社会開発調査部報告書

THE PEOPLE'S REPUBLIC OF BANGLADESH
FLOOD PLAN COORDINATION ORGANIZATION

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

FAP 8A

SUMMARY

NOVEMBER 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

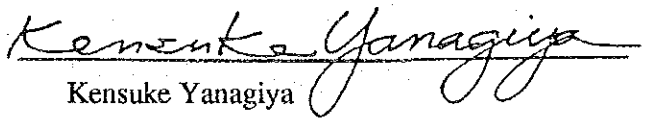
In response to a request from the Government of the People's Republic of Bangladesh, the Japanese Government decided to conduct a Master Plan for Greater Dhaka Protection Project (Study in Dhaka Metropolitan Area) of Bangladesh Flood Action Plan No. 8A and entrusted the study to the Japan International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

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

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

I wish to express my sincere appreciation to the officials concerned of the Government of the People's Republic of Bangladesh for their close cooporation extended to the team.

November,1991



Kensuke Yanagiya
President
Japan International Cooperation Agency

MASTER PLAN
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GREATER DHAKA PROTECTION PROJECT
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OF
BANGLADESH FLOOD ACTION PLAN NO. 8A

November,1991

Mr. Kensuke YANAGIYA
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

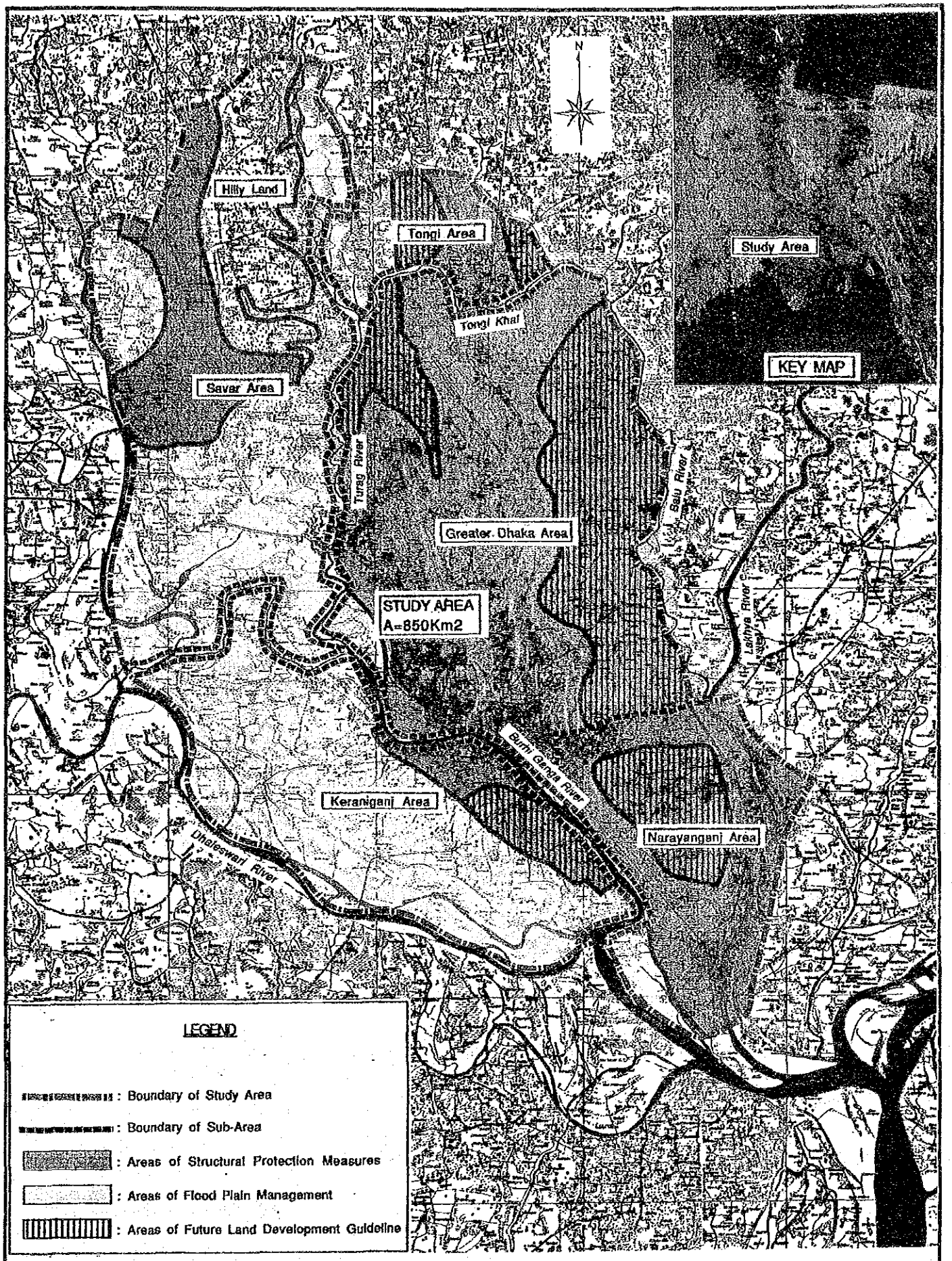
We are pleased to submit the final report entitled the "Master Plan for Greater Dhaka Protection Project (Study in Dhaka Metropolitan Area) of Bangladesh Flood Action Plan No. 8A". This report has been prepared by the Study Team in accordance with the contract signed on October 1, 1990 and May 7,1991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

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

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

Yours Faithfully,

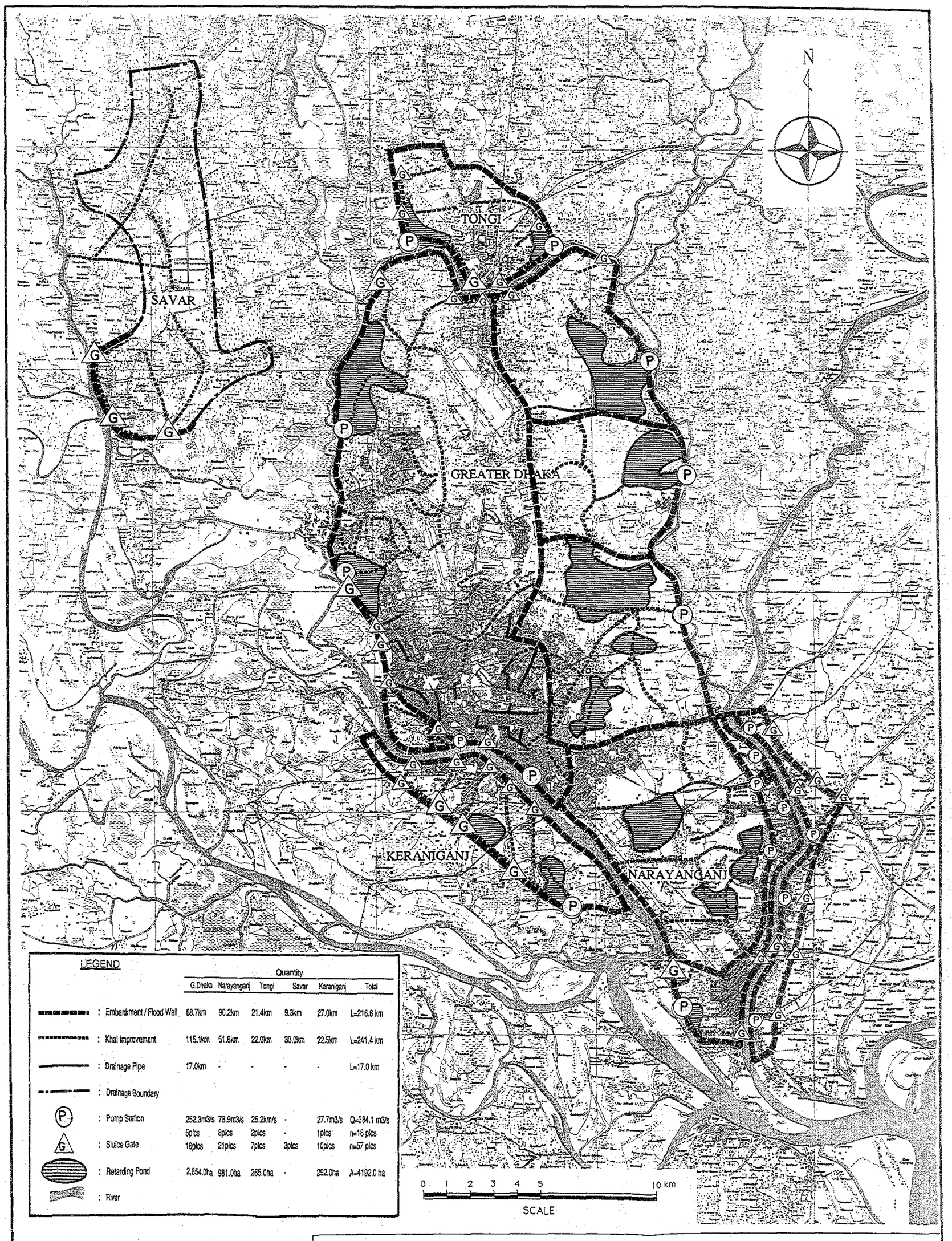
Hajime TANAKA
Team Leader



LOCATION MAP OF THE STUDY AREA

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

JICA



LEGEND

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

PROPOSED MASTER PLAN

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

JICA

Table of Contents

List of Tables

List of Figures

ABBREVIATIONS

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

SPARRSO	Space Research and Remote Sensing
UNCHS	United Nations Centre for Human Settlements
UNDP	United Nations Development Programme
WAPDA	Water and Power Development Authority
WASA	Water and Sewerage Authority
WMO	World Metrological Organization

SUMMARY

1 Introduction

The report presents the results of the study of Phase II for the Master Plan of Greater Dhaka Protection Project of Bangladesh Flood Action Plan No. 8 (FAP 8A).

This study aims at giving an exact picture of the actual situation in the study area, drawing up an optimum master plan for the areas, and selecting priority areas for F/S (Phase III).

The report consists of three parts: a main report giving an outline of the study results, proposed master plan, supporting reports (from A to M) giving a more detailed account of the study, and data books (I, II and III).

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 (GOB) and several action plans were proposed. The World Bank coordinated the studies and framed a Flood Action Plan (FAP) with 26 components as the initial stage for the development of a long term comprehensive system of flood control and drainage works.

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

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

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

This study was carried out as Phase II (Master Plan Study) by the JICA study team in collaboration with FPCO and the GOB study team from January 1991 to July 1991.

1.2 General Overview of Master Plan

This master plan proposes flood mitigation and drainage improvement measures that will enhance the safety, stability and development potential of the study area.

To accomplish these goals, this master plan calls for the following :

(1) Protection of the people in flood hazard zones through flood mitigation and stormwater drainage improvement arrangements, and warning and evacuation systems.

(2) Enhancement of the development potential of the study area.

(3) Assessment of high priority areas for a feasibility study.

After assessing the existing situation in the study area, the master plan on flood mitigation and stormwater drainage improvement for Dhaka Metropolitan area is proposed.

The proposed master plan is technically feasible and will likely be effective in economic, social and environmental terms as well except for Narayanganj East and Savar which seem unlikely to be feasible in economic terms.

According to the project evaluation, Greater Dhaka, DND and Narayanganj West will be the most urgent and important. The western part of Greater Dhaka has already been committed as a part of the immediate investment program by ADB.

The eastern part of Greater Dhaka, DND and Narayanganj West are identified as the priority areas for Phase III (F/S) of the JICA study.

2. Study Area and Flood Damage

The study area (approx. 850 km2) is situated in between lat. 23° 34'N- lat. 23° 59'N and long. 90° 13'E - long. 90° 33'E. It consists of Greater Dhaka, Tongi, Savar, Keraniganj and Narayanganj, located on the alluvial plain of the three major international rivers i.e. the Ganges, the Brahmaputra-Jamuna River and the Meghna River, their tributaries and distributaries.

The land form is as low as 2 m to 13 m above mean sea level, composed of alluvial terraces and low-lying areas

The low-lying areas are submerged 2.0 to 5.0 meters during the monsoon season for several months every year.

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

The climate is classified as a tropical monsoon type, characterized by the three seasons i.e. monsoon (rainy season), post-monsoon (dry season) and pre-monsoon (transitional season).

Average annual rainfall at Dhaka is about 2,000 mm, 90% of which occurs during the monsoon season from May to October.

Major floods in the study area were recorded in 1954, 1955, 1958, 1970, 1974, 1980, 1987 and 1988, in the period since 1945, when the water level observation was initiated at Mill Barak in Dhaka.

