社会開発協力部報告書

No. 7

THE PEOPLE'S REPUBLIC OF BANGLADESH
DEPARTMENT OF PUBLIC HEALTH ENGINEERING
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT
AND COOPERATIVES, LOCAL GOVERNMENT DIVISION

STUDY ON
STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT
IN DHAKA CITY

MAIN REPORT

OCTOBER 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

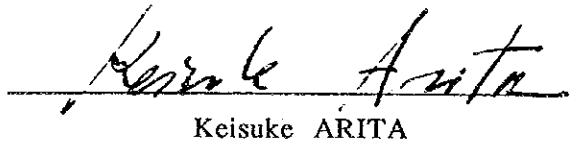
In response to the request of the Government of the People's Republic of Bangladesh, the Japanese Government has decided to conduct a study on Storm Water Drainage System Improvement Project in Dhaka City and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Bangladesh a study team headed by Mr. Naohito MURATA of Pacific Consultants International, from November 1986 to March 1987.

The team had discussions on the Project with the officials concerned of the Bangladesh Government and conducted a field survey in Dhaka City. After the team returned to Japan, further studies were made and the present report has been prepared.

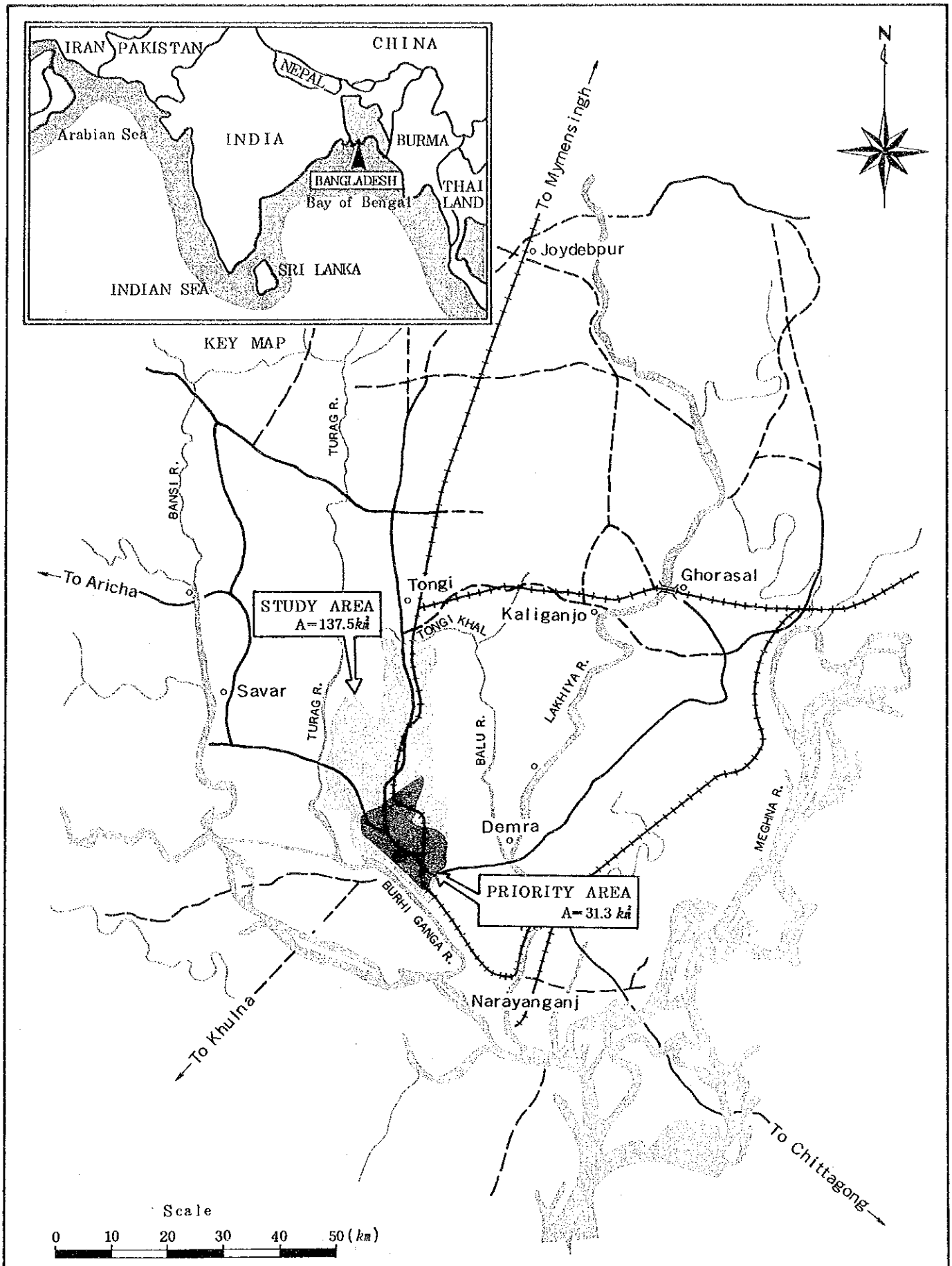
I hope that this report will be of use for the development of the Project and contribute to the promotion of the friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the People's Republic of Bangladesh for their close cooperation extend to the team.

October, 1987



Keisuke ARITA
President
Japan International Cooperation Agency

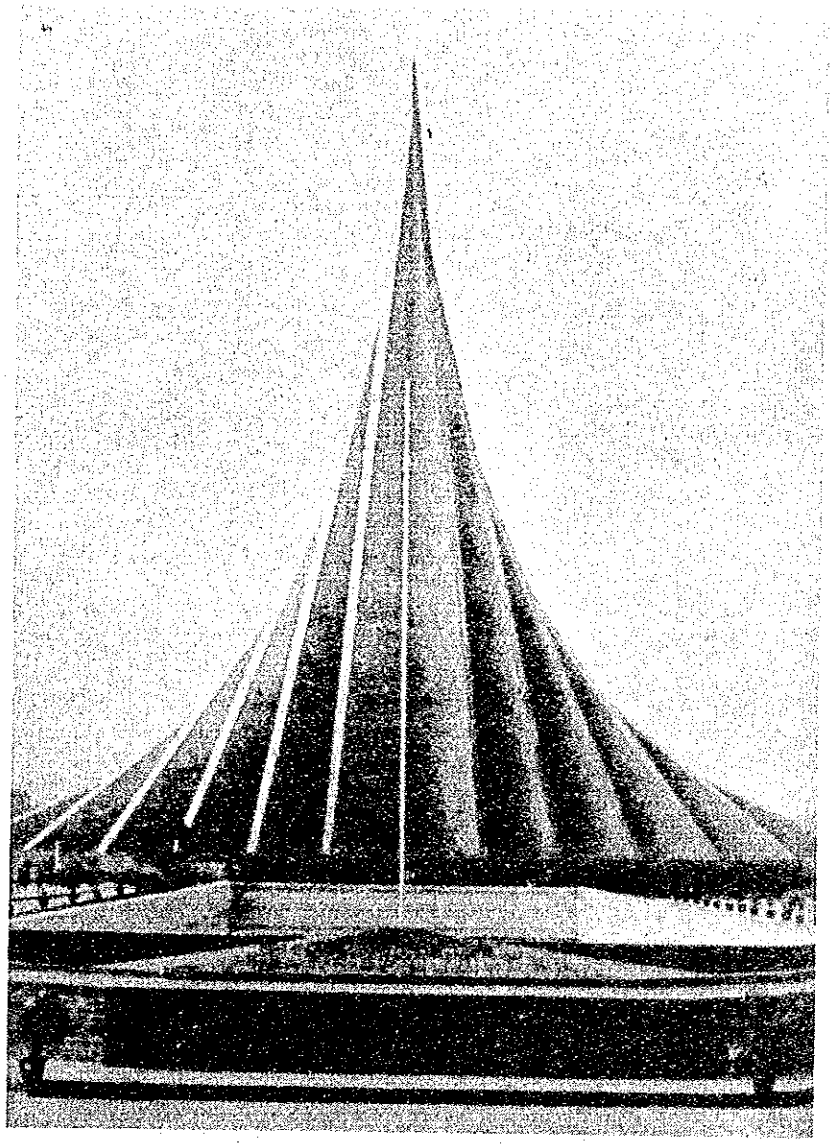


LOCATION OF STUDY AREA

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA 1987A.D

SUMMARY



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SUMMARY

1. Introduction

Dhaka City is located on the southern edge of the Madhupur Jungle Terrace and is surrounded by rivers on all sides. Flood waters overflowing the river banks frequently inundates the low-lying areas of the city. Heavy monsoon rains cause water logging in many places within the city, creating manifold problems for the citizens. The rapid urbanization in recent years has further worsened the flooding of Dhaka City.

To solve the above problems, the Study on Storm Water Drainage System Improvement Project in Dhaka City was carried out by the Study Team of the Japan International Cooperation Agency (JICA) in collaboration with officials of the Government of Bangladesh from November 1986 to October 1987.

2. Study Area

The Study Area covers 137 km^2 of developed land in Dhaka City. The central part of Dhaka City is developed on the hilly land with an elevation of 6 to 8 m above mean sea level (G.T.S.). The fringe areas are, however, located in the flood plains of the Buriganga and Balu Rivers with levels of 2 to 6 m G.T.S. The fringe areas are constantly flooded.

Average annual rainfalls in Dhaka is 2,060 mm. The monsoon season extends from May to October during which period about 90% of the rainfall occurs. Floods in the surrounding rivers of the Study Area usually reach their peaks in August or September after a slow steady rise throughout the monsoon season. The maximum flood water level of the Buriganga River at Dhaka City in the past was 6.59 m G.T.S.

The population of the Study Area has seen an increase of from 2.4 million in 1981 to 3.2 million in 1986 because of the large influx of people from the rural areas to Dhaka. It is expected that further increase will take place to 4.8 million in 2000. Due to the pressure of the increasing population, the rate of the built-up area in the Study Area will increase from 65% in 1986 to 77% in 2000. It will result in further aggravation of flood problems.

3. Existing Drainage System and Flood Damage

The land of the Study Area is divided into sections by reentrant valleys called "Khal". Storm water collected by drainage pipes is normally drained through these khals into the surrounding rivers. The major existing drainage facilities are a pump station, khals (drainage channels) and drainage pipes.

Floods of the Study Area are classified into two (2) types: one is of flood waters coming from the surrounding rivers (external floods), and the other is of floods by storm rainfall (internal floods). External floods generally occur in the low-lying fringe areas once every five (5) or ten (10) years. However, in some very low-lying areas, the floods occur annually.

On the other hand, internal floods occur in the inner areas of the city several times a year.

The estimated damage potentials of habitual and 10-year frequency floods in the years 1986 and 2000 are shown in Table S.1.

Table S.1 Estimated Flood Damage Potential

	Year	Flood Area (km^2)		Affected Population (10^3)	Flood Damages (million TK)
		Total Area	Built-up Area		
Habitual Flood	1986	45.7	10.8	586	187
	2000	45.7	15.0	1,008	335
10-year Frequency Flood	1986	57.3	19.3	1,012	404
	2000	57.3	24.8	1,521	700

External floods occur due to the lack of flood protection works. Internal floods are mainly caused by insufficient drainage facilities and their improper operation and maintenance as follows:

(1) Insufficiency of drainage pipe length
(2) Small discharge capacity of existing drainage pipes
(3) Clogging of existing drainage pipes
(4) Electrical breakdown of equipment at the existing pump station
(5) Impediment of khal waters due to encroachment of buildings and by bottlenecks caused by road and railway crossings.

4. Preparation of Phased Program

The phased program is prepared, based on the following planning policies and design criteria, for the efficient removal of surplus waters.

(1) The Study Area is divided into 10 drainage zones for which flood protection and internal drainage plans are proposed. The plans include not only structural measures but also non-structural measures.

(2) The proposed plans are prepared to meet the population and land use forecasted for the year 2000.

(3) The structural measures to be proposed are limited to major works required to meet a mid-term range necessity for flood protection and internal drainage improvements with the limited financial resources.

Lateral drains and branch drainage pipes are excluded from the phased program. They may be laid after completion of the proposed scheme, as and when necessary.

(4) The flood protection plan is prepared for all the low-lying built-up areas below the design flood water level. The proposed area covers not only the existing developed areas but also the future development areas.

The flood water level with a 30-year frequency is applied for the design of flood protection works.

(5) The internal drainage improvement will be attained by installation of additional trunk drainage pipes, improvement of the existing khals and installation of drainage pumps.

The rainfall intensity with a 5-year frequency is employed for the design of drainage pipes and khal improvements. for the design of pump stations, the two days consecutive rainfall with a 5-year frequency is proposed.

The proposed structural measures and estimated costs by drainage zone are summarized in Table S.2. Location of the drainage zones and proposed facilities is illustrated in Fig. S.1.

In addition to the structural measures, the following non-structural measures are recommended to improve the flood protection and drainage system:

(1) Reserving swampy areas totaling 264 ha for the proposed pump regulating ponds.

(2) Strict enforcement of controls to prevent any reduction of minimum khal sections proposed which could cause flood flows to be impeded and backing up of water in the upstream areas.

(3) Raising of low-lying fringe areas with land fill sufficiently higher than the proposed design flood level for future developments, except in the proposed flood protection areas.

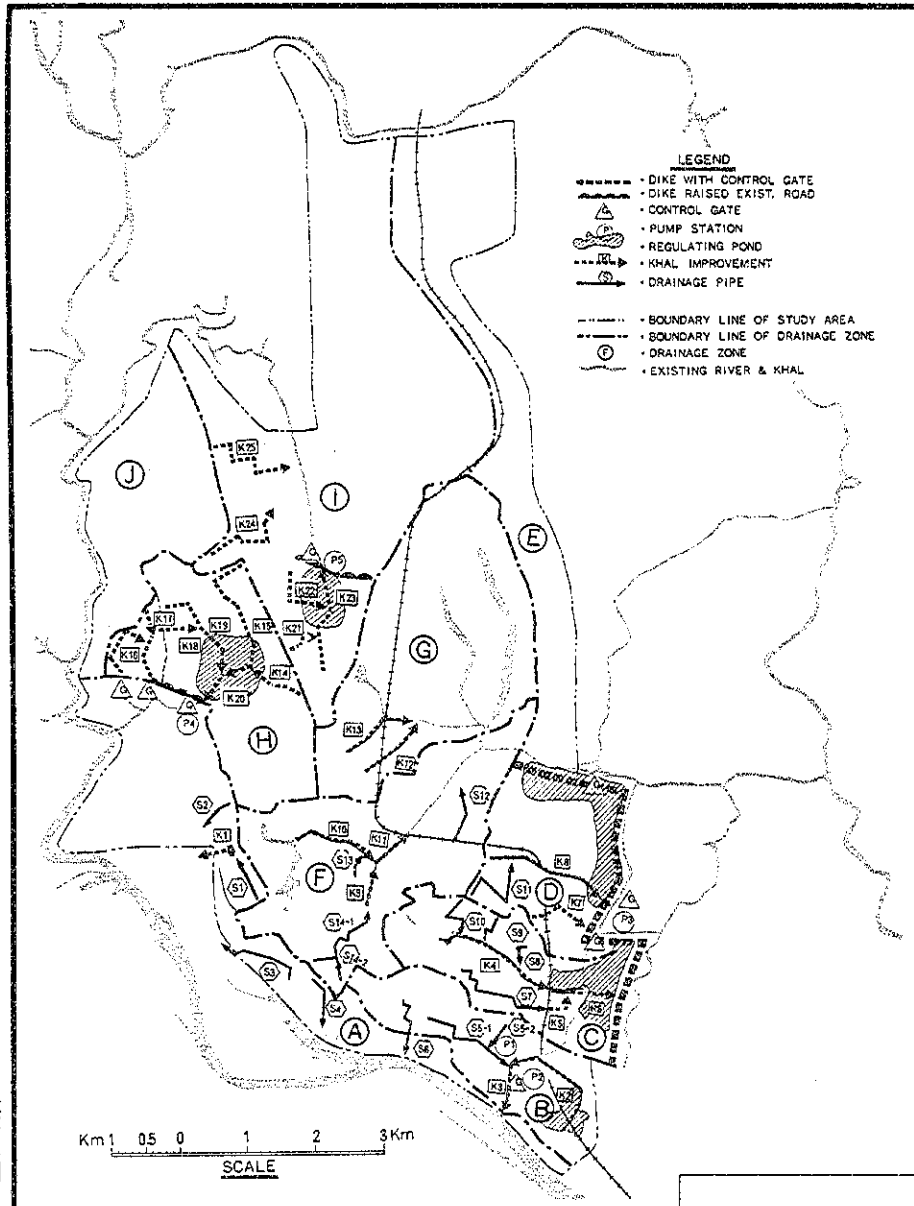
Table S.2 Proposed Facilities and Cost

(1986 price)

Drainage Zone	Flood Protection		Internal Drainage			Land Acquisition	Total Project Cost
	Protection Dike (km)	Control Gate (places)	Pump Station (m^3/s)	Khal Improvement (km)	Drainage Pipe (km)	(ha)	(million TK)
A	-	-	-	0.3	3.8	0.1	96.2
B	-	1	9.6**	4.2	4.3	4.5	430.1
C	2.4	1	7.5	5.1	4.8	23.5	728.8
D	7.0	2	9.5	4.6	1.7	59.9	921.1
E	-	-	-	-	-	-	-
F	-	-	-	3.8	3.4	4.8	214.0
G	-	-	-	2.9	-	2.2	41.0
H	3.0*	3	14.6	11.9	-	9.6	702.3
I	2.0*	1	4.5	6.9	-	4.9	299.9
J	-	-	-	-	-	-	-
TOTAL	14.4	8	45.7	39.7	18.0	109.5	3,433.4

Note (1): * Raising Existing Road Finish Level
** Utilizing Existing Narinda Pump Station

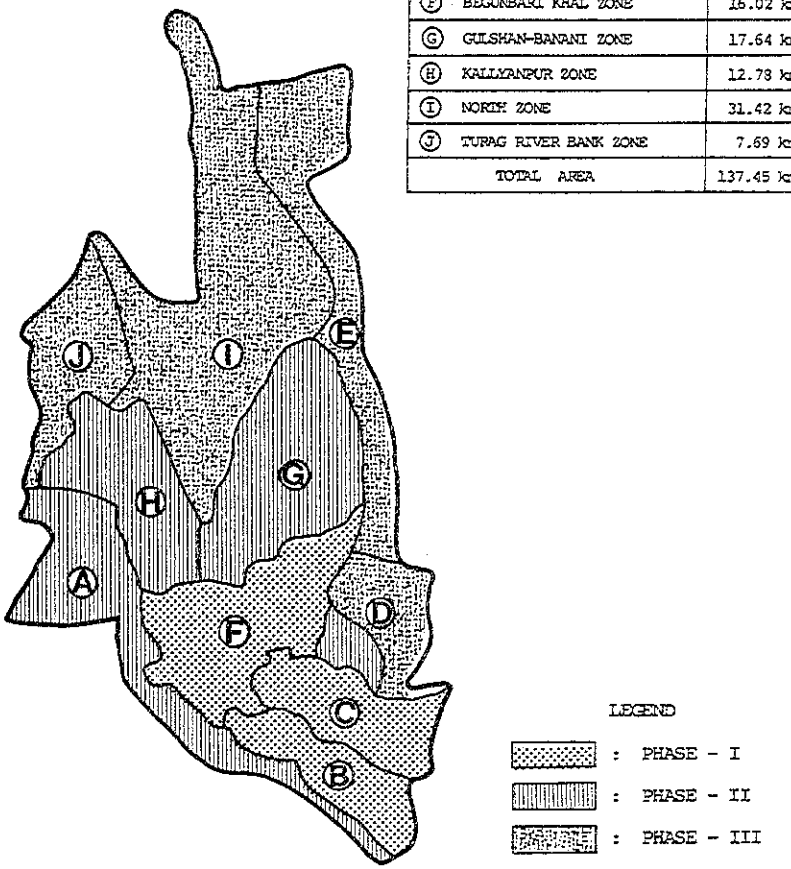
Note (2): Floods in E and J drainage zones shall be met by non-structural measures.



