarbari	35,086	32%	31%	37%	2.0%	51,100	52%	26,600	23%	11,800	25%	12,700	25,300	5,900	2,500	33,700	1,300	5,900	2,500	9,700	4,382	489		746		83		0	1,608	7,308	43,400	85%
17	West Madarbari	42,995	32%	31%	37%	3.0%	75,400	52%	39,200	23%	17,300	25%	18,900	37,200	8,700	3,800	49,700	2,000	8,700	3,800	14,500	6,457	720		1,099		122		0	2,369	10,767	64,200	85%
18	Uttar Pathantoly	30,423	32%	31%	37%	5.0%	76,900	52%	40,000	23%	17,700	25%	19,200	38,000	8,900	3,800	50,700	2,000	8,900	3,800	14,700	6,590	735		1,122		125		0	2,418	10,990	65,400	85%
19	Pathantoly	38,595	32%	31%	37%	6.0%	116,800	52%	60,700	23%	26,900	25%	29,200	57,700	13,500	5,800	77,000	3,000	13,500	5,800	22,300	10,004	1,116		1,703		190		0	3,670	16,683	99,300	85%
20	Gosail Danga	22,752	32%	31%	37%	4.5%	52,500	52%	27,300	23%	12,100	25%	13,100	25,900	6,100	2,600	34,600	1,400	6,100	2,600	10,100	4,499	502		766		85		0	1,651	7,503	44,700	85%
24	Uttar Agrabad	40,174	32%	31%	37%	4.5%	92,700	52%	48,200	23%	21,300	25%	23,200	45,800	10,700	4,600	61,100	2,400	10,700	4,600	17,700	7,940	885		1,352		151		0	2,913	13,241	78,800	85%
25	D. Agrabad	81,749	32%	31%	37%	4.5%	188,700	52%	98,100	23%	43,400	25%	47,200	93,200	21,700	9,400	124,300	4,900	21,700	9,400	36,000	16,164	1,802		2,752		307		0	5,930	26,955	160,300	85%
33	Rampur	25,831	32%	31%	37%	5.5%	71,400	52%	37,100	23%	16,400	25%	17,900	35,200	8,200	3,600	47,000	1,900	8,200	3,600	13,700	6,113	682		1,041		116		0	2,243	10,195	60,700	85%
	Total	**367,296**	**32%**	**31%**	**37%**	**4.4%**	**830,200**	52%	**431,600**	23%	**191,000**	25%	**207,600**	**410,000**	**95,800**	**41,300**	**547,100**	**21,600**	**95,800**	**41,300**	**158,700**	**71,115**	**7,932**	35%	**12,108**	30%	**1,349**	0%	**0**	**26,092**	**118,596**	**705,800**	**85%**
Panchlaish Thana																																	
11	Sulak Bohar	85,106	27%	30%	43%	4.0%	179,300	45%	80,700	23%	41,200	32%	57,400	76,700	20,600	11,500	108,800	4,000	20,600	11,500	36,100	14,137	1,806		1,381		180		5,175	6,397	29,076	144,900	81%
12	West Sholoshahar	53,080	27%	30%	43%	3.0%	93,100	45%	41,900	23%	21,400	32%	29,800	39,800	10,700	6,000	56,500	2,100	10,700	6,000	18,800	7,340	938		717	10%	93		2,687	3,321	15,096	75,300	81%
14	Jalalabad	45,732	27%	30%	43%	4.0%	96,400	45%	43,400	23%	22,200	32%	30,800	41,200	11,100	6,200	58,500	2,200	11,100	6,200	19,500	7,604	972		743		97		2,784	3,441	15,641	78,000	81%
26	Panchlaish	38,056	27%	30%	43%	4.0%	80,200	45%	36,100	23%	18,400	32%	25,700	34,300	9,200	5,100	48,600	1,800	9,200	5,100	16,100	6,323	807		618		80		2,314	2,861	13,003	64,700	81%
98	Chittagong Cantonment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-		13,638		-	3,847	17,485	-	-
	Total	**221,974**	**27%**	**30%**	**43%**	**3.8%**	**449,000**	45%	**202,100**	23%	**103,200**	32%	**143,700**	**192,000**	**51,600**	**28,800**	**272,400**	**10,100**	**51,600**	**28,800**	**90,500**	**35,404**	**4,523**	10%	**3,459**		**14,088**	17%	**12,960**	**19,867**	**90,301**	**362,900**	**81%**
Pahartali Thana																																	
21	Saripara	53,428	29%	30%	41%	4.0%	112,600	48%	54,000	23%	25,900	29%	32,700	51,300	13,000	6,500	70,800	2,700	13,000	6,500	22,200	9,203	1,110		405		53		2,530	3,752	17,053	93,000	83%
22	North Pahartali	43,859	29%	30%	41%	6.0%	132,700	48%	63,700	23%	30,500	29%	38,500	60,500	15,300	7,700	83,500	3,200	15,300	7,700	26,200	10,850	1,307		478		62		2,983	4,423	20,103	109,700	83%
23	Pahartali	50,007	29%	30%	41%	4.0%	105,400	48%	50,600	23%	24,200	29%	30,600	48,100	12,100	6,100	66,300	2,500	12,100	6,100	20,700	8,618	1,038		379		49		2,369	3,512	15,965	87,000	83%
34	Uttar Kattali	23,769	29%	30%	41%	5.5%	65,700	48%	31,500	23%	15,100	29%	19,100	29,900	7,600	3,800	41,300	1,600	7,600	3,800	13,000	5,368	647		236		31		1,476	2,188	9,946	54,300	83%
35	Dakhin Kattali	26,008	29%	30%	41%	5.0%	65,700	48%	31,500	23%	15,100	29%	19,100	29,900	7,600	3,800	41,300	1,600	7,600	3,800	13,000	5,368	647		236		31		1,476	2,188	9,946	54,300	83%
36	Uttar Halishahar	31,259	29%	30%	41%	6.0%	94,600	48%	45,400	23%	21,800	29%	27,400	43,100	10,900	5,500	59,500	2,300	10,900	5,500	18,700	7,736	933		341		44		2,127	3,154	14,335	78,200	83%
	Total	**228,330**	**29%**	**30%**	**41%**	**5.0%**	**576,700**	48%	**276,700**	23%	**132,600**	29%	**167,400**	**262,800**	**66,500**	**33,400**	**362,700**	**13,900**	**66,500**	**33,400**	**113,800**	**47,143**	**5,682**	6%	**2,076**	6%	**270**	17%	**12,960**	**19,217**	**87,348**	**476,500**	**83%**
Chand Gaow Thana																																	
27	Chandgaon	50,195	22%	38%	40%	3.0%	88,000	39%	34,300	30%	26,400	31%	27,300	32,600	13,200	5,500	51,300	1,700	13,200	5,500	20,400	6,662	1,019		289		38		1,484	2,677	12,169	71,700	81%
28	Mohara	54,058	22%	38%	40%	4.5%	124,800	39%	48,700	30%	37,400	31%	38,700	46,300	18,700	7,700	72,700	2,400	18,700	7,700	28,800	9,452	1,444		410		53		2,105	3,798	17,262	101,500	81%
29	Purba Sholoshahar	18,058	22%	38%	40%	4.5%	41,700	39%	16,300	30%	12,500	31%	12,900	15,500	6,300	2,600	24,400	800	6,300	2,600	9,700	3,161	482		137		18		704	1,270	5,772	34,100	82%
30	Purba Bakulia	29,540	22%	38%	40%	6.5%	97,700	39%	38,100	30%	29,300	31%	30,300	36,200	14,700	6,100	57,000	1,900	14,700	6,100	22,700	7,398	1,131		321		42		1,648	2,973	13,513	79,700	82%
31	Paschim Bakulia	46,262	22%	38%	40%	5.0%	116,900	39%	45,600	30%	35,100	31%	36,200	43,300	17,600	7,200	68,100	2,300	17,600	7,200	27,100	8,854	1,354		384		50		1,972	3,558	16,172	95,200	81%
32	D. Bakulia	54,034	22%	38%	40%	6.0%	163,500	39%	63,800	30%	49,100	31%	50,600	60,600	24,600	10,100	95,300	3,200	24,600	10,100	37,900	12,386	1,893		537		70		2,759	4,977	22,622	133,200	81%
	Total	**252,147**	**22%**	**38%**	**40%**	**5.0%**	**632,600**	39%	**246,800**	30%	**189,800**	31%	**196,000**	**234,500**	**95,100**	**39,200**	**368,800**	**12,300**	**95,100**	**39,200**	**146,600**	**47,913**	**7,323**	6%	**2,078**	6%	**270**	14%	**10,673**	**19,253**	**87,510**	**515,400**	**81%**
Chittagong Port Thana																																	
37	U.P. Halishahar	37,053	35%	39%	26%	6.5%	122,600	54%	66,200	28%	34,300	18%	22,100	62,900	17,200	4,400	84,500	3,300	17,200	4,400	24,900	10,980	1,244		648		126		7,421	5,759	26,178	109,400	89%
38	D.P. Halishahar	41,351	35%	39%	26%	5.0%	104,500	54%	56,400	28%	29,300	18%	18,800	53,600	14,700	3,800	72,100	2,800	14,700	3,800	21,300	9,359	1,062		552		108		6,326	4,910	22,317	93,400	89%
39	D. Halishahar	53,579	35%	39%	26%	6.0%	162,100	54%	87,500	28%	45,400	18%	29,200	83,100	22,700	5,800	111,600	4,400	22,700	5,800	32,900	14,516	1,646		856		167		9,811	7,614	34,610	144,500	89%
40	U. Patenga	45,722	35%	39%	26%	6.5%	151,300	54%	81,700	28%	42,400	18%	27,200	77,600	21,200	5,400	104,200	4,100	21,200	5,400	30,700	13,553	1,536		799		156		9,160	7,109	32,313	134,900	89%
41	D. Patenga	37,818	35%	39%	26%	6.0%	114,400	54%	61,800	28%	32,000	18%	20,600	58,700	16,000	4,100	78,800	3,100	16,000	4,100	23,200	10,248	1,161		604		118		6,926	5,375	24,432	102,000	89%
	Total	**215,523**	**35%**	**39%**	**26%**	**6.0%**	**654,900**	54%	**353,600**	28%	**183,400**	18%	**117,900**	**335,900**	**91,800**	**23,500**	**451,200**	**17,700**	**91,800**	**23,500**	**133,000**	**58,656**	**6,649**	10%	**3,460**	15%	**675**	52%	**39,644**	**30,767**	**139,850**	**584,200**	**89%**
Hathazari Thana																																	
13	J.D. Pahartali	30,297	9%	24%	67%	4.5%	69,900	18%	12,600	23%	16,100	59%	41,200	12,000	8,100	8,200	28,300	600	8,100	8,200	16,900	3,674	846		1,038		135		0	1,606	7,299	45,200	65%
	Total	**30,297**	**9%**	**24%**	**67%**	**4.5%**	**69,900**	18%	**12,600**	23%	**16,100**	59%	**41,200**	**12,000**	**8,100**	**8,200**	**28,300**	**600**	**8,100**	**8,200**	**16,900**	**3,674**	**846**	3%	**1,038**	3%	**135**	0%	**0**	**1,606**	**7,299**	**45,200**	**65%**
Municipality Total		**1,599,000**	**32%**	**33%**	**35%**	**4.5%**	**3,670,800**	**50%**	**1,825,400**	**25%**	**916,800**	**25%**	**928,600**	**1,734,200**	**459,500**	**185,500**	**2,379,200**	**91,200**	**459,500**	**185,500**	**736,200**	**309,173**	**36,777**	100%	**34,595**	100%	**18,135**	100%	**76,237**	**133,956**	**608,873**	**3,115,400**	**85%**
Hathazari (proposed)																																	
	Burir Char	14,098	13%	51%	36%	4.5%	32,500	20%	6,500	50%	16,300	30%	9,700	6,200	8,200	1,900	16,300	300	8,200	1,900	10,400	2,114	521		263		34		395	938	4,265	26,700	82%
	Chikandandi	32,718	13%	51%	36%	4.5%	75,500	20%	15,100	50%	37,800	30%	22,600	14,300	18,900	4,500	37,700	800	18,900	4,500	24,200	4,909	1,209		612		80		918	2,180	9,908	61,900	82%
	Dakshin Madrasha	18,332	13%	51%	36%	4.5%	42,300	20%	8,500	50%	21,200	30%	12,600	8,100	10,600	2,500	21,200	400	10,600	2,500	13,500	2,755	677		343		45		515	1,223	5,558	34,700	82%
	Shikarpur	15,792	13%	51%	36%	4.5%	36,400	20%	7,300	50%	18,200	30%	10,900	6,900	9,100	2,200	18,200	400	9,100	2,200	11,700	2,368	582		295		38		443	1,051	4,777	29,900	82%
	Total	**80,940**	**13%**	**51%**	**36%**	**4.5%**	**186,700**	20%	**37,400**	50%	**93,500**	30%	**55,800**	**35,500**	**46,800**	**11,100**	**93,400**	**1,900**	**46,800**	**11,100**	**59,800**	**12,146**	**2,989**		**1,513**		**197**		**2,271**	**5,392**	**24,508**	**153,200**	**82%**
Sitakunda (proposed)																																	
	Bhatiari	20,380	7%	32%	61%	5.0%	51,500	15%	7,700	45%	23,200	40%	20,600	7,300	11,600	4,100	23,000	400	11,600	4,100	16,100	2,995	805		380		49		570	1,354	6,153	39,100	76%
	Salimpur	32,960	7%	32%	61%	5.0%	83,300	15%	12,500	45%	37,500	40%	33,300	11,900	18,800	6,700	37,400	600	18,800	6,700	26,100	4,847	1,302		615		80		922	2,190	9,956	63,500	76%
	Total	**53,340**	**7%**	**32%**	**61%**	**5.0%**	**134,800**	15%	**20,200**	45%	**60,700**	40%	**53,900**	**19,200**	**30,400**	**10,800**	**60,400**	**1,000**	**30,400**	**10,800**	**42,200**	**7,842**	**2,107**		**995**		**129**		**1,492**	**3,544**	**16,109**	**102,600**	**76%**
Proposed Total		**134,280**	**11%**	**43%**	**46%**	**4.7%**	**321,500**	**18%**	**57,600**	**48%**	**154,200**	**34%**	**109,700**	**54,700**	**77,200**	**21,900**	**153,800**	**2,900**	**77,200**	**21,900**	**102,000**	**19,988**	**5,096**		**2,508**		**326**		**3,763**	**8,936**	**40,617**	**255,800**	**80%**
Grand Total		**1,733,280**	**30%**	**34%**	**35%**	**4.5%**	**3,992,300**	**47%**	**1,883,000**	**27%**	**1,071,000**	**26%**	**1,038,300**	**1,788,900**	**536,700**	**207,400**	**2,533,000**	**94,100**	**536,700**	**207,400**	**838,200**	**329,161**	**41,873**		**37,103**		**18,461**		**80,000**	**142,892**	**649,490**	**3,371,200**	**84%**

Note: Demand of Ward No. 98 Chitagtagong Cantonment is 3MGD based on the request.

CHAPTER 4

EXISTING WATER SUPPLY SYSTEM

CHAPTER 4 EXISTING WATER SUPPLY SYSTEM

4.1 Review of Existing Water Treatment Plant

4.1.1 Mohara Water Treatment Plant

(1) Treatment Facilities

The existing Mohara WTP has the production capacity of 20 MGD or 91,000 m^3/day, deriving surface water from the Halda River. High Rate Clarifier – Rapid Sand Filter treatment method is adopted in treatment process.

The plant consists of Intake Pumps (Raw Water Pumps), Desilting Basins, Flash Mixers, Clarifiers, Filters, Clearwater Reservoirs, Transmission Pumps (High Lift Pumps), a Wastewater Drainage Facility, an Administration Building and a Chemical Building. Treatment flow diagram is as shown in Figure 4.1-1. Design raw water turbidity is set at 350 NTU. Two desilting basins are provided for reduction of the load on Clarifiers and Filters. These basins are operated except the period for cleaning of the basins while the raw water turbidity indicates less than 100 NTU.

All mechanical equipment including intake pumps, flush mixers, transmission pumps, and drainage pumps is operated manually.

The intake facility is constructed with a space for future augmentation by an intake pump. Expansion space for treatment facilities is also secured but is rather narrow.

Outlines of facilities are summarized in Table 4.1-1.

Table 4.1-1 Outline of Facilities in Mohara Water Treatment Plant

Facilities	Dimension	Capacity
Intake Pump	40 m^3/min x 12.6 m x 132 kW x 4 units	8800gal./min x 41 ft
Desilting Basin	25.29 m x 134.11 m x 1.98 m x 2 units	20MGD
Rapid Mixing Chamber	2.29 m x 2.28 m x 1.45 m x 1 unit 2.29 m x 2.28 m x 1.00 m x 1 unit	for Lime for Alum
Clarifier	7.62 m x 7.62 m x 24 units	20MGD
Filter	(2.44 m x 9.14 m x 2) x 8 units	20MGD
Clear Water Reservoir	30.28 m x 39.27 m x Effective D. 2.88m	Total D 4.57m
Transmission Pump	15.8 m^3/min x 83 m x 350 kW x 5 units	3475gal./min x 271ft

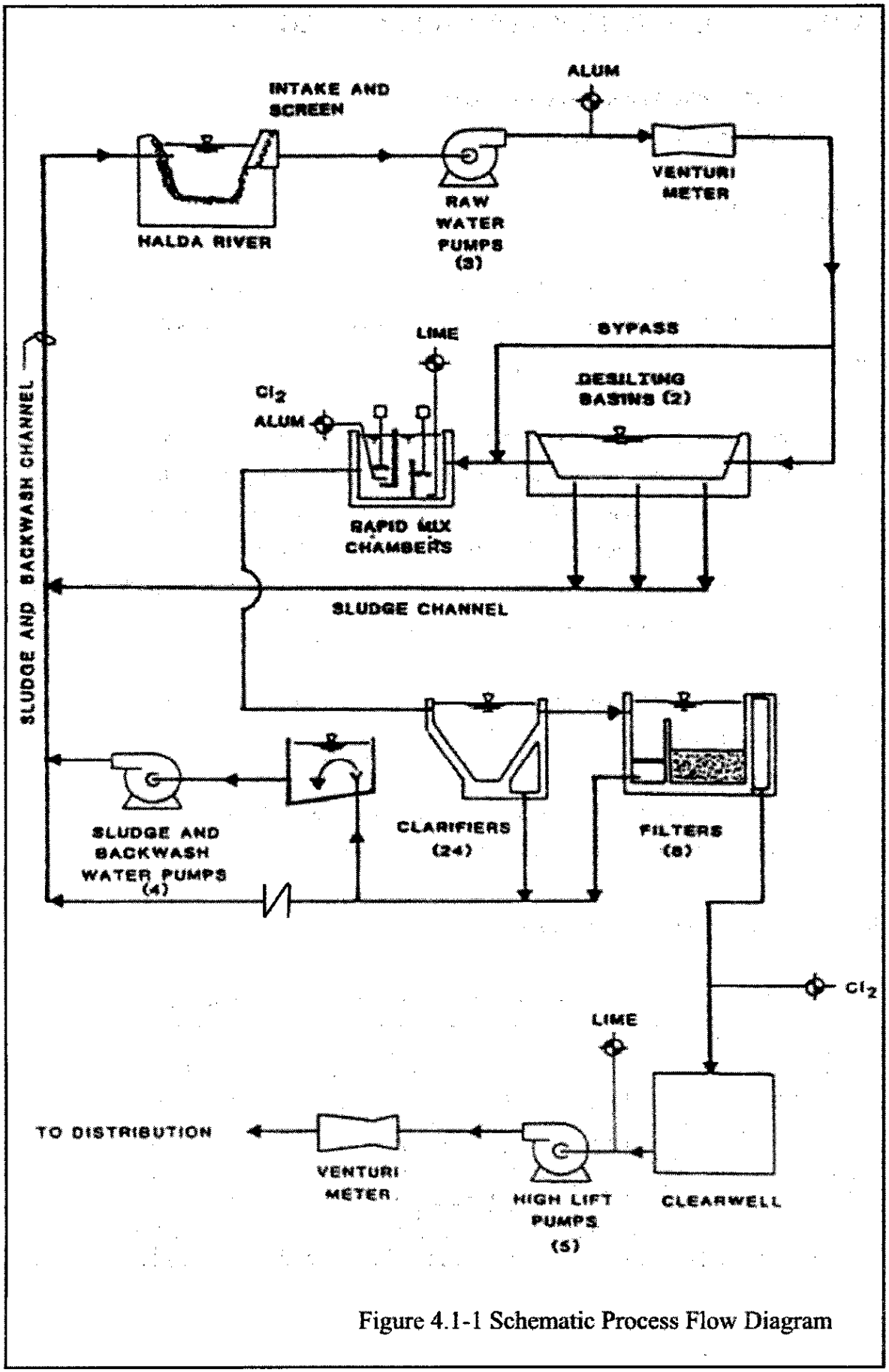

Figure 4.1-1 Schematic Process Flow Diagram

(2) Treatment Efficiency

Results of water quality analysis on raw and treated water during 1998 to 1999 are presented in Tables 4.1-2 and 4.1-3.

Turbidity of raw water was 830 NTU in maximum and that of treated water ranged from 0.60 NTU (min.) to 2.80 NTU (max.). Those are under the Bangladesh National Standard (10 NTU) and WHO Standard (NTU).

Manganese concentrations in raw water were 0.35 to 0.38 mg/L, and those of treated water were 0.1 to 0.16 mg/L. Those slightly exceed the National Standard of 0.1 mg/L, but are lower than WHO Standard of 0.1 mg/L. Manganese removal to the level of National Standard can be achieved by continuous pre- or mid-chlorination, which is currently practiced intermittently. Other water quality indices complied with the Standards.

Since current treatment method comprised of Clarifier and Rapid Sand Filter can treat the present raw water efficiently, same treatment method may be employed in the treatment facilities to be expanded. Present status of each facility is as follows:

(3) Present Status of the Existing Facilities

1) Intake Facility

Intake facility is comprised of an Intake Mouth and Intake Pumps. The intake mouth is constructed at the riverbank and pumps installed in the pump house are pumping river water after screening to desilting basins locating 300 m away. During three months from January to March, when turbidity of river water is low, water is directly pumped to rapid mixing chamber for cleaning of the desilting basins.

a) Intake Mouth

- One intake pump is installed for each intake mouth and five months are provided in total in the intake structure. An opening of intake mouth has a dimension of 1.8 m in width and 1.2 m in depth with stop logs and bar screen. Bar screen is installed in the position lower than the lowest water level at –1.21 m in order not to lose the dynamic water head by screen clogging with water plants.

Table 4.1-2 Water Quality at Mohara Treatment Plant (Raw Water)

Parameters		pH			Turbidity			T-Alkalinity as CaCO3			T-Hardness			TSS		Iron		NO3		PO4		SO4		TDS		NH3		DO			BOD			COD			Chloride		
Unit					NTU			mg/l			mg/l			mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l			mg/l			mg/l			mg/l		
		Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
1998	Jan	7.00	7.10	7.20	20	40	60	60	62	65	68	70	74	61	74	0.31	0.38	1.6	2.1			18	20	104	116	0.32	0.38										6	10	60
	Feb	6.80	7.00	7.00	20	70	300	50	55	65	60	70	82	175	337	0.34	0.41	1.8	2.2			16	18	116	121	0.30	0.34										6	7	9
	Mar	6.80	7.20	7.20	20	60	780	58	60	65	60	70	74	64	813	0.38	0.45	2.4	2.8			20	21	112	128	0.32	0.40		8.6			1.3			12		6	7	10
	Apr	6.80	6.90	7.20	20	80	600	56	58	63	69	72	78	135	631	0.54	0.98	2.5	2.6			18	22	116	125	0.39	0.41		7.8			1.4			13		5	8	10
	May	7.00	7.10	7.20	40	200	740	50	55	62	80	82	86	86	781	0.38	1.50	2.1	2.3			16	21	113	117	0.38	0.40		6.9			1.7			15		6	9	13
	Jun	6.80	6.90	7.20	230	350	640	40	50	54	50	70	81	362	732	1.00	1.30	2.1	2.6			20	24	126	131	0.37	0.41		6.7			1.6			14		6	10	11
	Jul	6.50	6.90	7.40	120	400	680	34	50	55	60	75	92	236	646	0.42	0.98	1.8	2.1			21	22	115	132	0.35	0.40		6.5			2.0			13		8	8	11
	Aug	6.70	6.80	7.00	100	200	460	40	42	50	50	75	86	134	438	0.39	0.58	1.8	2.3			15	18	112	125	0.30	0.35		8.2			1.3			12		7	8	10
	Sep	6.70	6.80	7.10	90	150	340	47	51	58	66	68	72	126	296	0.37	0.50	1.8	2.3			14	16	111	115	0.40	0.43		8.5			1.1			10		7	8	10
	Oct	6.80	7.00	7.20	90	120	170	52	54	58	60	64	65	122	198	0.32	0.38	1.9	2.5			17	19	119	121	0.28	0.31		8.8			1.1			12		6	8	9
	Nov	6.80	7.00	7.20	50	120	400	52	55	59	68	72	78	129	434	0.23	0.27	2.4	2.8	0.25	0.32	18	21	118	122	0.28	0.30	9.0		9.2	1.1		1.2	14		15	7		114
	Dec	6.90	7.10	7.30	40	80	150	52	55	62	62	64	80	94	108	0.21	0.38	1.8	2.4	0.21	0.32	15	17	114	117	0.32	0.39	8.8		9.8	1.0		1.2	14		16	7		105
1999	Jan	7.00	7.10	7.30	40	80	150	53		66	62	63	68	144	178	0.25	0.26	2.6	2.7	0.35	0.42	15	20	108	121	0.30	0.38	9.2		9.4	1.2		1.4	12		17	7		70
	Feb	7.00	7.20	7.30	20	40	150	50		68	68	70	72	67	78	0.21	0.31	2.8	3.0	0.48	0.51	13	18	112	125	0.29	0.34	8.6		9.8	1.3		1.5	14		15	5		13
	Mar	6.98	7.21	7.44	20	60	80	62		68	65		72	55	90	0.23	0.28	2.9	3.1	0.52	0.61	16	18	115	122	0.21	0.26	8.2		8.6	1.2		1.4	14		16	6		8
	Apr	7.04	7.10	7.41	30	70	250	62		69	70		75	112	168	0.18	0.32	2.8	3.1	0.47	0.51	18	21	118	121	0.25	0.28	8.4		8.6	1.2		1.4	17		18	6		48
	May	7.01		7.52	130		410	62		68	63		80	157	446	0.41	0.52	2.6	3.2			14	17	135	142	0.35	0.38	8.9		9.2	1.3		1.4	16		17	9		63
	Jun	6.89		7.31	350		640	52		68	78		84	396	679	0.58	0.76	3.2	3.4			26	28	129	134	0.31	0.34	9.4		9.8	1.3		1.4	15		18	5		12
	Jul	6.81		7.26	150		780	50		60	70		78	188	829	0.62	0.84	2.7	3.0			21	25	135	148	0.34	0.36	8.4		8.8	1.2		1.4	16		18	4		10
	Aug	6.80		7.29	110		830	48		58	75		86	143	874	0.38	0.45	2.4	2.8			19	24	128	141	0.21	0.39	8.0		8.4	1.3		1.4	13		16	5		8
	Sep	6.82		7.26	90		350	48		57				132	392	0.32	0.48	2.2	2.8			16	17			0.28	0.35	8.0		8.2	1.0		1.2	14		17	5		9
	Oct	7.00		7.31	60		160	50		55				98	191	0.30	0.41	2.1	2.6			16	21			0.28	0.30	8.5		8.8	1.0		1.3	12		13	5		13
	Nov	6.90		7.42	40		120	54		68				64	154	0.21	0.32	2.6	3.1			15	17			0.31	0.34	9.2		9.4	1.2		1.3	12		14	5		200
	Dec	7.10		7.47	50		160	60		68				78	194	0.24	0.35	1.6	2.0			14	20			0.28	0.29	9.0		9.5	1.4		1.5	13		16	7		40

Parameters	pH			Turbidity			T-Alkalinity as CaCO3			T-Hardness			TSS		Iron		NO3		PO4		SO4		TDS		NH3		DO			BOD			COD			Chloride		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
Statistcs:																																						
Min.	6.50	6.80	7.00	20	40	60	34	42	50	50	63	65	55	74	0.18	0.26	1.6	2.0	0.21	0.32	13	16	104	115	0.21	0.26	8.0	6.5	8.2	1.0	1.1	1.2	12	10	13	4	7	8
Max.	7.10	7.21	7.52	350	400	830	62	62	69	80	82	92	396	874	1.00	1.50	3.2	3.4	0.52	0.61	26	28	135	148	0.40	0.43	9.4	8.8	9.8	1.4	2.0	1.5	17	15	18	9	10	200
Avg.	6.87	7.03	7.27	80	133	392	52	54	62	65	70	78	140	407	0.37	0.56	2.27	2.66	0.38	0.45	17	20	118	126	0.31	0.36	8.69	7.75	9.11	1.19	1.44	1.36	14	13	16	6	8	36
Std.Dev.	0.1	0.1	0.1	78	107	257	7.1	5.3	5.5	7.8	5.00	6.8	86	274	0.2	0.3	0.5	0.4	0.1	0.1	3	3	8.5	9.2	0	0	0.5	0.9	0.5	0.1	0.3	0.1	1.6	1.51	1.5	1.1	1.1	47.0
Average	7.08			205			58			72			273		0.46		2.5		0.41		19		122		0.33		8.6			1.3			15			23		

Table 4.1-3 Water Quality at Mohara Treatment Plant (Treated Water)

Parameters	Unit	pH		Turbidity		Res. Cl		T-Alkalinity as CaCO3		T-Hardness		Ca-Hardness		Iron		NO3		PO4		SO4		TDS		NH3		Chloride		Mn	F	Al	Coliform C.
				NTU		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l	mg/l	mg/l	1/100ml
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.				
1998	Jan	7.01	7.22	0.72	0.98	0.50	0.60	50	58	68	74	26	35	0.30	0.35	1.6	2.0	0.21	0.30	16	21	104	116	0.30	0.33	6	50				nil
	Feb	6.98	7.24	0.68	0.98	0.50	0.62	42	58	60	82	34	36	0.31	0.40	1.6	2.2	0.24	0.31	14	19	116	121	0.20	0.31	5	70	0.3	0.7	0.2	nil
	Mar	6.91	7.28	0.60	1.40	0.50	0.64	46	58	60	74	36	39	0.30	0.42	2.4	3.0	0.20	0.28	18	22	112	128	0.28	0.32	6	10				nil
	Apr	6.94	7.35	0.60	1.00	0.50	0.60	44	54	69	78	38	40	0.48	0.80	2.4	2.6	0.31	0.38	18	21	116	125	0.38	0.42	5	9				nil
	May	6.93	7.24	0.60	1.40	0.50	0.60	42	52	80	86	24	35	0.31	0.91	2.0	2.3	0.28	0.32	14	20	113	117	0.35	0.39	7	14				nil
	Jun	6.92	7.25	0.74	2.80	0.50	0.62	32	47	50	81	35	48	0.84	0.86	2.0	3.0	0.26	0.34	17	22	126	131	0.37	0.40	7	13				nil
	Jul	6.90	7.33	0.74	2.00	0.50	0.60	38	42	60	92	25	42	0.40	0.90	1.6	2.0	0.18	0.30	20	24	115	132	0.34	0.42	7	11				nil
	Aug	6.95	7.58	0.60	2.00	0.50	0.61	32	44	50	86	31	33	0.32	0.50	1.6	2.6	0.22	0.35	15	20	112	125	0.28	0.31	6	11				nil
	Sep	6.94	7.23	0.70	1.20	0.50	0.62	37	47	66	72	26	34	0.35	0.50	1.6	2.6	0.40	0.32	16	18	111	115	0.38	0.41	7	10				nil
	Oct	6.95	7.28	0.76	1.40	0.50	0.61	40	47	60	65	24	35	0.30	0.34	1.6	2.6	0.18	0.26	17	20	119	121	0.26	0.30	6	9				nil
	Nov	6.91	7.27	0.60	1.40	0.50	0.62	40	52	68	78	30	42	0.23	0.25	2.6	2.8	0.28	0.35	16	22	118	122	0.27	0.38	7	14				nil
	Dec	6.98	7.29	0.72	1.40	0.50	0.62	44	56	62	80	29	45	0.20	0.35	1.4	2.0	0.25	0.42	15	18	114	117	0.30	0.38	7	105				nil
1999	Jan	6.94	7.12	0.74	2.40	0.51	0.72	49	58	62	68	28	32	0.24	0.28	2.6	2.8	0.32	0.39	12	17	108	121	0.28	0.34	8	80				nil
	Feb	6.90	7.15	0.72	1.40	0.52	0.71	50	56	68	72	32	36	0.22	0.30	2.4	2.9	0.45	0.50	14	20	112	125	0.27	0.30	8	15				nil
	Mar	6.92	7.22	0.78	1.40	0.58	0.71	50	58	68	78	34	41	0.20	0.24	2.6	3.0	0.48	0.52	14	17	115	122	0.22	0.27	6	9				nil
	Apr	7.08	7.21	0.80	1.60	0.60	0.71	51	59	74	76	36	39	0.15	0.28	2.6	3.0	0.45	0.51	17	22	118	121	0.22	0.36	6	48				nil
	May	7.01	7.28	0.84	1.40	0.58	0.72	52	58	65	88	35	43	0.48	0.59	2.8	3.2	0.48	0.52	13	18	135	142	0.28	0.37	8	50				nil
	Jun	6.91	7.22	0.78	1.80	0.50	0.72	41	57	80	90	41	48	0.68	0.82	2.8	3.1	0.28	0.30	18	20	129	134	0.28	0.32	6	11				nil
	Jul	6.90	7.20	0.84	1.40	0.58	0.72	39	51	72	82	38	43	0.65	0.72	2.4	2.7	0.21	0.32	17	24	135	148	0.22	0.38	4	9				nil
	Aug	6.91	7.21	0.84	1.40	0.60	0.72	40	48	76	84	41	46	0.32	0.40	2.1	2.6	0.62	0.71	17	22	128	141	0.20	0.41	5	8				nil
	Sep	6.90	7.21	0.80	1.40	0.60	0.72	38	47	68	78	32	37	0.38	0.40	2.4	2.8	0.68	0.71	15	18	127	134	0.31	0.34	5	7				nil
	Oct	6.90	7.20	0.80	1.20	0.55	0.71	38	46	55	88	25	38	0.28	0.31	2.0	2.7	0.52	0.62	16	20	121	137	0.27	0.31	5	13				nil
	Nov	7.02	7.34	0.80	1.20	0.60	0.72	42	57	78	86	32	38	0.24	0.32	2.5	3.0	0.48	0.56	14	18	126	135	0.25	0.30	5	200				nil
	Dec	7.02	7.28	0.80	1.20	0.62	0.72	50	58	70	85	30	37	0.25	0.32	1.3	2.1	0.60	0.65	15	19	120	128	0.21	0.28	6	150				nil

Parameters	pH		Turbidity		Res. Cl		T-Alkalinity as CaCO3		T-Hardness		Ca-Hardness		Iron		NO3		PO4		SO4		TDS		NH3		Chloride		Mn	F	Al	Coliform C.
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.				
Statistcs:																														
Min.	6.90	7.12	0.60	0.98	0.50	0.60	32	42	50	65	24	32	0.15	0.24	1.3	2.0	0.18	0.26	12	17	104	115	0.20	0.27	4	7				nil
Max.	7.08	7.58	0.84	2.80	0.62	0.72	52	59	80	92	41	48	0.84	0.91	2.8	3.2	0.68	0.71	20	24	135	148	0.38	0.42	8	200				nil
Avg.	6.95	7.26	0.73	1.49	0.54	0.67	43	53	66	80	32	39	0.35	0.48	2.12	2.65	0.36	0.43	16	20	119	127	0.28	0.35	6	39				nil
Std.Dev.	0	0.1	0.1	0.4	0	0.1	5.9	5.5	8.3	7	5.2	4.6	0.2	0.2	0.5	0.4	0.2	0.1	1.9	2	8.2	8.9	0.1	0	1.1	50.4				
Average	7.10		1.11		0.60		48		73		36		0.42		2.4		0.39		18		123		0.31		22					nil

- Screen flow velocity is set at 0.67 m/s against the maximum pump discharge while it becomes 0.55 m/s when 5 % of plant loss is accounted. Suction pipes with a length of 50 m lead water to the pump house.
- Suction pipes can be cleaned function utilizing discharge of other intake pumps by valve operation. Any mechanical measures for removal of sediments, such as silt and sand settled inside of mouths, is not provided,

b) Intake Pumps

- Installation space for five units of pumps, including a future expansion unit, is secured at the Intake Pump House. Four vertical shaft type pumps were already installed. One has a DC Motor and others are equipped with AC motors. One of AC motor driven pump has an inverter speed control unit, but it has gone out of order and is controlled manually. Purpose of such discharge control type pumps is to secure constant intake volume against river water level fluctuation caused by a climatic change and/or a tidal condition.
- Since this discharge control type pump was malfunctioning during the 1st field survey, intake volume was affected by tide. The Study Team measured intake volume for 24 hours using ultrasonic flow meter. River water level fluctuation exceeds 3 m and transition period from maximum to minimum water level is short, i.e. 7 or 8 hours, while shifting from minimum to maximum level requires 5 hours. Intake volume ranged between 3,291 m^3/h and 3,911m^3/h[1].
- This intake volume fluctuation should be reflected on coagulant injection rate and consequently on plant capacity. Since, volumetrically constant intake cannot be attained by valve operation, discharge control type pumps shall be equipped at least.

2) Desilting Basin

Two desilting basins are operated in order to reduce the load to consequent clarifiers and filters. Design turbidity is set at 350 NTU, but maximum turbidity of 830 NTU was recorded twice in 1999. Such high turbidity has been recorded in 9 months in a year except dry season. Pre-coagulation by Alum is conducted at inlet of these basins when turbidity exceeds 300 NTU. This pre-coagulation is executed for 3 or 4 months in a year.

[1] Though this intake volume measurement was conducted at the upstream of Venturi meter installed inside of a flow-metering vault, measured flow is seemed to be less than the actual volume by 10 % affected by turbulence flow caused by the Venturi meter. However, it may be judged that proportion of maximum and minimum flow is as measured. Direct measurement on conveyance pipe was considered for more accurate measurement but since it requires excavation and back filling of the said pipe installed in depth of 5 m. Therefore, it was

During the months from January to March, when turbidity is low, raw water is directly sent to the rapid mixing chamber without treatment in desilting basins and silt settled in the basins is dried and removed manually during these 3 months. During operation, sediment is removed every day by opening of four discharge pipes located at the bottom of each basin. However, its effect is limited.

3) Rapid Mixing Chamber

The rapid mixing chamber is composed of two units of flash mixers installed in series, and lime and alum are injected upstream of each mixer, separately.

When raw water is pumped to rapid mixing basins directly, water level rises above the designed water level (1.76 ft below the top of chamber) and sometimes overflows from chambers. The following may be reasons for this phenomenon:

- Water level in these chambers is affected by water level of consequent inlet channel of Clarifier. Overflow has been found at the beginning part of the inlet channel too.
- Floc is settled in inlet channel of Clarifier. Floc accumulated almost 1 m in depth before the cleaning, which was carried out during the 1st field work. These sediments have reduced effective flow area of inlet chamber.
- It seems that remarkable amount of floc settled in inlet pipes of clarifiers because of its structure. The pipes are laid horizontally in some portion and pipe diameter is reduced from 300 mm to 200 mm at the end.
- Intake pump has larger capacity than design production volume by 27 % and it might larger than the design plant capacity[2].

