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MASTER PLAN

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NOVEMBER 199[illegible]

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THE PEOPLE'S REPUBLIC OF BANGLADESH
FLOOD PLAN COORDINATION ORGANIZATION

MASTER PLAN
FOR
GREATER DHAKA PROTECTION PROJECT
(STUDY IN DHAKA METROPOLITAN AREA)
OF
BANGLADESH FLOOD ACTION PLAN NO.8A

FAP 8A

MAIN REPORT

NOVEMBER 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to a request from the Government of the People's Republic of Bangladesh, the Japanese Government decided to conduct a Master Plan for Greater Dhaka Protection Project (Study in Dhaka Metropolitan Area) of Bangladesh Flood Action Plan No. 8A and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Bangladesh a study team headed by Mr. Hajime Tanaka of Pacific Consultants International twice from October 1990 to August 1991.

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

I hope that this 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 the People's Republic of Bangladesh for their close cooporation extended to the team.

November,1991

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

MASTER PLAN
FOR
GREATER DHAKA PROTECTION PROJECT
(STUDY IN DHAKA METROPOLITAN AREA)
OF
BANGLADESH FLOOD ACTION PLAN NO. 8A

November,1991

Mr. Kensuke YANAGIYA
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

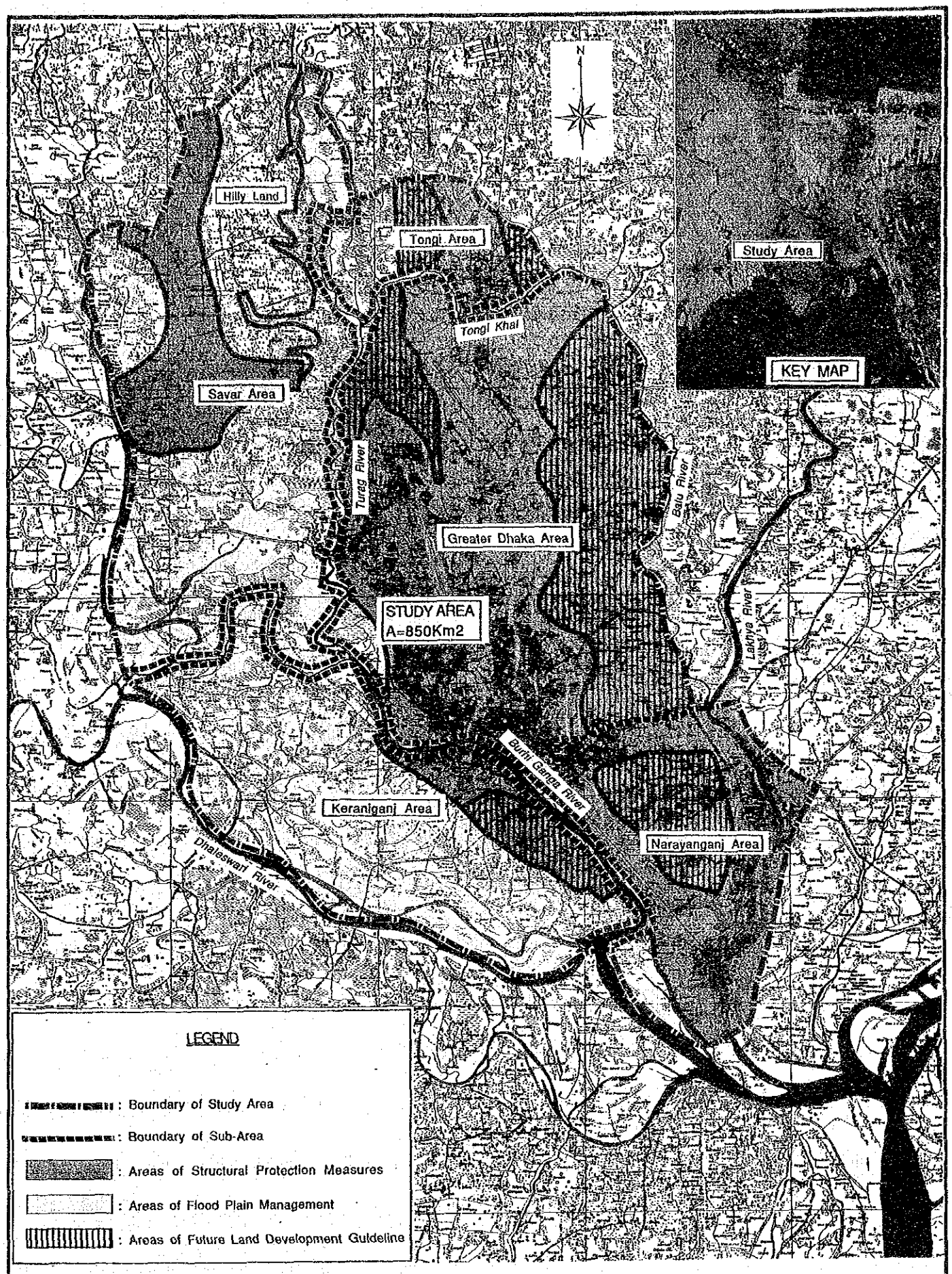
We are pleased to submit the final report entitled the "Master Plan for Greater Dhaka Protection Project (Study in Dhaka Metropolitan Area) of Bangladesh Flood Action Plan No. 8A". This report has been prepared by the Study Team in accordance with the contract signed on October 1, 1990 and May 7,1991 and September 20, 1991 between the Japan International Cooperation Agency and Pacific Consultants International.

In the study,the team has formulated a Master Plan on flood mitigation and stormwater drainage improvement measures for Dhaka Metropolitan area and identified priority areas for feasibility study.

All members of the Study Team wish to express appreciation to the personnel of your Agency, Advisory Commitee,Ministry of Foreign Affairs, Ministry of Construction, and Embassy of Japan in Bangladesh for their assistance. The team also like to thank officials and individuals of the Government of the People's Republic of Bangladesh.

