THE PEOPLE'S REPUBLIC OF BANGLADESH
FLOOD PLAN COORDINATION ORGANIZATION

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

FAP 8A

MAIN REPORT

JUNE 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

THE PEOPLE'S REPUBLIC OF BANGLADESH
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PREFACE

In response to a request from the Government of the People's Republic of Bangladesh, the Government of Japan decided to conduct a study on 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 4 times between October 1990 and June 1992.

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

June 1992

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

6

FEASIBILITY STUDY

ON

GREATER DHAKA PROTECTION PROJECT

(STUDY IN DHAKA METROPOLITAN AREA)

OF

BANGLADESH FLOOD ACTION PLAN NO.8A

June, 1992

Mr. Kensuke YANAGIYA

President

Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit the final report entitled the "Feasibility Study on 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 September 1991 and May 1992 between the Japan International Cooperation Agency and Pacific Consultants International.

In the study, the Study Team has carried out a Feasibility Study on the priority areas identified by the Master Plan which was conducted from October 1990 to August 1991.

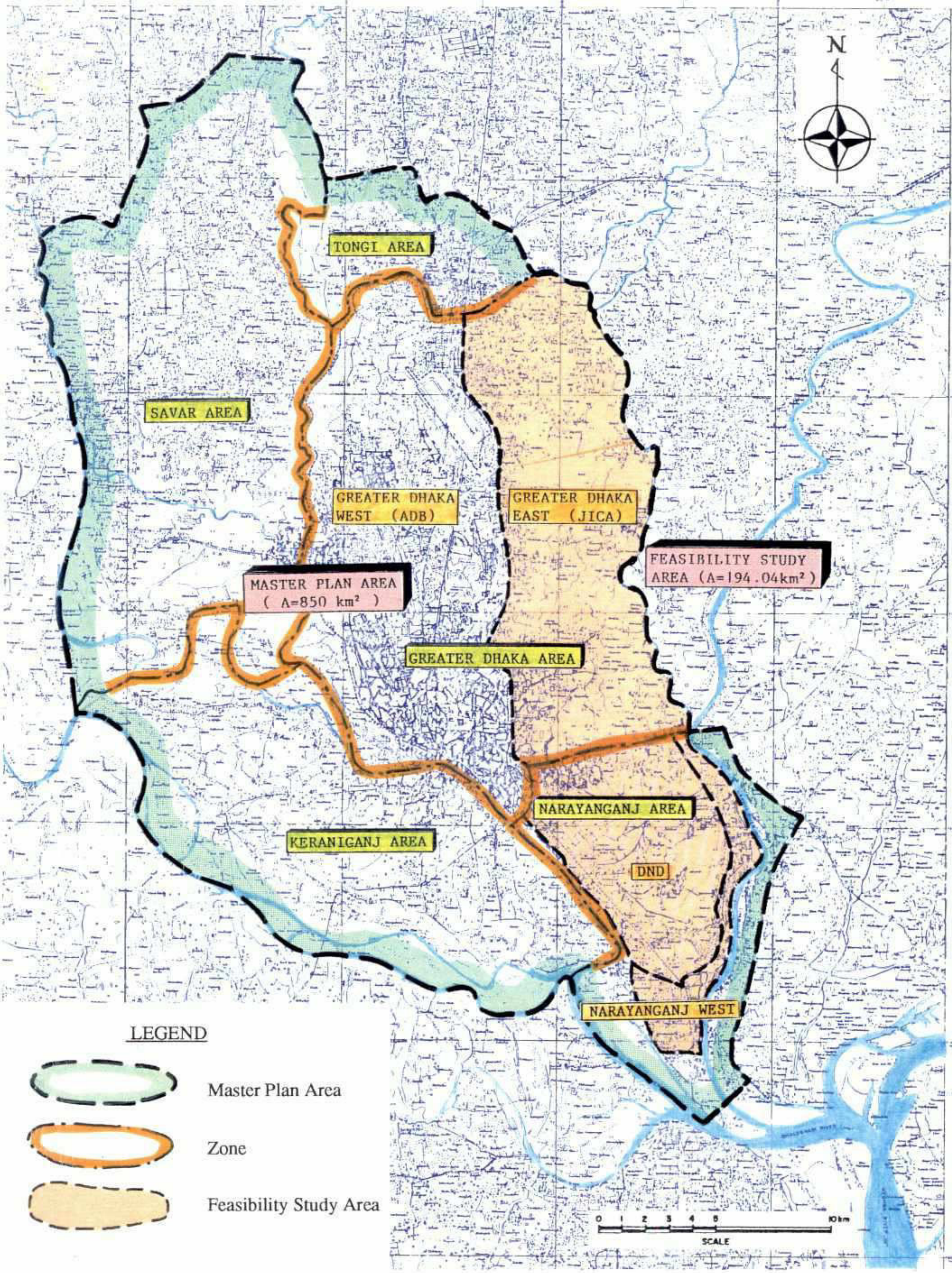
All members of the Study Team wish to express appreciation to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, and Embassy of Japan in Bangladesh for their assistance. The team also like to thank officials and individuals of the Government of the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

Yours Faithfully,

Hajime Tanaka

Hajime TANAKA

Team Leader



LOCATION MAP

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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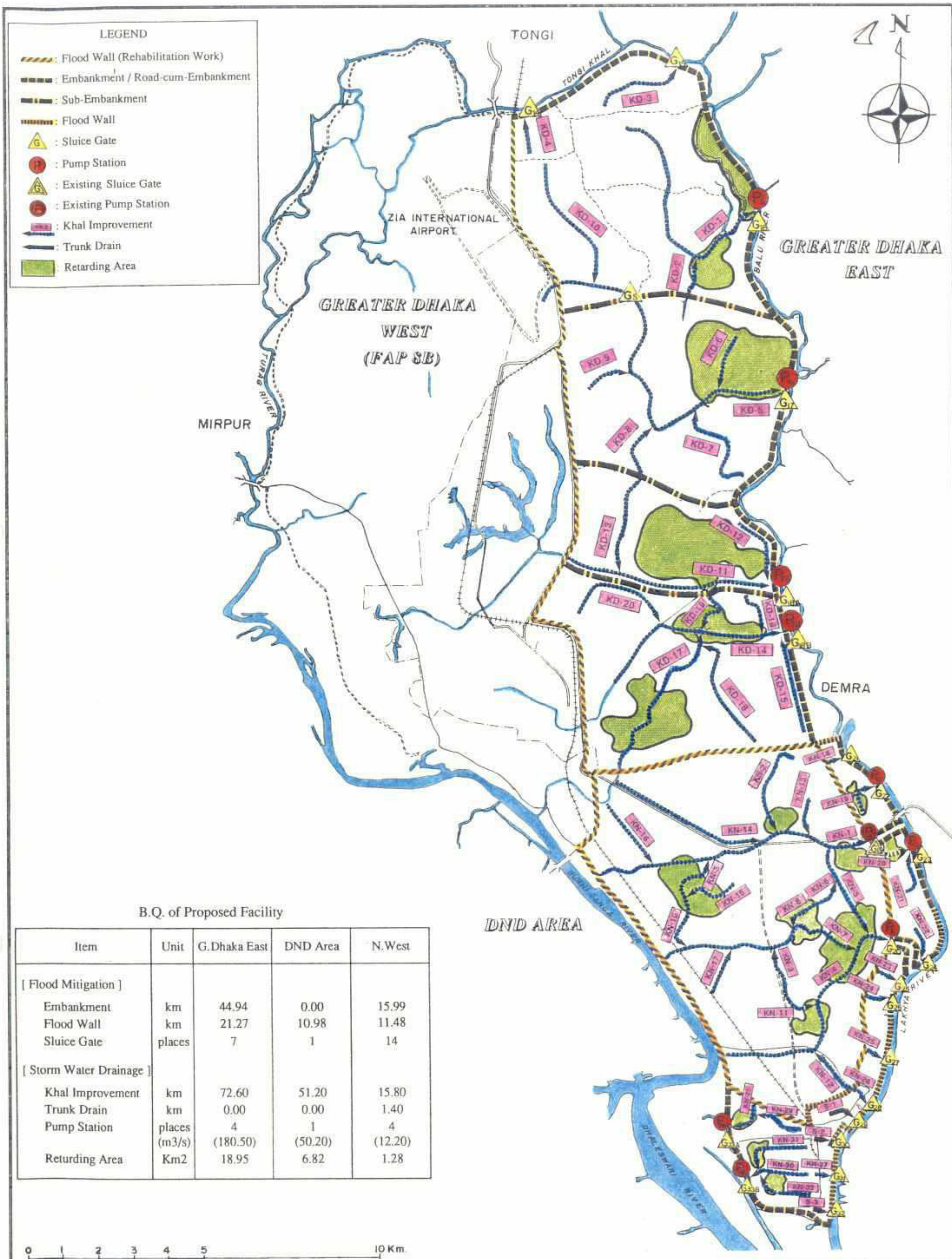

B.Q. of Proposed Facility

Item	Unit	G.Dhaka East	DND Area	N.West
[Flood Mitigation]				
Embankment	km	44.94	0.00	15.99
Flood Wall	km	21.27	10.98	11.48
Sluice Gate	places	7	1	14
[Storm Water Drainage]				
Khal Improvement	km	72.60	51.20	15.80
Trunk Drain	km	0.00	0.00	1.40
Pump Station	places (m3/s)	4 (180.50)	1 (50.20)	4 (12.20)
Returding Area	Km2	18.95	6.82	1.28

PROPOSED FLOOD MITIGATION AND DRAINAGE IMPROVEMENT PLAN

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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Table of Contents

20

22

List of Tables

02

(Chapter 11)

List of Figures

ↄd

(Chapter 6)

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ABBREVIATIONS

ADB	Asian Development Bank
AIT	Asian Institute of Technology
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CAAB	Civil Aviation Authority of Bangladesh
CARE	Cooperative for American Relief Everywhere
DCC	Dhaka City Corporation
DEPC	Department of Environment and Pollution Control
DIT	Dhaka Improvement Trust (now RAJUK)
DIFPP	Dhaka Integrated Flood Protection Project
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
IBRD	International Bank for Reconstruction and Development (world Bank)
IDA	International Development Association (of the world Bank)

IPH	Institute of Public Health
JICA	Japan International Cooperation Agency
MEF	Ministry of Environment and Forest
MIWDFC	Ministry of Irrigation, Water Development and Flood Control
MLGRDC	Ministry of Local Government, Rural Develop and Cooperatives
MOI	Ministry of Information
MOW	Ministry of work
MPO	Master Plan Organization
PC	Planning Commission
PDB	Power Development Board
PHD	Public Health Department
PWD	Public Works Department
RHD	Roads and Highways Department
RAJUK	Rajdhani Unnayan Katripakkha (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 Center
SPARRSO	Space Research and Remote Sensing
UNCHS	United Nations Center for Human Settlements
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Education Fund
USAID	US Agency for International Development
WAPDA	Water and Power Development Authority
WASA	Water and Sewerage Authority
WHO	World Health Organization
WMO	World Meteorological 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. The World Bank coordinated the studies and framed a Flood Action Plan (FAP) with 26 components as the initial stage in the development of a long-term for flood control, drainage and river management in Bangladesh. The activities are divided between 11 main components and 15 supporting studies or pilot projects.

The FAP was propose 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 N. 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 Flood Action Plan No. 8A (FAP 8A) within the general framework of technical cooperation between Japan and Bangladesh. The ADB decided to finance " Dhaka City Integrated Flood Protection Project" (FAP 8A).

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 the study in October 1990, and held a discussion on 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 1 : Preliminary Review (from October 1990 to December 1990)

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The objectives are :

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

The study plan was discussed with FPCO and the GOB study term and shown in the Inception Report (October, 1990). And after reviewing the existing conditions and the relevant previous studies, structural measures for the forecast urban areas by the target year of 2010 and non-structural measures for the other remaining rural areas were proposed and also, according to the concept, a detailed study plan of the Master Plan study (Phase II) on comprehensive flood mitigation and storm water drainage improvement measures for Dhaka Metropolitan area was prepared and compiled in the Preliminary Review Report (December, 1990).

Phase II : A Master Plan Study (from January 1991 to August 1991)

The objectives are :

- to carry out a master plan study on comprehensive flood mitigation and storm water drainage improvement measures for Dhaka Metropolitan area.

- to identified priority areas for a feasibility study.

A master plan study on comprehensive flood mitigation and storm water drainage improvement measures for Greater Dhaka, Narayanganj, Keraniganj, Tongi and Savar was conducted. For elimination of flooding and drainage problems from the areas, optimum measures were studied. The priority areas for a feasibility study were identified. The study results were presented in the Master Plan Report (November, 1991).

The identified priority areas are :

- Greater Dhaka West,
- Greater Dhaka East ,
- Narayanganj DND and
- Narayanganj West,

The priority area of Greater Dhaka West was taken by FAP 8B, ADB. The feasibility study of FAP-8B "Dhaka Integrated Protection Project" is already completed and taken up by GOB and ADB for implementation of the Project. It has been decided that the feasibility study of all the remaining areas be conducted under this FAP 8A study. The basic concept of storm water drainage improvement of the FAP 8A's master plan has already been incorporated in the F/S of FAP 8B.

Phase III : A Feasibility Study (from September 1991 to May 1992)

The objective is :

- to conduct a feasibility study on flood mitigation and storm water drainage improvement measures for the priority areas identified during the phase II.

During this phase, the proposed flood mitigation and storm water drainage improvement measures were studied and reported in the Interim Report (January, 1992). This Draft Final Report was prepared after the completion of entire field studies.

1.2 Study Objectives

The objectives of the study is to carry out a feasibility study on flood mitigation and storm water drainage improvements for the identified priority areas of Greater Dhaka East, Narayanganj DND and Narayanganj West.

1.3 Study Area

The study area will cover the forecast urban areas ($A = 194.04\ km^2$) of Greater Dhaka East, Narayanganj DND and West in the target year of 2010 (Fig. 1.1).

1.4 Methodology

In order to carry out the objectives, the study consists of the followings :

- Supplementary data collection, field surveys soil investigations, and ecological surveys,
- Detailed studies for flood mitigation and storm water drainage improvement measures,
- Preliminary designs of proposed facilities,
- Study for environmental impacts,

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- Preparation of B/Q and cost estimate,
- Assessment of environmental and social impacts,
- Preparation of an optimum implementation program,
- Evaluation of economic efficiencies, and
- Assessment of the project.

The study has been carried out in collaboration with FPCO, the GOB study team and the other related FAP studies.

1.5 Report Layout

This report presents all results of the engineering studies conducted during the period from September 1991 to March 1992. The comments raised on the Interim Report (January 1991) are duly incorporated. The report consists of the followings :

(1) Summary Report
(2) Main Report
(3) Supporting Reports

A. Urban Planning and Land Use
B. Flood and Flood Damage
C. Living Environment and Ecology
D. Meteo - Hydrology
E. Flood Mitigation and Storm water Drainage Improvement Plan.
F. Preliminary Design of Proposed Facilities
G. Operation and Maintenance
H. Cost Estimate
I. Project Evaluation
J. Supplementary Survey and Water Level Gauge Installation
K. Scope of Work and Minutes of Meeting.

1.6 Acknowledgments

The study has been carried out by the study team which was composed of the consultants retained by JICA and local sub-consultants in close cooperation with FPCO and the GOB study team.

The panel of experts of GOB and the Advisory committee of JICA acted as advisors to the study. A list of participants is shown in Appendix 1.

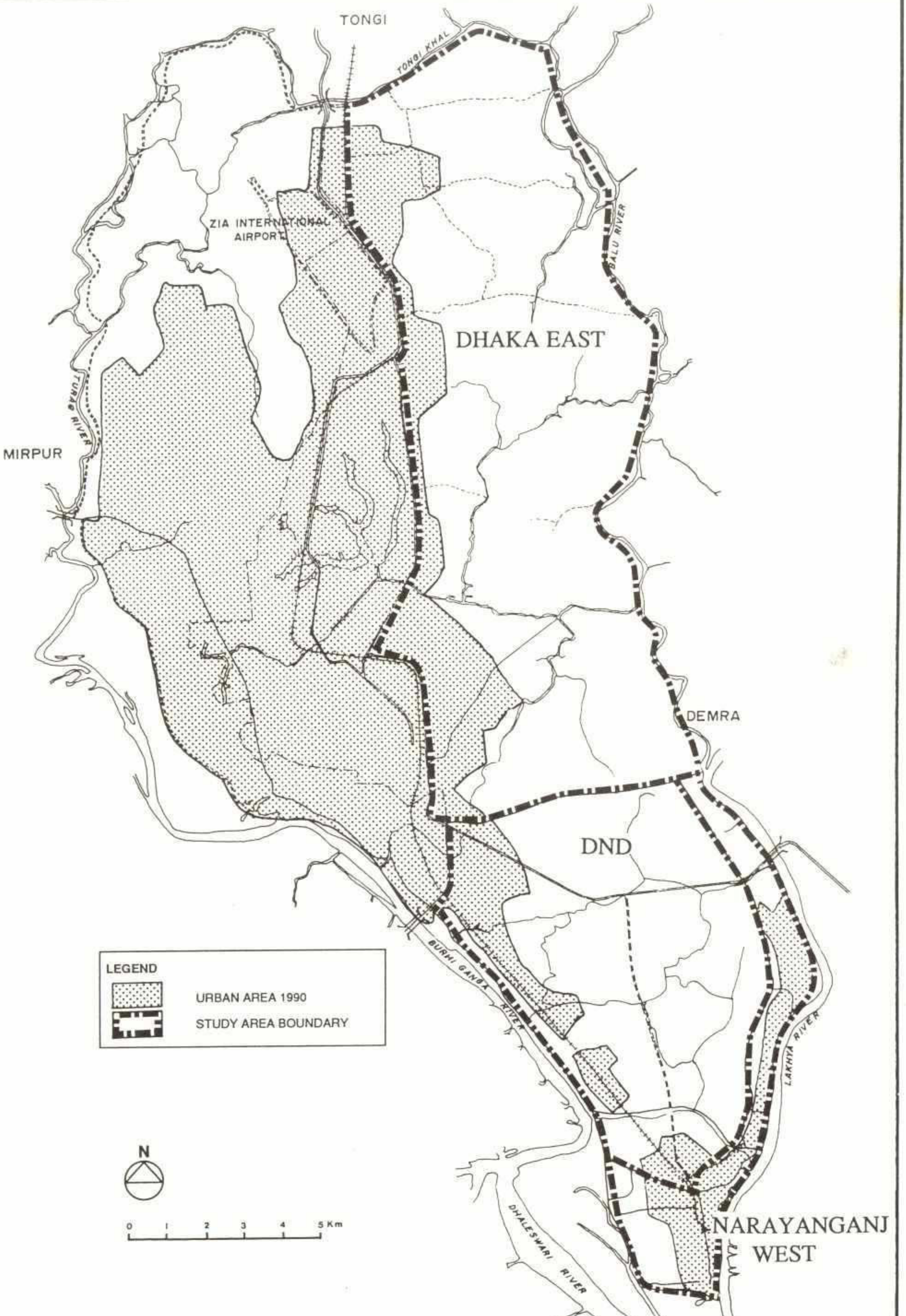

FIG. 1.1 LOCATION OF FEASIBILITY STUDY AREA

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

CHAPTER 2
STUDY AREA

Chapter 2 : Study Area

2.1 General

The feasibility study areas of Great Dhaka East, DND and Narayanganj West, constitute a continuous zone along the eastern side of the town area, though each area is at a different stage of urban development and has different characteristics.

The Greater Dhaka East (118.6 km^2) is by far the largest area but least developed among the feasibility study areas. This is mostly because, under current conditions, large parts of the central and southern areas are flooded for most of the year. Nevertheless, considerable peripheral development has taken place during the last decade.

The DND is the second largest area (56.8 km^2) bounded by road-cum-embankments and floodwalls. As the area was developed for irrigation, it is drained and generally flood free. Because of its proximity to the city and also being relatively flood free, the DND has developed quite rapidly during the last decade.

The Narayanganj West (18.6 km^2) is much smaller but much more intensively developed. The town is on relatively high land and developed independently from Dhaka. However, as Dhaka grew, the area between the two towns has become almost continuously built-up. The development of DND will see Narayanganj further becoming a part of Dhaka.

Due to the population and land use forecast by the Master Plan study, the population in 1990 and the target year of 2010 is estimated at 1.6 million and 4.4 million respectively. Accordingly the urban areas are likely to expand from 58 km^2 (30 % of the total area) in 1990 to 145 km^2 (75% of the total area) by 2010 (Table 2.1).

The existing built up areas are located mostly at the higher land above 5.0 m (GTS), however the forecast urban development areas, under current conditions, are still mostly flood prone and low-lying. The flood and storm water drainage problems would become severe constraints to future urban development. Optimum flood mitigation and storm water drainage improvement measures will be indispensable.

The climate of Dhaka area is classified as tropical monsoon type with three (3) annual seasons i.e. monsoon, post-monsoon and pre-monsoon. The monsoon is the rainy season, normally from May to October. In Dhaka area, 90% of the annual rainfall

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(approx. 2000 mm) occurs during the monsoon. The post-monsoon is the dry season from November to December. The pre-monsoon is the transitional season between the rainy season and the dry season. A little rainfall occurs during the pre-monsoon. The climatic conditions are shown in Table 2.2.

In the beginning of the monsoon and the post-monsoon, cyclones with strong wind hit Bangladesh and sometimes cause a destructive storm surge on the eastern coastal area. But Dhaka is usually outside the affected area.

The master plan study area is surrounded by the Tongi Khal, the Balu River, the Lakhya River, the Dhaleswari River and the Buriganga River. The floods are caused by these rivers, which are affected by the big flood discharge through the Ganges and the Brahmaputra - Jamuna River on the high backwater stage of the Meghna River. There are two types of floods, external and internal floods, in the study area. External floods are caused by flooding of the surrounding rivers, while internal floods are caused by storm water flooding in the built-up area due to insufficient and poorly maintained drainage facilities.

Major floods of the study area were recorded in 1954, 1955, 1958, 1970, 1979, 1980, 1987 and 1988, since the water level observation was initiated at Mill Barak in Dhaka in 1945. In 1987 and 1988, the study area experienced severe floods. The 1987 flood was one of the medium size floods and assessed at a 10-year return period, while the 1988 flood was the largest one on record and assessed at a 70-year return period. During the 1988 floods, also a large part of the build-up area, which is usually flood free, was submerged.

2.2 Greater Dhaka East

2.2.1 Physical Features

The area covers approx. 118.6 km^2. It is bounded on the north by the Tongi Khal, to the east by the Balu River, to the south by the Demra Road, and to the west by the Rampura-Biswa Road and the Dhaka-Mymensingh Road (Fig. 2.1).

The area except 8.45 km^2 of the northern part is drained east to the Balu River through the Begunbari Khal, the Jamair Khal and the Boalia Khal.

There is a relative high land area above 5.0 m (GTS) along the western border, the portion being to the north in Uttara East and in the south from Khilgaon to Jatrabari. The higher land is usually flood-free. However the most other areas, under current conditions, are low-lying and under water for over half year, of which perhaps half is under 2.0 m (GTS) (Fig. 2.2).

2.2.2 Existing Land Use and Proposed Development

The built-up area is still 23 km^2 (19 %). The other remaining area is mostly low-lying and under water for over half year, but cultivated for the rest of the year. A considerable peripheral development has taken place during the last decade by means of land fill, especially in the southern part close to the city centre (Fig. 2.3).

The construction of the Rampura road has provided a platform for further peripheral development to the east. Fig. 2.4 shows the areas currently under development. In addition, there are other areas where RAJUK intends to implement its own development and where development is intended in accordance with a RAJUK zonal plan. There are also commitments for large scale planned private developments. Elsewhere, unapproved developments are known to be proceeding. A continuation of such peripheral growth may be expected even without the flood protection afforded by embankment. But as public perception regarding flood protection becomes established, an acceleration may be anticipated. Such development, and its associated landfill, may affect the drainage pattern and prejudice the flood protection plan.

During the next decade, in the absence of any public transport system to allow for northern expansion, non-availability of large service areas will persist. Under such conditions, Greater Dhaka East, though low-lying, is one of the major areas where urban growth will become dominant.

In order to minimize encroachment upon the low land, it is important then to delineate all areas needed for flood mitigation and drainage improvement measures and other major infrastructures at the earliest, so that such reservation may be safeguarded until construction take place.

In the feasibility study, the area is planned to be divided into four compartments. The countermeasures could be implemented in phases, compartment by compartment, with progressing urbanization. However an optimum overall development plan for the whole area will be indispensable.

2.2.3 Population

The 1981 census and the 1991 JICA study provide the basis for estimation of the existing and future population of this area.

The population for 1990 and 2010 are estimated at 638,000 and 2,201,000 respectively, assuming that the present rate of growth will continue for all areas. However there may be some discrepancy since a variety of factors such as the execution of flood protection embankment, delivery of urban land etc., will affect the projection both for the whole area as well the individual zones.

It is remarkable that among the four compartments, the southern compartment- 2 would have a big pressure of urban development and a large area will likely be developed during the coming decade.

The population distribution among compartments is summarized below :

	1990	2000	2010
Northern Compartment	126,000	282,000	772,000
Central Compartment	61,000	140,000	259,000
Southern Compartment - 1	24,000	52,000	212,000
Southern Compartment - 2	427,000	677,000	958,000
Total :	638,000	1,151,000	2,201,000

2.2.4 Infrastructure

The present service level of public utilities are still very low. The existing service networks are shown in Fig. 2.5. The present framework of services is restricted to the areas already developed. It shows that infrastructure provision may influence the pattern of growth. Thus unplanned growth may follow the existing roads. The current infrastructure distribution suggests that over the next decade incremental peripheral development will continue. Flood protection measures, which may create a new area of development, will also influence the pattern.

62

2.2.5 Navigation

There are numerous canals which serve both as drainage channels and as navigation routes. Both passenger and freight services by small and large boats are depending on the waterways throughout the year in the Dhaka East area, between the Balu River and the Rampura-Biswa road area. The absence of all weather land routes allows transportation only by boats through the Begunbari Khal and others, except a short couple of months in the dry season.

Bamboo, sugarcane, building materials, poultry are brought in from the distant east along with passengers. However the existing water transport system will likely loss its significance due to development of road networks gradually with progressing urbanization.

2.2.6 Outline of Flood Mitigation and Drainage Improvement Strategy

The northern and eastern boundaries of the area will be defined by the main flood embankment against a 100 - year frequency flood. The western boundary, on the existing new road, will be raised and flood proofed to form a permanent partition within the compartmentalizing strategy. Similarly, the southern boundary of the zone, the existing flood wall on the Demra Road, will be rehabilitated to form a partition in the compartmentalizing system.

Though three drainage zones were proposed in the Master Plan, four compartments are proposed in the feasibility study instead (Fig. 2.6).

Each compartment will have a drainage system consisting of trunk drains with retarding areas and a pump station., except 8.45 km2 of the Northern comp. which is a gravity drainage zone.

Sub-embankments between the Northern compartment, the central compartment and the Southern compartment are proposed along the existing roads and the other between the southern compartment-1 and 2 is proposed along the south side of the Begunbari Khal.

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2.3 Narayanganj

2.3.1 DND

1) Physical Features

The area covers 56.8 km^2, which was developed as an agricultural development area in the mid 1960s (Fig. 2.7).

The area which is protected by the existing embankments, flood walls and drainage pumps (14.52 m^3/s), was marginally safe from the 1988 floods. and after the 1988 floods, the flood walls have been constructed. Most parts of the area is low-lying from 2.0 m to 5.0 m (Fig. 2.8). The entire DND area is crisscrossed by irrigation canals, the pump station pumps water in and out as per the irrigation and drainage requirement.

2) Existing Land Use and Proposed Development

Because of its proximity to the town areas and also being relatively flood-free, the area has been developed quite rapidly during the last decade, particularly in the north-west corner.

The built-up area is 21.7 km^2 (38%) and the agricultural area is 31.7 km^2 (56%). According to the forecast land use for 2010, the build-up area is to expand to 42.7 km^2 (75%) (Fig. 2.9).

Currently RAJUK is preparing a housing development program for the area and a part of it (Panchabati) is already in the land acquisition phase. RAJUK with RHD has started Dhaka-Narayanganj road. Further substantial development is anticipated over the next ten years (Fig. 2.10). The Metropolitan Development Plan to be commissioned in 1992 will make an in-depth study into this area vis-a-vis the rest of urban Dhaka. Their recommendation will directly influence the growth of the area along with safeguarding the flood protection plans.

3) Population

The population for 1990 and 2010 are estimated at 449,000 and 1,314,000 respectively.

The new development areas for the next decade of 1990-2000 are likely accurate and take into consideration the RAJUK's housing development program. However the figure for 2000-2010 is less accurate and could vary depending upon various factors.

4) Infrastructure

The new N-S spine road connecting middle of the Demra road and Narayanganj is now under construction. This road will stimulate the escalation of urban development in DND.

The present provision of services are clearly inadequate for any large scale development. Though electrical connections are quite developed and the proximity to the Siddirganj Power Station renders considerable potential, the water and gas services leaves a lot to desire. With the planned growth of the settlement areas these services, however, will develop rapidly as witnessed with similar trends in other areas of the city (Fig. 2.11)

5) Outline of Flood Mitigation and Drainage Improvement Strategy

Currently the DND area is protected by the existing raised flood wall along the existing road. The existing flood wall and embankment are proposed to be rehabilitated and leveled. The area is planned to be divided into two drainage zones and the existing pump house be used for the northern zone, where as a new pump facility need to be built for the southern zone. Retarding areas are also proposed for each drainage zone (Fig.2.12).

2.3.2 Narayanganj West

1) Physical Features

The area covers 18.6 km^2. It is the most urbanized area among the F/S areas. Narayanganj town area has been developed on the river terrace over 5.0m (GTS) and generally flood-free. A linear part of the Narayanganj West area extends all the way up to the Demra Road and is placed between the DND and the Lakhya river and is dominated by industrial and non-agricultural land use. Only small parts in the south west is low-lying below 3.0 m and remain unbuilt (Fig 2.8).

2) Existing Land Use and Proposed Development

Narayanganj is an important river port and also has an industrial area along the Lakhya River. The area is small but intensively developed.

However, as Dhaka grew, the area between the two towns has become almost continuously built-up. The development of DND area will bring Narayanganj further becoming a part of Dhaka. RAJUK's housing development plan of Panchabati overlaps into the Narayanganj West. The existing built up area is now 13.1 m^2 (70%) and the forecast built up area for 2010 is estimated at 17.2 km^2 (92%) (Figs 2.9 and 2.10).

3) Population

The total population in the Narayanganj West in 1990 is estimated at 470,000. This population is expected to increase to 696,000 by the year 2000. After the century the growth rate will decline from 4.0 % to 2.9% and the 2010 population is expected to be 927,000.

4) Infrastructure

The present service level of public utilities is reasonably high. Electricity, gas, and water lines follow all the existing road, leaving only the south west unserved. From the present level of development, it can be assumed that services will be extended further to urbanized area due to the demand increase (Fig. 2.11).

5) Outline of Flood Mitigation and Drainage Improvement Strategy

The town area is generally flood-free, however, the entire Narayanganj area is planned to be protected by embankment and flood wall against the floods of a 100-year return period. The narrow area along the Lakhya river is planned to be protected by floodwalls due to non-availability of land. The southern part is to be protected by embankments along the eastern rive bank, the southern river bank and the western side. About drainage improvement, the area is divided into five drainage zones. Four zones are drained by gravity and pump to the Lakhya River or the Dhaleswari River, and the other zone is drained by gravity to the Lakhya River (Fig. 2.12).

TABLE 2.1 SUMMARY TABLE OF LAND USE

YEAR 1990

F/S AREA	TOTAL AREA (ha)	DETAILED LAND USE(ha) Res'tial (ha)	Com'cial (ha)	Industry (ha)	Ins'tion (ha)	Agri'ture (ha)	Water (ha)	BUILT-UP AREA (ha)	POP'TION YR 1990 (person)
DHAKA EAST	11,862	2,249	40	1	23	8,814	735	2,313	637,500
		19%	0%	0%	0%	74%	6%	19%	
DND	5,679	1,864	56	196	59	3,173	332	2,174	448,590
		33%	1%	3%	1%	56%	6%	38%	
N'GANJ WEST	1,863	981	86	178	67	464	87	1,312	470,449
		53%	5%	10%	4%	25%	70%		
TOAL	19,404	5,094	182	375	149	12,451	1,154	5,799	1,556,539
		26%	1%	2%	1%	64%	6%	30%	

YEAR 2010

F/S AREA	TOTAL AREA (ha)	DETAILED LAND USE(ha) Res'tial (ha)	Com'cial (ha)	Industry (ha)	Ins'tion (ha)	Agri'ture (ha)	Water (ha)	BUILT-UP AREA (ha)	POP'TION YR 2010 (person)
DHAKA EAST	11,862	5,917	436	39	2,158	1,310	2,002	8,550	2,201,935
		50%	4%	0%	18%	11%	17%	72%	
DND	5,679	2,463	172	482	1,153	532	877	4,270	1,313,749
		43%	3%	8%	20%	9%	15%	75%	
N'GANJ WEST	1,863	827	173	292	427	8	135	1,720	926,820
		44%	9%	16%	23%	0%	7%	92%	
TOAL	19,404	9,207	782	813	3,739	1,850	3,014	14,540	4,442,504
		47%	4%	4%	19%	10%	16%	75%	

Note : The areas of water bodies are on the different basis for the Year 1990 and 2010. The water area in 1990 is based on the land use survey map which shows the land use pattern in dry season (which means minimum), while the area in 2010 is based on the proposed scheme of retarding ponds and major drainage channels (which means maximum including the right of way and reserved area).

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TABLE 2.2 CLIMATE CONDITION 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

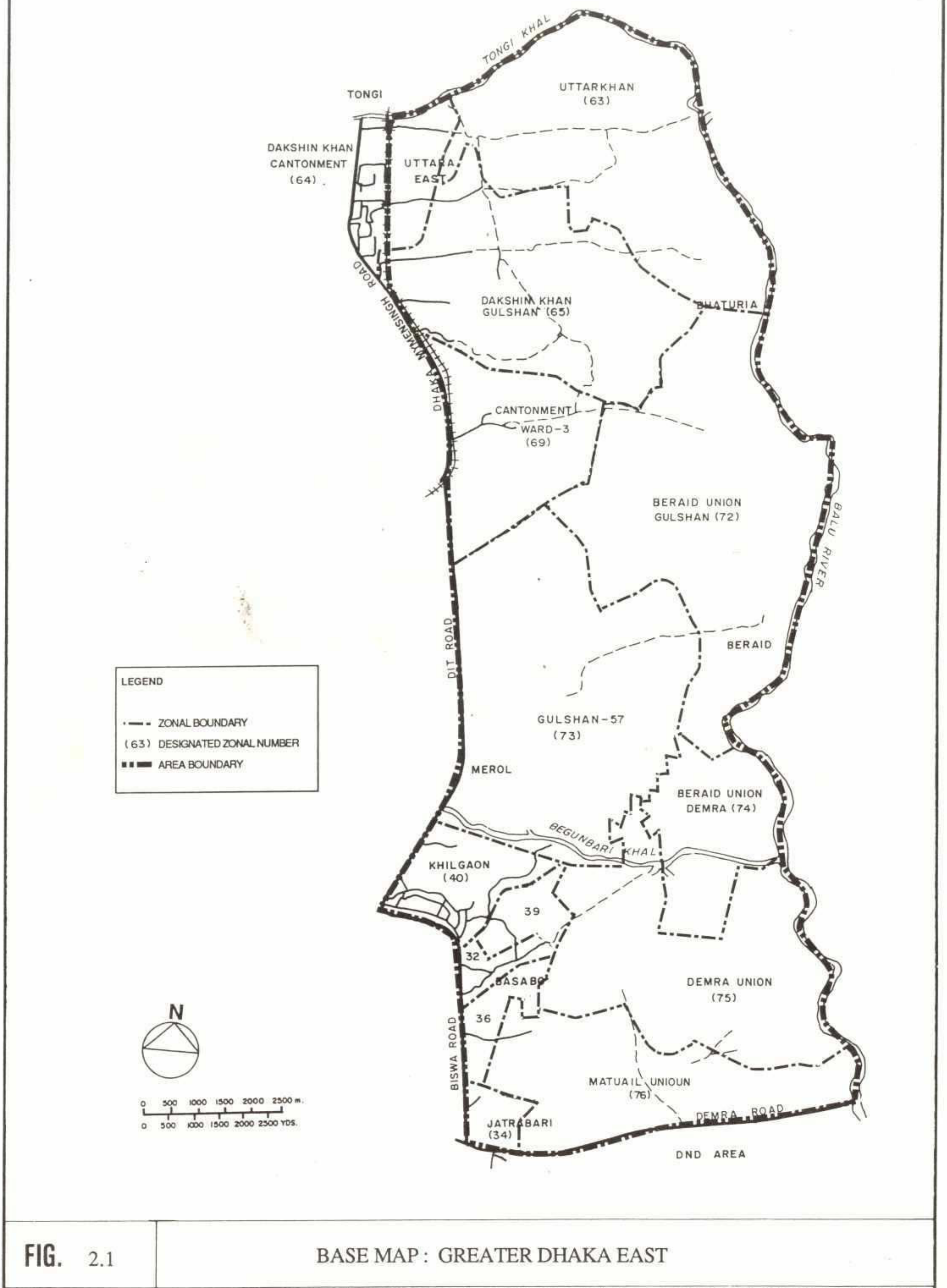

FIG. 2.1 BASE MAP : GREATER DHAKA EAST

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

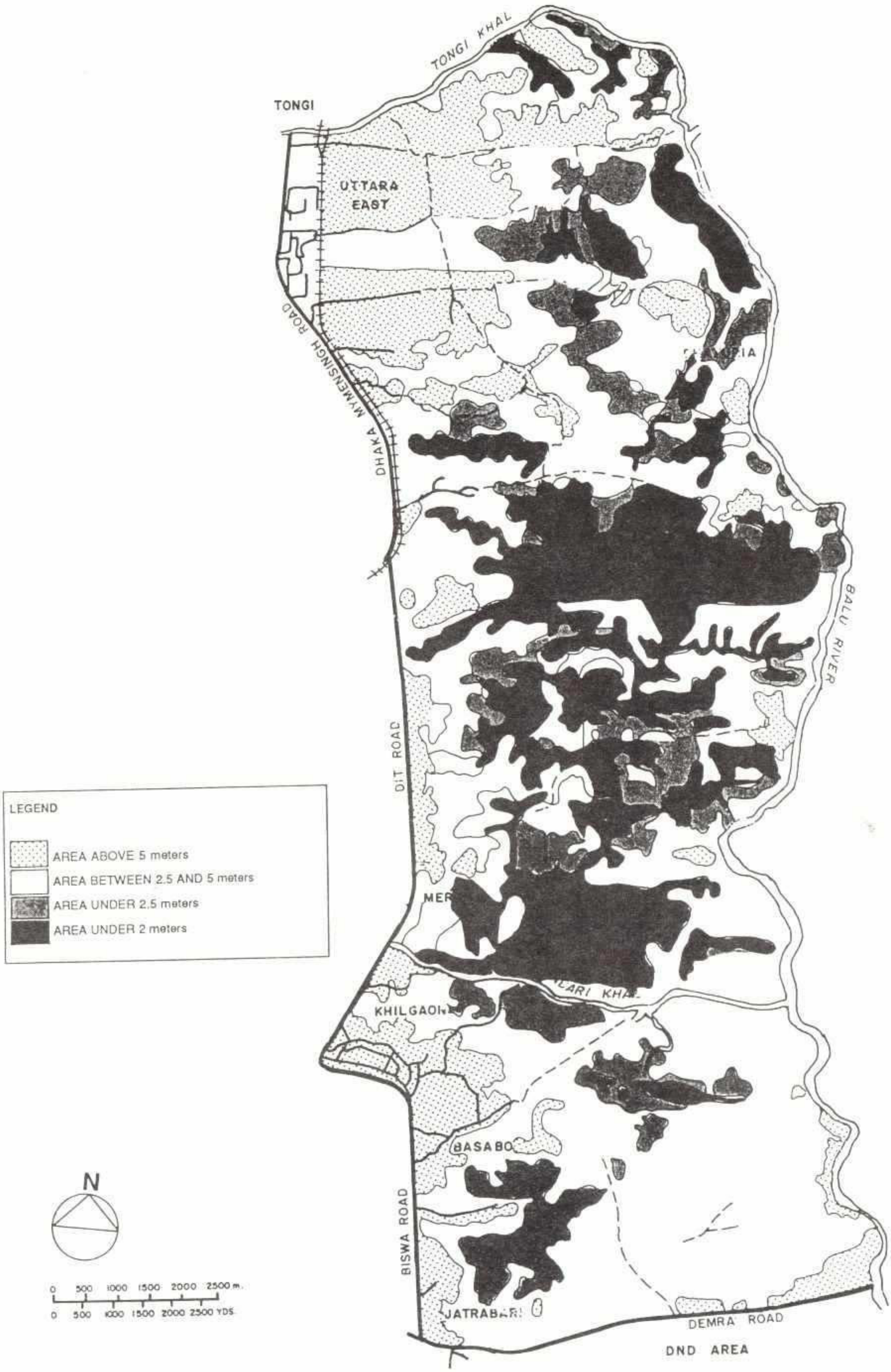

FIG. 2.2	EXISTING LAND HEIGHT : GREATER DHAKA EAST

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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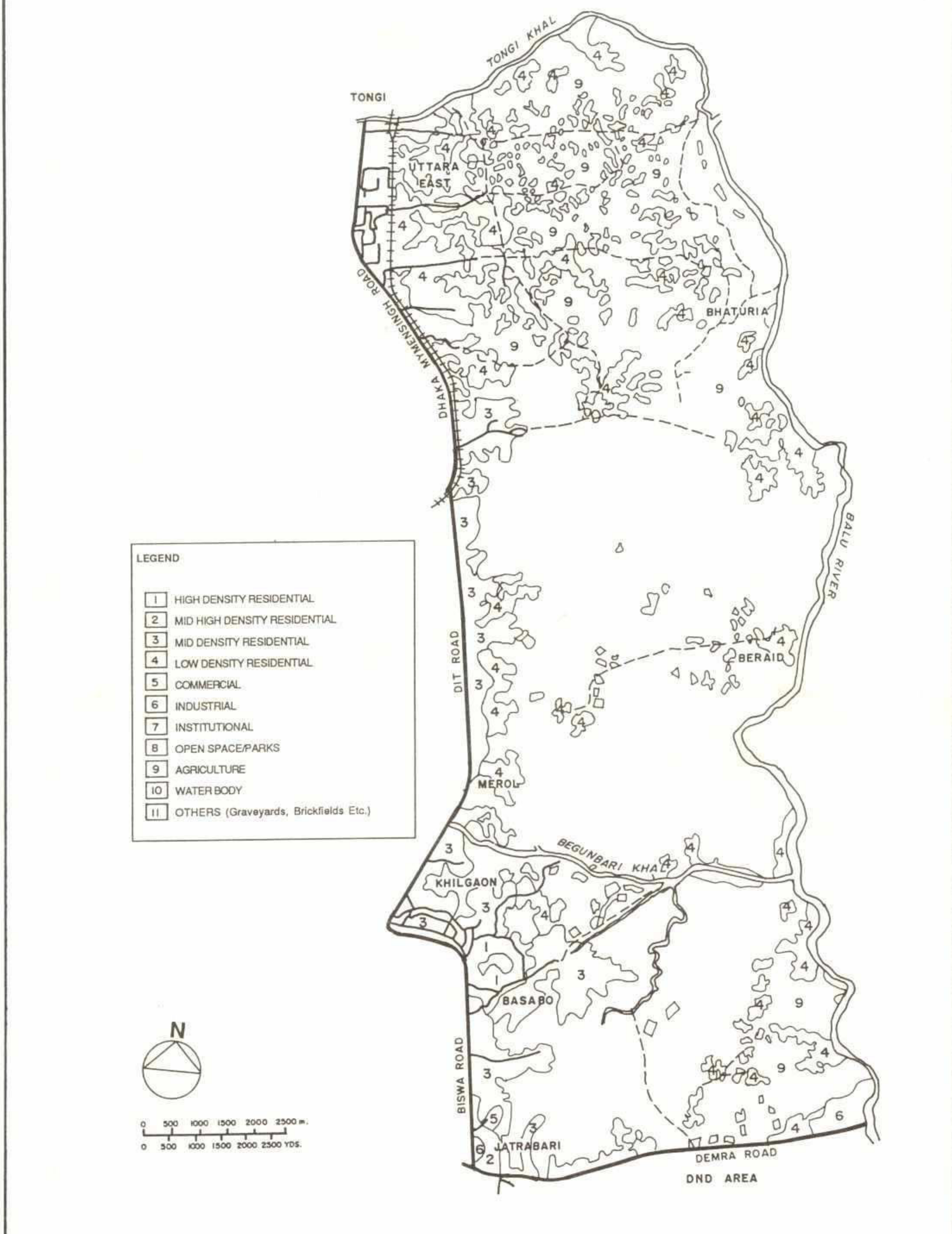

FIG. 2.3 EXISTING LAND USE : GREATER DHAKA EAST

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

460

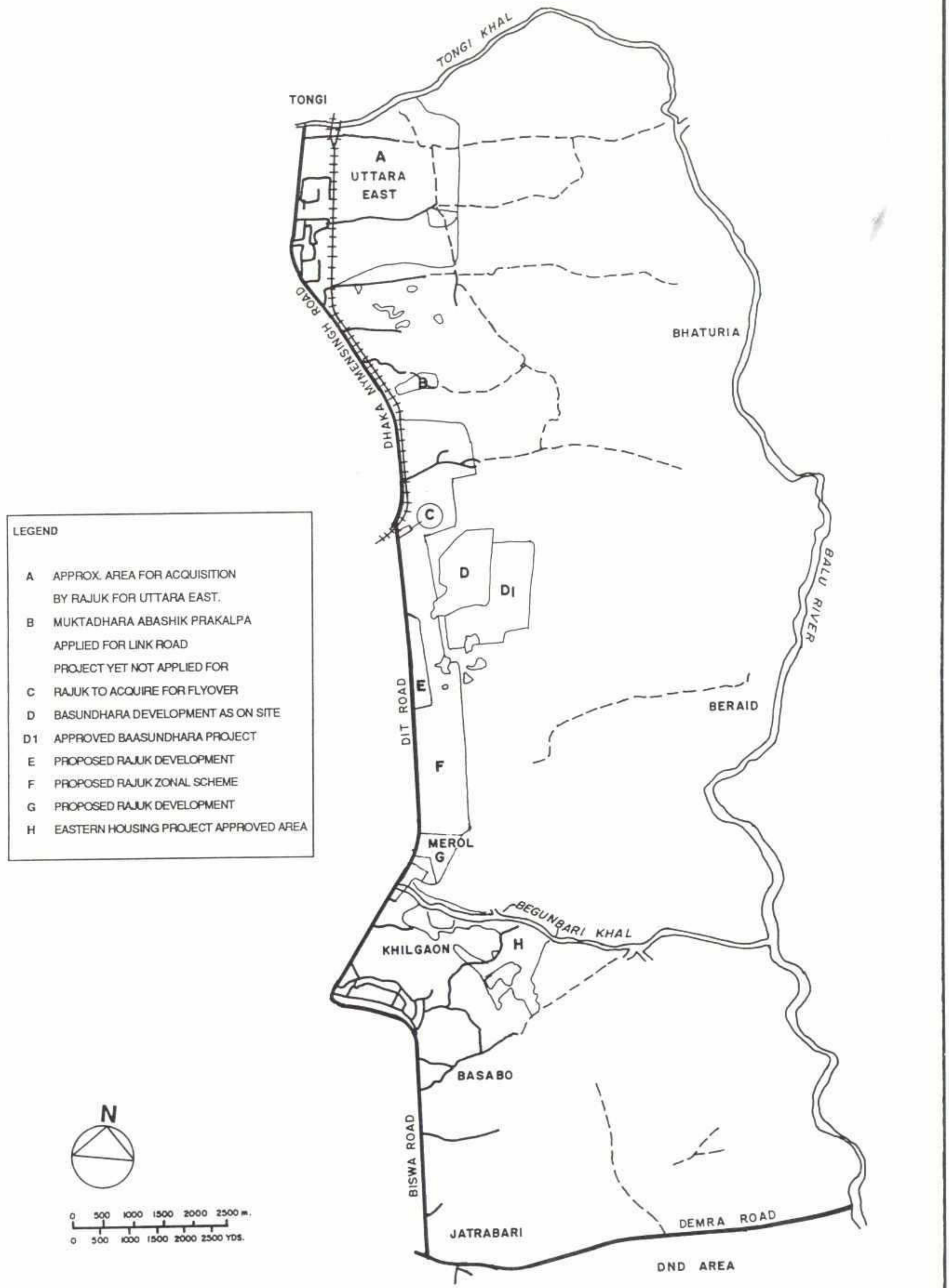

FIG. 2.4 DEVELOPMENT COMMITMENTS : GREATER DHAKA EAST

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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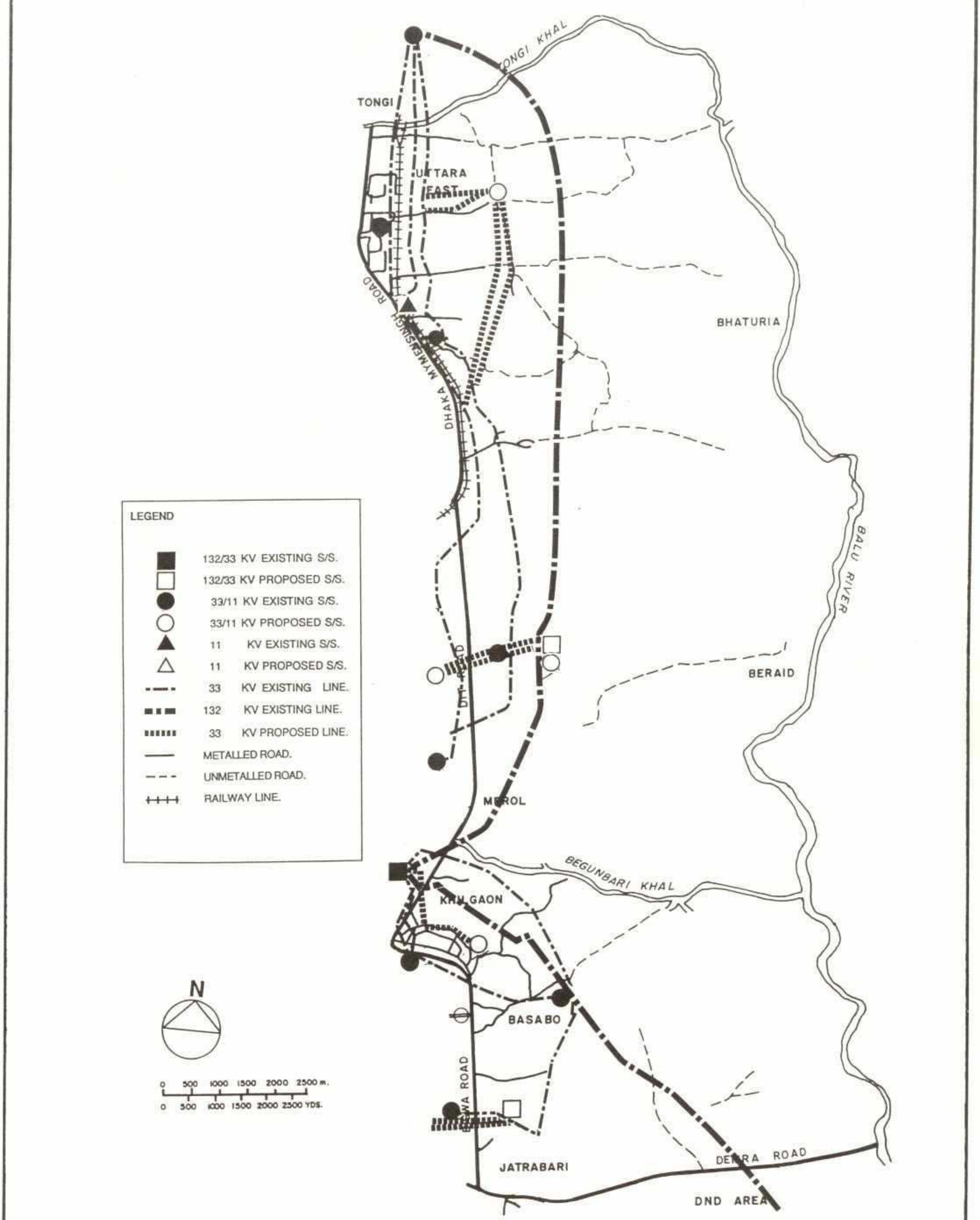

FIG. 2.5 INFRASTRUCTURE : GREATER DHAKA EAST

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

86

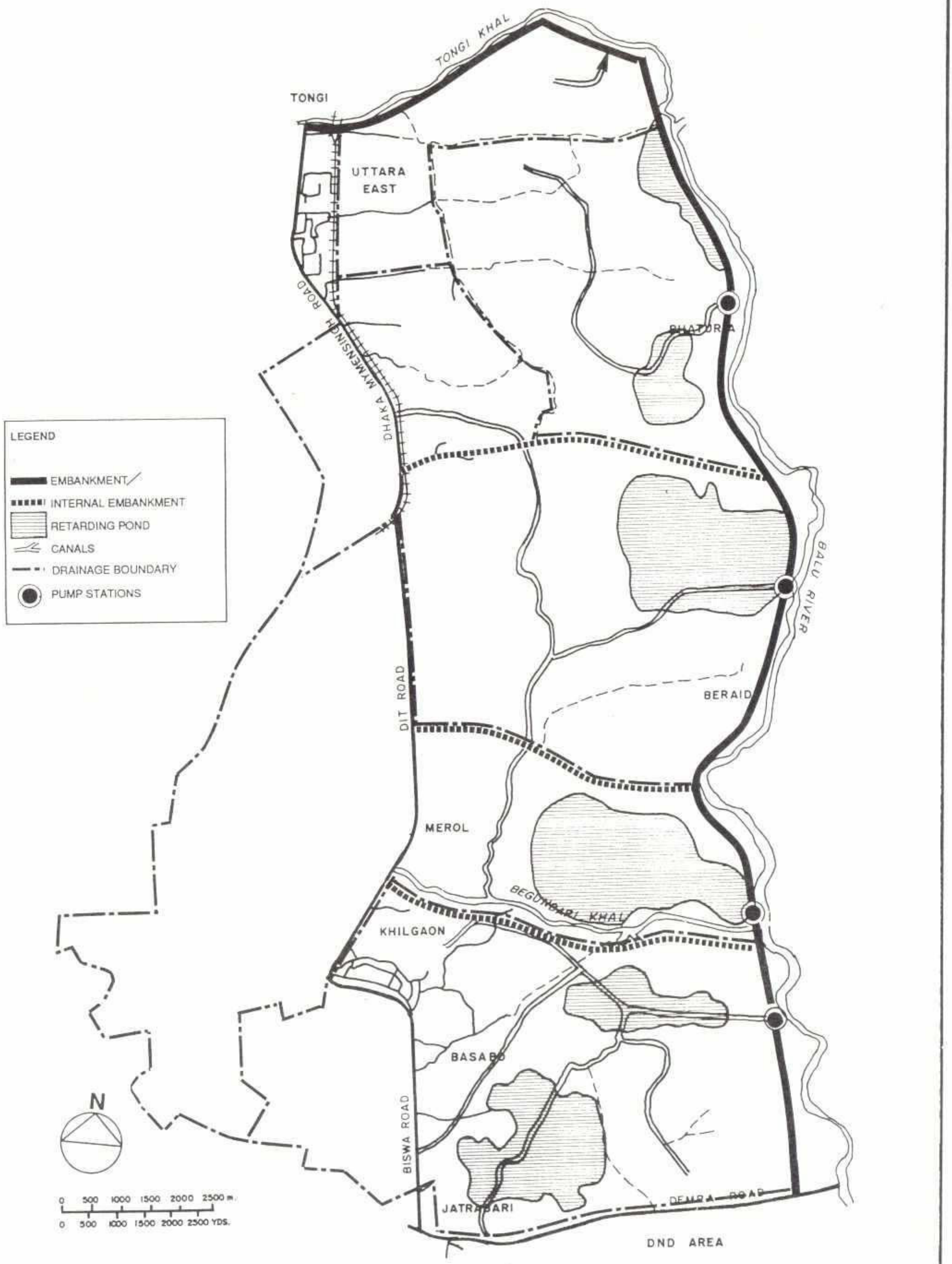

FIG. 2.6 FLOOD PROTECTION PROPOSAL : GREATER DHAKA EAST

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

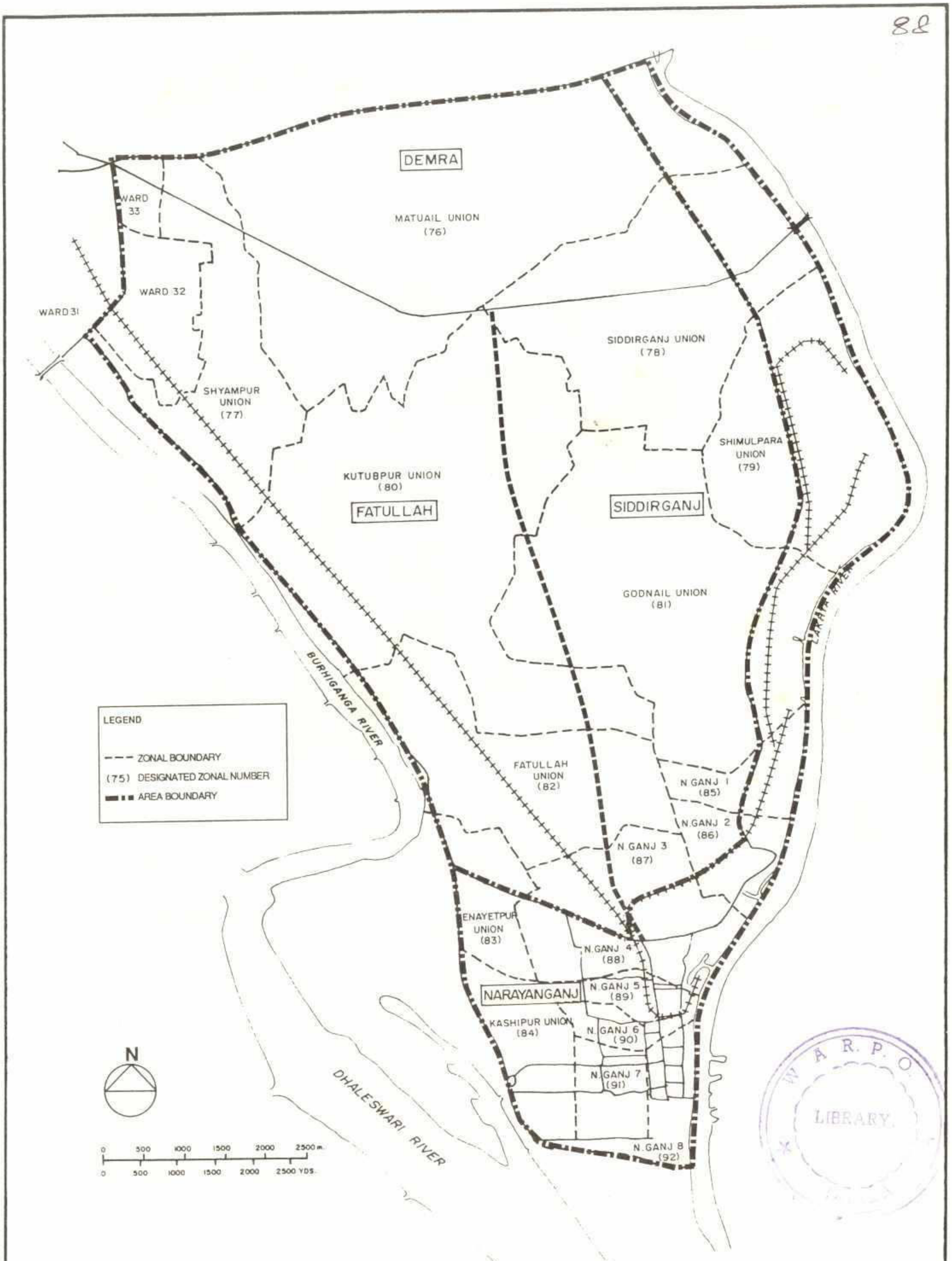

FIG. 2.7 BASE MAP : DND/NARAYANGANJ WEST

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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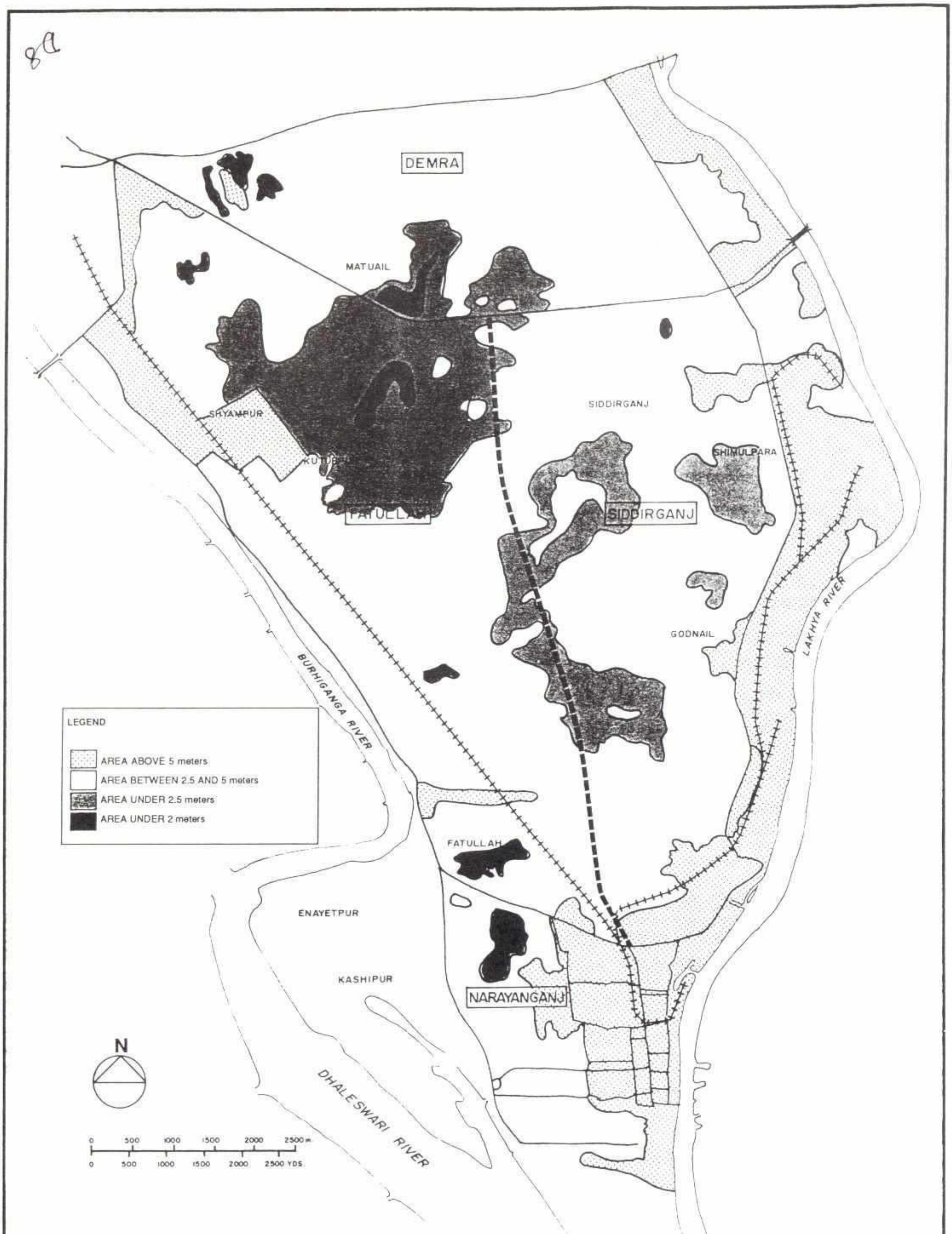

FIG 2.8 EXISTING LAND HEIGHT : DND/NARAYANGANJ WEST

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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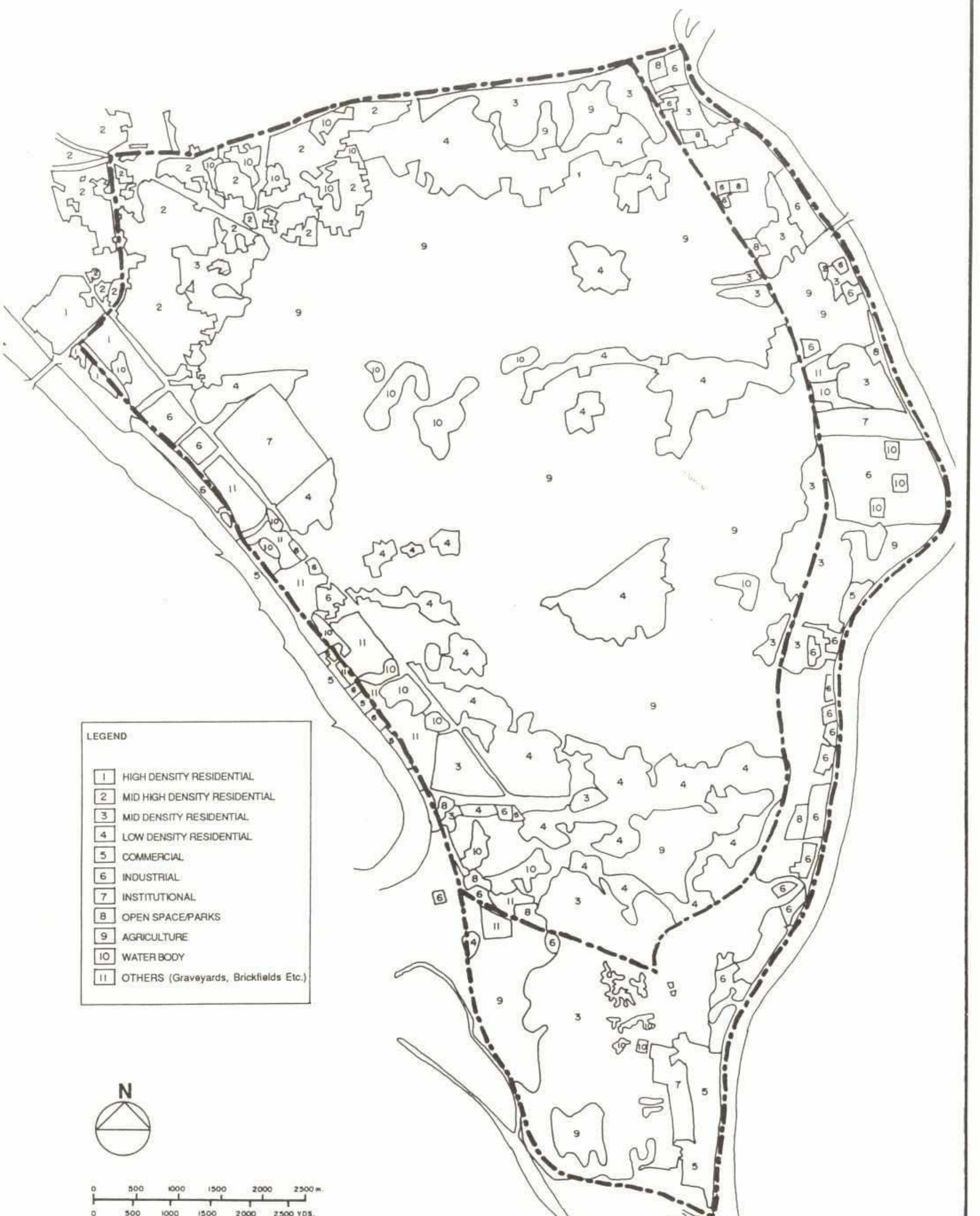

FIG. 2.9 EXISTING LAND USE : DND/NARAYANGANJ WEST

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

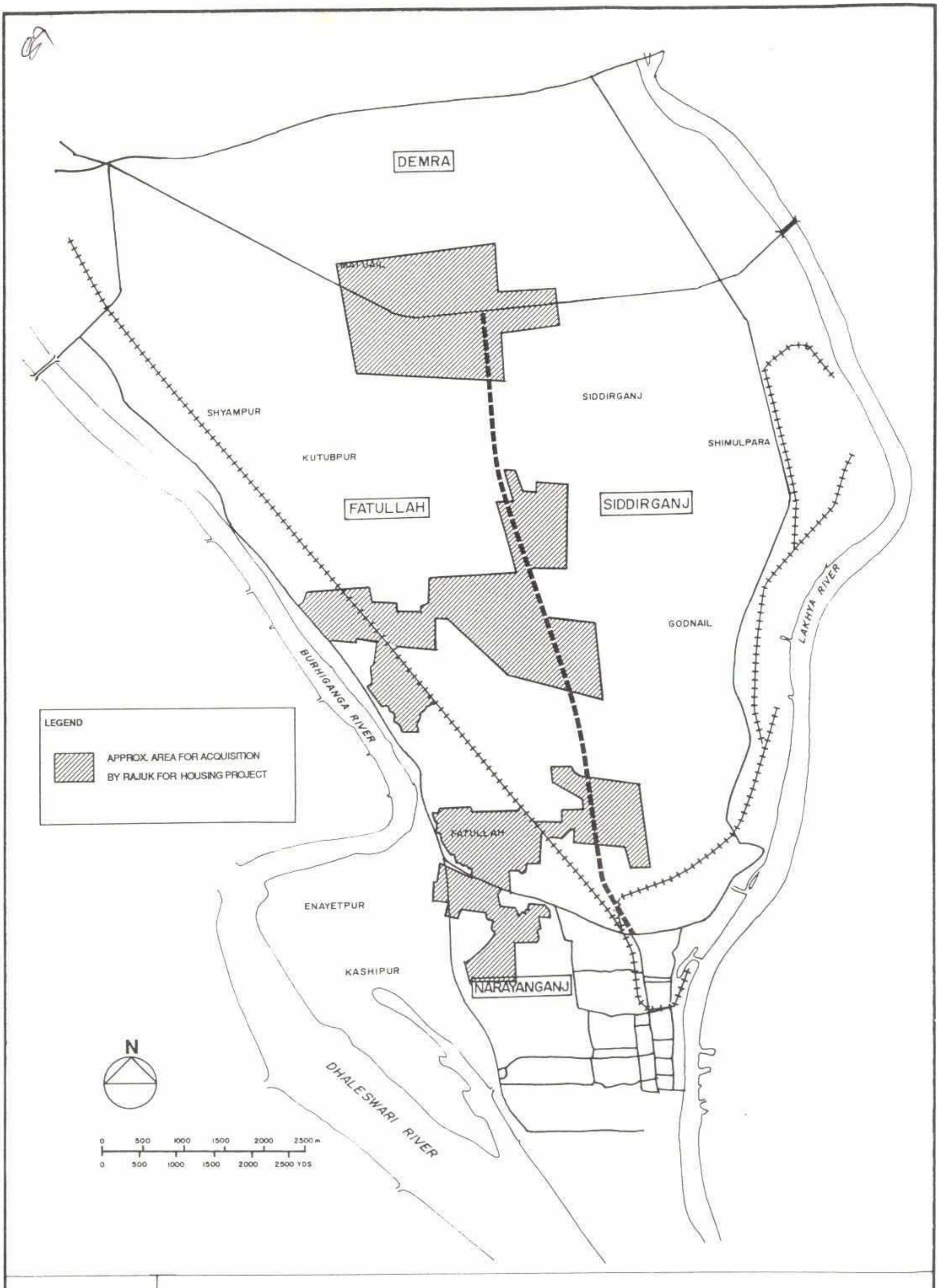

FIG. 2.10 DEVELOPMENT COMMITMENTS : DND/NARAYANGANJ WEST

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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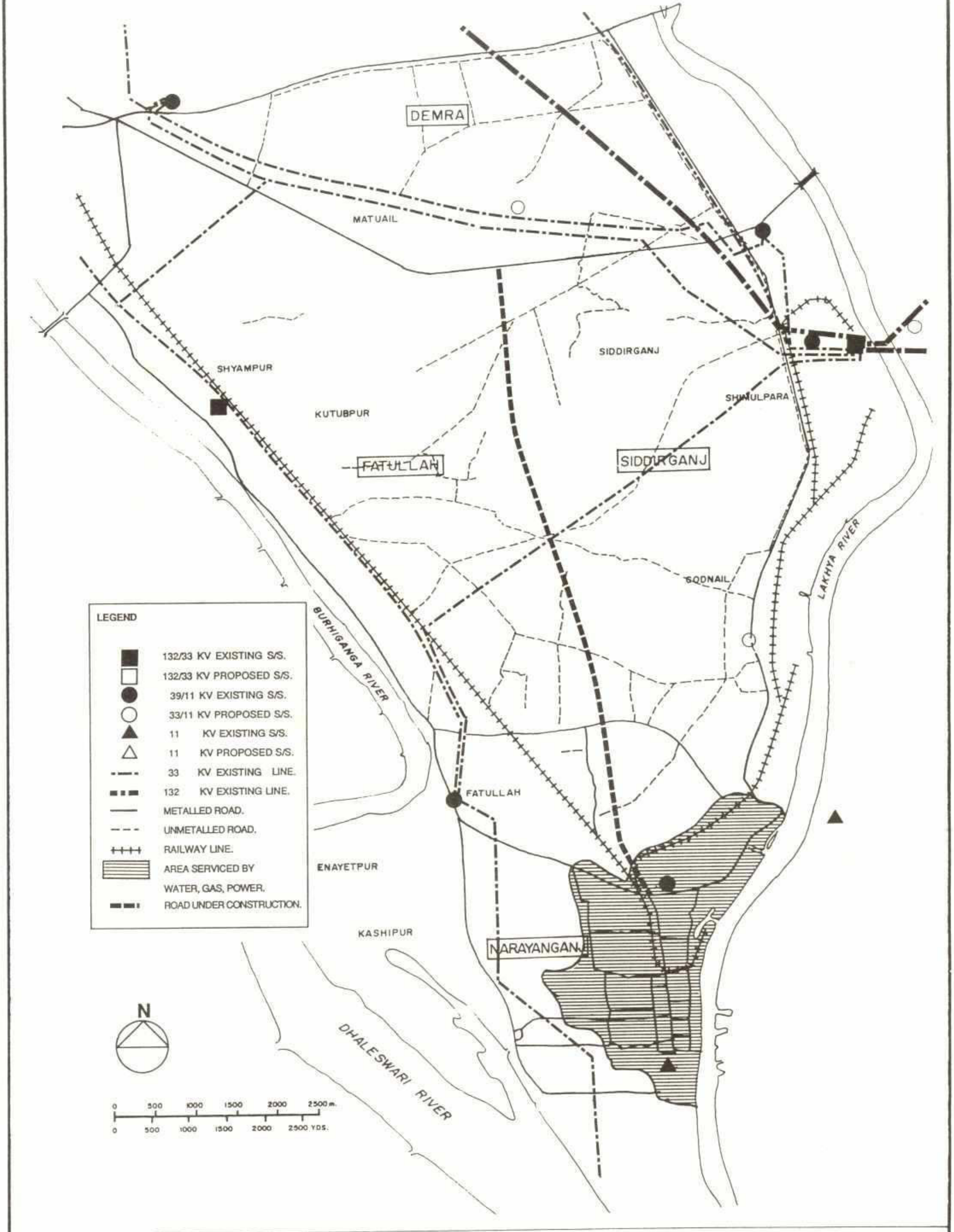

FIG. 2.11 INFRASTRUCTURE : DND/NARAYANGANJ WEST

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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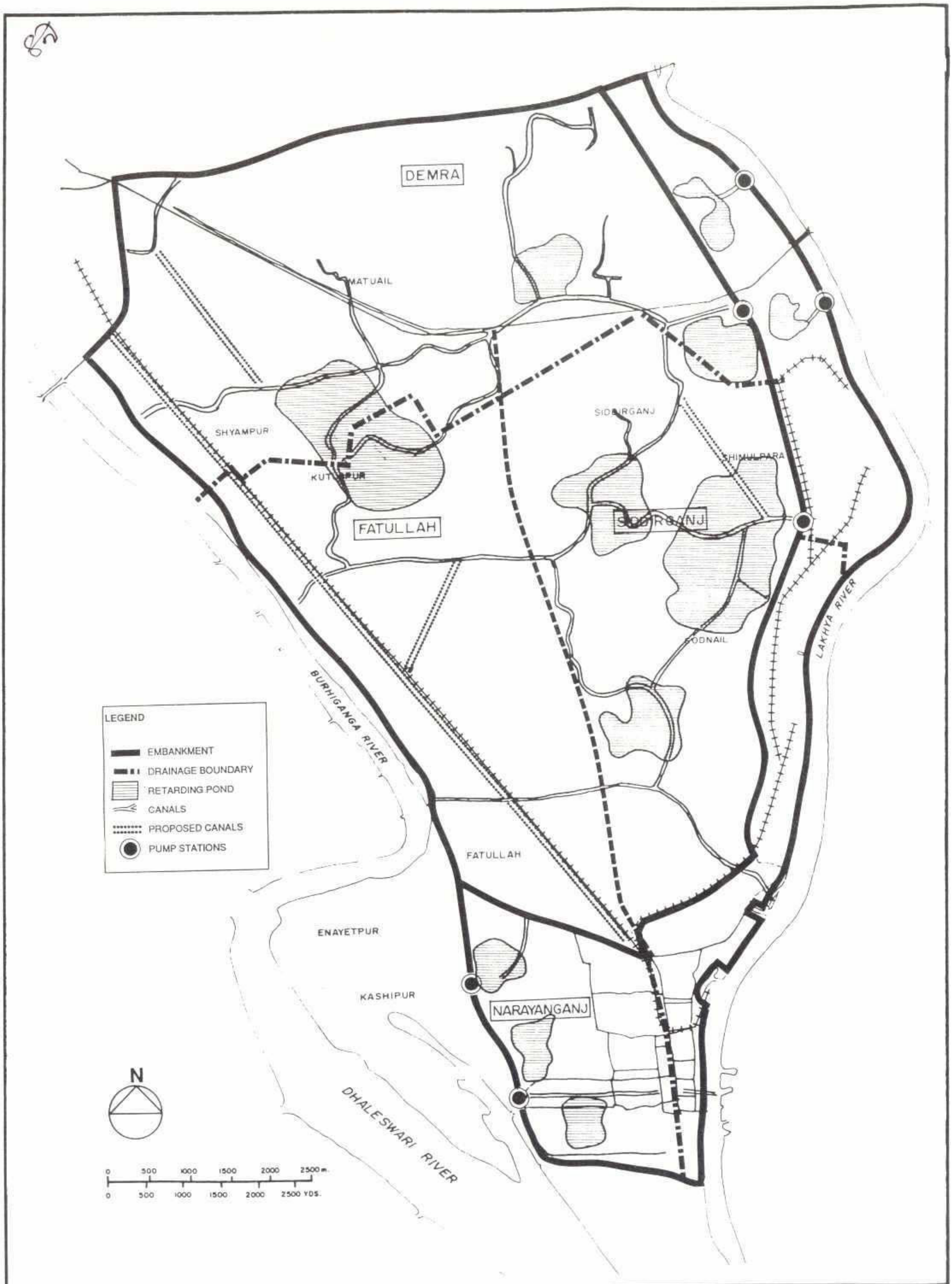

FIG. 2.12	FLOOD PROTECTION PROPOSAL : DND/NARAYANGANJ WEST

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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CHAPTER 3
HYDROLOGY

Chapter 3 : Hydrology

3.1 General

Hydraulic Simulation Models for drainage areas are studied in order to check the effects of proposed retarding ponds and pump stations.

3.2 River and Khal System

3.2.1 River System

The study area is strongly affected by the three international rivers of the Ganges the Brahmaputra-Jamuna River and the Meghna River.

The study area is surrounded by tributaries and distributaries of the Ganges and the Brahmaputra - Jamuna River. The river system is shown in Fig. 3.1.

The feasibility study area is surrounded by the Tongi Khal in the north, the Balu River and the Lakhya River in the east, the Dhaleswari River in the south and the Buriganga River in the west.

The floods are caused by these rivers, which are affected by the big flood discharge through the Ganges and the Brahmaputra-Jamuna River on the high backwater stage of the Meghna River.

3.2.2 Khal System

There are three big khal networks in the study area. They are the Begunbari khal, the Jamair khal and the Boalia Khal in Greater Dhaka East, and a braided khal system in Narayanganj DND. They are shown in Figs 3.2 (1) and (2).

3.3 Features of Storm Rainfall and Flood Water Level

3.3.1 Hydrological Observation Network and Available Data

The hydrological observation network in and around the study area is shown in Fig. 3.1. There are nine (9) active and two (2) closed rainfall gauging stations and fourteen (14) active water level gauging stations.

The period of gauging and available data at each gauging station is shown in Table 3.1. There were only two automatic rain gauges in the study area, but they have not been used since 1984. The others are all measured manually once a day at 9:00 A.M.

There is only one automatic gauging station at Mill Barak. The others are measured manually five times daily at 6:00, 9:00, 12:00, 15:00, 18:00.

Period of gauging and available data at each station is shown in Table 3.2.

There is some inconsistency with the water level data of Narayanganj (St. 180) during the transition period from BWDB to BIWTA, though the annual maximum water level data are the same. Hence, the data of this station is somewhat less reliable in comparison to others.

3.3.2 Features of Storm Rainfall

In the master plan, possible storm rainfall values were calculated. The pump drainage plans including retarding ponds were formulated by using two (2) days consecutive rainfall with a 5-year return period as the typical design hyetograph.

Furthermore, rainfall intensity and duration curves were formulated for various return periods. The drainage channels and culverts were planned by using the curve with a 5-year return period.

Areal reduction curves for converting point rainfall to basin main rainfall were made.

1) Probable Storm Rainfall

Probable storm rainfalls were calculated by Gamble-Chow's method by using the maximum one day, two days, five days and one month rainfall data shown in Tables 3.3 to 3.6 during the Master Plan Study stage.

The correlation among rainfall stations of Dhaka (B.M.D), Joydebpur (BWDB St. 17), Savar (BWDB St. 31) and Narayanganj (B.M.D), which have a long duration of observed data and are considered representative stations of the study area, were studied for two days consecutive rainfalls which are the most dominant rainfalls for causing internal floods of Dhaka area as described in the 1987 JICA study.

However no correlation could be found among them. It shows that using point rainfall data for a specific area seems more reasonable than using basin mean rainfall data.

The frequency analysis was carried out and the results are shown in Table 3.7, which shows that probable rainfalls at the four stations are almost same for one day and two days rainfall of a 2-year and a 5-year return periods. Then the probable rainfall values at Dhaka (B.M.D) for one day and two days rainfall of a 2-year and a 5-year return periods, are also applicable to Savar, Tongi and Narayanganj.

The difference in probable rainfall values at Dhaka (B.M.D) between the 1987 JICA study and this study is shown in the following table :

PROBABLE RAINFALL AT DHAKA (B.M.D)

(Unit : mm)

Duration	Return Period	This Study	1987 JICA Study
1 day	2 Year	137	135
	5 Year	184	192
2 day	2 Year	184	183
	5 Year	239	245

As shown above, probable rainfalls are almost same between the two studies.

Hence, the above values of the 1987 JICA Study are also applicable. Furthermore, the 1987 JICA Study's values of a 5-year return period are more safer than those of this study.

The design hyetograph for planning pump drainage facilities was determined to use the design rainfall of two days consecutive rainfall with a 5-year return period and shown in Fig. 3.3.

In order to get an appropriate rainfall runoff, various kind of calculation models including rational method, storage function method, NAM model etc. are available.

The Rational Method has been used by the study, because this is the most convenient and simplest method among the above rainfall runoff methods, and has been used in the storm water drainage improvement studies not only for Dhaka, but also for many major cities in Asia.

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2) Rainfall Intensity and Duration

The rainfall intensity and duration curves up to 120 minutes were made for the storm rainfall with short duration in the 1987 JICA study. However, in the master plan, the curves were modified and extended up to 24 hours (Fig. 3.4).

Drainage channels and culverts were designed by using the above rainfall intensity curve with a 5-year return period. The curve is expressed as follows :

$$i = 9005 / (t + 50) \quad \text{for } t \leq 2.0 \text{ hr}$$

$$i = 12{,}437 / (t + 115) \quad \text{for } 2.0 \text{ hr} \leq t \leq 24.0 \text{ hr}$$

where,

i : rainfall intensity (mm / hr)

t : duration (minutes).

3) Areal Reduction of Point Rainfall

In order to convert the design point rainfall at Dhaka (B.M.D) to a design basin mean rainfall of each sub-catchment in the drainage area, areal reduction curves were made in the master plan stage (see Fig. 3.5). These curves are also applied in this study.

3.3.3 Features of Flood Water Level

1) Historical Floods

Major floods recorded in the Dhaka Metropolitan area occurred in 1954, 1955, 1958 1970, 1974, 1980, 1984, 1987 and 1988.

The maximum water levels at Mill Barak (St.42) and Demra (St.7.5) and Savar (St. 69) during the major floods are listed as follows :

ANNUAL MAXIMUM DAILY WATER LEVEL

Flood Year	Demra (St. 7.5)	Mill Barak (St. 42)	Savar (St.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	6.60	8.30
1988	7.10	7.54	9.68

Note :

1) The above water levels of Mill Barak (St.42) and Demra (St.7.5) are revised based on the results of check survey conducted by the 1987 JICA study

2) 1988 Floods

The 1988 floods were the biggest recorded one. It was caused not just only by the abnormally heavy and intensive rainfall in the upper catchment areas of the Ganges and the Brahmaputra-Jamuna River from the end of August to the beginning of September, but also by the high backwater stage of the Meghna River which coincided with the floods.

The monthly rainfall amount during August and September, 1988 in and around Dhaka area was only 2/3 of annual average (Fig. 3.6).

Figs. 3.7 and 3.8 show the daily rainfall and the maximum water level during August and September, 1988.

The 1988 floods are likely characterized as follows :

(a) The contribution of the rainfall in Dhaka area to the floods was not much.

(b) The sharp hydrographs in the north western part and the gentle ones in the east and south parts confirm the fact that the 1988 floods came mainly from the direction of the Brahmaputra-Jamuna River.

3) Probable Flood Water Level

The available annual maximum water levels are shown in Table 3.8.

Probable flood water levels in and around the study area are revised based on the supplementary water level data from Narayanganj (BWDB St. 180).

In order to estimate water levels of long return periods like 50 years and 100 years, it is necessary to analyze data of long duration including the 1988 floods.

The following gauging stations were selected for the analysis :

1)	Mill Barak (St. 42)	:	37 years data
2)	Savar (St. 69)	:	33 years data
3)	Demra (st. 7.5)	:	35 years data by combining Demra (St. 7.5) and Demra (St. 179) using their correlation.
4)	Narayanganj (St. 180)	:	35 years data

Correlation between the water level data of Mill Barak (St. 42)/ Savar (st. 67)/ Demra (st. 7.5) and other data are checked. They are shown in Figs. 3.9 (1) to (3) and also listed as follows :

CORRELATION OF WATER LEVEL GAUGING STATIONS

Station (X) Station (Y)	Mill Barak (St. 42)	Savar (St. 69)	Demra (St.7.5)
Mirpur (St. 302)	Y = 1.15 x +0.344	-----	----
Tongi (St. 299)	Y = 1.04 x +0.267	-----	----
Hariharpara (St. 43)	Y = 0.848 x +0.543	-----	----
Nayarhat (st. 14.5)	---	Y = 1.105 x -0.432	----
Kalatia (St. 70)	---	Y = 0.867 x +0.367	----
Demra (St. 179)	----		Y = 0.943 x +0.267
Narayanganj (St. 180)	----		Y = 0.848 x +0.561
Pubali (St. 7)	----		Y = 1.066 x -0.130
Rekabi Bazar (St. 71A)	----		Y = 0.834 x +0.549
Kalagachia (St. 71)	----		Y = 0.752 x +0.896

For Mill Barak (St. 42), Savar (St. 69) and Demra (St. 7.5), frequency analysis is conducted by Gumble - Chow's method.
The other probable water levels are calculated by using the correlation above. They are shown in Table 3.9.

The return periods of the 1987 floods and the 1988 floods are estimated as follows :

RETURN PERIOD OF THE 1987 FLOODS AND THE 1988 FLOODS

Station	1987 Floods	1988 Floods
Demra (St. 7.5)	8-Year	50-Year
Mill Barak (St. 42)	10-Year	70-Year
Savar (St. 69)	15-Year	200-Year

3.4 Hydraulic Simulation for Drainage Area

3.4.1 Objective of Hydraulic Simulation

The objective is to check the effects of proposed storm water drainage improvement facilities such as drainage channels, retarding ponds and pump stations by one dimensional unsteady flow model using Mike 11 software.

Case 1-2 : Without retarding ponds and without pump stations under gravity flow condition.

Case 1-2 : Without retarding ponds and without pump stations under gravity flow condition.

Case 2-1 : Without retarding ponds and without pump stations under pump operating condition.

Case 2-2 : Without retarding ponds and without pump stations under pump operating condition.

2) Boundary Conditions :

(1) Rainfall run-off of sub-catchments

Rainfall run-off of sub-catchments are calculated by the Rational formula using the design hyetograph.

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(2) Water Level of the Lakhya River

Low water levels of the Lakhya River and the Balu River are 3.0 m (PWD) for gravity flow condition and high water levels for pump operating condition are 5.65~5.75 m (PWD) for the Lakhya River and 6,00~6.50 m (PWD) for the Balu River.

3.4.2 Hydraulic Simulation of Greater Dhaka East

1) Drainage Networks

In the Master Plan, the proposed drainage improvement facilities of drainage channels, pump stations and retarding areas were planned by using the following methods :

(1) Drainage Channel :

- Drainage channels is designed by using the design discharge given by rainfall runoff calculation.

- Rainfall runoff calculation is conducted by the Rational formula using the rainfall intensity curve of a 5-year return period.

- Channel size is determined mainly by conducting uniform flow calculation.