4) Clarifier

Twenty-four units of high rate sludge blanket type clarifier were provided in total. An inlet pipe with a diameter of 300 mm is provided at center of each clarifier. Raw water with injected alum and lime flows into clarifiers as downward flow in inlet pipes with a velocity of 1.1 m/s and bumps against the bottom then turned into upward flow raising floc through passing the existing floc layer and is entered into suspended slurry layer. Supernatant is collected by effluent troughs. Design upward flow velocity is set at 45.3 mm/min ranging from 40 to 60 mm/min.

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abandoned because earthwork might cause leakage.

[2] This fact has not been verified because of lack of appropriate flow measurement devices.

To retain the slurry interface at stable level, a sludge pocket is provided inside of each clarifier and slurry is drained by manual valve operation. Excess sludge is also drained by manual valve operation installed on sludge drainage pipe.

Nature of floc is basically good and sedimentation is occurred even in inlet channel of clarifiers. However, floc was small and carry-over was observed. This phenomenon seems to be caused by inappropriate chemical injection control against fluctuation of inlet water volume.

5) Filter

There are eight units of filters. They are self-backwashing type filters with surface-washing equipment. Filtration rate is 268 m/d, which rises to 306 m/d when one unit is backwashed, and 357 m/d when one unit is backwashed and one unit is suspended. Continuous filtration time ranges from 30 to 40 hours. Timing of backwashing is conducted when filter water depth reaches to the critical design depth, 3.66 m at maximum. Current backwashing period is eight (8) minutes. Five (5) minutes surface-washing follows three (3) minutes after start of backwashing. Backwash is operated manually by judgment of operators. Current backwashing time seemed to be not enough.

Surface-wash water is diverted from the transmission pipeline. At the beginning of operation of the WTP, pressure of the surface-wash water is reduced by a pressure-reducing valve. However, since it does not function, surface-washing is conducted during daytime when two transmission pumps are on duty and pressure is low. A pipeline of surface-wash water is made of PVC pipes and is deteriorated. There are many leakages from joints and dropping out of surface-wash branch pipes in the filters.

Design filter media thickness is 4" or 1.2 m. Measurement results on sand layer thickness are presented in the Supporting Report. According to the results of measurement at No.5 Filter, design thickness is almost maintained in western side while that in eastern side was only 0.81 m in average showing 30 % of sand was washed away. This supposed to be caused because western side underdrain or sand layer has been clogged and filtration and backwashing has been biased to eastern side of filter. In No.8 Filter, there is no biased thickness change but sand layer thickness decreased by 20 % and average thickness was 0.97 m. No supplemental sand has been supplied. Floc stuck on the sand surface implies improper backwashing.

PVC surface washing pipe has remarkable leakage. Since jetting angle is only 15 degree downward, proper washing effect cannot be expected. Moreover, level of sand layer surface was lowered and therefore distance between surface washing pipe and sand surface was widened. Consequently, effect of surface washing was lowered. As a result, turbidity of treated water exceeds the target

value of 1 mg/L.

6) Clearwater Reservoir

Chlorination channel is provided at the beginning of the clearwater reservoir. It has not been cleaned after commissioning of the plant because water cannot be stop due to its structure.

The reservoir is divided into two tanks with a capacity of 3,360 m^3 per one compartment. Its total capacity is 6,720 m^3 and retention time is 1.8 hours. Though nominal retention time is 3 hours with a capacity of 11,280 m^3, above-mentioned retention time is practical as an effective volume based on the capacity calculation taking account of the center level of transmission pump's suction pipe.

7) Wastewater Discharge Facilities

Wastewater generated at treatment plant is discharged to the Halda River via a wastewater drainage basin. When water level of the river is low, wastewater can be directly discharged to the river by gravity. While, if river water level is high, a flap gate installed in halfway of effluent pipe is closed and wastewater flows into a wastewater drainage basin. Wastewater stored in the sludge basin is drained and discharged to the river by slurry pump automatically operated by water level switch. This basin receives following wastewater generated in the plant:

- Sludge drained from the bottom of Desilting Basins
- Slurry drained from slurry blanket and sludge drained from the bottom of Clarifiers
- Backwashing wastewater from Filters

8) Chemical Dosage Facilities

Alum as coagulant and lime as pH adjustment agent are injected to raw water. Injection rate is determined based on turbidity, pH and results of jar test (refer to the Supporting Report).

Chemical injection facilities for alum and lime are provided. Though design turbidity for chemical dosage is set at 350 NTU, larger turbidities have been frequently recorded including the maximum value at 830 NTU. Reinforcement of these chemical dosage facilities shall be considered in line with plant expansion.

Post-chlorination is conducted for disinfection and pre-chlorination is also executed time to time to remove algae or insects. Since Manganese concentration of raw water exceeds the National Standard of 0.1 mg/L, pre- or mid-chlorination shall be conducted to facilitate Manganese removal by

Manganese coated sand in the filters.

9) Transmission Pump

Five units of transmission pumps including one unit of stand-by are installed in a Pump House. Four pumps have enough capacity in total to convey the whole produced volume to the Battali Hill reservoir.

However, at present, pumps are operated in low head and large discharge position to cope with the increased water demand and restrictions caused by connection with the Kalurghat System. Therefore, water does not reach to the Battali Hill reservoir and irregular pump operation; two units in daytime and three units in nighttime, has been obliged.

10) Others

- Intake pumps have been repaired frequently.
- Existing Venturi type flow meter installed for raw water volume measurement is malfunctioning. Installation of electromagnetic flow meter in near future is planned.

4.1.2 Kalurghat Iron Removal Plant and Booster Pump Station

(1) Outline of Kalurghat Iron Removal Plant and Booster Pump Station

The Kalurghat Iron Removal Plant (IRP) and Booster Pump Station (BPS) were constructed in 1977 with a nominal capacity of 10 MGD (45,460 m^3/day). Groundwater, which contains high iron, is pumped up and sent to the IRP from 24 tube wells scattered in MOD II area. The water quality analysis in 20 wells out of 24 reported that T-Fe concentration of the raw water, namely 4.8 mg/L (average), 12.4 mg/L (maximum) and 1.0 mg/L (minimum), exceeded the National Drinking Water Standard of 1.0 mg/L, (refer to Table 4.1-4 for details). Therefore, aerators, sedimentation basins and filters are provided in the plant for iron removal. Groundwater supplied by well pumps is aerated by gravity sprinkling aeration towers to increase Dissolved Oxygen for oxidization of iron and to disperse the volatile component, such as CO_2. Lime is injected at the inlet of a sedimentation basin to raise pH. Although chlorine injection facility is provided at the aerator, it is not executed at present. Then, water flows via sedimentation basins and oxidized iron is removed at rapid sand filters. Treated water flows into a clearwater reservoir and is directly distributed by pumps at the BPS.

Table 4.1-4 Results of Water Quality Analysis of Existing Deep Wells for Kalurghat Plant

No.	Name of TW	Sampling Date	Water Quality								
			pH	Turbid.	Cl (mg/l)	T-Fe (mg/l)	T-hard (mg/l)	Alka. (mg/l)	Mn (mg/l)	NO_3 (mg/l)	TDS (mg/l)
1	No. 1 TW										
2	No. 2 TW	Aug. 17, 1997	7.2	7	16	1.8	22			2.1	
3	No. 3 TW	Dec. 6, 1993	8.1	25	16	4.9			0.022	2.0	322
4	No. 4 TW	Dec. 1, 1993	6.8	25	22	6.4	30	142		11.2	328
5	No 5 TW	Dec. 27, 1993	6.9	25	22	4.8	22		0.015	9.0	
6	No. 6 TW										
7	No. 7 TW	Jun. 29, 1995	7.1		36	3.9	157	122	0.002	1.6	
8	No. 8 TW	Jul. 11, 1993	8.2		250	3.4	42	128			
9	No. 9 TW	Apr.24, 1997	6.9	< 25	32	1.0			0.002	1.4	115
10	No 10 TW	Jan. 28, 1995	7.2	< 25	82	4.4	102		0.210	1.5	
11	No.11 TW	Jan. 23, 1998	7.4		11	1.1	26	90	0.210		62
12	No.12 TW	Jan 24, 1995	7.7	< 25	26	5.5	36		0.280	1.2	84
13	No.13 TW	Sept.8, 1998	7.3	25	28	3.0	36	116	0.024	13.0	28
14	No.14 TW	Aug. 28, 1993	6.9		16	7.4	62	122			
15	No.15 TW	Aug.14, 1993	6.7		29	12.4	48	126			
16	No 16 TW										
17	No 17 TW	Sept. 7, 1996	6.6		40	6.1			0.170	0.4	238
18	No.18 TW										
19	No.19 TW	Jan. 25, 1998	7.5		22	2.1	68		0.023		110
20	No.20 TW	Jul. 11, 1993	7.7		22	8.4	70	104			12.3
21	No.21 TW	Feb.5, 1996	6.9	< 25	25	3.5	62		0.023	0.4	167
22	No.22 TW	May 28, 1995	6.4	25	15	6.5	124		0.010	1.2	167
23	No.23 TW	Dec. 5, 1993	8.0	< 25	36	4.9	20		0.032	4.0	301
24	No.24 TW	Feb 13, 1995	6.9	< 25	14	4.8	52	102		0.1	
Average (Kalurghat No.1-24)						4.815		116.89	0.079		
Max. (Kalurghat No.1-24)						12.4		142	0.280		
Min. (Kalurghat No.1-24)						1.0		90	0.002		
Water Drinking Standard			6.5-8.5	10	<600	<1.0	<500	-	<0.1	<1.0	<1,000

In addition to originally constructed facilities, new filters with a capacity of 5 MGD were constructed in 1987 next to southern edge of the clearwater reservoir. However, new well development has not been conducted. Construction of this new filter aimed to reduce the load on the existing old filters instead of amplification of plant capacity. The filters treat water without sedimentation treatment. Consequently present total treatment capacity of the IRP is 15 MGD while its source capacity is expected to be 12 MGD in 2005. The new filters have a blower so as to wash filters with air during backwashing. Old Filters, however, does not have air or surface washing equipment. Therefore, it is considered that the old filters have been operated under insufficient washing operation resulting choke of filter layers.

Presently, a construction project of another filter with a same capacity is under processing and its

completion is scheduled in 2002. However, future modification plan of the whole IRP is not decided yet. It will be established after confirmation of performance of new filters. Outline of this plant is presented in Table 4.1-5.

Table 4.1-5 Outline of Kalurghat Plant

Facilities	Dimensions	Capacity
Aerator	3.35 m×13.2 m x 4.44 mH x 2 units	5 MGD/unit
Sedimentation Basin	(46.38～34.16 m) x (79.19～68.52 m) x 3.05 mD x 2 units	5 MGD/unit
Old Filter	4.88 m x 6.71 m x 8 units	10 MGD
New Filter	8.23 m x 13.30 m x 4 units	5 MGD
Clearwater Reservoir	29.87 m x 98.45 m x 2.87 mH x 1 unit	Nominal Volume 2MG Actual Volume 1.86MG
Distribution Pump (Motor Drive)	14.2 m^3/min x 63 m x 250 kW x 1 unit	3,120 gal/min x 208 ft
	8.1 m^3/min x 63 m x 200 kW x 1 unit*	1,785 gal/min x 208 ft
	12.2 m^3/min x 72 m x 210 kW x 2 units	2,680 gal/min x 236 ft
Distribution Pump (Diesel Engine Drive)	14.2 m^3/min x 63 m x 349 kW x 1 unit	3,120 gal/min x 208 ft
	8.1 m^3/min x 63 m x 200 kW x 1 unit	1,785 gal/min x 208 ft

*: To be replaced with 2500/2700 GPM x 70m x 250 kW x 1 unit under the 2nd rehab. Project. In addition, 2 pumps with a capacity of 3000/3200 GPM x 80m x 280kW will also be augmented under the same project.

(2) Present Status of Iron Removal

In the original design, injection of chlorine and lime into the aerator was planned. However, it cannot be used for iron removal efficiently because chlorine is dispersed into the air. At present, only lime injection is executed at inlet of sedimentation basin. Chlorine injection for iron removal purpose is not practiced and oxidization is conducted by aerator only.

As shown in Tables 4.1-6 and 4.1-7, Total-Fe of treated water in the clearwater reservoir ranges from 1.08 to 1.22 mg/L, slightly exceeding the standard value of 1 mg/L. In Table 4.1-8, very high value of 2.0 mg/L is recorded.

Considering Total-Fe concentrations at inlet and outlet of each facility, the following findings were derived:

- ◊ Aerator has sufficient capacity in terms of oxidation and CO_2 dispersion and is working efficiently as a treatment facility.
- ◊ The sedimentation basin seems to be provided to maintain sufficient retention time to turn bivalent iron into trivalent iron and to settle the oxidized iron. However, iron removal effect in this basin is almost none. This might be caused by the reaction that settled iron in the bottom of basin turns into anaerobic condition and eludes into water again. As shown in Table 4.1-6, Total-Fe at inlet, center and outlet of the sedimentation basin show the trend of

slight increase along with flow.

◊ Supernatant of the sedimentation basin, with high DO, flows into the filter and oxidized iron is detained in the filter. Filter backwashing is practiced for eight minutes but backwashing is terminated remaining brown turbid water, seemingly contains high iron. Backwashing is not enough and it seems that turbid compound is still remaining in filter media. Backwashing is carried out without supplemental washing such as air-washing or surface-washing. Elevation difference between surface of filter media and effluent troughs became too large because of outflow of filter media. This causes not only low efficiency of backwashing but also carry over of iron into the clearwater reservoir through filter media.

Table 4.1-6 Iron Removal Status in Kalurghat Iron Removal Plant

Sampling No.	Iron (mg/l)	Sampling Point
No.1	2.68	before Aerator
No.2	2.73	After Aerator
No.3	2.62	Upstream of Sedimentation Basin
No.4	2.90	Middle of Sedimentation Basin
No.5	2.82	Downstream of Sedimentation Basin
No.6	2.58	Transmission Channel to Filter
No.7	1.32	After Old Filter
No.8	0.64	After New Filter
No.9	1.08	Clear Well

Sampling Date: 3.19.2000.

Table 4.1-7 Water Quality of Kalurghat IRP - 1

No.	Sampling Point	pH	T-Fe (mg/l)	P-Alkali (mg/l)	T-Alkali (mg/l)	Cl (mg/l)	Residual Cl (mg/l)	T-Hardness (mg/l)
1	Raw water (Aerator)	6.567	3.84	0	100	18	-	90
2	Before Filtration	7.533	2.8	0	120	18	-	82
3	Clear Well	7.259	1.22	0	115	18	0.58	72

Sampling Date: 1.17.2000.

Table 4.1-8 Water Quality of Kalurghat IRP - 2

	Sampling Point	pH (mg/l)	DO (mg/l)	T-Fe (mg/l)	pH (mg/l)	DO (mg/l)	T-Fe (mg/l)
No.1	Raw Water (Inlet Line)	6.3	1.1	4.0	7.1	2.3	5.0
No.2	After Aeration	7.3	6.2	4.0	7.3	6.7	5.0
No.3	Sedimentation Basin	7.5	6.5	4.0	7.2	6.8	4.0
No.4	Before Filtration	7.5	6.9	3.0	7.4	7.1	2.5
No.5	Clear Well	7.6	7.1	2.0	6.9	7.0	2.0
Sampling Date		1978.6.21			1978.7.20		

Note: Development Plan and Feasibility Study Final Draft Report, January 15 1979

New filter system was completed in 1987. Raw water is derived from the raw water conveyance pipe and flows into filters through a short channel. After the filters, treated water flows down to the clearwater reservoir. Iron removal efficiency of the new filters is better than the old one. Iron concentration of treated water is 0.64 mg/L as shown in Table 4.1-6, Sample No. 8. The reason for this better efficiency is that backwashing is conducted by sufficient water pressure utilizing distribution pumps, and air-washing is employed. Currently, back-washing pressure is rather higher since pressure-reducing valve in the middle of back-washing pipe is malfunctioning.

Since chlorine is injected at the inlet channel between the old filter and the clearwater reservoir, oxidized iron might be settled in this reservoir. The clearwater reservoir has only one unit and there is no bypass line to distribution pump. Therefore, no cleaning work has been executed for the clearwater reservoir. There is a possibility of re-elusion of settled iron.

Judging from the current operational status of the facilities as stated above, the effect of iron removal is not sufficient though much of iron is removed even in present situation.

(3) Current Operational Status of Other Facilities

Out of 24 units of production tube well, 15 units were connected to single conveyance pipe with a diameter of 600 mm. This caused mutual interference between well pumps, and therefore, planned intake volume, which shall be equivalent to the IRP capacity of 15 MGD, is not secured. Table 4.1-9 shows the inlet flow to the IRP in February 2000, ranging from 9 MGD at maximum to less than 8 MGD in usual. Some pumps are exploiting groundwater more than the safe yield. This caused the decline of groundwater table in the well resulting in frequent ON-OFF pump operation. Other well pumps might be affected each other because of such frequent change of operational status causing change of pressure in the conveyance pipe.

Pumps installed in the Booster Pump Station (BPS) are utilized as distribution pumps. Therefore the clearwater reservoir should act as a distribution reservoir, but its capacity is 1.86 MG with retention time of 4.4 hours against the plant capacity of 15 MGD. As shown in Table 4.1-10, when four units of pumps are operated, the clearwater reservoir becomes empty within five or six hours so that pumps must be stopped for recovery of the water level. As a result, pumps are forced to be operated intermittently, five to six hours during daytime and nine hours in nighttime. In principle, pumps shall be operated based on water demand fluctuation in the service area designated to fit against water distribution capacity and continuous pump operation with two or three units shall be conducted.

Table 4.1-9 Inflow of Kalurghat Iron Removal Plant in February 2000

Date	No.1 Inflow (gal/day)	No.2 Inflow (gal/day)	T.W.No.19 (m3/day)	T.W. No.20 (m3/day)	T.W. No.1 (m3/day)	Tubewell Total (m3/day)	Tubewell Total (gal/day)	Total (gal/day)	Total (m3/day)	No.1 Meter Indicator (gal)	No.2 Meter Indicator (gal)	T.W. No.19 Indicator (m3)	T.W. No.20 Indicator (m3)	T.W. No.1 Indicator (m3)
1	-	-	-	-	-					330,545,092	160,012,429	2,827,631	2,341,510	610,644
2	3,303,557	3,080,407	4,619	3,517	1,555	9,691	2,131,952	8,515,916	38,710	333,848,649	163,092,836	2,832,250	2,345,027	612,199
3	2,773,049	2,681,762	5,040	6,755	1,379	13,174	2,898,187	8,352,998	37,969	336,621,698	165,774,598	2,837,290	2,351,782	613,578
4	2,469,691	3,237,754	5,004	3,000	1,555	9,559	2,102,913	7,810,358	35,503	339,091,389	169,012,352	2,842,294	2,354,782	615,133
5	3,985,511	3,035,558	6,319	1,456	1,150	8,925	1,963,437	8,984,506	40,840	343,076,900	172,047,910	2,848,613	2,356,238	616,283
6	3,089,947	3,002,976	3,599	2,492	1,560	7,651	1,683,166	7,776,089	35,347	346,166,847	175,050,886	2,852,212	2,358,730	617,843
7	3,078,870	2,990,942	5,002	3,497	1,560	10,059	2,212,909	8,282,721	37,650	349,245,717	178,041,828	2,857,214	2,362,227	619,403
Avg.	3,116,771	3,004,900	4,931	3,453	1,460	9,843	2,165,427	8,287,098	37,670					
8	2,797,365	2,709,857	4,935	3,453	1,438	9,825	2,161,431	7,668,653	34,859	352,043,082	180,751,685	-	-	-
9	2,301,224	2,223,977	4,935	3,453	1,438	9,825	2,161,431	6,686,631	30,395	-	-	-	-	622,278
10	2,301,224	2,223,977	4,935	3,453	1,550	9,938	2,186,180	6,711,381	30,507	356,645,529	185,199,639	2,872,018	-	623,828
11	2,528,812	2,448,665	4,955	3,453	1,464	9,872	2,171,818	7,149,295	32,498	359,174,341	187,648,304	2,876,973	-	-
12	2,468,327	2,392,374	4,788	3,453	1,464	9,705	2,135,079	6,995,780	31,800	361,642,668	190,040,678	2,881,761	-	-
13	2,437,000	2,269,550	4,922	3,453	1,464	9,839	2,164,494	6,871,044	31,233	364,079,668	192,310,228	-	-	-
14	2,388,012	2,404,393	4,922	3,453	1,464	9,839	2,164,494	6,956,899	31,623	366,467,680	194,714,621	-	-	-
15	2,419,759	2,343,620	4,922	3,453	1,464	9,839	2,164,494	6,927,873	31,491	368,887,439	197,058,241	-	-	-
16	2,312,254	2,245,647	4,922	3,453	1,464	9,839	2,164,494	6,722,395	30,557	371,199,693	199,303,888	-	-	-
17	2,060,245	2,002,501	4,922	3,453	1,464	9,839	2,164,494	6,227,240	28,307	373,259,938	201,306,389	-	-	-
18	2,297,494	2,211,898	4,922	3,453	1,464	9,839	2,164,494	6,673,886	30,337	375,557,432	203,518,287	-	-	-
19	2,300,254	2,268,648	4,922	3,453	1,464	9,839	2,164,494	6,733,396	30,607	377,857,686	205,786,935	-	-	-
20	2,373,209	2,302,303	4,922	3,453	1,464	9,839	2,164,494	6,840,006	31,092	380,230,895	208,089,238	-	-	-
21	981,040	950,986	4,922	3,453	1,464	9,839	2,164,494	4,096,520	18,621	381,211,935	209,040,224	-	-	-
22	2,432,460	2,365,727	4,922	3,453	1,464	9,839	2,164,494	6,962,681	31,650	383,644,395	211,405,951	-	-	-
23	2,370,600	2,313,574	4,922	3,453	1,464	9,839	2,164,494	6,848,668	31,131	386,014,995	213,719,525	-	-	-
24	2,205,300	2,147,070	4,922	3,453	1,464	9,839	2,164,494	6,516,864	29,623	388,220,295	215,866,595	-	-	-
25	2,200,388	2,144,942	4,922	3,453	1,464	9,839	2,164,494	6,509,824	29,591	390,420,683	218,011,537	-	-	-
26	2,221,447	2,171,775	4,922	3,453	1,464	9,839	2,164,494	6,557,716	29,809	392,642,130	220,183,312	-	-	-
27	2,374,180	2,321,718	4,922	3,453	1,464	9,839	2,164,494	6,860,392	31,185	395,016,310	222,505,030	-	-	-
28	2,244,620	2,197,578	4,922	3,453	1,464	9,839	2,164,494	6,606,692	30,031	397,260,930	224,702,608	-	-	-
29	2,370,009	2,331,252	4,922	3,453	1,464	9,839	2,164,494	6,865,755	31,209	399,630,939	227,033,860	-	-	-
Avg.	2,290,237	2,226,911	4,919	3,453	1,466	9,838	2,164,197	6,681,345	30,241					

Note: adopted average value of one week in past record.

During first 7 days, inflow to new filters with a capacity of 5MGD was stopped. Therefore, total flow indicates all flow to the IRP. For remaining days, inflow to the old plant is indicated.

Table 4-1-10 Distribution from Kalurghat Booster Pump Station

Date	Time	Kalurghat Booster Pump Station													Mohara WTP		
		Pump (A)				Pump Pressure (psi)				Total Pump Pressure		Clearwater	Flow		Pressure	Flow	Pump
		N0.1	N0.2	N0.3	N0.4	N0.1	N0.2	N0.3	N0.4	(psi)	(kg/cm2)	Level (m)	(m3/h)	Remarks	(kg/cm2)	(m3/h)	duty
21-Feb	0:00	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
	1:00	350	280	340	350	87	85	90	90	65	4.6	2.95	4,841		6.1	-	3
	2:00	350	280	340	350	87	85	90	90	67	4.7	2.54	4,841		6.1	-	3
	3:00	350	280	340	350	87	85	90	90	67	4.7	2.13	4,841		6.1	-	3
	4:00	350	280	340	350	87	85	90	90	67	4.7	1.73	4,841		6.1	-	3
	5:00	350	280	340	350	87	85	90	90	67	4.7	1.37	4,841		6.1	-	3
	6:00	350	280	340	350	87	85	90	90	65	4.6	1.02	4,841		6.1	-	3
	7:00	350	280	340	350	87	85	90	90	60	4.2	0.66	4,841	7:00Pump Stop	5.5	-	3
	8:00	-	-	-	-	-	-	-	-	-	-	1.22	-		5.5	-	3
	9:00	-	-	-	-	-	-	-	-	-	-	1.68	-		3.3	-	2
	10:00	-	-	-	-	-	-	-	-	-	-	2.13	-		3.3	-	2
	11:00	-	-	-	-	-	-	-	-	-	-	2.54	-		3.0	-	2
	12:00	-	-	-	-	-	-	-	-	-	-	3.00	-		3.0	-	2
	13:00	-	-	-	-	-	-	-	-	-	-	3.40	-	13:00Pump Start	3.4	-	2
	14:00	350	280	340	350	87	85	90	90	55	3.9	3.05	4,819		3.4	-	2
	15:00	350	280	340	350	87	85	90	90	55	3.9	2.54	4,787		3.7	-	2
	16:00	350	280	340	350	87	85	90	90	55	3.9	1.98	4,796		3.8	3,207	2
	17:00	350	280	340	350	87	85	90	90	55	3.9	1.63	4,437		3.8	3,085	2
	18:00	350	280	340	350	87	85	90	90	55	3.9	1.22	4,646	18:45Pump Stop	3.8	3,330	2
	19:00	-	-	-	-	-	-	-	-	-	-	1.02	3,660		3.8	3,382	2
	20:00	-	-	-	-	-	-	-	-	-	-	1.52	-		3.5	3,331	2
	21:00	-	-	-	-	-	-	-	-	-	-	2.13	-		3.5	3,163	2
	22:00	-	-	-	-	-	-	-	-	-	-	2.74	-		3.5	3,389	2
	23:00	350	280	340	350	87	85	90	90	65	4.6	3.35	-	23:30Pump Start	3.5	3,394	2
22-Feb	0:00	350	280	340	350	87	85	90	90	67	4.7	3.40	2,578		3.5	4,755	2
	1:00	350	280	340	350	87	85	90	90	67	4.7	3.00	4,819		6.2	4,638	3
	2:00	350	280	340	350	87	85	90	90	67	4.7	2.59	4,801		6.2	4,668	3
	3:00	350	280	340	350	87	85	90	90	67	4.7	2.18	4,791		6.2	4,641	3
	4:00	350	280	340	350	87	85	90	90	67	4.7	1.78	4,819		6.1	4,423	3
	5:00	350	280	340	350	87	85	90	90	65	4.6	1.37	4,864		6.1	4,476	3
	6:00	350	280	340	350	87	85	90	90	65	4.6	1.02	4,796		6.1	4,529	3
	7:00	350	280	340	350	87	85	90	90	60	4.2	0.71	5,005	7:00Pump Stop	5.2	4,534	3
	8:00	-	-	-	-	-	-	-	-	-	-	1.22	-		5.0	4,480	3
	9:00	-	-	-	-	-	-	-	-	-	-	1.68	-		3.2	2,947	2
	10:00	-	-	-	-	-	-	-	-	-	-	2.13	-		3.2	2,971	2
	11:00	-	-	-	-	-	-	-	-	-	-	2.59	-		3.4	3,217	2
	12:00	-	-	-	-	-	-	-	-	-	-	3.15	-	12:30Pump Start	3.4	2,980	2
	13:00	350	280	340	350	87	85	90	90	55	3.9	3.20	2,382		3.8	3,241	2
	14:00	350	280	340	350	87	85	90	90	55	3.9	2.69	4,942		3.8	2,967	2
	15:00	350	280	340	350	87	85	90	90	55	3.9	2.18	4,978		3.8	2,949	2
	16:00	350	280	340	350	87	85	90	90	55	3.9	1.68	4,814		4.0	3,208	2
	17:00	350	280	340	350	87	85	90	90	55	3.9	1.22	4,928		4.0	3,428	2
	18:00	350	280	340	350	87	85	90	90	55	3.9	0.81	4,487	18:00Pump Stop	4.0	-	2
	19:00	-	-	-	-	-	-	-	-	-	-	1.37	-		3.7	-	2
	20:00	-	-	-	-	-	-	-	-	-	-	1.83	-		3.7	-	2
	21:00	-	-	-	-	-	-	-	-	-	-	2.39	-		3.7	-	2
	22:00	-	-	-	-	-	-	-	-	-	-	2.95	-		3.7	-	2
	23:00	350	280	340	350	87	85	90	90	0	0.0	3.51	-	23:00Pump Start	3.5	-	2
23-Feb	0:00	350	280	340	350	87	85	90	90	60	4.2	3.20	4,401		2.4	-	1

(4) Water Supply Conditions of Kalurghat Distribution System

Though iron content of treated water is high in the Kalurghat system, treated water of the Mohara system, with less iron content, is mixed to the treated water in the Kalurghat distribution system eventually. Interconnection of distribution trunk main of the Kalurghat system with a diameter of 600 mm with that of the Mohara system with a diameter of 900 mm does this mixture operation. The connection valve installed on interconnection pipe between these two trunk mains is not fully opened to avoid the strong influence each other. However, as shown in Table 4.1-10, Pumps at both pumping stations are influenced each other. As the number of pumps on duty at the MWTP is changed, pressure of the Kalurghat BPS is fluctuated to cope with the pressure of the system influenced by the MWTP pump operation.

Pumps of the MWTP are continuously operated setting the shift of two units during daytime and three units in nighttime, while four pumps of the Kalurghat system is operated in intermittent basis observing water level in the clearwater reservoir. Because of such operation situation, stable water supply is not maintained in both systems due to the large fluctuation in water supply flow and pressure.

4.2 Water Distribution System

4.2.1 Water Supply Pipeline by Diameter and Service Areas

Major Transmission and distribution pipelines in Chittagong City was installed from 1966 to 1979 under the World Bank's First Chittagong Water Supply and Sanitation Project. In the 1st project, AC Pipe was adopted as pipe material and DI Pipe was employed in the 2nd Project. For smaller pipes with diameter less than 300 mm, PVC Pipe has been applied recently. Total pipe length of the existing pipelines is 543 km. Pipe length and pipe materials by diameter are shown in Table 4.2-1.

Existing major water sources of the Chittagong water supply system are the Kalurghat IRP and the Mohara WTP. Several semi-isolated small-scaled systems with groundwater wells are scattered in the study area, especially in the city center area and fringe area. Location of those systems, routes of major trunk mains and service areas are as shown in Figure 4.2-1. Both of major systems, i.e. the Kalurghat system and the Mohara system, have an integrated structure without dividing into small service blocks. Even in the case of small-scaled elevated tank, distribution volume is controlled by open – close operation of supply valve, without delineating specific service block. At present, under the absolute water supply capacity shortage, valve operation is executed allopathic basis depending on end-users' request.

Table 4.2-1 Transmission and Distribution Pipes of Chittagong WASA

Diameter (mm)	Material	Length (m)	Remarks
1,200	DI	1,570	Mohara WTP～Arakan road
900	DI	10,325	Arakan road～Battali Hill Reservoir
750	DI	1,910	ADC Hill Reservoir～Patenga B.P.S.
600	DI	11,108	Battali Hill Rsvr.～ADC Hill Rsvr., ～Dhaka B.P.S., ～Patenga B.P.S.
	AC	13,060	
450	DI	1,123	
	AC	23,894	
	PVC	4,000	
300	DI	5,523	
	AC	46,417	
	PVC	6,280	
200	AC	17,720	
	PVC	66,260	
150	AC	18,920	
	PVC	62,180	
100	AC	8,720	
	PVC	243,990	
Total		543,000	

Source: CWASA, as of June 2000

In North Halishahar and Rampur Districts, located in south of the Dhaka Trunk Road BPS, are always suffered by chronic water shortage due to rapid population growth. Accounting Friday's day off of Chittagong Export Processing Zone (CEPZ), one of the largest consumer served by the Patenga BPS, water is sent to the said two districts from the Patenga BPS from Thursday's night to Friday's night by valve operation. Such arrangement is possible because many families have ground storage tank with a capacity of 10 m^3 or more on the premise of "intermittent water supply". System development status and water distribution operational status in Chittagong WASA are as follows:

(1) Kalurghat System

Distribution pumps installed at the Kalurghat BPS directly supply the treated water.

Distribution trunk main from the Kalurghat BPS having a diameter of 600 mm is connected to the Battali Hill reservoir (capacity: 3 MG or 13,600 m^3), the largest reservoir of the Chittagong water supply system. Since the Battali Hill reservoir is working as a balancing tank, single connection pipe with a diameter of 600 mm is used as inlet and outlet pipe, while the ADC Hill Reservoir (capacity: 1 MG or 4,545 m^3), the second largest reservoir of the system, is not connected with the Kalurghat system. From this distribution trunk main, more two semi-trunk mains with a diameter of 450 mm are extended to the Dhaka Trunk Road BPS and the Patenga BPS, respectively.

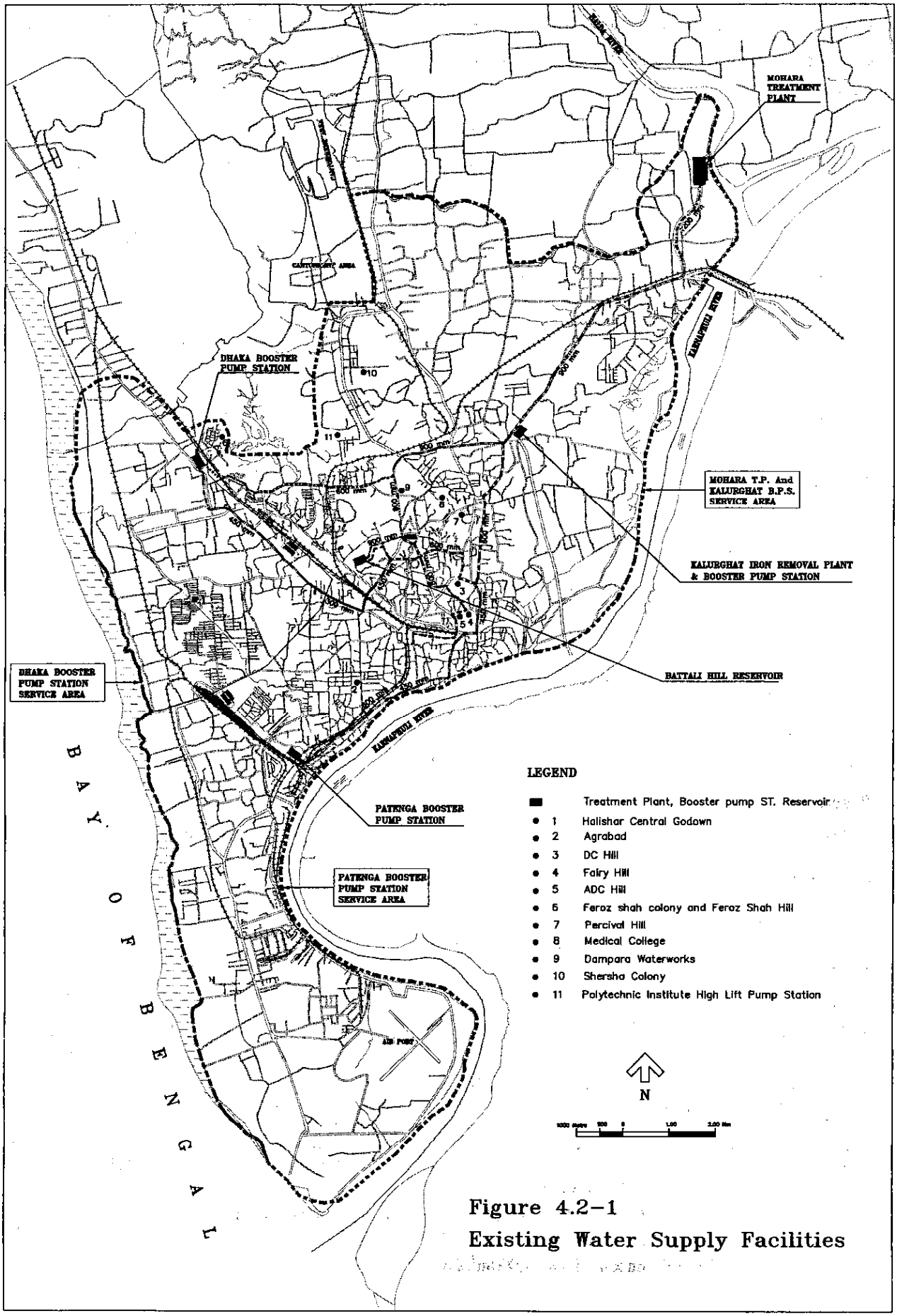


Figure 4.2-1
Existing Water Supply Facilities

However, currently, treated water is directly supplied by pumps from the Kalurghat BPS without utilizing the Battali Hill reservoir because of low working pressure in the system. Further, at the Bahaddarhat road crossing, intersection of the Arakan Road and the Asian Highway, interconnection pipe with a diameter of 450 mm connect the Kalurghat trunk main with the transmission trunk main from the Mohara WTP with a diameter of 900 mm. Treated water of the Mohara WTP is mixed with treated water of the Kalurghat System and directly distributed. However, Opening of connection valve is small. Besides of this interconnection, several interconnection valves connect the Kalurghat system with the Mohara transmission trunk main.

Major consumers are concentrated in the center of the city, namely in Chawk Bazar, Jamal Khan district. Distribution pipelines are also installed in areas along with Dhaka Trunk Road, coastal areas and CEPZ served by the Patenga BPS, but supplied water volume is not sufficient.

Four units of distribution pump is operated in the Kalurghat BPS, other one unit is for stand-by. But intermittent pump operation has been forced due to capacity shortage of the existing clearwater reservoir and production amount. Thus, some of treated water from the Mohara System is mixed during operation of pumps at the Kalurghat BPS, and only the water from the Mohara System is supplied when pumps are not operated.

(2) Mohara System

The Mohara System was planned and implemented aiming to send treated water to the Battali Hill Reservoir, the ADC Hill reservoir, the Dhaka Trunk Road BPS, and the Patenga BPS. By operation of four units of pumps out of five, one unit is for stand-by, whole design distribution flow can be pumped up to the Battali Hill reservoir with HWL of +51.5 m (refer to Table 4.2-2).

Table 4.2-2 Calculation of Pump Head

Diameter (mm)	Inner Diameter (mm)	Length (m)	Hydraulic Gradient (I)	Friction Coefficient (C)	Friction Loss (m)	Battali Hill Reservoir HWL (m)	Mohara WTP Pump Suction Head (m)	Required pump Head	
								(m)	(ft)
1200	1204.4	1,570	0.000793	110	1.244		2.45		
900	903.8	10,325	0.003209	110	33.128	51.5		83.4	274
Total					34.372				

Notes: Q = 90,918m^3/day = 1.052m^3/sec (20MGD)
Surplus Head of Reservoir H= 0m
400mm x 300mm x 3,475 GPM x 271ft x 350kw x 5units （1 stand-by）
3,475GPM = 15.80m^2/min
15.80m^2/min x 4units = 91,000m^3/day

A 1,570 m long transmission pipeline with a diameter of 1,200 mm was installed from the WTP to the Arakan Road, and it changes to 900 mm from the Arakan Road to the Battali Hill Reservoir with a length of 10,325 m. A 600 mm diameter diversion pipeline is also provided from above transmission pipe to the ADC Hill reservoir.