PROPOSED FACILITIES

DRAINAGE ZONE AREA

(A)	BURIGANGA RIVER BANK ZONE	12.85 km^2
(B)	DHOLAI KHAL ZONE	7.76 km^2
(C)	SEGUNBAGICHA KHAL ZONE	9.04 km^2
(D)	BASABO ZONE	8.32 km^2
(E)	NORTH-EAST EDGE ZONE	13.93 km^2
(F)	BEGUNBARI KHAL ZONE	16.02 km^2
(G)	GULSHAN-BANANI ZONE	17.64 km^2
(H)	KALLYANPUR ZONE	12.78 km^2
(I)	NORTH ZONE	31.42 km^2
(J)	TURAG RIVER BANK ZONE	7.69 km^2
TOTAL AREA		137.45 km^2



PHASING MAP

FIG. S.1 PROPOSED FACILITING IN STUDY AREA AND PHASING MAP OF DRAINAGE ZONE

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

S - 6

JICA 1987 A.D

Priority sequence of the drainage zones are decided by weighing and comparison of the following factors:

(1) Benefitting population
(2) Required project cost
(3) Required land acquisition area
(4) Flood conditions
(5) Damage to commercial and institutional activities
(6) Hindrance to traffic
(7) Land use classification

The whole project will be completed through a three (3) phase program carried out in conformity with the priority sequence obtained from the above comparison.

Phase-I Zone (First Priority Zone): B, C, F
Phase-II Zone (Second Priority Zone): A, D (part), G, H
Phase-III Zone (Third Priority Zone): D (part), E, I, J

5. Feasibility Study for the Priority Area

5.1 Selected Priority Area

The feasibility study was made for the flood protection and internal drainage projects of the priority areas selected in the phased program. The selected priority areas are B, C and F drainage zones covering the central part of Dhaka City.

The areas of B, C and F drainage zones proposed for the feasibility study are as follows:

B zone:	6.68 km^2
C zone:	10.92 km^2
F zone:	13.70 km^2
Total:	31.30 km^2

5.2 Proposed Plan

(1) Flood Protection

The low-lying areas of B zone are flooded by backwaters of the Buriganga River flowing backwards through the Dholai Khal. To prevent the backwaters, installation of a control gate is proposed at Narinda site.

The east fringe areas of C zone are affected by floods of the Balu River. Construction of the dikes having an overall length of 4.8 km is proposed to protect the fringe areas. The design crest elevation of the dikes is 7.6 m G.T.S.

F zone is generally free from floods of the surrounding rivers.

(2) Pump Drainage

Pump drainage is required for the low lands of B and C zones. A pump drainage system integrating the two (2) drainage zones is proposed.

The total required pump capacity is 18.8 m^3/s of which:

- 9.6 m^3/s is met by rehabilitation of the existing Narinda Pump Station.
- 9.2 m^3/s is performed by construction of an additional pump station.

The new pump station is proposed at a site near the existing Narinda Pump Station.

The above pump drainage system includes the following two (2) regulating ponds:

- Jatrabari Pond with a surface area of 1.38 km^2 (C zone)
- Gandaria Pond with a surface area of 0.47 km^2 (B zone)

(3) Khal Improvement and Drainage Pipe

Improvement of the existing six (6) khals and installation of additional nine (9) drainage pipe lines are proposed to attain a satisfactory level of storm water drainage together with the proposed pump drainage for B, C, and F zones.

The total length of the proposed khal improvement and drainage pipe installation are 13.1 km and 12.5 km, respectively.

The proposed flood protection works and internal drainage facilities are summarized in Table S.3. Location of those works and facilities are illustrated in Fig. S.2.

Table S.3 Summary of Proposed Works and Facilities

Item	Description	Unit	Zone			Total	Remarks
			B	C	F		
A. Dike	H=6.0 m	m	-	4,800	-	4,800	
B. Pump Station	9.2 & 9.6 m^3/s	place (m^3/s)	2 (18.8)	-	-	2 (18.2)	Rehabilitation and New Pump Stations
C. Gate	6.0mx6.0m	Place	1	1	-	2	
D. Khal Improvement Work	m	-	4,200	5,100	3,800	13,100	
1. Dredging	-	1,000 m^3	107	155	34	295	
2. Sodding	-	1,000 m^2	54	25	53	132	
3. Brick Protection	-	m	400	1,180	700	2,280	
4. Retaining Wall	Concrete Panel	m	-	480	280	760	
5. Box Culvert	B 4-7 m x H 4-6m	m Place	25 (1)	192 (12)	147 (8)	364 (21)	
6. Railway Bridge	L=12m x 3	Place	-	1	-	1	
E. Drainage Pipe		m	4,280	4,810	3,410	12,500	
1. Brick Pipe	D=1.5-3.7m	m	2,050	4,110	3,410	9,570	
2. Box Culvert	av. 3mx3m	m	2,230	700	-	2,930	

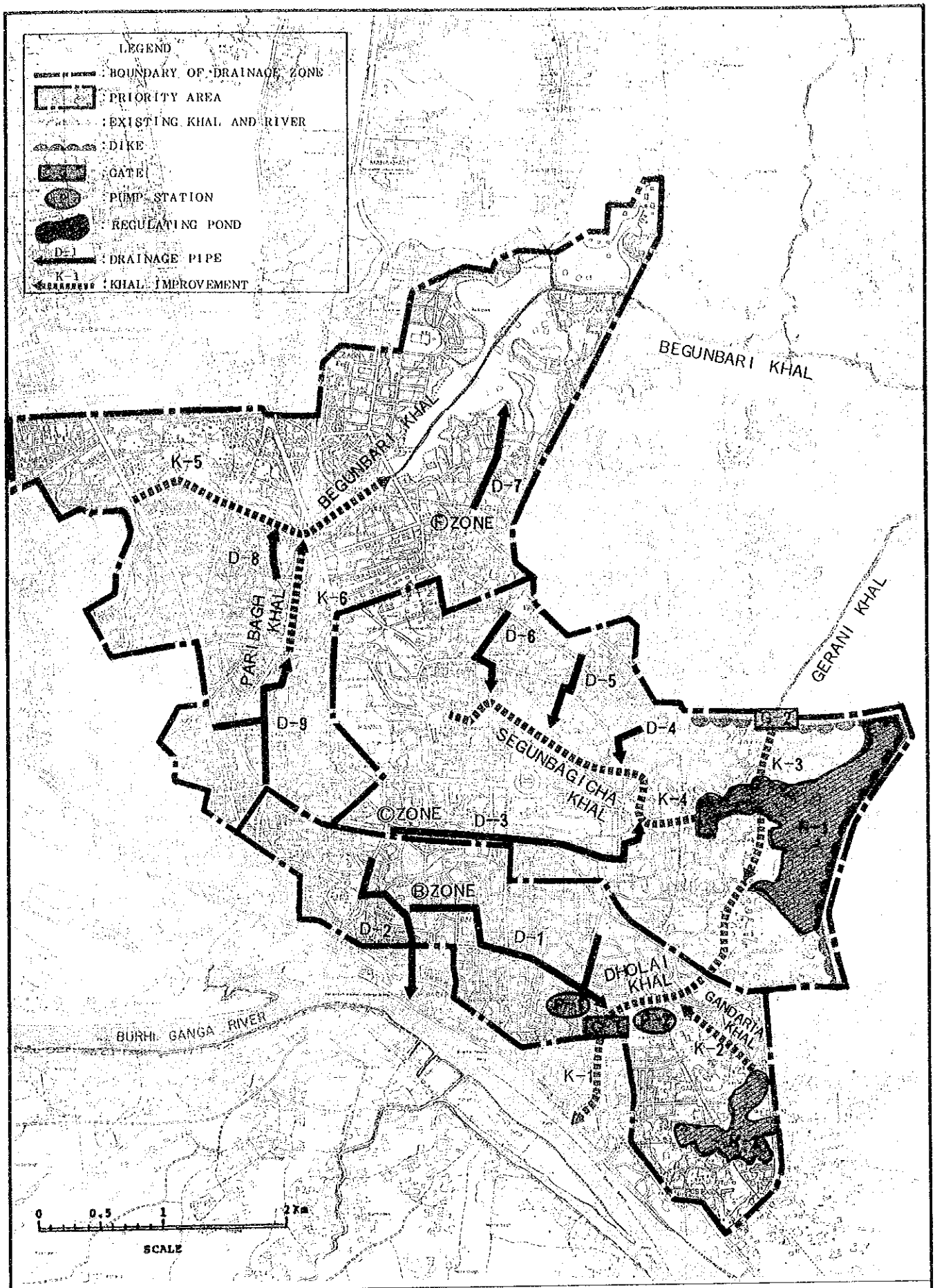


FIG. S. 2 PROPOSED FLOOD PROTECTION AND DARINAGE FACILITIES

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA 1987A.D

5.3 Project Cost and Implementation Schedule

The total project cost for the priority area is estimated to be 1,790.3 million TK at 1986 prices. The proposed works and facilities will be completed within six (6) years by staged construction.

The project cost including price contingency for six (6) years is estimated to be 2,609.2 million TK.

The breakdown of the project cost is shown in Table S.4.

Table S.4 Breakdown of Project Cost

Item	Cost
A. Construction Cost	1,237.3
(1) Dikes	(186.2)
(2) Pump Stations	(319.9)
(3) Gates	(69.5)
(4) Khal Improvement	(286.7)
(5) Drainage Pipe	(375.0)
B. Physical Contingency	123.7
C. Engineering	136.1
D. Land Acquisition	83.0
E. Office Establishment	25.5
F. Customs Duty & Tax	184.7
Total Project Cost (1) (At 1986 price)	1,790.3
G. Price Contingency (1988/1989 - 1993/1994)	818.9
Total Project Cost (2) (With Price Contingency)	2,609.2

5.4 Operation and Maintenance

(1) Operation and maintenance work

To sustain the expected effects of the existing and proposed drainage system of the Project area (B, C and F zones), the following major operation and maintenance works shall be performed:

- Cleaning the 91.2 km of drainage pipes (existing: 82.5 km, proposed: 12.5 km).
- Dredging of deposits and removal of garbage from the 13.1 km of khals.
- Maintenance and repair of 4.8 km dikes.
- Operation and maintenance of two (2) pump stations and two (2) control gates.
- Land use control, in cooperation with the agencies concerned, to maintain the regulating ponds and the khal areas, and to assure the required elevation of new land development.

(2) Organization

The organization required for construction consists of 15 engineers and other supporting staffs. The organization will perform the operation and maintenance after completion of the construction work.

(3) Operation and maintenance cost

The annual cost required for operation and maintenance of the Project areas (B, C and F zones) is estimated to be 25.4 million TK at 1986 price.

5.5 Project Evaluation

The expected major contributions of the Project are as follows:

- Reduction of general and public property damages
- Reduction of income/sales loss and vehicle running costs
- Increase in available land and its value
- Improvement of public health and amenities
- Creation of employment opportunities

The estimated investment efficiency of the Project is as follows:

Economic Internal Rate of Return (IRR):	17.1%
Benefit Cost Ratio (B/C):	1.24
Net Present Value (NPV):	188.9 million TK

5.6 Conclusion and Recommendations

(1) The proposed Project is technically, economically and socially justified. Urgent implementation of the Project is recommended in consideration of the present serious flood problems which the city is faced with.

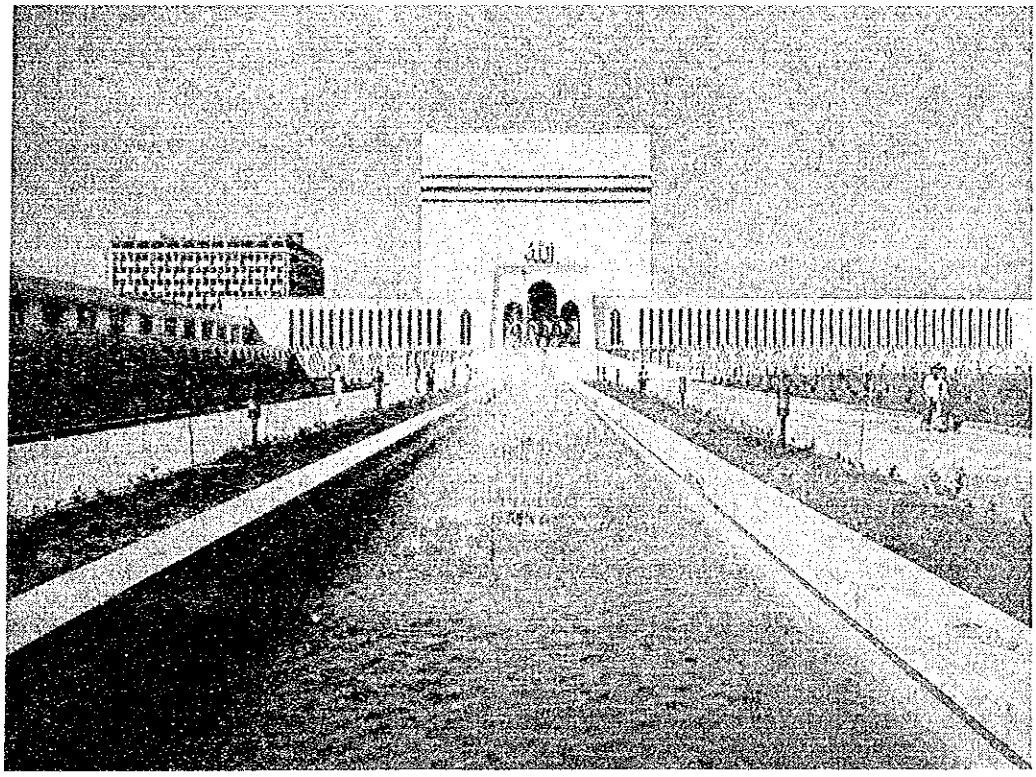
(2) Because of the high costs of the Project, foreign financial aid shall be obtained.

(3) In the detailed design stage, the proposed flood protection and drainage plans shall be coordinated in greater detail with the other relevant urban development plans. Especially, the multiple use of the proposed dikes for roads shall be discussed at greater length.

(4) The required land acquisition shall be completed before commencement of construction so that the smooth implementation of the Project, including financial aid procurement, can be achieved.

(5) A special organization for the Project shall be set up expeditiously in the Department of Public Health Engineering, Ministry of Local Government, Rural Development and Cooperatives.

MAIN REPORT



BAITUL MUKARRAM MOSQUE

TABLE OF CONTENTS

SUPPORTING REPORT

(Contained in Vol. II)

SUPPORTING REPORT	A	STUDY AREA
SUPPORTING REPORT	B	CLIMATE AND HYDROLOGY
SUPPORTING REPORT	C	WATER QUALITY
SUPPORTING REPORT	D	POPULATION AND LAND USE
SUPPORTING REPORT	E	EXISTING DRAINAGE SYSTEM AND FACILITIES
SUPPORTING REPORT	F	FLOOD AND FLOOD DAMAGE
SUPPORTING REPORT	G	PREVIOUS DRAINAGE STUDIES AND PROJECTS
SUPPORTING REPORT	H	PREPARATION OF PHASED PROGRAM
SUPPORTING REPORT	I	DRAINAGE IMPROVEMENT PLAN OF PRIORITY AREA
SUPPORTING REPORT	J	PRELIMINARY DESIGN OF DRAINAGE FACILITIES
SUPPORTING REPORT	K	OPERATION/MAINTENANCE, AND ORGANIZATION
SUPPORTING REPORT	L	PROJECT COST AND IMPLEMENTATION SCHEDULE
SUPPORTING REPORT	M	PROJECT EVALUATION
SUPPORTING REPORT	N	SUPPLEMENTARY STUDY
SUPPORTING REPORT	O	TOPOGRAPHIC SURVEY
SUPPORTING REPORT	P	SCOPE OF WORK

DATA BOOK (I)

DATA BOOK I	SURVEYS DRAWINGS

DATA BOOK (II)

DATA BOOK II-1	CLIMATE AND HYDROLOGY
DATA BOOK II-2	FLOOD AND FLOOD DAMAGE SURVEY
DATA BOOK II-3	HYDRAULIC CALCULATION
DATA BOOK II-4	WATER QUALITY

LIST OF TABLES

LIST OF FIGURES

Chater 9

Chapter 12

ABBREVAIATIONS

ADB	Asian Development Bank
BM	Bench Mark
BWDB	Bangladesh Water Development Board
cm	Centimeter
CMD	Cubic Meters Per Day
CMS	Cubic Meters Per Second
DIT	Dhaka Improvement Trust
DMAIUD	Dhaka Metropolitan Area Integrated Urban Development Project
DMC	Dhaka Municipal Corporation
DPHE	Department of Public Health Engineering, MLGRADC
DWASA	Dhaka Water and Sewerage Authority
Fig.	Figure
GOB	Government of Bangladesh
GOJ	Government of Japan
G.T.S.	Geographical Survey Datum of Bangladesh
ha	hectares (10,000 m^2)
hp	horsepower
hr	hours
HHWL	Highest High Water Level
HWL	High Water Level
JICA	Japan International Cooperation Agency
khal	A term commonly used in Bangladesh for "canal"
km	kilometers
m	meters
m^2	square meters
m^3	cubic meters
m^3/s	cubic meters per second
mm	millimeters
MLGRDC	Ministry of Local Government, Rural Development and Cooperatives, GOB
MOC	Ministry of Construction, GOJ
MWL	Mean Water Level
PCI	Pacific Consultants International
TK	Taka (Bangladesh Currency);
	US Dollar = approximately 30.0 TK
UNDP	United Nations Development Programme

BURIGANGA RIVER IN DRY SEASON

CHAPTER 1
INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Dhaka City is located on the southern edge of the Madhupur Jungle Terrace and is surrounded by rivers on all sides. Flood water from the rivers frequently inundates the low-lying areas of the city. Heavy rainfall causes water logging in many places within the city, creating manifold problems for the citizens. The rapid urbanization in the recent years has further worsened the flooding conditions of Dhaka City.

To cope with these problems, various flood protection and internal drainage plans have been proposed.

The first master plan was prepared by the Department of Public Health Engineering (DPHE) in 1968 to protect the developed area of 75 Km^2 from flood waters and to drain internal storm waters.