(2) Pump Station :

- Pump capacity is determined by mass curve analysis so as to discharge out the total runoff amount of 2 days consecutive rainfall with a 5-year return period within 2 days.

(3) Retarding Area :

- Retarding pond capacity is determined by mass curve analysis so as to pond the maximum difference between the accumulated amount of rainfall runoff and that of pump discharge during 2 days.

Due to the flat topography and a rather complex network of the drainage system, it is necessary to check the validity of the above design by unsteady flow calculation. Especially the retarding effect can be checked by the hydraulic simulation.

2) Basic Conditions

(1) Cases of Simulation

Cases of simulation for the area are following four cases :

There are three big khals in the Greater Dhaka East. They are the Boalia Khal, the Jamair Khal and the Begunbari Khal. The khal systems of the Jamair Khal and the Begunbari Khal are rather complicated, then the designs of drainage channels, pump stations and retarding areas are checked by one-dimensional flow model of Mike 11 for these khals.

The drainage zones of these khals are determined as follows:

Jamair Khal	:	Sub-drainage zone DC-2
Begunbari Khal	:	Sub-drainage zone DC-3
		Sub-drainage zone DC-4

The drainage networks for hydraulic simulation are shown in Figs.3.10(1) to (3).

(2) Boundary Conditions

Rainfall run-off of the sub-catchments area calculated by the rational formula using the design hyetograph and input in to the network as boundary discharge or lateral inflow.

Water level of the Balu River is LWL for gravity flow condition and HWL for pump operating condition.

	LWL(m)	HWL(m)	Pump capacity(m3/s)
DC - 2	3.00	6.15	54.6
DC - 3	3.00	6.05	53.1
DC - 4	3.00	6.00	47.2

3) Result of Simulation

The results of simulation show that the peak water levels without retarding ponds are higher than the design banks, but with retarding ponds lower than the design banks with a little larger allowance in the channels downstream of the retarding ponds (Fig.3.11).

The simple design method applied for this study can be said appropriate but somewhat conservative.

3.4.3 Hydraulic Simulation of DND

1) Drainage Network

The area is low-lying and flat and the drainage system is like a braided one. The drainage network is composed of drainage channels, retarding ponds and pump stations which are proposed for the storm water drainage improvement. The drainage channels the sub-catchments and the drainage network for hydraulic simulation are shown in Fig.3.12.

2) Boundary Conditions

Rainfall run-off of the sub-catchment areas were calculated by the Rational formula using the design hyetograph. The design hyetographs are created for each sub-catchment by each time of concentration as same as the design hyetograph.

Water level of the Lakhya River is LWL for gravity flow condition and HWL for pump operating condition.

	LWL(m)	HWL(m)	Pump capacity(m3/s)
KN - 2	3.00	5.75	14.5
KN - 4	3.00	5.65	50.2

3) Result of Simulation

The results of simulation shows that the peak water levels without retarding ponds are higher than the design banks, but with retarding ponds lower than the design banks (Fig.3.13).

It can be said that the simple design method using the rational formula, uniform flow calculation and mass curve calculation is adequate for designing drainage facilities such as drainage channels, pump stations and retarding areas.

TABLE 3.1 LIST OF RAINFALL GAUGING STATIONS AND AVAILABLE DATA

STATION NAME	AGENCY	STAION NO.		LOCATION	DATE OF ESTAB-LISHMENT	MEASUREMENT	DATA	REMARKS
1) DHAKA	B.M.D.	-	Latitude : Longitude :	23 deg. 46.0 min. N 90 deg. 23.0 min. E	1949	Manual Auto	1953 - 1990	Auto recorder(1957 - 1983)
2) NARAYANGANJ	B.M.D.	-	Latitude : Longitude :	23 deg. 37.0 min. N 90 deg. 30 .0min. E	1867	Manual	1948 - 1979	Closed in 1979
3) DHAKA	BWDB	9	Latitude : Longitude :	23 deg. 47.2 min. N 90 deg. 24.2 min. E	08. 07. 1960	Manual Auto	1957 - 1990	Incorporated into Dhaka(B.M.D.) in 1985
4) JOYDEBPUR	BWDB	17	Latitude : Longitude :	24 deg. 00.0 min. N 90 deg. 25.0 min. E	11. 03. 1961	Manual	1961 - 1990	
5) SAVAR	BWDB	31	Latitude : Longitude :	24 deg. 01.0 min. N 90 deg. 11.0 min. E	23. 11. 1961	Manual	1962 - 1990	
6) NARSINDI	BWDB	76	Latitude : Longitude :	23 deg. 57.3 min. N 90 deg. 44.5 min. E	06. 03. 1961	Manual	1961 - 1990	
7) BANCHARAMPUR	BWDB	351	Latitude : Longitude :	23 deg. 44.5 min. N 90 deg. 45.7 min. E	02. 03. 1961	Manual	1961 - 1990	
8) DAUDKANDI	BWDB	357	Latitude : Longitude :	23 deg. 32.0 min. N 90 deg. 43.0 min. E	27. 06. 1961	Manual	1983 - 1990	
9) MUNSHIGANJ	BWDB	365	Latitude : Longitude :	23 deg. 33.1 min. N 90 deg. 32.2 min. E	25. 11. 1960	Manual	1963 - 1990	
10) NARAYANGANJ	BWDB	368	Latitude : Longitude :	23 deg. 36.8 min. N 90 deg. 30.2 min. E	-	Manual	1961 - 1977	Closed in 1977
11) NAWABGANJ	BWDB	412	Latitude : Longitude :	23 deg. 39.5 min. N 90 deg. 10.0 min. E	13. 03. 1961	Manual	1965 - 1990	

42

TABLE 3.2 LIST OF WATER LEVEL GAUGING STATIONS AND AVAILABLE DATA

STATION NAME	AGENCY	STAION NO.	RIVER	LOCATION		DATE OF ESTAB-LISHMENT	MEASUREMENT	DATA OF WATER LEVEL	DATA OF DISCHARGE	DATA OF RATING CURVE
1) PUBAIL	BWDB	7	Balu	Latitude : Longitude :	23 deg. 56.5 min. N 90 deg. 29.8 min. E	26. 6. 1945	Manual	1945 - 1990	-	-
2) DEMRA	BWDB	7.5	Balu	Latitude : Longitude :	23 deg. 44.0 min. N 90 deg. 30.0 min. E	21. 10. 1964	Manual	1962 - 1990	1979 - 1989	1979 - 1987
3) NAYARHAT	BWDB	14.5	Bansi	Latitude : Longitude :	23 deg. 54.7 min. N 90 deg. 14.0 min. E	11. 06. 1963	Manual	1964 - 1988	1979 - 1989	1977 - 1989
4) MILL BARAK	BWDB	42	Buriganga	Latitude : Longitude :	23 deg. 41.9 min. N 90 deg. 25.3 min. E	10. 10. 1906	Manual Auto	1945 - 1990	-	-
5) HARIHARPARA	BWDB	43	Buriganga	Latitude : Longitude :	23 deg. 38.0 min. N 90 deg. 28.5 min. E	04. 06. 1945	Manual	1945 - 1990	-	-
6) SAVAR	BWDB	69	Dhaleswari	Latitude : Longitude :	24 deg. 01.0 min. N 90 deg. 11.o min. E	13. 07. 1945	Manual	1945 - 1990	-	-
7) KALATIA	BWDB	70	Dhaleswari	Latitude : Longitude :	23 deg. 42.9 min. N 90 deg. 15.9 min. E	01. 10. 1958	Manual	1968 - 1990	-	-
8) KALAGACHIA	BWDB	71	Dhaleswari	Latitude : Longitude :	23 deg. 34.7 min. N 90 deg. 32.7 min. E	15. 06. 1945	Manual	1977 - 1990	-	-
9) REKABI BAZAR	BWDB	71A	Dhaleswari	Latitude : Longitude :	23 deg. 34.4 min. N 90 deg. 29.7 min. E	16. 12. 1965	Manual	1968 - 1990	-	-
10) DEMRA	BWDB	179	Lakhya	Latitude : Longitude :	23 deg. 44.0 min. N 90 deg. 31.5 min. E	18. 06. 1945	Manual	1952 - 1990	-	1977 - 1989
11) NARAYANGANJ	BWDB BIWTA	180	Lakhya	Latitude :	23 deg. 38.1 min. N 90 deg. 38.8 min. E	26. 06. 1946	Manual	1947 - 1990	-	-
12) MEGHNA FERRY GHAT	BWDB	275.5	Surma-Meghna	Latitude : Longitude :	23 deg. 36.2 min. N 90 deg. 37.5 min. E	25. 09. 1965	Manual	1968 - 1990	-	-
13) TONGI	BWDB	299	Tongi Khal	Latitude : Longitude :	23 deg. 52.8 min. N 90 deg. 24.2 min. E	25. 03. 1960	Manual	1960 - 1990	-	-
14) MIRPUR	BWDB	302	Turag	Latitude : Longitude :	23 deg. 47.3 min. N 90 deg. 20.3 min. E	-	Manual	1953 - 1990	1983 - 1989	1977 - 1989

TABLE 3.3 ANNUAL MAXIMUM DAILY RAINFALL

(unit : mm)

NO.	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	BANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	NAWABGONJ
		B.M.D.	B.M.D	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
				STA. NO.9	STA. NO.17	STA. NO.31	STA. NO.76	STA. NO.351	STA. NO.357	STA. NO.365	STA. NO.368	STA. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1963-1990	1961-1977	1965-1990
NO.	YEAR											
1	1948		-									
2	1949		119									
3	1950		183									
4	1951	-	149									
5	1952		133									
6	1953	90	-									
7	1954	147	-									
8	1955	115	86									
9	1956	326	149									
10	1957	73	62	72								
11	1958	137	158	113								
12	1959	125	134	120								
13	1960	141	160	112								
14	1961	185	202	154	140		168	137			116	
15	1962	116	87	81	107	246	110	-			-	
16	1963	189	197	207	127	87	146	171		73	163	
17	1964	114	231	144	161	165	136	-		-	-	
18	1965	177	-	222	173	179	122	118		112	109	127
19	1966	257	216	283	137	122	186	164		83	216	179
20	1967	125	137	98	140	142	126	146		109	118	96
21	1968	145	135	137	177	163	101	97		144	135	180
22	1969	86	252	76	69	93	157	244		109	91	72
23	1970	152	81	113	112	82	192	90		137	81	108
24	1971	251	106	196	126	88	202	135		127	-	128
25	1972	231	167	165	77	114	116	64		102	-	224
26	1973	168	170	216	206	133	144	182		127	115	129
27	1974	-	-	107	165	136	181	108		127	166	109
28	1975	143	132	158	165	235	122	179		127	132	105
29	1976	163	105	158	107	162	186	121		136	147	-
30	1977	100	193	149	104	126	123	90		141	-	53
31	1978	128	-	134	184	165	226	181		127		99
32	1979	108	-	127	229	187	157	184		127		61
33	1980	91		91	95	-	164	55		-		79
34	1981	83		81	125	114	285	136		82		86
35	1982	146		146	129	165	106	65		239		-
36	1983	128		133	193	146	199	188	125	174		179
37	1984	150		151	112	184	181	161	107	161		78
38	1985	92		92	83	107	164	61	94	113		81
39	1986	176		176	167	109	147	212	104	206		-
40	1987	138		138	153	99	120	174	155	69		79
41	1988	135		135	155	-	122	189	119	108		-
42	1989	118		118	129	102	89	73	125	84		69
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	146	150	139	140	140	154	138	118	126	132	111

226

TABLE 3.4 ANNUAL MAXIMUM TWO-DAY RAINFALL

(unit : mm)

NO.	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	BANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	NAWABGONJ
		B.M.D.	B.M.D.	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
				STA. NO.9	STA. NO.17	STA. NO.31	STA. NO.76	STA. NO.351	STA. NO.357	STA. NO.365	STA. NO.368	STA. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1963-1990	1961-1977	1965-1990
	YEAR											
1	1948		-									
2	1949		143									
3	1950		233									
4	1951		165									
5	1952		172									
6	1953	127	-									
7	1954	255	-									
8	1955	120	124									
9	1956	346	178									
10	1957	98	97	102								
11	1958	140	166	176								
12	1959	179	171	178								
13	1960	223	238	151								
14	1961	185	202	189	152		205	207			177	
15	1962	141	130	123	156	297	133	-			-	
16	1963	257	307	278	131	110	181	184		108	167	
17	1964	206	266	195	254	196	244	-		-	-	
18	1965	181	-	225	221	184	225	118		154	133	129
19	1966	270	302	339	229	167	211	251		100	302	202
20	1967	147	207	141	231	161	189	232		150	207	96
21	1968	240	263	235	210	197	168	172		259	263	183
22	1969	104	255	122	107	117	196	258		182	165	92
23	1970	262	132	185	147	118	232	134		164	133	172
24	1971	328	188	272	162	139	319	135		229	-	166
25	1972	251	183	215	117	145	191	98		178	-	292
26	1973	177	204	224	221	133	255	213		203	136	213
27	1974	-	-	183	182	136	237	147		229	170	154
28	1975	212	246	257	264	371	227	353		198	246	112
29	1976	263	194	275	199	250	310	168		224	218	-
30	1977	133	228	155	115	150	148	109		208	-	93
31	1978	191	-	185	267	199	230	186		168		160
32	1979	166	-	168	330	268	191	212		218		79
33	1980	125		125	132	-	203	86		-		109
34	1981	148		148	201	160	288	170		123		122
35	1982	167		167	181	208	182	96		301		-
36	1983	194		199	290	249	362	321	242	248		189
37	1984	200		201	160	261	247	234	180	219		105
38	1985	132		105	142	159	217	95	151	117		142
39	1986	321		321	271	164	234	270	196	277		-
40	1987	172		172	230	168	193	209	201	107		119
41	1988	175		175	283	-	200	301	138	155		-
42	1989	151		151	160	155	112	119	127	145		107
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	194	200	192	198	187	218	188	176	187	193	145

TABLE 3.5 ANNUAL MAXIMUM FIVE-DAY RAINFALL

(unit : mm)

NO	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	BANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	NAWABGONJ
		B.M.D.	B.M.D	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
				STA. NO.9	STA. NO.17	STA. NO.31	STA. NO.76	STA. NO.351	STA. NO.357	STA. NO.365	STA. NO.368	STA. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1963-1990	1961-1977	1965-1990
NO.	YEAR											
1	1948		-									
2	1949		224									
3	1950		295									
4	1951		198									
5	1952		183									
6	1953	150	-									
7	1954	323	-									
8	1955	181	182									
9	1956	430	259									
10	1957	184	191	175								
11	1958	170	166	200								
12	1959	309	298	297								
13	1960	331	257	188								
14	1961	317	264	226	283		264	299			264	
15	1962	164	160	164	223	297	204	-			-	
16	1963	327	350	325	144	188	234	338		188	197	
17	1964	241	299	231	295	238	315	-		-	-	
18	1965	219	-	239	307	277	272	192		241	203	147
19	1966	288	343	360	279	190	347	389		212	327	244
20	1967	250	292	223	326	170	329	317		223	292	179
21	1968	379	343	325	263	289	314	345		377	387	301
22	1969	199	297	200	192	173	361	313		227	240	126
23	1970	303	163	248	254	157	347	229		269	142	204
24	1971	355	331	296	300	273	616	180		381	-	236
25	1972	314	215	263	163	202	283	205		394	-	377
26	1973	205	252	271	269	154	420	344		381	168	225
27	1974	-	-	236	209	174	285	211		508	220	202
28	1975	401	429	445	475	507	331	576		315	428	230
29	1976	436	318	447	368	358	410	305		288	380	-
30	1977	175	308	198	189	192	264	123		273	-	160
31	1978	216	-	244	288	283	324	311		338		231
32	1979	234	-	180	500	446	239	222		396		142
33	1980	259		259	215	-	307	140		-		188
34	1981	168		168	309	185	349	278		174		175
35	1982	193		193	209	254	361	105		338		-
36	1983	250		255	363	286	450	419	407	284		249
37	1984	296		296	315	377	491	452	330	319		146
38	1985	169		169	302	262	329	130	193	147		170
39	1986	401		401	331	255	361	355	236	402		-
40	1987	234		234	406	203	272	390	290	168		151
41	1988	301		301	413	-	369	399	243	191		-
42	1989	152		152	178	208	195	129	128	207		175
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	265	265	255	289	254	333	285	261	290	271	203

TABLE 3.6 ANNUAL MAXIMUM MONTHLY RAINFALL

(unit : mm)

NO.	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	BANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	NAWABGONJ
		B.M.D.	B.M.D.	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
				STA. NO.9	STA. NO.17	STA. NO.31	STA. NO.76	STA. NO.351	STA. NO.357	STA. NO.365	STA. NO.368	STA. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1963-1990	1961-1977	1965-1990
NO.	YEAR											
1	1948		-									
2	1949		414									
3	1950		711									
4	1951	-	484									
5	1952		438									
6	1953	392	552									
7	1954	810	-									
8	1955	502	340									
9	1956	690	387									
10	1957	487	415	349								
11	1958	267	374	280								
12	1959	568	605	544								
13	1960	655	533	489								
14	1961	856	489	495	-		-	537				
15	1962	395	298	430	393	-	477	486			-	
16	1963	621	418	678	355	-	573	711		-	-	
17	1964	629	451	673	512	554	912	-		-	-	
18	1965	480	-	442	592	575	705	484		-	-	416
19	1966	496	479	607	490	391	581	671		414	501	439
20	1967	504	525	476	550	395	563	504		431	509	304
21	1968	590	502	449	565	537	588	451		565	501	471
22	1969	540	428	494	498	628	754	489		459	434	448
23	1970	496	285	414	439	403	601	355		396	304	365
24	1971	550	644	485	629	595	911	384		930	-	471
25	1972	380	356	469	274	357	589	295		808	-	491
26	1973	621	521	618	536	444	875	524		953	-	462
27	1974	-	634	604	593	485	1048	604		1514	623	670
28	1975	559	627	625	634	647	490	608		876	655	399
29	1976	627	542	649	487	547	722	602		736	647	-
30	1977	381	539	593	385	392	504	290		526	-	422
31	1978	529	-	583	788	542	898	716		500		285
32	1979	525	-	437	685	707	635	299		632		196
33	1980	414		411	411	-	676	362		-		422
34	1981	411		320	485	-	672	446		334		392
35	1982	514		514	494	489	568	288		501		-
36	1983	408		434	639	401	705	552	-	611		344
37	1984	891		707	559	591	1065	773	963	567		378
38	1985	399		399	530	352	504	235	526	288		258
39	1986	687		687	498	477	590	558	422	596		-
40	1987	526		526	744	532	636	520	460	429		-
41	1988	580		579	716	-	692	1069	374	418		-
42	1989	347		347	484	-	332	211	362	329		-
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	537	481	509	534	502	674	501	518	600	522	402

TABLE 3.7 PROBABLE STORM RAINFALL

(Unit : mm)

DURATION	RAIN STATION	RETURN PERIOD (YEAR)					
		2	5	10	20	50	100
1 day	Dhaka (B.M.D.)	137	184	215	244	283	311
	Savar (BWDB Sta.31)	133	171	196	220	251	274
	Joydebpur (BWDB Sta. 17)	133	167	190	211	239	260
	Narayanganj (B.M.D.)	142	184	212	239	273	299
2 day	Dhaka (B.M.D.)	184	239	276	311	357	391
	Savar (BWDB Sta.31)	177	231	267	301	346	379
	Joydebpur (BWDB Sta. 17)	189	240	275	308	350	382
	Narayanganj (B.M.D.)	191	239	270	301	340	369
5 day	Dhaka (B.M.D.)	251	324	372	418	478	523
	Savar (BWDB Sta.31)	240	316	367	416	479	527
	Joydebpur (BWDB Sta. 17)	274	351	402	451	514	561
	Narayanganj (B.M.D.)	253	314	355	394	444	482
1 month	Dhaka (B.M.D.)	514	636	716	793	892	967
	Savar (BWDB Sta.31)	486	573	630	686	757	811
	Joydebpur (BWDB Sta. 17)	515	619	687	753	838	901
	Narayanganj (B.M.D.)	437	558	620	679	757	814

49

TABLE 3.8 ANNUAL MAXIMUM WATER LEVEL

COMPARISON OF ANNUAL MAXIMUM WATER LEVEL RIVISED BY CHECH SURVEY

(UNIT :PWD in m)

NO.	STATION	PUBAIL	DEMRA	NAYARHAT	MILL BARAK	HARIHARPARA	SAVAR	KALATIA	KALAGACHIA	RAKABI BAZAR	DEMRA	NARAYANGANJ	MEGHNA FERRY GHAT	TONGI	MIRPUR
		BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
		STA. NO.7	STA. NO.7.5	STA. NO.14.5	STA. NO.42	STA.NO.43	STA. NO. 69	STA. NO.70	STA. NO. 71	STA. NO. 71A	STA. NO. 179	STA. NO.180	STA. NO.275.5	STA. NO.299	STA. NO. 302
	RIVER	BALU	BALU	BANGSHI	BURIGANGA	BURIGANGA	DHALESWARI	DHALESWARI	DHALESWARI	DHALESWARI	LAKHYA	LAKHYA	SURMA-MEGHNA	TONGI KHAL	TURAG
	DATA	1945-1990	1962-1990	1964-1990	1945-1990	1945-1990	1945-1990	1968-1990	1977-1990	1968-1990	1952-1990	1947-1990	1968-1990	1960-1990	1953-1990
NO.	YEAR														
1	1945	-			6.00	-	7.41								
2	1946	-			5.96	5.28	6.84								
3	1947	5.53			5.60	-	6.98					5.09			
4	1948	5.82			6.26	-	7.20					5.36			
5	1949	-			5.96	5.94	7.23					5.33			
6	1950	5.43			5.72	-	7.04					5.27			
7	1951	-			-	-	7.35					5.27			
8	1952	5.41			5.45	-	7.10				5.58	5.33			
9	1953	-			5.66	5.24	7.06				5.58	5.27			6.27
10	1954	6.65			7.02	6.22	8.17				6.52	6.04			7.64
11	1955	-			7.05	6.40	8.26				6.77	6.16			7.66
12	1956	6.19			5.64	4.82	6.83				5.73	5.24			6.03
13	1957	5.92			5.32	5.06	7.20				5.52	5.58			6.20
14	1958	6.54			6.41	-	-				5.97	5.46			7.17
15	1959	6.08			5.74	5.33	7.12				-	-			6.52
16	1960	6.17			6.06	5.53	7.57				-	-		6.40	6.62
17	1961	-			5.48	-	7.30				-	-		-	5.98
18	1962	6.92	6.29		-	-	-				-	5.94		7.27	7.57
19	1963	-	5.92		-	-	-				-	-		6.55	6.75
20	1964	-	6.40	8.16	-	-	-				-	-		7.00	7.17
21	1965	-	5.81	7.62	-	-	-				5.83	-		6.54	6.56
22	1966	-	6.24	8.00	-	-	-				6.30	-		6.78	6.98
23	1967	-	5.43	7.07	-	-	-				5.46	-		5.87	-
24	1968	-	6.08	8.03	6.30	5.85	7.69	6.84		5.75	6.09	5.90	5.68	6.70	6.76
25	1969	6.19	5.85	7.55	5.89	5.63	7.08	6.46		5.47	5.87	5.58	5.63	6.34	6.37
26	1970	6.74	6.24	8.69	6.47	6.04	7.99	7.10		5.85	-	-	5.87	7.11	7.17
27	1971	6.42	6.03	-	6.19	5.85	7.36	6.81		-	6.08	5.76	-	6.72	-
28	1972	5.64	5.40	6.97	5.26	5.01	6.66	6.07		5.00	5.44	5.12	5.11	5.81	5.74
29	1973	6.25	5.88	7.70	5.84	5.55	7.21	6.55		5.46	5.88	5.52	5.44	6.36	6.36
30	1974	6.95	6.58	8.44	6.57	6.34	7.80	7.12		6.07	6.60	6.23	6.19	7.10	7.09
31	1975	5.73	5.60	-	5.39	5.23	-	-		5.18	5.60	5.36	5.29	-	-
32	1976	5.64	5.47	6.44	5.13	4.98	6.31	5.98		-	5.53	5.17	5.32	-	-
33	1977	6.03	5.92	7.15	5.60	5.39	6.88	6.34	5.34	5.39	5.81	5.52	5.59	6.03	5.99
34	1978	-	-	6.48	5.22	5.05	6.29	5.83	5.03	-	5.43	5.22	-	5.56	5.51
35	1979	-	5.59	6.46	5.25	5.08	-	-	-	-	5.49	5.00	-	5.60	5.54
36	1980	6.66	6.23	8.58	6.39	-	-	7.21	-	5.61	-	6.03	-	6.99	7.20
37	1981	-	5.74	6.74	5.42	-	-	-	-	-	5.65	-	5.40	-	5.79
38	1982	-	6.00	6.34	-	-	-	-	-	-	5.35	5.20	5.19	6.02	5.41
39	1983	6.05	5.90	7.23	5.73	5.43	6.96	6.38	5.44	5.49	5.81	5.54	5.56	6.40	6.03
40	1984	6.35	6.33	8.12	6.00	5.72	7.58	7.11	5.91	5.74	6.04	5.77	5.73	7.10	6.63
41	1985	5.83	5.70	7.04	5.37	5.12	6.70	6.18	5.06	5.28	5.57	5.33	5.44	5.75	5.79
42	1986	5.70	5.25	6.77	4.96	4.82	6.69	6.20	4.65	4.97	5.14	5.03	5.03	5.50	5.43
43	1987	6.90	6.46	8.74	6.60	6.23	8.30	7.53	5.92	6.02	6.38	6.09	5.99	7.02	7.30
44	1988	7.29	7.10	9.90	7.54	7.17	9.68	8.91	5.97	6.43	-	6.63	6.55	7.96	8.39
45	1989	5.47	5.44	6.21	5.06	4.78	6.34	5.92	5.04	5.10	5.34	5.23	-	5.38	5.42
46	1990	-	-	-	-	-	-	-	-	-	-	5.23	-	-	-
	AVERAGE	6.16	5.96	7.52	5.88	5.54	7.28	6.70	5.37	5.55	5.81	5.52	5.59	6.46	6.52

Notes : 1) The above water levels of Mill Barak, Mirpur, Tongi and Demra(Sta. 7.5) are revised by the results of check survey conducted in 1987 JICA STUDY .

2) The equations for the revision are as follows ;

Mill Barak : $Y=X-0.037$ where, X : raw data

Mirpur : $Y=X+0.042$ Y : revised data

Tongi : $Y=X+0.122$

Demra(7.5) : $Y=X+0.007$

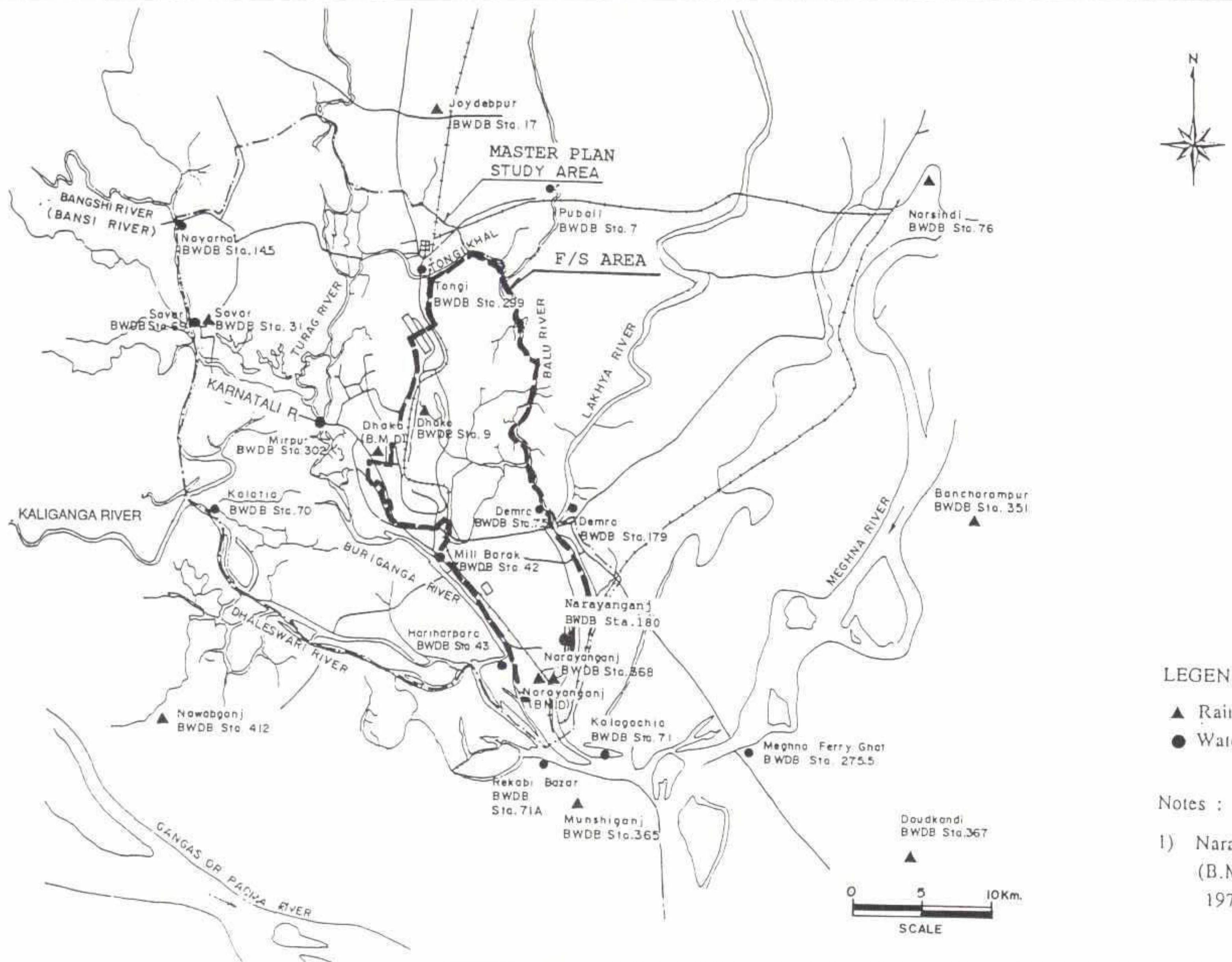
TABLE 3.9 PROBABLE FLOOD WATER LEVEL

(Unit : PWD in m)

WATER LEVEL STATION	RETURN PERIOD (YEAR) 2	3	5	10	20	30	50	100	200	300	400	500	1988 Flood	1987 Flood	1974 Flood
1) Pubail (BWDB Sta. 7)	6.15	6.34	6.55	6.83	7.09	7.24	7.43	7.67	7.93	8.08	8.17	8.26	7.29	6.90	6.95
2) Demra (BWDB Sta. 7.5)	5.89	6.07	6.27	6.53	6.77	6.91	7.09	7.32	7.56	7.70	7.79	7.87	7.10	6.46	6.58
3) Nayarhat (BWDB Sta. 14.5)	7.49	7.80	8.14	8.56	8.98	9.21	9.51	9.91	10.31	10.54	10.71	10.84	9.90	8.74	8.44
4) Mill Barak (BWDB Sta. 42)	5.78 (5.82)	6.03 (6.04)	6.30 (6.29)	6.65 (6.59)	6.98 (6.89)	7.17 (7.09)	7.40 (7.27)	7.72 (7.56)	8.04	8.23	8.36	8.46	7.54	6.60	6.57
5) Hariharpara (BWDB Sta. 43)	5.45	5.66	5.89	6.19	6.47	6.63	6.82	7.10	7.37	7.53	7.64	7.72	7.17	6.23	6.34
6) Savar (BWDB Sta. 69)	7.17	7.45	7.76	8.14	8.52	8.73	9.00	9.36	9.72	9.93	10.08	10.20	9.68	8.30	7.80
7) Kalatia (BWDB Sta. 70)	6.58	6.83	7.09	7.42	7.75	7.94	8.17	8.48	8.79	8.98	9.11	9.21	8.91	7.53	7.12
8) Kalagachia (BWDB Sta. 71)	5.33	5.46	5.61	5.81	5.99	6.09	6.23	6.40	6.58	6.69	6.75	6.81	5.97	5.92	-
9) Rakabi Bazar (BWDB Sta. 71A)	5.46	5.61	5.78	6.00	6.20	6.31	6.46	6.65	6.85	6.97	7.05	7.11	6.43	6.02	6.07
10) Demra (BWDB Sta. 179)	5.82	5.99	6.18	6.42	6.65	6.78	6.95	7.17	7.40	7.53	7.61	7.69	-	6.38	6.60
11) Narayanganj (BWDB Sta.180)	5.56	5.71	5.88	6.10	6.30	6.42	6.57	6.77	6.97	7.09	7.17	7.23	6.63	6.09	6.23
12) Tongi (BWDB Sta. 299)	6.28 (6.46)	6.54 (6.70)	6.82 (6.97)	7.18 (7.33)	7.53 (7.67)	7.72 (7.86)	7.96 (8.11)	8.30 (8.43)	8.63	8.83	8.96	9.07	7.96	7.02	7.10
13) Mirpur (BWDB Sta. 302)	6.30 (6.42)	6.59 (6.64)	6.90 (6.91)	7.30 (7.25)	7.68 (7.58)	7.90 (7.76)	8.17 (8.00)	8.53 (8.31)	8.90	9.12	9.27	9.39	8.39	7.30	7.09

Notes : 1) The results of the check survey for the water level gauging stations of Mill Barak, Mirpur, Tongi and Demra(Sta. 7.5) conducted by 1987 JICA STUDY are reflected.

2) Water levels in the parentheses are probable water levels of 1987 JICA STUDY.



LEGEND

▲ Rainfall gauging station

● Water level gauging station

Notes :

1) Narayangang Rainfall Station (B.M.D.) was closed in 1979.

FIG. 3.1	RIVER SYSTEM AND GAUGING STATIONS IN AND AROUND 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

90

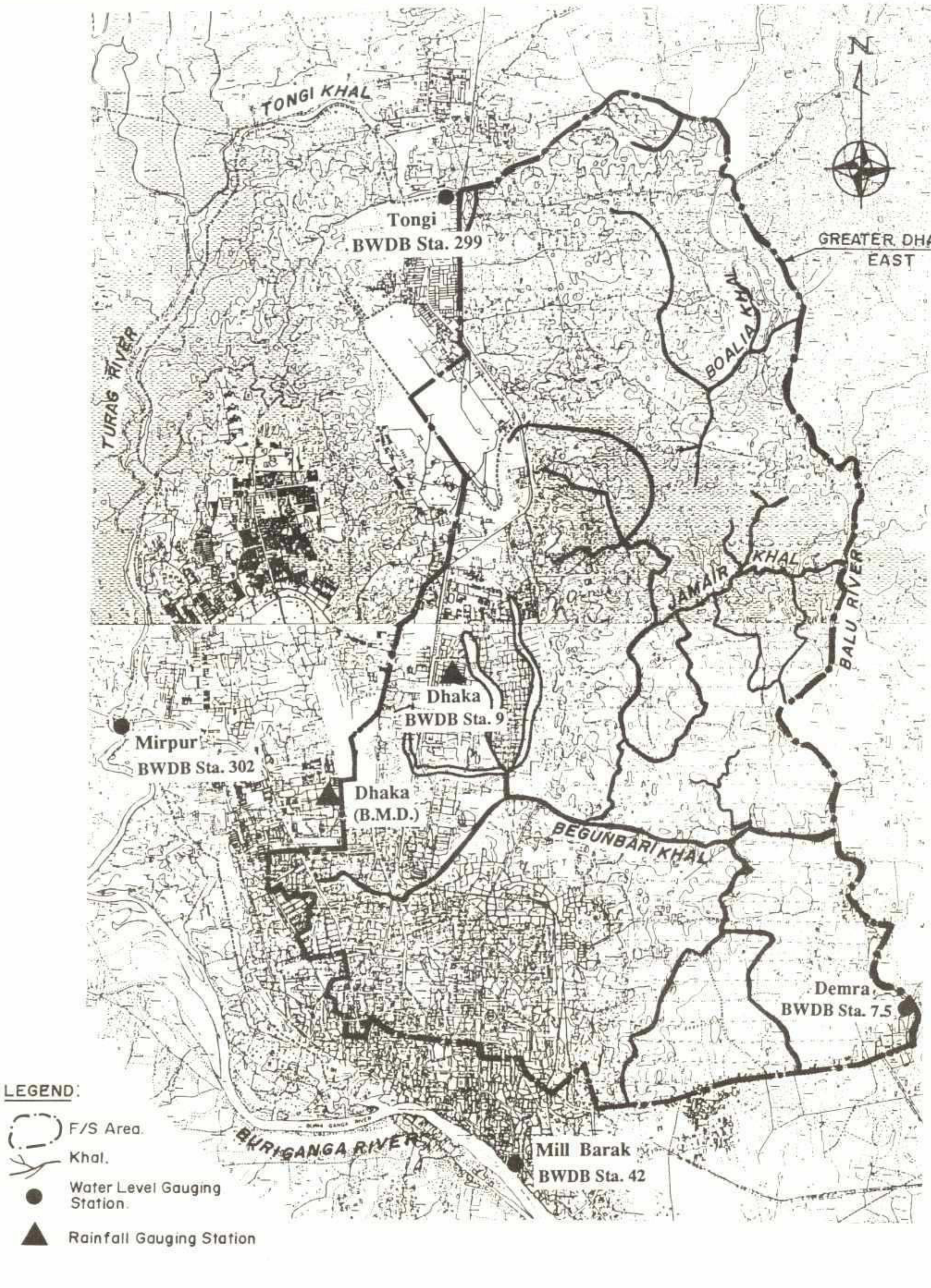


FIG. 3.2 (1) KHAL SYSTEM OF GREATER DHAKA EAST

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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92

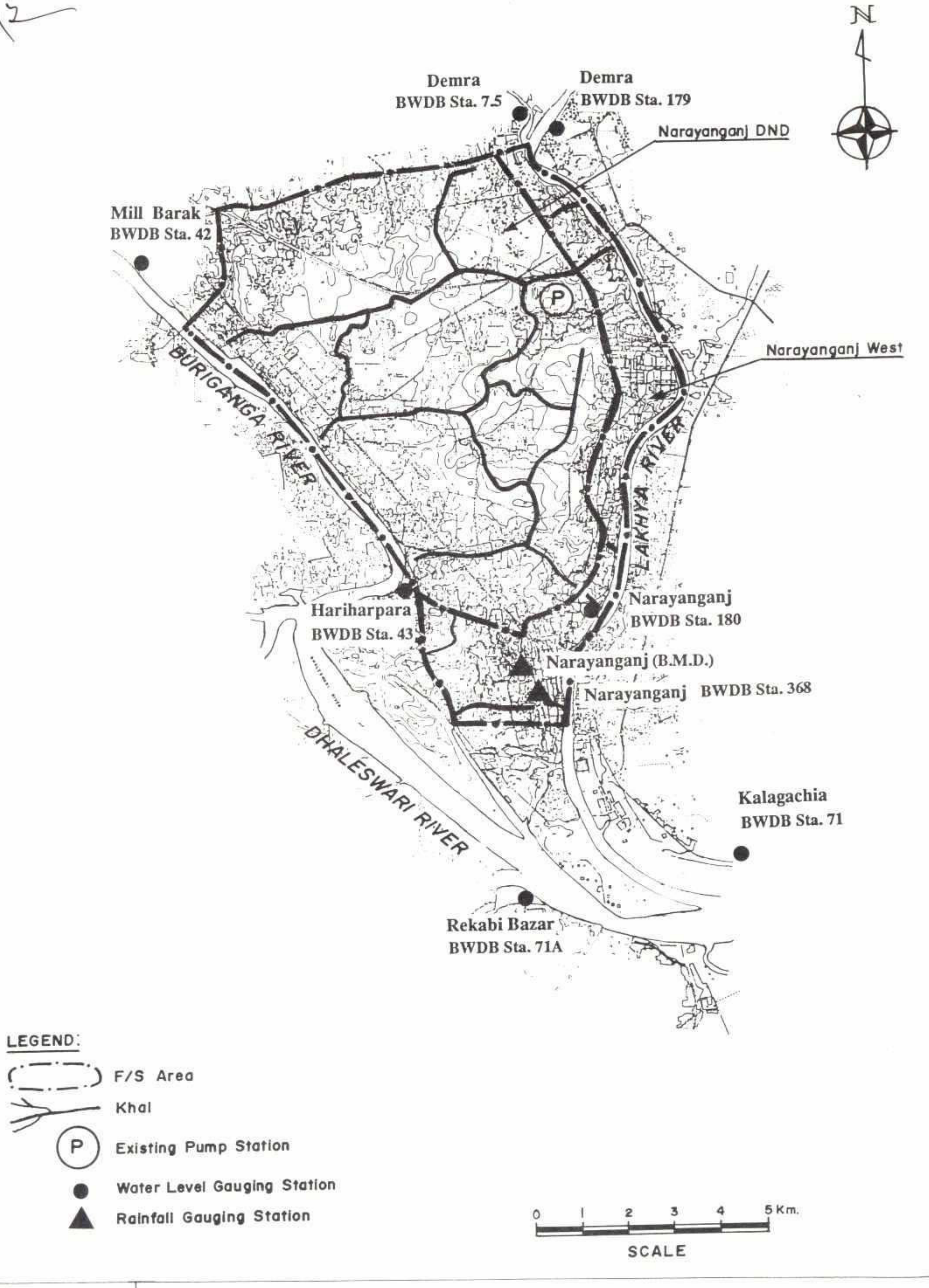
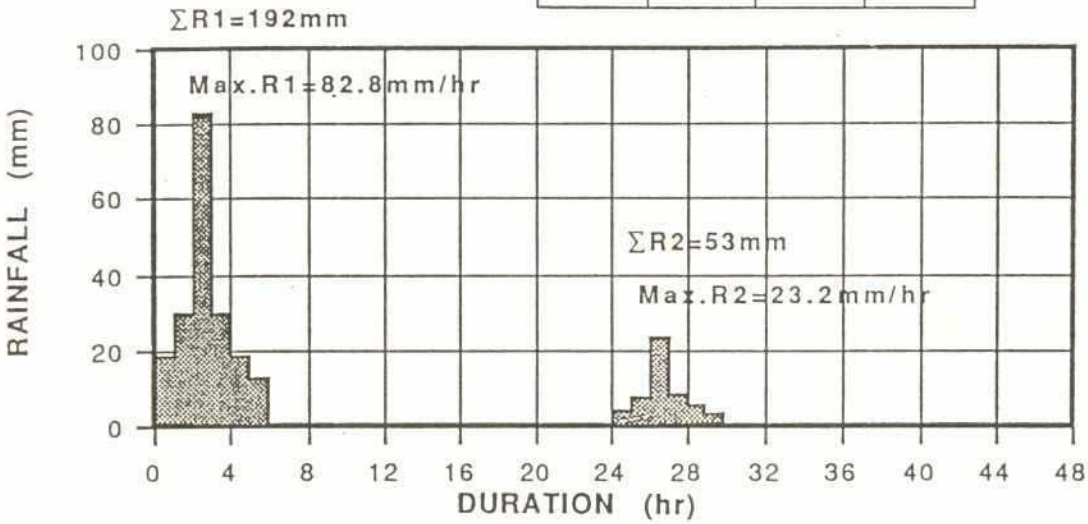


FIG. 3.2 (2) KHAL SYSTEM OF DND AND NARAYANGANJ WEST

HOURLY DISTRIBUTION

hr	%	R1	R2
1	9	17.4	4.8
2	15	28.3	8.0
3	44	82.8	23.2
4	16	30.6	8.5
5	9	18.0	5.0
6	7	14.9	3.5
TOTAL	100	192.0	53.0

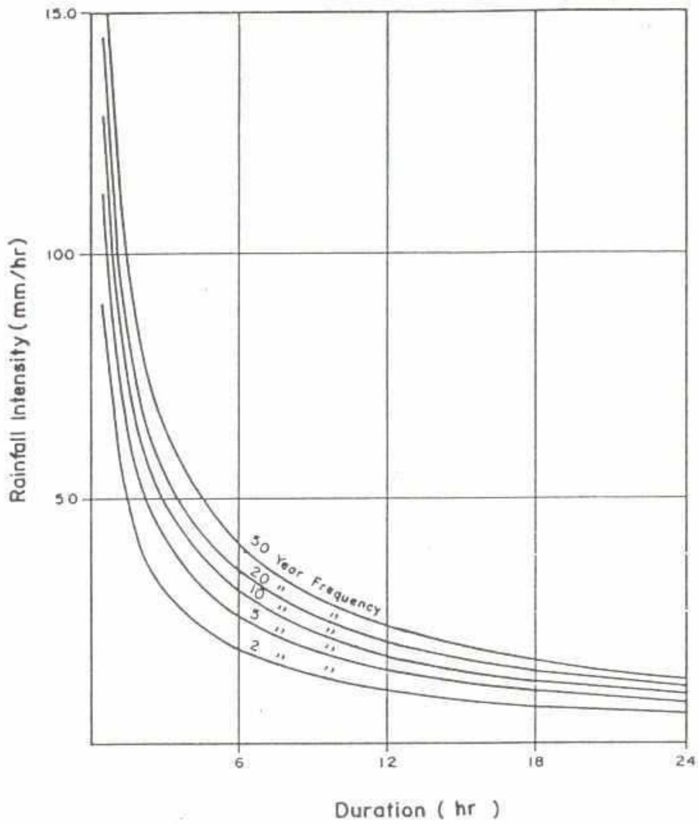


Source :

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

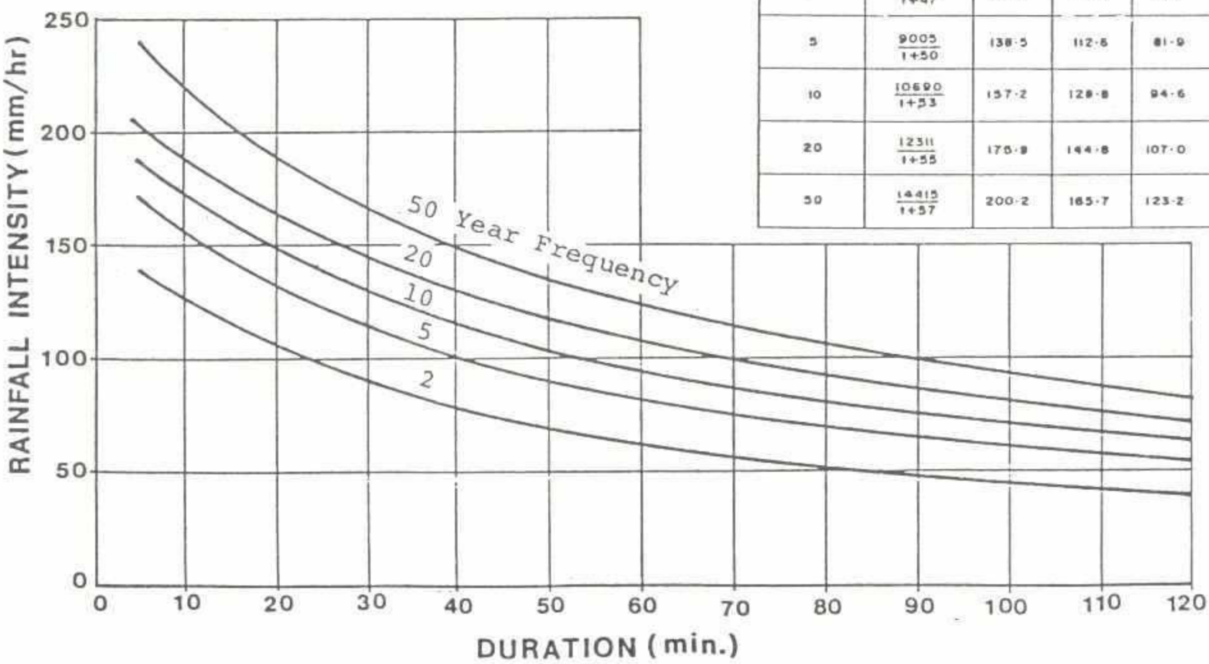
FIG. 3.3 PROPOSED DESIGN HYETOGRAPH FOR PUMP DRAINAGE PLAN

98



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
3	$\frac{7674}{t+47}$	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	61·8
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

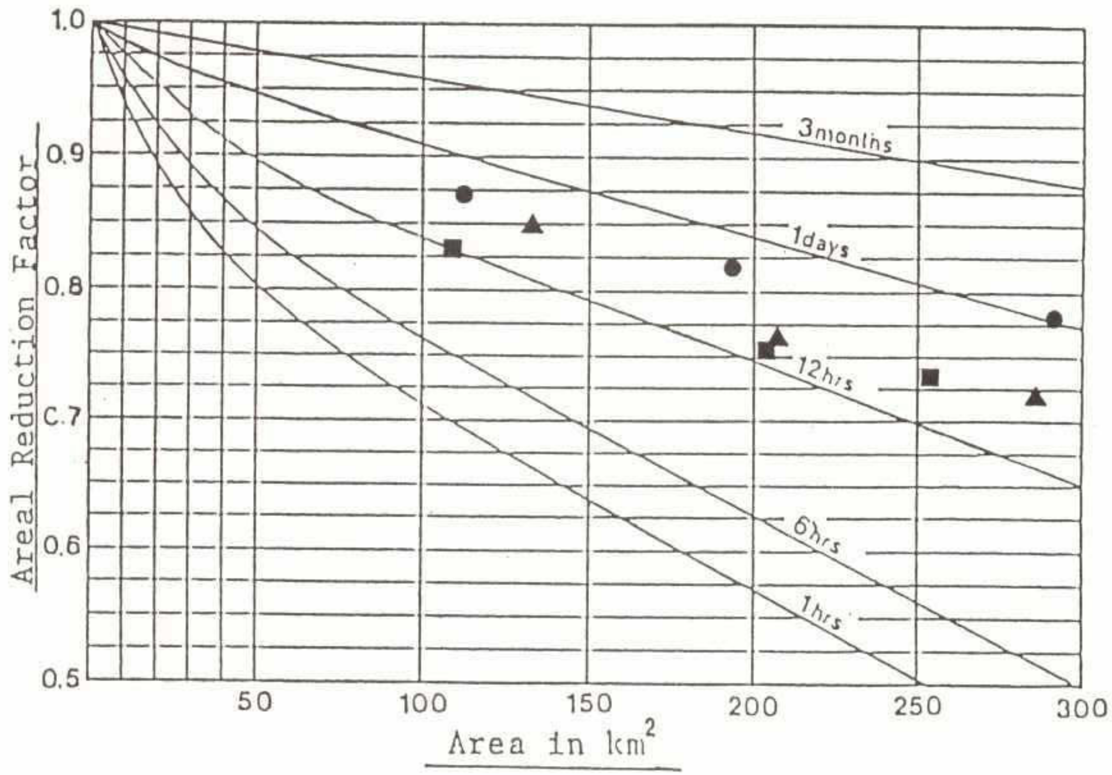


Source :

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

FIG. 3.4 RAINFALL INTENSITY AND DURATION RELATIONSHIP

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



Legend

Areal Reduction Ratio
of 1 Day Rainfall (Dhaka, B.M.D)

● : 1970. 7.13

■ : 1972. 5.25

▲ : 1975. 8. 8

Source :

NEDECO ; master Plan for Drainage and Flood Control of Jakarta, 1973

FIG. 3.5	AREAL REDUCTION CURVES FOR POINT RAINFALL

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

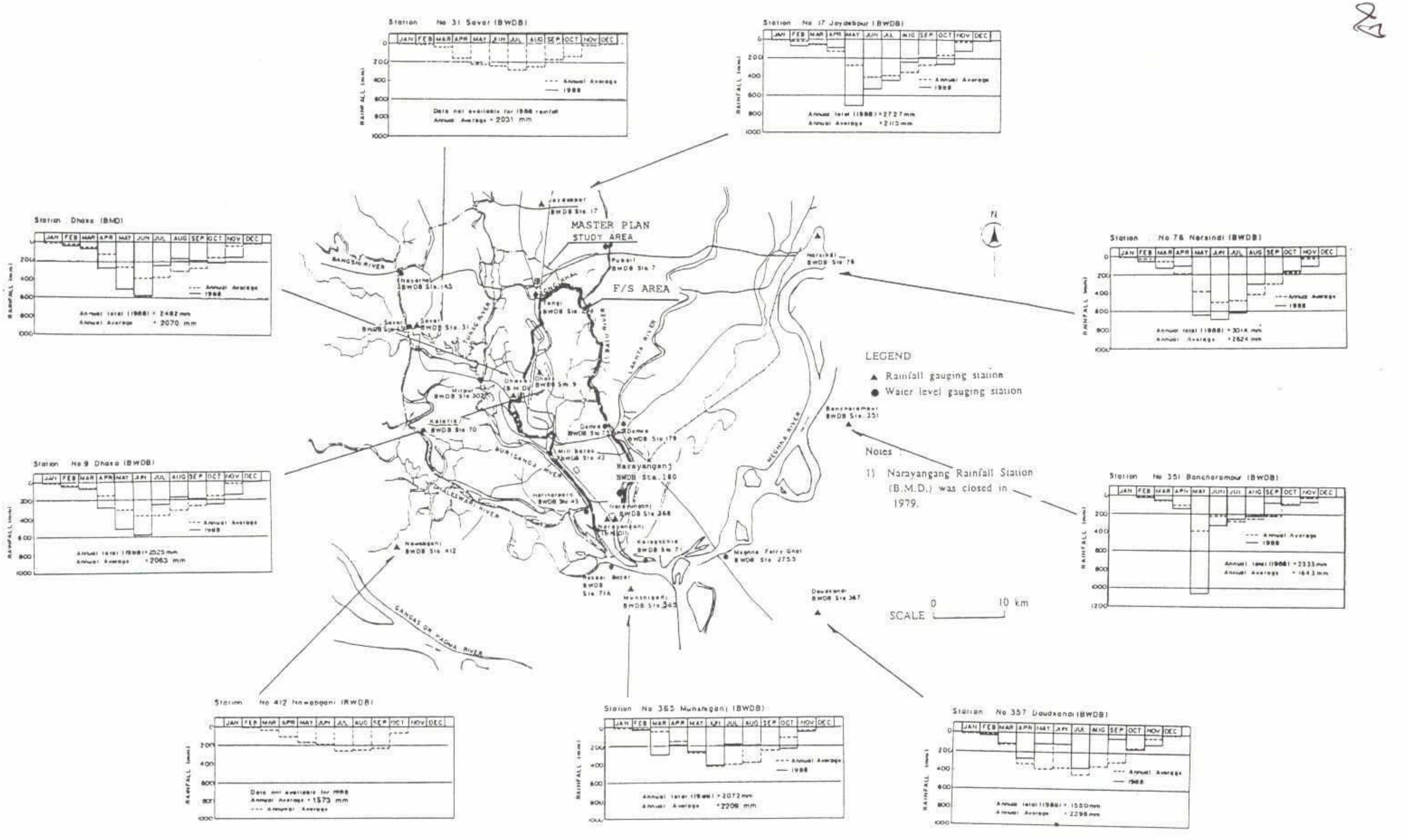


FIG. 3.6 MONTHLY RAINFALL-1988 AND ANNUAL AVERAGE

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

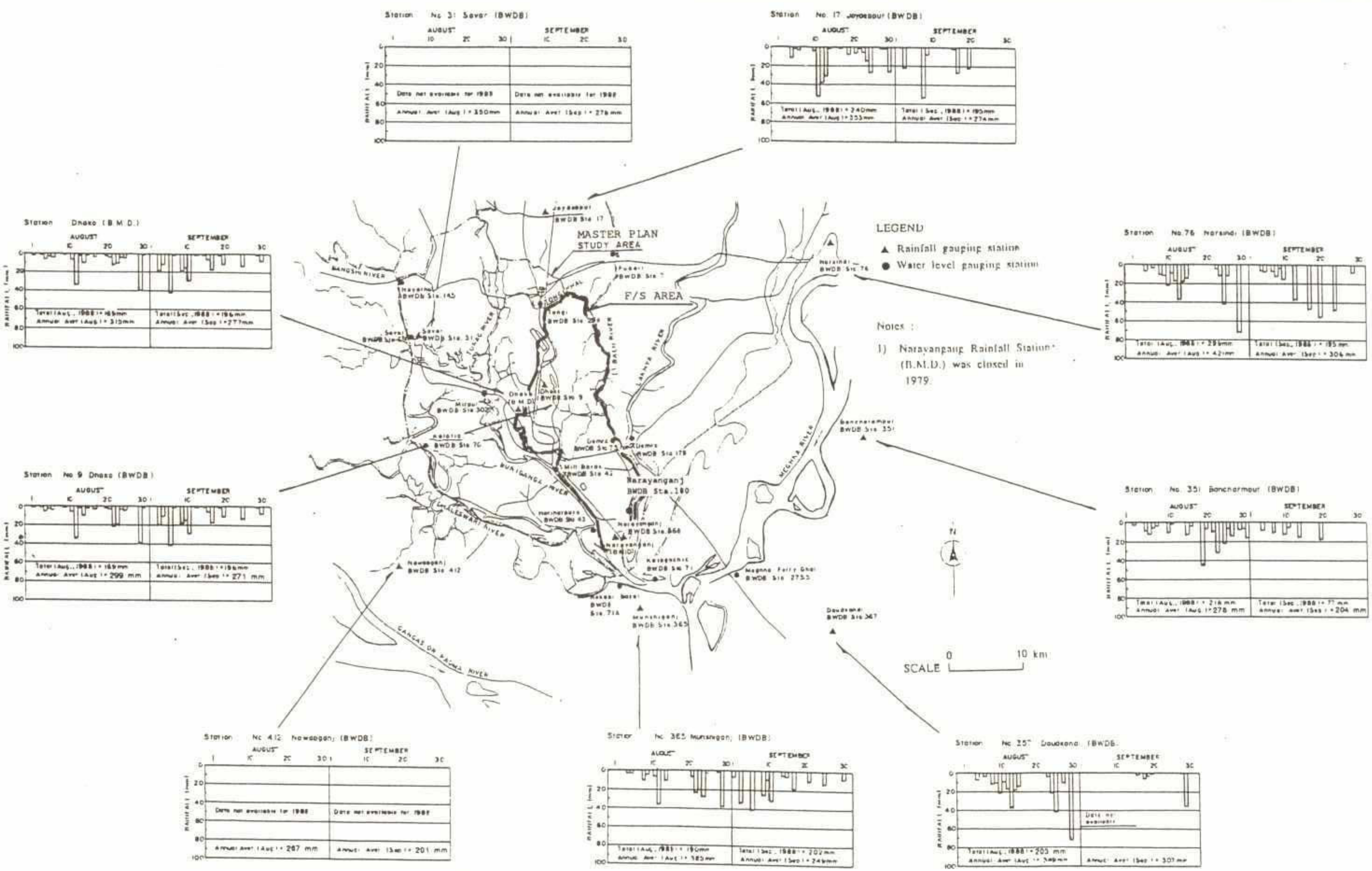


FIG. 3.7 DAILY RAINFALL DURING 1988 FLOODS

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

97

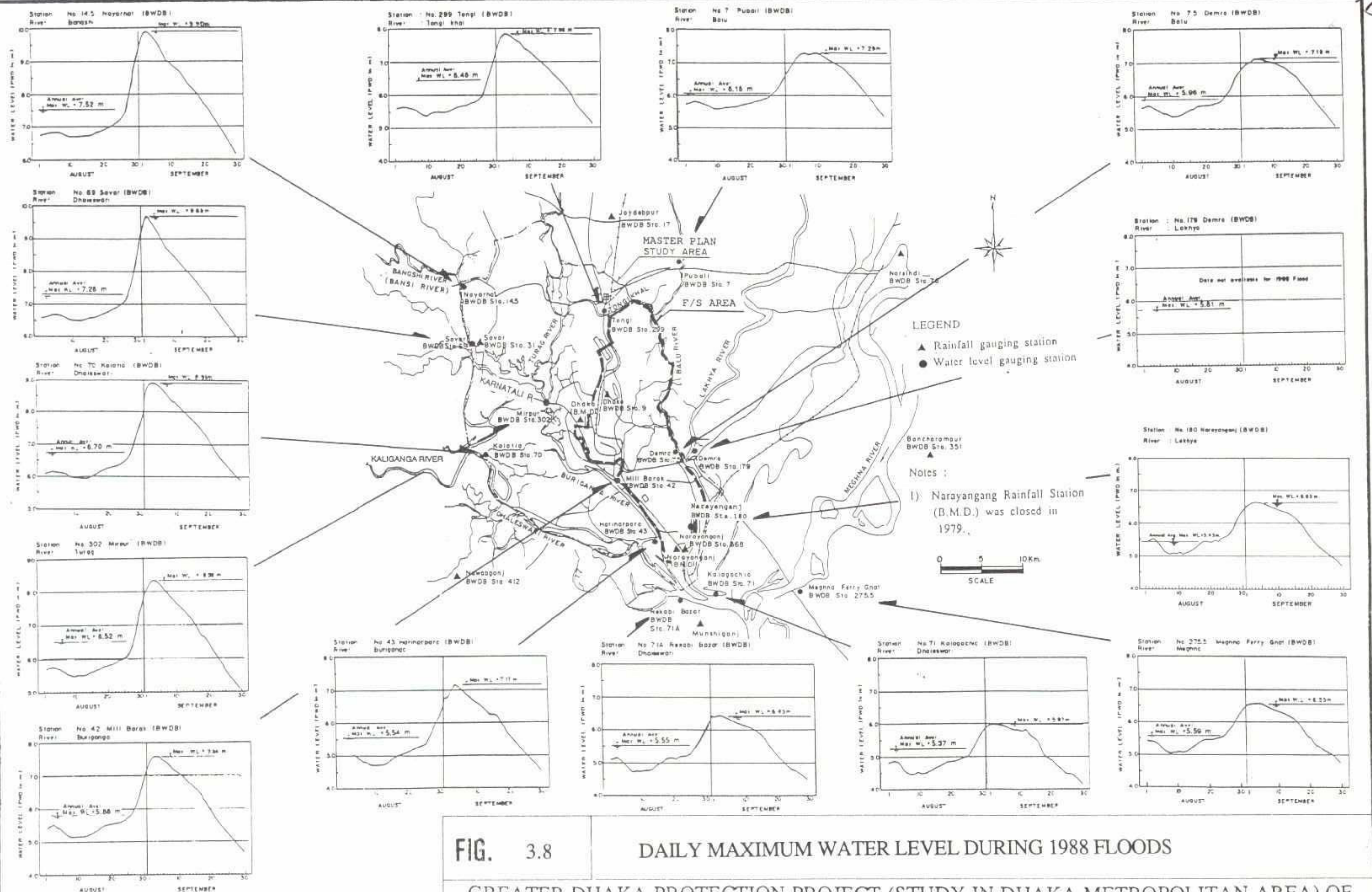


FIG. 3.8 DAILY MAXIMUM WATER LEVEL DURING 1988 FLOODS

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

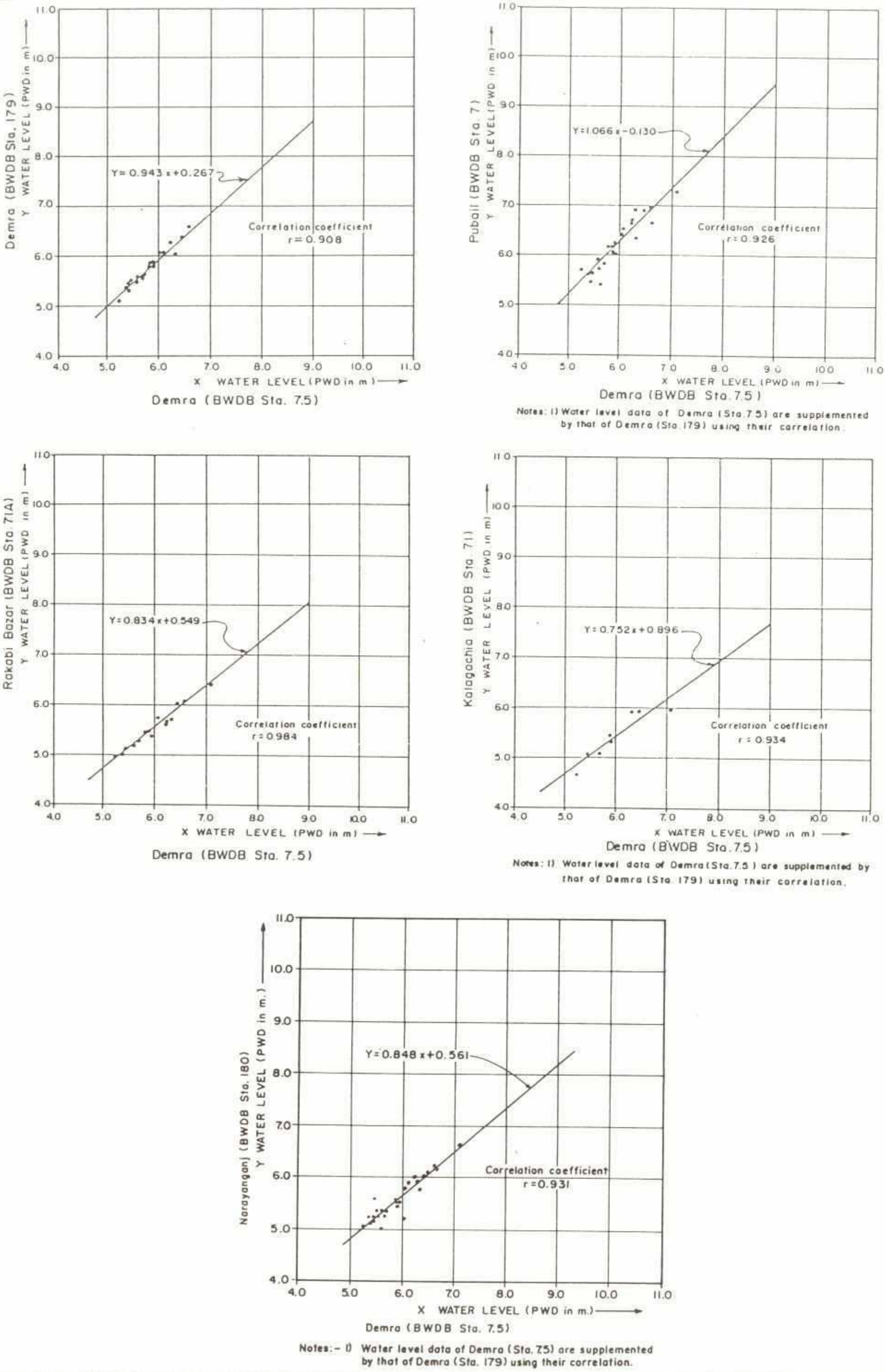
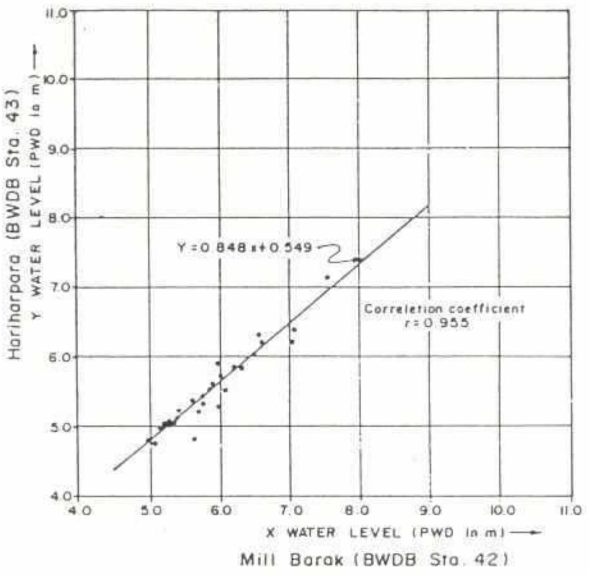
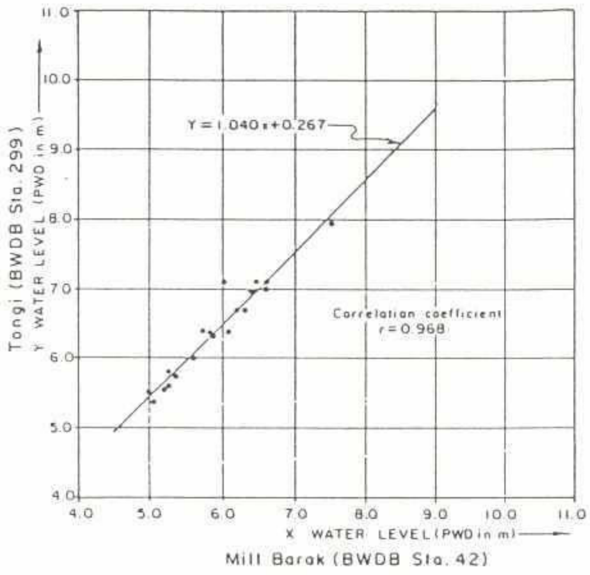


FIG. 3.9 (1) CORRELATION AMONG WATER LEVEL GAUGING STATIONS (1/3)

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

80





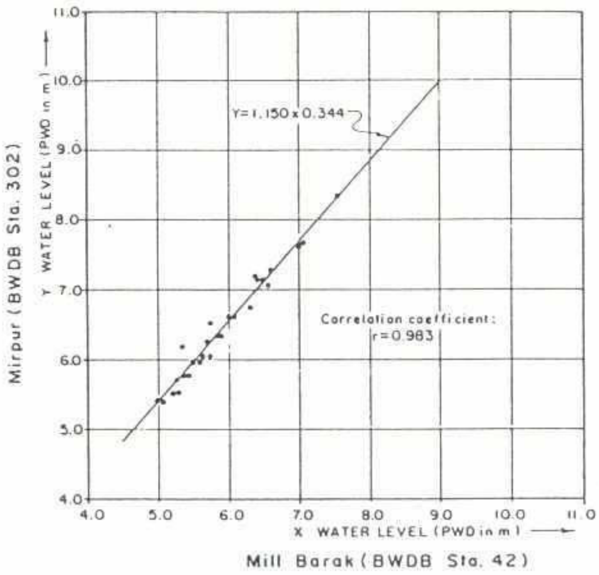


FIG. 3.9 (2)	CORRELATION AMONG WATER LEVEL GAUGING STATIONS (2/3)

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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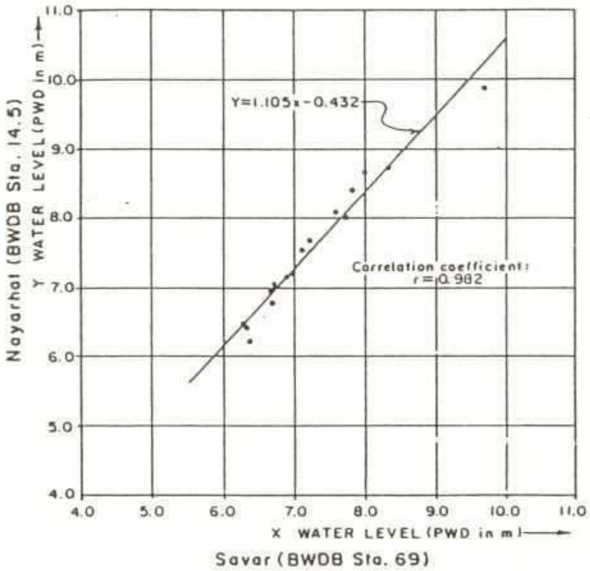


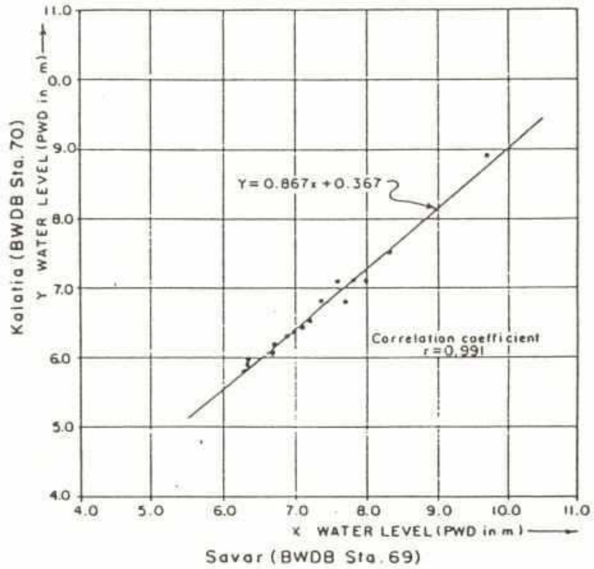
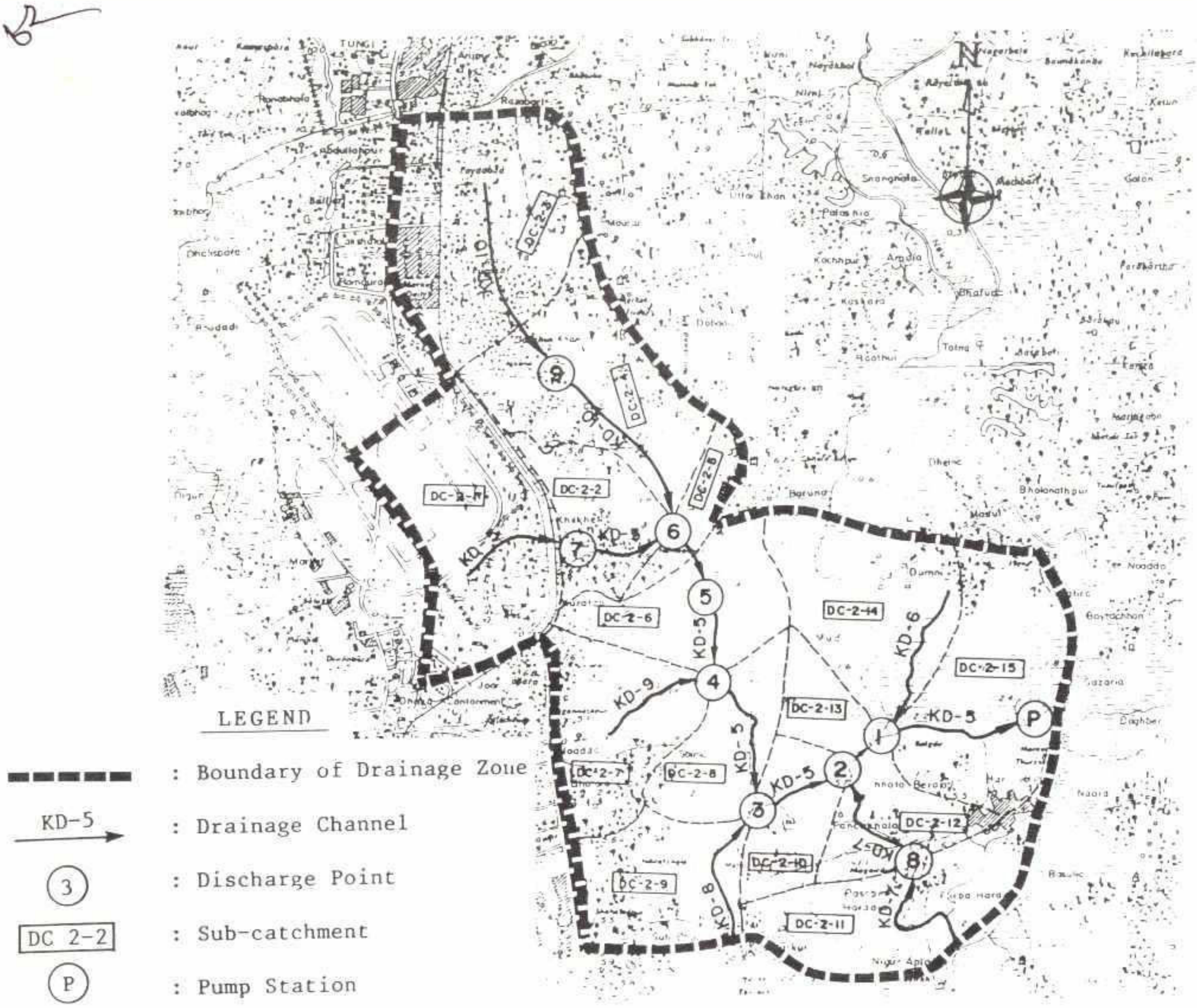
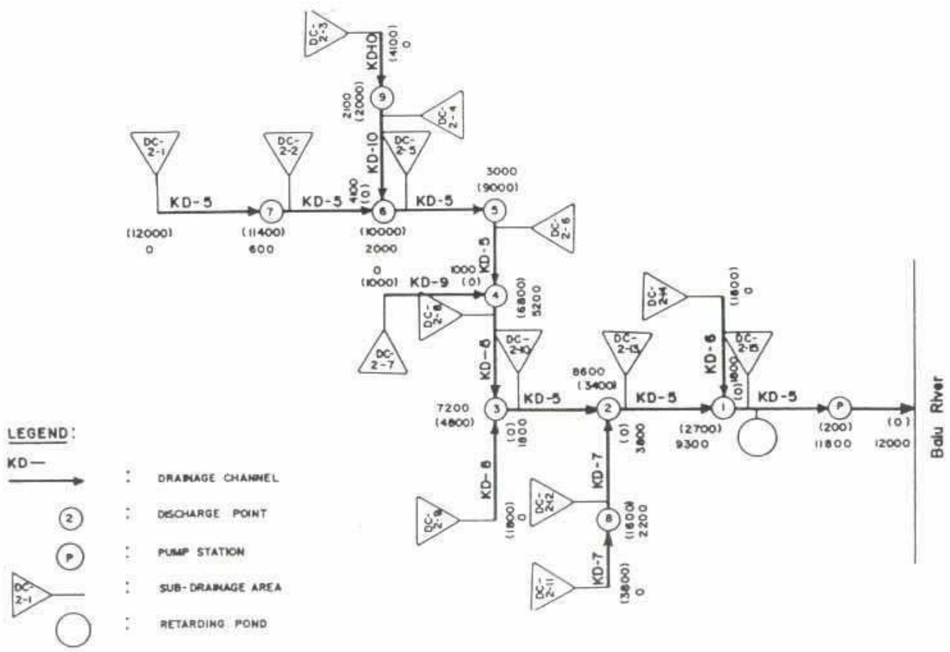


FIG. 3.9 (3) CORRELATION AMONG WATER LEVEL GAUGING STATIONS (3/3)

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



DRAINAGE CHANNELS AND SUB-CATCHMENTS



PROPOSED SIMULATION MODEL

FIG. 3.10(1) DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF SUB-DRAINAGE ZONE DC-2

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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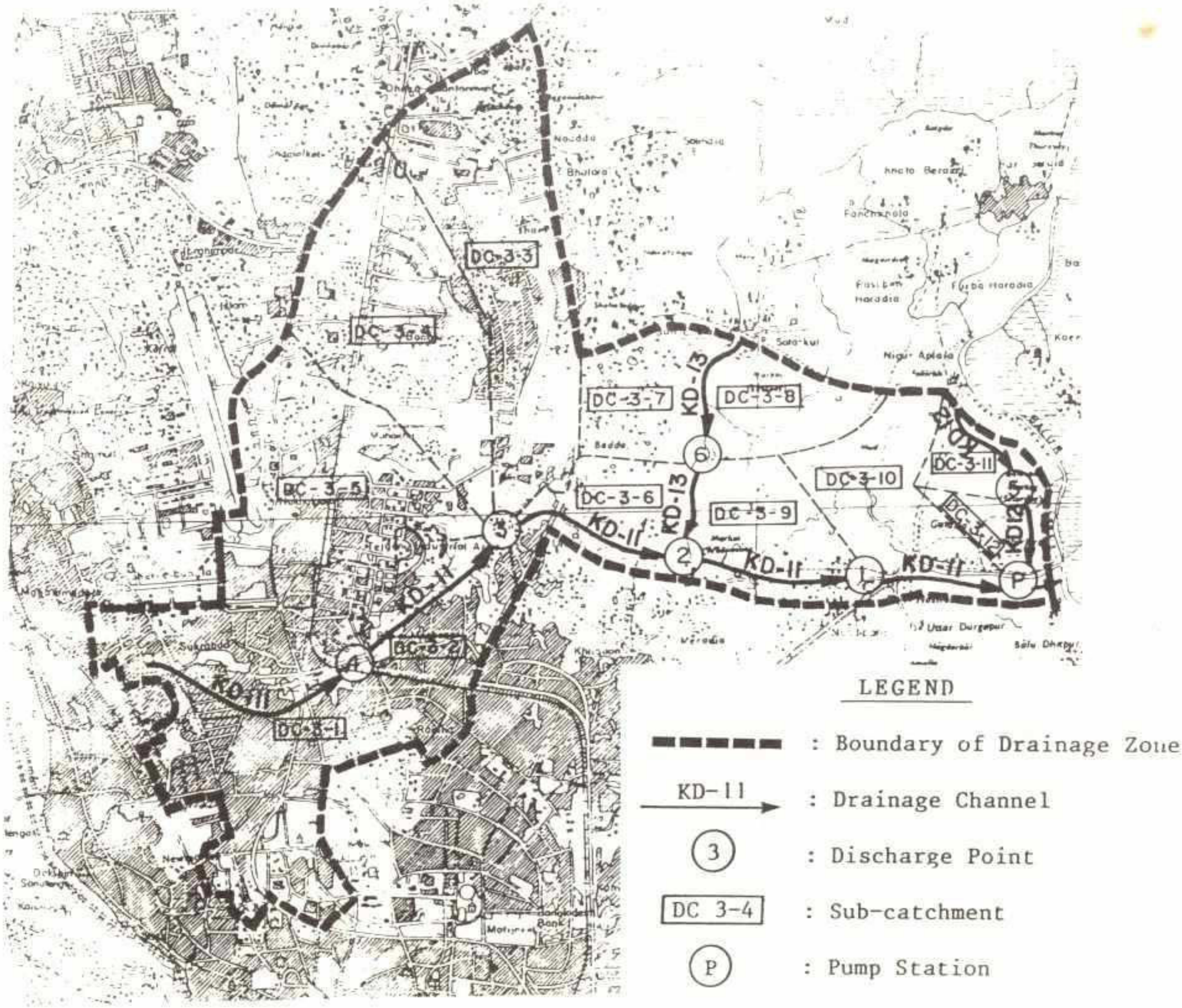
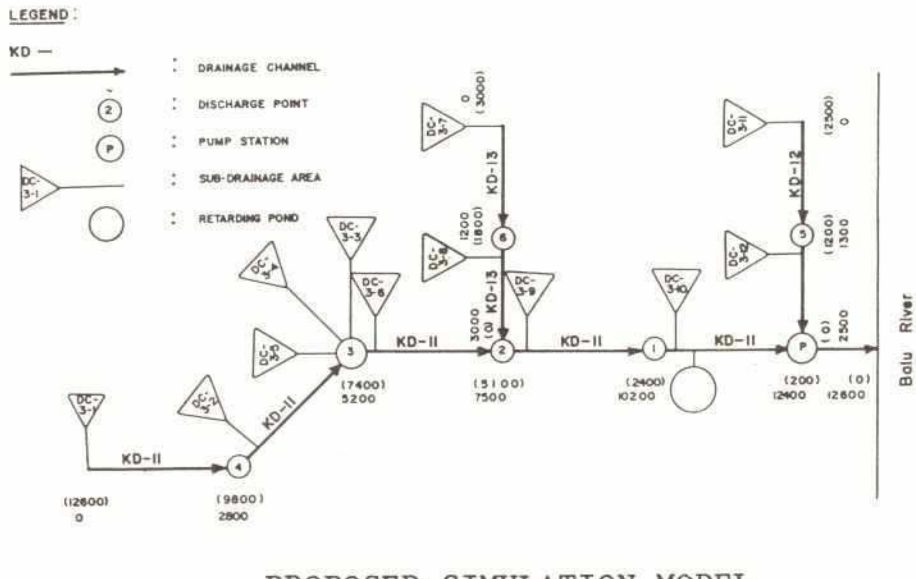


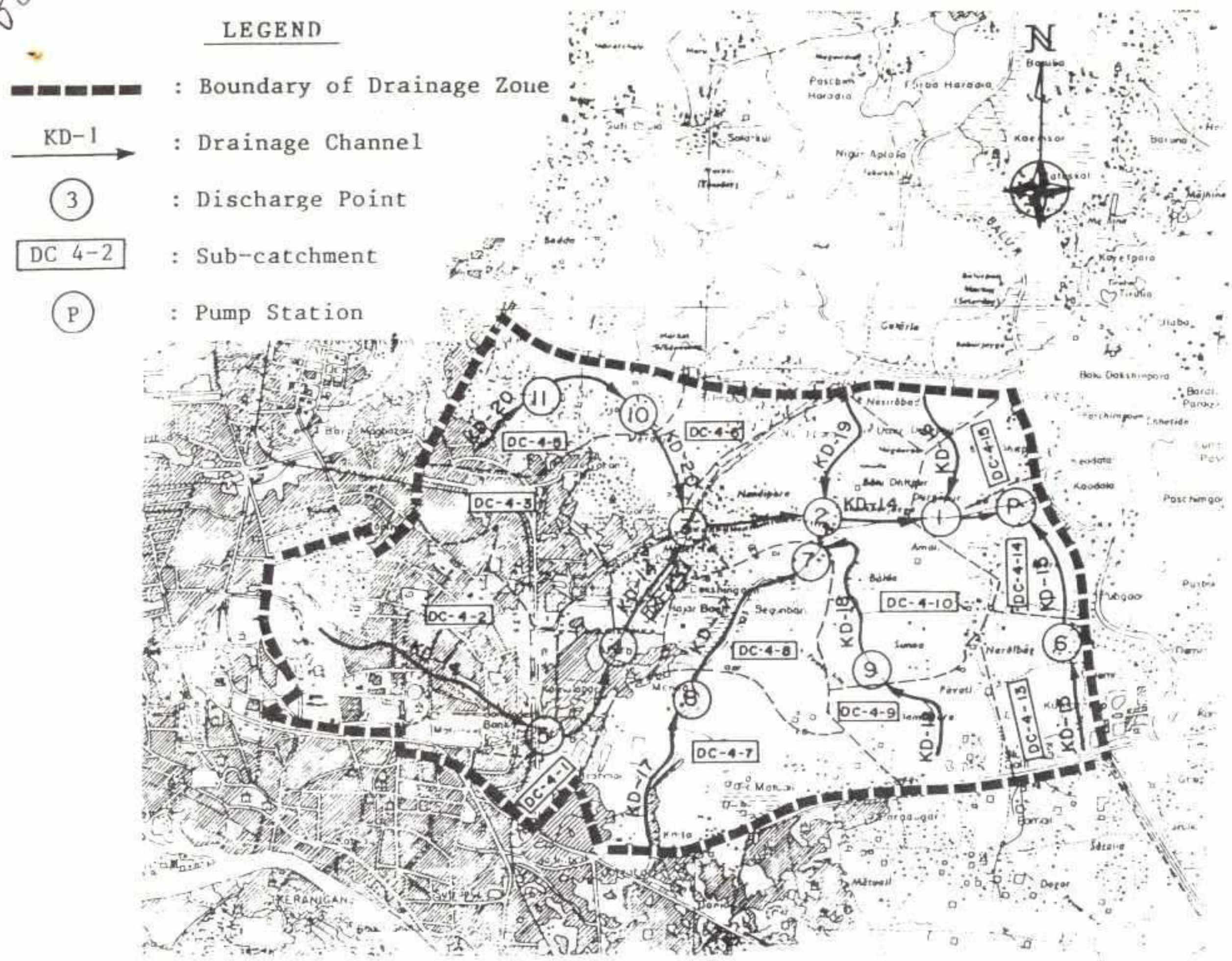
DRAINAGE CHANNELS AND SUB-CATCHMENTS



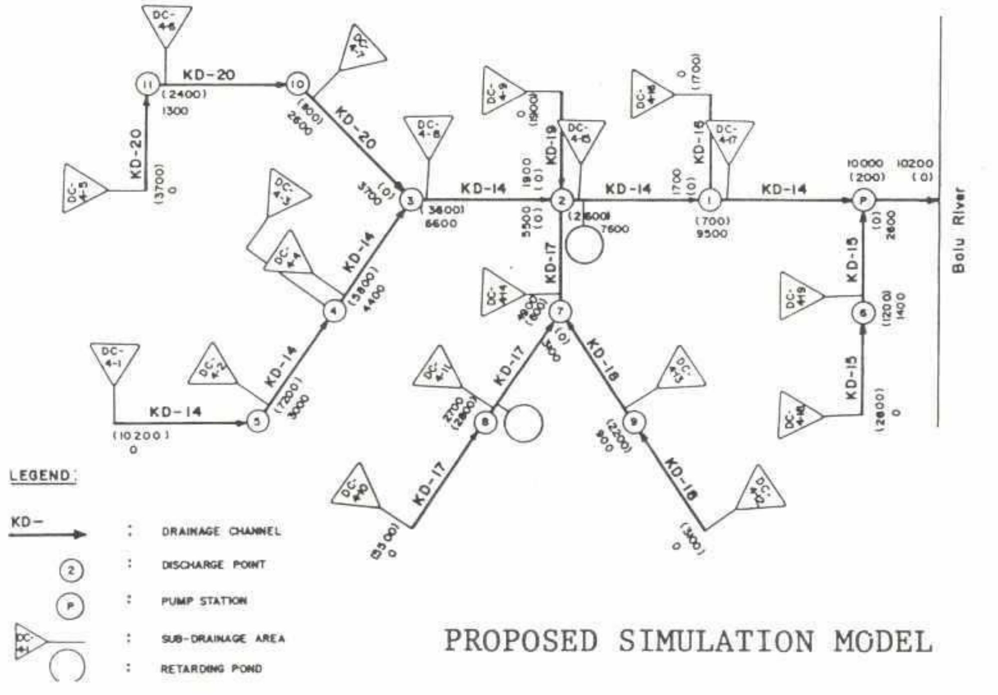
PROPOSED SIMULATION MODEL

FIG. 3.10(2) DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF SUB-DRAINAGE ZONE DC-3