The flood areas of annual flood, the 1987 flood and the 1988 flood were surveyed and are shown on Figs. S.1, S.2 and S.3. The 1987 flood was assessed as a middle size flood with a 10-year frequency, the 1988 flood as the largest one with a 70-year frequency. The 1988 flood marked the highest water level at every location of the study area. The peaks of the 1974, the 1987 and the 1988 floods and the probable flood water levels of 10-year, 50-year and 100-year at Mill Barak, Demra, and Savar are shown on the table below :

	Actual Flood			Probable Flood		
	1974	1987	1988	10-Year	50-Year	100-Year
Mill Barak	6.57	6.60	7.54	6.65	7.40	7.72
Demra	6.58	6.46	7.10	6.53	7.09	7.32
Savar	7.80	8.30	9.68	8.14	9.00	9.36

Note: Datum: P.W.D. (m)

Return periods of the 1987 and 1988 floods are assessed for the above stations as shown below :

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

The flood areas of the annual flood, the 1987 flood and the 1988 flood are estimated as follows:

Flood	Flooding Area	
Annual flood	39,737 ha	(48.0% of the Study Area)
1987 flood	49,202 ha	(59.5% of the Study Area)
1988 flood	62,046 ha	(75.0% of the Study Area)

Though total population in the study area is estimated at 6,534,316 in 1990, the number of forecast affected population for a scale of the 1987 and 1988 flood are estimated as follows :

	1987 Flood Scale	1988 Flood Scale
The study area	2,403,055	3,751,456
Dhaka	1,459,061	2,432,305
Narayanganj	277,144	484,934
Keraniganj	430,943	441,788
Savar	182,597	261,427
Tongi	53,310	131,002

Number of properties in the flooding area are also estimated based on the data in 1990 and summarized as follows :

	1987 Flood Scale	1988 Flood Scale
No. of houses	414,304	642,939
No. of shops	12,051	20,683
No. of factories	2,316	4,595
No. of Institutions	10,507	19,834

3. Hydraulic Simulation

In order to formulate a flood mitigation plan for the study area, it is necessary to know the difference of water levels between "with" and "without" flood protection plan, in order to assess the likely hydraulic impacts by the project.

The hydraulic simulation was conducted using MIKE 11 which is software for hydrological and hydraulic simulation for rivers. The Model consists of Rainfall Runoff Model, Channels flow Model etc. Furthermore, the software can be operated with introductory river structures such as embankment, weir, pump station etc.

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

The objective of SWSMP is :

(1) To develop a surface water simulation model for the whole country called the "General Model" .

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

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

The hydraulic simulation of the study area is conducted for the 1988 flood. In the simulation, daily rainfall data of Dhaka (B.M.D) are used and boundary discharges are calculated by using BWDB's rating curves for Nayarhat (Sta. 14.5) and Demra (Sta.179). Other boundary discharges are estimated by trial and error method in conducting calibration of the simulation.

Calibration of the simulation is conducted for the flood water level at all the water level gauging stations in the study area. The result of the hydraulic simulation shows no significant changes between "with" and "without" conditions, no change in water levels at Kalagachia, Mill Barak and Savar with the project, but 1 cm increase at Mirpur, 3cm increase at Demra, and 6 cm increase at Tongi.

4. Land Use and Urban Planning

The study of existing land use and the forecasts of population growth and distribution to the year 2010, provide the basis for determining which areas can most justifiably be considered for flood protection.

4.1 Land Use

The main features of existing land use are a preponderance of mixed uses, a low proportion of non-residential uses, a scatter of very poor slum and squatter areas, housing a third of the population within small areas, and high densities, especially in the inner city and slum/squatter settlements. These features reflect an intensity of land use caused by increasing population pressure, limited alternative development areas, and the lack of a transportation system which would allow more extensive development.

4.2 Metropolitan Area Population Forecast

This forecast is for 1981 - 2010, for the area expected to attract migrants and accommodate urban development. This area, and the extent currently built-up, is shown in Fig. S.4. Continuing high growth is predicted, as shown below :

1981	3.98 million
1990	6.32 million
2000	9.86 million
2010	13.48 million

Distribution is based on the 1981 census, as influenced by :

- the unfairness of urban land allocation between rich and poor. The poor 70% majority has access to only 20% of the city's land; almost all planned development is for the relatively rich while the poor are crowded into small, unplanned areas.

- population increase between 1981 and 1990 was 59% while the increase in land developed was 20%, leading to higher densities. Densities will continue to increase, reflecting urbanization and lack of new, serviced land.

- the need to live near to work also fosters density increases. Relatively flood-free land close to the city will be rapidly developed. Both factors will determine the

development pattern, though mass transit would allow development of higher, more distant areas.

1981 to 1990

As population increase was much greater than urban land increase in this period, most must have been in existing areas. We estimate the increase in new planned developments during the period accommodated some 236,000 better-off residents, with twice as many being accommodated in existing better housing areas.

The increase in the poor was 1.64 million, most being housed in existing areas as there was little new land. The natural increase element (625,000) is distributed as higher density in these areas. 30% of total increase (709,000) has been distributed in slum and squatter settlements. The residual 304,000 poor has been distributed in the identified new (1981-90) peripheral unplanned areas.

1990 to 2000

Distribution of the increase is based on the factors already noted, assuming that known commitments and current trends will continue. Again, a distinction is made between rich and poor, and between new and existing development areas.

The total increase in the richer 30% is estimated at 1.06 million. But capacities of proposed new 'rich' areas are three times higher than 1981-90. There should then be less pressure for higher densities and it is assumed that only half the natural increase (196,000 people), remains in existing better-off areas. The major known planned new areas should accommodate the remainder (866,000) of this growth.

An additional 2.5 million poor people will be living in Dhaka, most at even higher densities in existing and new unplanned areas. It is assumed that all the natural increase (916,000) will stay as higher density in existing poorer areas. A continuing 30% of total population growth (1.062 million) is distributed in slum/squatter areas, all over the city. The remainder (501,000), is distributed in the eight major unplanned peripheral areas.

2000 to 2010

It is assumed that more efficient land acquisition and servicing will allow substantial areas to be made available for all groups. This should reduce pressures causing higher densities, and allow more of the forecast population increase of 3.62 million to be housed in new areas. For the upper income group, a total 416,000 is distributed in existing better areas. For the poor, because of greater openings assumed elsewhere, only half the natural increase (620,000) is this time retained in existing areas.

Of the potential new peripheral development areas, the seven most likely to be developed have a capacity of 1.61 million compared to the 2.58 million requirement. 970,000 will therefore need new urban land outside these areas. Tongi-Joydebpur and Keraniganj are two possibilities. While a decision on the better area could await the proposed transportation and metropolitan planning studies, the need to protect Jinjira may have priority. The recommended alignment for such poldering would accommodate an extra 330,000 here, the remainder being housed in Tongi-Joydebpur.

Fig.S.5 shows the urban area in 2010, based on the increments to city growth already outlined and the nature and distribution of major flood protection elements. Fig. S.6 summarizes urban growth between 1981 and 2010.

4.3 Control and Management of Urban Development

To ensure land availability for flood protection measures, steps are needed to better control urban development and acquire and service land. Current methods are slow, fragmentary and inefficient and will prejudice implementation of flood protection measures. Streamlined acquisition procedures and revised legislation is needed to allow the government to recoup development costs so as to fund efficient land acquisition and servicing. The forthcoming metropolitan development plan should provide a legal zoning basis, while the adoption of the 1985 Draft Physical Planning and Development Control Ordinance would allow improved land use control.

5. Living Environment

The important direct environmental aspects concerned with the human urban environment are potable water, sewerage and sanitation, and solid waste management. The amount of slums/squatter settlement in the city signifies a degraded human living

environment which virtually lacks all basic sanitary amenities including sufficient space.

Accordingly, an inventory study covering the existing water supply, sewerage and sanitation and solid waste management facilities was conducted. Surface water quality was also assessed based both on available data and a sampling survey conducted by the study team, as this is the prime indicator of human living environmental pollution.

5.1 Water Supply

Groundwater is the major source of potable water for both piped and non-piped water supply cases. The provision of piped water supply in the study area by DWASA is confined to a portion of the existing urban areas of Dhaka and Narayanganj. The service area covers portions of the respective municipalities.

The water production capacity of the Dhaka system is 530 MLD of which 97% is obtained from groundwater. Population served is estimated at 3.2 million. The on-going WASA III is aimed at further enhancing service level with additional groundwater source development. However, widespread leaks in the existing old water distribution system are reported.

Narayanganj water supply system is underutilized, due to lack of progress in house connections. The system is predominantly surface source based. Total production capacity is 64 MLD, with a service potential to serve 94% of the total municipal population, after the recent major expansion and rehabilitation program by JICA accomplished in 1989.

In all non-piped water areas, groundwater is the sole source of potable water.

The provision of potable water supply and sanitation in all areas other than municipalities, i.e. semiurban and rural areas, is under the jurisdiction of DPHE. DPHE is implementing a tubewell development program to enhance potable water service with the assistance of UNICEF.

5.2 Sewerage and Sanitation

The service area extends to about 33% of the DCC area. The remaining population depends on on-site sanitation facilities.

The stabilization pond system is used as the method of sewage treatment. DWASA is implementing various sewerage improvement programs, encompassing service area and collection and treatment system,with financial assistance from JICA, IDA and ADB.

Provision of on-site sanitation or sanitary disposal of human waste is the responsibility of the municipality in all municipal areas, whereas DPHE is responsible in all other semiurban and rural areas.

The service level of good sanitary latrines, predominantly pit latrine, in general, is not more than 4% in all non-municipal areas. In order to raise this service level DPHE, with assistance from UNICEF, is at present implementing the construction of water sealed leaching pits as low cost sanitary latrines in semiurban and rural areas at subsidized rate.

5.3 Solid Waste Management

The service area of solid waste management is confined to the three municipal areas and is the responsibility of the municipality concerned. Solid waste generation in rural areas is not yet a problem, though some semiurban centers encounter problems. However, water supply and sanitation improvement measures would be of high priority.

The most serious concern of existing solid waste management practice, common to all three municipalities, is related to the disposal of waste. Solid waste is simply considered as a resource of land filling material to reclaim low-lying areas and accordingly transported and disposed at a variety of locations, overlooking the adverse environmental and public health implications of such a practice.

Under the Environmental Improvement Project funded by IDA, a site covering 25 ha. at Matuail along the Dhaka-Demra road, has been proposed as the future sanitary land filling area. A sanitary land fill is expected to be instituted with this IDA assistance, instead of just a solid waste dump site.

5.4 Surface Water Quality.

Surface water quality is the best indicator of recent pollution effects by human and other related activities on water bodies.

DOE has at present twenty (20) number monitoring stations throughout the whole country. Of these, five (5) surface water monitoring stations fall within study area. All these stations are located in the river reaches of the Buriganga (3 stations), Balu or Tongi Khal (1 station) and Lakhya (1 station).

In due consideration to the scarcity of available monitoring stations by DOE in the study area, JICA study team conducted water quality sampling at 21 selected locations during January-February 1991 (dry season) and July-August 1991 (rainy season). The results are considered to be representative of respectively, dry season and rainy season water quality. The sampling locations were selected to encompass rivers, khals, lakes and ponds in the whole study area, with due prominence given to the urbanized areas of Dhaka and Narayanganj.

An evaluation of water quality under the critical conditions of dry season is summarized below.

All the rivers sampled are relatively unpolluted (BOD less than 10 mg/l), while most khals are polluted (BOD 200 - 400 mg/l). Water quality of all five rivers,three Khals namely Begunbari Khal in Amin Bazar, Hydrebad Khal in Tongi and Lakhya Khal in Narayanganj, are found to be suitable for all beneficial use including as a potential water supply source. The three major Khals in the highly urbanized area, Begunbari Khal, Segunbagicha Khal and Dholai Khal are in fact open sewers with no beneficial use.

The stationary bodies of lakes and ponds are moderately polluted and, in an overall sense, fall between the rivers and khals.

6. Existing Flood Mitigation and Drainage Facilities

6.1 Flood Mitigation Facilities

Most of the existing flood mitigation facilities of the study area have been constructed after the 1988 flood.

The GOB prepared an urgent flood protection plan to enclose the existing Dhaka urban area and the DND project area as a Phase I project immediately after the 1988 flood. The Phase I Project has been implemented except some small portions. The major completed flood protection facilities are shown in Fig. S.7.

They are :

(1) The embankment on the left banks of the Turag River and the Buriganga River with a total length of 29.2 km from Tongi Railway bridge to Kellar More, with six (6) sluice gates,

(2) The flood wall of 4.31 km on the left bank of the Buriganga River from the Friendship Bridge to Mitford Hospital,

(3) The road-cum-embankment with a total length of 19.8 km from Tongi to Jatrabari along the eastern fringe of existing Dhaka urban area as a temporary measure,

(4) The embankment of 10.53 km enclosing Zia International Airport,

(5) The flood wall of 29.40 km surrounding DND project area.