There are five diversion points along the said transmission pipeline and all the diversion pipes are connected to the existing network. Two of them are connected to the existing booster pump stations: One has diameter of 600 mm and is connected to the existing pipe in front of the Dhaka Trunk Road BPS, via the Zakir Hossain Road and the Dhaka Trunk Road. Another has a diameter of 600 mm and reaches to the existing pipe in front of the Patenga BPS via the ADC Hill reservoir, the Ice Factory Road, the Dhaka Trunk Lane and the Strand Road.

Two other diversion pipes with diameter of 300 mm are connected to the existing network along the Hathazari Road in the West Sholashahar district and along the Baizid Bastami Road in the Sulakbahar district, respectively.

Remaining one is an interconnection pipe to the Kalurghat system, as described previously. Thus, the Mohara system was developed to supplement Kalurghat system.

Presently, the Mohara WTP directly supplies treated water by high lift pumps without passing the Battali Hill Reservoir. During daytime two units of pumps are operated while three units are operated in nighttime, from PM 11:00 or 12:00 to AM 8:00.

To cope with the fluctuation of distribution flow, such irregular plant operation has been forced with continuous monitoring of water level in the clearwater reservoir.

By this irregular plant operation, water pressure in areas, where originally to be served by reservoir by gravity, is reduced and areas suffered by water supply interruption has been expanding. In addition, distribution without reservoir cannot cope with peak demand and areas suffered by water supply interruption has also been expanding.

Presently, areas annoyed by water supply interruption during the daytime are served in nighttime by three-pump operation arrangement, but due to the absolute shortage in water supply capacity, there is no drastic improvement in terms of water supply interruption.

Excluding some specific areas, the service area of the Mohara and Kalurghat System spreads over plain terrain with elevation of about 5 m, more or less. Water demand is far larger than actual water

supply capacity so that areas located at the end of distribution pipelines or fringe areas of service area cannot receive sufficient volume and water supply interruption occurs frequently during the period when areas near to the WTP are receiving sufficient water. Therefore, transmission and distribution pumps in both systems are operated in lower head and larger discharge.

Water pressure at junction point of the transmission pipe of the Mohara system and the distribution pipe of the Kalurghat system are; the Mohara System, 20 m with operation of two units of pump or 30 m with operation of three units; the Kalurghat System, 15 m and 20 m being affected by pump operation of the Mohara System. Ordinary, water pressure of the Mohara System is higher than the Kalurghat system, and therefore treated water in the Mohara system flows into the distribution pipe of the Kalurghat system. Difference of this water pressure is 5 to 10 **m** when distribution pumps of the Kalurghat System is operated, but when they are not working, it rises up to 20 m.

This means that high lift pumps at the Mohara WTP cannot be operated with enough water pressure to transmit water to the Battali Hill reservoir and the ADC Hill reservoir.

(3) Small-scale Water Supply Systems

Excluding the Mohara and the Kalurghat systems, several small-scale water supply systems are also utilized. Those are served with groundwater. Typical system is represented by a well and a ground reservoir or an elevated tank installed in higher elevation and water supply by gravity. Most of them were constructed during the age of East Pakistan and no drawings are available. Most of groundwater pumped by the existing wells contains high iron (refer to the clause of "Groundwater Quality" for details). In the past, there was an accident caused by chorine cylinder so that chlorine disinfection has not been practiced since then and sanitary condition is unfavorable. There are some tanks with remarkable water leakage and some of them have structural defects.

1) Halishahar Central Godown

Two tube wells are utilized. Pumped groundwater is once stored in a ground reservoir, and then pumped to an elevated tank. Water is supplied by gravity.

Tube Well:	Halishahar 1
	Halishahar 2
Ground Reservoir:	50,000 Gallon or 227 m^3
RC Elevated Tank:	100,000 Gallon or 454 m^3
Distribution Pipe:	Less than 200 mm dia.

The ground reservoir and the RC elevated tank are utilized. Site has an enough area and used as material stockyard.

2) Agrabad

Two of three tube wells are utilized. Groundwater is directly pumped to an elevated tank and then supplied by gravity.

Tube well:	Agrabad 1
	Agrabad 2 (abandoned)
	Agrabad 3
Elevated Tank:	125,000 Gallon or 568 m^3
Distribution Pipe	Less than 300 mm dia.

3) DC Hill

Groundwater is pumped to an elevated tank on the DC Hill from a tube well at the Love Lane and supplied by gravity.

Tube well:	Love Lane
Elevated Tank:	100,000 Gallon or 454 m^3
Distribution Pipe:	Less than 300 mm dia.

4) Fairy Hill

Groundwater had been pumped to two elevated tanks in Fairy Hill from tube wells of Jubilee and Collegiate School but they are abandoned. One of the tanks was abolished and another is abandoned.

Tube well:	Jubilee
	Collegiate School 1
	Collegiate School 2
Elevated Tank:	100,000 Gallon or 454 m^3 （Abolished）
	175,000 Gallon or 795 m^3 （Abandoned, can be utilized）
Distribution Pipe:	Less than 300 mm

5) ADC Hill

Groundwater is temporarily pumped from wells at Jubilee and Goalpara to the ground reservoir located on the ADC hill. Water is supplied from the reservoir by gravity. Instead of said Fairly Hill reservoir, this reservoir has been operated.

Tube well:	Jubilee
	Goalpara
Ground Reservoir:	1,000,000 Gallon or 4,545 m^3

Distribution Pipe: Less than 300 mm

6) Ferojshah Colony and Ferojshah Hill

Groundwater is pumped from wells in Ferojshah Colony to a ground reservoir installed in the halfway of the hill, then pumped up to another reservoir on top of the hill. Water is supplied by gravity from these reservoirs.

Tube well:	Ferojshah Colony No. 1
	Ferojshah Colony No. 2
Ground Reservoir:	No. 1 10,000 Gallon or 45 m^3
	No. 2 50,000 Gallon or 227 m^3
Distribution Pipe	Less than 300 mm

Since water leakage was detected at ground reservoirs, they shall be repaired.

7) Percival Hill

Treated water from the Kalurghat system is sent to the receiving chamber and then is pumped to an elevated tank on the Percival Hill. Water is supplied by gravity.

Ground Reservoir:	15,000 Gallon or 68 m^3
Elevated Tank:	100,000 Gallon or 454 m^3
Distribution Pipe:	Less than 300 mm

8) Medical College

Water from the Kalurghat system flows into a receiving tank, and then it is pumped to a ground reservoir installed on the hill. An aeration tower, which seems to be operated in the past, was abandoned. Water is supplied by gravity to the College Hostel and Staff Quarters.

Aeration Tower:	10,000 Gallon or 45 m^3 (Abandoned)
Ground Reservoir:	100,000 Gallon or 454 m^3
Distribution Pipe:	Less than 300 mm

9) Dampara Waterworks

Water from the Kalurghat System and nearby Almas T.W. are sent to a ground receiving tank and is directly supplied to Lalkhan Bazar old System covering Lalkhan Bazar and adjacent area..

Ground Reservoir:	100,000 Gallon or 454 m^3
Distribution Pipe:	Less than 300 mm

10) Shersha Colony

Although groundwater has been pumped from wells in Baizid to a ground reservoir constructed on the hill, the ground reservoir was abandoned with broken roof.

Ground Reservoir 15,000 Gallon or 68 m^3 (abandoned)

Distribution Pipe Less than 200 mm

This facility cannot be utilized.

11) Polytechnic Institute High Lift Pump Station

Groundwater is pumped from a tube well to an elevated tank and then supplied by gravity. Jurisdiction of Chittagong WASA covers up to the ground reservoir and the remaining high lift pump and the elevated tank is owned by the Ministry of Education and managed by Polytechnic Institute.

Tube well: Polytechnic

Ground Reservoir: 100,000 Gallon or 454 m^3

The ground reservoir can be utilized. While, the RC elevated tank has many concrete cracks in columns and beams, and heavily deteriorated so that it needs re-construction as soon as possible.

4.2.2 Reservoir and Booster Pump Station

Among the existing reservoirs, the Battali Hill Reservoir has the largest storage volume of 3 MG (13,636 m^3), followed by the ADC Hill Reservoir having 1 MG (4,545m^3). Others are small, namely; Agrabad elevated tank with 0.125 MG (568m^3) and other elevated tanks and ground reservoirs have volumes of less than 0.1 MG (454 m^3). Storage capacity and water level of each reservoir and elevated tank are as shown in Table 4.2-3. There are two existing booster pump stations, namely, the Dhaka Trunk Road BPS and the Patenga BPS, having in-line boost structure without receiving tank, wet well or reservoir. Current status of these facilities is as follows:

Table 4.2-3 Reservoir and Elevated Tank

Reservoir Name			Capacity		Water Level		Remarks
			Gallon	m3	HWL(m)	LWL(m)	
1	Mohara T.P.		2,500,000	11,364	4.9	2.75	
2	Kalurghat IRP & BPS		2,000,000	9,092	3.32	0.0	
3	Halishahar Central Godown						
3-1	Tank 1	RC Elevated Tank	100,000	455	29.3	24.7	in use
3-2	Tank 2	RC Ground Reservoir	50,000	227	10.0	NA	in use
4	Agrabad	RC Elevated Tank	125,000	568	25.3	21.9	in use
5	DC Hill	RC Elevated Tank	100,000	455	48.8	43.9	in use

6	Fairy Hill						
6-1	Tank 1	RC Elevated Tank	100,000	455	40.5	36.0	Not in use at ADC Hill R.
6-2	Tank 2	SS Elevated Tank	175,000	796	36.1	28.8	No Tank at ADC Hill Re.
7	ADC Hill	Ground Type	1,000,000	4,546	38.1	33.5	in use with 3 tube wells
8	Ferojshah Hill	RC Ground Reservoir	50,000	227	46.0	NA	in use
9	Ferojshah Colony	RC Elevated Tank	10,000	45	15.0	NA	in use
10	Battali Hill	RC Ground Reservoir	3,000,000	13,638	51.5	42.7	in use
11	Percival Hill	RC Elevated Tank	100,000	455	42.7	38.1	in use
12	Medical College						
12-1	Water Tower	RC Elevated Tank	10,000	45	25.0	NA	in use
12-2	Reservoir	RC Ground Reservoir	100,000	455	43.6	40.2	in use
13	Dampara Waterworks	RC Ground Reservoir	100,000	455	15.0	NA	in use at CWASA Office
14	Shershah Colony	RC Ground Reservoir	15,000	68	NA	NA	Not in use
15	Parada Comer	RC Ground Reservoir	15,000	68	9.0	NA	in use
16	Polytecnic Institute High Lift Pump Station		100,000	455	15.0	NA	
	Total		10,150,000	46,142			

(1) Battali Hill Reservoir

Distribution trunk main of the Kalurghat system with a diameter of 600 mm and that of the Mohara system with a diameter of 900 mm is connected to the Battali Hill Reservoir. These pipelines are supposed to be used as inlet – outlet pipe and the Battali Hill Reservoir was planned and installed as a "balancing tank" for both systems. However, the Battali Hill Reservoir is not operated due to the following reasons:

- To cope with large water demand in the service area, distribution pumps in both systems are operated in low head and large discharge position in their pump characteristic curve. As a result, pumped water cannot reach to the Battali Hill Reservoir with HWL of +51.5 m.
- Further, it seems that the Battali Hill Reservoir, rectangular reservoir with a depth of 9 m, has structural defects. According to CWASA, heavy water leakage was detected during running test of the reservoir so that the leakage points were repaired. But reservoir has not been used since then. CWASA requested the Bangladesh University of Engineering & Technology, Dhaka (BUET) to investigate possibility of future utilization of the reservoir based on the existing drawings showing the results of crack investigation. Field investigation was done in April and the tentative evaluation result is given in May that the reservoir is possible to be used provided that some repair work is needed. Detailed report with recommendable repair method and cost estimates has not been prepared. CWASA requested BUET to issue them by the end of the year 2000.

(2) ADC Hill Reservoir

Transmission pipeline of the Mohara system is connected to the ADC Hill Reservoir but pumped water does not reach to the reservoir due to low pumping head, as same as the case of the Battali Hill Reservoir. Groundwater produced from existing two wells, named Jubilee, and Goal Para, has been pumped up to the ADC Hill Reservoir temporarily. However, since total production volume of these wells is small, said reservoir has not been displaying its full capacity. This reservoir shall be utilized through the future.

(3) Reservoirs and Elevated Tanks of Small-scaled Water Supply Systems

Large part of the service area has plain terrain, but some hilly inhabited areas also scattered in the service area. Several small-scale reservoirs and elevated tanks were installed to serve these hilly areas. These existing facilities, even though their scales are small, are playing important roles to serve elevated areas. Since ensuring of appropriate elevated open spaces for water supply facilities within the service area is difficult, as far as there is no structural defect, they shall be used through the future. Based on visual investigation, most of the existing reservoirs and elevated tanks are still operational and have been used actually as stated in sub-section 4.2.1.

(4) Booster Pump Station

There are two existing Booster Pump Stations, called as the Dhaka Trunk Road Booster Pump Station and the Patenga Booster Pump Station. Both BPS are In-line type and used for distribution purpose. Location of these BPSs and their service areas are shown in Figure 4.2-1. The Dhaka Trunk Road BPS is serving districts called Kattali, Saraipara, North Halishahar and North Agrabad, covering eastern zone of whole service area, while the Patenga BPS is supplying water to Middle and South Halishahar including the Chittagong Export Processing Zone.

However, service area covered by the Dhaka Trunk Road BPS has been suffered by chronic water shortage due to excessive demand increase caused by rapid population growth. Consequently, pumped water from the Patenga BPS is converted to this area by valve operation in every Friday, the day off of the Chittagong Export Processing Zone.

The Patenga BPS also cannot supply sufficient water to the Chittagong Export Processing Zone and other service areas, and therefore many complaints arise from consumers. Pump specifications of both Booster Pump Stations are shown below:

Table 4.2-4 Pump Capacity of Booster Pump Station

Name of Pump Station	Pump Capacity
Dhaka Trunk Road Booster Pump Station	200 mm × 327.6 - 595.2 m^3/h × 57.9 - 44.2 m × 90 kW × 3 units (1 standby)
Patenga Booster Pump Station	200 mm × 389 - 526 m^3/h × 39.6 - 33.5 m × 75 kW × 3 units (1 standby)

CHAPTER 5

STUDY ON WATER SOURCES

CHAPTER 5 STUDY ON WATER SOURCES

5.1 Water Quality Analysis

5.1.1 Water Quality Analysis for Mohara Water Treatment Plant

The intake facility of MWTP is located on the right bank of the Halda River. The water quality survey for MWTP was carried out to confirm the appropriateness of the Halda River as a water source for water supply. The water sampling was carried out both for the raw water in the river and for the treated water at MWTP.

The water sampling was carried out both in the dry and rainy seasons. The sampling time was as follows:

(1) Sampling time in the dry season

(a) Raw water in the river in front of the intake

- At the highest tidal time (14:15) on February 21, 2000 (spring tide)
- At the highest tidal time (12:00) on March 2, 2000 (neap tide)

(b) Treated water in the MWTP office

- Two (2) hours after sampling of the raw water

(2) Sampling time in the rainy season

(a) Raw water in the river in front of the intake

- At the highest tidal time (14:53) on August 17, 2000 (spring tide)
- At the highest tidal time (10:34) on August 10, 2000 (neap tide)

(b) Treated water in the MWTP office

- Four (4) hours after sampling of the raw water

Note: The sampling time of treated water is decided in consideration of approximate hour of treatment in MWTP. In the dry season, the de-silting basin is detoured.
The water sampling was conducted at the highest tidal time of a spring tidal day and a neap tidal day, in consideration of the possibility of salt-water intrusion.

The water quality analyses were carried out in two laboratories. The MWTP laboratory was mainly in charge of general and chemical items and the subcontractor's laboratory was in charge of heavy metals (Hg, Cu, Zn, Pb, Cr, Cd, As, F and CN).

The results of water quality analyses are summarized in Table 5.1-1 (results of the dry season) and Table 5.1-2 (results of the rainy season). As seen in the tables, the results between the dry season and the rainy season are basically not different. That is, the parameters of which value exceeds the standards are the same.

The results were compared with the Bangladesh Drinking Water Standard (BDWS) and also with the WHO standard as summarized as follows:

- All the heavy metals (As, Cd, Cr, Cu, Pb, Hg, Zn, CN) are within the standards.
- For the raw water, the parameters exceeding the standards (of drinking water) are Turbidity, Manganese, Suspended Solid (SS), DO, BOD, COD and Fecal Bacteria. However, as the raw water before the treatment, the water quality is good enough. But only the SS (over 50 mg/l) is slightly higher than the standard (of Japan: 25 or 50 mg/l depending on the treatment method).
- For the treated water, only Manganese slightly exceeds the standards (0.1 mg/l) but only once. The results of two times showed the limit value (the same as the standard limit) and another one time was within the standards. It may be no problematic issue as all the other parameters are within the standards. However, it is noted that the standard value of Manganese is 0.05 mg/l in Japan, 0.02 mg/l (Max. 0.05 mg/l) in UK. It was confirmed that the test results of Manganese are reliable as a checking test was carried out in another laboratory.

Table 5.1-1 Results of Water Quality Analyses for Mohara Water Treatment Plant (Sampling in Dry Season)

No.	Parameter	Unit	MWTP				BDWS	WHO DWS
			Raw Water*	Treated Water*	Raw Water**	Treated Water**		
1	Water Temp.	℃	25	24	26	25	-	
2	Conductivity	(μS/cm)	112	123			-	-
3	PH	-	7.5	7.1	7.8	7.2	6.5-8.5	-
4	Turbidity	NTU	24	0.68	30	0.8	10	5
5	T-Alkalinity	(mg/liter)	55	47	59	45	-	
6	Ca Hardness	(mg/liter)	40	35	40	42		
7	T-Hardness	(mg/liter)	70	75	60	70	500	-
8	NH_3-N (NH_3)	(mg/liter)	0.28	0.21	0.31	0.26	0.5	1.5
9	NO_3-N (NO_3)	(mg/liter)	0.41	0.18	0.53	0.22	44	
10	PO_4	(mg/liter)	1.38	1.09	1.42	1.28	6	-
11	SO_4	(mg/liter)	8.2	13	9.4	16	-	250
12	Chloride	(mg/liter)	7	6	7	6	600	250
13	Residual Chlorine	(mg/liter)	-	0.71	-	0.68	0.2	
14	T-Fe	(mg/liter)	0.58	0.21	0.52	0.19	1	0.3
15	Mn.	(mg/liter)	0.35	0.16	0.38	0.1	0.1	0.1
16	S.S.	(mg/liter)	58	-	57	-	10	
17	T.D.S.	(mg/liter)	-	136	-	129	1,000	1,000
18	D.O.	(mg/liter)	9.5	-	8.8	-	6	
19	B.O.D.	(mg/liter)	1.0	-	0.9	-	0.2	
20	C.O.D.	(mg/liter)	16	-	22	-	4	
21	Fecal Bacteria	(Col./100ml)	1800	0	2100	0		0
22	As	(mg/liter)	0.001	<0.001	<0.001	<0.001	0.05	0.01
23	Cd	(mg/liter)	<0.001	<0.001	N.D.	N.D.	0.005	0.003
24	Cr	(mg/liter)	0.009	0.005	0.004	0.004	0.05	0.05
25	Cu	(mg/liter)	0.70	0.60	0.40	0.35	1	1
26	Pb	(mg/liter)	0.009	<0.001	N.D.	N.D.	0.05	0.01
27	Hg	(mg/liter)	<0.001	<0.001	N.D.	N.D.	0.001	0.001
28	Zn	(mg/liter)	0.118	0.139	0.18	0.19	5	3
29	CN	(mg/liter)	<0.02	<0.02	<0.02	<0.02	0.1	0.07
30	F	(mg/liter)	0.30	0.15	0.20	0.19	1	1.5

Note: (Sampling Date) *: Feb.21, 2000, **: Mar. 2, 2000 BDWS: Bangladesh Drinking Water Standard (July 1991), N.D. = not detectable, WHODWS: Guidelines for Drinking Water Quality of WHO (1993)

Table 5.1-2 Results of Water Quality Analyses for Mohara Water Treatment Plant (Sampling in Rainy Season)

No.	Parameter	Unit	MWTP				BDWS	WHO DWS
			Raw Water*	Treated Water*	Raw Water**	Treated Water**		
1	Water Temp.	℃	29	28.5	29	28	-	
2	Conductivity	(μS/cm)	88	106	96	103	-	-
3	PH	-	6.95	7.21	7.03	7.18	6.5-8.5	-
4	Turbidity	NTU	90	0.9	300	1.0	10	5
5	T-Alkalinity	(mg/liter)	45	38	48	42	-	
6	Ca Hardness	(mg/liter)	25	26	28	26		
7	T-Hardness	(mg/liter)	46	42	56	50	500	-
8	NH_3-N (NH_3)	(mg/liter)	0.54	0.24	0.58	0.2	0.5	1.5
9	NO_3-N (NO_3)	(mg/liter)	0.32	0.25	0.42	0.3	44	
10	PO_4	(mg/liter)	1.38	1.31	1.48	1.2	6	-
11	SO_4	(mg/liter)	12	15	11.5	18	-	250
12	Chloride	(mg/liter)	7		9		600	250
13	Residual Chlorine	(mg/liter)	-	0.68	-	0.65	0.2	
14	T-Fe	(mg/liter)	0.48		0.48		1	0.3
15	Mn.	(mg/liter)	0.18	0.1	0.25	0.09	0.1	0.1
16	S.S.	(mg/liter)	58	-	57	-	10	
17	T.D.S.	(mg/liter)	-	112	-	10.8	1,000	1,000
18	D.O.	(mg/liter)	7.9	-	7.8	-	6	
19	B.O.D.	(mg/liter)	1.1	-	7.8	-	0.2	
20	C.O.D.	(mg/liter)	12	-	15	-	4	
21	Fecal Bacteria	(CoL/100ml)	1980	0	2250	0		0
22	As	(mg/liter)	<0.001	<0.001	<0.001	<0.001	0.05	0.01
23	Cd	(mg/liter)	<0.001	<0.001	N.D.	N.D.	0.005	0.003
24	Cr	(mg/liter)	0.04	0.014	0.024	0.006	0.05	0.05
25	Cu	(mg/liter)	0.05	0	0.10	0	1	1
26	Pb	(mg/liter)	N.D.	N.D.	0.01	N.D.	0.05	0.01
27	Hg	(mg/liter)	N.D.	N.D.	<0.001	N.D.	0.001	0.001
28	Zn	(mg/liter)	0.04	0.05	0.07	0.05	5	3
29	CN	(mg/liter)	<0.02	<0.02	<0.02	<0.02	0.1	0.07
30	F	(mg/liter)	0.25	0.29	0.13	0.05	1	1.5
31	Trihalomethanes	(mg/liter)	<0.001#	0.02#	-	-	-	-
32	THMFP	(mg/liter)	0.037#	-	-	-	-	-

Note: (Sampling Date) *: Aug.10, 2000, **: Aug. 17, 2000, #: Oct.20, 2000
BDWS: Bangladesh Drinking Water Standard (July 1991), N.D. = not detectable
WHODWS: Guidelines for Drinking Water Quality of WHO 1993）

Table 5.1-3 Analysis Results of Raw and Treated Water at Kalurghat Iron Removal Plant, and Well Water

No.	Source	Parameters			
		Turbidity (NTU)	Color (HAZEN)	T-Fe (mg/liter)	Arsenic (mg/liter)
1	KIRP Raw Water	28	110	5.3	0.004
2	KIRP Treated Water	5.2	35	1.4	0.002
3	TW 5	11	70	3.4	0.001
4	Love Lane TW	0.6	5-10	0.2	0.005
5	Shallow Well (TW 5)	12	90	3.8	0.002
6	Shallow Well (TW 11)	16	110	1.1	0.004
7	Shallow Well (Agrabad 1)	36	180	6.1	0.005
8	Distribution Pipeline (WASA point)	1.2	> 5	1.1	0.002
9	Mixed Water (2:1) MTWP & KIRP	1.4	>15	0.7	0.002
Bangladesh Drinking Water Standard		10	15	1.0	0.05
WHO Drinking Water Standard		5	15	0.3	0.01

Note, KIRP: Kalurghat Iron Removal Plant
CWASA has adapted 1.0 mg/liter from the range (0.3 mg/liter - 1.0 mg/liter) of T-Fe concentration in BDWS, which was confirmed in the meeting of March 15, 2000

5.1.2 Water Quality Analysis for Groundwater

To confirm safety of groundwater as water sources, quality of water in existing shallow and deep wells was analyzed. Selected deep wells for analysis are TW5 and Lave Lane TW managed and owned by CWASA, together with three shallow hand-pumps wells: Shallow Well (TW5) (located near TW5), Shallow Well (TW11) (near TW11), and Shallow Well (Agrabad I) (near Agrabad I TW).

In addition, raw and treated water at Kalurghat Iron Removal Plant (KIRP), sample water at a distribution pipeline, and water sample mixed both treated water from the MWTP and the KIRP with ratio of 2:1 were analyzed.

Sampling was carried out on February 21, 2000. Analysis items were T-Fe, Color, Turbidity, and Arsenic. The results of water quality analyses of groundwater are shown in Table 5.1-3.

Raw and treated water of the KIRP, shallow and deep groundwater from existing wells, distribution pipeline water, water sample mixed the treated water from the MWTP and the KIRP with ratio of 2:1 did not exceed in arsenic concentration standard of the Bangladesh. However, most water samples had excess in analysis parameters of turbidity, color, and T-Fe. As a result, it will be concluded that groundwater in this area has no arsenic contamination. On the other hand, most well water analyzed had high iron concentration resulting in higher color and turbidity than the BDWS.

5.2 Saltwater Intrusion

5.2.1 Past Records of Saltwater Intrusion

The saltwater intrusion to the Halda River and the Karnaphuli River has been a significant concern for water intake from these rivers. For water supply purpose, the chloride concentration of raw water is generally required to be less than 200 mg/l. It is generally difficult to reduce sufficiently this parameter by ordinary treatment methods.

The survey on saltwater intrusion (water quality) has been occasionally carried out since 1959. The report titled " Chittagong Water Supply Development Plan and Feasibility Study" prepared in 1979 by Parsons Overseas Company (in association with Engineering Science, Inc.) presents the conditions of saltwater intrusion as follows:

(a) Chloride concentration in 1960 in the Halda River

- April 25 - 30 : 575 – 962 mg/l (near Mardi Khal ; at daily highest tide)
  19 – 46 mg/l (at Sattarghat bridge; one hour after daily highest tide)
- May 12 : 3,025mg/l (near Mardi Khal; at daily highest tide)

124 mg/l (at Sattarghat bridge; one hour after daily highest tide)

Note: The Mardi Khal is located approximately 4.5 miles (7.2 km) upstream from the confluence with the Karnaphuli River, which is approximately 18.5 miles (29.6 km) from the river mouth.

The Sattarghat bridge is located approximately 13 miles (20.8 km) upstream from the confluence with the Karnaphuli River

(b) In 1961, no remarkable saltwater intrusion was observed near Mardi Khal.

(c) In 1962, the Kaptai power station started the operation by two units of generators.

(d) In 1966, some survey (all in the Karnaphuli River) show the following:

May – June (during high tide):

- 2 – 2,500 mg/l at 14.2 miles (22.7km) from the river mouth
- 4 – 300 mg/l at 15 miles (24km) from the river mouth
- 2 – 30 mg/l at 15.7 – 19.5 miles (25.1 – 31.2 km) from the river mouth

May 5 (no information of tide, but approximately 420 m^3/s from the Kaptai):

- 10,000 mg/l at 9.3 miles (14.9km) from the river mouth
- 3,200 mg/l at 12.5 miles (20km) from the river mouth
- 200 mg/l at 14.0 miles (22.4 km) from the river mouth

April 2 and 3 (no information of tide, but approximately 113 m^3/s from the Kaptai):

- 1,800 mg/l at 13.75 miles (22km) from the river mouth
- 380 mg/l at 15.4 miles (24.6km) from the river mouth
- 100 mg/l at 16.4 miles (26.4 km) from the river mouth
- 10 mg/l at 17.75 miles (28.4 km) from the river mouth

(e) From June 1977 to Jan. 1978, at Mohara WTP of the Halda River:

- 0 – 5 mg/l (during high tide):
- In May 1978, at Mohara WTP of the Halda River:
- 9 5 mg/l at Kalurghat Bridge, 17.9 miles (28.6km) in the Karnaphuli River from the river mouth
- 350 mg/l at 16 miles (25.6km) in the Karnaphuli River from the river mouth

The chloride concentration of intake water from the Halda River at the MWTP has been observed, together with the water level of the river in front of the intake, since 1995. According to the records, the normal concentration of chloride is in a range from 7 mg/l to 10 mg/l. However, the saltwater intrusion, with high chloride concentration, reached to the MWTP site occasionally as shown in Table 5.2-1.

Table 5.2-1 Records of High Chloride Concentration in Halda River at Intake Site of MWTP

Year	Month/day	Chloride Concentration (mg/liter)
1995	March 14 – March 18	50 – 875
1995	April 12 – April 17	56 – 450
1995	May 12 – May 20	22 – 6,800
1997	April 24 – April 30	55 – 210
1997	May 18 – May 22	23 – 1,000

Data Source: MWTP, CWASA

5.2.2 Survey for Saltwater Intrusion by JICA Study Team

The survey on saltwater intrusion in the Halda River was carried out as a part of the JICA study, although there are past records of chloride concentration. The survey was carried out both in the dry season and in the rainy season. The survey days are selected, during the site assignment periods of the engineer in charge, on February 22 (spring tide) and March 21 (neap tide) in the dry season and August 13 (equivalent to neap tide) and August 17 (spring tide) in the rainy season as summarized in Table 5.2-2.

Table 5.2-2 Time of Water Sampling

Date	Highest Tidal Time	Tidal Height	EC Measuring Hours
February 22, 2000	15:27	3.31 m	12:27 – 18:27
March 21, 2000	14:28	3.57 m	11:28 – 15:28
August 13, 2000	12:55	4.17 m	9:55 – 15:55
August 17, 2000	14:53	4.53 m	11:53 – 17:53

Note: Tidal height is the predicted daily highest water level at Sadarghat in the Karnaphuli River, by the Chittagong Port Authority

The survey was carried out hourly for three hours before and after the highest tidal time from a hired boat and by an EC measuring probe with a 20-m long cable. The measuring points were selected as shown in Table 5.2-3.

Table 5.2-3 EC Measuring Locations

In front of MWTP	Right bank side
Section A – A: at 100m downstream of MWTP	Right bank side
	Center
	Left bank side
Section B – B: at the confluence with the Karnaphuli River	Right bank side
	Center
	Left bank side

Note: The left/right bank side is located at a point approximately a quarter of the river width away from the riverbank.

The measuring points are located as shown in Figure 5.2-1. The river cross sections of Section A-A' and Section B-B' are roughly surveyed and the results are shown in Figure 5.2-2.

The EC measurement was carried out at every one-meter from the water surface (and 0.5 m from the surface in addition) to the bottom (close to the bottom).

The results of EC measurement during dry season are shown in Figures 5.2-5 to 5.2- 9. And those in rainy season are summarized in Table 5.2-4.

Table 5.2-4 Results of EC Measurement in Rainy Season by JICA Team

Unit : μS/cm (mg/l)

Location		Spring tide		Neap tide	
		Max.	Mini.	Max.	Mini.
At MWTP	Right bank side	N.A.	N.A.	N.A.	N.A.
Section A-A (100 m downstream from the intake)	Right bank side	135	60	139	103
	Center	136	61	151	110
	Left bank side	128	62	139	103
Section B - B (At the confluence with Kalnaphuli Ri.)	Right bank side	N.A.	N.A.	N.A.	N.A.
	Center	N.A.	N.A.	139	102
	Left bank side	N.A.	N.A.	N.A.	N.A.

Note: EC values show a range of records of 6 hours survey at a location.

No remarkable saltwater intrusion was observed at four times (two times in the dry season and two times in the rainy season) of survey. The major points identified from the EC measurement survey are as follows:

(a) The EC values varied from 117 to 203 μS/cm in dry season and 60 to 151 μS/cm in rainy season.

(b) The EC values during the high tide hours are nearly 180 - 200 μS/cm in rainy season and 100 - 130 μS/cm in rainy season.

(c) The EC values were relatively low, when the river flows to the downstream direction (ebb-flow). While, the EC values are relatively high when the flow direction is up (tide-flow) and the value were not changed remarkably by the water level changes during the time of tide-flow.

(d) In general, the EC values slightly increase toward a deeper point, but the increase rate from the surface to the bottom zone is mostly within 10%.

(e) The changes of EC values by the locations along the river (MWTP site, A-A section site, and B-B section site) are not remarkable. No definite change was found.

(f) The changes of EC values by the locations crossing the river (At the right side, the center, and the left side of the river) are not remarkable.

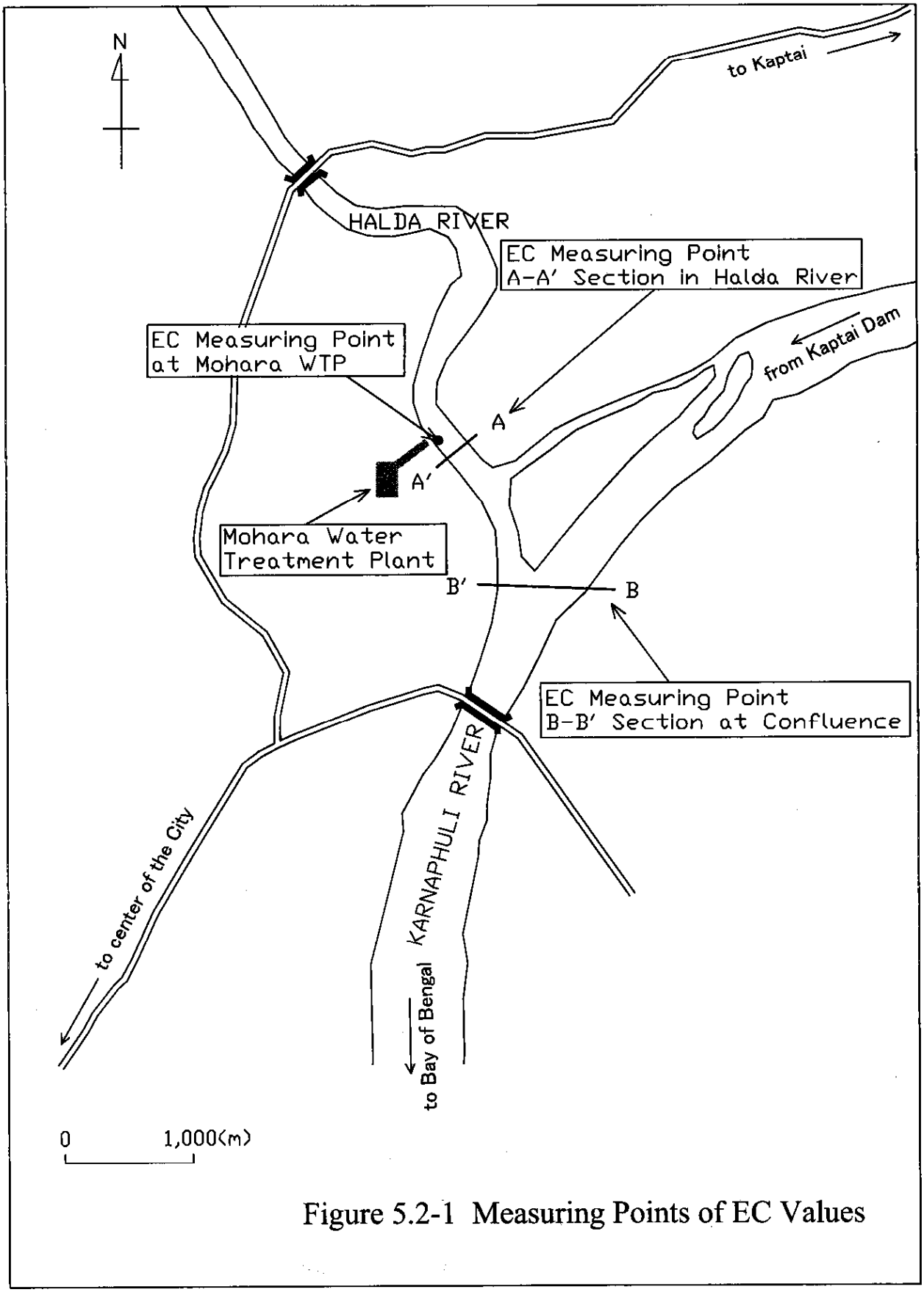
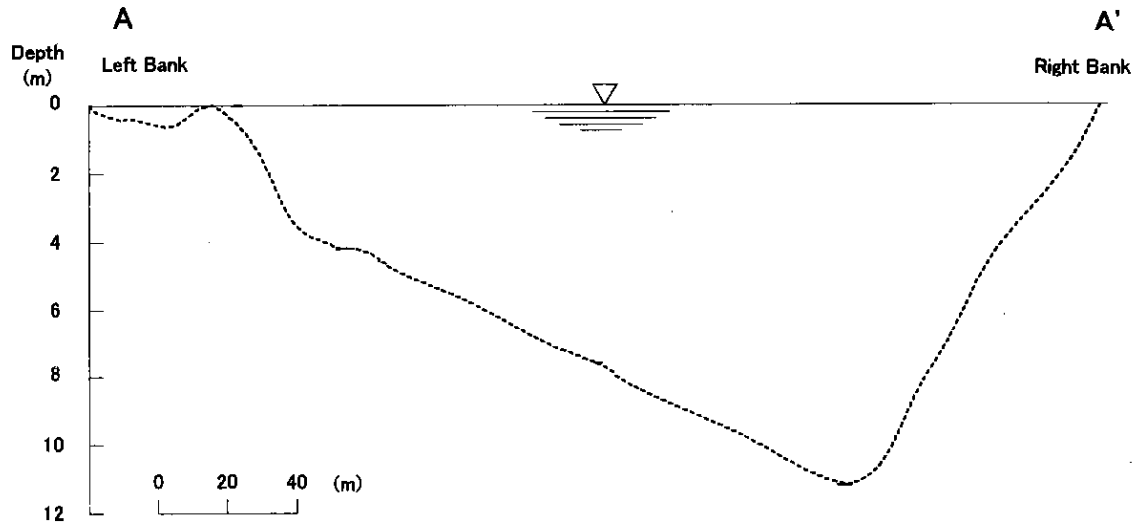
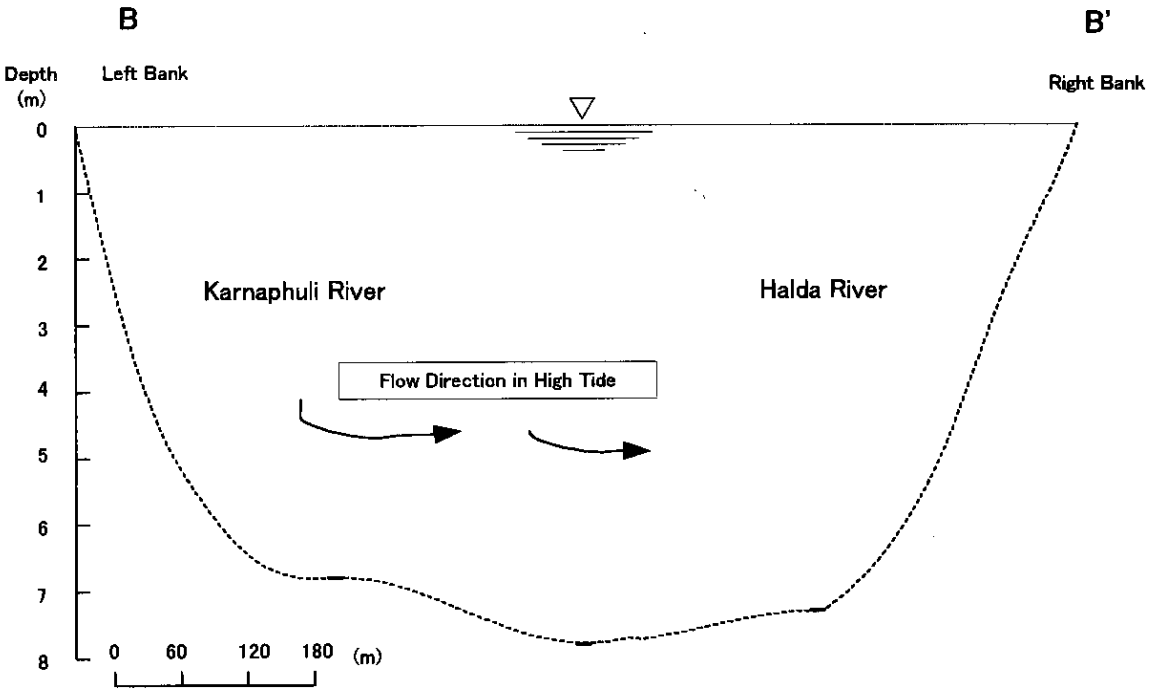


Figure 5.2-1 Measuring Points of EC Values



Cross Section in Halda River A – A'



Cross Section in Confluence Point B – B'

Figure 5.2-2 Cross Sections of Points A-A' and B-B'

(g) The salt-water intrusion at the MWTP was low enough for the raw water of water supply at least during the survey period. It is estimated that 100 μS/cm is equivalent to approximately 6 - 7 mg/l of chloride concentration from the laboratory test results of some samples. In this case, the chloride concentration was less than 20 mg/l at the maximum, which is sufficiently lower than the standard (200 mg/l).