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

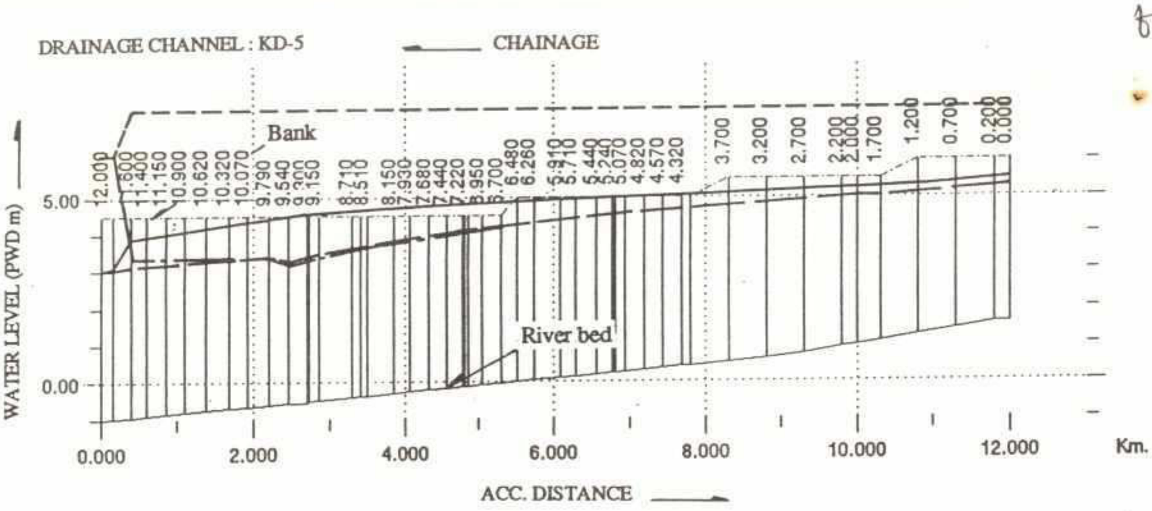


DRAINAGE CHANNELS AND SUB-CATCHMENTS

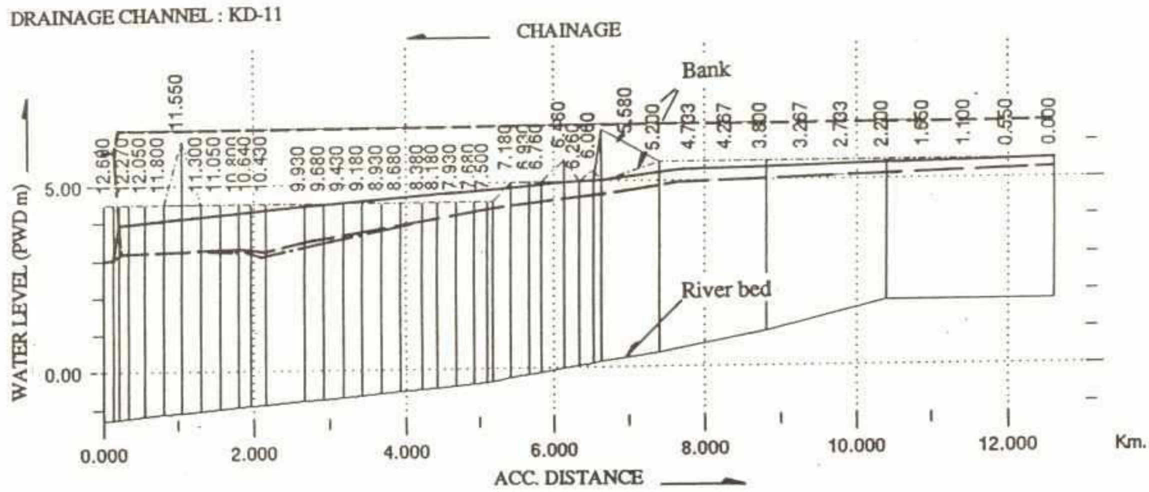


PROPOSED SIMULATION MODEL

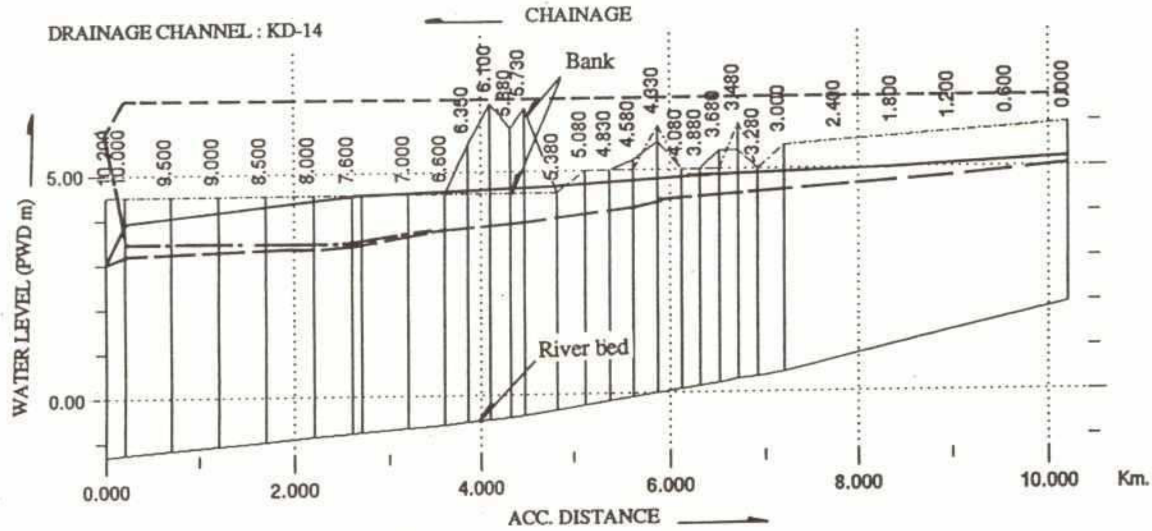
FIG. 3.10(3) DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF SUB-DRAINAGE ZONE DC-3



SUB-DRAIANGE ZONE DC-2



SUB-DRAIANGE ZONE DC-3



SUB-DRAINAGE ZONE DC-4

LEGEND :

Water Level

- Case 1-1 : Without retarding pond and without pump station
- Case 1-2 : Without retarding pond and with pump station
- Case 2-1 : With retarding pond and without pump station
- Case 2-2 : With retarding pond and with pump station

FIG. 3.11 PROFILE OF SIMULATED PEAK WATER LEVEL OF GREATER DHAKA EAST

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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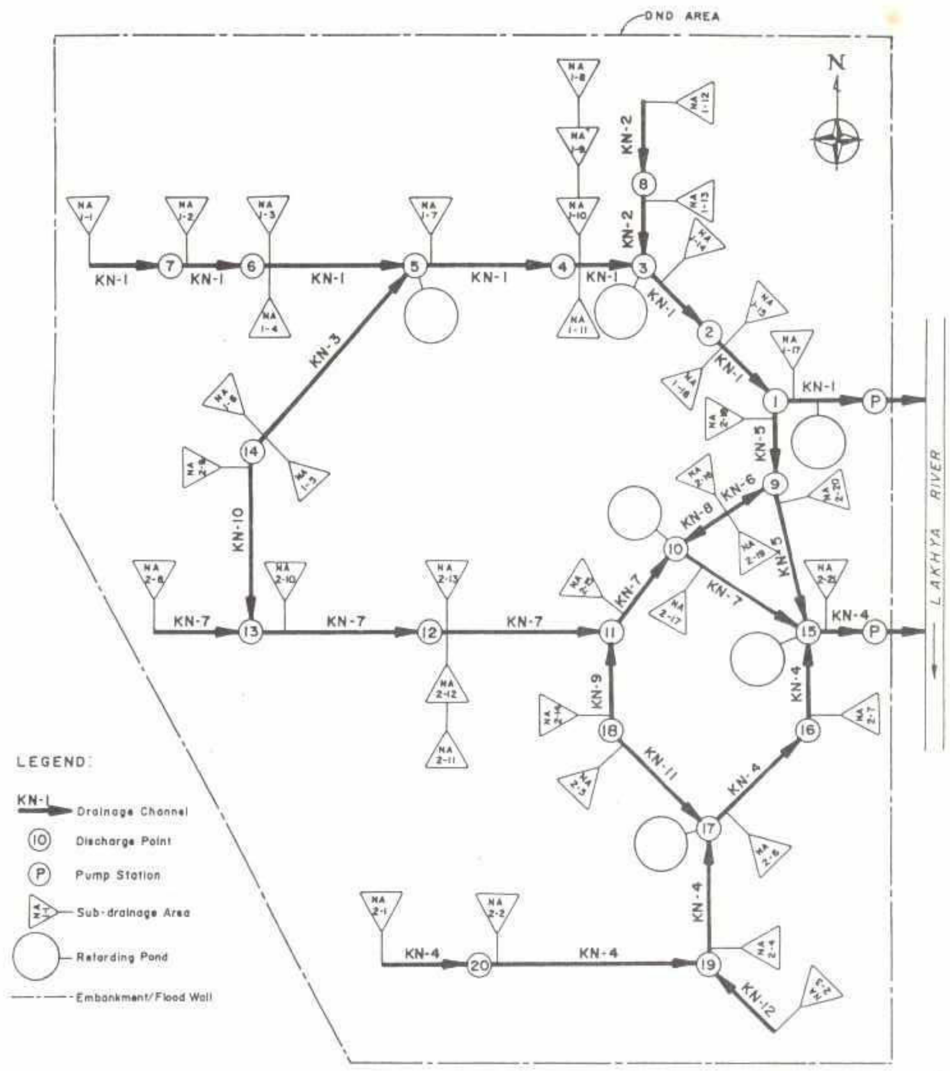
DRAINAGE CHANNELS AND SUB-CATCHMENTS OF NARAYANGANJ DND

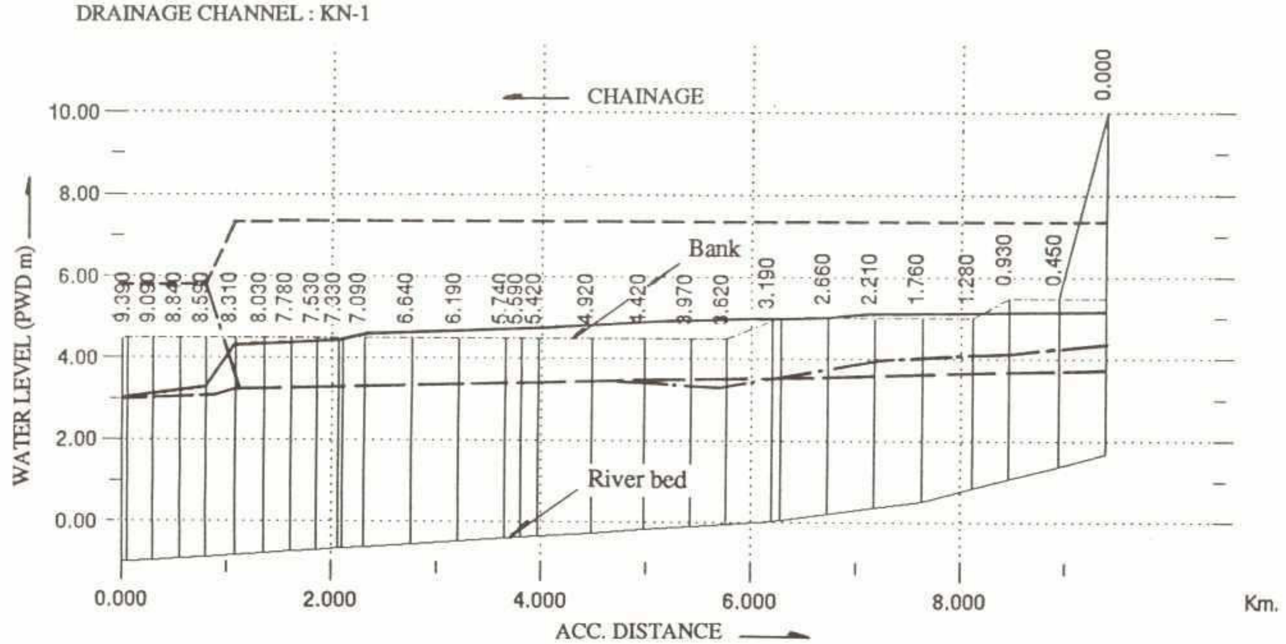


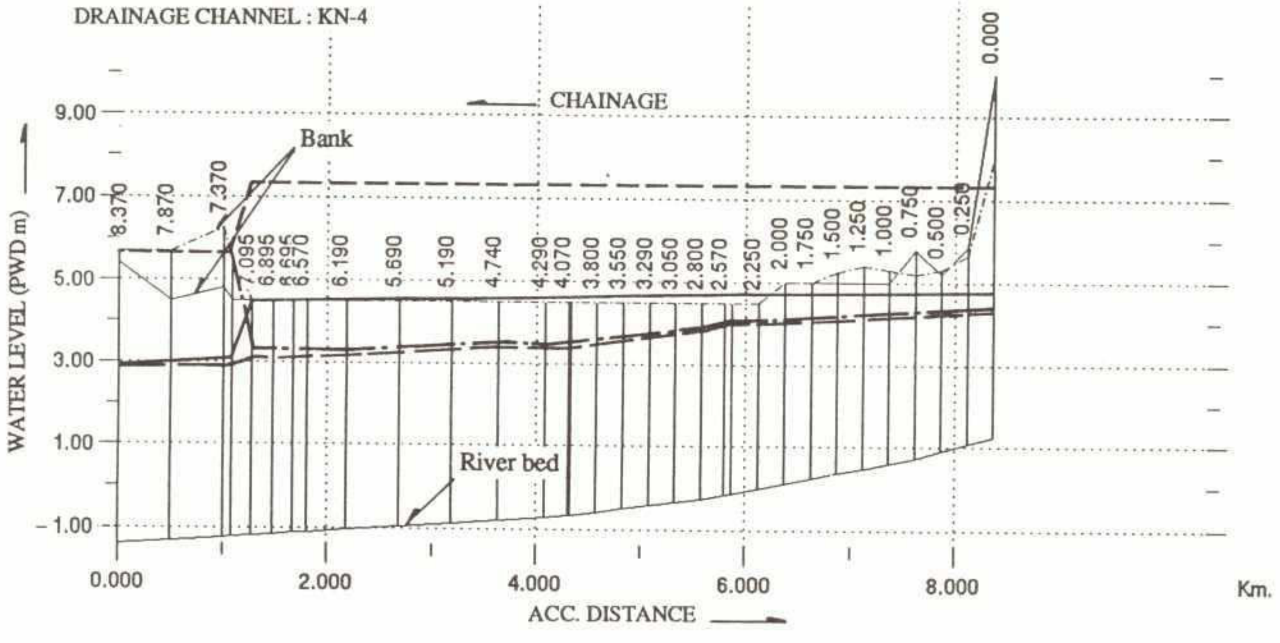
PROPOSED SIMULATION MODEL OF NARAYANGANJ DND

FIG. 3.12 DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF NARAYANGANJ DND

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

69





LEGEND :

Water Level

Case 1-1 : Without retarding pond and without pump station
Case 1-2 : Without retarding pond and with pump station
Case 2-1 : With retarding pond and without pump station
Case 2-2 : With retarding pond and with pump station

FIG. 3.13 PROFILE OF SIMULATED PEAK WATER LEVEL OF NARAYANGANJ DND

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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CHAPTER 4
LAND USE AND URBAN PLANNING

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Chapter 4 : Land Use and Urban Planning

4.1 General

The land needed for flood protection measures needs to be protected from further development prior to acquisition. The section outlines development control measures needed, and makes an initial assessment of suitable uses for retarding areas.

The urban development distributed in each area corresponds to the population increase forecast for each of these areas in the periods 1990 - 2000 and 2000 - 2010. These development areas have been drawn on the basis of land suitability, proximity to existing services, existing developments and required flood mitigation/drainage facilities.

4.2 Management of Future Urban Development

4.2.1 Development Pattern

The Development Pattern up to 1990 and land use forecasts for 2000 and 2010 are shown in Figs 4.1 to 4.4.

The Greater Dhaka East is the least developed among the feasibility study areas. This is mostly because, under current conditions, large parts of the central and southern areas are flooded for most of the year.

A considerable peripheral development has taken place during the last decade by means of landfill, especially in the southern portion close to the city centre. The construction of Rampura - Biswa road has also provide a platform for further peripheral development to the east. Further north, in Uttara, RAJUK has initiated sizable developments.

Further planned and unplanned peripheral development may be anticipated during the next decade. However more comprehensive development of the area would be preferred.

The DND has been developed quite rapidly during the last decade, particularly in the northwest corner, because of its proximity to the city areas as well being relatively flood-free. Currently RHD has started Dhaka-Narayanganj road and RAJUK is preparing housing development plans for the area. Further substantial development is anticipated over the next ten years.

The Narayanganj West is much smaller but much more intensively developed. The town area is on relatively high land and developed independent from Dhaka. The major settlement areas are in the south-east and the linear northern area. Density decreases progressively from east to west in the wider part of Narayanganj area. This leaves a small south-western part undeveloped.

4.2.2 The Need for Management

Management and control of land is needed if urban development is to proceed in accordance with a preferred strategy. The flood mitigation and drainage improvement strategy will be a major determinant of the city form. Since this will constitute the major expenditure, to ensure the availability of land where required, it will have to be delineated, and safeguarded. Management and acquisition authority should be sufficient to:

- maintain certain areas in agricultural, recreational and other conservation uses;
- acquire land for flood protection measures,
- control landfilling in areas to be acquired,
- prevent encroachment into land for flood mitigation facilities,
- ensure sufficient protection in low-lying areas by enforcing standards for in fill and road crest heights,
- control/modify particular development proposals that would affect efficient drainage or impede flood water flow.

The required authority/power should be available at the earliest to safeguard the area of land needed for flood control and protection, given the pace of peripheral urban development, and the rate of increase in land prices.

Control and acquisition are complementary measures, but the former is clearly preferable if a choice exists. It is particularly significant that funds for land acquisition will need to be found locally. Thus, as well as making maximum use of control methods to reduce acquisition costs, it is imperative that the government manage to recoup some of the benefits of its investments from the beneficiaries, to allow further development.

4.2.3 Existing Legislation

RAJUK is the planning and development authority for Dhaka metropolitan area. It is authorized to acquire land and prepare improvement schemes of both existing areas and new ones. The legislation that empower government bodies to integrate development projects are listed below ;

(1) Landuse Control and Construction Control :

The East Bengal Construction Act (1952), updated in 1961 and 1986 provides that within any area where Government may extend its application, all construction shall have previous permission from the designated "authorized officer". The Act also empowers the discontinuation of non-conforming use. RAJUK is responsible for control of construction in Dhaka.

The Town Improvement Act 1953 established the Dhaka Improvement Trust (DIT) as a development body with powers to take over, improve, and return land to and from private and municipal owners. For guidance, it was authorized to prepare "schemes" and "zone plans". Planning control took the form of urban on all construction not confirming to such plans. In 1958, references to scheme and zonal plans were replaced by references to a "master plan". At the same time, it was mandated that an official of DIT should be designated as the "authorized officer" for the area within the jurisdiction of DIT. RAJUK (DIT) has the power to approve or reject proposals for building which are not in conformity with the Master Plan. The development control system is minimal, being based on the need to apply for the granting of an exception where a proposal is not in conformity with the plan. But the plan, prepared in 1960, is now clearly outdated and only covers part of the RAJUK area - not including many of the peripheral areas where development pressures are greatest. In this peripheral urban area, RAJUK can prevent / permit development, but decisions are made on an ad hoc basis.

In practice, except in instances where private developers need official approval prior to obtaining a bank loan, most development proceeds without seeking for permission. There is also little control over development by public bodies.

22

(2) For Land Acquisition :

The Acquisition and Requisition of Immovable Property Act of 1982, with subsequent minor amendment, has replaced previous acquisition acts. The Act aims to ensure the organization requiring land for public and development purposes will decide upon the minimum requirement. RAJUK is the principal single land acquisition and development agency, but the private sector, overall, undertakes most development.

However, the legislation does have drawbacks. The Background Report to the Metropolitan Development Plan Preparation and Management, Dhaka and Chittagong, notes that difficulties arise from :

- high prices, most land that is developable on the urban fringe is privately held. Unless it can be serviced and released at the rate needed for urban growth, its shortage will fuel a continuing rise in land prices. However, as public authorities fail to recover services cost from beneficiaries, they lack the resources to services lent at the rate needed.

- the legal registration system, involving two ministries, the Ministry of Lands and the Ministry of Works, also hinders the efficient and speedy operation of the land market.

- lengthy land acquisition procedures further reduce the capacity to service land at the required rate.

- public sector landowners also contribute to land scarcity / high prices by failing to service and develop land. Public sector agencies hold about half the buildable land in Dhaka. Much remains vacant or under used.

The 1989 Property Emergency Acquisition Act provides for emergency acquisition to control inundation and prevent river erosion. Its duration is restricted to five years, but has so far only been applied in connection with the Jamuna Bridge Construction Project and the existing Dhaka Embankment. The Act attempts to speed up the acquisition process.

(3) For Cost Recovery :

The Betterment Fee Act (1952) allows the government to levy betterment if land value is enhanced as a result of any Government improvement scheme, fixed at one -half the increase in land value.

DMAIUDP notes serious inconsistencies and drawbacks in the legislation :

- it takes no account of increases in value unrelated to the Government improvement,
- it can levy betterment fees for works executed before 1953,
- procedure for determining market value is not laid down,
- there is no guidance for determining the extent of the area within which land values enhanced.

The Town Improvement Act 1953 contains the power to impose a betterment fee on DIT (RAJUK), though the legislation differs in some respect from the Act. The betterment laws have not, in the past, been enforced in Bangladesh.

The Wealth Tax Act of 1963 could (according to DMAIUDP) be used to realize a portion of windfall gains, but is not designed for such purpose and has been ineffective.

The East Pakistan Finance Act 1966 allows a capital gains tax to be collected on profits or gains arising from sale, transfer, or exchange of property. Capital gains are now treated as income, liable to tax. The 1976 Finance Ordinance attempted to reduce evasion by requiring tax authority approval prior to the issue of any document transferring any property valued over Tk. 20,000. As tax on capital gains is collected with income tax, it is not possible to discover how much of the increase in land value is recouped by the method.

The Gift Tax Act 1963 and The Estate Duty Act 1958 also attempt to recoup the unearned increment in land values. DMAIUDP concluded that this goal is unlikely to be achieved by this legislation, with reorganized tax administration and removal of loophole.

It is difficult to see any effective recovery of costs of infrastructure investment/land development by an agency such as RAJUK under the existing legislation as now applied. Without this, effective action to cater for anticipated rapid growth is not

28

possible, in any sector. Indeed, continuing failure to recoup costs, in this urbanization context, means that conditions in the capital will get worse rather than better, as the amount of land and the major infrastructure required cannot be provided in a sensible fashion.

Everyone in the feasibility study area would benefit from flood protection and drainage improvement measures, Everyone should in principle contribute towards the cost. A tax based on the increase in safety and land values (as suggested in the ADB Aid-memorie) would be an equitable measure. It shall reflect the disproportionate benefits that flood protection will bring to some owners (in allowing conversion from rural to urban) as well as the overall increase in land values as a result of flood protection.

4.2.4 Land Improvement Issues :

While this study is chiefly concerned with flood mitigation, certain issues regarding general land improvement guidelines, the determination of responsible authorities etc., needs to be discussed.

Issues which will affect flood mitigation schemes just as they do any other urban development activities are ;

- Legal, administrative and institutional frameworks which apply to urban development in general,
- The institutional structures of the government and a definition of their responsibility,
- Control of land use and land price by zoning,
- Development of land readjustment mechanisms, and
- Betterment taxes based on increase in land value.

There are some specific issues with regard to the flood mitigation project, especially control of huge areas required for retarding areas. They are ;

- The control by speedy zoning by which the existing land use may be frozen.

- Multiple or productive uses of the retarding areas.

- Private or any developers should provide their own retarding areas (approximately 12% of their land to be developed) in each of their housing projects.

- Preparation of zoning master plan for the feasibility area especially newly developing areas should be made by RAJUK incorporating flood protection needs.

4.2.5 Prospects for Improvements

A number of plans and proposals are underway to bring about more efficient land management and cost recovery. They include :

- Proposed Metropolitan Development Plan Study, which will prepare a detailed project plan / structure plan / master plan (incorporating flood protection needs),

- The Southern part of Greater Dhaka East and the DND area would be identified as areas where detailed plans will be given priority,

- FAP 15, "the land acquisition and resettlement study", will identify improvements in acquisition and resettlement procedures within areas under various flood action programmes.

- In connection with FAP 8B, ADB will provide technical assistance in the field of building and land development standards, cost recovery methods and Government land use.

These studies and proposals will examine and make subsequent recommendations with regard to the present inadequacies of current plans and mechanisms in a comprehensive manner. Until comprehensive measures are enacted, existing methods must be used more efficiently.

4.3 Development Control and Multiple Use of Retarding Ponds

4.3.1 Development Control Measures

Development control is required during execution and subsequent management of the flood protection project.

Development control is categorized into the followings :
- On and around flood prevention structures
- Regulation for site development

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1) On and Around Flood Prevention Structures

(1) Drainage channel

It is logical to assume that the development pressures will eventually lead to encroachment of the drainage channels. Technically, some setback distance from the drainage channel boundary is required for management of the area.

Technically for the sake of management and maintenance of the drainage channel areas, there is a need to have service roads along them as follows :

- The drainage channels should have roads on both sides.

- Plantation may be provided at the edge of the drainage channels. This would help keep a green belt along the water bodies.

- Some form of fencing should be provided, defending the edge of the channel area (or channel). This would enable better control and discourage encroachment.

(2) Embankment

There will be a great number attracted to the embankment from adjacent slum and squatter areas. The embankment offers a rent-free, flood free opportunity, close to place of work, to those whose other choices are few.

It would clearly be impossible to remove people sheltering on the embankment immediately after flooding.

From a flood protection point of view, habitation on the embankment should be resisted. To some extent, the numbers may be minimized by speedier land acquisition and resettlement procedures. Clearly, unhindered rights of way for maintenance must be preserved. It is recommended that the Government introduce building controls to restrict development with some 50 meter beyond the edge of the right of way of the embankment so as to preserve a strip of land along the country side of the embankment to accommodate any future roadway and also other type of land uses.

(3) Retarding Area

The retarding area is indispensable for the proposed drainage improvement plan. However it is required mostly in the wet season. During the dry season, the water body will occupy only a small part of the proposed retarding area and open up a large dry area, which may be used for agriculture as ever. The land use of retarding area should be controlled. However it is logical to assume that the development preserves will lead to encroachment of the retarding area. In order to reserve the proposed retarding area, multiple use or productive use of it should be encouraged.

2) Regulation for Site Development

(1) Minimum Height for Development

In addition to control activities associated with suitable land uses, control of minimum land fill levels is needed to ensure flood protection. Development of low-lying areas should be in compatible with the proposed drainage plan.

(2) Required On-site Retarding Area

For RAJUK's approval, the private developers are requested to prepare the public land, which is around 30-40% of the development area. These areas have to be kept for non-housing uses such as commercial, educational, medical and open space. A certain portion of the development area should be allotted to provide their own water storage as on-site retarding ponds.

4.3.2 Multiple Use of Retarding Areas

There will be a total estimated 26 km^2 retarding area. The primary use is for the flood protection, however the compensation cost and legal complications coupled with management issues clearly suggest that there should be certain economic utility for the retarding area. Otherwise enforcement of such concept may not be possible. Maximum multiple usage should be encouraged.

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1) Recreation

There is a popular demand for sports pitches. A total of 145 ha was considered to be available for public and semi-public recreation in the city, mostly in newer areas.

The study identified the reservation of large scale outdoor areas for day trips within easy traveling distance of the city as a major recreational requirement. This need is currently being (partly) met to the north of the city but a number of other potential locations were suggested. Within the metropolitan area also, some potential recreational locations were identified. None of these areas are located within the feasibility study areas.

DMAIUDP's underlying concept behind providing recreational space is to use the natural potential of the city environment to create a number of out door recreational spaces. An opportunity exists to use of the most suitable retarding ponds as recreational areas.

Not all the proposed retarding areas should be reserved for such use, and it is probably realistic to select some areas for recreational development.

Provision of the spaces for green, sports, fishing, boating, etc. will be possible at a part of the retarding area, especially in dry season.

The area on the south-eastern edge of the city is identified in DMAIUDP as "urgently requiring planned provision of public open spaces".

The southern compartment-2 and the DND seem to have high priority for recreational development in retarding areas.

2) Agriculture

In the long term, overall, as urban development proceeds, the effects of flood protection will be to reduce the area under agriculture use.

Due to the importance of agriculture on or near the metropolitan area, around 10% of the Greater Dhaka East and the DND feasibility study areas are zoned for agricultural use. In addition to that, it has been estimated in the Master Plan report that 70% of the retarding area would be cultivable for most of the year. Continuing agricultural activities should be encouraged.

3) Fishing ponds

Most flooded areas in Bangladesh are used for fishing. Self-contained ponds are usually fished in a managed fashion, while larger seasonal water bodies are fished in a less organized manner. Currently fish culture is practiced in a number of ponds in Khilgaon and in the DND canal. Less organized fishing takes place in the khal and ponds within the seasonally inundated areas.

Ponds may be leased to entrepreneurs or groups of fishermen by government. If the government leased or purchased land for retarding areas, the original owners could practice fish farming, with advice from the Ministry of Fisheries. Management would need to stock the ponds annually with large fingerlings produced by local hatcheries, as carp needs to reproduce in spawning grounds away from ponds.

At present, the capacity of hatcheries and nurseries in the Dhaka area may be insufficient to produce fingerlings for these areas of fish ponds.

A possible danger would derive from pollution as the city continued to grow. Large inflows of domestic sewerage would consume large amounts of oxygen, resulting in DO levels too low for good yields. Water quality management would thus be crucial. There could be dangers of chemical pollutants due to illegal discharges from industrial areas and from run-off of agrochemical.

For the considerable potential of fish farming in retarding areas, it is recommended that further study be carried out into :

- possible variety of fish and estimates of yield and markets for different types;
- costs and returns ;
- preferred institutional arrangements for managing ponds and nature of advising assistance required ;
- risk from agricultural and industrial effluents;
- prerequisites for further fish culture schemes in the area, in the form of nursery and hatchery requirements.

208

The importance of maintaining fish production may be gauged from the fact that 70% - 80% of animal protein supplies in Bangladesh is obtained from fish. Fish is also the cheapest form of such animal protein. While the construction of the embankment will likely affect the present pattern of fishing, it does also offer an opportunity for higher yields from culture fishery (aquaculture) or fish farming.

4) Oxidation ponds for sewage treatment

As the existing oxidation pond in Pagla has been provided for purification of sewage water from part of the Old Dhaka area, development of new oxidation ponds serving the other part of urban area and the new urban development area in low land zone would be one of the options for the future sewage treatment in the metropolitan area.

The proposed retarding areas would be potential location to facilitate those oxidation ponds. It is assumed that if all the generated sewage would be treated by new oxidation ponds in the whole feasibility study area, some 1000 ha of such oxidation ponds area is required.

And it is noticed that a multiple use , such as oxidation pond cum fishing pond or oxidation pond cum irrigation, of retarding area is more realistic.

Further investigation on the above options for the multiple use of the retarding area, are strongly recommended.

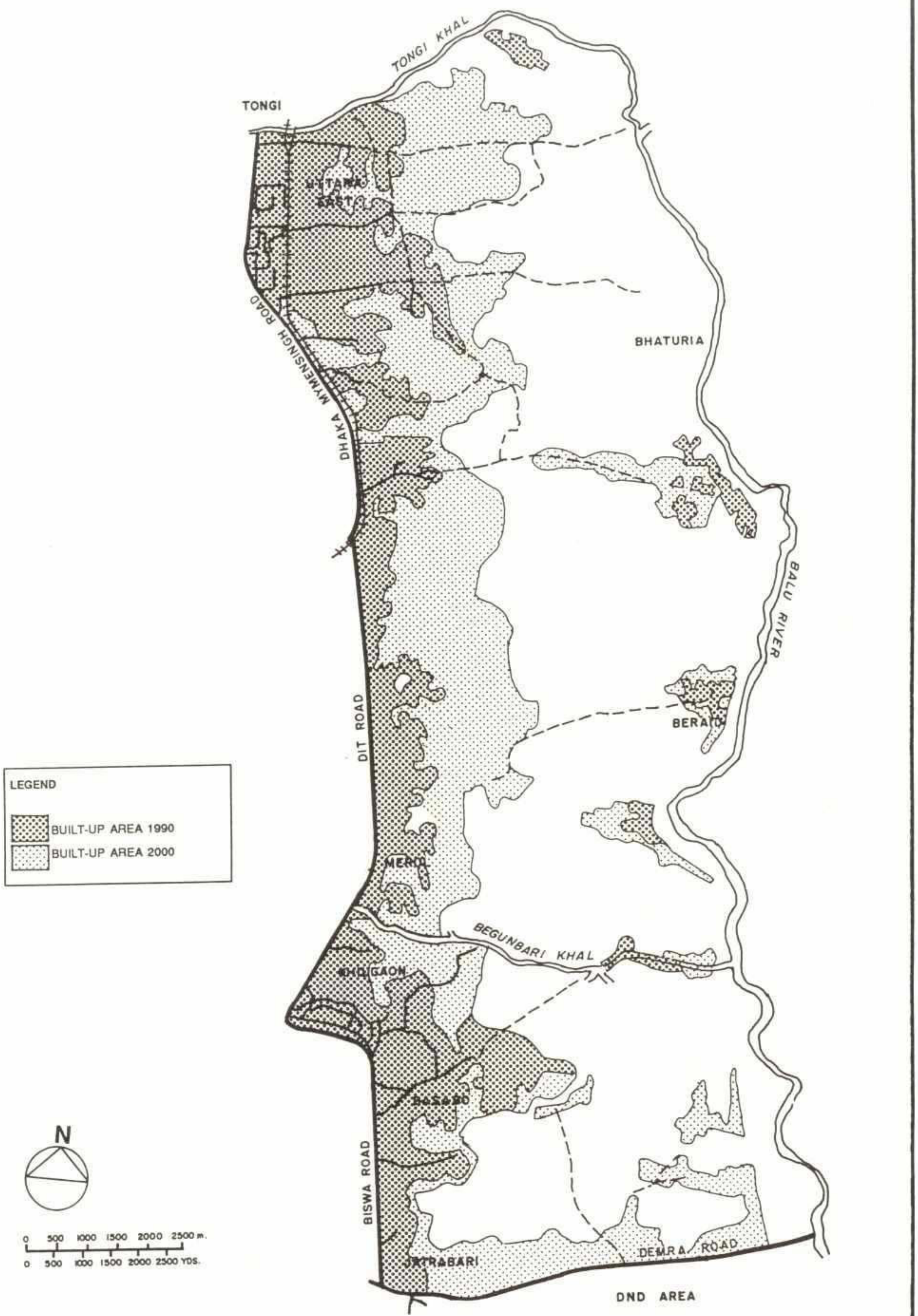

FIG. 4.1	BUILT-UP AREA 1990/2000 : GREATER DHAKA EAST

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

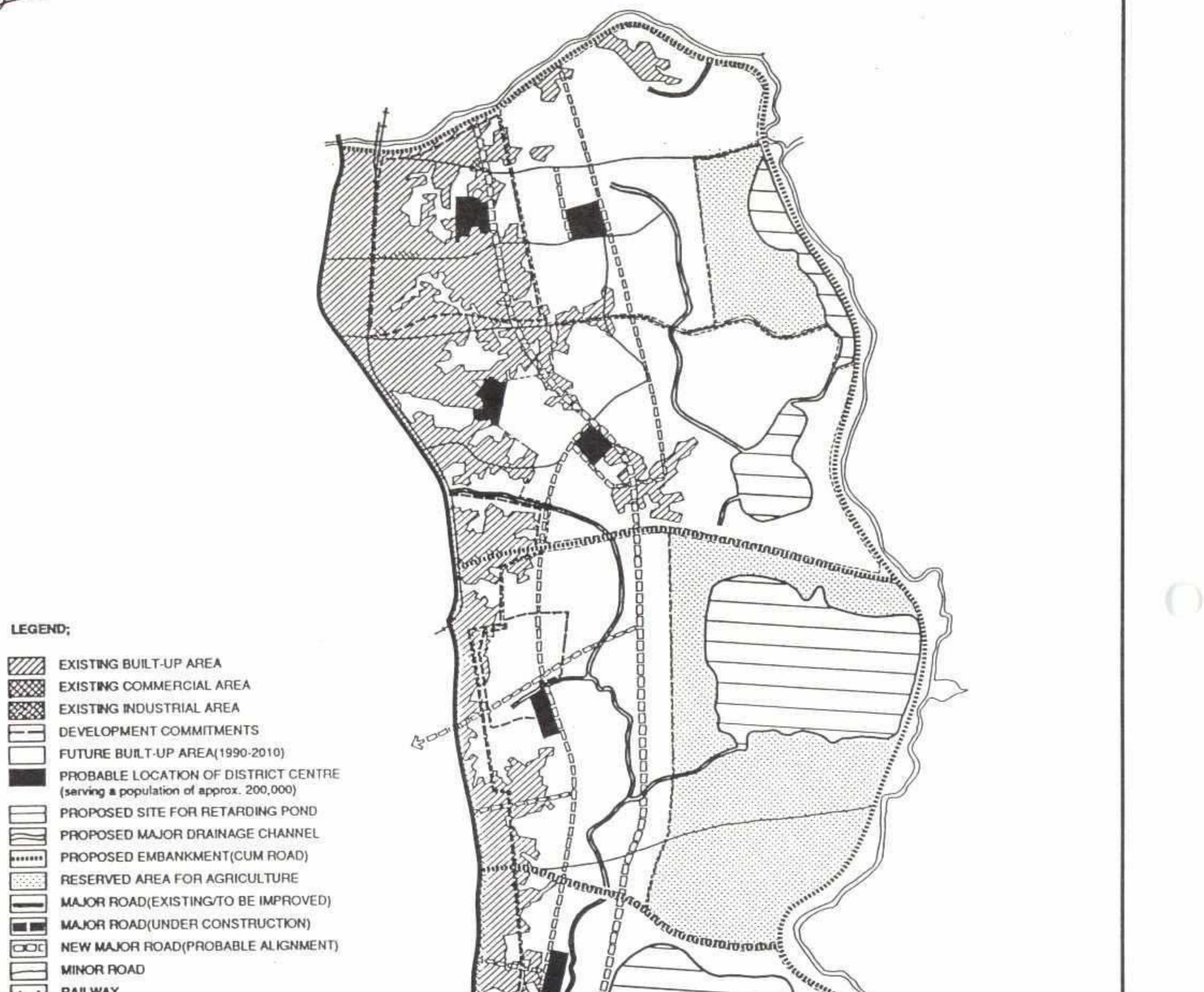

FIG. 4.2	INDICATIVE LAND USE MAP, 2010 : GREATER DHAKA EAST

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

206

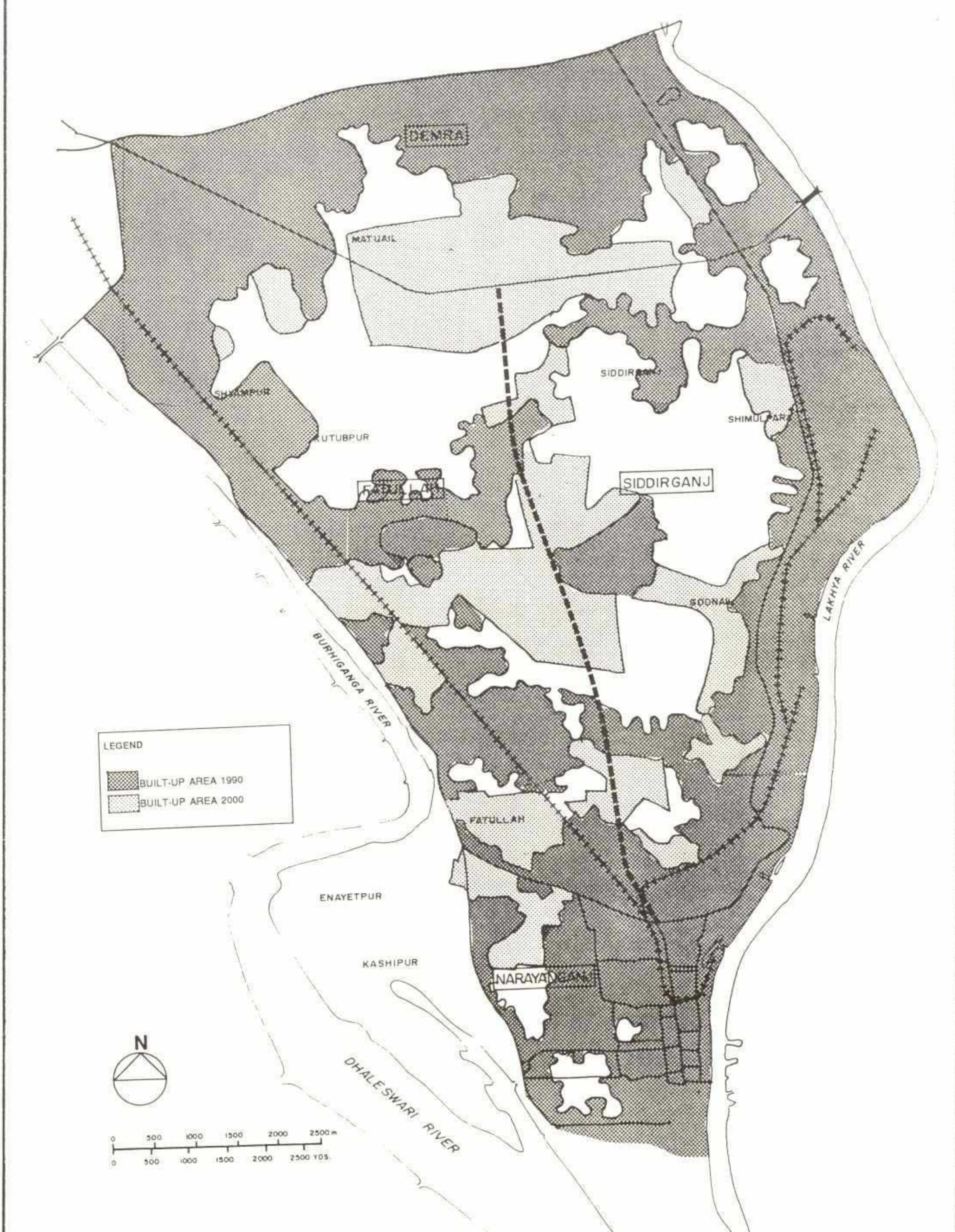

FIG. 4.3 BUILT-UP AREA 1990/2000 : DND/NARAYANGANJ WEST

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

208

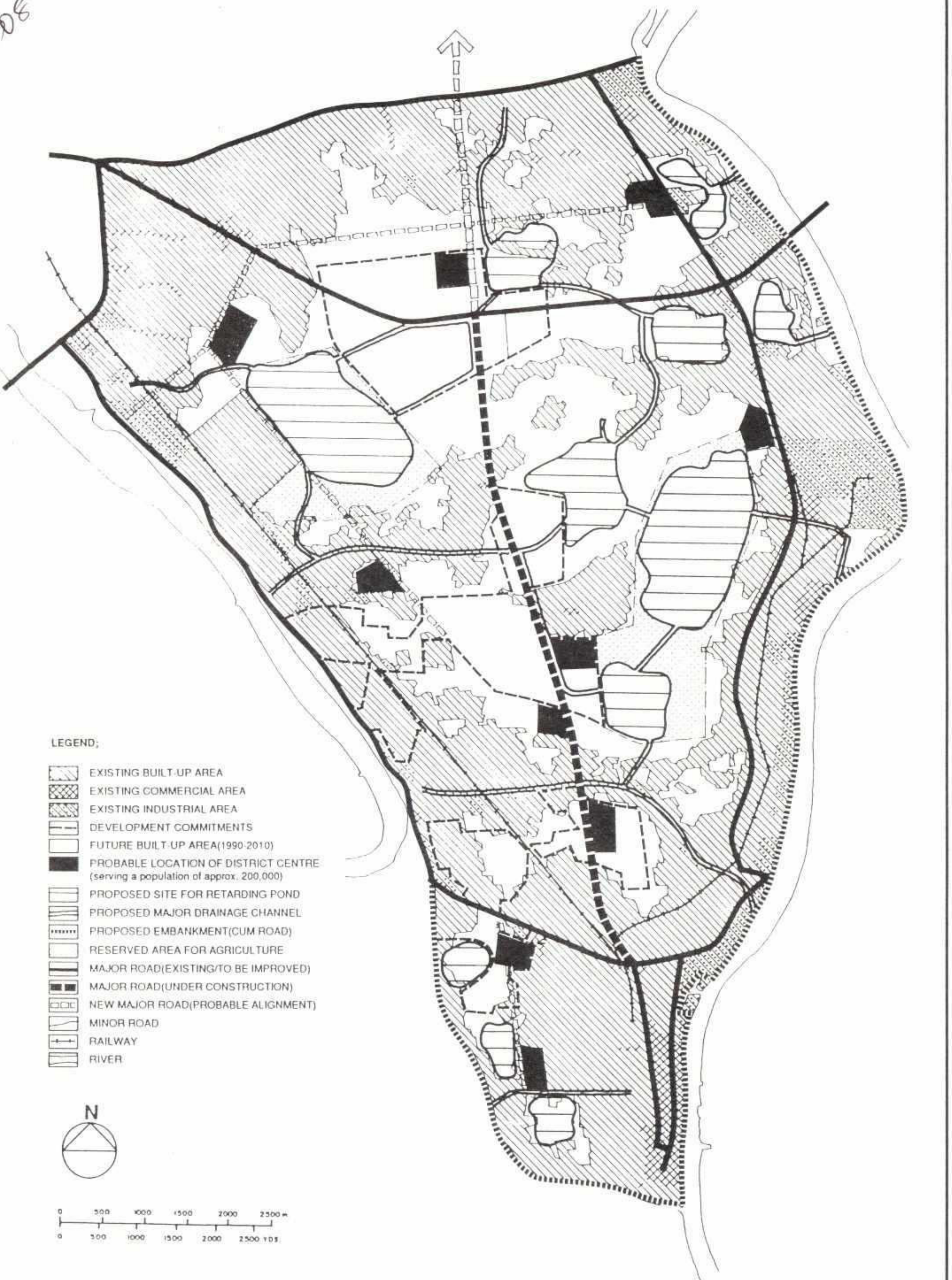

FIG. 4.4 INDICATIVE LANDUSE MAP OF NARAYANGANJ DND/WEST, 2010

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

CHAPTER 5
FLOOD DAMAGE ANALYSIS

209

Chapter 5 : Flood Damage Analysis

5.1 Flood Condition

5.1.1 General

During the Phase I (Preliminary Review Stage) and the Phase II (A Master Plan Study Stage), a questionnaire survey on "external and internal floods" in the study area of 850 km^2 was carried out. The survey on external floods was executed on the last three floods of the 1987 flood, the 1988 flood and the 1990 flood. The 1990 flood was considered as an "annual flood". The survey on internal floods was done on the annual flood and the worst one.

For this feasibility study stage, supplementary flood surveys on flood depth, duration and flood damages have been carried out for the F/S area including a related area of Dhaka City, which belongs to the drainage area of the Balu River.

Both the maximum depth of flooding and its duration relates to the damage to houses, assets and crops. Specifically, duration of inundation is an important factor affecting the degree of damage and inconvenience caused.

The supplementary surveys consist of the followings :

(1) Review of the flood depth and duration survey data in the Master Plan Study according to the land use of each administrative unit, and

(2) Collection of supplementary data and information on flood damages to public utilities and traffic, from RHD, DCC, Bangladesh Railways, Power Development Board, etc.

Concerning the internal flood conditions of zones No. 1 to 53 in the Dhaka Sub-Area, the survey results of the 1987 JICA Study were referred to.

5.1.2 Greater Dhaka East

The survey area covers the Greater Dhaka East (118.62 km^2) and a part of the Greater Dhaka West (47.74 km^2), mostly built-up, which drains off eastwards to the Balu River. The survey area consists of 39 zones based on the administrative division of wards and unions, and shown in Fig.5.1.

209

1) External Flood

(1) Annual Flood

The total flood area by the annual external flood was estimated at 7,850 ha, 47% of the survey area. No flooding in the built-up area. Most of the agricultural area in Greater Dhaka East is submerged during the flood season, and there are rural villages or settlements likely to be isolated, but still flood free because their house lots are built a little higher than the annual flood stage.

There are only limited cases of flooding by the annual flood. However, it does not mean that the study area is free from the annual flood. The flood depth and duration were surveyed only for houses and assets, which are mostly located on high plots that are safe from annual external floods. The annual flood area is shown in Fig. 5.3.

(2) 1987 Flood

The flood area by the 1987 flood is estimated at 10,716 ha, 64% of the survey area. Within the flood area, the built-up area is estimated at 1,121 ha, 17% of the total built-up area.

During the 1987 flood, the maximum flood depth and duration in the survey area were 0.91m and 22 days respectively, and the average depth and duration were 0.27 m and 7.47 days respectively. Fig. 5.4 shows the flood depth and the flood duration at houses and the flood depth around settlements. Flooded depth around settlement areas were from 0.4 m to 4.0m.

(3) 1988 Flood

The 1988 flood was the most severe to hit the study area. The flood areas were estimated at 13,173 ha, 79% of the survey area. The built-up area of 3,285 ha, 49% of the total built-up area was affected. The maximum flood depth and duration in the survey area were 2.13 m and 65 days respectively. The average flood depth and duration were estimated at 0.72 m depth and 19.66 days respectively.

Fig. 5.5 shows flood depth and duration by the 1988 flood. The flooded depth around rural settlements was estimated from 0.3 m to 4.6 m.

(4) Land use and Flood Area

The relationships between the flood areas and the land use are developed for 1990 and 2010 and shown in Fig. 5.6.

2) Internal Flood

(1) Annual Flood

The internal flood area is estimated at 417 ha, 3% of the survey area. The internal flood area is mostly in the highly built-up areas.

The maximum flood depth and duration are 0.61 m depth and 4 days respectively. Also, the average flood depth and duration are 0.37 m depth and 0.44 days respectively.

(2) Worst Flood

The internal flood areas by the worst flood are estimated at 417 ha, 3% of the survey area.

Fig. 5.7 shows internal inundation areas which are mostly distributed in the highly built-up areas.

The maximum flood depth and duration in the worst internal flood are estimated at 0.91 m depth and 6.0 days, respectively. On the other hand, the average depth and duration of inundation are estimated at 0.54 m and 1.19 days, respectively (refer to Fig. 5.8).

5.1.3 DND and Narayanganj West

1) DND

The DND area is consisting of 14 zones based on administrative divisions of wards and unions which are shown in Fig.5.2.

(1) External Flood

The DND area is mostly free from floods due to the existing embankment. During the 1987 floods, the DND area was not affected. However during the 1988 floods, the DND area was marginally safe from flooding principally due to the timely flood

203

fighting measures such as raising the embankment by sand bags. In fact the flood stage exceeded partly the top of embankment.

(2) Internal Flood

The annual internal flood area is estimated at 410 ha, 7% of the DND area. The maximum flood depth and duration of inundation are 0.15 m depth and 2.0 days, respectively. Also, the average flood depth and duration are 0.13 m and 2.0 days, respectively.

The worst internal flood area is estimated at 410 ha, 7% of the DND area. The maximum depth and duration of inundation by the worst flood were estimated at 0.76 m depth and 7.0 days, respectively. On the other hand, the average flood depth and duration are estimated at 0.28 m and 2.74 days respectively.

2) Narayanganj West

The study area is consisting of 14 zones based on administrative divisions of wards and unions which are shown in Fig.5.2.

(1) External Flood

The total flood area in the annual external flood is estimated at 111 ha, 6% of the Narayanganj West area, however no flooding in the built-up area.

There are only few cases of flooding due to the annual flood. However, it does not mean that the area is free from annual external flood. The flood depth and duration was surveyed on rural settlements, which are mostly located on high plots that are not affected by the annual floods.

The 1987 flood area is estimated at 606 ha, 33% of the Narayanganj West area. The built-up area affected by the flood is 379 ha, 29% of the total built-up area. The maximum flood depth and duration in the Narayanganj West area are estimated at 0.61 m depth and 15.0 days respectively, and the average depth and duration are 0.27 m and 8.11 days, respectively. Fig. 5.4 shows the flood depth and duration at houses of residence and the depth around settlements.

The 1988 flood areas are estimated at 1863 ha. The built-up area affected by the flood is 1312 ha, the whole of the built-up area. The maximum flood depth and duration are 1.63 m and 40.0 days respectively. The average flood depth and duration are estimated at 0.84 m depth and 21.69 days respectively. Fig. 5.5 shows the flood depth and duration. Flood depth around settlements is estimated from 0.8 m to 2.6 m.

(2) Internal Flood

The annual internal flood area is estimated at 87 ha, 5% of the Narayanganj West area. The internal flood areas are distributed mostly in the highly built-up areas. The maximum flood depth and duration are estimated at 0.12 m depth and 0.08 days respectively, and the average flood depth and duration are 0.12 m and 0.08 days respectively.

The worst internal flood area is estimated at 87 ha, 5% of the Narayanganj West areas. The internal inundation areas are located mostly in the highly built-up area. The maximum depth and duration in the worst internal flood are estimated at 0.82 m depth and 2 days, respectively. On the other hand, the average flood depth and duration are estimated at 0.28 m depth and 0.79 days, respectively.

5.2 Flood Damages

Flood damages are calculated for each of the annual, the 1987 and the 1988 external and internal floods. Flood damages take the form of direct damages to houses, shops, industries and institutions, income/profit losses for households, shops and factories, traffic damages, direct damages to infrastructures and profit losses for public enterprises. As a specific example the calculative steps leading to the estimation of the direct damages and income losses to houses by a 1987 - scale flood in Greater Dhaka East are explained in Annex 1 of Supporting Report B.

Direct damages to houses, shops, industries and institutions as well as income / profit losses for households, shops and factories are estimated based on the area, depth and duration of inundation and the unit value and the number of the above-mentioned respective properties.

In estimating the internal flood damages, the results of the "Study on Storm Water Drainage System Improvement Project in Dhaka City" in 1987 were referred to and utilized.

Flood damages are estimated for both the years of 1990 and 2010. Flood damages for 2010 will be greater than those in 1990 because the unit value and number /quantity of properties, the volume of traffic and the quantity of infrastructures will be greater in

222

2010 than in 1990. Various kinds of flood damages are added together and ultimately they are converted into "average annual flood damages".

5.2.1 Estimated Property Damages and Losses

Direct damages to properties and income/profit losses of economic units were together broadly classified as residential, commercial, industrial, institutional and agricultural damages.

Residential damages consist of damages to buildings, damages to household effects and income losses. Commercial and industrial damages consist of damages to buildings, damages to equipment & inventories and profit losses. Institutional and agricultural damages mean, respectively, damages to buildings and agricultural crops.

(1) Year 1990

There were no annual external flood damages in 1990 in the Study Area. Supposing the 1987-scale flood had hit the Greater Dhaka East area in 1990, damages and losses amounting to Tk. 493.0 million would have been incurred, of which 54.8% and 45.0% would have been accounted for by residential and agricultural damages, respectively. Most of residential damages would have been witnessed in the two southern compartments and agricultural damages around all over the area.

The 1987-scale flood would in 1990 have inflicted damages in the Narayanganj DND area amounting to Tk. 142.9 million, of which 82.0% and 17.7% would have been accounted for by residential and agricultural damages, respectively. Likewise, the same flood would have inflicted damages in the Narayanganj West area amounting to Tk. 75.5 million, of which 82.6% and 17.0% would have been accounted for by residential and agricultural damages, respectively.

Supposing the 1988-scale flood had hit the Greater Dhaka East area in 1990, damages and losses amounting to Tk. 3,086.0 million would have been incurred. Out of them, 76.9%, 14.4% and 8.7% would have been accounted for by residential, commercial / industrial / institutional and agricultural damages, respectively. The same flood would have inflicted damages in the DND area amounting to Tk. 1,864.1 million, of which 72.0%, 23.3% and 4.7% would have been accounted for by residential, commercial / industrial / institutional and agricultural damages, respectively. Similarly, the same flood would have inflicted damages in the Narayanganj West area amounting to Tk.

1,310.8 million, of which 77.5%, 20.9% and 1.6% would have been accounted for by residential, commercial / industrial / institutional and agricultural damages, respectively.

The annual internal flood in 1990 brought on the damages to house buildings and household articles in the Greater Dhaka East area amounting to Tk. 121.0 million. Most of the damages were witnessed in the two southern compartments. The same flood brought on the damages to houses amounting to Tk. 27.3 million and Tk. 0.8 million in the Narayanganj DND and West areas, respectively.

The worst internal flood in 1990 would have brought on the damages to house buildings and household articles in the Greater Dhaka East area amounting to Tk. 257.3 million. The same flood would have brought on the damages to houses amounting to Tk. 43.4 million and Tk. 9.9 million in the DND and the Narayanganj West areas, respectively.

(2) Year 2010

Supposing the annual external flood hit the Greater Dhaka East area in 2010, damages and losses amounting to Tk. 157.6 million would be suffered, most of which would be in the form of income losses of households. The same flood would cause damages amounting to Tk. 7.1 million and Tk. 6.1 million in the Narayanganj DND and West areas, respectively.

If the 1987-scale flood hit the Greater Dhaka East area in 2010, damages and losses amounting to Tk. 2,884.6 million would be suffered, of which 99.2% would be borne by the residential sector. The same flood would cause damages amounting to Tk. 518.8 million and Tk. 229.4 million in the DND and the Narayanganj West areas, respectively. Most of them would be borne by the residential sector.

If the 1988-scale flood hit the Greater Dhaka East area in 2010, damages and losses amounting to Tk. 12,995.7 million would be suffered, of which 88.2%, 11.6% and 0.2% would be borne by the residential, commercial / industrial / institutional and agricultural sectors, respectively.

The 1988-scale flood would in 2010 cause damages in the DND area amounting to Tk. 8,530.8 million, of which 74.3% and 25.6% would be borne by the residential and commercial / industrial / institutional sectors, respectively. The same flood would cause damages in the Narayanganj West area amounting to Tk. 5,678.1 million, of which

226

63.7% and 36.3% would be borne by the residential and commercial / industrial / institutional sectors, respectively.

If the annual internal flood hit the Greater Dhaka East area in 2010, the damages to house buildings and household articles would amount to Tk. 185.9 million. The same flood would bring on the damages to houses amounting to Tk. 109.1 million and Tk. 2.0 million in the DND and the Narayanganj West areas, respectively.

If the worst internal flood experienced in 1986 hit the Greater Dhaka East area in 2010, the damages to house buildings and household articles would amount to Tk. 389.9 million. The same flood would bring on the damages to houses amounting to Tk. 171.0 million and Tk. 24.4 million in the DND and the Narayanganj West areas, respectively.

5.2.2 Estimated Traffic Damages

1) Impacts of Floods on Vehicle Traffic

Traffic survey was conducted to know the volume of vehicle traffic and major flood vulnerable points in the Greater Dhaka East and the Narayanganj West.

Traffic damage survey was conducted along with traffic survey to know about the average sales, oil cost, incremental time cost, etc., per vehicle by type of vehicles for each type/scale of floods. The number of samples was 30 for each type of vehicles. The survey was conducted mostly in the Greater Dhaka east and related areas.

During the 1988 floods, vehicles could not operate for 20.1 days on average and also they were forces to operate slowly for 38.9 days on average. Likewise, in the 1986 floods which was the worst internal flood, vehicles could not operate for 1.3 days on average and also they operated slowly for 12.9 days on average.

Operating distance per day per vehicle is on average 131.0 km in normal time, while it is 104.7 km in slow-operating flood time. Operating speed is on average 41.5 km per hour in normal time, while it is 30.7 km per hour in flood time.
It is to be noted that operating hours per day per vehicle on average increases from 3.16 hours in normal time to 3.41 hours in flood time, oil consumption per km per vehicle increases from 0.235 liter in normal time to 0.279 liter in flood time and sales per km per commercial vehicle increases from Tk. 11.5 in normal time to Tk. 12.1 in flood time.

228

2) Estimated Traffic Damages

(1) 1987-scale Flood

Supposing the 1987-scale flood had hit the Greater Dhaka East area in 1990, traffic damages amounting to Tk.86.5 million would have been incurred, most of which would have occurred in the two southern compartments. The same flood would have inflicted traffic damages in the DND and the Narayanganj West areas amounting to Tk. 22.0 million and Tk. 23.2 million, respectively.

Supposing the 1987-scale flood hit the Greater Dhaka East area in 2010, traffic damages amounting to Tk. 256.5 million would be incurred. The same flood would inflict traffic damages in the Narayanganj DND and West areas amounting to Tk. 102.2 million and Tk. 71.4 million, respectively.

(2) 1988-scale Flood

Supposing the 1988-scale flood had hit the Greater Dhaka East area in 1990, traffic damages amounting to Tk.187.3 million would have been incurred, most of which would have occurred in the two southern compartments. The same flood would have inflicted traffic damages in the Narayanganj DND and West areas amounting to Tk. 47.3 million and Tk. 50.5 million, respectively.

Supposing the 1988-scale flood hit the Greater Dhaka East area in 2010, traffic damages amounting to Tk. 551.1 million would be incurred. The same flood would inflict traffic damages in the Narayanganj DND and West areas amounting to Tk. 220.5 million and Tk. 155.1 million, respectively.

(3) Worst Internal Flood

Supposing the 1986-scale flood which is the worst internal flood had hit the Greater Dhaka East area in 1990, traffic damages amounting to Tk.36.5 million would have been incurred. The same flood would have inflicted traffic damages in the Narayanganj DND and West areas amounting to Tk. 10.1 million and Tk. 10.3 million, respectively.

Supposing the 1986-scale hit the Greater Dhaka East area in 2010, traffic damages amounting to Tk. 119.8 million would be incurred. The same flood would inflict traffic damages in the Narayanganj DND and West areas amounting to Tk. 47.0 million and Tk. 32.0 million, respectively.

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5.2.3 Estimated Damages to Infrastructures and Profit Losses for Public Enterprises

1) Concept and Methodology

The JICA Study Team conducted interview surveys visiting the officials concerned in RHD, DCC, Dhaka District Council, NMC, Bangladesh Railways, Power Development Board, T&T, DWASA, NWASA, Titas Gas, CAA and other related agencies.

The study team wanted to gather information and data on the direct damages to infrastructures such as roads, bridges, railways, electricity supply facilities, telecommunication facilities, water supply facilities, sewerage facilities, gas supply facilities and the airport in each of the 5 types/scales of floods for each of the 3 areas. Also, the study team wanted to collect information and data on profit losses for public enterprises such as Bangladesh Railways, Power Development Board, T&T, DWASA, NWASA, Titas Gas and CAA.

The basic approach to the estimation of direct damages to infrastructures was the establishment of total quantity (length or number), construction cost per unit quantity and the ratio of repair cost to construction cost for each type of infrastructures. By combining these three factors direct damages to infrastructure will be arrived at.

The direct damages to infrastructures and profit losses for public enterprises for 2010 were forecast based on the projected number of properties such as houses, shops, factories and institutions.

2) Estimated Damages and Losses

(1) Direct Damages to Infrastructures

Direct damages to infrastructures in the Greater Dhaka East area was found to total Tk. 41.5 million in the annual external flood, Tk. 68.7 million in the 1987 flood, Tk. 458.1 million in the 1988 flood, Tk. 22.6 million in the annual internal flood and Tk. 58.1 million in the worst internal flood. Damages were concentrated in the two southern compartments.

Direct damages to infrastructures in the DND area totaled Tk. 1.4 million, Tk. 1.4 million, Tk. 22.4 million, Tk. 7.8 million, Tk. 10.3 million in the annual external, the 1987, the 1988, the annual internal and the worst internal floods, respectively.

Likewise, direct damages to infrastructures in the Narayanganj West area summed up to Tk. 5.5 million for the annual external flood, Tk. 17.5 million for the 1987 flood, Tk. 134.2 million for the 1988 flood, Tk. 19.1 million for the annual internal flood and Tk. 31.9 million for the worst internal flood.

Supposing the annual external flood hit the Greater Dhaka East area in 2010, direct damages to infrastructures amounting to Tk.133.7 million would be incurred. Likewise, the 1987-scale, the 1988-scale, the annual internal and the worst internal floods would inflict damages amounting to Tk. 221.1 million, Tk. 1,474.5 million, Tk. 72.9 million and Tk. 186.9 million, respectively. Damages will still predominate in the two southern compartments, but the growth of damages in the two northern compartments will be conspicuous.

Supposing the annual external flood hit the DND area in 2010, direct damages to infrastructures amounting to Tk.6.6 million would be incurred. Likewise, the 1987-scale, the 1988-scale, the annual internal and the worst internal floods would inflict damages amounting to Tk. 6.6 million, Tk. 106.0 million, Tk. 36.9 million and Tk. 48.8 million, respectively.

Supposing the annual external flood hit the Narayanganj West area in 2010, direct damages to infrastructures amounting to Tk.17.4 million would be incurred. Likewise, the 1987-scale, the 1988-scale, the annual internal and the worst internal floods would inflict damages amounting to Tk. 55.3 million, Tk. 422.8 million, Tk. 60.3 million and Tk. 100.7 million, respectively.

(2) Profit Losses for Public Enterprises

It was found out that profit losses for public enterprises are not marked compared to direct damages to infrastructures.

The 1987 and 1988 floods are estimated to have caused profit losses amounting to Tk. 6.2 million and Tk. 43.0 million respectively for public enterprises in the Greater Dhaka East area. Likewise, the two floods caused profit losses amounting Tk.1.1 million and Tk. 8.0 million respectively for public enterprises in the Narayanganj West area.

Supposing the annual external flood hit the Greater Dhaka East area in 2010, profit losses amounting to Tk. 1.5 million would be suffered by public enterprises. Likewise, the 1987-scale, 1988-scale, the annual internal and the worst internal floods would bring on profit losses amounting to Tk. 20.3 million, Tk. 138.6 million, Tk. 1.0

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million and Tk. 1.8 million respectively to public enterprises in the area. Also, the 1987-scale and 1988-scale floods in 2010 would bring on profit losses amounting to Tk. 3.6 million and Tk. 25.3 million respectively to public enterprises in the Narayanganj West area.

5.2.4 Summary of Flood Damages

1) Summary of Flood Damages by Type / Scale of Floods

Direct damages to properties, income / profit losses of economic units, traffic damages, direct damages to infrastructures and profit losses for public enterprises are added together by area, by type / scale of floods and by year. In doing so, 10% addition is done to the results of the above summation to rake up unaccounted-for damages. The 10% addition is explained and substantiated in Annex 2 of Supporting Report B.

The below table summarizes flood damages worked out in the above mentioned way.

(Unit : Tk. Million)

Area	External Flood			Internal Flood	
	Annual	1987-Scale	1988-Scale	Annual	Worst
1. 1990					
DC - 1	2.8	89.8	293.5	1.8	6.7
DC - 2	1.3	53.6	233.8	0.7	2.8
DC - 3	21.3	219.6	1,263.4	66.6	167.0
DC - 4	20.8	357.1	2,361.2	89.3	214.6
Dhaka East	46.2	720.1	4,151.9	158.4	391.1
Narayanganj DND	1.5	182.9	2,127.4	38.6	70.2
Narayanganj West	6.1	129.0	1,653.6	21.9	57.3
Total	53.8	1,032.0	7,932.9	218.9	518.6
2. 2010					
DC - 1	75.8	1,415.9	3,516.7	10.0	38.5
DC - 2	33.8	322.9	1,425.3	5.1	21.0
DC - 3	100.0	863.1	4,746.4	128.9	345.5
DC - 4	112.5	1,118.9	6,988.0	141.8	363.2
Dhaka East	322.1	3,720.8	16,676.4	285.8	768.2
Narayanganj DND	15.1	690.4	9,743.6	160.6	293.5
Narayanganj West	25.9	395.7	6,909.4	68.5	172.8
Total	363.1	4,806.9	33,329.4	514.9	1,234.5

(For more details refer to Tables B.30 and B.31.)

226

2) Average Annual Flood Damages

Based on the figures tabulated in the preceding section, average annual flood damages are calculated. (The methodology for the calculation of average annual flood damages is explained in 2.3.5 Estimation of Average Annual Flood Damages in Master Plan Supporting Report I). The results are shown in the below table.

(Unit : Tk. Million)

Area	1990	2010
DC - 1	43.2	648.4
DC - 2	26.4	176.7
DC - 3	195.1	628.5
DC - 4	293.0	791.3
Greater Dhaka East	557.7	2,244.9
Narayanganj DND	153.4	639.9
Narayanganj West	113.4	395.3
Total	824.5	3,280.1

As a specific example the calculative steps leading to the estimation of average annual flood damages for Greater Dhaka East are explained in Annex 3 of Supporting Report B.

The above-tabulated flood damages are expected in the "without" situation. In other words, the benefits of the same amount can be expected in the "with" situation. (The average annual flood damages broken down into external and internal flood damages are shown in Table 5.1).

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TABLE 5.1 AVERAGE ANNUAL FLOOD DAMAGES BY AREA BY YEAR

(Unit : Tk. Million)

Area	Average Annual Flood Damages		
	External Flood	Internal Flood	Total
1. 1990			
Dhaka East - 1	40.7	2.5	43.2
Dhaka East - 2	25.4	1.0	26.4
Dhaka East - 3	121.0	74.1	195.1
Dhaka East - 4	195.5	97.5	293.0
Dhaka East (Sub-Total)	382.6	175.1	557.7
Narayanganj DND	116.0	37.4	153.4
Narayanganj West	88.5	24.9	113.4
Total	587.1	237.4	824.5
2. 2010			
Dhaka East - 1	634.5	13.9	648.4
Dhaka East - 2	169.3	7.4	176.7
Dhaka East - 3	480.4	148.1	628.5
Dhaka East - 4	631.9	159.4	791.3
Dhaka East (Sub-Total)	1,916.1	328.8	2,244.9
Narayanganj DND	483.8	156.1	639.9
Narayanganj West	318.8	76.5	395.3
Total	2,718.7	561.4	3,280.1

Source : JICA

220

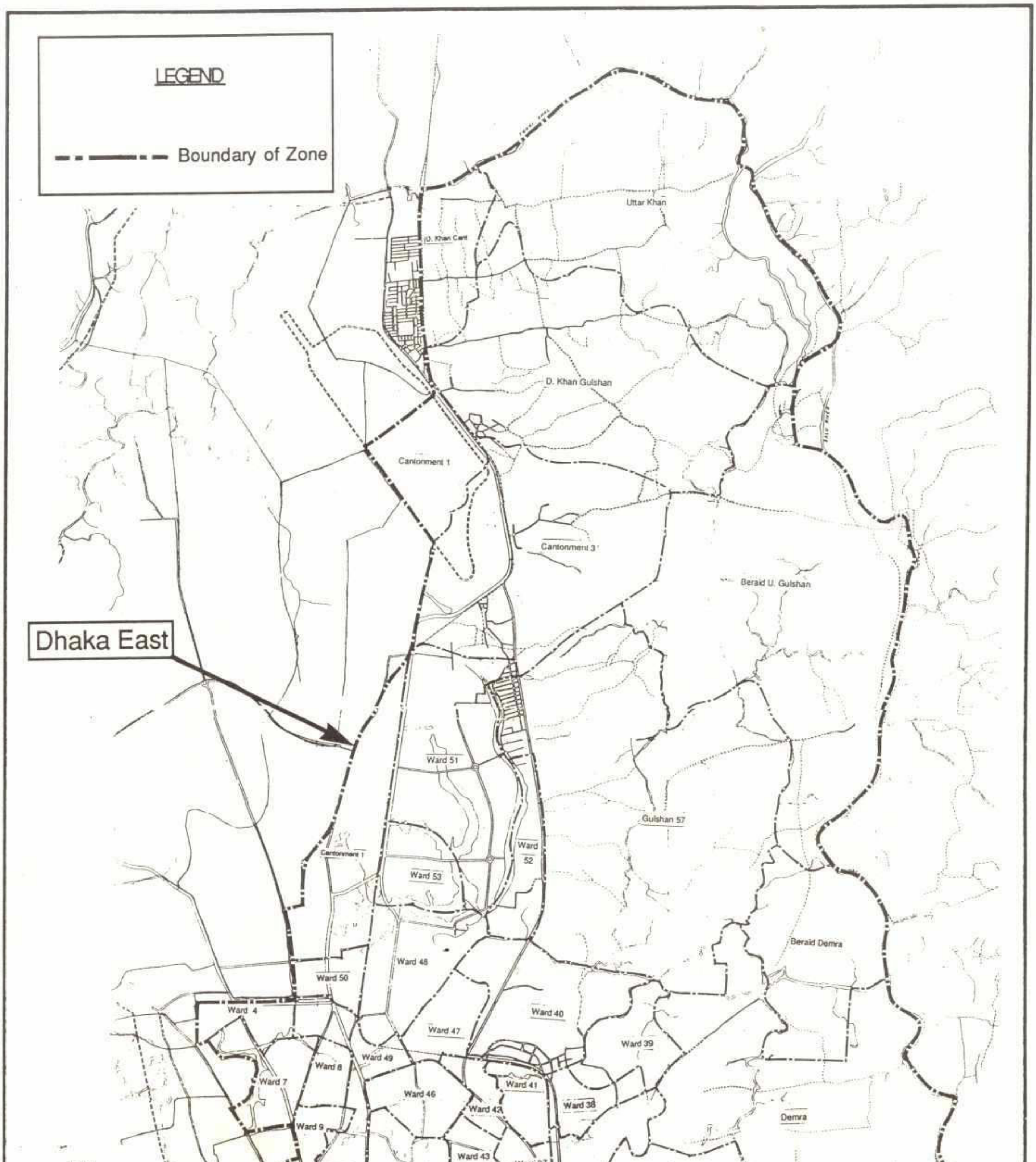

FIG. 5.1 DIVISION OF STUDY AREA BY ZONE : DHAKA EAST/DRAINAGE RELATED AREA

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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222

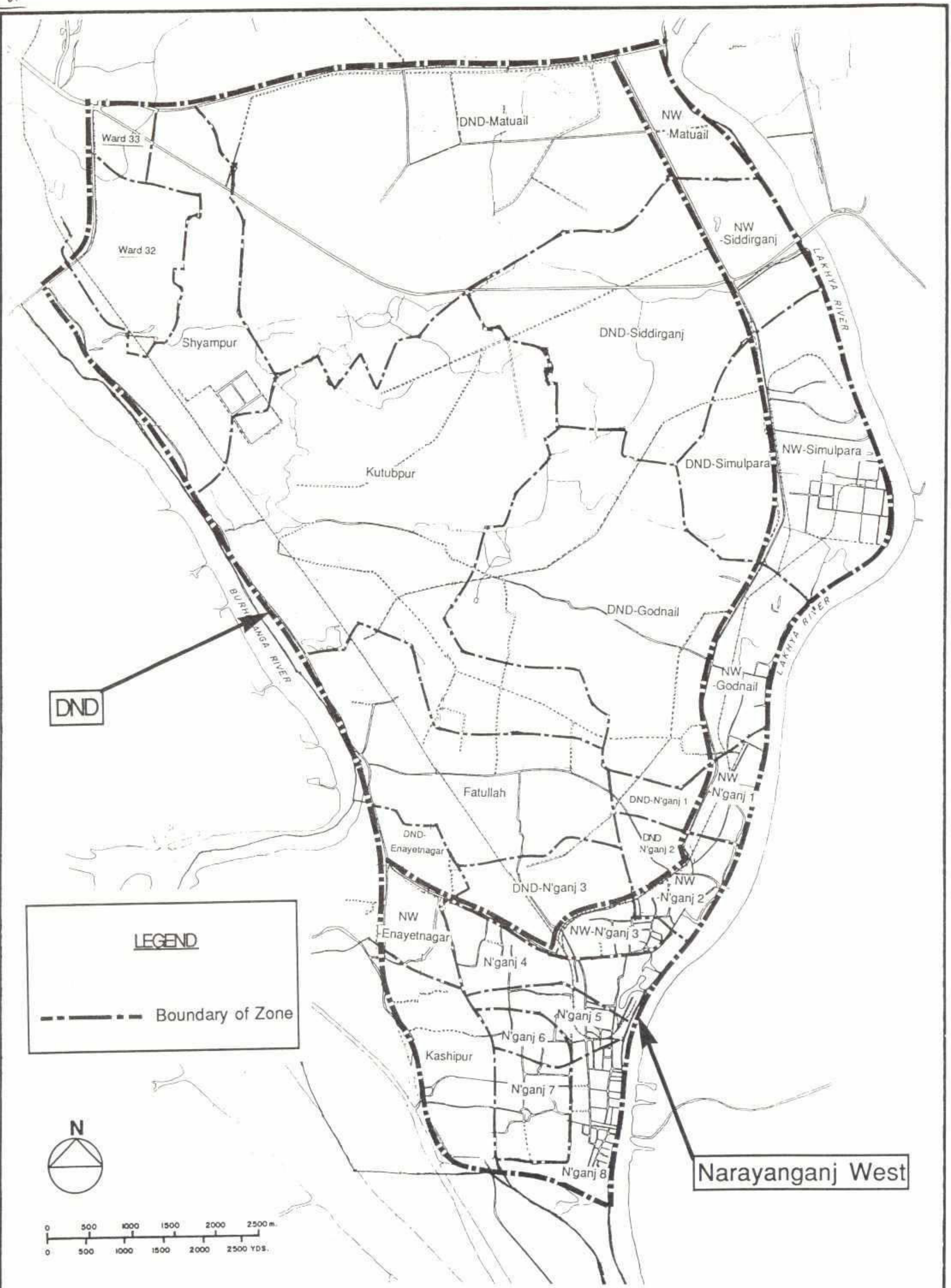

FIG. 5.2 DIVISION OF STUDY AREA BY ZONE - DND, NARAYANGANJ WEST

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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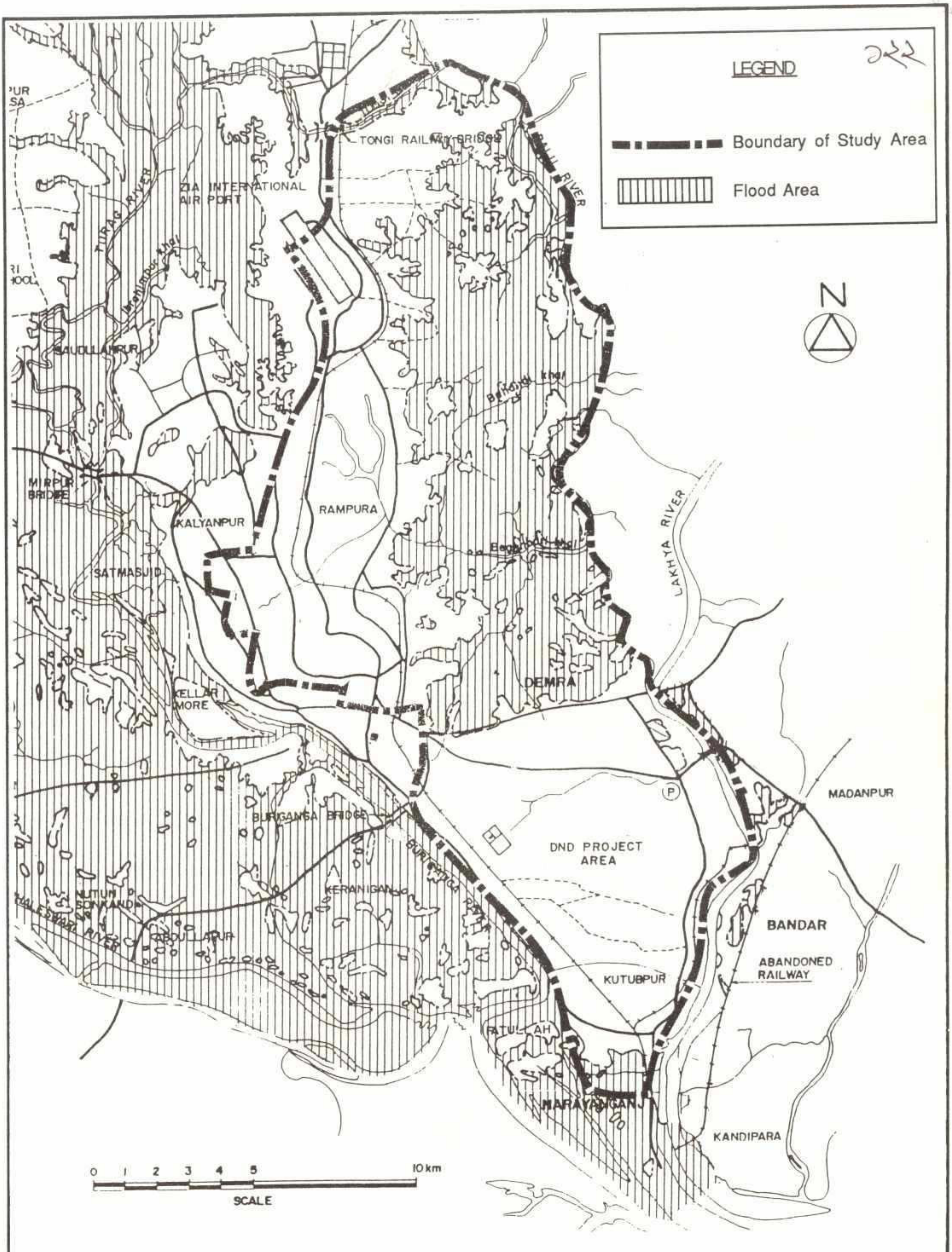

FIG. 5.3 EXTERNAL FLOOD MAP-ANNUAL FLOOD

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

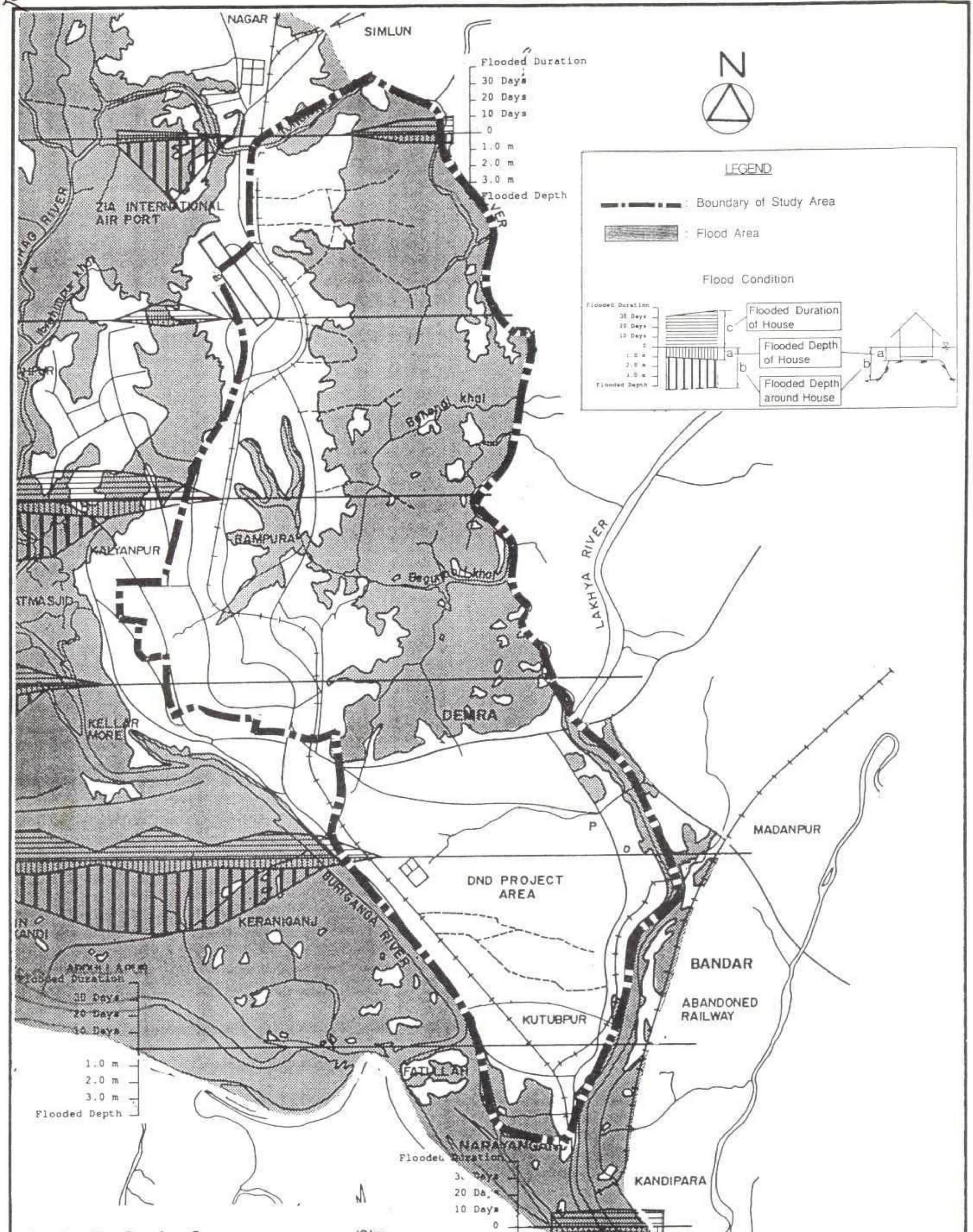

FIG. 5.4 EXTERNAL FLOOD MAP-1987 FLOOD

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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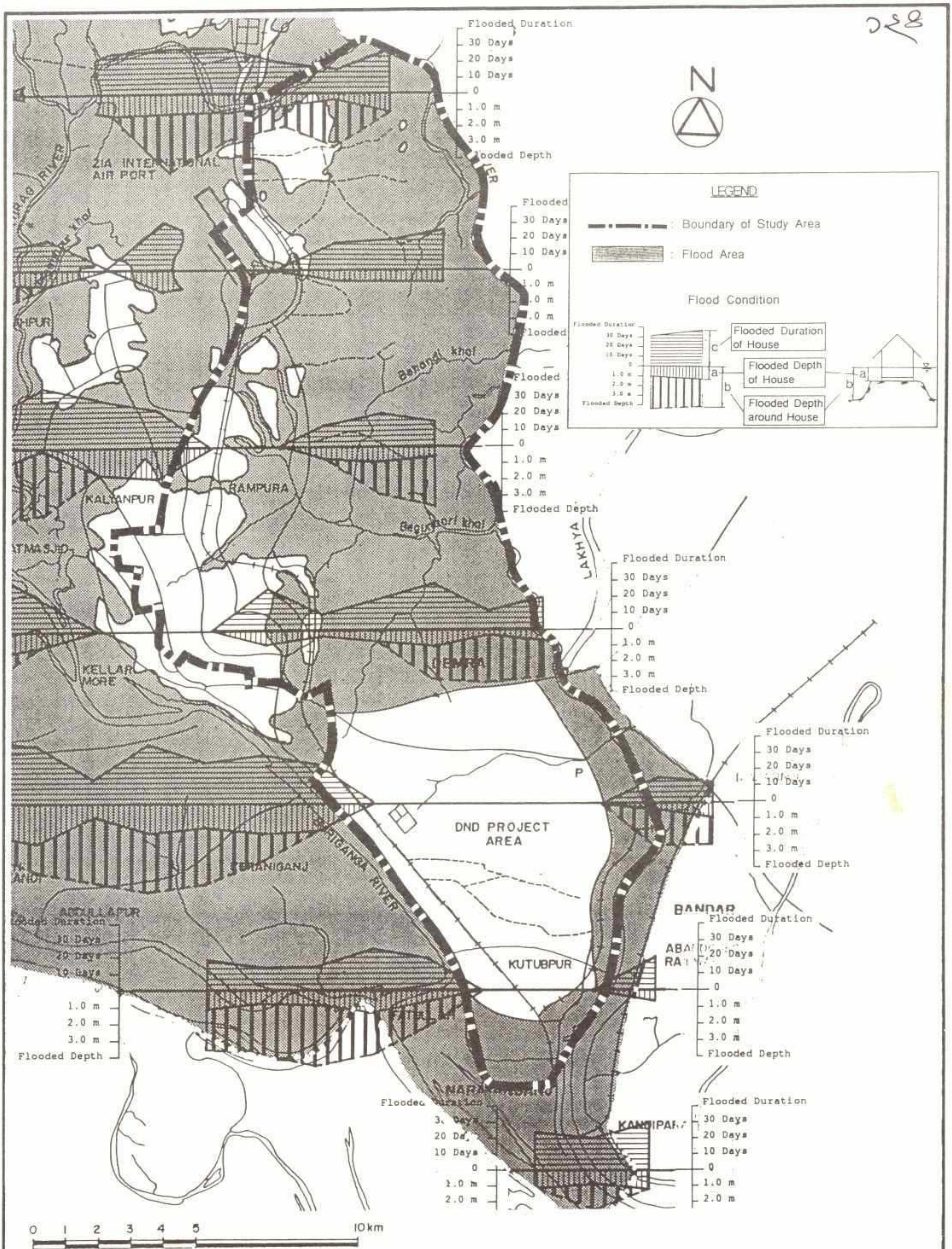

FIG. 5.5 EXTERNAL FLOOD MAP-1988 FLOOD

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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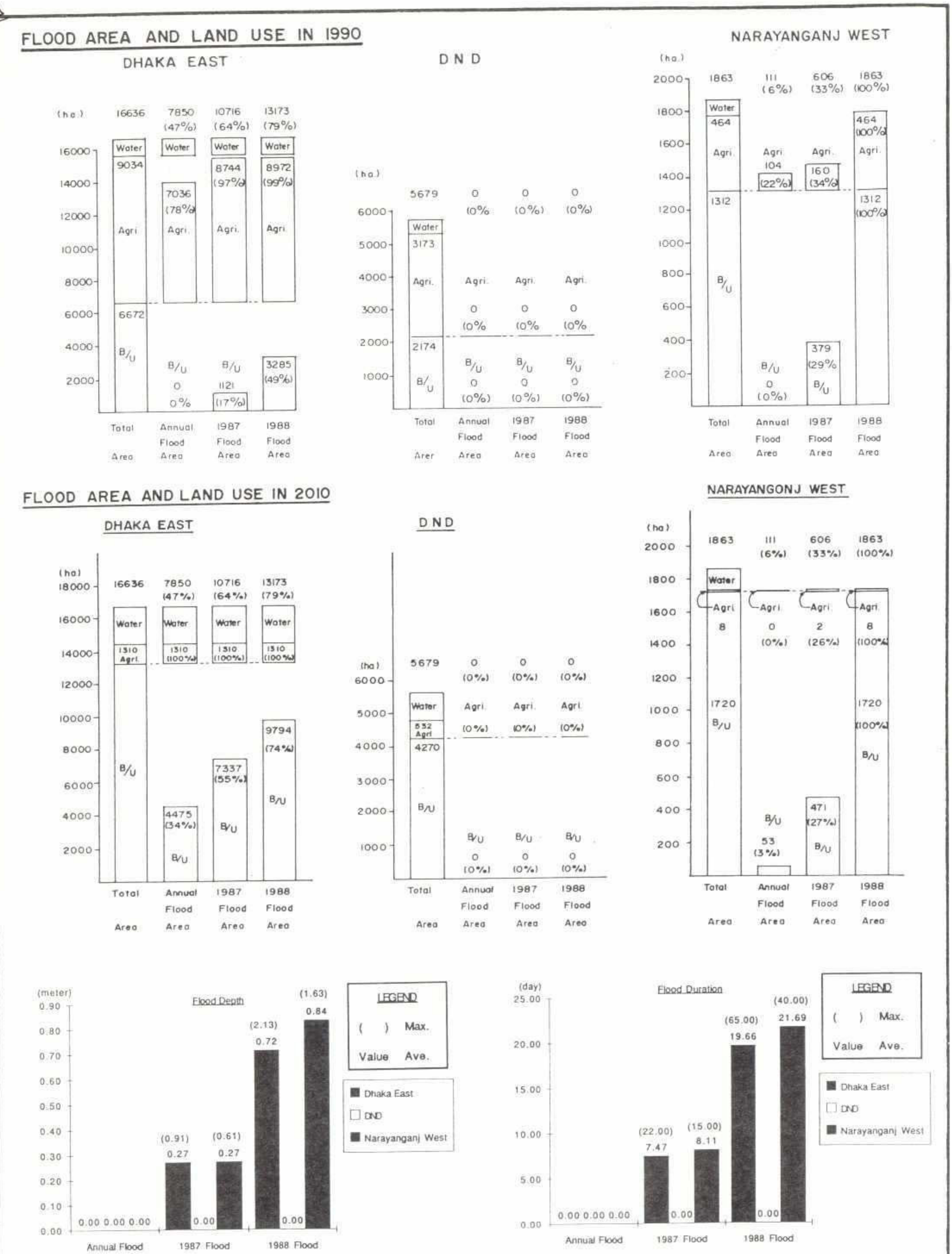

FIG. 5.6 EXTERNAL FLOOD CONDITIONS

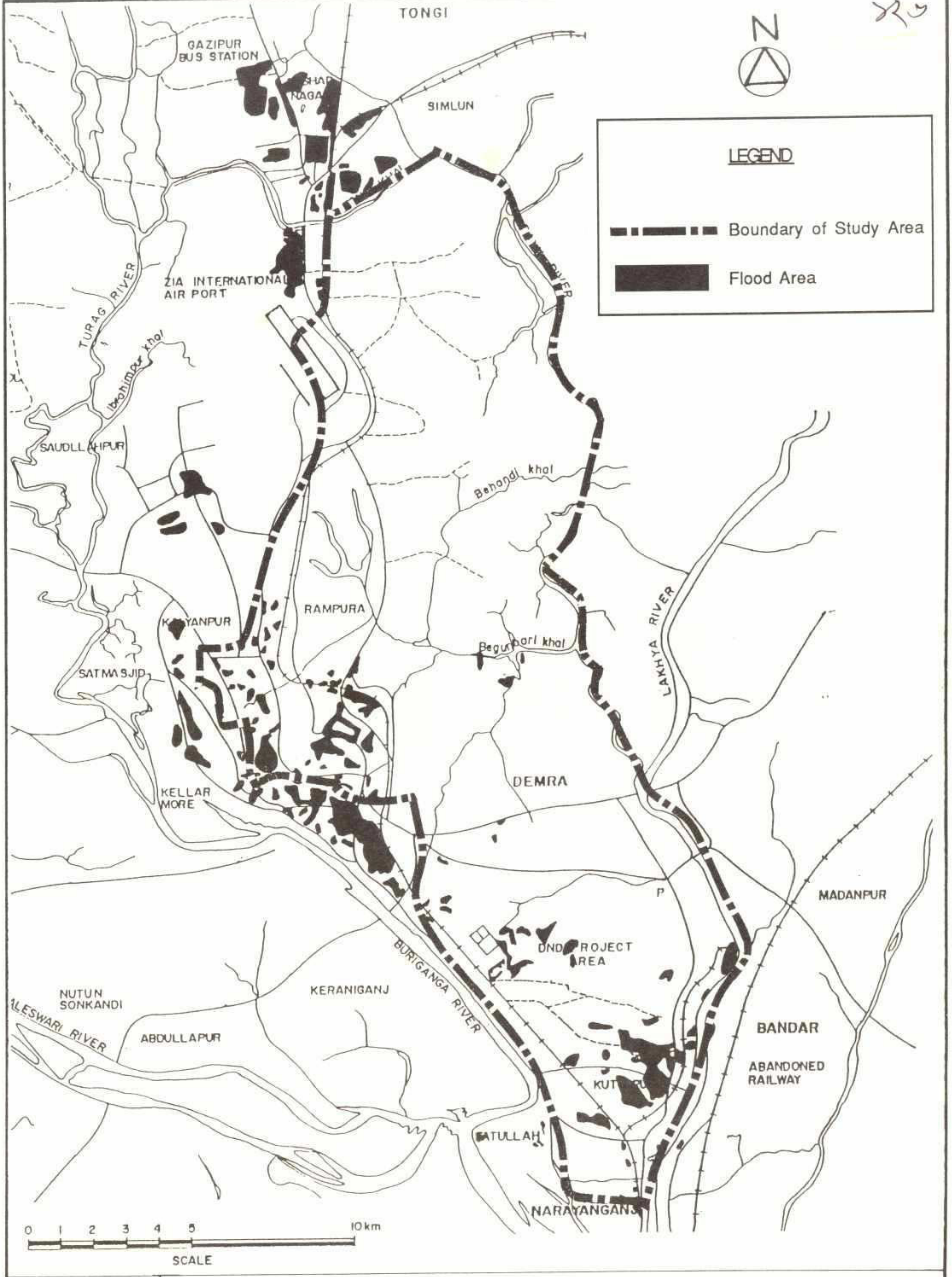

FIG. 5.7 INTERNAL FLOOD MAP

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

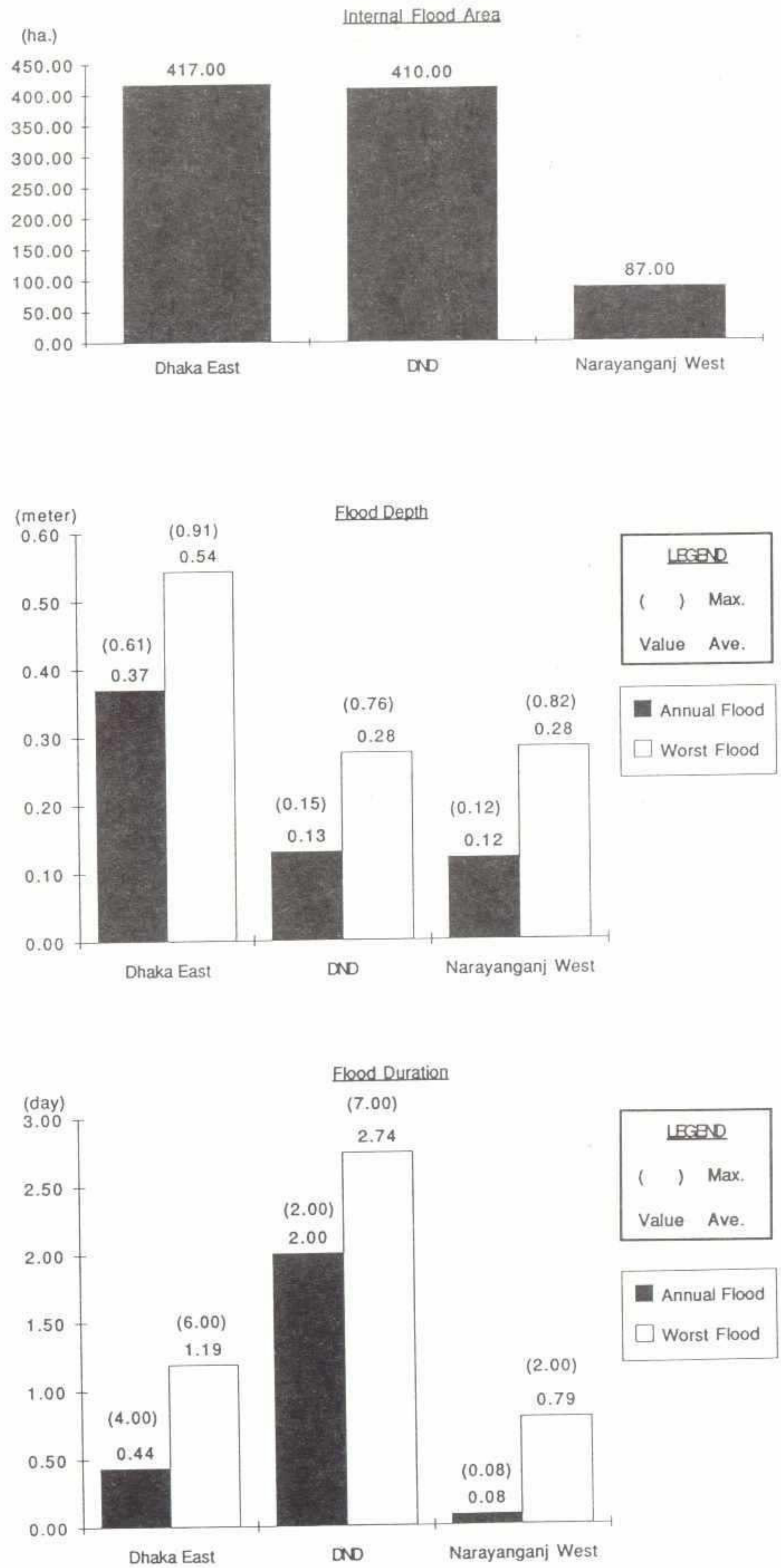

FIG. 5.8 INTERNAL FLOOD CONDITIONS

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

22b

CHAPTER 6
FLOOD MITIGATION AND STORMWATER DRAINAGE IMPROVEMENT FACILITIES

Chapter 6 : Flood Mitigation and Stormwater Drainage Improvement Facilities

6.1 Greater Dhaka East

6.1.1 Flood Mitigation Plan

1) Basic Concept

Landfill has continued for decades in the past and it will continue in future. It means that flood damage potential are increasing yearly, because the level of landfills is normally above the normal flood levels only, hence likely flood free from annual or normal floods. The difference between a 2-year flood stage and a 100-year flood stage is likely more than 1.43 meter, i.e. 2.02 meter at Tongi and 1.43 meter at Demra. It is necessary to protect the built-up areas by embankment against flood damages from the surrounding rivers.