However, the following construction works of the Phase I project have not been constructed yet.

(1) The flood wall of 2.88 km from Kellar More to Mitford Hospital on the left bank of the Buriganga River, and

(2) The raising of the railway embankment in the southern part of DND project area.

The government further prepared the Phase II project to protect the whole Greater Dhaka area of 263 km^2. The project includes an embankment of approximately 29 km on the right bank of Balu River from Tongi Railway Bridge to Demra and five (5) pump stations. Among them, two pump stations are on-going by JICA and IBRD.

The existing flood mitigation facilities were assessed by the study team, as follows :

(1) The embankment from Tongi to Kellar More

Though the elevation of the embankment was high enough last year except in some locations, according to the new survey data, many parts of the crown is below the design height, possibly due to poor foundation and poor compaction. Intensive remedial works for the existing embankment will be essential because large scale settlement with approx. 1.5 m to 3.0 m depth have been identified.

Total settlement is about 17 km in length. Furthermore, the slope of embankment also needs remedying because of erosion and sliding.

(2) The flood walls on the Buriganga River and DND project area.

The flood wall is assessed as not strong enough against vehicle collision. The flood wall around the DND area is not considered a permanent structure. Flood walls along the Turag and the Buriganga River should be reinforced with foot protection works.

(3) The road-cum-embankment along the eastern fringe of Dhaka urban area.

The elevation of the road is marginal and it is assessed as a temporary flood mitigation measure.

6.2 Drainage Facilities

The existing drainage systems are based on drainage pipe, khal and drainage pump.

(1) The central part of Dhaka City (approx. 60 km^2) has a drainage system with pipes of 110 km in length. The drainage pipe density installed is estimated to be 2.4 km/km^2.

(2) There are a number of khals of 437 km in total length.

(3) There are two pumping stations : Narinda in the Old Dhaka and Demra. The drainage areas and their capacities are as follows :

	Drainage Area	Design Discharge
Narinda :	4.23 km^2	9.6 m^3/s
Demra :	57.0 km^2	14.52 m^3/s

7. Proposed Flood Mitigation and Drainage Improvement Plan

7.1 General

In order to eliminate flood and drainage problems from the study area, the flood mitigation and drainage improvement plan should cover the followings :

(1) To take optimum structural measures to protect the existing urban and forecast future urban areas of the target year of 2010, from floods of a 100 year frequency or the scale of the 1988 flood. The urban areas in the study area are expanding to the surrounding low-lying area. The urban areas are estimated to expand from 200 km^2 in 1990 to 366 km^2 by 2010. The structural measures are proposed to eliminate flood problems in an area of 453 km^2, including preforcast future urban areas.

(2) To make a drainage improvement plan to meet the needs of the urban areas in the target year of 2010.

(3) To prepare non structural measures to protect the people outside the urban areas.

A number of scattered small farming communities were submerged and isolated during floods. 530,000 people were estimated to have suffered from the 1988 flood in these areas.

7.2 Flood Mitigation Facility Plan

The design flood stages at the representative river gauging stations are decided as follows :

Gauging Station	1988 Flood	100-year Flood	Design Stage
Mill Barak (Buriganga River)	7.54	7.72	7.80
Hariharpara (Buriganga River)	7.17	7.10	7.20
Mirpur (Turag River)	8.39	8.53	8.60
Tongi (Tongi Khal)	7.96	8.30	8.60
Demra (Balu River)	7.10	7.32	7.40
Kalagachia (Dhaleswari River)	5.97	6.40	6.40
Savar (Bansi River)	9.68	9.36	9.70

Design free boards are decided as follows :

Earth embankment	:	1.20 m
Concrete flood Wall	:	0.60 m

Embankments are the most suitable measure against floods in the study area. River training by dredging is not effective in lowering the flood stage due to the hydraulic characteristics such as backwater effects of the other rivers, and also difficult to maintain the design river bed due to a high sediment concentration.

Alternative plans for the urban areas were studied from technical, economical and social aspects.

Kamrangir Char, which was not included in the committee's proposal, but proposed in the last comments on the Interim Report FAP 8A (March, 1991), is included in the proposed plan. It might be considered as a part of Greater Dhaka. The area was also submerged during both the 1987 flood and the 1988 flood.The present population is estimated to be over 35,000.

The proposed facilities and the remedial works of the existing facilities are listed in Table S.1 and shown in Figs. S.8 to S.10.

7.3 Stormwater Drainage Improvement Plan

The design flood stage of 2-year frequency is applied for external rivers in each drainage area or zone based on the probable water level at each gauging station. The determined design flood stages are as follows:

	Drainage zone		Design Flood Stage (PWD : m)
(1)	Greater Dhaka		
	- Buriganga River left bank zone	:	5.80 to 6.45
	- Turag River left bank zone	:	6.45
	- Balu River right bank zone:	:	5.90
(2)	Tongi	:	6.45
(3)	Savar	:	7.20
(4)	Narayanganj	:	5.45 to 5.80
(5)	Keraniganj	:	5.45 to 5.80

The pump capacity is designed to be able to have sufficient capacity for a external river water stage of 100 - year flood frequency.

For the planning of pump facilities and retarding ponds, a 2-day consecutive rain-fall with a 5 - year frequency is adopted. For khal and trunk drain improvement, rain-fall intensity of a 5-year frequency is adopted and the areal reduction factor is also considered.

The study area is divided into the following twelve (12) drainage areas and shown in Fig. S.11 :

(Greater Dhaka West)

(1)	DA	:	Buriganga River left bank	A = 34.33 km^2
(2)	DB	:	Turag River left bank	A = 60.84 km^2

(Greater Dhaka East)

(3)	DC1	:	Northern Area of Balu River right bank zone	A = 45.86 km^2
(4)	DC2	:	Central Area of Balu River right bank zone	A = 30.65 km^2
(5)	DC3	:	Southern Area of Balu River right bank zone	A = 90.74 km^2

(Tongi Area)

(6)	TA	:	Tongi West zone	A = 13.24 km^2
(7)	TB	:	Tongi East zone	A = 11.06 km^2

(Savar Area)

(8)	S	:	Savar proposed whole Area	A = 56.52 km^2

(Narayanganj)

(9)	NA	:	DND project zone	A = 56.97 km^2
(10)	NB	:	Narayanganj West zone	A = 18.63 km^2
(11)	NC	:	Narayanganj East zone	A = 12.80 km^2

(Keraniganj)

(12)	K	:	Keraniganj proposed whole area	A = 24.27 km^2

The design discharges for khals and trunk drains of each drainage zone are summarized and shown in Table. S 2 (1) and (2). The required pump capacity and the storage volume of retarding ponds for each drainage zone are listed in Table. S .3.

The existing topographic conditions, drainage networks and forecast future urban areas were studied. An optimum drainage improvement plan for each drainage zone is summarized in Table S.1 and and shown in Figs S.8 to S.10.

7.4 Non-Structural Measures

In order to protect rural communities in the flood prone area from potential flood damage, flood warning and evacuation systems are essential. Guidelines for flood plain management are essential for proper land use development of low-lying areas.

7.4.1 Flood Forecasting and Warning System

Flood forecasting and warning is carried out by the Flood Forecasting and Warning Center of Hydrology-2, BWDB, in cooperation with MPO, SPARRSO and other agencies concerned.

The existing flood forecasting system depends on a few water level monitoring stations along the Ganges, the Brahmaputra-Jamuna River, the Buriganga River and the Lakhya River. The existing system needs to be reinforced by means to :

(1) reinforce observation networks,

(2) establish a telecommunication system linking the major monitoring stations and the Flood Forecasting and Warning Center,

(3) upgrade regional model for detailed regional forecasting,

(4) improve the flood warning system up to the Upazila level,

(5) train a group of flood warning and forecasting staff, and

(6) publish a flood hazard area map for proper operation of flood mitigation schemes.

7.4.2 Flood Evacuation System

For a number of rural communities away from flood free land, flood warning and evacuation facilities are needed. Measures needed should:

(1) improve the flood warning system at flood prone areas on the basis of likely danger flood water levels which indicate when evacuation is required.

(2) construct (or improve) evacuation road networks and flood shelters.

The evacuation roads are proposed based on the existing road networks and evacuation shelters are propoed to be built and used as shelters during floods, but normally used as public facilities such as schools and community centres. They are shown in Figs. 12 (1) and (2).

7.4.3 Development Control of Future Urban Areas

For flood mitigation and drainage improvement purposes, sufficient preservation of land for trunk drain channels and retarding ponds, will be required by the Government and some proper guidelines for landfill and development of the future urban areas which are protected from external floods by embankments, will also need to be prepared. The proposed minimum ground elevation of the landfill and development are illustrated in Fig. S.13.

7. 5 Summary of Planned Projects

The cost of proposed sub project are shown in Table S. 4. The total project cost is estimated to be 61,208 million Tk. at March 1991 prices.

(Structural Measures)

(Unit : million Tk.)

		F/C	L/C	Total
1.	Direct Cost	15,487.4	13,344.6	28,831.0
	- Construction Cost	(15,487.4)	(13,343.6)	(28,831.0)
2.	Indirect Cost	1,548.7	22,074.8	23,623.5
	- Land Acquisition Cost	(-)	(19,875.4)	(19,875.4)
	- Administration Cost	(-)	(865.0)	(865.0)
	- Engineering Service Cost	(1,548.7)	(1,334.4)	(2,883.1)
3.	Physical Contingency	3,872.0	3,335.9	7,207.9
	Total :	20,908.1	38,754.3	59,662.4

(Non-Structural Measures)

1.	Direct Cost	439.5	598.5	1,038.0
	- Construction Cost	(439.5)	(598.5)	(1,038.0)
2.	Indirect Cost	44.0	204.1	248.1
	- Land Acquisition Cost	(-)	(113.1)	(113.1)
	- Administration Cost	(-)	(31.2)	(31.2)

	- Engineering Service Cost	(44.0)	(59.8)	(103.8)
3.	Physical Contingency	110.0	149.6	259.6
	Total :	593.5	952.2	1,545.7
	Grand Total	21,501.6	39,706.5	61,208.1

Note : US$ 1.00 = Tk. 36 = ¥ 137

7.6 Phased Implementation Program

The implementation program for the project is based on the following consideration :

(1) The program is composed of three (3) phases with due consideration of the objectives of the project,

(2) The program is to be implemented within the project target year of 2010,

(3) The program needs to meet the trend of regional urban development and obtain quick benefits,

(4) The proper scale in terms of financial cost and disbursement,

(5) Parts of the proposed works for Greater Dhaka West have already been committed as a part of the immediate investment projects by ADB in July 1991.

The phased implementation program is shown in Table S. 5.

7.7 Environmental Impacts of the Project

Environmental impacts anticipated to result from the project are both direct and indirect, and short term and long term.

Short term impacts are defined as impacts by the construction of the project facilities. They will be identified and suitable mitigatory measures be proposed for incorporation in construction planning. Long term impacts will result from the change in land use and urbanization ; important impacts include pollution and demand for basic services. However, the adverse environmental impacts will not be significant.

7.8 Project Evaluation

The economic evaluation of the project was based on the comparison of costs with the benefits. Major benefits will derive from the reduction of direct flood damages to properties such as houses, shops, factories and institutions, the reduction of income

losses due to inability to engage in economic activities during floods and the reduction of direct flood damage to agricultural crops.

Reduction of direct flood damages to infrastructure such as roads, bridges, power supply, gas supply, water supply, telecommunication and transportation are also expected.

A reduction of the outbreaks of water borne diseases, elevation of cropping intensity in the flood protected agricultural areas, creation of employment through urbanization and economic activities inside the flood protected areas are additional benefits.

Flood mitigation and drainage improvement measures are a basic human need in the same manner as urban water supply, road network, medical service etc.

The period of project life was assumed to be 30 years. The opportunity cost of capital is assumed as 12% according to the Guidelines of Economic (Micro) Analysis (FAP).

The project evaluation is based on effectiveness in economic, social and environmental terms. However, the adverse environmental effects will not be significant, and may be non-existent.

According to the economic evaluation, all the projects except the Narayanganj East, and Savar projects, will be feasible from flood mitigation and drainage related benefits, though the EIRR values of the Tongi project and the Keraniganj project with 11.8% and 10.0% respectively seem marginal compared to the high discount rate of 12%.

However all projects will surely have a strong impact and a good effect to the areas in social and environmental terms.