As a follow up to the master plan, a detailed scheme was prepared by the Bangladesh Water Development Board (BWDB) in 1975 for an area of 145 Km^2. Another scheme for internal drainage system was prepared by DPHE in 1976. Both the proposals, however, were not approved due to difficulty in financing.

Instead, a crash program for removing standing water from the city was recommended and has been implemented by DPHE since 1976. The existing storm water drainage system is still inadequate for coping with the recurring heavy storms and floods.

A recent 1981 study, the "Dhaka Metropolitan Integrated Urban Development Project", was completed in which a framework for the future urban development of Dhaka was prepared and further detailed study for the drainage system improvement was recommended.

The Government of Bangladesh requested the Government of Japan to undertake the study recommended above. The Scope of the Study was agreed upon between the Ministry of Local Government, Rural Development and Cooperatives, the Government of Bangladesh, and the Mission of the Japan International Cooperation Agency (JICA) on June 5, 1986.

1.2 Objectives and Area of the Study

The objectives of the Study are:

(1) to prepare a phased program of the flood protection and internal drainage improvement project for the developed areas in Dhaka City, and to identify the high priority areas,

(2) to conduct a feasibility study of the proposed flood protection and internal drainage improvement projects for the selected high priority areas.

The study area of 260 Km^2 was proposed in the original Scope of Work. However, it was reviewed and reduced to 137 Km^2 in the actual study and the remaining area of 123 Km^2 will be left to be improved in future development program.

1.3 Implementation of the Study

The Department of Public Health Engineering (DPHE), Ministry of Local Government, Rural Development and Cooperatives was assigned as the executing agency for the Bangladesh side and JICA was assigned for the Japanese side.

The Study was carried out by the Japanese consultant team retained by JICA and counterpart staff of DPHE. The JICA Advisory Committee acted as advisors to the JICA Study Team.

The Study was conducted from November 1986 to October 1987. The members involved in the Study are listed below.

(1) JICA Study Team

Mr. N. Murata	(PCI)	: Team Leader
Mr. T. Tokumasu	(PCI)	: Deputy Team Leader/Drainage System Planning
Mr. T. Kadota	(PCI)	: Land-use Planning
Mr. I. Misono	(PCI)	: Hydrologic Analysis
Mr. T. Oshita	(PCI)	: Drainage Facility Planning
Mr. Y. Iwasaki	(PCI)	: Drainage Facility Planning
Mr. S. Suzuki	(PCI)	: Mechanical Facility design
Mr. Y. Katagiri	(PCI)	: Environmental Analysis
Mr. Y. Ohtoku	(AAS)	: Land Survey
Mr. A. Kojima	(PCI)	: Economic Analysis
Mr. S. Shigeoka	(PCI)	: Hydrologic Observation

(2) JICA Advisory Committee

Mr. T. Takeuchi	(MOC)	: Chairman
Mr. M. Seiji	(MOC)	: Member
Mr. T. Komura	(MOC)	: Member
Mr. K. Kumagai	(MOC)	: Member

(3) DPHE Officials

Mr. M. H. Khan	: Chief Engineer
Mr. M. A. Karim	: Superintending Engineer
Mr. M. A. B. Siddique	: Superintending Engineer
Mr. S. A. K. M. Shafique	: Superintending Engineer
Mr. Nasiruddin Ahmed	: Assistant Chief Engineer
Mr. Abdul Kalam	: Assistant Chief Engineer
Mr. M. D. Abdul Bari	: Executive Engineer
Mr. SK. Abu Jafar Shamsuddin	: Executive Engineer
Mr. Abdul Rahman Mia	: Executive Engineer
Mr. Kader Chowdhury	: Executive Engineer

(4) DPHE Counterparts

Mr. Abdul Rahman Mia	:	Chief Counterpart
Mr. Quader Chowdhury	:	Chief Counterpart
Mr. B. Rahman	:	Counterpart
Mr. Shafiur Rahman	:	Counterpart
Mrs. Ether	:	Counterpart
Mr. Abul Bashar	:	Counterpart

Special Abbreviations

MOC: Ministry of Construction
PCI: Pacific Consultants International
AAS: Asia Air Survey

1.4 Composition of Report

This report consists of three(3) volumes: Main Report, Supporting Report, and Data Book.

The Main Report presents the summarized results of all the studies. In Chapters 2 through 5, the basic information for the Study are described. In Chapter 6, the phased program for the long term drainage development is proposed. In Chapters 7 through 11, the feasibility study of the priority project is described. In Chapters 12 and 13, supplementary studies and recommendations are presented respectively.

The Supporting Report includes the following Studies:

A: Study Area
B: Climate and Hydrology
C: Water Quality
D: Population and Land Use
E: Existing Drainage System and Facilities
F: Flood and Flood Damage
G: Previous Drainage Studies and Projects
H: Preparation of Phased Program
I: Drainage Improvement Plan of Priority Area

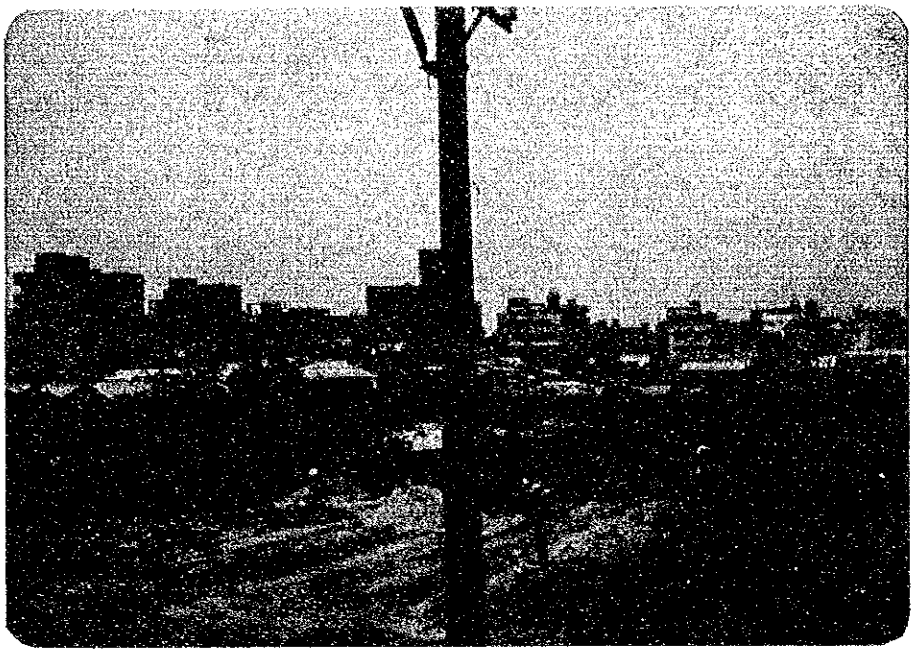
J: Preliminary Design of Drainage Facilities
K: Operation/Maintenance, and Organization
L: Project Cost and Implementation Schedule
M: Project Evaluation
N: Supplementary Study
O: Topographic Survey
P: Scope of Work

The Data Book contains the data of the following surveys:

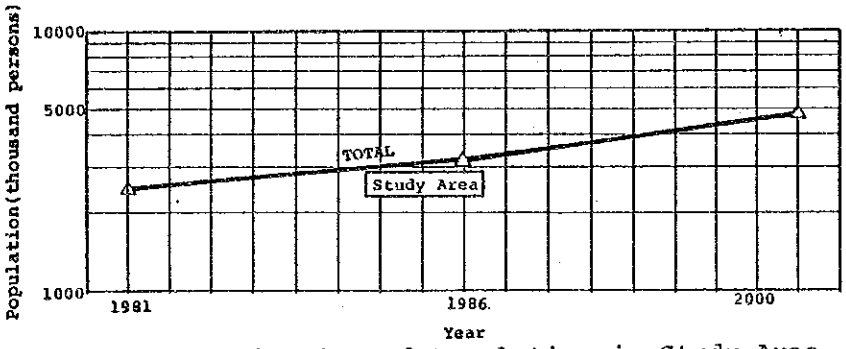
I: Topographic Survey
II-1: Climate and Hydrology
II-2: Flood and Flood Damage Survey
II-3: Hydraulic Calculation
II-4: Water Quality

1.5 Acknowledgement

In undertaking the Study, the Study Team has attached great importance to the incorporation of the views of departments and agencies of the Government of Bangladesh relating to the various aspects covered by the Study. The contributions to the Study by the officials of Ministry of Local Government, Rural Development and Cooperatives, Department of Public Health Engineering and other government agencies, and other individuals who have provided information and data, participated in discussions, given valuable advices, and provided other forms of assistance to the Study are greatfully acknowledged. A heartfelt gratitude is also extended to the officials of the Ministry of Foreign Affairs and Ministry of Construction of the Government of Japan who gave advice and provided various support during the performance of the Study. In reality, the Study can be regarded as a joint effort by the Bangladesh and Japanese officials and individuals concerned and the Japanese Study Team. The Study Team sincerely hopes that this joint effort will contribute to the future development of flood protection and drainage improvement in Dhaka City in particular, and to its socio-economic development and well-being in general.



LAND DEVELOPMENT OF LOWLAND
ALONG BEGUNBARI KHAL



Future Projection of Population in Study Area

CHAPTER 2
STUDY AREA

CHAPTER 2 STUDY AREA

2.1 Topography and Geology

2.1.1 Topography

(1) The Study Area is developed on the southern edge of the Madhupur Jungle Terrace lying between the Jamuna and Meghna Rivers. Central parts of the Study area are high enough to be free from the river flood waters.

Large lowlands surround the Study Area. To the west and south lies the flood plains of the Buriganga River: to the east lies the flood plain of the Balu River. Both these areas are flooded 2 to 4 m during six (6) months every year.

Due to the limited land resources, Dhaka City is now sprawling even into these areas by the use of land accretion.

(2) The topography of the Study Area is irregular with complicated contour lines. The land is divided into several sections by reentrant valleys called "Khal" with a bed level of about 3 m G.T.S. The major khals are Dholai Khal, Segunbagicha Khal, Gerani Khal and Begunbari Khal.

The elevation of the Study Area ranges from 2 to 13 m G.T.S. The business center and downtown of Dhaka City is developed on the land with a level of 6 to 8 G.T.S. It is slightly higher or lower than the maximum recorded flood level of 6.59 m G.T.S.

The land area above 8 m G.T.S. covers 20 km^2, equivalent to 15% of the total Study Area of 137 km^2. The land ranging from 6 to 8 m G.T.S. covers 75 km^2, or 55%. The land below 6 m G.T.S. covers 42 km^2, or 30%.

The topography of the Study Area is illustrated in Fig. 2.1.

2.1.2 Geology

The land of Bangladesh is floored with quarternary sediments deposited by the Ganges - Padma, Brahmaputra - Jamuna and Meghna Rivers, and their tributaries and distributaries.

In the Study Area, silt and clay are predominant in the upper layer of the sub-soil, having an approximate thickness of 10 to 20 m. Sands occupy the major portion of the lower deposits.

Fig. 2.2 illustrates sub-soil profiles across the line of boring which runs through the city of Dhaka from south to north.

2.2 Rivers and Channels

The Study Area drains directly or through drainage channels into the Turag River on the west, Buriganga River on the south, Balu River on the east and Tongi Khal on the north. The Tongi Khal connecting the Turag and Balu Rivers changes its flow direction according to the hydraulic conditions of both rivers.

Waters of the Turag, Buriganga and Balu Rivers are collected by the Dhaleswari River and finally conveyed to the Bay of Bengal through the Meghna and Ganges - Padma Rivers.

The river system related to the Study Area is illustrated in Fig. 2.3.

The major drainage channels in the Study Area are Dholai Khal, Gerani Khal, Segunbagicha Khal and Begunbari Khal. Dholai Khal drains into the Buriganga River and the others flow into the Balu River.

The drainage channels (khal) system in the Study Area is also illustrated in Fig. 2.3.

2.3 Climate and Hydrology

2.3.1 Climate

The climate of the Study Area belongs to tropical monsoon type, characterized by three distinct seasons: monsoon, cool, and warm. Average annual rainfall is 2,060 mm. Annual evaporation is estimated to be 1,123 mm.

The monsoon season extends from May to October during which about 90% of the rainfall occurs. Cyclonic storms, with destructive winds, are frequent during both the early and late stages of the monsoon season.

Following the monsoon, the cool season begins in November and continues through February. Rainfall is rare during the season.

The warm season, March and April, is characterized by high temperature accompanied by frequent thunderstorms. Rainfall during these two months accounts for about 10% of the annual precipitation.

Monthly climatic conditions and rainfall distributions of the Study Area is illustrated in Fig. 2.4.

2.3.2 Storm Rainfall

(1) Probability of Storm Rainfall

Probability of storm rainfall was estimated based on the records during the past 33 years (1953 - 1985) at Dhaka Meteorological Station. The calculations were made by the Gumbel Method for consecutive storm rainfalls of various duration days.

The consecutive rainfall - duration curves with a parameter of frequency are illustrated in Fig. 2.5.

(2) Rainfall intensity-duration curves were prepared by the Talbot pattern formula for various return periods of rainfall. The data used for calculation are rainfall depths for 15, 30, 60 and 120 minutes, read from the automatic recording charts at Dhaka Meteorological Station available during the past 27 years (1957 - 1983).

The results are illustrated in Fig. 2.5.

(3) Storm Rainfall Pattern

An analysis of hourly rainfall distribution pattern was made for the daily storm rainfalls larger than 100 mm/day at Dhaka Meteorological Station during the past 26 years (1958 - 1983). Accumulative curves of hourly consecutive rainfall in one day are illustrated in Fig. 2.6.

Most of the storm rainfalls are of high intensity for a six (6) hour period.

Illustrated in Fig. 2.6. is a proposed design rainfall pattern with a 6 hour duration and a peak hourly rainfall depth equivalent to 44% of the total rainfall.

2.3.3 River Water Level

(1) Seasonal Variation of River Water Level

Floods in the surrounding rivers of the Study Area usually reach their peaks in August or September after a slow steady rise throughout the monsoon season. During flood seasons, the flood water may rise above the elevation of 5 - 6 m G.T.S. or more. During the dry season, the water stage draws down to 1 - 2 m G.T.S. and reflects tidal effects from the Bay of Bengal.

Fig. 2.7 illustrates the seasonal variation of the Buriganga River stage at Millbarrak.

(2) Historical Flood Records

Major floods were recorded in 1954, 1955, 1958, 1970, 1974 and 1980. The maximum flood took place in Aug., 1955, recording the water levels of 6.59 m (G.T.S.) at Millbarrak of the Buriganga River and 7.20 m (G.T.S.) at Mirpur of the Turag River.

Fig. 2.7 presents the maximum water levels of the major floods at Millbarrak, Mirpur, Tongi (Tongi Khal) and Demura (Balu River). The location of Millbarrak, Mirpur, Tongi and Demura is shown in Fig. 2.7.

(3) Probability of Flood Water Level

Probabilities of flood water stage of Millbarrak, Mirpur and Tongi were calculated by using the records available during the past 42 years (1945 - 1985). Flood water levels at Millbarrak are estimated to be 5.36 m G.T.S. for a 2-year return period, 6.60 m G.T.S. for a 30-year return period, and 7.10 m G.T.S. for a 100-year return period.

The calculation results for the three (3) sites are summarized and illustrated in Fig. 2.8.

2.4 Population and Land Use

2.4.1 Population

According to the latest population census, the population of the Dhaka Metropolitan Area with an area of 402.5 km^2 was 2,068,000 in 1974 and 3,400,000 in 1981. The average annual growth rate during 1974 to 1981 was 7.54%. This high rate of growth can be attributed to the large influx of people from the rural areas to Dhaka.

The Study Area covers the central part of the Dhaka Metropolitan Area with an area of 137.45 km^2. The population of the Study Area in 1981 calculated by the Study Team was 2,428,000.

The population of the Study Area in 1986 was estimated to be 3,150,000, assuming an annual growth rate of 5.30% during the period of 1981 to 1986.

It will increase to 4,780,000 in 2000 with an annual growth rate of 3.03%.

The population of the Study Area in 1986 and 2000 is broken down by each drainage zone as shown in Table 2.1.

Location and area of the drainage zones are as shown in Fig. 3.1.

2.4.2 Land Use

(1) Present Land Use

The present land use are classified as follows:

(a) Residential area
- High Density: More than 700 persons/ha
- Middle Density: 200 - 700 persons/ha
- Low Density: Less than 200 persons/ha

(b) Commercial Area

(c) Industrial Area

(d) Institutional Area

(e) Others
- Open Space/Agriculture
- Park/Urban Open Space
- Waterbodies: River, Khal, Lake

A present land use map was developed as shown in Fig. 2.9. This map breaks down the Study Area into drainage zones as described in Table 2.2.

(2) Future Land Use

The future land use plan for the 2000 was prepared, based on the development policy proposed in the report of "Dacca Metropolitan Area Integrated Urban Development (Bangladesh Government, ADB, UNDP, 1981)". The policy is a combination of the following two strategies:

- Continuing peripheral expansion of the city without comprehensive flood protection (See Alternative B in Fig. 5.2).

- Expansion of the city to the north and west on land which does not require comprehensive flood protection (See Alternative C in Fig. 5.2).

The following criteria have been established for the planned development of the urban areas:

- It is assumed that the housing development planned by DIT, HSD, and commercial developers under the supervision of DIT will be implemented as scheduled.

- The large-scale land fill planned for the low lands in the west (Kamrangirchar Development) has been included for development in the year 2000.

The development of urban areas not covered by any proposed plan will be considered as follows:

At the present stage, the building of houses in the low lands in the east has been made on individually filled earth mounds or on stilts, and they are being built in consonance with the progress of road construction in their particular areas. In view of these present circumstances, it is assumed that the future pattern of un-planned housing will follow the present pattern and the expansion of the suburbs will be made strictly on the basis of the network of local road construction.

The proposed future land use plan for the year 2000 is illustrated in Fig. 2.10. The various land use areas are divided into drainage zones and are shown in Table 2.2.

2.5 Sewerage System

The existing system serves approximately 80 to 85% of the Old Dhaka City area with a population of about 2 million being served.

The sewerage system collects sewage from households, commercial buildings and industries through house connections, laterals and mains and conveys it to the treatment works of anaerobic ponds located at Pagla for the final treatment. The effluence from the treatment works is disposed of to the Buriganga River through the outfall pump station and outfall sewer.

The existing sewerage system comprises:

- Total sewer line length: 375 km
- Pump station: 14 stations
- House connection: 23,431 houses
- Sewerage treatment works: 1 plant

2.6 Water Quality

The present conditions of surface waters in the Study Area are as described below.

(1) Dhanmondi Lake is polluted to a large degree due to the waste water inflows from the surrounding areas. Average DO and BOD contents are 2.0 ppm and 69 ppm respectively. These figures show that the lake is not suitable for fish life and recreation. In some parts of the lake, a foul odour of H_2S is perceived.

(2) Gulshan Lake has relatively low level pollution.

(3) Ramna and Crescent Lakes are clean.