(1) Design High Water Levels and Top Levels of Embankment

The high water level of a 100-year flood frequency is adopted as the design high water level. It is the same protection level with the existing embankment in the Dhaka West. The design freeboard is decided as follows :

- Embankment : 120 cm
- Sub-embankment : 60 cm
- Flood Wall : 60 cm

They are shown in the following table :

Design High Water Level and Design Top Level (m PWD)

Place (Sta. No)	Design H.W.L.	Facility	Top EL
Tongi (E. 69)	8.60	Embankment	9.80
Patira (E. 33+200)	7.99	Embankment	9.19
(E. 33+200)		Sub-Emb. SA	8.59
		Flood Wall. R	8.59
Nigur Aplaid (E. 18+200)	7.73	Embankment	8.93
		Sub-Emb. SB	8.33
		Flood Wall. R	8.33
Outlet of Begunbari	7.60	Embankment	8.80
Khal (E. 11+150)		Sub-Emb. SC	8.20
		Flood Wall R	8.20
Demra (E. 0)	7.40	Embankment	8.60

260

(2) Alignments of Embankment and Sub-embankment

The alignment of embankment along the Balu River is decided to follow the proposed alignment by the GOB in the Phase II program of the Greater Dhaka Flood Control Committee. Though alternative alignments were studied at two parts of the Nali River portion and the Begunbari khal portion, it was decided to follow the original alignment of GOB from technical and social aspects.

It is informed that about 10% of the necessary land for the embankment has already been purchased by GOB, however the land acquisition procedure for the remaining is suspended so far, because the related FAP programs are on going.

The alignment of sub-embankments for compartmentalization is basically designed along the existing roads and two of them are designed along the existing roads, but the other is designed along the Begunbari khal. The alignments at urbanized areas, are planned so as to minimize relocations.

The provision of flood mitigation measures has been proposed by FAP-8B along the existing spine road to a 50-year flood frequency overtopping level. If it is implemented on schedule, the proposed flood wall from Tongi railway bridge to Saidabad would not be necessary. The proposed alignment of embankment sub-embankments and flood wall are shown in Fig. 6.1.1.

(3) Compartmentalized Development

In the Master Plan, the Greater Dhaka East was proposed to be divided into three drainage basins of the Boalia khal (31 km^2), the Jamair khal (48 km^2) and the Begunbari khal (88 km^2). However in the F/S the area has been reviewed and the Begunbari khal basin is divided into two basins. The study area is planned to be divided into four drainage compartments. They are summarized as follows and shown in Fig. 6.1.1. :

Name of compartment		Area of compartment (km^2)	Khal	Drainage Area (km^2)
1.	Northern Compt. (DC-1)	40.69	Boalia Khal	30.56
2.	Central Compt. (DC-2)	32.04	Jamair Khal	47.88
3.	Southern Compt-1 (DC-3)	14.57	Begunbari Khal	46.58
4.	Southern Compt-2 (DC-4)	31.32	Dholai Khal	41.34

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(4) Longitudinal Profile of Embankment

The longitudinal profile of the embankment along the Balu River is designed to be 1/23,000 based on the design high water levels at Tongi and at Demra, while those of the sub-embankments are designed level.

(5) Embankment Material

The embankment material is proposed to be obtained from near the site, from the riverside flat lowland.

According to the laboratory test results on soil samples from borrow pits along the alignment, the soil material is suitable in general for construction of a homogeneous type embankment. With the material, the required workability, shear strength and low permeability will likely be attained by a proper quality control during the construction stage.

(6) Foundation Treatment and Stage Construction for Embankment

The soil investigation results along the alignment show low N-values. A soft soil layer with N-values of less than 4 is developed close to the ground surface.

According to the relationship between the ground's bearing strength and the embankment stability by the Taylor's Stability Analysis Chart, the ground's bearing strength is partly not sufficient for the design height of embankment of which the maximum height is 8.5 m and the average height is 5.5 m. When the embankment would be built up to the design height without any foundation treatment, the embankment would likely subject to a sudden settlement or bearing failure.

However the consolidation settlement period is estimated to take approximately 10 years to obtain 80% consolidation of untreated soft bearing ground's top 5 m layer which affects the stability of the embankment.

In order to accelerate consolidation settlement, some foundation treatment method will be required even with the step embankment construction method. There are three consolidation acceleration methods. They are:

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(1) Sand drain-pile method,

(2) Geotextile drain-pile method,

(3) Sand compaction pile method.

Method (1) and (2) adopt the same vertical draining method and are classified by their material types. Method (3) uses large diameter sand piles only for accelerating consolidation settlement.

For the project the foundation treatment by vertical sand drain (ø 400 mm 2.0 x 2.0 m) or geotextile drain (100 x 8 mm, 1.25 x 1.25 m) with 2 to 3 stages construction are recommended with due consideration to existing bearing capacity and the required height of embankment.

(7) Standard Profile of Embankment

The following dimensions of the standard embankment are designed :

Crest width	:	4.0 m
Side slope	:	1V : 3 H
Berm width	:	3.0 m for river side
		5.0 m for land side

Revetment is designed in order to protect the embankment's toe and the slope from scouring by tractive forces due to current, flow pressure, wave action, etc. The flood water flow velocity is not so fast, about 1.0 ~ 1.5 m/s, so tractive force is not so strong. Scour is caused mainly by wind and navigation. The alignment of embankment has a distance of 20 - 30 meters to low-flow channel, so only high water revetment should be considered.

A ditch is also designed along the embankment of the land side in order to protect the foot of the embankment from local scouring by storm water flows.

The dimensions of sub-embankment are almost the same as those of the embankment, however no revetment is planned.

It would be necessary to locate drainage channels or borrow pits at a certain distance away from the embankment.

During the study, the possibility of wide embankments which would support roads, settlements, recreation areas etc. was discussed. It is recommended that optimum wide embankments be studied in the detailed design stage, after completion of the Metropolitan Development Plan Study by RAJUK, because optimum wide embankments have a close relation to land management and land use development plans along the proposed alignment of flood embankment and is beyond the basic requirement of flood protection.

(8) Standard Profile of Flood Wall

T-shaped flood wall is tentatively planned for road side by taking into account the possibility of crash loading from vehicles.

A I-shaped flood wall is also planned for housing areas.

Both types of flood walls are of reinforce concrete.

No special foundation treatment would be required for the flood wall except at some inverted T-shaped sections. The inverted T-shaped flood wall on soft foundation will require pile foundations.

(9) Sluices

Sluice gates are planned at crossing points of the existing drainage channels / khals with embankments and the proposed pump stations. Small drainage channels are combined with others in order to minimize the number of sluice gates. A sluice gate of Box Culvert Type is planned from economic and technical aspects of its lower cost for construction and easy O & M.

The flow areas of box culvert type sluice gate are decided based on the design discharges of khal improvements and the design velocity of 2.5 m/s. However the minimum flow area is assumed 1.0 m^2.

(10) Non-structural Measures

All necessary measures for flood mitigation and drainage improvement are planned to be carried out step by step systematically, based on optimum urban development plans. It will take some decades at least before the proposed measures can be fully implemented. Non-structural flood mitigation measures such as warning and evacuation roads may be required as an interim solution.

268

(2) Proposed Flood Mitigation Facilities

The proposed facilities are shown in Fig. 6.1.2. They are explained below:

(1) Embankment and Sub-Embankment

The longitudinal sections of the proposed embankment and sub-embankment are shown in Figs 6.1.3 (1) to 6.1.3 (5).

The standard cross sections of them are shown in Fig. 6.1.4.

The parts of embankment which require foundation treatment and stage construction are summarized as follows :

	Station No. From	To	Distance (km)
- Embankment (27.52km)	E. 7	E. 33	10.52
	E. 42+200	E. 59	6.55
	E. 60	E. 64+200	1.80
		Sub-Total =	18.87
- Sub-embankment (SA) (6.40km)	SA. 5+200	SA. 8+200	1.20
	SA. 10+200	SA.12+200	0.80
		Sub-Total =	2.00
- Sub-embankment (SB) (4.71km)	SB. 0	SB. 7+200	2.96
- Sub-embankment (SC) (6.31km)	Sc. 5+250	Sc. 13	3.56

(2) Revetment Works

The revetment is designed for the reaches where scoring by waves is expected. The strong wind recorded during the monsoon are mostly from the north east. Revetment works are planned to the following reaches :

St. No. E 15 to E 21 : 3.20 km
St. No. E 32 to E 39 : 3.05 km
St. No. E 44 to E 52 : 3.77 km
St. No. E 54 to E 60 : 2.80 km

Total : 12.82 km

(3) Sluice Gates

The main features of the proposed sluice gates are summarized below :

No.	Gate No.	Name of Khal	Sta. No.	Design Discharge (m^3/s	FL. of Outlet (m)	Remarks
1.	14	KD-4	E. 68+150	22.57	+2.45	-
2.	15	KD-3	E. 55	37.34	+2.45	-
3.	16	Boalia Khal (KD-1)	E. 43+320	83.18	- 0.7	Pump Station (P. 5)
4.	17	Jamair Khal (KD-5)	E. 28+150	114.61	- 1.0	Pump Station (P. 6)
5.	18A	Begunbari Khal (KD-11)	E. 11+340	129.49	- 1.3	Pump Station (P. 7 A)
6.	18B	Dholai Khal (KD-14)	E. 8+90	140.67	- 1.3	Pump Station (P. 7 B)
7.	Sub-	KD-5	SA 11+100	83.20	+ 0.64	

Note : 1) About design discharge refer Fig. 6.1.14

The proposed facilities are summarized as follows :

Proposed Flood Mitigation Facility : Dhaka East

Compartment	Facility	Main Features
1. Northern compt. (DC-1)	1. Embankment	L= 14.00 km (E.33 + 200 ~ E.69)
	2. Sub-Embankment	L= 6.40 km (SA.0 ~ SA.16)
	3. Flood Wall (R)	L = 5.85 km (R.16 + 150 ~ R.22)
	4. Sluice Gate	No = 4 Places (Main Emb. :3, Sub-Emb.1)
2. Central Compt. (DC-2)	1. Embankment	L= 6.00 km (E.18 + 200 ~ E.33+200)
	2. Sub-Embankment	L= -
	3. Flood Wall	L = 4.85 km (R.11 + 300 ~ R.16+150)
	4. Sluice Gate	No = 1 Place
3. Southern compt-1 (DC-3)	1. Embankment	L= 2.97 km (E.11 + 150 ~ E.18+200)
	2. Sub-Embankment	L= 4.71 km (SB.0 - SB.12)
	3. Flood Wall (R)	L = 2.50 km (R.8 + 300 ~ R.11+300)
	4. Sluice Gate	No = 1 Place
4. Southern Compt-2 (DC-4)	1. Embankment	L= 4.55 km (E.0 ~ E.11+150)
	2. Sub-Embankment	L= 6.31 km (SC.0 ~ SC.13)
	3. Flood Wall	L = 8.07 km (R.0 ~ R.8+800)
	4. Sluice Gate	No = 1 Place
	Total	
(DC-1 to DC-4)	1. Embankment	L= 27.52 km (E.0 ~ E.69)
	2. Sub-Embankment	L= 17.42 km (3 Sub-Embankments)
	3. Flood Wall	L = 21.27 km (R.0 ~ R.22)
	4. Sluice Gate	No = 7 Places

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6.1.2 Stormwater Drainage Improvement Plan

1) Basic Concept

(1) Drainage Area and Its Zoning

The total drainage area of 166.36 km^2 covers not only the entire area of Greater Dhaka East with 118.62 km^2, but also a portion of Greater Dhaka West with 47.74 km^2. This drainage related area of Dhaka West covers most urbanized and industrialized reaches of Dhaka city.

Apart from the small areas in the north of which drain into the Tongi khal, most of the areas drain into the Balu River through the major khal systems consisting of Segunbagicha khal, Gerani khal, Begunbari khal and Jamair khal (Fig. 6.1.5).

As shown in Fig.6.1.6, the area is divided into four drainage zones of DC-1 to DC-4, and nine sub-zones considering the existing topographic conditions, khal systems, road networks and the proposed four compartments. They are listed as follows :

Zone	Sub-zone	Area (km^2)	Name of Major khal
DC-1	DC 1-A	8.45	
	DC 1-B	22.11	Nali River, Boalia Khal
	Sub-total	30.56	
DC-2	DC 2-A	5.71	
	DC 2-B	10.13	Jamair Khal
	DC 2-C	32.04	
	Sub-Total	47.88	
DC-3	DC 3-A	32.01	Begunbari Khal, Gulshan-Banani Khal
	DC 3-B	14.57	Begunbari Khal
	Sub-Total	46.58	
DC-4	DC 4-A	10.02	Segunbagicha Khal
	DC 4-B	31.32	Gerani Khal
	Sub-Total	41.34	
	Total :	166.36	

Note : 1) Refer Fig. 6.1.6

2) DC 2-A is drained to DC 2-C through DC 2-B

(2) Design Flood Water Level

The design flood water levels of a 2-year return period are applied for demarcation of pump or gravity drainage system of each sub-zone along the Tongi Khal and the Balu River, based on the calculation of probable flood water levels at Tongi and Demra gauging stations. They are as follows :

- DC 1-A sub-zone : 6.40 m PWD
- DC 1-B sub-zone : 6.25 m PWD
- DC 2-C sub-zone : 6.15 m PWD
- DC 3-B sub-zone : 6.05 m PWD
- DC 4-B sub-zone : 6.00 m PWD

The pump equipment is designed to be operated during the flood of a 100-year flood frequency. Considering about 2 m difference in water levels between the floods of a 2-year and a 100-year flood frequency, the flood water level at the highest pump efficiency of 100% will actually be higher than that of a 2-year frequency flood.

The pump will be designed based on the most effective water level equivalent of the annual maximum water level on average which is equivalent about 2.3 - 2.8 return period.

(3) Design Rainfall

- For Pumping Station and Retarding Pond

  2 day consecutive rainfall with a 5-year return period is applied as the design rainfall for required pumping capacity and retarding pond volume. The design rainfall and its hourly distribution are presented in Fig.6.1.7.

- For Khal Improvement and Trunk Drain

  The rainfall intensity of a 5-year return period, is employed and rainfall runoff calculation is conducted by the rational formula for the design of trunk drain and khal improvements. A design rainfall-duration curve is made based on the point rainfall data at Dhaka station (B.M.D). For calculation of the design discharge, an areal reduction factor is considered. The applied rainfall intensity-duration curve and areal reduction curve are illustrated in Fig.6.1.8

(4) Run-off Coefficient and Run-off Ratio

The following values of run-off coefficient by land use projected for the target year 2010, are used for calculation of the design peak discharge by the Rational Formula :

Land Use	Runoff Coefficient
Commercial Area	0.65
Industrial Area	0.55
High Class Residential Area	0.30
Middle and Low Class Residential Area	0.50
Green Zone and Others	0.20
Water Bodies	1.00

The runoff ratio (total runoff/total rainfall) of 0.80 is employed for estimating required pump capacities and retarding pond volumes.

(5) Countermeasures

A drainage plan is prepared for the Greater Dhaka East of 118.62 km^2. The khal improvement works proposed by DIFPP financed by ADB (Fig. 6.1.9) are excluded from it.

Since 72% of the area is expected to become a built-up area by 2010, the proposed measures are composed of pumping facilities, retarding ponds, and khal improvements.

2) Proposed Pump Drainage Plan

(1) Pump Drainage Area

According to the existing topographic conditions and the design flood water levels of a 2-year frequency flood, each drainage zone except sub-zone of 8.45 km^2 in the northern part of DC-1, requires a pump drainage system. A gravity drainage system is adequate only for the sub-zone of DC 1-A. The pump drainage areas are summarized as below ;

Zone	Area (km^2)		
	Pump Drainage	Gravity Drainage	Total
DC-1	22.11	8.45	30.56
DC-2	47.88	----	47.88
DC-3	46.58	----	46.58
DC-4	41.34	----	41.34
Total :	157.91	8.45	166.36

Note : 1) Refer Fig. 6.1.6

(2) Required Pump Capacities and Retarding Pond Volumes

In order to economize the total pump drainage cost by reducing the required pump capacity, each pump drainage system is proposed to be combined with retarding ponds.

Specific requirements of pump capacities and retarding pond volumes are estimated to be $P = 1.14\ m^3/s/km^2$ and $V = 0.120 \times 10^6\ m^3/km^2$ respectively, by utilizing storage basin model as shown in Fig. 6.1.10.

The required pump capacity and the required volume of retarding pond for each pump drainage area are summarized below ;

Zone	Area (km^2)	Required Pump Capacity (m^3/s)		Required Storage Volume of Retarding Pond (x $10^6 m^3$)	
		Specific	Total	Specific	Total
DC-1	22.11	1.14	25.6	0.12	2.65
DC-2	47.88	1.14	54.6	0.12	5.75
DC-3	46.58	1.14	53.1	0.12	5.59
DC-4	41.34	1.14	47.2	0.12	4.96
Total :	157.91	-	180.5	-	18.95

Note : 1) Refer tables 6.1.1(1) and (2)

280

(3) Proposed Pumping Station and Retarding Pond

In view of the existing khal conditions and the economic efficiencies, the pumping station having the required capacity is proposed for each drainage zone at the cross point of the major khal and the proposed embankment along the Balu River.

The locations of the proposed pump stations are listed below :

Sub-drainage Area	No. of Pump Station	St. No. of Embankment	Name of Khal
DC - 1	P 5	E 43 + 320	KD-1 (Bualia Khal)
DC - 2	P 6	E 28 + 150	KD-5 (Jamair Khal)
DC - 3	P 7A	E 11 + 340	KD-11 (Begunbari Khal)
DC - 4	P 7B	E 8 + 90	KD-14

The frequent flood water level with a 2-year return period is basically applied as the design outlet flood stage of the pump station, considering employment of a more efficient and economic pump drainage system. However the pump facility is designed to meet the design flood stage of a 100-year flood frequency.

The outlet L.W.L is designed to be the average monthly river stage of about 3.00m (PWD) which is usually at the beginning of June and at the end of October (Fig. 6.1.11).

The hydraulic requirements of each pump station are shown in Table 6.1.1(1). The design concept of the pump station (DC-4) with a capacity of 47.2 m3/s is shown in Figs. 6.1.12(1) to (3)

(1) Proposed Retarding Area

The proposed retarding areas are selected at low-lying areas below 3.0 m PWD with likely low potential for development and high hydraulic efficiency. They are :

DC -1	:	2 sites (RP 5-1 and RP 5-2)
DC -2	:	1 site (RP 6)
DC -3	:	1 site (RP 7-1)
DC -4	:	1 site (RP 7-2 and RP 7-3)

The locations of the proposed retarding areas are shown in Fig. 6.1.10.
The design water levels of the retarding area are set at 3.00 m PWD (L.W.L) and at 4.00 m PWD (H.W.L). The retarding areas and the storage capacities are shown in Table 6.1.1(2).

3) Khal Improvement Plan

(1) Design Discharge

Each drainage zone is divided into approximately 10 to 20 sub-drainage zones based on the existing topographic condition and shown in Fig. 6.1.13.

The design discharges for khal improvements are estimated by the rational formula according to the short duration rainfall of a 5-year flood frequency and the land use projection for 2010, forecasting 80% of the catchment area to be urbanized.

Although the use of Mike 11 NAM model for estimation of the peak run-off of each khal was studied, the rational formula was only finally used. This is in due consideration to the fact that rational formula is simple and reasonable and also the required hydrological calibration data for Mike 11 are not available for setting representative values of hydrological parameters.

However the hydraulic storage effect of the retarding area is unlikely assessed by using the rational formula. Accordingly, the design discharge of some khals located downstream of the retarding area were reviewed and modified by utilizing the hydraulic simulation results of Mike 11.

Fig. 6.1.14 shows the proposed design discharges for each drainage zone.

(2) Proposed Khal Improvement

The existing khal channels require improvement by widening and dredging in order to increase their conveyance capacities.

Two types of trapezoidal shape channels with 1:2 slope lined by sodding (Type-1) and 1:1 slope lined by brick (Type-2), are proposed for the khal improvement.

282

Type (1) is applied for khal sections in the existing agricultural land where land acquisition is likely easy. Type (2) is proposed for those in the existing built-up areas at where land acquisition is likely difficult (Fig. 6.1.15).

Operation and maintenance roads with minimum width of 4.0 m including its shoulder is planned along both sides of a khal.

The proposed longitudinal and cross sections of khals are shown in Figs. 6.1.16(1) to (4).

As related structures, there are bridges to be reconstructed or newly constructed at the khals crossing with road and railway.

The locations of bridges and design concepts are shown in Figs. 6.1.17 and 6.1.18 (1) to (2)

The proposed khal improvement works by drainage zone are shown in Tables 6.1.2 (1) and 6.1.2 (2) and summarized below ;

Drainage Zone	Khal Improvement Length (km)		Bridge Construction (Nos.)	
	Type (1)	Type (2)	Road Bridge	Railway Bridge
DC-1	12.70	---	---	---
DC-2	24.30	---	8	1
DC-3	12.10	---	---	---
DC-4	21.90	2.20	4	---
Total :	71.00	2.20	12	1

786

6.2 DND

6.2.1 Flood Mitigation Plan

1) Basic Concept

(1) Design High Water Levels and Top Levels of Embankment

The design high water levels corresponding to a 100-year flood frequency are adopted for the DND area. The design H.W.L. and top levels of the flood wall are shown below :

Route/Location		H.W.L (m P.W.D)	Top E.L. (m P.W.D)	Remarks
1. Chasara to Buriganga Bridge (DW)				
Chasara	(DW. 0)	6.96	7.56	
Panchabati	(DW. 6+200)	7.20	7.80	More than 100-year
Buriganga Bridge	(DW. 27)	7.80	8.40	
2. Buriganga Bridge to Demra (DN)				
Buriganga Bridge	(DN. 0)	7.80	8.40	
Jatrabari	(DN. 6)	7.80 / 7.40	8.40 / 8.00	
Demra	(DN. 22)	7.40	8.00	
3. Chasara to Hajiganj (DS)				
Chasara	(DS. 0)	6.96	7.56	
Hajiganj	(DS. 6)	6.96	7.56	
4. Hajiganj to Demra (DE)				
Hajiganj	(DE. 0)	6.96	7.56	
Existing Pump Station	(DE. 18)	7.29	8.49	
Demra	(DE. 25)	7.40	8.00	

(2) Rehabilitation of the Existing Embankment and Flood Wall

The flood mitigation measures for the DND area are proposed to rehabilitate the existing flood wall.

288

The DND area is surrounded by the flood wall and the railway-cum-embankment. The I-shape concrete flood wall was built along the road after the 1988 floods.

The design top level of the existing flood wall was designed at the level of 1988 flood water level plus 2 feet.

Accordingly, most part of the flood wall are high enough against the floods of a 50-year frequency flood in terms of flood water level.

From structural view points, most parts of the flood wall are evaluated as a temporary structure due to its strength against expected external loads by heavy vehicle. The total length of the flood wall is measured at 31.5 km in length.

The embankment of the railway from Chasara to the crossing point with the Demra road was raised for flood protection purposes. The top elevation was set about 6.8 m to 7.4 m in P.W.D. While, the 1988 flood water level at Launch Terminal of IWTA of the Lakhya river is measured about 6.6 m PWD. This elevation corresponds to about a 50-year flood frequency in terms of flood water level.

(3) Longitudinal Profile and Standard Cross-Sections

The longitudinal profile of the flood wall is planned based on the design high water levels at specific water gauging stations plus the free board of 0.6m.

There are many portions of the existing flood wall which are higher than the design top level.

The standard cross-section of the existing flood wall is a I-shaped flood wall with 10 to 12 cm thickness.

The proposed rehabilitation works consist of the following based on their structural deficiency.

1. Heightening the wall
2. Strengthening the wall at foot portion.
3. Repairing the wall at damaged portion.

New designs of the flood wall is only proposed for a section where the existing wall has been seriously damaged and also its height to be raised.

(4) Sluice Gate

One sluice gate is planned at the proposed pump station at Adamjee Nagar.

One culvert type sluice gate is proposed from technical and economic aspects.

2) Proposed Flood Mitigation Facilities

The proposed facilities are shown in Fig. 6.2.1. They are explained below :

(1) Flood Wall and Rehabilitation Works

The longitudinal sections of the flood wall are shown in Figs 6.2.2(1) to (3), and the standard cross sections of the proposed rehabilitation works are shown in Fig. 6.2.3.

(2) Sluice Gates

One culvert type sluice gate is planned at the proposed pump station at Adamjee Nagar. The main feature of the proposed sluice gate is ;

Sluice Gate No.	Name of Khal	Sta. No.	Design Discharge (m^3/s)	EL. of out let (m PWD)	Remarks
20	K - 4	DE. 10+300	143.5	-1.4	Pump Station (P11)

(3) Stop Log Structure

There are many openings in the existing flood wall, which are being used for private or public access to the road.

As closing structures of the openings during the floods, stop log structures are proposed. The stop logs are designed for the openings of public use.

For small openings less than 5.0 m in width or 1.0 m in height, some simple counter measures such as sand bags and timber stoppers, are proposed.

The proposed facilities are summarized as follows :

Proposed Flood Mitigation Facility : DND Area

Route (Total length)	Facility	Main Features
1. Chasara to Buriganga Bridge (DW) (L= 10.63 km)	1) Flood Wall Construction :	L= -
	2) Rehabilitation Work :	
	(1) Foot Protection :	L = 3.63 km
	(2) Flood Wall Raising:	L = -
	3) Stop Log Structure :	14 places
2. Buriganga Bridge to Demra (DN) (L= 8.58 km)	1) Flood Wall Construction :	L = 0.58 km
	2) Rehabilitation Work:	
	(1) Foot Protection :	L = 5.6 km
	(2) Flood Wall Raising:	L = 4.4 km
	3) Stop Log Structure :	17 places
3. Chasara to Hajiganj (DS) (L= 2.15 km)	1) Flood Wall Construction :	L = 1.75 km
4. Hajiganj to Demra (DE) (L= 10.16 km)	1) Flood Wall Construction :	L = 1.05 km
	2) Rehabilitation Work:	
	(1) Foot Protection :	L = 8.40 km
	(2) Flood Wall Raising:	L = 3.20 km
	3) Stop Log Structure :	27 places
	4) Sluice Gate :	1 place
Total	1) Flood Wall Construction :	3.38 km
	2) Rehabilitation Works :	
	(1) Foot Protection :	17.60 km
	(2) Flood Wall Raising :	7.60 km
	3) Stop Log Structures :	58 places
	4) Sluice Gate :	1 place

6.2.2 Stormwater Drainage Improvement Plan

1) Basic Concept

(1) Drainage Area and Its Zoning

The DND area of 56.79 km^2 has been developed as an agricultural development area. However, the area is rapidly changing to an urban area. The area has been protected by the surrounding road-cum-embankments with concrete flood walls from flooding of the Buriganga River, the Balu river and the Lakhya river.

The entire area is crisscrossed by irrigation and drainage channels. The storm water is conveyed to Kharder Ghoshpara by the major khal (under one drainage basin) and discharged into the Lakhya River through the Demra pumping station as shown in Fig.6.2.4.

In order to cope with the increasing run-off due to the future forecast urbanization, another pumping station which drains storm water into the Lakhya River, will be required. The area is planned to be divided into two drainage zones, the northern and the southern zones (NA-1, NA-2) as shown in Fig. 6.2.5. Their drainage areas and main khal channels are summarized as follows :

Zone	Area (km2)	Main Khal
NA-1	25.10	Shampur Khal
NA-2	31.69	Pagla Khal, Fatulla Khal
Total :	56.79	

(2) Design Flood Water Level

The followings design flood water levels are adopted for each drainage zone based on the probable water levels at Demra and Narayanganj gauging stations.

- NA - 1 : 5.75 m PWD
- NA - 2 : 5.65 m PWD

Hydraulic conditions for the pump equipment design are the same as that of Greater Dhaka East.

(3) Design Rainfall, Run-off Coefficient and Run-off Ratio

The same criteria as for Greater Dhaka East is applied. (Figs. 6.1.7 and 6.1.8)

(4) Countermeasures

A drainage plan is prepared for the entire DND area of 56.79 km^2.

The proposed measures consist of pumping stations combined with retarding areas and trunk khal improvement works.

Secondary and tertiary drains are not included in the plan.

2) Proposed Pump Drainage Plan

(1) Pump Drainage Area

The entire DND area of 56.79 km^2 require two pump drainage systems due to the low ground elevation than the design flood water level.

(2) Required Pump and Retarding Pond Capacity

A pump drainage system combined with retarding ponds is recommended to economize the pump drainage cost by reducing the required pump capacity.

The required pump and retarding pond capacities are estimated based on the both specific requirements, $P = 1.14\ m^3/s/km^2$ and $V = 0.0120 \times 10^6 m^3/km^2$ respectively as shown below :

Zone	Area (km^2)	Required Pump Capacity		Required Storage Volume of Retarding Pond	
		Specific ($m^3/s/km^2$)	Total (m^3/s)	Specific (m^3/km^2)	Total (m^3)
NA-1	25.10	1.14	28.6	0.12	3.01
NA-2	31.69	1.14	36.1	0.12	3.80
Total :	56.79	-	64.70	-	6.81

(3) Proposed Pumping Station

In view of the continuous demand for irrigation and the economized pump drainage cost, the existing Demra pump station will be utilized in the plan. The existing pump capacity of 14.5 m^3/s is less than the required pump capacity of zone NA - 1 (28.6 m^3/s).

Since it is difficult to obtain the required additional space for the expansion of pump facilities at the Demra pumping station, the pump capacity of 14.1 m^3/s is to be added to the new pumping station planned in Zone NA - 2.

The locations of the proposed pump stations are listed below and shown in Fig. 6.2.6.

Sub-zone	No. of Pump Station	St. No. of Embankment	Name Khal
NA - 1	P 10 (Demra P.5)	DE 17 + 350	KN - 1
NA - 2	P11	DE 10 + 300	KN - 4

Hydraulic requirements of the proposed pump stations are shown in Table 6.2.1.

(4) Proposed Retarding Area

Three retarding areas for each zone are proposed in the low lying area where is likely to have a low potential for future urbanization and will remain as an agricultural land in 2010.

The design water levels are set at 3.00 m PWD (L.W.L) and 4.00 m PWD (H.W.L).

Location and hydraulic requirements of both facilities are shown in Table 6.2.1.

3) Proposed Khal Improvement Plan

(1) Design Discharge

In order to prepare deeper khal sections, the drainage zone is divided into 38 sub-drainage zones based on the existing topographic condition and khal networks as shown in Fig. 6.2.7.

The Design discharges for improvement of khals are estimated by the rational formula under the condition of short duration rainfall of a 5-year frequency and the projected land use in 2010.

As in the case of Greater Dhaka East, the design discharges of some khals located at the downstream of the retarding area are reviewed and modified according to the results of the hydraulic simulation using Mike 11.

Fig. 6.2.8 show the estimated design discharges.

(2) Proposed Khal Improvement

The conveyance capacities of the existing khal channels are too low to meet their future requirements. Khal improvements by widening and dredging are required. The provision of a new channel to connect the existing Demra pumping station with the new pump station is necessary.

The proposed types of khal improvement are as follows :

- Type (1) : Trapezoidal shape with 1:2 slope lined by sodding
- Type (2) : Trapezoidal shape with 1:1 slope lined by brick

Type (1) is applied for the khal situated in agricultural area where land acquisition is likely easy. Type (2) is proposed for the khal located in projected built-up areas where land acquisition is likely difficult. The typical cross section of the khal improvement is the same as that of Greater Dhaka East. The proposed longitudinal and cross sections of khals are shown in Figs. 6.2.9(1) and (2).

As related structures, concrete or steel bridges and aqueduct are planned to be reconstructed or newly constructed at khal, crossing with roads, railway and irrigation channels.
The location of the related structures are shown in Fig. 6.2.10.

The proposed khal improvement works are shown in Table 6.2.3 and summarized below :

	Open Channel (km)		Road Bridge		Railway Bridge	Aqueduct
Zone	Type (1) (1)	Type (2) (2)	Recons-truction	New Cons-truction	Recons-truction	Recons-truction
NA - 1	15.80	8.10	9	3	-	1
NA - 2	17.90	9.40	19	3	4	1
	Total :	33.70	17.50	28	6	4 2

7972

6.3 Narayanganj West

6.3.1 Flood Mitigation Plan

1) Basic Concept

(1) High Water Level (H.W.L) and Design Top Level

The design high water levels corresponding to the flood stage of a 100-year flood frequency are determined based on the result of statistical analysis of water level data. The design top levels of the embankment and flood wall are calculated by adding freeboards of 1.2 m and 0.60 m respectively.

The design H.W.L and design top levels at specific points are shown below:

Design High Water Level and Design Top Level (m PWD)

Route/Location		H.W.L (m P.W.D)	Top E.L. (m P.W.D)	Remarks
1.	Narayanganj to Panchabati (NW)			
	Narayanganj (NW. 0)	6.80	8.07/7.40	Embankment/ Flood wall
	Panchabati (NW. 29)	7.20	8.40	Embankment
2.	Narayanganj to Demra (NE)			
	Narayanganj (NE. 0)	6.80	7.40	Flood Wall
	Adamjee Nagar Back Levee (NE. 48)	7.10	7.70/8.30	Flood Wall/ Embankment
	Existing Pump Sta. Back Levee (NE. 72)	7.29	8.49	Embankment
	Demra (NE. 88)	7.40	8.60/8.00	Embankment/ Flood Wall.

(2) Alignment of Embankment (or Flood Wall)

The road-cum-embankment is planned from Panchabati to Narayanganj along Panchabati via Saiyedpur on the western part. This embankment is connected to the DND flood wall.

The alignment is planned along the existing road, as a trunk road in future.

The flood wall and embankment are planned from Narayanganj to Demra along the Lakhya river.

This alignment is planned along the river bank in order to protect the existing built up area and industrial asset as much as possible and also to minimize their relocations. (Fig. 6.3.1).

(3) Longitudinal and Standard Cross-Sections

The longitudinal profile of the Road-cum-Embankment (NW) is decided based on the design high water levels of Hariharpur and Rakabi Bazar water level Gauging stations.

The longitudinal profiles of flood wall and embankment along the Lakhya river are also decided in the same manner of that of the Western side polder. The H.W.L at Narayanganj down stream is decided based on the H.W.L. of Kalagachia and Rakabi Bazar gauging stations and that of upstream is based on Demra ganging station. The freeboards adopted are 1.2 m for embankment and 0.6 m for flood wall.

The standard cross-section of the road-cum-embankment is almost the same type with the embankment. The road-cum-embankment has a road space in addition to the berm on land side, while embankment section has only berms for the maintenance and stability of the embankment.

Two types of sheet pile type and inverted T-shaped wall type structures are proposed for the flood wall along the Lakhya river. However, some variations are to be made to particular portions according to the site conditions.

The standard cross-section of the embankment along the Lakhya river is the same type as that of Greater Dhaka East.

0.8 km of this stretch requires foundation treatment due to the poor soil foundation.

(4) Sluice Gate

Sluice gates are planned at crossing points of the existing khal channels and at the proposed pump stations.

A culvert type of sluice gate is selected from technical and economical aspects, easy maintenance and low construction cost.

286

(5) Stop Log Structure

For the flood wall along the Lakhya river, many land locks are required for loading and unloading at the godowns and the factories.

Stop log structures are planned as access to the road or to the river bank.

2) Proposed Flood Mitigation Features

(1) Road-Cum-Embankment, Embankment and Flood Wall

The longitudinal sections of the proposed road-cum-embankment and embankment alone are shown in Figs 6.3.2 (1) to (3). The standard cross sections of them are shown in Fig. 6.3.3

The portions of foundation treatment and stage construction are summarized as follows :

	Station		Distance
	From	To	(km)
Embankment	NE. 65	NE. 67	0.40
(5.70 km)	NE. 70	NE. 71	0.40
		Sub-Total =	0.80

(2) Revetment Works

St. No. NE 48-(1) R to NE 49	:	2.25 km
St. No. NE 62 A - NE 87	:	6.90 km
Total		9.15 km

(3) Sluice Gates

Fourteen (14) sluice gates are planned and the main feature of them are summarized below :

No.	Sluice Gate No.	Name	Sta. No.	Design Discharge (m^3/s)	EL. of outlet (m)	Remarks
1.	21	K-18	NE. 84+120	7.33	3.30	
2.	22	K-19	NE. 77+160	16.72	0.0	Pump Station (P12)
3.	23	K-20	NE. 69+100	20.04	3.0	Pump Station (P13)
4.	24	K-22	NE. 49+100	21.90	2.63	
5.	25	K-23	NE. 46+180	10.54	3.12	
6.	26	K-23	NE. 40+170	10.31	3.11	
7.	27	K-25	NE. 32	8.83	3.06	
8.	28	K-26	NE. 26+150	9.18	3.04	
9.	29	S-1	NE. 19	10.47	3.33	
10.	30	S-2	NE. 8+50	6.17	3.00	
11.	31	K-27	NE. 5+70	7.18	2.98	
12.	32	S-3	NE. 5+70	3.89	3.25	
13.	33A	K-28	NW. 1+150	26.97	0.50	Pump Station (NW) (P14A)
14.	33B	K-30	NW. 14+190	43.15	0.50	Pump Station (NW) (P14B)

The proposed facilities are summarized as follows :

Proposed Flood Mitigation Facility : Narayanganj West

Route Total length)	Facility	Main Features
1. Narayanganj to Panchabati (NW) (L = 5.64 km)	1) Road-Cum-Embankment	: 4.10 km (NW.8+100~ NW.29)
	2) Embankment	: 1.54 km (NW.0~NW.8 +100)
	3) Sluice Gate	: 2 places
2. Narayanganj to Demra (NE) (L = 21.83 km)	1) Flood Wall	: 11.48 km (NE.0~NE.48, NE.55~NE.62, NE.87~NE.88)
	2) Embankment	: 10.35 km (NE.48~NE.55, NE.62~NE.87)
	3) Sluice Gate	: 12 places
	4) Stop Log Structure	: 17 places
Total	1) Road-Cum-Embankment	: 4.10 km
	2) Embankment	: 11.89 km
	3) Flood Wall	: 11.48 km
	4) Sluice Gate	: 14 places
	5) Stop Log Structure	: 17 places

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6.3.2 Stormwater Drainage Improvement Plan

1) Basic Concept

(1) Drainage Area and Zones

The area covering 18.63 km^2 consists of a narrow strip between the Demra Narayanganj Road and the Lakhya River, and Narayanganj town area. The area is planned to be protected against external floods from the Dhaleswari River and the Lakhya River by embankment, flood wall and road-cum-embankment. The existing major khal channels are shown in Fig. 6.3.4.

As shown in Fig.6.3.5, the area is divided into small five drainage zones, NB-1 to NB-5, based on the proposed alignment of the flood protection facilities, inner drainage systems and road networks. The drainage area and the main khal of each zone are summarized below :

Zone	Area (km^2)	Main Khal
NB-1	2.30	K-19
NB-2	3.99	K-20, 21
NB-3	5.33	K-23, 24
NB-4	2.36	Shasongaon Khal (K-25)
NB-5	4.65	Mondal Para Khal (K-26)
Total :	18.63	

(2) Design Flood Water Level

The design flood water levels are adopted for each zone based on the probable water levels at Demra, Narayanganj, Hariharpara and Kalagachia gauging stations. They are:

- NB-1 zone : 5.80 m PWD
- NB-2 zone : 5.70 m PWD
- NB-3 zone : 5.45 m PWD
- NB-4 zone : 5.50 m PWD
- NB-5 zone : 5.45 m PWD

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(3) Design Rainfall, Run-off Coefficient and Run-off Ratio

The criteria is the same as that of Greater Dhaka East (refer to Figs. 6.1.7 and 6.1.8).

(4) Countermeasures

Since 70% of the area is already built-up, the proposed measures comprise pumping facilities with retarding ponds, and khal and trunk drain improvement works.

However lateral drains and tertiary drainage pipes are not considered.

2) Proposed Pump Drainage Plan

(1) Pump Drainage Area

Four drainage zones are proposed as pump drainage areas based on the existing ground levels and the design flood water level. Pump drainage areas are summarized below :

Zone	Area (km^2)		
	Pump Drainage	Gravity Drainage	Total
NB-1	1.73	0.57	2.30
NB-2	1.92	2.07	3.99
NB-3	---	5.33	5.33
NB-4	2.36	---	2.36
NB-5	4.65	---	4.65
Total :	10.66	7.97	18.63

(2) Required Pump and Retarding Pond Capacity

In order to economize the total pump drainage cost by reducing the required pump capacity, it is proposed to adopt a pump drainage system combined with retarding ponds.

Specific requirements of pump and retarding pond capacities are estimated to be P = 1.14 $m^3/s/km^2$ and V = 0.120 x 10^6 m^3/km^2 respectively, by utilizing storage basin model as shown in Fig 6.3.6.

The required pump and retarding pond capacities for each zone are summarized below ;

Zone	Area (km^2)	Required Pump Capacity Specific ($m^3/s/km^2$)	Required Pump Capacity Total (m^3/s)	Required Storage Volume of Retarding Pond Specific ($\times 10^6 m^3/km^2$)	Required Storage Volume of Retarding Pond Total ($\times 10^6 m^3$)
NB-1	1.73	1.14	2.0	0.12	0.21
NB-2	1.92	1.14	2.2	0.12	0.23
NB-4	2.36	1.14	2.7	0.12	0.28
NB-5	4.65	1.14	5.3	0.12	0.56
Total :	10.66	---	12.2	---	1.28

(3) Proposed Pump Station

Considering the required pump capacity, one small pumping station by each zone is proposed at the crossing of the main khal and the proposed flood embankment.

Even if this area is expected to be urbanized fast, low-lying areas having an enough storage potential are proposed as retarding pond areas.

The location of the proposed pump stations are listed below :

Sub-zone	No. of Pump Station	St. No. of Embankment	Name Khal
NB - 1	P 11	NE 77 + 160	KN - 19
NB - 2	P13	NE 69 + 100	KN - 20
NB - 3	P 14A	NW 23	KN - 28 (Shasongaon Khal)
NB - 4	P14B	NW 14 + 190	KN - 30 (Mondal Para Khal)

Hydraulic requirements of the proposed pumping station are shown in Table 6.3.1(1).

(4) Proposed Retarding Area

The proposed retarding areas are :

NB - 1	:	1 site (RP 12)
NB - 2	:	1 site (RP 13
NB - 3	:	1 site (RP 14-1)
NB - 4	:	2 site (RP 14-2 and RP 14-3)

The location of the proposed retarding area are shown in Fig.6.3.6. Hydraulic requirements are shown in Table 6.3.1(2).

3) Proposed Khal and Trunk Drain Improvement Plan

(1) Design Discharge

Design discharges for khal and trunk drain improvements are estimated by the rational formula under the condition of short duration rainfall a 5-year frequency and the land use projection in 2010. Sub drainage zones and the values of run-off coefficient are shown in Fig. 6.3.7 and the design discharge of each khal is shown in Fig. 6.3.8.

(2) Proposed Khal and Trunk Drain Improvement

The conveyance capacities of the existing khal and trunk drains located in the Narayanganj town do not meet to the design discharges. Improvement of khal channels by widening and dredging, or replacement of trunk drainage channels or pipes are required.

The proposed types for khal and drainage improvement are as follows :

(i) Open Channel

- Type (1) : Trapezoidal shape with 1:2 slope lined by sodding
- Type (2) : Trapezoidal shape with 1:1 slope lined by brick

(ii) Covered Channel / or Pipe

- Type (1) : Brick pipe (Max. diameter : ø 3000)
- Type (2) : Concrete box culvert (Discharge capacity : more than $10m^3/s$)

Open channel type (1) is applied for khal sections situated in agricultural areas where comparatively easy land acquisition is expected. Open channel type (2) are proposed for khal sections located in built-up areas where land acquisition is likely to be difficult. O & M roads with a minimum width of 4.0 m is proposed along both banks of each khal. Proposed longitudinal and cross sections for KN-30 is shown in Fig. 6.3.9.

The covered channel type (1) is basically applied for trunk drains. However the type (2) is proposed for the trunk drains sections with design discharge more than $10m^3/s$. Typical sections of the trunk drain are shown in Fig. 6.3.10.

As related structures, bridges are planned at khals crossing with the road etc. The locations of proposed bridges are shown in Fig 6.3.11. The design concept of those bridges is the same as that of Greater Dhaka East.

The proposed khal improvement works are shown in Tables 6.3.2(1) and (2) and summarized below :

Zone	Khal Improvement (km)		Trunk Drain		Bridge	
	Type (1)	Type (2)	Type (1)	Type (2)	Road	Railway
NB-1	1.20	0.40	---	---	1	---
NB-2	0.90	2.20	---	---		
NB-3	---	2.60	0.90	0.50	2	1
NB-4	1.40	1.40	---	---	2	2
NB-5	0.80	4.90	---	---	6	---
Total :	4.30	11.50	0.90	0.50	11	3

230

TABLE 6.1.1(1) HYDRAULIC REQUIREMENTS OF PROPOSED PUMPING STATION : GREATER DHAKA EAST

Proposed Pumping Station	Drainage Zone		Discharge Capacity (m^3/s)	Design Water Level (m, PWD)					Static Head (m)		Remarks
	No.	Area (km^2)		Outer			Inner		Design	Max.	
				H.H.W.L	H.W.L	L.W.L	H.W.L	L.W.L			
P 5	DC-1	22.11	25.60	8.15	6.25	3.00	4.00	3.00	3.25	5.15	
P 6	DC-2	47.88	54.60	7.90	6.15	3.00	4.00	3.00	3.15	4.90	
P 7A	DC-3	46.58	53.10	7.60	6.05	3.00	4.00	3.00	3.05	4.60	
P 7B	DC-4	41.34	47.20	7.55	6.00	3.00	4.00	3.00	3.00	4.55	

Note : 1. H.H.W.L. and H.W.L. of outer design water level means that of 100-year and 2-year frequency flood respectively

TABLE 6.1.1(2) HYDRAULIC REQUIREMENTS OF PROPOSED RETARDING POND: GREATER DHAKA EAST

Proposed Retarding Pond	Drainage Zone	Pond Area (ha)	Storage Capacity (x $10^6 m^3$)	Design Water Level (m, PWD)		Remarks
				H.W.L	L.W.L	
RP 5-1	DC-1	138	1.38	4.00	3.00	
RP 5-2	DC-1	127	1.27	4.00	3.00	
RP 6	DC-2	575	5.75	4.00	3.00	
RP 7A	DC-3	339	5.59	4.00	3.00	
RP 7B-1	DC-4	199	1.99	4.00	3.00	
RP 7B-2	DC-4	297	2.97	4.00	3.00	

TABLE 6.1.2(1) PROPOSED KHAL IMPROVEMENT WORKS : GREATER DHAKA EAST

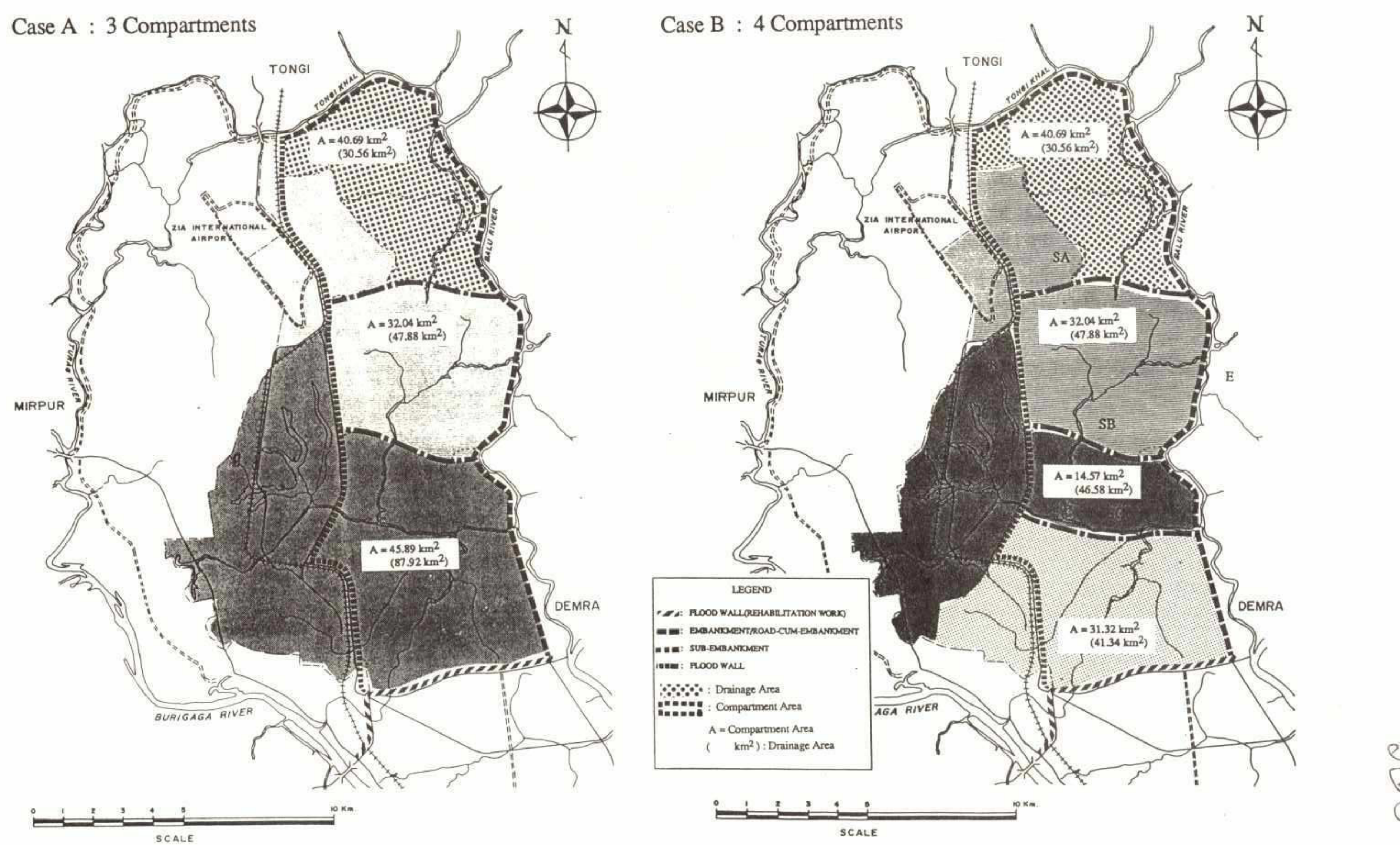
Dhaka East Zone (DC)

Zone	Khal No.	Khal Length (km)	Required Hydraulic Section Wb x Wu x H (m x m x m)	Open Channel: Brick Protection (km)	Open Channel: Sodding (km)	Covered Channel: Box Culvert (km)	Covered Channel: Brick Pipe (km)	Bridge (Places)	Aqueduct (Places)	Dredging (1000m3)	Maintenance Road (km)	Land Acquisition (ha)
DC-1	KD-1-1	0.50	20.0 34.8 3.7	-	0.50	-	-	-	-	25.10	0.50	1.88
	KD-1-2	1.90	17.5 32.3 3.7	-	1.90	-	-	-	-	36.90	1.90	2.35
	KD-1-3	2.30	13.0 27.8 3.7	-	2.30	-	-	-	-	65.95	2.30	7.47
	KD-1-4	1.70	7.5 22.3 3.7	-	1.70	-	-	-	-	32.30	1.70	6.72
	KD-1-5	1.00	2.0 16.8 3.7	-	1.00	-	-	-	-	22.90	1.00	2.93
	KD-2	1.40	2.0 16.3 3.6	-	1.40	-	-	-	-	1.86	1.40	1.66
	KD-3-1	1.30	5.0 21.0 4.0	-	1.30	-	-	-	-	0.00	1.30	3.88
	KD-3-2	1.40	2.0 18.0 4.0	-	1.40	-	-	-	-	0.00	1.40	3.85
	KD-4	1.20	2.5 10.5 4.0	1.20	-	-	-	-	-	3.86	1.20	1.63
	Sub-Total	12.70		1.20	11.50	0.00	0.00	0	0	188.87	12.70	32.37
DC-2	KD-5-1	2.50	27.5 43.5 4.0	-	2.50	-	-	-	-	148.44	2.50	8.01
	KD-5-2	0.70	27.5 43.5 4.0	-	0.70	-	-	-	-	49.47	0.70	3.18
	KD-5-3	1.40	23.0 39.0 4.0	-	1.40	-	-	-	-	79.81	1.40	5.55
	KD-5-4	2.00	21.5 37.5 4.0	-	2.00	-	-	-	-	81.70	2.00	6.80
	KD-5-5	2.20	19.5 35.5 4.0	-	2.20	-	-	-	-	61.03	2.20	8.67
	KD-5-6	1.00	16.0 31.7 3.9	-	1.00	-	-	-	-	32.40	1.00	4.40
	KD-5-7	1.40	6.5 21.7 3.8	-	1.40	-	-	-	-	18.80	1.40	5.18
	KD-6	1.80	2.0 17.4 3.9	-	1.80	-	-	-	-	13.62	1.80	3.08
	KD-7-1	1.60	7.0 23.0 4.0	-	1.60	-	-	-	-	27.68	1.60	3.53
	KD-7-2	2.20	6.0 21.3 3.8	-	2.20	-	-	-	-	23.40	2.20	4.54
	KD-8	1.80	2.5 17.9 3.9	-	1.80	-	-	-	-	6.91	1.80	2.85
	KD-9	1.00	2.0 17.7 3.9	-	1.00	-	-	-	-	1.59	1.00	1.59
	KD-10-1	2.00	9.0 24.0 3.8	-	2.00	-	-	3	-	39.34	2.00	7.06
	KD-10-2	2.10	7.0 14.2 3.6	2.10	-	-	-	5	-	154.25	2.10	7.29
	Sub-Total	23.70		2.10	21.60	0.00	0.00	8	0	738.44	23.70	71.73
DC-3	KD-11-1	2.20	24.5 41.7 4.3	-	2.20	-	-	-	-	135.81	2.20	2.38
	KD-11-2	2.70	29.0 46.2 4.3	-	2.70	-	-	-	-	155.96	2.70	5.49
	KD-11-3	1.70	26.5 43.0 4.1	-	1.70	-	-	-	-	110.73	1.70	6.66
	KD-12-1	1.20	2.0 17.2 3.8	-	1.20	-	-	-	-	37.82	1.20	2.97
	KD-12-2	1.30	2.0 15.0 3.3	-	1.30	-	-	-	-	35.89	1.30	4.44
	KD-13-1	1.80	2.0 18.6 4.2	-	1.80	-	-	-	-	14.81	1.80	2.73
	KD-13-2	1.20	2.0 18.2 4.1	-	1.20	-	-	-	-	4.01	1.20	1.23
	Sub-Total	12.10		0.00	12.10	0.00	0.00	0	0	495.03	12.10	25.90
DC-4	KD-14-1	0.50	24.5 41.7 4.3	-	0.50	-	-	-	-	159.04	0.50	5.60
	KD-14-2	1.90	23.5 40.7 4.3	-	1.90	-	-	1	-	153.30	1.90	8.62
	KD-14-3	1.00	18.5 35.7 4.3	-	1.00	-	-	-	-	117.04	1.00	6.41
	KD-14-4	0.70	11.5 20.1 4.3	0.70	-	-	-	-	-	45.15	0.70	1.27
	KD-14-5	1.50	10.0 18.4 4.2	1.50	-	-	-	1	-	111.59	1.50	4.32
	KD-15-1	1.20	2.0 18.8 4.2	-	1.20	-	-	-	-	61.56	1.20	2.96
	KD-15-2	1.40	2.0 16.5 3.6	-	1.40	-	-	-	-	86.64	1.40	5.05
	KD-16	1.70	2.0 16.4 3.6	-	1.70	-	-	-	-	78.98	1.70	5.14
	KD-17-1	0.60	3.0 20.0 4.3	-	0.60	-	-	-	-	6.40	0.60	0.36
	KD-17-2	2.20	2.0 18.3 4.1	-	2.20	-	-	1	-	81.88	2.20	3.46
	KD-17-3	2.70	5.0 20.4 3.8	-	2.70	-	-	-	-	117.99	2.70	4.47
	KD-18-1	2.20	3.0 19.3 4.1	-	2.20	-	-	-	-	56.14	2.20	4.23
	KD-18-2	0.90	2.0 16.8 3.7	-	0.90	-	-	-	-	19.80	0.90	1.87
	KD-19	1.90	2.0 16.0 3.5	-	1.90	-	-	-	-	14.16	1.90	1.65
	KD-20-1	1.10	3.5 20.3 4.2	-	1.10	-	-	1	-	47.40	1.10	3.45
	KD-20-2	1.30	3.0 11.2 4.1	1.30	-	-	-	-	-	34.40	1.30	3.14
	KD-20-3	1.30	3.0 11.0 4.0	1.30	-	-	-	-	-	46.24	1.30	4.53
	Sub-Total	24.10		4.80	19.30	0.00	0.00	4	0	1237.71	24.10	66.53
	Total	72.60		8.10	64.50	0.00	0.00	12	0	2660.05	72.60	196.53

202

TABLE 6.1.2(2) PROPOSED KHAL IMPROVEMENT RELATED WORKS (BRIDGE) : GREATER DHAKA EAST

Zone	Khal No.	Bridge No.	Existing Type	Existing Size (m x m)	Required Size (m x m)	Proposed Type	Proposed Size (m x m)	Proposed Width	Remarks
DC-1	KD-1-1	1	Cantilever	17.00 x 4.70	10.43 x 7.70	-	-	-	Road bridge
	KD-1-5	2	Girder bridge	6.58 x 4.70	6.58 x 4.70	-	-	-	" "
	KD-3-1	3	" "	11.50 x 6.50	9.10 x 5.00	-	-	-	" "
	KD-4	4	" "	6.00 x 5.10	7.00 x 5.00	-	-	-	" "
DC-2	KD-5-8	5	Deck-Rly	6.00 x 3.60	9.33 x 4.80	Deck Girder	9.4 x 4.80	1.7	Railway bridge
	KD-10-1	6	-	-	11.11 x 4.90	Girder bridge	11.2 x 4.90	3.66	Road bridge
	"	7	-	-	" "	" "	" "	"	" "
	"	8	-	-	" "	" "	" "	"	" "
	KD-10-2	9	-	-	6.98 x 4.80	" "	7.00 x 4.80	"	" "
	"	10	-	-	" "	" "	" "	"	" "
	"	11	-	-	" "	" "	" "	"	" "
	"	12	-	-	" "	" "	" "	"	" "
	"	13	-	-	" "	" "	" "	"	" "
DC-4	KD-14-2	14	-	-	24.92 x 5.30	Cantilever	25.00 x 5.30	3.66	" "
	KD-14-5	15	Girder bridge	11.00 x 5.30	9.50 5.30	-	-	-	" "
	"	16	-	-	9.88 5.20	Girder bridge	10.00 x 5.20	3.66	" "
	KD-17-2	17	-	-	9.59 5.20	" "	9.60 x 5.20	"	" "
	KD-20-1	18	-	-	8.17 x 5.30	" "	8.20 x 5.30	"	" "



266

FIG. 6.1.1	ALTERNATIVE OF COMPARTMENTALIZATION

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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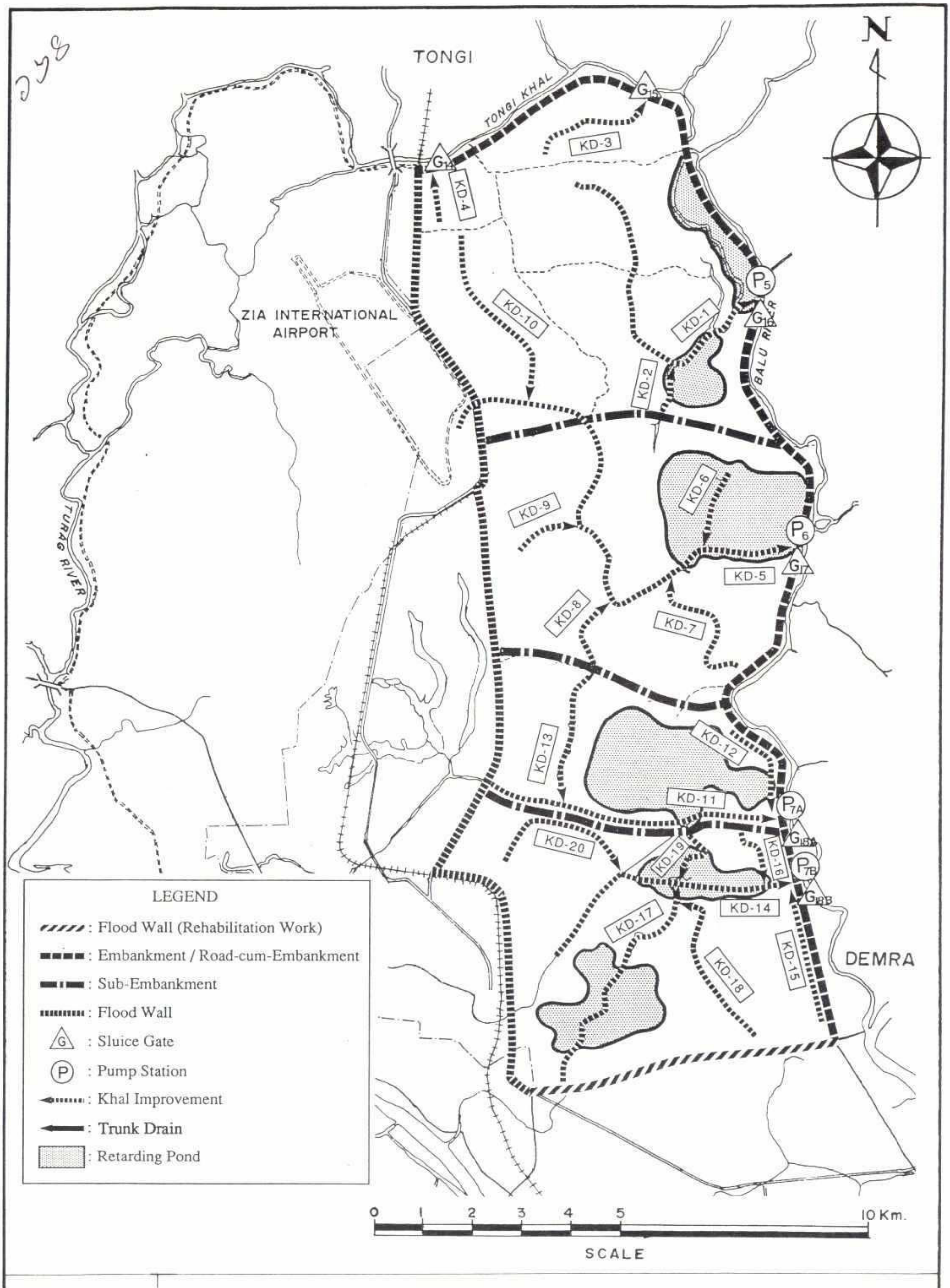
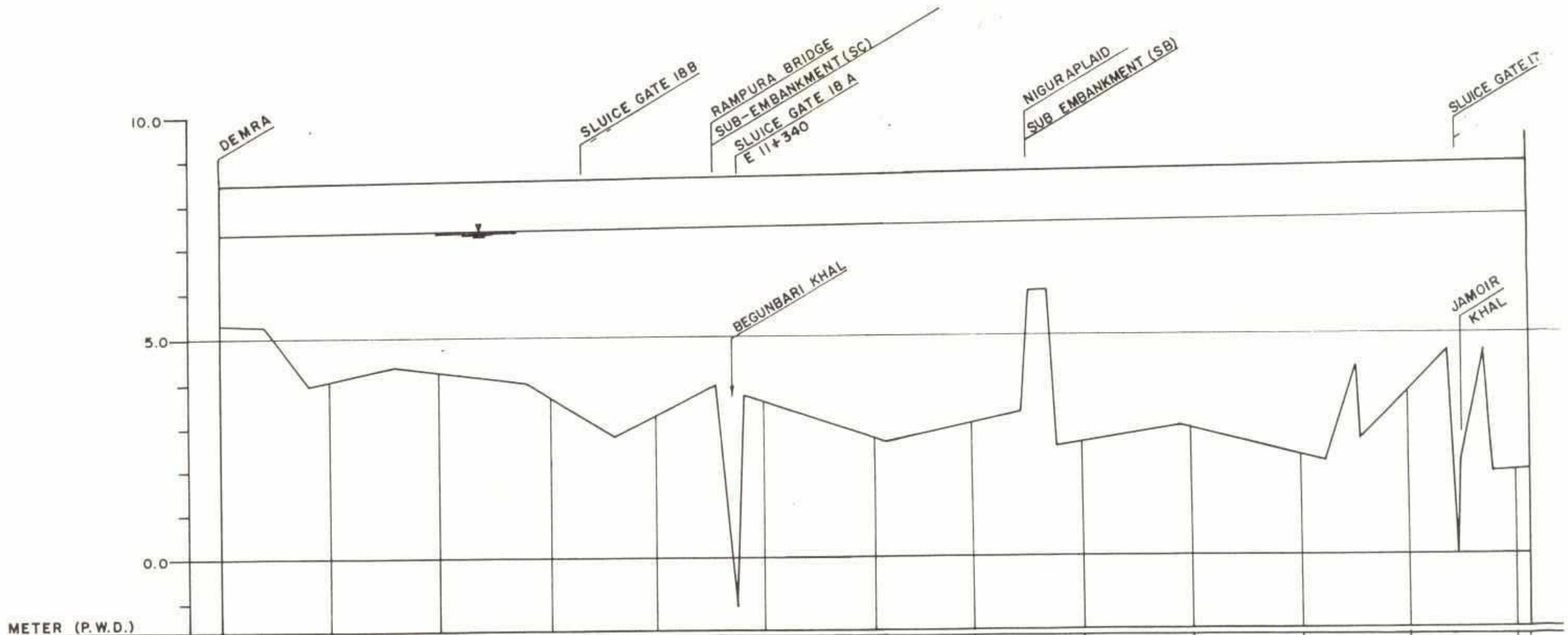


FIG. 6.1.2 PROPOSED FACILITIES : GREATER DHAKA EAST

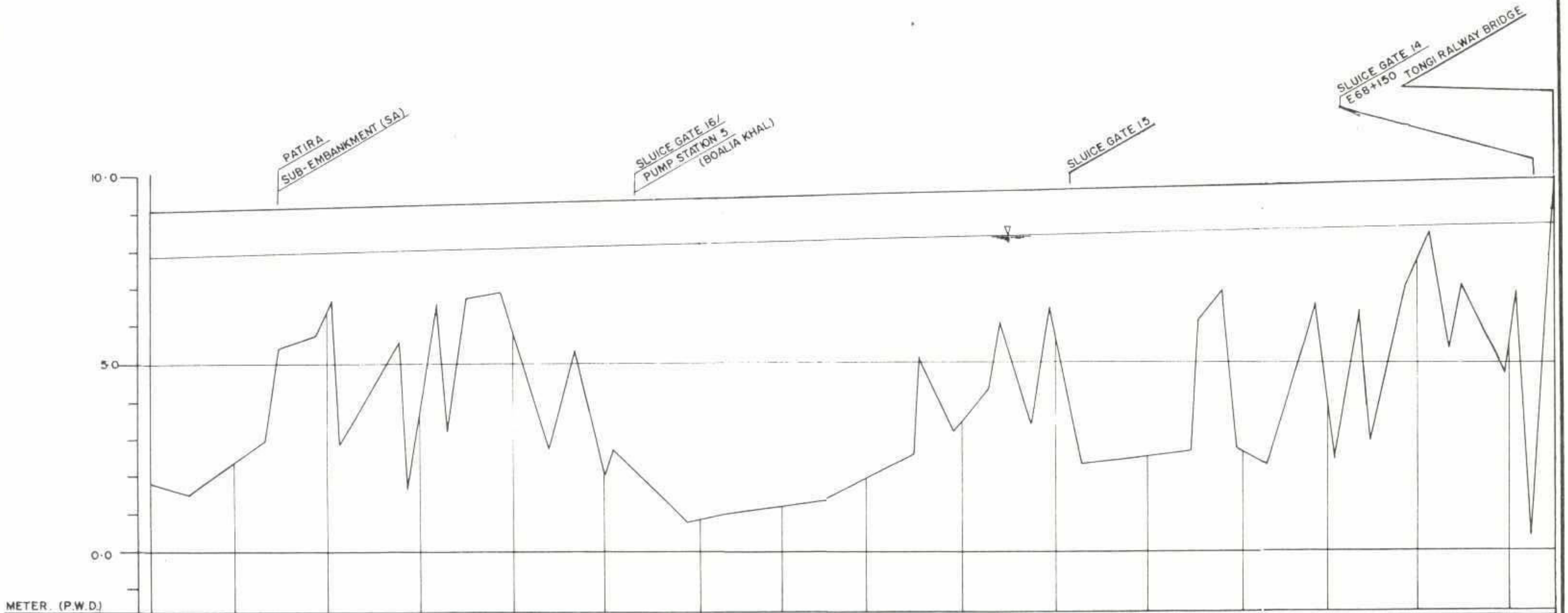
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROLOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH



DESIGNED	GRADIENT	I= 1/22,930													
DESIGNED	TOP OF EMBANKMENT	8.60	8.64	8.69	8.73	8.77	8.82	8.86	8.91	8.95	9.00	9.04	9.08	9.13	9.13
DESIGNED	H. W. L.	7.40	7.44	7.49	7.53	7.57	7.62	7.66	7.71	7.75	7.80	7.84	7.88	7.93	7.93
ACCUMULATED DISTANCE (KM)		0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	12.12

FIG. 6.1.3(1) LONGITUDINAL SECTION OF EMBANKMENT : DHAKA EAST (E_1)

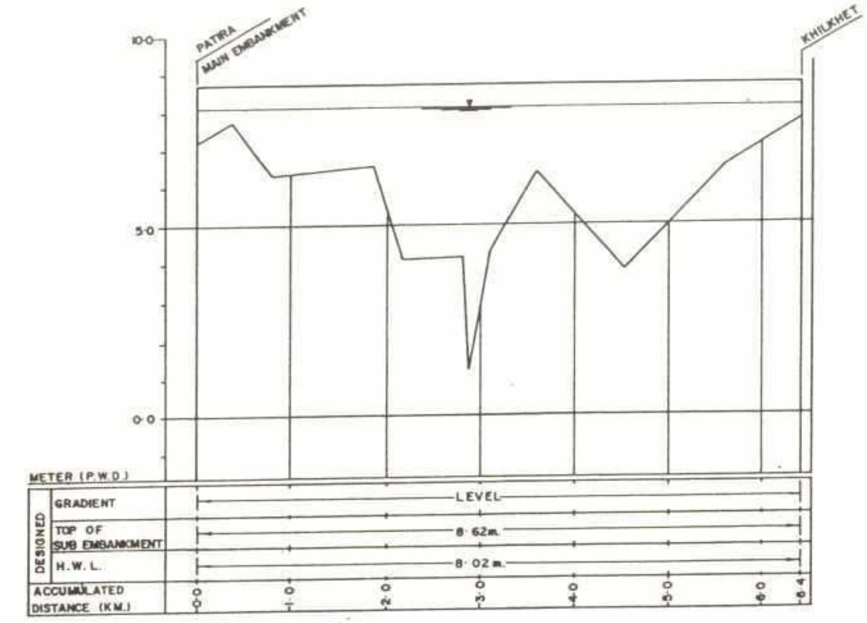
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

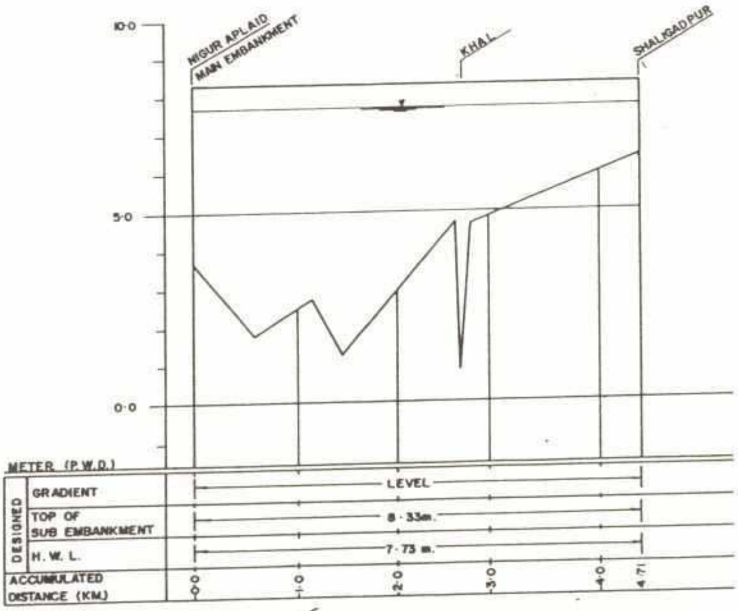


DESIGNED	GRADIENT	1 = 1/22,930																
	TOP OF EMBANKMENT	9.13	9.17	9.21	9.25	9.30	9.34	9.38	9.43	9.47	9.52	9.56	9.60	9.64	9.69	9.72	9.75	9.80
	H.W.L.	7.93	7.97	8.01	8.05	8.10	8.14	8.18	8.23	8.27	8.32	8.36	8.40	8.44	8.49	8.52	8.55	8.60
ACCUMULATED DISTANCE (KM)		12.12	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	27.52

FIG. 6.1.3(2) LONGITUDINAL SECTION OF EMBANKMENT : DHAKA EAST (E_2)

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





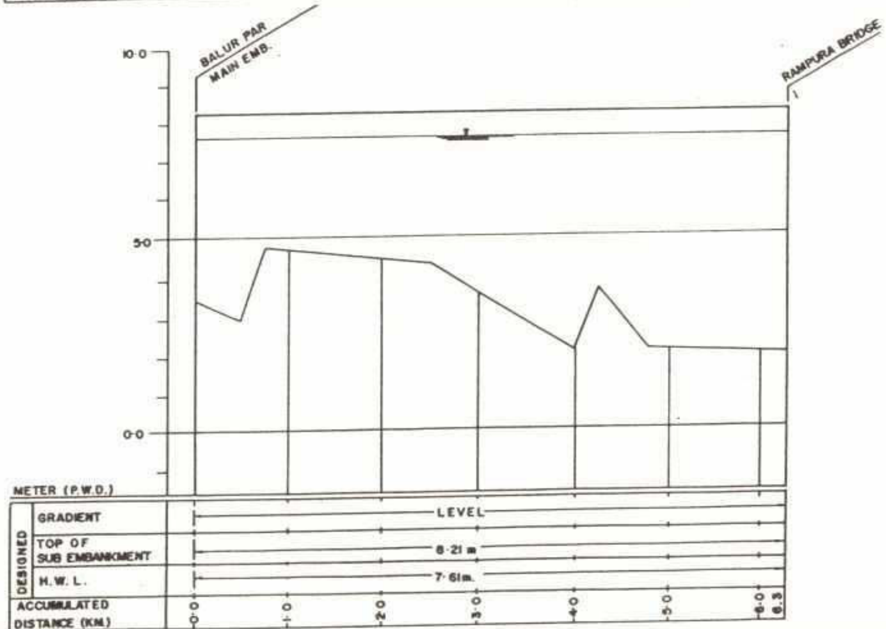


FIG. 6.1.3(3) LONGITUDINAL SECTION OF EMBANKMENT : DHAKA EAST (SA, SB AND SC)