Based on the economic efficiency and the likely social impacts assumed in 1990 and in 2010, Table S. 6, the priority order of projects is identified as follows :

1st priority area :

- Greater Dhaka West (A = 95.1 km²)
- Greater Dhaka East (A = 167.3 km²)
- Narayanganj DND (A = 56.8 km²)
- Narayanganj West (A = 18.6 km²)

2nd priority area :

- Tongi (A = 24.3 km²)
- Keraniganj (A = 24.3 km²)

3rd priority area :

- Narayanganj East (A = 12.8 km²)
- Savar (A = 50.5 km²)

8. Conclusions and Recommendations

8.1 Priority Project F/S

(1) The proposed flood mitigation and drainage improvement facility plan is technically feasible and will be effective in economical, social and environmental terms, though Tongi and Keraniganj seem marginal, and Narayanganj East and Savar may not be feasible in economic terms. All the study area needs immediate action for implementation of structural and non-structural measures, because the area is extremely vulnerable both to external floods and to internal floods due to its low and flat topography and difficult meteo-hydrological conditions.

According to the project evaluation on measures required in each urban area and at each sub project area, Greater Dhaka and Narayanganj DND / West are the highest priority areas.

(2) According to the report (July 1991) by the Fact Finding Mission of ADB, many parts of proposed structural measures for the western part of Greater Dhaka (DA /DB) have already been selected by ADB as a part of the immediate investment program for the first stage.

Accordingly the F/S on Greater Dhaka West (GDW) will be carried out by ADB (FAP 8B).

Among the remaining high priority areas, Greater Dhaka East and Narayanganj DND/West must be the areas needing the most urgent implementation. They need more detailed assessments for early implementation.

Greater Dhaka East and Narayanganj DND/West are identified for the phase III study (F/S). Each proposed area for the F/S is explained as follows :

(Greater Dhaka East)

- The flood mitigation and storm water drainage improvement plans for Greater Dhaka East were approved as phase II of the Greater Dhaka Flood Control Committee's proposal by the GOB.

- According to the projection of the future population and land use at the target year of 2010, population of Greater Dhaka will increase from 4.4 million in 1990 to 8.6 million in 2010. Flood mitigation and drainage improvements of Greater Dhaka will be one of the most urgent measures needed to cater for this increase.

- The master plan evaluation shows that the project is not only technically feasible, but will likely be effective in economical, social and environmental terms as well.

- The central part of Dhaka city (drainage area 44 km^2 of PD - 7) drains east to the Balu River. The protection of this eastern area is also needed if flood protection of the western part is to be safeguarded.

(DND Area)

- The DND irrigation project area is changing to urban. RAJUK is preparing a detailed development plan.

- This area has a high potential as a future urban area, according to the preliminary projection of future population and land use, and it is estimated that population of DND will increase from 0.45 million in 1990 to 1.3 million in 2010.

- The project is technically feasible and will be effective in economical, social and environmental terms.

- The area is expected to develop intensively. Accordingly it will be essential that flood mitigation and drainage improvement be provided as a basic need for enhancement of the area.

(Narayanganj West)

- The area has numbers of businesses / industries located along the Lakhya River and also a high population density. It is estimated that population of the area will increase from 0.47 million (359 people/ha) in 1990 to 0.93 million (539 people/ha) in 2010, according to the preliminary projection of future population and land use.

- The project is technically feasible and will be effective in economical, social and environmental terms.

8.2 Others

(1) Immediate completion of all the remedial works and rehabilitation works for the existing flood mitigation facilities of the western part of Greater Dhaka is the most urgent measure.

(2) Proper operation and maintenance of flood mitigation and drainage facilities are essential. After completion, security of the schemes will be very important. An O&M plan should be developed, and properly trained personnel will be needed to assume the required duties of inspection, etc.

(3) It is recommended that a project implementation organization be established for smooth execution of the master plan, in order to carry out structural and non-structural measures smoothly, and also to control land use effectively. A strong implementation /coordination organization at ministerial level, with considerable control and management abilities will be necessary.

(4) It is recommended that an environmental monitoring system for surface water, ground water and ambient air quality for environmental management be established. Without proper monitoring systems, the laws and regulation standards are useless.

(5) It is recommended that the following priority actions be carried out for enhancement of basic public health, related to living environmental conditions in the urban areas.

- Preparation of improvement plan of service level of on-site sanitation aspects.
- Preparation of solid waste management plan for sanitary land reclamation.
- Preparation of improvement plan for living environmental conditions and improvement and relocation of slums.
- Creation of a master plan and execution of expansion of water supply, sewerage, sanitation and solid waste management, to cope with increasing urbanization as the provision of the basic public health services.

Table S.1 List of Proposed Facilities

Area	Flood Mitigation			Stormwater Drainage		
1. Greater Dhaka						
1) West	a) Embankment (R)	:	16.7 km	a) Pump Station (No.)	:	73.2 m3/s (2plcs)
	b) Flood wall (R)	:	4.7 km	b) Khal Improvement	:	42.7 km
	c) Embankment	:	6.3 km	c) Drainage Pipe	:	8.1 km
	d) Flood Wall	:	3.0 km	d) Retarding Pond	:	770.0 ha
	e) Sluice Gate	:	11 plcs	e) Land Acquisition	:	43.7 ha
	f) Land Acquisition	:	37.0 ha			
2) East	a) Embankment	:	26.7 km	a) Pump Station (No.)	:	179.1 m3/s (3plcs)
	b) Sub Embankment	:	11.3 km	b) Khal Improvement	:	72.4 km
	c) Sluice Gate	:	5 plcs	c) Drainage pipe	:	8.9 km
	d) Land Acquisition	:	317.4 ha	d) Retarding Pond	:	1,884.0 ha
				e) Land Acquisition	:	168.0 ha
2.Narayanganj						
1)DND Area	a) Flood Wall (R)	:	20.2 km	a) Pump Station (No.)	:	50.2 m3/s (1plcs)
	b) Flood Wall	:	10.0 km	b) Khal Improvement	:	38.0 km
	c) Sluice Gate	:	2 plcs	c) Retarding Pond	:	681.0ha
	d) Land Acquisition	:	5.8 ha	d) Land Acquisition	:	90.8 ha
2) West	a) Embankment	:	6.1 km	a) Pump Station (No.)	:	16.2 m3/s (3plcs)
	b) Road-Cum-Embankment	:	4.3 km	b) Khal Improvement	:	6.4 km
	c) Flood Wall	:	10.5 km	c) Retarding Pond	:	170.0 ha
	d) Sluice Gate	:	7 plcs	d) Land Acquisition	:	12.2 ha
	e) Land Acuqisition	:	61.5 ha			
	% Evacuation Facilities		1 L.S			
3) East	a) Embankment	:	6.6 km	a) Pump Station (No.)	:	12.5 m3/s (4plcs)
	b) Road-Cum-Embankment	:	6.5 km	b) Khal Improvement	:	7.4 km
	c) Flood Wall	:	26.0 km	c) Retarding Pond	:	130.0 ha
	d) Sluice Gate	:	12 plcs	d) Land Acquisition	:	14.1 ha
	e) Land Acquisition	:	99.2 ha			
3. Tongi	a) Embankment	:	13.0 km	a) Pump Station (No.)	:	25.2 m3/s (2plcs)
	b) Road-Cum-Embankment	:	6.2 km	b) Khal Improvement	:	22.0km
	c) Flood Wall	:	2.2 km	c) Retarding Pond	:	265.0 ha
	d) Sluice Gate	:	7 plcs	d) Land Acquisition	:	42.5 ha
	e) Land Acquisition	:	100.9 ha			
	% Evacuation Facilities	:	1 L.S			
4.Savar	a) Embankment	:	9.3 km	a) Khal Improvement	:	30.0 km
	b) Sluice Gate	:	3 plcs	b) Land Acquisition	:	66.2 ha
	c) Land Acquisition	:	62.3 ha			
	% Evacuation Facilities	:	1 L.S			
5. Keraniganj	a) Embankment	:	23.3 km	a) Pump Station (No.)	:	27.7 m3/s (1plcs)
	b) Flood Wall	:	3.7 km	b) Khal Improvement	:	22.5 km
	c) Sluice Gate	:	10 plcs	c) Retarding Pond	:	292.0 ha
	d) Land Acquisition	:	163.7 ha	d) Land Acquisition	:	50.6 ha
	% Evacuation Facilities	:	1 L.S			

Note : 1) Embankment (R) : Rehabilitation Work of Embankment
2) Flood Wall (R) : Rehabilitation Work of Flood Wall
3) Land Acquisition : Retarding Pond is not included
4) Pump station (No.) : Total Capacity (Number of Pump Station)
5) On-Going Projects by JICA and IBRD are not included.

Table S. 2 (1) Design Discharge

Block No.	Drainage Area (km2)	Velocity (m/s)	Time of Concentration (min)	Rainfall Intensity (mm/hr)	Run-off Coefficient	Areal Reduction Factor	Run-Off (m3/s)
Buriganga River Left Bank Zone (DA)							
DA-1	6.96	0.80	97.73	60.96	0.40	0.96	45.25
Turag River Left Bank Zone (DB)							
DB-1	5.88	0.80	91.44	63.67	0.40	0.96	39.93
DB-2	7.48	0.80	100.58	59.80	0.40	0.95	47.22
DB-3	6.33	0.80	94.13	62.48	0.40	0.96	42.19
DB-4	22.89	0.80	160.96	42.69	0.40	0.90	97.71
DB-5	13.88	0.80	129.77	50.09	0.40	0.93	71.85
DB-6	23.95	0.80	164.19	42.04	0.40	0.90	100.69
DB-7	57.21	0.80	242.85	30.75	0.40	0.81	158.33
DB-8	3.63	0.80	76.13	71.39	0.40	0.98	28.22
Balu River Right Bank Zone (DC-1)							
DC-1-1	5.79	0.80	90.89	63.91	0.40	0.96	39.47
DC-1-2	16.84	0.80	140.91	47.17	0.40	0.92	81.20
DC-1-3	5.78	0.80	90.83	63.94	0.40	0.96	39.42
DC-1-4	9.75	0.80	112.00	55.59	0.40	0.94	56.61
DC-1-5	11.49	0.80	119.87	53.01	0.40	0.94	63.62
DC-1-6	35.57	0.80	195.72	36.65	0.40	0.85	123.11
DC-1-7	5.21	0.80	87.25	65.61	0.40	0.97	36.84
DC-1-8	3.14	0.80	72.21	73.69	0.40	0.98	25.19
DC-1-9	1.94	0.80	61.04	81.10	0.40	0.99	17.31
Balu River Right Bank Zone (DC-2)							
DC-2-1	3.97	0.80	78.70	69.97	0.40	0.97	29.94
DC-2-2	4.94	0.80	85.48	66.47	0.40	0.97	35.39
DC-2-3	10.99	0.80	117.67	53.71	0.40	0.94	61.65
DC-2-4	3.22	0.80	72.87	73.29	0.40	0.98	25.70
DC-2-5	21.54	0.80	156.74	43.56	0.40	0.91	94.86
DC-2-6	3.04	0.80	71.37	74.19	0.40	0.98	24.56
DC-2-7	30.65	0.80	183.11	38.63	0.40	0.87	114.45
Balu River Right Bank Zone (DC-3)							
DC-3-1	8.81	1.00	87.83	65.33	0.40	1.00	66.65
DC-3-2	11.80	1.00	100.97	59.65	0.40	0.94	73.51
DC-3-3	17.64	0.80	143.74	46.48	0.40	0.92	83.81
DC-3-4	35.12	0.80	194.60	36.81	0.40	0.85	122.11
DC-3-5	5.36	0.80	88.21	65.15	0.40	0.97	37.64
DC-3-6	47.94	0.80	224.00	32.87	0.40	0.83	145.30
DC-3-7	6.59	1.00	86.67	65.89	0.42	1.00	52.17
DC-3-8	13.15	1.00	105.47	57.92	0.40	0.93	78.70
DC-3-9	7.39	0.80	100.09	60.00	0.40	0.95	46.80
DC-3-10	6.64	0.80	95.92	61.71	0.40	0.96	43.71
DC-3-11	16.99	0.80	141.44	47.04	0.40	0.92	81.69
DC-3-12	90.74	0.80	300.66	25.68	0.40	0.77	199.37
Tongi West Zone (TA)							
TA-1	4.13	0.80	79.88	69.34	0.40	0.97	30.86
TA-2	5.16	0.80	86.93	65.77	0.40	0.96	36.20
TA-3	3.86	0.80	77.89	70.41	0.40	0.97	29.29
TA-4	9.52	0.80	110.91	55.96	0.40	0.94	55.65
TA-5	2.28	0.80	64.49	78.65	0.40	0.99	19.73
TA-6	1.44	0.80	55.36	85.47	0.40	0.99	13.54
Tongi East Zone (TB)							
TB-1	4.64	0.80	83.46	67.47	0.40	0.97	33.74
TB-2	2.72	0.80	68.59	75.93	0.40	0.98	22.49
TB-3	8.17	0.80	104.21	58.39	0.40	0.95	50.36
TB-4	2.08	0.80	62.49	80.05	0.40	0.99	18.32
TB-5	0.81	0.80	46.52	93.30	0.40	1.00	8.40