(4) The Buriganga River and Tongi Khal are polluted to a considerable degree. Average DO and BOD contents range 2.0 to 5.6 ppm and 6.0 to 43.0 ppm, respectively. The waters are not suitable for fish life.

(5) The small khals draining into the Buriganga Rivers at Farashgonj and Hazaribagh are highly polluted. The waters show DO and BOD contents ranging 0.5 - 0.9 ppm and 57 - 78 ppm, respectively.

The locations and observed water qualities are shown in Fig. 2.11.

Table 2.1 Present and Future Population by Drainage Zones
(in 1986/2000)

	Drainage Zone Within Study Area	Area (ha)	Population [Density per ha] 1986	Population Growth Rate 1986/2000 (14 years)	Population [Density per ha] 2000
A.	Buriganga R. B. Zone	1,285	442,300 [344]	1.29	570,300 [444]
B.	Dholai Khal Zone	776	597,900 [770]	1.09	649,600 [837]
C.	Segunbagicha Khal Zone	904	306,900 [339]	1.27	388,400 [430]
D.	Basabo Zone	832	329,300 [396]	1.87	615,600 [740]
E.	North-East Edge Zone	1,393	67,800 [49]	3.6	244,000 [175]
F.	Begunbari Khal Zone	1,602	480,900 [300]	1.31	631,800 [394]
G.	Gulshan-Banani Zone	1,764	227,900 [129]	1.48	337,000 [191]
H.	Kallyampur Zone	1,278	230,700 [181]	1.97	455,600 [356]
I.	North Zone	3,142	343,500 [109]	1.79	613,300 [195]
J.	Turag River Bank Zone	769	119,300 [155]	2.28	271,700 [353]
	Total	13,745	3,146,500 [299]	1.518	4,777,300 [348]

(Annual Rate: 3.03%)

Table 2.2 Present and Future Land Use by Drainage Zone
(in 1986/2000)

Land Use / Drainage Zone	Residential			Commercial	Industrial	Institutional	Others	Total
	High Density	Medium Density	Low Density					
A. Buriganga River Bank Zone	159 (130)	254 (640)	22 (10)	29 (58)	150 (168)	61 (73)	610 (206)	1,285 (1,285)
B. Dholai Khal Zone	539 (505)	100 (213)	- (-)	30 (60)	24 (30)	50 (520)	33 (16)	776 (776)
C. Segunbagicha Khal zone	- (-)	473 (471)	41 (41)	25 (45)	3 (-)	100 (100)	262 (247)	904 (904)
D. Bashabo zone	- (-)	425 (520)	30 (30)	6 (11)	- (-)	30 (30)	341 (241)	832 (832)
E. North-east Edge Zone	- (-)	58 (406)	694 (609)	6 (20)	- (-)	- (-)	635 (358)	1,393 (1,393)
F. Begunbari Khal Zone	56 (56)	863 (885)	148 (148)	33 (83)	100 (142)	178 (178)	224 (110)	1,602 (1,602)
G. Gulshan-Banani Zone	- (-)	115 (25)	550 (405)	26 (60)	105 (105)	546 (555)	422 (314)	1,764 (1,764)
H. Kallyanpul Zone	- (-)	280 (875)	275 (-)	6 (13)	- (-)	227 (276)	490 (114)	1,278 (1,278)
I. North Zone	- (-)	255 (560)	190 (10)	5 (10)	24 (24)	1,265 (1,330)	1,403 (1,208)	3,142 (3,142)
J. Turag River Bank Zone	- (-)	228 (290)	37 (5)	2 (3)	10 (12)	40 (44)	452 (405)	769 (769)
Total	754 (691)	3,051 (5,085)	1,987 (1,258)	168 (363)	416 (481)	2,497 (2,638)	4,872 (3,229)	13,745 (13,745)

Note: The figures in parenthesis show the land use area in the year 2000.

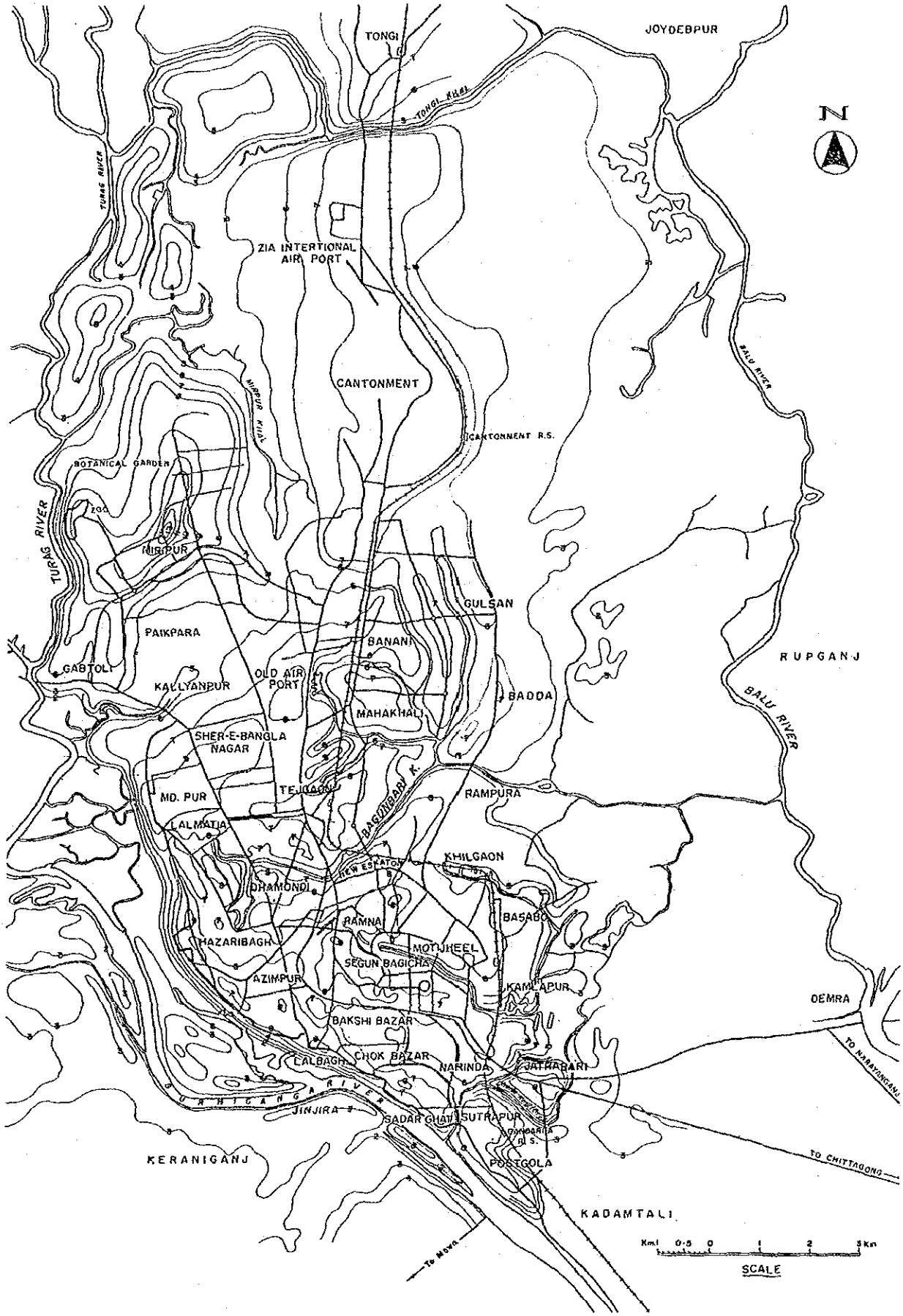
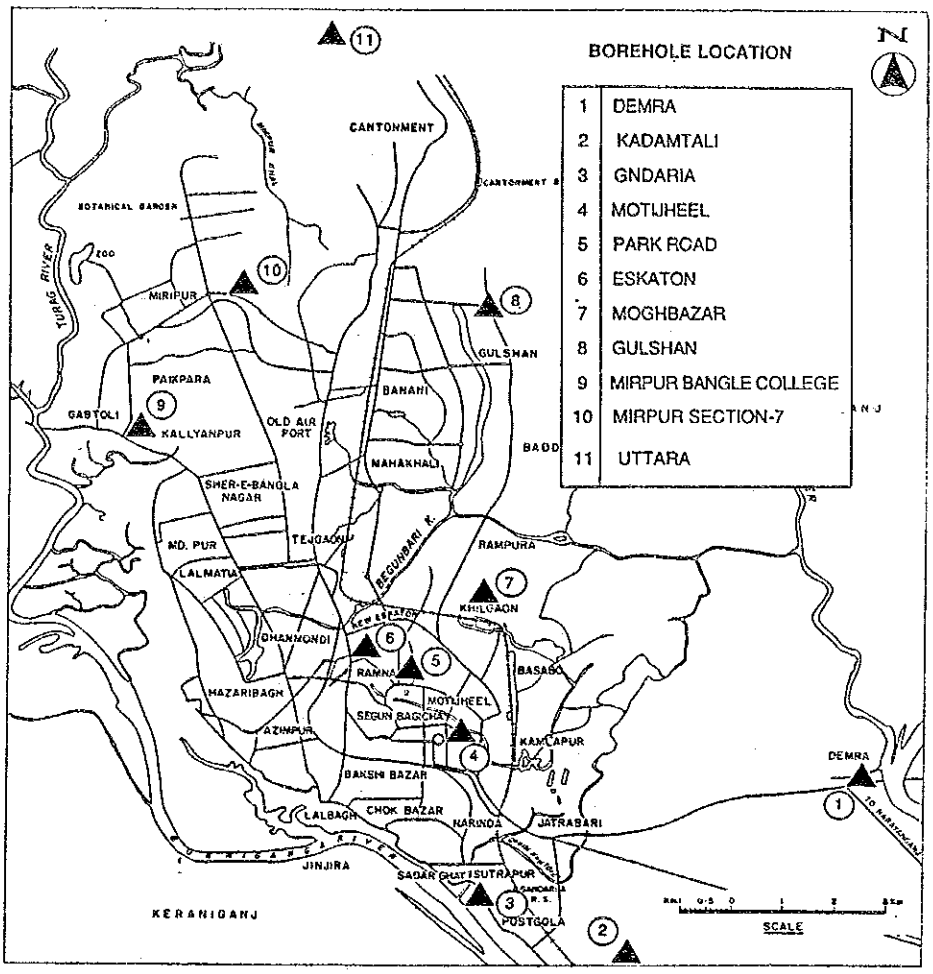


FIG. 2.1 TOPOGRAPHY OF STUDY AREA

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH



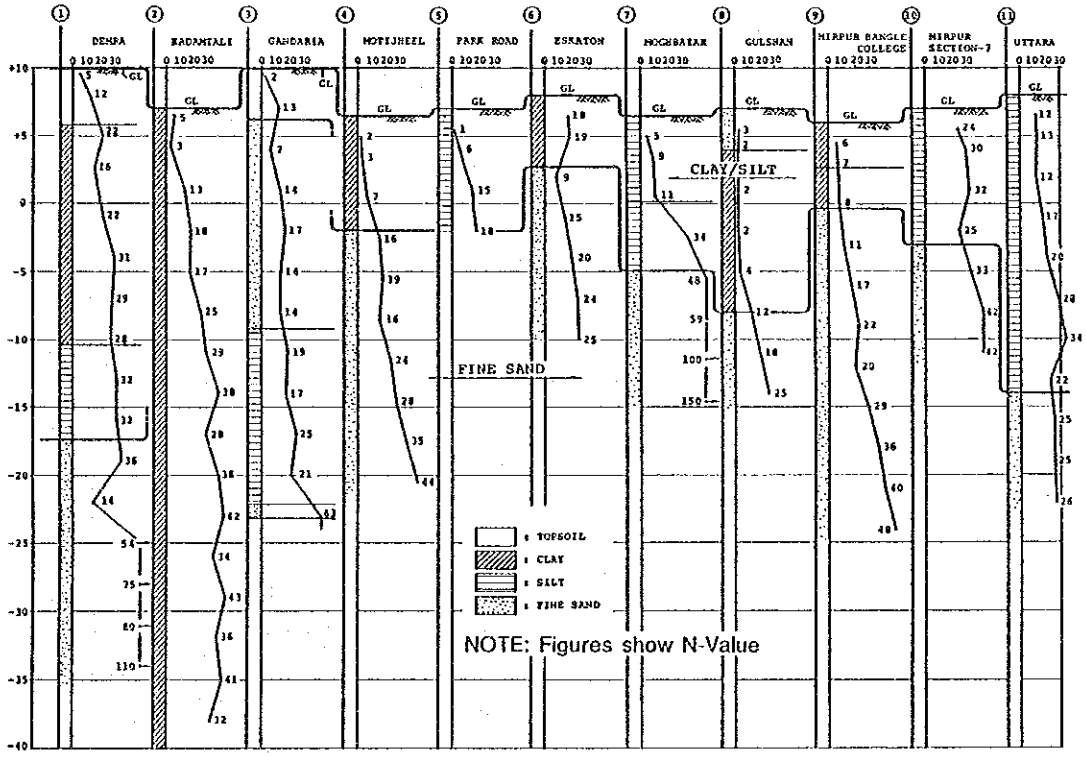
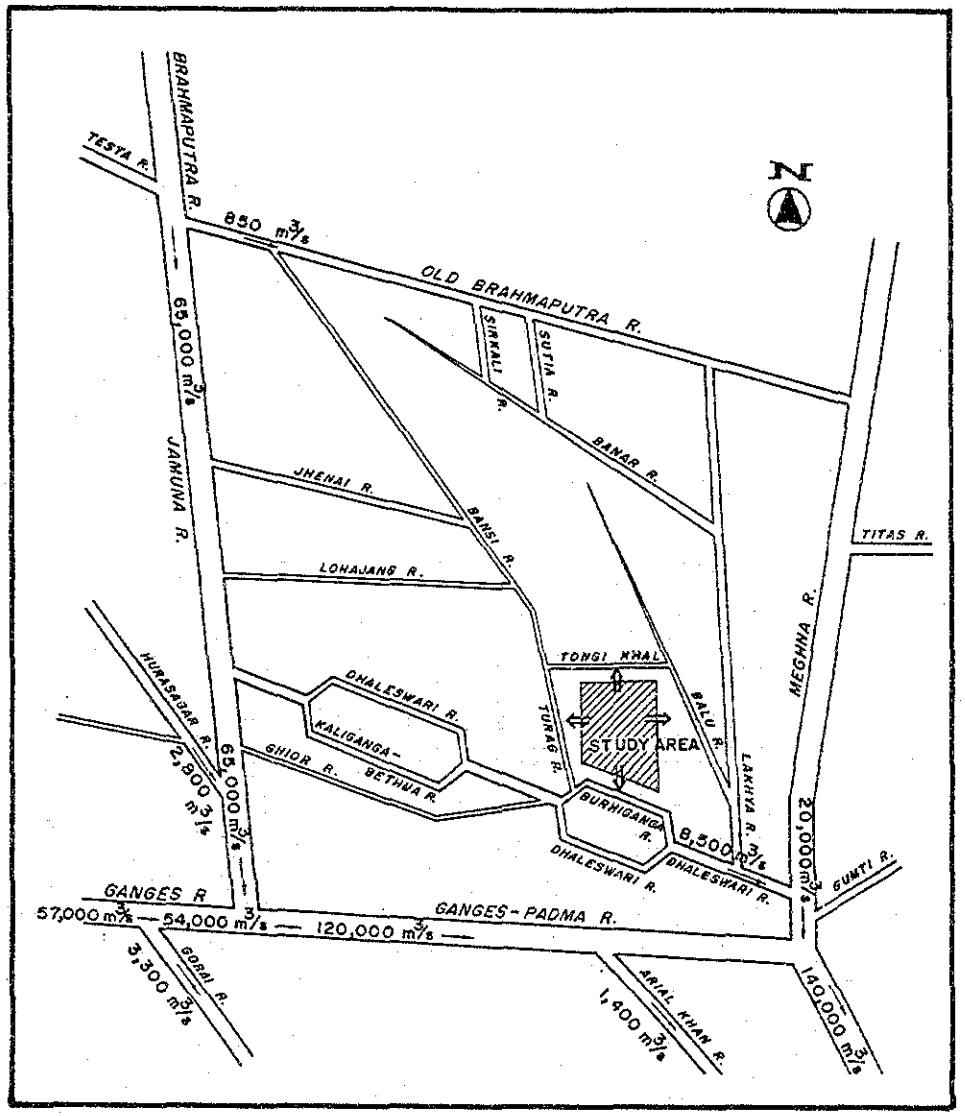
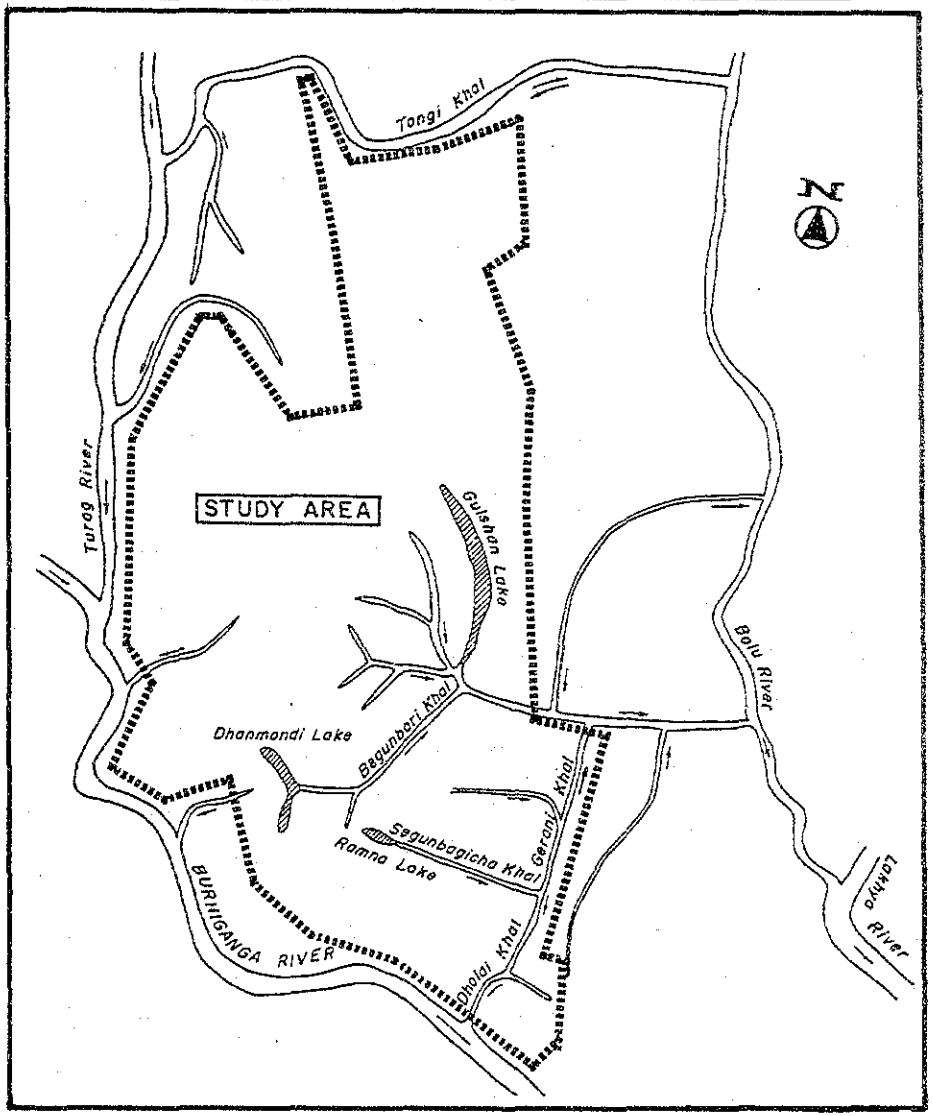