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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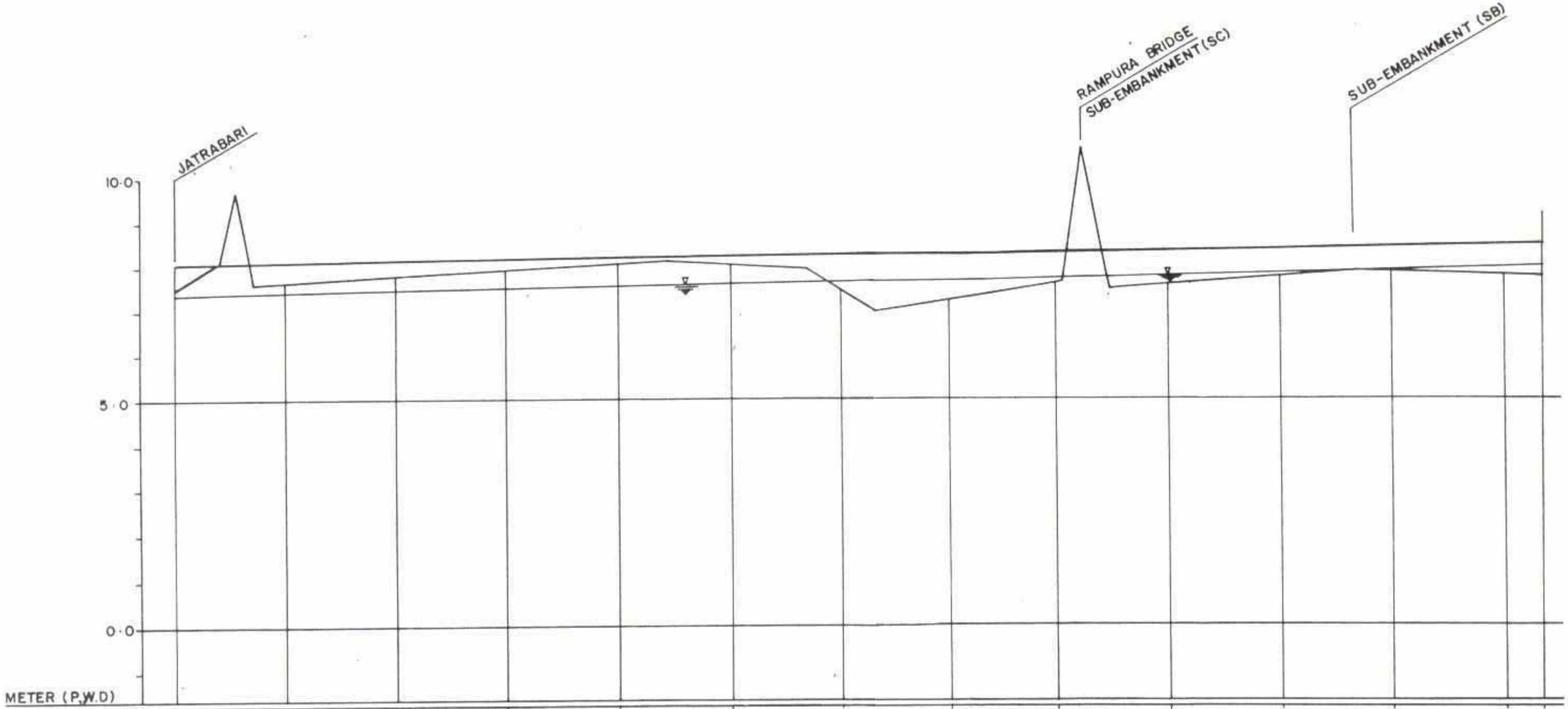
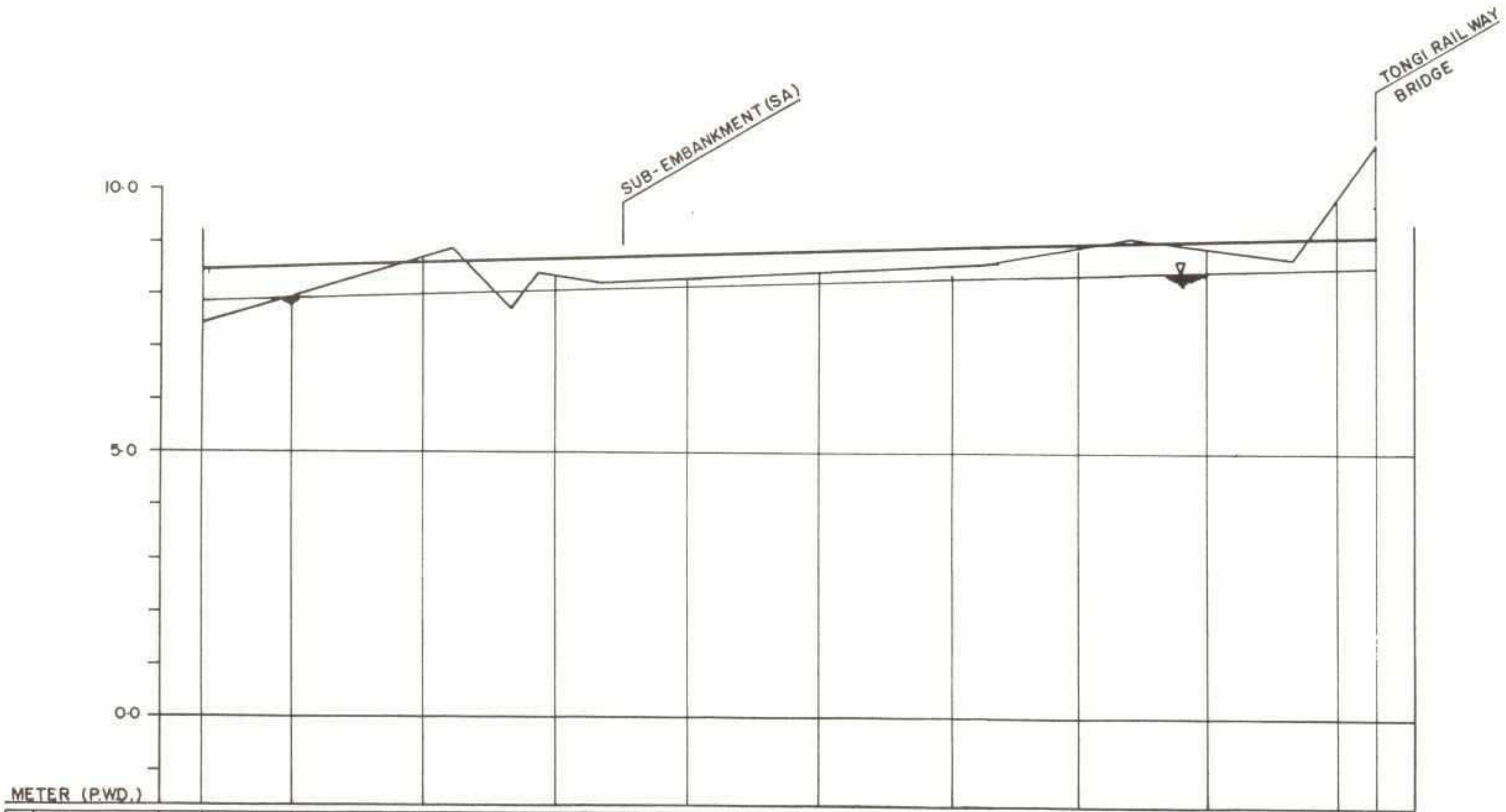


DESIGNED	GRADIENT	I = 1/39,190								I = 1/19,170		I = 1/16,210		
DESIGNED	TOP OF FLOOD WALL	8.00	8.02	8.05	8.08	8.10	8.13	8.15	8.18	8.20	8.25	8.30	8.35	8.42	8.46
DESIGNED	H.W.L.	7.40	7.42	7.45	7.48	7.50	7.53	7.55	7.58	7.60	7.65	7.7	7.75	7.82	7.86
ACCUMULATED DISTANCE (KM)		0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	12.3

FIG. 6.1.3(4) LONGITUDINAL SECTION OF FLOOD WALL : DHAKA EAST (R_1)

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



DESIGNED												
GRADIENT	I = 1/16,210				I = 1/10,300							
TOP OF FLOOD WALL	8.46	8.48	8.54	8.60	8.69	8.79	8.89	8.99	9.09	9.19	9.20
H. W. L.	7.86	7.88	7.94	8.00	8.09	8.19	8.29	8.39	8.49	8.59	8.60
ACCUMULATED DISTANCE (KM.)	12.3	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	21.3

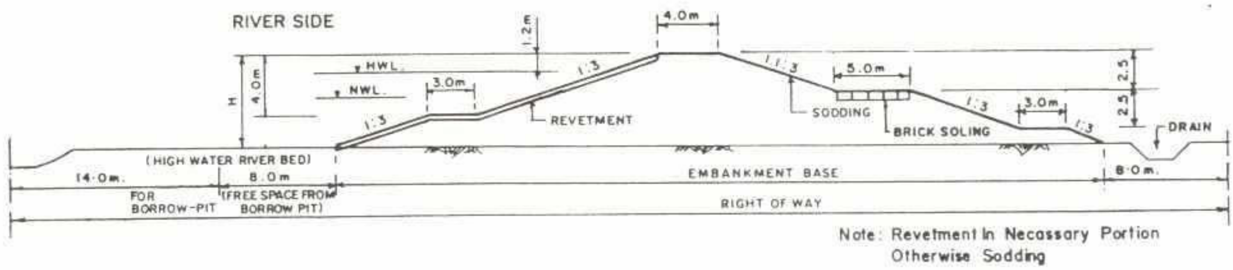
272

FIG. 6.1.3(5) LONGITUDINAL SECTION OF FLOOD WALL : DHAKA EAST (R_2)

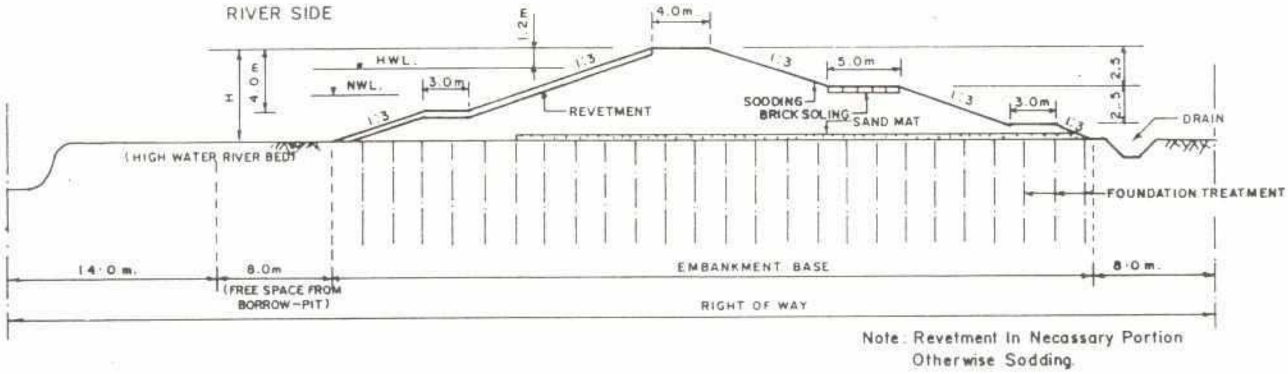
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

290

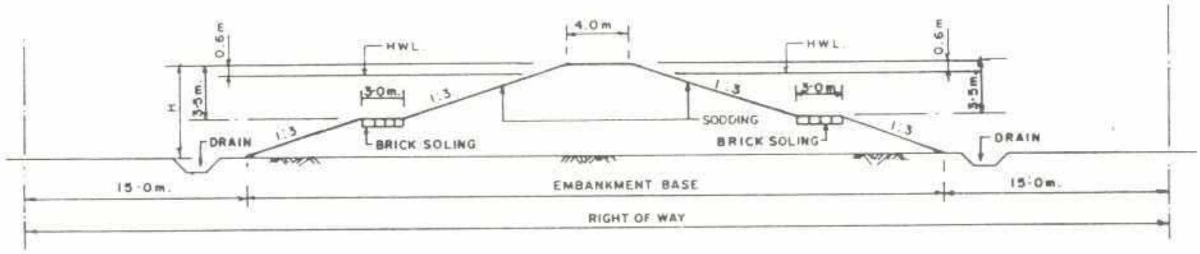
TYPICAL SECTION OF EMBANKMENT



TYPICAL SECTION OF EMBANKMENT WITH FOUNDATION TREATMENT



TYPICAL SECTION OF SUB-EMBANKMENT



TYPICAL SECTION OF SUB-EMBANKMENT WITH FOUNDATION TREATMENT

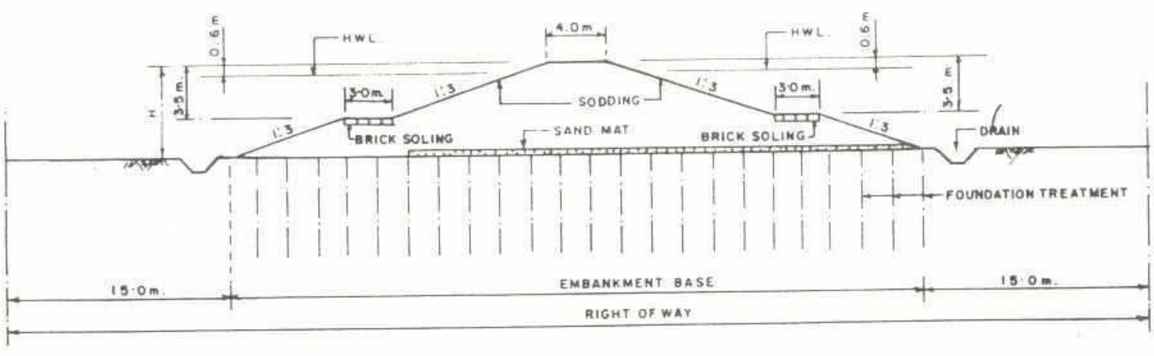


FIG. 6.1.4 STANDARD CROSS-SECTION OF EMBANKMENT/SUB-EMBANKMENT : DHAKA EAST

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

Khal Length

No.	Length(m)
K 1	820
K 2	1,640
K 3	4,100
K 4	440
K 5	3,040
K 6	1,940
K 7	640
K 8	3,540
K 9	1,760
K 10	1,600
K 11	1,400
K 12	740
K 13	1,700
K 14	740
K 15	2,600
K 16	2,200
K 17	800
K 18	1,920
K 19	3,220
K 20	1,640
K 21	2,700
K 22	5,320
K 23	4,820
K 24	3,420
K 25	2,420
K 26	1,800
K 27	2,200
Total	59,160

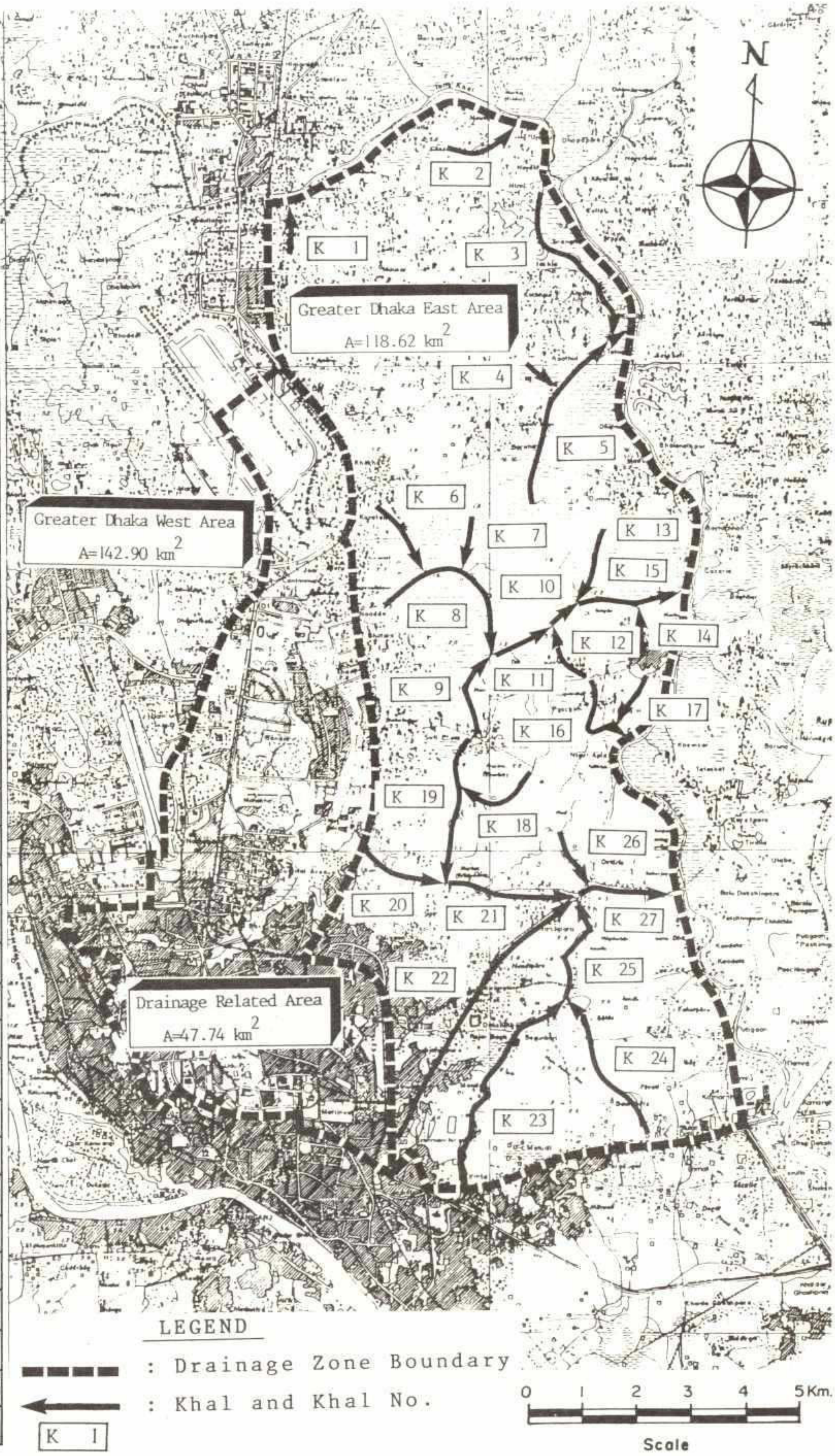
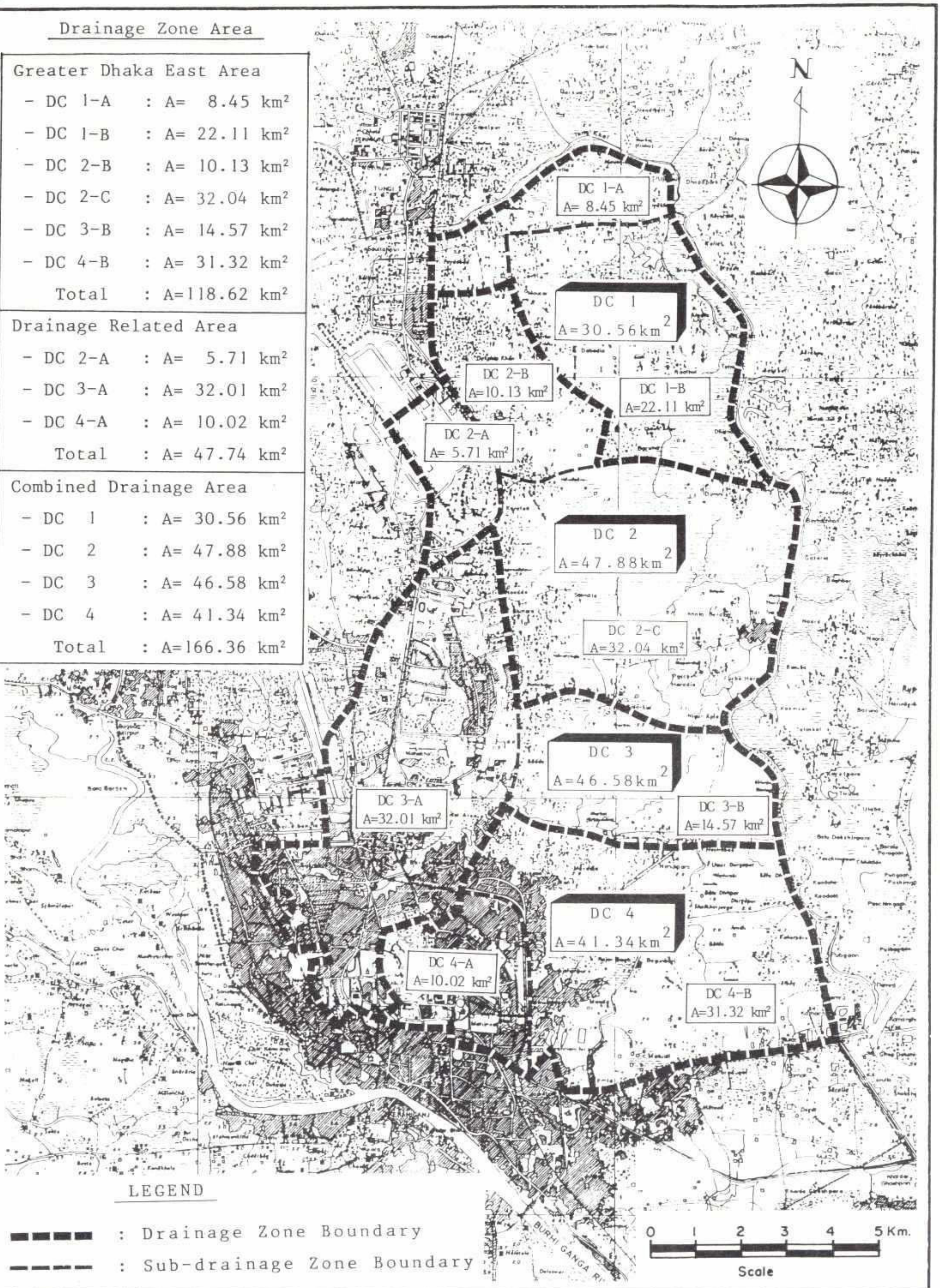


FIG. 6.1.5 EXISTING MAJOR KHALS : GREATER DHAKA EAST

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

Drainage Zone Area

Greater Dhaka East Area	
- DC 1-A	: A= 8.45 km²
- DC 1-B	: A= 22.11 km²
- DC 2-B	: A= 10.13 km²
- DC 2-C	: A= 32.04 km²
- DC 3-B	: A= 14.57 km²
- DC 4-B	: A= 31.32 km²
Total	: A=118.62 km²
Drainage Related Area	
- DC 2-A	: A= 5.71 km²
- DC 3-A	: A= 32.01 km²
- DC 4-A	: A= 10.02 km²
Total	: A= 47.74 km²
Combined Drainage Area	
- DC 1	: A= 30.56 km²
- DC 2	: A= 47.88 km²
- DC 3	: A= 46.58 km²
- DC 4	: A= 41.34 km²
Total	: A=166.36 km²



LEGEND

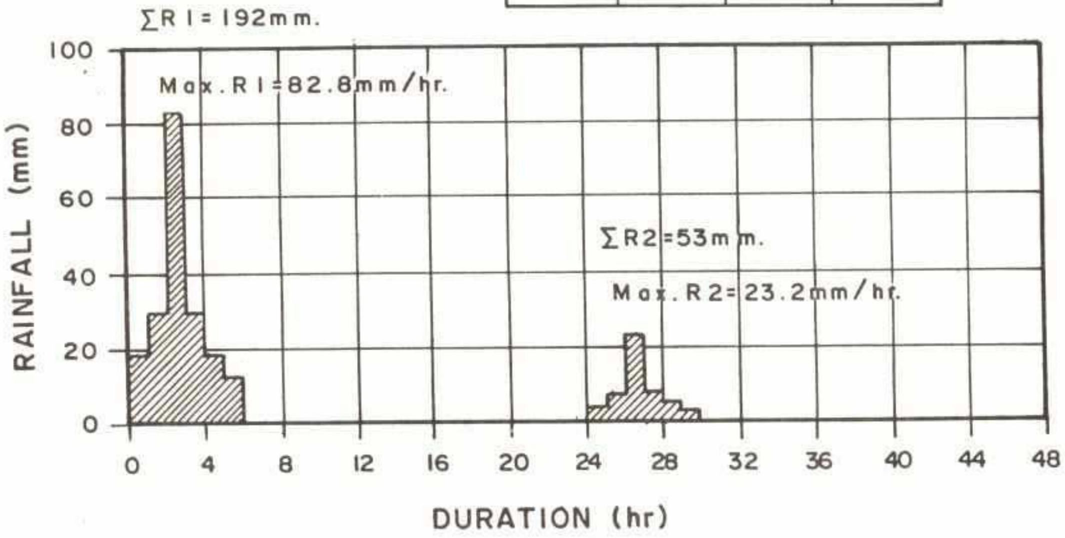
- : Drainage Zone Boundary
- : Sub-drainage Zone Boundary

FIG. 6.1.6 DRAINAGE ZONE : GREATER DHAKA EAST

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

HOURLY DISTRIBUTION

hr	%	R1	R2
1	9	17.4	4.8
2	15	28.3	8.0
3	44	82.8	23.2
4	16	30.6	8.5
5	9	18.0	5.0
6	7	14.9	3.5
TOTAL	100	192.0	53.0



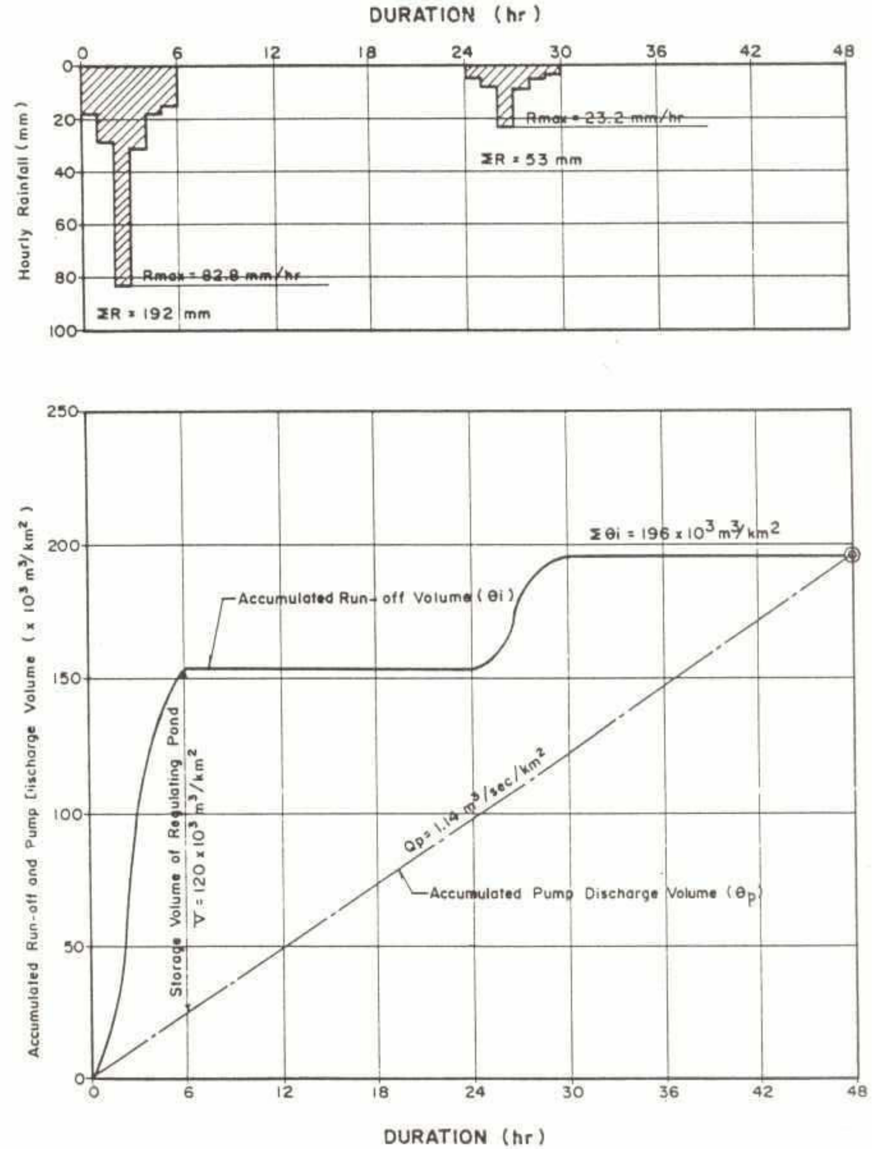
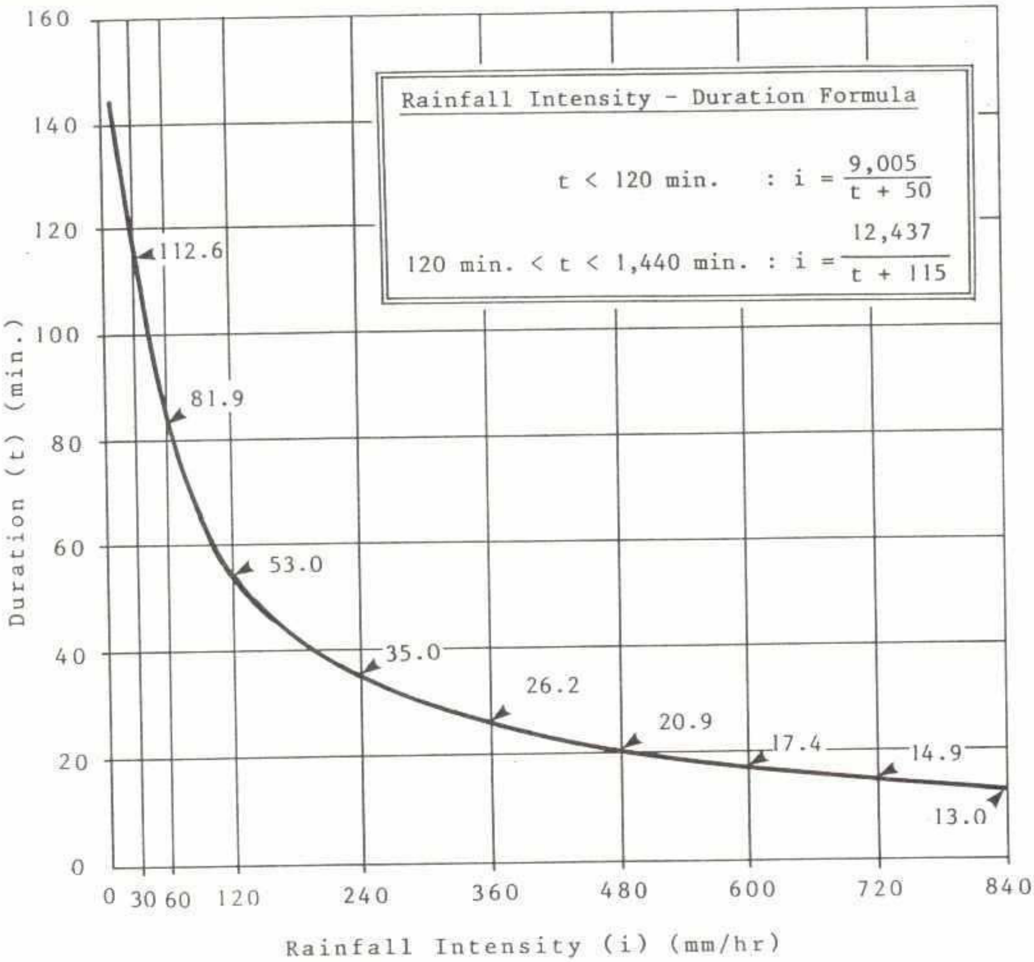


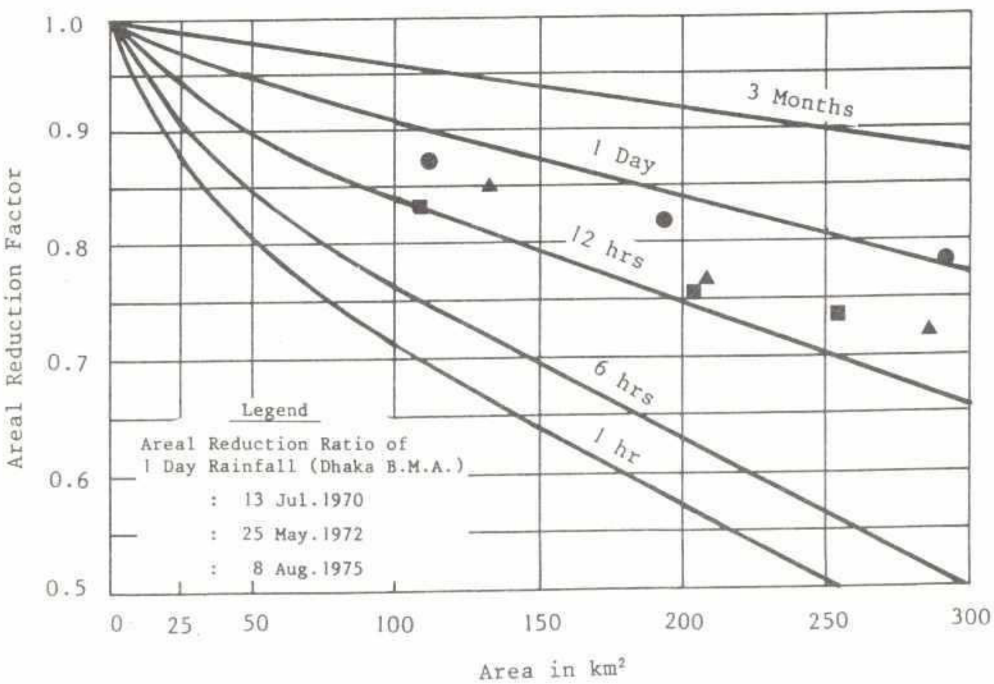
FIG. 6.1.7 DESIGN RAINFALL FOR PUMP DRAINAGE PLAN AND DESIGN SPECIFIC REQUIREMENTS OF PUMP AND RETARDING POND

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

296



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

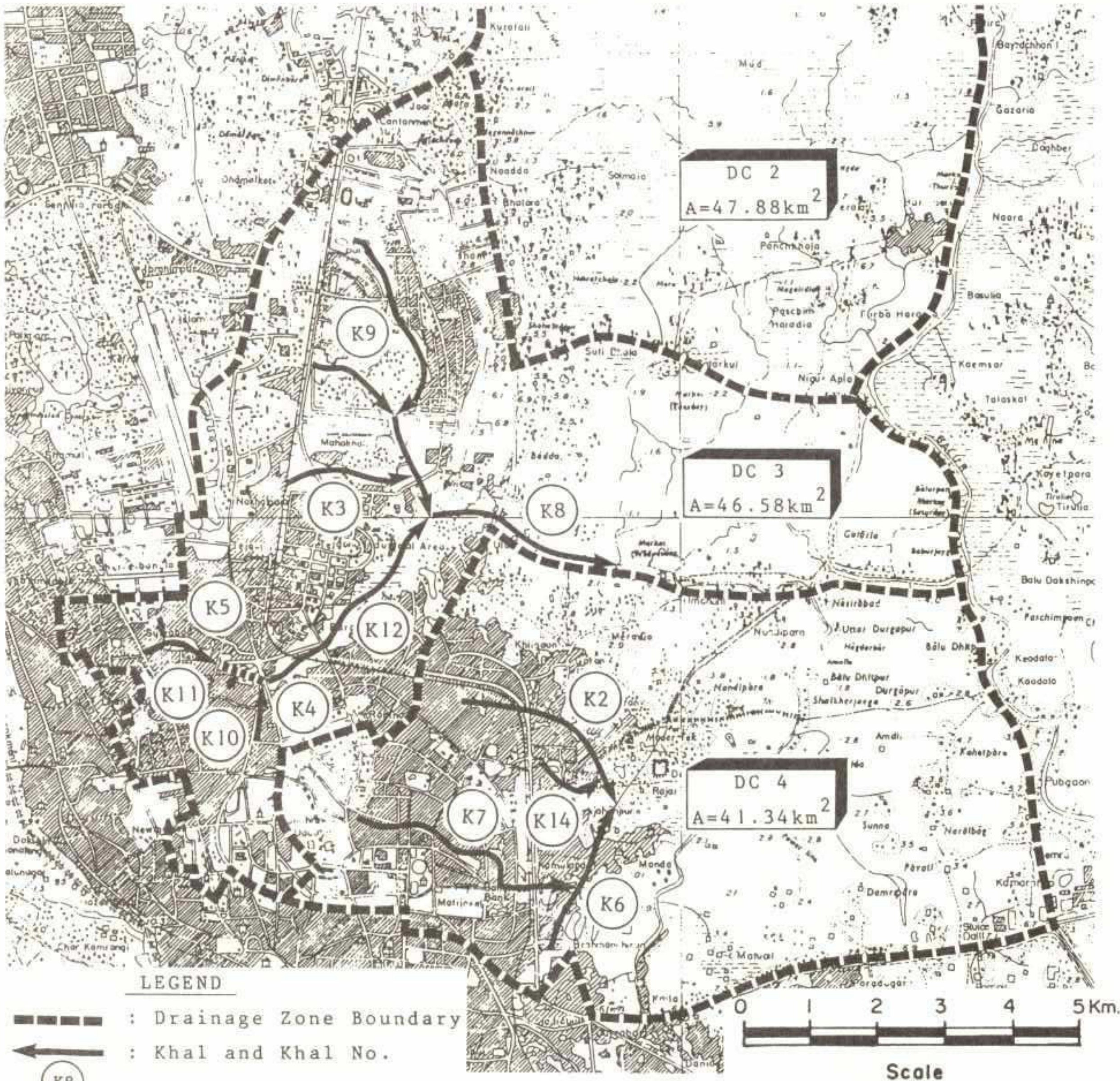


Source : NEDECO,Master Plan for Drainage and Flood Control of Jakarta,1973

FIG. 6.1.8	DESIGN RAINFALL AND AREAL REDUCTION CURVE FOR KHAL IMPROVEMENT 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



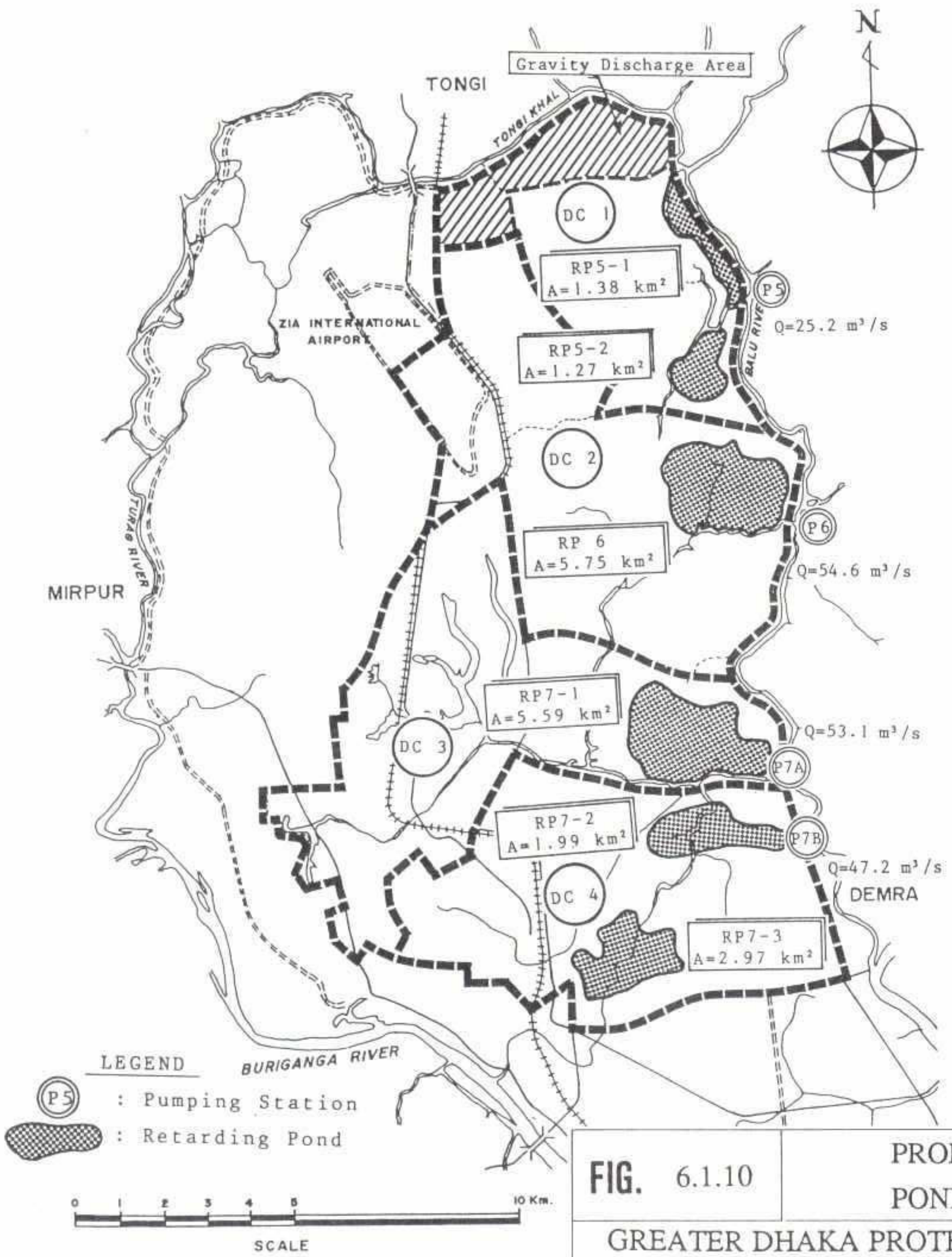
Sourse : ADB, Dhaka Integrated Flood Protection, FAP-8R, Sep. 1991

Phased Khal Improvement Work

Khal No.	Name of Khal	Improved Length(m)
Phase I Work (1991 - 1992)		
K 3	Mohakhali Khal	2,220
K11	BegunbariKhal	1,000
K 7	Segunbagicha Khal	2,366
K 5	Rajabazar Khal	195
K10	Kathalbagan Khal	110
	Sub-total	5,891
Phase II Work (1992 - 1993)		
K 2	Khilgaon-Basabo Khal	3,035
K 6	Gerani Khal	1,204
K 7	Segunbagicha Khal	1,576
K12	Begunbari Khal	1,000
K 9	Banani-Gulshan Khal	4,500
K 4	Paribagh Khal	767
	Sub-total	12,082
Phase III Work (1993 - 1994)		
K14	Mugda Khal	2,200
K 8	Begunbari Khal	4,820
	Sub-total	7,020
	Total	24,993

FIG. 6.1.9 KHAL IMPROVEMENT WORKS PROPOSED IN DIFPP FINANCED BY ADB

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



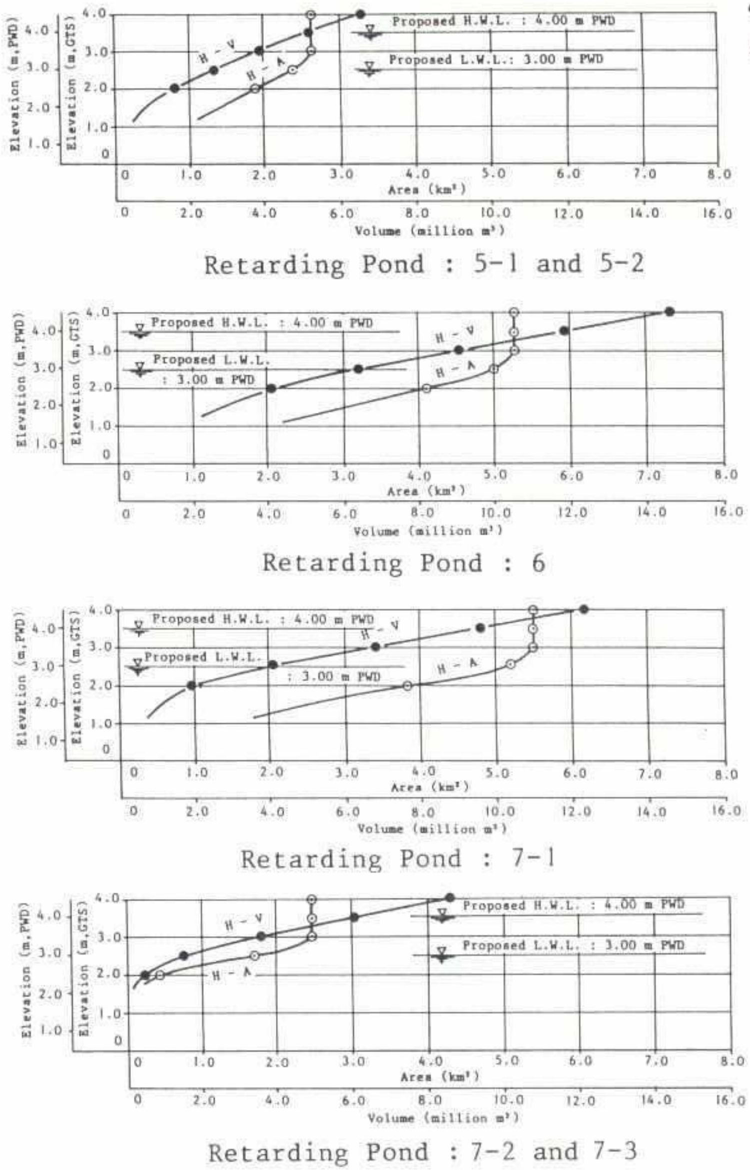


FIG. 6.1.10 PROPOSED REQUIREMENTS OF PUMP AND RETARDING POND : GREATER DHAKA EAST

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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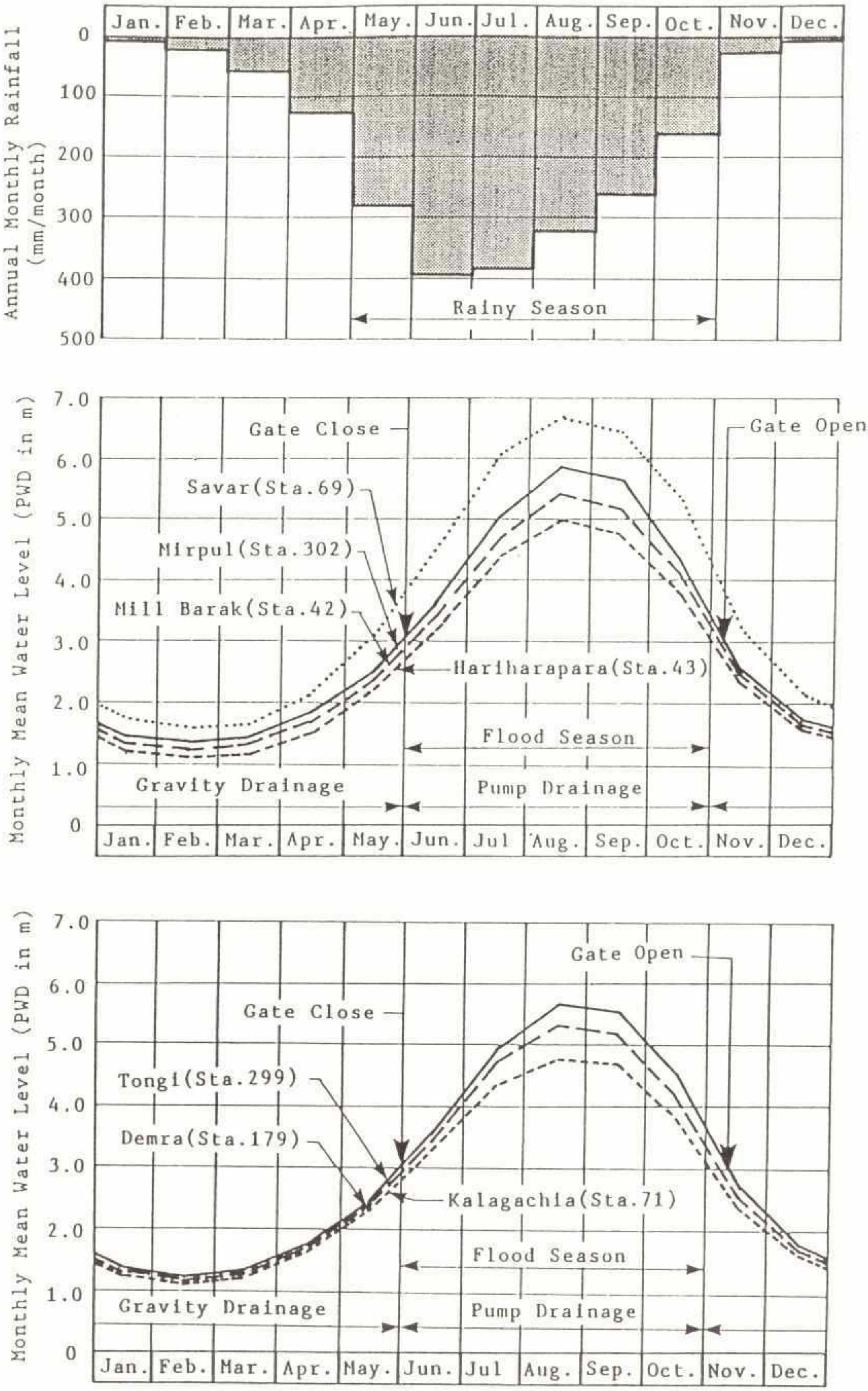

FIG. 6.1.11 SEASONAL VARIATION OF RAINFALL AND FLOOD WATER LEVEL IN DHAKA METROPOLITAN AREA

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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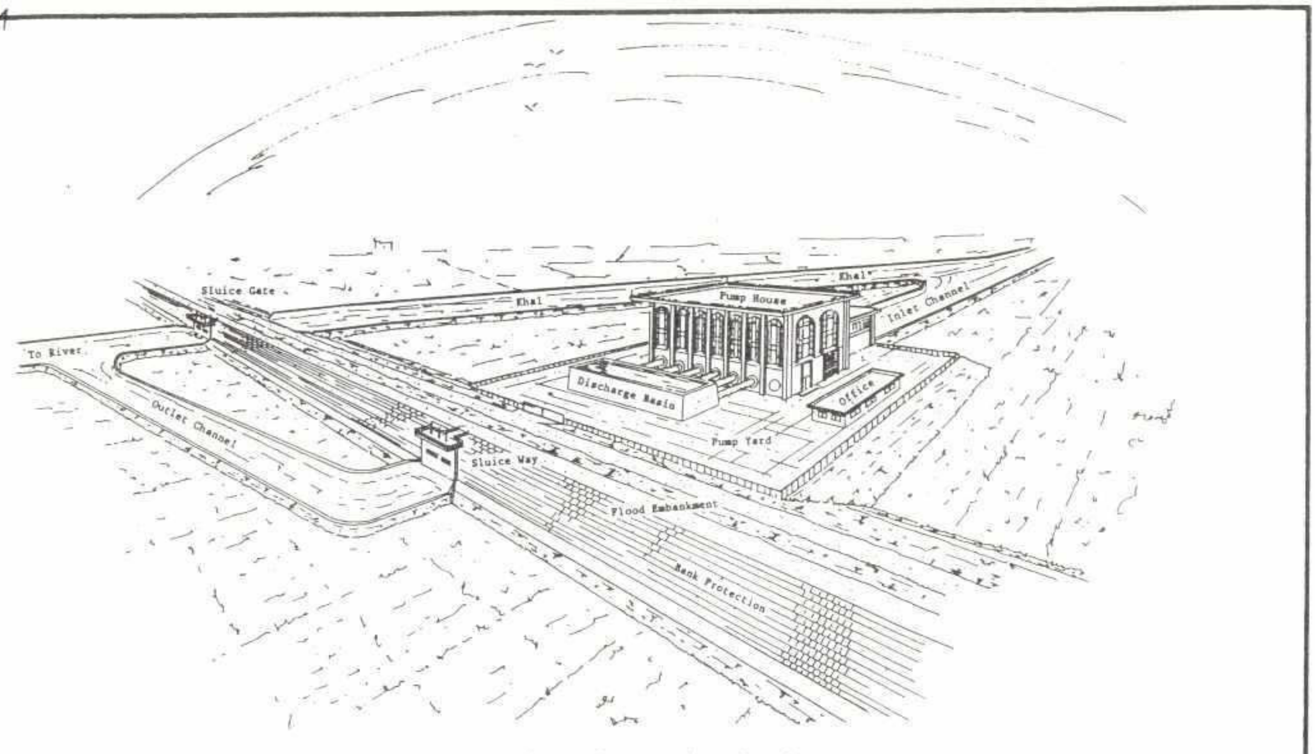
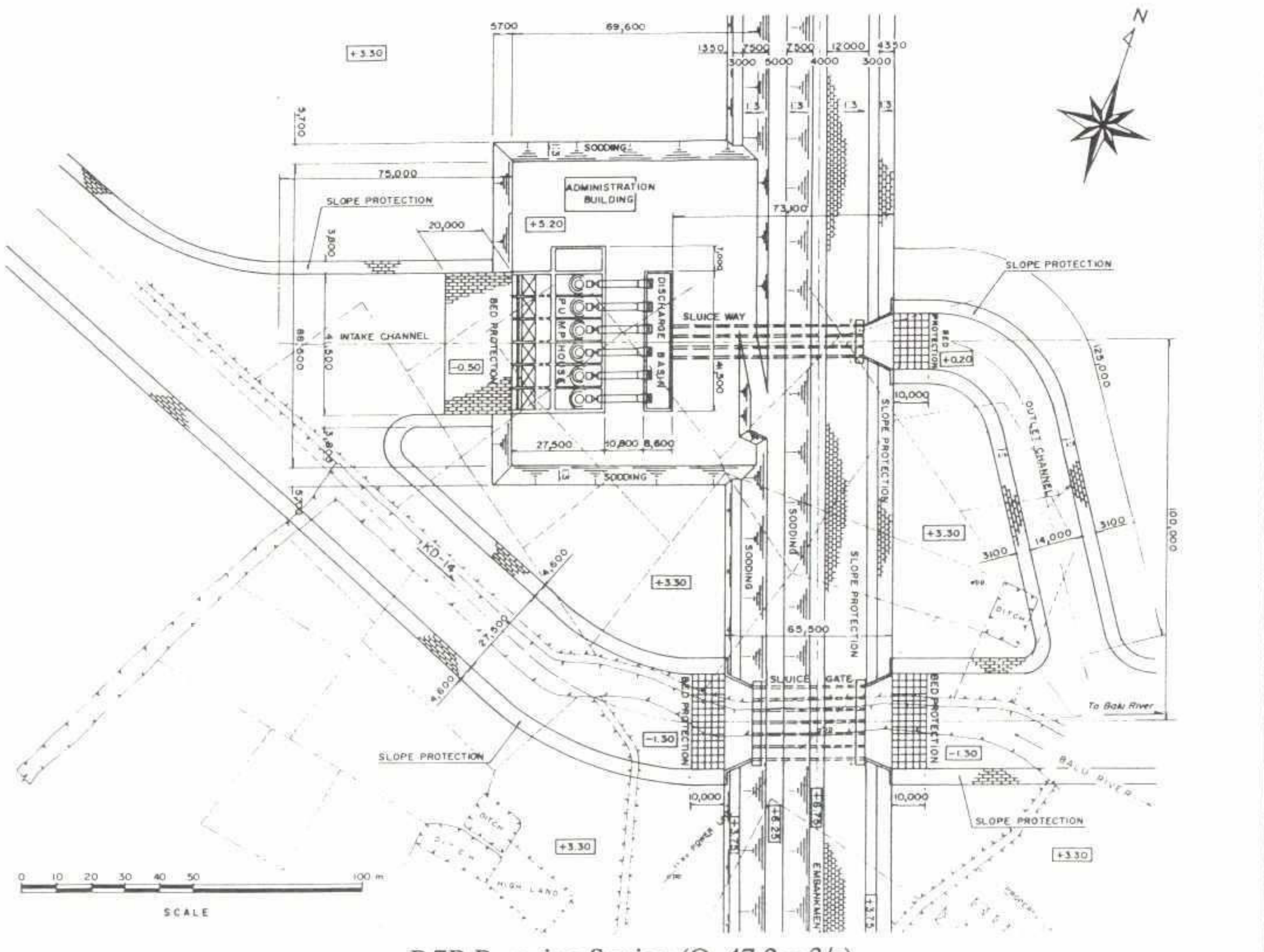


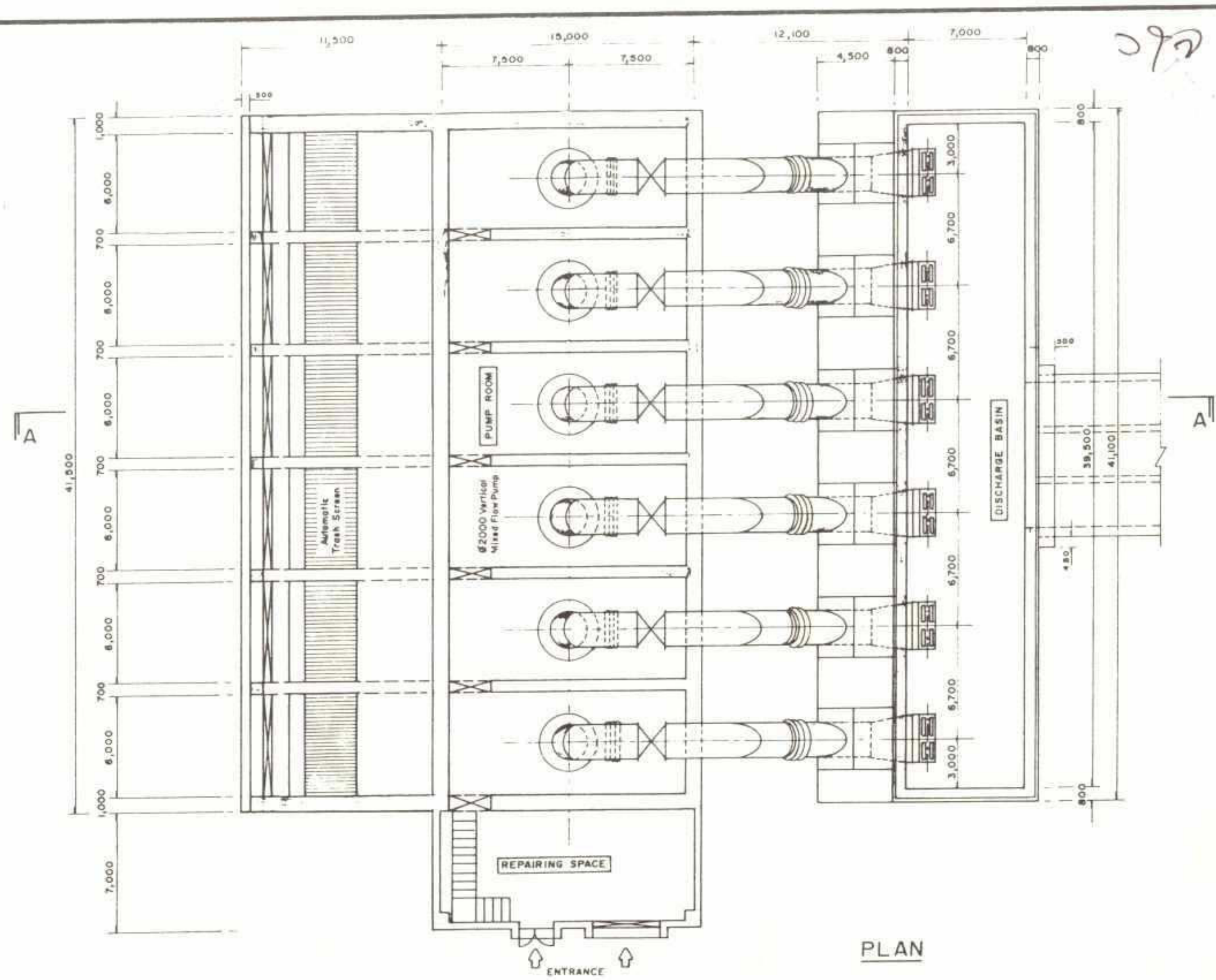
Perspective of Pumping Station



P.7B Pumping Station (Q=47.2 m3/s)

FIG. 6.1.12 (1) LAYOUT OF PROPOSED P7B PUMPING STATION

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



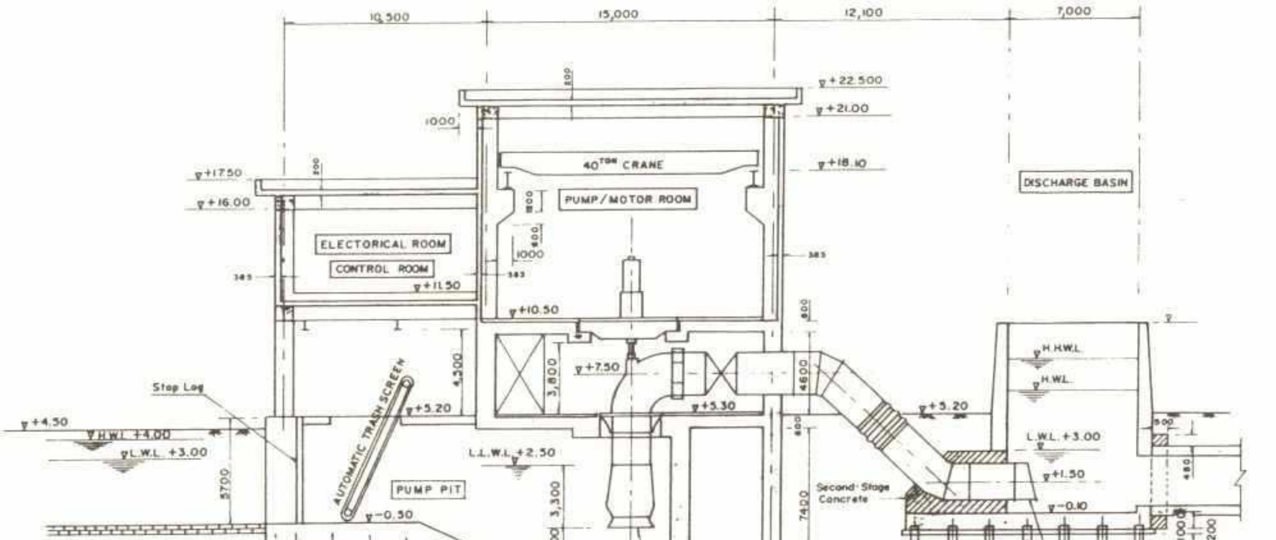
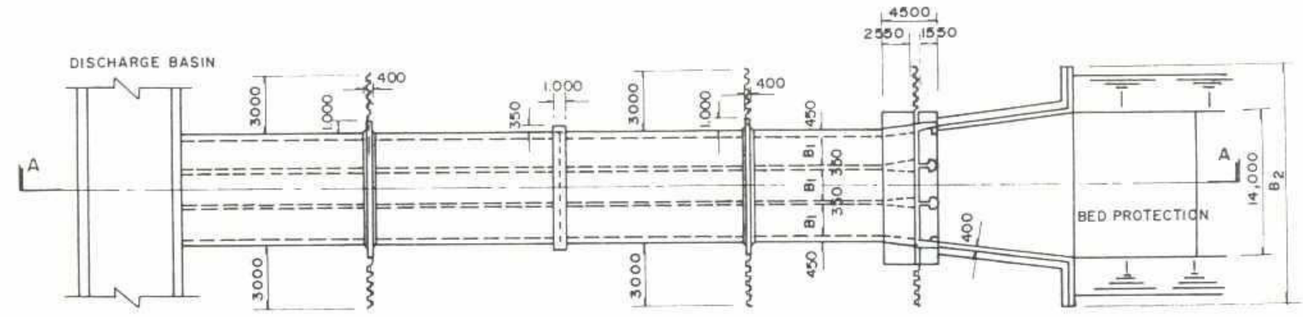


FIG. 6.1.12 (2) TYPICAL DESIGN OF PROPOSED 50 M^3/S CLASS PUMPING STATION (P6, P7A, P7B AND P11)

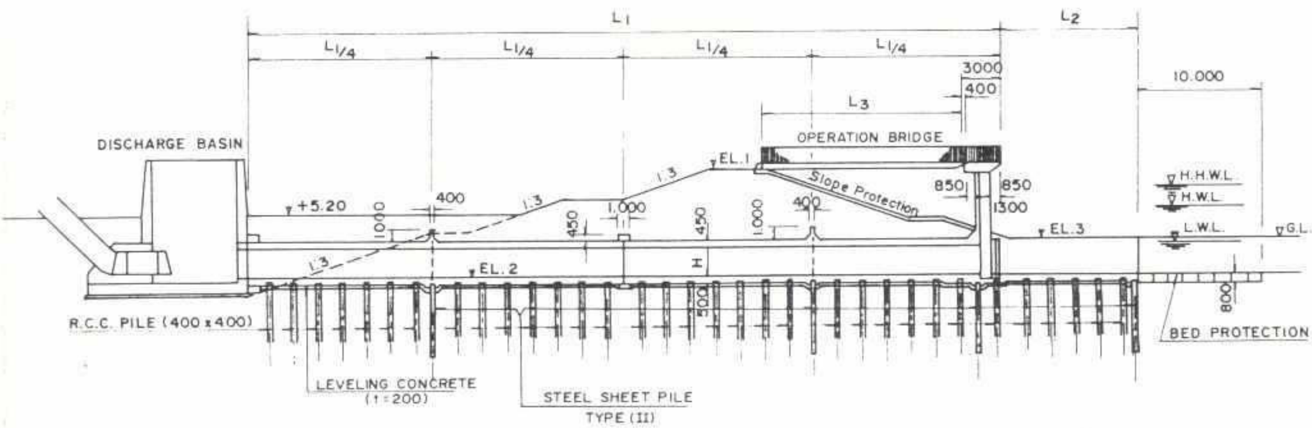
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA

PLAN



SECTION A-A



Main Feature of Sluice Way

Pump No.	Culvert				Outlet		0.Bridge	Elevation		
	B1 (mm)	H1 (mm)	L1 (mm)	n (Nos.)	B2 (mm)	L2 (mm)	L3 (mm)	EL.1	EL.2	EL.3
P.5	2,300	2,300	62,000	2	19,000	14,700	14,850	+9.35	+0.20	+1.70
P.6	2,700	2,700	61,200	3	20,000	14,000	14,800	+9.10	+0.20	+2.20
P.7A	2,700	2,700	60,000	3	21,600	13,400	14,500	+8.80	+0.20	+3.00
P.7B	2,500	2,500	60,000	3	22,200	13,100	14,650	+8.75	+0.20	+3.30
P.11	2,500	2,000	48,400	4	23,200	13,000	9,500	+8.00	+0.20	+3.80

FIG. 6.1.12 (3) TYPICAL DESIGN OF PROPOSED SLUICE WAY FOR 25 M3/S ~ 50 M3/S CLASS PUMPING STATION (P5, P6. P7A, P7B AND P11)

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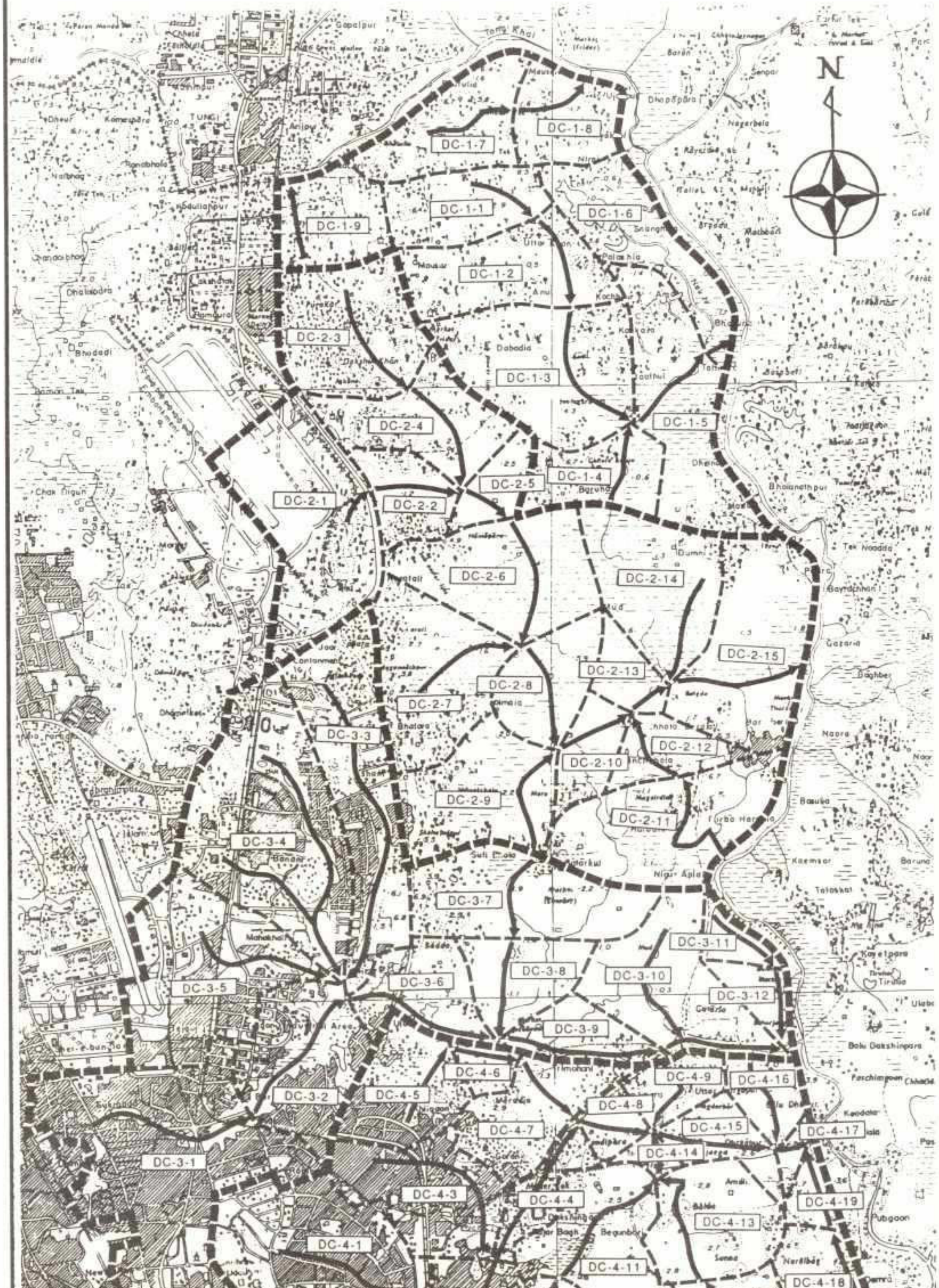

Block No.	Drainage Area (km2)	Run-off Coefficient f
	(DC-1)	
DC-1-1	2.53	0.39
DC-1-2	3.95	0.40
DC-1-3	5.01	0.44
DC-1-4	1.76	0.38
DC-1-5	5.09	0.33
DC-1-6	3.77	0.32
DC-1-7	3.38	0.39
DC-1-8	2.57	0.39
DC-1-9	2.50	0.42
	(DC-2)	
DC-2-1	5.71	0.38
DC-2-2	1.79	0.40
DC-2-3	4.08	0.44
DC-2-4	2.97	0.45
DC-2-5	1.29	0.42
DC-2-6	4.54	0.34
DC-2-7	3.52	0.40
DC-2-8	2.36	0.35
DC-2-9	3.33	0.40
DC-2-10	1.25	0.38
DC-2-11	4.98	0.38
DC-2-12	1.34	0.38
DC-2-13	1.23	0.35
DC-2-14	4.48	0.24
DC-2-15	5.01	0.25
	(DC-3)	
DC-3-1	8.81	0.47
DC-3-2	3.23	0.50
DC-3-3	5.54	0.42
DC-3-4	7.24	0.43
DC-3-5	6.29	0.43
DC-3-6	2.38	0.42
DC-3-7	3.42	0.38
DC-3-8	2.09	0.34
DC-3-9	1.86	0.30
DC-3-10	4.10	0.27
DC-3-11	0.69	0.40
DC-3-12	0.93	0.27
	(DC-4)	
DC-4-1	7.25	0.47
DC-4-2	2.11	0.48
DC-4-3	3.67	0.47
DC-4-4	1.03	0.43
DC-4-5	2.72	0.44
DC-4-6	0.61	0.44
DC-4-7	2.49	0.46
DC-4-8	0.70	0.29
DC-4-9	1.39	0.36
DC-4-10	5.30	0.37
DC-4-11	3.24	0.35
DC-4-12	2.91	0.44
DC-4-13	2.56	0.46
DC-4-14	0.30	0.29
DC-4-15	1.11	0.26
DC-4-16	1.10	0.43
DC-4-17	0.30	0.46
DC-4-18	1.96	0.44
DC-4-19	0.59	0.46

LEGEND

: Drainage Zone Boundary

: Sub-drainage Zone Boundary

DC-2-14 : Block No. of Sub-drainage Zone

: Khal

0 1 2 3 4 5 Km.

Scale

FIG. 6.1.13 SUB-DRAINAGE ZONE AND THEIR RUN-OFF COEFFICIENT : GREATER DHAKA EAST

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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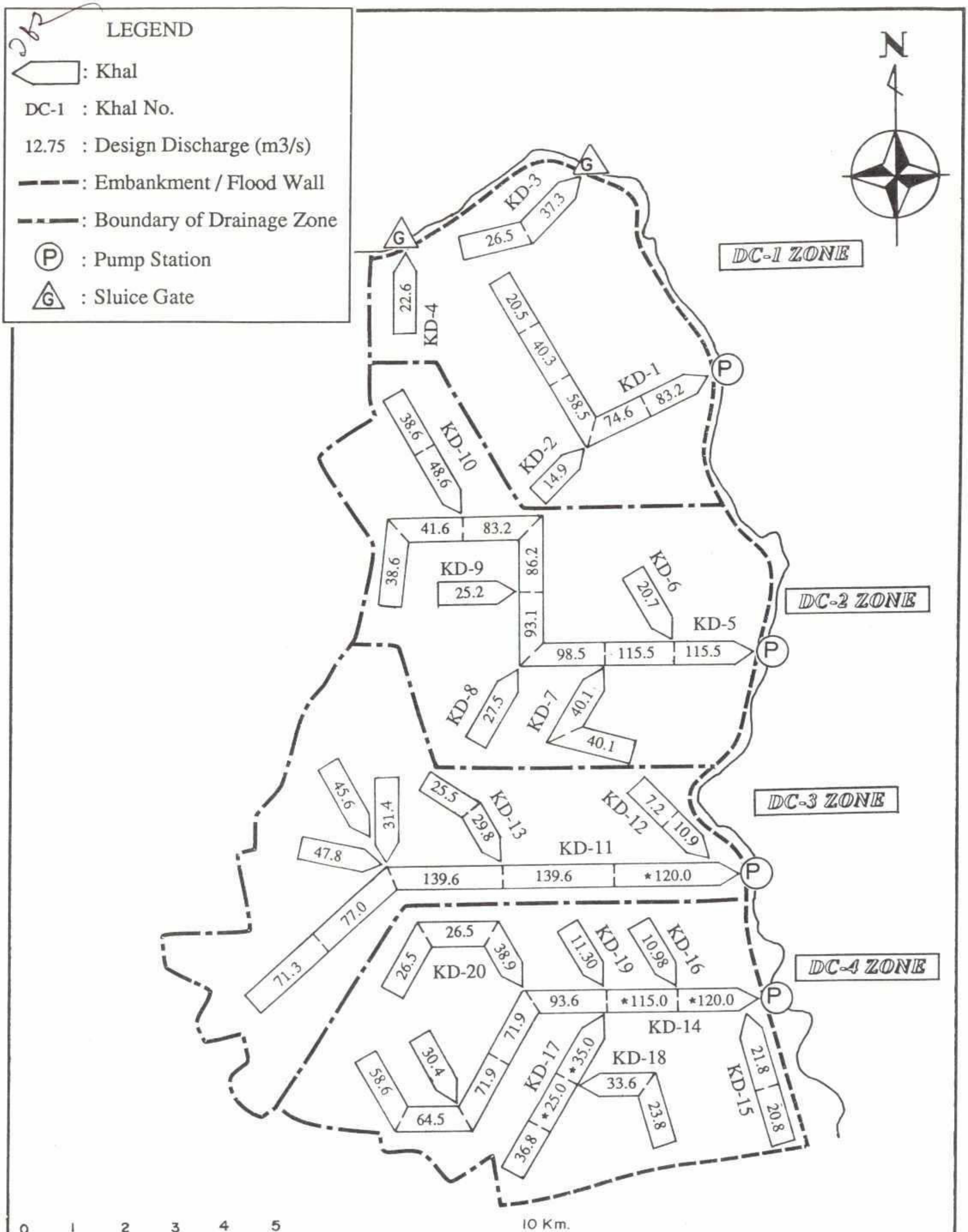

Note: The figures with (*) indicate the design discharge estimated in hydraulic simulation by Mike 11 model.

FIG. 6.1.14 DESIGN DISCHARGE FOR KHAL IMPROVEMENTS : GREATER DHAKA EAST

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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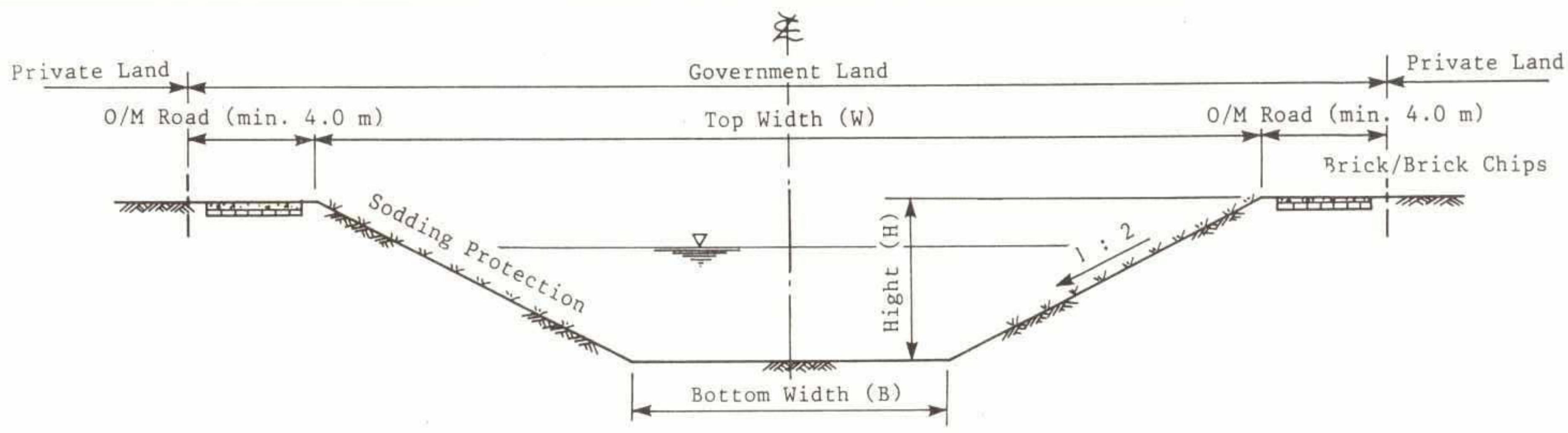
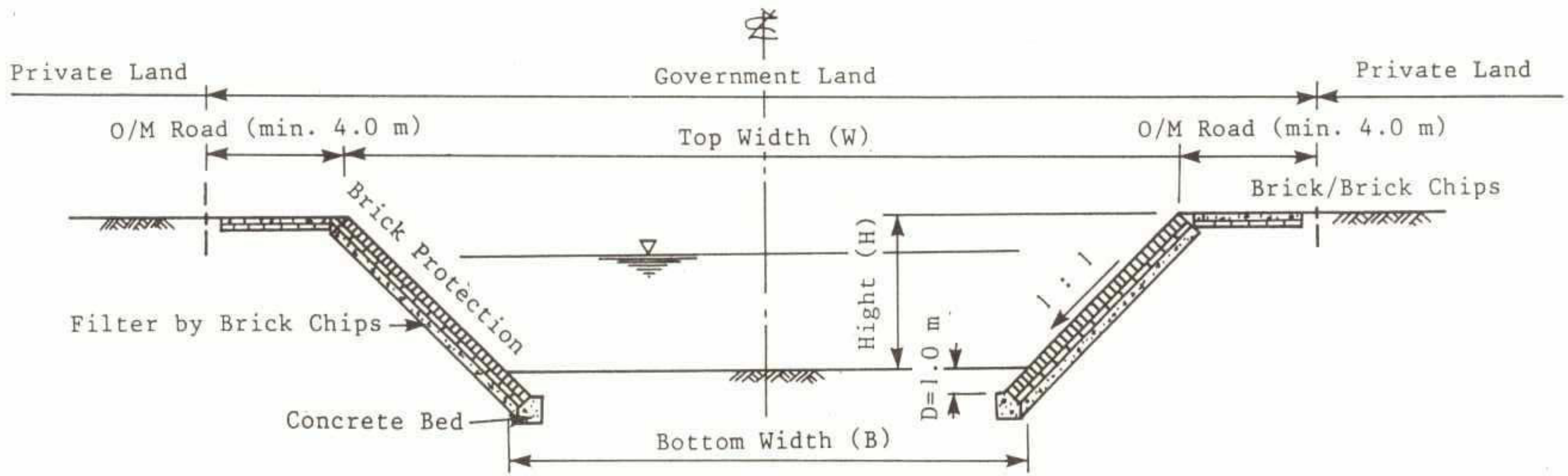


TYPE (1) : TRAPEZOIDAL SHAPE WITH 1 : 2 SLOPE PROTECTION BY SODDING



TYPE (2) : TRAPEZOIDAL SHAPE WITH 1 : 1 SLOPE PROTECTED BY BRICK

FIG. 6.1.15 TYPICAL SECTION OF PROPOSED KHAL IMPROVEMENT

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

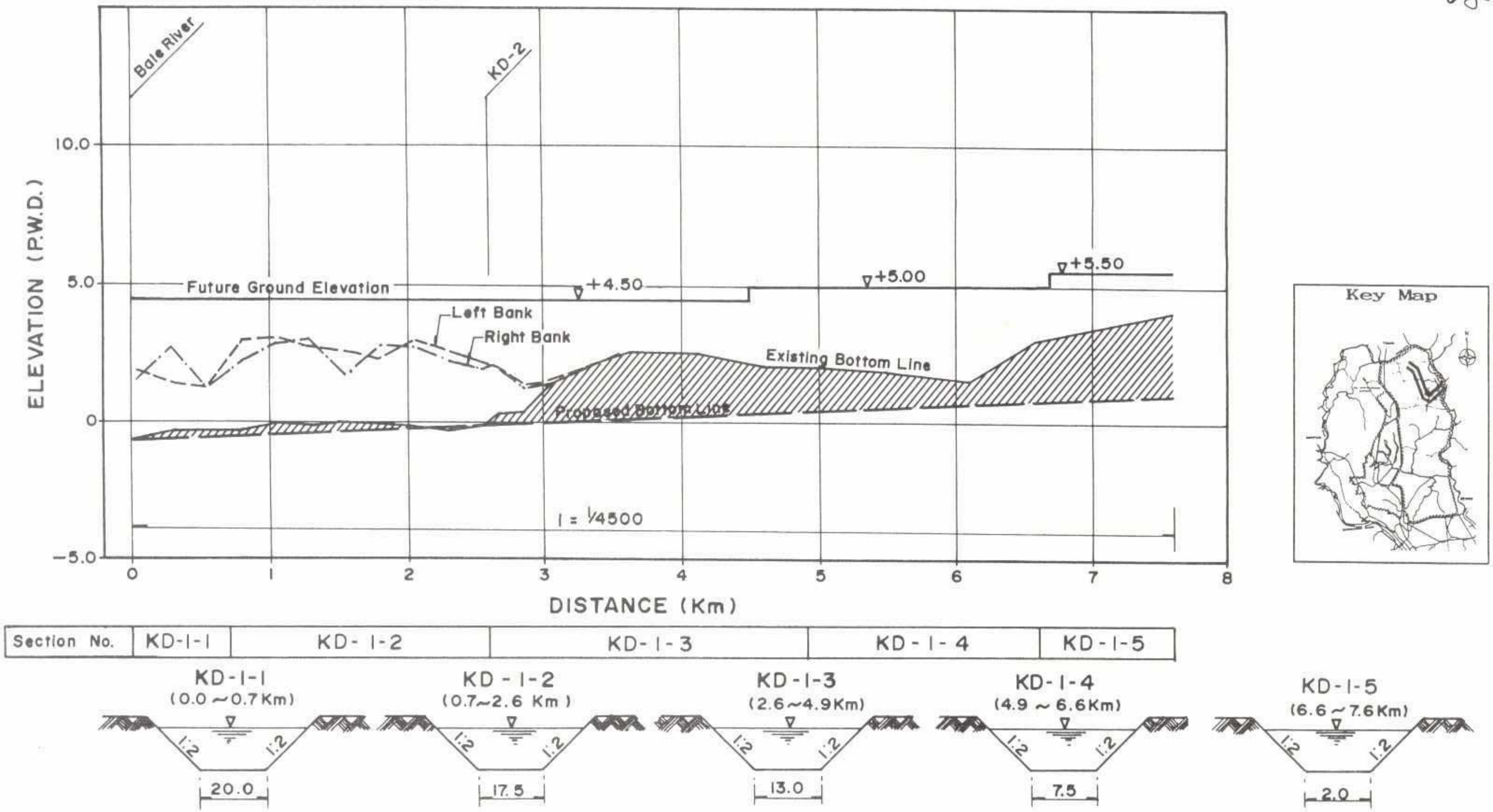


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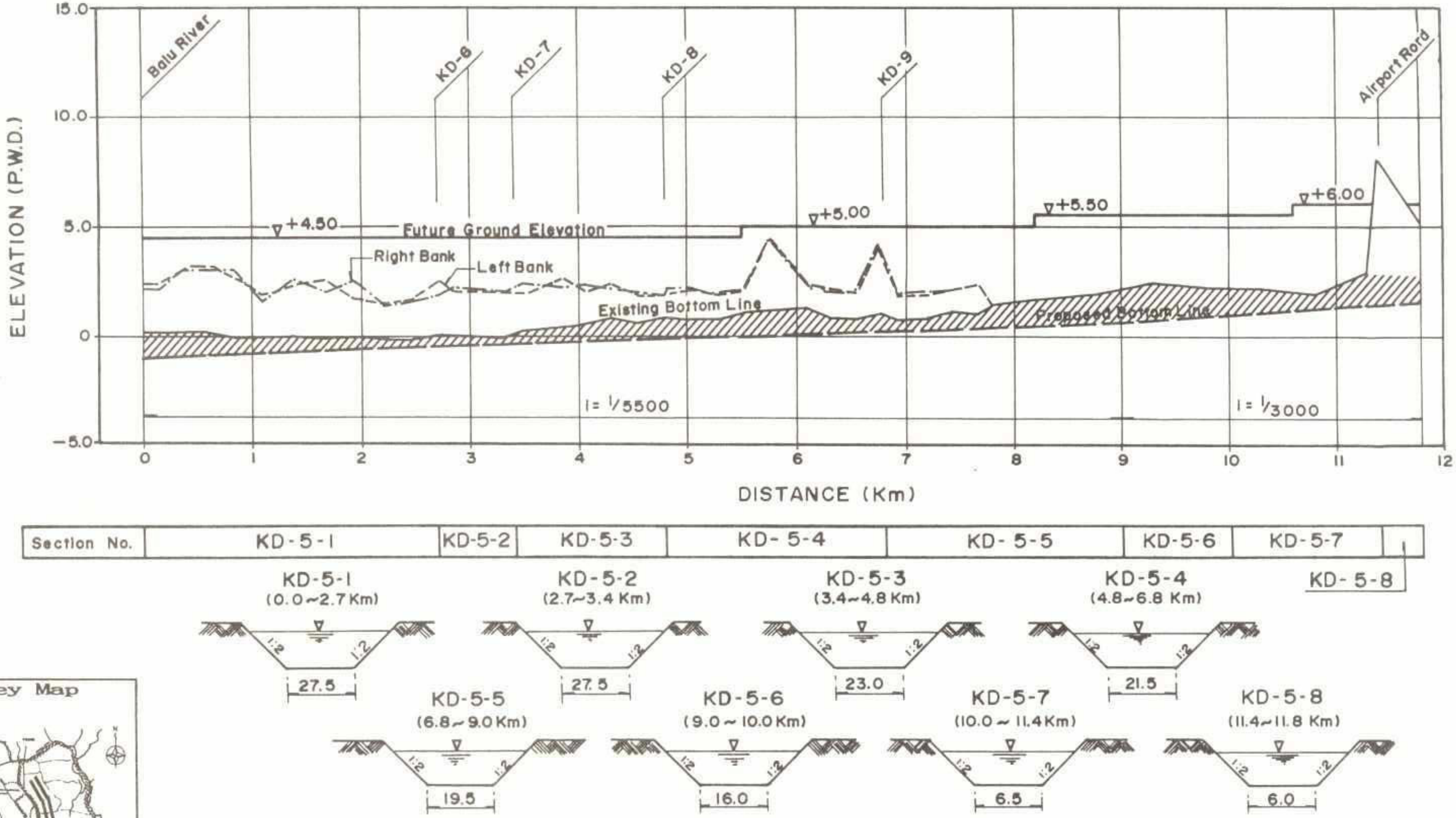
FIG. 6.1.16(1) PROPOSED LONGITUDINAL AND CROSS SECTIONS (KD-1)

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



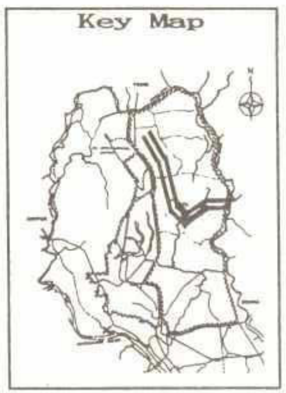
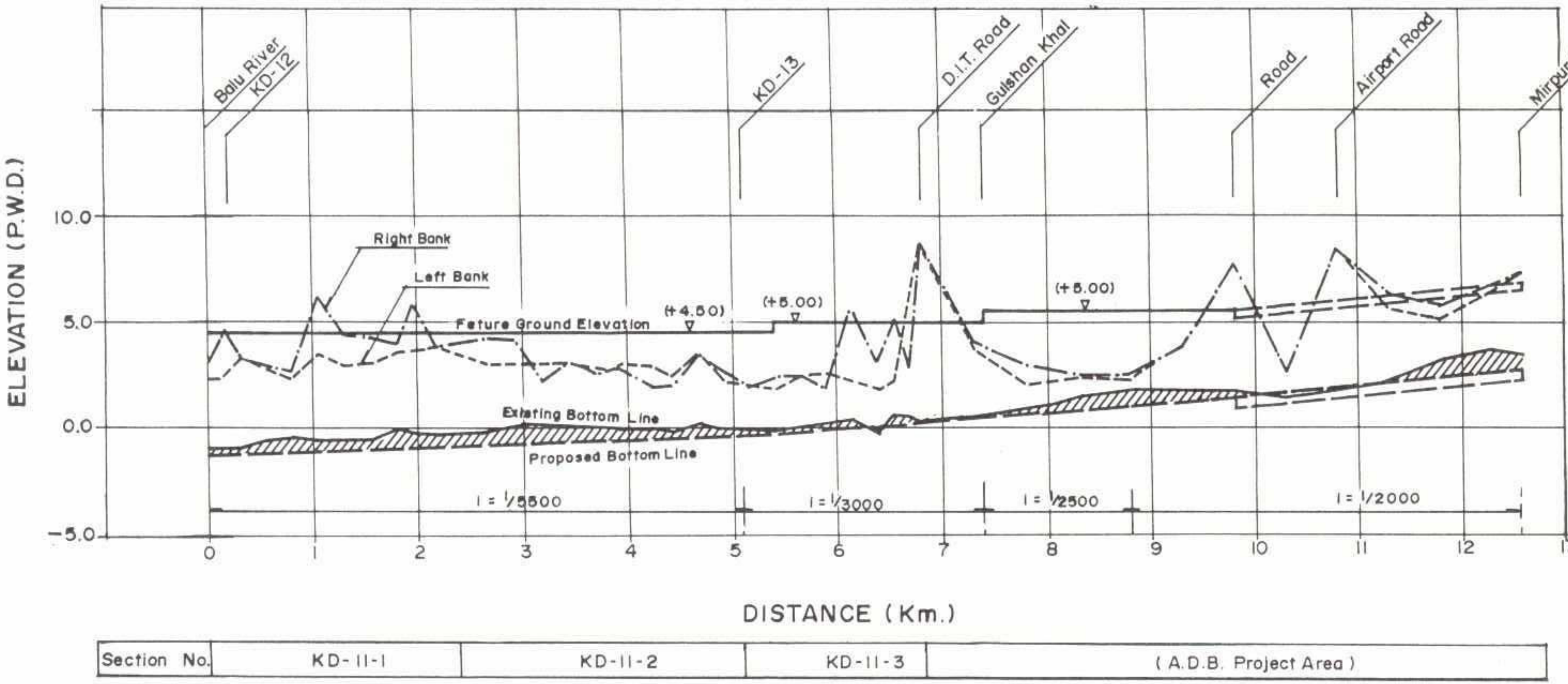
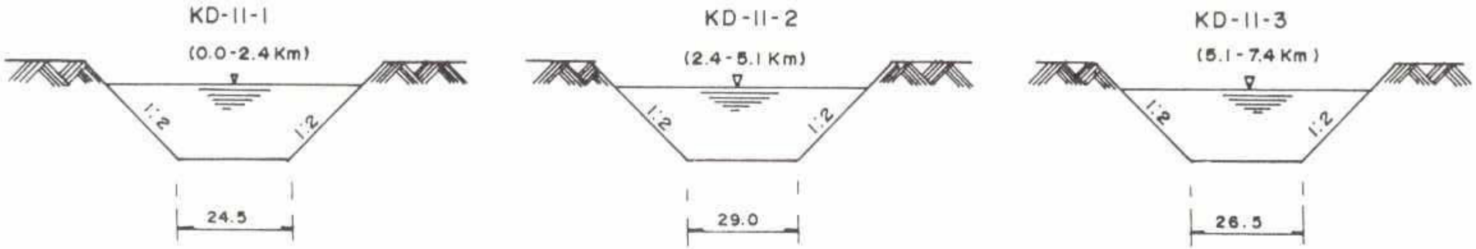