Table S. 2 (2) Design Discharge

Block No.	Drainage Area (km2)	Velocity (m/s)	Time of Concentration (min)	Rainfall Intensity (mm/hr)	Run-off Coefficient	Areal Reduction Factor	Run-Off (m3/s)
Savar Zone (S)							
S-1	6.23	0.80	93.54	62.74	0.40	0.97	42.12
S-2	10.70	0.80	116.38	54.12	0.40	0.94	60.49
S-3	4.60	0.80	83.19	67.61	0.40	0.97	33.52
S-4	4.16	0.80	80.09	69.22	0.40	0.98	31.36
S-5	14.21	0.80	131.06	49.73	0.40	0.93	73.03
S-6	26.47	0.80	171.58	40.64	0.40	0.88	105.18
S-7	4.94	0.80	85.48	66.47	0.40	0.97	35.39
S-8	1.14	0.80	51.46	88.76	0.40	0.99	11.13
S-9	2.01	0.80	61.77	80.57	0.40	0.99	17.81
S-10	0.86	0.80	47.32	92.53	0.40	1.00	8.84
S-11	6.11	0.80	92.83	63.05	0.40	0.97	41.52
S-12	9.36	0.80	110.14	56.23	0.40	0.94	54.97
S-13	5.19	0.80	87.12	65.67	0.40	0.97	36.73
S-14	16.63	0.80	140.15	47.36	0.40	0.92	80.51
DND Project Area (NA-1)							
NA-1-1	6.81	0.80	96.89	61.31	0.40	0.96	44.53
NA-1-2	3.41	0.80	74.41	72.38	0.40	0.98	26.88
NA-1-3	17.68	0.80	143.88	46.45	0.40	0.92	83.94
NA-1-4	3.30	0.80	73.52	72.90	0.40	0.98	26.20
NA-1-5	24.42	0.80	165.60	41.77	0.40	0.90	102.00
NA-1-6	4.61	0.80	83.26	67.58	0.40	0.97	33.58
NA-1-7	30.17	0.80	181.83	38.84	0.40	0.87	113.28
DND Project Area (NA-2)							
NA-2-1	7.78	0.80	102.18	59.17	0.40	0.95	48.59
NA-2-2	2.36	0.80	65.26	78.13	0.40	0.98	20.08
NA-2-3	14.39	0.80	131.76	49.54	0.40	0.93	73.67
NA-2-4	4.54	0.80	82.78	67.82	0.40	0.97	33.19
NA-2-5	2.68	0.80	68.23	76.16	0.40	0.98	22.23
NA-2-6	11.18	0.80	118.51	53.44	0.40	0.94	62.40
NA-2-7	26.62	0.80	172.01	40.56	0.40	0.88	105.57
Narayanganj West Zone (NB)							
NB-1	2.45	0.80	66.12	77.55	0.40	0.98	20.69
NB-2	5.52	0.80	89.22	64.68	0.40	0.96	38.08
NB-3	1.11	0.80	51.04	89.12	0.40	0.99	10.88
NB-4	2.41	0.80	65.74	77.80	0.40	0.98	20.42
NB-5	0.88	0.80	47.64	92.23	0.40	1.00	9.02
NB-6	3.57	0.80	75.67	71.66	0.40	0.97	27.57
NB-7	2.69	0.80	68.32	76.11	0.40	0.98	22.29
Narayanganj East Zone (NC)							
NC-1	1.02	0.80	49.76	90.27	0.40	0.99	10.13
NC-2	0.60	0.80	42.82	97.01	0.40	1.00	6.47
NC-3	3.27	0.80	73.28	73.05	0.40	0.98	26.01
NC-4	2.31	0.80	64.78	78.45	0.40	0.99	19.94
NC-5	1.92	0.80	60.82	81.25	0.40	0.99	17.16
NC-6	3.68	0.80	76.52	71.17	0.40	0.97	28.23
Keraniganj Zone (K)							
K-1	2.19	0.80	63.60	79.27	0.40	0.98	18.90
K-2	2.70	0.80	68.41	76.05	0.40	0.98	22.36
K-3	5.57	0.80	89.53	64.54	0.40	0.96	38.34
K-4	3.55	0.80	75.51	71.75	0.40	0.97	27.45
K-5	11.40	0.80	119.48	53.13	0.40	0.94	63.26
K-6	1.86	0.80	60.18	81.73	0.40	0.99	16.72
K-7	13.99	0.80	130.20	49.97	0.40	0.93	72.24
K-8	10.28	0.80	114.46	54.75	0.40	0.94	58.79

Table S.3 Required Pump Capacity and Storage Volume of Retarding Pond

Name of Area	Drainage Zone	Sub-Zone	Area (km^2)	Required Pump Capacity		Required Storage Volume of Retarding Pond		Remarks
				Specific ($m^3/s/km^2$)	Total (m^3/s)	Specific ($x10^6\ m^3/km^2$)	Total ($x10^6\ m^3$)	
Greater Dhaka	Buriganga River Left Bank Zone (DA)	PD-1(Kamrangi Char)	6.96	1.14	8.0	0.12	0.84	
		PD-2 (Old Dhaka)	6.75	3.29	22.2	0.03	0.21	World Bank Project
		PD-3 (Kallyanpur)	17.60	1.14	20.0	0.12	2.08	JICA Project
	Turag River Left Bank Zone (DB)	PD-4 (Northern Part)	57.19	1.14	65.2	0.12	6.86	
	Balu River Right Bank Zone (DC)	PD-5 (Northern Part))	35.57	1.14	40.6	0.12	5.50	
		PD-6 (Central Part)	30.65	1.14	35.0	0.12	3.68	
		PD-7 (Southern Part)	90.74	1.14	103.5	0.12	10.89	
Tongi	Tongi West Zone (TA) PD-8		11.80	1.14	13.5	0.12	1.42	
	Tongi East Zone (TB) PD-9		10.25	1.14	11.7	0.12	1.23	
Narayanganj	DND Project Zone (NA)	PD-10 (Northern Part)	30.17	1.14	14.5	0.12	3.62	Existing P.S.
		PD-11 (Southern Part)	26.62	1.14	50.2	0.12	3.19	
	Narayanganj West Zone (NB)	PD-12	2.45	1.14	2.8	0.12	0.29	
		PD-13	5.52	1.14	6.3	0.12	0.66	
		PD-14	6.26	1.14	7.1	0.12	0.75	
	Narayanganj East Zone (NC)	PD-15	1.02	1.14	1.2	0.12	0.12	
		PD-16	3.87	1.14	4.4	0.12	0.46	
		PD-17	2.31	1.14	2.7	0.12	0.28	
		PD-18	3.68	1.14	4.2	0.12	0.44	
Keraniganj	Keraniganj Zone (K) PD-19		24.27	1.14	27.7	0.12	2.92	
Total			383.97	—	455.5	—	45.44	

Table S.4 Summary of Project Cost

(Unit: million TK)

Project Area	G. Dhaka West			G. Dhaka East			Narayanganj DND			Narayanganj West		
	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
I. Structural Measures												
1) Construction Cost	2,746.2	2,163.3	4,909.5	6,217.6	5,384.5	11,602.1	1,460.7	1,064.0	2,524.7	697.8	552.3	1,250.1
2) Physical Contingency	686.6	540.8	1,227.4	1,554.4	1,346.1	2,900.5	365.2	266.0	631.2	174.4	138.1	312.5
3) Land Acquisition Cost	-	3,907.2	3,907.2	-	6,285.5	6,285.5	-	4,043.8	4,043.8	-	1,267.1	1,267.1
4) Engineering Cost	274.6	216.4	491.0	621.8	538.4	1,160.2	146.1	106.4	252.5	69.8	55.2	125.0
5) Administration Cost	-	147.3	147.3	-	348.1	348.1	-	75.7	75.7	-	37.5	37.5
6) Previous/On-going Projects	-	-	(3,351.2)	-	-	(226.1)	-	-	(138.5)	-	-	-
Sub-Total	3,707.4	6,975.0	10,682.4	8,393.8	13,902.6	22,296.4	1,972.0	5,555.9	7,527.9	942.0	2,050.2	2,992.2
			(3,351.2)			(226.1)			(138.5)			
II. Non-Structural Measures												
1) Construction Cost	-	-	-	-	-	-	-	-	-	10.0	15.0	25.0
2) Physical Contingency	-	-	-	-	-	-	-	-	-	2.5	3.8	6.3
3) Land Acquisition Cost	-	-	-	-	-	-	-	-	-	-	5.7	5.7
4) Engineering Cost	-	-	-	-	-	-	-	-	-	1.0	1.5	2.5
5) Administration Cost	-	-	-	-	-	-	-	-	-	-	0.8	0.8
Sub-Total										13.5	26.8	40.3
Total	3,707.4	6,975.0	10,682.4	8,393.8	13,902.6	22,296.4	1,972.0	5,555.9	7,527.9	955.5	2,077.0	3,032.5
			(3,351.2)			(226.1)			(138.5)			

Project Area	Narayanganj East			Tongi			Savar			Keraniganj		
	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
I. Structural Measures												
1) Construction Cost	932.0	781.8	1,713.8	1,129.4	966.0	2,095.4	644.3	755.1	1,399.4	1,659.4	1,676.6	3,336.0
2) Physical Contingency	233.0	195.5	428.5	282.4	241.5	523.9	161.1	188.8	349.9	414.9	419.1	834.0
3) Land Acquisition Cost	-	1,265.0	1,265.0	-	1,102.8	1,102.8	-	282.7	282.7	-	1,721.3	1,721.3
4) Engineering Cost	93.2	78.2	171.4	112.9	96.6	209.5	64.4	75.5	139.9	165.9	167.7	333.6
5) Administration Cost	-	51.4	51.4	-	62.9	62.9	-	42.0	42.0	-	100.1	100.1
6) Previous/On-going Projects	-	-	-	-	-	-	-	-	-	-	-	-
Sub-Total	1,258.2	2,371.9	3,630.1	1,524.7	2,469.8	3,994.5	869.8	1,344.1	2,213.9	2,240.2	4,084.8	6,325.0
II. Non-Structural Measures												
1) Construction Cost	-	-	-	20.0	30.0	50.0	148.5	202.5	351.0	261.0	351.0	612.0
2) Physical Contingency	-	-	-	5.0	7.5	12.5	37.2	50.6	87.8	65.3	87.7	153.0
3) Land Acquisition Cost	-	-	-	-	5.9	5.9	-	28.1	28.1	-	73.4	73.4
4) Engineering Cost	-	-	-	2.0	3.0	5.0	14.9	20.2	35.1	26.1	35.1	61.2
5) Administration Cost	-	-	-	-	1.5	1.5	-	10.5	10.5	-	18.4	18.4
Sub-Total				27.0	47.9	74.9	200.6	311.9	512.5	352.4	565.6	918.0
Total	1,258.2	2,371.9	3,630.1	1,551.7	2,517.7	4,069.4	1,070.4	1,656.0	2,726.4	2,592.6	4,650.4	7,243.0

Grand Total (I)			59,662.4
			(3,915.8)
Grand Total (I)+(II)			61,208.1
			(3,915.8)