Yours Faithfully,

Hajime TANAKA
Team Leader



LOCATION MAP OF THE STUDY AREA

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROLOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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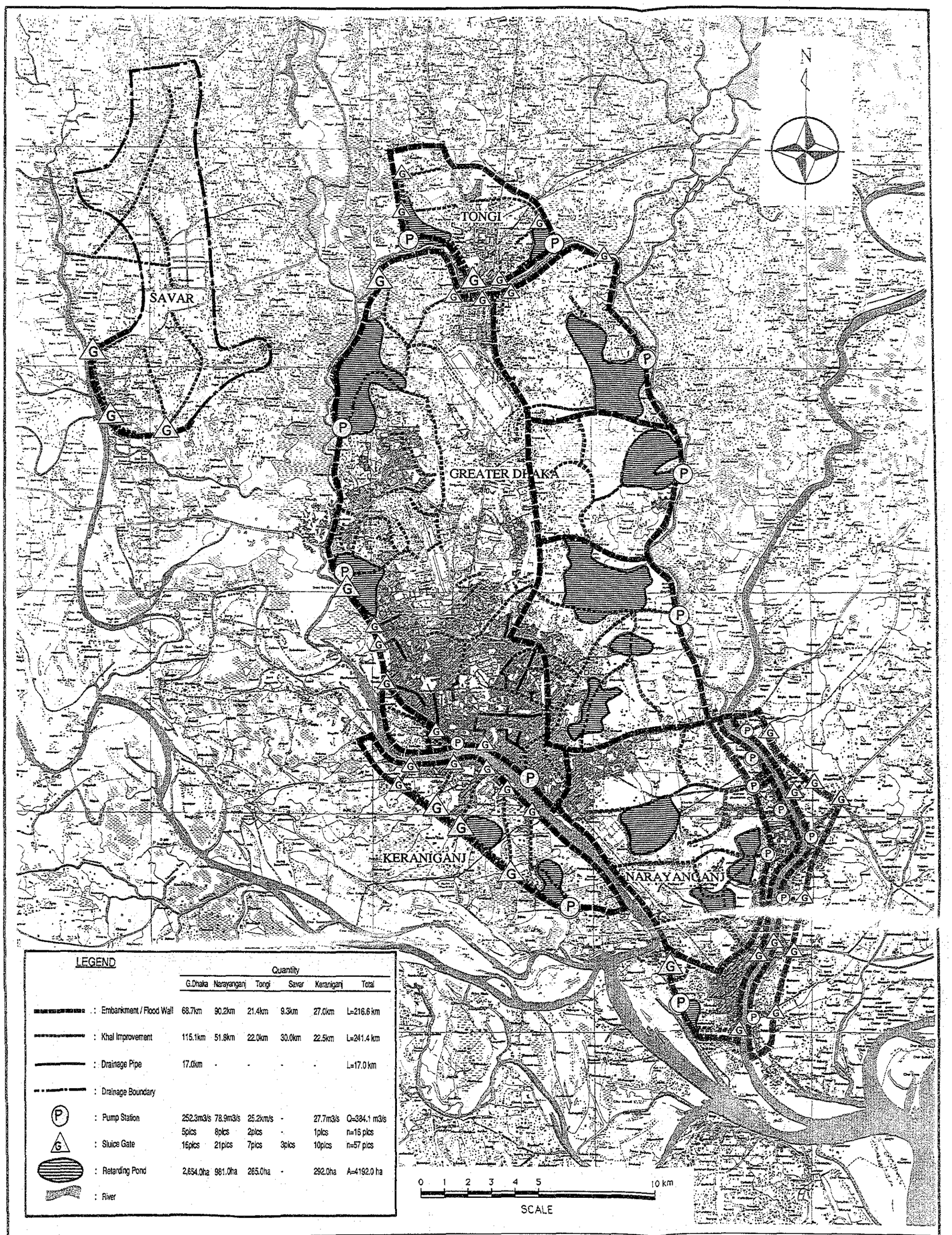

LEGEND

		Quantity					
		G.Dhaka	Narayanganj	Tongi	Savar	Keraniganj	Total
	: Embankment / Flood Wall	68.7km	90.2km	21.4km	9.3km	27.0km	L=216.6 km
	: Khal Improvement	115.1km	51.8km	22.0km	30.0km	22.5km	L=241.4 km
	: Drainage Pipe	17.0km	-	-	-	-	L=17.0 km
	: Drainage Boundary						
P	: Pump Station	252.3m3/s	78.9m3/s	25.2km/s	-	27.7m3/s	Q=384.1 m3/s
		5pics	8pics	2pics	-	1pics	n=16 pics
G	: Sluice Gate	16pics	21pics	7pics	3pics	10pics	n=57 pics
	: Retarding Pond	2,654.0ha	981.0ha	265.0ha	-	292.0ha	A=4192.0 ha
	: River						

PROPOSED MASTER PLAN

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA

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ABBREVIATIONS

ADB	Asian Development Bank
AIT	Asian Institute of Technology
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Metrological Department
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CAAB	Civil Aviation Authority of Bangladesh
DCC	Dhaka City Corporation
DIT	Dhaka Improvement Trust (now RAJUK)
DMAIUDP	Dhaka Metropolitan Area Integrated Urban Development Plan
DMC	Dhaka Municipal Corporation
DND Triangle	Dhaka-Narayanganj-Demra Triangle
DPHE	Department of Public Health Engineering
DOE	Department of Environment
DWASA	Dhaka Water and Sewerage Authority
ERD	External Resources Division, Ministry of Finance
FAP	Flood Action Plan
FPCO	Flood Plan Coordination Organization
GDPP	Greater Dhaka Protection Project
GDFCD Project	Greater Dhaka Flood Control and Drainage Project
GOB	Government of Bangladesh
IDA	International Development Association (of the World Bank)
JICA	Japan International Cooperation Agency
MIWDFC	Ministry of Irrigation, Water Development and Flood Control
MPO	Master Plan Organization
PDB	Power Development Board
PHD	Public Health Department

PWD	Public Works Department
RHD	Roads and Highways Department
RAJUK	Rajdhani Unnayan Katripakha (Capital Development Authority)
RRI	River Research Institute of the Ministry of Irrigation, Water Development and Flood Control
SOB	Survey of Bangladesh
SWMC	Surface Water Modelling Centre
SPARRSO	Space Research and Remote Sensing
UNCHS	United Nations Centre for Human Settlements
UNDP	United Nations Development Programme
WAPDA	Water and Power Development Authority
WASA	Water and Sewerage Authority
WMO	World Metrological Organization

CHAPTER 1.

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background

In 1987 and 1988, Bangladesh experienced two of the most severe floods on record. Soon after the floods, various studies were conducted by different agencies, countries and the Government of Bangladesh. Several action plans were proposed. The World Bank coordinated the studies and framed a Flood Action Plan (FAP) with 26 components as the initial stage for the development of a long term comprehensive system of flood control and drainage works.

The FAP was proposed in the London Conference held in December 1989 and agreed for implementation by the attendant agencies and countries concerned. As a follow up to the London Conference, the Government of Japan and the Asian Development Bank (ADB) agreed, at the Dhaka Conference held on January 1990, to undertake the Study on Dhaka Town Protection (FAP No. 8), consisting of a long term comprehensive master plan and feasibility studies.

In response to the request of the Government of People's Republic of Bangladesh (GOB), the Government of Japan decided to conduct the study on Greater Dhaka Protection Project (Study in Dhaka Metropolitan Area) of Bangladesh (FAP No. 8A) within the general framework of technical cooperation between Japan and Bangladesh. The ADB decided to finance "Dhaka City Integrated Flood Protection Project" (FAP No. 8B).

The Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of technical cooperation programs, was assigned to undertake the study, in close cooperation with the Flood Plan Coordination Organization (FPCO) and other concerned authorities of GOB.

The JICA study team commenced this Study in October 1990, after a discussion of the study program with the GOB study team. The study is composed of three (3) phases, and the respective period and objectives of each phase are as follows :

Phase I : from October 1990 to December 1990

- to prepare a general study program based on the Scope of Work,
- to review the existing conditions and to prepare a detailed study plan.

The following reports were issued :

Inception Report - October 1990

Preliminary Review Report - December 1990

Phase II : from January 1991 to August 1991

- to carry out a Master Plan study on comprehensive flood control and stormwater drainage for Dhaka Metropolitan area ,
- to identify priority projects for a Feasibility Study.

The following reports were issued :

Interim Report - March 1991
Master Plan Report - July 1991

Phase III : from September 1991 to April 1992

- to conduct a feasibility study on flood control and stormwater drainage for the priority area identified during Phase II.

1.2 Objectives of the Study (Phase II)

The objectives of the study are :

(1) to carry out a Master Plan study on comprehensive flood control and stormwater drainage in the Dhaka Metropolitan area.

(2) to identify priority projects for a feasibility study.

1.3 General Approach

The study has been carried out by the JICA study team in collaboration with FPCO, the GOB study team and the other related FAP studies such as FAP 3 and FAP 8B.

After establishing a clear picture of the actual situation in the study area and assessing the existing flood control and stormwater drainage facilities, optimum flood protection and stormwater drainage improvement measures were studied.

An optimum Master Plan including Priority Projects for the F/S study and phased implementation program were proposed.