It is noted that the timing of the EC measurement was not in a critical period (with less intrusion of saltwater). It would be necessary to carry out the EC measurement when the river flow is very low during the spring tide.

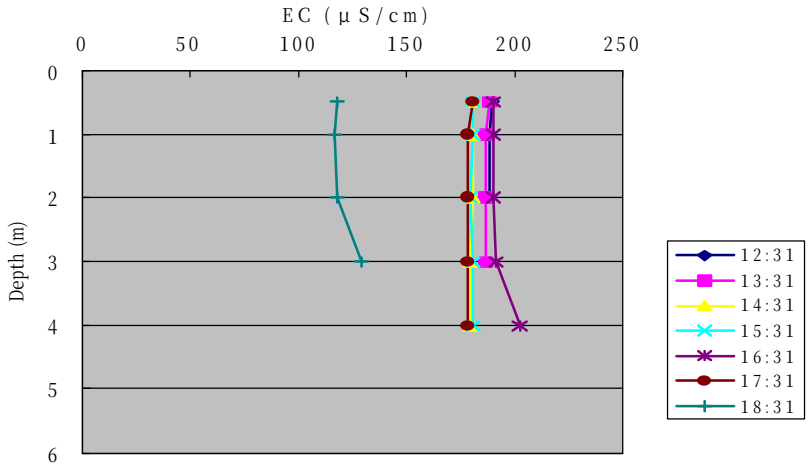


Figure 5.2-3 EC Measurement Results at MWTP Intake in Halda River (Measuring Date: Feb. 22, 2000)

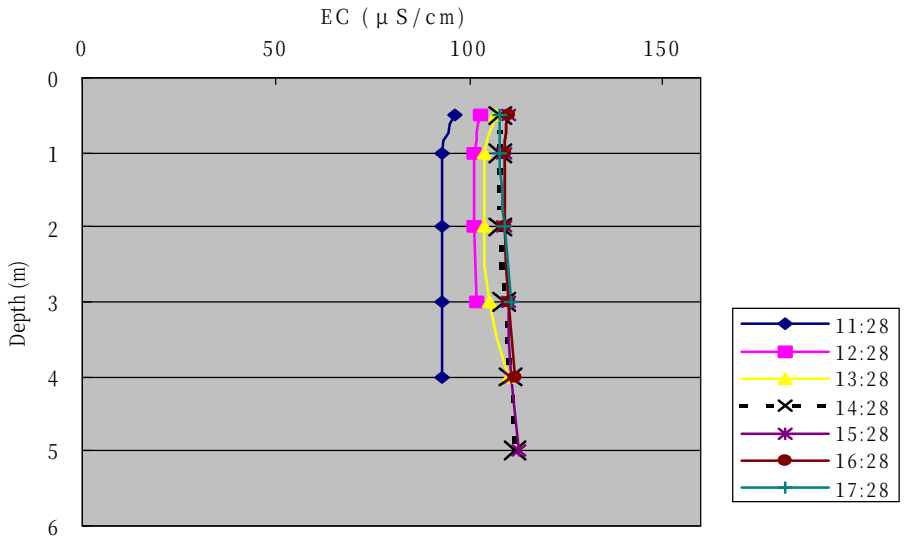


Figure 5.2-4 EC Measurement Results at MWTP Intake in Halda River (Measuring Date: Mar. 21, 2000)

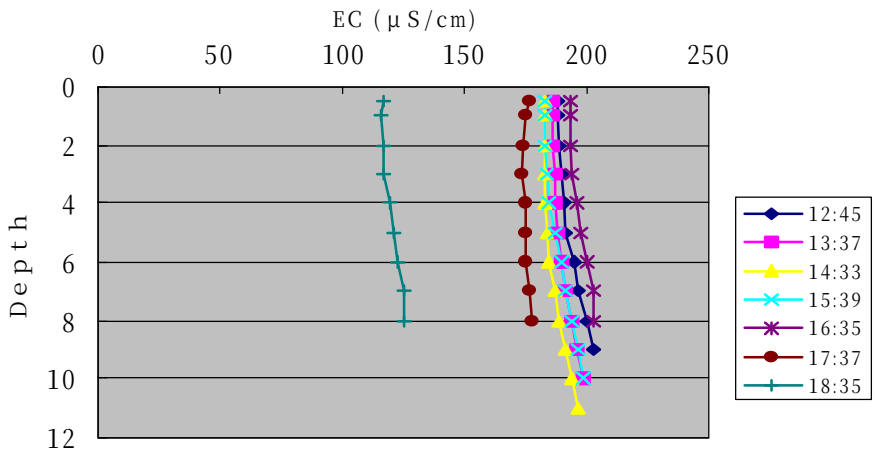


Figure 5.2-5 EC Measurement Results at A-A' Section in Halda River (1/4 from Right Bank) (Measuring Date: Feb. 22, 2000)

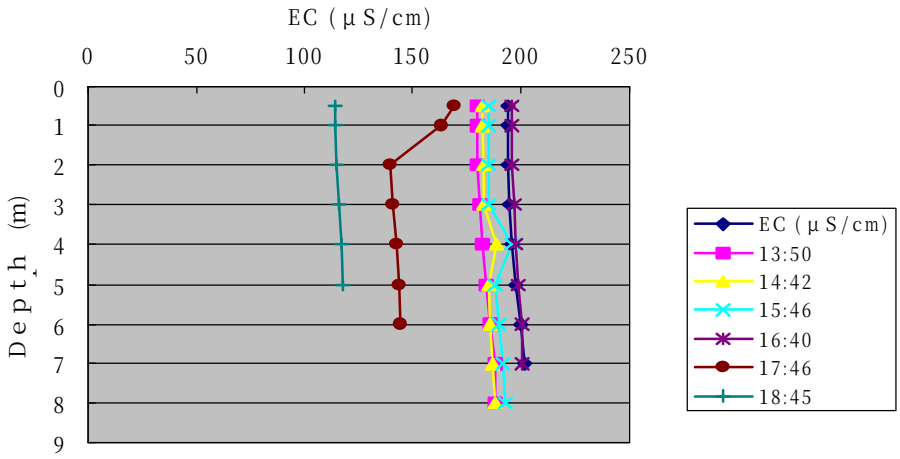


Figure 5.2-6 EC Measurement Results at A-A' Section in Halda River (2/4 from Right Bank) (Measuring Date: Feb. 22, 2000)

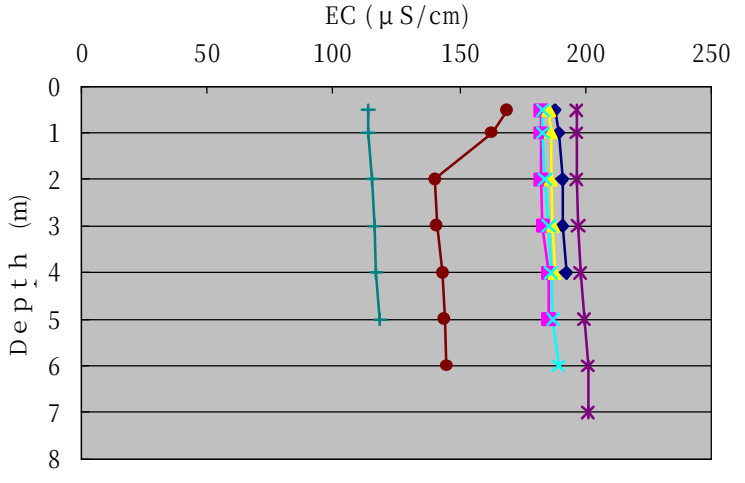


Figure 5.2-7 EC Measurement Results at A-A' Section in Halda River (3/4 from Right Bank) (Measuring Date: Feb. 22, 2000)

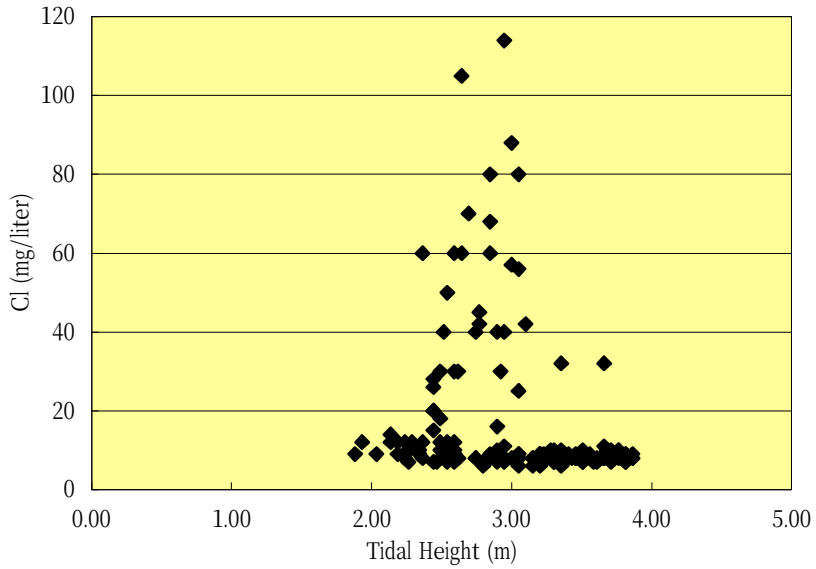


Figure 5.2-8 Relationship between High Tidal Height and Chloride Concentration of Intake Water at MWTP (1998/7 – 1998/12)

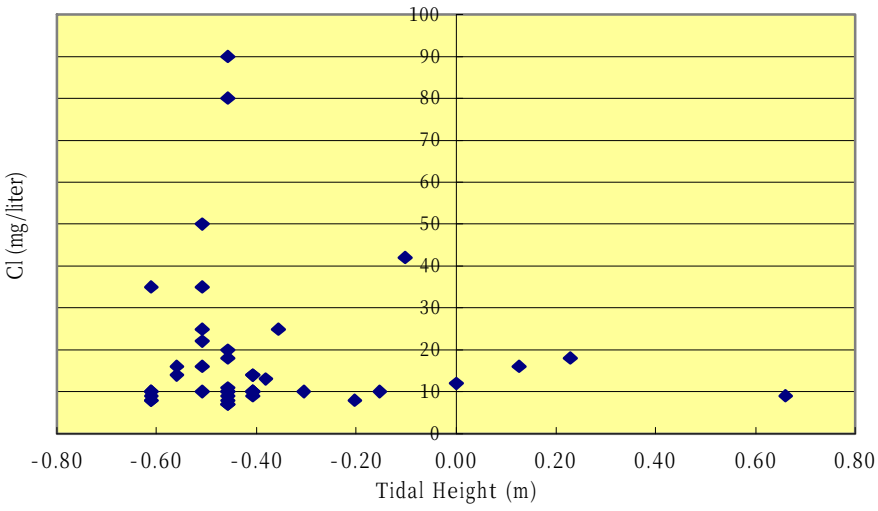


Figure 5.2-9 Relationship between Low Tidal Height and Chloride Concentration of Intake Water at MWTP (1998/7 – 1998/12)

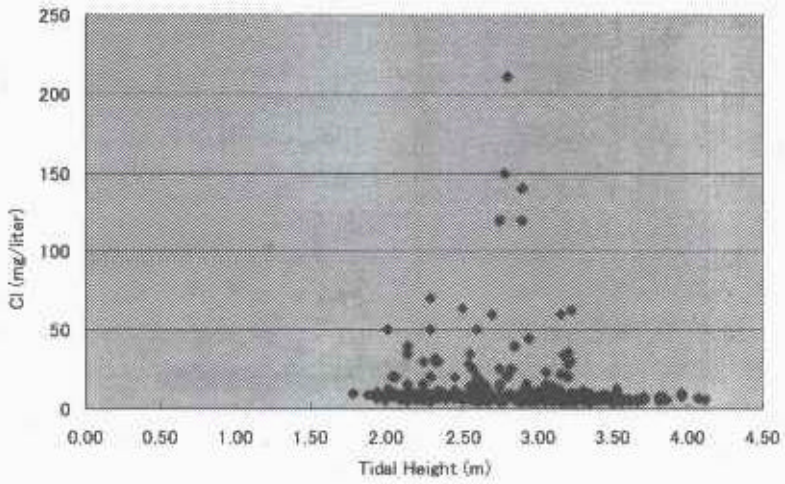


Figure 5.2-10 Relationship between High Tidal Height and Chloride Concentration of Intake Water at MWTP (1999/1 – 1999/12)

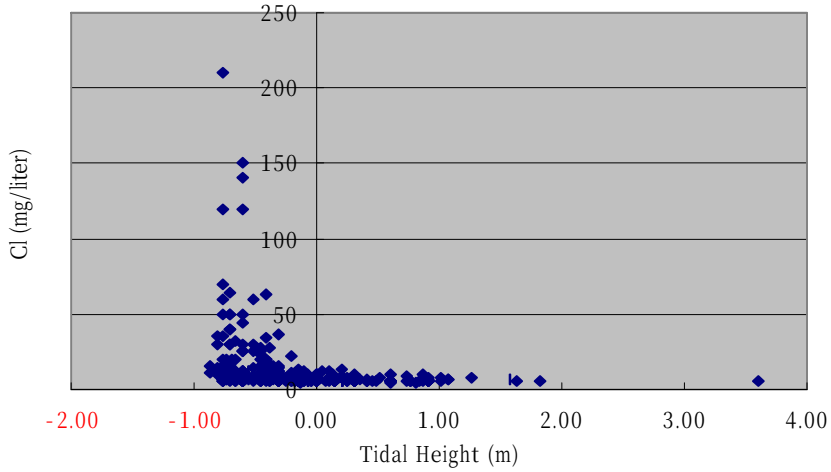


Figure 5.2-11 Relationship between Low Tidal Height and Chloride Concentration of Intake Water at MWTP (1999/1 – 1999/12)

5.2.3 Study on Saltwater Intrusion

There are some considerable causes or factors for happening of saltwater intrusion to the rivers (Karnaphuli and Halda) as listed below:

(a) Tide
(b) Discharge of the Karnaphuli River (Kaptai dam & power station)
(c) Discharge of the Halda River
(d) Others (Dredging, change of river course, cyclone, etc.)

These causes have compulsory effect on the scale of saltwater intrusion to the MWTP in the Halda River as summarized in Table 5.2-5.

Table 5.2-5 Effect of Different Causes to Saltwater Intrusion to MWTP Site

Cause/Factor	Large/High Scale	Small/Low Scale
Tide	High intrusion	Low intrusion
Discharge from Karnaphuli	High intrusion	Low intrusion
Discharge of Halda River	High intrusion	Low intrusion
Others	Not sure	Not sure

It is considerable that the saltwater intrusion at the MWTP site in the Halda River may be the highest in the following case:

(a) Spring Tide (especially in the flood tide)
(b) Kaptai dam does not discharge the water (or discharge very limited water) in an extreme dry season. The discharge from the residual river basin is very low.
(c) Discharge in the Halda River is very low in an extreme dry season.

In the past, the survey on saltwater intrusion has been carried out occasionally. However, these survey results does not seem to show the definite relations among these factors, although some reference information was obtained.

For example, the relationships between tidal height and chloride concentration at MWTP site in the Halda River are examined shown in Figures 5.2-8 to 5.2-11. These figures show that no definite relationship between the tidal height and chloride concentration.

As far as the results of survey in the past, there are rare cases (once 2 –3 years in general) of saltwater intrusion (exceeding the allowable concentration for the water supply) reaching to the MWTP site. However, there are some cases that the saltwater intruded deep into the Halda River as well as to the Karnaphuli River such as follows:

(a) In May 1960, the saltwater intruded close to the Sattarghat bridge in the Halda River, located approximately 13 miles (20.8 km) upstream from the confluence with the Karnaphuli River. The MWTP is located at only 1 km upstream from the confluence with the Karnaphuli River. There are no specific conditions of tide and discharge in the rivers at the time of the extreme saltwater intrusion in 1960. (reported in Development Plan and Feasibility Study in 1979)

(b) In May 1995, the chloride concentration at MWTP site in the Halda River reached over 6,000 mg/l. The discharge from the Kaptai dam was very low.

It is not sure if such extreme intrusion may happen again or not, when the extreme conditions (Flood tide, very low discharge in the both rivers) occur in the future. There are some considerable factors that cause lower/less intrusion of saltwater to the rivers as follows:

(a) The Kaptai power station discharges a certain amount of water for power generation even in the dry season. (2 units of 40MW in 1962, 1 unit of 50 MW in 1982, and 2 units of 50MW in 1988)

(b) River dredging increased the river section area (water storage volume in the river) in the downstream stretch of the Karnaphuli River, which may have function as a kind of buffer zone against the saltwater intrusion force.

Note: Although no definite relation was found between the dredging works and the saltwater intrusion, the dredging information was collected from the Chittagong Port Authority. The routine/regular dredging works in the Chittagong Port has been usually conducted at the mouth of the Karnaphuli River. The dredging periods in the Karnaphuli River are shown for a reference in Table 5.2-6.

Concerning the relationship between the discharge from the Kaptai Dam and the saltwater intrusion, the chloride concentration observed at the MWTP and the discharge from Kaptai dam are examined. The daily variations of the discharge and the chloride concentration in the dry seasons of 1995, 1997 and 1998 are respectively shown in Figures 5.2-12, 5.2-13 and 5.2-14.

As seen in the graphs in these figures, the discharges from the Kaptai dam and the chloride concentrations at the intake point of MWTP are fairly related each other, although they do not show a complete correlation. Incomplete/indefinite relationship would be derived from some other factors such as the inflow from the tributaries of the Karnaphuli River, the discharge of the Halda River, the time of water sampling, and the scale of tide.

Table 5.2-6 Dredging Period in Karnaphuli River by Chittagong Port Authority

Year	Month	Dredging Days	Location	Remarks
1995	January	23	Southern Anchorage	
1995	February	5	Outer Bar	
1995	March	15	Outer Bar	
1995	April	21	Outer Bar, Jetty Channel	3,8,10,11,12,15,16 & that date's dredging is in the jetty channel.
1995	May	9	Outer Bar	
1995	June	17	Outer Bar	
1995	July	20	Outer Bar	
1995	August	18	Outer Bar	
1995	September	12	Outer Bar	
1995	October	15	Outer Bar	
1996	October	13	Outer Bar	
1996	November	23	Outer Bar	
1996	December	10	Outer Bar	
1997	March	10	Outer Bar	
1997	April	11	Outer Bar	
1998	March	8	Outer Bar	
1998	April	12	Outer Bar	
1998	May	12	Outer Bar	
1998	August	10	Outer Bar	
1998	September	19	Outer Bar	
1998	October	15	Outer Bar	
1998	November	17	Outer Bar	
1998	December	14	Outer Bar	
1999	March	13	Outer Bar	
1999	April	17	Outer Bar	
1999	May	13	Outer Bar	
1999	June	10	Outer Bar	
1999	July	14	Outer Bar	
1999	August	11	Outer Bar	
1999	September	4	Outer Bar	
1999	October	16	Outer Bar	
1999	November	16	Outer Bar	
1999	December	19	Outer Bar	
2000	January	11	Outer Bar	

Note, source: Chittagong Port Authority (March, 2000)
Location: Outer Bar is situated in the mouth of the Karnaphuli River
Southern Anchorage is located south of offshore of the mouth of the Karnaphuli River
Jetty Channel is located in the Karnaphuli River near the Sadargat

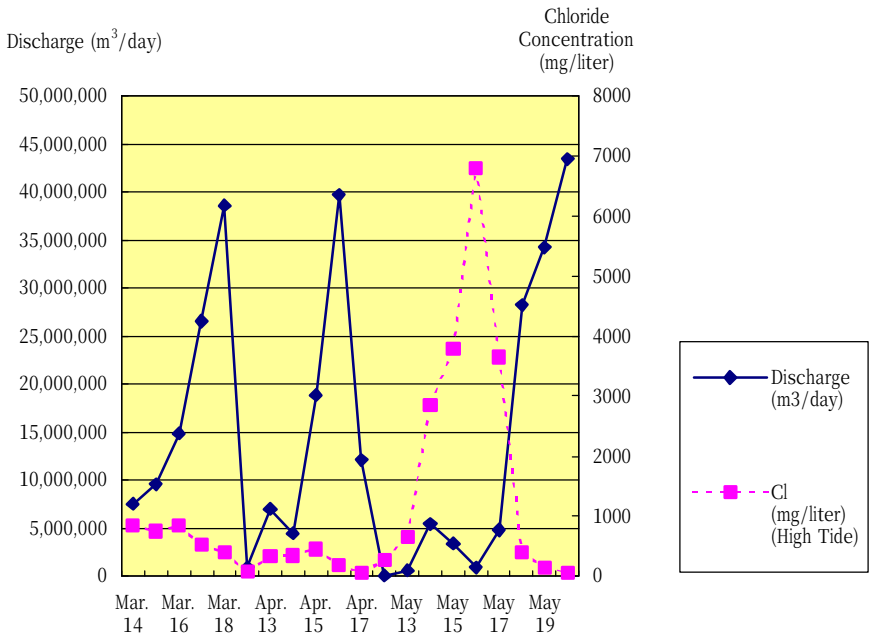


Figure 5.2-12 Discharge from Kaptai Dam and Chloride Concentration of MWTP Intake Water in 1995

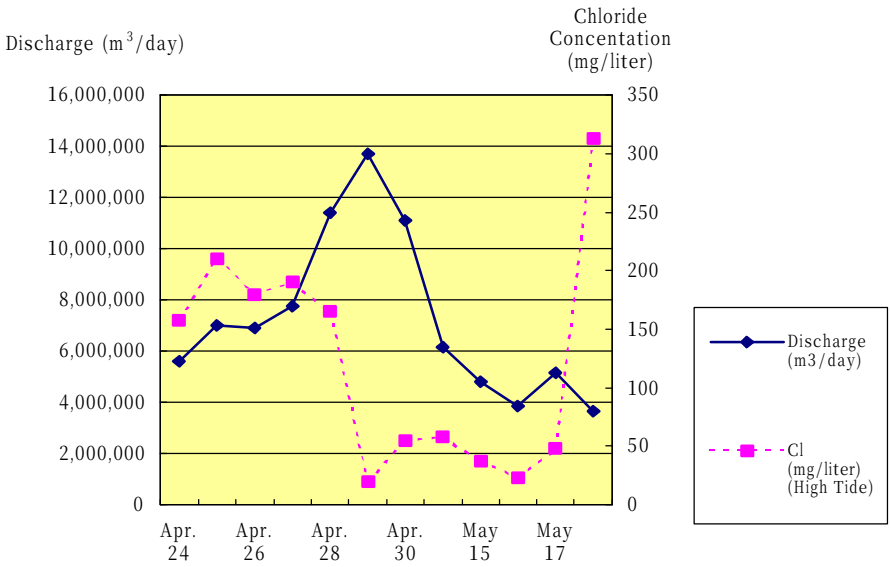


Figure 5.2-13 Discharge from Kaptai Dam and Chloride Concentration of MWTP Intake Water in 1997

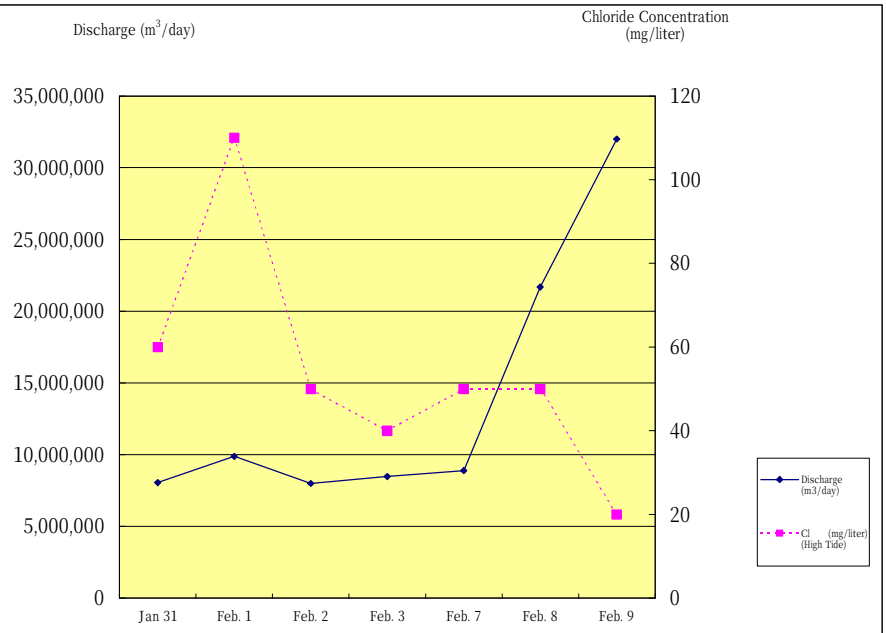


Figure 5.2-14 Discharge from Kaptai Dam and Chloride Concentration of MWTP Intake Water in 1998

5.3 Study on Surface Water Resources Development

5.3.1 Water Resources Development in Halda River

The intake point of the MWTP is located along the Halda River, upstream about 500 m from the confluence between the Karnaphuli and the Halda Rivers. In addition, the Italian project has a plan to establish a new Madunaghat Water Treatment Plant along the upstream of the Halda River, away about 4 km from the intake point of the MWTP. Development water volume for the water supply at the present and in the future amounts to 300,000 m^3/day in total as shown in Table 5.3-1. This section examines the possibility of the utilization of surface water in the Halda River.

Table 5.3-1 Development Water Volume for Water Supply from Halda River

No	Present and Future Water Source Development	Capacity (m^3/day)
1	Present supply capacity of MWTP	91,000
2	Future plan, Madunaghat WTP (Phase I) (Italian Project)	45,500
3	Future plan, Expansion Project of MWTP	91,000
4	Future plan, Madunaghat WTP (Phase II)	45,500
	Planned water development volume	300,000

Note: The MWTP actually intakes surface water corresponded to 110 % of treated capacity due to production loss and water use in the plant. Therefore, planned water development volume is calculated as addition of 10%.

The river is influenced by sea tide cycles and its river stages always change. Therefore, the river discharge is very difficult to be measured. No data on the river discharge is available so far.

Considering the above condition, the river discharge was estimated. In the river, the Water Development Board (WDB) under the Ministry of Water Sources has a gauging station at Panch Pukuria as shown in Figure 5.3-1. In this station, current velocities of the river and stages were measured two or three times per a month. These data are indicated in Table 5.3-2.

Table 5.3-2 Minimum and Maximum Discharges of Halda River at Panch Pukuria

Year	Minimum Discharge		Maximum Discharge	
	Discharge (m^3/sec.)	Month	Discharge (m^3/sec.)	Month
1995	0.40	March	195.79	August
1996	1.39	March	195.79	August
1997	2.38	March	244.23	September
1998	2.10	March	386.95	July
1999	8.08	March	548.67	July

Note, source: Water Development Board (March 2000)

According to these data, the river discharge at the gauging station was very small because of drought years during the years of 1994 to 1995. Therefore, the data of these drought years were excluded to calculate a base flow in normal years. Considering the above condition, minimum flow (1.39 m^3/sec) on March 1996 was selected as a representative of normal years for calculation of a base flow of the Halda River.

The catchment areas of the Halda River at Panch Pukuria and Madunaghat are 833 km^2 and 1,515 km^2, respectively. In this calculation, the catchment area at Madunaghat is roughly estimated to be the same size as that of the MWTP. The daily minimum discharge converts to that at the Madunaghat point.

This calculated minimum discharge, about 218,000 m^3/day at the Madunaghat point, shall correspond to a base flow of the Halda River as a representative. Therefore, the possibility of surface water utilization is examined based on this calculated base flow.

At the time of spring and neap tide, the flooding flow with high velocities in the upstream direction of the Halda River is usually observed by the drift of aquatic plants. The flooding flow is soon started after the turn of tide. The observation at the river survey indicated that the flooding flow was started with the stirring up of the mud and clay on the river bottom over the all area of the river.

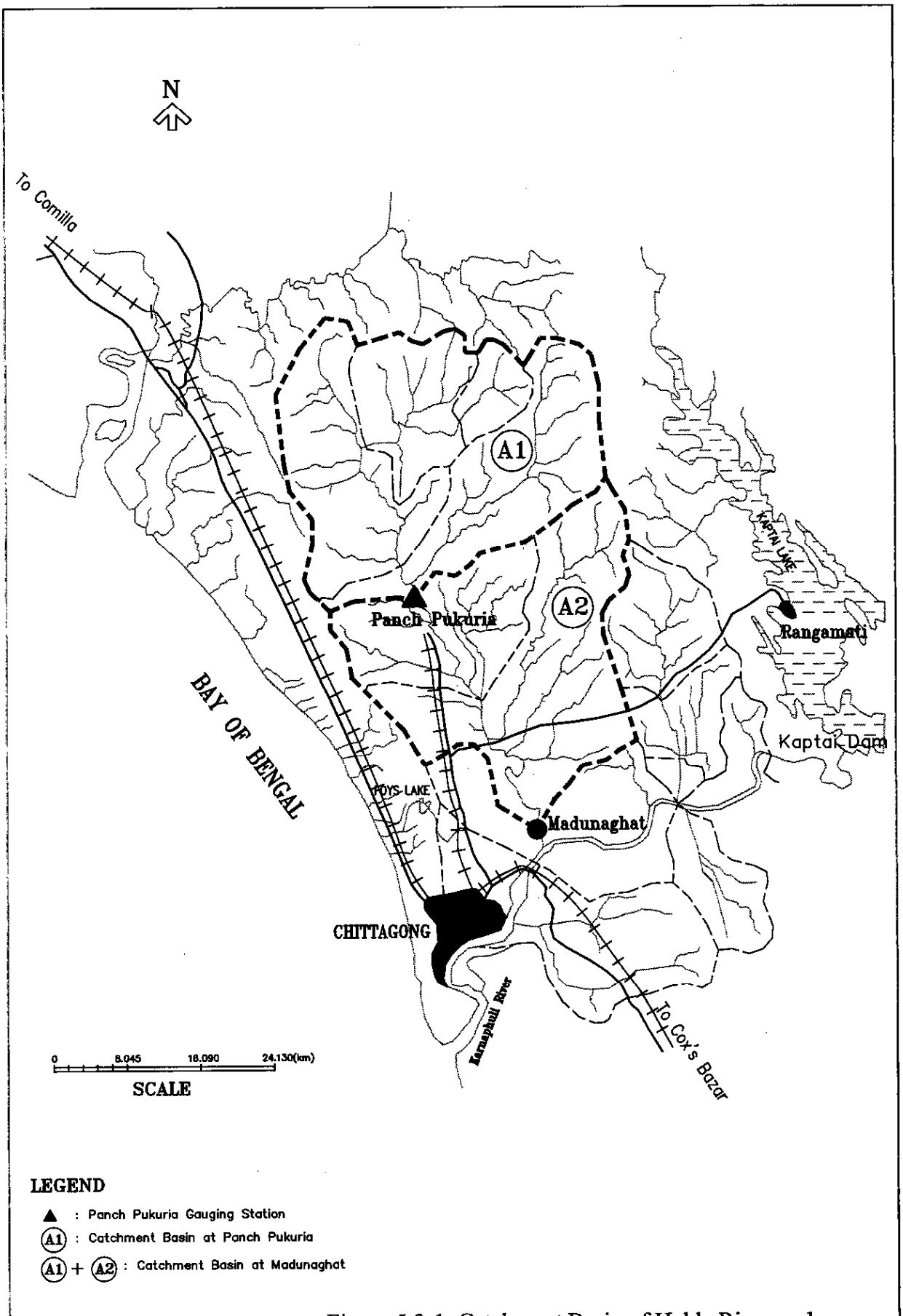


Figure 5.3-1 Catchment Basin of Halda River and Location of Panch Pukuria Gauging Station

In addition, at the saltwater intrusion survey in the Halda River on March 21, 2000, the flowing toward the Halda River from the Karnaphuli River was observed by the drag of the EC measuring probe at the high tide time. The water quality of the Halda River at flooding current time was fresh water, without saltwater intrusion. Furthermore, the Report on Development Plan and Feasibility Study (1979) described that the river stage in the downstream became higher than that of the upper stream at the points between near the confluence and the river mouth.

Considering the above-mentioned matter, it is concluded that flooding flow water in the Halda river is supplied by surface water of the Karnaphuli River, and the flooding flow is occurred at the all places in the vertical and cross sectional directions of the Halda River.

Based on the conclusion, the discharge of the flooding flow and the mixing ratio of the discharge of the Halda and Karnaphuli Rivers was estimated as follows.

1) Inflow from the Karnaphuli River to the Halda River at the flooding flow

The cross sectional area of the Halda River at the downstream about 200 m away from the MWT intake point was calculated.

A-A' cross sectional area indicted in the Figure 5.2-2 was estimated to be about 421 m^2.

The high tide is daily caused two times. Therefore, flooding flow occurs two times per day, namely every 6 hours. Based on the observation at the river survey, the average velocity of flooding current is supposed at 0.1 m/sec.

Flooding flow discharge (Q) = 421 m^2 x 0.1 m/sec = 42.1 m^3/sec

Total flooding flow discharge during 12 hours of flooding hours (Q_t) = 1,820,000 m^3

2) Mixing ratio (MR) of the discharge of the Halda and Karnaphuli Rivers

MR (%) = Halda River discharge / (Flooding flow discharge from the Karnaphuli River +Halda River discharge) = 218,000 / (1,820,000 + 218,000) = 10.7 %

3) Possibility of intake at MWTP as a future water source

The total discharge of the Halda River and the flooding discharge form the Karnaphuli River is summed up to be 2,038,000 m^3.

Planned water volume for intake from the Halda River is 300,000 m^3/day. (Total production capacity 273,000 m^3/day [60 MGD] x 1.1 [addition of production loss and consumption in Planned Future Water Treatment Plant] = 300,000 m^3 [planned intake water volume]).

Ratio between the planned water volume (300,000 m^3) and the total discharge (2,038,000 m^3) of the Halda River and the flooding discharge form the Karnaphuli River comes to be 14.7 %.

This planned water volume is considered fairy small, compared with the estimated total of the Halda River discharge and the flooding discharge from the Karnaphuli River and it shall not be influenced even in a viewpoint of maintenance flow.

5.3.2 Water Resources Development in Karnaphuli River

As described in sub-section 5.2.3, the discharge of the Karnaphuli River is considered to have a close relationship to the saltwater intrusion at the intake point of the MWTP in the past time. Therefore, the minimum flow of the river is a very important factor. This is also a key factor to consider the development possibility of surface water in the future. Table 5.3-3 indicates the monthly discharge from the Kaptai Dam in the period of from 1991 to 1999.

The Basic Plan frames to directly intake the quantity of 300,000 m^3/day (66 MGD) from the Karnaphuli River after the year 2010. In addition, the Halda River is somewhat influenced by the flooding flow accompanying with inflow from the Karnaphuli River at high tidal time. However, the mixing ratio of both surface water of the Karnaphuli and the Halda Rivers at the intake point of the MWTP is unknown due to the influence of sea tidal cycle.

According to the estimation of the flooding discharge form the Karnaphuli River to the Halda River (refer to 5.3.1 Water Resources Development in Halda River), the flooding discharge is considered to be consumed for the planned intake volume by MWTP due to the small baseflow of the Halda River. The total necessary intake volume from the Karnaphuli River is actually estimated to be 600,000 m^3/day [300,000 m^3/day for Mohara and Madunaghat WTPs plus 300,000 m^3/day for planned Karnaphuli WTP].

Availability of the planned intake volume 600,000 m^3/day from the Karnaphuli River is examined below. The river discharge is largely controlled by effluent from the Kaptai Dam that is a main source of the Karnaphuli River. According to the last nine years' monthly discharge data from the Kaptai Dam, the discharge largely fluctuates from 0.09 x 10^6 m^3/day to 766.23 x 10^6 m^3/day and especially, lower minimum discharge is concentrated during the period of November to May in the drought year of 1995. These minimum discharges are considered to occur as a special case. Therefore, excluding the special small discharges, the possibility of surface water development was estimated.