FIG. 2.2 SUB-SOIL PROFILE OF STUDY AREA

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH



RIVER SYSTEM



KHAL SYSTEM

FIG. 2.3 RIVER AND KHAL SYSTEM RELATED TO STUDY AREA

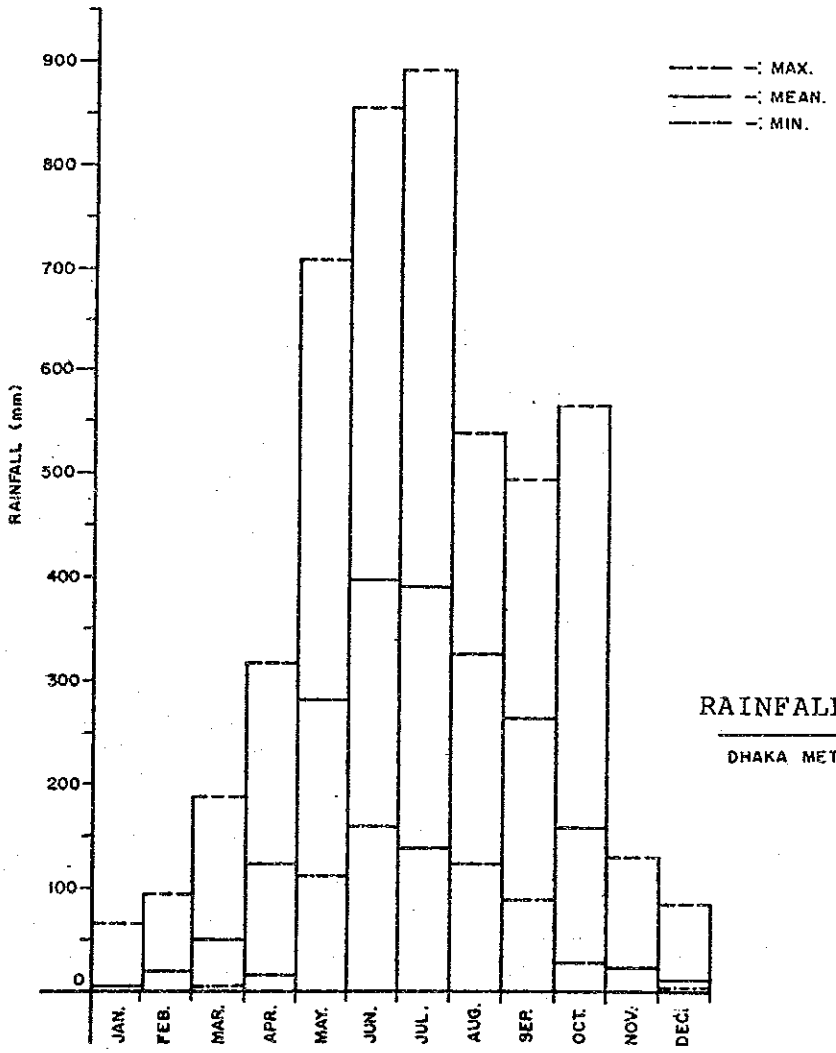
STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA 1987.A.D

CLIMATIC CONDITIONS IN THE STUDY AREA

MONTH	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Temperature, °C													
High (EXTREME)	34.2	36.6	40.6	42.3	40.6	38.4	35.2	35.9	35.3	38.8	33.3	31.2	
Low (")	5.6	4.5	10.4	15.6	18.4	20.4	21.7	21.6	22.0	10.4	10.6	6.7	
Avg.	18.8	21.5	26.1	28.7	28.9	28.7	28.7	28.7	28.7	27.4	23.6	19.8	
Relative Humidity, percent	70	66	63	71	79	86	87	86	86	81	75	74	
Evaporation, millimeters	104	79	81	77	78	83	87	130	118	106	75	105	1,123
Days of Rain, per month	1	2	4	8	14	19	22	22	16	9	2	1	
Average Rainfall, millimeters	6.5	20.2	52.3	124	283	398.2	391.4	328.0	264.0	160.0	25.3	7.4	2,060.3
Wind Velocities, NOTS (N.ts:1.852 Km/R)	2	2	3	5	5	4	4	4	3	2	1	1	

SOURCE : Bangladesh Meteorological department (1953-1985)
Evaporation : 1978-79 : H.R. Laboratory (DHAKA) No. E-10

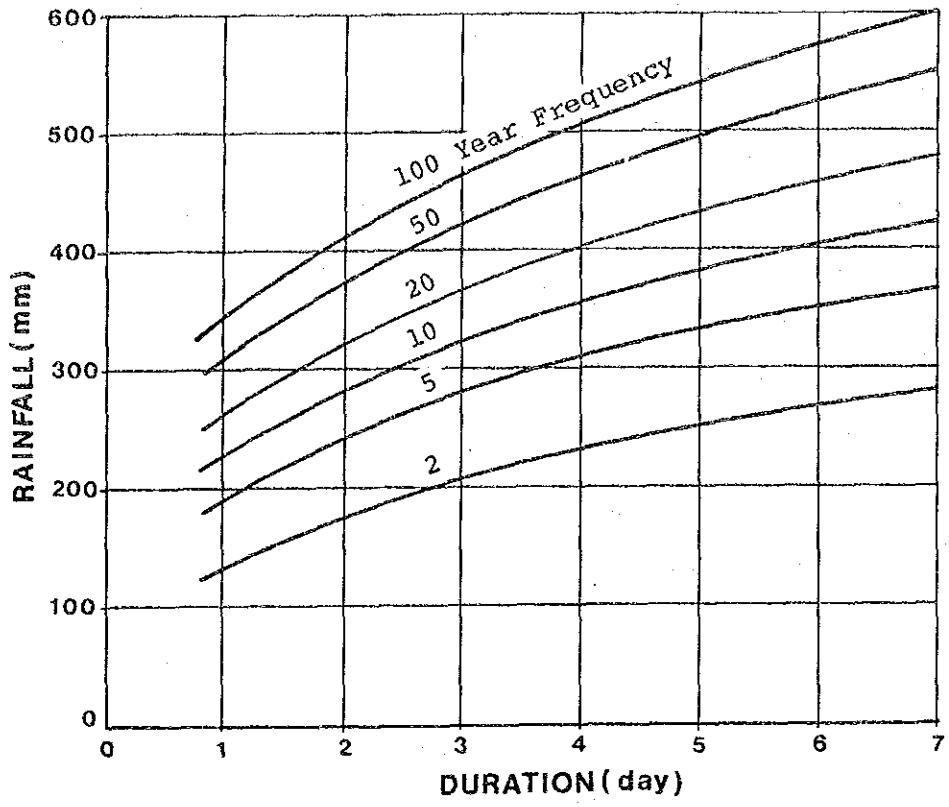


RAINFALL DISTRIBUTIONS

DHAKA MET. STATION (1953~1985)

FIG. 2.4 CLIMATIC CONDITIONS AND RAINFALL DISTRIBUTIONS

CONSECUTIVE RAINFALL-DURATION CURVE



RAINFALL INTENSITY-DURATION FORMULA

RETURN PERIOD	EQUATION	RAINFALL INTENSITY			
		15	30	60	120
2	$\frac{6689}{t+44}$	113·4	90·4	64·3	40·8
5	$\frac{7674}{t+47}$	123·8	99·7	71·7	46·0
5	$\frac{9005}{t+50}$	138·5	112·6	81·9	53·0
10	$\frac{10690}{t+53}$	157·2	128·8	94·6	61·9
20	$\frac{12311}{t+55}$	175·9	144·8	107·0	70·3
50	$\frac{14415}{t+57}$	200·2	165·7	123·2	81·4

RAINFALL INTENSITY-DURATION CURVE

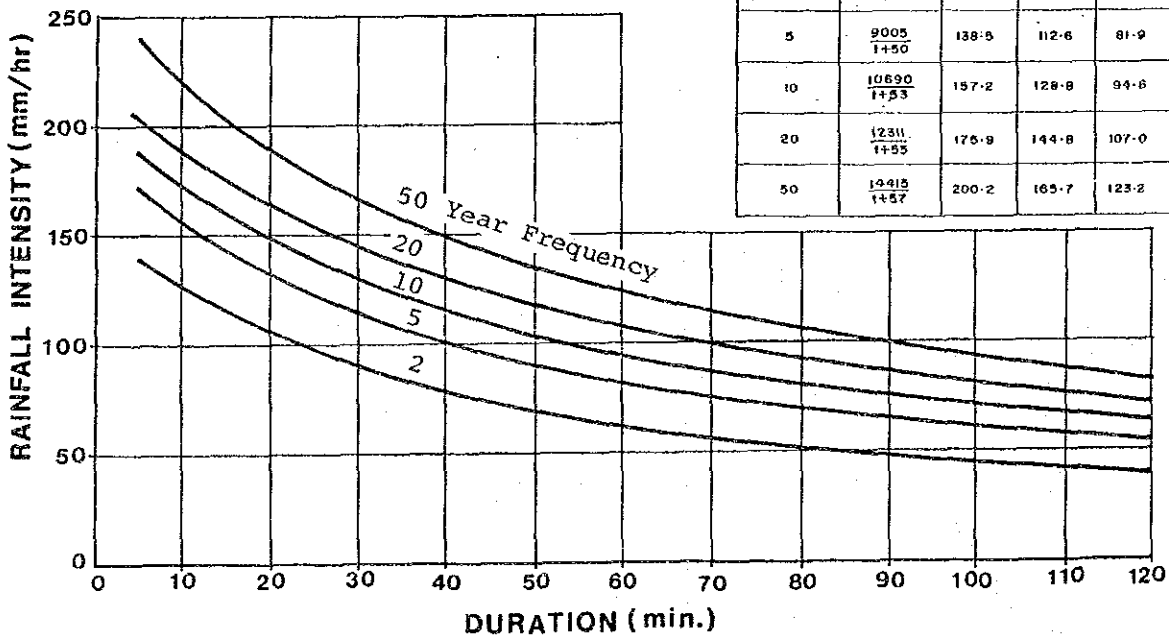
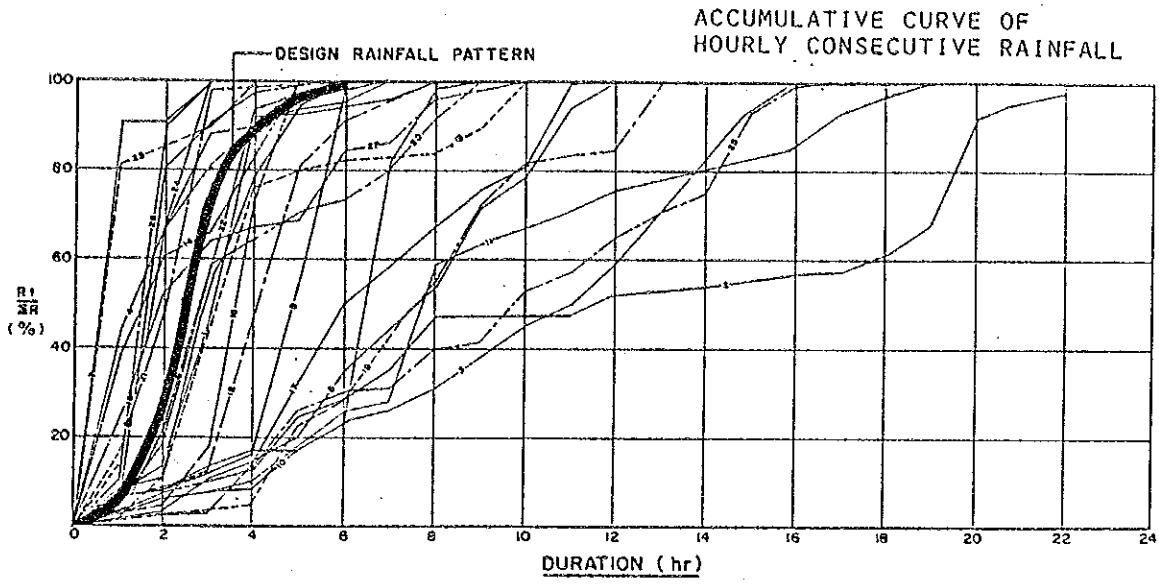
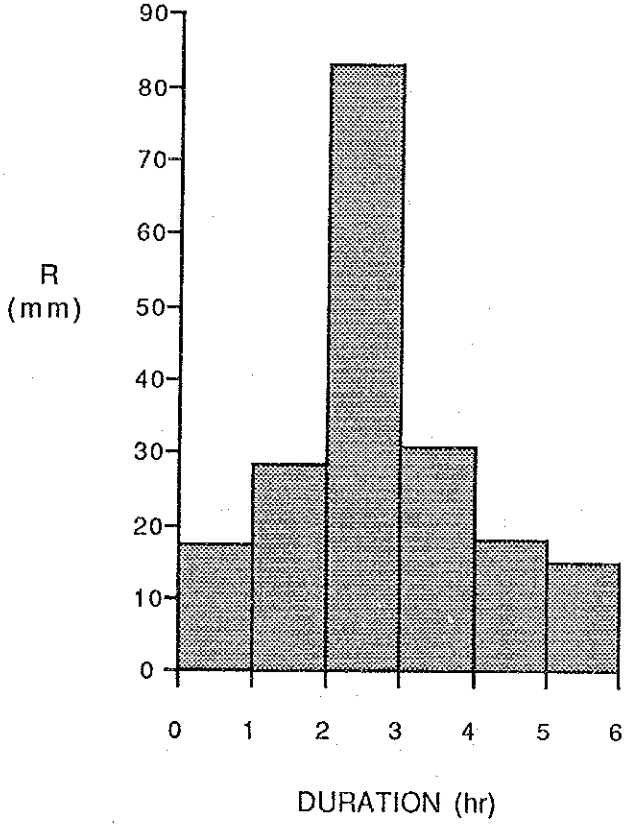


FIG. 2.5 CONSECUTIVE RAINFALL-DURATION AND RAINFALL INTENSITY-DURATION CURVES

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH





RAINFALL DISTRIBUTION

hr	%	R1/5
1	9	17.4
2	15	28.3
3	44	82.8
4	16	30.6
5	9	18.0
6	7	14.9
TOTAL	100	192.0

FIG. 2.6 PROPOSED DESIGN RAINFALL PATTERN

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

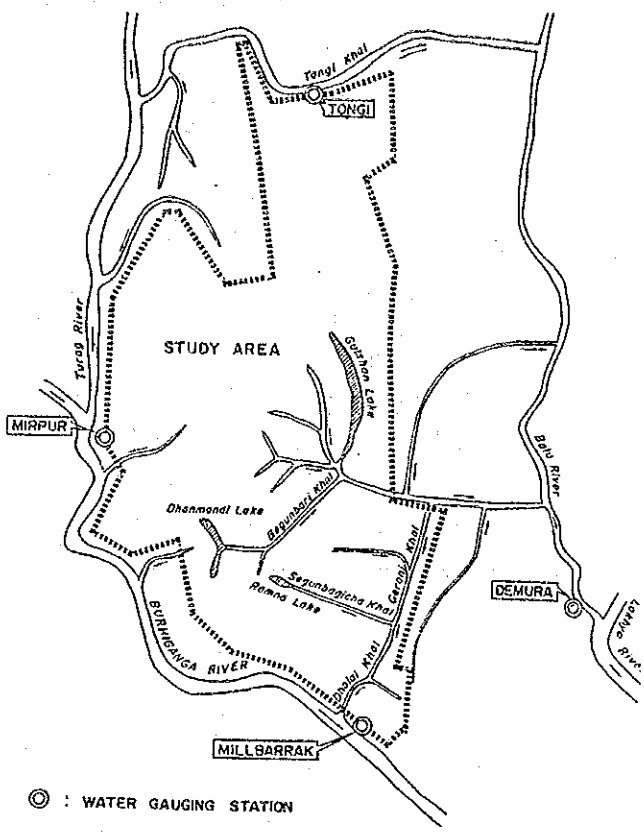
MAXIMUM WATER-LEVELS OF MAJOR FLOODS

W.L. (m) G.T.S.

YEAR	STATION & OBSERVATION PERIOD			
	MILL BARRACK [42]	TONGI [299]	DEMRA [7.5]	MIRPUR [302]
	1945-1981	1960-1981	1962-1986	1953-1981
1954	6.56 (Sept. 2)	N.A.	N.A.	7.12 (Sept. 5)
1955	6.59 (Aug. 18)	N.A.	N.A.	7.20 (Aug. 15)
1958	5.95 (Aug. 2)	N.A.	N.A.	6.73 (Sept. 2)
1970	6.01 (Aug. 6)	6.65 (Aug. 7)	5.78 (Aug. 8)	6.73 (Sept. 6)
1974	6.11 (Aug. 11)	6.64 (Aug. 12)	6.12 (Aug. 11)	6.63 (Aug. 13)
1980	5.93 (Aug. 27)	N.A.	5.77 (Aug. 27)	6.74 (Aug. 27)

Note : [ ] ; Station No. of B.W.D.B.
( ) ; Date
N.A.; Not Available

LOCATION OF EXISTING STATIONS



SEASONAL VARIATION OF BURHIGANGA RIVER AT MILL BARRACK STA.