1.4 Composition of Report

The report consists of three parts; a Main Report briefing the study results and the proposed master plan, and Supporting Reports from A to M dealing with detailed technical aspects of the study, and three Data Books. These outputs are listed below :

1) Main Report

2) Supporting Reports : I (A to F), II (G to M)

A	:	Geography and Topography
B	:	Socio-Economic Condition
C	:	Land Use and Urban Planning
D	:	Hydrology
E	:	Flood Conditions and Damages
F	:	Living Environment
G	:	Flood Mitigation
H	:	Storm water Drainage
I	:	Operation and Maintenance
J	:	Project Cost
K	:	Implementation Program
L	:	Project Evaluation
M	:	Scope of Work

3) Data Book

I	:	Hydrology
II	:	Land Use and Urban Planning, Flood and Flood Damage, and Living Environment
III	:	Topographic Survey Drawings

1.5 Execution of the Study

The study was carried out by the study team composed of Consultants retained by JICA, local sub-consultants, and officials of FPCO and concerned agencies of GOB.

The Panel of Experts of GOB and the Advisory Committee of JICA acted as advisors to the study team.

A list of study participants is shown in Appendix I.

Behanali Khal in Low Land Area of Balu River Right Bank Zone

Existing Slope Protection Works by DCC

CHAPTER 2.

STUDY AREA

CHAPTER 2 STUDY AREA

2.1 Geography and Topography

The study area (approx. 850 km2) is situated between lat. 23°34'N - lat. 23°59'N and long. 90°13'E - long. 90°33'E, and consists of the Greater Dhaka and parts of Tongi, Savar, Keraniganj and Narayanganj districts.

The study area is composed of alluvial terraces and low-lying areas. Dhaka city and the surrounding towns are located mainly on alluvial terraces, which are classified as a part of the Madhupur Tract of pleistocene era. In the cource of time, this tract had been merged and disected by recent Flood Plan in its fringe to form the present land form of Dhaka City and its surroundings.

A rough land form map showing the stretches of comparatively high land and low-lying land within the study area was prepared, based on the contour maps collected (refer to Fig. 2.1).

The map shows the following land form areas:

Land Form Area	Description
-1	higher than 10.0 meter (GTS)
-2	8.0 - 10.0 meter (GTS)
-3	6.0 - 8.0 meter (GTS)
-4	4.0 - 6.0 meter (GTS)
-5	2.0 - 4.0 meter (GTS)
-6	Lower than 2.0 meter (GTS)

The land form areas-1 and -2 are considered to be safe from normal floods, while land form area-3 is only marginally free from floods.

2.2 River System

The study area is strongly affected by the three international rivers of the Ganges, the Brahmaputra-Jamuna River and the Meghna River, though only 7.5% of their catchment areas are in Bangladesh. The catchment areas of these rivers cover five (5) countries; India, Nepal, China, Bhutan and Bangladesh.

The catchment areas of these three rivers are as follows :

1)	Ganges River (at the confluence with Jamuna River)	:	977,000 km^2
2)	Brahmaputra - Jamuna River (at the confluence with the Ganges)	:	580,000 km^2
3)	Meghna River (at the confluence with the Padma River)	:	77,000 km^2

The river system of the study area is composed of the Dhaleswari River, the Bansi River, the Turag River, the Balu River, the Buriganga River, the Lakhya River, Tongi Khal and their tributaries. They are tributaries and distributaries of the Ganges and the Brahmaputra-Jamuna rivers.

They are listed below :

1)	Dhaleswari River	:	Distributary of the Jamuna River
2)	Bansi River	:	- ditto -
3)	Turag River	:	Distributary of the Old Brahmaputra River
4)	Buriganga River	:	- ditto -
5)	Balu River	:	Tributary of the Lakhya River
6)	Lakhya River	:	Distributary of the Old Brahmaputra River
7)	Tongi Khal	:	Connecting the Turag River with the Balu River

Water levels of these rivers are lowest in January - February and highest in August - September.

The water levels in these rivers are affected not only by discharge from the Brahmaputra - Jamuna River and local rainfall, but at times also by backwater from the Meghna River, if there is heavy rain in the north eastern part of Bangladesh and a high tide in the Bay of Bengal at the same time.

In addition to these, the Dhaleswari River has a large tributary called the Kaliganga River. Though the Kaliganga River is located outside the study area, it is necessary to consider its flood discharge.

2.3 Meteo-Hydrology

The climate of the study area is classified as tropical monsoon type, characterized by three seasons; monsoon, post-monsoon and pre-monsoon. The monsoon season is normally from May to October. 90% of annual rainfall (approx. 2,000mm) in Dhaka occurs during monsoon season.

Post-monsoon is the dry season from November to December. Pre-monsoon is the transition season between the rainy season and the dry season. Some rainfall occurs in the pre-monsoon season. Annual average rainfall in Dhaka is about 2,000mm.

In the beginning of the monsoon season and the post monsoon season, cyclones with strong wind hit Bangladesh and sometimes causes destructive storm surge on the eastern coastal area. But, Dhaka is almost always outside the affected area.

Average temperature varies from about 20°C in December and January to about 30°C in April to September. Maximum temperature sometimes exceeds 40°C in March and April.

Monthly average evaporation varies from 80 to 130 mm. It is lowest in November and highest in August.

The climatic conditions in the Study Area are shown in Table 2.1.

2.4 Major Flood and Damage

2.4.1 Major Floods

Major floods in Dhaka Metropolitan area, all caused by over flowing of surrounding rivers, have been recorded in 1954, 1955, 1970, 1974, 1980, 1987 and 1988. The maximum water levels of the major floods at Mill Barak, Demra and Savar are tabulated below.

Annual Maximum Daily Water Level

(Unit: PWD in m)

Flood Year	Demra (Sta. 7.5)	Mill Barak (Sta.42)	Savar (Sta. 69)
1954	-	7.02	8.17
1955	-	7.05	8.26
1958	-	6.41	-
1970	6.24	6.47	7.99
1974	6.58	6.57	7.80
1980	6.23	6.39	-
1984	6.33	6.00	7.58
1987	6.46	6.66	8.30
1988	7.10	7.54	9.68

Note: 1) The water levels of Mill Barak and Demra (Sta. 7.5) were revised based on the check survey by the JICA Study in 1987.

The flow directions of 1970, 1974, 1980, 1984, 1987 and 1988 floods are shown in Fig. 2.2.

As shown on this figure, at the Tongi Khal, floods always flow west to east. However, at the Turag River, floods sometimes flow from north to south, sometimes south to north. This seems to be caused by a balance of discharge upstream of the Turag River and the discharge from the Dhaleswari River through the Karnatali River.

These floods were mostly caused when heavy rains coincided with high river stages of the Ganges and the Brahmaputra Rivers.

In addition to the above mentioned external floods due to surrounding rivers the built-up areas of the Study Area are also susceptible to internal floods due to local rainfall on account of insufficient stormwater drainage facilities.

2.4.2 1988 Floods

The 1988 floods were the largest ever recorded.

Most of the floods were caused when moderate to heavy rainfall from early June to late July coincided with the high river stages of the Ganges and the Brahmaputra-Jamuna Rivers. However this was not the case for the 1988 floods. It was reported that :

" During the last ten days of August and the first seven days of September, there was abnormally heavy and intensive rainfall in the northern part of the country as well as in the upper catchment areas in the Himalaya.The water levels in all the rivers rose sharply from 20 August onward and the peak discharge of the Ganges and the Brahmaputra-Jamuna Rivers were reached by 30th August -2 September. The flood peaks of both the river systems took place almost at the same time. The ten days rainfall in north east Bangladesh (Meghna catchment area) reached 800mm."

Source : T. G. H. Jansen : Recommendations to the Committee on Greater Dhaka Flood Control 1988.