Table S. 5 Phased Implementation Program

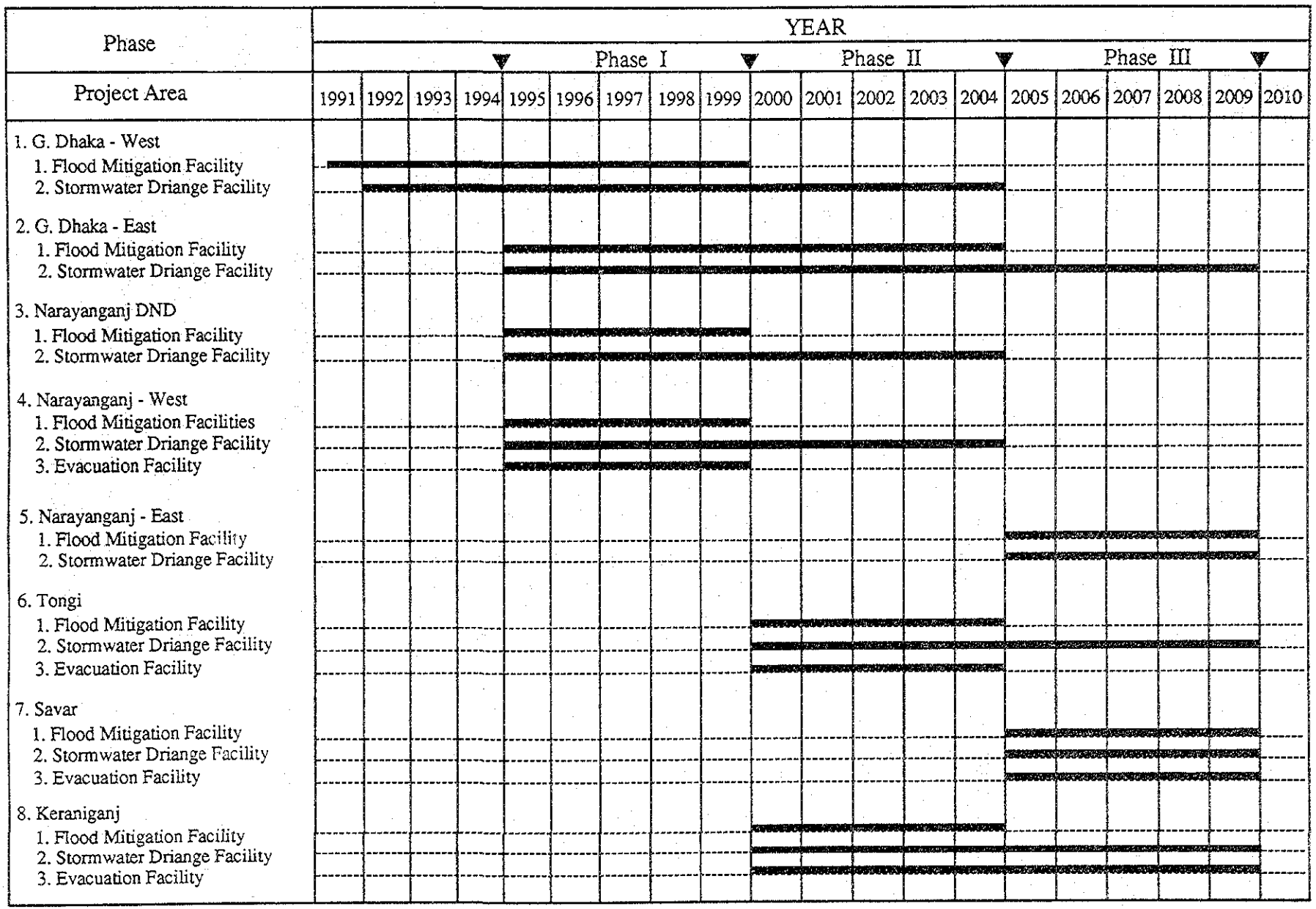


Table S.6 Project Evaluation

	Greater Dhaka		Narayanganj			Keraniganj	Savar	Tongi
	West 1/	East 2/	DND	West	East			
. EIRR (%)	18.3	12.3	14.2	13.7	7.4	10.0	-	11.8
	15.3		13.5					
NPV (Tk. Million)	4,433	149	363	177	-176	-263	-351	-24
	4,570		456					
B/C	1.52	1.02	1.16	1.14	0.69	0.85	0.23	0.98
	1.27		1.11					
Study Area (km2)	95.1	167.3	56.8	18.6	12.8	24.3	50.5	24.3
Social impact on .Built-up Area (km2) in 1990	50.6	68.6	21.7	13.1	7.5	7.4	20.6	10.3
. Population in 1990	2,264,000	2,178,000	449,000	470,000	131,000	221,000	131,000	138,009
. Population Density at Build-up area (Pop.ha)	447	317	207	359	175	298	63	134
Likely social impact on								
. New Develop Area (km2)	29.8	61.5	21.0	4.1	4.0	12.7	24.5	9.1
. Population in 2010	4,085,000	4,502,000	1,314,000	927,000	266,000	457,000	410,000	652,000
-Population Density	508	346	307	539	232	228	91	235
Environmental Adverse impact	not significant	not sig.	not sig.	not sig.	not sig.	not sig.	not sig.	not sig.
Evaluation 3/								
. Economic Efficiency	A	A	A	A	C	B	C	B
. Present Social Impact	A	A	B	A	C	B	C	B
. Future Social Impact	A	A	A	B	C	B	C	B
Area Priority	A	A	A	A	C	B	C	B

Note : 1) Greater Dhaka-West : Buriganga River/Turag River left bank zones
2) Greater Dhaka-East : Balu River left bank zone
3) Evaluation : High - Low
A B C