FIG. 6.1.16(2) PROPOSED LONGITUDINAL AND CROSS SECTIONS (KD-5)

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





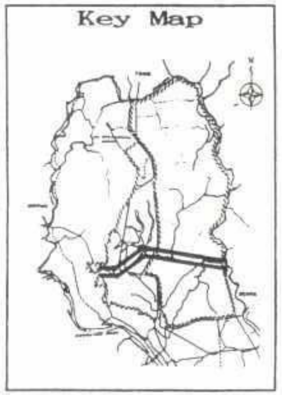
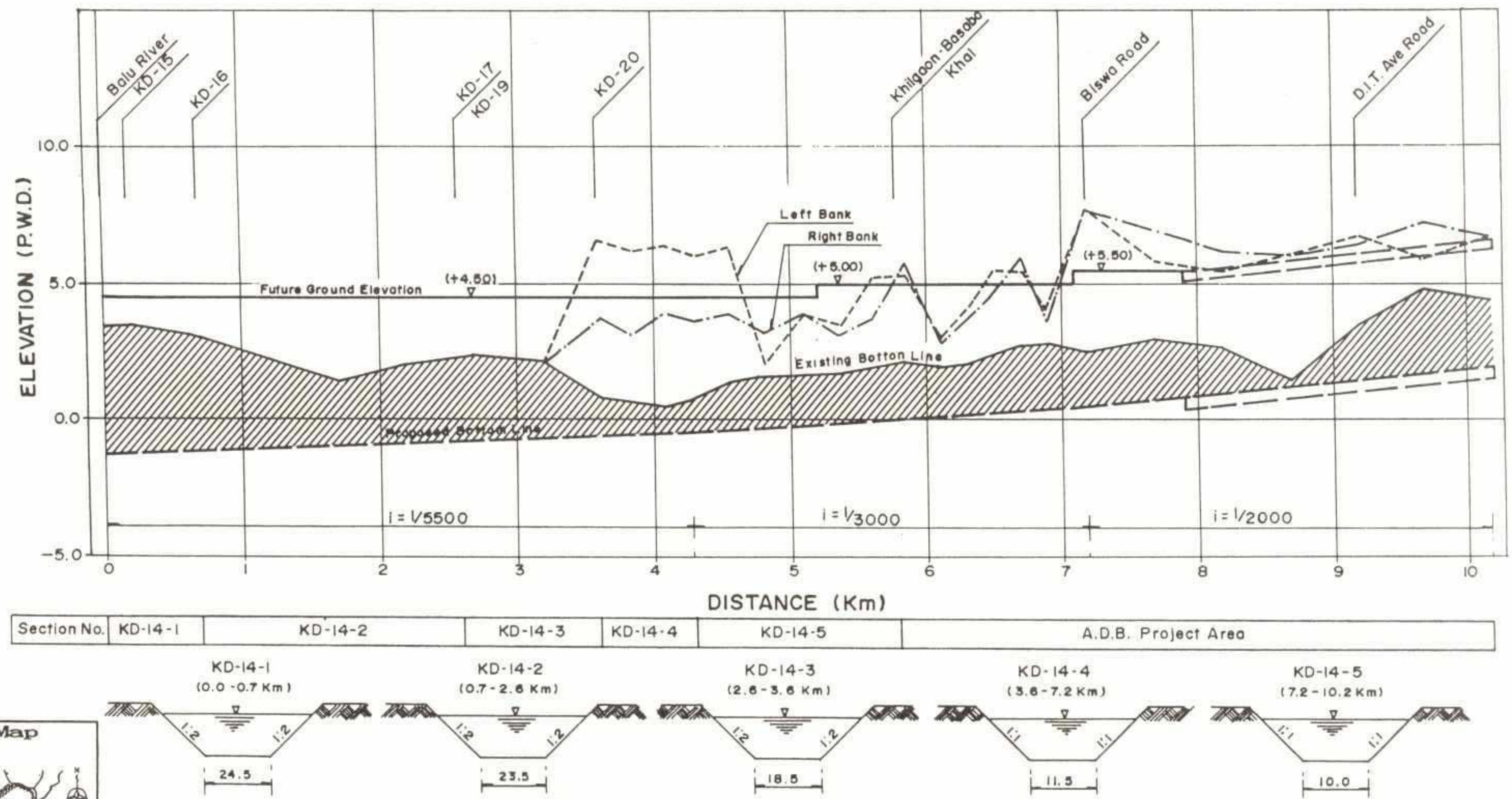


FIG. 6.1.16(3) PROPOSED LONGITUDINAL AND CROSS SECTIONS (KD-11)

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



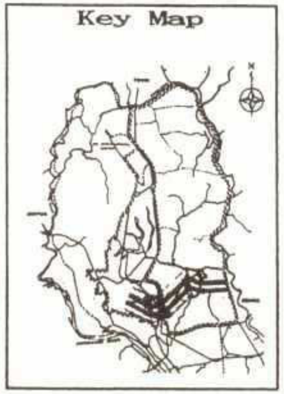
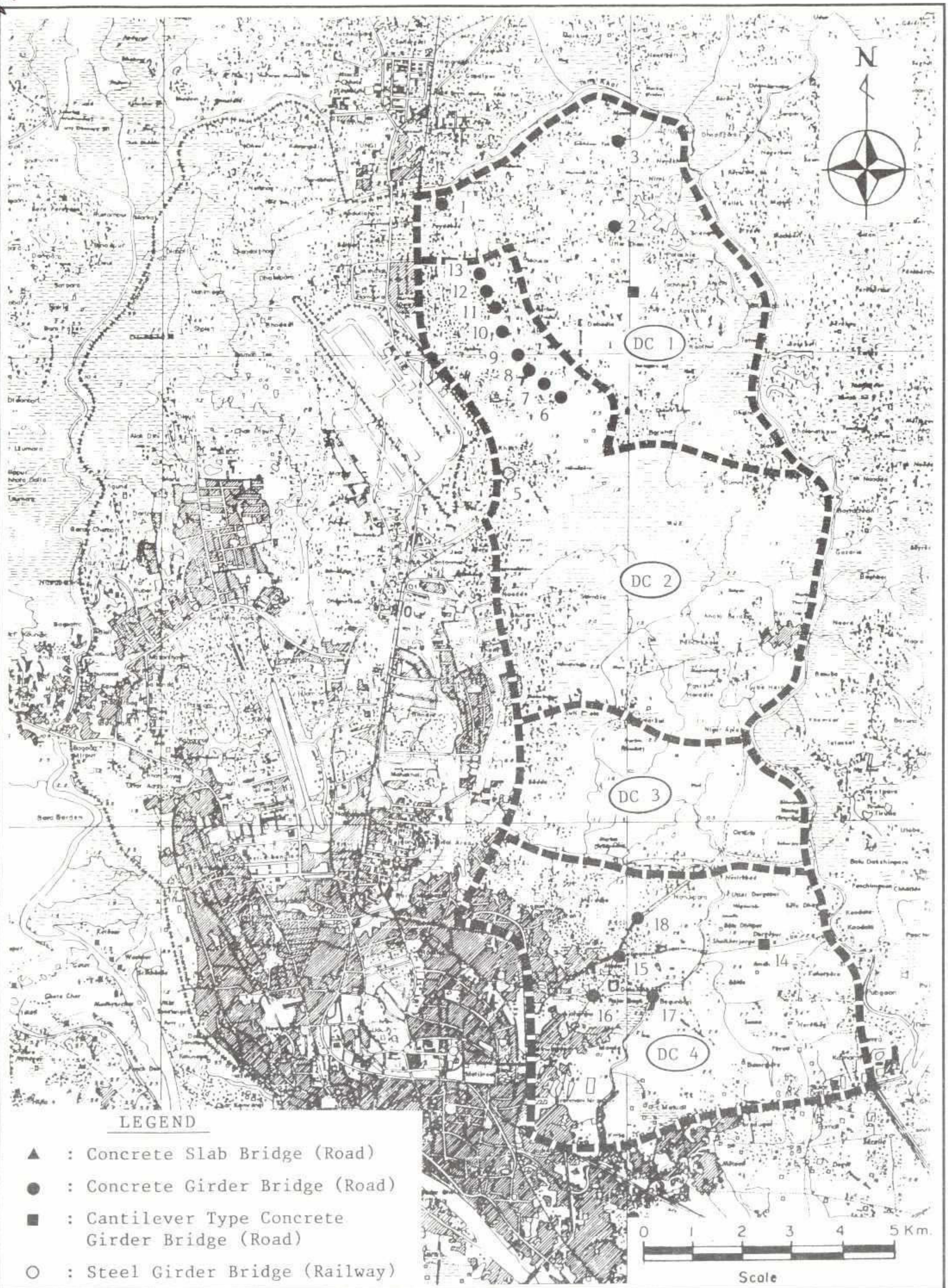


FIG. 6.1.16(4) PROPOSED LONGITUDINAL AND CROSS SECTIONS (KD-14)

69

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

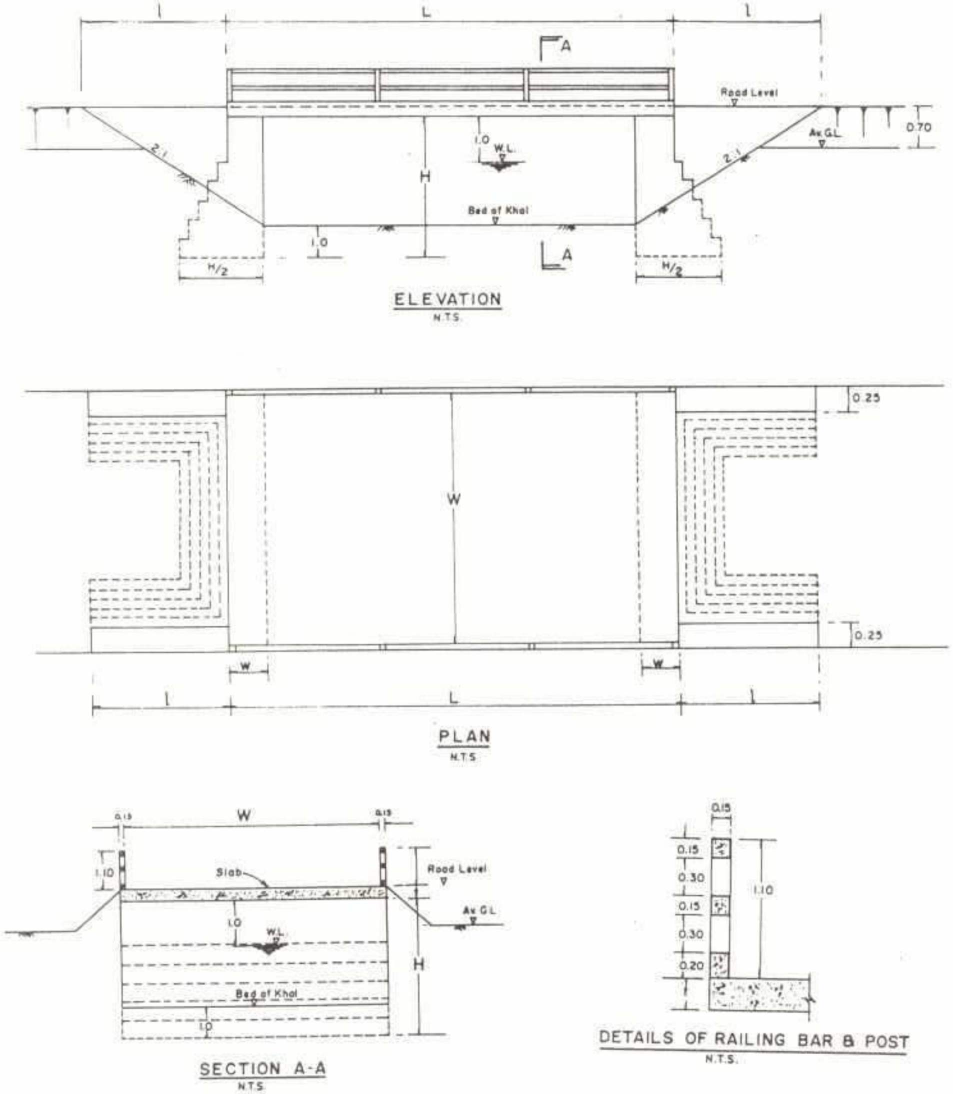


LEGEND

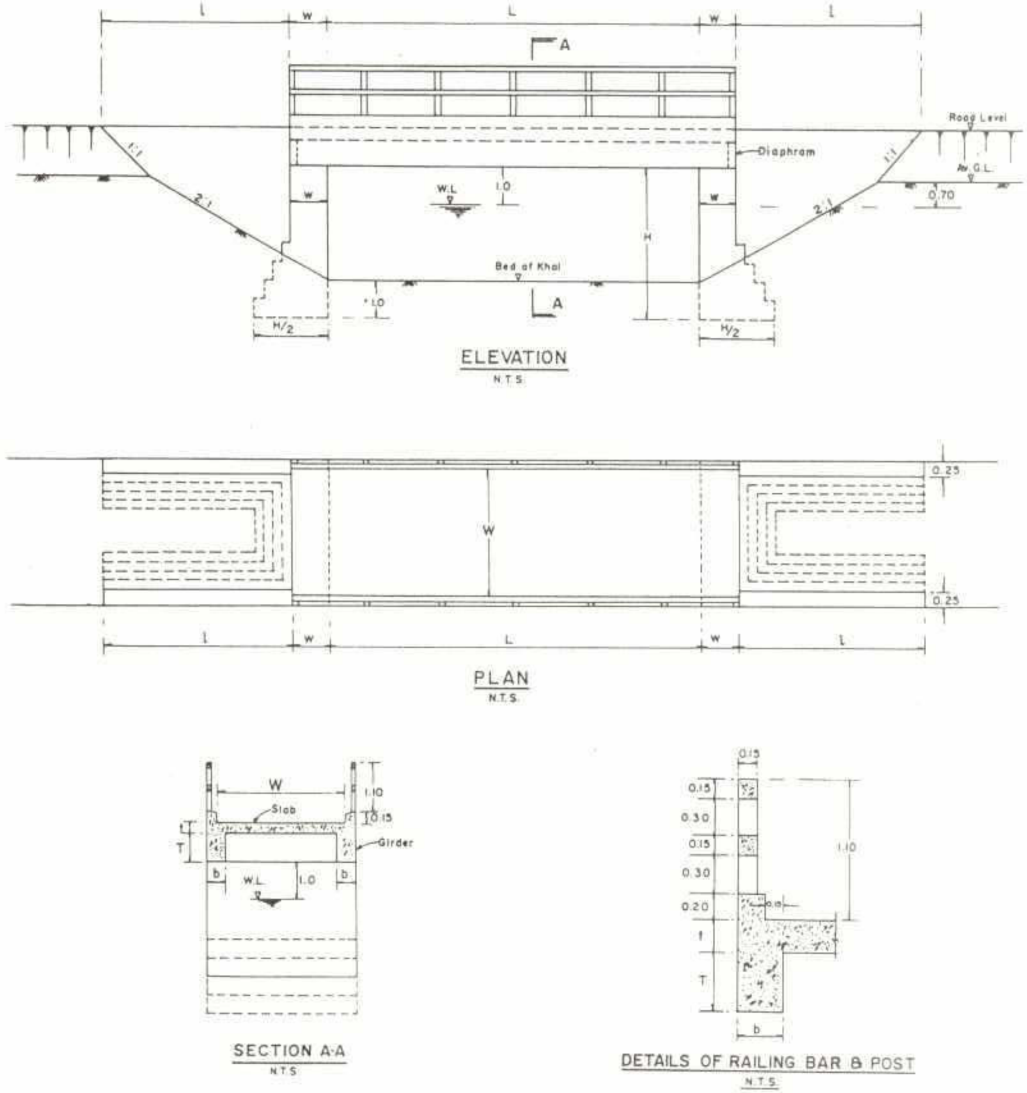
- ▲ : Concrete Slab Bridge (Road)
- ● : Concrete Girder Bridge (Road)
- ■ : Cantilever Type Concrete Girder Bridge (Road)
- ○ : Steel Girder Bridge (Railway)

FIG. 6.1.17 LOCATION OF PROPOSED BRIDGES : GREATER DHAKA EAST

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



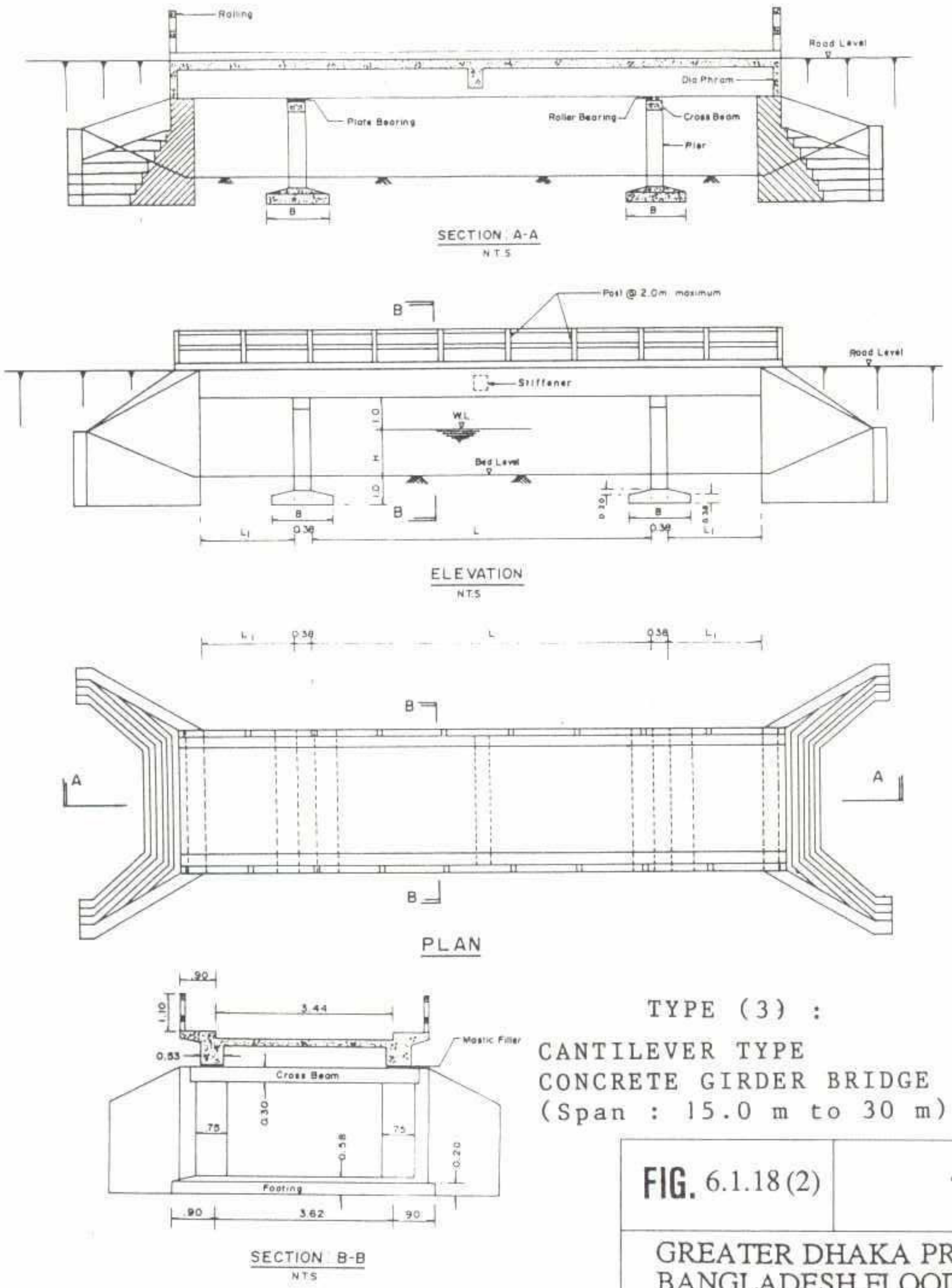
TYPE (1) : CONCRETE SLAB BRIDGE
(Span : Blow 5.0 m)



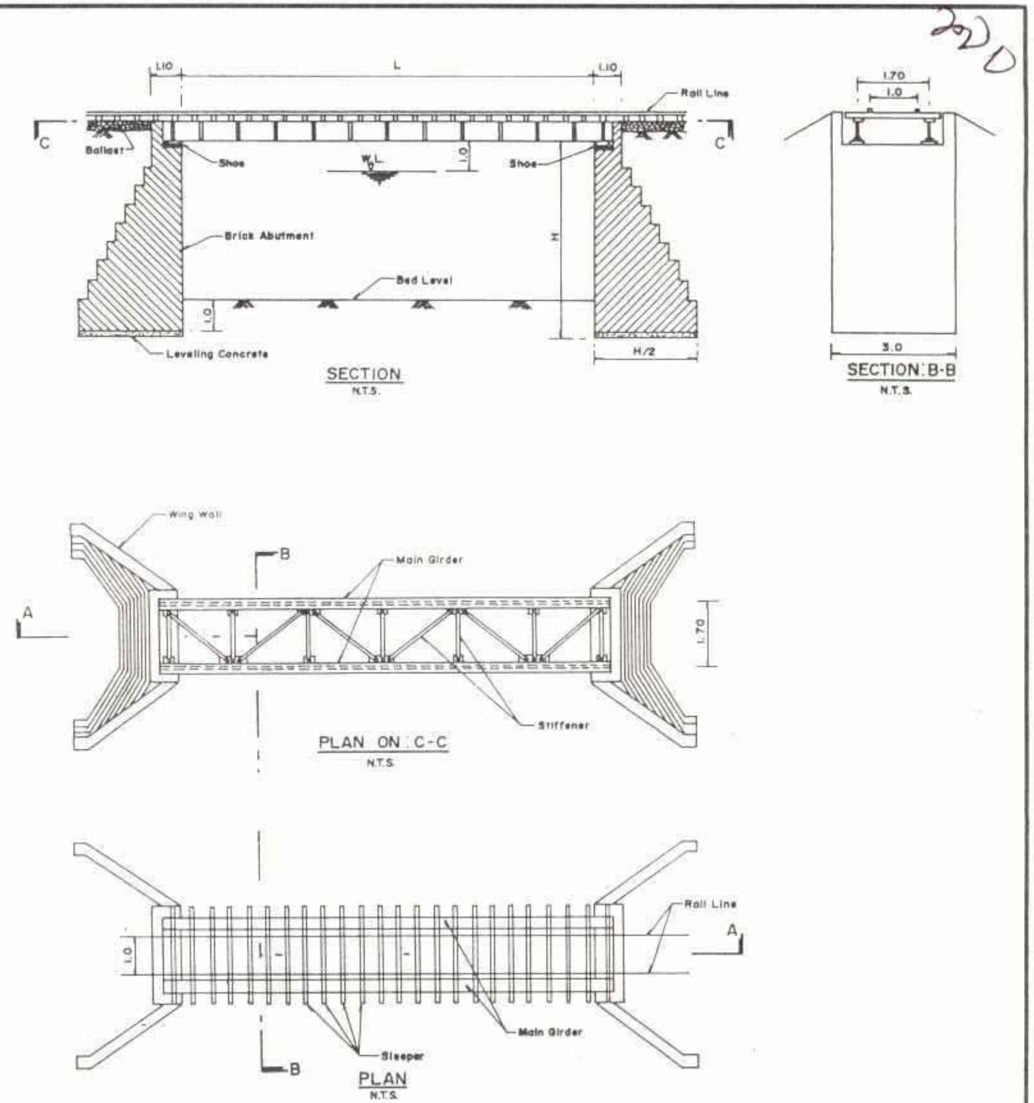
TYPE (2) : CONCRETE GIRDER BRIDGE
(Span : 5.0 m to 15.0 m)

FIG. 6.1.18(1) TYPICAL DESIGN OF PROPOSED BRIDGE (1)

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



TYPE (3) :
CANTILEVER TYPE
CONCRETE GIRDER BRIDGE
(Span : 15.0 m to 30 m)



TYPE (4) : STEEL GIRDER RAILWAY BRIDGE

FIG. 6.1.18 (2)	TYPICAL DESIGN OF PROPOSED BRIDGE (2)

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

TABLE 6.2.1(1) HYDRAULIC REQUIREMENTS OF PROPOSED PUMPING STATION : DND

Proposed Pumping Station	Drainage Zone		Discharge Capacity	Design Water Level (m, PWD)					Static Head (m)		Remarks
	No.	Area (km^2)	(m^3/s)	Outer			Inner		Design	Max.	
				H.H.W.L	H.W.L	L.W.L	H.W.L	L.W.L			
P 10	NA-1	25.10	14.50	---	5.75	3.00	1.80	1.00	4.75	---	Existing Pumping Station
P 11	NA-2	31.69	50.20	7.10	5.65	3.00	4.00	3.00	2.65	4.10	

Note : 1. H.H.W.L. and H.W.L. of outer design water level means that of 100-year and 2-year frequency flood respectively

TABLE 6.2.1(2) HYDRAULIC REQUIREMENTS OF PROPOSED RETARDING POND : DND

Proposed Retarding Pond	Drainage Zone	Pond Area (ha)	Storage Capacity (x $10^6 m^3$)	Design Water Level (m, PWD)		Remarks
				H.W.L	L.W.L	
RP 10-1	NA-1	196	1.96	4.00	3.00	
RP 10-2	NA-1	45	0.45	4.00	3.00	
RP 10-3	NA-1	60	0.60	4.00	3.00	
RP 11-1	NA-2	90	0.90	4.00	3.00	
RP 11-2	NA-2	225	2.25	4.00	3.00	
RP 11-3	NA-2	66	0.66	4.00	3.00	

322

TABLE 6.2.2(1) PROPOSED KHAL IMPROVEMENT WORKS : DND

DND Project Area (NA)

Zone	Khal No.	Khal Length (km)	Required Hydraulic Section Wb x Wu x H (m x m x m)	Open Channel Brick Protection (km)	Open Channel Sodding (km)	Covered Channel Box Culvert (km)	Covered Channel Brick Pipe (km)	Bridge (Places)	Aqueduct (Places)	Dredging (1000m3)	Maintenance Road (km)	Land Acquisition (ha)
NA-1	KN-1-1	2.10	5.5 13.5 4.0	2.10	-	-	-	-	-	22.27	2.10	0.61
	KN-1-2	0.70	14.5 30.5 4.0	-	0.70	-	-	1	-	34.44	0.70	1.72
	KN-1-3	1.00	13.0 29.0 4.0	-	1.00	-	-	1	-	43.02	1.00	2.54
	KN-1-4	0.60	10.0 26.0 4.0	-	0.60	-	-	-	-	11.90	0.60	0.82
	KN-1-5	1.80	10.0 26.0 4.0	-	1.80	-	-	1	-	76.88	1.80	4.83
	KN-1-6	1.40	8.5 24.0 3.9	-	1.40	-	-	1	-	49.86	1.40	3.98
	KN-1-7	1.20	3.5 17.0 3.4	-	1.20	-	-	-	-	29.51	1.20	2.67
	KN-1-8	0.60	2.5 8.8 3.1	0.60	-	-	-	-	-	5.91	0.60	0.22
	KN-2-1	1.60	2.0 17.5 3.9	-	1.60	-	-	3	1	34.36	1.60	3.70
	KN-2-2	1.60	2.5 9.4 3.5	1.60	-	-	-	2	-	21.32	1.60	2.37
	KN-3	1.70	2.0 17.4 3.9	-	1.70	-	-	1	-	16.78	1.70	2.92
	KN-13	1.20	2.0 17.6 3.9	-	1.20	-	-	1	-	39.35	1.20	3.49
	KN-14-1	1.50	6.5 22.0 3.9	-	1.50	-	-	-	-	48.18	1.50	4.92
	KN-14-2	1.50	3.0 18.0 3.8	-	1.50	-	-	-	-	36.30	1.50	4.45
	KN-14-3	1.60	2.0 8.2 3.1	1.60	-	-	-	1	-	27.68	1.60	3.18
	KN-15	1.60	2.0 14.8 3.2	-	1.60	-	-	1	-	11.69	1.60	4.32
	KN-16	2.20	4.0 11.4 3.7	2.20	-	-	-	-	-	43.04	2.20	4.68
	Sub-Total	23.90		8.10	15.80	0.00	0.00	13	1	552.49	23.90	51.42
NA-2	KN-4-1	1.80	33.5 41.8 4.2	1.80	-	-	-	3	-	229.56	1.80	4.37
	KN-4-2	1.30	10.5 27.2 4.2	-	1.30	-	-	-	-	118.68	1.30	4.93
	KN-4-3	1.20	10.5 27.2 4.2	-	1.20	-	-	2	-	61.65	1.20	2.61
	KN-4-4	1.50	5.5 21.7 4.0	-	1.50	-	-	2	-	73.93	1.50	4.16
	KN-4-5	1.80	4.0 11.2 3.6	1.80	-	-	-	4	-	24.91	1.80	1.27
	KN-4-6	0.80	3.5 10.0 3.3	0.80	-	-	-	1	-	20.80	0.80	0.67
	KN-5-1	1.80	22.5 38.7 4.1	-	1.80	-	-	-	-	256.96	1.80	6.03
	KN-5-2	1.00	9.5 17.5 4.0	1.00	-	-	-	-	-	67.23	1.00	2.40
	KN-6	0.90	2.0 17.9 4.0	-	0.90	-	-	-	-	18.44	0.90	1.36
	KN-7-1	2.40	12.0 28.7 4.2	-	2.40	-	-	1	1	196.23	2.40	7.92
	KN-7-2	0.80	12.0 28.7 4.2	-	0.80	-	-	-	-	42.41	0.80	2.52
	KN-7-3	1.20	7.0 15.1 4.1	1.20	-	-	-	-	-	24.82	1.20	1.36
	KN-7-4	1.40	4.5 11.9 3.7	1.40	-	-	-	6	-	34.30	1.40	1.18
	KN-7-5	0.80	2.0 8.8 3.4	0.80	-	-	-	1	-	8.70	0.80	0.58
	KN-8	1.00	2.0 18.4 4.1	-	1.00	-	-	-	-	20.54	1.00	1.65
	KN-9	1.30	2.0 18.3 4.1	-	1.30	-	-	1	-	31.32	1.30	2.20
	KN-10	1.80	2.0 16.3 3.6	-	1.80	-	-	2	-	20.00	1.80	2.43
	KN-11	1.40	2.0 18.2 4.1	-	1.40	-	-	-	-	30.19	1.40	3.14
	KN-12	1.60	2.0 9.3 3.6	1.60	-	-	-	1	-	8.96	1.60	0.76
	KN-17	1.50	2.0 15.8 3.5	-	1.50	-	-	1	-	47.32	1.50	4.18
	Sub-Total	27.30		10.40	16.90	0.00	0.00	25	1	1336.95	27.30	55.72
	Total	51.20		18.50	32.70	0.00	0.00	38	2	1889.44	51.20	107.14

TABLE 6.2.2(2) PROPOSED KHAL IMPROVEMENT RELATED WORKS (BRIDGE AND AQUEDUCT) : DND

Zone	Khal No.	Bridge No.	Existing		Required	Proposed			Remarks
			Type	Size (m x m)	Size (m x m)	Type	Size (m x m)	Width	
NA-1	KN-1-1	1	Girder bridge	12.50 x 5.00	6.65 x 5.00	-	-	-	Road bridge
	"	2	" "	8.40 x 5.00	6.50 x 5.00	-	-	-	" "
	KN-1-2	3	Box culvert	4.70 x 4.70	15.80 x 5.00	Girder bridge	15.8 x 5.00	40.00	Highway bridge
	KN-1-3	4	Girder bridge	11.00 x 3.00	14.75 x 5.00	" "	14.7 x 5.00	3.66	Road bridge
	KN-1-5	5	Box culvert	4.50 x 4.50	12.60 x 5.00	" "	12.6 x 5.00	40.00	Highway bridge
	KN-1-6	6	Slab bridge	4.85 x 2.30	11.32 x 4.90	" "	11.5 x 4.90	3.66	Road bridge
	KN-1-7	7	Deck-Rly.	11.00 x 4.88	6.26 x 4.88	-	-	-	Railway bridge
	"	8	Girder bridge	8.00 x 4.75	6.47 x 4.75	-	-	-	Road bridge
	NA-2-1	9	Aqueduct	4.00 x 0.61	6.68 x 0.61	Rect. Aqueduct	7.00 x 0.61	"	Rect. Aqueduct
	"	10	Pipe	0.91 x 2.00	6.68 x 4.95	Girder bridge	6.70 x 4.95	"	Road bridge
	"	11	Slab	1.09 x 1.57	6.77 x 4.90	" "	6.80 x 4.90	"	" "
	"	12	Pipe	0.91 x 1.00	6.77 x 4.90	" "	6.80 x 4.90	"	" "
	"	13	Slab	91.00 x 1.35	3.71 x 4.87	Slab bridge	3.80 x 4.87	"	" "
	KN-2-2	14	Pipe	0.91 x 1.00	3.94 x 4.65	" "	4.00 x 4.65	"	" "
	KN-3	15	-	-	6.73 x 4.90	Girder bridge	6.80 x 4.90	"	" "
	KN-13	16	-	-	6.69 x 5.00	" "	6.70 x 5.00	"	" "
	KN-14-3	17	-	-	2.96 x 4.70	Slab bridge	3.00 x 4.70	7.00	" "
	KN-15	18	-	-	4.92 x 4.80	" "	5.00 x 4.80	3.66	" "
NA-2	KN-4-1	19	Deck Rly.	18.3 x 7.00	26.18 x 5.20	Deck Girder	26.10 x 5.20	1.70	Railway bridge
	"	20	Pipe	0.45 x 2.00	29.18 x 5.20	Cantilever	26.10 x 5.20	3.66	Road bridge
	"	21	"	0.91 x 1.00	26.18 x 5.20	Deck Girder	26.10 x 5.20	1.70	Railway bridge
	KN-4-3	22	"	0.91 x 1.00	13.19 x 5.17	Girder bridge	13.20 x 5.20	3.66	Road bridge
	"	23	"	0.61 x 1.00	13.19 x 5.17	" "	13.20 x 5.20	"	" "
	KN-4-4	24	Girder bridge	5.50 x 3.70	9.37 x 5.10	" "	9.40 x 5.10	"	" "
	"	25	Arch bridge	4.50 x 4.85	9.50 x 5.04	" "	9.50 x 5.00	"	" "
	KN-4-5	26	Pipe	0.91 x 1.00	4.95 x 4.85	Slab bridge	5.00 x 4.90	"	" "
	"	27	"	"	5.02 x 4.80	girder bridge	5.10 x 4.80	"	" "
	"	28	"	"	5.09 x 4.75	" "	5.10 x 4.80	"	" "
	"	29	"	"	5.15 x 4.70	" "	5.20 x 4.70	"	" "
	KN-4-6	30	Box culvert	0.70 x 0.80	4.40 x 4.59	Deck Girder	4.40 x 4.60	1.70	Railway bridge
	KN-5-2	31	Girder bridge	13.00 x 5.00	13.30 x 5.00	-	-		Road bridge
	KN-6	32	" "	10.80 x 5.10	6.85 x 5.10	-	-		" "
	"	33	" "	7.00 x 5.20	6.85 x 5.20	-	-		" "
	"	34	" "	10.70 x 5.15	6.85 x 5.15	-	-		" "
	KN-7-1	35	Aqueduct	3.60 x 1.80	14.24 x 1.37	Rect. aqueduct	15.00 x 1.37	0.91	Rect. Aqueduct
	"	36	Slab bridge	2.40 x 2.50	14.24 x 5.17	Girder bridge	14.30 x 5.17	3.66	Road bridge
	KN-7-4	37	Pipe	0.91 x 2.00	5.26 x 5.07	" "	5.30 x 5.07	"	" "
	"	38	Slab bridge	0.95 x 1.65	5.28 x 5.05	" "	5.30 x 5.05	"	" "
	"	39	Pipe	0.61 x 1.00	5.35 x 5.00	" "	5.35 x 5.00	"	" "
	"	40	-	-	5.42 x 4.95	" "	5.45 x 4.95	"	" "
	"	41	Pipe	0.91 x 1.00	5.49 x 4.90	" "	5.50 x 4.90	"	" "
	"	42	Slab bridge	2.30 x 2.00	5.56 x 4.85	" "	5.56 x 4.85	"	" "
	KN-7-5	43	Pipe	0.45 x 1.00	3.47 x 4.72	Deck Girder	3.50 x 4.72	1.70	Railway bridge
	KN-9	44	Slab bridge	3.00 x 1.90	7.05 x 5.10	Girder	7.00 x 5.10	3.66	Road bridge
	"	45	Girder bridge	10.40 x 5.00	7.05 x 5.10	-	-	-	" "
	KN-10	46	Pipe	0.45 x 1.00	6.26 x 4.65	Girder bridge	6.30 x 4.60	3.66	" "
	"	47	"	0.45 x 2.00	6.26 x 4.65	" "	6.30 x 4.65	"	" "
	KN-12	48	Slab bridge	1.70 x 2.25	3.59 x 5.00	Slab bridge	3.60 x 5.00	"	" "
	KN-17	49	-	-	6.14 x 4.50	Girder bridge	6.20 x 4.50	"	" "

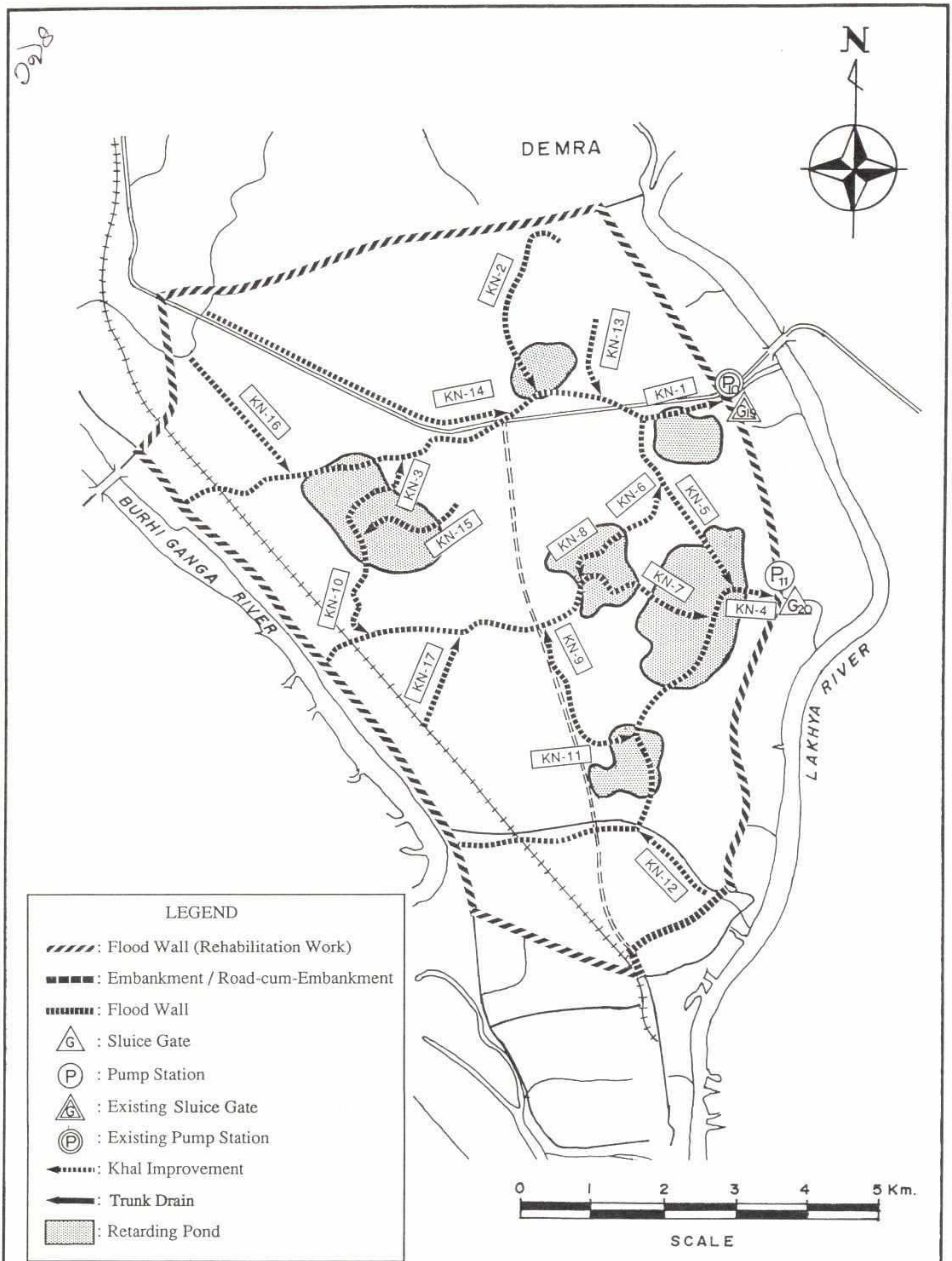
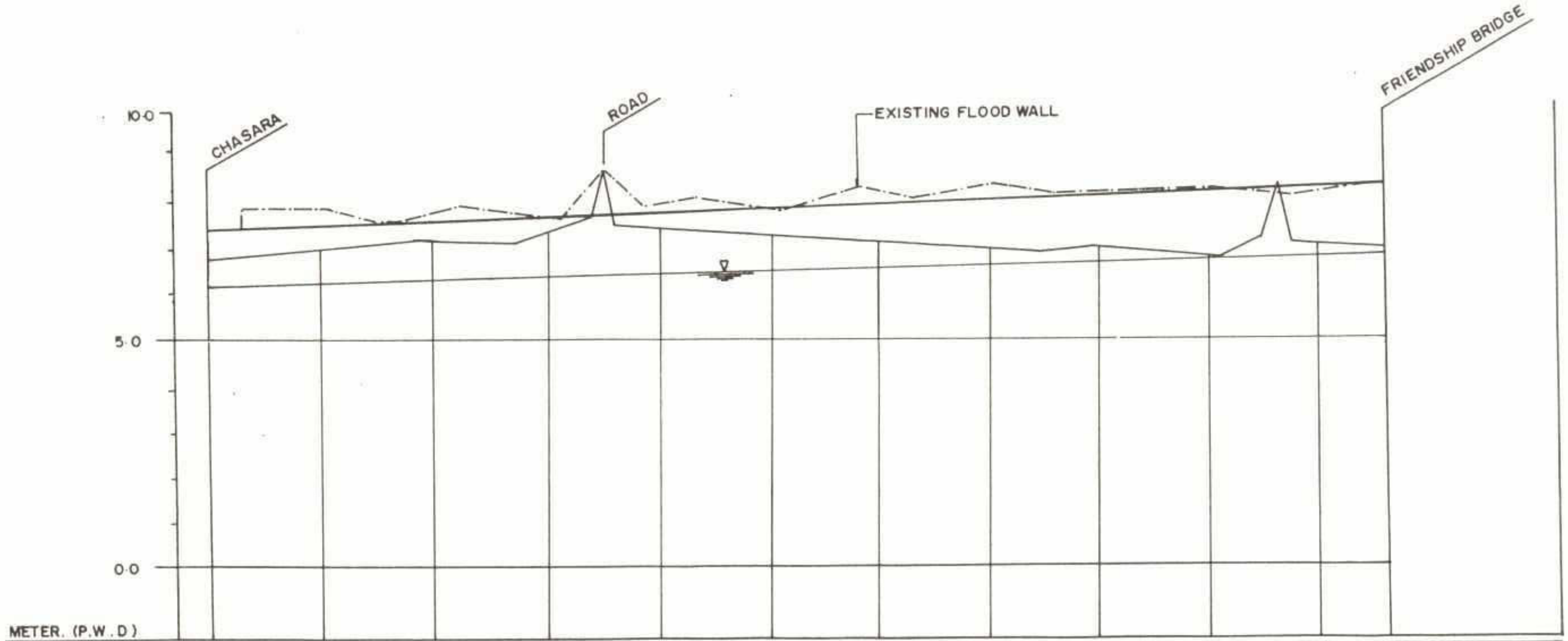


FIG. 6.2.1 PROPOSED FACILITIES : DND

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



GRADIENT		1=1/10,420			1=1/13,540								
DESIGNED	TOP OF FLOOD WALL	7.56	7.65	7.75	7.84	7.91	7.98	8.06	8.13	8.20	8.28	8.35	8.40
DESIGNED	H. W. L.	6.96	7.06	7.15	7.24	7.31	7.38	7.46	7.53	7.60	7.68	7.75	7.80
ACCUMULATED DISTANCE (KM)		0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	10.63

FIG. 6.2.2 (1) LONGITUDINAL SECTION OF FLOOD WALL : DND (DW)

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

2203

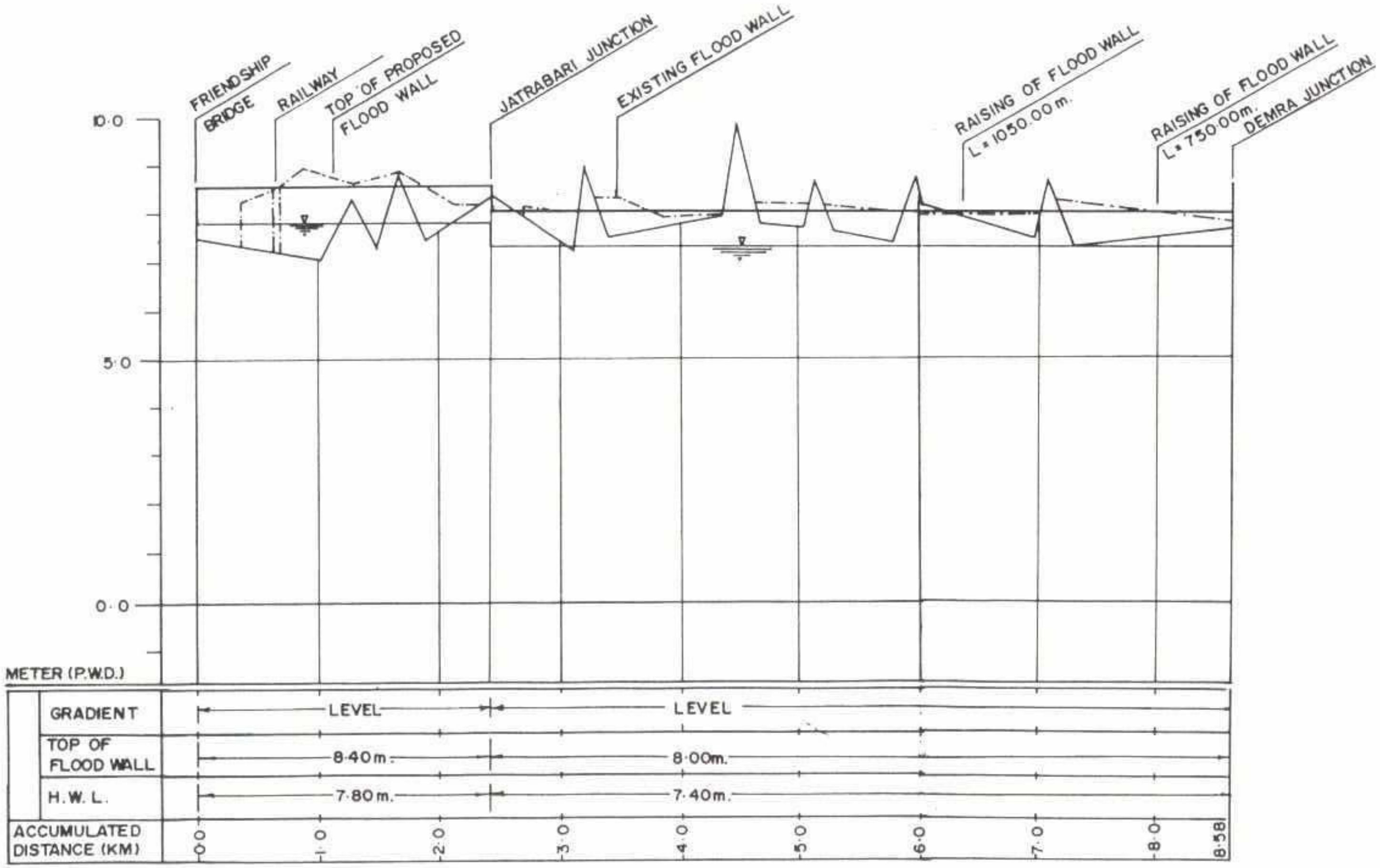


FIG. 6.2.2 (2)	LONGITUDINAL SECTION OF FLOOD WALL : DND (DN)

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

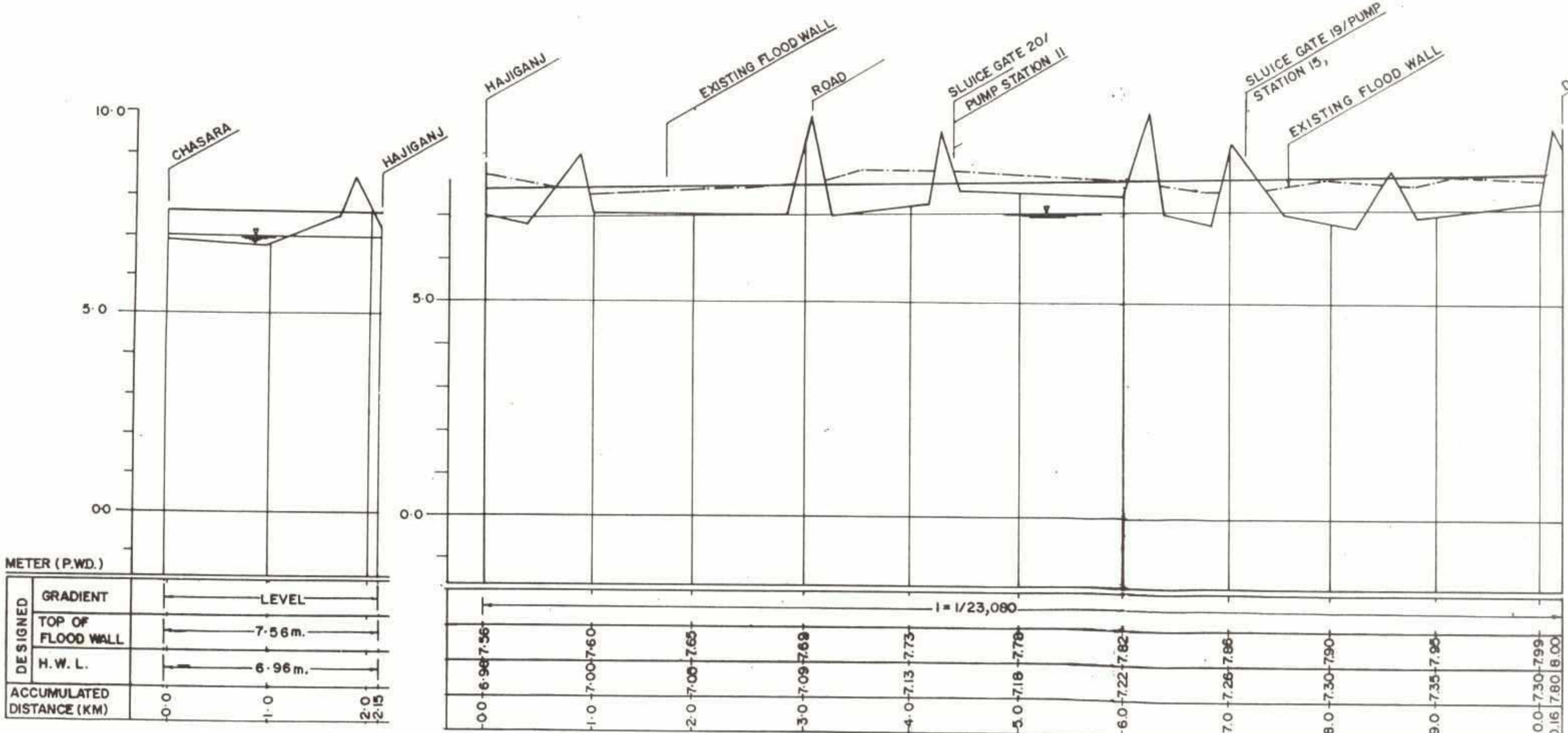
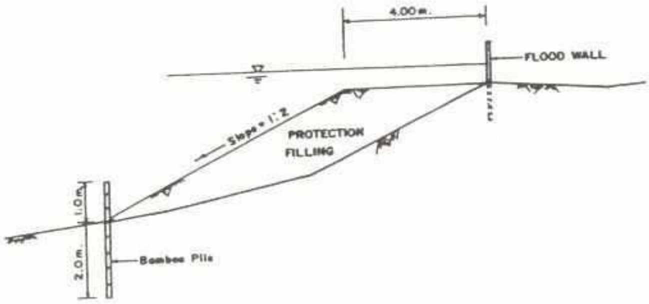
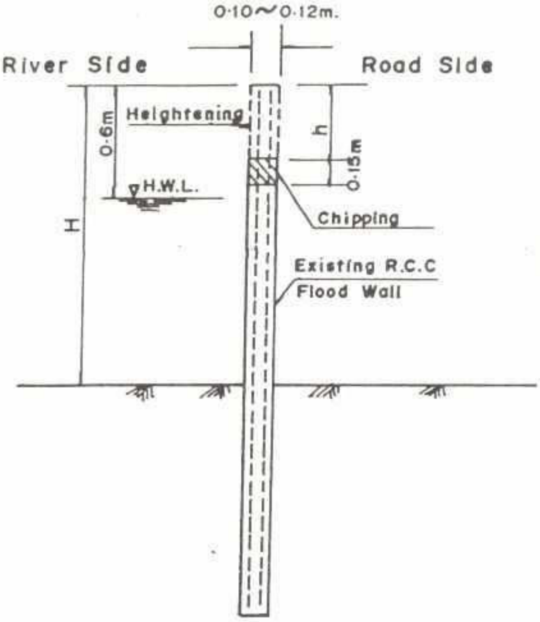
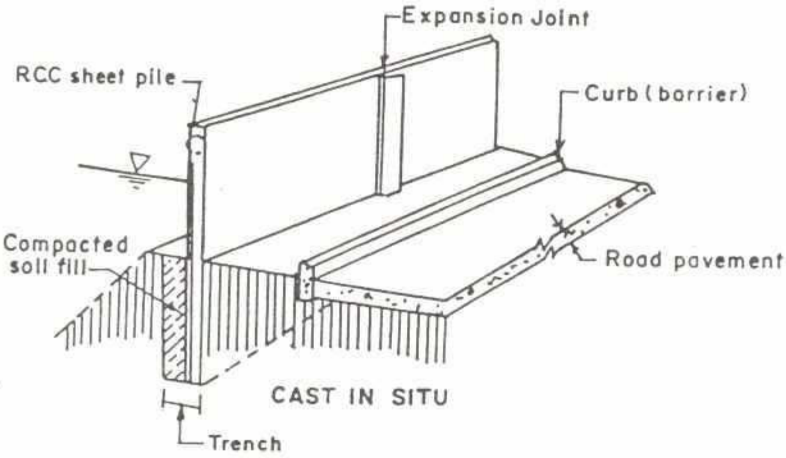


FIG. 6.2.2 (3) LONGITUDINAL SECTION OF FLOOD WALL : DND (DS AND DE)

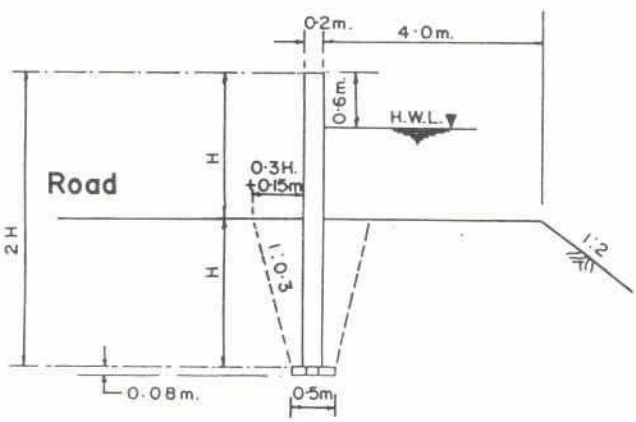
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH







TYPICAL SECTION OF FLOOD WALL



TYPICAL SECTION OF FLOOD WALL

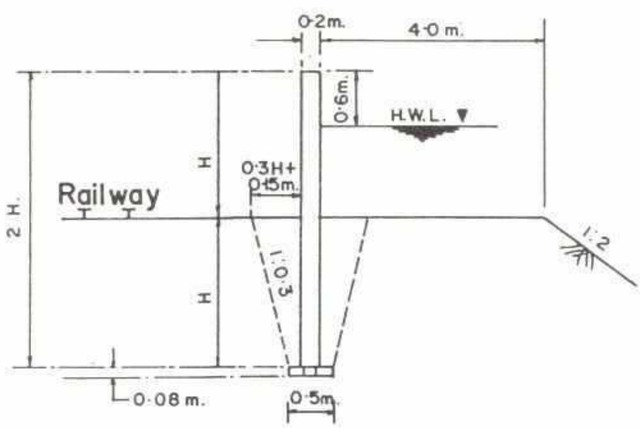
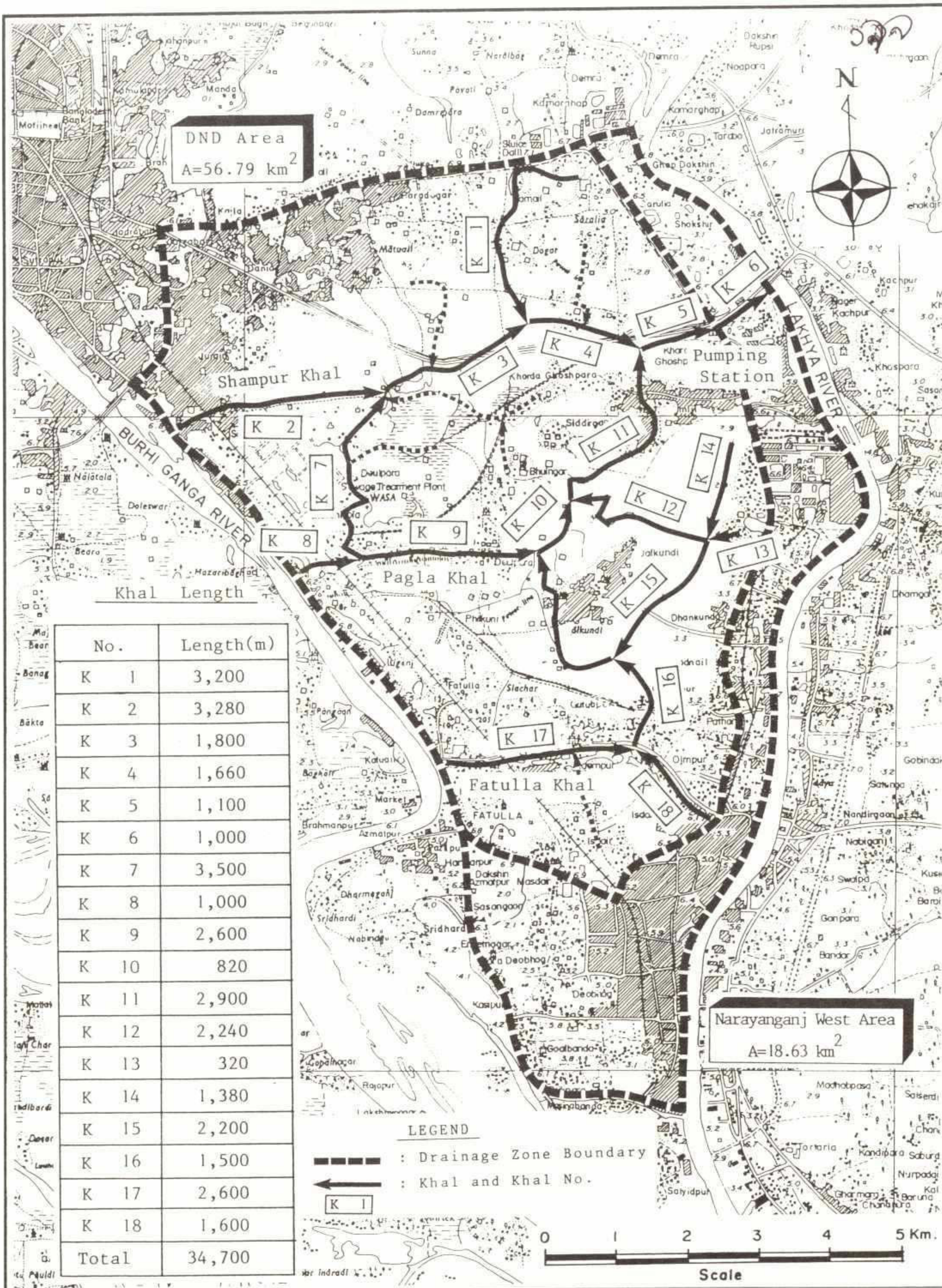


FIG. 6.2.3 TYPICAL SECTIONS OF FLOOD WALL REHABILITATION WORKS



Khal Length

No.	Length(m)
K 1	3,200
K 2	3,280
K 3	1,800
K 4	1,660
K 5	1,100
K 6	1,000
K 7	3,500
K 8	1,000
K 9	2,600
K 10	820
K 11	2,900
K 12	2,240
K 13	320
K 14	1,380
K 15	2,200
K 16	1,500
K 17	2,600
K 18	1,600
Total	34,700

FIG. 6.2.4 EXISTING MAJOR KHALS : DND

208

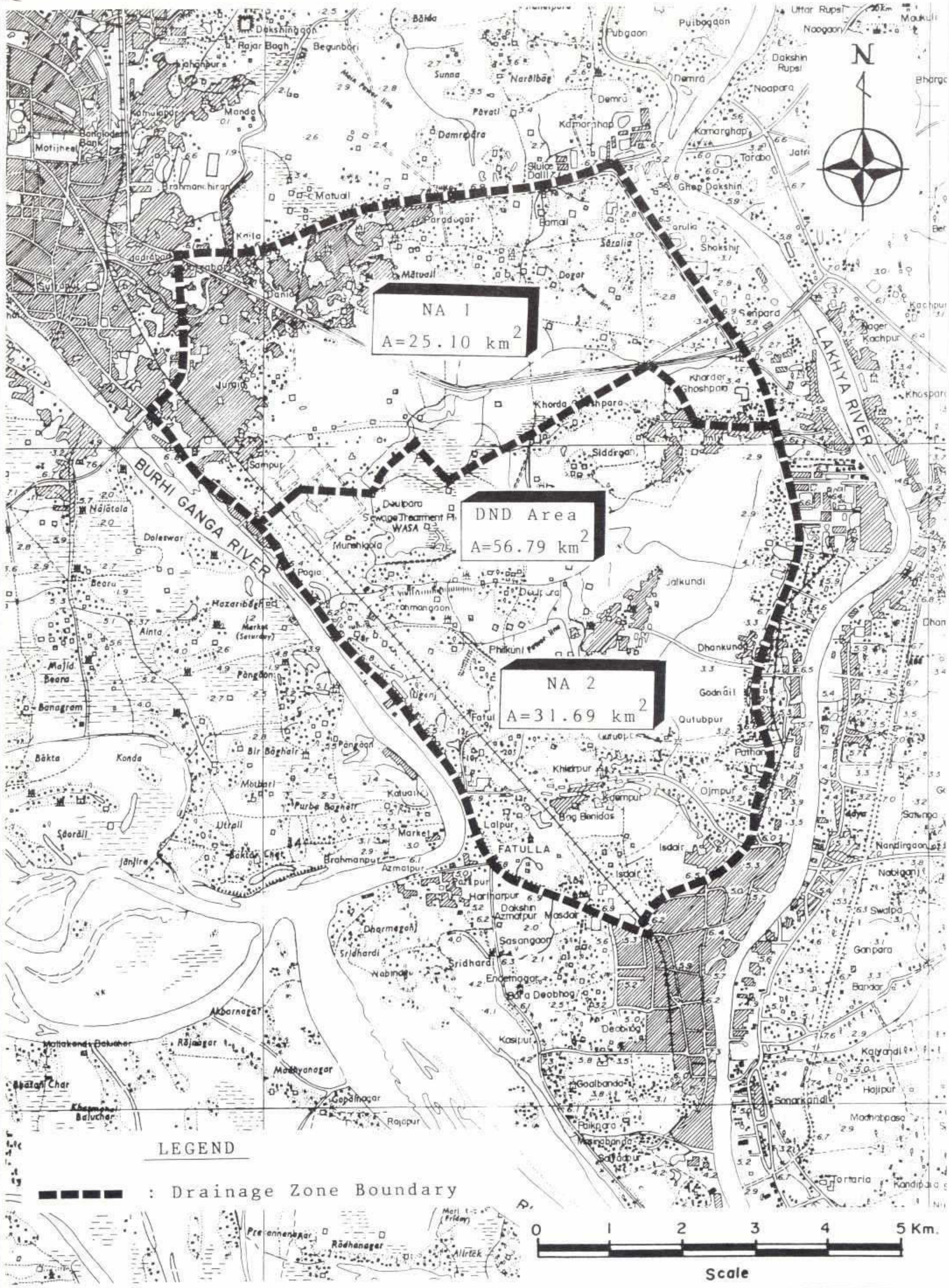


FIG. 6.2.5 DRAINAGE ZONE : DND

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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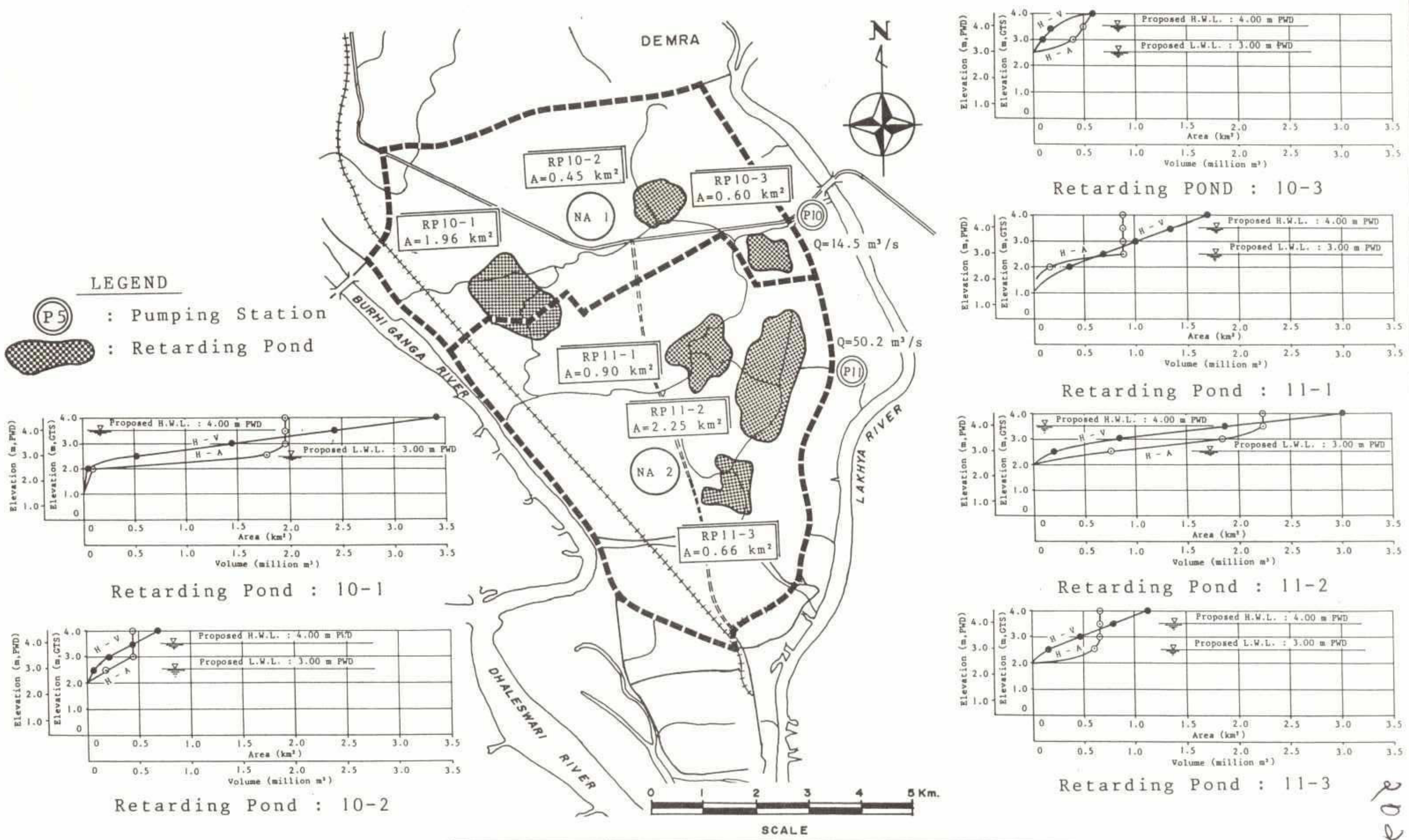
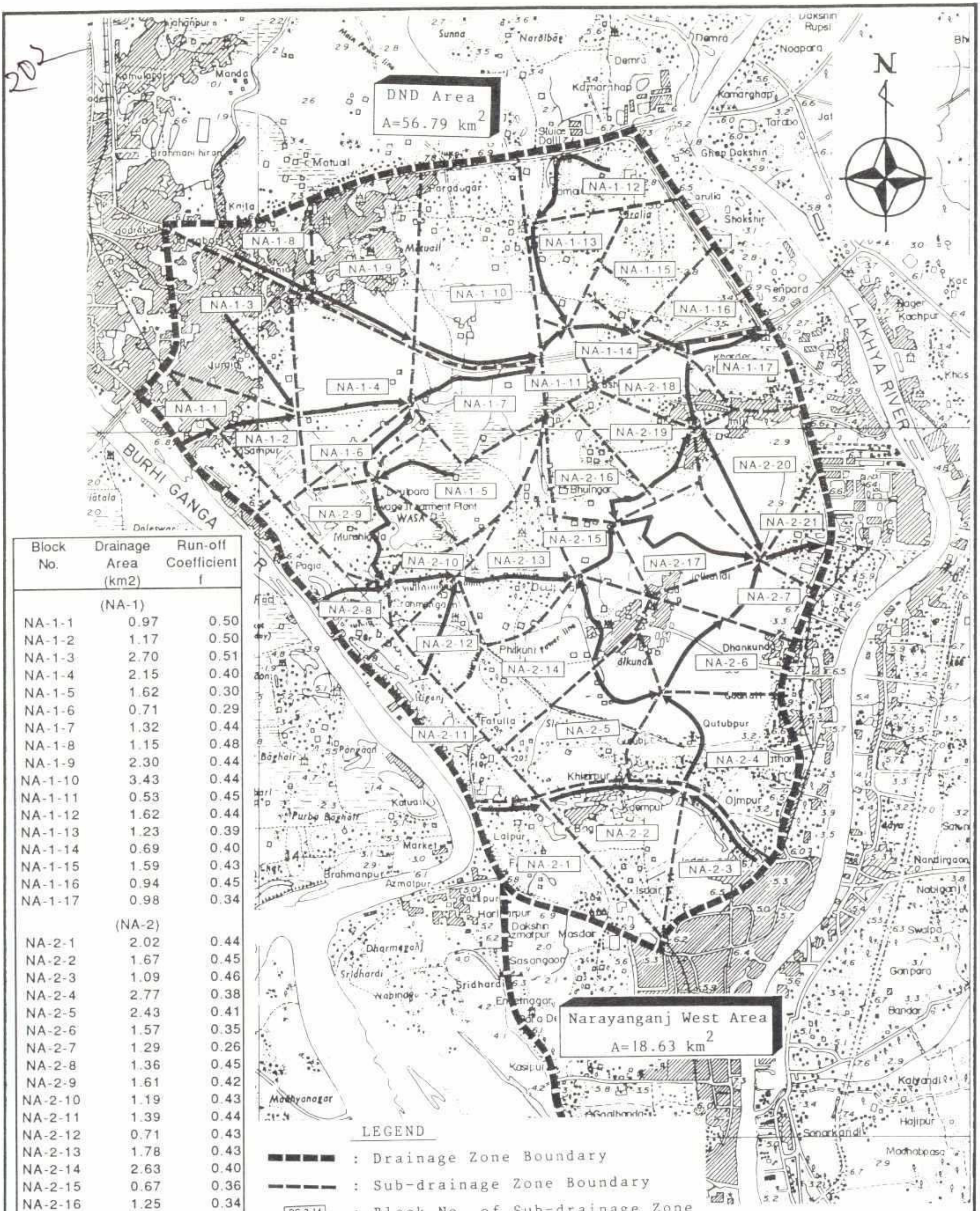


202

FIG. 6.2.6 PROPOSED REQUIREMENTS OF PUMP STATION AND RETARDING POND : DND

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

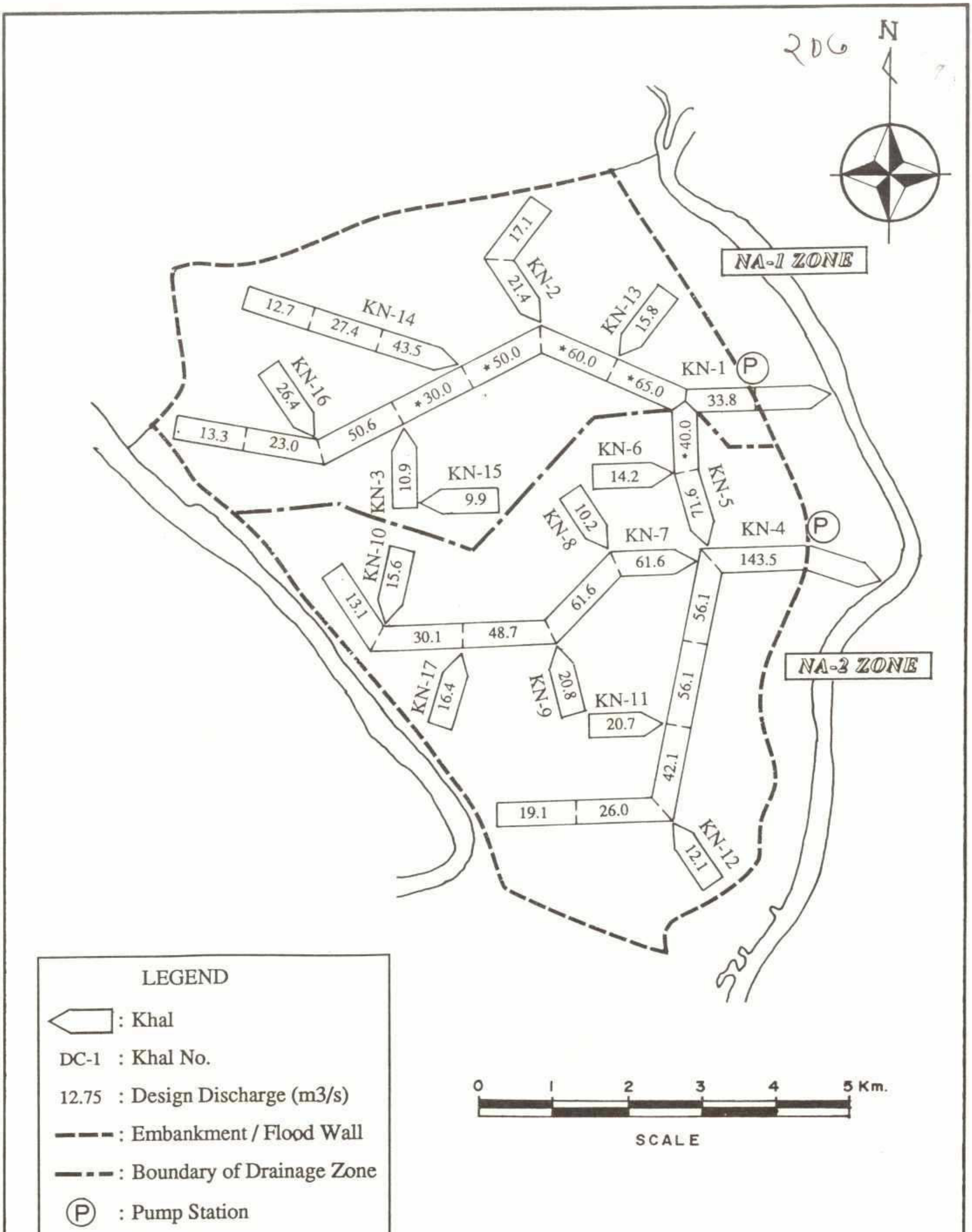
202



Block No.	Drainage Area (km2)	Run-off Coefficient f
(NA-1)		
NA-1-1	0.97	0.50
NA-1-2	1.17	0.50
NA-1-3	2.70	0.51
NA-1-4	2.15	0.40
NA-1-5	1.62	0.30
NA-1-6	0.71	0.29
NA-1-7	1.32	0.44
NA-1-8	1.15	0.48
NA-1-9	2.30	0.44
NA-1-10	3.43	0.44
NA-1-11	0.53	0.45
NA-1-12	1.62	0.44
NA-1-13	1.23	0.39
NA-1-14	0.69	0.40
NA-1-15	1.59	0.43
NA-1-16	0.94	0.45
NA-1-17	0.98	0.34
(NA-2)		
NA-2-1	2.02	0.44
NA-2-2	1.67	0.45
NA-2-3	1.09	0.46
NA-2-4	2.77	0.38
NA-2-5	2.43	0.41
NA-2-6	1.57	0.35
NA-2-7	1.29	0.26
NA-2-8	1.36	0.45
NA-2-9	1.61	0.42
NA-2-10	1.19	0.43
NA-2-11	1.39	0.44
NA-2-12	0.71	0.43
NA-2-13	1.78	0.43
NA-2-14	2.63	0.40
NA-2-15	0.67	0.36
NA-2-16	1.25	0.34
NA-2-17	1.56	0.28
NA-2-18	0.90	0.41
NA-2-19	1.51	0.44
NA-2-20	1.76	0.41
NA-2-21	0.53	0.45

FIG. 6.2.7 SUB-DRAINAGE ZONE AND THEIR RUN-OFF COEFFICIENT : DND

206



Note: The figures with (*) indicate the design discharge estimated in hydraulic simulation by Mike 11 model.