The flooded area of Bangladesh during the 1988 flood is shown on Fig. 2.3

The flood volume of the Brahmaputra-Jamuna River seems abnormally large. The study area was likely a part of the left bank of the Brahmaputra-Jamuna River during the 1988 flood. Furthermore, as the flood peak of the Meghna River and that of the Padma River occured almost at the same time, the backwater effect of the Meghna River to the other rivers in the study area was very strong.

The monthly rainfall and monthly maximum water level in 1988 are shown in Figs 2.4 and 2.5.

According to these data,

(1) the monthly rainfall of August and September in 1988 was about 2/3 of the annual average monthly rainfall. Thus, the rainfall in the study area seems to have not substantially affected the maximum water level of the river.

(2) the maximum water level was far higher than annual average maximum water level. The differences were about 2.6 m at Nayarhat, 1.4m at Hariharpara, 1.3m at Pubail, 1.2m at Demra (Sta. 7.5) and 0.7m at Kalagachia. These maximum water levels of the 1988 flood coincide with the fact that the 1988 flood came from the direction of the Brahmaputra-Jamuna River.

2.5 Socio-Economic Conditions

2.5.1 Population

The population of the study area in 1990 is estimated at 6,534,314, which corresponds to some 6% of national population. The average density of population in 1990 in the

study area is calculated at around 8,000 people per square km, which contrasts with the average national population density of 785 people per square km for the same year.

During the nine years from 1981 to 1990, the population of the study area is estimated to have grown at the average annual rate of around 5.2%. It is forecast to grow at a rate of some 4,5% from 1990 to 2000. After 2000, the growth rate is forecast to decrease to around 3.2%. At the national level, the growth rate of population from 1981 to 1990 and from 1990 to 2000 is estimated at 2.6% and 2.1% respectively. The population of the study area is, therefore, growing at about twice the national rate.

2.5.2 Economy

Per capita GDP in the Region of Dhaka to which the study area belongs was Tk. 6,275 in 1988-89. It corresponds to US$ 202 at the exchange rate of US$ 1 = Tk. 31. For the sake of comparison, the per capita GDP of Bangladesh was Tk. 5,701 or US$ 184 in the same year.

During the last four years, the GDP of Bangladesh grew at the average annual rate of 3.6%. Also, during the same period, the per capita GDP of Bangladesh grew at the average annual rate of 1.0%.

The average monthly income per household of the study area is calculated at Tk. 3,381 as of March, 1991, based on the flood damage survey. A household belonging to the low income class (<Tk. 2,500) earned Tk. 1,813 on average per month. The average monthly income per household of middle income class (Tk. 2,500 = < Tk. 7,000) was Tk. 4,724, while the average monthly income per household of high income class (Tk. 7,000 = <) was Tk. 18,151. Composition of respective income classes is estimated at 60%, 37% and 3%.

2.5.3 Number of Properties

The number of households in the study area is estimated at 1,098,073 as of 1990. Of these, farm houses numbered 160,006. The number of businesses / industries and institutions in the study area is estimated at 48,867 and 41,608, respectively. Their area-wise breakdown is shown in Table 2.2.

Table 2.1 Climate Conditions In The Study Area

MONTH	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	oct	Nov	Dec
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 (Extreme)	5.6	4.5	10.4	15.6	18.4	20.4	21.7	21.0	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
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	124.0	283.0	398.2	391.4	328.0	264.0	160.0	25.3	7.4
Wind Velocities, Knots (Knot=1,852 km/hr)	2	2	3	5	5	4	4	4	3	2	1	1

Data : 1) Bangladesh Meteorological Department (1953-1985)
2) Evaporation , H.R. Laboratory (Dhaka) No. E-10 (1978-1979)

Source : JICA; Study on Storm Water Drainage System Improvement Project in Dhaka City, 1987

Table 2.2 Number of Properties in the Study Area

Area	House	Farm House	Businesses/ Industries	Institutions
Dhaka	724,307 (66.0%)	89,497 (55.9%)	33,132 (67.8%)	30,275 (72.8%)
Narayanganj	206,775 (18.8%)	24,585 (15.4%)	9,034 (18.5%)	7,380 (17.7%)
Keraniganj	79,916 (7.3%)	17,690 (11.1%)	2,595 (5.3%)	635 (1.5%)
Savar	60,615 (5.5%)	23,055 (14.4%)	1,066 (2.2%)	1,190 (2.9%)
Tongi	26,460 (2.4%)	5,179 (2.6%)	3,040 (6.2%)	2,128 (5.1%)
Total	1,098,073 (100.0%)	160,006 (100.0%)	48,867 (100.0%)	41,608 (100.0%)

Note : 1 . On household basis.
2 . "Houses" includes "Farm Houses".