Table 5.3-3 Monthly Discharge from Kaptai Dam

(Unit: x $10^6 m^3$/day)

	Mode	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year Av.
1991	Maximum	31.27	45.50	63.28	54.63	205.54	263.82	94.63	90.23	69.76	56.62	102.70	34.33	92.69
	Minimum	15.11	15.83	21.37	17.87	12.63	76.24	34.86	20.77	18.26	20.40	22.82	15.56	24.31
	Average	22.45	28.57	35.44	26.56	91.48	140.22	70.84	48.23	35.67	29.19	37.32	26.50	49.37
1992	Maximum	64.00	45.37	58.22	45.63	21.38	28.49	36.79	41.52	43.40	53.74	37.40	19.94	41.32
	Minimum	20.16	22.49	26.03	13.63	10.17	4.95	18.80	20.98	20.62	16.88	14.65	13.75	16.93
	Average	40.64	30.78	40.61	25.82	15.57	14.24	28.41	33.26	30.63	30.34	18.27	16.56	27.09
1993	Maximum	24.10	16.47	26.14	63.27	73.70	160.96	766.23	96.94	82.74	38.74	32.00	48.79	119.17
	Minimum	5.68	4.97	6.41	2.70	10.44	42.46	58.30	37.83	25.82	12.18	4.69	7.43	18.24
	Average	14.95	11.25	17.40	25.07	54.97	81.51	213.23	76.55	54.93	28.27	15.21	23.14	51.37
1994	Maximum	69.29	87.47	42.76	83.46	67.94	42.02	42.64	56.66	50.36	26.60	26.95	24.76	51.74
	Minimum	11.44	8.15	2.62	1.48	8.93	6.08	10.97	12.87	5.67	4.42	0.76	0.34	6.15
	Average	34.51	35.23	18.42	39.24	28.60	17.29	29.09	26.07	16.80	13.53	10.41	7.28	23.04
1995	Maximum	44.01	45.28	39.84	39.68	44.76	63.82	69.46	69.14	59.74	55.95	40.73	34.90	50.61
	Minimum	1.19	2.30	0.09	0.94	0.09	8.28	17.49	20.12	8.66	12.72	6.64	9.20	7.31
	Average	15.03	17.42	13.88	14.36	19.00	29.32	49.44	44.05	43.40	31.22	18.86	20.95	26.41
1996	Maximum	56.66	67.59	61.16	68.25	54.70	50.31	70.85	65.64	58.75	43.39	43.91	38.14	56.61
	Minimum	13.25	3.44	1.58	10.06	9.80	6.79	19.51	42.89	21.32	21.57	16.95	5.10	14.35
	Average	32.57	32.95	21.20	33.51	30.66	27.18	50.29	55.72	40.51	34.87	30.63	25.75	34.66
1997	Maximum	44.47	54.12	45.50	28.71	49.41	45.88	452.45	68.86	84.62	145.66	46.51	38.00	92.02
	Minimum	12.50	20.90	13.46	4.25	1.03	11.14	24.91	42.42	17.69	10.21	12.86	9.80	15.10
	Average	28.96	32.63	30.41	11.83	11.15	24.61	72.77	60.30	46.00	46.47	27.97	22.89	34.67
1998	Maximum	52.32	78.35	64.60	56.48	115.36	137.25	258.41	103.06	77.14	58.66	43.51	31.77	89.74
	Minimum	4.42	2.93	19.05	1.49	8.77	21.30	20.66	38.54	45.30	9.38	5.14	4.75	15.14
	Average	33.16	42.31	36.79	22.26	32.20	74.08	130.83	70.09	65.39	31.78	15.99	13.81	47.39
1999	Maximum	30.52	56.90	72.71	64.02	36.19	195.16	431.89	170.32	77.66	65.93	43.78	22.47	105.63
	Minimum	4.06	9.28	18.55	4.27	4.73	17.27	59.35	48.37	45.27	20.45	5.16	4.84	20.13
	Average	16.63	43.38	37.24	21.02	17.69	45.92	157.44	86.70	58.08	43.05	18.69	11.15	46.42
Maximum Discharge:		766.23												77.73
Mimimum Discharge:		0.09												15.30
Average Discharge:		43.62												37.82

Source: Kaptai Dam Management Office (March, 2000)

Extremely low order data in monthly mimimum discharge is excepted as a exception caused by mechanical troubles and/or others.

Normal minimum effluent from the Kaptai Dam was supposed to be 5,000,000 m^3/day. Necessary intake amount 600,000 m^3/day corresponds to 12 % of the effluent from the Kaptai Dam.

Regarding water rights of the river, this country has no any rules and regulations. However, the provisional national water development policy worked out by the Ministry of Water Resources regulates that water supply has the first priority for the water utilization. From the viewpoint of river maintenance flow, intake of this amount is considered to be possible.

In addition, the effluent data indicated that the number of days of effluent less than 5,000,000 m^3/day was very few, except for drought years from 1994 to 1995 as shown in Table 5.3-4. Therefore, the intake of the water amount, 600,000 m^3/day was evaluated to be possible.

Table 5.3-4 Number of Days with Discharge of Less than 5 Million m^3/day

Years	Number of Days
1991	1 day
1992	1 day
1993	3 days
1994	18 days
1995	32 days
1996	2 days
1997	10 days
1998	4 days
1999	3 days

Note、Source: Kaptai Dam Management Office (March, 2000)

Based on the above consideration, (1) indirect intake volume (300,000 m^3/day) for the MWTP and the Madunaghat WTP at present and in the future and (2) direct intake volume (300,000 m^3/day) from the Karnaphuli River after the year 2010 will be possible to be developed.

However, the intake of large quantity from the Halda and the Karnaphuli Rivers in the future for the Madunaghat WTP, industrial water, and the Karnaphuli WTP is anticipated to change the present tidal river flow condition influenced by the sea tide at both the intake points of the MWTP and of the Karnaphuli WTP. This may cause saltwater intrusion at those intake points at that time. Further, data are almost unavailable on saltwater intrusion of the Karnaphuli River. Therefore, the further detailed survey on the saltwater intrusion will be necessary after the completion of the Madunaghat WTP, and at the planning stages for the intake of industrial water and the Karnaphuli WTP.

In addition, five power generators in the power plant of the Kaptai Dam are now operating. The effluent from the plant shall influence the stability of intake for water supply in the downstream of the

Karnaphuli River. In case that expansion project of generators in the plant shall conduct in the future, the discharge control shall be considered.

5.4 Study on Groundwater Resources Development

5.4.1 Existing Deep Wells Owned by CWASA

CWASA owns 40 existing deep wells for water supply in the Chittagong City area. These wells are mainly distributed in both the northeast and the south sides of the city, where they are divided into two wellfields: MOD I and MOD II areas. Of 40 in total, 16 wells are located in the MOD I area and remaining 24 wells in the MOD II area. The MOD I wells are directly distributed to the city area through the distribution network, while groundwater from the MOD II wells is collected to Kalurghat Iron Removal System and after treatment, clean water is distributed to the city area, jointly connecting to transmission pipelines from the MWTP. Locations of these wells are shown in Figure 5.4-1. The details of the wells are indicated in Table 5.4-1.

These wells have the depth ranging from about 80 m to 168 m, with exception 67.1 m of Police Line TW. The wells have the standard structure of telescope type: pump casing of 16" (rarely 18 ") with its length from30 m to 50 m, blind pipes and screens of 8" (rarely 10") with its length from 43 m to 137 m. The screens are of Johnson type made of stainless steel. Slot number of screen ranges from 40 to 60. The wells have gravel packing structure. The standard design of the existing wells is shown in Figure 5.4-2. The oldest operating well was constructed in the year of 1976, about 24 years ago. Static water level ranges from 7.63 m to 22.85 m, and dynamic water level from 15.25 m to 34.77 m.

These wells produce groundwater of about 90,000 m^3/day, according to the CWASA records in 1999. The production rate is indicated in Table 5.4-1. The production rate per well ranges from 210 m3/day to 5,200 m^3/day.

In these wells, groundwater contained high iron concentration ranging from 1.0 mg/liter to 12.4 mg/liter in the MOD II area and 0.1 mg/liter to 6.5 mg/liter in the MOD I area. Groundwater of all the wells in the MOD II area exceeded 1.0 mg/liter of Bangladesh Drinking Water Standard (BDWS). In the MOD II area, a half of existing wells had good water quality in iron concentration. In addition, a part of the wells had high concentration of Manganese from 0.17 mg/liter to 0.28 mg/liter and groundwater of most wells exceeded BDWS in nitrate concentration. Analyzed water quality of each well is tabulated in Table 5.4-2.

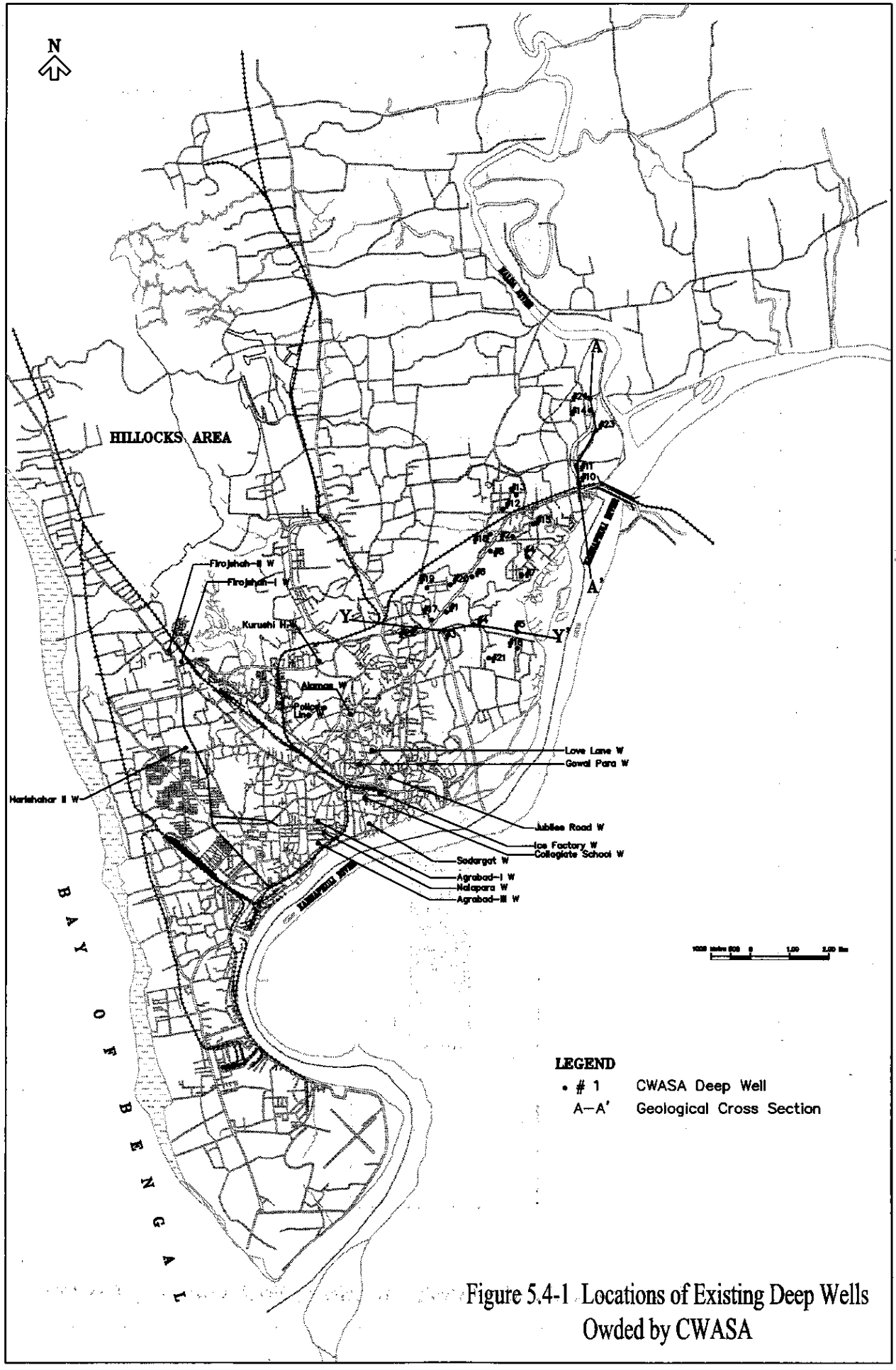


Figure 5.4-1 Locations of Existing Deep Wells Owded by CWASA

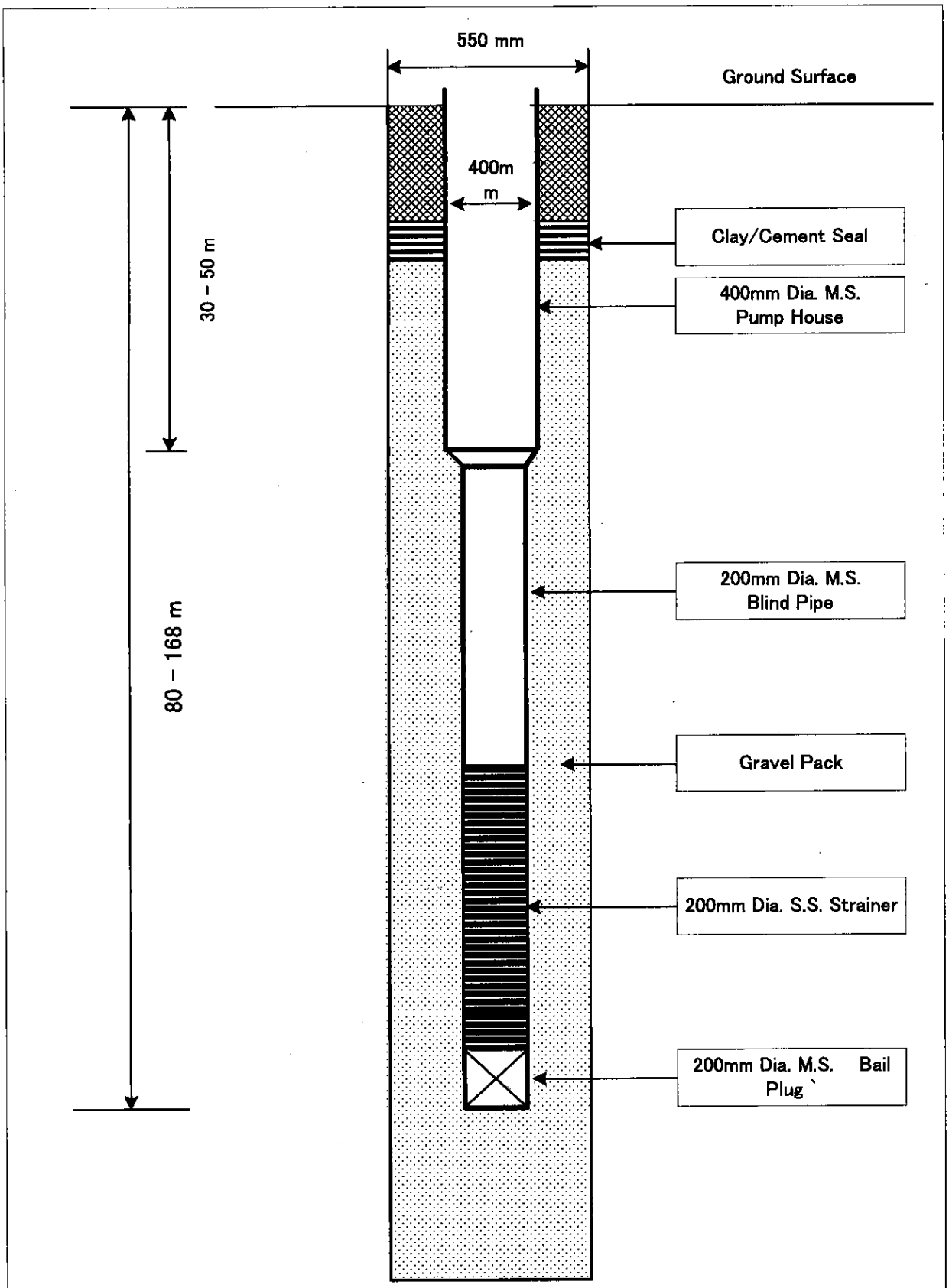


Figure 5.4-2 Standard Design of Existing Wells Owned by CWASA

Table 5.4-1 Inventory of Existing Deep Wells Owned by CWASA

No.	Well No.	Well Depth (m)	Casing Dia. (m)		SWL** (m)	DWL** (m)	Production *** (m^3/day)	Construction Year
			16"	8"				
MOD II (Kalurghat Area)								
1	TW1	105.66	36.00	69.66	10.98	31.42	1,366	Mar/1/1994
2	TW2	99.58	36.60	62.98	9.46		2,164	April/25/1985
3	TW3	109.15	42.00	67.15	11.59	31.42	1,290	Jan/19/1994
4	TW4	122.75	42.00	80.75	12.20	34.77	1,239	Jan/7/1994
5	TW5	132.21	41.39	90.82	10.68	34.54	2,359	Jan/22/1994
6	TW6	122.75	42.00	80.75	13.12	34.52	1,478	Mar/1/1994
7	TW7	119.83	36.59	83.24	9.61	31.47	3,315	July/25/1995
8	TW8	107.67	(18") 40.26	67.41	12.20	32.10	1,943	July/10/1993
9	TW9	89.37	36.60	52.77	8.69	31.26	1,678	Feb./6/1993
10	TW10	88.73	36.00	52.73	9.15	25.06	2,226	Feb./12/1995
11	TW11	87.15	38.24	-	8.44	23.99	3,395	Feb./27/1998
12	TW12	92.73	36.00	56.73	8.85	24.40	3,285	Feb./4/1995
13	TW13	79.91	36.60	43.31	7.63	29.28	4,486	Oct../9/1986
14	TW14	92.57	36.60	(10") 55.97	9.15	18.45	859	June/3/1983
15	TW15	124.85	42.02	82.83	9.00	28.26	1,570	Sept./28/1993
16	TW16	115.95	42.34	73.61	9.30	34.41	2,618	Oct../28/1993
17	TW17	95.42	42.00	53.42	11.29	34.52	2,255	Oct../11/1996
18	TW18	84.03	36.60	47.43	10.98	24.40	1,482	Nov./21/1996
19	TW19	113.46	36.60	76.80	12.05	27.45	4,917	July/20/1982
20	TW20	122.00	42.02	79.98	10.83	20.44	3,226	Aug/26/1993
21	TW21	154.56	42.00	112.56	10.17	30.60	2,235	Mar/17/1996
22	TW22	121.62	36.00	85.62	9.15	21.43	3,436	Aug/15/1993
23	TW23	98.75	42.00	56.75	8.39	22.01	2,504	Jan/11/1994
24	TW24	125.56	36.00	89.56	9.46	19.22	2,641	Mar/15/1995
Sub-total							57,967	
MOD I (City Area)								
25	Khulshi TW	131.15	44.99	86.16	21.34	33.53	521	Aug/14/1986
26	Alamas Cinema TW	129.02	35.69	93.33	19.18	29.96	3,185	1976
26A	"				-	-		May/15/1989
27	Love Lane TW	116.36	(12") 50.02	66.34	12.24	21.88	1,591	Aug/4/1976
27A	"				-	-		Jan./2000
28	Jubllie Road TW	146.40	33.55	112.85	19.50	30.17	3,769	Nov./28/1996
29	Ice Factory Road TW	114.38	30.50	83.88	14.02	29.56	2,233	Mar./20/1998
30	Collegiate Scool TW	122.75	40.00	82.75	13.71	21.63	2,606	Jan/26/1994
31	Sadarghat TW	133.85	42.68	91.17	10.97	30.17	2,488	Aug/6/1994
32	Police Line TW	67.10	30.50	36.60	21.94	25.90	614	Jan./7/1998
33	Agrabad-3 TW	184.45	(10")		9.25	15.25	610	1986
34	Nalapara TW	163.18	30.50	132.68	12.19	32.00	2,483	Oct./17/1997
35	Halishahar-II TW	129.65	48.00	81.65	21.12	30.47	1,146	Apr./26/1994
36	Feroz Shah-I TW				21.12	29.13	632	1978(Aprox)
37	Feroz Shah-II TW	99.54	(16")		17.06	29.74	737	May/12/1986
38	Gowal Para TW	167.75	30.50	137.25	22.85	28.95	4,463	Aug./30/1992
39	Agrabad-1 TW	183.53	(10")		18.12	30.29	1,061	Before 1962
40	Mehedibag TW	154.94	30.50	124.44	9.28	25.78	3,860	Jul./19/1998
41	Halishahar-I TW*	110.21	36.98	73.23	-	-		Jun./30/1996
Sub-total							31,999	
Total							89,966	

Note: * Abandon well, ** Data measured during 1993-1999, *** Production rate depends on CWASA achievement of 1999

Table 5.4-2 Water Quality Analysis Results in Existing Deep Wells Owned by CWASA

No.	Name of TW	Sampling Date	Water Quality								
			pH	Turbidity	Cl (mg/l)	T-Fe (mg/l)	T-hard (mg/l)	Alka. (mg/l)	Mn (mg/l)	NO_3 (mg/l)	TDS (mg/l)
1	No. 1 TW	-	-	-	-	-	-	-	-	-	-
2	No. 2 TW	Aug. 17, 1997	7.2	7	16	1.8	22	-	-	2.1	-
3	No. 3 TW	Dec. 6, 1993	8.1	25	16	4.9	-	-	0.022	2.0	322
4	No. 4 TW	Dec. 1, 1993	6.8	25	22	6.4	30	142	-	11.2	328
5	No. 5 TW	Dec. 27, 1993	6.9	25	22	4.8	22	-	0.015	9.0	-
6	No. 6 TW	-	-	-	-	-	-	-	-	-	-
7	No. 7 TW	Jun. 29, 1995	7.1	-	36	3.9	157	122	0.002	1.6	-
8	No. 8 TW	Jul. 11, 1993	8.2	-	250	3.4	42	128	-	-	-
9	No. 9 TW	Apr.24, 1997	6.9	< 25	32	1.0	-	-	0.002	1.4	115
10	No 10 TW	Jan. 28, 1995	7.2	< 25	82	4.4	102		0.210	1.5	-
11	No.11 TW	Jan. 23, 1998	7.4		11	1.1	26	90	0.210	-	62
12	No.12 TW	Jan 24, 1995	7.7	< 25	26	5.5	36		0.280	1.2	84
13	No.13 TW	Sept.8, 1998	7.3	25	28	3.0	36	116	0.024	13.0	28
14	No.14 TW	Aug. 28, 1993	6.9	-	16	7.4	62	122	-	-	-
15	No.15 TW	Aug.14, 1993	6.7	-	29	12.4	48	126	-	-	-
16	No 16 TW	-	-	-	-	-	-	-	-	-	-
17	No 17 TW	Sept. 7, 1996	6.6	-	40	6.1	-	-	0.170	0.4	238
18	No.18 TW	-	-	-	-	-	-	-	-	-	-
19	No.19 TW	Jan. 25, 1998	7.5	-	22	2.1	68	-	0.023	-	110
20	No.20 TW	Jul. 11, 1993	7.7	-	22	8.4	70	104	-	-	12.3
21	No.21 TW	Feb.5, 1996	6.9	< 25	25	3.5	62	-	0.023	0.4	167
22	No.22 TW	May 28, 1995	6.4	25	15	6.5	124	-	0.010	1.2	167
23	No.23 TW	Dec. 5, 1993	8.0	< 25	36	4.9	20	-	0.032	4.0	301
24	No.24 TW	Feb 13, 1995	6.9	< 25	14	4.8	52	102	-	0.1	-
25	Khulshi TW	-	-	-	-	-	-	-	-	-	-
26	Almas TW	May 9, 1999	6.8	>25	33	0.8	-	68	0.012	-	70
27	Love Lane TW	-	-	-	-	-	-	-	-	-	-
28	Jubilee Road TW	Nov. 29, 1995	6.8	-	29	1.8	54	68	0.22	2.0	-
29	Ice Factory Road TW	Nov. 17, 1997	7.2	<25	10	0.1	30	-	0.021	-	65
30	Collegiate School TW	Sept 30, 1993	7.2	4	6	6.5	-	-	0.090	2.5	-
31	Sader Ghat TW	Jun. 29, 1995	6.8	-	210	0.4	212	90	-	2.2	-
32	Police Line TW	Feb. 26, 1997	8.2	-	40	3.4	16	142	-	2.1	190
33	Agrabad III TW	-	-	-	-	-	-	-	-	-	-
34	Nalapara TW	Sept. 14, 1997	7.6	<25	16	1.4	32	-	0.001	2.3	105
35	Halishahar II. TW	-	-	-	-	-	-	-	-	-	-
36	Firojshah -I TW	-	-	-	-	-	-	-	-	-	-
37	Firiojshah II TW	-	-	-	-	-	-	-	-	-	-
38	Goalpara TW	Dec. 3, 1996	7.1	-	26	0.5	98	122	-	-	63
39	Agrabad-I TW	-	-	-	-	-	-	-	-	-	-
40	Mehedibag TW	Jan. 8, 1998	7.1	>25	10	1.1	38	-	0.014	-	115
Bangladesh Water Drinking Standard			6.5-8.5	10	<650	<1.0	<500	-	<0.1	<1.0	<1,000

Note, CWASA has adapted 1.0 mg/liter from the range (0.3 mg/liter - 1.0 mg/liter) of T-Fe concentration in BDWS which was confirmed in the meeting of March 15, 2000.
Source: existing data from CWASA Well Construction Department

In addition, T-Fe and Mn concentration of the CWASA deep wells were re-analyzed to reconfirm. Sampling was carried out in the period from March 24 to April 3, 2000. Analysis was conducted in the laboratory of the MWTP. As a result, most of the MOD II wells and many MOD I wells also had higher iron and manganese concentration in groundwater than those of BDWS.

5.4.2 Issues of Existing Wells

Deep groundwater in the Study Area almost includes high iron concentration more than 1.0 mg/liter. In most wells, the basements of the vertical turbine pumps are stained by iron rust and/or jelly of iron bacteria. The production rate often becomes very small in a few years after construction. This phenomenon is considered to be caused by the clogging of the well screens and/or gravel pack layers and aquifers due to the iron incrustation. To cope with decrease of the production rate, CWASA have been carried out regeneration using chemical matters (sodium hypochlorite, bleaching powder) and high-pressure air. The regeneration is carried out by two methods: 1) raw hiding, 2) high-pressure method.

These methods have fairly effectiveness for regeneration and often recover a production rate up to about three times of a pumping rate before treatment. When these methods have no distinct effectiveness, a new well often constructed in the same pump house and an old well with a pump is reserved as a standby pump.

According to CWASA record, the average well longevity in the MOD II area is about 14 years and that in MOD I area comes to 23 years as shown in Tables 5.4-3 and 5.4-4, though the well longevity span does not always represent a correct span to also relate the CWASA budget for the reconstruction. The difference of the well longevity between the MOD I and II shall be derived from the iron concentration in groundwater. The iron concentration relates to the clogging of screens and packed gravel.

According to the MOD section of CWASA, the regeneration method is effective for 7 months to a year. Therefore, the section sometimes repeats the regeneration using their budget. These methods are evaluated to be very effective according to the recovery ratio of production rate.

Table 5.4-3 History of Existing Deep Wells Owned by CWASA

No.	Well No.	First Construciton Well			Second Construciton Well			Third Construciton Well			Operating Years
		Const. Year	Aban. Year	Remarks	Const. Year	Aban. Year	Remarks	Const. Year	Aban. Year	Remarks	
1	Khulshi TW	Oct.14, 1986		Running	-	-	-	-	-	-	-
2	Almas TW	-	-	-	-	-	-	-	-	-	-
3	Love Lane TW	Nov.3, 1976			May 31,1999		Running	-	-	-	23
4	Jubilee Road TW	-	-	-	-	-	-	-	-	-	-
5	Ice Factory Road TW	1965			1998			-	-	-	33
6	Collegiate School TW	-	-	-	Mar.26, 1994		Running	-	-	-	-
7	Sader Ghat TW	Feb. 1981			Oct. 8, 1995		Running	-	-	-	14
8	Police Line TW	-	-	-	-	-	-	-	-	-	-
9	Agrabad 3No. TW	-	-	-	-	-	-	-	-	-	-
10	Nalapara TW	-	-	-	-	-	-	-	-	-	-
11	Halishahar II. TW	1963			-	-	-	-	-	-	-
12	Firojshah -I TW				1979			-	-	-	-
13	Firiojshah II TW	-	-	-	-	-	-	-	-	-	-
14	Goalpara TW	-	-	-	-	-	-	-	-	-	-
15	Agrabad-I TW	1964			-	-	-	-	-	-	-
16	Mehedibag TW	-	-	-	-	-	-	-	-	-	-
	Range of Operating Years of Existing Wells										14 - 33
	Average of Operating Years of Existing Wells										23

Note, source: CWASA design division (Feburary, 2000)

Table 5.4-4 History of Existing Deep Wells Owned by CWASA (MOD-II)

No.	Well No.	First Construction Well			Second Construction Well			Third Construction Well			Operating Years
		Const. Year	Abandoned Year	Remarks	Const. Year	Abandoned Year	Remarks	Const. Year	Abandoned Year	Remarks	
1	TW1	Oct.13, 95		Running	-	-	-	-	-	-	-
2	TW2	1980			Oct.26, 1997		Running	-	-	-	17
3	TW3	-	-	-	1984			Apr.17, 1994		Running	10
4	TW4	1980			Mar.25, 1994		Running	-	-	-	14
5	TW5	-	-	-	Mar.9, 1986			May 16, 1994		Running	8
6	TW6	Oct.18, 1977			-	-	-	Sept. 1, 1994		Running	17
7	TW7	Feb. 9, 1987		Sand yielding	Jan.21, 1996		Running	-	-	-	9
8	TW8	Mar.29, 1975			Sept. 8, 1993		Running	-	-	-	18
9	TW9	-	-	-	Apr. 6, 1985	Aug.28, 1997	Low yielding	Aug.28, 1997		Running	12
10	TW10	Mar.29, 1972			Apr. 23, 1995		Low yielding	-	-	-	23
11	TW11	1980			Apr. 5, 1998		Low yielding	-	-	-	18
12	TW12	May 7,1975			Mar.25, 1995		Low yielding	-	-	-	20
13	TW13	Oct. 5, 1986		Abandoned	Jun. 25, 1987			Jan.17, 1999		Running	12
14	TW14	Sept.3, 1985		Running	May26, 1985			-	-	-	-
15	TW15	-	-	-	Sept.13, 1993			Nov.6, 1993			-
16	TW16	Oct.16, 1987			Oct. 4,1993			Nov.29, 1993			6
17	TW17	Mar.30, 1973			Jan. 21, 1997			-	-	-	24
18	TW18	Nov.21, 1983		Running	-	-	-	-	-	-	-
19	TW19	Feb.8, 1984	Jun.20, 98	Low yielding	May13, 1998		Running	-	-	-	14
20	TW20	-	-	-	Oct.4, 1993		Running	-	-	-	-
21	TW21	Mar.3, 1986			Jul.9, 1996		Running	-	-	-	10
22	TW22	1988			Feb.13, 1996		Running	-	-	-	8
23	TW23	Oct.6, 1994		Running	-	-	-	-	-	-	-
24	TW24	Nov.21, 1995		Running	-	-	-	-	-	-	-
Range of Operating Years of Existing Wells											6 - 24
Average of Operating Years of Existing Wells											14

Note, source: CWASA design division (February, 2000)

5.4.3 Hydrological Conditions of Groundwater

The columnar sections of each well indicate that most formations belong to the alluvial formations, consisting of alternating and unconsolidated layers of clay, sand, and gravel. Deep groundwater of these wells is in confined condition. The locations of cross-section lines are shown in Figure 5.4-1, with geological cross-section maps of Figures 5.4-3 and 5.4-4.

The CWASA existing wells tap to two or three sand and gravel layers in order to withdrawal. These layers connect each other and form an aquifer with total thickness of average 60 m in the MOD II area. However, a part of the wells located in the MOD I area penetrate into the Tertiary formation, consisting of hard clay, and hard sand formations. This may imply that hillocks area extended from NNW to SSE are hidden under the alluvial plain in the south area of the city. Therefore, some wells were drilled in the hilly area and another wells were sunk in the alluvial area.

Some well water does not include high iron concentration in the MOD II area. The water quality of groundwater tapped into hilly tertiary formation is estimated not to include high iron concentration, different from those of the alluvial formation

Based on all of pumping test data, the transmissivity and the permeability were analyzed by Theis's recovery method [$T=(2.30Q/4\pi Sr) \times \log(t/t')$, Sr: remaining drawdown, t': time after stoppage of pumping]. Pumping test is usually conducted by step drawdown test, continuous pumping test and recovery test. However, the pumping test method for the CWASA wells was not carried out by formal manners. Thus, the results were used to roughly estimate the groundwater flowing flux. The analyzed results are shown below.

Analyzed average transmissivity (T) = 2,270 m^2/day

Average permeability (K) = 6.84×10^{-2} cm/sec.

The T and K values indicated that the aquifer had a fairly good permeability because of alluvial formation.

5.4.4 Possibility of Groundwater Resources Development

(1) Possibility of Groundwater Development

Using the calculated T and K values, the possibility of groundwater development was examined in the study area. The study area was subdivided into two areas as shown in Figure 5.4-5, from a viewpoint of the present and the future wellfields.

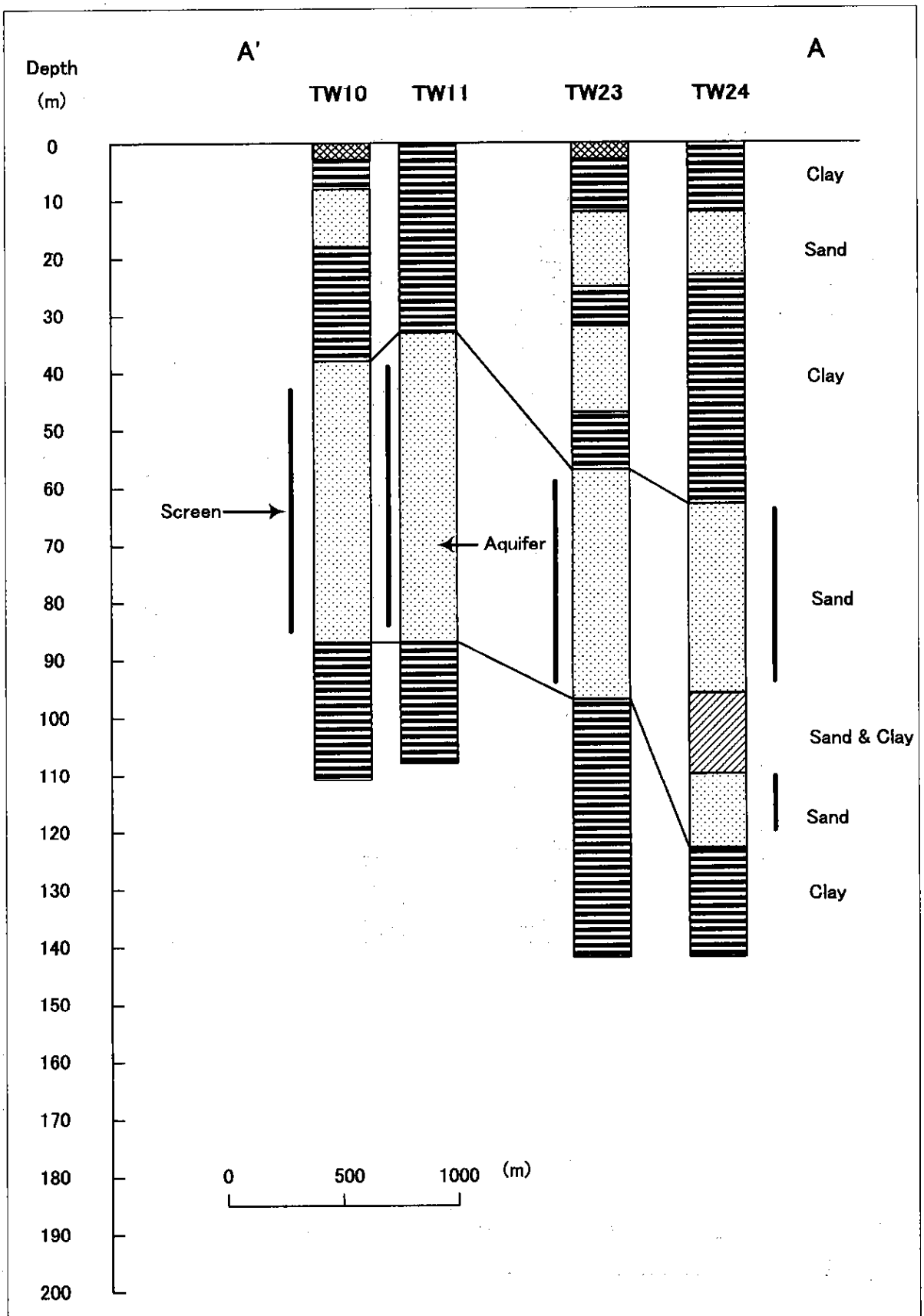


Figure 5.4-3 A-A' Geological Cross Section

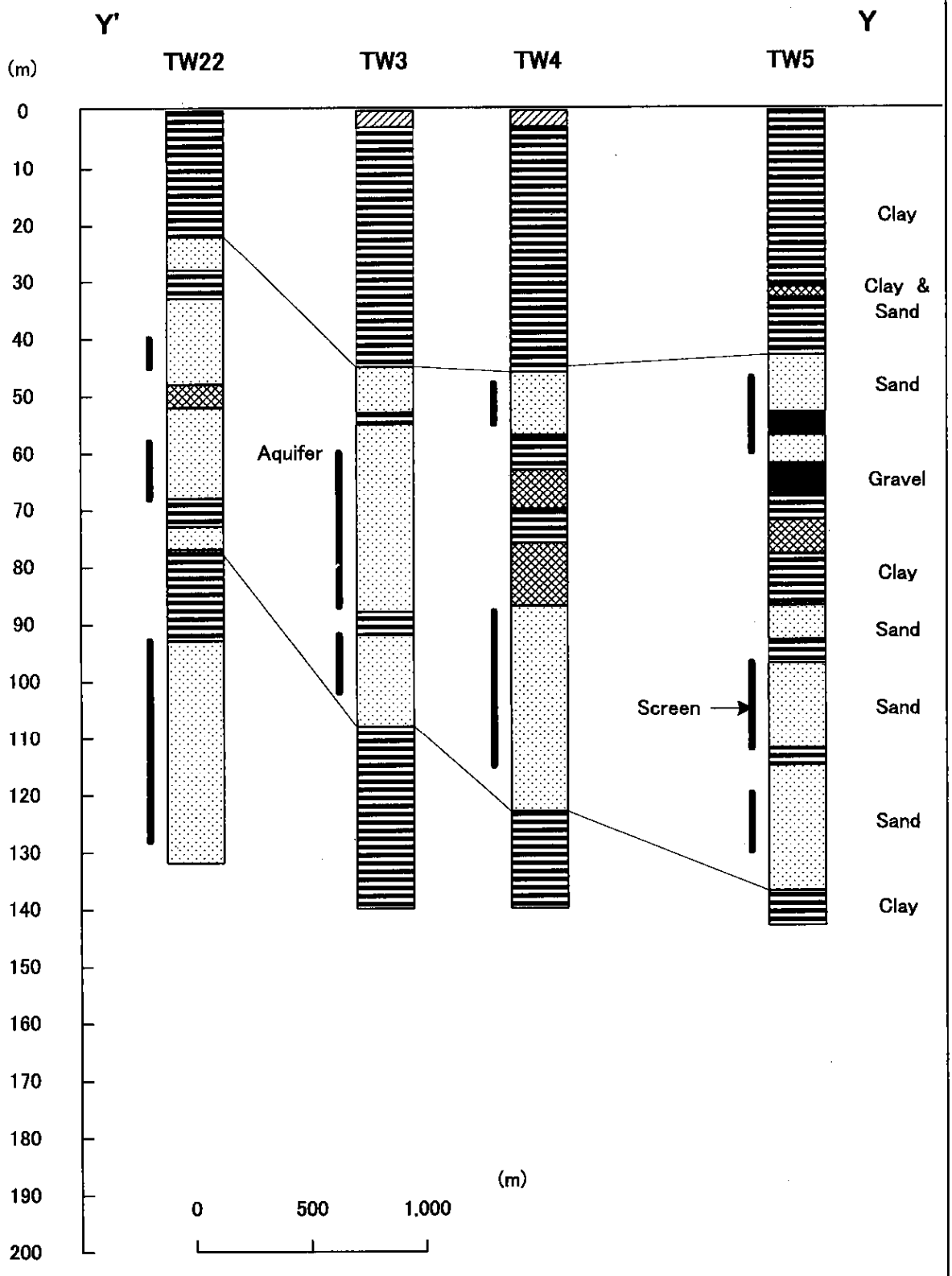


Figure 5.4-4 Y-Y' Geological Cross Section

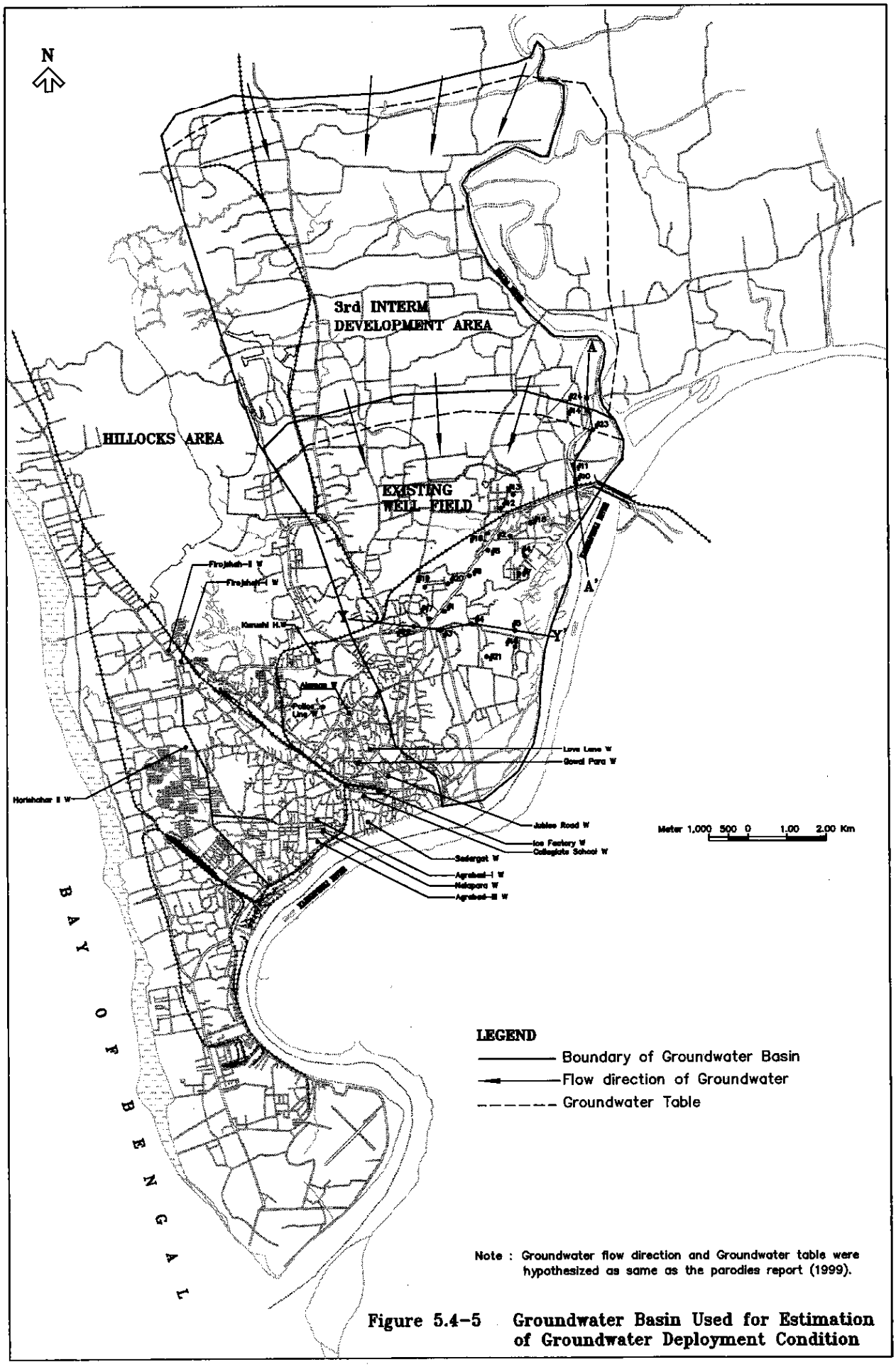


Figure 5.4-5 Groundwater Basin Used for Estimation of Groundwater Deployment Condition

In calculation of the groundwater flowing flux (GFF), the groundwater table is necessary to determine groundwater flow direction. However, suitable measured data of static water level at present time were not obtained due to operating condition of all the wells. Therefore, the water table in past time reported by F/S report - Parsons Overseas Company (1979) was referred to, supposing that natural condition in groundwater was almost not changed.