FIG. 6.2.8 DESIGN DISCHARGE FOR KHAL IMPROVEMENT PLAN : DND

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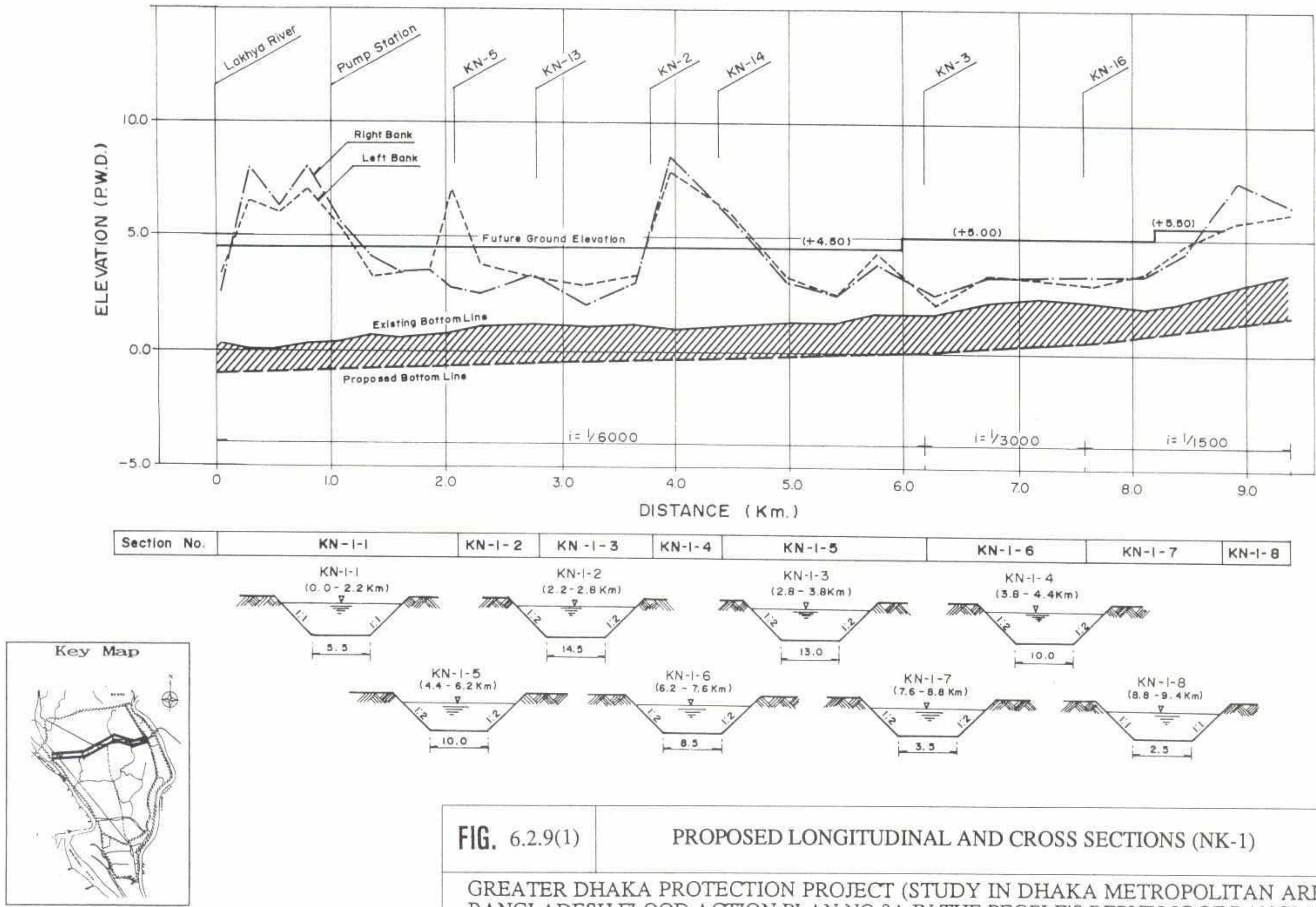
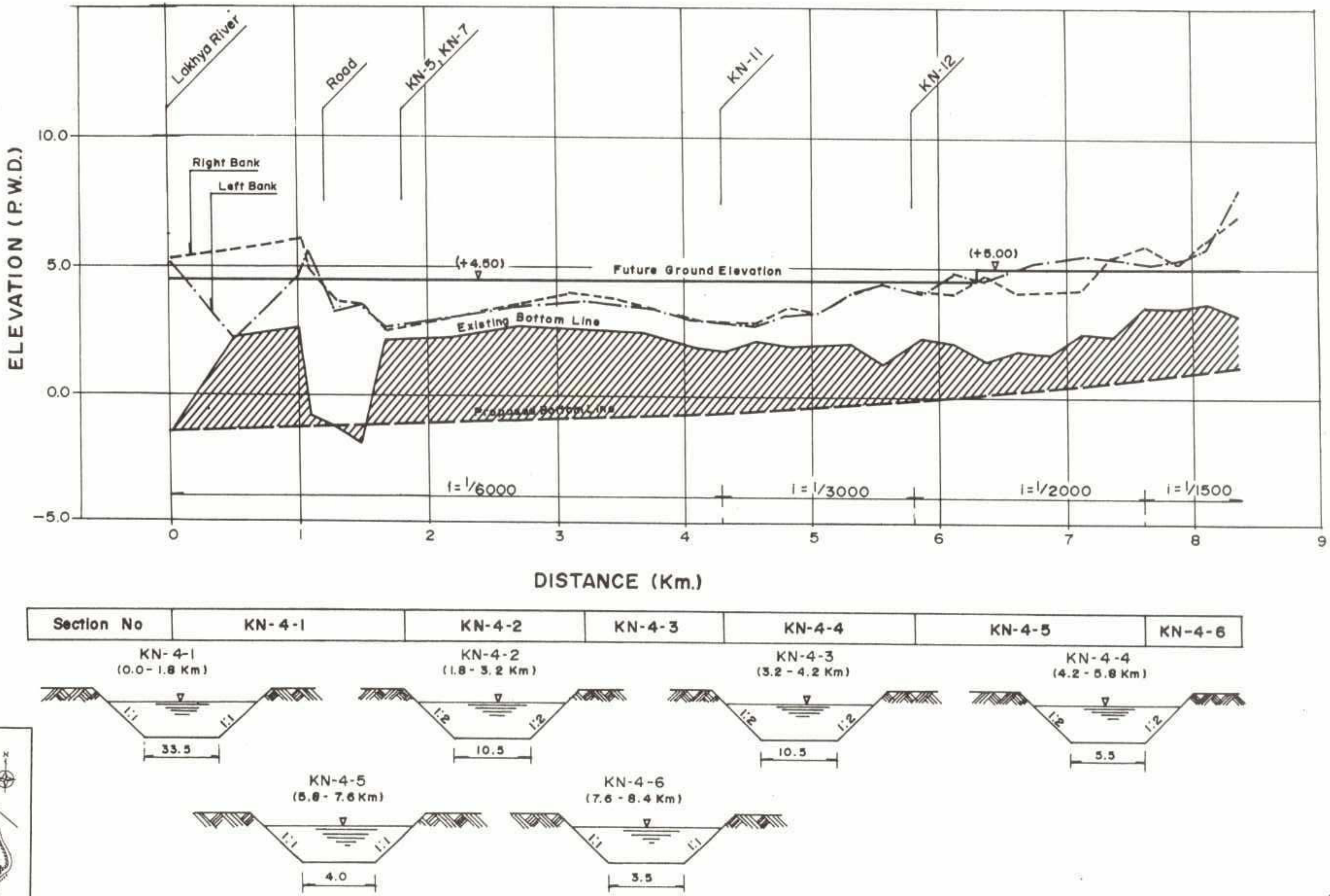


FIG. 6.2.9(1) PROPOSED LONGITUDINAL AND CROSS SECTIONS (NK-1)

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



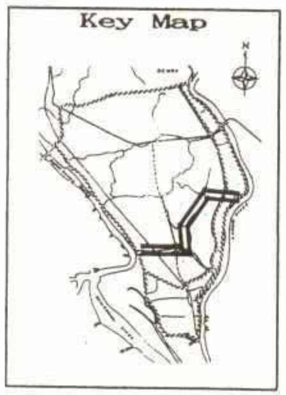


FIG. 6.2.9(2) PROPOSED LONGITUDINAL AND CROSS SECTIONS (NK-4)

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

204

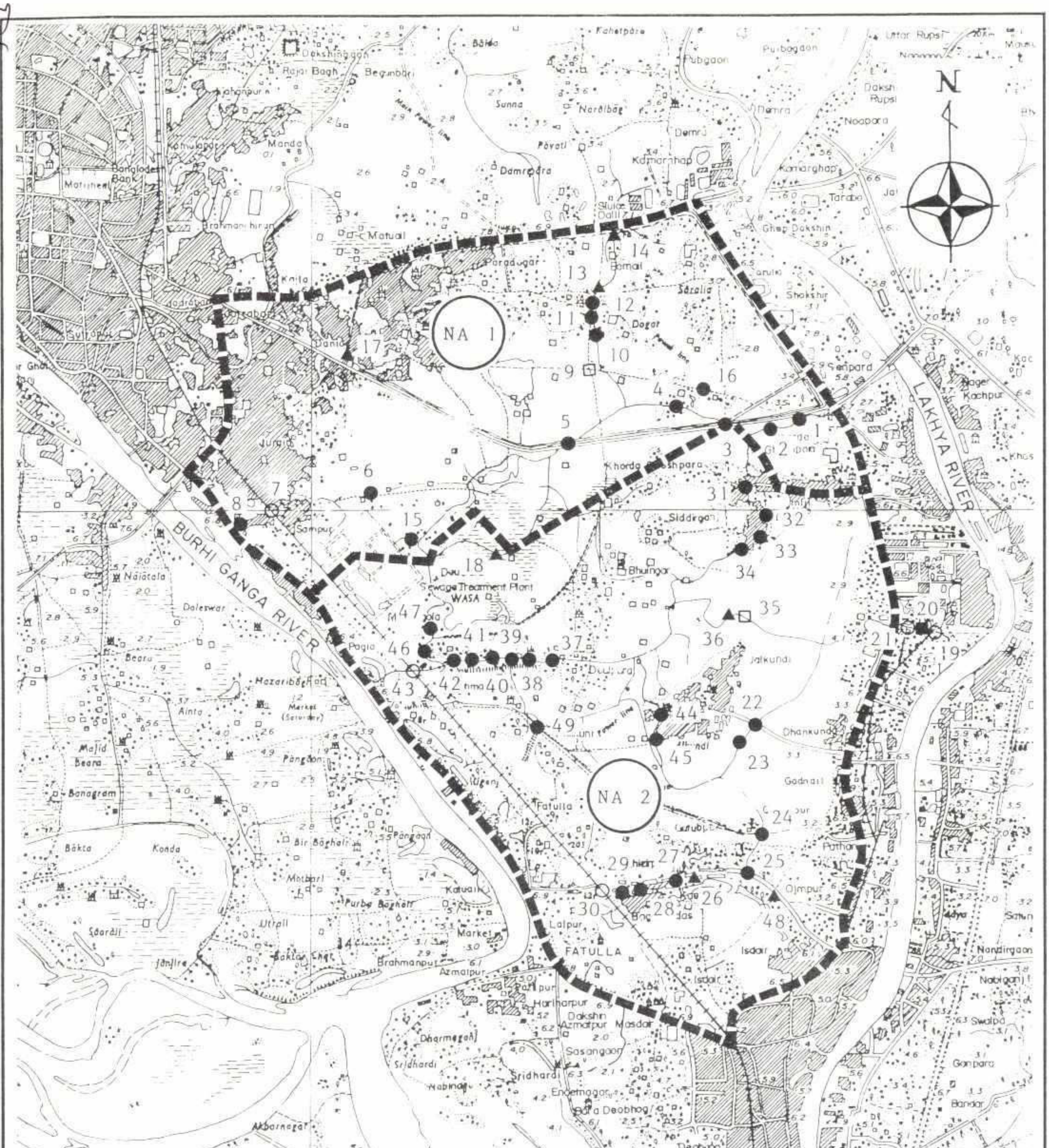


FIG. 6.2.10 LOCATION OF PROPOSED BRIDGES AND AQUEDUCT : DND

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

TABLE 6.3.1(1) HYDRAULIC REQUIREMENTS OF PROPOSED PUMPING STATION : NARAYANGANJ WEST

Proposed Pumping Station	Drainage Zone		Discharge Capacity	Design Water Level (m, PWD)					Static Head (m)		Remarks
	No.	Area		Outer			Inner				
		(km^2)	(m^3/s)	H.H.W.L	H.W.L	L.W.L	H.W.L	L.W.L	Design	Max.	
P 12	NB-1	1.73	2.00	7.35	5.80	3.00	4.20	3.00	2.80	4.35	
P 13	NB-2	1.92	2.20	7.25	5.70	3.50	4.60	3.50	2.20	3.75	
P 14-A	NB-4	2.36	2.70	7.10	5.50	3.00	4.50	3.00	2.50	4.10	
P 14-B	NB-5	4.65	5.30	6.97	5.45	3.50	4.60	3.50	1.95	3.47	

Note : 1. H.H.W.L. and H.W.L. of outer design water level means that of 100-year and 2-year frequency flood respectively

TABLE 6.3.2(2) HYDRAULIC REQUIREMENTS OF PROPOSED RETARDING POND : NARAYANGANJ WEST

Proposed Retarding Pond	Drainage Zone	Pond Area (ha)	Storage Capacity (x 10^6m^3)	Design Water Level (m, PWD)		Remarks
				H.W.L	L.W.L	
RP 12	NB-1	21	0.21	4.20	3.00	
RP 13	NB-2	23	0.23	4.60	3.50	
RP 14-1	NB-4	28	0.28	4.50	3.00	
RP 14-2	NB-5	26	0.26	4.60	3.50	
RP 14-3	NB-5	30	0.30	4.60	3.50	

209

208

TABLE 6.3.2(1) PROPOSED KHAL AND TRUNK DRAIN IMPROVEMENT WORKS: NARAYANGANJ WEST

Narayanganj West Zone (NB)

Zone	Khal No.	Khal Length (km)	Required Hydraulic Section Wb x Wu x H (m x m x m)			Open Channel Brick Protection (km)	Open Channel Sodding (km)	Covered Channel Box Culvert (km)	Covered Channel Brick Pipe (km)	Bridge (Places)	Aqueduct (Places)	Dredging (1000m3)	Maintenance Road (km)	Land Acquisition (ha)
NB-1	KN-18	0.40	2.0	7.0	2.5	0.40	-	-	-	-	-	5.52	0.40	0.65
	KN-19	1.20	2.0	14.0	3.0	-	1.20	-	-	1	-	29.85	1.20	2.43
	Sub-Total	1.60				0.40	1.20	0.00	0.00	1	0	35.37	1.60	3.08
NB-2	KN-20	0.90	3.0	13.0	2.5	-	0.90	-	-	-	-	8.46	0.90	0.90
	KN-21	1.40	2.0	7.0	2.5	1.40	-	-	-	1	-	26.90	1.40	2.50
	KN-22	0.80	4.5	10.5	3.0	0.80	-	-	-	2	-	9.84	0.80	1.60
	Sub-Total	3.10				2.20	0.90	0.00	0.00	3	0	45.20	3.10	5.00
NB-3	KN-23	0.60	2.5	7.5	2.5	0.60	-	-	-	1	-	7.80	0.60	1.02
	KN-24	0.70	2.5	7.5	2.5	0.70	-	-	-	1	-	11.20	0.70	1.20
	KN-25	0.40	2.0	7.0	2.5	0.40	-	-	-	-	-	0.00	0.40	0.37
	KN-26	0.60	2.0	7.0	2.5	0.60	-	-	-	-	-	0.00	0.60	0.12
	KN-27	0.30	2.0	7.0	2.5	0.30	-	-	-	-	-	1.80	0.30	0.31
	S-1	0.90	3.0	-	3.0	-	-	0.90	-	-	-	21.69	0.90	1.50
	S-2	0.30		2.5		-	-	-	0.30	-	-	5.76	0.30	0.46
	S-3	0.20		2.2		-	-	-	0.20	-	-	2.44	0.20	0.29
	Sub-Total	4.00				2.60	0.00	0.90	0.50	2	0	50.69	4.00	5.27
NB-4	KN-28-1	0.90	6.0	18.0	3.0	-	0.90	-	-	-	-	10.25	0.90	1.65
	KN-28-2	0.50	2.0	13.3	2.8	-	0.50	-	-	-	-	4.33	0.50	1.04
	KN-29	1.40	2.0	8.0	3.0	1.40	-	-	-	2	-	35.40	1.40	2.70
	Sub-Total	2.80				1.40	1.40	0.00	0.00	2	0	49.98	2.80	5.39
NB-5	KN-30-1	0.30	9.5	15.5	3.0	0.30	-	-	-	1	-	13.52	0.30	0.41
	KN-30-2	1.50	2.5	8.5	3.0	1.50	-	-	-	-	-	13.67	1.50	1.26
	KN-31-1	0.80	2.5	14.5	3.0	-	0.80	-	-	1	-	22.80	0.80	1.53
	KN-31-2	1.30	2.0	8.0	3.0	1.30	-	-	-	2	-	33.30	1.30	3.01
	KN-32	1.80	2.5	8.5	3.0	1.80	-	-	-	2	-	37.60	1.80	3.45
	Sub-Total	5.70				4.90	0.80	0.00	0.00	6	0	120.89	5.70	9.66
	Total	17.20				11.50	4.30	0.90	0.50	14	0	302.13	17.20	28.40

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TABLE 6.3.2(2) PROPOSED KHAL IMPROVEMENT RELATED WORKS (BRIDGE) : NARAYANGANJ WEST

Zone	Khal No.	Bridge No.	Existing Type	Existing Size (m x m)	Required Size (m x m)	Proposed Type	Proposed Size (m x m)	Width	Remarks
NB-1	KN-19	50	-	-	5.60 x 4.00	Girder bridge	5.6 x 4.00	-	Road bridge
NB-2	KN-21	51	-	-	2.60 x 4.00	Slab bridge	2.7 x 4.00	-	" "
	KN-22	52	-	-	5.25 x 4.00	Girder bridge	5.3 x 4.00	-	" "
	"	53	-	-	5.25 x 4.00	Deck girder	5.3 x 4.00	1.7	Railway bridge
NB-3	KN-23	54	-	-	3.50 x 3.50	" "	3.5 x 3.50	"	" "
	KN-24	55	-	-	3.50 x 3.50	" "	3.5 x 3.50	"	" "
	KN-25	56	Deck-Rly	6.10 x 6.10	3.15 x 3.50	-	-	-	" "
	"	57	Slab bridge	2x4.6 x 5.00	3.15 x 3.50	-	-	-	Roade bridge
	KN-26	58	Box culvert	4.60 x 4.90	3.15 x 3.50	-	-	-	" "
	KN-27	59	Girder bridge	6.00 x 4.70	3.15 x 3.50	-	-	-	" "
NB-4	KN-29	60	-	-	3.50 x 4.00	Slab bridge	3.50 x 4.00	3.66	Road bridge
	"	61	-	-	3.50 x 4.00	" "	3.50 x 4.00	"	" "
NB-5	KN-30-1	62	-	-	8.75 x 4.00	Girder bridge	8.80 x 4.00	"	" "
	KN-30-2	63	Girder bridge	11.80 x 5.10	3.85 x 4.00	-	-	-	" "
	KN-31-1	64	-	-	5.95 x 4.00	Slab bridge	6.00 x 4.00	3.66	Road bridge
	KN-31-2	65	-	-	3.50 x 4.00	" "	3.50 x 4.00	"	" "
	"	66	-	-	3.50 x 4.00	" "	3.50 x 4.00	"	" "
	KN-32	67	-	-	3.85 x 4.00	" "	3.90 x 4.00	"	" "
	"	68	-	-	3.85 x 4.00	" "	3.90 x 4.00	"	

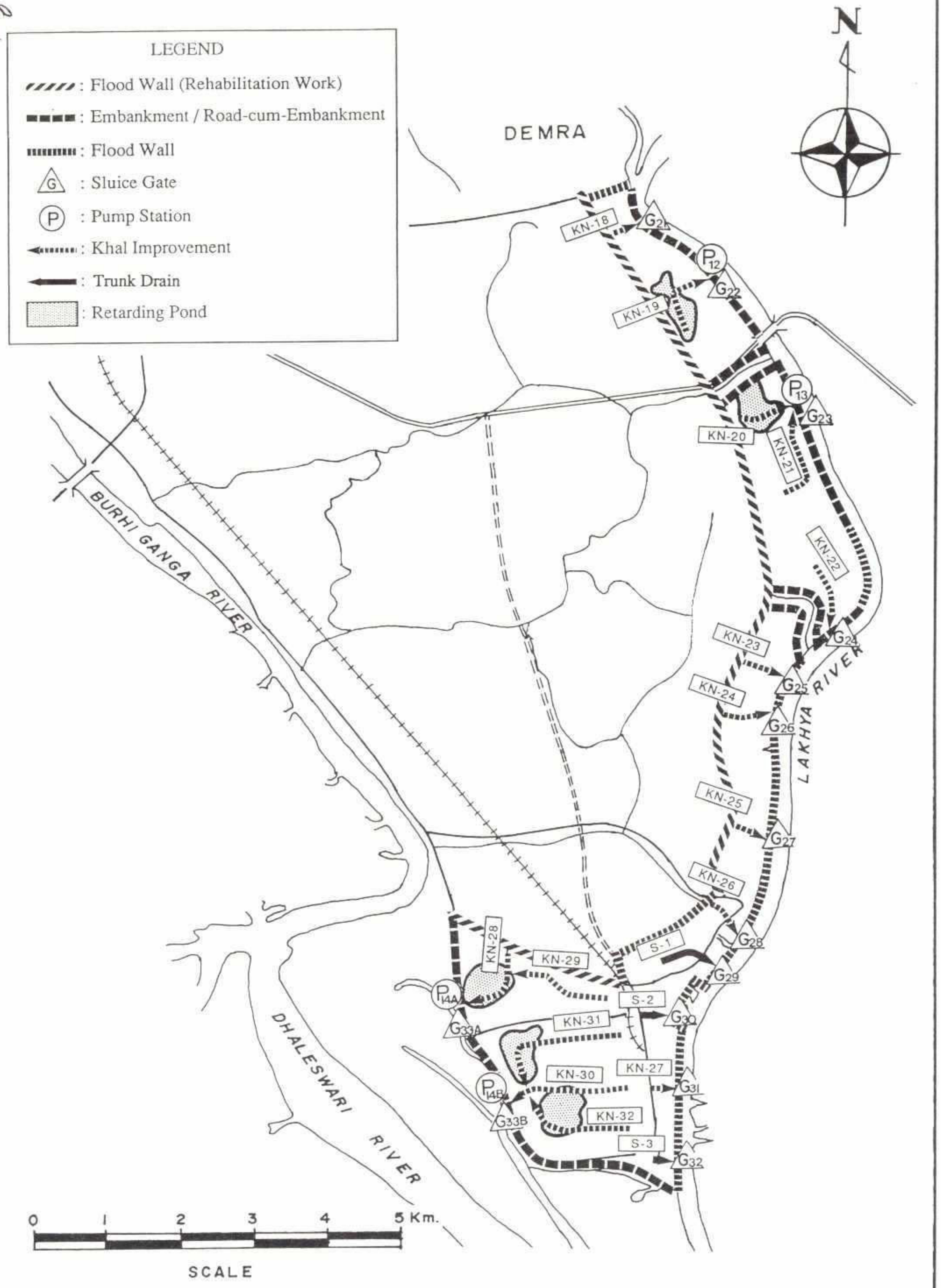

FIG. 6.3.1 PROPOSED FACILITIES : NARAYANGANJ WEST

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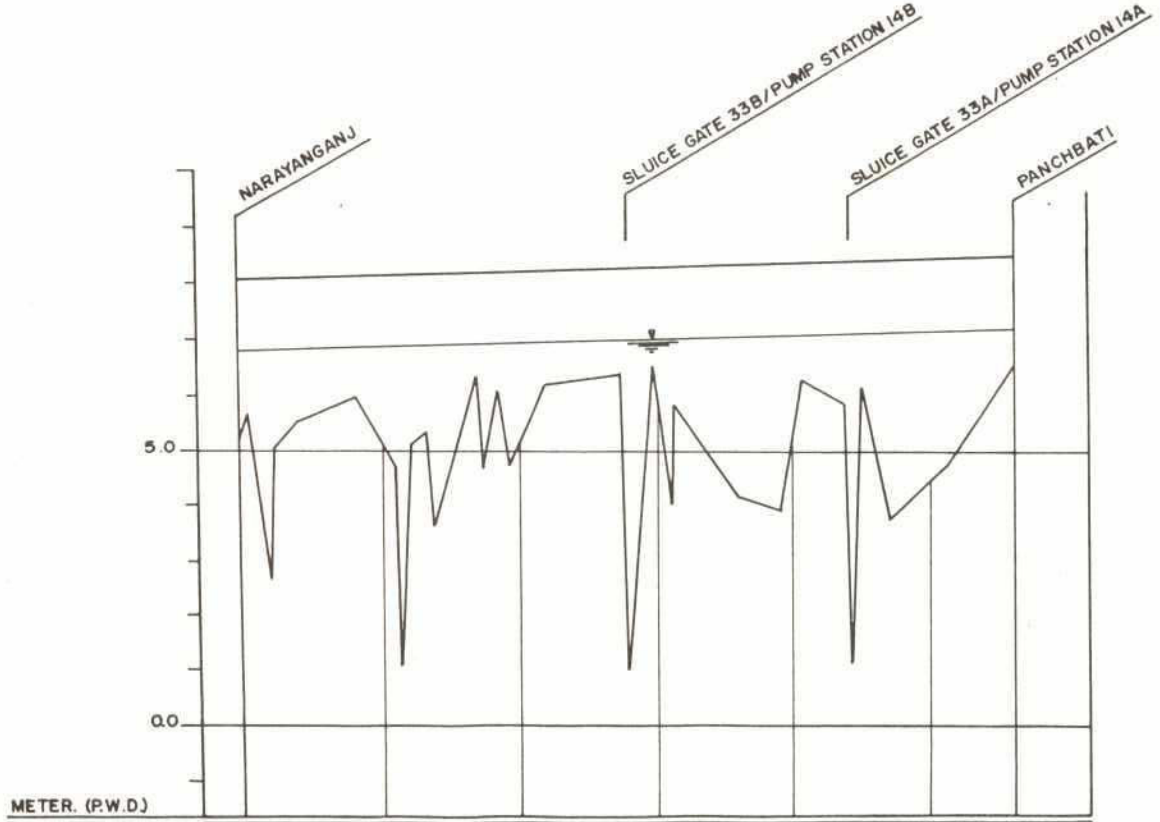
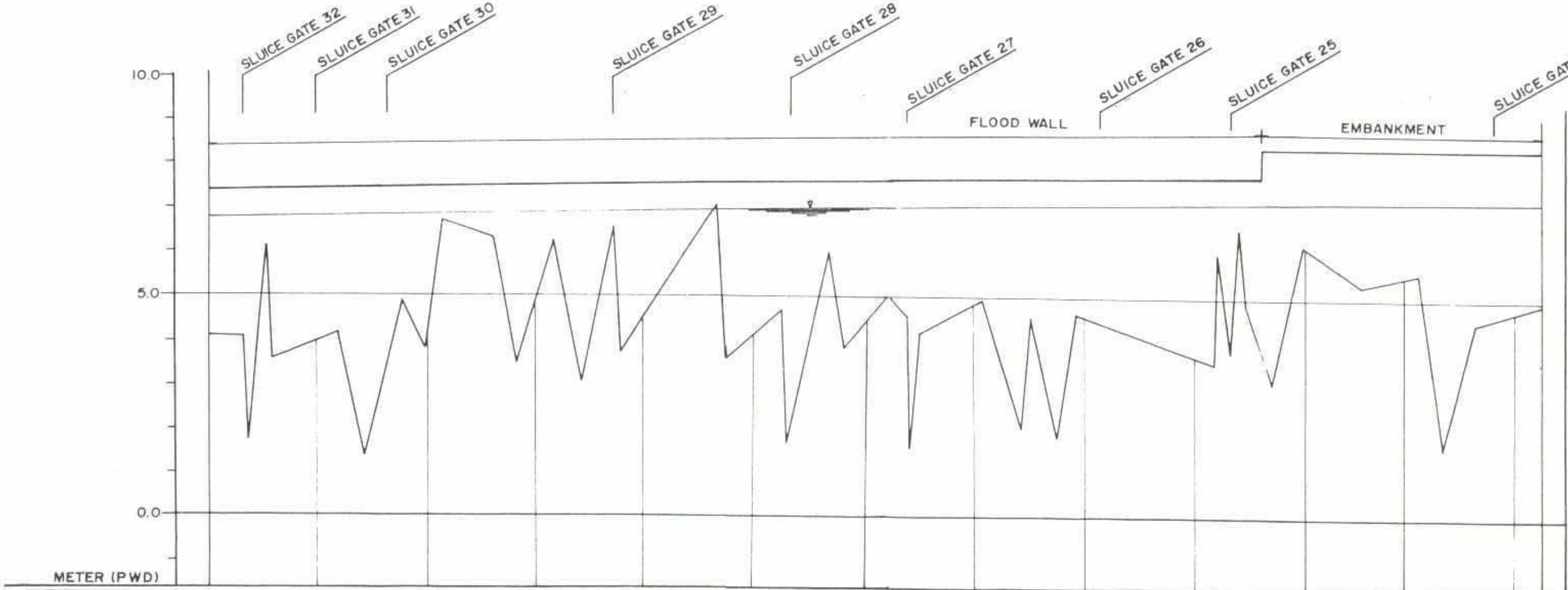


DESIGNED	GRADIENT	1 = 1/20,390			1 = 1/12,000			
	TOP OF EMBANKMENT	8.00	8.05	8.10	8.18	8.27	8.38	8.40
	H.W.L.	6.80	6.85	6.90	6.98	7.07	8.15	7.20
ACCUMULATED DISTANCE (KM)		0.0	1.0	2.0	3.0	4.0	5.0	5.6

FIG. 6.3.2 (1) LONGITUDINAL SECTION OF EMBANKMENT ROAD-CUM-EMBANKMENT (NW) NARAYANGANJ WEST

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



DESIGNED															
	GRADIENT	1 = 1/25,000		1 = 1/56,000			1 = 1/28,240					LEVEL			
DESIGNED	TOP OF FLOOD WALL /EMBANKMENT	7.40	7.44	7.48	7.50	7.52	7.54	7.57	7.61	7.65	7.68	8.30	8.30	8.31	8.32
DESIGNED	H.W.L.	6.80	6.84	6.88	6.90	6.92	6.94	6.97	7.01	7.05	7.08	7.10	7.10	7.11	7.12
	ACCUMULATED DISTANCE (KM)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	12.3

FIG. 6.3.2 (2) LONGITUDINAL SECTION OF FLOOD WALL/EMBANKMENT (NE-1): NARAYANGANJ WEST

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

226

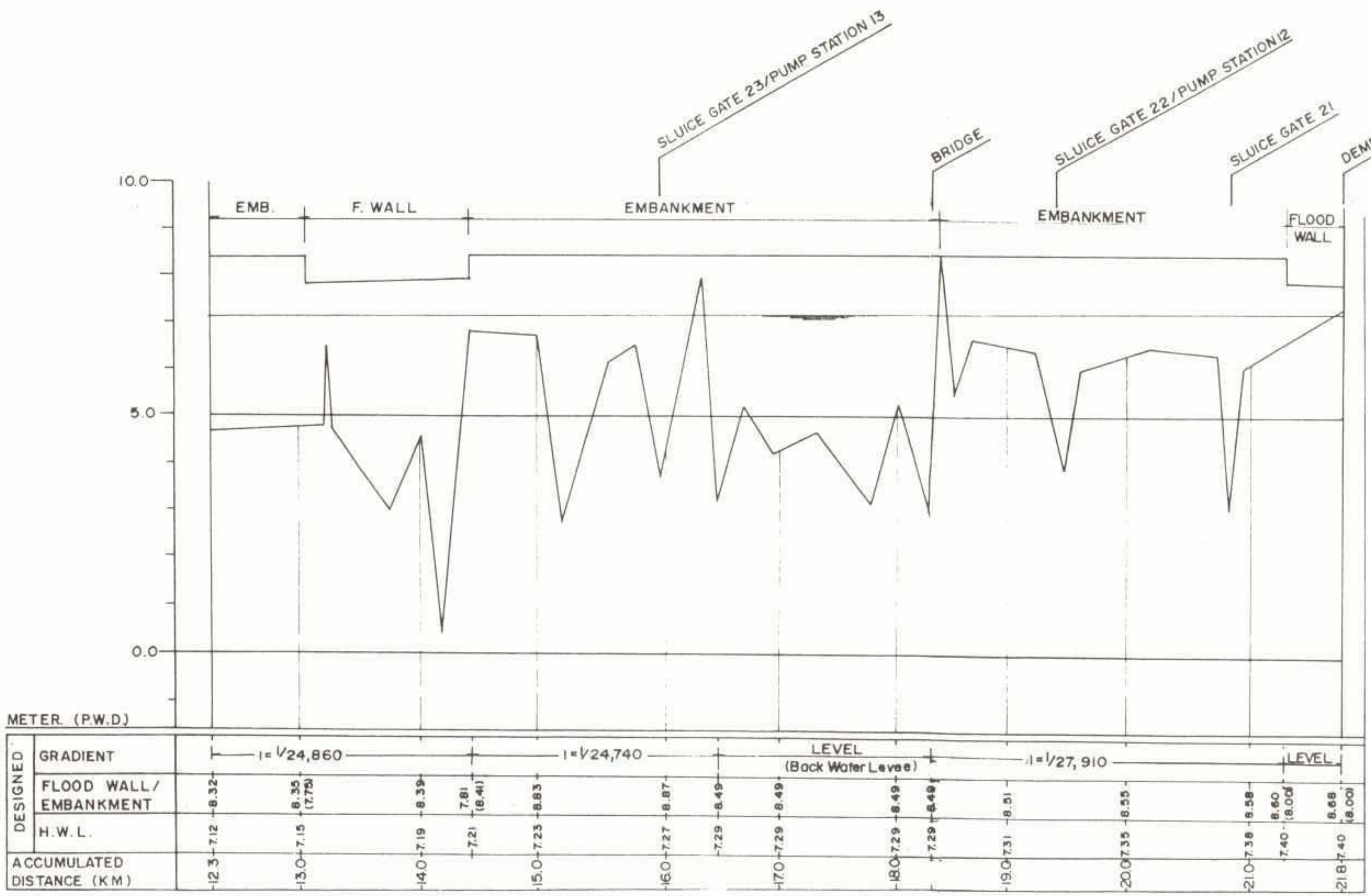


FIG. 6.3.2 (3) LONGITUDINAL SECTION OF FLOOD WALL/EMBANKMENT (NE-2): NARAYANGANJ WEST

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

228

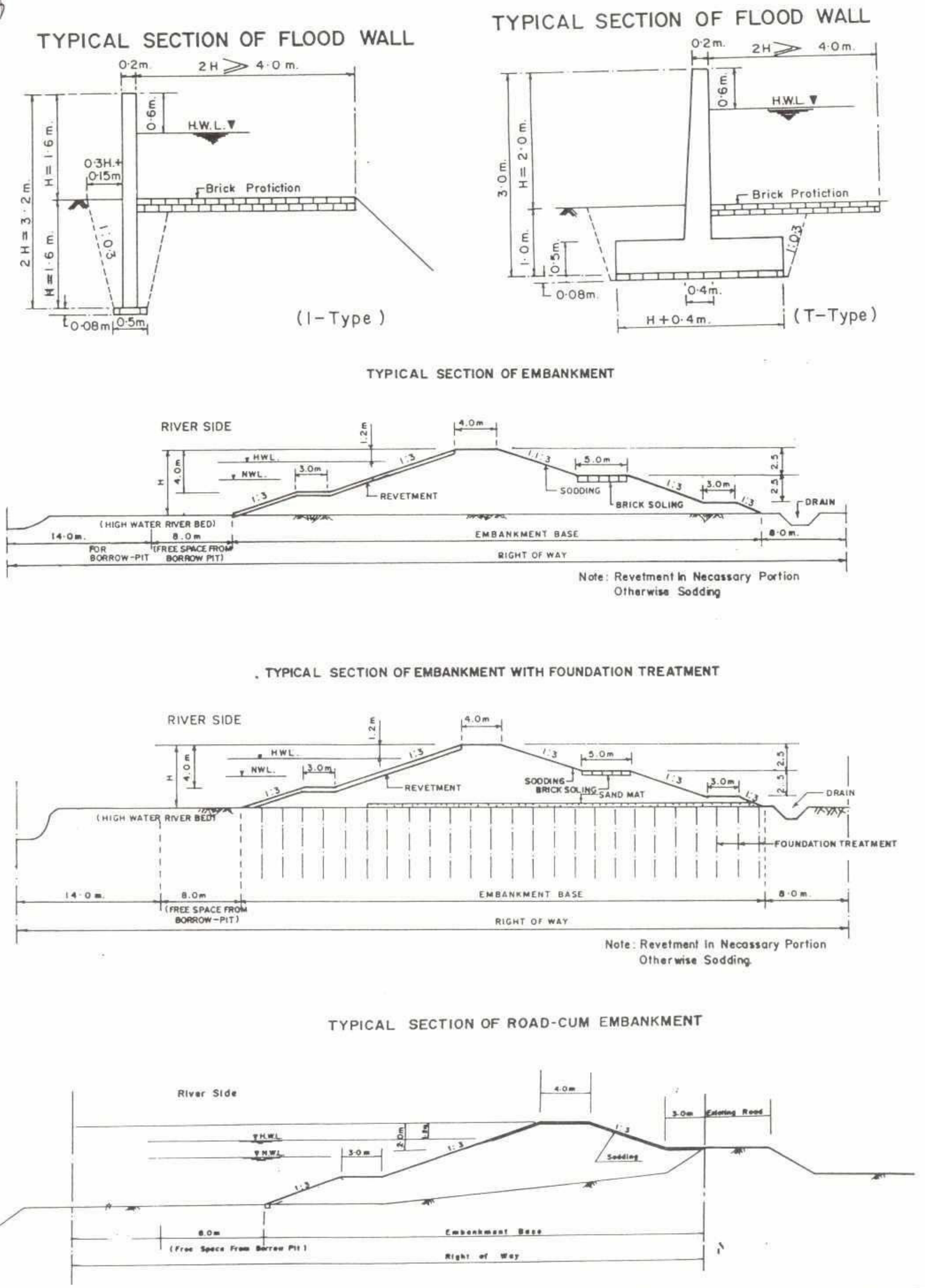
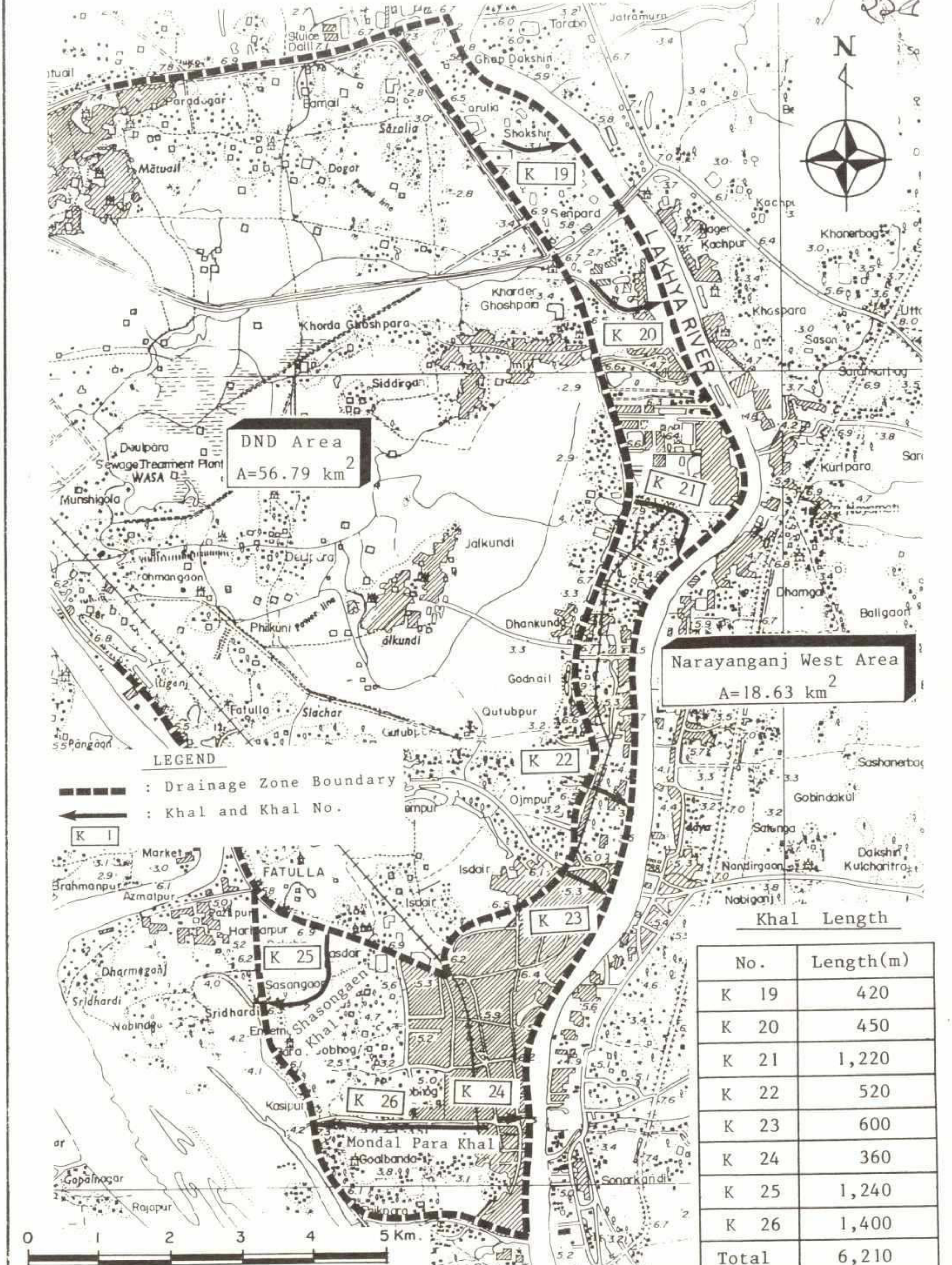


FIG. 6.3.3 TYPICAL CROSS-SECTION OF ROAD-CUM-EMBANKMENT/ EMBANKMENT AND FLOOD WALL



Khal Length	
No.	Length(m)
K 19	420
K 20	450
K 21	1,220
K 22	520
K 23	600
K 24	360
K 25	1,240
K 26	1,400
Total	6,210

FIG. 6.3.4 EXISTING MAJOR KHALS : NARAYANGANJ WEST

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

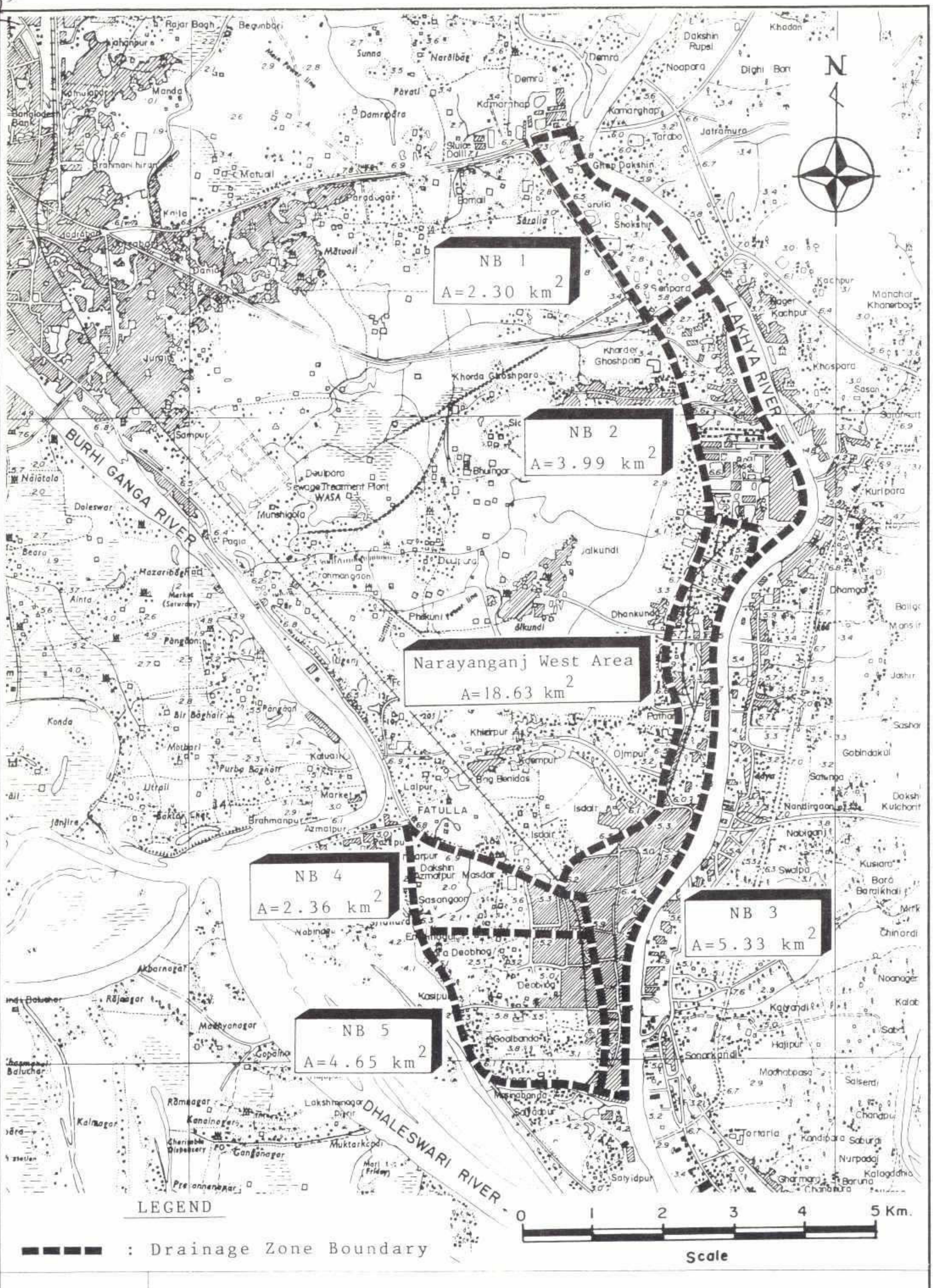


FIG. 6.3.5 DRAINAGE ZONE : NARAYANGANJ WEST

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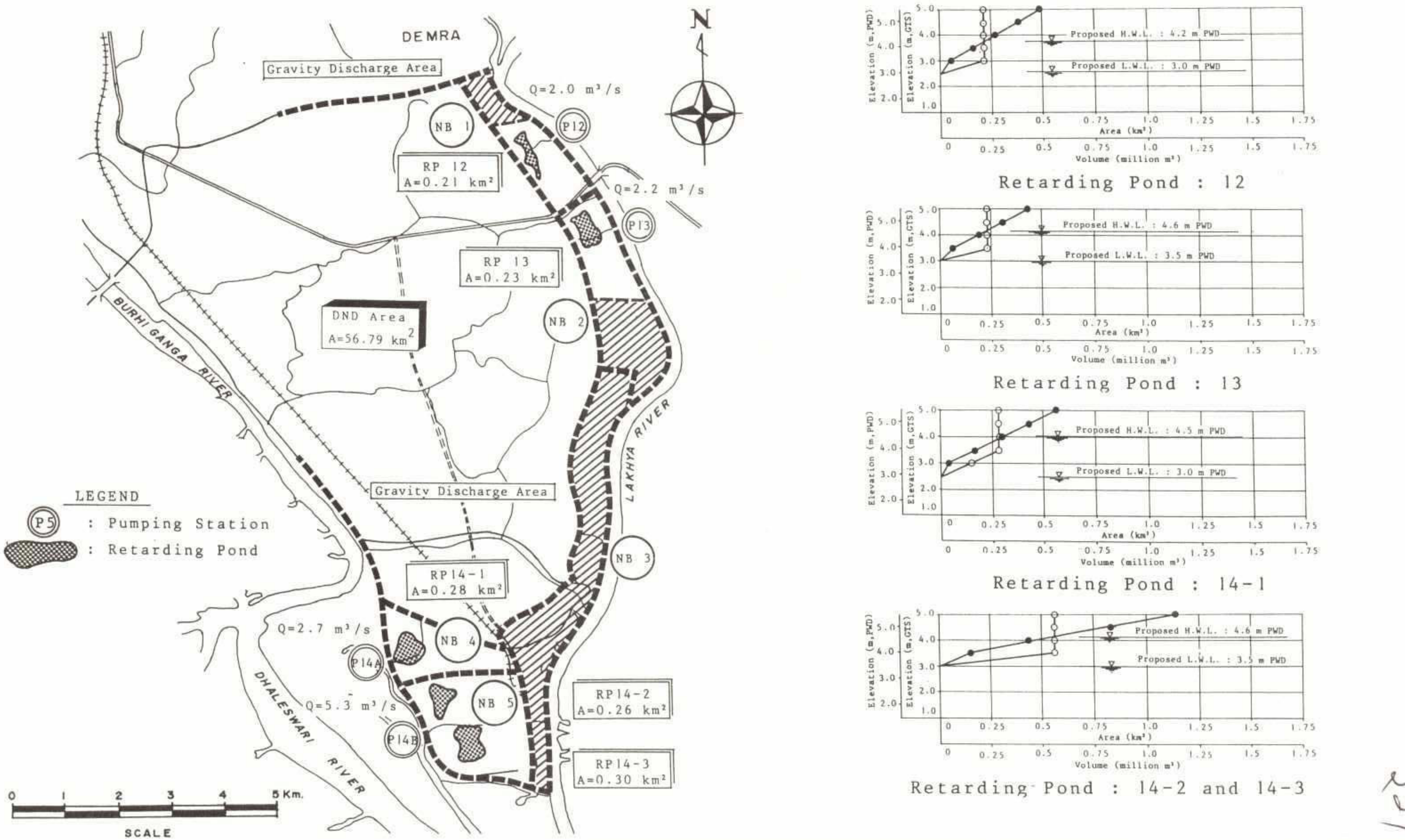
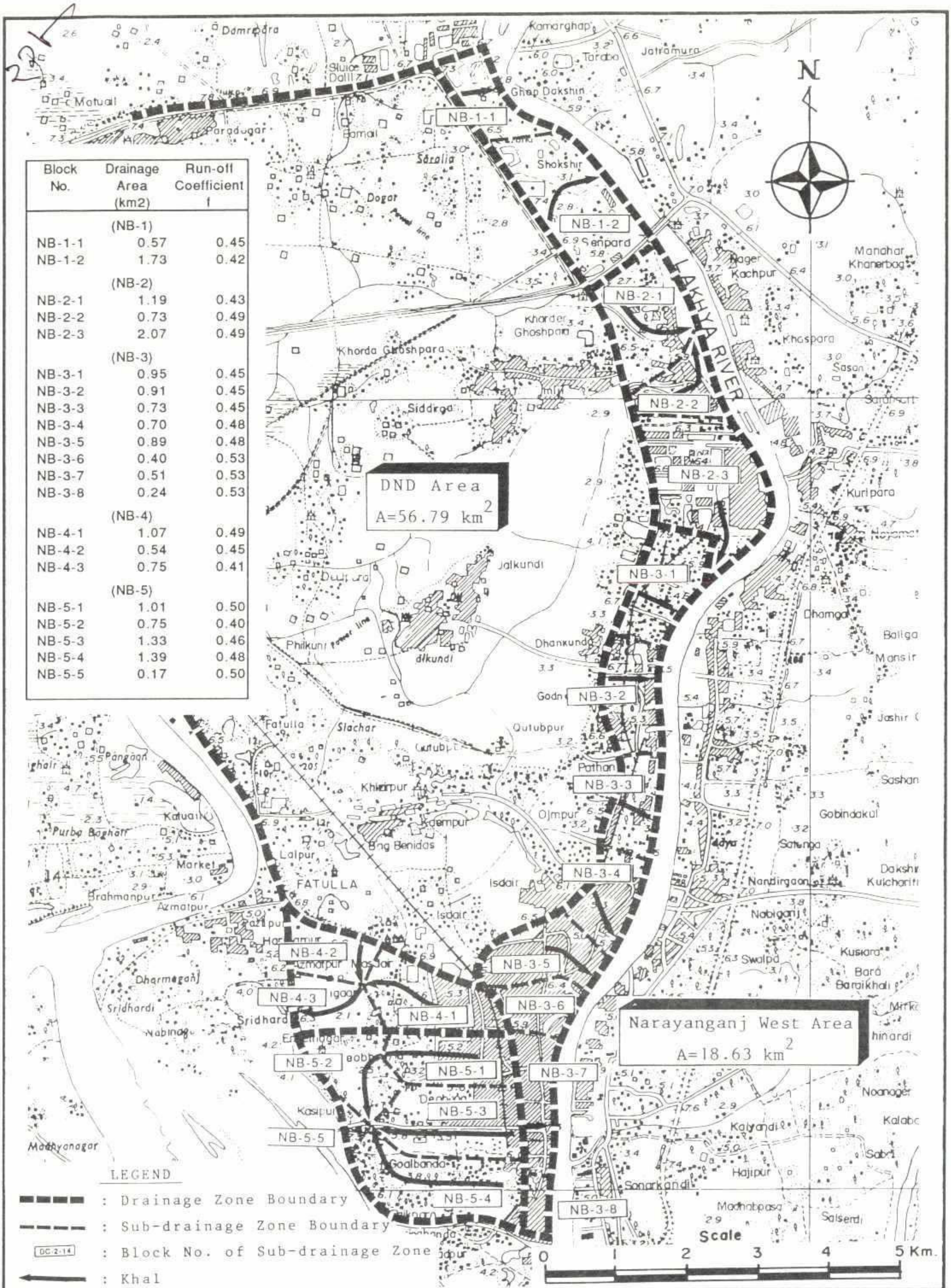


229

FIG. 6.3.6 PROPOSED REQUIREMENTS OF PUMP STATION AND RETARDING POND : NARAYANGANJ WEST

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

221



Block No.	Drainage Area (km2)	Run-off Coefficient f
(NB-1)		
NB-1-1	0.57	0.45
NB-1-2	1.73	0.42
(NB-2)		
NB-2-1	1.19	0.43
NB-2-2	0.73	0.49
NB-2-3	2.07	0.49
(NB-3)		
NB-3-1	0.95	0.45
NB-3-2	0.91	0.45
NB-3-3	0.73	0.45
NB-3-4	0.70	0.48
NB-3-5	0.89	0.48
NB-3-6	0.40	0.53
NB-3-7	0.51	0.53
NB-3-8	0.24	0.53
(NB-4)		
NB-4-1	1.07	0.49
NB-4-2	0.54	0.45
NB-4-3	0.75	0.41
(NB-5)		
NB-5-1	1.01	0.50
NB-5-2	0.75	0.40
NB-5-3	1.33	0.46
NB-5-4	1.39	0.48
NB-5-5	0.17	0.50

LEGEND

- : Drainage Zone Boundary
- : Sub-drainage Zone Boundary
- DC-2-14 : Block No. of Sub-drainage Zone
- : Khal

FIG. 6.3.7 SUB-DRAINAGE ZONE AND THEIR RUN-OFF COEFFICIENT : NARAYANGANJ WEST

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

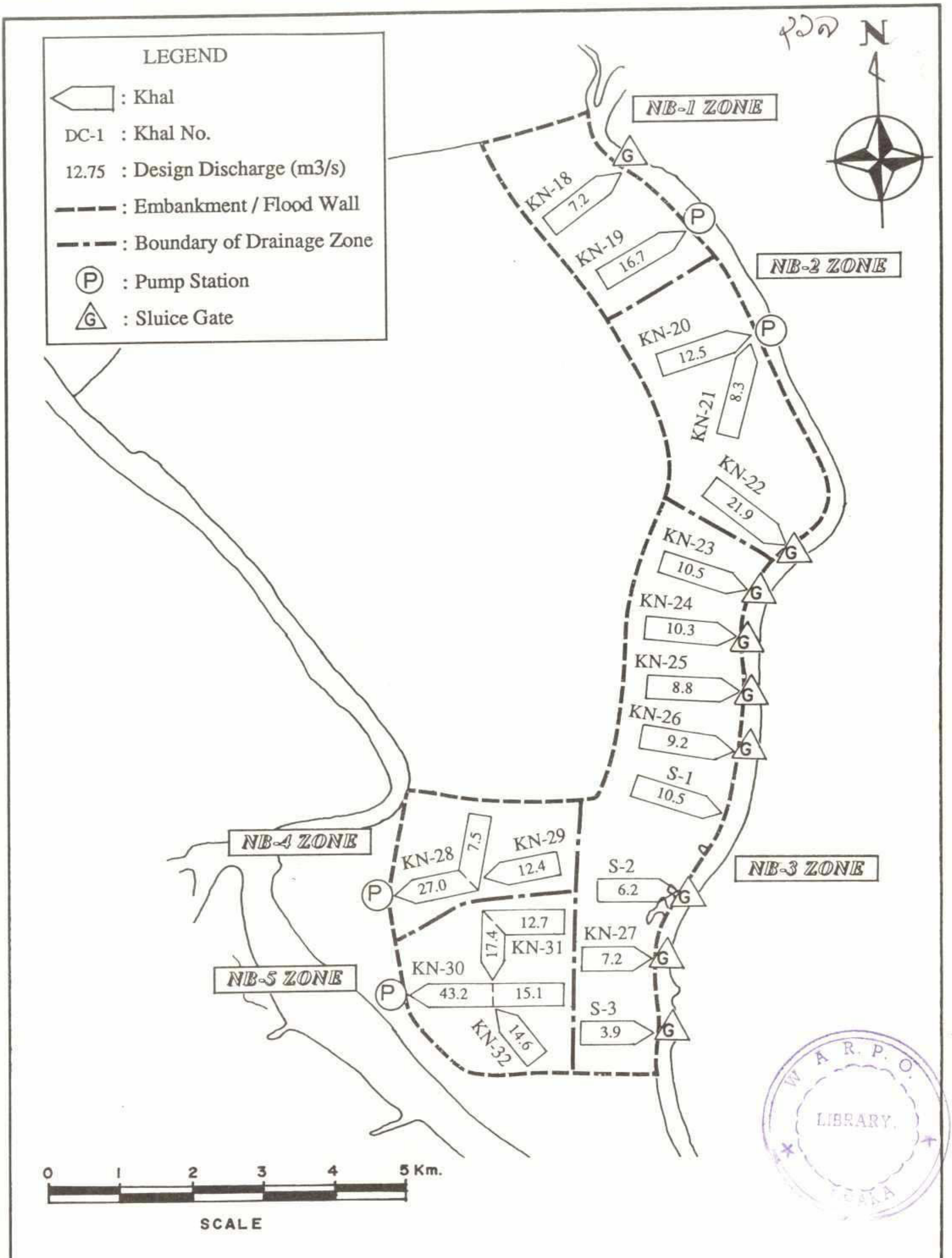


FIG. 6.3.8 DESIGN DISCHARGES FOR IMPROVEMENTS OF KHAL AND TRUNK DRAIN : NARAYANGANJ WEST-

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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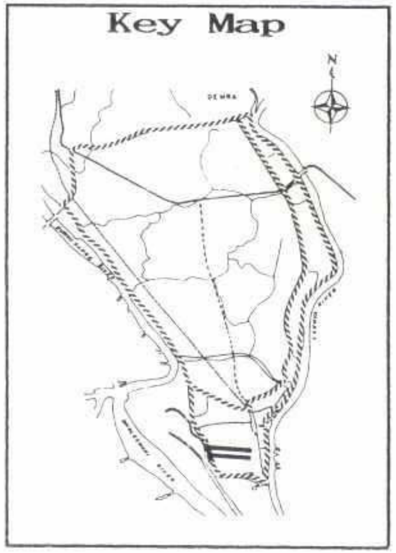


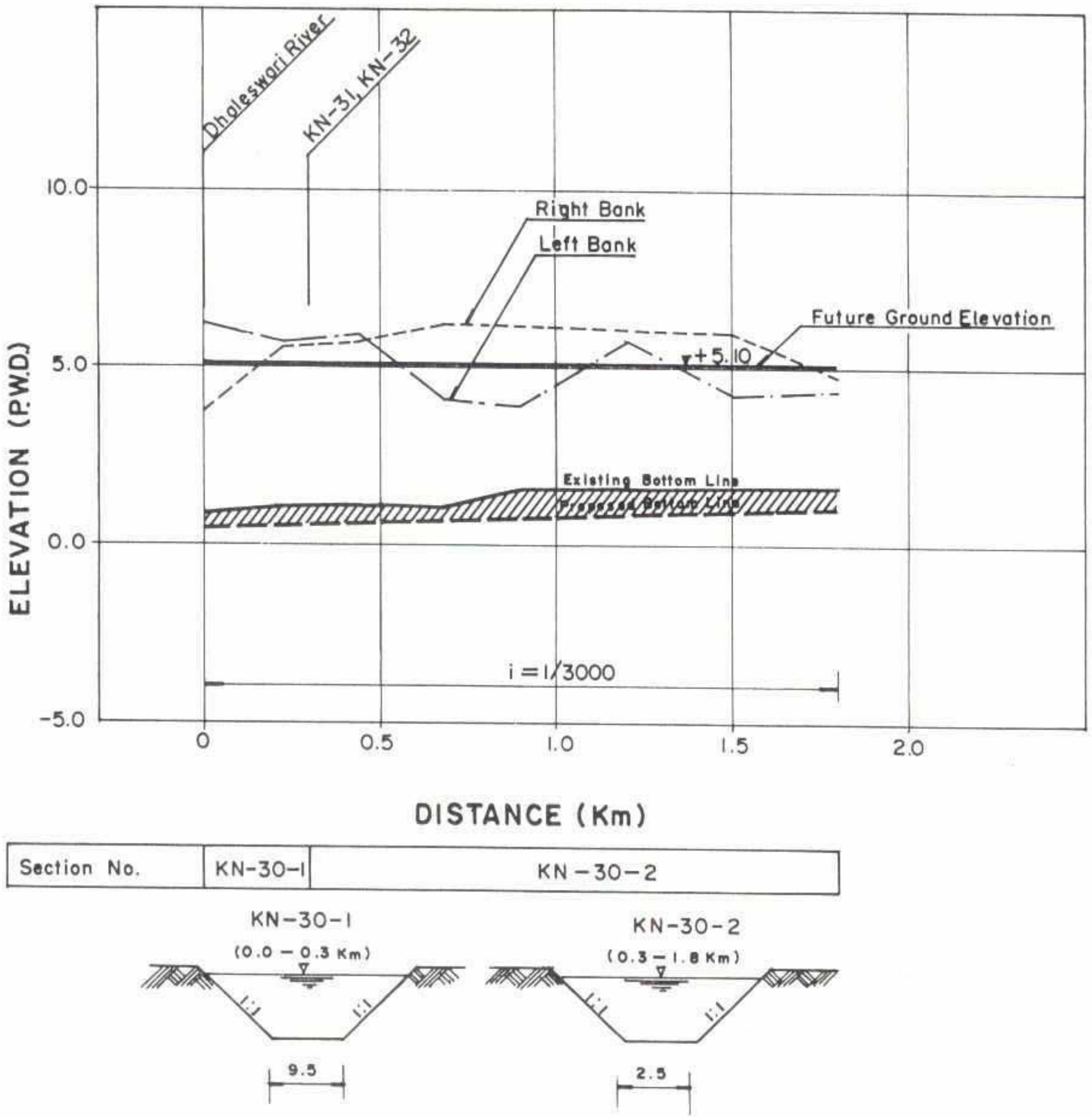
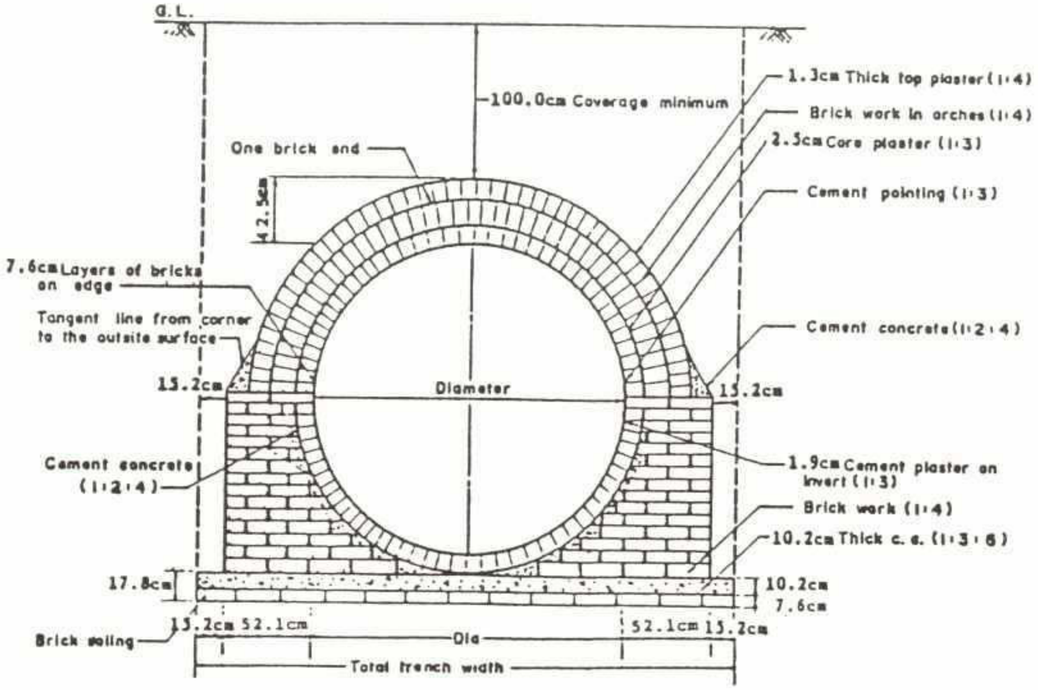


FIG. 6.3.9 PROPOSED LONGITUDINAL AND CROSS SECTIONS (KN-30)

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



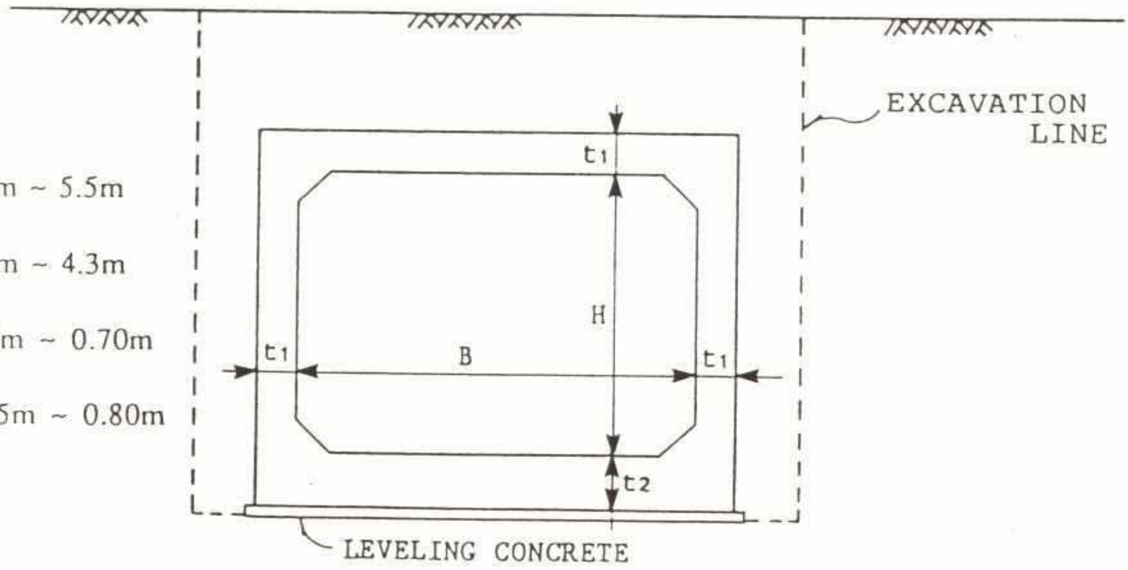
TYPE (1) : BRICK PIPE (Blow ϕ3,000 m/m)

B = 4.0m ~ 5.5m

H = 3.8m ~ 4.3m

t_1 = 0.25m ~ 0.70m

t_2 = 0.35m ~ 0.80m



TYPE (2) : SINGLE BOX CULVERT

FIG. 6.3.10	TYPICAL DESIGN OF PROPOSED TRUNK DRAIN

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

22

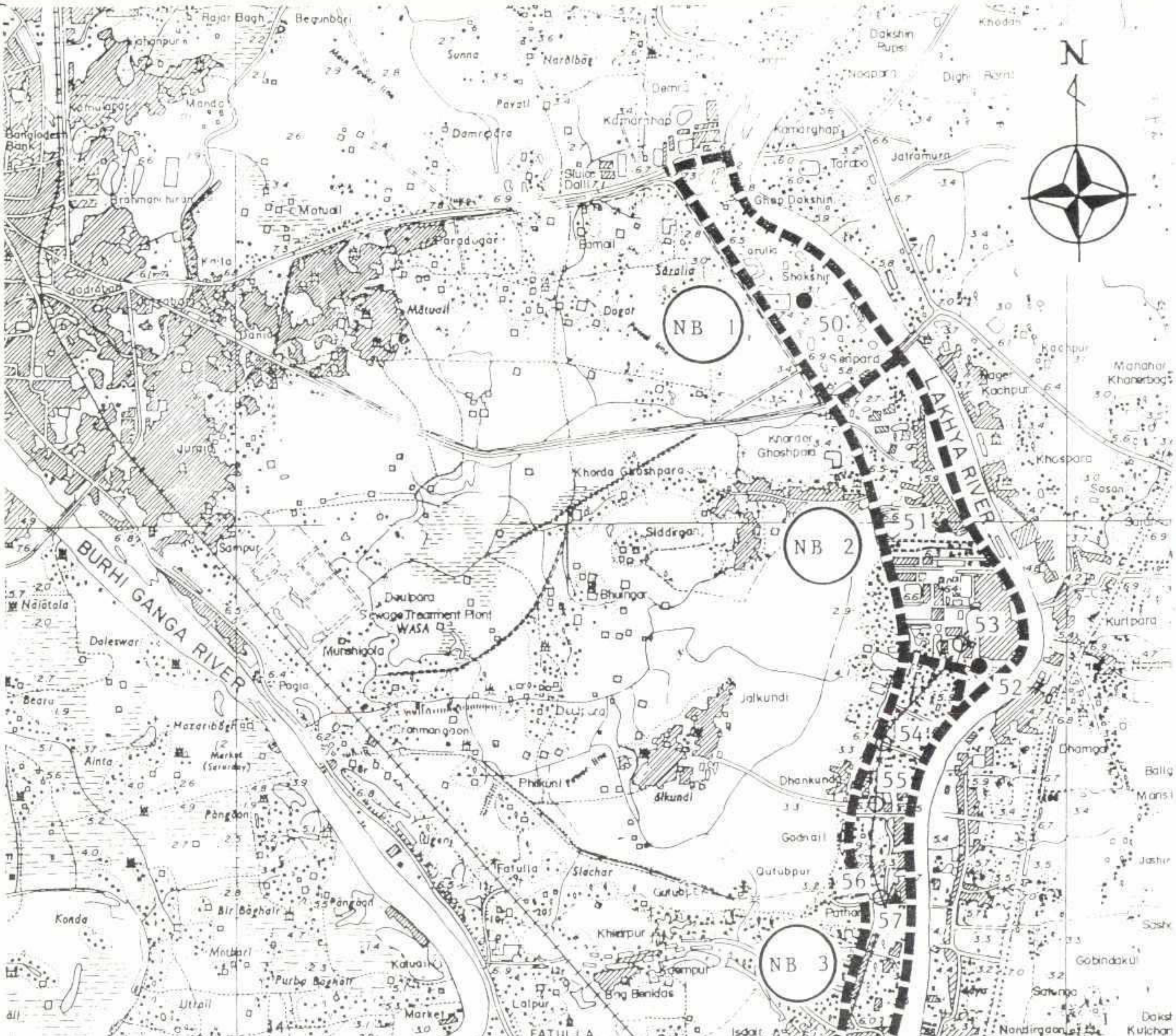


FIG. 6.3.11 LOCATION OF PROPOSED BRIDGES : NARAYANGANJ WEST

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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CHAPTER 7
ENVIRONMENTAL IMPACT

Chapter 7 : Environmental Impact

7.1 General

The environmental study in the feasibility study (FS) stage is principally targeted at the anticipated major environmental consequences, both of direct and indirect nature, by the implementation of the proposed flood control and drainage works. Though urbanization itself would lead to much direct environmental impacts, living environmental issue with specific concern to sanitation is only selected as the priority element for detailed consideration in this flood control and drainage project. The other major direct environmental issues of urbanization shall be addressed by future studies of direct concern. Nevertheless, major environmental effects, both of direct and indirect, are still identified along with their significance. The possible mitigatory measures are also recommended.

7.2 Ecology

A comprehensive ecological survey, based on available secondary data in combination with judicious field verification, was carried out for establishing the base line conditions of existing ecological resources in the priority area of Greater Dhaka and Narayanganj (ref. Fig. 7.1), and hence to identify the impacts on such resources by the project implementation, on a preliminary basis. The ecological resources targeted by the survey are flora and fauna, termed as general ecological resources, and agriculture and aquaculture, termed as productive ecological resources in consideration to their direct economic value.

The survey was conducted during the six (6) month period from October 1991 to February 1992, to encompass both the flood season and dry season conditions. This is in due consideration to the distinct environmental conditions in the flood plains that predominates in Greater Dhaka East.

The impacts by the project on ecology, both due to the direct dry up effect of embankments and the subsequent change in land use due to urbanization, is evaluated to be insignificant when assessed from a broad perspective on a national basis.

22a

7.2.1 General Ecology

Flora and fauna are the defined general economical elements. Fauna elements of an ecosystem could be grouped into four (4) categories. They are, in the sequential order of their evolutionary status, amphibian, reptiles, birds and mammals. Such a simple classification is impossible for flora due to their complex evolutionary status and varieties. Nevertheless floral elements in the priority area falls into two (2) broad categories of aquatic and terrestrial species. The aquatic species are classified into four (4) groups, namely, floating, completely submerged, partly submerged and marsh plants, while the terrestrial plant species are also grouped to four (4) categories of trees, shrubs, climbers and herbaceous weeds.

The total number of identified floral species and fauna species are 112 and 177 respectively. The surveyed fauna species is limited to that of wild origin.

Among the identified floral species, 81 are terrestrial belonging predominantly to the high lands, and 31 being aquatic of low lands and flood plains. Of the fauna species, 47 are aquatic, 122 are terrestrial and the remaining eight (8), that includes all amphibian, are both aquatic and terrestrial of origin.

However, all the fauna and floral species identified in the priority area are also distributed elsewhere in the country, and no species is confirmed as peculiar to the priority area.

The change expected to the general ecological elements due to embankment and the subsequent dry-up is the dominance of terrestrial species against the aquatic ones. Moreover, with the progressing residential development, even among the terrestrial species, those "domestic" species with direct economic significance to human welfare, like the planted floral species of jack fruit, mango and others, and the domestic fauna species like dog, cat, goat and others will become predominant.

7.2.2 Productive Ecology

The representative productive ecological elements are agricultural crops and aquacultural species of both natural (generally known as fishery) and artificially cultured (generally known as aquaculture).

During flood season, the lowland areas are encompassed by open water bodies. Such open water bodies are vast in the Greater Dhaka East. These open water bodies of potential aquaculture during flood season becomes agricultural lands during dry season. This is a very typical phenomenon in most lowlands of the whole country.

1) Agriculture

The environmental study area covers about 34,000 ha (ref. Fig.7.1). Under the existing conditions of land use, agriculture accounts for 44% of the total land use covering about 14,800 ha, which is very significant.

The land use distinguished between agriculture and others in Greater Dhaka and Narayanganj is summarized below.

Agricultural Land Use in 1990

Land Use	Greater Dhaka		Narayanganj		Priority Area (Total)	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agriculture	11,181	42.5	3,637	48.2	14,818	44
Others	15,126	57.5	3,905	51.8	19,031	56
Total	26,307	100	7,542	100	33,849	100

The farming practice comprises three annual seasons, namely Karif - I (March - June), Karif - II (July - October) and Rabi (November - February), which is practiced to suit the climatic and the related land and flood water area changes. Karif-I is the major crop production season, though Rabi the major planting season. Rice and wheat are the major crops cultivated. Their varieties are itemized below. The other products include oil seeds, potatoes, vegetables and pulses.

Rice (Boro)
HYV : Br-3, Br-8, Br-9, Br-12 and IR-8
Local : Amboro, Khaiyaboro, Chiniboro
Improved : Pyzam

Rice (Aman)
HYV : Br-3, Br-4, Br-10, Br-11and IR-20
Improved : Pyzam
Rice (Aus)
HYV : Br-12, Br-15, Br-16 and IR-8
Wheat

229

HYV : Sonalika, Balaka, Kanchan, Barkat ,Akbar and Ananda

Single cropping, which is confined to Rabi and Karif-I season, is predominant that covers 58% of the total agricultural lands which are mostly flood plains. While double cropping encompassing two seasons accounts for about 33% and triple cropping covering all three (3) seasons accounts for the remaining 9% of agricultural lands, being confined mostly to flood protected DND area.

Accordingly, the average cropping intensity in the whole objective area (priority area) becomes 152%, which is much less than the cropping intensity of Dhaka district with 171%. Hence, it could be concluded that this priority area that encompasses both the existing and the prioritized future urban area is more suited for urban land use than that of agriculture, based on the existing conditions. Nevertheless, it is to be admitted that flood mitigation and drainage would increase the potential cropping intensity of the protected agricultural land, which is predicted to increase up to 160%, but still less than 171% of Dhaka district. Breakdown of existing cropping pattern along with the respective areas is tabulated below.

Existing Cropping Pattern in Priority Area

Pattern	Location	Cultivated Area		Cropped Area	Cropping Intensity
		ha	%	ha	%
Single Cropping	Balu River Flood Plains - East Dhaka Buriganga - Turag River Flood Plains - West Dhaka	8,523	57.5	8,523	57.5
Double Cropping	DND Area Buriganga - Turag Drainage Basin - West Dhaka	4,945	33.4	9,890	66.8
Triple Cropping	DND Area	1,350	9.1	4,050	27.3
Total :		14,818	100	22,463	151.6

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The corresponding cropped area, yield and annual production of major agricultural crops are estimated as given below :

Crop	Cropped Area (ha)	Yield (ton/ha)	Annual Production (ton/annum)
Rice	19,863	3.24	64,342
Wheat	130	0.80	104
Potato	185	12.40	2,294
Oil Seeds	850	0.50	425
Pulses	290	0.69	200
Vegetables	1,085	19.20	20,832
Fruits	60	27.00	1,620
Total	22,463		89,817

The total existing annual net value added of agricultural production, is estimated at about Tk. 389 million.

The future agricultural land use in 2010 will occupy only a limited area, even if a portion of retarding areas which could be used for agriculture during dry season is included. Intensive agriculture practice in the remaining flood protected agricultural lands is recommended.

2) Aquaculture

Most low lands and flood plains of single cropped agriculture are the potential open water capture fishery areas of rainy/flood season. Balu river flood plain of Greater Dhaka East is the predominant spawning grounds of open water capture fishery. The low land of DND is also of considerable importance.

A total of 86 aquacultural species comprising 74 fish species, 10 freshwater prawn species, and two (2) crab species is identified in the priority area. In addition five (5) exotic species also exist. All cultured species are also found naturally in open waters. Of these 86 species 25 species are identified to be commercially important. Among both the commercially important and exotic species, eight (8), five (5) of commercial and three (3) of exotic, are noted as highly profitable for culturing (aquaculture).

22?

There exist four major fishery/aquaculture systems in the priority area. They are :

- River / Khal fishery
- Flood plain fishery
- Beel and reservoir fishery
- Culture fishery or aquaculture

Of the above four (4) fishery systems, both the flood plains and beel and reservoir open water fishery will be directly affected by the project, with the embankment and the subsequent dry-up of flood plains. As in the case of agriculture, the change in land use to urban will still critically limit even culture fishery (aquaculture) in these former flood plains, even though its potential will be enhanced with flood protection measure.

The ongoing urbanization will lead to increased pollution load generation. If urbanization proceeded with inadequate pollution control measures, then the resultant water quality deterioration of internal rivers and khals due to increased pollution load discharge would affect even the river/khal open water fishery, indirectly.

Hence pollution control measures with progressing urban, industrial and other developments are necessary for rendering the water bodies suited to a variety of beneficial use, including aquaculture/fishery.

7.2.3 Impact and Mitigation

1) Ecological Impact

Irreversible ecological change in the existing flood plains, predominantly in Greater Dhaka East, would result in consequent to the project implementation and the progressing change in land use to urban and others.

(1) General Ecology

The aquatic flora and fauna that is dominant in the existing low lands and flood plains will be replaced with terrestrial ones, other than in the proposed retarding areas and other water bodies. Moreover, with residential developments, even among the terrestrial species, those species of direct significance to human welfare will tend to predominate. The flood protected DND area depicts this state of ecological change, at present.

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(2) Productive Ecology

Potential loss to open water capture fishery in flood plains and beels is inevitable as a direct consequence of their dry-up by embankments. Though, the project will be beneficial to agriculture and culture fishery, the subsequent change in land use to urban will limit their development, other than in the reserved and retarding areas, and water bodies, an indirect effect.

2) Mitigatory Measures

The proposed mitigatory measures encompass both within and beyond the project area, the priority area (ref. Fig. 7.1). This is in consideration to the fact that Bangladesh as a whole is a delta with vast flood plains. Hence it is rational to undertake the mitigatory measures flexibly to suit the local conditions, as environment has no easily defined boundary.

(1) Measures within the priority area

(i) Establishment of an aquatic and terrestrial wild life sanctuary in Dhaka East, similar to the Mirpur botanical garden and zoo of Dhaka West shall be considered. Kaskara area adjacent to the proposed northern most retarding area (ref. Fig. 4.2), where the indicative land use in the year 2010 is agriculture, is a potential location recommended for detailed investigation.

(ii) Intensive agriculture and aquaculture in the reserved agricultural lands, retarding areas and other closed water bodies shall be practiced. Fish culturing and management technology, which is at a primitive level in comparison to agriculture, is in need of improvement in order to enhance the harvest biomass.

The above measures would compensate the inevitable ecological change imposed by the project to some extent.

(2) Measures beyond the priority area

It is emphasized that of the master plan area of 850 km^2, the low land flood plains demarcated for flood protection and subsequent urban development is confined principally to the Balu River flood plains of Dhaka East only. An area of about 328 km^2 in Keraniganj and Savar is proposed to remain as flood plain

242

management area with no urban development. Moreover, a high land rural area of about 43 km^2 in Savar also proposed to remain rural (ref. Fig. 10.1 of Chapter 10, Main Report, Master Plan), though there still remain vast flood plains even around the master plan area.

It is recommended that these rural master plan areas be targeted for conservation and development of ecology by future study programmes.

Finally in consideration to the availability of vast flood plains around the project area, and their potential to conservation and development of both the general and productive ecology, the limited irreversible environmental change that would occur in the future urban area is assessed to be insignificant, from a national view point.

7.3 Environmental Monitoring

7.3.1 Significance of Retarding Area

The proposed retarding areas of internal drainage and subsequent pumping are identified to be the most comprehensive future environmental monitoring stations of water quality. This is due to the fact that a retarding area would be temporary storage location of the whole surface run-off from the drainage basin concerned. Such surface run-off include the pollution load run-off due to all human and other related concerns such as domestic, institutional, industrial, agricultural and other activities.

Accordingly, the base line water quality under the existing conditions in the proposed retarding areas were monitored both during flood season (October 1991) and dry season (February 1992) at fifteen (15) locations. The sampling locations are shown in Fig.7.1. The water quality parameters measured respectively in field and in laboratory are the same as those of master plan study and itemized below.

(1) Field measurement :

Temperature, Colour, Odour, Turbidity, Ph, Electric Conductivity (EC) and Total Dissolved Solids (TDS).

(2) Laboratory measurement :

Suspended Solids (SS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Organic Nitrogen (Org-N), Ammonia Nitrogen (NH_4N), and Fecal Coliform Density (FC).

The results of water quality analysis of flood season and dry season are summarized respectively in Tables 7.1 and 7.2.

7.3.2 Water Quality Evaluation

The baseline water quality conditions as measured both during flood and dry seasons in the proposed retarding areas were evaluated based on the important beneficial uses of aquaculture, irrigation and other water contact activities.

It is to be noted that though most proposed retarding areas are just low lands and yet to serve their purpose, still three (3) sampling location in the Greater Dhaka West of FAP-8B project area, namely, location No. 12, 13, 14, already function as de facto retarding area to some extent due to the existing DFPP embankment constructed by GOB after the 1988 floods.

As expected, in an overall sense critical condition in water quality occurred under dry weather flow conditions, in dry season, during which the major composition of run-off is wastewater discharge. However, in some specific instances rainy season water quality may be deteriorated than that of dry season, in low-lying areas. This is because pollutants, that would otherwise be retained in or near the point of their generating source during dry season, are get washed off due to the availability of large quantity of rain-fall run-off.

The dry season water quality of Kesdanga bil and Trimohani khal (No. 7 and No. 8 in Fig. 7.1), which receive their run-off respectively via Segunbagicha cum Gerani khal from Motigheel commercial area, and Begunbari cum Gerani khal from almost the whole commercial and industrial area (Tejgaon) of Dhaka West, is extremely poor and sufficient to justify the necessity of urban pollution control measures.

The baseline water quality of the following eight (8) sampling locations are assessed to be suited for all major beneficial use, including aquaculture, on a year round basis, based on both the analysis results of rainy/flood and dry seasons.

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No.	Location No.	Name
(1)	2	Nayamati bil in DND
(2)	3	Kadamtoli pond in DND
(3)	4	Shimrail pond in Narayanganj West
(4)	5	Matuail khal in DND
(5)	6	Pagla pond in DND
(6)	9	Gazaria bil in Dhaka East
(7)	10	Baraid Bazar pond in Dhaka East
(8)	11	Dhamaahl bil in Dhaka East.

7.3.3 Recommendation on Monitoring

Institution of stream water quality monitoring station in the retarding areas, in the internal drainage channels (Khals) leading to those retarding areas and in the Balu-Lakya River, would become necessary with the implementation of this project. This will assist in formulating and implementing the necessary pollution control measures abreast the change in land use.

The parameters of monitoring shall be decided based on the inventory data of the existing sources of pollution load generation due to human living environment, industry and agriculture. However, it is strongly recommended to monitor at least all those living environment related water quality parameters, as measured by the Study Team. Additional parameters may be decided depending on the type of other industrial and agricultural activities in the drainage basin concerned. Begumbari khal at Rampura, the run-off of which includes the Tejgaon industrial area as well, is one such location for monitoring both the living environment and industrial pollutant.

The frequency of monitoring will depend on the degree of time series variation in water quality, but a minimum frequency of two (2) times a year, once each during dry season (December ~ February) and rainy season (July ~ September) is recommended in order to account for the maximum annual deviation in water quality.

Finally, it is to be emphasized that monitoring in itself is just a data collection process. Unless the derived data are translated into action programmes by the agency concerned, DOE, to identify and regulate the polluters, it has the danger of manifesting as a worthless effort of resource wastage.

Urban and industrial pollution control measures are the only means to render the internal drainage channels (khals) and retarding areas to be suited to a variety of beneficial use. Otherwise, they would simply serve as pollution transport, storage and discharge locations.

7.4 Living Environment

7.4.1 General

An inventory study covering the whole study area of master plan of 850 sq. km, which incorporated this priority area of 340 sq. km, concerning water supply, sewerage and sanitation and solid waste management, the prime living environment aspects, has already been presented in the master plan study (FAP-8A).

Most of the existing piped water service area, sewered area and solid waste service area (ref. Figs. 7.1, 7.2 of Master Plan), is encompassed within the priority area of this study. Hence, a supplemental living environment study targeting the on-site sanitation condition and its socio-economic aspects in the priority area was conducted.

7.4.2 Sanitation in Priority Area

1) Sewerage

The existing sewered area of DWASA, that covers about 33% of Dhaka City Corporation (DCC) area of 226 sq.km, is entirely encompassed by the Greater Dhaka area portion of the priority area of this study. This sewerage system is dealt with in details in Chapter 3 of Supporting Report F, Master Plan.

The sewerage system is estimated to serve only a 15% of the population even within its service area. Hence the whole objective area is principally dependent on some form of on-site sanitation system for human waste disposal.

2) Sanitation System

The population in the objective area are presently using various alternative methods or ways of human waste disposal such as septic tank, pit latrine/leaching pit, bucket latrine, katcha latrines (make-shift latrine) and public toilets and open defecation. There are no exact data available about sanitation system as no specific recent studies in the priority area was conducted.

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3) Socio-Economic Aspects of Sanitation

In the absence of no specific recent studies on sanitation, a sanitation survey conducted in Manikganj, a district town adjacent to Dhaka during August 1989, under the 18 District water supply and sanitation project in combination with information obtained from local authorities were used to determine the status of sanitation in relation to housing and income level. This is termed as socio economic aspects of sanitation.

It is determined that in Dhaka about 65% of population of high and medium income group with permanent and semi-permanent housings have adequate sanitation systems, being either sewered or having septic tanks. While, low income population of 30% with temporary housing have poor sanitation facilities like bucket latrine, makeshift latrine or no latrine.

This demonstrates the limitation of treating sanitation improvement measures as independent of overall socio economic community development, but still the priority to target low income communities for sanitation enhancement.

4) Operation and Maintenance

DWASA is responsible only for operation and maintenance of sewer system while DCC is responsible for all other sanitary facilities in Dhaka. In Narayanganj as there is no sewerage, municipality is the sole responsible organ for operation and maintenance of sanitary facilities. Due to improper operation and maintenance sewer line is blocked and broken in various places. There are even sewage disposal points towards low lands other than the designated Pagla Treatment Plant and are not at all maintained.

It is understood that at least 50% of the septic tanks and pit latrine are never desludged. Mostly hired cleaners do the desludging job. The average amount people pay to get their latrine or septic tank desludged/emptied is in the range of Tk. 300/= and Tk. 400/.

Operation and maintenance of sewerage and sanitation facilities require urgent attention of the concerned municipal authorities and DWASA.

5) On-going Sanitation Improvement Projects

A feasibility study of sanitation improvement was undertaken by ADB / UNDP under a sub-contract to the Housing Development Project (HDP) in 1985. The study comprised two study components namely Subcontract A and Subcontract B. Location of these study areas are as follows:

- Subcontract A, the old Dhaka project, involves the upgrading and development of sections of the oldest part of the city. The project is expected to be completed by 1997.

- Subcontract B, the Mirpur project, concentrates on the development/improvement of new urban areas in Mirpur, a relatively modern part of the city. The project is targeted for completion by 1994.

6) Sanitation Improvements Measures

The existing sanitary conditions and the available facilities and their operation and maintenance are very unsatisfactory.

The priority actions necessary for the improvement of sanitation are itemized below. They are elaborated in details under the FAP 8B comprehensive environmental management plan :

1. Organizing a public sector based scheme by the local authority like DCC/DWASA specifically on desludging of septic tanks.

2. Provision of twin leading pit toilets for low income population with makeshift or no toilet facilities.

3. Conversion of bucket latrines that remain into twin leaching pit type toilets and prohibition of construction of bucket latrines for new housings by the local authority concerned.

4. Education and campaign to increase the awareness of general population on the importance, means, and benefit of mitigating fecal-oral transmission of disease by adopting sanitary practice and customs.

7) Impact on Living Environment

269

The project in itself has only beneficial effects on living environment as flood mitigation and drainage measures contribute to public health improvements.

However the necessary means to meet the basic living environmental demands shall be taken up with progressing urbanization in the form of future water supply, sewerage and sanitation and solid waste management development programs.

7.5 Environmental Impacts and Remedial Measures

7.5.1 General

Environmental effects by the project will be predominantly beneficial though adverse to some extent. Specifically adverse effects would be social in nature that is felt by the immediate concerns in the vicinity of project implementation, such as those population displaced in making way for the project facilities and others.

These effects would be both of short term and long term and caused directly and indirectly by the project. Such effects are delineated below.

Both the significant direct and indirect environmental impacts by the project due to flood control and drainage and subsequent change in land use to urban and others are evaluated qualitatively in Table 7.3. An impact integer range from -3 to +3 is employed to represent respectively the maximum adverse and maximum beneficial effects. The necessity of future urban environmental improvement measures to realize a long term net benefit could be visualized from the above qualitative evaluation. Still, the project forms the basis of such measures.

It is emphasized that the direct benefits expected by the project implementation is overwhelming, for both the existing and future urban area of Dhaka, and the anticipated adverse effects in no way could justify the vice-versa.

7.5.2 Beneficial Effects

Major beneficial effects of short and long term realized by the project are summarized below.

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1) Short Term Effect

(1) Employment opportunity

Employment opportunities will be generated for construction works. In order to maximize such employment opportunities labour intensive methods will be adopted as far as possible. Also technical training opportunities are availed of for engineers/ technocrats.

2) Long Term Effect

(1) Flood damage mitigation

Mitigation of flood damage to properties, facilities and other economic activities will be realized, the basic reason for this project formulation. Also psychological stress and flood induced displacement of people will be eliminated.

(2) Enhanced land use potential

Enhanced land use potential of flood free lands for urban, institutional, industrial and agricultural uses would be realized. This will be reflected by increased land valve.

(3) Public health improvement

Public health improvement by mitigation of cross contamination of water resources inherent to flooding, and the resultant waterborne epidemics is very significant. Flood mitigation would also facilitate the applicability of on-site sanitation/human waste disposal means such as pit latrine/leaching pit.

(4) Generation of employment

Permanent employment along with technical training opportunities for operation and maintenance of the flood control and drainage facilities will be generated.

7.5.3 Adverse Effects

Significant adverse effects of short and long term are given below.

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1) Short Term Effect

(1) Severance

Severance in general implies inconvenience or difficulties which may be physical or psychological in nature experienced by those who are well adapted to the way of living under the conditions without project and are forced to re-adapt to the change in way of living imposed by the project. Such effects are interference to accessibility by embankments and flood walls.

(2) Navigation

Passenger and material transportation by boats is widely prevalent in the Greater Dhaka East during flood season, in the absence of any all weather land based road link between the Balu River and the Rampura-Biswa road.

However a compartmentalized development of the area would facilitate a gradual change over from water based to land based transportation with both functioning concurrently during the initial development stages. This would provide a time frame for those boatmen to switch over to alternative employment, thereby moderating the social impact.

(3) Construction effects

The construction activities involves earthen embankment by filling and compaction, khal improvements such as excavation and widening and pump stations.

The significant effect will be vibration and noise pollution and to some extent air pollution due to dust by the construction activities. However, embankment construction is widely practiced in Bangladesh, and the major embankment sites along Balu river and the retarding areas of pump stations are rural areas which means these effects will not be very significant.

2) Long Term Effect

(1) Resettlement

Resettlement of population displaced by land acquisition for the project, such as embankments and khals is an important negative social impact of the project. This is considered to be relatively long term in consideration to the movement and the subsequent adaptation involved by those moved. The cost of resettlement and compensation is incorporated as a negative benefit of the project.

(2) Living environment

This is a major indirect consequence by the project, due to subsequent urbanization and the resultant potable water, pollution load and solid waste generation by the increased population. The mitigatory measures are the provision of such basic public health amenities in future. In this regard, the water quality monitoring of retarding areas would help in assessing the change in condition and the required action with progressing urbanization.

(3) Change in land use on ecology

The existing agricultural and open water capture fishery lands, other than those retarding areas, would be changed to urban use in principle, another indirect consequence. Nevertheless, agricultural productivity and culture fishery will be enhanced in the flood protected lands, provided land is reserved for such uses. The retarding areas are suited for such uses at least during dry season.

Moreover, with progressing residential development, terrestrial homestead floral species and terrestrial domestic fauna species will become predominant in place of both the aquatic floral and fauna species and terrestrial fauna species of wild origin.

In consideration to the availability of vast flood plains around the priority area and their high cropping intensity in comparison to the priority area, effects of change in land use to urban in the priority area is assessed to be not very significant, with respect to both the general and productive ecological elements of flora, fauna, agriculture and aquaculture.

282

TABLE 7.1 FLOOD SEASON WATER QUALITY SAMPLING RESULTS IN RETARDING AREA (OCT. 1991)

Location		PH	EC	TDS	SS	DO	BOD	COD	Org - N	NH_4-N	FC
No.	Description		(Umho/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(No./100ml)
1	Shasongaon Kashipur	7.7	397	156	52	0.6	37	84	1.3	1.2	1.4×10^4
2	Nayamati Bil	7.0	260	134	34	4.9	0.8	16	0.7	1.0	7.1×10^3
3	Kadamtoli Pond	7.0	220	112	28	5.8	2.9	20	1.1	1.1	3.5×10^2
4	Shimrail Pond	7.2	190	97	26	2.9	4.0	8	1.4	1.3	1.0×10^4
5	Matuail Khal	7.0	120	64	32	3.1	5.7	12	0.7	1.4	9.0×10^4
6	Pagla Pond	7.0	380	193	42	2.3	8.5	20	1.1	1.1	1.3×10^3
7	Keodanga Bil Manda	7.0	167	84	26	7.4	4.2	24	1.8	0.2	9.0×10^3
8	Trimohani Khal	7.6	113	57	23	7.9	4.0	14	0.8	1.0	4.4×10^3
9	Gazaria Bil Mad	7.0	71	30	18	4.3	3.9	16	1.0	0.2	$<1.0 \times 10^2$
10	Baraid Bazar Pond	7.0	51	26	20	7.5	2.0	20	1.7	0.9	2.0×10^4
11	Dhamaahl Bil	7.3	49	25	15	7.1	2.0	12	1.2	0.1	8.0×10^3
12	Alakdi Khal Mirpur-12	7.1	166	83	32	5.1	0.7	16	1.6	0.5	2.5×10^3
13	Agunda Bil Mirpur-1	7.0	94	47	18	4.9	2.0	8	1.7	0.2	7.0×10^2
14	Gabtoli Bus Station Pond	6.9	218	109	32	5.8	4.0	12	2.0	1.5	5.7×10^3
15	Kamrangir Char	7.0	91	48	33	5.8	1.3	12	1.5	2.3	2.0×10^4

TABLE 7.2 DRY SEASON WATER QUALITY SAMPLING RESULTS IN RETARDING AREA (FEB. 1992)

Location No.	Location Description	PH	EC (Umho/cm)	TDS (mg/l)	SS (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Org - N (mg/l)	NH_4-N (mg/l)	FC (No./100ml)
1	Shasongaon Kashipur	7.0	406	203	42	4.4	1.0	12	1.1	0.4	2.2×10^{2}
2	Nayamati Bil	7.4	107	536	92	2.3	15	36	1.1	1.0	8.0×10^{2}
3	Kadamtoli Pond	7.3	480	239	52	6.0	2.9	12	1.1	1.5	7.0×10^{4}
4	Shimrail Pond	6.8	751	375	53	5.0	2.0	8	0.9	0.3	3.0×10^{4}
5	Matuail Khal	7.2	777	389	95	3.6	12	27	0.6	1.8	1.0×10^{2}
6	Pagla Pond	7.6	543	272	42	6.1	1.4	16	0.7	0.4	1.4×10^{3}
7	Keodanga Bil Manda	7.2	328	263	110	0	50	125	1.0	24.0	$1.8\ 10^{6}$
8	Trimohani Khal	7.6	261	230	105	0	55	175	1.9	18.5	2.7×10^{6}
9	Gazaria Bil Mad	7.0	394	197	88	4.6	2.4	12	0.5	0.2	8.0×10^{2}
10	Baraid Bazar Pond	7.0	382	191	45	6.1	0.7	8	0.6	1.5	1.2×10^{3}
11	Dhamaahl Bil	7.2	133	64	49	5.9	0.3	4	0.6	1.0	6.0×10^{2}
12	Alakdi Khal Mirpur-12	7.3	265	132	100	1.4	15	42	1.2	0.7	3.5×10^{4}
13	Agunda Bil Mirpur-1	6.9	785	392	24	7.1	1.6	8	0.4	4.3	1.4×10^{3}
14	Gabtoli Bus Station Pond	7.3	851	425	43	3.4	12	45	1.4	6.0	4.0×10^{2}
15	Kamrangir Char	7.4	558	279	22	2.7	7.7	10	0.4	15.5	3.0×10^{4}

28

TABLE 7.3 DIRECT AND INDIRECT ENVIRONMENTAL EFFECTS BY THE PROJECT

a) Direct Effect by Flood Control and Drainage

Item	Degree of Environmental Impact				Remarks
	Beneficial (+)		Adverse (-)		
	Short term	Long term	Short term	Long term	
1. Flood damage	-	+3	-	-	Major reason for project formulation
2. Landuse potential	-	+3	-	-	The principal benefit in future urban area
3. Employment	+3	+1	-	-	Construction employment benefit is short term while O/M is long term
4. Navigation	-	-	-1	-	Phased development of Greater Dhaka East will moderate the impact
5. Resettlement	-	-	-2	-1	Resettlement compensation is incorporated as a negative project benefit
6. Construction activity	-	-	-1	-	Better construction management will reduce even the short term impact
7. Aquatic wild flora and fauna	-	-	-	-1	Aquatic wildlife sanctuary/conservation is recommended
8. Terrestrial wild flora and fauna •	+2	-	-	-	Change in landuse to urban will exert long term effect
9. Agriculture •	+2	-	-	-	Change in landuse to urban will exert long term effect
10. Aquaculture/fishery •	-	-	-	-2	Effect due to dry up of flood plains of open water capture fishery
11. Public health •	+2	+1	-	-	Future urbanization and population increase will exert additional living environmental improvement demand.

b) Indirect Long Term Effect by Change in Landuse

Item	Degree of Environmental Impact (Long term)		Remarks
	Beneficial (+)	Adverse (-)	
8. Terrestrial wild flora and fauna •	-	-1	Terrestrial wildlife sanctuary/conservation is recommended
9. Agriculture •	-	-2	Effect due to change in agricultural landuse to urban and others
10. Aquaculture/fishery •	-	-1	Potential effect on culture fishery (aquaculture) due to change in landuse
11. Public health*•	(+2)	(-2)	Effect due to increased living environmental demand
12. Surface water quality*	(+3)	(-3)	Effect due to increased pollution load generation
13. Domestic flora of fauna	+2	-	Effect due to increased homestead plants and domestic animals with progressing residential development

Note : Evaluation point of impact is assigned qualitatively as an integer within the range of ±3

• An item encountered twice under both direct and indirect effects is treated as a single element

* The public health and surface water quality items are interrelated, and could be dealt with integrally as future living environmental and water quality improvement projects of water supply, sewerage and sanitation and solid waste management. Such measures are conditional in order to realize a long term urban environmental benefit.