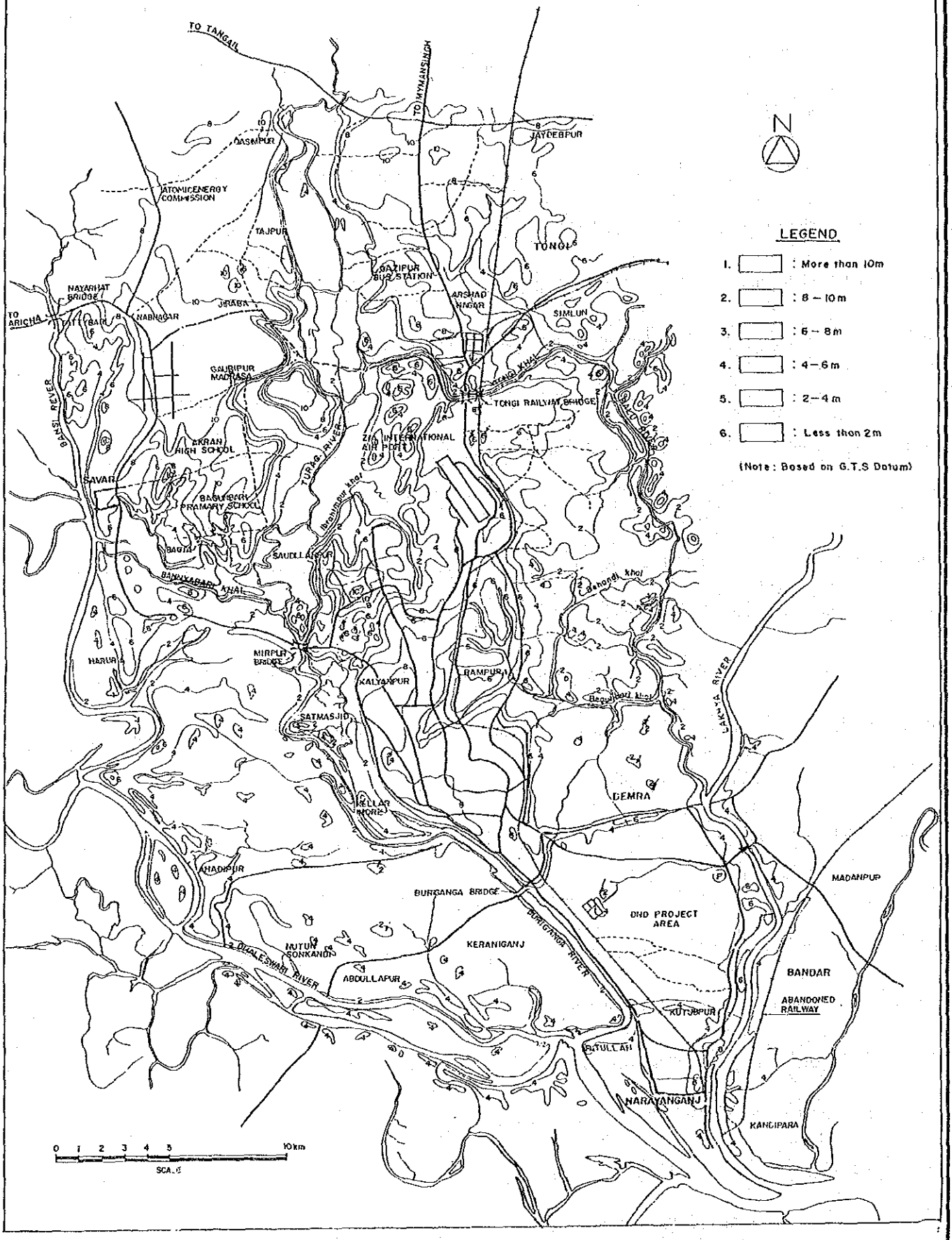

FIG. 2.1 LAND FORM OF THE STUDY AREA

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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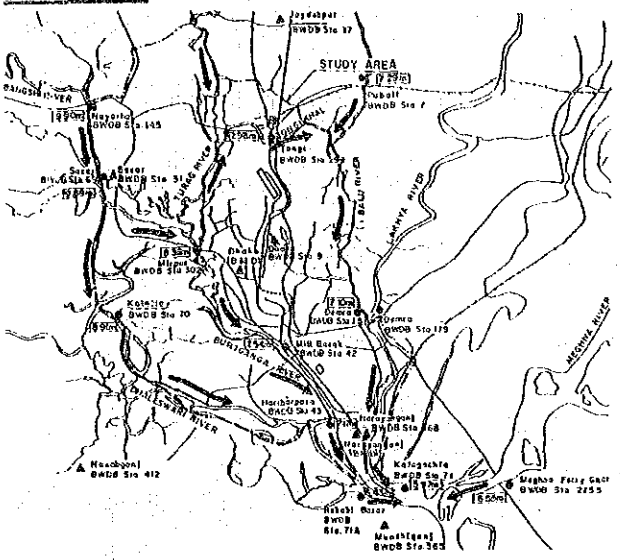
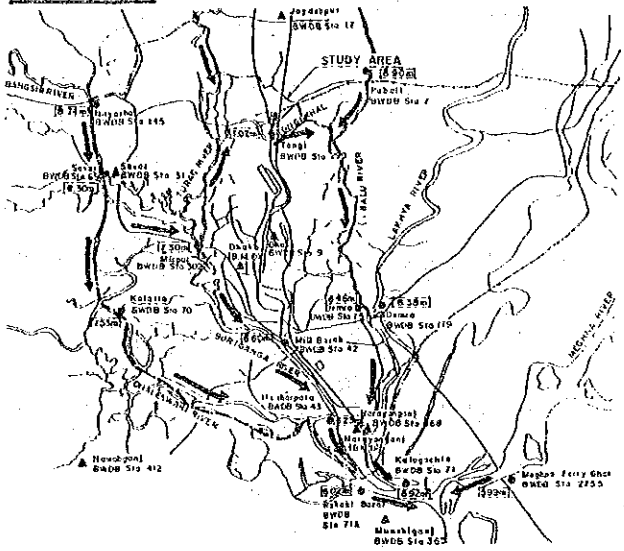
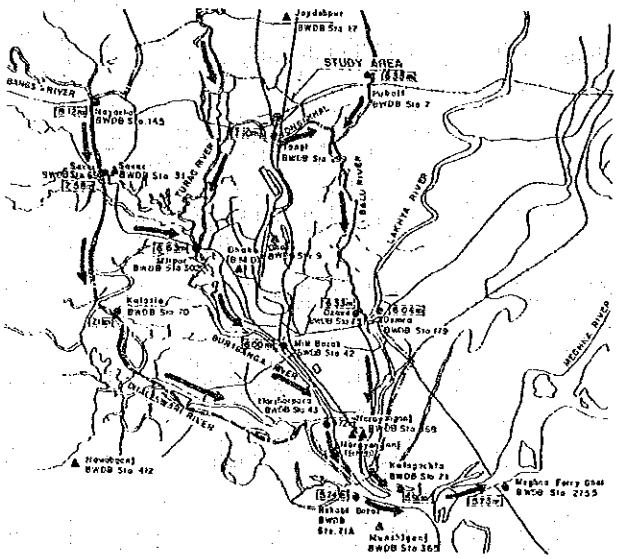
1988 FLOODS