In addition to the extraction by the existing wells, CWASA is now propelling to construct **1)** 12 new wells and a new filter in the Kalurghat Iron Removal Plant (2nd Interim Water Supply and Rehabilitation Project), and is proposing to conduct **2)** 15 new wells and the Fatehabad Iron Removal Plant by GOB fund (3rd Interim Water Supply and Rehabilitation Project). The planned treated volume of groundwater amounts to 22,500 m^3/day and 45,000 m^3/day, respectively. Therefore, planned extraction of groundwater comes to 25,875 m^3/day and 51,750 m^3/day. The planned well design is the same as those of the existing wells. Therefore, total withdrawal at present and in the future sums up as follows:

1) Present withdrawal by existing deep wells in MOD II area: 58,000 m^3/day (1999)
   (As a part of the deep wells in the MOD I area tap from the tertiary formation, this calculation excludes them.)
2) Ongoing project of the 2nd Interim WSRP: 25,875 m^3/day
   (Actual extraction of groundwater is estimated 1.15 times as large as planned pumping rate due to wastewater in the plant.)
3) Planned withdrawal in the 3rd Interim WSRP: 51,750 m^3/day
   (Actual extraction of groundwater is estimated 1.15 times as large as planned pumping rate due to wastewater in the plant.)

Total withdrawal: 135,625 m^3/day

On the other hand, the groundwater flowing flux is calculated as follows.

$$GFF\ (Q) = \text{Perimeter} \times \text{Aquifer Thickness} \times K \times (\Delta H / \Delta L)$$

Where, K = permeability,

$\Delta H / \Delta L$ = gradient of groundwater table

Considering the groundwater flow direction, the parameters necessary for the calculation were roughly determined as follows:

Perimeter = 17,000 m,

Aquifer thickness = 60 m,

Ave. K = 6.84 x 10^{-2} cm/sec.,

Gradient = 0.00625

As a result, GFF (Q) = 376,700 m^3/day. This flux is not so much, compared with the necessary projected total withdrawal (135,625 m^3/day). The total withdrawal corresponds to about 36 % of the calculated GFF. This rough estimation does not consider groundwater recharge from ground surface and hillocks and the rivers, and the present situation of groundwater table, together with aquifer continuity. In addition, the withdrawal and tapped depth of private wells are not unknown.

Therefore, further investigation shall be necessary to evaluate groundwater development. However, the estimation may give a rough warning that groundwater development in the CWASA wells aquifer is in near-limitation.

(2) Well Spacing

Appropriate well spacing is essential to avoid well interference. The withdrawal in production wells causes the lowering of water level with conical shape. The moderate slope of dynamic water table is continuous with a fairly large range up to an outer skirt. This lowering of water table influences to pumping condition of another adjacent wells. Therefore, the optimized well spacing is necessary.

At present, the CWASA wells are intermittently pumped up due to unstable electric power supply, every day. Therefore, well interference is not so big problem. However, the optimized well spacing shall ideally be considered when the new wells shall be constructed in the future.

Table 5.4-5 indicates only rough results for an optimized well spacing because the analyzed values of transmissivity (T) are derived from inappropriate pumping test procedures and data.
For the calculation, Jacob modified equation (1946) was used with the following conditions.

Jacob modified equation: $s = (0.183Q/T) \log (2.25\ Tt/r2S)$

Where, s = drawdown
Q = pumping rate
T = transmissivity
t = continuous pumping time
r = radius of interference
S = coefficient of storage

Calculation condition,

Permissible drawdown in interference radius = 20 cm,
Continuous pumping time (one month)

Table 5.4-5 Optimized Well Spacing

Production Range (m^3/day)	Calculated Well Spacing (m)
500 - 1,000	90
1,000 - 2,000	600
2,000 - 3,000	1,200
3,000 - 4,000	1,700
4,000 - 5,000	2,000

Note, Calculated well spacing indicates the interference radius.

Therefore, the actual well spacing shall be double.

The present well spacing has the distances ranging from 500 m to 2,000 m. Based on the above calculation results, the well spacing shall be kept at least about 1,000 m.

These results are based on the existing information and data limited. Therefore, the achievement has the constraint to actually be applied. To reveal the possibility of groundwater development in more detail, further study is necessary. The study shall include topographic and geological survey, electric resistively survey, construction of test wells, pumping test, electric logging, questionnaire survey of private deep wells (locations, depth, withdrawal, operating hours etc.), water quality analysis, experimental well test for regeneration, monitoring of groundwater level, and computer simulation etc.

5.5 Conclusions and Recommendations

(1) Necessity of Injection of Chorine for Well Water Supply System

In the MOD I area, well water is directly supplied without injection of chlorine through distribution pipelines. However, this system shall be improved from the viewpoint of safety as water supply system. After treatment, all iron content of groundwater shall be oxidized and colored. Therefore, iron removal systems shall be necessary to be set up.

(2) Training on Groundwater Analysis Techniques and Groundwater Hydrology

The pumping test is not carried out by a normal manner. The pumping test data that was carried out by normal manner is very useful for analysis and evaluation of effectiveness of regeneration. This seems to be derived from the shortage of groundwater analysis technology and information of groundwater hydrology. Therefore, the training and study on this field shall be necessary.

(3) High Mn Concentration of Supplied Water

According to an analysis result of water quality, Mn concentration in both surface water and groundwater often exceeds BDWS. Therefore, firstly, the reconfirmation of the concentration shall

be necessary for the crosscheck. If high concentration reconfirms, Mn removal process shall be considered.

(4) Possibility of Surface Water Development

As a result of the study, surface water of the Halda and the Karnaphuli was revealed to have fairly development possibility. In addition, saltwater intrusion in the Halda River is presumed to be mainly caused by the decrease of discharge in the Karnaphuli River due to a little effluent from the Kaptai Dam. Also, this phenomenon relates to the stress relationship among the discharges of the Halda and the Karnaphuli Rivers, and tidal flow toward upstream of both streams. The relationship may be changed if a new Madunaghat Treatment Plant (Italian Project) is constructed and/or intake of industrial water is planned. In addition, data are almost unavailable on saltwater intrusion of the Karnaphuli River. Therefore, further study on saltwater intrusion shall be necessary after completion of the Madunaghat plant in the future and at the planning stages of the intake of industrial water and the Karnaphuli WTP.

(5) Necessity of Future Monitoring of Surface Water Quality

According to EIA Report for CWASA Madunaghat Water Supply Project (BETS, 1999), there is the Madina Tannery in the upstream of the Halda River, and shipbuilding yards in the downstream. These industries are predicted to exhaust the pollutants such as heavy metals. However, the report describes that surface water pollution excess the BDWS was not observed. Also, this study conducted an analysis of the surface water of the Halda River, which amounts to a total of 30 chemical items including the heavy metals (As, Cd, Cr, Cu, Pb, Hg, Zn, CN) to check the pollution. As a result, the concentration of heavy metals was less than those of the BDWS with no outstanding water pollution.

In addition, the Karnaphuli River has a paper mill plant at Chandraghona away about 66 km from the river mouth. To check the safety of the water source in the future, water quality of 17 items were analyzed. The analysis values were compared with the water supply source standard in the Japanese Environmental Standard on the Preservation of Life Environment (1977). The result indicated that the river water had no problem as a water source for the water supply.

However, these industrial wastes may be increased with the enlargement of the future industrial production rate. Therefore, the monitoring of river water quality in the future shall be necessary.

(6) Possibility of Groundwater Development

After completion of the 3rd Interim Water Supply and Rehabilitation Project in the future, the possibility of groundwater development seems to become near the overdevelopment according to the

rough estimation. However, it results from the rough estimation based on limited information. Furthermore, it does not include the evaluation of groundwater development in the left bank in the Karnaphuli River and of that of deeper aquifers in the study area. Therefore, further groundwater study shall be necessary if groundwater development in new proposed area and of deeper aquifers in the study area is planned.

(7) Well Spacing

Optimized well spacing was calculated to avoid the well interference. The well spacing shall change with the magnitude of the parameters that consist of pumping rates and continuous pumping hours. At present, the well spacing approximately ranges from 500 m to 2,000 m. However, the well spacing shall at least take the distance of over 1,000 m.

CHAPTER 6

SYUDY ON MANAGERIAL ASPECTS OF WATER WORKS

CHAPTER 6 STUDY ON MANAGERIAL ASPECTS OF WATER WORKS

6.1 Central Government Level Institution

6.1.1 Sector Organization (Water Supply and Sanitation Sector)

The statutory responsibility for the water supply and sanitation sector is under the Ministry of Local Government, Rural Development and Cooperative (LGRD). The Ministry, together with the planning Commission shares the task of sectional resource allocation, funding and policy decisions as well as project appraisal, approve, evaluation and monitoring.

All projects in the sector are processed through the Ministry. The Ministry's Department of Public Health Engineering (DPHE) is responsible for planning, construction and operating water supply and sanitation facilities in smaller towns and rural areas. In Dhaka and Chittagong, the Government established Water Supply and Sanitation (DWASA and CWASA) as autonomous agencies responsible for provision of water supply and sewerage services. These authorities also come under LGRD as public utilities.

In the two cities, the Dhaka and Chittagong City Corporation (DCC and CCC) are responsible for all other sanitation activities other than water borne sewerage. Additionally, the Local Government Engineering Department (LGED), also under the Ministry, is responsible for providing technical assistance to sanitation and other municipal services to district towns that do not have municipal corporation status. DPHE and LGED assist local governments to construct water supply and sanitation facilities, either through donor or Government financing.

6.1.2 Sector Financing

Sector development in Bangladesh has mainly been financed by donor assistance, which has been mainly responsible for the tenfold increase in availability of water supply. Although the Government has declared its intention to develop safety water supply and sanitation, the level of investment in the sector has remained very low due to funding constrains. Between 1973 and 1990, public outlays for water and sanitation steadily dropped from 2.48, 2.14 percent of development expenditures in the first, second and third Five-Year Plans respectively.

This is significantly below allocation in other comparable countries in Asia e.g., Sri-Lanka (6.0 %), Nepal (4.0 %) and Myanmar (2.9 %). In the Fourth five-year Plan (1990-1995), allocations to the sector were budgeted to be 1.4 percent of the development expenditure, which is too low even to meet the

physical targets of the plan. The most recent three-year Rolling Investment Program for FY95-97, however, shows a reversal to this trend. Allocations for this period were 4.0 percent of the total expenditure.

Although DWASA and CWASA are supposed to be commercial and autonomous, their capacity to generate financial resource to finance their own investments has been limited. Donor responses for financing investments in the sector have normally been supplemented by Government equity contribution and grants. For operation and maintenance, tariff level revenue have generally been inadequate to fully meet all operating costs and cover debt servicing costs as mentioned in the relevant sections. The resulting deficits are usually financed by the Government indirectly by not servicing debt and interest.

6.1.3 Sector Issues and Conditions

(1) Funding of Investments and Resource Mobilization

The availability of local funds to support investments in the sector is generally inadequate. Government counterpart fund, even when budget for, are not always made available when required, due to competing demands, this delaying project execution. Inadequate tariffs, poor revenue collection and a high level of systems losses in DWASA hamper the mobilization of adequate internal resources to finance capital expenditures for water and sanitation.

CWASA has also the same issues except that arrears are distinctly low and the water physical loss is also remarkably low than DWASA. However, the latter seems due to the reason that water is supplied under comparatively low pressure and regulated likely to two-shift supply, half-day in daytime or evening/night time, depending upon the location conditions of service area such as high land and far distance from the distribution plants.

(2) Sector Management

Overall sector management is characterized by Government control and interference in the planning and operation of the water sector entities. While CWASA and DWASA are supposed to be autonomous, most management decisions, including tariff review and adjustments, staffing and investment decisions have been controlled by the Government through LGRD.

There are no clearly defined guidelines for sector development or mandates for WASA's operation. As a result, the WASA's have never had real commercial or management autonomy, which has significantly

hampered their performance. In additions, management and staff of these sector and training to effectively management, operate and maintain the system because of no chance to do so.

(3) Lack of Commercial Orientation

In Bangladesh, IDA has assisted the Government in the water supply and sanitation sector since 1963, having financial and technical assistance. IDA is executing the Forth Water Supply and Sanitation Program for DWASA in which Operation and management Supporting Program (Twinning Program) has being conducted with target data of the end of September 2000. IDA emphasizes in its interim report that DWASA suffers from a lack of commercial orientation and accountability, poor management system, and shortage of trained and motivated staff.

6.2 Study on Chittagong Water Supply and Sewerage Authority

This sub-section presents study results on organization framework, the management situation, the financial performance and tariff for smooth/certain implementation of Basic Plan established by the JICA study team, which will be undertaken by CWASA.

6.2.1 Organization/Institution of CWASA

CWASA bears responsibility for piped water supply and sewerage services for the City. However, the sewerage service, which is stipulated at CWASA by the regulation, at present is not commenced in CWASA. Therefore, there is no individual division for sewerage works in CWASA. Sewerage and draining works in the city are accordingly managed by the Chittagong City Corporation.

(1) Organization Chart

As a state-owned enterprise, CWASA is essentially expected to function in a financially viable manner by himself. The CWASA organization structure together with roles is shown in Figure 6.2-1.

As shown in the Figure 6.2.1, the organization of CWASA is formed an internal board consisted from four main members, which is Chairman, Administrative, Engineering and Finance members. The board with concerning section staffs is held about once a month and discussed various issues. Also, the board is in charge of decision-making such as annual budget, new tariff table and future investment.

CHAIRMAN

- **MEMBER ADMINISTRATION** - **SECRETARY** (sub-total: 158 persons)
  - **General Division**
  - **Land estate Division**
  - **Transport pool Division**
  - **Public relation Division**
  - **Board meeting implementation & co-ordination Division**
  - **Common service Division**
  - **Magistrate Division**
  - **Procurement Division**

- **MEMBER ENGINEERING** – **CHIEF ENGINEER** (sub-total: 373 persons)
  - **Planning/Construction Circle (P&C)**
    - **Design Division** - GIS
    - **Store Division**
    - **Construction Division**
    - **Construction Division**
  - **Treatment Plant Circle (TP)**
    - **Mohara WTP**
    - **Kalurghat Booster Station**
  - **Maintenance and Operation Circle (MOD)**
    - **Maintenance Operation Division 1** - Meter repairing workshop
    - **Maintenance Operation Division 2**

- **MEMBER FINANCE** – **COMMERCIAL MANAGER** (sub-total 192 persons)
  - **Accountant Division**
  - **Revenue Division**
  - **Sales Division**
  - **Computer Division**

- **AUDIT SECTION**: (sub-total 5 persons)
- **DEVELOPMENT SECTION**: (sub-total 8 persons)

Figure 6.2-1 Organization of CWASA

(2) Manpower Structure

Manpower structure of CWASA at present is presented in Table 6.2-1.

Table 6.2-1 Manpower Structure of CWASA

Class	Sanctioned (Revised After Dec. 1983)	Actual Number As of Apr. 2000	Kind of Works
Class-1	53 person	48 person	Main staffs
Class-2	21 person	21 person	Sub assistant staffs
Class-3	538 person	521 person	Operator, driver etc.
Class-4	125 person	160 person	*MLSS
Total	737 person	750 person	

Note: Member of Lower Subordinate Staff such as sweeper, cleaner and helper

The special staffs designated by the Government are Chairman, Member of administration, Member of engineering (now vacant) and Member of finance. Main staffs are referred in Supporting Report.

(3) Summarizing of Organization/Institution

Organization and Responsibility of each section in CWASA are summarized as follows:

1) The engineering function is divided into three sections; Planning and Construction circle (P&C), Treatment Plant circle (TP) and Maintenance and Operation circle (MOC). At present, all engineering functions are directed by the Chief Engineer.
2) Superintending Engineer (SE) for P&C is responsible for planning and construction for water supply facilities including pipeline and tube well. SE for TP is currently in charge by the SE for P&C circle. SE for MOD is responsible for operation and maintenance of tube wells.
3) Operation records in relation to production and distribution are informed to design section and also the Chief Engineer. Each data received from the fields are managed at design section belong to P&C circle. Management of these data such as recording and analysis is handling by manual, not computerized yet.
4) Account section belong to Commercial Manager is responsible for budget and financial plan. Revenue section is responsibility for billing and revenue. Meter reading for house connection is carried out by meter inspector, who are organized at 41 employees. The meter inspectors have routing work by means of meter reading and also billing delivery. Normally, they have a task to treat 600 dwellings per month per one inspector.
5) Secretary section is responsibility for personal employment, disciplinary matters and others. Also, establishment of Provident Fund and correspondences with Government, IDA and International Agencies, are including in this section.
6) Ledger books are ready computerized, resulting the monthly output of billing is printed out. The billing sheet is indicated Accounting No., Meter No., present reading meter and date, previous reading meter and date, and then showing the consumption volume. The charge amount for this month and arrears, if any are stated in the billing sheet. Regarding follow-up defaulters in case of non-payment within one month after received the billing, warning is given to the consumer following to a notice letter by mailing. The service connection would be closed after argument.

6.2.2 Legislation and Regulations Concerned with Water Management

The Dhaka/Chittagong WASA were authorized on the basis of the ordinance of the following;

(1) "The East Pakistan Water Supply and Sewerage Authority Ordinance in 1963" and "The Dhaka/Chittagong Water Supply and Sewerage Authority (Water Connection and Levy of Water Rate) Rules in 1966"

They would be summarized as follows:

To provide for improvement, expansion, operation and maintenance of water works.

May levy and collect water rates for its services provided that no water rate shall be levied or collected in any area until the Authority makes provision for the supply of water.

- May exempt a place of worship from the levy and collection of water rates.
- Rates or charges shall be reviewed once in every year, or at any time for special reasons and may be revised once in every five years or earlier. However, the revise of tariff cannot enforce if it is not approved by the Government.
- May cut-off: any unauthorized connection at any time; and water connection of a consumer for non-payment of water or sewer rate with one month's notice.
- No person shall make an unauthorized connection and such connection shall be construed as an offence under this Ordinance.
- Shall keep a revenue account and shall be credited proceeds of water rate and shall be applied to paying the cost of management and all operating costs.

Offences and penalties are defined in the ordinance and offences include: watering animals or bathing or washing at a well or other source of drinking water for the public; taking any water from any main or pipe with the permission of the Authority; and tampering with any main pipe or meter for the supply of water. Offences require a written complaint from the Authority to the court who apply the penalties which may constitute both fines and imprisonment. At present CWASA have many cases pending and have disposed of. They are mainly illegal reconnections of disconnected lines. Imprisonment has never been applied and the current level of actual fines, which are paid to CWASA, are insufficient to recover CWASA's costs of punishing them through the courts.

(2) "The Low of Bangladesh Government for Dhaka Set at August 17, 1996"

In the "Low of Bangladesh Government for Dhaka Set at August 17, 1996", a commitment of waterworks to private sectors is announced for DWASA. Responded to this law, the collection works are partially committed to the Co-operative Union (under Laver Union) and the Private Party at two MOD.

6.2.3 Water Tariff and Revenue

(1) Present Water Tariff System

Usually, water tariff rate is revised through following steps:

- CWASA prepares a proposal for change of the existing water tariff.
- CWASA reviews the tariff if there is increase in power (electricity) rate, and proposes to change it.
- The central Government of Water and Sewerage Sector further reviews and approves the proposal as final authorization. The proposal is sometimes denied by the Government.

Past changes of the average water tariff of CWASA are summarized in Table 6.2-2.

Table 6.2-2 History of Water Rate

(Unit: Tk /m^3)

Term	Domestic	Non-domestic
From 15/10/1980	1.32	4.40
From 1/7/1982	2.20 (66%)	6.16 (40%)
From 10/6/1986	2.75 (25%)	7.70 (25%)
*From 1/11/1987	3.03 (10%)	8.47 (10%)
*From 15/10/1990	3.33 (10%)	9.31 (10%)
*From 30/11/1992	3.83 (15%)	10.71 (15%)
*From 1/7/1997	4.06 (6%)	11.35 (6%)

Note*: Increase of Water rate owes to the adjustment of power cost.
Excise Duty is from 14th October 1990.
Value Added Tax is from 1st July 1992.
The figures in parentheses present the increasing percentage compared with before rate.

Before the year 1979, categories of water tariff were divided into four kinds of usage, which were domestic, industrial, commercial and non-metered. After meter installation in 1979, the categories were arranged into two kinds such as domestic and non-domestic uses. Domestic category at present includes Private (inhabitants), Government (hospital/school /courage /city-office), Street Hydrant (public tap) and Religious Institution (mosque). Non-domestic category includes Private (commercial / industry / hotel / shop) and Government (industry/city-market).

Cross subsidy between domestic and non-domestic is about 2.8 times which is almost average level in the world. Almost all connections are adopted metered rate system. However, Street Hydrant is calculated its consumption on the basis of 4,000 gallon per one connection per day. Water charge from Street Hydrant is billed to the Municipality. In case of Religious Institution, water charge is levied against the consumption of over 20,000 gallon per month to the Institution, while water charge is billed under 20,000 gallon per month to the GOB.

(2) Tariff Collection

Water tariff is paid in accordance with a bill. Meter inspectors visit users and read meter with reading-date. The data are inputted into the computer system of CWASA. After calculation, the data are outputted by the computer as the bill. Inspectors send the bill to the user. One inspector is in charge of about 600 connections per month. Users received bill pay a water charge at banks which exist 26 number in the city. The bill is separated into four seats that one is deposited by users, one for bank and other two for CWASA. Available payment period is about for one month. Value added tax is included in the bill amounted 15 percent of consumption volume. Surcharge is imposed five percent of

consumption charge at the case of delay of payment for one month, 10 percent for two months, 15 percent for three months, respectively. Area composes of surcharge and others.

Customer ledger is kept in computer of CWASA. Broken meters are about seven to eight percent of total installed.

Tariff collection system generally is required efficiency, correctness and fairness. At the same time, it is very important that staffs will effort for user's service through the appropriate inner or outer training. Human development is at present required in waterworks management and also in the field of meter inspectors.

(3) Trend of Other Price

1) Other public price

Regarding gas and electricity rates in Bangladesh, annual average retail prices are shown in Table 6.2-3.

Table 6.2-3 Comparison of Public Charges

Item	Specification	Unit	1994	1995	1996	1997	1998
Gas	Domestic, Double burner	Tk/month (%)	250	250 (0)	250 (0)	250 (0)	250 (0)
Electricity	Domestic.	Tk/kWh (%)	1.9	1.9 (0)	1.9 (0)	1.9 (0)	1.95 (2.6)

Note: Percent shows the increasing rate compared with previous year.
Source: Price Section, Bangladesh Bureau of Statistics (Statistical Pocketbook Bangladesh,1998)

According to up-rate of electricity in 1998, CWASA applied new tariff rate being up-rated six percent compared with previous year.

2) Consumer price and others

Consumer Price Index in the case of 100 at the year 1986 is shown in Table 6.2-4.

Table 6.2-4 Consumer Price Index (1986=100)

Item	1994	1995	1996	1997	1998
National (%)	164	178 (8.5)	190 (6.7)	195 (2.6)	209 (7.2)
Urban (%)	163	175 (7.4)	186 (6.3)	191 (2.7)	204 (6.8)
Rural (%)	164	179 (9.1)	192 (7.3)	196 (2.1)	210 (7.1)
Dhaka SMA (%)	175	186 (6.3)	196 (5.4)	201 (2.6)	219 (9.0)

Note: Percent shows the increasing rate compared with previous year.
Source: Price Section, Bangladesh Bureau of Statistics (Statistical Pocketbook Bangladesh, 1998)

House Rent Index in the case of 100 at the year 1974 in Dhaka is shown in Table 6.2-5.

Table 6.2-5 House Rent Index (1974=100)

Item	1994	1995	1996	1997	1998
Hose Rent Index (%)	1393	1462 (5.0)	1512 (3.4)	1535 (1.5)	1566 (2.0)

Note: Percent shows the increasing rate compared with previous year.
Source: Price Section, Bangladesh Bureau of Statistics (Statistical Pocketbook Bangladesh, 1998)

Wage Rate Index in the case of 100 at the year 1974 in Bangladesh, is shown in Table 6.2-6.

Table 6.2-6 Wage Rate Index (1974=100)

Item	1994	1995	1996	1997	1998
Nominal (%)	988	1032 (4.5)	1098 (6.4)	1150 (4.7)	1237 (7.6)
Real (%)	176	172 (-2.3)	176 (2.3)	184 (4.5)	190 (3.3)

Note*: Percent shows the increasing rate compared with previous year.
Source: Price Section, Bangladesh Bureau of Statistics (Statistical Pocketbook Bangladesh, 1998)

Macro-economic indicators including inflation ratio are shown in Table 6.2-7.

Table 6.2-7 Macro-economic Indicators

Item/Specification	Unit	1994	1995	1996	1997	1998
GDP at Current Market Price (%*)	billion Tk	1030.36	1170.26 (13.6)	1301.60 (11.2)	1403.05 (7.8)	1540.93 (9.8)
GDP Growth Rate at Constant Prices (%)	%	4.2	4.4 (4.8)	5.3 (20.5)	5.9 (11.3)	5.6 (-5.1)
Per capita GDP at Current Prices (%)	Tk	8754	9760 (11.5)	10660 (9.2)	11288 (5.9)	12181 (7.9)
Rate of Inflation ** (%)	%	1.8	5.2 (188.9)	4.1 (-21.2)	3.9 (-4.9)	6.3 (61.5)

Note*: Percent shows the increasing/decreasing rate compared with previous year.
Note**: Rate of Inflation in 1998 is for 12 months period (May '97-April '98). The rate of inflation has been estimated on the basis of CPI of middle-income group of Dhaka City (base year 1974).
Source: Bangladesh Economic Review 1998

As shown above Table, Rate of Inflation showed sharp increase in 1995. And, it is gradually decreasing from the year 1995 to 1997 indicated the rate of 5.2 to 3.9 percent. However, a big increase again showed in 1998 at the rate of 6.3 percent.

6.2.4 Financial Performance

(1) Analysis of Present Financial Situation

1) General

CWASA's past financial performance for four years from 1994 up to 1997 fiscal year based on audited data was reviewed and assessed to wit its financial viability while the performance in 1998 was based on partial audited. Further, the performance in 1999 and 2000 is estimated by CWASA, which is revised the operating incomes in accordance with reasonable connection number. Waterworks has an interrelationship between provided services and benefits of customers which is similar to services being rendered by private companies and is different from general public services, such as education, road network, etc., that are deemed difficult to quantify interrelationship between costs and benefits. Expenses to be incurred in water supply service are to be shouldered by customers corresponding to their benefits from the viewpoint of fair cost sharing using water meters.

Quality and quantity of water supply services and its water bills are governed by the principal of market economy, which are same as other services of private sector. However, reduction and exemption policy of water charge for social week people is required from the viewpoint of the public works and social justice owned by waterworks. In this regard, provision of water supply services at high quality and realization of low water tariff through efficient financial management are indeed required by customers. To comply with these basic requirements, an establishment of institutional and legislative set-up is indispensable as well as account on public enterprises. Taking into account the above-mentioned prerequisite, CWASA is undertaken financial management system in accordance with the business accounting principal, by means of double entry bookkeeping method consisting of the profit and loss (P/L) account (Income and Expenditure) and the balance sheet (B/S).

CWASA prepares the audited aforementioned profit and loss account, balance sheet and other financial statements and their attachments, and is conducting financial analysis every year taking into account of the above-mentioned subjects. Result of the analysis on these financial statements in short, however, is not sustainable and sound management of water supply works. In other word, the harmony among the Government, users and CWASA is insufficient such as water rate settlement, interest payment, remaining of arrears and commercial/business accountability.

Financial ratios such as ratio of fixed assets to equity capital, current ratio, etc., will be described and analyzed comparatively for several years in order to improve the accuracy and analysis of the financial performance in the subsequent context of this report.

2) Financial status

Financial statements, i.e. balance sheet, profit and loss statement, cash flow are shown below to analyze CWASA's financial status.

(a) Balance sheet

Balance Sheet for recent five years of CWASA is shown in Table 6.2-8.

This table shows that the long-term debt (No.14 shown in Table 6.2-8), which has been accumulated principal and interest almost year by year, is too high as equivalent amount of about 74 percent of property and assets (including fixed and current assets) in 1997. This long-term debt is amounted about 6.5 times of operating revenue in 1997.

Besides, Accreted Operating Deficit (No.15 shown in Table 6.2-8), which is deferred negatively in Income and Expenditure Statement, is amounted about 19 percent of total Capital Fund and Liabilities in 1997.

(b) Profit and loss statement (Income and expenditure)

Income and expenditure for recent five years of CWASA is shown in Table 6.2-9.

In this table, the net operating balance (No.24 shown in Table 6.2-9) is deficit every year due to the high level of interest payment (No.21 shown in Table 6.2-9) while the operating balance (No.19 shown in Table 6.2-9) is surplus to every year. However, the operating balance in 1998 has been down because of low increase ratio of operating income. Counted interest (No.21 shown in Table 6.2-9) is calculated about Tk 39 million in 1997, which is equivalent to about 19 percent of operating revenue in the year. Deficit brought forward (No.26 shown in Table 6.2-9), which is calculated the amount of Tk 409 million in 1997, is summed up big amount every year resulted negative situation in the net balance (No.27 shown in Table 6.2-9). Detail of interest payment is mentioned in the next context of this report.

(c) Cash flow

According to audited data, cash flow statements during the past three years from 1995 to 1997 are shown in Table 6.2-10.

In this table, the cash outflow (No.5 and 7 shown in Table 6.2-10) is about 1.6 (111,040/69,831) times of the cash inflow (No.1 shown in Table 6.2-10) in 1997 fiscal year. This shows the decrease of cash and bank balance (No.9 shown in Table 6.2-10) year by year as equivalent to the reduction of 33 percent in 1997 compared with previous year.

Table 6.2-8 Balance Sheet

Unit: 1000Tk

Balance Sheet (B/S)	Jun-94	(%)	Jun-95	(%)	Jun-96	(%)	Jun-97	(%)	*June 1998
Property and Assets									
(1)Fixed Assets less accumulated depreciation	1,108,344	66.45	1,130,669	64.81	1,123,632	62.09	1,138,230	61.42	1,114,800
(2)Capital Work-in-progress	59,755	3.58	42,686	2.45	62,510	3.45	73,409	3.96	130,670
(3)Investment	94,208	5.65	113,358	6.50	156,779	8.66	185,253	10.00	202,049
(4)Deferred Expenses	135	0.01	135	0.01	135	0.01	135	0.01	135
(5)=(1)+(2)+(3)+(4)	1,262,444	75.69	1,286,849	73.76	1,343,058	74.21	1,397,028	75.39	1,447,656
Current Assets									
(6)Stores	72,044	4.32	49,671	2.85	52,359	2.89	68,602	3.70	74,719
(7)Accounts Receivable less provision for bad debt	147,107	8.82	160,641	9.21	190,639	10.53	214,283	11.56	235,703
(8)Other Current Assets	58,139	3.49	106,794	6.12	100,432	5.55	91,149	4.92	127,305
(9)Cash and Bank Balance	128,235	7.69	140,756	8.07	123,268	6.81	82,058	4.43	57,133
(10)=(6)+(7)+(8)+(9)	405,527	24.31	457,865	26.24	466,699	25.79	456,094	24.61	494,862
(11)=(5)+(10)	1,667,972	100.00	1,744,714	100.00	1,809,757	100.00	1,853,123	100.00	1,942,519
Capital Fund and Liabilities									
(12)Capital Fund	767,739	46.03	767,739	44.00	767,739	42.42	767,739	41.43	767,739
(13)Assets Revaluation Reserve	44,874	2.69	44,852	2.57	45,048	2.49	45,473	2.45	45,473
(14)Long Term Debts	1,148,595	68.86	1,281,701	73.46	1,380,208	76.26	1,364,082	73.61	1,467,714
(15)Accumulated Operating Surplus(Deficit)	-344,655	-20.66	-382,572	-21.93	-409,106	-22.61	-349,002	-18.83	-368,188
(16)Excess of Physical Verification of Assets	280	0.02	280	0.02	280	0.02	280	0.02	280
(17)=(12)+(13)+(14)+(15)+(16)	1,616,834	96.93	1,712,000	98.12	1,784,170	98.59	1,828,572	98.68	1,913,019
Current Liabilities									
(18)Account Payable	32,125	1.93	14,646	0.84	13,947	0.77	12,493	0.67	14,786
(19)Employees Provident Fund	440	0.03	555	0.03	617	0.03	612	0.03	700
(20)Other Current Liabilities	18,570	1.11	17,511	1.00	11,022	0.61	11,444	0.62	14,012
(21)=(18)+(19)+(20)	51,137	3.07	32,714	1.88	25,587	1.41	24,550	1.32	29,499
(22)=(17)+(21)	1,667,972	100.00	1,744,714	100.00	1,809,757	100.00	1,853,123	100.00	1,942,519

Note*: June 1998 is including the badget data. Other data are the audited ones.

Table 6.2-9 Income and Expenditure Unit: 1000Tk

Income and Expenditure/Profi and Loss(P/L)	Jun-94	(%)	Jun-95	(%)	Jun-96	(%)	Jun-97	(%)	*June 1998
Income-Operating Revenue									
(1)Water Revenue	163,899	93.08	167,912	93.59	180,216	94.59	192,727	92.11	197,107
(2)Other Operating Revenue	12,190	6.92	11,504	6.41	10,314	5.41	16,517	7.89	13,111
(3)=(1)+(2)	176,089	100.00	179,416	100.00	190,530	100.00	209,245	100.00	210,219
Expenditure									
A. Operation									
(4)Wages	17,154	10.84	17,787	10.71	20,150	11.54	21,520	11.10	24,053
(5)Powers	48,218	30.46	48,259	29.07	52,255	29.92	63,109	32.55	74,986
(6)Chemicals	12,103	7.64	11,055	6.66	11,370	6.51	10,895	5.62	8,974
(7)Repairs and Maintenance	9,418	5.95	11,416	6.88	9,339	5.35	11,371	5.86	14,000
(8)Depreciation	35,572	22.47	36,955	22.26	38,816	22.23	40,944	21.12	31,422
(9)Other Expenditures	1,434	0.91	1,457	0.88	1,463	0.84	1,099	0.57	953
(10)=(4)+(5)+(6)+(7)+(8)+(9)	123,902	78.26	126,932	76.46	133,397	76.38	148,940	76.82	154,389
B. Collection									
(11)Salaries	5,837	3.69	6,095	3.67	6,290	3.60	6,845	3.53	7,947
(12)Bad and Doughtful Debts	500	0.32	0	0.00	0	0.00	0	0.00	0
(13)Other Expenditures	2,246	1.42	1,869	1.13	1,849	1.06	1,175	0.61	1,891
(14)=(11)+(12)+(13)	8,584	5.42	7,964	4.80	8,139	4.66	8,020	4.14	9,891
C. General and Administration									
(15)Salaries	13,993	8.84	19,696	11.86	21,497	12.31	22,905	11.81	23,632
(16)Other Expenditure	11,837	7.48	11,426	6.88	11,607	6.65	14,022	7.23	17,880
(17)=(15)+(16)	25,831	16.32	31,123	18.75	33,104	18.96	36,928	19.05	41,512
(18)=(10)+(14)+(17)	158,318	100.00	166,020	100.00	174,641	100.00	193,889	100.00	205,794
(19)=(3)-(18)Operating Balance	17,770	10.09	13,395	7.47	15,888	8.34	15,355	7.34	4,425
(20)Other Income-Interest	5,935		11,338		9,586		11,951		18,033
(21)Financial Expenses-Interest on F.C.Loan	-51,285		-51,222		-51,158		-39,110		-39,047
(22)Payment to national Ex-Chequer	-1,000		-1,000		-1,250		-1,500		-3,000
(23)=(20)+(21)+(22)	-46,349		-40,883		-42,821		-28,659		-24,014
(24)=(19)+(23)Net Operating Balance	-28,578		-27,488		-26,933		-13,303		-19,588
(25)Prior year's adjustment	632		-10,429		399		73,407		402
(26)Surplus/(Deficit) brought forward	-316,708		-344,655		-382,572		-409,106		-349,002
(27)=(24)+(25)+(26)Net Balance	-344,655		-382,572		-409,106		-349,002		-368,188

Note*: June 1998 is including the badget data. Other data are the audited ones.