288

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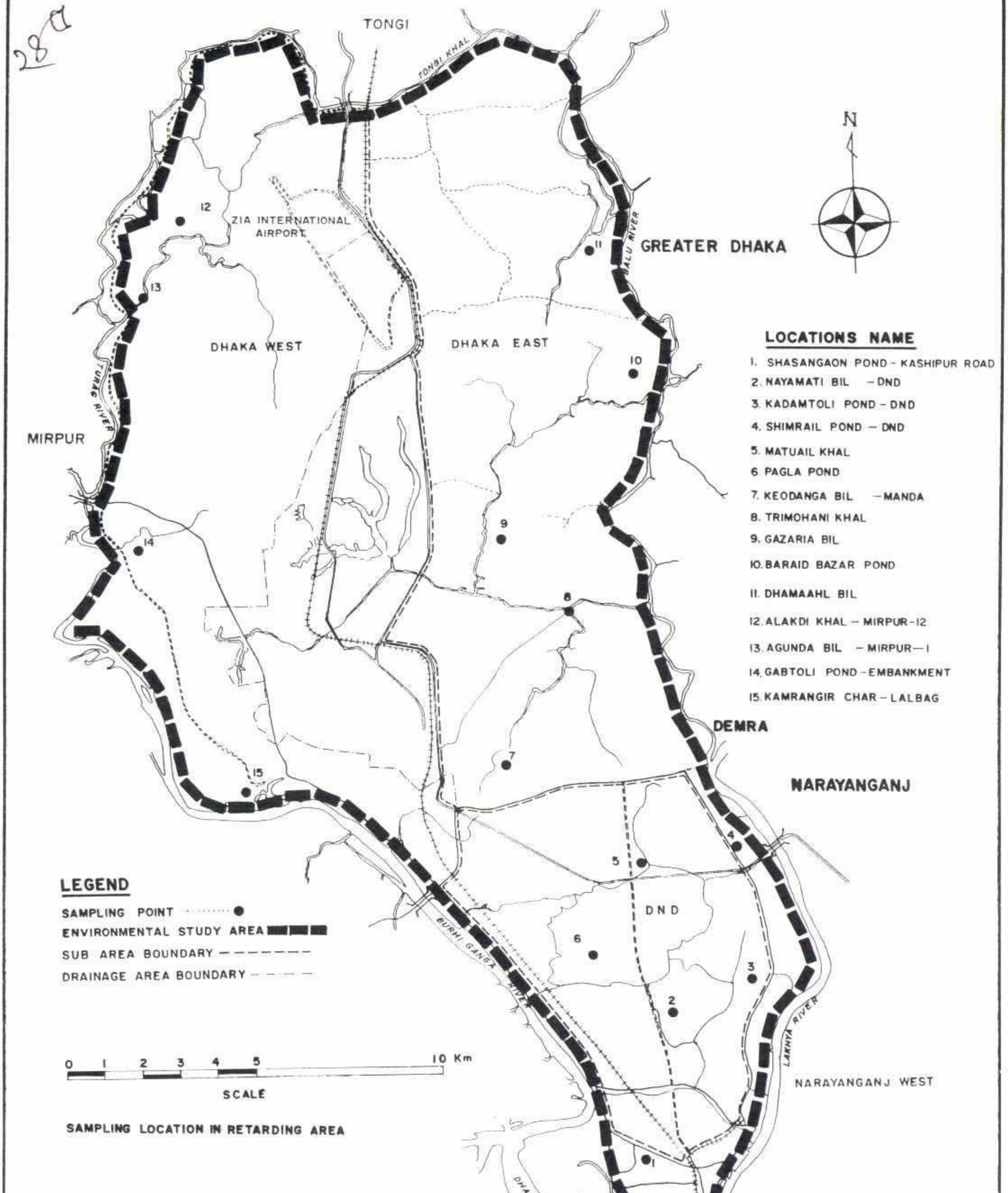

FIG. 7.1 WATER QUALITY SAMPLING LOCATION IN PRIORITY AREA

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

285

CHAPTER 8
OPERATION AND MAINTENANCE

Chapter 8 : Operation and Maintenance

8.1 General

The operation and maintenance (O & M) measures of the project are routine activities to get the expected benefits with the project. The flood mitigation and drainage improvement facilities, once completed, will encourage people to settle in areas where formerly they would not have settled because of a high risk of flooding. Accordingly inadequate O & M activities could lead to even a high risk of greater damage to life and property than without the project. The proper O & M activities will be indispensable for achievement of the project goals.

Although poor O&M activities widely pronounced and also budget constrictions are the most frequently sited constraint on O&M reported by the GOB.

The poor quality of O&M likely results partly from lack of finance, partly from lack of proper O&M programs.

An optimum O & M program should be prepared by BWDB / DWASA, before implementation of the project.

8.2 Basic Concept

Basic O & M demands for the flood mitigation and drainage improvement facilities are summarized as follows :

(1) The tasks and responsibilities of the O & M divisions of BWDB, DWASA and Narayanganj Municipality which are in charge of the O & M activities of the project, should be defined clearly.

(2) An active local participation should be considered in field level O & M activities or routine maintenance works. It will likely enhance a sense of public duty among local people and also increase employment opportunities for low income or landless people.

(3) Practical O & M manuals and routine programs should be prepared by the BWDB engineers concerned for the project before implementation of the project.

288

(4) Periodical training programs should be prepared for the GOB staff in supervision of the construction works of flood mitigation facilities and their O & M.

(5) Collaboration and coordination among the operating and the implementing agencies and other government agencies, should be improved in order to minimize adverse impacts and avoid operational conflicts.

(6) The budget constraints should be solved before implementation of the project. Everyone in Dhaka Metropolitan area would get benefit from flood protection measures. Everyone should in principle contribute towards cost.

8.3 O & M Demands for Major Facilities

8.3.1 Greater Dhaka East

1) Responsibilities for O & M

The responsible agencies for O & M activities are :

Facility	Responsible Agency	Assisting group
Flood Embankment / Flood wall	BWDB	Local participants
Drainage Pump / Sluice	BWDB	Local participants
Khal / Drainage channel	DWASA	Local participants

The O & M divisions of BWDB should be fully responsible to required O & M activities for flood mitigation facilities including drainage pumps, sluices and retarding areas. Similarly the O & M divisions of DWASA have full responsibility to O & M to drainage channels and pipes. Local people who live in unions or wards wherein facilities are located, had better be involved in routine O & M activities as assisting groups.

In general, people who share a common interest in O & M activities of flood mitigation facilities would participate in the creation of associations which will enable them to better deal with their water related problems at the bottom level.

Their responsibilities would cover both operation of the sluices and routine maintenance of the embankments / khals serving them.

2) Tasks and Responsibilities

Tasks and Responsibilities of BWDB and DWASA are as follows :

- to employ and organize O & M assisting groups of local people through the unions or wards wherein facilities are located,
- to prepare an optimum O & M manual and a routine O & M program,
- to provide local participants with proper training and guidance,
- to carry out major actions including repairing where necessary, according to the field surveys,
- to operate pumps and sluices according to an operation manual which should be prepared during the detailed study stage.

Tasks and Responsibilities of Assisting Groups are :

- to carry out year - round maintenance of embankments and their O & M roads including repair patching of surface, side slopes and wheel cuts created by vehicles under the guidance of BWDB's field staff.
- to operate and maintain sluices according to the guideline prepared by BWDB,
- to report conditions of embankments, damages, erosion, sliding, failures etc.

3) Routine O & M Activities

The routine O & M demands of the major facilities are as follows :

- Embankment
- Flood Wall
- Sluice
- Drainage Channel / pipe
- Pump Station
- Retarding Area

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4) Guidelines for Operation of Pumps and Sluices

For flood mitigation purposes, the pumps and sluices are planned to be operated according to the following concepts :

(1) The sluices along the Balu River, i.e. G. 16, G. 17, G. 18A and B, are planned to be closed for approximately five (5) months from June through October, when the river stage is higher than 3.00 m (PWD).

The river stage normally starts to rise in March, 3.00 m (PWD) around May to June, 5.00 m to 6.00 m in August to September, starts to fall in September, 3.00 m in approximately in November, and becomes the lowest stage in February.

(2) The pumps along the Balu River, i.e. P. 5, P. 6, P. 7A and B, are planned to control the water levels in land side between 3.00 m and 4.00 m (PWD) during the flood season. The pumps are designed to have a capacity to meet the flood stage of a 100-year flood frequency.

The pumps are planned to start operation when the water levels in land side start to rise due to the flood runoff from their own catchment areas.

The concept is based on flood mitigation and drainage improvement purposes. Then the proposed guideline might be reviewed and revised, if necessary, according to the results of further studies on productive uses of water resources in future.

5) Required O & M Organization

The executive engineer's office and sub-divisional engineer's offices which are planned to be established for implementation of the project, will be shifted to O & M offices after completion of the works.

The required O & M offices are planned to be as follows :

(1) The O & M activities for embankments and related facilities, are conducted under the executive engineer's office of Dhaka II (BWDB), through two new sub-divisional engineer's offices in the field. The field level routine activities are to be conducted by crews of local participants.

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(2) The O & M activities for drainage channels, are conducted under the executive engineer's office of DWASA, through a new sub-divisional engineer's office in the field. The field level routine activities are also be conducted by crews of local participants.

(3) For O & M activities of pumps and sluices

It is necessary to establish one superintending engineer's office, executive engineer's office and four new sub-divisional engineer's offices.

The proposed O & M organization for Greater Dhaka East is shown in Fig. 8.1 and required crew of each office are shown in Tables 8. 1 to 4.

8.3.2 DND

1) Responsibilities for O & M

The O & M divisions of BWDB should have a full responsibility for the flood mitigation and drainage improvement facilities, and local people should be involved in routine O & M activities as an assisting group.

2) Tasks and Responsibilities

The tasks and responsibilities of the government agencies and the local assisting groups are the same as those of the Greater Dhaka East.

3) Routine O & M Activities

They are the same as those for the Greater Dhaka East

4) Guidelines for Operation of Pumps and Sluices

For flood mitigation purposes, the pumps and sluices are planned to be operated according the following concepts :

(1) The sluices i.e. G. 19 and G. 20, are planned to be closed when the river stage is higher than 3.00 m (PWD),

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(2) The pumps are planned to control the water level in land side between 3.00 and 4.00 m (PWD).

5) Required O & M Organization

The sub-divisional engineer's office for implementation of the project, will be converted to the O & M office.

For O & M activities for the pump drainage system, the existing sub-divisional office is to be reinforced, up to the same scale as that of Table 8.4. O & M activities for embankment and drainage channels are to be done by local participants under the guidance of the sub-divisional engineer's office of Dhaka II, that is planned for the Greater Dhaka East (Fig. 8.1(2)).

8.3.3 Narayanganj West

1) Responsibilities for O & M

The O & M division of BWDB should have a full responsibility for the flood mitigation facilities, including pumps, sluices and stop logs. Narayanganj municipality should have a full responsibility for drainage channels. Local people should be involved in routine O & M activities as assisting groups.

2) Tasks and Responsibilities

The tasks and responsibilities of the government agencies and the local assisting groups are the same as those for the Greater Dhaka East.

3) Routine O & M Activities

They are the same as those for the Greater Dhaka East.

4) Guide line for Operation of Pumps and Sluices

For flood mitigation purposes, the pumps and sluices are planned to be operated according to the following concepts :

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(1) The sluice of G. 21 and G. 22 are planned to be closed when the river stage is higher than 3.00 m (PWD), but the sluices of G. 23 ~ G. 32, G. 32A and are to be closed when the river stage is higher than 3.50 m (PWD),

(2) The pumps of P. 12 and P. 13 are planned to control the water level in land side between 3.00 and 4.00 m, but the pumps of P. 14A and B are planned to control the water level between 3.50 m and 4.50 m (PWD).

5) Required O & M Organization

The sub-divisional engineer's office for implementation of the project will be converted to the O & M office.

For O & M activities for pumps and sluices, on sectional office will be required (Table 8.5).

Routine O & M activities for embankments and flood walls are to be conducted by local participants under the guidance of the sub-divisional engineer's office of Dhaka - II.

But O & M activities for drainage channels are to be conducted by local participants under Narayanganj Municipality's office (Table 8. 6 and Fig. 8.1(2)).

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Table 8.1 O & M Executive Engineer's Office and Sub-divisional Engineer's Office Drainage Channels (DWASA)

		Executive Engr's Office	Sub-divisional Engr's Office
1.	Executive Engineer	1	-
2.	Sub-divisional Engineer	1	1
3.	Sub-Assistant Engineer	1	2
4.	Head Assistant	1	-
5.	Estimator	1	-
6.	Assistant Accountant	1	-
7.	Draftsman	1	-
8.	Surveyor	-	2
9.	Cashier	1	-
10.	LDA Cum Typist	1	-
11.	Work Assistant	-	6
12.	Line Cleaner	-	6
13.	Driver	-	1
14.	Night guard	1	1
15.	MLSS	1	1
16.	Sweeper	-	1
	Total :	11	21

Note : 1) Annual expense for each Executive engr's office: Tk. 884,200
Sub-divisional engr's office : Tk.1,366,900
(including personnel expenses, office expenditure)

Table 8.2 O & M Executive Engineer's Office and Sub-divisional Engineer's Office for Embankment (BWDB)

		Executive Engr's Office	Sub-divisional Engr's Office
1.	Executive Engineer	1	-
2.	Sub-divisional Engineer	1	1
3.	Sub-Assistant Engineer	1	2
4.	Surveyor	-	2
5.	Draftsman	1	-
6.	Tracer	1	-
7.	LDA Cum Typist	2	1
8.	Senior Accountant	1	-
9.	Accountant Assistant Cum Typist	1	1
10.	Driver	-	1
11.	Guard	-	1
12.	MLSS	1	1
13.	Messenger	-	1
14.	Sweeper	-	1
	Total :	10	12

Note: 1. Executive Engr's office : one
2. Sub-divisional Engr's office : two
3. Annual expense for each Executive Engr's office : Tk. 736,500
Sub-divisional engr's office Tk. 700,100

Table 8.3 O & M Sub-divisional for the Pump drainage System of Pump Station, P5

(BWDB)		Sub-divisional Engineer's
1.	Sub-divisional Engineer	1
2.	Sub-Assistant Engineer (Mech.)	2
3.	Sub-Assistant Engineer (Elect.)	1
4.	Foreman (Mechanical)	1
5.	Mechanic	2
6.	Electrician	2
7.	Helper	2
8.	Sub-divisional Clerk	1
9.	Account Clerk	1
10.	Typist	1
11.	Office Peon	1
12.	Pump Operator	3
13.	Driver	1
14.	Sweeper Cum Mali	1
15.	Security Guard	3
15.	Khalasi / Labour	3
	Total :	26

Note : 1) Annual expenses : Tk. 1,331,700 (not including operation cost)

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Table 8.4 O & M Sub-divisional Engineer's Office for the Pump drainage System of Pump Station, P6 (m)

(BWDB)		Sub-divisional Engineer's
1.	Sub-divisional Engineer	1
2.	Sub-Assistant Engineer (Mech.)	2
3.	Sub-Assistant Engineer (Elect.)	2
4.	Foreman (Mechanical)	1
5.	Mechanic	1
6.	Assistant Mechanic	1
7.	Assistant Mechanic	1
8.	Electrician	1
9.	Assistant Electrician	1
10.	Assistant Electrician	1
11.	Pump Operator	4
12.	Helper	4
13.	Khalashi / Labour	6
14.	Security Guard	6
15.	Sub-divisional Clerk	1
16.	Account Clerk	1
17.	Store Keeper	1
18.	Typist	1
19.	Driver	1
20.	Office Peon	1
21.	Sweeper Cum Mali	1
22.	Barkan door	1
	Total :	40

Remark : 1) Apply for pump capacity is 47 to 54 m^3/s
2) This is also applied to pump stations, P.7A and B.
3) Annual expenses : Tk. 1,901,000 (not including operation cost)

Table 8.5 O & M Sectional Officer's Office for Pump Drainage Systems Narayanganj West

Sub-Assistant Engineer (Mech.)	1
Mechanic	1
Electrician	1
Assistant Electrician	1
Pump Operator	3
Helper	2
Khalasi / Labour	3
Sweeper Cum Mali	1
Security Guard	3
Total :	16

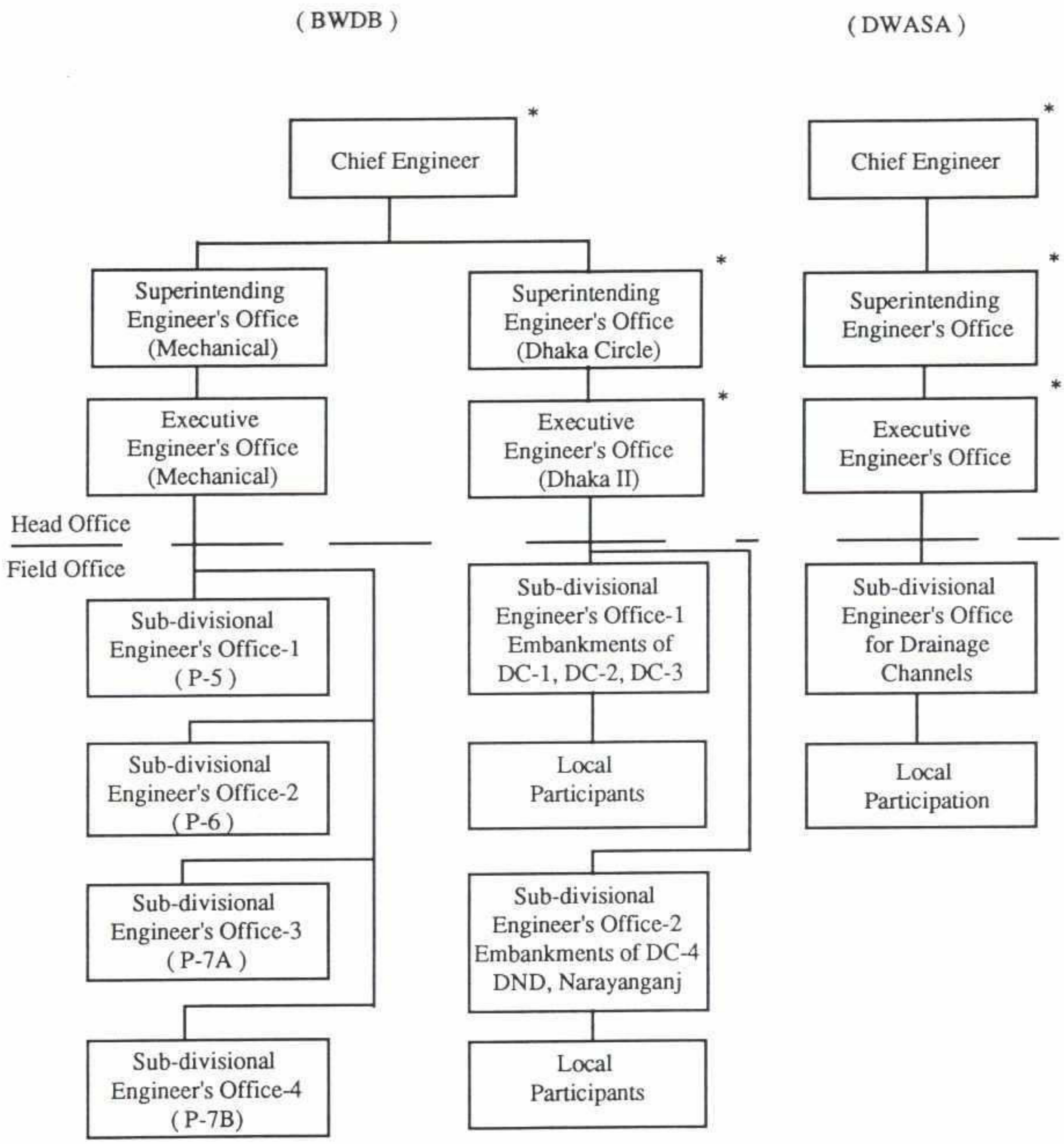
Note : 1) Annual expenses : Tk. 1,331,700 (not including operation cost)

Table 8.6 O & M Executive Engineer's Office and Sub-divisional Engineer's Office Narayanganj Municipality

		Executive Engr's Office	Sub-divisional Engr's Office
1.	Executive Engineer	1	-
2.	Sub-divisional Engineer	1	1
3.	Sub-Assistant Engineer	1	2
4.	Accounts Assistant Cum Clerk	1	1
5.	LDA Cum Typist	1	1
6.	Line Cleaner	-	4
7.	Driver	-	1
8.	Sweeper	-	1
9.	MLSS cum Messenger	1	2
10.	Night Guard	-	1
	Total :	6	14

Note: 1. Annual expenses
Executive engr's office : Tk. 516,800
Sub-divisional engr's office: Tk. 730,000

Required O&M Organization for Greater Dhaka East



Note : * Existing Office

FIG. 8.1(1) REQUIRED O&M ORGANIZATION FOR GREATER DHAKA EAST

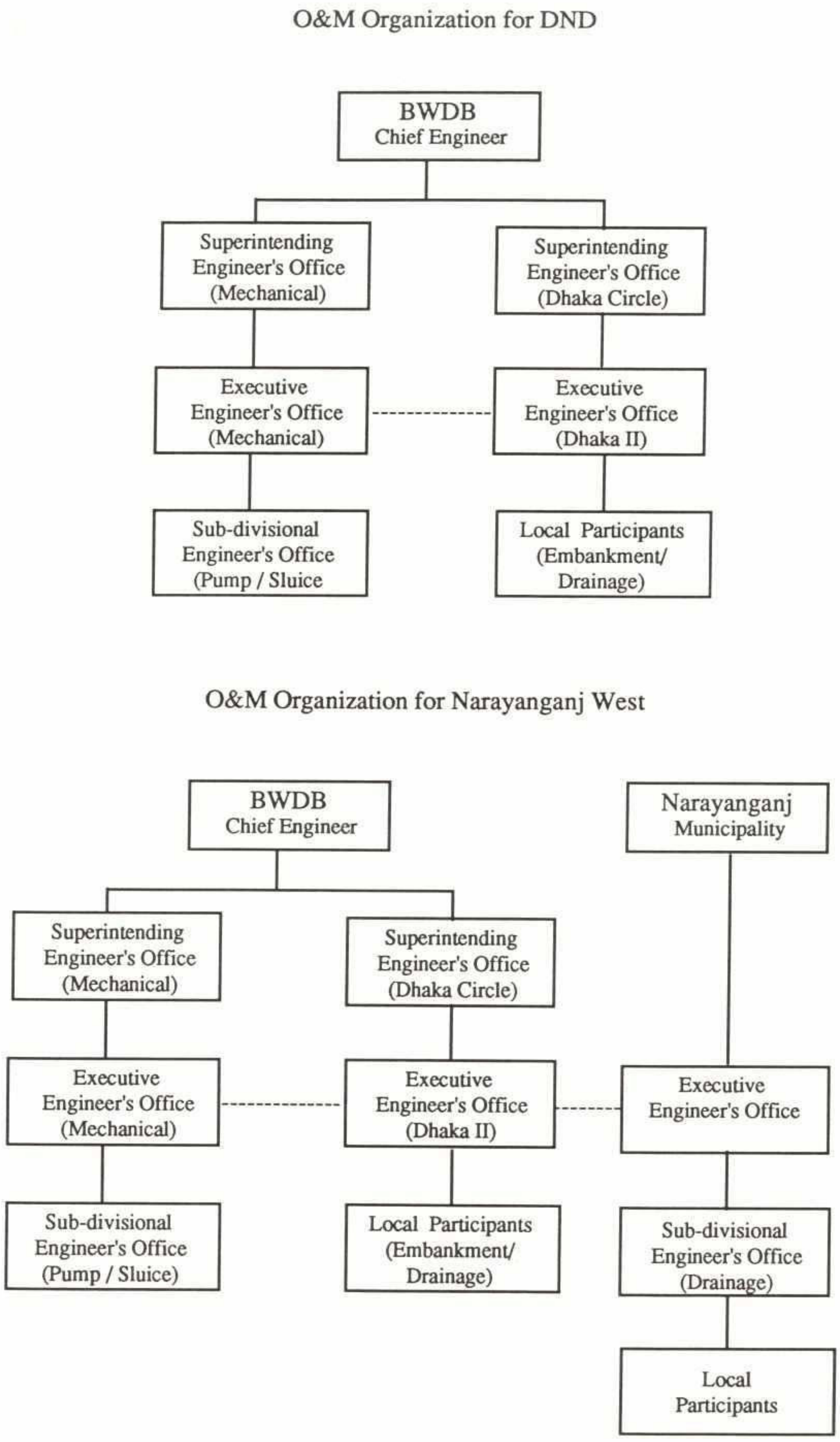


FIG. 8.1(2)	REQUIRED O&M ORGANIZATION FOR DND AND NARAYANGANJ WEST

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

CHAPTER 9
COST ESTIMATE

Chapter 9 : Cost Estimate

9.1 Basic Conditions

The project costs are estimated based on the preliminary designs, the proposed construction schedules and the following considerations.

(1) Component of the project cost

The project cost is composed of "direct costs", "indirect costs" and "contingency". They consist of the followings :

a) Direct Cost :

- Construction costs
- Procurement and installation costs for equipment

b) Indirect cost :

- Land acquisition and compensation costs
- Administration costs,
- Engineering service costs.

c) Contingency :

- Physical contingency.

(2) Price Level

The unit price and cost are estimated based on prevailing market prices in Dhaka in Taka during October, 1991, referring BWDB'S Standard Schedule of Rates.

(3) Mode of Contract

The construction works will be contracted to general contractors through international tenders.

(4) Currency Portion

The costs are divided into foreign currency and local currency portions as follows :

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(a) Foreign currency portion (FC)

- Imported equipment and material.
- Overhead for contractors,
- Expense of expatriate personnel

(b) Local currency portion (LC)

- Equipment and material available in the local marked,
- Land acquisition and compensation,
- Expense of local personnel,
- Overhead for local firms,
- Tax and tariff.

(5) Exchange Rate

The exchange rates of foreign currencies applied are :

Tk. 36 = US\$ 1.0 = ¥ 137

(6) Indirect Cost

The land acquisition and compensation costs are based on prevailing market price. However the others are estimated on the following assumptions :

(a) Administration cost : 3% of base construction costs,
(b) Engineering service cost : 10% of base construction costs plus physical contingency,

(7) Contingency

Physical contingency : 15% of base construction costs.

(8) Unit Price

The unit prices of labor, material and equipment are estimated based on prevailing market prices referring the data collected from BWDB and other agencies concerned. The unit costs of the construction works are divided into foreign currency portion and local currency portion based on the current data applied to similar projects.

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(9) O & M Cost

Routine O & M costs are estimated on a crew-month basis for O & M activities to be established. O & M for minor civil works are estimated at 1.0 ~3.0% of the capital investment costs. Also the operation costs and replacement cost of equipment are estimated.

(10) Customs Duty and Sales Taxes (CDST)

Most of the construction material are available locally, however particular equipment and material such as pump, gate, sheet pile, form steel, geotextile etc., must be imported. It is considered that the CDST for those imported equipment and material will be borne by the GOB and it will be exempted from the contractor's contract as it is being funded by the foreign aid program. The amount for CDST are estimated and shown in the following tables.

9.2 Project Cost

9.2.1 Greater Dhaka East

The total project cost is estimated at Tk. 18,296 million (F/C : Tk. 9,561 million, L/C : Tk. 8,735 million) and summarized as follows :

	Item		F/C	L/C	Total
1.	Construction Cost		7,558	3,358	10,916
	1)	Flood Mitigation	(3,732)	(1,964)	(5,696)
	2)	Drainage improvement	(3,826)	(1,394)	(5,220)
2.	Indirect Cost				
	1)	Land Acquisition/compensation	0	1,487	1,487
	2)	Administration	0	328	328
	3)	Engineering service	869	387	1,256
3.	Physical contingency		1,134	501	1,635
4.	CDST & Tax		0	2,674	2,674
	Total		9,561	8,735	18,296

The project cost of each compartment is shown in Tables 9.1.1(1) to (4).

228

9.2.2 DND

The total project cost is estimated at Tk. 4,594 million (F/C : Tk. 2,203 million, L/C : Tk. 2,391 million) and shown as follows:

	Item	F/C	L/C	Total
1.	Construction Cost	1,742	914	2,656
	1) Flood Mitigation	(82)	(32)	(114)
	2) Drainage improvement	(1,660)	(882)	(2,542)
2.	Indirect Cost			
	1) Land Acquisition/compensation	0	400	400
	2) Administration	0	80	80
	3) Engineering service	200	105	305
3.	Physical contingency	261	137	398
4.	CDST & Tax	0	755	755
	Total	2,203	2,391	4,594

Detailed costs are shown in Table 9.2.1

9.2.3 Narayanganj West

The total project cost is estimated at Tk. 4,097 million (F/C : Tk. 1,797 million, LC : Tk. 2,300 million) and shown as follows :

	Item	F/C	L/C	Total
1.	Construction Cost	1,421	633	2,054
	1) Flood Mitigation	(757)	(302)	(1,059)
	2) Drainage improvement	(663)	(331)	(994)
2.	Indirect Cost			
	1) Land Acquisition/compensation	0	1,082	1,082
	2) Administration	0	62	62
	3) Engineering service	163	73	236
3.	Physical contingency	213	94	307
4.	CDST	0	356	356
	Total	1,797	2,300	4,097

The detailed costs are shown in Table 9.3.1.

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TABLE 9.1.1(1) PROJECT COST OF DHAKA EAST (DC-1)

Unit : Million TK (1991Price)

Phase / Project Area	Construction Cost (x10^6) F/C	L/C	Total	Remarks
A.Construction Cost	2,332	1,127	3,459	
1.Flood Mitigation	1,675	852	2,527	
1).Embankment	1,541	800	2,340	Ref. H.3.13
2). Flood Wall	15	8	22	Ref. H.3.14
3).Sluice Gate	120	45	165	Ref. H.3.15
4).Related.Struc.Etc	0	0	0	
2.Storm Water Drainage	657	275	932	
1).Pump Sta.	513	121	634	Ref. H.3.17(1)
2).Khal Improve.	136	144	280	Ref. H.3.18
3).Bridge,Etc	7	10	17	Ref. H.3.19
B.Physical Contingency	349	169	518	Ax15%
C.Engineering	268	130	398	(A+B)x10%
D.Administration	0	104	104	Ax3%
E.Land Aquisition & Compensation	0	565	565	Ref. H.3.11
F. CDST & Tax	0	572	572	Ref. H.3.12
Total	2,949	2,667	5,616	

TABLE 9.1.1(2) PROJECT COST OF DHAKA EAST (DC-2)

Unit : Million TK (1991Price)

Phase / Project Area	Construction Cost (x10^6) F/C	L/C	Total	Remarks
A.Construction Cost	1,705	686	2,391	
1.Flood Mitigation	658	362	1,020	
1).Embankment	576	328	905	Ref. H.3.13
2). Flood Wall	16	8	24	Ref. H.3.14
3).Sluice Gate	66	26	92	Ref. H.3.15
4).Related.Struc.Etc	0	0	0	
2.Storm Water Drainage	1,047	324	1,371	
1).Pump Sta.	946	218	1,163	Ref. H.3.17(1)
2).Khal Improve.	101	106	208	Ref. H.3.18
3).Bridge,Etc	0	0	0	Ref. H.3.19
B.Physical Contingency	256	102	358	Ax15%
C.Engineering	196	79	275	(A+B)x10%
D.Administration	0	72	72	Ax3%
E.Land Aquisition & Compensation	0	272	272	Ref. H.3.11
F. CDST & Tax	0	706	706	Ref. H.3.12
Total	2,157	1,917	4,074	

TABLE 9.1.1(3) PROJECT COST OF DHAKA EAST (DC-3)

Unit : Million TK (1991Price)

Phase / Project Area	Construction Cost (x10^6) F/C	L/C	Total	Remarks
A.Construction Cost	1,667	661	2,328	
1.Flood Mitigation	664	361	1,025	
1).Embankment	594	335	930	Ref. H.3.13
2). Flood Wall	10	5	16	Ref. H.3.14
3).Sluice Gate	60	20	80	Ref. H.3.15
4).Related.Struc.Etc	0	0	0	
2.Storm Water Drainage	1,002	300	1,303	
1).Pump Sta.	927	206	1,133	Ref. H.3.17(1)
2).Khal Improve.	76	94	170	Ref. H.3.18
3).Bridge,Etc	0	0	0	Ref. H.3.19
B.Physical Contingency	250	98	348	Ax15%
C.Engineering	192	76	268	(A+B)x10%
D.Administration	0	70	70	Ax3%
E.Land Aquisition & Compensation	0	238	238	Ref. H.3.11
F. CDST & Tax	0	709	709	Ref. H.3.12
Total	2,109	1,852	3,961	

TABLE 9.1.1(4) PROJECT COST OF DHAKA EAST (DC-4)

Unit : Million TK (1991Price)

Phase / Project Area	Construction Cost (x10^6) F/C	L/C	Total	Remarks
A.Construction Cost	1,854	884	2,738	
1.Flood Mitigation	735	389	1,124	
1).Embankment	655	359	1,013	Ref. H.3.13
2). Flood Wall	19	10	29	Ref. H.3.14
3).Sluice Gate	61	20	81	Ref. H.3.15
4).Related.Struc.Etc	0	0	0	
2.Storm Water Drainage	1,120	495	1,614	
1).Pump Sta.	914	208	1,121	Ref. H.3.17(1)
2).Khal Improve.	202	282	484	Ref. H.3.18
3).Bridge,Etc	4	5	9	Ref. H.3.19
B.Physical Contingency	279	132	411	Ax15%
C.Engineering	213	102	315	(A+B)x10%
D.Administration	0	82	82	Ax3%
E.Land Aquisition & Compensation	0	412	412	Ref. H.3.11
F. CDST & Tax	0	687	687	Ref. H.3.12
Total	2,347	2,298	4,645	

TABLE 9.2.1. PROJECT COST OF DND

Unit : Million TK (1991Price)

Phase	Construction Cost (x10^6)			Remarks
Project Area	F/C	L/C	Total	
A.Construction Cost	1,742	914	2,656	
1.Flood Mitigation	82	32	114	
1) Flood.Wall Works	32	18	50	Ref. H.3.23
2)Sluice Gate	49	13	62	Ref. H.3.24
3)Related.Struc.Etc	2	1	3	Ref. H.3.25
2.Storm Water Drainage	1,660	882	2,542	
1).Pump Sta.	1,144	219	1,363	Ref. H.3.26
2).Khal Improve.	467	593	1,059	Ref. H.3.27
3).Bridge,Etc	49	70	119	Ref. H.3.28
B.Physical Contingency	261	137	398	Ax15%
C.Engineering	200	105	305	(A+B)x10%
D.Administration	0	80	80	Ax3%
E.Land Aquisition &	0	400	400	Ref. H.3.21
Compensation				
F. CDST & Tax		755	755	Ref. H.3.22
Total	2,203	2,392	4,594	

TABLE 9.3.1 PROJECT COST OF NARAYANGANJ WEST

Unit : Million TK (1991Price)

Phase	Construction Cost (x10^6)			Remarks
Project Area	F/C	L/C	Total	
A.Construction Cost	1,421	633	2,054	
1.Flood Mitigation	757	302	1,060	
1).Embankment	478	208	686	Ref. H.3.32
2). Flood Wall	159	52	211	Ref. H.3.33
3) .Sluice Gate	120	42	162	Ref. H.3.34
4) .Related.Struc.Etc	1	0	1	Ref. H.3.36
2.Storm Water Drainage	663	331	994	
1).Pump Sta.	440	96	536	Ref. H.3.37
2).Khal Improve.	216	223	439	Ref. H.3.39
3).Bridge,Etc	8	12	19	Ref. H.3.40
B.Physical Contingency	213	94	307	Ax15%
C.Engineering	163	73	236	(A+B)x10%
D.Administration	0	62	62	Ax3%
E.Land Acquisition &	0	1,082	1,082	Ref. H.3.30
Compensation				
F. CDST & Tax	0	356	356	Ref. H.3.31
Total	1,797	2,299	4,097	

CHAPTER 10
IMPLEMENTATION PROGRAM

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Chapter 10 : Implementation Program

10.1 General

The overall coordination for the project will be provided by the Ministry of Irrigation, Water Development and Flood Control (MIWDFC), and the execution of the Project will be the responsibility of the BWDB, which will be the lead Project Executing Agency. The other implementing agencies will be DWASA and Narayanganj Municipality. RAJUK and DOE will be involved in supportive roles such as land use management and environmental monitoring.

The construction works consist of embankment, flood wall, sluice gate, pump station, Khal improvement, box culvert, bridge works etc. for flood mitigation and storm water drainage improvement works. It is assumed that the detailed designs and construction works will be executed by international competitive bidding basis and completed by the target year of 2010.

The urban planning of the priority areas lags behind, as the Metropolitan Development Plan Study for Dhaka was commenced by RAJUK only in April, 1992. Nevertheless the study will prepare an integrated development plan for the area. The results of the study should be referred to before the implementation of storm water drainage improvement facilities.

The implementation program for the project is based on the following :

(1) The proposed flood mitigation and storm water drainage improvement works will be complete by the target year of 2010.

(2) The phased implementation programs proposed in the Master Plan Study, was reviewed from economical efficiency, social and environmental aspects, and modified in order to get a higher economic efficiency and to avoid adverse social impacts as much as possible.

(3) The other on-going project or committed projects, if any, will be considered to ensure consistency with the proposed phased implementation programs.

290

(4) Though three project components of the Greater Dhaka East, the DND and the Narayanganj West, were identified in the Master Plan Study for F/S areas, the Greater Dhaka East is divided into four compartments, considering effectiveness against floods, and easiness for O & M and economic efficiency.

The Greater Dhaka East is divided into the following four compartments :

1. Northern Compartment
2. Central Compartment
3. Southern - 1 Compartment
4. Southern - 2 Compartment

10.2 Basic Conditions

For preparing an optimum implementation program of the project, the following considerations have been taken as the basic concept of project implementation.

(1) Preparation of Detailed Design

The detailed design for major facilities shall be carried out under the management of international consultants according to the design concept.

The Metropolitan Development Plan study for the Greater Dhaka area has already been started by RAJUK in April, 1992. It is recommended to update and modify the proposed measures, if necessary, according to the study results.

(2) Mode of Construction

The construction works shall be carried out by contractors selected through international competitive bidding under supervision of international consultants.

(3) Workable Days and Working Hours

Standard workable days for respective works will be estimated based on river stages, daily rainfall records, Friday, national holidays and experience of similar works in and around the area. The annual workable days for earthwork and concrete work are assumed to be approximately 130 days from November to April, and 160 days from October to June respectively. Daily working hours is set at 9 hours with 1-hour overtime by considering the local working style in the area.

(4) Availability of Construction Plant and Equipment

Heavy construction equipment required for concrete work or earthwork are not available in the local market. However the construction works are planned to be carried out partly by heavy construction equipment with due consideration of the magnitude of work volume, the limited construction period and the quality of works.

(5) Arrangement of Borrow-pit

Borrow-pits for construction of the embankments shall be arranged nearby along the new alignment. While sand for the foundation treatment is to be brought from the places, as designated in the tender documents.

However the method of land fill by dredging should be studied when it become possible to develop a certain large area simultaneously as a result of the Metropolitan Development Plan study, because the method of land fill by dredging is generally feasible in economic terms.

(6) Construction Materials

Concrete materials, round and deformed type of reinforcing steel bars are available in the local market. However the shape steel such as H-steel, T-steel, and geotextile are yet to be available in the local market.

Local materials shall be used as much as possible.

(7) Work Items and Quantities

- Preparatory and Other Temporary Works

  The works will be considered as lump sum basis.

- Major Works of Flood Mitigation

292

The construction comprises the following major works :

(a) Embankment / Sub-Embankment
(b) Flood Wall
(c) Sluice Gate
(d) Land Lock

- Major Works of Storm water Drainage

(a) Pump Station
(b) Khal Improvement
(c) Box Culvert/Bridge

The above work items include rehabilitation of the existing facilities and temporary works.

10.3 Implementation Schedule

10.3.1 Greater Dhaka East

The implementing agency for flood mitigation and related facilities such as pumps and sluices will be BWDB, while DWASA will be responsible for Khal and drainage improvements.

The Greater Dhaka East is divided into four compartments and planned to be implemented in phases compartment by compartment with progressing urbanization. However the entire projects will be completed by the target year of 2010.

The proposed implementation program is composed of four stages i.e. preparation stage, construction stage, monitoring stage and completion stage.

The proposed construction schedule is arranged to avoid likely adverse effects caused by implementation of the proposed works as much as possible and also to conform the priority sequence. The area, which has a high development pressure and a high economic efficiency, is given a high priority for early implementation.

The construction schedule is based on the following assumptions :

(1) Financial and required arrangements shall be complete by the end of 1993.

(2) Detailed design shall be commenced in 1994 and completed within a period of 18 months.

(3) The construction works of southern compartments-2 shall be commenced in 1996 and completed within a construction period of four years.

(4) The construction works of Northern compartment, southern compartment-1 and central compartment shall be commenced in 2001, 2002 and 2007 respectively. However 60 to 70% of the proposed pump capacity shall be installed in the first stage.

(5) After completion of the first stage construction of each compartment, the drainage system shall be monitored and checked whether there are any gaps between the actual conditions and the assumed conditions.

(6) Before the completion stage of 2007 to 2010, the proposed plans shall be reviewed and modified, if necessary, based on the analyses of monitored data.

The proposed implementation schedule is shown in Fig.10.1.

10.3.2 DND

The implementing agency for the Project will be BWDB.

The construction schedule is based on the following assumptions :

(1) Financial and required arrangements shall be completed by the end of 1995.

(2) Detailed design shall be commenced in 1996 and completed within a period of 12 months.

(3) The construction works shall be commenced in 1997 and completed within three years. however about pump facilities, 60 to 70% of the proposed capacity shall only be installed in this stage.

298

(4) After completion of the works, the drainage system should be monitored, to check whether there are any gaps between the actual conditions and the assumption.

(5) During the final stage, the proposed facilities shall be reviewed and modified, if necessary, according to the monitored data.

(6) If it is possible for GOB to implement the flood mitigation measures for the Narayanganj West, the flood mitigation works for the DND may be deferred.

The proposed implementation schedule is shown in Fig.10.1.

10.3.3 Narayanganj West

The implementing agency for flood mitigation and related facilities will be BWDB, while that for drainage facilities will be Narayanganj Municipality.

The construction schedule is based on the following assumptions ;

(1) Implementation arrangement shall be completed by the end of 1996

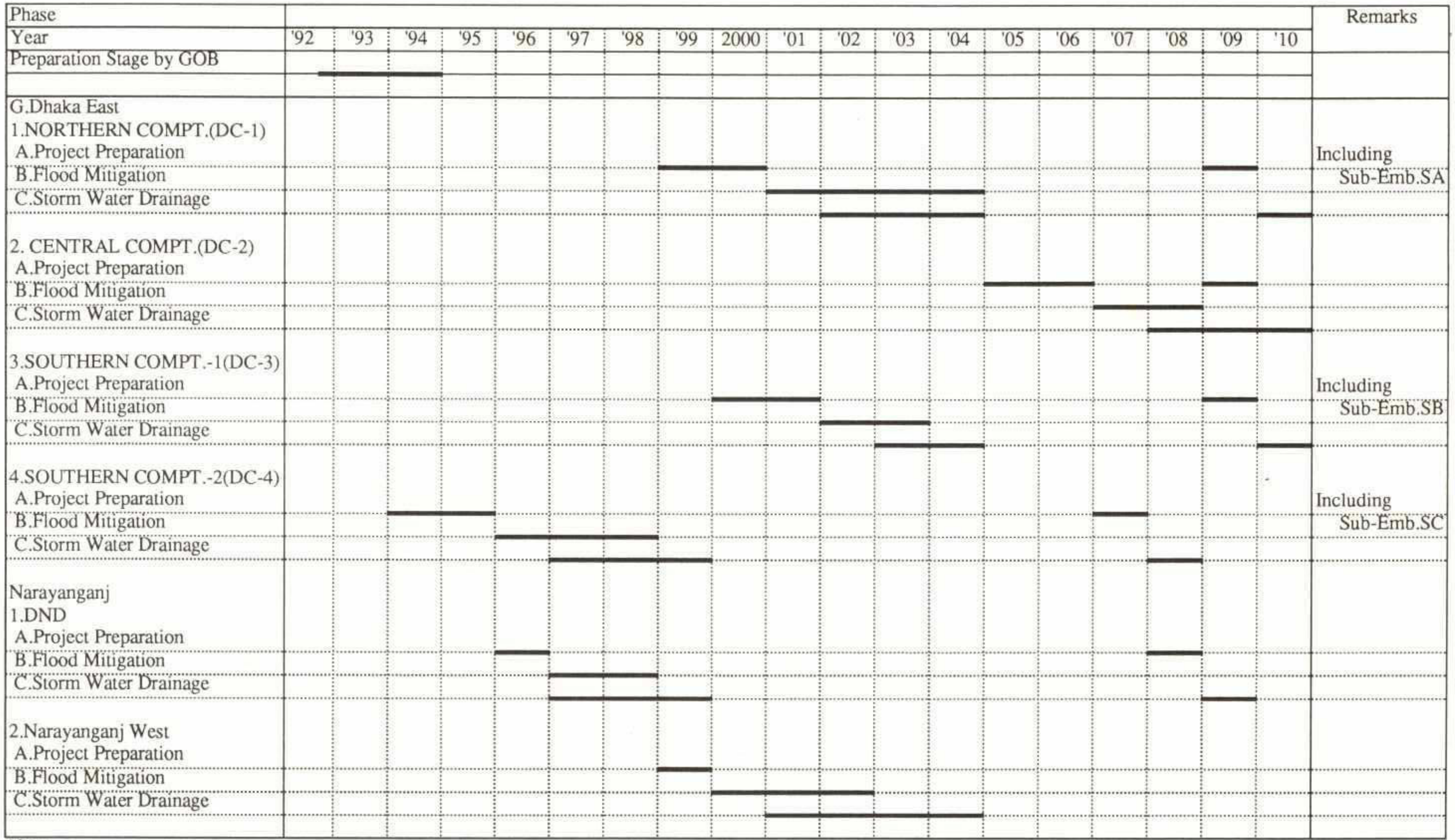
(2) Detailed design shall be commenced in 1999 and completed within a period of 12 months.

(3) The construction works shall be commenced in 2000 and completed within five years.

The proposed implementation schedule is shown in Fig.10.1.

10.4 Disbursement Schedule

The disbursement schedule of each project is shown in Table 10.1.



Note:
1).Preparation stage by GOB :Including development study, etc.
2).Sub-Emb:Sub-Embankment.

FIG. 10.1 PROPOSED IMPLEMENTATION SCHEDULE

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

TABLE 10.1 PROPOSED DISBURSEMENT SCHEDULE

Unit : Million Tk.

Year	'94	'95	'96	'97	'98	'99	2000	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	Total Project Cost
I G. Dhaka East																		
1. DC - 1 (Total)						498	499	900	1,181	1,181	1,179					3	175	5,616
(F/C)						134	134	506	702	703	696						74	2,949
(L/C)						364	365	394	479	478	483					3	101	2,667
2. DC - 2 (Total)												284	285	745	1,141	636	983	4,074
(F/C)												98	98	392	691	362	516	2,157
(L/C)												186	187	353	450	274	467	1,917
3. DC - 3 (Total)							263	263	746	1,118	607	610			6	348		3,961
(F/C)							96	96	395	678	346	348				150		2,109
(L/C)							167	167	351	440	261	262			6	198		1,852
4. DC - 4 (Total)	375	378	620	1,098	1,102	727								5	340			4,645
(F/C)	106	107	314	639	641	395									146			2,348
(L/C)	269	271	306	459	461	332								5	194			2,297
II DND																		
Total			723	1,191	1,192	1,143									5	340		4,594
(F/C)			200	630	631	592										150		2,203
(L/C)			521	533	533	523										87		2,197
III Narayanganj West																		
Total						717	799	1,047	745	389	400							4,097
(F/C)						163	294	459	462	208	211							1,797
(L/C)						554	505	588	283	181	189							2,300

290

CHAPTER 11
PROJECT EVALUATION

279

Chapter 11 : Project Evaluation

11.1 General

Project evaluation was done by comparing the flood damages in the "with" and "without project" situations.

To make an overall evaluation of the project, not only the economic aspect, but also the socio-economic and environmental aspects were taken into account. The socio-economic impacts of the project are expressed in quantitative terms as much as possible. Environmental impacts are usually hard to be quantitatively estimated, therefore qualitative analysis was employed for assessment of environmental aspects.

The period of project life was assumed basically to be 30 years. The opportunity cost of capital (OCC) is assumed as 12%. These are based on the "FAP: Guidelines of Economic (Micro) Analysis".

The estimation of NPVR(2) and the sensitivity analysis using such variables as the increase of capital costs, the increase of O&M costs and the reduction of benefits were done in accordance with the "Guidelines".

Financial analysis were also done, centering on the ways and means to get financial resources for O&M costs.

11.2 Estimation of Benefits and Costs

11.2.1 Estimation of Benefits

In the "with" situation flood damages expected under the "without" situation will be virtually avoided. That is to say, flood damages under the "without" situation just turn into project benefits in the "with" situation.

Economic losses deriving from floods and inundation are manifold and profound. They range from direct damages to houses, establishments, institutions, agricultural crops, infrastructures, etc. to income losses of households, to sales losses of private and public enterprises and to traffic damages in the form of reduced sales, increased operating cost and operating hours.

They have been estimated by project area, by type/scale of floods for 1990 and 2010 in "the Supporting Report B on Flood and Flood Damage". Ultimately they were converted into "average annual flood damages", that is, average flood damages to be expected annually, which were estimated based on probability theory. In the "with" situation they just become project benefits. (Refer to Table 11.1).

Project benefits are summarized as follows :

(Unit : Tk. Million)

Project	1990	2010
DC - 1	43.2	648.4
DC - 2	26.4	176.7
DC - 3	195.1	628.5
DC - 4	293.0	791.3
Greater Dhaka East	557.7	2,244.9
Narayanganj DND	153.4	639.9
Narayanganj West	113.4	395.3
Total	824.5	3,280.1

11.2.2 Estimation of Costs

Costs are divided into capital cost which is required to install/construct necessary equipment/facilities concerned, and operation and maintenance (O&M) cost which is required annually after the implementation of a project. Capital cost is further divided into initial cost and replacement cost. Replacement cost is required to replace pumping equipment.

In performing economic analysis costs were converted into economic costs. To convert capital cost into economic cost, a conversion factor was employed for a specific type of work.

Conversion factors employed are 89.8% for embankment, 85.2% for flood wall, 97.2% for sluice gate, 95.1% for pump station and 88.0% for khal improvement.

Land acquisition cost was valued as a stream of annual net benefits of production foregone.

Replacement cost is assumed to be required in every 15 years.

Economic costs are summarized as follows :

(Unit : Tk. Million)

Project	Costs		
	Capital	NBOPF*	O&M
DC - 1	4,955	2.3	37
DC - 2	2,991	1.1	30
DC - 3	3,457	1.0	29
DC - 4	3,920	1.7	32
Greater Dhaka East	15,323	6.1	128
DND	4,088	1.2	28
Narayanganj West	2,858	1.4	21
Total	22,269	8.7	177

Note : NBOPF : Annual Net Benefits of Production Foregone

In performing economic analysis, a part of the costs of the ADB project now under way under FAP 8B were incorporated into the costs of DC-3 and DC-4 Projects because beneficiary areas of the two projects encompass some of the ADB project areas.

The costs of the JICA drainage project now on-going were also incorporated into the costs of the DC-3 Project. Further, the costs of the raising of roads and the construction of flood walls around the DND were incorporated into the costs of the DND Project. The above table does not take into account these costs.

282

11.3 Economic Evaluation

Results of economic analysis on the 6 projects are described below. The case where the Narayanganj DND Project and the Narayanganj West Project are integrated is additionally taken up and economically evaluated under Supplementary Study in Supporting Report I. Also, an additional economic analysis applying the standard conversion factor (SCF) to the benefits is performed in the above Supplementary Study.

11.3.1 Calculation of EIRR and Other Decision Criteria

In accordance with the implementation schedule, initial costs were distributed over years for each project. Also, based on the initial cost distribution O&M and replacement costs were determined and allotted over years.

Benefits of each of the intermediate years between 1990 and 2010 and beyond were calculated based on the estimated benefits for 1990 and 2010 employing a simple equation. Benefits during the project implementation period were assumed to be realized in proportion to the extent of project implementation.

In this way cost benefit streams were prepared as shown in Tables 11.4 and 11.5.

Using those cost benefit streams economic internal rate of return (EIRR), net present value (NPV) and benefit cost ratio (B/C) were calculated. In addition, NPVR(2) was calculated. NPVR (2) is defined as NPV divided by the present value of capital and O&M costs. The results are shown under.

Project	EIRR (%)	NPV (Tk. Mln.)	B/C	NPVR(2)
DC - 1	14.8	274	1.22	0.162
DC - 2	8.0	- 98	0.74	- 0.155
DC - 3	13.9	263	1.19	0.147
DC - 4	18.9	1,032	1.55	0.416
Greater Dhaka East	15.8	1,501	1.31	0.228
DND	14.5	371	1.21	0.151
Narayanganj West	14.3	152	1.18	0.110

The DC-4 Project has the highest EIRR of 18.9%. The EIRR's of the DC-1, Narayanganj DND, Narayanganj West and DC-3 Projects are not much different, all being about 14%. All these five projects have EIRR's exceeding the OCC of 12%. The DC-2 Project has the EIRR of 8.0%.

In terms of NPV, the DC-4 Project is the biggest with Tk. 1,032 million. The second place goes to the DND Project with Tk. 371 million, followed by the DC-1 and DC-3 Projects with Tk. 274 million and Tk. 263 million, respectively. The Narayanganj West Project is placed fifth with the NPV of Tk. 152 million. The DC-2 Project has the negative NPV of Tk. -98 million.

The highest B/C of 1.55 is held by the DC-4 Project. The B/C of the DC-1, Narayanganj DND, DC-3 and Narayanganj West Projects are not much different, about 1.2. The DC-2 Project has the B/C of less than one (1) with 0.74.

Turning to NPVR(2), the DC-4 Project has the highest value of 0.416. It is expected that the project will contribute to the increase of national income by the amount corresponding to 41.6% of project costs. The NPVR(2)'s of the DC-1, Narayanganj DND, DC-3 and Narayanganj West Projects are mutually not widely apart, all ranging between 0.1 and 0.2. The DC-2 Project has the negative NPVR(2) with -0.155.

As seen in the above, the five projects, namely the DC-4, DC-1, Narayanganj DND, DC-3 and Narayanganj West Projects are judged to be economically feasible, while the DC-2 Project is marginal so far as economic evaluation is concerned. However, in case of social projects such as this one an EIRR of over 7% has proved to be on the high side.

Moreover, if the four Greater Dhaka East projects are combined together and treated as one entity (the Greater Dhaka East Project), which is reasonable because of their geographical, economic and social connections and interrelations, then the project has the EIRR of 15.8, NPV of Tk. 1,501 million, B/C of 1.31 and NPVR(2) of 0.228. These values are the highest among the three projects. Viewed in this way, the implementation of the DC-2 Project is justified.

284

11.3.2 Sensitivity Analysis

Sensitivity analysis was conducted to see whether the projects can maintain their viability and robustness, when placed under unfavorable circumstances during and after implementation.

In conducting sensitivity analysis, the FPCO Guidelines on Project Assesment was referred to.

In Case A the 15% increase of capital costs compared with the base case was assumed. In Case B the 100% increase of O&M costs was assumed. In Cases C and D the 15% reduction of benefits and one and a half year delay in achieving benefits were respectively assumed.

In Case E the switching values of capital cost increase were estimated. Likewise, in Case F the switching values of benefit reduction were estimated.

The results of sensitivity analysis are shown below. The decision criterion employed is EIRR.

(Unit : %)

Case	Greater Dhaka East					Narayanganj	
	DC-1	DC-2	DC-3	DC-4	Combined	DND	West
Base Case	14.8	8.0	13.9	18.9	15.8	14.5	14.3
Case A	12.9	6.6	12.5	16.6	13.9	12.8	12.4
Case B	14.2	6.7	13.4	18.2	15.1	13.9	13.6
Case C	12.5	6.1	12.2	16.1	13.5	12.4	12.1
Case D	12.7	6.9	12.5	16.2	13.7	12.6	12.4
Case E	22.7	-28.0	20.0	58.6	33.5	22.1	18.7
Case F	17.7	-35.0	15.9	35.4	22.8	17.4	15.1

As the table shows, in all the cases of A, B, C and D all the five above - OCC projects maintain their viability.

When the four Greater Dhaka East projects are combined together and treated as one entity, then this project stay viable in all the cases of A, B, C and D.

In Case E the switching value of the DC-4 Project is calculated at 58.6%, that is to say, it may still stay viable, supposing the capital cost overrun reaches 58.6%. Likewise, the switching values of the DC-1, Narayanganj DND, DC-3 and Narayanganj West Projects are calculated at 22.7%, 22.1%, 20.0% and 18.7%, respectively.

In Case F the switching value of the DC-4 Project works out at 35.4%, that is, it may still remain viable, supposing the benefits turn out to be less by 35.4%. Similarly, the switching values of the DC-1, Narayanganj DND, DC-3 and Narayanganj West Projects work out at 17.7%, 17.4% , 15.9% and 15.1%, respectively.

The switching value of the combined Greater Dhaka East Project is 33.5% in Case E and 22.8% in Case F.

It follows that all the above five (5) projects will stay above 12% OCC under any conceivable adverse circumstances, which is also true with the combined Greater Dhaka East Project.

As regard the DC-2 Project the 28% reduction of costs or the 35% addition of benefits will be necessary if it is to be feasible. Also it was found out as a result of simulation that the implementation of the project should be started in 2015 (10 years postponement) if we are to make it feasible.

11.4 Socio-Economic Impact Assessment

11.4.1 Negative Impacts

1) Displacement of People

It is estimated that the number of people to be displaced by the construction of embankments and khal improvement will reach 7,053. It is broken down to 1,337 for DC-1, 734 for DC-2, 433 for DC-3, 1,127 for DC-4, 1,783 for the DND and 1,639 for the Narayanganj West. Also, compensation for building demolition accompanying displacement is estimated to amount to Tk. 328.1 million. It is broken down to 34.4, 21.7, 13.6, 31.2, 61.7 and 165.5 in millions of Taka for the areas in the above order, respectively.

286

The JICA Study Team conducted the sampling questionnaire survey to grasp socio-economic aspects of the people to be displaced, in December 1991, towards people to be affected by the construction of the embankments along the Balu River. The number of sample was 61 houses.

The profile of the sampled subjects is that the average number of household members is 8.3; 62.3% are engaged in agriculture more or less, 11.5% in boating and 4.9% in fisheries; average monthly income is Tk. 6,266; 72.1% got either primary schooling or no schooling whatsoever.

As an overall assessment it can be said that the people concerned have on the whole positive mental attitudes towards resettlement, that proper amount of compensation is the central and crucial issue, and that proper job retraining/ reorientation is a "must". According to the surveys conducted on the people already displaced in such circumstances, the living standard of most of them deteriorated after the displacement. Systematic, detailed and long-term approach to this problem is, therefore, most important and essential.

2) Adverse Effects on Boating and Fishing People

There are many people who are earning their livelihood by boating and inland water fishing in the Greater Dhaka East area. When embankments are constructed along the Balu River and other protective measures are taken, the vast areas which are now under water in the rainy season will be saved from inundation. Then, those people who are making their living by transportation and fisheries will be threatened to lose their trade.

According to the assessment on the survey data by the study team, it can be said that the socio-economic impacts of the construction of the eastern embankment along the Balu River on the boating trade are not so much in comparative terms, because the people and their earnings to be more or less affected by the construction of the embankment account for 0.3 to 1.4% of the total labour force and 0.4 to 1.2% of the total earnings in the Greater Dhaka East.

Moreover, although the boating business is an age-old, traditional occupation that has given employment to a substantial number of people and has benefited millions of customers, it is not an efficient service both for the suppliers and the customers compared with land transport. Although utmost care and measures should be taken so that the people to be directly affected can redirect their occupation or find a new locations for their trade, the transfer of the transport mode from inland water navigation to land transport is the demand of the modern times. Land transport is bound to be developed where boating was the sole transport means, which is more economic and more contributory to the socio-economic development of the Greater Dhaka East area in long term.

It is said that over 756 households are involved with different intensity in fishing activities in the Study Area. More than 90% of them are occasional fishermen, the balance being constituted essentially by part-time fishermen. Full-time fishermen have proved to be few. Under these circumstances the impacts of the project on fishing people should not be exaggerated.

3) Loss of Farm Land and Occupation as Farmers

To make way for embankments, many people living on the left bank of the Balu River will have to part with their farm land. Or, after the construction of the embankments, the farm land inside the embankments will gradually be changed for residential and other uses.

The agricultural area in the Greater Dhaka East, the DND and the Narayanganj West in 1990 was 8,814 ha, 3,173 ha and 464 ha, respectively. It is forecast that in 2010 agricultural area in the 3 project areas will be reduced to 1,310 ha, 532 ha and 8 ha in the above order, respectively.

Farmers whose land is lost will often fail to reorient their occupation to a higher plane, ending up as squatters and so forth. Systematic long-term approach and programs by the government are sought to avoid or alleviate such a situation. One such approach is the provision of alternative farmlands, that remain unaffected in the surrounding flood plains of the priority area.

11.4.2 Positive Impacts

1) Population to be Saved from Inundation

In the "with" situation people living in the flood prone areas will be no longer affected by inundation.

269

It is estimated in the "without" situation that supposing the 1988-scale flood hit the feasibility study area in 2010, population to be affected would be 665,996 for DC-1, 261,856 for DC-2, 847,139 for DC-3, 1,218,397 for DC-4, 2,993,388 for the DND and 981,873 for Narayanganj West, totaling 5,326,040. In the "with" situation the same number of people would be saved from inundation.

2) Area to be Saved from Inundation

In the "with" case areas which are habitually or in time of big floods inundated will be free from such influences.

It is estimated in the "without" case that supposing the 1988-scale flood hit the Study area in 2010, built-up area to be affected would be 3,036 ha for DC-1, 1,146 ha for DC-2, 2,977 ha for DC-3, 2,635 ha for DC-4, 4,270 ha for the DND and 1,720 ha for the Narayanganj West, totaling 15,784 ha. In the "with" case the same area would be saved from inundation.

3) Creation of Employment

The implementation of the project will accompany the recruitment of a great number of labour force.

The project will provide employment during construction works to 10,693 people for DC-1, 8,616 people for DC-2, 5968 people for DC-3, 13,637 people for DC-4, 19,974 people for the DND and 7,625 people for the Narayanganj West, totaling 66,513 people on man-year basis.

After project implementation permanent jobs will be created for the operation and maintenance of equipment/facilities.

4) Reduction of Water-Borne Diseases

Water-borne epidemics such as dysentery, diarrhea, malaria, typhoid and cholera tend to break out following the visits of floods, especially, big and protracted ones. According to Statistical Yearbook of Bangladesh 1990, 144,521 more cases of dysentery, 8,930 more cases of diarrhea and 25,533 more cases of malaria were recorded in 1988 compared with 1987 in the Region of Dhaka. Connection with the 1988 flood is suspected for this unusual happening.

The JICA Study Team conducted the field survey to know about the incidence of water-borne diseases as well as medical costs of those diseases in the Study Area.

According to the survey results the incidence of water-borne diseases in the Study Area abruptly went up in the two flood years of 1987 and 1988: in normal years the annual number of cases works out at 17,789 on average, while it was 31,955 and 41,607 in 1987 and 1988, respectively. It means that one witnessed 14,166 more cases in 1987 and 23,818 more cases in 1988. Such cases of water-borne diseases will increase with increasing population in future.

Medical costs of such diseases are calculated at Tk. 3,178 per case on average. It means the additional loss of Tk. 45.0 million and Tk. 75.7 million in 1987 and 1988 respectively to the economy of the Study Area. (Such a loss will increase with increasing population). These amounts correspond to 0.3% and 0.5% of the estimated GDP of the Study Area in 1987 and 1988, respectively.

Supposing the higher incidence of water-borne diseases in 1987 and 1988 was primarily due to floods, such economic losses as estimated above are likely to be avoided in the "with" situation.

5) Removal of Psychological Burden

People of Bangladesh more or less suffer from psychological burden associated with the threats of floods. Once the flood protection and drainage project is realized in the Study Area, people there will be virtually freed from the inner load they are now forced to bear. It will surely affect their attitude toward life. They may get more positive and more active in their socio-economic activities.

6) Elevation of Land Use

After the project the existing low land mainly used for agriculture will be gradually developed and urbanized. It will be gradually converted into built-up areas. That is to say, houses, shops, factories and institutions will make their appearance, grow in number and finally get congested.

In the process more capital will be invested in the land for a higher use of it. It means that the value of the land will gradually go up, which will be reflected in a higher land price. This impact on the value of land can be enormous.

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11.5 Environmental Impact Assessment

The project is aimed at protecting from flooding the existing and future urban area of Dhaka and Narayanganj. The population in the Study Area is projected to increase by 2.2 times from 3,068,927 in 1990 to 6,710,661 in 2010. It means increased amount of wastewater, solid waste, etc. more than doubling the present level will be generated in future. (For more details refer to 3.3 of Supporting Report C). Unless proper vigilance and measures are taken most of the water courses crisscrossing the Study Area would become polluted. In order that such things may not happen, regular monitoring of water quality in major water courses in consideration with appropriate mitigatory measures is recommended. (Refer to 4. of Supporting Report C).

As mentioned already, agricultural and open water capture fishery land in the Study Area is bound to be greatly reduced after the construction of embankments. Therefore, possible negative impacts on agriculture and fishery should be viewed against this background. In other words, such impacts should not be inordinately exaggerated.

Environmental factors considered for possible negative impacts on them by a flood protection and drainage project also include general ecological elements of flora and fauna, productive ecological elements of agriculture and aquaculture fishery, public health, surface water quality and others in addition to the social impacts mentioned above. These are dealt with in details in Chapter 7. The anticipated direct and indirect effects of short and long term are also qualitatively evaluated in Table 7.3.

1) Adverse Effect on Water Quality and Its Far-Reaching Implications

Water in canals and ponds will be depleted and its free intercourse with river water outside the embankment will be obstructed after the project. This may lead to the stagnation of surface water. Besides, farmers will be encouraged to grow HYV more as there will be no flooding any more. But, HYV are more prone to pests and farmers will resort to more use of pesticide.

These things along with a more concentration of population are likely to pollute the water of canals and ponds and adversely affect fish and plant concerned. This can cause chain reactions in the overall ecological system in the study area. Future living environmental improvement and water pollution control measures are very essential to realize a long term benefit.

2) Adverse Effects on Soil Quality

Annual flooding in the rainy season in the low land areas bring with them fertile soil made up of organic matters and crops in the dry season are benefited by them. This way of things has continued from the time immemorial. but, once the circumstances are created where there are no more such flooding crops may not grow as before unless farmers take remedial steps.

Farmers will be encouraged to grow HYV because there will be no flooding in the farm land any more. It will lead to a more use of chemical fertilizer as the growing of HYV and the use of fertilizer are inseparable. This situation may contribute to the deterioration of soil quality. However, this effect is expected to be insignificant in consideration to the reduced agricultural land use in future.

3) Possible Change of River Courses

Environmentalists argue about the possible change of river courses as a result of the empoldering of a certain area and its possible adverse effects on the natural and social environments concerned. However such a condition in this case is extremely unlikely as per the backwater curve analysis conducted during the master plan study, in which even the change in river stage due to the embankments is assessed to be very insignificant.

4) Possible Breach of Embankments

Should an embankment fail and the bulged water surge into the erstwhile protected area, the resultant damages to properties, human life and farm land would be enormous. This is a man-made disaster that is not allowed to happen. An effective O&M of the facilities is very essential to minimize such a risk of embankment breach.

11.6 Financial Analysis

The implementation of the flood protection and drainage project will save the vast Study Area from inundation by floods.

Those lands which are now flood plains will be no longer inundated and majority of them will be developed for urban uses. That is to say, they will be raised with additional soil and infrastructures such as roads, bridges, electric lines, telecommunication lines, water supply, gas and sewerage pipes will be constructed there so that they can be used for residential, commercial, industrial and institutional purposes. This land development will be basically public undertakings. The costs of land development will reach an enormous amount.

Those areas which are already built up will also be no longer inundated.

The total capital costs of the flood protection and drainage project are estimated at Tk. 26,987 million. In addition, to maintain and operate the flood protection and drainage facilities recurrent costs amounting to Tk. 177 million will be annually required.

Through flood protection, drainage and land development majority of lands in the Study Area will turn into urban areas. In parallel with it the value, that is, price of land will go up to a great extent.

It follows from the above that land owners in the Study Area will be a major beneficiary of the project. However, the degree of benefits they will get will be different between those who now own flood plains and those who own already built-up areas. Also, it will be different between those who own commercial areas with high population density and those who own residential areas with low population density.

The JICA Study Team proposes that the authorities impose Land Development Tax on landowners to recover O&M costs.

The built-up area in Greater Dhaka East is estimated to increase from 6,675 ha in 1990 by 98.4% to 13,245 ha in the target year of 2010. Likewise, the built-up area in Narayanganj is estimated to increase from 3,487 ha in 1990 by 71.8% to 5,990 ha in 2010. In total, the built-up area in the Study Area will go up from 10,162 ha in 1990 by 89.3% to 19,235 ha in 2010.

It is assumed that Dhaka and Narayanganj have their own, separate jurisdictions for the collection of Land Development Tax rates. It implies that the tariff will be different between the two areas.

As mentioned above, the built-up area in Greater Dhaka East and Narayanganj is estimated in 2010 to reach 13,245 ha and 5,990 ha, respectively, while annual O&M costs of the project for the two areas in the same year are estimated at Tk. 128 million and Tk. 49 million, respectively. That is to say, to recover O&M costs annual rates of Tk. 9,664 and Tk. 8,180 per ha will be levied on landowners in Greater Dhaka East and Narayanganj, respectively. Supposing collection efficiency is 70%, their respective annual rates will be Tk. 13,806 and Tk. 11,686 per ha.

Using the local measure, Tk. 39 and Tk. 33 per decimal will be annually levied in Greater Dhaka East and Narayanganj, respectively. Supposing collection efficiency is 70%, their respective annual rates will be Tk. 56 and Tk. 47 per decimal.

As already mentioned, actually the tariff should be structured in such a way that rates will be different depending on various factors. For instance, they will be different between the land which is now agricultural and the land which is now already urban, and also between the highly built-up area and the built-up area with low population density. Rates will be determined partly in accordance with the level/intensity of infrastructure investments per unit area of land and partly in accordance with the convenience/utility of locations. They will all be reflected in the price of land.

11.7 Project Assessment

As already mentioned, the Greater Dhaka East, the DND, and the Narayanganj West Projects with their respective EIRR of 15.8%, 14.5% and 14.3% can be judged to be economically feasible without any reservation (ref. Table 11.4).

The economic efficiencies of the 4 compartments of the Greater Dhaka East area are varied from 8.0% to 18.9%, however the areas are geographically, socially and economically interdependent and inseparable. In case of the project with a strong social nature, the EIRR of over 7% have proved to be on the high side.

Values of other decision criteria and results of sensitivity analysis support the above evaluation.

In terms of socio-economic impacts of the projects, supposing the 1988-scale flood hit the Study Area in 2010, 5,660,700 people or 84.4% of the total population and 15,784 ha or 82.1% of the total built-up area would be saved from inundation. The projects will provide employment opportunities reaching 66,513 man-years.

They will surely reduce the breakout of water-borne diseases by tens of thousands of cases, saving the economic losses running into Tk. fifty to one hundred million. They will remove psychological burden and stresses from people's mind, nurturing positive attitude to life. Most importantly, the enormous and vast area of land will be set free from inundation, enabling it to be developed and used for human habitation and economic activity.

The resettlement and boating trade issues must be treated with the utmost care as the livelihood of people is involved. However, they are transitory in nature and an inescapable friction from the standpoint of overall economic development.

A summary of project evaluation is shown in Table 11.4.

Regarding environmental issues, it is indispensable and essential to concentrate all the human efforts to prevent, stop and lessen the negative environmental impacts of the project. The prime requirement is the urban environmental enhancement measures of living environment and water pollution control.

TABLE 11.1 AVERAGE ANNUAL FlOOD DAMAGES BY AREA BY YEAR

(Unit : Tk. Million)

Area	Average Annual Flood Damages		
	External Flood	Internal Flood	Total
1. 1990			
Dhaka East - 1	40.7	2.5	43.2
Dhaka East - 2	25.4	1.0	26.4
Dhaka East - 3	121.0	74.1	195.1
Dhaka East - 4	195.5	97.5	293.0
Dhaka East (Sub-Total)	382.6	175.1	557.7
Narayanganj DND	116.0	37.4	153.4
Narayanganj West	88.5	24.9	113.4
Total	587.1	237.4	824.5
2. 2010			
Dhaka East - 1	634.5	13.9	648.4
Dhaka East - 2	169.3	7.4	176.7
Dhaka East - 3	480.4	148.1	628.5
Dhaka East - 4	631.9	159.4	791.3
Dhaka East (Sub-Total)	1,916.1	328.8	2,244.9
Narayanganj DND	483.8	156.1	639.9
Narayanganj West	318.8	76.5	395.3
Total	2,718.7	561.4	3,280.1

Source : JICA

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TABLE 11.2 (1) ECONOMIC COSTS BY PROJECT

1. Capital Cost

(Unit : Tk. Million)

Item	Greater Dhaka East					Narayanganj		Total
	DC-1	DC-2	DC-3	DC-4	Sub-Total	DND	West	
A. Project Preparation								
1) Administration	85	59	57	67	268	66	51	385
2) Engineering	326	226	220	258	1,030	250	194	1,474
3) Compensation	34	22	14	31	101	62	166	329
Sub-Total	445	307	291	356	1,399	378	411	2,188
B. Flood Mitigation								
1) Embankment	2,101	813	835	910	4,659	0	616	5,275
2) Flood Wall	19	20	14	25	78	43	180	301
3) Sluice Gate	160	89	78	79	406	60	157	623
4) Related Struc.etc.	0	0	0	0	0	3	1	4
Sub-Total	2,280	922	927	1,014	5,143	106	954	6,203
C. Storm Water Drainage								
1) Pump Station	1,156	553	1,077	1,066	3,852	1,296	510	5,658
2) Khal Improvement	246	183	150	426	1,005	932	386	2,323
3) Bridge etc.	14	0	0	8	22	101	16	139
Sub-Total	1,416	736	1,227	1,500	4,879	2,329	912	8,120
D. Physical Contingency	425	294	285	337	1,341	326	253	1,920
E. Replacement	389	732	727	713	2,561	949	328	3,838
Total	4,955	2,991	3,457	3,920	15,323	4,088	2,858	22,269

TABLE 11.2 (2) ECONOMIC COSTS BY PROJECT

2. Annual Net Benefits of Production Foregone

(Unit : Tk. Million)

Item	Greater Dhaka East					Narayanganj		Total
	DC-1	DC-2	DC-3	DC-4	Sub-Total	DND	West	
Land Acquisition (ha)	197.9	96.2	83.1	146.3	523.5	107.1	121.2	751.8
Annual Net Benefits of Production Foregone	2.28	1.11	0.96	1.68	6.02	1.23	1.39	8.65

3. Annual Operating and Maintenance Cost

(Unit : Tk. Million)

Item	Greater Dhaka East					Narayanganj		Total
	DC-1	DC-2	DC-3	DC-4	Sub-Total	DND	West	
O & M Cost	37	30	29	32	128	28	21	177

Source : JICA

229

Table 11.3(1) Cost Benefit Streams - Greater Dhaka East Project

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:Tk Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1992	602	0	602	28	-574
2	1993	347	0	347	48	-300
3	1994	90	3	93	54	-39
4	1995	158	7	166	56	-110
5	1996	434	7	441	144	-297
6	1997	877	7	884	287	-597
7	1998	880	7	887	444	-443
8	1999	734	24	758	558	-200
9	2000	323	36	360	584	225
10	2001	820	36	856	684	-172
11	2002	1498	35	1533	964	-569
12	2003	1848	35	1883	1273	-610
13	2004	1382	48	1430	1533	103
14	2005	572	84	656	1684	1027
15	2006	144	96	240	1761	1521
16	2007	723	96	819	1882	1063
17	2008	925	100	1025	2025	1000
18	2009	629	113	742	2134	1392
19	2010	551	119	670	2245	1575
20	2011	6	130	136	2329	2193
21	2012	181	130	311	2414	2103
22	2013	6	135	141	2498	2357
23	2014	540	135	675	2582	1907
24	2015	6	135	141	2667	2526
25	2016	6	135	141	2751	2610
26	2017	6	135	141	2835	2694
27	2018	6	135	141	2920	2779
28	2019	303	135	438	3004	2566
29	2020	550	135	685	3089	2404
30	2021	6	135	141	3173	3032
31	2022	189	135	324	3257	2933
32	2023	6	135	141	3342	3201
33	2024	185	135	320	3426	3106
34	2025	646	135	781	3820	3039
35	2026	4	100	104	2405	2300
36	2027	188	100	288	2464	2176
37	2028	4	100	104	2524	2419
38	2029	4	100	104	2583	2479
39	2030	4	100	104	2783	2679
40	2031	2	63	65	1636	1571
41	2032	2	63	65	1442	1377
42	2033	2	63	65	1471	1406
43	2034	2	63	65	1718	1653
44	2035	1	30	31	365	334
45	2036	1	30	31	592	561

Table 11.3(2) Cost Benefit Streams - Narayanganj DND Project

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:Tk Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1992	234	0	234	0	-234
2	1993	0	0	0	0	0
3	1994	0	0	0	0	0
4	1995	0	0	0	0	0
5	1996	328	0	328	0	-328
6	1997	895	0	895	110	-786
7	1998	896	0	896	236	-660
8	1999	850	14	864	372	-492
9	2000	1	25	26	397	370
10	2001	1	25	26	421	395
11	2002	1	25	26	445	419
12	2003	1	25	26	470	443
13	2004	1	25	26	494	468
14	2005	1	25	26	518	492
15	2006	1	25	26	543	516
16	2007	1	24	25	567	542
17	2008	5	24	29	591	562
18	2009	171	24	195	616	420
19	2010	1	28	29	640	611
20	2011	1	28	29	664	635
21	2012	1	28	29	689	659
22	2013	1	28	29	713	684
23	2014	1	28	29	737	708
24	2015	771	28	799	762	-38
25	2016	1	28	29	786	757
26	2017	1	28	29	810	781
27	2018	1	28	29	835	805
28	2019	1	28	29	859	830
29	2020	1	28	29	883	854
30	2021	1	28	29	907	878
31	2022	1	28	29	932	903
32	2023	1	28	29	956	927
33	2024	180	28	208	980	772
34	2025	1	28	29	1005	976
35	2026	1	28	29	1390	1360

Table 11.3(3) Cost Benefit Streams - Narayanganj West Project

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:Tk Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1992	0	0	0	0	0
2	1993	0	0	0	0	0
3	1994	0	0	0	0	0
4	1995	0	0	0	0	0
5	1996	0	0	0	0	0
6	1997	0	0	0	0	0
7	1998	0	0	0	0	0
8	1999	369	0	369	0	-369
9	2000	376	0	376	44	-332
10	2001	603	0	603	121	-482
11	2002	606	0	606	207	-400
12	2003	286	16	302	256	-46
13	2004	295	16	311	311	-1
14	2005	1	21	22	325	302
15	2006	1	21	22	339	317
16	2007	1	21	22	353	331
17	2008	1	21	22	367	345
18	2009	1	21	22	381	359
19	2010	1	21	22	395	373
20	2011	1	21	22	409	387
21	2012	1	21	22	423	401
22	2013	1	21	22	438	415
23	2014	1	21	22	452	429
24	2015	1	21	22	466	443
25	2016	1	21	22	480	457
26	2017	1	21	22	494	472
27	2018	1	21	22	508	486
28	2019	329	21	350	522	172
29	2020	1	21	22	536	514
30	2021	1	21	22	550	528
31	2022	1	21	22	564	542
32	2023	1	21	22	579	556
33	2024	1	21	22	593	570
34	2025	1	21	22	607	584
35	2026	1	21	22	621	598
36	2027	1	21	22	635	613
37	2028	1	21	22	649	627
38	2029	1	21	22	772	750

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TABLE 11.4 PROJECT EVALUATION

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Item	Greater Dhaka East					Narayanganj		Remarks
	DC-1	DC-2	DC-3	DC-4	Combined	DND	West	
1. Economic Evaluation								
1) EIRR (%)	14.8	8.0	13.9	18.9	15.8	14.5	14.3	
2) NPV (Tk. million)	274	-98	263	1,032	1,501	371	152	
3) B/C	1.22	0.74	1.19	1.55	1.31	1.21	1.18	
4) NPVR(2)	0.162	-0.155	0.147	0.416	0.228	0.151	0.110	
2. Socio - Economic Impacts								
1) Population to be Saved from Inundation by 1988 - Scale Flood in 2010	665,996	261,856	847,139	1,218,397	2,993,388	1,685,439	981,873	
2) Area to be Saved from Inundation by 1988-Scale Flood in 2010 (ha)	3,036	1,146	2,977	2,635	9,794	4,270	1,720	
3) Labour Force to be Employed during Construction (man-years)	10,693	8,616	5,968	13,637	38,914	19,974	7,625	
4) Resettlement								
(1) No. of People to be Displaced	1,337	734	433	1,127	3,631	1,783	1,639	
(2) Compensation (Tk. million)	34.4	21.7	13.6	31.2	100.9	61.7	165.5	
5) Boating Trade to be Affected								
(1) No. of Boatmen to be Affected	853	415	1,207	150	2,625	-	-	
	118	-	305	150	573	-	-	....Seriously
(2) Annual Sales to be Affected (Tk.)	30,675,750	4,727,800	12,513,100	5,355,000	53,268,650			
	3,701,250	-	9,061,150	5,355,000	18,117,400	-	-	....Seriously

Source : JICA

600

CHAPTER 12
CONCLUSION AND RECOMMENDATION

(ODA)

Chapter 12 : Conclusion and Recommendation

Recommendations from the study are summarized below :

1. It is concluded that the proposed flood mitigation and storm water drainage improvement plans for the feasibility study areas, i.e. Greater Dhaka East, DND and Narayanganj West, will be feasible in technical, economical, social and environmental terms.

   The feasibility study areas constitute a continuous zone along the eastern side of the Dhaka Metropolitan area and anticipated to be under a high population pressure. The areas will most likely be developed as urban areas, however the areas are extremely vulnerable to floods due to low and flat topography. The flood and storm water drainage problems would be severe constraints to future urban development

   The whole study area needs immediate action for implementation of the proposed measures. However, in order to attain the expected project benefit, prompt actions will be required for improving land use management and O&M activities.

2. Also early execution of a comprehensive urban development study and supporting development studies including multiple uses of retarding areas are needed.

   The Metropolitan Development Plan commissioned in 1992 will make an in-depth study in these areas. Then the supporting development studies should be done based on their recommendations.

   The objectives of the supporting development studies should be :

   - Strategic development zones,
   - Transportation network system,
   - Housing / industrial / commercial development,
   - Recreation facilities development,
   - Major public facilities development,
   - Urban utilities and sanitation / solid waste management system development,
   - Multiple uses of flood mitigation facilities.

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3. Early establishment of proper management and control of land use are needed according to the urban development plan mentioned above.
The flood mitigation and drainage improvement strategy will be a major determinant of the urban development. If urban development is to proceed in accordance with preferred strategy, land use management and control will be very decisive.

RAJUK is the planning and land development authority for the Dhaka Metropolitan area. It should have the necessary authority to control development.

The existing legislation for land use control, and land acquisition may require revision in order to facilitate the implementation of the project.

4. Improvement of O&M activities for flood mitigation facilities are essential. After implementation of the project, proper O&M activities will be decisive measures for security of the schemes.

Although poor O&M activities are widely pronounced, the GOB is fully responsible for proper O&M activities.

Budget constraints are the most frequently cited constraint on O&M reported by the GOB. If so, it should be solved without fail.

Everyone in Dhaka would benefit from flood protection measures. Everyone should in principle contribute towards the cost. A tax based on the increase in land values (as suggested in the ADB Aide memories) would be an equitable measure.

Also the GOB should prepare routine O&M manuals and training programs for its staff and local participants.

5. Establishment of an environmental monitoring system for surface water is needed.

Surface water quality is the prime indicator of pollution, however available data and information are still quite limited. Without proper monitoring systems the environmental laws and regulation standards are useless.

6. Improvement of major access roads in the flood prone areas is needed for evacuation purposes.

   A number of rural settlements at low-lying areas are isolated during floods. By improvement of the major access roads. The situation will be greatly improved.

7. The projects are proposed to be implemented with progressing urbanization. In addition, monitoring and periodical review will be required.

   After implementation of the proposed facilities of the initial stage, the major facilities such as pumps, trunk channels and retarding areas shall be monitored and reviewed before undertaking the scheme in full scale.

8. The flood plain management area and other rural areas, in Keraniganj and Savar, of the proposed master plan are recommended for further studies concerned to ecological and nature conservation and development. A balanced development of these areas for aquatic and terrestrial flora and fauna, the defined general ecological elements, and the productive ecological elements of agriculture and fishery/aquaculture be encouraged.

608

APPENDIX I

List of Participant

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APPENDIX I : List of Participant

1. JICA Advisory Committee

Dr. Hiroyoshi Shigai	Chairman Professor, University of Tsukuba
Mr. Tadahiko Nakao	Ministry of Construction
Mr. Hidetoni OI	Development Specialist, JICA
Mr. Motoharu Sekizawa	Ministry of Construction
Mr. Atsushi Suzuki	Ministry of Construction
Mr. Nitoshi Baba	Hokkaido Development Agency

2. JICA Study Team

Mr. Hajime Tanaka	Team Leader
Mr. Toshiaki Tokumasu	Deputy Team Leader Drainage Planning Engineer
Mr. Isao Misono	Flood Prevention Planning Engr.
Mr. J.R. Jones	Urban Planner
Mr. Hiroshi Matsuo	land Use Analyst
Mr. Takashi Furukawa	Hydrologist/Hydraulic Engineer
Mr. Kunihiko Okada	Drainage Facility Engineer
Mr. Kimio Takeya	River Structure Engineer
Mr. Tokihiko Ina	Construction Planner/Cost Estimator
Dr. S. Jayamohan	Environmental Engineer
Mr. Yuichi Hashimoto	Flood Damage Survey Expert
Mr. Naomichi Ishibashi	Socio-Economist
Mr. Yoshiaki Ohtoku	Mapping Specialist
Mr. Etsuro Warashina	Topo. Survey Expert

3. GOB Study Team

Mr. M.N. Huda	FPCO	Chairman, Local Panel of Experts
Mr. A.M.M. Nurul Huq	FPCO	Chief Engineer
Prof. Ainun Nishat	FPCO	Member POE
Mr. K.B.M. Shafiuddin	FPCO	SE
Mr. A.K.M. Halimur Rahman	FPCO	SE
Mr. Md. Masud Ahmed	FPCO	SE
Mr. Emamuddin Ahmed	FPCO	SE

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Mr. Md. Abdur Rahman	BWDB	SE
Mr. Yusuf Harun	BWDB	SE
Mr. A. Quader Choudhury	DWASA	SE
Mr. Md. Mehedi Ali Khan	DDC (DMC)	SE
Mr. Emdadul Islam	RAJUK	EE
Mr. Md. Moksed Alam	LGEB	EE
Mr. Md. Farhad Hossain	RHD	EE
Mr. Abu Taleb Khandaker	DOE	DD
Mr. M. Anwarul Islam	DOE	DD
Mr. Joynul Abedin Khan	HSD	EE
Mr. Abullah	HSD	SDE

4. Panel of Experts

Mr. W. Van Allen	Panel of Expert
Mr. Hidetoni OI	Panel of Expert
Mr. Tadahiko Nakao	Panel of Expert

5. World Bank

Mr. Ross Wallace	Co-ordinator

6. Surface Water Modelling Center

Mr. Alasdair Macdonald, PHD	Team Leader
Mr. Muzharul Islam	SE
Mr. Ranjit Galappatti, PHD	Computational Hydraulic Engr.

7. Local Consultants

Development Design Consultants Ltd.
Engineering and Planning Consultants Ltd.
AQUA Consultant & Associates Ltd.

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