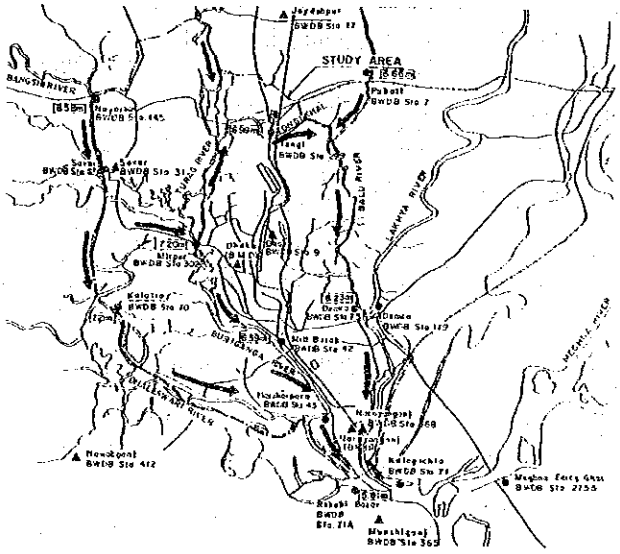
1987 FLOODS



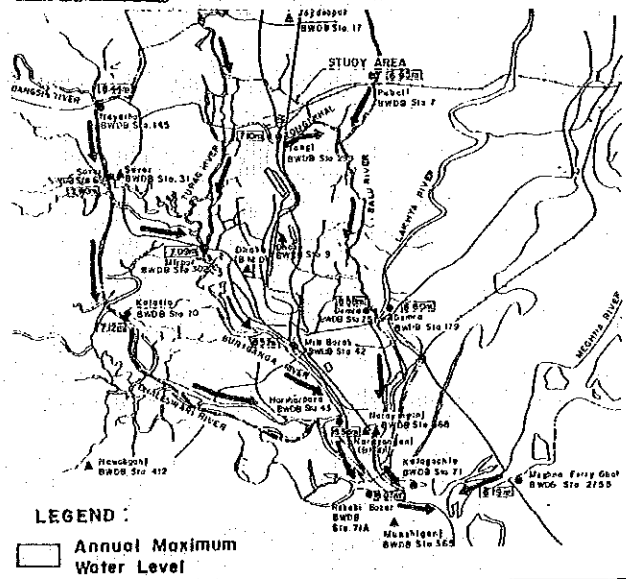
1984 FLOODS



1980 FLOODS



1974 FLOODS



1970 FLOODS

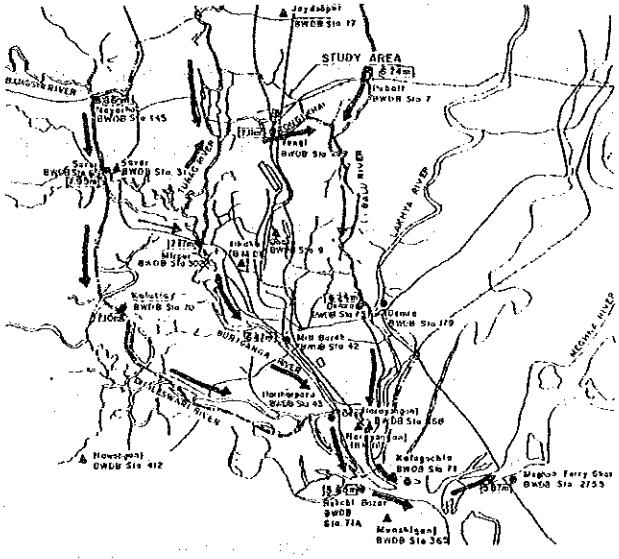


FIG. 2.2 ESTIMATED FLOW DIRECTION OF MAJOR FLOODS

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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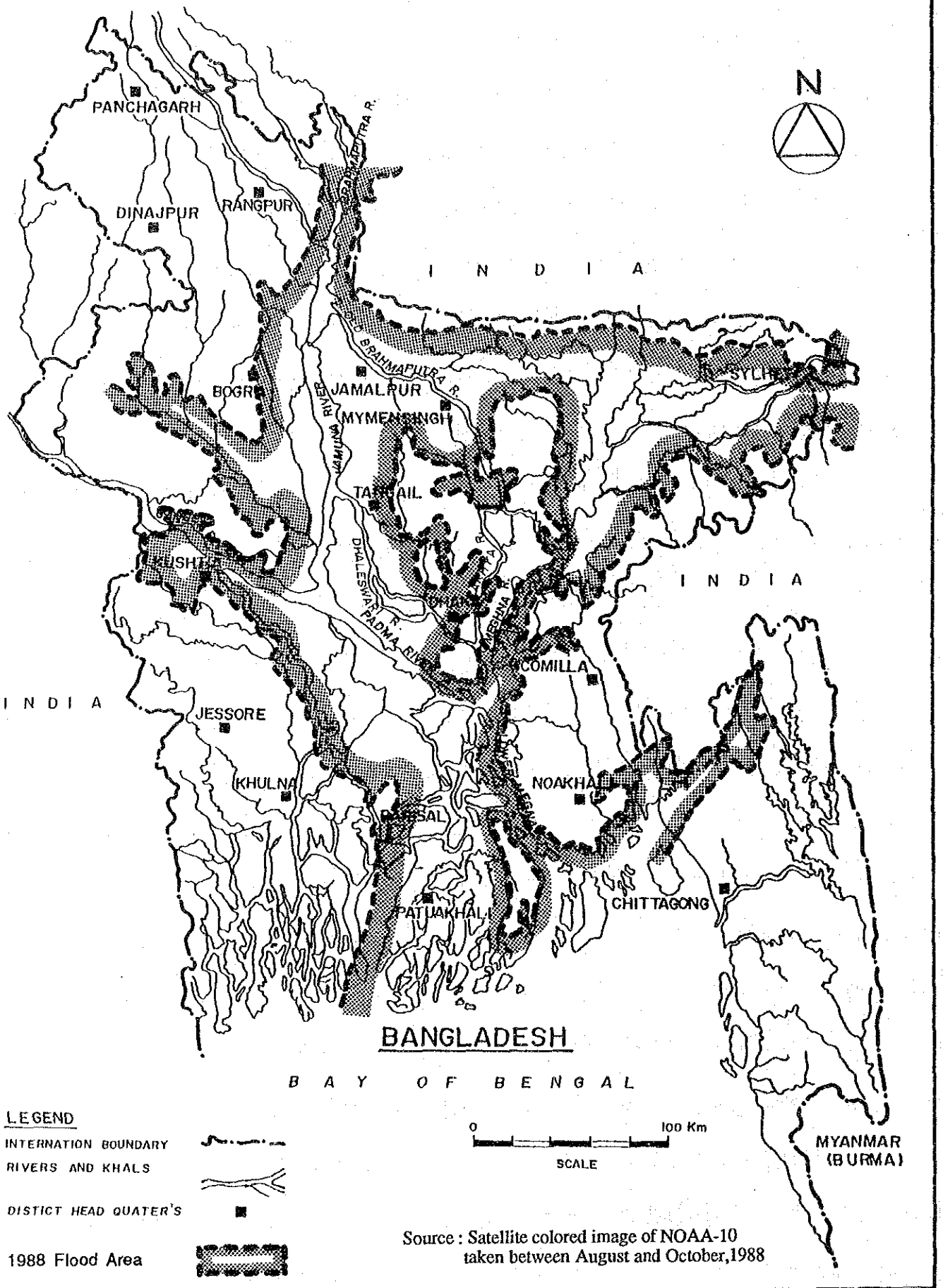

FIG. 2.3 1988 FLOODS IN BANGLADESH

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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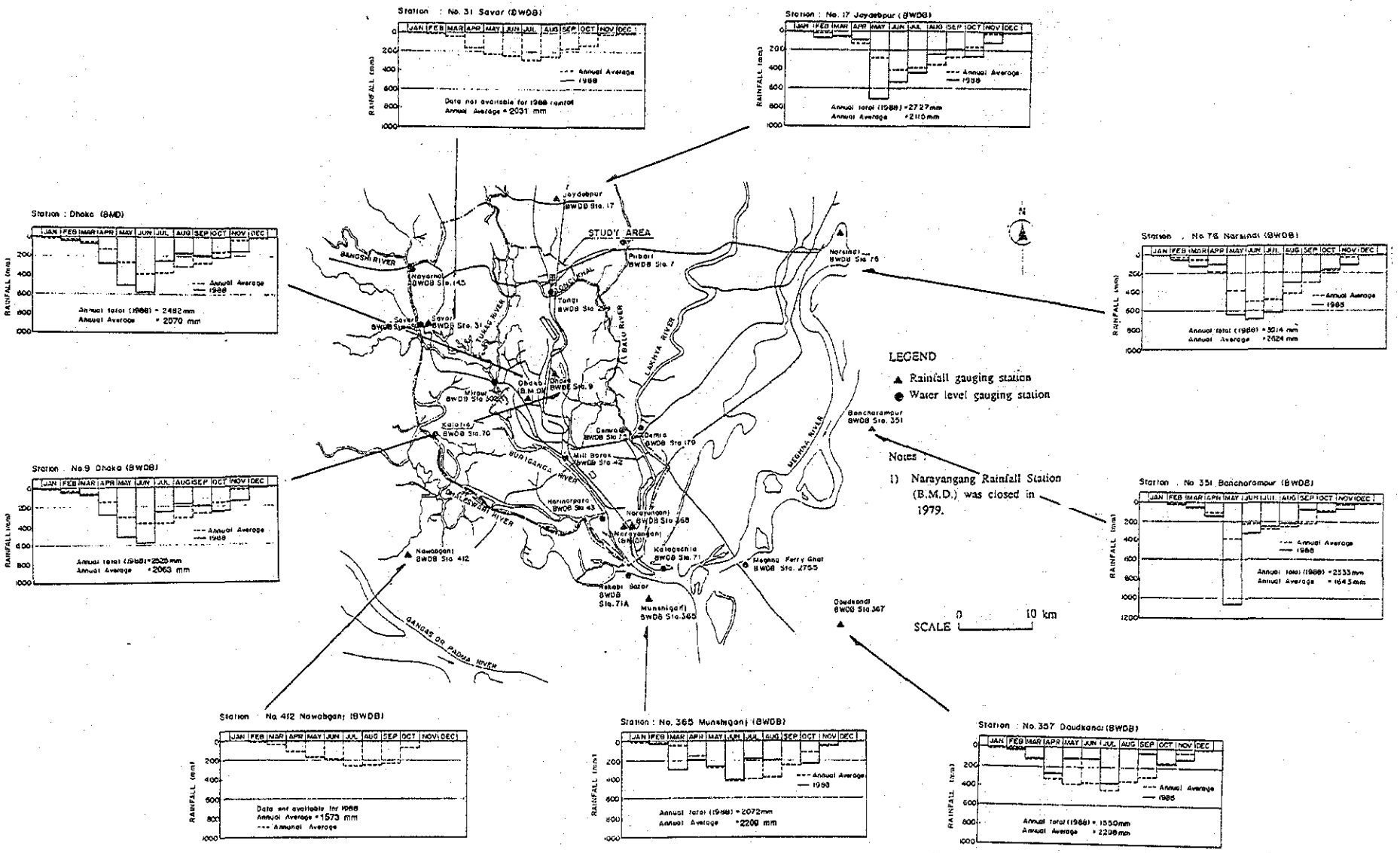