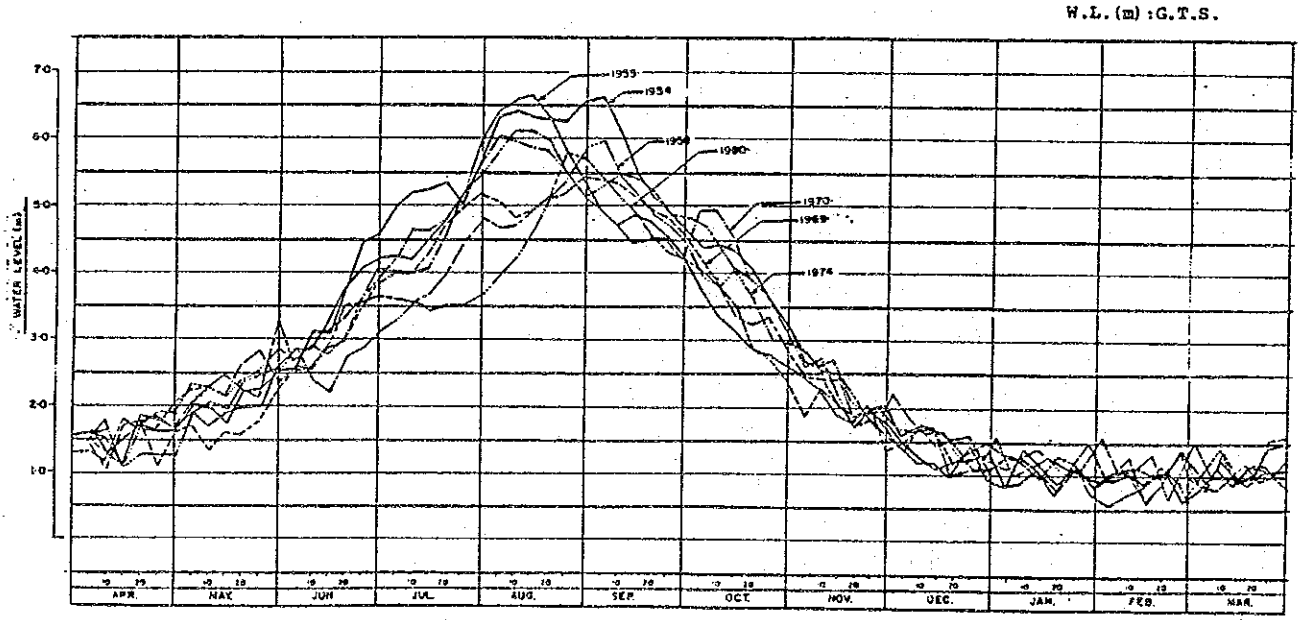


FIG. 2.7 MAXIMUM FLOOD WATER LEVELS AND SEASONAL VARIATIONS

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

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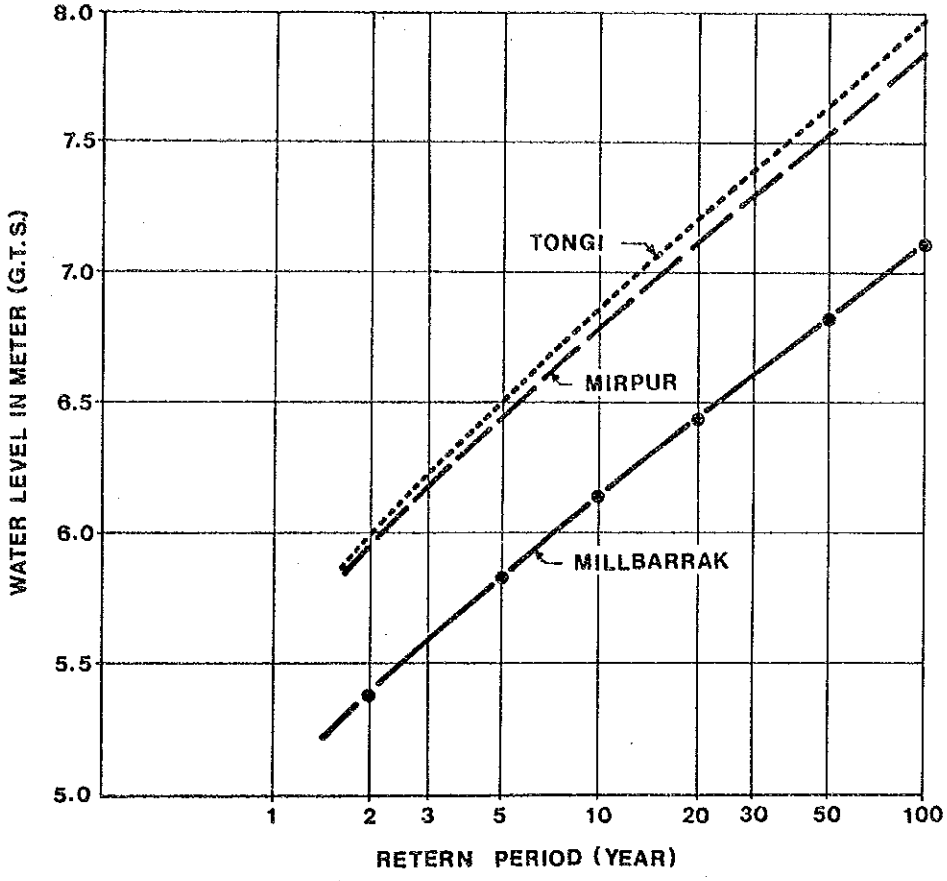


W.L. (m) : G.T.S.

Return Period in Year	MILL BARRAK	MIRPUR	TONGI
2	5.36	5.96	6.00
3	5.58	6.18	6.24
5	5.83	6.45	6.51
10	6.13	6.79	6.87
20	6.43	7.12	7.21
30	6.60	7.30	7.40
50	6.81	7.54	7.65
100	7.10	7.85	7.97

FIG. 2.8 PROBABILITY OF FLOOD WATER LEVELS

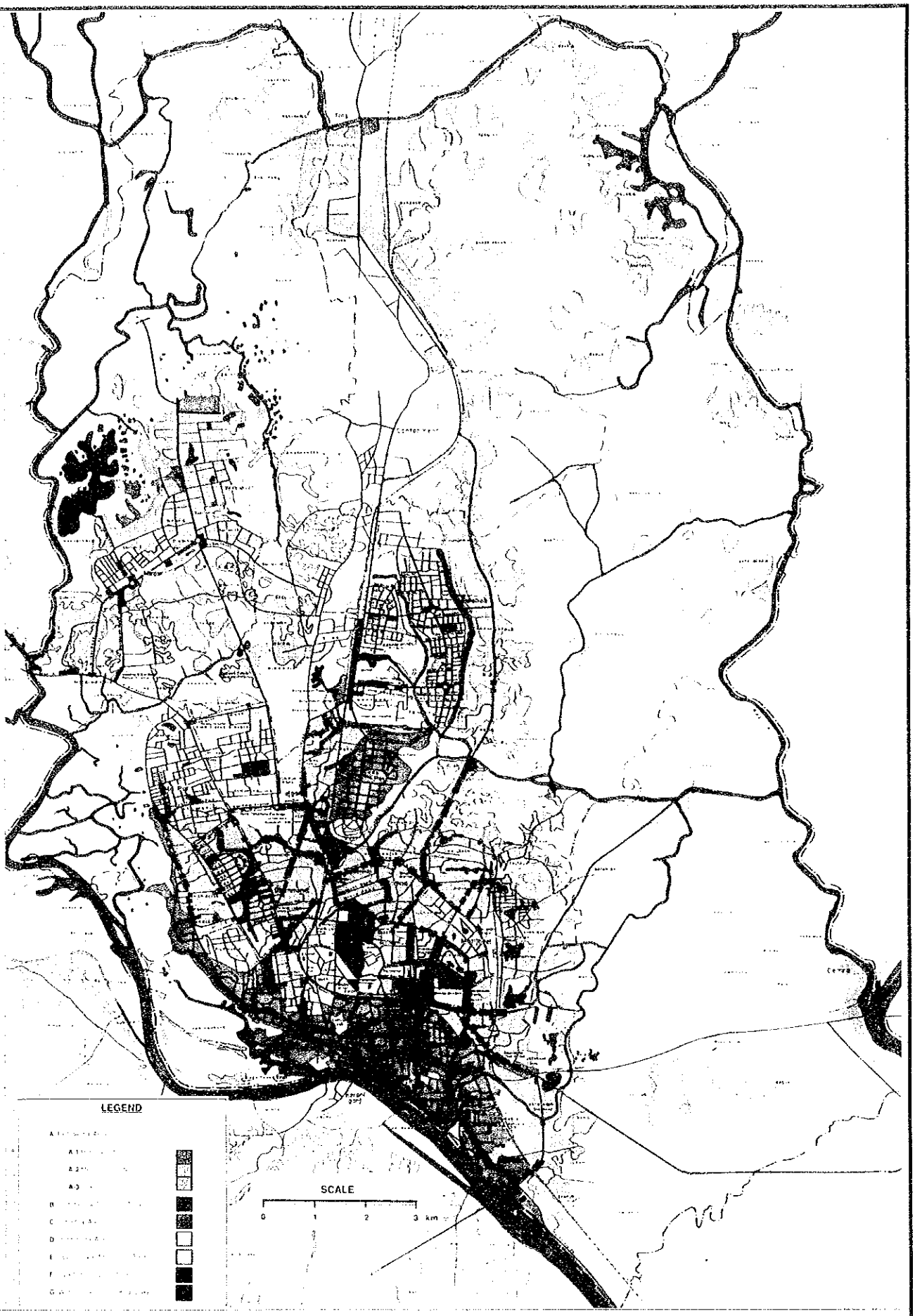


FIG. 2.9 PRESENT LAND USE OF STUDY AREA IN 1986

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

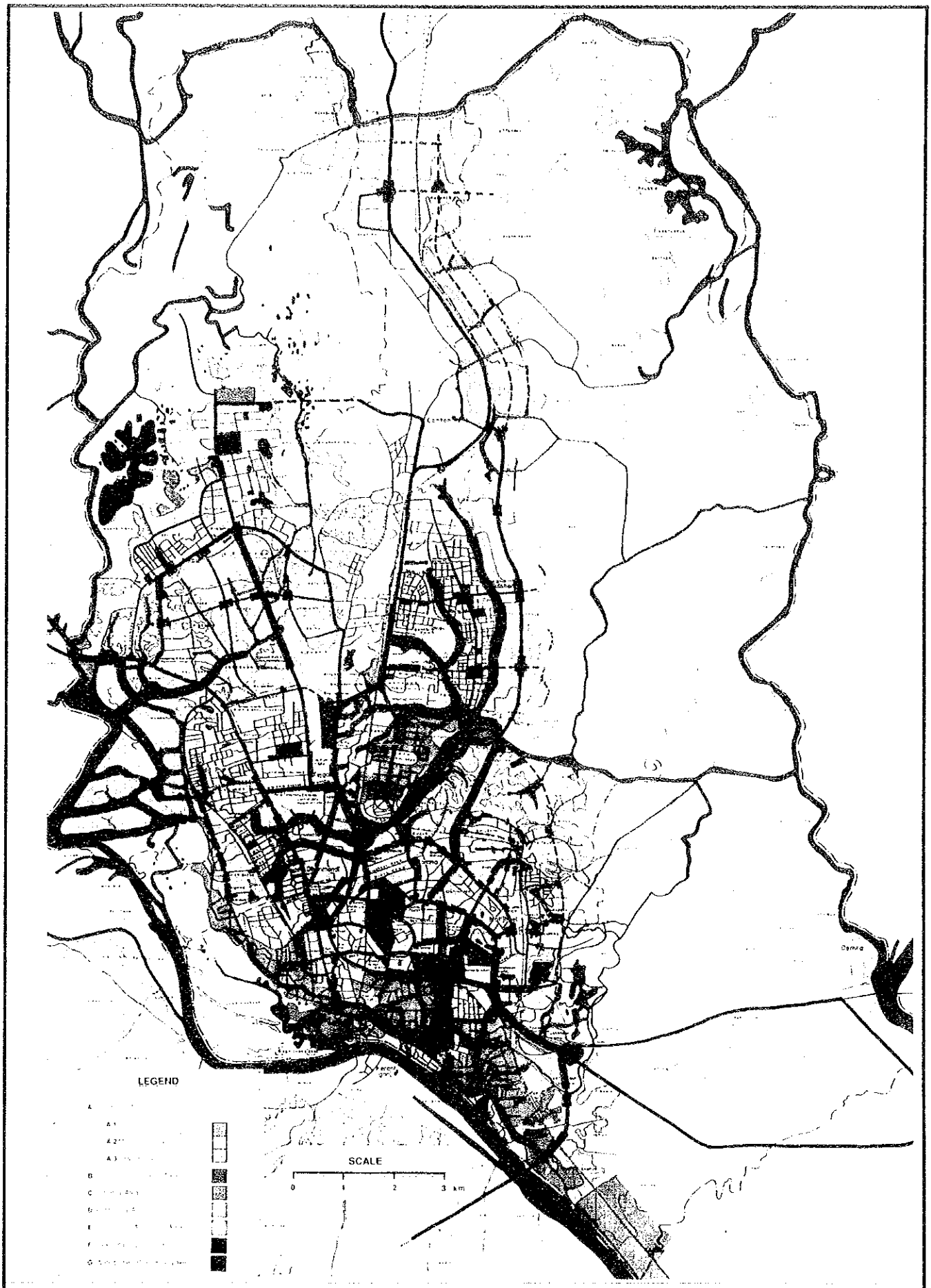
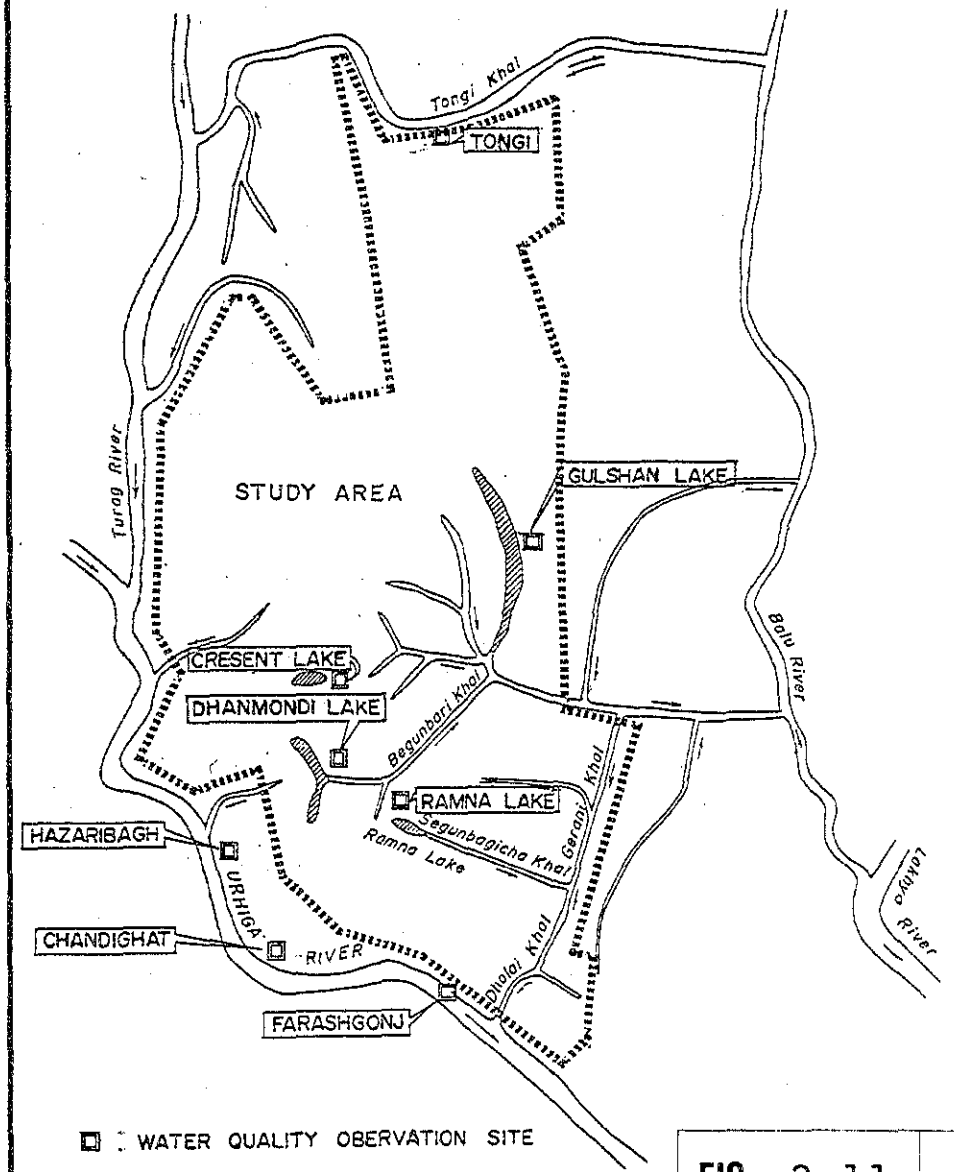


FIG. 2.10 FUTURE LAND USE OF STUDY AREA IN 2000

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

LOCATION MAP OF WATER QUALITY OBSERVATION



OBSERVED WATER QUALITY

	PH	E.C (micromho/cm)	DO (p.p.m)	BOD (p.p.m)	Turbidity (p.p.m)
Dhanmondi Lake	6.4(5.7-7.1)	878(720-1,350)	2.0(1.0-3.5)	69(24-117)	143(100-210)
Ramna Lake	6.8(6.5-7.1)	93(90-99)	7.5(3.0-13)	4.9(2.6-10)	51(45-65)
Cresent Lake	7.5(6.6-8.0)	105(91-138)	7.2(5.7-8.2)	0.8(0.1-1.6)	< 25
Gulshan Lake	7.1(6.7-7.2)	138(89-270)	9.0(7.0-11)	5.1(3.8-6.1)	< 25
Burhiganga River			-		
Farashgonj	7.1(6.0-7.4)	409(253-540)	2.0(0-4.2)	43(1.8-150)	
Hazaribagh	7.0(5.5-8.5)	340(64-3,050)	5.6(1.4-8.7)	6.0(1.0-53)	
Chandighat	6.8(5.6-8.0)	249(64-557)	4.5(1.5-9.5)	6.2(0.6-31)	
Tongi of Tongi Khal	6.9(5.6-8.4)	207(56-447)	4.8(0-10)	13(0.7-85)	
Khal at Farashgonj	6.7(5.5-8.5)	307(100-900)	0.9(0-21)	78(16-153)	
Khal at Hazaribagh	7.3(5.2-9.7)	5090(122-12500)	0.5(0-2.5)	57(0.3-200)	

Note : 1) Figures outside the parentheses are average values.
2) Figures inside the parentheses are the maximum and minimum observed values.

FIG. 2.11 PRESENT CONDITION OF WATER QUALITY IN STUDY AREA

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

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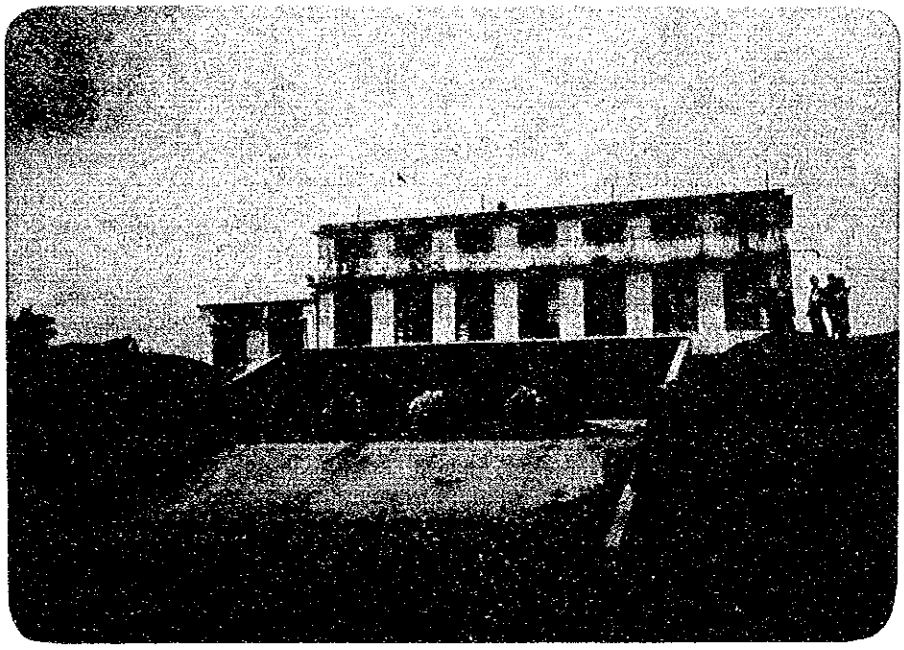

NARINDA PUMP STATION CONSTRUCTED IN 1975

CHAPTER 3
EXISTING DRAINAGE SYSTEM AND FACILITIES

CHAPTER 3 EXISTING DRAINAGE SYSTEM AND FACILITIES

3.1 Drainage Area and Drainage System

The Study Area is divided into 10 drainage zones. These are illustrated in Fig. 3.1 and described below:

(1) Buriganga River Bank Zone (12.85 km^2)

This zone has many loading facilities for river transport and their related business lots. The area consists of a narrow strip of the built-up area at the western edge of Dhaka City and a part of the flood plain on the left side of the Buriganga River.