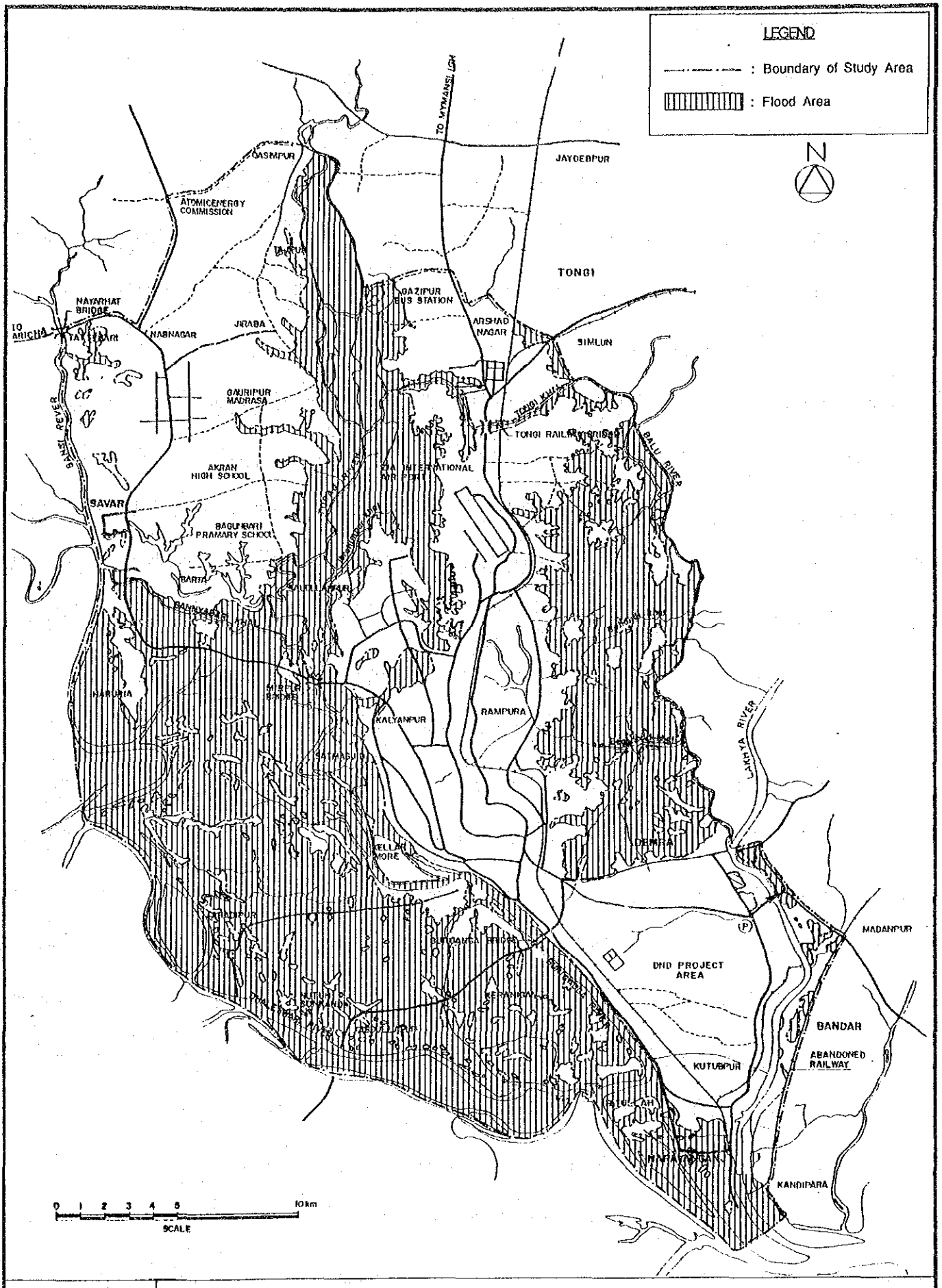


FIG. S.1 **EXTERNAL FLOOD MAP - ANNUAL FLOOD**

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

JICA

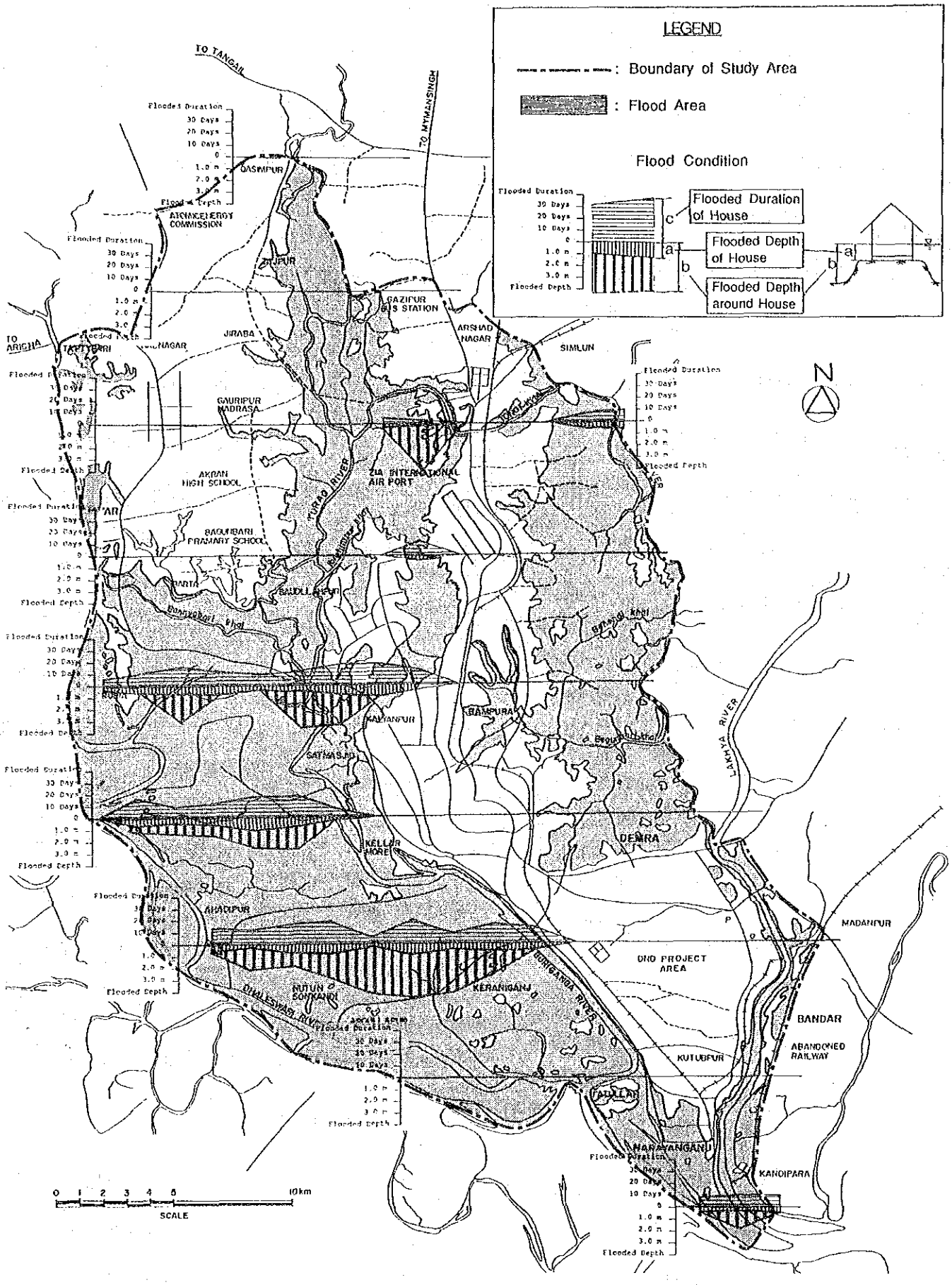


FIG. S.2 EXTERNAL FLOOD MAP - 1987 FLOOD

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

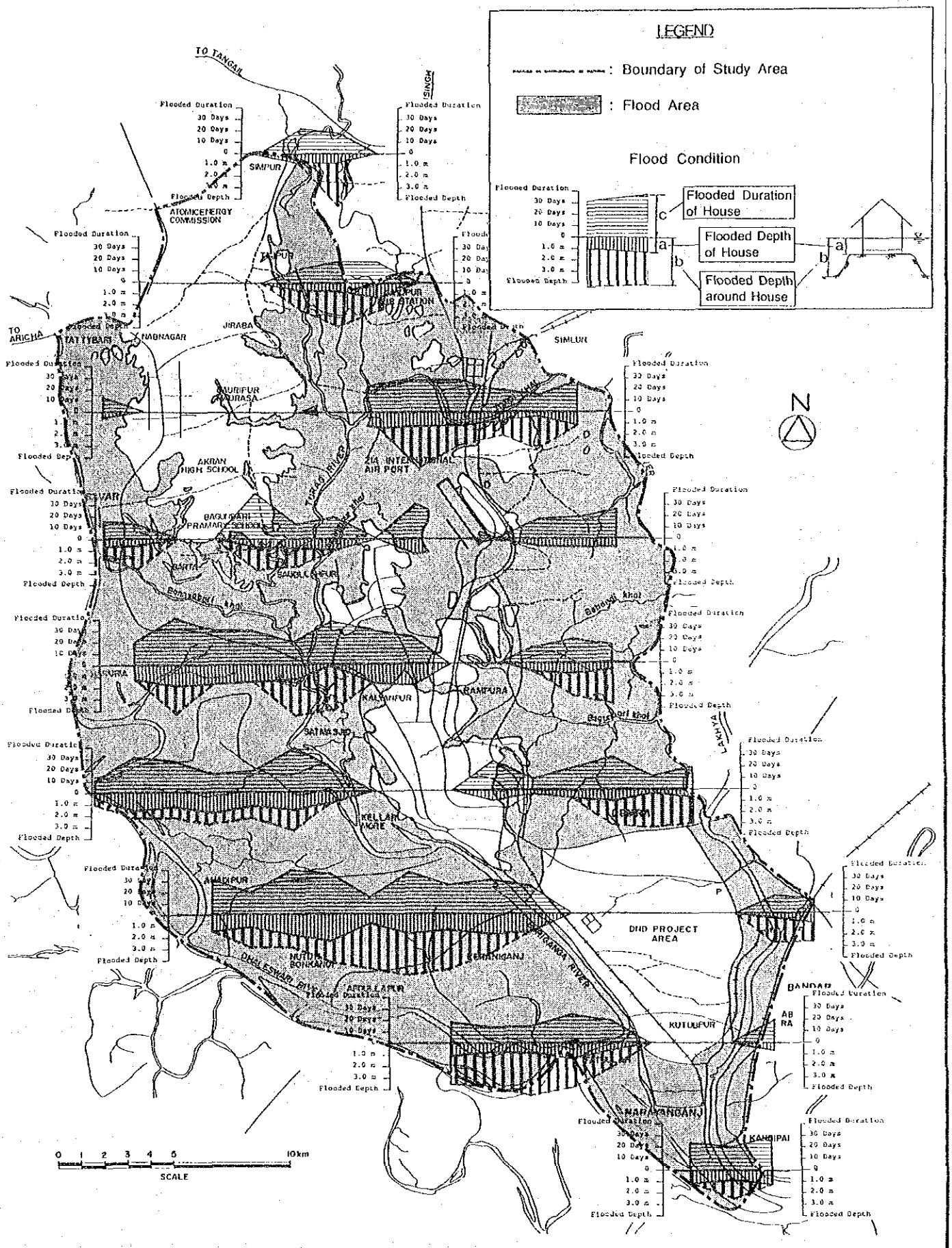


FIG. S.3 EXTERNAL FLOOD MAP - 1988 FLOOD

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

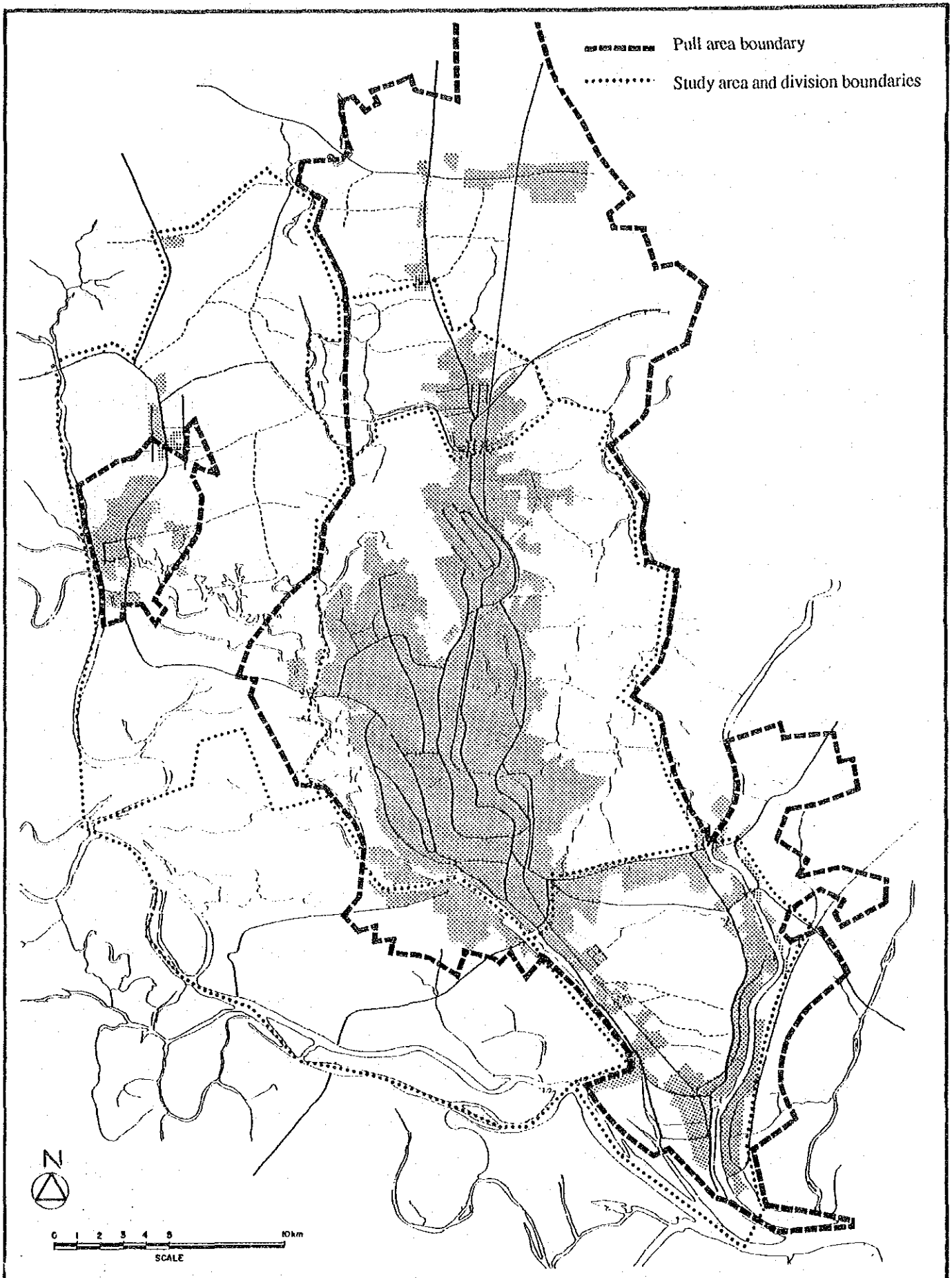


FIG. S.4 PULL AREA STUDY AREA AND DIVISION BOUNDARIES

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

JICA

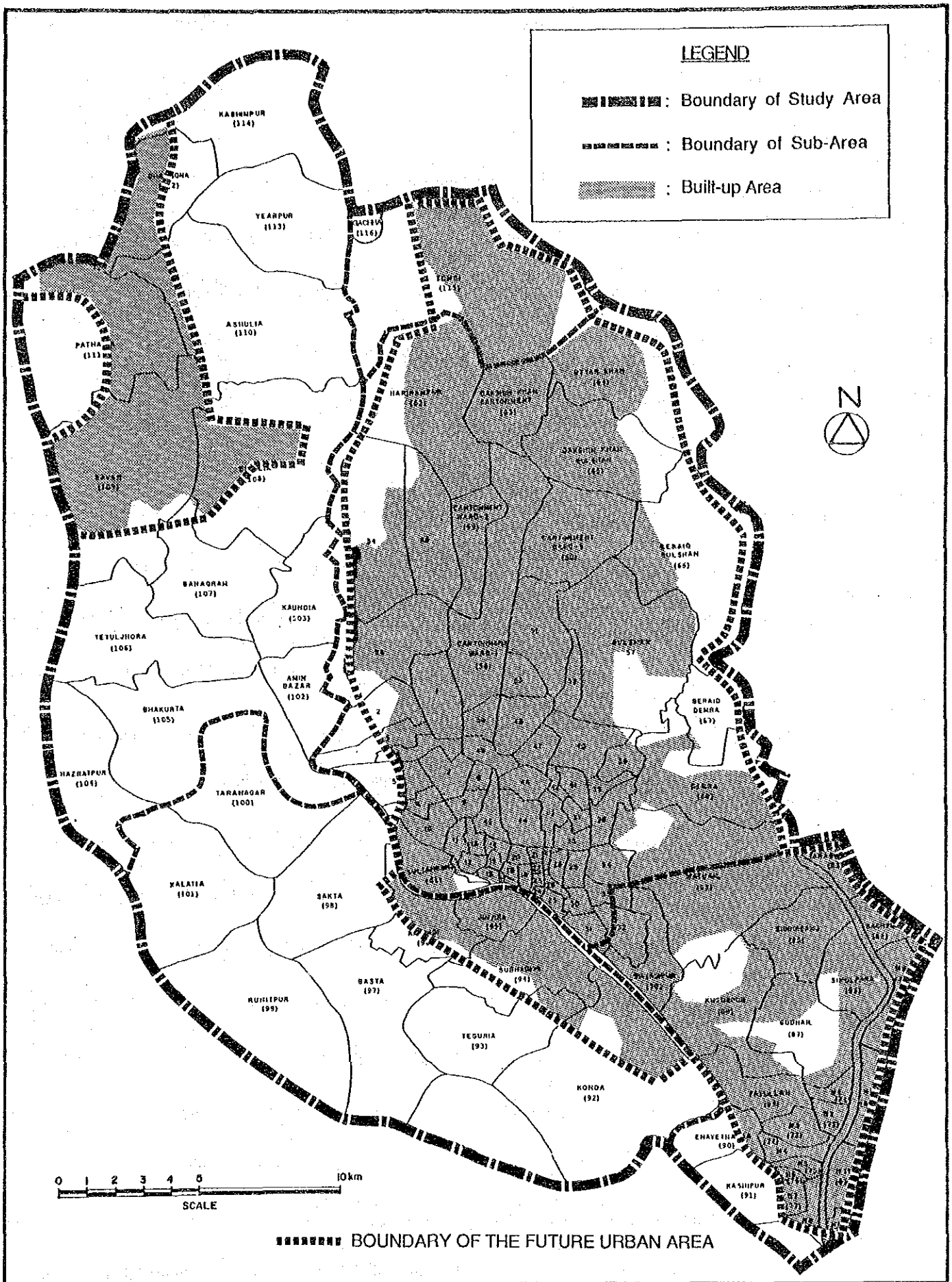


FIG. S.5 **BUILT-UP AREA, 2010**

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

JICA

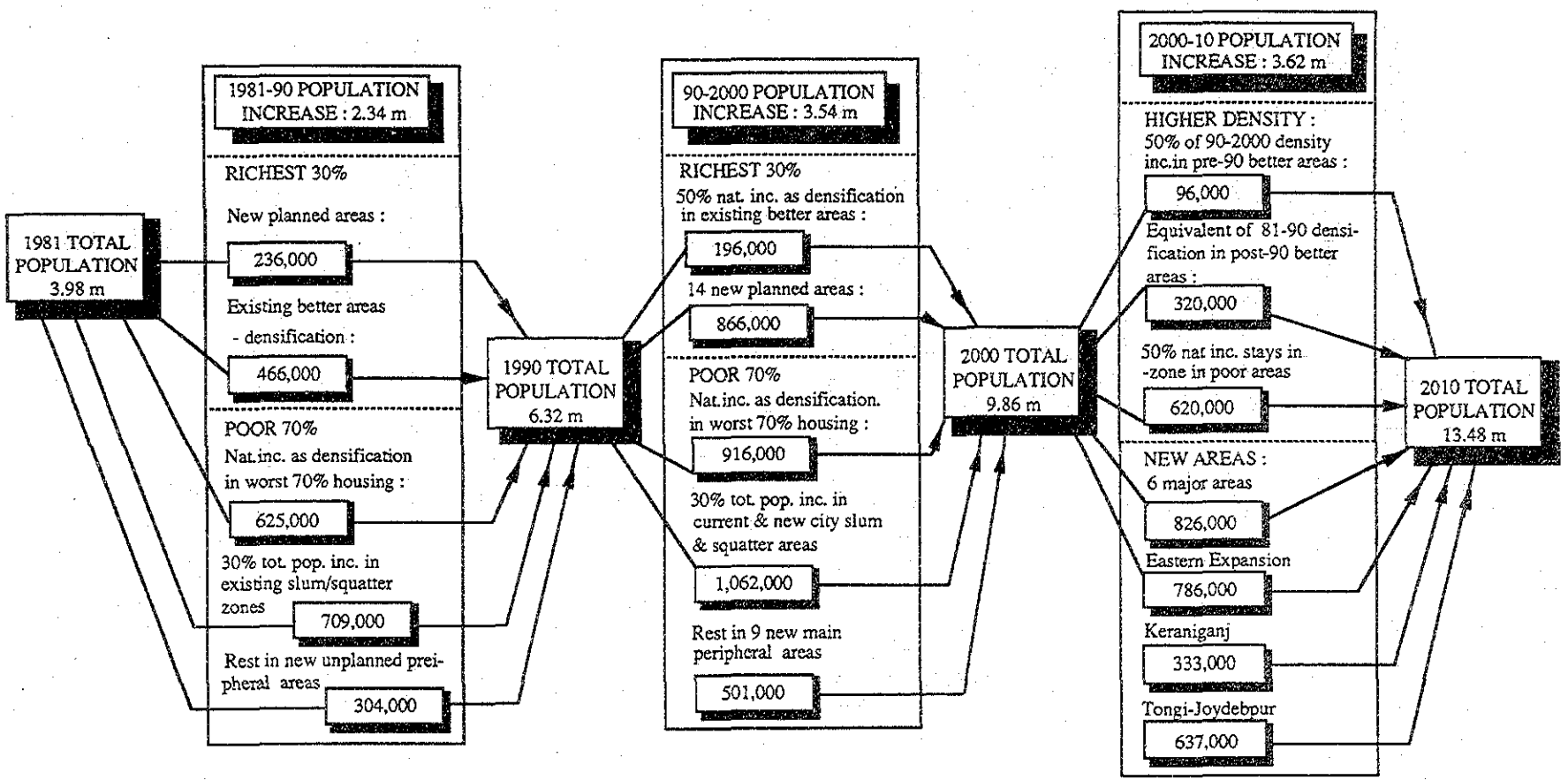


FIG. S.6 DHAKA METROPOLITAN 'PULL' AREA : DISTRIBUTION OF POPULATION GROWTH

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

JICA

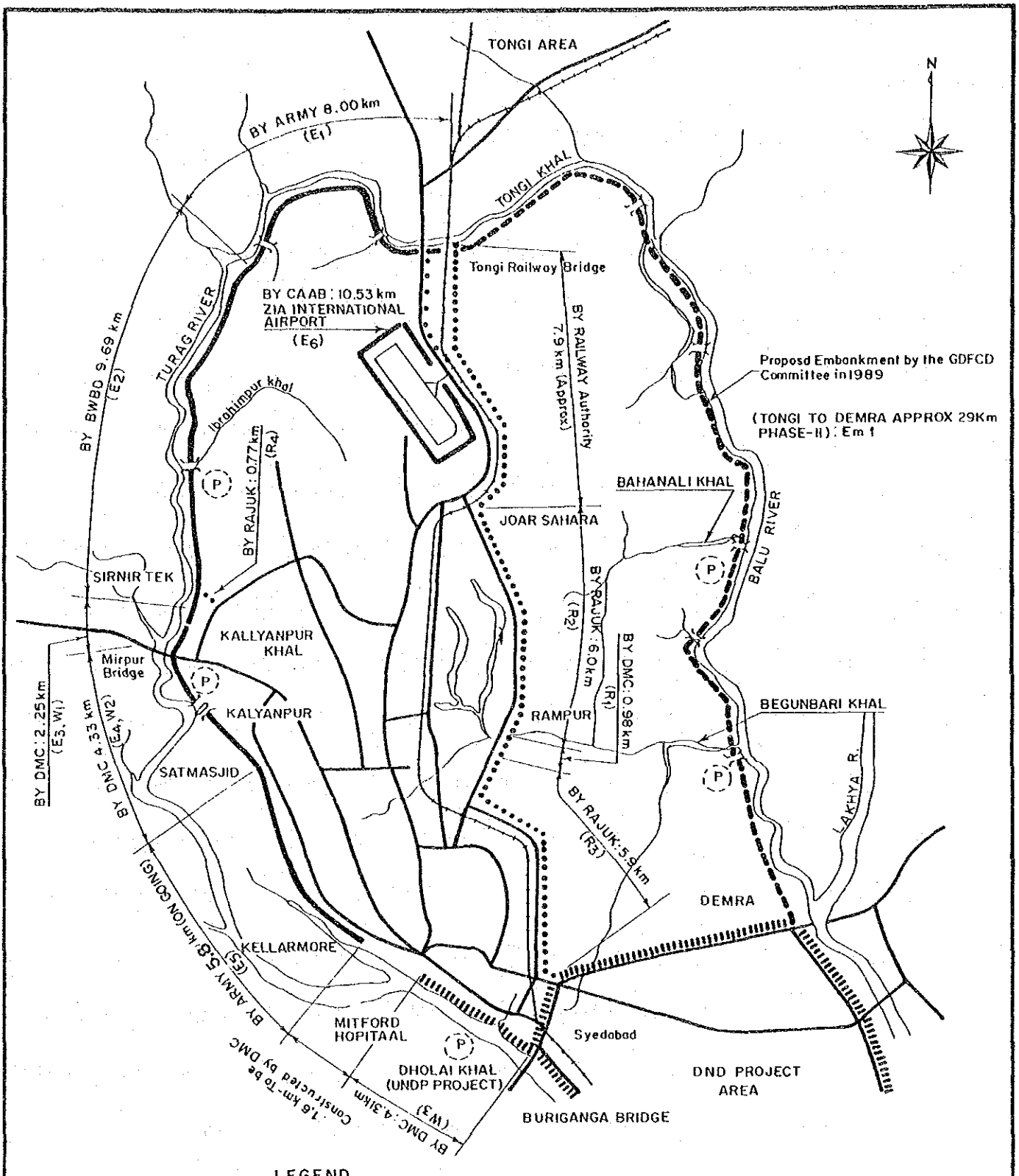
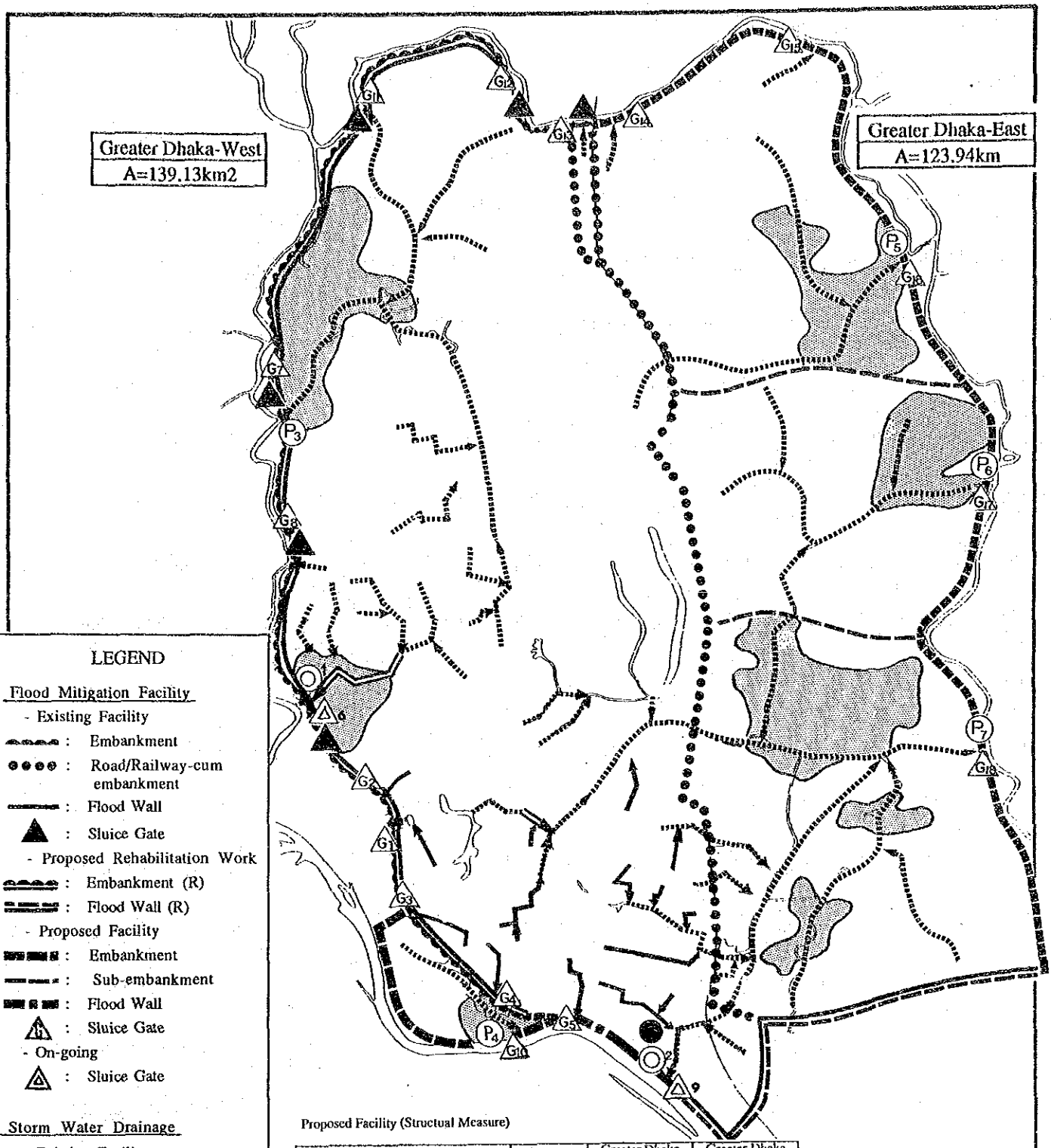


FIG. S.7 EXISTING FLOOD CONTROL PLANS AND FACILITIES - GREATER DHAKA

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

JICA



LEGEND

Flood Mitigation Facility
- Existing Facility
  - : Embankment
  - : Road/Railway-cum embankment
  - : Flood Wall