FIG. 2.4 MONTHLY RAINFALL-1988 AND ANNUAL AVERAGE

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

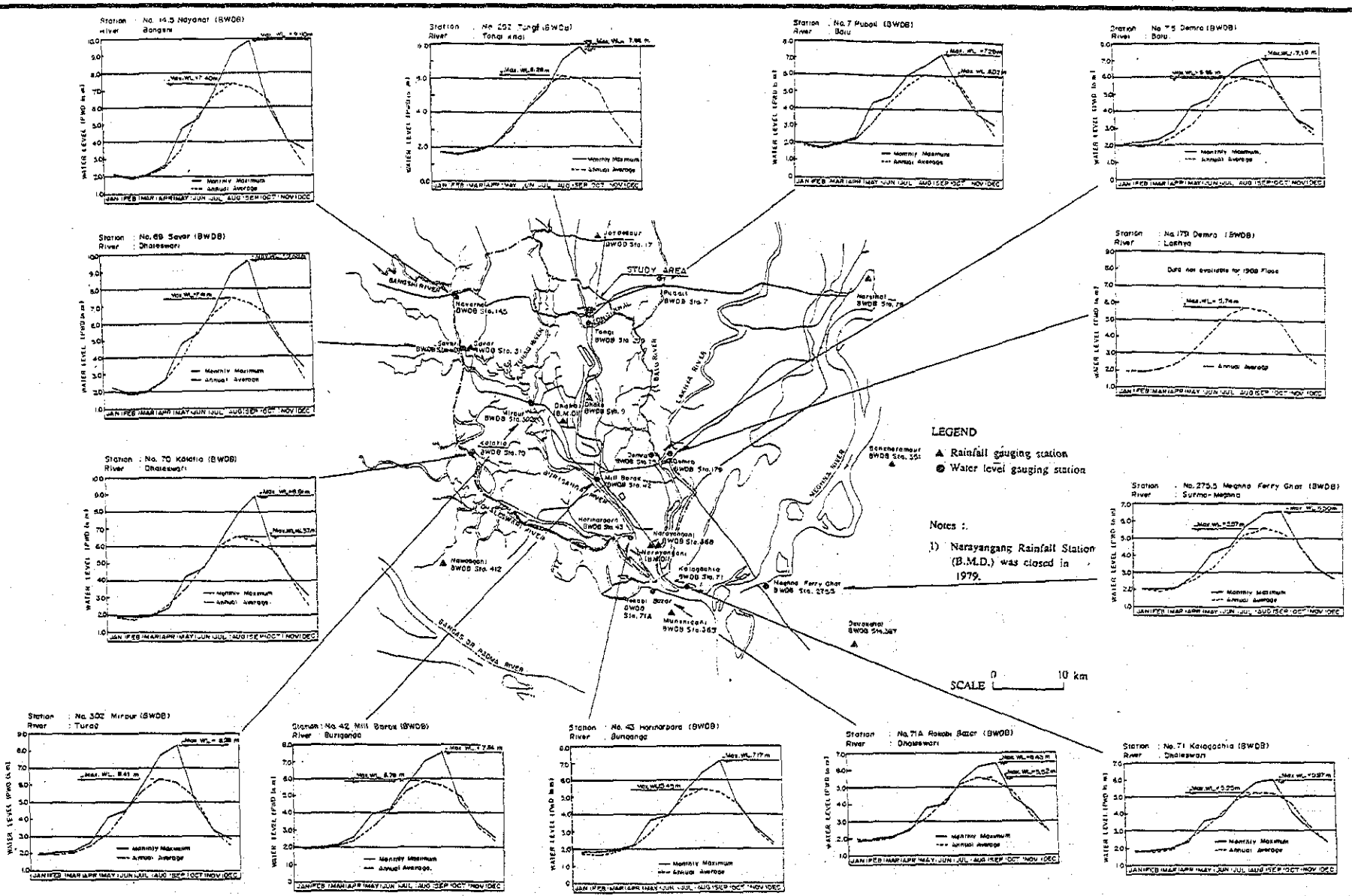
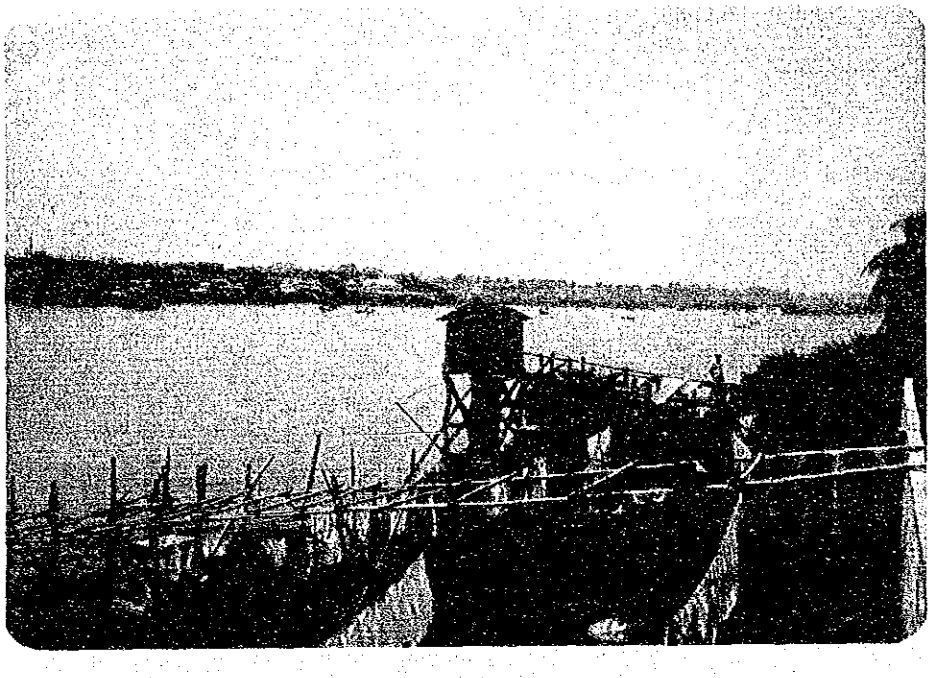