The existing built-up area is high in elevation and is not affected by the Buriganga River floods. The Buriganga River flood plain area will be developed before 2000 and its reclaimed elevation is expected to be above the flood water level of the river.

The area drains directly into the Buriganga River. Drainage pipes are provided in some limited areas.

(2) Dholai Khal Zone

This zone has many small commercial and institutional lots huddled together. Institutional and educational facilities are also located here. The area covers the entire Old Dhaka and adjoining Gandaria areas. Dholai Khal runs through the area from north to south, draining the whole area.

The area is divided into two (2) sub-areas by Dholai Khal. One is the Old Dhaka area with a catchment area of 4.23 km^2, equivalent to 55% of the total area. Storm water is collected and conveyed through the drainage pipes to Narinda for final discharge, by pump, into Dholai Khal. The other is the remaining area of 3.53 km^2 which drains by gravity into Dholai Khal. This sub-area is frequently affected by the flooding of the Buriganga River which backs up through Dholai Khal during flood seasons.

(3) Segunbagicha Khal Zone

This zone includes the wide spread business and Government office areas of Dhaka City. Paddy fields are spread out at the eastern edge of this zone.

The area consists of two (2) sub-areas: upstream high elevation area of 6.2 km^2 and low-lying fringe area of 2.84 km^2; they are distinctly separated by the Bangladesh railway. The upstream area is above 6.0 m G.T.S. in elevation and is generally free from external river floods, while the low-lying fringe area is habitually flooded.

The upstream area collects storm water by means of drainage pipes and drains it through Segunbagicha Khal. The low-lying fringe area drains directly to the surrounding swamp lands. Segunbagicha Khal flows a distance of 3.4 km through the center of the area.

The existing drainage pipes serve a considerable part of the upstream area; the total length reaches 20.3 km.

(4) Bashabo Zone (8.32 km^2)

This zone is now under development for the residences and multistory residential buildings can be seen. The area covers part of the south-east low-lying fringe area including Bashabo and Khilgaon.

The built-up area is not so high in elevation and frequently suffers from external river floods.

The inner part of the area is drained through tributaries of Gerani Khal, while the other parts are drained directly into the surrounding swamp lands. Drainage pipes are hardly provided at all.

(5) Northeast Edge Zone (13.93 km^2)

This zone is mainly paddy fields and the development for residence has just commenced. Urban development is underway by land fill in the northern part and is also expected in the other parts of the zone.

The area consists of a narrow strip extending along the fringe of the Dhaka Terrace from Begunbari Khal to Tongi Khal.

The existing built-up area is high enough to be free from external river floods and the future urban development areas are also expected to be filled up high enough to be free from floods.

The existing built-up area drains directly into the east low-lying areas. No drainage pipes are provided.

(6) Begunbari Khal Zone (16.02 km^2)

This zone covers a large central part of Dhaka City including Dhanmondi residential and Tejgaon industrial areas.

Begunbari Khal flows a distance of 5.3 km from the Dhanmondi Lake to DIT Road through the center of the area. The built-up areas are comparatively high and, therefore, are hardly ever affected by external river floods, even though the flood waters back up to the inner part of the area through Begunbari Khal.

The whole area drains into Begunbari khal from all directions; through drainage pipes in some areas and directly by surface flow in other areas.

(7) Gulshan-Banani Zone (17.64 km^2)

This zone contains the high income residential areas of Gulshan and Banani and part of the Tejgaon industrial areas.

The whole area is high enough to be free from external river floods. The area is divided into many sections by the tributaries of Begunbari Khal.

The area is provided with a system of small rectangular roadside ditches. The area drains well into the tributary khals through those roadside ditches. There are no drainage pipes.

(8) Kallyanpur Zone

This zone consists of the new capital area in the southern part, and medium and low density residential areas in the northern part.

The area drains into the Turag River through natural watercourses. However, the low-lying residential areas located in the northern part are vulnerable to the floods of the Turag River. Drainage pipes exist only in some limited areas.

(9) North Zone (31.42 km^2)

This zone contains Tongi development area, Cantonment area and Mirpur new area. The new airport is in this zone.

Existing built-up areas are generally high enough to be free from external river floods except for the Katchukhet area in the southernmost part. Future urban development areas are also expected to be filled up high enough except for the southernmost area.

The area drains into the Turag River through its tributaries and natural water courses. There are no drainage pipes.

(10) Turag River Bank Zone (7.69 km^2)

This zone contains the western edge of Mirpur area.

The existing built-up areas are generally high and not affected by floods of the Turag River.

The area drains directly into the Turag River. There are no drainage pipes.

3.2 Drainage Facilities

3.2.1 Inventory

The existing major drainage facilities are drainage pipes, khals, pump station and related structures of culverts and bridges.

(1) Drainage Pipe

The Study Area is provided with drainage pipes, having a total length of 109 km and a diameter ranging from 0.3 m to 3.0 m. Pipe length by diameter and drainage zones are shown in Table 3.1.

Location of the trunk drainage pipes is illustrated in Fig. 3.2.

(2) Khal

There are a number of khals in the Study Area totalling 53 km in length.

Major khals included are Dholai Khal, Segunbagicha Khal, Gerani Khal, and Begunbari Khal. The total length including tributaries and catchment areas of the above khals are shown below:

	Total Length (km)	Catchment Area (km^2)
Dholai Khal	4.0	16.8
Segunbagicha Khal	3.4	6.7
Gerani Khal	3.5	8.3
Begunbari Khal	6.5	37.7
Total	17.4 km	69.5 km^2

Location of the khals is illustrated in Fig. 3.3.

(3) Pump Station

Narinda is the only existing pump station. It drains all of Old Dhaka that has a catchment area of 4.23 km^2. The total design discharge capacity is 9.6 m^3/S. Details are described in 3.2.3.

The location is illustrated in Fig. 3.2.

(4) Culverts and Bridges

Culverts and bridges are installed in the sections of the khals where roads and railway cross. Their locations are illustrated in Fig. 3.3.

3.2.2 Discharge Capacity

(1) Major Drainage Pipe

Discharge capacities of the major drainage pipes in the Study Area are estimated. The specific discharge capacities of the existing trunk drainage pipes are mostly in the range of 1.0 $m^3/s/km^2$ to 3.0 $m^3/s/km^2$. These capacities are very small compared to the required ones of 8 $m^3/s/km^2$ to 15 $m^3/s/km^2$.

(2) Segunbagicha Khal

Segunbagicha Khal, originating in the Ramna Lake, flows a distance of 2.8 km in open channel to the Bangladesh railway crossing, where it covers a drainage area of 4.95 km^2.

The average gradient of stream for this stretch is estimated to be 1/5,000.

The khal is crossed by roads and railways at 13 sections in this stretch. The profile is illustrated in Fig. 3.4(1).

The khal is provided with retarding ponds in certain places but is extremely narrowed by the road and railway crossings, and at the many sections where there are building encroachments.

Discharge capacities of these bottleneck sections are mostly below 5.0 m^3/s.

The specific discharge capacities of the sections are mostly less than 3 $m^3/s/km^2$, which are too small in comparison with the required ones of 6 $m^3/s/km^2$ to 8 $m^3/s/km^2$.

(3) Begunbari Khal and Paribagh Khal

The main Begunbari Khal starts from the outlet of the Dhanmondi Lake and runs through the central developed area of Dhaka City to the DIT Road crossing in the easternmost part.

The catchment area at the DIT Road Crossing is 16.02 km^2. The total length of this stretch is 5.3 km of which 2.5 km is upstream from the New Airport Road crossing and 2.8 km downstream from the same road crossing. The khal sections are wide enough in the downstream reaches. On the other hand those in the upstream reaches are narrowed at several places by roads and railway crossings and building encroachment.

The average gradient of the upstream reaches is estimated to be 1/2,500. The profile is illustrated in Fig. 3.4(1).

Discharge capacities at the narrow sections are estimated to be mostly below 30.0 m^3/s. The specific discharge capacities of the sections are mostly less than 5 $m^3/s/km^2$, which are small compared to the required ones of 5 $m^3/s/km^2$ to 7 $m^3/s/km^2$.

Paribagh Khal is one of the tributaries of the Begunbari Khal, which joins with the main khal between Airport road and Old Railway road crossings.

The catchment area at the confluence is 3.41 km^2. The total khal length is 1.0 km. The average khal width is 10 m, more or less.

The khal bed gradient is estimated to be 1/3,300 on an average. The profile is illustrated in Fig. 3.4(2).

Discharge capacities at the narrow sections are estimated to be 1 m^3/s to 3 m^3/s. The specific discharge capacities of the sections are less than 1 $m^3/s/km^2$, which are also too small comparing to the required ones of 9 $m^3/s/km^2$ to 10 $m^3/s/km^2$.

(4) Dholai Khal

Dholai Khal drains an area of 16.8 km^2 covering B and C drainage zones. The khal stretches approximately 3.0 km from Jatrabari to the confluence with the Buriganga River. The khal is connected with Gerani Khal in the upstream, which flows in the opposite direction i.e. northerly.

The khal sections with natural trapezoidal shape are rather wide, ranging 10 m to 30 m. However, the depths are shallow, from 2.0 m to 4.0 m.

The average gradient of the Khal bed is estimated to be 1/10,000. The profile is illustrated in Fig. 3.4(2).

Discharge capacities of the sections are estimated to be 3 m^3/s to 50 m^3/s.

3.2.3 Narinda Pump Station

3.2.3-1 General

The Narinda Pump Station drains almost the entire Old Dhaka area into the Dholai Khal. It is equipped with four (4) pumps, one (1) reservoir tank, One (1) gravity drainage channel, one (1) emergency channel, and three (3) gates.

The main features of the pump station are:

Drainage area:	4.23 km^2
Total design discharge capacity:	9.6 m^3/s
Design suction water level (L.W.L.):	0.236 m G.T.S.
Target water level of suction (L.W.L.):	Approximately 0.5 m G.T.S.
Design discharge water (H.W.L.):	8.64 m G.T.S.
Required pump up head:	8.4 m for No. 2 and No. 3 pumps
:	6.5 m for No. 1 and No. 4 pumps
Pump facilities:	Vertical shaft axial flow pump, dia. 1,000 mm x 4
Reservoir tank:	Surface area: 4,600 m^2
:	Effective water depth: 5.636 m G.T.S.
:	Effective volume: 18,850 m^3
Gate:	2.1 m x 2.1 m, 1.9 m x 1.9 m, 3.5 m x 3.5 m
Installed year:	1975

The plan and cross section of the pump station are illustrated in Fig. 3.5.

3.2.3-2 Operation Problems

The pump station is in operation from late May through early December every year.

The existing pump station does not produce satisfactory drainage effects because of the following problems:

(1) The suction water level must be kept lower than originally designed in order to support a required hydraulic gradient of the drainage pipes and to secure smooth collection of storm water to the pump station. This operation, however, requires excessive pumping power, causing overheating of the motors.

As a result, continuous operation time of the pump is limited to several hours.

(2) A hydraulic head loss of 0.3 ~ 0.6 m is caused by collected trash at the screen although it is removed manually.

Efficient removal of trash is required.

(3) Gates and other equipment are damaged. It impedes effective pump operation.

Table 3.1 Existing Trunk Drainage Pipe

Zone		Pipe Length (km)	Remarks
A	(A = 12.85 km^2)	8.76	
B	(A = 7.76 ")	19.71	
C	(A = 9.04 ")	20.28	
D	(A = 8.32 ")	2.83	
E	(A = 13.93 ")	-	
F	(A = 16.02 ")	42.53	
G	(A = 17.64 ")	9.82	
H	(A = 12.78 ")	5.29	
I	(A = 31.42 ")	-	
J	(A = 7.69 ")	-	
Total (A = 137.45 km^2)		109.22 km	

Pipe Size	Pipe Length	Remarks
10'-0" Dia	2,900 ft	
9'-0"	2,124	
8'-6"	1,000	
8'-0"	1,100	
7'-6"	1,300	
7'-0"	3,800	
6'-6"	1,800	
6'-0"	8,970	
5'-6"	9,540	
5'-0"	12,660	
4'-6"	13,950	
4'-0"	26,700	
3'-6"	20,350	
3'-0"	44,900	
2'-6"	48,860	
2'-0"	115,100	
1'-6"	38,800	
1'-0"	1,600	
Total	358,454 ft. = 67.88 miles = 109.22 km	

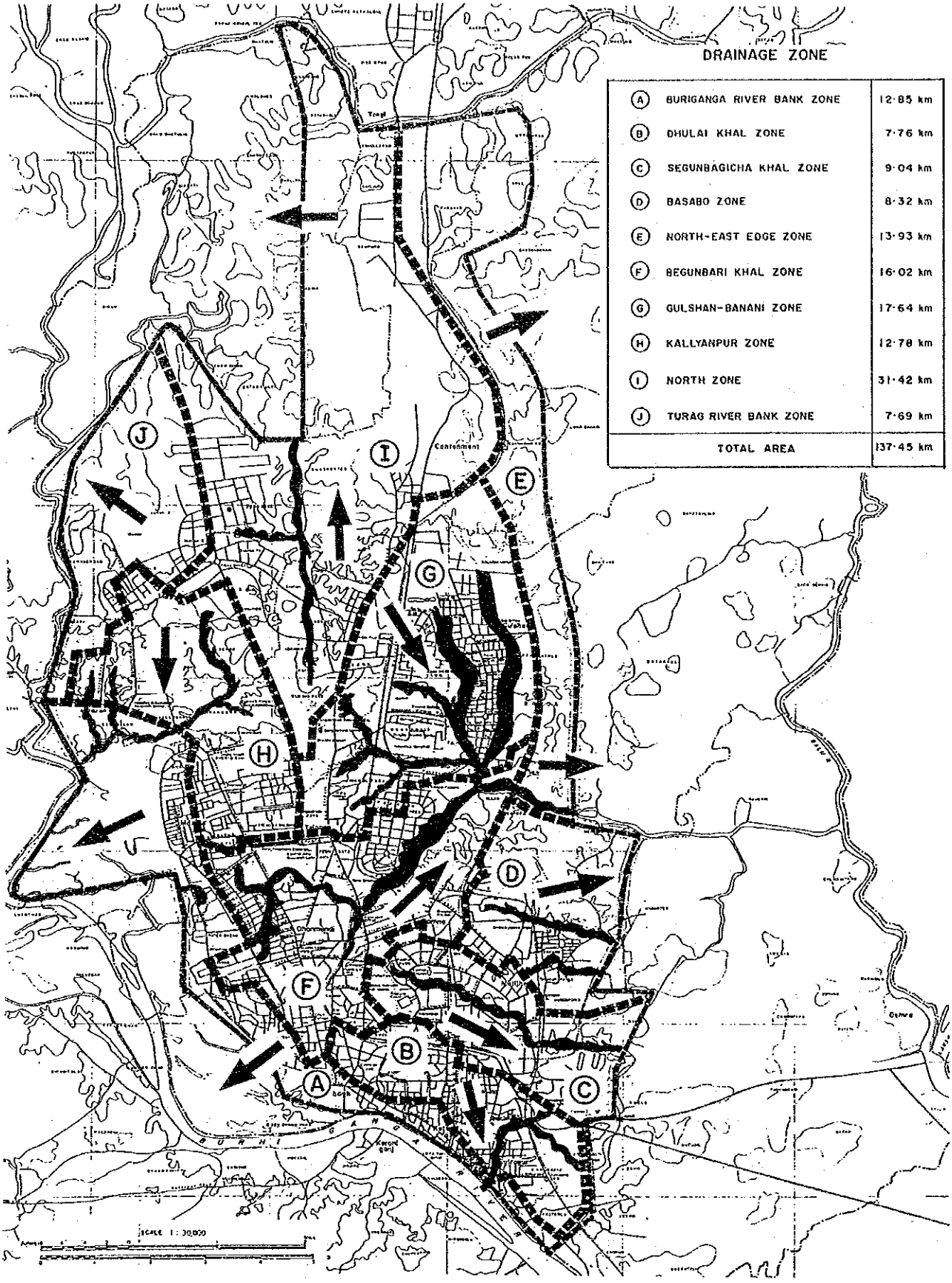

FIG. 3.1 DRAINAGE ZONES

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

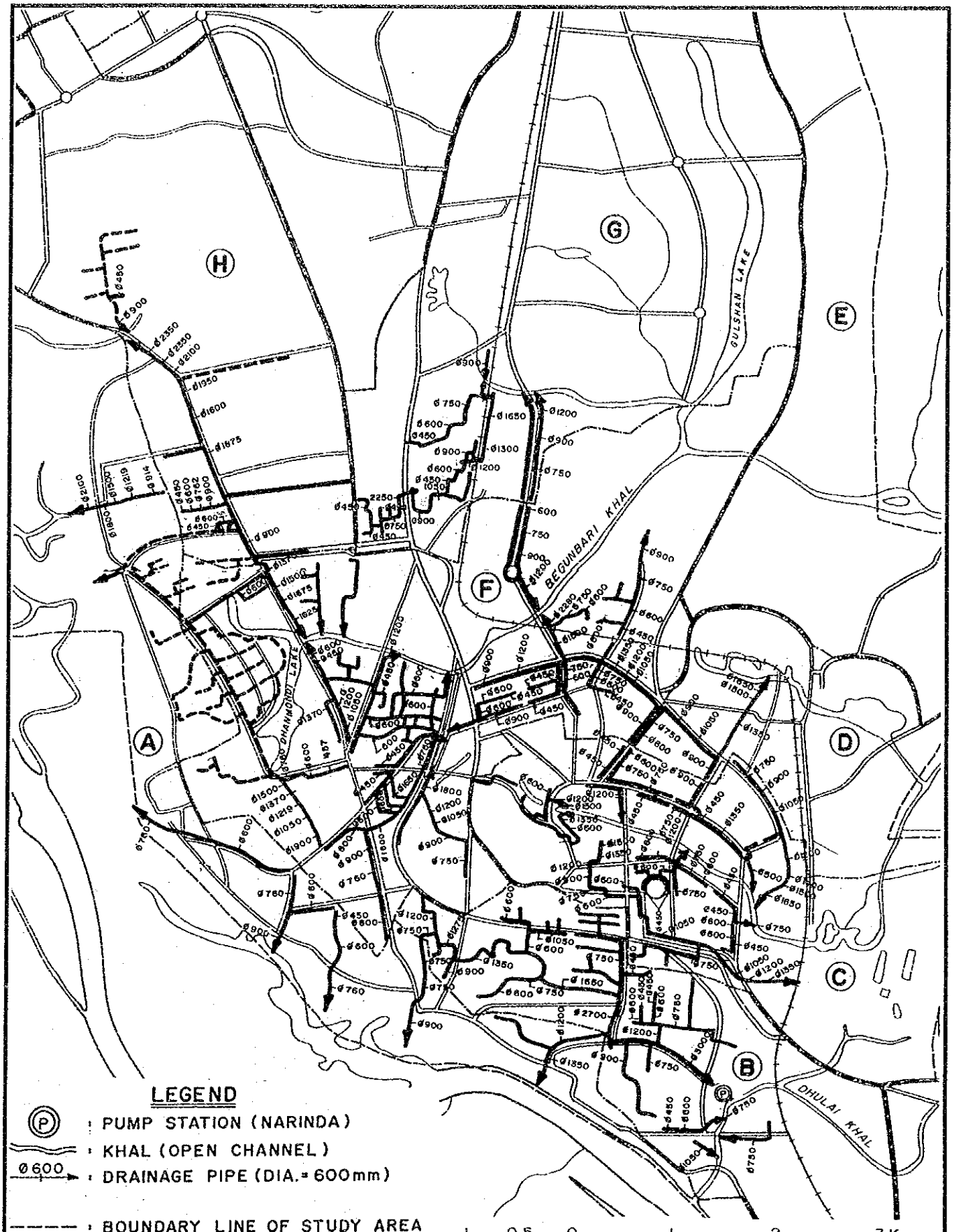

FIG. 3.2 EXISTING DRAINAGE FACILITIES (1)