Table 6.2-10 Cash Flow Statement

Unit: 1000Tk

Cash Flow	Jun-95	Jun-96	Jun-97
(A) Cash from Operating Activities			
(1)Net Cash inflow/(outflow) from Operating activities	-59,224	-20,970	69,831
(B) Cash from Investing Activities			
(2)Purchase of Fixed Assets	-59,280	-31,779	-55,541
(3)Addition Capital Work-in-progress	17,069	-19,824	-10,898
(4)Investment in FDR	-19,149	-43,420	-28,473
(5)=(2)+(3)+(4)Net Cash inflow/(outflow) from Investing activities	-61,360	-95,025	-94,914
(C) Cash from Financing Activities			
(6)Loan received	133,105	98,507	-16,126
(7)=(6)Net Cash inflow/(outflow) from Financing activities	133,105	98,507	-16,126
(8)=(1)+(5)+(7) Increase/Decrease in Resources	12,520	-17,488	-41,209
Check			
(9)Closing Cash and Bank Balance	140,756	123,268	82,058
(10)Less: Operating Cash and Bank Balance	128,235	140,756	123,268
	12,520	-17,488	-41,209
Details of Net Cash inflow/outflow from Operations(1):			
Net Operating income/(loss) during the year	-27,488	-26,933	-13,303
Depreciation	36,955	38,816	40,944
Prior year's adjustment	-10,429	399	73,407
Assets Revalued	-22	196	424
Decrease/(increase) in stock and stores	22,372	-2,687	-16,243
Decrease/(increase) in Accounts Receivable	-13,534	-29,997	-23,643
Decrease/(increase) in Other Current Assets	-48,654	6,362	9,282
Decrease/(increase) in Accounts Payable	-17,479	-699	-1,453
Decrease/(increase) in Current Liabilities	-1,058	-6,489	422
Decrease/(increase) in employee's Provident Fund	115	62	-5
	-59,224	-20,970	69,831

Source: Annual audited report

3) Results of financial analysis

(a) Current ratio

The current ratio means the current asset divided by the current liability, and implies the ability of the debt repayment. Generally, this is desirable to maintain high percentage. In case of CWASA, it is calculated at 1,678 % in 1998, 1,858 % in 1997, 1,824 % in 1996, 1,400 % in 1995 and 793 % in 1994, respectively. These are fairly high rate resulted in having the ability the debt repayment in view of financial situation. This implies amounts of current assets such as accounts receivable/stores is too large comparing with the amounts of current liabilities such as account payable.

According to the audited report in 1997, the amount of accounts receivable is netted by bad debt. Schedule of both accounts receivable and bad debt were not available for the auditor's verification. And, it is reported that management should prepare and maintain a complete schedule of continuously review, which is necessary for making provision for bad debts.

As for stores, while comparing the Physical Inventory Report (PIR) as at 30/06/97 (made by the Committee, formed by CWASA) with Store Ledger (SL), the auditors observed that some disagreement between two records. Few instances are given in Table 6.2-11.

Table 6.2-11 Comparison of PIR/SL

Particulars	As per SL (Quantity)	As per PIR (Quantity)
Salvage Brick	155,611	48,030
6" Gate Valve	11	Nil

Besides, it is reported that stores held by Persons Corporation are not evidenced by any conformation; instead, a list of materials carried forward from 1979 was provided to the auditors. And, the auditors proposed that stores held by Persons Corporation should be written off after proper scrutiny. Further, it is reported that the auditors observed that bin-card have not been recorded timely.

The figure of CWASA excluding in 1994 showed good results comparing with the figure of DWASA in 1998/99 at the rate of 1,221 percent. (Detail of comparison is shown in section 6.4) From this result, CWASA has higher ability of debt repayment than DWSA in simple comparison. However, from the reason above mentioned, the verification of current assets needs more detailed study.

(b) Fixed assets to equity capital ratio

The ratio of fixed assets to equity capital, defined to be the fixed assets divided by the owned capital and surplus, and implies the financial management stability of the entity. The desirable ratio is considered to be less than 100 percent, while in case of CWASA, it is calculated at 250 percent in 1998, 245 in 1997, 278 in 1996, 263 in 1995 and 231 in 1994, respectively.

The figure of CWASA generally shows worse results and worse results comparing with the figure of DWASA in 1998/99 at the rate of 78 percent. This means that owned capital and surplus are little compared with fixed assets in one aspect, resulted in low ability of long-term trust of CWASA.

(c) Profit ratio to gross capital

The profit ratio to gross capital, being expressed by the net operating profit divided by the total average liability and capital, and means the profitability of the concerned business. It is commonly known that the larger the ratio increases, the more the business operation is

profitable. CWASA has recorded at 12 percent in 1998 and 1997, 11 in 1996 and 1995, respectively. The results achieved by CWASA showed much bigger figures comparing with the figure of DWASA in 1998/99 at rate of nine percent. (Detail of comparison is shown in section 6.4)

This means that CWASA is better level of management achievement compared with DWASA in simple comparison.

Other indicators for comparison are shown in section 6.4, comparing with the situation of DWASA.

(2) Investment Planning of Overall CWASA

1) CWASA's investment project assisted by World Bank

CWASA has been conducted big investment project assisted by World Bank. Owed to this project, CWASA has had big long-term liabilities.

Until the 1960's the only form of water supply was tube wells with distribution to local areas. After formation of CWASA and with the help of the World Bank (IDA) the First Chittagong Water Supply Project was launched in 1968. This involved the construction of an iron removal plant at Kalurghat, treating water from 17 new tube wells together with the construction of a pumping station at the treatment site, a large water reservoir on Battali Hill and the installation of over 50 km of transmission lines. These works were commissioned in 1978 and raised the total supply capacity from 13,000 to 45,000 m^3/day.

In 1981, with further assistance from the IDA, the Second Chittagong Water Supply Project was launched. This involved the construction of Mohara Treatment Plant, which treated 90,000 m^3/day from the River Halda. In addition there were further extensions at Kalurghat Treatment Plant with the treatment of five new boreholes. A new storage reservoir on ADC Hill and two new booster stations were also constructed together with transmission and distribution lines. This increased the supply capacity to 160,000 m^3/day.

The Third Chittagong Water Supply Project is now at the implementing stage and prior to the planning the Unaccounted Water Management Programme has been set up to assess the current situation and to identify and implement a strategy.

Past and present investments of CWASA under the financial assistance of multilateral and bilateral lending institutions were reviewed.

2) Long-term loan

In the Balance sheet audited at June 30 1997, the long-term loan is summed up Tk 1,364 million as long-term debts. According to the audit report, the followings are recorded:

(a) International Development Association (IDA) Loan (1st Phase)

Tk 63.5 million was received in 1973 as loan repayable with three percent interest per annum in 30 equal annual installments commencing from the year 1982-83. As per ledger, Tk 2.1 million has been paid during the year under audit as 15th installment (Total repayment of principal until this year amounts Tk 31.5 million: 15 years x Tk 2.1 million = Tk 31.5 million.)

(Recorded amount Tk 31.7 million, which is remained in principal, is 2.3 percent of summed up amount Tk 1,364 million.)

(b) IDA Loan (2nd Phase)

The above loan was made by the Government to CWASA against development credit agreement with IDA and is repayable in 20 equal annual installments together with interest @ seven percent per annum commencing from 30 June 1991. It was reported that the auditors noted that the annual installment of principal has not been paid. However, Tk five million so far has been paid up to 1995-96 as lump sum, which is allotted in interest payment.

(Recorded amount Tk 544 million, which is remained in principal, is 39.9 percent of summed up amount Tk 1,364 million.)

(c) 1st Interim Water Supply & Rehabilitation Project (IWSRP) Loan

The amount was received as loan granted by the Ministry of Finance for IWSRP repayable with 7.5 percent interest per annum that has been provided in the accounts.

(Recorded amount Tk 248 million, which is remained in principal, is 18.2 percent of summed up amount Tk 1,364 million.)

(d) 2nd IWSRP Loan

The amount was received as loan during the previous year 1995-96 against proposed project cost of Tk 239 million granted by the Government of Bangladesh. CWASA has already applied to the Government of Bangladesh to dismiss the loan. Interest for the above amount has not been provided for the accounts.

(Recorded amount Tk 30.7 million, which is remained in principal, is 2.3 percent of summed up

amount Tk 1,364 million.)

(e) Un-accounted Water Management Program

The above loan was received (Tk 1.6 million during the year). It is reported that auditors have not seen relevant loan agreement for verification of terms and conditions of the loan, repayment schedule etc. Interest for the above amount has not been provided for the accounts.

(Recorded amount Tk 4.9 million, which is remained in principal, is 0.4 percent of summed up amount Tk 1,364 million.)

(f) Accrued interest on IDA Loan (1st and 2nd Phase) and IWSRP Loan (1st Phase)

In these interests, provision amount for the year was added all of them while less amount by payment/adjustment was provided for in the accounts of IDA Loan (1st and 2nd Phase). Details are seen in the following Table 6.2-12.

(Recorded amount Tk 501 million, which is remained in total interest, is 36.7 percent of summed up amount Tk 1,364 million.)

Table 6.2-12 Long-term Debts

(Unit: 1000 Tk /year)

Item		1997	1996	1995	1994
IDA Loan	1st Phase	31,728 (*2,115)	33,844 (*2,115)	35,959 (*2,115)	38,074
IDA Loan	2nd Phase	544,223 (*0)	544,223 (*0)	544,223 (*0)	544,223
IWSRP Loan (GOB)	1st Phase	248,725 (*0)	248,725 (*0)	241,975 (*0)	174,000
IWSRP Loan (GOB)	2nd Phase	30,750 (*0)	30,750 (*0)	-	-
Reimbursable Loan For Sewerage (GOB)	-	2,700 (*0)	2,700 (*0)	2,700 (*0)	2,700
UFW Management Program (IDA)	-	4,900 (*0)	3,250 (*0)	3,000 (*0)	-
Sub-total	-	863,027 (*2,115)	863,492 (*2,115)	827,857 (*2,115)	758,998
(Accrued interest on):					
IDA Loan	1st Phase	7,565 (*2,519)	8,069 (*1,583)	8,574 (*1,646)	9,078
IDA Loan	2nd Phase	432,875 (**71,906)	466,686 (*5,000)	421,606 (*0)	371,526
IWSRP	1st Phase	60,614 (*0)	41,959 (*0)	23,663 (*0)	8,992
Sub-total	-	501,054 (*2,519) (**71,906)	516,715 (*6,583)	453,843 (*1,646)	389,597
Total	-	1,364,082 (*4,634) (**71,906)	1,380,208 (*8,698)	1,281,701 (*3,761)	1,148,595

Note (*): Payment made during the year (less amount)

(**): Adjustment for the provision of excess interest (less amount)

Above table, the redemption of principal and interest is amounted huge one, which is about 6.8 times to annual sales income. CWASA has already applied to the Ministry of Finance of Bangladesh to dismiss the loan.

6.2.5 Water Supply Management

Water supply management principally requires fair charge collection on the basis of appropriate tariff table. On this policy, it is necessary not only appropriate user's management but also reduction of wasteful expenditure in the waterworks itself.

(1) Collection Ratio

Present situation of the financial management is shown in the following. The yearly collection ratio for past five years is presented in Table 6.2-13.

Table 6.2-13 Yearly Collection Ratio

(Unit: Million Tk)

	1995	1996	1997	1998	1999
Billing	167.54	179.71	191.99	196.36	204.70
Collection	156.79	153.21	173.73	178.69	198.66
Collection Ratio (%)	93.6	85.3	90.5	91.0	97.0

Source; Computer Division of CWASA dated 05/04/2000. Computer system of customer ledger started in Dec. 1988 of two areas and covered 33 areas in Jun. 1989.

In the above table, the trend of collection ratio increases for recent three years. The collected amount by category is as shown in Table 6.2-14.

Table 6.2-14 Collected Amount by Category

Category		1996		1997		Rate
		Tk/year	%	Tk/year	%	(Tk/m^3)
Domestic	Private	60,249,803	33.4	66,310,290	34.4	4.06
	Government	26,616,602	14.8	27,894,606	14.5	4.06
	Hydrant	17,264,792	9.6	17,264,792	9.0	4.06
	Religious Inst.	1,452,413	0.8	1,452,412	0.8	4.06
	Subtotal	105,583,610	58.6	112,922,100	58.6	-
Non-domestic	Private	33,925,561	18.8	36,917,935	19.2	11.35
	Government	40,202,585	22.3	42,149,965	21.9	11.35
	Subtotal	74,128,146	41.1	79,067,900	41.0	-
Loose Water Sales		504,769	0.3	737,912	0.4	-
Total		180,216,525	100	192,727,912	100	-

Source: Annual audited report

Note: The rate is applied from July 1st, 1997.

In the above table, Domestic usage is about 59 percent while Non-domestic is 41 percent out of the total consumption. Further, Private section is about 54 percent, Government 36 percent, Street hydrant nine percent, Religious institution and Loose water sales about one percent, respectively.

(2) Management Situation

Management situations of CWASA from the viewpoint of finance aspect are shown in the Figure 6.2-2 to the Figure 6.2-9. In these Figures, the data from 1995 to 1997 are audited while the data from 1998 to 2000 are not audited implicating somewhat provision. Furthermore, water revenue is considered appropriate amount on the basis of increase of customer numbers at the year of 1999 and 2000. According to the change of water revenue, operating balance and net operating balance, which are very important indicators for analyzing of management situation, are revised compared with CWASA's financial projection for the year 1995-2010. Management situation based on above- mentioned premise is shown in Table 6.2-15.

The variation of each item, which represents the management situation in passing year, is shown below with brief analysis.

1) Items related cost

(a) Water sold

Water sold for past six years from 1995 to 2000 is shown in Figure 6.2-2. Water sold is directly in relation with water revenue, so it is needed to count correctly. As shown in this figure, the trend is slowly increasing year by year because of increase of production and consumption.

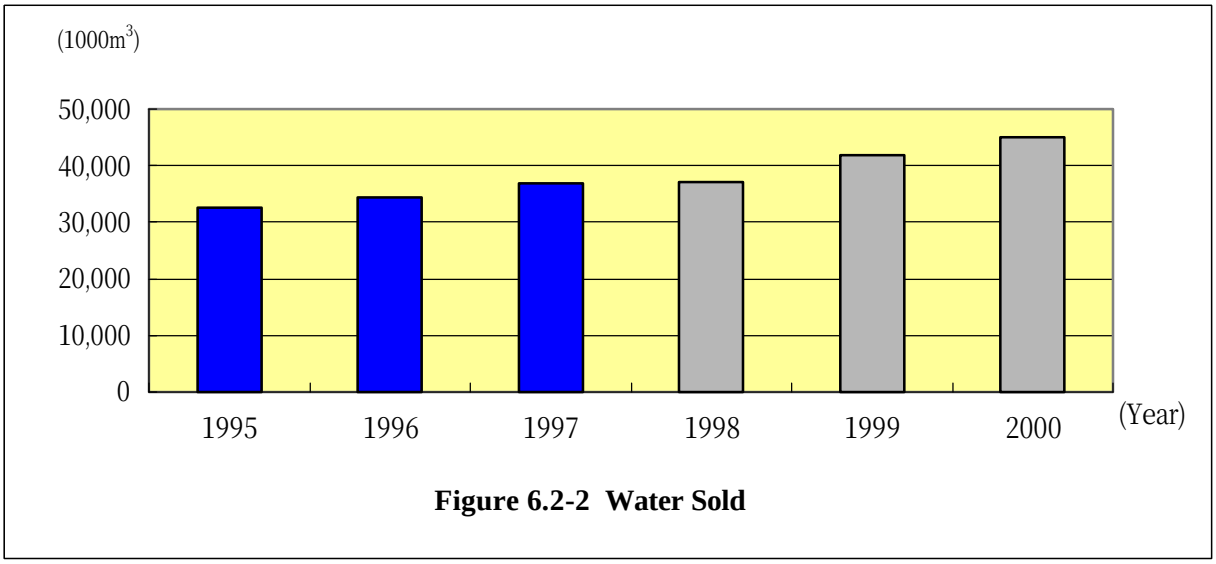


Figure 6.2-2 Water Sold

Table 6.2-15 Management Status

Unit: Million Tk

(Income/Expenditure Base)	Actual(audited)						Actual(not-audited)				
	1995	(%)	**1996**	(%)	**1997**	(%)	**1998**	(%)	**1999**	(%)	**2000**
Water Production(m^3/day)	146,255	3.99	152,096	0.52	152,882	7.77	164,764	10.09	181,385	5.26	190,930
Loss of Production(%)	5		5		5		5		5		5
Water Distribution(m^3/day)	139,405	3.65	144,488	-0.47	143,803	9.12	156,918	10.09	172,748	5.26	181,838
Water Sold(m^3/day)	89,049	6.21	94,581	6.80	101,008	0.73	101,742	12.91	114,882	7.63	123,649
UFW after distribution(%)	36	-2.78	35	-14.29	30	16.67	35	-4.29	33.5	-4.48	32
Number of Customer	27,403	5.34	28,867	3.95	30,006	2.67	30,807	2.43	31,557	1.40	32,000
Incom(Operating Revenue)											
(1)Water Revenue	167.91	7.33	180.22	6.94	192.73	2.27	197.11	2.44	201.91	1.40	204.74
(2)Other Operating Revenue	11.51	-10.43	10.31	60.23	16.52	-20.64	13.11	2.44	13.43	1.41	13.62
(3)=(1)+(2)	179.42	6.19	190.53	9.83	209.25	0.46	210.22	2.44	215.34	1.40	218.36
Expenditure(Operating Expenses)											
(4)Wages	17.79	13.27	20.15	6.80	21.52	14.59	24.66	21.90	30.06	15.04	34.58
(5)Power	48.26	8.29	52.26	20.76	63.11	18.36	74.70	8.19	80.82	5.00	84.86
(6)Chemicals	11.06	2.80	11.37	-4.13	10.90	-8.35	9.99	12.31	11.22	4.99	11.78
(7)Repair & Maintenance	11.42	-18.21	9.34	21.73	11.37	9.50	12.45	15.02	14.32	15.01	16.47
(8)Other Expenses	1.46	0.00	1.46	-24.66	1.10	5.45	1.16	10.34	1.28	10.16	1.41
(9)=(4)+(5)+(6)+(7)+(8)	89.89	5.22	94.58	14.19	108.00	13.85	122.96	11.99	137.7	8.28	149.10
Collection											
(10)Salaries	6.09	3.28	6.29	8.90	6.85	25.11	8.57	20.54	10.33	15.00	11.88
(11)Other Expenses	1.87	-1.07	1.85	-36.76	1.17	12.82	1.32	9.85	1.45	10.34	1.60
(12)=(10)+(11)	7.96	2.26	8.14	-1.47	8.02	23.32	9.89	19.11	11.78	14.43	13.48
General & Administration											
(13)Salaries	19.70	9.14	21.50	6.56	22.91	3.14	23.63	27.42	30.11	15.01	34.63
(14)Other Expenses	11.43	1.49	11.60	20.86	14.02	27.53	17.88	10.01	19.67	10.02	21.64
(15)=(13)+(14)	31.13	6.33	33.10	11.57	36.93	12.40	41.51	19.92	49.78	13.04	56.27
(16)=(9)+(12)+(15)Total Operating Expenditure	129.08	5.22	135.82	12.61	152.95	14.00	174.36	14.28	199.26	9.83	218.85
(17)=(3)-(16)Working Balance	50.34	8.68	54.71	2.91	56.30	-36.31	35.86	-55.16	16.08	-103.05	-0.49
(18)Depreciation	-36.95	5.06	-38.82	5.46	-40.94	-23.25	-31.42	47.14	-46.23	16.29	-53.76
(19)=(17)+(18)Operating Balance	13.39	18.67	15.89	-3.34	15.36	-71.16	4.43	-780.59	-30.15	79.93	-54.25
(20)Incom from Fixed Deposit	11.34	-15.43	9.59	24.61	11.95	50.88	18.03	-39.93	10.83	101.39	21.81
(21)=(19)+(20)Net Operating Blance before interest	24.73	3.03	25.48	7.18	27.31	-17.76	22.46	-186.02	-19.32	67.91	-32.44
(22)Interest (1st & 2nd Phases)	-51.22	-0.12	-51.16	-23.55	-39.11	-0.18	-39.04	44.47	-56.40	-0.12	-56.33
(23)Divident to Government	-1.00	25.00	-1.25	20.00	-1.50	100.00	-3.00	50.00	-4.50	11.11	-5.00
(24)=(21)+(22)+(23)Net Operating Balance	-27.49	-2.04	-26.93	-50.61	-13.30	47.22	-19.58	309.70	-80.22	16.89	-93.77
(25)Prior year's adjustment	-10.43		0.40		73.41		0.40		-		-
(26)Surplus/Deficit brought forward	-344.66		-382.57		-409.11		-349.00				
(27)=(24)+(25)+(26)Net Balance	-382.57	6.94	-409.11	-14.69	-349.00	5.50	-368.19		-		-

Note: Percentage shows the increase/decrease ratio compared with previous year.

(b) Structure of water supply cost

Structure of water supply cost at the year 1997 is presented in Figure 6.2-3.

As shown in this figure, the highest ratio is Power cost, the second Wages/Salaries cost, third Depreciation and fourth Interest, respectively.

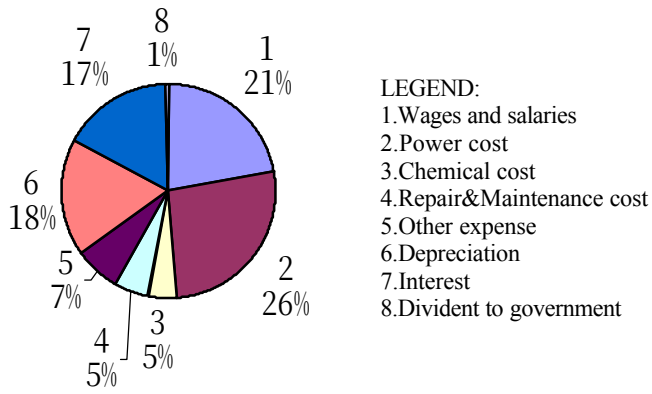


Figure 6.2-3 Distribution of Water Supply Cost

(c) Wages and salaries

Wages/Salaries for past six years from 1995 to 2000 are shown in Figure 6.2-4. As shown in this figure, the trend develops gradually since 1999 hence it is needed the arrangement of increase up-rate for the sake of stable management.

(d) Power cost

Power cost for past six years from 1995 to 2000 is shown in Figure 6.2-4. Power cost that is almost by electric cost that holds the highest portion in the total operating. As shown in this figure, the power cost in 2000 estimates twice of it in 1995. From the view of technology, it is needed more efficient system such as energy saving facilities.

(e) Chemical cost

Chemical cost for past six years from 1995 to 2000 is shown in Figure 6.2-4. Generally speaking, chemical cost indicates proportional to the production amount. As shown in this figure, however, chemical cost shows the fluctuation in indicated six years. In this regard, further study is needed why the chemical cost in 1998 was low.

(f) Repair and maintenance costs

Repair/Maintenance costs for past six years from 1995 to 2000 are shown in Figure 6.2-4. As

shown in this figure, the trend indicates slowly increasing since 1996. According to deterioration of aged materials, this increasing trend may be continuing if not treated.

(g) Other expense

Other expense for past six years from 1995 to 2000 is shown in Figure 6.2-4. As shown in this figure, the trend is increasing since 1997 hence it is needed the reduction of wasteful expenditure for the sake of stable management. If water rate will be up, this expenditure will be at first looked up for reduction.

(h) Depreciation

Depreciation for past six years from 1995 to 2000 is shown in Figure 6.2-4. Depreciation is in amount of each year's expense so as to decrease of economical worth on fixed assets. This amount occurs financial effect such as reservation in the company. Generally, in the case of setting new tariff, this will be counted in the cost calculation. As shown in this figure, the amount in 1998 is counted rather low.

(i) Interest

Interest for past six years from 1995 to 2000 is shown in Figure 6.2-4. As shown in this figure, the trend shows rather fluctuation. Further situation in detail is mentioned in subsection 6.2.4.

(j) Dividend to government

Dividends to Government (Payment to national ex-checker) for past six years from 1995 to 2000 are shown in Figure 6.2-4. As shown in this figure, the trend shows the sharp increase since 1998.

(k) Unit water supply costs and selling cost (average)

Unit water supply cost and selling cost (average) for past six years from 1995 to 2000 are shown in Figure 6.2-5. Water supply cost means the net operating expenditure divided by water sold, while Unit price of selling cost means the revenue on water sales divided by water sold. As shown in this figure, water supply cost is higher than selling cost at the range of one third to one forth in recent years.

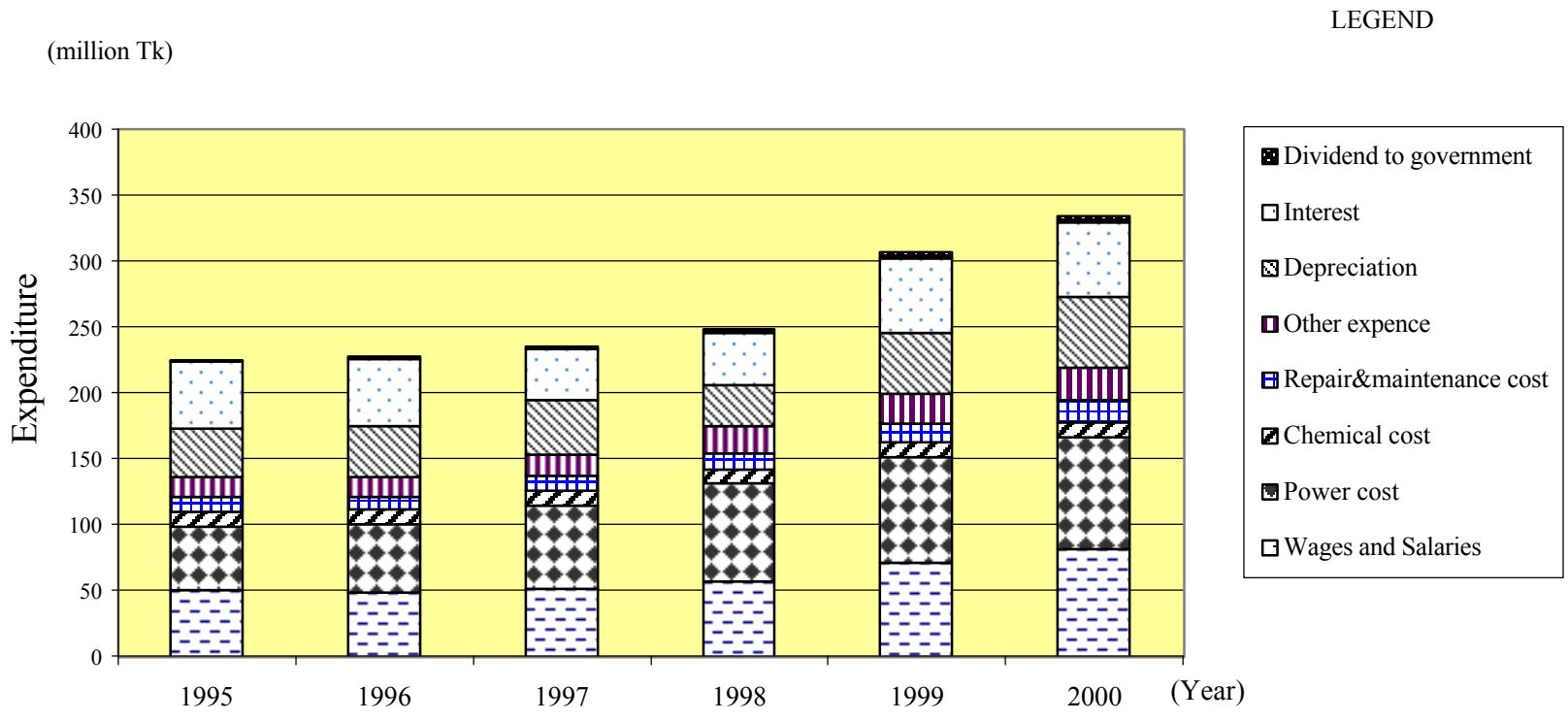


Figure 6.2-4 Composition of Expenditure

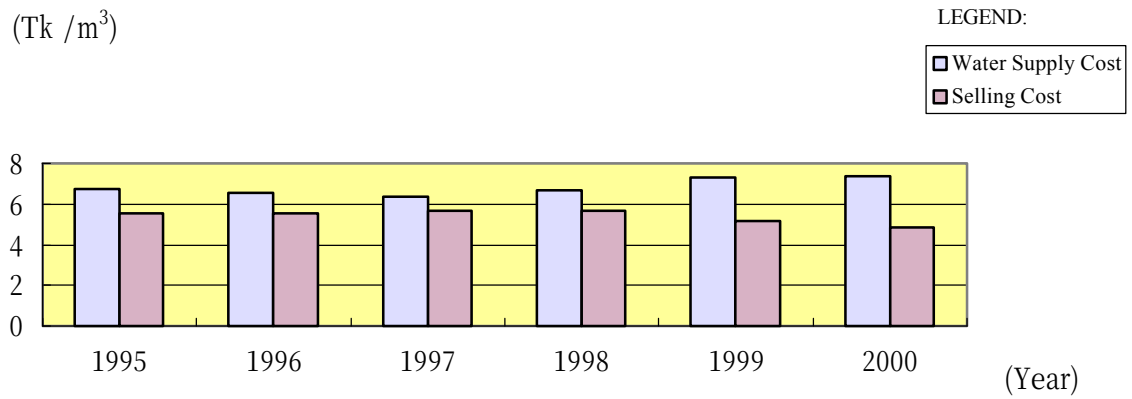


Figure 6.2-5 Water Supply Cost/Selling Cost (Average)

2) Items related finance

(a) Water sales revenue

The water sales revenues for past six years from 1995 to 2000 are shown in Figure 6.2-6. As shown in this figure, the trend is very slowly increasing year by year. An up-rate of tariff is enforced in 1997 with the rate of six percent. However, it conspicuously cannot be seen the revenue increase, that might be flood affection brought by cyclone.

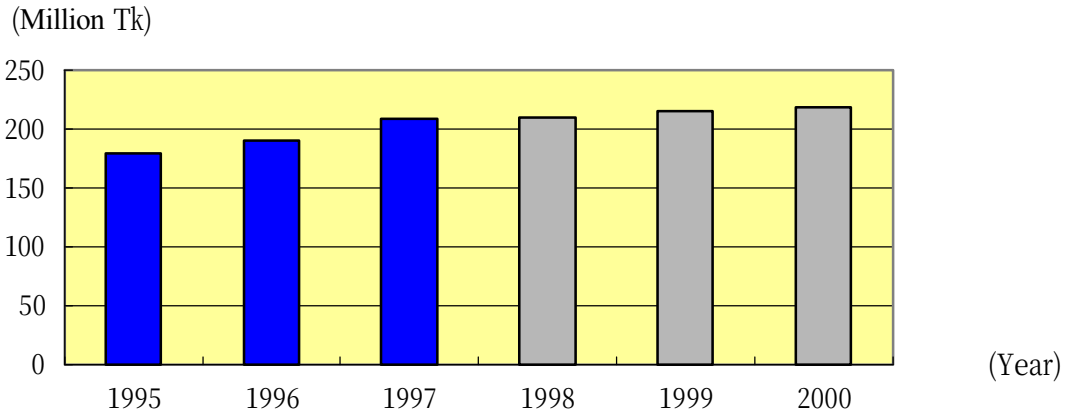


Figure 6.2-6 Water Sales Revenue

(b) Working balance

Working balances for past six years from 1995 to 2000 are shown in Figure 6.2-7. Working balance means operating incomes minus operating expenses without depreciation. As shown in this figure, the working balance changes to minus since 2000. Because it is presumed that the

increasing ratio between income and expenditure are about 1.4 percent and 9.8 percent, respectively as shown in Table 6.2-15.

(c) Operating balance

Operating balances for past six years from 1995 to 2000 are shown in Figure 6.2-7. Operating balance means operating revenue minus operating expenses including depreciation. As shown in this figure, the operating balance changes to minus since 1999. Because it is presumed that the increasing ratio between income and expenditure compared with previous year are about 2.4 percent and 14.3 percent, respectively as shown in Table 6.2-15. Besides, depreciation cost amounts Tk 46.23 million.

Generally, it will be needed to make revision of tariff table (increase of revenue) or reduction of expenses at the time of changing to minus.

(d) Net operating balance

Net operating balances for past six years from 1995 to 2000 are shown in Figure 6.2-7. Net operating balance means operating revenue minus net operating expenses. Net operating expenses include costs, depreciation and interest payment. As shown in this figure, the net operating balance indicates all minus (loss) because of large interest payment during all years.

(e) Net loss at the period

Net losses (minus) at the period for past six years from 1995 to 2000 are shown in Figure 6.2-8. Net loss at the period takes account of special income/loss in net operating balance. As shown in this figure, these are in deficit every year.

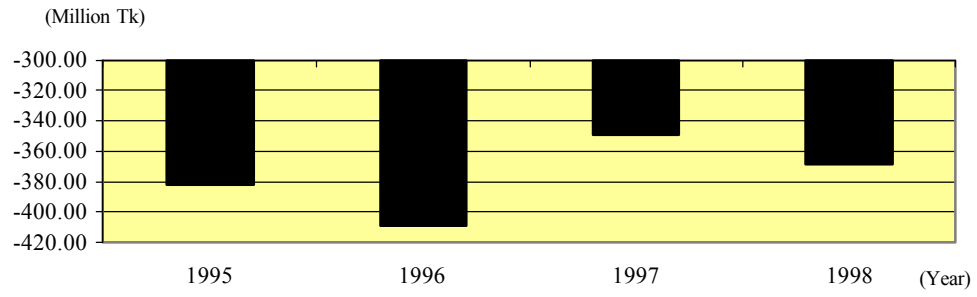


Figure 6.2-8 Net Balance (Loss)

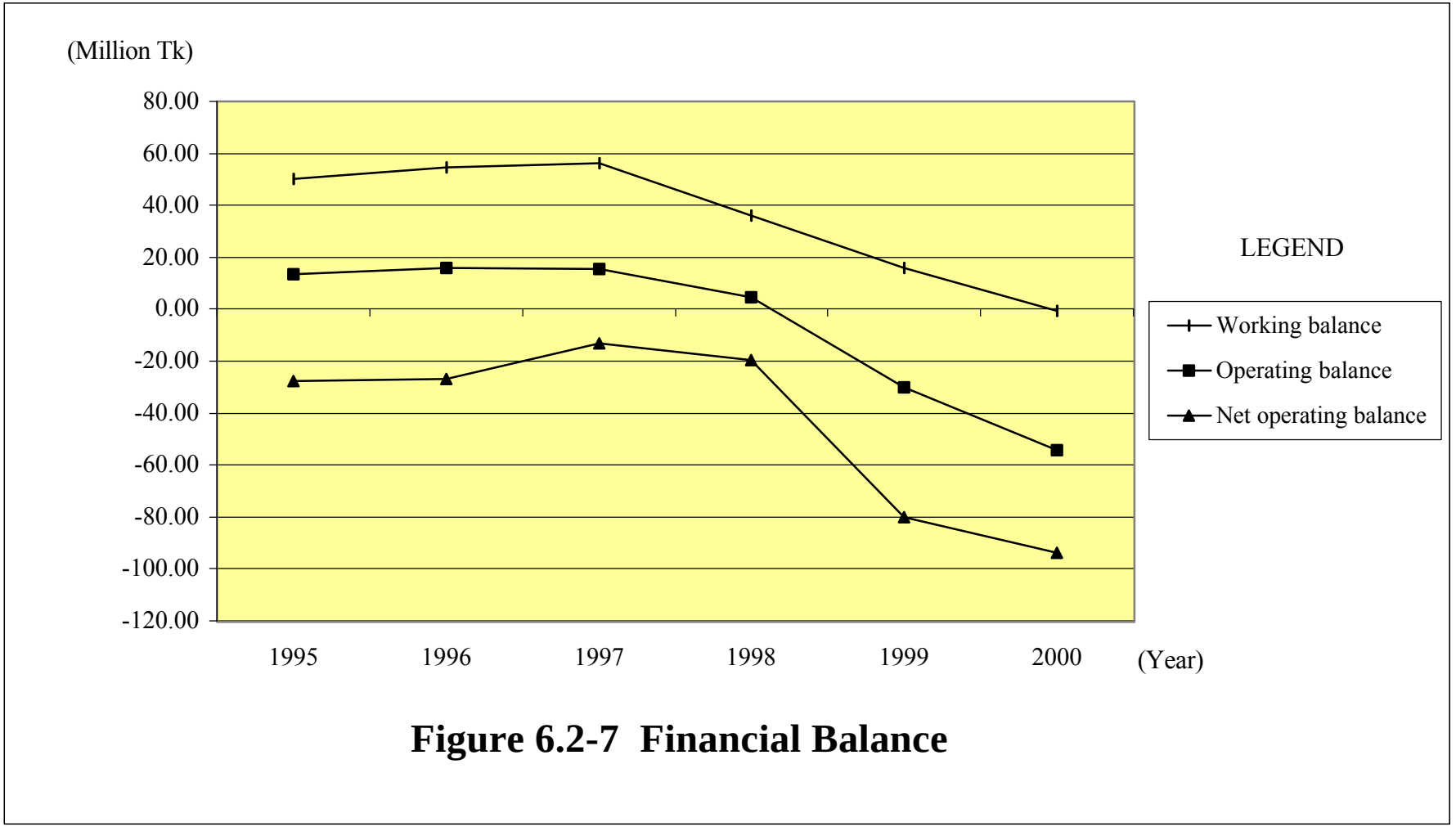


Figure 6.2-7 Financial Balance

(f) Long-term debt balance

Long-term debt balances including principal and accrued interest for past four years from 1994 to 1997 are shown in Figure 6.2-9. These data are all audited. The total long-term debt balance comprised of each project cost amounts about seven times of annual water revenue.