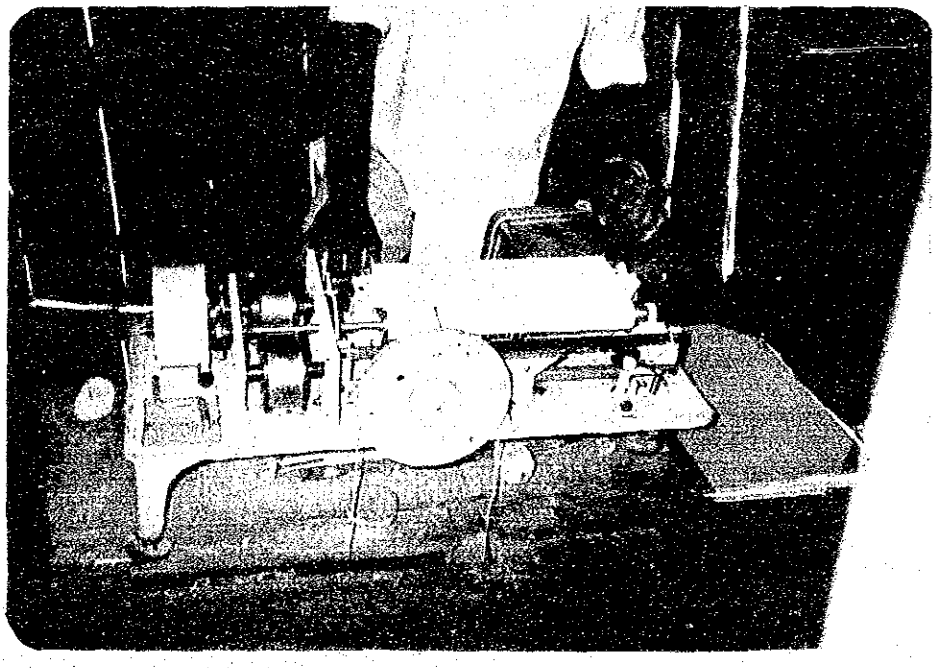
FIG. 2.5 MONTHLY MAXIMUM WATER LEVEL-1988 AND ANNUAL AVERAGE

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA



Buriganga River and Mill Barak Gauging Station



Automatic Recorder of Mill Barak Station

CHAPTER 3

HYDROLOGY

CHAPTER 3 HYDROLOGY

3.1 Hydrological Data

3.1.1 Rainfall and River Stage

There are ten (10) active and two (2) closed rain gauges, and twelve (12) acting water level gauges in and around the study area. The available data are shown in Tables 3.1 and 3.2. Their location is shown in Fig. 3.1

The rainfall data are measured manually once a day at 9:00 A.M and river stage data are measured manually five times daily at 6:00, 9:00, 12:00, 15:00 and 18:00.

Regarding the river stage, there is one automatic gauging station at Mill Barak. It is also reported that there are two automatic rain gauges in the study area, but that they have not been used since 1984.

3.1.2 River Cross Section

Available river cross sections and their locations, data collected from BWDB, are shown in Fig. 3.2. In addition to these cross sections, a supplementary river cross sectional survey was conducted by the study team and is also shown in Fig. 3.2.

3.2 Probable Storm Rainfall Analysis

Maximum rainfall data for one day, two days, five days and one month are collected for the 11 gauging stations shown in Fig. 3.1. Of these stations, Greater Dhaka, Narayanganj, Savar, and Tongi stations, which have a long duration of observed data, are considered representative stations of the Study Area.

Master Plan Area		Representative station
(1)	Greater Dhaka	: Dhaka (B.M.D)
(2)	Narayanganj	: Narayanganj (B.M.D)
(3)	Savar	: Savar (BWDB Sta. 31)
(4)	Tongi	: Dhaka (B.M.D) or Joydebpur (BWDB Sta. 17)

Data from these four (4) stations have no specific correlation. Accordingly it seems that using point rainfall data for a specific area is more reasonable than using basin mean rainfall data. Frequency analysis is conducted for these four stations and shown on Table 3.3.

Probable rainfalls at the four stations shows almost the same amount for one day and two day rainfall for the two year and five year return periods. Due to this reason, probable rainfall values at Dhaka (B.M.D), for one day and two days rainfall with two year and five year return period, are also applicable to Savar, Tongi and Narayanganj. The probable storm rainfall and consecutive rainfall duration curves of Dhaka (B.M.D) are shown in Fig. 3.3.

The design hydrograph for pump drainage plan is the same hyetograph as the one used by the 1987 JICA Study (Fig. 3.4), which is based on the data collected from the auto recording charts of Dhaka (B. M.D).

Rainfall intensity-duration curves for durations of less than one day are based on the 1987 JICA Study's curves, which show short duration rainfall of less than two hours (Fig. 3.5).

Areal reduction factors of point rainfall are studied in order to make an optimum drainage plan. Daily rainfall data for Dhaka (B.M.D) with more than 100 mm/day are obtained from the data between 1970 and 1978. Daily rainfall data for the same dates as Dhaka's data are obtained for Joydebpur (Sta. 17), Savar (Sta. 31) and Narayanganj (B.M.D). Isohyetal maps are made from the selected data with very small rainfall only at Joydebpur, Savar and Narayanganj. From these isohyetal maps, areal reduction rates of the point rainfall at Dhaka (B.M.D) were calculated and plotted on the curve developed by NEDECO (Fig. 3.4). NEDECO's curve gives a little safer value than the areal reduction rates of Dhaka. These curves are applied to this study.

Note : Master Plan for Drainage and Flood Control of Jakarta, 1973 by NEDECO.

3.3 Probable Flood Water Level Analysis

The annual maximum water level series are collected for the 13 gauging stations shown on Fig. 3.1.

In order to estimate an accurate water level for a long return period like 100 years, it is necessary to use data of long duration, including the 1988 flood which is the largest flood so far observed.

Out of 13 stations, only three gauging stations, Mill Barak (Sta. 42), Savar (Sta. 69) and Demra (Sta. 7.5), having 33 to 37 years data, are available for analysis of a probable flood water level. Probable flood water levels of the other stations are estimated on the basis of correlation with the above stations, as shown below;

Correlations of River Stage Stations

Station (X) Station (Y)	Mill Barak (Sta.42)	Savar (Sta.69)	Demra (Sta. 7.5)
Mirpur (Sta.302)	Y = 1.15 x +0.344	-	-
Tongi (Sta.299)	Y = 1.04 x +0.267	-	-
Hariharpara (Sta.43)	Y = 0.848 x +0.543	-	-
Nayarhat (Sta.14.5)	-	Y = 1.105 x-0.432	-
Kalatia (Sta.70)	-	Y = 0.867 x+0.367	-
Demra (Sta.179)	-	-	Y = 0.943 x+0.267
Pubail (Sta. 7)	-	-	Y = 1.066 x-0.130
Rakabi Bazar (Sta.71A)	-	-	Y = 0.834 x +0.549
Kalagachia (Sta.71)	-	-	Y = 0.752 x+0.896

Probable flood water levels are calculated by Gumbel - Chow's Method and shown on Table 3.4 and Fig. 3.6.

Return periods of the 1987 flood and the 1988 flood are estimated as follows :

Return periods of the 1987 flood and the 1988 flood

Station	1987 Flood	1988 Flood
Demra (Sta. 7.5)	8-year	50-year
Mill Barak (Sta. 42)	10-year	70-year
Savar (Sta. 69)	15-year	200-year

The return period of the 1988 flood, which is said to be 50 to 100 years, is estimated at 50-year at Demra and 70-year at Mill Barak. At Savar, the return period of the 1988 flood is much longer than generally supposed. That of Kaltia (sta. 70) is estimated as long as 300 years.
The return period of the 1988 flood might be longer in the North - Western part of the study area, due to the 1988 flood of the Brahmaputra-Jamuna River which was probably of larger scale than a 100-year flood frequency

At Savar (Sta. 69), available data is for 33 years only, while the water levels was probably for a long return period of 200 to 300 years. Accuracy is therefore likely to be uncertain.

3.4 Hydraulic Simulation Model

3.4.1 Mike 11 Software and SWSMP

Mike 11 is a software for hydrological and hydraulic simulation of rivers. It consists of Rainfall Runoff Model, Channels Flow Model, etc.

The software can be operated by introducing river structures such as embankments, weirs, pump stations etc. and it can be run by 16-bit or 32-bit microcomputers under MS-DOS or UNIX operating systems.

The Surface Water Simulation Modeling Programme (SWSMP) has been conducted by GOB since 1986, in recognition of the fact that effective control and utilization of water resources in Bangladesh is vital to the economic and social development of the country.

The objectives of SWSMP are :

(1) to develop a surface water simulation model for the whole country. This is called the "General Model", and

(2) to develop fully operational models for various regions, known as the "Regional Models", for example, the South East Region Model, the South West Region Model, and the North West Region Model.

All these are being developed, but the development of the "General Model" and the "South East Region Model" are in the final stage. Furthermore, the "Flood Forecasting Model" for Dhaka Metropolitan area and the "North Central Regional Model" for the North Central Region including Dhaka Metropolitan area, are under development.