  - : Sluice Gate
- Proposed Rehabilitation Work
  - : Embankment (R)
  - : Flood Wall (R)
- Proposed Facility
  - : Embankment
  - : Sub-embankment
  - : Flood Wall
  - : Sluice Gate
- On-going
  - : Sluice Gate

Storm Water Drainage
- Existing Facility
  - : Pump Station
- Proposed Facility
  - : Pump Station
  - : Khal Improvement
  - : Drainage Pipe
  - : Retarding Pond
- On-going
  - : Pump Station
  - : Khal Improvement

Proposed Facility (Structual Measure)

Facility	Unit	Greater Dhaka West	Greater Dhaka East
-Flood Mitigation			
1. Embankment (R)	Km	16.7	-
2. Flood Wall (R)	Km	4.7	-
3. Embankment	Km	6.3	26.7
4. Sub Embankment	Km	-	11.3
5. Road-Cum-Embankment	Km	-	-
6. Flood Wall	Km	3.0	-
7. Sluice Gate	plcs (m^2)	11 (162.8)	5 (199.5)
8. Land Acquisition	ha	37.0	317.4
- Storm Water Drainage			
1. Pump station	plcs (m^3/s)	2 (73.2)	3 (179.1)
2. Khal Improvement	Km	42.7	72.4
3. Drainage Pipe	Km	8.1	8.9
4. Retarding Pond	ha	770.0	1,884.0
5. Land Acqisition	ha	43.7	168.0

Note :
1) On-going projects by JICA and IBRD are not inclueded.
2) (R) : Rehabilitation Work

FIG. S.8 PROPOSED FLOOD MITIGATION AND STORMWATER DRAINAGE FACILITIES (1),(GREATER DHAKA WEST AND EAST)

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

JICA