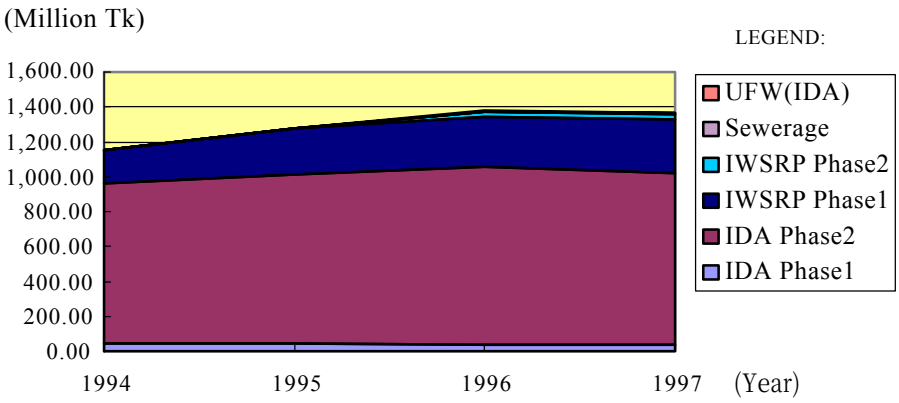


Figure 6.2-9 Long-Term Debt Service

6.2.6 Evaluation and Recommendation on Management System

(1) Evaluation

1) It was observed that, as a whole, the CWASA's operations seem to suffer from a lack of commercial/business orientation and accountability, insufficient management system and shortage of trained and motivated staff. The operational performance is required to improve though a series of training such as operation and maintenance, management and finance, management information system, personal management and training and computerization.
2) Recognition for improvement of Accounted for Water is rather low so as to be scheduled an actual UFW reduction plan.
3) Despite revenue improvement by computerizing for ledger book recording, billing and collection, CWASA could not fully service its interest obligations in recent years, and was in default on some covenants for the credits.
4) Many of issues have been continuous and pervasive in CWASA, because WASA's tariffs are currently regulated by the Central Government and do not reflect the cost structure and hence the tariffs could not designed to respond to changes in the financial requirement.

(2) Recommendation of Performance Reform

CWASA would be set up a reform program that would be improve CWASA's institutional and

financial efficiency and performance to enable CWASA for operation as a more autonomous and commercially managed water supply institution.

The program should be involved the followings:

- To prove CWASA with operating conditions that would approximate to established commercial organization under companies/business act;
- To seek internal change in CWASA's operation, financial management and performance;

In order to meet such objectives the following program may be suggested:

1) Internal Changes in CWASA's Performance;
   - Establishment of Organization Reform and Responsibility System
   - Arrangement of documents
   - Staff Training Program
2) Rearrangement of consumer ledger book
3) Examination of Tariff Collection System Improvement
4) Introduction of Cost Management System for improvement of production.
5) Systematic Financial Management and Establishment of Inner audit
6) "Improvement Plan of Crash Meter Rehabilitation";
7) "Review of Leak Detection and Rehabilitation Program";
8) "Introduction of Management Information System (MIS)".

6. 3 Study on Dhaka Water Supply and Sewerage Authority

6.3.1 Profile of DWASA

(1) General

As mentioned in the preceding section 6.1, Dhaka Water Supply and Sewerage Authority (DWASA) is the autonomous agency responsible for provision of water supply and sewerage services in the Dhaka Metropolitan.

Upon June 1989, the servicing area covered under DWASA was limited up to Dhaka Metropolitan area. During first half of 1990 the responsibility of supplying water in Narayanganj area was given under the jurisdiction of DWASA. At present, therefore, the service area covered by DWASA is from Mirpur to Uttora in the North and extended up to Narayanganj in the South.

(2) Zoning of Service Area

DWASA is divided into seven geographical zones considering its management, maintenance and consumer's service. One of which six zones are in Dhaka area and one zone is in Narayanganj. For

each zone there is a zonal office from where maintenance and revenue collection work are done.

(3) Organization

Recently, DWASA introduced an external Board Member system that consists of 13 members. The organization structure of DWASA is divided mainly into three departments under the Managing Director who is a member of Board that is Administration, Engineering and Finance and Commercial. Presently there are 3,215 persons are working as officers and staff. Staff distribution is given hereunder by department wise:

- Engineering Department 2,248 persons
- Finance and Commercial 563 persons
- Administrative 404 persons

Considering the present situation and increased demand of services of DWASA, the proposal has been placed to the concerning Ministry for modification and structural-organization of the present set up. The present organization structure of DWASA was set on 1984. Therefore, it seems becoming difficult to control entire management system at the same time giving proper services to consumers that has enhanced to a great number of service in the past few years.

6.3.2 Water Supply Condition

(1) Present Condition

By the end of 1997-98 fiscal year, 237 deep tube wells have been commission. There are operational three water treatment plants. Those are Chandonighat WTP in Dhaka and Godnail and Sonahanda WTPs in Narayanganj.

By the beginning of the said year, supply of water was 870,000 m^3/day, which increased by the end of the year into 930,000 m^3/day, which is an increment of 6.9 percent as shown below.

Table 6.3-1 Water Production Capacity and Demand in Dhaka Area in 1998

Component (unit)	June, 1997	June, 1998	Remarks
1. Water Treatment Plant (Nos.)	225	237	+ 5.3 %
2. Deep Tube Well (Nos.)	3	3	
3. Water Production (m^3/day)	870,000	930,000	+ 6.9 %
4. Water Demand (m^3/day)	1,350,000	1,400,000	+ 3.7%
5. Water Pipeline (km)	1,475	1,610	+ 9.1%
6. Water Connection (Nos.)	163,675	171,855	+ 5.0 %
7. Sewer line (km)	516	624	+ 20,9 %
8. Sewer Connection (Nos.)	43,377	44,127	+ 1.7 %

Source: DWASA annual report in 1998, DWASA

(2) Water Short-fall

The water demand for approximately 8.0 million inhabitants of Dhaka City in 1998 was assumed to be 180 l/day per person, that is required water supply distribution is 1,440,000 m^3/day against which the actual distribution level was 930,000 m^3/day. Therefore, it was only possible for DWASA to cater water supply 65 percent of the demand. Table 6.3-2 shows the past record on the water demand and distribution since 1970.

Table 6.3-2 Past Record on Water Demand and Distribution

Year	Population (million)	Water Demand (m^3/d)	Water Distribution (m^3/day)	Coverage Ratio (%)	Nos. of DTW in Operation (Number)
1970	1.46	260,000	180,000	69.2	47
1980	3.03	550,000	300,000	54.5	87
1990	5.56	1,000,000	510,000	51.0	156
1996	7.25	1,300,000	810,000	62.3	216
1997	7.50	1,350,000	870,000	64.4	225
1998	8.00	1,400,000	930,000	66.4	237

Aiming for the solve of the water supply shortage problems of Dhaka City, the project for Sayedabad WTP has been commissioned with a expected production capacity of 225,000 m^3/day, which will be completed by the middle of 2003. Distribution mains have also been constructed under IDB.
To curtail the dependency upon ground water, the surface WTP has been selected as most priority project in Dhaka.

6.3.3 Sewerage System in Dhaka

(1) Present Condition

Although in 1923 sewerage system had been installed in Dhaka City, due to insufficient funding, the facilities for sewerage in all area of Dhaka City could not be installed as yet.
The area still remains un-serviced are North part of Dhaka City. To bring these areas under planned sewerage system, a feasibility study by the name of North Dhaka Sewerage Development Project has been executed under the technical assistance of JICA.

(2) Existing Sewerage Facilities

Existing sewerage facilities are shown below.

- Pagla STP: Capacity (Dry season) 120,000 m^3/day
  (Rainy season) 180,000 m^3/day
- Sewer Lift Station: 23 stations
- Sewer Pipeline: 624 km
- Sewer Connection: 44,127 connections

(3) Problem with Sewerage

Blockage and seepage of the sewer line, and clogged of solid wastes by means of like garbage, coconut shell, poly bag, bricks etc., by local inhabitants, come out overflowing the manholes in different areas. Also, connections of surface drainage line with sewerage line flows in night soils are observed. To solve these problems, an action plan has been undertaken for creating awareness among City dwellers.

The basic problem is this that existing sewer lines of Dhaka City is year-old and deteriorated, which has become obstruct and insufficient in comparison to population growth and demand for service. Recently, construction of hundreds of multi-storied building in all part of Dhaka City has created such situation for both water and sewerage service facilities.

(4) Development Plants for Sewerage System

As the installation of sewerage service is costly, many area of Dhaka City still remains un-served. In cope with the immediate problem and the output of sewer in flow, a USCR Project for Pagla STP has been completed and now under operating, which was constructed under Japanese Grant Assistance in 1992. However, the northern part of Dhaka City is still remains un-served and could not be brought servicing facilities under the only sewer treatment plant in Pagla due to its distance and cost involvements. To bring the North of Dhaka under modern sewerage system, a master plan has been formulated by JICA in 1998.

6.3.4 Finance and Business

(1) Customer Relation

DWASA's main source of income in the servicing charges levied on water and sewer facilities is by served inhabitants. Therefore, increasing service connections for its client and by identifying illegal connection those are not recorded, count to be the most important factor towards the increase of DWASA's revenue income.

By the end of June 1998, total consumers stand as 171,855 numbers out of which 166,047 are in Dhaka City area and rest 5,808 numbers are in Narayanganj. Apart from which there are public hydrants numbering 1,209 numbers in Dhaka and 434 numbers are in Narayanganj. Table 6.3-3 shows a statistical consumer's status for last five years.

Table 6.3-3 Statistical Consumer's Status for Last 5 Years

Year	Connections With Meter (%)	Connections Without Meter (%)	Total Number of Connections	Nos. increase during this year (%)
1993-94	102,184 (71)	40,809 (29)	142,993 (100)	--
1994-95	113,491 (74)	39,832 (26)	153,323 (100)	10,330 (10.8)
1995-96	120,324 (73)	43,470 (27)	163,794 (100)	10,471 (7.2)
1996-97	122,867 (73)	44,575 (27)	167,442 (100)	3,648 (2.2)
1997-98	128,891 (75)	42,964 (25)	171,855 (100)	4,413 (2.6)

Following is a statistical record on revenue billing, collection and dues for DWASA for last 10 years.

(2) Financial Advancement of Last Year

Statistical Record on Revenue Billing, Collection and Arrears for last 10 Years is shown in Table 6.3-4.

Table 6.3-4 Statistical Record on Revenue Billing, Collection and Arrears

Year	Total Billing (Million Tk)	Total Collection (Million Tk)	Arrears (Million Tk)	Un-collected Ratio (%)
1988-89	349.44	368.94	19.50	5.6
1989-90	349.00	393.31	44.31	12.7
1990-91	380.26	379.52	0.74	0.2
1991-92	477.27	440.07	37.20	7.8
1992-93	629.07	572.41	56.66	9.0
1993-94	806.34	603.75	202.59	25.1
1994-95	843.43	716.93	126.50	15.0
1995-96	813.87	648.49	165.38	20.3
1996-97	866.32	758.35	107.97	12.5
1997-98	1,041.97	768.65	273.32	26.2

Source: DWASA Annual Repot 1997-98, DWASA

Due to certain incumbent 100 percent serving of bills to consumers for collection of revenue could not be achieved. One of the major problems in the financial aspect in DWASA is pointed out to be high level of arrears at the moment of which un-collected ratio for last three years is 19.7 percent in average. In case including the un-billing to consumers the ratio is estimated come up to 30 percent. Revenue collection by DWASA except zone-2 and zone-3 are quit satisfactory. Zone-4 and zone-5 have been leased out to WASA employees co-operative and they capable for collecting billed revenue on their own duty. Zone-6 is mostly metered connection, so there are fewer defaulters in the area.

It is informed that in case of metered connection, arrear collection can be handled by serving notice to the consumers or by disconnection or by legal cases to force payment from the consumers, but mostly arrear is lied uncollected from without metered connections and forced billings. Specifically in zone-2, covering from old Dhaka, WASA does not have any account for un-metered connections, where bill are served upon assumption. Bills are served to household owners with sewer-connection only, as a rule water bills are made based on property valuation without having any record of actual consumption of water used in such household. Another rule also implicated in case of determine in revenue amount for household with no sewer connection that is, the holdings for long period used of a running sewer-line but the owner of such holdings purposely did not connection with WASA line, in such cases bill are also served to the owner of such household on assumption, which are hardly paid up.

Huge amount of piped water used by the slum dwellers remains unpaid for billing, although some places in the slum area there are master meter system, in actual case no one in particular takes the charge of collecting bills from the slum dwellers. Many places, individual agency has sunk their own tube well where bill served by DWASA remains unpaid mostly, even the Government agencies has become defaulters in this way.

DWASA and GOB offices have totally knowledge on this situation and they do well know that out of total billed amount served by the revenue 20 to 25 percent is under assumption amount and has less possibility for collection, but year after year such billing system has been going on as a practice and thereby accumulated arrear of non-collected revenue is raising.
The following is a sample of the explanation of such situation at zone-2.

Table 6.3-5 Numbers of Connection and Billed Amount

Components	Billed Amount 1997	Nos. of Connection	Cumulative Arrears 1997	Arrears (%)
With Meter	15.30	233	1.35	8.8
Without Meter	8.16	127	5.33	65.3
Only Sewer Connection	0.60	13	0.44	73.3
Without Sewer Connection	0.17	65	0.88	82.4

6.4 Comparison of Business between CWASA and DWASA

Comparison of business between CWASA and DWASA will suggest useful measures for improvement of CWASA's management. However, comparing the following data must take note that there are some difference of condition between CWASA and DWASA, namely DWASA has sewerage sector as well as water supply sector while CWASA has water supply sector only.

(1) Basic Data of CWASA's/DWASA's Condition for Comparison

The basic data of DWASA/CWASA for comparison are shown in Table 6.4-1. These data are based on audited ones.

Table 6.4-1 Basic Conditions of DWASA/CWASA

Item	Unit	DWASA		CWASA
		1998	1999	1997
(Basic Index):				
Population Served	person	-	3,530,000	1,142,000
Population Served Ratio	%	64	66	44
Water Distribution	M^3/day	870,000	930,000	143,803
Water Sold	-ditto-	609,000	651,000	101,008
UFW after Distribution	%	30	30	30
Number of Connection (water)	Number	-	180,129	30,006
Number of Connection (sewer)	-ditto-	-	45,325	-
Number of Hydrant	-ditto-	-	1,643	900
Number of Staff	Person	-	3,215	750
Un-collected Ratio (Arrear)	%	-	26	9.5
(Income/Expenditure Index):				
Operating Revenue	million Tk	1,127	1,251	209
Working Expenditure	-ditto-	833	812	153
Operating Expenditure	-ditto-	982	1,034	194
Net Operating Expenditure	-ditto-	1,098	1,197	233
(Balance Sheet Index):				
Property and Assets	million Tk	11,467	13,457	1,853
Capital Fund and Liabilities	-ditto-	11,467	13,457	1,853
Current Liabilities	-ditto-	48	154	(25)

Note: Current liabilities of CWASA shown at (25) is including in Capital fund and liabilities of CWASA.

From above Table, the following characteristics are observed:

1) Population served ratio is 44 and 66 percent for CWASA and DWASA, respectively. This means water supply situation in CWASA is mostly critical and expansion of the supply system is urgently needed.
2) Un-collected ratio is 9.5 and 26 percent for CWASA and DWASA, respectively. This means service section in CWASA managed better than DWASA.
3) Operating expenditure (including depreciation) is Tk 194 million and Tk 1,034 million for CWASA and DWASA, respectively. These are both lower than operating revenue indicated Tk 209 million and Tk 1,251 million for CWASA and DWASA, respectively.
4) Net operating expenditure (including depreciation and interest) is Tk 233 million and Tk 1,197 million for CWASA and DWASA, respectively. Comparing net operating expenditure and operating revenue, furthermore, net operating expenditure is higher than operating revenue indicated Tk 209 million in CWASA. However, net operating expenditure is lower than operating revenue indicated Tk 1,251 million in DWASA. This means operating revenue in DWASA covers its interest, but not in CWASA.

The breakdown of operating expenditures of DWASA in 1999 and CWASA in 1997 is comparatively shown in Figure 6.4-1 linked in Table 6.4-1. In this Figure, the provision for bad debt and the drainage expenses are not counted in CWASA. Salary and wages in DWASA is 3.7 times of CWASA. Besides, contingency of DWASA is 6.4 times of CWASA.

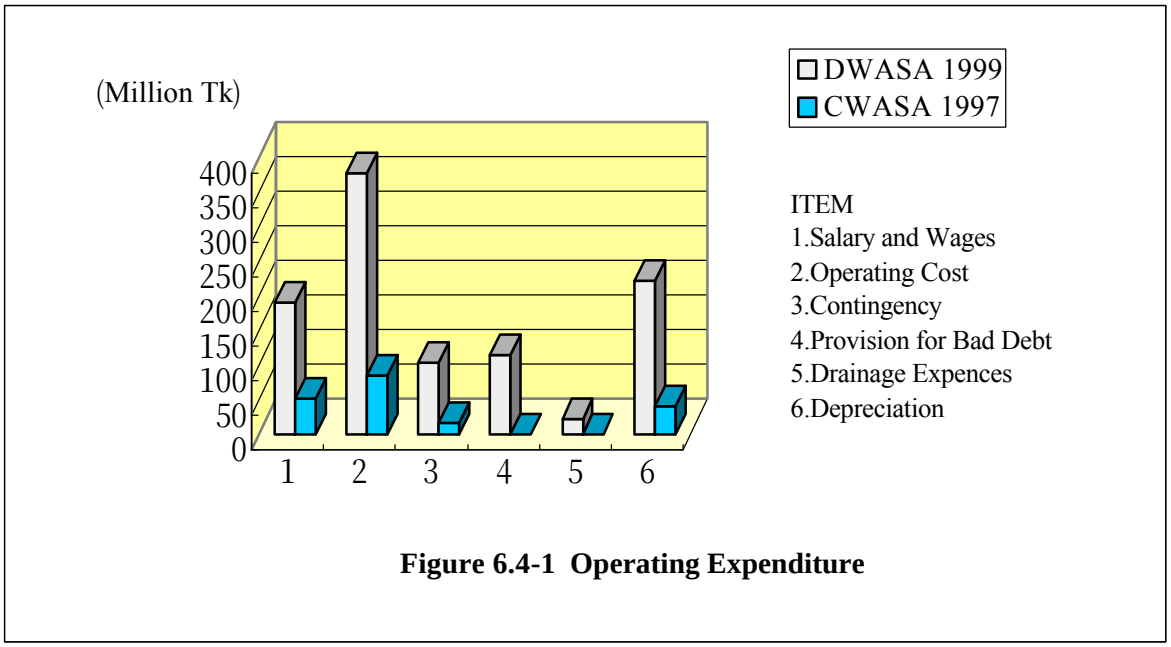


Figure 6.4-1 Operating Expenditure

The breakdown of balance sheet of DWASA in 1999 and CWASA in 1997 is comparatively shown in Figure 6.4-2 linked in Table 6.4-1. In this Figure, the long–term debt of DWASA is minimally 1.9 times of CWASA, while the capital work-in-progress of DWASA is maximally 43.2 times of CWASA. This means that CWASA is in rather high amount of long-term debt nevertheless less construction works.

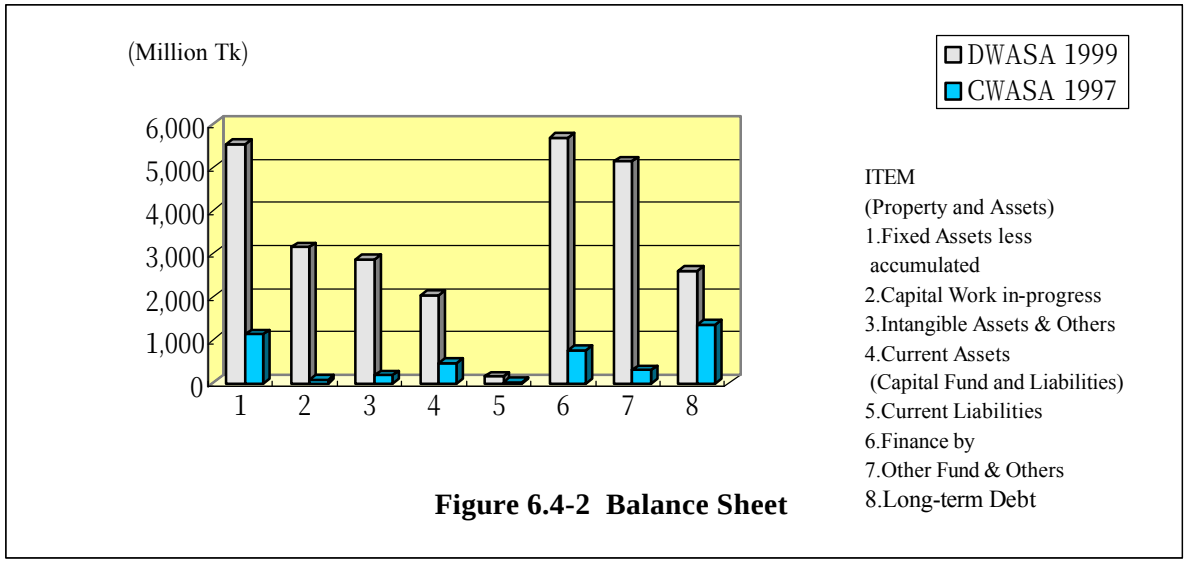


Figure 6.4-2 Balance Sheet

(2) Comparison used Management Indexes between CWASA and DWASA

The comparative indexes on water supply management from the viewpoint of operation, management and finance are shown in Table 6.4-2. These indexes are compared with the DWASA's management and implied how to improve the CWASA's management efficiency. As mentioned in previous section, the data of DWASA is including sewerage and used of the year 1999.

Table 6.4-2 Management Index

Item	CWASA				DWASA
	1995	1996	1997	1998	1999
(Operating Indication):					
Accounted for Water after Distribution (%) (Water Sold/Water Distribution) x 100	64	65	70	65	70
Daily Average Supply per capita (l/person/day) (Water Distribution/Population Served)	122	127	126	137	263
(Management Indication):					
Selling Cost (Tk /m^3) (Operating Revenue/Water Sold)	5.52	5.52	5.68	5.66	5.27
Water Supply Cost (Tk /m^3) (Net Operating Expenditure/Water Sold)	6.71	6.58	6.36	6.67	5.04
Number of Population Served per one Employee (person) (Population Served/Stuff Number)	-	-	-	1,523	1,372
Water Sold per one Employee (1000m^3/employee/year) (Water Sold/Stuff Number)	43	46	49	50	92
Operating Revenue per one Employee (1000Tk/employee/year) (Operating Income/Stuff Number)	239	254	279	280	389
(Financial Indication)					
Collection Ratio per year (%) (Collected Amount/Billing Amount) x 100	93.6	85.3	90.5	91.0	73.9
Working Ratio per year (%) (Operating Revenue/Working Expenditure) x 100	139.0	140.3	136.8	120.6	154.1
Operating Ratio per year (%) (Operating Revenue/Operating Expenditure) x 100	108.1	109.1	107.9	102.2	120.9
Salaries Ratio of Employee to Expenditure (%) (Salaries Cost/Working Expenditure) x 100	33.8	35.3	33.5	32.6	23.6
Current Ratio (%) (Current Assets/Current Liabilities) x 100	1,400	1,824	1,858	1,678	1,221
Fixed Assets to Equity Capital Ratio (%) (Fixed Assets/Owned Capital & Surplus) x 100	263	278	245	250	78
Profit Ratio of Gross Capital (%) (Net Operating Profit/Liabilities & Capital) x 100	11	11	12	12	9

The results of analysis are shown below.

(1) Operating indication

(a) CWASA's accounted for water during the previous four years except for 1997, presents rather low percent compared with DWASA.

(b) Daily average supply/distribution per capita of CWASA is about 52 percent of DWASA.

(2) Management indications

(a) Selling cost is lower than water supply cost in CWASA, but it is opposite in DWASA.

(b) The trend of operating revenue per one employee for past several years in CWASA is gradually increasing year by year, however, that of CWASA in 1998 is only 72 percent of DWASA.

(3) Financial indication

(a) Collection ratio of CWASA is better than that of DWASA.

(b) Operating ratio of operating revenues to operating expenditure of CWASA is worse than of DWASA.

(c) Salaries ratio of employee to working expenditure in CWASA are higher than that of DWASA.

6.5 Inhabitant's Awareness Survey on Water Supply and Environmental Sanitation

6.5.1 Objective of the Questionnaire Survey

The questionnaire survey on the " Inhabitant's Awareness on Water Supply and Environmental Sanitation" was intended to scrutinize the following aspects covering a total of about 60 households in the Study Area.

(1) Existing water supply conditions,
(2) Proposition of the water charge to income/expenditure of the families,
(3) Willingness and affordability to pay for water supply,
(4) What is the consumers' wanted issues to CWASA for improvement of the water supply system and services, and
(5) Knowledge on public hygiene causality between water borne/related/vector diseases and hygienic condition.

6.5.2 Questionnaire Survey

(1) Questionnaire Form

A set of questionnaire form covering the aforementioned survey contents was prepared in the Study Team (refer to Supporting Report). The questionnaire form was designed primarily to be answered as "Yes" or "No" and chosen from plural answers, which were prepared in advance by the Study Team as forecasted/expected answers for convenience in statistical evaluation, while some questions required narrative answers. This survey was carried out by local engineers under the supervision of the Study Team.

(2) Questionnaire Target

The target number of households to be interviewed was initially separated into two categories:

1) Approximately 50 households are to be consumers who are served piped water through house connections or public hydrants and the other 10 households are to be one un-served piped water.
2) 50 percent, 30 percent and 20 percent of the families to be interviewed are living in Pucca, Semi-pucca or Kutcha types of housing so as to represent the present proportion of the number of households in the Study Area.

The number of interviewed households was resulted as shown in Table 6.5-1.

Table 6.5-1 Number of Interviewed Households

Name of Thana		Pucca	Semi-pucca	Kutach	Total
1	Kotwali	5	1	1	7
2	Double Mooring	11	2	1	14
3	Panchlaish	4	3	1	8
4	Pahartali	2	4	1	7
5	Chandgaon	2	2	2	6
6	Chittagong Port	2	3	2	7
7	Hathazari	2	1	1	4
8	Hathazari (P)	1	0	2	3
9	Sitakunda (P)	2	1	1	4
Total		31	17	12	60

6.5.3 Survey Results

(1) Income and Expenditure

1) Monthly income

Distribution of number of interviewed families by income per month is shown in Table 6.5-2.

Table 6.5-2 Distribution of Number of Interviewed Families by Income

Income Tk/Month	Number of Families	Percent (%)	Cum. Percent
Less than 5,000	11	18.6	18.6
5,000 to 7,000	10	16.9	35.5
7,000 to 10,000	14	23.7	59.2
10,000 to 15,000	11	18.7	77.9
15,000 to 20,000	7	11.9	89.8
20,000 to 25,000	4	6.8	96.6
25,000 to 30,000	2	3.4	100.0
More than 30,000	0	-	-
Total	59	100.0	-

The average monthly income of interviewed families was approximately Tk 9,000, and majority of the families fell on Tk 20,000 /month. Please refer to Figure 6.5-1.

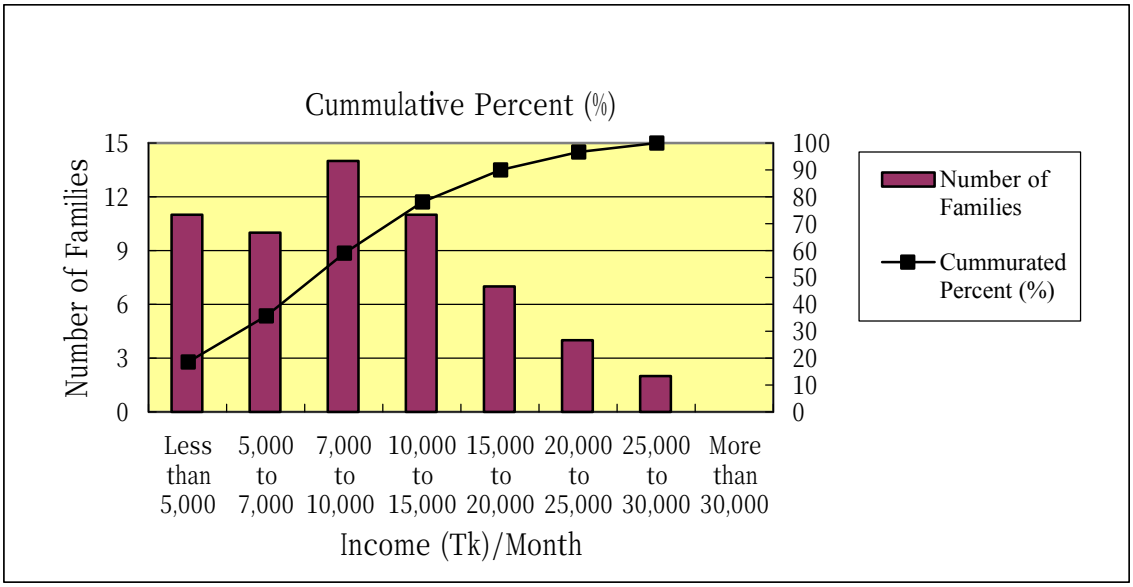


Figure 6.5-1 Distribution of Number of Interviewed Families by Income

2) Ratio of water charge to income

Number of families by water charge ratio to income by income bracket is shown below.

Table 6.5-3 Ratio of Water Charge to Income

Income per Month (Tk)	Ratio of Water Charge to Income					
	Less 1.0 %	1.0 to 2.0%	2.0 to 3.0%	3.0 to 4.0%	4.0 to 5.0%	More 5.0%
Less than 5,000	–	3	3	1	–	2
5,000 to 7,000	–	3	–	–	2	–
7,000 to 10,000	–	1	4	3	1	4
10,000 to 15,000	4	3	1	–	–	–
15,000 to 20,000	2	1	1	–	1	
20,000 to 25,000	1	–	–	1	–	–
25,000 to 30,000	1	–	–	–	–	–
Total	8	11	9	5	4	6

The number of interviewed families by ratio of water charge by income is shown in Table 6.5-4 and Figure 6.5-2.

From the survey result mentioned above, it is found that half of the families interviewed pay less than 2 percent of their income amount for water charge that is approximately Tk 180 per month.

Table 6.5-4 Number of Families by Ratio of Water Charge

Ratio of Water Charge to Income	Number of Families	Percent (%)	Cum. Percent (%)
Less than 1.0 %	8	21.1	21.1
1.0 % to 2.0 %	11	28.9	50.0
2.0 % to 3.0 %	5	13.2	63.2
3.0 % to 4.0 %	4	10.5	73.7
4.0 % to 5.0 %	4	10.5	84.2
More than 5.0 %	6	15.8	100.0
Total	38	100.0	

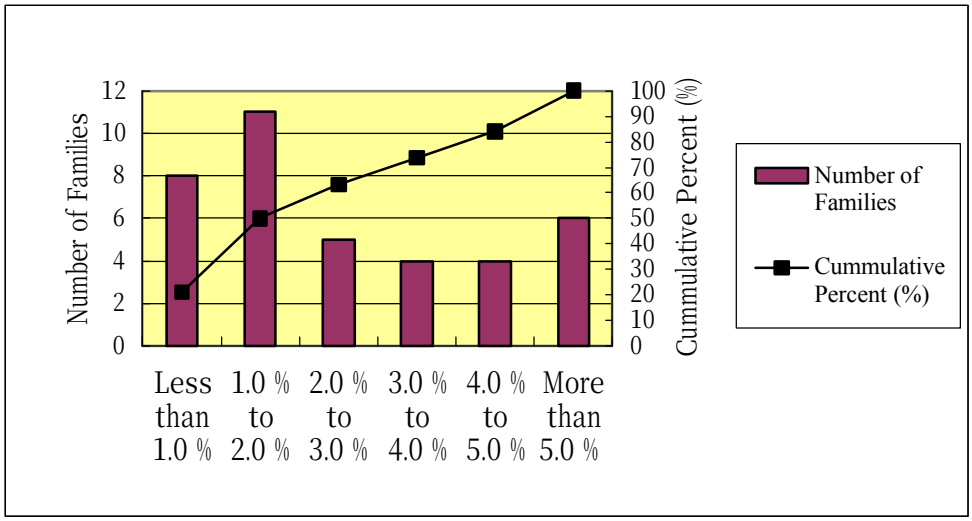


Figure 6.5-2 Number of Families by Ratio of Water Charge

3) Ratio of electrical and fuel charge to income

At the same time, ratio of electric and fuel charge to income was surveyed. The survey result is shown in Table 6.5-5.

Table 6.5-5 Ratio of Electrical and Fuel Charge to Income

Ratio of Electrical/Fuel Charge to Income	Number of Families	Percent (%)	Cum. Percent (%)
Less than 1.0 %	5	11.6	11.6
1.0 % to 3.0 %	3	7.0	18.6
2.0 % to 5.0 %	3	7.0	25.6
5.0 % to 7.0 %	4	9.3	34.9
7.0 % to 9.0 %	11	25.6	60.5
9.0 % to 11.0 %	8	18.6	79.1
More than 11.0 %	9	20.9	100.0
Total	43	100.0	

(2) Number of Households Receiving Piped Water

Number of households who are served with CWASA's water through house connections or public hydrants and no public water are also surveyed. The survey result is shown in Table 6.5-6.

Table 6.5-6 Number of Families Receiving Piped Water

No.	Name of Thana	House Connection		Hydrant	No Piped Water			Total
		With Meter	No Meter		Pucca	Semi-	Kutach	
1	Kotowali	5	0	0	0	0	0	5
2	Double Mooring	12	0	1	0	0	0	13
3	Panchlaish	7	0	0	0	1	0	8
4	Pahartali	7	0	0	0	0	0	7
5	Chandgaon	4	0	1	0	0	0	5
6	Chittagong Port	3	0	0	1	1	1	6
7	Hathazari	3	0	0	0	0	2	6
8	Hathazari (P)	0	0	0	1	0	2	3
9	Sitakunda (P)	0	0	0	2	1	1	4
Total		41	0	2	4	3	4	54

(3) Willingness and Affordability to Pay for Water Supply

Table 6.5-7 shows the number of families grouped by income range and by the affordability to pay for water charge, provided that CWASA's services are improved.

Table 6.5-7 Willingness to Pay by Income Bracket

Income (Tk/Month)	Affordability to Pay for Water Charge						Total
	No change	Up to 1.5 times	Up to 2.0 times	Up to 2.5 times	Up to 3.0 times	More 3.0 times	
Less than 5,000	7	2	2	0	0	0	11
5,000 to 7,000	4	1	1	0	0	0	6
7,000 to 10,000	5	4	4	0	0	0	13
10,000 to 15,000	5	0	4	0	0	0	9
15,000 to 20,000	0	2	1	1	1	1	6
20,000 to 25,000	1	0	0	0	0	0	1
25,000 to 30,000	1	0	1	0	0	0	2
More than 30,000	0	0	0	0	0	0	0
Total	23	9	13	1	1	1	48

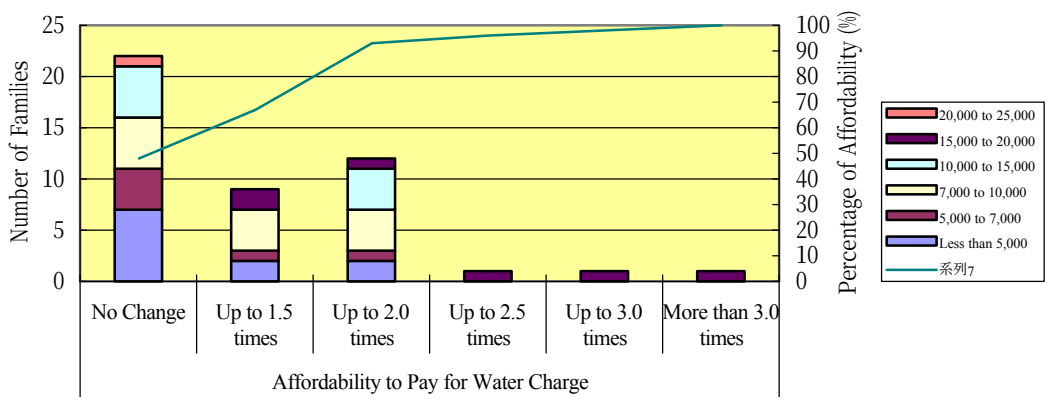


Figure 6.5-3 Willingness to Pay

Result of the willingness survey is different by largely depending on income level, especially low-income class wanted to be maintained the present charge. However, more than 50 percent of interviewed families show a willingness to pay as charged by meter reading, when the current water supply conditions are improved. This response is verified by the other questions on the priority for water supply improvement, namely first ranked request is " continuous supply ", the second is " enough water pressure" and "safety for drinking" and following to "low water rate/charge". (Refer to the succeeding sub-section)

(4) Request to CWASA for Improvement of Water Supply Services

Table 6.5-8 shows the priorities to be improved the water supply services that is requested to CWASA. The survey was carried out by means of selection and allowable plural answers from the given answers in advance as forecasted request/claim to CWASA.

Table 6.5-8 Request for Improvement of Water Supply Services

Improvement Item	Number of Families Requested
1. Continuous supply	51
2. Enough water pressure	29
3. Cheap water charge	29
4. Safe for drinking	27
5. Good quality water supply	25
6. Others	0

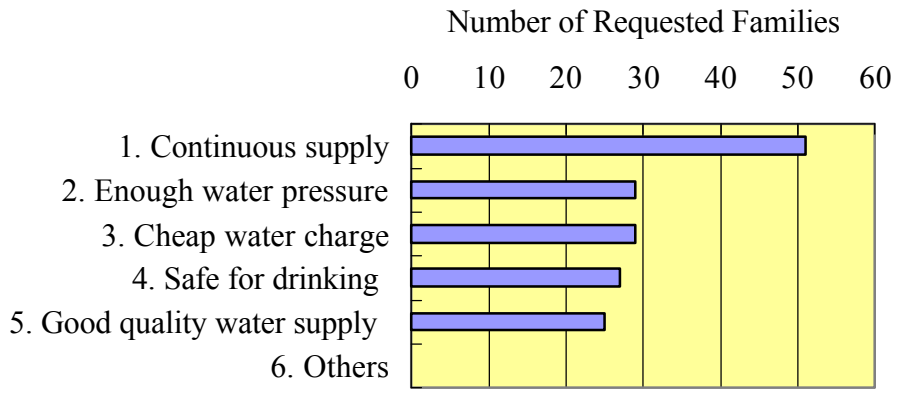


Figure 6.5-4 Request for Improvement of Water Supply Services

(5) Awareness on Hygienic and Sanitation

1) Health condition

About 60 percent of the families interviewed answered that none of their household member had ever any cause of sickness. The other 40 percent of the families answered that they had causes of sickness like diarrhea, dysentery, skin disease, and they think that is caused by bad quality of the drinking water.

2) Awareness on hygiene and sanitation

Sixty percent of the interviewed were aware of relationship between the unhygienic conditions/contaminated drinking water and the water borne/related/vector diseases.