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

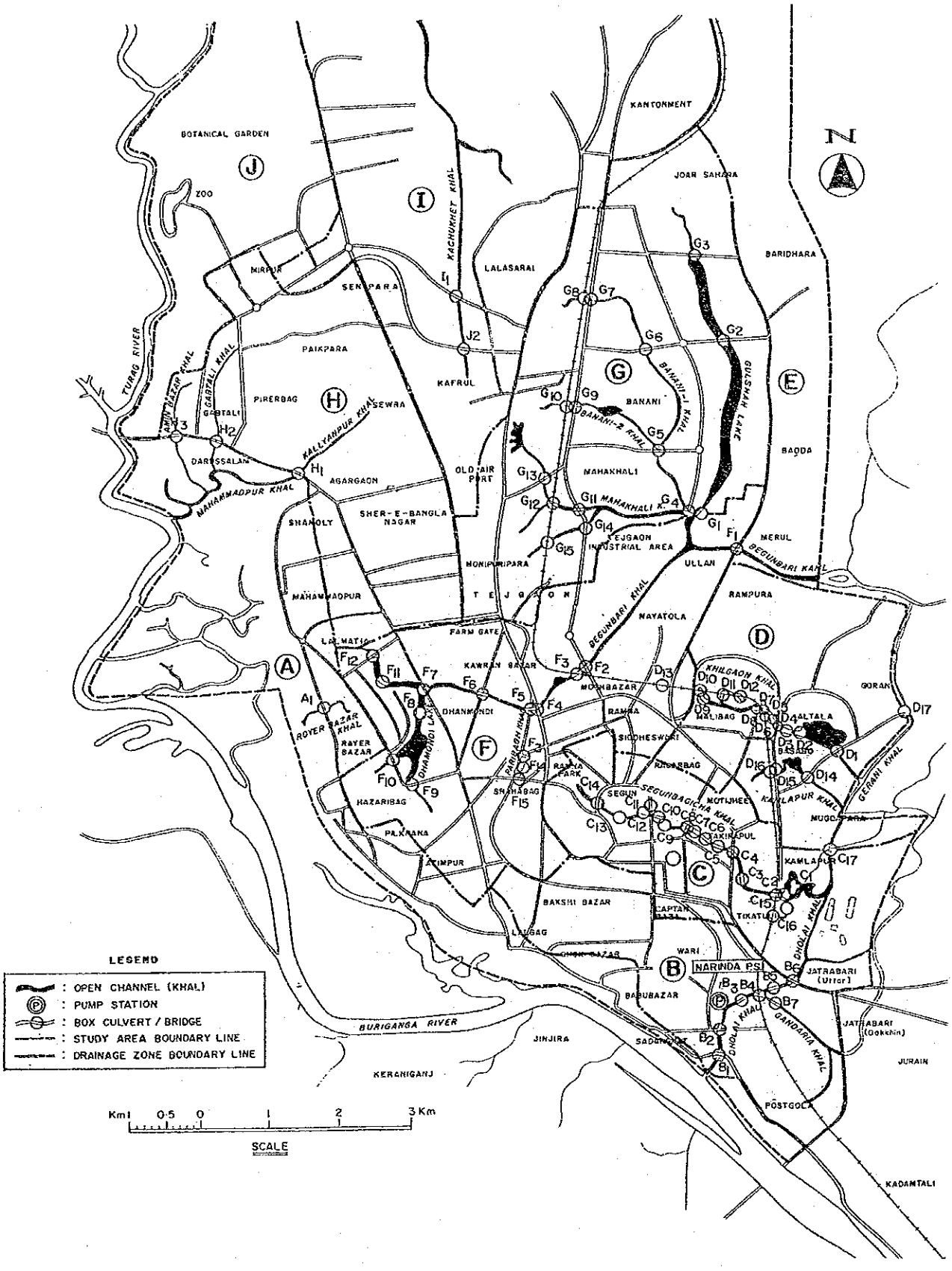

FIG. 3.3 EXISTING DRAINAGE FACILITIES (2)

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

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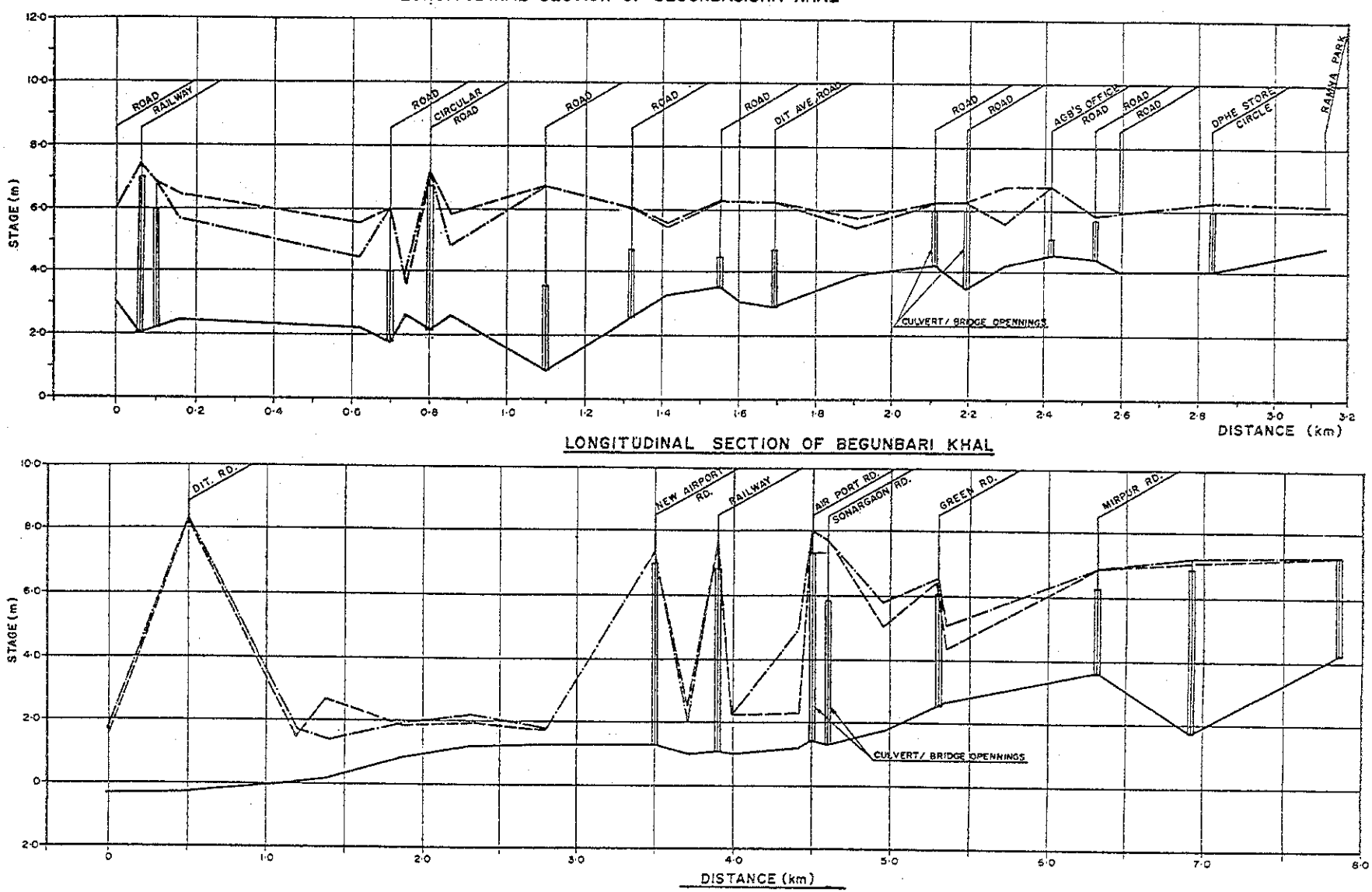
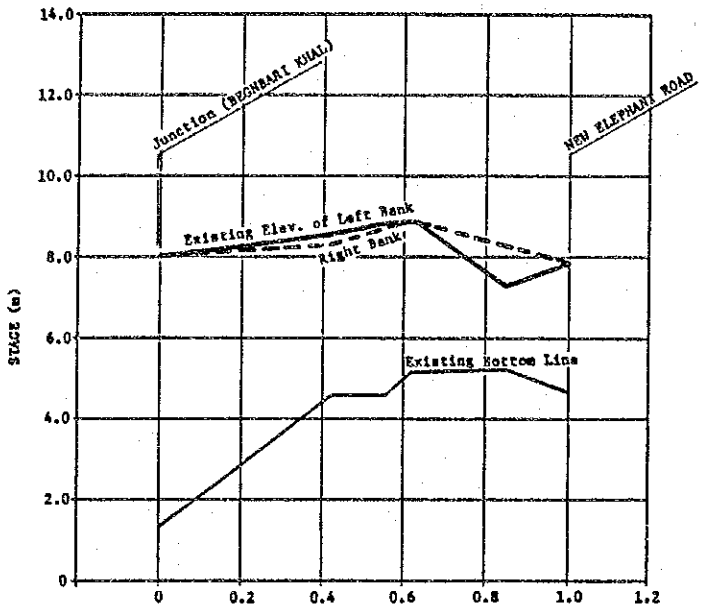


FIG.3.4(1) LONGITUDINAL SECTIONS OF SEGUNBAGICHA KHAL AND BEGUNBARI KHAL

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

LONGITUDINAL SECTION OF PARIBAGH KHAL



LONGITUDINAL SECTION OF DHOLAI KHAL

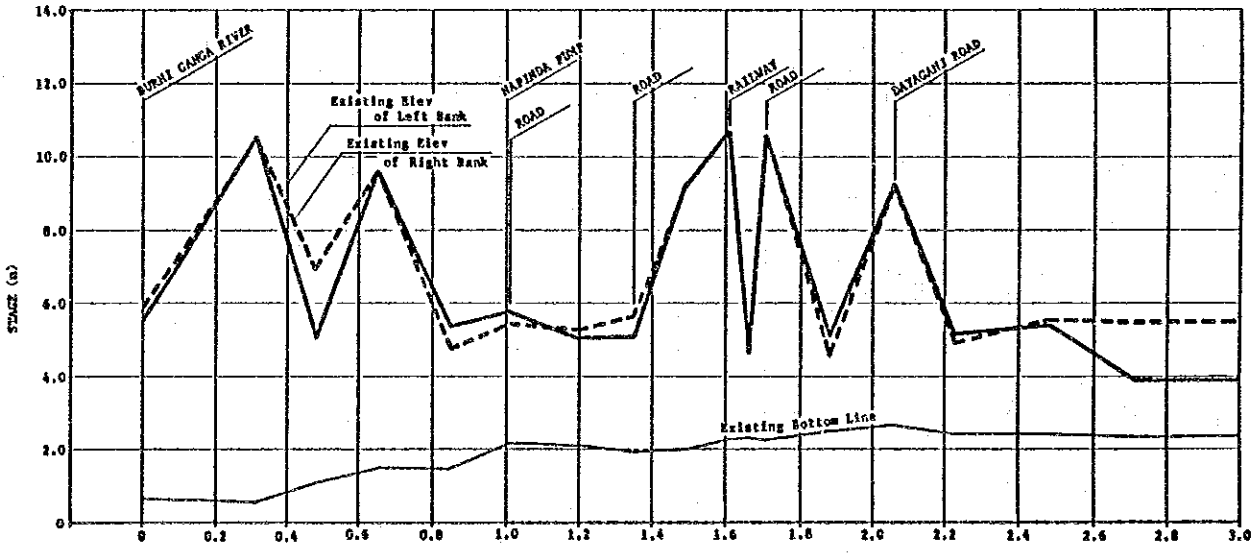
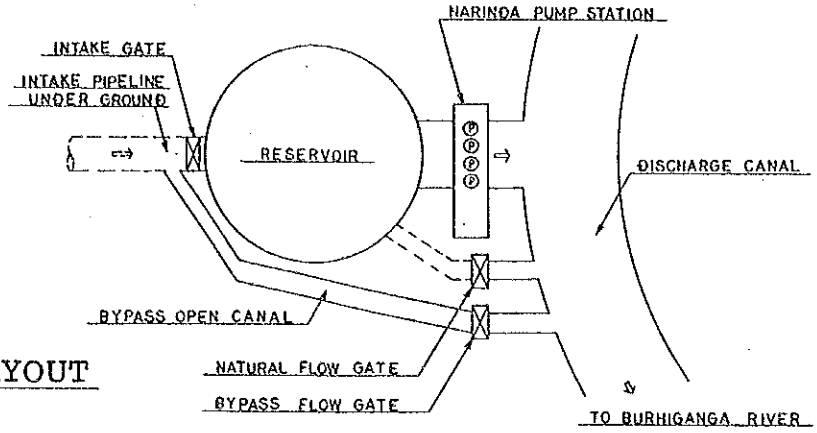
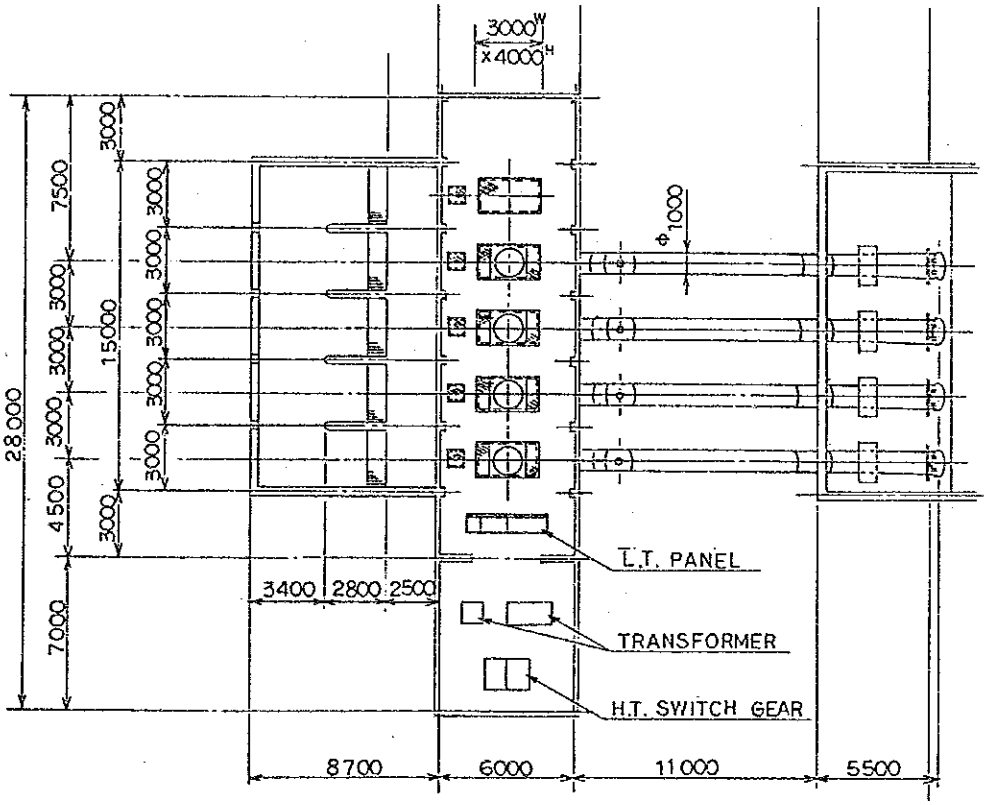


FIG. LONGITUDINAL SECTIONS OF PARIBAGH KHAL AND DHOLAI KHAL

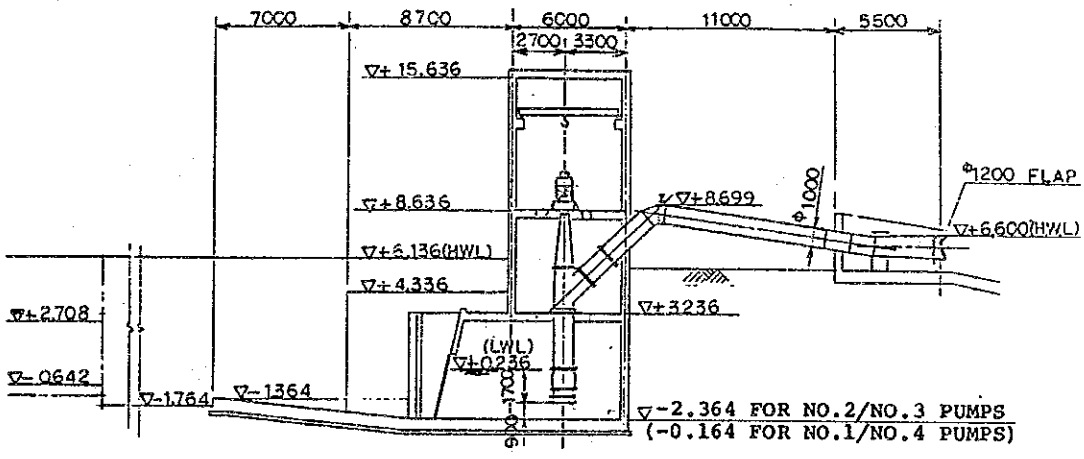
STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH



GENERAL LAYOUT



PLAN



CROSS SECTION

FIG. 3.5 EXISTING NARINDA PUMP STATION

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

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